Preface

It is an honour and a privilege to welcome you to the NAC Conference 2020!

Founded in 1992 by the Royal Dutch Academy of Arts and Sciences (KNAW), the Royal Dutch Geological and Mining Society (KNGMG) and the Dutch Research Council (NWO), the NAC conference is now organized for the 16th time. Over those years, NAC has grown into the most prominent Earth scientific conference in The Netherlands that since 2019 is now held annually, and encompasses all branches of the Earth Sciences in their broadest sense. From geology to biogeochemical cycles, from mantle processes to coastal dynamics, from atmospheric physics to soil science, it is all there. And there is more than science alone. What I really like about the NAC Conference is that it aims to serve as platform to build bridges between Earth scientific disciplines; and aspires to connect the Earth scientific expertise in The Netherlands to the need of society to address the Grand Challenges of our time. I am convinced young scientists are key to both! They are the ones working on the most innovative research, and have the freshest minds not yet chained by traditions, conventions or disciplinary boundaries. I am therefore proud that NAC has always made an extra effort to enable young scientists to participate. But whether you are an MSc student at your first conference or the most senior expert in your field, I wish you an exciting, interesting and energizing conference, and hope that together with you we can make the NAC Conference 2020 as memorable as ever.

Boris Jansen
Chair Programme Committee
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<td>KEYNOTE LECTURE 1: JOS LELIEVELD Impacts of anthropogenic emissions on public health, rainfall and climate</td>
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<td>KEYNOTE LECTURE 2: ANNY CAZENAVE Climate change and sea-level rise</td>
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<td>Ruisdael Solid Earth IODP/ICDP Coastal zone processes/eutrophication</td>
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**DEMOS & EXHIBITS**

**POSTER SESSION - A**
Posters related to Thursday’s parallel sessions

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**PLENARY AWARD:** VENING MEINESZPRIJS

**EVENING PROGRAMME**

Live music Band

Drinks

Dinner
PROGRAMME SESSIONS: DAY 1

Ruisdael – Oudegracht 1 – Convenor: Herman Russchenberg
13:00 – 13:15  Hossein Maazallahi, Methane mapping, emission quantification and attribution in two European cities; Utrecht, NL and Hamburg, DE pg 18
13:30 – 13:45  Folker Boersma, Quantifying NOx emissions from a city and a small country with the TROPOMI and OMI satellite instruments pg 20
13:45 – 14:00  Marco de Bruine, High-resolution modelling of carbon dioxide and methane in the Dutch atmosphere pg 21

Solid Earth – Oudegracht 2 – Convenor: Janne Koornneef
13:00 – 13:15  Nemanja Krstekanic, Large-scale strain partitioning during oroclinal bending of the Carpatho-Balkanides (south-eastern Europe): inferences from analogue modelling pg 26
13:15 – 13:30  Antoine Bracco Gartner, On the origin of young intraplate volcanism in the Carpathian-Pannonian region pg 27
13:30 – 13:45  Marcel Mizer, Low-temperature Plasticity of Naturally Deformed Calcite in the Hungaroa Fault Zone, Hikurangi Subduction Margin, New Zealand pg 28
13:45 – 14:00  Markus Ohl, Silicate fault mirrors and implications for crustal fault rheology in the absence of melting pg 29

IODP/ICDP – Oudegracht 3 – Convenor: Martin Ziegler
13:00 – 13:15  Frida Hoem, First results from IODP expedition 382, Iceberg Alley and Subantarctic Ice and Ocean Dynamics pg 34
13:15 – 13:30  Lena Thöle, Glacial-interglacial ACC dynamics in the Pleistocene: Biomarker and dinocyst-based reconstructions of paleoceanographic changes in two areas of the Southern Ocean pg 35
13:45 – 14:00  Poster Pitches IODP & ICDP posters pg 37

Coastal zone processes/ eutrophication – Oudegracht 4 – Convenor: Furu Mienis
13:00 – 13:15  Peter Kraal, Interaction with nutrients destabilizes iron minerals: double eutrophication trouble? pg 42
13:15 – 13:30  Niels van Helmond, Phosphorus dynamics in sediments of the Stockholm Archipelago, Baltic Sea pg 43
13:30 – 13:45  Annemieke Kooijman, Resilience in coastal dune grasslands: pH and SOM effects on P nutrition, plant mycorrhizal strategies and soil communities pg 44
13:45 – 14:00  Martijn Hermans, Biogeochemical Impact of Cable Bacteria in Coastal Black Sea Sediment pg 45
Sea-level change – Domtoren 3 – Convenor: Aimée Slangen
13:00 – 13:15 Carolina Camargo, Revisiting the Global and Regional Steric Sea-level Trends in the Satellite Era pg 50
13:30 – 13:45 Riccardo Riva, Detecting non-linear sea-level variations in tide gauge records: a study case along the Dutch coast pg 52
13:45 – 14:00 Maria Chertova, Incorporating large datasets of synthetic tropical cyclones with Global Tide and Surge Model (GTSM) for global assessment of extreme sea levels pg 53

Geological Remote Sensing – Domtoren 4 – Convenor: Mark van der Meijde
13:00 – 13:15 Frank van Ruitenbeek, Information theory and hydrothermal processes pg 58
13:30 – 13:45 Veronica Tollenaar, Towards an Antarctic meteorite hotspot map pg 60
13:45 – 14:00 Olivier den Ouden, A low-cost mobile multidisciplinary measurement platform for monitoring geophysical parameters pg 61

Geomorphology/Natural Hazards – Domtoren 5 – Convenor: Tjalling de Haas
13:00 – 13:15 Daniel Draebing, Adjustment of rockwalls to deglaciating conditions and warming climate – examples from an alpine valley pg 66
13:15 – 13:30 Jana Eichel, Feedbacks between plants and geomorphic processes in alpine environments pg 67
13:30 – 13:45 Remi Charton, Modelling the dynamicity of past source-to-sink systems: an example from Morocco pg 68
13:45 – 14:00 Jeroen Schoorl, Late Quaternary landscape evolution of the Kula Badlands: LEM LAPSUS sensitivity to lithological and tectonic drivers pg 69

DeepNL – Domtoren 6 – Convenor: Oliver Plümper
13:00 – 13:15 Aukje Veltmeijer, Early detection of stress changes and failure using acoustic measurements pg 74
13:15 – 13:30 Samantha Kim, A particle method strategy to estimate subsidence induced by a high-dimensional disc-strain model for reservoir compaction pg 75
13:30 – 13:45 Takahiro Shinohara, Quantifying grain contact and grain volume stress-strain fields in simulated sandstone: a high-resolution FEM approach pg 76
13:45 – 14:00 Jesper Spetzler, Moment Tensor Solutions and Hypocenter Relocation of Induced Earthquakes in Groningen, the Netherlands, using a 3D Regional Model pg 77
**Ruisdael – Oudegracht 1 – Convenor: Maarten Krol**

15:30 – 15:45  **Fred Bosveld**, Fifty years of Atmospheric Boundary-Layer Research at Cabauw serving Weather, Air Quality and Climate  pg 22

15:45 – 16:00 **Ulrike Dusek**, The new aerosol-cloud infrastructure at the Lutjewad field station  pg 23

16:00 – 16:15 **Marc Schleiss**, Vertical profiles of raindrop size distributions and their value for quantitative precipitation estimation: first results from an experiment near Cabauw  pg 24

16:15 – 16:30 **Jordi Vila-Guerau de Arellano**, Analyzing the Synoptics, Meso and Local Scales Involved in Sea-Breeze Formation and Frontal Characteristics  pg 25

**Solid Earth – Oudegracht 2 – Convenor: Oliver Plümper**

15:30 – 15:45  **Remi Charton**, Is the Central Atlantic Rift thermal signature recorded and preserved in apatite fission tracks?  pg 30

15:45 – 16:00 **Merel Swart**, South Sandwich subduction initiation and the kinematic evolution of the South Atlantic and South Pacific regions since the Jurassic  pg 31

16:00 – 16:15 **Vincent Strak**, Mantle flow induced by retreating and advancing slabs: insights from analogue subduction models analysed with a tomographic Particle Image Velocimetry technique  pg 32

16:15 – 16:30 **Jesse Reusen**, Matching the static gravity field of North America using a dynamic earth model  pg 33

**IODP/ICDP – Oudegracht 3 – Convenor: Martin Ziegler**

15:30 – 15:45  **Evi Wubben**, Eastern Equatorial Atlantic climate and ecological variability during the Miocene Climatic Optimum  pg 38

15:45 – 16:00 **Allix Baxter**, Occurrence and distribution of bacterial GMGTs in an East African crater lake: Implications for their use as paleotemperature proxy  pg 39

16:00 – 16:15 **Aleksandra Cvetkoska**, Time-divergent contribution of basin-scale environment and global climate in driving diatom community structure over 1.36 Ma history in ancient Lake Ohrid  pg 40

16:15 – 16:30 **Martin Ziegler and Timme H. Donders**, IODP & ICDP News & Updates, plus IODP/ICDP Person of the Year!  pg 41

**Sedimentary Systems – Oudegracht 4 – Convenor: Kim Cohen**

15:30 – 15:45  **Philip Minderhoud**, The sinking mega-delta: accelerating land subsidence poses existential threat to the Mekong delta  pg 46

15:45 – 16:00 **Jaap Nienhuis**, Land loss predictions for global river deltas in the 21st century  pg 47

16:00 – 16:15 **Safaa Naffaa**, Sediment yield of the Amazon and the possible impacts on the Suriname Coast as a result of its projected change  pg 48

16:15 – 16:30 **Joris Eggenhuisen**, Quantifying fluxes through submarine canyons to the deep sea  pg 49
### Carbon Cycle – Domtoren 3 – Convenor: Liesbeth Florentie

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<td>Naomi Smith</td>
<td>Spring enhancement and summer reduction in carbon uptake during the 2018 drought in northwestern Europe</td>
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<td>15:45 – 16:00</td>
<td>Melanie Martyn</td>
<td>The role of inland freshwaters in summer CO2, CH4 and N2O emissions from northeast Siberian Arctic tundra</td>
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<td>Tessa van der Voort</td>
<td>Uncovering Hidden Treasures: quantifying marine sediment carbon storage on a global level</td>
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<td>16:15 – 16:30</td>
<td>Gerbrand Koren</td>
<td>Persistent impact of the 2015 El Niño drought in the Amazon during 2016</td>
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### Natural Hazards and Earth Observations – Domtoren 4 – Convenor: Mark van der Meijde

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<td>Sobhan Emtehani</td>
<td>Sediment Deposition Quantification in Tropical Regions</td>
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<td>15:45 – 16:00</td>
<td>Tjalling de Haas</td>
<td>Spatio-temporal patterns of debris-flow erosion and deposition in the Illgraben torrent</td>
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<td>Steven de Jong</td>
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<td>Paul Vermunt</td>
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<td>Jantiene Baartman</td>
<td>What do models tell us about water and sediment connectivity?</td>
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<td>Cynthia van Leeuwen</td>
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<td>Harm Jan Pierik</td>
<td>How tides and rivers shape levees and crevasses: Holocene overbank phases of the Old Rhine river, the Netherlands</td>
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<td>Marijn van der Meij</td>
<td>Morphological response of dam-passing channels to sand suppletion</td>
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### DeepNL – Domtoren 6 – Convenor: Femke Vossepoel

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<td>La Ode Marzujriban Masfara Rachman</td>
<td>Localizing hypocenters of induced earthquakes using a Hamiltonian Monte Carlo scheme</td>
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<td>Rhys Hawkins</td>
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<td>Meng Li</td>
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## FRIDAY 13 MARCH 2020

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### PLENARY OPENING

**KEYNOTE LECTURE 3:** ANNE SCHULP
Meet T. rex in person

### PLENARY CLOSING NAC 2020 - Prizes & Awards, including the KNGMG Escher- & Jelgersma Prizes

**KEYNOTE LECTURE 4:** CLAIRE CHENU
Are soils a solution for climate change?
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### Poster session - B
Posters related to Friday’s parallel sessions

<table>
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<tr>
<th>DEMOS &amp; EXHIBITS</th>
<th>Role(s) of scientists in political debates</th>
<th>Research strategy Earth Observation 2020–2025</th>
<th>NWO Roadshow on Knowledge Utilization, and PPS Fund</th>
<th>NWO Grant Workshop</th>
<th>The professional development of a geologist (KNGMG hosted.)</th>
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<th>DEMOS &amp; EXHIBITS</th>
<th>Methods in Biogeo- sciences</th>
<th>Geochronology</th>
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<th>DEMOS &amp; EXHIBITS</th>
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**PROGRAMME SESSIONS: DAY 2**

### Atmospheric Sciences – Oudegracht 1 – Convenor: Ilse Aben

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<tr>
<th>Time</th>
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<tr>
<td>13:15 – 13:30</td>
<td>Vishal Vijay Dixit</td>
<td>Counter-gradient Convective Momentum Transport in the Large Eddy Simulations of subtropical Clouds pg 86</td>
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<td>13:30 – 13:45</td>
<td>Wouter Mol</td>
<td>Surface Moisture Exchange Under Vanishing Wind in Simulations of Idealized Tropical Convection pg 87</td>
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<td>13:45 – 14:00</td>
<td>David Donovan</td>
<td>The Earth Clouds and Radiation Explorer (EarthCARE) Satellite: a Multisensor Cloud, Aerosol, Precipitation, and Radiation mission pg 88</td>
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<tr>
<td>14:00 – 14:15</td>
<td>Rupert Holzinger</td>
<td>Volatile organic compounds (VOC) in the Arctic atmosphere during Spring 2018 pg 89</td>
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### Solid Earth – Oudegracht 2 – Convenor: Jelle Assink

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<tr>
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<td>Reinoud Sleeman</td>
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<tr>
<td>13:45 – 14:00</td>
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<td>14:00 – 14:15</td>
<td>Sujania Talavera-Soza</td>
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<tr>
<th>Time</th>
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<tr>
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<td>Michelle van Vliet</td>
<td>Quality matters for water scarcity mitigation pg 102</td>
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<tr>
<td>13:30 – 13:45</td>
<td>Remco de Kok</td>
<td>Hydrological drivers of the Karakoram anomaly pg 103</td>
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<td>13:45 – 14:00</td>
<td>Dominik Schumacher</td>
<td>Atmospheric supply of moisture and heat to water- and energy-limited ecosystems pg 104</td>
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<td>14:00 – 14:15</td>
<td>Ruben Imhoff</td>
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### High Latitude and cold climate dynamics – Oudegracht 4 – Convenor: Francien Peterse

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<th>Time</th>
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<tr>
<td>13:15 – 13:30</td>
<td>Clement Delcourt</td>
<td>Carbon emissions from wildfires in larch forest ecosystems of Northeast Siberia pg 110</td>
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<tr>
<td>13:30 – 13:45</td>
<td>Fabian Ercan</td>
<td>Comparison of elevated temperature experiments on shrubs in Finland, Greenland and Poland pg 111</td>
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<td>13:45 – 14:00</td>
<td>Kirsi Keskitalo</td>
<td>Composition and characteristics of particulate organic matter on a spatial transect off a retrogressive thaw slump in the Canadian Arctic pg 112</td>
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<td>14:00 – 14:15</td>
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13:30 – 13:45 Hugo de Boer, Functional significance of Bristlecone pine needle elongation responses to growing season temperature variations pg 119
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15:15 – 15:30  Olivier Sulpis, Current estimates of carbonic acid dissociation constants appear inconsistent with measured CO2 system parameters in cold oceanic regions pg 148
15:30 – 15:45  Furu Mienis, Whittard Canyon: a pathway and sink for organic carbon pg 149
Keynote lecture 1: JOS LELIEVELD

Impacts of anthropogenic emissions on public health, rainfall and climate

Anthropogenic greenhouse gases and aerosols are associated with climate change and human health risks. We used a global model to estimate both the climate and public health outcomes attributable to fossil fuel use, indicating the potential benefits of a phase out. We show how much excess mortality from outdoor air pollution can be avoided worldwide. Because aerosols affect the hydrologic cycle, removing the anthropogenic emissions in the model significantly increase rainfall over densely populated regions in India, northern China, Central America, West Africa and the drought-prone Sahel, thus contributing to water and food security. Since aerosols mask the anthropogenic rise in global temperature, removing fossil fuel generated particles liberates about 0.5°C (global mean), up to 2°C over North America and Northeast Asia. The steep global temperature increase from removing aerosols can be moderated to about 0.35°C by the simultaneous reduction of tropospheric ozone and methane. We conclude that a rapid phase-out of fossil fuel related emissions and major reductions of other anthropogenic sources are needed to save millions of lives, restore aerosol-perturbed rainfall patterns, and limit global warming to 2°C.

Professor Jos Lelieveld is an atmospheric chemist and director of the Atmospheric Chemistry Department at the Max Planck Institute for Chemistry in Mainz (Germany). He is the winner of the 2019 Vilhelm Bjerknes Medal of the EGU.

Keynote lecture 2: ANNY CAZENAVE

Climate change and sea-level rise

It is now well established that the Earth’s climate is warming and that the main reason is the accumulation inside the atmosphere of greenhouse gases produced by anthropogenic fossil fuel combustion and change in land use. Global warming has already several visible consequences, in particular increase of the Earth’s mean temperature and of ocean heat content, melting of glaciers, and ice mass loss from the Greenland and Antarctica ice sheets. Ocean warming causes thermal expansion of sea waters, hence sea level rise. Similarly, land ice melt that ultimately reaches the oceans, also causes sea level to rise. In this presentation, we summarize the most up-to-date knowledge about impacts
of climate change on ocean warming, land ice melt and sea level rise. We highlight the contribution of space observations, in particular from satellite altimetry and space gravimetry, to measure ice sheet mass loss and sea level rise. We also discuss the various causes of sea level rise at global and regional scales and show that in terms of global average, we are now able to close the sea level budget. Finally, we discuss the importance of measuring sea level change at the coast, as well as the many complex processes at work in such regions (due to natural phenomena and anthropogenic forcing) that cause important adverse effects and significant vulnerability to coastal populations.

Dr. Anny Cazenave is a space geodesist and one of the pioneers in satellite altimetry. She works for the French space agency CNES and is deputy director of the Laboratoire d’Études en Géophysique et Océanographie Spatiale (LEGOS) at Observatoire Midi-Pyrénées in Toulouse (France), as well as director of Earth sciences at the International Space Sciences institute (ISSI), in Bern (Switzerland).

Day 2

Keynote lecture 3: ANNE SCHULP

Meet T. rex in person

*Tyrannosaurus rex* is a dinosaur we all think we would be able to recognize if one were to meet. Popular culture provides countless opportunities to encounter this iconic, Late Cretaceous carnivorous dinosaur, but does the mental picture we collectively share of its appearance, its behaviour, its biology, come anywhere near current scientific knowledge? Naturalis Biodiversity Center, the national natural history museum of the Netherlands, excavated a well-preserved specimen of *Tyrannosaurus rex* in Montana, USA, in 2013. The skeleton is now on display at the new dinosaur gallery at the museum in Leiden. Although the first discoveries of *T. rex* date back more than a century, new specimens and new technology still provide new insights in our understanding of tyrannosaurid biology. The new specimen RGM.792.000, nicknamed ‘Trix’, adds numerous interesting pathologies to the record, including healed bone fractures, as well as bite marks in its lower jaw. As the specimen represents a ‘robust’ morph, chances are it represents a female. The spectacular preservation is directly linked to the specimen becoming buried soon after its death by a thick layer of sand, and isotopic evidence from its tooth enamel presents a record of seasonality and diet. Histological analyses tell of the advanced age this 12-metre specimen achieved, whereas a detailed biomechanical analysis of the well-preserved tail allows to model the locomotion and energy expenditure of this particular individual.
All in all, this and other research provided exciting opportunities for STEM outreach and education alike, which by now has reached an audience of c. 1.5 million visitors.

**Professor Anne Schulp** is a researcher with Naturalis Biodiversity Center in Leiden, the national natural history museum of the Netherlands, and professor of vertebrate palaeontology at Utrecht University. He has a special interest in reptiles from the Age of Dinosaurs.

**Keynote lecture 4: CLAIRE CHENU**

**Are soils a solution for climate change?**

The international initiative “4 per 1000”, launched by France on 1 December 2015 at the COP 21, consists of federating all voluntary stakeholders of the public and private sectors (national governments, local and regional governments, companies, trade organisations, NGOs, research facilities, etc.) under the framework of the Lima-Paris Action Plan (LPAP). The aim of the initiative is to demonstrate that agriculture, and in particular agricultural soils can play a crucial role where food security and climate change are concerned. An annual growth rate of 0.4% in the soil carbon stocks, or 4‰ per year, in the first 30–40 cm of soil, would significantly reduce the CO2 concentration in the atmosphere related to human activities. The “4 per 1000” initiative is intended to complement those necessary efforts to reduce greenhouse gas emissions, globally and generally in the economy as a whole. It is voluntary; it is up to each member to define how they want to contribute to the goals. Maintaining organic carbon-rich soils, restoring and improving degraded agricultural lands and, more generally, increasing soil carbon, play an important role in addressing the three-fold challenge of food security, adaptation of food systems and people to climate change, and mitigation of anthropogenic emissions.

**Professor Claire Chenu** is a Professor of Soil Sciences at AgroParisTech (Paris, France) with a strong academic track record, accomplished experience of the science-policy-practice interface and committed involvement in awareness raising activities. She is the winner of the 2019 Philippe Duchaufour Medal of the EGU.
Methane mapping, emission quantification and attribution in two European cities; Utrecht, NL and Hamburg, DE

Hossein Maazallah
Julianne M. Fernandez, Malika Menoud, Rebecca Fischer, Daniel Zavala Araiza, Zachary D. Weller, Stefan Schwietzke, Joe von Fischer, Luise Westphal, Hugo Denier van der Gon and Thomas Röckmann

Quantifying and attributing methane emissions within various boundaries, from city to national scales, is important for designing effective mitigation decisions from environmental, safety, and financial perspectives. Mobile real-time measurements of methane in ambient air offer a fast and effective method to identify and quantify local methane emissions in urban areas. We carried out extensive campaigns to measure methane mole fractions at the street level in Utrecht, The Netherlands (2018 and 2019) and Hamburg, Germany (2018). Methane elevations across both cities were translated to emissions using an empirical equation from Weller et al., (2019). Extrapolation of the detected elevations to the complete road network in Utrecht and Hamburg yields total emissions of 154.0 t/yr for Utrecht and 436.2 t/yr for Hamburg. Online measurements of the ethane/methane ratio (C2/C1) and isotope measurements (δ13C-CH4 (δ13C) and δ2H-CH4 (δD)) on air samples collected in larger methane plumes allow to discriminate thermogenic from biogenic methane enhancements. In Utrecht 93% of emissions (69% of peaks; based on C2/C1 analysis), and in Hamburg 64% of emissions (33% of peaks; based on C2/C1 analysis) and 79% of emissions (38% of peaks; based on isotope characterization of a limited sub-sample) have thermogenic origin. Our results confirm previous observations that a few large leakages are responsible for a major part of the methane emissions. In Utrecht, 35% of total emission originated from 1 leak and in Hamburg 29.5% from 2 leaks. Attribution of elevations by δ13C, δD and C2/C1 analysis can lead to more effective use of resources to minimize leak repair efforts. About 50% of reported thermogenic emissions was fixed by the local gas utility in Hamburg, although most of the smaller elevations were not detected. Methane emissions from larger facilities in or close to both cities were quantified based on a Gaussian plume dispersion model, and the results show that these facilities can be major contributors to total methane emissions of a city.

Characterisation of methane sources in Lutjewad, The Netherlands, using high temporal resolution isotopic composition measurements

Malika Menoud
Carina van der Veen, Bert Scheeren, Huilin Chen, Barbara Szenasi, Randulph P. Morales, Dominik Brunner and Thomas Röckmann

Reducing methane emissions is an important goal of climate change mitigation policies. Uncertainties regarding the global methane budget concerning emission rates and locations, as well as temporal and spatial variability of the different sources, need to be addressed. Measurements of CH4 isotopic composition are often used to characterise emission sources on collected samples, but in-situ experiments providing high-precision data were only performed recently. Here we present high temporal resolution isotopic measurements performed during 5 months at Lutjewad tall tower, in the North of the Netherlands. Time-series of CH4 mole fractions, δ13C-CH4, and δD-CH4 in ambient air were analysed using the Keeling plot approach, and in relation to the wind direction. Resulting source signatures ranged from -67.4 to -52.4 ‰ V-PDB and from -372 to -211 ‰ V-SMOW, for δ13C and δD respectively, indicating a prevalence of biogenic sources. We find that (i) emissions from off-shore oil and gas platforms in the North Sea were not detected during the study period, (ii) contributions from fossil fuel sources are detected when the air is advected from the east (possibly the Groningen gas field or further sources in Germany).

The measurements were compared with model results, from CHIMERE and FLEXPART-COSMO using TNO-MACC_III and EDGARv4.3.2 emission inventories. Both models reproduce methane elevations and average isotope signatures relatively well. The largest differences originate from the isotopic composition of the background, and from the fact that the rather coarse models smoothen out some of the variability.

The high-time resolution isotope data help constrain the methane budget on a regional scale, and may be used in inverse modelling approaches. Future measurements at other European locations will inform on the spatial variations of source isotopic signatures, to improve the modelling of methane isotopic composition over the continent.

This work is part of the Marie Sklodowska-Curie Initial Training Network MEMO2.
Quantifying NOx emissions from a city and a small country with the TROPOMI and OMI satellite instruments

Folkert Boersma
M. Zara, A. Lorente, H. Eskes and M. Krol

The TROPOMI and OMI satellite sensors provide an exciting perspective on the sources, dispersion, and fate of air pollution, and in particular on nitrogen dioxide (NO2). Yet it is still difficult to relate satellite observations of tropospheric NO2 columns to the underlying NOx emissions and their trends. Robust interpretation of satellite data relies on a good understanding of the accuracy and representativeness of the satellite data itself, but also on the relationship between NOx emissions and the observable NO2 amount. This relationship is influenced by local chemistry, mixing and dispersion. We address these issues via two examples:

1. We analyse the observed build-up of NO2 pollution over Paris along with the wind. Over the city, recently emitted NOx has been oxidized to limited degree, facilitating the use of TROPOMI data to directly determine the strength and distribution of emissions from the city. From the observed build-up of NO2 pollution, we find highest NOx emissions on cold weekdays in February 2018, and lowest emissions on warm weekend days in spring 2018.

2. We use the QA4ECV OMI NO2 record to investigate trends in tropospheric NO2 columns over The Netherlands between 2005 and 2018. In spite of the differences in metrics and sampling techniques, the NO2 measured in the Dutch atmosphere from space and from the ground follows a trend that is consistent with predictions by emission inventories. Surface NO2 is reduced by 32% in 2018 relative to 2005, OMI NO2 by 35%, and NOx emissions by 32%–38% depending on the inventory. Interestingly, the Dutch surface concentrations reveal an upward trend in the NO2:NO ratio in line with O3 increases. This suggests that the NO2 makes up an increasing share of the NOx in the lower atmosphere as NOx emissions decline. This needs to be accounted for when interpreting NO2 trends as proxy for NOx trends.
High-resolution modelling of carbon dioxide and methane in the Dutch atmosphere

Marco de Bruine
Sander Houwelen

The Ruisdael Observatory pushes the limits of atmospheric modelling to enable more detailed forecasts of the weather and air quality in the Netherlands. Using the Dutch Atmospheric Large-Eddy Simulation (DALES) model we simulate the atmosphere at a resolution of only 100 meters.

The aim of our project is to implement realistic high-resolution emissions of pollutants (e.g. CO2 and CH4) as well as transport of pollutants across the lateral boundaries of a domain centered over the Netherlands. Annually averaged, total emissions are rather well quantified, but disaggregating these emissions in time and space introduces many challenges. For example, how to implement emissions from mobile sources like cars? At what time do people turn on the heating in their homes? How high do the emissions from power plants rise into the atmosphere?

This presentation will focus on the importance and challenges of simulating the emission and transport of atmospheric pollutants at a high resolution. What is needed to relate air quality regulations to human exposure, or to assess urban and agricultural emissions of greenhouse gases using independent atmospheric measurements?
Fifty years of Atmospheric Boundary-Layer Research at Cabauw serving Weather, Air Quality and Climate

Fred Bosveld
Peter Baas, Anton C.M. Beljaars, Albert A.M. Holtslag, Jordi Vilà-Guerau de Arellano and Bas van de Wiel

The construction of the Cabauw 213 m meteorological tower in The Netherlands started about 50 years ago. Since then the Cabauw research facility has played an important role in the international atmospheric boundary layer research community. In the first 15 years of its existence emphasis was on dedicated experiments to better understand and describe the convective and stable atmospheric boundary layer and its interaction with the surface. In the next 15 years emphasis shifted toward long time monitoring. And in the last 15 years the Cabauw site has grown into an atmospheric observatory with a comprehensive observational program encompassing almost all aspects of the atmospheric column including its boundary conditions. This is accomplished by the Cabauw Experimental Site for Atmospheric Research (CESAR) a consortium of knowledge institutes and of universities. CESAR plays an important role in the educational programs of the CESAR universities. Very recently CESAR has become part of the Ruisdael Observatory. High lights of results from 50 years of Cabauw research will be given with emphasis on the structure and dynamics of the atmospheric boundary layer.
The new aerosol-cloud infrastructure at the Lutjewad field station

Ulrike Dusek  

The Lutjewad atmospheric measurement station fulfils the role of coastal station within the Ruisdael observatory. It is located on the northern coast of the Netherlands situated directly behind a the Wadden Sea dike and contains a 60m high measurement tower. The coastal location of the station provides that relatively clean marine background air can reach the sampling tower in contrast to more polluted air masses coming with the prevalent south-east to south-westerly winds. It is an ICOS class 2 station and has a long record of greenhouse gas measurements.

For the Ruisdael project this station is expanded with an aerosol-cloud infrastructure. Aerosol in-situ measurements will include size distribution, chemical composition, and cloud condensation nuclei sampled after a 20m high inlet system that has recently been designed and tested. In this presentation we describe the new aerosol cloud infrastructure, the aerosol inlet system and its particle loss characteristics. A previous aerosol sampling campaign conducted over four seasons is used to illustrate the contrast between clean and polluted conditions and aerosol source contributions at this site.
Vertical profiles of raindrop size distributions and their value for quantitative precipitation estimation: first results from an experiment near Cabauw

Marc Schleiss
Ricardo Reinoso-Rondinel

In November 2018, a vertically pointing micro-rain radar (MRR) was installed near Cabauw, right in between the IDRA X-band research radar and the operational C-band weather radar of KNMI in Herwijnen. The measurements from the MRR were used to retrieve vertical profiles of raindrop size distributions and simulate polarimetric radar variables such as differential reflectivity Zdr and specific differential phase Kdp. By comparing the predictions from the MRR to the actual measurements of IDRA and Herwijnen, important biases due to calibration errors in operational radars can be identified and removed. This results in more accurate precipitation estimates and more reliable polarimetric variables. However, retrieving raindrop size distributions using a MRR is a delicate process, especially in times of heavy rain and convection. In this talk, I outline some of the biggest challenges and present some first encouraging results based on 15 rain events in the winter of 2018–2019.
Analyzing the Synoptic, Meso and Local Scales Involved in Sea-Breeze Formation and Frontal Characteristics

Jordi Vila-Guerau de Arellano
Jon A. Arrillaga, Pedro Jimenez, Maria A. Jiménez, Carlos Roman-Cascon, Mariano Sastre and Carlos Yague

Sea-breeze (SB) frontal passages, the relevant factors influencing their formation and their interaction with local turbulence are analyzed. To proceed, numerical simulations from the Weather Research and Forecasting (WRF) model are compared with a comprehensive observational database from the Cabauw Experimental Site from the Ruisdael observatory, spanning a 10-year period (01/2001-12/2010). The fine horizontal resolution of 2 km and the replication of the observational vertical levels allows for a more precise comparison. An algorithm based on objective and strict criteria was applied to both observations and simulations to select the SB events. By carrying out a filter-by-filter comparison, we find that the simulated large-scale conditions show a good rate of coincidence with the reanalysis (69%). Small biases in the large scale wind direction, however, induce important deviations in the surface-wind evolution. Regarding mesoscale forcings, the land-sea temperature gradient is overestimated in average up to 4 K, producing stronger SB fronts in WRF. The analysis of the SB characteristics and impacts is carried out by classifying the events into three boundary-layer regimes (convective, transition and stable) based on the value of the sensible-heat flux at the SB onset. The stronger SB in the model leads to enhanced turbulence particularly in the convective and transition regimes: the friction velocity, for instance, is overstated by around 50% at the SB onset. In addition, the arrival of the SB front enhances the stable stratification and gives rise to faster afternoon and evening transitions compared with situations solely driven by local atmospheric turbulence.
Large-scale continental strike-slip faults often display distributed deformation associated with significant strain partitioning in releasing or restraining bends and map-view curvatures ending in horse-tail structures. Commonly, these strike-slip faults are associated with indentation, where shortening in front of rigid blocks is transferred laterally to transpression, strike-slip and the formation of transtensional and extensional basins. The strain partitioning during such indentation and the effects of the indenter’s geometry on the deformation are still not fully understood. We performed a series of crustal scale analogue experiments to improve the understanding of large-scale strain partitioning around indenters, which are compared with the natural example of the Moesian indentation in the Carpatho-Balkanides system of south-eastern Europe. Our models consist of a stable rigid block with variable geometry, which was surrounded by layered crustal brittle-(ductile) system. This deformable crust was further translated and rotated around the rigid block. The modelling demonstrates that the geometry of the indenter’s margins is the major controlling parameter on strain partitioning and transfer of deformation from thrusting, transpression to strike-slip and transtension. Deformation of the lower, ductile crust controls the mode of strike-slip splaying into extension behind the indenter. These results show very good correlations with the example of the Carpatho-Balkanides system, where the >100 km Cerna-Timok dextral offset is partitioned to thrusting in front of the Moesian indenter and transtension and extension behind it. The modelling infers that the gradual transfer of strike-slip deformation from Timok-Cerna system to thrusting/transpression and extension/transpression explains their observed variability in offset along strike.
The Carpathian-Pannonian region is host to sporadic intraplate volcanism since Late Miocene times. These basaltic eruptions are surprising because they postdate the main phase of extension in the Pannonian Basin, which had ceased by the Late Miocene. As do other intracontinental occurrences not underlain by hot mantle plumes, their geodynamic origin remains controversial. To resolve this issue, we examine the quantitative relationship between basalt geochemistry and the conditions of melt production. First, rare-earth element inversion is employed to calculate the melt fraction and depth of the melting column. The melt source is then used to independently predict the concentrations of other elements, which are compared to those observed. What we find is that the composition of all basalts requires the mantle to have undergone less than 1% melting in the garnet-spinel transition zone. Using a parameterisation of hydrous mantle melting, we obtain a mantle potential temperature of ca. 1,264°C, i.e. a real temperature of 1,295°C at 65 km beneath the Pannonian Basin. The lithospheric thickness and geotherm show that melting occurs because the base of the lithosphere is close to the solidus temperature. The most likely cause of intraplate volcanism is convective upwelling in the mantle below the thin lithosphere, which moves mantle material just enough for it to cross its solidus and produce small volumes of melt.
Low-temperature Plasticity of Naturally Deformed Calcite in the Hungaroa Fault Zone, Hikurangi Subduction Margin, New Zealand

Marcel Mizera
Carolyn Boulton, Maartje Hamers, Inigo A. Müller, Martin Ziegler, André Niemeijer and Timothy Little

The Hungaroa Fault Zone (HFZ), an inactive thrust fault along the Hikurangi Subduction Margin, accommodated large displacements (~4–10 km) at the onset of subduction in the early Miocene. Within a 40 m-wide high-strain fault core, calcareous sediments display evidence for mixed-mode viscous flow and brittle fracture, including (1) discrete faults; (2) extensional veins containing stretched calcite fibers; (3) shear veins with calcite slickenfibers; (4) calcite foliation-boudinage structures; (5) calcite pressure fringes; (6) dark dissolution seams; (7) stylolites; (8) embayed calcite grains; and (9) an anastomosing phyllosilicate foliation.

Detailed optical and electron backscatter diffraction-based texture analysis of syntectonic calcite veins and isoclinally folded limestone layers within the fault core reveal that calcite grains have experienced intracrystalline plasticity and interface mobility, and local subgrain development and dynamic recrystallisation. Clumped isotope geothermometry performed on six syntectonic veins indicate formation temperatures between 69.8±6.4°C (N=22) and 89.1±13.6°C (N=14; 95% confidence interval). These temperatures exclude shear heating and the migration of hotter fluids as an explanation for dynamic recrystallisation of calcite at shallow crustal levels (<5 km depth).

Our results indicate that brittle fractures play a pivotal role in fault zone deformation by providing fluid pathways that promote fluid-enhanced recovery and dynamic recrystallisation in the deforming calcite at remarkably low temperatures. Fluid-enhanced low-temperature plasticity of calcite has major implications for fault rheology (strength) at shallow crustal levels in subduction zones containing calcareous sediments. Together, field geology, microscopy, and clumped isotope geothermometry provide a powerful method for constraining the multiscale slip behavior of large-displacement fault zones.
Silicate fault mirrors and implications for crustal fault rheology in the absence of melting

Markus Ohl
Oliver Plümper and Martyn Drury

The awareness about recurring seismic events in regions with tectonic activity is crucial for reducing future seismic hazards. To this date, Pseudotachylites, solidified frictional melts of silicate rocks, are the only unambiguous, accepted structure of fossil earthquakes. Also, natural ultra-polished fault surfaces have received scientific attention to provide possible evidence as paleo-seismicity indicators. Although silicate rocks generally respond to deformation by melting, fault mirror surfaces are reported also for silicate lithologies (Kirkpatrick et al., 2013). The fault-mirror formation in silicates raises the question what difference in deformation conditions lead to a highly polished surface, instead of melting.

We investigate high-polished, natural fault mirror surfaces developed in Rhyolites from Dixie Valley, Nevada, USA. State-of-the-art electron microscopy analyses are carried out with focus on electron backscatter diffraction and transmission electron microscopy to unravel the underlying formation mechanisms.

Nanostructural analyses show that the first few nanometers of the fault surface are covered with a composite material of an amorphous solid and clay minerals. The underlying cataclasite preserves a crystallographic preferred orientation indicating temperatures during above 600°C. During the post-deformational phase, the nanostructure recovered and formed a well-interlocked fabric with triple junctions and additional clay growth along grain boundaries. What are the rheological impacts and why does this material form a polished surface rather than a melt? We will highlight possible deformation mechanisms and phase transitions and, evaluate the implications for crustal fault rheology.

Is the Central Atlantic Rift thermal signature recorded and preserved in apatite fission tracks?

Remi Charton
Mohamed Gouiza, Quinten Boersma and Giovanni Bertotti

Apatite Fission Track (AFT) dating potentially allows for the investigation of the cooling history of the upper part of Earth’s crust. In the Central Atlantic margins, the vast majority of AFT data was obtained in the domain adjacent to the rifted margins and a large portion of the ages correspond to the early post-rift phase. To explain this, some authors have argued that the rift thermal signature outreached its rift zone, and affected the geothermal gradient of the unstretched continental crust, resulting in a reset of the AFT ages rapidly followed by cooling after continental break-up. Others have submitted tectono-climatic processes such as: i) far-field stresses, ii) enhanced erosion by climatic/landmass position change(s), and/or iii) dynamic topography.

To test the above-mentioned hypotheses, we compiled over 1000 AFT ages from the rim of the Central Atlantic Ocean. We discuss AFT spatial and temporal patterns in regards to the pre-, syn- (Triassic to Early Jurassic), and post-rift phases. Further, we run a tailored geodynamic model in order to monitor the evolution of the Apatite Partial Annealing Zone (APAZ) through time in the unstretched continental crust.

We observe a 500–600 km-wide band along the rifted margin lacking pre-rift AFT ages, suggesting a potential syn-rift reset. However, the modelling results do not illustrate any significant shifts of the APAZ in the unstretched crust. Combined, these results suggest that the cooling recorded by the AFT is the response of km-scale erosional exhumation events and were probably driven by tectono-climatic processes.
The Scotia Sea and Drake Passage between the South Pacific and South Atlantic cut through a long-lived orogen and volcanic arc and are key for paleoceanography. This gateway formed after ~50 Ma following Cenozoic back-arc basins opening that evolved above the enigmatic, isolated, South Sandwich subduction zone that initiated near the Antarctic Peninsula and Patagonia. The origin of this subduction zone is debated: some inferred minor, Late Cretaceous-Paleocene Antarctica-South America convergence, others suggest Cretaceous compression that also closed the Rocas Verdes Basin in Patagonia. Understanding Rocas Verdes Basin closure and possible Antarctic Peninsula-Patagonia convergence requires assessing whether the Antarctic Peninsula was part of East or West Antarctica, which in Cretaceous to Cenozoic times were separated by the West Antarctic Rift System. Here, we present a kinematic reconstruction of the major plates surrounding the Scotia Sea, using marine geophysical constraints from the South Atlantic and South Pacific, as well as intra-continental deformation of South America and Antarctica since Gondwana break-up. Our reconstruction suggests that the Antarctic Peninsula has been part of East Antarctica since after the Jurassic break-up of Gondwana. Our plate circuit shows up to ~170 km of ~70–59 Ma Patagonia-Antarctic Peninsula convergence, after which Scotia Sea subduction occurred in an intra-plate setting, whereby plate area consumed by subduction equaled area gained by back-arc extension. We identify the causes of the delay of 9 Myr between subduction initiation and initial extension within the Scotia Sea, as a next challenge to understand the causes of Scotia Sea opening and evolution.
Mantle flow induced by retreating and advancing slabs: insights from analogue subduction models analysed with a tomographic Particle Image Velocimetry technique

Vincent Strak
Wouter P. Schellart

Mantle flow induced by subduction of slabs that roll back is known to occur in a strong quasi-toroidal pattern that displaces mantle material from below the slab to around the lateral slab edges and toward the mantle wedge. This quasi-toroidal flow can deflect mantle plumes, transport hot mantle sources and have an upwelling component that thereby generate atypical intraplate volcanism laterally away from the subduction zone and above the mantle wedge. Slab rollback-induced mantle flow in retreating subduction zones is thus known to have a significant geodynamic impact on Earth. However, the mantle flow generated by advancing slabs remains unstudied and its geodynamic significance is unclear. We therefore conducted analogue buoyancy-driven subduction models to investigate the mantle flow generated in both retreating and advancing subduction modes. We analysed our models using a tomographic Particle Image Velocimetry (tomoPIV) technique, allowing us to compute the 3-D velocity field in a volume of the mantle. The results show that the advancing subduction mode has a slab rollover geometry that produces a mantle flow with a toroidal component displacing mantle material from the mantle wedge domain to the sub-slab domain, opposite to the retreating mode. This slab rollover-induced mantle flow may have implications on subduction of the Tethyan oceanic lithosphere below Asia and on associated surficial deformation and distribution of geochemical signatures in East Asia.
Matching the static gravity field of North America using a dynamic earth model

Jesse Reusen
Bart Root and Wouter van der Wal

The current state of the lithosphere can be investigated by using the static gravity field. Near Hudson Bay, a negative gravity anomaly is present that closely matches the area depressed by the Laurentide ice sheet during the Last Glacial Maximum. After this ice sheet melted, the ground is slowly rebounding, a process known as Glacial Isostatic Adjustment (GIA). Hence, researchers are inclined to believe that the anomaly in the static gravity field is (at least partly) linked to GIA. At the moment, the extent of the contribution of GIA to this anomaly is still disputed with estimates ranging from 25 percent to more than 80 percent.

In this study, a dynamic earth model is used to tackle this issue. This model is based on a force balance and incorporates crustal inhomogeneities, GIA and mantle convection (SMEAN2). Deflections due to flow in the mantle (dynamic topography) and GIA are of dynamic origin and corrected for before the assumption of isostasy is made. Results are matched with the static gravity field as observed by XGM 2016. The best match is found when GIA is contributing at least 60 percent, which is the case for lower mantle viscosities >10^{22} Pa s.
First results from IODP expedition 382, Iceberg Alley and Subantarctic Ice and Ocean Dynamics

Frida Hoem

Michael E. Weber, Maureen Raymo, Victoria Peck, Trevor Williams and IODP Expedition 382 scientific participants.

International Ocean Discovery Program (IODP) Expedition 382 drilled five sites east of the Drake Passage, recovering nearly 3 km of marine sediment cores. We recovered continuously deposited late Neogene sediment to investigate the history and fluctuations of the Antarctic ice sheet (AIS) as well as associated changes in oceanic and atmospheric circulation. Several identifiable biostratigraphic events and magnetic reversals show robust stratigraphic continuity of the highly resolved sediment records. The core material and data collected during the expedition has the potential to reconstruct past variability back to the mid-Miocene in sea ice, sea surface temperatures, deep water currents and oceanic and atmospheric fronts in the vicinity of the Antarctic circumpolar current. The southern Scotia Sea drill sites, located in the appropriately named Iceberg Alley, record iceberg-rafted detritus (IBRD) to assess the magnitude of iceberg flux during key intervals, while mineralogical, geochemical, and isotopic analysis of the IBRD can determine the regional sources of AIS mass loss. Dust proxy records between the Scotia Sea and Antarctic ice cores show strong correlation with possibility to extend the ocean dust record beyond the last 800,000 years. Post-cruise investigations will further improve our understanding of Southern Ocean paleoceanography, AIS dynamics and its relation to global sea level and climate change.
Glacial-interglacial ACC dynamics in the Pleistocene: Biomarker and dinocyst-based reconstructions of paleoceanographic changes in two areas of the Southern Ocean

Lena Thöle
Anja S. Studer, Elisabeth Michel, Alexandra Auderset, Simone Moretti, Alain Mazaud, Dirk Nürnberg, Henk Brinkhuis, Alfredo Martínez-Garcia, Samuel L. Jaccard, Francesca Sangiorgi and Peter K. Bijl

The Antarctic Circumpolar Current (ACC) plays a crucial role in the redistribution of nutrients, the delivery of heat to the marine-terminating Antarctic ice sheet, and the upwelling of CO2-rich sub-surface water masses in the Southern Ocean. Yet, projections of its future behaviour and associated sea level rise are hampered due to ambiguous reconstructions of past ACC dynamics and an insufficient perception of its dependence on the Southern Hemisphere westerly winds.

We reconstruct past ACC dynamics by measuring the difference in sea surface temperatures (SST) across the (modern) ACC. We report TEXL86-based SST reconstructions for two sites in the Southern Indian Ocean, located in the modern Antarctic Zone and Subantarctic Zone, respectively, enabling us to determine SST gradients since the penultimate glacial period between these two sites. We infer that the ACC may have shifted equatorwards during glacials, thereby lowering CO2 outgassing, and polewards during interglacial MIS 5e, leading to enhanced CO2 outgassing. This is corroborated by reconstructions based on dinocyst assemblages. The tight coupling between our reconstructed SST gradient and differences in the Southern Hemisphere insolation suggests a major control of the atmosphere on ACC dynamics.

As a next step, we will revisit two sites from ODP leg 189 in the Tasman Gateway in the Southern Pacific Ocean, located in the Subantarctic Zone and north of the Subtropical Front, respectively. Using biomarkers and dinocyst assemblages, we will further constrain past ACC dynamics in this area, enabling us to compare different regions of the Southern Ocean.
Studies on the role of ice-ocean interactions on past Antarctic ice sheet behavior are hindered by a limited understanding of the oceanography of the Southern Ocean and the conditions of the Antarctic Circumpolar Current (ACC). The Miocene (23.03 to 5.3 Myrs ago) experienced atmospheric CO2 concentrations varying between lower than today to those projected for the near future, and as such represents an analogue to future conditions. The Miocene experienced periods when the ice sheets were substantially retreated, but the ocean conditions during such intervals are poorly understood. Here we reconstruct Miocene paleoceanographic conditions using dinoflagellate cyst (dinocyst) assemblages and TEX86 paleothermometry in sediments from ODP Site 1168 off the west coast of Tasmania, which is supposed to be the northern limit of the ACC: the subtropical front (STF). The Miocene Climatic Optimum (MCO; 17–14.8 Ma) is characterised by warm oligotrophic waters, and represents the onset of STF-like conditions at the site, perhaps initiated by the progressive northward migration of Australia away from Antarctica. Post-MCO cooling was characterized by dinocyst assemblages suggesting a strengthening and successive southward migration of the STF, indicating a progressive strengthening of the ACC. Although the TEX86 record corroborates a general ocean cooling trend, some of the results are strongly biased by overprints, indicating changes in depositional conditions on the Tasmanian Margin. These preliminary results suggest strong oceanographic changes during the late Miocene (around 8 Ma), and a transition of Southern Ocean conditions towards modern-day-like conditions.
IODP/ICDP Poster Pitches

The last slot of this session has been allocated to the presenters of the posters related to the IODP and ICDP programmes. The presenters will have the opportunity to give a short appealing pitch on their posters.
The Miocene Climatic Optimum (MCO, ±17–15 Ma) marks a relatively warm interval within a prominent Cenozoic cooling trend and can be regarded as a suitable analogue for assessing future climate change. Proxy- (Mg/Ca or TEX\textsuperscript{-86}) and model-derived temperatures show ±3–8°C higher temperatures during the MCO than present day and atmospheric pCO\textsubscript{2} values of 500–600 ppmv.

Interestingly, large swings in climate and the carbon cycle occurred on orbital time scales superimposed on this warmth. We aim to reconstruct Climate Sensitivity and Polar Amplification of climate change across this variability. To this end, we generate high resolution bulk stable carbon and oxygen isotope data, TEX\textsubscript{86}-derived sea surface temperature reconstructions, dinoflagellate cyst paleoecological reconstructions and 13C-fractionation of dinoflagellate cysts for pCO\textsubscript{2} reconstructions across the MCO at Ocean Drilling Program Site 959, offshore West- equatorial Africa.

Results show prominent warming simultaneous to a drop in \(\delta^{18}O\) initiating at ±17.7 Ma which predates the previously dated onset of the MCO at 17 Ma. We do however see an increase in \(\delta^{13}C\) at ±17 Ma (“Monterey Excursion”). Dinocyst paleoecology is dominated by species indicating high productivity conditions during the onset of the MCO. Low resolution 13C fractionation values of Spiniferites ramosus at the onset of the MCO increase seemingly parallel to the bulk \(\delta^{13}C\) trend indicating a possible relative increase in atmospheric pCO\textsubscript{2} at that time.
Occurrence and distribution of bacterial GMGTs in an East African crater lake: Implications for their use as paleotemperature proxy

Allix Baxter
F. Peterse, L.G.J. van Bree, D. Verschuren and J.S. Sinninghe Damsté

Branched glycerol monoalkyl glycerol tetraethers (brGMGTs) are a group of membrane spanning lipids, which were initially identified in marine settings and have more recently been found in peats and lake sediments. Relatively little is known about brGMGTs, although their abundance appears to increase under warmer climate conditions, and their relative distribution in a suite of East African lake sediments has been linked to mean air temperature (MAT). To elucidate their origin and identify potential environmental factors driving their production in lakes, we here investigate their occurrence and distribution in the water column, lake sediments, and catchment soils of the East African crater Lake Chala (Kenya/Tanzania). We find that only four of seven known brGMGTs occur in the water column of the lake, predominantly below the oxycline, and that their abundance does not consistently respond to seasonal lake mixing or temperature variation on a multi-year time scale. While the concentrations of brGMGTs within the water column are relatively low, high concentrations of the full suite of brGMGTs are found in surface sediments, revealing that the majority of brGMGT production takes place there. This has important implications for their use as a paleotemperature proxy, particularly when applied to deep lakes, as the greater offset between bottom water and air temperature may introduce uncertainties. The influence of lake depth on the temperature relation will be assessed by analyzing brGMGTs in the ~250-kyr sediment record of Lake Chala in comparison to lake-level and temperature reconstructions based on independent proxies from the same sediments.
Global environmental and climate change trigger biodiversity loss at unprecedented rates. However, understanding the causes, and disentangling the relative influence of the individual drivers determining species communities is challenging, as ecosystems are simultaneously affected by variable drivers acting on different spatial and temporal scales. Paleolimnological data provide crucial information on long-term community change and their underlying drivers. Multi-proxy analysis of changes in the aquatic environments can be used to study the response of biota to repeated fluctuations in key variables. Here, we investigated the planktonic diatom communities in a continuous, 1.36 Ma sedimentary succession from Europe’s oldest and most biodiverse freshwater lake, Lake Ohrid (North Macedonia/Albania). Extended biogeochemical dataset from the DEEP site sedimentary record, recovered as part of the ICDP deep drilling campaign, and variables representing global climate variability were used to disentangle the relative contribution of basin-scale environment and global-scale climate variability in driving community patterns over time. The results show that the structure of planktonic communities was primarily determined by the basin-scale environment, particularly, nutrient availability and water temperature, but also local tectonic processes. However, since the onset of the penultimate glacial period 0.185 Ma ago, global-scale climate variability became the principal driver of the limnological parameters important for diatom community structure. Our proxy time-series illustrates how various factors at different spatial scales may determine the freshwater planktonic communities over geological time-scales. Extended periods of stable communities can be terminated by changes in climate, environmental conditions and/or lake ontogeny, leading to species extinctions and community turnovers.
IODP & ICDP News

Martin Ziegler and Timme H. Donders

We would like to inform you about new drilling proposals, important project outcomes and key papers that came out of scientific drilling projects in the Netherlands. Last year at the NAC the new membership of the Netherlands to ICDP was signed, and the renewal of IODP was approved, both for 5 year (2020-2025). The ECORD’s entry into the second phase (2019-2023) of IODP has been formalized by the signature of the ECORD Memorandum of Understanding (MoU) by its current 15 members. In parallel, ECORD has developed concrete operational plans for the next mission-specific platform (MSP) expeditions and started to plan efforts designed to consider the future of scientific ocean drilling beyond 2023.

ICDP has currently (as per December 31st, 2019) 22 members including 21 countries. The GFZ German Research Centre for Geosciences in Potsdam is the Executive Agency of the ICDP and acts on behalf of the ICDP members. ICDP fosters proposals through international workshops that assist researchers in the development of a drilling proposal. To date, more than 90 of these workshops have been funded and have resulted in a total of 48 ICDP supported and successfully executed drilling projects.

Finally, the IODP/ICDP person of the year will be announced.
Iron (oxyhydr)oxides (FeOx) such as ferrihydrite (Fh) and lepidocrocite (Lp) control the mobility and availability of key nutrients such as phosphorus (P) and silicon (Si) in aquatic systems. Conversely, the structure and reactivity of FeOx can be altered by sorption of nutrients. Their elevated concentrations in eutrophic aquatic systems may therefore have far-reaching but currently poorly understood consequences for coupled iron-nutrient cycling. Here, I present laboratory and field experiments to elucidate the effects of P and Si sorption on the structure and reactivity of FeOx under controlled and natural conditions. Advanced structural analyses (X-ray absorption spectroscopy and high-energy X-ray scattering) were combined with laboratory-based dissolution experiments (abiotic and microbial) and field experimentation. The results show that P and Si have a major impact on Lp structure, but not on Fh structure. Interestingly, despite minor structural changes Fh was still destabilized by P and Si sorption as evidenced by enhanced rates of reduction and dissolution. Differences in reactivity were not observed during field experiments in terrestrial sediments with Fe(II)- and P-rich pore-water, where similar rates of Fh crystallization were observed. These rates were much slower than those previously found in lab-based experiments, likely due to FeOx surface passivation by P. In marine H2S-rich sediment, Fh with P and Si was more susceptible to sulfidation while nutrient sorption has the opposite effect for Lp. Overall, nutrients may destabilize FeOx, a previously unexplored feedback mechanism in the eutrophication process. The novel field experimentation used here can fuel exciting new insights into environmental cycling of Fe.
Phosphorus dynamics in sediments of the Stockholm Archipelago, Baltic Sea

Niels van Helmond
Martijn Hermans, Tom Bastiaan, Wytze Lenstra, Sterre Haas, Jacob Carstensen, Daniel Conley and Caroline Slomp

Increased inputs of nutrients, mainly derived from anthropogenic sources, have led to eutrophication of coastal areas in the Baltic Sea. Bottom waters in many of these areas have become (seasonally) hypoxic or even euxinic. Insight in the processes responsible for nutrient (re)cycling, transformation and removal in coastal areas is critical for the design of management strategies to improve water quality. Recent studies suggest that a significant proportion of the phosphorus (P) inputs from land into the Baltic Sea are removed in coastal areas through burial. Particularly archipelagos appear to be very effective as a filter for P.

In this study, we identify and quantify the main P-burial phases at ten sites in the Stockholm Archipelago, capturing a range of bottom water redox conditions, from oxic to euxinic. Large differences are observed in the P contents in the surface sediments, which is attributed to the variable presence of iron(hydr)oxides, a temporary sink for P. Organic P is quantitatively the most important burial sink for P at all sites. At seven of our sites, there is no evidence for sink-switching of organic or Fe-oxide bound P to authigenic P minerals. At two sites in the inner archipelago, however, our data suggests formation of a vivianite-type Fe(II)-P mineral at depth. Furthermore, at the most seaward study site, we find evidence for a role of the manganese carbonate rhodochrosite as a quantitatively important P sink. We will discuss the implications of our findings for mitigation strategies of eutrophication in the Baltic Sea.
Resilience in coastal dune grasslands: pH and SOM effects on P nutrition, plant mycorrhizal strategies and soil communities

Annemieke Kooijman
Elly Morrien and Jaap Bloem

We tested pH and SOM effects on nutrient availability, plant strategies and soil community composition in calcareous and acidic dunes with different resilience to high atmospheric N deposition. SOM influenced biomass parameters and network complexity. However, differences in pH fundamentally affected P availability and plant mycorrhizal strategies. In calcareous dunes with low grass-encroachment, P availability was low despite high amounts of inorganic P, due to low solubility of calcium phosphates and strong P sorption to Fe oxides at high pH. Calcareous dunes were dominated by low-competitive arbuscular mycorrhizal (AM) plants, which profit from mycorrhiza especially at low P. In acidic dunes with high grass-encroachment, P availability increased as calcium phosphates dissolved and P sorption weakened with the shift from Fe oxides to Fe-OM complexes. Weakly sorbed and colloidal P increased, and at least part of the sorbed P was organic. Acidic dunes were dominated by nonmycorrhizal (NM) plants, which increase P uptake through exudation of carboxylates and phosphatase enzymes, which release weakly sorbed P, and disintegrate labile organic P. The shift in plant strategies in turn changed the soil community. Surprisingly, the bacterial pathway was more important in acidic than in calcareous dunes, possibly due to exudation of carboxylates and phosphatases by NM plants, which serve as bacterial food resource. Also, the fungal AM pathway was enhanced in calcareous dunes, and fungal feeders more abundant, due to the presence of AM fungi. In turn, soil community changes overruled differences in N cycling, which made P the most important driver.
Biogeochemical Impact of Cable Bacteria in Coastal Black Sea Sediment

Martijn Hermans
Nils Risgaard-Petersen, Filip J.R. Meysman and Caroline P. Slomp

Cable bacteria can strongly alter sediment biogeochemistry. Here, we used laboratory incubations to assess whether cable bacteria can establish in FeS-poor coastal Black Sea sediment and the impact of their activity on the cycling of iron (Fe), phosphorus (P) and sulphur (S). Pore water depth profiles of oxygen, sulphide, pH and electric potential combined with FISH analyses showed a rapid development (<5 days) of cable bacteria, followed by a long period of activity (at least 200 days). The FeS in the surface sediment showed little change with time and pore water sulphide was low (<5 µM). This implies that sulphate reduction was the main source of sulphide for cable bacteria throughout the experiment. Pore water Fe2+ reached levels of up to 1.7 mM during the incubations, due to the dissolution of siderite, a Fe carbonate mineral. Following upward diffusion of Fe2+, a surface enrichment of Fe oxides formed. Hence, besides FeS, siderite may act as a source of Fe for Fe oxides in coastal surface sediments where cable bacteria are active. Using micro-XRF, we show that the enrichments in Fe oxides induced by cable bacteria are located in a thin subsurface layer of a few mm. We show that similar subsurface layers enriched in Fe and P are also observed at field sites where cable bacteria were recently active and little bioturbation occurs. This suggests that such Fe oxide layers could potentially be a marker for recent activity of cable bacteria.
The sinking mega-delta: accelerating land subsidence poses existential threat to the Mekong delta

Philip Minderhoud
Gilles Erkens, Hans Middelkoop and Esther Stouthamer

The Mekong delta is heading towards an existential crisis as land subsidence rates are rapidly accelerating over the past decades up to ~5 cm/yr. As large parts of the delta plain are elevated less than one meter above sea level and sedimentation on the delta plain decreases rapidly due to sediment starvation in the Mekong river, these high sinking rates strongly increase rates of relative sea-level rise. This exacerbates vulnerability to flooding, salinization, coastal erosion and, ultimately, threatens 18 million delta inhabitants with permanent inundation, already in coming decades.

Delta subsidence is the result of combined effects of different drivers, both natural and anthropogenic. This presentation will provides an overview of the five years of research towards the main contributing subsidence drivers in the Mekong Delta, reserving a lead role for the groundwater extraction, but also natural compaction of Holocene deltaic sediments following delta evolution and the impact of land-use practices. Combining numerical modeling of future subsidence under different groundwater extraction pathways with eustatic sea-level rise and an elevation model of the delta, enabled to create a model of future delta elevation of the Mekong delta. These analyses reveal the alarming situation in the Mekong delta. Adequate groundwater management aimed at strongly reducing current extractions is key in mitigating accelerating sinking rates and crucial to ensure the survival of the Mekong delta. However, the window of opportunity to act is swiftly closing as the delta is rapidly running out of elevation, and therefore time.
Land loss predictions for global river deltas in the 21st century

Jaap Nienhuis
R.S.W. van de Wal

River deltas are low lying areas that will likely experience significant land loss because of relative sea-level rise. Most future projections of delta land loss, however, assume passive coastal inundation (using so-called -œbath-tub- models) and as such they tend to be unvalidated and exclude morphodynamic processes such as sedimentation. To improve future projections of delta land area change, here we apply a morphodynamic model of delta response to RSLR to all 10,000 deltas globally. We use historic RSLR, sediment supply, and observed delta land area change from 1985–2015 to calibrate and validate our model.

Applying our model using future RSLR scenarios, we find that by the end of this century deltas globally will have lost land under all RCP scenarios. Modern human influence on river delta land loss is mostly caused by subsidence and river dams, but sea-level rise under RCP8.5 will likely dominate future change. RSLR expected under RCP8.5 will force delta land loss at rates exceeding 900 km²/yr by 2100. We predict cumulative land loss under RCP8.5 up to 2100 of ~35,000 km², or about 4% of total global delta area.
Sediment yield of the Amazon and the possible impacts on the Suriname Coast as a result of its projected change

Safaa Naffaa
L.P.H. (Rens) van Beek, Frances E. Dunn and Steven M. de Jong

The Amazon river is an important source of the sediment that is transported and accumulating along the coast of Suriname. This maintains the coast line by forming mud banks along the coast preventing its erosion. Accordingly, a steady supply of sediment from the Amazon river is required especially with enhanced coastal erosion rates that may occur due to sea level rise. Simultaneously, global warming may change the hydrological regime of the Amazon and its transport capacity affecting the sediment transport to its mouth. Furthermore, the sediment fluxes are likely to change due to dam construction and land cover change.

In order to understand the mentioned intricacies and to quantify how future changes affect the mean rate of sediment supply and its variability for the Suriname coast, a spatial-temporal process-based model and a set of plausible scenarios of future changes based on combinations of (SSP-RCP) are required. Thus, two models were used, PCRGLOB-SET based on RUSLE equation to assess the local sediment supply and include the effects of land cover changes and PCRGLOB-WB to simulate the hydrological response under climate change and land use change as well as to add the trapping efficiency of the reservoirs. This model was applied to a business-as-usual scenario for the 21st century (SSP 2 with RCP 6.0) and uncertainty in the projected climate covered by 5 GCMs. For validation, the observations of six stations along the river were compared to the model estimations between (1971–2010) as a reference run to evaluate changes in sediment yield.
Quantifying fluxes through submarine canyons to the deep sea

Joris Eggenhuisen
EuroSEDS Team

Submarine canyons are conduits for transport of matter from shallow to deep parts of marine basins and oceans. The most powerful currents in canyons transport mud, sand, and even boulders, in events called turbidity currents. Quantifying the flux of sediment during turbidity currents has been a challenge to sedimentologists for decades due to the interdependence of the primary variables: The amount of sediment that can be transported depends on current strength, and the current strength is determined by the mass of sediment in transport. This challenge has been overcome through synthesis of the combined work of the Eurotank Studies of Experimental Deepwater Sedimentology (EuroSEDS) and literature. The EuroSEDS Sediment Budget Estimator (SBE) tool evaluates fluxes of sediment through submarine canyons at time scales from seconds to hundreds of thousands of years.

Now that the threshold problem of turbidity current flux has been mostly resolved, we want to ask the question: What contribution can our work make to other fields of marine research? This presentation addresses (and calls for feedback on) the potential of the EuroSEDS-SBE to be developed to quantify fluxes of other phases to the deep ocean such as organic carbon (both marine and terrestrial), nutrients, micro- and nano-plastics, Persistent Organic Pollutants (POPs) or metal compounds adhered to clay particles, salt, dissolved matter, and heat.

The aim of this presentation is to plant a seed for a diverse community of researchers who are interested in fluxes of matter through submarine canyons.
The steric component of sea-level change comprises variations in the temperature (thermosteric) and salinity (halosteric) of the oceans, which alter the water’s density, leading to volumetric variations of the water column. Although its importance is unarguable, throughout the literature there is a disagreement on how much the steric component actually contributes to sea-level change.

Here, we investigate two sources of uncertainty to steric trends, both at global and regional scale. First, we look at how the use of different temperature and salinity datasets influences the estimated steric height. For that, we analyzed 15 datasets, combining different techniques (hydrographic profiles, Argo floats and ocean reanalyses). Second, since the estimation of uncertainties for linear and quadratic trends requires the adoption of a noise model, we compare the performance of several different noise models. We find that by varying both the dataset and noise-model, the global mean trend and uncertainty from 2005 to 2015 can vary from 0.566 to 2.334 mm/yr and 0.022 to 1.646 mm/yr, respectively. This range becomes even larger at regional scales. At a global scale, the selection of datasets has a larger influence on the trend, while at a regional scale the choice of the noise model dominates the spread in steric sea-level trends. Our results emphasize the need to use an ensemble of datasets to infer steric changes, and to carefully choose a noise model.
The effect of changes in Land Water Storage (LWS), causes an increasing pressure on water demand resulting in groundwater depletion, and is thereby one of the drivers of sea-level rise over the 21st century. Up to now, the effect of LWS on regional sea-level change, under projections of future water use, has not been quantified for different climate change scenarios. This study analyzes the contribution of LWS change to regional sea-level rise by considering five Coupled Model Intercomparison Project Phase 5 (CMIP5) climate models forced by three different Representative Concentration Pathway (RCP) scenarios. For this analysis, we used LWS output of the global hydrology and water resources model PCR-GLOBWB 2 in order to project its regional sea-level fingerprints over the 21st century. Projections of ensemble means indicate a range of LWS-driven sea-level rise with larger differences in projections among climate models than between scenarios. Our results suggest that LWS change will likely contribute around 10% to the projected global mean sea-level rise by the end of 21st century. The contribution of LWS to regional sea-level rise is projected to be considerably larger than the global mean over several regions including Pacific islands, the south coast of Africa and the west coast of Australia.
Detecting non-linear sea-level variations in tide gauge records: a study case along the Dutch coast

Riccardo Riva
David Steffelbauer, Jan Kwakkel, Jos Timmermans and Mark Bakker

Tide gauges are the main source of information about sea-level changes in the Industrial Age. When looking at global mean values, century-long reconstructions produce rates between 1–2 mm/yr, while estimates over the last three decades reveal a much faster rise of about 3 mm/yr, as also indicated by satellite altimetry observations. In spite of this evidence for a recent acceleration, its quantification remains a challenging and relevant task, because results are highly dependent on the length of the record and on the reconstruction technique, whereas decision makers require clear proof to legitimise action.

While global mean results are very important to understand climate change, regional to local variations are more relevant for the purpose of planning mitigation and adaptation measures. However, mainly due to natural variability, looking at individual tide gauge stations hampers the accurate determination of linear and non-linear trends.

We analyse tide gauge records along the Dutch coast by means of advanced statistical techniques, with the main objective of determining whether and under which conditions it is possible to detect departures from secular trends. We particularly focus on how to handle noise in the natural system, which for the Dutch coast is mainly represented by local atmospheric effects and by variability in ocean dynamics in the NE Atlantic.
Coastal flooding due to tropical cyclones (TC) is one of the world’s most threatening hazards. The potential increase in the probability of these events in the future, due to climate change, necessitates the more accurate simulation of their potential hazard and resulting risks. In this contribution, we develop a computationally efficient method for more accurately simulating current and future TC hazard and risk, by incorporating large datasets of tropical cyclones within the Global Tide and Surge Model (GTSM). The first step is simulating the spatially explicit extreme sea levels for a large number of synthetic TCs. However, running GTSM models is computationally expensive, with duration of one simulation of ~5 days (1yr). Until now each TC was simulated separately, which is not feasible when modelling thousands of TCs. Here we present the development of an algorithm for the spatio-temporal optimization of the placing of TCs within GTSM in order to allow optimal use of the computational resources. This can be achieved because the region of influence of a particular TC in the model is limited in space and time. This will allow us to run a large number of TCs in one simulation and will significantly reduce the required total computation time. We investigate a large range of parameters, such as distance between cyclones, time to the landfall, category of cyclone, and others, to optimize the distribution of TC within a single model run. We expect a significant speedup relative to the sequential running of the cyclones within a single simulation.
Spring enhancement and summer reduction in carbon uptake during the 2018 drought in northwestern Europe

Naomi Smith

We used observed changes across the Integrated Carbon Observation System (ICOS) network, biosphere and inverse modeling, and remote sensing to analyse the gross primary productivity (GPP), total ecosystem respiration (TER), and the resulting net ecosystem exchange (NEE) of carbon dioxide by the terrestrial biosphere during this extreme event. We compared GPP simulated using the Simple Biosphere Model version 4 (SiB4) to independent, yet highly correlated, reductions in productivity from the remote sensing products sun-induced fluorescence and vegetative near-infrared reflectance, as well as eddy-covariance measurements taken at ICOS ecosystem sites. All products were in good agreement over GPP, NEE, TER, and soil moisture as applicable and indicated a significant decrease (SiB4: -57 TgC) in the summer uptake of carbon dioxide from the atmosphere by the region’s vegetation, covering an area of 1.6 million km². We found low soil moisture to be the primary stress factor causing this reduction in uptake.

We used the predicted NEE of SiB4 as a biosphere prior for the CarbonTracker Europe (CTE) inverse model, and assimilated data from the densely-sampled ICOS network of atmospheric sites. We found a similarly strong drop in NEE (-37 TgC) during the July-September period, offset by increased uptake during the spring when conditions were warm and sunny but soil moisture was still widely available.
Inland waters can be significant sources of greenhouse gases (GHGs; CO2, CH4 and N2O) to the atmosphere, yet they are often excluded from terrestrial GHG balances. Vast stocks of carbon stored in the Arctic tundra permafrost soils are vulnerable to mobilisation due to permafrost thawing accelerated by the amplified effects of climate change at high latitudes. The carbon released becomes available to partial degradation producing GHGs which inland waters emit to the atmosphere, thus forming a positive feedback to climate change. As N2O is the third most important GHG and hot spots of N2O emissions from tundra soils have been identified, it is also considered.

We use combined terrestrial and freshwater GHG observations from the Siberian Arctic tundra to improve understanding of the role of inland water GHG emissions. In one of the sampling years part of the study area was flooded, the effects of this were also analysed. Upscaling of CH4 and CO2 fluxes shows that while the study region remains a GHG sink, inclusion of freshwater emissions reduces its sink capacity by 28% during July. Assuming that 10% of the study area is flooded in July reduces the terrestrial GHG sink estimate by 45%, partially due to N2O oversaturation in the flood water in relation to the atmosphere whereas N2O concentrations in lakes, streams and ponds are close to zero. Overall the results show that if the Siberian Arctic tundra becomes wetter or more frequently flooded due to climate change it will significantly affect the terrestrial GHG balance.
Coastal ocean sediments form a crucial link between terrestrial and oceanic carbon cycling. In the context on unprecedented global change, (coastal) ocean sediments especially can be strongly impacted. Most studies are oriented towards a specific river outflow area or a single region only. There is a gap in understanding of carbon sedimentation between the regional and global scale. In this study, we combine a uniquely large global dataset of ocean carbon (MOSAIC, Modern Ocean Sediment Archive and Inventory of Carbon) and use Bayesian modelling to make an estimation natural carbon storage globally. We consider the carbon stocks of the -œactive- sediment layer (i.e. first 20 cm) that can be remobilized under changing environment conditions.

Statistical interpolations show which global areas which have the largest uncertainties in carbon stock estimation and can therefore most benefit from increased data acquisition and sampling. Initial results show that ocean carbon stocks in national water territories (Economic Exclusive Zones) can equal or exceed carbon stocks stored on land. These insights can elucidate patterns of region-specific carbon burial budgets and amplify the perceived importance of ocean carbon by connecting biogeochemical insights to the economic and governance spheres.
Persistent impact of the 2015 El Nino drought in the Amazon during 2016

Gerbrand Koren

The Amazon experienced major droughts in 2010 and 2015 that resulted in a reduction of CO2 uptake by vegetation and an increase of CO2 fire emissions, leading to anomalously high global growth rates of atmospheric CO2. The direct effects of these droughts on the Amazon were studied before, but little is known about their delayed impacts. We used CO2 profiles collected by aircraft over the Amazon to quantify the net ecosystem exchange for the years 2010-2017 using the CarbonTracker South America (CT-SAM) inverse modelling system. We use prior biosphere fluxes from the process-based model SiBCASA and a machine learning approach from the Max Planck Institute. Fire emission estimates were based on GFED4, the default GFAS and GFAS optimized with a CO inversion by the TM5-4DVAR system using IASI observations. In addition, we used independent CO2 column observations from OCO-2, sun induced fluorescence (SIF) from GOME-2 and near-infrared reflectance of terrestrial vegetation (NIRv) from MODIS. We find a markedly different response for the post-drought years 2011 and 2016, the first being close to the multi-year mean (a carbon sink of -0.5 to -0.1 PgC), whereas more CO2 is released in the year 2016 (estimates ranging from -0.1 to +0.3 PgC), suggesting a persistent effect of the preceding drought. Based on analysis of MSWEP precipitation data, GRACE terrestrial water storage anomalies and GLEAM moisture estimates, we hypothesize that the different response is related to the (1) timing of the preceding drought; and (2) amount of rainfall following the drought.
Information theory and hydrothermal processes

Frank van Ruitenbeek
J. Goseling, W.H. Bakker and K.A.A. Hein

Hydrothermal processes modify the chemical and mineralogical composition of a rock. These modifications can be regarded as a form of information imposed on the rock by hydrothermal processes and may potentially be quantifiable. However, there are no existing single measures to quantify these effects, nor do we have a good notion of what such a parameter should measure precisely. In this presentation, concepts from information theory are used to provide new insights into the effect of hydrothermal processes on rock and they enable the measurement and quantification of it. The Shannon entropy was used to quantify the differences in chemical compositions and shortwave infrared spectral response between altered and unaltered rocks. The results showed that the Shannon entropy can capture these differences in compositions, where hydrothermally altered rocks have lower entropies compared to their precursors. A relationship was found between heat of a magma source and Shannon entropy, where the heat of a cooling sub volcanic intrusion drove fluid circulation in the hydrothermal system causing intense alteration of rock and a decrease in Shannon entropy. We show that the Shannon entropy has potential to be used as a proxy for parts of the thermodynamic entropy of hydrothermally altered environments. The insights from this study enable new directions of research on the relationships between hydrothermal processes, entropies, information and the effects on mineralized and early life environments.
Identification of Coal Mine Locations Using Deep Learning Techniques

Logambal Madhuanand
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Coal is an important energy source for both the local and global economy. Coal mines are also a source of CH4 emissions, the second most important greenhouse gas. Monitoring CH4 emissions caused by coal mining, from space, requires exact location of coal mines. Identifying coal mines can be treated as an image classification problem wherein pixels are clustered into different Land Use/Land Cover categories based on specific features and spectral characteristics. However, open cast coal mines are composed of different features like barren land, industrial complex, storage areas, transport facilities etc. and their spectral characteristics may vary from country to country. Convolutional Neural Networks (CNN) have proved to be capable of such complex land use/land cover classification tasks. With a list of known coal mine locations, a dataset of coal mines from different countries was prepared using the Sentinel-2 satellite images with 13 spectral bands. Following the EuroSAT dataset as a benchmark, multiple image patches were created for each coal mine location. A total of 3500 coal mine image patches along with image patches of other land use/land cover features are used to train three deep learning models (VGG, ResNet, DenseNet) with different network architectures. Since all three architectures were similar in performance the simplest architecture (VGG) using small convolutional filters combined with transfer learning was chosen to reduce the computational time. An overall classification accuracy of 98% has been achieved. The model was tested on images outside the training dataset from different countries and found to perform well in identifying coal mines.
Towards an Antarctic meteorite hotspot map

Veronica Tollenaar
Harry Zekollari, Stef Lhermitte and David Tax

Meteorites contain information on the formation and evolution of the Solar System. Antarctica is the most productive region for collecting meteorites, as the visually contrasting meteorites are easily detectible and tend to concentrate at specific areas exposing blue ice. Blue ice areas act as meteorite stranding surfaces if the flow of the ice sheet and specific geographical and climatological settings combine favorably. Previously, possible meteorite stranding surfaces were identified by chance or through visual examination of remote sensing data, which has limitations in discovering new locations for future meteorite searching campaigns.

In this study, datasets are combined in a novel machine learning approach in order to estimate the likeliness of a blue ice area to be a meteorite stranding surface. Input data consists of ca. 13,000 meteorite finding locations and 2,000,000 unlabeled observations, for which the presence of meteorites is unknown. Features of the observations, such as the surface velocity, the surface temperature, and the ice thickness, are extracted from geospatial datasets. Individual features and correlations between features indicate that positive observations differ from unlabeled observations.

The classification is evaluated quantitatively with positive and negative observations, where the latter are defined after investigating fieldwork reports. With an estimated accuracy of 83%, the classification shows promising initial results. The influence of the different features on the classification does confirm the current, qualitative, understanding of the meteorite concentration mechanism and provides a quantification of how individual features affect meteorite concentration. This information will be helpful to plan future meteorite reconnaissance missions.
A low-cost mobile multidisciplinary measurement platform for monitoring geophysical parameters

Olivier den Ouden
Jelle Assink, Corné Oudshoorn, Dominique Fillipi and Láslo Evers

Geophysical studies and real-time monitoring of natural hazards, such as volcanic eruptions or severe weather events, benefit from the joint analysis of multiple geophysical parameters. However, typical geophysical measurement platforms still provide logging solutions for a single parameter, due to different community standards and the higher cost rate per added sensor. In this work, the ‘infrasound-sputnik’ is presented, which has been designed as a low-cost mobile multidisciplinary measurement platform for geophysical monitoring. The lower costs allow for high spatial sampling, to complement existing high-fidelity geophysical sensor networks. The platform is designed using digital Micro-electromechanical Systems (MEMS) sensors that are embedded on a Printed Circuit Board (PCB). The MEMS sensors on the PCB are: a GPS, three-component accelerometer, barometric pressure sensor, anemometer and a differential pressure sensor. A programmable microcontroller unit controls the sampling frequency of the sensors. A weather and waterproof casing is used to protect the mobile platform. The casing is created with a stereolithography (SLA) Formlabs 3D printer, using durable resin. Thanks to a low power consumption (9 Wh over 2.5 days), the system can be powered by a battery or solar panel. Besides the description of the platform design, we discuss the calibration and performance of the individual sensors. It is found that the selected MEMS sensors are in good agreement when compared to high-fidelity equipment. Moreover, there is good consistency between the individual MEMS sensors.
Sediment Deposition Quantification in Tropical Regions

Sobhan Emtehani
Victor Jetten and Cees van Westen

Floods and associated landslides account for a large number of natural disasters and affect many people wherever they occur. Sediment-free floods are rare, and in most cases, floods carry notable amount of sediments. Mass movement processes also transport a huge amount of sediments within a short period. The mobilized sediments cause significant costs and damages as soon as they reach urban or rural environments. These damages and costs include (but are not limited to) cleaning or dredging cost, damage to contents of buildings (e.g. furniture, electric appliances, etc.), and blockage of drainage and sewer systems which get filled up with sediments. Dominica is significantly vulnerable to tropical storms and hurricanes. It is a mountainous island covered by tropical rainforests and located about halfway between the French islands of Guadeloupe and Martinique in the Eastern Caribbean sea. Hurricane Maria made landfall on this island on September 18th, 2017 and it heavily impacted the housing, transport infrastructure, tourism, agriculture, and education sectors. The intense rainfall caused flash floods, landslides, and debris flows resulting in a massive amount of sediments being deposited in urban and rural areas. The overall damages and losses are estimated at approximately USD 1.3 billion. Dominica’s Ministry of Public Works reported that the total cost related to deposition of sediments (e.g. dredging rivers, cleaning streets and main roads, and clearing of airports and seaports) exceeds USD 92 million which is a considerable portion of total damages and costs. This implies the significance of the risk imposed by sediment deposition. This study aims to achieve a reliable sediment deposition quantification which is useful for assessing the risk of such events. Three methods were proposed for this purpose. First, the sediment deposition height was determined in the field and the average height was estimated. Second, deposition surface was simulated using trend interpolation and DEM was subtracted from that to get deposition height. Third, the deposition height and extent were determined by calculating the difference in elevation using pre- and post-event drone and LiDAR flights. The results were compared with each other and the findings of in-situ investigations of deposition. They indicate similar deposition heights and volumes, however, the pattern and extent of deposition are not the same. The practicality of the third method depends on the availability of data, but when data is available its outcomes provide a reliable assessment of sediment deposition volume. However, this cannot be trusted unless an in-situ investigation is performed.
Spatio-temporal patterns of debris-flow erosion and deposition in the Illgraben torrent

Tjalling de Haas
W. Nijland, S.M. de Jong and B.W. McArdell

Debris flows can grow greatly in size and hazardous potential by eroding bed material, but effective hazard assessment and mitigation is currently hampered by limited understanding of erosion and deposition dynamics. We have collected high-resolution pre- and post-flow topography with drone-based photogrammetry in the Illgraben channel in the Swiss Alps. We present erosion and deposition patterns as a result of six debris flows and intensive subcatchment activity over a 3.3 km long unconsolidated reach with check dams, and interpret these erosion and deposition patterns with in-situ flow measurements. We show that the spatio-temporal patterns of erosion and deposition in natural debris-flow torrents are highly variable and dynamic. We identify a memory effect where erosion is strong at locations of strong deposition during previous flows and vice versa. Large sediment inputs from subcatchments initially result in new channel erosion through the subcatchments deposits and at the same time upstream deposition as a result of backwater effects. It is generally believed that erosion increases with debris-flow magnitude, but we show that there is a limit to debris-flow bulking set by channel geometry. Large flows that overtop their channel deposit large amount of sediment in levees and on overbanks, leading to net deposition despite strong thalweg erosion, and thus a decrease in flow volume. These findings provide key guidelines for flow volume forecasting, emphasizing the importance of memory effects and the need to resolve both erosion and deposition for accurate flow volume estimation.
Detection of Landslides in Remote Areas in Canada using the Landsat Satellite Image Archive

Steven de Jong
Axel A.J. Deijns, Alexandre R. Bevington, Marten Geertsema and Scott McDougall

Landslides in northern British Columbia repeatedly occur and magnitude and frequency will probably increase due to global warming, permafrost degradation and shifting precipitation patterns. The landslides do damage to the forest resources and might dam rivers causing floods and risk on flash floods in case of dam breaches. We used the Landsat satellite image archive, 1985 to 2017, to detect and date the landslides in the Bucking horse River area in a semi-automatic way. Images were selected with low cloud cover and between 1 April and 30 September avoiding winter snow cover. When landslides occur in remote regions, they often leave scars of bare rock and soil for a period of time which are detectable in timeseries of NDVI spectral indices. A harmonic function was fit to the mean NDVI values over time accounting for the seasonal cycle of the NDVI. A drop in the harmonic fit was used to detect possible landslides, each one was visually checked whether it was a true landslide or whether there was another reason for the drop in NDVI value. The date of landslide was deduced from the satellite image acquisition dates before and after the drop. We identified 66 landslides and for 85% of the landslide the automatic dating was correct. The method is portable but the pixel size puts its limits.
Satellite constellations and satellites in geosynchronous orbits are able to monitor the Earth’s surface multiple times per day. When such satellites carry radar instruments, such as ESA’s candidate mission HydroTerra, this opens up opportunities to monitor (eco) hydrological processes which are currently difficult to monitor. Examples could be (1) early detection of anomalies in daily cycles of vegetation water content (VWC) as a result of water stress, and (2) spatio-temporal measurements of rainfall interception, an important part of the water balance. However, first, we need to understand the effect of internal and external canopy water on sub-daily fluctuations of radar backscatter.

An intensive field campaign was conducted in Florida, USA, in the spring of 2018. A sweet corn field was scanned every hour with a truck-mounted polarimetric L-band scatterometer, from sowing to harvest. We installed sensors just outside the radar footprint to measure soil moisture, plant hydraulics, and water droplets on the canopy every 15 minutes. In addition, seasonal and sub-daily variations in internal canopy water were measured through regular destructive sampling. Here, results will be presented from this field campaign, particularly focusing on the sub-daily measurements.
Adjustment of rockwalls to deglaciating conditions and warming climate – examples from an alpine valley

Daniel Draebing
Till Mayer, Benjamin Jacobs and Samuel T. McColl

Paraglacial adjustment of rock slopes is characterized by enhanced sediment supply during initial stages of deglaciation followed by an exponentially decline as deglaciated slopes become stabilized. Currently, most Alpine environments are affected by glacier retreat due to a warming climate and an increase of sediment supply in form of rockfall could be expected. In our study, we will quantify rockfall in a small Alpine valley, Hungerli Valley (CH), and use our results to test the paraglacial concept. For this purpose, we (i) reconstruct glacier retreat history based on existing LGM ice extent models, mapping of moraines and analysis of historic photos, (ii) quantify rock fracture damage using laboratory-calibrated seismic refraction tomography, (iii) model permafrost distribution, (iv) model patterns of frost weathering using physical based numerical modelling, and (v) quantify rockfall volumes by applying terrestrial laserscanning. All data is collected on rockwalls surrounding a small cirque glacier with increasing distance to the glacier. Applying a space-for-time substitution using glacier retreat history reveals that rockwall retreat rates are increased in proximity to the glacier where rockwalls experience permafrost and a high frost cracking intensity. In conclusion, our data suggest a synergy of paraglacial processes, frost cracking and permafrost thaw in preparing and triggering rockfalls. This synergy follows an altitudinal gradient that moves upwards with glacier retreat, permafrost thaw and frost cracking trajectories.
Feedbacks between plants and geomorphic processes play a key role for the configuration and evolution of fluvial and coastal landscapes. Similar biogeomorphic feedbacks shape alpine landscapes but have been considerably less studied. Yet, they play a key role for alpine sediment transport and ecosystem resilience in a changing climate.

Based on examples from glacier forelands and alpine hillslopes in the Swiss Alps and the Southern Alps, New Zealand, this study presents an overview on (1) how plants can affect geomorphic processes on alpine hillslopes, (2) under which geomorphic and ecologic conditions feedbacks between plants and geomorphic processes can occur and (3) how biogeomorphic feedbacks shape alpine glacier foreland landscapes and ecosystems.

(1) Prostrate, densely growing alpine ecosystem engineer plants limit soil erosion processes, stabilize hillslopes by strong roots and can promote the development of landforms. (2) Plant species with adapted traits can affect geomorphic processes under certain process magnitude and frequency conditions, termed ‘biogeomorphic feedback window’. (3) In alpine glacier forelands, ecosystem engineer plants decrease sediment transport and promote soil and vegetation development once high-magnitude geomorphic processes conditioned by glacier retreat cease. These biogeomorphic feedbacks stop when the landscape is stabilized and mature ecosystems have developed.

Thus, temporal and spatial extent of biogeomorphic feedbacks possess a strong impact on the configuration and evolution of alpine landscapes and ecosystems.
Modelling the dynamicity of past source-to-sink systems: an example from Morocco

Remi Charton
Giovanni Bertotti and Jonathan Redfern

Paleo-altimetry, stratigraphy, and sediment budgets may be evaluated with numerical models commonly referred to as ‘Landscape Evolution Models’ (LEMs). Source-to-sink studies have limitations: the spatial and temporal resolution of each component for instance or the quality of the sedimentary record. This renders the examination of past source-to-sink systems a challenging task, however the range of possible outcomes can be partially addressed by building multiple models using process-based modelling tools such as LEMs. In Morocco, the distribution of eroded sediments in the rifted margin is controlled by the drainage systems connected to the hinterland. However, most of paleo-river systems were not fossilised or are not exposed, resulting in a lack of data for their size, sediment flux, and entry-point position.

In order to better understand Moroccan Mesozoic source-to-sink systems, we use the LEM ‘pyBADLANDS’ code (Salles et al., 2018). We input the timing, location and amplitude of exhumation events, as documented by low-temperature thermochronology data. Two time periods are investigated, the Early Cretaceous and Early Jurassic, and models are generated for the Anti-Atlas belt located in central Morocco.

Results show the control of the Anti-Atlas on sediment routing. During the Early Jurassic, the region formed a positive relief. Numerous rivers were exporting eroded material from the belt into surrounding basins in virtually every direction. The relief was eroded away prior to the Early Cretaceous. New fluvial systems were established, cutting through the Anti-Atlas belt and bringing eroded material from the south into the Atlantic passive margin to the north, until the Aptian-Albian.
Late Quaternary landscape evolution of the Kula Badlands: 
LEM LAPSUS sensitivity to lithological and tectonic drivers

Jeroen Schoorl
Selçuk Aksay and A. (Tom) Veldkamp

How did the contemporaneous Mediterranean Badlands came into existence? Using computer simulation (LEM: Landscape Evolution Modelling) this research mainly focusses on the temporal and spatial erosion and sedimentation dynamics in a Mediterranean Badlands context, in order to finally mimic the, still under investigation, sedimentation history, stratigraphy and geochronology of the Kula Badlands in Turkey (NWO ALWOP.221).

The main objective of this research is to simulate the sensitivity of LEM LAPSUS to some relatively unexplored controlling driving factors: (i) stratigraphy (lithological erodibility differences, and the 3D configuration) and (ii) regional tectonics (movements and weakness zones) for a intensively eroding landscape in Western Turkey: the Kula Badlands. The relative contribution of these factors is estimated based on scenarios, and their interactions with standard parameterisations are simulated at different temporal and spatial resolutions and extents.

Although their separate as well as their joined effects are spatially significantly different, even though they might vary an order of magnitude, both simulated factors play a role individually and together in shaping the landscape in the Kula Badlands. Consequently, these results infer, depending on the complexity of the tectonic and stratigraphic setting of a particular Badlands, a need for mapping and understanding the 3D stratigraphy of the eroding parent materials at an adequate resolution.
Connectivity has been embraced by the geosciences community as a useful concept to describe hydrological functioning and sediment movement through catchments. Mathematical modelling has been used for decades to quantify and predict erosion and transport of sediments. Being intrigued by both models and the connectivity concept, as a group of modellers we aimed at investigating what different models could tell us about connectivity. Therefore, we evaluated the response of contrasted models to landscape connectivity features. A total of 53 scenarios were built with varying field sizes and orientations, as well as the implementation of soil conservation measures. These scenarios were simulated, for two rainfall intensities, with five event- and process-based water and soil erosion models – EROSION3D, FullSWOF_2D, Land Soil, OpenLISEM and Watersed. Results showed that rainfall amount plays the most important role in determining relative export and connected area of runoff and sediment in all models, indicating that functional aspects of connectivity were more important than structural connectivity. There was no overall agreement between models regarding the effects of field sizes, crop allocation pattern, and conservation practices; agreement was also low on the spatial patterns of connectivity. This overall disagreement between models was unexpected. The results of this exercise suggest that the correct parameterization of runoff and sediment production and of routing patterns may be more important than model structure. Our results also suggest that structural connectivity indices may not suffice to represent connectivity in this type of catchment (relatively simple and monotonous land cover).
The impact of altitude on dust emissions and aeolian processes

Cynthia van Leeuwen
L.H. Cammeraat, W. Fister, H.C. Vos and N.J. Kuhn

Aeolian processes are responsible for shaping a large variety of landscapes. Wind sculptures the landscape by eroding, transporting and depositing material. These processes are an important agent in regions with sparse vegetation. However, these processes are not extensively studied at higher altitudes. We carried out a field experiment along an altitude gradient in Switzerland between 330 m and 3400 m altitude to study the critical threshold friction velocities at which sediment entrainment starts. This research used the Portable In-Situ Wind Erosion Lab (PI-SWERL) and previous research showed that the PI-SWERL was able to accurately measure the emission potential of a large variety of surfaces and land forms. We specifically quantified the threshold friction velocity for PM10 emission for two materials of interest: a fine sand from the Netherlands (NS1) and a loamy sand from Denmark (DS1). For NS1 comparable thresholds were identified around an average of 0.33 m s⁻¹, and 0.25 m s⁻¹ respectively at 330 m altitude. The altitude gradient yielded a decrease of approximately 30% in air density, which significantly impacted the threshold friction velocity for PM10 emission, and corresponding emission fluxes. Indeed, a negative linear relationship was found between the threshold friction velocity and air density.
How tides and rivers shape levees and crevasses: Holocene overbank phases of the Old Rhine river, the Netherlands

Harm Jan Pierik
Jelle I.M. Moree, Lonneke Roelofs, Marcio Boechat Albernaz, Antoine Wilbers, Bert van der Valk, Marieke van Dinter, Tjalling de Haas and Maarten G. Kleinhans

Building land by natural levee and crevasse splay sedimentation can help improving flood safety around estuaries, yet their formative controls are not well known. We here focus on the Old Rhine estuary (active ca. 6500–1000 yr BP) and compiled large amounts of geological data added with new dates to reconstruct levee and crevasse evolution over time. We correlated these to changing boundary conditions and used numerical modelling to test the inferred mechanisms.

Orientation, abundancy and size of crevasse splays indicates an increasing tidal influence towards the estuary mouth. Field data shows that large-scale crevassing started when floodplain vegetation changed from a reed swamp to an alder swamp after 5000 BP. Back then, the tidal influence was large because the coastline was relatively close and the mouth was wide. Our model results confirm these observations by showing that low densities of floodplain vegetation (i.e. wood instead of reed) and high-frequency water level fluctuations trigger most abundant crevasse formation. In the middle of the channel belts’ lifespan around 3800–3000 cal yr BP, – the thickest and siltiest levees formed. In line with our model results, this coincides with infilling phases of the mouth, reducing the tidal backwater effect that feed the crevasses and as well as with increased river discharge from upstream.

These insights provide important clues on what could be the effect of human induced changes in land use, sediment load or river discharge on sediment distribution in vulnerable wetland landscapes.
Morphological response of dam-passing channels to sand suppletion

Marijn van der Meij
G.J. Maas

Channelized and dammed lowland rivers are currently restored to improve their ecological value and water storing capacity. However, remeandering of the streams and removal of dams is not always possible due to conflicting interests in the surrounding catchment. An alternative can be found in the development of relatively small dam-passing channels. These channels do not always meet their ecological targets because often the desired sediment dynamics are disturbed by the channel design, and extra measures in the form of sand suppletion and placement of obstacles in the stream are required to adjust the sediment dynamics of the stream. Monitoring of these dynamics is essential for developing sustainable dam-passing channels and sediment management strategies.

We performed a sand suppletion experiment to mitigate vertical erosion of the bed of a dam-passing channel located in the river Overijsselse Vecht near the town of Ommen. We monitored the morphological response by measuring topography and bathymetry before and after the sand suppletion using lidar and GPR measurements and by monitoring the suppletion using a time-lapse camera. Our results show that the morphology of the channel is highly dynamic. The sand suppletion compensated only part of the vertical erosion. Sandbanks developed around wooden obstacles, but downstream of these structures deep incision occurred. The current channel design does not show the intended morphological behavior and the applied management measures compensate only part for the natural sediment dynamics of the channel. These lessons can aid in the design of other dam-passing channels.
Early detection of stress changes and failure using acoustic measurements

Aukje Veltmeijer
Milad Naderloo, Auke Barnhoorn and Kees Wapenaar

Local stress changes in a rock can cause irreversible damage by the formation of micro-cracks. The first formed micro-fractures are precursors to the real large-scale failure of the sample. Therefore, the detection of the transition from the elastic to the inelastic deformation is crucial for measuring the formation of micro-cracks and predicting the imminent failure. During fracturing, the strain energy is also released as an acoustic emission (AE). In the laboratory the failure process can be measured using AE (passive) and ultrasonic (active) methods combined.

In this study within the DeepNL project, we used an ultrasonic pulse transmission method to record the change in waveform across this transition during the fracturing process in combination with AE monitoring. The most important observation we have made so far is that we can see when the very first micro-fractures are formed from the changes in the wave amplitude of the direct wave and even more so in the characteristics of the scattering coda of the p-wave. However, s-waves are expected to be more sensitive to material changes, therefore, we also investigate the change of s-waves during fracturing. We use simultaneous acoustic emission monitoring and active acoustics to determine the relationship between (micro-)seismicity and the precursory signature of acoustic measurements. Additionally, results from uniaxial tests show that the cumulative count of AE can be related to the failure phase.
A particle method strategy to estimate subsidence induced by a high-dimensional disc-strain model for reservoir compaction

Samantha Kim
Femke Vossepoel, Ramon F. Hanssen, Marius Wouters, Rob Govers and Esther Stouthamer

This work is part of the “Subsidence” DeepNL project which aims to identify subsurface drivers of subsidence above the Groningen (the Netherlands) gas field and to forecast future subsidence. The hydrocarbon extraction in Groningen induces a pressure reduction in the gas reservoir which triggers compaction and land subsidence. This deep-subsurface process is modeled by a disc-shaped reservoir model, which is a superposition of individual nuclei of strain based on the Geertsma’s approach. We estimate the surface deformation and the strength of the disc strain using a particle method. We apply the method to one single nucleus of strain at 3 km depth and extend to a disc-shape geometry. Synthetic experiments with a single nucleus of strain and with discs of varying sizes, 2.2 km to 13.3 km diameter, at 3 km depth are performed to assess the performance of the method for an increasing degree of complexity. Sequential Importance Resampling prevents the sample degeneracy when the number of nuclei increases. Adding a jitter noise in the resampling step avoids an impoverishment of the ensemble values. The results indicate that the method estimates the surface deformation and the strength for a large number of sources and for a relatively small effective ensemble size. In further investigations, localization can provide an additional means to deal with increasing dimensions and a relatively small ensemble size.
Quantifying grain contact and grain volume stress-strain fields in simulated sandstone: a high-resolution FEM approach

Takahiro Shinohara
Cedric A.P. Thieulot and Suzanne J.T. Hangx

Fluid extraction from subsurface reservoir sandstones frequently results in surface subsidence and induced seismicity, such as observed in the Groningen Gas field (the Netherlands). The cause lies in reservoir compaction driven by the increase in effective overburden stress. Deformation of sandstone includes instantaneous elastic deformation, inelastic, time-independent processes, such as critical grain breakage and/or compaction of intergranular clay rims, creep due to stress corrosion and pressure solution. However, no physics-based models exist to predict inelastic reservoir compaction under in-situ conditions, limiting the ability to evaluate the impact of reservoir exploitation. Deformation is driven by stresses transmitted across grain-to-grain contacts. Therefore, it is key to relate the grain-scale deformation mechanisms to grain-scale stress distribution, grain strength and deformation rate. We performed 2D FEM simulations on sandstone aggregates, consisting of quartz, feldspar and/or intergranular clay, with porosities in the range 10–25%, up to 2% volumetric strain. Our simulations showed significant stress concentrations at contact edges, which increased in magnitude with increasing porosity. Intergranular clay rims with a thickness of up to 0.5% of the grain diameter significantly reduced the stress concentration between quartz-quartz contacts, while also reducing the macroscopic Young’s modulus by up to 80%. A more extensive zone of tensile stress is observed within feldspar grains, compared to quartz grains. Our results suggest that composition plays an important role in controlling the grain contact and volume stress-strain behavior, which could lead to over/underestimation of the magnitude of local stress, hence the driving force for grain-scale deformation, if not adequately accounted for.
The province of Groningen in the north-east of the Netherlands is subjected to induced earthquakes caused by the depletion of a large onshore gas field. The dense network of borehole stations continuously record seismic activity over the gas field since 2015. The moment tensor solution of the strongest events and the hypocenter location of most induced events are estimated from the recorded waveform data.

The KNMI research earthquake catalog consists currently of 515 relocated events. It is observed that the relocated events correlate well with fault-structures and are confined to the gas reservoir. The newest implementation of the hypocenter method based on the equal differential-time formulation (EDT) by Anthony Lomax is currently operational for a 3D velocity model for Groningen. In an early attempt, the KNMI-EDT methodology included local 1D velocity profiles. It is found that the implementation of the 3D velocity model considerably helps to improve the hypocenter resolution of induced earthquakes in Groningen.

Full moment tensor inversion results, using a full waveform probabilistic optimization method (Pyrocko/Grond), show normal faulting along steep (50–70 degrees) dipping faults. These results enable a direct connection with existing faults at reservoir level. Most reactivated faults do show a small throw. Some events show a large (40–50%) negative isotropic component, indicating a volume decrease that is expected in a compacting environment.
Probabilistic earthquake source localization can be tedious and computationally expensive with conventional schemes such as a simple grid search or Metropolis-Hastings. To reduce these costs, in this study, we use the Hamiltonian Monte Carlo (HMC) scheme to sample the posterior. The scheme is known to have better sampling density and faster convergence which results in fewer iterations and well-distributed posteriors. We apply the scheme to a 2D Groningen velocity model which is known for its induced seismic events. Synthetic travel times are computed by means of the fast marching method and we perform ray tracing to the model that gives the travel time and wavepaths from an artificial source location to the receivers. Applying the HMC scheme to the synthetic data involves iterative evaluation of the travel-time misfit (or likelihood) associated with different source locations. Importantly, contrary to conventional Metropolis-Hastings’ schemes, the posterior is not probed randomly, but the sampling is guided by the gradient of the posterior. Consequently, we need less iterations to obtain a good estimate of the probability density of the source locations.
Since the 1970s, the field of seismic tomography has attempted to resolve the Earth’s structure using information contained in seismograms. Early efforts picked individual seismic phases and used ray theory approximations of seismic wave propagation. Modern seismic tomography uses the full seismogram by computing wave propagation commonly using finite difference, finite element and spectral element techniques. However, there is a large computational cost associated with full waveform simulation, requiring the use of supercomputing clusters.

By taking advantage of recent advances in the field of Localized Model Order Reduction Methods we will show that we can significantly reduce the computational time while maintaining a satisfactory level of accuracy. This will be demonstrated in the context of a standard seismology spectral element discretization for wave propagation. The Localized Model Order Reduction technique is able to “compress” this discretization, dramatically reducing the degrees of freedom using a criteria to select important features to retain in the compressed approximation. In our case, we use the frequency band limited nature of seismograms to maintain accuracy within a frequency range of interest.

We will present early test cases of this joint research between Utrecht and Twente as part of the DeepNL project, as well as areas of application in the tomographic reconstruction and monitoring of the Groningen gas field.
Dynamic and quasi-dynamic modelling of earthquake sequences from zero to three dimensions: choose model complexity as needed

Meng Li
Casper Pranger and Ylona van Dinther

Understanding earthquake sequences is fundamental for the research of induced and natural earthquakes and may ultimately help to better assess long-term seismic hazard. Numerical models are well-suited to overcome limited spatiotemporal observations and improve our understanding on this topic. However, large models in 3D are still computational time and memory consuming. Moreover, this may not be optimal if the aspects of lateral or depth variations within the results are not needed to answer a particular objective. This inspired us to investigate the advantages and limitations of various dimensional models by simulating seismic cycles on a strike-slip fault with rate-and-state friction law in 0D, 1D, 2D and ultimately 3D.

We developed a C++ numerical library called GARNET to deal with the various dimensional models in one simulator. By adding dimensions, we simulate a more detailed structure of the seismic cycle. The higher dimensional models present both the validity and the limitations of the lower dimensional ones. For example, inertial waves are not possible to present in 0D while a quasi-dynamic radiation damping term can be added here instead. Another example is that due to lack of grid extension along the fault, both 0D and 1D model fail to reveal an earthquake nucleation phase. However, some important observables, such as the seismic cycle period, maximum/minimum stress and slip rates, are calculated accurately in lower dimensional models, which are much faster than higher dimensional models. We also implemented and compared quasi- and fully dynamic models in the same way. This could provide us with guidance to identify the appropriate model complexity for various problems. We will also present 3D modeling results, which will be compared to their 2D equivalent. Finally, we present our results for the SCEC SEAS benchmarks BP3 and 4 and compare them to other participating codes (Erickson et al., 2019).
This study investigates the effect of erroneous parameter values for state and parameter estimation using data assimilation. The numerical model chosen for this study solves the van der Pol equation, a second-order differential equation that can be used to simulate oscillatory processes, such as earthquakes. In the model, discrepancies in the parameter values can have a significant influence on the forecasted states of the model, which is even more significant if its behaviour is highly nonlinear. When observations of the state variables are assimilated to update the parameters along with the state variables, this improves the quality of the state forecasts. The results suggest that corrections in the model parameter not only recover the actual parameter values but also reduce state-variable errors after a certain time period. However, data assimilation that updates the state variables but not the parameter can lead to erroneous estimates as well as forecasts of the oscillation. Since the study is performed on a simplified nonlinear model framework, the consequences of these results for data assimilation in more realistic models remains to be investigated.
Posters

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1. **Steven Knoop** Doppler wind lidar activities at Ruisdael Observatory, station Cabauw
2. **Bas van de Wiel** Fruit frost prevention using wind machines
3. **Herman Russchenberg** Observations of ice particle growth processes in clouds using spectral polarimetric radar data
4. **Chiel van Heerwaarden** Shedding light on cloud shadows
5. **Fredrik Jansson** The DALES model and its applications in the Ruisdael project
6. **Hugo Denier van der Gon** The Ruisdael Observatory Rotterdam – monitoring atmospheric composition from a complex industrial-urban environment
7. **Arnoud Apituley** Overview of activities during the 2019 TROpomi vaLiIdation eXperiment (TROLIX'19)
8. **Jesse Assink** Influence of Atmospheric Boundary Layer Turbulence on a Micro-barometer Array for Infrasound Detection
9. **Michiel van der Molen** Loobos: 24 years of flux measurements and a new start
10. **Bart Schilperoort** Measuring and tracking nighttime inversions within a forest canopy
11. **Wim Som de Cerff** Ruisdael Data Platform for FAIR sharing the Ruisdael data
12. **Arnoud Apituley** The Role of Cabauw in Ruisdael Observatory
13. **David Donovan** Ruisdael uv depolarization lidars
14. **Douwe van Hinsbergen** Arc-type magmatism due to continental-edge plowing through ancient subduction-enriched mantle
15. **Eszter Bekesi** Active deformation of the Los Humeros caldera floor inferred from Envisat and Sentinel-1 InSAR
16. **Colin Reeves** African geology, the Bouvet mantle plume and the early opening of the Gondwana margins
17. **Arijit Laik** Collision and Subduction: towards building large scale 3D models
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Counter-gradient Convective Momentum Transport in the Large Eddy Simulations of subtropical Clouds

Vishal Vijay Dixit
Louise Nuijens and Kevin Helfer

It is well known that atmospheric moist convection transports heat and water vapour upwards from the surface and drives planetary scale circulations. It is less clear if it also transports horizontal momentum upwards and if so how much? This has remained an enigma as classically used climate models do not resolve the scales of moist convective motions and it is a challenge to observe the associated small scale pressure gradients for variety of convective situations.

We utilize unique multi-day large eddy simulations run over the tropical Atlantic under German HDCP2 project to evaluate the convective momentum transport (CMT) effects by shallow convection. We show that the CMT flux is counter-gradient in the cloud-layer and acts as a cumulus friction on the surrounding flow. The traditional mass-flux parametrization of climate models captures the right sign of the counter-gradient momentum transport but underestimates it. The analysis of the momentum flux budget allows to separate the impact of mean flow shear and convection on the transports. In the cloud layer, the counter-gradient flux is driven by shallow convection. This mechanism is likely not represented adequately in climate models.
Surface Moisture Exchange Under Vanishing Wind in Simulations of Idealized Tropical Convection

Wouter Mol
Chiel van Heerwaarden and Linda Schlemmer

Under radiative-convective equilibrium (RCE), an idealized representation of the tropical atmosphere, surface moisture fluxes drive convection, while convectio-driven winds regulate surface fluxes. Most simulations of RCE do not resolve the boundary-layer turbulence that drives near-surface winds due to too coarse grid spacing and instead parameterize its effects by enforcing a minimum wind speed in the computation of the ocean-atmosphere exchange. We show from RCE simulations with fully resolved boundary-layer turbulence that capturing wind dynamics at low speeds impacts the spatially averaged surface moisture flux, as well as its spatial distribution. A minimum wind speed constraint of only 1 m s\(^{-1}\) leads to \(~10\%\) increase in spatially averaged surface flux in the evolution towards RCE and reduces the surface flux differences between windy and calm regions with more than a factor of two. Hence, the ability of simulations to let wind vanish is key in representing the wind-induced surface heat exchange feedback and is potentially important in convective self-aggregation.
The Earth Clouds and Radiation Explorer (EarthCARE) Satellite: a Multisensor Cloud, Aerosol, Precipitation, and Radiation mission

David Donovan
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The Earth Clouds Aerosol and Radiation Explorer (EarthCARE) mission is a combined ESA/JAXA mission to planned for launch in 2022. The mission consists of a cloud-profiling radar, a high-spectral resolution cloud/aerosol lidar, a cloud/aerosol imager, and a three-view broadband radiometer covering both long and short-wave bands. EarthCARE will extend the record of active space-based cloud and aerosol measurements started by CloudSat and CALIPSO. The data will be used in multiple ways ranging from cloud-aerosol model evaluation studies, to cloud microphysical property parameterization development, to radiative closure studies, and even data assimilation activities. In this presentation, an overview of EarthCARE will be given, describing the scientific motivation of the mission and highlighting the multi-sensor nature of the level-2 product chain. Particular attention will be given to the advanced simulation work aimed at facilitating the development and implementation of the level-2 algorithms.
During the PAMARCMIP campaign (March 10 to April 8, 2018) a proton-transfer-reaction mass-spectrometer (PTR-MS) was operated during 13 research flights from Station Nord (81°43′N, 17°47′W), Greenland, on board of the POLAR 5 aircraft. A full mass spectrum analysis revealed approximately 100 compounds (hydrocarbons, oxygenated organics, halogenated organics, peroxy-nitrates and dimethyl sulfide) with periods above the limit of detection (LOD), which was typically 2–20 pmol/mol and mostly limited by instrumental contamination. The highest mixing ratios of ~600, 400, and 150 pmol/mol were detected for acetone, methanol and methylethylketone, respectively. Benzene, toluene, and acetonitrile are combustion tracers for fossil fuel (only benzene and toluene) and biomass burning. Typical background mixing ratios in the Arctic atmosphere were 40, 10, and 25 pmol/mol, respectively. Mixing ratios up to 100 pmol/mol of acetonitrile revealed biomass burning pollution in April 2018 at altitude above 4000 m. The low ratio benzene/toluene indicated the absence of fresh pollution, except during a few plume encounters. Surprisingly high levels of isoprene around 20 pmol/mol indicated biogenic activity. Sources, sinks, transport and reactivity of the observed organics in the Arctic atmosphere will be discussed.
The coupling of clouds, convection and circulation: Insights from the research vessel Meteor during the EUREC4A field campaign

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The trade winds – being the inflow branches of the large-scale Hadley circulation – modulate ocean currents and upwelling, turbulent fluxes at the sea surface and its temperature, which are all crucial for atmospheric processes, including clouds and convection as well as their organisation. On the other hand, clouds and convection may modulate the trade winds via momentum transport, slowing down and turning the wind. To advance our understanding of such interplay between clouds, convection and circulation and their role in climate change as well as the wind’s potential for renewable energy production, the EUREC4A field campaign takes place from 20 January until 20 February 2020 in the North-Atlantic trades. During that period, numerous aircrafts, ships and other means are deployed in and around Barbados.

During EUREC4A, we deploy two wind lidars onboard the research vessel ‘Meteor’ to continuously measure wind profiles. Together with other measurements (including radiosonde soundings, cloud radar measurements and satellite overpasses), these will give us a complementary picture of the wind and cloud conditions in the trades. In this presentation, we give a preliminary overview of these findings.
Methane is the second most important greenhouse gas after CO2. Unlike CO2, methane has an atmospheric lifetime of only 10 years. Hence, reducing methane emissions offers an impactful way to mitigate climate change on a short timescale. Discovering which facilities are the biggest emitters offers easy targets for reducing methane emissions. TROPOMI is a Dutch/ESA satellite remote-sensing instrument launched in October 2017. It provides daily global coverage of methane concentrations at 7 km x 5.5 km resolution. The Canadian company GHGSat operates a satellite that observes methane for select 12 km x 12 km domains, at 50 meter x 50 meter resolution. Recently, the synergy between TROPOMI and GHGSat was used to discover a large gas leak in Turkmenistan that was subsequently fixed. Here we present a method of using TROPOMI data to guide GHGSat observations, and to identify more emission reduction opportunities. The millions of spatial and temporal data points provided by TROPOMI call for an advanced and automated method to globally detect methane plumes and locate their origin. We will show how we have used TROPOMI’s daily global coverage combined with meteorological data to pinpoint the most likely locations of emissions for further investigation by GHGSat. Through targeted observations at high resolution, GHGSat can identify the specific infrastructure responsible for the methane enhancements seen in TROPOMI data, and actions can be taken to address the issue. Thus, we offer a proof of concept for the detection and identification of methane sources guided by satellite remote-sensing instruments.
What can clumped isotopes tell us about biogeochemical cycles of H2 and CH4?

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H2 and CH4 are important for the atmospheric composition and chemistry, but also relevant in the study of microbial and geologic processes. Stable isotope measurements have been used to constrain the biogeochemical cycles of these gases. Until recently, isotope investigations have generally targeted molecules with only one isotopic substitution, e.g. δD in H2 or CH4, or δ13C in CH4. Recently developed high-resolution, high-sensitivity isotope ratio mass spectrometers enable the measurement of multiply substituted isotopologues, like ΔD2 in H2, or ΔCD2H2 and Δ13CDH3 in CH4. These are new isotopic signatures, independent on the bulk isotopic composition, and can thus give different type of information on the sources and processes affecting these gases.

We will give an overview of the potential applications, in the context of the recently started projects on this subject in our laboratory. These measurements offer new ways to constrain and understand biogeochemical processes, and they also offer new opportunities for interdisciplinary collaboration.
Carbonyl sulfide (COS) is the most abundant sulfur-containing trace gas in the atmosphere, with an average mixing ratio of 500 parts per trillion (ppt). It has a relatively long lifetime of about 2 years, which permits it to travel into the stratosphere. There, it likely plays an important role in the formation of stratospheric sulfur aerosols (SSA), which have a cooling effect on the Earth’s climate. Furthermore, during photosynthetic uptake by plants, COS follows essentially the same pathway as CO2, and therefore COS could be used to estimate gross primary production (GPP). Unfortunately, significant uncertainties still exist in the sources, sinks and global cycling of COS, which need to be overcome. Isotopic measurements of COS could be a promising tool for constraining the COS budget, as well as for investigating its role in the formation of stratospheric sulfur aerosols. The aim of the COS-OCS project is to perform the first, world-wide characterization of COS isotopes by measuring seasonal, latitudinal and altitudinal variations in the troposphere and stratosphere. I will present the potential of using COS isotopes to characterize the global COS and CO2 budget and I will present the first measurements results of COS isotopes in the upper troposphere and lower stratosphere.
In this study, we investigate and discuss the potential of two economic geophysical measurement techniques for geothermal reservoir characterization and monitoring: Passive seismic interferometry for better subsurface characterization through seismic imaging (static model) and satellite-based radar interferometry for geodetic imaging (dynamic model). Seismic imaging using passive seismic techniques allows for subsurface characterization via Ambient Noise Tomography, and supports the assessment of geothermal resources without requiring the use of shooting, reducing the cost compared to active seismics. Geodetic imaging, by measuring the surface displacements during and after production, allows for the monitoring of the effects of production and constrains reservoir modelling, and can be achieved through the use of (freely available) satellite imagery.

We discuss the results of both techniques over two high enthalpy geothermal sites in Iceland: Reykjanes Peninsula and Torfajökull volcano. While the Reykjanes Peninsula has geothermal fields that have been producing for decades, Torfajökull’s geothermal field, despite being the largest in Iceland, is not producing. For the subsurface characterization, we use S-wave velocity tomographic images derived from ambient noise seismic interferometry over the two geothermal sites. Within the tomographic images, low- and high-velocity anomalies are used to characterize subsurface structures, which complement, with information at greater depths, current geological models. From the monitoring point of view, radar satellite deformation measurements over both areas show displacements (subsidence) due to production (Reykjanes) and due to natural phenomena (Torfajökull). Finally, we summarize the lessons learnt and discuss outcomes on each technique.
The continuous recordings of the broadband seismometers deployed by KNMI on Saba and St. Eustatius in the Lesser Antilles provide a unique dataset to measure temporal seismic velocity variations (dv/v) at two active volcanoes without recent eruptions (Mt. Scenery and The Quill). We compare results from single-station cross-component correlations (SC) with cross-station correlations (CC) and achieve the best similarities within frequency band 1.3–2.1 Hz, justifying the use of SC as proxy for CC at these frequencies. Temporal dv/v variations derived from 13 years of data show different characteristics at both islands. At St. Eustatius dv/v highly correlates with air temperature and can be modeled by a simple sine wave with a period of 1 year. Remaining residuals reveal co hurricane dv/v drops. At Saba subsurface dv/v shows temporal coseismic changes, thus showing high sensitivity to ground shaking. Our dataset shows a linear relation between coseismic dv/v drops and peak ground velocity (PGV) at Saba around 1.3 Hz. We model the associated seismic velocity recovery with an exponential decay function and estimate the recovery time at 2 years. After subtracting the coseismic drop and recovery model, dv/v at Saba obtained from CC data correlates with the sine model. SC may be an appealing alternative for CC for monitoring purposes, however the use of a small network is preferred to reduce the variance in dv/v and detect dv/v variations unrelated to volcanic activity (e.g. hurricanes). We continue work on the implementation of CC in the daily monitoring of Mt. Scenery and The Quill.
The vertical motion of low magnitude earthquakes, why do we care?

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Up to now, almost all of the ground motion modeling and hazard assessment for induced seismicity in Groningen, the Netherlands, has been focused on the horizontal components of the observed elastic waves. Including the vertical component in site response studies is hardly being done for low magnitude earthquakes. Recordings over a range of depth levels in a borehole in Groningen show that most of the amplification occurs in the upper 50 meters of the sedimentary cover. We not only observe a strong amplification from shear waves on the horizontal component, but also from longitudinal waves on the vertical component. A better understanding of the vertical component of low magnitude earthquakes aims to support the design of re-enforcement measures for buildings in areas affected by seismicity.

This study presents the observations of longitudinal wave amplification in the frequency band 1–10 Hz, corresponding to resonance periods of Dutch buildings. From 19 seismic events (Mw>2), we retrieved transfer functions (TFs) from the vertical component, showing a strong site response at certain locations. In addition, we calculate event V/H ratios and VH factors from the surface seismometer. These results are compared with the TFs and show a similar pattern in terms of site response. Furthermore, the sites with highest vertical amplification correspond to very low (800–900 m/s) P-wave velocities. Our study shows that vertical amplification is highly site dependent. However, the question whether the vertical motion is significant enough to form a real hazard can only be answered through cooperation between seismologist and structural engineer.
Seismic tomographic models based only on wave velocities are unable to provide robust estimates of Earth’s temperature and composition. Seismic attenuation, or loss of a waves’ energy, can help answer elemental questions such as the origin of the large low-shear velocity provinces beneath Africa and the Pacific. Their origin, it being thermal or compositional, is fundamental to understand mantle convection evolution, as a thermal anomaly will be short-lived and a compositional anomaly long-lived. Attenuation measurements need to differentiate between scattering and focusing in order to distinguish intrinsic attenuation (transformation of energy to heat) and scattering (redistribution of energy). This has proven problematic in the past, specially when working with body and surface waves, that require approximation methods to correct for velocity effects on the wave’s propagation. Normal modes, or whole Earth oscillations, allow us to include focussing and scattering, without the need for such approximations. This is achieved both through cross-coupling (or resonance) between modes, and the large wavelengths of the standing waves, which do not scatter off small-scale structure.

Splitting functions, depth-averaged models of how one particular mode ‘sees’ the Earth, are used to measure modes. They are linearly dependent on heterogeneous and anisotropic structure, and for this reason can be easily incorporated by other scientists in tomographic models. Anelastic splitting functions model attenuation and elastic splitting functions model velocity and density. Previous studies of 3D attenuation in the upper mantle agree on finding anti-correlation between elastic and anelastic measurements. The anti-correlation indicates that upper mantle anomalies have a thermal origin, with strong attenuation found beneath spreading ridges and back arcs, and weak attenuation in shield regions (Dalton et al., 2008). The lower mantle has no 3D attenuation consensus as only two studies using body waves exist (Lawrence & Wysession, 2006; Hwang et al., 2011).

Here, we present new normal mode measurements of mantle 3D attenuation, and explore the whole mantle using several modes spanning different depth sensitivities.
Comparing two inversion methods in normal mode tomography

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Normal modes are low frequency standing waves along Earth’s surface and radius. The shape and position of normal mode peaks in frequency spectra are sensitive to Earth’s large-scale 3D structure. Normal modes are, in addition to constraining seismic velocity perturbations $\delta V_s$ and $\delta V_p$, the only data sensitive to density perturbations $\delta \rho$. Density is important in determining the unknown nature of LLSVPs (large low shear velocity provinces), which are always present in tomographic images. However, density is notoriously difficult to measure (e.g. Kuo & Romanowicz, 2002), hence the method chosen to invert normal mode data for 3D structure becomes important.

We can take two approaches in the problem of inverting the measured frequency spectra for an Earth model: 1) two-step inversion: first inverting the spectra for splitting functions, and then inverting those for a mantle model; 2) one-step inversion: inverting normal mode spectra directly for a mantle model. We have the unique opportunity to compare the methodology and results of both approaches starting with exactly the same normal mode data set by Deuss et al. (2013). We are continuing the work done by Li et al. (1991), and extending it to higher spherical harmonic degrees and including cross-coupling (resonance) between modes. We use both inversion approaches to make a 3D S-wave velocity mantle model.

As in Li et al. (1991), both approaches give reasonable and similar models for $V_s$, although spectral misfits are consistently lower for the one-step inversion. Furthermore, the success of the two-step inversion depends more on weighting and regularization than the one-step inversion. We expect that for $V_p$ and especially density, which have less normal mode sensitivity, the inversion method of choice matters more. We will explore these parameters in future work.
The 2010 Haiti Earthquake Disaster: The ShakeMap That Could Have Been...

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When an earthquake occurs, it is important to rapidly assess the severity of the consequences. The distribution of shaking intensity around the epicenter, known as the ShakeMap, is a key component in this process and is crucial for guiding first responders to the region. Whereas earthquake source characteristics, e.g., location and magnitude, can be rapidly determined using distant seismic stations, ground motion measurements from stations in the near-source region are needed to generate an adequate ShakeMap. When few or no seismometers exist in the region, ground motions are only estimated and the ShakeMap can be grossly inaccurate.

Besides seismic waves, earthquakes generate infrasound, i.e., inaudible acoustic waves in the atmosphere. Due to the low frequency nature of infrasound, and facilitated by waveguides in the atmosphere, signals propagate over long ranges with limited attenuation and are detected at ground-based stations. Here we show, that acousto-ShakeMaps, indicating the relative shaking intensity, can be rapidly generated using remotely detected infrasound. We illustrated this with infrasound from the 2010 Mw 7.0 Port-au-Prince, Haiti earthquake, detected in Bermuda, over 1700 km away from Haiti.

Such observations are made possible by: (1) An advanced array processing technique that enables the detection of coherent wavefronts, even when amplitudes are below the noise level, and (2) A backprojection technique that maps infrasound detections in time to their origin on the Earth’s surface.

Infrasound measurements are conducted globally for the verification of the Comprehensive Nuclear-Test-Ban Treaty and together with regional infrasound networks allow for an unprecedented global coverage. This makes infrasound as an earthquake disaster mitigation technique feasible for the first time.
Towards toroidal mode constraints on mantle anisotropy

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Our understanding of dynamic processes inside the Earth can be improved by studying seismic anisotropy, which is a useful parameter for constraining deformation and mantle flow. A good tool to estimate anisotropy are whole Earth oscillations or normal modes, which are excited after large earthquakes. These modes are standing waves along Earth’s surface and radius and are sensitive to 3D variations in Earth’s velocity, density and attenuation structure. Due to their large period, normal mode observations represent large scale averages of the Earth’s structure.

Normal modes can be divided in toroidal modes, dominated by horizontal surface- or SH-motion, and spheroidal modes, involving a combination of horizontal and vertical surface- or P-SV motion. Toroidal modes, which are similar to Love waves, are our main interest here. In combination with spheroidal modes, they provide important constraints on anisotropy.

Normal modes are most easily measured using the splitting function approach (e.g. Giardini et al., 1986). Splitting functions enable us to recover radial and azimuthal anisotropy for P- and S-velocity simultaneously. For 20 years toroidal modes haven’t been measured, since Resovsky & Ritzwoller (1998) and Tromp & Zanzerkia (1995). Here, we will expand the more recent spheroidal mode study by Deuss et al. (2013), by focussing specifically on toroidal mode observations by adding horizontal component data for all new large earthquakes from the last 35 years.

The new horizontal data recordings enable us to refine and extend the isolated self-coupling measurements for toroidal modes. Due to cross-coupling (i.e. exchange of energy) between fundamental toroidal and spheroidal modes, toroidal mode energy may become visible on the vertical component instead of only on the horizontal components. The effect of rotation of the Earth on toroidal-spheroidal cross-coupling is well known. Here, we will investigate the occurrence of additional cross-coupling due to radial and azimuthal anisotropy. Our mantle sensitive mode measurements indicate the presence of radial anisotropy in the whole mantle. This together with additional measurements may provide constraints on radial and azimuthal anisotropic structure of Earth’s mantle, like suggested by Beghein et al. (2008).
Not all rocks are perfect. Frequently heterogeneities will be present, either in the form of pre-existing fractures, or in the form of sealed fractures. Data is lacking on the effect of such single planar heterogeneities. We have performed Brazilian Disc tests on limestone samples, investigating strength and fracture orientation of damaged samples. We used Indiana limestone samples, pre-fractured with the Brazilian Disc method, and Treuchtlinger Marmor samples which contained central stylolites. All experiments were filmed. The planar heterogeneity was set at different rotation angles of approximately 0–20–30–45–60–90°, where 90° is in line with the principal load direction. The planar heterogeneity of the Indiana limestone samples represents a cohesion-less interface, whereas the stylolites in the Treuchtlinger Marmor samples are heterogeneities which have some strength. Imperfect samples are always weaker compared to an intact sample, regardless of the interface properties. For the cohesion-less interface the amount of weakening is angle-dependent. Only at low angles (<30°) the orientation of the new fracture is unaffected by the initial fracture. In the stylolite samples strength is isotropic. For all cases several new cracks appeared, of which the orientation is influenced by the orientation of the stylolite. The fracture pattern and associated stress drops increases in complexity with increasing angle. In these samples always several fracture formed, whereas in the samples with a cohesionless interface usually only one fracture occurred. This suggest a potential for higher fracture density when hydrofracturing a stylolite-rich interval.
Quality matters for water scarcity mitigation

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Water scarcity threatens people in various regions, and has predominantly been studied from a water quantity perspective. However, the provision of water for human uses and environmental health is dependent on both sufficient water availability but also appropriate water quality for the intended use.

Our study presents the first estimates of global water scarcity driven by both water quantity and water quality issues and including impacts of desalination and treated wastewater reuse. We have developed a new water scarcity framework combining model simulations of multiple global hydrological models and global surface water quality models (water temperature, salinity, organic pollution, nutrients) and spatially-explicit datasets of desalination and treated wastewater reuse capacities globally.

Our results show that 40% of the world’s population currently lives in regions with severe water scarcity, which is driven by a combination of water quantity and quality issues. Impacts of water quality are in particular high in river basins in eastern China. Here, excessive water withdrawals and polluted return flows degrade water quality, exacerbating water scarcity. Our results show that expanding desalination and treated wastewater reuse capacities can strongly reduce water scarcity in most river basins, although the side-effects (e.g. brine production, high energy demands and costs) must be considered.

We conclude that effective water scarcity reduction requires that we expand our focus from conventional measures, which mainly focus on improving water supply for sectoral use, to solutions that also promote water quality improvements.
Glaciers are growing in a part of High Mountain Asia (HMA), contrary to the demise of glaciers worldwide. This phenomenon, often referred to as the Karakoram anomaly, is not easily explained in the context of global warming. We investigated different possible causes of the Karakoram anomaly using a regional climate model, coupled to a glacier model, as well as a moisture tracking algorithm and the analysis of reanalysis data. We found that the pattern of HMA glacier mass balances that includes the Karakoram anomaly can be understood from the combination of temperature and precipitation trends, and the climate sensitivities of the glaciers. The increase of irrigation in Central Asia was found to be especially important in creating the increase in snowfall that can explain the Karakoram anomaly.
Atmospheric supply of moisture and heat to water- and energy-limited ecosystems

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Terrestrial ecosystems dampen the increasing atmospheric carbon dioxide concentrations arising from anthropogenic fossil fuel emissions, and thus crucially impact the climate system. The ability of the land biosphere to act as a net carbon sink is largely governed by the prevailing climate, as it determines the energy and water availability required by plants to flourish. The climate in a certain area is not only a consequence of local surface-atmosphere fluxes of heat and moisture, in conjunction with entrainment of the latter from aloft and precipitation, but also crucially depends on advected heat and moisture from upwind. Here, this impact of remote regions on gross primary production is analyzed from an aerial perspective, concentrating on the five ecoregions with the highest interannual variability in peak productivity around the globe. Using the atmospheric Lagrangian trajectory model FLEXPART, driven by ERA-Interim reanalysis data, the air residing over ecoregions is tracked back in time to infer the origins of moisture and heat that affect ecosystem productivity. Utilizing the evaporative source regions supplying water for precipitation, as well as source regions of heat advected to these ecosystems, we estimate the contribution of heat and moisture advection on gross primary production. Our results indicate that source regions of heat and moisture are not congruent: upwind land surfaces typically supply most of the advected heat, whereas upwind oceans tend to provide more moisture. Furthermore, low gross primary productivity in water-limited and heat-stressed ecosystems is often accompanied by reduced moisture yet enhanced heat advection, exacerbated by upwind land surface flux anomalies. Findings demonstrate that anomalous atmospheric advection can cause ecosystem productivity extremes.
Accurate and timely hydrological forecasts highly depend on their meteorological input. Current numerical weather predictions (NWP) do not have sufficiently high spatial and temporal resolutions for adequate use for short lead times (<6 hours). Therefore, radar rainfall nowcasting, the process of statistically extrapolating the most recent radar rainfall observation, is increasingly used. To determine the predictive skill of nowcasting, a large-sample analysis of 1481 events spread over twelve lowland catchments (6.5–957 km²) was performed. Four algorithms were tested and compared with Eulerian Persistence: Rainymotion Sparse and DenseRotation, Pysteps deterministic and probabilistic with 20 ensemble members. We focused on the nowcast skill dependency on: event duration, season, catchment size and location. Skillful lead times increased for longer event durations, with average maximum skillful lead times of: 25 min for 1-h, 39 min for 3-h, 56 min for 6-h and 116 min for 24-h durations. This was caused by the more persistent character of events with longer durations. During winter, with more stratiform precipitation, we found three times lower mean absolute errors than for convective summer precipitation. For the fractions skill score, we found higher skill after upscaling, which is in the advantage of larger catchments. Catchment location matters too: up to two times higher skillful lead times were found downwind of the radars than upwind. Pysteps algorithms outperformed Rainymotion benchmark algorithms due to the presence of rainfall field evolution estimations. Most errors originated from growth and dissipation processes which are not or only partially (stochastically) accounted for.
Freshwater availability and scarcity are usually considered to be local aspects, and thus water management at the scale of watersheds appears adequate. Yet, precipitation as a main source of freshwater may originate from upwind evaporation, far away from the watershed under study. As terrestrial evaporation can be limited or even absent during droughts, such deficits can put local but also downwind freshwater availability at risk. These spatio-temporal dependencies of precipitation on evaporation are typically not considered in water assessment studies. However, to adequately address threats to freshwater availability, an improved understanding of the terrestrial–atmospheric system and its interactions across watershed boundaries is required.

In this study we present a watershed precipitation recycling network, that illustrates the atmospheric flow of water between watersheds, and provides an atmospheric perspective on the vulnerability of freshwater. Using the Lagrangian trajectory model FLEXPART driven by ERA-Interim reanalysis data from 1980–2016, we estimate the land contribution to precipitation over European watersheds via moisture recycling. Our results indicate that up to 74% of summer precipitation over European watersheds originates from other watersheds. These results highlight a strong inter-watershed dependence for freshwater supply, and challenge the notion of autarkic watersheds that is deeply rooted in hydrological sciences. Inspection of the network reveals that a few watersheds dominate the freshwater flow and modulate freshwater availability in other watersheds. The proposed network approach enables the objective assessment of freshwater vulnerability and the risk of water scarcity under global change, emphasizing the need for global water governance to secure freshwater availability.
Land Surface Temperature and Miombo forest canopy phenophases: what induces leaf fall and leaf flush?

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Knowing what induces leaf fall in Miombo forest species during the dry season is important for studying the consequence of e.g., climate change on Africa’s most widespread seasonal woodland and forest formation. To better understand the driver of leaf fall we employed a simple remote sensing and statistical analysis approach using long term averages (2009–2018) of Land Surface Temperature (LST), vegetation water content (i.e. NDWI), plant photosynthetic activities and leaf cover (i.e. NDVI), actual evaporation (Ea), and root zone soil moisture (SM). Results showed that NDWI, NDVI, Ea and SM begun to decline immediately following the end of the rainy season in mid-April while the LST remained relatively constant before it began to decline in May when leaf fall in some Miombo species begins. High rates of decrease in NDWI and NDVI values were observed between July and September the same period when LST increased and when leaf fall intensifies. Hysteresis plots showed that NDWI responded quicker to changes in both LST and SM. Correlation analysis revealed strong season-dependent LST relationship with NDWI, NDVI and SM with the rainy season exhibiting strongest (R² > 0.77) negative linear correlation. SM showed strong (R² > 0.5) positive linear correlations with NDWI and NDVI in both seasons. The correlations imply that soil water content, vegetation water content and the photosynthetic activities and leaf cover declines with increase in LST indicating the possibility of LST being a major inducing element of leaf fall and changes in canopy structure in the Miombo woodland.
Hydrological implications of land use change: a mechanistic framework for local feedbacks and downwind effects

Sofie te Wierik

Green water, which is the plant-available soil moisture, is a substantial subset of the terrestrial fresh water. Land use change alters green water dynamics, subsequently triggering soil moisture directly or indirectly via feedbacks in the soil-vegetation-climate system. Ongoing deforestation around the world, as well as growing interest in reforestation projects, begs the question of the eco-hydrological impact of land use change on various spatial-temporal scales. The discussion of forests as water users versus water producers, provides evidence for both outcomes, although it is not clear under which conditions they occur and which mechanisms are important. Accordingly, this requires a systematic, mechanistic understanding of green water dynamics in relation to land use change, and the interactions with the soil-vegetation-climate system in which it is embedded.

In this literature review, we provide an overview of the dynamics and feedback mechanisms in this soil-vegetation-climate system in relation to green water. We relate empirical observations from different parts of the world to simulated approximations from various modelling approaches. Local, downstream and downwind impacts are specifically addressed. The review shows that some regions are more vulnerable to land use change than others and can affect local as well as distant hydrology of landscapes, triggering a spill-over effect. Resulting from this review, we derive an mechanistic framework and relevant eco-hydrological indicators to address the direct and indirect impact of land use change on hydrology on various spatial-temporal scales. This framework can support further context-specific research to minimize the negative impact of land use change on water availability for nature and society.
How simultaneous occurrence of heavy rainfall and wet initial conditions leads to peak discharges

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The severity of pluvial floods is determined by both the rainfall event and the initial catchment wetness. In this study, we investigate which combinations of rainfall sum and initial groundwater level lead to high discharges and how the occurrence probabilities of the two factors and the resulting discharge peaks are affected by climate change.

We used the Wageningen Lowland Runoff Simulator (WALRUS) to simulate discharge in 12 Dutch lowland catchments. As forcing, we used 109-year time series of rainfall and potential evapotranspiration from the current climate (de-trended observations) and eight climate scenarios.

For each discharge peak, we linked effective rainfall sum and initial groundwater depth to peak discharge.

In mildly sloping catchments with shallower aquifers, discharge peaks are more sensitive to effective rainfall sum, while in flatter catchments with thick aquifers, discharge is more sensitive to initial groundwater depth. With climate change, extreme precipitation events and wet initial soil conditions will occur more often simultaneously, leading to more frequent and higher peak discharges year-round. Groundwater will be shallower in winter and spring, resulting in higher and more frequent floods, while groundwater will be deeper in summer and the beginning of autumn, resulting in fewer floods, even though more precipitation is projected for autumn.
The boreal forest is one of the largest terrestrial carbon reservoirs on Earth and accounts for approximately 30% of the world’s forest cover. The boreal carbon balance is thus of global significance. Wildfires affect the boreal carbon balance, releasing large amounts of carbon into the atmosphere when soil organic layers and aboveground biomass are combusted. The boreal forest is warming faster than the global average. These higher temperatures lead to increases in the frequency and severity of wildfire disturbance in boreal regions.

Deciduous needleleaf larch forest growing on continuous permafrost is a unique ecosystem of Siberia. Although these larch forests cover approximately 20% of the boreal biome, the consequences of intensifying fire regimes on the carbon stocks and vegetation dynamics of these ecosystems remain poorly understood.

We conducted a field campaign in larch forests around Yakutsk, Northeast Siberia, during the summer of 2019 with the goal of filling parts of these knowledge and data gaps by collecting ground measurements of carbon combustion from two large fire events in 2017 and 2018. During this campaign, we sampled 42 burned sites in two fire scars that cover gradients of fire severity, vegetation composition and landscape position. Within these sites, we performed a wide range of measurements to quantify aboveground and belowground carbon emissions, constrained by data from 12 unburned sites. We investigated major drivers of pre-fire carbon stocks and subsequent combustion at the site level. Our results will reduce uncertainties in larger scale estimates of carbon emissions from Siberian fires.
Comparison of elevated temperature experiments on shrubs in Finland, Greenland and Poland

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In-situ warming experiments on dwarf Birch Betula nana from Finland, Greenland and Poland are being compared on the microphenological response of the Undulation Index of the leaf epidermal cells. The experiment locations represent different portions of the B. nana occurrence range, with the Arctic sites in Finland and Greenland on both sides of the Atlantic Ocean, and the continental site in Poland as B. nana refugium in lowland central Europe. The comparison of UI between ‘control’ and ‘warm’ treatments at different sites throughout the range of B. nana will sophisticate the understanding about the reaction of this key-species to warmer environmental conditions, namely in the arctic, under past and present climate change. A warmer environment generally causes a response in plant-performance, reflected in epidermal cell UI changes. This reaction to temperature is a response with a reaction span of one generation of leaves, making it a yearly response. Over the course of a gradual increase of temperature as projected in current and future climate change, the net change in plant performance might be significant and contribute greatly to different ecosystem dynamics. These effects might result in scenario’s as Arctic Greening and shrubification. The results of these scenario’s vary from phenological mismatch of interacting species to the introduction of new species and changes in water balance, competition between species, nutrient balance, microbial activity, and soil formation. As a paleo-proxy, the usefulness of UI as ‘paleo-thermometer’ is attested, where the lower response limit might be in the range of the Greenlandic experiment.
Composition and characteristics of particulate organic matter on a spatial transect off a retrogressive thaw slump in the Canadian Arctic

Kirsi Keskitalo
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In the Arctic, temperatures have been rising twice as fast as the global average during the last decades. Northern circumpolar permafrost soils (i.e. perennially frozen ground), that store almost half of the global belowground organic carbon (OC), are susceptible to thaw upon climate warming. The potential remineralisation of released permafrost OC to the atmosphere as greenhouse gases can further enhance climate warming. On the Canadian Peel Plateau, the number and size of retrogressive thaw slumps has increased in the recent decades due to rising temperatures and higher precipitation. These thermokarst features caused by the rapid collapse of ice-rich permafrost release organic matter dominantly as particulate organic carbon (POC). However, we currently do not know the fate (i.e. release to the atmosphere as greenhouse gases or burial to sediments) of the released POC. In this study, we sampled POC and sediments along a fluvial transect (~12 km) downstream from a retrogressive thaw slump. We measured the concentrations of both POC and dissolved organic carbon (DOC) in streams as well as OC in recently-deposited sediments. Furthermore, we use extractable lipid biomarkers (n-alkanes and n-alkanoic acids), non-extractable macromolecules using pyrolysis-GCMS, and bulk carbon isotopes (δ13C, Δ14C) to characterise the composition and degradation status of the released organic matter.

In the rapidly changing Arctic, it is important to understand the fate of permafrost carbon after its release to be able to better predict the climate impacts of these increasingly abundant permafrost thaw features.
Pine Island Glacier is among the fastest changing outlet glaciers in Antarctica with large consequences for global sea level. Over the last decades the glacier has accelerated, retreated and thinned rapidly. If these changes continue, a sufficient weakening of the ice shelf may result in marine ice sheet instability with substantial grounding line retreat. Yet, assessing how much, how fast the ice shelf and glacier will change, remains a major uncertainty as many of the processes that control the retreat are not well understood. The weakening of ice shelves due to damage in the shear zones is considered one of the least understood processes in marine ice sheet dynamics.

Here, we study the impact of damage-induced weakening on ice shelf buttressing on the Pine Island Glacier, for realistic topography and velocities. This is done with the BISICLES-CDM ice sheet model, which incorporates a continuum damage model to include the effect of damage in the simulation. Inverse damage modelling is applied to minimize the misfit between observed (remote sensing) and modelled surface velocity data. Model results that include the damage mechanism highlight the importance of damage for ice shelf stability and grounding line retreat. With damage feedback included, the glacier flow accelerates to velocities within a decade that otherwise would only be expected after at least half a century. The grounding line retreat is ~100km more with damage than without, in the span of a century. Existing shear zones expand, and new shear zones appear, weakening the remaining ice shelf further.
A late Quaternary record of Saharan dust transport from the tropical Atlantic Ocean

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The Sahara Desert in northern Africa is the largest dust source on Earth. Wind blown mineral dust affects human health, may play a role in the eutrophication of surface waters and is generally considered as a key player in the climate system. A large part of the dust export travels westward and ends up in the tropical Atlantic Ocean. To assess the causes of variability of Saharan mineral dust export on time-scales of 10^2-10^5 years, we studied a marine sediment record from the tropical Atlantic Ocean collected during the NICO expedition in 2018. The core was collected on the Mid-Atlantic Ridge at ~11N from the crater of an inactive volcano at 2644 m water depth. We established oxygen isotope stratigraphy, which indicates that the chronology is continuous and the base is ~500,000 years old. Elemental ratios obtained with XRF core scanning and ICP-MS calibration of elements, allow assessment of quantitative dust fluxes. We find that Saharan dust fluxes strongly follow precession pacing over five glacial-interglacial cycles, with increased dust fluxes during Northern Hemisphere insolation minima. Shifts in the Inter-tropical Convergence Zone (ITCZ) primarily controlled the export of dust out of the Sahara. A planktic foraminiferal Modern Analog Technique approach, shows that sea surface temperatures (SST) over the past 150,000 years were remarkably stable and seasonality was low. This finding in combination with published data suggests that (sub)tropical South Atlantic SST variability may play a more important role in the driving mechanisms of Saharan dust export than previously considered.
Hot summers ahead? Multi-decadal spring season warming precedes sudden summer temperature rise in pre-anthropogenic climate change

Rike Wagner
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Waning annual seasonality is documented in an up to one-month advance in spring onset since the 1980’s in northern latitudes, perturbing ecosystem functioning and socioeconomic performance. Summer temperatures, in contrast, have been rising only recently, indicating an offset in seasonal warming. The limited time span of observational data makes this asynchronous pattern difficult to quantify, hindering projections of intra-annual dynamics. We explore temporal phase relations of seasonal warming over the Late Pleniglacial/Bølling and the Younger Dryas/Holocene climate transitions that preceded present anthropogenic warming. We determine past spring onset and thermal properties from dwarf birch paleo-phenology. Reconstructed spring warming led maximum summer warming by about a century during both transitions. Long-term reconstruction of intra-annual temperature regimes provides the perspective required for seasonal response analysis. Our results document that multi-decadal spring season warming precedes sudden summer temperature rise also during natural climate change. The rapidity of present seasonality changes, however, is unprecedented.
Proxy potential of lipid biomarkers in suspended particulate matter in the water column of Lake Chala, tropical East Africa

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Lake sediments are important archives of past continental climate evolution, especially in the tropics, from which ice cores or speleothems are lacking. Past environmental changes can be reconstructed using lipid biomarkers preserved in the lake sediments, where the occurrence or relative distribution of specific molecules potentially reflect an environmental parameter. For example, the distribution of long chain n-alkanes derived from higher plants can be representative of the vegetation type around the lake. Still, the biomarker toolbox can be further expanded. In this study, we analyzed the seasonal variation of biomarkers in suspended particulate matter (SPM) in the water column of Lake Chala, an equatorial crater lake in East Africa, at 8 distinct depths over a 17-month period (n=136) between September 2013 and January 2015. With a depth of 90m, Lake Chala has permanently anoxic bottom waters. The depth of the upper oxygenated layer is controlled by seasonal changes related to the movement of the Intertropical Convergence Zone (ITCZ) such that during wet conditions the lake is more intensely stratified and during dry and windy intervals the oxycline depth is extended to ~40–60m. The occurrence and distribution of biomarkers in SPM will be compared with environmental data, such as temperature, dissolved oxygen, and pH obtained by long-term monitoring of the water column to identify the drivers of their production and thus potential as climate proxies.

Initial results indicate that a group of sterols derived from higher plants, mostly occurs during the wet season (October-December & March-May) at intermediate depth (25-50m), indicating terrestrial input. Furthermore, a possibly yet unknown unsaturated appears predominantly during shallow-mixing (January-February). Although 1,14-diols are generally linked to diatoms, other long chain diols (1,15–C30 and –C32 diols), as well as diagnostic diatom markers loliiolide and iso-loliolide mostly occur during deep-mixing (June-September). Further exploration of the dataset is ongoing.
Reconstructing 20th century droughts in Western Mesoamerica

Kees Nooren
Margarita Caballero, Sarah Metcalfe, Gert-Jan Reichart and Rike Wagner-Cremer

Although climate change played a major role in the development and disintegration of Mesoamerican societies, magnitude and duration of climatic events are still poorly understood, due to the lack of high resolution palaeoclimatic reconstructions from the area. Here we demonstrate the potential of the sedimentary archive of a deep crater lake in Western Mesoamerica for palaeoprecipitation reconstruction.

A 45 cm long sediment core (representing the last 120 years), was taken from the deepest part of lake Santa Maria del Oro. The core was studied on multiproxies (clastic and organic content, bulk element composition, magnetic susceptibility, CaCO3, pollen, diatoms, and microcharcoal). Age control was based on 210Pb and 137Ce dating, and the presence of a cryptotephra layer, tentatively related to the 1913 eruption of Colima.

The evaporative concentration of minerals during dry and warm years cause authigenic CaCO3 precipitation, registered in the sediments as distinct white laminae and peaks in CaCO3 influx rates. One of the most prominent peaks occurred around 1910, indicating that the ‘Revolution drought’ of 1909-1910 was probably one of the most severe droughts of the last century. Although human induced lake water eutrophication strongly influenced the diatom assemblage, an increasing trend in lake water salinity is apparent from the record, with the polyhalobous diatom Tryblionella granulata appearing since approximately 1980 CE. We recommend the study of a longer sediment core from this lake to understand the possible link between climate change and the rise and fall of past civilizations, and to identify the underlying climate forcing mechanisms.
In recent years, bacterial and archaeal membrane lipids have become widely used as organic proxies in paleoenvironmental reconstructions. For example, branched glycerol dialkyl glycerol tetraethers (brGDGTs), produced by soil bacteria, have yielded insight in (past) changes in soil pH and mean annual air temperature (MAAT) from a variety of environments and ages. Recently, a novel class of brGDGTs, so-called H-brGDGTs, were identified. They are characterised by a covalent bond between the alkyl chains and are so far predominantly reported in peats and East African tropical lakes. The relative abundance of H-brGDGTs over regular brGDGTs appears to correlate to MAAT, and also the relative abundances of the different H-brGDGTs in lake sediments show a strong correlation with MAAT. While these results clearly indicate a general temperature effect on H-brGDGTs, a large-scale inventory of their occurrence, an assessment of their microbial origin, controlling environmental factors and proxy potential of these compounds has not been attempted. Here we assess the distribution of H-brGDGTs in various depositional environments (lakes, peats, soils, marine sediments) in both recent and deep time datasets, and test for correlation with environmental factors such as temperature and pH. Emerging proxies are then applied to reconstruct the paleo-environment in datasets from the Paleocene-Eocene Thermal Maximum (PETM) and the Middle Eocene Climatic Optimum (MECO). Finally, microbial 16S-rRNA data will be used in combination with H-brGDGT data to narrow down the range of possible producing organisms of H-brGDGTs.
Functional significance of Bristlecone pine needle elongation responses to growing season temperature variations

Hugo de Boer
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Bristlecone pine (Pinus longaeva) is well known for its millennial-length tree ring chronologies. Lesser known is that Bristlecone pine needles have extremely long retention times (30 years) and that needle elongation responds to summer temperatures during the year of needle formation. Here we explored whether temperature-induced variations in needle elongation relate to radial stem growth and leaf gas exchange as expressed in tree ring widths and stable carbon isotopes. Needles were sampled from 17 specimen growing in the Californian White Mountains (USA). Needle fascicles were absolutely dated and span the period 1897–2015. Individual needles were analyzed for functional and anatomical traits as well as stable carbon isotopes in relation to climate variability and previously published tree ring chronologies. We observed correlated interannual variation in needle lengths between individual trees and negative correlation between the elevation of the tree growth locality and tree-average needle length. Detailed analyses on a subset of needles from five specimen showed positive correlations between needle length and summer temperature during the year of needle formation as well as ring widths formed in the same year. Comparison of δ13C in bulk needle tissue and tree ring cellulose revealed that needle signals lagged foliar signals one to two years. No consistent relationship was found between the needle age and needle δ13C, yet foliar nitrogen content was highest in needles sampled in the year of their formation. Our data thereby suggest that needle length variations constitute a functional adaptation to optimize tree growth in the year of needle formation.
Using microorganisms to restore degraded soils via improving hydraulic properties

Oksana Coban
Gerlinde de Deyn and Martine van der Ploeg

Soil, the living skin of the Earth, provides ecosystem services critical for life: soil acts as a water filter and a growing medium, offers habitat for billions of organisms, and supplies most of the antibiotics. Currently, due to climate change, droughts are becoming more common, also in humid climates, and the combination of erratic weather patterns with an increased pressure on land by human activities leads to soil degradation. Soil degradation results in a loss of fertile topsoil, thereby altering the soil hydrology completely. As the consequences, soil water holding capacity decreases, hydrophobicity increases, and more runoff is observed, that leads to further soil degradation. Thus, soil hydrology is the key for a healthy functioning topsoil/soil ecosystem. We are in urgent need for novel solutions for improving soil hydraulic properties that will lead to restoration of degraded soils.

In this study, we investigate a possibility of restoring degraded soil using microorganisms. The hypothesis is that microorganisms can improve soil hydraulic properties such as infiltration and water retention, and reduce hydrophobicity that will facilitate further ecosystem restoration. To test this hypothesis, we have inoculated sandy soil with a bacterium Bacillus mycoides and then measured its hydraulic properties using evaporation and pressure plate methods. Evaluation of an effect of bacteria addition on the soil water holding capacities and unsaturated water conductivity have been conducted as a comparison between inoculated soil and uninoculated (control). Results of this ongoing study will be presented here.
Is there evidence for ‘primary organisms’ based on fossil ‘clay-life’ genetics?

Jos van Oijen

Is there evidence for ‘primary organisms’ based on fossil ‘clay-life’ genetics?
Rattle stones as a starting point for thinking out of the box.

For his hypothetical ‘vital mud’, with genetic information stored in particularly evolved clays, A.G. Cairns-Smith (1982) proposed the idea of primary organisms ‘[b]uilt on a somewhat larger scale’.
Clay (=silicon) based genetics would be effective in a ‘clumsier’ way compared to proteins. If that is true, geologists should be on the lookout for less recognizable remnants of an amoeboid ‘bacterial’ configuration, detectable without a microscope. Are such finds to be made?
Cross sections of brittle rattle stones: iron-enriched, dehydrated loam concretions, sometimes reveal complicated and enigmatic structures which are very similar to those involved in the spore germination process in (Myxo)bacteria. In bacteria sporulation is the life phase resulting in hardened parts of those otherwise slimy creatures. Thin slides of the stones reveal additional information. A simple explanation of these complicated patterns by geochemical processes, e.g. Liesengang rings, precludes a true understanding of what could be a ‘life changing’ phenomenon.
The deposition of bowl-shaped accumulations, in rows up to 700 meters raise questions on the origins of these formations. Earlier ore-mining, resulting in now empty pits visible upon the Dutch ice pushed ridges, emphasize the superficial and restricted character of these deposits. Further investigations both on small (clay mineral determination) and large (Ground Penetrating Radar) scale seem to be challenging.
The potential for Fe-mediated anaerobic oxidation of methane in coastal sediments: a model study

Leo de Jong
W.K. Lenstra and C.P. Slomp

Methane is an important greenhouse gas and atmospheric concentrations have been steadily increasing since the industrial revolution. Rates of methane formation in many coastal sediments are high. The methane efflux from sediments is generally very low, however, due to a variety of oxidation processes. The dominant pathways for methane removal are typically thought to be anaerobic oxidation of methane coupled to sulfate reduction and aerobic oxidation. Recently, iron-mediated anaerobic oxidation of methane (Fe-AOM) was discovered to contribute to methane oxidation in sediments as well. Though several studies have found geochemical evidence for this process in marine sediments, its quantitative importance remains unclear.

In this study, we assess the key factors affecting rates of Fe-AOM in coastal sediments by performing a sensitivity analysis with a 1-dimensional multicomponent reactive transport model. We use a coastal site in the Baltic Sea for our baseline scenario. We then focus specifically on the effects of variations in bottom water oxygen and salinity, sedimentation rate, organic carbon input, and the input of iron oxyhydroxides. Our results show that Fe-AOM can become a quantitatively important pathway for methane oxidation in coastal environments with low salinities and high inputs of iron oxyhydroxides. Climate change is leading to changes in both bottom water salinity and iron oxyhydroxide input in coastal systems. This emphasizes the need for a better understanding of the role of Fe-AOM in methane removal.
Microbial carbon, sulfur and nitrogen cycling in an anoxic bioreactor mimicking brackish sediment conditions

Paula Dalcin Martins
Arslan Arshad, Jeroen Frank, Mike S.M. Jetten, Huub J.M. Op Den Camp and Cornelia U. Welte

Microorganisms are main drivers of the sulfur, nitrogen and carbon biogeochemical cycles. Given the spread of marine oxygen-deficient zones, it is imperative to study microbial interactions that affect sedimentary biogeochemical cycling under anoxia in order to predict future changes under eutrophication and climate change. Here, we investigated a sulfur, nitrogen, and carbon-cycling microbial community in a laboratory-scale bioreactor that mimicked anoxic estuary or brackish sediment conditions.

The bioreactor simultaneously consumed sulfide, methane and ammonium at the expense of nitrate. Anammox bacteria, Candidatus Methanoperedens archaea, Ca. Methylomirabilis bacteria and two proteobacterial groups mostly accounted for such reactions. Metagenomic analysis revealed a novel organism that represented a new family within the Nitrospirae phylum. A high quality draft genome of this new species was recovered, and analysis showed high metabolic versatility. Thus, this new organism was named Ca. Nitrobium versatile. Related microbial groups were found in diverse environments where sulfur, nitrogen and methane cycling take place. Transcriptomic analyses revealed that the two most highly transcribed metabolic genes in Ca. Nitrobium versatile were a sulfide-quinone oxidoreductase and both subunits of the nitric oxide reductase, indicating this organism may couple sulfide oxidation to nitric oxide reduction.

In summary, we characterized a microbial community cycling carbon, nitrogen and sulfur under anoxic, brackish sediment conditions, and identified a novel, globally distributed microorganism that may link sulfur and nitrogen biogeochemical cycling in sedimentary ecosystems. Further elucidating microbial interactions between such microorganisms and the metabolism of Ca. Nitrobium versatile may aid in future bioremediation of climate change-impacted marine sediments.
A sequential extraction procedure for manganese and implications for manganese cycling in marine sediments

Wytze Lenstra
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Manganese (Mn) is a key element in marine systems and its dynamics can affect the cycling of many elements, such as iron (Fe), phosphorus (P) and carbon (C). The biogeochemical impact of Mn depends on its form in the sediment. For example, Mn oxides can be involved in the oxidation of dissolved Fe, organic matter and methane. Mn(II)-phosphates and P-bearing Mn carbonates may promote the burial of P in sediments. While sequential extractions are widely used to discern between various sediment forms of Fe, P and sulfur, no sequential extraction procedure is currently available to investigate the solid phase speciation of Mn.

In this study, an extraction procedure that is widely used for the speciation of Fe in sediments, is calibrated for Mn using a range of standards. The standards consist of various Mn oxides, Mn carbonates, Mn(II)-phosphate minerals, Mn sulfides and clays. We show that the extraction procedure allows us to discern most of the Mn phases, and is especially successful in distinguishing Mn oxides from Mn carbonates.

Additionally, we applied the sequential extraction to a range of marine sediments. The results show that at most sites surface sediments are enriched in Mn oxides whereas burial takes place in the form of Mn carbonates, Mn in pyrite and Mn in clays. We also find evidence for the presence of Mn oxides below the sulfate-methane transition at one location, suggesting that at this site, Mn oxides could potentially contribute to the anaerobic oxidation of methane.
Tracing organic matter input from the Mississippi River and its influence on the marine environment in the Gulf of Mexico across the Late Pliocene/Early Pleistocene transition

Yord Yedema
Francesca Sangiorgi and Francien Peterse

The Late Pliocene-Early Pleistocene interval encompasses the shift from relatively warm climate conditions to the onset of Northern Hemisphere glaciation. The associated formation of the Laurentide Ice Sheet had large impact on North American climate and Mississippi River discharge. To trace changes in the discharge of the Mississippi River and its influence on coastal ecosystem dynamics, we here analysed a marine sediment record from the northeastern Gulf of Mexico (GoM; ODP Site 625B) covering the interval from ~2.9 to 2.5 Ma. Terrestrial input, sea surface temperatures (SSTs) and environmental conditions were reconstructed using lipid biomarkers, pollen grains, and dinoflagellate cysts stored in these sediments. SSTs based on lipid biomarkers (alkenones and GDGTs) decrease 2–3 °C at ~2.7 Ma, marking the onset of glacial cooling. Nevertheless, plant leaf waxes and river transported pollen remain low during the whole interval, indicating that Mississippi River discharge had little influence on this site. An increase in the influx of bisaccate pollen after ~2.7 Ma however possibly indicates stronger winds blowing in the direction of the drill site. At the same time, open ocean oligotrophic dinoflagellate taxa become dominant. This shows that despite the onset of Northern Hemisphere glaciation and the expected sea level lowering, ODP Site 625 remained relatively distant from the coast and was more likely influenced by a change in currents rather than by Mississippi River input following NH glaciation.
Stratigraphic understanding of pre-Carboniferous strata in the subsurface of the Netherlands is very limited, leaving the lithostratigraphic nomenclature for this time-interval rudimentary and informal. In two wells from the southwestern part of the Netherlands (KTG–01 and O18–01), Silurian strata have repeatedly been reported close to these wells’ terminal depths, suggesting these to be the oldest sedimentary rocks ever recovered in the Netherlands. This hypothesis has not been tested by biostratigraphic data. A similar lack of biostratigraphic control exists for the overlying Devonian succession in these and adjacent wells in the southwestern part of the Netherlands. We here present the results of a palynological study of core material from well KTG–01 and S05–01, with the aim of obtaining biostratigraphic control and insight into the past depositional environment.
Bioturbation is an important process in the early diagenesis of soft marine sediments. Benthic infaunal activity, such as feeding, burrowing and ploughing redistributes particles within the surface sediment. Therefore, recently deposited particles are mixed into deeper sediment depth layer and old material remains longer in the surface sediment. A sediment layer thus contains an assemblage of particle ages. Under certain assumptions, bioturbational mixing can be modelled as a diffusive process with macroscopic mixing coefficient $D_B$. Here we model the age distribution of the bioturbated sedimentary record with a depth dependent mixing coefficient $D_B(z)$. The age bias introduced by mixing is typically higher than multiples of the mean mixed layer residence time, which scales linearly with sediment accumulation rate and mixed layer depth. The increasing mixing intensity has only a minor effect, as most marine environments are already in a high mixing regime.
Many rivers have been channelized in large parts of the world in the past centuries. However, in the last decades, realization has grown that channelization has negative consequences: it results in loss of ecological niches and high discharge peaks that may lead to flooding. Therefore, rivers worldwide are currently being restored. One of the most used restoration measures in small, low-energy rivers is to re-meander the river channel pattern, often by mimicking the sinuous pattern from before channelization. However, it remains largely unknown how sinuous patterns of low-energy rivers naturally form and develop with time, because they do not have sufficient energy to erode their banks, and generally do not show lateral migration.

The work that we present here is based on the finished PhD research of Jasper Candel, in which we aim to understand and predict the channel pattern formation of low-energy rivers. Distinctive channel patterns form in valleys with a peaty, heterogeneous and sandy floodplain. For each river type, a palaeogeographic reconstruction was performed using coring, ground-penetrating radar and geochronological data from different valley cross-sectional research sites. Based on these reconstructions, conceptual models were developed on how these channel patterns develop. The bank strength was identified as a key forming factor of the channel pattern of low-energy rivers, and incorporated in a newly developed channel pattern prediction tool, which has a high prediction success. River restoration can benefit from the insights of this research and focus on restoring natural processes of low-energy rivers in a scientifically sound way.
Cross-comparison of last glacial Radiocarbon and OSL ages using periglacial fan deposits

Jakob Wallinga
Sanne Palstra (First Author!), Wim Viveen, Jeroen M. Schoorl, Meindert van den Berg and Johannes van der Plicht

Two cores from a Weichselian periglacial alluvial fan were dated using 14C and OSL, to verify the reliability of both methods and check the dating limit of the 14C method. Both dating methods yielded a similar chronology for core Eerbeek-I, with infinite 14C dates for the lower part where OSL dates indicated ages of over 45 ka. Finite 14C dates were obtained throughout the core for Eerbeek-II, despite stratigraphic and OSL evidence suggesting ages beyond 14C limits. Apparently, additional chemical pre-treatment to remove younger carbon fractions, did not work adequately for samples from this core. We hypothesize that the difference between both cores may be related to a larger influence of younger age humin fractions in the mainly sandy Eerbeek-II deposits compared to those buffered by a thick peat layer of Eerbeek-I. We suggest that (local) stratigraphy, percolation and humification processes on 14C ages of organic deposits may be more important than commonly assumed, and should receive more attention. Moreover, a new method to assess robustness and validity of OSL dates is introduced and demonstrates the applicability of OSL dating methods in this setting. Our results highlight that the 14C method requires additional verification methods, such as OSL, for deposits older than 30 ka.
Aluminium induced precipitation affecting molecular characteristics of dissolved organic matter determined by high resolution mass spectrometry (LC-QTOF-MS)

Olaf Brock
Rick Helmus, Sina Shahabi Ghaftari, Timo Heimovaara, Karsten Kalbitz and Boris Jansen

In podzols leaching of organic acids and minerals results in the formation of a B horizon, which is often characterized by a reduced water permeability. Precipitation of aluminium (Al) and organic matter (OM) as Al-OM complexes is important in the formation of Podzol B horizons, but the processes involved are not yet well understood at the molecular level. Therefore, we studied how the molecular composition of dissolved organic matter (DOM) affects the quantity and composition of Al-OM precipitates, by characterizing DOM before and after Al-OM precipitation using an in-house developed non-target screening method that uses liquid chromatography coupled to high resolution mass spectrometry (LC-QTOF-MS). DOM sources included leaf litter and fermentation layer material collected from three Podzols in The Netherlands with deciduous, coniferous or mixed vegetation input; and a commercially available humic acid. OM composition did effect the quantity of precipitates formed, with more precipitates formed for the humic acid than for DOM derived from leaf litter and fermentation material. Only minor changes were found in molecular characteristics and compound class distribution following Al induced precipitation and modelling showed that at pH 4.5 precipitation was probably due to charge neutralization and at pH 5.5 due to sweep flocculation or coprecipitation. For charge neutralization functional groups are important, while other OM properties, such as double-bond-equivalence (DBE), aromaticity and molecular weight, might become more important when DOM precipitates due to adsorption to amorphous Al hydroxides (sweep flocculation/coprecipitation).
Phosphate (P) as an essential resource for food production is becoming scarce. Its uncontrolled loss from agricultural areas is in conflict with the principles of a circular economy. Enhanced loading of surface waters with P is the main cause for eutrophication and presents a key challenge in meeting the objectives of the EU Water Framework Directive. Understanding and controlling environmental P fluxes therefore is key to target both problems, to develop new methods and approaches to manage environmental P fluxes, and to improve surface water quality.

In March 2019 the EU Marie Sklodowska-Curie Innovative Training Network P-TRAP has been launched. P-TRAP establishes a framework of partners from multiple science and engineering disciplines. Integration of non-academic partners from various stakeholder groups into the P-TRAP consortium paves the way for direct implementation of the acquired knowledge. The project is targeting the diffuse flux of phosphate (P) into surface waters, i.e. the problems of understanding and controlling environmental P fluxes. P-TRAP aims to develop new methods and approaches to trap P in drained agricultural areas and in the sediments of eutrophic lakes. Trapping of P involves the application of iron(Fe)-containing by-products from drinking water treatment. P-TRAP aspires the ideas of a circular economy and aims at recovering the retained P in agricultural systems. Novel microbial technologies will be developed to convert P-loaded Fe-minerals into marketable fertilizers whose suitability will be evaluated. The P-TRAP technologies have in common that they rely on the naturally strong connection between P and Fe and the innovative P-TRAP strategies will be underpinned by process-orientated investigations on the behaviour of P during the transformation of Fe minerals. The latter are key in trapping and recycling of P in agricultural systems and lakes. The poster will present the structure and the planned research of the project, including a first overview of achievements of the first year.
Soil organic carbon stocks and stability affected by their molecular composition in the Peruvian Andes

Songyu Yang
Boris Jansen and Erik Cammeraat

Alpine grasslands of the Peruvian Andes are characterized by high soil organic carbon (SOC) stocks, which sustain their ecosystem services such as water provision. However, the potential effects of climate change on the high SOC stocks and their stability are less studied, especially for the underlying mechanisms at the molecular level. To investigate the potential effects of climate change on SOC stability, we collected samples from limestone soils (LSs) and acid igneous rock soils (ASs) from two sites with contrasting precipitation levels. For the study at the molecular level, we applied a novel combination of pyrolysis-GC/MS assisted by tetramethylammonium hydroxide and a 76-day incubation of intact versus crushed soil aggregates. We found that the highest SOC stocks were in the LSs of the wet site (405±42 Mg ha$^{-1}$) and the lowest stocks were in the LSs of the dry site (153±27 Mg ha$^{-1}$). The results of pyrolysis-GC/MS showed that lignin- and polysaccharide-derived compounds had the largest variation (CV=1.49 and 1.36) between different soil samples, whereas compounds derived from short-chain fatty acids had the smallest variation (CV=0.49). SOC contents were positively correlated with compounds derived from lignin and polysaccharides, but had negative correlations with aliphatic compounds. In addition, SOC mineralization rates during the incubation were strongly associated with unsaturated fatty acids ($P<0.001$). After the 76-day incubation, the LSs of the dry site, which had the lowest SOC stocks and stability, were characterized by an accumulation of short-chain fatty acids and N-bearing compounds and a depletion of other compounds. This suggests the low capacity to stabilize these depleted compounds for the LSs of the dry site. Our results suggest a potential association between SOC storage and their molecular composition in the studied soils under the gradients of precipitation and soil mineralogy.
Neither land nor water: earth surface processes and geochronology of peat initiation in bog landscapes

Cindy Quik
Sanne Palstra, Jasper Candel, Bart Makaske, Ype van der Velde, Roy van Beek, Marjolein van der Linden, Lucy Kubiak and Jakob Wallinga

The transition from a dry landscape to a bog landscape is often reflected in a gradual stratigraphical boundary from mineral soil to peat. Varying criteria are used to define peat initiation, resulting in divergent approaches to date the onset of peat accumulation. These methodological dissimilarities indicate limited understanding of the geochronology of peat initiation and consequently selection of appropriate dating samples is debatable. The peat base is often characterised by an amorphous layer of highly humified peat, which is thought to form during alternating wet and dry conditions at the turning point from a drier to a wetter environment. This layer may also contain carbon from mobile humic acids that leached from higher layers in the peat profile. Limited presence of plant macro remains in this layer may require resorting to bulk sampling for radiocarbon dating, which could obscure interpretation of dating results. Depending on the time frame during which the peat base forms, sampling plant remains from higher positions in the peat profile may no longer reflect peat initiation. We aim (1) to enhance understanding of peat initiation in bog landscapes by analysing lithological, biostratigraphical and geochronological characteristics of the mineral-to-peat transition; and (2) to determine and compare quality and suitability of multiple types of radiocarbon dates using samples originating from a range of stratigraphical levels around the mineral-to-peat transition. In this poster we will present our methodology and some preliminary results. Outcomes will contribute to development of protocols for dating peat initiation in bog environments.
The progress being made in the field of exoplanet detection is striking. With all these newly discovered planets, one of the most intriguing and crucial themes to research is the possibility of sustained liquid water on these planets and therefore possibly life. Excellent candidates for testing this conjecture are the so-called super-Earths, planets with a mass \( \leq 10M\oplus \). The composition and mass of a planet are just as important to its livability as its orbital parameters.

Therefore, analyzing the influence of planet size on the evolution of steady-state temperatures is key to understanding the conditions that shape the habitability of extra-solar planets. The long-term carbon cycle is able to regulate planetary climates due to its negative-feedback characteristic. Elevated temperatures increase the weathering rate, drawing CO2 from the atmosphere in the process, resulting in lower temperatures. This feedback system as induced by the long-term carbon cycle is modelled for super-Earths. Assuming Earth-like conditions, the surface temperature rises slowly with mass and results in a 7.1 K increase for 10M\(\oplus\). The higher temperature is traceable to a raise in atmospheric CO2 content resulting from higher amounts of melt generated, due to a significant increase in plate velocity. Comparatively more CO2 gets inserted into the atmosphere by degassing than is withdrawn by weathering. This finding has profound implications for the habitability of terrestrial exoplanets: the long-term carbon cycle could be an effective regulator for the surface temperature on super-Earths.
Tracing the evolution of polycyclic aromatic hydrocarbons from the interstellar medium to planetary surfaces

Nina Kopacz
Arjen Boosman, John Brucato, Maria Angela Corazzi, Claudia-Corina Giese, Helen King, Giovanni Poggiali and Inge Loes ten Kate

Polycyclic aromatic hydrocarbons (PAHs) are formed through combustion processes in circumstellar regions and are abundant throughout the Universe, as observed through the 3-15 μm infrared emission bands. Macromolecular carbon in the form of PAHs and kerogen comprises up to 75% of the organic content of carbonaceous chondrites, and as such has been delivered in significant quantities to Earth and Mars. This begs the question of whether extraterrestrially-delivered organic matter contributed to prebiotically-relevant molecules, as opposed to those being produced by endogenous synthesis. The chemical evolution of PAHs on the journey from their place of origin to planetary surfaces is complex. Once incorporated into ice and rock in bodies like IDPs, asteroids, comets and planets, PAHs experience a wholly different evolution than in gas phase. Here we experimentally test whether PAHs degrade when adsorbed to meteoritic, early-Earth or Martian minerals and exposed to UV radiation. The experiments were monitored with in-situ diffuse reflectance infrared spectrometry (DRIFTS) measurements. Clay minerals were especially targeted as environments which foster further chemical complexification.
The surface habitability of planets is greatly affected by their atmospheric CO2 content. Whereas on Earth the atmospheric CO2 is regulated by the long-term carbonate-silicate cycle, stagnant-lid planets such as Mars or Venus lack subduction zones and thereby efficient carbon recycling into the mantle. Freshly produced basaltic crust can be weathered if liquid water is present, but carbonated crust that is buried by new volcanic eruptions will be subject to metamorphic decarbonation. On the other hand, degassing of CO2 from the mantle is smaller due to a lack of mid-ocean ridges. We employ a thermal evolution model of stagnant lid planets and combine it with a model of carbon degassing, weathering and decarbonation in order to derive the climate evolution of stagnant-lid planets.

We find that the initial mantle temperature is crucial for the atmospheric CO2 during the entire evolution. An initially hot mantle results in rapid early outgassing of CO2, which cannot be recycled back into the mantle. This in turn results in large decarbonation rates at later stages. Furthermore, the oxidation state of the mantle has a substantial effect on the atmospheric CO2 as it controls the concentration of CO2 in the melt. We also show that after 3 billion years the atmospheric CO2 decreases with time, which is caused by an increasing decarbonation depth due to mantle cooling. This circumstance may partially compensate for the surface temperature increase caused by increasing solar luminosity with time, thereby keeping the planet habitable in the long-term.
The long-term carbon cycle on Earth provides an important control mechanism for the atmospheric CO2 concentration on geological timescales. Given the importance of the gas for the regulation of Earth’s climate, we aim to investigate the possible effects a long-term carbon cycle on the evolution of the amount of CO2 in the atmospheres of Earth-like exoplanets. For Earth, plate tectonics plays a crucial role in the long-term carbon cycle, motivating us to investigate the potential role plate tectonics could play in shaping the carbon cycles of these Earth-like exoplanets.

We develop a box-model consisting of a 1D parametrized mantle convection model and a simple carbon cycle model for a planet with plate tectonics. The carbon cycle is coupled to mantle convection through the plate speed, which is dependent on the Rayleigh number. The evolution of the atmospheric carbon content after 1 Gyr is found to be independent of the initial distribution of carbon throughout the various reservoirs modeled. Furthermore, we investigate the influence of variations in planetary properties such as radioactive isotope abundance, total carbon budget and evolution of the radiative flux received from the host star. In the next step, we aim to investigate the sensitivity of the carbon cycle efficiency on planetary mass and core size, and the resulting effects on the evolution of the atmospheric CO2 content.
Experimental and analytical constraints on the early magmatic evolution of the Moon

Joshua Snape
A.A. Nemchin, M.J. Whitehouse and W. van Westrenen

The Moon provides unique insights into the formation and early evolution of rocky planets, which are not available from terrestrial samples. For example, recent analyses of lunar volcanic rocks have provided crystallisation ages and Pb isotopic compositions, which have been used to construct a model describing the earliest magmatic history of the Moon. This model has the potential to place new constraints on the age of the Moon and timing of lunar differentiation, but is currently restricted by uncertainties surrounding the way in which U and Pb will partition into different mineral phases, particularly during the so-called Lunar Magma Ocean (LMO) stage. Complimentary to these analytical advances are experimental studies, which have provided a guide for the mineral assemblages that would have formed in the LMO. For this study, a series of high pressure and temperature experiments have been performed to simulate conditions in the LMO, to address the uncertainties in U and Pb partitioning. Initial results from these experiments appear to indicate that the Moon formed at ~4.5 billion years ago; consistent with recent Lu-Hf and Hf-W isotope studies, which argue against the late formation of the Moon (<4.5 billion years) proposed in several studies over the past decade. Nevertheless, the extreme variation in the U/Pb ratios predicted for the mantle sources of lunar rocks remains challenging to explain.
Initiation and flow conditions of contemporary flows in Martian gullies

Tjalling de Haas

Understanding the initial and flow conditions of contemporary flows in Martian gullies, generally believed to be triggered and fluidized by CO2 sublimation, is crucial for deciphering climate conditions needed to trigger and sustain them. We employ the RAMMS (RApid Mass Movement Simulation) debris flow and avalanche model to back-calculate initial and flow conditions of recent flows in three gullies in Hale crater. We infer minimum release depths of 1.0–1.5 m and initial release volumes of 100–200 m³. Entrainment leads to final flow volumes that are 2.5–5.5 times larger than initially released, and entrainment is found necessary to match the observed flow deposits. Simulated mean cross-channel flow velocities decrease from 3–4 m s⁻¹ to ~1 m s⁻¹ from release area to flow terminus, while flow depths generally decrease from 0.5–1 m to 0.1–0.2 m. The mean cross-channel erosion depth and deposition thicknesses are 0.1–0.3 m. Back-calculated dry-Coulomb friction ranges from 0.1 to 0.25 and viscous turbulent friction between 100–200 m s⁻², which are values similar to those of granular debris flows on Earth. These results suggest that recent flows in gullies are fluidized to a similar degree as are granular debris flows on Earth. Using a novel model for mass-flow fluidization by CO2 sublimation we are able to show that under Martian atmospheric conditions very small volumetric fractions of CO2 of ~1% within mass flows may indeed yield sufficiently large gas fluxes to cause fluidization and enhance flow mobility.
Tidal dissipation makes Jupiter’s moon Io to the most active body in the Solar system. Processes that cause the volcanic pattern of the moon are not fully understood yet. Here, we focus on the question: What is the influence of the upper-mantle viscosity and thickness on the density distribution, the total number, and spatial relation of Io’s observed volcanoes? To this aim, we compare Io’s observed volcano pattern with the up-and downstream patterns and lateral heat flow characteristics resulting from non-uniformly heated steady-state mantle convection.

We investigate three different aspects: i) the effect of lateral heat flow on the global volcano density variations, ii) the total number of volcanic system, and iii) the spatial relation between volcanic centers based on the up-stream characteristics of laminar flow. All aspects are dependent on the Rayleigh-Roberts number but are independent of the location and assumed mechanism of tidal heating. Results favor either a thick mantle of high viscosity or a thin asthenosphere of low viscosity.
Earlier studies have developed global element maps for the elements Fe, K, Th, Si, Cl, H2O, Al, Ca, and S by using the data of the gamma-ray instrument on the Mars Odyssey satellite. Mainly due to the spatial of 200-500 km/pix, of these global element maps, there is much uncertainty about the geological processes behind the element distribution. In our study we aim to increase our understanding of the element distribution by modelling the concentrations with mineralogical information from infrared spectroscopy data from the CRISM (Compact Reconnaissance Imaging Spectrometer) instrument. The results shows that the accuracy of these models varies per element. Besides some regions on Mars have higher accuracies for most of the models than others. The most accurate model is for chlorine, with 45% explained variance, and lowest for calcium, 12% explained variance. The interpretation of the results still includes some work in progress. But it is thought that the lower accuracy can either be explained because not all minerals can be mapped with the CRISM instrument, or the element distribution is not homogeneous in the subsurface (top meter). The gamma-ray measure gamma-rays that can come from the first meter while CRISM as an imaging spectrometer only measures the surface. Current work focuses on the differences of impact of the various spectral parameters on the statistical model. By studying these differences is attempted to develop a better understanding of the element distribution.
Effects of mesoscale ocean flows on multidecadal climate variability

 André Jüling
 Anna von der Heydt, Henk A. Dijkstra

Climate variability on decadal to multidecadal time scales appears to be organized in pronounced patterns with clear expressions in sea surface temperature, such as the Pacific Multidecadal Variability and the Atlantic Multidecadal Variability. These patterns are now well studied both in observations and in global climate models and are important in the attribution of climate change. Results in CMIP5 models have indicated large biases in these patterns with consequences for ocean heat storage variability and eventually the global mean surface temperature. In this paper, we use two multi-century Community Earth System Model simulations at coarse (1°) and fine (0.1°) ocean model horizontal grid spacing and study the effect of the representation of mesoscale ocean flows on major patterns of multidecadal variability. We find that resolving mesoscale ocean flows both improves the characteristics of the modes of variability with respect to observations and increases the amplitude of the heat content variability in the individual ocean basins. However, the effect on the global mean surface temperature is relatively minor.
Resolution-dependent variations of sinking particle trajectories in general circulation models

Peter Nooteboom
Philippe Delandmeter, Peter Bijl, Erik van Sebille, Anna von der Heydt and Henk Dijkstra

Any type of non-buoyant material in the ocean is transported by currents during its sinking journey. This transport can be far from negligible for a low sinking velocity. To estimate the lateral transport, the material is often modelled as a set of Lagrangian particles advected by currents that are obtained from Ocean General Circulation Models (OGCMs).

State-of-the-art OGCMs are often strongly eddying, providing flow fields with a resolution of the order of 10 km in space on a daily basis. Many long term climate modelling studies (e.g. in paleoclimate) rely on lower-resolution models that cannot capture mesoscale features.

In this study, we simulate the transport of sinking Lagrangian particles using low and high resolution OGCMs, and assess the transport differences resulting from the difference in spatial and temporal resolution.

We find major differences between the transport in the non-eddying OGCM and in the eddying OGCM. However, addition of stochastic noise to the particle trajectory parameterises the effect of eddies well in some cases (e.g. in the North Pacific gyre).

A reduction in the temporal resolution (5-daily to monthly) induces a smaller difference compared to a lowering of the spatial resolution (0.1° to 1° horizontally).

We recommend to apply sinking Lagrangian particles only with velocity fields from eddying OGCMs, which basically excludes all paleo-simulations.
Using network theory to understand changes in the Atlantic Ocean transport patterns

David Wichmann
Erik van Sebille

The ocean currents transport large amounts of tracers such as heat, salt, nutrients and debris around the globe. Local currents can produce global transport features such as large-scale accumulation, coherent transport structures or transport barriers, which can be relevant for many applications in ocean and climate sciences. However, the relationship between local (Eulerian) currents and large-scale transport properties is not straightforward because of the high-dimensionality and complexity of the ocean circulation, making it difficult to identify global transport patterns without costly numerical experiments. The analysis of large-scale ocean transport phenomena therefore requires a low-dimensional representation that preserves important features of the real ocean, and that can be analyzed with a reasonable computational cost.

We use Lagrangian particle tracking in combination with ocean circulation model output to construct low dimensional representations of tracer transport in the ocean as networks that represent the flow of particles within and between different geographic regions. Using tools from network science such as clustering algorithms, we identify flow features such as coherent transport structures of the global ocean transport. We then analyze how transport patterns in the Atlantic Ocean change under a changing climate, using modeled ocean current projections for the next 100 years.
The sedimentation of ocean plastic in a 3-D Lagrangian model

Delphine Lobelle
Erik van Sebille

Plastic debris has become a ubiquitous issue in oceans around the globe. As well as numerous unknowns, such as the severity of the threat to ecosystems and human health, plastic’s distribution in the oceans is still currently under investigation. With only around 1% of the total estimated global plastic entering the ocean being found at the surface, it is paramount to improve the understanding of where the plastic ends up once it is in the ocean. Here, we present a framework, using the OceanParcels Lagrangian particle-tracking model, to explore and compare some of the three-dimensional processes that are still poorly understood. The focus is to model the vertical transport or sedimentation of ocean plastic as a result of biofouling (biological growth on plastic). This framework can shed light on which processes are most important to the fate of plastic litter, and hence where previous estimations on plastic’s distribution throughout ocean basins can most effectively be improved.
Absolute temperature seasonality from skeletal carbonates – Techniques and limitations of oxygen- and clumped isotope analyses

Niels de Winter
Rob Witbaard, Clemens V. Ullmann, Anne M. Sørensen, Nicolas Thibault, Inigo A. Müller, Ilja J. Kocken, Philippe Claeys and Martin Ziegler

The carbonate skeletons of marine organisms are unique archives for high-resolution climate reconstructions. Well-preserved specimens allow for seasonal to even daily scale variability reconstructions of climate and environment in deep time (pre-Quaternary), providing snapshots of climate variability during greenhouse periods. However, uncertainties about past seawater compositions complicate the use of the popular stable oxygen isotope ratio ($\delta^{18}O$) as paleotemperature proxy. The independent carbonate clumped isotope ($\Delta^{47}$) paleothermometer, which is insensitive to changes in seawater composition, on these promising fossil archives is complicated by sample size limitations. In an attempt to circumvent these issues and use the $\delta^{18}O$ and $\Delta^{47}$ measurements jointly for accurate seasonal reconstructions of temperature and seawater isotope composition, we present a novel data reduction approach that combines $\Delta^{47}$ measurements on small (~100 µg) serially sampled aliquots to estimate summer and winter temperatures from mollusk shell records. When applied on $\Delta^{47}$ and $\delta^{18}O$ measurements in the same specimens with accurate shell chronologies, this approach reconstructs seasonal ranges in temperature and seawater composition in a coastal site from the Campanian (Late Cretaceous) high-latitudes.

To test the robustness of these reconstructions, we apply different approaches of combining $\delta^{18}O$ and $\Delta^{47}$ data on a wide range of simulated data representing various scenarios of variability in growth rate, temperature and sea water composition typical for the natural shallow marine environments of carbonate-producers. This approach tests how choices such as sampling resolution and the method of data collection and reduction influence the accuracy and reproducibility of (paleo)seasonality reconstructions in these scenarios.
Chemical and microscopic investigation of iron nanoparticles in the Rainbow hydrothermal plume

Kristin Anna Ungerhofer
Oliver Plümper, Gert-Jan Reichart and Peter Kraal

Iron (Fe) is an essential nutrient that modulates marine primary productivity in large parts of the open ocean. Hydrothermal vents represent a significant source of Fe to the global ocean by expelling geothermally heated, chemically altered (Fe-rich) seawater back into the overlying water column. However, the speciation, bioavailability and fate of Fe derived from hydrothermal systems, as well as the impact of intense localized Fe emissions on other biogeochemical cycles, remain poorly understood.

Here, we use chemical methods and nano-scale microscopy to analyze particulate and dissolved Fe as well as associated key elements such as manganese (Mn), phosphorus (P) and sulfur (S) in the water column and sediment near an active hydrothermal vent field in the North Atlantic Ocean (the sulfide-rich black smokers of the Rainbow vent field, 36°N). We find carbon-coated aggregates of nano-scale crystalline Fe sulfides (chalcopyrite) and amorphous Fe (oxyhydr)oxides that precipitate in the plume, scavenge dissolved P from the water column and trap it in the surface sediments, indicating that high venting activity has the ability to deplete the deep-sea dissolved P pool. Furthermore, our results suggest that amorphous ferric nanoparticles represent an important and highly dynamic fraction of vent-derived iron, providing new insight into the bioavailability of operationally-defined iron pools as well as mechanisms of stabilization and long-range transport of Fe in the ocean.
Current estimates of carbonic acid dissociation constants appear inconsistent with measured CO2 system parameters in cold oceanic regions

Olivier Sulpis
Siv K. Lauvset and Mathilde Hagens

Seawater absorption of anthropogenic atmospheric carbon dioxide (CO2) has led to a range of changes in carbonate chemistry, collectively referred to as ocean acidification. Stoichiometric dissociation constants used to convert measured carbonate system variables (pH, pCO2, dissolved inorganic carbon, total alkalinity) into globally comparable parameters are crucial for accurately quantifying these changes. The temperature and salinity coefficients of these constants have generally been experimentally derived under controlled laboratory conditions. Here, we use field measurements of carbonate system variables taken from the GLODAP and SOCAT databases to evaluate the temperature dependence of the carbonic acid stoichiometric dissociation constants. By applying a novel iterative procedure to a large dataset of 948 surface-water, quality-controlled samples where four carbonate system variables were independently measured, we show that the set of equations published by Lueker et al. (2000), currently preferred by the ocean acidification community, overestimates the stoichiometric dissociation constants at low temperatures, below ~8°C. We apply these newly derived temperature coefficients to high-latitude Argo float and cruise data to quantify the effects on surface-water pCO2 and calcite saturation states. These findings highlight the critical implications of uncertainty in stoichiometric dissociation constants for future projections of ocean acidification in polar regions and the need to improve knowledge of what causes the CO2 system inconsistencies in cold waters.
Submarine canyons provide effective connections between the productive shelf waters and the nutrient poor deep-sea, playing an important role in lateral transport of organic matter. In order to establish the magnitude, rate and quality of lateral transport of organic carbon and particulate matter in the Whittard Canyon, two moored observatories with sediment traps were deployed for one year along its thalweg. Particulate matter composition and transport were investigated based on near-bottom current dynamics, temperature variability, total mass fluxes and geochemical analysis. Results indicate that significant amounts of particulate matter were transported by both internal waves and intermittent gravity flows year-round. Elevated mass flux events at the stations were associated with gravity flows resulting from storms and possibly anthropogenic activity in the region, whereby highest organic carbon fluxes were recorded coincident with elevated mass flux events. Chl-a and 210Pb activity of the samples indicate that particulate matter transported by these gravity flows was mainly composed of resuspended and degraded organic matter. However, large amounts of fresh organic matter and phytodetritus were transported rapidly due to the coincidence of a phytoplankton bloom and storm-related gravity flow in the months October and November. This study improves our understanding of the underlying relation between canyon morphology, bottom current dynamics, seasonality, lateral transport processes and particulate matter composition and flux. Moreover, it determines role of the canyon as a pathway and sink for organic matter towards the deep oceans and hence its importance as an element of the global marine carbon cycle.
Poster number, author, title

1. Liesbeth Florentie Satellite-based CO2 flux estimates with CarbonTracker Europe
2. Jan Fokke Meirink Retrieving and forecasting surface solar irradiance from Meteosat observations
3. Gert-Jan Marseille Aeolus – the first Doppler wind lidar in space
4. Bart van Stratum Downscaling a weather model with high-resolution large-eddy simulation
5. Sylvia Walter MEMO2 MEthane goes Mobile- MEasurements and Modelling
6. Jin Ma Inverse modelling of global COS budget
7. Ara Cho Inverse modelling of the coupled COS and CO2 budgets
8. Peng Yao Seasonal and diurnal variation of carbonaceous aerosol sources and brown carbon concentrations at the CESAR site in the Netherlands
10. Frenk Out Geomagnetically induced currents in the Dutch high voltage powergrid
11. Sigrid van Grinsven Methane oxidation and nitrate reduction in a eutrophic lake – are they coupled, who is involved?
12. Thomas van der Linden Towards a quantitative paleogeography calculator
13. Henry Brett Inner core anisotropy measured using new ultra-polar PKIKP arrivals with mantle corrections
14. Rúna van Tent The importance of mantle azimuthal anisotropy for the coupling of Earth’s normal modes
15. Erika Neeft Comparison of natural and artificial carbon-14 fluxes
16. Fiorenza Deon Rare Earth Elements (REEs) in mine waste: a way to solve the rising worldwide REEs demand?
17. Annet Baken Nucleation of barite: linking rates and mechanisms to solution stoichiometry
18. David Riedinger Understanding BaSO4 nucleation at diverging \{Ba^{2+}\}:{SO_{4^{2-}}} ratios in aqueous environments
19. Willem Zaadnoordijk On the creation of piezometric contours of groundwater heads
20. Gaby Gründemann Extreme precipitation return levels on a global scale
22. Femke Smessaert Moisture sources affecting Rio de Janeiro during heatwave events
23. Paolo Scussolini Hydroclimate of the Last Interglacial: precipitation, river discharge, floods and storm surges
24. **Philip Kraaijenbrink** Climate change decisive for Asia’s snow meltwater supply
25. **Ryan Teuling** Climate change, reforestation/afforestation, and urbanization impacts on evapotranspiration and streamflow in Europe
26. **Arthur Lutz** Importance and vulnerability of the world’s water towers
27. **Edward Jones** Quantifying global desalination and wastewater re-use capacities for global water scarcity assessment
28. **Swagatam Chakraborty** Multi DNA-tracer transport experiments in a laboratory 3D aquifer tank for groundwater flow characterization
29. **Teun van Woerkom** Sensitivity analysis of dike macro-stability: It’s just hydro-logic!
30. **Samuel Sutanto** Drought deviates from low flow
31. **Yuchen Tang** Transport Behaviour of Silica-encapsulated-DNA-based Microparticle as a Surface Water Tracer: Proof of Concept
32. **Willem-Jan Dirkx** Piping and subsurface heterogeneity: A scale model
33. **Alraune Zech** What happens below construction pits? The long-term erosion of temporary barriers to groundwater flow
34. **Biao Lu** Using real polar ground gravimetry data to solve the GOCE polar gap problem in satellite-only gravity field recovery
35. **Bas van de Schootbrugge** Microbial mediation of carbon storage in Arctic glendonites
36. **Runa Magnússon** Arctic Greening, Arctic Browning or Arctic Drowning?
37. **Bas de Boer** Global coupled climate – ice sheet model simulations for the penultimate deglaciation and the last interglacial
38. **Catrien Hoffman** Spring season, atmospheric CO2 and vegetation dynamics during the late Holocene in Northern Denmark based on paleobotanical proxies
39. **Jelte de Bruin** Freeze-thaw dynamics in a synthetic permafrost soil columns with variable organic carbon content
40. **Dirk Jong** Permafrost organic carbon transport and degradation on a transect from the Kolyma River to the East Siberian Shelf
41. **Anna von der Heydt** Cascading transitions in the Climate System
42. **Rea Vaz** Carbon isotope stratigraphy for the 2.5-billion-year-old Dales Gorge Member, Australia: Correlation potential and Paleoclimatic significance
43. **Maarten Prins** Identifying sediment transport mechanisms from grain size-shape distributions
44. **Harold Berghuis** A revised stratigraphy for the hominin-bearing strata of Trinil, East Java (Indonesia)
45. **Josephine Joordens** Resolving the complex stratigraphy and geochronology of the Homo erectus type locality Trinil (Java, Indonesia)
46. **Jimmy de Rooij** A large 67 million year old Triceratops death assemblage
47. **Eduard Pop** Quantitatively studying bone taphonomy of Homo erectus fossils from Trinil (Indonesia) using surface texture and CT analyses
48. **Xianduo Dai** Long-term Cycles of climate change during Middle Triassic through Late Jurassic in South China: Insights from chemical weathering indices and clay mineralogy

49. **Thomas Giesecke** Vegetation response to rapid warming at 11.7 ka provides benchmarks for predicting the future

50. **Marloes Jobse** Late Glacial vegetation development recorded at the eastern edge of the coversand deposits in the Den Treek area, central Netherlands

51. **Jingjing Guo** Reconstructing deglacial warming of monsoonal East Asia using clumped isotopes of land snail shells in the Chinese Loess Plateau

52. **Lisanne Krom** Vegetation and marine ecosystem change during the Early Pleistocene in the Netherlands

53. **Joost Frieling** Core-top calibration and first application of the dinoflagellate cyst based pCO2 barometer

54. **Jan-Berend Stuut** Present-day Saharan dust fluxes across the Atlantic Ocean

55. **Sander Hoogendoorn** High-resolution XRF and stable carbon isotope analysis of the ~2.5 Ga Brockman Iron Formation

56. **R.M. Ebner** Slowing down the overturning – Insights from conceptual modelling on a stably stratified Mediterranean Sea during the Messinian Salinity Crisis

57. **Laura Pacho Sampedro** Development of foraminifera-based proxies for the marine inorganic carbon system

58. **Mike Vreeken** Deconvolving temperature and precipitation variability over the last deglaciation in East Asia using branched tetraether lipids in the western Chinese Loess Plateau

59. **Louise Fuchs** Identifying the drivers of vegetation change on the Chinese Loess Plateau over the last deglaciation

60. **Remco Bos** Long-term phytotoxicity and mutagenesis in terrestrial vegetation following the Triassic-Jurassic boundary

61. **Anna Bui** IMS 1300-HR3: a versatile ion microprobe for Geosciences

62. **Theresa Pfluger** Application of a Self-learning Algorithm to Analyse Microscopic Images of Stomata

63. **Pieter Dirksen** The mechanism of sapropel formation in the Mediterranean Sea: Insight from long duration box-model experiments

64. **Siham de Goeyse** Carbonic anhydrase contribution in benthic foraminiferal calcification

65. **Nina Papadomanolaki** Drivers and climatic impact of organic carbon burial: comparing OAE2 and the PETM

66. **Wesley Plugge** Fate of organic carbon discharged by the Atchafalaya and Mississippi Rivers into the Gulf of Mexico

67. **Diego Miralles** Soil moisture effect on human heat stress during hot spells
68. **Jinfeng Wu** Low watershed hydrological and erosion response after fire can be explained by connectivity

69. **Daan Reijnders** Assessing Ocean Surface Connectivity in the Arctic: Capabilities and caveats of community detection in Lagrangian Flow Networks

70. **Erik van Sebille** Developments of the OceanParcels Lagrangian Ocean Analysis framework

71. **Frida Hoem** Surface ocean conditions offshore Ross Sea continental margin, Antarctica, during the Oligocene to Early Miocene

72. **Sebastian Mulder** EuroMoonMars, HI-SEAS 2020: Analysis of secondary mineralization of igneous rocks in lava tubes on Mauna Loa, Hawaii; insights in extraterrestrial environments

73. **Annelotte Weert** EuroMoonMars, HI-SEAS 2020: Hydrous alteration of lava flows on Mauna Loa (Hawaii) compared to Martian volcanic soils

74. **Mahid Ahmed** Iceland/Azores lava tubes as analogue environments for Mars. Link between petrology and microbial mats

75. **Linah Krigee** The effect of planetary formation and early evolution on the long-term carbon cycle and the atmospheres of rocky exoplanets

76. **Miriam Sterl** Influence of barotropic tidal currents on transport and accumulation of floating microplastics in the global open ocean

77. **Mikael Kaandorp** Inverse modelling of plastic sources and sinks in the Mediterranean sea by assimilating observational data and Lagrangian models

78. **Szabina Karancz** The role of upwelling regions in modulating past atmospheric CO2 levels: a multi-proxy reconstruction of marine inorganic carbon chemistry

79. **Arjan Dijkstra** Rare Earth Elements in polymetallic nodules from the Pacific Ocean

80. **João Trabucho** Alexandre Watch and Learn: Promoting Student Autonomy and Competence in the Field with Just-in-Time Knowledge Clips

81. **R.M. Ebner** You can’t be what you can’t see - The Young Women of Geosciences
Workshops

Workshop 1  Role(s) of scientists in political debates. The climate crisis debate as an example

Domtoren 3  11:45 - 12:15 h

Moderator: Jelle Beumer

This workshop / discussion will be on the Earth scientist roles in political debates, with a panel comprising earth scientists with different backgrounds from which is mainly concerned about the climate question. However, the arguments in this debate might also apply to other issues that need scientific input (e.g. nitrogen, Groningen, etc.). Questions that could be posed to the panel (and the audience!) are: How do you see your role before the debate? Why join an activist group like XR and/or S4F as a scientist? Civil disobedience and non-violent action (XR) or scientific support only (S4F)? Does participation in activist groups affect your scientific integrity, independence and bias? Can your role as scientist activist be misused by media and, if yes, how can that be avoided if that is possible at all? Do different roles as scientists in the climate crisis debate affect your future job opportunities?

Global climate change has triggered several grass root initiatives among which Scientists4Future (S4F) and Extinction Rebellion (XR). Scientists4Future NL is a self-organised, self-initiated alliance of scientists from Dutch universities and research institutes. Many scientists are worried about climate change but do not speak out because they are concerned this may have negative consequences (media backlash, perceived loss of objectivity, etc). Scientists4Future NL is a space to discuss and address these concerns and find ways to be active. Extinction Rebellion is an international movement that uses non-violent civil disobedience in an attempt to halt mass extinction and minimise the risk of social collapse. At the core of Extinction Rebellion’s philosophy is nonviolent civil disobedience. XR promotes civil disobedience and rebellion because they think it is necessary – they are asking people to find their courage and to collectively do what is necessary to bring about change.

Please do bring your mobile phone to this workshop.
Workshop 2  
**Research strategy Earth Observation 2020–2025**

Domtoren 4  11:45 - 12:15 h

E. van Sebille, C. van der Tol, W. van der Wal and B. Wouters

The goal of this presentation is to present and discuss a strategic plan for Earth Observation (EO) research in The Netherlands, which has recently become available as a joint effort of the Dutch EO scientific community supported by NSO. The report formulates priorities and goals that are common to the disciplines that are represented: atmosphere, land, ocean and coastal zone, cryosphere, and solid earth. A short summary will be provided of the contents of the report, focusing on five main recommendations that are made concerning research, infrastructure, education, and the connection to society. Furthermore, a proposition will be presented of how to make best use of this report, for which we would like reach out to the audience for comments and further suggestions.

Workshop 3  
**NWO Roadshow on Knowledge Utilization and PPS Fund**

Domtoren 5  11:45 - 12:15 h

NWO will use four new, harmonised main lines for funding of public-private collaboration within the Knowledge- and Innovation Covenant 2020-2023. We will provide you with the most recent information about these funding opportunities, expected call timelines, and options for partnerships and large, strategic collaborations. In this roadshow colleagues from the NWO Science Domain will elaborate on these funding opportunities, and answer all your questions.

Workshop 4  
**NWO Granting Workshop.**

Domtoren  11:45 - 12:15 h

Within the NWO Science Domain there are quite a few funding schemes, among which the NWO Open Competition Domain Science – KLEIN, and the NWO Talent Programme Veni, Vidi and Vici.

In the NWO Open Competition Domain Science - KLEIN researchers can apply individually or in collaboration for curiosity-driven, fundamental research in the research fields of
the NWO Domain Science. KLEIN grants are intended for realising curiosity-driven, fundamental research of high quality and/or scientific urgency. The KLEIN grant offers researchers the possibility to elaborate creative and risky ideas and to realise scientific innovations that can form the basis for the research themes of the future. There are three categories of KLEIN grants: KLEIN-1 (1 scientific position), KLEIN-2 (2 scientific positions in collaboration) and KLEIN-0 (investments) that are assessed in competition with each other.

This Talent Programme provides three grants for talented, creative researchers who engage in innovative research: Veni, for researchers who have recently obtained their PhD; Vidi, for researchers who have gained several years of research experience after their PhD; and Vici, for senior researchers who have demonstrated an ability to develop their own line of research. The Talent Programme offers personal grants to talented, creative researchers. The funding enables applicants to do their own line of research. This boosts innovative research and promotes mobility within scientific research institutes.

In this Workshop NWO colleagues will give an overview of the above funding programmes, as well as elaborate on recent developments, e.g. the narrative CV, and the DORA.

NWO has introduced a uniform narrative curriculum vitae format in the upcoming Vici round. This measure dovetails with a new approach for recognising and rewarding scientists and follows on from the position paper Room for everyone’s talent, which NWO recently published with its partners. Moreover, NWO has had good experiences in recent years with the narrative CV in the pre-application pilot for the Veni in the NWO domains SSH, AES and ZonMw. A uniform CV has several advantages: there are no longer any differences between the domains, and the CV is compatible with the principles of the DORA declaration which NWO recently signed. As a result, CVs will be assessed much more on their quality and (sustainable) impact than on their quantity and prestige.

DORA is a global initiative that aims to reduce dependence on bibliometric indicators (such as publications and citations) in the evaluation of research and researchers, and increase the use of other criteria. The declaration outlines a set of recommendations on how to improve research evaluation. KNAW, NWO and ZonMw fully endorse the principles laid out in the DORA declaration and will adapt their own procedures to it.
Workshop 5  The professional development of a geologist

Domtoren 7  11:45 - 12:15 h

Hosted by the KNGMG (Royal Netherlands Earth Sciences Society).

Students who graduate with degree in earth sciences are qualified for employment in a wide range of careers, including resource management, geotechnical and environmental consulting, petroleum and mining industries, geological surveys, or pursue a career in an academic environment. The KNGMG (Royal Geological and Mining Society of the Netherlands), is the learned society in the Netherlands which tose with a career in Earth Sciences with the opportunity to meet and extend their network. For this the KNGMG organizes meetings, scientific conferences, and other networking opportunities, as well as publishes the Geo.brief and the Netherlands Journal of Geosciences – Geologie en Mijnbouw.

Furthermore, in the Netherlands the KNGMG is handling the accreditation process for the European Geologist title in cooperation with the International License Body van de European Federation of Geologists (EFG). The European Geologist title is a professional title created by the European Federation of Geologists which recognises the ability to deliver a high quality of services within the practice of geology. This certification held by a professional geologist means that the holder has achieved suitable academic training and a level of professional experience, skill and competence to perform tasks within their professional practice. It also means that the geologist undertakes continuing education and training, demonstrating a personal commitment to stay up to date and informed within the sphere of their professional work.

In this workshop representatives from the Society will elaborate on the possibilities for early career earth scientists, and provide them with insights concerning their professional development as an earth scientist.
Organisation

Programme Committee NAC 2020

Boris Jansen, UvA (Chair)
Ilse Aben, SRON
Jelle Assink, KNMI
Erik Cammeraat, UvA
Kim Cohen, UU
Tjalling de Haas, UU
Rolf Hut, TUD
Oscar Kamps, UT
Janne Koornneef, VU
Inge Luijkx, WUR
Stef Lhermitte, TUD
Furu Mienis, NIOZ
Mark van der Meijde, UT
Wouter Peters, RUG & WUR
Francien Peterse, UU
Oliver Plümper, UU
Bart Root, TUD
Mónica Sánchez-Román, VU
Wouter Schellart, VU
Aimée Slangen, NIOZ
Femke Vossepoel, TUD
Guido van der Werf, VU
Martin Ziegler, UU

Advisory Council

The Advisory Council consists of Maarten Krol, Luc Lourens (members of the NWO advisory table for Earth Sciences) and Fraukje Brouwer. The Advisory Council is responsible for the composition of the Programme Committee, based also on advice given by the conference organisers.

Conference Organisers

The team from NWO tasked with the organisation of NAC 2020 consists of Bernard Westerop, Sebastiaan de Vet, René Prop and Jill van Heesen.
**Exhibitor**

**Stand location**

- **COVRA**
  - Lobby stand number 1

- **KNGMG**
  - Lobby stand number 2

- **Cameca/Amatek**
  - Oudegracht stand number 3

- **Deltaries**
  - Oudegracht stand number 4

- **Shell**
  - Oudegracht stand number 5

- **Springer Nature**
  - Domtoren stand number 6

- **TNO**
  - Domtoren stand number 7

- **TNO GDN**
  - Domtoren stand number 8