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Orals and poster presentations @ AGU 2018

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Book of Abstracts

CliSAP/CEN will be present at the fall meeting of AGU from 10 – 14 December in Washington D.C., US at booth # 1013 in the Walter E. Washington Convention Center located at 801 Mount Vernon Place, NW, Washington, DC 20001.
You are warmly invited to come by.

U Union
A Atmospheric Sciences
B Biogeosciences
C Cryosphere
EP Earth and Planetary Surface Processes
GC Global Environmental Change
H Hydrology
IN Earth and Space Informatics
NH Natural Hazards
OS Ocean Sciences
PP Paleoceanography
S Seismology
V Volcanology, Geochemistry, and Petrology

Monday, 10th of December

Orals:

GC12C: **Global Vegetation and Land Surface Dynamics in a Changing Climate I**
10:20 – 12:20, Convention Center - 147B

10:50 – 11:05	GC12C-03 **Driver Attribution of Vegetation Greening and Browning Trends of Natural Ecosystems** (**Alexander J Winkler** and Victor Brovkin)

Abstract:
Satellite observations over the last 35 years reveal that the terrestrial vegetation is changing across the globe. Various ecosystems from polar tundra to subtropical drylands show a widespread increase in vegetation greenness ('greening'). Some regions also exhibit declining trends ('browning'). Changes of vegetation greenness are indicative for an altering photosynthetic activity, and thus, have direct consequences for the terrestrial carbon cycle, hydrological cycle as well as biophysical surface properties. However, the mechanisms underlying observed greening and browning trends are not yet fully understood.
Here, we present a comprehensive attribution analysis of the four key drivers (climate change, CO2 fertilization, nitrogen deposition, and fire disturbance) of leaf area index (LAI) trends of natural ecosystems. We follow two conceptually different approaches, a process-based modeling and statistical observation-based approach. For the former, we conduct factorial experiments using the fully coupled Max-Planck-Institute for Meteorology Earth system model (MPI-ESM) in its current version. The model is driven by observed conditions to simulate the historical period. In each factorial experiment we retain one particular driver at preindustrial conditions to disentangle its effect on vegetation greenness. We apply Optimal Fingerprinting to quantify the factors contributing to LAI trends and assess their regionally varying importance. Alongside the process-based driver attribution, we develop a statistical framework making use of Generalized Additive Models (GAM). GAMs enable a statistical factor quantification and attribution solely based on observations. In the synergy of the process-based and statistical approach, we present a robust driver attribution of the observed Earth greening trend.

GC13B: **Carbon Cycle Climate Variability: Observation, Modeling, and Data Assimilation in the Modern Data-Rich Era I**

13:40 – 15:40, Convention Center – Salon A

14:04 – 14:16 GC13B-03 **Integrating multiple top-down and bottom-up approaches to evaluate the tropical land sink response to El-Niño in 2015/16**

(**Ana Bastos**, Pierre Friedlingstein, Stephen Sitch, Arnaud Mialon, Jean-Pierre Wigneron, Vivek Arora, Peter Briggs, Kevin W Bowman, Josep Gili Canadell, Philippe Ciais, Frédéric Chevallier, Lei Cheng, Christine L Delire, Vanessa Elizabeth Haverd, Atul K Jain, Fortunat Joos, Etsushi Kato, Sebastian Lienert, Junjie Liu, Danica L. Lombardozzi, Joe Melton, Ranga B Myneni, Julia Nabel, Julia Pongratz, Benjamin Poulter, Christian Rödenbeck, Roland Seferian, David Schimel, Hanqin Tian, Nicolas Viovy, Nicolas Vuichard, Anthony Walker, Andy Wiltshire, Jia Yang, Soenke Zaehle, Ning Zeng, Dan Zhu and Christel van Eck)

Abstract:

Evaluating the response of the land carbon sink to anomalies in temperature and drought imposed by El-Niño provides insights into the present-day C-cycle and its climate driven variability. Additionally, ENSO affects key regions and processes that are sources of uncertainty in future C-cycle projections; thus, it is worth testing whether process-based models are able to simulate the response to the land C-cycle to ENSO.

We present an in-depth analysis of the response of the terrestrial C-cycle to the 2015/16 El-Niño that imposed extreme warming and dry conditions in the tropics. We provide a synthesis of the spatio-temporal evolution of anomalies in net land-atmosphere CO2 fluxes estimated by two in-situ based atmospheric inversions (CAMS and CarboScope) and 16 land-surface models (LSMs), during the onset, peak and demise of El-Niño in 2015/16. We further compare these estimates with those of the latest Global Carbon Budget (GCB2017, LeQuéré et al., 2018) and with other works. Simulated changes in ecosystem gross primary productivity (GPP), decomposition rates and fire emissions are also investigated and compared with satellite-based leaf-area index, GPP and aboveground biomass C-stocks.

Inversions and LSMs point to a decreased land carbon sink during 2015/16 and generally agree on the temporal patterns of decrease and subsequent recovery of the land sink in response to El-Niño conditions. LSM simulate a decrease in productivity throughout all tropical regions, rather than increase in respiration, dominated the CO2 flux anomalies in response to ENSO, mainly associated with prolonged drought conditions, and that fire emissions had a moderate contribution.

The simulated spatial patterns of leaf-area index anomalies and changes in GPP and C-stocks were generally consistent with satellite-based data. However, some of the regional anomalies and driving processes appear to be partly inconsistent with the GCB2017 estimates and other studies analyzing the C-cycle response to ENSO (e.g. Liu et al., 2017). The differences between LSM estimates and those of other studies have been further investigated. In particular, the consistency of model simulations with the fluxes from NASA's Carbon Monitoring System Flux (CMS-Flux) project was further analyzed for the years 2011 (La Niña) and 2015/16 (El Niño).

GC14A **Advances in Monitoring and Reporting Greenhouse Gas (GHG) Emissions and Sinks Across Land Use Categories I**
16:00 – 18:00, Convention Center - Salon A

17:45 – 18:00 GC14A-08: **Reconciling Global Model Estimates and Country Reporting of Anthropogenic Forest CO_2 Sinks**

(**Giacomo Grassi**, Alessandro Cescatti, Joanna House, Werner A Kurz, Glen P Peters, Richard A Houghton, Maria sanz Sanchez, Raul Abad Viñas, Ramdane Alkama, Almut Arneth, Alberte Bondeau, Frank Dentener Dr, Marianela Fader, Sandro Federici, Pierre Friedlingstein, Atul K Jain, Etsushi Kato, Donna Lee, Julia Nabel, Lucia Perugini, Alexander Nassikas, Simone Rossi, Stephen Sitch, Nicolas Viovy, Andy Wiltshire, Sönke Zaehle and Charlie Koven)

Abstract:
Achieving the long-term temperature goal of the Paris Agreement (PA) requires forest-based mitigation. Collective progress towards this goal will be assessed by the PA's Global Stocktake. Currently, there is about a 4 $GtCO_2$/y discrepancy in global anthropogenic net land use emissions between global models (reflected in IPCC Assessment Reports) and aggregated national greenhouse gas (GHG) inventories (under the UNFCCC). We show that this discrepancy is largely explained (about 3.2 $GtCO_2$/y) by conceptual differences in anthropogenic forest sink estimation, related to representation of environmental change impacts and the areas considered managed. For a more credible tracking of collective progress under the Global Stocktake, these conceptual differences between models and inventories need to be reconciled. We implement a new method of disaggregation of global land model results that allows greater comparability with GHG inventories. This deepens understanding of model-inventory differences, allowing more transparent analysis of forest-based mitigation and facilitating a more meaningful Global Stocktake.

A14E: **Convective Clouds: Processes, Dynamics, and Links to Weather and Climate II**
16:00 – 18:00, Convention Center – 151 A

17:45 – 18:00 A14E-08 **Organization Controls on Precipitating Convection**
(**Cathy Hohenegger** and Bjorn Stevens)

Abstract:
An ubiquitous aspect of the precipitation distribution over tropical land areas is its organization on various scales. In this study, we investigate whether the land surface tends to support or impede the organization of convection. As the effects of the land surface are often blurred by the complexity of the land-atmosphere system or biased by the use of convective parameterizations, we take a simpler approach and apply the radiative convective equilibrium (RCE) framework to an idealized land planet that only retains the basic control of the land surface on precipitation.
In contrast to an oceanic surface, the land surface is characterized by a smaller heat capacity and by a finite supply in soil moisture. Results of our convection-permitting simulations show that the smaller heat capacity of the land surface favors the aggregation of convection, whereas the fact that the land can dry out acts against it. In both cases the spatial distribution of precipitation is determined by thermally driven circulations of various origins that are confined in the boundary layer. We find no evidence that wetter soils or the gradual moistening of the atmosphere by surface fluxes control the spatial distribution of precipitation.
In a second step, we use observations to test the findings of our RCE experiments. In agreement with the results of our idealized experiments, we show that tropical rainbands widen over land in the sense that in years with drier soil moisture conditions over Africa, the monsoon rains moves further inland.

Tuesday, 11th of December

Orals:

B22D: **Vulnerability of Permafrost Carbon to Climate Change I**
10:20 – 12:20, Convention Center – 143 A-C

B22D-08 **Including microbial dynamics is essential for modelling Arctic methane emissions**

12:05 – 12:20

(**Sarah Chadburn**, Yuanchao Fan, Tuula Aalto, Mika Aurela, Annett Bartsch, Julia Boike, Eleanor Burke, Casper Christiansen, Edward Comyn-Platt, A Johannes Dolman, Thomas Friborg, Nicola Gedney, Garry Hayman, David Holl, Gustaf Hugelius, Ko J van Huissteden, Mathilde Jammet, Lars Kutzbach, Hanna Lee, Annalea Lohila, Maija E Marushchak, Frans-Jan W Parmentier, Andreas Richter, Torsten Sachs and Narasinha J Shurpali)

Abstract:
Methane (CH4) emissions from the high latitudes represent a potentially important feedback mechanism with the Earth's climate. Latest estimates of CH4 emissions from high latitude wetlands range between 20-70 TgCH4/yr, out of a global total 500-600 TgCH4/yr, and this region is experiencing a rapid warming under climate change, which could lead to major changes in CH4 emissions, which would impact global warming. Thus it is important to include high latitude CH4 emissions in climate models.
Several recent land surface schemes – which are used in climate models – include process-based CH4 models, which represent production, oxidation, emission, and the various transport mechanisms of CH4 through the soil and into the atmosphere. These build upon the original CH4 schemes in such models, which are simple functions of soil temperature, wetland area and substrate. However, while the recent transport schemes are well-developed, a simple function is still used for CH4 production. We study two land-surface schemes (CLM and JULES) and find that CH4 production is a key determinant of wetland emissions. Thus more attention should be focussed on modelling production of CH4.
We then show that it is possible to recreate the observed CH4 fluxes over a number of sites by including microbial dynamics. Microbial dynamics explain an apparent large temperature sensitivity in CH4 emissions: the active microbial biomass increases during the summer, which amplifies the summertime emissions. The RMSE between the timeseries of CH4 emissions in model and observations is reduced for every site by including microbial dynamics.
For this work we made use of detailed observations from a range sites, including two cold permafrost sites in Siberia (Samoylov and Kytalyk), two somewhat warmer sites in Scandinavia (Abisko and Lompolojankka), and Seida in Western Russia. CH4 was measured by eddy covariance and adjusted to include only the wetland flux. High resolution timeseries of soil temperatures over multiple years, along with soil carbon profiles, were used to model the CH4 fluxes.
We include the new microbial CH4 production model in a global land-surface scheme (JULES) and assess pan-Arctic CH4 emissions. This work will lead to improved projections of Arctic carbon-cycle feedbacks.

B23C-01: **Cascading the terrestrial soil organic carbon to hydrology within MPI-ESM: Global distribution of riverine DOC concentration and seasonality at major river basins**

(**Swati Gehlot**, Stefan Hagemann and Victor Brovkin)

13:40 – 13:55, Convention Center – 150A

Abstract:

The current state of the art Earth System Models (ESMs) do not simulate the lateral transport of terrestrial carbon to oceans via the global river network. Carbon cycling is primarily evaluated based only on vertical gas exchange processes between atmosphere and land. In high latitudes, however, the permafrost plays an important role in contributing riverine organic carbon to the ocean. The interaction between permafrost and lateral hydrology is a substantial factor impacting the organic carbon inflow to the Arctic Ocean and its associated atmospheric exchange.

This study quantifies the riverine transport of terrestrial soil organic carbon to the oceans using the hydrological discharge scheme (HD Model) of MPI-ESM (Max-Planck Institute for Meteorology Earth System Model). The terrestrial soil carbon classification is based on the YASSO scheme. The water-soluble fraction of the soil carbon pools is attributed to the dissolved organic carbon (DOC) flushing into the rivers via runoff (fast carbon pool, above ground) and base-flow (slow carbon pool, below ground). The HD model, which simulates the river discharge for all land areas at a resolution of 0.5 degree, is extended with the carbon cascade (transport) scheme. The flow properties of the transported soil organic carbon are the same as for the transported water depending on terrain slope and reservoir storage. The fraction of available water soluble soil carbon as a source for transport into the river stream is evaluated by model sensitivity tests in comparison to observations and previous studies over selected river basins. For river basins in high latitude areas influenced by permafrost, the availability of liquid water in comparison to ice is considered as a change in source of terrestrial soil organic carbon entering the river system. The study is aimed to derive a global distribution of model derived terrestrial DOC concentration together with the DOC seasonality over major river networks. The simulation of carbon transfers along the terrestrial-aquatic continuum over tropical and high-latitude river reservoirs will be evaluated based on observations (Arctic Great Rivers Observatory data) as well as on similar studies by other ESMs.

GH22A: **Global Warming, Urban Heat Island, and Public Health: Vulnerability, Impacts, and Adaption I**
10:20 – 12:20, Marriot Marquis – Independence F-H

11:08 – 11:20 GH22A-05 **Local Climate Zones and their Potential as a Heat Assessment Tool**
(Matthias Demuzere, Benjamin Bechtel, Jason Ching, Ariane Middel, Gerald Mills, Frieke Van Coillie and Marie-Leen Verdonck)

Abstract:
Urban areas are the nexus of human activity, housing more than 50% of the global population as well as 70-90% of economic activity. Together with a continuous population growth and related global urbanisation, these developments pose major challenges to a sustainable future. The effect of urbanisation on the environment is an outcome of its physical form (i.e. the land-cover, the materials and the geometry of buildings) and its functions (the transportation, energy usage, generation of waste products) that sustain human activities. These drive environmental change at multiple scales and adversely affect, amongst others, the local climate often leading to enhanced risks to public health.
While there has been substantial progress in the characterisation of built up areas, and more specifically approaches to characterise urban areas at the neighbourhood level, these typically lack global consistency and thus comparability. We argue that the typology of Local Climate Zones (LCZs) meets these requirements providing consistent descriptions of form and function of neighbourhoods to represent their climatic impact on larger scales and evaluate climate mitigation and adaption options.
The generic character of LCZs and their transferability across large and distant regions is illustrated using the state-of-the-art cloud computing resources from Google's Earth Engine and a wide range of earth observation datasets. In addition, their intrinsic meta-information on form is assessed using state-of-the-art products such as EU's Urban Atlas building height database and big data approaches to calculate spherical surface fractions (e.g. sky view factor, imperviousness, tree coverage) from Google Street View images. In addition, LCZs are evaluated in terms of land surface temperatures for cities worldwide and for ambient temperatures for a selected set of cities. This is a huge step forward in developing a comprehensive global archive of urban data and associated tools that will be needed to address the pressing nexus of climate change, population dynamics and increasingly, urbanisation issues such as heat risk.

PP23C: **Understanding the Indian–Asian–Australian Monsoon: Evolution and Links to Tectonic, Climatic, and Biogeochemical Cycles**
13:40 – 15:40, Convention Center – Salon I

14:25 – 14:40 PP23C-04 **Sea surface temperature and productivity in the Northern Indian Ocean (Maldives Sea) during the last ~550 ka (MIS 13 to present)**

(**Montserrat Alonso-Garcia**, Teresa Rodrigues, Maria Padilha, Carlos A Alvarez Zarikian, Dick Kroon, Tereza Kunkelová, Christian Betzler, Mayuri Inoue, Hodaka Kawahata and Fatima F G Abrantes)

Abstract:
The Maldives Inner Sea is a natural sediment trap located in the Northern Indian Ocean affected by the South Asian Monsoon (SAM) seasonal reversing wind pattern, which drives modern oceanography in the region. Moreover, variations in oceanic productivity and in the extension of the oxygen minimum zone (OMZ) in the northern Indian Ocean are intimately related to the SAM. Therefore, the Maldives Sea is a perfect location to study past changes in tropical climate and ocean circulation related to monsoon dynamics throughout the Pleistocene.
In this work, we studied sediments from IODP Site U1467, cored during IODP Expedition 359 in the Inner Sea of the Maldives, at a water depth of 487 m. Our study focuses on the last ~550 ka (present to MIS 13, middle-late Pleistocene). We reconstructed sea surface temperature (SST), using the alkenone unsaturation index (Uk'37), and estimated past surface ocean productivity (related to coccolithophores), using total alkenone concentration. This work aims to better understand the oceanographic changes linked to monsoon dynamics in the Northern Indian Ocean.
At present, seasonal SST variation is rather small in the Maldives Inner Sea (between 28.27 and 29.38 ºC) and our reconstructed SST record also shows very small variability between glacial and interglacial periods (~1ºC). However, our record shows distinctly warm temperature during all interglacial stages and substages compared to glacial periods. Interestingly, MIS 11 was not the warmest interglacial of the studied interval, and MIS 13 shows warmer SST than MIS 11. Our productivity record shows higher values during interglacial periods, although the surface ocean productivity is not always coupled with SST changes. It seems that the initiation of interglacial intervals was characterized by low productivity and a few thousand years after the Termination an abrupt change in productivity happened, which may be related to either oceanographic or atmospheric changes. A good example of this can be observed during MIS 11 and 9. The comparison of our Indian Ocean reconstructions with other records, particularly those in the Atlantic Ocean, will provide key information to improve our understanding of the evolution of global climate and ocean circulation during the Pleistocene.

Posters:

OS21C: **Novel Data Analysis Techniques for Big Data Applications in Marine Science**
08:00 – 12:20, Convention Center – Hall A-C (Poster Hall)

OS21C-1214 **A Large Ensemble Testbed to Evaluate pCO_2 Interpolation Methods**
(**Lucas Gloege**, Galen A McKinley, Peter Landschutzer, Christian Rödenbeck, Steve Jones, Keith B Rodgers, Tatiana Ilyina, Nicole S Lovenduski, John C Fyfe, Yohei Takano, Sarah Schlunegger and Amanda R Fay)

Abstract:
Accurately quantifying ocean CO_2 uptake is imperative to reducing uncertainty in the global carbon budget and assessing whether the goals of the UNFCCC Paris agreement are being achieved. Quantifying the CO_2 flux across the air-sea interface requires time-dependent maps of surface ocean pCO_2. Even though there is a paucity of pCO_2 observations within any given month and global coverage is sparse, various techniques have been developed to create monthly maps of surface pCO_2, either by interpolating pCO_2 observations or using global monthly maps of physical and biogeochemical variables as regressors. However, the carbon cycle community lacks the ability to test the accuracy of these gap-filling methods when the true value is unknown. We bridge this gap by evaluating each method in three independent coupled ocean-atmosphere models. Here, we present a testbed using multiple large ensembles from three independent models suitable for such an evaluation. We use this testbed to statistically evaluate how well three different gap-filling approaches are able to reconstruct the spatial pattern of pCO_2 in different climate states. A suite of statistical techniques is used to compare the reconstructed and modeled pCO_2. Preliminary results suggest reconstruction methods perform well in large regions of the global ocean, with high correlations (>~0.9) in the Equatorial Pacific and North Atlantic and low correlations (~0.5) in regions of the Southern Ocean.

S21E: **Heterogeneity and Scaling Relations Impacting the Geomechanical Behavior of Fault Zones**
08:00 – 12:20, Convention Center – Hall A-C (Poster Hall)

S21E-1474: **Coupled Seismic Cycle - Earthquake Dynamic Rupture - Tsunami Models**
(**Alice-Agnes Gabriel**, Joern Behrens, Michael Bader, Ylona van Dinther, Tomy Gunawan, Elizabeth Madden, Leonhard Rannabauer, Sebastian Rettenberger, Thomas Ulrich, Carsten Uphoff, Stefan Vater, Stephanie Wollherr and Iris van Zelst)

Abstract:
We attain physically consistent initial conditions for a megathrust earthquake, capture the full dynamics of the rupture, and determine the resulting seafloor displacements that source a tsunami by coupling a subduction zone seismic cycle model to a dynamic rupture model of a

single earthquake, and then coupling this earthquake model to a tsunami propagation and inundation model.
The seismic cycle model is a 2D seismo-thermo-mechanical simulation of long term deformation and slip instabilities that approximates earthquakes which arise spontaneously within the subduction zone channel. The material properties, stress field, fault strength parameters, and fault geometry for a single slip event are used as input for the 3D dynamic earthquake rupture model. The earthquake model is run with SeisSol (www.seissol.org), which employs an arbitrary high-order derivatives discontinuous Galerkin discretization scheme with an unstructured tetrahedral mesh. Initial conditions for the SeisSol model are mapped from the seismic cycle model using ASAGI, an open-source library with a simple interface to access Cartesian material and geographic datasets in massively parallel simulations. The resulting time-dependent seafloor displacements are then transferred to the tsunami model as input. An accurate and efficient representation of the evolution of the tsunami and the following coastal inundation are achieved with an adaptive mesh discretizing the shallow water equations with a Runge-Kutta discontinuous Galerkin scheme.
This workflow allows for the evaluation of how initial stress and strength conditions and fault geometry affect earthquake rupture behavior, and how the resulting seafloor displacements influence hydrodynamic wave propagation and coastal inundation. This coupled system also serves as a benchmark for comparison with other coupled models. We also present two simpler benchmarks for coupled models of dynamic earthquake rupture and tsunami wave propagation only. This work is part of the project "Advanced Simulation of Coupled Earthquake and Tsunami Events" (ASCETE), funded by the Volkswagen Foundation.

T23E: **Oceanic Lithosphere: Structure and Evolution from Creation to Destruction**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

T23E-0420 **Seismic structure of Triassic oceanic and stretched continental lithosphere in the eastern Mediterranean from surface wave tomography**
(Anke Dannowski, Amr Mohammed Mahmoud Elsayed El-Sharkawy, Thomas Michael Meier, Christian Huebscher, Sergei Lebedev, Ireland and Heidrun Kopp)

Abstract:
The eastern Mediterranean basin system is tectonically complex. The present day stress field is controlled by the Africa-Eurasia convergence, subduction in the Hellenic, Cyprus, and Calabrian arcs, the collision between the Arabia and Eurasia and the displacement of the Anatolian-Aegean microplate. The early evolution of the Levant Basin and the Ionian Sea are closely related to the history of the Neo-Tethys. The tectonic nature of the lithosphere in the Levant Basin is debated. It may represent old oceanic or stretched continental lithosphere.
A surface wave tomography is performed. We calculated new high resolution Rayleigh wave phase velocity maps using an unprecedentedly large number (200.000) of fundamental mode dispersion curves. For the first time, broadband waveform data from the Egyptian National Seismological Network (ENSN) have been combined with data from IRIS and EIDA in order to ensure good path coverage especially for the southern part of the study area. We aim to determine what type of crust underlies the individual basins, how shear wave velocities vary in

the lower crust and upper mantle through the region, and whether the Vp/Vs ratio is indicative for the nature of the crust. In order to examine the variability of the crust and the mantle lithospheric structure, we constructed broadband local phase-velocity dispersion curves for the Levant Basin (deformed continental) and the Ionian Sea (oceanic). Each local dispersion curve is inverted individually for 1D shear wave velocity model using a newly implemented Particle Swarm Optimization (PSO) algorithm. In order to minimize the trade-off between the crustal velocities, mantle velocities and the crustal thickness, we constrained our inversion with accurate local P-wave initial models. Beneath the Levant basin, a Vp/Vs ratio of < 1.8 is obtained pointing to stretched continental crust, whereas a value > 1.8 at the Ionian Sea indicates oceanic nature. A shallow asthenosphere is highly pronounced beneath the Levant Basin with ~70 km of LAB depth. Anomalously higher shear-velocities beneath the Ionian Sea indicate a very thick oceanic lithosphere (200 km). Based on our model for the upper mantle of the Ionian Sea we show that, on average, the Ionian oceanic lithosphere has continued to cool well beyond the 80 m.y. age, contrary to the "plate model" prediction.

A23G: **Assessment, Enhancement, and Integration of Arctic Observing Systems I**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

A23G-1662 **Arctic Sea Observing Requirements Derived from Simulated Variability Pattern of Surface Height, Bottom Pressure and Hydrography**

(**Guokun Lyu**, Detlef Stammer and Nuno Serra)

Abstract:

Variability pattern of the Arctic Ocean circulation is evaluated with respect to observing requirements tailored to capture changes of changing ocean conditions. To this end, sea surface height variability in the Arctic Mediterranean and its relation with bottom pressure, thermosteric and halosteric components are analyzed by separating them into different spectral bands.

For timescale smaller than 30 days, sea surface height show significant variability (~12 cm) in marginal seas and the variability is coherent with bottom pressure for most of the regions, except for the strong current regions such as East Green Current, Norwegian Atlantic Current where steric effect governs sea surface height variability. Increasing the timescale to 300 days, the coherence between sea surface height and bottom pressure is reduced which indicates increasing baroclinic effect. For decadal timescale, sea surface height shows variability of ~6 cm in the Amerasian Basin, the Greenland Sea, and the Norwegian Sea. The Amerasian Basin sea surface height variability is dominated by halosteric components related to salinity changes in the mixed layer and the freshwater layer below, with more significant contributions from isopycnal motion. In the Greenland Sea and the Norwegian Sea, the decadal sea surface height variability is governed by thermosteric effect related to mixing.

To monitor the high sea level variability in the marginal seas, the tide gauge system and altimeter observation will provide valuable information. High-frequency mooring system in the Norwegian Atlantic current (observing temperature) and East Greenland Current (observing salinity) is essential. In the Amerasian Basin, low frequency (annually) shipboard salinity

observation and the altimeter data may be enough to monitor the variability. Low-frequency temperature observation system such as shipboard observations or Argo system may be enough to monitor the decadal variability in the Greenland Sea and the Norwegian Sea.

A23J: **High-Resolution Weather and Climate Modeling on Large Supercomputers**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

A23K-3027: **RCEMIP: Radiative-Convective Equilibrium Model Intercomparison Project**
(**Allison A Wing**, Kevin A Reed, Satoh Masaki**,** Bjorn Stevens, Sandrine Bony)

Abstract:
RCEMIP, an intercomparison of multiple types of models configured in radiative-convective equilibrium (RCE), has recently been organized. Here, we describe the scientific objectives of RCEMIP and present preliminary results. First, clouds and climate sensitivity will be investigated in the RCE setting. This includes determining how cloud fraction changes with warming (a large source of uncertainty in estimates of climate sensitivity) and the role of self-aggregation of convection (which has potentially large but unknown implications for climate sensitivity). Second, RCEMIP will quantify the dependence of the degree of convective aggregation on temperature. Finally, by providing a common baseline, RCEMIP will allow the robustness of the RCE state, cloud feedbacks, and convective aggregation across the spectrum of models to be assessed. A novel aspect and major advantage of RCEMIP is the accessibility of the RCE framework to a variety of models, including cloud-resolving models, general circulation models, global cloud-resolving models, and single column models.

A23K-3028 **Convective Self Aggregation and Radiative Convective Equilibrium across the MPI-M model hierarchy**
(Bjorn B Stevens, **Tobias Becker**, Nicolas Rochetin, Sally Dacie, Cathy Hohenegger, Sebastian Karl Müller and James H Ruppert Jr)

Abstract:
Simulations of radiative convective equilibrium (RCE) have greatly influenced the understanding of climate, and climate change. Early simulations were performed with very simple one-dimensional models of the atmosphere, followed by cloud-resolving simulations. In the last five years it has also become common practice to simulate RCE with comprehensive general circulation models.
These recent studies revealed that different RCE states can be found, depending on how convection aggregates, even in the absence of external asymmetries in the forcing, and have motivated the RCEMIP project, which defines a standardized experimental protocol, to study RCE across a range of models. In this poster we present findings from our investigation of simulations performed — with the full spectrum of models developed and applied at the Max Planck Institute for Meteorology — as a contribution to RCEMIP and the World Climate Research Programmes Grand Challenge on Clouds Circulation and Climate Sensitivity. Our analysis emphasizes how commonalities (or differences) are manifest in the base RCE state, how this base RCE state depends on convective aggregation, how convection self-aggregates, and how these properties respond to warming. Simulations are performed using the UCLA-LES and ICON-LEM models (which resolve shallow clouds but with different microphysics), the cloud-resolving configuration of the ICON-NWP model, along with ECHAM and ICON-A, the atmosphere components of the MPI-ESM and ICON-ESM, respectively. The simulations and

their differences are interpreted with the help of KONRAD, a simple one-dimensional model with a relaxed convective adjustment scheme and a simple prescription of cloud properties.

A23J: **High-Resolution Weather and Climate Modeling on Large Supercomputers**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

A23J-1738 **Coordinated Global High Resolution Climate Modelling – PRIMAVERA and CMIP6 HighResMIP**
(Malcolm J Roberts, Pier Luigi Vidale, Helene Hewitt, Rein Haarsma, Torben Koenigk, Virginie Guemas, Louis-Philippe Caron, Chris D Roberts, Adrian New, Alessio Bellucci, Laurent Terray, Tido Semmler and Jin-Song von Storch)

Abstract:
One of the uncertainties in the role that model resolution plays in global climate simulation has been the lack of a coordinated experimental design and a large ensemble of multi-model, multi-resolution simulations to enable detailed analysis of the relevant processes. The European H2020 project PRIMAVERA has 7 different coupled (and 6 different atmosphere-only) models following the CMIP6 HighResMIP protocol for 1950-2050, at resolutions ranging from 130km-1° to 25km-1/12°, and as such is providing a rich data source for analysis.
With a focus on the Atlantic and European climate variability and change, initial analysis has examined mean state biases such as SST, precipitation, Gulf Stream position and variability, as well as fluxes of heat and moisture between the Atlantic and Arctic systems. Aspects of variability such as the Atlantic Meridional Overturning Circulation (AMOC) and links to the Atlantic Multidecadal Oscillation have also been examined, as well as Atlantic tropical cyclone simulation.
One of the main challenges in analysing datasets such as these are the data volumes – the project expects to locally store at least 3 PB of data. All the data from the models will, for at least the next 2 years, be available on one platform (CEDA-JASMIN), on which our joint analysis is ongoing. We have ongoing coordinated analysis with a variety of other partners (e.g. CLIVAR, tropical cyclone community), for which the application of standardised methods and algorithms will enable us to share results more easily - this approach emphasises moving the algorithm to the data rather than vice versa. The datasets will also be uploaded to the CMIP6 ESGF once that becomes available.
In addition to the model analysis, the project is developing new parameterisation schemes targeted at higher resolution models. These include upper ocean mixing schemes based on Langmuir turbulence and internal mixing processes, as well as the representation of sea-ice dynamics and thermodynamics such as rheology and multi-layer sea-ice.

PP21D**: Chasing Carbon Cycle Perturbations Through the Cenozoic Posters**
08:00 – 12:20, Convention Center – Hall A-C (Poster Hall)

PP21D-1448 **The Influence of Carbonate Platforms on the Global δ^{13}C Values in Carbonate Sediments During the Miocene**

(**Peter K Swart**, Gregor Paul Eberli, Christian Betzler, Dick Kroon and James Wright)

Abstract:
It has been shown that Plio-Pleistocene sediments deposited adjacent to Modern carbonate platforms and ramps, such as the Bahamas, Maldives, and Great Barrier Reef, produce records of δ13C values unrelated to the global oceanic values as a result of the input of aragonite sediments with relatively positive δ13C values. This is particular evident during the past 3 myrs during which the amplitude and frequency of sea level has increased significantly. The question arises as to whether this phenomenon only occurred during Plio-Pleistocene, perhaps only extant during periods of high amplitude sea-level change, or whether such influences also affected earlier times. In order to investigate this we cored a series of sites through Miocene aged sediments in the Maldives archipelago during IODP expedition 359. While all these cores exhibited the phenomenon of increased δ13C values during the past 3 myrs, they also appear to show changes remarkably similar patterns of δ13C values to these seen in the Monterey event suggesting that older sediments associated with carbonate platforms might track global carbon variations. However, a close comparison of the δ13C values with the sedimentary architecture indicates that the apparent correlation with the Monterey Event is probably an artifact. In the Maldives, pulses of isotopically positive sediment are produced during times of relatively high sea level as a result of increase productivity from the shallow water carbonate platforms. While these higher sea levels may also be responsible for an increase burial of organic carbon and therefore linked to the carbon isotopes variations seen in the Monterey (CM1 to CM6), these mechanisms for producing the elevated signals in the oceanic records are different than those in the Maldives. These findings document the influence of platform-derived sediments upon the δ13C values of marginal sediments during older time periods than were documented in the Bahamas and further support concern regarding using apparent changes in the records of δ13C values of shallow-water sediments to infer information regarding the global carbon cycle.

B23F: **Picky Eating in the Deep Subsurface?**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

B23F-2563 **Microbial native sulfur formation in the subsurface without oxygen**

(Amanda Leane Labrado, Benjamin Brunner, Katherine A Giles, Stefano M Bernasconi and Jörn Peckmann)

Abstract:
In the subsurface, large native (elemental) sulfur deposits can be found as part of carbonate caprock assemblages at the top of or in lateral position to salt diapirs. Carbonate caprock assemblages are formed when hydrocarbons (i.e. oil or methane) come in contact with gypsum and/or anhydrite associated with salt diapirs. It is presumed that in such environments, sulfate-reducing bacteria (SRB) drive replacement of gypsum/anhydrite with carbonate by reducing sulfate to sulfide and oxidizing hydrocarbons to carbonate. The prevailing concept for native sulfur formation in carbonate caprock assemblages is sulfide produced by SRB is oxidized to native sulfur by molecular oxygen (O2) carried into the caprock environment by deeply circulating groundwater. Although possible, such a scenario is problematic for several reasons. First, exposure to oxygen would inhibit microbial sulfate reduction, impeding the process that produces sulfide. Secondly, excess supply of oxygen would convert sulfide into sulfate rather than native sulfur. Lastly, to produce large native sulfur deposits, enormous amounts of oxygenated water would need to percolate into the environments in which carbonate caprocks form.

We propose an alternative process for the formation of elemental sulfur in carbonate caprocks, which operates in absence of an external oxidant. Based on oxygen, carbon and sulfur isotope signatures, we believe native sulfur is formed in carbonate caprock systems that have little solute exchange with the ambient environment rather than a system with ample supply of dissolved oxygen. Such a setting would lead to the accumulation of sulfide, which at high levels becomes toxic SRB. To avoid sulfide poisoning, SRB – or microbes that cooperate with SRB – could shift to the production of biologically harmless native sulfur. To recreate such conditions, we have used microbial slurries in which we promote high levels of sulfide accumulation. We present the initial findings of these experiments to demonstrate that genesis of native sulfur in absence of O2 is thermodynamically feasible and provide geochemical evidence that supports our hypothesis of native sulfur in carbonate caprock assemblages formed in oxygen-depleted systems.

Wednesday, 12th of December

Orals:

GC32B: **Large Ensemble Climate Model Simulations: Exploring Natural Variability, Climate Change Signal, Extremes, and Compound Events at Various Spatiotemporal Scales**
10:20 – 12:20, Convention Center – Salon C

10:35 – 10:50 **GC32B-02 ENSO Change in Climate Projections: Forced Response or Internal Variability?**

(**Nicola Maher**, Daniela Matei, Sebastian Milinski and Jochem Marotzke)

Abstract:
The Max Planck Institute Grand Ensemble (MPI-GE) is the largest ensemble of a single comprehensive climate model currently available, with 100 members for the historical simulations and each of four future forcing scenarios. We introduce MPI-GE and use it in combination with the Community Earth System Large Ensemble Project (CESM-LE) to investigate internal variability in El Niño-Southern Oscillation (ENSO) characteristics and future projections of ENSO.
The two large ensembles are used to quantify the extent to which internal variability can contribute to long-term changes in ENSO characteristics. We diagnose changes that are externally forced and distinguish between multi-model simulation results that differ by chance and those that differ due to different model physics. The range of simulated ENSO amplitude changes in the large ensemble historical simulations encompasses all CMIP5 historical simulations. Model differences are, in addition, important in moderate (RCP4.5) and strong (RCP8.5) warming scenarios.
We investigate projections of both ENSO pattern and strength, by completing an empirical orthogonal function (EOF) analysis across the ensemble dimension. When considering projected ENSO pattern changes, we find that model differences are important, with some agreement found in the second EOF pattern projections from the two ensembles. The combination of pattern and strength changes suggests that the forced amplitude change in the Niño3 and Niño4 regions is likely to be zero or positive, but not negative. However, we find that ENSO has high variability, and that single realizations of a model can produce very different results to the ensemble mean response.
Due to this large variability between ensemble members we conclude that small ensembles and single realizations cannot be used to investigate ENSO changes. Finally, we find that approximately 30-40 ensemble members of a single model are needed to robustly sample ENSO variance using a 30-year analysis window (<10% error), with larger ensembles or longer analysis periods needed to decrease the error to below 5%.

OS32D: **Understanding Changing Ocean Biogeochemistry II**
10:20 – 12:20, Convention Center - 101

10:35 – 10:50 OS32D-02 **Regional divergence of dominant modes of the air-sea CO2 flux variability** (**Peter Landschuetzer**, Tatiana Ilyina and Nicole S Lovenduski)

Abstract:
The air-sea exchange of carbon dioxide (CO2) removes roughly 25% of current anthropogenic emissions from the atmosphere. Recent observation-based estimates, benefitting from the collection of surface ocean partial pressure of CO2 (pCO2) measurements, however, indicate that strong variability exists around this globally-integrated ocean uptake, exceeding modeled variability by a factor of 2-5. Understanding the source and magnitude of this variability is essential in order to quantify the future contribution of the ocean in removing excess carbon from the atmosphere, particularly in light of the Paris climate target of limiting global worming below 2°C. Here, we combine the surface ocean pCO2 measurements assembled within the SOCAT database in combination with a neural network-based extrapolation algorithm to reconstruct the surface ocean pCO2, i.e. the main contributor to the sign and magnitude of the air-sea exchange, over the past 35 years. A Fast-Fourier Transformation (FFT) of the de-trended pCO2 timeseries reveals the dominant modes of pCO2 variability across a range of ocean regions. While in the tropics high frequency variability in the order of 5 years, linked to modes of ENSO, dominate the magnitude of the pCO2 spectrum, the North Atlantic and Southern Ocean variability are dominated by lower frequency signals with decadal oscillation periods corresponding to spectral peaks in the Atlantic Multidecadal Oscillation (AMO) and the Southern Annular Mode (SAM), respectively. We further find the lowest oscillation frequency in the Pacific Ocean gyres. Performing a wavelet (or running FFT) analysis on a 1000 year CESM control simulation illustrates that these regional oscillations are well represented in a state-of-the-art climate model. Over the course of 1000 years, however, the dominant frequency signals strongly change, prohibiting us from concluding that the observed oscillations are representative for the coming decades or centuries.

C32C: **Remote Sensing of Sea Ice I**
10:20 – 12:20, Convention Center – Salon I

11:50 – 12:05 C32C-07: **Spatio-Temporal Variability of Antarctic Sea-Ice Thickness and Volume Obtained from ICESat Data Using an Innovative Algorithm**

(**Huan Li**, Hongjie Xie, Stefan Kern, Wei Wan, Burcu Ozsoy, Stephen F Ackley and Yang Hong)

Abstract:
We use total (sea ice plus snow) freeboard as estimated from Ice, Cloud and land Elevation Satellite (ICESat) Geophysical Laser Altimeter System (GLAS) observations to compute Antarctic sea-ice thickness and volume. In order to overcome assumptions made about the relationship between snow depth and total freeboard or biases in snow depth products from satellite microwave radiometry, we implement a new algorithm. We treat the sea ice-snow system as one layer with reduced density, which we approximate by means of a priori information about the snow depth to sea-ice thickness ratio. We derive this a priori information directly from ICESat total freeboard data using empirical equations relating in-situ measurements of total freeboard to snow depth or sea-ice thickness. We apply our new algorithm (One-Layer Method or OLM), which uses the buoyancy equation approach without the need for auxiliary snow depth data, to compute sea-ice thickness for every ICESat GLAS footprint from a valid total freeboard. An improved method for sea-ice volume retrieval is also used to derive ice volume at 6.25 km scale. Spatio-temporal variations of sea-ice thickness and volume are then analyzed in the circumpolar Antarctica as well as its six sea sectors: Pacific Ocean, Indian Ocean, Weddell East, Weddell West, Bell-Amund Sea, and Ross Sea, under both interannual and seasonal scales. Because the OLM algorithm relies on only one parameter, the total freeboard, and is independent of auxiliary snow depth information, it is believed to become a viable alternative sea-ice thickness retrieval method for satellite altimetry.

NH33A: **Interdisciplinary Tsunami Science III**
13:40 – 15:40, Marriot Marquis – Marquis 9-10

14:10 – 14:25 NH33A-03 **Localized Non-Hydrostatic Wave Modeling**
(**Joern Behrens**, Anja Jeschke and Leila Wegener)

Abstract:
Long wave modeling is often performed with linear or non-linear shallow water wave theory, implemented in corresponding hydrostatic computer models. However, for more realistic features, in particular wave dispersion, non-hydrostatic approaches implemented by Boussinesq-type equations are used. One type of such models utilizes non-hydrostatic corrections to shallow water equations.
In this presentation we introduce a Runge-Kutta discontinuous Galerkin (RKDG) implementation of a non-hydrostatic projection method, which is formally and experimentally of second order consistency.
Since the computation of the non-hydrostatic correction requires the computationally involved solution of an elliptic problem, an adaptive local restriction of the non-hydrostatic region is proposed. It can be shown that the dispersive wave properties can be maintained with much less computational effort, compared to a global projection method.

P34B: **Titan: Looking Backward, Looking Forward II**
16:00 – 18:99, Convention Center – 207A

17:30 – 17:55 P34B-07 **From how far away can we hear waves on Titan? - Maria microseismicity on Titan**

(**Simon C Staehler**, Mark P Panning, Ralph D Lorenz, Celine Hadziioannou, Steve Vance and Sharon Kedar)

Abstract:
Earth's oceans are the dominant source of seismic noise between 3 and 15 second period. While the strongest sources are in the open sea of the Northern Atlantic and the Southern Ocean, waves in smaller seas, like the Baltic Sea and even in large lakes have been shown to create an observable seismic signal. On Earth, microseismic noise has been used widely to infer crustal thickness and composition in the regions with low seismicity.
Since Titan is the only other place in the solar system with persistent surface lakes, microseisms might be observable and very valuable for interior studies, e.g. in the context of the proposed Dragonfly mission.
We estimated the strength of microseismic noise from Titan's seas, based on self-consistent interior models and wind estimates from global circulation models (GCMs). While waves of more than a few millimeters have never been observed by radar measurements of the lakes, GCMs predict winds of several meters per second, which would be strong enough to create meter-high waves. Due to the lower density of liquid hydrocarbons compared to water and the surface gravity of 1/7 g,
the wave-generated pressure on the sea floor is much lower than on earth for a given wave height, but the same wind speed can excite much higher waves.
Because the impedance contrast between the methane ocean and the water ice below is lower than the contrast between liquid water and rocks on Earth, the amplification of secondary microseism is lower than on earth, but almost frequency- and depth-independent, so microseismic noise could be created over the whole area of the lakes. The smooth western coastline of Kraken Mare could be reflecting ocean waves coherently enough to fulfill the Longuet-Higgins-criterion and therefore generate microseisms. The same effect could be reached by fast moving storm cells, creating opposing ocean wave trains.
Taking all these considerations into account, we estimate the global level of microseismic noise and find that it can match Earth levels only on stormy days. On such days however, the noise could be heard by a broadband seismometer globally. A wideband instrument, like the SP on the InSight Mars lander could still hear the waves thousands of kilometers from a sea, allowing remote monitoring of sea state from a long-lasting lander.

Posters:

GC33J: **Large Ensemble Climate Model Simulations: Exploring Natural Variability, Climate Change Signal, Extremes, and Compound Events at Various Spatiotemporal Scales Posters**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

GC33J-1485**: Attributing Changes of Internal Variability to Global Warming Using a Large Ensemble**

(**Sebastian Milinski**, Juergen Bader, Johann H Jungclaus and Jochem Marotzke)

Abstract:
Internal variability is often assumed to be a property of the climate system that conceals the forced signal, but is itself not changing in response to the forcing. However, internal variability describes deviations from the forced signal, and thus has a direct influence on the magnitude and frequency of anomalous or even extreme events. Therefore, a change of internal variability may cause a perceptible change of anomalous events in the climate system.
We introduce a method to robustly detect a change in internal variability and attribute it to a change in the external forcing. We apply this method to global mean specific humidity from the Max Planck Institute Grand Ensemble (MPI-GE).
Internal variability in the observational record or a transient climate simulation cannot be assumed to be independent of the forcing, therefore we need an analysis method to account for this. We use the ensemble dimension in a large ensemble to quantify internal variability. In contrast, analysing variability in the time domain does not provide a well-defined estimate whenever internal variability is changing with time. The large ensemble size is necessary to sample the phase space of internal variability adequately at different forcing states. Only then can we attribute a detected change in variability to the external forcing change and not to undersampling of internal variability.
Our analysis method is presented for global mean specific humidity because an increase of the variability of specific humidity would be expected in a warmer atmosphere based on thermodynamic constraints. Furthermore, a change in specific humidity implies a change in the hydrological cycle that would include changes in precipitation. We use an idealised strong warming experiment with a prescribed increase of atmospheric CO_2 levels by 1% per year. This experiment from the MPI-GE consists of 100 realisations.
In contrast to the common analysis method, we use the ensemble dimension instead of the time domain to quantify internal variability. We argue that this approach, which is only possible in combination with a large ensemble, allows us to robustly detect a change of internal variability and attribute it to a change in the external forcing.

B31H**: Interactions Between Hydrological and Biogeochemical Change in Permafrost Environments**
08:00 – 12:20, Convention Center – Hall A-C (Poster Hall)

B31H-2586 **Impacts of Permafrost Disturbance on DOC, Total Dissolved Solids and Suspended Sediment in Low Arctic Coastal Catchments**

(**Caroline Coch**, Justine Lucille Ramage, Scott F Lamoureux, Hanno Meyer, Christian Knoblauch and Hugues Lantuit)

Abstract:
Arctic climate change leads to permafrost degradation and to associated changes in freshwater quality. There is a limited understanding how disturbances impact water biogeochemistry on a catchment scale. In this study, we investigated concentrations and fluxes of dissolved organic carbon (DOC), total dissolved solids (TDS), suspended sediment (SS) and water stable isotopes in paired and adjacent Low Arctic watersheds that have been subject to permafrost slope disturbance. We combined data on permafrost disturbance between 1952 and 2015 with data on geochemistry along longitudinal stream profiles.
Our results show a decrease in total disturbed area by 41 % between 1952 and 2015, whereas the total number of disturbances increased by 66 % for the six studied watersheds. The spatial variability of hydrochemical parameters is connected to catchment properties, which are not necessarily reflected at the outflow. Degrading ice wedge polygons were found to increase DOC concentrations in one headwater stream, whereas hydrologically-connected disturbances were linked to increases in TDS and SS downstream. Although hydrochemical concentrations varied considerably in the paired watersheds, we found a linear relationship between catchment size and daily DOC and TDS fluxes for all six streams. Suspended sediment flux did not show a clear relationship as a hydrologically connected retrogressive thaw slump impacted the overall flux in one of the streams. Overall, water composition in this Low Arctic landscape is influenced by permafrost degradation and understanding the spatial variability will help to model the geochemical fluxes from Arctic catchments.

GC33J: **Large Ensemble Climate Model Simulations: Exploring Natural Variability, Climate Change Signal, Extremes, and Compound Events at Various Spatiotemporal Scales**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

GC33J-1481 **The Max Planck Institute Grand Ensemble (MPI-GE) - Enabling the Exploration of Climate System Variability**
(Jochem Marotzke, **Nicola Maher**, Sebastian Milinski, Laura Suarez Gutierrez, Michael Botzet, Jürgen Kröger, Luis Kornblueh, Rohit Ghosh, Christopher Hedemann, Hongmei Li, Elisa Manzini, Dirk Notz, Dian Putrasahan, Yohei Takano, Lena Boysen, Martin Claussen, Chao Li, Dirk Olonscheck, Thomas Raddatz, Christian H. Reick and Bjorn Stevens)

Abstract:
The Max Planck Institute Grand Ensemble (MPI-GE) is the largest ensemble of a single comprehensive climate model currently available, with 100 members for the historical simulations and each of four future forcing scenarios. It is currently the only large ensemble available that includes scenario RCP2.6, which has become vital for projections given the targets set by the Paris agreement. The ensemble also has the advantage that it is initialized by sampling the control state both for the ocean and atmosphere, which means that, except for

long-timescale deep-ocean variables, the ensemble can be directly investigated from the beginning of the model runs. Given this initialization, deep ocean drift can also be efficiently removed using the parallel control simulation. These advantages make MPI-GE the most powerful large ensemble available today.
We present an overview of MPI-GE and its components. A novel approach for comparing model internal variability with observed variability is demonstrated, with six interesting regions highlighted. The power of MPI-GE to accurately estimate both the forced signal and internal variability is also shown, with the Atlantic Meridional Overturning Circulation (AMOC) used as an example. In this example, we quantify the forced signal as the ensemble mean and the internal variability as the standard deviation across the ensemble dimension. Finally, MPI-GE can be used to determine the ensemble size needed to investigate a specific application. Here, we find that 30-40 members are sufficient to quantify the projected sea level pressure trend and its variability in RCP4.5 over the period 2007-2099. We suggest that MPI-GE can be used to estimate the ensemble size needed for many future studies.

GC33J-1504 **Time of Emergence Large Ensemble Intercomparison for Ocean Biogeochemistry and Observerables**
(**Sarah Schlunegger**, Keith B Rodgers, Jorge L Sarmiento, John P Dunne, Tatiana Ilyina, Yohei Takano, James R Christian, Matthew C Long and Thomas L Froelicher)

Abstract:
The contemporary ocean carbon sink is an important mitigator of global warming and the dominate driver of ocean acidification. Detecting future changes in the ocean carbon sink and its constituent pumps requires quantification of not only the magnitude of the change (anthropogenic signal) but also the natural background variability inherent to the climate system (noise). Here we use Large Ensemble (LE) experiments from 4 Earth System Models to estimate the Time of Emergence (ToE) for anthropogenic signals in the ocean carbon cycle, partition uncertainty in future projections of the ocean carbon cycle, and for the first time, quantify the model sensitivity of internal variability in the ocean carbon cycle. For sea surface temperature (SST) and air-sea CO2 fluxes, the LEs agree on global and regional ToE (20 – 30 years, with the exception of the Southern Ocean), despite model differences in the magnitude of warming and ocean carbon uptake. For the biological carbon pumps, ToEs estimates are 50+ years and differ (by multiple decades) between the LEs. Finally, as an emergent constraint on ToE estimates, we utilize data-based products to validate LE natural decadal variability.

PP33E: **Understanding the Indian–Asian–Australian Monsoon: Evolution and Links to Tectonic, Climatic, and Biogeochemical Cycles IV**
13:40 – 18:00, Convention Center – Hall A-C (Poster Hall)

PP33E-1764 **Pliocene and Pleistocene wind variability over the Indian Ocean (IODP Exp. 359, site U1467, Maldives)**
(**Christian Betzler**, Sebastian Lindhorst, Dick Kroon and Liviu Giosan)

Abstract:
The lithogenic fraction of carbonate drift sediments from the Maldives provides a unique record of atmospheric transport over the northern central Indian Ocean during the past 3.5 to 4

Myrs. The record stems from the Inner Sea, which is a perched basin in this carbonate platform with a relief of more than 2000 m above the surrounding seafloor. The percentage of particles in the medium to coarse silt size fraction (8-63 µm), which is indicative of aeolian flux sums up to values of up to 35 % of the lithogenic fraction. This portion remains stable at a lower level (20 - 25 %) until about 1.4 Ma. In younger times, there is an increase in wind-transported material to 25 - 30 % and the variability is higher, starting with the Mid Pleistocene Transition (MPT). The size of the largest particles fed into the system (range 10-20 µm), indicated by the d90 of the grain-size distribution, increases between 4 and 3.5 Ma, and remains on a high level throughout the Pliocene Climate Optimum (3.3-3.0 Ma). Subsequently, there is a fining until 1.4 Ma, and a slight coarsening afterwards combined with a higher grain size variability. Superimposed onto these large trends there are pronounced higher frequency fluctuations with durations of 400 and 100 kyrs. The wind transport intensity rather follows a precessional controlled variability. This, however, is at the limit of the temporal data set resolution. Strontium and Neodymium isotope analysis of the lithogenic material indicate a mixed origin of the dust particles from two sources: A North Africa-Arabian-Middle East source and a Thar Desert Indian source.

PP33E-1780 **Ostracod Response to Late Pleistocene Oceanographic Changes in the Tropical Indian Ocean**

(C**arlos A Alvarez Zarikian**, Chimnaz Nadiri, Montserrat Alonso-García, Patricia Hernandez, Franco Marcantonio, Dick Kroon, Tereza Kunkelová, Christian Betzler, Teresa Rodrigues and Sebastian Lindhorst)

Abstract:
Sedimentary records from IODP Sites U1467 and U1471 uncovered a mostly unread sedimentary archive of oceanographic and climatic changes in the Maldives Inner Sea, located in the northern Indian Ocean, that are associated with intensity variations of the South Asian Monsoon (SAM). The SAM is an intense climatic phenomenon that provides ample precipitation to southern Asia, and is linked to a seasonal reversing wind pattern that controls the modern ocean circulation and productivity in the north and central Indian Ocean. Thus, deep-water ventilation and the development of the oxygen minimum zone (OMZ) in the water column are also closely related to the SAM.
Well-preserved and abundant calcareous microfossils in the cored Pleistocene sequence at Site U1467 has enabled us to use benthic biota as indicators of past oceanographic conditions. In this study, we present ostracod assemblages combined with biogeochemical data from Sites U1467 and U1471 (X-ray fluorescence core scanning, biomarkers, sediment grain size, trace elements [Baxs, Uauth], and total organic carbon) to study the late Pleistocene history of bottom water ventilation and variability of the OMZ in the northern Indian Ocean. The new micropaleontological and geochemical records reveal oscillations in surface and bottom water conditions that are clearly associated with glacial/interglacial cyclicity and sea level variations. Interglacial ostracod faunas include taxa usually predominant in modern low-oxygen, organic-rich sediments, and their distribution points to periods of SAM intensification, high surface productivity, bottom water oxygenation minima, and expansion of the OMZ in the northern Indian Ocean during MIS 1, 5, 7, 9, 11 and 13. In contrast, glacial ostracod faunas predominantly consist of epifaunal species primarily found in well-oxygenated environments. This assemblage is interpreted to represent increased bottom water circulation and ventilation, lower bottom water temperature, and variable levels of food supply. In addition, the presence of common

deep sea, cold water genera (e.g., Bradleya and Poseidonamicus) during times of lower seal level may point to the influence of Antarctic Intermediate Water in the Maldives Inner Sea and the northern Indian Ocean during glacial times.

B31K: **Forest Response to Extreme Events Using Remote Sensing II**
08:00 – 12:20, Convention Center – Hall A-C (Poster Hall)

B31K-2633 **Monitoring insect outbreaks following a drought event in southwest USA**
(**Johanna Schweiger**, Ana Bastos and Julia Pongratz)

Abstact:
Forests act as carbon sinks and have a large share in the terrestrial sink term of the global carbon cycle. Yet the sink behaviour can be highly dynamic. A major source of short-term variability and possible long-term trends are disturbances. In order to fully assess carbon fluxes during disturbances, it is important to evaluate the impact of combined disturbances.After extreme weather conditions, such as droughts, a significant increase of insect outbreaks can be observed within forests.
There are currently no detection methods for insect outbreaks to generate homogeneousglobal data sets at large scale. The detection of outbreaks during or right after another disturbance can be complicated by the difficulty to disentangle the signals of the difference disturbances. This study aims at analyzing the possibility to detect outbreaks of insects in forests by using Moderate Resolution Imaging Spectroradiometer(MODIS) data,with a specific focus on data from a 500,000 km² area in Western USA in the years 2001 – 2006. A strong drought affected this region until 2003, and in the following year a peak of insect disturbances was identified in aerial detection surveys from the USA Forestry Service.
Based on the analysis of MOD13Q1 products, including MIR (2.105-2.155 µm) and the normalized difference vegetation index (NDVI) with a resolution of 250m and 16 days, we tried to identify the particular fingerprint of insect disturbance on forested areas. On a second step, two detection methods based on anomalies of NDVI and MIR or their temporal evolution proposed in the literature were evaluated for this study region. Due to low performance, we tested possible modifications for the particular study region and for the type of insect. In total, overall accuracy of about 77% could be obtained. Finally, possible causes for the low performance were examined, such as contamination from recovery from previous fires and land-cover misclassification.

Thursday, 13th of December

Orals:

OS43B: **Sea Level Change and Coastal Impacts and Flooding I**
13:40 – 15:40, Convention Center – 102AB

14:50–15:00 OS43B-07 **Downscaling Regional Sea Level Change Projections in the North Atlantic**

(**Armin Koehl**, Frank Siegismund and Detlef Stammer)

Abstract:
The dynamic topography is one of the components to be considered when projecting future sea level change. Though zero globally by definition, on a regional to local scale long-term variations in dynamic topography can be a significant contributor to the overall change and have to be considered for future adaptation strategies. The representation of dynamic topography including its temporal variations, however, strongly depends on the spatial resolution of the dynamic model applied for the projection. We present here results of a dynamical downscaling of CMIP5 climate change projections of the Earth System model of Max Planck Institute of Meteorology in medium resolution (MPI-ESM-MR). Results from the historical and RCP 4.5 and 8.5 integrations of the climate model are applied as forcing for a high resolution set-up of the Massachusetts Institute of Technology General Circulation Model (MITgcm) covering the North Atlantic starting from 30°S and including the Arctic Mediterranean. For long spatial scales similar patterns and temporal evolvement of sea level is observed in both models, while strong deviations exist from regional to local scales. Both models show a general strengthening of the subpolar gyre in both projections while only the MITgcm reveals a northward shift of the Gulf Stream around 70°W and a significant increasing trend in sea level along the U.S. east coast between 28-35°N of up to 12 cm (18 cm) for the time average and 24 cm (25 cm) as maximum annual mean over the period 2060-2099 of the RCP 4.5 (8.5) projection. To further analyse the projected regional changes and its relation to changes in the North Atlantic circulation, the variations in dynamic topography are decomposed into its thermo-steric, halo-steric and bottom pressure component, respectively, and differences between the two models and the two projections are discussed.

Posters:

NG41B: **Nonlinear Statistical, Mathematical, and Computational Physics in Complex System Science: Theoretical Advances and Geophysical Applications**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

NG41B-0940 **How Predictable Are the Arctic and North Atlantic Oscillations? Exploring the Variability and Predictability of the Northern Hemisphere**

(Daniela Domeisen, Gualtiero Badin and **Inga Monika Koszalka**)

Abstract:
The North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) describe the dominant part of the variability in the Northern Hemisphere extratropical troposphere. Because of the strong connection of these patterns with surface climate, recent years have shown an increased interest and an increasing skill in forecasting them. However, it is unclear what the intrinsic limits of short-term predictability for the NAO and AO patterns are. This study compares the variability and predictability of both patterns, using a range of data and index computation methods for the daily NAO and AO indices. Small deviations from Gaussianity are found along with characteristic decorrelation time scales of around one week. In the analysis of the Lyapunov spectrum it is found that predictability is not significantly different between the AO and NAO or between reanalysis products. Differences exist, however, between the indices based on EOF analysis, which exhibit predictability time scales around 12–16 days, and the station-based indices, exhibiting a longer predictability of 18–20 days. Both of these time scales indicate predictability beyond that currently obtained in ensemble prediction models for short-term predictability. Additional longer-term predictability for these patterns may be gained through local feedbacks and remote forcing mechanisms for particular atmospheric conditions.

PP41C: **Lessons for the Future from Cenozoic Warm Climates**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

PP41C-1858 **Warm climates: Differences and analogies in the monsoon response to past and future forcing**

(Simona Bordoni, Roberta D'Agostino, Juergen Bader and Johann H Jungclaus)

Abstract:
Precipitation and circulation patterns of Northern Hemisphere monsoons are investigated in Coupled Model Intercomparison Projects phase 5 simulations of mid-Holocene and future climate scenario rcp8.5. While these two experiments show similar warming of the Northern Hemisphere and enhanced inter-hemispheric thermal contrast in boreal summer, they result in different monsoon responses. Changes in the spatial extent of the Northern Hemisphere monsoons in rcp8.5 do not exceed the simulated shift in mid-Holocene and only the Indian monsoon is stronger in rcp8.5 than mid-Holocene. A decomposition of the moisture budget in thermodynamic, dynamic and transient eddy contributions suggests that under global warming the African, Indian and North American monsoons are affected differently by each component of the budget, with strong regional monsoon behaviors. On the other hand, the dynamic component alone, with strengthened monsoonal circulations across different regions resulting from enhanced net energy input over land, determines most of the mid-Holocene land monsoonal rainfall response.

PP43E: **The Global Expression of the 8.2 ka Event**
13:40 – 18:00, Convention Center – Hall A-C (poster Hall)

PP43E-1971 **Effect of the 8.2 ka event on the circulation, oxygen content and P cycling of Sapropel Intermediate Water (500-1800m) in Eastern Mediterranean**

(**Eleen Zirks**, Michael Krom, Dongdong Zhu, Beverly Goodman-Tchernov and Gerhard H Schmiedl)

Abstract:
Sapropels are the sedimentological record of recurring anoxic events in the Eastern Mediterranean Sea (EMS). The most recent of those events, S1, occurred in the early Holocene (~6-10.4 ka BP) and the 8.2 ka BP cooling event can be identified within the sediment records. Recent modelling and field studies have suggested that during S1 the water column was divided into 4 layers. Below the surface thermohaline circulation there was a Sapropel Intermediate Water mass (SIW; 500-1800m) and a deeper fully stagnant water mass. A key difference between SIW and the deeper water mass was that a reventilation event associated with the 8.2 ka global cooling event was observed only in SIW over the entire basin but not deeper. SIW was formed in the Aegean Sea and spread to the east and west. In the Aegean SIW became suboxic while In the Adriatic and the S.E. Levantine basin, it became anoxic. In this study, we examined S1 from a sediment core collected from 1250m offshore from Israel. The extent of sapropel was defined by Ba/Al and TOC and the oxygen status of the overlying water determined from benthic foraminifera abundance and species distribution and V/Al as a redox sensitive trace metal. Our results show that the beginning of S1a was gradual over 400-500 years. The system became anoxic for ~1400 years. The 8.2 ka BP event was visible as an interruption in the sapropel in Ba/Al and TOC. As in other locations across the EMS, S1b was suboxic i.e. somewhat less intense than S1a. The P speciation in the sediment as determined by SEDEX measurements showed that changes in P content were controlled both by the redox state of the overlying water and the input from the nearby Nile. Our results show the effects of natural climate change and the 8.2 ky event on the oxygen status of deeper waters of the EMS. It is important to understand past hypoxic/anoxic events since oxygen minimum zones are spreading in the oceans nowadays which may cause major environmental problems.

OS43C **Temporal Variability in Oceanic Mesoscale Activity, from Seasonal to Multidecadal Records**
13:40 – 18:00, Convention Center – Hall A-C (poster Hall)

OS43C-2101 **Travelling eddies in the South China Sea - multi-decadal statistics and large-sale conditioning**

(**Hans von Storch**, Meng Zhang, Shengquan Tang, Xueen Chen and Dongxiao Wang)

Abstract:
The multi-decadal simulation STORM with the state-of-the-art and eddy-permitting model MPI-OM has been examined with respect to the formation and travelling of near-surface eddies in the South China Sea. The derived statistics are broadly consistent with the statistics derived from the AVISO data set.

The grid-resolution of STORM of about 0.1 degrees allows the formation of broad features of such eddies; in an additional model experiment it is shown how the level of eddy generation – which represents unprovoked noise in the sense of the statistical climate model for the generation of low-frequency variations – increases with decreasing grid-resolution.
A significant question is if the spatial and temporal variations of the eddy statistics, in terms of density and intensity, are conditioned by "external" factors, such as ENSO or global warming. EOF analyses of the fields of such seasonal statistics lead to white eigenvalue spectra, and thus reveal hardly any external steering. Even when including the annual cycle, with its monsoonal alternation, the spatial density of travelling eddies varies hardly in a deterministic manner.

Friday, 14th of December

Orals:

B52C **Tropical Forests Under a Changing Environment II**
10:20 - 12:20, Convention Ctr- 147B

11:35 – 11:50

B52C-06 **Modeling the drought response of Amazon forests and its impact on land-atmosphere interactions: The roles of leaf phenology and tree mortality**
(**Hao-Wei Wey**, Kim Naudts, Julia Pongratz, Julia Nabel and Lena Boysen)

Abstract:

The Amazon forests are one of the largest ecosystem carbon pools on Earth. However, more frequent and prolonged droughts have been predicted under future climate in this region, and the vulnerability of Amazon forests to drought has yet remained largely uncertain. Previous studies have shown that few models succeeded in capturing the overall vegetation response to drought. In this study, we present a new version of the land surface model JSBACH, which incorporates new formulations of leaf phenology, litter production and tree mortality based on intensive field measurement from the throughfall exclusion (TFE) experiments performed in the Amazon. The new version includes the leaf longevity measured in the field, a direct dependence of litter production on leaf shedding rate, as well as enhanced tree mortality due to drought, represented by an adaptive turnover rate of wood. Further, a re-assessment of soil hydrological parameters has been performed to optimize the fit of soil moisture and evapotranspiration to observations. With these changes on parameterization and formulation, the new model version outperforms the old one regarding gross primary production (GPP), whole-ecosystem respiration, and net ecosystem production (NEP) at both control and drought site. With this new model we can separate short-term effects by drought impacts on leaf phenology from longer-term effects of tree mortality. Overall, our results will serve as a more robust modeling approach to simulate the drought effects of Amazon forests and provide an insight into its feedback on land-atmosphere interactions.

T52C **Shallow Subduction Zone Structure and Dynamics II**
10:20 - 12:20, Marriott Marquis- Liberty N-P

11:50 – 12:05

T52C-07 **Using coupled models of the 2004 Sumatra-Andaman earthquake and Indian Ocean tsunami to examine the impact of fluid pressure and megathrust geometry**

(**Elizabeth Madden**, Stefan Vater, Thomas Ulrich, Leonhard Rannabauer and Alice-Agnes Gabriel)

Abstract:
Geophysical data suggest low effective and differential stresses and low frictional strength on megathrusts that host large earthquakes. These characteristics are compatible with high fluid pressure on a fault near failure. To test the influence of these conditions on tsunami sources, we present coupled models of the 2004 Sumatra-Andaman earthquake and Indian Ocean tsunami. The earthquake is modeled with SeisSol (www.seissol.org), based on an arbitrary high-order derivatives discontinuous Galerkin scheme and featuring unstructured tetrahedral meshes to solve for rupture dynamics and wave propagation. The tsunami is modeled with sam(oa)2, which uses dynamic meshing to discretize the shallow water equations with a Runge-Kutta discontinuous Galerkin scheme. We include a non-planar megathrust and 3 steeply dipping splay faults, as identified from seismic reflection surveys, bathymetry and seismicity. High fluid pressure decreases fault slip and seafloor displacements, and therefore lowers earthquake magnitude, but does not affect slip or displacement patterns. In all models, only one landward dipping splay fault is activated. The preferred earthquake model has fluid pressure approaching lithostatic and produces displacements that match near-field GPS data. 12m of dip-slip on the megathrust result in 2.5m of seafloor uplift, while 1.5m of dip-slip on the forethrust result in 1.5m of uplift. However, the splay fault has no effect on the modeled tsunami. In addition, the tsunami waves generated by this earthquake die out close to the source. The preferred tsunami model produces waves that match buoy and satellite data, but is sourced by an anomalously large earthquake under hydrostatic fluid pressure. These results suggest that the slip magnitudes are correct in the preferred earthquake model, but distributed incorrectly. The highest slip is concentrated along the central megathrust. More slip may be required on the splays or on the megathrust at the trench, as observed in the 2011 Tohoku earthquake. In light of this, we quantify the range of epistemic uncertainty in source characteristics by exploring the range of uncertainty in the maximum compressive stress orientation. We compare the resulting earthquake models by their megathrust and splay fault slip, seafloor displacements, and the coupled tsunami models.

V53A **A Perfect Match: Bringing Together Models of Geodynamics and Thermodynamics to Understand Geochemical and Petrological Observations**
13:40 - 15:40, Marriott Marquis- Liberty I-K

14:40 – 14:55 V53A-05 **Thermodynamically consistent fluid dynamics of a strombolian volcanic conduit**

(**Jost von der Lieth**, and Matthias KG Hort)

Abstract:
Active volcanoes, as spectacular research targets as they are, pose the nuisance that, whereas their surface activities may readily be observed, their internal processes are obscured from direct view. The key to their investigation is to bridge the gap between them and field measurements, as well as remote sensing, by physical models, either numerical or analogue ones. For a long time, thermodynamic models of magmatic petrology and fluid dynamic models of the flow within volcanic conduits have been developed side by side, but now it is

time and computationally feasible to develop joint models that better describe the volcanic interior.
Here, we concentrate on strombolian activity that is characterized by recurrent explosions of moderate intensity from an open conduit system of low-viscosity basaltic magma. The canonical theory ascribes these eruptions to the rise and burst of gas pockets (called slugs) that become dynamically pressurized during their ascent.
The magma's rheology is the main factor controlling the flow regimes in the volcanic feeding system. As magma is a mixture of liquid melt, solid crystals or lithics, and small volatile-filled gas bubbles, its behaviour deviates significantly from a Newtonian fluid. Furthermore, the modal composition is not constant but varies with temperature, pressure and bulk composition.
Based on a thermodynamic model giving the magma composition for a specific scenario at different depths, we first derived a realistic depth- and shear-rate-dependent rheological model and then fed it into a CFD simulation of the slug ascent.
In contrast to purely Newtonian simulations, a low viscosity aureole develops in the high-shear zone surrounding the gas slug, the apparent viscosity dropping by almost two orders of magnitude, having a significant impact on the conduit flow pattern and eruptive behaviour, actually reducing the explosive overpressure. This gain in insight highlights the importance of combining thermo- and fluid dynamics in geodynamical modelling.

B53A **Land Management in the Earth System: Measurements and Models I**
13:40 - 15:40, Convention Ctr- 150B

15:25 – 15:40 B53A-08 **Land Management in the Earth System: An Overlooked Driver of Temperature Extremes in Low-Emissions Scenarios**

(**Sonia I Seneviratne**, Annette Hirsch, Benoit Guillod, Steven J Phipps, Andy Pitman, Richard Wartenburger, Victor Brovkin, Edouard Davin, Markus Donat, Wim Thiery, Martha Vogel and Detlef van Vuuren)

Abstract:
Land management affects temperature extremes through modifications of albedo, evapotranspiration and the carbon cycle. Recent studies have shown that these effects are large, in particular at regional scale and for low-emissions scenarios. This presentation will provide an overview of new findings in this area, with a focus on the following topics: Land radiative management from surface albedo modifications in cities and agricultural areas (Seneviratne et al. 2018, Nature Geoscience), effects of irrigation on temperature extremes (Thiery et al. 2017, JGR; Hirsch et al. 2017, JGR), land use changes in Integrated Assessment Models (IAM) and relevance for the development of low-emissions scenarios (e.g. for 1.5°C or 2°C global warming; Seneviratne et al. 2018, Phil. Trans. Roy. Soc. A.; Hirsch et al. 2018, Earth's Future). The latter analyses show in particular that biogeophysical effects of land management are generally not accounted for in IAMs, potentially affecting the assessment of trajectories for ambitious-mitigation scenarios and their relevance for changes in extremes and regional impacts.

Posters:

A51H: **Climate Variability and Ocean–Atmosphere Interaction over the North Atlantic**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

A51H-2243 **Nonlinear changes in the North Atlantic Ocean Circulations under Global Warming**
(**Rohit Ghosh**, Dian Putrasahan, Johann Jungclaus, Juergen Bader, Katja Lohmann, Ralf Hand and Paul Keil)

Abstract:
The ocean meridional heat transport in the Atlantic Ocean plays a crucial role in determining the North Atlantic climate. Using the Max Planck Institute Grand Ensemble (MPI-GE) simulations under 1% CO_2 increase-per-year condition for 150 years, we investigate the reasons behind the changes in the mean state of the meridional overturning- and gyre-related heat transports in the North Atlantic under increased greenhouse gas forcing. While the overturning-related heat transport in the lower latitudes linearly decreases with increasing CO_2 forcing, the gyre-related heat transport shows a non-linear characteristic. A strong increase of the latter for CO_2 concentrations between the recent level and CO_2 doubling is succeeded by a gradual decrease between CO_2 doubling and CO_2 quadrupling. During the period of the first doubling of the CO_2, the increase in the gyre heat transport is preceded by an intensification of the subpolar gyre. The subpolar gyre intensification is also followed by a stronger heat transport through the Iceland-Scotland ridge, which leads to rapid decrease in the sea ice cover over the Barents Sea region. During the period of the second doubling of CO_2, the subpolar gyre does not intensify further and maintains its new steady state. However, we find a northward shift of the subtropical gyre, which helps build a warmer state in the mid-to-high latitudes than that in the first half. We further investigate causes of the subpolar gyre changes, which initiates and leads the associated non-linear changes in the heat transport and the climate over the North Atlantic.

A51H: **Climate Variability and Ocean–Atmosphere Interaction over the North Atlantic**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

A51H-2244 **Changing Relations in Northern Hemispheric Climate Variability to the North Atlantic Oscillation under Global Warming**
(**Dian Putrasahan**, Jin-Song von Storch, Rohit Ghosh and Johann H Jungclaus)

Abstract:
The North Atlantic Oscillation (NAO) has substantial influence on climate variability over Europe, Africa and North America, on various timescales. However, under global warming scenarios, does the NAO variability change and would that influence its relation to northern hemispheric climate variability? On what timescales would there be significant changes? We address these questions using the Max Planck Institute Grand Ensemble under a 1% CO2-increase-per-year scenario over 150 years with 100 ensemble members. Variability and its relationships at different timescales are obtained by computing their power spectra, squared

coherence and phase spectra. By using a large ensemble size for spectral averaging, this enhances the confidence level of spectral peaks without having to sacrifice lower frequency signals.
We find that while wintertime NAO variability does not change under such forcing, its relationship to wintertime surface temperature and precipitation over different parts of the Northern Hemisphere is modified. For instance, on 20-year timescale, coherence between NAO and surface temperature over eastern Canada and western Greenland are out of phase, while they are in-phase over northern Europe. All these regions, while keeping the same phase relationships, show a marked decline in their coherence under severe global warming. A corresponding decrease in out-of-phase coherence between NAO and precipitation is diagnosed over eastern Canada and Greenland, but changes are much less for the in-phase coherence over northern Europe. On interannual-to-decadal timescales, northern Europe surface temperatures exhibit a decrease in their in-phase coherence with respect to NAO, while over the Sahara desert, a concomitant increase in their out-of-phase coherence is seen. We see a corresponding reduction of in-phase coherence between precipitation and NAO over northern Europe, while a general augmentation in out-of-phase coherence is seen over southern Europe. These results reveal spatially-differing evolution of the relationships between NAO and surrounding regional climate variability in a changing climate. This implies caution when using these relationships as it might change its characteristic in the future, which can enhance or jeopardise our capability for regional climate predictability.

B51E: **Carbon Feedbacks in Earth's Climate System: Beyond Emergent Patterns and Toward Mechanistic Processes to Reduce Future Climate Uncertainty**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

B51E-1987 **Lower Land Use Emissions Increased Net Land Carbon Sink During the Slow Warming Period**
(Shilong Piao, Mengtian Huang, Zhuo Liu, Xuhui Wang, Philippe Ciais, Josep Gili Canadell, **Kai Wang**, Ana Bastos, Pierre Friedlingstein, Richard A Houghton, Corinne Le Quere, Yongwen Liu, Ranga B Myneni, Shushi Peng, Julia Pongratz, Stephen Sitch, Tao Yan, Yilong Wang, Tao Wang, Zaichun Zhu and Donghai Wu)

Abstract:
The terrestrial carbon sink has accelerated after 1998, concurrently with the slow warming period, but the mechanisms behind this acceleration are unclear. Here we analyse recent changes in the net land carbon sink and its driving factors using atmospheric inversions and terrestrial carbon models. We show that the linear trend of NLS during 1998-2012 is about 0.17±0.05 PgC yr-2 - three times larger than during 1980-1998 (0.05±0.05 PgC yr-2). According to terrestrial carbon model simulations, the intensification of the net land carbon sink cannot be explained by CO_2 fertilization or climate change alone. We therefore use a bookkeeping model to explore the contribution of changes in land-use emissions and find that decreasing land-use emissions are the dominant cause of the intensification of the land carbon sink during the slow warming period. This reduction of land-use emissions is due to both decreased tropical forest area loss and increased afforestation in northern temperate regions. The inversion-based estimate shows consistently reduced land-use emissions, while another bookkeeping model did not reproduce such change probably due to missing the signal of reduced tropical deforestation. These results highlight the importance of better constraining emissions from land-use change to understand recent trends in land carbon sinks.

B51J: **Land Management in the Earth System: Measurements and Models**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

B51J-2079 **Enhanced weathering for carbon dioxide removal in phosphorus poor systems**

(**Daniel S Goll**, Thorben Amann, Jens Hartmann, Jessica Strefler and Philippe Ciais)

Abstract:
Early and sustained deployment of a mix of Carbon Dioxide Removal (CDR) technologies is needed to keep global climate warming below 2°C. Enhanced weathering (EW) is a land-based CDR option that accelerates the natural process of carbon dioxide fixation by weathering by soil amendment with crushed rocks. EW has a low technical risk, no direct impacts on water resources, and can be co-deployed with other land use practices - but its CDR potential is only partly assessed as positive effects on soil fertility have been omitted.
To address this gap, we use a land surface model coupled to a weathering model to explore the CDR potential of EW from the release of phosphorus (P) contained in basalt rock soil amendments. The highest CDR potential of EW can be expected in tropical systems, which are characterized by low soil supply of plant-available P. We hypothesize that EW provides a key source of additional P to increase carbon storage in tropical forests.

OS51E **Sea Level Change and Coastal Impacts and Flooding**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

OS51E-1294 **Centennial-scale Sea Level Variability in Past-1000-Year Model Runs**

(**Mark L Carson**, Armin Koehl and Detlef Stammer)

Abstract
Climate model runs of the past 1000 years contain regional sea level variability on centennial time scales in the Arctic and Southern Ocean regions. The coarser (median longtudinal grid size of 2.6 degrees) Millennium project model displayed centennial-scale sea level variability of up to 4 cm (standard deviation) or up to +/- 10 cm, regionally, in the Southern Ocean, and up to 3 cm in the Arctic. The higher resolution (median longtudinal grid size of 1.2 degrees) past-1000-year run with the MPI-ESM-P model displays a lower variability in the Southern Ocean, but a higher variability in the Arctic. This suggests that centennial-scale variability in the Southern Ocean could be sensitive to model resolution, but that this low-frequency variability in the Arctic is a fairly robust feature in these models. Breaking the Arctic sea level into steric components, it is clear that the centennial-scale changes are halosteric in nature, similar to what has been previously reported for decadal changes in this region. Low-frequency changes in the export of freshwater out of the Arctic is lag-correlated with the halosteric variability in the basin. A full analysis of the freshwater forcing components and wind-forced currents on very low frequency time scales is provided to further explore the mechanisms behind these centennial changes in sea level.

OS51E **Sea Level Change and Coastal Impacts and Flooding**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

OS51E-1301 **DFG Special Priority Program (SPP-1889) Regional Sea Level Change and Society ('SeaLevel')**
(**Eleni Tzortzi** and Detlef Stammer)

Abstact:
The Deutsche Forschungsgemeinschaft (DFG) Special Priority Program (SPP-1889) 'Regional Sea Level Change and Society (SeaLevel)' performs a comprehensive, interdisciplinary analysis to advance our knowledge on regional sea level change (SLC), while accounting for the human-environment interactions and socio-economic developments in the coastal zone. SeaLevel consists of 20 projects, bringing in synergy over 80 natural and social scientists from 23 German research institutions and a wide range of disciplines, such as physical oceanography, geophysics, geodesy, hydrology, marine geology, coastal engineering, geography, sociology, economics and environmental management. By combining diverse modern methodologies, observations and models, natural and social scientists jointly aim to create a scientific base for quantitative, integrated coastal zone management (ICZM), applicable to many endangered places globally and essential for safety, coastal/land use planning, and economic development. The program focuses on the North and Baltic Seas with potential impacts on Germany, and the South-East Asia/Indonesia region, encompassing coastal megacities, low-lying islands and delta regions. These study regions contrast developed/developing countries, thus differ fundamentally in their socio-politico-economic and cultural contexts, societal impact, adaptation and response strategies towards SLC.
SeaLevel is organized around 3 interactive working packages: A. Origin of Regional Sea Level Changes at Annual to Multi-Decadal Scale, B. Regionalization of Decadal Sea Level Projections, and C. Socio-economic Impacts and Risk Governance. The program's main research activities include to improve the physical knowledge of SLC and regional-to-local scale projections, investigate which socio-institutional factors enable/hinder coastal societies to cope with SLC, determine the natural and social coastal systems' responses to future SLC, and assess adaptation strategies under given technical, cultural, socio-politico-economic constraints. Such integrated analyses require SLC information (local SL projections, storm surges, waves and extremes), uncertainty and risk measures to be provided at the coastlines. Here we describe the goals and status of the SeaLevel program.

OS51E-1308 **Sensitivity Of Sea Level Response In FAFMIP Experiments To Model Resolution**
(**Sayantani Ojha**, Armin Köhl, Helmuth Haak, Johann H Jungclaus and Detlef Stammer)

Abstract:
We present an inter-comparison study of the response of the MPI-ESM coupled Atmosphere-Ocean
General Circulation model (AOGCM) in global as well as regional sea level to surface flux anomalies applied under two different model resolutions.The study is being performed as part of the
CMIP6 Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP) which aims to identify forcing mechanism of regional sea level response and changes in the ocean density and circulation
pattern under well-defined conditions and their sensitivity to model resolution.

As part of the experiment, two configurations of the same climate model with different resolution
are driven by the same surface forcing anomalies in heat, freshwater and momentum flux targeted to
understand the mechanisms of sea level changes under climate change scenarios. In the experiments, a prescribed set of surface flux perturbations, resulting from CMIP5-AOGCM projections for doubled CO_2 concentration, is applied to the ocean. The two configurations are the
MPI-ESM1.2-LR and MPI-ESM1.2-HR version that are also applied for historical and scenario experiments in the upcoming CMIP6. MPI-ESM-1.2LR features a resolution of ca. 200 km in the atmosphere (ECHAM6.3 T63L47) and 150 km in the ocean (MPIOM1.6 GR1.5/L40). MPI-ESM-1.2HR features a resolution of ca. 100 km in the atmosphere (ECHAM6.3 T127L95) and 40 km in the ocean (MPIOM1.6 TP04/L40).
The inter-comparison of the two resolutions shows that the geographical patterns of the global dynamic sea level (DSL) change relative to the pi-control are similar although they differ in magnitude over some regions. Noticeable difference in DSL change is visible over the North Atlantic Ocean in all the three sensitivity experiments. In the high-resolution model the DSL change
is lower in magnitude over the Southern Ocean in both the momentum and fresh water flux perturbation experiments. Compared to the other two experiments, the regional sea level response
of the heat flux perturbation experiment shows less sensitivity to model resolution.

V51E **Volcanic Ash Plumes: Generation, Dynamics, Electrification, Dispersion, and Impacts**
08:00 – 12:20, Convention Center – Hall A-C (poster Hall)

V51E-0151 Unsteadiness Timescales of Volcanic Explosions Through Electrical Monitoring of Ash Plumes
(Corrado Cimarelli, **Damien Gaudin**, Matthias KG Hort, Alec Bennett, Daisuke Miki and Masato Iguchi)

Abstract:
Observations at active volcanoes indicate that gas-particle mass flux during explosive volcanic eruptions can dramatically change showing high unsteadiness even during short-lived explosions (e.g. Taddeucci et al, 2012; Scharff et al., 2015). How the timescales of these fluctuations imprint on the development of the resulting volcanic plume is far from being well understood. Model calculations suggest that eruption column height strongly depends on temporal mass flux output (Scharff, 2012), with crucial consequences on tephra distribution in the environment. Field observation and experimental work on plume electrification show that electrical discharge rate is dependent on mass eruption rate (Cimarelli et al. 2014; 2016; Gaudin et al., 2018) thus suggesting that volcanic lightning monitoring can provide complementary information on the dynamics of the explosions. Here we present observation of the explosive activity of Minamidake crater at Sakurajima volcano (southern Japan) using combined information derived from synchronised Thermal Infrared (TIR) imaging, high-speed Doppler radar and electrical measurements. Two antennas at different distances from the active vents within Minamidake nested crater. The mini-array of antennas reveals a effective tool to monitor the explosive activity at Sakurajima, able to provide continuous recording of ash plume activity in all weather conditions and allowing for the discrimination of the explosion

sources. Comparison of TIR video recordings with electrical activity shows a positive correlation between magnitude of the explosions and height of the eruptive columns with the number and size of the associated electrical discharges. Our data show excellent match between the occurrence of electrical discharges and the peek velocity of particle ejection thus enabling the distinction of discrete consecutive pulses during larger explosive events.

OS53D **Beyond Constant Eddy Diffusivities: Estimation, Implementation, Impacts, and New Approaches to the Parameterization of Lateral Mixing in Ocean Models**
13:40 – 18:00, Convention Center – Hall A-C (poster Hall)

OS53D-1373 **Is the Eddy-driven Velocity Different for Different Tracers?**

(**Jin-Song von Storch** and Eileen Hertwig)

Abstract:
Following Andrews et al (1987), the eddy flux of a tracer can be decomposed into components parallel and perpendicular to the tracer gradient. The divergence of the component perpendicular to the tracer gradient can be shown to be identical to an advection of the tracer. This advection velocity, also referred to as the eddy-driven velocity, is described by a streamfunction B that is a function of the eddy flux of the tracer considered and the distribution of this tracer (Olbers et al. 2012). Since the distribution of tracer A generally differs from the distribution of tracer B, the eddy-driven velocity of tracer A is expected to be different from that of tracer B, even when the eddy fluxes of both tracers are parallel to each other. Using a 0.1° simulation performed with the May-Planck Institute Ocean Model, we address the question of whether the eddy-driven velocity is different for different tracers. Three tracers, temperature, salinity, and density, are considered. For each tracer, the eddy-driven velocity is diagnosed from the respective eddy flux and the spatial distribution of the tracer. We found that the eddy-driven velocity for temperature is significantly different from the eddy-driven velocity of salinity. Both have amplitudes larger than that of density. The result implies that in a non-eddy resolving model, the eddy-induced transport has to be parameterized differently for different tracers, rather than described by the same advection velocity as it is the case in the state-of-the-art ocean models with the Gent-McWilliams parameterization.