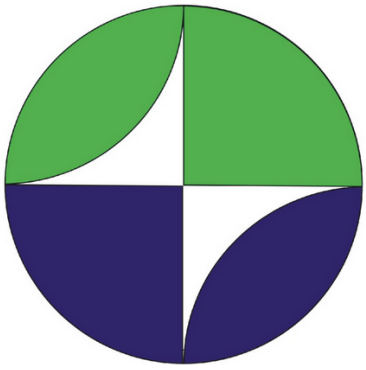

Belgian National Comittee for Geodesy and Geophysics

Study day on 'Belgian contributions to Earth Sciences in a Changing World'

Abstract and Programme Book

Palace of the Academies, Hertogstraat 1 Rue Ducale, 1000 Brussels

4 November 2022

Organising and Scientific Committee

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Aim

The study day aims at bringing together the Belgian scientific community active in Earth Sciences and on presenting ongoing activities in themes covered by the eight associations of the International Union of Geodesy and Geophysics (IUGG):

- Cryospheric Sciences (IACS)
- Geodesy (IAG)
- Geomagnetism and Aeronomy (IAGA)
- Hydrological Sciences (IAHS)
- Meteorology and Atmospheric Sciences (IAMAS)
- Physical Sciences of the Oceans (IAPSO)
- Seismology and Physics of the Earth's Interior (IASPEI)
- Volcanology and Chemistry of the Earth's Interior (IAVCEI)

The Belgian National Committee for Geodesy and Geophysics (BNCGG) is the Belgian member of the International Union of Geodesy and Geophysics (IUGG)

Programme

08:30-09:00 Registration
09:00-09:05 Opening: Philippe Huybrechts *(BNCGG President, Vrije Universiteit Brussel)*
09:05-09:15 Welcome: Alexander Rudloff *(IUGG Secretary General*, *GFZ Potsdam)*
09:15-10:00 Invited lecture: Richard Allan *(University of Reading, UK)*
10:00-10:30 IAG talk: Véronique Dehant *(Royal Observatory of Belgium)*

10:30-11:15 Coffee break in Atrium

11:15-11:45 IAGA talk: Romain Maggiolo *(Royal Belgian Institute for Space Aeronomy)*
11:45-12:15 IASPEI talk: Thomas Lecocq *(Royal Observatory of Belgium)*
12:15-12:45 IACS talk: Frank Pattyn *(Université Libre de Bruxelles)*

12:45-13:15 Poster presentations in Atrium with all authors in attendance

13:00-14:00 Lunch (sandwiches) in the Atrium

14:00-14:30 IAVCEI talk: Pierre Delmelle *(UC Louvain)*
14:30-15:00 IAMAS talk: Simon Chabrillat *(Royal Belgian Institute for Space Aeronomy)*
15:00-15:30 IAPSO talk: Sébastien Legrand *(Royal Belgian Institute of Natural Sciences)*
15:30-16:00 IAHS talk: Patrick Willems *(KU Leuven)*

16:00-16:30 Coffee break in the Atrium

16:30-18:00 Poster presentations in the Atrium with all authors in attendance

Practical information

Poster boards

Size is 2 m tall by 1 m wide, suitable for A0 Portrait (recommended) or A1 Landscape.

Velcro strips for attachment are provided.

Posters are grouped according to association, the numbering is provided in the list of abstracts and will be displayed on the boards.

Wifi

SSID: KVAB; password: welcome2022 (or: Welcome2022)

Location

The meeting is organised in the Palace of the Academies, Hertogstraat 1 Rue Ducale, 1000 Brussels

The lectures will be held in the Albert II Auditorium in the main building (number 1 on the map below)

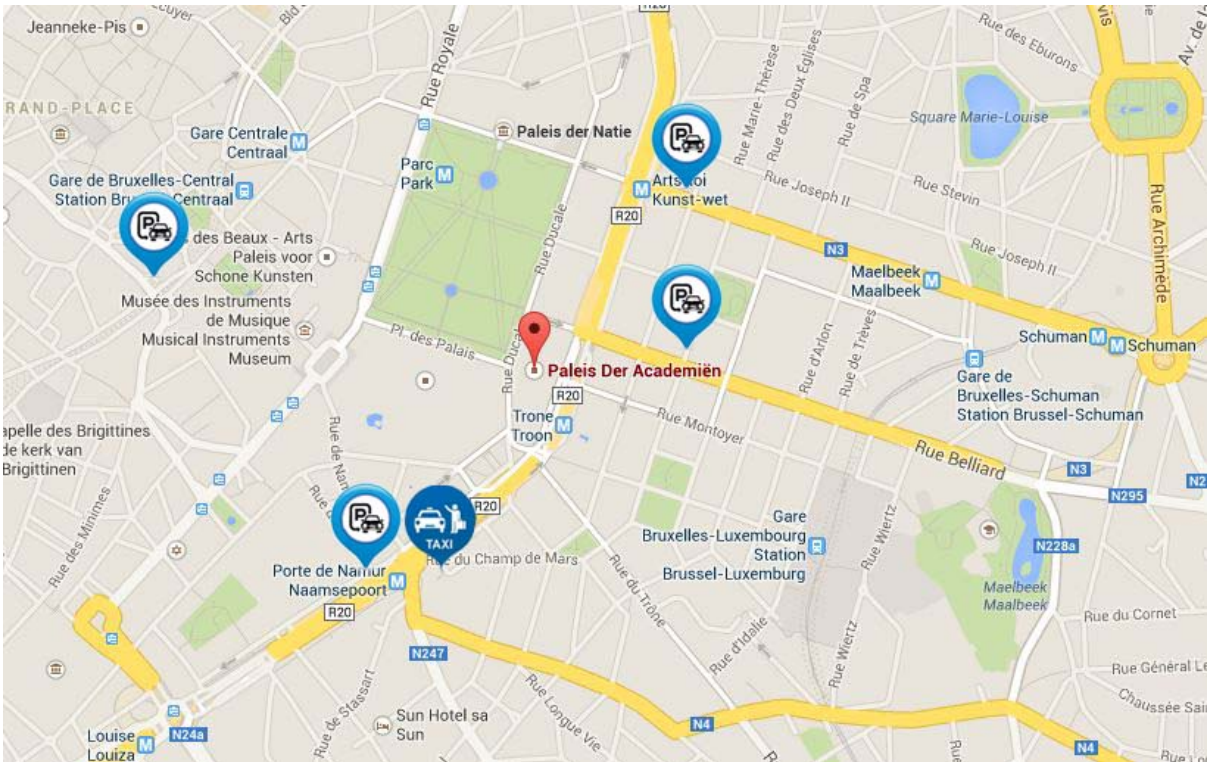
The coffee pauzes, lunch, and the poster presentations will take place in the Atrium (number 4 on the map below)

Map

How to reach the Academy

The Palace of the Academies is best reached by bicycle or public transport. The nearest metro station is ‘Troon/Trône’. There are nearby bus stations for lines 12, 21, 38, 54, 71, 95. The venue is within walking distance (10’) from the train station ‘Brussel-Centraal/ Bruxelles-Central’.

Parking is very limited at the premises of the Academy. Below is the location of parking garages in the neighbourhood.



Keynote lecture

Observing Earth to Monitor, Understand & Predict Climate Change

Richard P. Allan, Department of Meteorology and National Centre for Earth Observation, University of Reading, UK

Climate change influences and is influenced by multiple dimensions of geophysics. In this talk I will summarise recent findings from the 6th assessment report of the Intergovernmental Panel on Climate Change in which the cycles of carbon, energy and water are interwoven. Although Earth's climate has always varied, it is now an established fact that human activities are driving current environmental change, which are widespread, rapid and unprecedented in thousands of years. Human activities are intensifying heavy rainfall, heat waves and droughts and every bit of global warming increases the magnitude of climate change and associated extremes. Limiting warming to 1.5°C requires immediate, rapid, and large-scale reductions in greenhouse gas emissions. I will include some recent examples of how projected changes in the water cycle are already emerging in the observational record but also that the pattern of recent warming has differed from expectations from models, with implications for climate sensitivity. Adapting to and mitigating climate change requires ongoing monitoring of climate change through exploitation of satellite and conventional data and interpretation in the context of paleoclimate reconstructions, physical understanding across the geophysics and detailed modelling of the Earth System.

IAG association presentation

Geodesy

Véronique Dehant, Royal Observatory of Belgium.

The Earth system is a complex system involving spatial scales from micrometers to global and temporal scales from seconds to billions of years. All these time and spatial scales are involved in geodesy that integrates mainly "three pillars" into a system providing information on (1) mass transport and gravity field, (2) changes in Earth's shape, surface deformations, and (3) Earth rotation and dynamics. These "three pillars" are intrinsically linked to each other as they relate to the same Earth system processes. Together, the corresponding observations provide the basis to determine the geodetic reference frames with high accuracy, spatial resolution and temporal stability. The Global Geodetic Observing System, GGOS, is a unifying umbrella for the IAG Services related to these pillars. We have identified two additional pillars, one related to remote sensing of surface and atmosphere and one to planetary geodesy, which are both important in Belgium. We will provide the associated descriptions and we will discuss the present challenges and future mission with the objective aimed at in the UN resolution on improving and homogenizing time and space references on Earth.

IAGA association presentation

Do planetary magnetic fields protect atmospheres?

Romain Maggiolo, Royal Belgian Institute for Space Aeronomy.

Some planets, like the Earth, possess an intrinsic magnetic field. This magnetic field extends far beyond the atmosphere and insulates it from the solar wind, a stream of electrically charged particles continuously flowing outward from the Sun. Conversely, other planets, such as Venus and Mars, are unmagnetized. The solar wind therefore directly interact with their atmosphere and can potentially sweep away its upper layers. The presence of a large-scale planetary magnetic field is thus considered a protective factor for atmospheres. For instance, it is still thought that after Mars lost its protective magnetic field, the solar wind stripped it of much of its air and water.
However, the observed atmospheric escape rates from Venus, Earth and Mars are similar, putting this latter hypothesis into question. There is no observational evidence that, for current conditions, a planetary magnetic field minimizes the escape of planetary atmospheres. Nevertheless, it does not mean that planetary magnetic fields do not play a role on the long-term evolution of planetary atmospheres. Indeed, in the early solar system, the Sun was more active and planetary atmospheres were different from now. That is the current challenge: understanding the effect of planetary magnetic fields on atmospheric escape for conditions that are not accessible to observations.

IASPEI association presentation

Thomas Lecocq, Royal Observatory of Belgium.

IACS association presentation

Ice in the climate system: past, present, future

Frank Pattyn, Laboratoire de Glaciologie, Université libre de Bruxelles (ULB)

Snow, ice sheets, glaciers, sea ice and permafrost, known as the cryosphere, act as Earth's thermostat and deep freeze, regulating temperatures by reflecting heat from the Sun and storing most of our fresh water.

Ice sheets and glaciers are both actors and archives of climate change. Deep drillings in the major ice sheets (Greenland, Antarctica) provide archives of the past climate, and aim to disentangle the role of greenhouse gases with changing temperatures on time scales of thousands to millions of years. However, ice sheets also react to changes in climate, thereby modulating global sea level. Major uncertainties in predicting future sea level rise stem from potential unstable behaviour of both ice sheets through a number of feedback mechanisms. Ice sheets and sea ice also affect the climate through changes in the Earth's radiation balance and ocean circulation.

Belgian researchers are on the forefront of polar cryosphere research with respect to understanding and predicting changes in glaciers, ice sheets and sea ice and their role within the global climate system on time scales ranging from the (deep) past, the present onto the future.

IAVCEI association presentation

Volcano science in Belgium: research landscape and challenges ahead

Pierre Delmelle, Earth and Life Institute, UCLouvain

Volcanoes are openings, or vents, in the Earth’s crust where lava, tephra (pieces of rocks) and steam erupt onto the Earth's surface. Volcanic eruptions can last days, months, or even years. There are about 1,350 potentially active volcanoes worldwide, not counting the volcanoes under the oceans. About 500 of these have erupted in the past 100 years. Volcanoes have created more than 80% of our planet’s surface, laying the foundation that has allowed life to thrive. However, volcanic eruptions pose many dangers to societies and considerable effort is made to better understand why, how and when a volcano erupts. In parallel, researchers from

different backgrounds increasingly investigate volcanic risk, a multifaceted and complex issue where social, economic, physical, infrastructural and cultural elements interact dynamically. The science of volcanology is relatively young; it emerged in the 20th century following the growth of the geological sciences in the post-Enlightenment period. The beginning of IAVCEI, the International Association of Volcanology and Chemistry of the Earth's Interior, can be traced back to the first General Assembly of IUGG in 1922. IAVCEI represents the primary international focus for: (i) research in volcanology, (ii) efforts to mitigate volcanic disasters, and (iii) research into closely related disciplines, such as igneous geochemistry and petrology, geochronology, volcanogenic mineral deposits, and the physics of the generation and ascent of magmas in the upper mantle and crust. Although not directly exposed to volcanic activity, Belgium has been and continue to be the host of a lively research community interested in these questions. Here we provide an overview of the Belgian research landscape in the field of volcanology and highlight some of the grand challenges in volcano science.

IAMAS association presentation

Stratospheric chemistry modelling: a Belgian contribution to the Copernicus Atmosphere Monitoring Service

Simon Chabrillat, Royal Belgian Institute for Space Aeronomy.

Stratospheric chemistry is an important topic of research at BIRA-IASB since its founding in 1964, including through the development of numerical models. This modelling effort is mature enough to allow the production of chemical analyses, i.e. model output which is corrected by ingestion of satellite-derived observations in a process named data assimilation. Thanks to the development of BASCOE, one of the first systems performing such Chemical Data Assimilation in near-real time, BIRA-IASB was able to join the development team of the Copernicus Atmosphere Monitoring System (CAMS). Our contribution comprises a stratospheric chemistry module which was extracted from BASCOE and inserted into the global Integrated Forecast System (IFS) which is routinely run at ECMWF to enable Numerical Weather Prediction and also CAMS.
In this talk we will briefly introduce the topic of stratospheric chemistry and polar ozone depletion, CAMS as user-driven service implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF), and our contribution to CAMS. We will explain some past modelling efforts which allowed us to reach that stage and provide an outlook on some currently "hot" topics which will be addressed thanks to the extension of IFS to stratospheric chemistry modelling.

IAPSO association presentation

An overview of the Belgian Research in Oceanography

Sébastien Legrand, Royal Belgian Institute of Natural Sciences.

IAHS association presentation

Floods and droughts in Belgium: impacts of climate change

Patrick Willems, Hydraulics and Geotechnics Section, KULeuven

This year we had one of the driest summers on record in our country and last year one of the wettest. Our region is very vulnerable to such extreme weather conditions due to our high population density and degree of urbanization. Flanders and Brussels are the region with the highest water scarcity in NW Europe. Moreover, climate change is causing worrying evolutions. But how exactly will the frequency and intensity of floods and droughts change? And what are the consequences? And how strong is the influence of urbanization? Which sustainable climate adaptation solutions should we implement in water management and what is the status of climate adaptation planning at the moment?

IACS poster abstracts

IACS #2

Drivers and predictability of extreme summer Arctic sea ice conditions with rare event simulation methods

Jerome Sauer, Francesco Ragone, François Massonnet

Due to climate change, Arctic sea ice area has been decreasing since at least the late 1970s. On top of the downward trend, internal variability contributes to the year-to-year variations and associated extreme events of the annual Arctic sea ice minimum. Extreme sea ice reduction, as in the summers of 2007 and 2012, has implications for Arctic Ocean accessibility and impacts climate. However, the seasonal predictability of these events and the relative contributions of forced and natural variability to them remain open problems. In particular, a better understanding of processes and conditions favouring extreme summer sea ice conditions is crucial to improve seasonal predictions of these extreme events and to quantify their risk under different climate change scenarios.
One difficulty in studying extreme events is the lack of robust statistics in the short record of satellite-based sea ice observations and in the computationally expensive climate models. In the PhD project, we will couple the climate models Planet Simulator and European community Earth-System-Model version 3 to rare event algorithms to gather robust statistics regarding events with extreme summer Arctic sea ice area. Recently introduced to climate science, rare event algorithms are computational techniques allowing to guide an ensemble simulation to oversample rare dynamical trajectories leading to extreme events of interest. Finally, we will investigate predictors of the risk of extreme summer Arctic sea ice area, examine the predictability of these events and analyze how the risk of extreme deviations in sea ice area from the downward trend shifts under different climate change scenarios.

Affiliations:

- Jerome Sauer (Université catholique de Louvain)
- Francesco Ragone (Université catholique de Louvain)
- François Massonnet (Université catholique de Louvain)

IACS#28

Drivers of extreme Antarctic ice extents in summer over the period 1979-2022

Bianca Mezzina, Hugues Goosse, François Klein, François Massonnet

The Antarctic sea ice variability and its underlying drivers remain overall unsettled, particularly since the sea ice extent (SIE) during the last two decades has first exhibited a slight increase, somewhat in contrast with the global warming trend, followed by a rapid reduction in the more recent years. The unprecedented SIE minimum registered in February 2022 has received great attention and already constitutes an important case study, as the prior record low in 2017. However, other extreme anomalous events are present in the observational record, and a comprehensive analysis of both minima and maxima in the summer SIE is essential to identify and separate potential common drivers from event-specific dynamics, ultimately advancing our general understanding of the Antarctic sea ice and climate variability.

In this work, we aim at assessing the relative roles of atmospheric and oceanic processes in the summer SIE extremes and at disentangling the dynamic contributions to sea ice changes - such as wind-driven transport and divergence - from the thermodynamic part (freezing and melting). Furthermore, we identify the key regions at play during such events, the local dominant mechanisms, and the mutual interactions that result in a total maximum or minimum. The timing and persistence of the sea ice, atmosphere and ocean anomalies in the prior months are also examined to clarify the time scales of the processes during the melting season that lead to the summer extremes.

We use observations and reanalysis data over the satellite period (1979-2022) and compare our main findings with results obtained from an ocean-sea ice model (NEMO-LIM) driven by prescribed atmospheric fields from ERA5 on the same period. While the model may not be able to capture all the extremes in the observational record, examining its own variability provides valuable insights on the dynamics of the Antarctic sea ice extremes.

Affiliations:

- Bianca Mezzina (Earth and Life Institute, Université Catholique de Louvain)
- Hugues Goosse (Université Catholique de Louvain, Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Louvain-La-Neuve, Belgium)
- François Klein
- François Massonnet (Université catholique de Louvain)

IACS#30

Modelling the historical and future evolution of multiple glaciers in the Kyrgyz Tien Shan, Central Asia, using a 3D ice-flow model

Lander Van Tricht, Philippe Huybrechts

High Mountain Asia (HMA) contains the largest concentration of glaciers outside the polar regions. These glaciers play an essential role in terms of water supply for the surrounding densely populated lowland areas of countries such as Kyrgyzstan, Kazakhstan and Uzbekistan. During summer months, the contribution of glacier meltwater to fresh water supply for households, agriculture and industry can increase to more than 50%. The retreat of these glaciers consequently can have a major impact on societies. However, few detailed modelling studies exist that examine in detail how individual ice bodies in the area are responding to climate change. Further, different climatic and topographic settings ensure a heterogenous impact on ice masses in the area. In this study, we focus on the western part of the Tien Shan mountain range in the northwest of HMA. During the Soviet era, various glaciological measurements were carried out in this region. After abandonment in the nineties, different measurement programs have reinitiated in the last decades. We use several recent measurements and reconstructions of the ice thickness, surface elevation, surface mass balance and ice temperature to study in detail six different ice masses in the Kyrgyz Tien Shan: 5 valley glaciers and 1 ice cap. The selected ice bodies are located in different sub-regions of the Tien Shan with different climate regimes, and they are all characterised by detailed recent glaciological measurements. A 3-dimensional higher-order model is calibrated and applied to simulate the evolution of the ice masses since the Little Ice Age and to make a prognosis of the future evolution up to 2100 under different SSP climate scenarios.

Affiliations:

- Lander Van Tricht (Vrije Universiteit Brussel)

- Philippe Huybrechts (VUB)

IACS#32

Antarctic blue ice as a porthole to the Solar System and Earth's changing climate

Veronica Tollenaar, Harry Zekollari, Devis Tuia, Vinciane Debaille, Stef Lhermitte, Benjamin Kellenberger, Marc Rußwurm, Steven Goderis, David (D.M.J.) Tax, Philippe Claeys, Frank Pattyn

Almost the entire Antarctic ice sheet is covered with snow (ca. 99%), but scattered over the continent bare ice is exposed, in so called Blue Ice Areas (BIAs). Despite their limited size, BIAs are the most prolific places on Earth to recover meteorites and to find ice of up to millions of years old. To understand the mechanism and evolution of BIAs and unravel how they act as traps for meteorites and old ice, we combine numerical modelling and big data approaches, such as machine learning on remote sensing data.
To this end, we first created a continent-wide map that indicates the likeliness of the presence of meteorites. This map aids Antarctic meteorite missions to collect more samples that are crucial for research about our Solar System. Secondly, we are taking a data-driven approach in pinpointing and understanding the exact location of BIAs. Here, we use satellite observations of different sensors and combine these in a convolutional neural network to obtain outlines of BIAs. Next, we will explore the potential of BIAs to sample old ice to derive the climate of the past. Compared to ice retrieved from vertical drilling efforts, old ice at BIAs would be easily accessible in large quantities and could cover a larger time span.
Through various collaborations, outcome of this research directly contributes to the fields of glaciology and geochemistry and their future Antarctic expeditions.

Affiliations:

- Veronica Tollenaar (Université libre de Bruxelles (ULB))
- Harry Zekollari (Swiss Federal Institute of Technology in Zürich (ETH))
- Devis Tuia (École polytechnique fédérale de Lausanne (EPFL))
- Vinciane Debaille (Université libre de Bruxelles (ULB))
- Stef Lhermitte (Katholieke Universiteit Leuven (KU Leuven))
- Benjamin Kellenberger (École polytechnique fédérale de Lausanne (EPFL))
- Marc Rußwurm (École polytechnique fédérale de Lausanne (EPFL))
- Steven Goderis (Vrije Universiteit Brussel (VUB))
- David (D.M.J.) Tax (Delft University of Technology (TU Delft))
- Philippe Claeys (Vrije Universiteit Brussel (VUB))
- Frank Pattyn (Université libre de Bruxelles (ULB))

IACS#33

Deriving the Østrem curve to quantify supraglacial debris-related melt-altering effects on the Djankuat Glacier, Caucasus, Russian Federation

Yoni Verhaegen, Victor V. Popovnin, Oleg Rybak, Philippe Huybrechts

We have derived the glacier-specific Østrem curve to quantify the influence of a supraglacial debris cover on the mass and surface energy balance components of the Djankuat Glacier, a northwest-facing and partly debris-covered temperate valley glacier in the Caucasus region, which has been selected as a 'reference glacier' by the WGMS. A 2D energy balance model, in combination with meteorological data from automatic weather stations and ERA5-Land reanalysis data, are used to assess the melt-altering effect of supraglacial debris on the overall glacier runoff during 1 complete balance year. The main results show that both the surface energy balance and mass balance fluxes are modified significantly due to the presence of debris on the glacier surface. For very thin debris, a slight relative melt-enhancement occurs due to a decreased surface albedo. If debris, however, further thickens, the insulating effect becomes dominant and reduces the melt and runoff of the underlying ice significantly, as thermal conduction becomes the dominant process to induce ice melt beneath such thick debris layers. The above-mentioned effects are modelled to be increasingly pronounced with an increasing thickness of the superimposed supraglacial debris cover, and can be of great importance with respect to future glacio-hydrologic regimes and glacio-geomorphological processes.

Affiliations:

- Yoni Verhaegen (Earth System Science and Department of Geography, Vrije Universiteit Brussel)
- Victor V. Popovnin
- Oleg Rybak
- Philippe Huybrechts (VUB)

IACS#34

Hysteresis and orbital pacing of the early Cenozoic Antarctic ice sheet

Jonas Van Breedam, Philippe Huybrechts, Michel Crucifix

The early Cenozoic Antarctic ice sheet has grown non-linearly to a continental-scale ice sheet close to the Eocene-Oligocene boundary when environmental conditions were favourable. These favourable conditions included the movement of the continent towards the South Pole, the thermal isolation of the Antarctic continent and declining atmospheric CO2 concentrations. Once the threshold for ice sheet growth was reached, a series of positive feedbacks led to the formation of a continental-scale ice sheet.

The thresholds for growth and decline of a continental-scale ice sheet are different. The ice sheet state is dependent on the initial conditions, an effect called hysteresis. Here we present the hysteresis behaviour of the early Cenozoic Antarctic ice sheet for different bedrock elevation reconstructions. The ice sheet-climate coupler CLISEMv1.0 is used and captures both the height-mass balance and the ice-albedo feedback accurately. Additionally, the influence of the different orbital parameters on the threshold to glaciation and deglaciation is investigated in detail. It appears that the long-term eccentricity cycle has a significant influence on the ice sheet growth and decline and is able to pace the ice sheet evolution for constant CO2 concentration close to the glaciation threshold.

Affiliations:

- Jonas Van Breedam (Vrije Universiteit Brussel)
- Philippe Huybrechts (Vrije Universiteit Brussel)
- Michel Crucifix (UCLouvain)

IACS#37

Subglacial hydrology modulates basal sliding response of the Antarctic ice sheet to climate forcing

Elise Kazmierczak, Sainan Sun, Violaine Coulon, Frank Pattyn

Major uncertainties in the response of ice sheets to environmental forcing are due to subglacial processes. These processes pertain to the type of sliding or friction law as well as the spatial and temporal evolution of the effective pressure at the base of ice sheets. We evaluate the classic Weertman/Budd sliding law for different power exponents (viscous to near plastic) and for different representations of effective pressure at the base of the ice sheet, commonly used for hard and soft beds. The sensitivity of the above slip laws is evaluated for the Antarctic ice sheet in two types of experiments: (i) the ABUMIP
experiments in which ice shelves are instantaneously removed, leading to rapid grounding line retreat and ice sheet collapse, and (ii) the ISMIP6 experiments with realistic ocean and atmosphere forcings for different Representative Concentration Pathway (RCP) scenarios. Results confirm earlier work that the power in the sliding law is the most determining factor in the sensitivity of the ice sheet to climatic forcing, where a higher power in the sliding law leads to increased mass loss for a given forcing.Here we show that spatial and temporal changes in water pressure or water flux at the base modulate basal sliding for a given power, especially for high-end scenarios, such as ABUMIP. In particular, subglacial models depending on subglacial water pressure decrease effective pressure significantly near the grounding line, leading to an increased sensitivity to climatic forcing for a given power in the sliding law. This dependency is, however, less clear under realistic forcing scenarios (ISMIP6).

Affiliations:

- Elise Kazmierczak (Université libre de Bruxelles)
- Sainan Sun (Department of Geography and Environmental Sciences, Northumbria University, Newcastle upon Tyne, UK)
- Violaine Coulon
- Frank Pattyn (Université libre de Bruxelles)

IACS#50

Quantifying future sea-level rise from a coupled atmosphere-ocean-ice sheet model

Sébastien Le clec'h, **Chloë Paice**, Xavier Fettweis, Philippe Huybrechts

The evolution of the Greenland ice sheet results from complex feedbacks between components of the Earth System. The mass loss of the Greenland ice sheet has increased sixfold since the 1990s. With accelerated ice mass loss rates, it could become the largest contributor to sea-level rise in the 21st century. Both the surface mass balance and outlet glacier retreat control this ice mass loss. The latter is decomposed between ice flow changes in the lower trunks of outlet glaciers (discharge) and calving of marine-terminating outlet glaciers. We use the GISM ice sheet model, fully coupled to the RCM MAR, and forced by heat content changes from the surrounding ocean, to assess the 21st century ice mass loss and investigate the associated processes. The poster will show results from experiments driven by several CMIP6 GCM models. Of particular interest is the partitioning between mass loss from surface mass balance changes and outlet glacier retreat.

Affiliations:

- Sébastien Le clec'h (Vrije Universiteit Brussel)
- Chloë Paice (Vrije Universiteit Brussel)
- Xavier Fettweis (Université de Liège)
- Philippe Huybrechts (VUB)

IAG poster abstracts

IAG#12

Belgian contribution to the maintenance of the European coordinate reference system

Carine Bruyninx, Juliette Legrand, Andras Fabian

EUREF is the IAG Reference Frame Sub-Commission for Europe, integrated in the IAG Sub-Commission 1.3, Regional Reference Frames, under Commission 1 – Reference Frames. EUREF's primary mission is to establish and maintain the European coordinate reference system and physical height reference system, which are the basis for precise geo-referencing in Europe, and are endorsed by the European Union INSPIRE (Infrastructure for Spatial Information in the European Community) directive, EuroControl and EuroGeographics. These systems are also used for Earth Science research and several multidisciplinary applications.

The EUREF Permanent Network (EPN) is the key infrastructure for the collection, archiving, processing, and analysis of a data stemming from a network exceeding 350 GNSS stations homogeneously covering the European continent. The EPN-related services (EPN Data Centers, Central Bureau, Analysis Centers, Product Coordinators) and products are providing the backbone of the European Terrestrial Reference System, ETRS89.

This poster will give an overview of the Belgian contribution to maintenance of the EPN and ETRS89.

Affiliations:

- Carine Bruyninx (Royal Observatory of Belgium)
- Juliette Legrand (ROB)
- Andras Fabian (ROB)

IAG#13

Belgian GNSS contribution to the European Plate Observing System

Carine Bruyninx, Juliette Legrand, Fikri Bamahry, Florian Bodranghien, Andras Fabian, Anna Miglio

It is the ambition of the European Plate Observing System (EPOS, https://www.epos-eu.org/) to offer a collaborative framework to provide, through a unique portal, open access to multidisciplinary data to help understanding the complex Earth's dynamic system.

The GNSS component of EPOS presently consists of a European network of more than 1500 GNSS stations and provides access to GNSS data, metadata and products, such as ground deformations.

This poster summarizes the pan-European GNSS services the Royal Observatory of Belgium (ROB) is preparing to deliver to EPOS from 2023 on. These services have been built on ROB's EUREF services in operation since many years to maintain the European Terrestrial Reference System. With

the support of BELSPO, these EUREF services are currently upgraded to respond to EPOS needs, resulting in
- A new pan-European data node making the EUREF data discoverable to EPOS;
- A GNSS station metadata management service, guiding EPOS-GNSS towards application of FAIR data principles;
- A GNSS observation data quality monitoring system;
- An analysis center computing the velocity field and the associated station position time series of the EUREF stations. They provide information on ground deformations, especially valuable for geophysical research.

Affiliations:

- Carine Bruyninx (Royal Observatory of Belgium)
- Juliette Legrand (Royal Observatory of Belgium)
- Fikri Bamahry (Royal Observatory of Belgium)
- Florian Bodranghien (Royal Observatory of Belgium)
- Andras Fabian (Royal Observatory of Belgium)
- Anna Miglio (Royal Observatory of Belgium)

IAG#20

Belgian metadata catalogue for permanently tracking GNSS stations in Europe

Andras Fabian, **Carine Bruyninx**, Anna Miglio, Juliette Legrand

The Metadata Management and Distribution System for Multiple GNSS Networks (M3G, https://gnss-metadata.eu), hosted by the Royal Observatory of Belgium, is one of the services of the European Plate Observing System (EPOS, https://www.epos-eu.org) and EUREF (http://euref.eu). M3G provides the scientific as well as the non-scientific community with a state-of-the-art archive of information on permanently tracking GNSS stations in Europe, including the station description, the GNSS networks the stations contribute to, whether station observation data are publicly available, and how to access them.
Since its first public release (2018), M3G has been under continuous development, to respond to the evolving needs of the GNSS community, to progress towards FAIR data principles and comply with GDPR.
This poster will give an overview of M3G, the metadata that it provides and how these metadata can be accessed.

Affiliations:

- Andras Fabian (ROB)
- Carine Bruyninx (Royal Observatory of Belgium)
- Anna Miglio (Royal Observatory of Belgium)
- Juliette Legrand (ROB)

IAG#23

Moving towards FAIR GNSS data: putting principles into practice

Anna Miglio, Carine Bruyninx, Andras Fabian, Juliette Legrand, Stefanie De Bodt, Paula Oset Garcia, Inge Van Nieuwerburgh

Nowadays, in the context of scientific research becoming more and more data-driven, it is essential that data are properly documented, preserved and accessible to both humans and machines.
FAIR data principles are a community-agreed set of guidelines for finding, accessing, integrating, and reusing data in such a manner that researchers could interpret, reproduce, communicate and share information efficiently. However, FAIR data principles are general principles and putting them into practice can be challenging.

Recently, during its 2021 annual meeting, the IAG Reference Frame Sub-commission for Europe (EUREF) issued a resolution explicitly stating that EUREF *"[...] recognising that FAIR data principles increase the value and the reuse of digital resources, by humans as well as machines, encourages the EUREF community to adopt these principles in all aspects of data management"*.
It is indeed within the frame of the historical EUREF Permanent GNSS data repository that the Royal Observatory of Belgium (ROB) has embarked on a project focused on the application of FAIR principles to improve GNSS data management and foster reuse of GNSS data for scientific purposes.

Here we will present an overview on the methodology, the challenges and the first results obtained in the process of applying FAIR principles our GNSS data.
In particular, we focus on:
- use of available tools and metrics to assess the initial level "FAIRness" of the data ,
- restructuring of the GNSS data repositories,
- use of Persistent Identifiers for GNSS data,
- proposals for metadata standards for GNSS data

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IAG#25

Development of EPOS-GNSS data monitoring – web portal and alarms

Fikri Bamahry, Carine Bruyninx, Florian Bodranghien, Juliette Legrand

As a part of the Belgian contribution to the European Plate Observing System (EPOS), the Royal of Belgium (ROB) is developing a new web portal (https://gnssquality-epos.oma.be) and alarms to monitor the availability and quality of GNSS (Global Navigation Satellite Systems) data that are stored in distributed EPOS data repositories. These data repositories are maintained by EPOS-GNSS data nodes and synchronized to the EPOS-GNSS Data Gateway (DGW) to be accessed by the public via an Application Program Interface (API) and a web portal.

ROB's new web portal visualizes the availability and quality of the daily GNSS data that are discoverable through EPOS. On one hand, it allows users to check the distribution and the availability

of the EPOS-GNSS station data by GNSS network, data node, or operational center. On the other hand, the web portal provides plots of several GNSS data quality indicators, such as the number of observed versus expected observations, the number of missing epochs, the number of observed satellites, the maximum number of observations, the number of cycle slips, the Standard Point Positioning (SPP) results, and the multipath values on code observations.

The alarms are designed to warn EPOS-GNSS data nodes when the GNSS data expected to show up at their node are not available. They are sent automatically on a weekly and monthly basis. In addition, an alarm prototype is currently developed to automatically detect degraded GNSS data quality indicators and find the root cause of the degradation. This prototype is based on the statistical behavior of GNSS data quality indicators.

This poster will present the current development of the web portal, the possible usage of data quality indicator plots for GNSS analysis in geophysical applications, and the preliminary results of the developed alarms.

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IAG#38

GNSS-based remote sensing of atmospheric water vapor at ROB for meteorology and climate: Status, perspectives, and challenges.

Eric Pottiaux, Carine Bruyninx

Atmospheric water vapor is a key observation for weather prediction. Global Navigation Satellite Systems (GNSS e.g., GPS, Galileo, GLONASS, Beidou...) are an all-weather observation technique that is capable of precisely and continuously sensing this atmospheric water vapor at a high spatiotemporal resolution. The Royal Observatory of Belgium (ROB) uses GNSS observations to deliver European meteorologists with data collections to improve their weather forecasts. This service is operated 24x7 in the framework of the EUMETNET EIG GNSS Water Vapour Program (E-GVAP).

However, since its inception, GNSS evolved in a drastically changing landscape, more particularly over the last decade: GNSS has seen the deployment of new constellations, new satellite technologies, the availability of new signals in space, the exponential increase of available ground stations, but also with new, more demanding, user requirements from the meteorological community. All of this increases the potential of GNSS for meteorology but also brings additional scientific and technological challenges and increases the complexity of the task.

An example is the use of GNSS to support very-short term weather forecasting. This requires reduced data delivery delay, hence moving towards real-time GNSS data acquisition and processing. In that context, ROB already services the meteorologists with data collections delivered every 15 minutes. To improve further its service, ROB also developed a prototype based on the GNut/Tefnut software from the Geodetic Observatory Pecny (GOP) and participates today in the IAG working group on 4.3.5 “Real-time Troposphere Monitoring”.

Another example is to improve the information content that can be retrieved from GNSS observations. This is particularly important during severe weather, but not solely, and this requires the development of a processing technique capable to reconstruct the atmospheric content in the direction of the satellites (gradients and slant delays) and ultimately the 3D water vapor field. In this context, ROB participates in the IAG working group 4.3.6 “Sensing small-scale structures in the lower atmosphere with tomographic principles” and is preparing benchmark data collections that will allow testing different fusion tomography approaches to study the severe floodings that we experienced in July 2021.

Similarly, ROB recently delivered a multi-year data collection in the framework of the H2020 ALARM project (https://alarm-project.eu/) to train machine learning algorithms for the forecasting of severe weather initiation to increase aviation safety.

Atmospheric water vapor is also the most important natural greenhouse gas as it contributes to about 60% of the natural greenhouse effect and constitutes strong positive feedback to anthropogenic climate forcing from CO2, hence playing a dominant role in the climate change debate and the understanding of the Earth’s climate.

In the past, ROB already contributed to climate studies with e.g., the CORDEX.be project (“COordinated Regional Climate Downscaling EXperiment”, 2014-2017, http://cordex.meteo.be/). ROB’s contribution to CORDEX.be was to study and validate the humidity field from 4 Belgian high-resolution Regional Climate Models.

Today, with almost 30 years of continuous observations at some ground stations, GNSS can today contribute further to climate studies with tailored data collections taking advantage of the latest advances. The length of the time series is close now to the one necessary for climate normals, enabling us to derive statistically significant figures about the climate. The recent increased availability and centralization of accurate meta-information for the ground stations are essential in that context to achieve climate-quality data collections. Harvesting and curating such meta-information for thousands of GNSS stations remains however challenging. This is one of the important missions operated by ROB in the framework of EPOS, the European Plate Observing System. Thanks to this initiative, GNSS observations from more European stations with curated meta-information are available to generate data collections over a longer period, enabling research that goes far beyond the GNSS contribution to CORDEX.be.

We are now timely aligned to develop a research infrastructure that can provide FAIR open data collections and scientific services using GNSS for climate research and contribute significantly to the freshly established Belgian climate center. Such infrastructure would enable ROB to sustainably connect at the national level to other Federal Scientific Institutes, Belgian universities, and regional agencies active in the climate domain and at the international level to European and worldwide initiatives like the IAG ICCC (https://iccc.iag-aig.org/), Copernicus Climate Change Service (https://climate.copernicus.eu/)...

In this poster, we will summarize ROB’s contributions to GNSS-Meteorology and GNSS-Climate research and services and outline the main perspectives and challenges we are facing.

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IAG#40

The gravimeter “B-grave” developed at the ROB for in-situ gravity measurements at surface of an asteroid

Michel van Ruymbeke

We investigate a miniaturized 3D compact gravimeter as part of geophysical instrument package dedicated to small bodies of solar system like Asteroids.
The described prototype will be setup on a cubesats assemblage which land on the secondary object in the Didymos system.
Specificities of selected solution meets problematic to measure very tinny 50µm/sec² gravimetric field corresponding to 5 ppm of Earth gravity. The system will operate in a hash thermal environment without leveling, with strictly limited power, mass and signal treatment facilities.
A system with three components mounted in an orthogonal geometry allows obtaining the gravity field in amplitude and in all angular positions without any requirement of levelling.
We set-up the gravimeter in a vertical position to reject the Earth gravity field.
We induce by tilt of the system µchange of forces similar to the Asteroid one.
B-GRAVES will use a in-situ calibration process to control the laboratory transfer function determination.

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IAGA poster abstracts

IAGA#9

Influence of the solar activity on the boundaries in the magnetosphere: plasmapause, radiation belts, auroral oval

Viviane Pierrard

The solar wind influences the space weather and the different regions in the magnetosphere. Using the most recent observations of the solar wind (Parker Solar Probes, Solar Orbiter) and the kinetic model that we have developed, we determine the influence of the most energetic electrons in the acceleration of the solar wind. Moreover, we study the links between magnetospheric boundaries during geomagnetic storms. The plasmapause marks the limit of the plasmasphere and is characterized by a sudden change in plasma density. It influences the other regions of the magnetosphere, including due to different waves circulating inside and outside the plasmasphere. Comparing the positions of the plasmapause measured by the NASA Van Allen Probes in 2015 and those of the SWIFF plasmasphere model (SPM), we investigate the links that can exist with the radiation belt boundaries using satellite observations of PROBA-V/EPT, an instrument that has been developed at CSR/UCLouvain with BIRA-IASB and QinetiQ Space. We show that the inward motion of the outer radiation belt associated with sudden flux enhancements of energetic electrons can be related to the plasmapause erosion during geomagnetic storms, suggesting possible links. The equatorward motion of the plasmapause projected in the ionosphere is also related to the equatorward edge motion of the auroral oval that goes to lower latitudes during storms due to the geomagnetic perturbation, like the low altitude plasmapause and the outer radiation belt. The links between these different regions are investigated during quiet periods, for which the plasmasphere is widely extended, as well as during geomagnetic storms for which plumes are generated, and then afterwards rotates with the plasmasphere. The results show the importance of the magnetic field topology and of the convection electric field in the interactions between these different regions eventually leading to the coupling between magnetosphere and ionosphere.

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IAGA#14

Comparison of high energy electron fluxes in the outer Van Allen radiation belt using PROBA-V/EPT and RBSPB/MagEIS

Alexandre Winant, Viviane Pierrard , Edith Botek

Science class spectrometers have been recording fluxes of high energy particles in the near space environment of the Earth for a decade now. In this work, we compare simultaneous measurements of the maximum solar activity year 2014 from two different instruments. The first one is the Energetic Particle Telescope (EPT), onboard the ESA satellite PROBA-V on a low Earth polar orbit at an altitude of 820 km. The second instrument is the Magnetic Ion Spectrometer (MagEIS) onboard the Van Allen Probes (VAPs) from NASA circulating on a highly elliptic equatorial medium Earth orbit. A larger focus is brought on EPT measurements, which are used to characterize the main events that led to sharp variations in electron and proton populations during this year. Those observations are also compared to the AE-8 and AP-8 empirical model of the belts from NASA. The comparison of the two instruments is carried out for the outer belt electron fluxes on two intervals of three months, at different locations in the outer belt and for various energies. Moreover, the effect of the value of the pitch angle of equatorial electrons is investigated. We found that during those periods, the decrease of the flux with the energy is faster at low altitude than near geomagnetic equator. In addition, dropout events were found to be much more intense for EPT measurements than for MagEIS. For the first data set, ranging from January to March, observations of the two instruments are well correlated throughout the outer belt, especially for electrons with a low pitch angle value at the equator. On the other hand, for data taken between October and December, the correlation between the two instruments decreases and more particularly near the inner edge. This decrease is found to most likely be caused by a difference in geomagnetic activity between the two periods.

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IAGA#22

Atmospheric Erosion for the Terrestrial Planets: A Semi-Empirical Model

Maria Luisa Alonso Tagle, Romain Maggiolo, Herbert Gunell, Johan De Keyser, Gaël Cessateur, Giovanni Lapenta, Viviane Pierrard, Ann Carine Vandaele

Studying atmospheric erosion is a key factor to understand the evolution of planetary atmospheres and their ability to retain water, a crucial element to determine their habitability.
The solar wind interacts with planetary atmospheres, driving the loss mechanisms. Since the planets' formation, the magnetic field of the planets has significantly changed and the solar wind flux has decreased. In this study, we investigate the effects of these changes on atmospheric escape, in order to constrain the atmospheric loss over geological time scales. We present the latest development of a semi–empirical model of atmospheric erosion, for Venus-like, Earth-like and Mars-like planets. We consider seven different escape mechanisms to estimate the total atmospheric escape rate over a range

of planetary magnetic moments and solar wind pressures.
We show that the escape rate peaks for high solar wind pressures on a weakly magnetized planet, contradicting the common assumption that the magnetic field of the planet protects its atmosphere from erosion. Indeed, a weakly magnetized planet is associated with an intense erosion from the polar regions. Our results imply also, that when the Sun was younger and more active, the planets suffered more atmospheric loss than nowadays.

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IAGA#29

Alfvén wave decay from MHD to kinetic scales in magnetic shears

Fabio Bacchini, Francesco Pucci, Francesco Malara, Giovanni Lapenta

Alfvén waves (AWs) on large spatial scales (e.g. in the solar wind, solar corona, etc.) are known to be able to follow several possible decay routes that cause mode conversion and the creation of small-scale kinetic Alfvén waves (KAWs). One such decay route, the so-called phase mixing, has been so far heavily underexplored in numerical simulations. In particular, the response of ions and electrons to the decay of large-scale AWs into KAWs in the presence of magnetic shears is not fully understood; with particle-in-cell calculations, we show that phase mixing in this situation can result in substantial electron and ion heating, with possible consequences in the interpretation of observational results.

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IAGA#36

The Changing-Atmosphere Infra-Red Tomography explorer (CAIRT): an ESA Earth Explorer 11 candidate to improve our knowledge of the coupling of atmospheric circulation, composition and regional climate change

Quentin Errera

The aim of this contribution is to introduce the Changing-Atmosphere Infra-Red Tomography explorer (CAIRT). CAIRT is a mission candidate for ESA Earth Explorer 11 (EE11) to be launched in 2031 or 2032 that has been selected for a Phase 0 among three other candidates. This mission has been proposed in order to achieve a step change in our understanding of the coupling of atmospheric circulation, composition and regional climate by quantifying: (A) the middle-atmosphere circulation change, (B) the atmospheric gravity wave momentum flux and wave driving, (C) the change in stratospheric ozone due to transport and chemistry, (D) the impact of transient solar events and space weather on climate variability, (E) the upper troposphere and lower stratosphere (UTLS) aerosol composition and precursor gases and (F) the UTLS variability and its impact on tropospheric composition and air quality. This can be achieved by atmospheric tomography through infrared limb imaging. The CAIRT concept proposes to perform tomography of the atmosphere from the troposphere to the lower thermosphere (about 5 to 115 km altitude) with a swath of 400 km and having high spatial and spectral resolution to provide a three-dimensional picture of atmospheric structure at unprecedented scales. Flying in loose formation with the Second Generation Meteorological Operational Satellite (MetOp-SG) will enable combined retrievals with observations by the New Generation Infrared Atmospheric Sounding Interferometer (IASI-NG), as well as from the other nadir sounders, resulting in consistent atmospheric profile information from the surface to the lower thermosphere.

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IAHS poster abstracts

IAHS#6

Detection and attribution of climate change impacts on flow and sediment load in the Nile basin

Albert Nkwasa, Annika Schlemn, Celray James Chawanda, Job Ekolu, Ann van Griensven

Several studies have reported different spatial contemporary flow regimes in the Nile basin. Thus, assessing whether changes in historical river flow and sediment load trends can be attributed to climate change would provide for a better understanding of the regional hydrology as well as for reliable future projections of river flow and sediment regimes. In this study we use a model-based approach for detection and attribution using a hydrologically calibrated SWAT+ model for the Nile basin. Factual and counterfactual climate data from the 6th phase of the Coupled Model Intercomparison Project (CMIP6) spanning from 1951 – 2019 is used for impact attribution. Results show a great spatial variation of trends in river flows and sediment loads across the Nile basin. A modified Mann-Kendall trend analysis showed a predominantly increasing trend (upstream of the Nile) in the lake Victoria basin which can be attributed to an increase trend signal in precipitation within the lake Victoria basin. However, a slight decreasing trend in river flows and sediment loads is observed in the Blue Nile basin and the lower Nile basin (upstream of Aswan dam). Other parts of the basin show no significant trends in historical records. Thus, the analysis provides a mixed result of clear and non-clear signals of climate change impacts on historical river flows and sediment loads spatially across the Nile basin.

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IAHS#39

Implementing sectoral water usage in the Community Earth System Model (CESM)

Ioan Sabin Taranu, Wim Thiery, David Lawrence, Yoshihide Wada, Ting Tang

In 2012 the Global Energy and Water Exchanges Project (GEWEX) concluded that the gaps in describing human-water interactions are one of the grand challenges in Earth system modeling. Despite this initiative, a decade later, very little effort was made in this direction.

The objective of our current project is to reduce this gap, by enhancing the Community Earth System Model to support all major water use sectors, including domestic, livestock, thermoelectric, manufacturing and mining (the irrigation being already implemented).

Some unique features of our development are:
- Full coverage of human water usage
- Sector priority
- Application of consumption fluxes on surface soil, to accentuate role of human water usage on land-atmosphere interactions
- Fully coupled between routing-land-atmosphere components
- Usage of new water withdrawal/consumption datasets not yet explored in any other global hydrological or land models

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IAMAS poster abstracts

IAMAS#3

Determination and analysis of time series of CFC-11 (CCl_3F) from FTIR solar spectra, in situ observations, and model data in the past 20 years above Jungfraujoch (46ºN), Lauder (45ºS), and Cape Grim (40ºS) stations

Irene Pardo Cantos, Emmanuel Mahieu, Martyn P. Chipperfield, Dan Smale, Marina Friedrich, Paul Fraser, Paul Krummel

Trichlorofluoromethane (CFC-11) is the second most important chlorofluorocarbons (CFCs) in the Earth's atmosphere. CFCs are long-lived chemicals which were exclusively produced by the industry and broadly used as aerosol spray propellants, refrigerants, inflating and insulating agents in the production of foam materials, as well as solvents. CFCs are transported into the stratosphere where they are photodissociated by UV radiation, releasing chlorine atoms that catalytically destroy stratospheric ozone.
The atmospheric concentration of CFC-11 has declined in response to the phase-out of its production by the Montreal Protocol. Nevertheless, this atmospheric concentration decline suffered a slowdown around 2012 due to emissions from non-reported production. Since CFC-11 remains one of the most important ozone-depleting halocarbons, its continuous monitoring is essential.
We present the CFC-11 total column time series (2000 – 2020) retrieved in a consistent way from ground-based high-resolution solar absorption Fourier transform infrared (FTIR) spectra. These observations were recorded at two mid-latitude stations of the Network for the Detection of Atmospheric Composition Change (NDACC.org): the Jungfraujoch station (Northern Hemisphere; 46.5ºN) and the Lauder station (Southern Hemisphere; 45ºS). These time series were compared with Cape Grim station (40.7ºS) in situ surface observations conducted within the Advanced Global Atmospheric Gases Experiment (AGAGE) network and with total column datasets calculated by the TOMCAT/SLIMCAT 3-D chemical transport model implementing the unreported emissions. Trend analyses were performed in order to identify and characterise the timing and magnitude of the trend change in both hemispheres. The observations are consistent with the model results and confirm the slowdown in the CFC-11 atmospheric concentration decay, since ≈ 2011 in the Northern Hemisphere, and since ≈ 2014 in the Southern Hemisphere.

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IAMAS#4

The different response of the climate system to astronomical parameters, GHG and ice sheets during past interglacials

Zhipeng Wu, Qiuzhen Yin, Zhengtang Guo, André Berger

The response of the climate system to astronomical parameters, greenhouse gases (GHG) and ice sheets is an important scientific issue, but the regional difference need to be better understood, including the forcing mechanisms, internal processes and feedbacks. Based on the numerical simulations during past interglacials using the model LOVECLIM, we investigate the different response of the sea ice and sea surface temperature (SST) to astronomical parameters, GHG and ice sheets at different regions. Our results show that the Arctic sea ice variation is primarily controlled by local summer insolation, while the Southern Ocean sea ice variation is more influenced by the CO2 concentration but the effect of local summer insolation can't be ignored. In terms of the astronomical parameters, precession plays a dominant role on the Arctic sea ice, while obliquity plays a dominant role on the Southern Ocean sea ice. As far as the SST is concerned, it shows a strong precessional signal at low latitudes in both hemispheres. For the SST in the mid and high latitudes, obliquity plays a dominant role in the SH whereas precession is more important in the NH. The internal processes and feedbacks will be given in detail in the presentation. In addition, the different response of the sea ice and SST to GHG and ice sheets based on the transient simulations will be investigated in the future study.

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IAMAS#5

Temporal and spatial climate diversity and underlying mechanisms over East Asia during Heinrich Events 1-6

Ming-Qiang Liang, Qiuzhen Yin

Increasing abrupt and extreme climate events that can cause catastrophic impact on society have been observed with the global warming and these abrupt, extreme and widespread climate changes with major impacts have also occurred repeatedly over the past, when the Earth system was forced across thresholds. The most-known are the Dansgaard–Oeschger (DO) events and the Heinrich (H) events that occurred during the last glacial period. However, what's their causes (Insolation, CO2, Fresh water and Ice sheet) and impacts (Hemispheric consistency or regional discrepancy) are still in debate. In my Ph.D thesis, we plan use an innovative approach combining global (HadCM3) and regional (RegCM4) climate models as well as vegetation model (BIOME4) to understand the temporal and spatial climate diversity of six Heinrich events during the last glacial over East Asia and the work strategy of this method is the following:
Step 1: In order to provide global atmospheric boundary conditions to RegCM4, HadCM3 will be used for global climate simulations for each H event.
Step 2: RegCM4 will be driven by the outputs of the HadCM3 simulations to simulate the regional

climate over East Asia.
Step 3: The climate outputs of RegCM4 will then be used to drive BIOME4 to simulate the vegetation and land surface characteristics.
Step 4: The RegCM4 simulations will be repeated with the updated vegetation provided in step 3 as boundary condition.
The results obtained will allow to explore the impact of different external forcings and internal feedbacks. In particular, comparing the outputs of step 1 and 2 allows to investigate what's the "added value" of regional climate modelling. Comparing step 2 and step 4 allows to investigate the impact of vegetation. Finally, a comprehensive analysis of all the results will help to understand what has caused the spatiotemporal discrepancies of the H events climate in East Asia.

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IAMAS#8

Diverse response of global terrestrial vegetation to astronomical forcing and CO2 during the MIS-11 and MIS-13 interglacials

Qianqian Su, Anqi Lyu, Zhipeng Wu, Qiuzhen Yin

Disentangling the links between terrestrial vegetation changes and astronomical forcing as well as CO2 is of great help to understand the sensitivity of contemporary vegetation and predict future vegetation and climate changes, yet it remains challenging. Given the distinct differences in astronomical configurations and CO2 concentration between Marine Isotope Stage (MIS) 11 and 13, here we investigate the role of astronomical forcing and CO2 on global vegetation changes during these two interglacials based on transient simulations performed with the model LOVECLIM1.3. Our results show that during these two interglacials, astronomical forcing plays a dominant role in vegetation evolution, with the effect of CO2 being relatively small. The effect of astronomical forcing on vegetation can be explained successively by the relationship between climate (temperature, precipitation) and the astronomical parameters and the relationship between vegetation and climate. The relative effect of precession and obliquity on vegetation strongly depends on regions and on interglacials. In general, obliquity plays a more important role in vegetation variations during MIS-11, while precession is more important during MIS-13. Our results also reveal a clear half-precession cycle (~10 ka) in the variations of temperature, precipitation and vegetation in the tropical area during MIS-13, as a direct response to the equatorial insolation. However, no obvious half-precession cycle is simulated during MIS-11 due to its weak precession variation but large obliquity variation, indicating that the half-precession cycle is not stable in time.

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IAMAS#10

Evaluation of the N2O rate of change as a diagnostic of the stratospheric Brewer-Dobson Circulation in a Chemistry-Climate Model

Daniele Minganti, Marta Abalos, Justin Alsing, Simon Chabrillat, Quentin Errera, Rolando Garcia, Nicholas Jones, Douglas Kinnison, Emmanuel Mahieu, Maxime Prignon, Matthias Schneider, Dan Smale

The Brewer-Dobson Circulation (BDC) determines the distribution of long-lived tracers in the stratosphere; therefore, their changes can be used to diagnose changes in the BDC. We evaluate decadal (2005-2018) trends of nitrous oxide (N2O) in two versions of the Whole Atmosphere Chemistry-Climate Model (WACCM) by comparing them with measurements from four Fourier transform infrared (FTIR) ground-based instruments, the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS), and with a chemistry-transport model (CTM) driven by four different reanalyses. The limited sensitivity of the FTIR instruments can hide negative N2O trends in the mid-stratosphere because of the large increase in the lowermost stratosphere. When applying ACE-FTS measurement sampling on model datasets, the reanalyses by the European Centre for Medium Range Weather Forecast (ECMWF) compare best with ACE-FTS, but the N2O trends are consistently exaggerated. The N2O trends obtained with WACCM disagree with those obtained from ACE-FTS, but the new WACCM version performs better than the previous above the Southern Hemisphere in the stratosphere. Model sensitivity tests show that the decadal N2O trends reflect changes in the stratospheric transport. We further investigate the N2O Transformed Eulerian Mean (TEM) budget in WACCM and in the CTM simulation driven by the latest ECMWF reanalysis. The TEM analysis shows that enhanced advection affects the stratospheric N2O trends in the Tropics. While no ideal observational dataset currently exists, this model study of N2O trends still provides new insights about the BDC and its changes thanks to relevant sensitivity tests and the TEM analysis.

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IAMAS#18

Different Regional Sensitivity of Summer Precipitation in East Asia to Astronomical Forcing, CO2 and Ice Volume

Anqi Lyu, Qiuzhen Yin, Michel Crucifix, Youbin Sun

The relative influence of insolation, CO2, and ice sheets on the East Asian summer monsoon (EASM) is not well understood especially at regional scale. We use a Gaussian emulator based on simulations with HadCM3 to quantitatively assess how astronomical forcing, CO2, and northern hemisphere ice sheets affect the variation of the summer precipitation over the last 800 thousand years. Our results show that in the north of 25° N of the EASM domain, the variation of the summer precipitation is dominated by precession, and ice volume only modulates the effect of insolation through influencing the land-sea pressure contrast. This leads to strong 23-ka cycles in the summer precipitation. In the southern part (south of 25° N),the impact of ice volume becomes more important, leading to strong 100-ka cycles. Ice volume controls the precipitation in the southern part via its dominant control on the location of the Intertropical Convergence Zone and the Hadley cell. The effect of ice volume on summer precipitation depends on background astronomical configurations and vice versa. The relationship between summer precipitation and glaciation level varies among latitudes and for different astronomical configurations. Obliquity and CO2 have little effect on the summer precipitation as compared to precession and ice sheets.

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IAMAS#19

Paleo-Pedo-Climatology: Modeling the paleosol formation on the Chinese Loess Plateau during the Quaternary interglacials

Keerthika Nirmani Ranathunga, Peter Finke, Qiuzhen Yin, Zhipeng Wu

The loess-paleosols sequences in the Chinese Loess Plateau (CLP) are the most comprehensive terrestrial palaeoenvironmental records for paleoclimates, reflecting global scale climatic oscillations, glacial-interglacial phases. Environmental conditions over the Quaternary period have resulted in continuous loess deposits during glacials (cold-dry), which nevertheless interrupted by paleosols during interglacials (warm-humid) in the CLP. However, paleosols in there are least well understood in response to relative contributions of various soil forming factors, including climate conditions during interglacials (e.g. precipitation, evapotranspiration), duration of soil formation, dust deposition etc. Therefore, the overall theme of this research is to better understand paleosol formation in the CLP, particularly through quantitatively assessing paleosol responses to interglacial climates and ultimately to evaluate soil functioning in terms of soil-based ecosystem services.
To achieve this we combine a dynamic process-based climate and –soil model (LOVECLIM1.3-

SoilGen2) to identify important drivers for paleosol development over the past 500 kyr. The structure of this PhD research is described below. First, we calibrate the soil model for various soil process parameters by confronting simulated and measured soil properties for interglacial soils formed in the CLP and test the effect of reconstructed dust addition patterns on soil development in the loess plateau. Second, we apply the calibrated model to assess the relative contributions of precipitation, temperature, evapotranspiration, vegetation and dust addition on paleosol formation. For the first time, we investigate paleosol response to the precessional and ice volume changes. Finally, the research highlights the potential of using SoilGen2 with LOVECLIM1.3 for quantifying soil-based ecosystem services.

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IAMAS#21

Coupling geophysical data, microtopography and high-resolution imagery to map a permafrost degradation gradient at the Stordalen mire, Abisko, Sweden: implications for iron-organic carbon interactions

Maxime Thomas, **Éléonore du Bois d'Aische**, Maëlle Villani, François Jonard, Sébastien Lambot, Kristof Van Oost, Veerle Vanacker, Reiner Giesler, Carl-Magnus Mörth, Sophie Opfergelt

Arctic is warming nearly four times faster than the global average, and as a result, the permafrost temperature has increased by up to 0.39 ± 0.15 °C in the years 2007-2016. This warming is expected to generate a permafrost carbon feedback on the climate by enhancing permafrost thaw and biogeochemical transformation of previously frozen soil organic carbon. Yet, between 30% and 80% of soil organic carbon in permafrost is estimated to be stabilized by geochemical interactions with mineral elements such as iron and therefore less likely to be emitted as a greenhouse gas. These iron-organic carbon interactions may be modified by changing hydrological conditions in areas where thaw of ice-rich permafrost results in local subsidence and development of thermokarst landforms. The challenge is to identify the early stage of thermokarst landforms, and to quantify the influence of thermokarst development on iron-organic carbon interactions released upon thawing. Here, we investigate the relationship between geophysical parameters and microtopography with thermokarst development and the implications for iron-organic carbon interactions at Stordalen mire, Abisko, northern Sweden (discontinuous permafrost region). This site presents three stages of permafrost degradation: (i) a well-drained palsa on top of permafrost (poorly degraded); (ii) a bog with fluctuating water table depth (intermediate state of degradation); and (iii) a fully thawed and inundated fen which has undergone ground subsidence. We produced orthomosaics and digital elevation models of the study site by photogrammetry and we conducted spatially continuous electrical conductivity measurements of the soil by electromagnetic induction. We also monitored the temporal evolution of soil moisture, soil temperature and soil conductivity together with the geochemistry of the soil pore water along the gradient. Our results show that continuous bulk electrical conductivity is contrasted along the gradient and consistent with the results of the landscape classification derived from the orthomosaics and digital elevation models. This illustrates the effectiveness of the permafrost degradation gradient mapping: fen areas are saturated with water, bog areas are richer in solutes and sloped, and palsas are flat areas with significantly lower bulk conductivity. Bog areas are well identified as transitional zones based on bulk conductivity, salinity,

and pH values at depth that are significantly higher than those found in the palsa or fen. The Fe^{III} concentrations in soil solution are at least an order of magnitude higher in bog and fen areas compared to palsa areas. These data support that physical degradation of permafrost and subsequent changes in soil moisture with thermokarst landform development from palsa to fen likely influence the geochemical conditions for the stability of iron-organic carbon interactions.

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IAMAS#24

Mechanistic approach towards the analysis of tree mortality in Belgian forests impacted by extreme weather events

Arpita Verma, Louis Francois, Ingrid Jacquemin, Merja Tölle, Benjamin lanssens

Tree mortality is a key driver of forest dynamics, and it is expected to become more common in the future as a result of climate change. Episodes of tree mortality associated with drought and heat stress have been reported in forests over the last decades and are expected to increase under ongoing climate change. Forests are the main contributors to the terrestrial carbon sink which can mitigate atmospheric CO2 rise and reduce global warming. However, tree mortality reduces this carbon sink and may even turn it into a source. Tree mortality at the ecosystem level remains challenging to quantify since long-term, tree-individual, reliable observations are uncertain. For this reason, here we adapted a satellite-model approach to work on regional forests and upscale the results to the global forest.
In Belgium, 30% of the territory of Wallonia is covered by forest which is the highest among all the three regions. The consecutive recent extreme events, especially the droughts and heat waves of 2018, 2019, and 2020, caused water stress and bark beetle attack. According to the 35 years (1985-2020) land use land cover change extracted by LANDSAT 5,7 and 8 satellite, there is no significant change in forest land in Wallonia, Belgium. Meanwhile, in the current years 2021-2022, there is a decrease in forest land with intensive forest management due to tree mortality. On the other hand, in Wallonia, the forest is distributed insignificant plots of broadleaf deciduous, coniferous, and mixed forests. However, we found that after the consecutive drought events and water stress with the Norway

spruce, other tree species are also in vulnerable states. For example: In a mixed forest when bark beetle or Scolytidae attacked the spruce tree it is more attracted to the other trees and in this consequence tree species like – birch and oak are now also in premature death or deteriorating tree health.
In this study, we are using a high spatial resolution 25 cm drone image to find out pixel-based tree mortality by using artificial intelligence (deep learning) and machine learning techniques. In addition, the high-resolution tree mortality extracted data have been used in the CARAIB dynamic vegetation model to analyze the impact of extreme events on forest trees during the recent past and the future (until 2070). In conclusion, with this study, we better constrain our model regarding tree species mortality aspects, towards an improved prediction of tree species' vulnerability under future extreme weather events.

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IAMAS#27

Cloud-Aerosol Interactions over Dronning Maud Land in COSMO-CLM²

Florian Sauerland, Niels Souverijns, Alexander Mangold, Preben Van Overmeiren, Heike Wex, Nicole Van Lipzig

By serving as condensation and ice nuclei, aerosols play a vital role in the formation of clouds. This might have significant implications for the radiation balance and precipitation amounts over the Antarctic Ice Sheet. Little is known about the interaction in this remote location with sparse observations, where type and amount of aerosols differ significantly from other places. We added a module to COSMO-CLM² aimed at improving the parametrisation of the aerosol-cycle which includes prognostic equations for aerosol concentrations and a two-moment cloud scheme. The model was integrated for the region around the Princess Elisabeth Antarctic research station (PEA) in Dronning Maud Land for a period of 10 days in January 2016 with varying concentrations of cloud condensation nuclei (CCN) and ice nucleating particles (INP), based on observations from PEA. Results were compared with observations of cloud structure and precipitation amounts taken at PEA, as well as the unmodified COSMO-CLM² model. They indicate that the number of INP has a significant impact on the microphysical composition of clouds, with higher numbers being associated with a lower amount of liquid water content of clouds and higher precipitation amounts. Additional runs are performed to confirm and extend these findings, taking into account possible climatological effects by integrating over an entire year.

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IAMAS#31

Sensitivity of global surface moisture dynamics under changed land cover and land management

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Land cover and land management changes (LCLMC) have often been highlighted as crucial regarding climate change mitigation (e.g., enhanced carbon uptake on land through afforestation), but their potential for adaptation has also been suggested (e.g., local cooling through irrigation). Regarding the latter, the effects of LCLMC on the climate remain uncertain. LCLMC can have strong implications on surface moisture fluxes and have even been linked to changes in large scale atmospheric circulation. Here, we study the effects of three LCLMC (i) global afforestation, (ii) global cropland expansion and (iii) large-scale irrigation extension on climate by employing three fully coupled Earth System Models (CESM, MPI-ESM, and EC-EARTH). Sensitivity simulations were performed under present-day conditions and extreme LCLMC, of which the effects on moisture fluxes and atmospheric circulation are investigated. We do this by first analyzing the surface moisture fluxes using monthly precipitation and evaporation data to perform a moisture convergence analysis, before performing a moisture tracking analysis with the Water Accounting Model (WAM-2 layers) , this model solves the atmospheric moisture balance and requires sub-daily data from the sensitivity experiments as an input. Here we focus on the results from CESM, cropland expansion has shown to cause an average shift southward of the Intertropical convergence zone as well as a weakening in westerlies strength and consequent decrease in moisture transport. This causes an increase in continental moisture sources over most of the Northern Hemisphere. Afforestation, in contrast, shows an average shift northward of the Intertropical convergence zone and enhanced westerlies and moisture transport. Lastly, irrigation expansion enhances the moisture convergence over areas where irrigation is applied, causing an increase in both precipitation and evapotranspiration.

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IAMAS#35

Evolvement of irrigation-induced impacts on near-surface climate under future scenarios

Yi Yao, Thiery Wim

Recent observation-based and modelling studies have highlighted the impacts of irrigation on near-surface climate, and it has been stressed that irrigation can alleviate hot extremes, change precipitation patterns and increase air moisture. However, most of the previous studies only focused on historical periods, while potential climate change, land cover conversions and irrigation method advances may alter both the magnitudes and patterns of irrigation-induced effects, thus the influence of irrigation in the future remains uncertain. To address this question, we will employ version 2 of the Community Earth System Model (CESM2) with an updated irrigation scheme considering different irrigation techniques, to detect the impacts of irrigation on near-surface climate under different future scenarios. To include the influence of climate, land cover and irrigation method, several Representative Concentration Pathways (RCP) and Shared Socio-economic Pathways (SSP) scenarios will be selected, and different scenarios of Irrigation Method Distribution (IMD) evolvement will be designed in line with SSP scenarios for this study. Different combinations of RCP, SSP and IMD scenarios will be used to force the model, and the outputs of these experiments will be analysed and compared. We anticipate that our results will reveal how irrigation-induced impacts on near-surface climate will evolve under different scenarios.

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IAMAS#48

Monitoring Earth's Energy Imbalance from space

Steven Dewitte, Thorsten Maurtisen, Luca Schifano, Lien Smeesters, Francis Berghmans

The Earth Energy Imbalance (EEI) is the most Essential of all Climate Variables (ECVs). The EEI is the direct cause of the global temperature rise. The accurate and stable measurement of the EEI is required [Hansen et al, 2005], [Von Schuckmann et al, 2016] to understand current climate change, and its monitoring is urgently needed to verify whether the Paris Climate Agreement is adequately implemented.

Despite its fundamental importance, the EEI is defying accurate and stable measurements. The EEI is the difference of two nearly equal terms: the term of the Incoming Solar Radiation (ISR), and the term of the Total Outgoing Radiation (TOR), both of the order of 340 W/m². Currently, from space, the ISR and the TOR are measured with separate instruments, each with their own calibration errors. The sum of these calibration errors, of the order of 5 W/m², overwhelms the EEI to be measured, of the order of 0.9 W/m². The current space based EEI stability is 0.5 W/m²dec, which is unacceptably large. During the so-called hiatus period from 1998 to 2013, the EEI could be both decreasing [Dewitte et

al, 2019] or increasing with an unprecedented rate [Loeb et al, 2021]. A breaktrough in the accuracy and stability of the EEI can be obtained if a single dedicated instrument – a wide field of view radiometer [Schifano et al, 2020] – is used to make a differential sun-earth observation. The optimal required accuracy and stability for the EEI are 0.1 W/m² and 0.1 W/m²dec respectively.

Currently the EEI is monitored by the NASA CERES program using two complementary sun synchronuous orbits: the so-called morning orbit with a Local Time of Descending Node (LTDN) around 10:00, and the so-called afternoon orbit with LTDN around 02:00. Without a European follow-on mission for the Ceres Terra mission, EEI monitoring from the morning orbit will be discontinued from 2026 onwards. In contrast to a downgrade of a 2-orbit sampling to a 1-orbit sampling, an optimal sampling of the EEI diurnal cycle, requires the upgrade to a 4-orbit constellation: the morning orbit, the afternoon orbit, the dusk-dawn orbit with LTDN around 18:00, and an inclined orbit with 82° inclination, providing both global coverage, and a statistical sampling of the full diurnal cycle in a 90 day period.

We propose the future deployment of a dedicated small satellite constellation for the monitoring of the EEI. The systems simplicity and inherent multiplicity means it could robustly monitor Earths radiation balance as the world's nations struggle to live up to the Paris agreement to stabilize global warming below 2 degrees in the coming decades.

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IAMAS#49

Centennial Total Solar Irradiance Variation

Steven Dewitte, Jan Cornelis, Mustafah Meftah

Total Solar Irradiance (TSI) quantifies the solar energy received by the Earth and therefore is of direct relevance for a possible solar influence on climate change on Earth. Following a long held belief, based on [Eddy, 1976], the solar radiative forcing would have slowly increased from the solar Maunder Minimum (MM) from 1645 to 1715, to the present, and thus the sun would have made a small contribution to global warming.

We analyse the TSI space measurements from 1991 to 2021, and we derive a regression model that reproduces the measured daily TSI variations with a Root Mean Square Error (RMSE) of 0.17 W/m2. The daily TSI regression model uses the MgII core to wing ratio as a facular brightening proxy and the Photometric Sunspot Index (PSI) as a measure of sunspot darkening. We reconstruct the annual mean TSI backwards to 1700 based on the Sunspot Number (SN), calibrated on the space measurements with an RMSE of 0.086 W/m2.

The analysis of the 11 year running mean TSI reconstruction confirms the existence of a 105 year Gleissberg cycle [Feynman and Ruzmaikin, 2014], which leads to a fundamental revision of [Eddy, 1976]. The TSI level of the current grand minimum is only about 0.15 W/m2 higher than the TSI level of the grand minimum in the beginning of the 18th century. For the last 50 years, the sun has caused a modest cooling radiative forcing of the climate on earth of approximately -0.125 W/m2, while for the next 50 years, we can expect a modest positive (heating) solar radiative forcing.

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IAPSO poster abstracts

IAPSO#7

Evolution of oxygen levels in the Black sea from 1950 to present

Catherine Meulders, Luc Vandenbulcke, Anne Mouchet, Arthur Capet, Loïc Macé, Marilaure Grégoire

The Black Sea is one of the biggest anoxic basins in the world. While the Northwestern shelf is shallow and might experience episodes of seasonal hypoxia, the open sea is strongly stratified and its deep waters are characterized by permanent anoxia. Between the well-oxygenated surface layer (50 m) and the anoxic sulfidic deep layer (100m - 2000m) lies a biogeochemical transition zone in which both O2 and H2S concentrations are extremely low. Many redox processes (reduction of nitrate, manganese oxide or iron oxide) occur within this transition layer which exhibits changes in thickness (at the decadal time-scale) presumably related to climate variability.
Long-term analyses evidenced that the upper interface of the transition layer has shoaled over the past decades due to a decrease of the oxygen penetration depth. Yet, very little is known about the long term trend of the lower interface. Here, we provide results from numerical experiments with the 3D coupled physical-biogeochemical model (NEMO-BAMHBI) between 1950 and present. The investigation of the results allows assessing the evolution of the oxygen content through time and its variability and trend resulting from natural variability and climate change. Changes in the oxygen content will be linked with modification of the ventilation mechanisms and eutrophication.

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IAPSO#15

Insolation threshold triggered abrupt changes of Atlantic overturning circulation at the end of interglacials

Qiuzhen Yin, **Zhipeng Wu**, André Berger, Hugues Goosse, David Hodell

Paleoclimate records show that the end of interglacials of the late Pleistocene was marked by abrupt cooling events and increased millennial variability. Strong abrupt cooling occurring when climate was still in a warm interglacial condition is puzzling and its cause remains uncertain. In this study, we performed transient climate simulations for all the eleven interglacial (sub)stages of the past 800,000 years with the model LOVECLIM1.3. Our results show that there exists a threshold in the astronomically induced insolation below which abrupt changes at the end of interglacials occur. When the summer insolation in the Northern Hemisphere (NH) high latitudes decreases to a critical value, it triggers a strong, abrupt weakening of the Atlantic meridional overturning circulation (AMOC)

followed by high-amplitude variations. The mechanism involves sea ice feedbacks in the Northern Nordic Sea and the Labrador Sea. The abrupt weakening of AMOC in turn lead to strong cooling in the NH and its abrupt oscillations lead to similar abrupt oscillations in the simulated temperature, precipitation and vegetation from low to high latitudes. Our simulated results are supported by observations from marine and terrestrial records. Our study shows that the astronomically-induced slow variation of insolation could trigger abrupt climate changes. The insolation threshold occurred at the end of each interglacial of the past 800,000 years, suggests its fundamental role in terminating the warm climate conditions at the end of interglacials. Our results show that the next insolation threshold will occur in 50,000 years, suggesting an exceptionally long interglacial ahead, which is in line with what has been suggested by early studies.

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IAPSO#16

SolveSAPHE: reliable and robust carbonate system pH calculations made in Belgium

Guy Munhoven

SolveSAPHE-v1 (Solver Suite for Alkalinity-PH Equations -- version 1 (Munhoven, 2013, DOI:10.5194/gmd-6-1367-2013) was the first to offer carbonate chemistry speciation calculations that were (1) robust, (2) fast, (3) universally convergent for any physically meaningful pair of total alkalinity (A_T) and dissolved inorganic carbon (C_T) values, and (4) self-starting, i.e., did not require any a priori knowledge of the solution.

The solution approach developed for SolveSAPHE-v1 was recently extended to process A_T-CO_2, A_T-HCO_3^- and A_T-CO_3^{2-} problems in a similar way (Munhoven, 2021, DOI:10.5194/gmd-14-4225-2021). The mathematical analysis of the modified alkalinity-pH equations reveals that the A_T-CO_2 and A_T-HCO_3^- problems always have one and only one positive root, for any physically sensible pair of data (i.e., such that, resp., $[CO_2]>0$ and $[HCO_3^-]>0$). For A_T-CO_3^{2-} the situation is completely different: there are pairs of data values for which there is no solution, others for which there is one, and still others for which there are two of them. Similarly to SolveSAPHE-v1, SolveSAPHE-r2 offers automatic root bracketing and efficient initialisation schemes for the iterative solvers. The A_T-CO_3^{2-} problem is furthermore autonomously and completely characterised: for any given pair of data values, the number of solutions is determined and non-overlapping bracketing intervals are calculated.

The numerical solution of the alkalinity-pH equations for the three new pairs is far more difficult than for the A_T-C_T pair. The A_T-CO_2 pair is computationally the most demanding. With the Newton-Raphson based solver, it takes about five times as long to solve as the companion A_T-C_T pair, while

A_T-CO_{3}^{2-} requires about four times as much time. All in all, the secant based solver offers the best performances. It outperforms the Newton-Raphson based one by up to a factor of four and leads to equation residuals that are up to seven orders of magnitude lower. For carbonate speciation problems posed by A_T and either one of [CO_2], [HCO_3^-] or [CO_{3}^{2-}] the secant based routine from SolveSAPHE-r2 is clearly the method of choice; for calculations with A_T-C_T, the SolveSAPHE-v1 solvers will perform better, due to the mathematically favourable characteristics of the alkalinity-pH equation for that pair.

SolveSAPHE is Free and Open-Source Software, made available on Zenodo.

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IAPSO#17

The rate of information transfer as a measure of ocean-atmosphere interactions

David Docquier, Stéphane Vannitsem, Alessio Bellucci

Exchanges of energy between the ocean and atmosphere are of large importance in regulating the climate system. Here we apply a relatively novel approach, the rate of information transfer, to quantify interactions between the ocean and atmosphere over the period 1988-2017 at monthly time scale. More specifically, we investigate dynamical dependencies between sea-surface temperature (SST), SST tendency and turbulent heat flux in satellite observations. We find a strong two-way influence between SST / SST tendency and turbulent heat flux in many regions of the world, with largest values in eastern tropical Pacific and Atlantic oceans, as well as in western boundary currents. The total number of regions with a significant influence of turbulent heat flux on SST and on SST tendency is reduced when considering the three variables, suggesting an overall stronger ocean influence compared to the atmosphere. We also find a relatively strong influence of turbulent heat flux taken one month before on SST. Additionally, an increase in the magnitude of the rate of information transfer and in the number of regions with significant influence is observed when looking at interannual and decadal time scales, compared to monthly time scale.

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IAPSO#26

USING A COUPLED HYDROBIOGEOCHEMICAL OCEAN MODEL IN DOWNSCALING TO ASSESS THE NORTH SEA POTENTIAL IN CARBON SEQUESTRATION

Evgeny Ivanov, Luc Vandenbulcke, Marilaure Grégoire

Upon realisation of the enormous anthropogenic impact on the coastal ocean, the coastal countries have been trying to assess and manage this impact using the tool of ocean modelling. Since then, numerous models were set for all major European seas, while other models cover the entire global ocean. However, while the first generally have a resolution sufficient to tackle specific medium-scale coastal ocean processes, at their borders they fully depend on the boundary conditions provided by the large-scale models, which often fail to capture coastal ocean's variability of hydrodynamics and biogeochemical processes. Lack of standardisation and evaluation criteria to assess model performances has also been a challenge. The European CE2COAST project uses an approach of dynamic downscaling (implementation of the high-resolution local models into the large-scale models) to study ocean pressures and services important for the local ocean. The standardised assessment of the model performances will help to overcome shortcomings of the local high-resolution models.

Nowadays the shallow North Sea is surrounded by several developed countries, which are using it on a daily basis for fisheries, shipping, offshore structure installation (wind farms), etc. This creates anthropogenic pressures, demanding an accurate assessment and the long-term prediction for the managerial purposes. In the frame of the Belspo FaCE-IT project, our another coupled system (hydrodynamics-wave-sediment & OmexDia) was already used to assess the impact of the biodeposition process of offshore wind farm biofouling fauna on primary production and carbon sequestration at the scale of the Southern Bight of the North Sea.

In CE2COAST, our goal is to develop and calibrate a coupled hydrodynamic-wave-sediment-biological-biogeochemical model in order to predict evolution of different ocean pressures (warming; circulation; acidification; river inputs) and services (CO_2 uptake; carbon sequestration, i.e. through anthropogenic impact such as wind farms; primary production) until 2100 using climate projections from IPCC. Projection up to the end of this century will be realised under three scenarios of changes (i.e. SSP-2.6, 4.5 and 8.5) The long term predictions of the state of the North Sea in terms of circulation, temperature and alkalinity, as well as the insights in its potential to uptake and sequester the carbon will allow better management of the North Sea by all the neighbouring countries and will contribute to the EU Green strategies (the Blue Growth, the Marine Spatial Planning, the Marine Strategy Framework Directive) and will ensure the possibility to sustainably manage the coastal ocean.

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IAPSO#41

The causes of North Atlantic sea surface temperature bias in general circulation models

Xia Lin, François Massonnet

The North Atlantic sea surface temperature (SST) cold bias is a remarkable feature of general circulation models (GCMs). The bias is a primary concern in climate science because they directly affect the skill of predictions and the confidence in projections on the North Hemisphere climate. Here the causes of the cold bias are investigated by combining Atmospheric, Ocean, and Coupled Model Inter-comparison Project (AMIP6/OMIP6/CMIP6) simulations with observations. It is found that the cold North Atlantic SST bias is primarily caused by weak Gulf Stream currents induced weak

heat transport in ocean models. These biases are much reduced by increasing the ocean model resolution to 0.25 degree or higher. The radiation heat flux bias in AMIP6, OMIP6, and CMIP6 model are small. The large turbulent heat flux bias linked to SST bias in CMIP6 models is not shown in AMIP6 models, which implies that the SST bias dominates the turbulent heat flux bias in coupled models. Our results suggest that to reduce the North Atlantic SST bias in the coupled models, the development of ocean model parameterization is crucial.

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IASPEI poster abstracts

IASPEI#11

Multi-attribute stationarity evaluation of ambient noise H/V shapes in the Einstein Telescope installation region (Belgium)

Yawar Hussain, Hans-Balder Havenith

Previous results obtained from short-term ambient noise records in the prospective region of Einstein Telescope (super sensitive Gravitational-wave observatory), indicated various peaks (low and high frequency) on the spectra. These variations may have been caused by numerous factors (e.g., anthropogenic activity, windmills proximity, civil engineered structures, meteorological factors and green function of site among others). However, in order to better understand seismic resonance variations and their source mechanisms, detailed investigations are required. To that end, continuous ambient noise has been recorded with seven broadband velocimeters CMG-6TDs, started in February 2020, installed in private properties (cellars) along the BE-NL-DE borders.
The stationarity of the low (<1 Hz) and high-frequency (>1 Hz) peaks appeared on horizontal-to-vertical spectral ratio (H/V) curves are investigated. A multi-attribute peak-stationarity evaluation criteria has been adopted. Additionally, ambient noise displacement RMS are calculated and compared with H/V peaks variations and other climatological causative factors. Preliminary results showed large variations in the H/V peaks especially, sensitive to the S-wave modifications as well as changes in ambient noise levels in the region.

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IASPEI#47

Seismica: Open science and community building in a new diamond open access journal

Thomas Lecocq, The Seismica group

Seismica, a new diamond open-access journal in Seismology and Earthquake Science, launched in July 2022. Seismica is an independent journal, designed and built by a global community of researchers with the aim of making scientific research freely available, with no publication or subscription fees.
Beyond traditional research articles, Seismica publishes an innovative set of peer-reviewed reports including fast reports, null results/failed experiments, software reports, and instrument deployment/field campaign reports. Seismica accepts papers within the very broad scope of fault slip and earthquake source phenomena, earthquake records, imaging the Earth, theoretical and computational seismology, beyond Earth-tectonic applications, techniques and instrumentation, earthquake engineering and engineering seismology, and community engagement, communication, and outreach.
Seismica is led by an international team of over 40 people spanning these disciplines, including experts in open science and data; equity, diversity and inclusion; outreach and communication; and

digital media and branding. These volunteers cover traditional editorial roles as well as the journal's full-time management and operation (including technical support, copy editing, branding and communications). Seismica values their labour and service by crediting reviewers, authors, and contributors.
This talk will discuss the evolution of Seismica, both as a journal and as a community dedicated to science transparency, and supporting not only open-access articles, but also a fully open research process. It will cover the work involved in starting up a new journal, including partnerships with external organizations, funding considerations, a mentorship program for editors and reviewers, practical application of open science workflows, and ultimately how we are rethinking and meeting the challenges of creating, recording and sharing open geoscience information while responding to community needs.

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IAVCEI poster abstracts

IAVCEI#43

Volcanic explosive eruptions sequestrate more carbon in soils than what they emit into the atmosphere

Pierre Delmelle, Sebastien Biass, Mathilde Paque, Benjamin Lobet

Burial of surface soil can store large amounts of stable organic carbon (Corg) at depth. In volcanically-active regions, widespread tephra deposits emplaced by explosive eruptions repeat this process through time, each event providing a fresh substrate for formation of a new volcanic soil and rapid Corg accretion. However, these eruptions also emit copious amounts of gaseous CO2, possibly annihilating the carbon flux from atmosphere to soil. The efficacy of soil organic carbon (SOC) sequestration by tephra is not known, hindering estimate of the true Corg stock held in multi-layered volcanic soils and assessment of the carbon balance of an explosive eruption. Here we develop a novel modelling framework for predicting the spatio-temporal evolution of the SOC stock in areas recurrently affected by tephra fallout. We first validate our hypothesis by quantifying the store of Corg in a soil buried by tephra >2000 years ago. We then apply our model to the Ecuadorian Andes and find that a large amount of tephra-buried Corg accumulated throughout the Holocene, possibly representing ~30% of the country's SOC stock (to a depth of 1 m). In addition, results show that the cumulative Corg mass buried by Holocene tephra is consistently higher than the total magmatic carbon emitted explosively over the same period. Our analysis identifies an underrated pathway for carbon storage on the millennial timescale in volcanically-active regions and also reveals, counterintuitively, that explosive eruptions ultimately act as carbon sinks.

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IAVCEI#44

Grain size modulates volcanic ash retention on crop foliage and potential yield loss

Noa Ligot, Patrick Bogaert, Sébastien Biass, Guillaume Lobet, Pierre Delmelle

Ash fall from volcanic eruptions endangers crop production and food security and jeopardises agricultural livelihoods. As the population in the vicinity of volcanoes continues to grow, strategies to reduce volcanic risks to and impacts on crops are increasingly needed. This effort involves the use of quantitative relationships to anticipate crop damage from ash exposure. However, current limited models of crop vulnerability to ash rely solely on ash thickness (or loading) and fail to reproduce the complex interplay of other volcanic and non-volcanic factors that drive impact. Amongst these, ash retention on crop leaves affects photosynthesis and is ultimately responsible for widespread damage to crops. In this context, we carried out greenhouse experiments to assess how ash grain size, leaf pubescence, and humidity conditions at leaf surfaces influence the retention of ash (defined as the percentage of foliar cover coated with ash) in tomato and chilli pepper plants, two crop types

commonly grown in volcanic regions. For a fixed ash mass load (~570 g m-2), we found that ash retention decreases exponentially with increasing grain size and is enhanced when leaves are pubescent (such as in tomato) or their surfaces are wet. Assuming that leaf area index (LAI) diminishes with ash retention in tomato and chilli pepper, we derived a new expression for predicting potential crop yield loss after an ash fall event. A corollary result is that the measurement of crop LAI in ash-affected areas may serve as a useful impact metric. Our study demonstrates that quantitative insights into crop vulnerability can be gained rapidly from controlled experiments, thereby providing a mean to improve models that can predict ash risks to crops accurately. We advocate this approach to broaden our understanding of ash-plant interaction and to validate the use of remote sensing methods for assessing crop damage and recovery at various spatial and time scales after an eruption.

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IAVCEI#45

Assessing the potential of enhanced silicate weathering in a tropical soil to remove atmospheric CO2 and improve soil fertility: a modelling study

Juliette Glorieux, Marlon Calispa, Pierre Delmelle

Concentrations of carbon dioxide in the atmosphere are higher than at any time in human history. Enhanced silicate weathering (ESW) is a process that aims to accelerate the natural weathering by spreading finely ground silicate rock, such as basalt, onto surfaces which speeds up chemical reactions between rocks, water, and air. Applied to cropland soils, ESW could remove significant quantities of CO2 from the atmosphere, while inducing ancillary benefits to soil fertility and crop growth. However, many uncertainties remain as to the CO2 removal (CDR) efficacy of this approach. Here we use a reactive transport model to investigate the effect of adding crushed olivine and basalt to a highly weathered soil (Oxisol) on chemical weathering and atmospheric CDR. We show that basalt is more efficient in consuming CO2 than olivine. However, the rate of basalt-induced CDR decreases gradually with time, whereas it remains stable when olivine is used. Based on our simulation results, we estimate that 3.3 to 10.4% of the current annual anthropogenic CO2 emissions may be removed after 30 to 100 years of ESW. We also found that basalt application may lead to higher co-benefits for soil fertility as significant concentrations of potassium, calcium and magnesium are released into the soil solution. Because ESW with olivine and basalt induces a significant increase in the soil solution pH, these nutrients will be readily available to crop plants. Further modelling studies are underway to assess the potential long-term changes in soil mineralogy and physico-chemical properties resulting from repeated silicate applications.

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IAVCEI#46

High surface fluoride content on ash from the 2021 Tajogaite eruption, Cumbre Vieja, Canary Islands

Arnaud Denis, Elena Maters

Explosive activity of Cumbre Vieja volcano led to recurrent ash fall on La Palma, Canary Islands, for almost three months in autumn 2021. A multi-day time series of ash samples were collected throughout the eruption in stations set up by the Instituto Volcanológico de Canarias at distances of 2–10 km from the vent complex. To investigate the ash as a possible source of fluoride to the environment, we examined the water leachate and bulk composition of 30 ash samples and the surface (topmost 2–10 nm) composition of seven ash samples erupted from 19 September–16 November. Water leachate F- concentrations ranged from 13–683 mg kg-1 with pH values from 5.3–5.8. Bulk F concentrations of the ash ranged from 634–1830 mg kg-1. Surface F concentrations ranged from 8.3–52.4 at.% (excluding C and O, normalised to 100%); reaching higher values than any reported F content on volcanic ash to date by X-ray photoelectron spectroscopy. These surface F concentrations were greatly reduced on all except one of the ash samples analysed after leaching in water, suggesting that most of the surface F is water-soluble. Comparison of F- concentrations in water leachates and 0.1 mol L-1 HCl leachates supports this, although for several samples a large fraction of F- only dissolved in acid. Salts such as Na2SiF6 and NaF formed by ash-HF(g/aq) reactions may be the source of soluble F-, while less-soluble F may occur in other salts (e.g., CaF2), minerals (e.g., Ca5(PO4)3F) or the glass. Our findings prompt further consideration of the nature and origin of F on ash surfaces and have potential implications in terms of toxic and nutrient element release from the ash in the environment.

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