Inter-Commission Committee on Geodesy for Climate Research (ICCC)

President: **Annette Eicker** (Germany)
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Terms of Reference

The Inter-Commission Committee on Geodesy for Climate Research (ICCC) was formally approved and established during the 27th IUGG General Assembly in Montreal 2019 to advance the use of geodetic observations for climate research.

The growing data record from numerous geodetic observation techniques (GNSS station observations, satellite radio occultation and reflectometry, satellite gravimetry, satellite altimetry, InSAR, VLBI, GNSS-controlled tide gauges, etc.) provides a new quantitative view on various variables that are relevant for climate research, such as tropospheric water vapor, thermospheric neutral density, terrestrial water storage, ice sheet and mountain glacier mass , steric and barystatic sea level, sea surface winds, ocean waves, subsurface and surface currents, or sea ice extent and -thickness. Many of these are listed as Essential Climate Variables (ECV) according to the definition by the Global Climate Observing System (GCOS).

Geodetic methods provide unique information on the Earth's surface geometry, its large-scale mass transports such as fluctuations in Earth's water cycle, and the global energy imbalance. Time series of geodetic data start to reveal a complex picture of natural climate variability, long-term climate change and anthropogenic modifications. Combined with other observations by means of, e.g., global or regional Earth system simulations or reanalyses, they provide excellent tools to improve our understanding of climate-related processes. Furthermore, due to their advantage of being independent of other data commonly used to drive and evaluate coupled climate models, geodetic observations have strong potential for either being used as input for numerical models as constraints (e.g. water budget, sea level budget) or for a posteriori model assessment.

While it is generally recognized that geodetic data provide invaluable information for studying the planet's changing climate, programmatic obstacles, technical limitations such as the length of time series, and scientifically open questions have been identified that hamper the broader recognition of geodesy as an important source of information for climate research. In order to better promote and facilitate the use of genuinely geodetic data in the climate community, and to better explore the synergies between the different geodetic branches with respect to observing climate signals, we propose to establish an Inter-Commission Committee on "Geodesy for Climate Research". It will be based on the work started in the 2015-2019 IAG period's Joint Working groups 2.6.1 "Geodetic Observations for Climate Model Evaluation" and 4.3.8 "GNSS Tropospheric Products for Climate". It will continue the roadmap initiated at the workshop "Satellite Geodesy for Climate Studies" (Bonn 2017), which brought together geodesists representing all different observation techniques and climate scientists in a dedicated framework.

The topic of the suggested ICC is positioned at the interface between geodesy and climate science and is of high relevance for the entire scientific discipline geodesy. Various geodetic observables provide complementary information on climate change processes. Examples include (but are not limited to) the following: climate change related mass transport (e.g. ice melting, sea level rise, changes in the continental and oceanic water cycle as well as their impact on water resources) are among the primary signals derived from (satellite) gravity observations and can also be detected directly by geometrical measurements of volume change (satellite altimetry for water bodies/ice, InSAR over aquifers) or indirectly via crustal deformations induced by surface loads (terrestrial GNSS, InSAR, VLBI). Furthermore, by changing the Earth's moments of inertia and relative momentum term, mass transports also lead to measurable variations in Earth orientation parameters.

Climate change related variations of the atmosphere affect the propagation of geodetic signals and thus can be inferred from long time series of VLBI and ground and satellite based GNSS observations. Finally, a stable global geodetic reference frame (GGRF) is an indispensable requirement for providing a uniform reference for monitoring global change processes, as has recently been recognized by the corresponding UN resolution[1]. However, synergies between the different geodetic observing systems for monitoring climate change have not yet been fully exploited and the interaction with the climate communities needs to be intensified in order to achieve a broader – and better recognized – use of geodetic data for climate research.

Objectives

- To deepen the understanding of the potential (and limitations) of geodetic measurements for the observation, analysis and identification of climate signals
- To advance the development of geodetic observing systems, analysis techniques and data products regarding their sensitivity to and impact on Essential Climate Variables, this way also supporting activities of the IPCC
- To advance the improvement of numerical climate models, climate monitoring systems, and climate reanalysis efforts through incorporating geodetic observations
- To stimulate scientific exchange and collaboration between the geodetic and the climate science communities
- To make geodetic variables more user-friendly by sharing them publicly and explaining their usefulness

Program of Activities (tentative):

- The ICC will establish a workshop series to intensify the exchange between different geodetic communities and the climate monitoring and modeling communities.
- The ICC will create opportunities for communication and discussion through suggesting/organizing sessions at international scientific meetings and conferences.
- The ICC will develop reference (best-practice) methods for evaluating/improving climate models with geodetic data and publish these methods (e.g. in a 'white paper').
- The ICC will seek to organize special issues on its topic in appropriate international journals.
- The ICC will work towards a better recognition of geodesy as an essential provider of precise information about long-term changes in the Earth system.
- The ICC will establish links to other climate science related bodies, e.g. the IUGG Union Commission on Climatic and Environmental Change (CCEC) or the IAMAS International Commission on Climate (ICCL).
- The ICC will maintain a website for dissemination of ICC related information

List of Joint Working Groups:

JWG C.1: Climate Signatures in Earth Orientation Parameters
Chair: *Jolanta Nastula* (Poland)
Vice-Chair: *Henryk Dobslaw* (Germany)
(Affiliation: Commission 3, GGOS, IERS)

JWG C.2: Quality control methods for climate applications of geodetic tropospheric parameters
Chair: *Rosa Pacione* (Italy)
Vice-Chair: *Marcelo Santos* (Canada)
(Affiliation: Commission 4, IGS, IVS)

JWG C.3: Geodesy for the Cryosphere: advancing the use of geodetic data in polar climate modelling
Chair: *Bert Wouters* (Netherlands)
Vice-Chair: *Ingo Sasgen* (Germany)
(Affiliation: Commission 2, Commission 3, GGOS)

JWG C.4: Sea level and vertical land motion
Chair: *Roelof Rietbroek* (Germany)
Vice-Chair: *Riccardo Riva* (Netherlands)
(Affiliation: Commission 1, 2 & 4, GGOS)

JWG C.5: Understanding the monsoon phenomenon from a geodetic perspective
Chair: *Balaji Devaraju* (India)
Vice-Chair: *Matthias Weigelt* (Germany)
(Affiliation: Commissions 2, 3 & 4, GGOS)

JWG C.6: Numerical Simulations for Recovering Climate-Related Mass Transport Signals
Chair: *Roland Pail* (Germany)
Vice-Chair: *Wei Feng* (China)
(Affiliation: Commission 2, GGOS, IGFS)

JWG C.7: Satellite geodetic data assimilation for climate research
Chair: *Mehdi Khaki* (Australia)
(Affiliation: Commission 2, GGOS)

JWG C.8: Methodology of comparing/validating climate simulations with geodetic data
Chair: *Jürgen Kusche* (Germany)
(Affiliation: Commisison 2, ICCT)

Steering Committee:

President: *Annette Eicker* (Germany)
Vice-President: *Carmen Boening* (USA)
Representative of Comm.1: *Christopher Kotsakis* (Greece)

Representative of Comm.2: *Wei Feng* (China)
Representative of Comm.3: *M. Schindelegger* (Germany)
Representative of Comm.4: *Anna Klos* (Poland)
Representative of GGOS: *Mayra Oyola* (USA)
Representative of IAMAS: *Vincent Humphrey* (USA)
Member at Large: *Felipe Nievinski* (Brazil)

Joint Working Groups

Joint Working Group JWG C.1: Climate Signatures in Earth Orientation Parameters

Affiliation: Commission 3, GGOS, IERS
Chair: *Jolanta Nastula* (Poland)
Vice-Chair: *Henryk Dobslaw* (Germany)

Introduction

Earth orientation parameters comprising variations of both the position of the rotational pole and the spin rate are precisely observed by modern space geodetic techniques for several decades already. Moreover, optical astrometric observations extending back in time over more than 100 years provide even carry information about the mass transport and mass distribution processes acting on Earth at historical times that might be explored to quantify slow and subtle variations in the Earth's climate. This working group will study the various contributors of the global and interactively coupled climate system to the observed changes of the Earth's orientation on time-scales from days to centennials. It will explore possibilities to validate numerical climate models and its individual components by means of assessing the angular momentum budget and the associated torques. The working group will further investigate predictive limits of various Earth system state and flux variables in order to aid short- and long-term prediction of polar motion and changes in the length-of-day, and might ultimately foster the incorporation of Earth Orientation Parameters into contemporaneous global re-analyses of the Earth System by means of data assimilation.

Objectives

- Detection of climatic signals in Earth's rotation from days to centennials
- Modelling of climatic trends on the Earth rotation from days to centennials
- Assessment of angular momentum budgets of global numerical climate and Earth system models
- Fusion of Earth rotation parameters and global geophysical fluid models by means of data assimilation

Activities

- Establishment of the "best practices" for deriving angular momentum and torque estimates from numerical climate model data
- Contributions to the future development of the Global Geophysical Fluid Centre (GGFC) of the International Earth Rotation and Reference Systems Service (IERS)
- Active participation at major geodetic conferences via both session proposals and contributing abstracts
- Annual working group meetings aligned to a major geodetic conference

Members

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Nikolay Sidorenkov (Russia)
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Joint Working Group JWG C.2: Quality control methods for climate applications of geodetic tropospheric parameters

Chair: *Rosa Pacione* (Italy)
Vice-Chair: *Marcelo Santos* (Canada)
Affiliation: Commission 4, IGS, IVS

Introduction

Zenith Total Delay (ZTD) estimates are determined on a regular basis by several processing centers. For example, the IGS Analysis Centers have all their own independent ZTD solutions but, unlike other estimated parameters (e.g., orbits and satellite clocks) they are not combined. The official IGS

ZTD product is the result of an independent and dedicated solution based on a precise point positioning solution. On the other hand, EUREF performs combination of ZTD estimates on a regular basis as well as the IVS, which combines ZTD estimates coming from VLBI sessions. Nonetheless, not all IGS and IVS analysis centers make available their ZTD estimates. GNSS is reaching the "maturity age" of 30 years when climate normals of ZTD and gradients can be derived. But what would be the best series to serve the climate community? What series would offer the most realistic trends? As the IGS moves towards its third reprocessing campaign (REPRO3) where all ACs are to be make available their own ZTD and gradient estimates, as the IVS is moving towards its ACs also providing ZTD and gradient estimates and as the PPP-derived IGS product continues to be produced, there is a huge opportunity to perform quality control, using the tools of combination of parameters, to assess what would be the ZTD and gradient product best suited to be made available to climate studies.

Objectives

Potential scientific questions include:

- Are there advantages of combining ZTD estimates over not combining them? Is there any 'loss of information' in performing combinations?
- Would there be difference in trends derived from them? If so, how much implication for feeding information to climate?
- Can we trust in a combined ZTD as we trust any combined products (e.g., orbits, clock, site coordinates)?
- What the best combination strategy can be done (not necessarily to combine exactly the same way as other products)?
- Under what criteria can we use spectral analysis to demonstrate that a 'good' combined product have the same properties of the contributing solutions?
- What metrics should be used to ascertain that the optimal set of ZTD estimates, gradients and their trends, are provided to the climate community?

Activities

- Collaborate with IGS and IVS in the forthcoming reprocessing campaign.
- Participate actively in IAG, AGU and EGU conferences and organize sessions
- Organize working group meetings, splinter group meetings at the said symposia

Members

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Olalekan Isioye (South Africa)
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Joint Working Group JWG C.3: Geodesy for the Cryosphere: advancing the use of geodetic data in polar climate modelling

Affiliation: GGOS, Commission 2 & 3
Chair: *Bert Wouters* (Netherlands)
Vice-Chair: *Ingo Sasgen* (Germany)

Introduction

Over the last two decades, tremendous progress has been made in the development and use of geodetic methods to observe the rapidly emerging changes in the cryosphere. Variations in mass, elevation, grounded ice extent and flow speed are now being monitored on a routine basis using geodetic techniques such as gravimetry, (In)SAR, altimetry, GNSS and the like. Additionally, observations of land motion provide indirect information on the past evolution of ice masses. These geodetic observations have led to a leap forward in our understanding of the cryosphere as part of the climate system, and unambiguously have shown that the Earth's ice sheets and glaciers are increasingly losing mass and now represent the largest land-based contribution to global mean sea level rise.

Yet, compared to other fields of climate science (e.g. hydrology, oceanography and atmospheric sciences), inclusion of geodetic data is lagging behind in cryosphere modelling and remains mostly limited to validation of model output at large spatial scales. Data assimilation and the combination of multiple observables are still at an early development stage and rarely used to exploit the full potential of the geodetic measurements. To date, it remains a challenge incorporate the geodetically observed transitions in the cryosphere into future simulations. Within this JWG, we aim to bridge the currently existing gap between the geodetic and modelling communities, as detailed in our objectives below.

Objectives

Within this JWG, we aim to:

- identify current bottlenecks in using geodetic data for validation and assimilation efforts in ice sheet and glacier modelling
- communicate the possibilities and limitations of geodetic data to the modelling community
- document the wishes of the modelling community for geodetic data (resolution, projection, uncertainty definitions, etc.)
- identify geodetic data relevant for the evaluation of projection ensembles
- based on the above, list a set of recommendations for the geodetic community to advance the use geodetic data in modelling efforts.
- Explore potential of future geodetic observables for their use in glaciology

Program of Activities

- Summarize and gather state-of-the-art papers on geodetic observation techniques and data on the IAG website for non-geodetic audiences
- In close collaboration with the representatives of the cryosphere modelling community or through a open survey, identify requirements and derive concepts of geodetic data assimilation into ice sheet and glacier modelling
- List a set of recommended processing steps and standards for the geodetic community on the IAG website or in a white paper
- Schedule a yearly strategic splinter meeting to review progress and define strategic tasks for the upcoming year
- Acknowledge and promote work of talented young scientist contributing into the aims of JWG, through a yearly award or promotion on the ICCC website
- Communicate activities through IAG's social media accounts

Members

Mike Bevis (USA)
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Joint Working Group JWG C.4: Regional Sea level and vertical land motion

Affiliation: Commissions 1, 2 & 4, GGOS
Chair: *Roelof Rietbroek* (Germany)
Vice-Chair: *Riccardo Riva* (Netherlands)

Introduction

Global mean sea-level change is an excellent overall indicator of the state of the climate and the cryosphere, but societal impact is better represented by regional to local sea-level change, which can be very different from the global mean. Regional sea-level change may be more accurately described by dedicated time series, which incorporate knowledge of the designated coastal zone and vertical land motion. The non-uniform response of sea level to terrestrial mass changes causes regions in the far field of melting glaciers and ice sheets to be more sensitive to mass loss. Furthermore, long-term changes in wind fields, ocean heat uptake and circulation can change regional sea level. Finally, the difference between relative and geocentric sea level can be significant in places where vertical land motion is present. This can be caused by the ongoing glacial isostatic adjustment of the solid earth, but also by local subsidence from groundwater extraction and sediment compaction and loading.

The construction of sea-level change records which reconcile satellite measurements (e.g. radar altimetry, satellite gravimetry, lidar) with terrestrial measurements (GNSS stations, tide gauges and terrestrial gravimetry) on both global and regional level remains a challenging topic. This working group aims to increase the understanding of local/regional geophysical signals present in geodetic measurements, with the aim of encouraging a more widespread use of geodetic datasets in multi-disciplinary fields.

Objectives

- Encourage the use of geodetic datasets for multi-disciplinary studies related to sea-level changes.
- Communicate the need for a consistent treatment of observations and models of sea-level change and vertical land motion to non-geodetic scientific communities.

- Advance the science of regional and global sea-level research by identifying open questions and gathering state-of-the-art work.
- Communicate and coordinate activities with other relevant working groups (specifically: Geodesy for the Cryosphere), in particular on the topic of vertical land motion.

Program of Activities

- Summarize and gather state-of-the-art papers on sea level on the IAG website for non-geodetic audiences.
- Create an inventory of geodetic datasets useful for sea-level research, to be organised according to agreed standards and made freely available. Provide and gather, under a creative commons license, free to use visuals for communicating aspects of (regional) sea-level change and its (geodetic) observing system.
- Schedule a yearly strategy meeting to review the past year and define tasks for the upcoming year.
- Organize inter-JWG communication directly related to the study of vertical land motion, involving participants from the JWG Geodesy for the Cryosphere (e.g., shared web-page on IAG site, mutual participation in yearly strategy meetings).
- Communicate activities through IAG's social media accounts.
- Report activities back to relevant IAG working groups.

Members

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Joint Working Group JWG C.5: Understanding the monsoon phenomenon from a geodetic perspective

Affiliation: Commissions 2, 3 & 4, GGOS
Chair: *Balaji Devaraju* (India)
Vice-Chair: *Matthias Weigelt* (Germany)

Introduction

The monsoon phenomenon is one of the large-scale atmospheric circulation processes that drives the water cycle affecting nearly one-third of the global population. It is predominantly acting in the Inter-Tropical Convergence Zone and it controls the agricultural productivity of the countries that fall within this region. Researchers from multiple disciplines have tried to understand and model the monsoon. A century of research efforts has led to a greater understanding of the monsoon phenomenon, but research gaps and open questions remain. Improved understanding will lead to better modelling of the monsoon as well as better forecasting, which will help mitigate some of the potential hazards and risks. Currently, meteorological forecasts on timing and duration of the monsoon, its strength, and its regional distribution are limited. Furthermore, it has been observed that ongoing climate change is linked to and alters the monsoon phenomenon. Many studies point to a weakening of the monsoon, which would mean reduced rainfall to the regions that it feeds. The consequences of such weakening could be disastrous and will threaten food and water security for the region. Therefore, it becomes imperative to observe, monitor and understand the monsoon with every possible means.

The bulk of research on monsoon has been mainly conducted by meteorologists, oceanographers, atmospheric and climate scientists with oceanographic, hydrological and hydrometeorological datasets and modelling. In the recent years, geodetic sensors have been recognized as a very insightful tool for studying climate processes and their spatio-temporal changes. This has been made possible by the increased accuracy and spatial coverage of geodetic sensors, which has enabled detecting the response of the Earth's shape and gravity field to climate-related processes. At the same time geodetic sensors and their data have become integral to Earth system science, and represent critical monitoring tools. Of all geodetic methods satellite altimetry, satellite gravimetry and GNSS positioning have contributed significantly towards understanding sea level change, sea ice change, ice sheet and glacier mass balance, and the hydrological cycle, to name a few. Further, they have opened new pathways in Earth system science including the demand for improved ground networks for calibration. With the advent of satellite-based GNSS reflectometry, geodetic sensors are providing observations of soil moisture and wind speed at unprecedented horizontal scale and temporal resolution.

There is currently a deluge of geodetic sensor data spanning periods of 20 to 100 years, and therefore, perfectly suitable for climate change analysis. It presents a great opportunity to explore the signatures of various environmental and geophysical phenomena. The monsoon is one such phenomenon whose signatures in geodetic sensor data have largely remained underexplored. Some attempts have been made in the past to use geodetic sensor data in monsoon research. For example, satellite altimetry has been used to estimate the geostrophic contribution of monsoon currents. Similarly, precipitable water vapour estimates from continuously observing GNSS stations have been used to study the variations in monsoon precipitation. Nevertheless, the full integration of geodetic sensors data into monsoon modelling has not be achieved yet.

In this context we like to propose a working group to analyse geodetic sensor data in order to identify geodetic variables that are sensitive to the monsoon process, and the signatures that the monsoon leaves in geodetic data. Furthermore, we would like to explore the possibilities of complementing/supplementing monsoon forecast models, and thereby, improve their efficacy. The geodetic sensors to be used include, but are not limited to, satellite altimetry, continuously operating GNSS stations, tide gauges, gravimetric satellites (for example, GRACE, GRACE-FO and SLR), interferometric/polarimetric SAR, and terrestrial gravimeters. We will complement the geodetic sensors with meteorological data, remote sensing data and reanalysis products in global and regional climate models (such as PRECIP, BCC-CSM1.1, ECMWF-SYS4, NCEP-CFS2) to achieve our objectives.

Objectives

- Identify geodetic sensors, and in turn their observables, that are most sensitive to the monsoon phenomenon
- Identify the signatures (amplitudes, scales) of the monsoon phenomenon in geodetic sensor data
- Study the evolution of the monsoon phenomenon in time and space through geodetic sensor data
- Identify limitations and/or the necessity for additional and/or more accurate measurements including in situ networks
- Quantify the sensitivity to error sources, for example, tidal or non-gravitational force modelling
- Compare geodetic sensor data with reanalysis products in global and regional climate models
- Identify the possibility of assimilating geodetic sensor data into monsoon prediction models
- Understand relationships between extreme events and the monsoon phenomenon

Program of Activities

- Participate actively in IAG, AGU, AOGS and EGU conferences and organize sessions
- Organize working group meetings, splinter group meetings at the said symposia
- Collate geodetic sensor data along with their quality information and enable public accessibility via web services
- Conduct dedicated workshops and seminars on monsoon research with focus on geodetic sensor data
- Organize a special issue in a journal or an edited book

Members

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Peng Yuan (Germany)

Joint Working Group JWG C.6: Numerical Simulations for Recovering Climate-Related Mass Transport Signals

Affiliation: Commission 2, GGOS, IGFS
Chair: *Roland Pail* (Germany)
Vice-Chair: *Wei Feng* (China)

Introduction

Gravity field missions are a unique geodetic measuring system to directly observe mass transport processes in the Earth system. Past and current gravity missions such as CHAMP, GRACE, GOCE and GRACE-Follow On have improved our understanding of many mass change processes, such as the global water cycle, ice mass melting of ice sheets and glaciers, changes in ocean mass being closely related to the mass-related component of sea level rise, which are subtle indicators of climate change, on global to regional scale. Next Generation Gravity Missions (NGGMs) expected to be launched in the midterm future have set high anticipations for an enhanced monitoring of mass transport in the Earth system with significantly improved spatial and temporal resolution and accuracy. Science and user needs have been collected and consolidated mainly for the application fields hydrology, cryosphere, ocean and solid Earth, and a corresponding resolution on the need of NGGMs was expressed by IUGG resolution no. 2 adopted in 2015. However, mass transport observations are also very valuable for long-term climate applications. According to GCOS, in general time series of minimum 30 years are needed to decouple natural and anthropogenic forcing mechanisms. Up to now, this hypothesis has never been checked and evaluated for gravity field observations.

Objectives

The main objective of this working group is to set-up and run long-term numerical simulation studies to evaluate the usefulness of gravity field missions for climate-related applications. As a first step, mass transport time series containing long-term changes of climate relevant signals have to be generated in close interaction with climate modelers. They shall then be used for the numerical simulations on the recoverability by means of different NGGM concepts, e.g. GRACE-type in-line single-pair missions, Bender double-pair mission being composed of a polar and an inclined satellite pair, or high-precision high-low tracking missions following the MOBILE concept. In this respect, special emphasis shall be given to the separability of natural and anthropogenic forcing mechanisms in dependence of the length of the measurement time series, the quantification of robustness of derived trends and systematic changes, and the evaluation of their impact to climate modeling.

Program of Activities

The following activities shall be performed:

- Generation of mass transport time series for a time-span of at least 30 years containing climate-relevant signals
- Numerical closed-loop simulations for various mission concepts that are currently in discussion as potential candidates for an NGGM
- Evaluation of recoverability of climate-related signals from these mass transport time series
- Detectability of climate change pathways in the future mass transport time series
- Investigation of separability of natural and anthropogenic forcing processes
- Evaluation of impact for climate model applications towards societal applications
- Evaluation of the detectability of thresholds for early warning

Members

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Joint Working Group JWG C.7: Satellite geodetic data assimilation for hydro-climate research

Affiliation: Commission 2 and GGOS
Chair: *Mehdi Khaki* (Australia)

Introduction

The recent advancements in the space geodetic techniques have gained a lot of attention for improving our understanding of Earth's climate system and its hydrology. Traditionally, various types of models such as hydrologic and atmospheric models have been used for modelling/simulating and predicting hydro-meteorological processes at regional and global scales. Nevertheless, due to various sources of uncertainties such as imperfect modelling, data limitations on both temporal and spatial resolutions, their errors, as well as limited knowledge about empirical model parameters, the accuracy of model simulations can be degraded. Assimilation of satellite geodetic data such as satellite gravimetry, satellite radar and radiometer measurements, synthetic-aperture radar (SAR) and radar interferometry data, and satellite altimetry has been shown to be effective for improving the models' performance and their forecasting skills. This allows us to better study, for example, water resources and their distributions, mass variations and balance, extreme events such as droughts and floods, ice transfer, and help to adapt to long-term environmental challenges posed by climate changes on continental scales.

Data assimilation (DA) facilitates this data integration by constraining the models' simulations based on observations and error associated with them. The method has become more popular with the advent of the space era since scientific observational methods were not limited any more to terrestrial only and offer high spatiotemporal resolution data with global coverage. Specifically, the application of satellite geodetic measurement has been proven to successfully improve various models such as atmospheric and oceanic models, hydrological models and also coupled (e.g., land-atmosphere) systems. For example, the Gravity Recovery And Climate Experiment (GRACE) terrestrial water storage (TWS) data has been used to enhance land surface model performance. Satellite radar altimetry data over the ocean has been used for enhancing oceanic models. Altimetry-derived surface water over land has been recently applied for improved routing as well as rainfall-runoff estimates. Satellite soil moisture, e.g., from Soil Moisture and Ocean Salinity (SMOS) radiometer and Soil Moisture Active Passive (SMAP) has been used for hydrologic DA and more recently for land-atmosphere coupled DA to better study soil moisture feedback to atmospheric components. The use of space geodetic techniques for DA can be further extended with the development of new missions such as NASA's Surface Water and Ocean Topography (SWOT) global surface water, GRACE Follow-on, and Cyclone Global Navigation Satellite System (CYGNSS) soil moisture. Therefore, satellite geodetic DA has a great potential in hydro-climate studies and it requires more concentrations within the geodesy community. The main objective of establishing this working group within IAG is to bring together people with this expertise to share their knowledge, address the current challenges, and draw more attention to the application of geodetic techniques for DA.

Objectives

- To investigate the contributions of space geodetic DA in Earth systems.
- To develop and analyze theoretical and numerical methods for the efficient integration of satellite measurements with models.
- To better analyze model-data uncertainties in satellite DA and their influence on the model's simulations.
- To explore the application of satellite DA for model calibrations
- To investigate the application of new geodetic platforms for DA objectives.

Program of Activities

- To actively participate in geodetic meetings and promote space geodetic DA, and to monitor current progress and identify challenges.
- To share efforts, ideas, and information regarding the working group objectives.
- To organize related sessions at international events.
- To provide opportunities for more collaborations between group members (within the joint working groups) on satellite DA and publishing important findings.
- To create a web page with information relevant to the working group, bibliographic list of publications, and available research opportunities to also share significant DA outcomes with the public.

Members

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Joint Working Group JWG C.8: Methodology of comparing/validating/testing climate simulations to/with geodetic data

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Introduction

Climate model simulations provide a unique tool for understanding past and present climates, and projecting future climate under given scenarios. Comparing simulations to observed data is of key importance for understanding uncertainties and systematic errors, attributing causal relations among competing hypotheses, and lending confidence to predictions. One way geodesy contributes to climate sciences is via providing a unique data record for comparing, validating and testing climate model simulations, e.g. with respect to observed sea level change, mass redistribution or water vapor timeseries. However, what is required from geodesy is beyond 'just' providing long and stable data sets, and challenges must be addressed that require revisiting the methodology.

Climate model simulations often consist of large, single- or multi-model ensembles that need to be evaluated as a whole (i.e. not just the ensemble mean which averages out real variability). Model simulations encompass hundreds of dynamically linked variables with increasing spatial and temporal resolution, as e.g. in climate monitoring applications. Simulations are prone to drifts and biases, and climate science is not only interested in 'deterministic' (or mean) outcomes but e.g. in how statistics of extreme events or turbulent phenomena like eddy kinetic energy varies over time. Testing climate models e.g. for the anthropogenic fingerprint requires that such statistics are derived from (geodetic) data, where uncertainties must be assigned that characterize both measurement and sampling errors. This will require that geodetic methods are critically reviewed and new approaches e.g. that deal with large data quantities and ensembles and/or the reconstruction of data gaps, and that capture statistics beyond the mean and RMS be developed. Moreover, as geodetic techniques evolve (and are integrated with non-geodetic observables), new climate observables as e.g. Earth's Energy Budget come into reach and new methods must be developed.

Objectives

- To contribute to the understanding of past, present and future climate via comparing/validating/testing climate models with geodetic data
- To promote and advance the development of rigorous methods across climate science and geodesy
- To safeguard the proper evaluation of the complex geodetic data sets, which are often built from multiple techniques, over overlapping or non-overlapping time periods, in the presence of background model and other analysis technique changes, in the presence of instrumental errors and biases and the intricacies of geodetic reference frames (i.e. develop 'best-practice' examples)
- To facilitate communication of climate scientists and geodesists with respect to methodological issues
- To enable the reanalysis of long geodetic data sets

Program of Activities

- The WG will first seek to stimulate exchange and collaboration across geodesists from different background (atmospheric remote sensing, altimetry, GRACE) and climate scientists.
- It will organize splinter meetings along conferences and promote session proposals e.g. at EGU and AGU conferences.
- It will eventually seek to consolidate the geodesy methodology and disseminate results in form of a white paper / review paper.

Members

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