Contemporary regional and global sea level rise: assessment of satellite & in-situ observations and climate models.

1. Abstract

Tide gauge records and satellite altimetry indicate that sea level is rising fast since 1900 (>20cm since 1900) in response to global warming and anthropogenic greenhouse gases (GHG) emissions (IPCC, 2013), while geological records reveal much lower rates over the past 3000 years (Kemp et al. 2011). State-of-the-art Ocean-Atmosphere General Circulation Models (GCMs) show that this rise will continue and likely accelerate in the future if GHG emissions continue to rise. GCM projections of future sea level rise range from +26 cm to +82 cm (years 2081-2100 relative to 1986-2005), depending on the warming scenario of the 21st century and the GCM considered (IPCC, 2013). These significant increases in sea level will likely have severe impacts on low-lying islands and coastal zones (Nicholls and Cazenave 2010). To adapt and prepare for these impending changes, it is essential to assess these potential future impacts. However, it is still challenging to do so because the uncertainty in future sea level rise projections is large. For example, for a medium-range 21st century warming scenario (RCP 4.5), GCMs project a future global mean sea level change towards the end of this century between +32 cm and +63 cm. Highlighting the uncertainty in particular of 21st century ice sheet melt, other projections reveal the possibility for even higher sea level changes above 1 meter (e.g., Perrette et al., 2013).

The objective of this ISSI proposal is to (1) evaluate state-of-the-art GCMs against observations of sea level rise and (2) select those models, which best simulate the observed sea level changes and its contributors over the last 100 years. Our goal is to assess both the regional and global sea level rise in historical runs of GCMs (1860 through 2005/2014) by carefully comparing models with observations with a particular focus on near-global satellite observations.

In a first step we propose to estimate the 20th century sea-level rise and its contributors from the Climate Model Inter-comparison Project phase 5 (CMIP5) GCMs simulations. The contributors to sea level over the 20th century are essentially ocean warming, glacier melt, land water storage changes and changes in Greenland surface mass balance. We will then compare these estimates with observations of sea level (from satellite altimetry and tide gauge records) and its contributors (observed with ocean temperature records, ocean reanalyses, space gravimetry, satellite altimetry over ice sheets, in situ observations of glacier length changes, glaciers and ice sheet models forced with atmospheric reanalyses). At the end of the project we will be able to select those CMIP5 GCMs that best simulate the observed 20th century sea level rise. This study should open the way to future research based on the subset of validated GCMs towards 1) the development of new projections of sea level rise over the 21st century with reduced uncertainties 2) refined characterization of the sea level variability at 1-30 year time scales 3) enhance detection/attribution studies in the satellite altimetry and tide gauge signals 4) and provide valuable input for the optimal design of future Earth observing systems.

In this framework, an ISSI international team appears to be the best tool to gather our expertise into a common project that will provide feedbacks on both climate models and satellite observations for climate studies. Please note that with this proposal we intend to apply for ISSI Bern (and not ISSI-BJ) because Bern would be a much easier place to reach than Beijing for the different members of our team.

2. Scientific Rationale, Goals and Timeliness of the project

2.1 Background

In recent years, sea level rise induced by global warming and its impacts on coastal zones has become a major scientific issue involving a wide range of disciplines (IPCC, 2013) with broad societal impacts. It is now well established that global warming is essentially due to the increasing atmospheric concentration of GHG and particularly carbon dioxide from anthropogenic fossil fuel combustion and land use changes (IPCC, 2013). Global warming has already several visible consequences such as the increase of the Earth's mean temperature and ocean heat content (more than 90% of the GHG-heat ends up in the ocean), the melting of sea ice and glaciers, the loss of ice mass from the Greenland and Antarctica ice sheets. As the oceans warm, seawater expands and sea level rises. Similarly, water from melting land ice ultimately reaches the oceans and also causes sea level to rise. Over the last 20 years, land ice melt and ocean warming caused sea level to rise at a rate over 3 mm/yr, which is an order of magnitude faster than the sea level variations over the last 3000 years, which did not exceed 0.3 mm/yr (Kemp et al. 2011). Over the 20th century, direct sea level observations available from in situ tide gauges indicate that sea level rose actually at the rate of 1.7 +/- 0.3 mm/yr (Church and White, 2011). Since 1993, precise satellite altimeters show that sea level is rising even faster at a rate of 3.2 +/- 0.4 mm/yr (Meyssignac and Cazenave 2012). In addition, satellite altimetry revealed that the rate of sea level rise is not uniform over the ocean but displays large regional variations (some places experience a sea level rise 4 times faster than the global mean since 1993). All state-of-the-art climate models (i.e. GCMs) indicate that sea level will continue to rise – and more likely will accelerate - during the next decades and centuries in response to increasing GHG concentrations in the atmosphere. This future sea level rise is expected to have severe impacts on low lying islands and coastal areas including permanent submergence, increased flooding due to higher sea levels during storm surges, saltwater intrusion into surface waters and aquifers, accelerated erosion, etc

To assess the potential impacts of future sea level rise it is essential to estimate the most accurate and reliable sea level rise projections at both global and regional scales. But current sea level rise projections are highly uncertain (Slangen et al. 2014). For any given warming scenario of the 21st century, GCMs indicate global and regional sea level rise over the period 2081-2100 that can differ by a factor of 2 or more (IPCC, 2013). This large uncertainty arises essentially from inappropriate (or sometimes missing) model representations of some physical or dynamical processes that affect sea level in the climate system.

In a recent study, Church et al. (2013) showed that the range of an ensemble of 13 GCM simulations of the 20th century sea level rise encompasses the observed sea level rise within its large uncertainty. Yet this is not sufficient to make accurate, useful (in terms of adaptation and mitigation strategies) projections. Here, we want to go further and reduce the uncertainty of the ensemble of available climate models by validating each climate model estimates of the 20th century sea level rise and its contributors against observations. The proposal consists of three phases. In the first phase (Task 1) we estimate from GCM outputs the 20th century sea-level rise and its contributors, which are essentially ocean warming, glaciers ice melt, land water and ice-sheet mass loss. In the second and third phases (Tasks 2 and 3) we propose to compare these estimates with observations of sea level (from satellite altimetry, tide gauge records, 2D sea level reconstructions and ocean reanalysis), ocean warming (from ocean temperature records and ocean reanalysis) and land ice loss (from space gravimetry, satellite altimetry, in situ observations of glacier and ice sheet mass balance, ice sheet and glacier mass balance models forced with atmospheric reanalysis) that are available over the 20th century.

Our approach to this problem is through an ISSI international Team since satellite-derived observations are key to all observational aspects: satellite altimetry observations of sea level changes and ice sheet surface height, space gravimetry observations of ocean, ice sheet and glaciers mass, ocean and atmospheric reanalysis products and 2D sea level reconstructions. In particular whenever available and possible, we will use the ESA-CCI essential climate variable products computed by the Climate Change Initiative project from ESA (CCI-sea level, CCI-glaciers and CCI-ice sheets) in our validation of the GCMs.

2.2 Task 1: Sea level estimates from GCMs

Over the 20th century the major contributors to sea level variations are 1) the thermal expansion of the ocean, 2) the glaciers mass loss, 3) the Greenland ice sheet Surface Mass Balance changes (SMB), 4) the land water storage 5) and a vertical land motion contribution from the solid Earth's visco-elastic response to the last deglaciation and the 20th century land ice mass loss (Gregory et al. 2013a). Antarctic ice mass loss is relatively small over the 20th century (Huybrechts et al. 2011) and the dynamical contribution from the Greenland ice sheet is considered negligible since the Greenland ice sheet was close to equilibrium until the beginning of the 1990s (Rignot et al. 2008). Task 1 is dedicated to the computation of the 5 major contributors to the 20th century sea level rise from outputs of GCM historical runs. These contributions will be summed up in Task 3 to estimate the sea level from each of the GCM since 1900. All CMIP5 GCMs that provide all necessary outputs will be analyzed. The methods we will apply is described in the following:

1) The global and regional thermal expansion of the ocean will be computed with the 3D ocean temperature data fields from GCM historical runs. It will be obtained by integrating the density equation from the bottom of the ocean up to the surface at each grid point. The resulting thermosteric sea level will be drift-corrected, and corrected for the cold bias due to the fact that many GCM historical runs where initialized with control runs in which volcanic forcing is omitted (see Gregory et al., 2013b for details).

2) Mountain glaciers are typically too small to be explicitly represented in the coarse CMIP5 GCMs. Thus, glacier mass loss and its contribution to sea level cannot be directly estimated from CMIP5 GCM outputs. Instead, we will use offline glacier models forced by the regional Surface Air Temperature (SAT) and precipitation outputs from CMIP5 GCMs (e.g. Marzeion et al. 2012). We propose here to test 2 different glacier models from Marzeion et al. (2012) and from Slangen and van de Wal (2011).

3) Similar to the glaciers, the Greenland SMB contribution to sea level is not correctly modeled in CMIP5 GCMs because they have a coarse horizontal spatial resolution (~300 km) which limits their capability of capturing essential SMB changes on the narrow ablation zone, and because they lack (in general) a realistic representation of the snow/firn/ice processes in the upper ice sheet. To overcome this problem, we will use different downscaling methods to estimate the Greenland SMB from the GCMs outputs. We propose to test 2 different methods: i) the downscaling method developed by Geyer et al. (in press) which gives the Greenland SMB from the SAT, the precipitation and the snowmelt outputs of the CMIP5 GCMs and ii) a regional downscaling deduced from Fettweis et al. (2013) (calibrated against the Greenland regional climate model MAR) which gives the Greenland SMB for each draining basin based on GCM precipitation and 600hPa summer temperature outputs.

4) Concerning the land-water storage contribution, it is actually mainly of anthropogenic origin over the 20th century due to dam building and groundwater pumping (Wada et al., 2012, Konikow, 2011). This anthropogenic contribution is not modeled in CMIP5 GCMs. Thus, we will use estimates of the land water storage contribution based on 20th century observations (from Konikow, 2011 and Wada et al., 2012) to complete our estimates of the 20th century sea level rise from CMIP5 GCMs before comparing it to sea level observations. From 2003 onwards, we will use GRACE observations to estimate the land water component of sea level changes (e.g., Boening et al., 2012).

5) The contribution of the solid Earth's response to the 20th century sea level changes is probably small and close to the response of the solid Earth to the last deglaciation (20,000 years ago) only, because not much land ice has melted since 1900 (Marzeion et al. 2012). However, we will estimate it with a state-of-the-art "sea level equation" model, which takes into account the 3D deformations of the Earth, the gravitational interactions between the solid Earth, the ice sheets and the ocean and the rotation of the Earth. Giorgio Spada from the University of Urbino (Italy) has kindly agreed to provide this estimate.

The approach outlined above to compute the contributors to sea level from GCM outputs may produce different results depending on which model is used. Controlled comparisons will shed new light on the commonalities and differences among the methods and the models, will reveal robust features of the results and will help to quantify their uncertainties. These are the goals of the first task and will be addressed during the first meeting of the team.

2.3 Task 2: comparison of the sea level contributors estimates with satellite & in-situ observations

In Task 2 we will compare estimates of the contributors to the 20th sea level rise from CMIP5 GCMs with observations. The objective is to evaluate the GCMs performances in terms of sea level variations simulation over the 20th century (e.g., Landerer et al., 2013). We also expect to quantify more accurately the GCMs uncertainty, to identify potential problems in GCMs simulation of sea level change and its contributors, and to point the way for both model and observations improvements as well as directions for future research and observations. Our approach is as follows:

1) The thermal expansion down to 700m depth computed from bias-corrected GCM runs will be compared with ocean temperature data from Domingues et al., 2008, Ishii and Kimoto,

2009 and Levitus et al., 2012 for the period 1961-2005 when temperature data have a nearly global coverage. Unfortunately, for the deeper ocean below 700 m, data is much more sparse and near-global coverage is only available with the Argo project since 2004. While the Argo record is short, it will still help in validating GCMs for the last decade. To validate the deeper ocean on a longer period, we propose to use 2 ocean reanalyses which assimilate temperature and salinity profiles over the period 1958-2010 plus satellite altimetry: GECCO2 (Köhl 2014) and ORAS4 (Balmaseda et al. 2013). These reanalysis data sets provide estimates of the thermal expansion of the ocean down to the bottom and can be compared with the GCMs estimates over the last 50 years for validation purposes.

2) Over the 20th century several sources of observations give information on glacier mass loss. These observations use different techniques and cover different time periods. In-situ observations of glacier length and altitude or glaciers models forced with atmospheric reanalysis (Marzeion et al., 2012, Cogley, 2009, Leclercq et al., 2011, Radić et Hock 2011) are two techniques, which give information over the whole 20th century. Satellite gravimetry observations also provide some information but only since 2004 and the launch of GRACE. We intend to use these 3 techniques to validate the GCMs derived estimates of glaciers mass loss at decadal to centennial time scales. In addition, if available, we will also test the GCMs' estimates of glaciers mass loss against the CCI-glaciers dataset.

3) Concerning the Greenland surface mass balance, direct observations are available from space with satellite altimetry since the beginning of the 1990s (CCI-ice sheets for example) and with GRACE since mid-2002. In addition, to validate the GCMs estimates over longer time periods, we will also compare the GCMs based Greenland SMB estimates with those of the regional climate model MAR (Fettweis 2013) over Greenland forced by atmospheric reanalysis over the 20th century (from ECMWF and from NOAA). With these comparisons we expect to identify those climate models that have the smallest biases over the Greenland region and are thus best suitable for sea level estimates.

These are the goals of the second task and will be addressed during the second team meeting.

2.4 Task 3: comparison of the sea level estimates with observations

In this last task we will merge all estimates of the sea level contributors from GCMs to compute the total sea level changes for each GCM over the 20th century and into the first decade of the 21st century. We will then compare these estimates with observations of the sea level from tide gauge records over the 20th century, from 2D sea level reconstructions (Church and White 2011, Hamlington et al. 2011, Meyssignac et al. 2012) over the last 60 years and from satellite altimetry over the last 20 years (with the CCI-sea level dataset). Compared to other sources of observations discussed above, sea level observations over the 20th century are more accurate and consistent over long periods. So we expect that they will provide a more stringent validation of the GCMs and that they will help in better characterizing the GCM uncertainties. In particular, this should lead to a rigorous selection of only those GCMs which simulate climate changes over the 20th century that are consistent with the observed sea-level rise. The outcomes of this study will then form the foundation to make revised sea level projection for 2081-2100 with refined estimates of the uncertainties and underlying causes.

These are the goals of the third task and will be addressed during the third team meeting.

3. Logistical Information

List of confirmed team members: Benoit Meyssignac (Team Leader, France), Ole Andersen (Denmark), Nicolas Champollion (Switzerland), John Church (Australia), Xavier Fettweis (Belgium), Benjamin Hamlington (USA), Felix Landerer (USA), Stefan Ligtenberg (Netherlands), Ben Marzeion (Austria), Angélique Melet (France), Matt Palmer (UK), Kristin Richter (Austria), Jeff Ridley (UK), Aimée Slangen (Australia).

Added value from ISSI:

ISSI provides a unique opportunity to fund "international teams" around a very inter-disciplinary scientific project and in providing facilities where the international team members can share their knowledge and work together. This funding format fits very well the scope of our scientific project in which the team members need to address and work together through the technical details required to plan, collect, and discuss the data and interpretation of our planned intercomparisons. Moreover, our team includes members from 8 different countries and ISSI Bern provides a central location that is conveniently located for the majority of us. An essential part of our work of validation of climate models against observations relies on satellite observations either through direct comparisons of GCMs with satellite datasets like altimetry and space gravimetry, or through comparisons with global reanalysis datasets (and 2D sea level reconstructions) which include the global suite of satellite observations in their assimilation systems. By facilitating our meeting and the intercomparison of results, ISSI may help to advance the state-of-the-art in climate models and highlight the special value of certain research satellite observations (in particular the ESA-CCI essential climate variables) for the problem of sea level rise in response to climate change.

Schedule of the project: We plan three 4-day meetings in Bern. Prior to the first meeting we will collect details of the various data sets that will be contributed, and define a preliminary set of requirements via email. Team members will be encouraged to bring existing data to the first meeting planned for autumn 2014 to complete preliminary analysis for Task 1. We will also discuss relevant comparisons needed for Task 2 and finalize the data plan for Task 1, 2 and 3. Data from observations and GCMs will be collected between the first and second meetings. The second meeting will be essentially dedicated to the comparison between GCMs estimates of sea level contributions and corresponding observations, including a thorough review and discussion of existing skill metrics and their applicability for the tasks laid out above. It will also partly be used for interpretation and figure selection for the first publication on Task 1 and 2. Comparisons between GCMs sea level estimates and sea level observations will begin between the second and the third meetings. The third meeting will be used for interpretation and discussions on the second publication on Task 3. It will also be used to discuss the potential for using the set of validated GCMs for new projections of sea level rise in 2100, for a characterization of the natural variability in sea level changes, and for attribution/detection studies.

Tentative schedule: Meeting 1 in autumn 2014, duration 4 days; Meeting 2 in spring or early summer 2015, duration 4 days; first journal article submission in autumn 2015; Meeting 3 in early winter 2016, duration 4 days. ; second journal article submission in winter 2016. Final report to ISSI in early spring 2016.

Financial Support requested: We request hotel and per diem for 14 team members including 4 young scientists. Per diem will be needed for approximately 4 days for each participant for each of three meetings, and travel support for either the team leader or a designated participant in need.

Expected Outcomes: The immediate outcome of our team's work is expected to be 2 papers: (1) A review paper on the use of GCMs outputs for understanding sea level variations over the 20th century; (2) A paper on the validation of CMIP5 GCMs against observations of sea level rise over the 20th century. The longer-term outcome is the publication of several papers that address sea level related problems on the basis of the few GCMs that are consistent with sea level observations over the 20th century. Examples of these scientific questions include: new sea level projections in 2100 with reduced uncertainties; assessing how the leading modes of sea level variability from validated GCMs help to characterize the internal variability in sea level changes and provide a constraint on the emergent pattern of dynamic sea level change; establishing what the timescales are on which we might expect the patterns associated with Greenland surface mass loss to emerge from the variability in regional sea level; and others…

Facilities Required: Meeting room for 14 people. Wired and/or wireless internet connection. Projector and cables. A black board/white board could also be useful. Open website with a password protected team directory. IT support for website.

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Annexe

Short CVs for each member including a short list of publications.

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EDUCATION

Ph.D.in Space Oceanography, The University of Toulouse, 2012.

Engineer degree from the Ecole Polytechnique (Palaiseau), Sept. 1999 - July. 2002.

EXPERIENCE

Scientist in Geodetic Science, 2009–present, Laboratoire d'Etudes en Géophysique et Océanographie Spatiale (LEGOS) at Centre National d'Etudes Spatiales (CNES).

Astrodynamics research engineer, 2004–2009; Dept. of space dynamics at Centre National d'Etudes Spatiales (CNES).

SELECTED AWARDS

'Picot de Lapeyrouse' PhD award from the Toulouse Academy of Sciences 2013.
WCRP award for outstanding scientific presentation, WCRP conference 2011.
AGU award for outstanding scientific paper, AGU Fall Meeting 2010.

SELECTED INTERNATIONAL PROGRAM MEMBERSHIP AND SCIENTIFIC COMMITEES:

2011 - present : Principal Investigator, NASA/CNES TOPEX/POSEIDON and Jason Missions
2012 – present : Scientific committee member of LEGOS and GRGS, chair for the OSTST.

SELECTED RELEVANT PUBLICATIONS

Cazenave A., Dieng H.B., Meyssignac B., von Schuckmann K., Decharme B. and Berthier E. (2014) The rate of sea level rise. Nature Climate Change. doi: 10.1038/NCLIMATE2159.

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Education

Masters in Geophysics, University of Århus (1992)
Ph. D. in Geophysics (geodesy/oceanography), University of Copenhagen (1996)

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1992 Partic. Int. Summer school on Altimetry for Geodesy and Oceanography, Trieste, Italy.
1994 Guest scientist at Proudman Oceanographic Lab., Bidston Observatory, UK, 8 month.
1998 Guest scientist at: Uni of Tasmania+CSIRO marine labs, Hobart, Tas, Australia, 8 month.
2004 Guest scientist at NASA Goddard Space Flight Center, Geodesy, Washington for 8 month.
2013 Guest scientist at the Universtiy of Newcastle, Australia for 3 month.

Employment

Research scientist KMS geodetic division 1995, Senior research scientist at KMS, 1998.
Senior research scientist at Danish National Space Center / DTU Space, since 2005
Responsible for section: “Marine remote sensing” within Geodesy department

Management and ongoing Scientific projects.

Project Leader. HYDROGRAV (Danish Research Councils, 2007-2011) – 6 mill kr.
Project Leader, Altimetry for Earth Geopotential Model 2014, Funded by National Geospatial-Intelligence Agency, USA.
Currently participating in: GUTS 2+3(ESA, 2008+2013), MyOcea1+2 (EU-7th Framework, 2008), Monarch-A (EU-7th Framework, 2009), BLAST (EU Interreg project, 2010), LOTUS (EU 7th FW, 2012), ESA CP40 (2012)

International Appointments.

Member of science working team for Jason-1, Jason-2 and GRACE.
Member of Science Advisoary Group for ESA, GPS and GNSS mission GEROS (Launch, 2019)
Chair for GMES Sentinel-3 Calibration and Validation team (Launch 2015).
Scientific committee member (ESA living planet, ESA Coastal Altimetry, OSTST, EGU)
Appointed lecturer for the Int Association of Geodesy: Buenos Aires (2009), St Petersburg, 2011).
Invited Lecturer at NKG schools: Oslo (2005), Bornholm (2007), Lamni (2012)
Danish National Representative to the International Association of Geodesy (IAG), Fellow of IAG

Key Research Topics

Geodesy, gravity, oceanography, hydrology, remote sensing.

Awards/Grants.

Received Inge Lehmans Grant of 95.000kr in 1997 to work with the University of Tasmania.
Received Danish Research Agency grant (105.000kr) to work as guest scientist at NASA, GSFC (2004)
Nominated for AGU Geodesy Award for special contribution to geodesy (December, 2006)
Nominated (1999) for the Guy Bomford Price (International Association for Geodesy) for outstanding contribution to Geodesy by young scientist.
Recievet Inge Lehmanns Grant in 2012 to visit Australia for co-suprevision of student at Newcastle University

Publications

More than 68 Peer Reviewed International journal publications

Bookchapters

Andersen, O. B (2012). Satellite altimetry for geoid determination. in eds (Sanso and Sideris) The Geoid, Springer Verlag, Heidelberg, Germany 2012

Andersen, O. B., and R. Scharroo (2010), Range and geophysical corrections in coastal regions, book chapter in eds. (Vignudelli i et al), Coastal altimetry, ISBN: 978-3-642-12795-3

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Curriculum Vitae

Academic studies

- 2013 **Ph. D.**, Grenoble University, France. Title, *Evolution of the snow surface on the Antarctica Plateau: satellite and in situ observation*. Supervisors, Ghislain Picard (associate professor, Joseph Fourier University (UJF) Grenoble, France) and Michel Fily (full professor, UJF, Grenoble, France).
- 2009 **Research Master of Science**, UJF, Grenoble, France. Specialty, *Ocean, Atmosphere, Hydrology and Environmental Engineering*, upper second-class honors (14.50 / 20).
- 2003 **High School Graduation**, Camille Vernet high school, Valence, France.

Professional works

- 2014 – 2016 **Postdoctoral position** at the International Space Science Institute (ISSI), Bern, Switzerland, on Earth Sciences, especially on the cryopshere observation by remote sensing.
- 2009 – 2013 **Contractual Ph. D.** at the « Laboratoire de Glaciologie et de Géophysique de l'Environnement » (LGGE), Grenoble, France, on snow surface evolution of Antarctica Plateau.
- 2010 – 2014 **Delegate of students** at the UJF scientific council (2012 – 2014), at the « Terre Univers Environnement » (TUE) doctoral school council (2011 – 2012) and at the LGGE laboratory council (2010 – 2011).

Technical skills

- Programming languages: python, bash, matlab, fortran
- Radiative transfer modeling
- Satellite data processing
- Time series data & image processing

References

- **Champollion, N., Picard, G., Arnaud, L., Lefebvre, E. and Fily, M.** (2013). Hoar crystal development and disappearance at Dome C, Antarctica: observation by near-infrared photography and passive microwave satellite. The Cryosphere 7, 1247–1262, doi :10.5194/tc-7-1247-2013.
- **Champollion, N.**, Picard, G., Arnaud, L. and Fily, M., A new method to estimate snow surface density at Dome C, Antarctica, from AMSR-E passive microwave observation, MicroRad, Rome, 2012.
- Picard, G., Kerr, Y., Macelloni, G., Champollion, N., Fily, M., Cabot, F., Richaume, P. and Brogioni, M., Spatial variations of L-band emissivity in Antarctica, first results from the SMOS mission, IGARSS, Vancouver, 2011.

John Alexander Church

Dr John Alexander Church, FAA, FTSE
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Web Site: http://www.cmar.csiro.au/sealevel/

Education:

1972 B.Sc. (Hons.), Physics, Queensland University; 1979 Doctor of Philosophy

Selected Professional Experience:

1979–1993	Research Scientist/Senior/Principal Research Scientist (CSIRO Oceanography)
1982	Visiting Scientist, Woods Hole Oceanographic Institute, USA
1990–1997	Leader, Climate Program and Climate and Ocean Processes Program (CSIRO)
1986	Visiting Scientist, Woods Hole Oceanographic Institute, USA
1991–2003	Leader, Southern Ocean Processes and Polar Waters Program, Antarctic CRC
1993–2003	Leader, Oceanography, Australian National Antarctic Research Expeditions.
1994	Science Adviser, Department of Environment, Sport and Territories.
1997	Visiting Research Scientist, Southampton Oceanography Centre, UK.
1997–2003	Project Leader, Southern Ocean Processes Project, CSIRO Marine Research
2003 and 2004	Deputy Chief, CSIRO Marine Research (Oct 2003-Jan 2004, Apr-Jun 2004).
2003-2010	Chief Research Scientist, CSIRO,Leader, Sea-level Rise Program, Antarctic Climate and Ecosystems CRC.
2010-present	Research Fellow, CSIRO Marine and Atmospheric Research.
2013	Visiting Research Scientist, Southampton Oceanography Centre, UK.

Recent Awards and Recognition

November 2004	Fellow, Australian Academy of Technological Sciences and Engineering Fellow, Australian Meteorological and Oceanographic Society
June 2006	Roger Revelle Lecture and Medal, Intergovernmental Oceanographic Commission
January 2007	Medal for Research Achievement, CSIRO
August 2007	Eureka Prize for Scientific Research
January 2008	Clarke Lecture and Medal, Australian Meteorological and Oceanographic Society
May 2012	Fellow, Australian Academy of Science

Selected International Program Membership and Scientific Committees:

1987 — present	Principal Investigator, NASA/CNES TOPEX/POSEIDON and Jason Missions
1989 — 1993	Member, World Ocean Circulation Experiment Core 1 Working Group.
1992 — 1998	Member, Scientific Steering Group, World Ocean Circulation Experiment.
1994 — 1998	Co-chair, Scientific Steering Group, World Ocean Circulation Experiment.
1994 — 1998	Member, CLIVAR Scientific Steering Group.
1998 — 2001	Co-convening Lead Author, Sea Level Chapter, IPCC Third Assessment Report.
1999 — 2006	Member, Joint Scientific Committee, World Climate Research Programme
2004 — 2006	Vice-Chair, Joint Scientific Committee, World Climate Research Programme
2006 — 2008	Chair, Joint Scientific Committee, World Climate Research Programme
2010 — 2013	Co-convening Lead Author, Sea Level Chapter, IPCC Fifth Assessment Report.
2011 — 2014	Lead Author, the IPCC Fifth Assessment Report, Synthesis Report.

Publications:

Refereed papers and book chapters: 129 (including 14 in Nature Journals or Science)
Edited Books: 3; Other reports: 83
Career Citations: Over 5500 plus (ISI, Hirsch Index 34; including book chapters and edited books; Google Scholar citations >8000, H Index 44)

Curriculum vitae of Dr Xavier Fettweis

Name: Xavier Fettweis
Address: University of Liège, Department of Geography
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Phone: +32 4 3665722
Email: xavier.fettweis@ulg.ac.be
Web: http://www.climato.be/fettweis
Birth date and place: 10/10/1977, Waremme (Belgium)
Status: married, 4 children
Eduction:

1996-2000	Master in Mathematics at the University of Liège (ULg, Belgium).
2000-2001	Master degree in physics sciences (climatology) at the Université catholique de Louvain (UCL, Belgium).
2001-2006	PhD thesis in climatology at UCL. Title: Reconstruction of the 1979-2005 Greenland ice sheet surface mass balance using satellite data and the regional climate model MAR. Promoters: Jean-Pascal van Ypersele and Hubert Gallée

Work experience:

2001-2002	Assistant in physics at UCL.
2002-2004	Research Fellow from the F.R.S-FNRS at UCL.
2004-2007	Research engineer in climatology at UCL.
2007-2009	Assistant in climatology at ULg.
2009	Research fellow from the F.R.S-FNRS at ULg.
2010	Post-doc at the Institute for Marine and Atmospheric Research Utrecht (IMAU, Prof M. van den Broeke) from the Utrecht University (The Netherlands).
2011-2013	Research fellow from the F.R.S-FNRS at ULg.
2013-...	Research Associate from the F.R.S-FNRS at ULg.

Award:
I was awarded (in Avril 2013) the Arne Richter Award for Outstanding Young Scientists (from the European Geosciences Union) for my fundamental contributions in understanding and quantifying the current and future surface mass balance of the Greenland ice sheet (http://www.egu.eu/awards-medals/arne-richter/2013/xavier-fettweis/).

2. Selected bibliography

According to *Google Scholar (14/03/2014)*, my number of citation is 1130, of peer-reviewed papers 51, while my H-Index is 19. Hereafter, 5 of my more relevant publications:

1. **Fettweis, X.** (2007). Reconstruction of the 1979–2006 Greenland ice sheet surface mass balance using the regional climate model MAR. *The Cryosphere*, 1, 21-40.
2. **Fettweis, X.**, Hanna, E., Gallée, H., Huybrechts, P., & Erpicum, M. (2008). Estimation of the Greenland ice sheet surface mass balance for the 20th and 21st centuries. *The Cryosphere*, 2, 117-129.
3. **Fettweis**, X, Franco, B, Tedesco, M, van Angelen, J, Lenaerts, J, van den Broeke, M, & Gallée, H. (2013). Estimating the Greenland ice sheet surface mass balance contribution to future sea level rise using the regional atmospheric climate model MAR. Cryosphere (The), 7, 469-489.
4. Harper, J, Humphrey, N, Pfeffer, W, Brown, J, & **Fettweis**, X. (2012). Greenland ice-sheet contribution to sea-level rise buffered by meltwater storage in firn. *Nature*, 491, 240–243.
5. Hanna, E, Navarro, F, Pattyn, F, Domingues, C, **Fettweis**, X, Ivins, E, Nicholls, R, Ritz, C, Smith, B, Tulaczyk, S, Whitehouse, P, & Zwally, H. (2013). Ice-sheet mass balance and climate change. *Nature*, 498, 51–59.

You can find the full list of my publications on my homepage: http://www.climato.be/fettweis

Biographical Sketch – Benjamin Hamlington

EMPLOYMENT

2013-Pres. Research Scientist II, University of Colorado, Cooperative Institute for Research in Earth Science (CIRES)

2011-2013 Research Associate, University of Colorado**,** Colorado Center for Astrodynamics Research

2003-2007 Research Assistant, Washington University in St. Louis**,** Soft Matter Laboratory

EDUCATION

2007-2011 Doctor of Philosophy in Aerospace Engineering Sciences
University of Colorado at Boulder

2006-2007 Master of Science in Mechanical Engineering
Washington University in St. Louis

2002-2007 Bachelor of Science in Aerospace Engineering
Washington University in St. Louis, graduated with honors.

Synergistic Activities. My research interests include satellite altimetry and its application to ocean climate monitoring, sea level rise, and natural hazard assessment and warning. I have been actively involved in oceanographic research for the past 5 years, and have worked on the problem of long-term ocean variability for the past 3 years. I have developed a novel technique for reconstructing climate variables back through time, relying on cyclostationary empirical orthogonal functions and a regression technique. Recently, I used this technique to produce a reconstructed sea level dataset spanning the period from 1950 to 2010 that will be hosted by NASA/JPL PO.DAAC and made available to the scientific community. I have collaborated closely with professors at Seoul National University and make yearly trips to South Korea to further our involvement and share my scientific findings.

SELECTED PUBLICATIONS

Hamlington, B.D., Leben, R.R., Strassburg, M.W., Nerem, R.S., Kim, K.-Y., 2013: Contribution of the Pacific Decadal Oscillation to Global Mean Sea Level Trends, *Geophys. Res. Lett.*, **40,** 50950.

Hamlington, B.D., Leben, R.R., Strassburg, M.W., Kim, K.-Y., 2013: Cyclostationary Empirical Orthogonal Function Sea Level Reconstruction, *Geosci. Data Jour., in press.*

Han, W., Meehl, G.A., Hu, A., Alexander, M.A., Yamagata, T., Yuan, D., Ishii, M., Pegion, P., Zheng, J., **Hamlington, B.D.,** Quan, X-W., Leben, R.R., 2013: Intensification of Decadal and Multi-Decadal Sea Level Variability in the Western Tropical Pacific During Recent Decades, *Clim. Dyn.*, DOI: 10.1007/s00382-013-1951-1.

Hamlington, B.D., Leben, R.R., Wright, L.A., Kim, K.-Y., 2012: Regional Sea Level Reconstruction in the Pacific Ocean, *Marine Geodesy,* **35**, 98-117.

Hamlington, B.D., Leben, R.R., Kim, K.-Y., 2012: Improving Sea Level Reconstructions Using Non-Sea Level Measurements, *Jour. Geophys. Res,* **117**, C10025.

Hamlington, B.D., Leben, R.R., Godin, O.A., Gica. E., Titov. V.V., Haines, B.J., Desai, S.D., 2012: Could Satellite Altimetry Have Improved Early Detection and Warning of the 2011 Tohoku Tsunami?, *Geophys. Res. Lett.,* **39***,* L15605.

Leben, R.R., **Hamlington, B.D.,** Haines, B.J., 2012: SEASAT and GEOSAT revisited: using sea level measurements to improve satellite altimeter orbits, *Jour. of Astro. Sci.,* **58:3.**

Hamlington B.D., Leben R.R., Nerem R.S., Han, W., Kim K.-Y., 2011: Reconstructing sea level using cyclostationary empirical orthogonal functions, *Jour. Geophys. Res,* **116,** C12015.

Hamlington B.D., Leben R.R., Nerem R.S., Kim K.-Y., 2011: The effect of signal-to-noise ratio on the study of sea level trends, *J. Climate,* **24,** 1396-1408.

Godin O.A., Irisov V.G., Leben R.R., **Hamlington B.D.,** Wick G.A. 2009: Variations in sea surface roughness induced by the 2004 Sumatra-Andaman tsunami, *Nat. Hazards Earth Syst. Sci.,* **9.**

Felix W. Landerer - Research Scientist

Jet Propulsion Laboratory, 4800 Oak Grove Dr., MS. 238-600, Pasadena, CA 91109
Phone: 818-354-2242, Fax: 818-393-4965, E-mail: felix.landerer@jpl.nasa.gov

Dr. Landerer has 10 years of experience in Earth System research, in particular in the analysis and simulation of surface mass changes over oceans, land, and ice-covered regions. He has extensive experience in analysing regional and global sea level changes in CMIP-type models, and contributed to several studies that address the global sea level budget and connections to geodetic indices, as well as studies that examine regional sea level processes from GRACE, altimetry, re-analysis, and models. He is a contributing author to the IPCC 5th assessment report.

Professional Experience

Since 7/2010: Research Scientist; Jet Propulsion Laboratory/Caltech
2008–2010: NASA Postdoctoral Fellow at Jet Propulsion Laboratory / Caltech
2007–2008: Max Planck Institute for Meteorology (Hamburg): Research Scientist

Current Projects

GRACE Science Team; OST Science Team
IPCC-AR5 Contributing Author (Chapter-09)
Scientist for the GRACE and GRACE Follow On projects;
MEaSUREs-2012 (PI); PI & Co-I (NASA Physical Oceanography);
NASA obs4MIPs Working Group

Education

Ph.D. (2007) Physical Oceanography (University of Hamburg / Intl. Max Planck Research School on Earth System Modelling).
M.Sc.(2004) Geophysics (University of Kiel)

Recent Selected Publications

Volkov, D. L.; Landerer (2013), Non-seasonal fluctuations of the Arctic Ocean mass observed by GRACE , J. Geophys. Res., under review.

Landerer, F.; Gleckler, P. & Lee, T. (2013), Evaluation of CMIP5 dynamic sea surface height multi-model simulations against satellite observations Climate Dynamics, Springer Berlin Heidelberg, 1-13.

Volkov, D. L.; Landerer, F. W. & Kirillov, S. A. (2013), The genesis of sea level variability in the Barents Sea, Continental Shelf Research, 66, 92 – 104.

Fasullo, J. T., C. Boening, F. W. Landerer, and R. S. Nerem (2013), Australia's unique influence on global sea level in 2010–2011, Geophys. Res. Lett., 40, 4368–4373, doi:10.1002/grl.50834.

Ivins, E. R., T. S. James, J. Wahr, E. J. O. Schrama, F. W. Landerer, and K. M. Simon (2013), Antarctic contribution to sea level rise observed by GRACE with improved GIA correction, J. Geophys. Res. Solid Earth, 118, doi:10.1002/jgrb.50208.

Lee T., D.E. Waliser, J. Li, F. W. Landerer, and M. M. Gierach (2013): Evaluation of CMIP3 and CMIP5 Wind Stress Climatology Using Satellite Measurements and Atmospheric Reanalysis Products, J. Climate 26, 5810-5826, doi:10.1175/JCLI-D-12-00591.1.

Landerer, F. W., and D. L. Volkov (2013), The anatomy of recent large sea level fluctuations in the Mediterranean Sea, Geophys. Res. Lett., 40, doi:10.1002/grl.50140.

Perrette, M., Landerer, F., Riva, R., Frieler, K., and Meinshausen, M. (2013): A scaling approach to project regional sea level rise and its uncertainties, Earth Syst. Dynam., 4, 11-29, doi:10.5194/esd-4-11-2013.

Boening, C., M. Lebsock, F. Landerer, and G. Stephens (2012), Snowfall-driven mass change on the East Antarctic ice sheet, Geophys. Res. Lett., 39, L21501, doi:10.1029/2012GL053316.

Boening, C., J.K. Willis, F.W. Landerer, R.S. Nerem, J. Fasullo (2012): The 2011 La Ni?a: So Strong, the Oceans Fell, Geophys. Res. Lett., doi:10.1029/2012GL053055

Roemmich, D., Willis, J., Gilson, J., Stammer, D., Koehl, A., Yemenis, T., Chambers, D. P., Landerer, F. W., Marotzke, J., Gregory, J. Suzuki, T., Church, J., White, N., Domingues, C., Cazenave, A. and LeTraon, P.-Y., 2010: Global Ocean warming and sea level rise. In: Understanding Sea-Level Rise and Variability, Blackwell Publishing.

Landerer, F. W., Jungclaus, J. H., Marotzke, J., 2009: Long-term polar motion excited by ocean thermal expansion, Geophys. Res. Lett., 36, L17603, doi:10.1029/2009GL039692.

Landerer, F. W., Jungclaus, J. H., Marotzke, J., 2008: ENSO Signals in Sea Level, Surface Mass Redistribution, and Degree-Two Geoid Coefficients, J. Geophys. Res., 113, C08014, doi:10.1029/2008JC004767.

Landerer, F. W., Jungclaus, J. H., Marotzke, J., 2007: Ocean Bottom Pressure Changes Lead to a Decreasing Length-of-Day in a Warming Climate, Geophys. Res. Lett., 34, L06307, doi:10.1029/2006GL029106.

Landerer, F. W., Jungclaus, J. H., Marotzke, J., 2007: Regional dynamic and steric sea level change in response to the IPCC-A1B scenario, J. Phys. Oceanogr., 37, 296--312.

Curriculum Vitae

Name	Stefan Ligtenberg
Birth	20 September 1986
Telephone nr.	+31650926107
E-mail	s.r.m.ligtenberg@uu.nl
Website	www.staff.science.uu.nl/~ligte104
Nationality	Dutch

Education

1998 – 2004	Secondary school degree. Het Nieuwe Eemland College, Amersfoort, The Netherlands.
2004 – 2007	Bachelor of Science degree “Soil, Water and Atmosphere”. Wageningen University, Wageningen, The Netherlands.
2007 – 2009	Master of Science degree “Meteorology and Air Quality”. Wageningen University, Wageningen, The Netherlands.
Jan 2008 – Apr 2008	Advanced courses in Meteorology, Oceanography and Climate at University of Reading (UK).
Feb 2010 – present	PhD research, entitled “The present and future state of the Antarctic firn layer”. Institute for Marine and Atmospheric Research (IMAU), Utrecht University, The Netherlands. Approved by committee, dissertation date: 23 April 2014
Feb 2014 – present	Post-doctoral researcher at IMAU, Utrecht University

Further Relevant Activities

2010	Summer school “Ice sheets and glaciers in the climate system”, Karthaus, Italy.
2010	Training course on the parameterization of physical processes in climate models, KNMI, De Bilt.
2010 – 2012	Teaching assistant, BSc course “Hydrodynamics and Turbulence”, IMAU, Utrecht University.
2011 – present	Thesis supervising of BSc students at IMAU.
2012 – present	Teaching assistant, MSc course “Introduction to Remote Sensing”, IMAU, Utrecht University.
2013	Convener of a Cryosphere-session at AGU Fall Meeting 2013

Selected Publications

Gardner, A. S., G. Moholdt, J. G. Cogley, B. Wouters, A. A. Arendt, J. Wahr, E. Berthier, R. Hock, W. T. Pfeffer, G. Kaser, S. R. M. Ligtenberg, T. Bolch, M. J. Sharp, J. O. Hagen, M. R. van den Broeke, and F. Paul. 2013: A reconciled estimate of glacier contributions to sea level rise: 2003 to 2009. Science, 340, 852-857, doi: 10.1126/science.1234532.

Ligtenberg, S. R. M., W. J. van de Berg, M. R. van den Broeke, J. G. L. Rae and E. van Meijgaard. 2013: Future surface mass balance of the Antarctic ice sheet and its influence on sea level change, simulated by a regional atmospheric climate model. Climate Dynamics, 41, 867-884, doi: 10.1007/s00382-013-1749-1.

Sheperd, A., E. R. Ivins, A. Geruo, IMBIE project group. 2012: A Reconciled Estimate of Ice Sheet Mass Balance. Science, 338, 6111, 1183-1189, doi: 10.1126/science.1228102.

Pritchard, H. D., S. R. M. Ligtenberg, H. A. Fricker D. G. Vaughan, M. R. van den Broeke and L. Padman. 2012: Antarctic ice sheet loss driven by basal melting of ice shelves. Nature, 484, 502-505, doi: 10.1038/nature10968.

Ligtenberg, S. R. M., M. M. Helsen, M. R. van den Broeke. 2011: An improved semi-empirical model for the densification of Antarctic firn. The Cryosphere, 5, 809-819, doi: 10.5194/tc-5-809-2011.

Curriculum Vitae of Dr. Ben Marzeion

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http:\\www.marzeion.info

Research Experience & Education

since 2011	Assistant Professor (tenure-track) at the Institute of Meteorology and Geophysics, University of Innsbruck, Austria.
2008 - 2010	Assistant Professor at the Institute of Geography, University of Innsbruck, Austria.
2008	Postdoctoral Research Fellow at Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA.
2006 - 2008	Postdoctoral Researcher at Nansen Environmental and Remote Sensing Center and Bjerknes Centre for Climate Research, Bergen, Norway.
2003 - 2006	PhD Student at the Geophysical Institute, University of Bergen, Norway.
2002 - 2003	Master thesis at Institut for Marine Science, Kiel, Germany, and University of Hawai'i, USA.

Selected Publications

Marzeion, B.; Levermann, A., 2014: Loss of cultural world heritage and currently inhabited places to sea-level rise, *Environmental Research Letters* **9**, 034001, DOI: 10.1088/1748-9326/9/3/034001

Marzeion, B.; Jarosch, A.H.; Gregory, J.M., 2014: Feedbacks and mechanisms affecting the global sensitivity of glaciers to climate change, *The Cryosphere* 8, 59–71, DOI: 10.5194/tc-8-59-2014

Levermann, A.; Clark, P.U.; **Marzeion, B.**; Milne, G.A.; Pollard, D.; Radic, V.; Robinson, A., 2013, The multimillennial sea-level commitment of global warming, *Proceedings of the National Academy of Sciences*, 110, 13745 - 13750, DOI:10.1073/pnas.1219414110

Gregory, J.M.; White, N.J.; Church, J.A.; Bierkens, M.F.P.; Box, J.E.; van den Broeke, M.R.; Cogley, J.G.; Fettweis, X.; Hanna, E.; Huybrechts, P.; Konikow, L.F.; Leclercq, P.W.; **Marzeion, B**.; Oerlemans, J.; Tamisiea, M.E.; Wada, Y.; Wake, L.M.; van de Wal, R.S.W., 2013, Twentieth-century global-mean sea-level rise: is the whole greater than the sum of the parts?, *J. Climate*, 26, 4476-4499, DOI:10.1175/JCLI-D-12-00319.1

Church, J.A.; Monselesan, D.; Gregory, J.M.; **Marzeion, B**., 2013, Evaluating the ability of process based models to project sea-level change, *Environ. Res. Lett*., 8, 014051, DOI:10.1088/1748-9326/8/1/014051

Marzeion, B.; Jarosch, A.H.; Hofer, M., 2012, Past and future sea-level change from the surface mass balance of glaciers, *The Cryosphere*, 6, 1295 - 1322, DOI:10.5194/tc-6-1295-2012

Curriculum Vitae of Dr. Angélique Melet

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Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
18 av. Edouard Belin, 31401 Toulouse, France
Tel: +33561332902
Email: angelique.melet@legos.obs-mip.fr

Research Experience & Education

since 2014 Postdoctoral Research Associate at Centre National d'Etudes Spatiales (CNES), Laboratoire d'Etudes en Geophysique et océanographie Spatiale (LEGOS), Toulouse, France. In collaboration with CNRM, France.

2011 - 2013 Postdoctoral Research Associate at Princeton University, Program in Atmospheric and Oceanic Science, and at the NOAA/Geophysical Fluid Dynamics Laboratory (GFDL), Princeton, NJ, USA.

2010 - 2011 Postdoctoral Researcher at Laboratoire des Ecoulements Géophysiques et Industriels (LEGI/MEOM), Grenoble, France.

2006 - 2009 PhD at the Laboratoire des Ecoulements Géophysiques et Industriels (LEGI/MEOM), University of Grenoble, France.

04-09/2006 Master thesis at IFREMER, Laboratoire de Physique des Océans (LPO), Plouzané, France.

Selected Publications

- **A. Melet**, L. Gourdeau, J. Verron, 2010. « Variability of the Solomon Sea from altimetry sea level data ». *Ocean Dynamics*, vol 60 (4), pp 883-900, doi: 10.1007/s10236-010-0302-6.
- L. Gourdeau, J. Verron, **A. Melet**, W. S. Kessler, F. Marin, B. Djath, 2014. « Exploring the mesoscale activity in the Solomon Sea: a complementary approach with a numerical model and altimetric data ». *Journal of Geophysical Research - Oceans*, in press.
- **A. Melet**, R. Hallberg, S. Legg, M. Nikurashin, 2014. « Sensitivity of the ocean state to Lee wave driven mixing ». *Journal of Physical Oceanography*, vol 44, pp. 900-921, doi: 10.1175/JPO-D-13-072.1
- **A. Melet**, M. Nikurashin, C. Muller, S. Falahat, J. Nycander, P. Timko, B. Arbic, J. Goff, 2013. « Abyssal hill roughness impact on internal tide generation: Linear theory ». *Journal of Geophysical Research - Oceans*, vol 118 (11), pp. 6303-6318, doi: 10.1002/2013JC009212.
- **A. Melet**, R. Hallberg, S. Legg, K. Polzin, 2013. « Sensitivity of the Ocean state to the vertical distribution of internal-tide driven mixing ». *Journal of Physical Oceanography*, vol 43, pp. 602-615, doi: 10.1175/JPO-D-12-055.1.

Dr. Matthew D. Palmer
Lead Scientist – Sea Level Research

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Areas of expertise:

- Global and regional sea level
- Ocean and climate modelling
- Subsurface ocean observations
- Meridional overturning circulation
- Detection and attribution
- Decadal prediction and ocean syntheses

Career Outline:

2013-present	Lead Scientist – Sea Level Research, Met Office Hadley Centre, UK
2010-2013	Lead Scientist – Ocean Climate processes, Met Office Hadley Centre, UK
2008-2010	Senior Scientist – Climate Monitoring and Attribution, Met Office Hadley Centre, UK
2005-2008	Scientist – Climate Monitoring and Attribution, Met Office Hadley Centre, UK
2001-2005	PhD Physical Oceanography – National Oceanography Centre, Southampton, UK
2001-2001	Summer Internship – Met Office Hadley Centre, UK
1997-2000	Bsc (Hons) Oceanography with Physics – University of Southampton, UK

Professional Activities:

- Leadership of sea level research activities at Met Office, including collaborative research and commercial projects with the National Oceanography Centre, UK, University of Reading, and CSIRO.
- Principal Investigator for (WP3 – climate models and process understanding) the NERC project "Diagnosing Earth's Energy Pathways for Climate" (DEEP-C).
- Leadership of Ocean Obs '09 Community White Paper on "Future Observations for Monitoring Ocean Heat Content" (21 international co-authors).
- Past coordinator (previous role) of model assessment for Met Office coupled model development.
- Member of World Climate Research Programme Climate Variability and Predictability Global Synthesis and Observations Panel (WCRP/CLIVAR GSOP).
- Member of Ocean Observations Panel for Climate (UNESCO, IOC) task team for a Deep Observing Array Strategy.
- Expert reviewer for IPCC 5th Assessment Report: Working Group I, Chapters: 3 - Observations: Oceans; 10 - Detection and Attribution; 13 - Sea Level Change.
- Reviewer for numerous scientific journals, thesis examiner (University of Tasmania).
- Numerous reports/briefings prepared for UK Department for Energy and Climate Change (DECC) and UK Department for the Environment, Food and Rural Affairs (DEFRA).

Selected Publications:

Palmer, M.D. and D.J. McNeall "Internal variability of Earth's energy budget simulated by CMIP5 climate models", Env. Res. Lett., in press
Abraham, J.P. & co-authors (incl. **M.D. Palmer**) "A review of global ocean temperature observations: Implications for ocean heat content estimates and climate change", Rev. Geophys., doi:10.1002/rog.20022
Palmer, M.D. (2012) "Climate and Earth's Energy Flows", Surv. Geophys., doi: 10.1007/s10712-011-9165-8
Palmer, M.D., D.J. McNeall and N.J. Dunstone (2011) "Importance of the deep ocean for estimating decadal changes in Earth's radiation balance", Geophys. Res. Lett., doi:10.1029/2011GL047835
Palmer, M.D. and P. Brohan (2011) "Estimating sampling uncertainty in fixed-depth and fixed-isotherm estimates o
Lyman, J.M., S.A. Good, V.V. Gouretski, M. Ishii, G.C. Johnson, **M.D. Palmer**, D.M. Smith and J.K. Willis (2010) "Robust Warming of the Global Upper Ocean", Nature,doi:10.1038/nature09043
Palmer, M. & Co-Authors (2010) "Future Observations for Monitoring Global Ocean Heat Content" in Proceedings of Ocean Obs '09 doi:10.5270/OceanObs09.cwp.68
Palmer, M. D., S. A. Good, K. Haines, N. A. Rayner and P. A. Stott (2009) "A new perspective on warming of the global oceans", Geophys. Res. Lett. doi:10.1029/2009GL039491
Palmer M.D. and K. Haines (2009) "Estimating oceanic heat content change using isotherms", J. Clim., doi:10.1175/2009JCLI2823.1

Kristin Richter, PhD

Personal Data

Place and Date of Birth:	Gardelegen, Germany — 26 May 1981
Nationality:	German
Affiliation:	Institute of Meteorology and Geophysics University of Innsbruck Innrain 52f, 6020 Innsbruck, Austria
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Work Experience and Education

2013 – current: PostDoc, Institute of Meteorology and Geophysics, University of Innsbruck, Austria: The role of internal variability in sea surface height projections.

2012–2013: PostDoc, Geophysical Institute and Centre for Climate Dynamics, University of Bergen, Norway: Contributions to regional sea surface height changes.

2010–2011: Research Assistant Uni Research, Bergen, *Bjerknes Centre for Climate Research*: Analysis of changes in sea level along the Norwegian coast during the last 50-100 years. Observed changes, steric changes, land rise.

Aug 2011: PhD Physical Oceanography, University of Bergen, Norway
Thesis: "Influence of large-scale atmospheric forcing on North Atlantic - Nordic Seas Ocean Circulation"

Jul 2005: M.Sc Physical Oceanography, University of Bergen, Norway
Thesis: "Mixing and internal waves at high latitudes"

1999–2003: Undergraduate/graduate studies of Physics, University of Potsdam, Germany

Publications

Richter, K., R.E.M. Riva and H. Drange (2013), Impact of self-attraction and loading effects induced by shelf mass loading on projected regional sea level rise, Geophys. Res. Lett. 40, doi:10.1002/grl.50265

Richter, K., J.E.Ø. Nilsen, and H. Drange (2012), Contributions to sea level variability along the Norwegian coast for 1960–2010, J. Geophys. Res. 117, C05038, doi:10.1029/2011JC007826

Richter, K., O.H. Segtnan, and T. Furevik (2012), Variability of the Atlantic inflow to the Nordic seas and its causes inferred from observations of sea surface height, J. Geophys. Res. 117, C04004, doi:10.1029/2011JC007719

Richter, K. and S. Maus (2011), Interannual variability in the hydrography of the Norwegian Atlantic Current: frontal versus advective response to atmospheric forcing, J. Geophys. Res., 116, C12031, doi:10.1029/2011JC007311

CV Dr Jeff Ridley - Met Office Hadley Centre

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History

1987 PhD (Physics) – University of Kent at Canterbury (Satellite instrumentation)
1987-1997 PostDoc – University College London (Satellite remote sensing)
1997-2001 Met Office – NWP. Specialising in the assimilation of satellite observations of ocean winds and total column water vapour
2001-present Met Office – Climate Research. Specialising in cryospheric processes and sea level rise.

Expertise

- Ice sheet projections in global climate models
- Model projections of sea ice, ice sheet and glaciers
- Global climate models – cryospheric processes

Programmes

- ESA GlobIce – User representative
- EU Framework-7: Participant in Ice2sea – to improve estimates of future sea level rise from ice sheets
- EU Framework-7: Participant in HighNoon – to estimate the influence of climate change on future water availability from Himalayan glaciers.
- EU Framework-7: Participant in Combine – interactive ice sheets in GCMs
- EU Framework-6: Reviewer of Damocles – Arctic change

Relevant publications

Fitzgerald, P. W., J. L. Bamber, **J. K. Ridley**, and J. C. Rougier (2012), Exploration of parametric uncertainty in a surface mass balance model applied to the Greenland ice sheet, J. Geophys. Res., 117, F01021

Gregory, J. M., Browne, O. J. H., Payne, A. J., **Ridley, J. K**., and Rutt, I. C. (2012), Modelling large-scale ice-sheet–climate interactions following glacial inception, Clim. Past, 8, 1565-1580, doi:10.5194/cp-8-1565-2012.

Rae, J. G. L., Aðalgeirsdóttir, G., Edwards, T. L., Fettweis, X., Gregory, J. M., Hewitt, H. T., Lowe, J. A., Lucas-Picher, P., Mottram, R. H., Payne, A. J., **Ridley, J. K**., Shannon, S. R., van de Berg, W. J., van de Wal, R. S. W., and van den Broeke, M. R.: Greenland ice sheet surface mass balance: evaluating simulations and making projections with regional climate models, The Cryosphere, 6, 1275-1294, doi:10.5194/tc-6-1275-2012, 2012.

Ridley JK, Gregory JM, Huybrechts P, Lowe JA (2010) Thresholds for irreversible decline of the Greenland ice sheet, Clim. Dyn. DOI 10.1007/s00382-009-0646-0

Ridley J, Lowe J, Simonin D (2008) The demise of Arctic sea ice during stabilisation at high greenhouse gas concentrations, Clim. Dyn., 30, 333-341.

Bougamont M, Bamber JL, **Ridley JK**, Gladstone RM, Greuell W, Hanna E, Payne AJ, Rutt I (2007) Impact of model physics on estimating the surface mass balance of the Greenland ice sheet, Geophys. Res. Lett., 34, L17501.

Ridley JK, Huybrechts P, Gregory JM and Lowe JA (2005) Elimination of the Greenland ice sheet in a high CO_2 climate, J. Clim., 18, 3409–3427

CURRICULUM VITAE

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Employment History

May’13-present
Postdoctoral research fellow CSIRO Marine and Atmospheric research, Hobart, Australia.
Dec.’12-April’13
Postdoctoral researcher, Institute for Marine and Atmospheric research Utrecht (IMAU), Utrecht University, The Netherlands.
April ’08-July’08
Internship at Meteo Consult, Wageningen, The Netherlands.
Sept.’07-March’08
Internship at Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands.

Education

Sept.’08-Dec.’12
PhD, Institute for Marine and Atmospheric research Utrecht (IMAU), Utrecht University, The Netherlands.
March’07-July ´07
Master courses, Eidgenössische Technische Hochschule (ETH) Zürich, Switzerland.
Sept.’06-July ’08
Master ‘Meteorology and Air Quality’, Wageningen University, Netherlands.
Specialisation ‘Meteorology and Climate’.
Sept.’03-July ’06
Bachelor ‘Soil, Water and Atmosphere’, Wageningen University, Netherlands.
Specialisation ‘Meteorology and Air Quality’.

Relevant publications

1. Slangen, A. B. A., and M. Carson, C.A. Katsman, R.S.W. van de Wal, A. Koehl, L.L.A. Vermeersen and D. Stammer (2014) Projecting twenty-first century regional sea-level changes. *Accepted for publication in Climatic Change,* doi: 10.1007/s10584-014-1080-9.
2. IPCC WG1 Fifth Assessment report (2014) Contributing author, Chapter 13: Sea Level Change.
3. Han, G. and Z. Ma, H. Bao, A. Slangen (2014) Regional Differences of Relative Sea Level Changes in the Northwest Atlantic: Historical Trends and Future Projections, J. Geophys. Res. Oceans, 119, 156-164, doi: 10.1002/2013JC009454.
4. A.B.A. Slangen (2012) Modelling regional sea-level changes in recent past and future, Ph.D. thesis, Utrecht University. ISBN 978-90-393-5868-9.
5. Slangen, A.B.A., C.A. Katsman, R.S.W. van de Wal, L.L.A. Vermeersen and R.E.M. Riva (2012) Towards regional projections of twenty-first century sea-level change based on IPCC SRES scenarios, Climate Dynamics, 38(5-6), 1191-1209, doi: 10.1007/s00382-011-1057-6.
6. Slangen, A.B.A. and R.S.W. van de Wal (2011) An assessment of uncertainties in using volume-area modelling for computing the twenty-first century glacier contribution to sea-level change, The Cryosphere, 5, 673-686, doi: 10.5194/tc-5-673-2011.