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Report of the 3rd WCRP Grand Challenge on Regional Sea Level Change and Coastal Impacts

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Executive Summary

The WCRP Grand Challenge (GC) on Regional Sea Level Change and Coastal Impacts held its 3rd meeting on 14-15 October 2018 in Boulder, Colorado, USA.

The GC Sea Level is an integrated interdisciplinary program on sea level research reaching from the global to the regional and coastal scales. In particular, the program aims for close interaction with relevant coastal stakeholders to make sure that results of the proposed scientific research are most useful for coastal zone management, and impacts and adaptation efforts.

This particular meeting focused on progress and future plans of the GC's individual Work Programmes, with a particular emphasis on the co-design of activities with coastal managers and policy makers. The sea level aspects of the recent 1.5 C as well as the upcoming Oceans and Cryosphere IPCC reports were discussed. New paleoclimate insights were highlighted as well as important activities with partner organizations. From the modelling perspective progress with the WCRP Coupled Model Intercomparison Project were analysed, in particular the Ice Sheet Model Intercomparison Project.

The meeting participants decided on the need for a number of focused workshops, for example on "sea level science for services" to explore what science can provide in relationship to coastal zone management and on the importance of land subsidence on a global scale. It was felt that a Sea Level Conference should be held in 2022/2023, with robust engagement of decision makers, noting the interest from organizations such as the World Bank and the World Economic Forum.

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Day 1: Sunday, 14 October 2018

1. Introduction and Aims

D Stammer opened the meeting on behalf of all three co-chairs. After introductions and logistical information he outlined the main goals of the meeting:

- Discuss progress of individual Work Packages
- Reports on ISMIP6 and FAFMIP
- Plan workshops and new activities
- Coordinate and plan sea level work regarding CMIP6
- Identify and coordinate other required sea level work in the wake of the NY conference (co-design)
- Initiate requirement documents
- Discuss/ finish review papers and any other writing assignments
- Information on national programs and proposal opportunities

The importance of integrating all sea level activities within WCRP was discussed, with the GC Sea Level acting as a focal point.

M Sparrow gave a brief update on progress with regards to the WCRP Strategic and Implementation Plans, noting that the former will be approved by the WCRP JSC at the end of October.

2. The IPCC Assessments

Roderik van de Wal updated the participants on the outcomes of the IPCC Special Report on 1.5 C as well as progress with the Special Report on the Oceans and Cryosphere. For the former he highlighted the relevant text:

- B2.2. Sea level rise will continue beyond 2100 even if global warming is limited to 1.5°C in the 21st century (high confidence). Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in multi-meter rise in sea level over hundreds to thousands of years. These instabilities could be triggered around 1.5°C to 2°C of global warming (medium confidence).
- B2.3. Increasing warming amplifies the exposure of small islands, low-lying coastal areas and deltas to the risks associated with sea level rise for many human and ecological systems, including increased saltwater intrusion, flooding and damage to infrastructure (high confidence). Risks associated with sea level rise are higher at 2°C compared to 1.5°C. The slower rate of sea level rise at global warming of 1.5°C reduces these risks enabling greater opportunities for adaptation including managing and restoring natural coastal ecosystems, and infrastructure reinforcement (medium confidence).

2.1. WP 1 An integrated approach to historic sea level estimates (paleo time scale)

N Gomez gave an update on WP 1. As well as science highlights and upcoming meetings she emphasized:

Important future Research Directions for WP 1 to push:

- Paleoclimate insight into future sea level projections, linking past with future
- Interdisciplinary (variety of disciplines involved in paleo sea level meetings)
- Role of the solid Earth feedbacks into the climate system generally, and the implications of realistic rheological variations (e.g. 3-D viscosity variations) for model predictions

Partnerships with SCAR-SERCE: Solid Earth Response and influence on Cryospheric Evolution and SCAR's new planned activity on Antarctic Sea Ice Dynamics and Sea Level (ASIDSL) were emphasized. It was noted that Tim Naish is both the co-chair of ASIDSL and the WCRP GC on Melting Ice.

2.2. WP 2 Quantifying the contribution of land ice to near-future sea level rise

S Nowicki outlined progress and plans for WP2. She focused on the Ice Sheet Model Intercomparison Project for CMIP6, ISMIP6, including other relevant MIPs such as initMIP and ABUMIP. The following issues were highlighted:

Delay in AGCM/AOGCM DECK simulations will mean that time is extremely tight.

- impacts how soon the evaluation of polar climate can happen, and therefore the start of the standalone ISM runs
- also impact the coupled ISM-AOGCM runs, since modelling centers will first focus on the AOGCM runs

How to obtain forcing for standalone ice sheet model from the CMIP6 climate models?

2.3. WP 3 Contemporary regional sea level variability and change

B Meyssignac reported on the outcomes of the recent ISSI workshop "Understanding the Relationship between Coastal Sea Level and Large-Scale Ocean Circulation" 5–9 March 2018. There were a number of outcomes from the workshop, including a Special issue of Survey of Geophysics and hardcover book as part of the Space Science Series of ISSI by Springer. The various input from the GC SL group to OceanObs19 were also noted.

D Stammer continued the discussion, highlighting a number of issues:

- Cost-benefit analysis can be used up to ~2040, before scenarios diverge, with low risk-aversion, if a PDF is available.
- The PDF stops where we can no longer quantify probability. Beyond that we can consider confidence that $P > 0$ in e.g. 0.5 m intervals.
- Users with high risk-averseness and long planning timescales particularly need high-end scenarios, provided they could change their practices: nuclear industry, critical infrastructure (ports, bridges), flood managers in developed countries and coastal megacities.
- Mean sea level change is the main factor, but combination of river and coastal flooding increases the risk.
- Can a "very likely" range for mean sea level rise be quantified for AR6?

- When will this be able to give scenario-dependence for the high-end?
- Is it useful to translate the SL uncertainty to a time-uncertainty?
- There is a need for continued monitoring e.g. of ice-sheet surface melting.
- How can we bridge the gap between WG1 science and the needs of coastal planners?
Could some international agency (WGCP, GOOS, GCOS) give guidance for planning?

Action: There is a need for a workshop “sea level science for services “ to explore what science (e.g. WP 3) can provide in relationship to coastal zone management (WP 5), in conjunction with other efforts (Chairs; planning ASAP)

2.4. WP 4 Predictability of regional sea level

J Gregory presented on behalf of WP 4. He highlighted that good progress had been made with regards to most objectives except for “Limits of predictability of sea level as function of space and time scale and the role of changing climate modes for sea level predictions.”

FAFMIP, ISMIP6 and GlacierMIP are underway, with many conclusions already. Projections consistent with AR5 can be estimated to 2300 and for SSPs using the two-box model, the step model and other calibrated simple models.

GMSLR by 2100 is less for 2 K than 1.5 K by ~0.1 m (SR15) or 0.05 m (~AR5). GMSLR depends on the temperature-time integral. Cumulative CO₂ determines the rate at 2100, but cutting emissions sooner reduces the level at 2100.

There is GCM evidence for potential irreversibility of Greenland ice sheet mass loss. There is a very large commitment to Antarctic ice sheet mass loss on the long term.

Several ongoing questions were raised that are topics of future investigation: Is it reliable to make high-end projections dependent on scenario? What confidence should we have in observationally calibrated SEMs, compared with emulators of AOGCMs and glaciological models? How best to make projections consistent across contributions and scenarios? What would be useful for IPCC regarding methods and results for projections?

2.5. WP 5 Sea level science for coastal zone management

R Nicholls presented progress with WP 5. In terms of future activities there is a need to support activities such as CoastMIP [Hinkel] and end-user adaptation needs. WP 5 also brought up the need for a science to services workshop (see earlier Action).

The following activities were highlighted:

1. Complete high end guidance paper [Detlef leading]
2. A review of coastal subsidence to inform changes in relative sea-level rise and coastal management, including a workshop in 2019 [ongoing – Pietro leading]
3. A WP3/WP5/others workshop on climate services before 5 (below) [Nicholls, Goneri and others to champion]
4. Better guidance for climate services in coastal areas, including a workshop in 2020 (linked to Berlin INSeaPTION workshop) [Goneri, Jochen to lead – input from Kathy]
5. Illustrations of the decision support methodologies outlined by Hinkel et al (2018) – for 2023 Conference [Nicholls, Hinkel to champion]
6. Further work on sea-level rise and adaptation decision-making – for 2023 Conference [Nicholls to champion]

7. Detection of major accelerations in sea-level rise – to support adaptation pathways approaches [where does this happen?]
8. Maintain and enhance the co-production approach and strong links to the range of end-users, including the conference [Nicholls, Behar, White to champion; WP5 team and other WPs, to participate; ongoing]

This needs an ongoing process with regular discussions about the science, user needs and actionable information. This includes consideration of other dissemination approaches – e.g., policy briefs. Links to other processes such as NSF proposals and even opportunities to seek funding – such as week-long meeting partial funded by Aspen Global Change Institute with 100 participants.

Needs a robust process for co-design/co-production among the SLR communities (decision makers, scientists) - could be more urgently emphasized and even central in the work plan of the entire Grand Challenge. This is latent in general and perhaps in the WCRP GC process as well. To connect with decision needs we need decision early adopters interacting early and often with scientists – the co-production dynamic correctly implemented.

Action: Proposal for a workshop look at the importance of land subsidence on a global scale (global review and assessment methods). Should include input from the World Bank, World Economic Forum and other relevant entities. (Nicholls and others: ASAP)

R Nicholls and M Sparrow highlighted that the next World Economic Forum's Global Risks Report will have a chapter on “City risks associated with rising sea levels”. M Sparrow attended the workshop and will continue to liaise between the WEF and the GC.

Action: M Sparrow to continue to liaise between the GC SL and the WEF to explore future synergies (M Sparrow, GC Chairs; Ongoing)

Unni – Lack of long-term measurements in Indian Ocean

Discussion on importance of USEFUL sea level information for services. Mentioned the new WCRP SP and wording therein. >

Day 2: Monday, 15 October 2018

3. Other Reports relevant to the work of the GC on Sea Level

3.1. US CLIVAR

S Elipot presented on behalf of US CLIVAR. He noted the various synergies with the GC SL, including the US CLIVAR Sea Level Research Survey, which is in progress.

This survey is collecting information from each agency on agency program priorities, participating programs/operating units, and funded projects:

- includes proposal-driven and base funded research projects
- by Inter Agency Group (IAG) programs and beyond as appropriate
- does not include operational activities

He noted that the US CLIVAR Phenomena, Observations, and Synthesis Panel includes Sea Level within its Priorities. A US CLIVAR funded workshop “Sea Level Hotspots from Florida to Maine: Drivers, Impacts, and Adaptation” will take place on April 23-25, 2019, Norfolk, VA

Action: GC to look at use of US CLIVAR Sea Level Survey (Who ?; When available)

3.2. NASA Sea Level Team

B Hamlington highlighted the work of the NASA Sea Level Team. Their main interests are:

- To improve understanding of contemporary and future regional relative sea level rise.
- To advance scientific knowledge of sea level rise on a range of topics à each individual project has specific science goals.
- Having a particular focus on the use of satellite observations.
- To increase collaboration and communication between different communities/disciplines studying sea level rise.
- As a mechanism to force scientists to think about how the "pieces" fit together.
- To Create tools that summarize recent science results that can be shared on the web portal.

Action: Invitation to WP leaders to be inclusive in terms of NASA and other relevant activities.

3.3. IOC/GLOSS

G Mitchum summarised the history of GLOSS as well as its evolving mission. GLOSS is in process in rewriting its implementation plan. GLOSS is presently defined by the Core Network and the data streams, but it should be defined by the missions it serves. IOC and WMO via JCOMM (soon to be JCOM) are charged with coordinating some of these missions. GLOSS needs to carefully define its missions to make sure that none are neglected, including its interactions with the GC SL.

GLOSS was originally a minimal climate observing system for climate. High standards, not all gauges included. Now covers e.g. altimeter stability. Some gauges e.g. for Tsunamis are not so accurate, but for a "small" additional cost could be made climate capable.

4. Updates on science papers

4.1. Sea level terminology

J Gregory presented the draft of the paper on sea level terminology. THE GC members discussed various aspects of the paper. Some further discussion needed to follow up particular terms. Jonathan will share.

Action: J Gregory to share Sea Level Terminology paper and GC members to provide feedback (J Gregory, all; ASAP)

4.2. Coastal Sea Level science paper

The GC members discussed whether there was a need for this paper. The conclusion was that it would be useful and should include a summary for policy makers.

Action: R Nicholls to lead Coastal sea level paper, probably with a view to submit to Review of Geophysics (R Nicholls; ASAP)

4.3. High-end sea level paper

D Stammer presented progress with the high-end sea level paper. This paper was motivated by the fact that Stakeholders have a strong need for information on high-end or upper bound scenarios. However, different perspectives on high-end scenarios exist. This needs to be reconciled to one that provides the best scientific data in support of governments and coastal decision-makers. When discussing a practical path to high-end estimates, the following questions were raised:

- Can we get real on what is being discussed in the figure in generic terms?
- Can we go through practical exercises to provide a path to obtain high-end estimates?
- We should reflect on their quality and improvements above estimates existing in the literature, including probabilistic approaches.
- What would be helpful for the decision-making community to provide in this paper?

In order to tackle these the GC could provide:

- Case studies (in time and by risk averseness);
- Contrasting studies; ideally global and from people using information in different ways.
- Accounting for natural variability or not in regional projections;
- H++ and adaptive management approach. (Jason)
- Include some information on communicating high end scenarios; local effects; down scaling;
- Include more social science expertise? How do we measure risk aversion.
- Can we provide the likelihood once we go into the grey boxes in the diagram? Or should this be rather only confidence statements for users to consider when making assessment?

The point was made that Stakeholders have a strong need for information. The paper should provide a less ambiguous message to the science and stakeholder communities. There was a discussion on actual concept of high-end. Needs to be translatable to plain English.

5. CMIP6 Sea Level Analysis

J Gregory led a discussion on the approach to CMIP6 Sealevel Projections, highlighting:

- The increase the confidence in estimates of the sea level contribution from anthropogenic intervention in terrestrial hydrology.
- The need to understand and reduce regional inter-model spread in predicted sea level change due to change in ocean properties (temperature, salinity, circulation).
- FAFMIP will address the uncertainties in the ocean contribution to sea level change (ocean heat uptake efficiency, ocean dynamic topography change).
- Should incorporate ice-sheets in ESMs used for projections, because of their interaction with atmosphere and ocean climate change and the solid Earth.
- ISMIP6 will address the uncertainties in the ice-sheet contribution to sea level change (surface mass balance with evolving topography, ice dynamic response to ice-shelf basal and surface mass balance with evolving ice-shelf thickness, grounding line and bathymetry).
- ISMIP6 will begin to address the effects of interactions between the ice sheets and other elements of the Earth system.

- Need to reduce the uncertainty in the thresholds of climate change beyond which the Greenland and Antarctic ice-sheets would be partially or largely eliminated, and in whether the ice-sheet mass loss would be irreversible on the long term.
- Should provide reliable uncertainties for sea level predictions and projections, including those for the contributions from ice sheets and glaciers, with particular attention to the high-end projections.
- Requirement to have discussions with WP5 and the wider community on the limitations and uncertainties of sea level projections, and how to interpret these in a policy-relevant way.
- Begin a discussion on working towards sea-level projections for IPCC AR6. How would we revise the methods given today's state of knowledge? What is the role of expert elicitation and semi-empirical approaches?

Having projections to 2150 or 2200 rather than just 2100 and 2300 would be useful for policy makers.

Action: Production of “recipe book” for dealing with ISMIP6 results. (Detlef, Roderik et al)

6. Generating New Reports:

6.1. Sea level Observing Requirements

A short discussion was held on sea level observing requirements including the upcoming OceanObs19 meeting. The importance of deep Argo and under ice measurements were highlighted, as were the needs for more coastal zone measurements.

Action: Re-look at observation gaps for sea level after submission of white papers to OceanObs19 (All, led by chairs; after submission of white papers to OceanObs)

6.2. Model improvement requirements for sea level

Action: GC to produce overall summary and then publish and send to WCRP modelling council. (Detlef to lead)

7. 2023 Sea Level Conference

A general discussion was held on the need for a sea level conference in 2022 or 2023. Should be in a region affected by sea level rise e.g. Bangkok, Jakarta, Shanghai etc. Should include a robust engagement of decision makers. Also need to look into a possible clash with the WCRP OSC, which is still in the very early stages of planning.

Action: Co-chairs to continue to discuss location and timing of final GC Sea Level Open Science Conference (co-chairs; ongoing)

Annex 1 - List of Participants

For a meeting the annexes should include a list of participants and the meeting agenda. All reports should include a list of acronyms or abbreviations.

Title	Institute	Role	Country	Part.
Detlef Stammer	CEN, Universität Hamburg	Co-Chair	Germany	yes
Robert Nicholls	U. Southampton	Co-Chair	UK	yes
Roderik van de Wal	U. Utrecht	Co-Chair	The Netherlands	yes
Pietro Teatini	U. Padova	Member	Italy	no
Kevin Horsburgh	NOC	Member	UK	Yes
Kathy McInnes	CSIRO	Member	Australia	Yes
Gonéri Le Cozannet	BRGM	Member	France	Yes
A.S. Unnikrishnan	NIO	Member	India	Yes
Jonathan Gregory	U. Reading	Member	UK	Yes
Jianjun Yin	U. Arizona	Member	USA	no
Benoit Meyssignac	LEGOS	Member	France	yes
Catia Domingues	U. Tasmania	Member	Australia	yes
Rui Ponte	AER	Member	USA	Yes
David Holland	Courant	Member	USA	no
Tony Payne	U. Bristol	Member	UK	no
Mark Tamisiea	Center for Space Research	Member	USA	yes
Natalya Gomez	McGill University	Member	Canada	no
Anny Cazenave	LEGOS	Member	France	no
Bette Otto-Bliesner	NCAR	Member	USA	yes
Jochen Hinkel	Global Climate Forum	Member	Germany	no
Guests:				
Shane Elipot	US CLIVAR			
Ben Hamlington	NASA			
Sophie Nowicki	ISMIP6			
Kate White				
Dave Behar				
Steve Nerem				
Gerry Michum	IOC			
Mike Sparrow	WCRP/JPS			
Jeff Becker	US CLIVAR			
Guy Brasseur	JSC			

The ICPO contact for the CLIVAR Research Foci "Regional Sea Level Change and Coastal Impacts" is Jing Li.

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