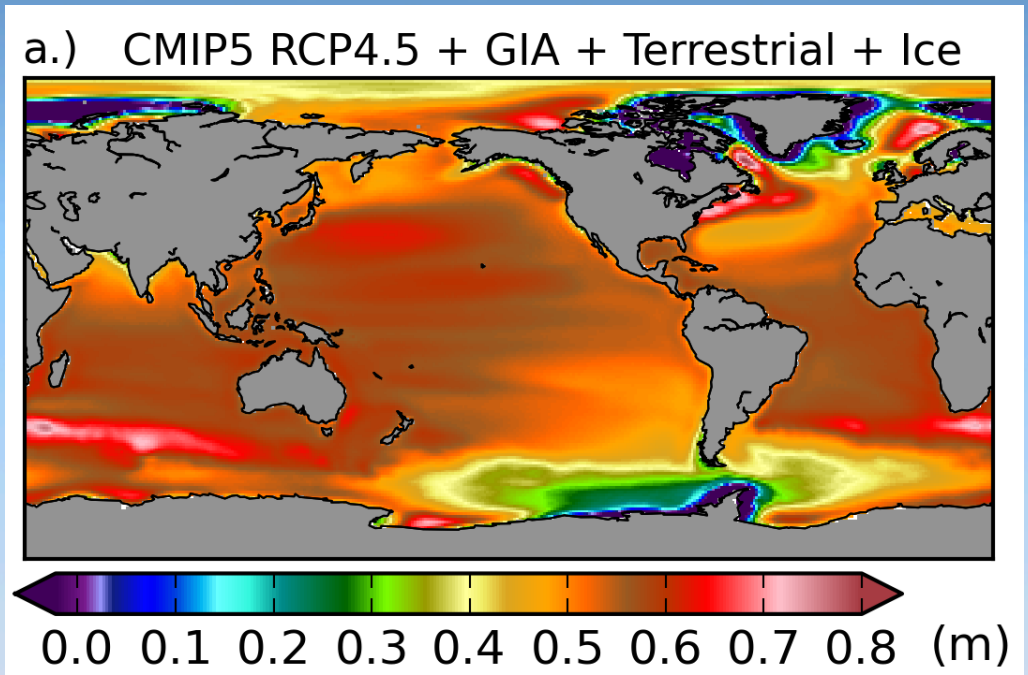
GC Regional Sea-Level Change and Coastal Impacts



Slangen et al., 2014
Carson et al., 2015

Robert Nicolls, Detlef Stammer, Roderik van de Wal.
The GC Sea Level Steering Team

WCRP
World Climate Research Programme

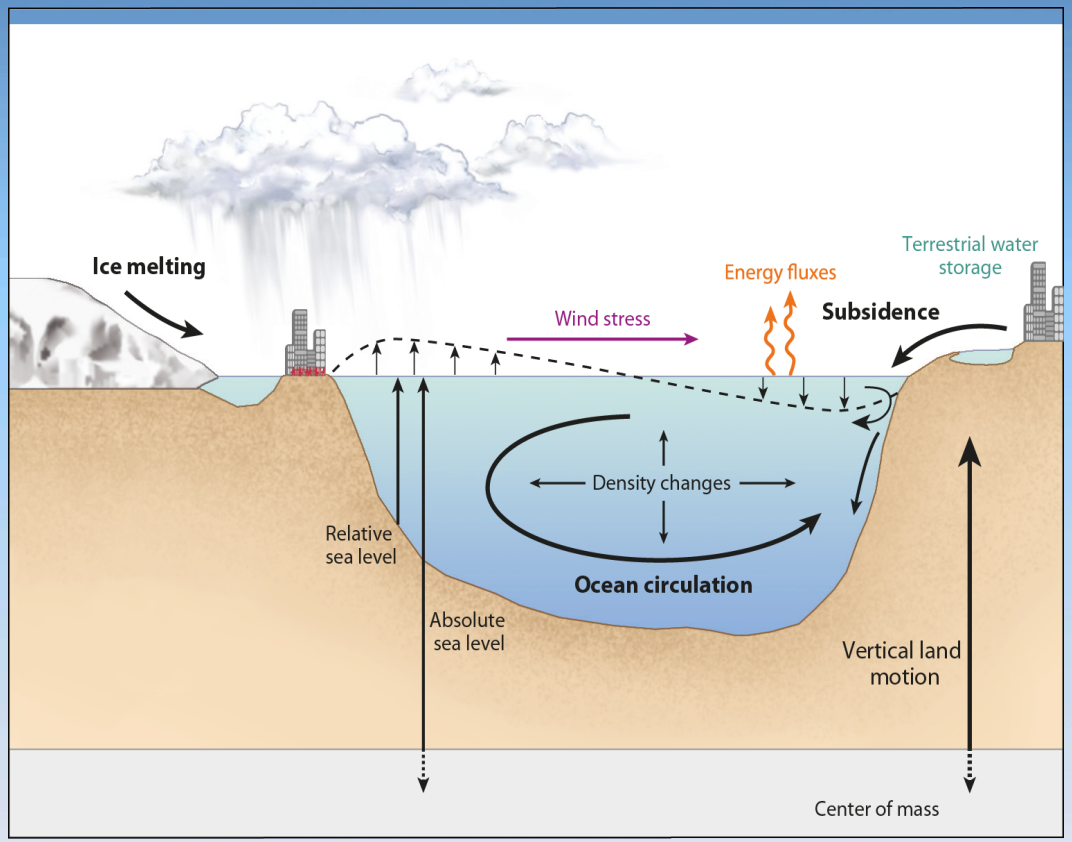
Overarching Goal

Integrated interdisciplinary program on SL research reaching from the global to the regional and local scales to:

- Establish a **quantitative understanding** of the natural and anthropogenic mechanisms of regional to local sea level variability;
- Promote advances in observing systems required for an integrated SL monitoring;
- Foster the development of SL predictions and projections that are of increasing benefit for coastal zone management.

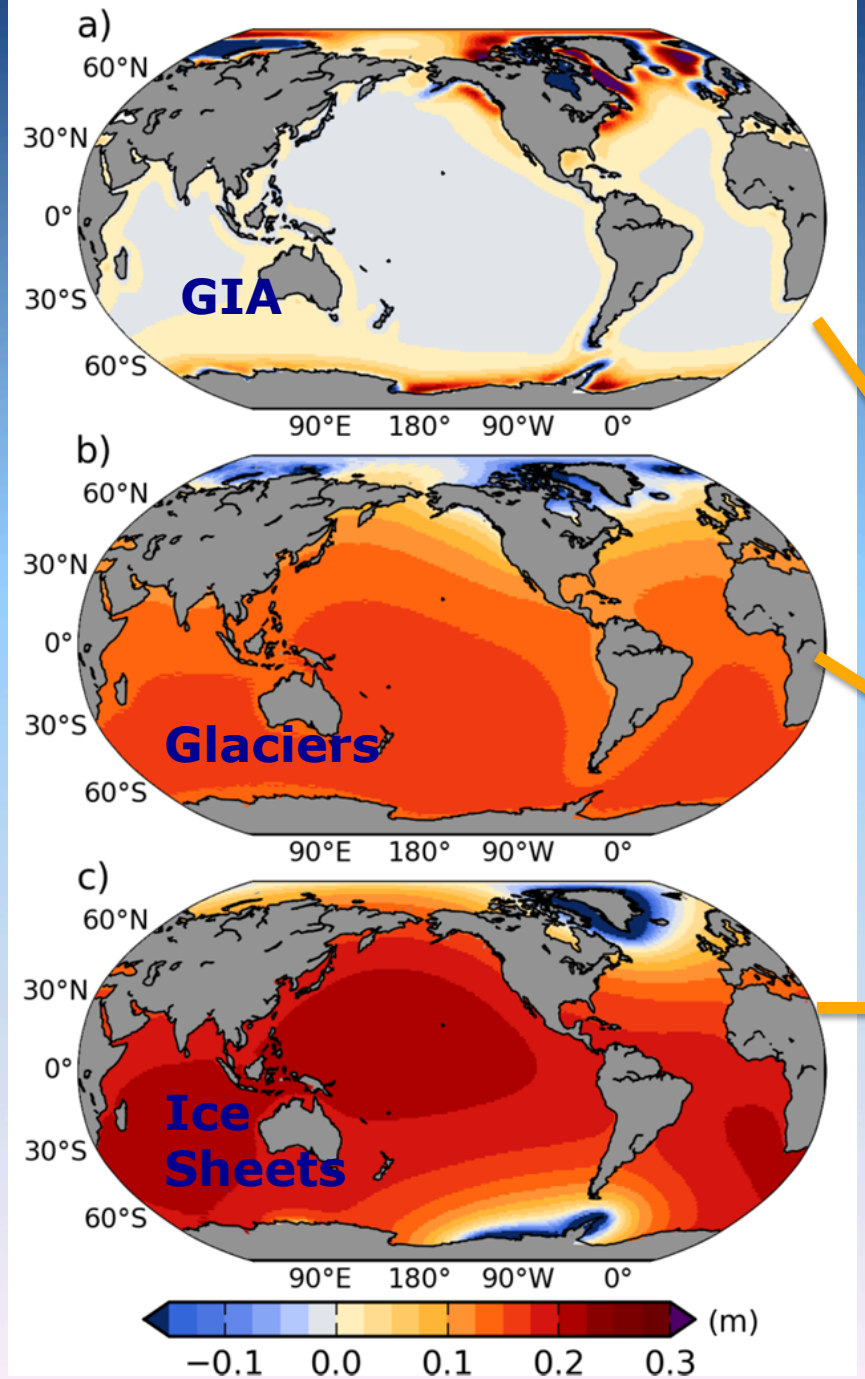
Regional Sea Level

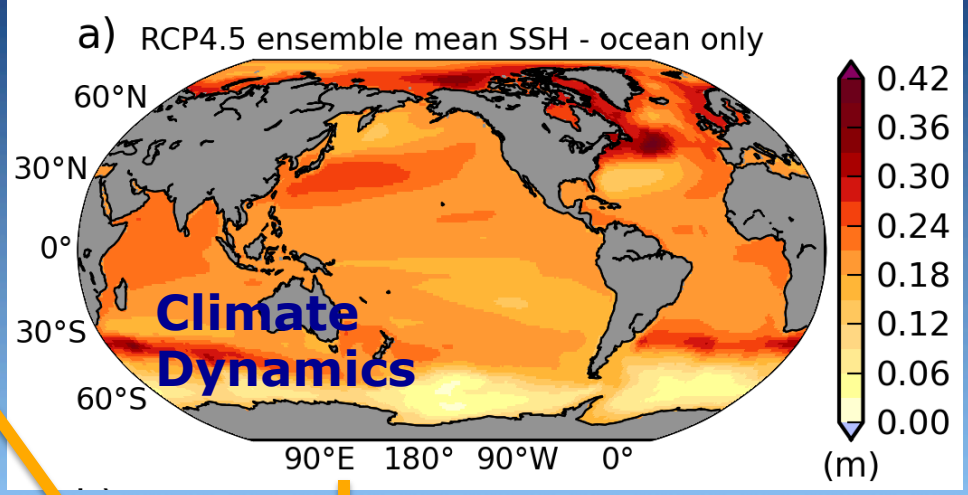
- Climate parameter with immediate societal relevance
- Affected by all climate components: its changes are an integral measure of climate change
- Strong contributions not related to climate (not covered by WCRP)



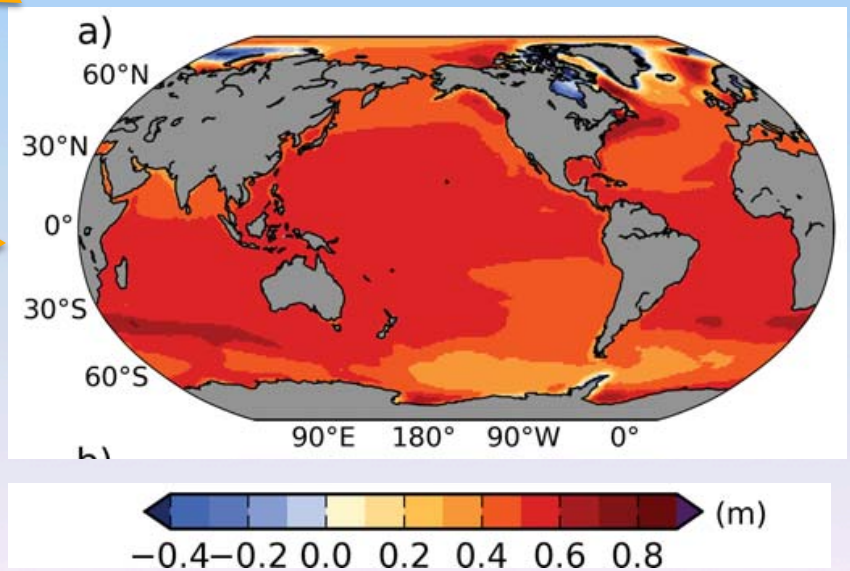
(Stammer et al., 2013)

Dealing with sea level requires interaction with many communities within and outside WCRP.





Net Sea Level Change
(plus a few other terms)



Slangen et al.(2014)

Work Programm

Five parallel, but interconnected, working groups:

1. **An integrated approach to paleo time scale sea level estimates**
2. **Quantifying the contribution of land ice to near-future sea level rise**
3. **Causes for contemporary regional sea level variability and change**
4. **Predictability of regional sea level**
5. **Sea level science for coastal zone management**

- The GC group will provide an **assessment of the state of affairs of sea level research every 2 years** and will use the resulting information to make adjustments of its science plan and recommendations for international sea level research efforts.
- The GC team will write **summaries on data and modeling issues**, bringing together information and recommendations from all working groups.

Sea Level Steering Team

Expertise	Name	Country	Partner Organization
Geodesy/ Geophysics	Natalya Gomez	Harvard, USA	
	Mark Tamisiea	NOC, UK	
Glaciology/ Ice sheets	Roderik van de Wal	U. Utrecht, The Netherlands	Co-Chair
	Tony Payne	U. Bristol, UK	CliC
	Ayako Abe-Ouchi	Japan	PAGES
Regional processes, Reconstrcutions Climate modes Climate modeling	David Holland	Courant, USA	CliC
	Rui Ponte	AER, USA	
	Detlef Stammer	CEN, Germany	Co-Chair
	Catia Domingues	U. Tasmania, Australia	CLIVAR
	Benoit Meyssignac	LEGOS, France	
	Jianjun Yin	U. Arizona, USA	
	Jonathan Gregory	U. Reading, UK	
Subsidence, Extremes, storm surges, waves and coastal impacts and adaptation.	A.S. Unnikrishnan	NIO, India	
	Gonéri Le Cozannet	BRGM, France	
	Kathy McInnes	CSIRO, AU	
	Kevin Horsburgh	NOC	IOC/WMO JCOMM
	R. Nicholls	U. Southampton, UK	Co-Chair
	Pietro Teatini	U. Padova, Italy	

Expected Outcome

- Many new science results!
- Coastal **Community Requirements Report**
- Document outlining a multidisciplinary **long-term program of SL research in support of coastal community.**
- Bi-annual **Assessment Report**: Update on state-of-understanding (SREX style) and future SL estimates.
- **Database of climate quality observational data set including uncertainties (paleo to present) and Data requirement document**
- **Model requirement document.**
- **Model intercomparison analyses on sea level variability and change and** participation in CMIP6 design.
- Metrics recommendations for CMIP outputs
- **Observing System requirements** for monitoring, model development, model evaluation/validation, initialization – both satellite and in-situ.

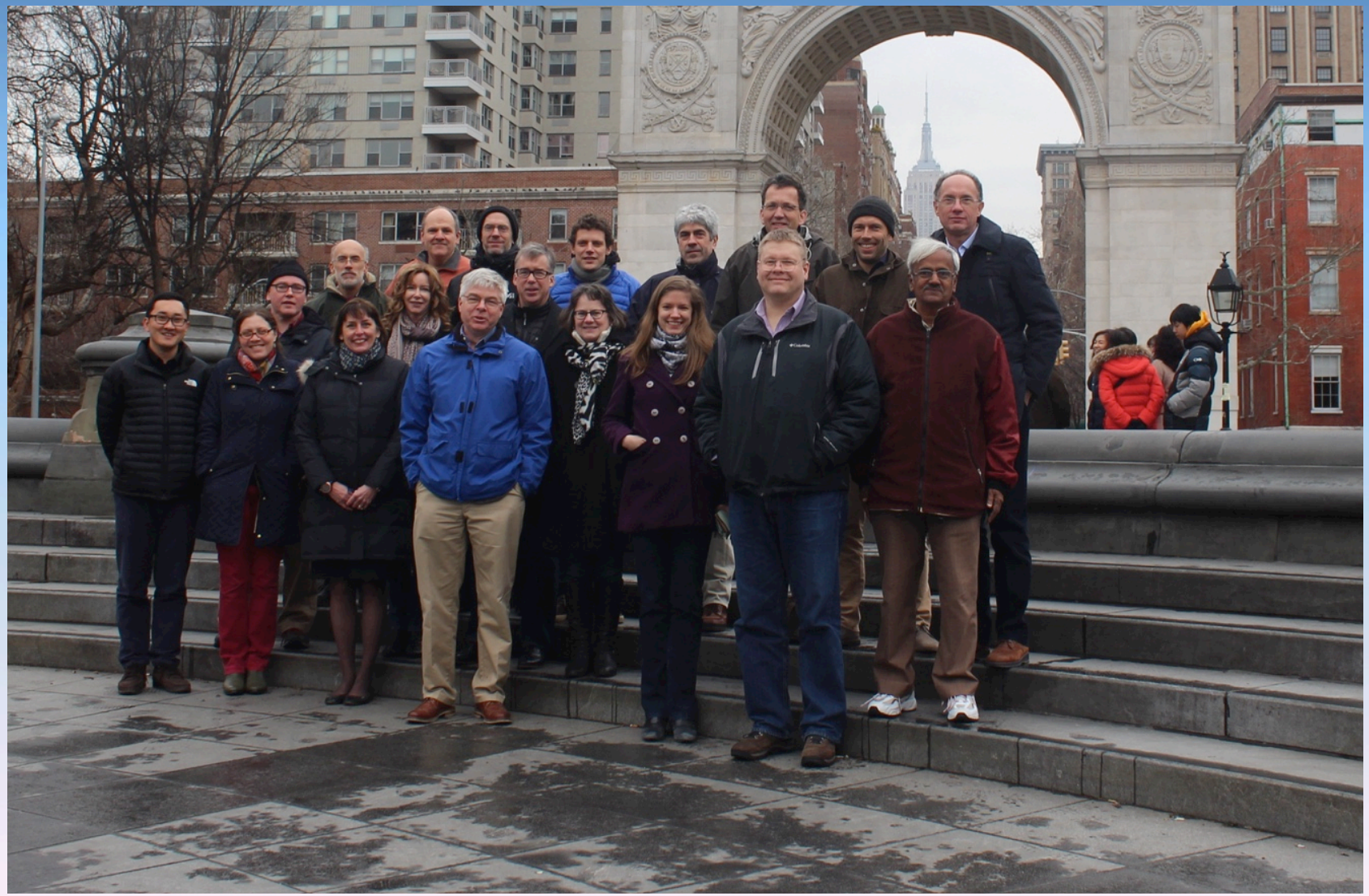
Outreach Component

- Sea level relevant **data "clearing house"**
- Local **data recovery and quality control** activities (e.g., tide gauge data meta data)
- Establishment of regional actions plans with WMO Regional Climate Centers, and in coordination with the GC on Regional Climate Information, to **promote and sustain regional sea level activities with developing countries.**
- Regional workshops with coastal communities in developing countries to foster data sharing, co-production of knowledge and to encourage local community and government involvement.
- **Training courses on sea level data management** in developing countries, in coordination with GLOSS.
- Participation in the 2017 and 2021 Sea Level –Symposia

2nd GC SeaLevel SSC Meeting
New York University, Febr. 8/9, 2016

- Finalize the science and implementation of WPs
- Review progress of individual WPs
- Reports on CMIP6 and FAFMIP
- Plan workshops and new activities
- Review and revise WP teams
- Planning the Sealevel Conference 2017
- White paper and any other writing assignments
- National programs and proposal opportunities
- Summer Schools

2st Meeting, New York



Meeting Participants

- Natalya Gomez U. McGill, Canada
- Mark Tamisiea NOC, UK
- Roderik van de Wal U. Utrecht, NL
- Tony Payne U. Bristol, UK
- David Holland NYU, USA
- Rui Ponte AER, USA
- Detlef Stammer CEN, Germany
- Catia Domingues U. Tas., Australia
- Benoit Meyssignac LEGOS, France
- Jonathan Gregory U. Reading, UK
- A.S. Unnikrishnan NIO, India
- Kathy McInnes CSIRO, AU
- Kevin Horsburgh NOC, UK
- R. Nichsolls U. Southampton, UK
- Pietro Teatini U. Padova, Italy
- Lei Han CLIVAR Project Office

Guests:

- Jochen Hinkel Global Climate Forum,
- Kate White CRREL, USA
- Felix Landerer JPL, USA
- Sophie Nowicki GSFC, USA

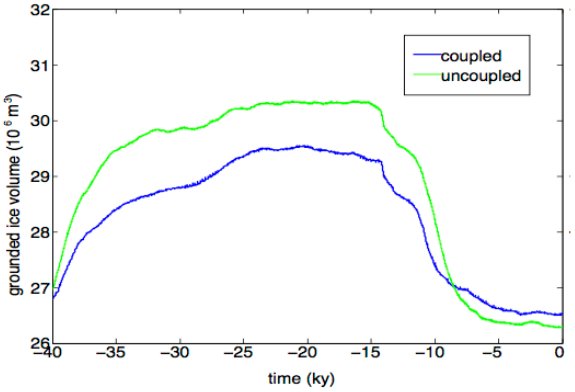
WP 1: An integrated approach to paleo time scale sea level estimates

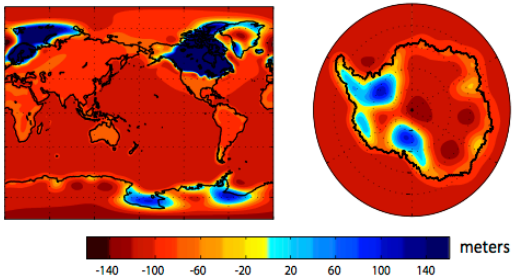
Leads: Natalya Gomez, Roderik van de Wal, Mark Tamisiea

- Generate a **consistent sea level budget** for different time periods:
  - Last glacial max, – far-field indicators consistent with total ice volume
  - The Eemian interglacial, when temperatures were only slightly higher than today but sea levels were much higher
  - The 20th century and recent budgets considered in WP 3.
- **Self-consistent interaction** between models of ice, land, ocean, atmosphere.
- Understanding ice and sea level histories over Holocene
- Assessing the effects of a lateral variations in earth structure and non-Maxwell rheologies
- Supplementing geologic sea level indicators with geodetic data, while accounting for other contributors to these observations
- Identifying weaknesses in the **observational paleo data set** of sea level change

Coupled ice sheet – sea level modeling

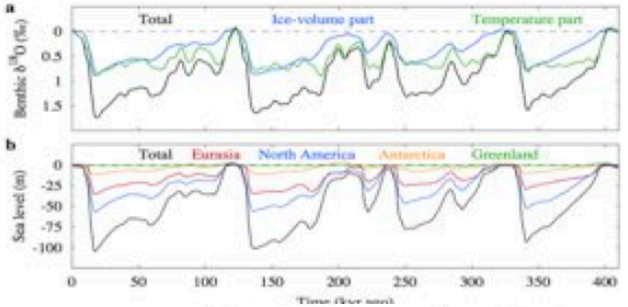
Antarctic ice sheet growth and retreat over the last 40ky dampened by sea-level coupling

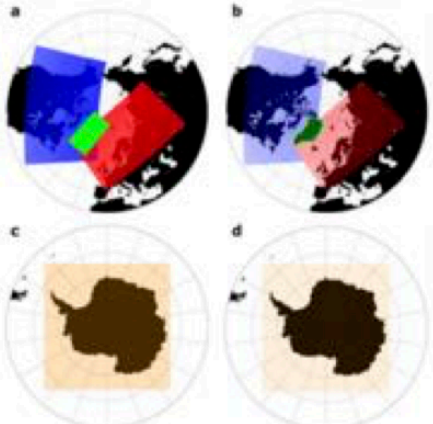




Gomez et al. (2013)

Global dynamic ice cover changes coupled to a global sea level model





De Boer et al. (2014)

Others: Konrad, Berends, Bradley…

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

Leads: Tony Payne, David Holland, Roderik van de Wal, Ayako Abe-Ouchi

- Improving understanding of **key processes**, such as iceberg calving and ice-ocean interactions around Antarctica.
- Improve global **glacier and ice cap modeling**, and establish coordinated approaches to making future projections of global glacier mass balance.
- Test the numerical basis of the new generation of ice sheet models in a range of idealized test cases, in particular related to processes affecting the Marine Ice Sheet Instability.
- Validate **CMIP climate simulations** of atmospheric and oceanic climate above and around the ice sheets of Greenland and Antarctica.
- Conduct a range of **model inter-comparison exercises** for the both the Greenland and Antarctic ice sheets.
- Characterize the high-magnitude, low-probability end of future sea-level's probability density function.
- Stimulate the **inclusion of ice sheets in global coupled climate models.**
- **Tipping points** for Greenland and western Antarctica ice sheets (CliC)

Ice Sheet Model Intercomparison Project for CMIP6

S. Nowicki (USA), T. Payne (UK), E. Larour (USA)

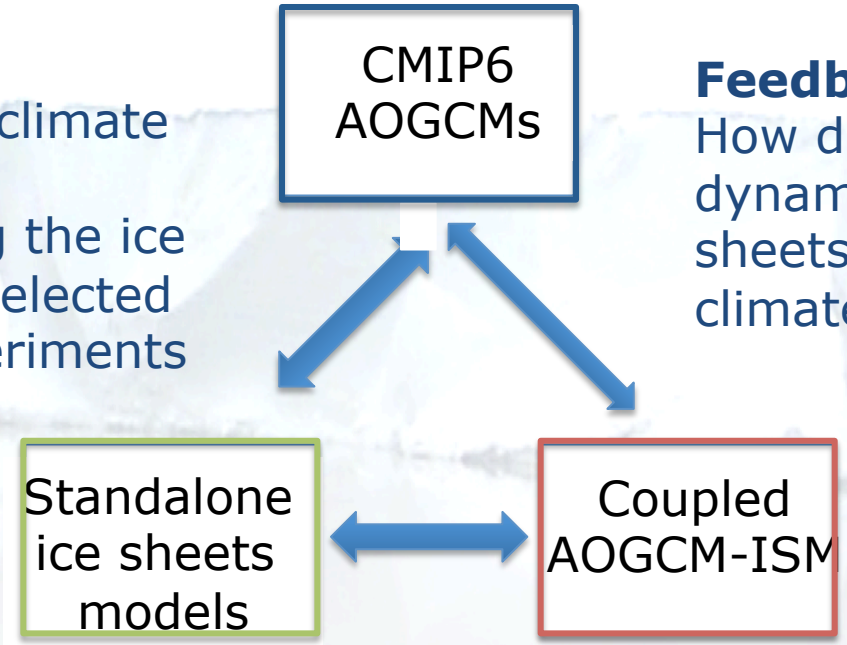
A. Abe Ouchi (JP), H. Goelzer (Uetr. U.), J. Gregory (UK)

W. Lipscomb (USA), H. Seroussi (USA), A. Shepherd (UK).

CliC Climate and Cryosphere

Experimental framework for ISMIP6

Forcings
Analysis of climate over and surrounding the ice sheets for selected CMIP6 experiments



Feedbacks
How do dynamic ice sheets affect climate?

Projections
Past and future sea level due to ice sheets, along with associated uncertainty due to ice sheets and climate forcing

Ice Sheet Model Intercomparison Project for CMIP6

More information:
http://www.climate-cryosphere.org/activities/targeted/ismip6

ISMIP6 Participants

Climate Modeling Centers:

CanESM (CA) (diagnostic only)
CESM (USA)
CNRM-CM (FR)
EC-Earth (SWE + 9EU)
GISS (USA)
INM (RU)
IPSL (FR)
MIROC-ESM (JP)
MPI-ESM (DE)
UKESM (UK)

Ice Sheet Models (and hopefully more):

ARC-PISM
AWI-ISSM
BGC-BISICLES
DMI-PISM
ILTS-SICOPOLIS
IMAU-IMAU-ICE
JPL-ISSM
LANL-CISM
LGGE-Elmer
LSCE-GRISLI
MIROC-IcIES
MPIM-PISM
ORNL-CISM
UAF-PISM
VUB-GISM

clic Climate and Cryosphere

ISMIP6

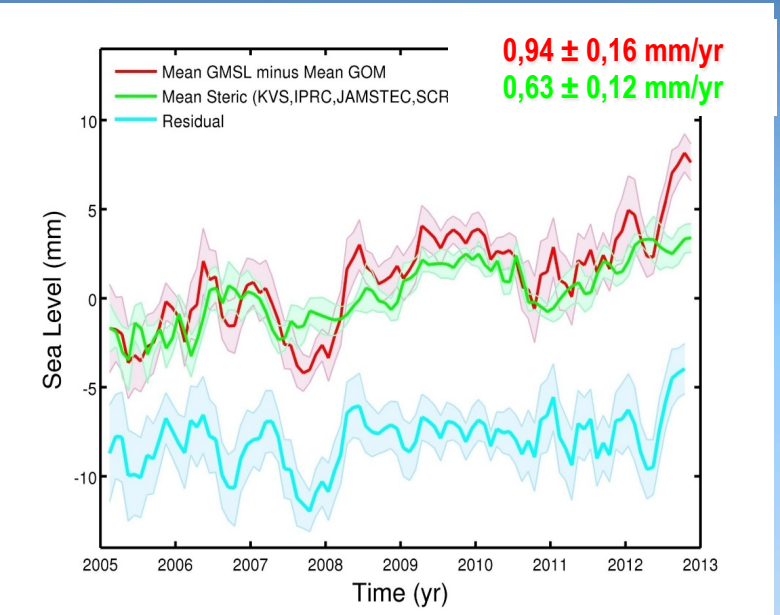
Ice Sheet Model Intercomparison Project for CMIP6

WP 3: Causes for contemporary regional sea level variability and change

Leads: Rui Ponte, Catia Domingues, Benoit Meyssignac, D. Stammer

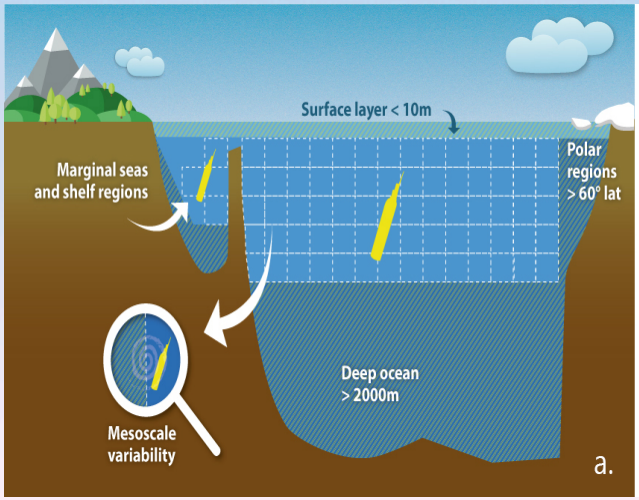
- Understand and reduce **uncertainties in mass and steric contributions** to contemporary sea level budgets at global, regional and local spatial scales.
- Determining the **role of climate modes** (e.g., ENSO, IOD, PDO, SAM, NAO, AMO) and internal variability in general on sea level.
- Understanding the role of **coastal and ocean interior processes** (e.g., shelf sea dynamics, ocean mixing, freshwater input, etc) on local sea level.
- **Attribution of regional sea level change** to natural (e.g., solar, volcanic) and anthropogenic (e.g., tropospheric aerosols, greenhouse gases) radiative forcing agents.
- Requirements for an optimal and integrated (satellite and ground-based) **sea level observing system**.

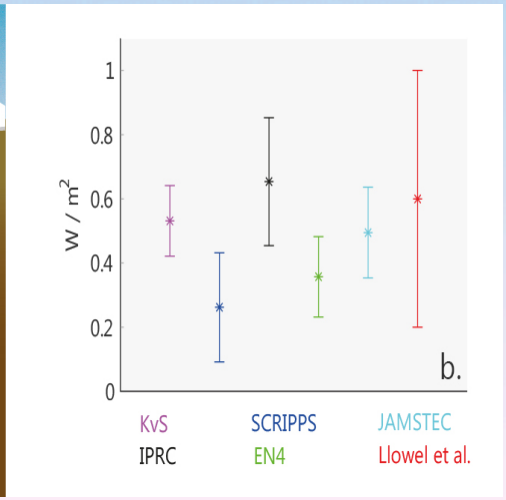
Sea level budget: data errors and missing contributions



- Sea level budget residual = Deep ocean (>1500m) contribution + errors : ~ 0.3 ± 0.4 mm/yr
- Constraint on the Earth energy imbalance
  ~ 0.6 ± 0.4 W/m^2

Dieng et al. (2015,Survey of Geophysics)
von Schuckmann et al. (2016, Nat CC)
Slangen et al. (2016 Nat CC)

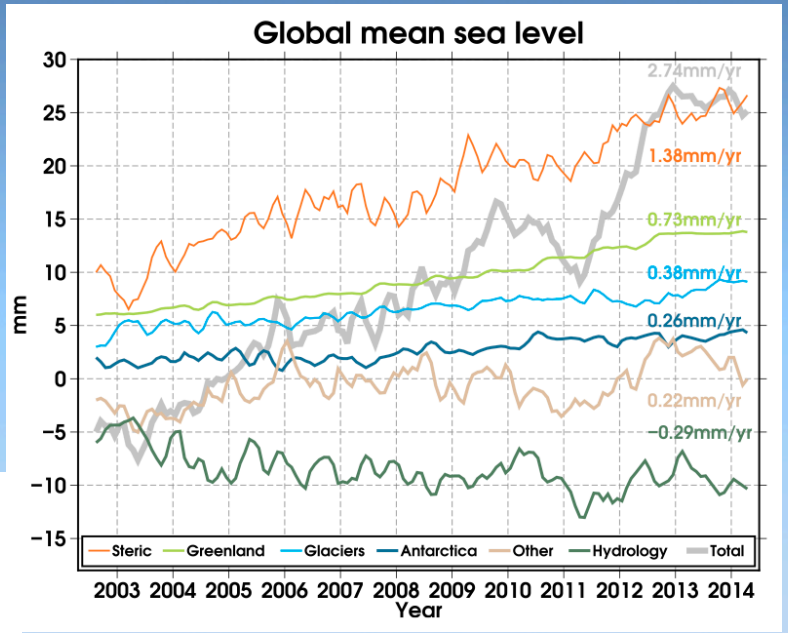




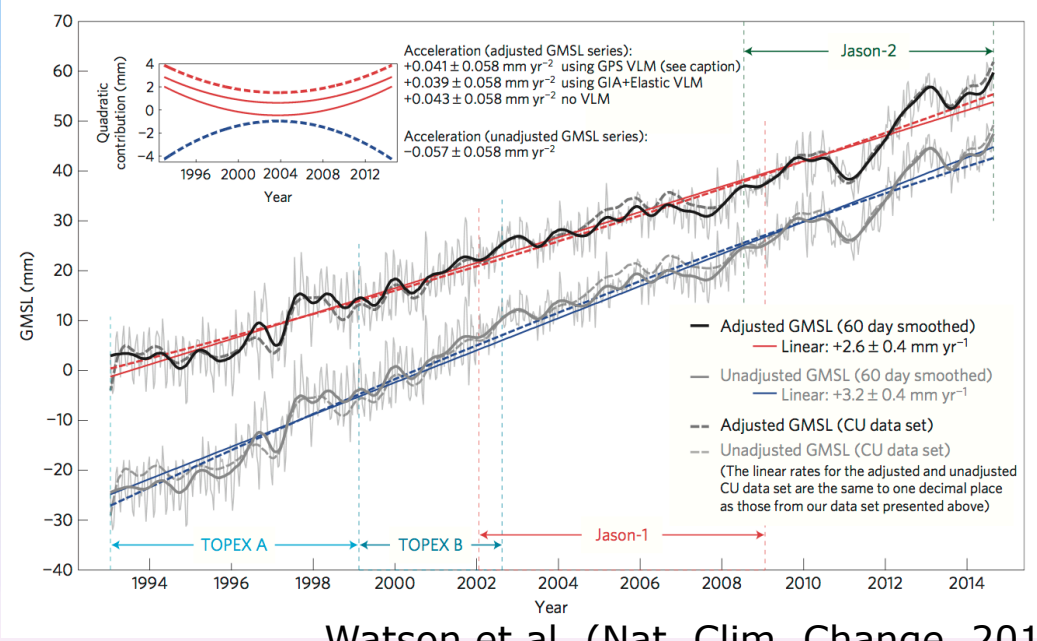
Llovel et al. and Dieng et al.

New data+model stories

- Sensitivity to data treatment and methodology, importance of re-examining old data
- Mostly overlapping estimates?
- Conflicting stories for other variables, e.g., Antarctica contributions from Zwally et al. (2015, J. Glaciology)



Rietbroek et al. (PNAS, 2016)



Watson et al. (Nat. Clim. Change, 2015)

- **Reanalyses comparisons (Palmer et al., Storto et al., 2015, Clim. Dyn.)… better deep ocean data**

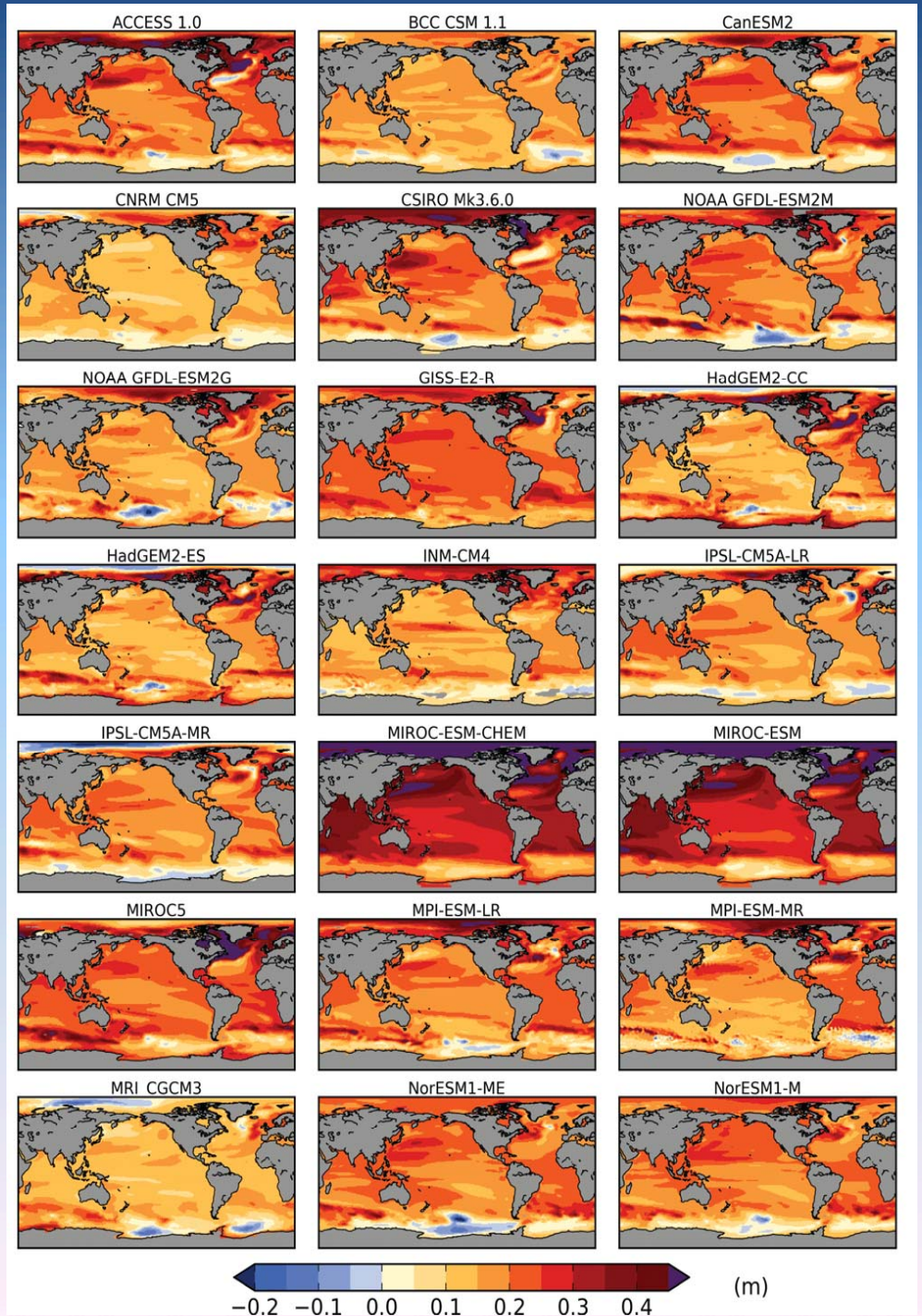
WP 4: Predictability of regional sea level

Leads: Jonathan Gregory, Jianjun Yin, Tony Payne, Detlef Stammer

- Determining **limits of predictability of sea level** as function of space and time scale and the role of changing climate modes for sea level predictions.
- Understanding and reducing **regional inter-model sea level spread** in predicted sea level due to change in ocean properties (temperature, salinity, circulation, mass distribution).
- Provide **reliable uncertainties for sea level predictions** and projections, including those for ice sheets and glacier projections.
- Incorporate **processes relevant for regional sea level change in AOGCMs**, especially glaciers, ice-sheets. Including ice-sheets will place a focus on a better representation of polar regions in climate models.
- Provide reliable estimates of **terrestrial hydrology**.

Uncertainty:
Inter-model spread

… reflecting strong differences in ocean circulation changes (steric changes)



Slangen et al. (2014)

FAFMIP (flux-anomaly-forced models)

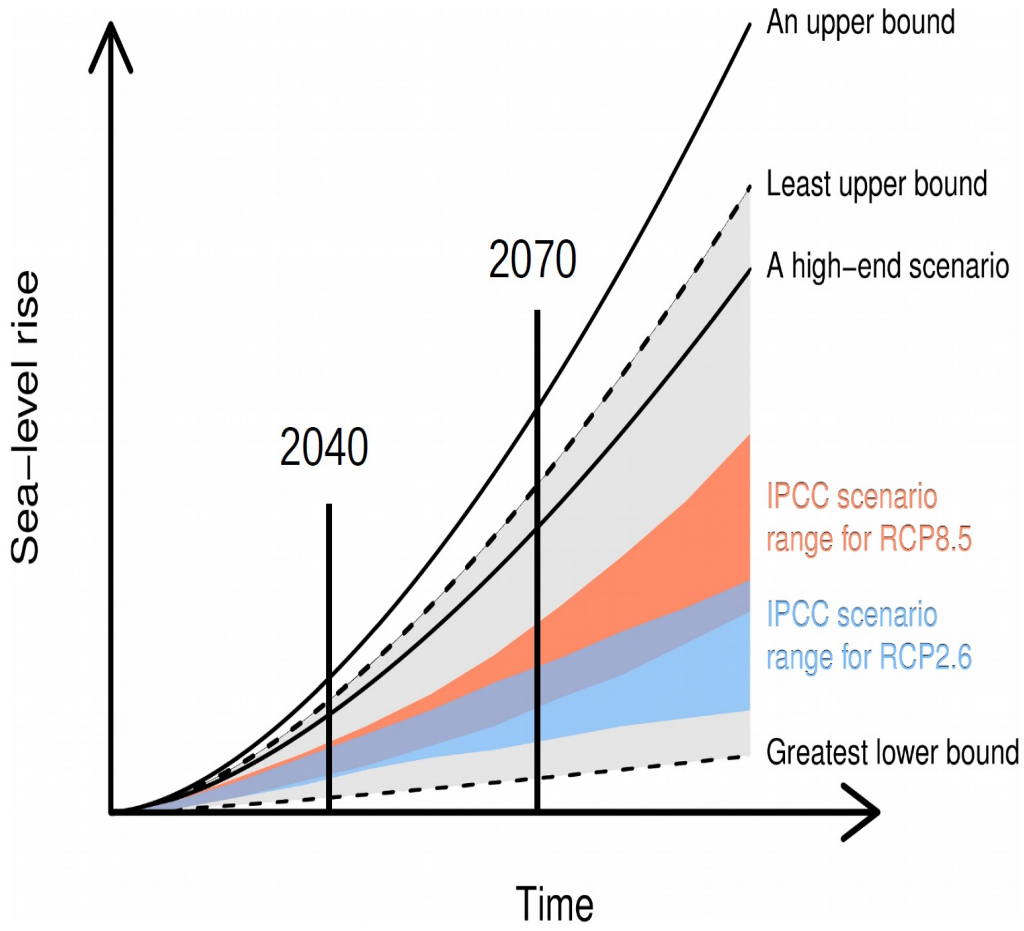
- **Scientific motivations:**
  - Patterns of sea level change – how much depends on model rather than flux
  - Efficiency of ocean heat uptake from experiment (2), $\partial T/\partial t$ diags requested
  - Sensitivity of AMOC to buoyancy forcing from experiments (2) and (3)
- In foregoing work, one model was forced with anomalous fluxes from each of many models.
- **In this project, many models will each by forced with the same anomalous fluxes (like "hosing" experiments).**
- Climatological monthly mean surface flux anomalies will be obtained from the ensemble mean of years 61-80 of the CMIP5 1%CO2 experiments i.e. time-independent common surface forcing for 2xCO2. (No CO_2 forcing.)
- Tier 1 (mandatory) (1) Windstress, (2) Heat flux, (3) Freshwater flux
- Tier 2 (optional) (5) All together (6) Passive heat
- Experiments are 70 years long if possible.
- **For AOGCMs (CMIP6) or OGCMs (e.g. CORE-II). Nine groups have agreed to participate, four more possibly.**

WP 5: Sea level science for coastal zone management

Leads: Robert Nicholls, Goneri Le Cozannet, S. Unnikrishnan, Kathy McInnes, Kevin Horsburgh, Pietro Teatini, Jochen Hinkel

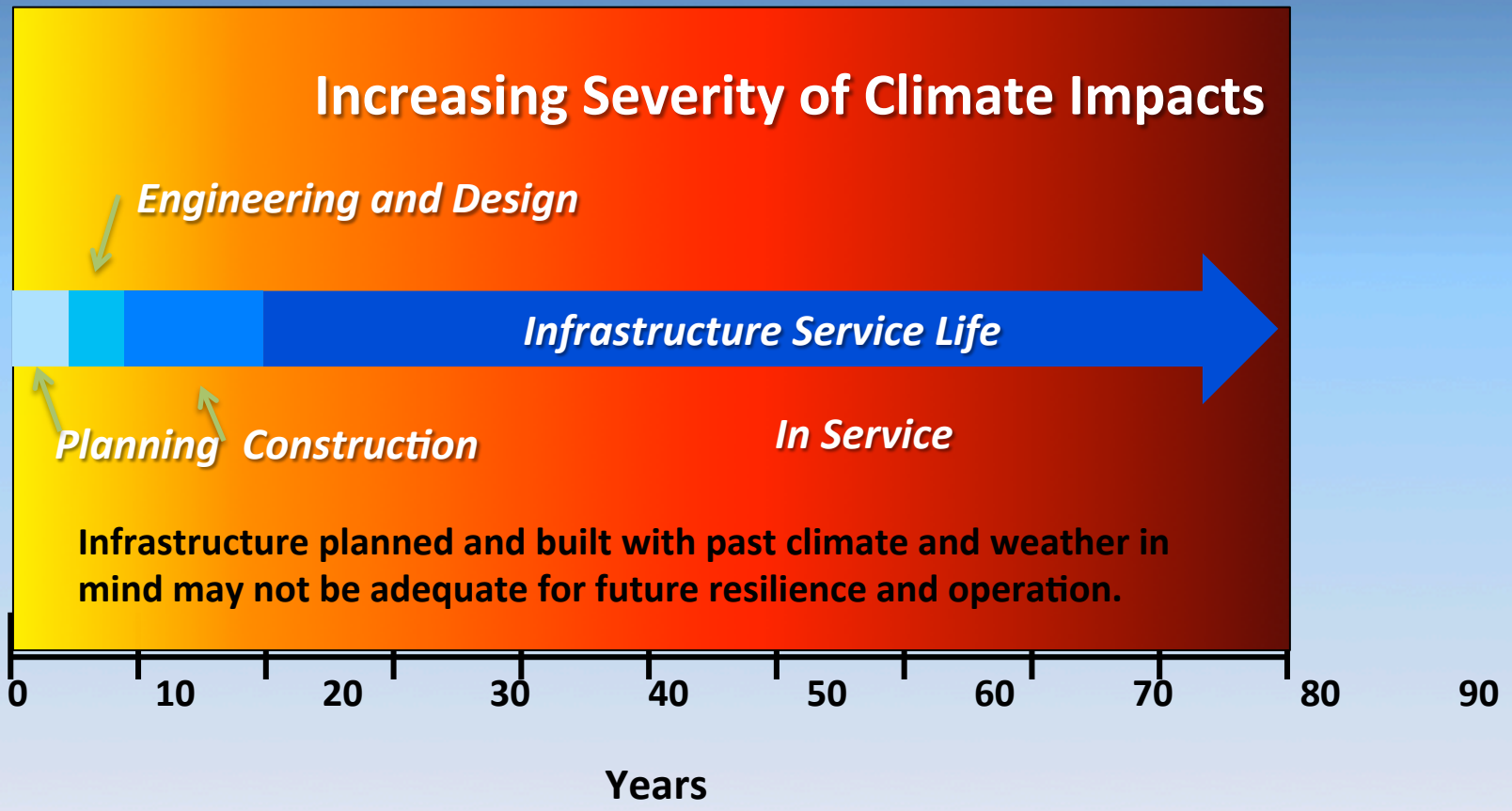
- **Sea level information** potentially useful for coastal community
- **Transitioning sea level variability and uncertainties** from regional to local coastal scale,
- **Probabilistic information** and return-period from combined effects of sea level rise and changes in extremes (e.g., storm surges).
- **Pilot studies** for mega city, delta, island state, etc. using accurate sea level products from working groups 1-4.

Upper bounds



Source: Hinkel et al. Nature Climate Change (2015)

Consider Long Lead Time and Long Service Life

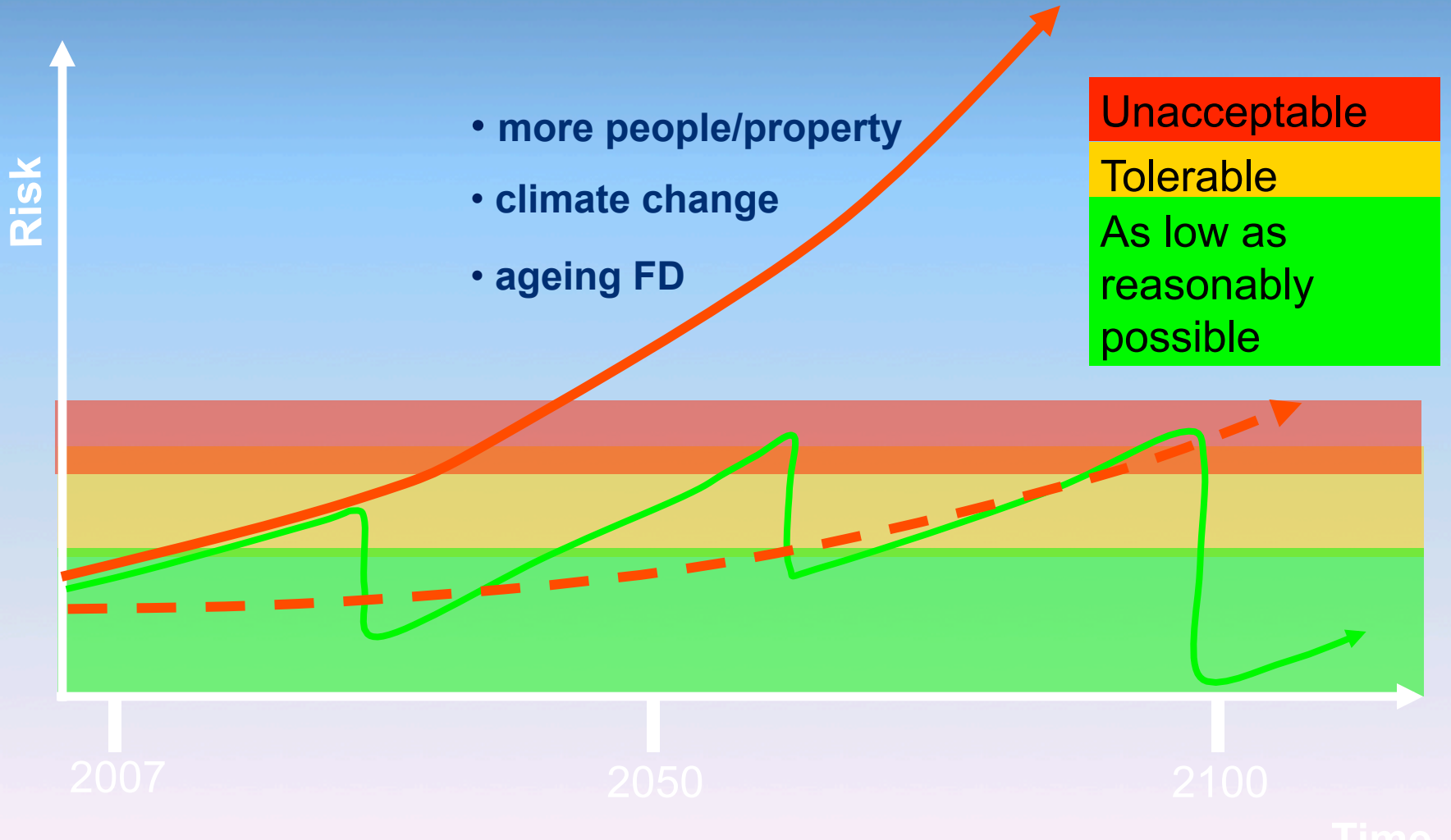


After United States Ports: Addressing the Adaptation Challenge, Mr. Mike Savonis

The 100th Thames Barrier Closure

Source: Environment Agency

Managing Flood Risk through the Century

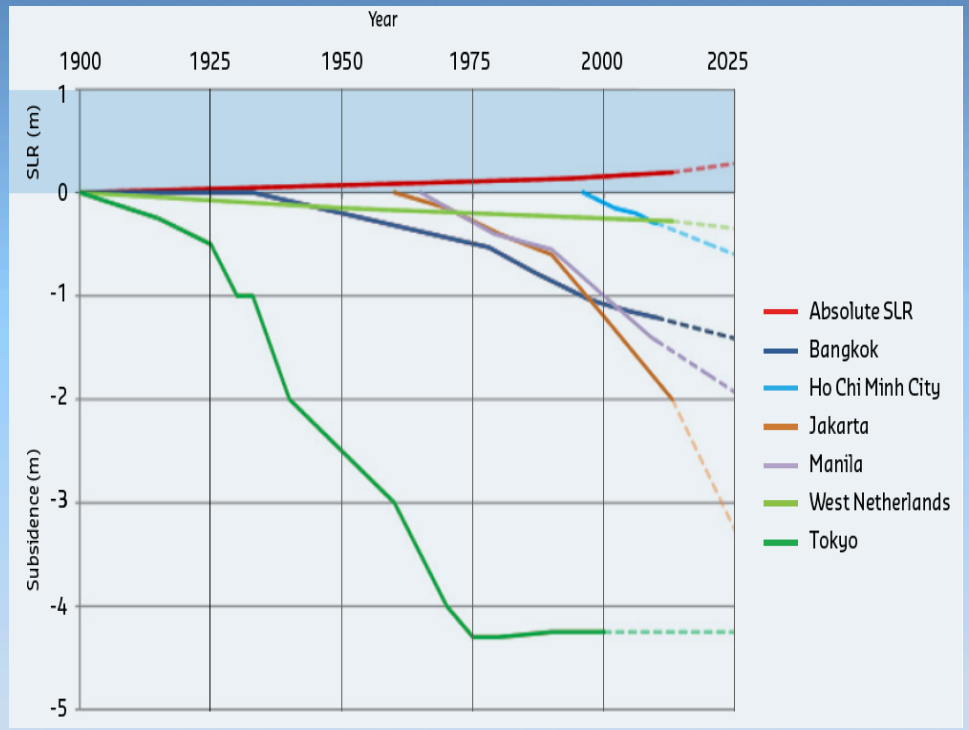


Source: Environment Ager

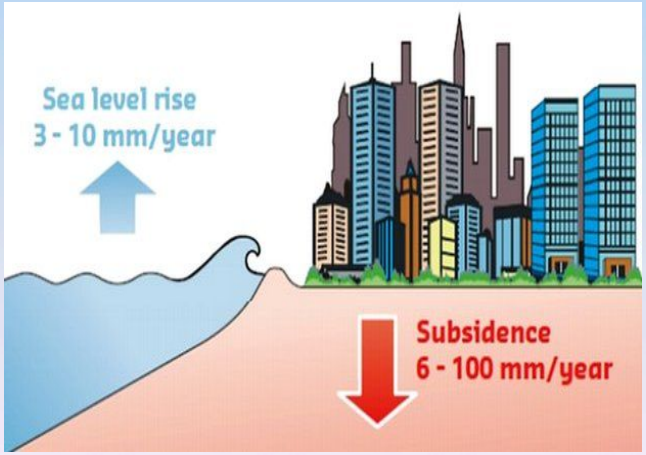
Coordinated Ocean Storm Surge Climate Project (COSSCLIP)

Storm surges are a coastal problem and manifest on the continental shelf.

WHAT WE LEARNED FROM THE PAST



Land subsidence can contribute to RSLR much more than SLR



In Preparation

- Terminology paper
- White paper on status of sea level research
- Paper on uncertainties at coastlines

Regional Sea-level Changes and Coastal Impacts

July 10 – 15, 2017
New York University, NY

A joint GC SeaLevel– IOC Conference

Conference venue

Kimmel Center for University Life
60 Washington Sq. South
New York City, NY 10010
USA

Conference website

www.sealevel2017.org

Conference sponsors

NEW YORK UNIVERSITY

WCRP World Climate Research Programme

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

NASA

esa

EUMETSAT

Contact

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Robert Nicholls (R.J.Nicholls@soton.ac.uk)
Detlef Stammer (detlef.stammer@uni-hamburg.de)
Roderik van de Wal (R.S.W.vandeWal@uu.nl)

Design
Meike Ruhnau (meike.ruhnau@uni-hamburg.de)

WCRP World Climate Research Programme

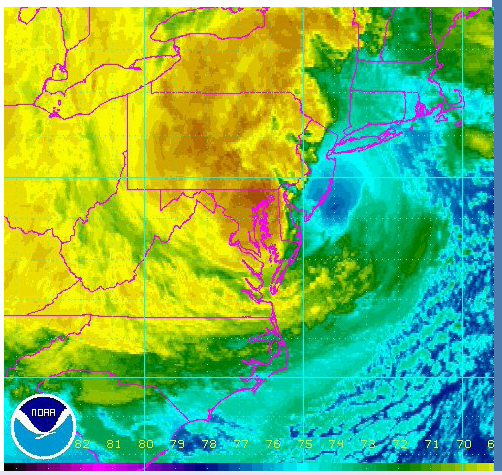
International WCRP/IOC Conference

Regional Sea Level Changes and Coastal Impacts

July 10-14, 2017

NEW YORK UNIVERSITY

New York, NY, USA



Sea level change is already now impacting coastal communities globally and will continue to do so.

To meet urgent societal needs for useful information on sea level, the World Climate Research Program (WCRP) has established the theme "Regional Sea-Level Change and Coastal Impacts", as one of its cross-cutting "Grand Challenge" (GC) science questions.

The GC Sea Level has designed and developed 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 the results effectively support impact and adaptation efforts and wider coastal zone development and management.

The WCRP, jointly with the Intergovernmental Oceanographic Commission of UNESCO (IOC), is organizing an international conference on sea level research that will address the existing challenges in describing and predicting regional sea level changes, and in quantifying the intrinsic uncertainties.

It follows 11 years after the first WCRP sea level conference (Paris, 2006), and three years after the last Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). It will provide a comprehensive summary of the state of worldwide climate-related large scale sea level research.

Conference Objectives

WCRP, jointly with the Intergovernmental Oceanographic Commission of UNESCO (IOC), is organizing an international **conference on sea level research** that will address the existing challenges in describing and predicting regional sea level changes, and in **quantifying the intrinsic uncertainties**.

It follows 11 years after the first WCRP sea level conference (Paris, 2006), and three years after the last Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

It will provide a comprehensive summary of the state of worldwide climate-related large scale sea level research.

Expected Participation

- We expect participation from **up to 400** people from natural sciences , social sciences and the coastal management community.
- It will be an **open conference** with limited participation.
- The new approach is to **include the coastal zone management** community to enhance interaction and networking as well as knowledge transfer in both directions.

Draft Conference Program

- **5-day event** with a leading theme guiding the activities of every day.
- **The structure will consist of plenary sessions followed by extensive poster sessions.**
- We envision evening think tank sessions where frontiers will be discussed that could lead to new activities.
- The conference will be accompanied by side evens such as a meeting of the coastal community.

- **It is planned to have Wednesday night public event in the NYU theater (800 people)**

Conference Sessions (draft)

Monday, 10. July 2017
Contemporary regional sea level variability and change

Tuesday, 11. July 2017
Quantifying the contribution of land ice and inland water to future sea level rise

Wednesday, 12. July 2017
Sea level science for coastal zone management

Thursday, 13. July 2017
An integrated approach to paleo time scale sea level research

Friday, 14. July 2017
Predictability of regional sea level

Science organizing committee

Co-Chairs
Robert Nicholls, Detlef Stammer, Roderik van de Wal

Members

- Thorkild Aarup
- Jérôme Benveniste
- **Anny Cazenave (JSC)**
- John Church
- Gonéri Le Cozannet
- Catia Domingues
- Natalya Gomez
- Jonathan Gregory
- Jochen Hinkel
- David Holland
- Kevin Horsburgh
- Felix Landerer
- Eric Lindstrøm
- Kathy McInnes
- Mark Merrifield
- Benoit Meyssignac
- R. Steven Nerem
- Tony Payne
- Rui Ponte
- Mark Tamisiea
- Pietro Teatini
- A. S. Unnikrishnan
- Jianjun Yin
- Kathleen White

Thank you!

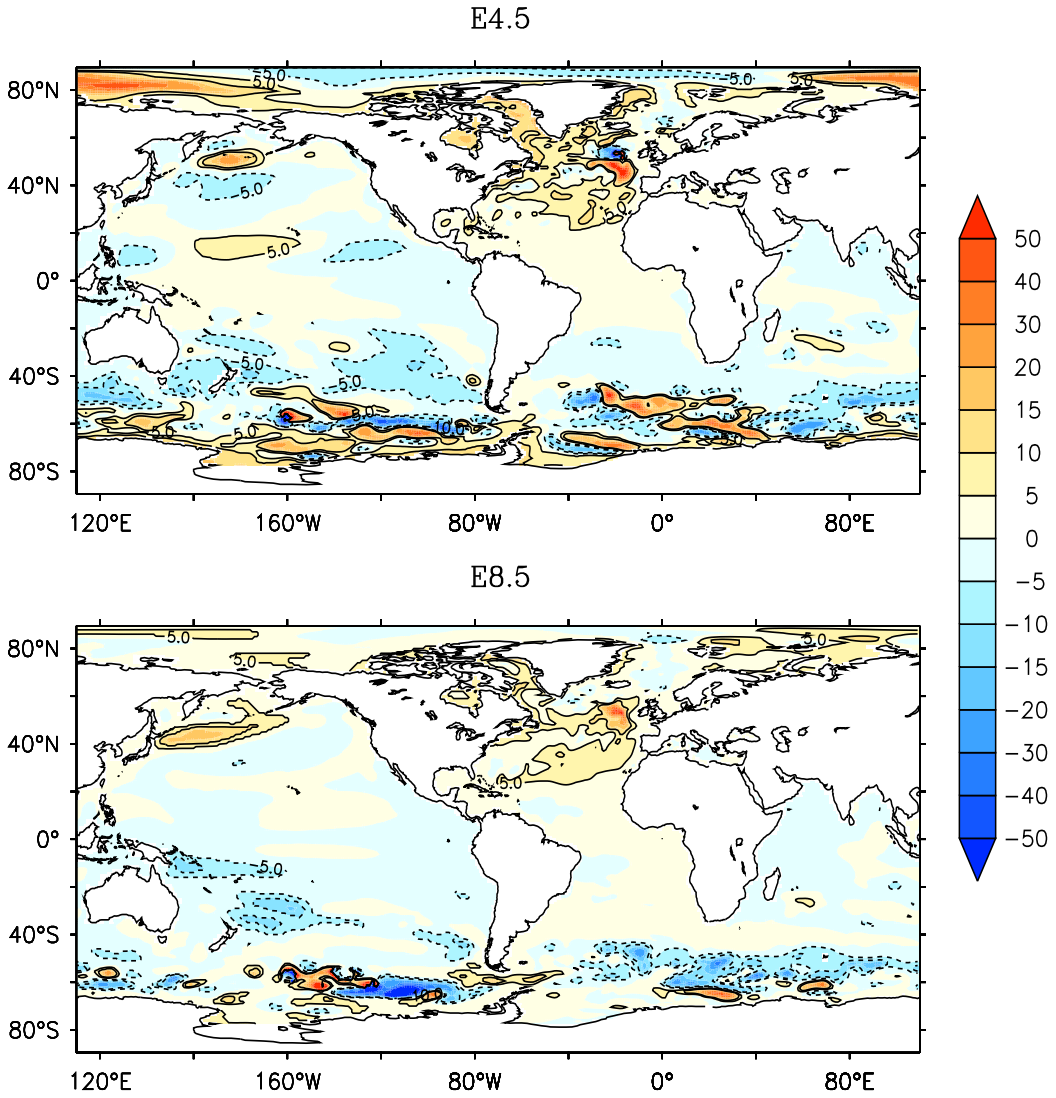
Overarching Goal

- The GC effort will focus on all components of **global to local sea level changes** and will consider the necessary analyses on global and regional **climate change data and simulations**, extreme events and potential impacts, including the evaluation of **sea level rise impacts for coastal zones**.
- Program aims for **close interaction with coastal communities** to assure that results of the proposed scientific research are incorporated into practices of **coastal zone management, and impacts and adaptation efforts**.
- Studies related to detailed impact assessments and the development of adaptation plans cannot be performed as part of this WCRP GC on SL.

Structure of the GC Sea Level

- **GC steering team** and **working groups (WG, order 30 people, each)** underneath, focusing on individual subjects.
- **GC Sea Level co-chairs (3) provide expertise on ocean, cryosphere, coastal applications**.
- Jointly with three co-chairs, the WG leadership makes up the **GC Sea Level steering team**.
- In each working group, led by several co-chairs representing different core disciplines, an **integrated approach** is pursued involving theoretical concepts, observations and models.
- Membership within WGs involves members from CLIVAR/CLIC/ GEWEX/SPARC, modeling groups, but also from other relevant programs outside WCRP (e.g, PAGES, IAG).

Percentage SSH Change (2100 - 2000) in MPI-ESM



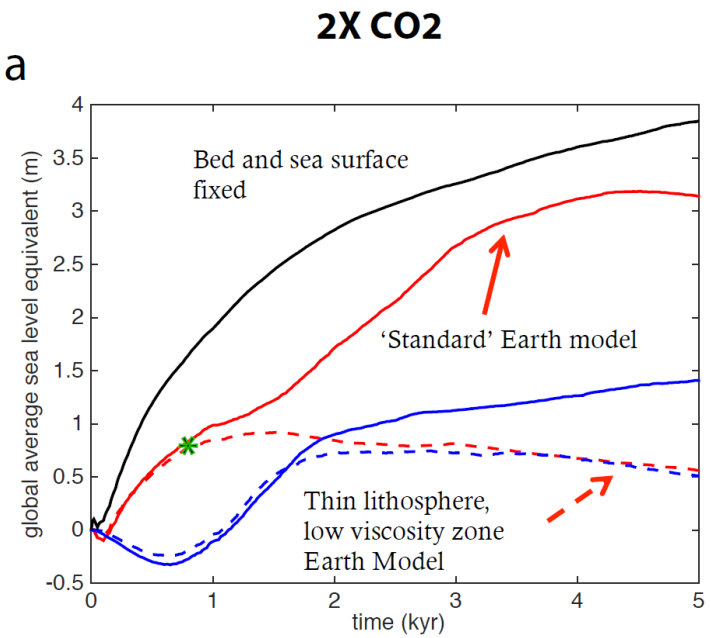
Ensemble uncertainty remains large.

Requires probably 10 members or more.

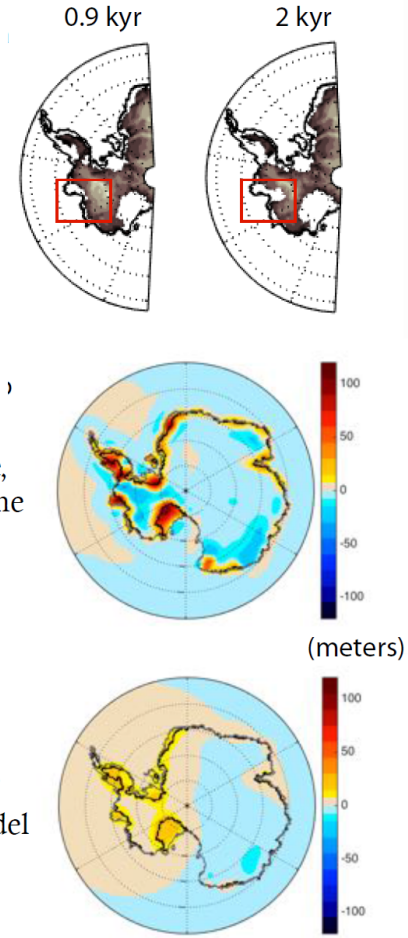
Might be true to all sea level analyses.

Coupled Model: Future Antarctic Retreat (next 5ky)

Lowering mantle viscosity and thinning the elastic lithosphere localizes deformation to the ice-sheet grounding line, and causes more uplift to occur sooner in the simulation.



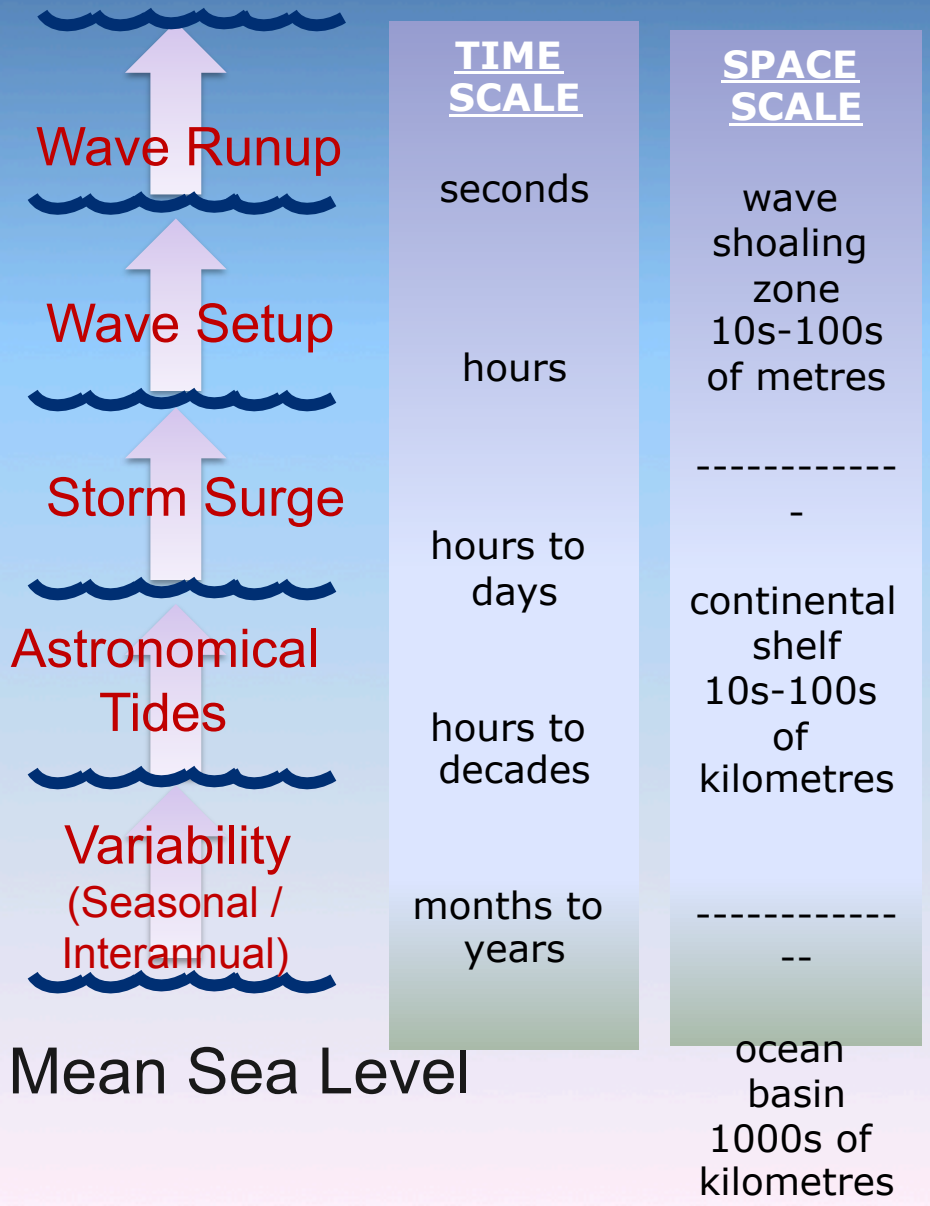
red + black: 1yr ramp. blue: 1000 yr ramp



Gomez et al., 2015

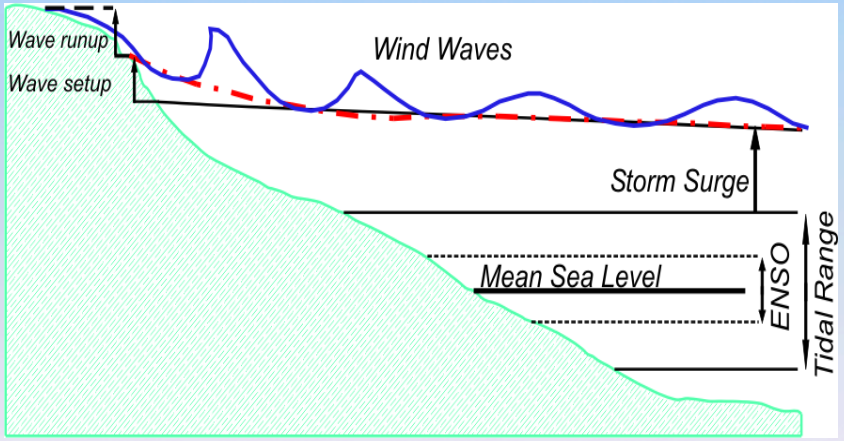
Extreme Sea Levels

Many factors can contribute



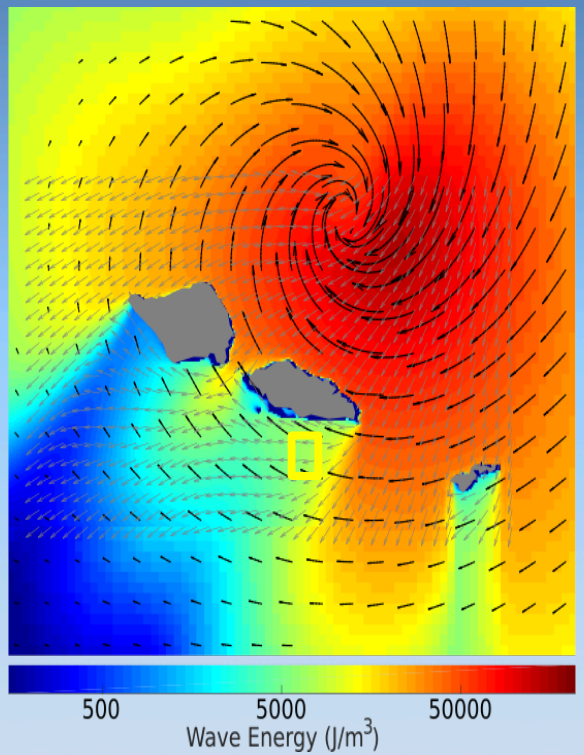
Need to

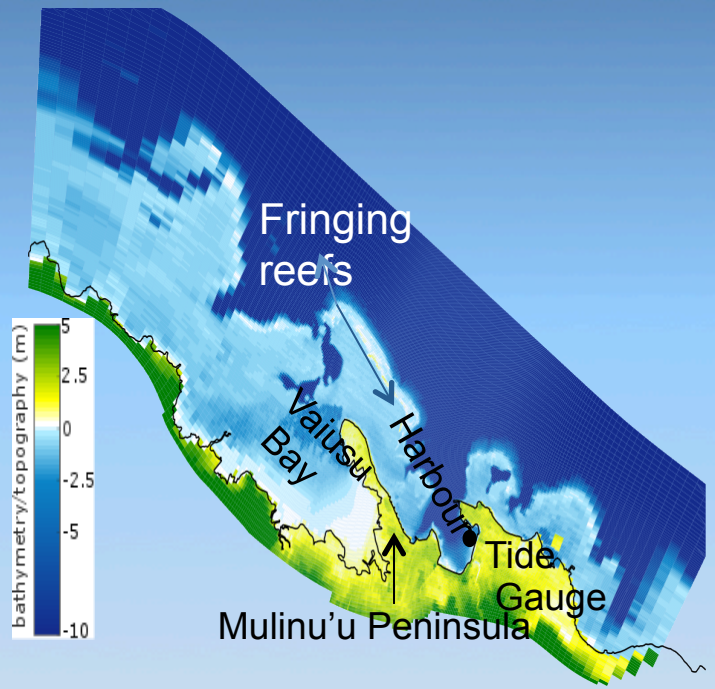
- **Understand contributing factors**
- **Quantifying extreme sea level exceedence probabilities**
- **Projecting changes to extreme sea level risk**
- **Assessing impacts of extreme sea levels**



Challenges for Adaptation Planning in the Pacific

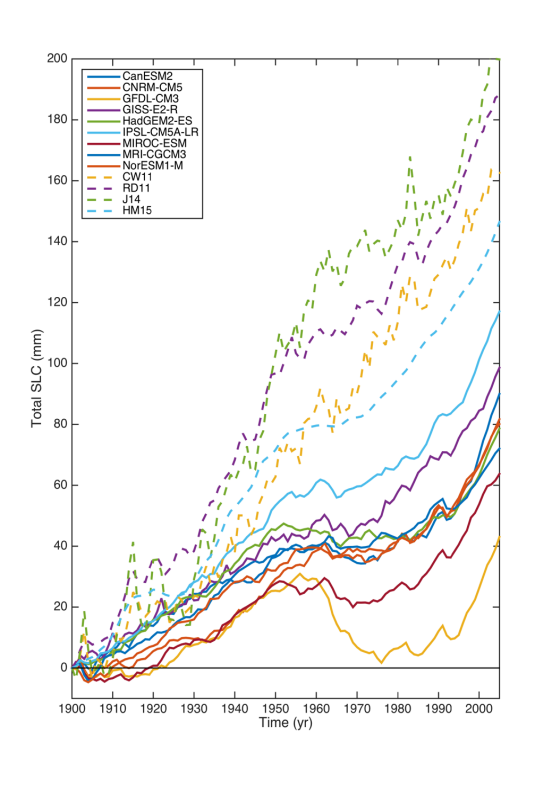
(Source: Hoeke et al, J. Marine Science and Engineering, 2015)



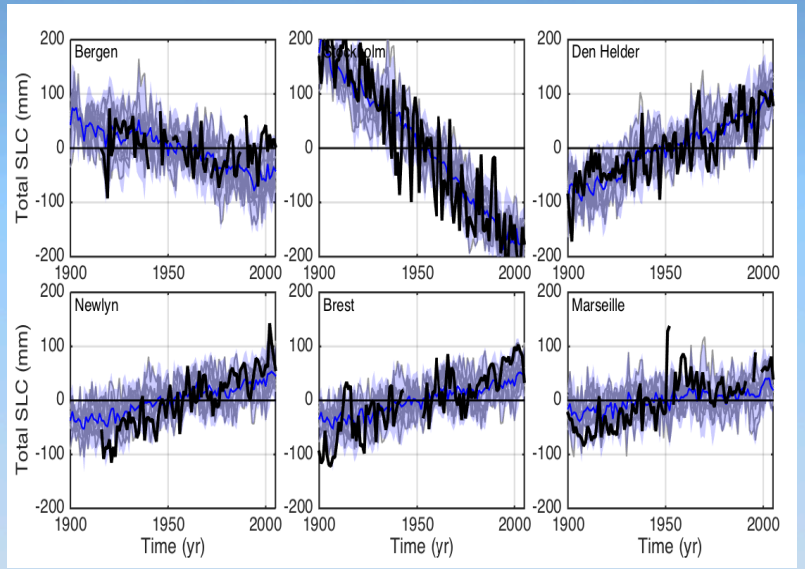


Sea level rise will reduce wave setup and wind setup (by 10-20%) but will increases wave energy reaching the shore (up to 200%)

Sea level variability: Assessing climate models in total sea level



Slangen et al. in prep



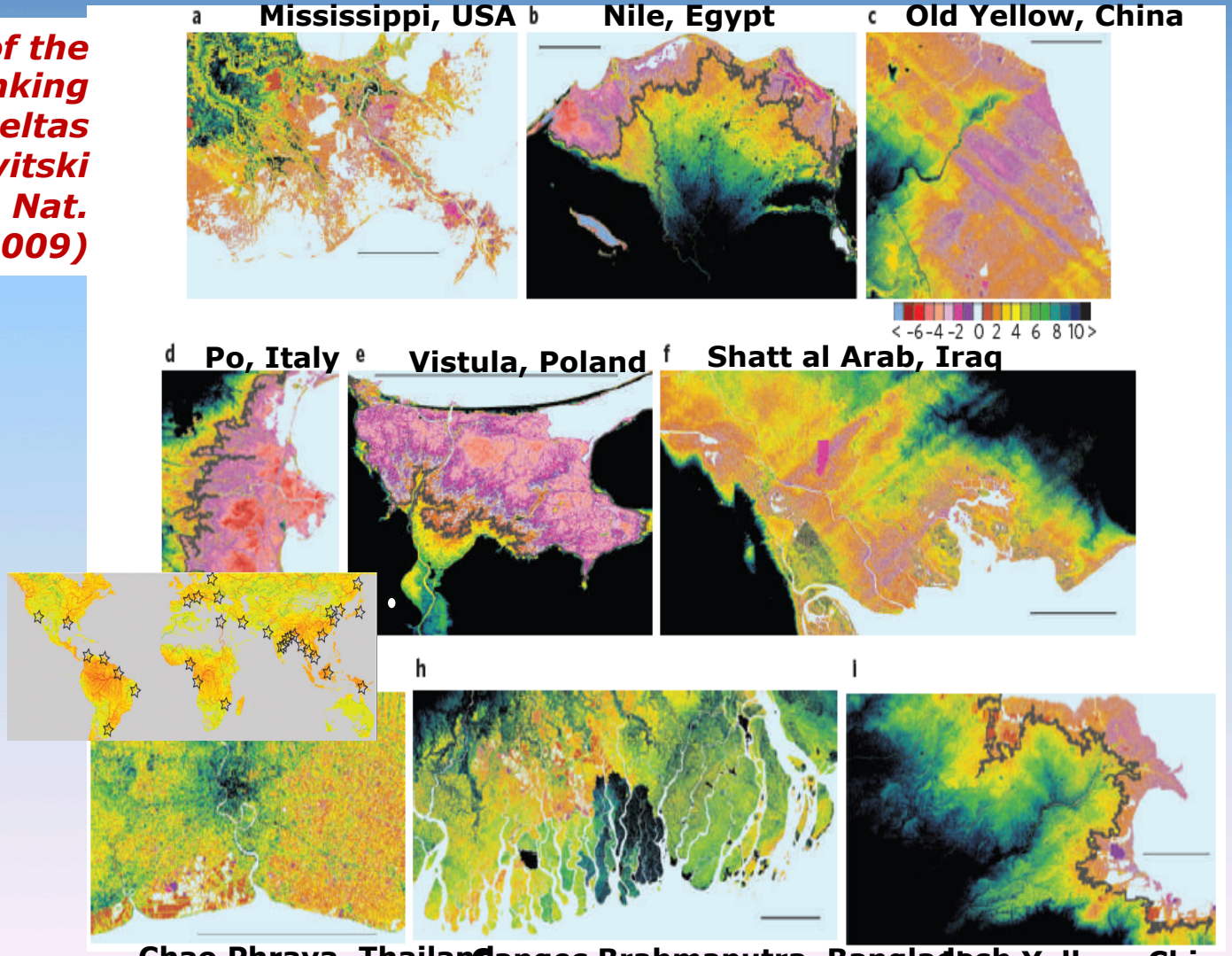
Meyssignac et al. in prep

Indiv.Models
Ensemble (2σ)
Observations

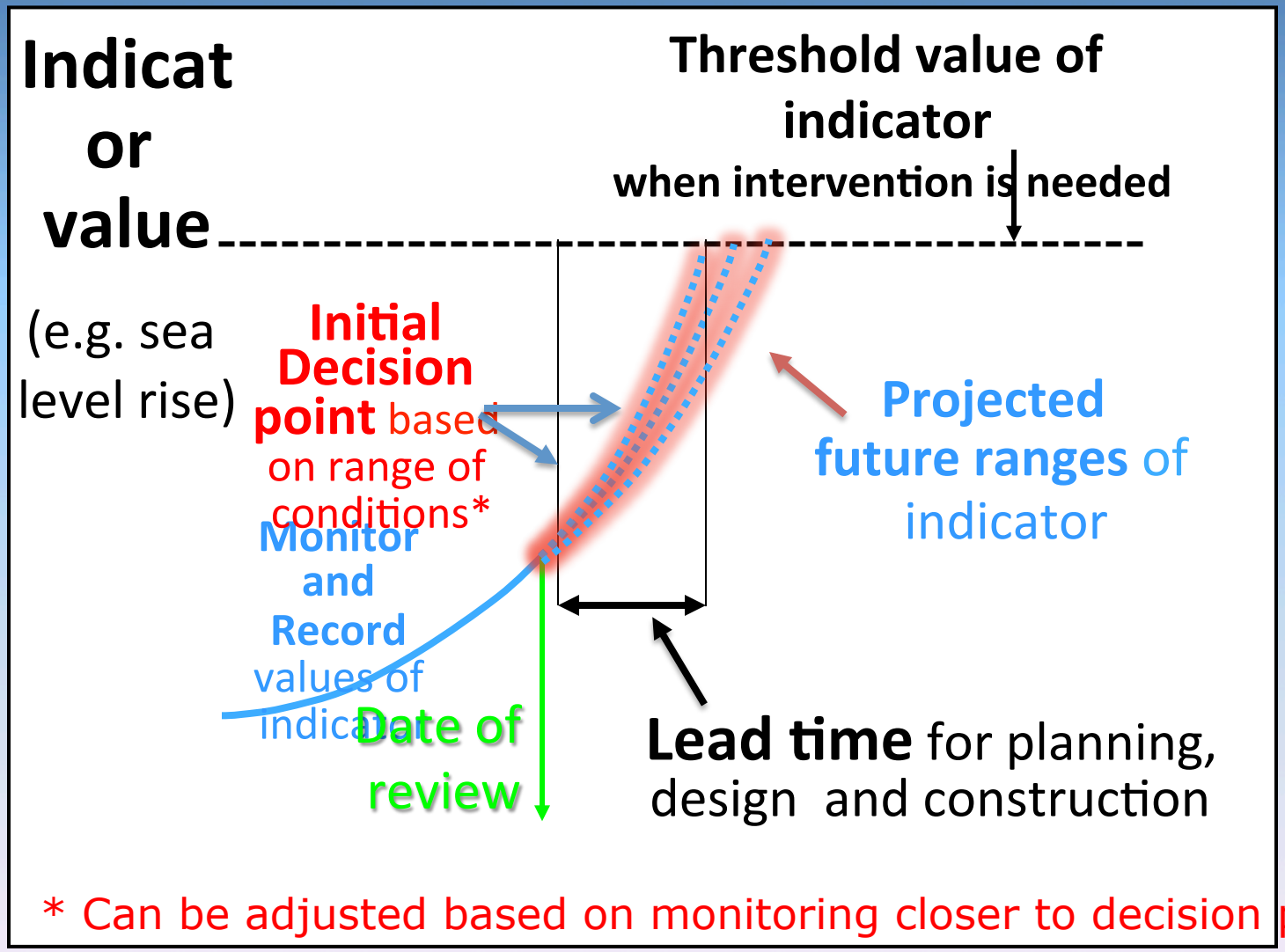
- Preliminary results: compared to reconstructions there is a gap in GMSL of a few tenth of mm/yr: Antarctica residual?, Greenland early warm period?
- Regional comparison with tide gauges is encouraging

COASTAL AREAS PRONE TO BE STRONGY AFFECTED BY RSLR: DELTAS

DEM of the main sinking deltas (after Syvitski et al., Nat. Geosci., 2009)



Preparing for the Long Term: When to Make Decisions?



Conference Outcome

In detail the conference will:

I. Identify the key factors contributing to past, present and future regional sea level rise and variability.

II. Organize a systematic attack on the error budget of these factors.

III. Identify stakeholder needs for sea-level information for coastal planning and management purposes.

IV. Define the requirements for new and augmented research, technical development and observations consistent with the above.