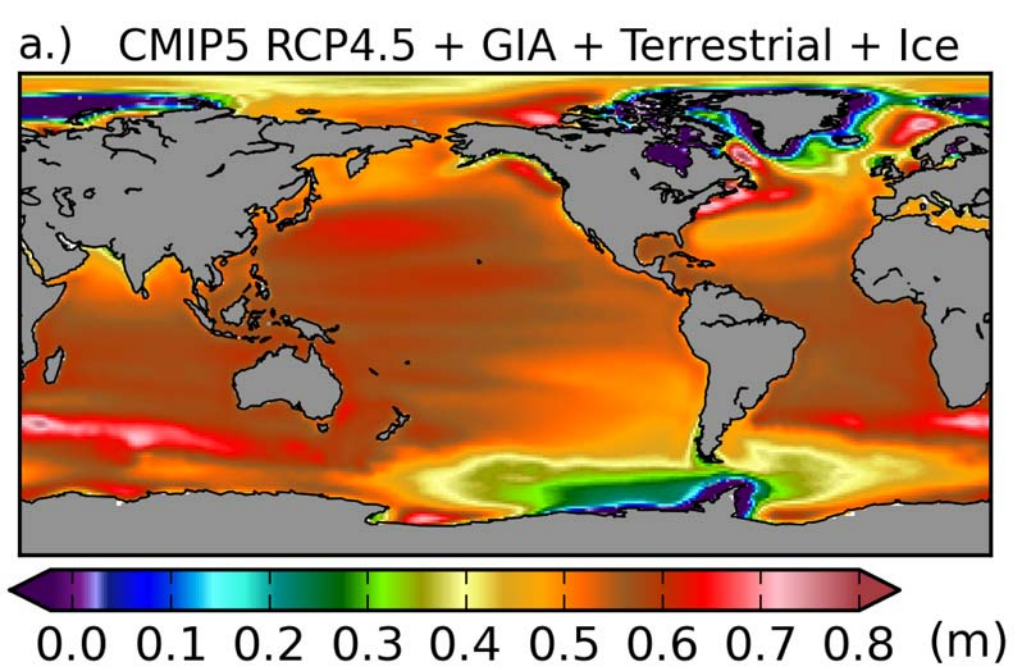
Regional Sea-Level Change and Coastal Impacts



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

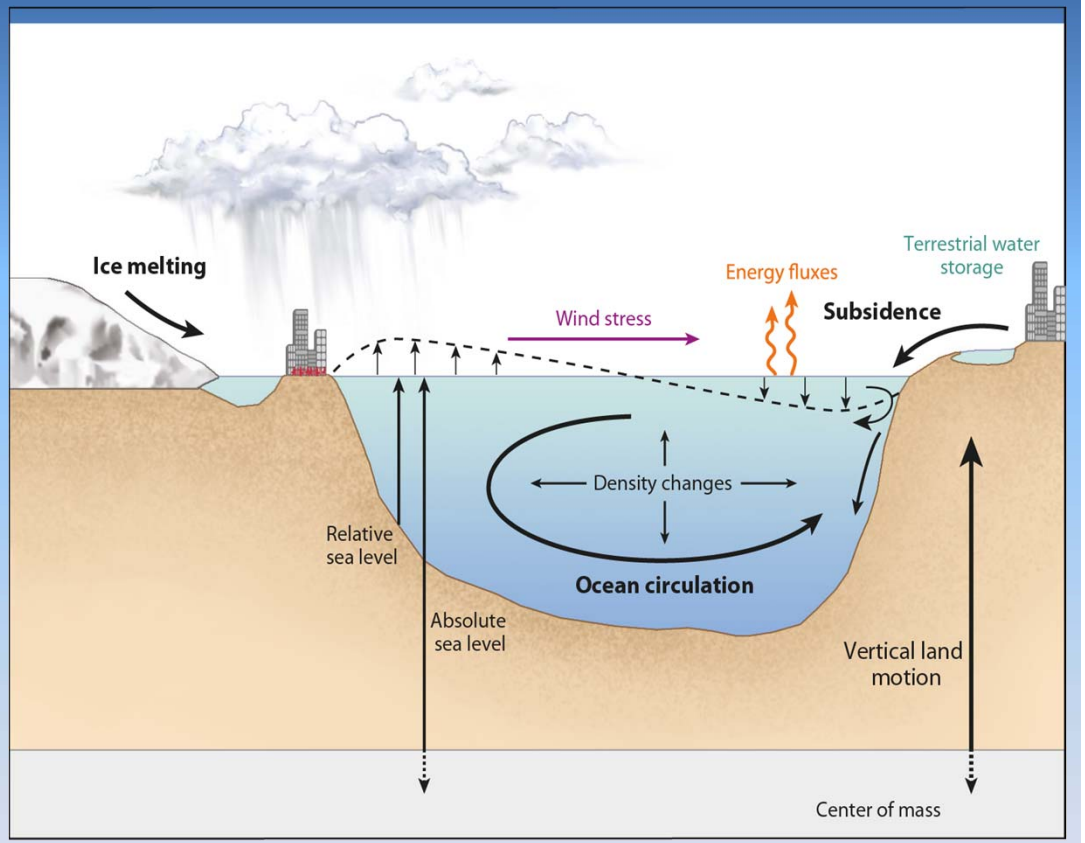
The GC Sea Level Steering Team

WCRP World Climate Research Programme

CLIVAR

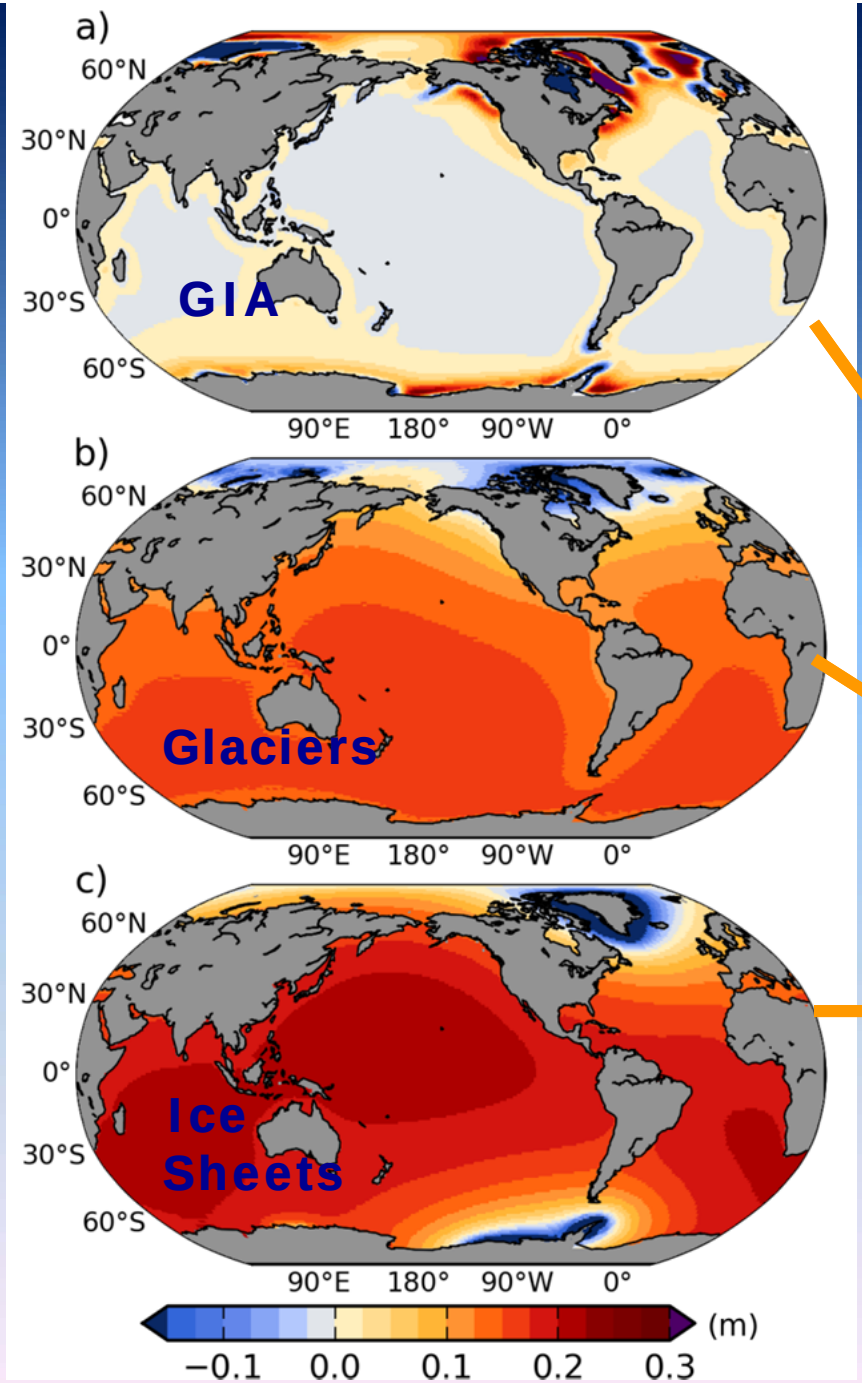
Regional Sea Level

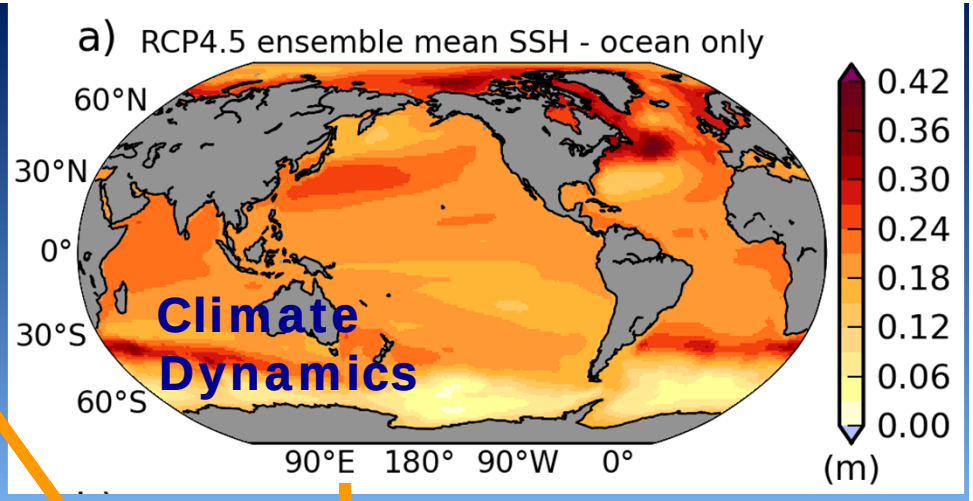
- Climate parameter with immediate societal relevance
- Affected by all climate components: its changes are an integral measure of climate change
- Strong contributions not related to climate (not covered by WCRP)



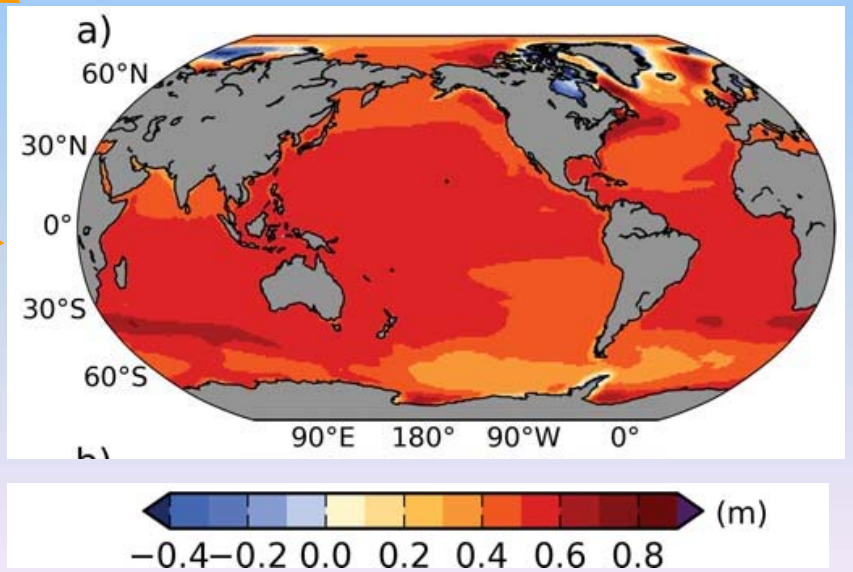
(Stammer et al., 2013)

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



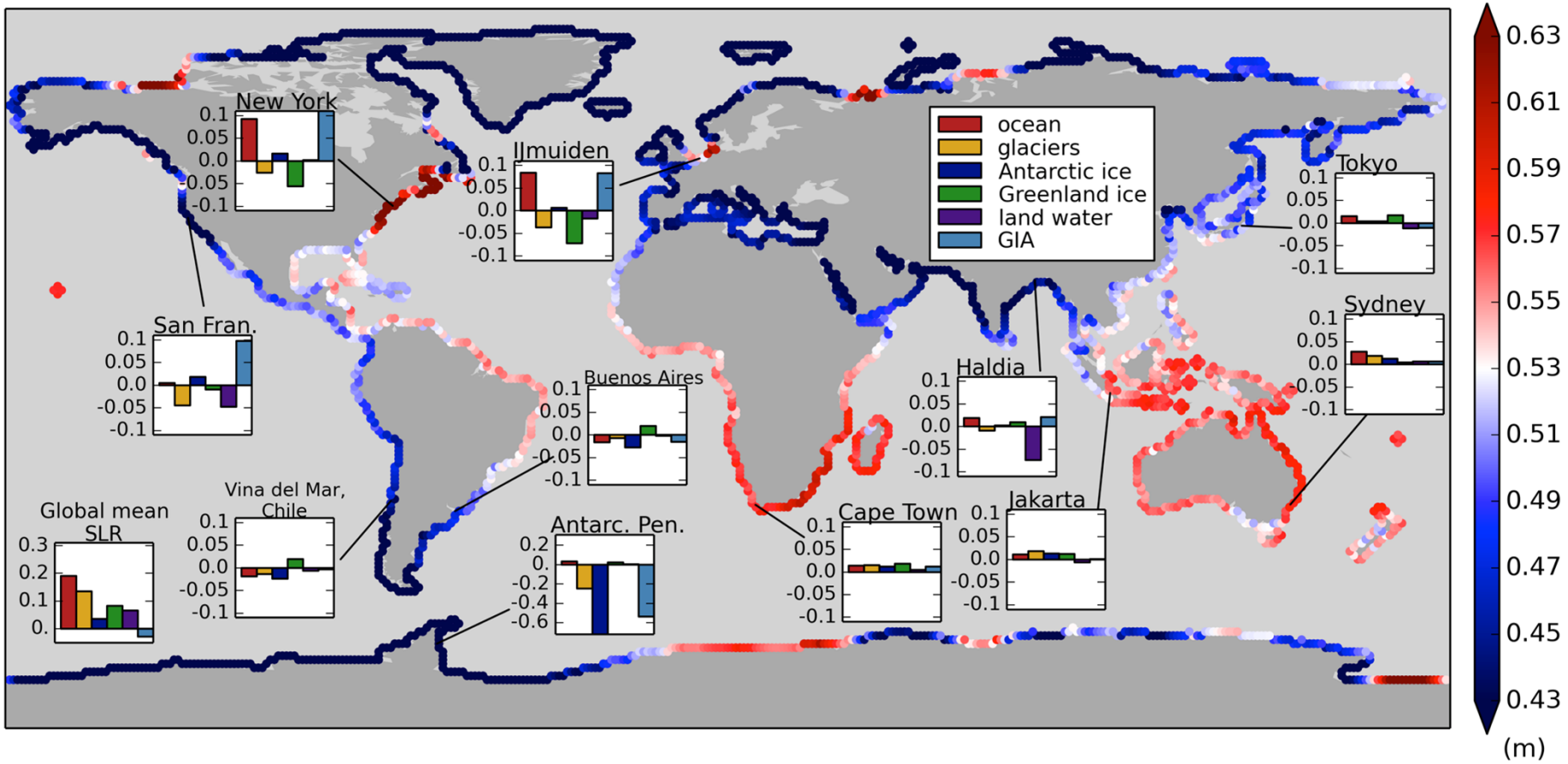


Net Sea Level Change
(plus a few other terms)



Slangen et al.(2014)

Coastal sea level by component.



(Carson et al., 2015)

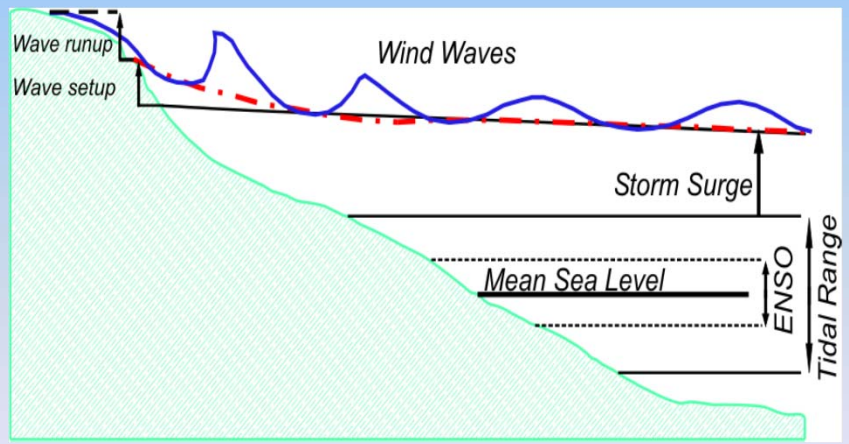
Extreme Sea Levels

Many factors can contribute

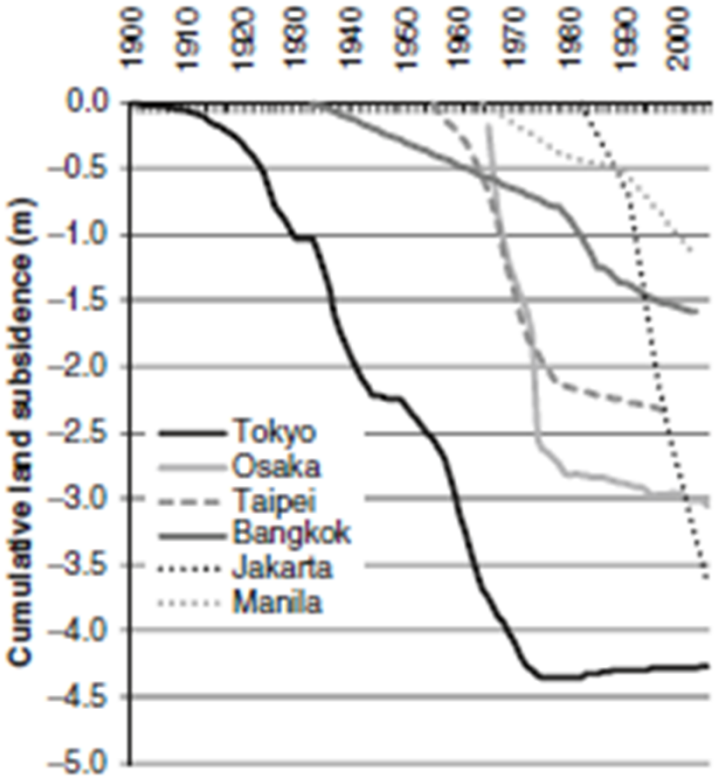
TIME SCALE	SPACE SCALE
seconds	wave shoaling zone 10s-100s of metres
hours	----------
hours to days	continental shelf 10s-100s of kilometres
hours to decades	----------
months to years	ocean basin 1000s of kilometres

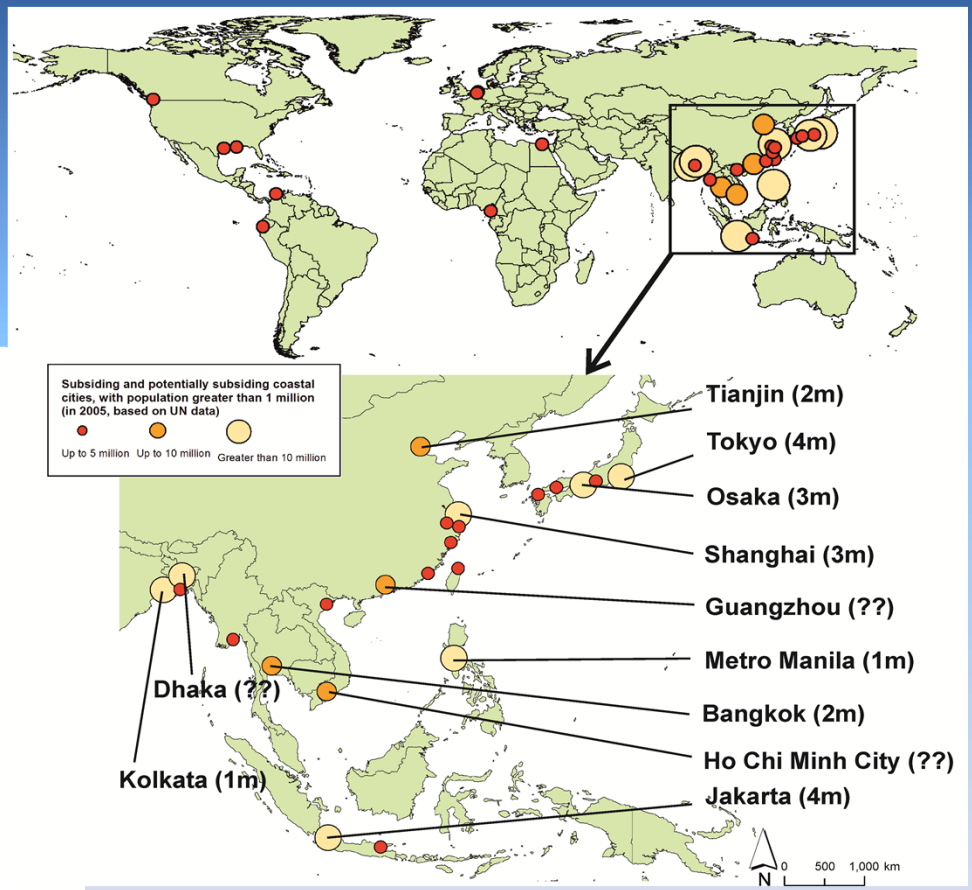
Need to

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



Cumulative land subsidence in large coastal cities





Source: Kaneko and Toyota, 2011 (left); Nicholls, 2014 (above)

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.

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

- Structure of GC Sea Level effort consists of a **GC steering team** and **working groups (WG, order 30 people, each)** underneath, focusing on individual subjects.
- **GC Sea Level co-chairs (3) involve ocean, cryosphere, coastal sciences**.
- 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 envisioned, involving theoretical concepts, observations and models.
- Membership within WGs involves members from CLIVAR/CLIC/GEWEX/SPARC, modeling groups, but also from other relevant programs (e.g, PAGES, IAG).

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.

Status and Steps ahead

- Approval of science plan at CLIVAR SSG 21 (Nov. 2014)
- First Steering team meeting: March 19/20 2015.
- Report to JSC in April 8/9 2015
- Work in WPs started
- Workshop with coastal community in planning stage
- Sea Level conferences 2016 and 2021
- Outreach activities
- Summer schools every 2nd year

1st GC Sea Level SSC Meeting
Utrecht, March 19/20, 2015

- Finalize the science and implementation of WPs
- Setting up WP teams
- CMIP6, ISMIP6, and FAFMIP
- Start the planning for the Sea-level Conference 2016 (with a second planned a few years later, e.g., 2021).
- National programs and proposal opportunities
- Outreach
- Any other activity

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	

1st Meeting, Utrecht

(Solar Eclips!)

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

- 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 2016 and 2021 Sea Level -Symposia
- 2015 Summer School (every 2 years)

„Big“ Milestones

- **White paper on what is required for sea level research; what are the challenges; what is required to solve them?**
- **Document: Usage of sea level information for coastal communities**
- **Report: What information is required to inform coastal zone management and climate mitigation?**
- **New GIA model**
- **DEM of areas below 10m for the global coast line (including islands)**
- Set-up of Sea level relevant data “clearing house”
- Workshop with coastal communities.
- 2016 Summer School (building on Delft 2014, every 2 years)
- **2016 Sea Level Symposium, e.g., New York**
- 2021 Sea Level Conference, e.g., Bangladesh

Data and Modeling Efforts

- The GC team will write summaries on data and modeling issues, bringing together information and recommendations from all working groups.

- ISMIP6
- FAFMIP

Ice Sheet MIP for CMIP6

Steering Group has been formed and has started meeting regularly via skype.

Discussing **first inter-comparision** which will be announced at the **EGU** and will be focussed on **initial states for the ice sheets.**

Modelling communities represented: AOGCM, oceans, ice-sheet and glaciers.

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

A. Abe Ouchi (JP) H. Goelzer (BE) J. Gregory (UK)

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

Major Questions:

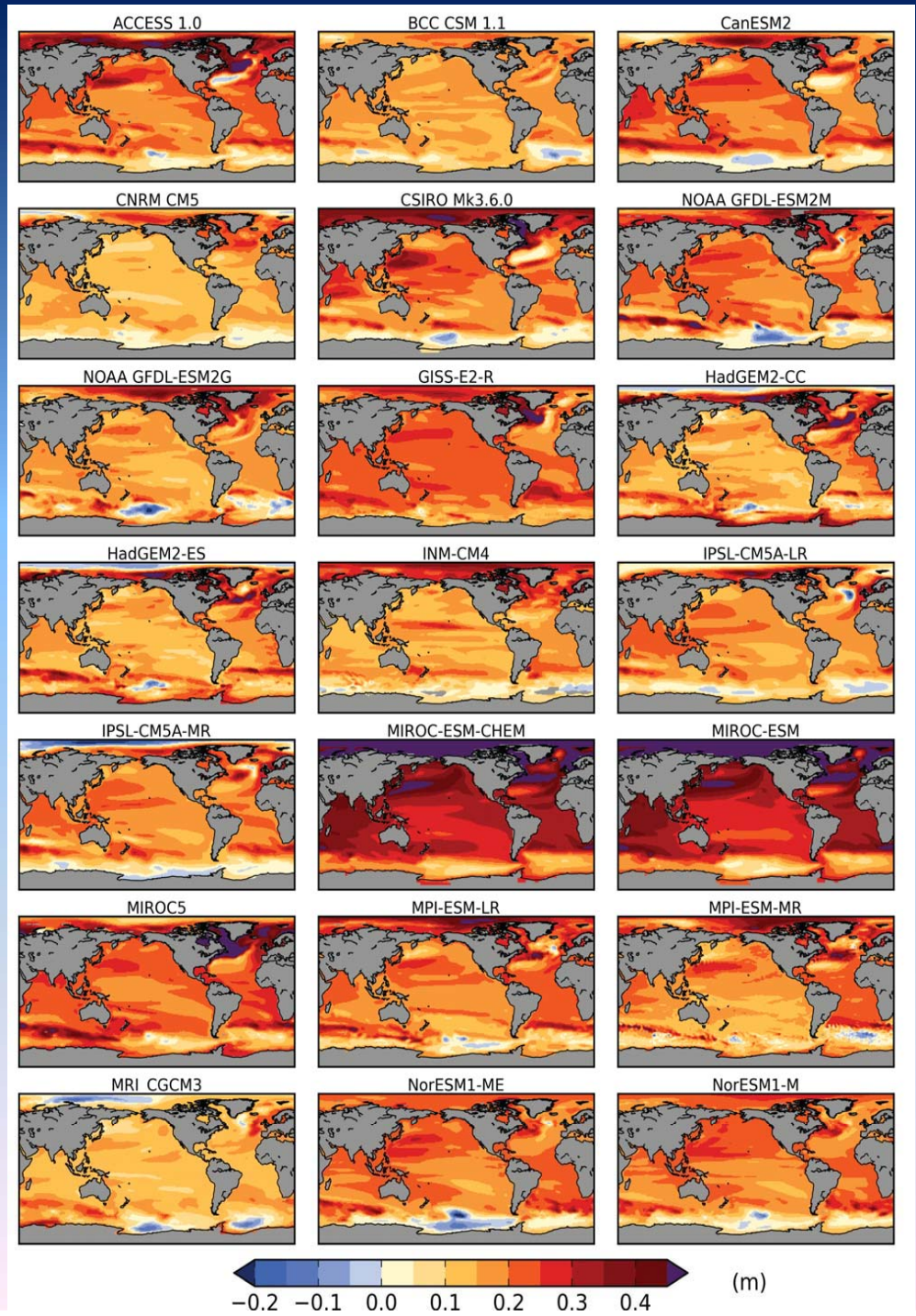
- How close are we to having models that could run as part of a CMIP-style ESM? And how adequate are CMIP models over the cryosphere?
- What are the major obstacles to credible projections of the cryospheric components of sea level?
- What data sets are needed (model + observations)?
- What experiments (coupled or not) should we run for Greenland and Antarctica?

Major outcomes

- Several climate models have an interactive ice sheet component
- Coupled experiments with Greenland to be proposed, primarily to encourage development in this area
- Not yet realistic to expect this for Antarctica.
- Standalone experiments for both ice sheets using off-line forcing from CMIP.
- **Ensemble-based approach seems essential.**

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.**

Sea Level Conference 2016

- Chairs: co-chairs of GC Sea Level

- Science Steering Committee: GS SSC plus J. Church (link to 2006);
- Potential advisor: Phil Woodworth;
- To be clarified: role of IOC

- Potential venues:
- Paris
- NYU
- Boston (Harward; Dan Schrag)
- Singapore

- To clarify with IOC: Connection to NY United Nations

Thank you!

Topic *I: 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 data set of paleo sea level change

Topic 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)

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

Leads: Rui Ponte, Catia Domingues, Benoit Meyssignac, Kevin Horsburgh, 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.
- Understanding contemporary subsidence and extremes.

Topic 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.

Challenge 5: **Sea level science for coastal zone management**

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

- **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.

WCRP Grand Challenges