Coastal/regional perspective on observational and synthesis requirements for characterizing contemporary sea level rise and predictability

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1) Contributions to regional sea level rise

2) Coastal versus deep ocean sea level

3) Vertical Land Motion(VLM)

4) Extreme coastal water levels

Projections of regional sea level change, IPCC AR5

2081-2100 relative to 1986-2000

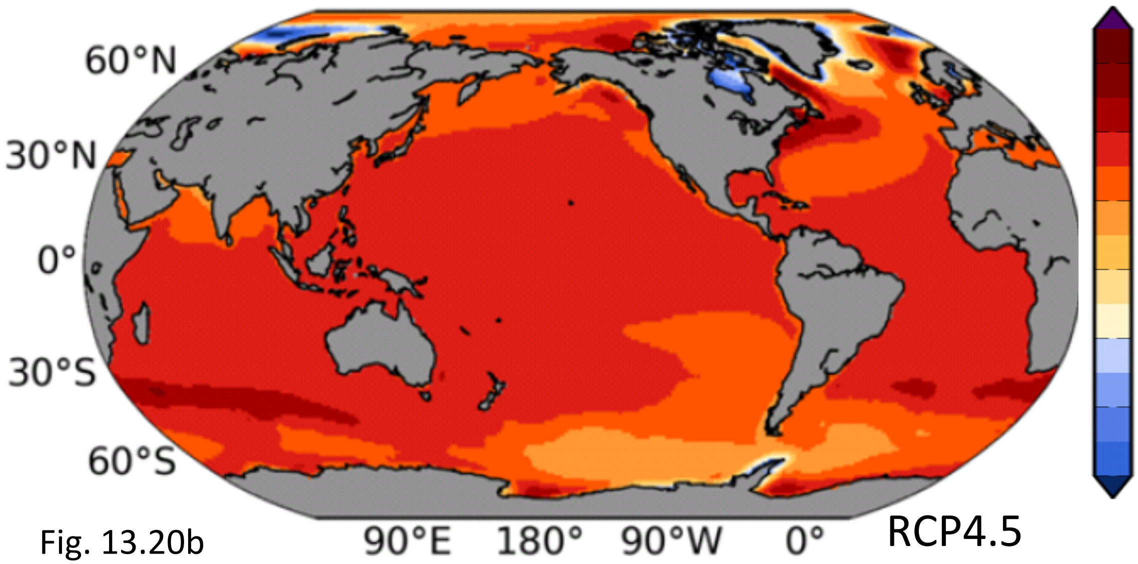
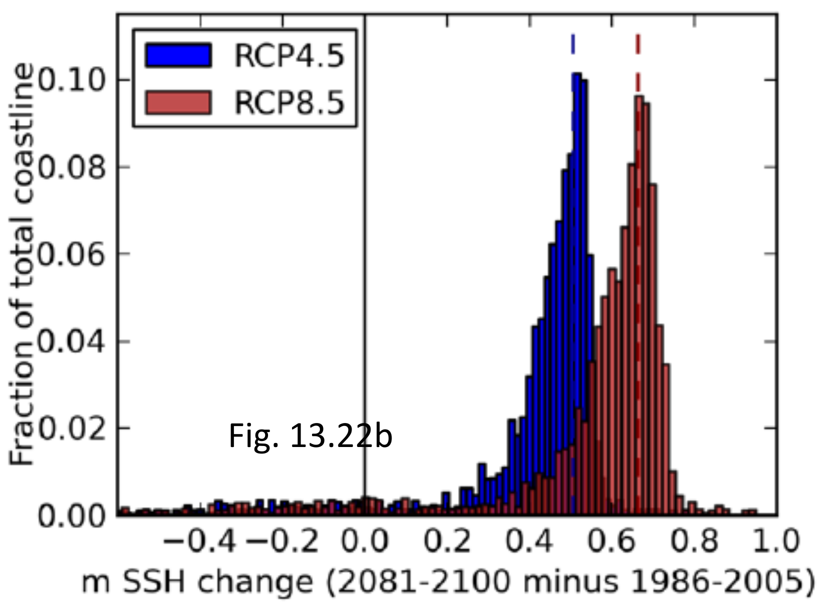


Fig. 13.20b



Regional sea level changes result from ocean dynamical processes, movements of the sea floor, and changes in gravity due to water mass-redistribution (land ice and other terrestrial water storage).

About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change.

Global vs. regional sea level rise

Global Mean Sea Level

Ocean
- Density
  - Temperature

Land Ice Mass Change
- Glaciers
- Ice sheets
  - Surface Mass Balance
  - Ice Dynamics

Land Water Storage
- Groundwater extraction
- Reservoir Storage

Regional Sea Level

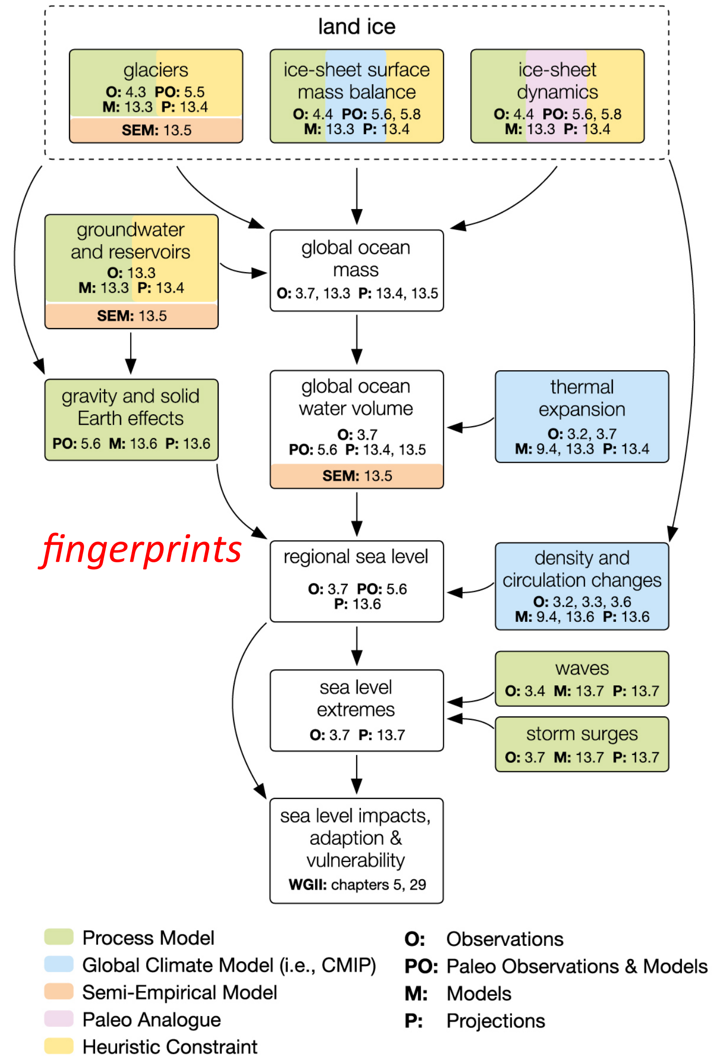
Ocean
+ Circulation
- Density
  + Salinity

Land Ice Mass Change
+ Gravitational Effect
+ Solid Earth Deformation
+ Rotation Changes

Land Water Storage
+ Gravitational Effect
+ Solid Earth Deformation
+ Rotation Changes

+ Vertical Land Movement
- Glacial Isostatic Adjustment

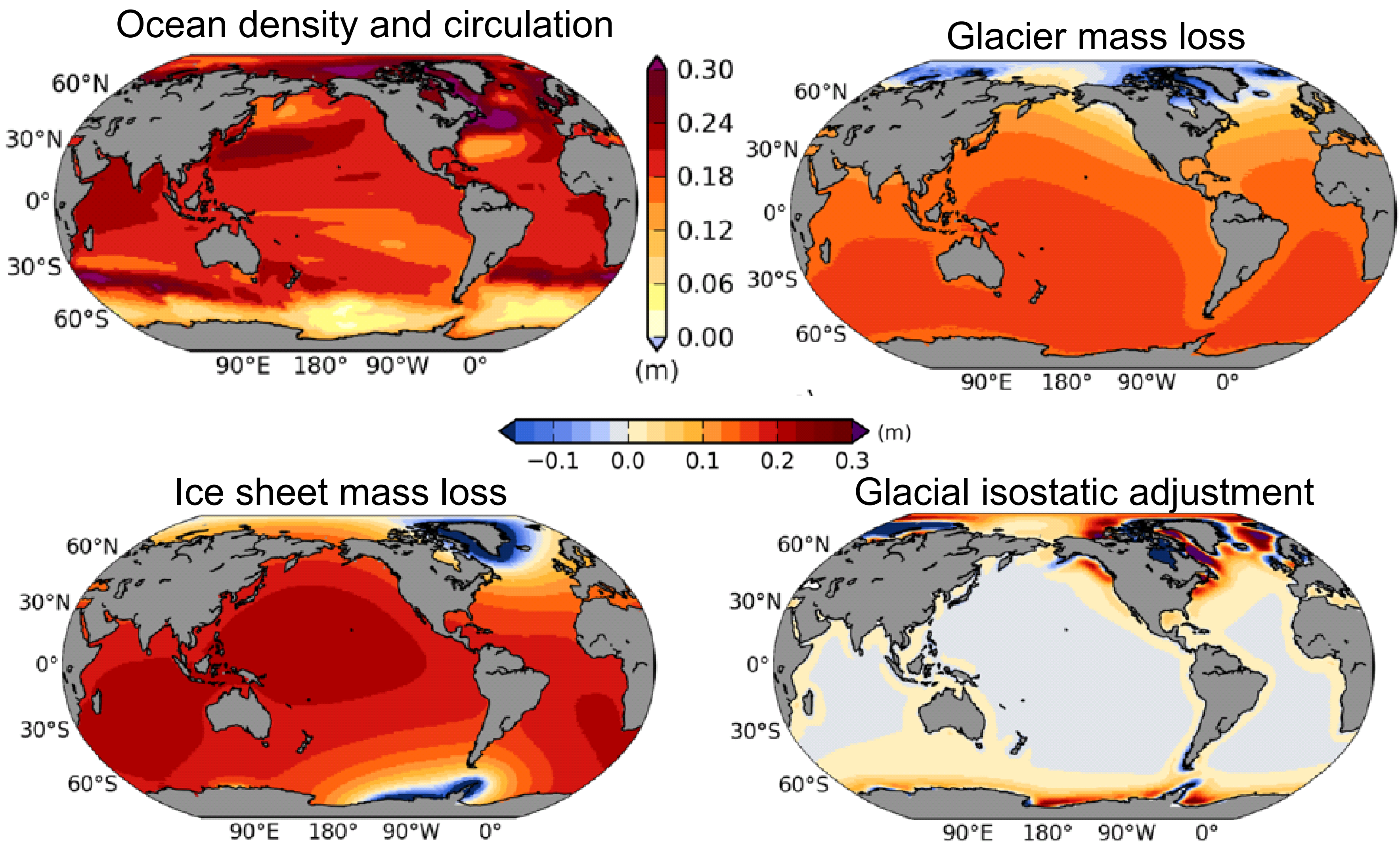
+ Atmosphere
- Inverse Barometer



Slangen, WCRP/Conference 2017

IPCC, AR5,WG1 Fig. 13.2

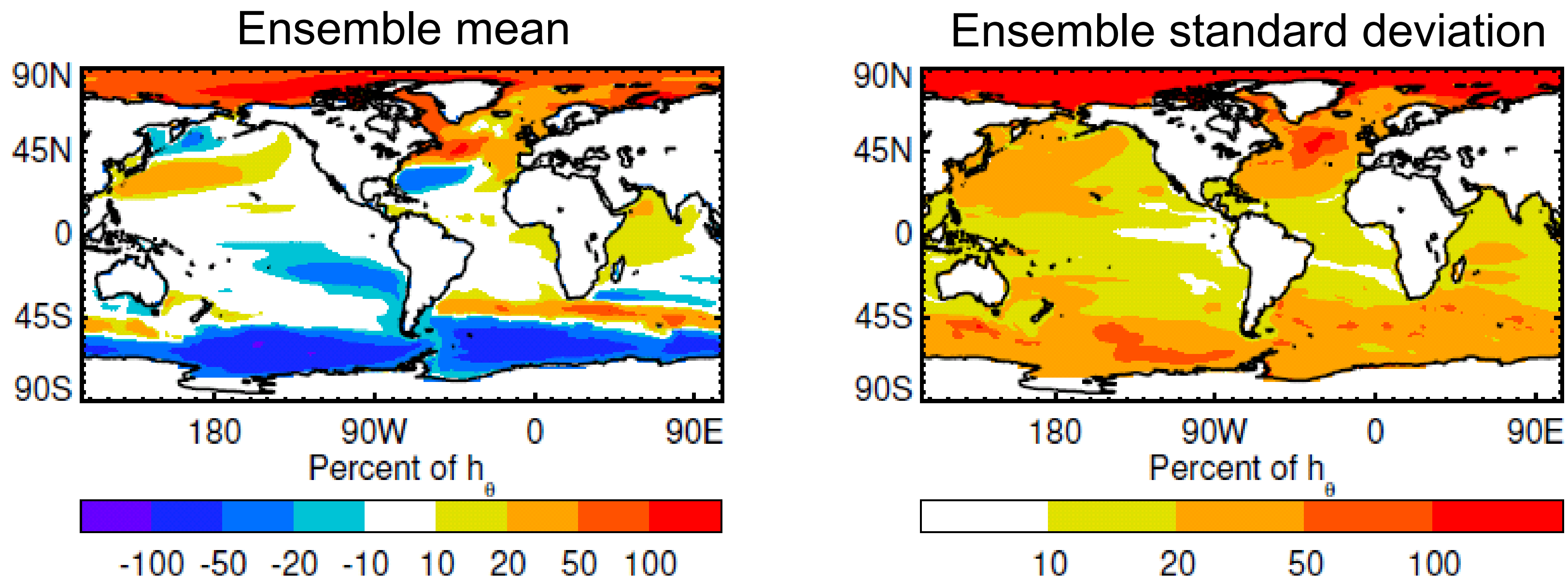
Contributions to the geographical variation of sea level rise



Figures 13.16 and 13.18, for RCP4.5 2081-2100

Gregory, WCRP/Conference 2017

Dynamic sea-level change $\Delta\zeta$ (% of global mean thermosteric SL rise) in the CMIP5 ensemble for 2081-2100 under RCP4.5



Gregory, WCRP/Conference 2017

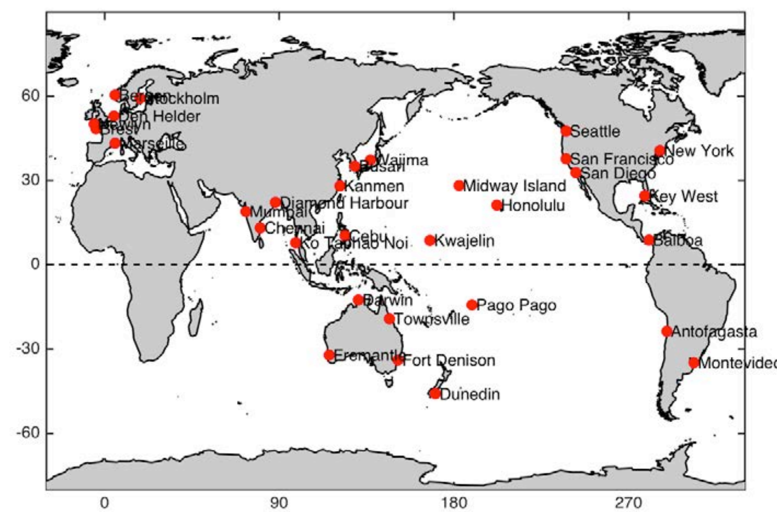
Future:
CMIP6 models
Coupling to ice sheet models (freshwater forcing)

Context

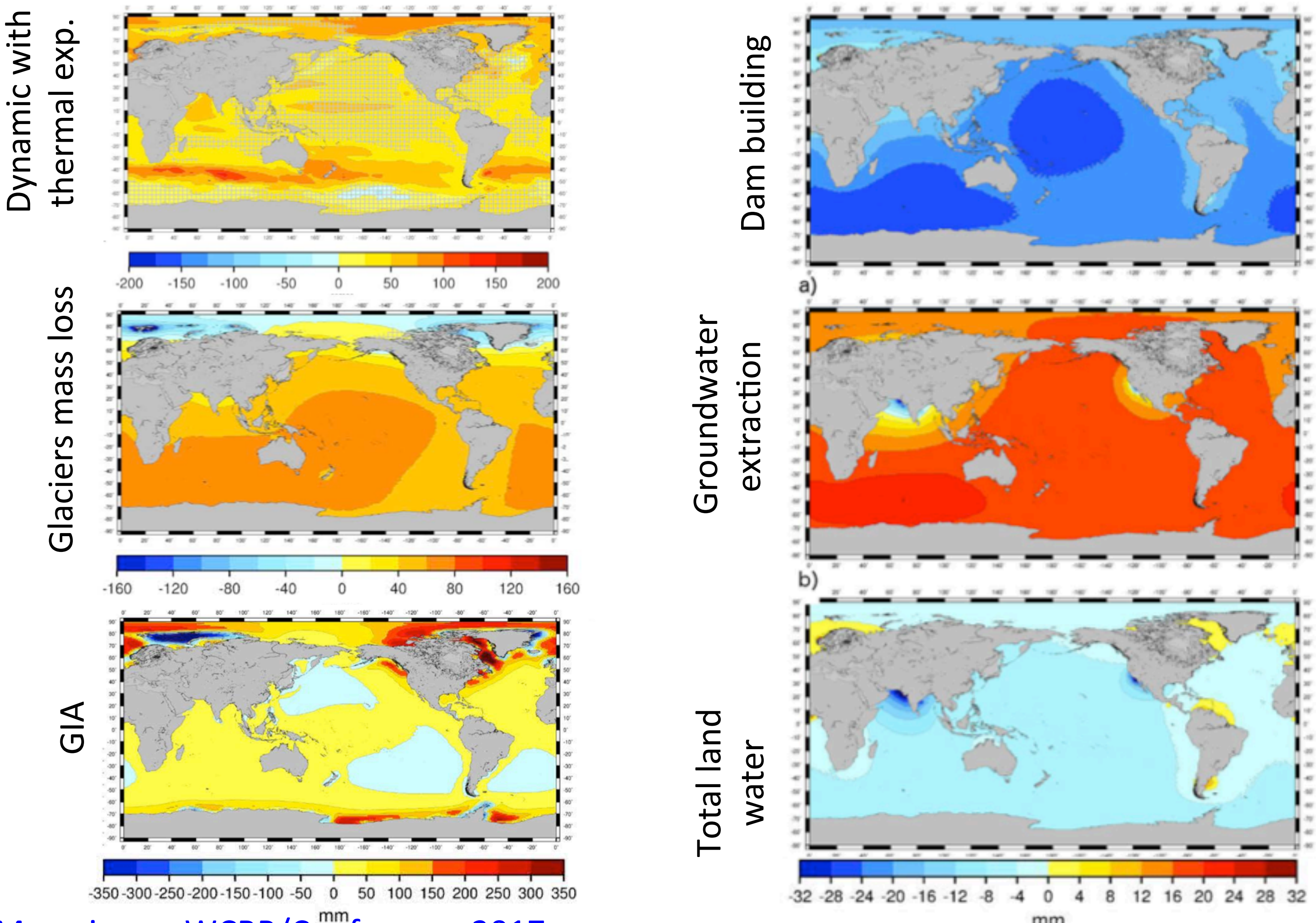
Aim: **Assess the simulation of 20th century global and regional relative sea level changes in CMIP5 climate models**

Method:

- Estimate **dynamic sea level, glaciers mass loss, ice sheet SMB** contributions from **12 CMIP5 climate model** simulations
- Estimate **GIA** contribution from GIA models
- Add observations of the **ice sheet dynamics** and **land water storage** changes
- Compare total global and regional sea level changes with **27 TG records**



Modelled sea level: 1996-2015 wrt 1901-1920

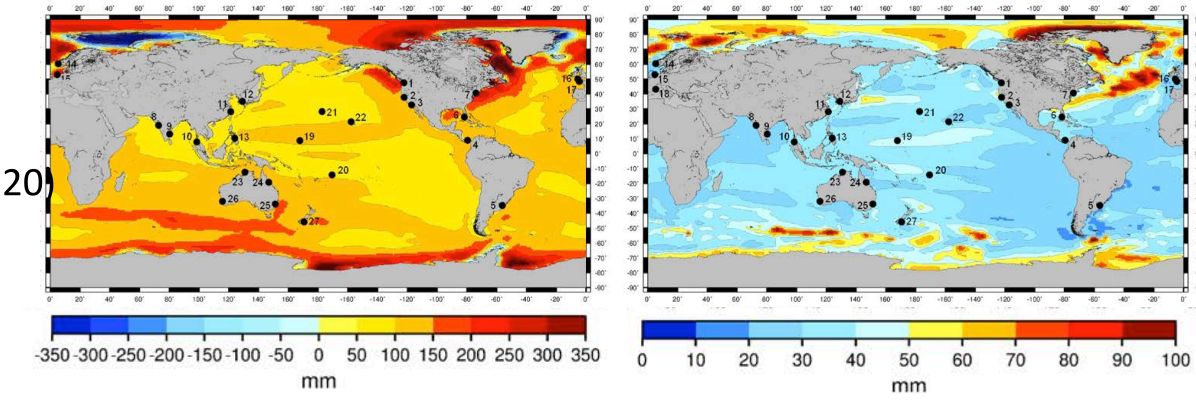


Meyssignac, WCRP/Conference 2017

Comparison with tide gauge records

Total sea level

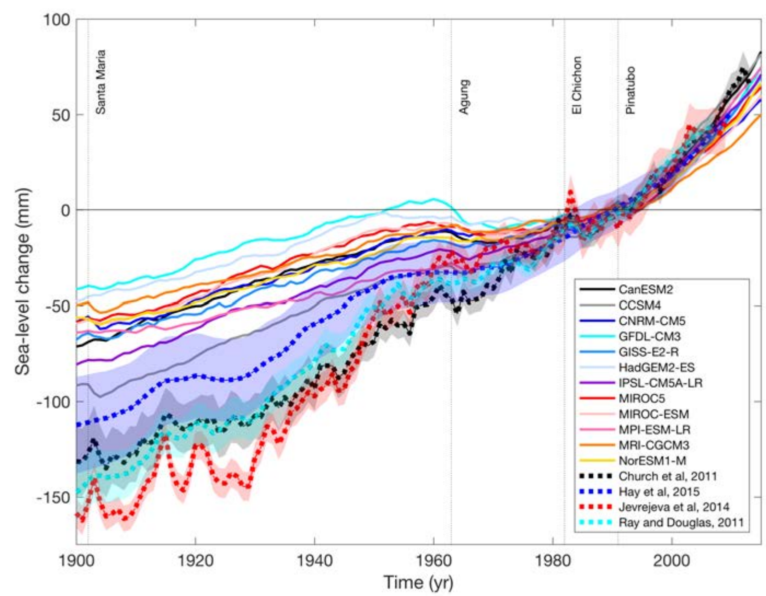
(1996-2015 wrt 1901-1920)



Global Total sea level vs observations:

50 ± 30% explain over 1901-2007

102 ± 33% explain over 1993-2015

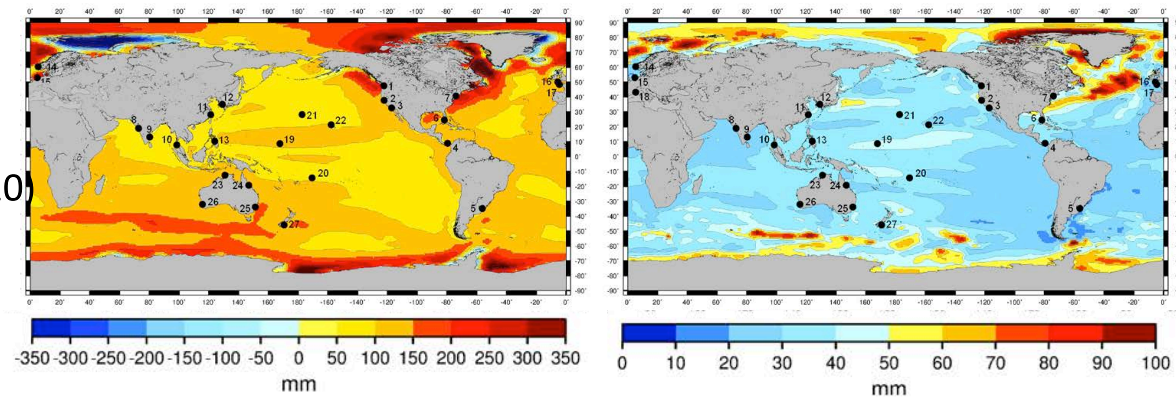


Meyssignac, WCRP/Conference 2017

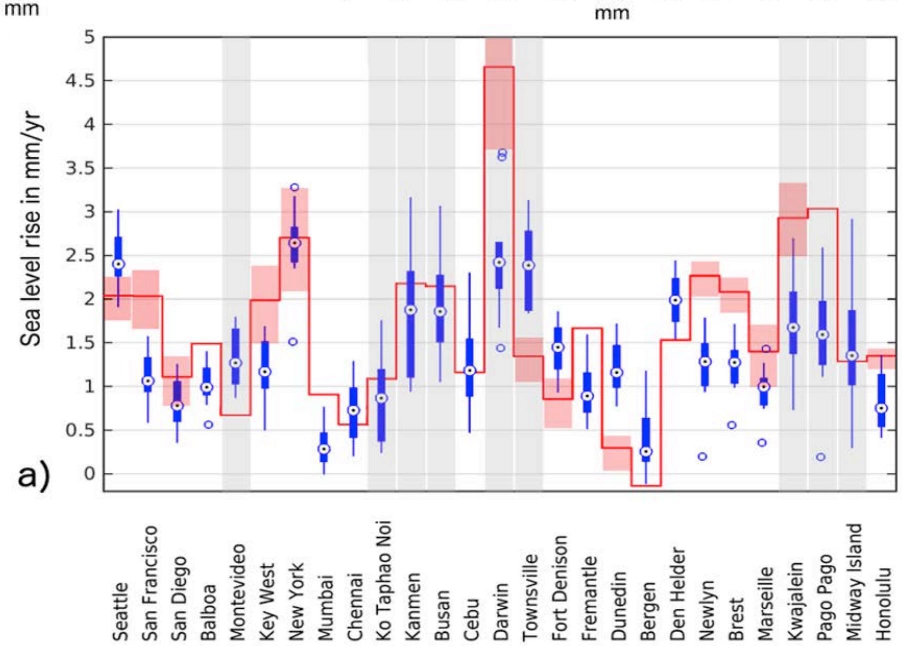
Comparison with tide gauge records

Total sea level

(1996-2015 wrt 1901-1920)

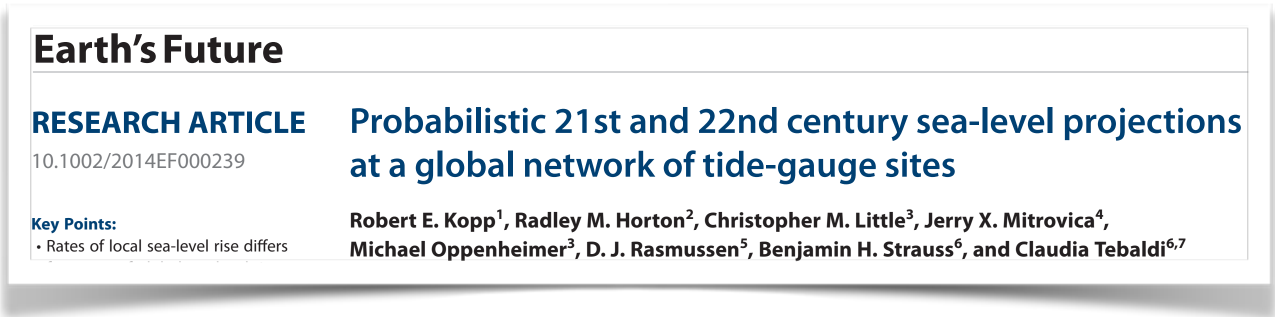


Total sea level vs local observations:
Diff: 0.27 ± 0.77 mm yr^{-1}



Meyssignac, WCRP/Conference 2017

Kopp et al. 2014 probabilistic framework

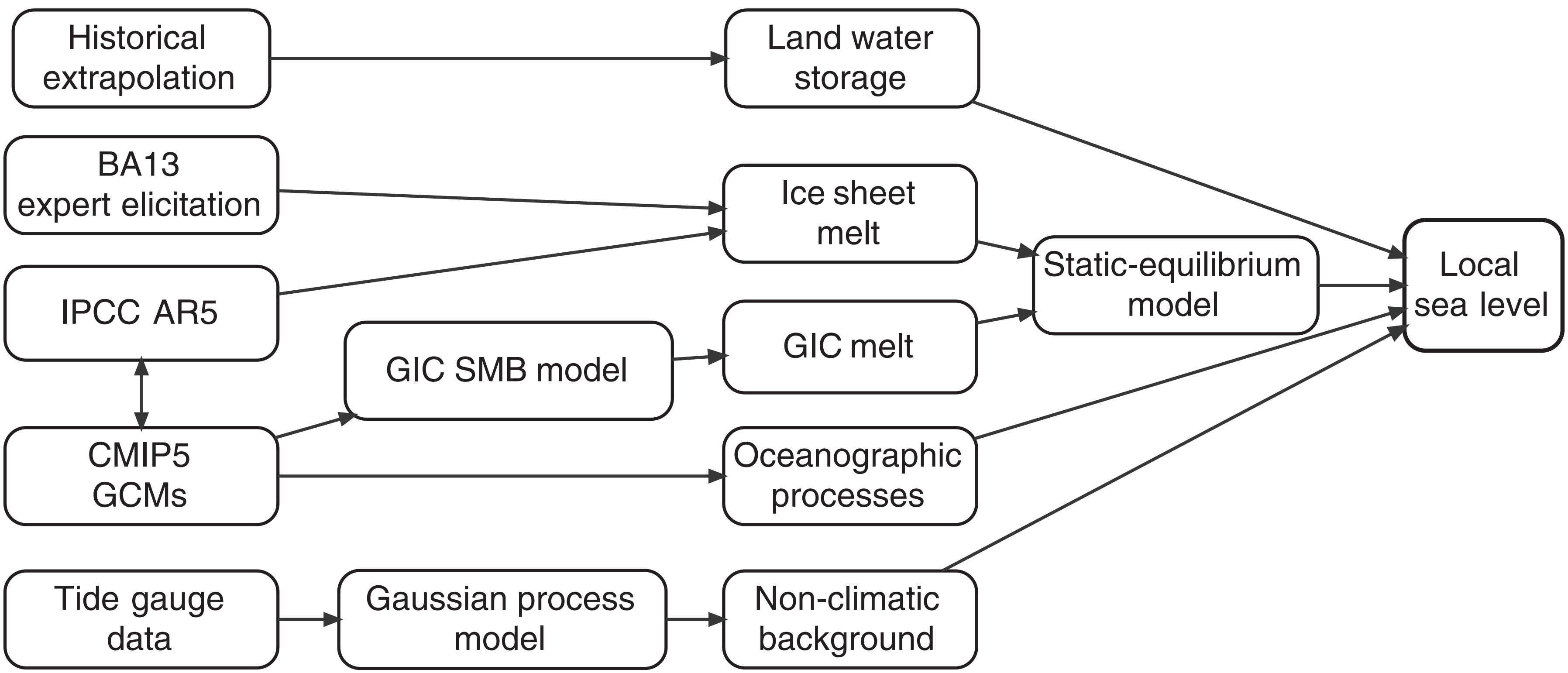

Earth's Future

RESEARCH ARTICLE
10.1002/2014EF000239

Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites

Robert E. Kopp[1], Radley M. Horton[2], Christopher M. Little[3], Jerry X. Mitrovica[4], Michael Oppenheimer[3], D. J. Rasmussen[5], Benjamin H. Strauss[6], and Claudia Tebaldi[6,7]

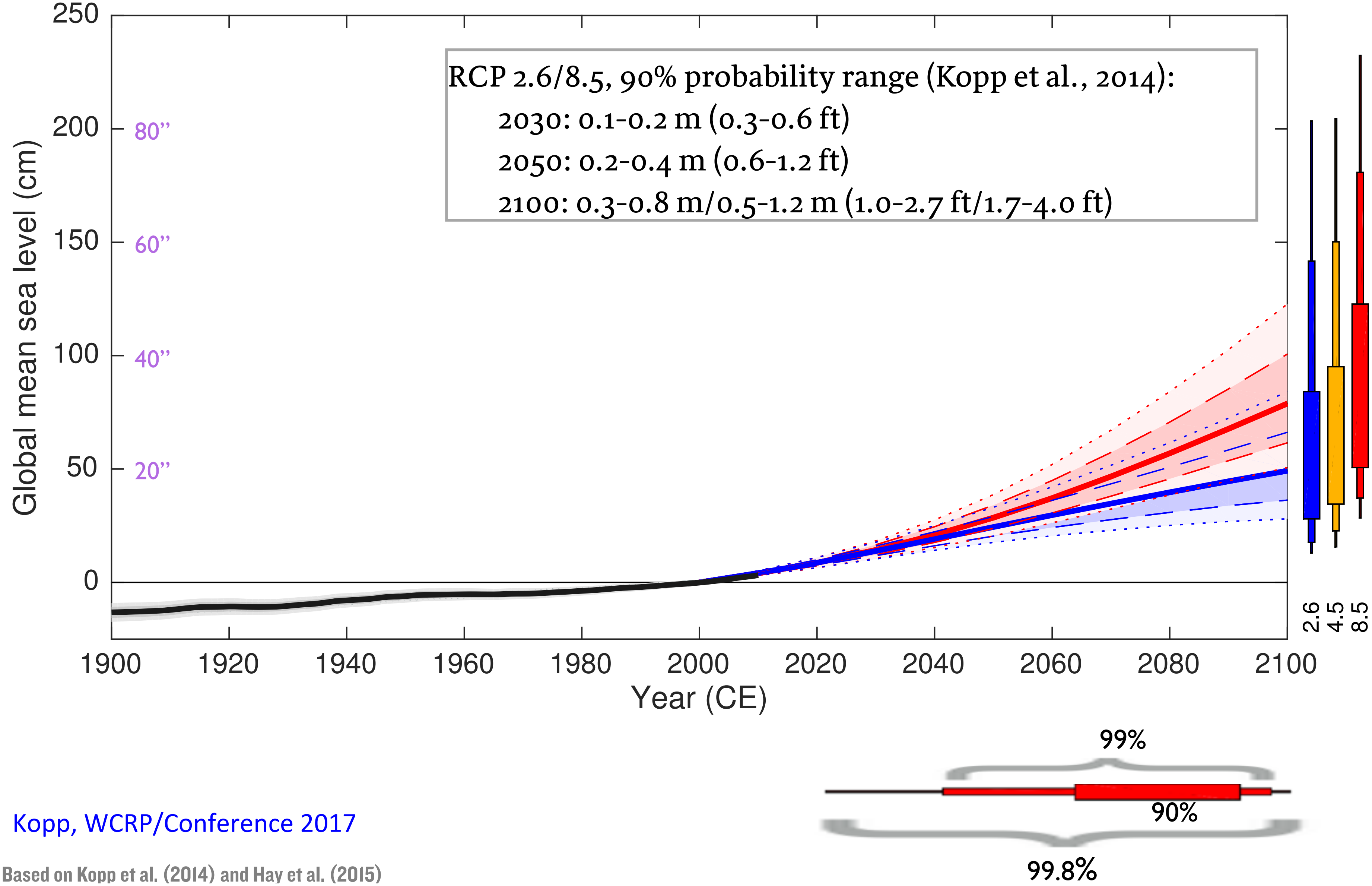
Key Points:
• Rates of local sea-level rise differs



Kopp et al. (2014)

Kopp et al 2014 probabilistic projections of global sea-level rise

Centimeters/Inches global mean sea-level rise above year 1991-2009 levels



Kopp, WCRP/Conference 2017

Based on Kopp et al. (2014) and Hay et al. (2015)

“Natural Variability of Regional Sea Level in a High Resolution Global Coupled Climate Model”

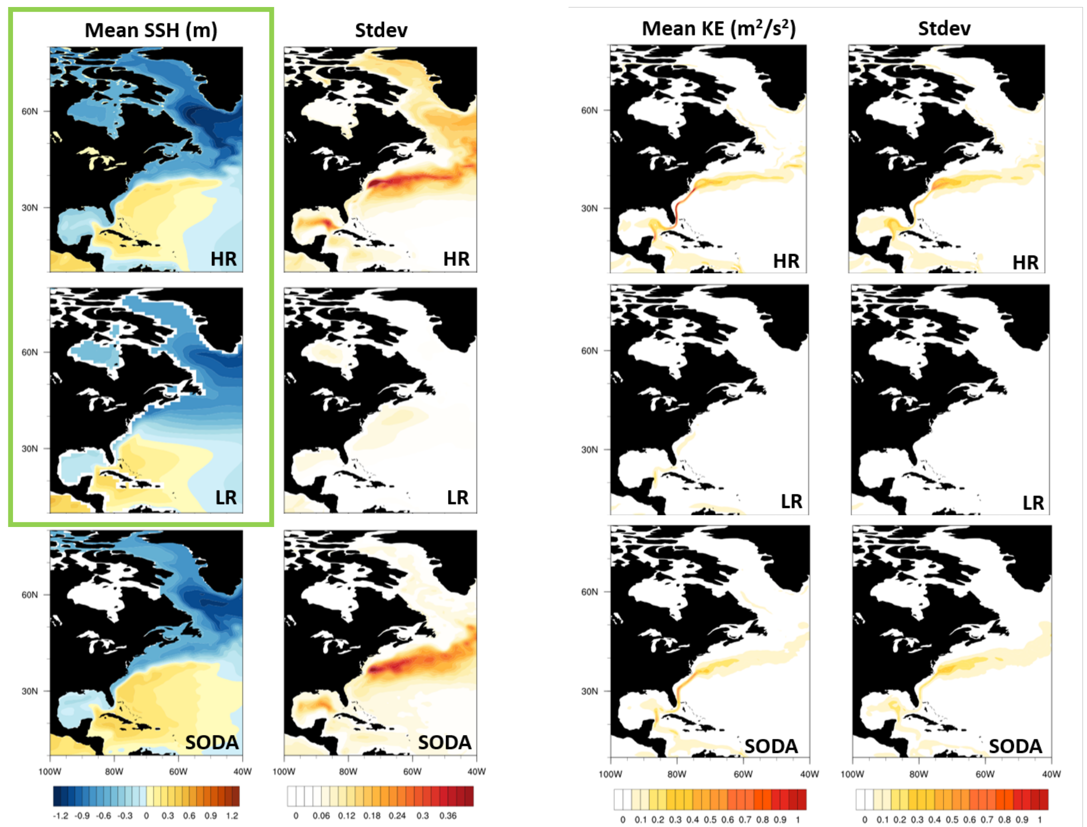
Diane Palko and Ben Kirtman

CCSM4

- Fixed 1990 forcing
- 4 high resolutions (HR) runs
  0.1° in the ocean
  220 years
- 1 low resolution (LR) run
  1.0° in the ocean
  100 years

SODA Reanalysis

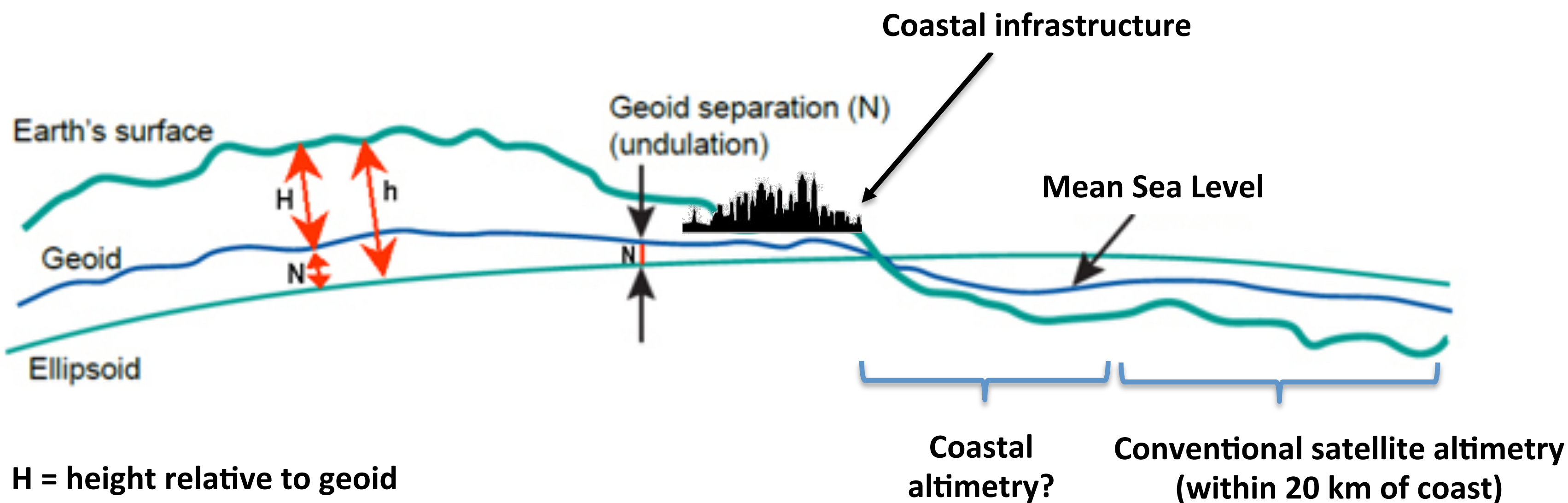
- 0.5° in the ocean
- Detrended
- Corr = .65 between SODA and tide gauges



Palko and Kirtman, WCRP/Conference 2017

Assessing Coastal Inundation

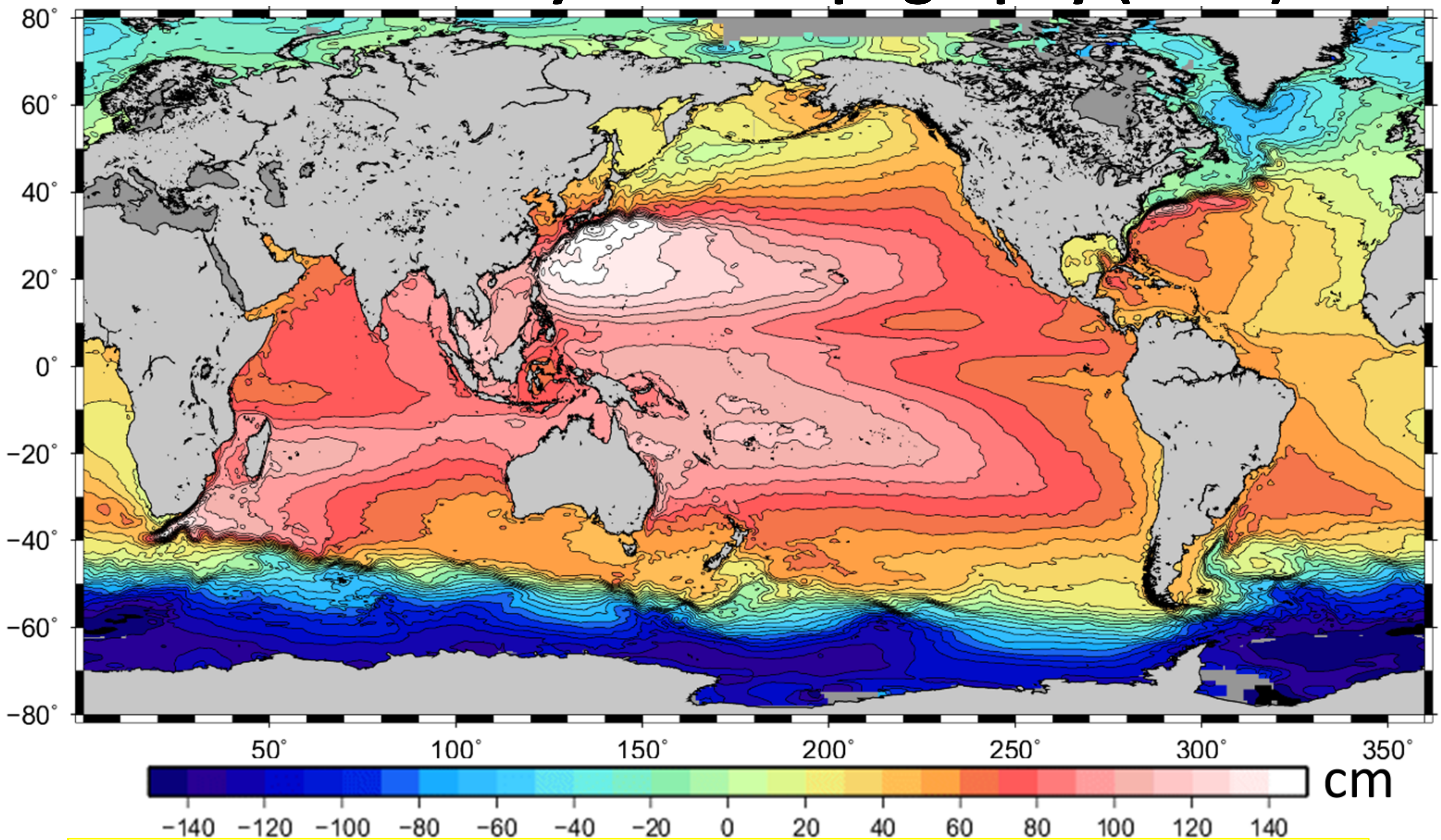
To compute the potential inundation from future sea level rise projections, we need to know mean sea level (relative to a well-defined time, e.g. 2000.0) relative to the coastal topography (from a DEM). Tide gauges can provide this, but we need to know this at all coastal locations. Satellite altimetry, when coupled to DEMs, can provide this, but we need coverage into the coastal zone because coastal mean sea level can be quite different from the open ocean.



H = height relative to geoid
h = height relative to ellipsoid
N = geoid height

Steve Nerem, CU

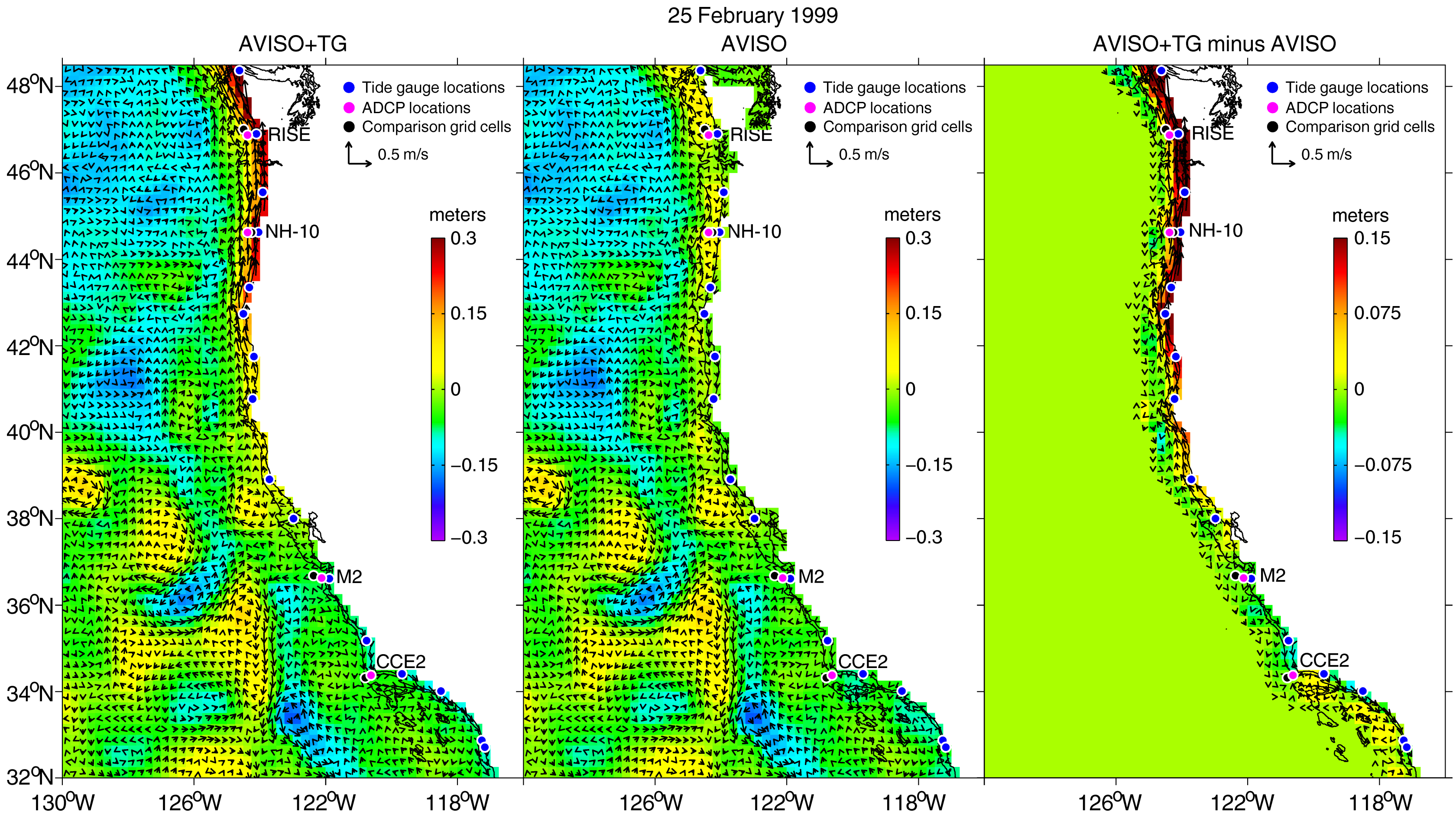
Aviso Mean Dynamic Topography (MDT)



Coastal currents can cause open ocean MDT to be quite different from coastal MDT.

Steve Nerem, CU

Coastal currents from altimetry and tide gauges



Ted Strub, OSU

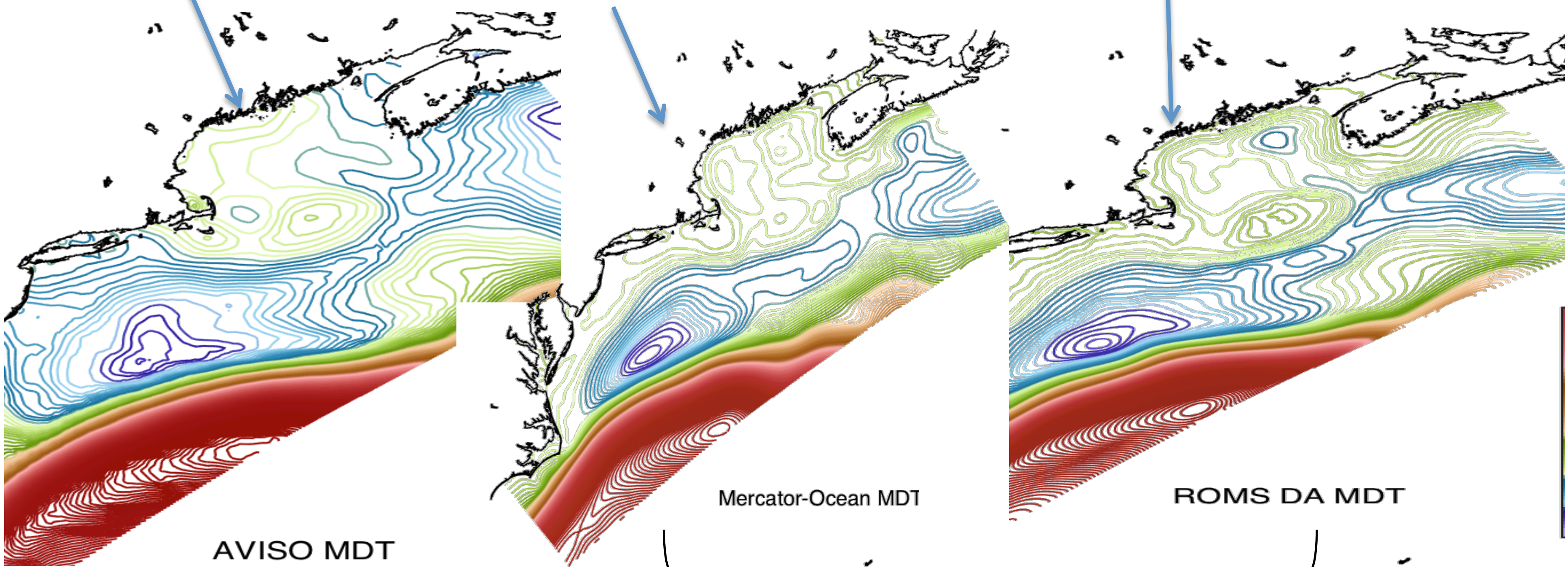
Regional MDT: Northeast USA

To have ADT suitable for coastal oceanography, especially DA, we need MDT accurate to the coast

Regional model after 4DVAR DA on climatological CTD, velocity &wind stress

AVISO MDT

Mercator mean surface height

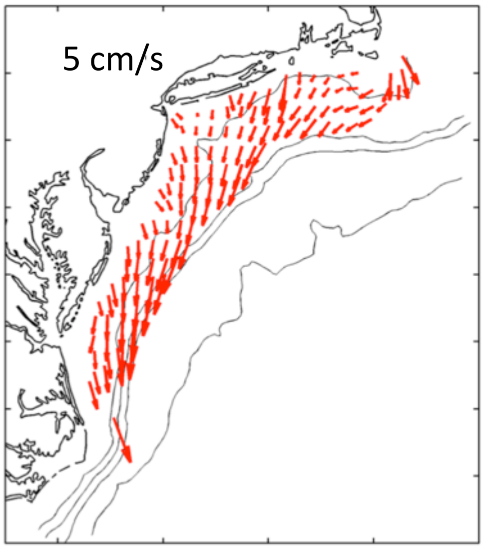


ROMS MDT matched to Mercator sea level datum in open ocean

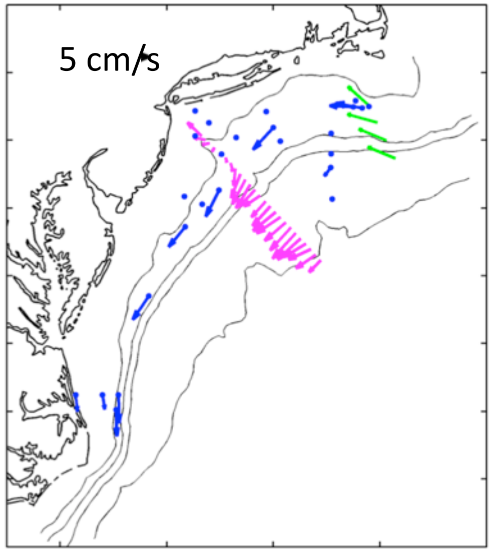
John Wilkin, Rutgers

4DVAR analysis of mean climatological ocean state

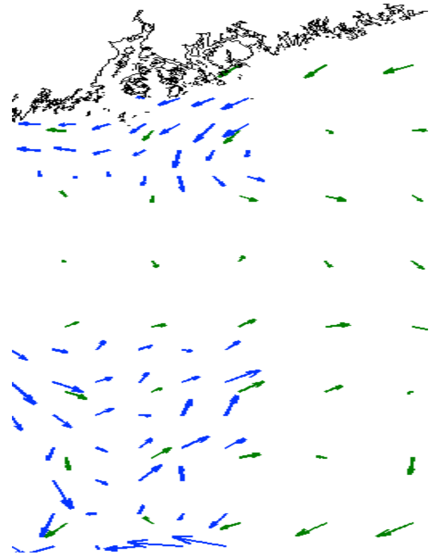
velocity obs. from:
CODAR (red)



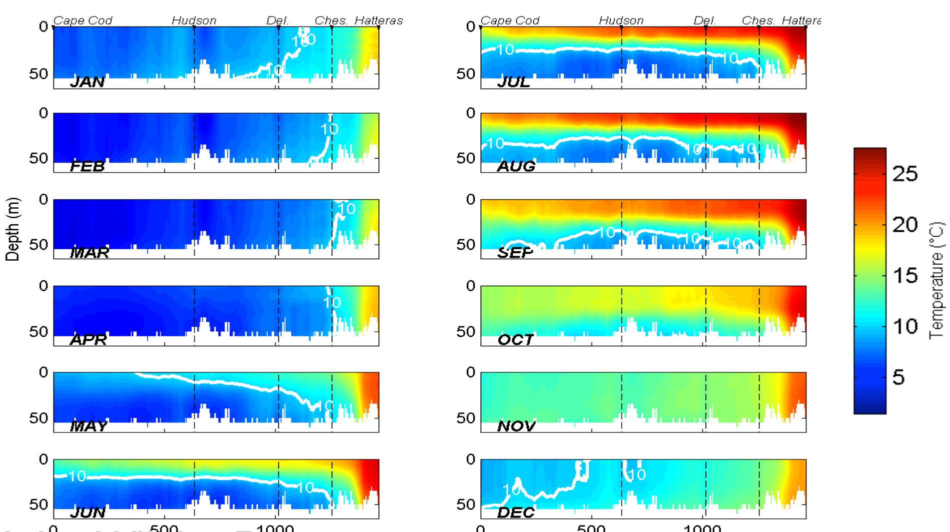
moorings (blue, green)
ship ADCP (magenta)



surface drifters
(blue, green)



+ high-res regional T/S climatology



John Wilkin, Rutgers

ROMS 4DVAR on climatological mean data yields a dynamically and kinematically adjusted MDT and T,S,u,v for OBC bias removal

Recent north-south asymmetry in regional sea level rise

Thompson & Merrifield (2014)

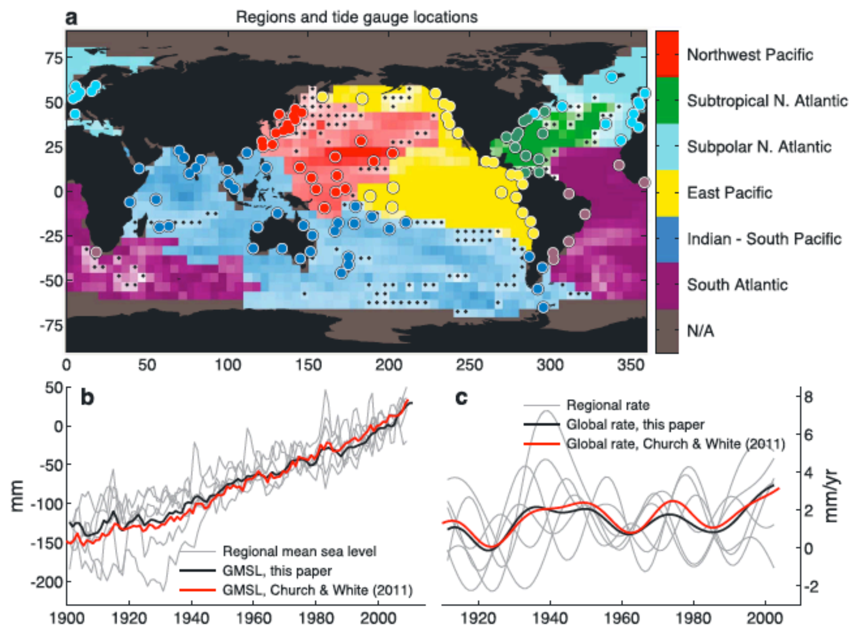


Figure 1. (a) Objectively defined ocean regions and the tide gauge locations averaged within each region. The color saturation of each cell reflects the relationship of each cell to the other cells in its region (see section 2.1). Cells in which the relationship is not significant at the 95% level are marked with small black circles. (b) Regional mean sea level in eacl region and GMSL from *Church and White* [2011] and the area-weighted average of the regional time series. (c) Twenty year rates of change in regional sea level, the area-weighted average of the regional rates, and rates from *Church and White* [2011].

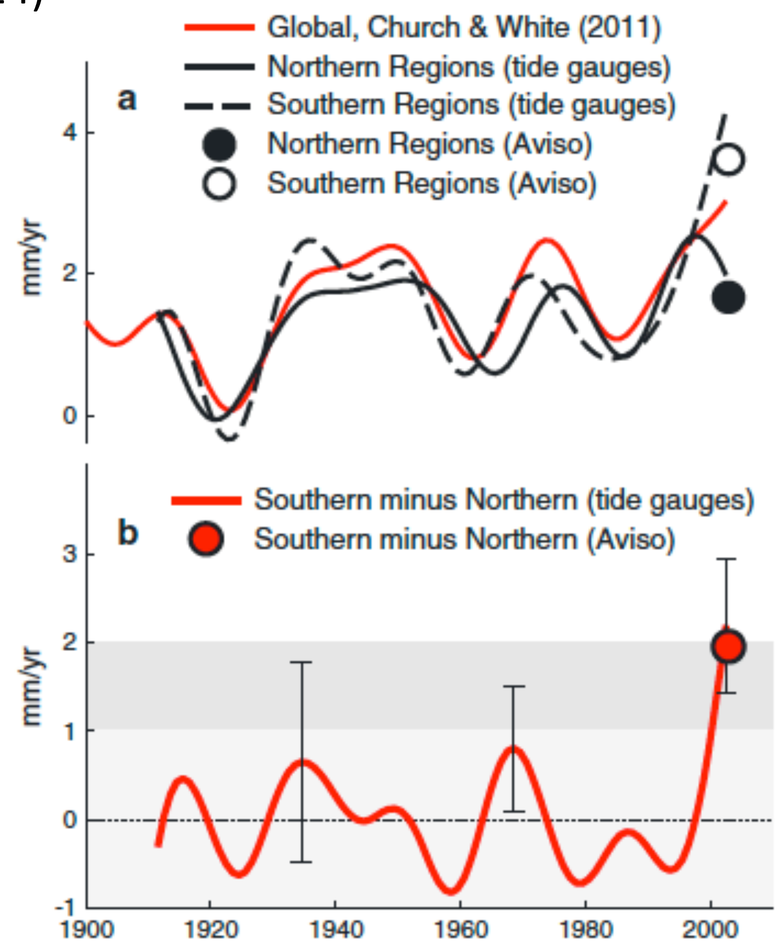
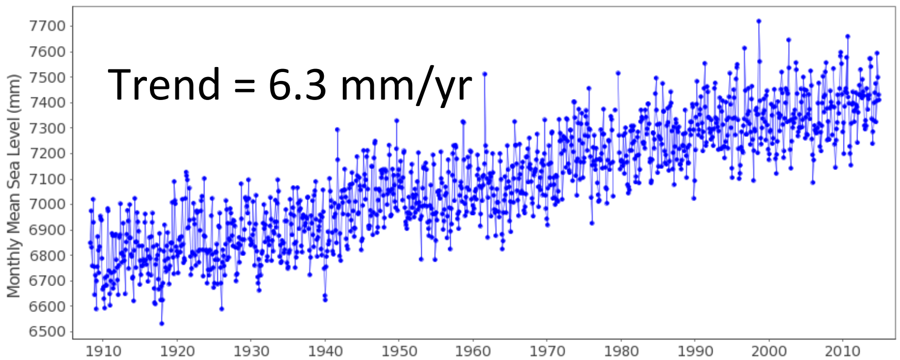
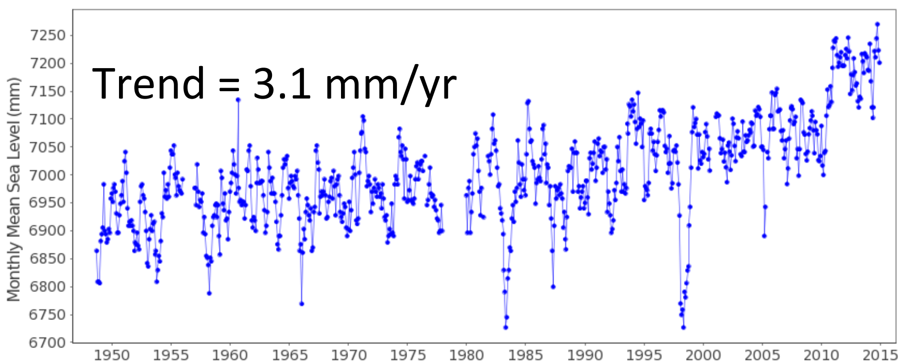


Figure 4. (a) Twenty year rates of change in mean sea level over northern and southern regions from tide gauges, Aviso, and *Church and White* [2011]. (b) The difference between mean rates over northern and southern regions from tide gauges and satellites. Uncertainties (1σ) are shown for the three largest differences in rate from tide gauges.

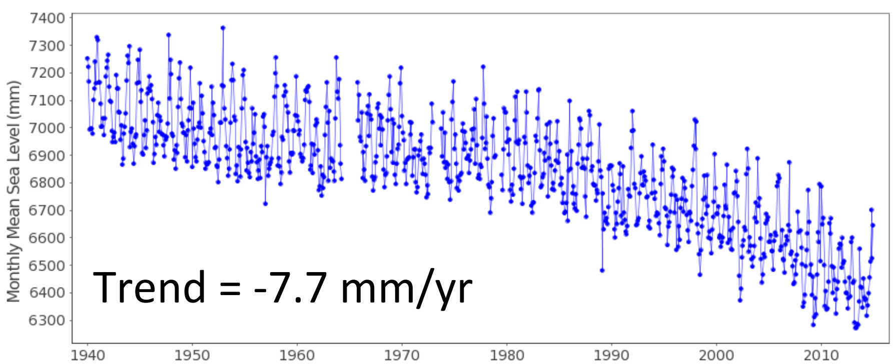
Examples of Vertical Land Motion



Galveston: Subsidence from groundwater/oil extraction



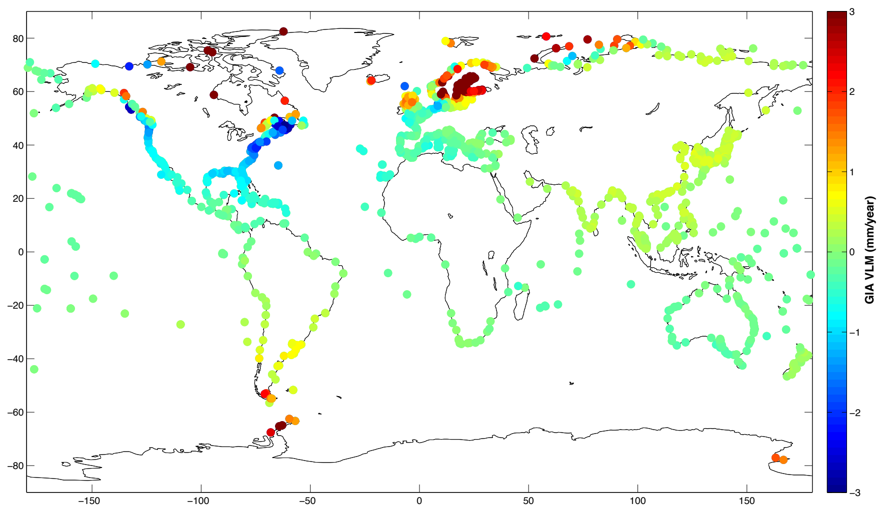
Pago Pago: Earthquakes



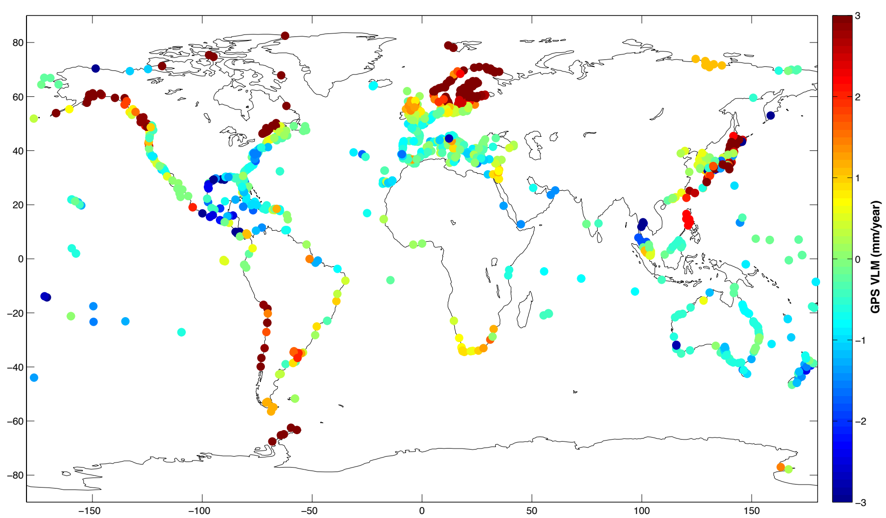
Yakutat: Glacial Isostatic Adjustment (GIA)

Ben Hamlington, Old Dominion

GLOSS Implementation Plan – continuous GNSS monitoring of VLM at core network tide gauges



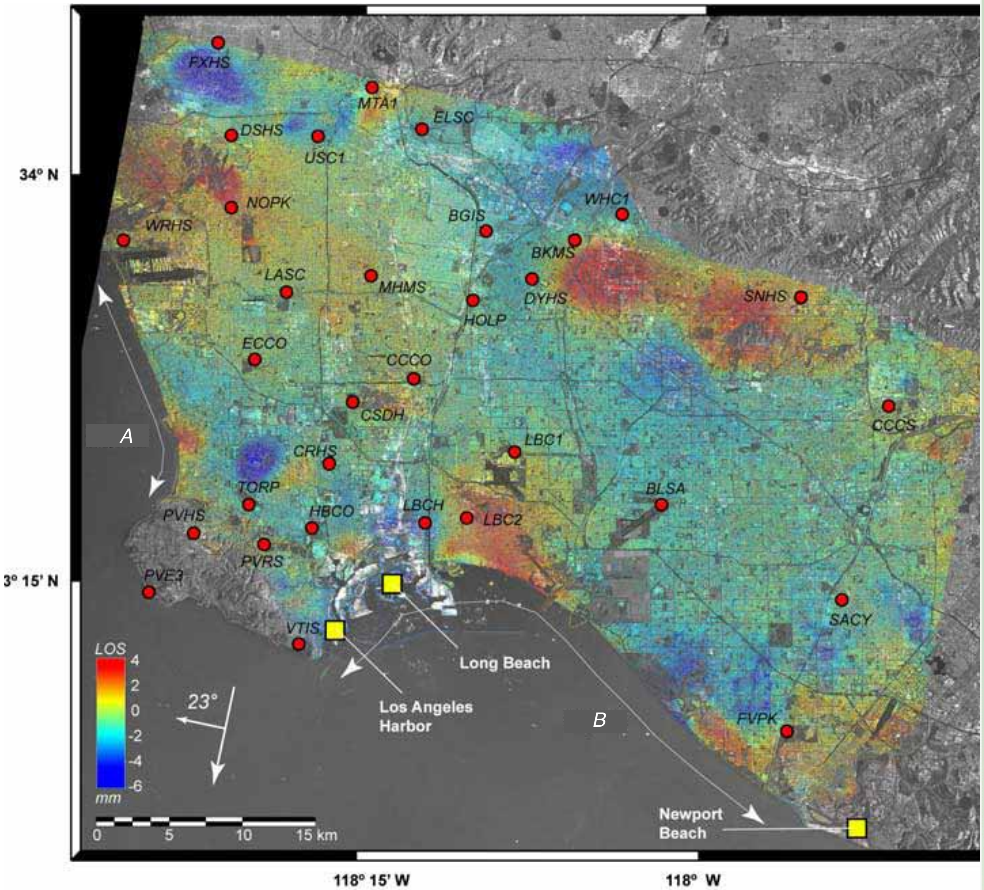
GIA Model



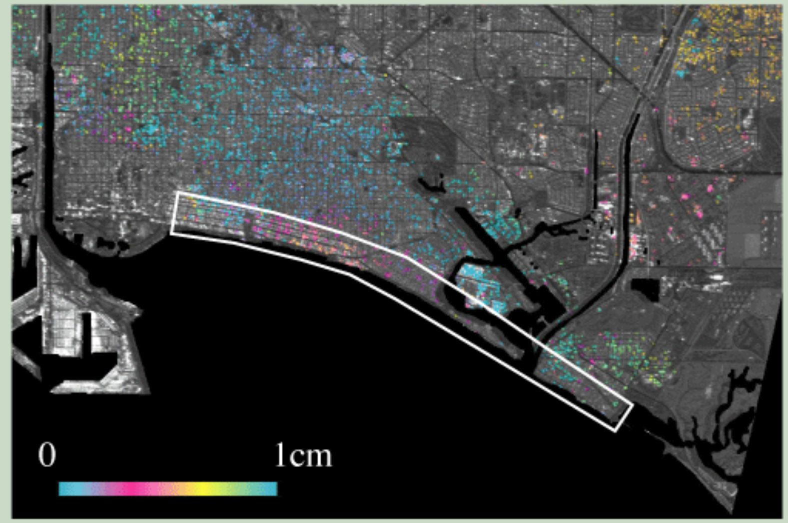
GNSS Observations

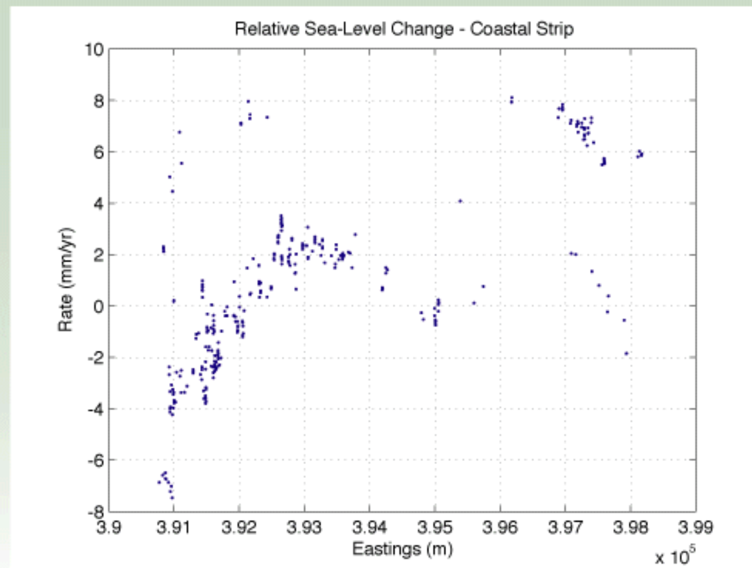
Ben Hamlington, Old Dominion

InSAR and Vertical Land Motion (VLM): Example from Southern California



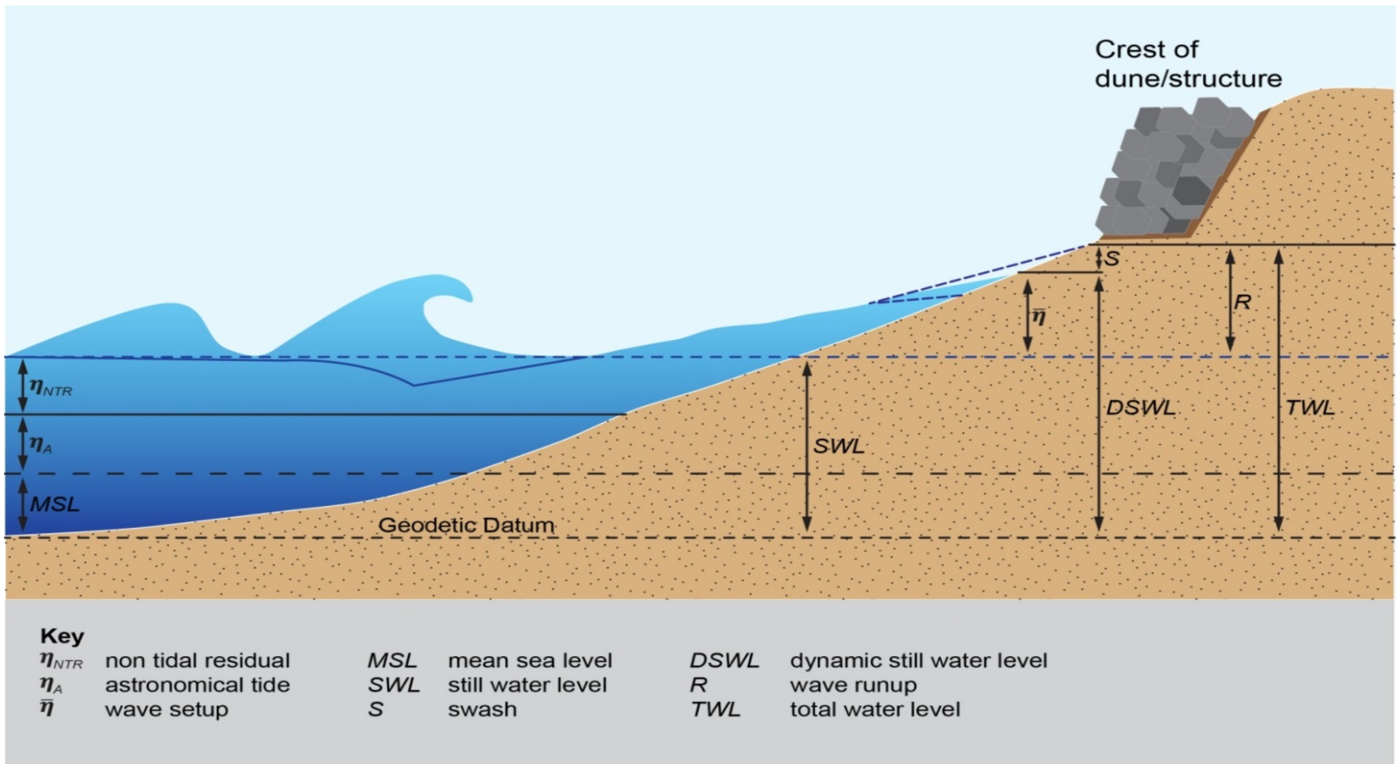
Brooks et al. (2007)





Computing Total Water Levels

$$TWL = MSL + \eta_A + \eta_{NTR} + R_{2\%}$$



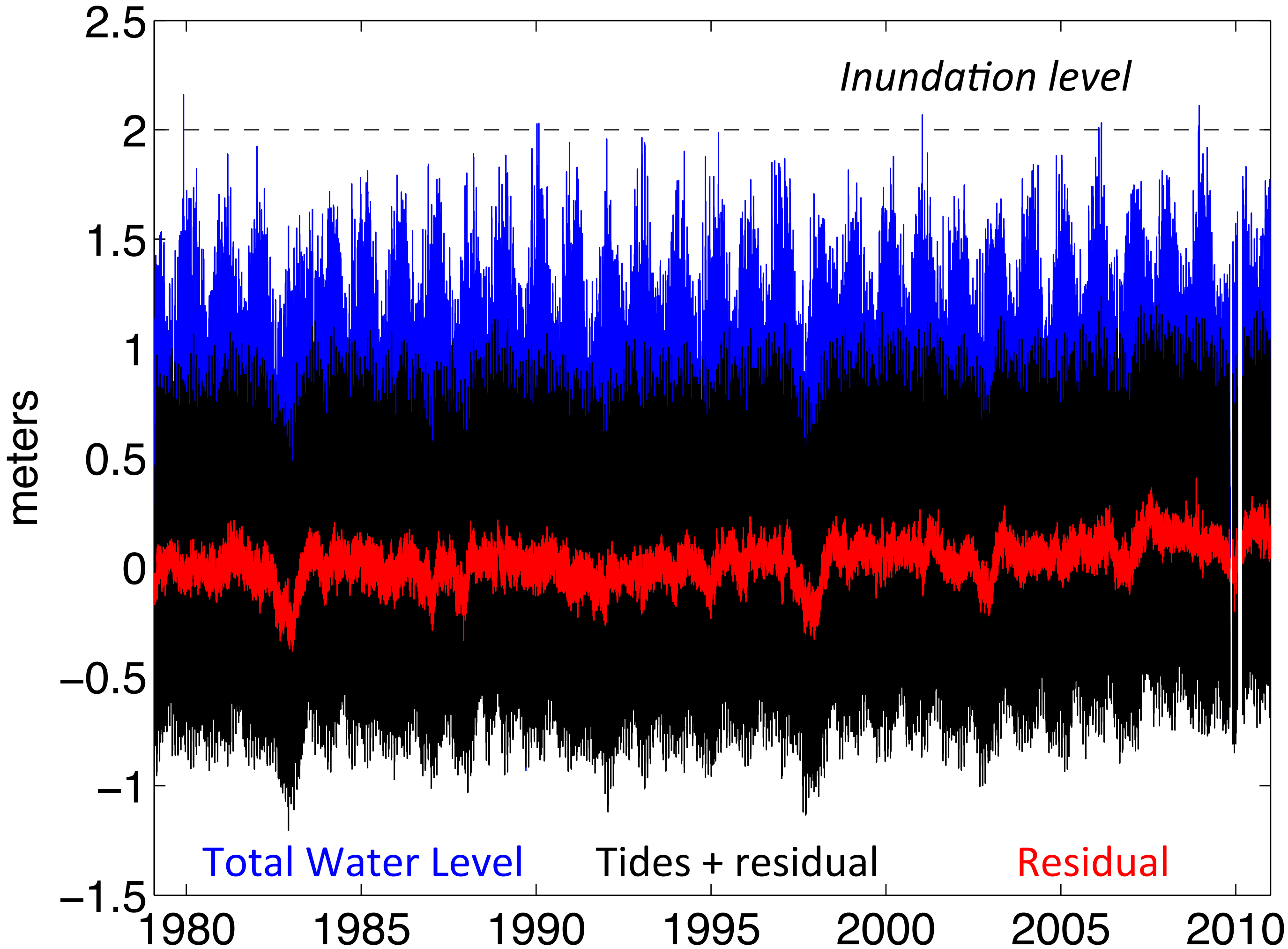
where:

$\eta_{NTR} = \eta_{MMSLA} + \eta_{se} + \eta_{ss}$

$R_{2\%} = f(H_0 L_0 \beta)$ Stockdon et al., 2006

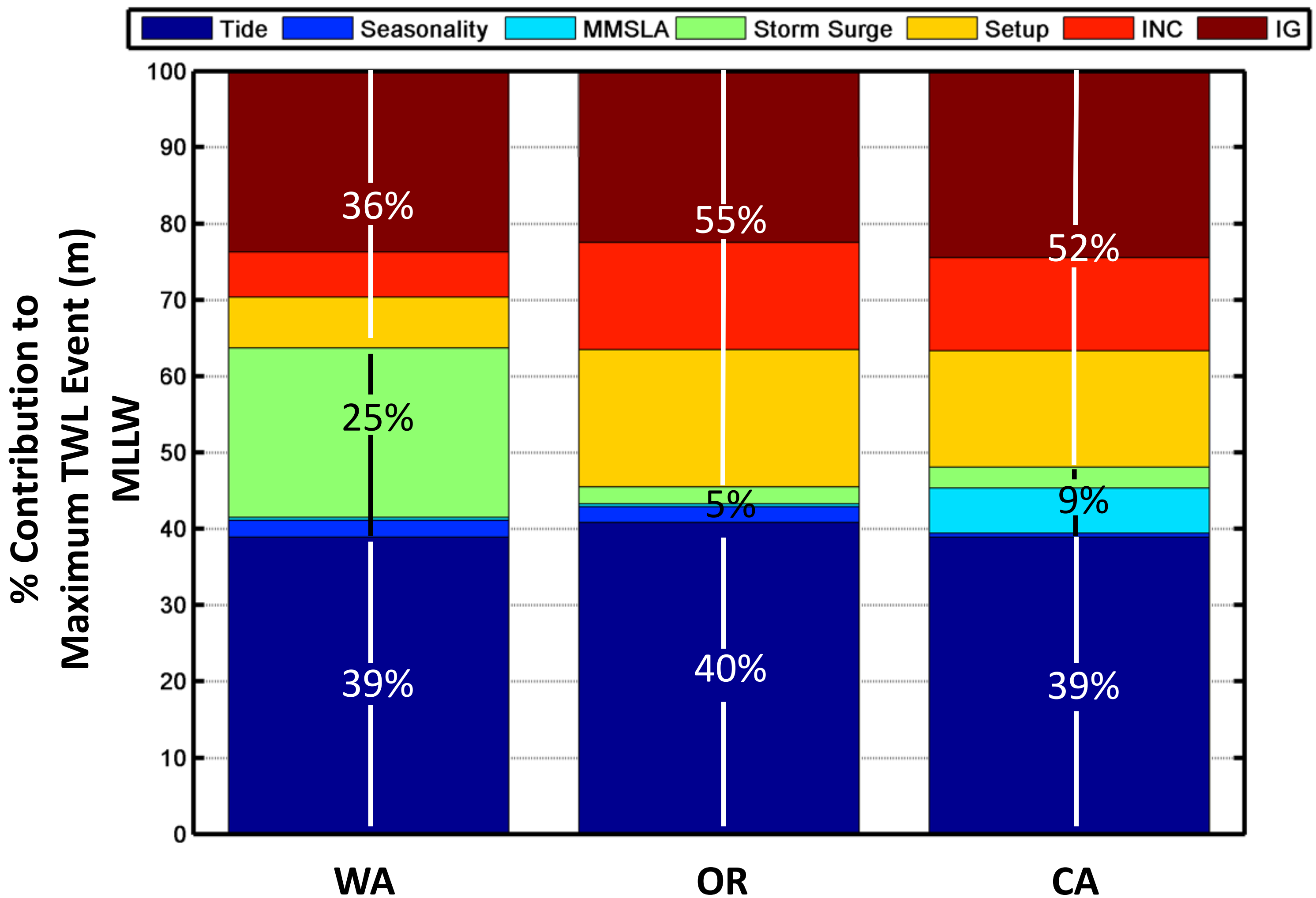
Serafin et al. (2015)

Roi-Namur Total Water Level 1979-2010



Merrifield et al. (2014)

Relative Contribution to Maximum TWL Event



Serafin et al. (2015)

Wind wave projections

~2075-2100 compared with ~1980-2009

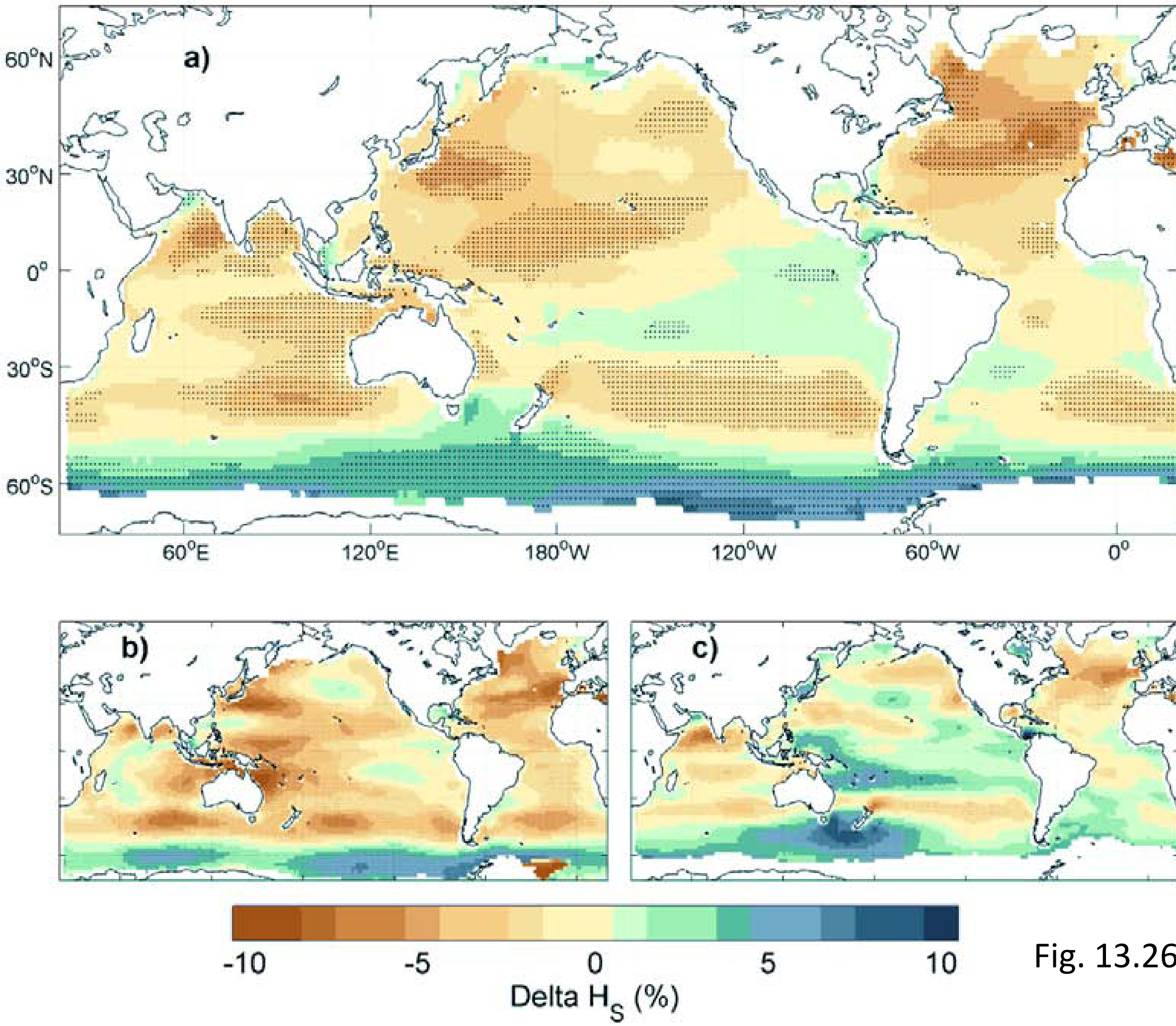


Fig. 13.26a-c

In general, there is *low confidence* in region-specific wind wave projections due to the *low confidence* in tropical and extratropical storm projections, and to the challenge of downscaling future wind fields from coarse-resolution climate models.

Percentage difference in a) annual, b) January-March, and c) July-September mean significant wave height.

Key Points

- Regional sea level rise assessments require coordinated ocean (circulation) and land (ice, water storage) observing/modeling systems
- Linkage to the coast may require additional observing/modeling capabilities to capture near-boundary circulation
- Continuous GNSS monitoring needed to assess various contributors to VLM
- Extreme coastal water level projections must take in to account changes in the wave-driven components