



Royal Netherlands Institute for Sea Research

# Regional sea-level projections

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# Introduction:

## Global vs. Regional sea-level change

### 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

Regional sea-level change:

-> more **processes** important

-> most **relevant** for coastal management

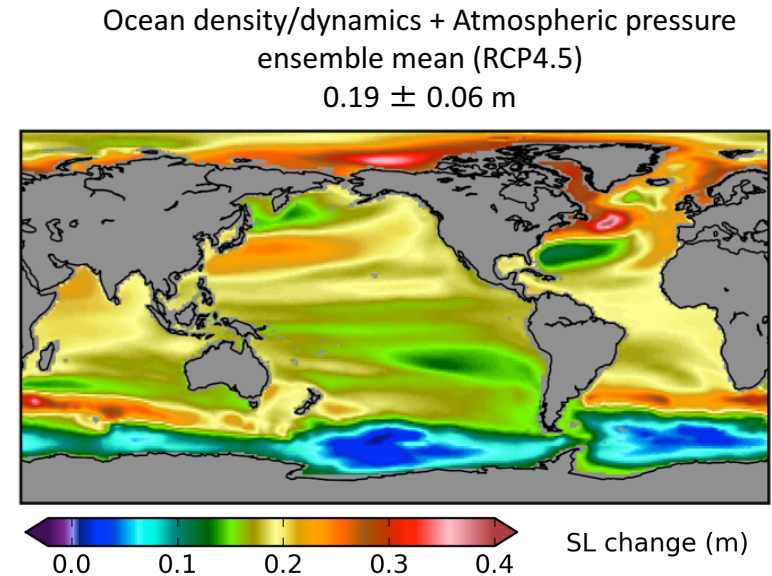
**Nobody lives at the global mean!**



# Contributions: Ocean Changes

From climate models (CMIP5):

- **Density** variations from temperature & salinity changes
- Temperature, salinity and momentum fluxes -> ocean **dynamics** changes
- **Atmospheric pressure**:
  - increase -> sea-level fall, mainly in low latitudes
  - decrease -> sea-level rise, mainly in high latitudes
  - Small effect (<5 cm by 2100)

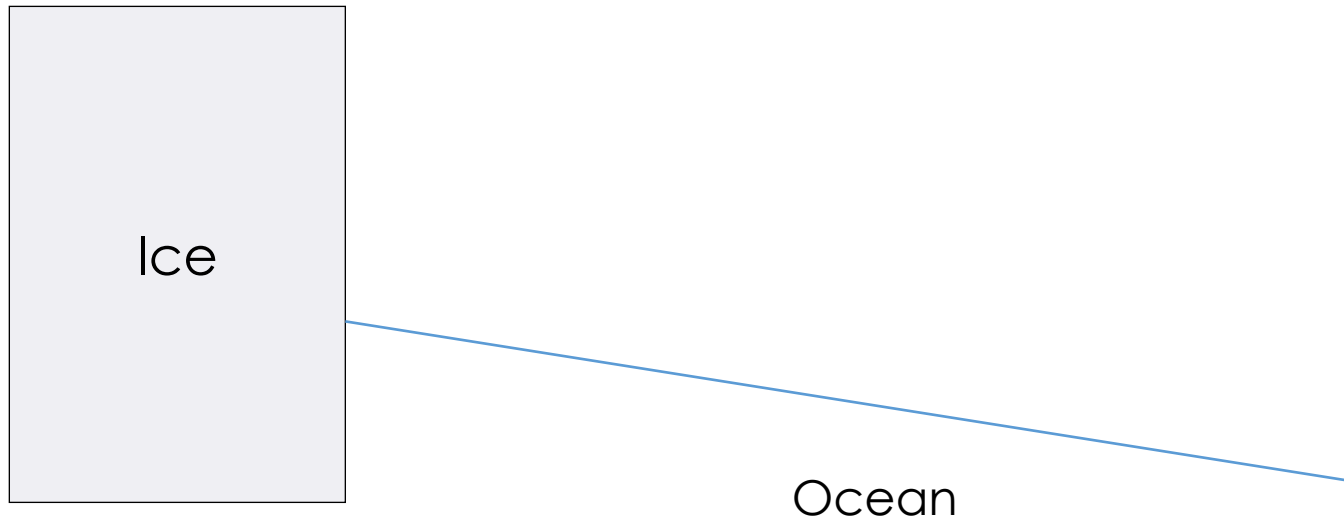




# Contributions: Mass Changes

All **mass** redistribution (land ice, terrestrial water) causes regional changes due to:

- gravitational
- deformational
- and rotational effects

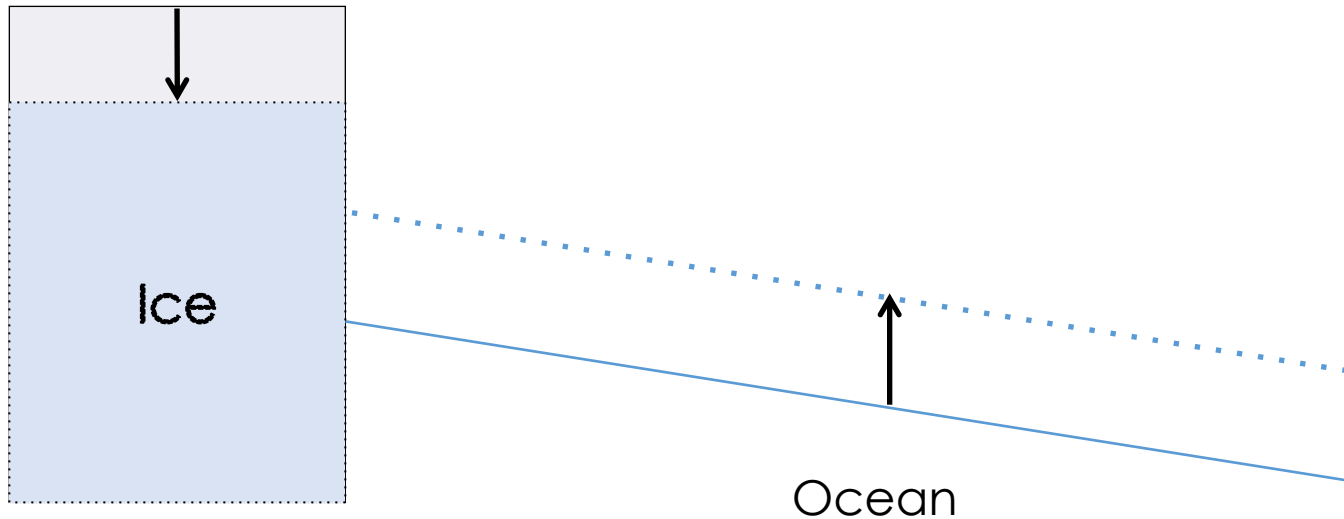




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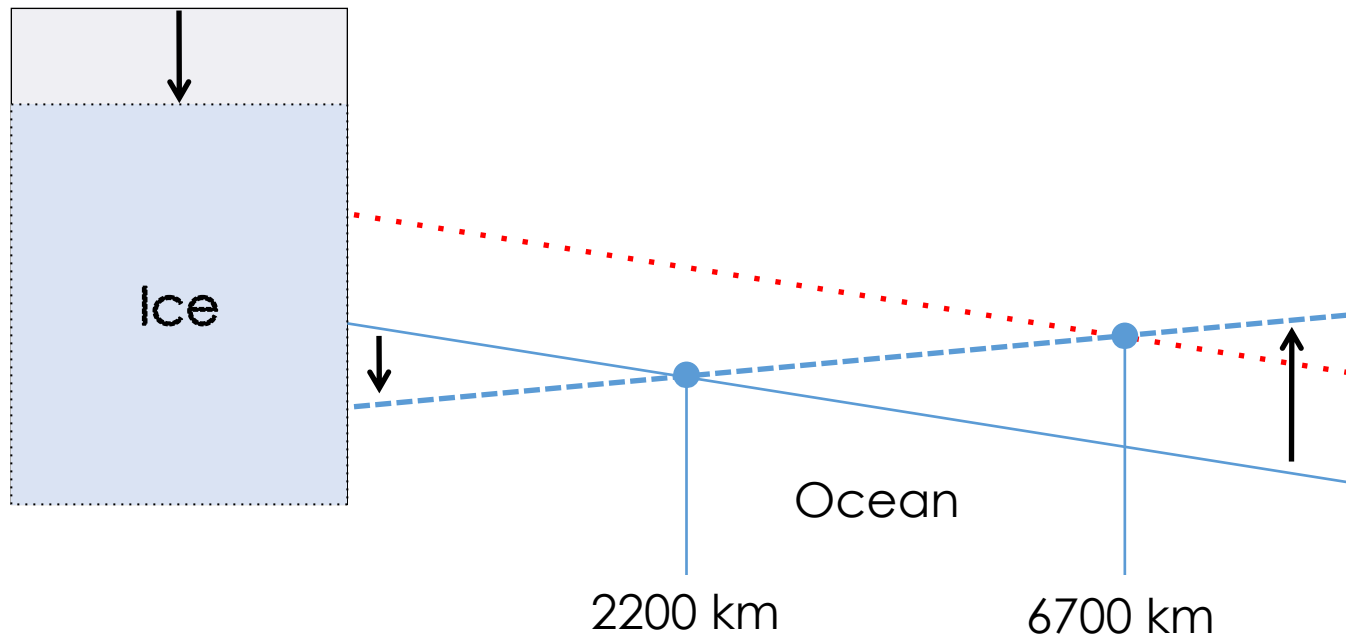




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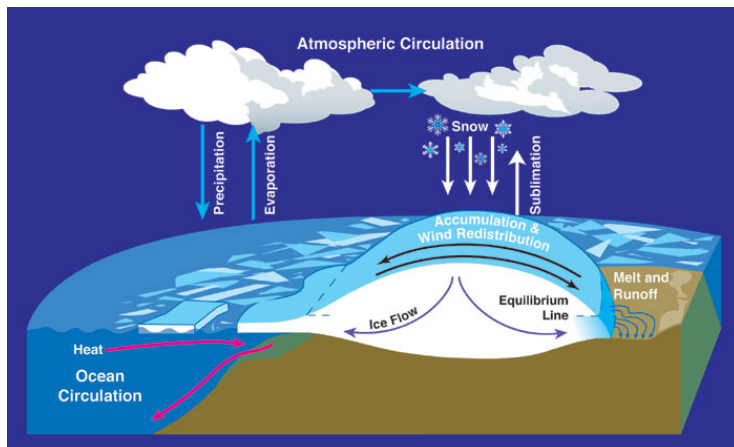
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- and rotational effects



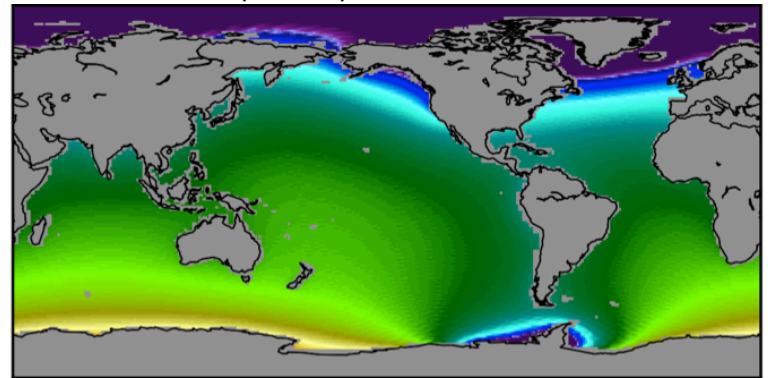
# Contributions: Glaciers & Ice Sheets

Use **glacier & ice sheet models** (driven by climate model output) -> use sea-level model for **regional** sea-level changes

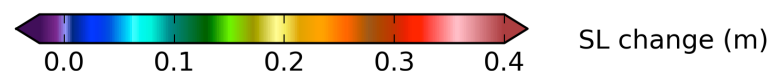
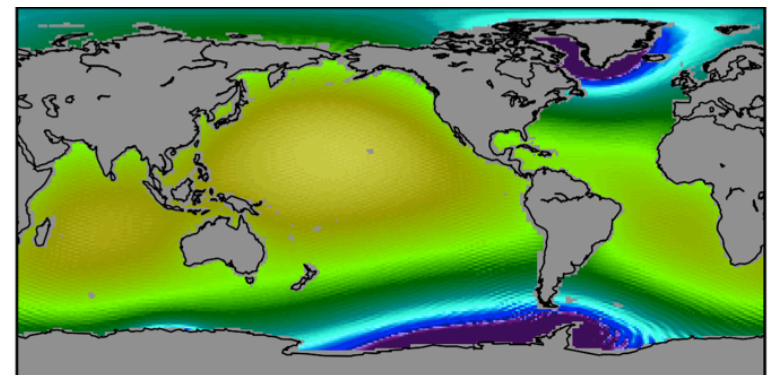
- Glaciers & Ice Caps
- Ice sheet Surface Mass Balance (= accumulation – ablation)
- Ice sheet dynamics (changes to ice discharge and flow) -> large uncertainties



Glaciers + Ice caps ( $0.15 \pm 0.03$  m)  
+ Ice sheet SMB (Ant  $-0.06 \pm 0.03$  m, Gre  $0.03 \pm 0.03$  m)  
Ensemble mean (RCP4.5)



Ice sheet dynamics (Ant  $0.09 \pm 0.06$  m, Gre  $0.06 \pm 0.05$  m)

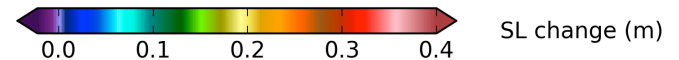
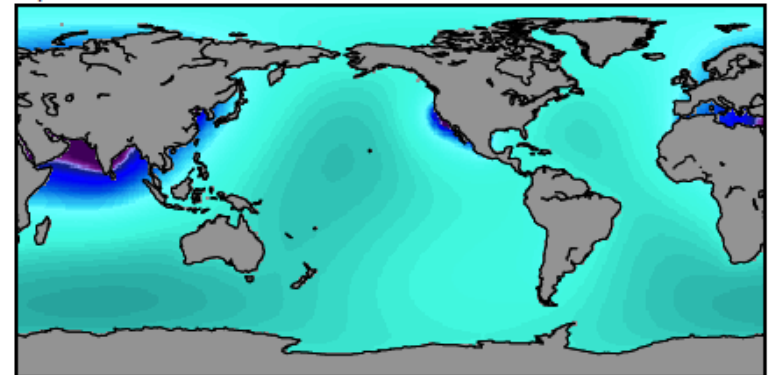




# Contributions: Landwater Storage Change

- Landwater storage change:  
**natural** (eg snow) and **human**  
(groundwater, dam building)
- Largest human effect =  
**groundwater** extraction
- Assume no (or little) future  
dam building

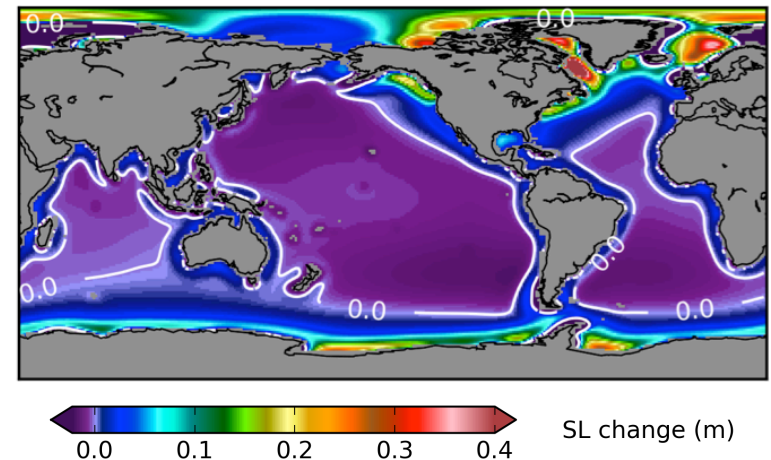
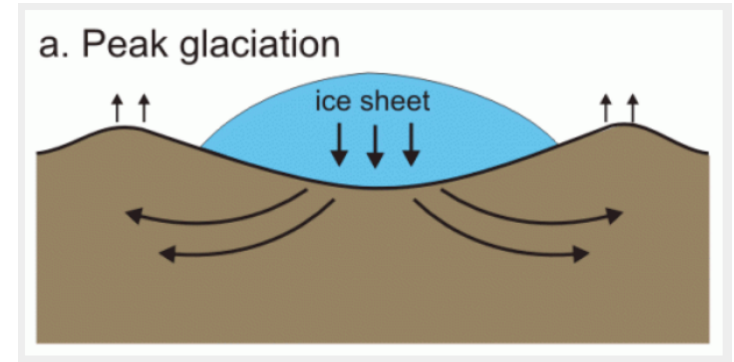
Groundwater model from Wada et al, (2012):  
 $0.08 \pm 0.01$  m by 2100



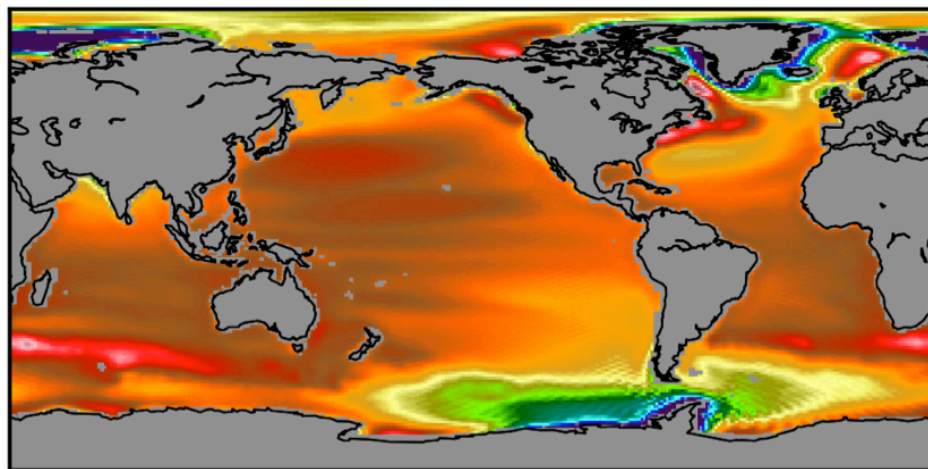


# Contributions: Glacial Isostatic Adjustment

- GIA = **solid Earth** response to ice growth and melt on ice age timescales
- Global mean sea-level change  $\sim 0$
- **Regional** effect substantial in areas close to Laurentide and Fennoscandian ice sheets; e.g. in Sweden up to 1 cm per year



# Total regional sea-level projections



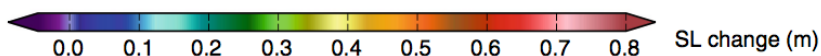
Previous contributions **combined**:

$$0.54 \pm 0.19 \text{ m}$$

← (RCP4.5 = moderate warming)

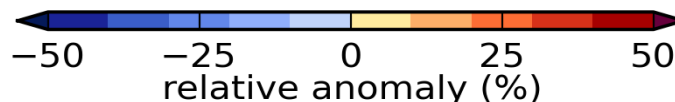
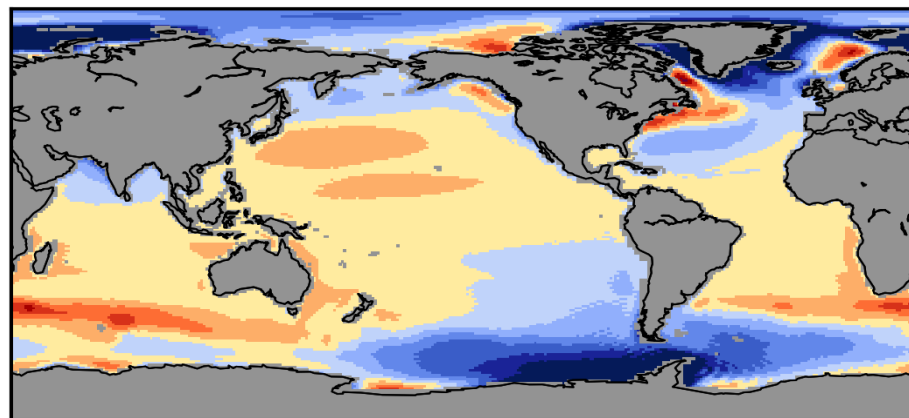
$$0.71 \pm 0.28 \text{ m}$$

(RCP8.5 = ~business-as-usual)



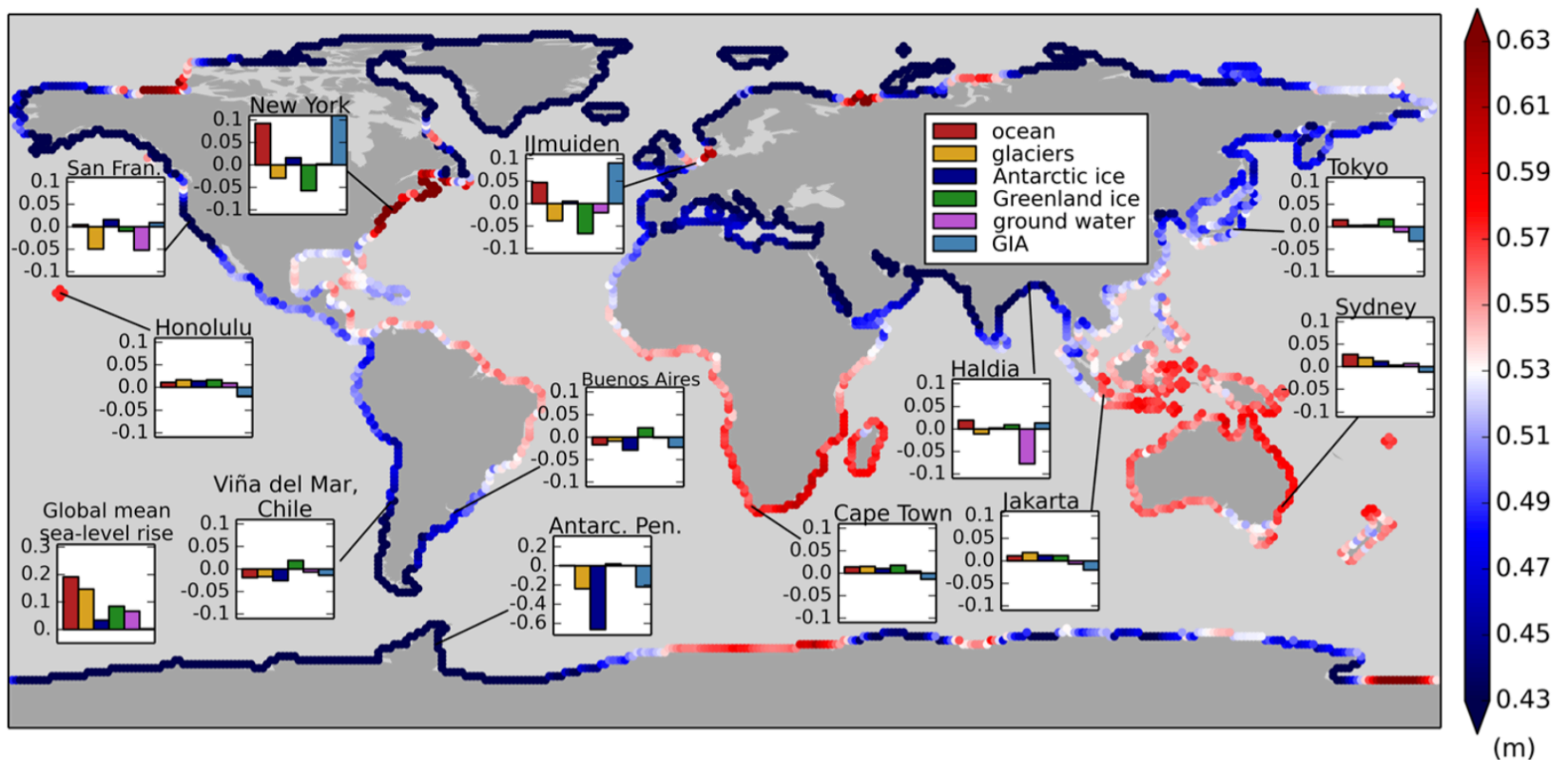
**Regional deviations** from global mean:

- +30% in Southern Ocean & around North America
- -50% in Arctic Ocean and around Antarctic Peninsula



# Coastal Sea-Level Projections

- Sources of sea-level change depend on **location**





# Progress since IPCC AR5

- Not all work published in time for IPCC AR5 deadline (March 2013) -> lots of papers since
- New **estimates** & increased understanding for individual contributions (glaciers, higher ice sheet estimates)
- Steric/dynamic SL projections now use climate model output from CMIP5 database – new results expected from **CMIP6**

- **Regional** assessments:

*“Estimates of twenty-first century sea-level changes for Norway” (Simpson et al, 2014),  
“Regional differences of relative sea level changes in the Northwest Atlantic” (Han et al, 2014)  
“Sea-level rise projections for Australia: information for impact and adaptation planning” (CSIRO, McInnes et al, 2015)  
“Constructing scenarios of regional sea level change using global temperature pathways” (de Vries et al, 2014)*

- Research showing full **probability** distributions -> possibilities for low-probability/high risk events



# Conclusions

- **Regional projections** important for coastal management
- Different types of individual contributions can determine SLC locally
- Regional deviations range from -50% to +30% of global mean SLC
- Progress: estimates of individual contributions are being improved, better understanding & more complete models, more complete probability distributions
- Looking ahead:
  - Think about projections beyond 2100
  - Add other processes, like subsidence
  - Link sea-level projections to coastal impacts

