Modeling Sea-Level Rise (SLR) and Its Uncertainties under Climate Change

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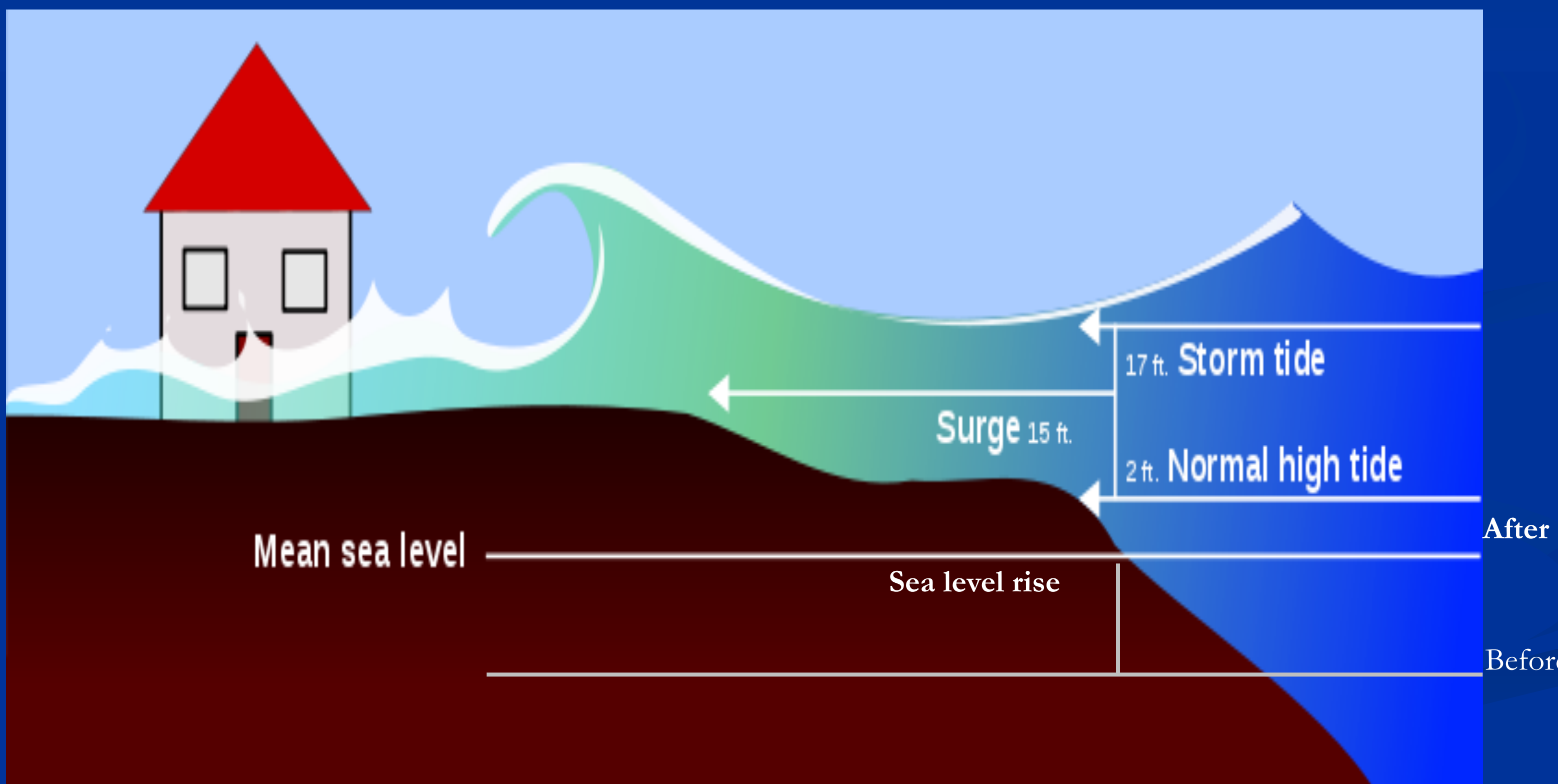
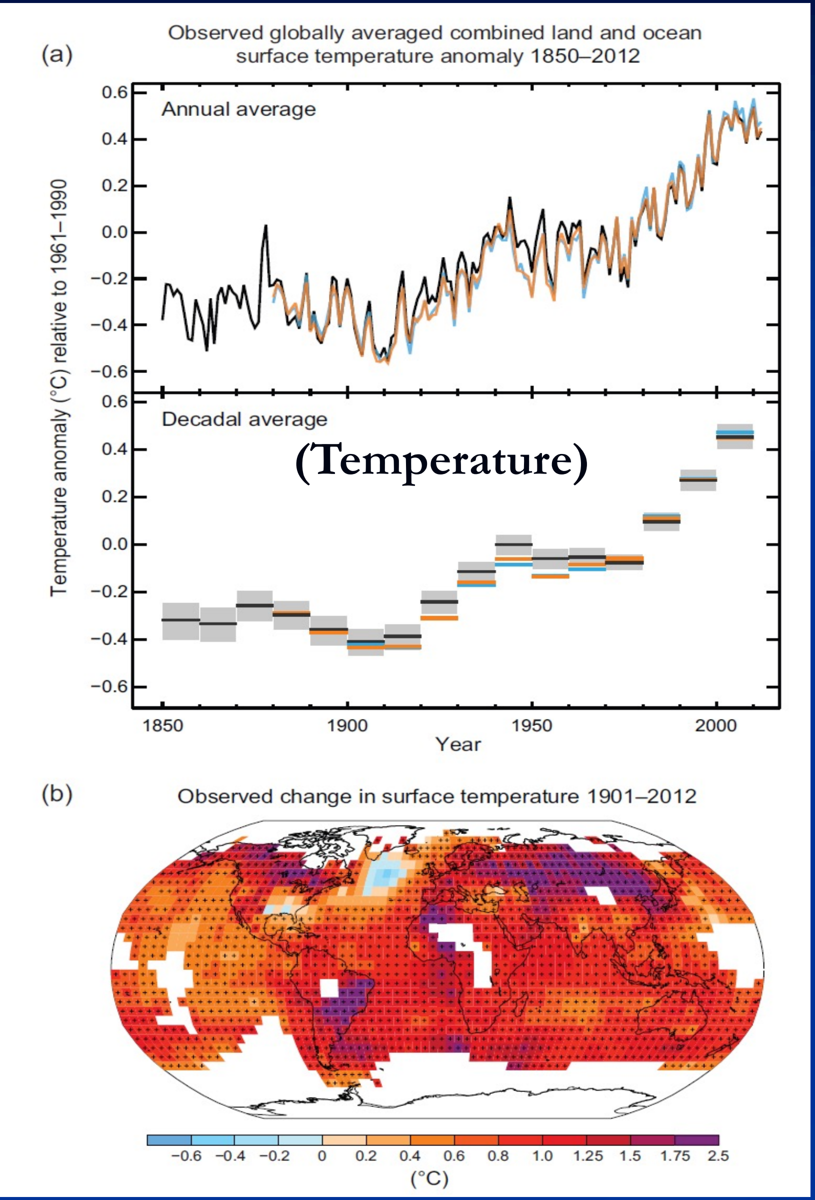
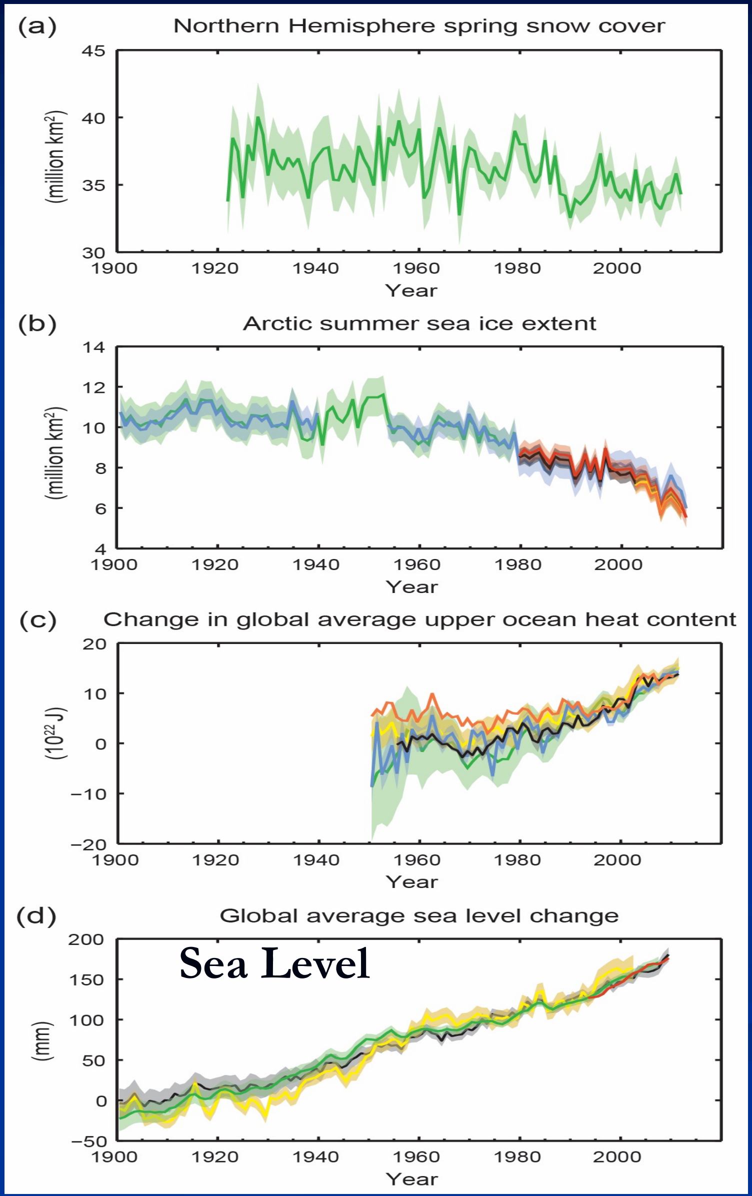
Risks of Flooding: Relative Water Level

MSL + Normal High Tide + Storm Surge + Breaking Waves



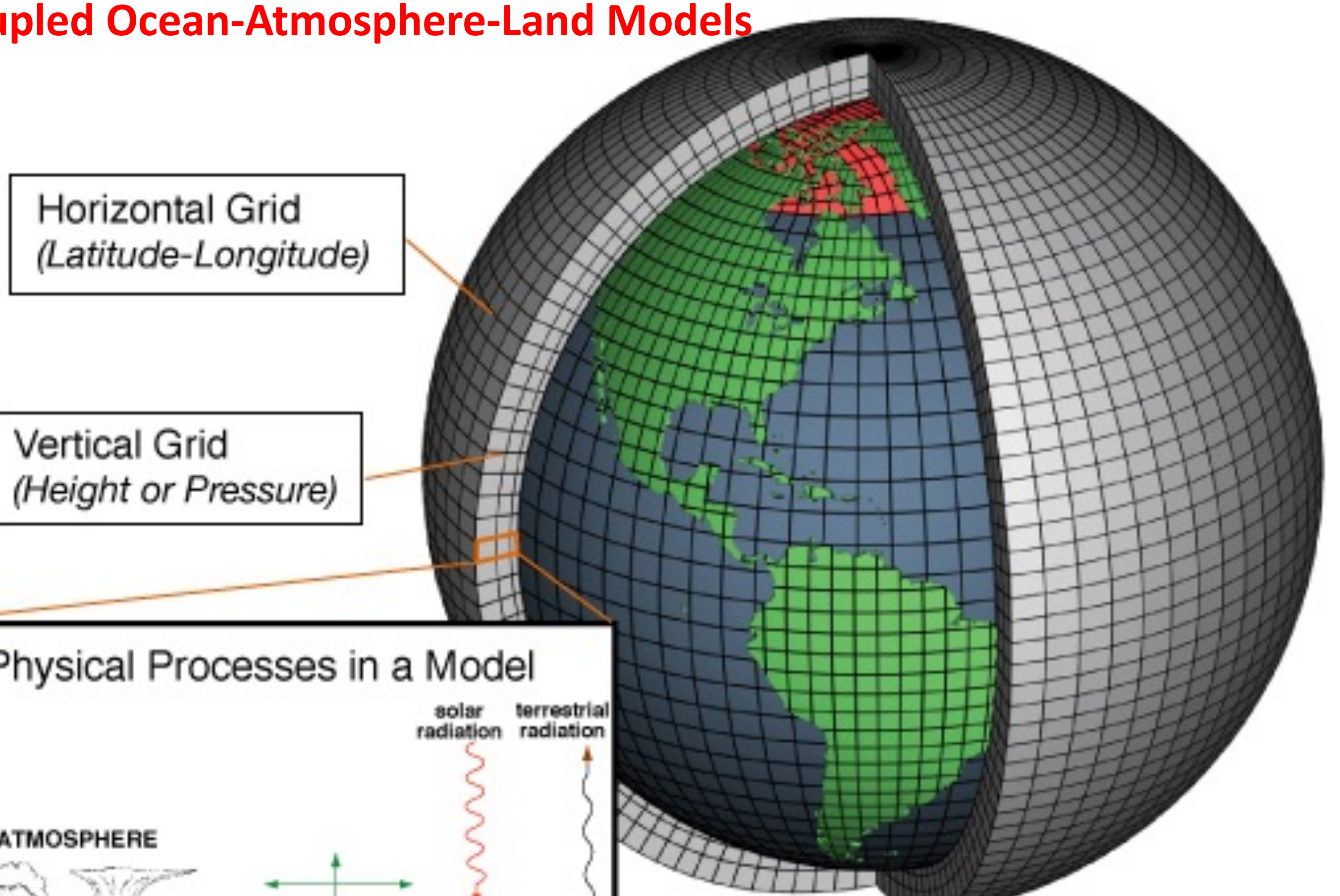
SLR in the last century

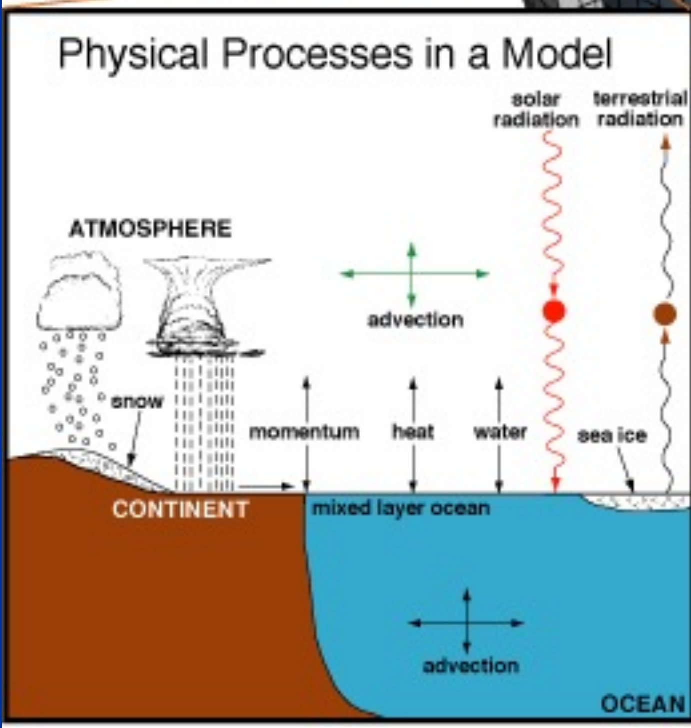


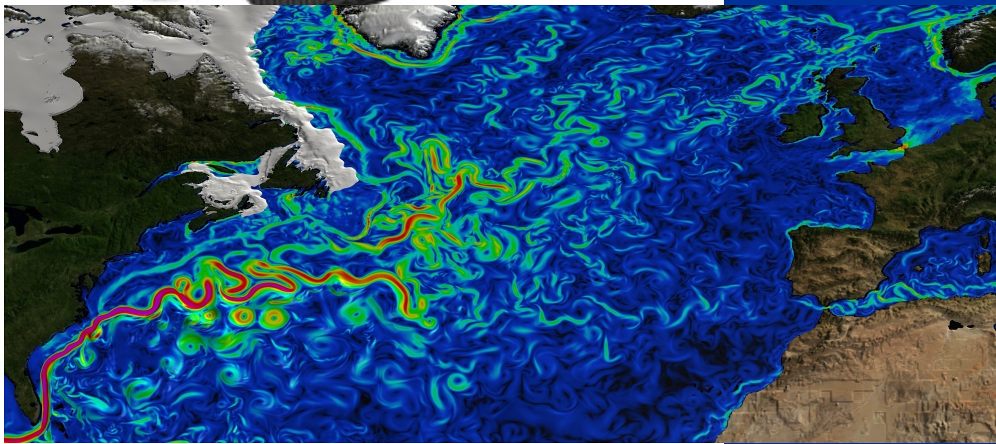


(IPCC AR5, 2013)

Coupled Ocean-Atmosphere-Land Models







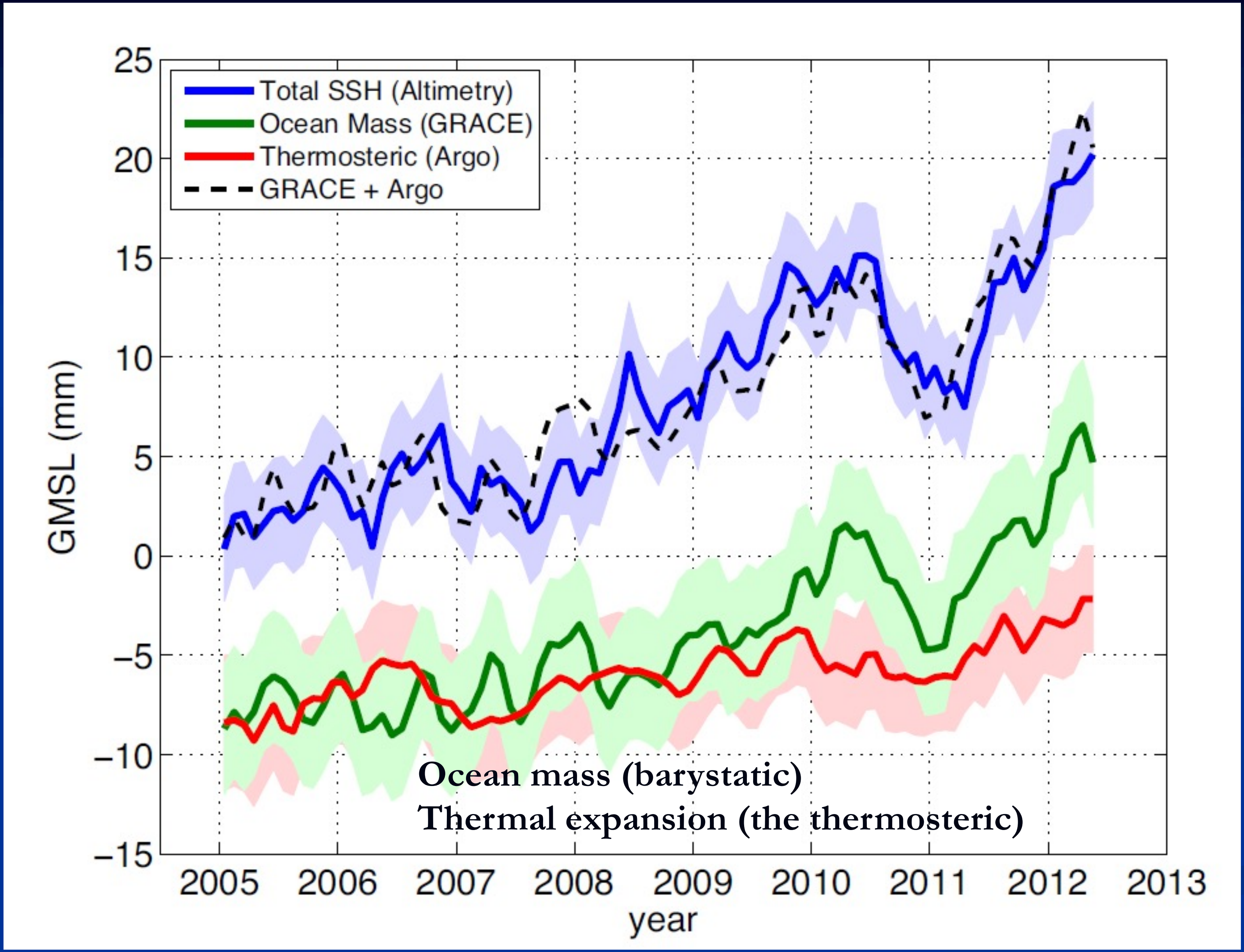
Causes of Sea Level Rise

1. **"steric (thermosteric)": global averaged changes in sea level due to thermal expansion and salinity change**

2. **"eustatic": change of water mass (glaciers, ice sheets, soil moisture) (Spatial scale very different!)**

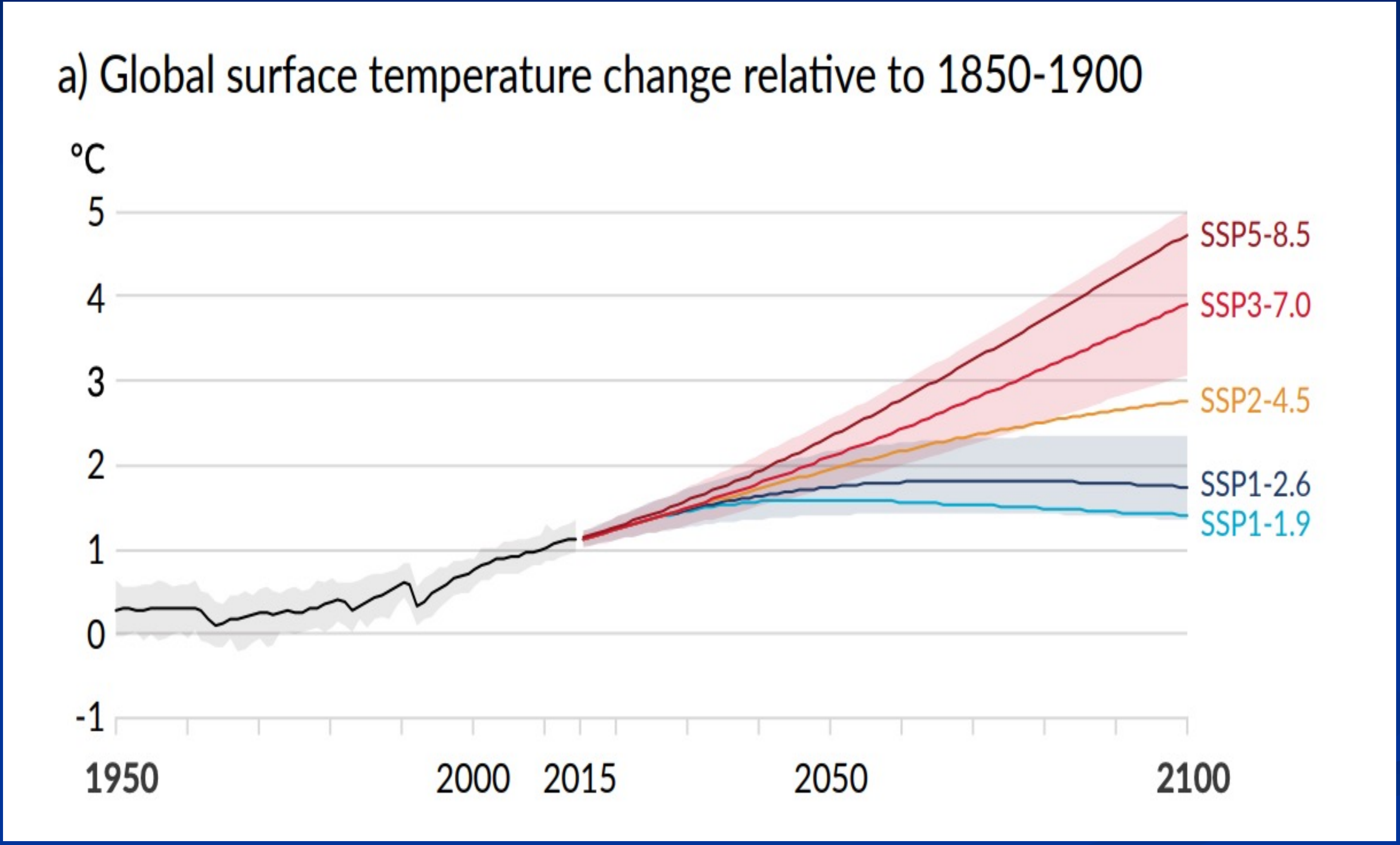
3. **"dynamic": redistribution by currents, spatial inhomogeneity of temperature and salinity, changes in surface air pressure**

4. **"isostatic": changes in the level of the land from tectonic process (Post Glacial Rebound) (temporal scale very different!)**



SLR in Recent Records

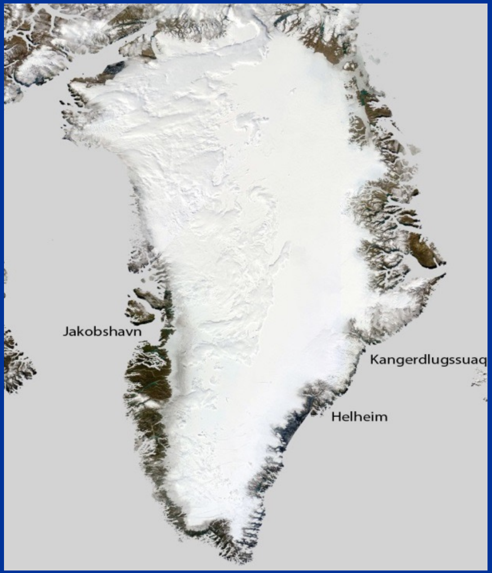
Driver of thermostatic SLR Uncertainty



(Arias et al. 2021)

Driver of Ocean Mass Uncertainty

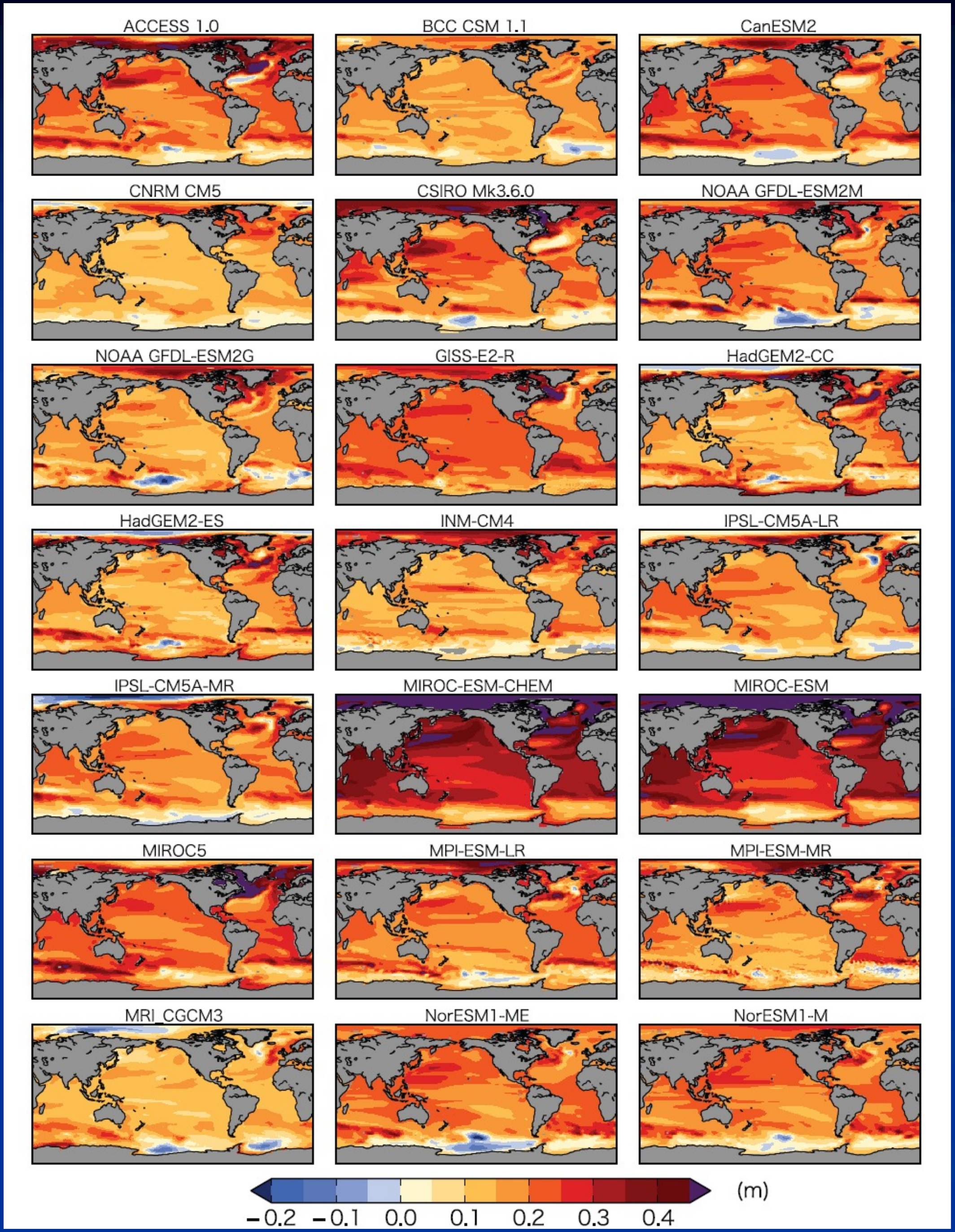
Wolverine Glacier, Alaska. Photo by Rod March.



Glacier

Ice Cap

Ice Sheet



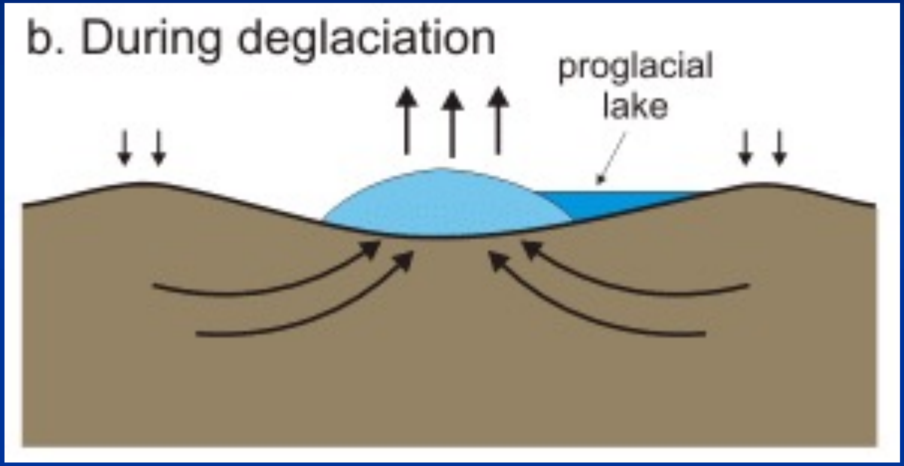
Results from Different Models

Main Sources of Differences:

Magnitude of Warming

Ice Sheet Models

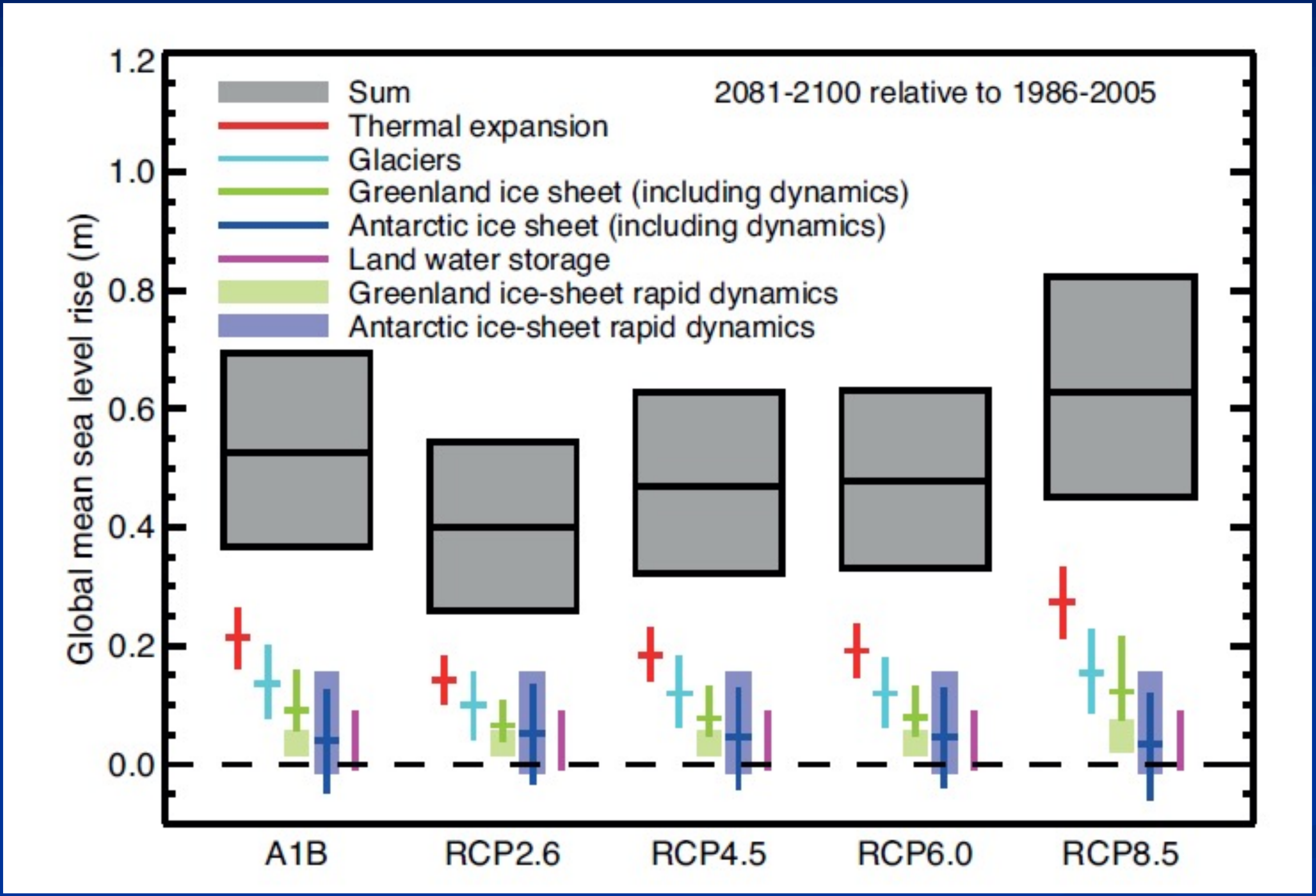
Driver of Uncertainty in Post Glacial Rebound



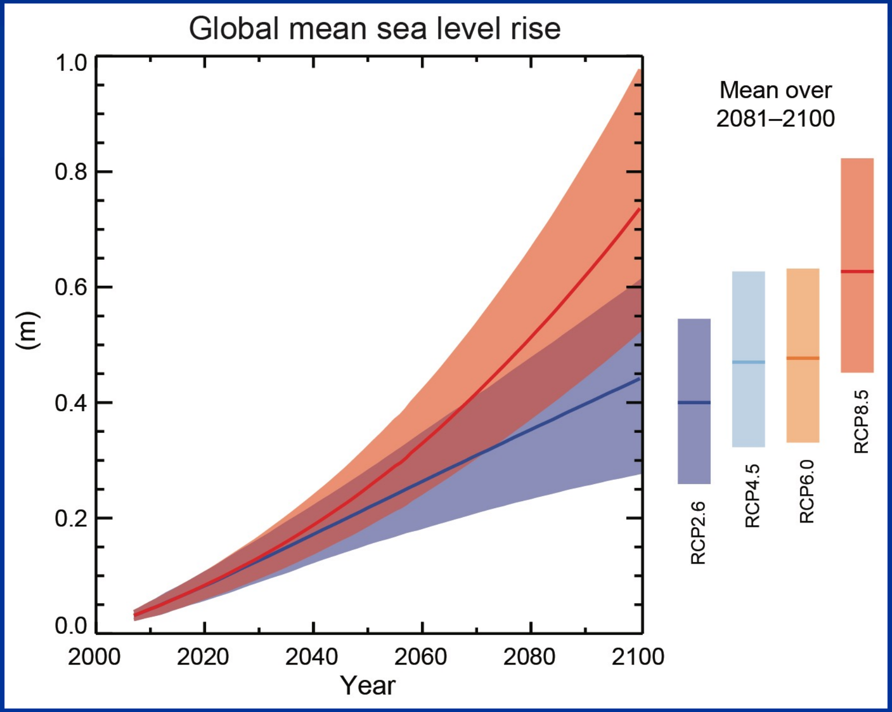
$$S(\theta,\lambda,t) = C(\theta,\lambda,t)\left[\int_{-\infty}^{t} dt' \iint_{\Omega} d\Omega'\, L(\theta',\lambda',t')\, G^{L}(\gamma, t-t') + \frac{\Delta\Phi(t)}{g}\right]$$

(Peltier, 2004)

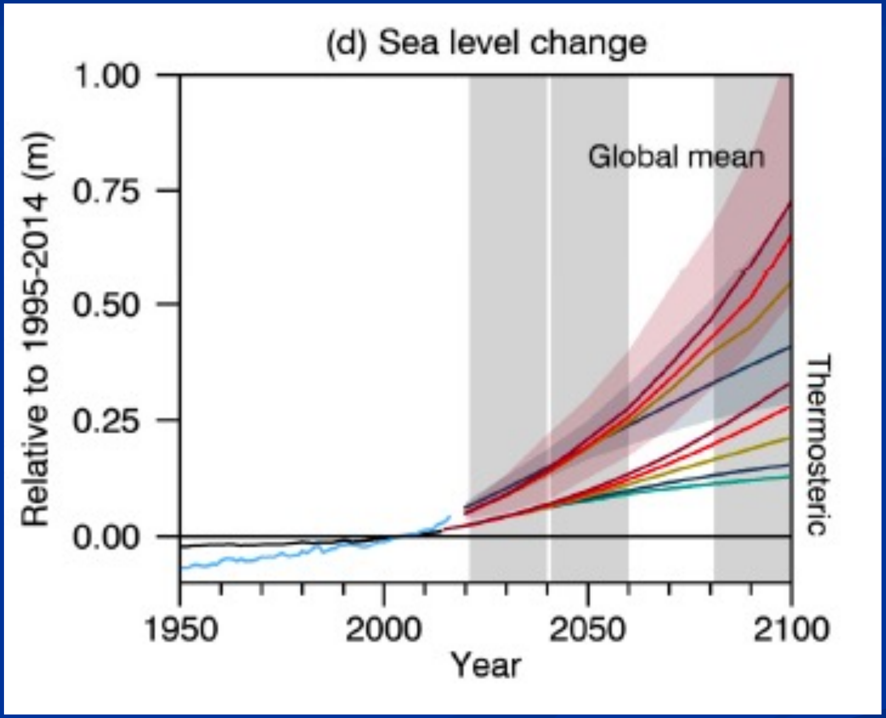
Global SLR and Uncertainties



SLR Projections



(IPCC AR5, 2013)



(IPCC AR6, 2021)

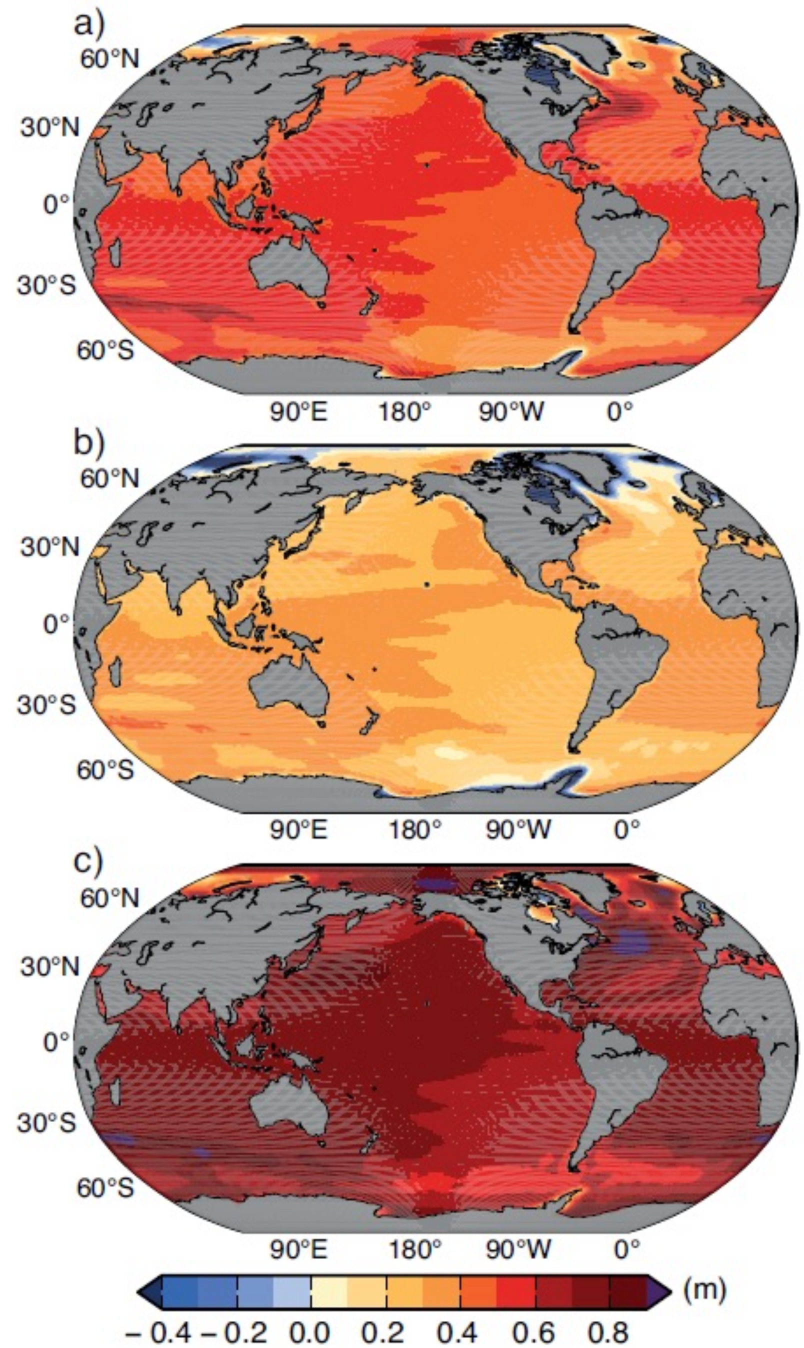
(Adhikary, 2021)

RCP 4.5
2080-2100 Projection

Average

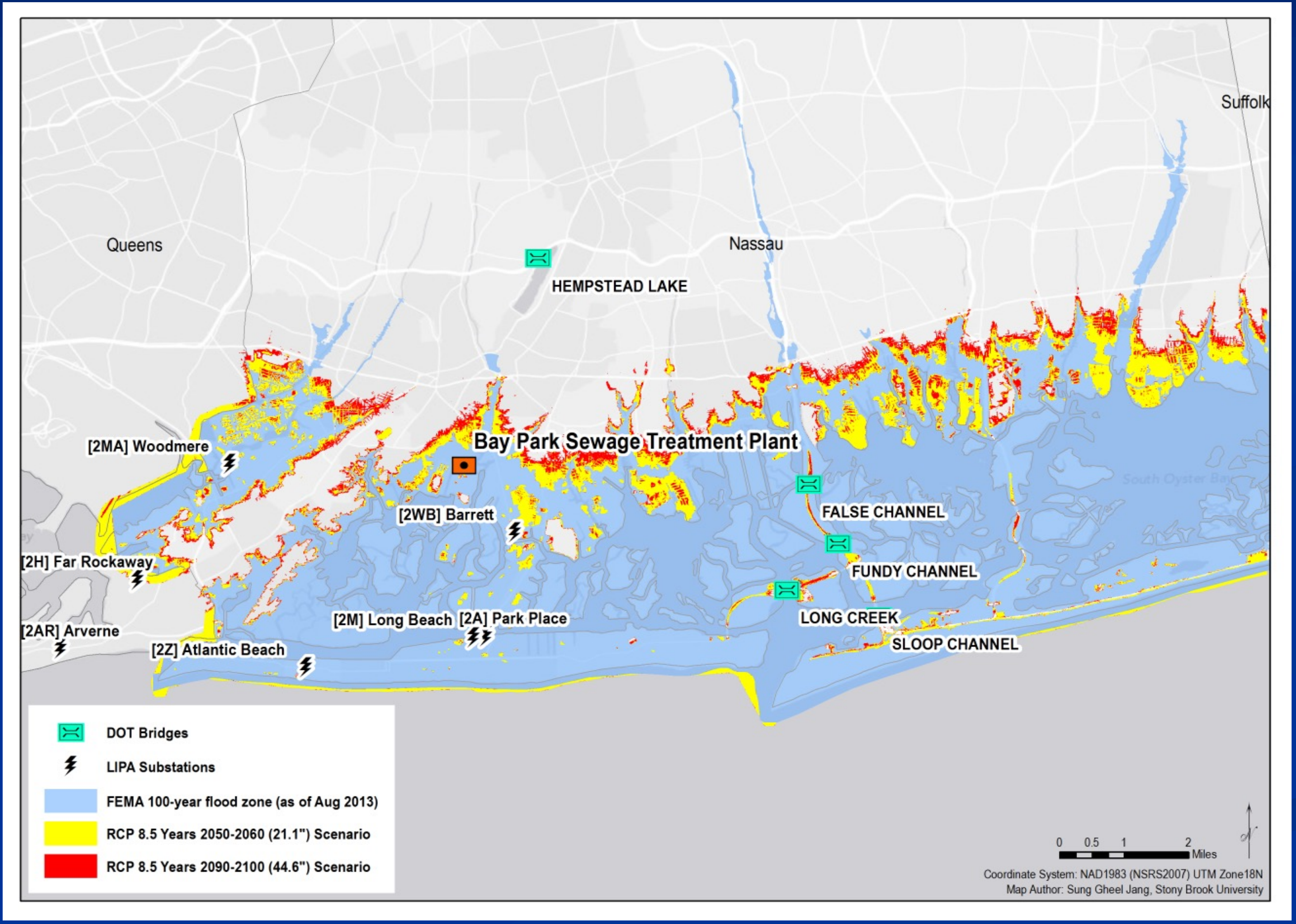
10^{th} Percentile

90^{th} Percentile



(IPCC AR5, 2013)

What Matters?
Vulnerable Infrastructure & Community



(Zhang et al. 2014)

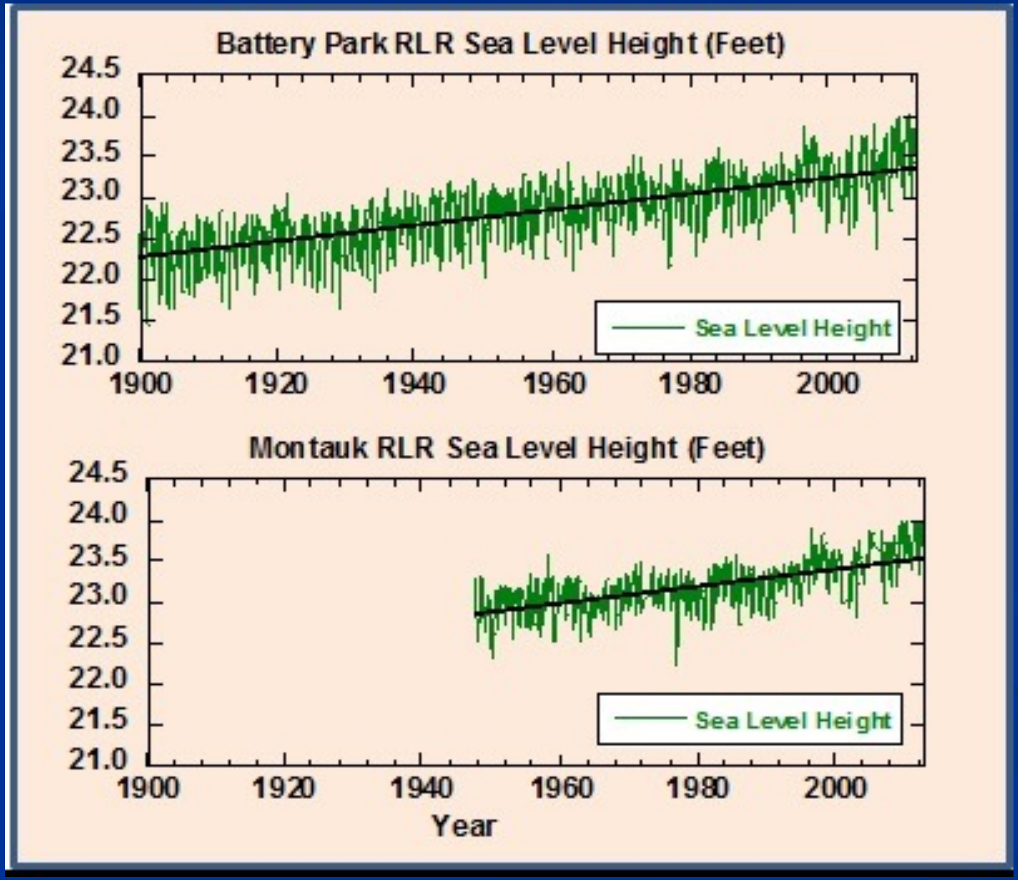
Bay Park Sewage Treatment Plant

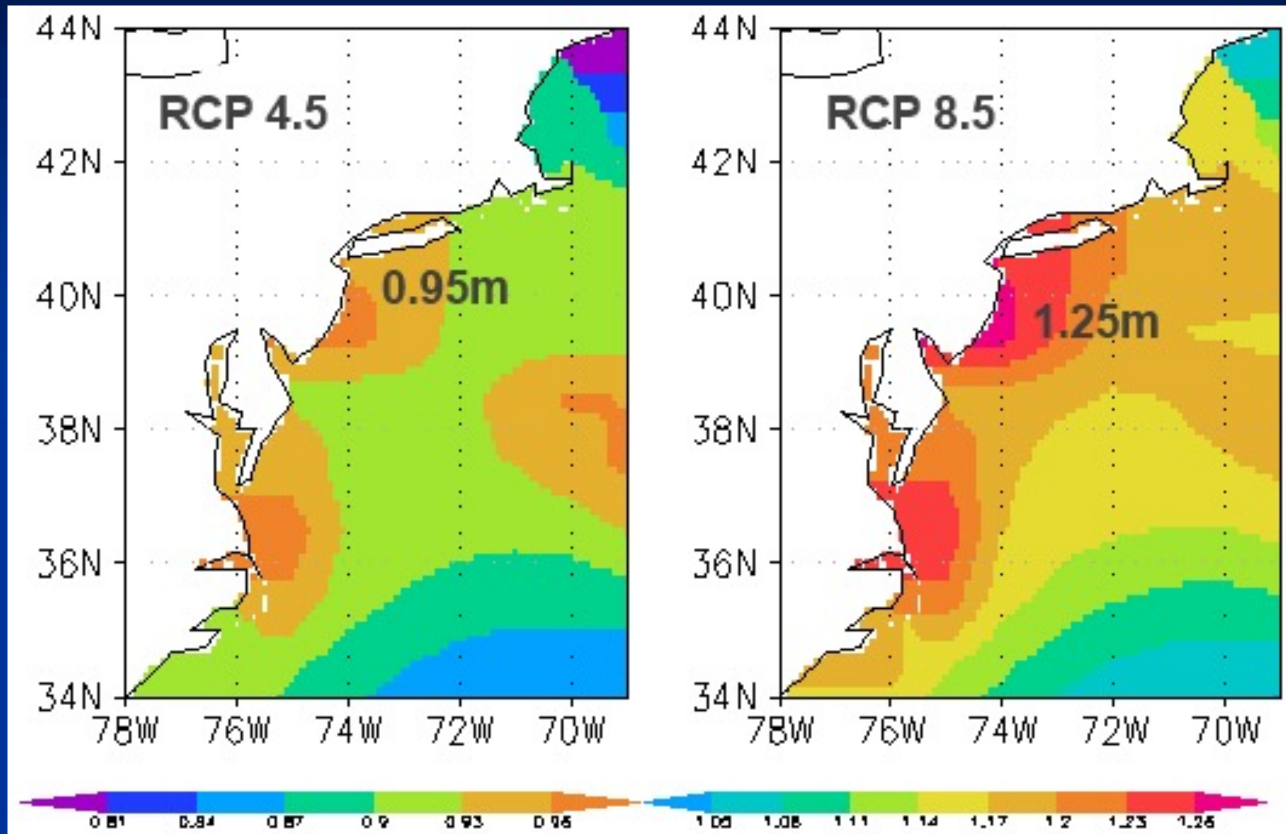
Failed

Treatment Plant

Cesspool

SLR at Battery Park and Montauk



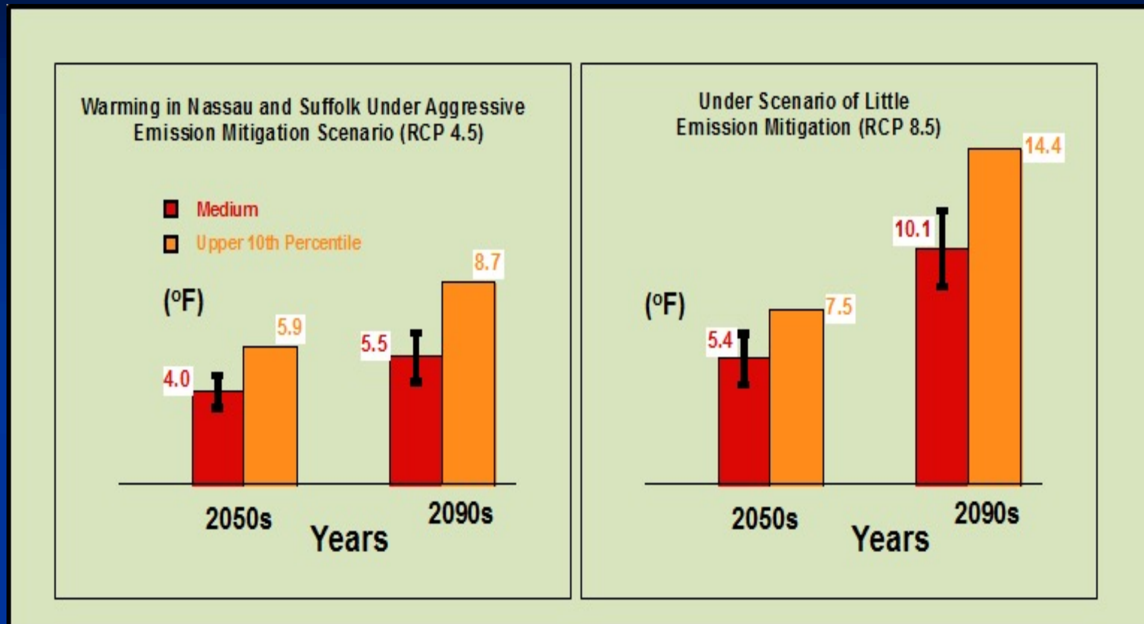


Upper 90th percentile estimate of sea-level rise in 2090s under two climate change scenarios

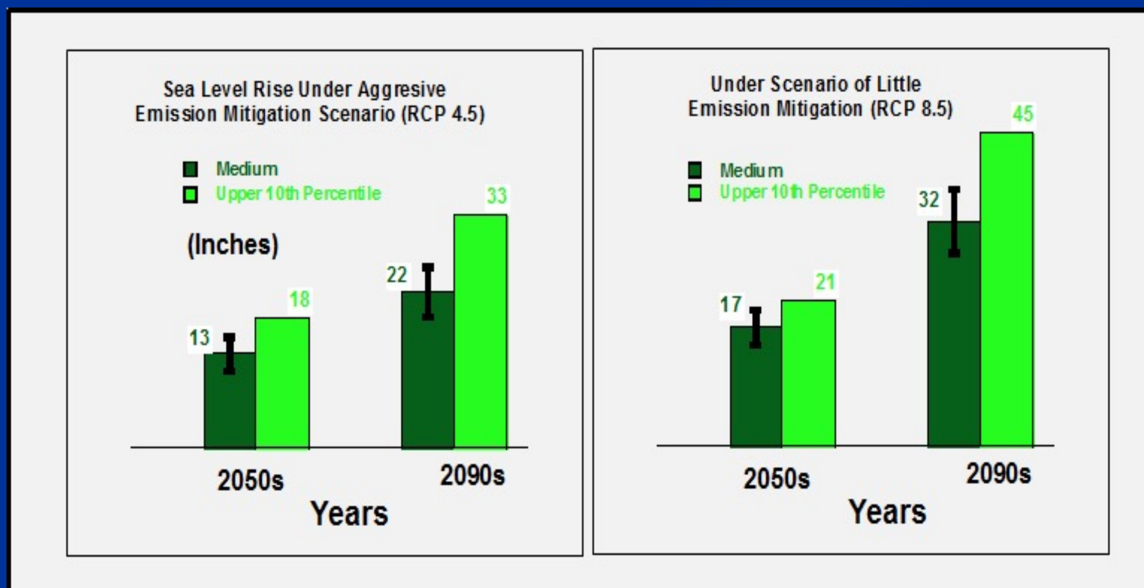
(Zhang et al. 2014)

RCP 4.5 RCP 8.5

Projected Warming

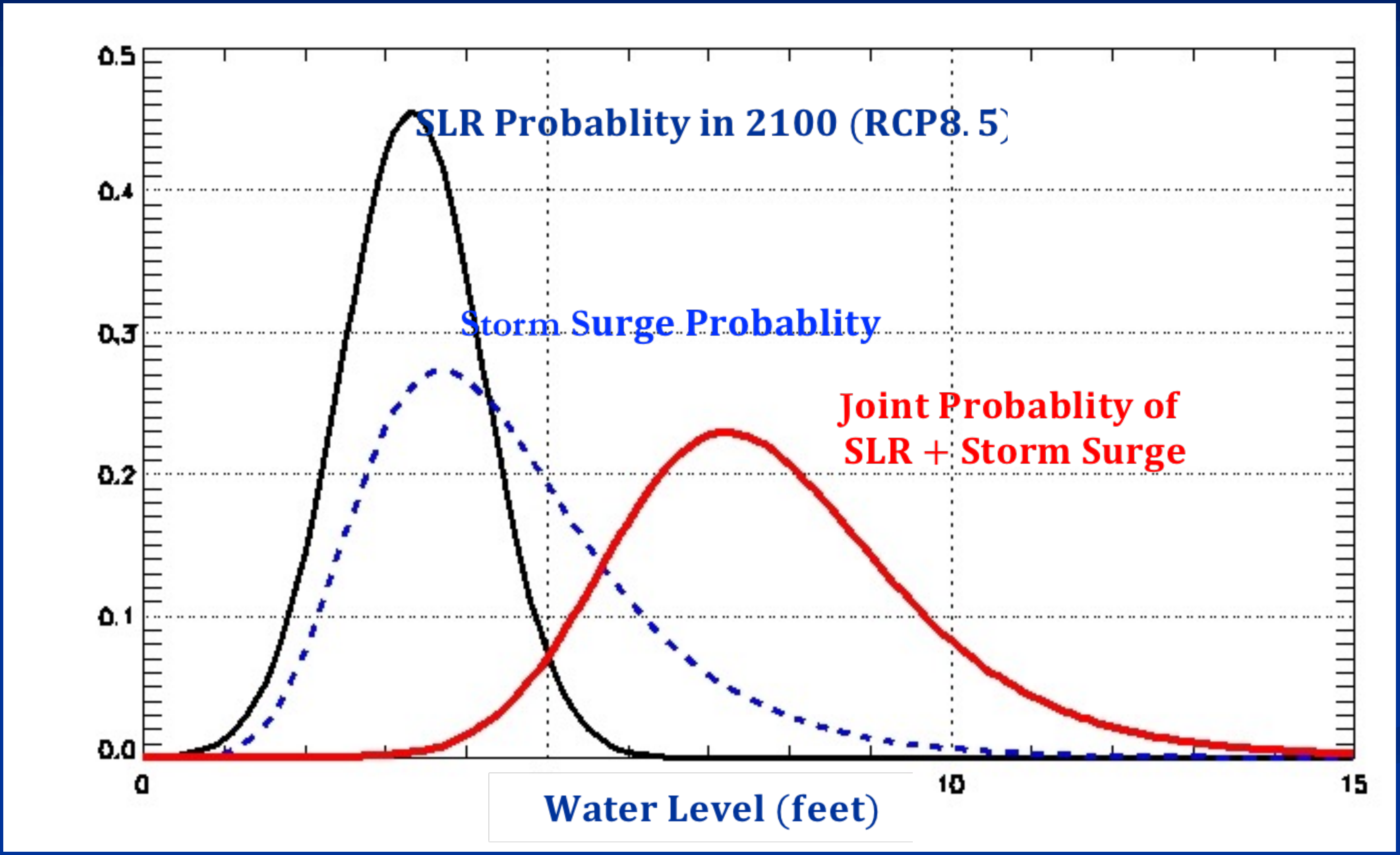


Projected SLR



(Zhang et al. 2014)

Example: Flooding Risk at the Bay Park Sewage Rebuild Treatment Plant in Nassau County to Account for SLR



Decision with Uncertainty

Without action:

$$Cost_1 \sim \int P(risk) * P(Cost/Risk_1)\, dRisk_1$$

With action:

$$Cost_2 \sim \int P(risk) * P(Cost/Risk_2)\, dRisk_2$$

Cost of action: $Cost_3$

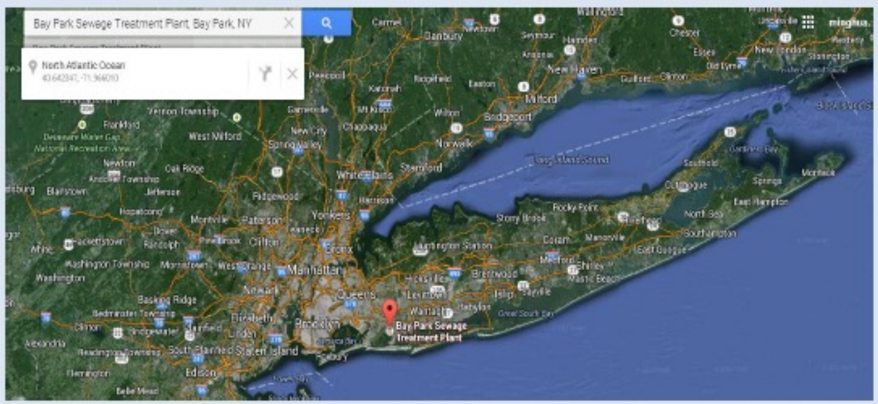
$Cost_i$ = $Cost_i$ (health, economical, social, ecological, ..

Decision: maximize $R = (Cost_1 - Cost_2) / Cost_3$

or $C = (Cost_1 - Cost_2) - Cost_3$

Climate Risk Report for Suffolk and Nassau

Prepared for the NYS Office of Storm Recovery by NYS Resilience Institute for Storms and Emergencies (RISE)



April 2014

Build a 17ft Wall!

(Zhang et al. 2014)

Summary

- Modeling SLR involves a vast range of temporal and spatial scales. Two of the four drivers are currently calculated separately.

- Sources of uncertainties can be identified but need to be quantified.

- SLR around the NY coasts is projected to be in the range of 0.4 m to 0.7 m at the end of the 21^{st} century. The 90^{th} upper bound under the worst emission scenario is 1.25 m.

- Decisions of adaptation and mitigation can take into account uncertainties (the probability of risks) and the associated costs as well as the costs of mitigation.