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Predicting future coastal sea level rise:
statistical models based on local observations versus climate model predictions

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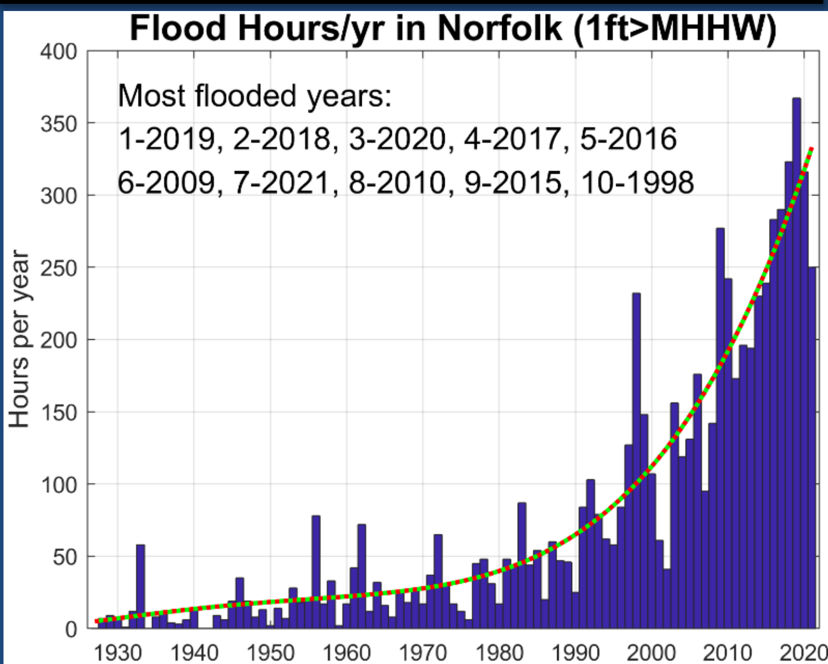
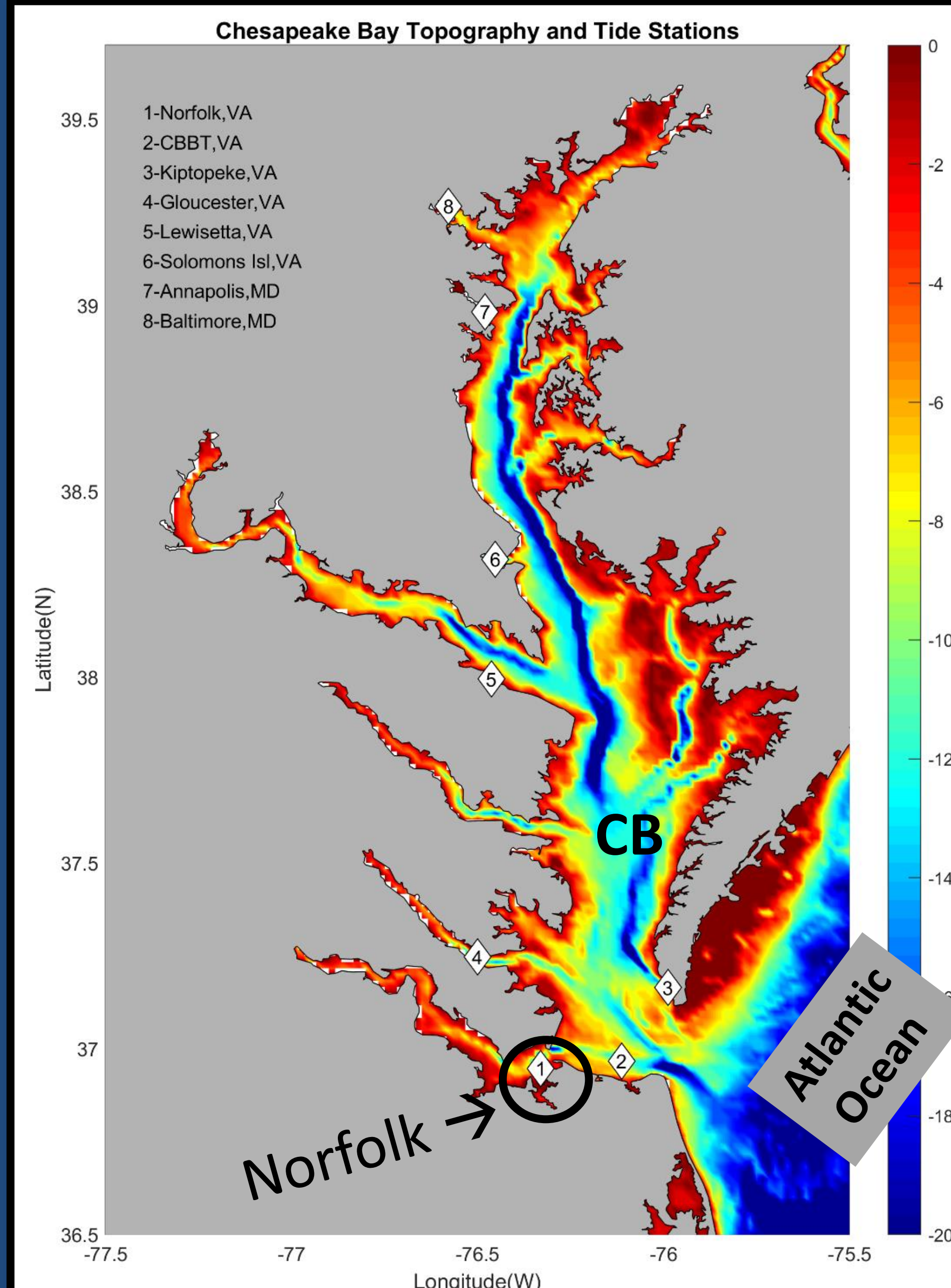
Editor-in-Chief: Ocean Dynamics - by - SPRINGER NATURE

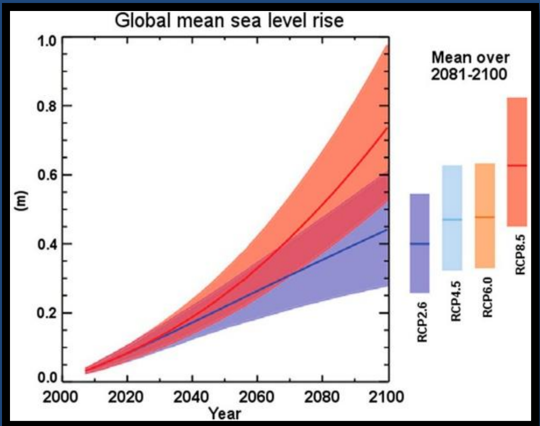
Norfolk, VA as a test case: one of the US cities with the highest risk of flooding





To predict future floods at specific location we need to consider:

Global Sea Level Rise



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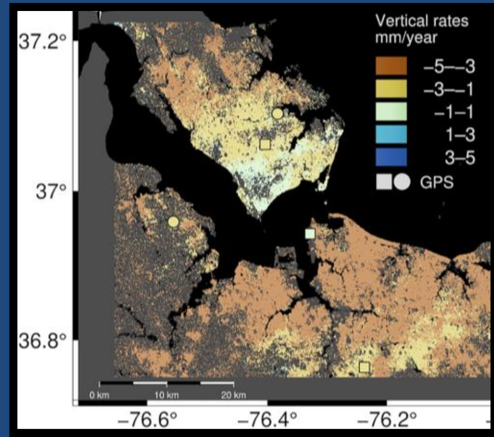
Local Land Subsidence



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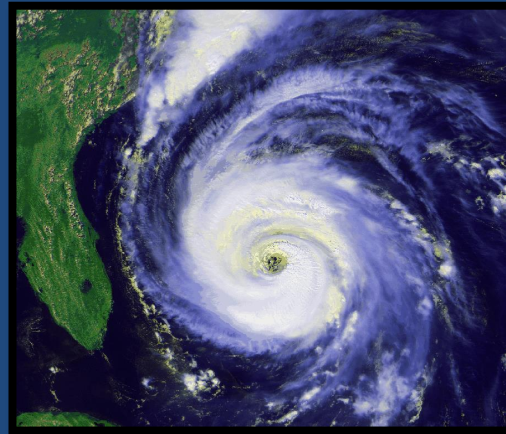
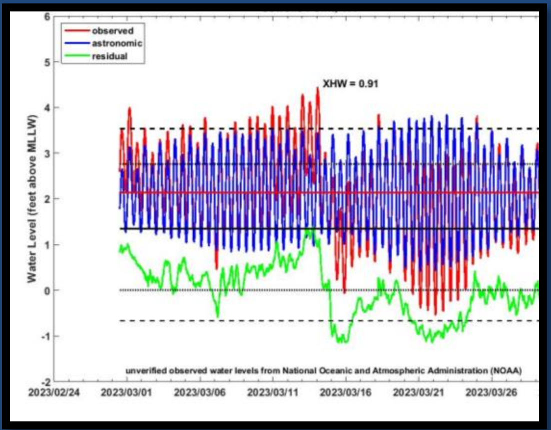
Storm Surges



Tides



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Waves

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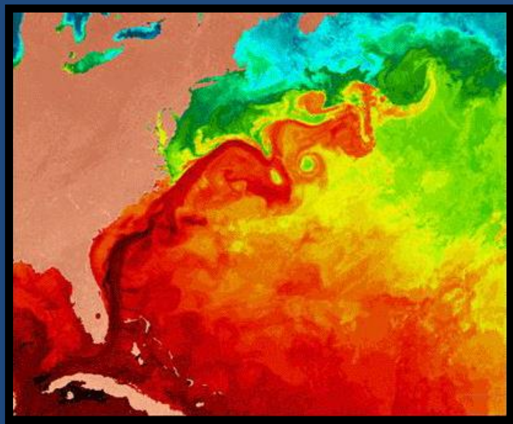
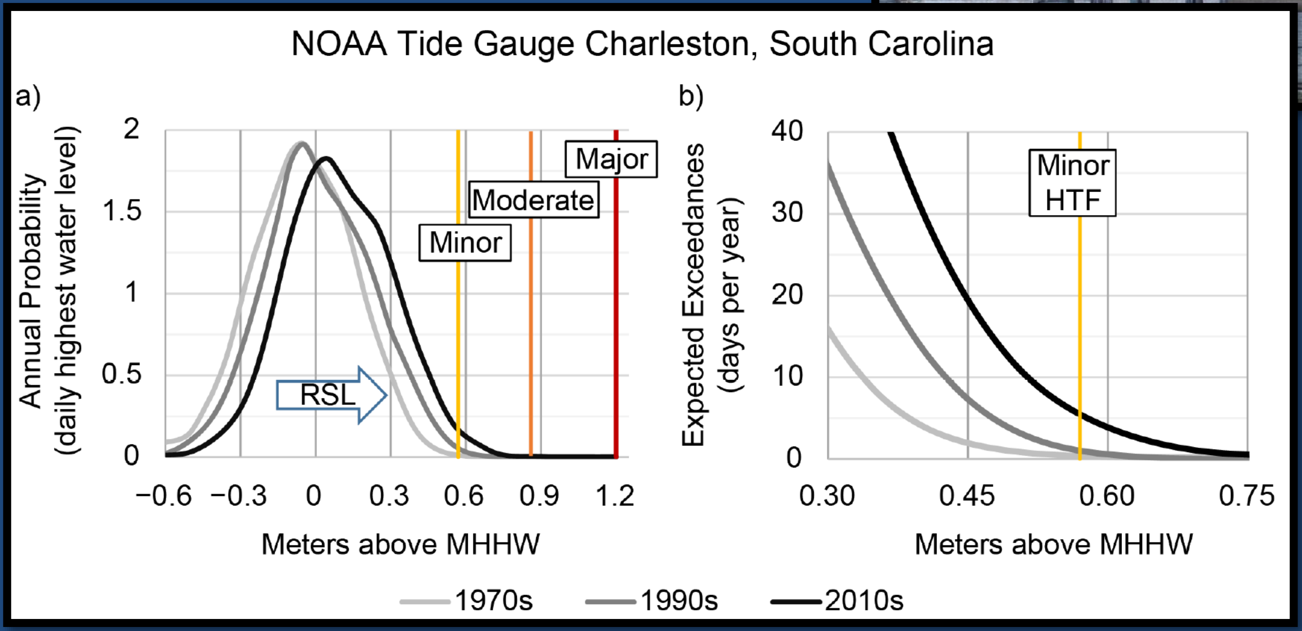
Ocean Dynamics



… and possibly other factors like interannual and decadal variations (NAO, ENSO, AMOC, etc.)

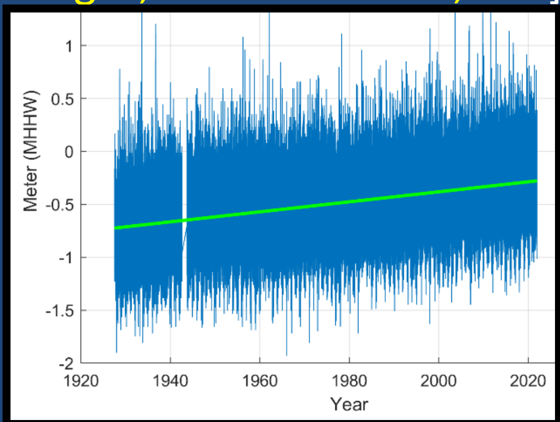
NOAA provides annual reports on SLR projection for the US based on a probabilistic approach (using a probability function of recurrent flooding)



But how useful is this information for practical purposes, say for a resident living near water who wants to know how many hours of flooding he can expect in 10 years if his house is 1m above the high tide?

A simpler flood prediction based on statistics of past data by randomly sampling hourly water level (Norfolk: 1927-2021 > 800,000 data points)

[data already combine tides, waves, storm-surges, interannual var, etc.]



} Hourly WL observations

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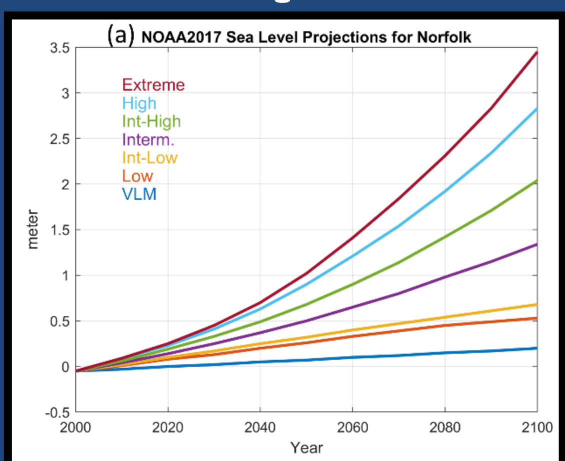

} 3 projections

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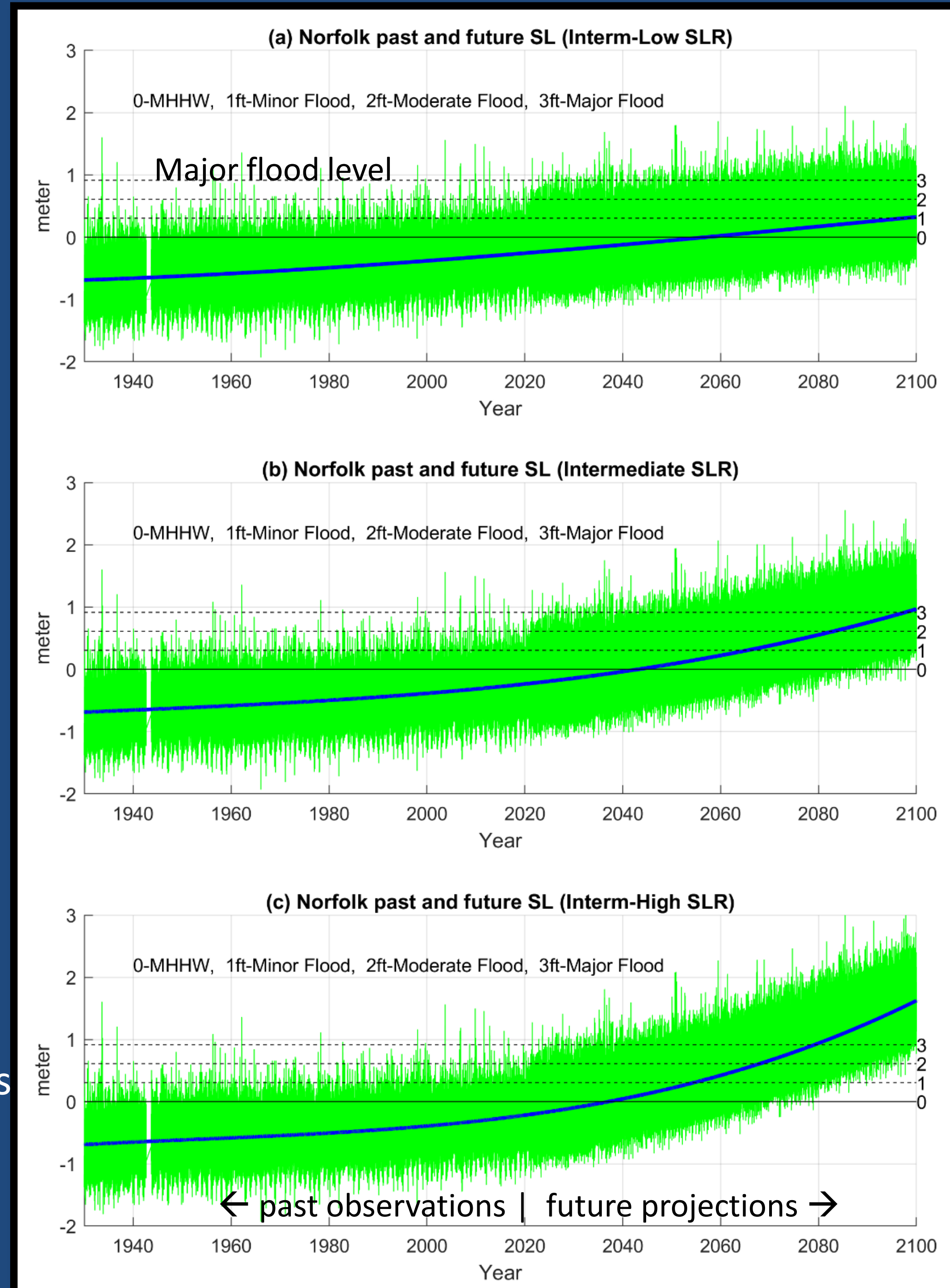
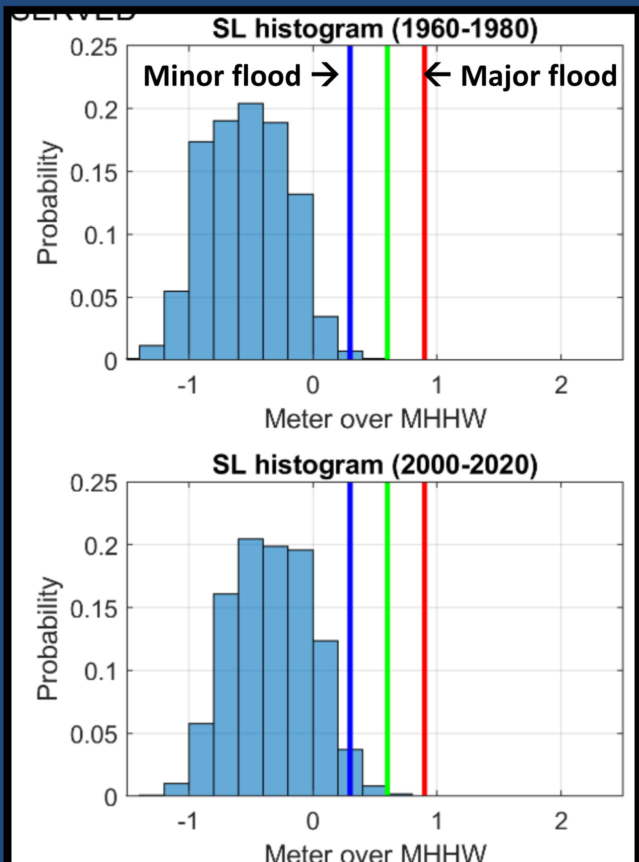
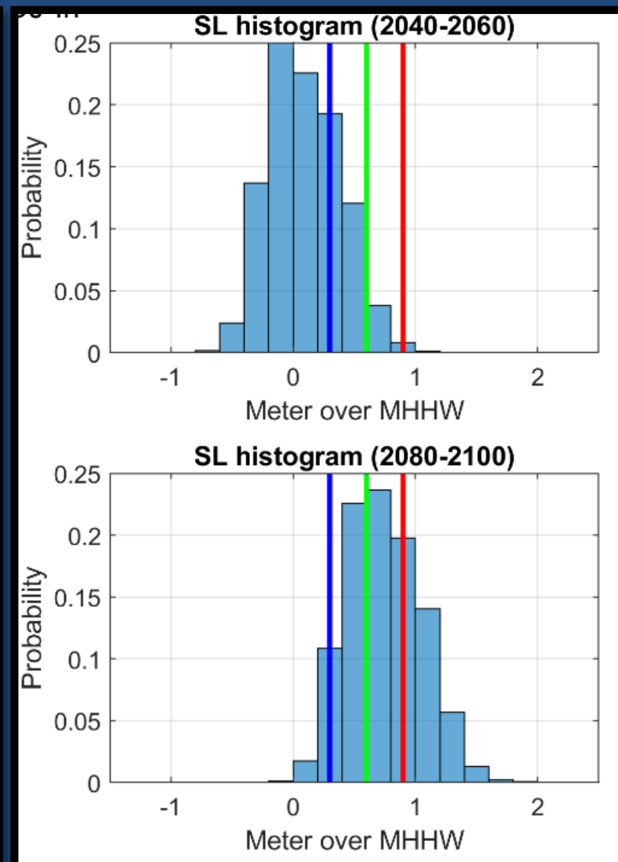


Flood projections for 3 SLR scenarios and 3 flood levels

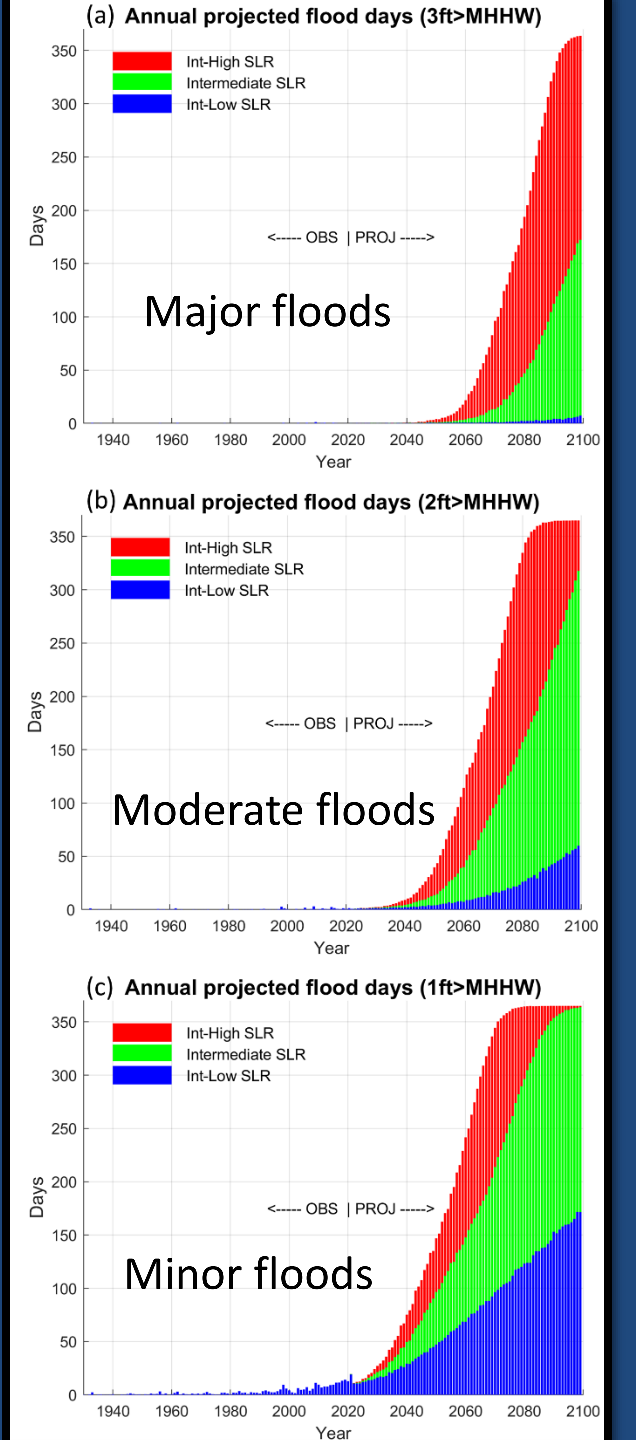
Past increase in flooding 1960-2020

Future increase in flooding 2040-2060





Intermediate SLR



We noticed that rate of increase in flood hours for low-intermediate SLR is the same for past data and future projection (on a logarithmic scale), so that an empirical formula can estimate minimum flooding.

Percent of time that Norfolk is flooded:

$$P(\%)=10^{(0.02Y-2.4F-39.6)}$$

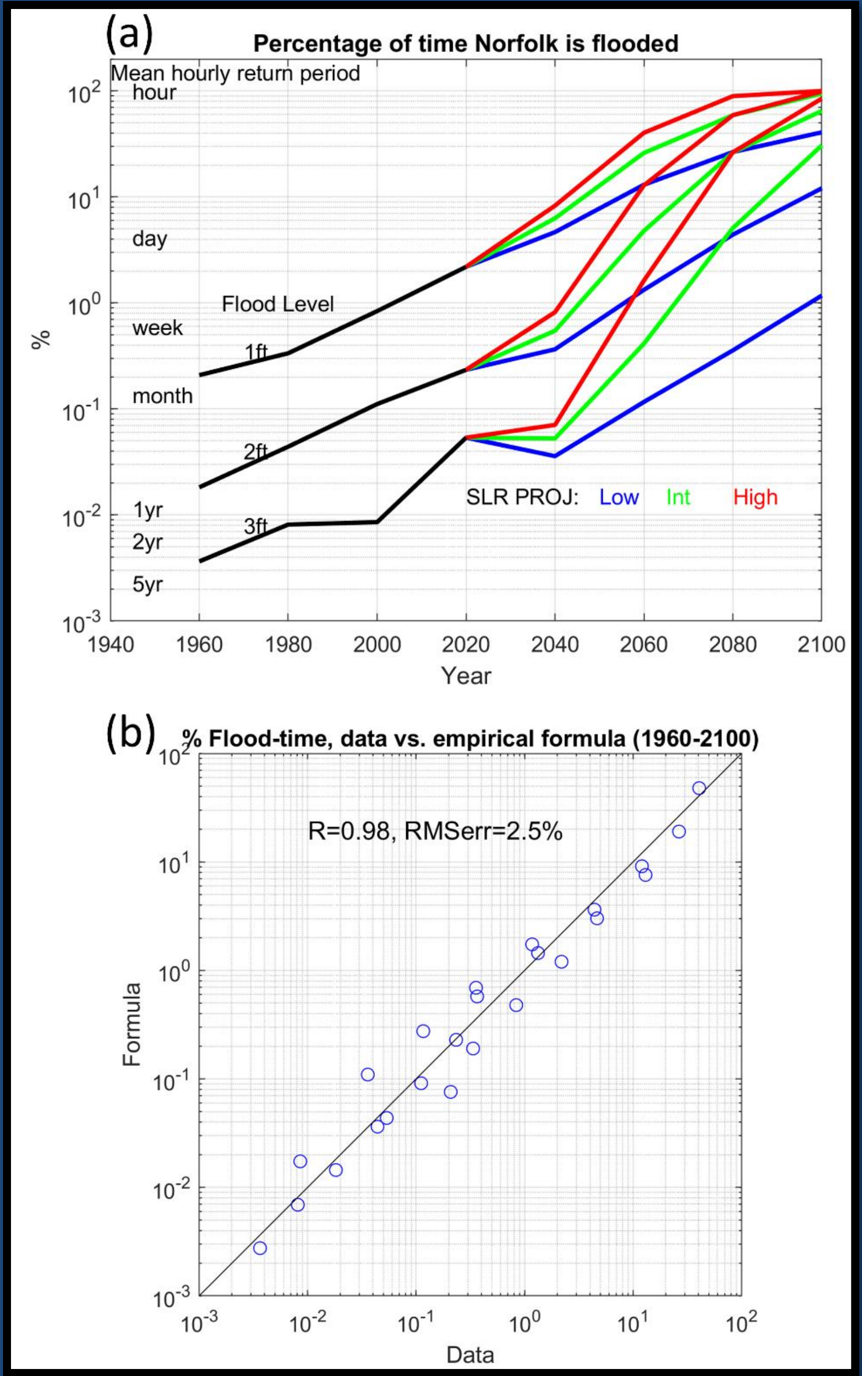
Y=year (1960-2100)

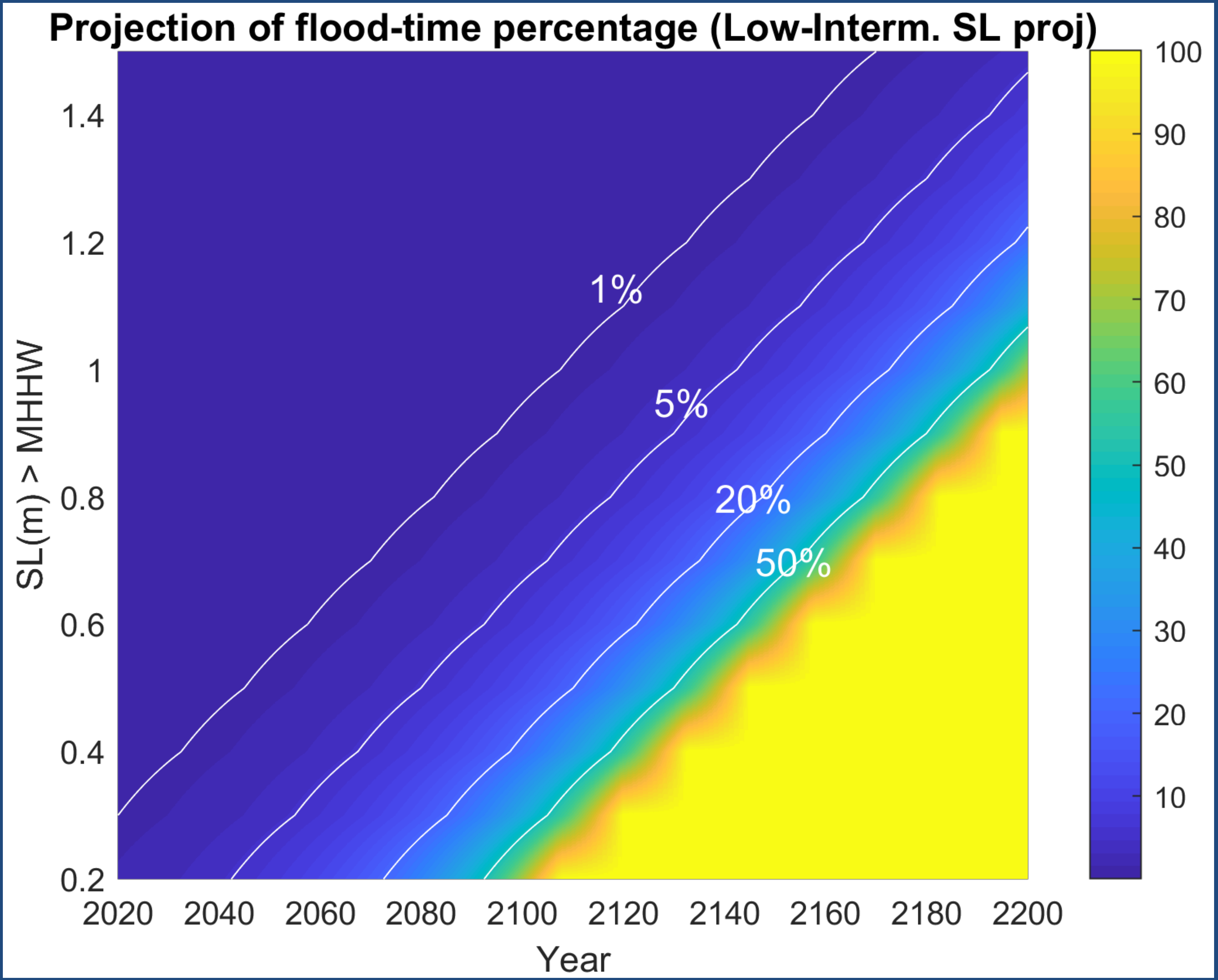
F=flood level (m>MHHW)

Year when flood occurs 100% of time:

$$Y(100\%)=2080+120F$$

So, by 2080 location that is now flooded only during high tide (F=0) will be permanently under water…



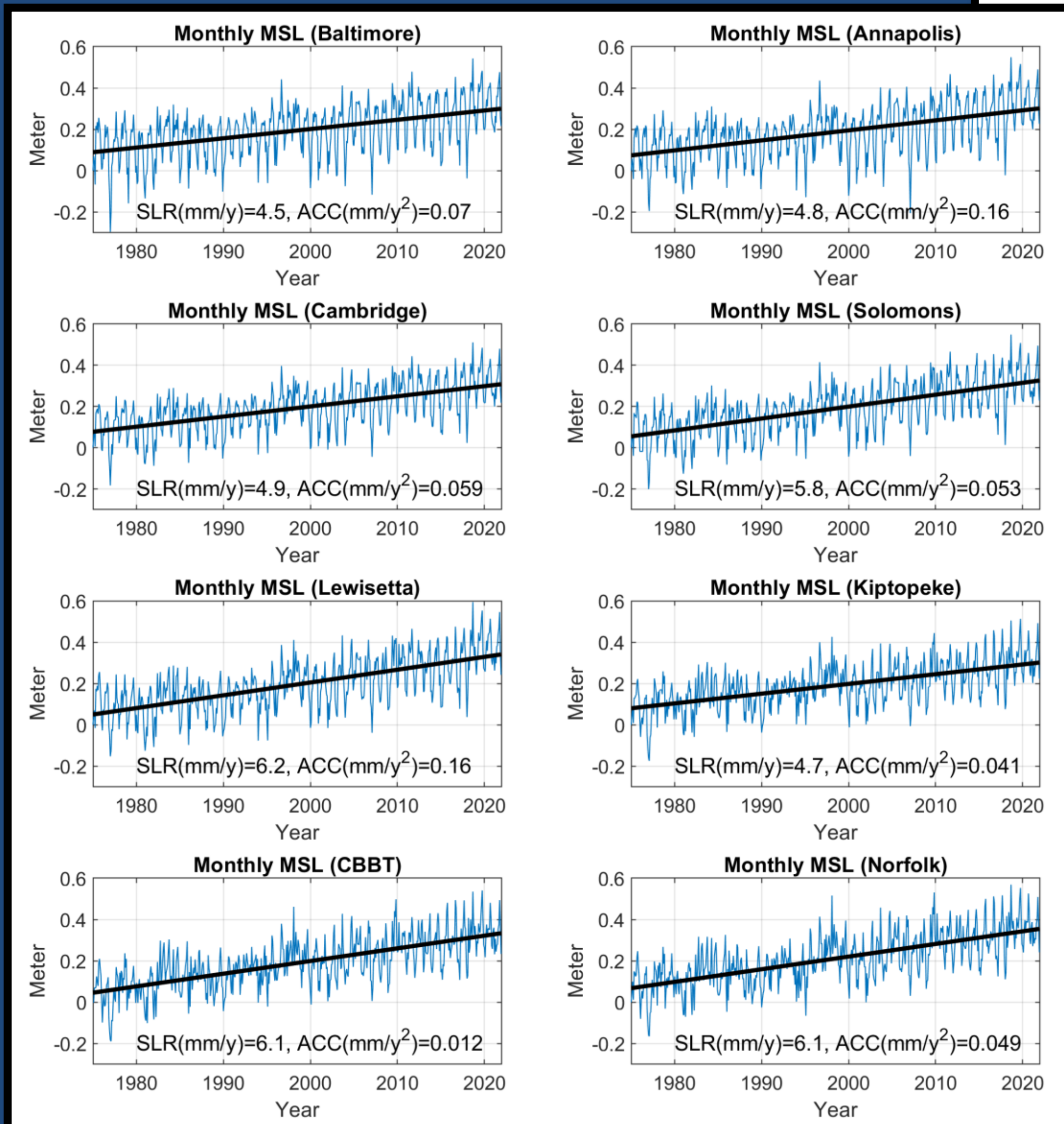


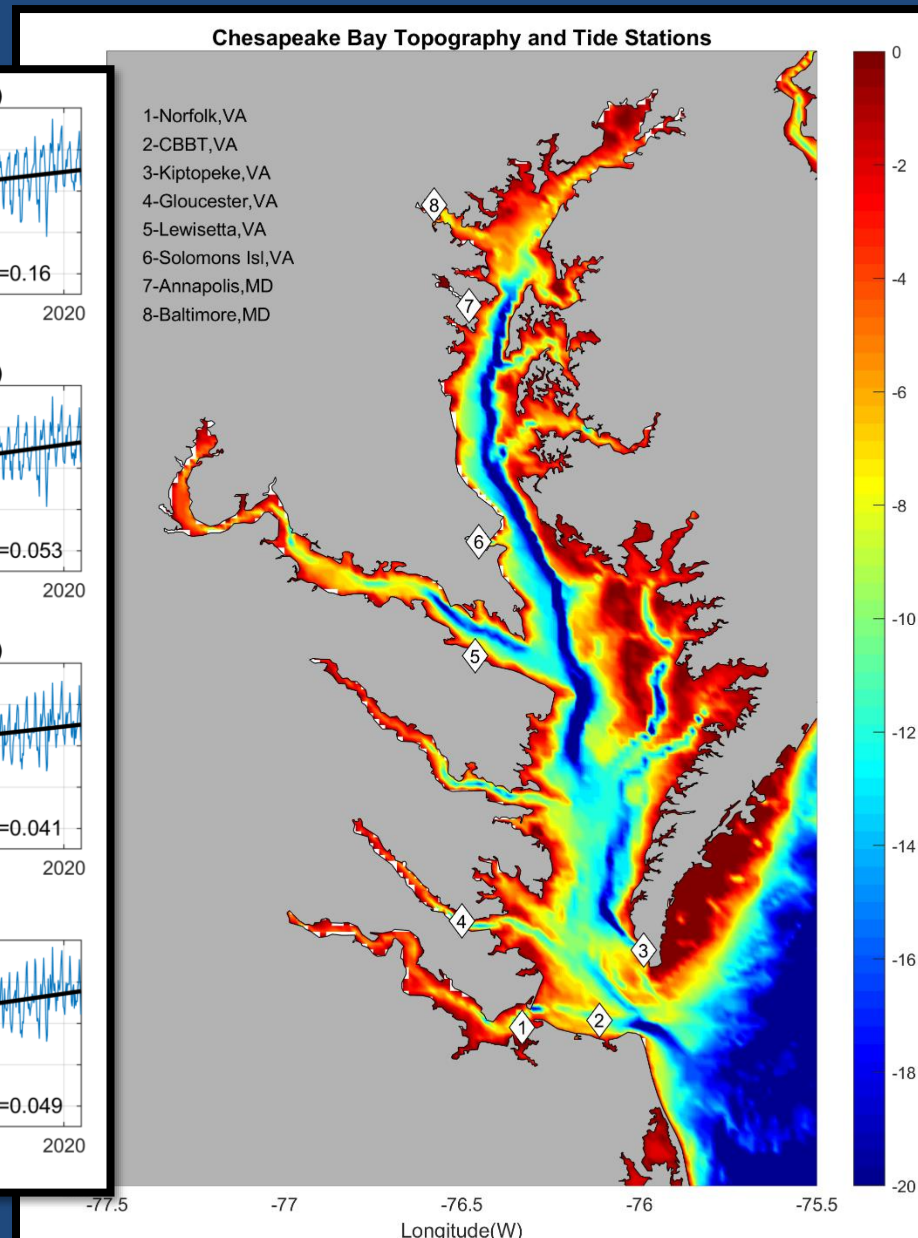
Projection of flood-time percentage (Low-Interm. SL proj)
SL(m) > MHHW
Year
1%
5%
20%
50%
0.2
0.4
0.6
0.8
1
1.2
1.4
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
10
20
30
40
50
60
70
80
90
100

What about spatial variations in SLR, can projections capture them? Example: Chesapeake Bay

For 1975-2021: SLR rates are between **4.5 mm/y** and **6.2 mm/y** (global SLR~3.5 mm/y)

SL Acceleration rates: **0.01 mm/y2** and **0.16 mm/y2**





Variations within Chesapeake Bay:

Linear SLR

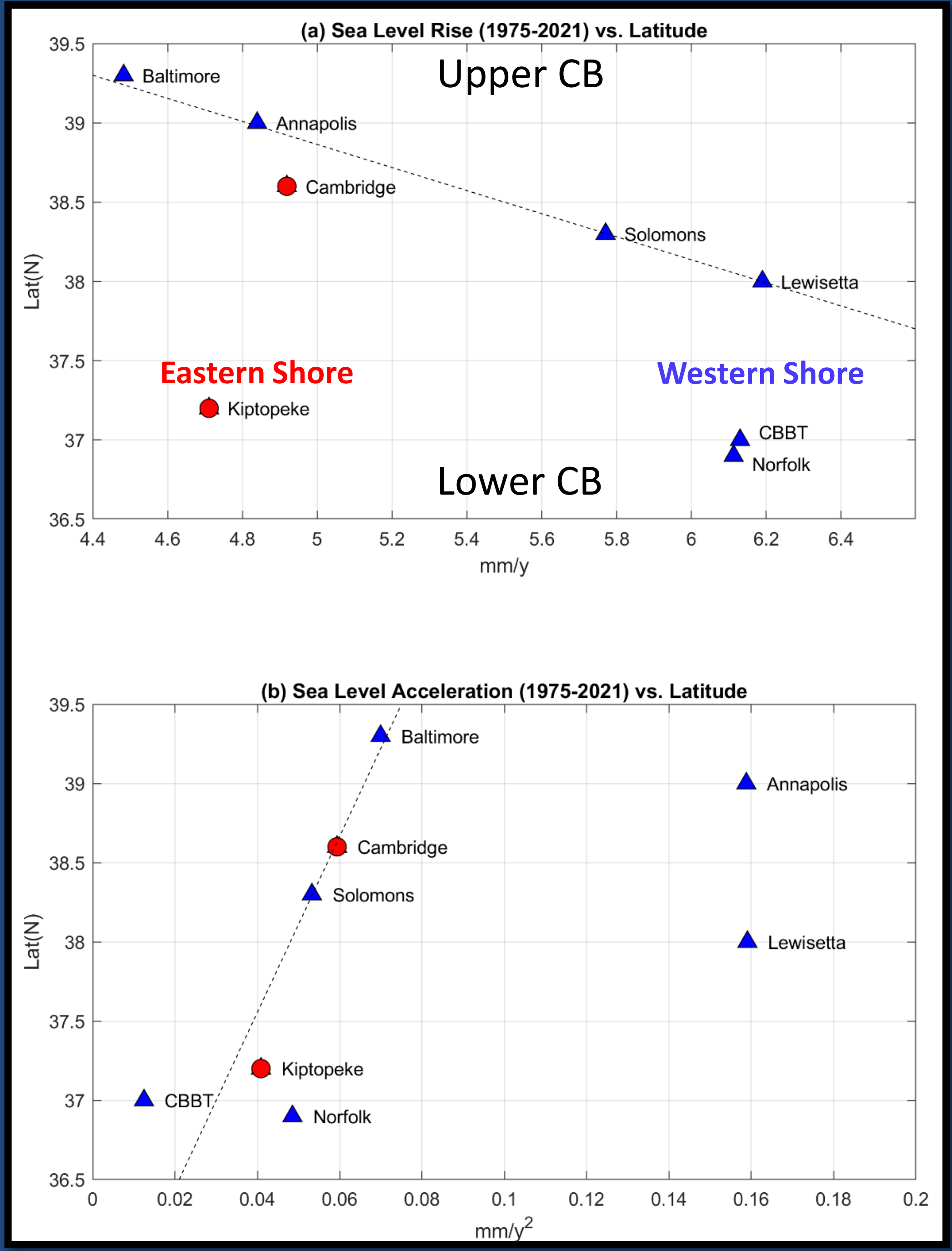
increased toward lower Bay

(land subsidence)

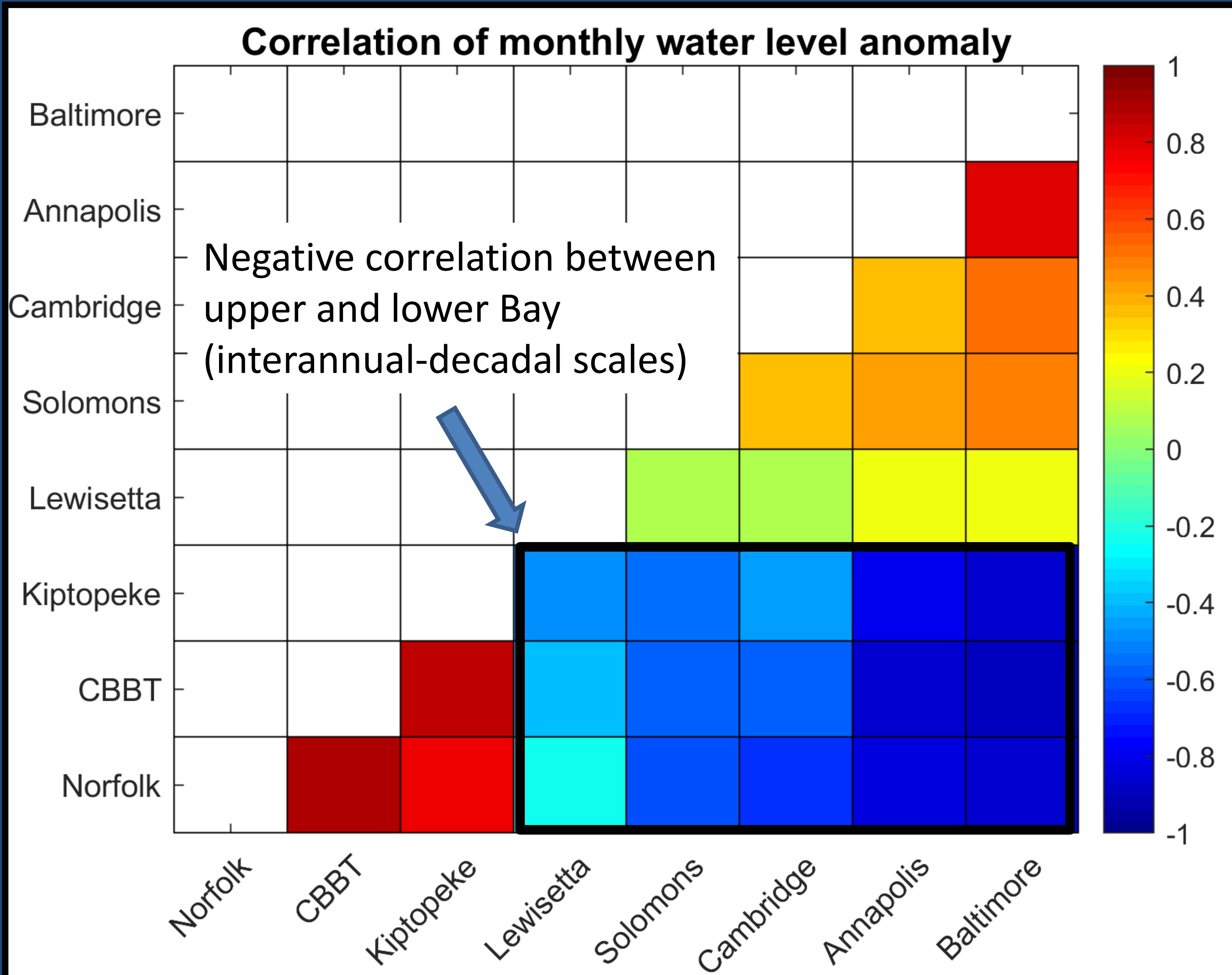
Acceleration in SLR

increased toward upper Bay

(local dynamics)

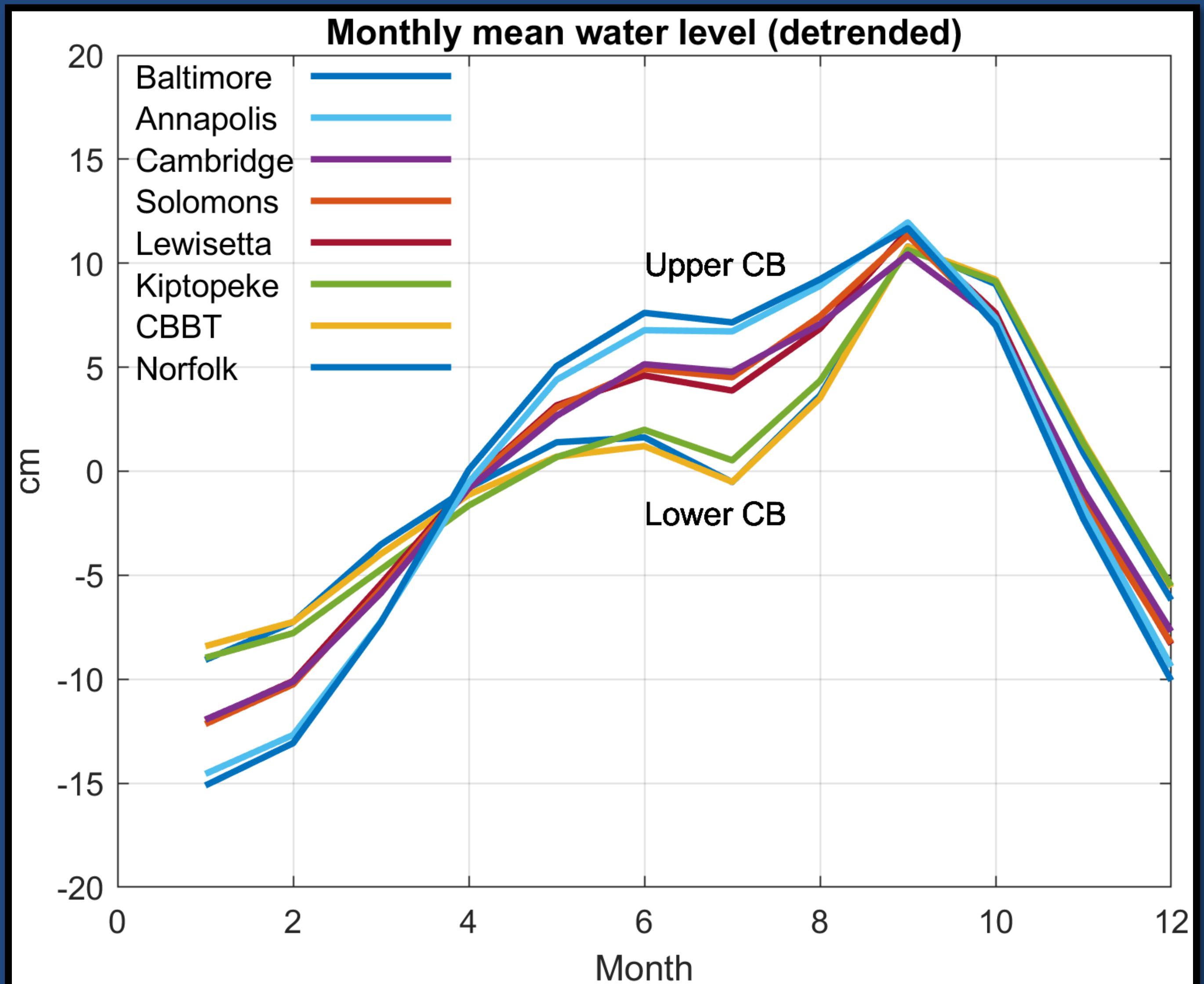


Local dynamics also play a role- how can SLR prediction account for that?



Even the seasonal cycle of sea level is different between the upper and lower Bay due to annual and semi-annual tides (not thermosteric effect of seasonal temperature!)

This is another effect that global climate models cannot capture

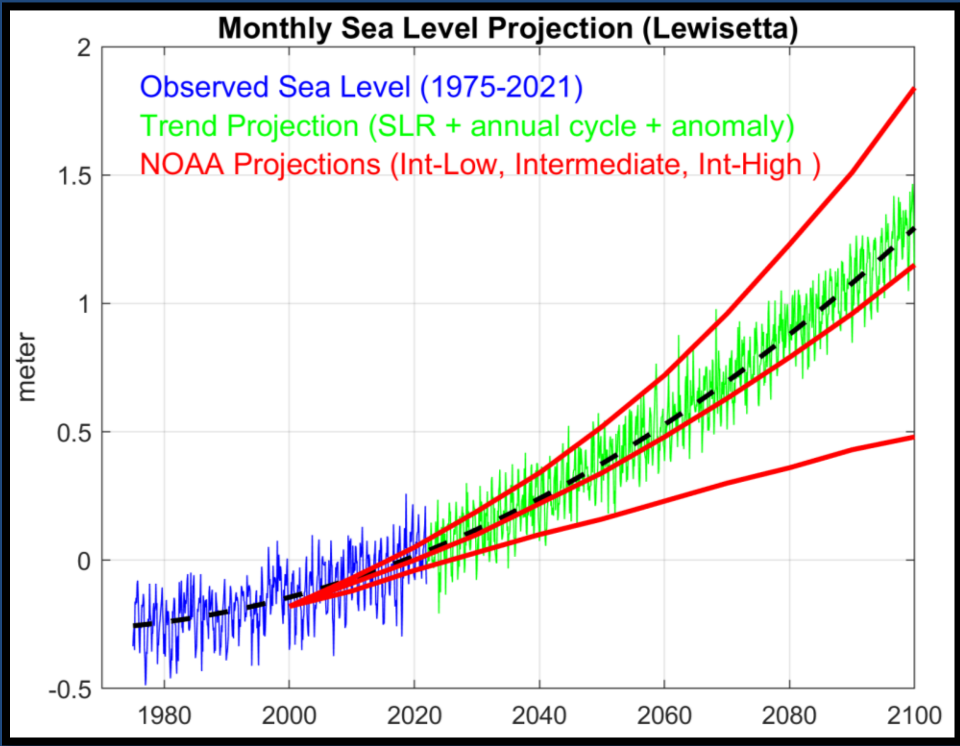


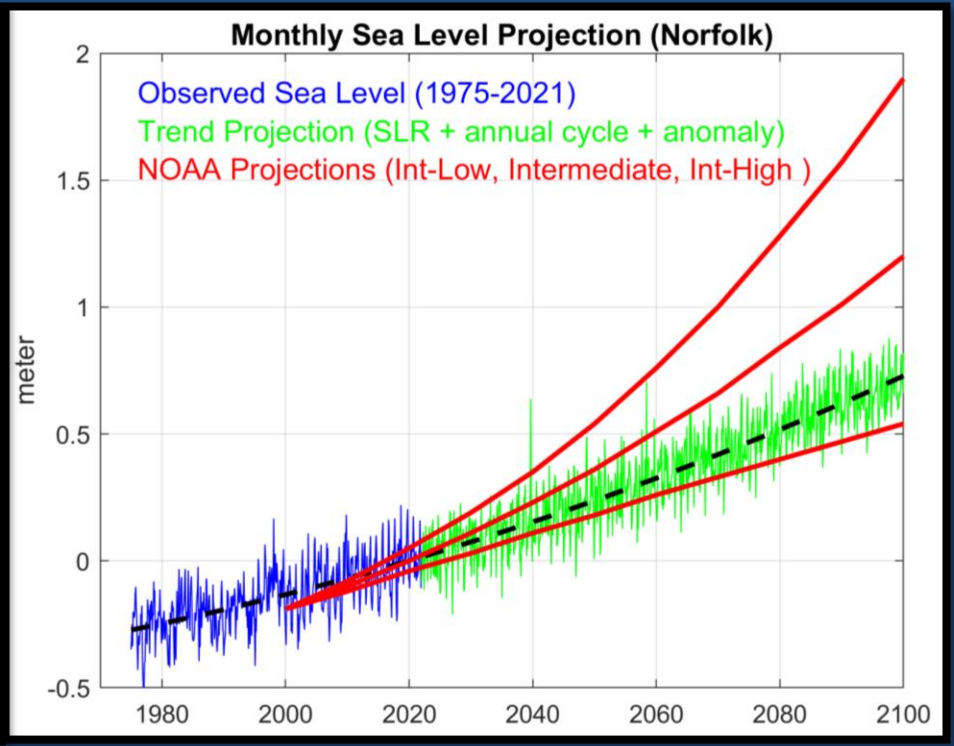
Comparison of monthly sea level projections

NOAA projections: climate models scenarios + local subsidence

Statistical projections: SLR + Acceleration + monthly variability

- Very different results because climate models projection neglect local dynamics
- Which projection is more accurate? An open question…





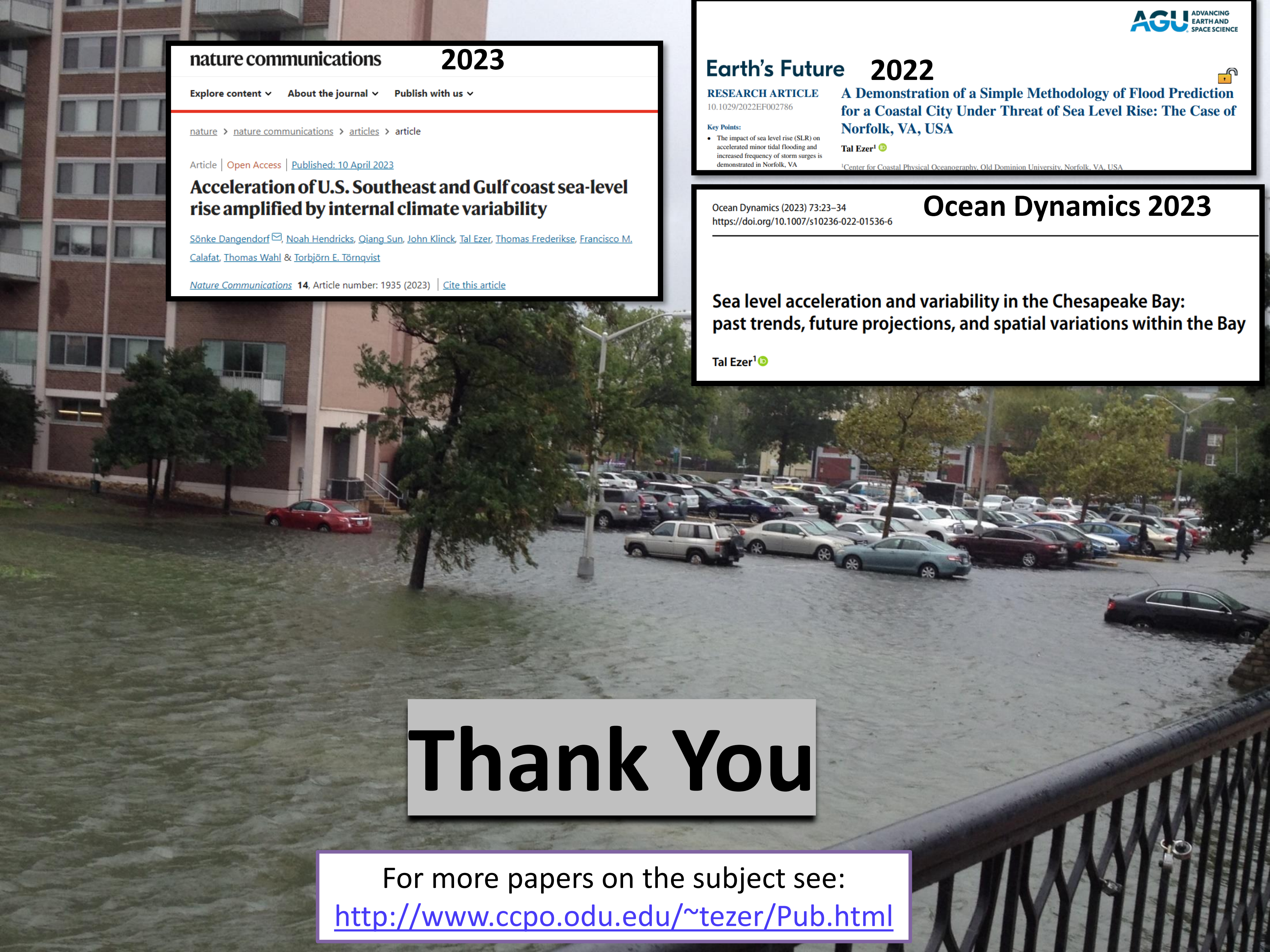
Summary

- Simple sea level projection based on past observations can provide useful information of future flooding for mitigation and adaptation planning.

- Predicted floods for 2100 shows potential catastrophic flooding to many low-lying locations. In Norfolk, for example, the highest storm surge that happened once in the past 100 years, will occur almost daily by 2100.

- Statistical-based projections and climate models-based projections can be very different, so how can we account for local dynamics?

- Other options: downscaling from global climate models to high-resolution regional and local hydrodynamic forecast models (an issue relevant to the COSS-TT group).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RESEARCH ARTICLE
10.1029/2022EF002786
A Demonstration of a Simple Methodology of Flood Prediction for a Coastal City Under Threat of Sea Level Rise: The Case of Norfolk, VA, USA
Key Points:
The impact of sea level rise (SLR) on accelerated minor tidal flooding and increased frequency of storm surges is demonstrated in Norfolk, VA
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[1]Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, VA, USA
Ocean Dynamics (2023) 73:23–34
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Ocean Dynamics 2023
Sea level acceleration and variability in the Chesapeake Bay: past trends, future projections, and spatial variations within the Bay
Tal Ezer[1]
Thank You
For more papers on the subject see:
http://www.ccpo.odu.edu/~tezer/Pub.html