Potential Climate Change Impacts on the Chesapeake Bay

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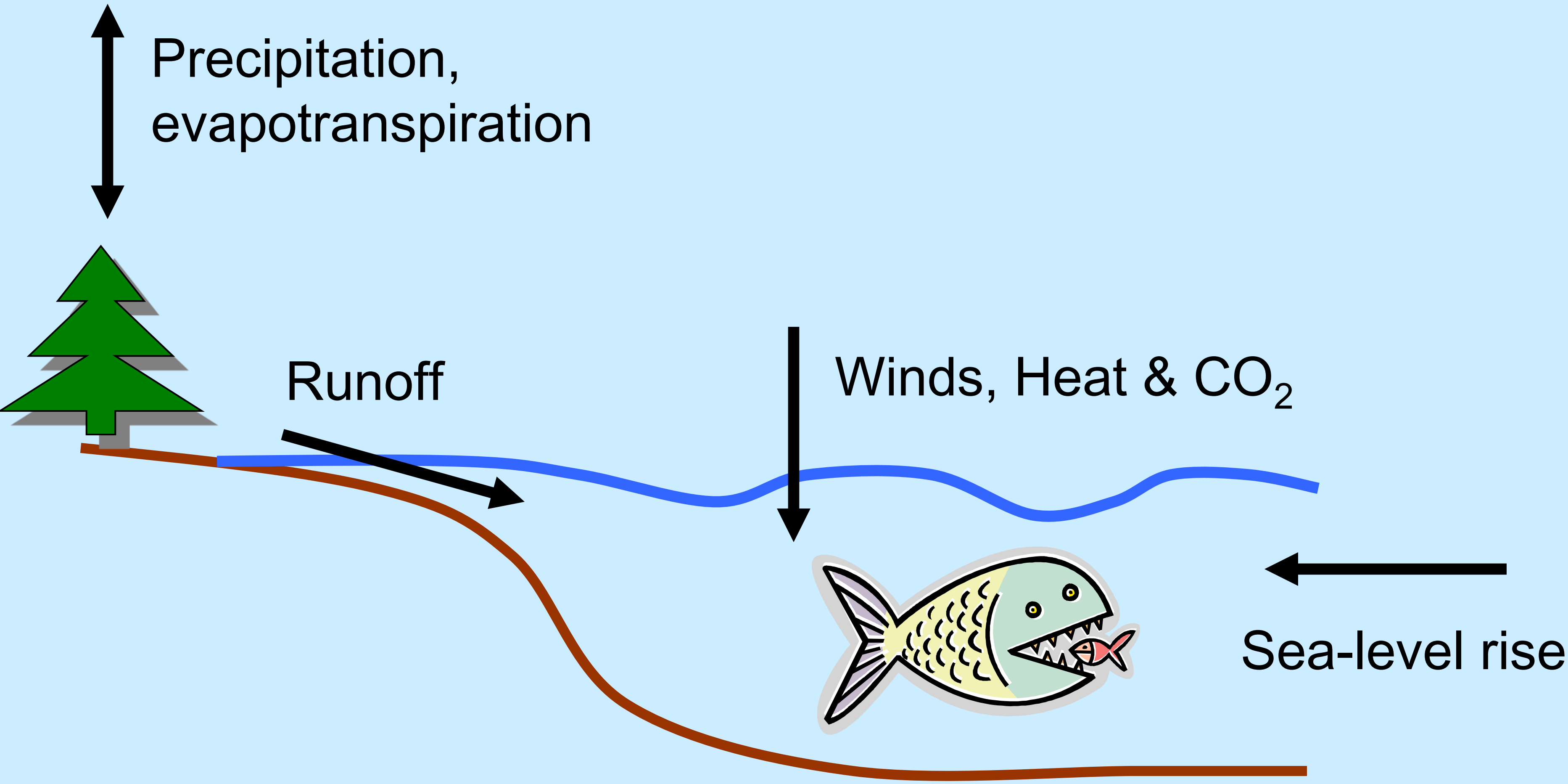
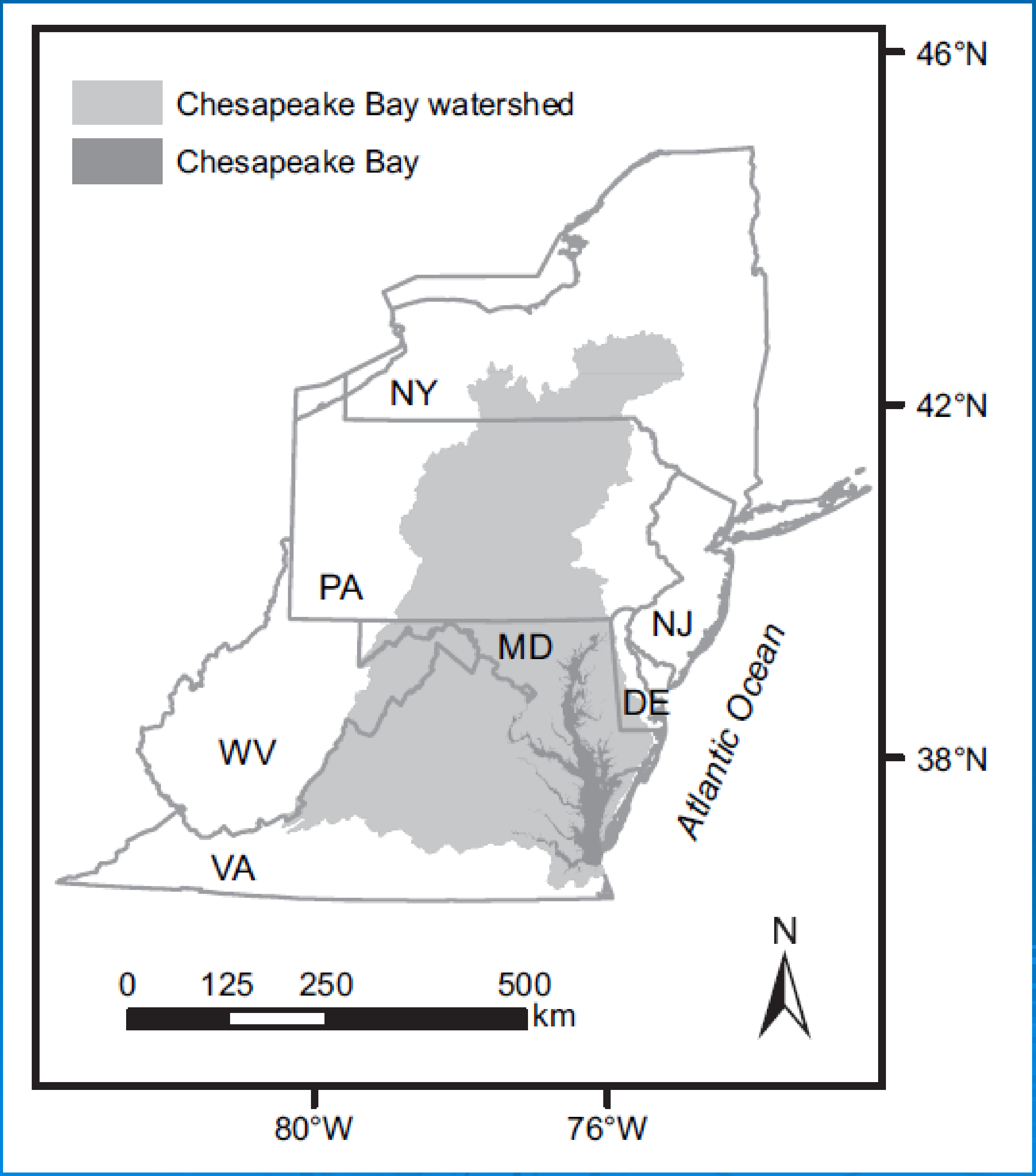
Estuarine, Coastal and Shelf Science, 86, 2010, 1-20

Climate change and estuaries



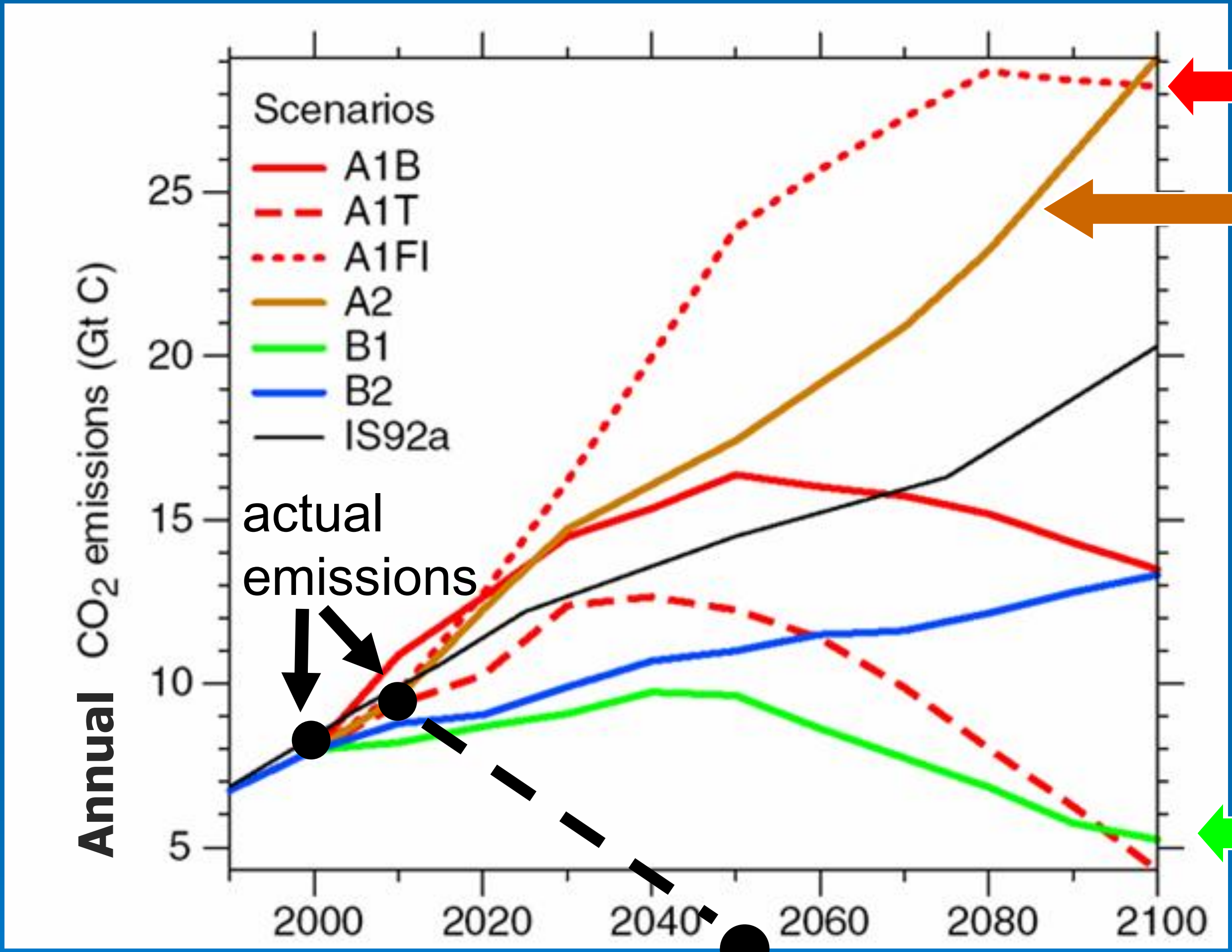

Chesapeake Bay watershed
Chesapeake Bay
46°N
42°N
38°N
NY
PA
NJ
MD
DE
WV
VA
Atlantic Ocean
N
0
125
250
500
km
80°W
76°W

Chesapeake outline

- Climate and hydrology
- Watershed sediment and nutrient fluxes
- Bay physics, biogeochemistry, vascular plants, fish, and shellfish
- Policy & research implications

Climate and hydrology

IPCC Emissions scenarios



HIGHER

A1FI (CO_2 = 940 ppm)

HIGHER

A2 (CO_2 = 840 ppm)

pre-industrial
CO_2 = 280 ppm

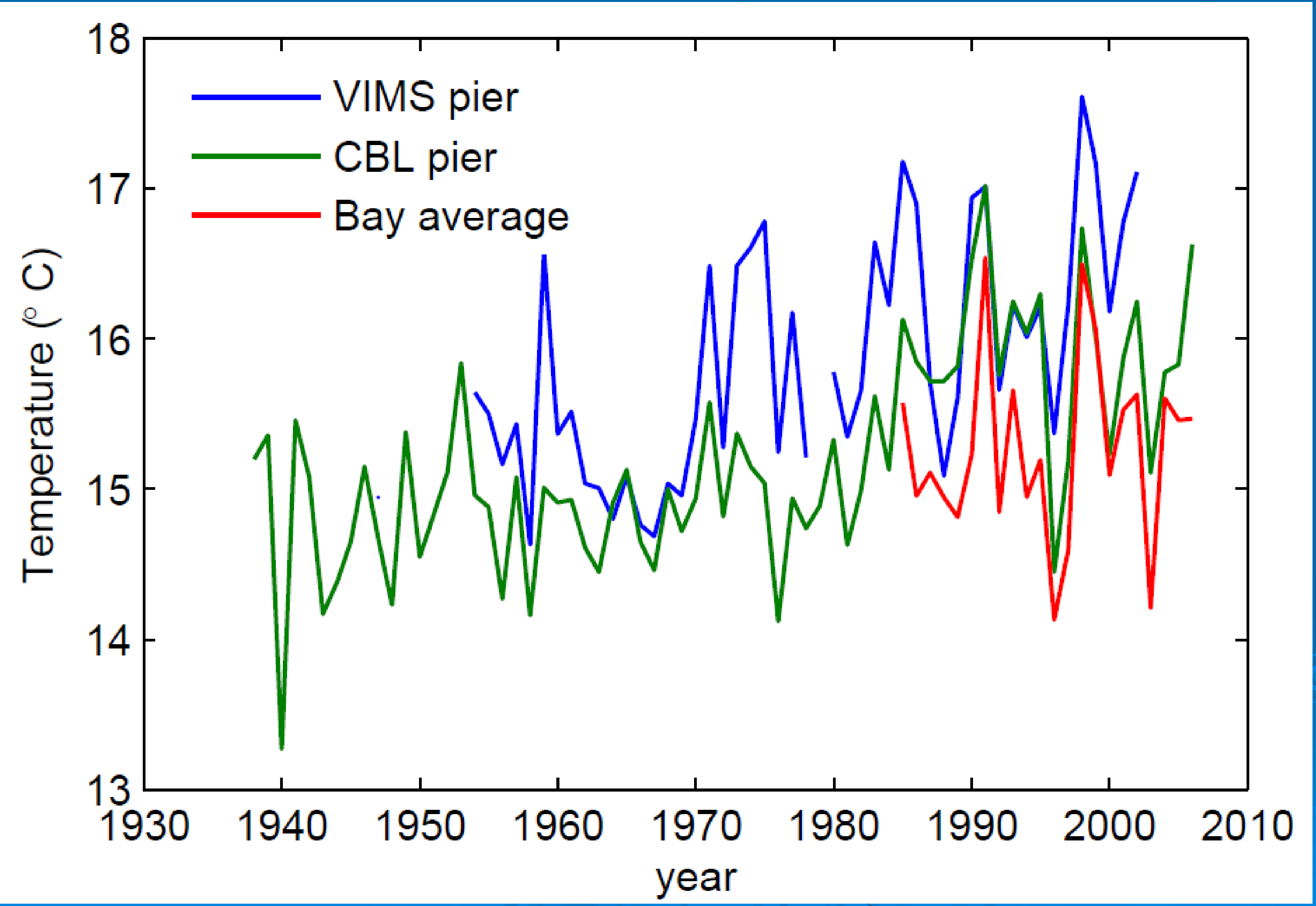
LOWER

B1 (CO_2 = 550 ppm)

Commonly proposed target: 20% of current emissions by 2050—estimated warming of 2° C.

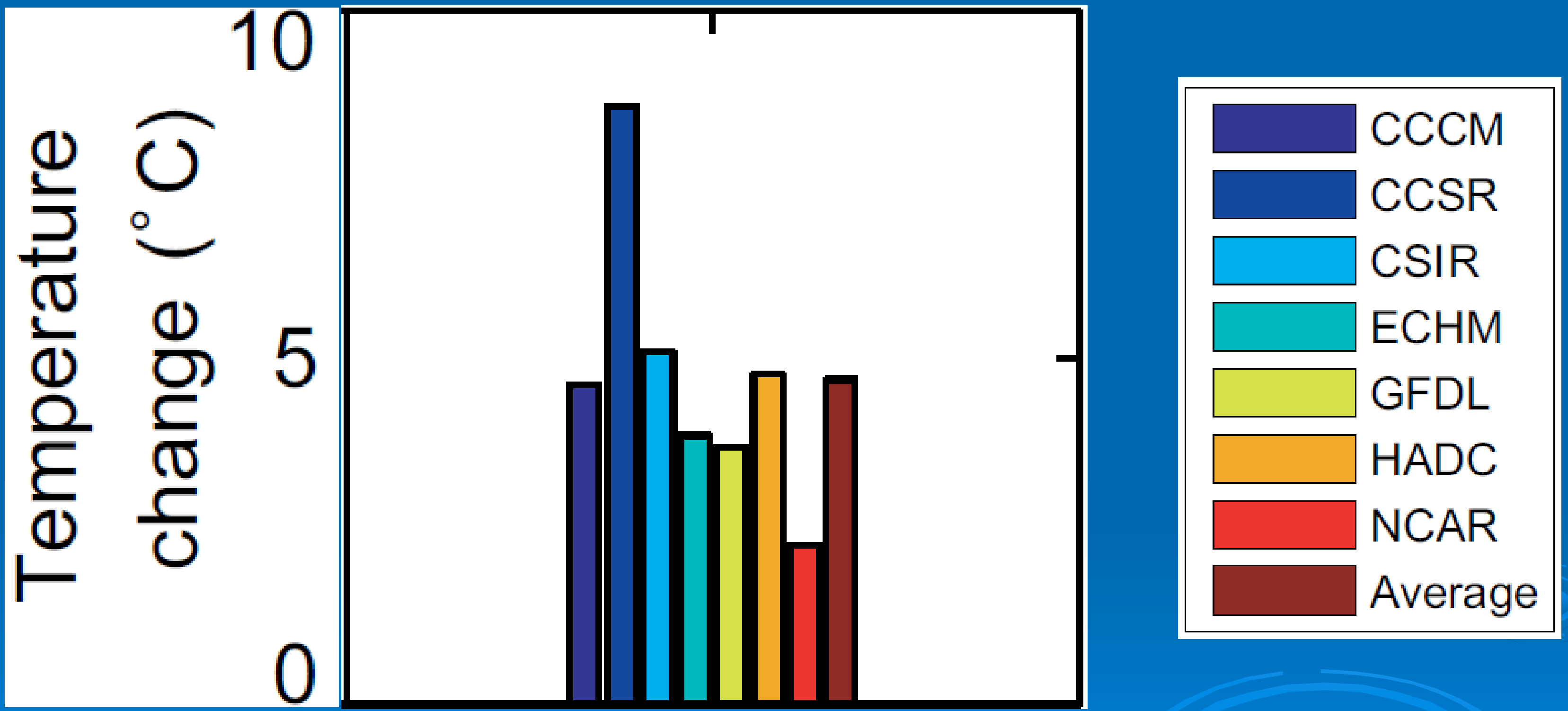
Source: Nakićenović & Swart (2000)

Chesapeake Bay is warming



Source: CBP & VIMS archive, Kaushal et al. (2010)

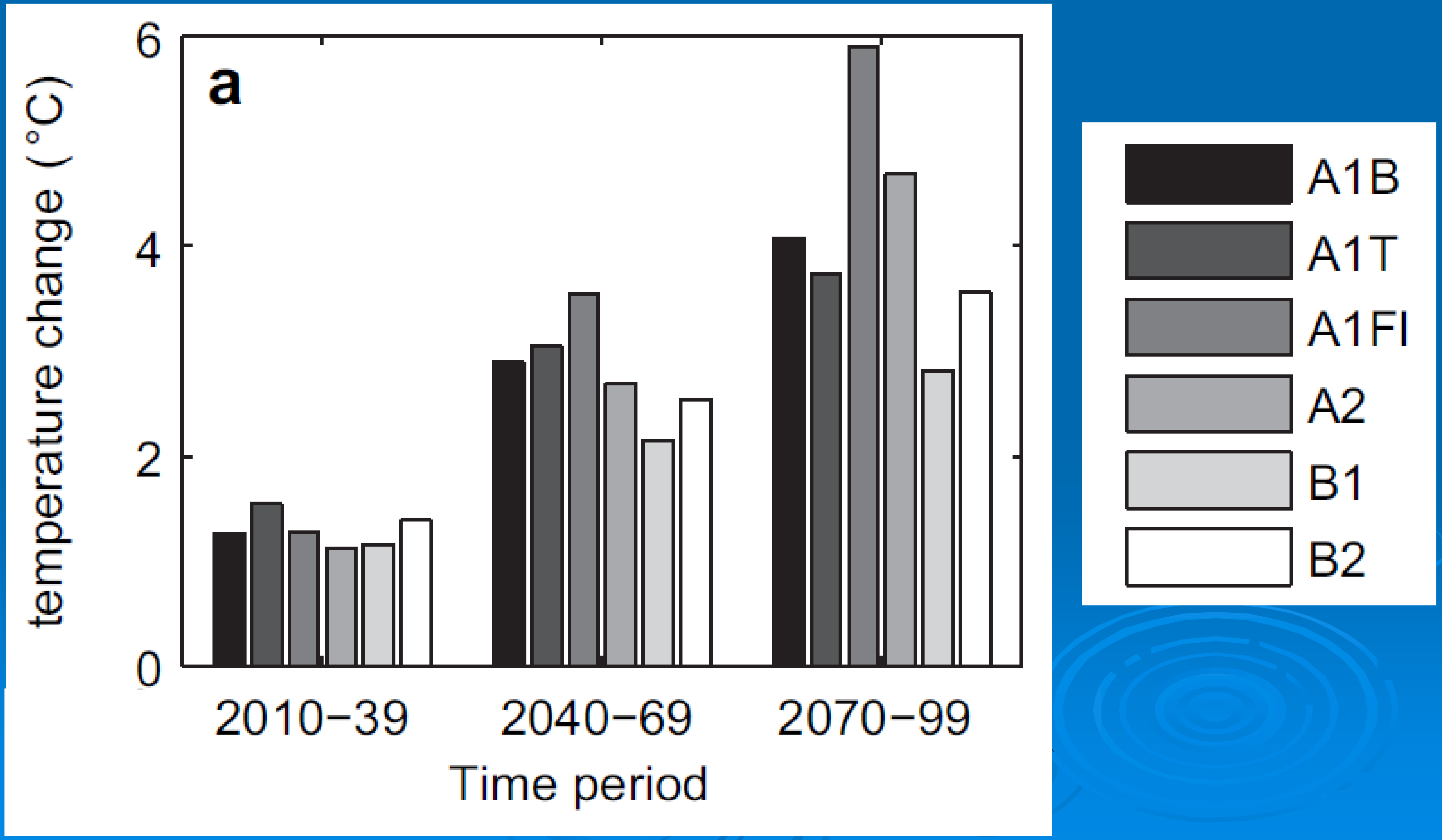
Bay watershed temperature projections by various climate models



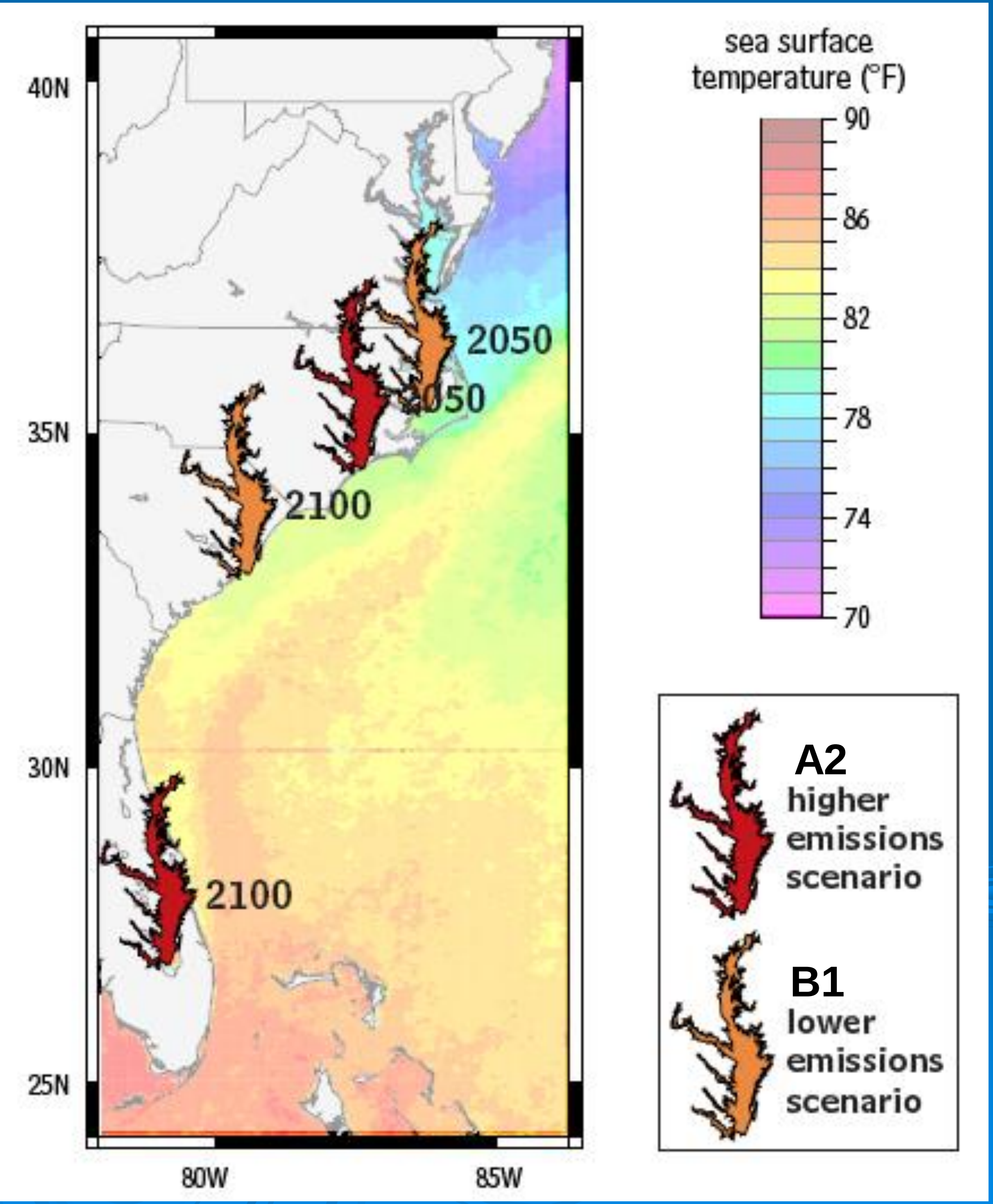
2100 projections under A2 emissions scenario

Najjar et al. (2009)

Multi-model-average Bay watershed temperature projections under various emissions scenarios

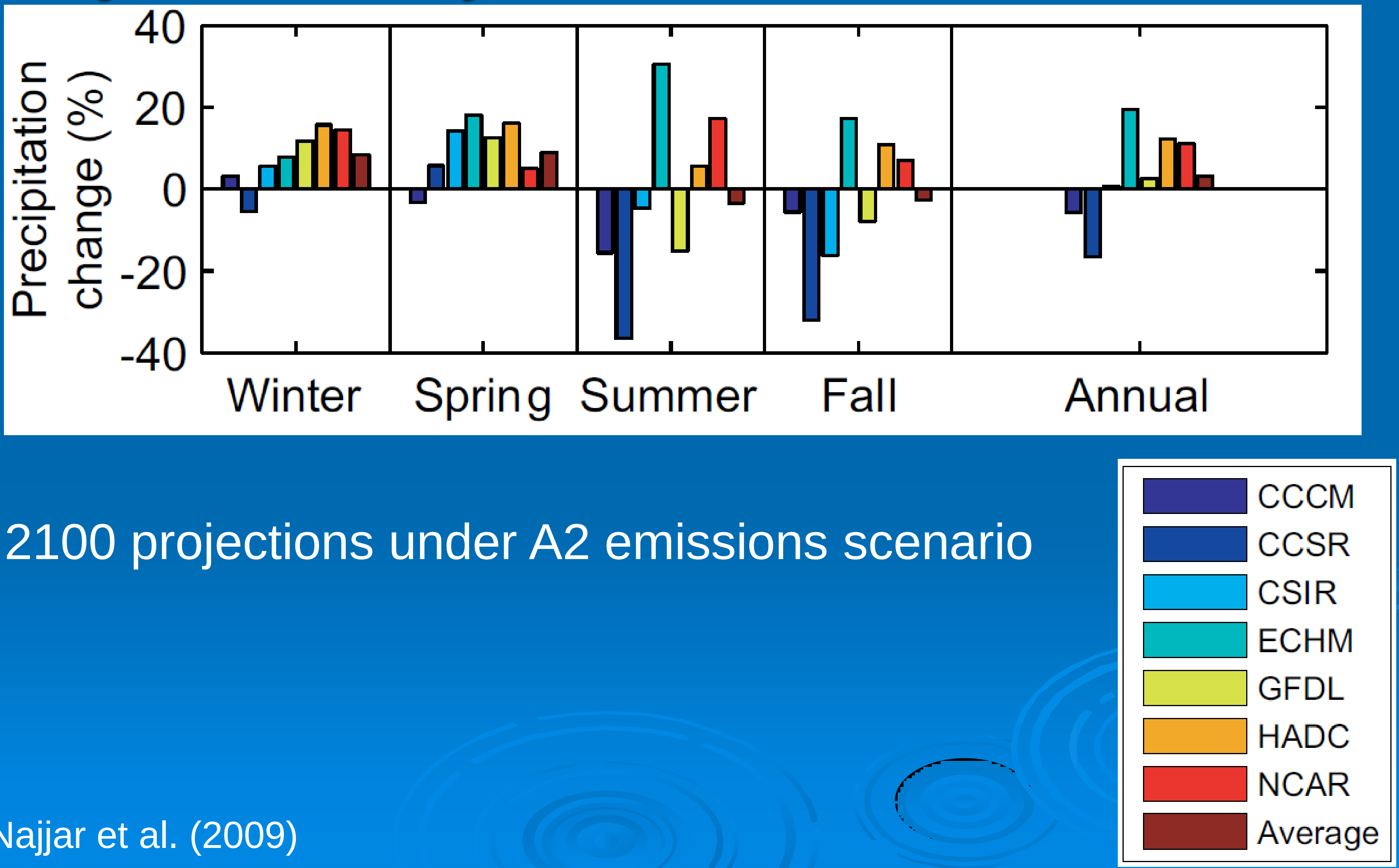


Moving estuary analogue: summer temperature change



Boesch (2008)

Bay watershed precipitation projections by various climate models



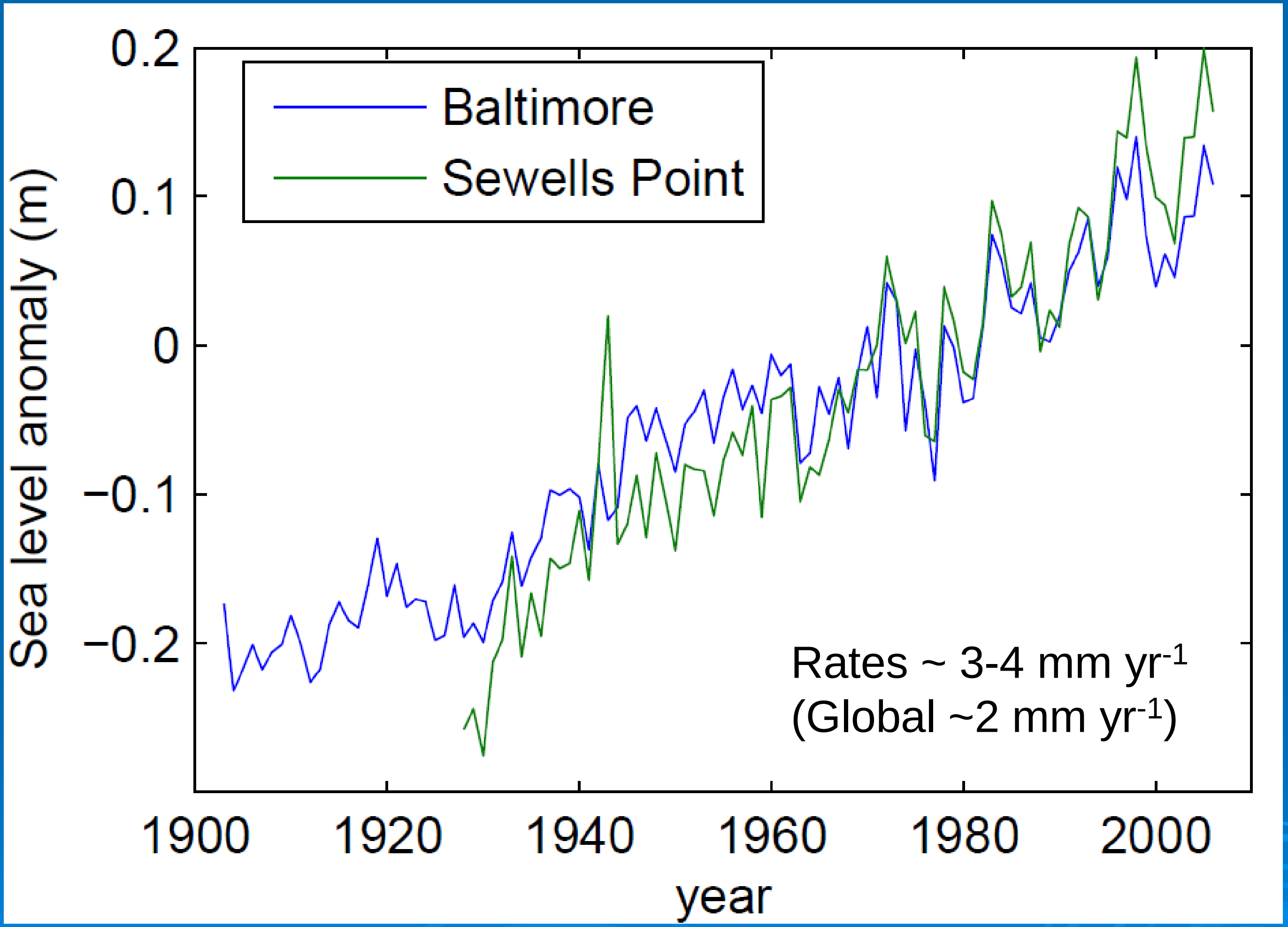
2100 projections under A2 emissions scenario

Najjar et al. (2009)

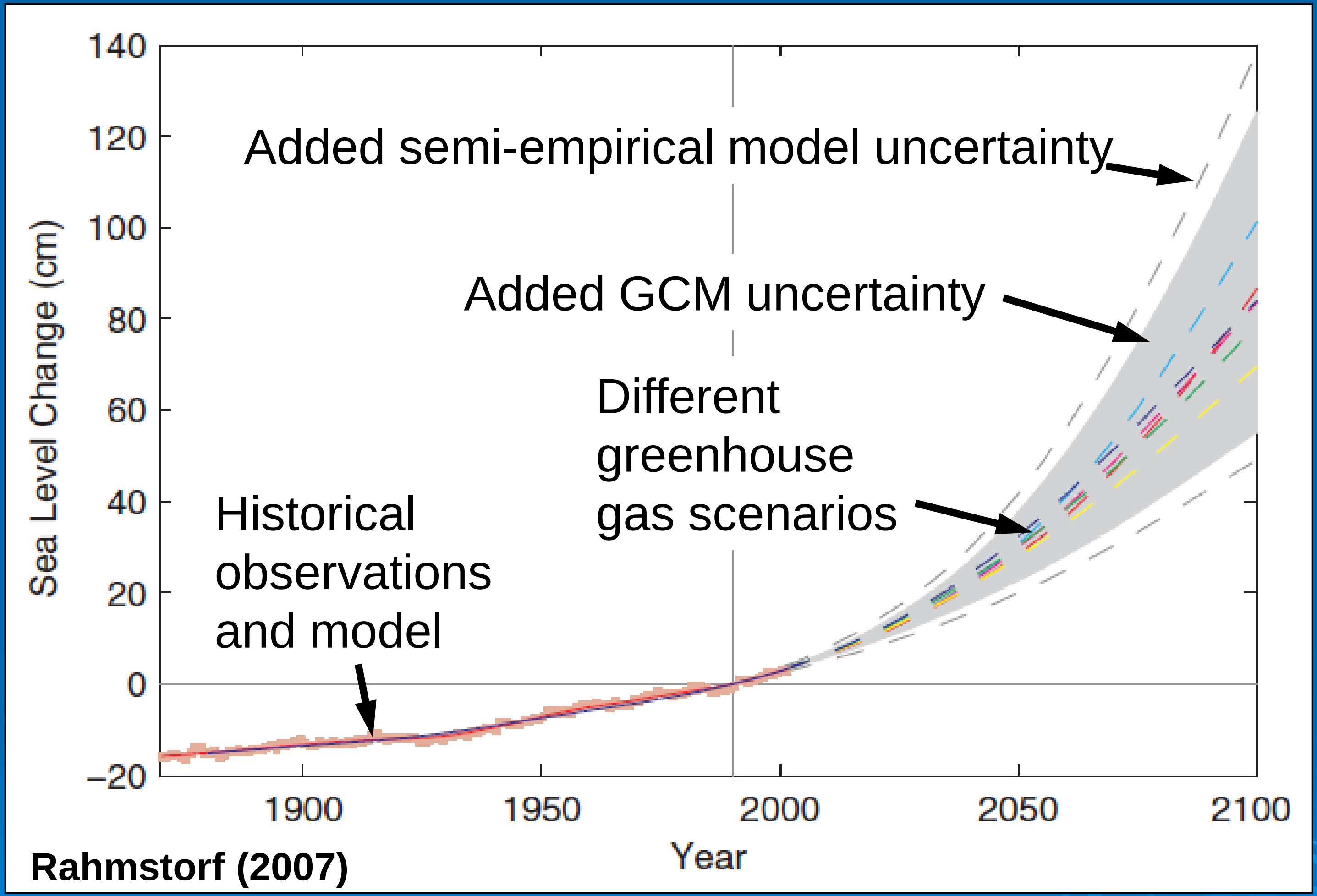
Future changes in mid-Atlantic streamflow

- Very uncertain: -40% to +30% by late century
- Due to compounded uncertainty in evapotranspiration and precipitation change
- Likely increases in winter and spring flow
- Likely more episodic

Sea level change in Chesapeake Bay



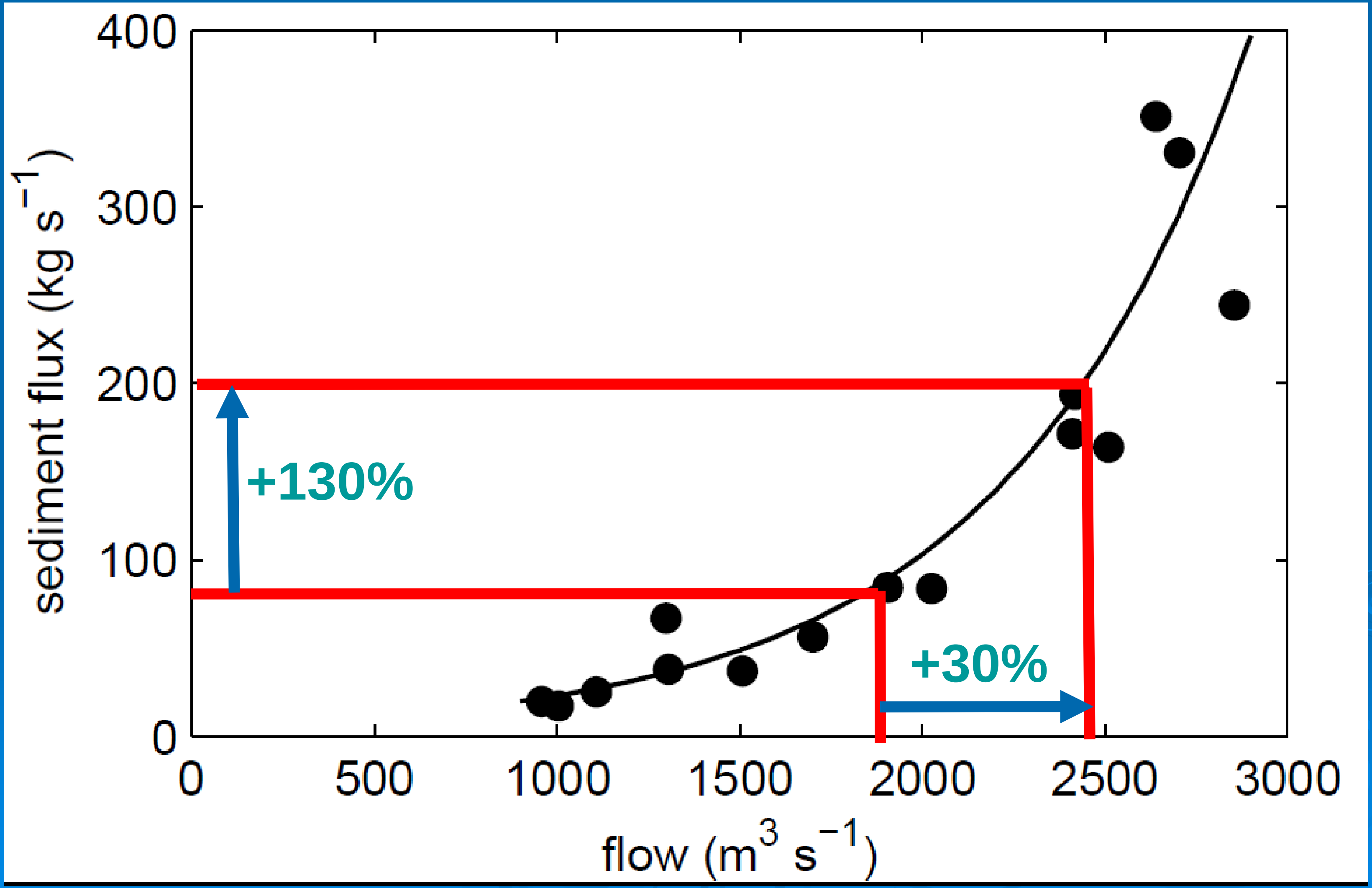
Global sea-level change



Chesapeake: 0.7 to 1.6-m rise by 2100 (includes subsidence)

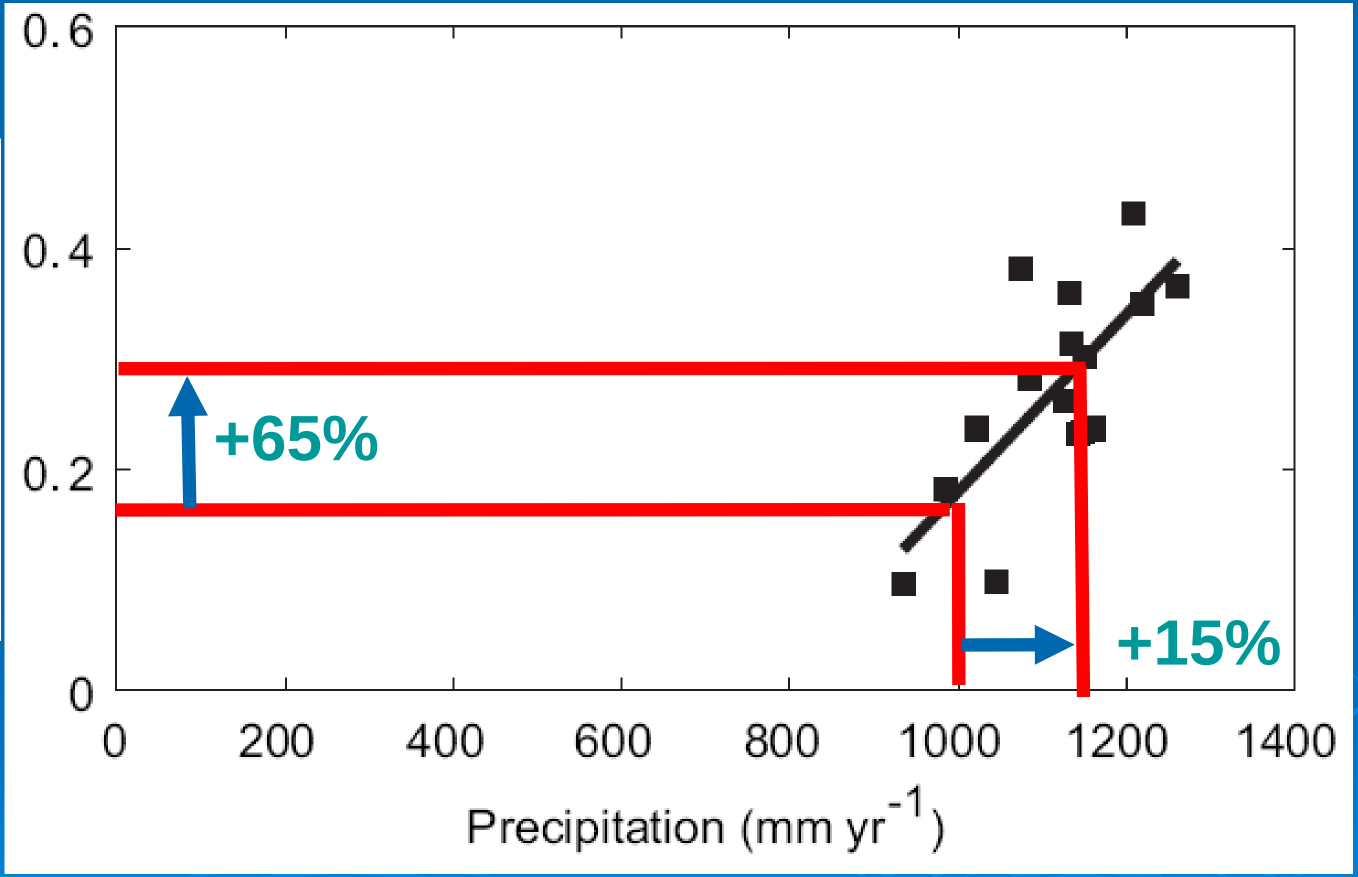
Watershed sediment and nutrient fluxes

Annual sediment load to Bay as function of annual flow (1990-2004)



Howarth et al. (2006) synthesis of 16 Northeast US watersheds

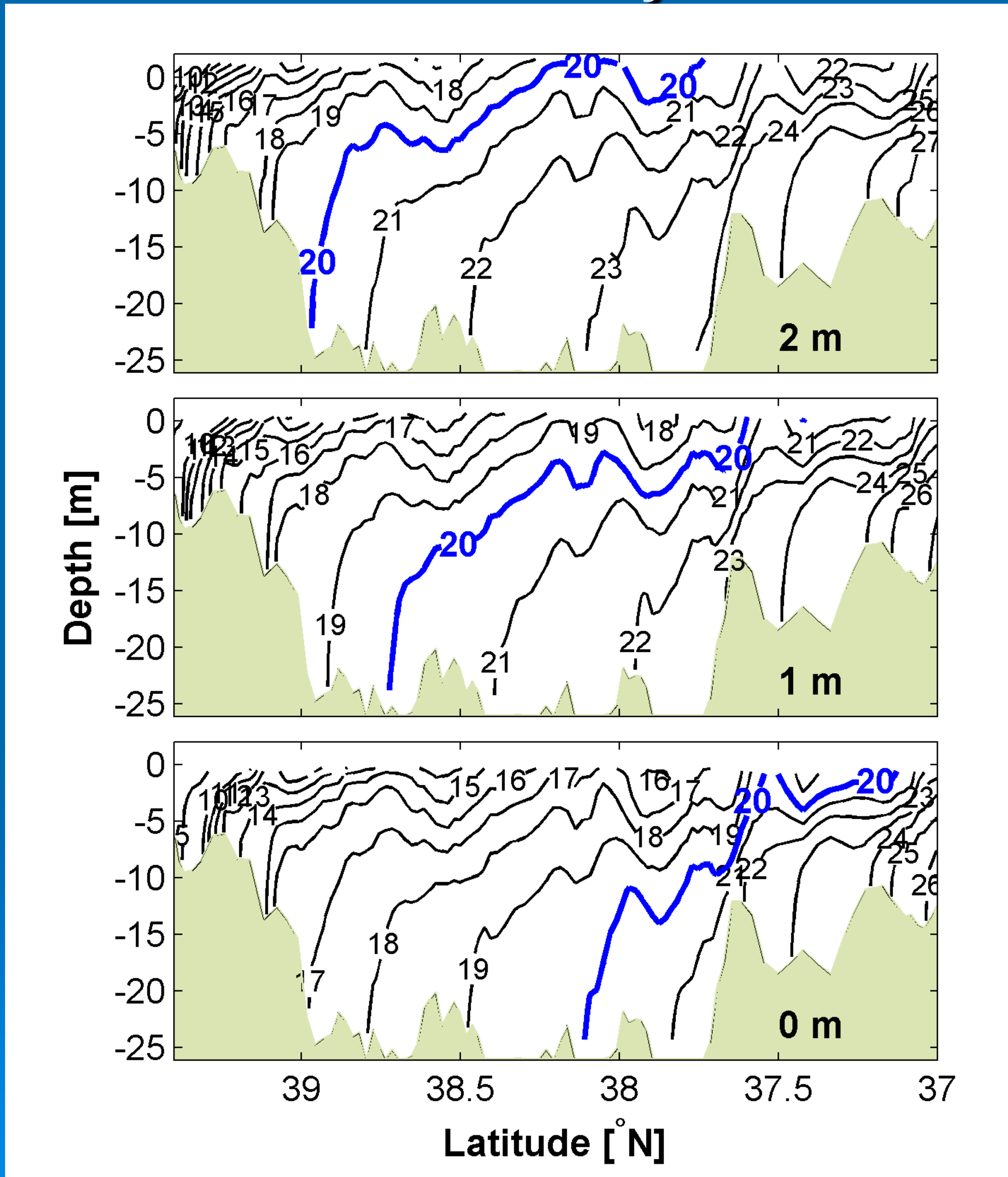
Fraction of net anthropogenic nitrogen inputs (NANI) to a watershed that is exported to its estuary



But warming could decrease NANI (Schaefer and Alber, 2007)

Impacts on the Bay

Modeled Salinity in the Chesapeake Bay



2-m sea-level rise

1-m sea-level rise

Current sea level

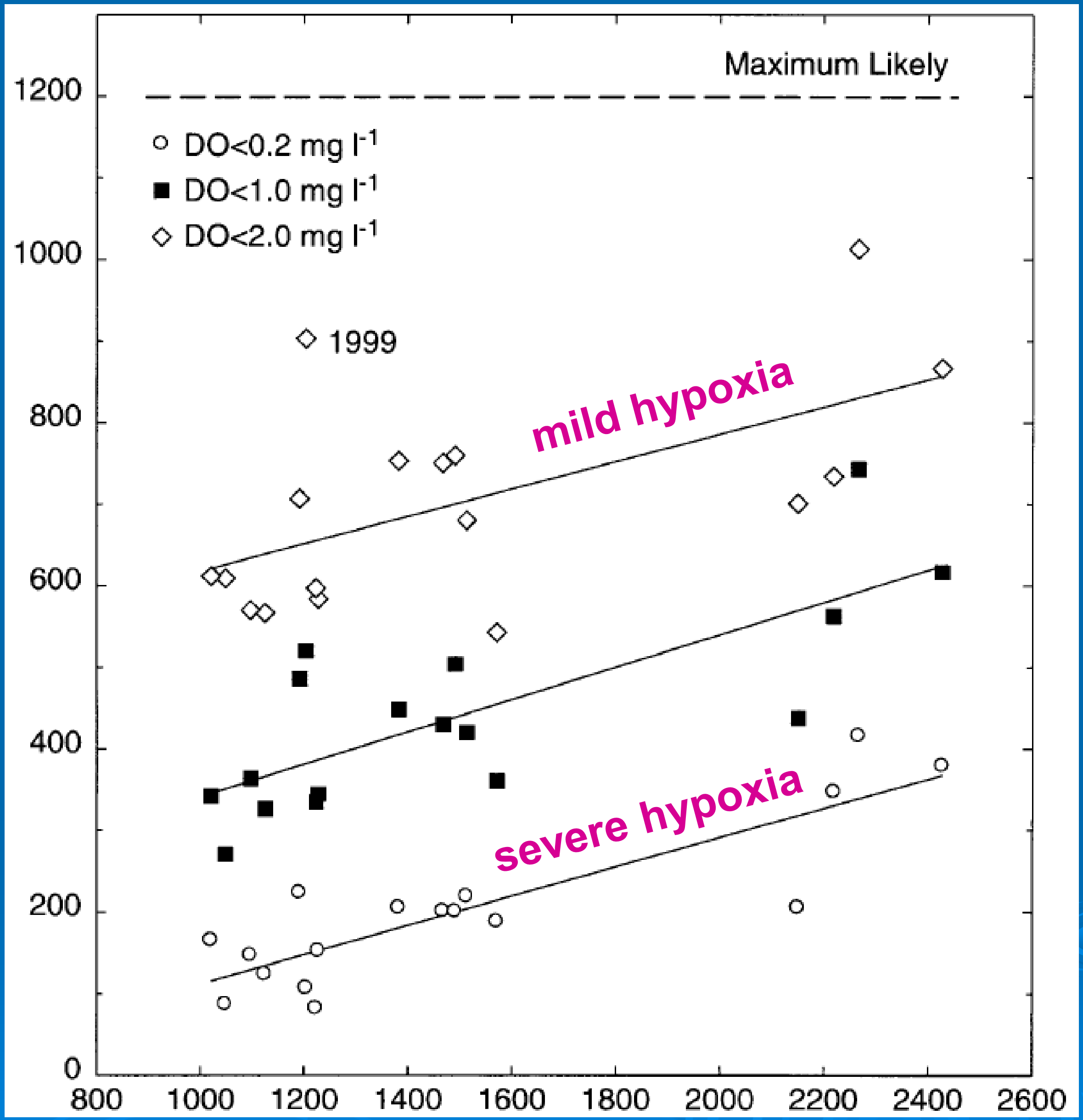
Li *et al.* (2010)

Estuarine physics

Increase in:	**Due to an increase in:**
Salinity	Sea level
Tidal range	Sea level
Summer stratification	Spring streamflow
Residual circulation	Spring streamflow
Salinity variability	Multiple factors

Sources: Zhong et al. (2008), Hilton et al. (2008), Hagy (2002)

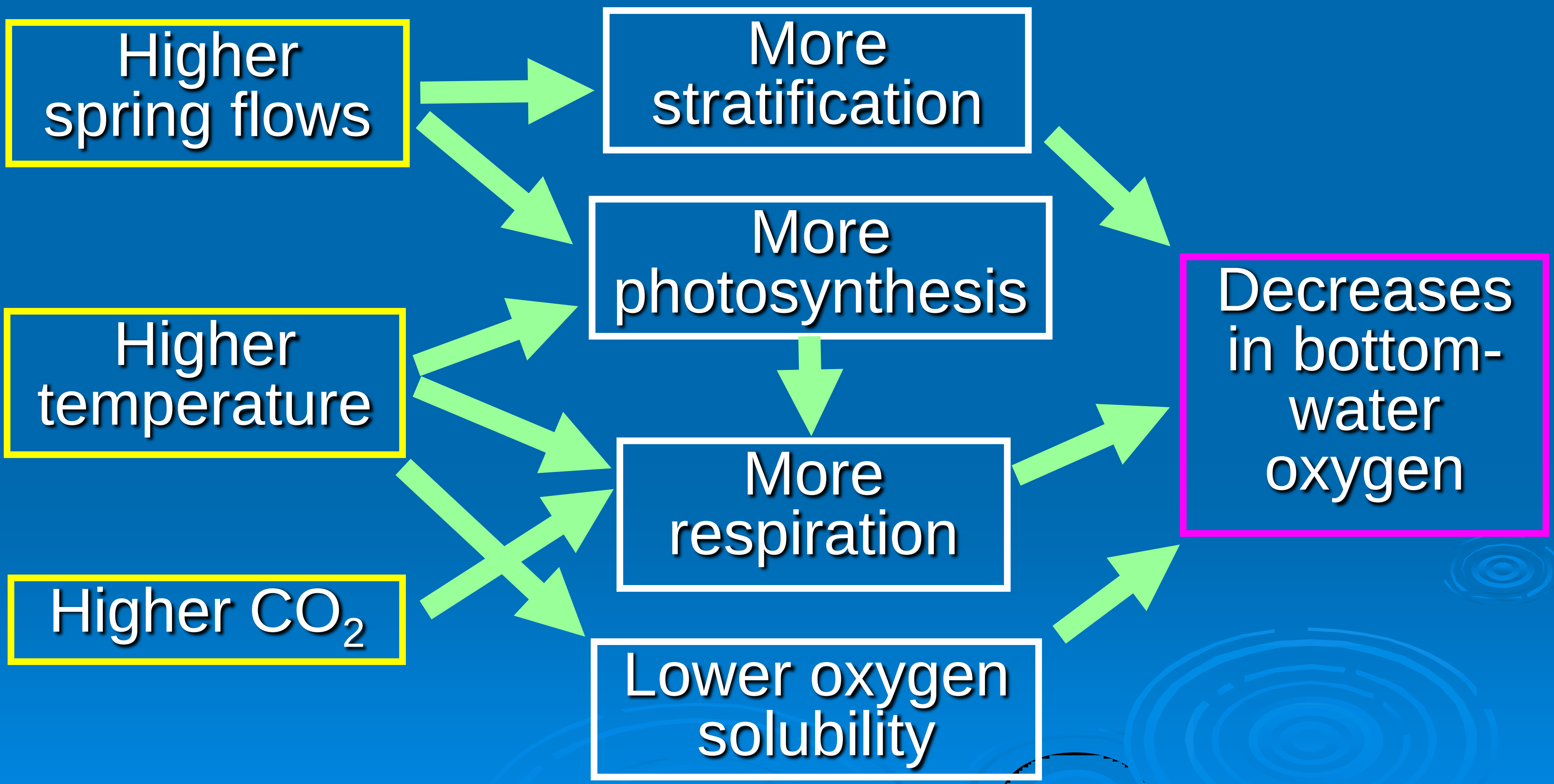
Annual hypoxic volume days (10^9 m^3 days)



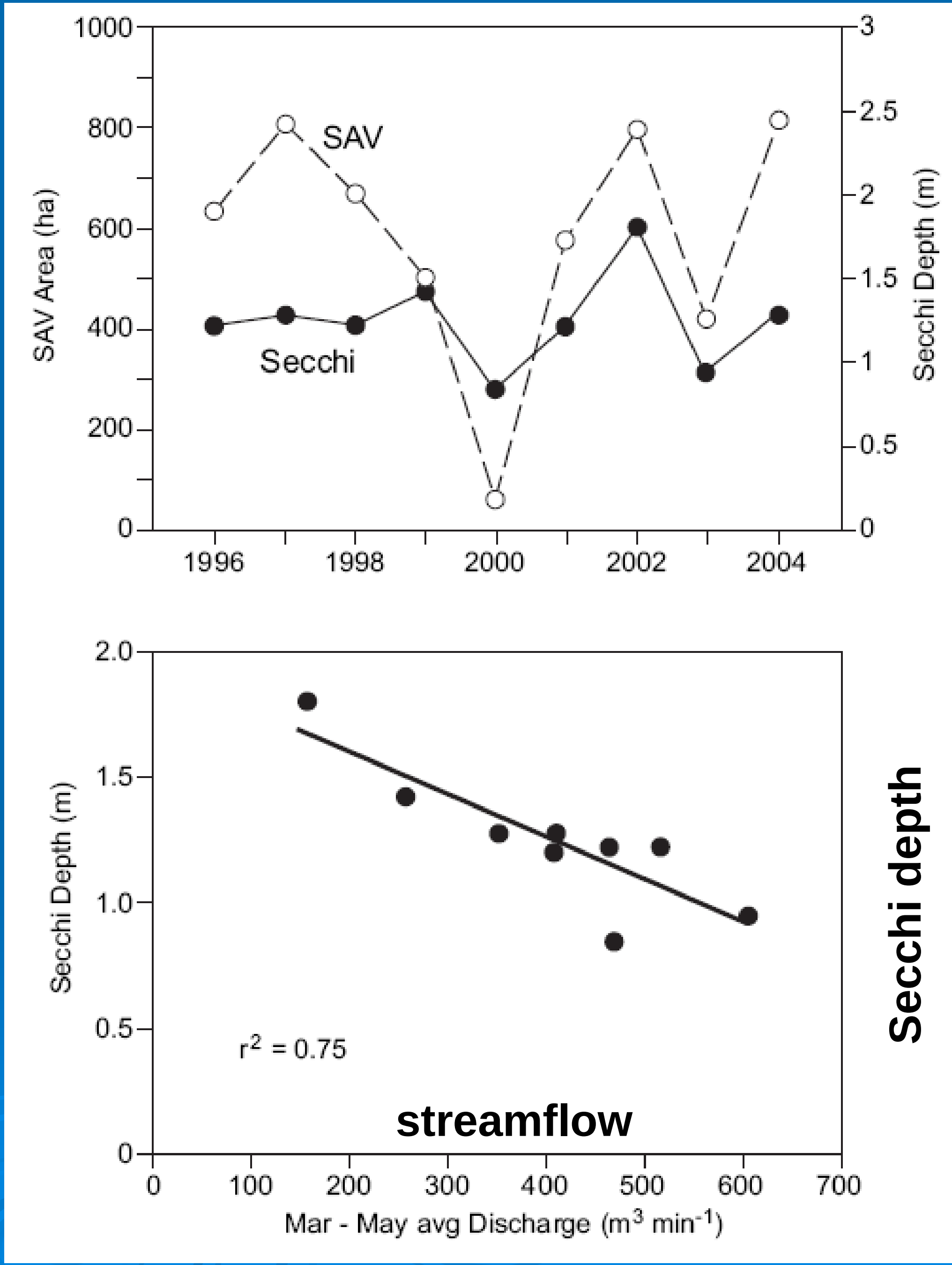
January-May Average Susquehanna River Flow (m^3 s^{-1})

Hagy et al. (2004)

Multiple impacts on bottom-water dissolved oxygen

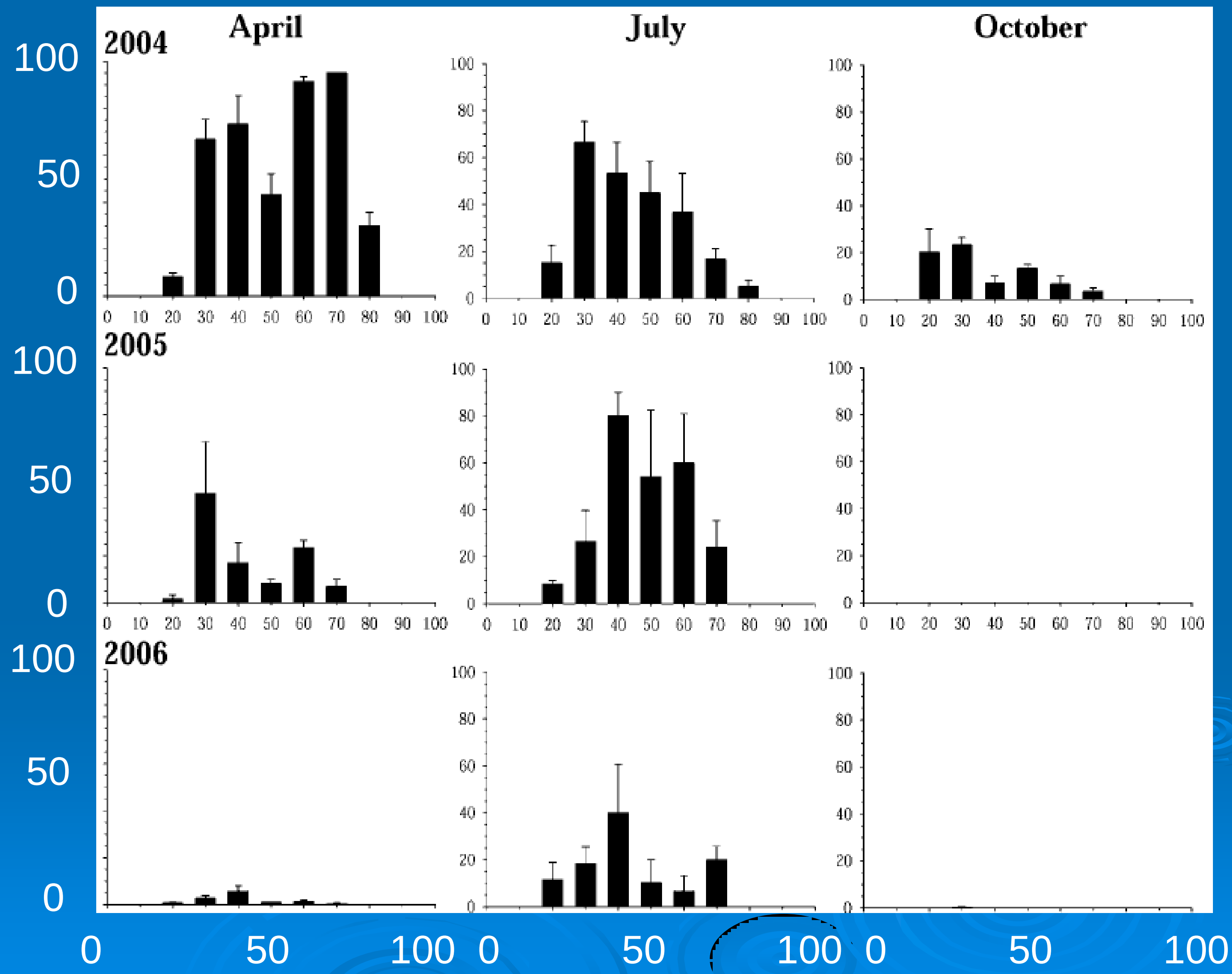


Submersed aquatic vegetation (SAV, primarily *Ruppia maritima*) in the lower Choptank estuary



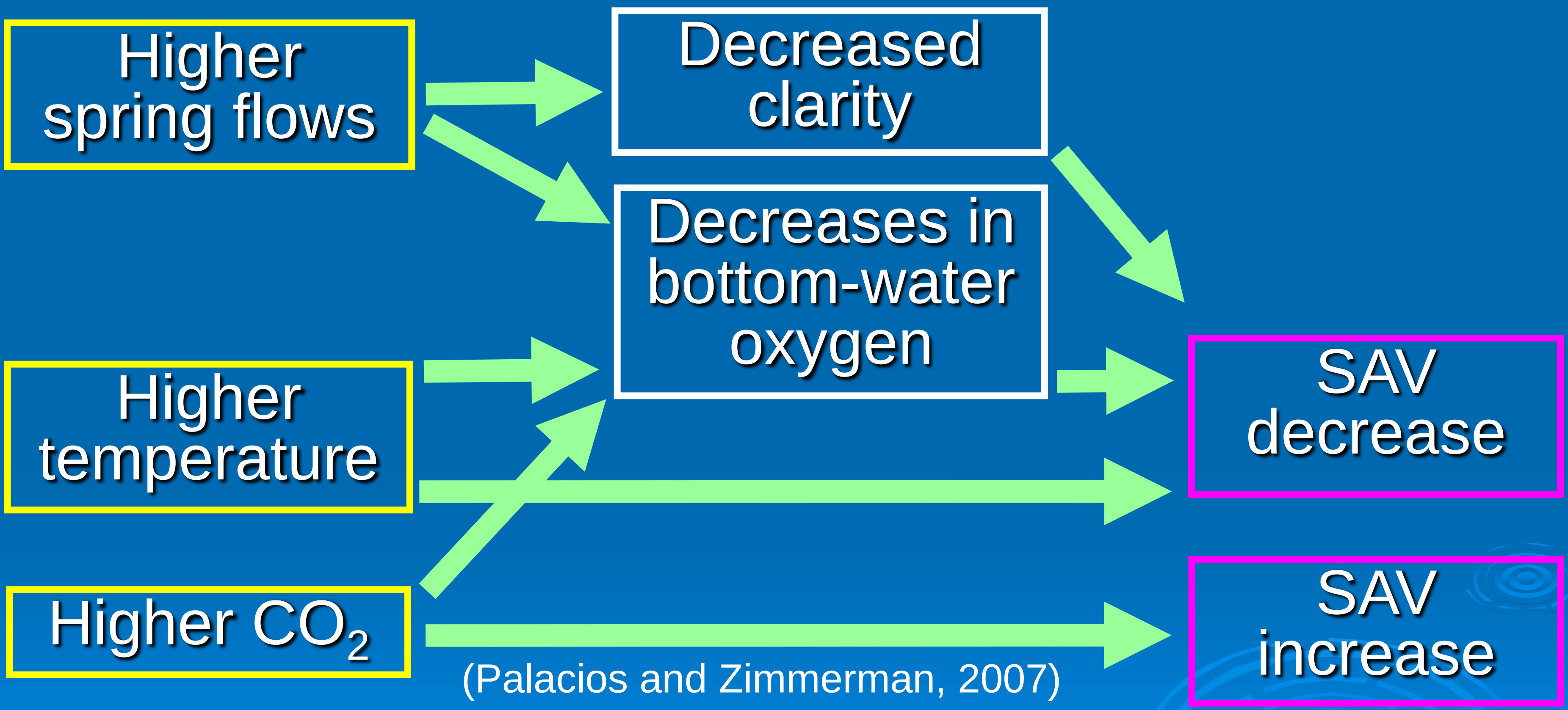
Analysis by M. Kemp

Eelgrass coverage near Gloucester Pt.



Moore & Jarvis (2008)

Multiple impacts on Eelgrass



(Palacios and Zimmerman, 2007)

Areas Vulnerable to Sea Level Rise in Dorchester County Maryland

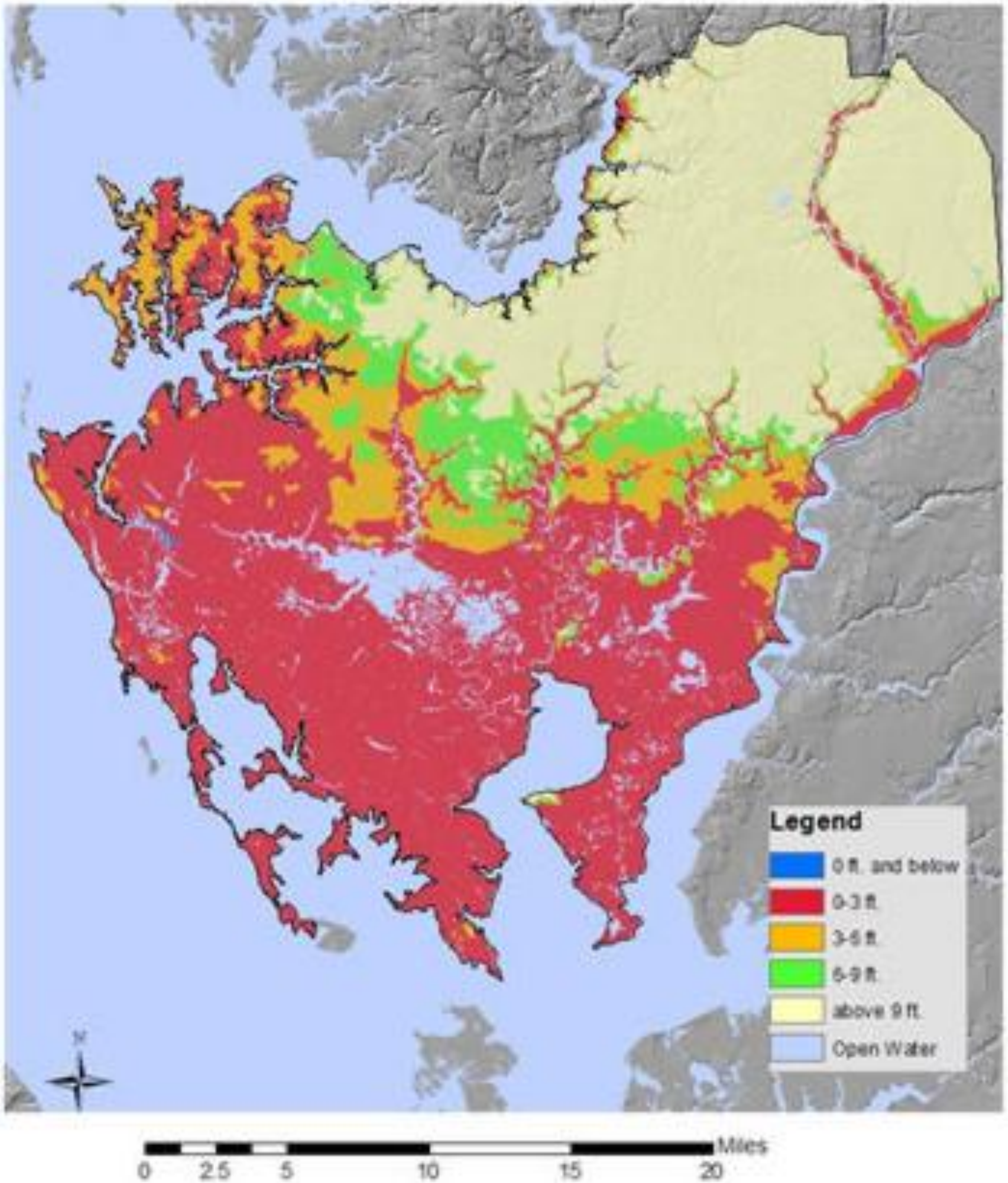


Table 1: Areas Vulnerable to Sea Level rise

Zones	Area (sq. miles)	Area (sq.km)	% Area
0 ft. and Below	4.0	10.4	0.71
0-3 ft.	287.0	742.9	50.41
3-6 ft.	60.6	156.8	10.64
6-9 ft.	36.9	95.6	6.49
Above 9 ft.	180.8	468.0	31.76
Total	569.3	1473.8	100.00

Table 2: Number of People Vulnerable to Sea Level Rise

Zone	# of People	% of People
0 ft. and Below	174	0.6
0-3 ft.	3757	12.2
3-6 ft.	1997	6.5
6-9 ft.	1609	5.2
Above 9 ft.	23137	75.4
Total	30674	100.0

Table 3: Landuse in Risk Zones (sq. mi)

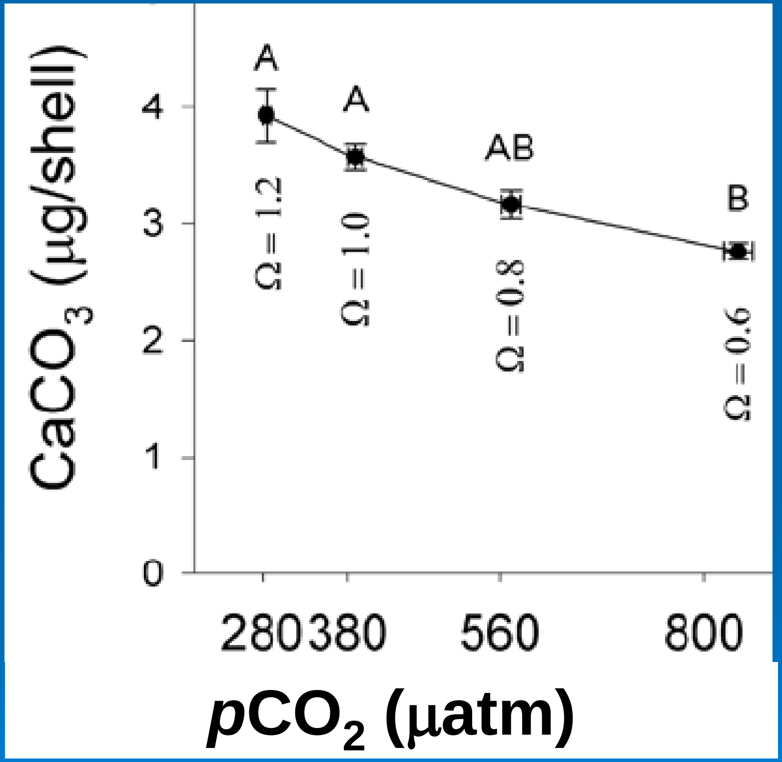
	0 ft. and Below	0-3 ft.	3-6 ft.	6-9 ft.	Above 9 ft.
Open Water	2.7	33.7	1.0	0.4	1.0
Developed	0.1	2.9	0.9	0.6	6.6
Barren	0.0	1.0	0.1	0.1	2.8
Forest	0.0	31.3	15.1	8.3	43.0
Agriculture	0.1	28.5	26.0	17.8	104.1
Wetland	1.1	189.6	17.5	9.7	23.3

Wu et al. (2009)

Bay vascular plants: wetlands

- Wu et al. (2009): 1700 km^2 land in VA and MD lie below 0.7-m contour; ~half is wetlands
- Greater sea level variability → more frequent flooding
- Rate of sea-level rise is increasing; not clear if accretion rates can keep up
- CO_2 increases accretion rates of *S. Olneyi* (Megonigal 2008)
- Development limits landward migration
- Salinity and temperature also important

Impact of ocean acidification on oyster larvae (*C. virginica*) calcification



Miller et al. (2009)

Smithsonian Marine Station

Shellfish

- Acidification has the potential to reduce calcification of some shellfish
- Commercially important soft clam *Mya arenaria* near southern distribution limit
- Over-wintering impacts positive (juvenile survival, blue crabs) and negative (oyster pathogens)

Science summary

- Climate projections by 2100: warmer (2-6º C), wetter winter and spring, greater storm intensity, higher sea level (0.7-1.6 m).
- Precipitation (and streamflow) projections are generally within interannual variability; temperature is not
- Future fluxes of water, nutrients, and sediments from watersheds highly uncertain

Science summary (cont.)

- Likely Impacts:
- Increase in submergence of estuarine wetlands
- Increase in salinity variability
- Increase in harmful algae
- Increase in hypoxia
- Reduction of eelgrass
- Substantially altered interactions among trophic levels

Policy implications

- Climate change is likely to dramatically alter Chesapeake Bay and efforts to restore it
- Climate change and impacts over next 30 years nearly independent of emissions → adaptation is critical
- Climate change and impacts beyond 2040 depend strongly on emissions over next 30 years → mitigation is critical

Research needs

- Improved precipitation and streamflow projections for the Bay watershed
- Whole-system monitoring and modeling (supplemented by process studies) that can capture the likely non-linear responses of the Chesapeake Bay system to climate variability and change.

Thank you

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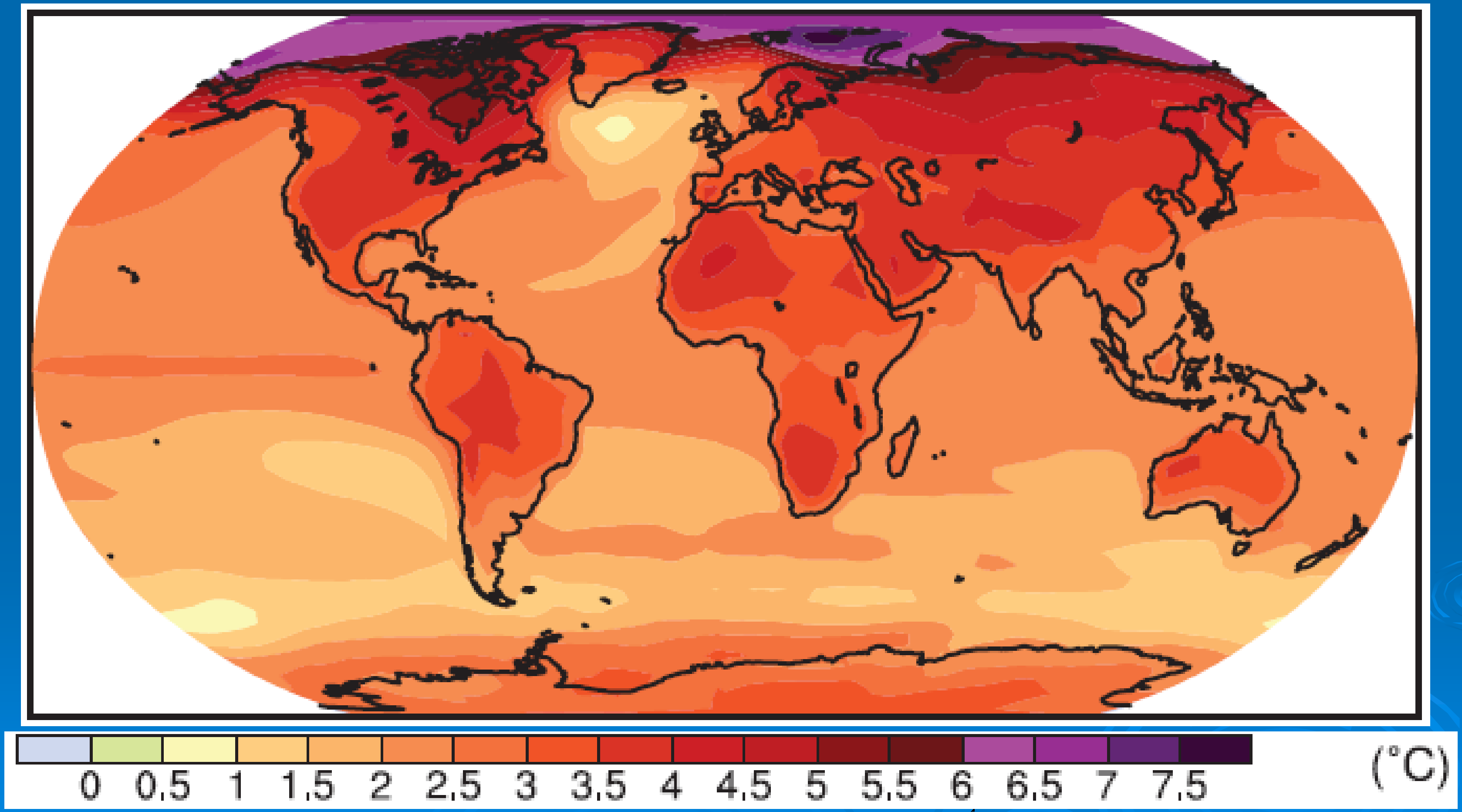
Extra Slides

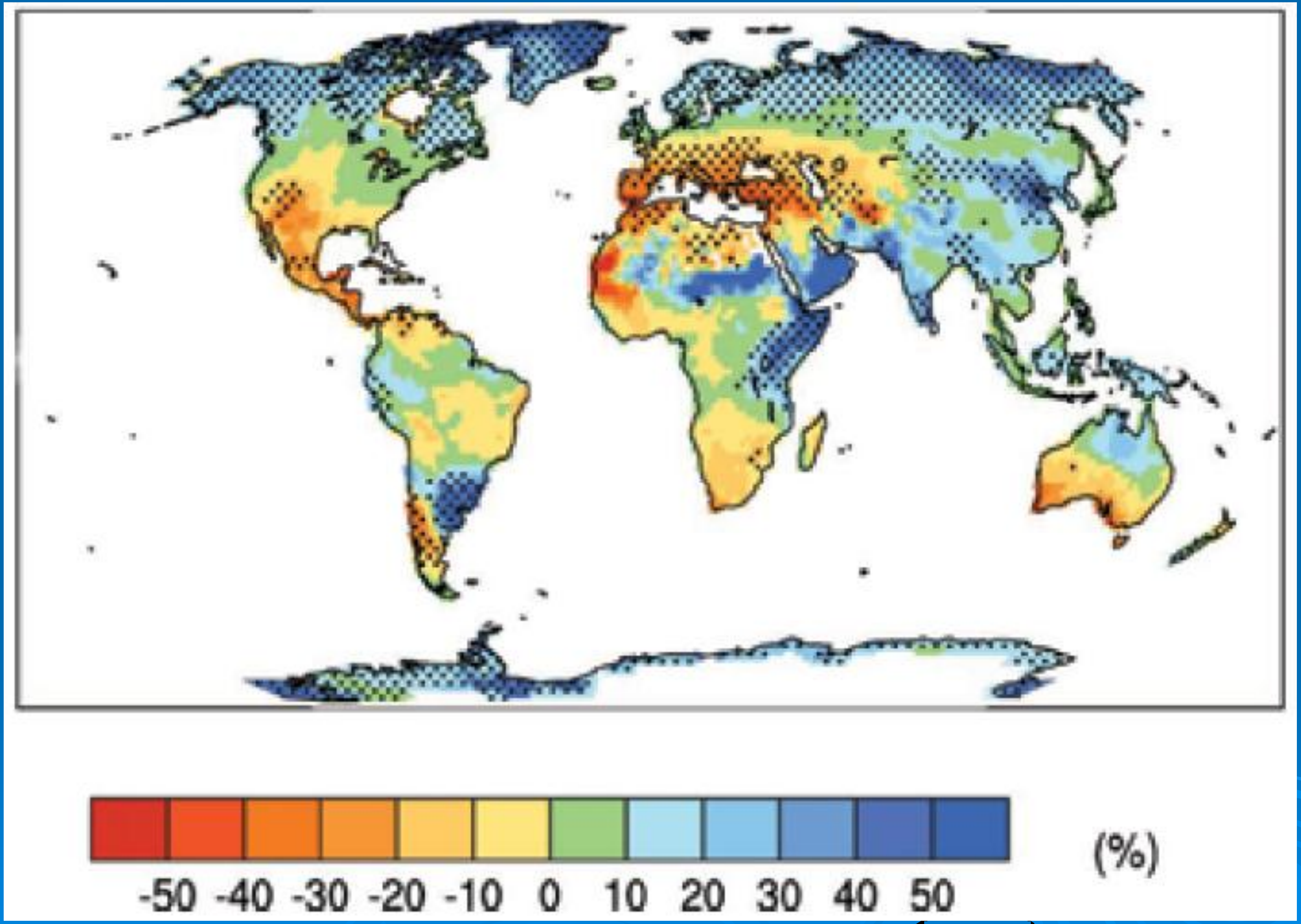
Projected surface temperature changes (A1B, 2080-2099 minus 1980-1999)

Multi-model ensemble mean



Meehl et al. (2007)

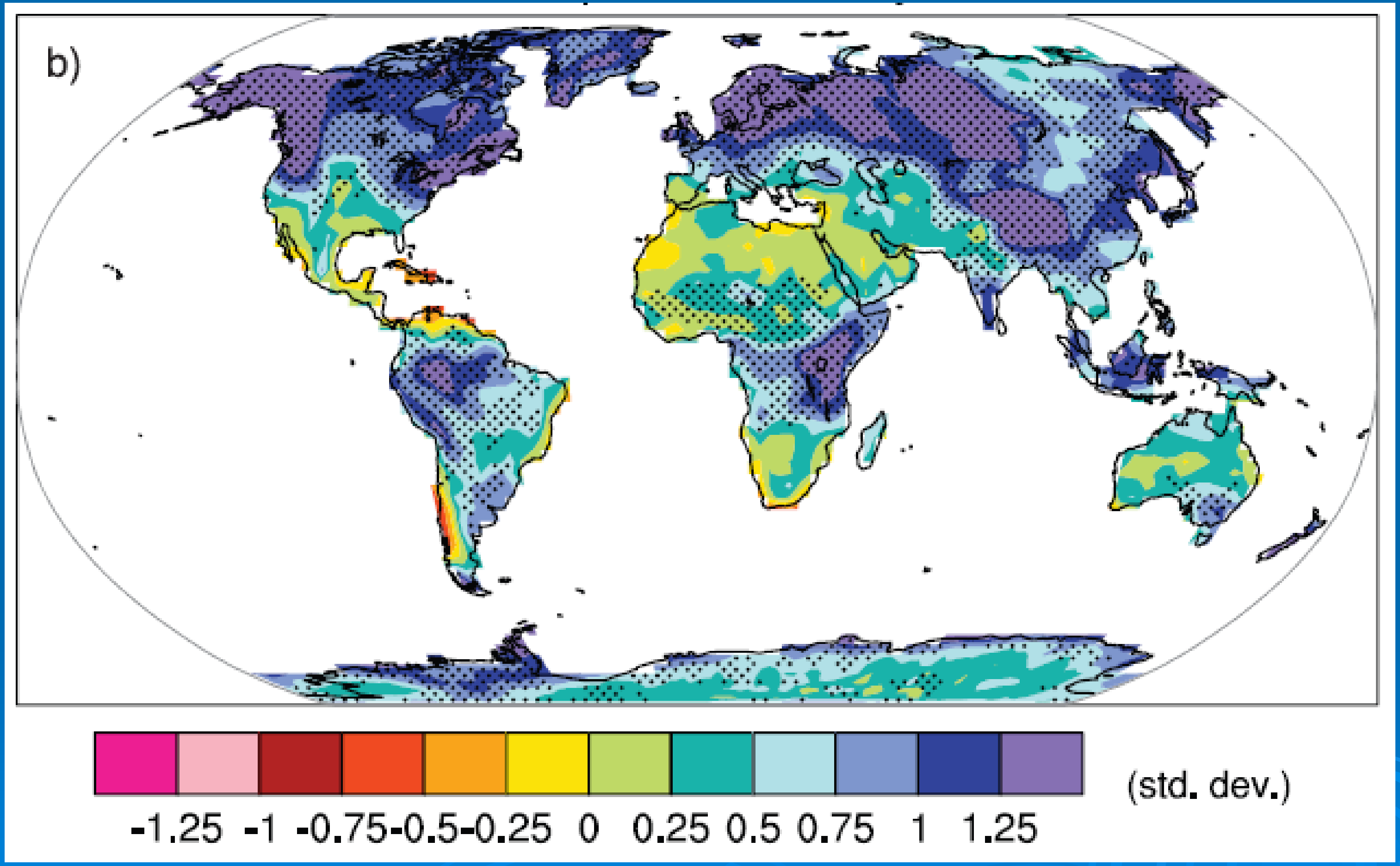
Projected surface runoff changes (A1B, 2080-2099 minus 1980-1999)



Meehl et al. (2007)

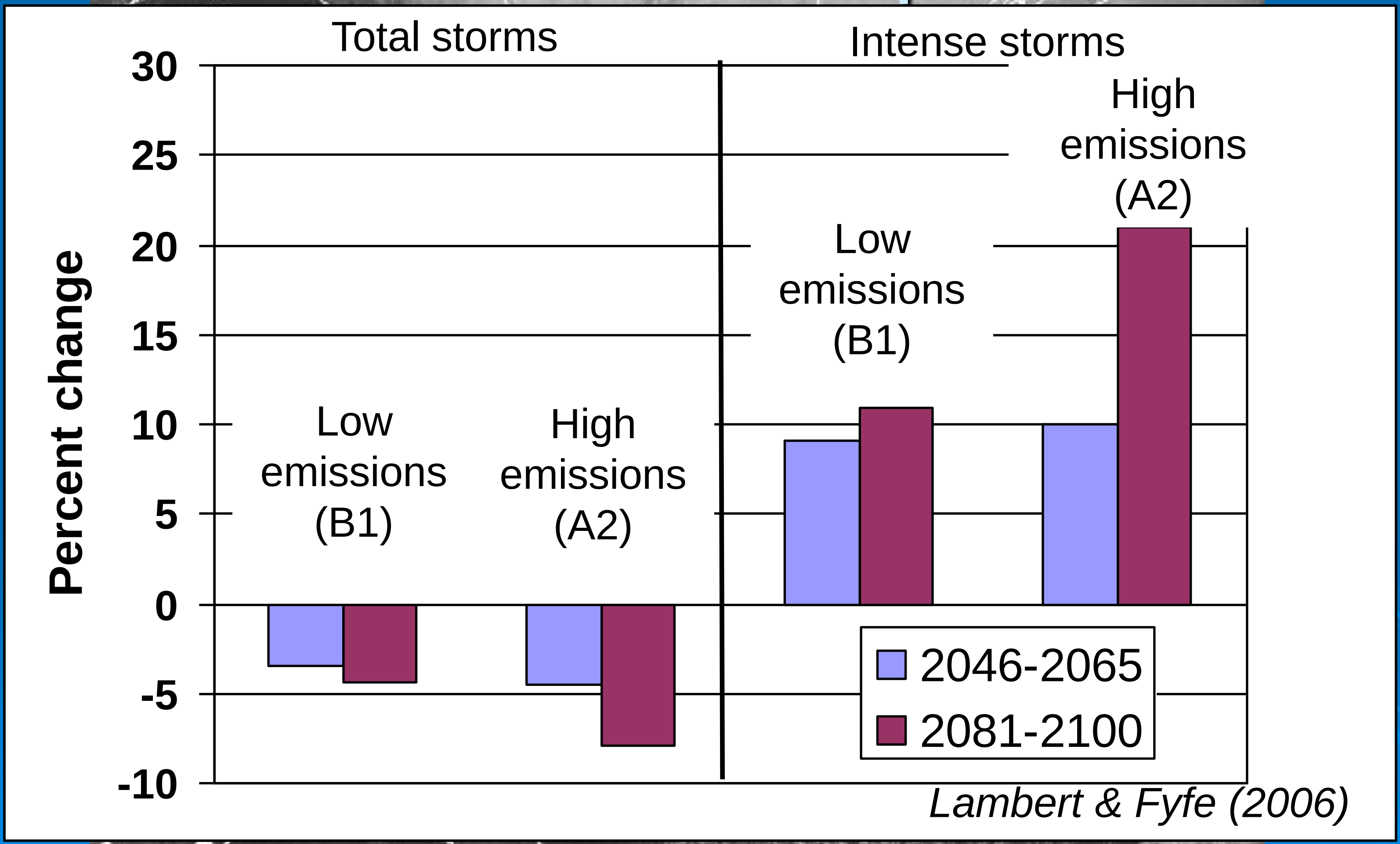
15-model mean. Stippling: >80% of models agree on sign of change.

Change in precipitation intensity (A1B, 2080-2099 minus 1980-1999)

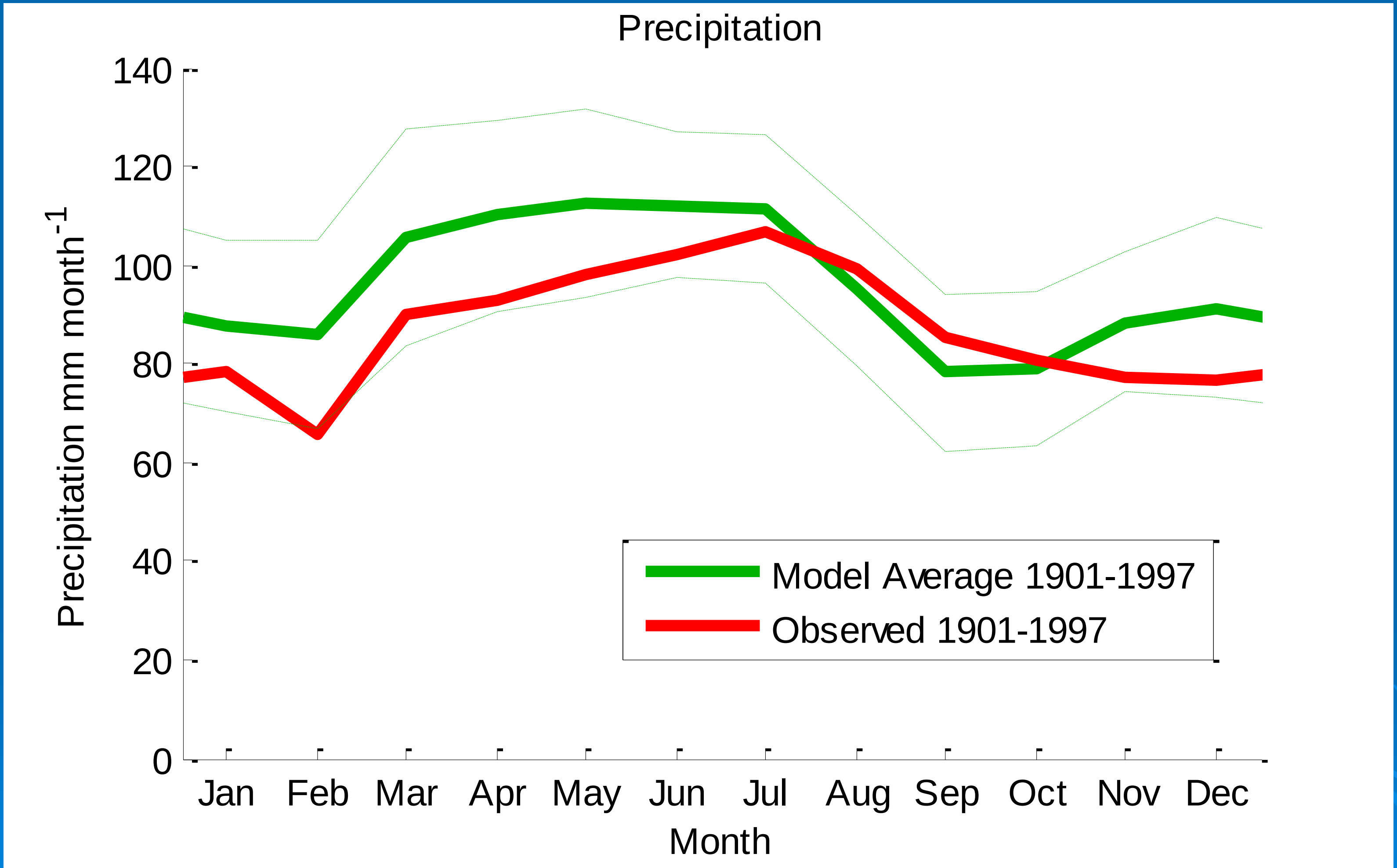


Meehl et al. (2007)

Changes in extratropical winter storms in the Northern Hemisphere

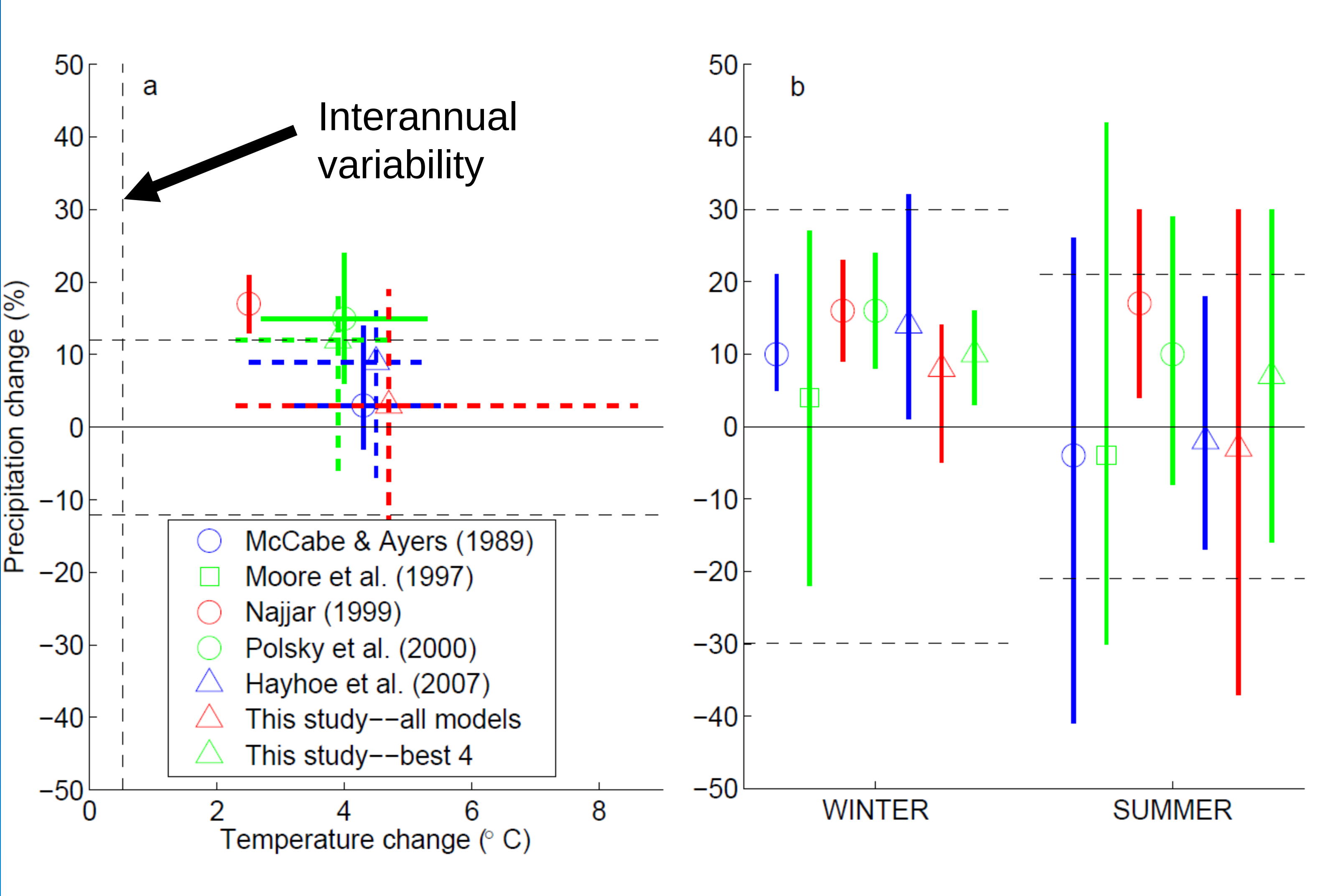


PA precipitation: GCMs vs. observations



Shortle et al. 2009

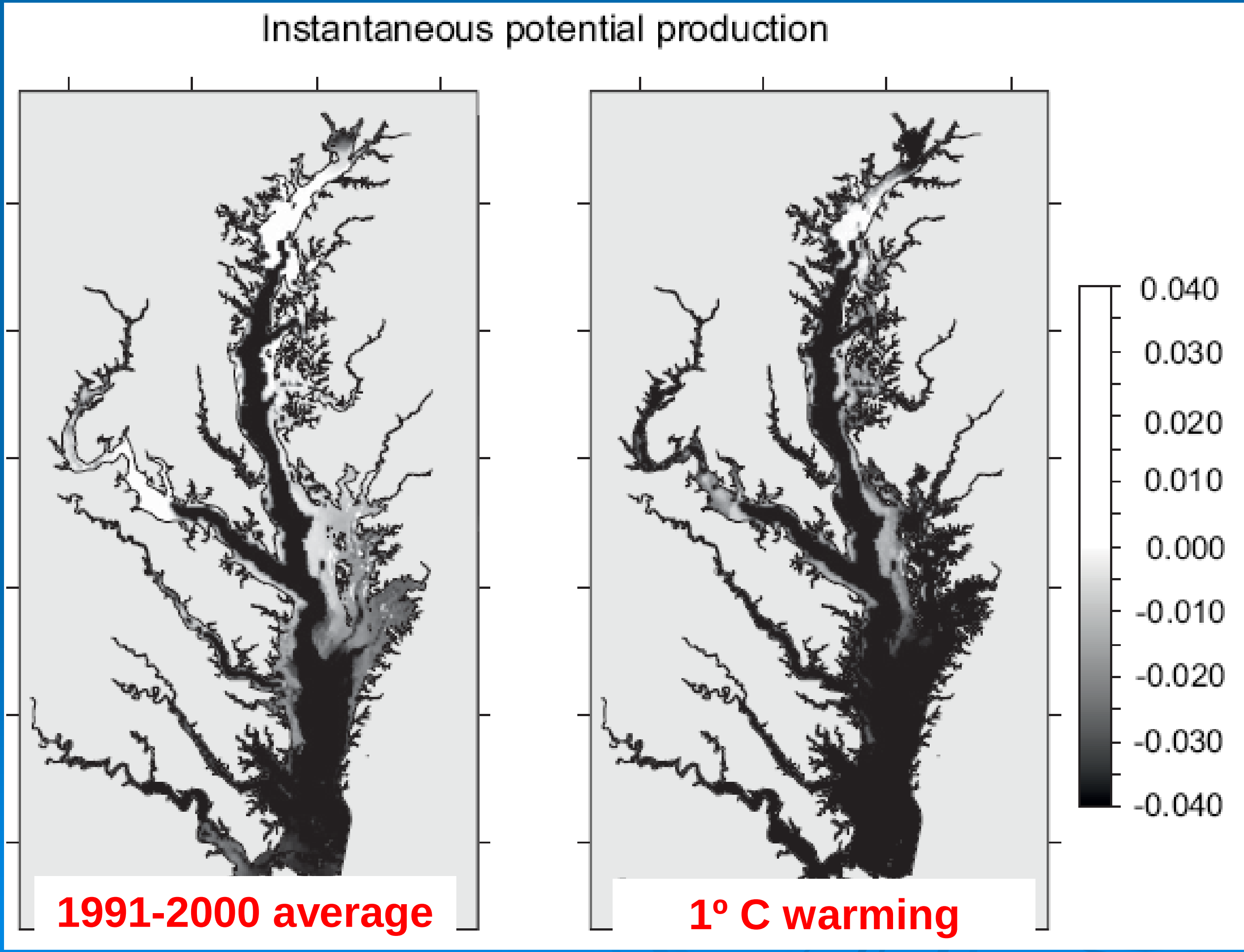
Mid-Atlantic temperature and precipitation change synthesis



Najjar et al. (2009)

Fish and Shellfish

Temperature-O_2 synergistic impact on fish



Habitat suitability for young-of-the-year Atlantic sturgeon in bottom waters of the Chesapeake Bay during July (Niklitschek and Secor, 2005)