The Hydrologic Cycle

ES 383

Colby at Bigelow, September 2018

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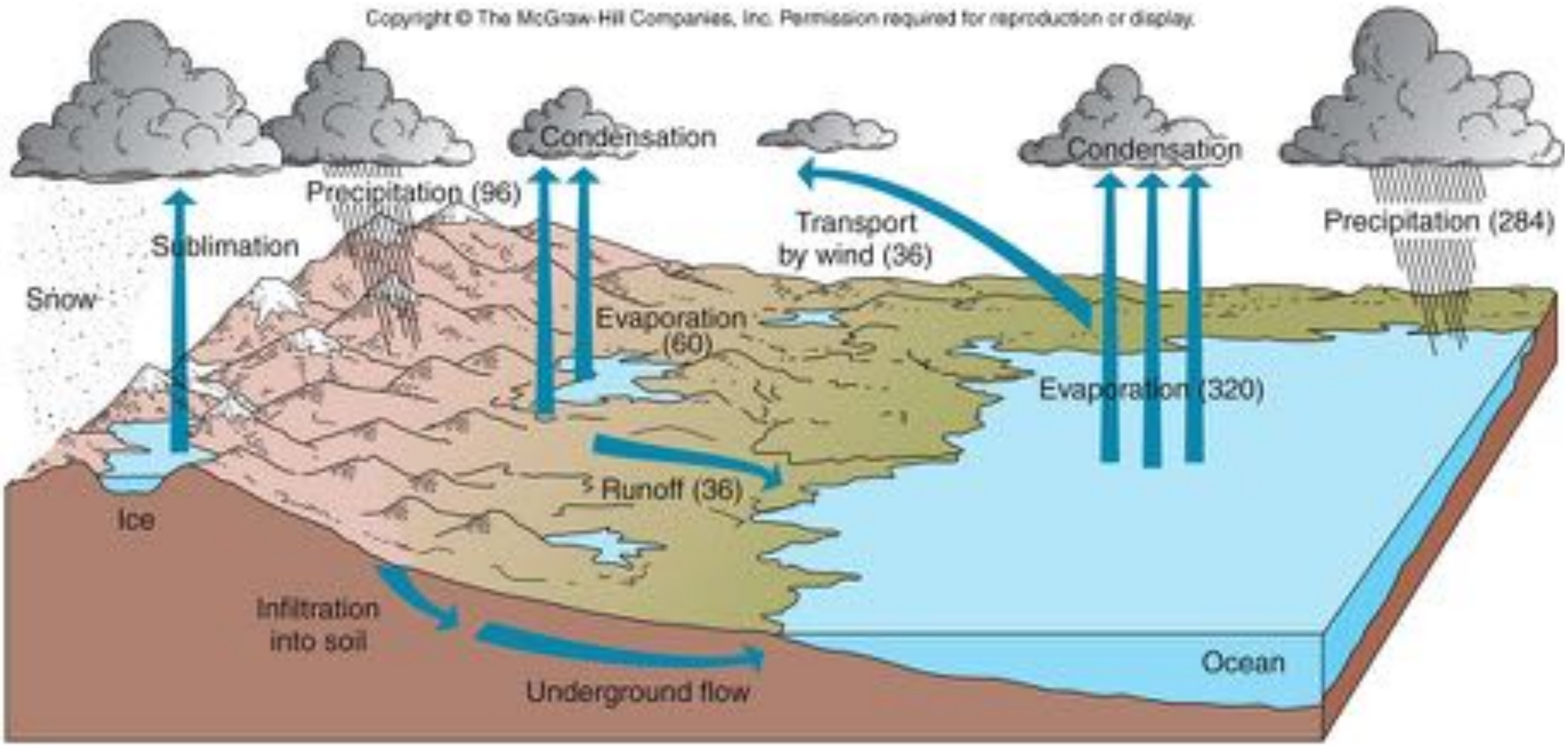
Flows in 10^3 km^3 year^{-1}



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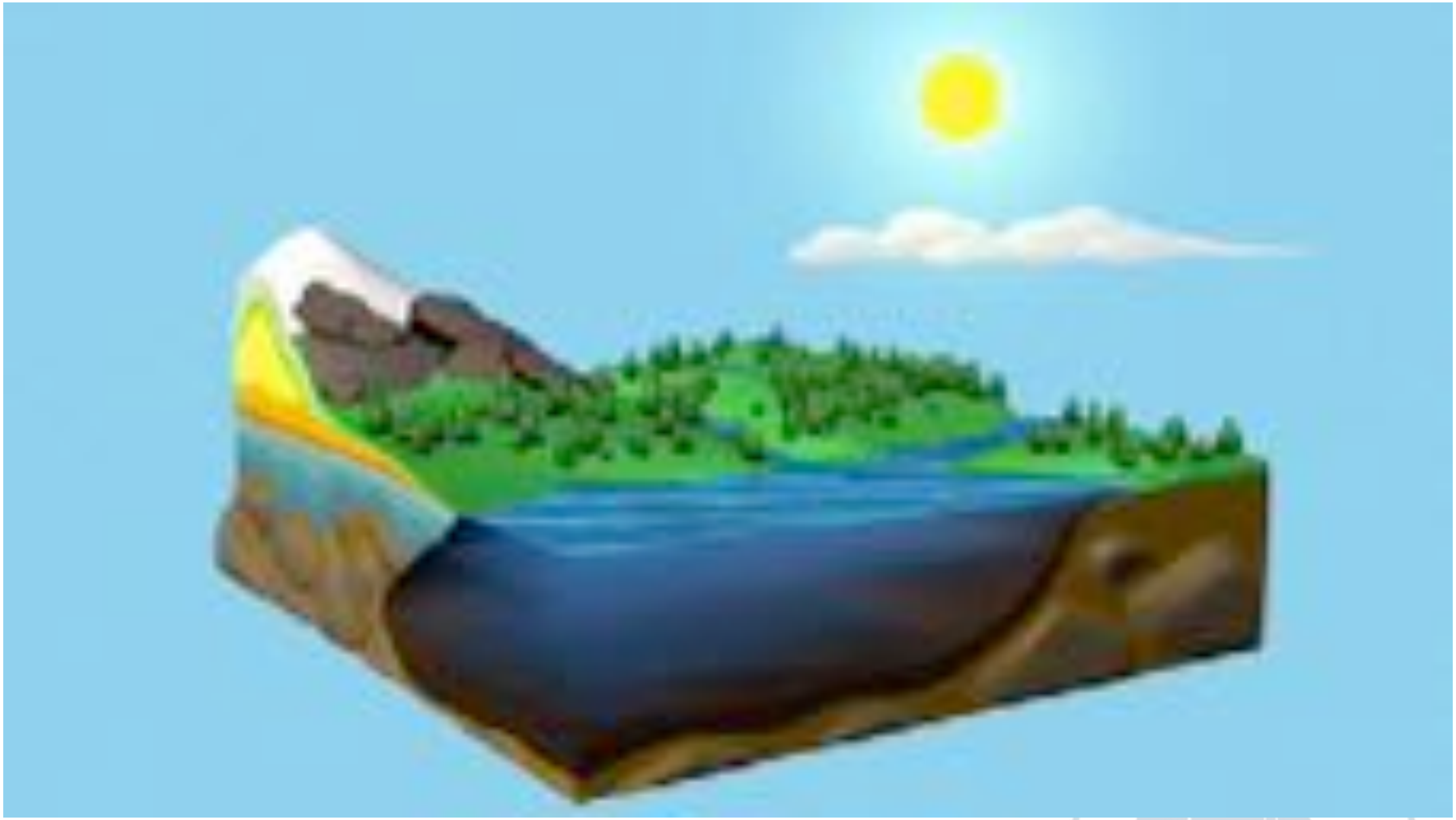

http://svs.gsfc.nasa.gov/goto?10501

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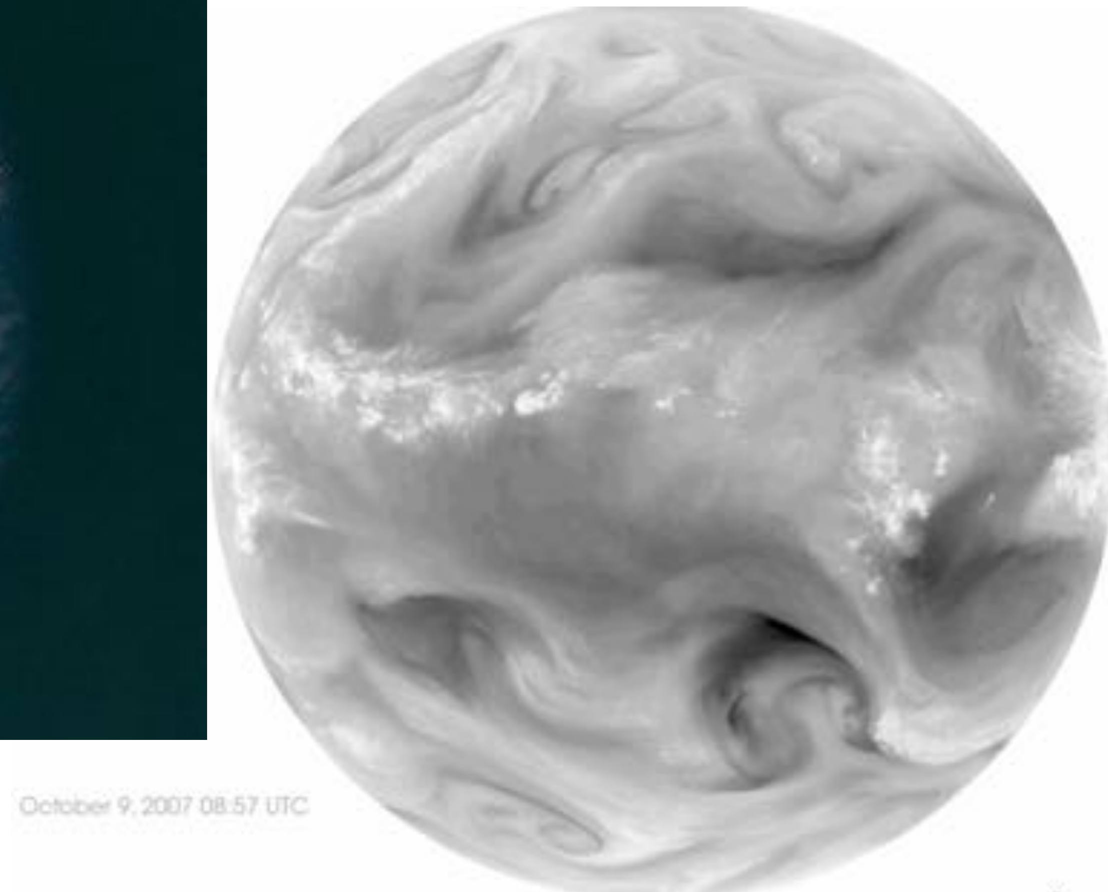
<u>Components of the hydrologic cycle</u>

- Atmosphere
- Freshwater storage
- Groundwater storage
- Ice and snow
- Oceans
- Springs

<u>Processes</u>

- Condensation
- Evaporation
- Evapotranspiration (evaporation + transpiration)
- Groundwater flow
- Infiltration
- Precipitation
- Snowmelt runoff
- Streamflow
- Sublimation
- Surface runoff



White= H_2O vapor; black= dry

9/2/2010 Meteosat-9; over Africa

http://earthobservatory.nasa.gov/Features/GISSTemperature/Images/seviri_water_vapor_720p_best.mov

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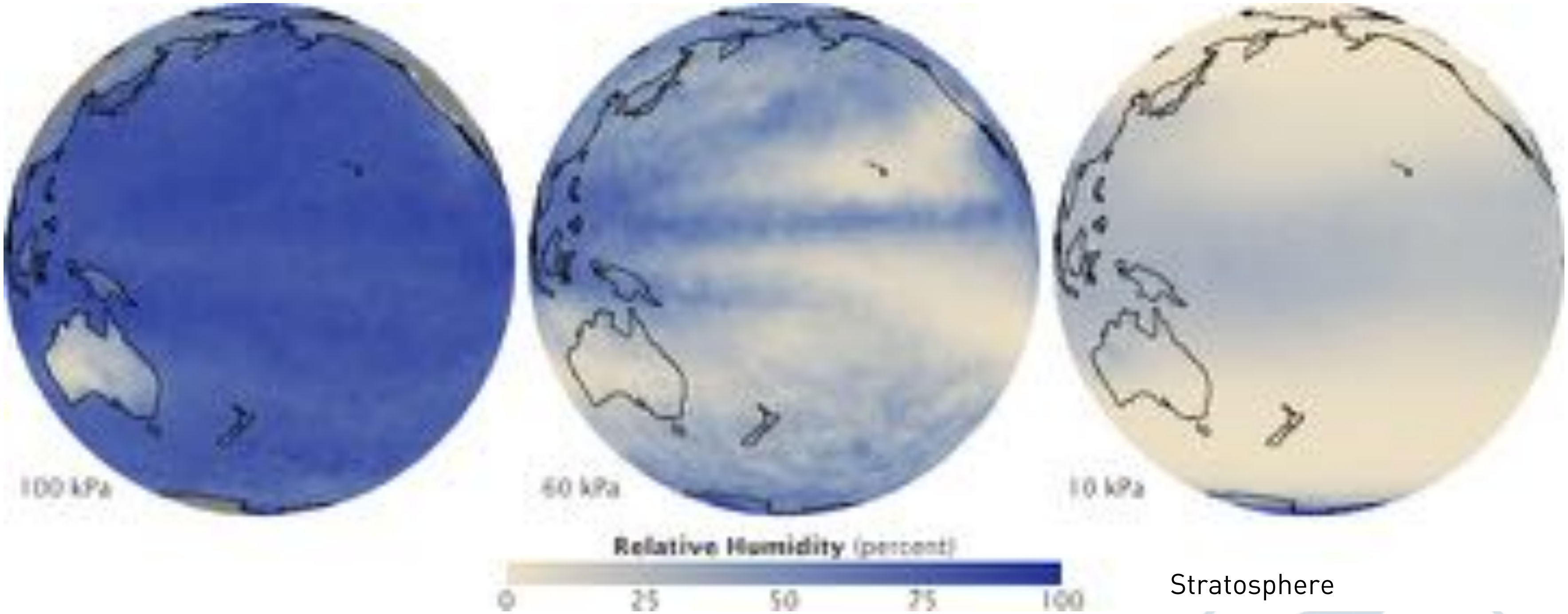
Zooming out



Sea surface

Stratosphere

NASA Aqua satellite

Residence Time

Average length of time a H_2O molecule (or any other element or compound or water mass) spends in any one reservoir.

$$\text{Water residence time} = \frac{\text{vol. water in reservoir}}{\text{rate at which water is replaced}}$$

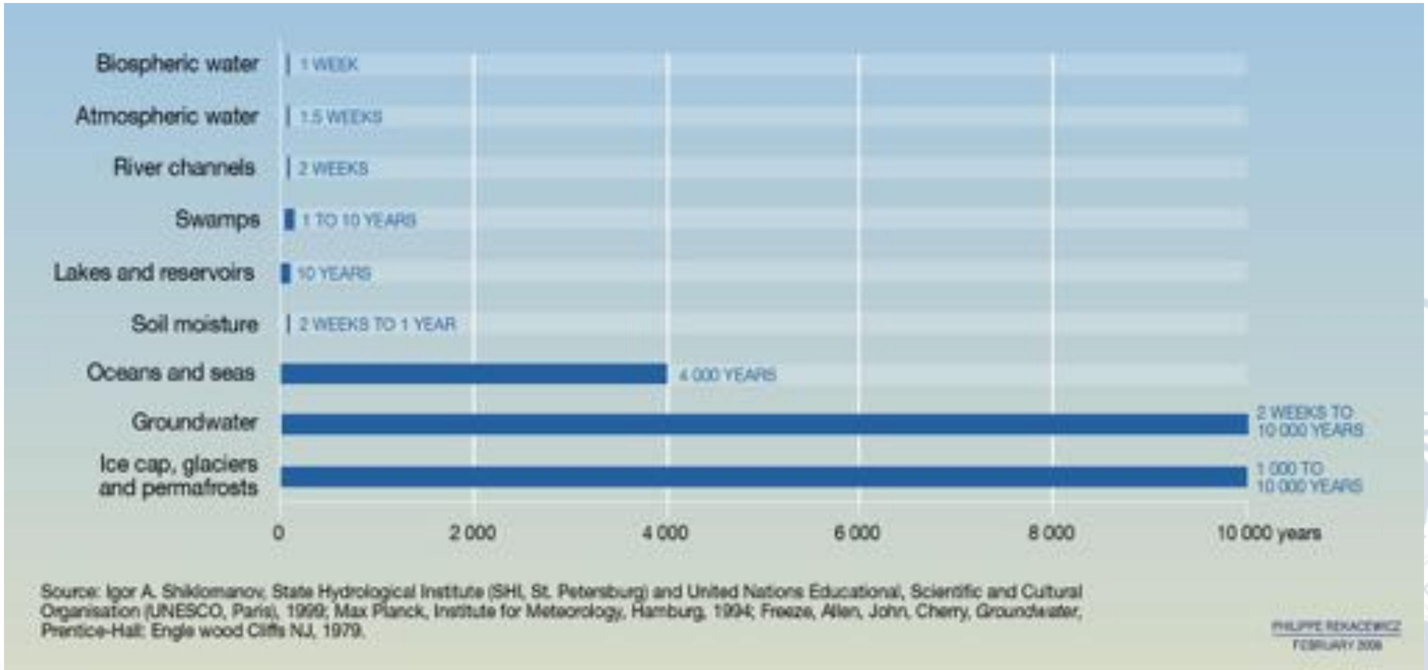


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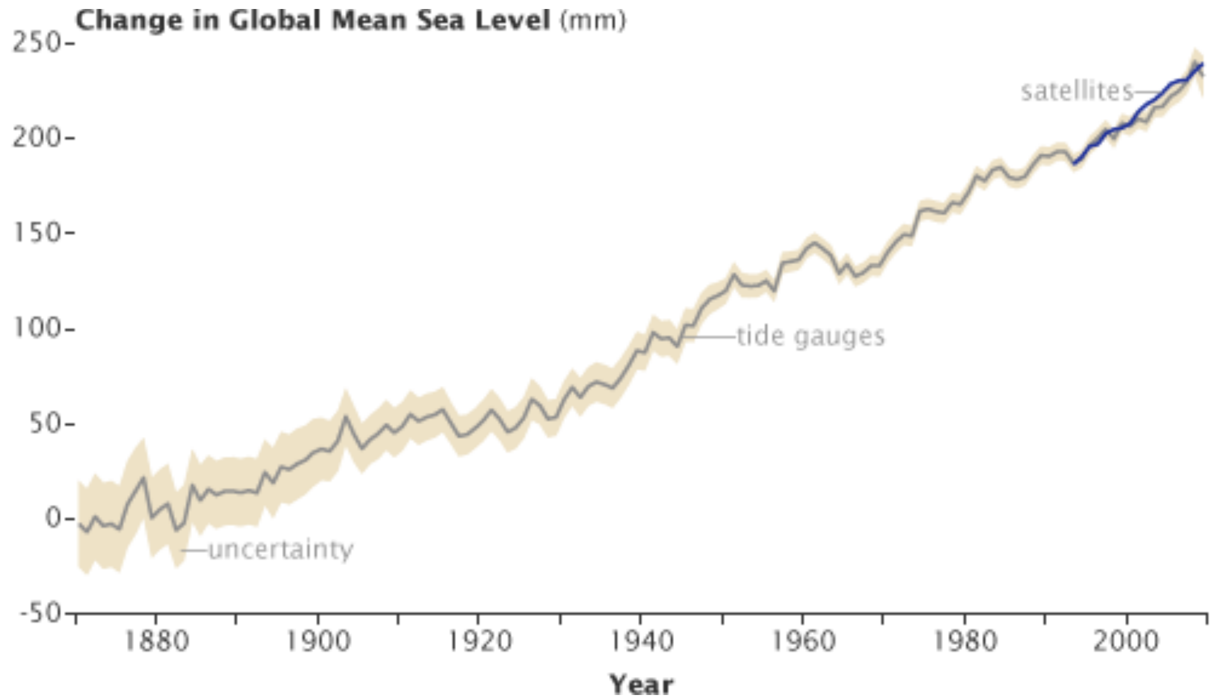
Table 1.3 The Earth's Water Supply

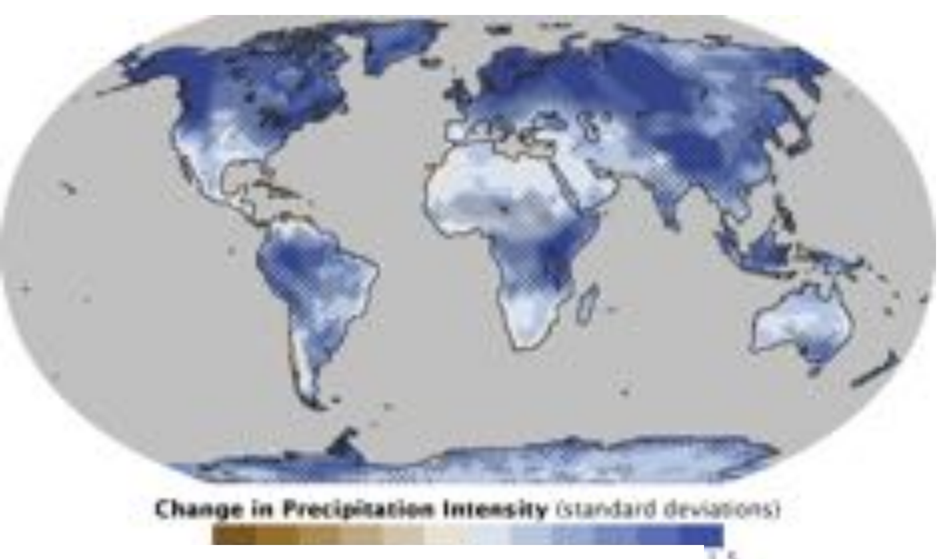
	Approximate Water Volume		
Reservoir	**(km³)**	**(mi³)**	**Approximate Percent of Total Water**
Oceans and sea ice	1,338,500,000	320,600,000	97.24
Ice caps and glaciers	29,289,000	7,000,000	2.14
Groundwater	8,368,000	2,000,000	0.61
Freshwater lakes	125,500	30,000	0.009
Saline lakes and inland seas	105,000	25,000	0.008
Soil moisture	67,000	16,000	0.005
Atmosphere	13,000	3,100	0.001
Rivers	1,250	300	0.0001
Total water volume	1,376,468,750	329,674,400	100

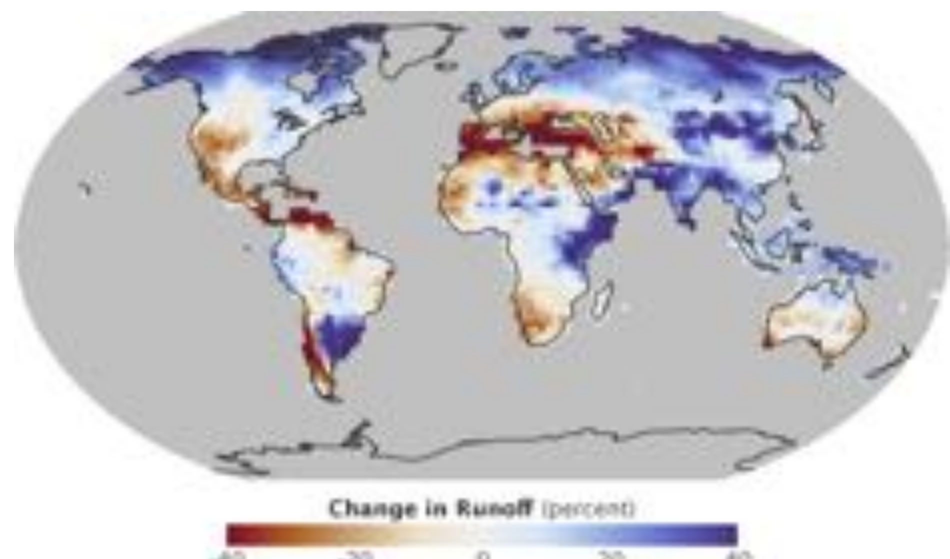
Water in the Anthropocene

http://www.igbp.net/multimedia/multimedia/waterintheanthropocenedatavisualization.5.19895cff13e9f675e252f1.html

How the global water cycle is changing as a result of human influence







IPCC Fourth Assessment Report

Milly, NOAA GFDL

Oroville Dam reservoir, north of Sacramento.
Photo Credit: California Department of Water Resources.

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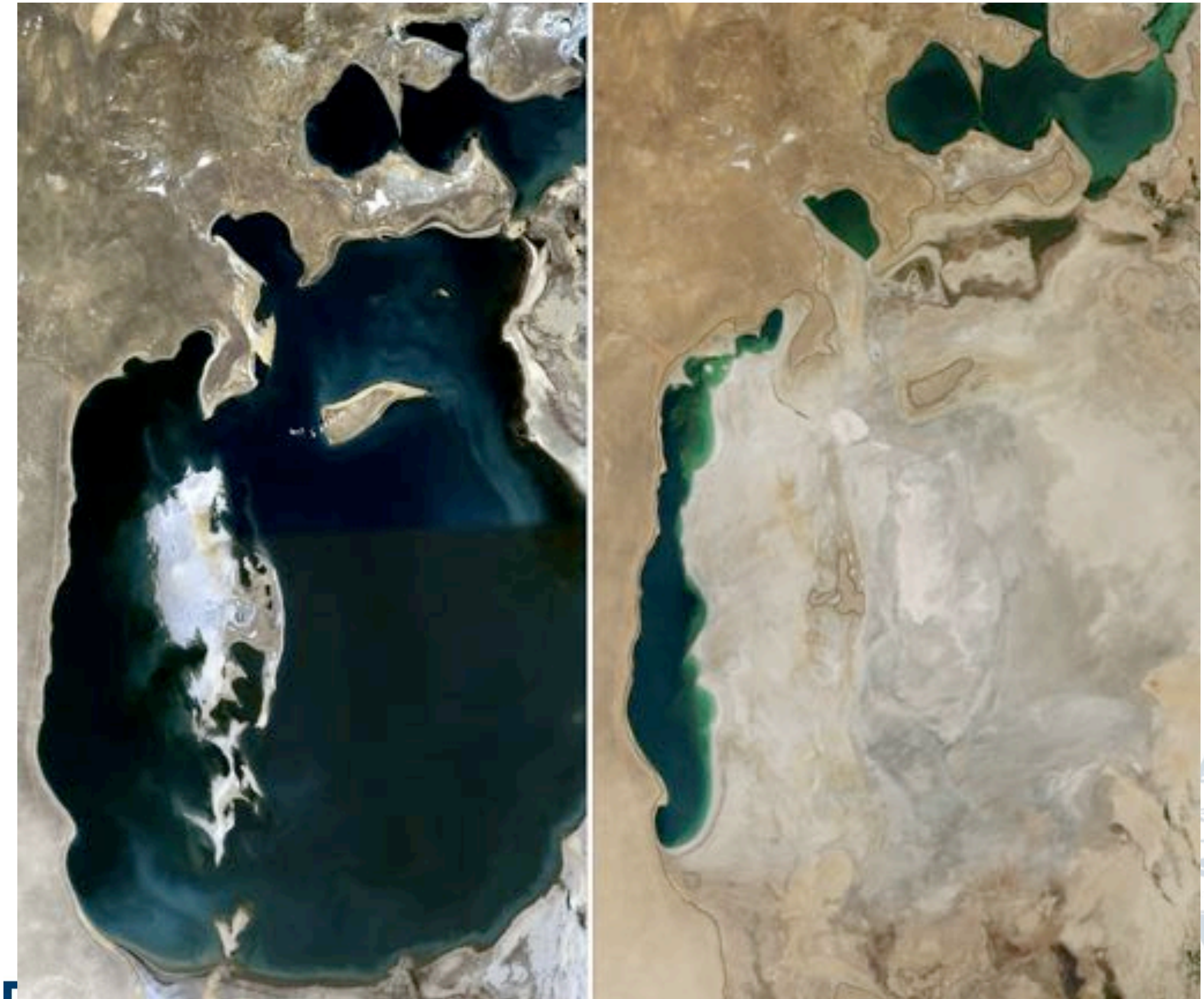
Aral Sea: The world's 4th largest lake

Aral Sea: The world's 4th largest lake



Rivers diverted for irrigation

Shrunk to <10% of size

Then basin completely dried up

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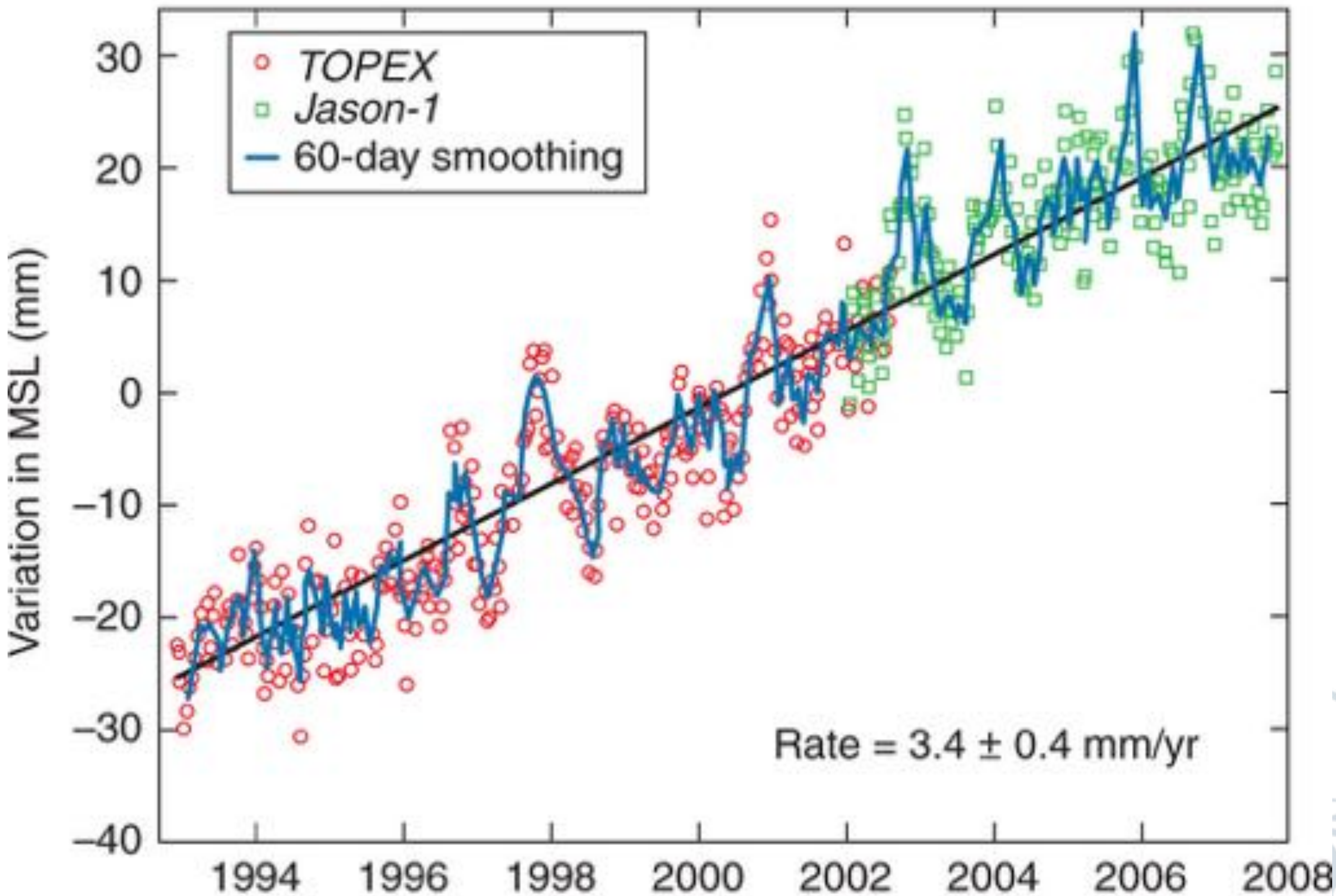
Rising sea level



From Leuliette, E. W., R. S. Nerem, and G. T. Mitchum, 2004: Calibration of TOPEX/Poseidon and Jason altimeter data to construct a continuous record of mean sea level change. Marine Geodesy, 27(1–2), 79–94. http://sealevel.colorado.edu. Reprinted with permission from the Colorado Center for Astrodynamics Research.

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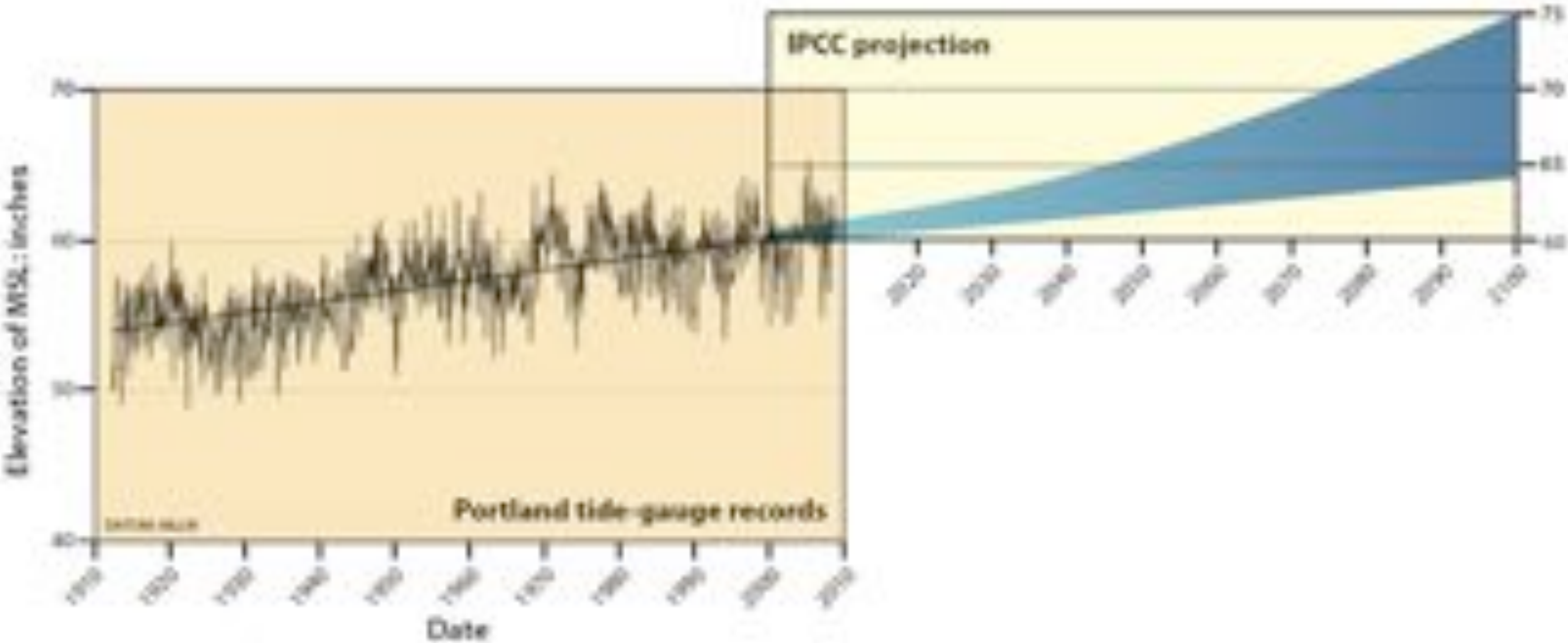

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Sea level- regional variability
Nicholls et al. 2011

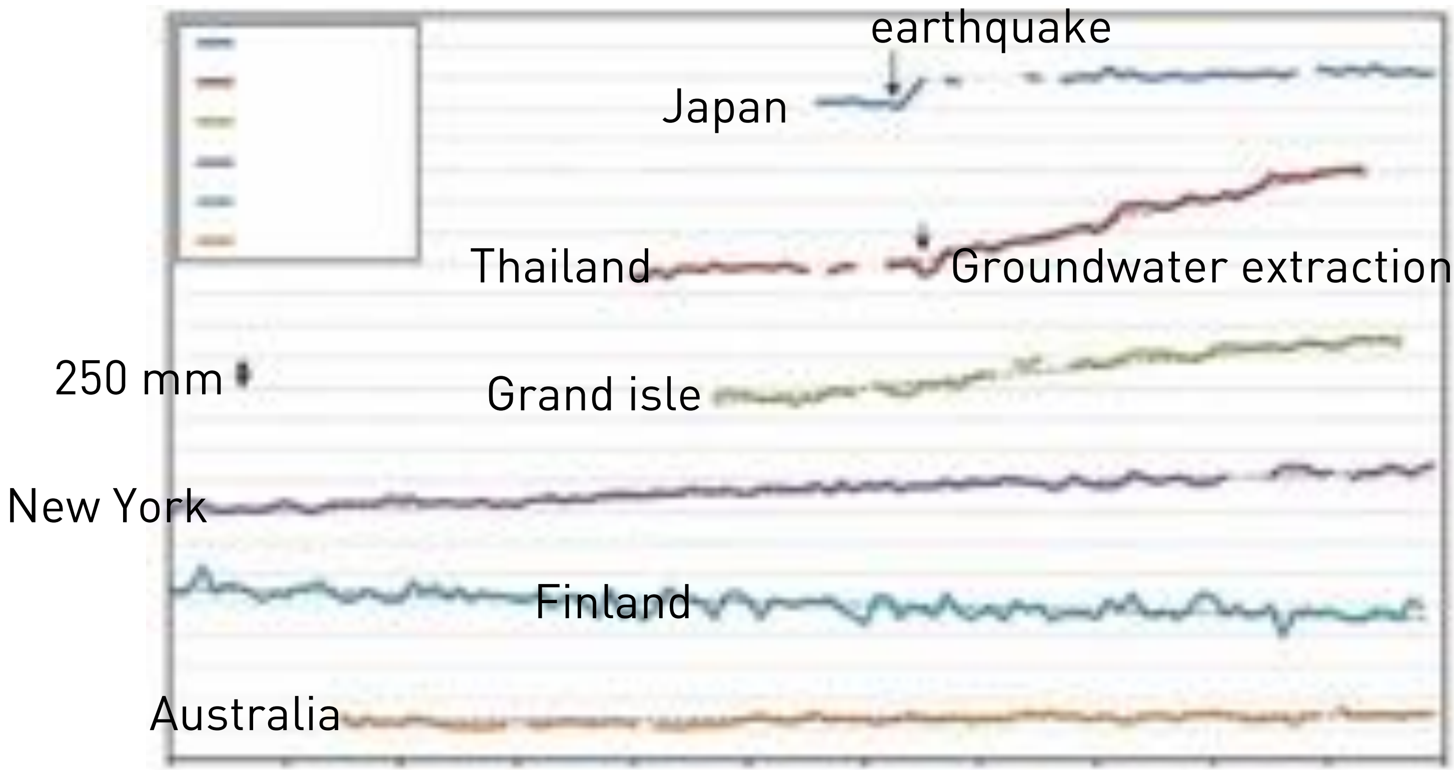

Figure 1. Selected relative sea level observations since 1900. Helsinki shows a falling trend (-2.0 mm yr–1), Sydney shows a gradual rise (0.9 mm yr–1), New York is subsiding slowly (3.0 mm yr–1), Grand Isle is on a subsiding delta (9.3 mm yr–1), Bangkok includes the effects of human-induced subsidence (20.7 mm yr–1 from 1962 to 2003), and Nezugaseki shows an abrupt rise due to the 1964 Niigata earthquake.

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Vulnerability of coasts, islands, and deltas to sea level rise on a global basis

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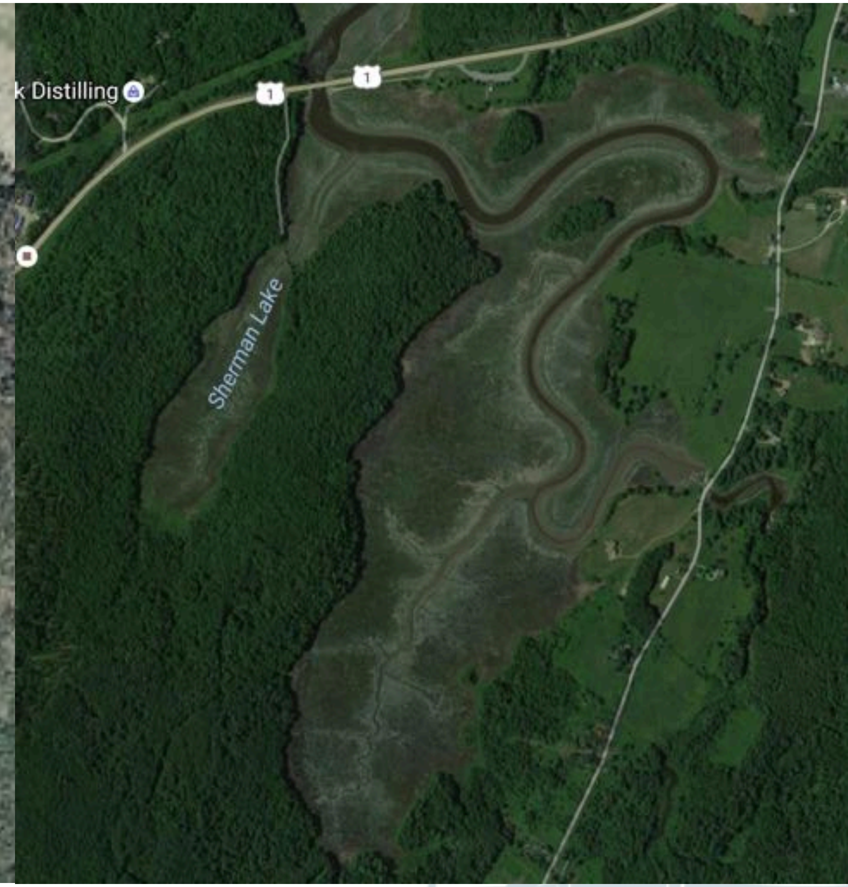
Effects of sea level rise and adaptations

NATURAL SYSTEM EFFECT		POSSIBLE INTERACTING FACTORS		POSSIBLE ADAPTATION APPROACHES
		Climate	Non-climate	
1) Inundation / flooding	**a) Surge (from sea)**	Wave/storm climate, erosion, sediment supply	Sediment supply, flood management, erosion, land reclamation	Dikes, surge barriers, closure dams, dune construction, building codes, flood-proof buildings, land use planning, hazard mapping, flood warnings
	b) Backwater (from rivers)	Runoff	Catchment management, land use	
2) Wetland loss (and change)		CO_2 fertilization, sediment supply, migration space	Sediment supply, migration space, land reclamation	Nourishment, land use planning
3) Erosion of soft morphology		Sediment supply, wave/storm climate	Sediment supply	Coast defenses/seawalls, land claim, nourishment, building setbacks
4) Saltwater intrusion	**a) Surface waters**	Runoff	Catchment management, land use	Saltwater intrusion barriers, changewater extraction
	b) Groundwater	Rainfall	Land use, aquifer use	Freshwater injection, change water extraction
5) Impeded drainage, higher water table		Rainfall, runoff	Land use, aquifer use, catchment management	Drainage systems, land use change, land use planning, hazard deliniation

Maine’s moving coastline


1
Sherman
Lake

k Distilling
1
Sherman Lake

1992

1996

Google Earth
(now?)

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How do we address the changing coastline?

Breakwaters and jetties


Drakes Island
Image © 2012 TerraMetrics

Seawalls

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Wells, ME

Saco, ME

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What will happen as sea level rises?

Portland high tide (photo credit A. Pershing)

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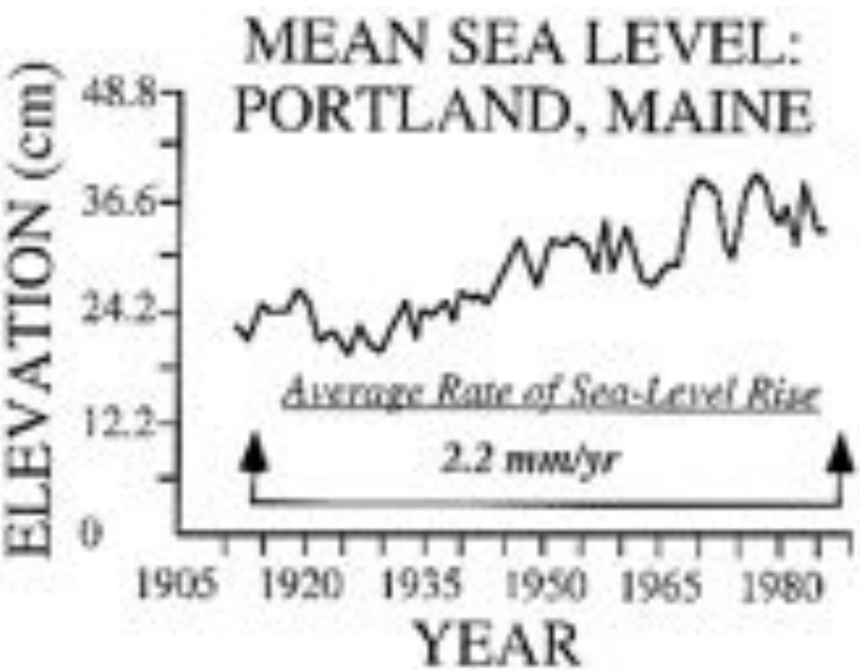
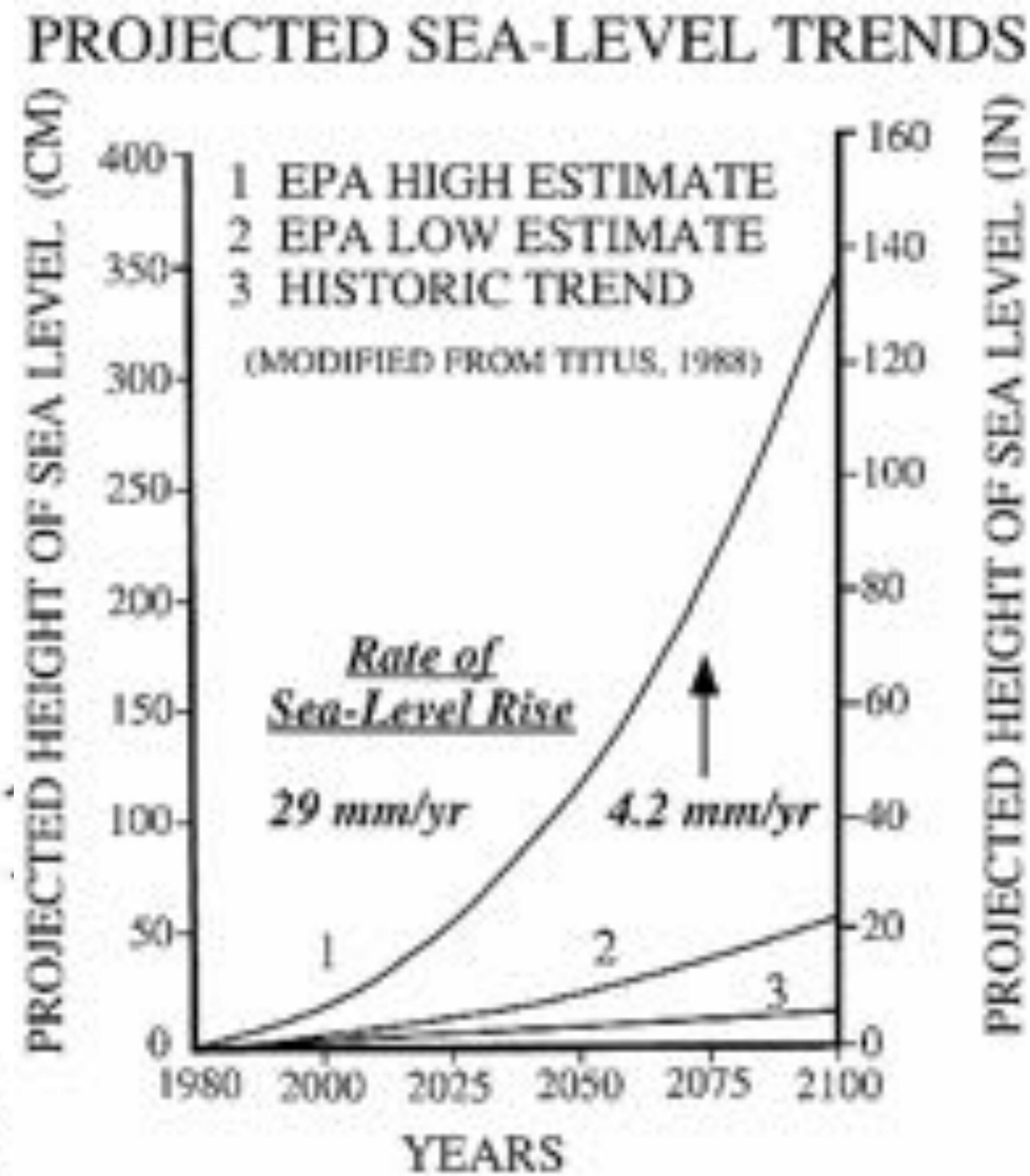
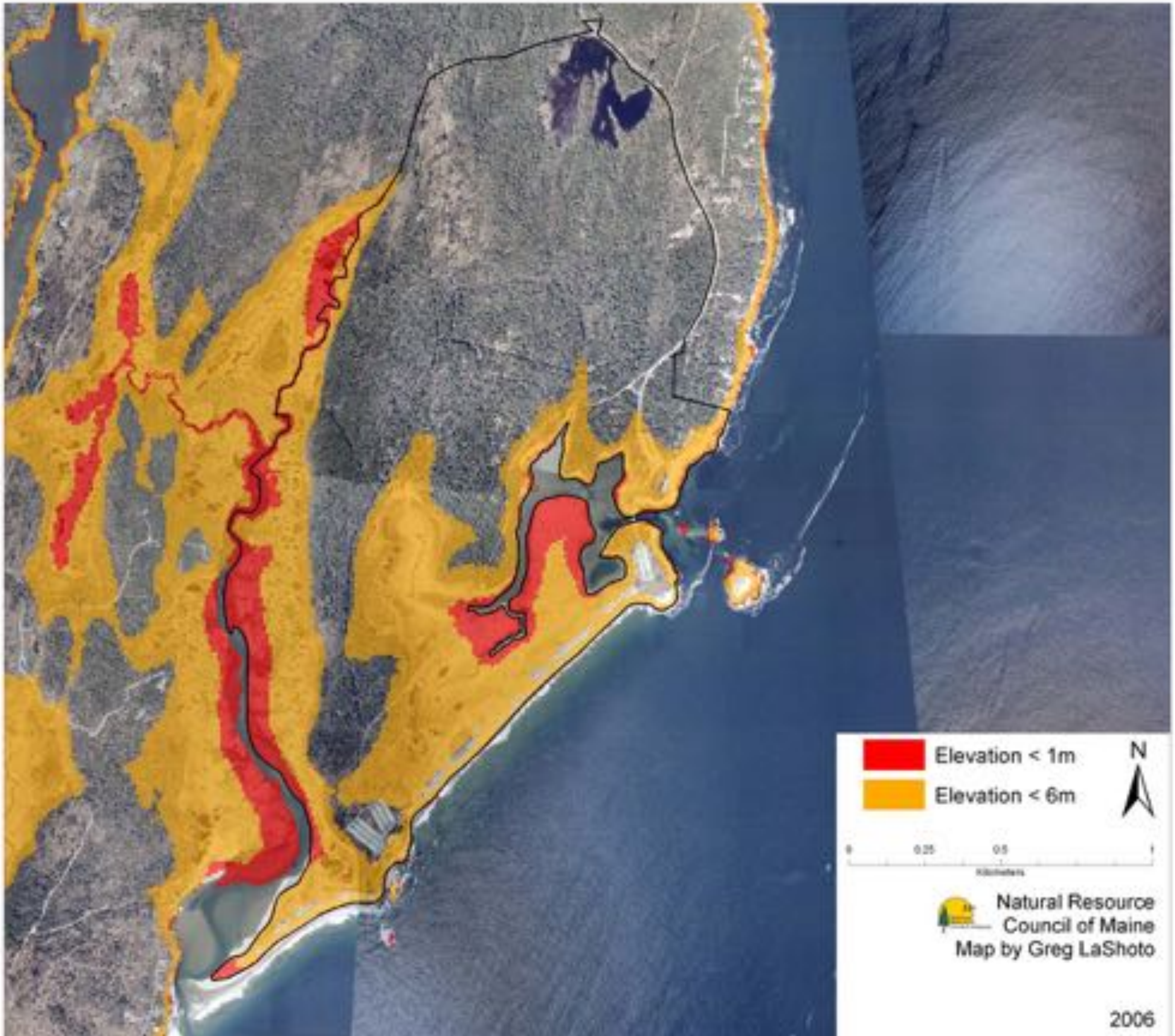




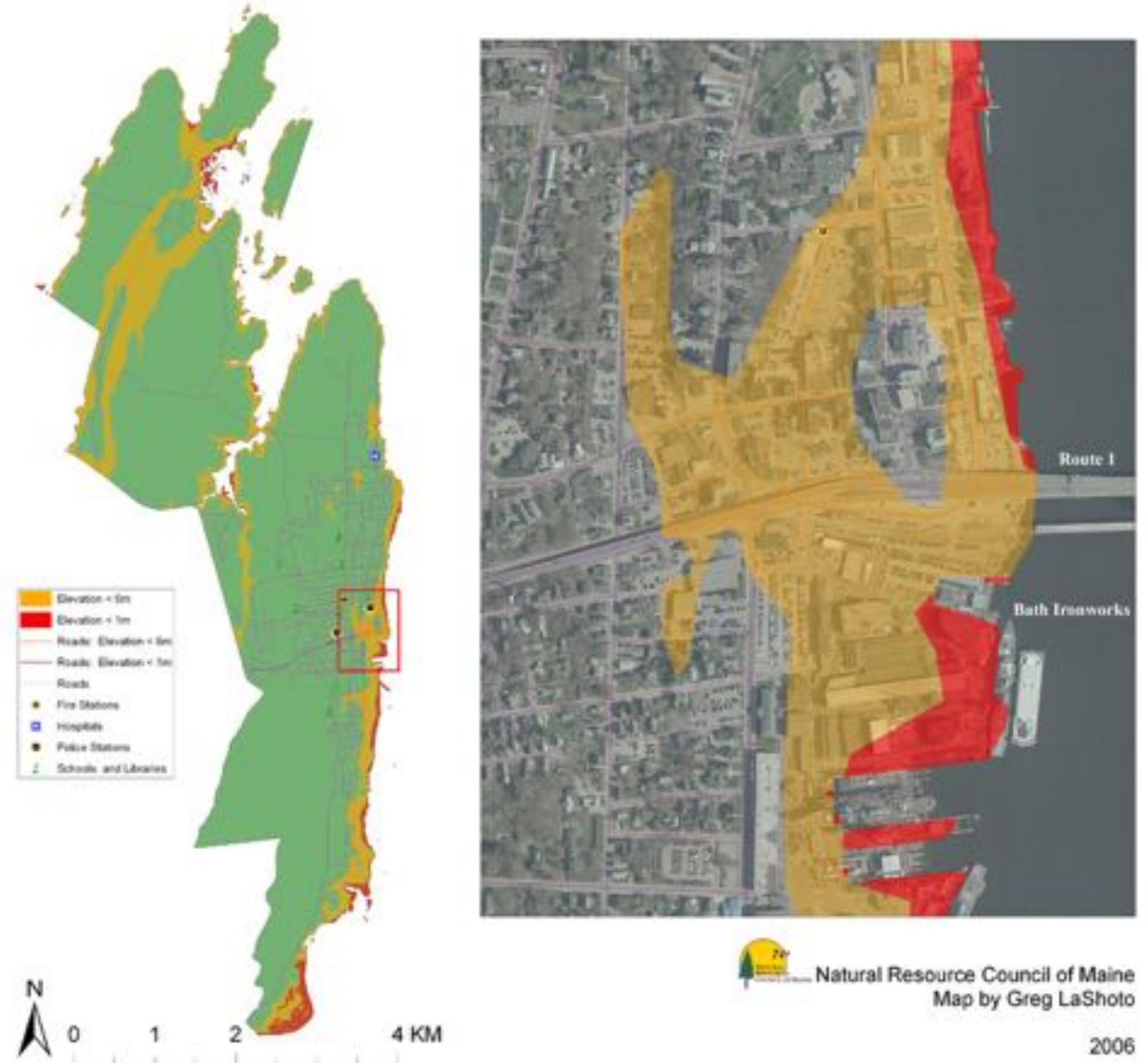
Maine geological survey / Environmental Protection Agency

Impact of Sea Level Rise on Reid State Park, Georgetown, Maine



Natural Resources
Council of Maine

Impacts of Sea Level Rise on Bath, Maine



Natural Resources
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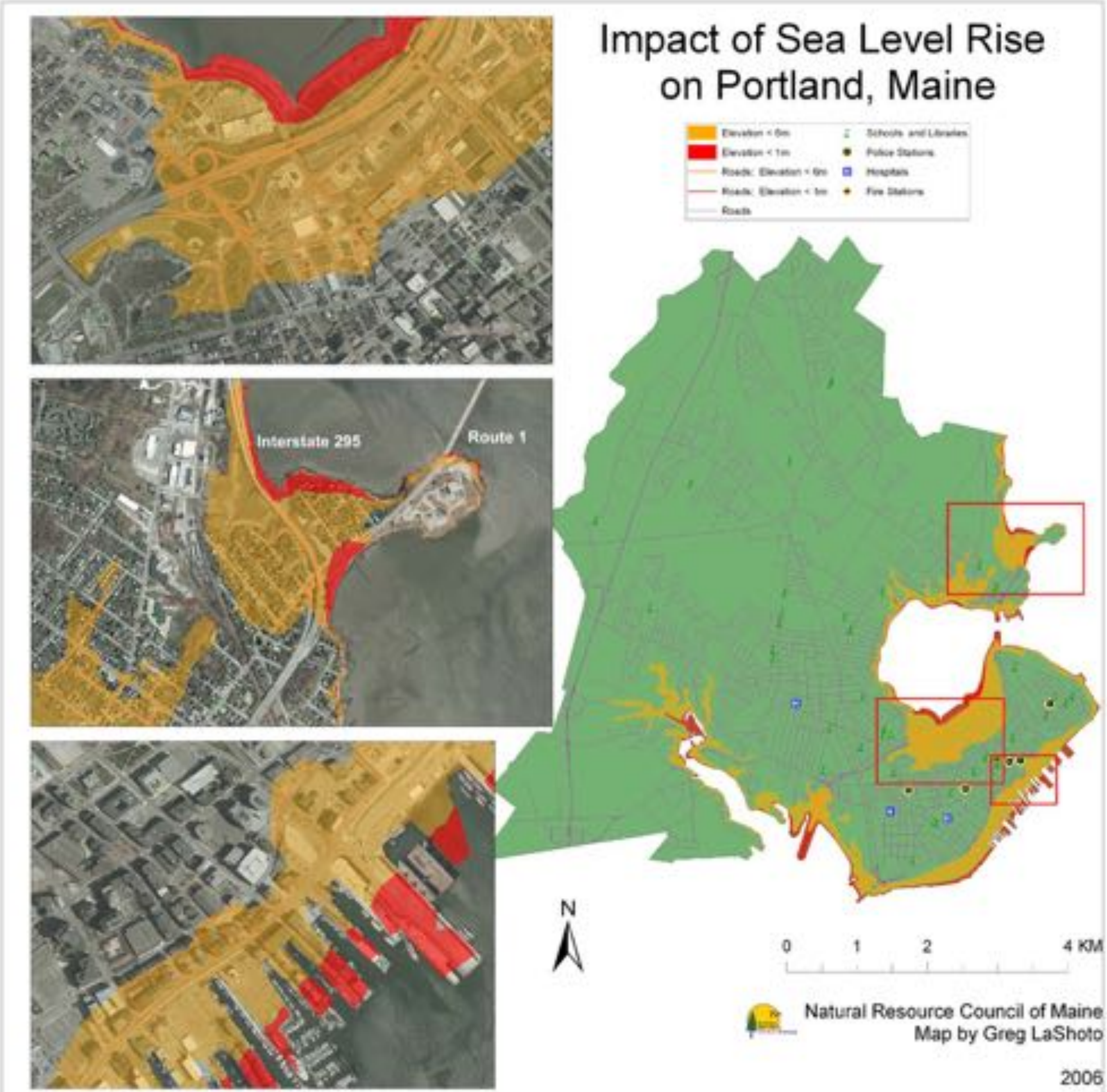

Natural Resources
Council of Maine

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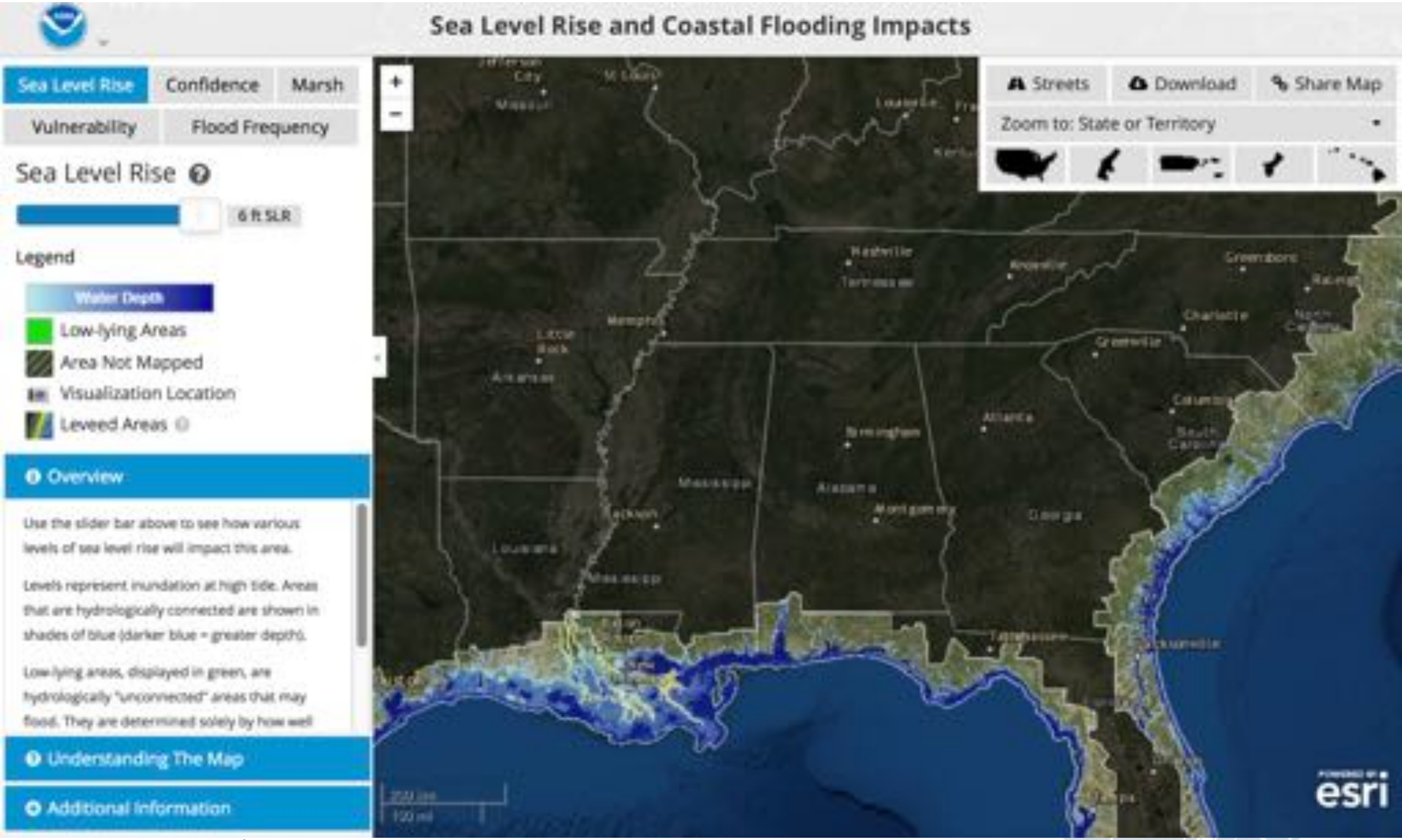
Natural Resources Council of Maine

Impact of Sea Level Rise on Walker's Point

Natural Resources Council of Maine, 2006

Natural Resources
Council of Maine

US sea level rise visualizer: https://coast.noaa.gov/slr/



Scientific Papers

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Scientific Papers

"*Probably what you should learn…is not a large number of facts, especially if they are in books, but what the important problems are, and to sense which experiments, work that has been done, probably aren't quite right.*"

- James Watson (of Watson & Crick)

- Before reading an article, ask yourself: *What am I looking for in this article?*

- **AUTHORS**
  - Where and with whom are they working?
  - What is their expertise?

- **TITLE**
  - Read and digest the title.
  - Is the "take-home message" in the title?

- **ABSTRACT**
  - Read carefully and try to understand it. Take some time here.
  - Does the abstract align with your expectations for the article?
  - Take-home message(s)

Scientific Papers

- **FIGURES, TABLES, LEGENDS**
  - What does each figure show?
  - Reference the methods where necessary.
- **INTRODUCTION**
  - In the first few paragraphs, the objective should be clear.
  - What gap does this study fill?
  - Look for assumptions
  - Generally, the Intro and Literature Cited sections go hand-in-hand.
- **RESULTS**
  - Should align with figures
- **DISCUSSION**
  - Authors should explain WHY they saw what they saw
  - Beware of unfounded speculation
  - ...though new hypotheses are okay
  - Look for caveats to “take-home messages”

Scientific Papers

- **HYPOTHESIS**
  - Is there a hypothesis?
  - Some types of hypothesis

    Simple: cause → effect

    eg: smoking leads to cancer

    Complex: multiple cause → multiple effect

    Null hypothesis: no relationship

    H0: There is no relationship between atmospheric CO_2 and global temperature.

    Alternative hypothesis: an alternative to a discounted (usually null) hypothesis

    H1: Increasing atmospheric CO_2 leads to increasing global temperature by trapping heat.

    Statistical hypothesis: validated statistically

Abrupt mid-twentieth-century decline in Antarctic sea-ice extent from whaling records

William K. de la Mare

Australian Antarctic Division, Department of the Environment, Sport and Territories, Channel Highway, Kingston, Tasmania 7050, Australia

ABSTRACT

- Knowledge gap
- Take home message(s)
- Hypothesis?
- What potential questions or problems arise?

FIGURES

- What information is contained?
- Take home message(s)
- What information is missing?

Abrupt mid-twentieth-century decline in Antarctic sea-ice extent from whaling records

William K. de la Mare

Australian Antarctic Division, Department of the En
Sport and Territories, Channel Highway, Kingston,

A decline in Antarctic sea-ice extent is a commonly predicted effect of a warming climate. Direct global estimates of the Antarctic sea-ice cover from satellite observations, only possible since the 1970s[1–4], have shown no clear trends. Comparisons[1] between satellite observations and ice-edge charts obtained from early ship records[5] suggest that sea-ice extent in the 1970s was less than during the 1930s, an indication supported by limited regional observations[6]. But these observations have been regarded as inconclusive, owing to the limited spatial and temporal scope of the early records[2]. A significant data source has, however, been overlooked. The southern limit of whaling was constrained by sea ice, and since 1931 whaling records have been collected for every whale caught[7], giving a circumpolar coverage from spring to autumn until 1987. Here, an analysis of these catch records indicates that, averaged over October to April, the Antarctic summer sea-ice edge has moved southwards by 2.8° of latitude between the mid 1950s and early 1970s. This suggests a decline in the area covered by sea ice of some 25%. This abrupt change poses a challenge to model simulations of recent climate change, and could imply changes in Antarctic deep-water formation and in biological productivity, both important processes affecting atmospheric CO_2 concentrations.

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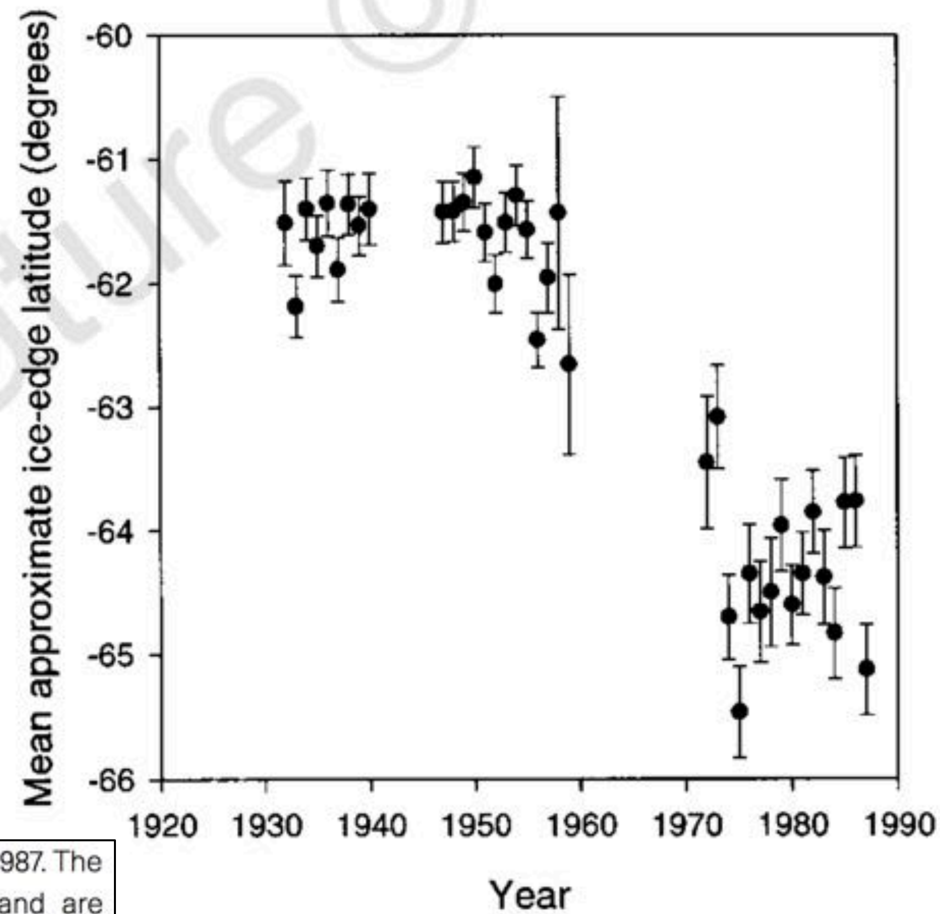

Figure 1 Mean approximate ice-edge latitude in Antarctica from 1931 to 1987. The estimates are from a linear model fitted to whale-catch records, and are standardized to first 10-day period of January and the longitudinal sector 20°–30° E. The year is defined by the first decade (ten days) in January, and so, for example, 1932 is the mid-point of the 1931/32 season. The predictions are most precise at the centre-of-mass of the data, and so the selected decade and longitude are based on the mean value of each factor weighted by the number of observations at each of its levels. The year effects are corrected for decade and longitude, and so describe a generalized effect for the latitude of catches with time. The actual pattern over time for a given sector and decade would not necessarily correspond exactly to the pattern shown because there are likely to be interactions between the factors. However, these could not be estimated with the data available. The error bars represent ±1 standard error.

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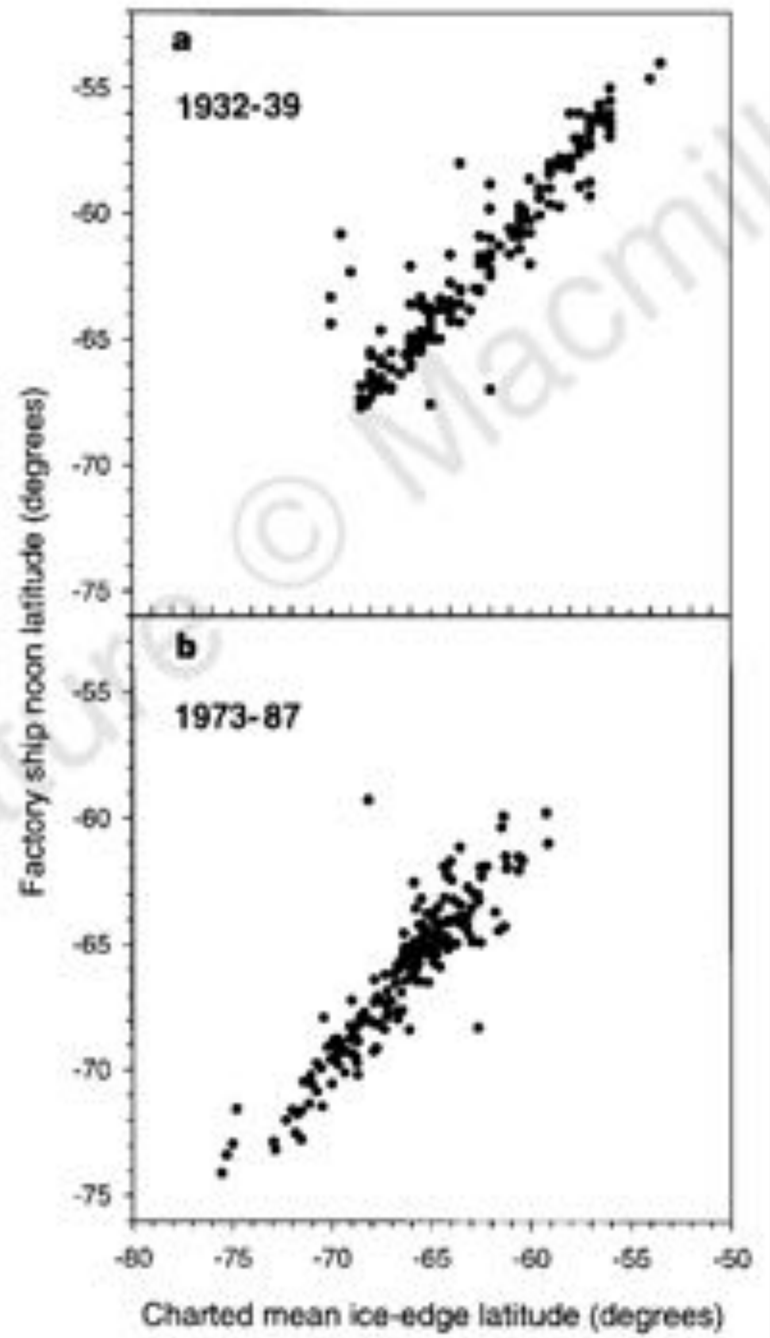

Figure 3 The relationship between the latitudes of the southernmost whale catches, in terms of the factory-ship noon positions, and information on the ice-edge given in charts published in reports[5] of the Discovery Committee (**a**) and from data[3] derived from charts published by the Joint Ice Center (JIC) (**b**). The Discovery data cover the 'years' 1932–39, and the JIC data cover 1973–87. There are 178 observations where the Discovery and southernmost-catch data can be compared. A linear regression of the catches on the Discovery data gives $R^2 = 0.88$, with a slope of 0.845 (standard error, 0.024). There are 196 observations where the JIC and southernmost-catch data sets can be compared. The regression of catch positions on the JIC data gives $R^2 = 0.832$, with a slope of 0.875 (standard error, 0.028).