Sea-level change along the Atlantic coast of the United States

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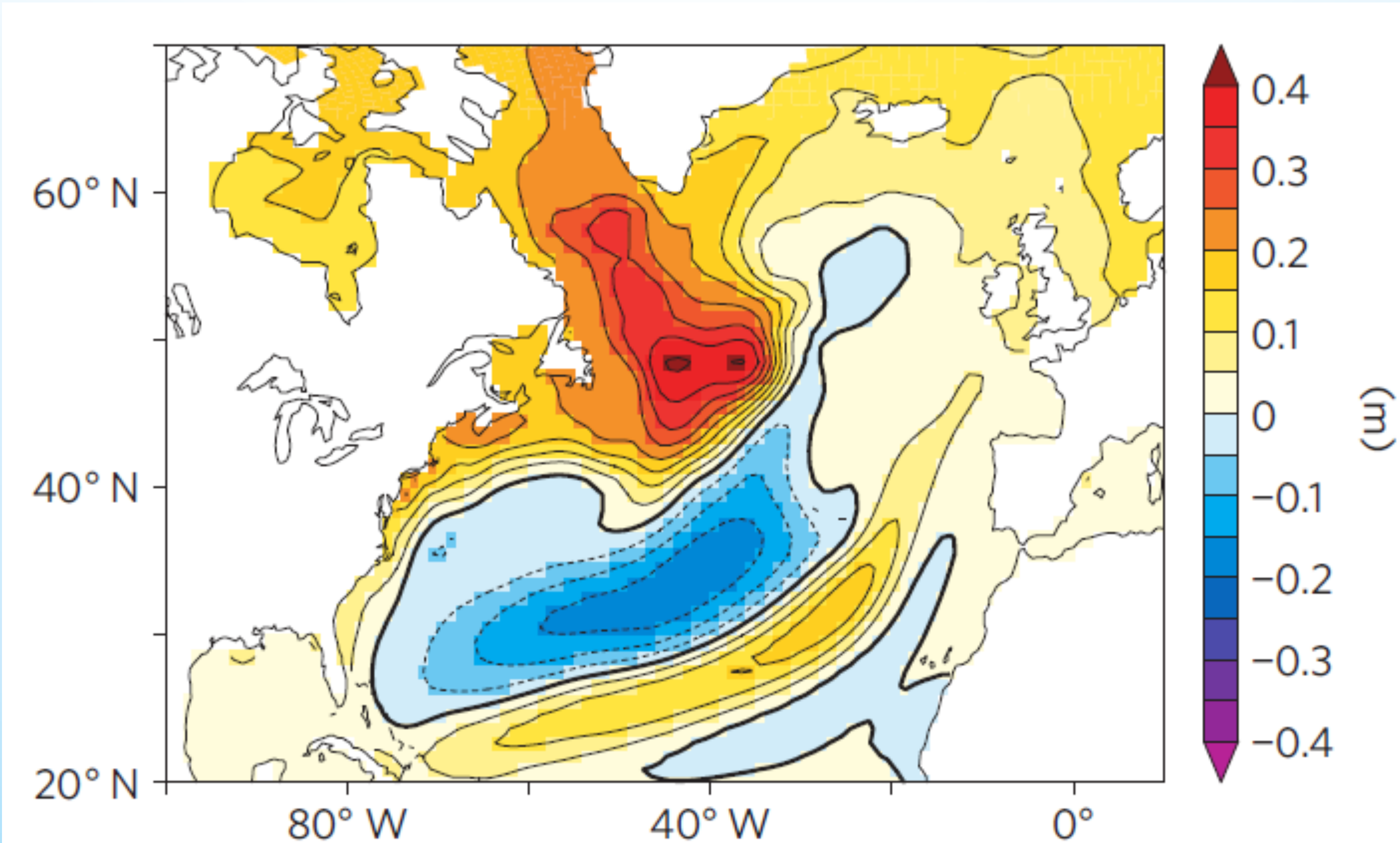
1. Sea-level change and AMOC variability?

Yin et al 2009, Nature Geo



The dynamic sea-level change induced by an idealized 0.1 Sv freshwater input for 100 years . The AMOC weakens by 37% over 100 years.

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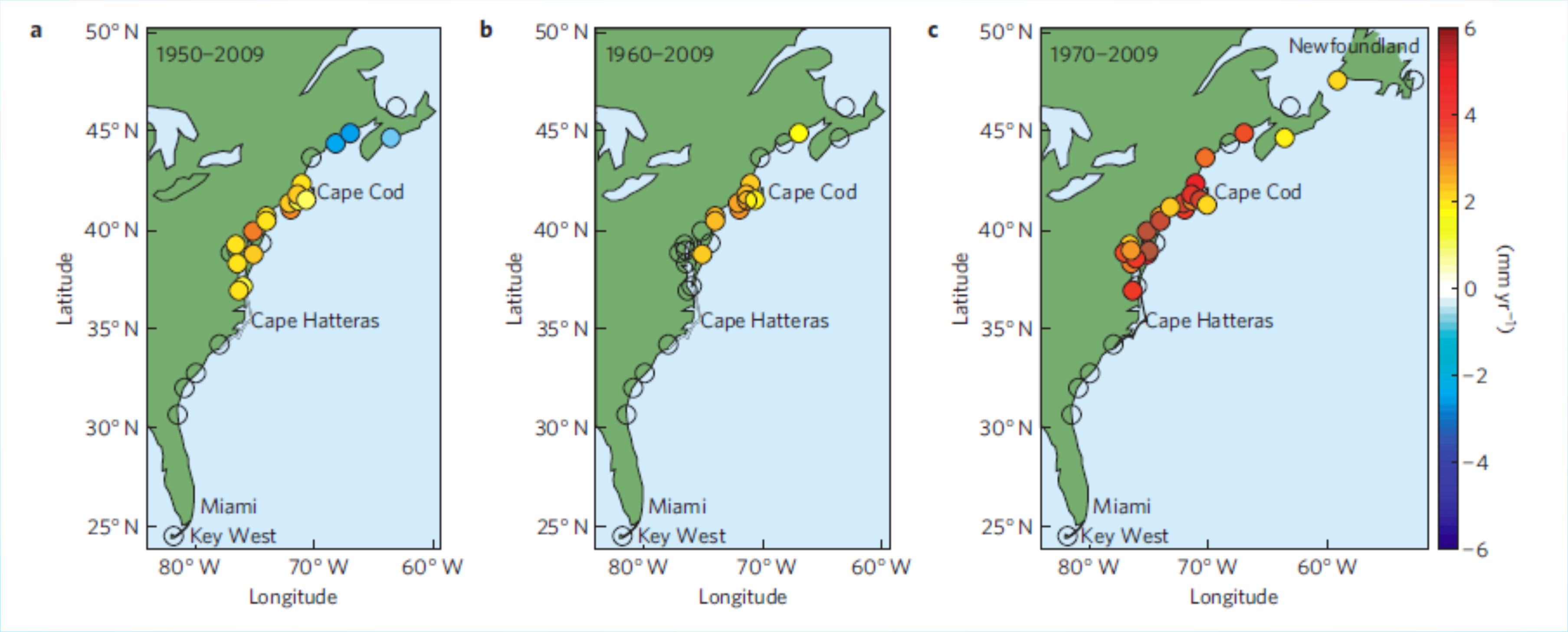
2. How does this relationship change by region?

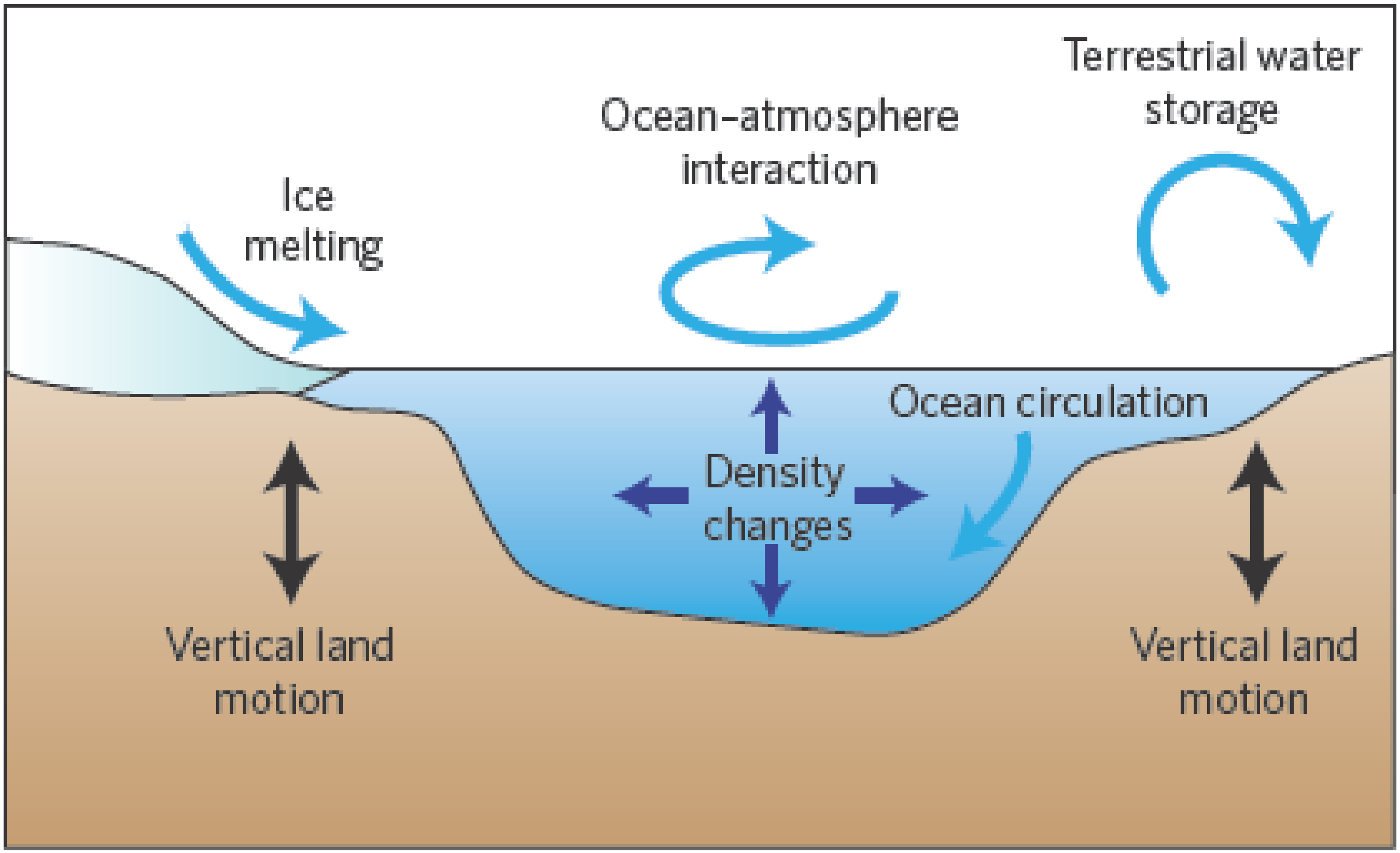
Sallenger et al 2012, Nature CC



Spatial variations of Sea Level Rate Difference (SLRD)

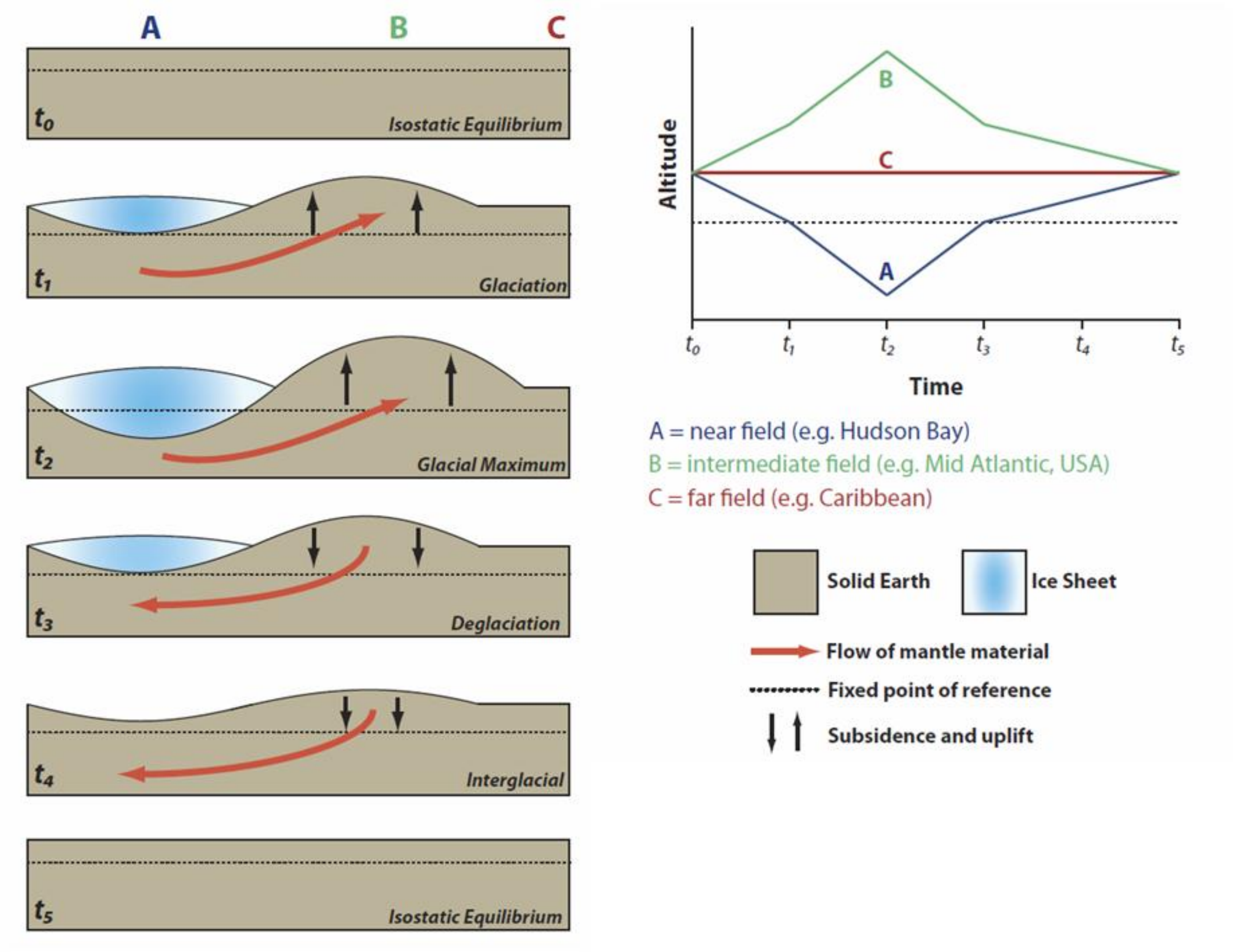
a, 1950–2009. b, 1960–2009. c, 1970–2009.

3. Paleo records of sea level as a proxy for AMOC?

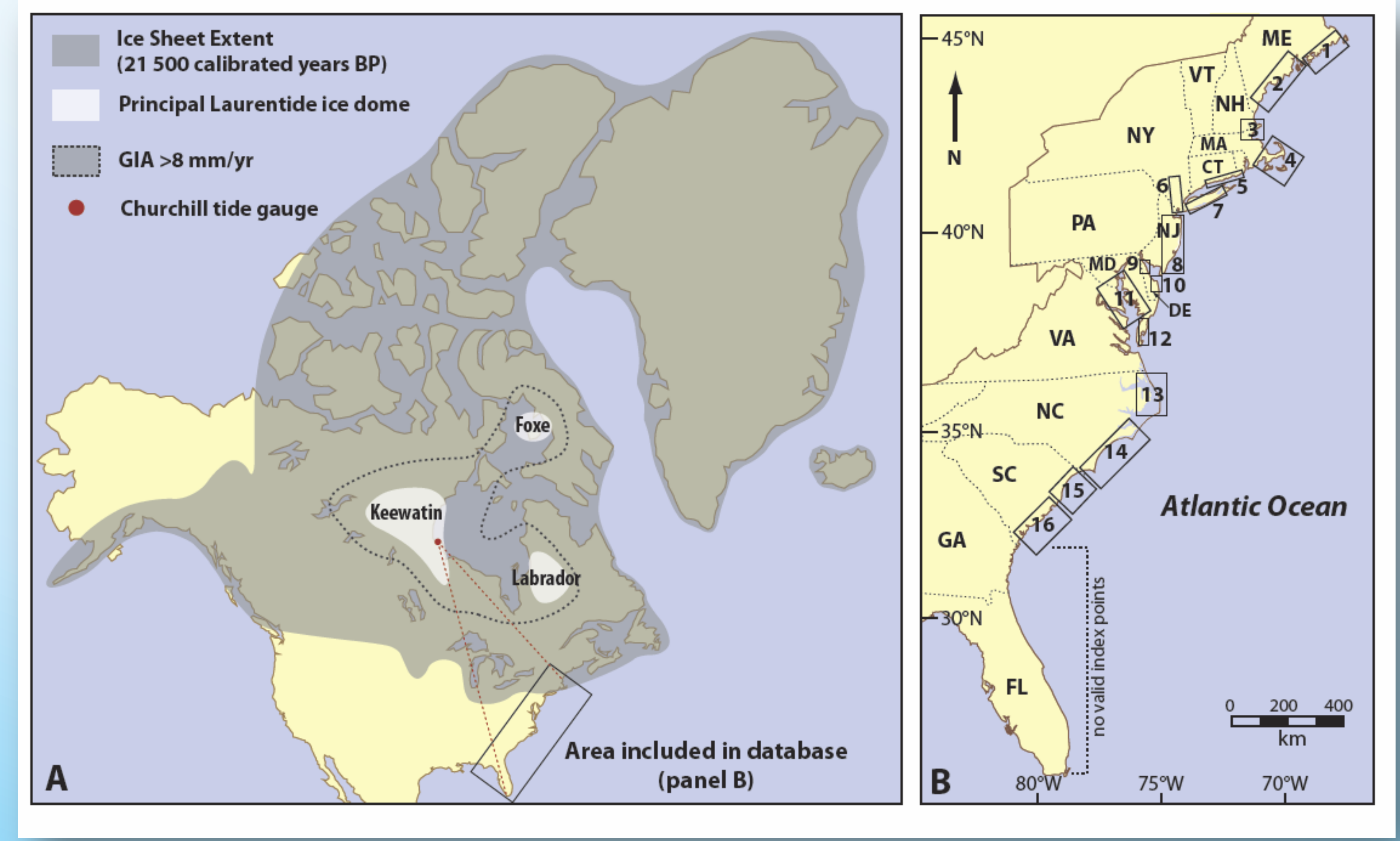


SLR= Oceans + Land

Regional variability: vertical land motion



Validated sea-level database



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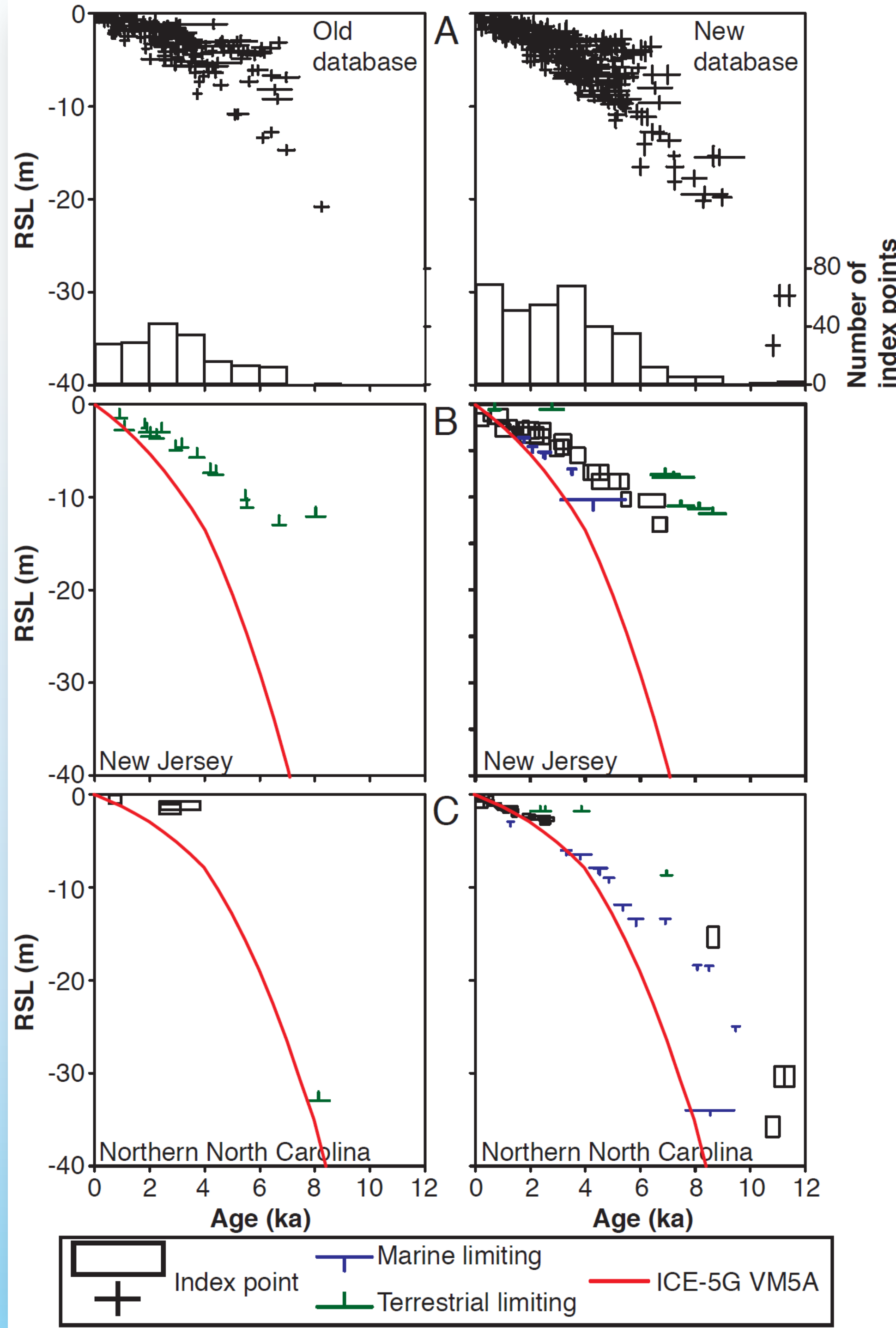
Old vs New

- Increased number (>650 data points) compared to Peltier (1996)
- Identifiction of sea-level indicators
- Elevation errors
- No assessment of compaction or tidal range change
- **Significant implication for GIA model**



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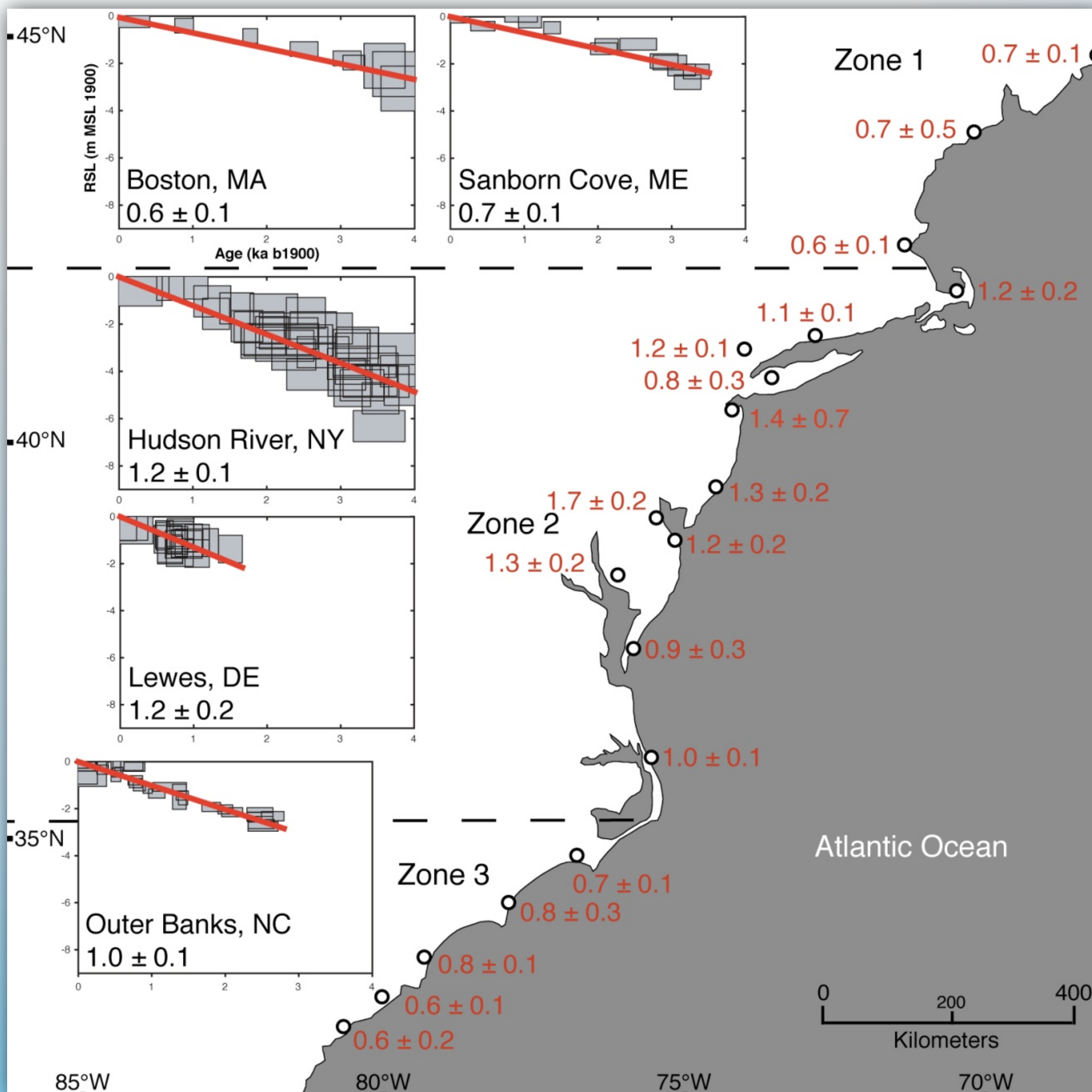
Sea level changes for the past 4000 years (mm/yr)

Background rates



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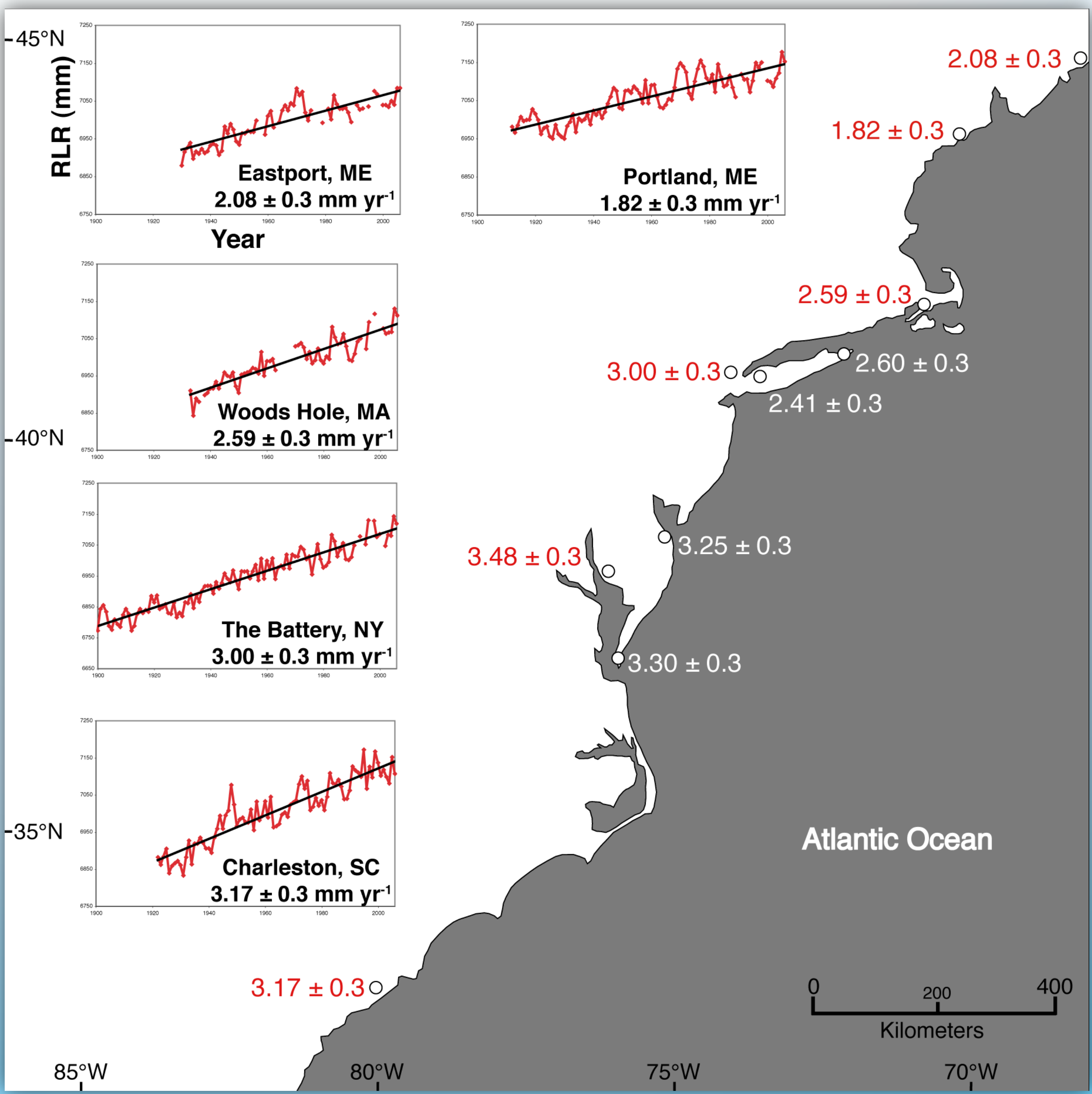
20th century RSL changes (mm/yr)



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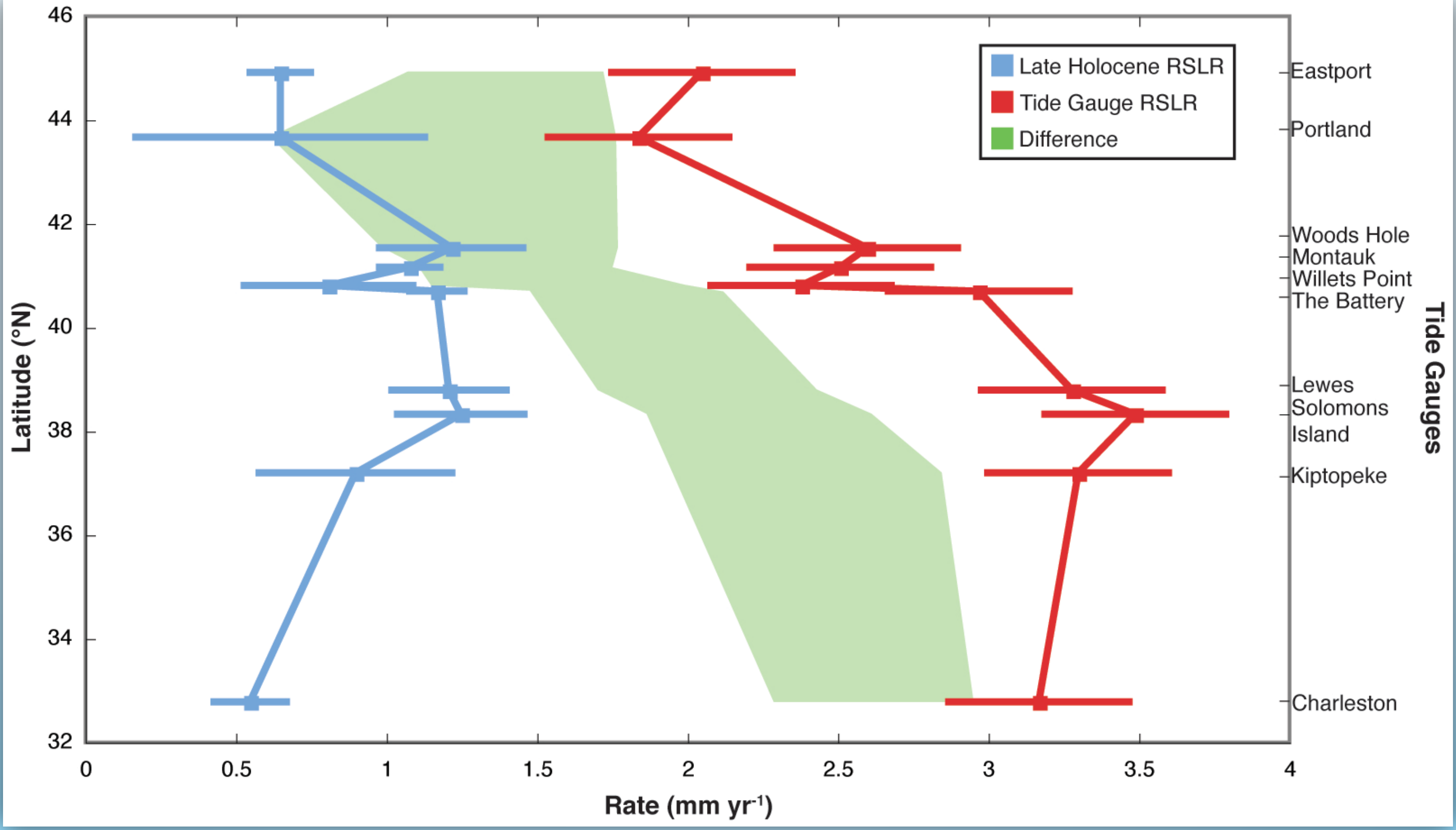
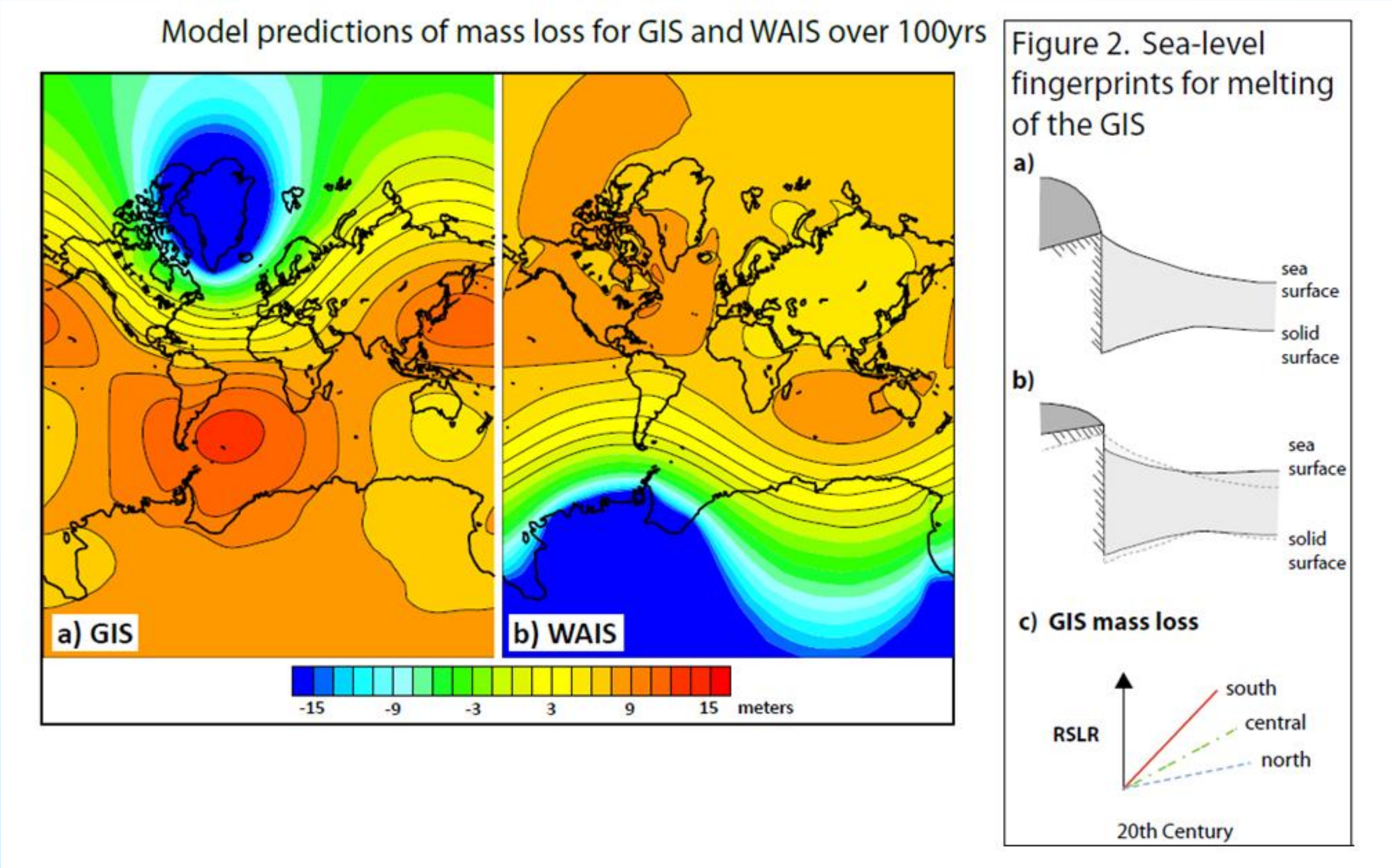
20th Century sea-level rise trend



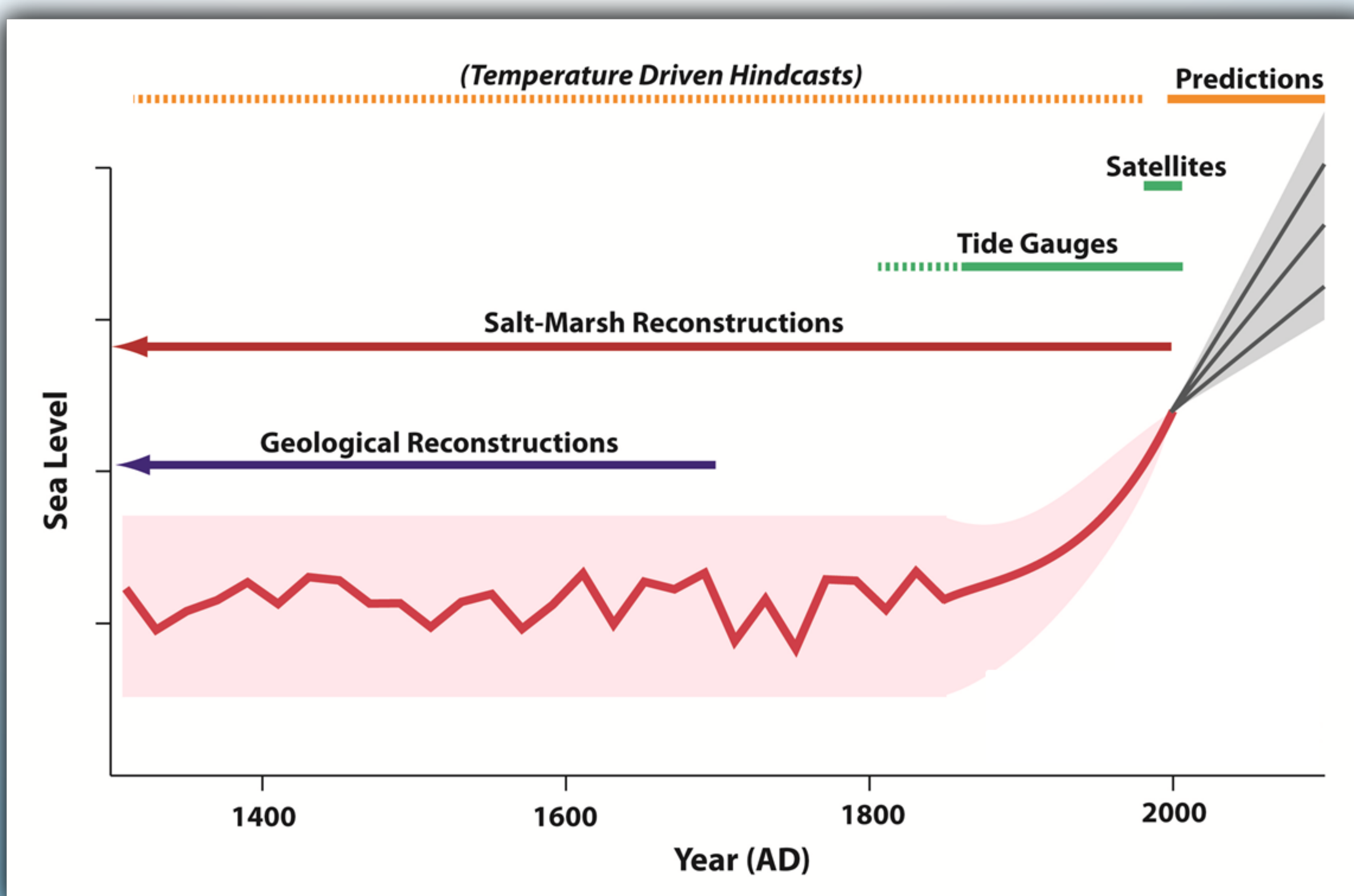
Detrending of 20th century tide-gauge records of RSLR with late Holocene RSLR for 10 locations along the U.S. Atlantic coast

Regional variability: sea level fingerprint



If the ice sheet melts, the attraction is reduced and SLR increases in areas geographically distal to the melting ice sheet

We need a new generation of sea-level records



Archaeological, micro-atolls and salt-marsh sea-level indicators have the precision to be compared with the instrumental record

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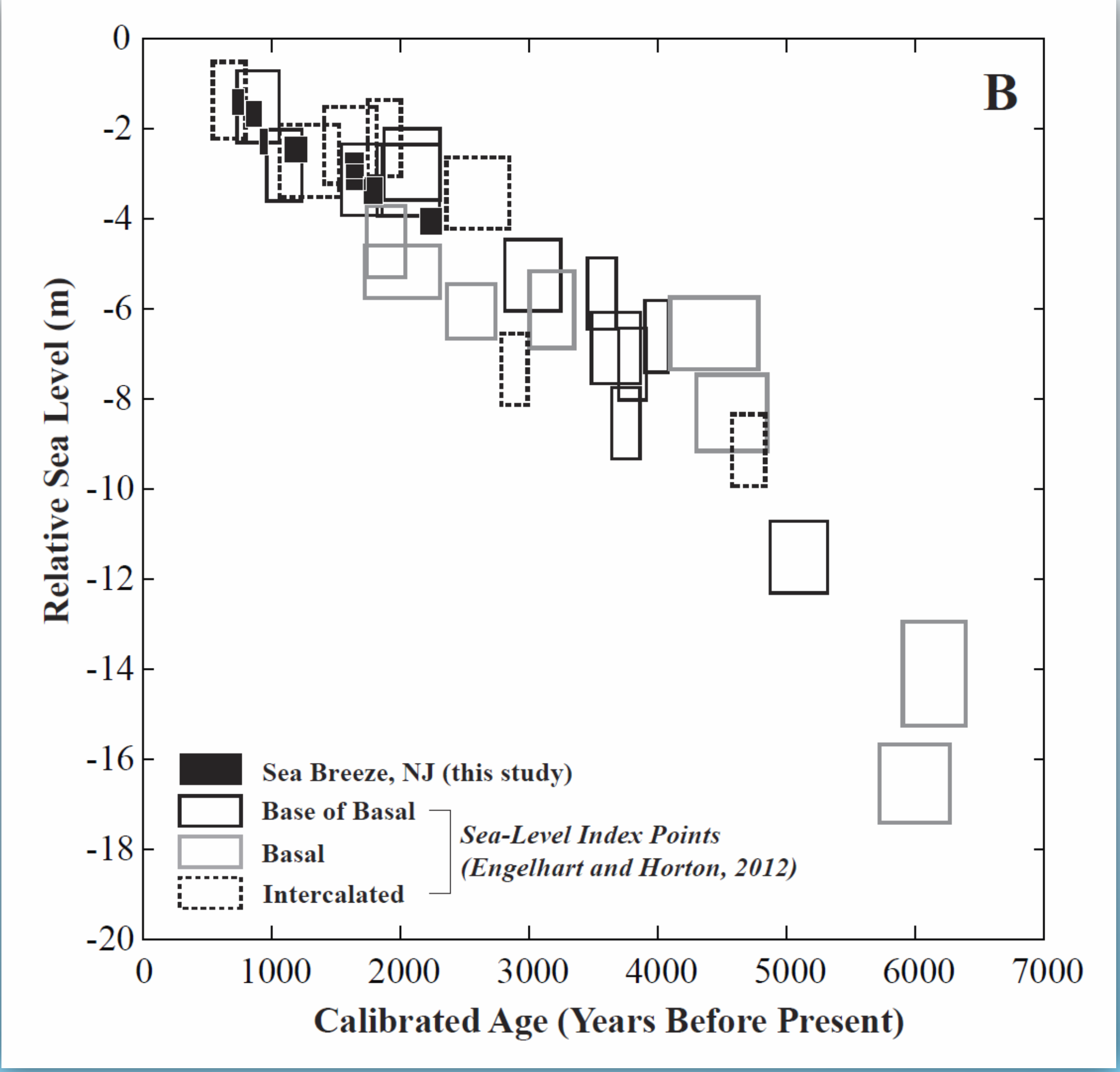
For example…



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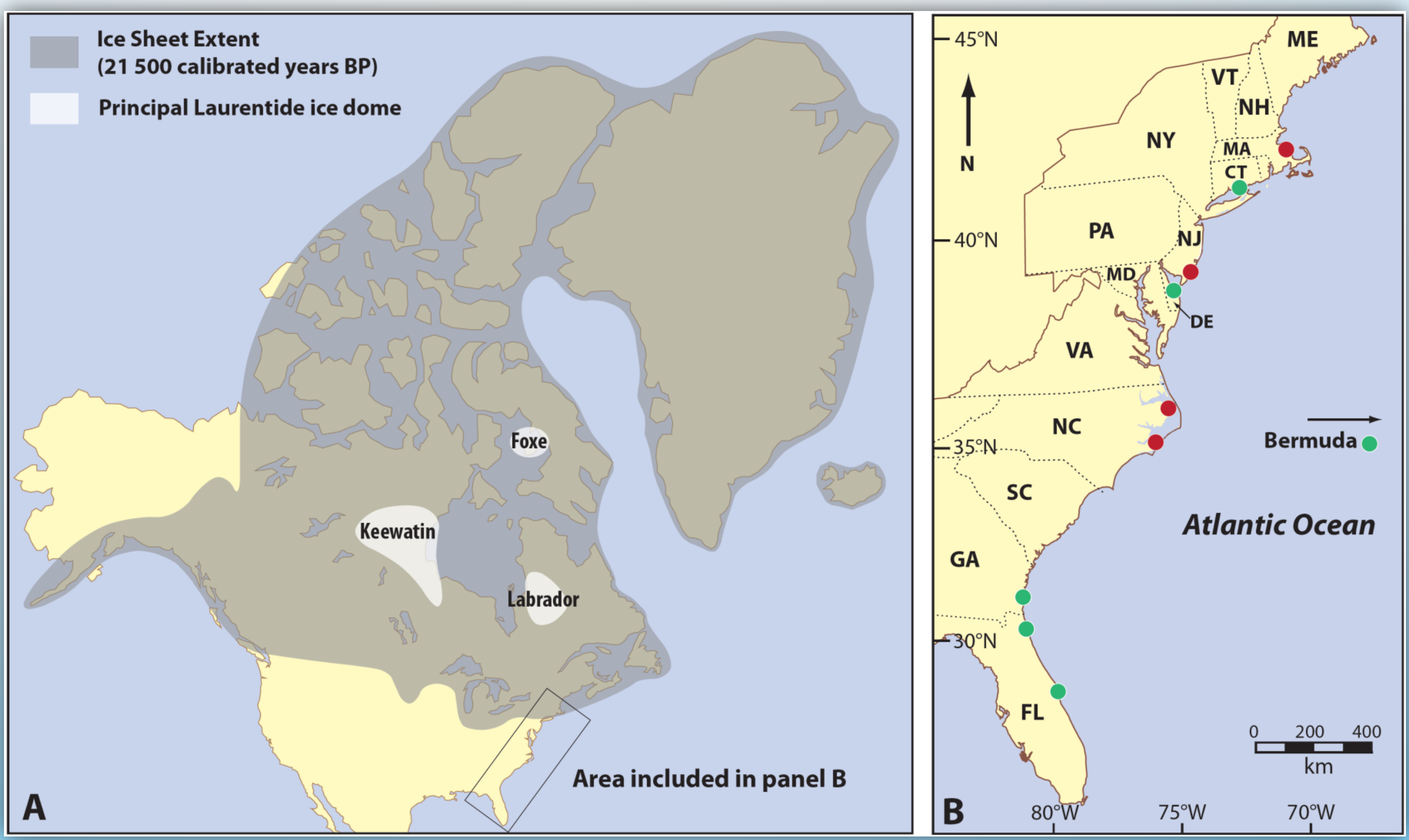
Study areas


Ice Sheet Extent
(21 500 calibrated years BP)
Principal Laurentide ice dome
Foxe
Keewatin
Labrador
Area included in panel B
A
45°N
40°N
35°N
30°N
N
ME
VT
NH
NY
MA
CT
PA
NJ
MD
DE
VA
NC
SC
GA
FL
Bermuda
Atlantic Ocean
0
200
400
km
80°W
75°W
70°W
B

North Carolina

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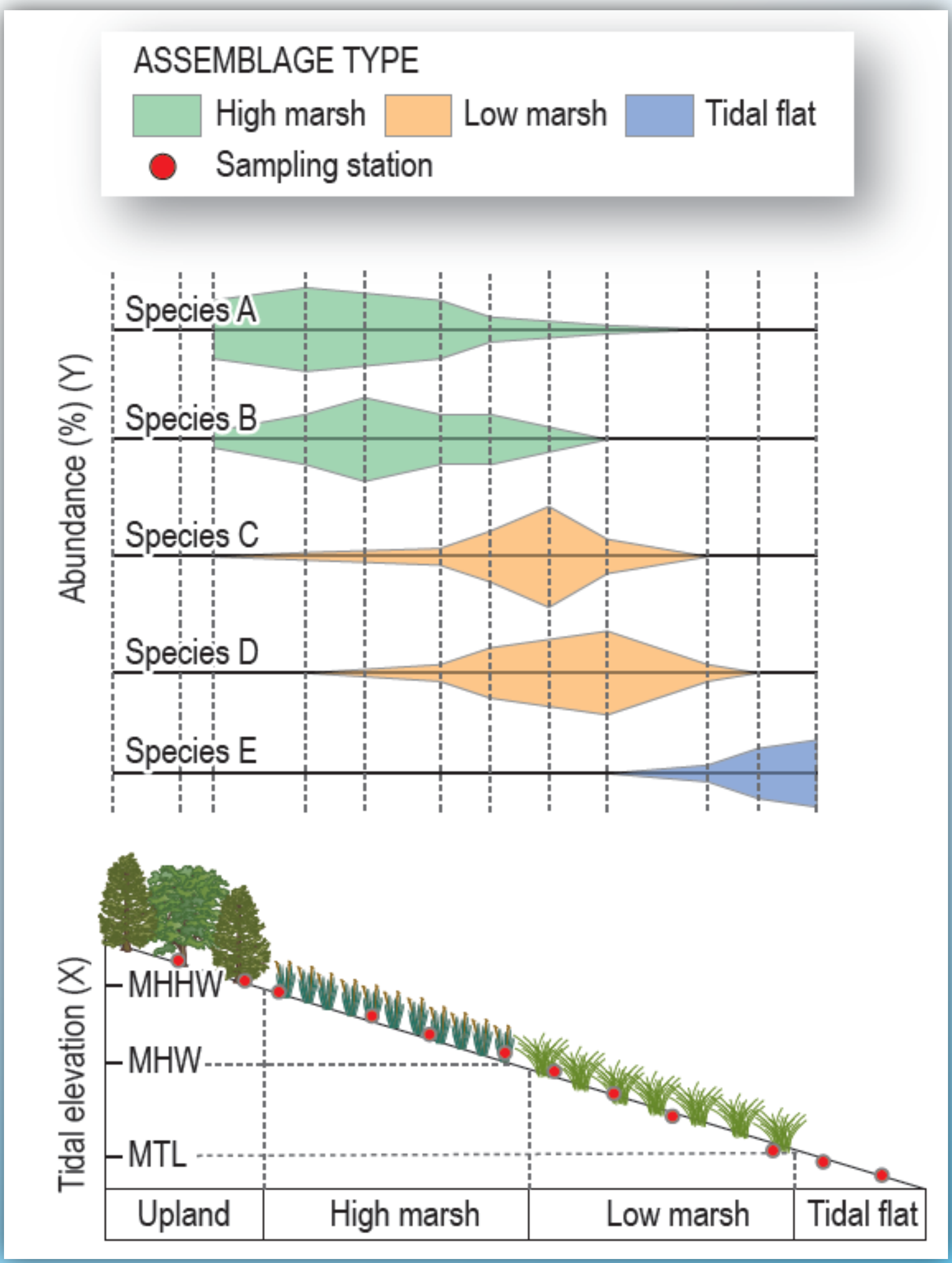
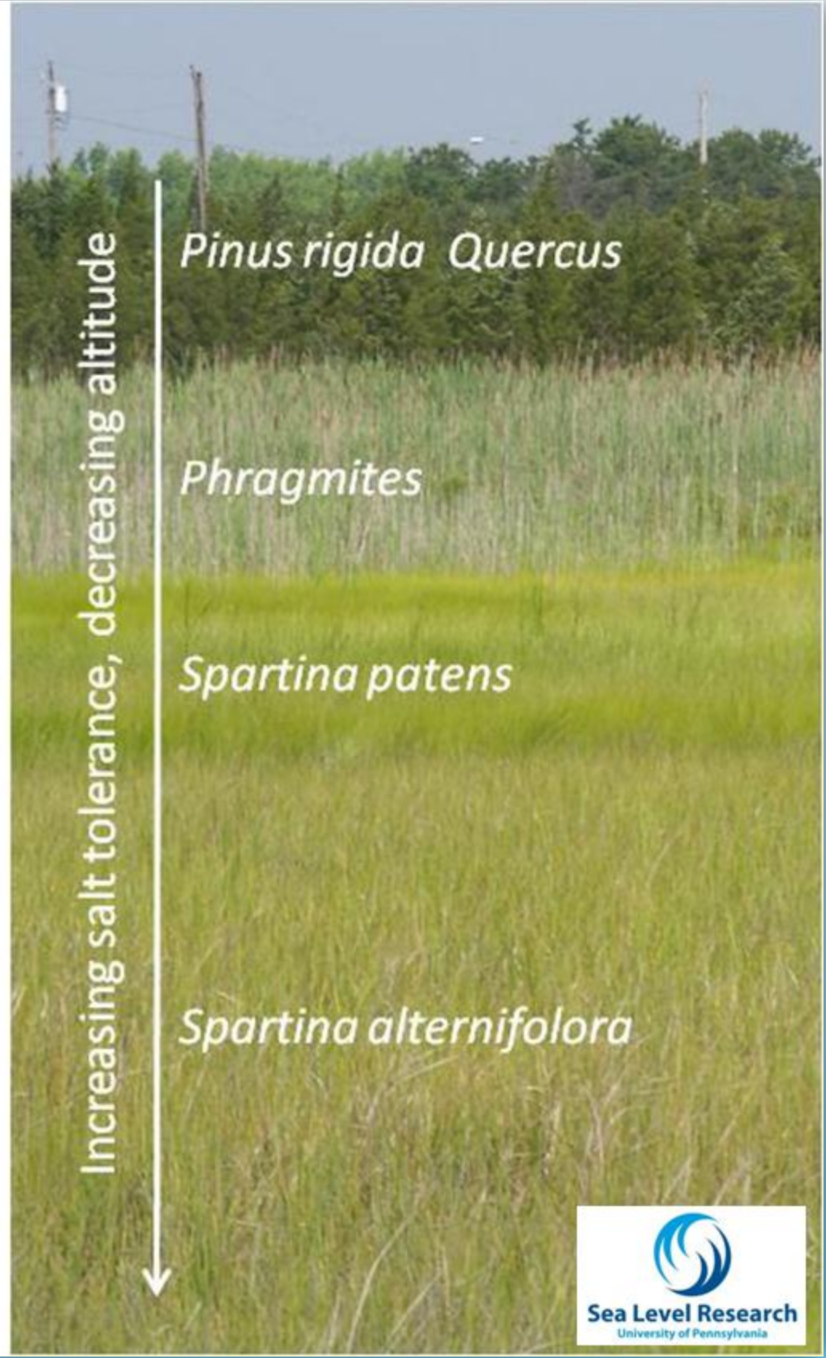
Quantitative models to reconstruct former sea levels

Three-fold process

Sampling stations are placed along an elevations gradient. Foraminifera are counted at each station




Increasing salt tolerance, decreasing altitude
Pinus rigida Quercus
Phragmites
Spartina patens
Spartina alternifolora
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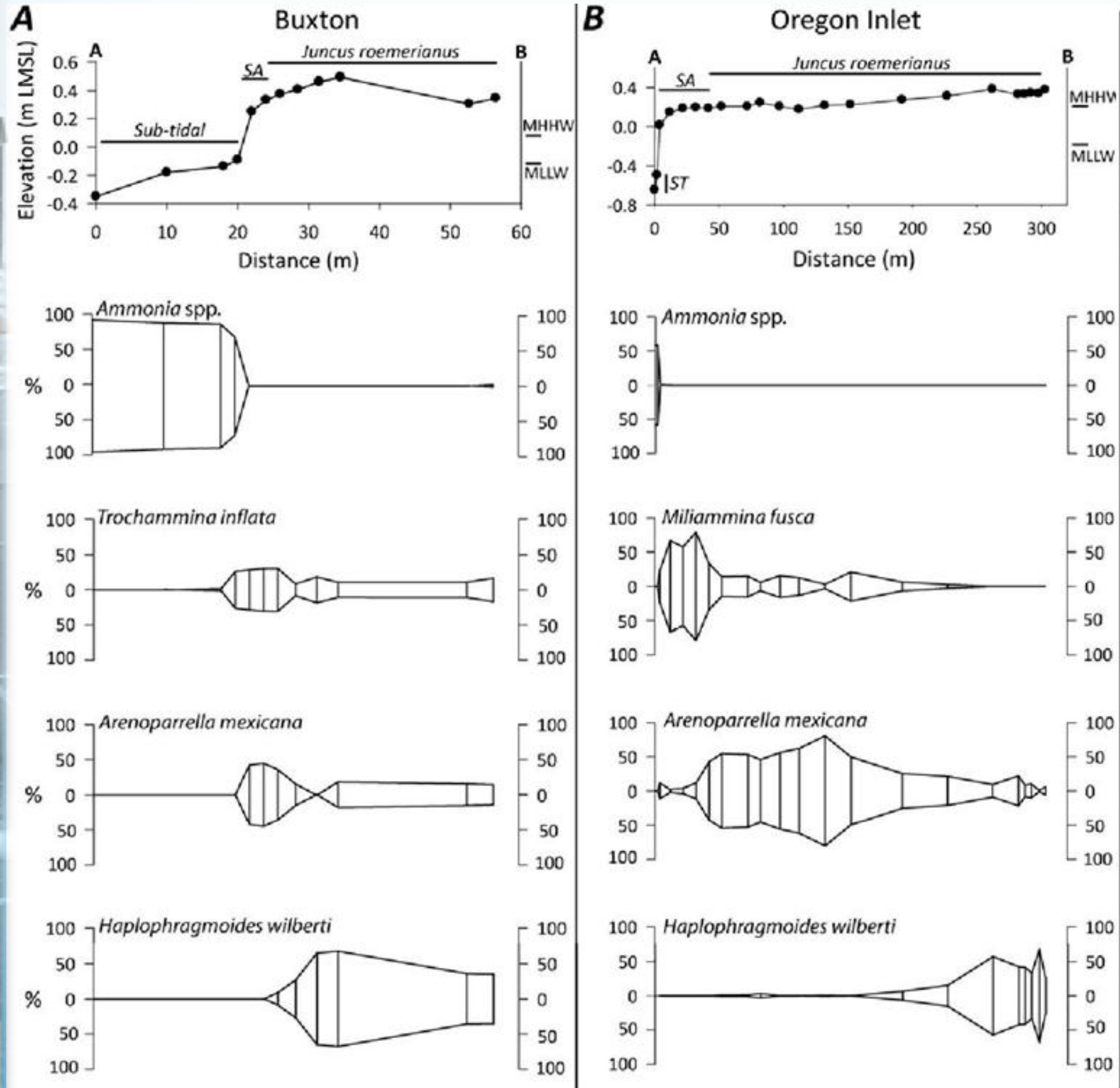
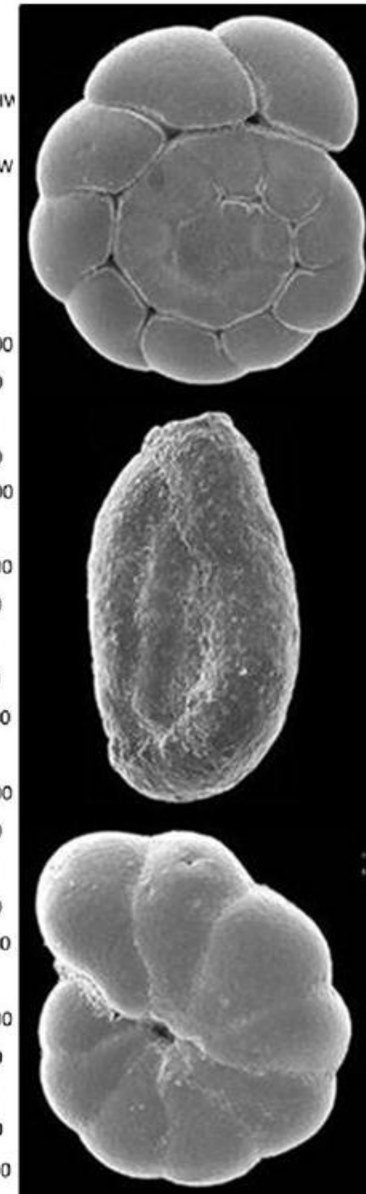
Examples of foraminiferal distributions





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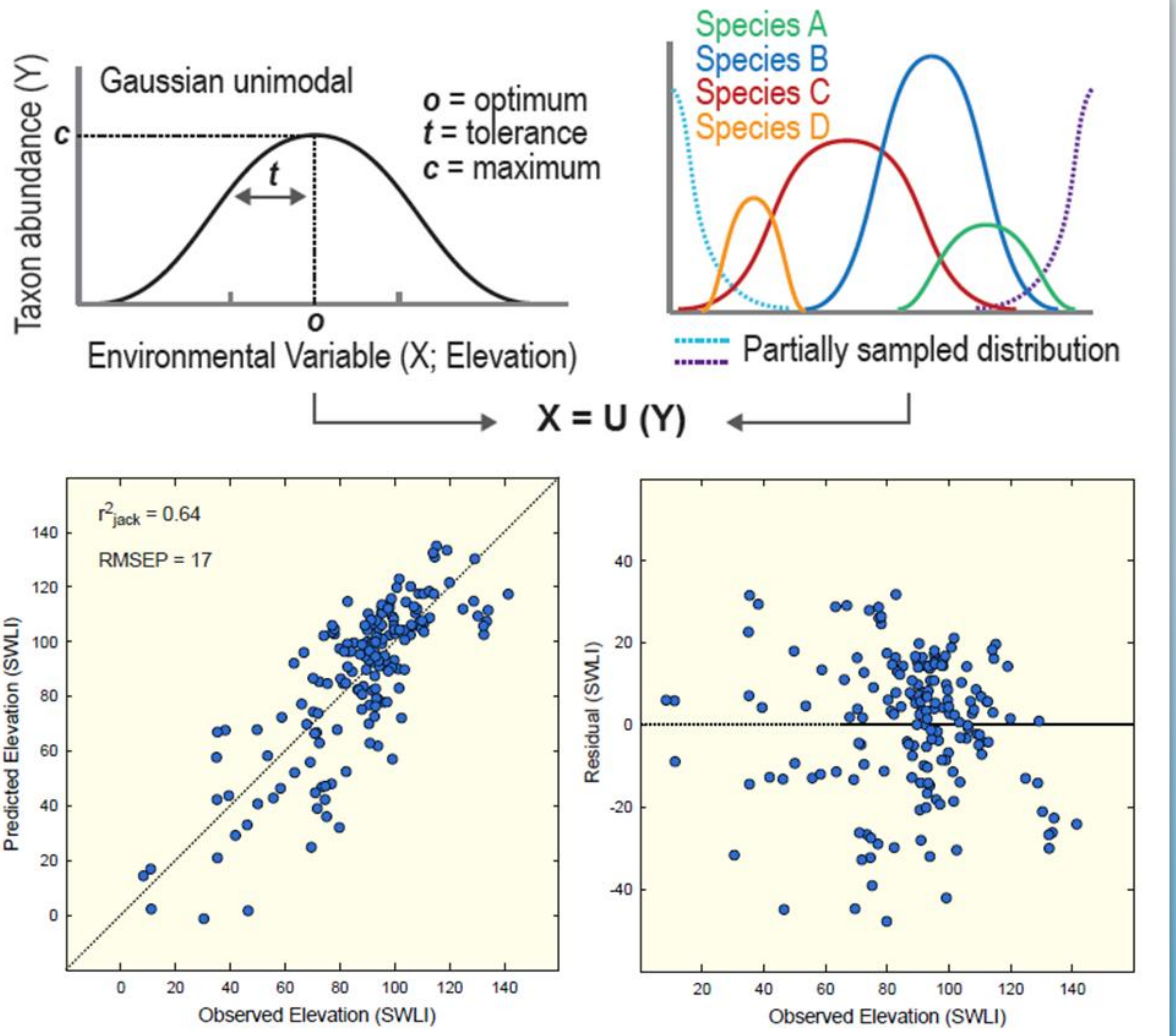

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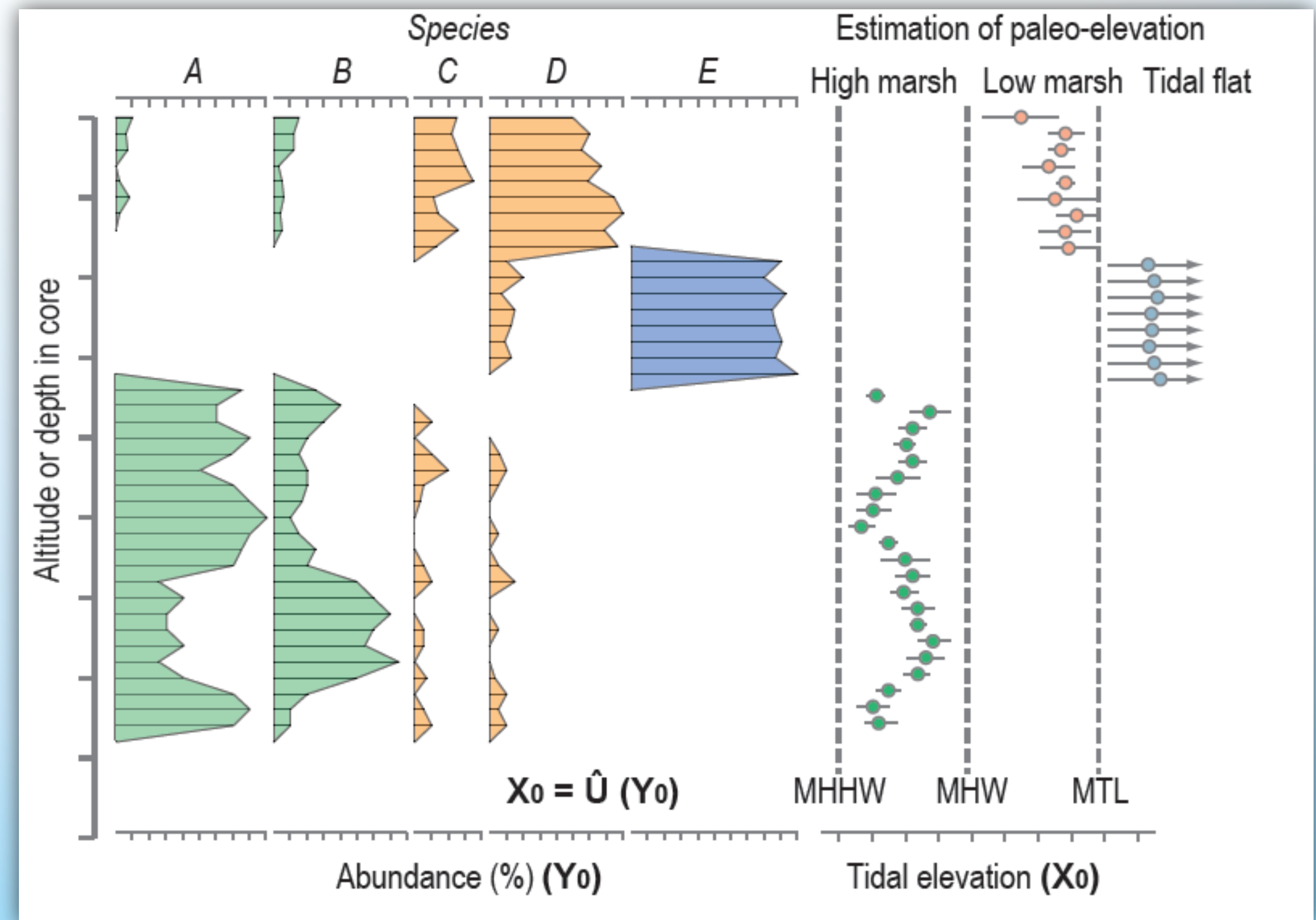

Fossil foraminifera (Y_0) are observed by documenting assemblages in sedimentary archives. The transfer function estimates the elevation (X_0) with respect to sea level at which each sample formed.

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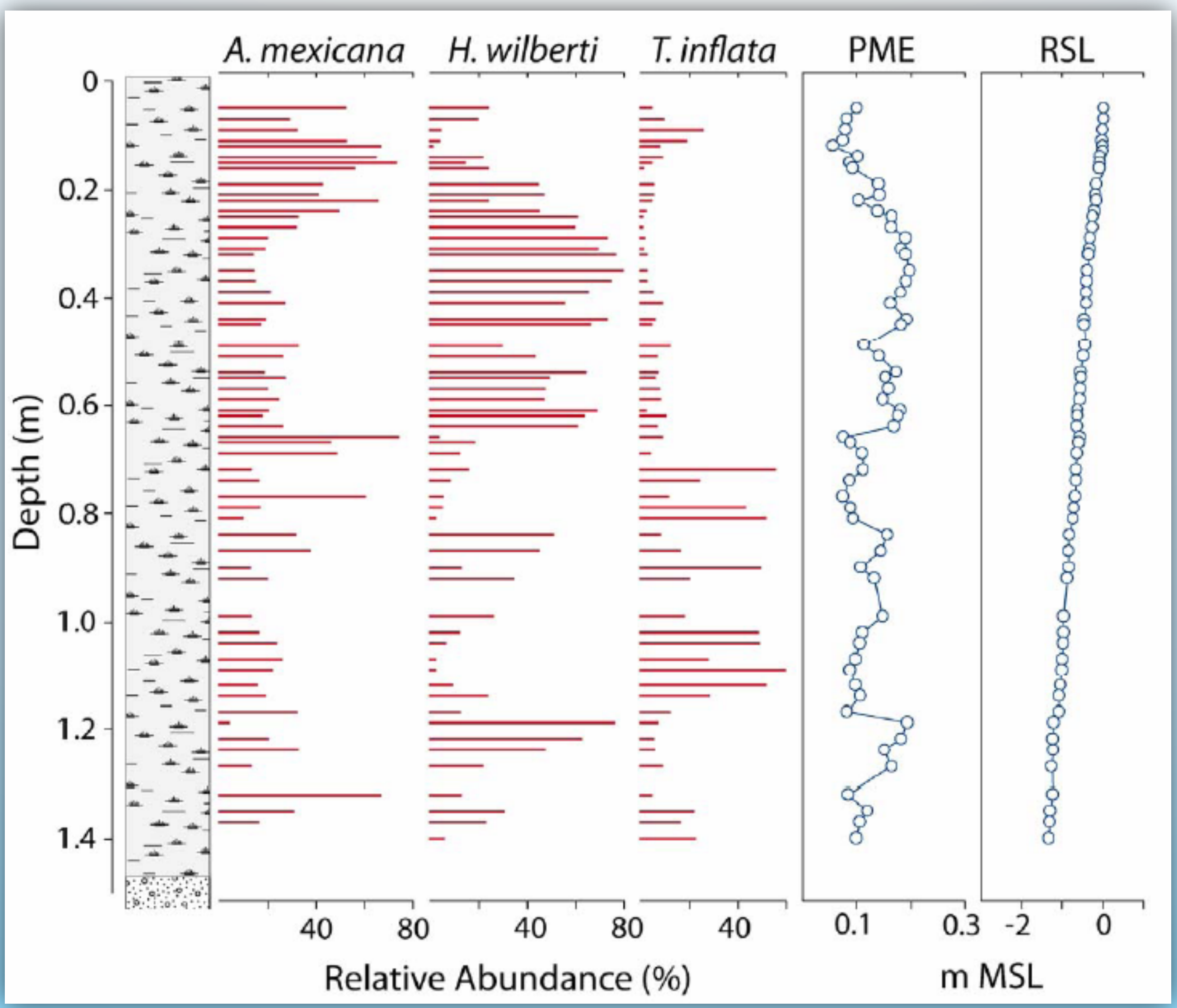
Detailed biostratigraphy



Foraminifera are well preserved and are counted down core at high resolution.

'Fossil' foraminifera provide estimates of former sea levels.

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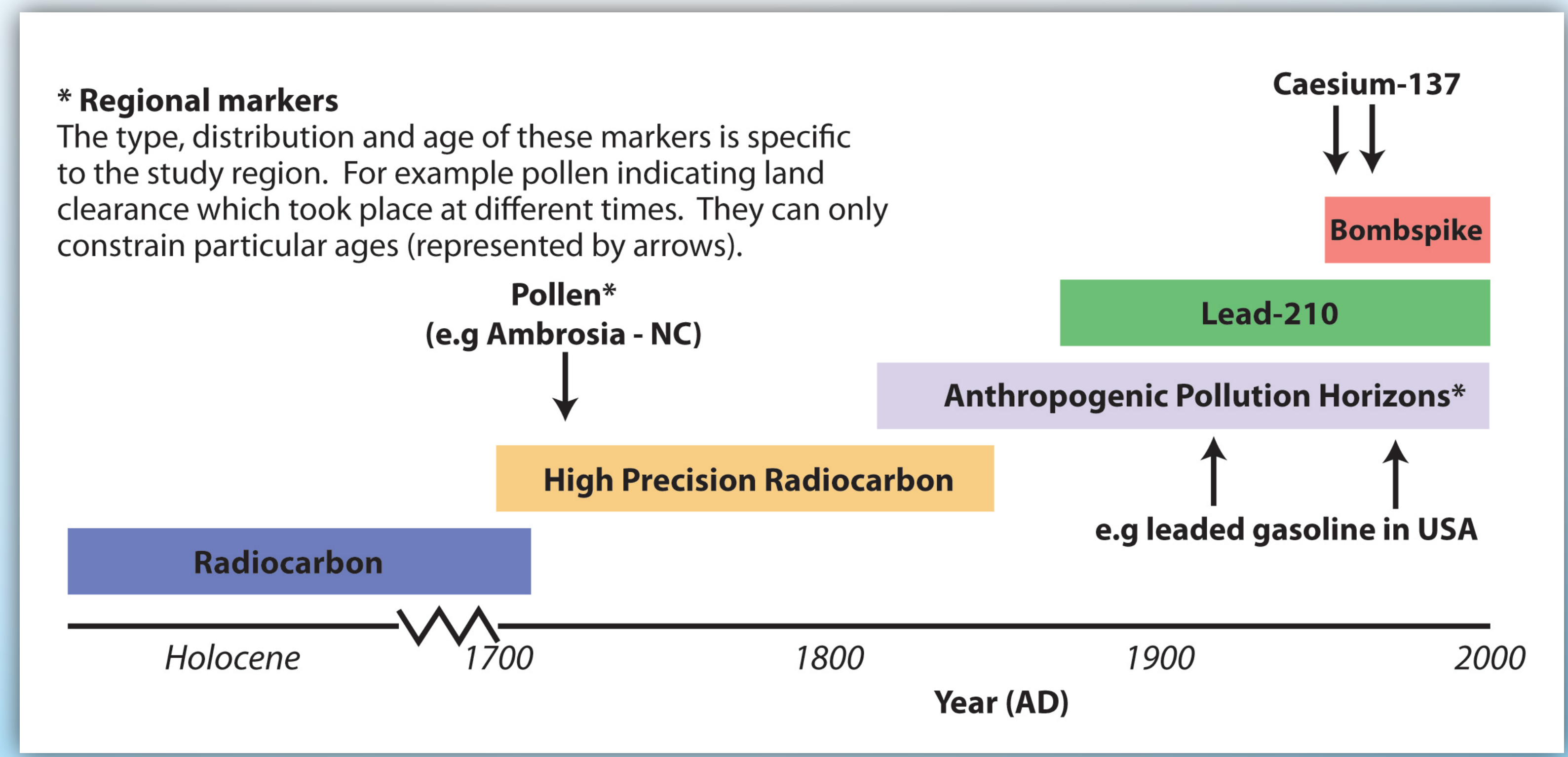
Composite Chronologies



Detection of short-lived fluctuations of sea level in the period AD 1700 to present is hindered by fluctuations in the radiocarbon calibration curve and requires confirmation by other dating methods

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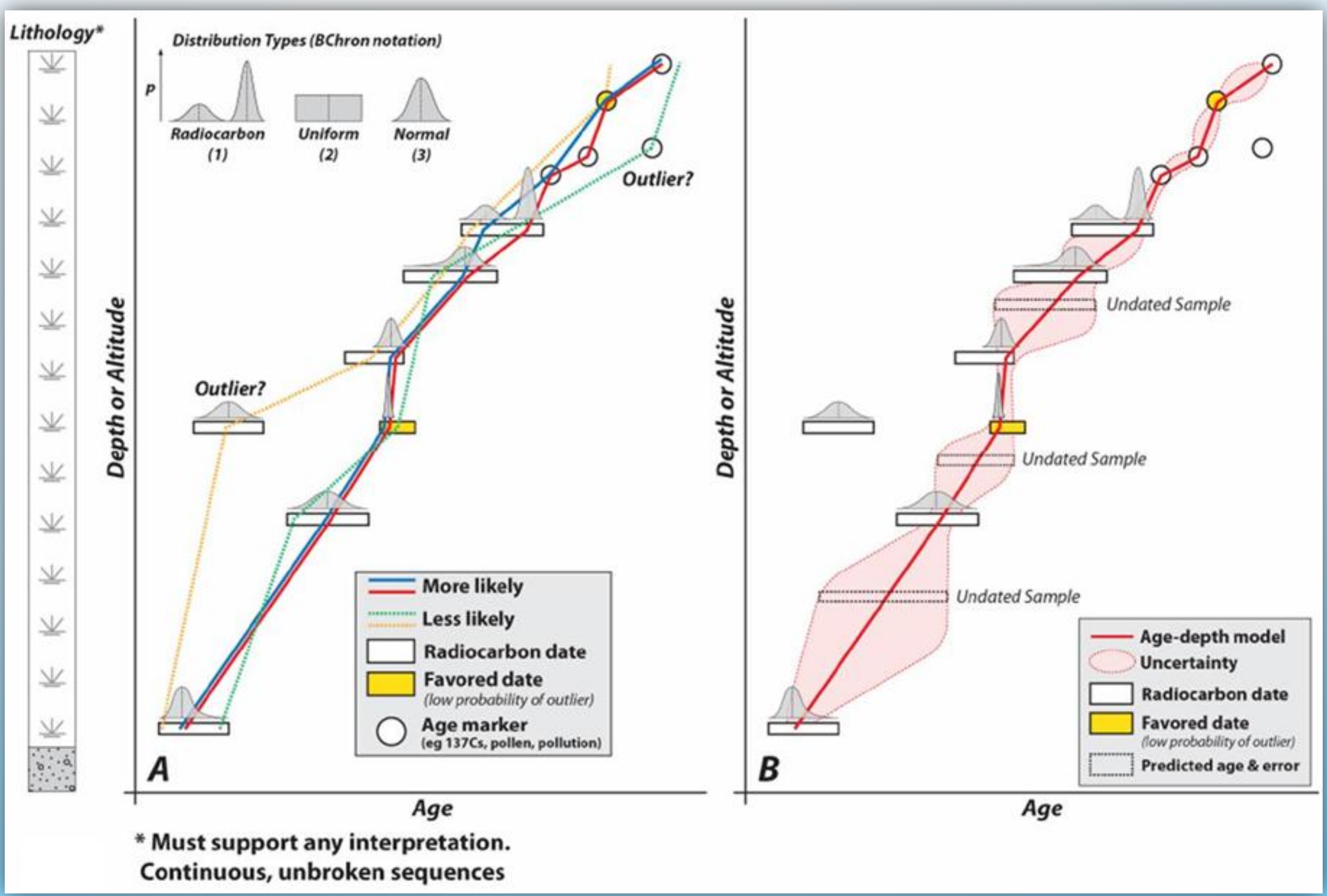
Age – depth models



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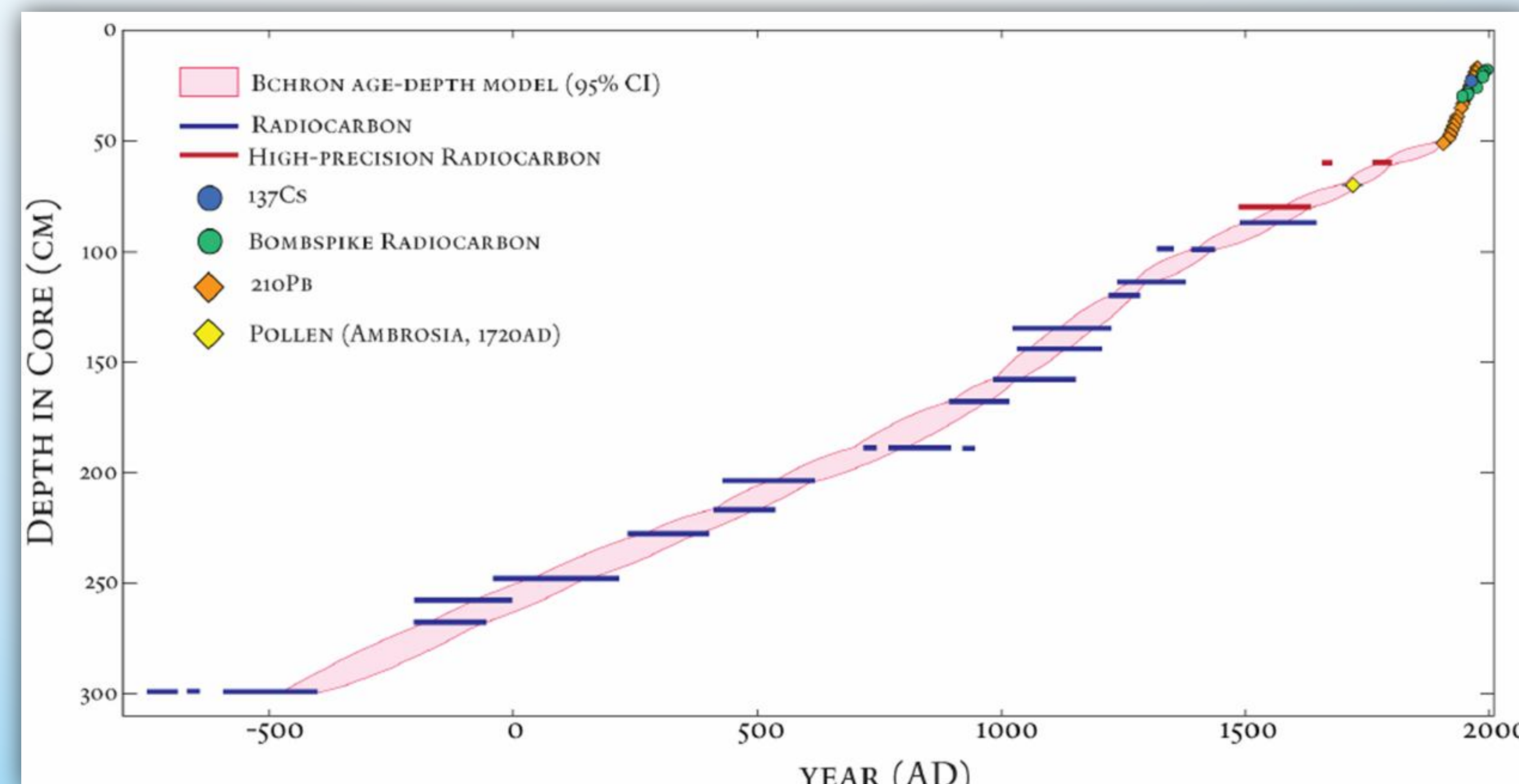
Age – depth model for Sand Point



Age-depth model uses many iterations to estimate most likely accumulation history. Reduces error and estimates age of any sample (with uncertainty) = Decadal Resolution

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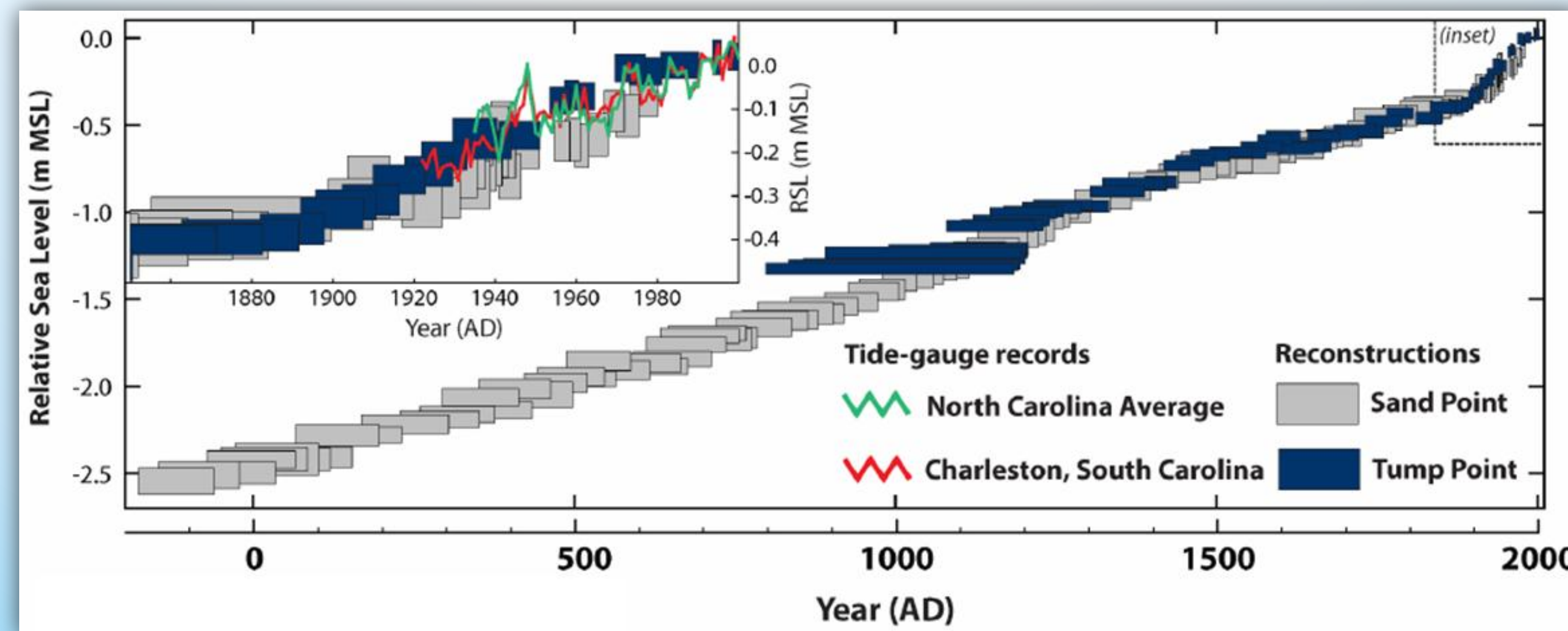
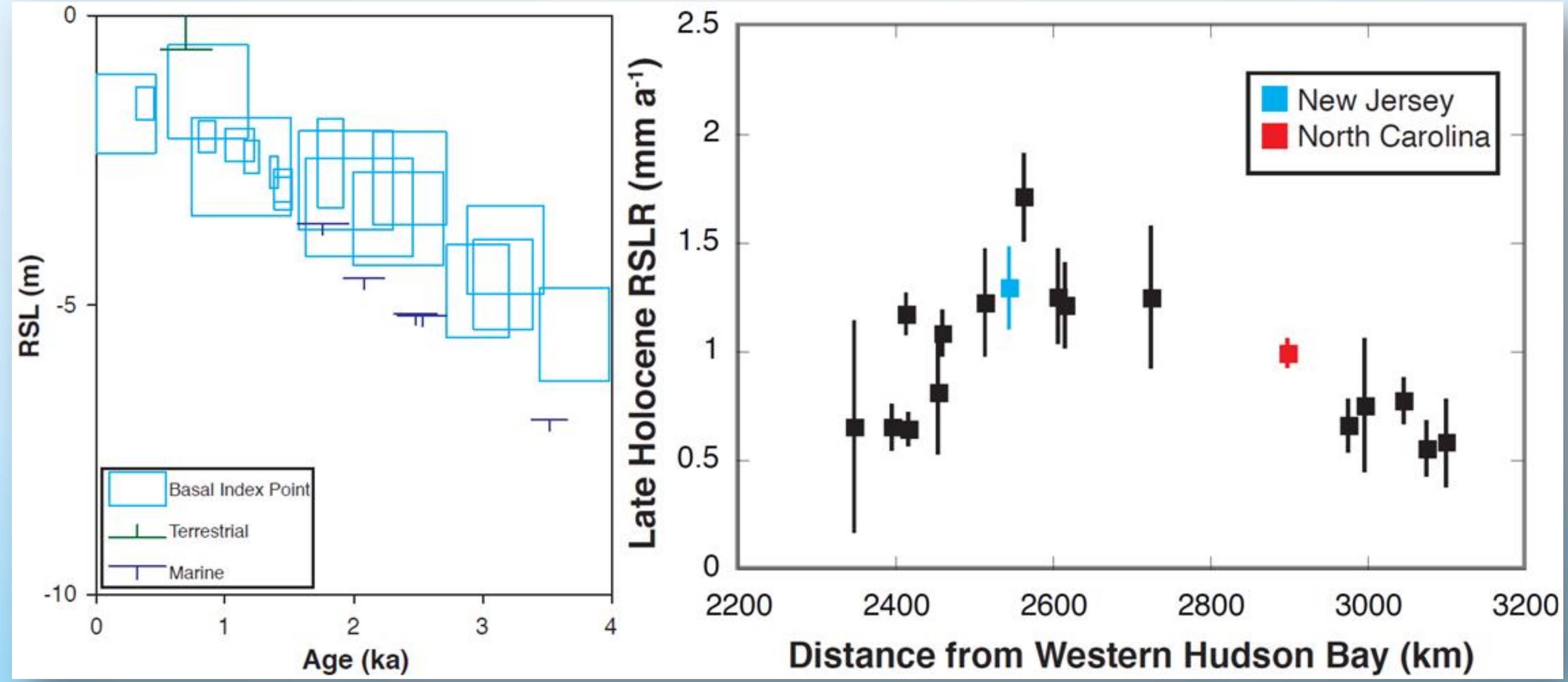
Sea levels for the last 2200 years for North Carolina



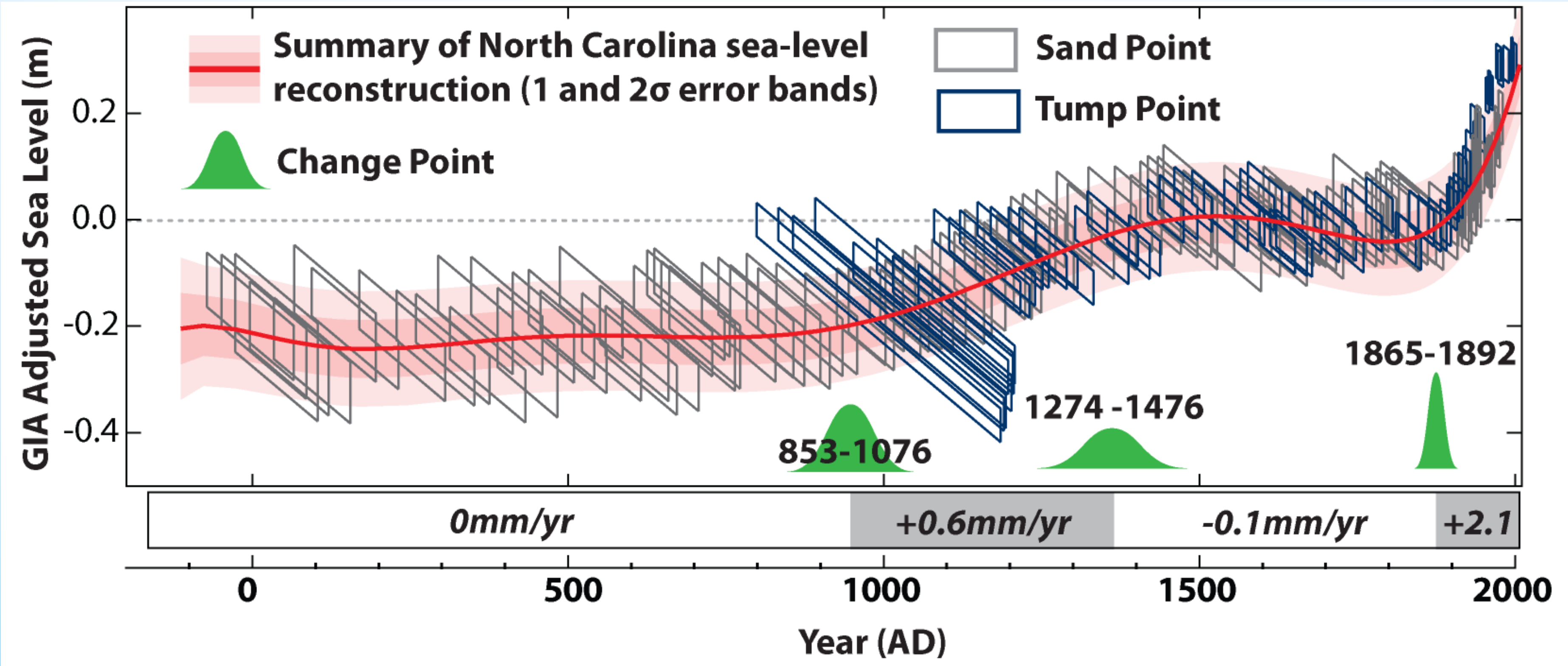
* Records from Sand Point and Tump Point are in agreement, and reconciliation of tide gauge records provides provide confidence
* 2 sites are >120 km apart and in different water bodies so local (and tectonic) factors assumed to be negligible

Decontaminating RSL records for GIA



Rate of GIA is a function of distance from the center of the Laurentide Ice sheet

GIA corrected sea level in NC

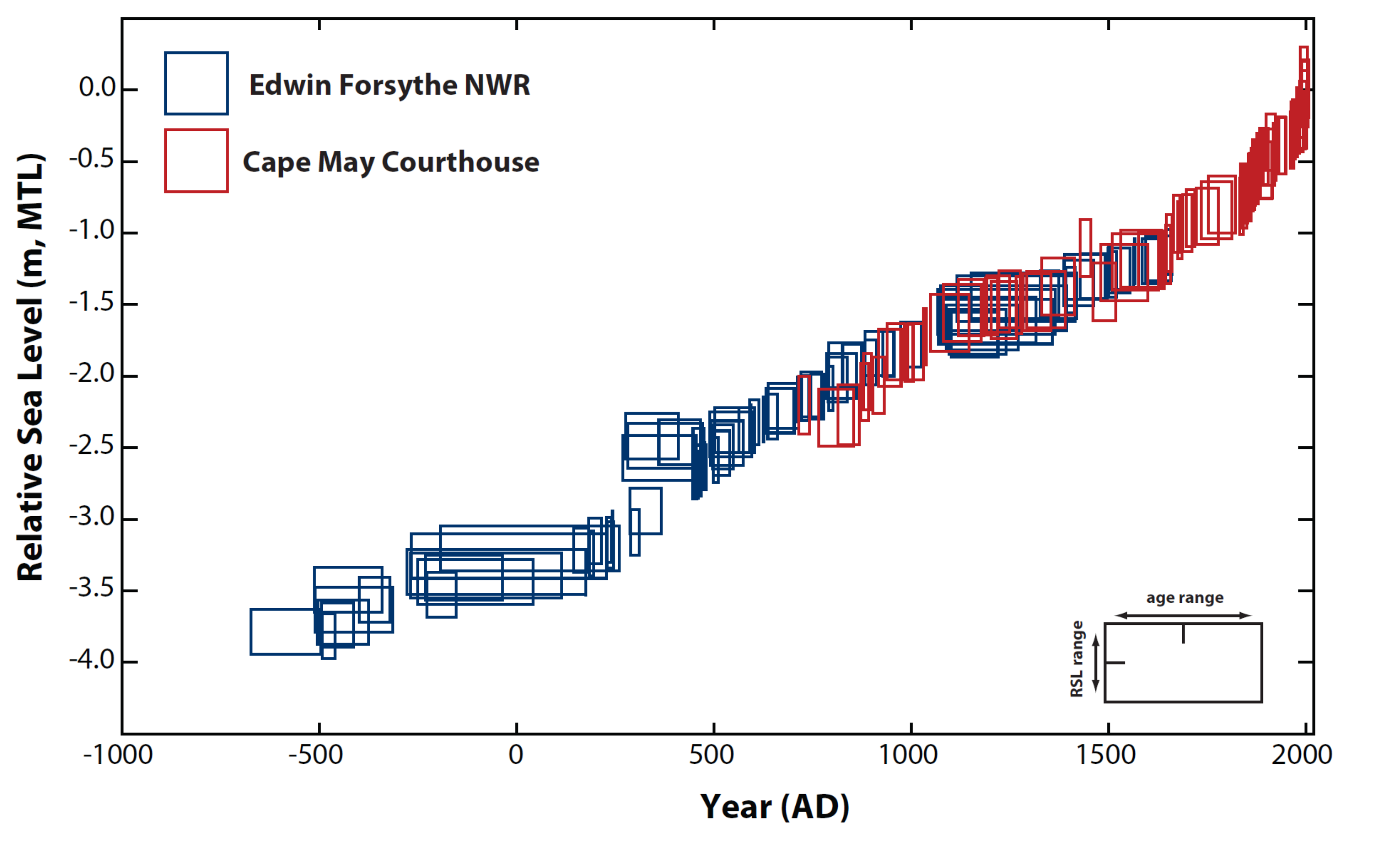


(1) Stable sea level from BC 100 to AD 950. It then increased for 400 years at 0.6 mm/yr, followed by further stability that that persisted until the late 19th century

(2) RSL acceleration at the end of the 19th century. In NC, the timing is AD 1865 - 1892

(3) In NC 20th century sea level has increased at an average 2.1 mm/yr, representing the steepest increase of the past two millennia

RSL for the last 2500 years in New Jersey



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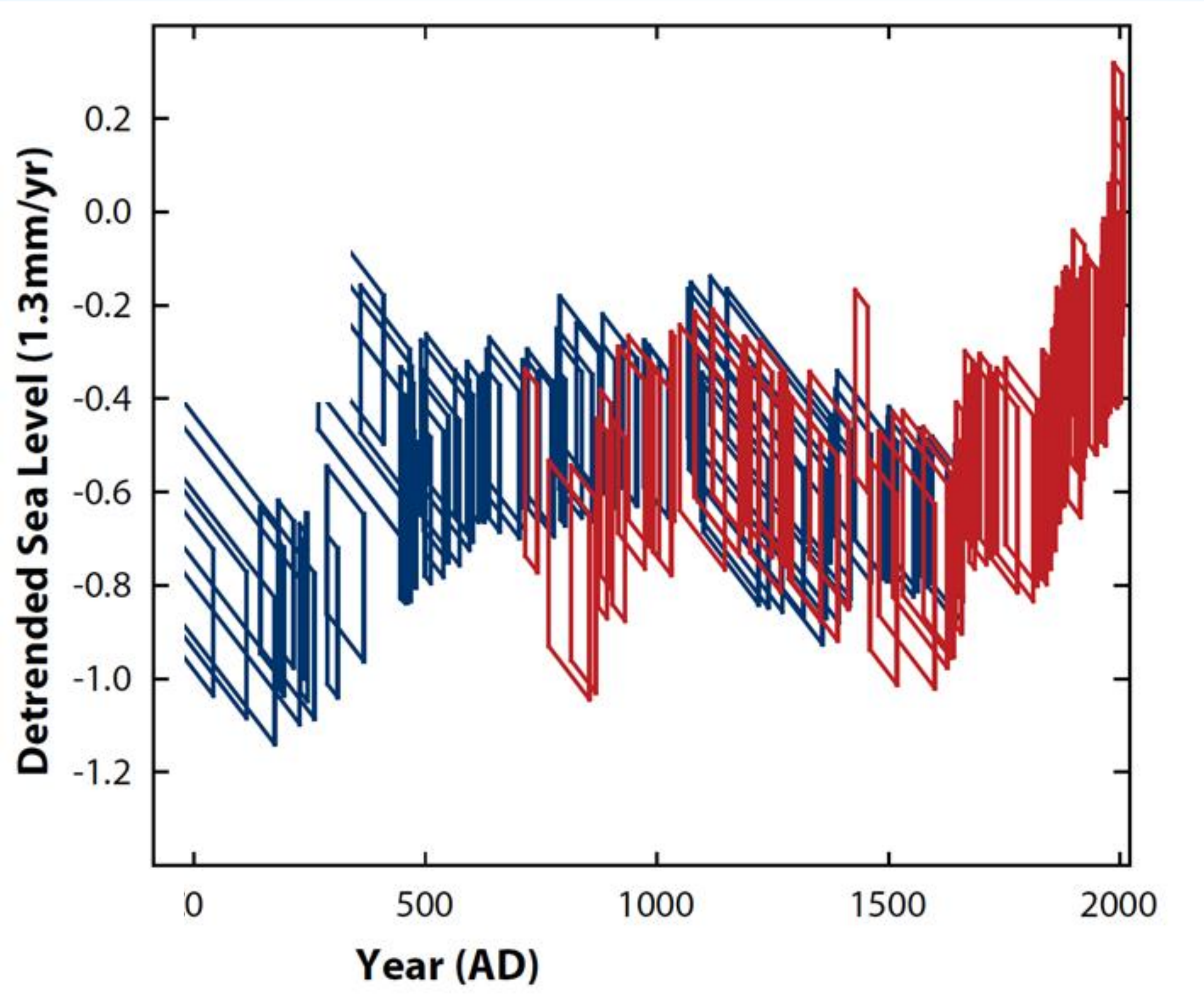
GIA corrected sea level in NJ



Sea level has increased by 2 mm/yr since AD1850; the steepest increase of the past two millennia

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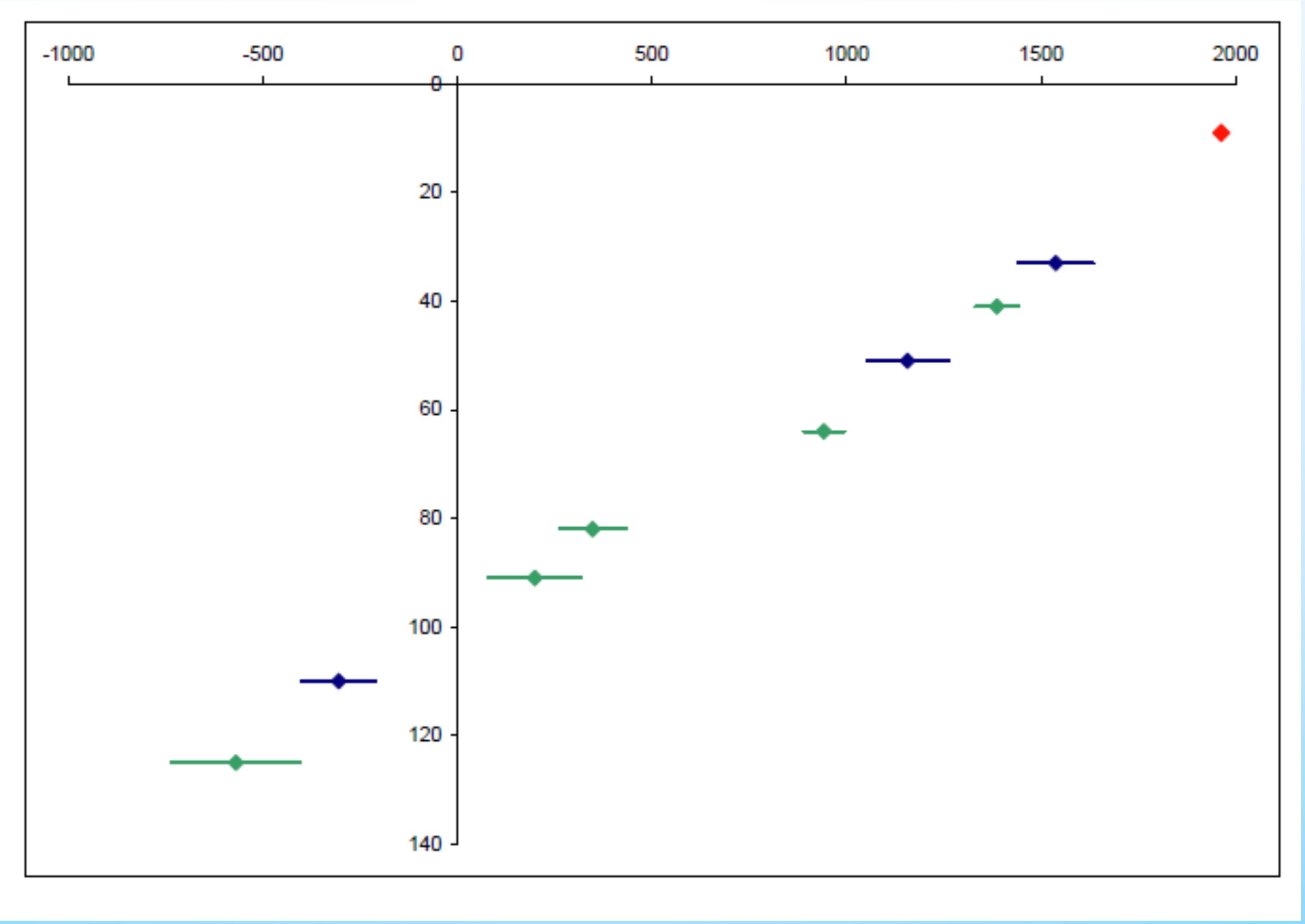
Preliminary RSL for the last 2000 years in Florida



In Florida we have the potential of a 8000 year record!!

Summary of a high resolution study

(1) High resolution records derived from salt-marshes

(2) Temporal and spatial variability over the past 2000 years illustrated

(3) Stable/falling sea level from AD 500 until the 19^{th} century

(4) 20^{th} century sea level has increased to > 2 mm/yr, representing the steepest increase of the past two millennia

BUT… there are a very limited number of studies

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Thank you

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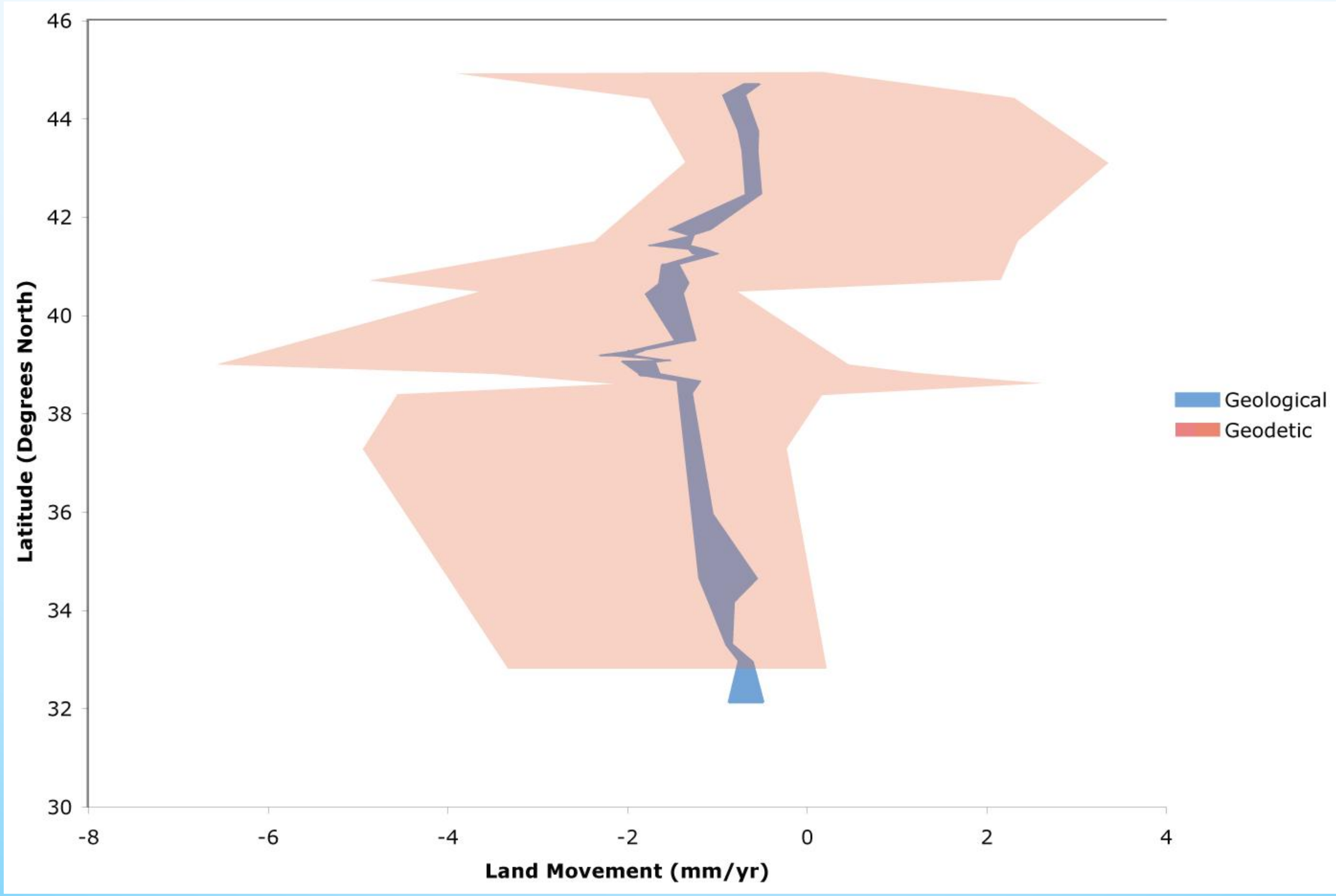
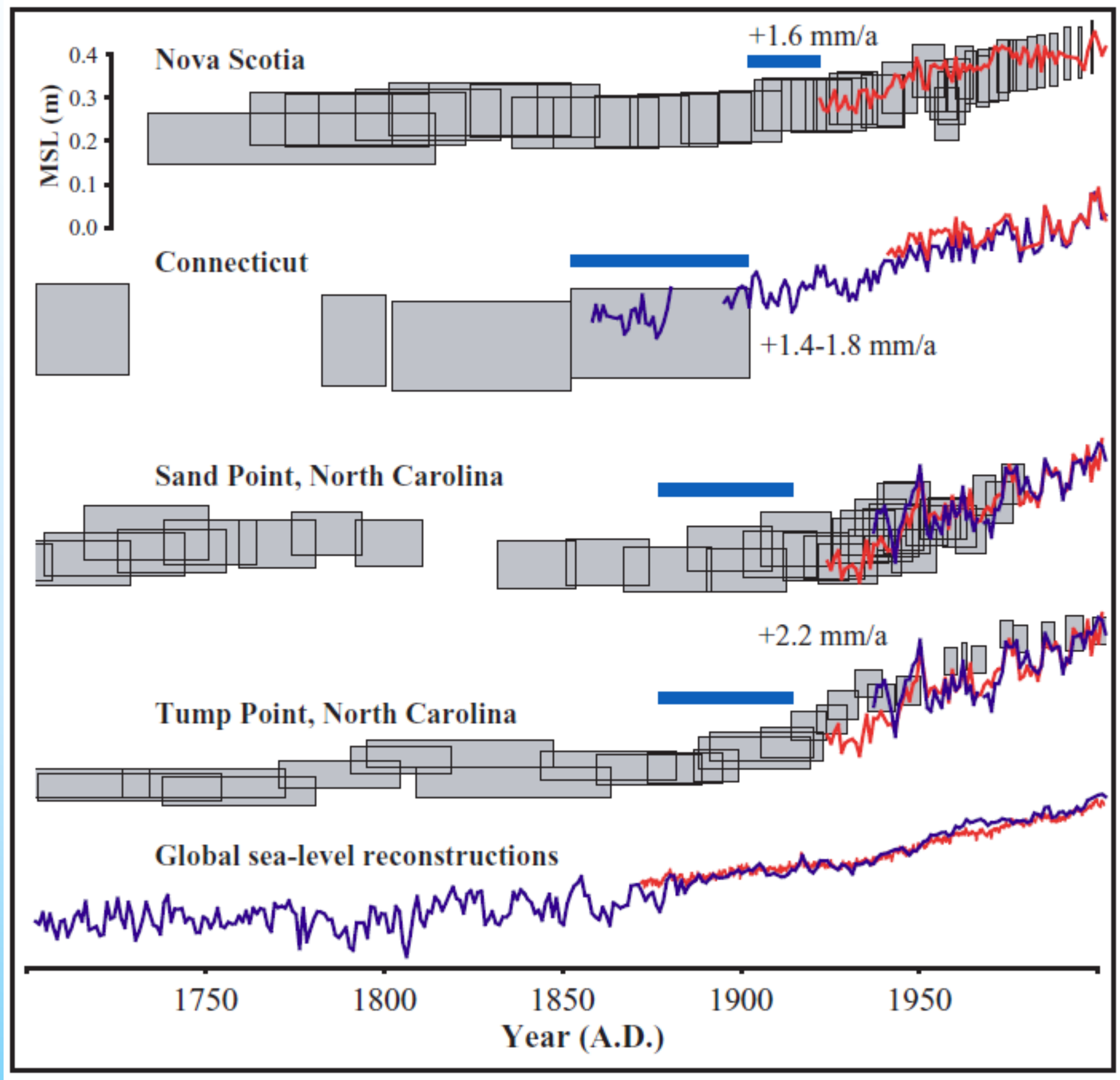


Geodetic data from Snay et al (2007), Journal of Geophysical Research

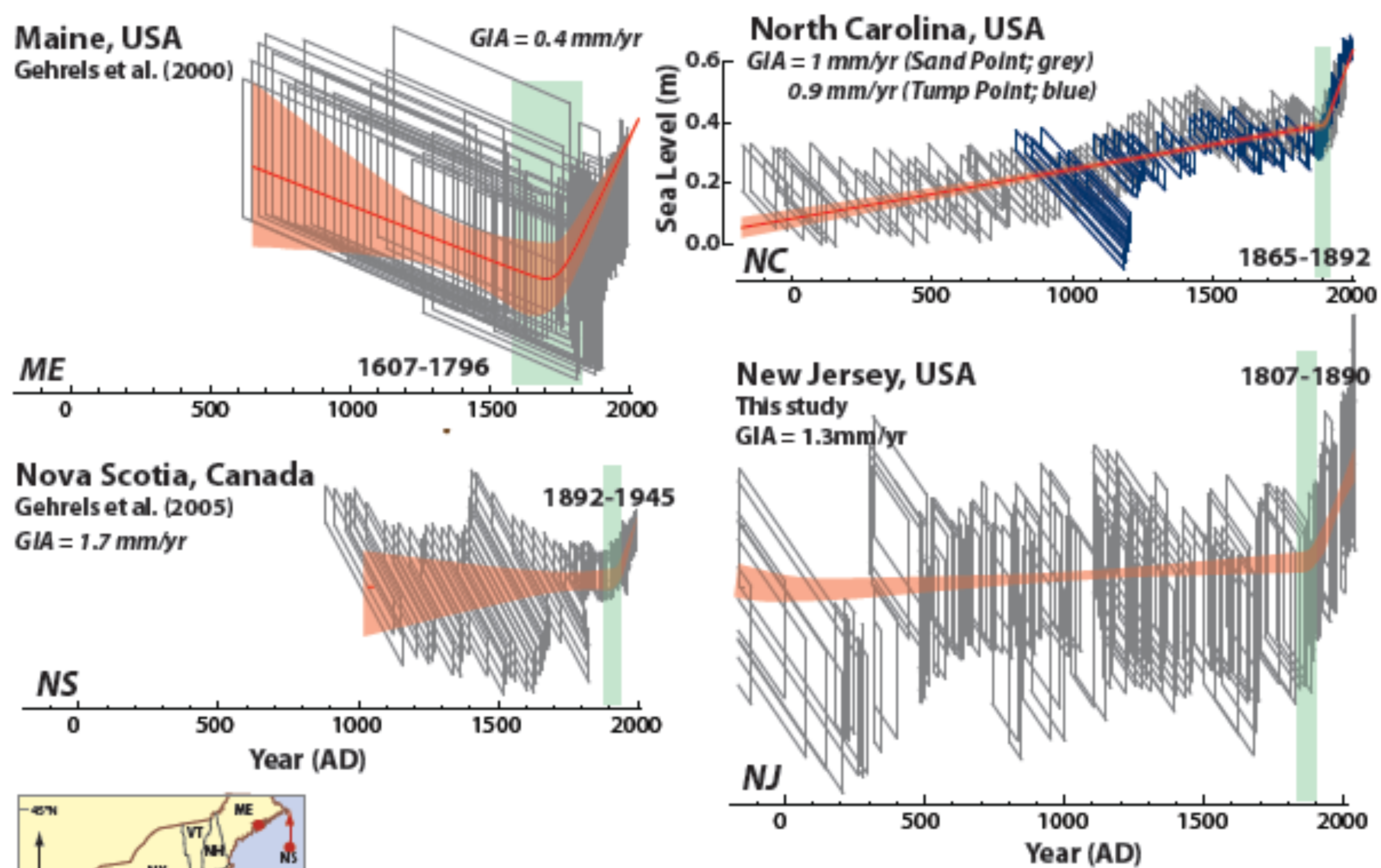


MSL (m)
0.4
0.3
0.2
0.1
0.0
Nova Scotia
+1.6 mm/a
Connecticut
+1.4-1.8 mm/a
Sand Point, North Carolina
+2.2 mm/a
Tump Point, North Carolina
Global sea-level reconstructions
1750
1800
1850
1900
1950
Year (A.D.)

Transition from late Holocene to modern rates of sea-level rise

Rapid rates of sea-level rise during the 20th century, as recorded in many places around the globe, represent a significant departure from late Holocene trends of sea-level change

The IPCC AR4 states with 'high confidence' that the onset of modern rates of sea-level rise occurred between 1850 and 1950



North American salt-marsh records

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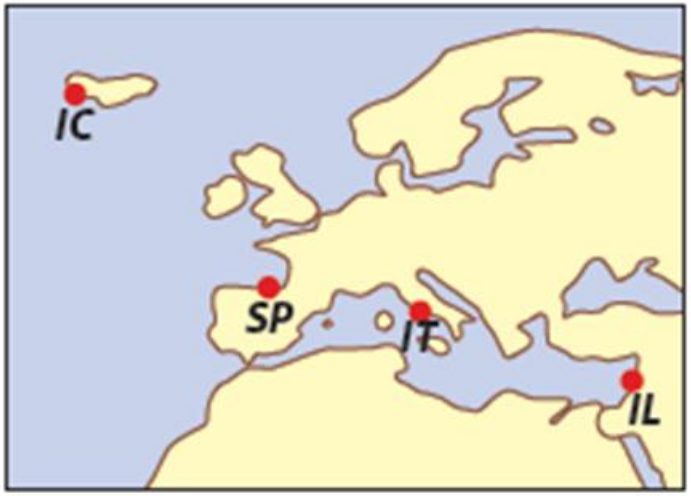
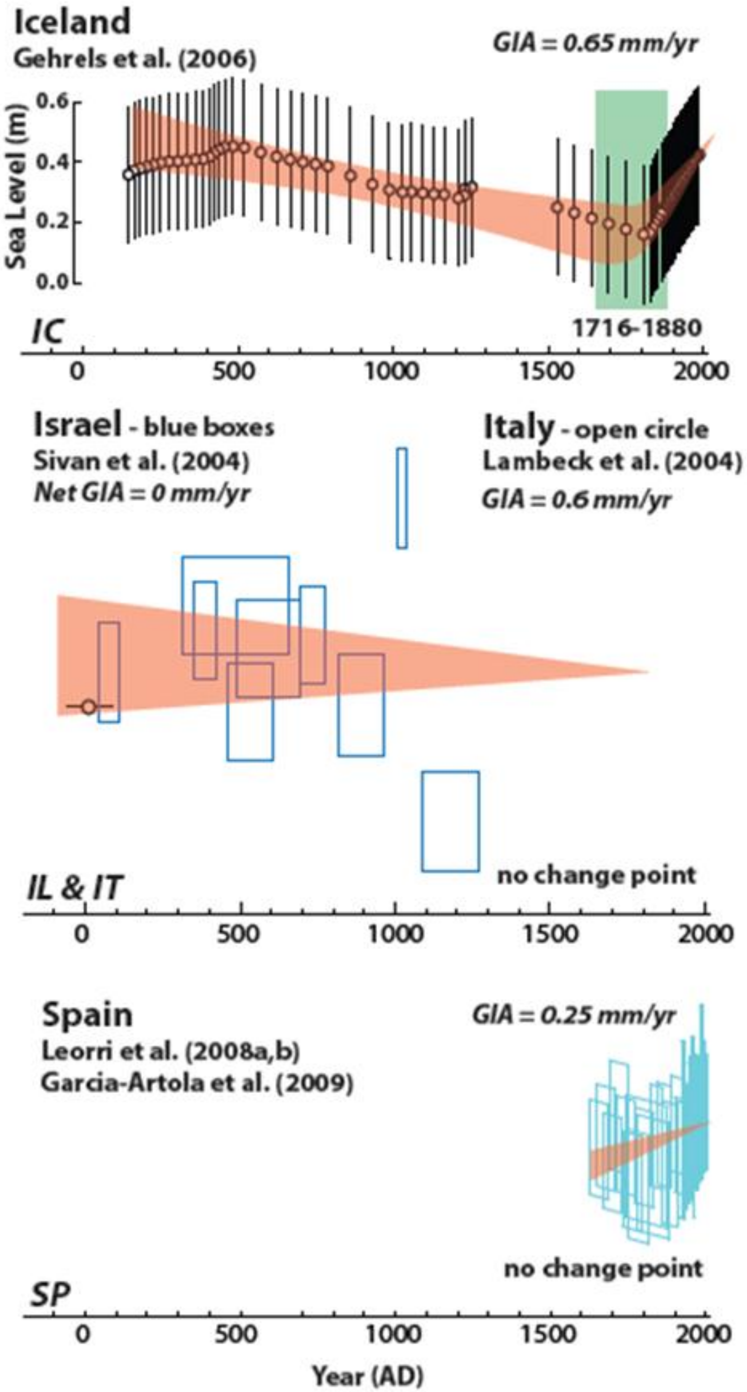
European salt-marsh and archaeological records





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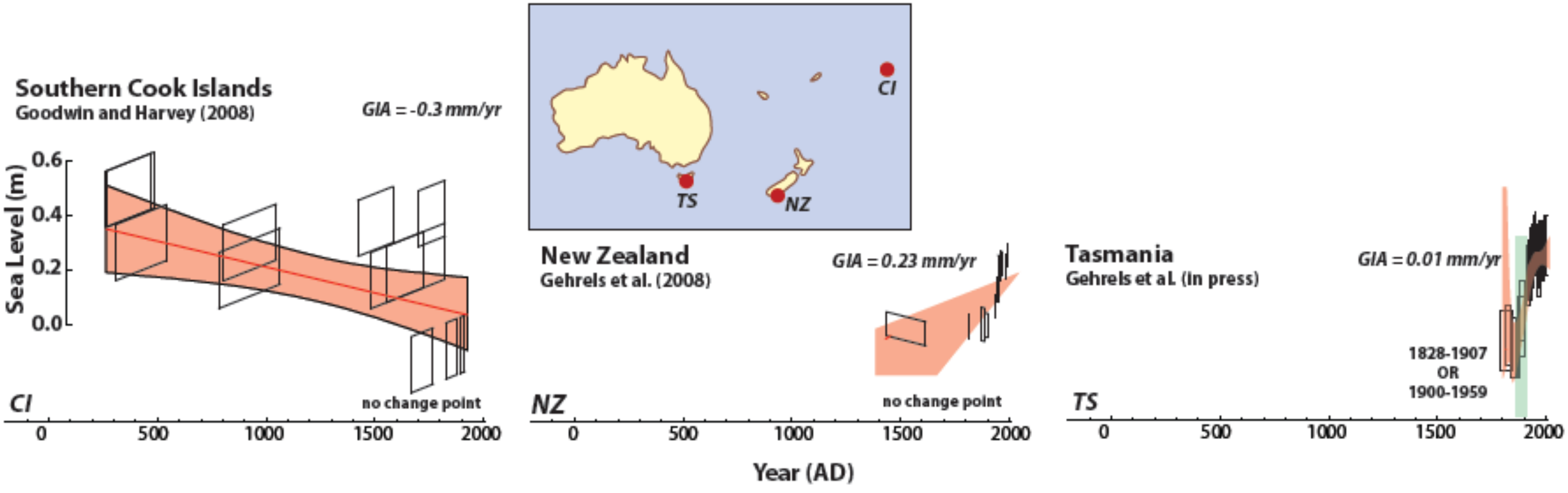
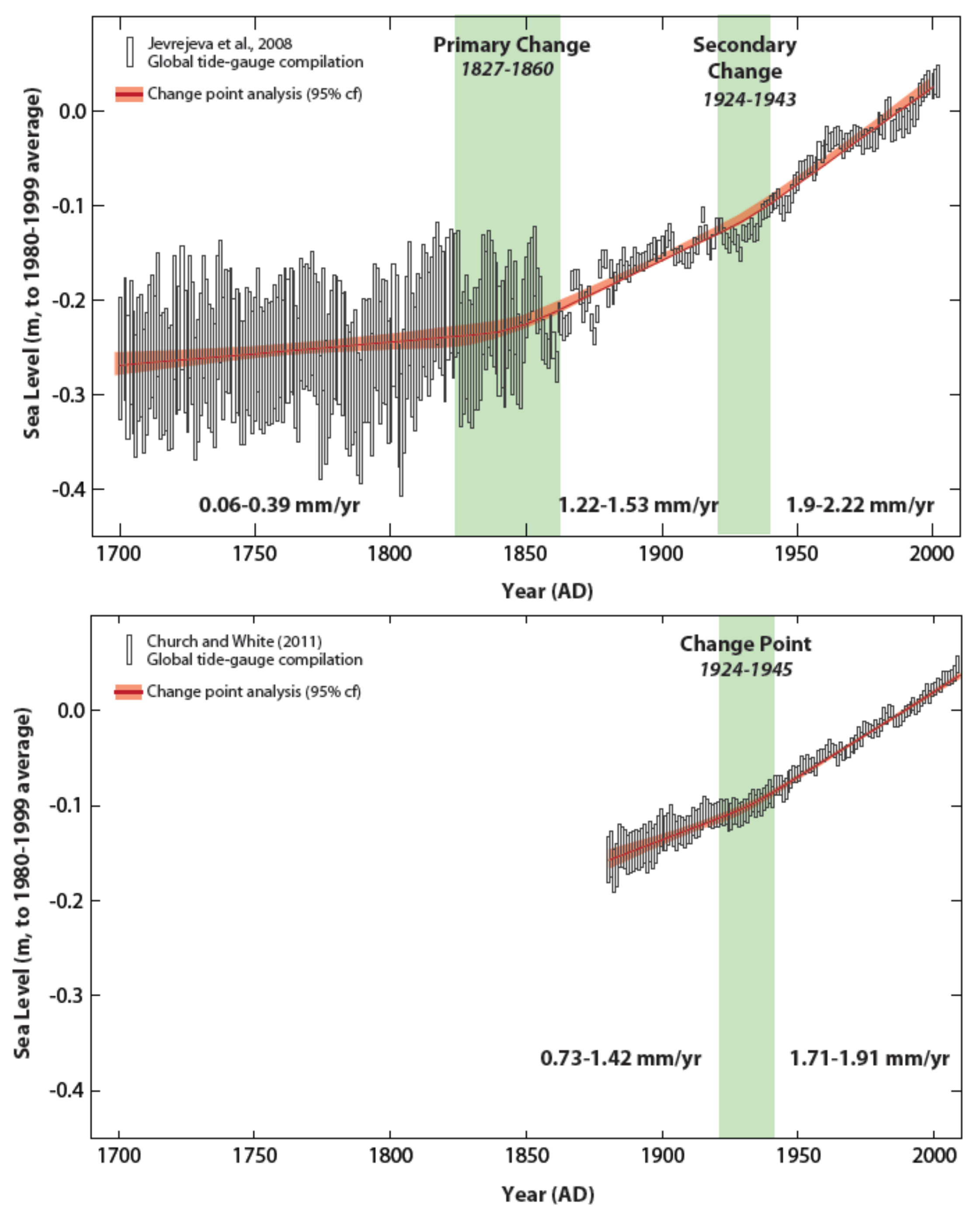
Southern hemisphere salt-marsh and coral micro atoll records



Global tide gauges



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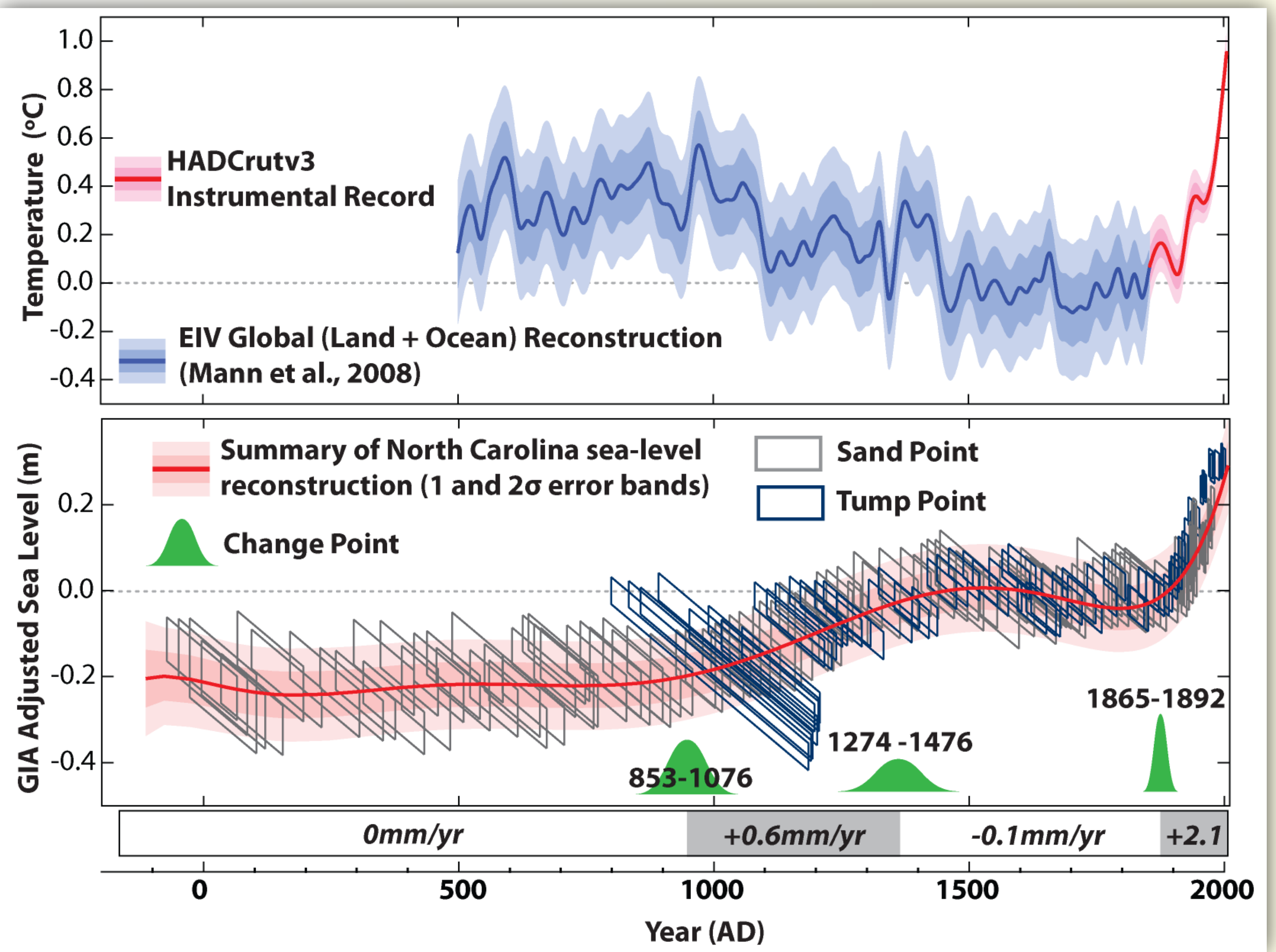
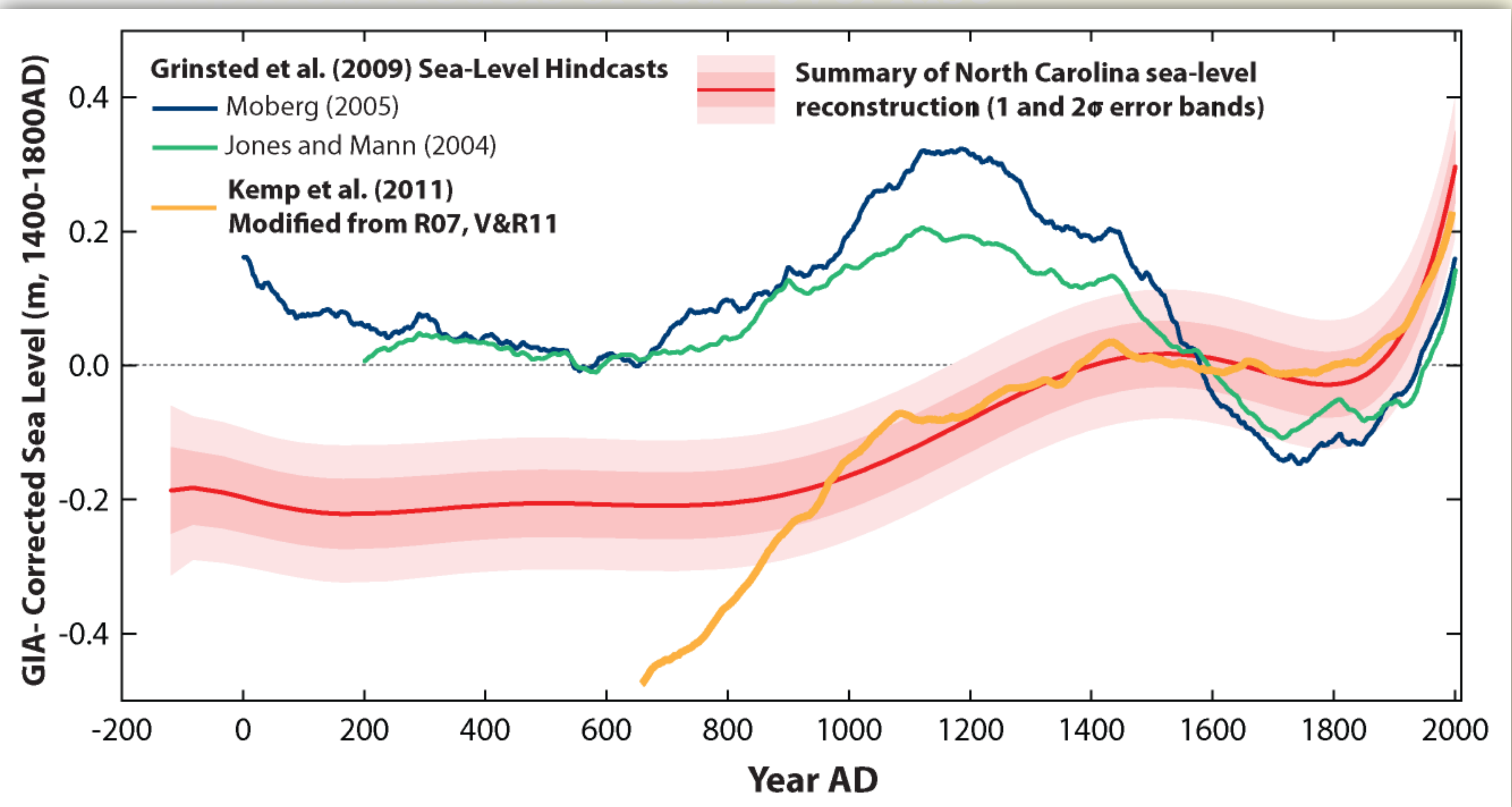
Rates of GIA adjusted sea-level change before and after change point

Location	Before	After	Timing
Nova Scotia	0.1	1.9	1892-1946
Maine	-0.3	1.5	1607-1796
North Carolina	0.1	2.2	1865-1892
New Jersey	0.1	2.4	1807-1890
Iceland	-0.2	1.2	1716-1880
Tasmania	-0.1	2.7	1828-1907
Global tide gauges	0.2	2.1	1827-1860

Sea-Level and Climate Variability

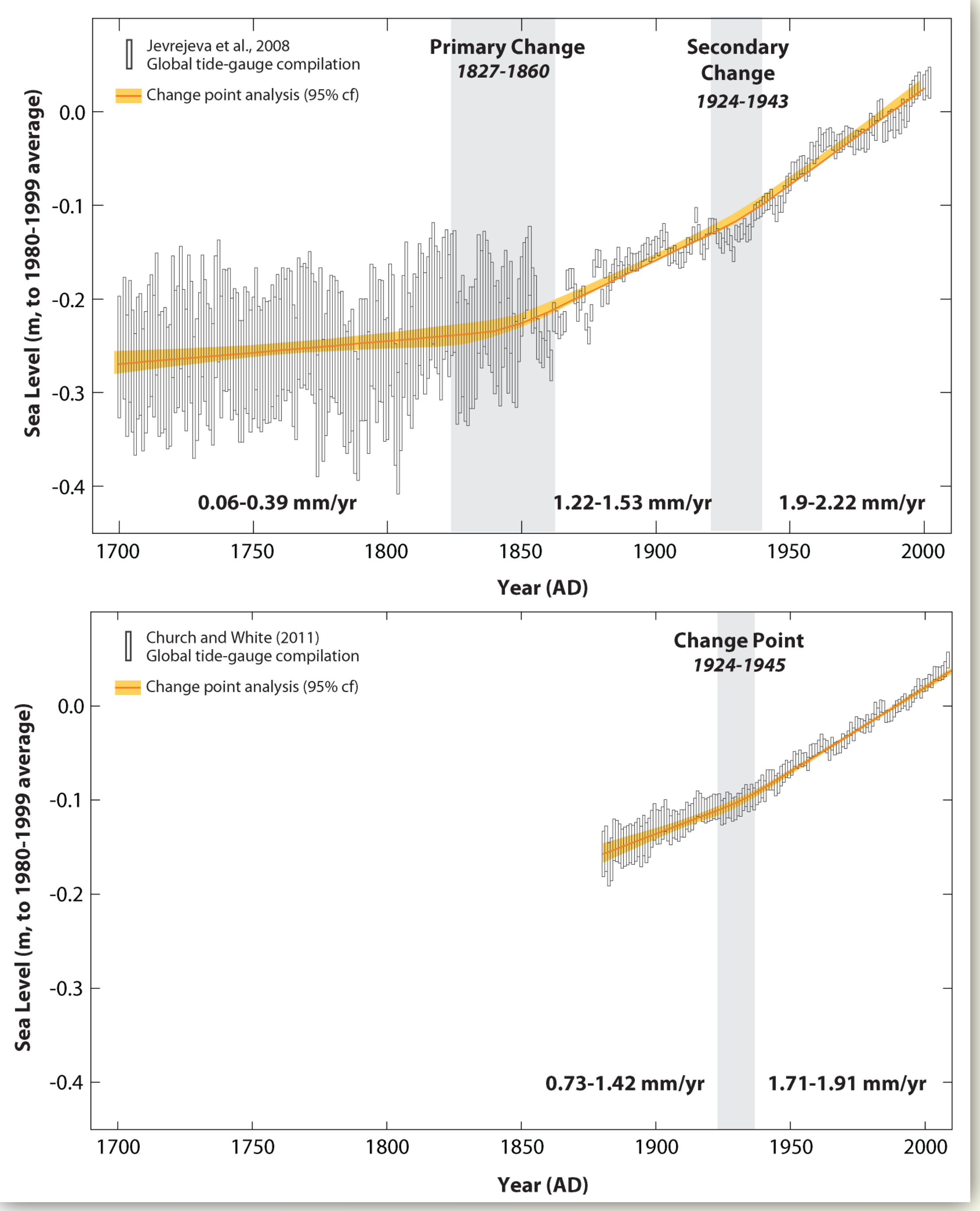




Semi-empirical models feature in IPCC AR5

Proxy data uniquely extend calibration period to include stable sea level, long term response

Proxy data show misfit – are projections reliable?



When Did Modern Sea-Level Rise Begin?

Instrumental rate>background rate

1924-1943 but global tide gauges are too short to catch primary switch

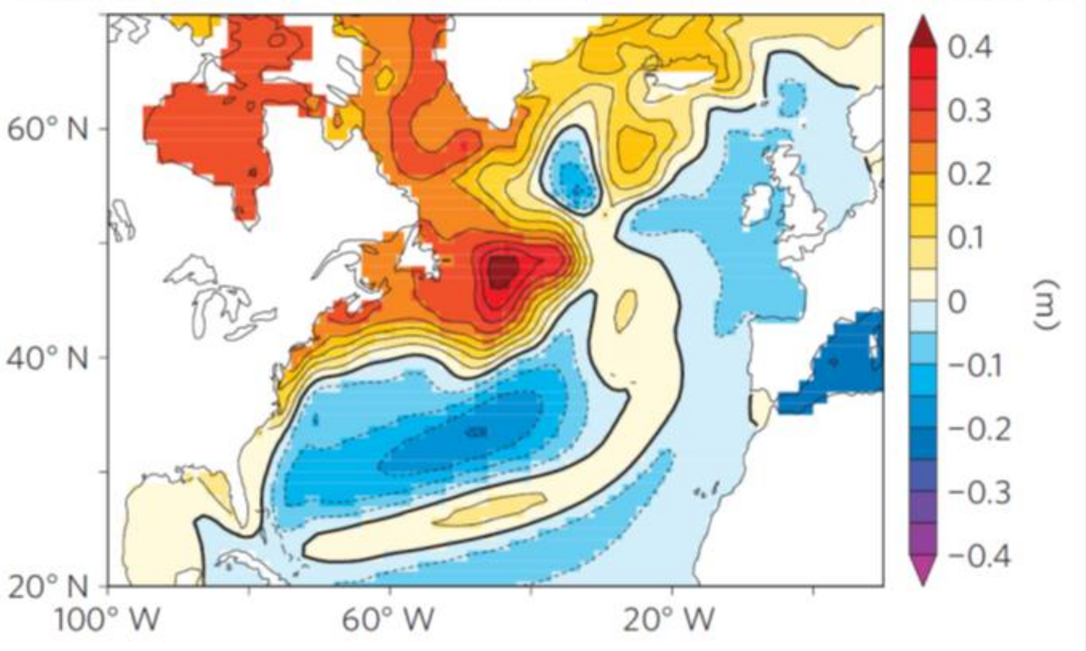
1827-1860, but based on only 3 gauges in Europe

NJ (1835-1869) and NC (1865-1892)

Sea-Level in Bermuda

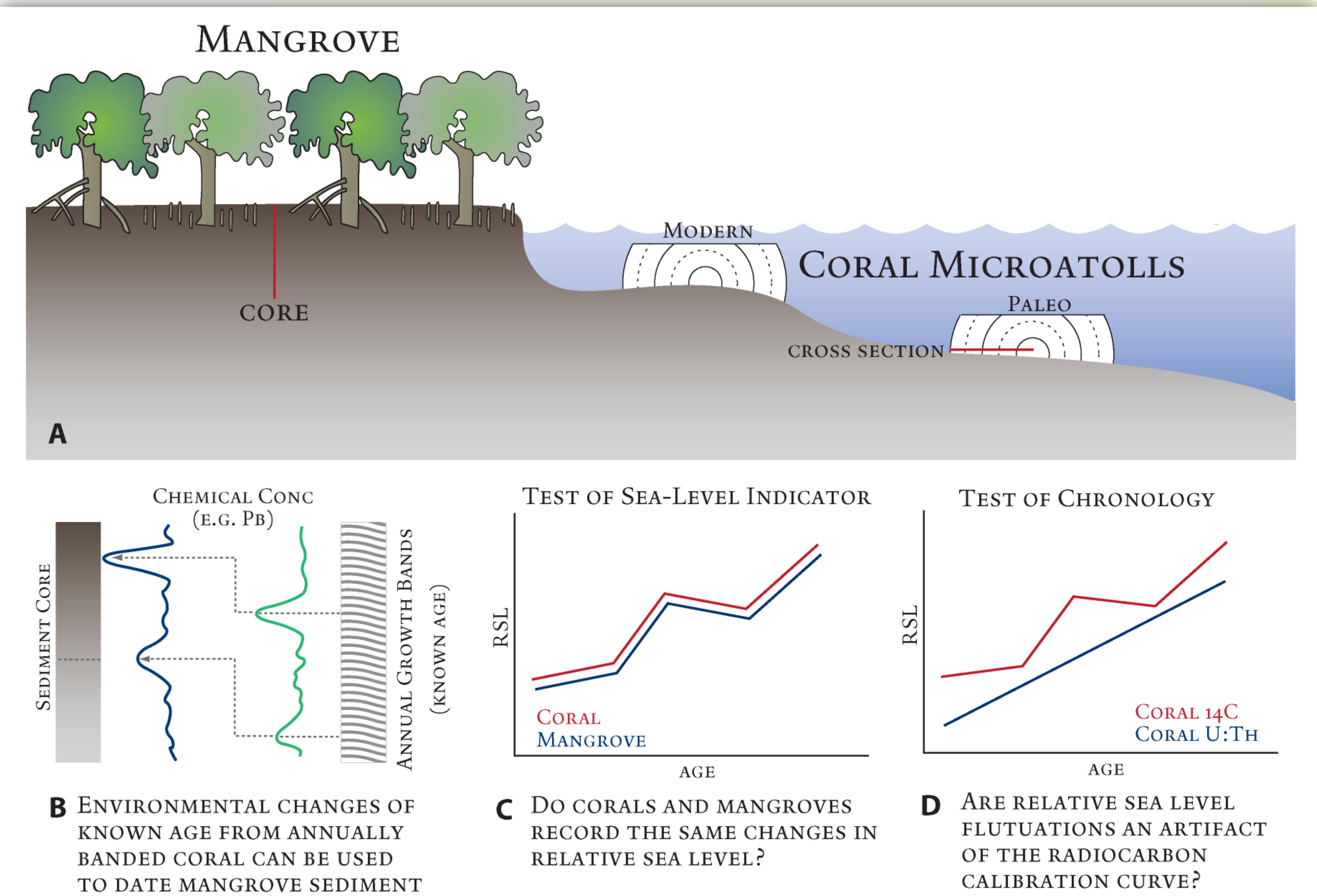
- Ocean circulation contributes to RSL.
- Bermuda lies at the center of the North Atlantic gyre and can test the influence of circulation compared to NC/NJ.
- GIA estimates to decontaminate GRACE mass measurements
- 2100 years of mangrove development

NASA Funded (2011-2013)



Dynamic sea level caused by Atlantic circulation Yin et al (2009)

Sea-Level Rise from Oceanic Islands



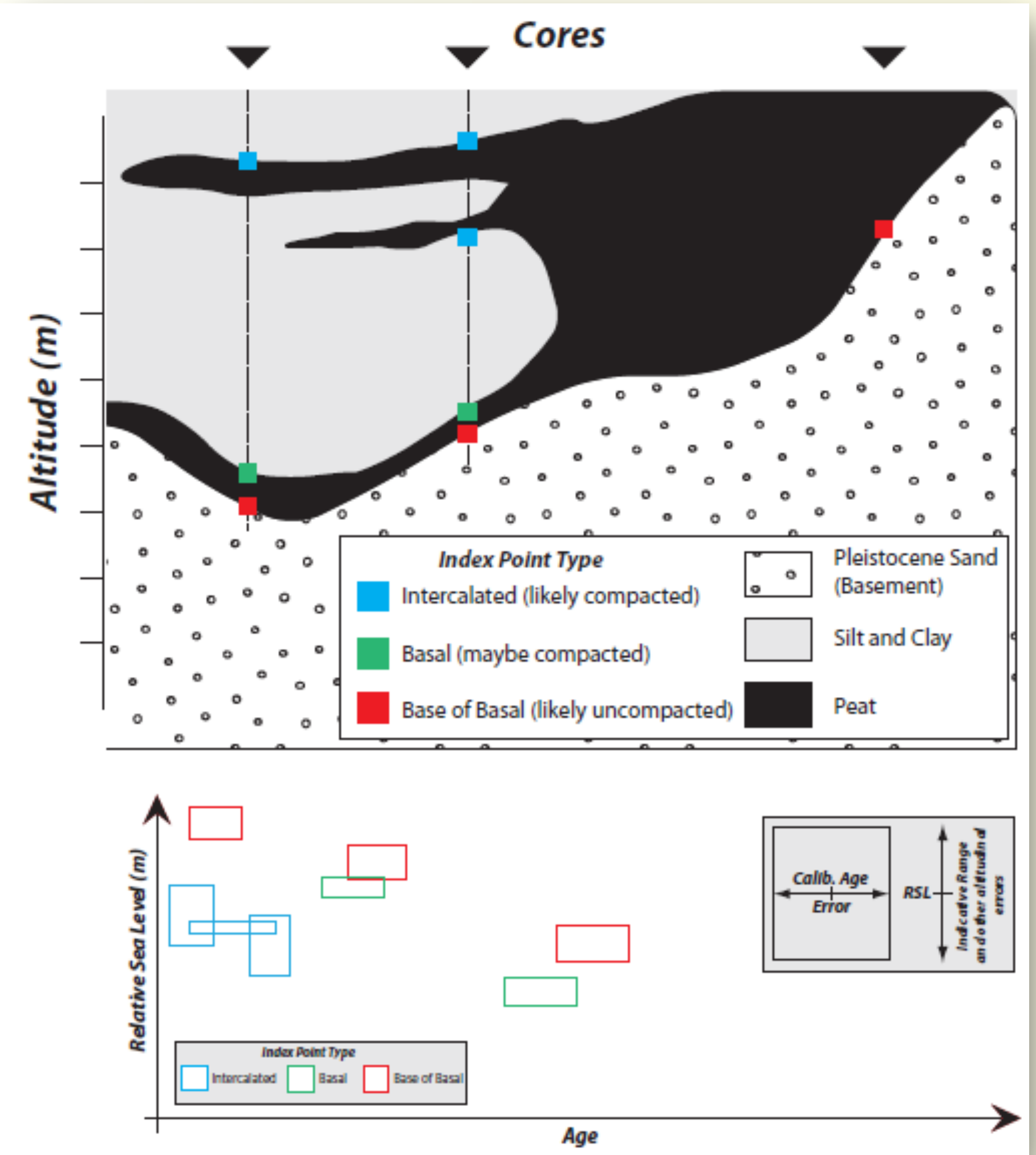
Oceanic islands provide a unique test of sea-level reconstruction

Assessment of compaction $\Delta\xi_{local}(\tau,\varphi)$

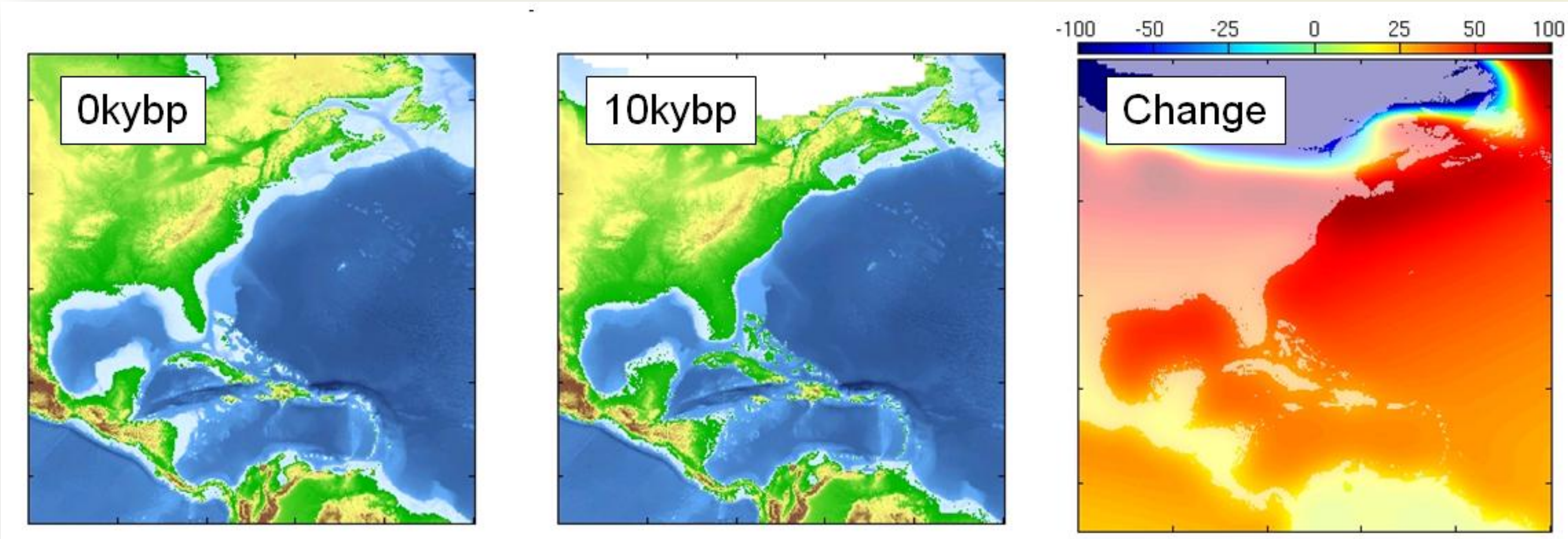
Base of basal are within 0.05m of the presumed uncompressible substrate and are less than 0.1m thick.

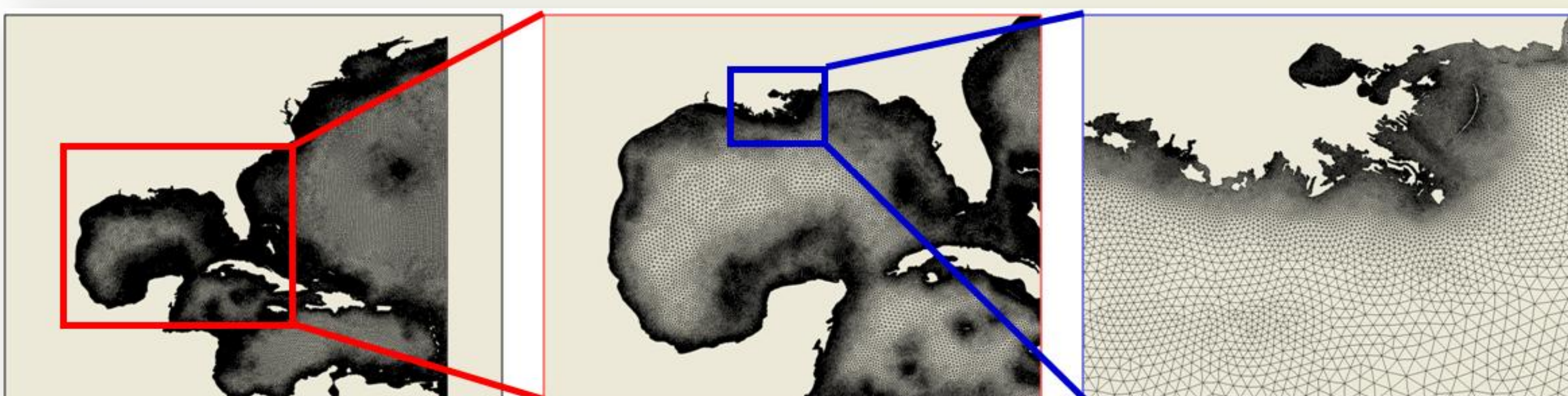
Basal are within the sedimentary unit that overlies uncompressible substrate but not from the base of the unit.

Intercalated are under and overlain between different sedimentary units



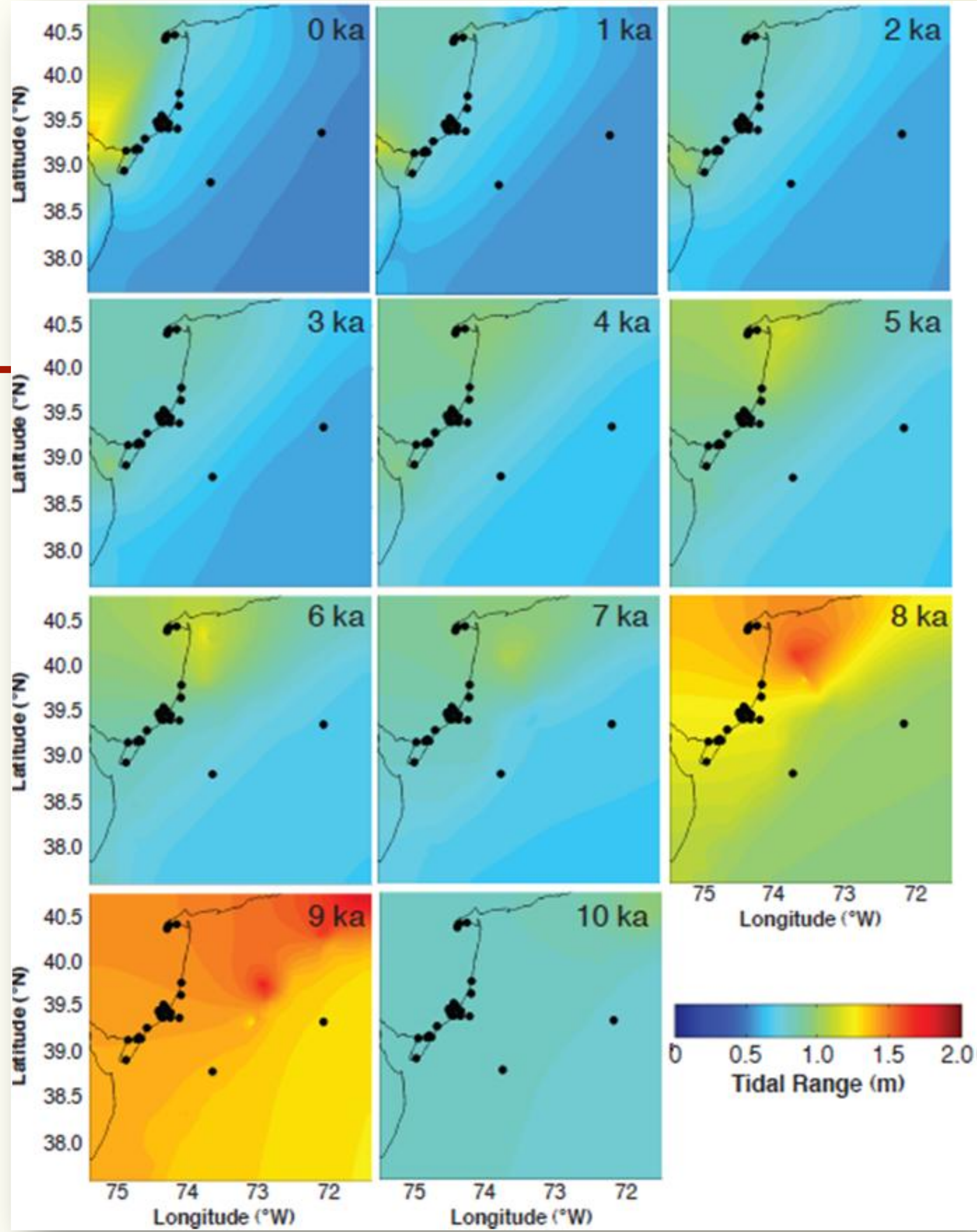
Methodology – ICE 5G paleobathymetry and ADCIRC regional tidal model





Holocene tidal range change in New Jersey

- Tidal range (MHHW – MLLW) largely follows the trends in M2, the largest constituent
- Even at 5kybp, only small changes noticed
- Dramatic amplification occurs at 8 to 9K

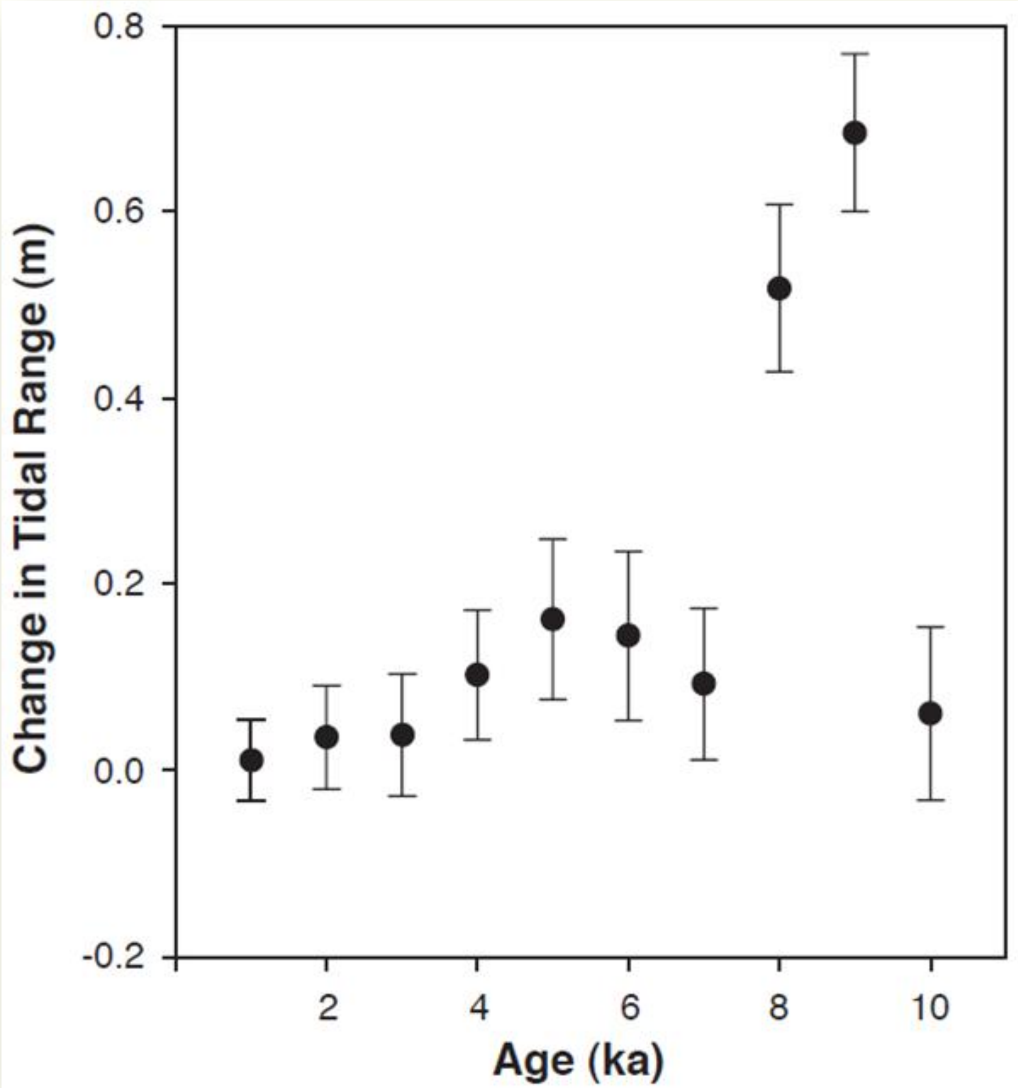


Tidal range change through time

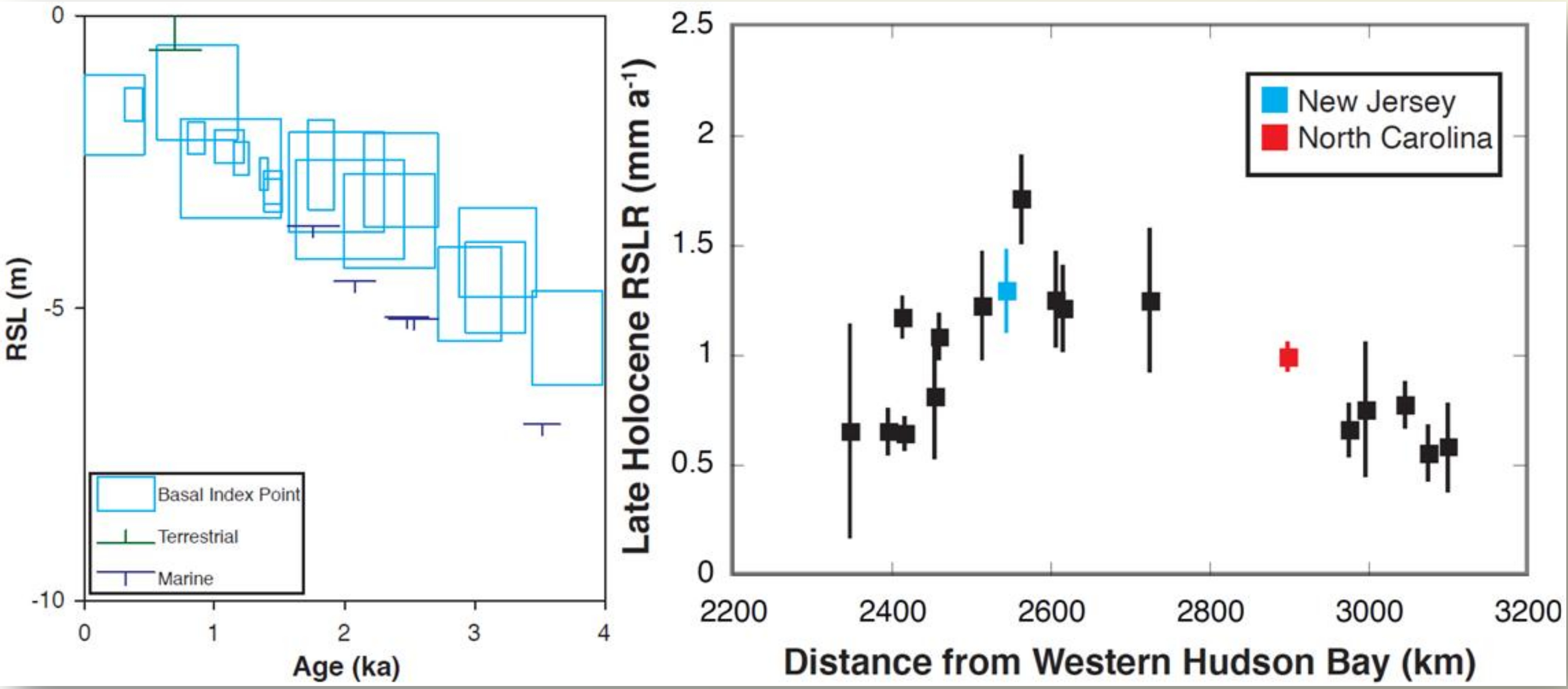
Possible explanations:

- Bathymetric and water depth changes are bringing the Atlantic more into resonance
- Reduced tidal dampening because of a smaller continental shelf

Uehara et al., 2006. JGR, 111.
Arbic, et al., 2009. Atmosphere-Ocean, 47



Decontaminating RSL records for GIA



1.3 ± 0.1 for southern New Jersey is (based on linear regression through basal index points from 2K to AD 1900)

Engelhart et al. Geology, 2009; Engelhart and Horton QSR 2011

Transition from late Holocene to modern rates of sea-level rise

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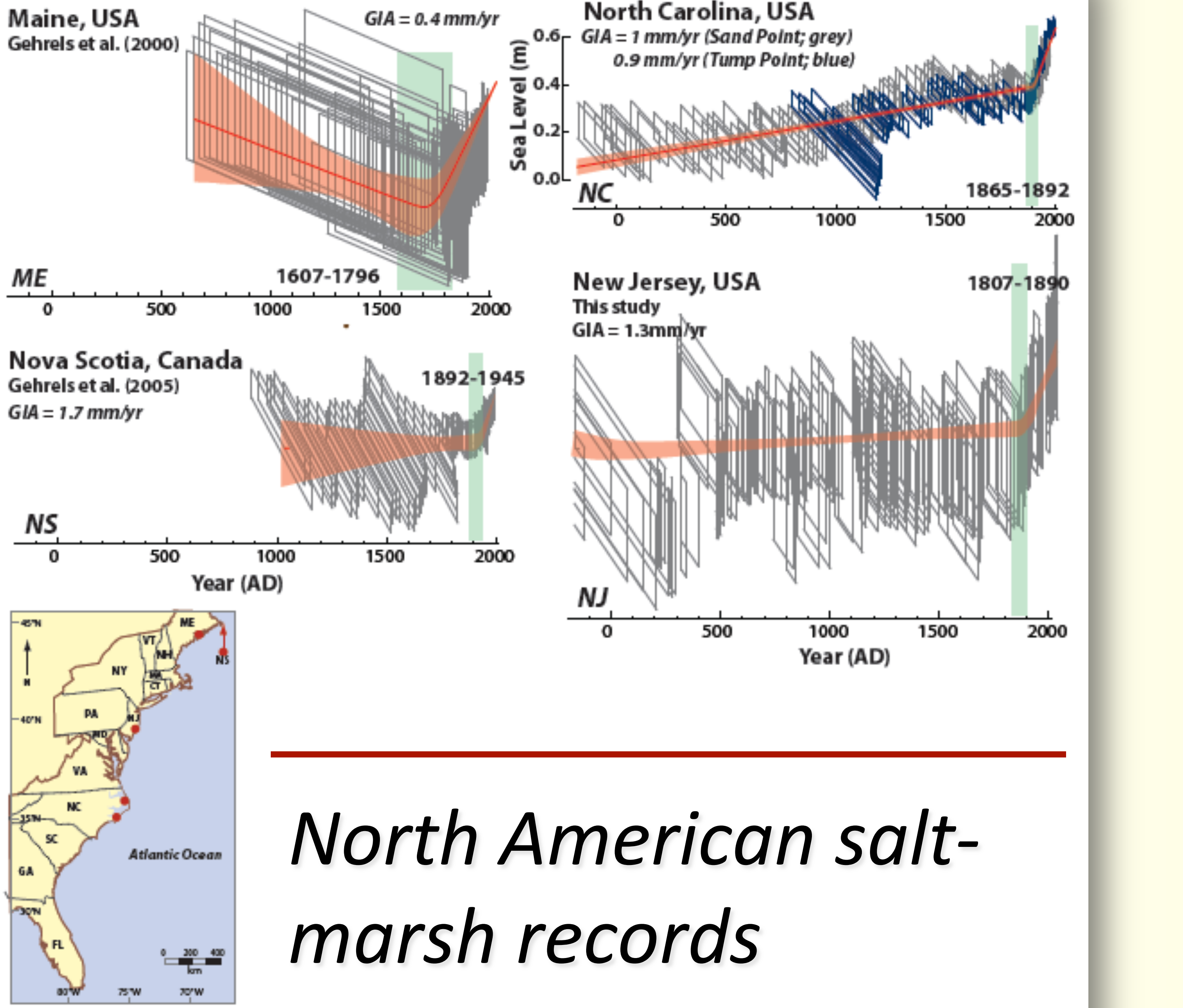

North American salt-marsh records

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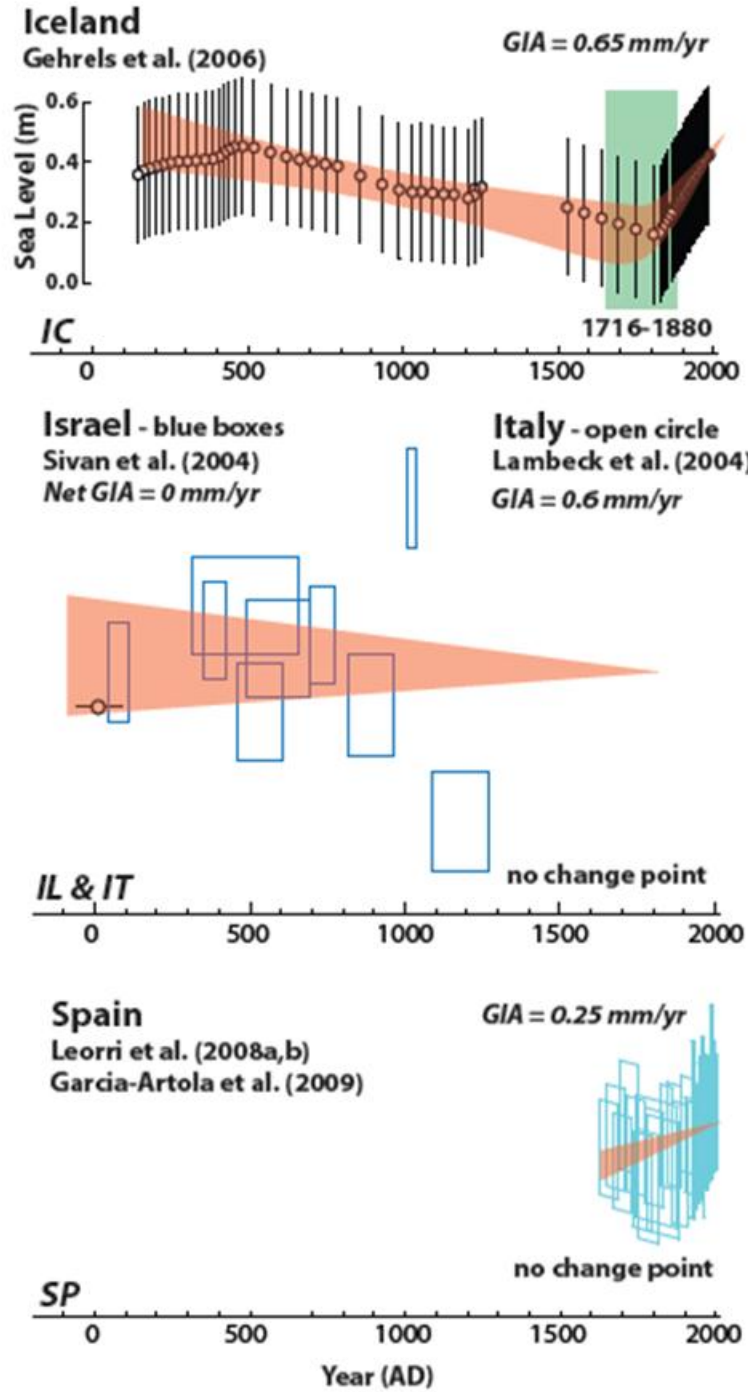
European salt-marsh and archaeological records



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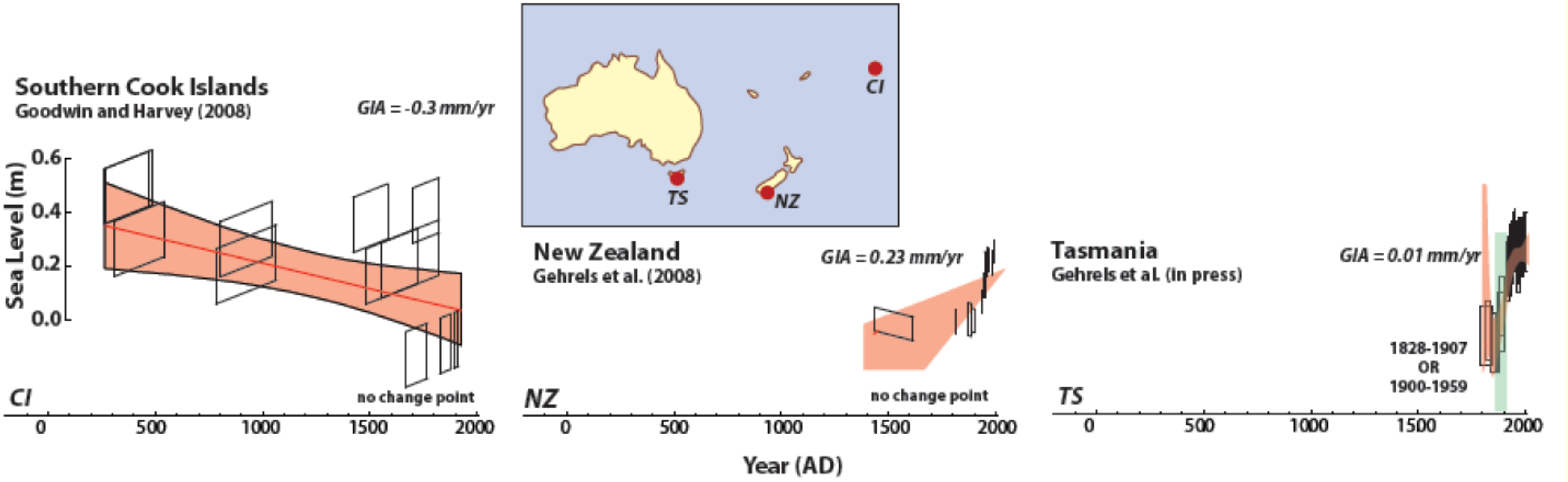
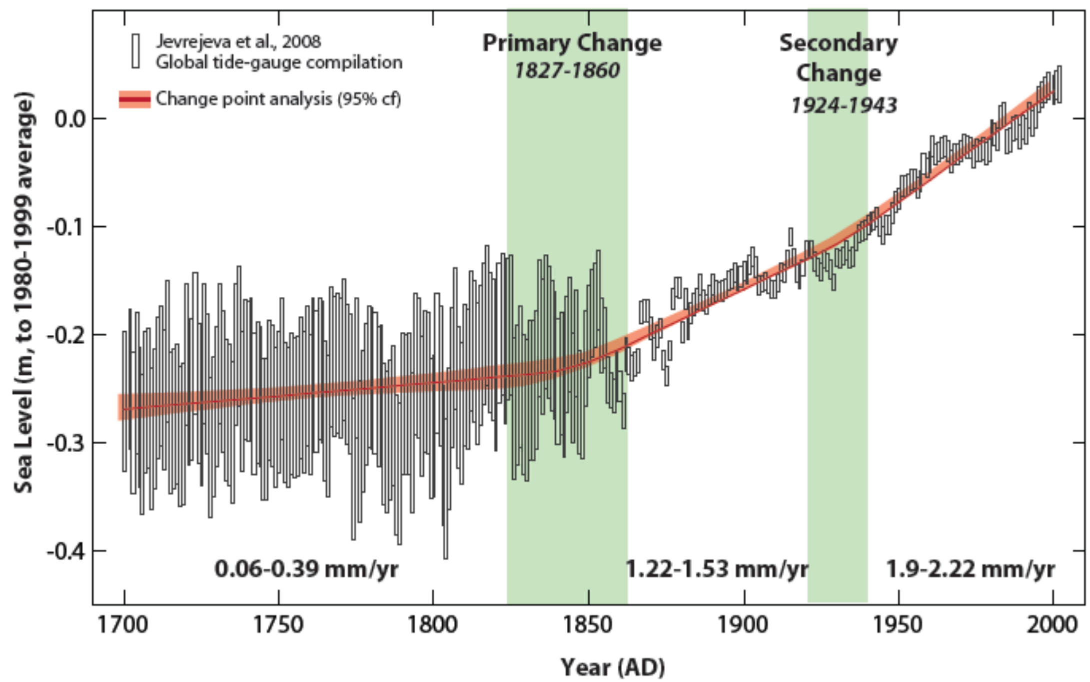
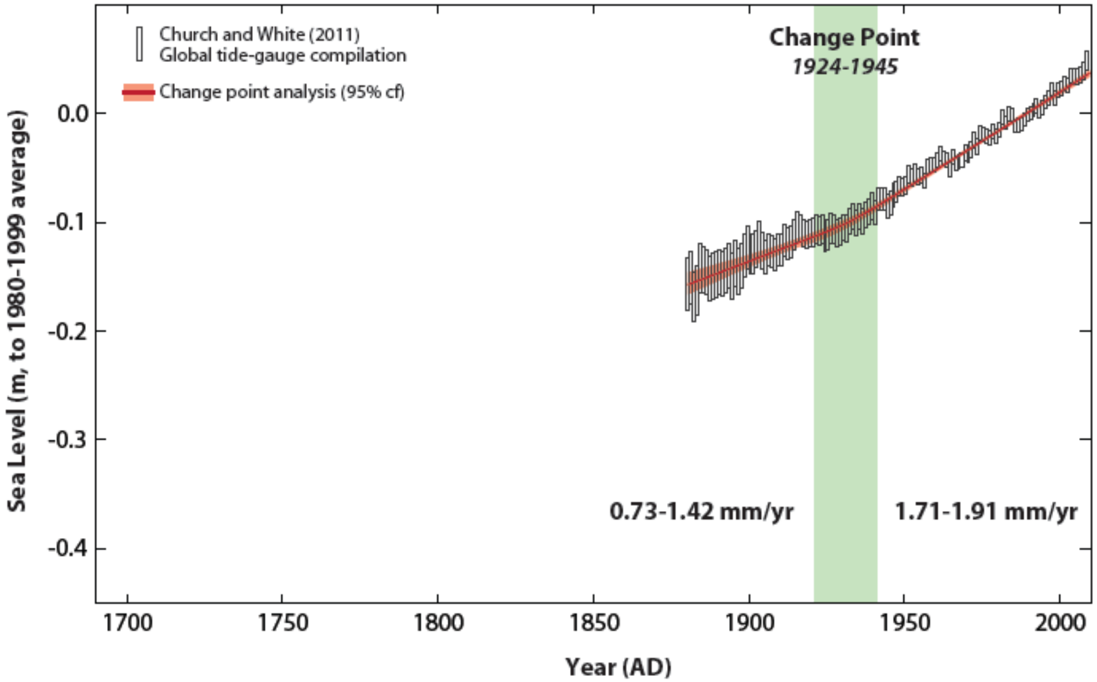


Global tide gauges





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