Paleotempestology: Geological Records of Prehistoric Hurricane Activity

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What is the return period of a category-5 hurricane like Camille to *directly* hit New Orleans?

(or Houston) **(or Miami)** **(or New York)**

Multi-Billion-dollar question

Historical record provides little clue to answer this question because New Orleans has not been *directly* hit by a cat 4 or 5 hurricane in the last 150 years

Geological record offers the only means to extend the period of observation to centuries or millennia, thus shedding light on the frequency of these extreme storms

Hence ***paleotempestology***

What is Paleotempestology?

Paleotempestology is a young field of science that studies past hurricane activities by means of geological and archival techniques

Principal approach:

Detection of storm signal in geological proxy

Requirements for useful proxy:

Instrumentally measurable and individually resolvable

Preservable (i.E., Not eroded by subsequent events)

Datable

Verifiable by modern analog

Attributable solely (or at least principally) to storms (i.e., preclusion of other causes)

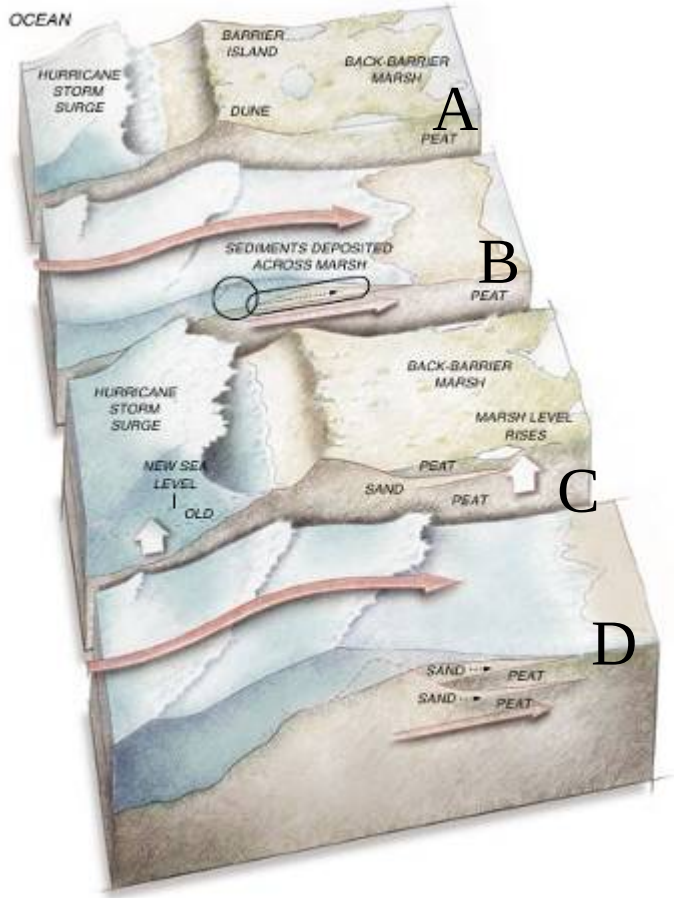
Overwash Sand Layers

Before **After**

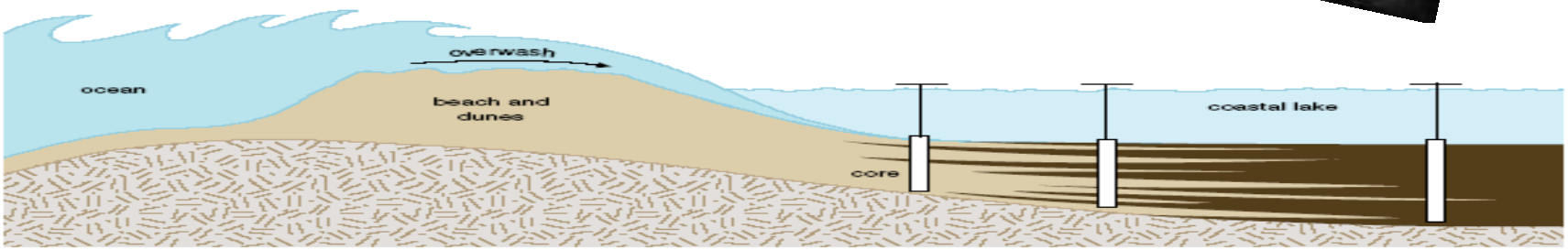
Hurricane Isabelle, September 2003

Rodanthe, North Carolina

Detection of overwash events caused by intense hurricanes



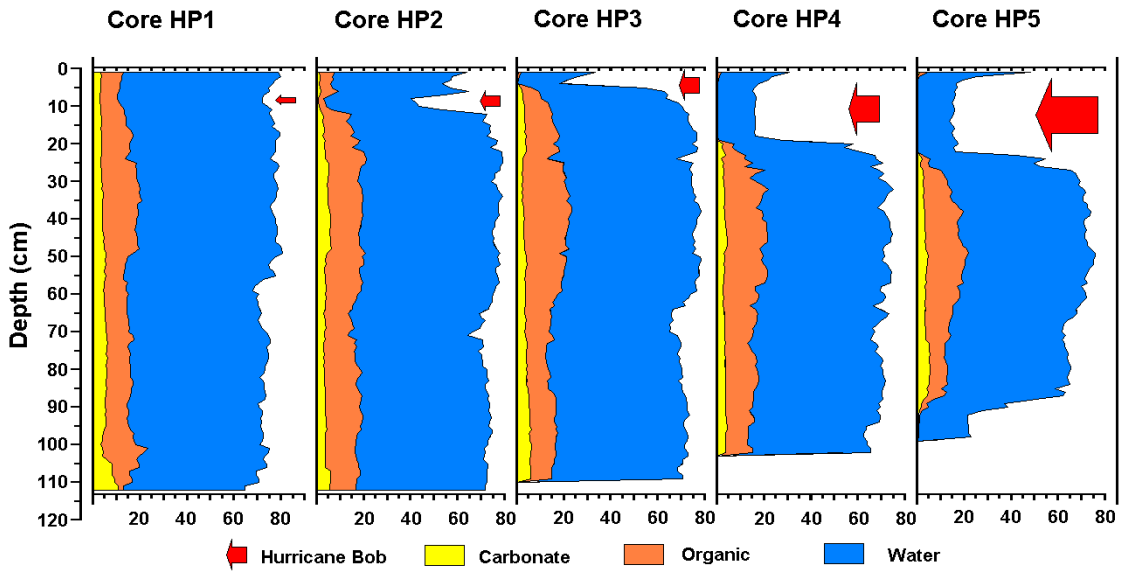
http://www.nytimes.com/images/2001/07/24/science/



Overwash Sand Layers in Coastal Sediments

Identify Clastic Layers

Demonstrate marine origin

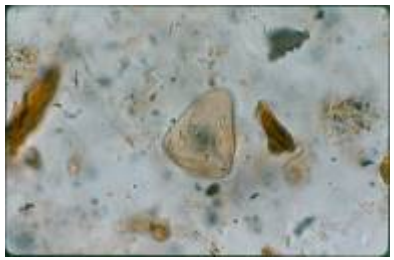


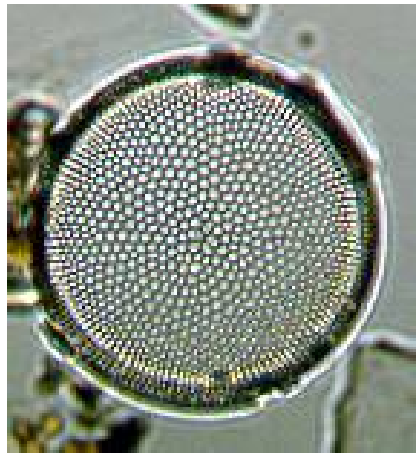
Clastic layers should be thicker, coarser near the ocean

Structure

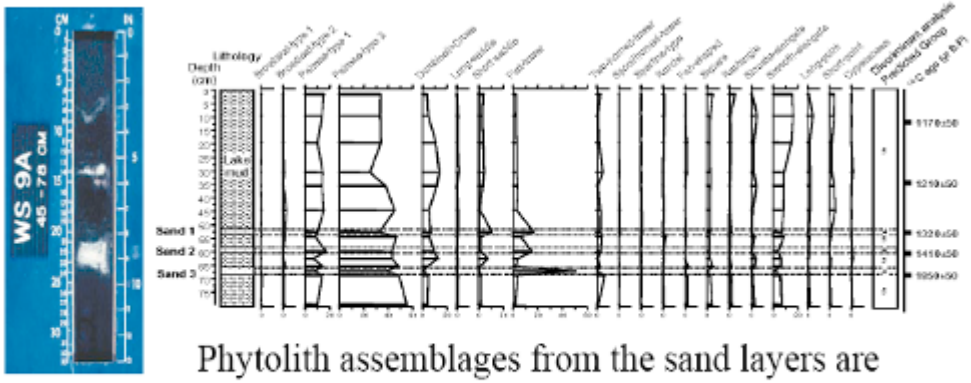
Macrofossils

Microfossil Data
(diatoms, foraminifera, pollen, phytoliths)
Used to indicate seawater intrusion and transportation of materials from the sand dunes.

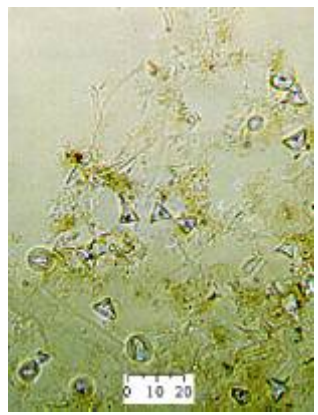




Western Lake, Florida



Phytolith assemblages from the sand layers are similar to those derived from sand dunes, thus supporting the notion that the sand was deposited by overwash processes.



Tsunamis

Tsunamis and hurricanes can leave similar, though distinguishable, sedimentary signatures

Tsunami deposits are generally:

- Less well sorted
- Bi-directional, depositing both terrestrial and marine material
- Capable of moving larger material to higher elevations and/or farther inland

Dating

Radiometric

Carbon 14

Lead 210

Cesium 137

Stratigraphic

Construction

Volcanic eruption

Vegetative changes

Control for Changing Conditions

Sea level rise

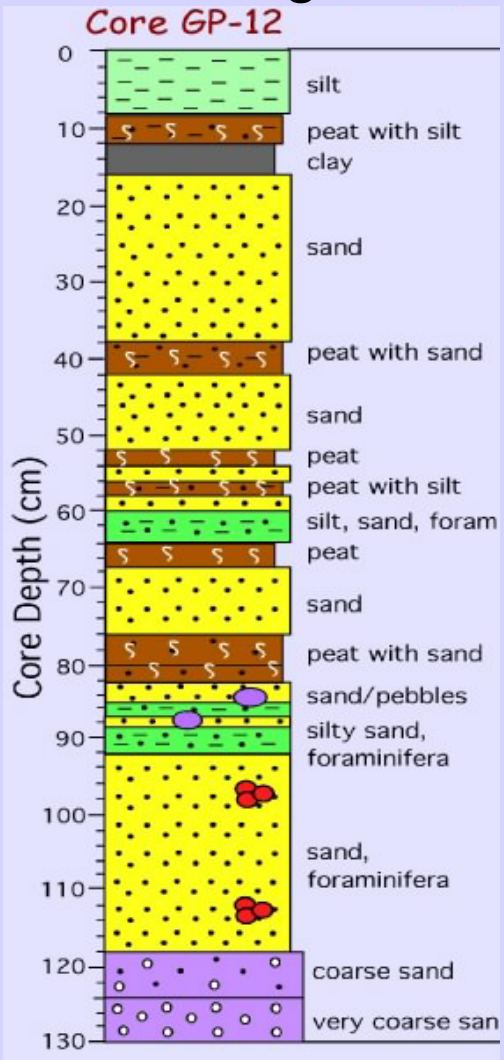
Changing distance to the sea

Geomorphic change

Opening/closing of barriers

Combination of literature review and internal evidence

Lithologs



Analyses

Loss on Ignition

Macro/micro fossils

Shell hash

Composition

Color

Structure

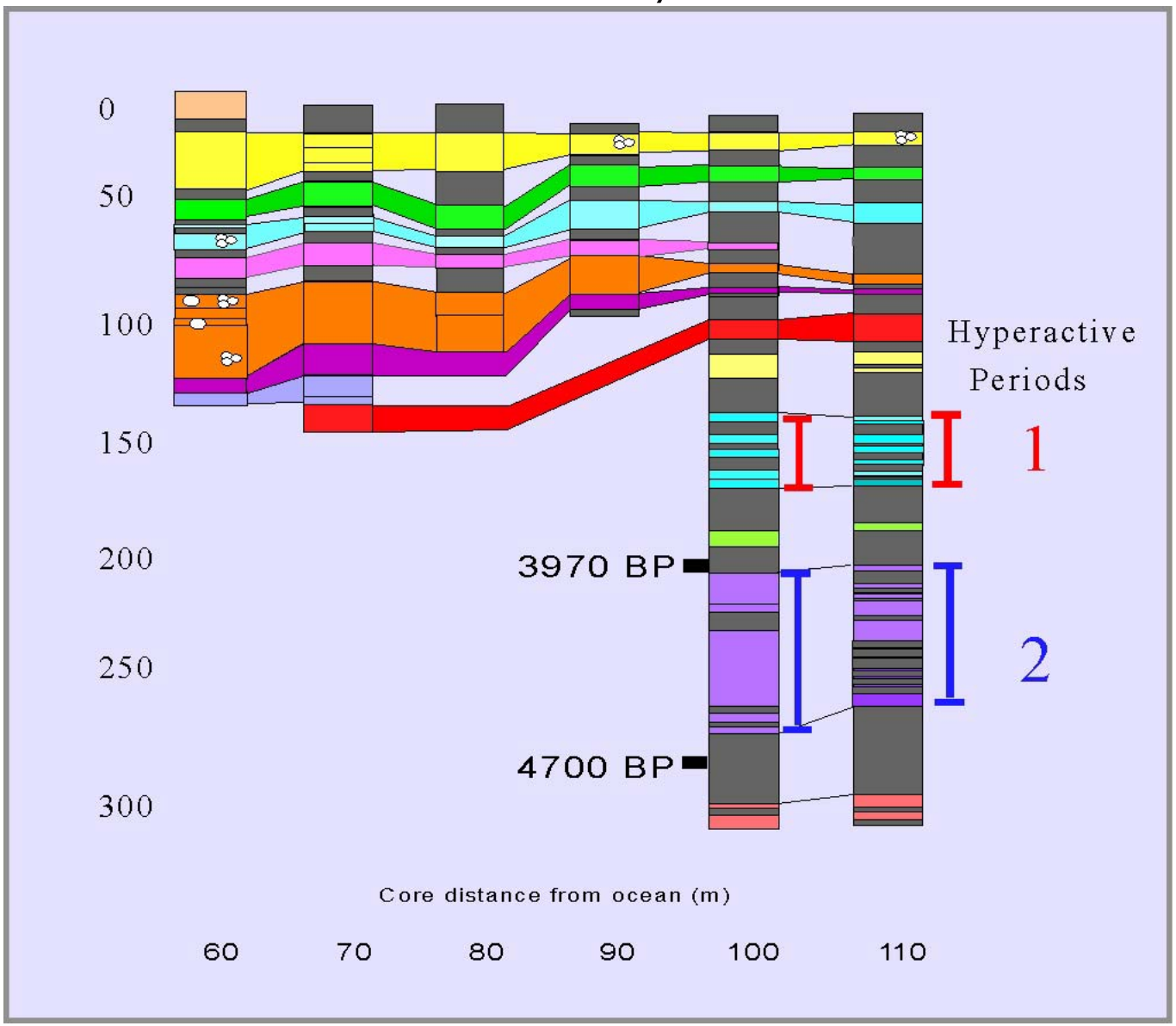
Fining upward

Truncations

Amalgamations

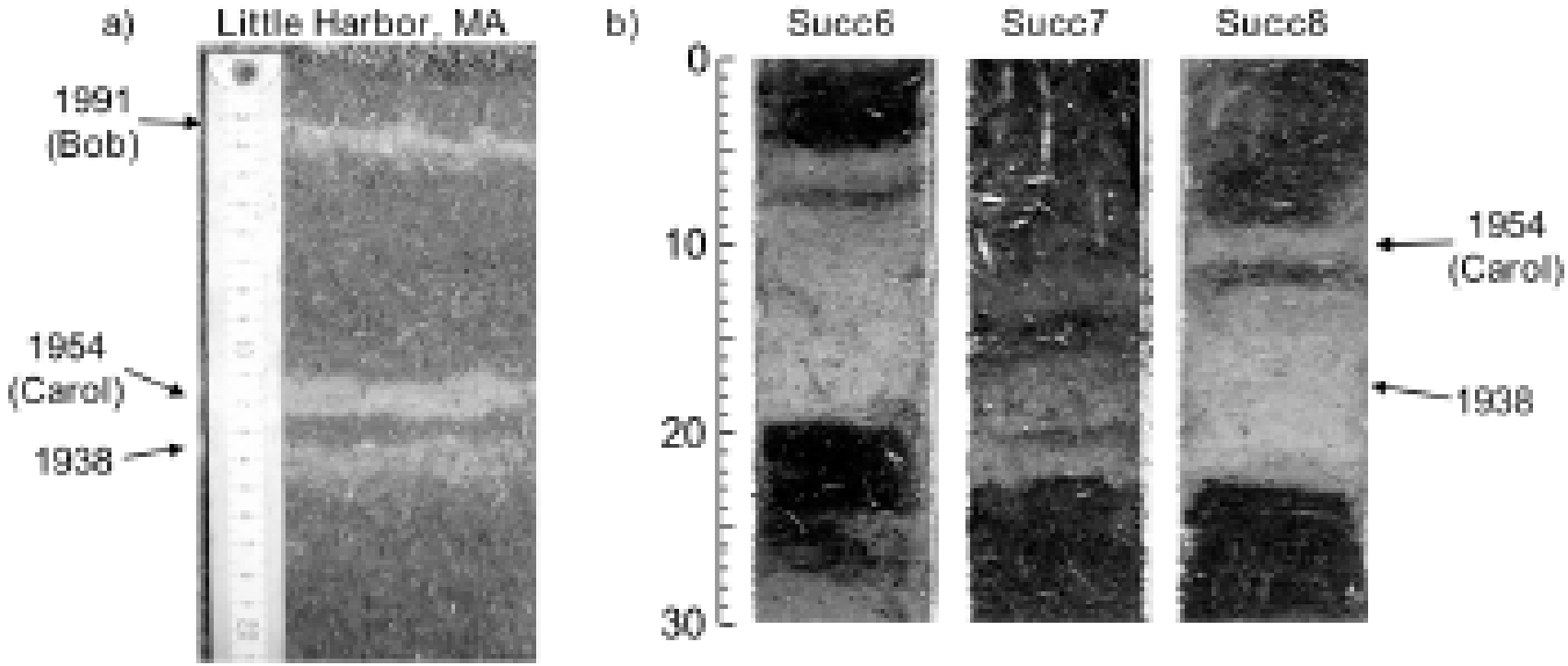
Event layers

Gales Point, Belize

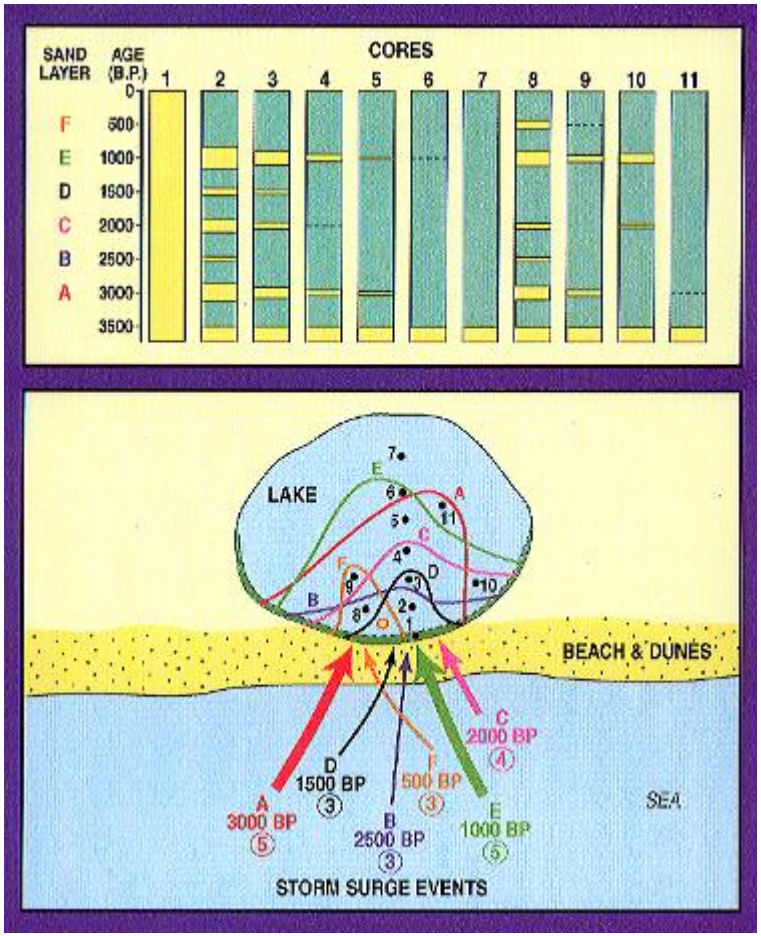


(McCloskey and Keller 2008)

Identified Historic Storms



Potential Information



Model of overwash sand deposition in a lake and its stratigraphic implications (Liu and Fearn 2000)

Frequency

Relative intensity (at site)

Direction of travel

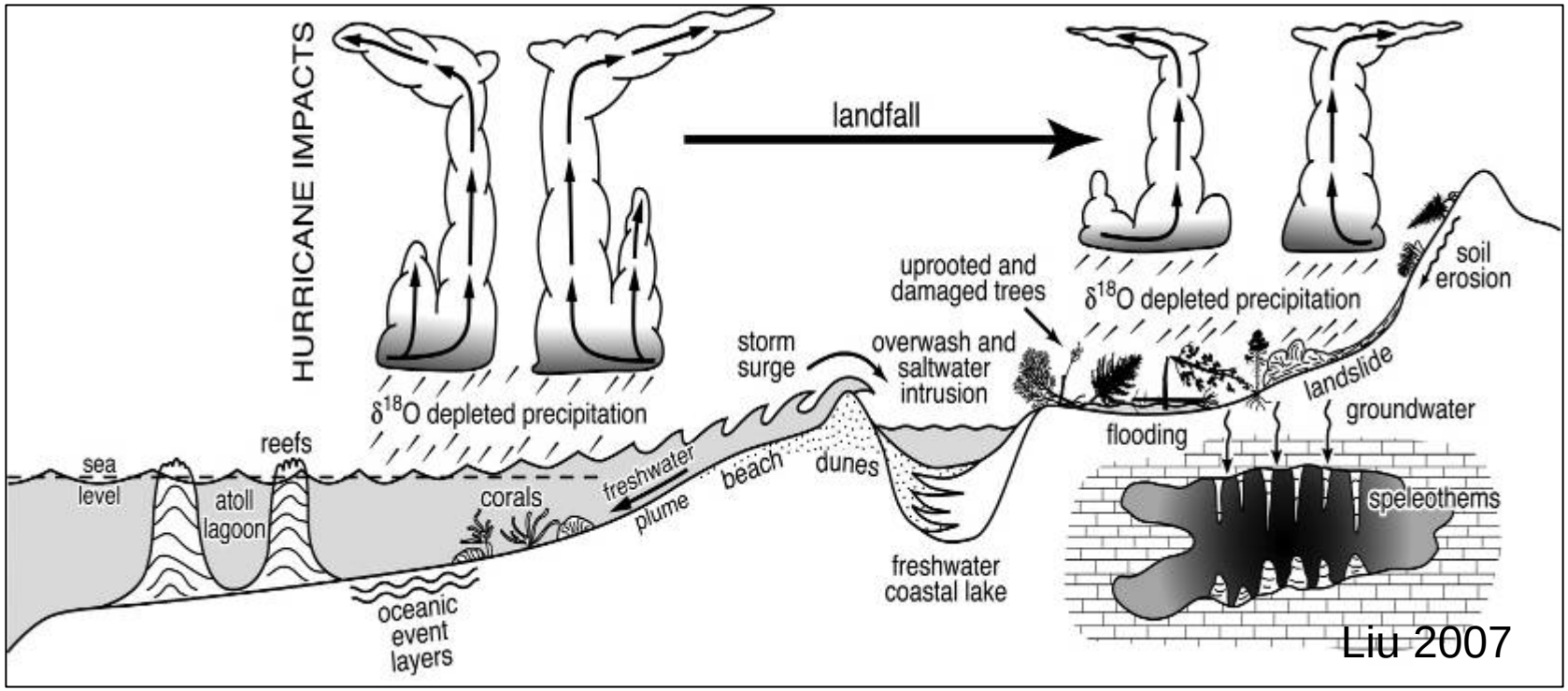
This is a Landfall/Storm surge proxy

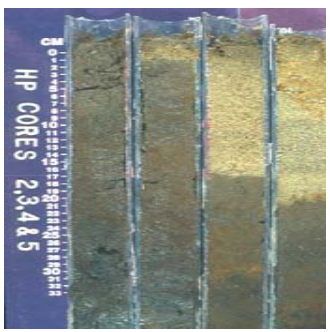
Does not inform as to track

Very local record

The Expanding Frontiers of Paleotempestology …

Multi-proxy Reconstruction of Prehistoric Hurricane Activities

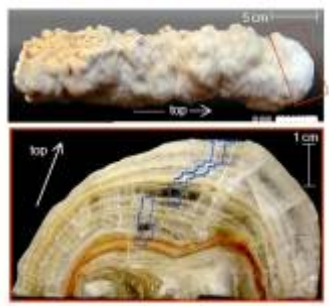




sediments


documents

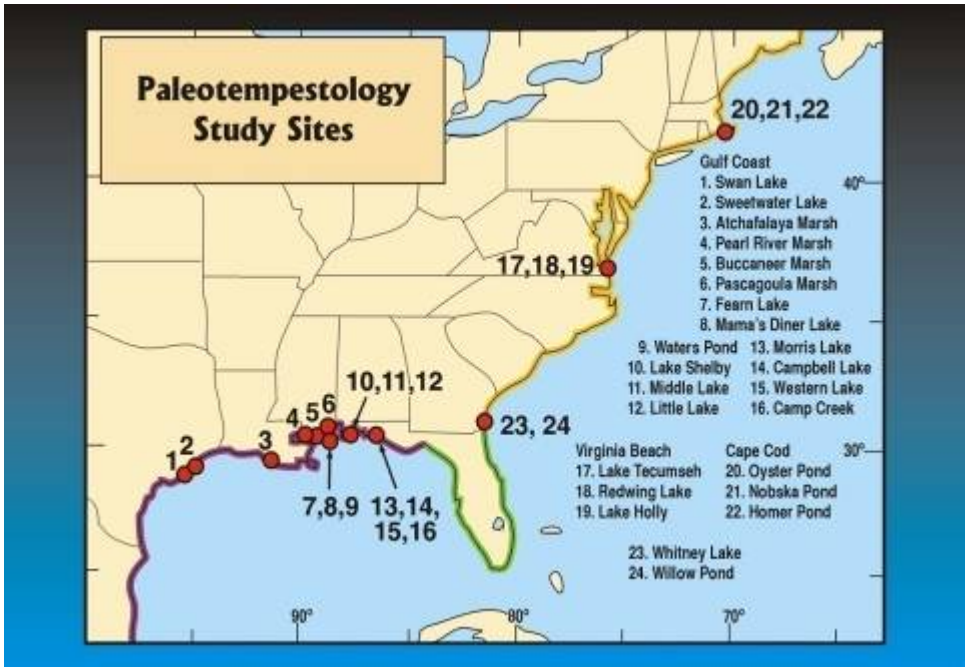

tree rings



speleothems


corals

Study Sites: U.S. Gulf Coast and Atlantic Coast

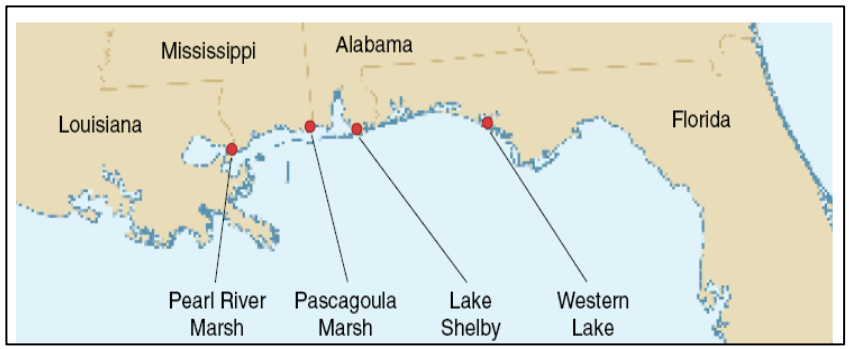


Lake Shelby, Alabama

Atchafalaya Marsh

Western Lake, Florida

Major Findings from Gulf Coast Proxy Records:



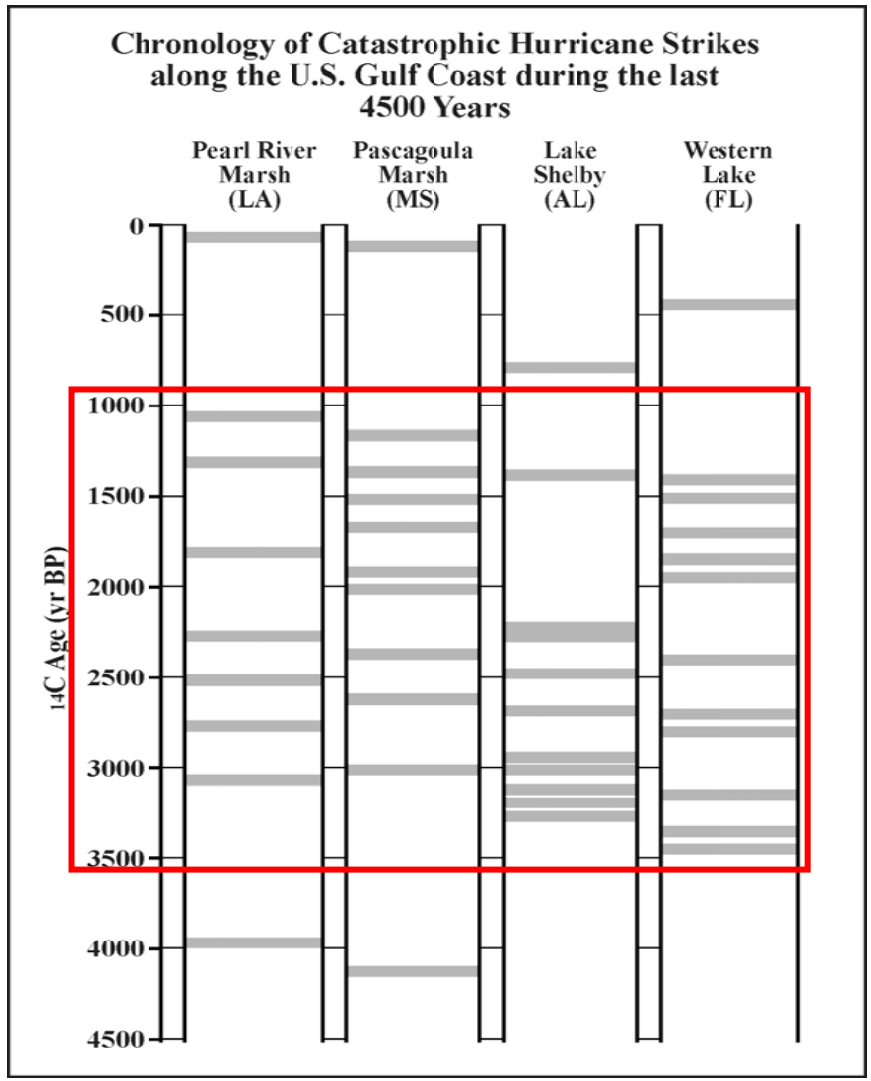
Return period for catastrophic (category 4 or higher) hurricanes:

~300 years

(p = 0.3%/yr)

Millennial-scale variability

Hyperactive period from ~ 3,800–1,000 years before present



(Liu 2004, 2007)

Millennial-Scale Variability

For the Gulf coast, the past millennium is in the low-activity phase of the mega-cycle of hurricane activity. (*We haven't seen anything yet!*)

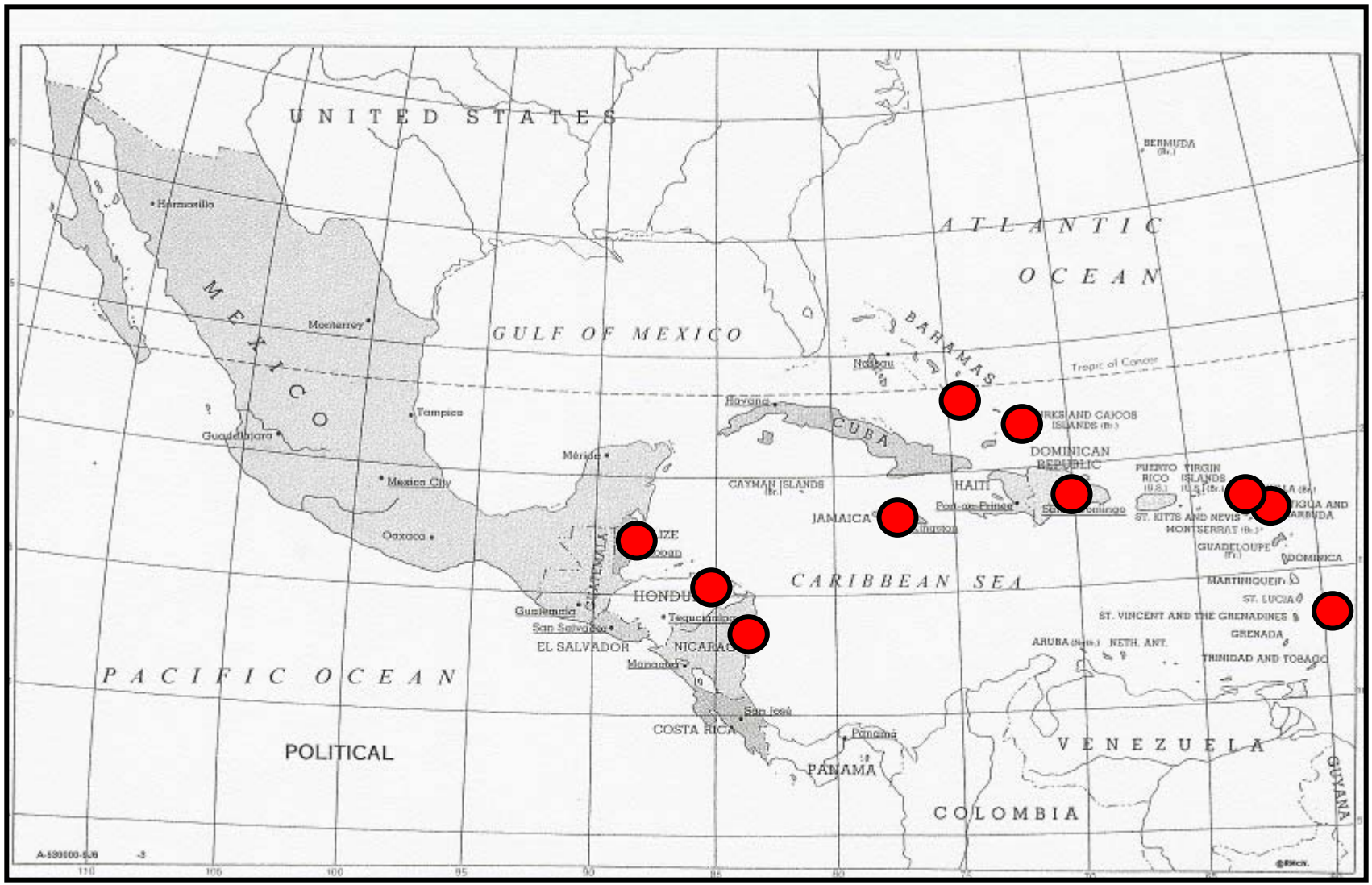
If the climate regime characteristic of the hyperactive period returns in the future, hurricane landfall probability for the Gulf coast may increase by 3–5 times.

Potential Identification of Responsible Mechanisms

Identifying correlations between changes in hurricane landfall behavior with paleoclimatic conditions should help identify the atmospheric mechanisms responsible for these changes

Such an identification may lead to improving the predictability of similarly forced short-term changes in track pattern and frequency

Caribbean Paleotempestology:
The LSU Research Initiative since 2003



Millennial-Scale Variability

Multi-centennial to millennial-scale variability in hurricane landfall activity has been found for numerous locations along the Gulf and Atlantic coasts of the United States as well as for several Caribbean locations

New England, South Carolina, Puerto Rico, Belize, and Saint Martin

Millennial-Scale Variability

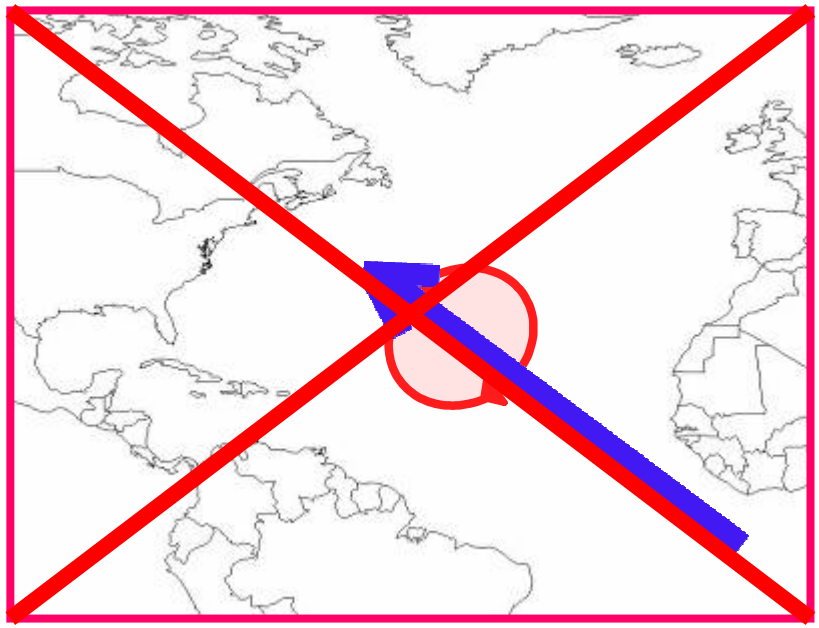
Two Contending Theories

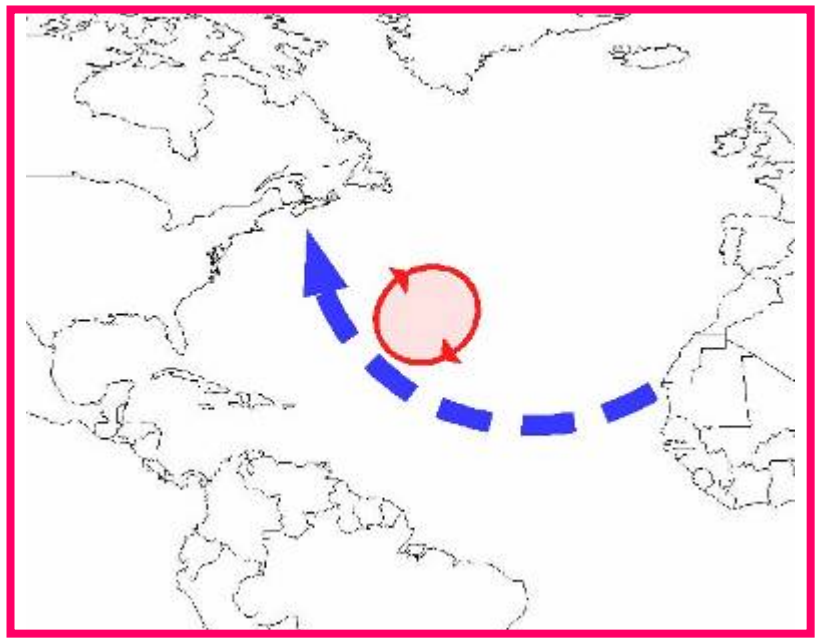
Basin wide increase/decrease in activity

Latitudinal migration of the location of maximum landfall

The Bermuda High Hypothesis

Bermuda High provides the steering mechanism that determines hurricane tracks

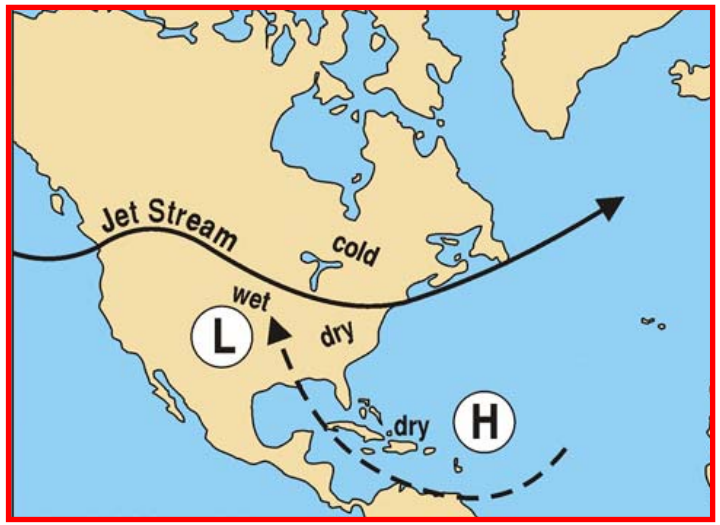




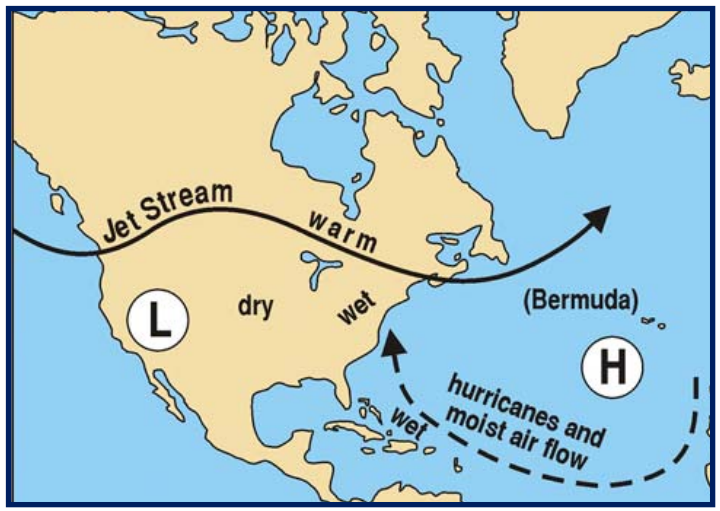
The Bermuda High Hypothesis

Long term average position of the BH explains hyperactivity in hurricane landfall

A southwest position for the BH (~3,800-1,000 BP) funnels hurricanes into the GOM

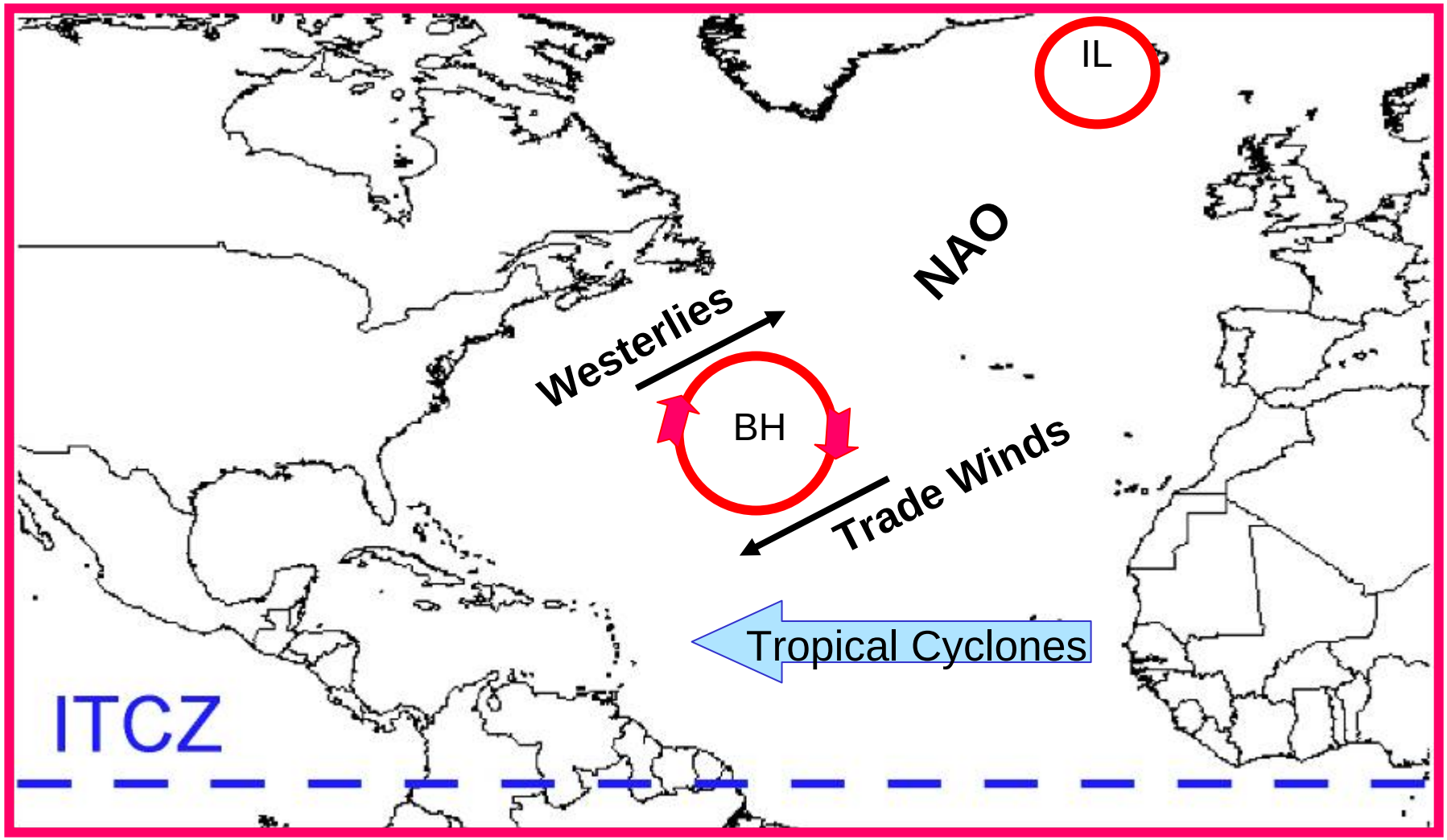


A northeast position for the BH (earlier than 3,800 BP; 1,000 BP to present) directs hurricanes onto the Atlantic coast Liu & Fearn 2000



Paleoenvironmental records support the proposed timing

North Atlantic Circulation



ITCZ Latitudinal Location since 14 K BP

Proxy record from varved cores from the anoxic Cariaco basin off Venezuela

N

I T C Z

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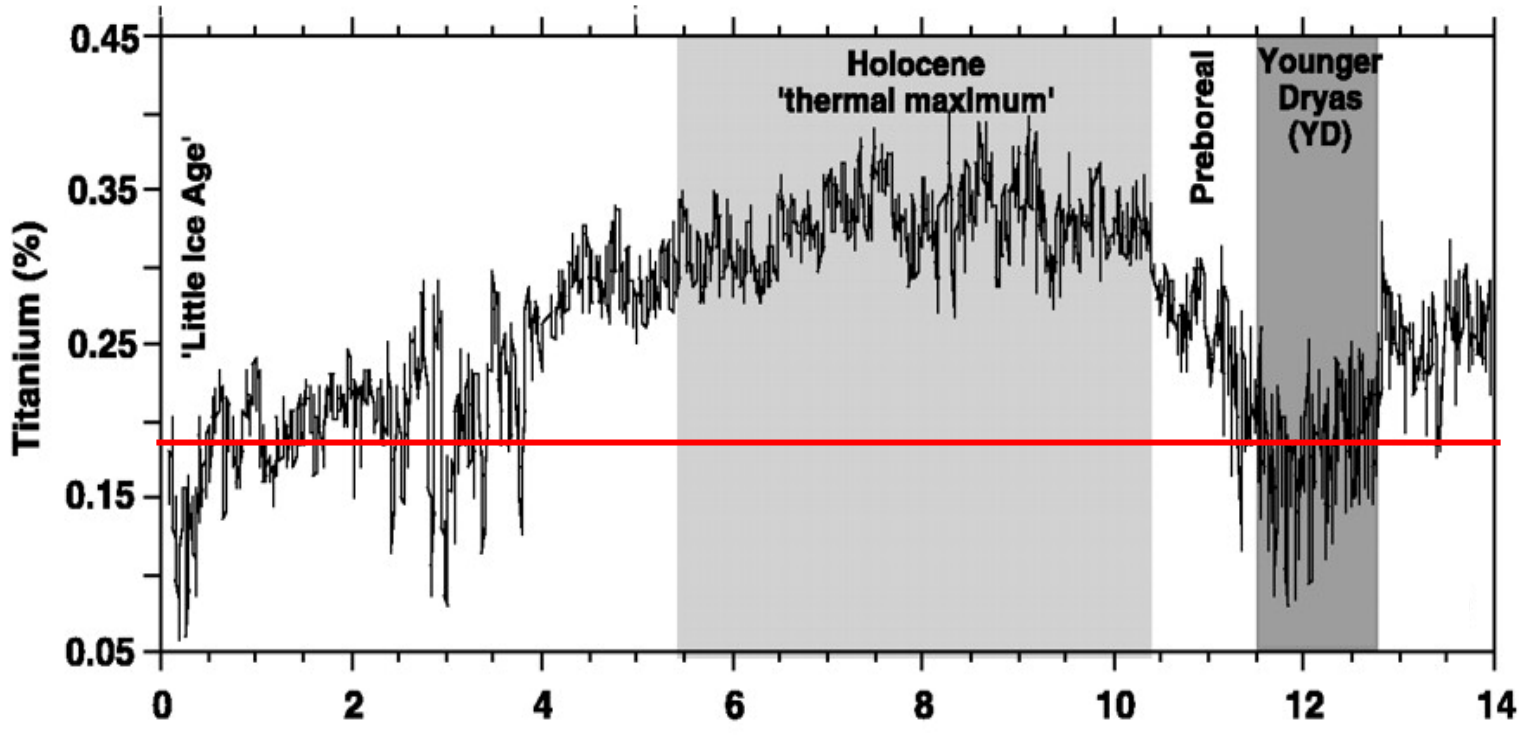
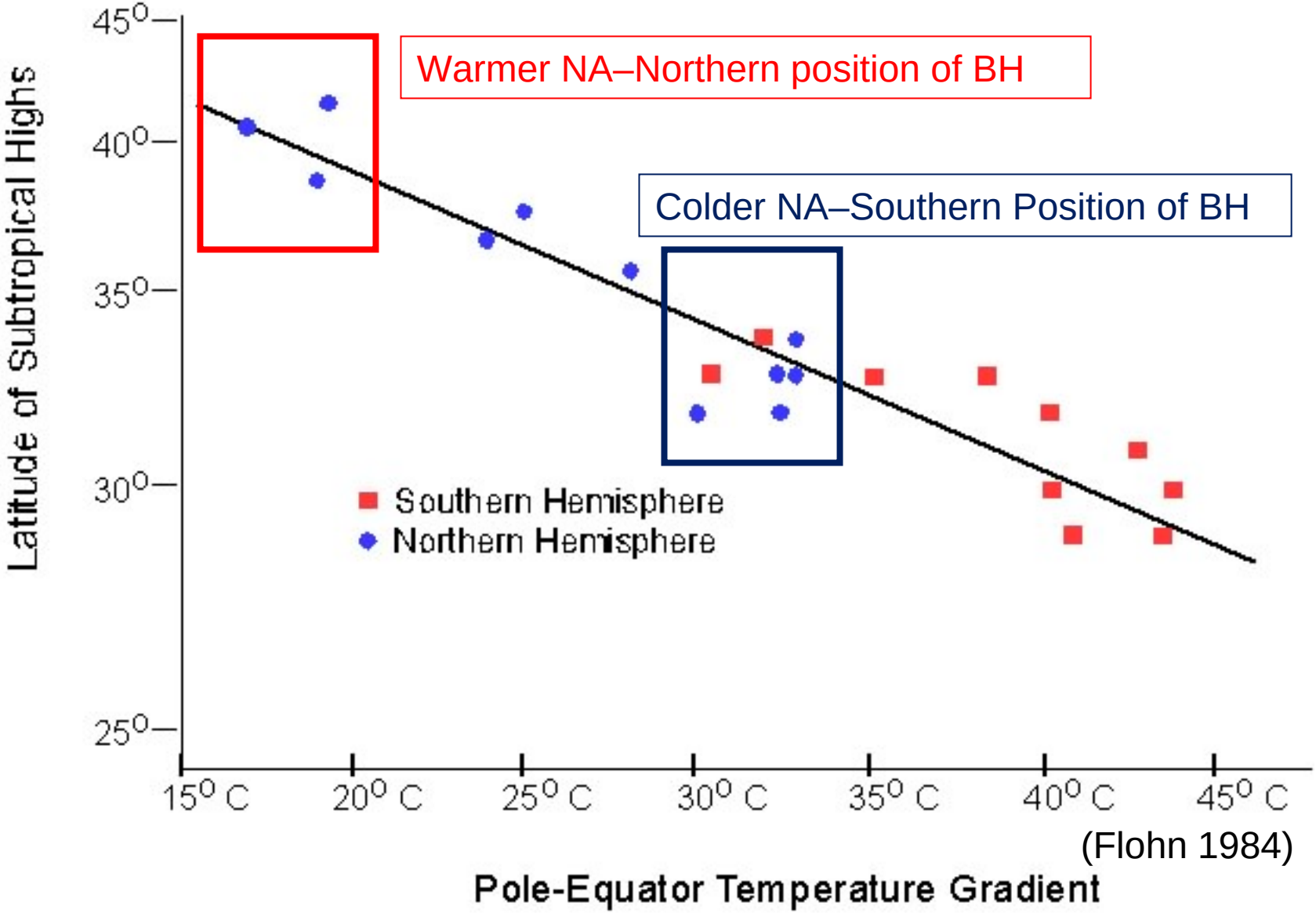


(Haug et al. 2001)

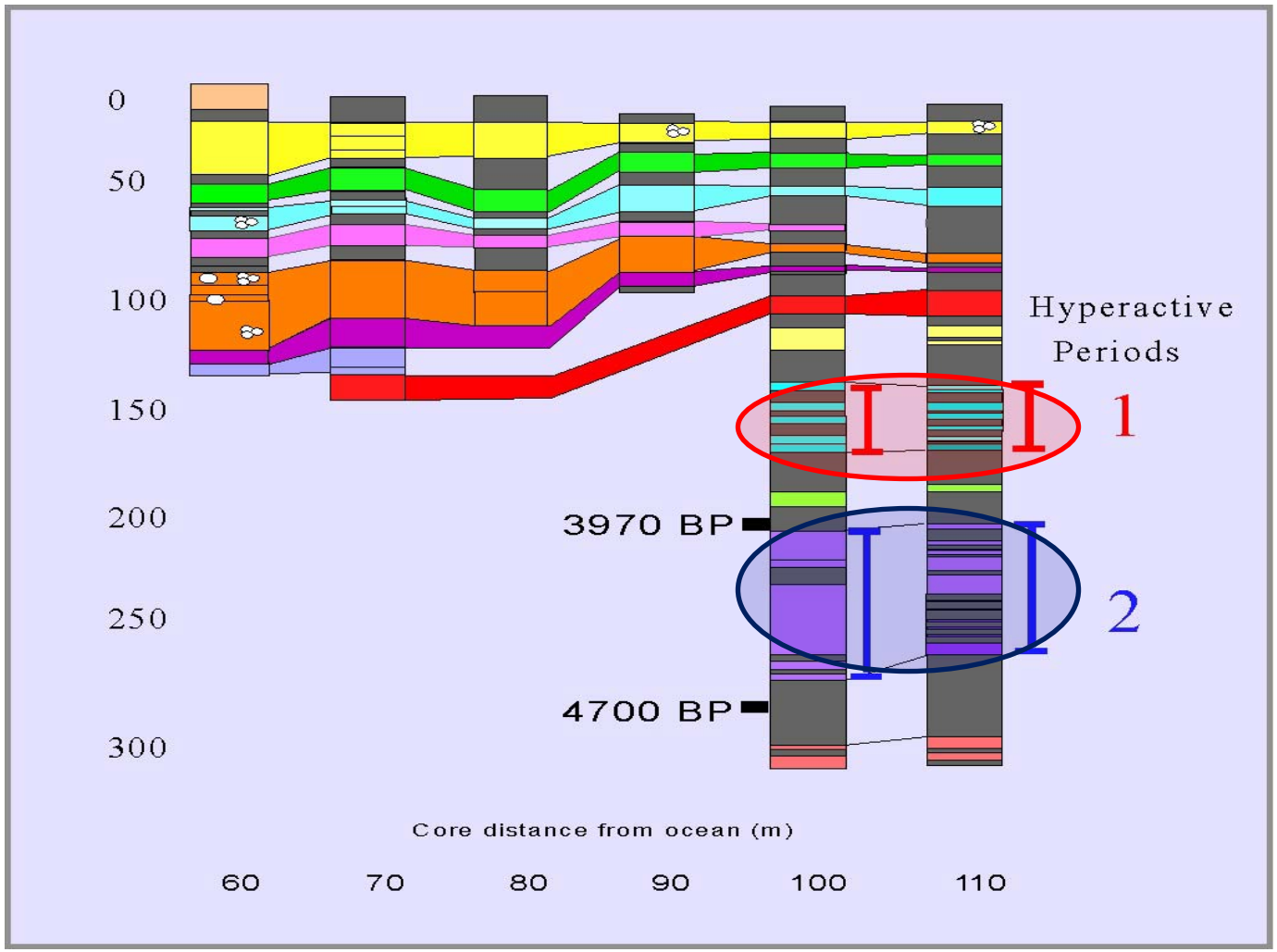
Southward migration of the Intertropical Convergence Zone through the Holocene

BH Movement



(Flohn 1984)

Gales Point, Belize



Two hyperactive periods between ~5,500–2,500 BP

Incomplete record
missing interval

Two other transects (with preliminary dates) indicate increased activity for last 500 yrs

(McCloskey and Keller 2008)

Conclusions

For the northern GOM the average return period for catastrophic hurricanes is ~ 300 yrs

However, this is the average of two different activity regimes, with such storm being 3–5 times more frequent during the hyperactive period from ~ 3,800–1,000 BP

Multi-centennial to millennial scale variability in hurricane landfall has been observed throughout the region

Unresolved as to whether this results from

Basin-wide shifts in activity regimes

Latitudinal movement of the zone of maximum hurricane landfall

Acknowledgments: NSF, IAI

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McCloskey, T. A. and G. Keller. 2009. 5000 year sedimentary record of hurricane strikes on the central coast of Belize. Quaternary International 195:53–68. doi:10.1016/j.quaint.2008.03.003