Using Paleotempestology in Support of Decision-making Under Uncertainty of Hurricane Climate Variability

Kam-biu Liu

Louisiana State University

What is Paleotempestology ?

"Paleotempestology is a new field of science that studies past hurricane activities by means of geological and archival techniques" (Liu, 2004)
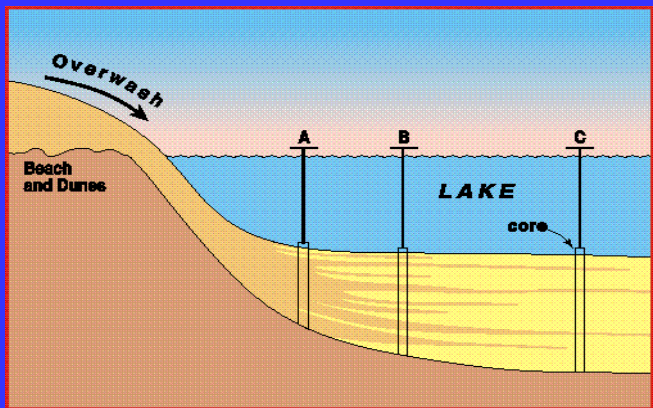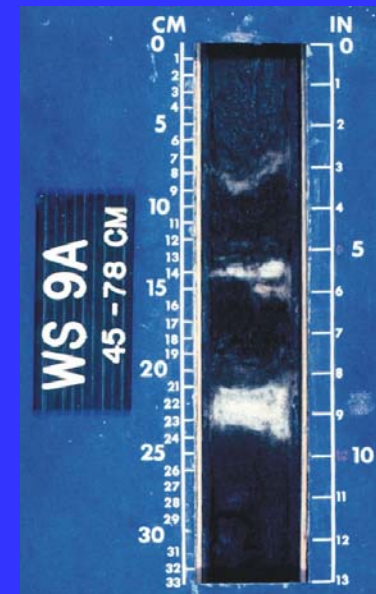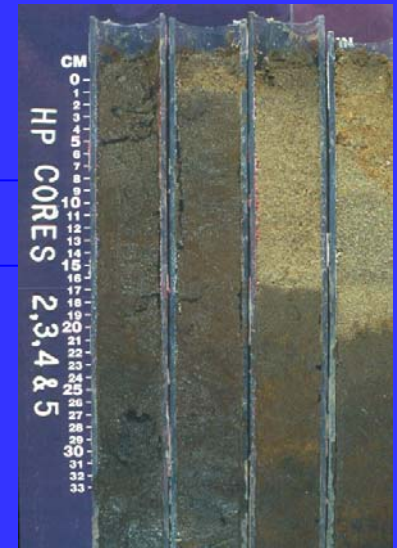

Homer Pond, Cape Cod

Fig. 1. Hypothetical pattern of sand-layer deposition in a coastal lake subjected to repeated overwash processes caused by intense hurricane strikes.

Coastal lake-sediment record of past hurricane strikes
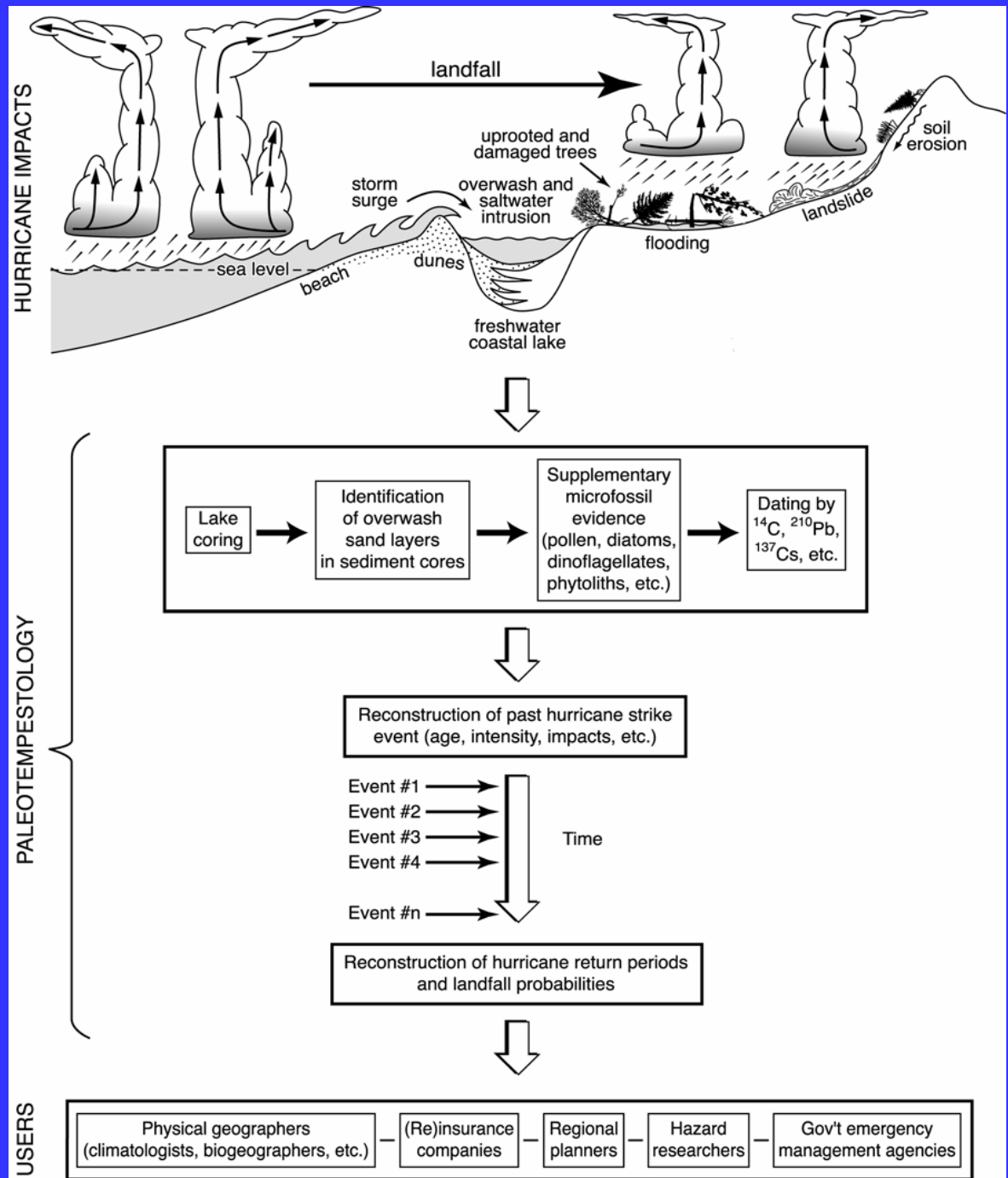
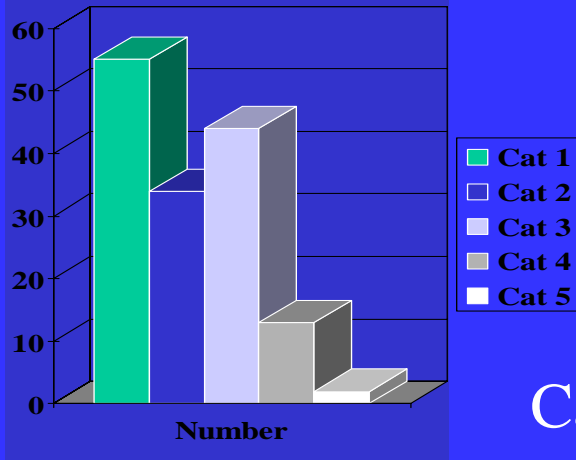# **Paleotempestology**

Principles:

Methods:

Applications:

Users:

Why Study the Past?

- Historical hurricane record only goes back 150 years.

- A long-term perspective is essential in determining the return period of the "Big Ones" (cat 4-5 catastrophic hurricanes).

- Are these 50-year events or 500-year events ?

Category 4 & 5 hurricanes are extremely rare

Multi-decadal variability

1947-1969 ⟶

1970-1987 ⟶

Decadal Variability

(a)

1947 to 1969
(23 years)
Category 3, 4, 5
hurricane tracks

(b)

1970 to 1987
(18 years)
Category 3, 4, 5
hurricane tracks

W. Gray
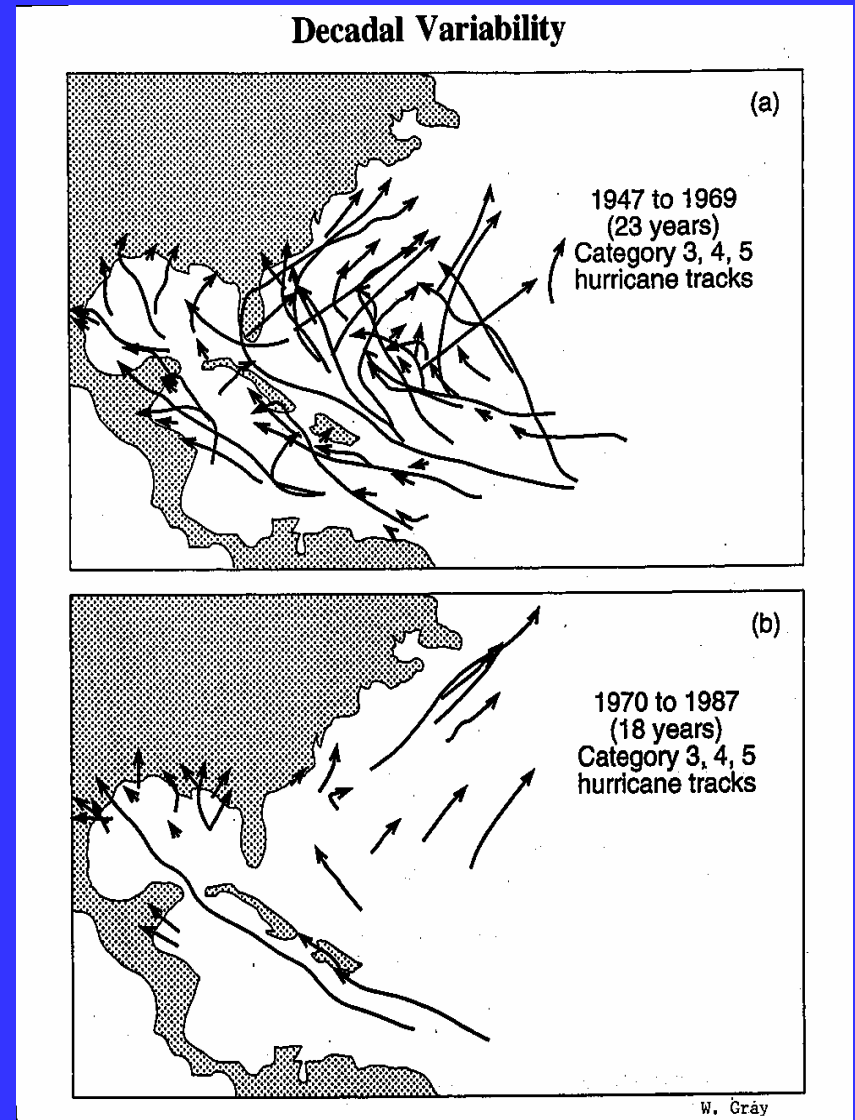
** Are there bigger cycles superimposed on these multi-decadal cycles?

In a nutshell ….

- **Paleotempestology can be used to define and quantity the uncertainty about hurricane risk by generating long-term records of catastrophic hurricane strikes that encompass a much wider range of variability than that contained in the historical record of the last 150 years.**

- **Areas of uncertainty:**
  - **Return period**
  - **Temporal variability**
  - **Spatial variability**
  - **Worst-case scenario**
  - **Future climate change and variability**

Uncertainties about Hurricane Risk

- What is the probability for any specific place on the U.S. coasts to be directly hit by a catastrophic hurricane of category 4 or 5 intensity?

- How does this landfall probability vary temporally, and at what timescales?
  - Do hurricane activities vary from one century (millennium) to the next?

- What about spatial variability along Gulf vs East Coast?
  - What controls hurricane tracks and landfall locations?

- Are the 1940s to 1960s worst case scenario? If not, how bad can it be?

- How are these long-term changes in spatial and temporal patterns related to global climate changes?

Paleotempestology Study Sites

- There are fewer than ten well-dated, well-validated proxy records on the U.S. Gulf coast and Atlantic coast.
- Large data gaps exist.
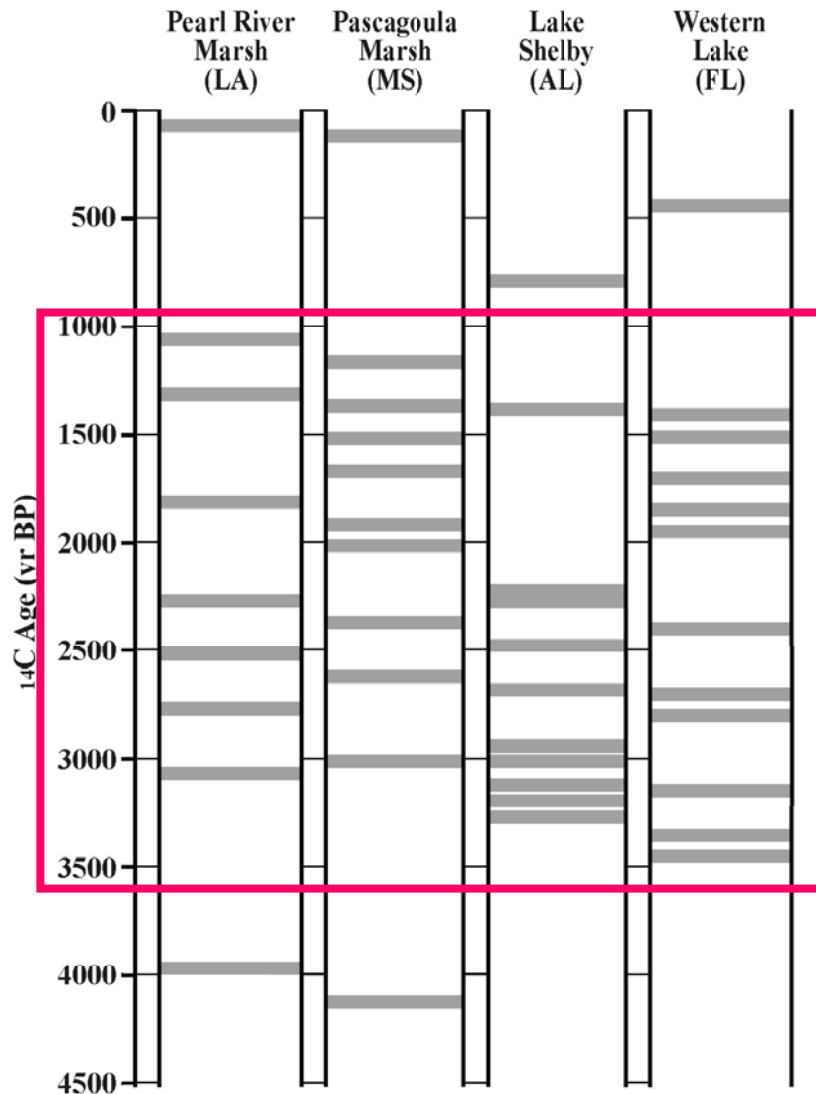- Need more "paleo-weather stations" !
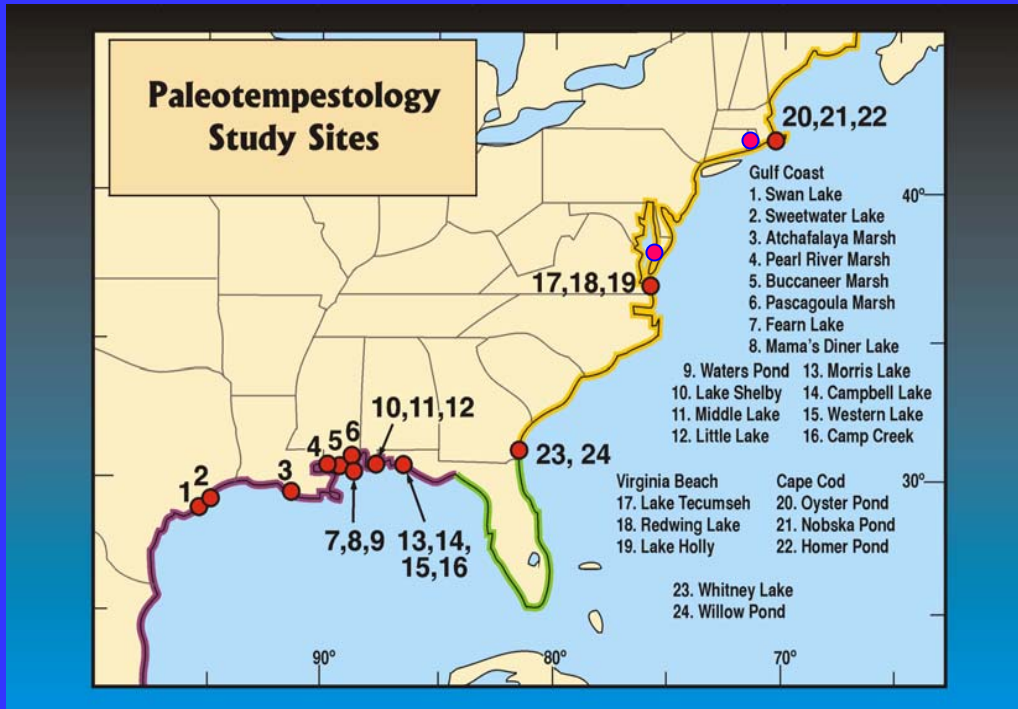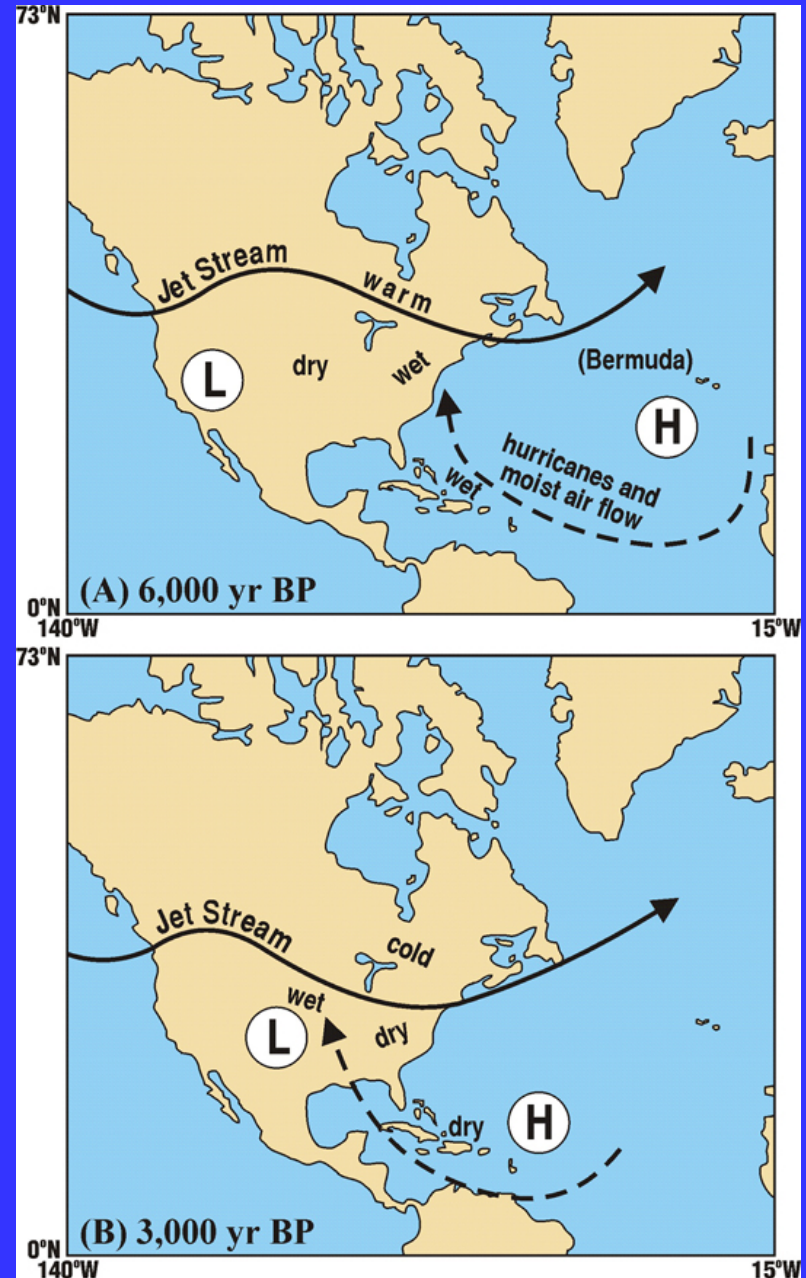

U.S. Gulf coast and Atlantic coast

Caribbean region
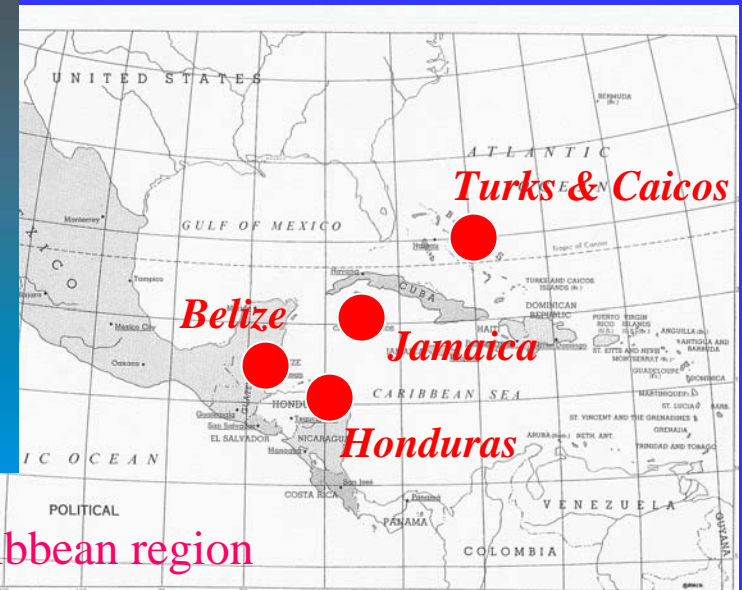
Chronology of Catastrophic Hurricane Strikes along the U.S. Gulf Coast during the last 4500 Years

- Major Findings from Gulf Coast Proxy Records:

- Return period for catastrophic hurricanes = 300 yr
- Millennial-scale variability
- Hyperactive period 3400-1000 yr ago

The Bermuda High Hypothesis

- Bermuda High provides the steering mechanism that determines hurricane tracks

- A southwestward shift of the Bermuda High at 3400 BP steered more hurricanes towards Gulf coast

- Implication: Hurricane activities along the Gulf coast and Atlantic coast should be negatively correlated (anti-phase pattern)

Spatial and Temporal Variability:
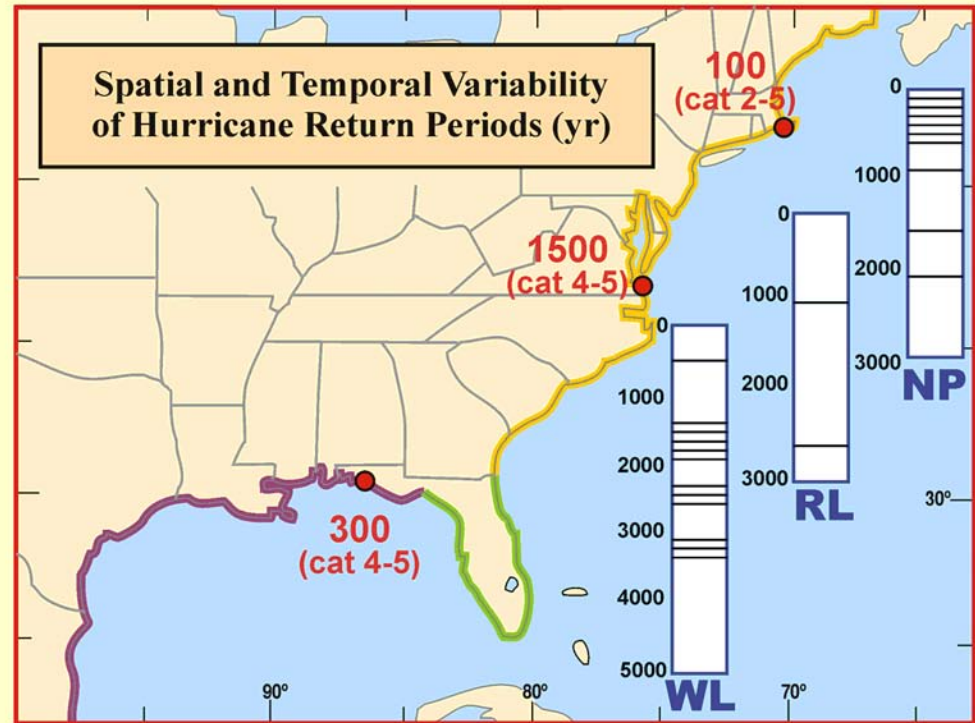
Gulf Coast vs Atlantic Coast

Fig. 18. Summary of proxy records and return periods from Nobska Pond (NP), Redwing Lake (RL), and Western Lake (WL) showing possible anti-phase pattern between the Atlantic coast and Gulf coast.

- Data support the hypothesis that hurricane activities along the Gulf Coast and Atlantic Coast are in a see-saw (anti-phase) pattern controlled by the Bermuda High.

- U.S. East Coast is in the active phase in the long-term hurricane activity cycle.

Is there a link between hurricane and fire ?
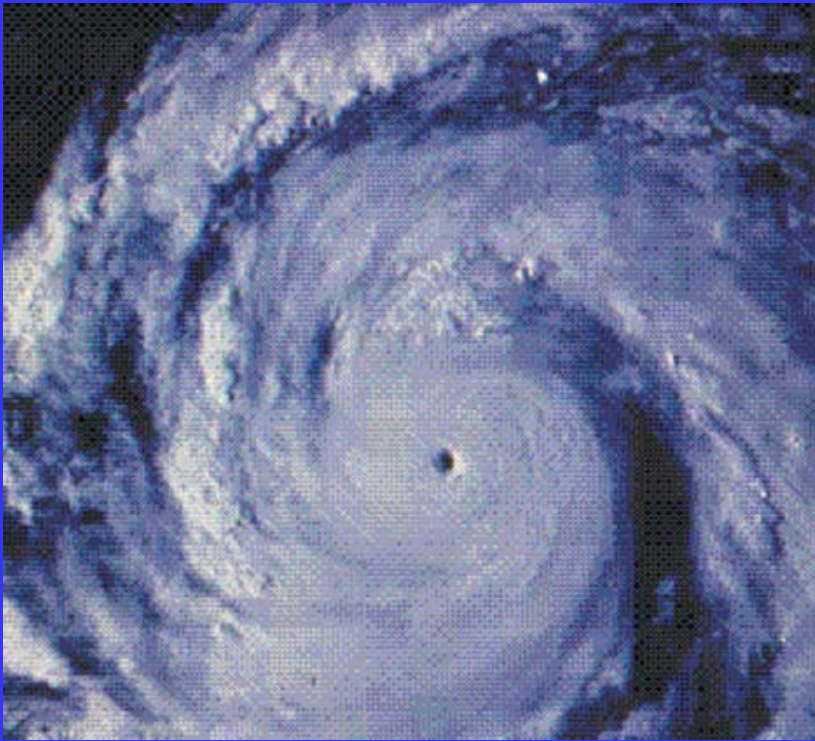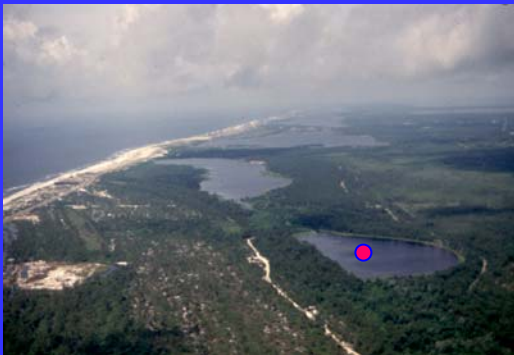

Hypothesis of hurricane-fire interactions: Fire hazard increases significantly after a major hurricane strike due to fuel accumulation (dead biomass).
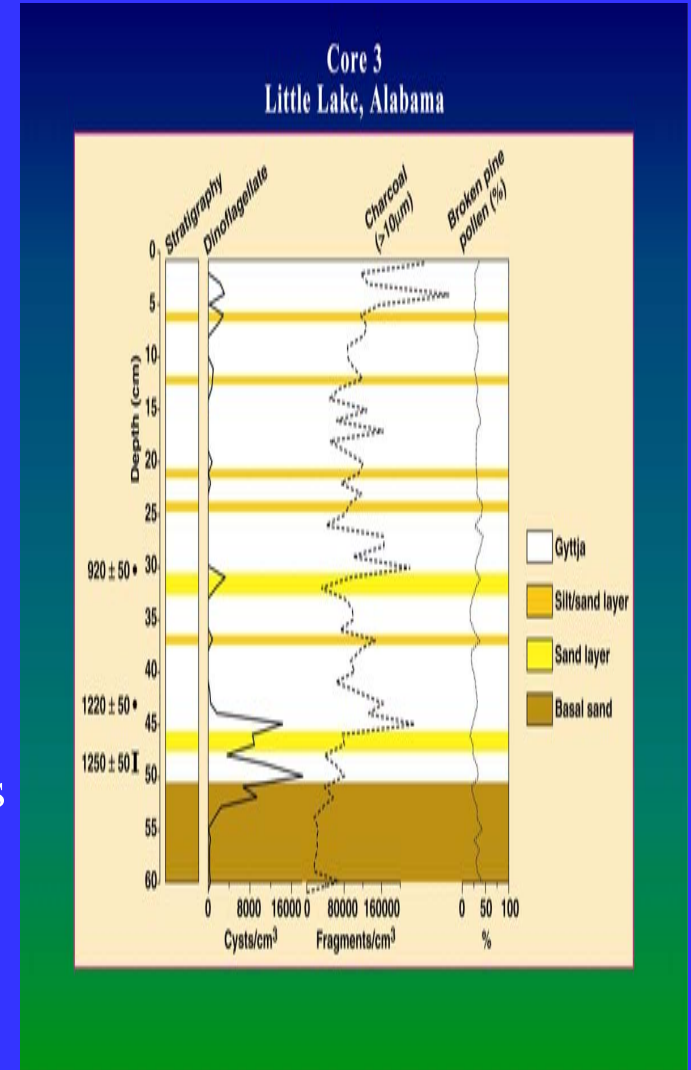
Increased hurricane activity also means increased fire risk

Ivan's ecological impacts: massive tree mortality

Occurrence of charcoal peaks above sand layers indicates catastrophic wildfires after major hurricane strikes.

Lessons Learned from Paleotempestology

- Paleotempestology helps us understand the climate mechanisms controlling hurricane activities (e.g., Bermuda High & storm tracks)

- For Gulf coast locations, catastrophic hurricanes (cat 4-5) have a return period of ca. 300 years ($p = 0.3\%$/yr)

- 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 (upper limit of hurricane risk).

Paleotempestology – Implications for Decision-making

- 100-billion-dollar question: *What is the probability for any U.S. coastal location to be directly hit by a catastrophic hurricane?*
- How would a worst-case scenario of a quadrupled hurricane risk impact the insurance industry, real estate market, population growth, and migration pattern of a coastal region?
- In rebuilding New Orleans, should we construct a levee system that can only withstand a category 3 hurricane?
- Regional planning; building codes; real estate values; tourism
- Disaster management and Emergency response
- Future: Sea-level rise and global warming; coastal communities

Hong Kong

Cancun

Pressing Issues in Paleotempestology

Barriers:
- Need to inform public (decision-makers) on need for long-term perspective (outreach)
- Need more funding to support both basic science and applications

Information needs:
- Need more well-dated, well-validated records ("paleo-weather stations") from data gaps
- Caribbean region

Research priorities:
- Increase regional data networks
- Use modern analogs (e.g., Ivan, Katrina) to calibrate proxy records
- Encourage paleoclimate model-data comparison
- Development of multiple proxies

Communications:
- Improve communications with stakeholders, e.g., Corps of Engineers, FEMA, risk managers
- Increase collaboration & partnership among scientists, industry, & government
- Increase collaboration between paleotempestologists & decision/social scientists
- Increase multi- and cross-disciplinary collaboration