# Reconstructing Holocene Hydroclimate from the Sediments of Ombrotrophic Peatlands

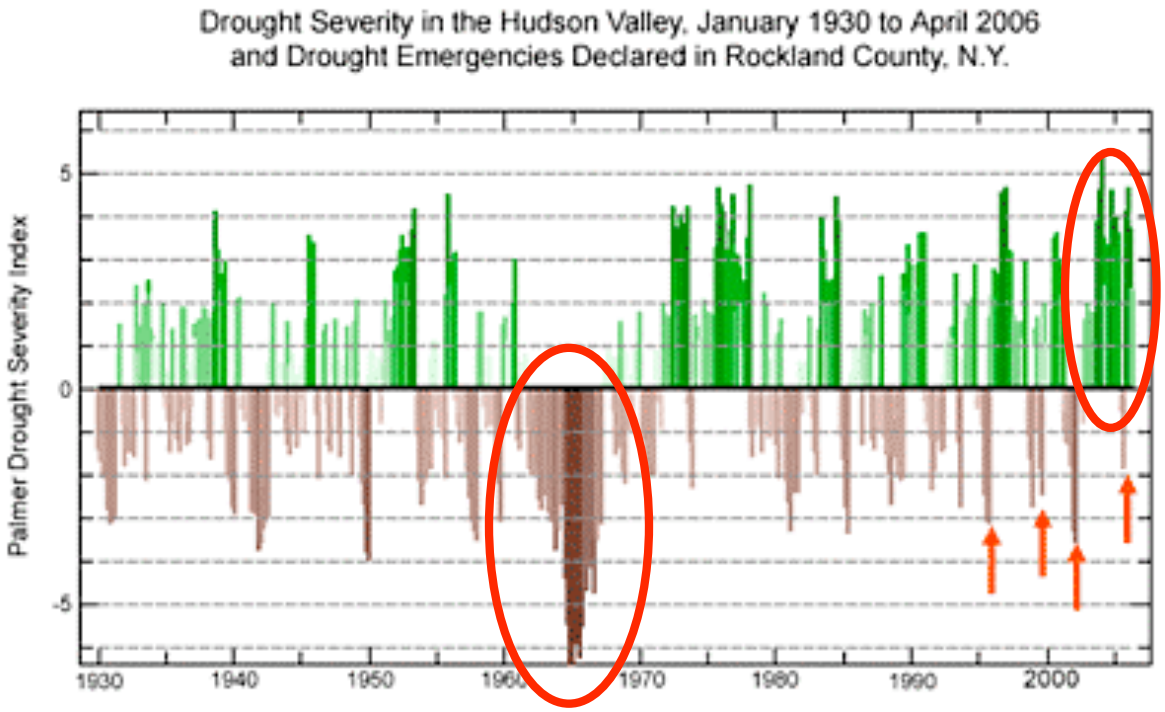
Jonathan E. Nichols

NASA Postdoctoral Program Fellow (NPP)

Goddard Institute for Space Studies

# Implications of Hydroclimatic change

Boston Globe/AP Photo



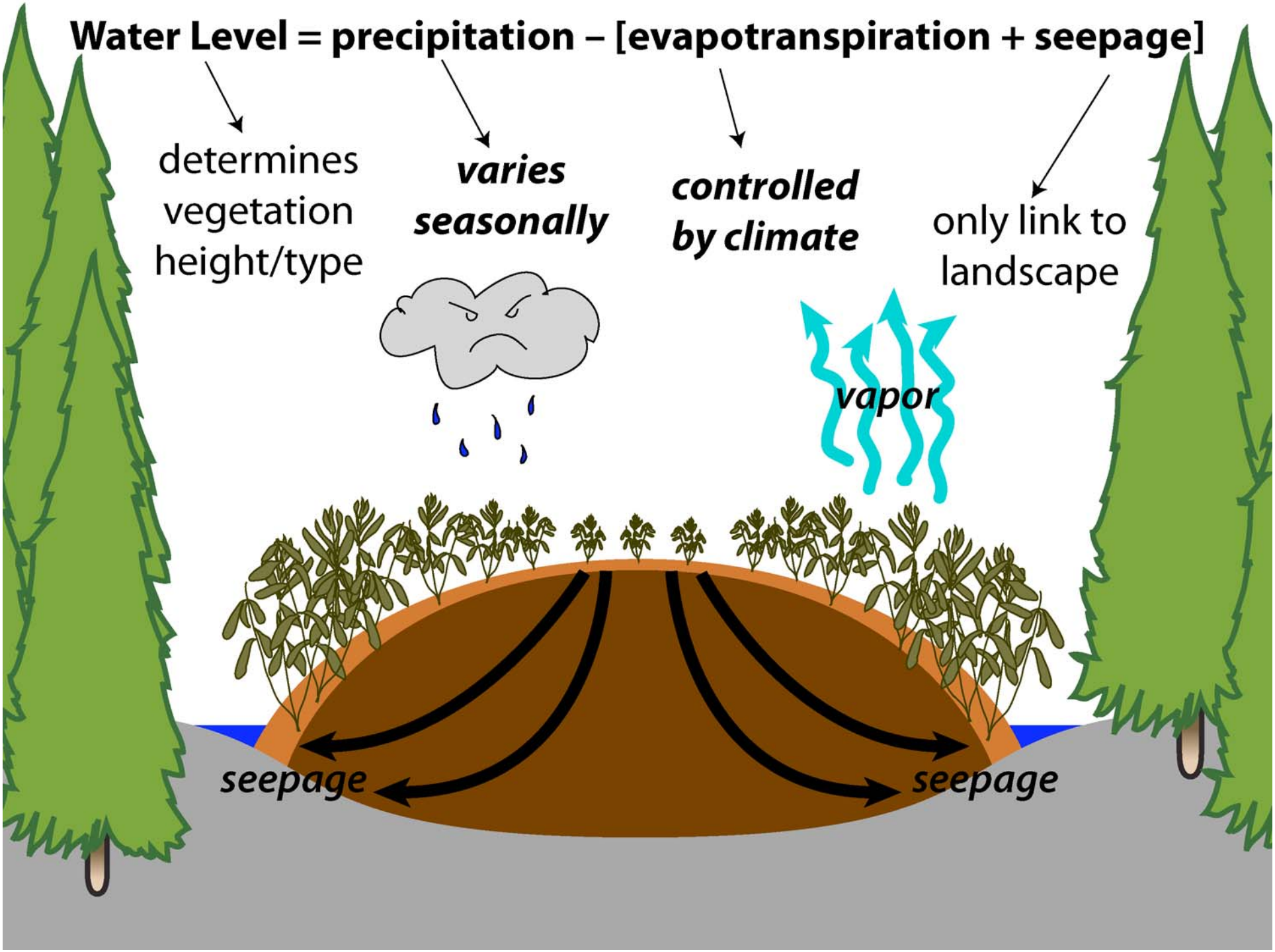
http://www.earth.columbia.edu/

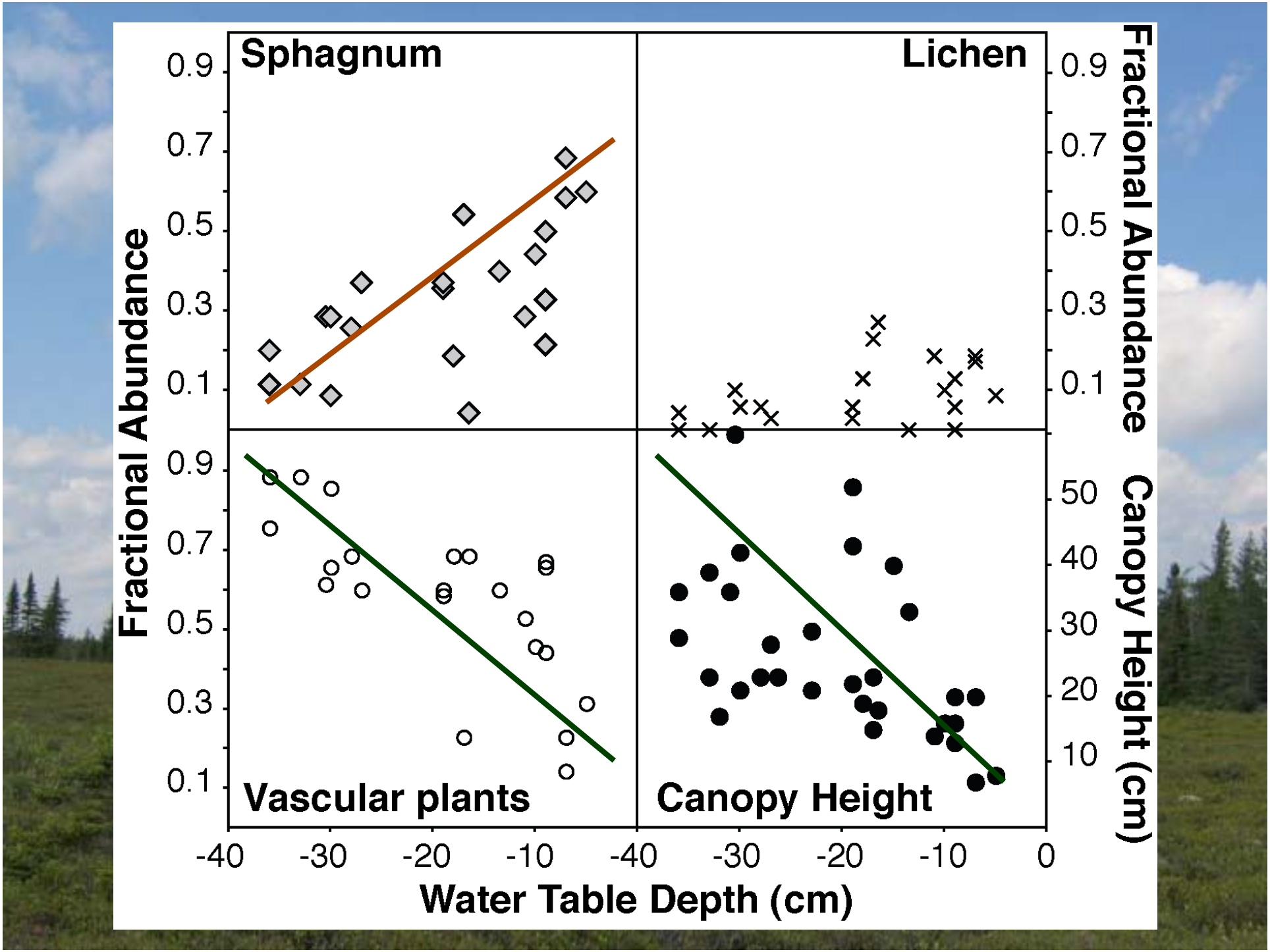
# Why Peatlands?

- Extremely sensitive to hydrologic change
  - Only input is precipitation
- Common features of recently glaciated, moist regions
- High acidity and anoxia preserve fossil molecules well (among other things)
- Cover 3% of Earth's surface but contain 30% of soil carbon

# Two Purposes

- Develop more *quantitative* proxies for hydroclimatic & carbon cycle parameters
- Apply new proxies to develop hypotheses about mechanisms of climate change


Water Level = precipitation – [evapotranspiration + seepage]
determines vegetation height/type
varies seasonally
controlled by climate
only link to landscape
vapor
seepage
seepage


Sphagnum
Lichen
Vascular plants
Canopy Height
Fractional Abundance
Fractional Abundance
Canopy Height (cm)
Water Table Depth (cm)
0.9
0.7
0.5
0.3
0.1
50
40
30
20
10
-40
-30
-20
-10
0

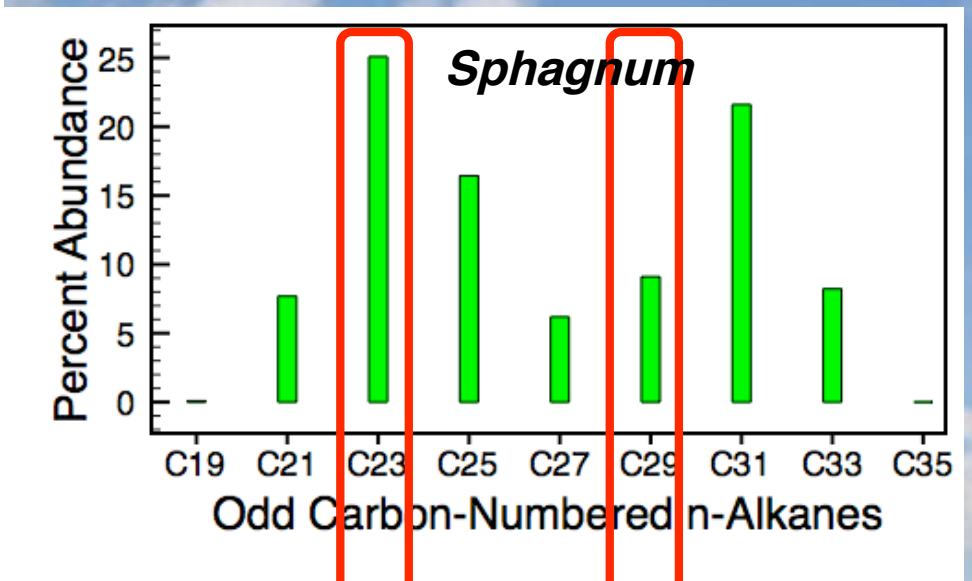
# New Peatland Proxies

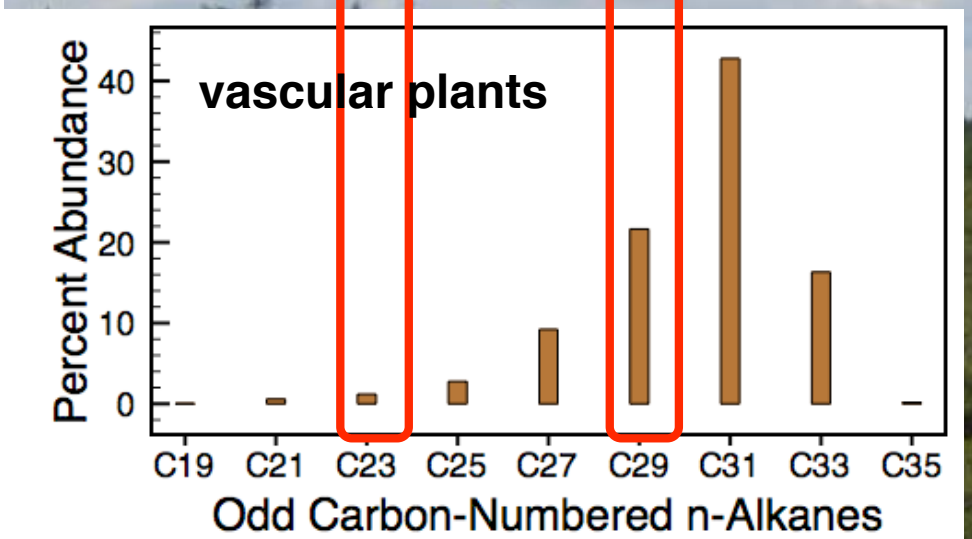
1. *Sphagnum*/Vascular Ratio (**SVR**)

2. Hydrogen Isotopes of Precipitation (**$\delta D_P$**)

3. Evaporation Remainder (***f***)

# *n*-Alkanes as Biomarkers

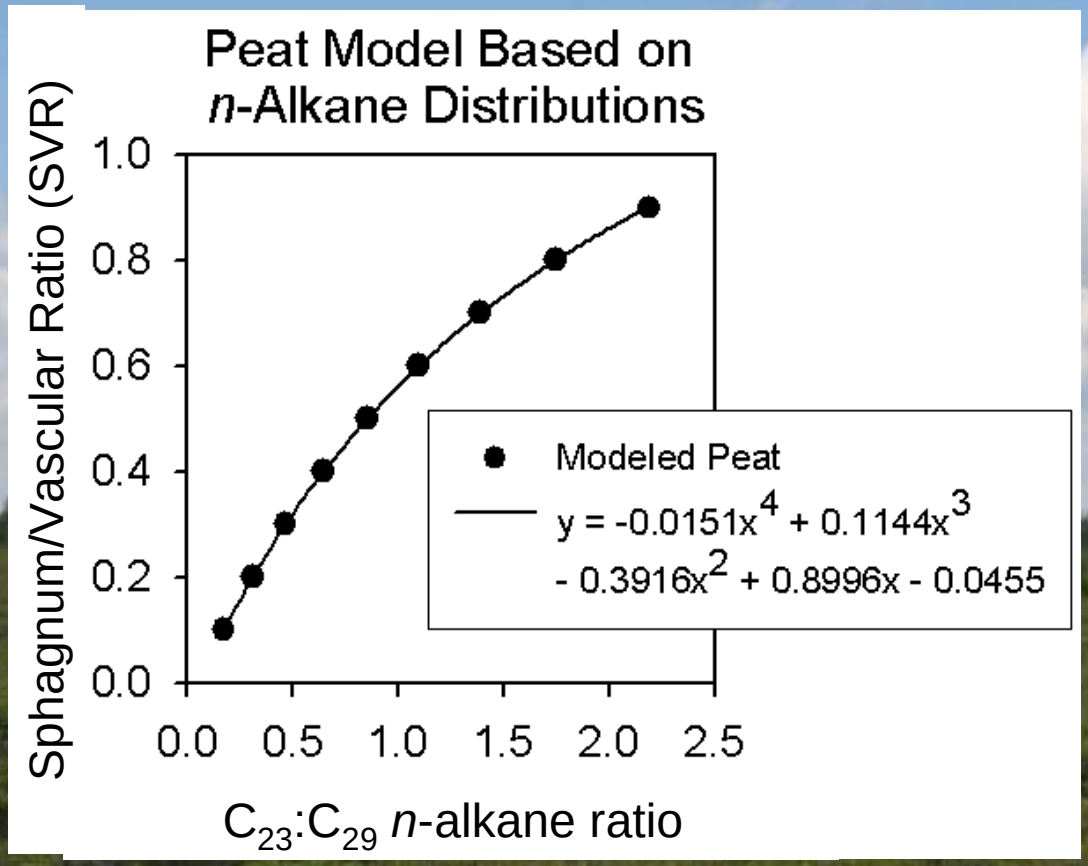



- *Sphagnum* and vascular plants have different average *n*-alkane distributions
- We can take advantage of this difference to measure changes in hydrology
- A ratio of $C_{23}$ to $C_{29}$ n-alkane in peat samples shows the relative productivity of each group

# *Sphagnum*/Vascular Ratio (SVR)

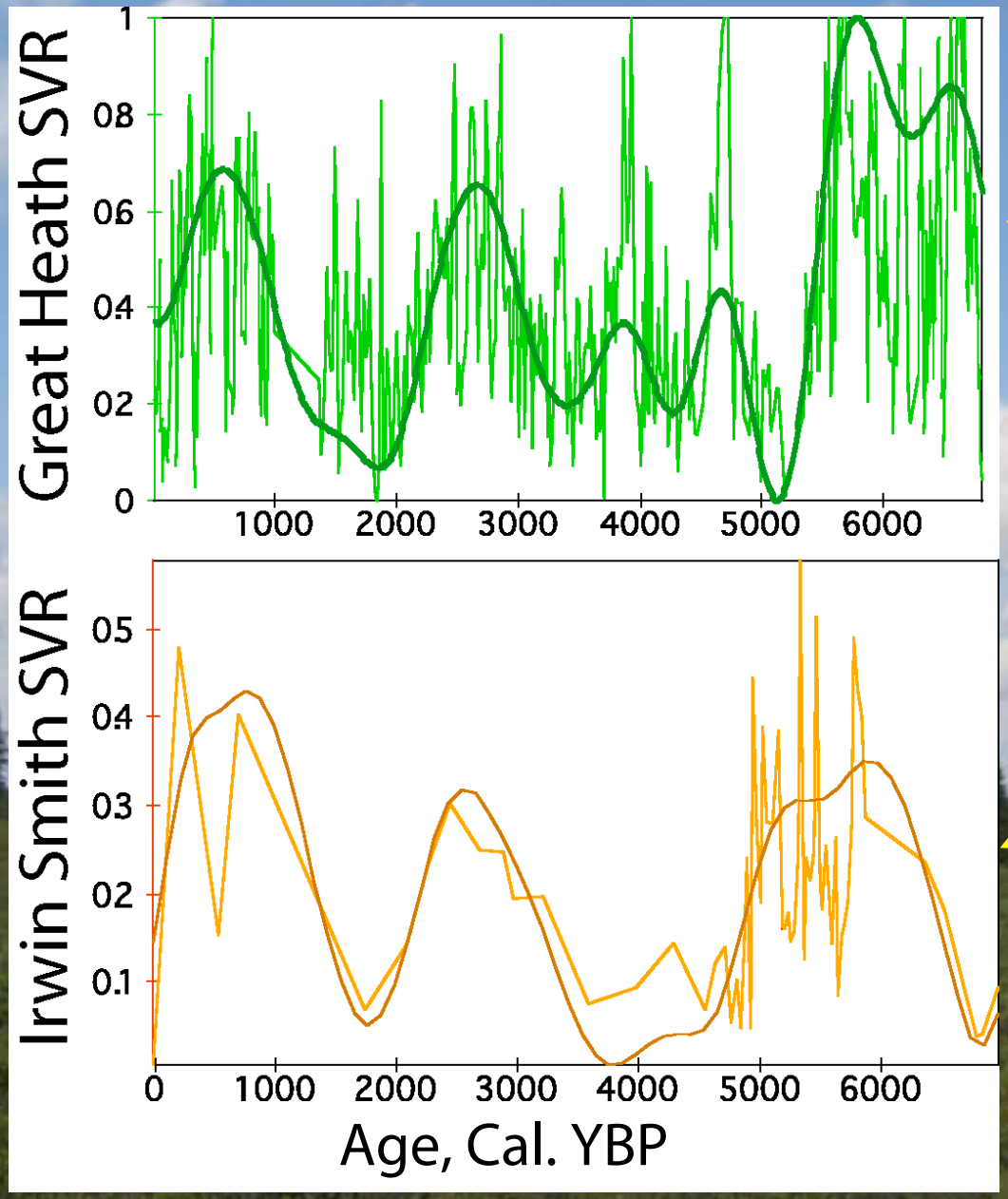
A two-part mixing model translates the $C_{23}$:$C_{29}$ ratio in a peat sample into a *Sphagnum* to vascular plant productivity ratio (SVR)

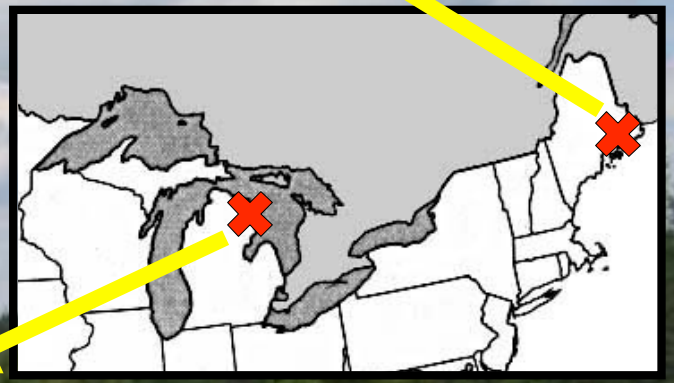



***Wet conditions***:
*Sphagnum* prospers
More $C_{23}$, **High SVR**

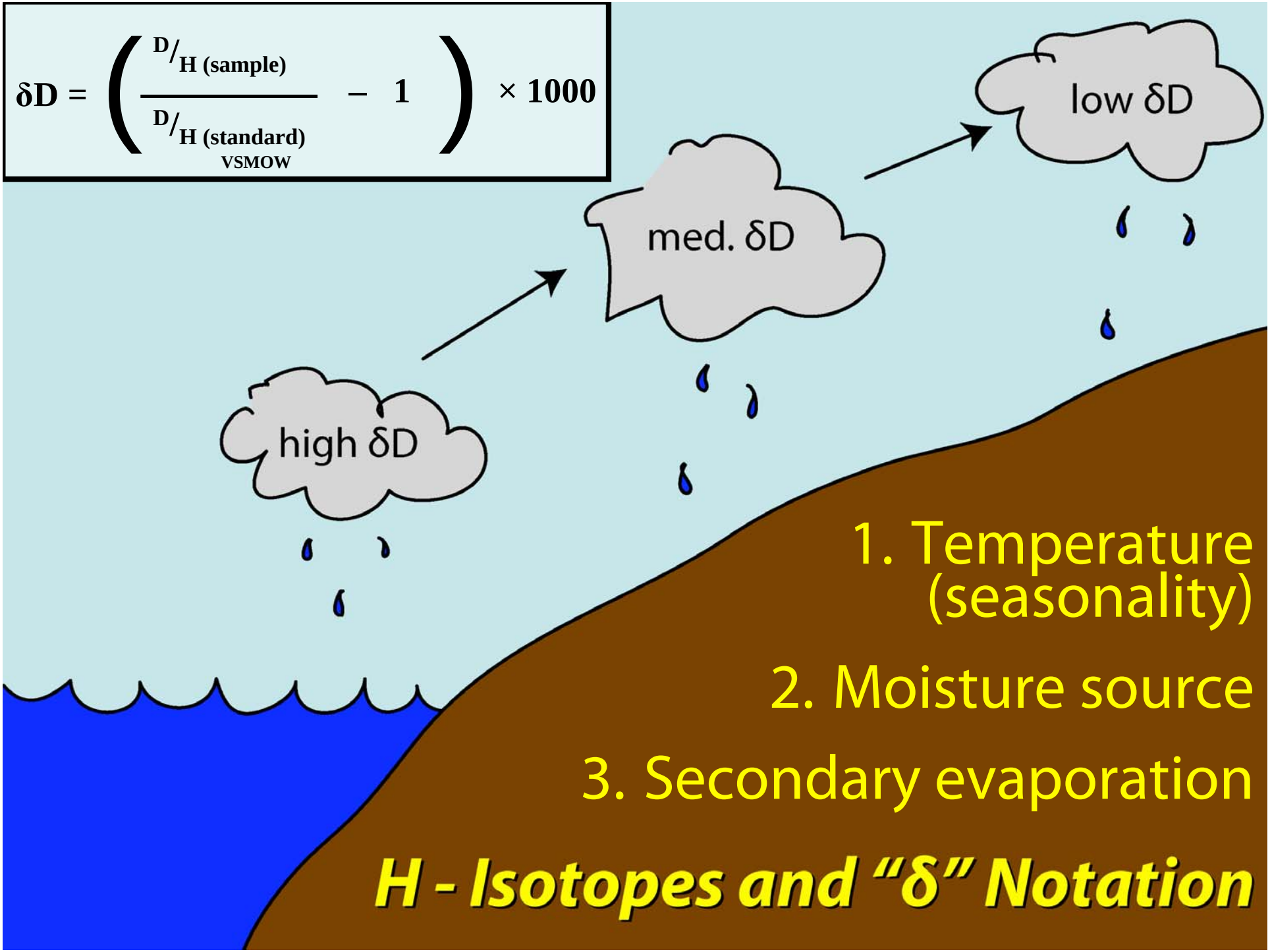
***Dry conditions***:
*Sphagnum* dries out and vascular plants are more productive
More $C_{29}$, **Low SVR**

# Similar Changes in Distant Peatlands



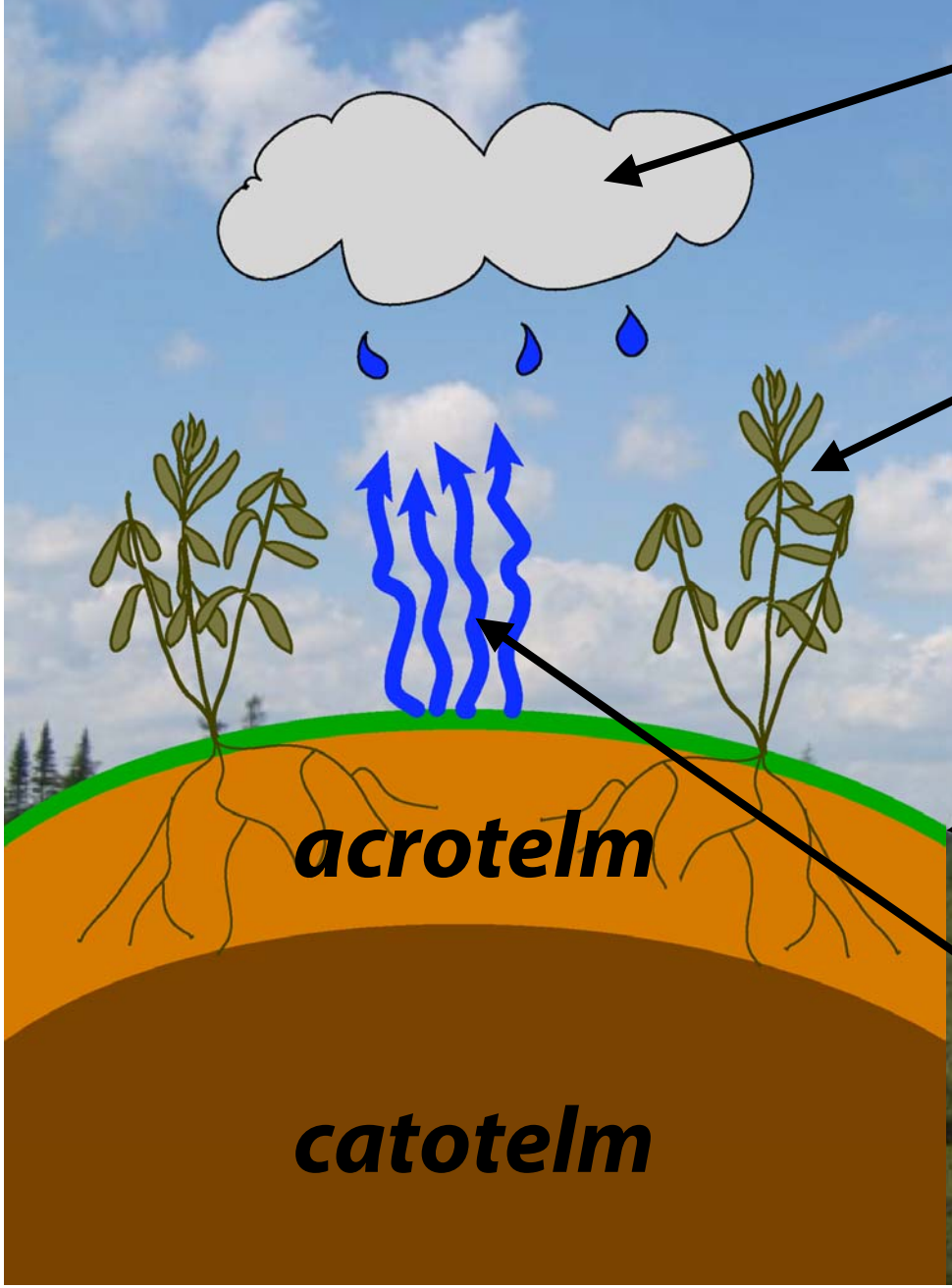
$$\delta D = \left( \frac{{}^{D}/_{H\ (sample)}}{{}^{D}/_{H\ (standard)}\ \text{VSMOW}} - 1 \right) \times 1000$$




1. Temperature (seasonality)
2. Moisture source
3. Secondary evaporation

# *H - Isotopes and "δ" Notation*

# *Hydrogen Isotopes and Peatland Hydrology*



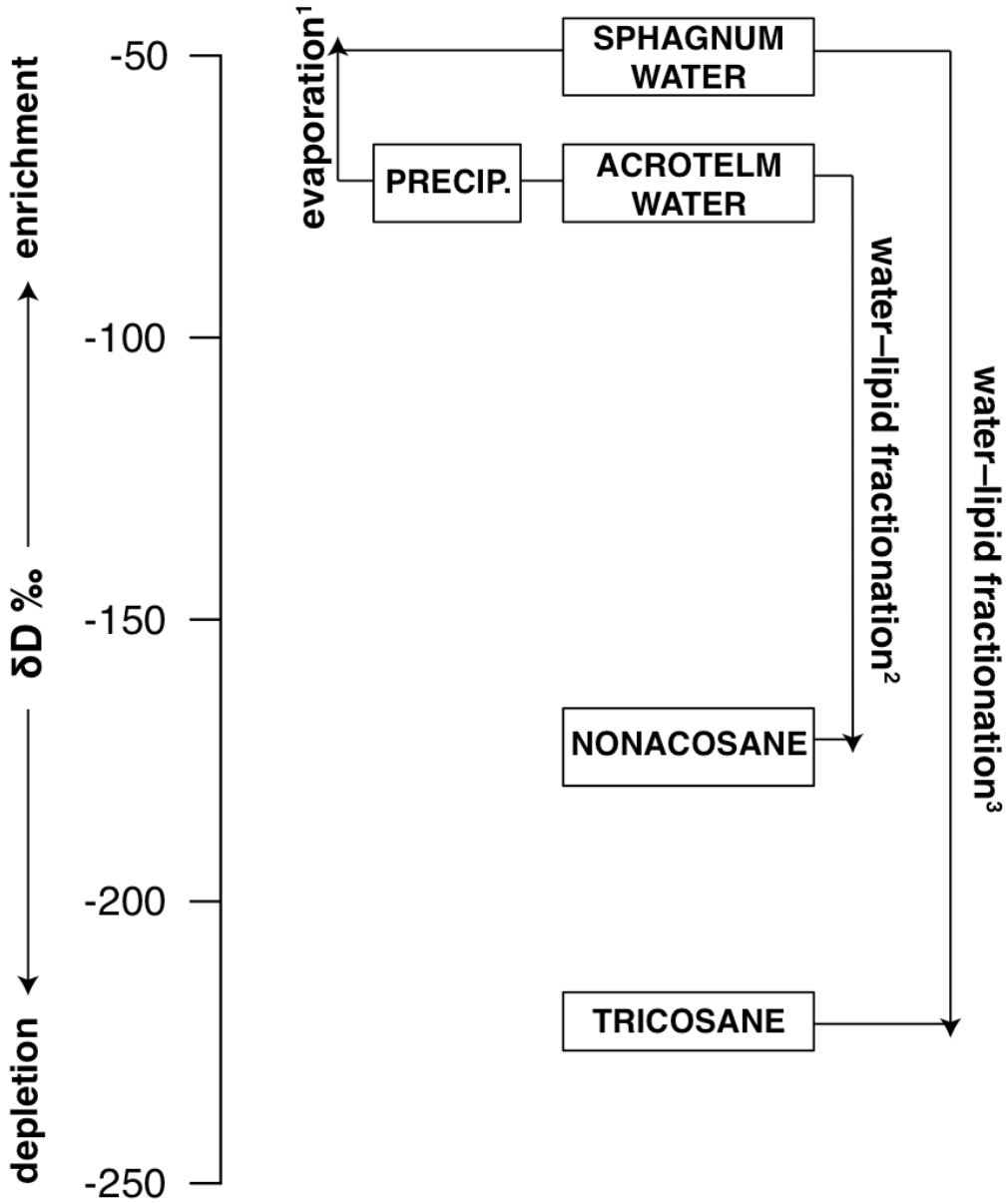

**Rain** Falls on the Bog and percolates to the **acrotelm**.

**Vascular plants** use the acrotelmic water which is *not* enriched by evaporation

While ***Sphagnum*** uses water at the surface

Which *is* enriched by **evaporation**

# Isotope Ratio Change Schematic




**Rayleigh Evaporation Model:**

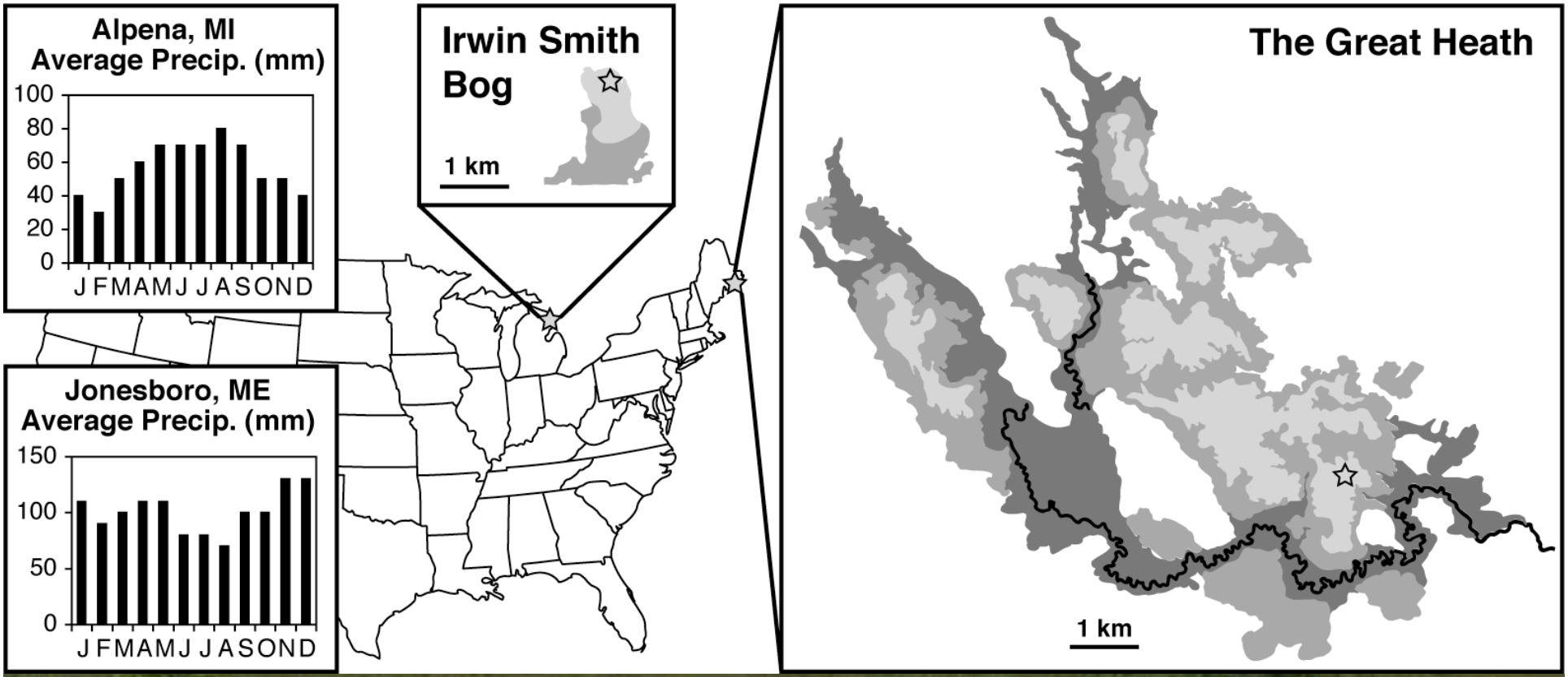
$$\ln f = \frac{\delta D_a - \delta D_s}{\varepsilon_k + \varepsilon^*}$$

We trace precipitation δD and evaporation back from sedimentary lipids

# Climate Questions

1. Mid-Holocene abrupt climate shifts
2. North Atlantic region: hydroclimate change forcings? Mechanisms?

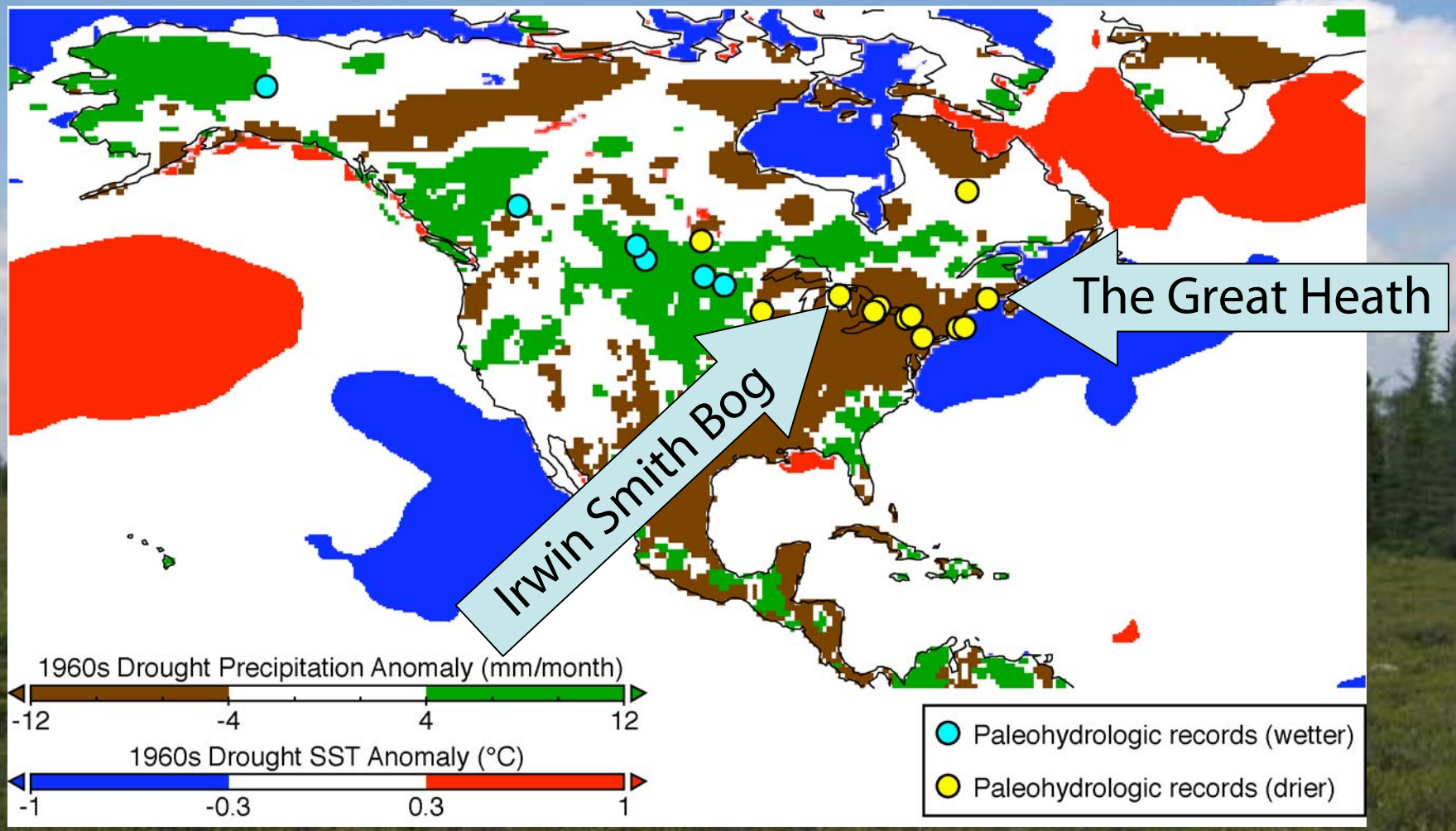
# Site Locations and Monthly Precipitation at Nearest Weather Stations



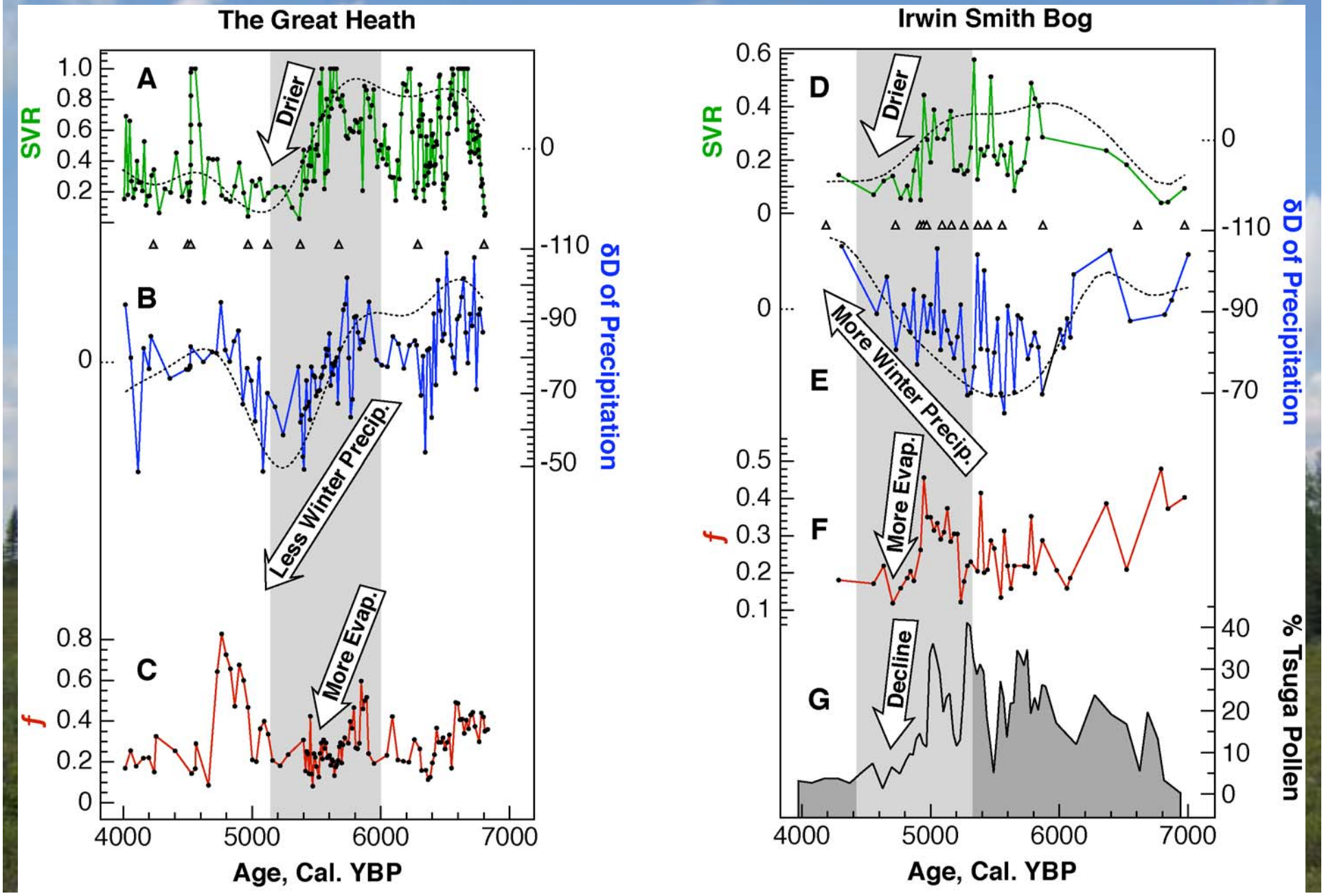
# Mid-Holocene Transition

- Global changes in hydroclimate at ~5.5ka
- Manifests as abrupt shift toward **dry** conditions in eastern North America
  - Contributed to the Hemlock Decline (abrupt ecological change)
- Drought from modern era as an analogue:
  - "1960s Drought" 1962–1965

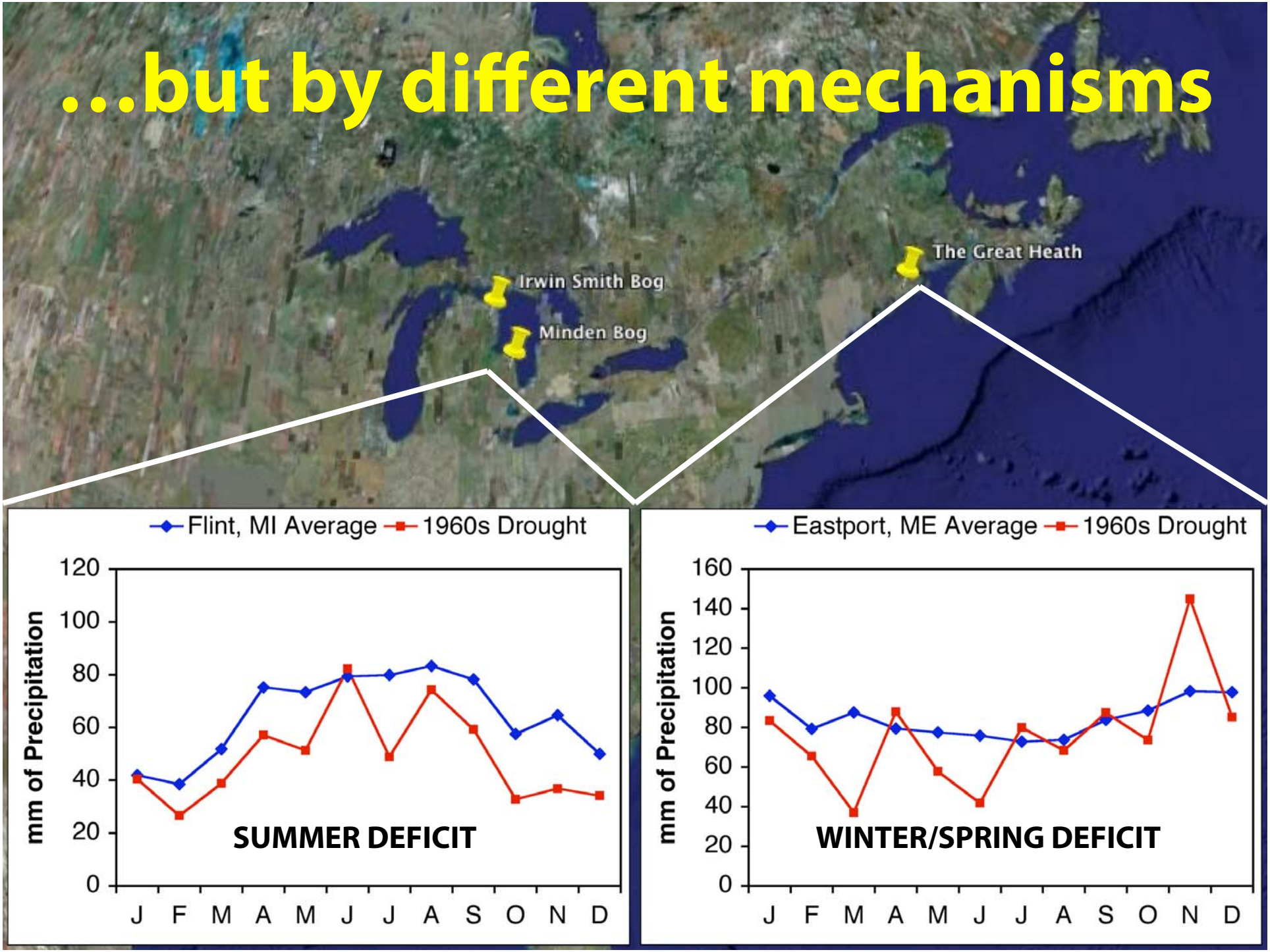
# 5.5ka Paleohydrologic Records
# **AND**
# 1960s Drought Anomalies



# Both locations experience drought…

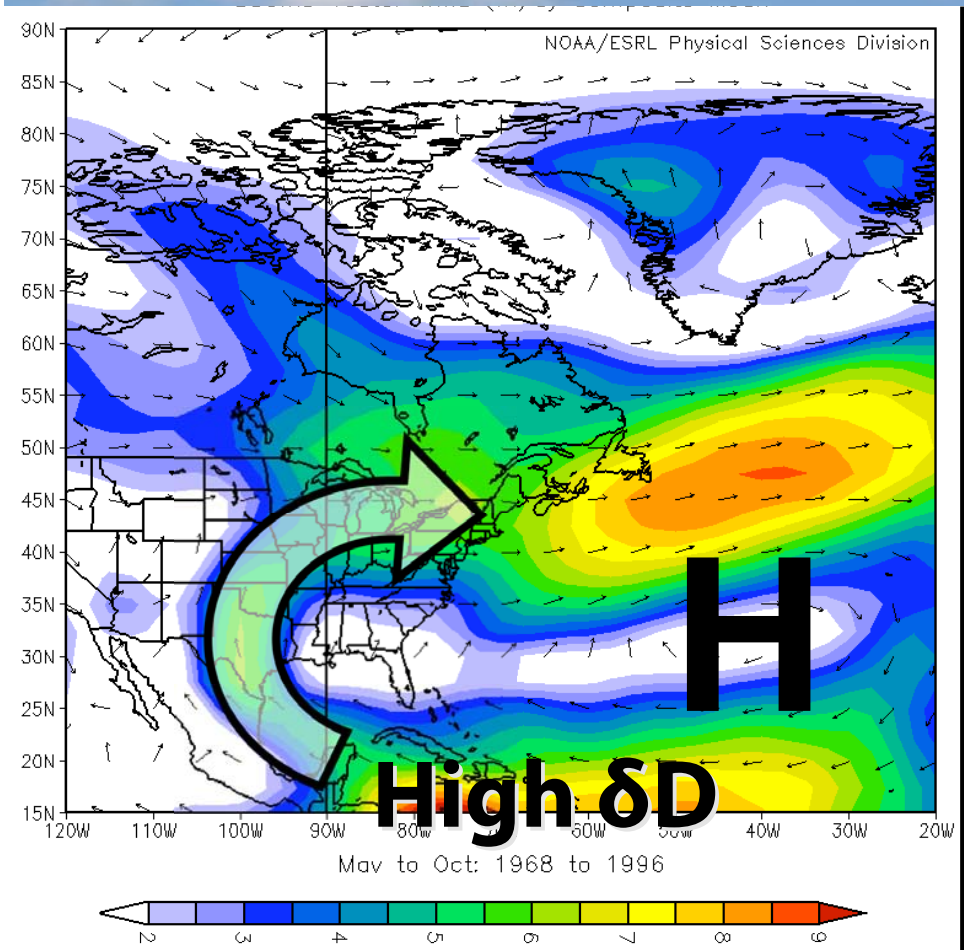


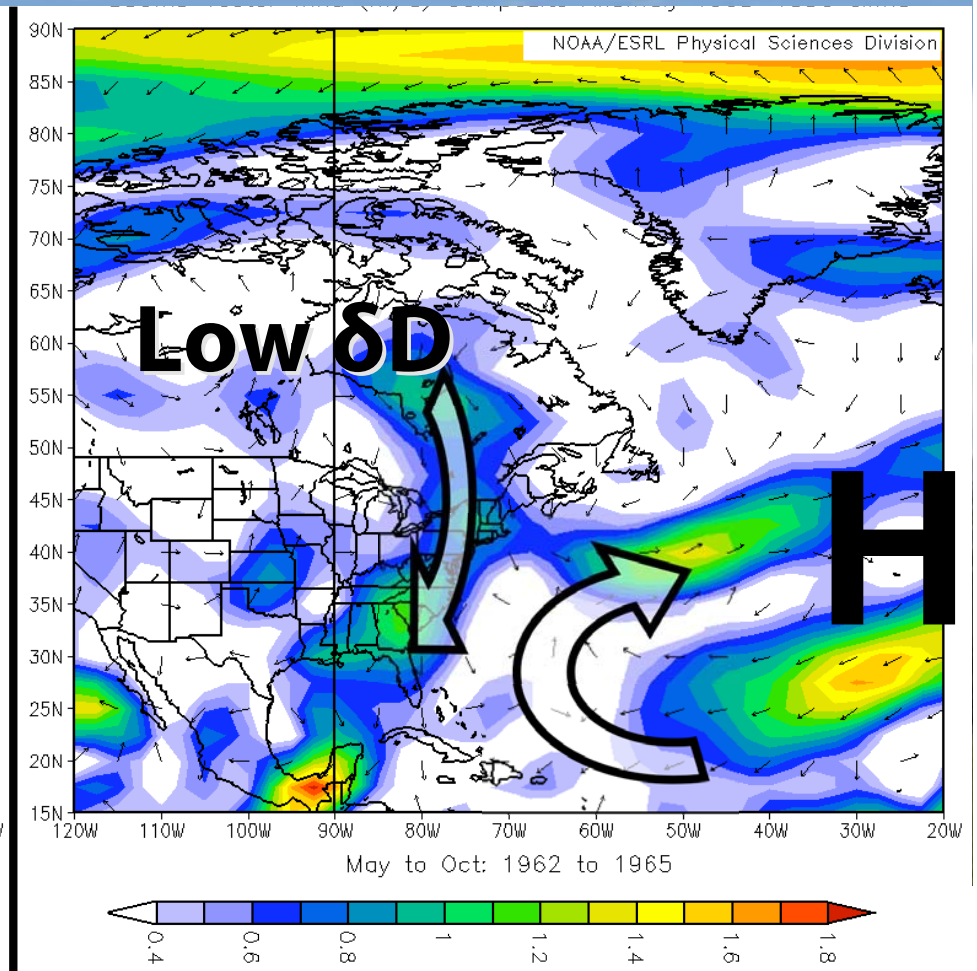
# …but by different mechanisms



# Summer Mechanism: Subtropical High Position

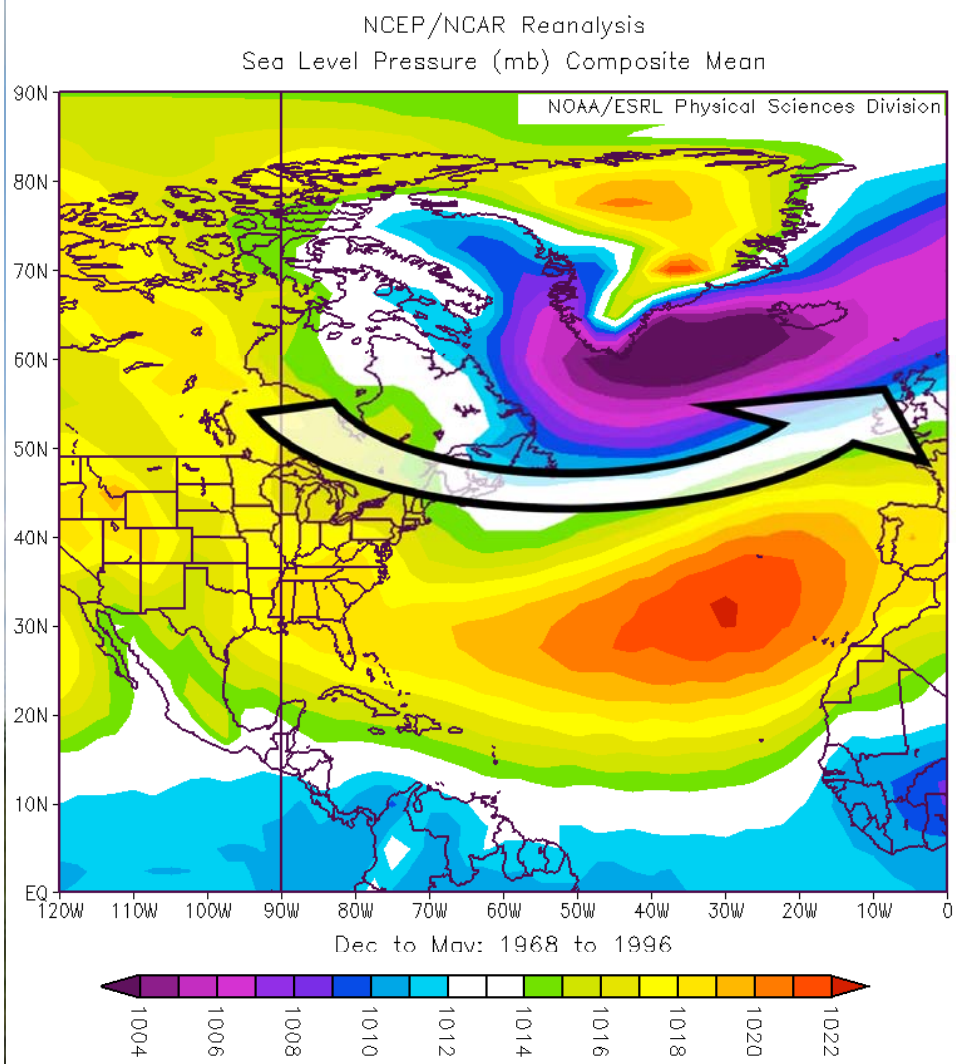
## 850mb Wind Vectors, May-Oct.

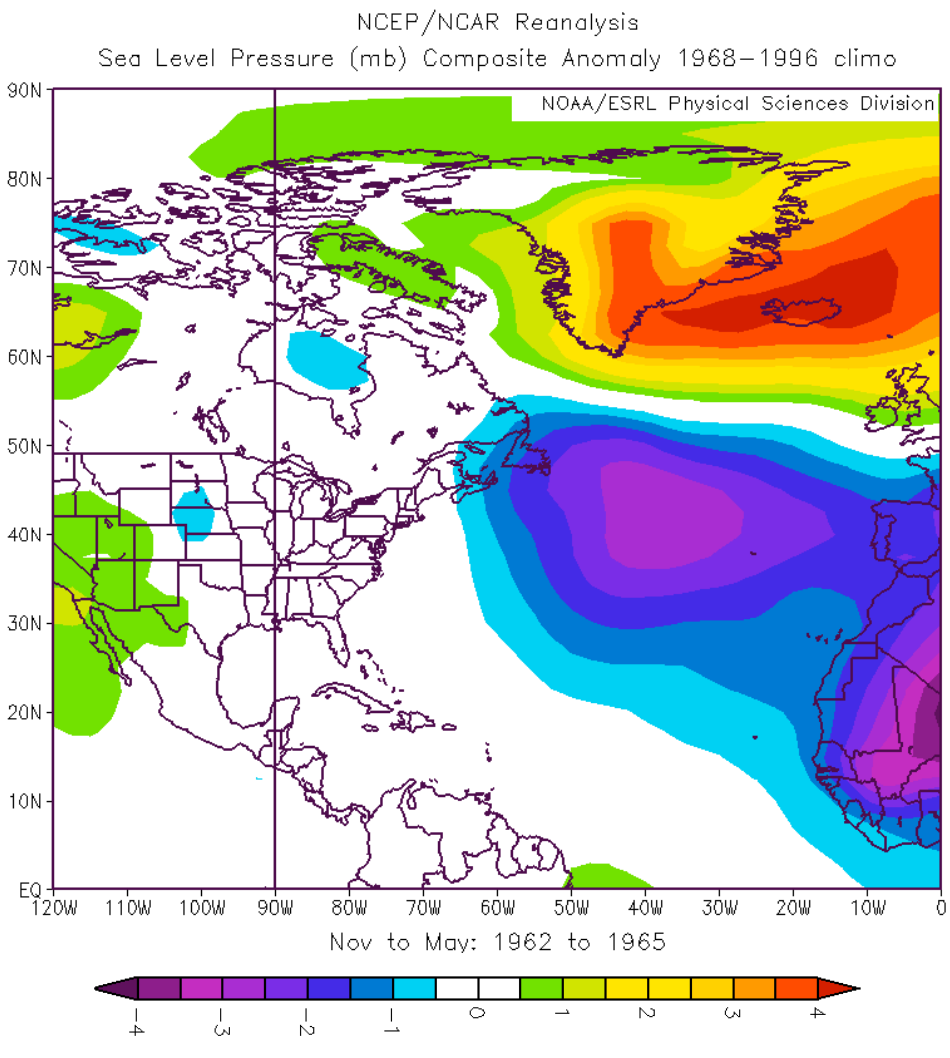



**Mean** **1962-1965 Anomaly**

# Sea Level Pressure, Nov. - April



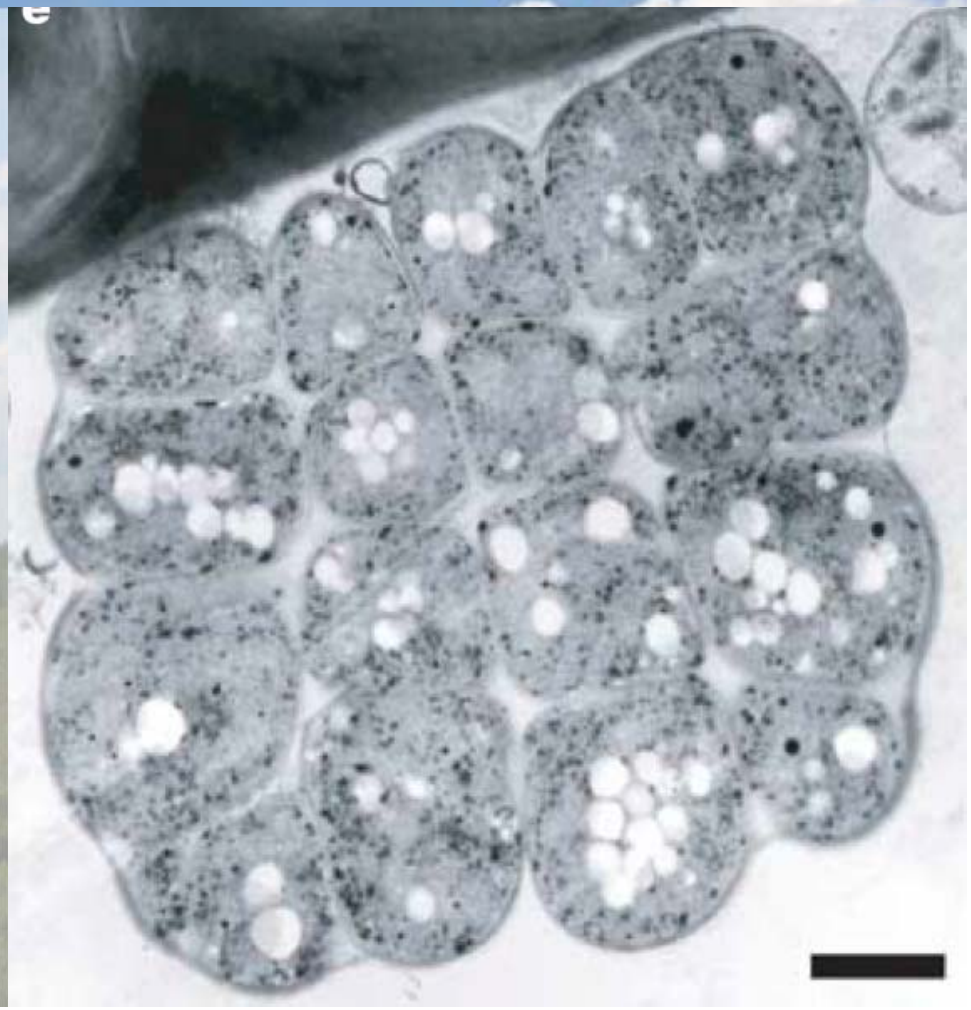




**Mean**

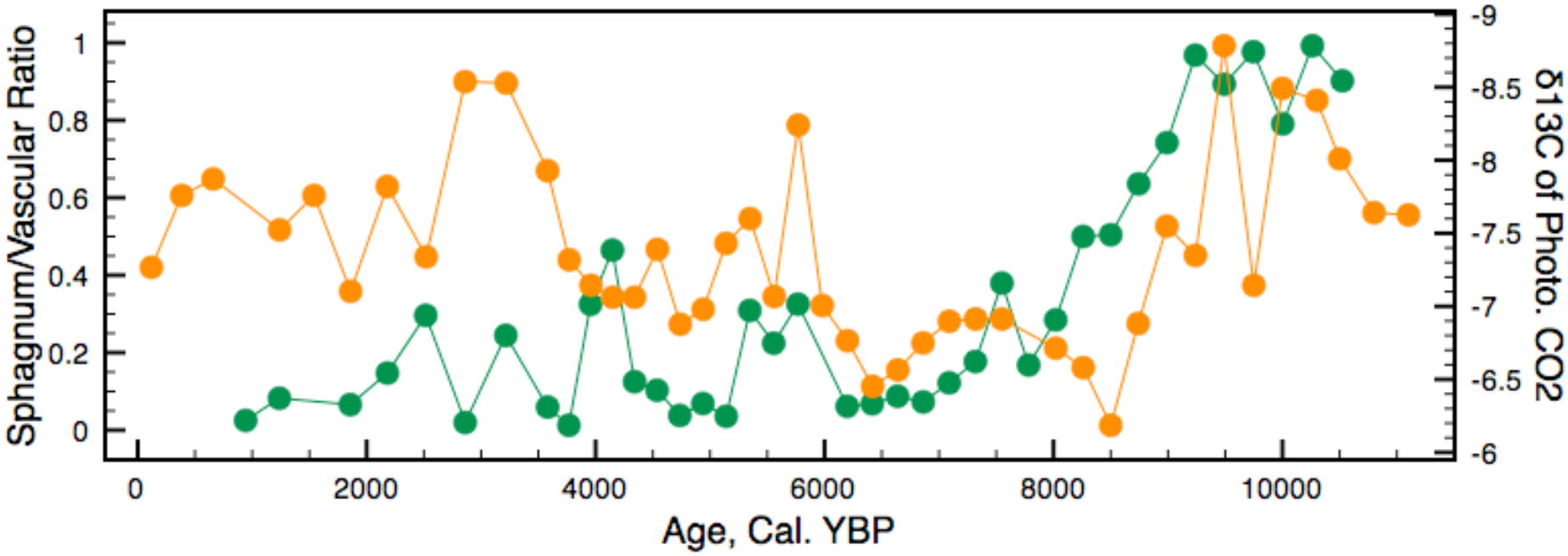
**1962-1965 Anomaly**

# Carbon

- Northern Peatlands: 3% of land area but 30% of soil carbon
- 5–10% of atmospheric methane load
- Methane flux is strongly dependent on hydrology
- Symbiotic methanotrophs provide $\delta^{13}C$ depleted $CO_2$



Wetter conditions --> more methane reaches surface




More methane at surface --> lower $\delta^{13}C$ of sphagnum biomarkers

# Summary

- New Peatland Hydrologic Proxies
  - **SVR** – total hydrologic balance
  - **δD of $C_{29}$ n-alkane** – δD of precipitation
  - ***f*** – evaporation remainder
- Mechanisms for North Atlantic Climate Change
  - Subtropical High Position
  - NAO-like mode of variability
- Future work will provide mechanistic understanding of hydrology/methane feedback

# Thank You

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