

Abrupt Climate Change: A BRIEF Overview

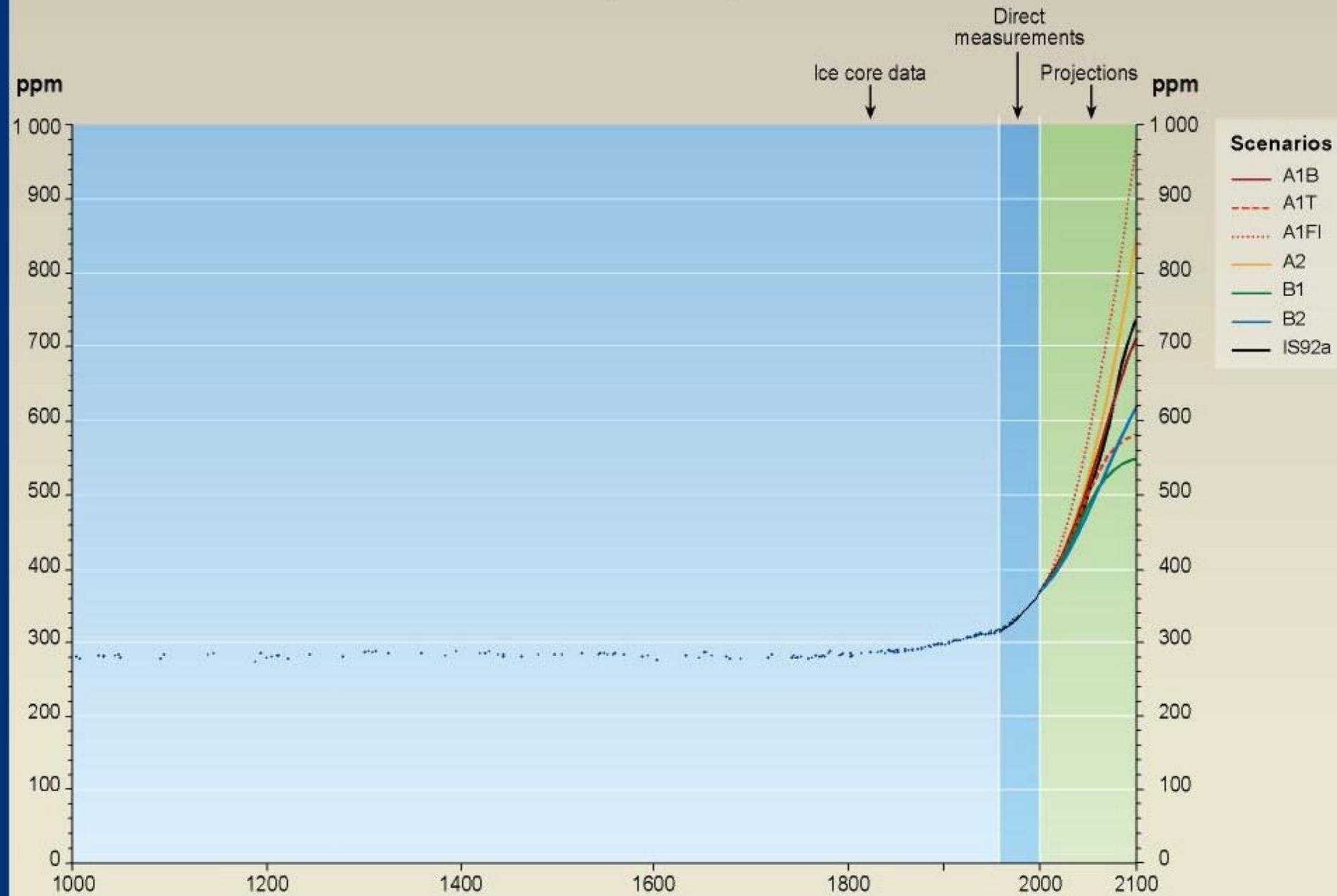
Richard B. Alley

Evan Pugh Professor of Geosciences
The Pennsylvania State University

Humans are changing climate (UN-IPCC story):

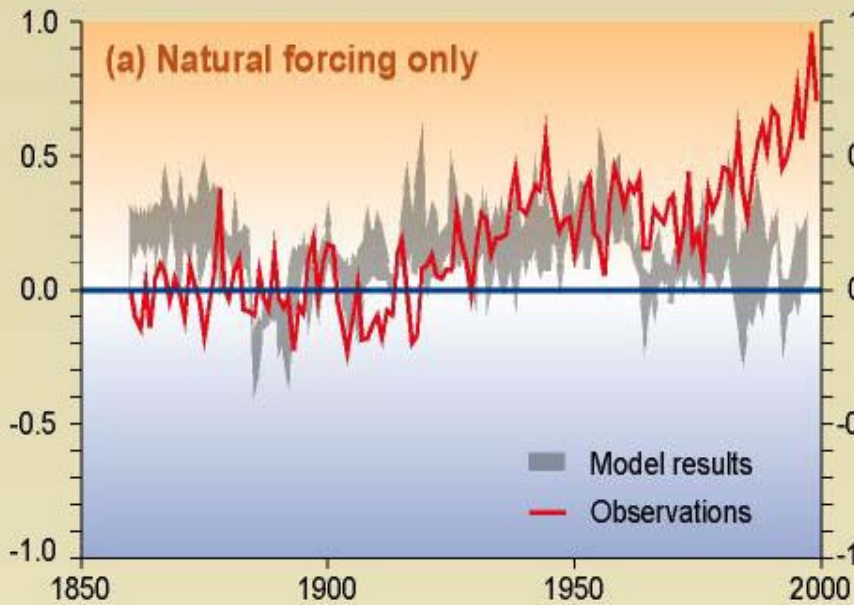
- We're changing atmosphere (ice-core and instrumental histories of gases);
- World is warming (thermometers, melting glaciers, warming ground & oceans agree);
- Attribution exercise (early 20th century mostly natural changes, latter 20th century mostly human changes with nature apparently pushing toward cooling a bit);

Past and future CO₂ atmospheric concentrations

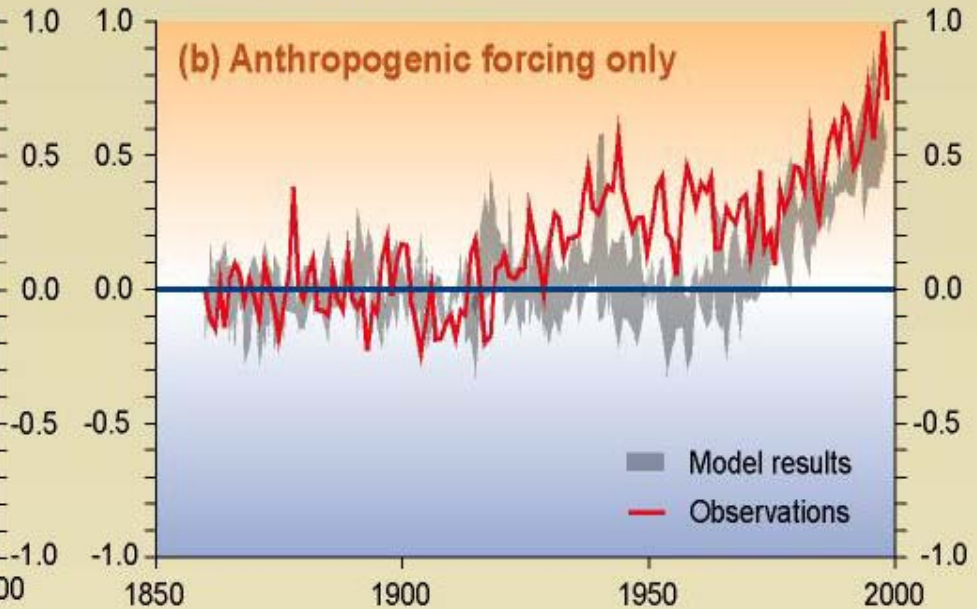


Comparison between modeled and observations of temperature rise since the year 1860

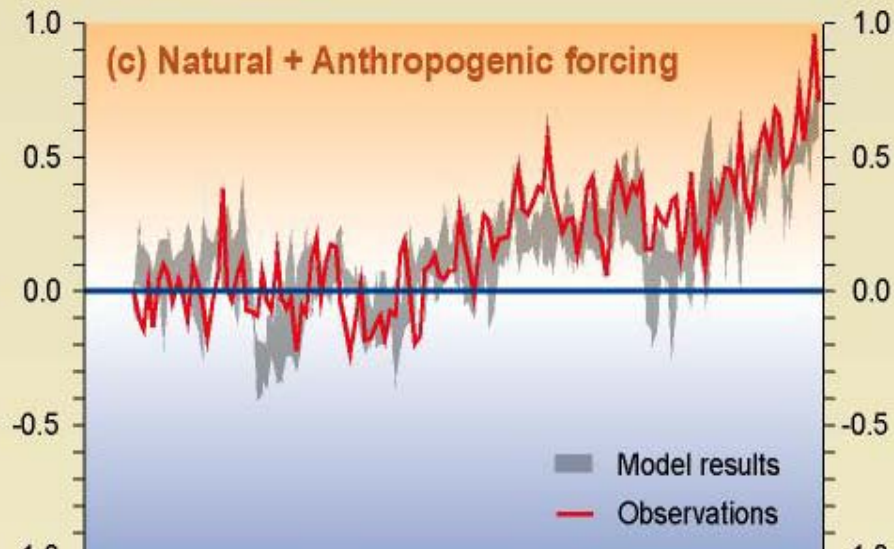
Temperature anomalies in °C



Temperature anomalies in °C



Temperature anomalies in °C



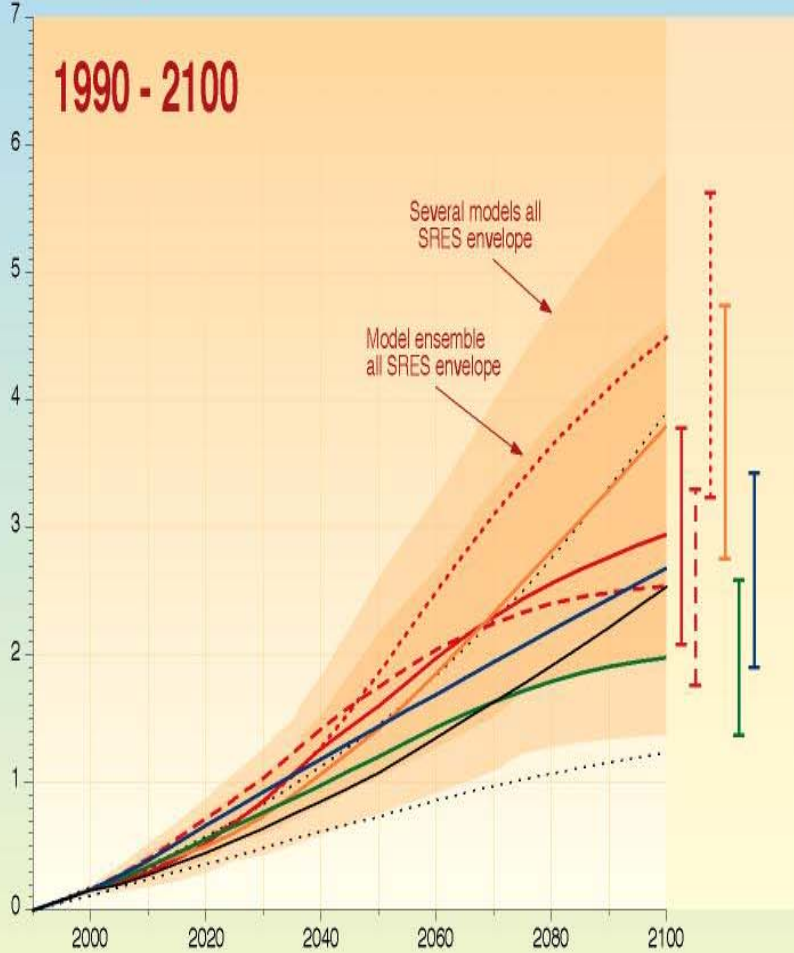
Humans will continue to change climate (UN-IPCC story):

- Greenhouse gases will continue to rise without intervention;
- Future temperature projected to rise along; strong agreement among models;
- In past, high greenhouse-gas concentrations and warm Earth have gone together tightly, and the greenhouse gases provide the only plausible explanation we have.

Temperature change (1760 - 2100)

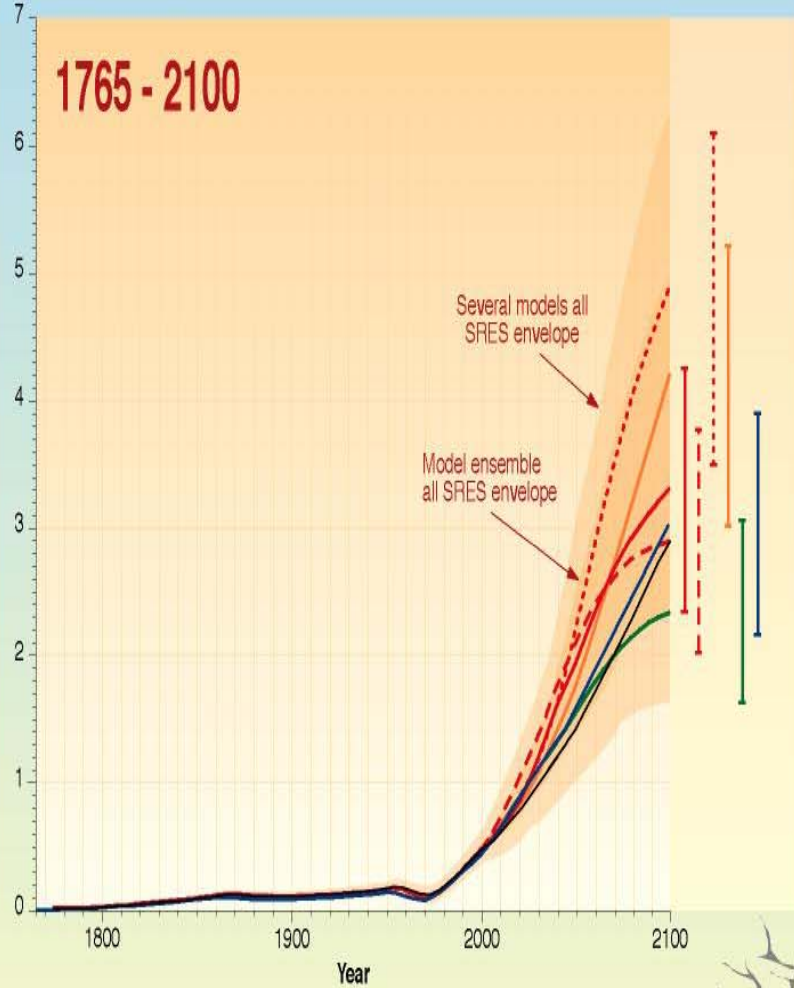
Temperature change (°C)

1990 - 2100



Temperature change (°C)

1765 - 2100



Scenarios

- A1
- - - B1T
- · · A1FI
- A2
- B1
- B2

- · · IS92e high (TAR method)
- IS92a (TAR method)
- · · IS92c low (TAR method)

Range in 2100

Bars show the range in 2100 produced by several models



Brief summary of likely impacts:

- Slight warming perhaps economic benefit to high-latitude industrial economies, harm to low-latitude
- Much warming economic harm;
- Likely grain-belt drying for crops, sea-level rise, spread of tropical diseases, loss of unique ecosystems (polar bears...), difficulty of ecosystem migration with humans in the way;
- Even hard-nosed economists often find that some investment in slowing progression makes money in the long run; damages to poor people bigger than economic damages.

UN-IPCC may be optimistic:

- US debate usually whether things could really be this bad; but
- It is hard to make the UN-IPCC story better, and easy to make it worse;
- Models tend to underestimate past changes;
- IPCC curves smooth but world isn't; faster and less-expected changes harder to handle;
- Abrupt climate changes can make variability very large, fast and widespread.

What is abrupt climate change? NRC says:

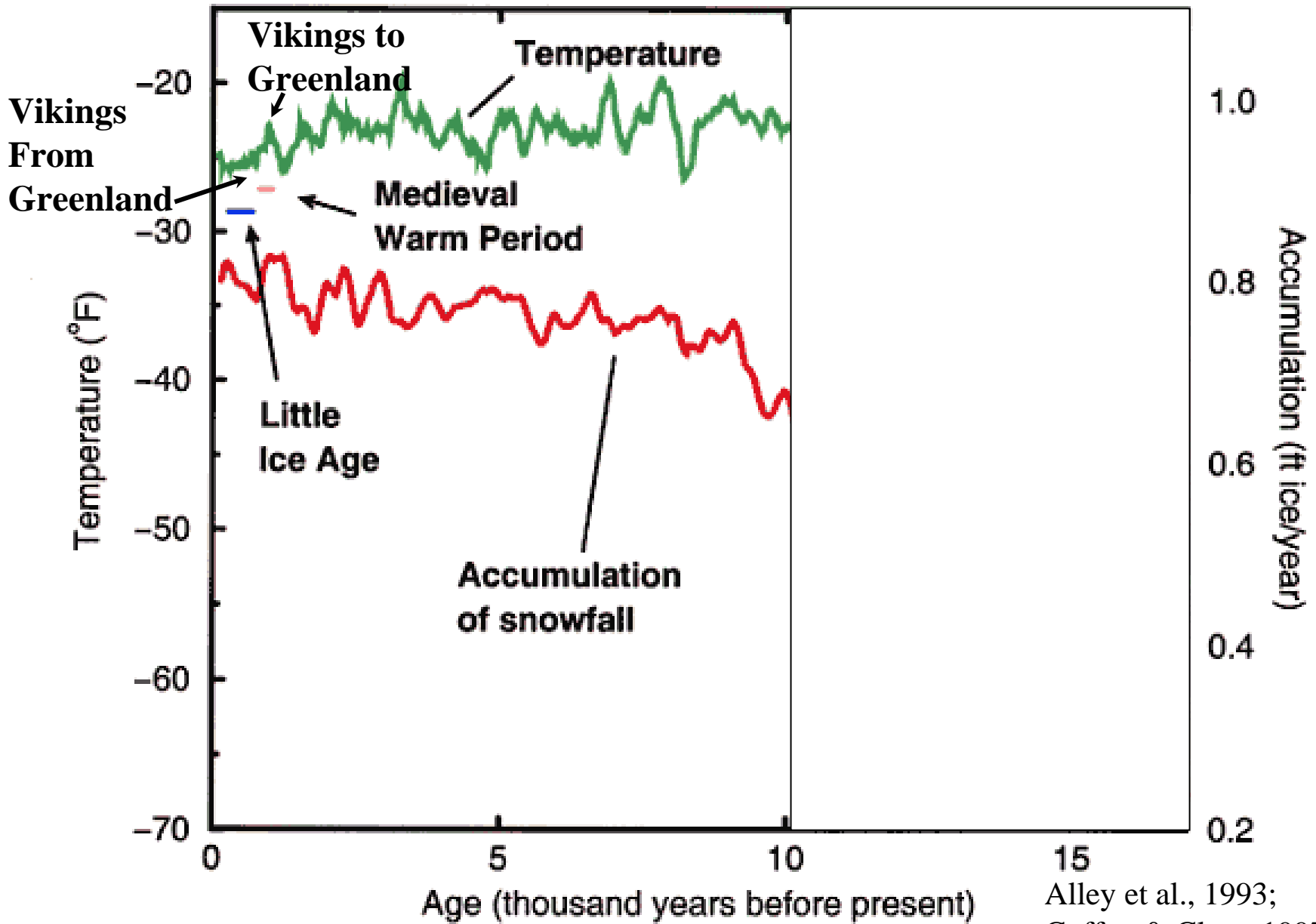
- Change faster than its cause; threshold crossing followed by evolution to new, persistent state at rate determined by the system (leaning to flip a canoe);
- Change large, fast enough that ecosystems and economies have difficulty adapting.

An example of Abrupt Climate Change:

- Big North Atlantic jumps;
- Caused by freshening there;
- Not *The Day After Tomorrow*, but worth a look.

Today

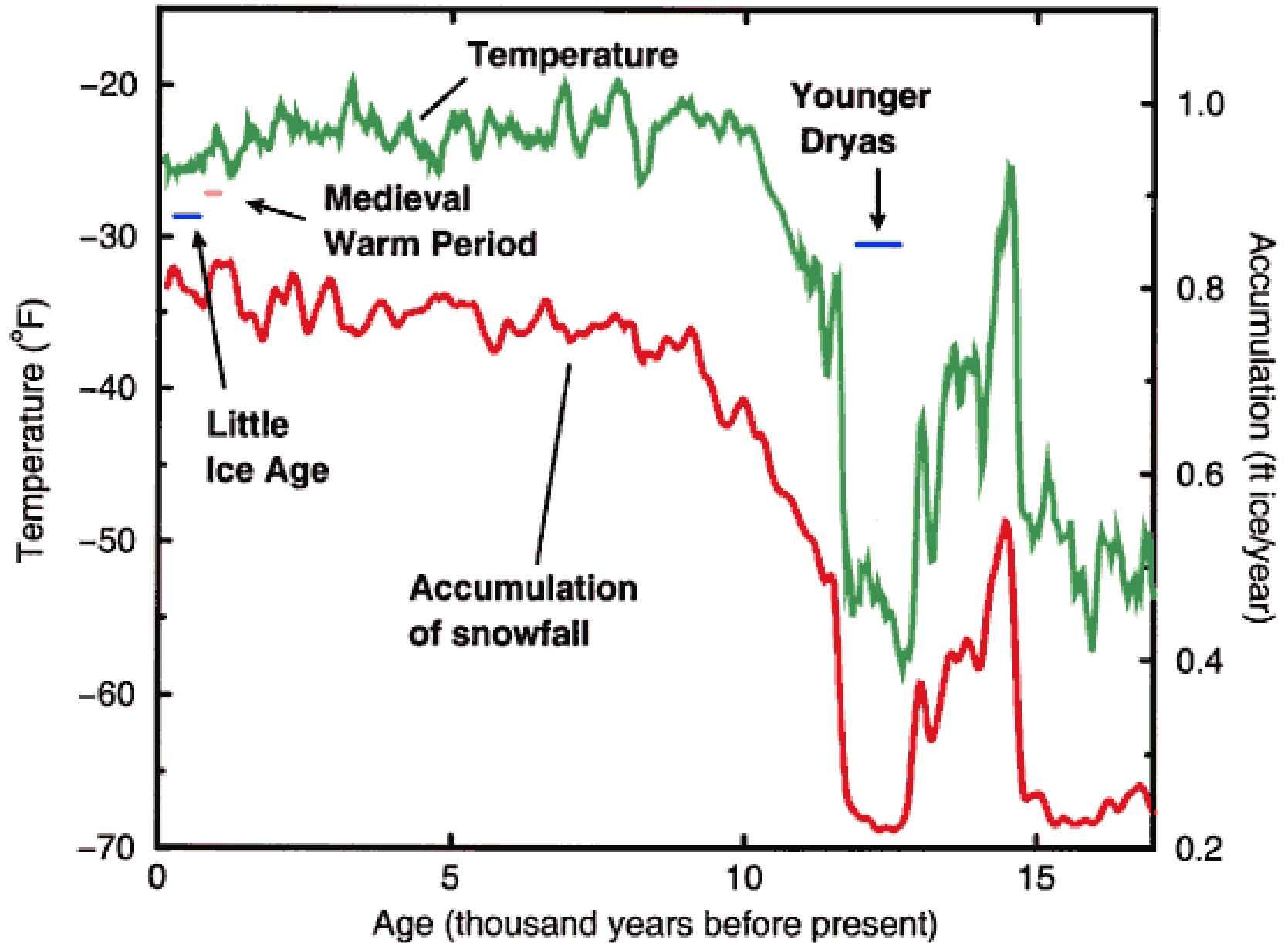
10ka



Alley et al., 1993;
Cuffey & Clow, 1997

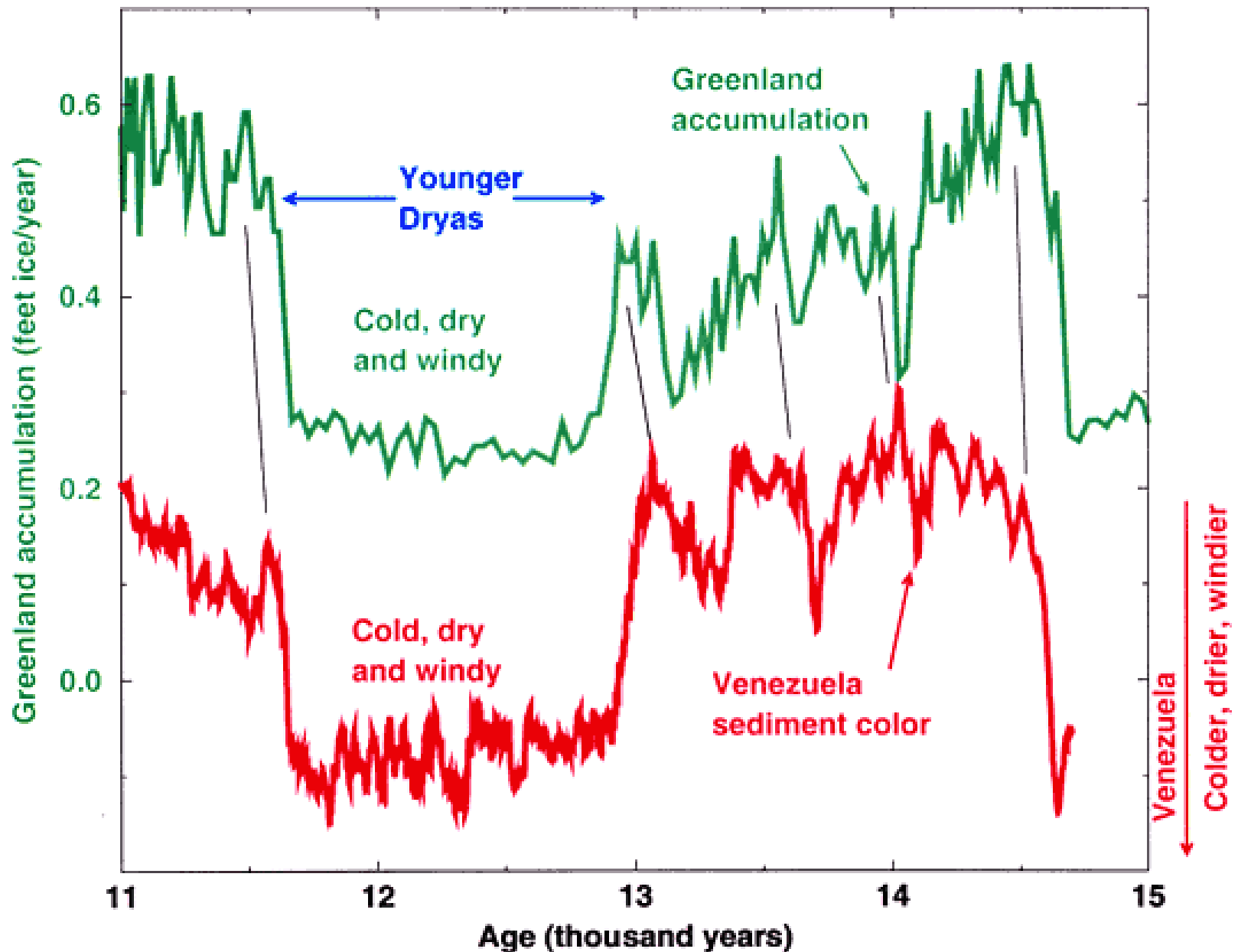
Central Greenland Climate

GISP2, NSF



Venezuela and Greenland

Hughen et al., Hughen, pers. comm., Alley et al.



**COLD &
DRY,**

COLD

**COLD, DRY,
WINDY**

COLD

**DRY &
WINDY**

COLD

FRESH

COLD

DRY

**FRESH,
COLD**

DRY

DRY

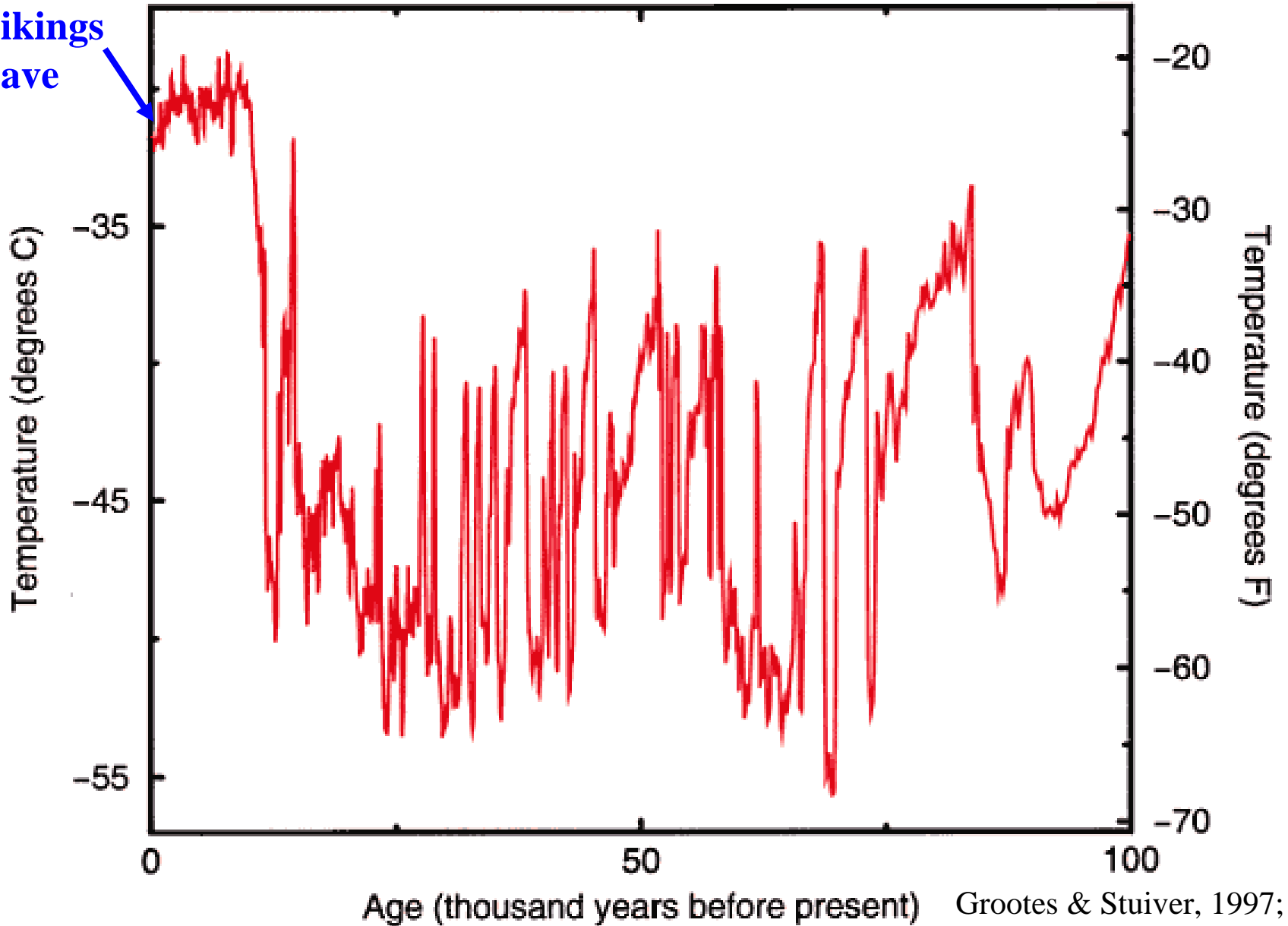
WINDY

**DRY
DRY**

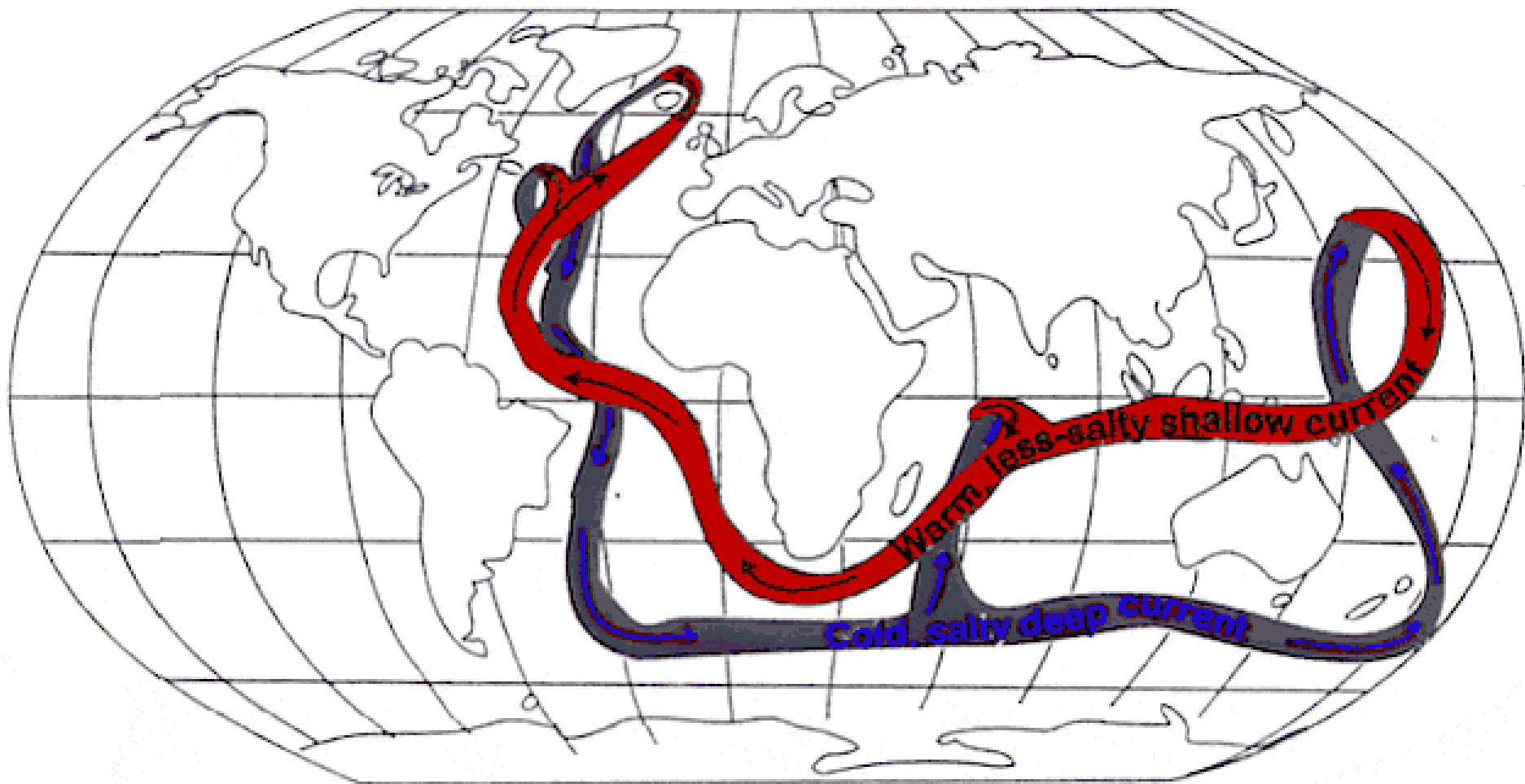


Temperature in central Greenland

Greenland
Vikings
leave



Grootes & Stuiver, 1997;
Cuffey & Clow, 1997



So, N Atlantic abrupt changes:

- Large, widespread and persistent;
- Especially prominent during ice age, but;
- Possible even in “warm” state like today;
- Linked to N Atlantic freshening, but may have other causes in or beyond N Atlantic;
- Models skillful but undersensitive.

So what? Focuses attention on:

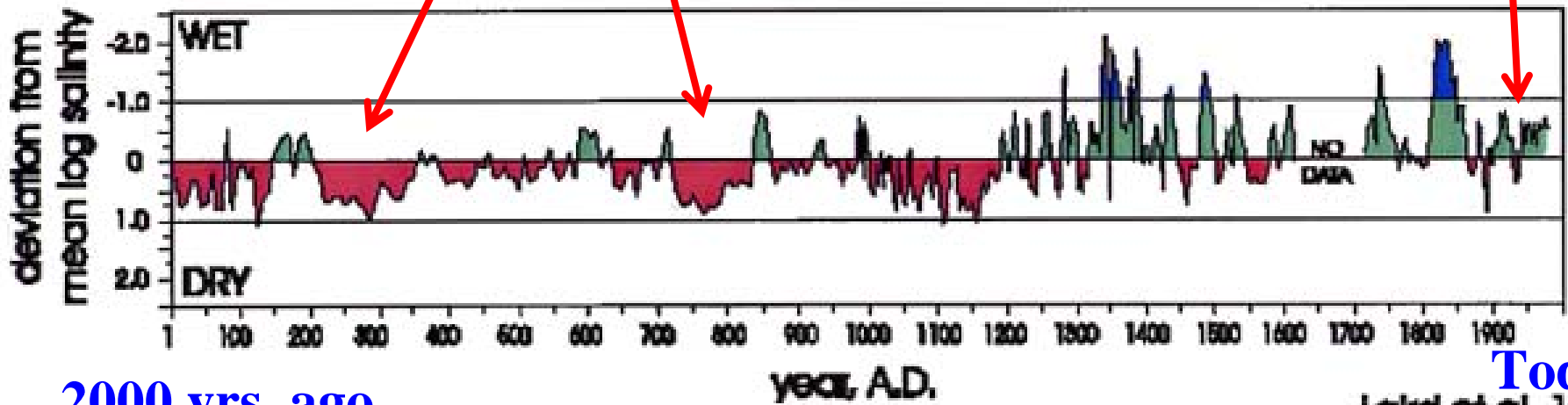
- Variability;
- Undersensitivity of models (tropical-extratropical and other linkages);
- Understanding N Atlantic (probably not the world's biggest worry, but matters);
- Thresholds generally
 - Too much warming will dump ice sheets;
 - Others (coral reefs? ENSO, etc.)?
 - Drought (Dust Bowl clearly not a big drought);

North Dakota Salt-sensitive diatoms

Interesting
Times

Dust
Bowl

SALINITY as a MEASURE of DROUGHT, MOON LAKE



2000 yrs. ago

Today
Laird et al 1996

Possibly useful analogy:

- We know days are warmer than nights and summers are warmer than winters, but we still value weather forecasts for day-to-day and severe weather. We know more CO₂ warms more, but understanding likely changes and possible big changes (Abrupt Climate Change) seems similarly sensible.

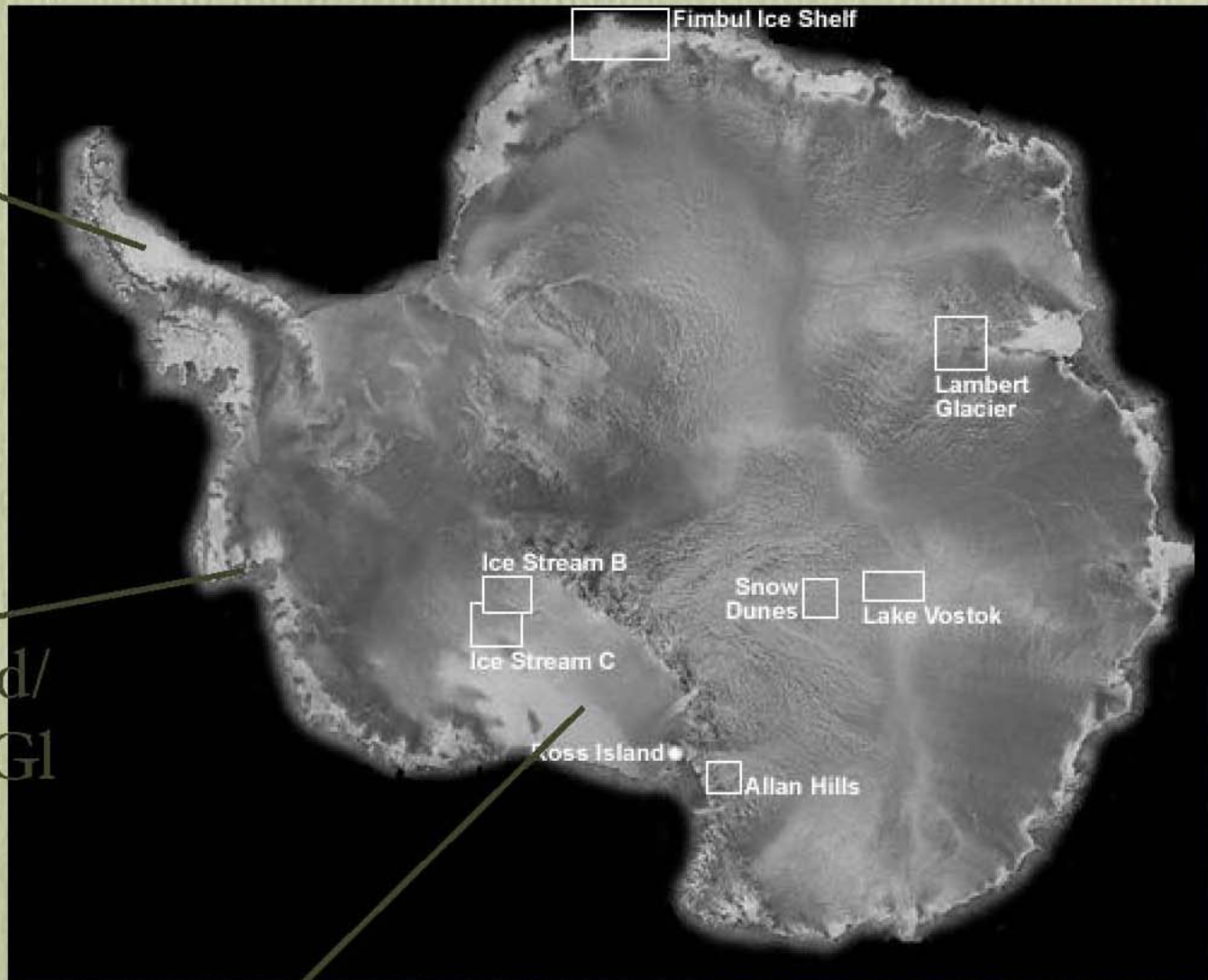








Radarsat image



Larsen B
Ice Shelf

Pine Island/
Thwaites Gl

Ross Ice Shelf

Fimbul Ice Shelf

Lambert
Glacier

Ice Stream B

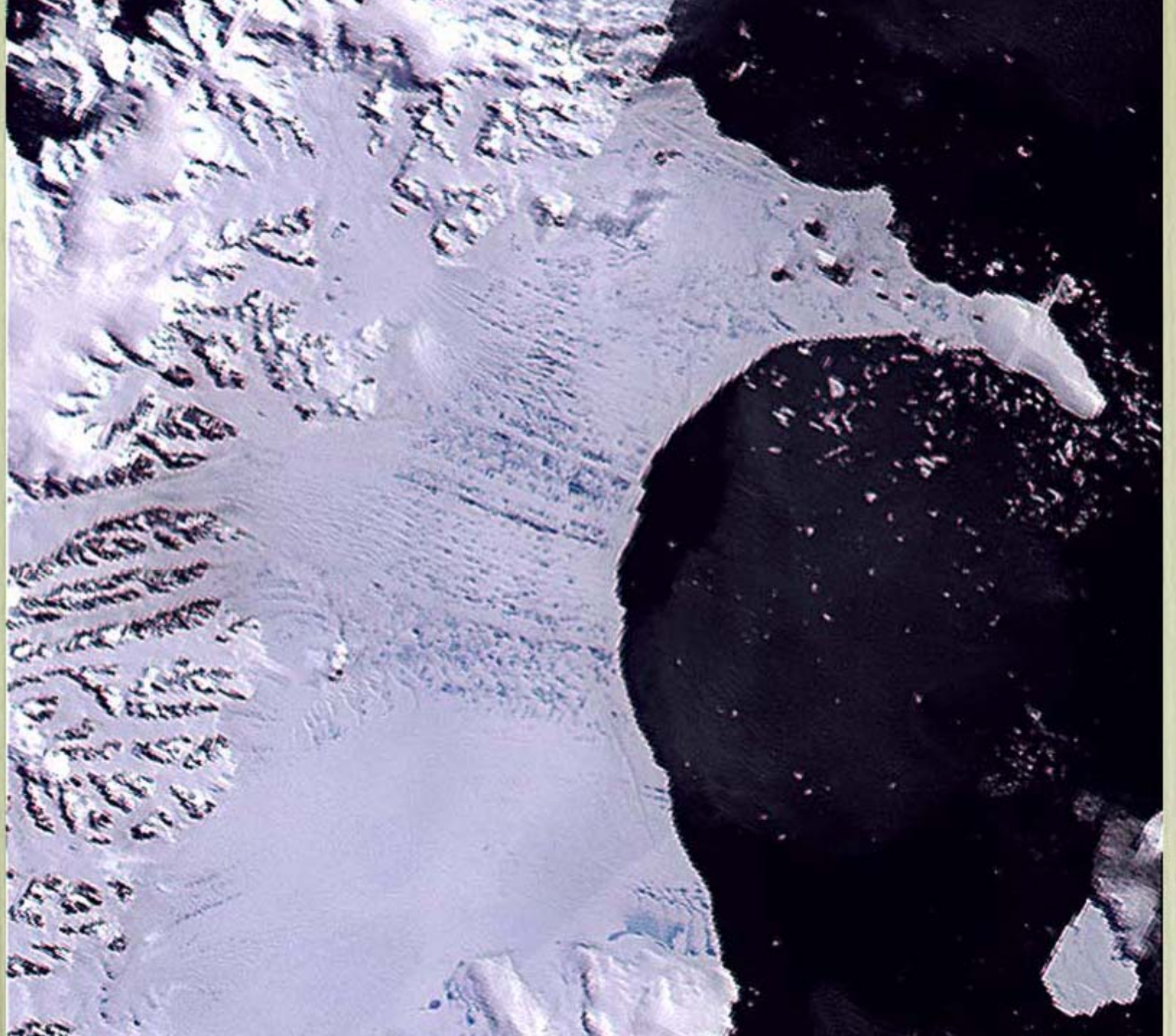
Ice Stream C

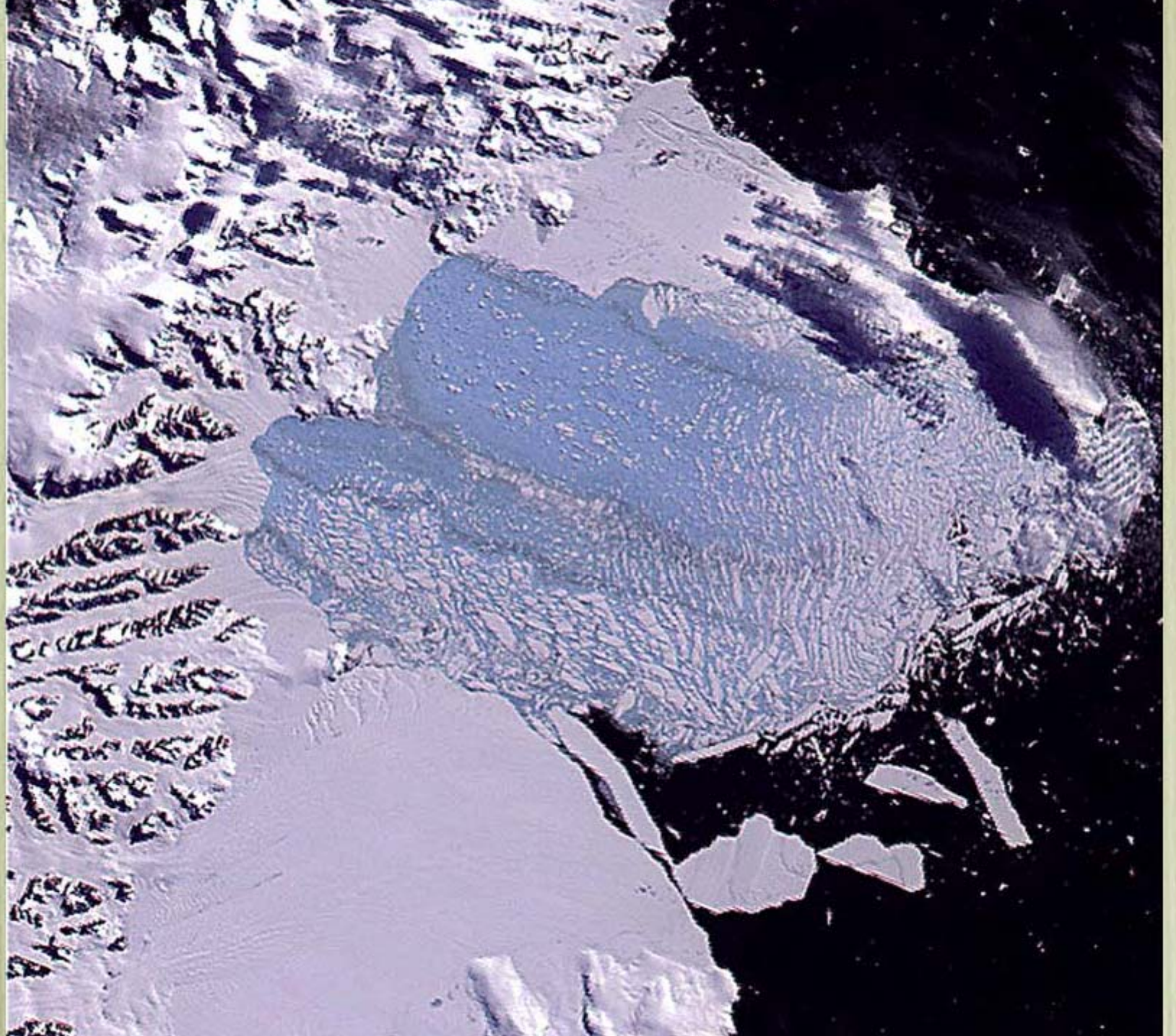
Snow
Dunes

Lake Vostok

Cross Island

Allan Hills

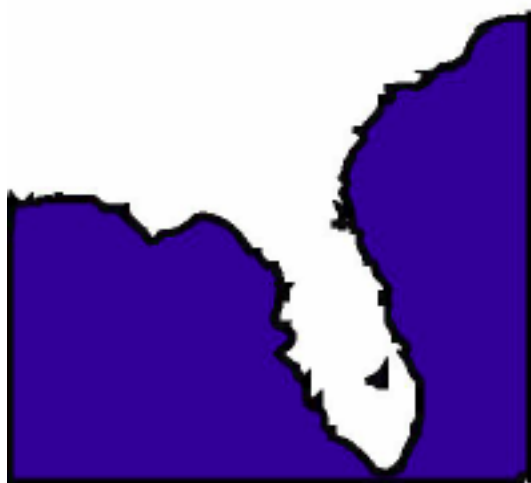




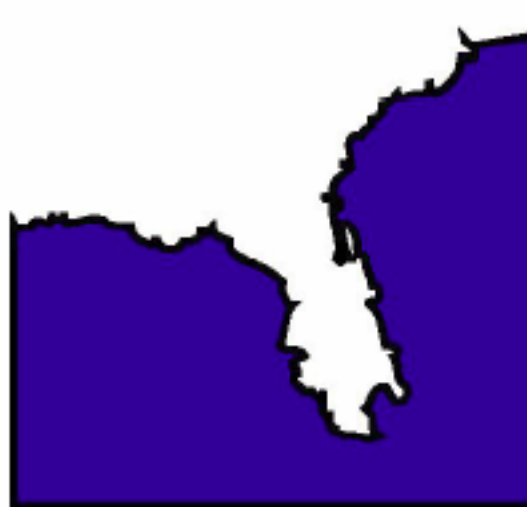
Future of ice sheets worrisome:

- Models agree humans can melt Greenland;
- Some models allow loss of West Antarctic;
- Models indicate East Antarctic stable;
- Humans may push CO₂ to levels that had no permanent land ice;
- The “reassuring” models don’t seem to make the poles as warm as they were then.

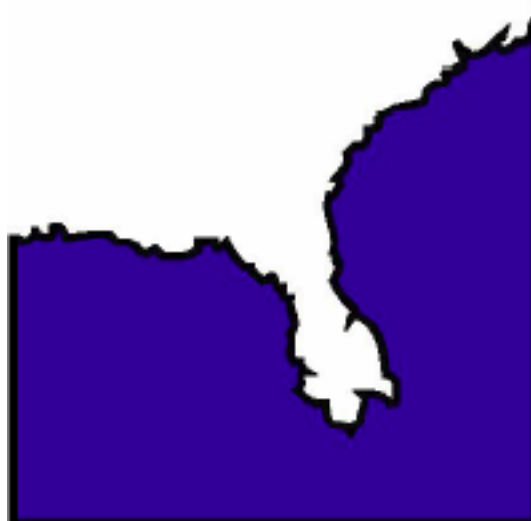
Modern Florida



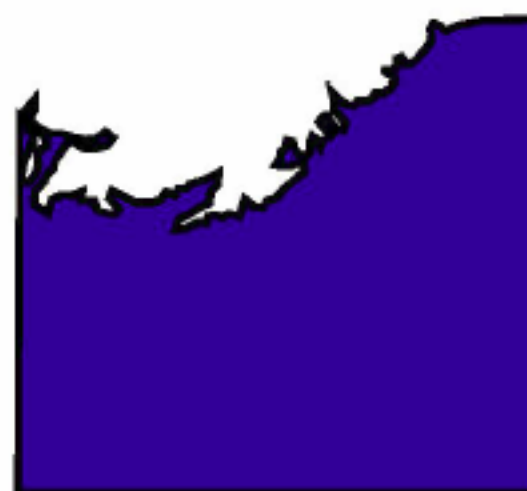
Florida w/o GIS



Florida w/o WAB+GIS



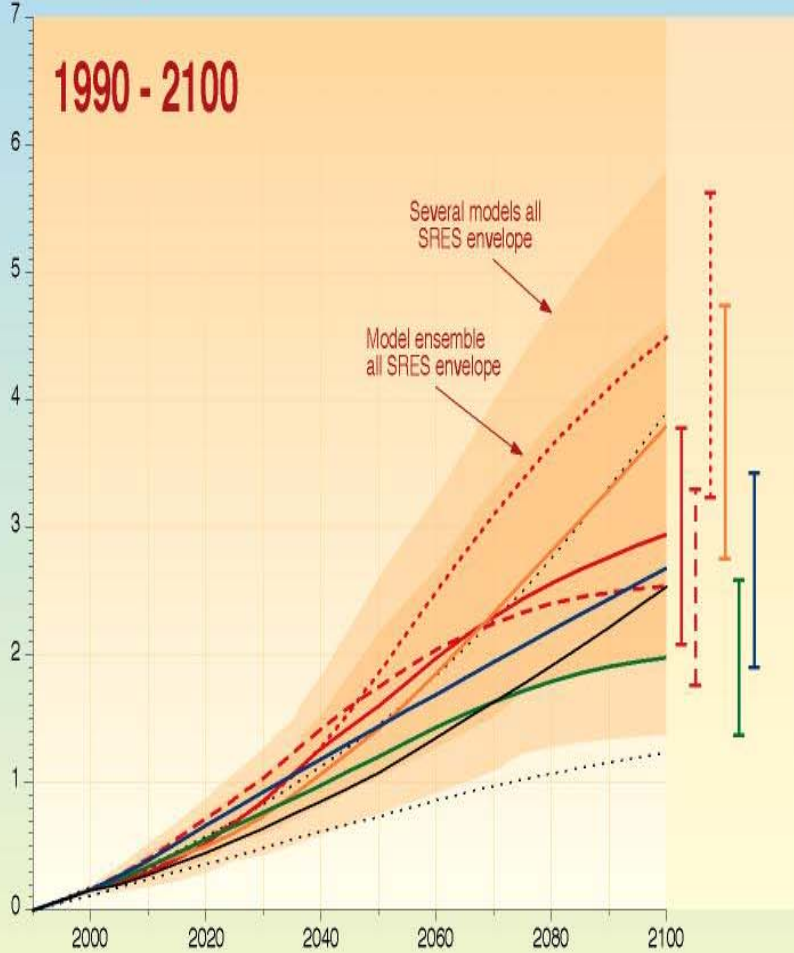
Florida w/o WAB+GIS+EAIS



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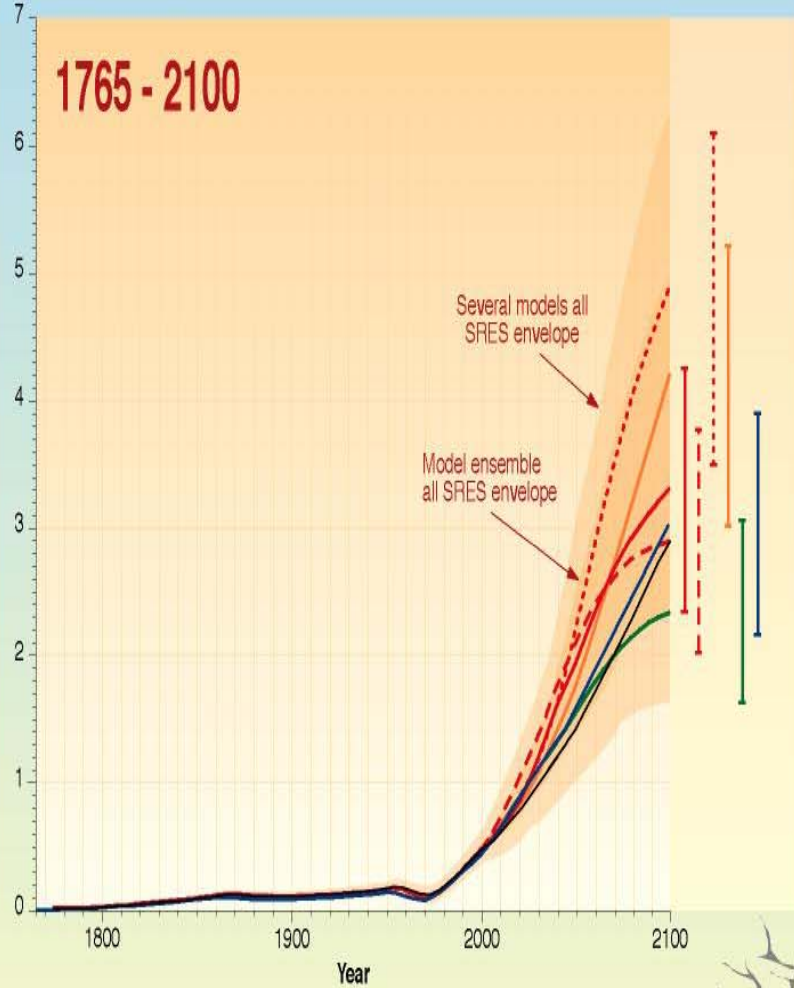
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Humans are “rocking the boat” changing climatic factors:

- May not “flip the boat” by causing a large, persistent change (north Atlantic shutdown, ice-sheet collapse, extensive drought, etc.);
- But, may do so;
- If so, not the end of the world (things alive today experienced abrupt changes before);
- But could be costly and damaging;
- IPCC projections smooth hence optimistic.