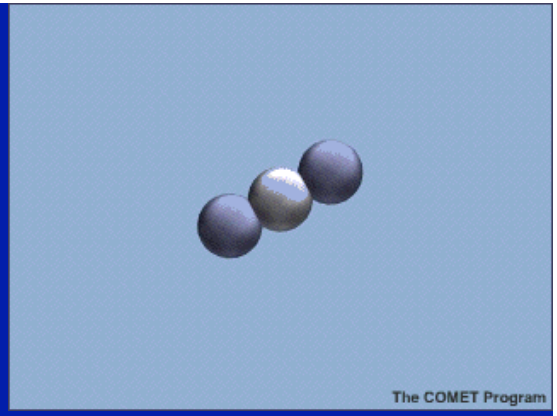


Our Climate: A Global Challenge

Academy for Lifelong Learning
Denver, CO

Mar. 19, 2015

JFOrmes@comcast.net

Today

- Climate vs. weather
- Greenhouse effect
- Earth's climate history

First some basic facts

- Greenhouse gases are those that transmit solar radiation and absorb infrared radiation
  - H_2O, CO_2, N_2O, CH_4, and more complex molecules
- Some are naturally occurring like water vapor and others are produced in human processes
  - Humans have increased the concentration of CO_2 by more than 40% since the industrial revolution
  - We can measure this directly over the planet
  - Proof that warming comes from human activities is indirect. I will try and show you the evidence.

"The atmosphere is a *global commons*."
Kevin Trenberth, NCAR, Boulder, CO

Climate vs. Weather

Welcome to the anthropocene!

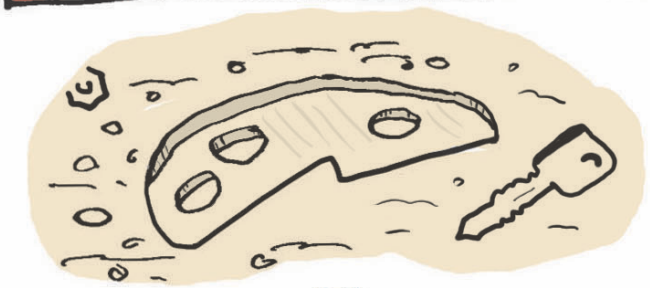
Can we adapt fast enough?


What's the difference between weather and climate?


You can't weather a tree, but you can climate.

FOSSILS FROM THE ANTHROPOCENE

JOEL PETT



SUV PARTS
(BRAKE PAD-BRACHIOPOD)

FACTORY FARM CHICKEN
(DISGUSTUS INGESTUM)

SMALL ARMS
(PROLIFERUS ABSURDUM)

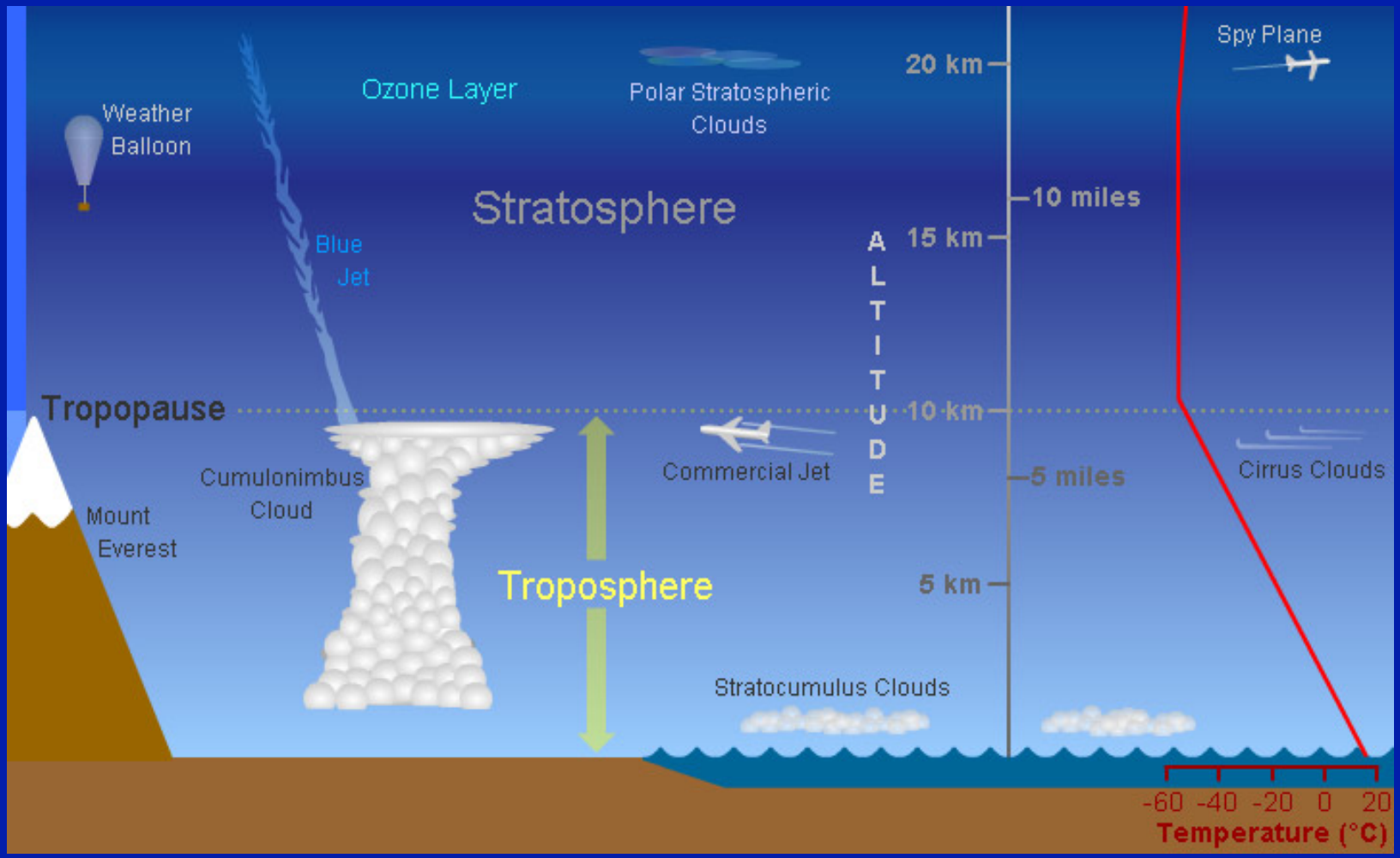
TV REMOTE
(DISTRACTUM COLLOSSUS)

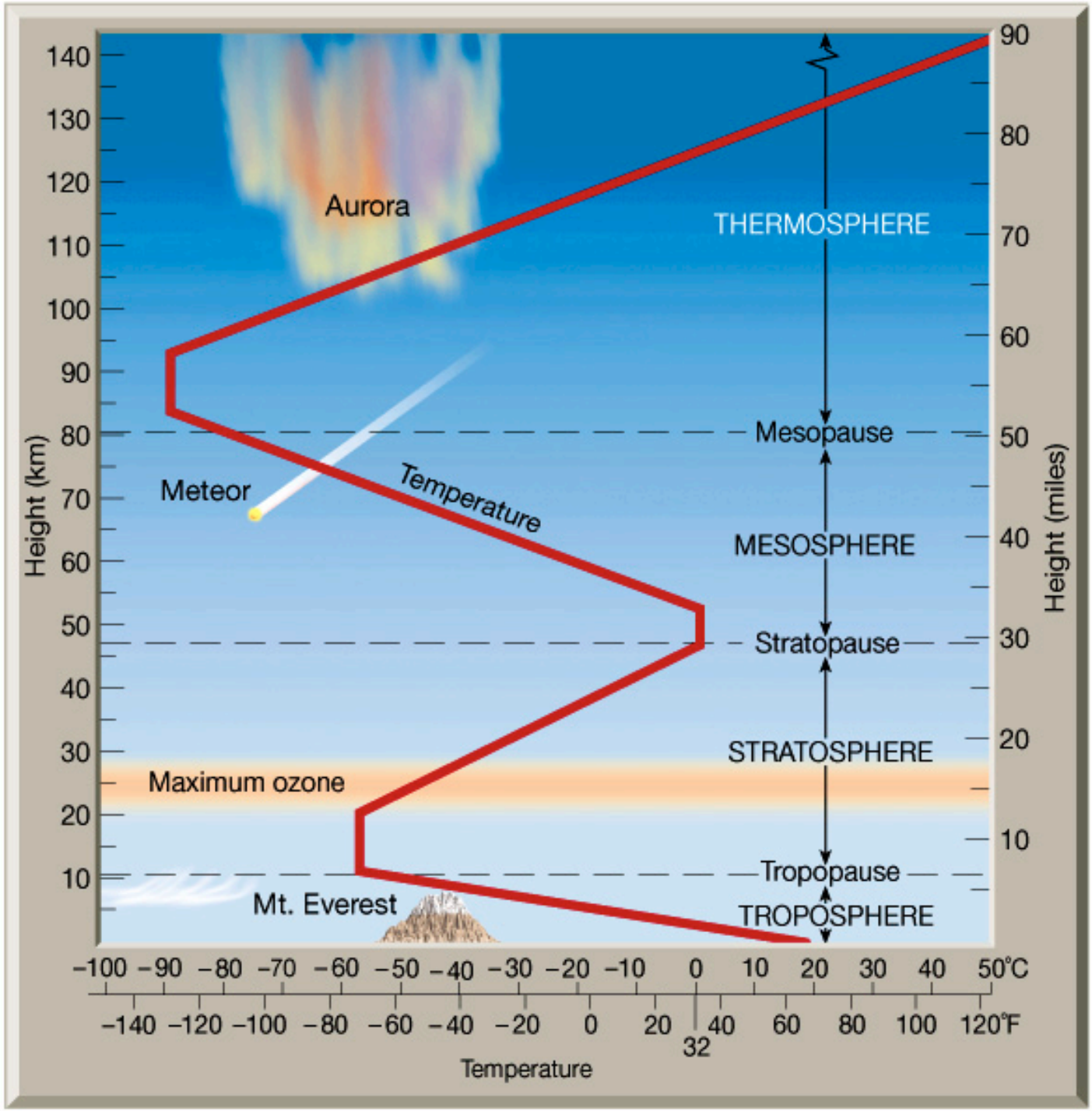
CLIMATE-CHANGE DENIER
(CRANIUM IMPENETRUS)

CONFERENCE I.D.
(PRESSURUS GLOBALUM)

11/2016

Troposphere (where weather develops)




Aurora
THERMOSPHERE
Mesopause
Meteor
Temperature
MESOSPHERE
Stratopause
STRATOSPHERE
Maximum ozone
Tropopause
Mt. Everest
TROPOSPHERE
Height (km)
Height (miles)
Temperature
140
130
120
110
100
90
80
70
60
50
40
30
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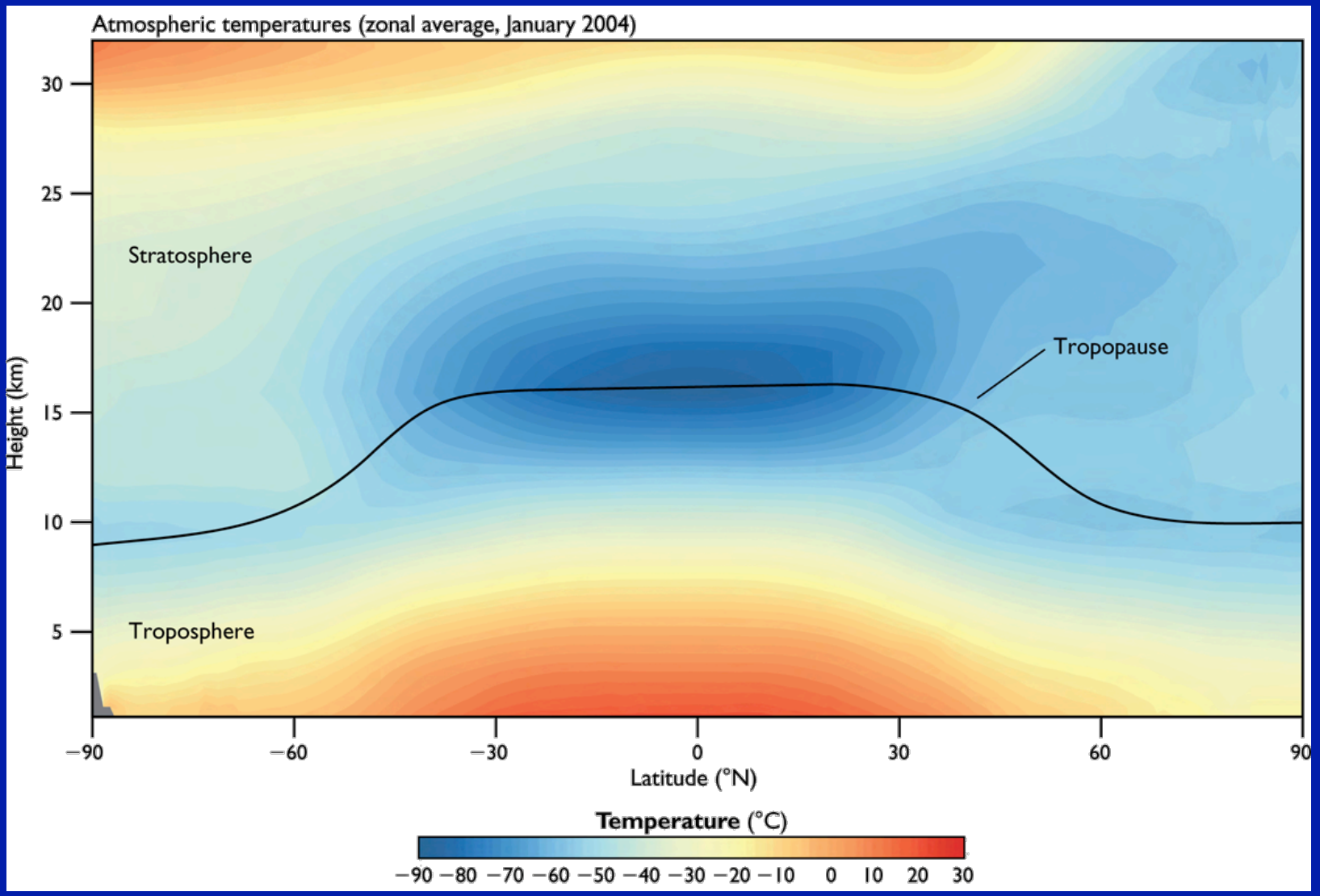
10
−100 −90 −80 −70 −60 −50 −40 −30 −20 −10 0 10 20 30 40 50°C
−140 −120 −100 −80 −60 −40 −20 0 20 40 60 80 100 120°F
32

Latitudinal structure of the Tropopause



Weather vs. Climate
what's the difference?

- If you don't like the weather:
  - *Wait five minutes!*
- If you don't like the climate:
  - *Move!*

"Climate is what you expect;

weather is what you get."

—Robert Heinlein,
1973 in
Time Enough for Love

Mark Twain collected amusing student responses, one of which was
"Climate lasts all the time and weather only a few days."

www.extremeinstability.com

Climate is Place

- Depends on where you live:
  - Latitude!
  - Altitude (mountains vs valley)
  - What's upwind (ocean vs land)
- Changes very slowly (wrt human timescales)
- Very predictable
- We can predict that Miami is warmer than Minneapolis for precisely the same reasons that we can predict a warmer future!

Location! Location! Location!

Time scales: weather or climate?

- Weather: days to years
  - Driven by initial conditions
    - weather predictions – 10 days
  - Macro-weather is years (almanac?)
    - El Niño Southern Oscillation
    - North Atlantic Oscillation
- Climate: 10s of years and beyond (to billions)
  - It takes decadal (or longer) data sets to establish climate trending.
  - We now have ~50 years of direct measurements
    - We use proxies for longer time scales
  - Paleo-climate data going back almost a million years

Climate or Weather

http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

What Weather Means:

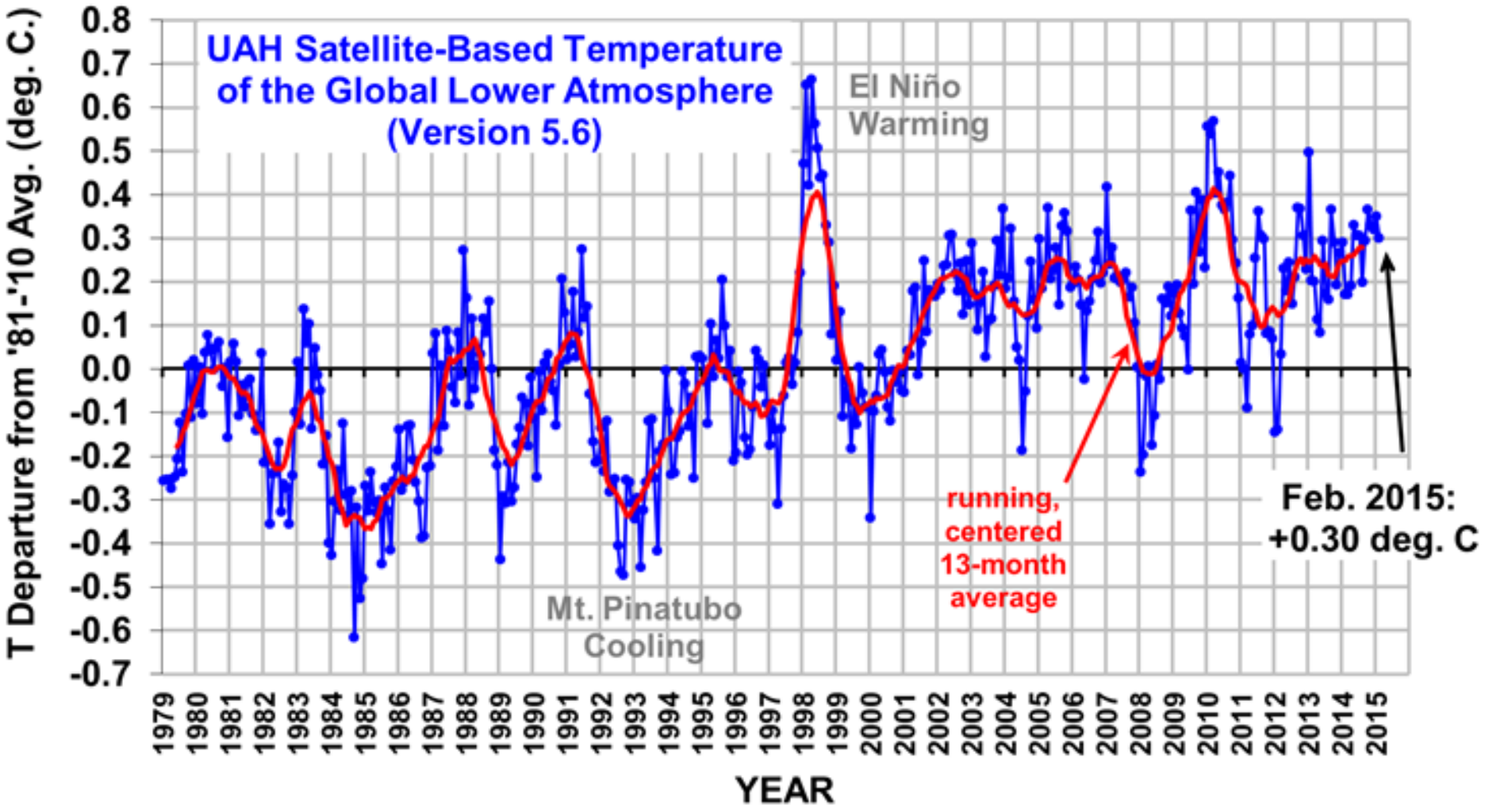
- Weather is basically atmospheric behavior.
- Weather is temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure.
- Weather predictions few days ahead

What Climate Means:

- Climate is the long-term (usually 30 years) average weather for a particular region.

Long periodic oscillations in the ocean such as the El Niño Southern Oscillation are thought of as climatic oscillations that affect weather patterns worldwide.

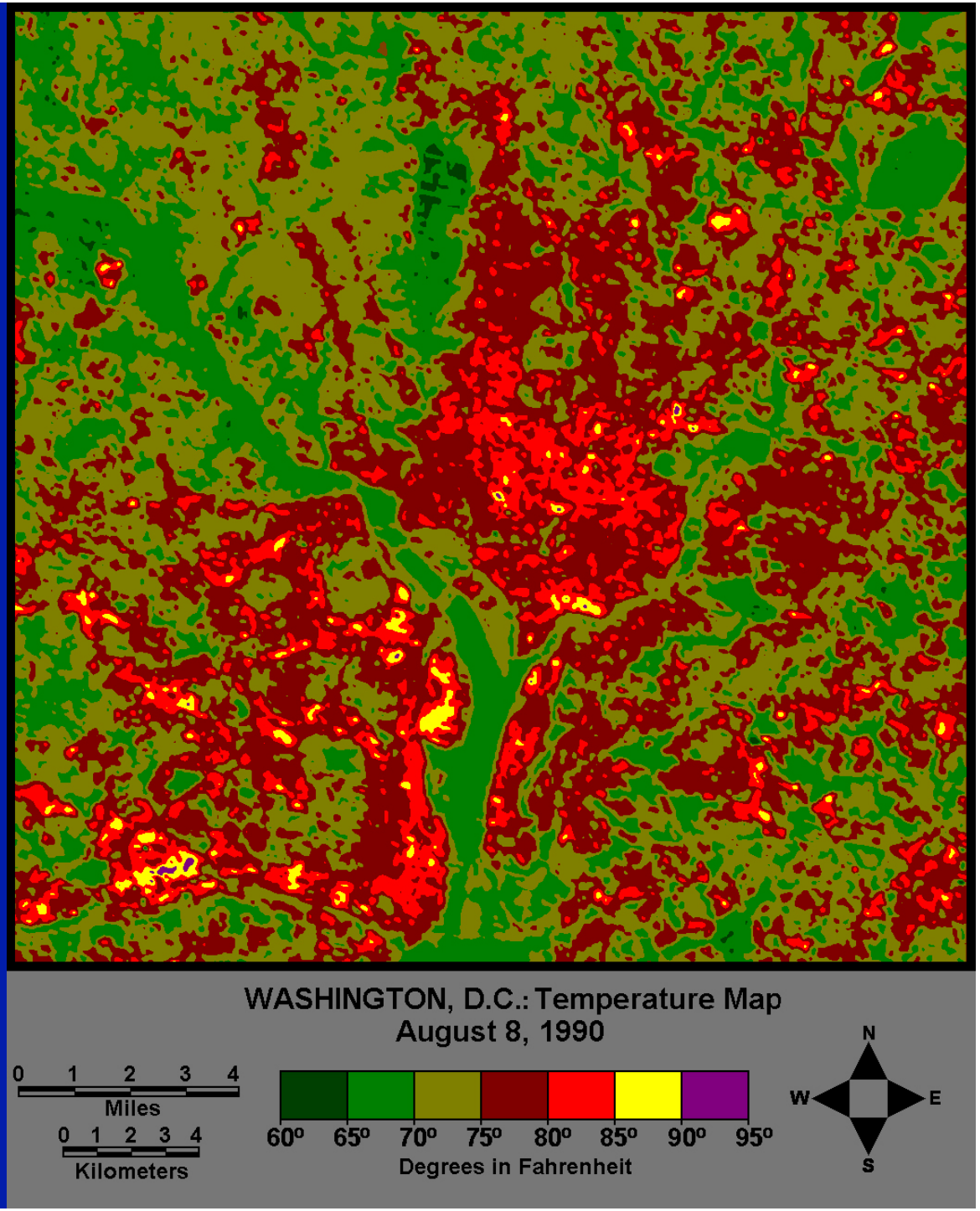
Natural cycles: beware of short time scale thinking



Different temperature records

- Lower atmosphere
  - line of sight satellite through troposphere and stratosphere
- Global average: land and sea surface temperatures (NOAA and NASA agree)
  - global temp =
    0.708 x ocean temp + 0.292 x land temp
- Ave. global land temp (reanalyzed)
  - e.g. Berkeley group

Correct for "heat island" effects



Global surface temperatures

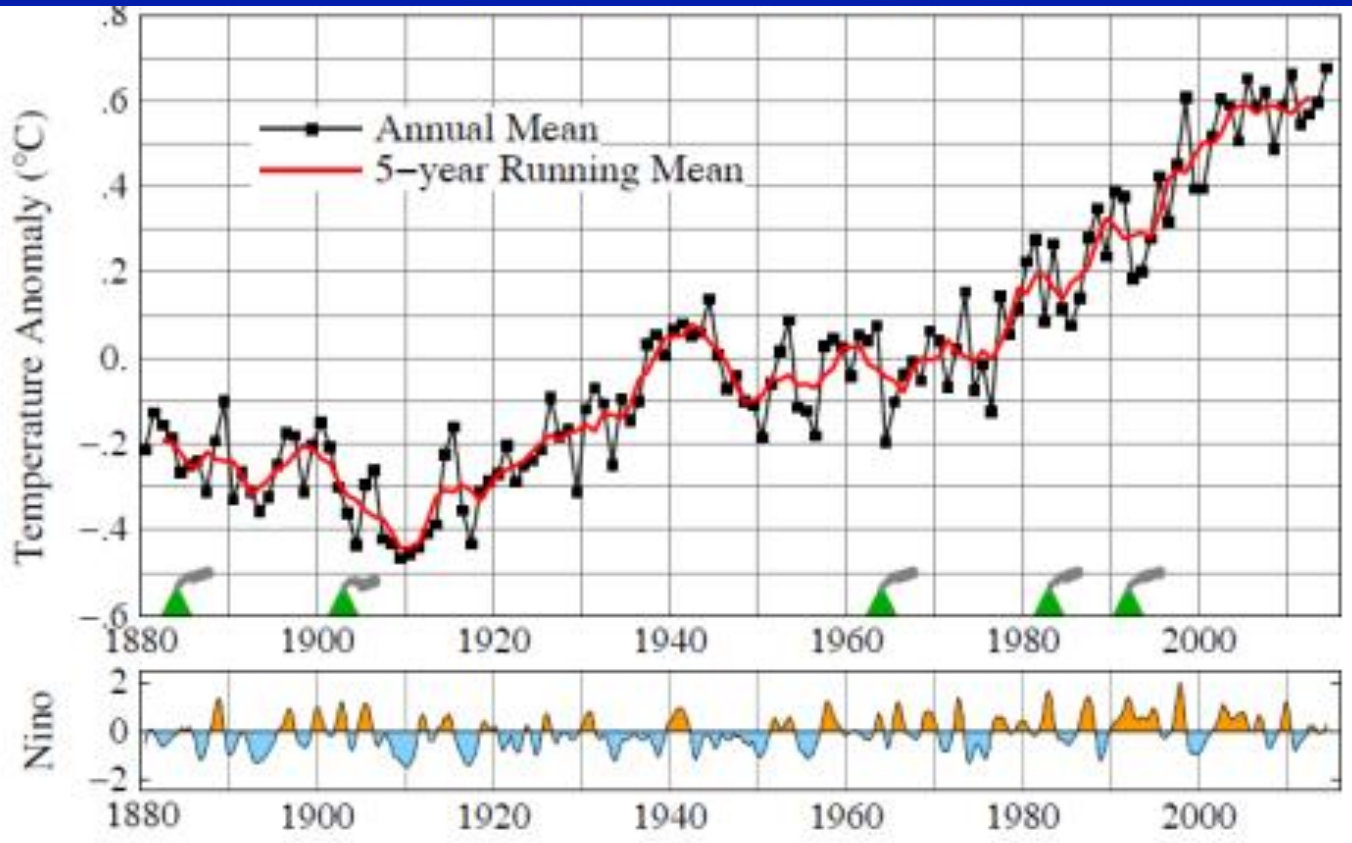
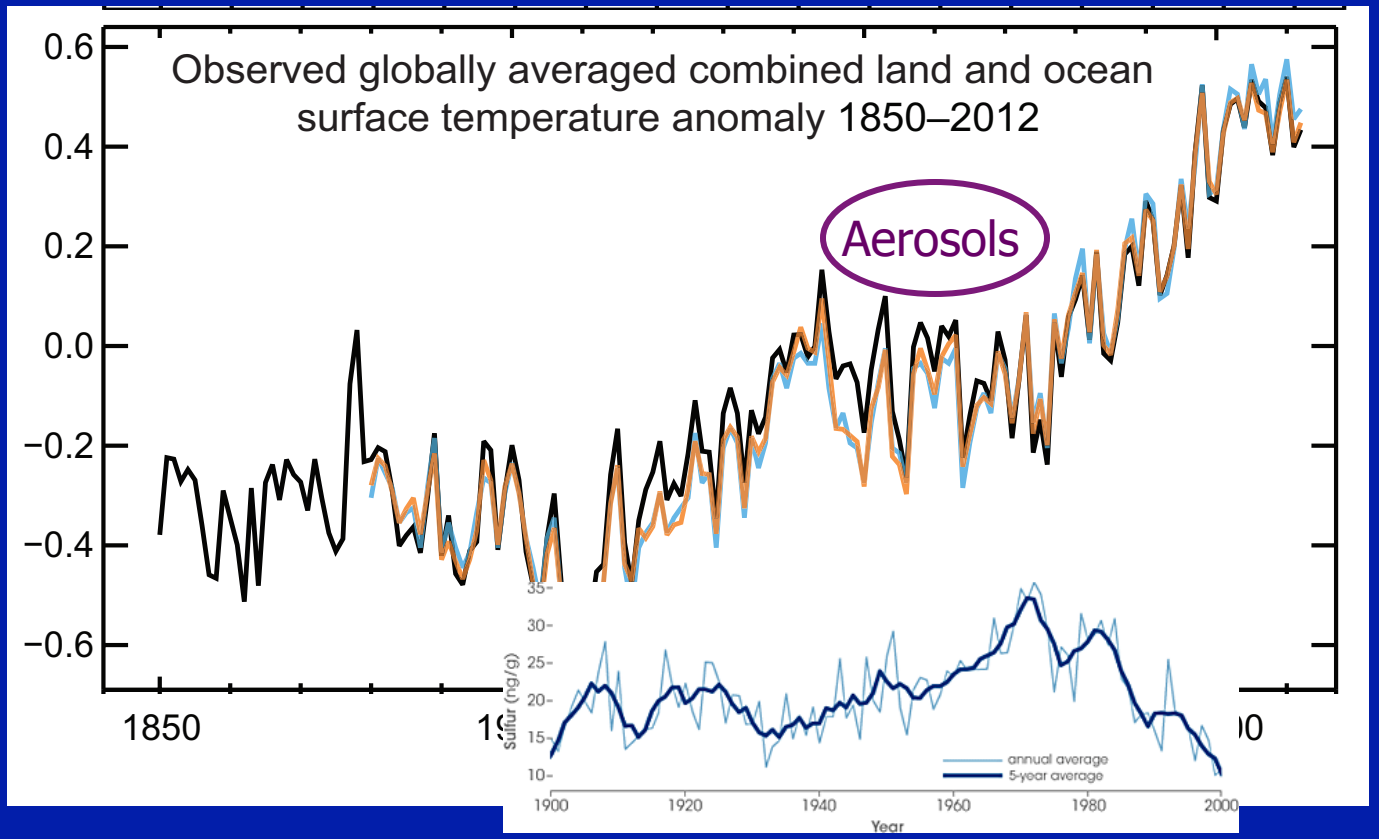


Fig. 1. Global surface temperatures relative to 1951-1980. ENSO index (12-month running mean) is based on sea surface temperature in Niño 3.4 area (5N-5S, 120-170W) in tropical Pacific[3] for 1951-1980

Global Average Temperature

Temperature anomaly (°C) relative to 1961–1990

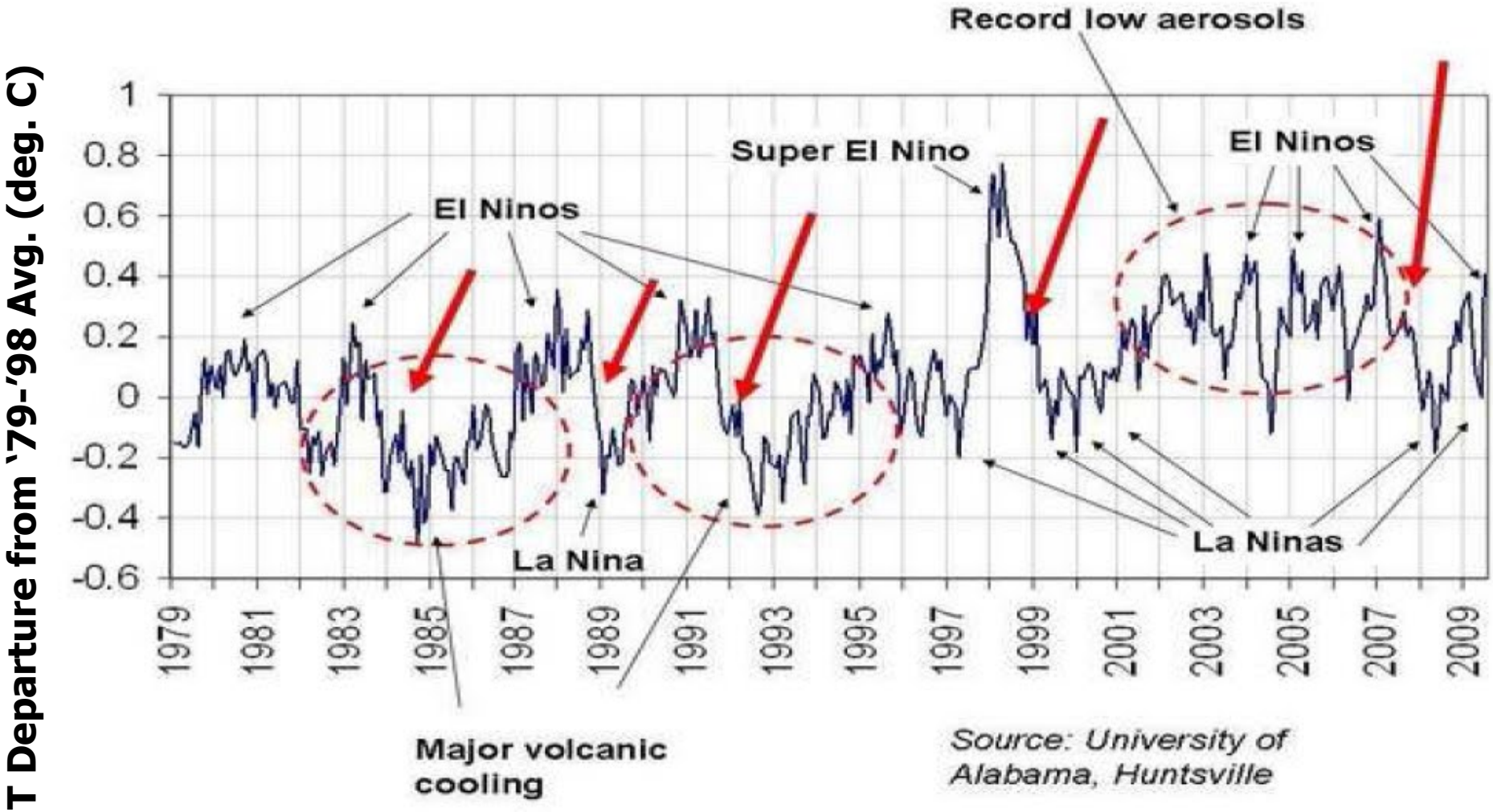


Requires $5x10^{22}$ – 10^{23} Joules
That's 50-100 sextillion Joules

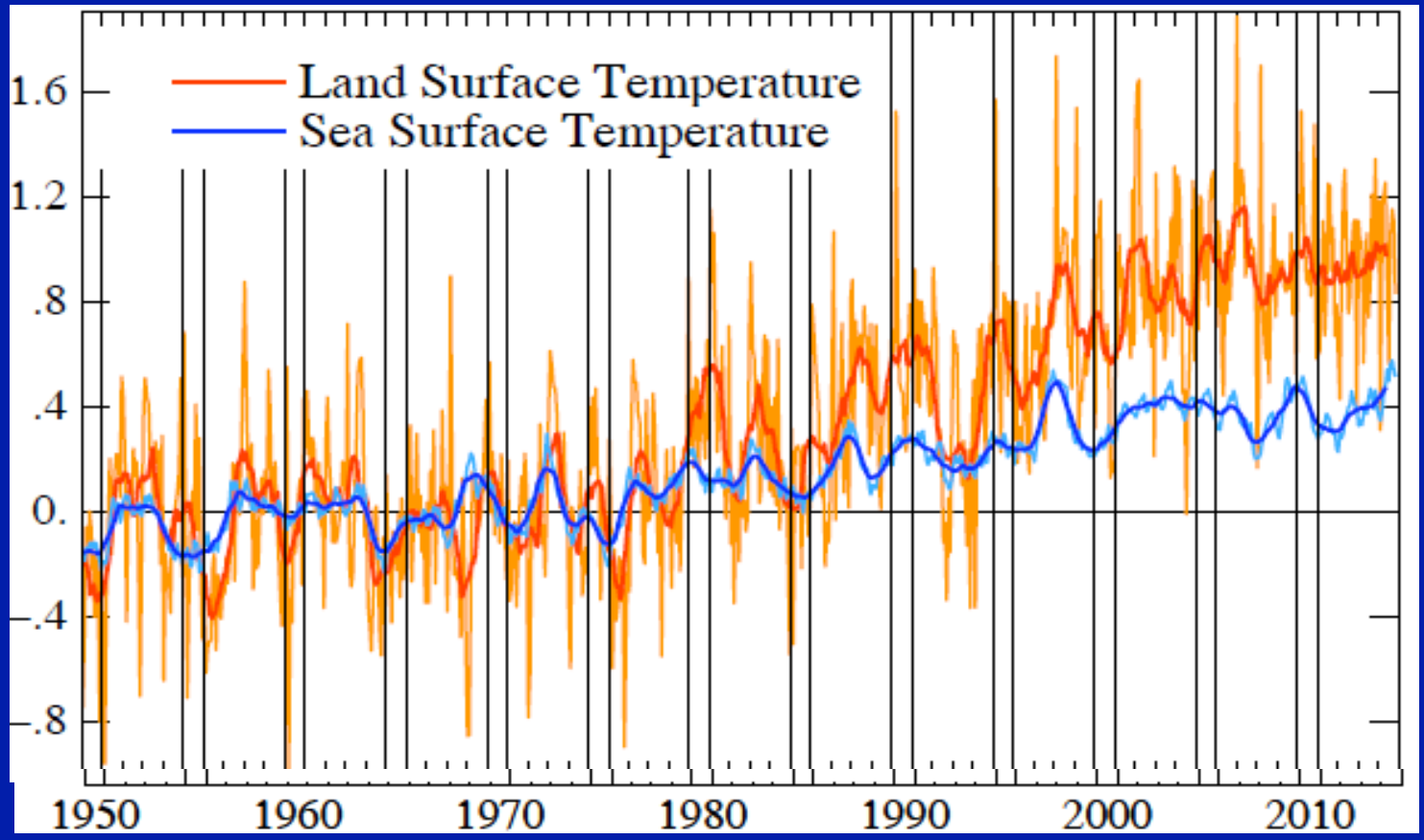
How do we know aerosols were responsible after WW2?
We see the aerosol particles in the Artic ice layers!

Natural cycles: El Niño and La Niñas

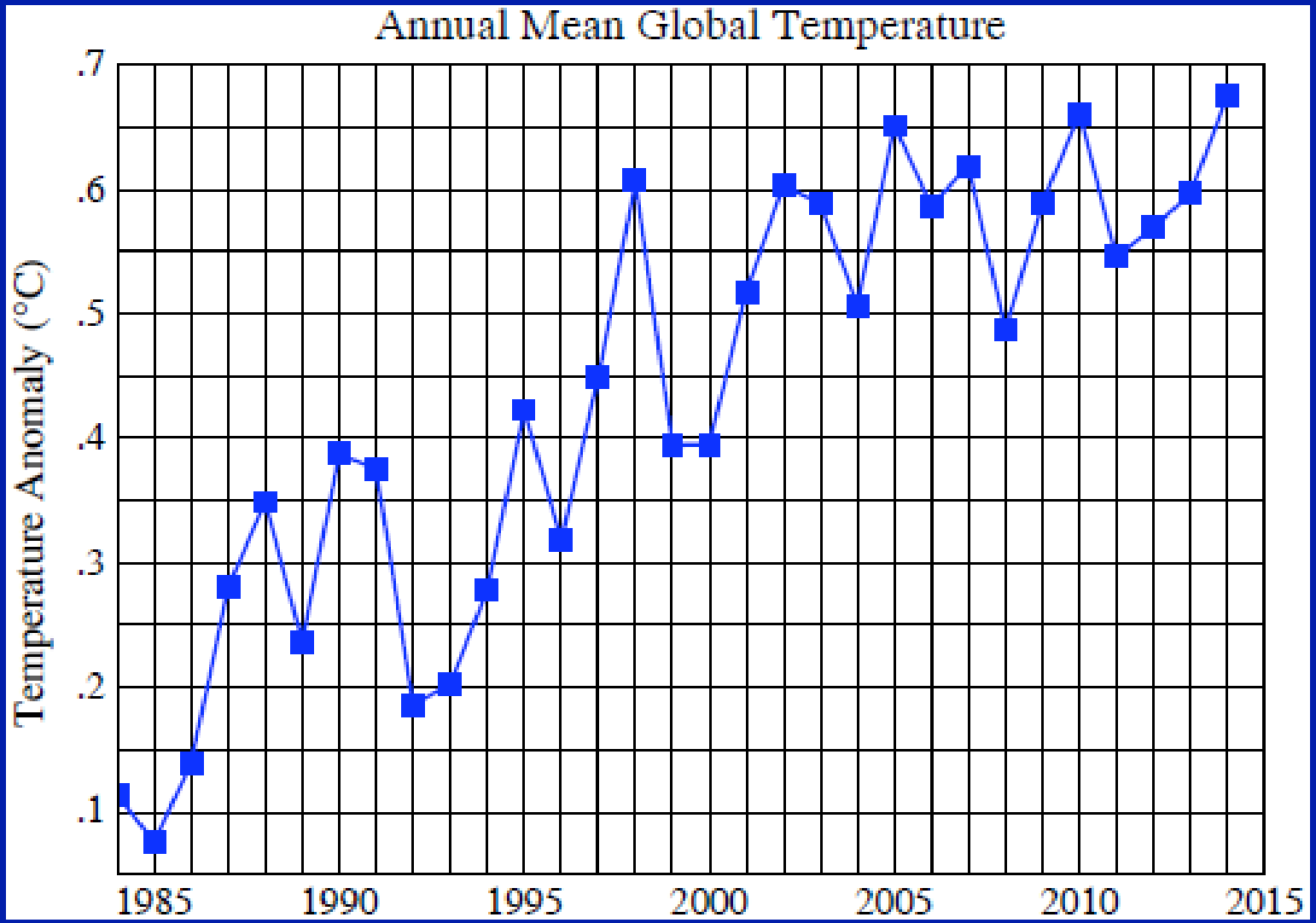
Heat goes back and forth from the ocean to the atmosphere.



Land temp is rising faster



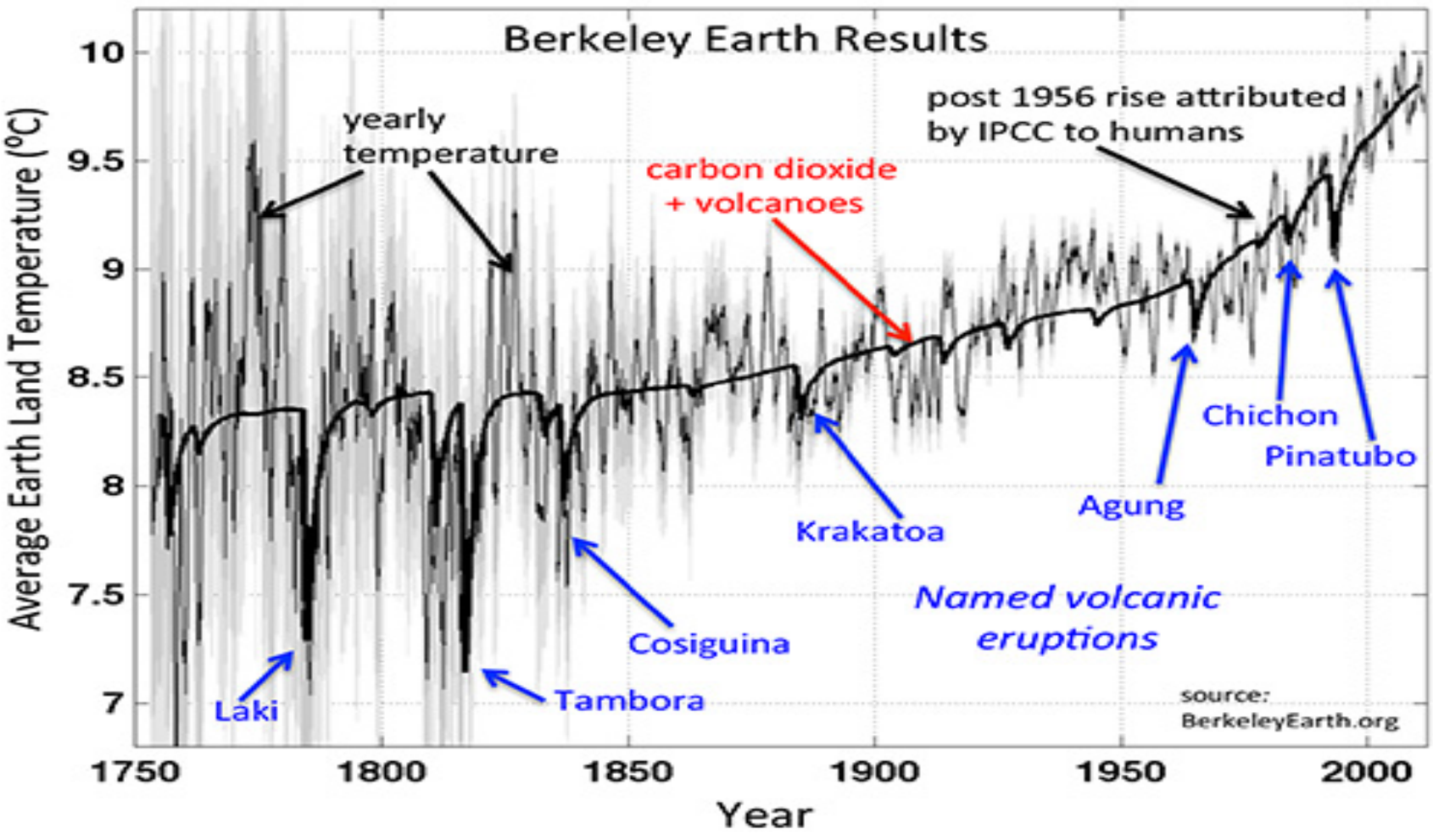
Recent year to year variations

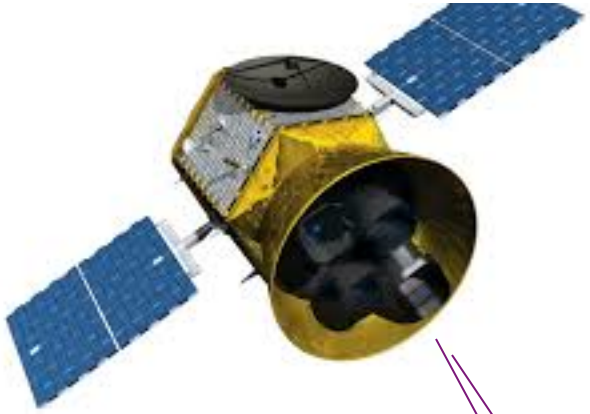


Reanalysis by "Berkeley Earth"

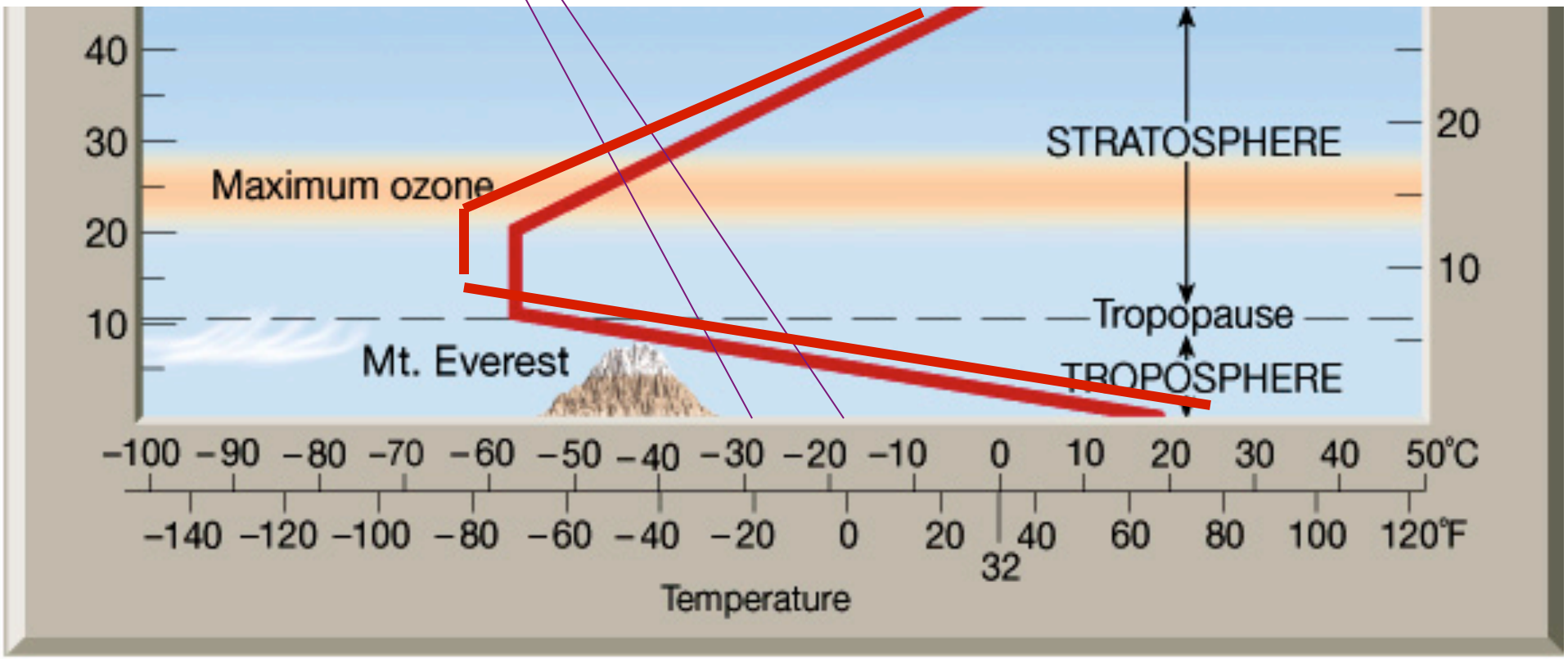
Tavg fit by function f(Ln(CO_2) - 1.5 x mVS (Tg))

mVS = Mass of Volcanic Sulfates in Terragrams



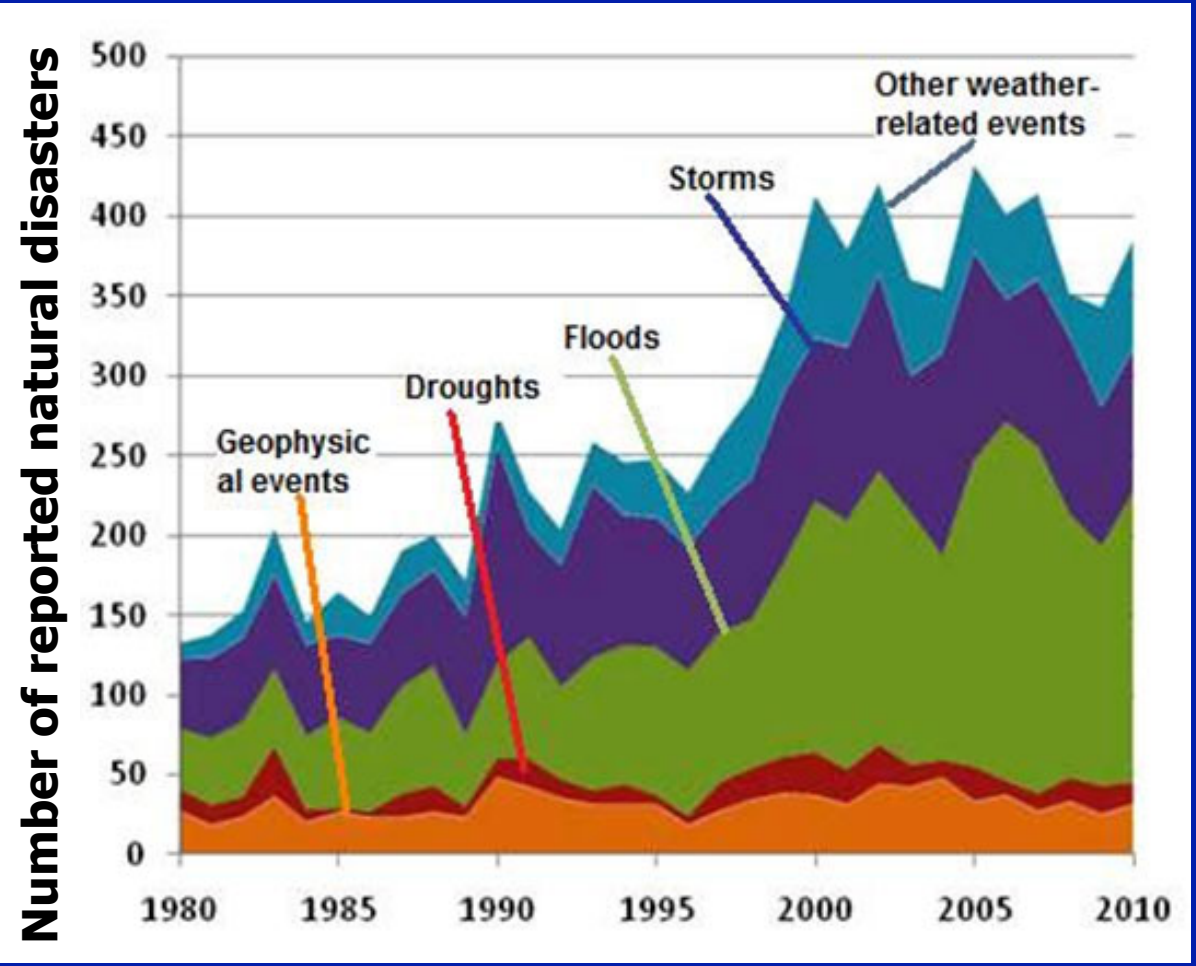


Measuring atmospheric temperatures from space is a tricky and controversial business.



Weather!

Too much water

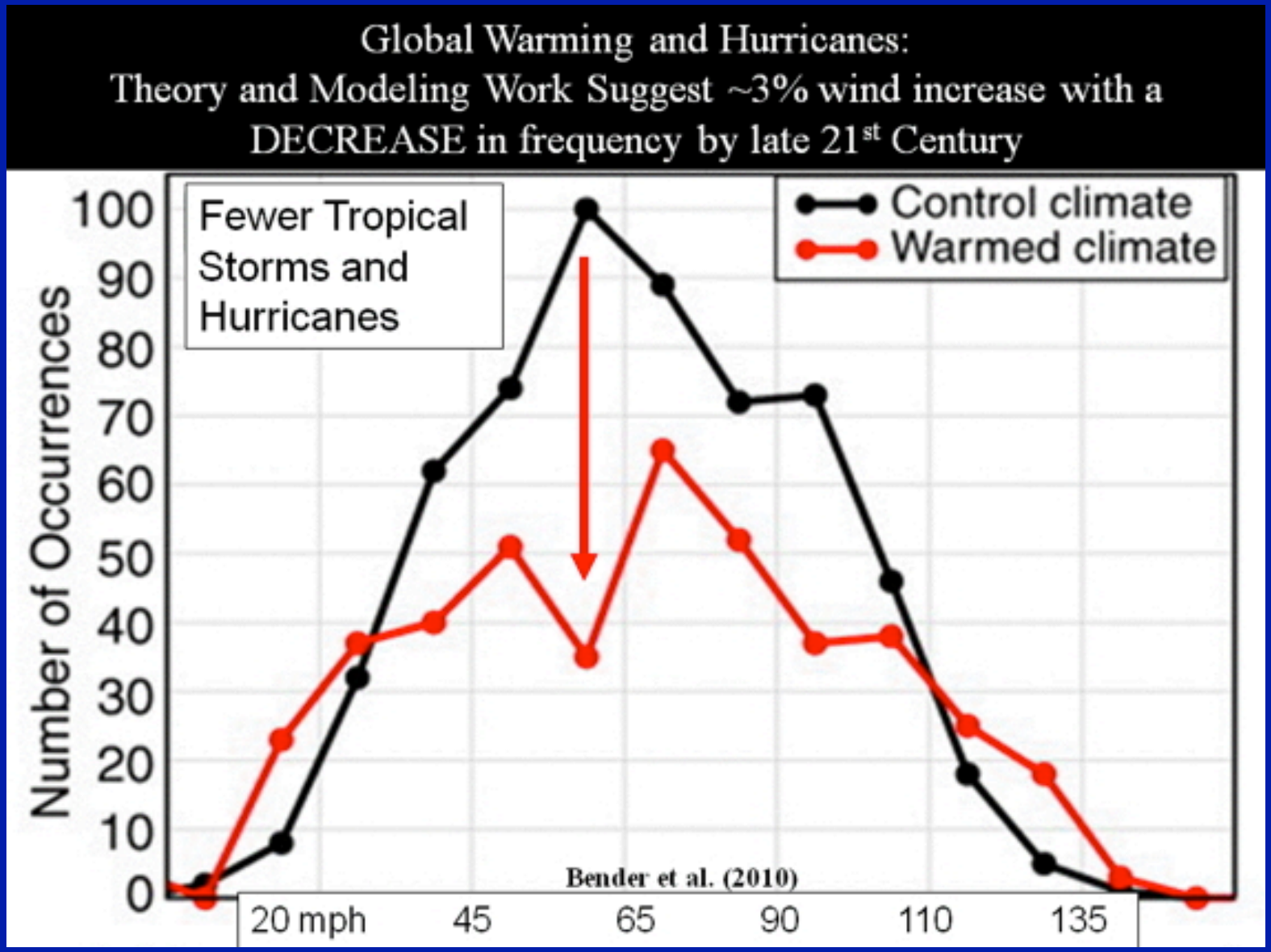


Trends in number of reported natural disasters
World meteorological organization:
http://www.itu.int/net/newsroom/wrc/2012/features/natural_disasters.aspx

Hurricanes
(and other tropical storms)

- Hurricanes could be slightly stronger now
- Climate model predictions have now converged
- Warmer air
  - More energy for hurricanes to tap into
  - But vertical wind shear increases making it harder for hurricanes to form
  - net is only a few % increase in intensity and a decrease (by as much as 25%) in number of storms by the end of the century

Bender et al, 2010: http://www.aoml.noaa.gov/hrd/Landsea/gw_hurricanes/



Bender et al, 2010: http://www.aoml.noaa.gov/hrd/Landsea/gw_hurricanes/


How do hurricanes see?


With one eye!


What type of lightning likes to play sports?


Ball lightning!


Whatever happened to the cow that was lifted into the air by the tornado?


Udder disaster!


What did the one tornado say to the other?


Let's twist again like we did last summer.


What happens when it rains cats and dogs?


You have to be careful not to step in a poodle.