Greenland ice cores has an abrupt change in dust content at the YD too

Is the atmosphere change (inferred from dust) a response to the thermohaline shutdown or is it the cause?

What about the future?

Bitz on local NPR...

Fig 15-1 box

What forces climate during the Holocene?

- Orbital? (only when you look at the whole period)
- Volcanoes, via aerosols
- Sunspots, via insolation
- Greenhouse gases (more after Midterm)
Sunspots and Climate Change

Sunspots cause solar intensity $S$ to vary

- $S$ is measured with satellites for past 27 yrs
- $S$ varies by about 0.1% giving about 0.2 W/m$^2$ change in radiative forcing (very uncertain)
- which would give 0.1 C global temperature change

Prior to satellite era, we rely on sunspot number to infer $S$

- Telescopes since Galileo 1610
- Naked eye
- Aurora frequency - historical literature
- Cosmic Rays - create $^{14}$C and $^{10}$Be isotopes then measured in ice cores
  - variations like those during the Little Ice Age are common
  - no smoking gun for ice ages

What other data tell us about sunspot activity?

But their number is related to $S$ in an uncertain way => controversy

The Controversy: Global temperature resembles sunspots

What is wrong with this comparison?

Volcanoes and aerosols

- Volcano spews ash and sulfuric dioxide (SO$_2$) high in the atmosphere
- Ash falls quickly (days to a few weeks at most)
- SO$_2$ reacts with H$_2$O forming a cloud of H$_2$SO$_4$ (sulfuric acid) aerosols
- Aerosols that reaches the stratosphere can spread globally and hang out for upto several years

Shuttle picture of Pinatubo aerosol layer 1991
What is an aerosol?

- Material condensed in liquid or solid particle, suspended in the atmosphere
- Interact with radiation (like a dispersed cloud)
- Scatter (mostly sunlight)
- Absorb (both sunlight and IR)
- Radiate (mostly IR)

Remember this figure for high thin clouds?
Are you tempted to think of it for an aerosol “cloud”?

Don’t be!
Must account for sunlight back scatter (aka reflection) from aerosol “cloud”

1) Unlike high clouds, reflected sunlight causes cooling at the surface
2) Like high clouds, absorption of IR (and sunlight) by aerosols warms the atmosphere

Stratospheric warming is quite easy to measure:
1982 El Chichon and 1991 Pinatubo

Fig 15-6 “Composite” of 5 recent eruptions aligned in time shows modest surface cooling

This kind of averaging increases “Signal to noise”
Signal = volcanic response
Noise = random variability

Why didn’t Mt St Helens eruption have a climate effect?

- Small eruption (didn’t seem so around here!)
- Not much SO\textsubscript{2} in eruption cloud
- Much of blast went sideways - didn’t get to stratosphere
- Too far poleward

Indonesia’s Tambora Eruption in 1815

- Largest eruption in modern times (44km high plume, 100-150 km\textsuperscript{3} of ash)
- 92,000 died
- Year without a summer in Europe and Asia (~3°C decrease in avg summer temperature)