The Holocene Express:-

What is the Holocene?

-Technically, the period since the Pleistocene, or roughly the last12 thousand years

What has changed during the Holocene?

- orbital configuration
- lower boundary conditions (ice volume and extent)
- CO_2(?)/vegetation
- human impacts?

Why should we care?

- baseline against which past and future expectations about climate are judged.

What is the cartoon?

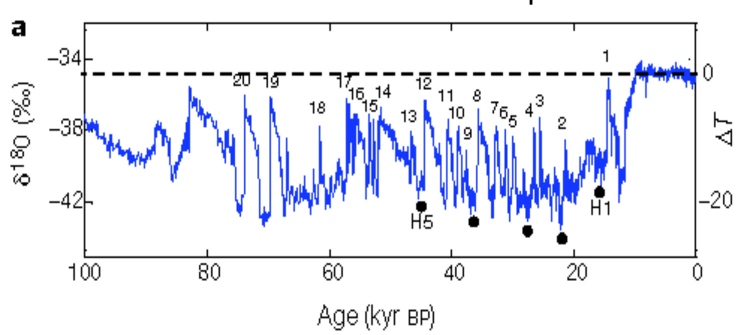
During the last glacial stage, the Greenland temperature record demonstrates large rapid jumps.

For example, the Dansgaard/Oeschger (D/O) events show:

- Rapid onset of warming at Greenland (10 K in < 30 years!)
- Long-lived (~ 200 - 600 years)

During the Holocene, Greenland is quiescent.

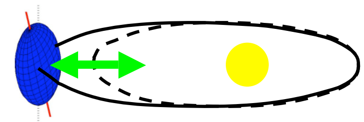
Greenland annual mean temperature



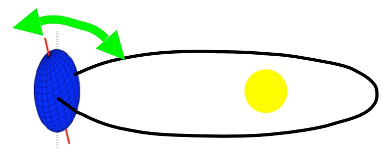
Primer on orbital parameters

- Earth's orbit varies over time due to influence of the Sun, Jupiter, and the Moon.

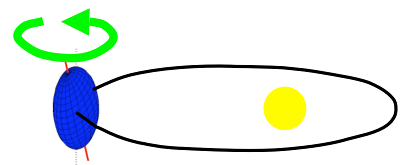
- **Eccentricity** (ellipticity)
  ~100 kyr, 400 kyr



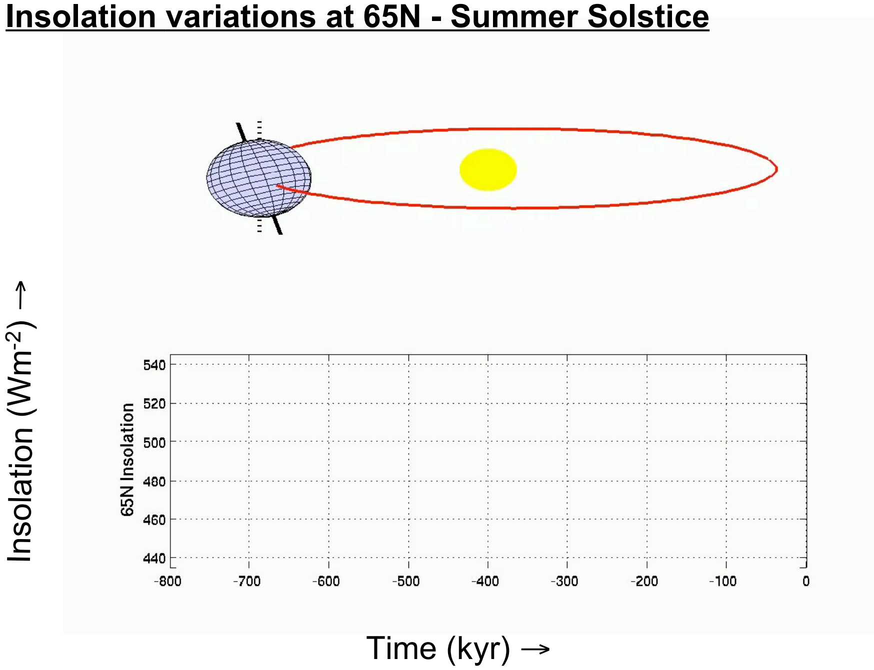
- **Obliquity** (tilt)
  ~41 kyr



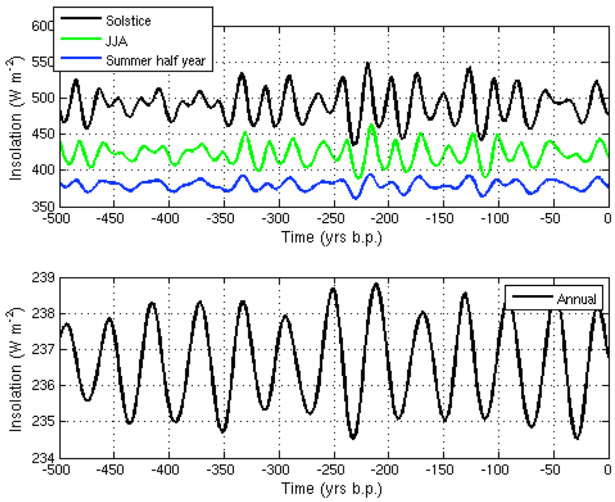
- **Precession** (wobbly top)
  ~19, 23 kyr



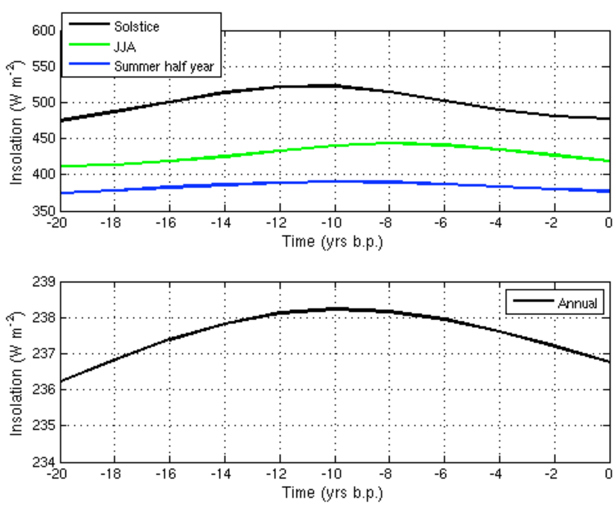
Primer on orbital variations
Insolation variations at 65N - Summer Solstice



How has insolation changed?
60N summer insolation last 500 thousand years

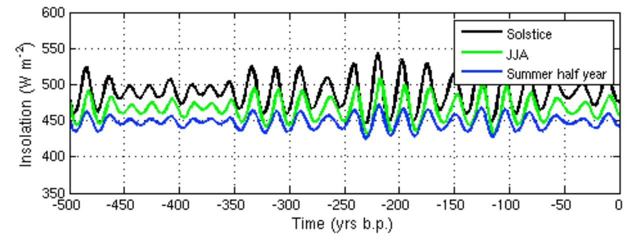


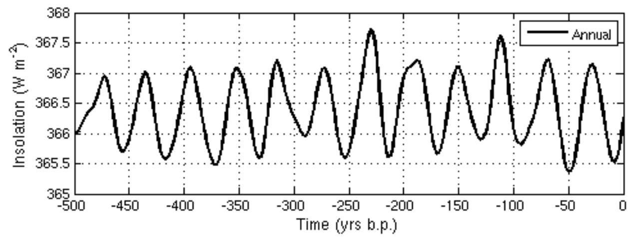
How has insolation changed?
60N summer insolation last 20 thousand years



How has insolation changed?

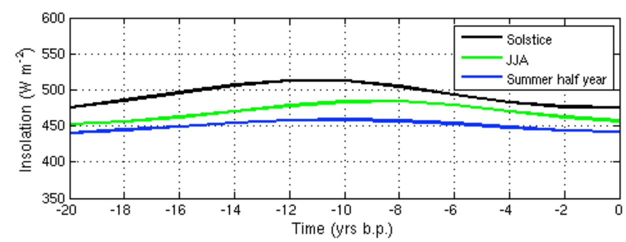
30N summer insolation last 500 thousand years

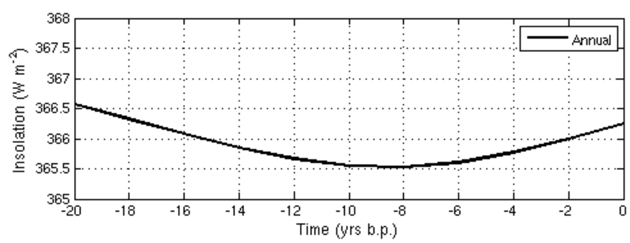




How has insolation changed?

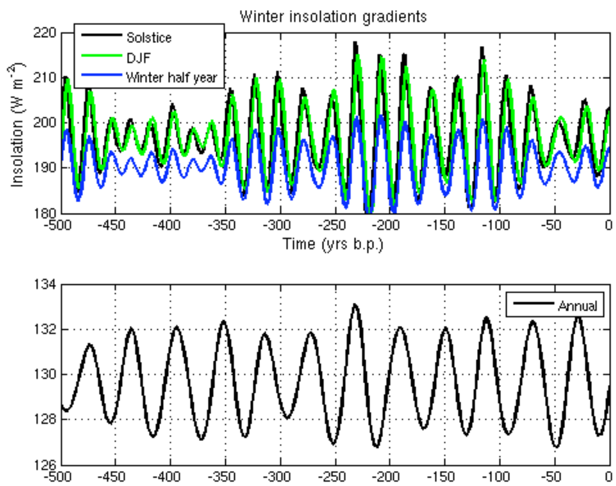
30N summer insolation last 20 thousand years





How have insolation gradients changed?

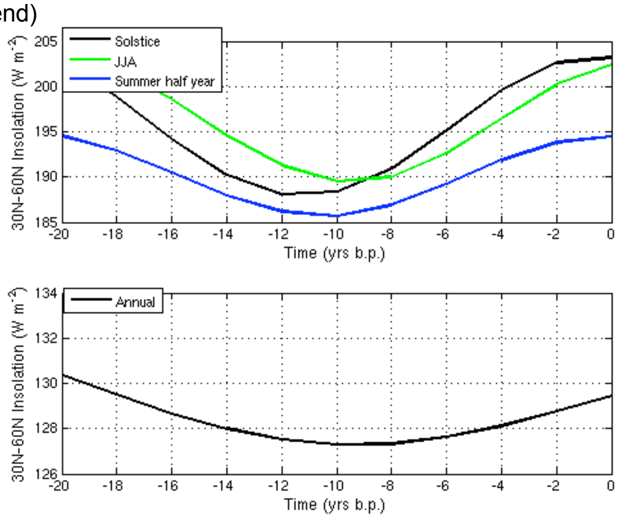
30N-60N winter insolation last 500 thousand years



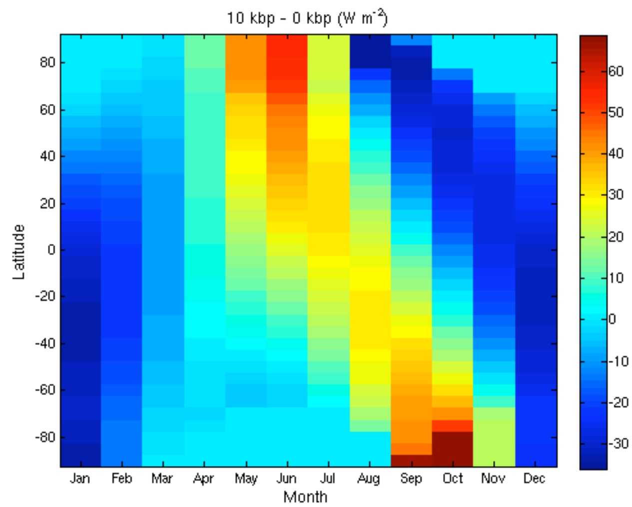
How have insolation gradients changed?

30N-60N winter insolation last 200 thousand years

(ignore legend)



Insolation at 10 kbp minus 0 kbp, by month



Summary of insolation changes

Northern hemisphere at 10 thousand years ago-

summer insolation goes up a lot (~5 to 10%)
winter insolation decreases a little (~5%)
-> increased seasonality in insolation.

winter gradients in insolation decrease ~10%

Southern hemisphere

fall increase in insolation (5to10%) (is this right?)

<u>What does solar forcing mean c.f. anthropogenic forcing?</u>

1% change in solar = ~3.4 W m^{-2}

c.f.

2 x CO_2 = ~4 W m^{-2}

But some serious differences:

Solar = shortwave forcing, primarily seasonal, surface.

CO_2 = longwave forcing, annual mean, top of atmosphere.

<u>What is default expectation at mid Holocene?</u>

-Increased seasonality in insolation in northern hemisphere:-

Confident:-

- increased seasonality in temperature over land
  (hotter summers/cooler winters)
  (except monsoons)?
- increased land sea contrasts - more intense monsoons?

Other aspects of climate:-

- atmospheric circulation (Siberian high, patterns of
surface winds, shift of storm tracks?
intertropical convergence zone/Hadley Cell?)

Hydrological cycle:-

- precipitation minus evaporation
- warmer equals wetter?
- or greater evaporation rate/precipitation rate?)
- drought/floods (extreme events)

Storminess:-
• hurricanes - warmer summers equals more?
• midlatitude storms - meridional gradients are important?
• monsoons - more intense equals stormier?
(Weather is hard!)

Ocean circulation:-
• Wind driven gyres?
• Mass and heat overturning circulations?

Questions to ask about Holocene proxies:

How good is the record (quality, resolution, age model)?

How does it reflect climate?
- what atmospheric variables influence it (& how certainly)?
- annual mean or seasonal (peak or average)?

What does the record show?
1. About the Holocene?
   - are there clear trends in the mean and/or variability?

2. Compared to Glacial and/or observations?
   - mean/ and/or variability

Does the record confirm or challenge our expectation about climate dynamics, or does it have nothing to say?

What does an (old) Global Climate Model say?

Kutzbach and Guetter (1986)

Series of GCM experiments for the last 18 yr.

JOHN E. KUTZBACH AND PETER J. GUETTER

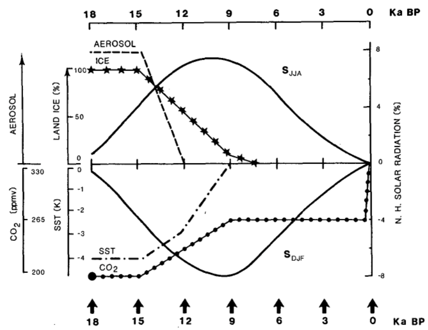


FIG. 1. Schematic diagram of major changes since 18 kyr BP in external forcing (Northern Hemisphere solar radiation in June–August (S_{JJA}) and December–February (S_{DJF}), as percent difference from present) and internal boundary conditions: land ice (ICE) as percent of 18 kyr BP ice volume (CLIMAP Project Members, 1981; Denton and Hughes, 1981); global mean-annual sea-surface temperature (SST), including calculated surface temperature over sea ice, as departure from present, *K* (CLIMAP Project Members, 1981); excess glacial-age aerosol (AEROSOL), arbitrary scale (Petit et al., 1981; Thompson and Mosley-Thompson, 1981); and atmospheric CO_2 concentration (CO_2), in ppmv (Neftel et al., 1982; Lorius et al., 1984). The arrows correspond to the seven sets of simulation experiments with the CCM. One experiment for 18 kyr BP included the lowered CO_2 concentration (200 ppmv, large solid circle); the main series of experiments used the same CO_2 concentration as the control case (330 ppmv) rather than the stepwise increase. Experiments incorporating the increased glacial-age aerosol loading are planned but not included here.

Boundary conditions input into the model

(n.b. no albedo feedback)

(perpetual January, July runs)

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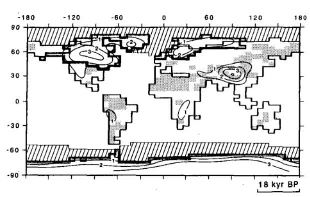
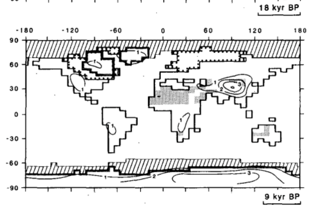
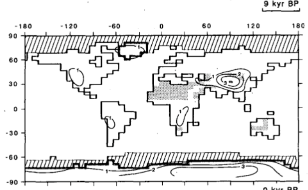


18 kbp



9 kbp



0 kbp

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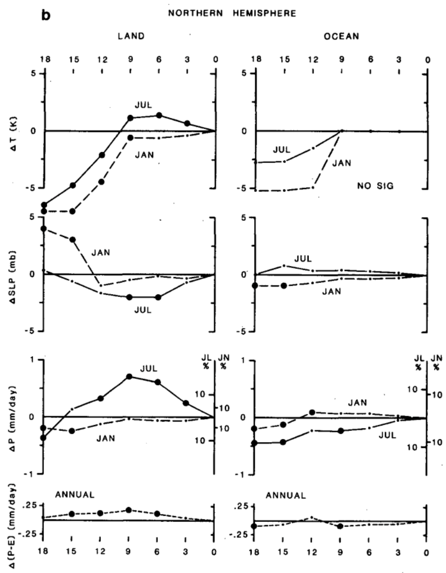

Model results:
Averaged over northern hemisphere