Lecture 21: Orbital Scale Interactions in the Climate System

Chapter 11 (p. 191-205)

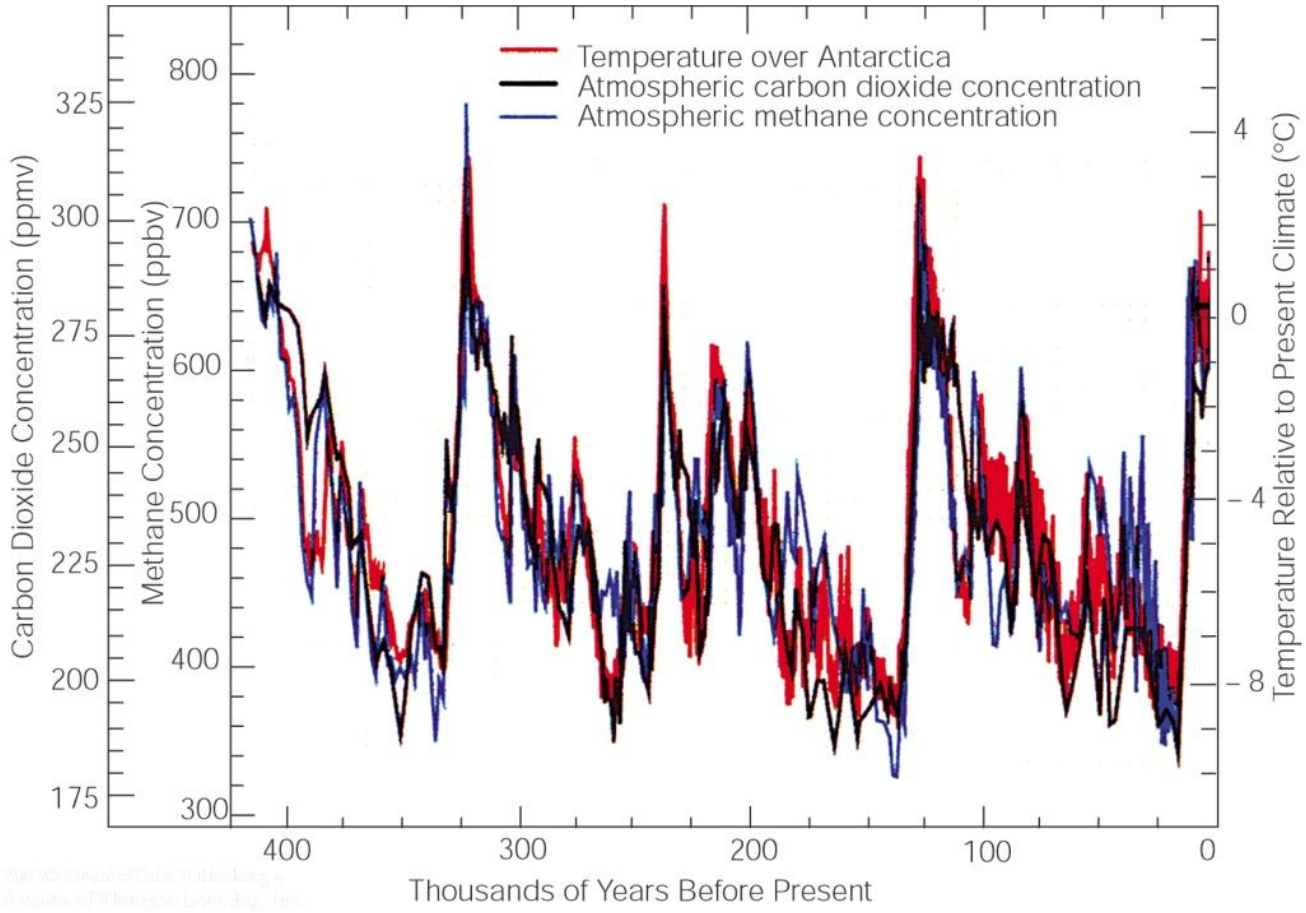
Orbital-Scale Interactions in the Climate System

Which factors drive changes in climate?

Which factors are internal responses?

Orbital-scale insolation changes *ultimately* drive changes in monsoons, ice sheets and greenhouse gases.

CO_2 ←→ ice sheets: The most crucial chicken-and-egg question

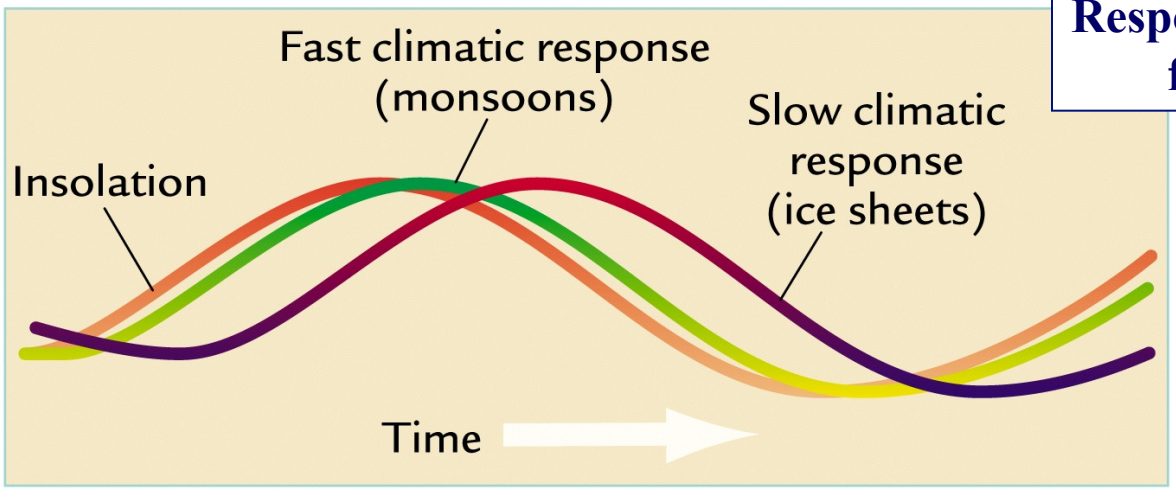


Land vegetation, ocean temperature, wind-blown dusts

What explains 100,000-yr cycles during the last 0.9Myr?

Orbital-Scale Forcing and Response Revisited

Responding to (external) insolation forcing



A Insolation forcing

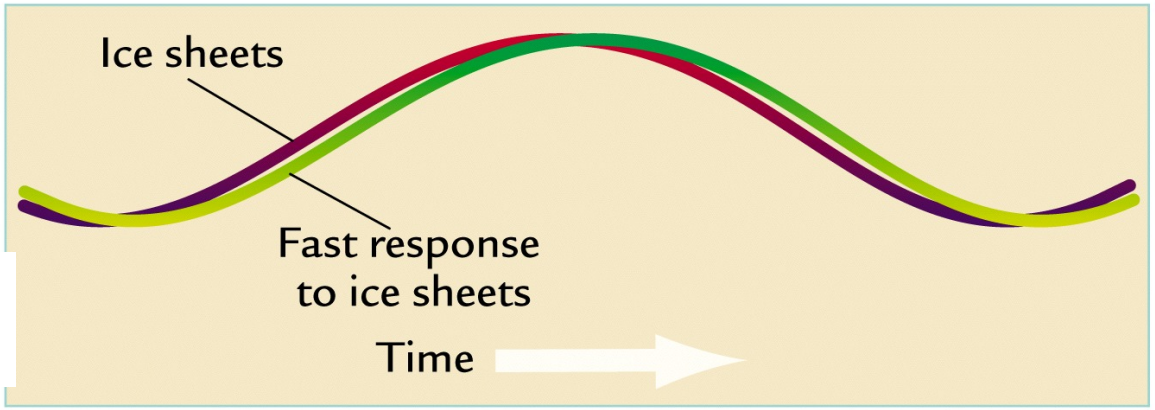
Fast-responding system in North Africa

Slow-responding ice sheets at high northern lat.

Responding to (internal) ice sheet forcing

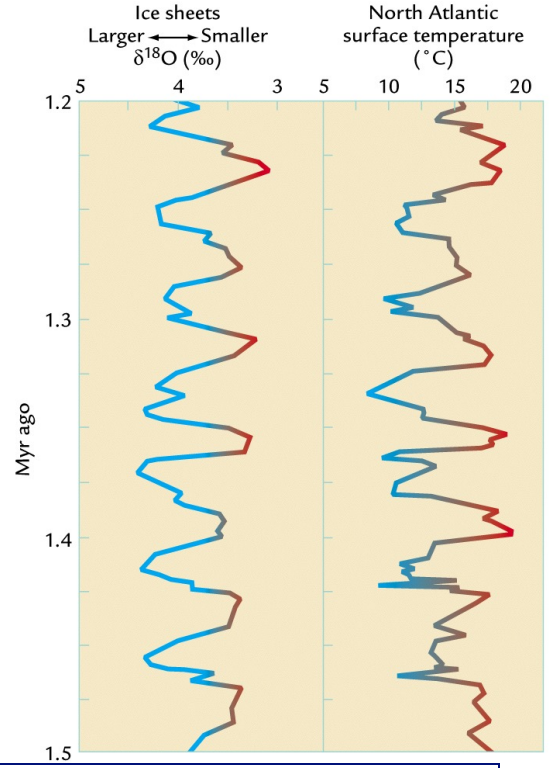
Slow-responding parts set the tempo for fast-responding parts

Air temperature quickly responds to ice sheet forcing

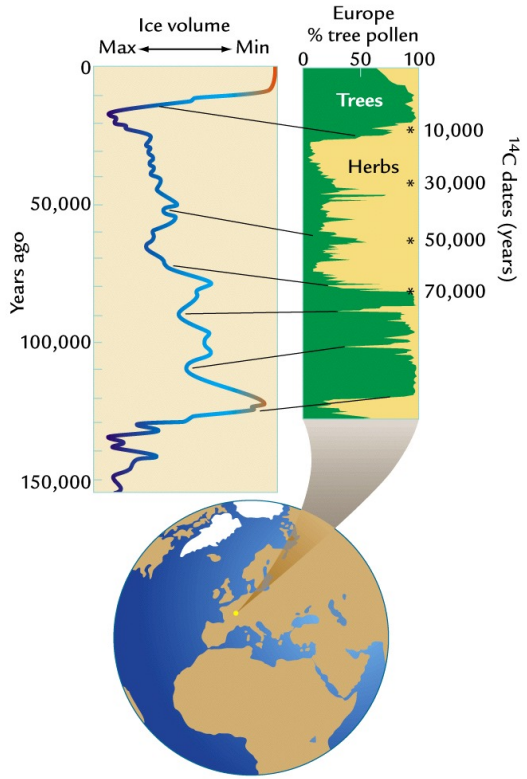


B Ice sheet forcing

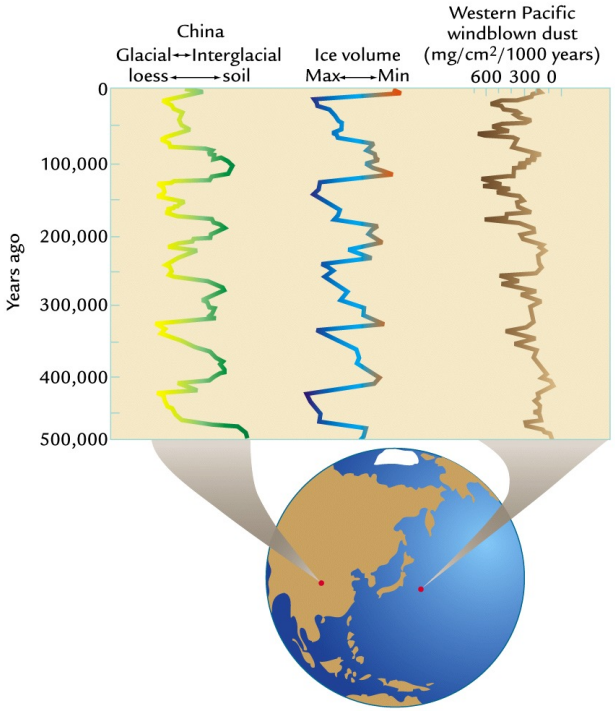
Ice Driven Responses in High Northern Latitudes



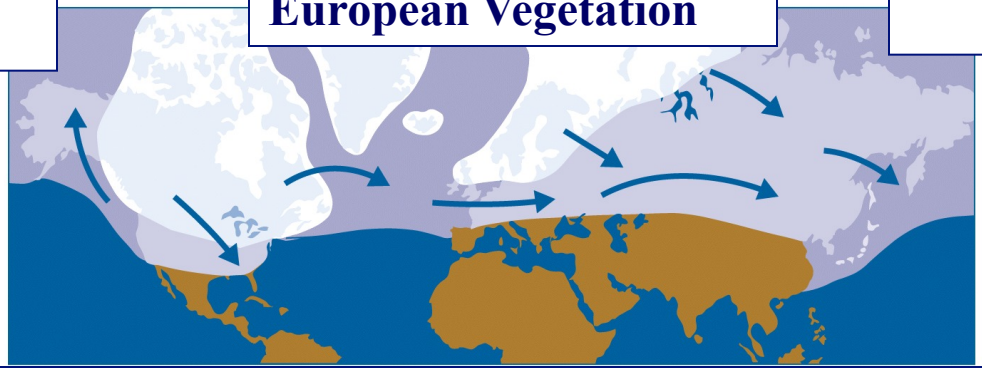
North Atlantic Ocean Temperature



European Vegetation



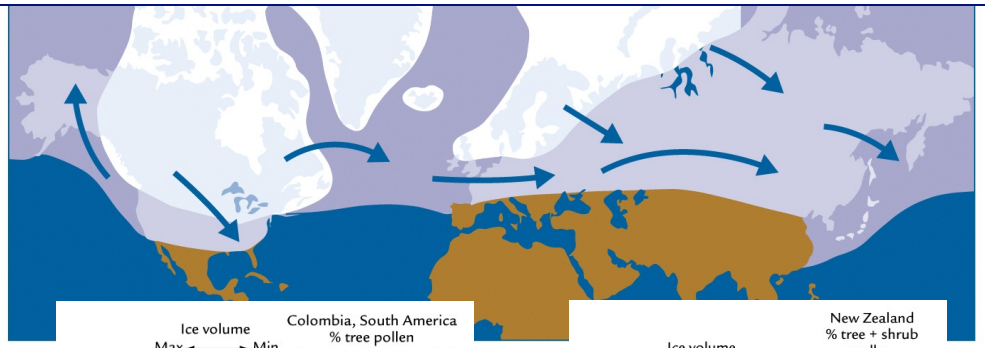
East Asia Windblown Debris

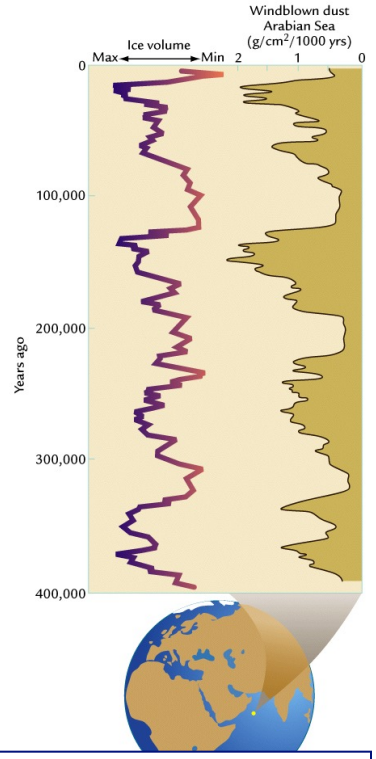


Ocean temperatures, vegetation & dusts respond quickly to ice sheets forcing

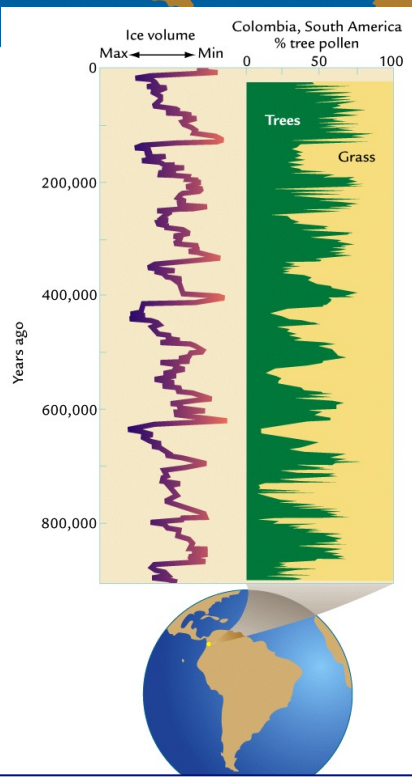
Orbital Cycles in Regions Remote from N.H. Ice

N.H. ice sheets signal (100,000-yr cycle) shows in many faraway regions.

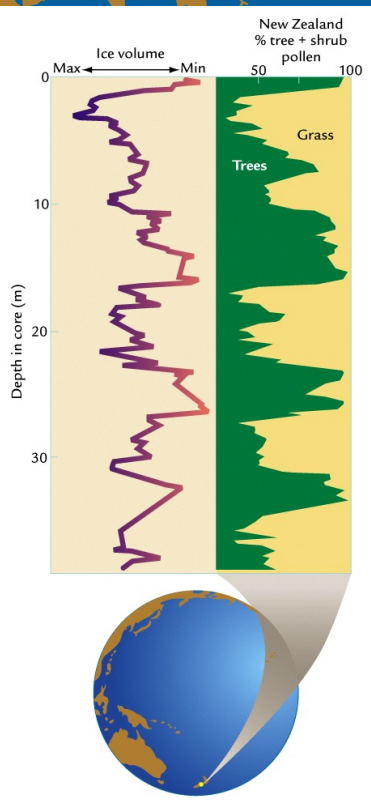




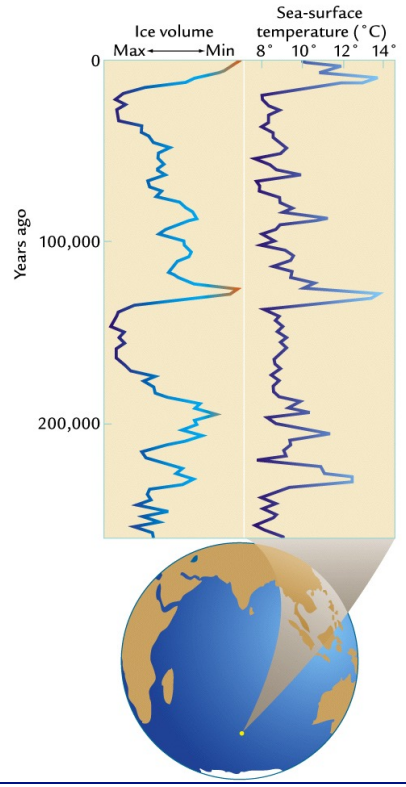
Arabian Desert Windblown Debris



Southern American Pollen



New Zealand Pollen



Southern Ocean T

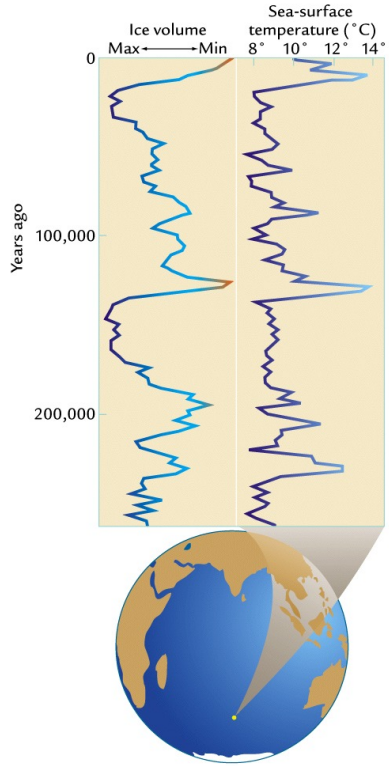
Northern or Southern Ice Sheet Forcing?

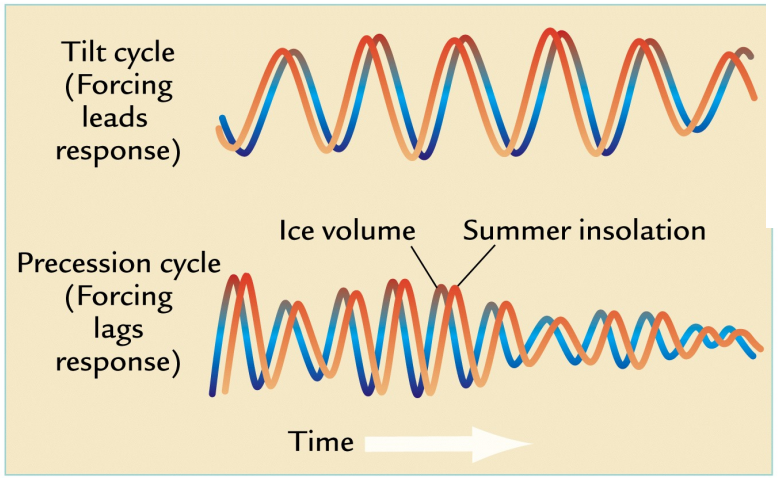
Which ice sheets drive the above regional climate responses?

Relative small changes in the size of the Antarctic ice sheet

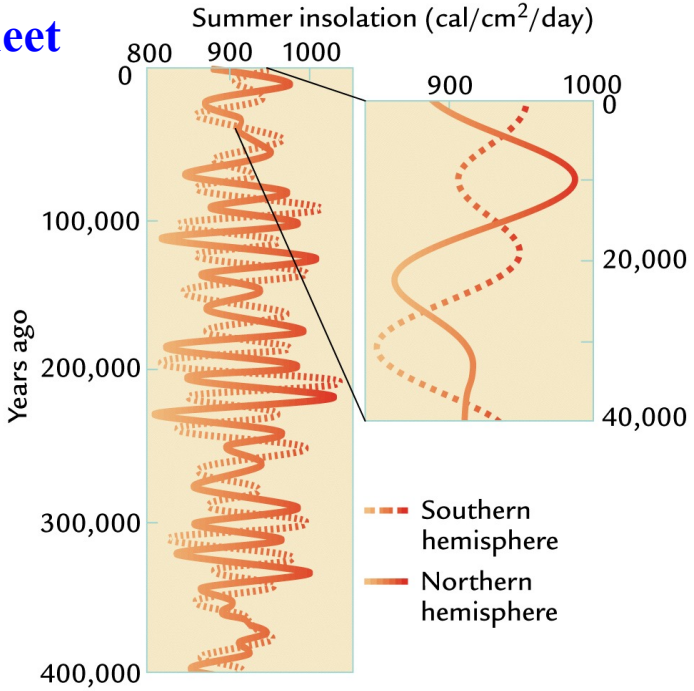
Relative large changes in the size of the N.H. ice sheets

Summer insolation changes (23000-yr cycles) in the south polar region lag thousands of years behind ice sheet response.





B Southern hemisphere



Out-of-phase summer insolation between hemispheres

Northern ice sheets drive the above regional climate responses!

CO_2 Level and Ice Volume: Which Drives Which?

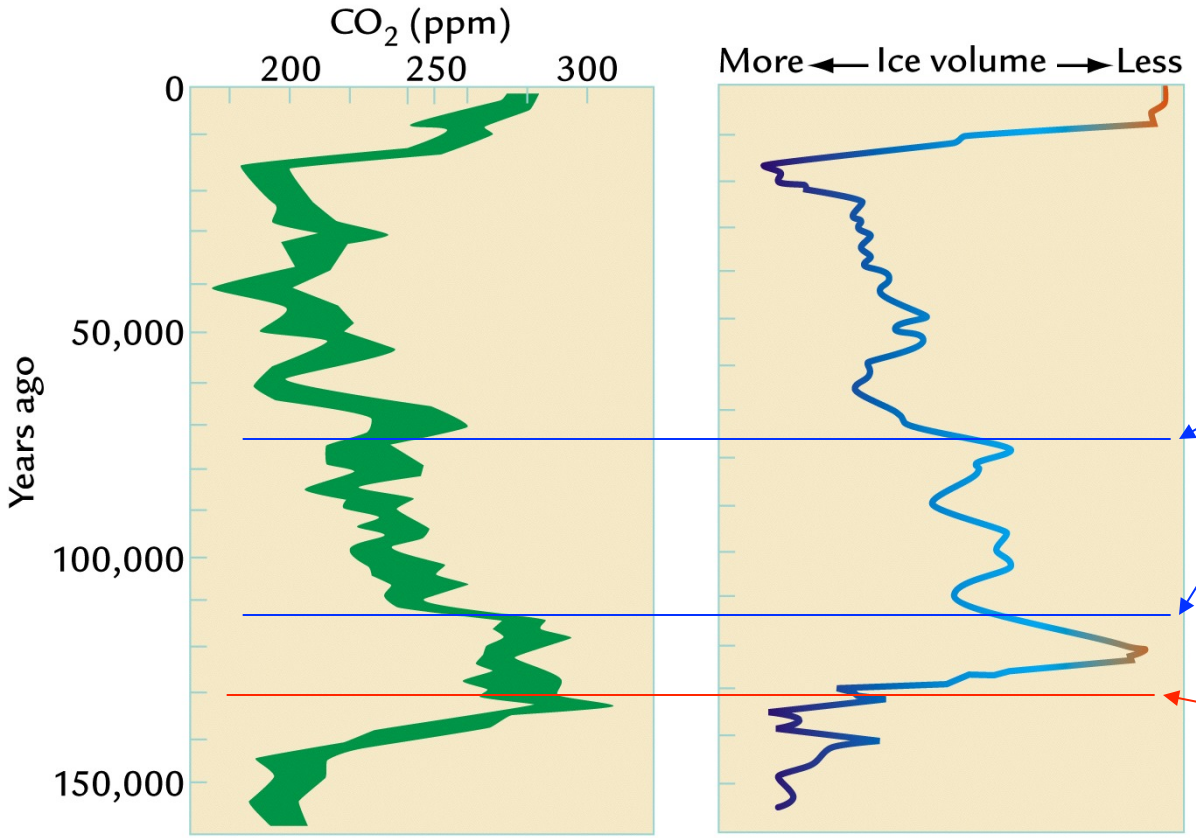
Ultimately, both are driven by changes in Earth's orbit.

Strong correlation suggests two signals are linked. But which is driving which?

Insolation → ice sheets → CO_2 levels → positive feedback to ice sheet changes

CO_2 levels can have global impacts!

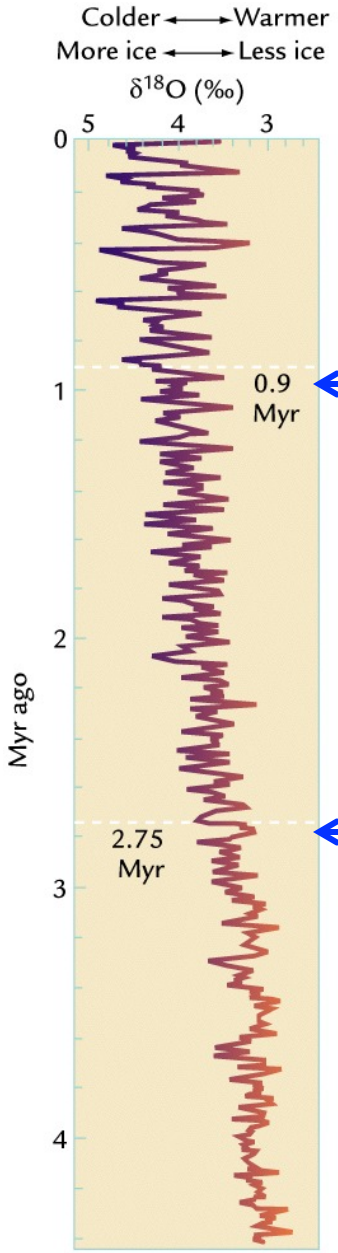
Still not fully understood!



High CO_2 but ice growth

Rising CO_2 before ice melts

The Mystery of the 100,000-Yr Cycle



Since 0.9 Myr, larger ice sheets, 100,000-yr cycles dominate

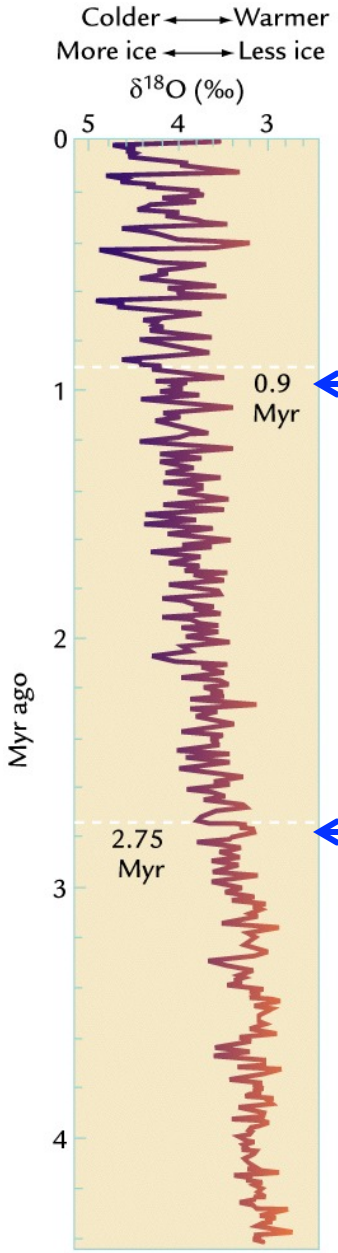
Between 2.75 and 0.9 Myr ago, smaller ice sheets, 41000 and 23000-yr cycles

2.75 Myr ago, first appearance of northern hemisphere ice sheets

Three mechanisms:

- Ice interaction with bedrock: cooling trends allow large-ice sheet to grow, which modulates local climate and harder to melt.
- Procession modulated by eccentricity, created maximum solar radiation at ~ 100KY period
- Positive feedbacks between Ice and CO_2

The Mystery of the 100,000-Yr Cycle



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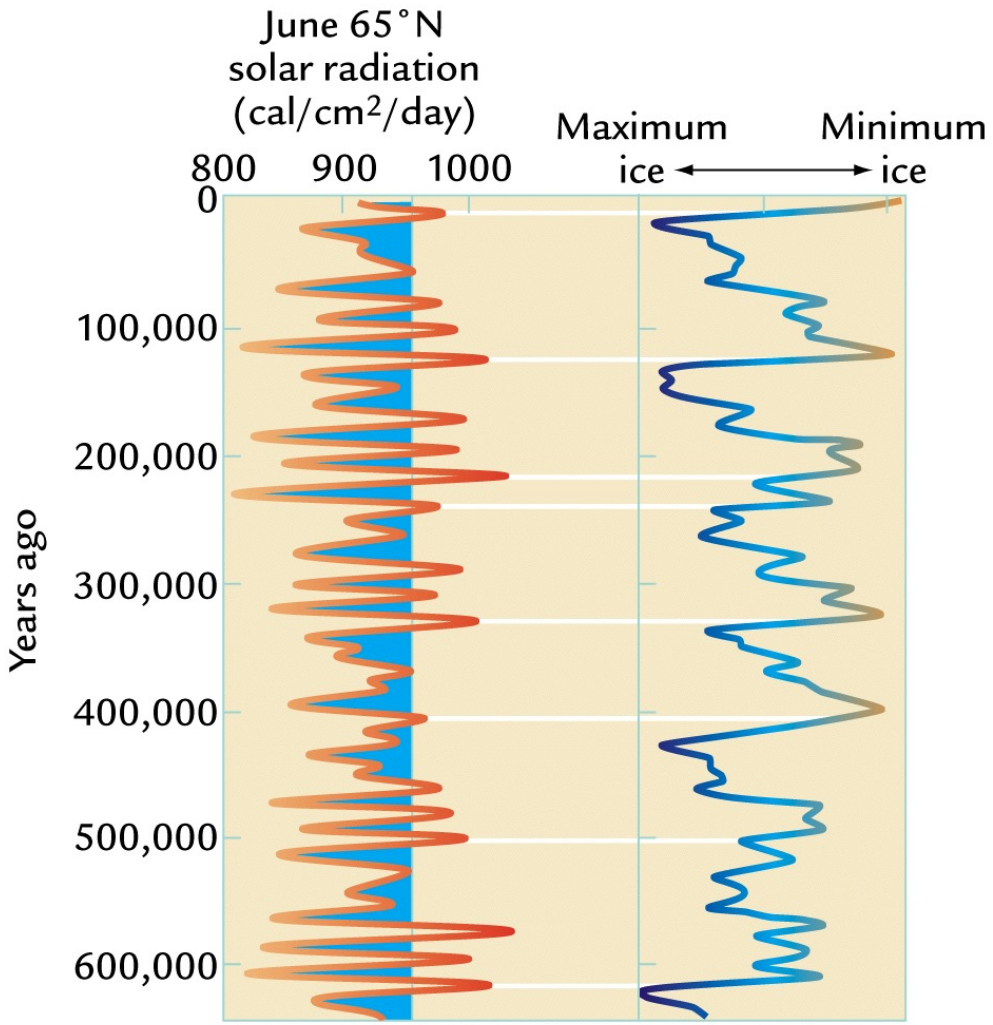
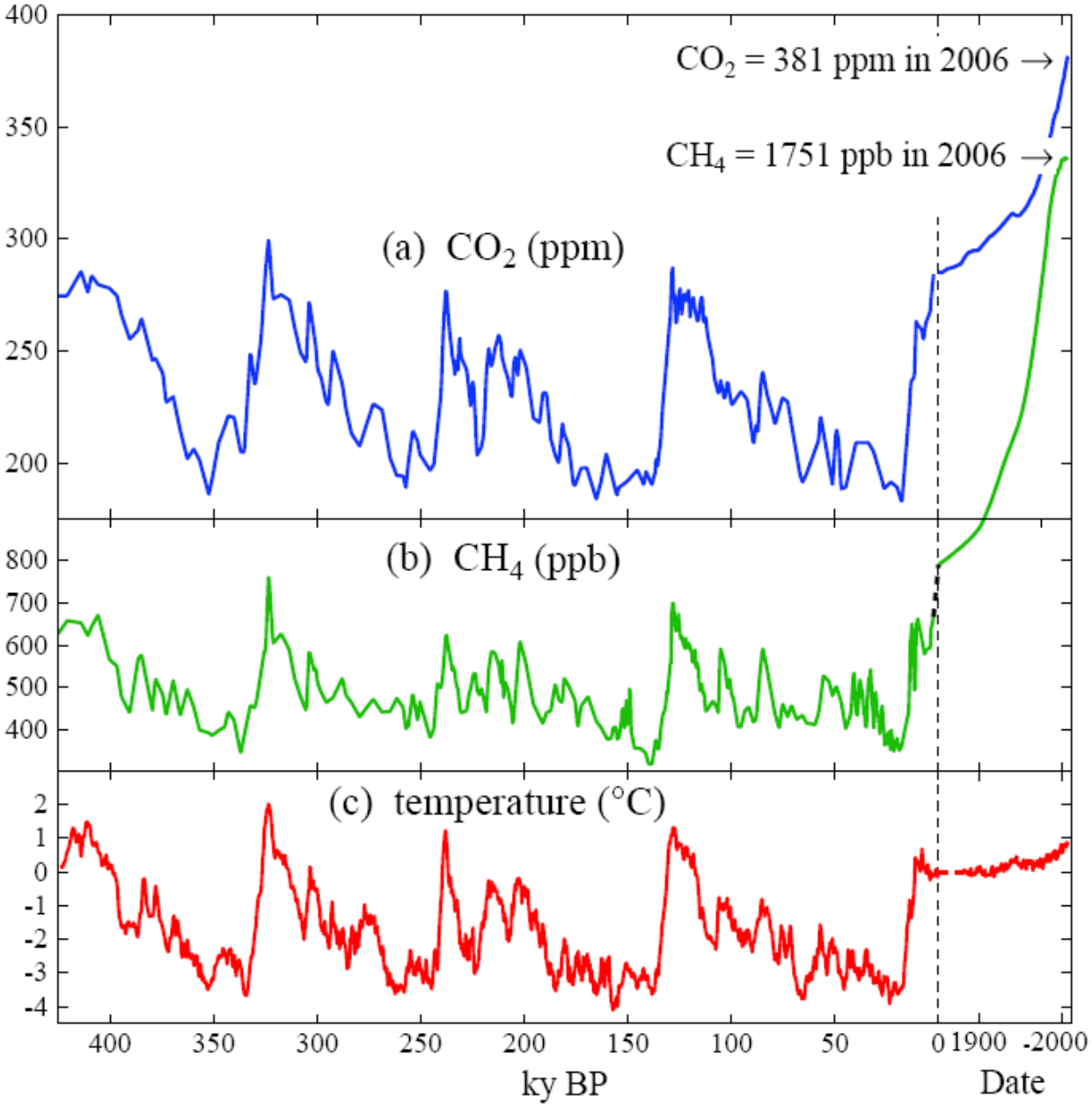
100,000-yr modulations of 23,000-yr precession cycle



Climate Change in the Past 425 k yrs



Implications of Pleistocene Climate Change

1. Chief instigator of climate change was earth orbital change, a very weak forcing.
2. Chief mechanisms of Pleistocene climate change are GHGs & ice sheet area, as feedbacks.
3. Climate on long time scales is very sensitive to even small forcings.
4. Human-made forcings dwarf natural forcings that caused glacial-interglacial climate change.
5. Humans now control the mechanisms for global climate change, for better or worse.

The Earth's Climate History

1. **Over the last century, the earth's surface temperature has increased by about 0.75°C (about 1.35°F).**
2. Little Ice Age = 1350 A.D. – 1850 A.D. (N.H. temperature was lower by 0.5°C, alpine glaciers increased; few sunspots, low solar output)
3. Medieval Warm Period = 950 A.D. – 1,250 A.D. (N.H. warm and dry, Vikings colonized Iceland & Greenland)
4. Holocene Maximum = 5,000-6,000 ybp (1°C warmer than now, warmest of the current interglacial period)
5. Younger-Dryas Event = 11,000 ybp (sudden drop in temperature and portions of N.H. reverted back to glacial conditions)
6. Last Glacial Maximum = 18,000 ybp (maximum North American continental glaciers, lower sea level exposed *Bering land bridge* allowing human migration from Asia to North America)

Discuss-summary:

- What are the key evidences to show that 100KY cycle occurred globally?
- What might cause 100KY climate change in the Southern Hemisphere?
- What are the possible mechanisms responsible for 100 KY cycle?
- How do today's CO_2 and CH_4 concentrations compare to those in last 400KY? What can we learn from this paleoclimate phenomenon?