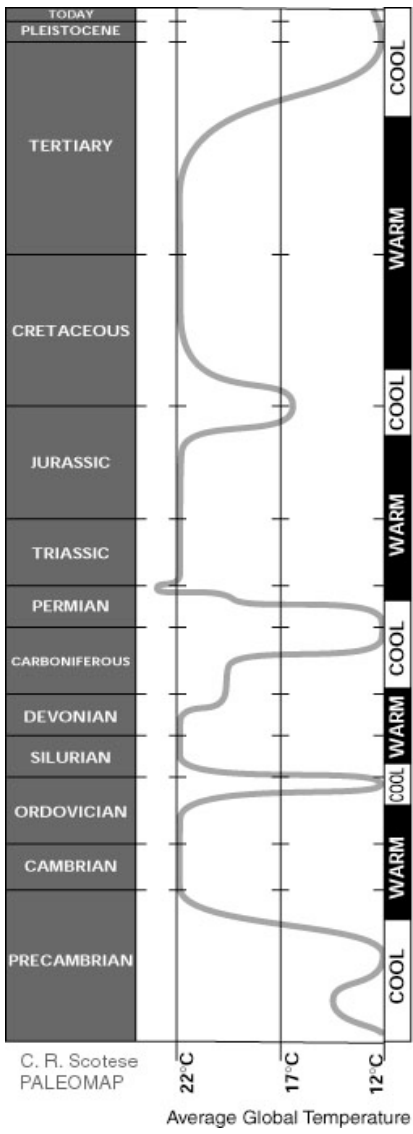


Causes of global climate change

Cyclicity of orbital parameters =
Milankovitch Effect

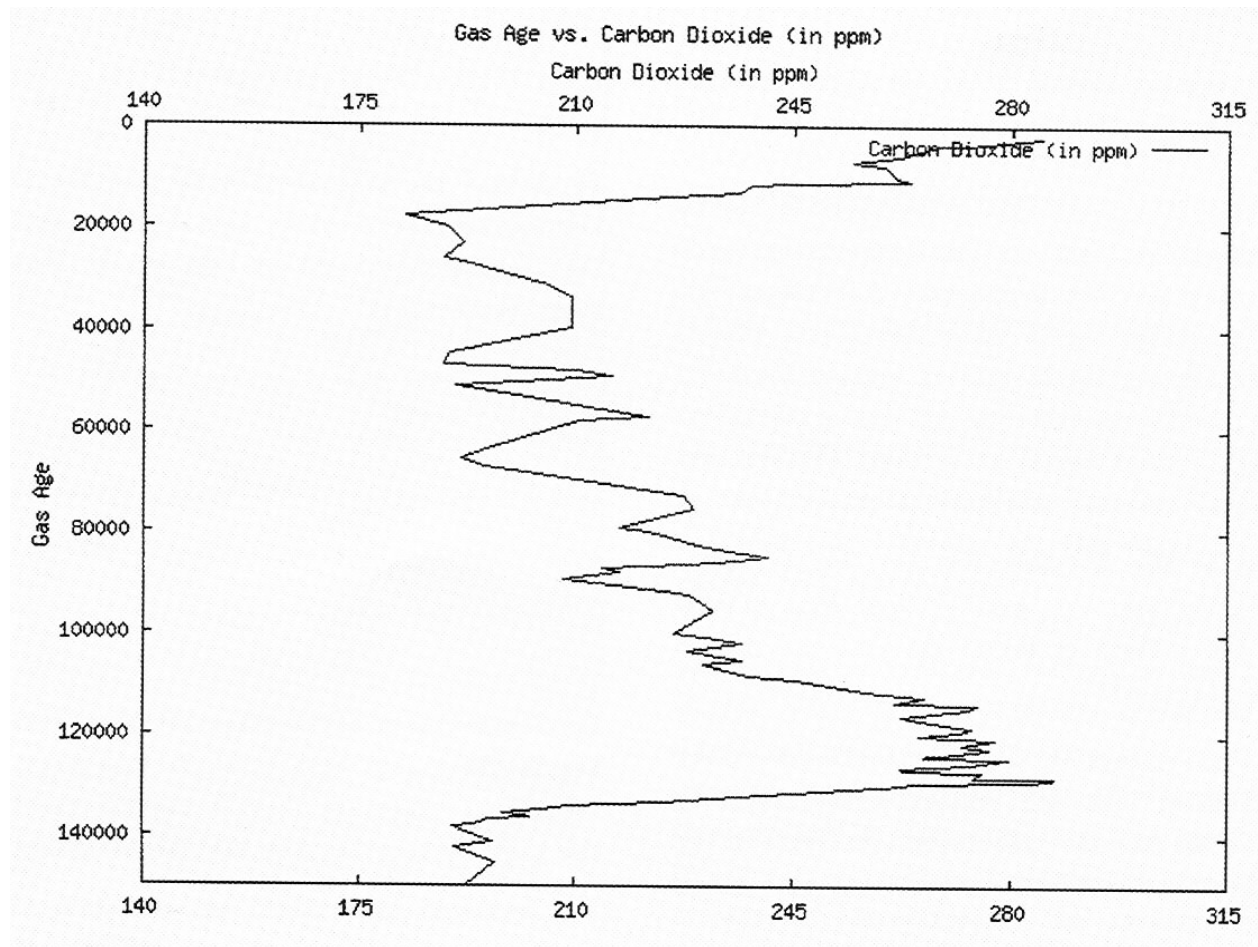
Not all climate change is
anthropogenic!!

There appears to be a cyclic nature to global climate



When viewed at a very large scale..

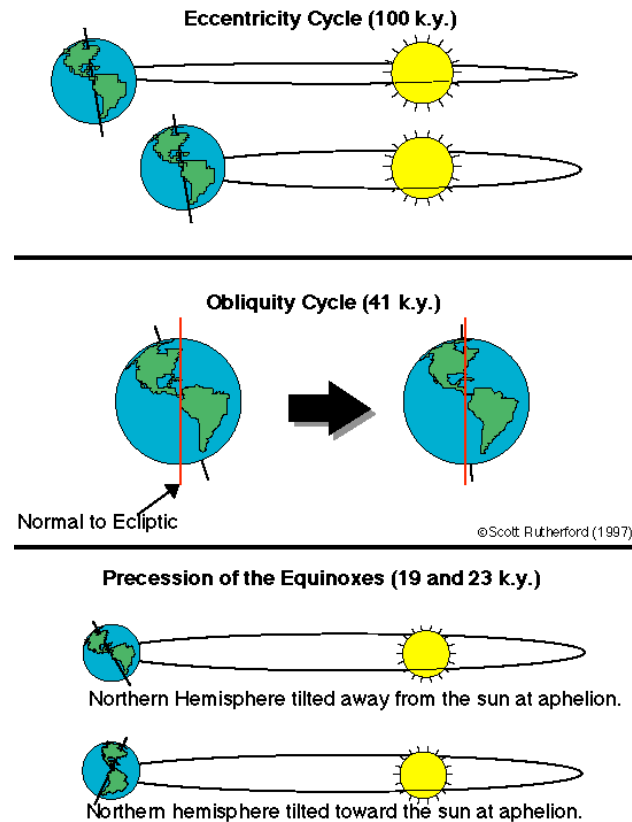
The cyclic nature of atmospheric CO₂ - as well as global climate - has been noted

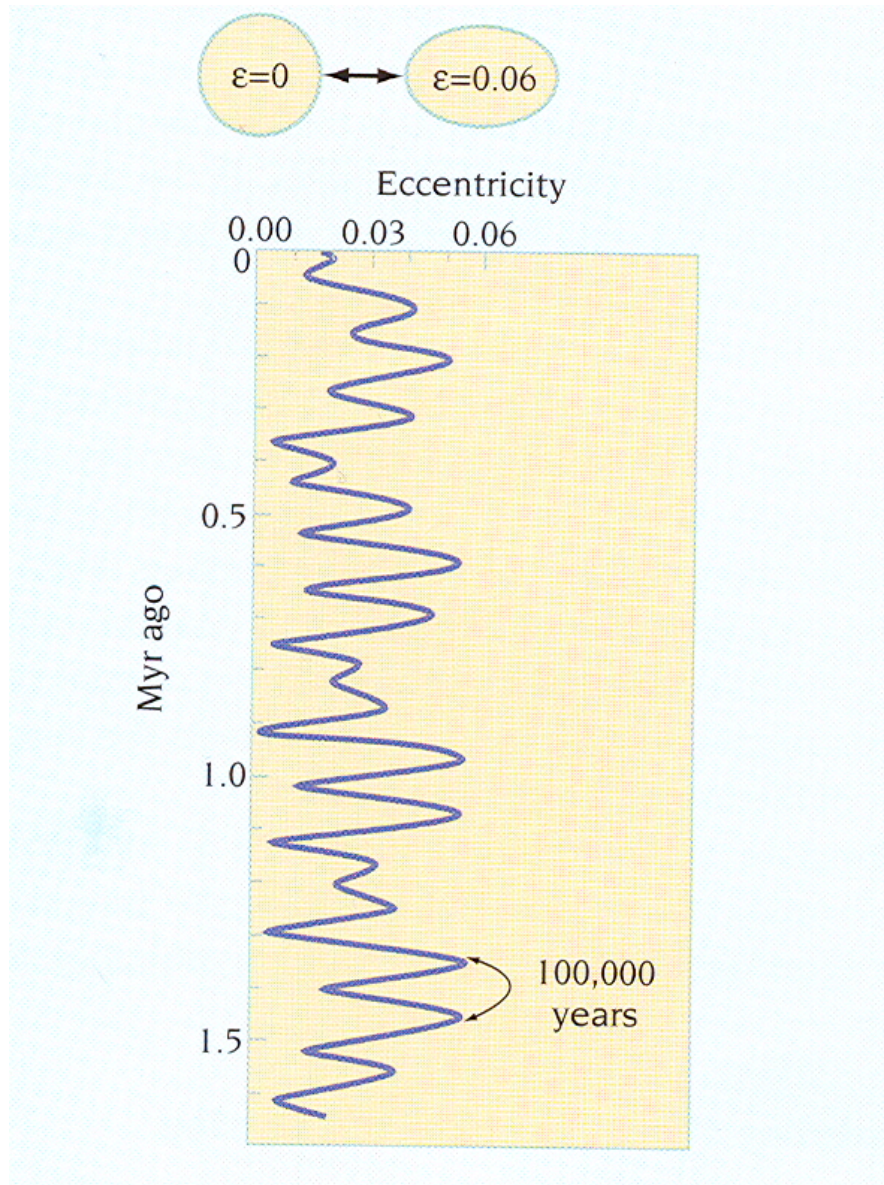


Atmospheric CO₂ fluctuations over 140K

Cyclic variation in orbital parameters first noted by Milankovitch

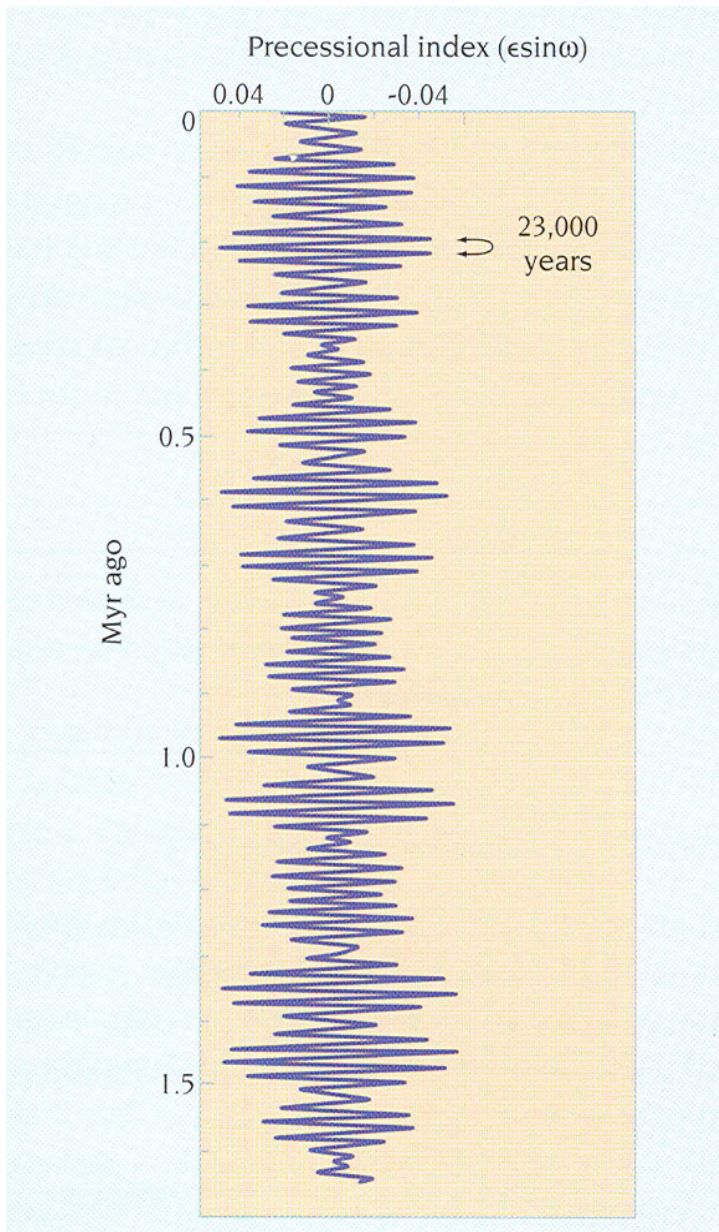
- Serbian astrophysicist who devoted his life to developing a mathematical model describing orbital earth models and climate change



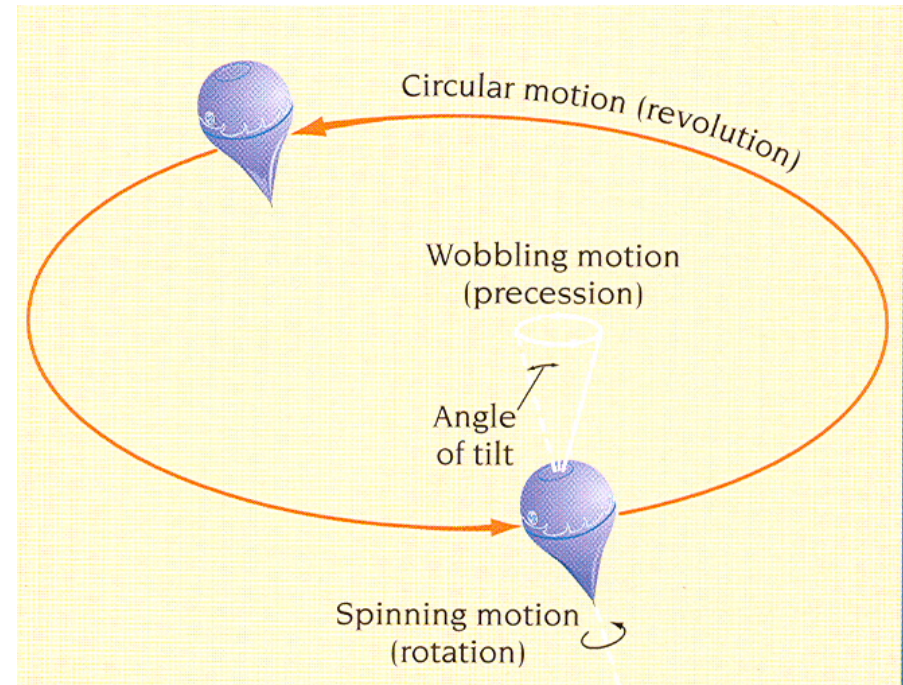


Eccentricity in the Earth's orbit: it is not a circle but an ellipse, and its shape varies over time.

Changes in elliptical shape occur on a **cycle of 100,000** years: when the Earth is closer to the sun, Earth temps rise, when further (more eccentric), then cooler.

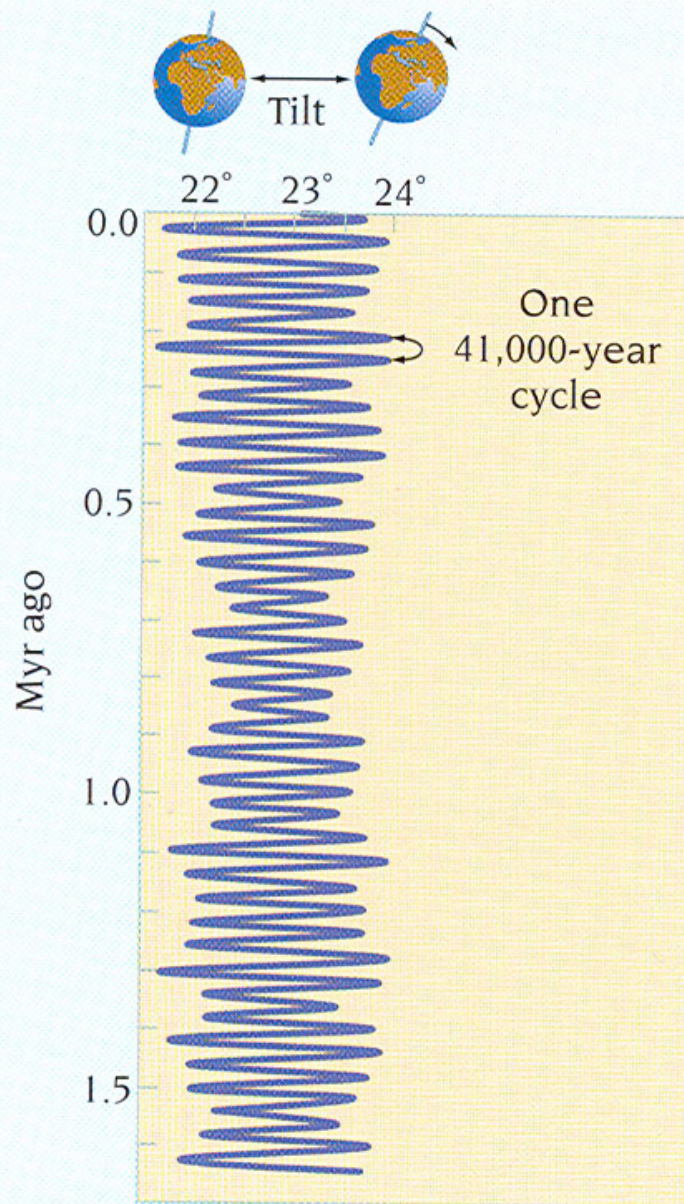


Precession of the Earth



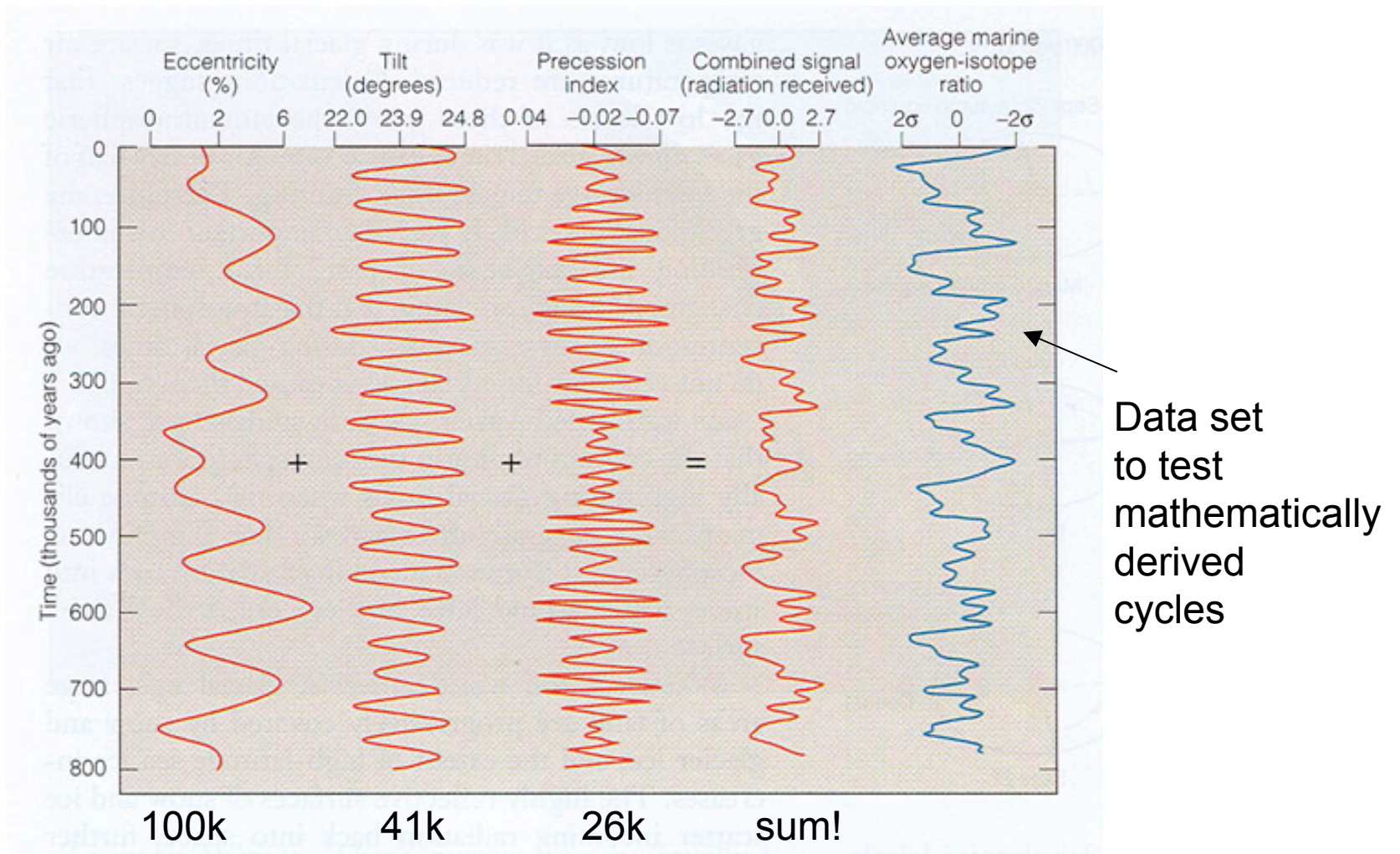
Like the wobble of a rotating spinning top, the Earth's rotation wobbles in a **cycle of ~26,000 years**

Seasonality can be accentuated/damped



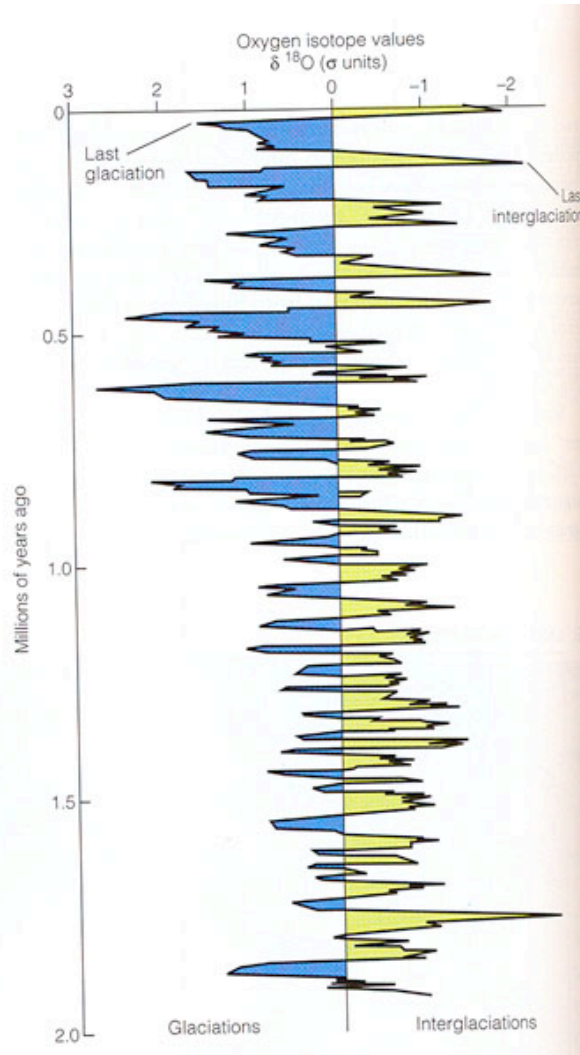
Obliquity:
Variation in the tilt of the Earth's axis of rotation: currently 23.5° but has varied between 22.1° and 24.5° following a **cycle of 41,000 years**

Seasonality can be accentuate/
damped



This diagram shows the sum of the orbital variation (3 curves on the left) and resulting changes in radiation from the sun received by Earth. The curve on the right shows the result of avg temp resulting, as measured by $O_{18}/_{16}$ isotopes..great agreement between prediction and observation

The implication of the Milankovitch cycles is that there will be cyclic variation in global average temps



New news on this front: other possible cyclic changes!

Sun's fickle heart may leave us cold

- * 25 January 2007
- * From New Scientist
- * Stuart Clark

There's a dimmer switch inside the sun that causes its brightness to rise and fall on timescales of around 100,000 years - exactly the same period as between ice ages on Earth. So says a physicist who has created a computer model of our star's core.

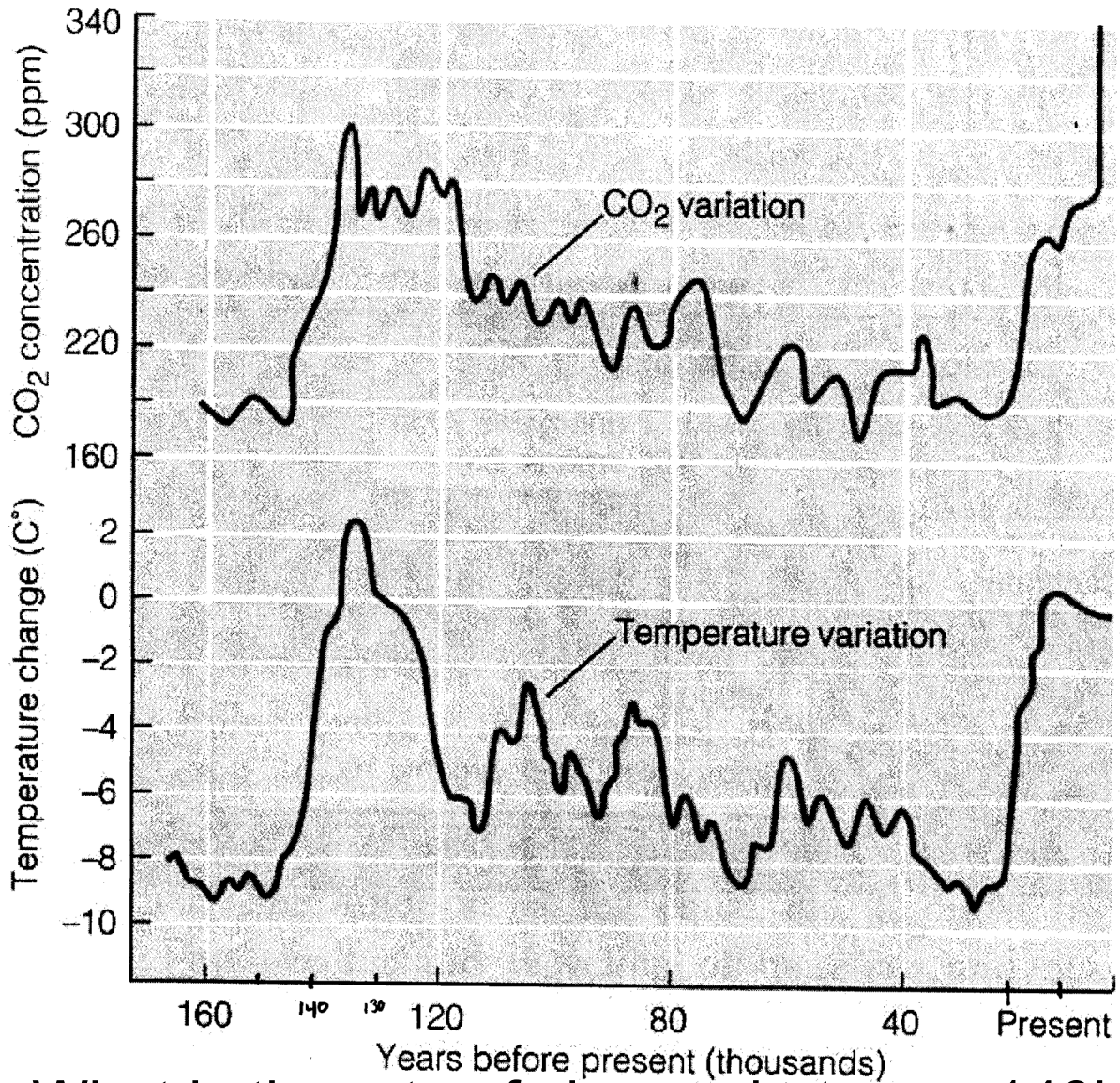
Robert Ehrlich of George Mason University in Fairfax, Virginia, modeled the effect of temperature fluctuations in the sun's interior.

Implications for modeling climate.....

- Most definitely, there IS a “normal” component to climate change! Changes in solar output and orbital variation WILL produce climate change over the scale of 10,000’s years. The global cooling that led to the last ice age is at least in part, attributed to orbital variation

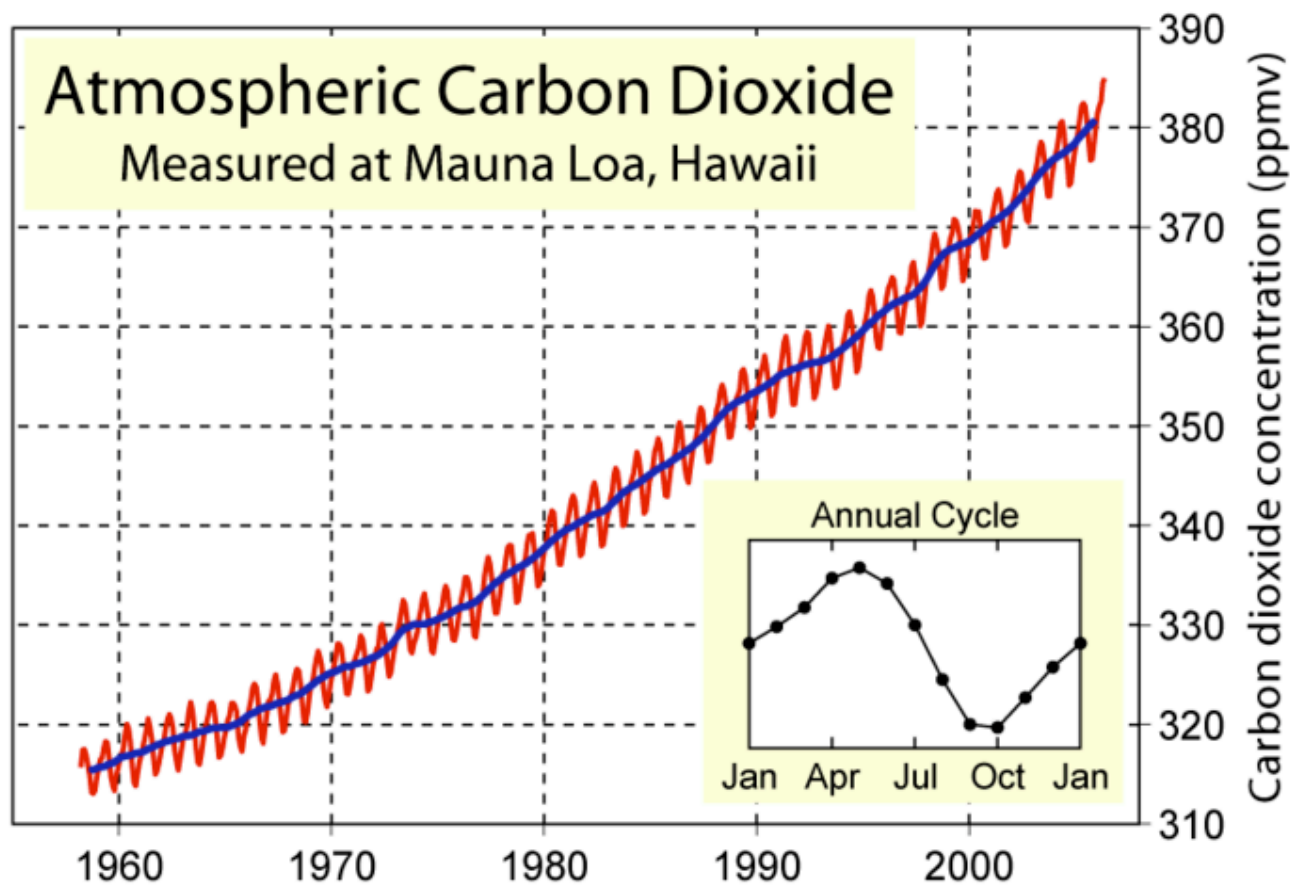
However.....

Looking at cycles: data from an ice core from Antarctica



Ice traps tiny bubbles of gas from the atmosphere. As ice builds up the gas bubbles from the past are buried deeper and deeper in the ice. Coring the ice enables us to retrieve tiny samples of the atmosphere from the past.

What is the rate of change between 140ka and 70ka?



Compare the rate of change of atmospheric CO₂ from 1965 to 2005:

If you did your arithmetic correctly:

- The rate of change in relatively recent geologic history is ~ 1.8 ppmv per 1,000yrs or 0.0018ppmv/year
- The rate of change over the past 40 years is ~ 1.5 ppmv/year
- The difference between the rate of change of atmospheric CO₂ levels from geologic to recent times is a factor of 1,000, i.e., we are changing CO₂ levels 10^3 times faster than ever in Earth's history