Ice Ages

Summary

- Adams, Maslin & Thomas 1999
  Sudden climate transitions during the Quaternary
  - My thoughts, not just on this paper
    1. Demonstrate frequency response by the insolation cycle at a given latitude with the result of the temperature at that latitude - in the frequency spectrum
    2. Play around with non-linear equations to see effect on freq response
    3. Find Munk & Cartwright 1966 paper on tides
    4. Model eliptical orbits - total energy by day & by year over year as a function of e
    - total energy absorbed by day and year as a function of latitude of ice extent as obliquity changes

Classic

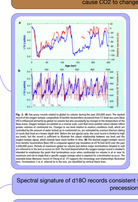
- Imbrie & Imbrie 1980
  Modeling the climate response to orbital variations
  - " On the one hand, climatologists have attacked the problem theoretically by adjusting the boundary conditions of energy-balance models, and then observing the magnitude of the calculated response. If these numerical experiments are viewed narrowly as a test of the astronomical theory, they are open to question because the models used contain untested parameterizations of important physical processes.
    Work with early models suggested that the climatic response to orbital changes was too small to account for the succession of Pleistocene ice ages (30, 31). But experiments with a new generation of models (14-17) suggest that orbital variations are sufficient to account for major changes in the size of Northern Hemisphere ice sheets. "
  - " In 1968, Broecker et al. (34, 35) pointed out that the curve for summertime irradiation at 45°N was a much better match to the paleoclimatic records of the past 150,000 years than the curve for 65°N chosen by Milankovitch. (Although subsequent studies in the time domain have confirmed this correlation (21, 36), it should be kept in mind that statistical correlations of this type do not point unambiguously to an underlying physical mechanism (37).) "
  - " In fact, one purpose of this article is to contribute to the solution of one of the remaining major problems: the origin and history of the 100,000-year climatic cycle. At least over the past 600,000 years, almost all climatic records are dominated by variance components in a narrow frequency band centered near a 100,000-year cycle (9-8, 12, 21, 38). Yet a climatic response at these frequencies is not predicted by the Milankovitch version of the astronomical theory-or any other version that involves a linear response (5, 6). "
  - " Eccentricity controls only the amplitude of the precession effect; its frequency components do not appear in the precession spectrum"
  - " Another problem is that most published climatic records that are more than 600,000 years old do not exhibit a strong 100,000-year cycle. "
  - Para on last page about flip flop models and Lorenz
- Hays JD, Imbrie J, Shackelton NJ (1976) Variations in the Earth's orbit, pacemaker of the ice ages
  - " Additionally, it has been argued that as almost intransitive system, climate could alternate between different states on an appropriate timescale without the intervention of any external stimulus or internal timescale. " - reference Climate Determinism, EN Lorenz 1968
  - "All versions of the orbital hypothesis of climatic change predict that the obliquity of the earth's axis (with a period of about 41,000 years) and the precession of the equinoxes (period of about 21,000 years) are the underlying, controlling variables that influence climate through their impact on planetary insolation."
  - GJ Kukla 1972
    Insolation & Glacials, Boreas 1
  - GJ Kukla 1975
    Missing link between Milankovitch and climate, Nature (London)
- Hartmut Heinrich 1988
  Origin and consequences of cyclic ice rafting in the Northeast Atlantic Ocean during the past 130,000 years
  - Good review paper
  - " It is still unclear how the climate on a regional or even global scale can change as rapidly as present evidence suggests. It appears that the climate system is more delicately balanced than had previously been thought, linked by a cascade of powerful mechanisms that can amplify a small initial change into a much larger shift in temperature and aridity (e.g., Rind and Overpeck, 1993). "
  - " The result could be a very sudden climate change to colder conditions, as has happened many times in the area around the North Atlantic during the last 130 ka. The models used by Seidov and Maslin (in press) show that Heinrich events did cause a total collapse of the deep-water thermohaline conveyor belt. However, this cessation of the conveyor is independent of the origin and magnitude of the meltwater produced during a Heinrich event as the essential prerequisite for cessation is that enough meltwater is transported to the central northern North Atlantic convection sites. "
  - " It is, thus, extremely difficult to quantify the risk of a sudden switch in global or regional climate because the mechanisms behind all past climate changes (sudden or otherwise) are incompletely understood...
    ...As we do not know how often decadal timescale changes occurred in the recent geological past, we are handicapped in trying to find mechanisms which might be used for forecasting future events. Even if we knew everything there was to know about past climate mechanisms, it is likely that we would still not be able to forecast such events confidently into the future. This is because the system will have been influenced by probabilistic processes (due to the chaotic nature of the ocean climate system, with runaway changes coming from minuscule differences in initial conditions – e.g., Crowley and North, 1991). Hence, it is not justifiable to talk in terms of what 'definitely' will or will not happen in the future – even though the public and policy-makers are looking for certainties. "
  - " Judging by its past behaviour under both glacial (e.g., the ending of the Younger Dryas) and interglacial conditions (e.g., the various Holocene climate oscillations leading up to the twentieth century; Alley et al., 1997b), the climate has a tendency to remain stable for most of the time and then suddenly 'flip' – at least sometimes over just a few decades – as a result of the influence of the various triggering and feedback mechanisms. Such observations suggest that even without anthropogenic climate modification there is always an axe hanging over our head in the form of random, very large-scale changes in the natural climate system; a possibility policy-makers should perhaps bear in mind when considering contingency plans and international treaties designed to cope with sudden famines on a greater scale than any experienced in written history. By disturbing the system, humans may simply be increasing the likelihood of sudden events which might have occurred anyway. "

Wunsch

- Wunsch 2004
  Quantitative estimate of the Milankovitch-forced contribution to observed Quaternary climate change
  - "We will show however, that even in
    tuned records, the fraction of the variance in the myriadic band derived from the insolation forcing is so small that the inference it controls the overall record is not an obvious one. This point of view is an old one (e.g., Kominz and Pisias, 1979; Imbrie and Imbrie, 1980), but it has been not much heeded. One is led to ask "what would be the nature of climate variability on a hypothetical earth with fixed obliquity in a circular orbit about a sun with unchanging output?"
    ...
    " Given the chaotic/stochastic nature of weather and climate over the duration of the instrumental record—in a system driven by periodic forcing at diurnal and annual time scales—it is reasonable to propose that this hypothetical earth would similarly display a rich variability in climate, even in the absence of astronomical variations. Higher frequency phenomena, including weather, ENSO fluctuations, the Arctic Oscillation, etc., as well as much lower frequency, as yet undetected, atmospheric, oceanic, and cryospheric fluctuations would be expected to generate a much lower frequency variability even in the absence of orbital changes."
    ...
    "Most of the records
    however, show that the 100 ka energy is indistinguishable from a broadband stochastic process. The most straightforward hypothesis is that it too, is a form of random walk, whether involving some type of large-scale instability of the climate system under full glacial conditions, as a number of authors have proposed, or merely one displaying the intermittent build up and asymmetric (in time) removal of ice, or some combination (Wunsch, 2003). Occam's razor suggests at least maintaining this hypothesis until it is proved untenable. The long-standing question of how the slight Milankovitch forcing could possibly force such an enormous glacial–interglacial change is then answered by concluding that it does not do so. "
  - "The main issue is the small sample size: seven Pleistocene ice ages with six intervals. The resulting record of myriadic climate variability in deep-sea and ice cores is dominated by processes indistinguishable from stochastic, apart from a very small amount (less than 20% and sometimes less than 1%) of the variance attributable to insolation forcing. Climate variability in this range of periods is difficult to distinguish from a form of random walk with small superimposed deterministic elements.
    Evidence that Milankovitch forcing "controls" the records, in particular the 100 ka glacial/interglacial, is very thin and somewhat implausible, given that most of the high frequency variability lies elsewhere. These results are not a proof of stochastic control of the Pleistocene glaciations, nor that deterministic elements are not in part a factor. But the stochastic behavior hypothesis should not be set aside arbitrarily—as it has at least as strong a foundation as does that of orbital control.
    There is a common view in the paleoclimate community that describing a system as "stochastic" is equivalent to "unexplainable". Nothing could be further from the truth (e.g., Gardiner). "
- Wunsch 2003
  The spectral description of climate change including the 100 Kyr energy
  - " A more rigorous calculation would find the fraction of the core record energy coherent with the insolation, as is done in the analogous problem of tidal forcing (Munk and Cartwright 1966), but such a calculation is postponed, because of concern over the accuracy of the age/depth relations. " - my note to review this paper to see what kind of spectrum we get from something like this
  - "Examination of a few typical records supports the inference that the contribution of the Milankovitch frequencies to climate change at most represents only a small fraction of total climate variance."
  - "Beginning with the classical paper of Hays et al. (1976), great effort has been directed to studying "cyclostratigraphic" current climate records, either at the Milankovitch periods or otherwise (e.g., Chapman and Shackleton 2000). "
  - Slight bulges in the spectrum occur near 4000 year and 1500 year periods; the latter may well include some of the aliased annual cycle discussed by Wunsch (2000).
  - Equation (5) was used by Hasselmann (1976) in his stochastic theory of climate and by many later investigators. It appears that much of the climate system is best understood in terms of such random walks (e.g., Wunsch 1992 for the ocean; Mitchell 1976 for the climate system in general, and a large specific literature for the modern climate system). Arbitrarily more complex stochastic memory processes can be generated by using higher derivatives in Eq. (5) and of course, by recognizing that spatially varying structures will also be present and contribute. More complex discrete representations are available, and there is an elaborate literature on stochastic differential systems, e.g., Gardiner (1985), or Gillespie (1996).
  - Hasselmann 1976
    Stochastic climate models. Part 1 Theory.
    Tellus 28: 473–485
- Wunsch 2000
  On sharp spectral lines in the climate record and the millennial peak. Paleoceanography 15: 417–424
- Wunsch 1992
  Decade-to-century changes in the ocean circulation. Oceanography 5: 99–106

Wolff

- Wolff, Fischer & Röthlisberger 2009
  Glacial terminations as southern warmings without northern control
  - Southern Hemisphere causes end of ice ages..
    - " The change from a glacial to an interglacial climate is paced by variations in Earth's orbit. However, the detailed sequence of events that leads to a glacial termination remains controversial. It is particularly unclear whether the northern or southern hemisphere leads the termination. Here we present a hypothesis for the beginning and continuation of glacial terminations, which relies on the observation that the initial stages of terminations are indistinguishable from the warming stage of events in Antarctica known as Antarctic Isotopic Maxima, which occur frequently during glacial periods. Such warmings in Antarctica generally begin to reverse with the onset of a warm Dansgaard–Oeschger event in the northern hemisphere. However, in the early stages of a termination, Antarctic warming is not followed by any abrupt warming in the north.
    We propose that the lack of an Antarctic climate reversal enables southern warming and the associated atmospheric carbon dioxide rise to reach a point at which full deglaciation becomes inevitable. In our view, glacial terminations, in common with other warmings that do not lead to termination, are led from the southern hemisphere, but only specific conditions in the northern hemisphere enable the climate state to complete its shift to interglacial conditions. "
- Fischer,. Wolff 2010
  The role of Southern Ocean processes in orbital and millennial CO2 variations – A synthesis

- Köhler,. Masson-Delmotte 2010
  What caused Earth's temperature variations during the last 800,000 years? Data-based evidence on radiative forcing and constraints on climate sensitivity
- Huybers & Denton 2008
  Antarctic temperature at orbital timescales controlled by local summer duration
  - " We conclude that the duration of Southern Hemisphere summer is more likely to control Antarctic climate than the intensity of Northern Hemisphere summer with which it (often misleadingly) covaries. In our view, near interhemispheric climate symmetry at the obliquity and precession timescales arises from a northern response to local summer intensity and a southern response to local summer duration. "
  - " Thus we speculate that the increasing summer and decreasing winter durations caused by the alignment of aphelion with southern summer solstice coordinates the effects of summer radiation balance, winter sea ice and atmospheric CO2 so as to increase Antarctic temperature. "
    Nice curve fits of southern summer duration with SH temperature
- Denton, Anderson, Toggweiler, Edwards, Schaefer & Putnam 2010
  The Last Glacial Termination
  - " However, increasing northern summer insolation also occurred elsewhere in the glacial record where no terminations took place.. Therefore, rising insolation alone is insufficient to explain terminations. " - nice fig 2b to back it up
  - Too much ice causes the end of the glacial, via ice melt slowing down the MOC and causing more ***cooling***
  - " In the north, recession of the Laurentide and Scandinavian ice sheets was underway at least by 20 ka, as sea level started to rise and as meltwater from European ice sheets and mountain glaciers began to enter the Bay of Biscay (3). Presumably this recession was in response to an increase in summer insolation that caused ablation zones to enlarge, intensify, and migrate northward. "
  - " Explaining the near coincidence of the last termination in both polar hemispheres has been a long-standing problem. For example, following Milankovitch's reasoning that glaciers at middle to high latitudes wax and wane in response to varying summer insolation,Mercer noted that recession of middle-latitude SH mountain glaciers during the last termination, that is, a period of declining local summer insolation intensity from the precession effect (18 to 11 ka), "defies explanation." Broecker (56) suggested that changes in atmospheric CO2 would help resolve this problem by synchronizing the hemispheres, but he could not identify a mechanism that would cause CO2 to change before NH ice volume.
  - 
    Fig. 2. (**B**) Five-point records related to global ice volume during the past 250,000 years. The original data on the August insolation anomalies at 65°N (supplemental references 27 to 29) are plotted on the same scale (*[illegible]*) and are shifted by 5 ka to allow for a lag between ice volume and insolation (*[illegible]*). Deep ocean (foraminifera) oxygen isotopic records (*[illegible]*) are plotted on a common scale, with their more positive values (*[illegible]*) at the top of the figure. The ice volume records (*[illegible]*) are plotted on a common scale, with the maximum ice volume at the top of the figure. The ice volume record (*[illegible]*) is dominated by ice volume in Antarctica and is influenced by a relatively constant deep-water temperature (*[illegible]*). The ice volume record (*[illegible]*) is dominated by ice volume in the Northern Hemisphere and is influenced by local and global temperature (*[illegible]*). The ice volume record (*[illegible]*) is a composite of the Antarctic and Northern Hemisphere records (*[illegible]*). The Antarctic record (*[illegible]*) is influenced by both ice volume and temperature. The Antarctic temperature record (*[illegible]*) is influenced by local insolation (*[illegible]*). The Northern Hemisphere record (*[illegible]*) is influenced by local insolation (*[illegible]*). The insolation record (*[illegible]*) is a function of the earth's orbital parameters