Key Climate Studies; Drought, Climate Change, SST, and Etc.

- There is summary information about 7 or 8 key climate studies in this text (plus more).

- We emphasize the climate patterns that are steady for 10 to 30 years, and then shift.

- Some examples:
  - Cause of 1930s droughts in USA
  - Western Africa monsoon rain and number of hurricanes near USA
  - Ocean SST forcing of African Sahel rainfall
  - They make better predictions of El Niño for 148 years
  - A century of climate shifts for the Pacific Ocean
  - Total runoff of different continents, 1900 – 1980

- Ready to scan May 24, 2004 (54 p), RJ0354

Added May 26, 2004:

263 Regional climate shifts caused by gradual global cooling in the Pliocene epoch
A C Ravelo, D H Andreasen, M Lyle, A O Lyle & M W Wara

Describes climate from 3 mid years ago to now. Lots of charts, good.
Nature May 2004
- R Jenne

May 24, 2004
Roy Jenne
Key Climate Studies; Droughts, Climate Change, SST and etc.

- Index -

Roy Jenne
May 18, 2004

1. Cause of 1930’s droughts in USA

The cause was anomalous tropical sea surface temperatures in that decade (colder Pacific water and warmer Atlantic gave US drought)
   - This work was by Schubert, et al (Science 19 Mar 2002). They used NASA climate models.

2. West African monsoon rain and hurricanes near the USA.

When the African Sahel has wet years, there are many hurricanes near the USA.

3. Make better predictions of El Nino for 148 years

   - They make better hind predictions of El Nino for 1857 to 2003, using an ocean-atmos model.
   - This is encouraging! (See Nature 15 Apr 2004, p 733)
   - Paper is by Chen, Cane and others.

4. Oceanic Forcing of African Sahel Rainfall

Model simulations indicate that anomalously warm waters in the Indian Ocean caused the droughts in the African Sahel during the 1970’s and 1980’s. (It was not desertification from overgrazing).
   - By Giannini, et al. They used a climate model developed at NASA Goddard
   - See Science 7 Nov 2003, P 999 and P 1024-1027 and 1027-1030.

5. A century of climate change for Pacific Ocean

   - See links of Pacific Decadal Oscillation to
     1. Global air temp  2. Atmospheric circulation index
   - This is an important climate paper from a fisheries group
   - From Science, 10 Jan 2003, P 217-221 (full title: From Anchovies to Sardines and back: Multidecadal change in the Pacific Ocean)

6. Total runoff of different continents 1900-1980
The show plots of the river runoff for five continents. It is very interesting to look at the long spells of dry or wet on each continent, and to note the relationships between continents. This implies changes of 10-30 year length in sea surface temperatures and the atmospheric circulation. (From Probst and Tardy, 1987)

7. Patterns of drought over the US, 1895-1983

Two publications from Asheville show drought patterns for each month during the 89 year period. A selection of drought charts, mostly for the 1930's is given here. They are very interesting!

8. European climate since 1500

By Luterbacher (Science, 5 Mar 2004, P 1499)

9. Antarctica was warmer from 2500 to 4000 years ago.

See the story (Science News, Sep 8, 2001)

10. World temperature trends for a few thousand years (A longer document)

Another document has about 42 summaries of climate change work. About 13 of these are for the periods longer than 5000 years, and up to 160,000 years or more. The title page and the index is give (document RJ0322)

11. Sharp cooling of the Northern Hemisphere 650 – 280 BC

See the story (PAGES News, April 2004)

12. Future global warming scenarios (The panic story)

Some panic stories claim that there may be a huge climate change within one decade. Wally Broecker says “No”. He does not like the panic story. I agree (16 Apr 2004, Science)

13. Temperature of Greenland Ice for 100,000 years.

The warm spell of 1000 AD is clearly shown. The even warmer period from 5000 to 8000 years ago is clearly shown. It was about 2.5° C warmer than now. There is a clear up and down cycle in temperature during at least the past 2000 years (period about 200 years). (9 Oct 1998, Science)
14. Superlakes, Mega floods and Abrupt Climate Change  

The huge ice age lakes caused some big climate changes when they broke the ice dams and gushed huge amounts of fresh water into the ocean. At this time, we no longer have huge lakes with ice dams. (Science, 15 Aug 2003, P 922)

15. Arctic Lake in NE Siberia promises hot data on past climate

They now have a mud core with 400,000 years of climate information. It will be possible to get 3.6 million years of climate mud. This lake has never been covered by glaciers. (Nature, 15 Apr 2004)

16. The Isthmus of Panama and the Ice Ages

The Isthmus of Panama formed about 3 million years ago. Then it was high enough to stop the water flow from the Pacific Ocean into the Caribbean. The ice ages started about 2.4 ma. The water flow had started to get weaker about 5 ma as described in this story. I suspect that the Panama Isthmus just rose in place, rather than moving in from the west as shown here.

- When ice ages start they cause more erosion, and that draws down CO₂, causing it to cool even more.
- This story about Panama and ocean circulation is just fascinating to me!

17. The Day After Tomorrow

Hollywood has produced a big scary movie about rapid climate change. It will come out May 28, 2004

- And Al Gore is working to advertise this movie.
- Nuclear Power
The Cause of the 1930's USA Dust Bowl
(Study the period 1902 – 2001)

Roy Jenne
May 19, 2004

1. The cause was anomalous Tropical Sea surface temperatures in that decade

2. Colder Pacific water, warmer Atlantic gave 1930's US drought

3. This NASA group (Schubert, et al) forced a climate model with observed ocean water temperature during 1902 – 2001. They show observed drought and model drought during this period.


5. This is a very useful study. But it still doesn’t explain why the ocean surface water temperatures were the way that they were.
Dust clouds prepare to engulf a Kansas farmstead in 1935, at the height of the Dust Bowl drought. Researchers say the drought conditions were created by a rare alignment of ocean surface temperatures in the Pacific and the Atlantic.

Model shows patterns of Dust Bowl

Colder Pacific, warmer Atlantic led to ‘black blizzards’ of 1930s

By Lee Bowman
Scripps Howard News Service

NASA scientists using a climate-modeling computer have fingered the cause of one of the worst climatic events in American history, the "Dust Bowl" drought that devastated the Southern Great Plains during most of the 1930s.

The researchers report today in the journal Science that their model shows a combination of colder-than-normal water in the tropical Pacific and warmer tropical Atlantic temperatures combined to create the conditions that produced "black blizzards" that carried dust across the Plains, at times all the way to New York City and Washington.

For much of the 1930s, up to 65 percent of the country was suffering severe or extreme drought. But the disaster hit parts of Kansas, Colorado, Oklahoma, Texas and New Mexico the hardest, driving thousands of people off farms and deepening the impact of the Great Depression.

"The 1930s drought was the major climatic event in the nation’s history," said Siegfried Schubert, a researcher at NASA's Goddard Space Flight Center in Greenbelt, Md., and lead author of the study.

The computer model was based on 20 years of NASA satellite observations of clouds, solar radiation and precipitation across the United States. "Just in the last five years, the model has gotten much better at linking up what happens in the ocean to what goes on over land," Schubert said.

"We know the computer matches well with what’s gone on the past few decades," he said, "but we want to test it against other well-documented events from the past, like the Dust Bowl drought, to confirm it against real-world events."

The model found that from 1931 through 1939, the dominant pattern over the Pacific was similar to the cold-water La Niña episodes documented in recent decades. Climatologists have noted for more than a decade that La Niña tends to reduce rainfall over the center of the country.

It was the warm temperatures in the Atlantic that produced a "double-whammy for the people in the Plains states," Schubert said. "There is a persistent low-level jet stream that moves west across the Gulf of Mexico that is almost always there. It pumps water vapor from the tropics up into the center of the country."

"But the model shows that jet stream weakened and moved farther south than normal, and this made the drought much worse in the summer and fall months."
On the Cause of the 1930s Dust Bowl

Siegfried D. Schubert,1 Max J. Suarez,1 Philip J. Pégion,1,2 Randal D. Koster,1 Julio T. Bacmeister1,3

During the 1930s, the United States experienced one of the most devastating droughts of the past century. The drought affected almost two-thirds of the country and parts of Mexico and Canada and was infamous for the numerous dust storms that occurred in the southern Great Plains. In this study, we present model results that indicate that the drought was caused by anomalous tropical sea surface temperatures during that decade and that interactions between the atmosphere and the land surface increased its severity. We also contrast the 1930s drought with other North American droughts of the 20th century.

In the United States, the 1930s were characterized by a decade of rainfall deficits and high temperatures that desiccated much of the land surface of the Great Plains. The drought and its associated dust storms created one of the most severe environmental catastrophes in U.S. history and led to the popular characterization of much of the southern Great Plains as the “Dust Bowl” (1, 2).

While progress has been made in understanding some of the important processes contributing to drought conditions (3–7), the mechanisms by which a drought can be maintained over many years are not well established. A number of studies have used the historical record of meteorological and oceanographic observations to identify statistical relations between slowly varying Pacific Ocean sea surface temperatures (SSTs) and precipitation over the Great Plains (8, 9). The record of observations, however, is too short to provide definitive results for long-term drought. Understanding the causes of the 1930s drought is particularly challenging in view of the scarcity of upper-air meteorological observations prior to about 1950.

Several recent studies using state-of-the-art atmospheric general circulation models (AGCMs) have shown how SST anomalies can produce prolonged drought conditions. Tropical SST anomalies, in particular, were found to contribute to recent prolonged drought conditions over much of the northern middle latitudes (10), to drought in the Great Plains (11), and to drought conditions in the African Sahel region during the 1970s and 1980s (12).

The importance of the Pacific SSTs (the pan-Pacific pattern) in forcing long-term precipitation variations in the Great Plains led us to expect that this pattern would be an important factor during the Dust Bowl when drought was most severe. SST anomalies, however, were surprisingly weak throughout the tropical Pacific during the 1930s. This prompted a much closer look at the relationship between SST anomalies and the generation of the Dust Bowl.

Our study is based on a number of century-long simulations carried out with the NASA Seasonal-to-Interannual Prediction Project (NSIPP) atmospheric general circulation model (13), the same model used in (11) and (12), although run here at a somewhat coarser horizontal resolution (14). The basic model simulations are an ensemble of fourteen 100-year (1902 to 2001) runs forced by observed monthly SSTs (15). These simulations will be referred to as the C20C runs, because they were carried out as part of the Climate of the 20th Century project (16). The runs differ only in their initial atmospheric conditions. As such, the degree of similarity in the runs (the “signal”) provides us with an assessment of how much the SSTs control Great Plains climate variations, while the disagreement among the runs (the “noise”) provides us with an estimate of the unpredictable component of the climate variability.

Figure 1 shows time series of the precipitation averaged over the Great Plains and filtered to retain time scales longer than about 6 years, using data from observations (17) and from the 14 simulations. The time series of the observed and simulated anomalies show considerable variability, with extended periods of both above- and below-normal conditions throughout the century.

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Fig. 1. Time series of precipitation anomalies averaged over the U.S. Great Plains region (30°N to 50°N, 95°W to 105°W; see box in insets). A filter (28) is applied to remove time scales shorter than about 6 years. The thin black curves are the results from the 14 ensemble members from the C20C runs. The green solid curve is the ensemble mean. The red curve shows the observations. The maps show the simulated (left) and observed (right) precipitation anomalies averaged over the Dust Bowl period (1932 to 1938). Units, mm/day.
West African Monsoon Rain and Hurricanes near the USA

Roy Jenne
May 21, 2004


- When the African Sahel has wet years, there are many hurricanes near the USA, and more of them move into the US.

- When the Sahel has dry years, the hurricanes near the USA are fewer and weaker.

Note: Also see the other paper in this text:

- "Oceanic Forcing of the African Sahel Rainfall"

And a second paper in Sep 1990 (by Bill Gray)
WEST AFRICAN MONSOONAL RAINFALL AND INTENSE HURRICANE ASSOCIATIONS

By
Christopher W. Landsea

Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523

October 7, 1991

Atmospheric Science Paper No. 484
Figure 5.17: June to September African rainfall anomalies during the ten wettest (A) and the ten driest (B) June to September Seedling Index rainfall years. Contours are in $\sigma = \pm 0.25$, 0.50, and 0.75. Solid contours indicate positive deviations (i.e. wetter than normal) and dashed contours indicate negative deviations (i.e. drier than normal).
Figure 5.19: Hurricane tracks in the ten wettest (A) versus the ten driest (B) Western Sahel years between 1949 and 1989.
Figure 5.20: Intense hurricane tracks in the ten wettest (A) versus the ten driest (B) Western Sahel years from 1949 to 1989.
Strong Association Between West African Rainfall and U.S. Landfall of Intense Hurricanes

WILLIAM M. GRAY

Intense hurricanes occurred much more frequently during the period spanning the late 1940s through the late 1960s than during the 1970s and 1980s, except for 1988 and 1989. Seasonal and multidecadal variations of intense hurricane activity are closely linked to seasonal and multidecadal variations of summer rainfall amounts in the Western Sahel region of West Africa.

Hurricane Activity and Sahel Rainfall Variations

In general, the annual frequency of intense Atlantic hurricanes was appreciably greater from 1947 to 1969, when plentiful amounts of rainfall occurred in West Africa, than during the years between 1970 to 1987, when drought conditions prevailed.

Fig. 4. Comparison of tracks for all major hurricanes (Saffir-Simpson category 3, 4, and 5) for the 23-year period 1947 to 1969 (A) when West Africa was wet versus the 18-year period 1970 to 1987 (B) when it was dry.

Sahel rainfall data indicate that alternating multidecadal wet and dry conditions prevailed during the following approximate periods of the last century. These include: the 25 to 30 years before 1900 (generally wet); 1900 to 1914 (distinctly dry); 1915 to 1935 (generally wet); 1936 to 1946 (generally dry); 1947 to 1969 (distinctly wet); 1970 to 1987 (distinctly dry); and 1988 to 1989 (becoming wet). Annual values of category 3, 4, and 5 hurricane days for these wet and dry periods also show large differences. An

Fig. 5. Comparison of 5-year running averages for June through September rainfall in the Western Sahel (solid line) versus the percent variability of Saffir-Simpson category 3, 4, and 5 hurricanes (dashed line) and of category 3, 4, and 5 hurricane days (dotted lines).
Causes of Multidecadal Variability

Multidecadal climate cycles are a pervasive feature of the global ocean-atmospheric circulation, appearing in meteorological and ocean data as far back as measurements have been made. The factors most directly responsible for variable Sahel rainfall conditions on multidecadal time scales appear to be linked to basic changes in the larger scale global circulation patterns; these changes in turn appear to be linked to long-term variations in global-scale sea-surface temperature (SST) anomalies. Although not yet well understood, such SST variations are generally thought to be associated with variations of ocean circulation and vertical mixing processes, which

![Graph showing multidecadal mean annual values of hurricane potential destruction (PD) with years and dates indicated at the top (est., estimated).]

An Update (May 2004)

Bill Gray, Colo State U, has been running a hurricane outlook forecast service for many years.

The relationships between wet/dry Sahel and the number of hurricanes worked well for many years, but it has not worked well for about 7 years. It is now out of the forecast equations. A major shift in climate patterns may be happening.

- Roy Fanne
A major requirement for seasonal forecasting is the ability to predict ENSO events, which continue to have the potential to cause widespread disruption. For example, 1997–98 saw one of the largest El Niños in the instrumental record (Fig. 1, overleaf), followed by La Niña. Damage was estimated to exceed US$20 billion, although beneficial effects in certain regions possibly offset this figure. If ENSO events can be predicted, steps can be taken to mitigate the losses. So successful forecasting of ENSO variability would be of great practical benefit. But such forecasting is immensely challenging—one difficulty being that the number of past events on which models can be tested is quite small owing to the lack of data. Chen et al., however, have been able to test their model on events stretching back to before the 1877 El Niño, thus covering a much longer period than is normally considered.

From their results, the authors argue that a large ENSO event might be predictable two years in advance, much longer than hitherto expected. For example, their Fig. 3 (page 734) shows forecasts of six of the largest El Niños since 1856, including that of 1997–98. Even forecasts began two years before the peak of the latter at the end of 1997 are reasonably good; and those from October 1996 capture the growth, maturity and decay in 1998 very well. These results are all the more impressive given that an earlier version of this model failed totally during the ‘real-time’ forecasting of the 1997–98 event. Many other models also performed poorly for this period, although there was some success at the shorter range of a few months.

So why are the new forecasts so much better than before? A major source of difficulty in climate prediction is model error, possibly the single biggest problem with physically based models. One way to deal with the issue is to improve the models, but this is a long, hard process; another is to accept that a model has error, but to try to mitigate the effects. That is what Chen et al. have done. To allow for model errors, corrections are made to the ocean state and to the sea surface temperature (SST) before its effects are ‘passed’ to the atmosphere; and corrections are made to the atmospheric wind before it is used to drive the ocean. ENSO forecasting requires knowledge of the ocean initial conditions and, to a small extent, those of the atmosphere. Through their strategy for correcting model errors, Chen et al. also produce better initial conditions.

The ‘training period’ for deriving the model corrections is 1980–2000. As this includes both the 1997–98 event and the other big El Niño of 1982–83, there could be some artificial ‘skill’ in the predictions of this event. In general, the more choices and tunable parameters in a forecast methodology, the greater the risk of overestimating the forecast skill. Nonetheless, as the number of
past cases grows, the risk of this being a serious problem becomes less likely.
Increasing the number of cases is one of the more complicated capabilities is not straightforward, as there are no direct observations of ocean initial conditions before 1990. Considerable information about the ocean state can be gleaned from the winds near the Equator, but unfortunately, these were not adequately measured before the 1970s. The large-scale, slowly changing wind field can be derived from SSTs, however, and these are better known. Indeed, reconstructions go back to the middle of the nineteenth century and so ocean initial conditions can be indirectly generated. One might expect that the ocean initial conditions would be less well determined the further back in time one went, but Chen and colleagues' six-month forecasts for the 1877 El Niño are remarkably good, a result that would surely have delighted the forefathers of seasonal prediction.

For those involved in studies of ENSO evolution and predictability, much debate has centered on the importance of an energetic feature of the tropical atmosphere, the Madden–Julian Oscillation (MJO)\textsuperscript{14,5}; it has a timescale of the order of 50 days and can be associated with strong westerly winds near the Equator. In February 1997 there was a massive MJO in the west Pacific, which excited a big oceanic response that travelled along the Equator all the way to the east Pacific and was commonly seen as the reason for the large 1997 El Niño. Chen and colleagues’ model represents only the slow variations in the atmosphere and cannot represent MJO variability. Nonetheless, forecasts from well before February 1997 show good predictive skill. From this and other results, they argue that MJO activity isn’t as big a limitation on prediction as previously thought.

Overall, the authors give an optimistic outlook for ENSO forecasting, at least for large events: predicting smaller ones remains much trickier. Most operational models make predictions for six to nine months ahead of an ENSO onset. If the new results are confirmed, that range should be increased to at least a year. Rivaling or beating these forecasts is a challenge for more sophisticated global general-circulation models, such as those described in ref. 9. Another challenge, of course, concerns Chen and colleagues’ model — will its success in predicting the future match that of its performance in predicting the past?

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8. www.ecmwf.int/publications/library/docs/references/list/17124

Mars

Blueberry fields for ever

Jeffrey M. Moore

The Mars saga continues. The latest finds — wide areas covered in balls of haematite, or 'blueberries', and large sulphate deposits in rocks — enable us to draw in more detail of the planet’s past climate.

We have known for thirty years that channels and valleys were carved into the martian landscape long ago by a fluid that was probably water. But unambiguous evidence for aqueous deposits has been frustratingly lacking. In 2000, images from the Mars Orbiter Camera, on board the Mars Global Surveyor, showed extensive rock outcrops with ledges and scars, which were interpreted as being sedimentary layers that had been deposited under water\textsuperscript{1}. However, the absence of spectroscopic observations from orbiting instruments to reveal abundant water-modified minerals raised questions about the ubiquity and persistence of liquid water on the surface\textsuperscript{1}. In the hope of building a clearer picture of water on Mars, NASA dispatched two rovers, Opportunity and Spirit, last summer to land at sites that were thought most likely to host accessible aqueous deposits. But before the rovers landed in January this year, the Mars Orbiter Camera provided the first incontrovertible evidence for the fluvial origin of a martian layered deposit: an exhumed river delta, resedimented with sands and a recognizable upstream branching drainage basin\textsuperscript{2,3}.

Then, last month, came a flood of new evidence from the Opportunity rover and the European Space Agency’s Mars Express orbiter. At briefings at NASA headquarters...
Predictability of El Niño over the past 148 years

Dake Chen1,2, Mark A. Cane1, Alexey Kaplan1, Stephen E. Zebiak1 & Daji Huang2

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Forecasts of El Niño climate events are routinely provided and distributed, but the limits of El Niño predictability are still the subject of debate. Some recent studies suggest that the predictability is largely limited by the effects of high-frequency atmospheric ‘noise’1-3, whereas others emphasize limitations arising from the growth of initial errors in model simulations4-9. Here we present retrospective forecasts of the interannual climate fluctuations in the tropical Pacific Ocean for the period 1857 to 2003, using a coupled ocean–atmosphere model. The model successfully predicts all prominent El Niño events within this period at lead times of up to two years. Our analysis suggests that the evolution of El Niño is controlled to a larger degree by self-sustaining internal dynamics than by stochastic forcing. Model-based prediction of El Niño therefore depends more on the initial conditions than on unpredictable atmospheric noise. We conclude that throughout the past century, El Niño has been more predictable than previously envisaged.

Present estimates of El Niño’s predictability are mostly based on retrospective predictions for the last two or three decades, encompassing a relatively small number of events10-11. With so few degrees of freedom, the statistical significance of such estimates is questionable. In principle, predictability can also be estimated by perturbing initial conditions in numerical model experiments, but the answer is model dependent, and existing models have not been shown to be realistic enough for this purpose. El Niño is evident in instrumental observations dating back to the mid-nineteenth century and in proxy data sets over much longer periods, but no successful attempt to ‘hindcast’ the historic El Niño events before the mid-twentieth century has been reported. This is due partly to the lack of adequate data for model initialization and partly to the inability of present models to make effective use of available data. The study reported here represents the first (to our knowledge) retrospective forecast experiment spanning the past one-and-a-half centuries, using only reconstructed sea surface temperature (SST) data12 for model initialization.

The intrinsic predictability of El Niño is surely limited, but there has been considerable debate about what the limitations really are13,14. Classic theories consider El Niño and the Southern Oscillation (ENSO) as a self-sustaining interannual fluctuation in the tropical Pacific15-16, being chaotic yet deterministic17,18. Thus its predictability is largely limited by the growth of initial errors, and the potential forecast lead time is likely to be of the order of years19,20. On the other hand, some recent studies emphasize the importance of atmospheric noise4-7, particularly the so-called westerly wind bursts in the western equatorial Pacific4-7. In such a scenario, ENSO is a damped oscillation sustained by stochastic forcing, and its predictability is more limited by noise than by initial errors. This implies that most El Niño events are essentially unpredictable at long lead times, because their development is often accompanied by high-frequency forcing. Such a view is not supported by the present findings.

The observed and predicted SST anomalies averaged in the central equatorial Pacific are shown in Fig. 1a. (See Methods section...

Figure 1 Retroactive predictions of El Niño and La Niña in the past 148 yr. a, Time series of SST anomalies averaged in the NINO3.4 region (5° S-5° N, 120°-170° W). The red curve is monthly analysis of ref. 12 and the blue curve is the LDOE5 prediction at 6-month lead. b, Composite El Niño and La Niña from 24 warm events and 23 cold events. Top panels are observations, and the rest are predictions at different lead times. The colour bar shows the range of SST anomalies in degrees Celsius.
Oceanic Forcing of African Sahel Rainfall

Model simulations indicate that anomalously warm waters in the Indian Ocean caused the droughts in the African Sahel during the 1970's and 1980's. (It was not desertification from overgrazing).

- By Giannini, et al. They used a climate model developed at NASA Goddard
- See Science 7 Nov 2003, P 999 and P 1024-1027 and 1027-1030.
Drought in the Sahel
Ning Zeng

Since the late 1960s, the Sahel—a semi-arid region in West Africa between the Sahara desert and the Guinea coast rainforest—has experienced a drought of unprecedented severity in recorded history. The drought has had a devastating impact on this ecologically vulnerable region and was a major impetus in the establishment of the United Nations Convention on Combating Desertification and Drought. Two reports in this issue shed light on the likely causes of the drought and its consequences for atmospheric dust transport.

Two main hypotheses have been proposed for the cause of the drought. The first focuses on anthropogenic factors such as overgrazing and conversion of woodland to agriculture. Both of these processes tend to increase surface albedo (less sunlight is absorbed) and reduce moisture supply to the atmosphere. They thus lead to less precipitation and even less favorable conditions for vegetation (1–3). The second invokes large-scale atmospheric circulation changes triggered by multidecadal variations in global sea surface temperature (4–6) (see the figure).

On page 1027 of this issue, Giannini et al. (7) report the most comprehensive modeling study to date of the ocean temperature scenario. The authors analyzed the results from a state-of-the-art atmospheric general circulation model (GCM) developed at NASA Goddard Space Flight Center. When forced by observed global sea surface temperatures from 1930 to 2000, the model reproduced much of the variability in the observed Sahel rainfall. The results provide strong evidence that global sea surface temperature is a major forcing in this region. Using a statistical tool called principal components analysis, Giannini et al. show that Sahel rainfall is most closely related to a largely tropical sea surface temperature anomaly pattern that spans the Pacific, Atlantic, and Indian oceans.

Another characteristic of the Sahel rainfall variability is the apparently different influence from different ocean basins on interannual and interdecadal time scales (6, 8). By decomposing the modeled Sahel rainfall into a high-frequency and a low-frequency component, Giannini et al. achieve high reproducibility compared to the observations on both interannual and interdecadal time scales. Furthermore, they identify the contributions from different ocean basins on different time scales.

The Sahel is one of the most climatically sensitive zones in the world because of the influence of a wide range of factors, such as its unique geographic location. The results reported by Giannini et al. are encouraging signs that GCMs have improved substantially in recent years, raising the hope for better climate prediction on seasonal to interannual time scales.

Compared to the ocean scenario, the role of land use change has been more difficult to quantify. Given a large change in land surface properties that could conceivably be caused by human activities, atmospheric models can simulate a substantial reduction in rainfall. However, the question more relevant to the recent Sahel drought is whether such large anthropogenic disturbance has actually taken place. A recent study of population dynamics and land use history suggests a modest land use change over the last 35 to 40 years that is not nearly enough to explain the observed drought (9).

This is not to say that sea surface temperatures are the whole story. Similar to many earlier model studies, Giannini et al. were able to obtain only 25 to 35% of the observed rainfall change. What is missing may well be land-atmosphere feedbacks that work to enhance the drying tendency initiated by the changes in global sea surface temperature. One such feedback involves natural vegetation (10), which would be reduced in response to an initial decrease in rainfall. The subsequent feedbacks through increased albedo and reduced evaporation are similar to those proposed in the land use change mechanism.

It is very likely that sea surface temperature change, natural vegetation processes, and land use change have acted synergistically to produce the unusual drought in the Sahel (see the figure). This speaks for the need to monitor the global oceans even for regional climate prediction. The importance of atmosphere, land, and ocean processes is emphasized in field experiments such as the upcoming African Monsoon Multi-disciplinary Analysis (AMMA).

A much less studied consequence of drought in semiarid regions is atmospheric dust. On page 1024 of this issue, Prospero dust sources account for about half of the global total today, the drought in recent decades may have increased the total global dust loading by one-third. Dust in the air reflects sunshine and changes cloud properties, thus modifying the energy balance in the atmosphere and at the surface. The dust minerals also serve as a nutrient for marine phytoplankton in iron-limited regions. A substantial change in dust supply may modify the global carbon cycle and climate, as might have happened during the ice ages (12). Thus, regardless of the relative importance of natural versus anthropogenic causes, the drought in the Sahel may have an unexpected influence on global climate.

The quantification of natural and anthropogenic causes is important. If humans are mostly responsible for the drought, further land degradation may lead to a catastrophic reduction in the

Complex feedbacks. The recent Sahel drought was likely initiated by a change in worldwide ocean temperatures, which reduced the strength of the African monsoon, and was exacerbated by land-atmosphere feedbacks through natural vegetation and land cover change. Land use changes by humans may have also played an important role. SST, sea surface temperature; ITCZ, intertropical convergence zone.
Oceanic Forcing of Sahel Rainfall on Interannual to Interdecadal Time Scales

A. Giannini, R. Saravanan, P. Chang

We present evidence, based on an ensemble of integrations with NSIPP1 (version 1 of the atmospheric general circulation model developed at NASA's Goddard Space Flight Center in the framework of the Seasonal-to-Interannual Prediction Project) forced only by the observed record of sea surface temperature from 1930 to 2000, to suggest that variability of rainfall in the Sahel results from the response of the African summer monsoon to oceanic forcing, amplified by land-atmosphere interaction. The recent drying trend in the semi-arid Sahel is attributed to warmer-than-average low-latitude waters around Africa, which, by favoring the establishment of deep convection over the ocean, weaken the continental convergence associated with the monsoon and engender widespread drought from Senegal to Ethiopia.

Fig. 1. Indices of Sahel rainfall variability. Observations used the average of stations between 10°N and 20°N, 20°W and 40°E. Model numbers were based on the ensemble-mean average of grid-boxes between 10°N and 20°N, 20°W and 35°E. The correlation between observed and modeled indices of (JAS) rainfall over 1930–2000 is 0.60. (Time series are standardized to allow for an immediate comparison, because variability in the ensemble mean is muted in comparison to the single observed realization. The ratio of observed to ensemble-mean standard deviations in the Sahel is 4.)

African Droughts and Dust Transport to the Caribbean: Climate Change Implications

Joseph M. Prospero and Peter J. Lamb

Great quantities of African dust are carried over large areas of the Atlantic and to the Caribbean during much of the year. Measurements made from 1965 to 1998 in Barbados trade winds show large interannual changes that are highly anticorrelated with rainfall in the Soudano-Sahel, a region that has suffered varying degrees of drought since 1970. Regression estimates based on long-term rainfall data suggest that dust concentrations were sharply lower during much of the 20th century before 1970, when rainfall was more normal. Because of the great sensitivity of dust emissions to climate, future changes in climate could result in large changes in emissions from African and other arid regions that, in turn, could lead to impacts on climate over large areas.
A Century of Climate Change for Pacific Ocean

- An important review paper (Science, 10 Jan 2003, p 217)
  - See next 2 pages here.

- An atmospheric circulation index for 1905 – on
  - Describes dominance of zonal or meridional flow in the Atlantic – Eurasian region.

- The global air temp does change in step with the circulation index.
  - So does the fish regime.
  - And so does CO2 at Hawaii.

- There was a shift in regimes about 1976.
  - In the mid-1970s, the Pacific changed from a cool “anchovy regime” to a warm “sardine regime.”
  - They ask: Was there another regime shift in the late 1990s?

- Years (two full cycles in the Pacific): their numbers:

  1900 – 1925 Cool phase
  1925 – 1950 Warm phase
  1950 – 1975 Cool phase
  1975 – mid 1990s Warm phase

- Global air temp changes; my numbers:

  1910 – 1943 Atmosphere is warming
  1943 – 1976 Atmosphere is cooling
  1976 – recent Atmosphere is warming

Roy Jenne
Jan 21, 2003
From Anchovies to Sardines and Back:
Multidecadal Change in the Pacific Ocean

Francisco P. Chavez, John Ryan, Salvador E. Lluch-Cota, Miguel Núñez C.

In the Pacific Ocean, air and ocean temperatures, atmospheric carbon dioxide, landings of anchovies and sardines, and the productivity of coastal and open ocean ecosystems have varied over periods of about 50 years. In the mid-1970s, the Pacific changed from a cool "anchovy regime" to a warm "sardine regime." A shift back to an anchovy regime occurred in the middle to late 1990s. These large-scale, naturally occurring variations must be taken into account when considering human-induced climate change and the management of ocean living resources.

Landings of sardines show synchronous variations off Japan, California, Peru, and Chile (1). Populations flourished for 20 to 30 years and then practically disappeared for similar periods. Periods of low sardine abundance have been marked by dramatic increases in anchovy populations (2-5). Several important conclusions can be drawn from this. First, the mechanism responsible for the variability must have been similar in all cases and, some argue, relatively simple and direct (6). Second, the variability is difficult to explain on the basis of fishing pressure. Third, the variability must be linked to large-scale atmospheric or oceanic forcing.

The discovery of these so-called biological regime shifts preceded the description of the underlying physical variability. A decade or more after the observations of sardine variations (1), scientists discovered fluctuations in air temperatures, atmospheric circulation and carbon dioxide (7-9), and ocean temperatures (10) that were remarkably similar in phase and duration to the biological records (Fig. 1). As a result, it has been suggested (11) that a regime or climate shift may even be best determined by monitoring marine organisms rather than climate. Recent theoretical work supports the idea that complex food webs can undergo substantial changes in response to subtle physical forcing (12). Here, we review physical and biological fluctuations with periods of about 50 years that are particularly prominent in the Pacific Ocean. We also highlight the evidence for a change in the middle to late 1990s.

Climate Indices and Regime Shifts

The sardine and anchovy fluctuations are associated with large-scale changes in ocean temperatures (Fig. 2); for 25 years, the Pacific is warmer than average (the warm, sardine regime) and then switches to cooler than average for the next 25 years (the cool, anchovy regime). Instrumental data provide evidence for two full cycles: cool phases from about 1900 to 1925 and 1950 to 1975 and warm phases from about 1925 to 1950 and 1975 to the mid-1990s (Fig. 1). A wide range of physical and biological time series in the Pacific Ocean basins show systematic variations on this same time scale. Anomalies, representing deviations from the mean value, were negative from about 1950 to 1975 and positive from about 1975 to the middle to late 1990s (Fig. 1). Because each index or parameter is influenced by forcings that act on multiple time scales, differences are expected in the timing of index sign changes and in the duration of the negative and positive phases. The mid-1970s change has been widely recognized in a myriad of North Pacific climatic (13) and biological (14, 18) time series and has been referred to as the 1976-1977 regime shift (15, 16), even though its precise timing is difficult to assess. Some indices suggest that the shift occurred rapidly whereas others suggest a more gradual change, though all indicate a shift in the 1970s.

The "sardine regime" of the 1930s and 1940s (Fig. 1E) (5) was most notable for the sardine fishery off California and its collapse, the subject of a memorable novel, by Steinbeck (17). From the 1950s through the early 1970s, an "anchovy regime" led to the establishment of the largest single-species fishery in the world, the Peruvian anchoveta fishery (18). To extend the southeastern Pacific anchoveta time series, we constructed an ecosystem index (Fig. 1F) from seabird abundance data (19) and anchovy and sardine landings off Peru (Fig. 1G). The seabird record, compiled from guano harvest and direct bird counts, extends back to the early 1900s. The seabirds are represented primarily by a single species, the cormorant (Phalacrocorax bougainvillii), which feeds almost exclusively on anchoveta (the anchovy, Engraulis ringens). The ecosystem index suggests a regime shift in the mid-1990s (Fig. 1F); the sardine catch decreased from 4 million metric tons in the late 1980s to 40,000 metric tons in 2001. At the same time, anchovy populations recovered (Fig. 1G).

The Big Picture

In a simplified conceptual view of the Pacific, the trade winds set up a basin-wide slope in sea level, thermal structure, and, importantly for biology, nutrient structure (Fig. 2). The shallow thermocline in the eastern Pacific leads to enhanced nutrient supply and productivity (20). Higher sea level in the western Pacific leads to a deep thermocline and nutrient and to lower productivity. These basin-scale east-west gradients are disrupted by large-scale climatic phenomena like El Niño and its counterpart, La Niña (20), which affect not only eastern boundary systems but also the western boundaries, subtropical gyres, and equatorial upwelling systems, leading to the concept of a "basin-wide ecosystem" (21).

The multidecadal fluctuations have basin-wide effects on sea surface temperature (SST) and thermocline slope that are similar to El Niño and La Niña but on longer time scales; El Niño occurs more frequently, once every 3 to 7 years. During the cool eastern boundary anchoya regime, the basin-scale sea level slope is accentuated (lower in the eastern Pacific, higher in the western Pacific). A lower sea level is associated with a shallower thermocline and increased nutrient supply and productivity in the eastern Pacific; the reverse occurs in the western Pacific. In addition to thermocline and SST, there are regime shifts in the transport of boundary currents, equatorial currents, and of the major atmospheric pressure systems. Changes in the abundance of anchovies and sardines are only a few of many biological perturbations associated with regime shifts (Fig. 3), and these are reflected around the entire Pacific.

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A stronger and broader California Current, brought about during the anchovy regime, is associated with a shallower coastal thermocline from California to British Columbia, leading to enhanced primary production (Fig. 2). Off Peru, biological variability is similar to that observed off California.
Figure 1. Comparison between the total runoff fluctuations for the different continents and for the whole world. Five-year moving averages were calculated on standardized data. [From Probst and Tardy, 1987.]
ATLAS OF MONTHLY PALMER DROUGHT SEVERITY INDICES (1931-1983) FOR THE CONTIGUOUS UNITED STATES

by Tom Karl and Richard Knight

Publ. Apr. 1985

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE / NATIONAL CLIMATIC DATA CENTER ASHEVILLE, N.C. APR 1985
European Seasonal and Annual Temperature Variability, Trends, and Extremes Since 1500

Jürg Luterbacher,1,2* Daniel Dietrich,3 Elena Xoplaki,2 Martin Grosjean,1 Heinz Wanner1,2

Multiproxy reconstructions of monthly and seasonal surface temperature fields for Europe back to 1500 show that the late 20th- and early 21st-century European climate is very likely (>95% confidence level) warmer than that of any time during the past 500 years. This agrees with findings for the entire Northern Hemisphere. European winter average temperatures during the period 1500 to 1900 were reduced by ~0.5°C (0.25°C for annual mean temperatures) compared to the 20th century. Summer temperatures did not experience systematic century-scale cooling relative to present conditions. The coldest European winter was 1708/1709; 2003 was by far the hottest summer.

Detailed insight into high-resolution temporal and spatial patterns of climate change during previous centuries is essential for assessing the degree to which late 20th-century changes may be unusual in the light of preindustrial natural climate variability (1–3). Climate change at seasonal to annual resolutions for recent centuries has been highlighted in a number of studies, which have included climate modeling experiments with estimated natural and anthropogenic radiative-forcing changes (4–6) and empirical hemispheric or global reconstructions. Such reconstructions are based either on natural archives only (such as ice cores, tree rings, speleothems, varved sediments, and subsurface temperature profiles obtained from borehole measurements) or on multiproxy networks that amalgamate natural proxy indicators with climate information obtained from early instrumental and documentary evidence (7–14). A number of these reconstructions support the conclusion that the warmth of the late 20th century is likely unprecedented in the Northern Hemisphere.

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An interesting story

We need to see what mountain glaciers were doing

We should see the rise of the year to year fluctuations for months like Jan & July or for seasons, winter & summer
Hemispheric and global temperature reconstructions do not provide information about regional-scale variations, such as the intrinsic seasonal patterns of climate change as they have occurred in Europe during the past centuries. The few European-scale temperature reconstructions (7, 16–19) have revealed information for the winter or summer half-year or for annual to multianual mean values. Changes in the full annual cycle have typically not been addressed, because of the limited year-round information provided by most natural climate proxy data (2, 20).

Regional and temporal high-resolution reconstructions also illuminate key climatic features, such as regionally very hot or cool summers and very mild or cold winters, that may be masked in a hemispheric or global reconstruction (15, 16). Thus, regional studies and reconstructions of climate change are critically important when climate impacts are evaluated (21–23). Extremes at regional scales, such as the hot summer of 2003 in many European areas, exhibit much larger amplitudes than extremes at the global scale, and they may thus markedly affect the local to regional natural environment, society, and economy, including most aspects such as water supply and agriculture.

Here we present a new gridded (0.5° × 0.5° resolution) reconstruction of monthly (back to 1659) and seasonal (from 1500 to 1658) temperature fields for European land areas (25°W to 40°E and 35°N to 70°N) (19). This reconstruction is based on a comprehensive data set that includes a large number of homogenized and quality-checked instrumental data series, a number of reconstructed sea-ice and temperature indices derived from documentary records for earlier centuries, and a few seasonally resolved proxy temperature reconstructions from Greenland ice cores and tree rings from Scandinavia and Siberia (fig. S1 and tables S1 and S2). We discuss the evolution of European winter, summer, and annual mean temperatures for more than 500 years in the context of estimated uncertainties, emphasizing the trends, spatial patterns for extreme summers and winters, and changes in both extreme and mean conditions.

Fig. 1A presents the winter [December through February (DJF)] European surface temperature variations since 1500 (relative to the 1901 to 1995 average) and the 95% confidence range (=2 standard error (SE)) (19). The uncertainty is larger in the earlier reconstructions. From the 16th to the beginning of the 18th century, the two SEs of the filtered wintertime series are in the order of 1.3°C, and they reduce to 0.4°C from 1865 onwards. The larger uncertainties in the earlier centuries are mainly due to a smaller number of uniformly distributed instrumental records (none before 1659), but are also due to fewer proxy series and additional uncertainties in the documentary data (20, 24–26) and natural proxies (2, 27).

We calculated the return period of a European-wide event such as the coldest winter of 1708/1709. This calculation is based on fitting a spline function and is sensitive to the trend over the period 1750 to 2002 and the assumption of Gaussian distributed residuals (19). We obtained a return period of 200 to 500 years for winter conditions from 1750 to ~1900. The warming of the 20th century leads to an increase in the return period, which amounts to more than 100,000 years at the turn of the 21st century (fig. S2A). However, the uncertainties of the estimates are large, and the return periods should be considered with caution (fig. S2A).

Fig. 2C presents anomaly (1901 to 1995 average subtracted) composites and the corresponding standard deviations (SDs) for the ten coldest European winters, excluding 1708/1709. The anomaly composite resembles the 1708/1709 winter. It indicates continental cold with the largest deviations and highest variability over northern and eastern Europe, western

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1. European Winter (DJF) Mean Temperature 1500–2003
2. European Summer (JJA) Mean Temperature 1500–2003
3. European Annual Mean Temperature 1500–2003

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**Fig. 1.** (A) Winter (DJF), (B) summer (JJA), and (C) annual averaged-mean European temperature anomaly (relative to the 1901 to 1995 calibration average) time series from 1500 to 2003, defined as the average over the land area 25°W to 40°E and 35°N to 70°N (thin black line). The values for the period 1500 to 1900 are reconstructions; data from 1901 to 1998 are derived from (44). The post-1998 data stem from (45); Goddard Institute for Space Studies (GISS) NASA surface temperature analysis is given on a 1° × 1° resolution (46). Temperature data from (44) and (45) are very similar and correlate at 0.98 for each season within the common period 1901 to 1998 for the chosen area; they do not indicate any absolute bias. The thick red line is a 30-year Gaussian low-pass filtered time series. Blue lines show the ±2 SEs of the filtered reconstructions on either side of the low-pass filtered values. The red horizontal lines are the 2-SD lines of the period 1901 to 1995. The warmest and the coldest winters, summers, and years are depicted in blue and red, respectively. The winter y axis uses a different scale. Recon., reconstructed; CRU, Climatic Research Unit (44); TT, temperature; wtr, as compared to.
Warmer from 2,500 to 4,000 years ago

- From near-shore ocean sediments
- Land data gives same story (warmer and ice free at times in the past)

Antarctic sediments muddy climate debate

Ocean-floor sediments drilled from Antarctic regions recently covered by ice shelves suggest that those shelves were only 2,000 years old. This finding could compel scientists to reassess whether the current destruction of polar ice is due primarily to human-caused global warming.

In the early 1990s, part of the ice shelf atop the Prince Gustav Channel, which separates the Antarctic peninsula and James Ross Island, broke apart in the area formerly covered by the shelf. The channel's water depth is between 600 and 800 meters. Scientists collected sediment cores 5 to 6 m in length from the ocean floor in February and March 2000.

Scattered throughout the seafloor ooze were telling grains of rock, says Carol J. Pudse, a geologist with the British Antarctic Survey in Cambridge, England. She and her colleague Jeffrey Evans separated the grains larger than about 1 millimeter from the smaller particles, which may have been washed into the area by ocean currents.

They found that some of the flecks and pebbles had been scraped from James Ross Island and the Antarctic mainland by the glaciers that fed the ice shelf. However, other grains and pebbles didn't match the types of rock in nearby sources and could only have been carried into Prince Gustav Channel by far-traveling icebergs. Those icebergs, in turn, would have dropped their sedimentary burden in the channel only if the ice shelf was absent during at least part of the year.

By carbon-dating the organic material found in sediment layers rich in large grains, the researchers could determine when icebergs had wafted into the channel. Their analysis suggests that from about 2,000 to 5,000 years ago, much of the channel was seasonally open water. In areas where sediments had accumulated slowly, cores included berg-delivered material from as much as 30,000 years ago, Pudse notes. She and Evans report their findings in the September GEOLOGY.

A surge in temperatures along the Antarctic peninsula in the past few decades has been linked to the demise of several ice shelves there. Larsen A, the southern neighbor of the Prince Gustav ice shelf, disintegrated during a strong summer storm in January 1995 (SN: 5/12/01, p. 298). The Larsen B ice shelf, which used to sit adjacent to Larsen A, continues to shed icebergs and may disappear within the next decade.

Some scientists suspect the dramatic rise in carbon dioxide and other industrial greenhouse gases is to blame for the recent regional warming. Several climate models predict that global warming would be accentuated in polar regions. However, the news that the Antarctic peninsula's ice shelves may have come and gone at least once since the end of the last ice age, about 11,000 years ago, suggests that people may not be fully to blame for the disappearance now under way.

"The current rate of warming may be unusual, but our research shows definitively that this area has been warm and ice free at times in the past few thousand years," says Pudse. Because she and Evans analyzed core segments between 5 and 10 centimeters in length—each corresponding to at least a century—they weren't able to calculate the precise rate of past warming episodes.

The new data from the Prince Gustav Channel should help indicate whether the instability of the Antarctic peninsula's ice shelves is part of a natural cycle, says Olafur Ingolfsson, a geologist at Goteborg University in Sweden. The new evidence for past warming backs up data garnered from land-based studies of lake sediments and ancient, abandoned penguin rookeries, he notes. According to that research, conditions along the peninsula were warmer and more humid between 2,500 and 4,000 years ago.

The collective indication is that the Prince Gustav ice shelf, and others in the area, are short-lived, Ingolfsson adds.

—S. Perkins

SCIENCE NEWS, VOL. 160
SEPTEMBER 8, 2001
World Temperature Trends for a Few Thousand Years

It is important to have global or hemispheric temperature estimates for the past several thousand years so that the present warming can be properly compared with the natural temperature changes of the past.

- Our goal here is not to show people the exact answers, but to guide people to the published work and the temperature estimates for different regions.

- There have been rather heated discussions about what the best estimate of temperature during 800 – 2000 A.D. really does look like.

- This document includes estimates of when glaciers advanced and retreated during the past several thousand years.

- A little information about changes in solar forcing is included. The solar changes produce certain isotopes which can be measured.

- This text includes temperature information for the whole last ice age cycle from 120,000 years ago to 10,000 years ago.

- Ready to scan Jan 5, 2004 (93 pages), document RJ0322.

Roy Jenne
Jan 5, 2004

Doc RJ0322
- Index on next 3 pages

Please also see this document which has 93 pages. It is on line at NCAR.
World Temperature Trends for a Few Thousand Years
Roy Jenne
Dec 17, 2003

This text has info and debates about the world temperature trends on three time scales:
  a. The past 150 years
  b. The past 1200 years
  c. Changes over several thousand years
  d. Climate change for past century and for a few thousand years (Jenne, Feb 2003)
      • This has text and references

1. Climate change for past century and for a few thousand years (Jenne, Feb 2003).
   • A previous list of papers.
2. Temperature trend for a few thousand years (Dec 2002).
   • A three page discussion of the issues about these debates on
temperature trends. With references.
3. Atlantic region temps 30,000yrs to 85,000 years ago (Science, 20 Feb 2003).
4. 130,000 years of climate for Greenland, Portugal, Greece.
5. Climate Indian Ocean, China 36,000-54,000 yrs.
7. The Dead Sea had 4 high stands in the past 6000 years (2p).
8. Solar forcing of cycle’climate change in Alaska (12,000 yrs).
   (Dansgaard).
    • Up and down temps each 1000-2000 years for 10,000 years.
11. Temperature of Greenland ice for 100,000 years.
    • A bi warm period at 1000 AD.
18. A century of climate change for pacific ocean. (10 Jan 2003, Science)
   • First cold for 25 years, then warm for 25, etc. This warming and cooling of the pacific is also in step with global temperature changes.
   • A very nice paper.
20. The US pan evaporation is down. Why?
21. Notes from a meeting in Asheville about temperature trends.
   • Trends in the lower atmosphere.
23. Increasing river discharge to the Arctic Ocean.
25. Warm arctic melted much ice.
27. Ups and downs of CO2 uptake.
29. MSU temperatures affected by sea ice.
31. Past climate of the earth, ice ages and more. This points to Doc RJ108, 72p.
32. US climate data from tree rings, 1500’s and 1900’s.
33. Summer temps in Europe and China, 6000 yrs ago
34. Change of glaciers for 7000 years.
35. Glaciers and sea ice during the past 2000 years.
36. Lake Baikal, Russia, climate for 800,000 years.
37. 160,000 years of sand dunes and winds in Arabia.
38. Climate in Ethiopia 160,000 years ago.
39. Little Ice Age, China, 850-1980 AD.
40. Temperature for Antarctica.
41. Utility of past proxy records—past temps.
42. Climate for 1000 years by Soon and Baliunas (mar 2003)
Sharp Cooling of the Northern Hemisphere in the Early Subatlantic Age (650 - 280 BC)

V. V. Klimenko
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About 2,500 years ago, a strong cooling happened on the Earth. The evidence for this is found not only in numerous climatic indicators (glacier and tree-line position in the mountains, tree ring thickness, fossil pollen spectra, isotopic composition of ice, lacustrine and marine deposits) but in social history as well. Papers by many ancient authors (Herodotus, Livy Andronicus, Eratosthenes), as well as Chinese and Babylonian chronicles, describe a climatic pattern that differs greatly from the present, not only in temperature but also in humidity. They come from that period when the Scandinavian legend of Ragnarök originated (the doom of the gods and the entire world). Presumably, it implies that there was a critical change in the common natural environment. It is not surprising that it was this cooling that was chosen in paleoclimatology as a universal chronological boundary separating the penultimate (Subboreal) from the present (Subatlantic) epoch. However, there are still no satisfactory answers to the following fundamental questions:

- Was the Subatlantic cooling global?
- When and at what level was the maximum cooling attained?
- What was the distribution pattern of temperature and precipitation during this period?
A few highlights of my study, which addresses these questions, are presented here. Detailed information is given elsewhere (Klimenko, 2004).

There are grounds to believe that the cooling of the Early Subatlantic Age (ESA), along with the Little Ice Age (LIA), was one of the strongest throughout the Late Holocene and, hence, marks the lower boundary of the natural climatic change at a millennial timescale. Not only climatology is actively interested in studying the ESA cooling, since its chronological boundaries roughly correspond to what Karl Jaspers referred to as the ‘axial age’ of history, i.e. the epoch of a remarkable, unique outburst of human intellectual and spiritual life that left clear historical evidence in different parts of the world. That such a coincidence is not accidental is confirmed by historical/climatological comparative studies (Klimenko 1998).

Even though the fact that a sharp cooling occurred during the ESA does not itself seem to be questioned, there are appreciable discrepancies concerning the chronological boundaries of this event. The majority of the data fall within the range of 2500-2200 radiocarbon yr BP, or 650-280 B.C. according to modern calibration (Stuiver et al., 1998). A thorough study of the most precisely dated experimental material enables the ESA event to be characterised as an asymmetrical double cold episode, in which two cooler stages were separated by a short-term warming between ca. 450 and 380 B.C. The second cool stage was more prominent, culminating at 280±50 B.C.
Future Global Warming Scenarios

In a study commissioned by the Pentagon, Peter Schwartz and Doug Randall (1) present a very alarming scenario regarding the short-term consequences of global warming. This scenario, which predicts a shutdown of the Atlantic Ocean’s conveyor circulation in the next 10 to 15 years, is based on analogies to two large and abrupt climate changes, which occurred 12,700 and 8200 years ago. Both are thought to have been triggered by catastrophic releases of meltwater stored in lakes that formed along the southern margin of the retreating Canadian ice sheet. These floods appear to have squelched deep water formation in the North Atlantic and, by as yet unknown mechanisms, caused Earth’s climate to plunge back toward its glacial condition. Clearly, if global warming were to cause a repeat of such an abrupt change, the consequences would be akin to those alluded to in the warning to the Pentagon, namely, a large cooling of northern Europe. But there is no reason to believe that the impacts could occur in a mere decade, nor would they be so awesome.

“Exaggerated scenarios serve only to intensify the existing polarization over global warming. What is needed is not more words but rather a means to shut down CO₂ emissions to the atmosphere.”

—Broecker

As the one who first pointed out the link between the Atlantic’s conveyor circulation and abrupt climate changes, I take serious issue with both the timing and the severity of changes proposed in the Pentagon scenario. Computer simulations do suggest that a greenhouse-induced warming would increase the delivery of precipitation and river runoff to the North Atlantic and, further, that given a large enough warming, this excess fresh water could cause the conveyor to sag and, in the extreme, shut down. However, the time required for this to happen is more likely a century, not a decade. Further, no full-fledged global model has yet reproduced the immense impacts coincident with the two meltwater floods. We suspect that the required amplifier involves sea ice formation in the North Atlantic. If indeed this is the case, then as the globe warms, amplification by this mechanism becomes ever less likely.

Exaggerated scenarios serve only to intensify the existing polarization over global warming. What is needed is not more words but rather a means to shut down CO₂ emissions to the atmosphere. Although we are powerless to accomplish this by 2015, we certainly have the wherewithal to do it by 2075.

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Reference

16 April 2004
Science

The Panic Story

1) There may be a huge climate change in a decade

2) Wally Broecker says “No”

—He doesn’t like the Panic Story
Temperature of Greenland Ice for 100,000 Years

- The ice from one year of snow has the annual average surface air temperature from when it fell.
- Now people measure the ice temperature.
- It got colder from 100,000 years ago to 25,000 years ago.
- It was warmer than now (by 2.5°C) from 8500 to 5000 years ago.
- There was another warmer spell about 1000 years ago.

Past Temperatures Directly from the Greenland Ice Sheet
D. Dahl-Jensen, K. Mosegaard, N. Gundestrup, G. D. Clow, S. J. Johnsen, A. W. Hansen, N. Balling

The record implies that the medieval period around 1000 A.D. was 1 K warmer than present in Greenland. Two cold periods, at 1550 and 1850 A.D., are observed during the Little Ice Age (LIA) with temperatures 0.5 and 0.7 K below the present. After the LIA, temperatures reach a maximum around 1930 A.D.; temperatures have decreased during the last decades (26). The climate history for the most recent times is in agreement with direct measurements in the Arctic regions (27). The climate history for the last 500 years agrees with the general understanding of the climate in the Arctic region (28) and can be used to verify the temperature amplitudes. The results show that the temperatures in general have decreased since the CO and that no warming in Greenland is observed in the most recent decades.
Perspectives

Paleoclimate

Superlakes, Megafloods, and Abrupt Climate Change

Garry Clarke, David Leverington, James Teller, Arthur Dyke

As concern about the magnitude and rate of future climate change looms, it becomes increasingly important to understand the mechanisms underlying past abrupt climate change events. A cold event that occurred 8200 years ago, although much less extreme than some events during the Ice Ages, is probably most amenable to detailed examination because it is the most recent such event.

According to the ice-core record from Greenland, the abrupt cooling 8200 years ago was the largest climate excursion of the past 10,000 years (1, 2). The mean temperature dropped by about 5°C for about 200 years (see the figure, A), snow accumulation decreased sharply, precipitation of chemical impurities increased, and forest fires became more frequent. The event, which affected much of the Northern Hemisphere (3–5), appears to have been triggered by the sudden release of fresh water from a huge, glacier-dammed lake that had formed during the deglaciation of North America (6).

Changes in the volume and extent of the ice sheets that once covered much of North America directly influenced the freshwater balance of the North Atlantic and are implicated in many abrupt climate events of the past 100,000 years (7, 8). During the last Ice Age, when a kilometers-thick ice sheet covered most of Canada and parts of the northern United States, armadas of icebergs were episodically launched into the North Atlantic. The melting of this freshwater ice and the associated freshening of ocean surface waters are believed to have changed the strength of the oceanic thermohaline circulation (9), thereby causing abrupt climate changes.

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The deglaciation of North America produced large volumes of glacial meltwater, which also appears to have influenced the circulation of the North Atlantic. The Younger Dryas cooling event, which began about 12,700 years ago, is thought to have been triggered by an outburst of waters from a large ice-dammed lake and sustained by the redirection of meltwater from the Mississippi to the St. Lawrence Valley (7, 10). To explain the 8200-year cold event, a search for large sources of fresh water is thus a good starting point.

Around 8500 years ago, the Laurentide Ice Sheet, which at its maximum formed a 3-km-thick dome over Hudson Bay, was disintegrating rapidly. A marine calving bay extended into Hudson Bay from the Labrador Sea (see the figure, B). The southern margin of the ice sheet retreated northward, it left behind a depressed land surface that sloped toward the position of the former ice dome. Glacial melt and precipitation runoff collected in the basin created by the sloping land surface and the ice barrier to the north. The estimated rate of inflow to this basin was ~0.1 sverdrup (1 sverdrup = 10⁶ m³ s⁻¹). Overflow waters from the resulting lake flowed through the St. Lawrence Valley into the North Atlantic.

Shortly before the Laurentide Ice Sheet finally disintegrated, the glacial lake—Lake Agassiz—had become a superlake (see the figure, B). Its maximum volume has been estimated as 163,000 km³ (11)—at least double that of the largest contemporary lake, the Caspian Sea. The maximum elevation of the lake surface was fixed by a spillway about 230 m above sea level.

The ultimate release of Lake Agassiz waters to Hudson Bay was unavoidable. On the basis of radiocarbon dating, the outburst occurred 8450 years ago (6). A marine geophysical survey (12) provides evidence for high rates of water discharge in Hudson Bay associated with one or more outburst floods from the lake. The 8200-year cold event was thus most likely triggered by a flood of fresh water from superlake Agassiz that flowed northward through Hudson Bay into the North Atlantic.
Arctic lake promises hot data on past climate

Quirin Schiermeier, Munich

A preliminary excursion to a remote Russian lake has raised scientists' hopes that it will offer the most reliable terrestrial records yet of Arctic climate history.

Located in the extreme northeastern tip of Siberia, Lake El'gygytgyn is unique, climate researchers say. Unlike most of the Arctic, the lake has never been covered by glaciers, which disrupt the accumulation of sediment. This means that El'gygytgyn's floor offers an uninterrupted view of past climate patterns.

"Drilling cores from the lake should provide a fantastic climate archive," says Thomas Stocker, a climate researcher at the University of Bern in Switzerland. "It would be a valuable supplement to marine drillings, whose information is always filtered by the ocean."

During a four-month expedition last year, geologists and limnologists from Germany, Russia and the United States probed the lake's sediments and surrounding permafrost soil to check out their likely usefulness. And at a meeting in Leipzig, Germany, late last month, they announced that their study had confirmed the lake's potential.

"Our survey has revealed that the bedding of the lake floor sediments is perfectly undisturbed," says Marin Melles, a geologist at the University of Leipzig and member of the expedition.

The lake is now being put forward as a site for the International Continental Drilling Program, a collaboration of 11 countries that aims to extract cores from the continental shelf, which would conduct a 400-metre deep-drilling project there in 2007.

Icy yield: drilling at Lake El'gygytgyn has already retrieved a climate record for the past 400,000 years.

El'gygytgyn, which is about 175 metres deep and 15 kilometres across, fills the larger part of a crater created by a meteorite impact 3.6 million years ago. It is on the Chukotka peninsula, opposite Alaska, an area far from any settlement and very difficult to reach.

The expedition team and nine tonnes of equipment were flown to the lake last April by helicopter from Pevek, a small town on the East Siberian Sea.

Getting to the lake was difficult, Melles says. At first, Russian customs in St Petersburg declined to clear several items, including a snowmobile, which never made its way east. And summer evacuation from the camp, which was beginning to drown in seasonal mud, was delayed for a few days because available Russian helicopter pilots had hit statutory limits on their monthly flying hours. To get out, the researchers eventually had to hire a helicopter from a local gold-mining company.

But the scientific yield was worth the effort, says Julie Brigham-Grette, a geologist at the University of Massachusetts in Amherst. Brigham-Grette, in collaboration with Melles and with researchers at the North-East Interdisciplinary Scientific Research Institute in Magadan in far-eastern Russia, is analysing mineralogy and organic traces in the lake-floor sediments.

Seismic profiling shows that the sediments are some 400 metres thick, and probably contain an exceptional record running from the meteorite impact, in the Pliocene warm period, up to the present day. The expedition recovered a drilling core 16 metres long, representing the past 400,000 years, from the centre of the lake.

Deep drilling in Lake El'gygytgyn would help researchers study Arctic climate change before the onset of glaciation 2.2 million years ago, explains Brigham-Grette.

www.lcpd-online.de/welcome.html

This lake is very interesting

- They now have a mud core with 400,000 years of climate info
- It will be possible to get 3.6 million years of climate mud

- Roy Jorna

15 April 2004

Nature
The Isthmus of Panama and the Ice Ages

The formation of the Isthmus of Panama about 3 million years ago (Ma), a fairly small event in terms of plate tectonics, had dramatic effects on evolution, ocean circulation, and Earth's climate. Previously isolated North and South American land faunas mixed, and the separation of Atlantic and Pacific waters imposed changes in ocean circulation. One hypothesis is that these changes in ocean circulation triggered the ice ages; the onset of severe Northern Hemisphere glaciation was about 2.5 Ma. Long-term changes in ocean circulation can be monitored using neodymium (Nd) and lead (Pb) isotopes, which reflect the regional geology of exposed continental rocks bordering ocean basins. Thus, different waters will have different isotopic compositions, so their mixing and circulation can be resolved.

Frank et al. and Reynolds et al. analyzed Nd and Pb isotopes from several ferromanganese crusts in the Atlantic and Pacific oceans and showed that the amount of water being exchanged through the Panama gateway waned noticeably before about 5 Ma, as the Isthmus began to form. This implies that the major effects on ocean circulation occurred considerably before glaciation increased. These records, along with new records of Nd isotopes from foraminifera preserved in sediments from near the Labrador Sea, reported by Vance and Burton, also show that formation of the ice sheets in North America and Eurasia increased erosion dramatically during the past 2 million years. — BH

*Geology 27, 1147 (1999); Earth Planet. Sci. Lett. 173, 381 (1999); Earth Planet. Sci. Lett. 173, 365 (1999).*

The Isthmus of Panama and the Ice Ages

The Isthmus of Panama formed about 3 million years ago. Then it was high enough to stop the water flow from the Pacific Ocean into the Caribbean. The ice ages started about 2.4 ma. The water flow had started to get weaker about 5 ma as described in this story. I suspect that the Panama Isthmus just rose in place, rather than moving in from the west as shown here.

- When ice ages start they cause more erosion, and that draws down CO₂, causing it to cool even more.
- This story about Panama and ocean circulation is just fascinating to me!
In Search of Paleo-ENSO

Yair Rosenthal and Anthony J. Broccoli

In the past several years there has been a shift in the perceived importance of the tropical Pacific Ocean to global climate on glacial-interglacial and millennial time scales. Modeling studies have indicated that the El Niño–Southern Oscillation phenomenon (ENSO), which is the primary source of year-to-year variations in tropical sea surface temperature (SST) in the modern world, may be highly sensitive to orbital influences (1, 2). In these studies, the dynamical interaction between the atmosphere and ocean in the tropics is influenced by the modulation of the seasonal cycle of solar radiation by the precession of Earth; simulated tropical Pacific SST anomalies, akin either to warm El Niño or cold La Niña events, can be sustained for several hundreds to thousands of years and generate a globally synchronous climate response. Just as ENSO-related SST variations exert a major effect on modern atmospheric circulation and climate, models suggest that changes in tropical Pacific SST patterns might also have had large consequences for global climate during the last glacial maximum (LGM) about 20,000 years ago (3). There is, however, still a large uncertainty as to the relationships between ENSO characteristics and the background mean climate state. Given that instrumental data are limited to the past century, paleoceanographic records can provide better constraints for assessing future effects of global warming on ENSO and their ramifications for Earth’s climate (4).

Because ENSO is an interannual phenomenon with a strong seasonal signal, its long-term history is best reconstructed from annually banded corals (5). However, their reliability as recorders of long-term climate change is still debatable (6). Similarly, lake sediments with annually resolved varves provide valuable insights into variations in ENSO throughout the Holocene, but as yet we have no record that spans the LGM (7, 8). More recently, however, lower resolution sediment records from key locations in the tropical Pacific have also been used to infer long-term variability in ENSO and its possible role on both orbital and millennial time scales. In particular, two lines of evidence, both based on reconstructions of SST and salinity from measurements of Mg/Ca and δ¹⁸O in foraminifera shells, have been proposed in support of long-term ENSO variability.

The first of these suggests that LGM relaxation of SST gradients within the cold tongue of the eastern equatorial Pacific was likely a result of reduced upwelling caused by weakening of the trade winds in an “El Niño–like” fashion (9). The second, which argues for “super ENSO” conditions during the cold Northern Hemisphere stadial intervals, is based on changes in the distribution of surface salinity and, by inference, precipitation in the western equatorial Pacific (10). These observations are very intriguing, yet they raise questions as to whether they are representative of the entire tropical oceans or only reflect local conditions (11). For example, the western Pacific salinity record is in a site that is currently strongly influenced by the east Asian monsoon system, which is tightly linked to Northern Hemisphere climate (12). There are also questions as to the fidelity of, and compatibility among, different paleo-proxies. For instance, faunal-based studies argue for intensification of the eastern equatorial Pacific cold tongue with the corollary of prevailing La Niña–like conditions during the LGM, in contrast with Mg/Ca-based SST reconstructions (13, 14). These concerns about the reliability of paleo-proxies in capturing the full scope of climate variability clearly need to be addressed (15).

Even in the absence of important uncertainties in paleoceanographic records, interpreting proxy evidence for changes in
Rapid climate change

Hollywood has produced a big scary movie about rapid climate change. It seems designed as a thriller, and to scare people about climate change. And they no doubt want to advance a certain type of climate change politics.

The movie will come out May 28, 2004.

-Roy Dante

5/4/2004 12:07 PM
Welcome, rajahoreo
Yahoo! News
Tue, May 18, 2004

Welcome, rajahoreo
Yahoo! News
Tue, May 18, 2004

Movies - E! Online
Gore Stumps for "Tomorrow"

Mon May 17, 8:30 PM ET

By Joal Ryan

It's the most surprising plot twist of The Day After Tomorrow.
Rupert Murdoch working together with Al Gore (news - web sites).

To be accurate, Murdoch and Gore aren't technically working together, but they are working toward the same end: The conservative media mogul's selling a movie, and the liberal former vice president's helping him selling it.

The movie is The Day After Tomorrow, a $125 million summer disaster flick from Murdoch's Fox, opening May 28.

Paul Dergarabedian, of the box-office tracking firm Exhibitor Relations, calls the would-be blockbuster "a popcorn movie with a message."

Its message: The world's going to hell in a handbasket. Tornadoes in Los Angeles. The ice age in Manhattan. Earthquakes (news - web sites), tidal waves, unbelievable gridlock.

The cause of all this consternation, Dennis Quaid's professor character in the film tells us, is global warming. The movie was said to be inspired by the cataclysmic tome The Coming Global Superstorm.

Murdoch presumably is hoping the special effects, if not the topic, will fatten the Fox bottom line. Gore definitely is hoping the topic, if not the end-of-the-world imagery, will make audiences think about the environmental bottom line.

"I do want to take advantage of the opportunity presented by the movie...to talk about what the real issues are," Gore told reporters in a telephone press conference last week.

To that end, Gore has teamed with the activist group, MoveOn.org, to publicize an education campaign on global warming and the
greenhouse effect timed to the release of *The Day After Tomorrow*.

MoveOn.org volunteers are being encouraged to buy tickets to the film's Memorial Day opening weekend, and hand out informational flyers to other moviegoers.

The flyers, MoveOn.org executive director Peter Schurman told reporters, "will answer questions people will have" after seeing the film. (Make that, questions about global warming. It's unlikely the organization knows what Day After costar Jake Gyllenhaal's intentions are toward Kirsten Dunst.)

Schurman said Fox has been notified of its plans, and its representatives invited to a May 24 so-called town hall rally in New York City featuring Gore and environmentalist Bobby Kennedy Jr.

Fox, for its part, has agreed to screen the film for Gore and a small group of others before the film's gala premiere, also scheduled for May 24 in New York City.

Outside of that lone coordinated effort, the two sides will go their own ways. Fox will push *Day After* as a big-budget summer flick from the director of *Independence Day* (with a nod to the environment through its partnership with Future Forests, a London-based company that shows businesses how to minimize their carbon-dioxide emissions); Gore's camp will push *Day After* as an important, if exaggerated, cautionary tale.

If MoveOn.org is a group with a political bent unlike Murdoch's, his studio isn't griping.

"We think it's wonderful for the movie," Fox spokeswoman Florence Grace says of the MoveOn.org campaign. "The issues addressed [make the film] all the more topical, all the more interesting. We think it's great."

Certainly mountains of op-ed articles and months of pre-release protest only served to fuel box-office receipts for Mel Gibson (news)'s *The Passion of the Christ* ($368.9 million and counting through last weekend).

No one thinks Gore and MoveOn.org are going to supply a Passion-like bump for *Day After*, but Mitch Litvak, president of the entertainment marketing firm The L.A. Office, says the free publicity, even in the form of an environmental lecture, can't hurt.

"[Among] younger moviegoers there's such a strong interest in seeing the film based on the early advance trailer, adults may not think it's right for them," said Litvak. "What MoveOn does is make it relevant to them."

"It's kind of like the Good Housekeeping seal of approval."

Fox'll take it, politics be damned.

Says Dergarabedian: "Any extra butt you can put in a movie seat is an extra 10 bucks in the pocket of the studio and the theater."

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'Only nuclear power can now halt global warming'

Leading environmentalist urges radical rethink on climate change

By Michael McCarthy Environment Editor

24 May 2004

'Only nuclear power can now halt global warming'
'The ice is melting much faster than we thought'

Guru who tuned into Gaia was one of the first to warn of climate threat

James Lovelock: Nuclear power is the only green solution

Global warming is now advancing so swiftly that only a massive expansion of nuclear power as the world's main energy source can prevent it overwhelming civilisation, the scientist and celebrated Green guru, James Lovelock, says.

His call will cause huge disquiet for the environmental movement. It has long considered the 84-year-old radical thinker among its greatest heroes, and sees climate change as the most important issue facing the world, but it has always regarded opposition to nuclear power as an article of faith. Last night the leaders of both Greenpeace and Friends of the Earth rejected his call.

Professor Lovelock, who achieved international fame as the author of the Gaia hypothesis, the theory that the Earth keeps itself fit for life by the actions of living things themselves, was among the first researchers to sound the alarm about the threat from the greenhouse effect.

He was in a select group of scientists who gave an initial briefing on climate change to Margaret Thatcher's Conservative Cabinet at 10 Downing Street in April 1989.

He now believes recent climatic events have shown the warming of the atmosphere is proceeding even more rapidly than the scientists of the UN's Intergovernmental Panel on Climate Change (IPCC) thought it would, in their last report in 2001.

On that basis, he says, there is simply not enough time for renewable energy, such as wind, wave and solar power - the favoured solution of the Green movement - to take the place of the coal, gas and oil-fired power stations whose waste gas, carbon dioxide (CO2), is causing the atmosphere to warm.

He believes only a massive expansion of nuclear power, which produces almost no CO2, can now check a runaway warming which would raise sea levels disastrously around the world, cause climatic turbulence and make agriculture unviable over large areas. He says fears about the safety of nuclear energy are irrational and exaggerated, and urges the Green movement to drop its opposition.

In today's Independent, Professor Lovelock says he is concerned by two climatic events in particular: the melting of the Greenland ice sheet, which will raise global sea levels significantly, and the episode of extreme heat in western central Europe last August, accepted by many scientists as unprecedented and a direct result of global warming.

These are ominous warning signs, he says, that climate change is speeding, but many people are still in ignorance of this. Important among the reasons is "the denial of climate change in the US, where governments have failed to give their climate scientists the support they needed".

He compares the situation to that in Europe in 1938, with the Second World War looming, and nobody knowing what to do. The attachment of the Greens to renewables is "well-intentioned but misguided", he says, like the Left's 1938 attachment to disarmament when he too was a left-winger.

He writes today: "I am a Green, and I entreat my friends in the movement to drop their wrongheaded objection to nuclear energy."
His appeal, which in effect is asking the Greens to make a bargain with the devil, is likely to fall on deaf ears, at least at present.

"Lovelock is right to demand a drastic response to climate change," Stephen Tindale, executive director of Greenpeace UK, said last night. "He's right to question previous assumptions.

"But he's wrong to think nuclear power is any part of the answer. Nuclear creates enormous problems, waste we don't know what to do with; radioactive emissions; unavoidable risk of accident and terrorist attack."

Tony Juniper, director of Friends of the Earth, said: "Climate change and radioactive waste both pose deadly long-term threats, and we have a moral duty to minimise the effects of both, not to choose between them."

Also in Environment

'Only nuclear power can now halt global warming'
Guru who tuned into Gaia was one of the first to warn of climate threat
'The ice is melting much faster than we thought'
How trains, planes and parties are driving Britain barking mad
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