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USING THE PRECESSION METHODOLOGY TO TIME PAST GLACIAL AND INTERGLACIAL CLIMATES

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Abstract

Eccentricity and precession values time interglacial and glacial climates when compared with the Devils Hole, Nevada, $\delta^{18}O$ climate change chronology. The pattern of eccentricity minima (more circular orbit) and precession maxima in the southern hemisphere identifies the interglacial events represented in the ~500,000-yr Devils Hole record. This pattern also identifies the timing of the transition from interglacial toward glacial periods when greater Devils Hole $\delta^{18}O$ values change toward smaller values. The timing and number (either 4 or 5) of southern hemisphere summer radiation maxima between interglacial events identifies glacial periods (smaller isotope values in the Devils Hole $\delta^{18}O$ record) as well as when these smaller $\delta^{18}O$ values begin a change toward greater values (glacial terminations). This pattern shows that the last 400 k.y. cycle can be divided into glacial, interglacial, and intermediate (transitions between glacial and interglacial and vice versa) climate states based on precession values and paced by eccentricity minima.

If this relation is valid, then climate is approaching a major change in state out of present-day interglacial climate. Long lacustrine climate records show that interglacials often end with a short, warm period. If present climate corresponds to this short, warm period, it could be amplified by human-driven warming over the next few centuries. Correspondence between the timing of the termination of interglacial events in the Devils Hole record and maximum precession (increased summer solar radiation) in the southern hemisphere summer indicates that northern hemisphere climate begins a cooling trend when heat is being added to the southern hemisphere. This relation indicates that a link between glacial and interglacial periods and tropical insolation may exist.

How the color bars are determined

1. The second northern hemisphere summer solar radiation maximum going forward in time from an eccentricity minima begins the interglacial climate state (red bands). This interglacial climate state always begins at the last northern hemisphere summer solar radiation maximum, either #4 or #5 depending on the number of precession peaks in a sequence, just prior to the I event. This interglacial state lasts to the I event (southern hemisphere maximum #1).

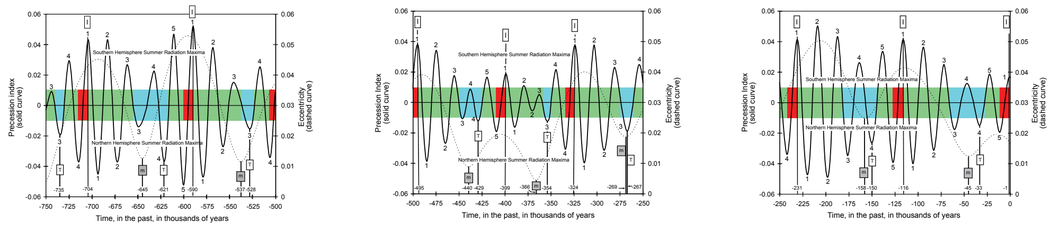
2. From the I event to where the precession curve crosses zero between the southern hemisphere summer solar radiation maximum #3 and northern hemisphere summer solar radiation maximum #3, intermediate climate occurs (green bands following red bands).

3. The glacial climate (blue bands) is defined as beginning where the intermediate climate ends in #2 above. The end of the glacial climate is defined as the point where the precession curve crosses zero just forward in time following a T event [the northern hemisphere summer solar radiation maximum precession #3 (if a four-sequence) or #4 (if a five-sequence)].

4. An intermediate climate (green bands following blue bands) is defined to exist following the end of the glacial climate until the final northern hemisphere summer radiation maxima in the precession sequence. Intermediate climates always end at the northern hemisphere summer radiation maxima prior to the next I event.

The well-dated Devils Hole, chronology (Landwehr et al., 1997) is used here to ask if this Earth-based record of climate change fits orbital parameter sequences. Because the Devils Hole record is well dated, it is possible to use it to find related patterns in orbital parameters rather than using orbital parameters to date a climate proxy record, as is often the case with ice or marine records.

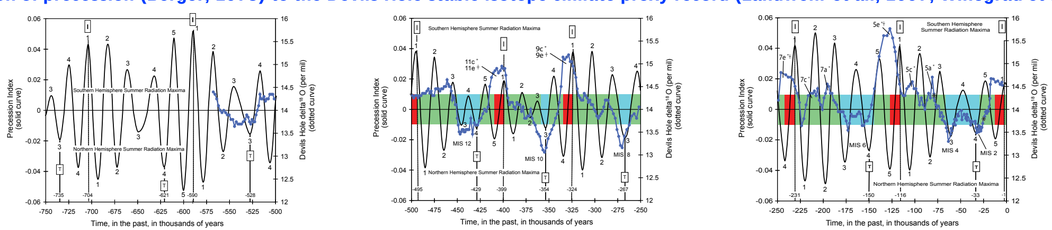
Fig. 1 **Precession and Eccentricity for the past 750 ka (Berger, 1978)**



Colored bars designate general climate states: Red = interglacial, Blue = glacial, Green = intermediate

- Numbers 1 through 4 or 5 indicate summer solar radiation maxima in the southern hemisphere (top of graphs) or summer solar radiation maxima in the northern hemisphere (bottom of graphs).
- m = eccentricity minima denoting a more circular orbit than higher values.
- T = initiation of transition from glacial to interglacial climate and is determined by the first northern hemisphere summer solar radiation maximum after the eccentricity minimum.
- I = initiation of transition from interglacial to glacial climate and is determined by the second southern hemisphere precession peak after the T event.
- Note that all the I events for the past ~750,000-yr are located two southern hemisphere maxima precession peaks forward in time from each T event. The span from one I event to the next encompasses a precession sequence. The number of precession peaks or cycles in past sequences is randomly either four or five.

Fig. 2 **The relation of precession (Berger, 1978) to the Devils Hole stable isotope climate proxy record (Landwehr et al., 1997; Winograd et al., 1992)**



Devils Hole stable isotope data (closed circles) are reported relative to Vienna standard mean ocean water (VSMOW). The greater $\delta^{18}O$ values in the Devils Hole record interglacial climates, the smaller values record glacial climate.

- I events for the ~500,000-yr Devils Hole record correspond to times when greater Devils Hole $\delta^{18}O$ values (interglacials and other warm periods) are changing toward smaller values. These interglacial periods are shown as red bars in Figs. 1 and 2.
- T events correspond to times when smaller Devils Hole $\delta^{18}O$ values (glacial periods) are changing toward greater values. Terminations of glacial periods (blue bars, Figs. 1 and 2) follow eccentricity minima.
- MIS equals Marine Isotope Stage; * MIS substages as in Winograd et al., 1997; † MIS substages as in Prokopenko et al., 2001.
- Stars designate the two tie points between calcite samples in cores DH-11, DHC2-3, and DHC2-8 (Winograd et al., 2006).

Describing the patterns

The timing, pattern, and magnitude of each glacial period correspond with the number of precession peaks in a precession sequence (I to I event). The timing and pattern of interglacial to glacial periods in the Devils Hole record show a remarkable consistency during the last eccentricity cycle (~400,000-yr).

When compared to the Devils Hole record:

- The precession sequences with five precession peaks have a glacial period with two episodes (double-trough) of low isotope values (MIS 12, 6, 4, 2).
- The precession sequences with four precession peaks have a single low isotope value (MIS 10, 8) near the southern hemisphere summer radiation maxima 3.
- Each precession sequence (I event to I event) from 425 to 4.5 ka in the Devils Hole chronology (except MIS 4 and 2), begins with an I event in an interglacial period, moves into a glacial period, and then moves toward another interglacial period as it nears the next I event. If glacial MIS 4 and 2 are considered one double-trough glacial period, this sequence is consistent for the last ~400,000-yr.
- Warm substages generally occur between the southern hemisphere summer radiation maxima 1 and 2 and between 2 and 3. Cold and warm episodes associated with the numbered substages also appear in other paleoenvironmental records worldwide.

Credit goes to Richard M. Forester who first noticed these patterns. See: U.S. Geological Survey, 2001, Future Climate Analysis, ANL-NBS-GS-000008 REV 00 ICN 01. Denver, Colorado: U.S. Geological Survey. ACC: OL.20011107.0004.

For more details, see: Sharpe, S.E., 2007, using modern through mid-Pleistocene climate proxy data to bound future variations in infiltration at Yucca Mountain, Nevada, in Levich, R.A., and Stuckless, J.S., eds., The Geology and Climatology of Yucca Mountain and Vicinity, Southern Nevada and California: Geological Society of America Memoir 199, p. 155-205.

Conclusions

- Precession index corresponds to shifts between glacial and interglacial climate states recorded at Devils Hole, Nevada, for the last ~500,000-yr, therefore precession may be a primary driver of climate change.

- We are currently in the warmest period of the present interglacial period according to the relation between the Devils Hole record and precession during the last 4 interglacial periods. This warm period may be amplified by anthropogenic warming during the next few centuries, thus potentially enhancing the consequences of global warming.

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