# *b32* Causes of the Ice Ages < multiple hypotheses >

> Fasten your seat belts. It's going to be a bumpy night! —Bette Davis in *All About Eve* (1950).[3]
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> The scientific celebrities, forgetting their molluscs and Glacial Periods, gossiped about art, while devoting themselves to oysters and ices with characteristic energy. —Alcott, *Little Women*.[4]

Many hypotheses have been proposed for what cause(s) Ice Ages. These hypotheses can be categorized as variation of insolation, albedo, greenhouse gases, or ocean currents. Each offers a feedback mechanism(s) that amplifies and then retards its operation, and none is necessarily exclusive of the others. All are hard to test because no theory for weather forecasting yet exists better than when Mark Twain wrote: "One of the brightest gems in the New England weather is the dazzling uncertainty of it."[5] However, the geologic record of long-term climate variation is increasingly known from its record in accumulation layers of deepsea sediments, ice sheets, and varved clays.

Evident are geologically short-term cyclic climatic variations. Today, the northern midwinter solstice, December 21, 22, occurs almost at perihelion (the point in Earth's orbit when it is closest to Sun), January 3. The precession of the equinoxes is that 11,000 BP (years before the present), the northern midwinter solstice occurred at aphelion (the point in Earth's orbit when it is most distant from Sun) and northern midsummer was at perigee. Climates have episodically warmed since the chilly then. What is now the Sahara Desert 5,300-8,500 BP was lush with vegetation, many tropical fauna (including hippopotamuses), extensive human settlements, large rivers, and higher lake levels.[6] J. Imbrie and K. P. Imbrie in *Ice Ages*, 1979, suggest that then Asian and northern African monsoons would have been stronger bringing more rain throughout the region during the summer months.[7] Elsewhere, cave stalagmite-record of monsoonal shifts is of Asia arid when North Atlantic is chilly.[8]


The Holocene Epoch has been a time of deglaciation with rapid climate swings, including the "Little Ice Age" in the Recent, but even that was mild, as defines an interglacial, when compared to the severe cold of glacials of the "Great Ice Age" of the Pleistocene Epoch. Holocene warmth has been since 11,800 vyr (varve years) BP when abruptly ended a millennium of cold, the Younger Dryas stadial, that officially ended the Pleistocene Epoch. Before, a short duration of warmth, the Allerød interstadial, could equally have been the end of the Pleistocene had it persisted following the Older Dryas stadial. Annually laminated sediments from Lake Meerfelder Maar (MFM) in the Eifel, Germany record that the Older Dryas ended 12,680 vyr BP and had lasted a brief 190 years. The Bølling interstadial, about 12,850-14,700 years ago,[9] followed the 13,800 vyr BP abrupt end of the *Oldest Dryas* stadial that had lasted some 3 millennia.[10]

Climate oscillations in the north Atlantic regions are recorded by variations in $^{18}O$ in land ice and in shells of marine planktonic. To account, Richard Alley and **Wallace (Wally) Smith Broecker** hypothesize rapid reorganizations of the North Atlantic thermohaline circulation[11] (***Figure b32.1***) as a decisive climate-forcing factor. The trigger for an ice age could be a northern glaciers' melt-event (warming) that releases freshwater that caps (floats on the warm saline waters of) and shuts off the north-Atlantic thermocline circulation. The albedo of the more extensive sea ice, which would then form, would prolong winter chill though summer. Thereafter, land snowfields would be more extensive and their albedo would increase the chill, and so on, into ice-age conditions.

Synchronous with north-Atlantic climate change for the last 15,000 years have been variations in the grayness of deepsea sediments (darkness is a measure of material other than $CaCO_3$) in equatorial Atlantic where trade winds cause upwells and organic productivity varies accordingly. Konrad A. Hugen posits trade-wind variation is a decisive climate-forcing factor as is so for the El Niño Southern Oscillation (ENSO).[12]

Earth's climatic zones are clearly related to latitude and this can be related to Sun's radiation budget distributed on the spherical and rotating Earth (*see* Topic *b33*). The total radiation budget received (the insolation) must vary as a whole as the eccentricity of Earth's orbit changes, hemispherically as Earth precesses, and as a whole and hemispherically with the precession of the equinoxes. The test would be to show that the calculable periodicity of these celestial variations is matched by details of the recorded terrestrial climatic variations.[13] Presently, paraphrasing Will (William James) Durant's wry humor: "Civilization exists by geological consent, subject to change without notice."[14] ❑