A theory of long scale climatic oscillation, which explains global warming using a closed model of polar-tropical oceanic heat transfer.

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By Livingston Davies and Kyle L. Davies

Extended Abstract

Introduction

This paper proposes a theory of climatic oscillation that would explain ice age periodicity. The creation and destruction of ice caps over both land and water is viewed as an artifact of a natural cycle of the related creation and destruction of tropic-to-polar region ocean currents. The theory assumes a simplified earth-ocean model, which absorbs a constant amount of solar radiation and re-radiates a constant amount of heat. The system therefore has a constant heat budget. Heat alternates between being concentrated in the tropic regions and being relatively disbursed to the temperate/polar regions. When pole-bound currents are weak or absent, relatively little heat is transferred out of the tropics. A band of warm water centered along the equator will widen due to a broad and slow migration of surface water away from the equator in a generalized Eckman transport. Localized solar heating results in an increasing depth of the thermocline in tropical regions. Corresponding cooling in the polar regions ultimately produces ice caps. Warm water above the thermocline is less dense than the cold water below the thermocline. As the depth of the thermocline in the tropics increases and the latitude at which the thermocline reaches the ocean surface decreases, the height of the water column in the tropics increases relative to that in the temperate and polar zones. Therefore, the gradient of ocean surface elevation increases. When the gradient is small, tropical surface water spreads gradually and fairly evenly toward higher latitudes. However, when the gradient becomes sufficiently large, it may induce the creation of pole-bound currents at the western edges of the oceans. Polar ocean warming and corresponding warming of high latitude land masses due to circumferencal winds causes the melting of both ocean and land ice caps. When the ice caps disappear and the latitude where the thermocline meet the ocean surface moves toward the poles, the ocean surface elevation gradient becomes small. Therefore, less water flows out of the tropics and the pole-bound currents collapse.

The model predicts a rising and lowering of the thermocline depth in the tropics on the same period as the occurrence of ice ages. It also predicts a rapid increase in surface temperature in high latitude temperate zones when water borne ice caps substantially disappear. A periodic rise and fall of the thermocline would result in a similarly periodic creation and disappearance of warm pole-bound currents.

Generalized Eckman Transport

Warm surface currents have a profound effect on weather and climate conditions as they transfer heat from the tropics to upper latitudes. But the major currents that carry water away from the equator are sub-surface currents. This mechanism is called Eckman transport after the oceanographer who discovered it. Sub-surface Eckman transport occurs at all longitudes and is generally perpendicular to the equator. Net Eckman transport is particularly strong under normal conditions at the western ocean edges because western ocean edges have a buildup of water due to prevailing wind conditions.

In today's oceans, surface currents at or near the equator generally flow from east to west under the influence of the prevailing winds. Prevailing winds create mountains of warm water at the western edges of the oceans. To some extent the mountains of warm water displace lower depth and higher density cold water. The depth to the thermocline is therefore greater in the western side of a given ocean than on the ocean's eastern side. In addition to supporting Eckman transport currents, that water then flows downhill to fuel the principle warm currents such as the Gulf Stream, and the Kuroshio, Brazil, and East Australian currents. Warm water thereby leaves the tropics to head toward the poles.

Sometimes, the tropical prevailing winds collapse or reverse causing the buildup of water at the western ocean edges to subside. That, in turn, can cause a local and temporary reversal in the direction of the Eckman transport currents and generally cause *el nino* phenomena. But even in the absence of surface winds, Eckman transport must occur. The mass of water in a particular water column is the integrated density of that water over the column. Since warm water is less dense than cold water, the tropical warm water column can be expected to be higher than that in cooler regions. There is therefore a broad ridge of water around the equator. Gravitational force will tend to force that ridge to spread and thin at all longitudes. That will reduce the integrated mass of the water column and induce the high-density water below the thermocline to rise. Water will move away from the equator. It will move generally perpendicular to the equator but its direction will be modified westward by the Corriollis force. It will also be limited by any existing continental barriers. A continental barrier at the western edge of an ocean will obstruct the western flow due to Correolis force and induce pole bound currents. West-bound surface winds will induce a buildup of water will tend to increase both Eckman transport and surface currents. In the absence of strong prevailing equatorial surface winds that create mountains of warm water at the western ocean edges, Eckman transport might be the only major mechanism of warm water transport away from the tropics.

Initial Conditions

Assume a simplified earth system consisting of:

1. a solid rotating earth sized sphere
2. covered by deep water
3. a single land mass extending from pole to pole
4. radiated by a sun at a constant distance

5. solar radiation absorbed at the equator is sufficient to keep equatorial ocean water liquid
6. solar radiation absorbed at the poles is not sufficient to keep polar water liquid absent heat transfer from the equatorial regions

Assume that the system has initial conditions of
1. no water currents
2. constant water temperature of 10°C

Transitional and Oscillation Phases

How will the system behave over time given these initial conditions? The system will absorb solar radiation and convert that radiation to heat. It will also re-radiate some of that heat back into space. To a first approximation, heat is both absorbed and emitted only at the surface of the earth/ocean system. The amount of heat emitted through black body radiation is proportional to the absolute temperature of the item emitting the radiation. This means that heat emitted from ocean water will be a function of the local surface temperature of the ocean. It will be unaffected by the temperature of water at depth. An ocean acts as a much more effective heat reservoir than does land. Neither light nor heat penetrates land to a significant depth. Moreover, there is no flow of material within solids so heat transport is limited to conduction rather than circulation. By contrast, the oceans experience both greater penetration of the sun's radiative energy and are also subject to heat transport due to circulation. Ocean water is semi-transparent to sunlight. Although most of the energy is absorbed close to the surface, solar radiation penetrates the ocean to a depth of up to 1000m. Essentially all of that energy gets converted to heat through one or another process. In addition, and unlike the condition on land, heat is disbursed in the oceans through mixing of the water. Mixing occurs both vertically and horizontally.

Absent other influences, the system will approach an equilibrium state with regard to its heat content. The amount of heat absorbed through solar radiation will then equal the amount of heat re-emitted by the earth.

The characteristics of the equilibrium state depend critically on the unusual properties of water. As with most substances, at constant pressure, water generally expands and becomes less dense as its temperature increases. Layers of warm water therefore generally float on top of cooler water. But unlike most substances, the density of water does not decrease monotonically with increasing temperature. In fact, when water freezes and becomes ice, its density becomes significantly less than that of liquid water. Ice therefore floats. Moreover, unlike nearly all other liquids, the density of liquid is not at its maximum at a temperature immediately above its freezing point. The different properties of salt vs. fresh water are not important for purposes of this model. The temperatures at which salt water freezes and at which it is at its maximum density are slightly reduced relative to fresh water, but its density/temperature characteristics are qualitatively similar. The remainder of this paper ignores the difference. Liquid water has a maximum density at temperature of approximately 2 degrees centigrade. This means that water that is either warmer or colder will float above it. If a layer of ice exists floating on warm water (say at 10° C), the ice will chill the upper layer of the water. The water immediately adjacent to the ice will have a temperature close to 0° C. Over a small distance, the temperature will transition to 10° C, the temperature of the dominant layer. A small layer will be chilled to 2° C. As water is chilled to that temperature, it will sink because it is more dense than the water that is either warmer or colder. In other word, the dense water will downwell and be replaced by warmer water. As more maximum-density water is create through the cooling process, an increasing layer of high density water of temperature 2° C will be created. That is the origin of the thermocline. The high density water below the thermocline will fill the ocean to the point that an equilibrium condition exists.

The system should be expected to go though transitional phases resulting either oscillation about an unstable equilibrium. During the transitory phases, deep oceans will fill will with water at the maximum density temperature. A thermocline will be created that extends from pole to pole but varies in depth. It will rise to the ocean surface in polar regions and be at significant depth (probably around 2km) at the equator. Water will freeze at the poles creating ice caps (with a long time constant of creation and destruction). The ice-water interface will insure a continuous supply of down-welling 2° water. The down-welling water will migrate toward the tropics as it seeks a constant elevation (it will effectively flow down the hill of the thermocline.) Surface water will be pushed up in the tropics to a level higher than average sea level. That warm water will flow down hill toward the polar regions where it will melt the ice caps. When the ice caps are melted, down-welling will substantially cease and the upward pressure on the warm tropical water will decrease thus causing a collapse in tropic to pole surface currents. That sets up the conditions for a repeat of the last few phases of the process.

Phase 1 – cooling of water at deep sea depths with all temperatures above 2°

Polar regions: Although above 2°, water cools and sinks. There is a buildup of cool water throughout the oceans at depth. At any given point on the earth, the temperature of the water column will decrease monotonically with depth. Warmer water at the surface, water of decreasing temperature as depth increases. Consistent with increasing water density as temperature falls as long as temperature is above 2°C.

Equatorial regions: water heats. Since warm water is lighter than cold, it forms a blanket of warm water around the equator.

Phase 2 – creation of the thermocline

Polar regions: Heat continues to leave through radiation and conduction (with atmospheric contact.) Water surface temperature drops to 2°. Surface water becomes heavier than lower water and so sinks to ocean floor. From there, the heavy water spreads out along the entire ocean floor. A thermocline begins to build over the entire ocean floor.
Temperature profile of water column (as function of increasing depth):
Uppermost layer: cold (0-2°)
Mid–layer(s): temperature ranges from 2° to higher temperatures

Lowermost layer: 2° (below thermocline)

Equatorial regions: blanket of warm water covers tropical region. As a result of local mixing (wind blown turbulence) the warm water extends to some depth. Temperature profile: warm to cool to abruptly cold as thermocline is crossed

Phase 3 – ice cap creation

Polar regions: The thermocline has filled up to the point that it breaks surface at the poles. Further polar cooling causes freezing of surface water. An ice cap is formed. It accretes from above through snowfall. It melts at the ice-water interface from below the ice cap. At the ice-water interface, the temperature of the ice is 0° (or slightly lower to the extent that salt water has frozen.) Temperature profile: Well below 0° inside the ice cap. At ice-water interface, 0°. Within centimeters of the water surface, 2° all the way to the ocean floor.

Equatorial region:
Temperature profile: At lowermost depth, 2°. Same up to thermocline depth. Then increasing monotonically to surface temperature of 30°. The high density water below the thermocline will seek a constant elevation, thus forcing a thinning of the warm tropical layer. The upper warm layer will thin as a result of generalized Eckman transport (i.e. currents perpendicular to the equator. That will cause the boundaries of the tropical layer to move toward the poles. If the thermocline exists at a depth sufficiently far below the surface, there will be little upward pressure on the tropical layer and little tendency toward thinning. Thus, the amount of pressure exerted on the tropical layer will be related to the depth of the thermocline.

Phase 4 – creation of north-south currents

Absent the north-south landmass barrier to circumglobal currents, there would still be upward pressure by the dense water below the thermocline forcing the tropical warm layer to spread of its edges toward the poles. This broad flow can be considered to be a generalized Eckman transport. However, without a continental barrier against which west-bound winds could build a mountain of warm water, a stable equilibrium could be reached. The phenomenon of the ‘roaring fifties’ of the southern hemisphere (where there is no land barrier to stop circumglobal current flow) demonstrates relatively rapid mixing of waters. Not surprisingly, warm surface currents in the southern hemisphere are not nearly as strong nor do they extend to as high latitudes as their counterparts in the northern hemispheres.

But in the presence of a land barrier which limits circumglobal flow, and in the presence of prevailing westbound tropical winds, the winds tend to create a mountain of warm water in the western edge an ocean. The elevation at any given spot on the ocean will be related to the integrated density of the water column at that spot. Since warm water is less dense than cold water, a water column containing a lot of warm water will be taller than on containing less warm water.

The warm water layer will then tend to dissipate via two mechanisms. First, it will tend to flatten under its own weight like a blob of viscous oil. It will tend to flatten out away from the equator. Sub-surface water will participate in the ex-tropic transport. This can be considered to be a generalized Eckman transport mechanism. Second, the mountain of warm water will dissipate through water on the surface flowing down-hill. That transport mechanism will be limited to surface water which will also tend to be the warmest water. If the warm water mountain is high enough, it will tend to set up strong surface currents moving from low to high latitudes. In order for the current to be sustained, the warm water on the mountaintop needs to be continually replenished. That could occur via one or both of two mechanisms. The first mechanism is a buildup of warm water brought by westbound wind. That mechanism depends on the extent of prevailing westbound winds. When the prevailing westbound winds collapse, as for example, prior to an *el nino* event, the warm water mountain will not be augmented by wind-driven water. The second mechanism for building a warm-water mountain is upward pressure by the more dense water layer below the thermocline trying to equalize its depth. The sub-thermocline layer will rise to the extent that mass of the water column above it is less than the mass of the water column elsewhere. So, for example, if the warm upper layer gets lighter either due to generalized Eckman transport or due to ex-tropic surface flow, hydraulic pressure will cause the thermocline to rise locally.

Phase 5 - melting ice caps – 'global warming'

The heat transferred to high latitudes by strong western-ocean-edge surface currents will tend to raise the temperature of polar seas and will melt the ice caps. Any existing land based ice caps will be melted by circumferencial winds bring heat from the now warmed ocean.

Phase 6 – collapse of mid-latitude currents bringing tropical water toward poles

As the ice caps melt, there will be a decrease in the amount of ice-water interface. There will therefore be a corresponding decrease in the amount of water brought to the maximum density temperature of 2°. There will be a decrease in down welling water. The level of the depth of the thermocline will tend to become more equal across latitude. There will be less upwelling pressure on the warm water layer in the tropics, and correspondingly less strong currents bringing warm water to higher latitudes. If the ice caps melt entirely, there would be no down welling into below the thermocline. Tropic to high latitude currents would collapse. There would be relatively little oceanic heat transfer from tropics to high latitudes.

Phase 7 – ice cap growth

> Once the ice caps have melted and the tropic to high latitude currents have collapsed, conditions have been re-established for creation of new ice caps. Go to Phase 3.

Oscillation - Repeat phases 3-6

> A complete cycle through these phases constitutes a cycle from ice age through warm age and back to ice age.

It is interesting to note that in the absence of the north-south continental barrier, the system would appear to stabilize rather than oscillate. If water could flow circumglobally anywhere near the tropics, the conditions for pole-bound warm-water surface currents would not exist.

Conclusion and suggestions for future research

Numerous areas of highly speculative future research are suggested by the above theory. The authors consider the following to be particularly interesting questions. Clearly, some of these questions could be addressed only by computer simulation. Others lend themselves to field research. (1) If strong prevailing equatorial surface winds were to collapse over an extended period, as they do for a short period preceding an *el nino* event, would that cause a collapse in the major pole-bound warm currents? (2) Where would one look for empirical evidence of a change in the depth of the thermocline on the same period as the ice ages? (3) Under what continental configurations would you expect to find periodic ice ages? (4) For example, if water could flow circumglobally in the tropics, would the absence of western-ocean-edge warm-water mountains mean that there would be no pole-bound surface currents? (5) What is the required height of a warm-water mountain necessary to cause the creation of a pole-bound surface current? (6) What is the height of the mountain necessary to sustain that current? (presumably, the elevation required to sustain a flow will be less than that required to create it initially. Further work on this subject will be discussed at the conference.