Natural Influences on Climate

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Abstracts. *There are a number of natural factors that influence Earth's climate. These factors include external influences such as explosive volcanic eruptions, natural variations in the output of the Sun, and slow changes in the configuration of Earth's orbit relative to the Sun. in addition, there are natural patterns of wind circulation, precipititation, and surface temperature. These are the problems discussed in this paper.*

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1.Volcanic aerosols. Explosive volcanic eruptions have the potential to inject substantial amounts of sulfate aerosols into the lower troposphere, aerosols that enter the stratosphere may remain for several years before setting out, because of the relative absence of turbulent motions there. Consequently, aerosols from explosive volcanic eruptions have the potential to affect Earth's climate. Less-explosive eruptions that are less vertical in orientations, have a lower potential for substantial climate impact. Furthermore, because of large-scale circulation patterns within the stratosphere, aerosols injected within tropical regions tend to spread out over the globe, whereas aerosols injected within midlatitude and polar regions tend to remain confined to the middle and high latitudes of that hemisphere. Tropical eruptions, therefore, tend to have a greater climatic impact than eruptions occuring toward the poles. In 1991 the moderate eruption of Mount Pinatubo in the Philippines provided a peak forcing of approximately 4 Watts per square meter and cooled the climate by about 0.5^{o} C over the following few years. By comparison, the 1815 "year without a summer" in Europe and North America believed to have been associated with a radiative forcing of approximately 6 watt per square meter.

While in the stratosphere, volcanic sulfate aerosol actually absorbs longwave radiation emitted by Earth's surface, and absorption in the stratosphere tends to results in a cooling of the troposphere below [1]. This vertical pattern of temperature change in the atmosphere influences the behariour of winds in the lower atmosphere, primarily in winter. Thus, while there is essentially a global cooling effect for the first few years following an explosive volcanic eruption, changes in the winter patterns of surface winds may actually lead to warmer winters in some areas, such as Europe. Some modern examples of major eruptions include Krakatoa (Indonesia) in 1883, El-Chichon (Mexico) in 1982, and Mount Pinatubo in 1991. There is also evidence that volcanic eruptions may influence other climate phenomena such as El Nino.

2. Variation in solar output

Direct measurements of solar irradiance, or solar output, have been available from satellites only since the late 1970 s. These measurements show a very small peak – to – peak variation in solar irradiance. However indirect measures of solar activity are available from historical sunspot measurements dating back through the early 17 th century [2,3]. Attempts have been made to reconstruct graphs of solar irradiance variations from historical sunspot date by calibrating them against the measurement from modern satellites.

However, since the modern measurement's span only a few of the most recent 11 year solar cycles, estimates of solar output variability on 100-year and longer timescales are poorly correlated. Different assumptions between the amplitudes of 11 years solar cycles and long-period solar output changes can lead to considerable differences in the resulting solar reconstructions. These differences in turn lead to fairly large uncertainty in estimating positive foraing by changes in solar irradiance since 1750. Even more challenging, given the lack of any modern analog, is the estimation of solar irradiance during the so-called Maunder Minimum, a period lasting from the 18th century when very few sunspots were observed. While it is likely that solar irradiance was reduced at this time, it is difficult to calculate by how much. However, additional proxies of solar output exists that match reasonable well with the sun sport – derived records following the Maunder Minimum. Hese may by used as crude estimates of the solar irradiance variations.

In theory it is possible to estimate solar irradiance even farther back in time, over at least the past millennium, by measuring levels of cosmogonic isotopes such as carbon-14 and berilium-10. Cosmogonic isotopes are isotopes that are formed by interactions of cosmic rays with atomic nuclei in the atmosphere and that subsequently fall to Earth, where they can be measured in the annual layers found in ice cores. Since their production rate in the upper atmosphere is modulated by changes in solar activity, cosmogenic isotopes may be used as indirect indicators of solar irradiance. However, as with the sunspot date, there is still considerable uncertainty in the amplitude of past solar variability implied by these date.

Solar forcing also affects the photochemical reactions that manufacture ozone in the Stratosphere. Through this modulation of stratospheric ozone concentrations, changes in solar irradiance (particularly in the ultravilet portion of the electromagnetic spectrum) commodify how both shortwave and longwave radiation in the lower stratosphere are absorbed. As a result, the vertical temperature profile of the atmosphere can change, and this change can in turn influence phenomena such as the strength of the winter jet steams.

3. Variations in Earth’s orbit

On timescales of tens of millennia, the dominant radiative forcing Earth’s climate is associated with slow variations in the geometry of Earth’s orbit around the Sun. These variations include the precession of the equinoxes (that is, changes in the timing of summer and winter), occurring on a roughly 26.000 – year timescale [4] and changes in the tilt angle of Earth’s rotational axis relative to the plane of Earth’s; orbit around the Sun, occurring on a roughly 41,000-year timescale; and changes in the eccentricity (the departure from a perfect circle) of earth’s orbit around the Sun, occurring on a roughly 100 000 year timescale. Changes in eccentricity slightly influence the top of Earth’s atmosphere, but the primary influence of all the orbital variations listed above is on the seasonal and latitudinal distribution of incoming solar radiation over Earth’s surface. The major ice ages of the Pleistocene Epoch were closely related to the influence of these variation on summer insolation at high nothern latitudes. Orbital variations thus exerted a primary control on the extent of continental ice sheets. However, Earth’s orbital changes are generally believed to have had little impact on climate over the past few millennia, and so they are not considered to be significant factors in present – day climate variability.

4. Feedback mechanisms and climate sensitivity

There are a number of feedback processes important to Earth’s climate system and, in particular, its response to external radiative forcing. The most fundamental of these feedback mechanisms involves the loss of longwave radiation to space from the surface. Since this radiative loss increases with increasing surface temperatures according to the Stefan-Boltzmann law, it represents a stabilizing factor (that is, a negative feedback) with respect to near – surface air temperature.

Climate sensitivity can be defined as the amount of surface warming resulting from each additional watt per square meter of radiative forcing. Alternatively, it is sometimes defined as the warming that would result from a doubling of CO_2 concentrations and the associated addition of 4 watts per square meter of radiative forcing. In the absence of any additional feedbacks, climate sensitivity would be approximately 0,25^{0}C for each additional watt per square meter of radiative forcing. Stated alternatively, if the CO_2 concentration of the atmosphere present at the start of the industrial age (280 ppm) were doubled (to 560 ppm) the resulting additional 4 watts per square metre of radiative forcing would translate into a 1^{0}c increase in air temperature. However, there are additional feedbacks the exert destabilizing, influence, and these feedbacks tend to increase the sensitivity of climate to somewhere between 0,5 and 1,0^{0}c for each additional watt per square meter of radiative forcing.

5. Weter vapour feedback

Unlike concentracions of other greenhouse gases, the concentration of water vapour in the apmosphere cannot freely vary. Instead, it is determined by the temperature of the lower atmosphere and surface thruugh a physical relationship known as the Clausius-Clapeyron equation, named for 19 th - century French engineer Emile Clapeiyron and 19 th century German engineer and physicist R. Chausius. Under the assumption that is a liquid water surface in equilibrium with the atmosphere, this relationship indicates that an increase in the capacity of air to hold water vapour is a function of increasing temperature of that volume of air. This assumption is relatively good over the oceans, where water is plentiful, but not over the continents. For this reason the relative humidity is approximately 100 percent over ocean regions and much lower over continental regions – approaching 0 percent in arid regions. Not surprisingly, the average relative humidity of Earth’s lower atmosphere is similar to the fraction of Earth’s surface covered by the oceans (that is, roughly 70 percent). This quantity is expected to remain approximately constant as Earth warms or cools. Slight changes to global relative humidity may result from human land-use modification, such as tropical deforestation and irrigation, which can affect the relative humidity over land areas up to regional scales [5].

The amount of water vapour in the atmosphere will rise as the temperature of the atmosphere rises. Since water vapour is a very potent greenhouse gas, even more potent than CO_2, the net greenhouse effect actually becomes stronger as the surface warms, which leads to even greater warming. This positive feedback is known as the “water vapour feedback”. It is the primary reason that climate sensitivity is substantially greater than the previously stated theoretical value of 0,25^{0}C for each increase of 1 watt per square metre of radiative forcing.

6. Cloud Feedbacks

It is generally believed that as Earth’s surface warms and the atmosphere’s vapour content increases, global cloud cover increases. However, the effects on near- surface air temperatures are complicated. In the case of low clouds, such as marine stratus clouds, the dominant radiative feature of the clouds is its albedo. Here any increase in low cloud cover acts in much the same way as an increase in surface ice cover: more incoming solar radiation is reflected and Earth’s surface cools. On the other hand, high clouds, such as the towering cumulus clouds that extend up to the boundary between the troposphere and stratosphere, have a quite different impact on the surface radiation balance. The tops of cumulus clouds are considerably higher in the atmosphere and colder than their undersides. Cumulus cloud tops emit less longwave radiation out to space than the warmer cloud bottoms emit downward toward the surface. The end result of the formation of high cumulus clouds is greater warming at the surface.

The net feedback of clouds on rising surface temperatures is therefore somewhat uncertain. It represents a competition between the impacts of high and low clouds, and the balance is difficult to determine. Nonetheless, most estimates indicates that clouds on the whole represent a positive feedback and thus additional warming.

7. Ice albedo feedback

Another important positive climate feedback is the so-called ice albedo feedback. This feedback arises from the simple fact that ice is more reflective (that is, has a higher albedo) than land or water surfaces. Therefore, as global ice cover decreases, the reflectivity of Earth's surface decreases, more incoming solar radiation is absorbed by the surface, and the surface warms. This feedback is considerably more important when there is relatively extensive global ice cover, such as during the height of the last ice age, roughly 25000 years ago [6]. On a global scale the importance of ice albedo feedback decreases as Earth's surface warms and there is relatively less ice available to be melted.

8. Carbon cycle feedbacks

Another important set of climate feedback's involves the global cycle. In particular, the two main reservoirs of carbon in the climate system are the oceans and the terrestrial biosphere. These reservoirs have historically taken up large amounts of anthropogenic CO_2 emissions. Roughly 50-70 percent is removed by the oceans, whereas the remainder is taken up by the terrestrial biosphere. Global warming, however, could decrease the capacity of these reservoirs to sequester atmospheric CO_2. Reductions in the rate of carbon uptake by these reservoirs would increase the pace of CO_2 building in the atmosphere and represent yet another possible positive feedback to increased greenhouse gas concentration [7].

In the world's oceans this feedback effect might take several parts. First, as surface waters warm, they would hold less dissolved CO_2. Second of more CO_2 were added to the atmosphere and taken up by the oceans, bicarbonate ions (HCO_3) would multiply and ocean acidity would increase. Since calcium carbonate ($CaCO_3$) is broken down by acids solutions, rising acidity would threaten ocean – that incorporate $CaCO_3$ into their skeletions or shells. As it becomes increasingly difficult for these organisms to absorb oceanic carbon, there would be a corresponding decrease in the efficiency of the biological pump that helps to maintain the oceans as a carbon sink. Third, surface temperatures might lead to a slowdown in the so-called thermohaline circulation, a global pattern of oceanic flow that partly drives the sinking of surface waters near the poles and is responsible for much of the burial of carbon in the deep ocean. A slowdown in this flow due to an influx of melting fresh water into what are normally saltwater conditions might also cause the solubility pump, which transfers CO_2 from shallow to deeper waters, to become less efficient. Indeed, it is predicted that of global warming continued to a certain point, the oceans would cease to be a net sink of CO_2 and would be a net source.

As large sections of tropical forest are lost because of the warming and drying of regions such as Amazonia, the overall copal capacity of plants to sequester atmospheric CO_2 would be reduced. As a result, the terrestrial biosphere, though currently a carbon sink, would become a carbone source. Ambient temperature is a significant factor affecting the pace of photosynthesis in plants, and many plant species that are well adapted to their photosynthetic rates. As temperatures increase and conditions begin to exceed the optimal temperature range for both photosynthesis and soil respiration, the rate of photosynthesis would decline. As dead plants decompose, microbial metabolic activity (a CO_2 source) would increase and would eventually outpace photosynthesis.

Under sufficient global warming conditions, methane sinks in the oceans and terrestrial biosphere also might become methane sources. Annual emissions of methane by wetlands might either increase or decrease, depending on temperatures and it is possible that wetlands could switch from source to sink. There is also the potential for increased methane release as a result of the warming of Arctic permafrost (on land) and further methane release at the continental margins of the oceans (a few hundred meters below sea level). The current average atmospheric methane concentration of 1,750ppb is equivalent to 3,5 gigatons of carbon equivalent stored in Arctic permafrost and as much as 10000 gigatons of carbon equivalent trapped on the continental margins of the oceans in a hydrated crystalline form known is clathrate. It is believed that some fraction of this trapped methane could become unstable with additional warming, although the amount and rate of potential emission remain highly uncertain.

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ბუნებრივი გავლენა კლიმატზე

რეზიუმე

ნაშრომში განხილულია ბუნებრივი ფაქტორების დედამიწის კლიმატზე გავლენის პროცესები. მათგან ხაზგასმით არის გამოყოფილი ვულკანური აეროზოლების, მზის გამოსხივების ცვალებადობის, დედამიწის ორბიტის ვარიაციები პრეცესიის გამო, წყლის ორთქლის, ღრუბლების, ალბედოს, ნახშირორჟანგისა და სხვა ფაქტორების წრებრუნვის მოვლენები. გარჩეულია მათი მოქმედების მექანიზმები და უარყოფითი შედეგები.