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Cosmic rays, total cloud cover and terrestrial temperature

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Abstract. We have used the Thermodynamic Model of the Climate to estimate the effect of variations in the fraction of the global cloud cover, on the surface temperature of the Earth in the North Hemisphere, during the period 1984-1990. We assume that the variations in the cloud cover are proportional to the variation of the cosmic ray flux measured during the same period. The results indicate that the effect in the temperature is significant when considering the superficial hemispheric temperature on July 1987, when an average temperature anomaly between 0.04° C and 1.4° C is observed in a latitudinal band of 20°-40°. The region that corresponds to Mexico presents an average temperature anomaly of ~ 0.06° C. The superficial temperature averaged globally in the north hemisphere suffers a decrease ~ 0.01°C wich is almost the same for continents and oceans; however this value is within the uncertainties of the model.

1. Introduction

Recently some authors have proposed a possible connection between the global cloud cover and the cosmic ray flux (Svensnsmark and Friis-Christensen 1997). They carried out a study of the behavior of these two parameters using satellite data compiled by the International Cloud Climatology Project (ISCCP). The data covers the period between 1984 and 1990, also it comprises only the oceans. They found a good correlation between the cloud cover and t he cosmic ray flux (r > 0.9) .

If cosmic rays can influence the nucleation processes and in turn affect the cloud formation (Tinsley, 1991), we expect that this flux should have an effect in the global radiation balance of the earth-atmosphere system and therefore in the terrestrial superficial temperature field.

The purpose of the present work is to estimate the proposed effect of the cosmic rays on the superficial temperature through the behavior of the oceanic cloud cover.

2. Cloudiness effect on the global balance of terrestrial radiation

The clouds have two important effects on the radiation arriving at the atmospheric top, depending on the wavelenght of this radiation: at short wave lengths the effect of the albedo increases the quantity of solar radiation reflected toward the space and there is a tendency for a cooling of the Earth due to a decrement in the incoming flow of short wave radiation. For long wave lengths we have the opposit effect: due to the absorption of the long waves by clouds there is a reduction of the radiation of long waves emitted outside the earth-atmosphere system, therefore there is a tendency for a warming of the Earth (Hartmann, 1994).

The effect of increasing the cloud cover depends on the type of clouds that are increased, an increment of low altitude clouds causes a cooling, while an increment of high altitude clouds produces warming of the planet. It is supposed that an increment in the total cloud cover will lead to a cooling of the Earth (Hartmann, 1994).

We construct an empiric parametrization of the variations of the global cloud cover over oceans, which is shown in Fig. 1. We fit a function that depends exclusively on time and in order to quantify the effect on the superficial temperature we introduce this cloud forcing function in the Thermodynamic Model of the Climate (Adem, 1962). The series of monthly data corresponding to the cloud cover for the period of 1984 - 1990, was taken from Svensmark and Friis-Christensen (1997).

3. The model

The basic idea of the Thermodynamic Model of Climate (TMC) (Adem, 1962) is that the energy that maintains the atmospheric circulation is the solar radiation and then the fundamental problem is to explain quantitatively how the transformation of radiant energy in mechanical energy is carried out. It considers the law of the conservation of energy and the radiation balance in the atmosphere-ocean- continent system.

The model consists of an atmospheric layer of ~10 km of height, which includes a cloud layer, an oceanic layer of 100 to 50 m in depth and a continental layer of negligible depth. It also includes a layer of ice and snow over the continents and the ocean. The basic equations are those of conservation of thermal energy applied to the atmosphere-ocean-continent system.

A monthly time averaging of the variables is used and it is assumed that the equations of hydrostatic balance, perfect gas and continuity apply to the time-averaged variables.

We have selected this model because it is suitable for obtaining hemispheric averages (20° at 90° in latitude) of the anomalies of different meteorological variables, in particular the superficial temperature. It is appropriate to produce monthly, annual and seasonal predictions.

We introduce the cloud cover anomaly as a variable wich is only time dependent. As the cloud cover used corresponds only to the oceans, it is introduced in the TMC only in oceans. However the change of the oceanic cloud cover should affect also the continental part due to the internal coupling of the atmosphere-ocean-continent system given by the model itself.

3. Results

Experiment 1: we ran the TMC without the cloud forcing (Adem, 1965). We obtain the anomalies in the continental superficial temperature (Fig. 2a, dotted line), in the ocean part (Fig. 2b, dotted line) and in the complete hemisphere (Fig. 2c, dotted line). The model was adapted to obtain the anomalies of the monthly average temperature in the North Hemisphere along July 1984 to december 1990. In all the figures the bell-shaped curve is the oceanic cloud cover.

Experiment 2: we introduce in the TMC the cloud forcing obtaining the profile of the anomalies in temperature of the same three regions: continent, ocean and hemisphere, the profiles correspond to the thin solid line in Figs. 2a, 2b and 2c respectively.

Experiment 3: We obtain the differences between the temperature anomalies whith and without cloud forcing for july 1987. In this date the change in the oceanic cloud cover reached its maximum value. The result is show in Fig. 3.

Experiment 4: In this experiment the model was adapted to obtain the anomalies of the monthly average temperature but only in the region that corresponds to Mexico for the same period. In spite of the fact that this region is located in the lower geomagnetic latitudes it is also affected because of the coupling in the atmosphere – ocean- continent system given by the model. The results are show in Fig. 4.

4. Discussion

From Figs. 2a, 2b and 2c we notice that the difference between cloud and no cloud forcing is small for the ocean, continent and hemisphere. The average of the absolute values of the differences between both cases is about 0.01°C. This value is not significant because is of the same magnitude that the model numerical errors. It is observed that when the change in the cloud cover is positive occurs an average decrease of ~ 0.01°C in the superficial temperature (negative anomaly).

We had plotted the differences between hemispheric temperature anomalies obtained with and without cloud forcing on July 1987. There is a latitudinal band between 20° - 40° where the difference between the anomalies goes from -0.06°C to -1°C. This interval contain significative values in comparisson with the model erors. The temperature anomalies are larger in the Asian part.

When we analysed the case of Mexico we find two periods when the average of the absolute values of the differences between both profiles is about 0.06°C, this value is close to the model significance range (0.1°C). The two periods are: from month 25 to month 26 and from month 35 to month 39.

The fact that negative anomalies in the superficial temperature are present together with a positive change in the variation of the cloud cover means that the effect of short wave solar radiation income dominates over the long wave radiation in the earth- atmosphere system.

If in fact the oceanic cloud cover is modulated by the cosmic ray flux, then our results are in agreement with those obtained by Veretenenko and Pudovkin (1999); they reported a decrease in the entrance of solar radiation associated with an increase in cosmic rays, although their study is restricted to a latitudinal band of 60° to 68° north.

We suggest that the obtained decrement in the temperature would be strengthened by an extra effect: according to Lean (1997), the solar radiometers measured a decrease in the total solar irradiancie of 1.3 Wm^{-2}(0.1%) at the top of the terrestrial atmosphere during the solar minimum of 1986, relative to the solar maxima of 1980 and 1990. In agreemente with them, this decrease in the solar irradiance induces a climatic forcing of about 0.22 W/m^2. This effect added to the effect of the oceanic cloud forcing proposed here would produce a larger decrement of the superficial temperature of the Earth due to solar activity. Additionaly, as the ocean has a great thermal inercia its response to radiative forcing is small. If the cloud forcing is also present in the continental cloud cover then the response in the superficial temperature could be even stronger because the continental part is more senssible to radiative forcing.

5. Conclusions

According to our results the change observed in the oceanic cloud cover produces an imbalance in the net flow of radiation of the earth – atmosphere system, then the superficial temperature averaged globally in the north hemisphere suffers a decrease of ~ 0.01°C wich is almost the same to continents and oceans. However, this value is close to the model errors.

The most intense negative anomalies in the hemispheric superficial temperature take place during July 1987. In this period occurs the maximum change in the oceanic cloud cover. There is a latitudinal band from 20° to 40° where negative temperature anomalies are ~ 0.06° C and 1.4° C, these value are significant in comparisson with the model errors.

In the region corresponding to Mexico the difference between cloud and no clud forcing is in averge ~0.06° C. This value is close but larger than the model significance level.

We conclude that the modulation of the oceanic cloud cover can have an appreciable effect on the superficial temperature of some regions of the the North Hemisphere.

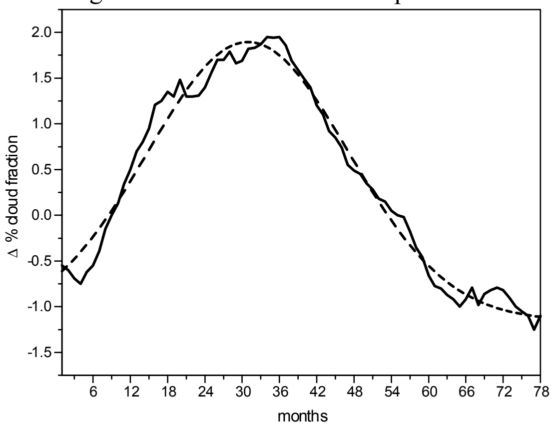

Fig. 1. The solid curve is a 12 month running average of the oceanic cloud cover as changes in percent (ISCCP-2 monthly data) (Svensmark and Friis-Christensen, 1997). The dotted (bell-shaped) curve is a fit of the observed data.

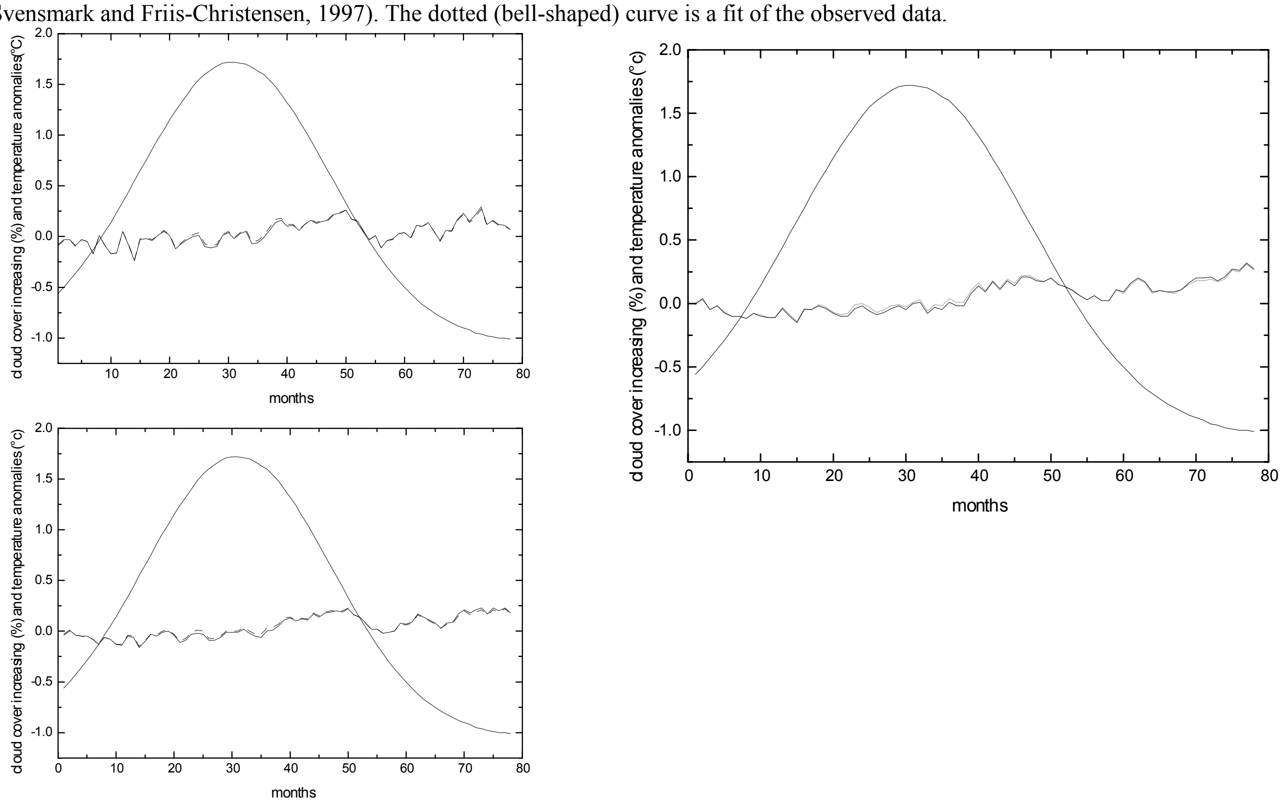

Fig. 2. Monthly anomalies of the superficial temperature averaged globally for the North Hemisphere. The thin solid line corresponds to the case with cloud forcing. The dotted line corresponds to the case with no cloud forcing. **(a)** Continent; **(b)** Ocean; **(c)** Hemispheric. The bell-shaped curves represent the variation of the cloud cover over oceans.

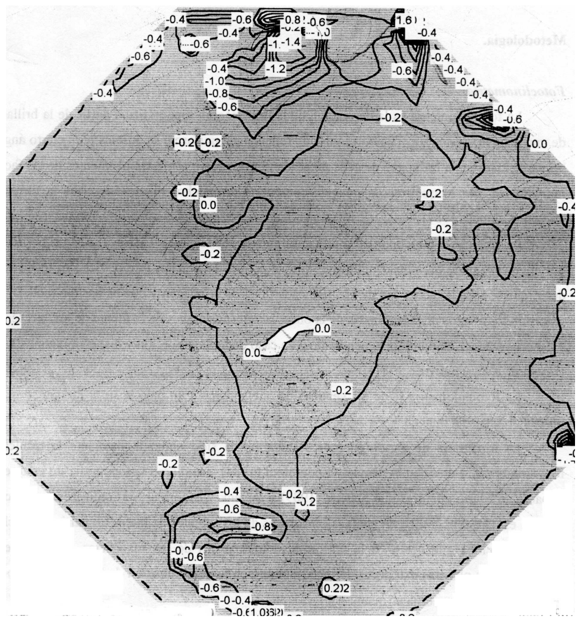

Fig. 3. Differences between the hemispherics temperature anomalies with and without cloud during for July 1987 in a chart of isothermic lines (the values are in tenths of degree).

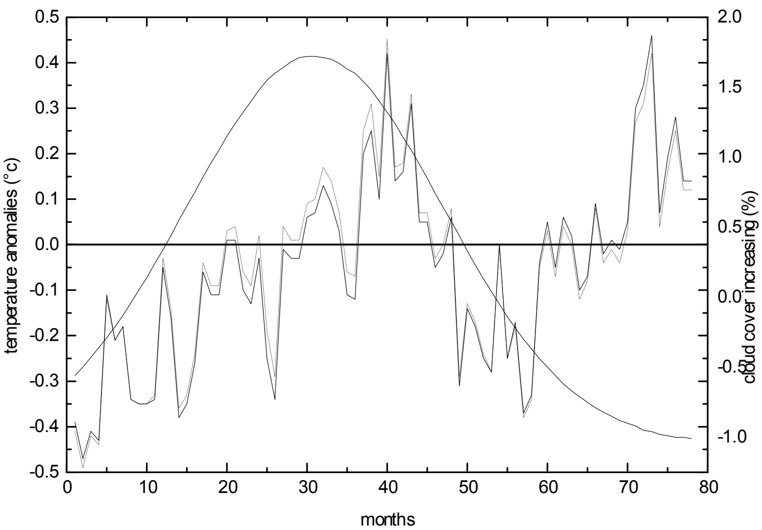

Fig. 4. Monthly anomalies of the superficial temperature in Mexico . The thin solid and dotted lines corresponds to the cases with and without cloud forcing. The bell-shaped curve represents the va riation of the cloud cover over oceans.

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