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RESPONSE OF THE LMD ATMOSPHERIC GENERAL CIRCULATION MODEL TO SOLAR IRRADIANCE VARIATIONS

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1. Introduction

Changes in total solar irradiance can be linked to changes in regional temperature and precipitation. Natural processes involving changes in the Sun could have a powerful effect on global temperature warming, similar to increase of carbon dioxide (CO_2) concentration in the atmosphere. A possible mechanism responsible for this linkage begins with the absorption of varying amounts of solar energy by the tropical oceans which creates ocean temperature anomalies (Perry, 1992). These anomalies are then transported by major ocean currents to locations where the stored energy is released into the atmosphere, altering atmospheric pressure and moisture patterns that can ultimately affect regional meteorological variables.

According to satellite measurements, the mean value of the solar constant is S = 1367 +/- 4 W/m^2. The possible 0.22% of this amount of energy equals 3 W/m^2. The variation of 0.22% does not affect climate in its entirety. The solar constant defines the amount of energy which just reaches the outside of the earth's atmosphere. 30% of this energy is not absorbed by the atmosphere, it is reflected. Furthermore, it has to be taken into account that the irradiated sectional area of the earth constitutes only a quarter of the surface to which this thermal energy has to be distributed. So there is only 239 W/m^2 available to heat the atmosphere. Consequently, the variation of 3 W/m^2 has only a climate effect of 0.53 W/m^2 (Landscheidt, 1998). How this affects global temperature depends on the general circulation model used to assess the climate sensitivity.

Since the Maunder Minimum, over the past 300 years there probably has been an increase of 0.1 to 0.6% in the solar constant value, with climate models often using a 0.25% increase. Stott et al (2003) found that current climate models underestimate the observed climate response to solar forcing over the twentieth century as a whole, indicating that the climate system has a greater sensitivity to solar forcing than do models, and concluded that the best estimate of the warming from solar forcing is estimated to be 16% or 36% of greenhouse warming depending on the solar reconstruction.

The main purpose of this work is to understand the possible impact of solar irradiance variation on the South America climate, using the response of the LMD AGCM (Atmospheric General Circulation Model) to solar irradiance variation measured by different sources (maximum and minimum values observed) on some atmospheric variable as surface temperature and precipitation.

2. Model Description

This study used the version 3.2 of LMD atmosphere general circulation model, which is an improved version of the initially written by Sadourny & Laval (1984). Model is based on finite differences and it uses variables staggered on an Arakawa C-grid (Arakawa & Lamb, 1977). The details of physical parameters are described in Li (1995) and Li (1998). This work used a horizontal spatial resolution of 73 points in longitude and 48 in latitude (5º X 3,75º). The vertical coordinate is the sigma coordinate (σ=p/pS), which it's the normalized pressure according with your value at surface. In the current version, model has 19 irregularly spaced levels in the vertical, with more detailing in the lower atmosphere (Harzallah & Sadourny, 1995).

3. Methodology and Data

In order to estimate the climatic impact of a variation in the Total Solar Irradiance (TSI), three experiments with LMD model had been realized using three different values of (TSI): 1360, 1370 (control) and 1380 Wm^{-2}. These values (not real), were based in the minimum and maximum average values presented in the historical table showed in Hoyt and Schatten (1997). The other model characteristics were maintained. In all simulations, the model was integrated for 11 years, and the results presented in this work are the averages of the last 5 years.

The sea surface temperature (SST) data are from the optimum interpolation (OI) sea surface temperature analysis (REYNOLDS AND SMITH, 1994). These data are from the period of 1971-2000 and the monthly averages were interpolated for daily values in order to force the model. The initials data correspond to the climatological average of the first January day coming from the NCEP/NCAR (National Centers goes Environmental Prediction–National Center for Atmospheric Research) (KALNAY et al., 1996). Among these data are: surface temperature , surface atmospheric pressure, and the vertical distribution values of temperature, relative humidity, and the zonal and meridional components of the wind.

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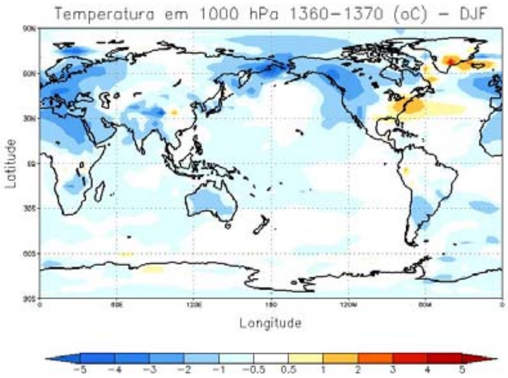
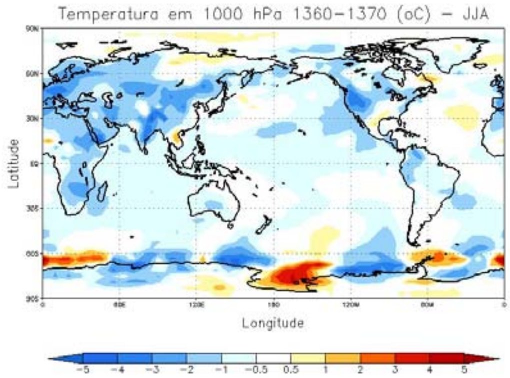
4. Results

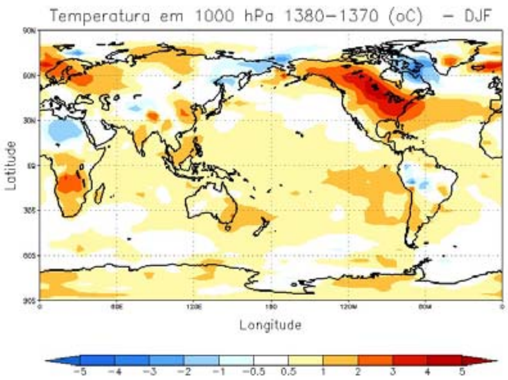
Figure 1 shows results of surface temperature anomalies for two different simulations: the South Hemisphere summer (DJF) and the winter (JJA) period for two cases: 1360 – 1370 Wm^{-2} and 1380 - 1370 Wm^{-2}. In this work it will be enphasised the South America analysis. The minimun value experiment (figures 1a and 1b) shows a important cooling in surface temperature over the souht Atlantic ocean (brazilian coast) and in the souht America continental area. This cooling is more important in the winter over the ocean and in the summer over the continental area. An exception can be observed over the north part of Peru, where a heating area was observed (1a). Another interesting point is the cooling of south Brazil, north Argentina, Paraguay and north Chili during the summer and no signal was observed for the winter. The souht Pacific ocean is practically not affected.



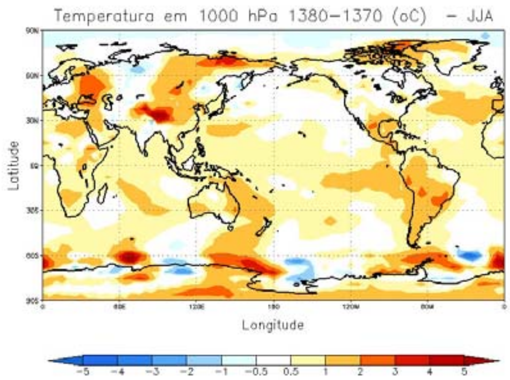
(a)



(b)



(c)



(d)

Figure 1: Surface Temperature anomalies (ºC): (a) 1360 –1370 Wm^{-2} DJF simulation, (b) 1360 – 1370 Wm^{-2} JJA simulation, (c) 1380 –1370 Wm^{-2} DJF simulation and (d). 1380 – 1370 Wm^{-2} JJA simulation.

In the second case, the maximum value experiment (figues 1c and 1d), it is observed a general heating and in the opposite way the souht Pacific is more affected than the south Atlantic for both cases. This heating can be reach 2^{o}C above the mean value. Some cooling areas can be seem over the sother part of Amazon. During the winter period the continental area of the south America continent is more affected by the heating than during the summer season. This heating can be reach values above 3^{o}C over southeast states in Brazil.

Precipitation anomalies are shown in the figure 2. For the minimum experiment (2a and 2b), the model simulated precipitation shows an important decrease in the ITCZ region. The south ocean areas are more affected than the continental areas. The opposite result, more precipitation is observed in the maximum experiment (2c and 2d). In both case, the continental area is less affect than the ocean area, an execption is observed over tropical region of south America continent during the summer period, where an increase of precipitation rates are shown.

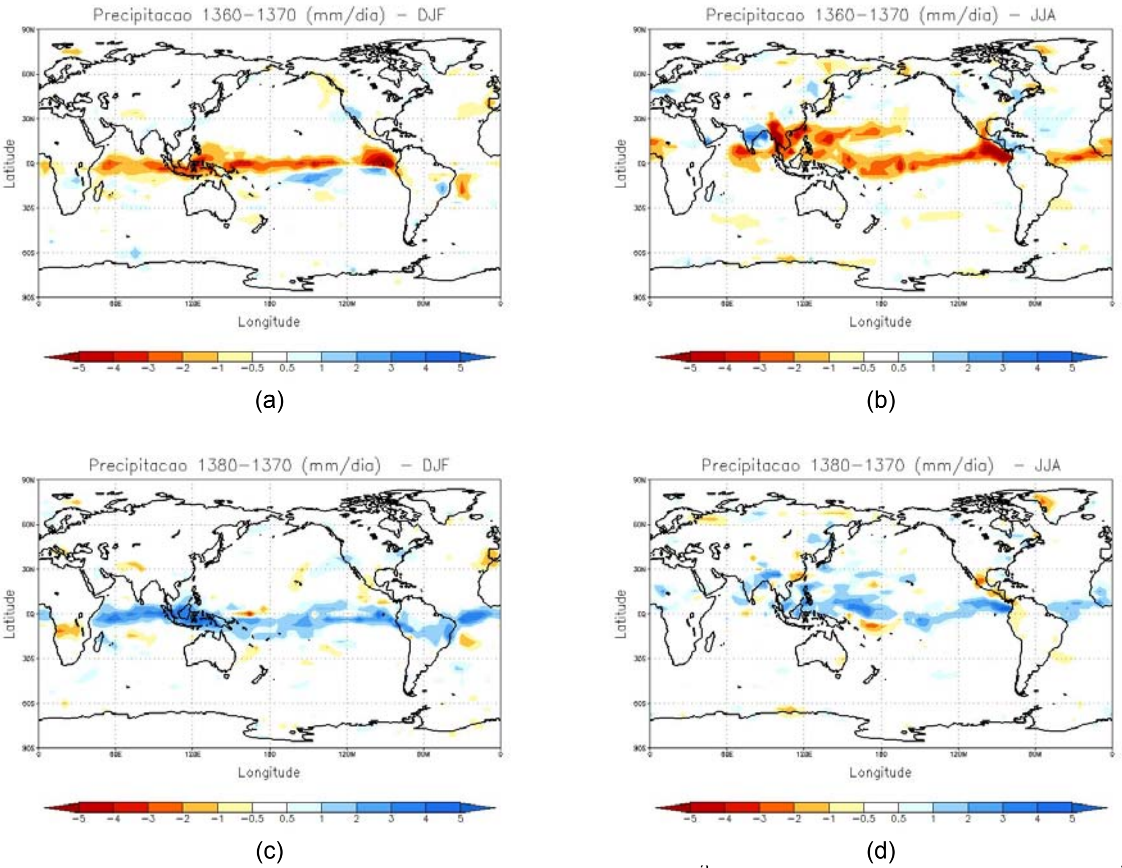


Figure 2: Precipitation anomalies (mm/day) for (a) 1360 –1370 Wm^{-2} DJF simulation, (b) 1360 – 1370 Wm^{-2} JJA simulation, (c) 1380 –1370 Wm^{-2} DJF simulation and (d). 1380 – 1370 Wm^{-2} JJA simulation.

5. Conclusions

In this study three experiments were realized with LMD model. The objective was to verify the effect of TSI (Total Solar Irradiation) variation can be produce in the climate, specially in the South America Continent.

The TSI values had been taken from observated values made since 1838 till nowadays. The averages are made with minimum and maximum values observed during this time. These experiment values are in such way overestimated, but the results shown interesting points about the surface temperature and precipitation rates.

In fact results have shown that with a decrease of TSI, the climate becames cooler over South America, the greater impact is over the continental area close to the central part of the brazilian coast (reaching –2^{o}C). The cooler of SST can be reach –1^{o}C. If an increase of TSI is observed, the model estimate an increase of surface temperature mainly over southern part of south America and over the Pacific Coast from noth Chile coast to Peruvian coast (reaching 2^{o}C) that can amplify the effects of El Niño phenomena.

For the precipitation anomalies, the model suggests an important decrease of precipitation over the ITCZ area for a decrease in TSI value and an increase of precipitation for a TSI increase. In the first case the ocean area is more affected and in the second case both, ocean and continent are affected remarking an increase of precipitation for the brazilian northeast region.

Futher works will be donne with more realistics values and simulating other important meteorological phenomenons.

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