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Climate interaction mechanism between solar activity and terrestrial biota

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Abstract. The solar activity has been proposed as one of the main factors of Earth's climate variability, however biological processes have been also proposed. Dimethylsulfide (DMS) is the main biogenic sulfur compound in the atmosphere. DMS is mainly produced by the marine biosphere and plays an important role in the atmospheric sulfur cycle. Currently it is accepted that terrestrial biota not only adapts to environmental conditions but influences them through regulations of the chemical composition of the atmosphere. In the present study we used different methods of analysis to investigate the relationship between the DMS, Low Clouds, Ultraviolet Radiation A (UVA) and Sea Surface Temperature (SST) in the Southern Hemisphere. We found that the series analyzed have different periodicities which can be associated with climatic and solar phenomena such as El Niño, the Quasi-Biennial Oscillation (QBO) and the changes in solar activity. Also, we found an anticorrelation between DMS and UVA, the relation between DMS and clouds is mainly non-linear and there is a correlation between DMS and SST. Then, our results suggest a positive feedback interaction among DMS, solar radiation and cloud at time-scales shorter than the solar cycle.

Keywords. Dimethylsulfide, Solar Activity, Sun-Earth Relations, Climate, Wavelet Analysis, Fractals, Vector Autoregressive Analysis.

1. Introduction

The solar activity has been proposed as an external factor of Earth's climate change. Solar phenomena such as total and spectral solar irradiance could change the Earth's radiation balance and hence climate (Solanki 2002). However, biological processes have also been proposed as another factor of climate change through its impact on cloud albedo. One of the most important issues regarding the Earth function system is whether the biota in the ocean responds to changes in climate (Charlson *et al.* 1995; Miller *et al.* 2003). According to several authors, the major source of cloud condensation nuclei (CCN) over the oceans is dimethylsulfide (DMS) (Andreae & Crutzen 1997; Vallina *et al.* 2007). Solar radiation is the primary driving mechanism of the geophysical context and is responsible for the growth of the phytoplankton communities. Clouds modify both albedo (short-wave) and long-wave radiation. In particular, for low clouds over oceans, the albedo effect is the most important result of cloud radiation interaction and has a net cooling effect on the climate(Chen *et al.* 1999). The DMS, solar radiation, and cloud albedo are hypothesized to have a negative or positive feedback interaction (Shaw *et al.* 1998; Gunson *et al.* 2006). The purpose of the present study is to examine the relationship between DMS and climatic and solar phenomena, through clouds, sea surface temperature (SST) and the ultraviolet radiation A (UVA) in a selected location and at time-scales shorter than the solar cycle.

2. Region of study and data

The data analysis was performed for the Southern Hemisphere between $40^o - 60^o$S latitude for the entire strip length. We are interested in this area because it is the least polluted in the world, the so-called pristine zone, then solar effects on biota and climate should be more evident. The studied period is 1983-2008, containing almost 25 year of data. The DMS data set was obtained from the site *http://saga.pmel.noaa.gov/dms*. We also use the SST time series, obtained from The Climatic Research Unit *http://www.cru.-uea.ac.uk/cru/data/temperature/hadsst2sh.txt*. Another time series we use is the low cloud cover anomaly data (LCC) from the International Satellite Cloud Climatology Project (ISCCP) *http://isccp.giss.nasa.gov*. Two series of low cloud cover anomaly were obtained: Visible-Infrared (VI-IR)and Infrared (IR). Finally, we work with ultra violet radiation A data (UVA), which comprises from 320 to 400 nm, because the 95% of wavelengths longer than 310 nm reach the surface (Lean *et al.*, 1997) and has a large impact on marine ecosystems (Toole *et al.* 2006; Hefu *et al.* 1997; Slezak *et al.* 2003; Kniventon *et al.* 2003; Häder *et al.* 2011). We use the UVA composite series from the Nimbus7 (1978-1985), NOAA-9 (1985-1989), NOAA-11 (1989-1992)and SUSIM satellites between 1992 and 2008 (DeLand *et al.*, 2008).

3. Results and Discussion

Some of the previous efforts on elucidating a plausible contribution of DMS on the Earth's climate have been mostly based on correlation analysis models. The fact that two series have similar periodicities does not necessarily imply that one is the cause and another is the effect. Here we apply one non-linear analysis to study the time series: *The Wavelet Coherence Analysis*. In Fig. 1 present the coherence analysis between DMS vs SST, DMS vs LCCIR, DMS vs LCCVI-IR and DMS vs UVA respectively along 1992-2008. We choose this time interval because the DMS time series has the largest quantity of data. For each panel, the time series appears at the top, the wavelet coherence spectrum appears at the middle and the global wavelet coherence spectra is at the right. Fig. 1a, shows that the DMS and SST time series have the most persistent and prominent coherence ∼4 yrs and tend to be in phase. The DMS and LCCIR time series in Fig. 1b present the most prominent and persistent coherence ∼5 yrs, and tend to be in anti-phase. The DMS and LCCVI-IR time series show persistent coherences ∼3 and 5 yrs, they tend to be in phase and anti-phase respectively. The DMS and UVA time series show persistent coherence at ∼3 yrs but it is not very prominent, in fact the prominent coherences are between ∼0.4 and 1.2 yrs, they are very localized in time and tend to be in anti-phase. There is predominance in the periodicity between 3 and 5 years. Peaks shorter than 1 yr may be due to seasonal climatic phenomena. The ∼2 yrs period can be associated with the Quasi-Biennial Oscillation (QBO) in the stratosphere(Holton *et al.* 1972; Dunkerton 1997; Baldwin *et al.* 2001; Naujokat 1986; Holton *et al.* 1980) and with the solar activity(Kane, 2005).The periodicities ∼3 and 4 yrs could be related to the El Niño-Southern Oscillation (ENSO) (Nuzhdina 2002; Njau 2006: Enfield 1992) that is a large-scale climatic phenomenon. The periodicities ∼5 yrs can be a harmonic of the 11-yrs solar cycle (Djurović & Páquet 1996). From Fig. 1, we notice a consistent correlation between DMS and SST and an anticorrelation between DMS and UVA, the relation between DMS and clouds is mainly non-linear. The anticorrelation between UVA and DMS suggest a positive feedback, as discussed in other works (Larsen 2005) or as implied by the findings of other papers (Mendoza & Velasco, 2009; Lockwood 2005; Kristjánsson *et al.* 2002).

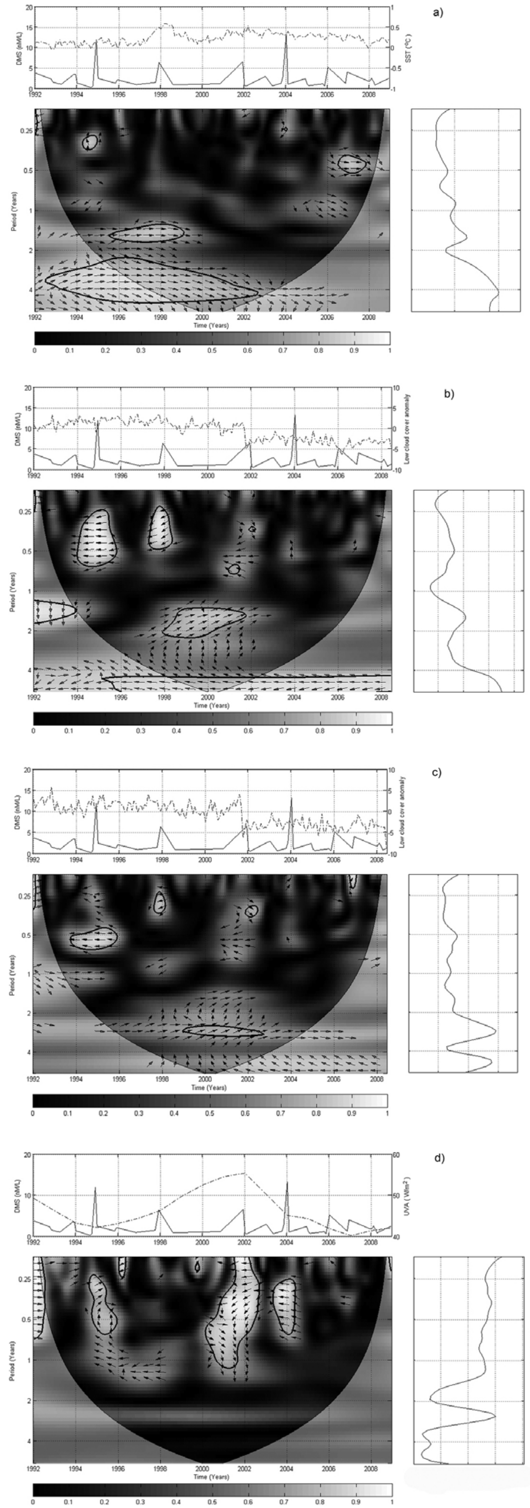

Figure 1. Wavelet coherence analysis. For each panel at the top there is the time series, at the middle the wavelet coherence spectra and at the right the global wavelet coherence spectra. The gray code indicating the statistical significance level for the spectral plots appears at the bottom of the figure; in particular the 95% level is inside the black contours. DMS (pointed line) SST, LCCIR, LCCVI-IR and UVA (dashed line).

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4. Conclusions

Here we study relationship between DMS and the SST, LCCIR, LCCVI-IR and UVA using Wavelet Analysis. The DMS, SST, LCCIR and LCCVI-IR series show persistence and therefore have the possibility of a future estimation. For the UVA, the results are not realistic and this is due to the shortness of the series that have prominent periodicities for 11 years. Using the wavelet method of spectral analysis, we found a predominance of periodicity between 3 and 5 yrs. The periodicities ∼3 and 4 yrs could be related to the ENSO. The periodicities ∼5 yrs are associated with solar activity. We found a correlation between DMS and SST and an anticorrelation between DMS and UVA, the relation between DMS and clouds is mainly non-linear. Then, our results suggest a positive feedback interaction among DMS, solar radiation and clouds. The analysis shows the existence of strong relations among clouds, DMS and SST and between the SST and DMS.

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