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The total column stratospheric ozone in the tropics during solar cycles 21-24

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SOLAR PHYSICS UTOV

Abstract: The Sun is an active and variable star. Instabilities and non-stationary processes connected to solar magnetic field and evolutionary mechanisms modify his radiative and particle output on different time scales, from seconds to the evolutionary scale of the star. The main feature of solar activity, at least in the last centuries, is the quasi-11-years Schwabe cycle. The Schwabe cycle is distinctly observed with different physical (e.g., Total and Spectral Solar Irradiance, MgII or F10.7 fluxes) and synthetic (e.g., sunspot number) indexes. Over this period, changes in the Total Solar Irradiance are ~0.1% with different spectral intervals contributing in different amounts. Solar Irradiance in the UV spectral region varies up to 10%. Such UV radiation is responsible for the temperature increase above the tropopause and the production and destruction of stratospheric ozone which dictates the chemistry, temperature and dynamics of the stratosphere. In order to investigate the time correlations between the total column stratospheric ozone in tropics regions and solar UV irradiance we decompose the ozone NIWA signal and solar MgII index in the various Intrinsic Mode Functions (IMFs) by means of the Empirical Mode Decomposition (EMD) technique. The MgII index is the most appropriate to reproduce the 122-200nm FUV band variation. The analysis of ozone and MgII IMFs associated with Schwabe period unambiguously establish that the total column stratospheric ozone in tropics regions is modulated by UV radiation. Moreover, the detailed analysis of the correlation trajectory in the IMFs plan offers ways to explore and investigate the dynamics of the relationship between stratospheric ozone and solar UV.

Mg II index

Mg II core-to-wing ratio is a proxy for solar UV and facular component of the Total Solar Irradiance. The Mg II index is calculated as the ratio between h and k emission doublet at 280 nm, which originates in the solar chromosphere, and a reference continuum intensity at specific wavelengths in the wings of the Mg II absorption band. It is calculated as:

Where I is Mg II index, and E_λ is spectral irradiance measured at particular wavelengths. Mg II index data used is the Bremen composite.

Figure 1. Mg II index time series

Figure 2. Total colum ozone anomaly between 25° north and south

Ozone data set

NIWA (National Institute of Water and Atmospheric Research, New Zealand) data set is the combined total column ozone data–base assimilated from the satellite measurements.

As our work is focused on the tropis, only measurements between 25° north and south were taken into account, for which the ozone anomalous time series has been produced (Fig 2).

EMD technique

Solar irradiance signals, as well as ozone signals are intrinsically non-stationary and nonlinear, therefore adaptive analysis is required. The EMD is a signal processing technique designed to analyse such kind of signals. The EMD's main aim is to synthesize any signal as the sum of a finite number of Intrinsic Mode Functions (IMFs) computed directly from the signal. The IMFs generated with this process satisfy the conditions:

1. the number of zeros and of extrema differs at most by one;
2. the mean value of the envelopes of maxima and minima is approximately zero.

Figure Empirical mode decomposition applied on Mg II index time series (left) and NIWA total column ozone anomaly in the tropics (right)

Figure IMF5 corresponding to the 11 year variability extracted from the Mg II index time series (left) and NIWA total column ozone anomaly (right)

Conclusions

The investigation of the variability on quasi-11 year scale has shown that the total column stratospheric ozone in tropical regions is modulated by the UV radiation. Moreover, the detailed analysis of the correlation trajectory in the IMFs plan offers ways to explore and investigate the dynamics of the relationship between stratospheric ozone and solar UV.

Figure correlation trajectory on the scale of 11 years (extracted from the original signal using the EMD technique) of the ozone NIWA and Mg II index

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Mg II index data have been freely retrieved from Institute of Environmental Physics, University of Bremen

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