Sunspots, the QBO, and the Stratosphere in the North Polar Region: An Update*

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Abstract The 11-year sunspot cycle (SSC) strongly affects the lower stratosphere. However, in order to detect the solar signal it is necessary to group the data according to the phase of the Quasi-Biennial Oscillation (QBO). Although this is valid throughout the year the effect of the SSC and the QBO on the stratosphere was largest during the northern winters (January/February). As the stratosphere can affect weather at the ground, the SSC effect on the lower stratosphere might provide a mechanism for solar-climate links. Here we analyse an extended, 65-year long data set of solar variability, QBO, and lower stratospheric dynamics. The results fully confirm earlier findings and suggest a significant effect of the SSC on the strength of the stratospheric polar vortex and on the mean meridional circulation.

1 Introduction

Even after 200 years of research, the relation between solar variability and Earth's climate remains a matter of debate in the scientific literature and a topic of foremost interest to the Earth science community. Effects of solar variability related to the 11-year sunspot cycle are most obvious in the stratosphere, though still not fully understood (van Loon and Labitzke 2000; Crooks and Gray 2005; Matthes et al. 2006). Hence, the effect of solar variability on climate at the ground might well proceed via the stratosphere.

Labitzke suggested in 1982 that the Sun influences the intensity of the north polar vortex in the stratosphere in winter, and that the Quasi-Biennial Oscillation (QBO) is needed to identify the solar signal. Based on these results, Labitzke found

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in 1987 that a signal of the 11-year sunspot cycle (SSC) emerged when the arctic stratospheric temperatures and geopotential heights were grouped into two categories determined by the direction of the equatorial wind in the stratosphere (QBO). The signal involves a change in strength of the northern polar vortex in the stratosphere. Through the mechanism of downward propagation (Baldwin and Dunkerton 2001) it might affect the sea-level pressure (SLP) field and lead to changes in the so-called Arctic Oscillation (AO) (Thompson and Wallace 1998).

This first study was based on 30 years of data (1957–1986), which is barely three solar cycles. Several publications criticized the short data record.

In the mean time, 20 more years of data became available, and the records have been extended into the past. Altogether, 65 years of data are now available, that is, 6.5 solar cycles, (see Fig. 3). In this paper we analyse the 65-year data set with respect to trends and to solar effects in the lower stratosphere (based on Labitzke et al. 2006).

2 Data and Methods

The work presented in this paper is mainly based on NCEP/NCAR reanalysis data (e.g., Kalnay et al. 1996) since 1948. In order to address the polar vortex in the stratosphere we use 30 hPa geopotential height at the North Pole. These data were extended back to 1942 using statistical reconstructions based on historical upper-level data as described in Labitzke et al. (2006). Reconstruction and validations methods as well as the historical data are identical to those used in Brönnimann et al. (2007a). The statistical approach is based on the assumption of a stationary relationship between predictors (mostly radiosonde data from the midlatitudes, but also from the Arctic) and the predictand. Hence, we are measuring the strength of the polar vortex via its imprint in the mid- to high-latitude upper troposphere. It is important to note, however, that the reconstructions are independent of both the QBO (no data south of 30°N were used) and solar variability and can therefore be used for the following statistical analyses. The skill of the reconstructions is shown to be sufficient for the analyses presented here (Labitzke et al. 2006). Data for the AO index were taken from Thompson and Wallace (1998).

The significance of our results depends on the number of solar cycles available. With these new data we have reached 6.5 solar cycles and we can now safely say that the results for the northern winters, especially in the west phase of the QBO, with a coefficient of correlation r reaching 0.7, are highly significant ($r = 0.5$ and 0.66 correspond to the 95% and 99% confidence levels, respectively).

The QBO is an oscillation in the atmosphere which is best observed in the stratospheric winds above the equator, where the zonal winds change between east and west with time. The period of the QBO varies in space and time, with an average value near 28 months at all levels, see reviews by Naujokat (1986) and Baldwin et al. (2001).

Information on the phase of the QBO was taken from the FU Berlin data back to 1953 (Labitzke et al. 2002). The series was extended back to 1942 based on pilot