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Evidence of change after 2001 in the seasonal behaviour of the mesopause region from airglow data at El Leoncito

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Abstract

Airglow intensities and rotational temperatures of the OH(6-2) and O_2b(0-1) bands acquired at El Leoncito (32°S, 69°W) provide good annual coverage in 1998–2002, 2006, and 2007, with between 192 and 311 nights of observation per year. These data can therefore be used to derive the seasonal variations during each of these seven years, in airglow brightness and temperatures at altitudes of 87 and 95 km. From 1998 to 2001, seasonal variations are similar enough so that they can be well represented by a mean climatology, for each parameter. On the other hand, these climatologies do not agree with what is usually observed at other sites, maybe due to the particular orographic conditions at El Leoncito. With respect to the last three fully documented years (2002, 2006, and 2007), the similarity from year to year deteriorates, and there are greater differences in the seasonal behaviour, more or less in all the parameters. The differences include, e.g., maxima occurring earlier or later than "normal", by one or two months. All this may suggest the build-up of a new regime of intraseasonal variability, with a possible relationship to corresponding changes in wave activity.

Keywords: Mesopause region; Airglow; Temperature; Seasonal variation; Interannual variation; Climatology

1. Introduction

Since the mesopause is defined as the height of the temperature minimum in the terrestrial upper atmosphere between about 80 and 100 km, the observation of its temporal evolution requires temperature measurements. Observations of the temperature profile in this height range with potassium and sodium resonance lidars led to the discovery of the existence of two different mesopause heights between which the atmosphere switches in the course of the year (von Zahn et al., 1996; She and von Zahn, 1998; Xu et al., 2007). During most of the year, the mesopause is close to 100 km, but around summer solstice, it is at about 86 km. This means that it makes no sense to use the term "mesopause" associated to a fixed altitude, and is another good reason to refer to the entire height range of 80–100 km as the "mesopause region".

Temperature time series from the OH airglow emission corresponding to a nominal altitude (87 km) practically at the ideal summer mesopause height, and from the O_2 emission at about 95 km, not far from the upper mesopause level, are available at different sites of the world. These data are suitable to study the temperature and airglow brightness climatology in the mesopause region, adding valuable information to the one obtained from lidars and satellite instruments. Since airglow observations can easily be automated and do not require extremely good weather conditions, they are capable of supplying data sets which are long and dense enough to describe the seasonal variation and its eventual changes from year to year.

Seasonal airglow intensity climatologies have been derived as early as the 1920s, for the 558 nm line emission of atomic oxygen (see Hernandez and Silverman, 1964), strongly correlated with the O_2 airglow. This line has also been used to measure temperature from its Doppler width

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(Armstrong, 1968), but the greatest amount of data presently is obtained as rotational temperatures for the molecular bands of OH and O_2.

A number of recent papers discuss mean temperature climatologies for the mesopause region at tropical and lower midlatitudes from several years of ground-based observations. These are based on lidars (States and Gardner, 2000; Chu et al., 2005; Yuan et al., 2008) and airglow instruments (Takahashi et al., 1995; López-González et al., 2004; Zhao et al., 2007; Gelinas et al., 2008). Most of these airglow studies also discuss the seasonal climatology of airglow intensities which supply complementary geophysical information to the seasonal behaviour of temperatures.

Here, we report airglow results obtained at lower midlatitudes in Argentina, which describe a somewhat unusual seasonal pattern. Another major objective is the analysis of interannual differences.

2. Instrumentation, data, and processing

Zenith intensities of the OH(6-2) and O_2b(0-1) airglow bands and the corresponding rotational temperatures were measured with the Argentine airglow spectrometer (Scheer, 1987) at Complejo Astronómico El Leoncito (31.8°S, 69.3°W). The instrument uses a tilting interference filter to sample the airglow spectrum at seven positions, obtaining a time resolution of 81 s (Scheer and Reisin, 2001). Since the instrument operates in photon counting mode and uses only one single filter well protected against environmental humidity in a hermetic enclosure, eventual aging effects are well under control and a consistent intensity scale (expressed in relative units) can be assured. This stability can be verified by comparison with the galactic stellar background; see, e.g., Scheer and Reisin (2000), and also the more recent comparison at http://www.iafe.uba.ar/aeronomia/stabilit.html. Of course, rotational temperatures are completely unaffected by the intensity scale.

The observing site at 2500 m above sea level and located about 50 km east of the Andes mountain range with peaks above 6000 m can be expected to exhibit aeronomical conditions influenced by orographic forcing in a way not encountered at other places, so that the data from this site are not necessarily representative of the whole latitude zone.

The number of nights with useful data, and the total number per year of groups of data (each group comprises the four measured parameters) are shown in Fig. 1 (data for 1988, 1990, and 1994 were obtained at other sites in Argentina, and in Spain). The data before 1998 have been obtained in campaign mode, and therefore only cover a few weeks or a few months per year, which is not enough for this climatological study (unless interannual variability is assumed to be negligible).

During the five years since the onset of fully automatic data acquisition in 1998, a yearly coverage of about 200 nights or more has been established. There is a data gap from 2003 to 2005 due to instrument failure, repair and

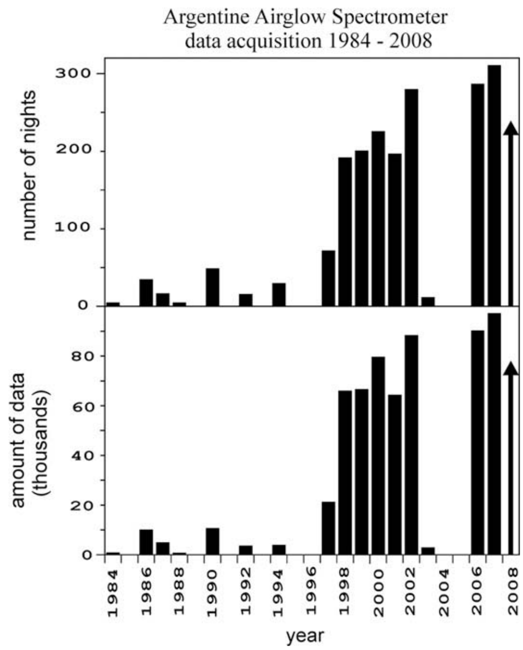

Fig. 1. Annual data acquisition with the Argentine airglow spectrometer. Number of nights with good data (upper panel), amount of data per year (lower panel), for each of the four measured parameters. The arrows for 2008 reflect the status until 7th September.

refurbishment. After a new calibration to take the modifications in the filter tilt mechanism and the spectral sensitivity of the new photomultiplier into account, measurements continue since early 2006. In 2007, the greatest coverage of 311 nights was reached. The data set used here is composed of 65 thousand to nearly 100 thousand independent groups of good data per year. Assuming that each measurement corresponds to 88 s of observation (the mean value for a complete night without data gaps), this means that a single year contained between 1600 and 2400 measurement hours (discounting data gaps).

Note that the temperature scales for OH and O_2 are independent to a certain degree, because rotational temperatures for both emissions are based on completely different molecular physics which introduces different systematic errors for both bands. This means that the exact absolute temperature scales are still unknown. A satellite intercomparison based on the second mission of the CRISTA instrument in 1997 (Scheer et al., 2006) has permitted to establish a common temperature scale for both emissions. However, the precision of this determination was limited by the short duration of the flight, and its validity terminates with the instrument modifications mentioned above. Therefore, the corresponding adjustment will here only be applied where a direct comparison of both temperatures makes this necessary.

The detailed seasonal distribution of the data for the years 1998–2002, and 2006–2008, which we use in this study, is shown in Fig. 2. The only longer data gaps (between one and two months) are present in 1998, 2001, and 2006, but in the other years, gaps are short and leave