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Unexpected East-West effect in mesopause region SABER temperatures over El Leoncito

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ABSTRACT

We find that mesopause region temperatures determined by the SABER instrument on the TIMED satellite during nocturnal overpasses at El Leoncito (31.8°S, 69.3°W) are several kelvins higher when SABER observes from the East than when it observes from the West. We distinguish between altitudes corresponding to the nominal emission heights of the OH and O_2 airglow layers. The East-West temperature differences of 4.5 K obtained for OH-equivalent height, and of 3.5 K for O_2-equivalent height are surprising, because an effect of the South Atlantic Anomaly on SABER temperature is unexpected. However, the ground-based data obtained with our airglow spectrometer at El Leoncito show that such a SABER artifact can be ruled out. Rather, the phenomenon is explained as a consequence of the temporal sampling of the nocturnal variation, which is mostly due to the semidiurnal tide. The monthly mean tide is strongest from April to September with a mean amplitude of 6.9 K for OH, and of 10.5 K for O_2 rotational temperature, but the contribution to the East-West effect varies strongly from month to month because of differences in the temporal sampling. This mechanism should be active at other sites, as well.

1. Introduction

As has often been emphasized, ground-based and satellite-based observations of the upper atmosphere are complementary. Satellite data may provide global coverage while local time coverage at a given place is limited. In case of a sun-synchronous orbit, data for only two fixed local times are obtained at a given site. On the other hand, ground-based data may provide near continuous local time coverage but of course, only near a given geographical site. For this reason, the combination of ground-based and satellite data is useful to overcome these limitations. Such a combination has widely been used in the literature and even for the specific topic of mesopause region temperatures there have been several recent geophysical studies, e. g., Xu et al. (2006), French and Mulligan (2010), Yuan et al. (2010), Reisin et al. (2014). In the same context, also data quality assessments may be cited, e. g., von Savigny et al. (2004), Siskind et al. (2005), Oberheide et al. (2006), Scheer et al. (2006), López-González et al. (2007), Kumar et al. (2008), Mulligan and Lowe (2008), Remsberg et al. (2008), Smith et al. (2010), Scheer and Reisin (2013), Liu et al. (2015).

Among the papers mentioned, von Savigny et al. (2004), Siskind et al. (2005), Oberheide et al. (2006), Scheer et al. (2006), Xu et al. (2006), López-Gónzalez et al. (2007), French and Mulligan (2010), Smith et al. (2010), and Liu et al. (2015) report mesopause region temperature intercomparisons, and are therefore most relevant to the context of the present paper. Most comparisons (7 of 9) are with the SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) instrument (Russell III et al., 1999) on the TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) satellite. The other two instruments are SCIAMACHY and CRISTA used by von Savigny et al. (2004) and Scheer et al. (2006), respectively.

All of these satellite instruments operate in limb scan mode, which implies the need for conversion from the observed signal variations to vertical profiles. The volume element of interest in the upper atmosphere (the tangent point, TP) is at great distance from the satellite (depending on the heights of the satellite and the TP). In comparison with ground-based observations, exactly the same volume element is nearly never involved, so that miss distance and miss time effects have to be dealt with. Also, satellite overpass data inevitably only represent a small fraction of the available ground-based data because overpasses typically do not occur more than twice per 24 h. Meaningful intercomparisons therefore typically require considerable averaging.

While averaging can be expected to improve statistics, it does not in itself remove any trace of possible bias. For example, such a bias can be produced by the satellite position with respect to the TP. Auroral contamination is likely to depend on observation geometry, and so does particle precipitation in the region of the South Atlantic Anomaly.

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Particle precipitation may cause effects as dramatic as memory errors in satellite electronics, more moderate reduction of data quality as in the spectra of the TIDI instrument on the TIMED satellite (Niciejewski et al., 2006), or small drifts as in the DORIS oscillator frequency on the SPOT-5 satellite (Štěpánek et al., 2013).

In the present paper, we use our own dataset of mesopause region temperatures obtained with the ground-based spectrometer at the Argentine midlatitude site El Leoncito in combination with SABER temperatures at the same altitude. We find a pronounced perspective effect in the satellite data depending on viewing direction towards El Leoncito, from the Atlantic or the Pacific Ocean, which mimics a South Atlantic Anomaly effect. Comparison with ground-based data is vital for leading to the correct interpretation of this surprising East-West asymmetry.

2. Ground-based and SABER data

The ground-based data from El Leoncito (LEO; 31.8°S, 69.3°W) are obtained with the Argentine Airglow Spectrometer (AAS), a tilting filter spectrometer for the nocturnal emissions of the OH(6-2) and $O_2b(0-1)$ airglow bands (Scheer, 1987; Scheer and Reisin, 2001). The OH and O_2 band intensities and rotational temperatures are obtained with a time resolution of about 80 s. These temperatures correspond to the nominal centroid heights of the OH and O_2 layers, at 87 km and 95 km, respectively. We here use the temperatures from 2006 to 2014, excluding the previous data to avoid the issue of systematic offset discussed in Scheer and Reisin (2013). Data coverage is excellent for most years. From 2008 to 2013, there are at least 346 nights with data per year, and the only major data gap was between March and July 2014 (see http://www.iafe.uba.ar/aeronomia/Months.html).

The SABER instrument measures height profiles of various atmospheric parameters, since late January 2002, including temperatures derived from the brightness of CO_2 emissions (see, e.g., Rezac et al., 2015 and references therein). Here we use nocturnal temperatures, in the height range of interest to us, from 2002 to 2014 (data version V2.0, see http://saber.gats-inc.com/temp_errors.php).

For better comparison with our AAS data, we calculate "airglow-equivalent" SABER temperatures, for which SABER temperature profiles are averaged with Gaussian weight functions. These weight functions are centered at 87 km (for OH) or 95 km (for O_2), with 8 km full width at half maximum (to represent the typical shape of both airglow layers). We have used the same parameters with CRISTA profiles (Scheer et al., 2006) and more recently also with SABER profiles (Scheer and Reisin, 2013). Similar approaches have been used by other investigators (e.g., for OH, French and Mulligan, 2010).

We always use an average over all SABER temperatures at tangent points inside a miss distance circle centered at LEO with 1000 km radius. To reduce the mean miss distance, only overpasses with at least 3 tangent points (TP) are taken into account (up to 6 TPs may occur), which leads to a mean miss distance of 370 km. In what follows, we always use the term "overpass" with these conditions implied.

We treat SABER data separately, according to whether the satellite is on the western ("*fromW*") or eastern side ("*fromE*") of the TP. Since such a distinction, to our knowledge, has not been made in the literature, the following explanations may be warranted. The satellite position with respect to the TP depends on the orbital node (ascending or descending), but not only. It also depends on the phase of the yaw cycle ("North viewing" or "South viewing" in the expression used by Russell III et al., 1999; see also Zhang et al., 2006 for a thorough discussion of these topics). The relation between orbital node and *fromE* or *fromW* observing perspective is inverted in each yaw maneuver, which the satellite performs after (approximately) 60 days, during the odd-numbered months (January, March, ..., November). More precisely, in the North viewing phase, SABER observes from West in the descending node (Fig. 1, left), but in the South viewing phase, in the ascending mode (Fig. 1, right). The opposite holds for observation from East. The North viewing phase of the yaw cycle is centered on February, June, and October, and the South viewing phase on April, August, and December. Since the distance between SABER and the TP is about 2600 km, the satellite position for *fromW* observations is well over the Pacific, and for *fromE* observations clearly in the South Atlantic Anomaly area.

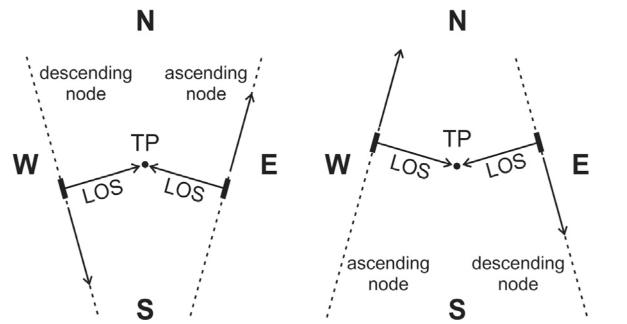

Fig. 1. Schematic maps of SABER observing geometry for the "North viewing" (left) and "South viewing" phase (right) of the satellite yaw cycle, showing the line of sight (LOS) from the satellite position to the tangent point (TP) for the ascending and descending orbital nodes.

3. Results

3.1. All LEO overpasses

First we consider the SABER data of all LEO overpasses, whether there are simultaneous AAS data or not. This means, for 2002 to 2014 all the overpasses (compliant with the selection criteria mentioned) are used, which includes the years practically without any AAS data (2003 to 2005). The annual averages of the nocturnal airglow-equivalent SABER temperatures around LEO are obtained separately for both perspectives (*fromE* and *fromW*). Temperatures *fromE* are systematically higher than temperatures *fromW* for all years and for both airglow-equivalent altitudes (Fig. 2). Each annual mean is based on no less than 179 overpasses (each containing 4.4 profiles, on average) leading to statistical errors smaller than 0.77 K. The differences

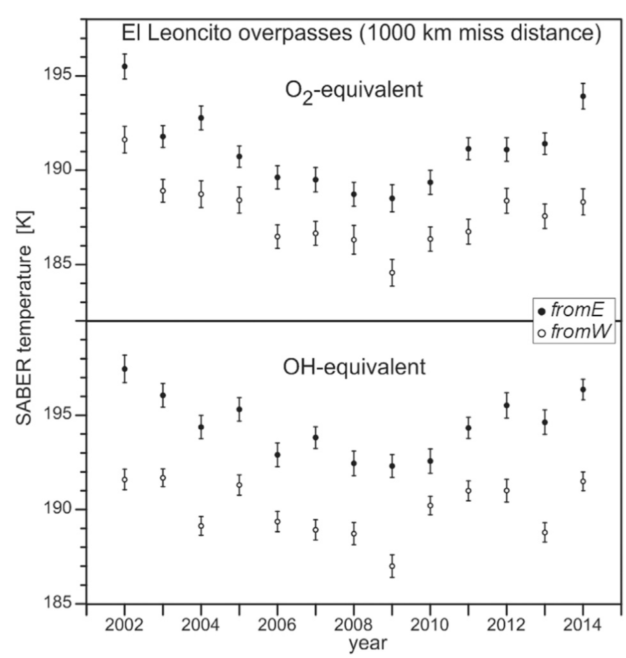

Fig. 2. Yearly averages of airglow-equivalent nocturnal temperatures measured by SABER over El Leoncito (LEO), separately for both observing perspectives (*fromE*, *fromW*).