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* Manuscript

Detection of meteor radar wind signatures related to strong short-duration day-to-day airglow transitions at sites 2600 km apart

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Abstract

Bursts of strong day-to-day variations in airglow brightness and temperature for the mesopause region that last one or a few nights have frequently been observed at El Leoncito (LEO; 31.8ºS 69.2ºW), since 1997. After the start of the operation of the meteor wind radar at Cachoeira Paulista (CAP; 22.7ºS 45.0ºW, about 2600 km further NNE) in March 1999, a number of the strongest airglow events at LEO were found to be followed, one to three days later, by negative (westward) zonal wind excursions of about -30m/s that seem to be related. Meridional wind disturbances are absent or only weak. The zonal wind perturbation at CAP closely matches the altitude range defined by the airglow emission at LEO, i.e. an OH emission event corresponds to a lower-altitude wind signature, and an O_2 emission event, to one at a higher altitude. The strong differences in seasonal occurrence patterns of airglow bursts at LEO observed earlier (with O_2 bursts peaking in April, and OH bursts, in June) are confirmed by the more recent data presented here. Most of the observed features of the two-site events could be explained by anticyclonic vortices (with 2000 km diameter) propagating zonally with the eastward background wind. International collaborations like the Global Airglow Transition Detection and Tracking (GATDAT) campaign are expected to provide the information required to further the understanding of these phenomena.

keywords: Airglow; Mesopause region; Atmospheric dynamics; Meteor radar; Winds; Solitons

1. Introduction

Day-to-day variations are a well-known (but not necessarily well understood) part of the geophysical variability in the lower atmosphere. In the mesopause region, interest in transient day-to-day variations has surfaced only recently. It was spawned by the discovery of the spring-time airglow transition in 1992 as discussed by Shepherd et al. (1999; 2004) and, e.g., Manson et al. (2002). Like its autumn counterpart (Taylor et al., 2001), these strong deviations of nocturnal mean airglow brightness and temperature last several days. Modeling studies with the TIME-GCM (Liu et al., 2001) suggest a relation to the equinoctial change between the summer and winter states of planetary wave activity.

Events of very strong day-to-day variation with pronounced airglow intensity and/or temperature enhancements that often last only one night were observed at the Argentine site El Leoncito (31.8ºS 69.2ºW) (Scheer and Reisin, 2002). For lack of a generally accepted name for the phenomenon, we call it "burst" event (this term adequately reflects the abrupt change of nocturnal means, from night to night). Like the equinox transitions, burst events show a clear seasonal occurrence pattern. However, this pattern is quite different, for the two airglow emissions observed: for the O_2 emission (that originates at an altitude of 95 km), the events are concentrated in April, while for OH (from about 87 km), they occur mainly from May to July, but not in April. These events are strongly associated with quasi-monochromatic gravity wave signatures (Scheer and Reisin, 2002).

Those airglow emissions are very sensitive to vertical motions. This is because they depend on atomic oxygen with its strong vertical mixing ratio gradient in the mesopause region. Therefore, downward (or upward) motions may produce very strong increases (decreases) in airglow brightness, while the corresponding adiabatic temperature rise (decrease) caused by the ambient pressure change remains more moderate. Note that airglow events of maximum brightness lead to airglow data of the best possible signal-to-noise ratio (and to the best derived temperatures), and so represent the most reliable information available.

A practical problem with these infrequent short-duration events is that they are easily missed by ground-based optical observations due to bad weather conditions. Maybe, this explains why attempts to track events by optical observations at distant sites have previously met with success only for the longer-duration equinox transitions reported in the literature (G. Shepherd et al., 1999; 2004; Taylor et al., 2001; Manson et al., 2002; M. Shepherd et al., 2002).

Hence, one should look for remote signatures of day-to-day airglow events also in parameters other than airglow. For example, meteor radar wind measurements permit continuous weather independent monitoring at altitudes that cover both airglow layers. However, meteor radar data are expected to be less sensitive to these events than airglow observations, since vertical winds cannot be measured with sufficient precision.

In this paper, we describe cases where the signature of airglow events at El Leoncito (LEO) has also been observed in the meteor wind data at the Brazilian site Cachoeira Paulista (CAP, 22.7ºS 45.0ºW), at a distance of about 2600 km.

2. Data acquisition

2.1 Airglow

Zenith airglow observations of the OH(6–2) and O_2(0–1) Atmospheric band with the Argentine Airglow Spectrometer (Scheer, 1987; Scheer and Reisin, 2001) are done at LEO routinely, since August 1997. Both emissions come from narrow layers, with the OH layer nominally centered at 87 km, the O_2 layer at 95 km, and mean widths of 6–10 km (and we assume that height and width variations are not strong or long-lasting enough to affect us here).

From the spectral shape of the bands, temperatures at each height are derived, which are then used to convert intensities sampled at different spectral positions into values representing the total intensity of each band. One set of OH and O_2 band intensities and temperatures is obtained every 80 seconds. Automatic operation and good observing conditions have resulted in more than 200 nights of good data per year (Scheer and Reisin, 2001; Reisin and Scheer, 2002).

Because the percentage of nights with poor data coverage is only small, nights with less than 150 data can be discarded with little loss. Thus, a minimum nocturnal coverage of 3.6 hours is guaranteed, minimizing tidal contamination of the nocturnal means. Therefore, the nocturnal means used to detect day-to-day events are based on 350 individual measurements, on average. Hence, statistical errors become completely negligible (Reisin and Scheer, 2002).

Airglow observations at CAP have been done with a multi-channel tilting filter photometer that measures the OH(6–2) and O_2(0–1) bands to provide intensities and rotational temperatures, and the intensities of the Na, OI 558 nm, and OI 630 nm emissions. The sodium emission comes from an altitude close to the OH emission. The OI 558 nm emission corresponds to a similar altitude as the O_2 band, but also has a thermospheric contribution that can be estimated from the observed OI 630 nm emission.

2.2 Radar

The meteor radar at CAP is a Genesis SkiYmet system. It is in operation since March 1999, measuring automatically 24 hours each day of the year. It delivers hourly values of mesopause region zonal and meridional winds in 3 km bins from 82 to 100 km (for more details, see Clemesha et al. 2001). In order to reduce unrelated variability, also due to tidal effects, diurnal means (0:00 - 24:00 UT) for each wind component are used for the present analysis. The data were combined into two altitude ranges for easier comparison with the airglow layers: the altitudes 82–88 km to approximately match the OH layer, and 91–98 km, to match the O_2 layer. This definition of only two altitude ranges, which involves on average about 2100 and 3000 daily wind data, respectively, also reduces statistical fluctuations (these numbers increased, after a transmitter power upgrade from 6 to 12 kW in November 2001).

3. Airglow events at El Leoncito

As mentioned, for the O_2 and OH emissions, exceptionally high nocturnal means occur at different times of the year (Scheer and Reisin, 2002). An updated list of the strongest events observed at LEO between 5 August 1997 and 25 September 2002, which represents the 73 nights out of 1080 data nights with the highest deviations from average conditions of nightly mean intensities or temperatures, leads to the histogram shown in Fig. 1. These cases are so defined by their nocturnal mean (with the ranking table technique also used below) without the need to pre-establish a threshold value. They range from about 1.7 to 2.4 times the long-term mean intensity, or 12 K to 29 K above mean temperature. This extreme nocturnal mean is used as a proxy for short-duration day-to-day bursts, which does not depend on the availability of data from neighboring nights. When data from neighboring nights are available, the burst nature of the events can be distinguished from normal quasi-periodic, planetary-wave-driven modulation. Most of the events can thus be positively identified as bursts.

Fig. 1 clearly reveals the strong tendency of the O_2 layer events (in airglow brightness as well as temperature) to occur in April, and of the OH layer events, in May, June, and July. Most of the May events (some of which also affected the O_2 emission) have appeared only since 2001, signalling a certain level of interannual variability. Apart from this, the histogram confirms the earlier findings (Scheer and Reisin, 2002). It is surprising that the small layer separation creates such a different seasonal pattern. This behaviour also shows clearly that external factors like solar activity cannot be the cause of the bursts.

A strong association between high nocturnal means and quasi-monochromatic gravity wave signatures in at least one of the airglow layers was found by Scheer and Reisin (2002) in 50% of the cases, in contrast to only about 5% of the nights, in general. This is now confirmed in that 38 of the 73 nights with the highest nocturnal means were accompanied by such gravity waves. As pointed out previously (Scheer and Reisin, 2002), the gravity wave signatures often do not appear in the same airglow layer as the burst events (30% occur only in the other layer), and therefore the physical connection between quasi-monochromatic gravity waves and bursts is not likely to be trivial.

4. Two-site events

We have looked for striking changes in the airglow data at CAP that might be related to the airglow events at LEO. Several of the strongest airglow events at LEO occurred in 1998. High O_2 intensities were observed on April 20, 22, and 25. Because of data gaps on April 21 and 23, it is not clear whether these were separate short burst events, or a planetary-wave-like modulation (see Fig. 2).

There may be a relation to a strong O_2 (and also OI 558 nm) intensity burst observed at CAP, on April 22 (as documented by a run of complete nocturnal data from April 21 to 24; see Fig. 2). However, the data gaps at LEO, as mentioned, and the gaps before April 21 and on April 25 and 26 at CAP prevent us from clearly diagnosing a relation between both sites. At any rate, such an activity was absent in the OH emission at both sites (and in the Na emission, at CAP, which, as mentioned, corresponds to a height similar to OH).

If this is really a two-site event, it was confined to the upper (O_2 and OI 558) airglow heights. The fact that the events appear in the same height range is also a feature of other cases involving radar data (see below).

Because of data gaps (and maybe, the nature of the burst phenomenon, as suggested below), other airglow coincidences between LEO and CAP have not been found, until now. However, there is hope that new airglow data from CAP and other sites in Brasil will supply more evidence in the future.

The highest nocturnal mean O_2 intensity at LEO was observed on April 25, 1999. Its identification as a short-duration burst event was possible from the available neighboring nights. This "most prominent airglow night" has previously been subjected to a detailed case study (Scheer and Reisin, 2002). The night also had higher than usual O_2 temperature, and a very strong quasi-monochromatic wave signature in OH intensity.

When the CAP meteor radar data were inspected for any evidence of the LEO burst events, a strong negative zonal wind excursion was found for 27 April, 1999. This aperiodic day-to-day variation is only present in the upper altitude range (91–98 km), but absent in the lower altitude (see Fig. 3). The meridional component shows no signature of the event, at none of the two altitude ranges. As suggested by the figure, this event seems to be associated with the 25 April burst at LEO, where it is very pronounced in O_2 intensity, but completely absent, in OH. (Note the local time shift between the dates of the nocturnal means at LEO and the diurnal means at CAP: the local-midnight-centered airglow data are identified by the evening date, while the wind data are centered at UT noon. This 7.4-h difference must be considered in the delays between LEO and CAP).

Fig. 3 also shows another O_2 airglow burst at LEO, on 10 April, which is also followed by a strong negative zonal wind excursion at CAP, on 12 April. As on 25 April, in this weaker airglow event the OH layer is not involved. In this case, the CAP zonal wind variation appears in both altitudes but is stronger in the upper one (corresponding to the airglow burst). Again, there is no simultaneous signature in the meridional wind. Note that apart from these two (delayed) coincidences (signalled by the arrows, in Fig. 3), there are no other suggestive events attributable to an airglow burst during the two-month interval shown.

The OH layer airglow burst event at LEO, on 11 July 1999, was not accompanied by an O_2 layer signature (see Fig. 4). As happens with many burst events (Scheer and Reisin, 2002), this night showed quasi-monochromatic gravity wave signatures, in this case present in both emissions. This event has a counterpart at CAP as a negative zonal wind excursion in the lower altitude range, on 12 and 13 July (see Fig. 4). The diurnal wind values for these dates are similar, because the event peaks near midnight of 12/13 July. A 24-h running mean permits to locate the peak of -18 m/s more closely at 4:30 UT, on 13 July. As at LEO, there is no significant signature in the upper altitude range. Neither is there a meridional wind disturbance, at any altitude.

It turns out that the 3-day interval 12 to 14 July had previously been studied (close to CAP, at São José dos Campos, 23.0ºS 45.5ºW) by Clemesha et al. (2001). This paper discussed lidar observations of sporadic sodium events related to downward-propagating waves, which were also manifest in the CAP meteor wind data. These wave features were especially noticeable in the meridional wind component, unlike the two-site events discussed here.

Near midnight on 13/14 July, photometers and airglow imagers at CAP observed "an unusual airglow wave event", that is, different manifestations of intense wave activity related to a bore-like airglow feature (Medeiros et al. 2001). These different phenomena, although not simultaneous, may be due to some special geophysical conditions being present over an extended time. The relations between both groups of events in Brasil were further studied in Batista et al. (2002).

Some other high-intensity airglow nights in late June also stand out in Fig. 4, but are probably only due to a superposition of planetary-wave-like perturbations during about a week, and have no conspicuous wind signatures. During the 5-month time span documented in Fig. 4, there is practically no other negative zonal wind excursion similar to the 12/13 July event. That is, the wind excursions are also rare events. The chance of a false identification of airglow-wind events is therefore small, and the coincidences reported here are bound to be significant. We shall return to this point later.

A very intense OH burst was observed at LEO, on 15 December 2000 (not shown here). This was another remarkable example of the association with strong gravity waves. The event may be related to a wind anomaly in Brasil, on December 18. However, this zonal wind deviation was weaker than the other cases, and did not rise as much above the mean variability (more details will be given below). Therefore, the identification of the wind response is not as convincing as in the other cases.

In 2001, the data coverage at LEO was nearly as complete as in the other years; however, the airglow events observed were not very strong, and could not be identified with any wind disturbance at CAP.

A dramatic airglow burst, particularly in the OH emission, occurred on 24 May 2002 (also of considerable intensity in O_2, but peaking one day earlier). As shown in Fig. 5, the very pronounced May 25-27 zonal wind deviation at CAP is probably related to this airglow event. Weather conditions at LEO have however been unfavorable, at that time: the airglow data for the nights May 23 and 24 are not complete and may be subject to some positive tidal bias, which means that the true height of the airglow burst may be somewhat smaller than what is shown in Fig. 5. Data for May 25 are missing, so that the evidence for the termination of the event depends on the data for May 26 (a fortunately clear full-moon night), when the intensity has returned to normal. Because of the following data gap, only the rising edge of the airglow disturbance is well documented.

On the other hand, the wind event at CAP is certainly one of the strongest and clearest zonal wind disturbances on record, although of considerably slower development. The negative excursion lasts three days, but the whole disturbance may have been as long as ten days, if the following positive overshoot were part of it. Besides these differences, the other characteristics of the airglow/wind coincidence are similar to the rest.

In the O_2 emission, the burst at LEO seems to have started one or two days earlier. Also in the radar winds, the upper altitude channel shows a zonal wind excursion, about two days earlier than at the lower altitude. We can treat them as if there were two separate events, one at each altitude level, propagating from LEO to CAP, each conserving their respective altitudes (however, both are probably not really independent). While in the other cases, the meridional wind was essentially unaffected, here one notices a certain meridional wind perturbation (for both height ranges), although much weaker than the zonal wind effect.

All the two-site events observed are summarized in Table 1, where each one is identified by an alphabetic label, for easier reference. To better quantify the airglow (intensity and temperature) and zonal wind perturbations, we subtract from each daily mean the running mean over the ten neighboring (i.e., the five closest previous, and following) values. By this high-pass filter, we effectively suppress slower variations, so that the day-to-day bursts can be compared independently of the average level. This is particularly important for the winds where the mean values vary strongly (including changes of sign), and a simple absolute proxy as applied to the airglow cannot work.

Thus, nocturnal mean intensity deviations so quantified can be ranked as shown in Table 2 for OH, and in Table 3 for the O_2 band, with the strongest airglow bursts on top. The corresponding perturbations in the other airglow parameters are also given. In order to make the intensity deviations in both emissions directly comparable, they are divided by the respective long-term mean intensities (this is just a change of scale, but *not* a relative deviation with respect to the local unperturbed state). The main message of these tables is that all the two-site events discussed above are indeed present, and occupy principal positions (signalled by the same labels as in Table 1). This independently confirms our previous identification of the strongest airglow bursts at LEO.

The intensity bursts in Tables 2 and 3 in relation to the general night-to-night variability amount to at least three standard deviations, with the strongest OH bursts (D, F, C) reaching five to six standard deviations. Four of these cases also have considerable temperature enhancements of 16 to 18 K, in the airglow burst layer, while cases C and D have also positive but smaller deviations. On the other hand, most of the airglow events in the rankings have negligible intensity perturbation in the emission complementary to the burst.

For the two-site events, the corresponding zonal wind perturbations for the two height channels are also shown in Tables 2 and 3. The numerical values confirm that the wind signatures in the height channel corresponding to each airglow burst are consistently strong (from -19 to -35 m/s). To put these numbers into perspective, note that for the zonal wind perturbations in general, the standard deviations vary between 11 and 16 m/s (depending on season), so that most cases surpass considerably the general level of variability.

Unfortunately, some of the top cases in the rankings are prior to the radar installation and therefore no wind data are available. Among the stronger cases, there is only one case (19 Jan 2002) with no detectable wind signature. This case is also an OH burst, but with considerably smaller perturbation. This is possibly only a short-period planetary-wave perturbation, and its identification as a genuine burst is questionable.

From the sixth position in both ranking tables onwards, no case has an identifiable wind perturbation. This is maybe because the burst intensity level is already too weak. These cases are only included by lack of an objective criterion of where to stop.

We note that entry number 8 in the OH ranking corresponds to the night following the famous "Bastille Day" solar flare event of 14 July 2000. As expressed by its position in the table, the airglow enhancement is not very strong (and even much smaller in O_2). This is however not the place to discuss a possible relationship to the flare event.

For the two-site events, there is a mean temperature effect of 14 ± 2 K. The corresponding zonal wind disturbances given in the table lead to a mean zonal wind disturbance of -30 ± 3 m/s at the altitude corresponding to each airglow burst.

An independent ranking of the zonal wind perturbations (not shown here) reveals that the four strongest wind perturbations identified as two-site events are among the 1% top negative zonal wind deviations. The relative frequency of negative zonal wind deviations not weaker than most of the detected two-site events is lower than 5×10^{-3} per day (this estimate is based on the analysis of 888 daily zonal wind deviations). This leads to an expectation of less than one event by chance in five months, corroborating the visual impression from Fig. 4.

We also note that the distribution of zonal wind perturbations is approximately symmetric, that is, positive excursions are about as strong and as frequent as negative ones. We will attempt below an explanation why none of the positive excursions has been associated with an airglow burst.

5. Discussion

For nearly all of the strongest airglow bursts on record, we find pronounced zonal wind perturbations, which form part of a rather small subset of the most extreme wind deviations. This means that our results must be statistically quite robust.

Certain common features of the events summarized in Table 1 suggest themselves clearly, and we can draw the following tentative conclusions:

- Perturbation height is maintained between sites. That is, airglow events in the OH emission are observed as lower-altitude wind events, O_2 events as higher-altitude wind events. Wind events tend to be absent (or weak), in the height channel alternative to the airglow level.
- The observed zonal wind perturbation is negative, that is, westward.
- Only the zonal wind component is affected, but not the meridional wind.
- Events tend to be first observed at LEO, and one to three days later at CAP.

The typical delay is 1.7 days (including the correction of -0.31 days for the different date and time notations, as mentioned). If any localized perturbation had moved in a straight line from LEO to CAP (in east-north-east direction), a horizontal propagation speed of about 18 m/s is needed to cover the distance of 2600 km. If, on the other hand, the perturbation behaves more like a plane wave front, or an extended horizontal "tongue" structure, this speed would represent an upper limit for the front velocity. However, it is hard to see how an arbitrary localized perturbation, wave front, or tongue structure should produce a wind disturbance always affecting only the zonal wind.

It is commonly believed that day-to-day variations, in general, are a manifestation of planetary wave activity. However, the very short duration of the airglow bursts and most of the two-site events makes a direct relation to planetary waves unlikely. At most, the slow wind variation for the May 2002 event(s) may possibly be due to a planetary wave (and wavelet analysis for this case indeed suggests the presence of a 16-day oscillation), but since the observed airglow burst is no longer than three or four days, a direct mediation by planetary waves meets with difficulties. This does not rule out the possibility of a more complex link involving planetary waves, or simply a superposition of planetary waves and faster short-term variations, at CAP.

We here propose a scheme involving the translation of a spatial pattern to explain the two-site events. Such a pattern that relates variations of airglow intensity, temperature, and horizontal wind and that involves only well-known mechanisms might be a localized temperature disturbance accompanied by vertical motions, and surrounded by the thermal wind (e.g., Andrews et al., 1987) corresponding to the horizontal temperature gradient. Let us imagine, for simplicity, a circular field of temperature enhancement of fixed shape that propagates zonally in an eastward direction, with the prevailing zonal wind (see map view in Fig. 6). If the temperature enhancement is due to vertical (downward) motion, it is accompanied by an airglow enhancement, as observed. For a maximum effect at El Leoncito, the structure must travel at the same latitude. This is symbolized by the concentric circles (left-hand) in Fig. 6. The corresponding thermal wind surrounds this temperature field in a counterclockwise (anticyclonic) direction (on the northern hemisphere, it would be clockwise).

After the mean observed delay of 1.7 ± 0.2 days, the pattern reaches the longitude of Cachoeira Paulista (Fig. 6, right-hand circles). The average speed to cover the corresponding displacement (about 2300 km) is therefore 15.6 ± 2.3 m/s, and, for an airglow event that lasts one day, the radius of the structure must be roughly 1000 km. The displacement speed is in close agreement with the mean zonal background wind of 16 ± 5 m/s at CAP. If the background wind at the latitude of LEO is the same, the spatial structure might simply be carried eastwards by the background wind.

The zonal wind measured at CAP is modified by the westward thermal wind during the passage of the disturbance (see Fig. 6). For the geometry suggested in the figure, a temperature enhancement of typically 15 K, and a vertical extension of the temperature field of about one scale height, it is not hard to calculate a thermal wind close to the observed wind disturbance (following formulas 3.2.6, p.120 in Andrews et al., 1987). This means that the thermal wind would not only have the correct sign, but may be consistent even with the observed size of the wind perturbation. The latitudes of LEO and CAP are not so low as to rule out the applicability of the thermal wind equation. Arguments of scale involving the Rossby radius can be brought forward against the horizontal size suggested in Fig. 6, but we feel there is sufficient space for adjusting the quantitative details to this scheme, especially when taking the potential complexity of the real atmosphere due to nonlinear effects (as suggested, for example, by Onishchenko et al., 2004) into account.

This is the only wind modulation, in the daily average, since the mean effect on the meridional wind component is zero, in this scheme. The passage of the disturbance will not create strong airglow effects at CAP. This would also explain the difficulty of finding coincident airglow bursts at both sites.

Although this simple model presently lacks independent confirmation, it allows predictions about the wind (and airglow) effects to be expected at other places. It can therefore be tested, in principle, by suitably-spaced airglow and wind observations. For example, Fig. 6 suggests that at 40ºS, positive zonal wind enhancements, instead of reversals, would be expected to accompany airglow perturbations passing over LEO. It is even conceivable that such vortices might be detected by existing radar networks alone, if a systematic search is performed. Note that the proposed scheme does not imply that other vortices not easily detectable with the given geometry of observing sites cannot exist. For instance, a vortex with a different trajectory could cause more complex signatures or be completely missed. It may be relevant in this context to note that in recent model experiments with a three-dimensional general circulation model (Yamazaki et al., 2004; applied to the atmosphere of Jupiter), which produces anticyclonic vortices similar to our simple scheme, the latitudinal drift of the vortices is much smaller than the zonal drift.

At least, the scheme is compatible with most of the observed characteristics. The altitude behaviour is not as easily understandable, in this context. Anomalies in the vertical structure, which also lead to the ducting conditions suggested by the association with monochromatic gravity waves (Scheer and Reisin, 2002), are likely to play a role. As mentioned, such gravity wave signatures are also strongly present in various of the events discussed here. The observations of the wave features at LEO on 11 July 1999, and at CAP on 13/14 July (the night after the corresponding wind event), suggest that ducting conditions may spread over such a wide area.

Although it is not essential for the present argument, note that anticyclonic vortex structures like the scheme proposed here are expected to maintain their shape while propagating long distances, because dissipation is compensated by wave dispersion. In this view, anticyclones are part of the family of solitary wave phenomena (or briefly, solitons; see Drazin and Johnson, 1989), which exist at different scales and at different altitude levels in the atmosphere, including the mesopause region (the bore phenomenon; Dewan and Picard, 1998, 2001; Smith et al., 2003). The spatial scale of the features we diagnose here is similar to anticyclones or Rossby solitons in the lower atmosphere. Objects of this size may however be missed in data from orbiting platforms (or compounded by other wave features, unless systematically searched for), because of the difficulty of tracking them continuously. This may be the reason why their existence in the terrestrial mesopause region is still hypothetical (apart from several unconfirmed reports, e.g., Grechko et al., 1989) while the solitonic interpretation of vortices in the atmosphere of Jupiter stands on firm ground (see, e.g. Williams, 1996; 2002, and the literature cited therein).

What is not at all evident from this scheme is why the seasonal occurrence frequency of the lower (OH) or higher (O_2 or OI 558 nm) altitude events should be as different as is observed at LEO (Fig. 1). This differs considerably from the consistent behaviour of both groups of airglow emissions or altitude regimes as reported for the equinox transition (Shepherd et al., 1999; Taylor et al., 2001; Manson et al., 2002). On the other hand, the association between airglow peaks and zonal wind reversals is a common feature of the equinox transition (at least, this is what observations at northern hemisphere mid to high latitudes teach us; see Manson et al., 2002; Shepherd et al., 2004), so that our present finding should not be a surprise. The observation of a semiannual variation of mean zonal winds at CAP, at the lower altitudes, and an annual variation at the higher levels (Batista et al., 2004) shows that strong differences in the behaviour of the two altitudes do exist. However, much further work is certainly still required to establish the detailed mechanisms involved.

6. Summary

Among the airglow data at El Leoncito and the meteor wind data at Cachoeira Paulista simultaneously available from March 1999 to October 2002, about half a dozen of two-site events have been encountered.

They all share the following characteristics. First, a high-intensity airglow burst and temperature enhancement lasting one or a few nights are observed at LEO. They involve either the OH or the O_2 band, depending on season. About two days later, a strong negative (i.e. westward) zonal wind perturbation (of about -30 m/sec, in the diurnal mean) is observed at CAP. It appears at the altitude corresponding to the airglow layer showing the burst at LEO, but tends to be weaker or absent, at the other height level. There is no (or only a small) meridional wind signature.

Anticyclonic vortices (with a diameter of about 2000 km) propagating zonally with the eastward background wind would explain most of the observed features. However, the existence of such objects in the mesopause region is still unconfirmed. This proposed mechanism implies that the sign and direction (zonal or meridional) of the observed wind perturbation is not a universal feature but depends on observing site geometry.

The strong differences in seasonal occurrence patterns of airglow bursts at LEO observed earlier are confirmed by the more recent data presented here.

To promote a systematic investigation of these airglow bursts and equinox transitions on a global scale, the Global Airglow Transition Detection and Tracking (GATDAT) campaign was designed, already in the context of the SCOSTEP project Planetary Scale Mesopause Observing System, from which further progress is expected.

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Figure captions:

Fig. 1. Monthly distribution of high nocturnal means (based on observations at El Leoncito, 5 August 1997–25 September 2002), with respect to the four different parameters. The monthly coverage of observations is shown in the lowest panel.

Fig. 2. Nocturnal mean airglow intensities at LEO (dotted lines) and CAP (solid and dashed lines), 20 April – 2 May, 1998. The emissions shown are OH(6–2) (open circles), Na (open triangles), O_2 (0–1) (solid circles), and OI 558 nm (solid triangles). Intensity units are relative to long-term (several-year) means.

Fig. 3. Nocturnal mean airglow intensities at El Leoncito in April and May 1999 compared to daily means of meridional and zonal meteor wind components at Cachoeira Paulista. Solid dots and lines correspond to the upper level emission (O_2, at 95 km nominal), and mean radar winds averaged over 91–98 km; open circles and dotted lines are for the lower altitude emission (OH, at 87 km), and radar winds at 82–88 km.

Fig. 4. As Fig. 3, but for June to October 1999. Notation is opposite to the one in Fig. 3; solid dots and lines: OH emission at 87 km, and radar winds at 82–88 km; open circles and dotted lines: O_2 emission at 95 km, and radar winds at 91–98 km.

Fig. 5. As Figs. 3 and 4, but for May and June 2002. Same symbols as Fig. 4 (Solid dots and lines: OH emission at 87 km, and radar winds at 82–88 km; open circles and dotted lines: O_2 emission at 95 km, and radar winds at 91–98 km).

Fig. 6. Hypothetical mesopause region temperature and wind field in a plane map view over El Leoncito (LEO, 31.8ºS 69.2ºW) and Cachoeira Paulista (CAP, 22.7ºS 45.0ºW). Concentric circles show isotherms (with higher temperature towards the center), circles with arrows show the corresponding thermal wind. The pattern (dotted) centered over LEO corresponds to the time of the airglow burst observed there, and the other one (solid) to the maximum wind disturbance at CAP, about two days later.

Figure 1

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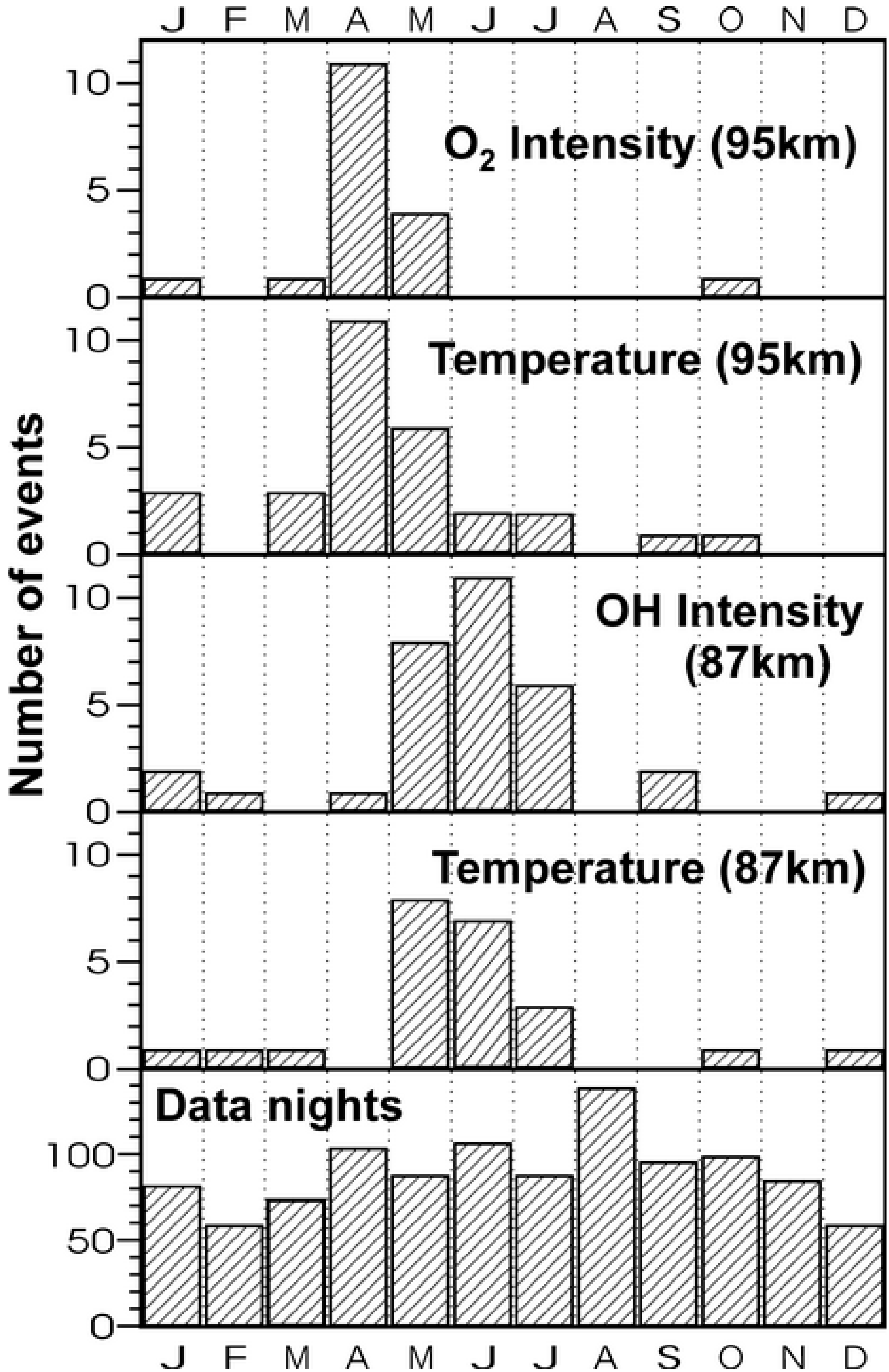

Figure 2
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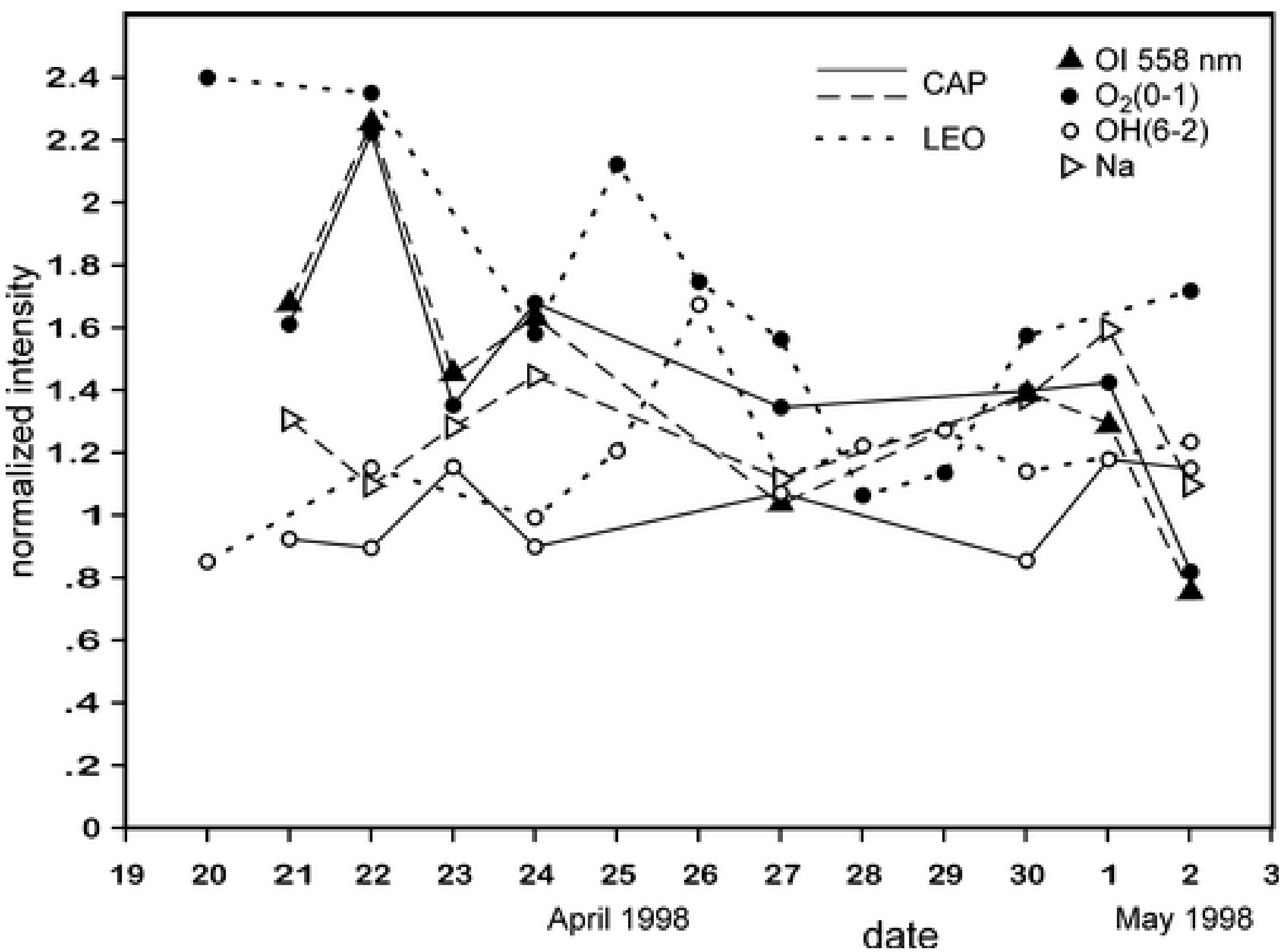

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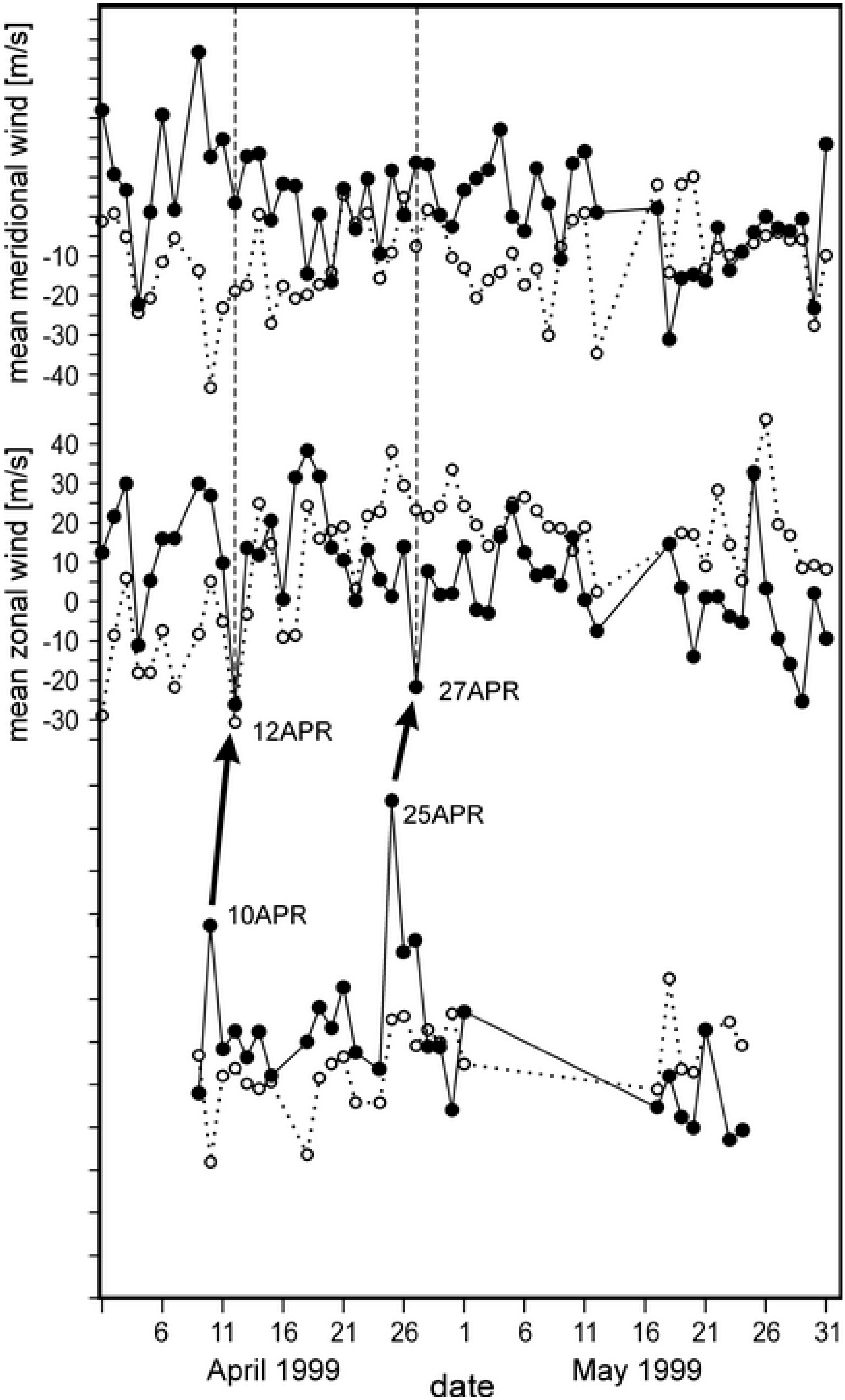

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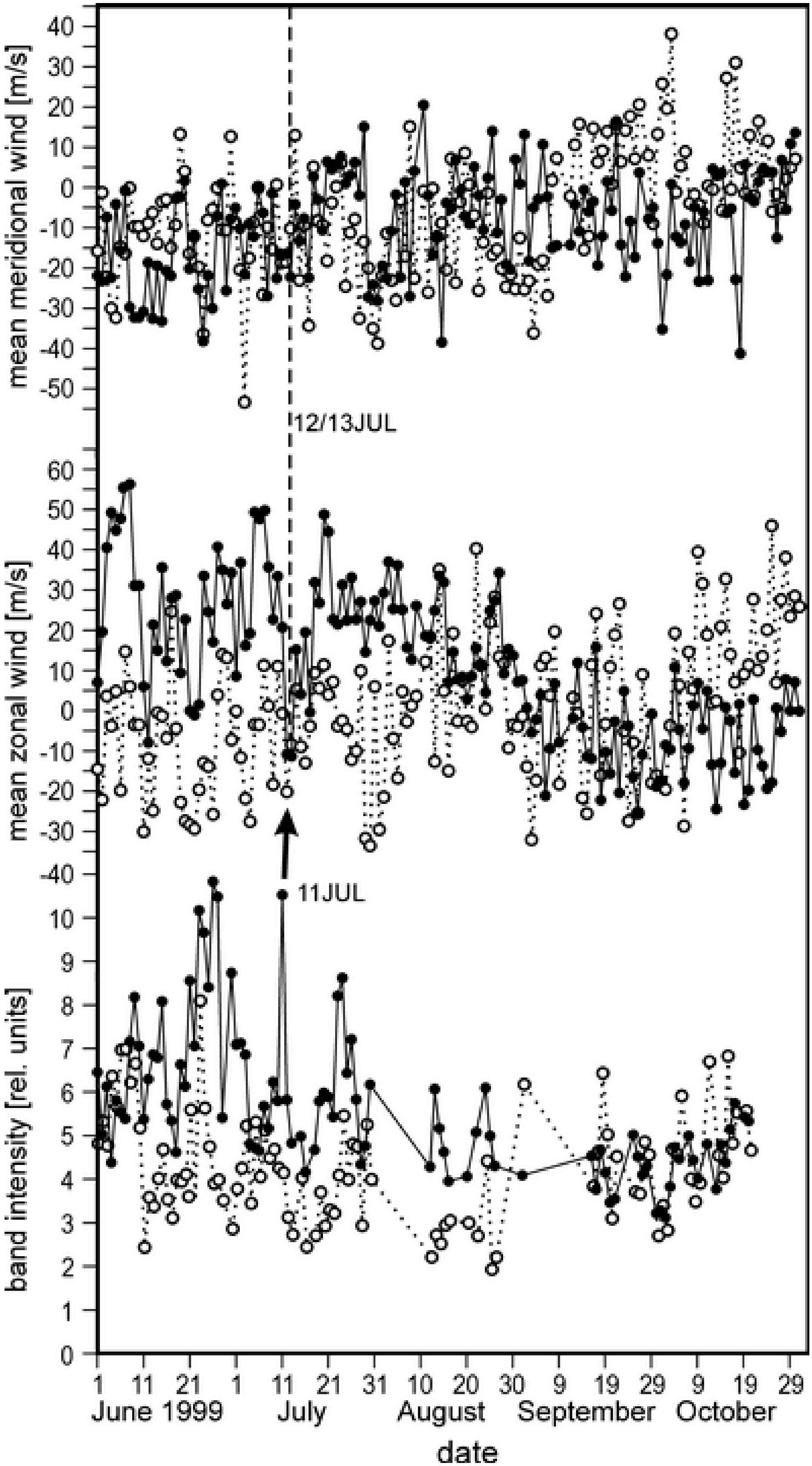

Figure 5

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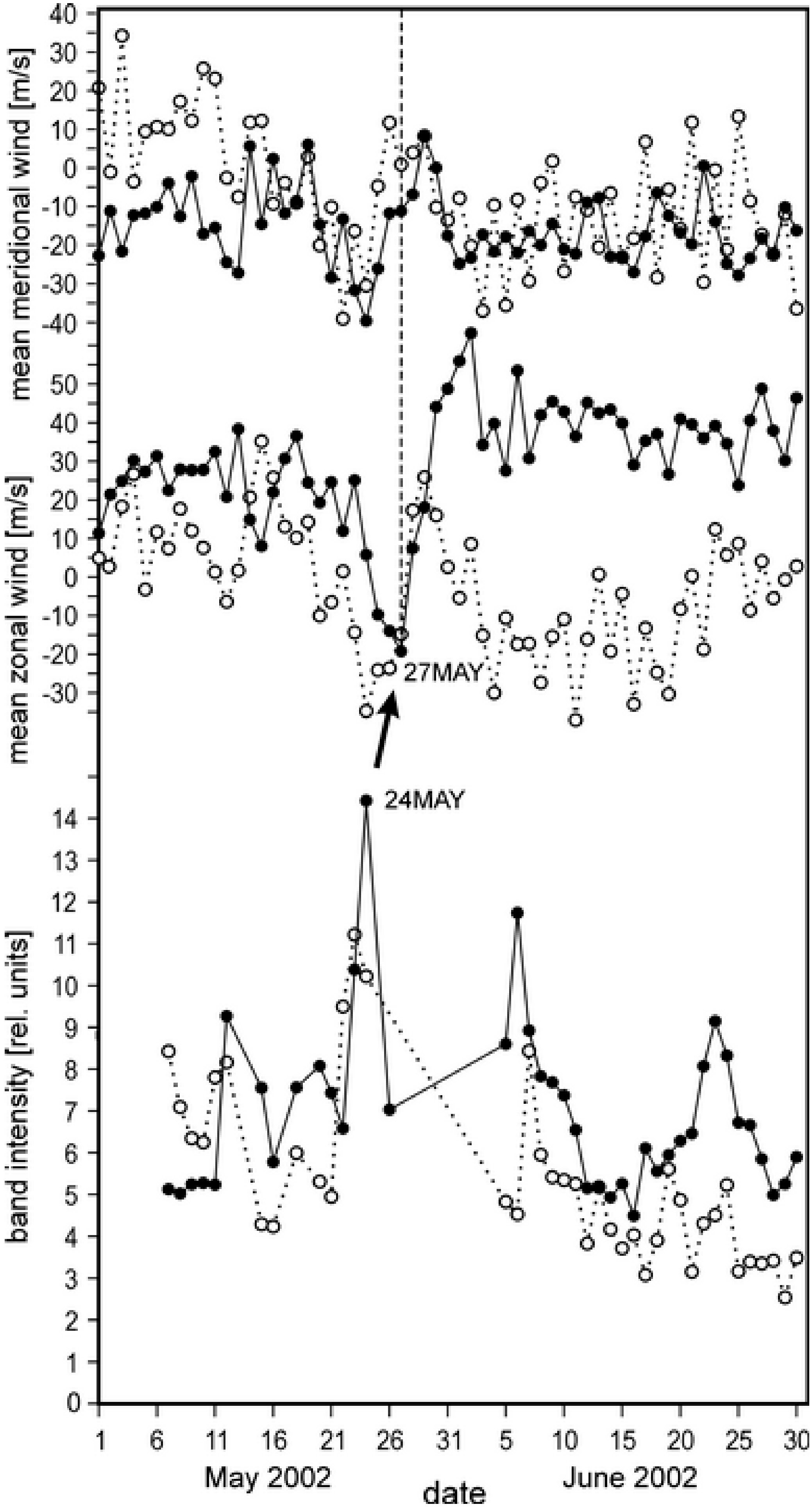

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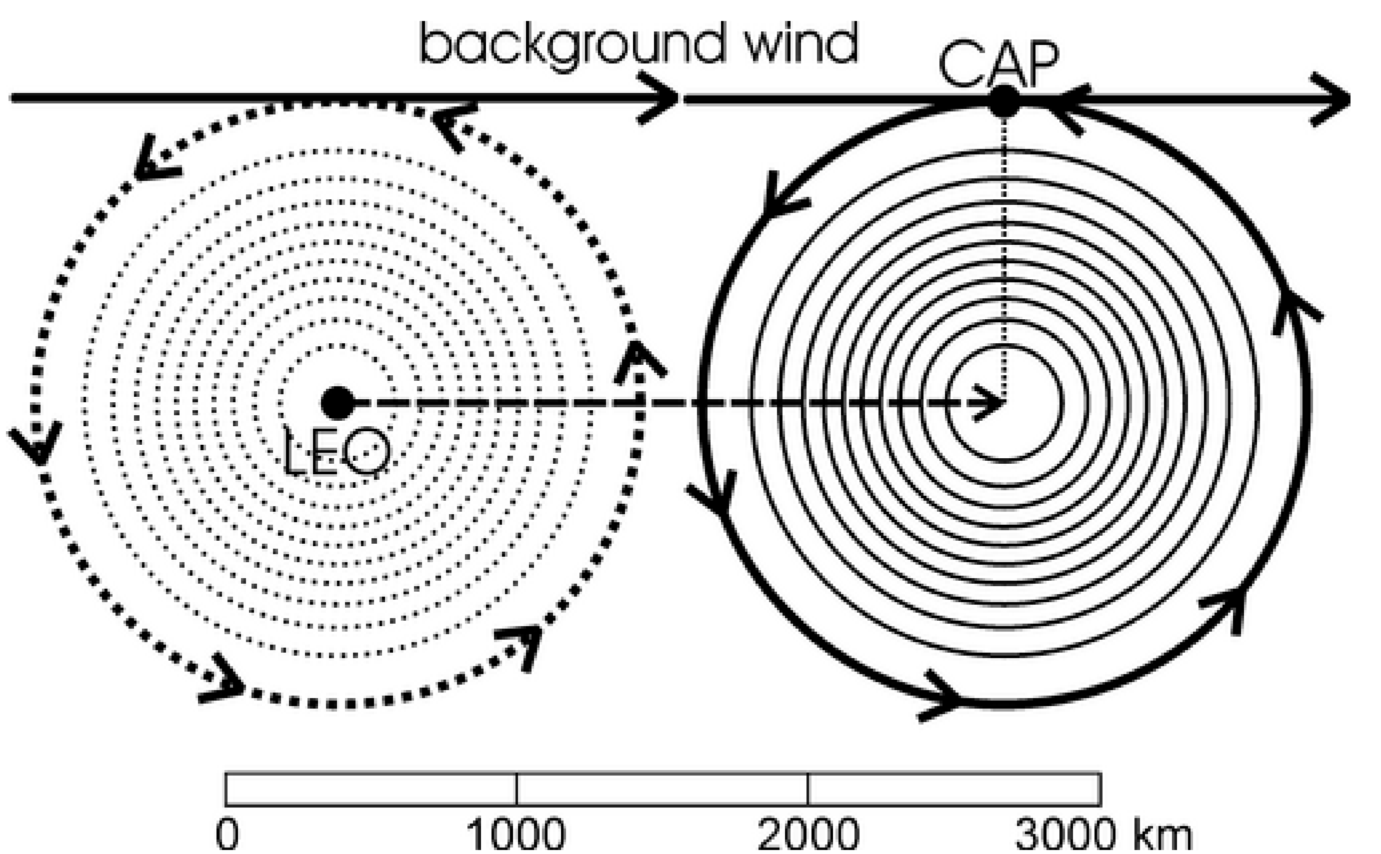

Table 1

Table 1: Two-site events observed as airglow bursts at LEO and meteor wind disturbances at CAP.

	LEO airglow burst		CAP zonal wind disturbance	
ID	date	emission	date	height range
A	10 APR 1999	O_2	12 APR	91-98km, 82-88km
B	25 APR 1999	O_2	27 APR	91-98km
C	11 JUL 1999	OH	12/13 JUL	82-88km
D	15 DEC 2000	OH	18 DEC	82-88km, 91-98km
E	22/23 MAY 2002	O_2	24 MAY	91-98km
F	24 MAY 2002	OH	25-27 MAY	82-88km

Table 2

Table 2: Ranking of strongest OH intensity bursts (δI_{OH}) normalized by constant long-term means, after applying the high-pass filter (see text). The two-site events are marked by the IDs of Table 1. Deviations of OH and O_2 temperatures (δT_{OH}, δT_{O2}), and O_2 intensity (δI_{O2}) are also given. For the two-site events, the delayed zonal wind disturbance (δu) at CAP is added for the two altitude levels.

#	date	ID	δI_{OH} (norm.)	δT_{OH} [K]	δI_{O2} (norm.)	δT_{O2} [K]	δu [m/s] low	δu [m/s] high
1	15 DEC 00	D	1.20	5.23	0.38	2.87	-19	-18
2	24 MAY 02	F	1.12	18.13	0.77	12.86	-39	-11
3	17 JUN 98		1.05	6.84	0.07	1.47	no wind data	
4	11 JUL 99	C	1.01	9.35	0.08	-1.64	-30/-29	-18/-5
5	01 JUL 98		0.82	4.73	-0.25	-4.12	no wind data	
6	05 JUN 01		0.68	8.85	0.01	-1.65		
7	19 JAN 02		0.67	27.21	1.06	15.92		
8	14 JUL 00		0.66	6.86	0.46	9.12		
9	13 SEP 00		0.66	-0.09	0.17	-3.34		
10	06 JUN 02		0.60	-5.79	-0.55	-19.15		

Table 3

Table 3: Ranking of O_2 intensity bursts. Same notation as Table 2 (but different column order).

#	date	ID	δI_{O2} (norm.)	δT_{O2} [K]	δI_{OH} (norm.)	δT_{OH} [K]	δu [m/s] low	high
1	18 OCT 98		1.32	14.16	0.08	19.69	no wind data	
2	25 APR 99	B	1.11	16.26	0.16	6.67	-1	-20
3	19 JAN 02		1.06	15.92	0.67	27.21		
4	23 MAY 02	E	1.03	16.61	0.32	12.04	-3	-31
5	10 APR 99	A	0.86	16.28	-0.31	4.80	-24	-35
6	23 JUN 99		0.81	13.37	0.45	6.97		
7	03 JAN 02		0.79	9.80	0.30	11.43		
8	16 SEP 02		0.79	22.07	-0.02	6.10		
9	07 AUG 98		0.78	16.62	-0.01	3.99	no wind data	
10	24 MAY 02		0.77	12.86	1.12	18.13		