Comparison of southern hemisphere radiosonde and LIMS temperatures at 100 mb

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SUMMARY

Radiosonde and satellite-derived 100 mb temperatures over New Zealand at 12 GMT are compared for the 1978–79 summer. The satellite measurements are made by the Nimbus-7 Limb Infrared Monitor of the Stratosphere (LIMS) instrument. The co-located LIMS temperature information consists of synoptically-mapped values (for 12 GMT), as well as the primary nighttime orbital retrievals valid at ~1030 GMT.

The radiosonde time series of temperature is dominated by temporal fluctuations associated mainly with the eastward passage of waves which have characteristic periods of 4–5 and 11–12 days and peak-to-peak amplitudes of 10–15 K. In agreement with previous (northern hemisphere) 100 mb LIMS validation studies, the New Zealand orbital LIMS temperatures for 100 mb compare quite favourably with the 'ground-truth' radiosonde measurements (r.m.s. difference of ~1.6 K). The corresponding LIMS-mapped temperature time series is also found to exhibit quite close agreement, in terms of temporal phase, with the radiosonde information. However, it is shown that the LIMS-mapped temperature fluctuations suffer from a noticeable attenuation in amplitude (approaching 50% for higher frequency fluctuations), which will therefore impact on the accuracy of LIMS-derived estimates of dynamical quantities such as wind velocity and relative vorticity in the lower stratosphere.

1. INTRODUCTION

The extratropical southern hemisphere tropospheric circulation is characterized during summer by quite vigorous medium-scale transient wave activity in the zonal wavenumber 4–7 range, which attains maximum intensity near 200 mb and often exhibits eastward phase propagation with typical periods of 1–2 weeks in mid-latitudes (e.g. Salby 1982; Fraedrich and Kietzig 1983; Hamilton 1983; Randel and Stanford 1985). These disturbances are apparently closely related to baroclinic processes (storm tracks) in the lower-middle troposphere (see e.g. Trenberth 1982, Figs. 11c, d) and occasionally will exert a marked influence on the lower stratospheric summer circulation. For example, analysis of Nimbus-7 temperature and trace gas information provided by the Limb Infrared Monitor of the Stratosphere instrument (LIMS) during the 1978–79 southern hemisphere summer indicates that the occurrence of medium-scale wave activity can lead to enhanced meridional transfers of quasi-conservative tracers such as potential vorticity and ozone (Miles and Grose 1986). Given the transient, propagating nature of these medium-scale eddies, it is natural to ask to what extent the archived LIMS satellite data have successfully resolved such fluctuations. A time-series intercomparison of in situ and LIMS temperature information has therefore been made to aid in further assessing the quality of the LIMS orbital and synoptically-mapped temperature data which serve as a basis for calculating satellite height fields and, hence, more complex dynamical quantities such as relative vorticity.
2. Data

The aforementioned observational studies indicate that transient medium-scale wave activity is most prominent near 45°S in the upper troposphere and lower stratosphere. Radiosonde (RAOB) temperature data have therefore been obtained in time-series format from the Invercargill Airport Station in New Zealand (~46°4'S 168°3'E) for the duration of the LIMS experiment (25 October 1978 to 28 May 1979). In this note, the 12 GMT 100 mb time series for summer is described (1 November 1978 to 28 February 1979). The 12 GMT data have been selected because this is the archived map time for the gridded LIMS temperature data; furthermore, the 12 GMT Invercargill RAOB ascents are night soundings and uncertainties related to a solar heating bias are therefore absent from the intercomparison. There are several reasons for considering the 100 mb time series: Firstly, 100 mb is the lowest LIMS archived analysis level; secondly, the actual medium-scale temperature wave amplitudes attain largest values as the tropopause region is approached (see e.g. Randel and Stanford 1985); and finally, the accuracy and reporting frequency of radiosonde measurements deteriorate above the 100 mb level. The Invercargill measurements were made using the U.S.A. VIZ instrument and radiation corrections were not applied at the station. Recent evaluations of RAOB measurement errors indicate that the VIZ 100 mb night temperature measurements have a mean negative bias of ~-0.5 K (long-wave cooling error) and a random r.m.s. error of about 0-4 K (Schmidlin et al. 1982, 1986; Nestler 1983; Nash 1986). The RAOB time-series data for the 1978-79 summer have been smoothed with a 1-2-1 operator for the present analysis (missing datum for 13 days are filled by linear interpolation).

Two types of LIMS temperature information are compared with the Invercargill RAOB data: (i) co-located orbital profile values for 100 mb retrieved from the LIMS infrared radiance measurements (IPAT data); and (ii) synoptically-mapped (12 GMT) gridded temperature analyses (MAT data), which are derived from a Kalman filter procedure. The Nimbus-7 LIMS experiment provided temperature and trace gas profiles for the region 64°S to 84°N with the IPAT data archived at ~4° latitude increments and interpolated on to standard constant pressure surfaces starting at 100 mb. The IPAT profiles were retrieved using a limb inversion method which was independent of a priori statistical temperature profile information (Gordley and Russell 1981). The MAT data, in turn, were derived from Kalman-filtering of both ascending and descending IPAT data, which enabled zonal waves 1-6 to be analysed for the mid-latitude 100 mb synoptic map sequence for 12 GMT (Haggard et al. 1986). The synoptic assimilation, which is made in terms of Fourier zonal coefficients, does not explicitly include a latitudinal or vertical (pressure) dependence. Hence, the 12 GMT MAT temperature analyses used in this comparison are smoothed 1-2-1 in latitude to suppress two-grid-length noise. Relaxation times, which vary with zonal wavenumber and pressure, are estimated from a preliminary filter run and range from about five to two days for wavenumbers one and six, respectively, at 100 mb during January 1979.

In contrast to nadir-viewing satellite radiometer systems (e.g. TIROS N SSU), the LIMS observing system is characterized by relatively high vertical resolution, which is ~2.5 km for both the IPAT and MAT temperature information at 100 mb. That is, the minimum vertical extent of wave features that the LIMS instrument can resolve vertically is a temperature disturbance with a half wavelength of 2.5 km and amplitude of 2 K for a signal-to-noise ratio of two. Simulations indicate that the amplitudes of these vertical waves will be attenuated by the combined measurement/retrieval process. A 6-5 km wave will have its 2 K amplitude attenuated by 50%. It should be noted, however, that if adjacent MAT levels are used to study vertical structure, the IPAT resolution of 2.5 km will be degraded to ~3-7 km at 100 mb due to the coarser vertical sampling of the MAT results (e.g. there is ~2.5 km separation between measurements at the 100 and 70 mb levels). The IPAT resolution of 2-5 km applies to any single MAT level. Orbital viewing geometry, retrieval problems, cloud contamination, and smoothing along a tangent-viewing path of ~300 km are additional factors which will, in contrast to the RAOB 'point' measurement, lead to uncertainties in the LIMS temperature data. Thus, one would not expect LIMS to record the full amplitude of the radiosonde time-series temperature pattern.

For further information concerning the LIMS experimental design, performance, and validation of temperature data, the reader is referred to Gille and Russell (1984), Gille et al. (1984) and Ramsberg (1986). The 12 GMT MAT temperature analyses for 44°S and 48°S at 168°3'E have been linearly interpolated to the Invercargill station latitude. The IPAT nighttime data have also been co-located with the 12 GMT RAOB data, when they are located within ~250 km of the station. These orbital profiles are available in the New Zealand sector at ~1030 GMT every six days or so—when the LIMS experiment is operating.
Figure 1. Time-series comparison of 100 mb temperature at Invercargill, New Zealand, between radiosonde 12 GMT measurements (solid line) and LIMS retrievals mapped to 12 GMT (dashed line). Solid circles denote the LIMS orbital retrieved temperatures at ~1030 GMT located within ~250 km of Invercargill.

3. RESULTS

The 100 mb temperatures at Invercargill for the 1978–79 summer are presented in Fig. 1 and consist of the 'ground-truth' 12 GMT RAOB measurements (solid line), and the LIMS IPAT (~1030 GMT) and MAT (12 GMT) estimates (solid circle and dashed line, respectively). The 100 mb temperature time series is dominated by quasi-regular fluctuating wave components which tend to be characterized by dominant periods of about 4–5 days (e.g. 20–28 January), 11–12 days (e.g. 10–27 November), and 22 days (3–25 February). The 4–5 and 11–12-day oscillations are apparently related to eastward-propagating medium-scale weather disturbances in the troposphere which during summer, in particular, tend to be concentrated in a storm track at 45°–55°S from the Indian Ocean to the New Zealand region (Trenberth 1982). This type of organized wave activity is readily discernible from inspection of the daily 100 mb MAT summertime temperature map series (example for November shown in Fig. 2). The dominant periods of oscillation observed over Invercargill are also in accord with the (zonally-averaged) spectral estimates of Salby, Fraedrich and Kietzig, and Randel and Stanford cited in section 1. The 100 mb time series undergoes a noticeable change during February with the emergence of a lower frequency oscillation. Trenberth and Mo (1985) have shown that the New Zealand sector is occasionally influenced during summer by persistent

Figure 2. Southern hemisphere LIMS 100 mb temperature distribution (4 K interval) for 12 GMT on 18, 23 and 28 November 1978 (A, B and C respectively). A polar stereographic map projection for the domain 32°S–60°S is used and the location of Invercargill, New Zealand, is denoted by the solid circle.
stationary anomalies in the form of cut-off lows and highs which are apparently related to increased planetary-scale wave activity. The 100mb temperature fluctuations observed at Invercargill are thus probably more correctly interpreted as being characterized by a superposition of the low and high frequency wave perturbations, as noted by Salby (1982) and Randel and Stanford (1985).

From a general perspective, the results in Fig. 1 indicate a close qualitative level of agreement between the LIMS and RAOB data in detecting the passage of the medium-scale eddies. This is particularly evident in terms of the quite similar temporal trends in the phase of these cold and warm fluctuations. Note that because the LIMS temperature retrieval method is not constrained by RAOB profile information, this measure of agreement (in terms of phase) is primarily a reflection of the overall quality of the LIMS orbital radiance measurements, retrieval and Kalman mapping.

The available IPAT temperatures, of which about one third are located within ~50 km of the RAOB station, exhibit quite close agreement with the RAOB measurements. A comparison of the (unsmoothed) RAOB data and IPAT values (interpolated to Invercargill) yields an average difference (RAOB − IPAT) of about −0.3 K, which is similar to the systematic bias for the 100 mb nighttime VIZ measurements noted in section 2. The corresponding r.m.s. difference between RAOB and IPAT for this (rather small) sample is ~1.6 K, which is nevertheless in agreement with the 100 mb LIMS IPAT validation statistics documented in Gille et al (1984) based on several hundred U.S.A. (VIZ) intercomparisons (which also included daytime RAOB soundings).

Differences between the RAOB and MAT temperatures are larger, with a mean bias (RAOB − MAT) of −1.2 K and a r.m.s. difference of 2.5 K calculated from the entire 120-day sample. Some of this difference is apparently due to an ascending mode (day), descending mode (night), difference in the zonal mean temperature coefficient from the LIMS IPAT data—night being colder than day by about 1 K. If this difference is real, then the combined (day + night) MAT data shown in Fig. 1 are too warm at 12 GMT by about a half (0.5 K), causing the RAOB − MAT bias to be more like −0.7 K. The amplitudes of the temporal oscillations portrayed in the MAT time series are seen to be smaller than depicted in the RAOB information. This apparent loss of intensity is particularly evident during intervals of more rapid temporal variability (e.g. during late November and mid-January). This deficiency may arise from temporal smoothing inherent in the Kalman filtering since the IPAT values are seen to agree more closely with the RAOB fluctuations. By contrast, during the February low frequency oscillation both IPAT and MAT values are in close agreement with RAOB. Of course, the IPAT data, whilst having smaller systematic and random errors, are asymptotic in format and suffer from missing or rejected orbits, and hence must be mapped onto a regular synoptic grid for large-scale dynamical applications.

4. CONCLUSION

The time-series intercomparison described here provides several useful clues as to the benefits and limitations of the LIMS MAT database for performing dynamical studies of transient waves in the lower stratosphere. Perhaps the most encouraging finding to emerge from this study is the apparent qualitative success of the MAT analysis in determining the actual geographical and temporal phase structure of medium-scale transient eddies in the summer lower stratosphere. This achievement implies that the time continuity of the Kalman-filtered temperature maps is of quite a high standard, at least for this class of transient eddies. A less encouraging feature of the comparison, however, is the apparent attenuation of the actual wave amplitudes in the MAT analyses which, it can be assumed, will impact on the accuracy of derived dynamical quantities, such as hemispheric potential vorticity distributions. This loss of amplitude appears to have arisen not only as a result of the spatial resolution of the IPAT data but also from the space- and time-smoothing properties in the MAT processing. For example, amplitudes of vertical waves can be reduced just during the vertical interpolation of the IPAT data to the 100 mb pressure level prior to use of the Kalman filter. Intercomparisons have also been made for the 50 mb level (although fewer RAOB reports are available) and, in general, similar conclusions apply. It should be noted that Invercargill RAOB winds are also available, although to date, they have not been intercompared. (The reader is referred to the LIMS-RAOB/ROCOCB wind comparison by Smith and Bailey (1985).)
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