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THE ACCURACY OF TEMPERATURE DISTRIBUTIONS USED TO DERIVE THE NET TRANSPORT FOR A ZONALLY AVERAGED MODEL

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1 INTRODUCTION

Distributions of tracer-like species can be derived using a zonally-averaged residual mean circulation (RMC). The net diabatic heating rate for the RMC is calculated using temperature, ozone and water vapor data sets. Guthrie *et al.*, [1990] (hereafter G90) compared RMCs from a 4-year (1978-1982) National Meteorological Center (NMC) data set with those from Limb Infrared Monitor of the Stratosphere (LIMS) temperatures. They used LIMS ozone and water vapor in both calculations. They found that RMC differences were largest in the upper stratosphere and lower mesosphere at lower latitudes. Their calculated N_2O tracer distribution from the LIMS-derived RMC showed better agreement with the N_2O from the Stratospheric and Mesospheric Sounder (SAMS) than that calculated with the NMC data. They also carried out sensitivity studies by changing the temperature and ozone data sets and found that the RMCs were particularly sensitive to the temperatures.

Callis *et al.*, [1987] (hereafter C87) derived RMCs using LIMS Kalman - filtered temperature and ozone (Remsberg *et al.*, [1990]) available on the LIMS Map Archive Tape (LAMAT). They also derived an RMC using the Barnett and Corney [1985] (hereafter BC) multiyear climatology and the Keating and Young [1985] (hereafter KY) ozone climatology. The LIMS LAMAT water vapor was used in both of their calculations. Corrections were applied to the net heating in both cases in order to preserve global mass balance in the net circulation at a given pressure level. Differences in the corrected net heating for March (LIMS minus BC) are greater than 1°K/day at high latitudes (see C87, their Fig. 14c). The LIMS and KY ozone mixing ratios agree within their error bars. However, the LIMS/BC temperature differences are as much as 10°K. Methods for calculating the infrared cooling due to CO_2 must also be accurate (Olaguer *et al.*, [1992]).

Both G90 and C87 attribute the differences in calculated RMCs to temperature differences. G90 dismisses interannual variability in the temperature as a problem based on the observed variations in the 4-year NMC data set, but C87 suggest that the RMC differences in LIMS (specific year) and BC (multiyear) may be due to interannual variability. Although C87 note that high vertical resolution temperatures are necessary for accurate calculations of the heating rates, neither G90 nor C87 have explored the issue of accuracy in any detail.

2 OBJECTIVE AND APPROACH

The LIMS data set used by G90 and C87 are from measurements made in 1978-79. The NMC temperatures used by G90 and the BC temperatures used by C87 are multiyear climatologies. Temperature differences in the two data sets can arise from interannual variability, measurement errors or the objective analysis technique.

In this study we compare LIMS/NMC monthly zonal mean temperatures for the same time period and address the issue of temperature accuracy. Since NMC analyses in the upper stratosphere are derived from nadir-viewing sounder data, we compare LIMS/NMC temperatures with time series of high vertical resolution rocketsonde and radiosonde (RAOB) data. We also compare LIMS temperatures with the BC climatology and with the SAMS temperatures.

The constituent retrieval from a mid-infrared limb emission measurement is particularly sensitive to error in the black body source function and thus the input atmospheric profile. For example, a 2°K bias error in the temperature at 10 hPa can introduce a 20% error in retrieved ozone mixing ratio (Remsberg *et al.*, [1984]), and a 15% error in retrieved water vapor mixing ratio (Russell *et al.*, [1984]). The SAMS N_2O and CH_4 results are even more sensitive to temperature bias at 10 hPa (Jones and Pyle, [1984]). Thus, the independent comparisons of correlative and satellite retrieved constituent mixing ratios are an indirect measure of the accuracy of the temperature profiles. We verify our estimates of temperature bias by referring to the quality of LIMS ozone and water vapor and SAMS N_2O and CH_4.

3 THE QUALITY OF STRATOSPHERIC TEMPERATURES

Temperature differences for April 1979 for LIMS minus NMC are shown in Fig. 1. (Note that the difference plot [Figure 3-f] in G90 is for NMC minus LIMS. Also their NMC is from the 4-year climatology). Both the LIMS and NMC temperatures are analyses at 12 UTC. The NMC fields used here have been modified for easier use in the analysis of stratospheric temperature fields. That is, the originally gridded NMC data are represented as coefficients of a harmonic series. Then the monthly zonal mean plots are created using the first coefficient. The NMC analyses

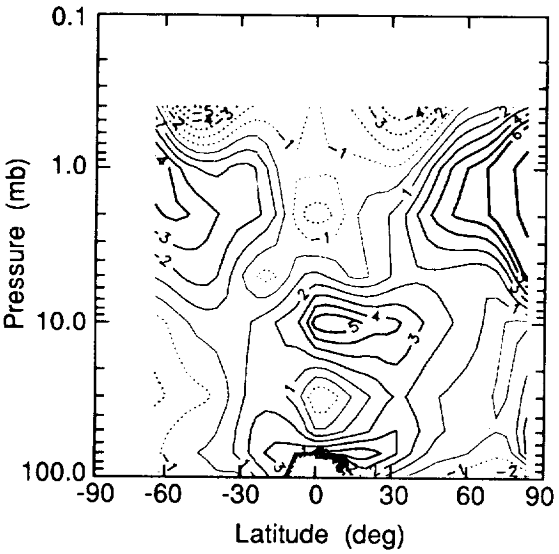

Fig. 1 Zonally-averaged, monthly-mean temperature differences for LIMS minus NMC for April 1979.

from 70 to 0.4 hPa in the southern hemisphere are based on satellite soundings. In the northern hemisphere the NMC analyses are based on satellite soundings and rocketsonde data from 5 to 0.4 hPa. Prior to 1984 the northern hemisphere NMC stratospheric analyses rely on RAOB data from 70 to 10 hPa. In addition, the results equatorward of 20° N are extrapolated from that latitude (Randel, [1987]). Differences near 100 hPa in Figure 1 at low latitudes are because LIMS retrievals do not follow the sharp tropical tropopause and are too warm. Differences at 10 hPa are primarily due to the NMC extrapolation of N. H. RAOB data to the Equator; thus, the effects of tropical waves are masked there.

LIMS temperatures have a vertical resolution of about 2.5 km. The information content in NMC data between 5 and 0.4 hPa comes from nadir-viewing Vertical Temperature Profile Radiometer (VTPR) and Stratospheric Sounding Unit (SSU) (after 2/25/79) instruments. The effective vertical halfwidth for VTPR and SSU channels in the upper stratosphere (Peckham [1974]) is of the order of 15 to 17km. NMC uses a vertical regression procedure which improves the resolution of its retrieved profiles to about 10km. Such a coarse resolution affects the accuracy of NMC temperatures at a given pressure-altitude. The temperature error patterns for nadir-sounders oscillate with a wavelength equivalent to the vertical resolution of the measurement (Jackson *et al.*, [1990]). This characteristic is particularly evident in the upper stratosphere at low latitudes. Similar error patterns will apply to the low resolution nadir-sounder BC temperatures and the medium resolution limb viewing SAMS temperatures. Temperature accuracy during disturbed atmospheric conditions is also affected if the NMC climatological profile shape used for regression is not representative. This aspect of the NMC retrievals may also degrade their accuracy at high latitudes near the stratopause.

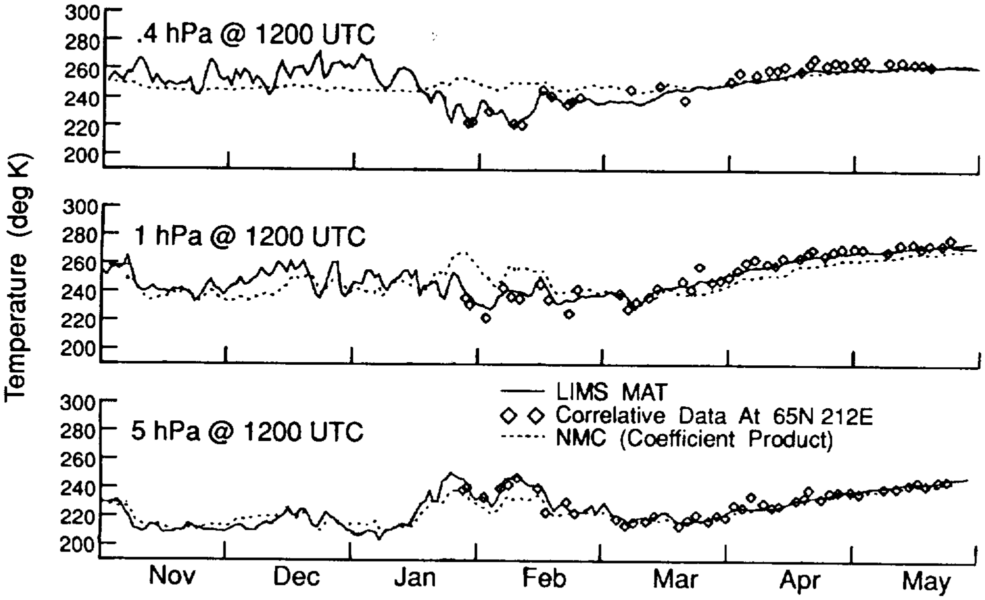

Fig. 2 Temperature-time series at Poker Flat, Alaska (65N, 212E) at a) 0.4 hPa, b) 1 hPa and c) 5 hPa. Solids are LIMS, dotted are NMC and diamonds are rocketsondes.

4 RESULTS

Previous comparisons of LIMS temperatures with correlative datasonde values (Gille *et al.*, [1984]) showed agreement to better than 3°K from 50 to 0.5 hPa over the 7-month LIMS period. However, significant differences may have occurred within a subset of that period. To check this, we show time series comparisons (Fig 2) at Poker Flat (65N 212E) at three pressure levels (5, 1 and 0.4hPa). LIMS reflects the day-to-day variations in temperature recorded by high resolution datasondes. NMC also follows the datasonde values, although the variations are much smoother. This behavior for NMC is expected given its lower vertical resolution. There are also clear biases for NMC for some periods. For example, Fig. 1 shows LIMS to be 5 K warmer than NMC at 1 hPa and 65N. Figure 2 shows a similar difference at 1 hPa for April, but the datasonde points support the LIMS results. The comparisons in Figure 2 also verify that there is little information in the NMC result at 0.4 hPa. Large-scale variations at low latitudes such as semi-annual oscillations, are underestimated by NMC, which will lead to significant biases in a derived RMC at those heights.

Because the effects of planetary wave activity are weak for both hemispheres during April, the vertical temperature distribution is fairly uniform in latitude and hence it becomes easier to identify and interpret small differences between two different climatologies. We show the LIMS minus BC zonal mean for April in Figure 3. The BC climatology relies on radiosonde data between 100 hPa and 30 hPa and nadir sounder satellite data (SCR and PMR) above 30 hPa. There are marked differences in the patterns for Figures 1 and 3 in the upper stratosphere and mesosphere, part of which may be due to the different years of the BC climatology. However, there is a curious horizontally-banded structure in the patterns of Figure 3. We relate this feature to the error patterns that occur between temperature profiles of differing vertical resolution (Jackson *et al.*, [1990])-LIMS is about 2.5 km, BC ranges from 12 km in the stratosphere to 20 km in the mesosphere.

Figure 4 is the LIMS minus SAMS temperature difference for April 1979. Again a banded structure is present in the difference pattern, but the vertical wavelength for that pattern is shorter than in Figure 3. This change is expected because vertical resolution for SAMS is between 8 to 12 km. Although the difference pattern is most uniform with latitude for April, the results are similar for other months.

5 DISCUSSION

The retrievals of ozone, water vapor, NO_2 and HNO_3 from the LIMS instrument are based on temperatures retrieved as a function of pressure. As noted earlier, the errors in temperature can introduce noticeable errors in retrieved species. Suppose that the differences of order +5°K at 10 hPa in Fig. 1 are due to LIMS temperature errors. This would cause LIMS to underestimate ozone by nearly 50% (Remsberg *et al.*, [1984]) and water vapor by 40%. Remsberg and Wu [1989] reported LIMS ozone comparisons with the Solar Backscatter Ultraviolet (SBUV) version 5 data for the period 1978-79. The SBUV diffusor plate degradation is believed to have been minimal during this period. Those comparisons for Umkehr layer 6 (centered at 11 hPa) are better than 8% for April at all latitudes. The comparison for layer 5 (22 hPa) shows that LIMS calculates more ozone compared to SBUV for layer 5 in the tropics by about 30%. If LIMS temperatures are too warm based on Fig. 1, then the corrected LIMS temperatures would lead to even larger differences between LIMS and SBUV ozone in layer 5. Remsberg and Wu [1989] also show that LIMS and SAGE I ozone agrees at 10 hPa. Collectively, these comparisons indicate that the LIMS temperatures are accurate to better than ±2°K.

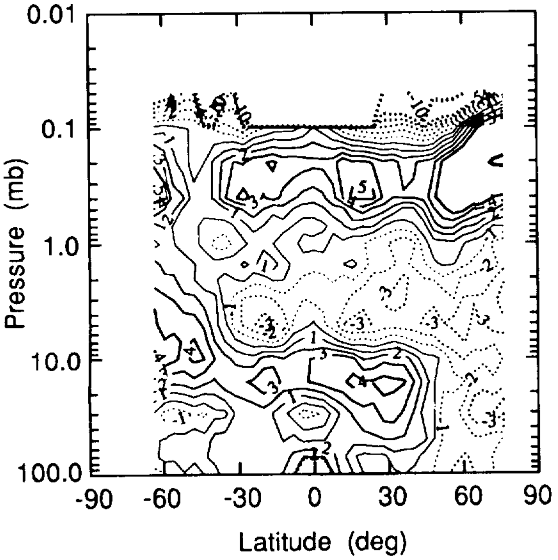

Fig. 3 Same as in Figure 1, but for LIMS minus BC for April.

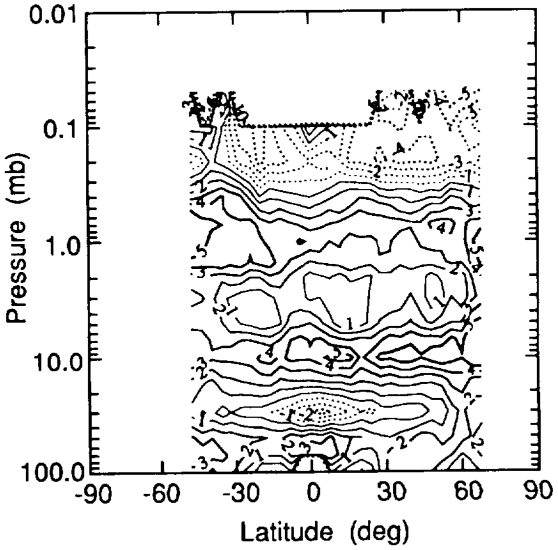

Fig. 4 Same as in Figure 1, but for LIMS minus SAMS for April 1979.

Similarly, the retrieved LIMS water vapor is very sensitive to the input temperature profile. Bhatt *et al.*, [1990] have shown that LIMS agrees with ATMOS and SAGE II water vapor for May at 30N to better than 20 percent.

Jones and Pyle [1984] report significant differences between SAMS profiles and correlative balloon measurements of N_2O and CH_4 at 26 to 32 km–an altitude region where the SAMS retrievals are particularly sensitive to temperature bias (see their table 2). If we assume that the LIMS temperatures at 10 hPa are correct, then Figure 4 indicates that SAMS temperatures are too cold by 4°Kwhich could easily explain the observed bias between the SAMS species and the correlative measurements. On the other hand, temperature differences at 7 to 2 hPa are less than 2°K; the SAMS species results should be relatively free of temperature bias there.

6 CONCLUSIONS

Comparisons of satellite-derived temperatures with correlative temperatures indicate that the LIMS temperatures are accurate and contain more of the needed vertical resolution for calculating a residual mean circulation for transporting tracer-like species. Generally, the LIMS temperatures are accurate to at least 2°K. Other satellite data sets are comprised of temperatures with coarser vertical resolution, leading to biases that occur with an error pattern that is characteristic of their resolution. Their biases exceed 2°K at some altitudes.

Retrievals of species using an infrared limb emission technique are sensitive to any temperature bias. Generally, the LIMS comparisons with other data sets for ozone and water vapor are good to better than 20%; this represents an independent confirmation of the quality of LIMS temperatures. Zonal mean comparisons between LIMS and SAMS temperatures also indicate agreement to better than 2°K from about 7 to 2hPa. Therefore, we are confident that SAMS N_2O and CH_4 are relatively free of temperature bias in that region. These factors support the generally good agreement in G90 between model N_2O transported using a LIMS-derived RMC and the N_2O contours from SAMS.

REFERENCES

Barnett, J. J., and M. Corney, Temperature data from satellites, in *Middle Atmosphere Program Handbook, vol 16*, Edited by K. Labitzke, J. J. Barnett, and B. Edwards, 3-11 and 47-85, 1985. (Available from SCOSTEP Secretariat, Univ. of Illinois, 1406 Green St., Urbana, IL, 61801).

Bhatt, P. P., E. E. Remsberg, J. M. Russell III and L. L. Gordley, Revised determination of stratospheric water vapor from Nimbus 7 LIMS, *EOS Trans. AGU, 71*, 1247, 1990.

Callis, L. B., R. E. Boughner, and J. D. Lambeth, The stratosphere: climatologies of the radiative heating and cooling rates and the diabatically diagnosed net circulation fields, *J. Geophys. Res., 92*, 5585-5607, 1987.

Gille, J. C., J. M. Russell III, P. L. Baily, L. L. Gordley, E. E. Remsberg, J. H. Lienesch, W. G. Planet, F. B. House, L. V. Lyjak, and S. A. Beck, Validation of temperature retrievals obtained by the limb infrared monitor of the stratosphere (LIMS) experiment on Nimbus 7, *J. Geophys. Res., 89*, 5147-5160, 1984.

Guthrie, P. D., C. H. Jackman, T. L. Kucsera, and J. E. Rosenfield, On the sensitivity of a residual circulation model to differences in input temperature data, *J. Geophys. Res., 95*, 873-882, 1990.

Jackson, D. R., R. S. Harwood, and E. Renshaw, Tests of a scheme for regression retrieval and time-space interpolation of stratospheric temperature from satellite measurements, *Q. J. R. Meteorol. Soc., 116*, 1449-1470, 1990.

Jones, R. L., and J. A. Pyle, Observations of CH_4 and N_2O by the NIMBUS 7 SAMS: a comparison with in situ data and two-dimensional numerical model calculations, *J. Geophys. Res., 89*, 5263-5279, 1984.

Keating G. M., and D. F. Young, Interim reference ozone models for the middle atmosphere, in *Middle Atmosphere Program Handbook, vol 16*, Edited by K. Labitzke, J. J. Barnett, and B. Edwards, p.205, 1985. (Available from SCOSTEP Secretariat, Univ. of Illinois, 1406 Green St., Urbana, IL, 61801).

Olaguer, E. P., H. Yang, and K. K. Tung, A reexamination of the radiative balance of the stratosphere, *J. Atmos. Sci. 49*, 1242-1263, 1992.

Peckham, G., The information content of remote measurements of atmospheric temperature by satellite infra-red radiometry and optimum radiometer configurations, *Q. J. R. Meteorol. Soc., 100*, 406-419, 1974.

Randel, W. J., Global atmospheric circulation statistics, 1000-1 mb, *NCAR Tech Note, TN-295*, Boulder, CO. 245 pp., December 1987.

Remsberg, E. E., and C.-Y. Wu, Comparisons of satellite ozone data in the lower stratosphere for 1978/1979, *J. Geophys. Res., 94*, 6419-6434, 1989.

Remsberg, E. E., J. M. Russell III, J. C. Gille, L. L. Gordley, P. L. Bailey, W. G. Planet and J. E. Harries, The validation of Nimbus 7 LIMS measurements of ozone, *J. Geophys. Res., 89*, 5161-5178, 1984.

Remsberg, E. E., K. V. Haggard and J. M. Russell III, Estimation of synoptic fields of middle atmosphere parameters from Nimbus 7 LIMS profile data., *J. Atmos. Ocean Tech., 7*, 689-705, 1990.

Russell, J. M. III, S. Solomon, L. L. Gordley, E. E. Remsberg, and L. B. Callis, The variability of stratospheric and mesospheric NO_2 in the polar winter night observed by LIMS, *J. Geophys. Res., 89*, 7267-7275, 1984.