LIMS Version 6 Level 3 Dataset

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Contents

Abstract

This report describes the Limb Infrared Monitor of the Stratosphere (LIMS) Version 6 (V6) Level 3 data products and the assumptions used for their generation. A sequential estimation algorithm was used to obtain daily, zonal Fourier coefficients of the several parameters of the LIMS dataset for 216 days of 1978-79. The coefficients are available at up to 28 pressure levels and at every two degrees of latitude from 64°S to 84°N and at the synoptic time of 12 UT. Example plots were prepared and archived from the data at 10 hPa of January 1, 1979, to illustrate the overall coherence of the features obtained with the LIMS-retrieved parameters.

1 Introduction

The Nimbus 7 Limb Infrared Monitor of the Stratosphere (LIMS) instrument operated from October 25, 1978 through May 28, 1979 [Gille and Russell, 1984]. Its measured limb radiance profiles were processed originally with Version 5 (V5) Level 2 and 3 algorithms and archived in 1982-83. Subsequently, improved Level 2 profiles were retrieved with an updated, Version 6 (V6) algorithm and archived in 2002, in order to provide results that are more compatible with datasets from the Upper Atmosphere Research Satellite (UARS) (1991-2005), the Earth Observing System (EOS) Aura satellite (2004-present), and the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite (2002-present). The quality and improvements for the LIMS V6 profiles were reported for temperature and geopotential height, for ozone, for water vapor, and for nitric acid and nitrogen dioxide, respectively, in Remsberg et al. [2004; 2007; 2009; and 2010].

The Nimbus 7 satellite operated in a Sun-synchronous, near polar orbit, and LIMS obtained its profiles at about 1:30 pm and 10:30 pm local time at low to middle latitudes. LIMS had a duty cycle of about 5-6 days on, followed by 1-2 days off for much of its 7¼ month mission life. The orbital measurements of LIMS and its retrieved profiles for any given day are necessarily asynoptic on the global scale (i.e., not a "snapshot" of its global field). A sequential estimation (SE or Level 3) algorithm was applied to each of the V6 profile parameters, in order to provide their synoptic fields and having no daily gaps. Their Level 3 daily, zonal Fourier coefficients were obtained as a function of pressure and latitude for the synoptic time of 12 UT in the manner of Remsberg et al. [1990]. Such data products have been very useful for studies of the effects of atmospheric transport on the various LIMS parameters (e.g., Leovy et al. [1985]).

The present report characterizes that V6 Level 3 (map) product. Of course, important gains were already made for the absolute values of the V6 profile parameters, as a result of improvements in the registration of the LIMS radiance profiles, in the spectroscopic line parameters for their retrieval, and in accounting for the effects of any interfering species. The V6 profile retrievals also used all the sampled points of the radiance profiles, leading to the somewhat better precisions (σ) that are part of the input to the SE algorithm. Furthermore, it is noted that because the V5 SE algorithm used σ-values that were set 1.5 to 2 times larger than the V5 precisions, the V6 SE results should be revealing more details in the fields of its mapped parameters. Section 2 is a brief description of the approach to the V6 SE analysis and of the parameters that control its algorithm. Section 3 reports on some findings from the V6 zonal coefficients that indicate the coherence and relative accuracy of their fields, as well as several of the limitations that remain.

2 Data characteristics and algorithm approach

The LIMS V6 profiles were generated and output at about every 1.6 degrees of latitude along their orbital, tangent-point tracks and tabulated at 18 levels per decade of pressure and with a nearly equal vertical spacing of 0.88 km. Conveniently, the UARS Level 3A data have pressure increments that are a subset of the LIMS V6 profile levels. In an attempt to obtain somewhat more detail about variations of the LIMS V6 parameters, it was decided to generate zonal Fourier coefficients from these profiles that can be used to generate synoptic maps of their parameters. The coefficients are calculated at every two degrees of latitude and at 28 pressure levels from 0.01 hPa to 316 hPa, which is the approximate pressure range of the LIMS temperature and geopotential height profiles. In other words, SE analyses were conducted at 6 levels per decade of pressure or at a vertical spacing of about 2.64 km. By comparison the LIMS V5 Level 3 product was obtained from profiles at only every 4 degrees of latitude and at a maximum of 18 pressure levels that were not spaced at equal intervals of log pressure. LIMS V6 also has profiles of geopotential height (Gphgt); they were processed to Level 3, too.

The SE algorithm that was used for the V5 Level 3 map analysis at each pressure level and latitude is described in detail in Remsberg et al. [1990] and in references therein. For example, synoptic fields of temperature T were estimated at a particular time t=12 UT (local noon at the Greenwich meridian or 0 longitude), latitude θ, and pressure p, according to the vector expression

$$T_{t,\theta,p}(\lambda) = \mathbf{K}^T(\lambda) \bullet \mathbf{X}_{t,\theta,p} \tag{1}$$

$$\text{where} \quad \mathbf{K}^T(\lambda) = [1, \cos\lambda, \sin\lambda, \cos2\lambda, ..., \sin M\lambda] \tag{2}$$

λ is longitude
M is the order of the Fourier series, less than or equal to 6, and
$\mathbf{X}$ is the vector of Fourier coefficients $\mathbf{X}_j$ (j = 1,2,…, 2M+1).

The superscript T denotes the transpose of a vector. For the rest of this report, the subscripts θ, t, and p will be understood. The SE algorithm yields a best fit field for a particular (UT) time, and it is applied in its discrete form

$$T_n = \mathbf{K}_n^T \bullet \mathbf{X}_n \tag{3}$$

where T_n is the measured value of the field at time t_n and longitude λ_n. This approach is suited to handling any asynoptic dataset, where the instrument is off for whole orbits or even days.

The SE algorithm transforms a time series of asynoptic data points to a set of zonal Fourier coefficients at a given synoptic time. In effect, an initial estimate of the parameter field is assumed and then the estimate is updated by the sequential assimilation of each measurement from a data time series. In addition, there must be estimates available of both the uncertainty in the input data and the rate of increase of the uncertainty of the field. In other words, since all the measurements T_n that are used to calculate the field $\mathbf{X}_n$ involve some error (assumed to be random), there is an uncertainty associated with $\mathbf{X}_n$ represented by an error covariance matrix $\mathbf{S}_n$. That uncertainty is expressed as a variance σ_n^2, according to

3

$$\sigma_n^2 = \mathbf{K}_n^T \mathbf{S} \, \mathbf{K}_n. \tag{4}$$

When $\mathbf{X}_n$ is used to estimate the field at times other than t_n, the error covariance matrix must be increased by an amount $(d\mathbf{S}/dt) \, \Delta t$. In a first pass through the data the value of $d\mathbf{S}/dt$ must be assumed, but thereafter it may be calculated from the output and used for subsequent runs.

The SE algorithm functions according to the elements of its so-called "virtual dataset," or $\sigma_{n,m}^2$, $d\mathbf{S}/dt$, and $d\mathbf{X}/dt$. These three elements determine how closely the SE algorithm must try to fit the individual points in a time series of the profile data. The most important element is $\sigma_{n,m}$, which is based on an empirical estimate of the measurement precision for single profiles of a given LIMS parameter. Those estimates were obtained as the minimum standard deviations from among the sets of 6 adjacent profiles along orbits near 64˚S for November 8, 1978. They are given in Table 1 for each parameter, and they remain unchanged with latitude and for each 28-day analysis sequence. Values in Table 1 beyond each of their retrieved pressure ranges for the LIMS species have been merely extrapolated. Note that part of the precision estimate may be due to the real, small-scale atmospheric variability for a given parameter. In fact, the precision estimates for ozone grew larger than expected for the levels of 146 to 316 hPa, so those estimates were reset to 0.10 ppmv. Precision estimates for geopotential height were set to 30 meters below the 1-hPa level; its estimates for the mesosphere were set to the minimum values from the ascending orbital segments near 50˚S on January 16, 1979, when the presence of the summer, stratospheric easterlies inhibit the upward propagation of planetary wave activity.

The second important element of the "virtual dataset" is the error covariance matrix or $\mathbf{S}$, which multiplies the vector of the 13 prescribed longitudes (the maximum number of coefficients or the sine and cosine values for the 6 zonal waves plus the zonal mean value). More critical is the estimate of how $\mathbf{S}$ grows in time. That element, $d\mathbf{S}/dt$, is approximated by

$$d\mathbf{S}/dt = \mathbf{S}_{clim} / \tau \;\;, \tag{5}$$

where $\mathbf{S}_{clim}$ is the climatological covariance matrix for the observed parameter field, and τ is an estimate of the time for the autocorrelation of the wave amplitude as it decays to the noise level or precision of the data. The parameter, $d\mathbf{X}/dt$, can be used for the calculation of τ [Remsberg et al., 1990]; but, all of its elements were set to zero for V6. The so-called "relaxation times" or τ-values are a function of the amplitude of a given zonal wavenumber, and they are intended to represent the memory of how the data fields appeared at a previous time step. That memory is typically short for the small-amplitude, intermediate-scale and traveling waves, but longer for the zonal mean and for the standing, zonal-waves 1 and 2. Data gaps for the LIMS measurements occurred about every 5 days, but for no more than a day or two. Therefore, the minimum relaxation time had to be of that order. In addition, memory is typically no longer than 3 to 4 days for the zonal mean and even shorter for waves 1 and 2 during dynamically active, wintertime periods [Remsberg et al., 1990]. For this reason the values of τ in Table 2 were used for the SE algorithm for all latitudes, pressure levels and months of the LIMS V6 data.

The steps for an operational SE processing are given in Section 4 of Remsberg et al. [1990]. The values for $\mathbf{S}_{clim}$ in Eq. (5) were obtained by allowing $d\mathbf{S}/dt$ to be large and independent of

wavenumber in each preliminary, 28-day run. The preliminary run was constrained primarily by the precision values of Table 1. New values of dS/dt for the final runs were obtained from the output fields of the preliminary runs and the values of τ from Table 2. The quality of the final result can be judged by the continuity of its mapped product with pressure, latitude, and time.

The SE algorithm generates daily vectors (**X**) of sine and cosine coefficients representing the zonal mean and the 6 lowest zonal wave numbers, all at the synoptic time of 12 UT. By considering both the ascending and descending orbital data segments, a total of up to 13 daily, zonal coefficients were generated at a given pressure and latitude. Separate analyses extend to only 4 zonal waves for the subsets of the descending and of the ascending orbital data segments. The V6 SE algorithm was applied to the Level 2 data in 28-day sequences that overlapped at end points. The algorithm was run forward and then backward in time; their separate daily results were then averaged and output to file. For the case of the diurnally-varying NO_2, the SE algorithm was applied separately to its daytime and its nighttime profiles. Thus, the Level 3 output for NO_2 merely indicates the effects of the zonal waves on its daytime or nighttime distributions, while ignoring the rather large changes near sunrise and sunset that must be present in a truly synoptic map of NO_2.

The Level 3 output files for a given parameter contain the Fourier coefficients for a given measurement mode (ascending-1, descending-2, or combined-3) and at a latitude and pressure level. The number that follows the coefficients for each output line of the Level 3 profile is the RMS of the set of differences of the observed LIMS Level 2 values and their estimates as obtained using the Fourier coefficients at the longitudes of each of the observed profiles. Essentially, it is a measure of the fit between the estimated 12 UT field and all the profile data taken within 12 hours of that time. If the measured field is stationary and the SE model is adequate, then the RMS difference should approximate $\sigma_{n,m}$. The last value of each output data line is the estimated uncertainty for the coefficients themselves.

The Level 3 files have been written to a DVD in ASCII format along with separate "Read Me" and plot files. They are archived at the NASA Goddard Earth Sciences and Data Information Services Center or GES DISC (http://disc.gsfc.nasa.gov/).

3 Comments about the LIMS V6 Level 3 products

One set of postscript files named "jan1_10mb.ps" was generated and archived in addition to the Level 3 coefficients. That set consists of 8 polar stereographic plots of the various LIMS V6 Level 3 parameters at 10 hPa for January 1, 1979. These example fields were created using grid point values calculated from the Fourier coefficient data at the latitude spacing of 2 degrees (plots from 64°S to Equator and also from 84°N to Equator) and with a longitude spacing of 5.625 degrees (0 to 360°E). The northern and/or southern hemispheric plots indicate the good continuity of the data fields and their coherent structures due to the effects of large-scale transport by the zonal waves. One can envision being able to regenerate daily sequences of ozone and geopotential height [e.g., Leovy et al., 1985], time series of temperature and potential vorticity [e.g., Dunkerton and Delisi, 1986], and time series of potential vorticity, ozone, water vapor, and nitric acid [e.g., Butchart and Remsberg, 1986]. It is expected that similar diagnostic analyses of the V6 data will be shown to be even more representative of the atmospheric state of 1978/79 than was the case from the V5 data.

Hitchman and Leovy [1985] compared the day minus night differences in the LIMS V5 temperatures with those reported from rocketsonde soundings taken at equatorial latitudes. They reported that the tidal amplitudes from the LIMS V5 dataset appeared to be dampened considerably, at least compared with those from the rocketsonde measurements. Remsberg et al. [2004] gives several examples of the improved agreement for the V6 temperature profiles as compared with co-located rocketsondes, particularly for the mesosphere. It is noted that the V6 Level 1 and 2 algorithms provide for a better estimate of the orbital attitude of the LIMS instrument, which slightly alters the registration of its measured radiance profiles. The V6 temperature retrievals were also begun at altitudes of the mesosphere that are higher than those for V5, and this change has improved the accuracy of the V6 temperatures in the middle mesosphere. Even so, the apparent tidal amplitudes are not increased by much with V6, perhaps because of the moderate vertical resolution of the retrieved profiles.

There are also some limitations from the Level 3 coefficients. For instance, the successive up/down radiance scans from LIMS were averaged along the orbits, in order to minimize the effects of intermediate-scale, spacecraft motions prior to profile retrieval. But a net effect of the averaging is a smoothing of the signatures of vertically-propagating gravity waves. In another example, one can analyze the LIMS V6 temperature profile data for signatures of Kelvin waves, in the manner of Hitchman and Leovy [1986]. In Section 3a of their paper they reported finding Kelvin wave amplitudes from their analyzed LIMS V5 temperatures that appeared to be dampened. The amplitudes of vertically-propagating Kelvin waves are similar to those of the temperature tides. While it should be easy to resolve the amplitude and vertical propagation of the slow to intermediate scale Kelvin waves, the time variations of the diurnal tide signals are under-sampled with the sun-synchronous measurements of LIMS. The 12 UT ascending and descending wave-1 coefficients of LIMS Level 3 are really only representative of two local times that are separated by about 10 hours. Therefore, a clear separation of Kelvin wave-1 from the tidal signatures may be somewhat problematic with the LIMS dataset, particularly in the mesosphere. Similar caveats apply to ozone, which also varies diurnally in the upper stratosphere and mesosphere.

References

Butchart, N., and E. E. Remsberg (1986), The area of the stratospheric polar vortex as a diagnostic for tracer transport on an isentropic surface, *J. Atmos. Sci., 43*, 1319-1339.

Dunkerton, T. J., and D. P. Delisi (1986), Evolution of potential vorticity in the winter stratosphere of January-February 1979, *J. Geophys. Res., 91*, 1199-1208.

Gille, J. C., and J. M. Russell III (1984), The limb infrared monitor of the stratosphere: experiment description, performance and results, *J. Geophys. Res., 89*, 5125-5140.

Hitchman, M. H., and C. B. Leovy (1986), Evolution of the zonal mean state in the equatorial middle atmosphere during October 1978-May 1979, *J. Atmos. Sci., 43*, 3159-3176.

Hitchman, M. H., and C. B. Leovy (1985), Diurnal tide in the equatorial middle atmosphere as seen in LIMS temperatures, *J. Atmos. Sci., 42*, 557-561.

Leovy, C. B., C.-R. Sun, M. H. Hitchman, E. E. Remsberg, J. M. Russell III, L. L. Gordley, J. C. Gille, and L. V. Lyjak (1985), Transport of ozone in the middle stratosphere: evidence for planetary wave breaking, *J. Atmos. Sci., 42*, 230-244.

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

Remsberg, E., M. Natarajan, B. T. Marshall, L. L. Gordley, R. E. Thompson, and G. Lingenfelser (2010), Improvements in the profiles and distributions of nitric acid and nitrogen dioxide with the LIMS version 6 dataset, *Atmos. Chem. Phys. Disc., 10*, 2769-2808.

Remsberg, E., M. Natarajan, G. S. Lingenfelser, R. E. Thompson, B. T. Marshall, and L. L. Gordley (2009), On the quality of the Nimbus 7 LIMS version 6 water vapor profiles and distributions, *Atmos. Chem. Phys., 9*, 9155-9167.

Remsberg, E., G. Lingenfelser, M. Natarajan, L. Gordley, B. T. Marshall, and R. E. Thompson (2007), On the quality of the Nimbus 7 LIMS version 6 ozone for studies of the middle atmosphere, *J. Quant. Spectrosc. Rad. Transf., 105*, 492-518, doi:10.1016/j.jqsrt.2006.12.005.

Remsberg, E. E., L. L. Gordley, B. T. Marshall, R. E. Thompson, J. Burton, P. Bhatt, V. L. Harvey, G. S. Lingenfelser, and M. Natarajan (2004), The Nimbus 7 LIMS version 6 radiance conditioning and temperature retrieval methods and results, *J. Quant. Spectrosc. Rad. Transf., 86,* 395-424, doi:10.1016/j.jqsrt.2003.12.007.

Table 1—LIMS Version 6 Precision Estimates

P (hPa)	Temp (K)	O3 (ppmv)	NO2 (ppbv)	H2O (ppmv)	HNO3(ppbv)	Gphgt (km)
0.01000	3.67	0.32	0.34	0.24	0.16	0.159
0.01468	3.67	0.32	0.34	0.24	0.16	0.159
0.02154	3.67	0.32	0.34	0.24	0.16	0.154
0.03162	2.40	0.32	0.34	0.24	0.16	0.151
0.04642	1.89	0.32	0.34	0.24	0.16	0.147
0.06813	1.60	0.212	0.34	0.24	0.16	0.143
0.1000	1.39	0.10	0.34	0.24	0.16	0.136
0.1468	1.24	0.065	0.34	0.24	0.16	0.132
0.2154	1.10	0.060	0.34	0.24	0.16	0.124
0.3162	1.00	0.056	0.34	0.24	0.16	0.112
0.4642	0.90	0.060	0.34	0.24	0.16	0.101
0.6813	0.82	0.062	0.34	0.24	0.16	0.080
1.000	0.76	0.068	0.34	0.24	0.16	0.053
1.468	0.70	0.075	0.27	0.24	0.16	0.03
2.154	0.63	0.085	0.25	0.25	0.14	0.03
3.162	0.60	0.10	0.34	0.22	0.13	0.03
4.642	0.55	0.12	0.53	0.20	0.125	0.03
6.813	0.52	0.13	0.64	0.175	0.12	0.03
10.00	0,50	0.125	0.68	0.16	0.115	0.03
14.68	0.50	0.12	0.66	0.15	0.112	0.03
21.54	0.49	0.10	0.50	0.15	0.11	0.03
31.62	0.51	0.085	0.33	0.155	0.11	0.03
46.42	0.56	0.080	0.22	0.17	0.11	0.03
68.13	0.63	0.087	0.16	0.215	0.115	0.03
100.0	0.76	0.095	0.16	0.32	0.135	0.03
146.8	0.93	0.10	0.16	0.45	0.17	0.03
215.4	1.25	0.10	0.16	0.45	0.49	0.03
316.2	2.75	0.10	0.16	0.45	0.49	0.03

Table 2—Relaxation times (days) versus zonal wavenumber

Wave-number	0	1	2	3	4	5	6
Time	3.5	2.5	2.5	2.5	1.5	1.5	1.5

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14. ABSTRACT

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15. SUBJECT TERMS

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