Summary of Progress and Results

The operational reprocessing of the 216 days of LIMS Level 2 (profile) data was performed due to improvements in all LIMS parameters, updates in spectroscopy since 1980 and in other aspects of the LIMS forward model. We have also realized an important improvement in our knowledge of the spacecraft attitude, based on a matching of the calculated and LIMS-observed CO_2 radiances in the lower mesosphere for each scan during a first pass of the algorithm to retrieve temperature versus pressure T(p) profiles. This update to the attitude information was then used for the final retrieval of T(p) and then for the retrieval of the species profiles. The minor seasonal and hemispheric asymmetries in the original, archived Version 5 (V5) LIMS data have been largely corrected with this update. Vertical resolution of the profiles has been improved, and profile spacing along an orbit is 1.6 degrees of latitude or less (at higher latitudes). First-order aerosol corrections have also been applied to all the species. As a result of these changes, the revised data are much more compatible with those from UARS. Further, this revised data set can be considered as a precursor to both that expected from the HIRDLS experiment on EOS AURA and the SABER experiment on TIMED. All LIMS Level 2 reprocessing was completed November 5, 2001. This work was performed under contract number NAS1-19570.

Brief summaries of the improvements are given here. The revised temperatures are warmer in the mesosphere, but colder at the tropical tropopause-both in excellent agreement with correlative measurements for the middle atmosphere. Day/night differences indicate tidal signatures. Revised ozone is slightly larger (10%) than V5 in the upper stratosphere, but significantly lower in the lower stratosphere. These changes generally agree with other measurements of ozone within their combined error bars. Day minus night ozone is of order +5% or less in the middle stratosphere. Non-LTE effects in daytime ozone in the mesosphere are smaller, but still present. The nitric acid distributions are nearly unchanged except in the upper stratosphere, where the interfering effects of CO_2 are known better and are being accounted for in the retrieval. Water vapor has better hemispheric and seasonal symmetry and ranges from about 3.0 ppmv in the lower tropical stratosphere to about 6.5 ppmv in the upper stratosphere and at higher latitudes. The nighttime NO_2 is nearly 20% less than V5 in the upper stratosphere and in good agreement with the HALOE sunset values of NO plus NO_2. Daytime NO_2 is decreased by a smaller percentage. In addition, the revised Level 2 product contains profiles of geopotential height that have been referenced to the 50-mb heights that were originally provided to the Nimbus 7 experiment teams by the National Meteorological Center (NMC).

The revised Level 2 profiles have been screened for obvious cirrus and polar stratospheric cloud signature effects, as seen in the retrieved ozone profiles. The screened data will be transferred to CD-ROM media in ASCII format for easy use and eventual archival at the Goddard DAAC. The format for those data is given below.

LIMS V6 Screening Criterion

The screened level 2 product has certain species-specific, pressure-altitude limits and certain maximum mixing ratio limits.

The data is screened using 4 criteria in addition to applying an altitude cutoff. The screening is done in this order.

1. Variances
2. Max values
3. Cloud check
4. Output limit

1. Screen with variances

This screening criterion is based on the sign (negative/positive) of the retrieval variances. The variances are defined as

(NEN/K) squared

where NEN, the noise equivalent radiance in W/m2 sr, is

channel	NEN
NO_2	0.00055
H_2O	0.0023
O_3	0.0037
HNO_3	0.0015
CO_2(W)	0.0055
CO_2(N)	0.0014

and K is the derivative of the signal with retrieved parameter.

During the retrieval process, the variances are set to a negative of their actual value if the retrievals do not converge or if the retrieval restarts. Note that a restart will force the retrieval to use a constant mixing ratio above the first good retrieved layer; the output profile will not show the constant values, but instead will contain the actually retrieved values above where the retrieval restarted. The negative variances are used to indicate this fact and make it clear which values in the retrieved profile are valid. Note that the variance data is only available in the intermediate 1b file.

In general, the screening is done over two altitude ranges. For the upper altitude checking, it starts at a particular height and moves upward. When the algorithm detects a retrieval variance that is negative, it then sets the retrieved species from that point upward to 1.0e-24 to indicate that the retrieval failed for some reason. For the lower altitude screening, the algorithm starts at some altitude and moves downward. When it encounters a negative variance, it sets the retrieved species to 1.0e-24 from that point downward.

The altitude ranges (pressure levels) for screening are given below. The algorithm begins by checking from the top pressure upward and then from the bottom pressure downward. The middle region is unchecked since no negative variances are expected.

	top pressure	bottom pressure
temperature	0.046mb	114mb
O_3	0.19mb	53mb
HNO_3	1.9mb	53mb
H_2O	1.3mb	53mb
NO_2	0.88mb	53mb

2. Screen with max values

The next check of the profiles is based on maximum allowed values. Each species has different maximum allowed values as well as different altitude ranges over which the profile values are checked. If the maximum value is exceeded, the entire profile is pitched. These scans are listed on the web site as the "removed scans" file for each day.

The O_3 profile is checked from approximately 0.22mb to 46mb (layers 43 to 85 in the standard profile) and the maximum allowed value is 20ppmv. HNO_3 is checked from approximately 2.2mb to 46mb (indicies 61 to 85) using its maximum permitted value of 30ppbv. H_2O is screened from 1.47mb to 46mb (layers 58 to 85) using a maximum value of 12ppmv. NO_2 is checked over two regions. The first region is from about 1.0mb to 32mb (layers 55 to 82) using 25ppbv; the second region is from about 36mb to 68mb (layer indicies 83 to 88) which uses 10ppbv. Note that no maximum threshold criterion was set for NO_2 above the 1mb level so that polar night NO_2 signatures would be retained for the mesosphere. The temperature retrievals are not screened.

3. Cloud check

$$\frac{[qn - q_{n-1}]}{qn - 1}$$

The code screens for clouds next. The cloud detection algorithm is based on (1) the vertical gradient of the retrieved ozone mixing ratio q and (2) its minimum mixing ratio. The cloud check was conducted below the 45mb level n for latitudes equator ward of 30 degrees but below the 100mb level for higher latitudes. When q > 0.5 ppmv and the mixing ratio fraction f, is greater than 0.25, a cloud flag is set.

A search for polar stratospheric cloud (PSC) signatures in ozone was conducted poleward of 45N and between 10 and 100mb. Two criteria were used. First, when q<0.2 ppmv, a flag is set to indicate that the mixing ratio has fallen to near zero and must be likely due to excessive attenuation of the tangent layer signal in regions where the temperatures very cold. Second, when $[q_n - q_{n-1}]$ exceeds 1.7 ppmv and f is greater than 0.7, PSC contamination is considered very likely. Cloud signatures are found generally at the same level for the ozone and nitric acid (the narrow) channels. The flag for H_2O and NO_2 (the wide) channels is set at the previous (higher) altitude level, n-1. No high cloud contamination effects are noted for the temperature, and it has not undergone a cloud screen.

Some cloud and PSC contaminated data are not caught by the screening algorithm and must be identified manually or with the aid of variance exceedence criteria in the level 3 mapping algorithm.

4. Output limits

Finally, the data are pitched above a specified altitude level for several species. For HNO_3, data starting at roughly 1.7mb and above is removed. For H_2O, data at and above 1.3mb is removed. Lastly, the NO_2 profiles at and below 60mb are deleted. Temperature and O_3 are not screened with altitude.

5. Data Format And Example

The screened data are written one scan at a time (there are no EOR or EOF markers). The top of each days' data file has a description block, and the top of each scan has a brief description; see the readers provided for details. Note that the data for a given day are based on complete orbits. For example, the data for a day will not start at midnight but when the first orbit on that day begins. Also, the data does not end at midnight but continues until the last orbit is complete.

The first scan header line parameters are

nl_std	=>	Number of tangent layers (number of points) in the profile. Standard spacing from 1000mb to 0.001mb (approximately 0.88km spacing).
ngs1	=>	Number of species mixing ratios present
nch	=>	Number of radiance channels present
alat	=>	Latitude of 30km tangent point
alon	=>	Longitude of 30km tangent point (degrees east)
iorbit	=>	Orbit Number
irec	=>	Record Number (currently from level 1 file)
iday	=>	LIMS Day number (Julian)
time	=>	GMT time
idn	=>	Day/Night Flag (1=DAY, 2=NIGHT)
iud	=>	Scan Direction 1=UP, 2=DOWN on unaveraged data 0 on averaged radiances (up/down pair averaged)
alt	=>	Space Craft Altitude (km)
gt1	=>	Time used for gradient calculation (ignore)
gt2	=>	Time used for gradient calculation (ignore)
icloud	=>	Index of lowest level uncontaminated by clouds (ignore)
iad	=>	Orbit Mode (1=ASCENDING, 2=DESCENDING)
sunasc	=>	right ascension of the sun (radians/1.0e-8)
sundec	=>	solar declination (radians/1.0e-8)
grncha	=>	Greenwich apparent sideral time (radians/1.0e-6)
avrl	=>	angular rate of scan plane (AVerage Rate Last). Units are in percent stretch c
tkm	=>	effective twist (radians) of optics with respect to horizon
plat	=>	spacecraft latitude

plon	=>	spacecraft longitude (degrees east)
szad	=>	solar zenith angle (radians)
shift	=>	scan twist correction (radians)
nleavep(1)	=>	number of interleaves in T/P retrieval
max_p_reg_it	=>	5 values (one for each interleave) of the maximum number of registration ite

Next, there are 6 header lines (one for each channel--CO_2N, CO_2W, O_3, HNO_3, H_2O, NO_2). The parameters for each channel are

is	=>	index for start of good data (ignore)
ie	=>	index for end of good data (ignore)
iqw	=>	quality word for level 1 processing
resig	=>	1 sigma value for Gaussian FOV from level 1 processing (km)
npa	=>	number of profiles averaged in retrieval
quality_p	=>	pressure of top good data level
good_data_index(1)	=>	index of top good data layer
quality_p(2)	=>	pressure of bottom good data level
good_data_index(2)	=>	index of bottom good data layer
cloud_flags_pr	=>	lowest pressure where data is not contaminated by cloud
cloud_flags_index	=>	index of lowest layer where data is not contaminated by cloud

The retrieved data follows the header lines. Each of the 109 tangent layers contains the following

dang_std	=>	depression angle (radians)
zt_std	=>	height (km)
pt_std	=>	pressure (mb)
tt_std	=>	temperature (K)
rad_std(1)	=>	co2 narrow channel radiance (w/m2-sr)
rad_std(2)	=>	co2 wide channel radiance (w/m2-sr)
rad_std(3)	=>	o3 channel radiance (w/m2-sr)
rad_std(4)	=>	hno3 channel radiance (w/m2-sr)
rad_std(5)	=>	h2o channel radiance (w/m2-sr)
rad_std(6)	=>	no2 channel radiance (w/m2-sr)
tg_std(1)	=>	near side temperature gradient (K/arc degree); gradients are obtained from th and generally do not go above 0.1mb
tg_stg(2)	=>	far side temperature gradient (K/arc degree); gradients are obtained from the and generally do not go above 0.1mb
qmix_std(1)	=>	co2 mixing ratio (always 325 ppmv)
qmix_std(2)	=>	o3 mixing ratio
qmix_std(3)	=>	hno3 mixing ratio
qmix_std(4)	=>	h2o mixing ratio
qmix_std(5)	=>	no2 mixing ratio
geo_heights	=>	geopotential height (km)

Data Example (day 312)

first scan header line looks like

```
109 5 6 24.1859 335.4459 204 1 312 0:36:12 2 0 947.6079
0.00 0.00 90 2 387100488 -28130831 3370145 0.8588 0.7113
-2.1 348.1 166.6 -2.803E-05 5 2 2 2 2 2
```

parameters are

nl_std	=>	109
ngs1	=>	5
NCH	=>	6
alat	=>	24.1859 degrees
alon	=>	335.4459 degrees (east)
iorbit	=>	204
irec	=>	1
iday	=>	312
time	=>	0:36:12
idn	=>	2 (night)
IUD	=>	0 (averaged)
alt	=>	947.6079 km
gt1	=>	0.00 (ignore)
gt2	=>	0.00 (ignore)
icloud	=>	90 (ignore)
iad	=>	2 (descending)
sunasc	=>	387100488 radians/1.0e-8
sundec	=>	-28130831 radians/1.0e-8
grncha	=>	3370145 radians/1.0e-6
avrl	=>	0.8588%
tkm	=>	0.7113 radians
plat	=>	-2.1 degrees
plon	=>	348.1 degrees (east)
szad	=>	166.6 degrees
shift	=>	-2.803E-05 radians
nleavep(1)	=>	5
max_p_reg_it	=>	2 2 2 2 2

header for each channel
next 6 lines (one for each channel) look like

```
1270 0 2.1562 1 0.000 0 0.000 0 0.000 0 2.457E-03
1270 0 2.1562 1 0.007 16 464.159 103 113.646 92 2.457E-03
1270 0 2.1562 1 0.013 21 100.000 91 113.646 92 2.457E-03
79270 0 2.1562 1 1.896 60 100.000 91 113.646 92 2.457E-03
55270 0 2.1562 1 1.468 58 77.426 89 87.992 90 2.457E-03
75270 0 2.1562 1 0.599 51 52.750 86 87.992 90 2.457E-03
```

parameters are for each channel (using the 6th channel as an example)

is	=>	75 (ignore)
ie	=>	270 (ignore)
iqw	=>	0
resig	=>	2.1562 km
npa	=>	1
quality_p	=>	0.599 Mb
good_data_index(1)	=>	51
quality_p(2)	=>	52.750 Mb
good_data_index(2)	=>	86
cloud_flags_pr	=>	87.992 Mb
cloud_flags_index	=>	90
rad_diff_rms	=>	2.457E-03 (same for all channels)

Parameters 6-11 will always be 0 for channel 1 (narrow CO_2 channel)

The next 109 lines are the data on the 109 level standard grid

An example of a line would be

5.027660E-01 4.44010E+01 1.668100E+00 2.669080E+02 5.380070E-01 2.080630E+00
5.709640E-01 2.648560E-03 1.902880E-02 5.695570E-03 3.632860E-02 -7.752310E-01
3.250000E-04 4.706740E-06 1.000000E+24 6.981660E-06 9.021640E-09 4.409225E+01

parameters are for each layer

dang_std	=>	5.027660E-01 radians
zt_std	=>	4.44010E+01 km
pt_std	=>	1.668100E+00 Mb
tt_std	=>	2.669080E+02 k
rad_std(1)	=>	5.380070E-01 w/m2-sr
rad_std(2)	=>	2.080630E+00 w/m2-sr
rad_std(3)	=>	5.709640E-01 w/m2-sr
rad_std(4)	=>	2.648560E-03 w/m2-sr
rad_std(5)	=>	1.902880E-02 w/m2-sr
rad_std(6)	=>	5.695570E-03 w/m2-sr
tg_std(1)	=>	3.632860E-02 k/arc degree
tg_stg(2)	=>	-7.752310E-01 k/arc degree
qmix_std(1)	=>	3.250000E-04
qmix_std(2)	=>	4.706740E-06
qmix_std(3)	=>	1.000000E+24 (missing)
qmix_std(4)	=>	6.981660E-06
qmix_std(5)	=>	9.021640E-09
geo_heights	=>	4.409225E+01 km