Description of GUVI Neutral Density Profile (NDP) Level 2B Data Product Files

Version 13

Robert R. Meier

Department of Physics and Astronomy
George Mason University
4400 University Dr., MS 3F3
Fairfax VA 22030
703-973-5482
rmeier@gmu.edu

and

Code 7630
Space Science Division
Naval Research Laboratory
Washington DC 20375
202-767-2773
robert.meier@nrl.navy.mil

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This document describes the contents of the IDL save files that contain the geophysical data products from the inversion of the GUVI limb scan data. The latest database is Version 13 (Versions 11 and 12 were not released.) Changes from Version 10 to Version 13 are described in Section I.

Descriptions of changes constituting upgrades to prior versions are in the appendices of this document. Appendix A describes earlier modifications resulting in the upgrade to Version 6. All GUVI limb inversions so far have used Level 1B (Version 8) Imaging (Disk & Limb) files available at the GUVI website in the table, GUVI Data Archive (http://guvi.jhuapl.edu/data_fetch_l2b_ndp_idlsave) or via the VITMO website (http://vitmo.jhuapl.edu/). Users of Level 1B (Version 8) radiance data are cautioned that those files do not include the revised pointing information and calibrations described in this readme file and implemented in the Level 2B limb Neutral Density Profiles.

Contents

I. Principal Changes for Version 13

There are two important changes between Version 10 (the prior online database) and Version 13:

1) I decided to return to retrieval of 7 parameters in the forward model. Four are scalars of the NRLMSIS00 model and three are scalars of the magnitudes for simulating each of the GUVI measurements (channels or colors) used in the retrieval process. The reason for the return to the more general retrieval scheme is that discussions with Mike Picone convinced me that use of fixed the magnitude scalars can introduce unwanted bias into the retrieval process.

2) The forward model now uses the SEE Version 11 solar spectral irradiance database as the initial guess for the forward model. Version 10 of the GUVI limb database used SEE Version 10.

The principal reason for fixing the magnitude scalars in the GUVI Version 10 limb database was to reduce uncertainty and nonphysical behavior at large solar zenith angles (See Appendix 2 of the *Meier et al*. [2014] manuscript mentioned below in this section). This presumes no relative drift in instrument sensitivity between GUVI and SEE. The concomitant reduction in the attributed 1-sigma uncertainty of the number densities is factors of 2-3 when the magnitude scalars are fixed. The anomalous non-physical behavior then did not take place until beyond about 70^o SZA, thereby significantly increasing the amount of reliable molecular data, as well as increasing the precision of the remaining parameters.

However, more recent analyses discovered a long-term trend between GUVI and SEE. To mitigate the influence of this drift, we returned to retrieving of all seven scalars in Version 13. While the accuracy of the data products is higher in Version 13, but the precision is lower. The most reliable data are those taken with SZA $< 60^o$, except for atomic oxygen, which is accurate to perhaps 70^o or larger. In future versions of the database, pending sponsor funding, we hope to correct for this trend and assess the biases introduced when fixing the magnitude scalars, which if minor, will allow us to follow the approach taken in Version 10 of the GUVI limb database. Improving the flexibility of the scaled NRLMSIS model may also help in reducing the uncertainties.

These changes as well as the entire retrieval process are described in a manuscript that has been submitted for publication. [Meier, R. R., J. M. Picone, D. Drob, J. Bishop, J. T. Emmert, J. L. Lean, A. W. Stephan, D. J. Strickland, A. B. Christensen, L. J. Paxton, D. Morrison, H. Kil, B. Wolven, Thomas N. Woods, G. Crowley, S. T. Gibson (2014), Remote sensing of Earth's limb by TIMED/GUVI: Retrieval of thermospheric composition and temperature, Submitted to *Earth and Space Science*]. Currently it is still in the review stage.

To evaluate the difference between the more accurate but less precise Version 13 of the GUVI limb database and the less accurate but more precise Version 10, I carried out a point-by-point comparison of more than 300,000 data points at low geomagnetic activity. This assessment revealed differences of 1 (±2) %, 2 (±4) %, and 1(± 1)% for O, N_2, and O_2 number densities, respectively, at 194 km in the middle thermosphere. While these are not large, the ratios and uncertainties increase with altitude, motivating the production of the more accurate database.

II. Limb Retrieval Database Factoids

1- Each limb scan (of averaged pixel data) is inverted independently.
2- Geolocation of the limb scan is assigned to the tangent point near the peak of the airglow layer, roughly 160 km.
3- GUVI Level 1B radiance data files on line at the GUVI website have not been corrected for a sine-wave-like angular offset in the GUVI scan mirror angles discovered by Hyosub Kil from star observations. The offset has been found to vary with beta angle and with time, the latter possibly being due to cam wear. Corrections for these offsets have been incorporated in the limb inversion software. Intensities in the limb retrieval data base have had this correction applied to the local zenith angle and the tangent altitude.
4- Only data for absolute latitude less than 60 deg are inverted. This is imposed to avoid auroral contamination, although during geomagnetic storms the auroras extend to lower latitudes.
5- The retrieval algorithm allows for the variation of the solar illumination along the line-of-sight. Therefore full vector calculations of the pointing directions and the integration steps for the forward intensity model allow for variation of the excitation rate (g-factor) with solar zenith angle.

   The retrievals use data taken at less than 80 deg solar zenith angle on the limb. It is probably dangerous to go beyond that point, but retrievals can be carried for selected cases upon request. <u>There is some evidence for a minor systematic problem beyond 70-75 deg sza that appears to be related to the loss of sensitivity to molecular species at large solar zenith angles.</u> Users should contact R. Meier for the latest information on this point.
6- The inversion algorithm assumes that the atmosphere only varies (spatially) with altitude. (Of course, the individual initial guess and retrieved atmospheric composition for each limb scan do vary geographically and with time.) This assumption is reasonably accurate for low latitudes, but worsens toward higher latitudes or during geomagnetic disturbances, where horizontal gradients become important. Future versions of the data products may incorporate horizontal variability. GUVI disk images can give some indication of where the atmosphere is uniform.
7- Only data for tangent altitudes less than about 310 km are inverted. This avoids the poor counting statistics at high altitudes, as well as avoiding contamination of the dayglow by tropical ionospheric recombination emission in the 1356 channel. Note that because the GUVI limb radiance data files (Level 1B, vers 8) have had backgrounds removed, at high altitudes (and even occasionally at 310 km in LBHS) the counting statistics result in a negative intensity. When this happens (infrequently), the negative intensity is set equal to a very small positive number to avoid problems in the inversion software.
8- Error estimates of the retrieved densities and temperature are due to estimated variances for the data as described in Section IV. Because of background removal, it is incorrect to assume that the standard deviation is given by the square root of the number of counts.

Because pointing errors are the major source of uncertainty, the 1-sigma values assigned to the densities (obtained by using the propagation of errors of the retrieved model parameters (scalars) into uncertainties in the retrieved densities and temperatures) are lower limits. True errors will be larger as the result of a careful error budget analysis, a task in progress.

9- Data periods in 2002 (only) that appear to be compromised due to loss of mirror cam fiducial or other pointing problems are:

Day < 260	corr =0.21
Day 74	corr =0.11
Day 81	corr =0.11
Day 119 – 129	corr =0.11 (*note: the GUVI wide slide was used during this period, so the retrievals may not be accurate.*)
Day 192	corr =0.11
Day 193	corr =0.11

The term "corr" refers to the correction in local zenith angle that was applied to obtain the tangent altitude. 2003 and 2004 appear to be without such problems. Occasionally the spacecraft appears to move and the min tan altitudes spike upward with a quick return. These spikes also appear in the dayglow layer altitudes. Examples are 2002195, 2002264 and 2002268.7. They appear to last for about one rev. Unless the changes are evident in the dayglow, no corrections have been applied.

10- An improved g-factor approach over that of Meier and Picone [1994] was adopted. The g-factors are pre-computed for the chosen day of year, filling a two-dimensional table of g-factors vs total vertical column density and solar zenith angle (up to 90 deg). The g-factor at any point along the GUVI line of sight is then obtained using a table lookup (bi-cubic spline interpolation procedure from *Numerical Recipes*). The g-factors thus obtained directly from the AURIC model are more accurate than used previously and allow better implementation of variability with solar zenith angle.

III. File Names

GUVI limb data are contained in a file that covers a single rev. The database files are of a type,

GUVI_im_limb_v008r00_2003191_REV08582.L1B,

which must be read with an ncdf reader.

The retrievals are carried out for the rev in question and the results are saved in an IDL save file of the type that incorporates the original file name:

t_GUVI_im_limb_v008r00_2003191_REV08582.L2B.sav,

which can be accessed using the IDL restore command:

restore, 't_GUVI_im_limb_v008r00_2003191_REV08582.L2B.sav'

The retrieved and ancillary data were originally written directly into the file and used by various plot procedures. In order to minimize the recoding needed to produce production-processed data and so that standard plot procedures could be used, some original but extraneous data were left in the files in databases prior to Version 8. **These have now been removed.**

IV. Contents of Data Structures.

The key information for the Level 2B geophysical data products is contained in three IDL structures:

1. **morbit**
2. **dorbit**
3. **ndpsorbit**

These are the only files that should be used for analysis of GUVI data

This section describes the principal parameters contained in each of these structures. In the following, the index, i, stands for the i-th limb scan within the rev.

1. **morbit(i)** Structure containing the model parameters and other information and contstraints

morbit(i).m array of model parameters, which are retrieved from the inversion process. The principal parameters are scalars of F107 (which influences the height profile of the model atmosphere) and altitude-independent scalars of the atomic oxygen, molecular nitrogen, molecular oxygen number densities, scalars of the forward model radiance for each of the three GUVI channels and a scalar of the overall solar EUV flux. Note that the scalars of the three GUVI channels and the solar EUV flux are held constant in the final inversion process. This reduces the uncertainties in the retrieved model parameters.

morbit(i).minit array of initial guesses of the parameter vector, **m**. Usually these are set at unity, except for the magnitude scalar. Unity for the model atmosphere parameters returns NRLMSIS values.

morbit(i).name Array containing the string name of the model parameter. Note that not all of the parameters are used in the retrievals. (see morbit.change)

morbit(i).change Array indicating the parameters that are allowed to vary during the inversion process. When change=0, the parameter is held fixed at the initial value; change = 1 allows the parameter to vary.

morbit(i).lowerlimit and morbit.upperlimit Arrays indicating the lower and upper limits of the parameter. This helps stabilize the inversion process in the event something bad happens, like a star on the topside. Currently the upper and lower limits for the parameters are set at 5 and 0.1, except for the f10 scalar, which has limits of 2 and 0.5.

morbit(i).covfit Covariance matrix for the retrieved model parameters. The diagonal elements give the variances of the retrieved parameters, and the off diagonal elements are related to the covariances between parameters. To obtain the 1-sigma uncertainties of the retrieved parameters, take the square root of the diagonal element for the named parameter. For example, the 1 sigma uncertainty of the F107 scalar retrieved during limb scan i is given by sqrt(morbit(i).covfit(0,0)).

2. **dorbit** Structure containing the data, retrieved fits, and other information.

dorbit(i).din Array containing original data. For the range of about 310 km to the lower end of the limb scan, about 110 km, there are usually 12 tangent altitudes, or 36 data points for the 1356, LBHS, and LBHL channels combined.

dorbit(i).name Array containing the name of the measured intensity (eg, 1356 or LBH)

dorbit(i).d Array containing the best fit model intensities. That is, these are the intensities calculated using the morbit(i).m model parameters.

dorbit(i).d0 Array containing the intensities computed using the initial guess parameters. That is, these are the intensities calculated using the morbit(i).minit model parameters (NRLMSIS)

dorbit(i).alt Array containing the tangent altitudes for the intensities. These are the tangent altitudes for pixel 8.

dorbit(i).covdata Array containing the covariance of the data. First it is assumed that each measurement is independent of the others. This means that the off-diagonal elements of the data covariance matrix can be set to zero. The diagonal elements are populated by the variances of the data and these are used to weight each of the data points in the inversion process. The overall procedure is the “Maximum Likelihood” method, which is the optimal way to fit data with a parameterized model when the counting statistics are Gaussian. The square of the standard deviation from the mean of the 14 data points defines the variances in the radiances. A better approximation would be to define the standard deviation using the best-fit model value at the tangent altitude (rather than the mean), since that is a measure of the “parent population” than the mean of the data. But this is a procedure that requires continual changing of the parent population values throughout the iterative inversion process, and has not yet been implemented.

The more serious consideration is that the full extent of the error budget has not yet been incorporated. The counting statistics are reasonably approximated using the average of 14 data points. The principal uncertainty in the data (as has been known for some time in the early error budget analyses) is caused by pointing errors. The pointing uncertainty has not yet been estimated with confidence. Consequently, the error estimates on the data, which propagate through to the uncertainties in the retrieved m parameters, and ultimately to the concentrations and temperature, are lower limits.

3. ndpsorbit Structure containing the neutral density and temperature profiles.

This structure includes both the retrieved values from the inversion process and the initial (NRLMSIS) guess. The structure also contains the 1-sigma uncertainties of the retrieved densities and temperature. As noted above, these uncertainties are based only on the sampling statistics. They do not include estimates of systematic uncertainties, nor other observational (eg, pointing) and model uncertainties. The structure also contains values of the solar-geophysical parameters used in the NRLMSIS model. Note that in NRLMSIS, I have used the daily Ap index, not the 3 hour index. This is acceptable because NRLMSIS is used primarily to initiate the retrieval process. Nonetheless, this should be kept in mind when comparing the retrieved results with NRLMSIS.

NRLMSIS Parameters:

ndpsorbit(i).iyd	day of year
ndpsorbit(i).sec	UT (sec)
ndpsorbit(i).glat	geolocated latitude as defined above for the limb scan (deg)
ndpsorbit(i).glong	longitude (deg)
ndpsorbit(i).stlp	solar time (hr)
ndpsorbit(i).f107a	81 day average of solar 10.7 cm radio flux
ndpsorbit(i).f107	previous day 10.7 cm flux
ndpsorbit(i).ap	Daily geomagnetic Ap index
ndpsorbit(i).sza	Solar zenith angle at the geolocated tangent point

Retrieved results

ndpsorbit(i).zm	Altitude grid in model (km)
ndpsorbit(i).ox	atomic oxygen number density (cm-3)
ndpsorbit(i).n2	molecular nitrogen number density (cm-3)
ndpsorbit(i).o2	molecular oxygen number density (cm-3)
ndpsorbit(i).t	temperature (K)
ndpsorbit(i).sigox	1 sigma uncertainty in the O number density (cm-3)
ndpsorbit(i).sign2	1 sigma uncertainty in the N2 number density (cm-3)
ndpsorbit(i).sigo2	1 sigma uncertainty in the O2 number density (cm-3)
ndpsorbit(i).sigt	1 sigma uncertainty in the temperature (K)
ndpsorbit(i).qeuv	solar energy flux from the SEE data (mW/m^2 (multiply Qeuv by morbit(0).m(4) x morbit(0).m(7) to obtain the solar flux required to fit the GUVI dayglow)
ndpsorbit(i).o_n2	O/N2 column ratio computed from retrieved O and N_2 densities
ndpsorbit(i).o_n20	O/N2 column ratio computed from NRLMSIS O and N_2 densities

NRLMSIS predictions

ndpsorbit(i).ox0	atomic oxygen number density (cm-3)
ndpsorbit(i).n20	molecular nitrogen number density (cm-3)
ndpsorbit(i).o20	molecular oxygen number density (cm-3)
ndpsorbit(i).t0	temperature (K)

Retrieval Information

ndpsorbit(i).n_steps	number of iteration steps for a given limb scan
ndpsorbit(i).flag(j)	data quality flag (most data with flags set to 1 have been removed)

flag(j) = 0 (retrieval nominal), except when

flag(0) = 1: n_steps reaches 20 without convergence in the retrieval process
flag(1) = 1: any of the model parameters hits the a priori upper and lower limits
flag(2) = 1: set when altitude of peak intensity is too close to a boundary

If any of the flags are set, retrievals should be used with caution, or preferably not used at all.

Note that the retrieved densities and temperatures are given for the full zm (110 – 667 km) altitude range. But the highest accuracy is due to sensitivity of the dayglow between about 150 and 300 km to the parameters. So densities outside of that altitude range should be viewed as extrapolations of the best-fit model within that interval. However, our initial comparisons with total mass densities above 400 km from satellite drag and accelerometers show good agreement with the GUVI retrievals—a very promising result.

V. Sample IDL procedures

1. Extracting and plotting number densities and temperature.

```
;pro plt_production_panels
;
;This opens a dit retrieval file and makes plots of concentrations for all limb scans
;   in the file
;
filename=''
read,'filename =? ',filename
folder='G:\retrievals\prod_fix260\

restore,folder + filename

nscans=n_elements(ndpsorbit)    ;number of limb scans in the file

nplots=fix(sqrt(nscans)) +1     ;determine number of plot panels on one side of the figure

!p.multi=[0,nplots,nplots]   ;set up number of panels within the plot

xra=[1.e6, 1.e12]          ;range for density axis
yra=[100,500]            ;range for altitude axis

;make plots comparing retrieved and NRLMSIS densities
;Note that temperatures are multiplied by 10^8 to put them on scale

   for n=0,nscans-1 do begin
   ;get time for plot label
   timep=ndpsorbit(n).sec/(60.*60.)         ;time of limb scan in hours
   timet=strcompress(timep,/remove_all)   ;time as a string for plots

   plot_oi,ndpsorbit(n).n2, ndpsorbit(n).zm, xrange=xra, yrange=yra, title='UT = '+timet  $
      ,xtitle='Number Density (cm-3)', ytitle='Altitude (km)',xstyle=1, ystyle=1

   oplot,ndpsorbit(n).ox, ndpsorbit(n).zm, linestyle=1
   oplot,ndpsorbit(n).o2, ndpsorbit(n).zm, linestyle=2
   oplot,ndpsorbit(n).t*1.e8,ndpsorbit(n).zm,  linestyle=3
   ;
   ;now overplot NRLMSIS densities
   oplot,ndpsorbit(n).n20, ndpsorbit(n).zm, color=3
   oplot,ndpsorbit(n).ox0, ndpsorbit(n).zm, linestyle=1,color=3
   oplot,ndpsorbit(n).o20, ndpsorbit(n).zm, linestyle=2,color=3
   oplot,ndpsorbit(n).t0*1.e8,ndpsorbit(n).zm,  linestyle=3,color=3

   endfor

end
```

2. Calculating chi-squared for the best fit

The following code snippet does this:

```
for n=0,nscans-1 do begin
ioxd=dorbit(n).din          ;observations of 1356 and LBHS
ioxm=dorbit(n).d            ;best fit model
sig2=dorbit(n).covdata   ;variances of the data (currently an underestimate)
npoints=float(n_elements(dorbit(n).d))
;degrees of freedom--assumes only model atmosphere parameters are important
deg_freed=4.

chisq_t(n)=total( (ioxd-ioxm)^2/sig2)/(npoints-deg_freed)
endfor   ;loop over number of limb scans
```

Appendix A: Principal changes for Version 6

A major upgrade took place during mid 2006, in which the LBHL (long wavelength) channel data were included in the retrieval process. This so-called 3-color inversion now includes the OI 1356, N2 LBHS, and N2 LBHL channels. The principal motivation for this upgrade was the continuing concern that the 2-color algorithm was not returning the correct O2 concentration, as mentioned in prior versions of the on-line user readme file. Incorrect O2 concentrations also negatively impact the accuracy of N2 and O retrievals because the peak of the airglow layer is affected. The O2 concentrations retrieved with the 3-color algorithm are now in much better agreement with NRLMSIS as well as with a recent database obtained with the NRL SUSIM instrument on the UARS satellite that observed O2 absorption of sunlight. The principal changes included in the upgrade are:

1) A synthetic spectrum for the N2 LBH and VK bands was incorporated to correctly account for the spectral distribution of the radiation within the LBHL channel. Also included was the NI 174.3 nm feature produced from N2 dissociative excitation. The VK magnitude and branching ratio (fraction of VK emitted in the LBHL channel passband) were set by a comparison of the AURIC model to HUT spectral observations of the dayglow. The HUT data have sufficient resolution to resolve an isolated feature of the VK band. The g-factor code was also upgraded to include VK excitation. VK quenching follows that given in AURIC. The late James Bishop kindly provided the spectral details, the information on the VK observations, and the modified version of the AURIC g-factor code.
2) The O2 extinction part of the inversion algorithm was completely overhauled to include both the detailed spectral and temperature dependences of the cross sections at each of the principal lines and bands. Tables of cross sections vs wavelength and temperature were kindly provided by Stephen Gibson of ANU.
3) Scalars are retrieved independently for the magnitudes of all three channels. These scalars define the amount that the solar flux has to be adjusted in order to reproduce the GUVI observations of the dayglow.
4) The 2-color inversions were carried out by including another pointing correction of 0.11 deg in the retrieval algorithms. The arguments for including it are complex and are not documented herein. It now appears that this correction should not have been included in the limb retrieval algorithm. The 3-color retrievals are significantly better with this correction removed. For example, systematic offsets between the altitude of the dayglow peaks (in all channels) and the forward model disappeared when the 0.11 deg correction was removed..
5) Version 9 SEE solar EUV fluxes are used in the retrieval process. Orbital values kindly supplied by Judith Lean were used. for the XPS data.
6) A small change was made in the $e+N_2$ LBH emission cross section. The value currently used in the retrieval code is: 4.08×10^{-18} cm^2. Details describing the choice of this value are described in a white paper ["Estimating Cascade Contributions to the N_2 LBH Emission Rate", R. R. Meier, February 6, 2008]. Copies are available upon request.

7) A number of other upgrades are planned for the retrieval algorithm, including the use of all 14 pixels in the retrieval process. These should improve the quality of the retrieved data products as well as provide the products at a higher cadence without averaging.

Appendix B: Principal changes for Version 7

1. In all previous versions of the limb database, seven parameters were retrieved from each limb scan: four parameters that fixed the altitude profiles of N_2, O_2, and O, and three scalars for each of the three "colors" used in the retrievals. The three colors consist of the following three GUVI channels: OI 135.6 nm, N_2 (LBHS) and N_2 (LBHL). The scalars were included to allow for possible discrepancies between the SEE solar EUV flux that was used to initiate the retrievals, as well as possible differences in relative calibration among the three channels.

   The mean values of the retrieved magnitude scalars from the V6 database were 0.674, 0.689, and 0.664 for the 135.6, LBHS and LBHL channels, respectively. There is no evidence of changes in these with time or solar activity (see Woods et al., "XUV Photometer System (XPS): Improved solar irradiance algorithm using CHIANTI spectral models", submitted for publication in JGR, 2008). In the V7 database the scalars are fixed at these values. This results in:

   i. Fewer degrees of freedom in fitting the limb data. Consequently chi-squared is larger.
   ii. The standard deviations on the retrieved densities and temperatures are smaller than in previous versions.
   iii. Most of the unphysical variation of densities with solar zenith angle. Caution is still urged for sza's greater than 70 deg.
   iv. Holding the magnitude scalars constant presumes that the variations of the solar EUV flux are properly measured by SEE. But the discrepancy between the magnitude of the GUVI dayglow measurements and the SEE solar flux remains. Currently the SEE solar fluxes must be multiplied by an average factor of 0.676 to match GUVI dayglow.

2. SEE solar EUV fluxes (after multiplication by the factors described in 1. above) are used as input to the inversion model. These are now input at the TIMED orbital cadence (once an orbit) rather than daily averages, as used in the GUVI Limb V6 database.

3. As discussed in the Version 6 readme file, APL has determined that the GUVI dayglow calibrations need to be revised. The observed 135.6 nm LBHS and LBHL have been scaled by factors of 1.148, 1.194, 0.916. These adjustments, which are the averages of pixels 6-9, have been derived from the dayglow used and are close to those determined by APL from stellar calibrations and intercomparison with simultaneous SSUSI observations. They have not been incorporated into the Level 1B (Version 8) GUVI data limb radiance files online, but **have been incorporated in the retrieval files described by this document**.

4. The fine pointing corrections provided by Hyosub Kil are now slightly smoother than previous versions due to the removal of occasional spikes that were deemed nonphysical.

Appendix C Principal Changes for Version 8

1. Values of latitude, longitude, solar zenith angle, and local solar time have been corrected for each observation location. These values, which are assigned to the tangent altitude in the Version 1B radiance files, were recomputed due to correction for the pointing offset problem described in Section II.4 and in Appendix B.4. The uncorrected values were inadvertently assigned to the Version 7 database. Only small errors are present in most of these values.

2. O/N_2 column density ratios computed from the limb retrievals are now included in the ndpsorbit structure. See Section 4.3 for description.

3. Qeuv, the solar energy flux computed from the SEE solar fluxes (Version 9 SEE data) is now included in ndpsorbit structure. See Section 4.3 for description.

4. Extraneous data and some parameters that were in the database files have now been removed to avoid confusion. The new file sizes are much smaller. (Note that earlier versions of the readme document warned that the extraneous data should not have been used.) Now only the ndpsorbit, morbit, and dorbit IDL structures are available. Along with these structures, the solar flux name (SEE), the solar flux file, and the original Level 1B radiance file used in the inversion remain defined in the file.

Appendix D Principal Changes for Version 9

1) Fix an error in the averaged intensity points at the beginning and end of revs. This should not affect parameter retrievals.

2) Fix an error in averaging limb scans when the night sector occurs in the middle of a rev.

   A new orbit number is assigned at the ascending node of the orbit (when the spacecraft crosses the equator, heading north). If this occurs during the day, there can be a gap in the inverted dayglow data when the spacecraft heads toward night in the north and reenters sunlight in the south. Prior versions of the database did not properly average the limb scans on either side of the gap.

3) In prior versions of the database, the assignment of the solar radio flux and Ap was incorrect if the day number changed when the ascending node took place during daytime. That problem was caused by differences between the day number in the name of the NetCDF Level 1B radiance data file and the day number contained within the data file itself. Using the correct solar/geophysical parameters for these few cases would require computation of g-factors for each limb scan (a dramatic increase in computation time). For now, I have simply ignored those few limb scans and will investigate a fix for future databases.

4) Fix an error due to improper averaging of data when there are gaps in the data due to data dropouts. Version 9 now allows for up to two data gaps. If there are more than two, the rev is skipped.

5) The net result of these changes is a reduction in the number of limb scan data points from 378,448 (Version 8) to 367,897 (Version 9) or 2.8%. Future versions of the limb database will not suffer from most of these issues (see note below).

   On the other hand, these changes have eliminated many outliers in the database. Examination of distribution functions for the various retrieved scalars shows that the results are better fit with log-normal functions, especially in the wings of the distributions.

Appendix E Comparison of Version 10 Pixel Summing with Earlier Versions

The projection of the GUVI slit on the airglow limb of the earth is curved due to optical distortion in the instrument. Precise knowledge of the pointing information for pixels away from the center of the slit had been compromised due to uncertainty in the on-orbit knowledge of the orientation of the curvature. Knowledge of the exact pointing of a pixel is crucial for correct inversion of the radiance profiles. Consequently, prior versions of the GUVI limb database (Versions 9 and earlier) had only used the central four pixels of each limb scan and averaged five limb scans to produce radiance profiles with sufficiently good statistics for inversion into composition and temperature. After a great deal of analysis, the correct pointing information has been validated on-orbit (using a very large average of limb dayglow observations) and is consistent with preflight measurements of the *relative* angular response functions for each pixel along the slit.

Figure E1 illustrates the different ways in which pixels are combined in limb database Version 9 (and earlier) and in Version 10. Five successive limb scans (scans n-2 through n+2) are displayed for each case of each version. The upper two rows in the figure (Case 1) illustrate pixel combinations when pixel 13 is lead, and the lower two are when pixel 0 leads. The "lead" pixel is that pixel which observes a geospace region first along the spacecraft path. Whether pixel 0 or 13 is lead depends on the yaw configuration of TIMED. Each limb scan is tested for lead pixel knowledge. Pixels shaded in yellow indicate those that have been averaged together.

The top row of 5 limb scans shows how the 20 pixels were combined for Version 9 (and earlier) using and central pixels 6-9. This combination smeared over a region of geospace that covered about five degrees along the orbit. Unshaded pixels in Case 1, Version 9 were not included in the average.

The second row (pixel 13 leading) illustrates how 14 pixels are combined in Version 10. Note that data from only three (rather than five in Version 9) successive limb scans is required in the averaging process. The region of geospace covered in the averaging process is about a factor of five smaller than for Version 9 (about one degree along the orbit).

In Case 2, the leading edge is pixel 0. While the same central pixels (6-9) were averaged together in Versions 9 and earlier, the Case 2 pixel numbers included for Version 10 are the reverse of Case 1 for limb scans n-1 and n+1.

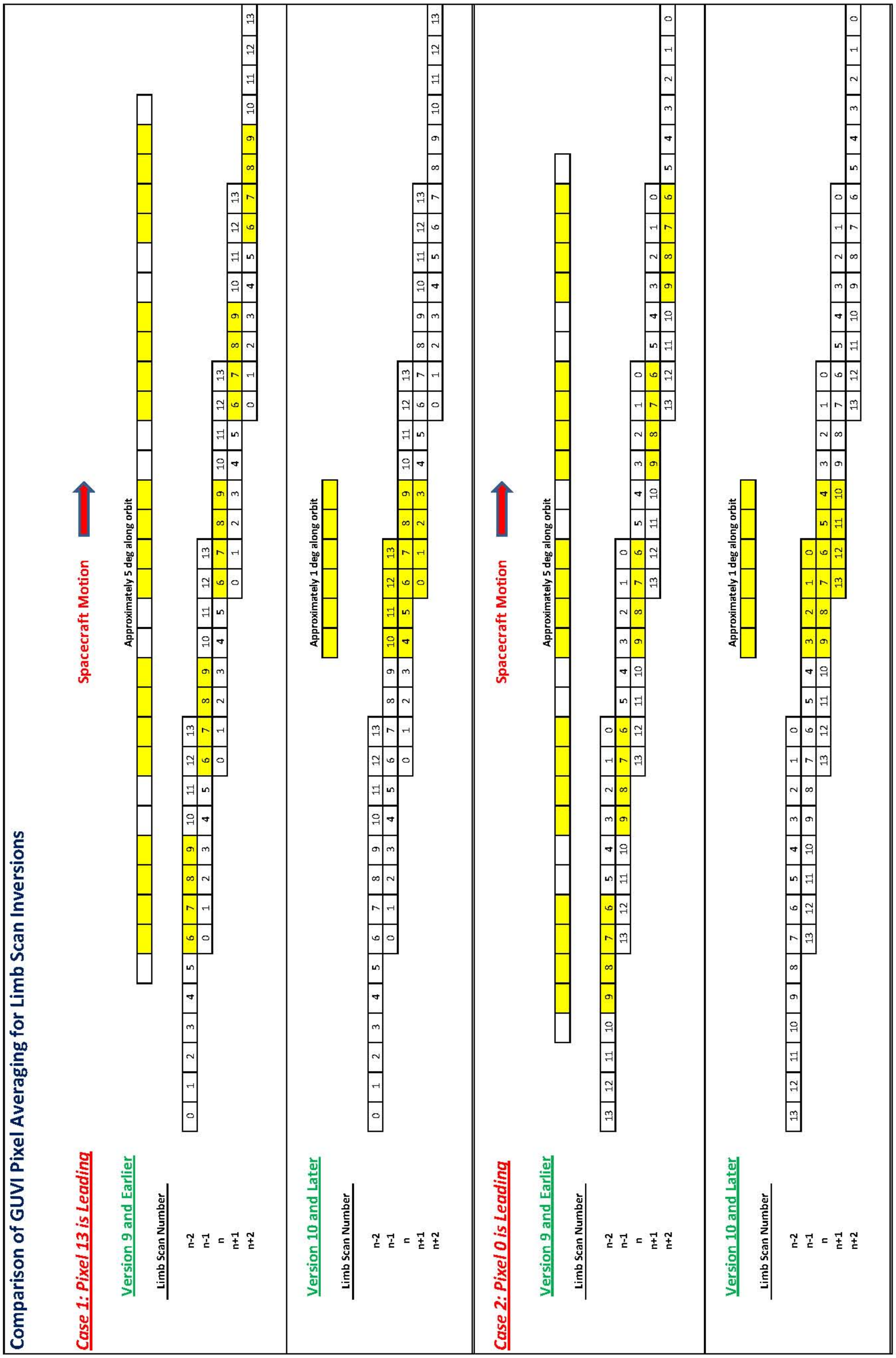
Comparison of GUVI Pixel Averaging for Limb Scan Inversions
Case 1: Pixel 13 is Leading
Version 9 and Earlier
Limb Scan Number
n-2
n-1
n
n+1
n+2
Spacecraft Motion
Approximately 5 deg along orbit
Version 10 and Later
Approximately 1 deg along orbit
Case 2: Pixel 0 is Leading

Figure E1

Appendix F Principal Changes for Version 10

All prior versions of the GUVI limb database have used the averaged radiances from four central pixels (pixels 6-9) because pointing information for pixels near the edges of the slit are affected by optical curvature that is not taken into account in the Level 1B (Version 8) radiance files. Curvature has little effect on pixels 6-9. To improve counting statistics in Version 9 and earlier, five successive limb scans were averaged together, producing 20 samples of a region of the limb in geospace approximately 5 deg along the orbit.

Version 10 incorporates the correct pointing information for all pixels. Details on how pixels are combined for multiple samples of selected regions of geospace are given in Appendix E. There, comparison with Version 9 (and earlier) show that the spatial resolution on the limb of the retrieved data products increases from about 5^o along the orbit to about 1^o. The number of samples decreases from 20 to 14, thereby increasing the counting error but decreasing the spread due to sampling of different regions of geospace. The number of individual inverted limb scans has increased from 378,448 (Version 9) to 1,754,512 (Version 10).

In order to include all 14 pixels, the inversion software required major revisions. Of course, these changes are transparent to users of the database—the Version 10 database remains in the same format as Version 9.

As with Version 9, the database was produced using SEE EUV solar fluxes as input to forward model. The SEE solar fluxes have been scaled by 0.675 in order to obtain agreement with the GUVI radiances. This factor was independently obtained with Version 10 by initially retrieving the solar flux scalar from 2002-2007. It was found to be the same as for Version 9. SEE fluxes are available once per orbit.

As with Version 9, the calibrations of the GUVI radiance channels (colors) have been revised to accommodate differences between pre-flight calibrations, and on-orbit stellar and dayglow observations. (The stellar and dayglow observations are consistent and also agree with independent simultaneous SSUSI dayglow observations.) The GUVI Level 1B (Version 8) radiances are scaled by (see Appendix B, section 3):

Channel 0 (H Lyman alpha): 1.8
Channel 1 (OI 130.4 nm): 1.4
Channel 2 (OI 135.6 nm): 1.148
Channel 3 (N_2 LBHS): 1.194
Channel 4 (N_2 LBHL): 0.916

As with Version 9 and earlier, the pointing information in Level 1B (Version 8) has been corrected by using stellar observations. See Section II.4 below.

A modification to the code was made to ignore a small number of instances when the radiances provided in the Level 1B (Version 8) input data files contained zeros.