TES Limb Retrievals using MIPAS Algorithm

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The Tropospheric Emission Spectrometer (TES) on board NASA's Aura satellite (launched on July 15, 2004) is an infrared (650-4250cm^{-1}), high resolution FTS that measures emission features from atmospheric trace gases. TES operates in two different ways: as a downlooking (nadir) sounder and as a limb sounder. In its limb mode, the 16 detectors simultaneously measure spectra from the surface to about 33 km. The analysis of limb scanning sequences allows the determination of vertical profiles of many atmospheric constituents. Here we present TES limb retrievals using a MIPAS algorithm, developed at the University of Oxford. MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) is a high resolution limb sounder flying on board ESA Envisat satellite. MIPAS measures infrared (685-2410cm^{-1}) atmospheric limb emission spectra over an altitude range of 6-68 km. The Oxford retrieval algorithm for MIPAS uses an Optimal Estimation Technique with a-priori information to constrain the retrieval. The retrieval is based on the use of selected spectral intervals (microwindows) containing the best information on the target parameters. In the new resolution mode, following problems with the interferometer slide mechanism, the MIPAS spectral resolution has been reduced by 40%, 0.0625 cm^{-1}. For future comparison between MIPAS and TES limb, we decided to resample the limb TES spectra at 0.0625 cm^{-1} and therefore to use the microwindows selected for MIPAS that are present in the four TES spectral arrays. Here we present the first tentative retrieval of pressure, temperature and 5 target species (H_2O, O_3, HNO_3, CH_4 and N_2O) for run 2147, scan 4, of 20 September 2004..
We also illustrate an application of the Singular Value Decomposition to the TES limb data for the same day of TES measurements.

Rather than using all the available measurements, it is usual to select narrow spectral intervals, called ‘microwindows’, containing the best information on the target parameters. The use of microwindows avoids the analysis of spectral regions that are more affected by systematic errors (i.e. instrumental effects or non-target species interference).
The upper panel of Fig. 1 shows the position (altitude versus spectral domain) of the microwindows selected for pressure and temperature profiles and the VMR profiles of five target species (H_2O, O_3, HNO_3, CH_4 and N_2O). These microwindows are located in two TES spectral regions 1B1 (820 – 1050 cm^{-1}) and 2A1 (1100 - 1350 cm^{-1}) for the altitude range 6-40 km. Band 2B1 (650 – 900 cm^{-1}) has been avoided because it is highly noisy, while there are no microwindows selected for band 1A1 (1900 – 2250 cm^{-1}). The lower panel of Fig. 1 shows the radiance contributions of the different target species at 21 km for the two spectral bands.
Fig. 2 shows the profile error estimates obtained from the microwindows selection process for temperature and the 5 target species. Each plot represents the total error (K for temperature and % VMR for the species) as a function of altitude. The total error (solid line) is given by random (dotted line) and the systematic (dashed line) profiles; the different symbols represent the major systematic components that affect the accuracy of the retrieval. The accuracy for retrieving water vapor is limited by the random error, because there are only two H_2O microwindows available in the TES spectral bands.
Fig. 3 shows the latitudinal variations of temperature, H_2O, O_3, HNO_3, CH_4 and N_2O for run 2147, scan 4. Pressure, temperature and water vapor are retrieved jointly, while the other species separately in sequence.

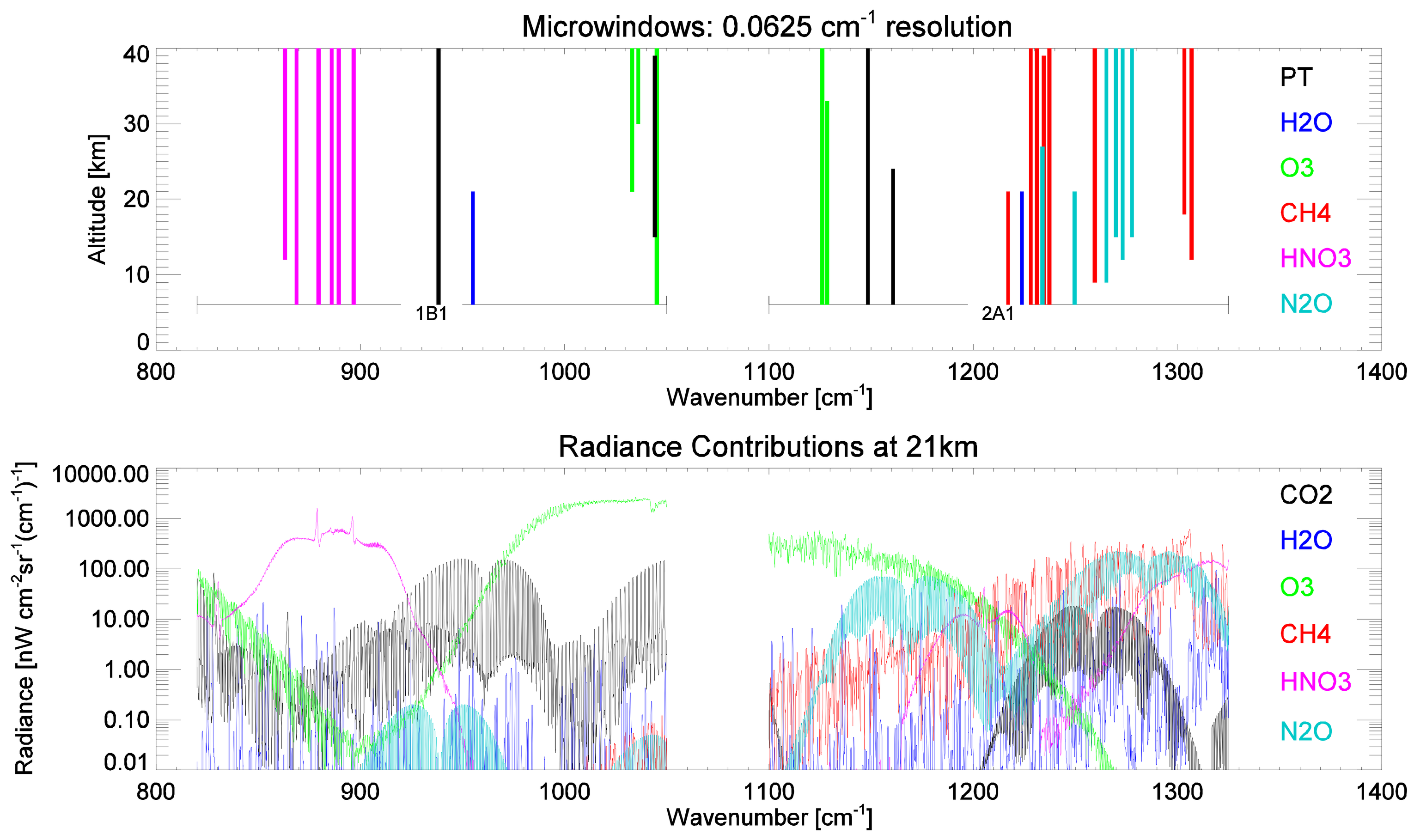

Fig.1: Position of the microwindows in the spectral and altitude domain (top) and radiance contribution at 21 km.

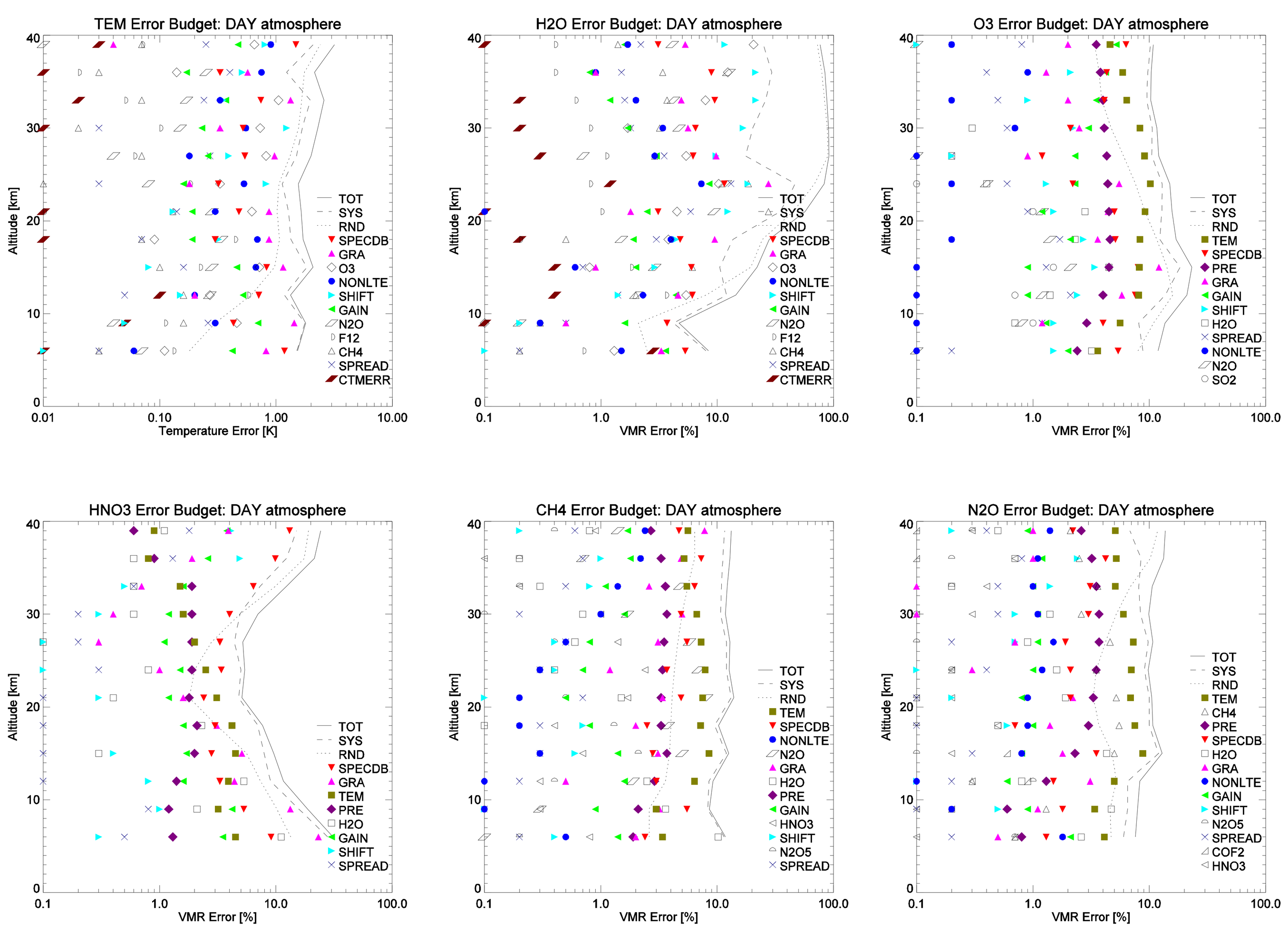

Fig.2:Total error budget on single profile retrieval for T(K), H_2O, O_3, HNO_3, CH_4 and N_2O (%VMR).

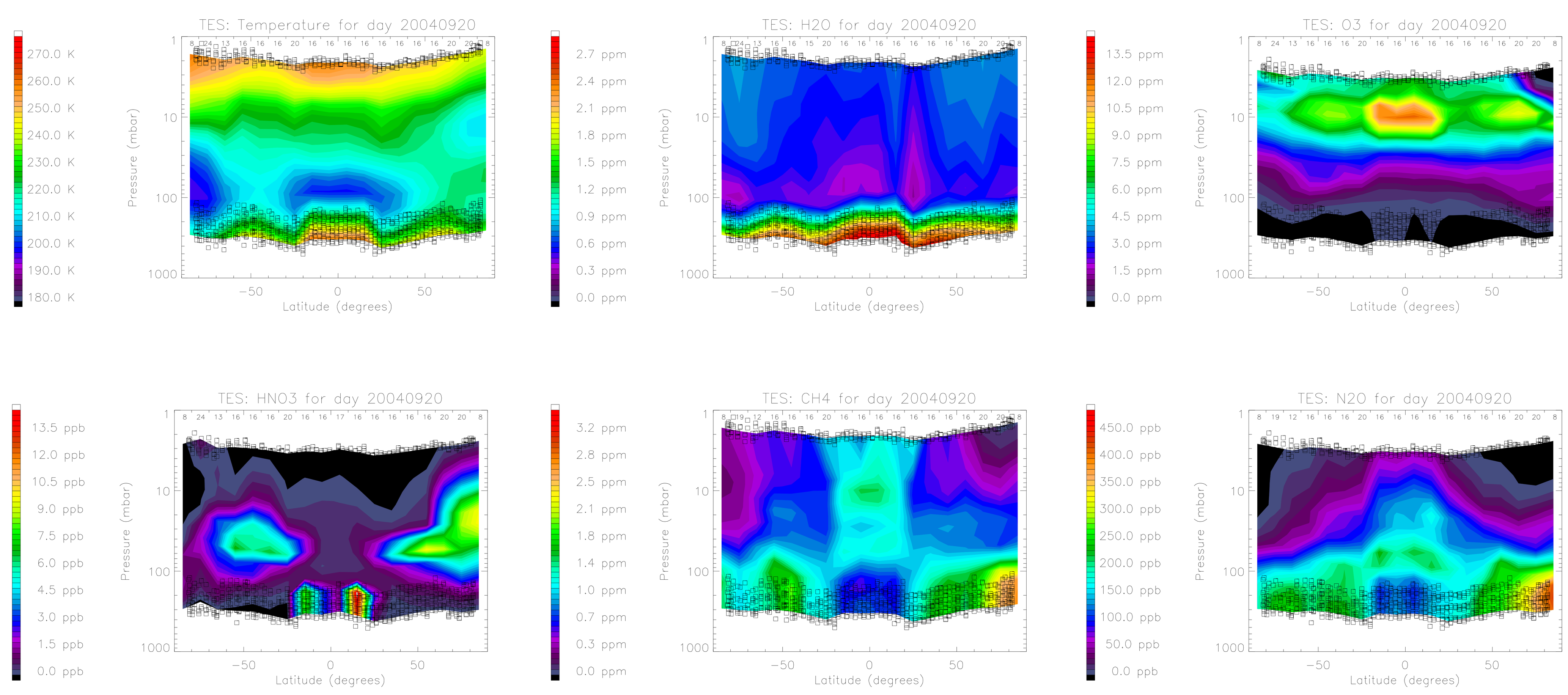

Fig.3: Latitudinal variation of Temperature, H_2O, O_3, HNO_3, CH_4, and N_2O for run 2147, scan 4. Squares: measurements not used (e.g. clouds).

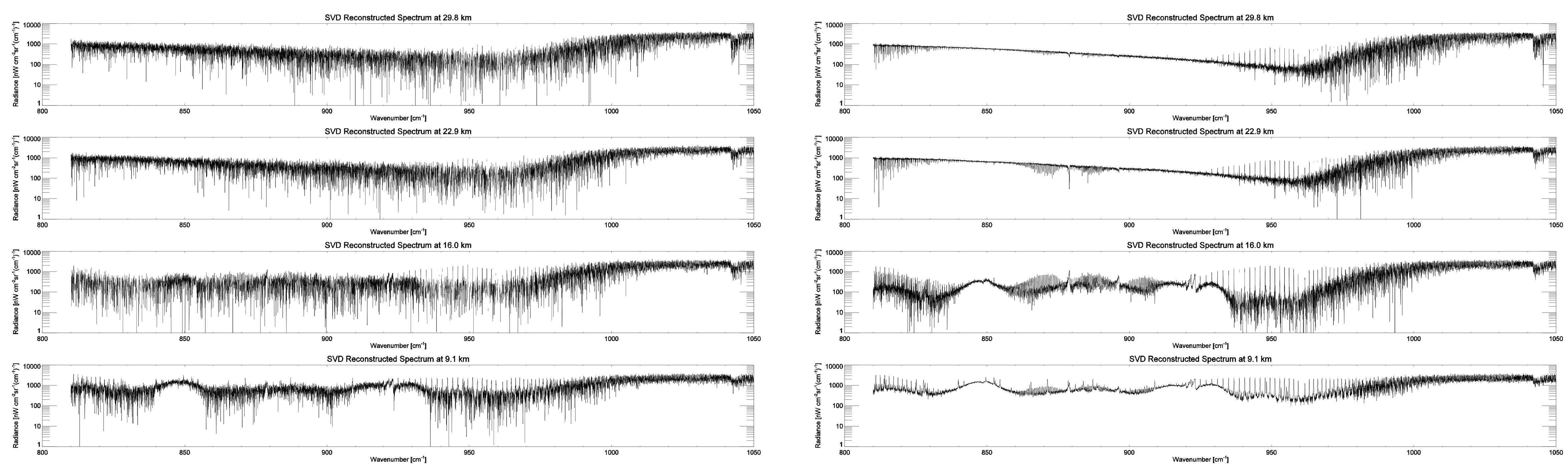

Fig.4:Example of SVD analysis. TES limb spectra (on the left) and reconstructed spectra (on the right) using 20 singular vectors obtained by a sample of 1600 spectra.

Singular Value Decomposition

High resolution spectra generally contain fewer independent quantities than the number of spectral elements.
A singular vector analysis of a large sample of spectra can be used to identify independent variations in the spectra, due to both atmospheric and instrumental causes. This includes the separation of the noise from the signal, and hence “de-noising” spectra.
Here we present an example of this approach using a sample of 100 TES limb sequences. Fig. 4 shows on the left the original spectra and on the right the reconstructed spectra using the first 20 singular vectors, for four altitudes of sequence 57, scan 4.

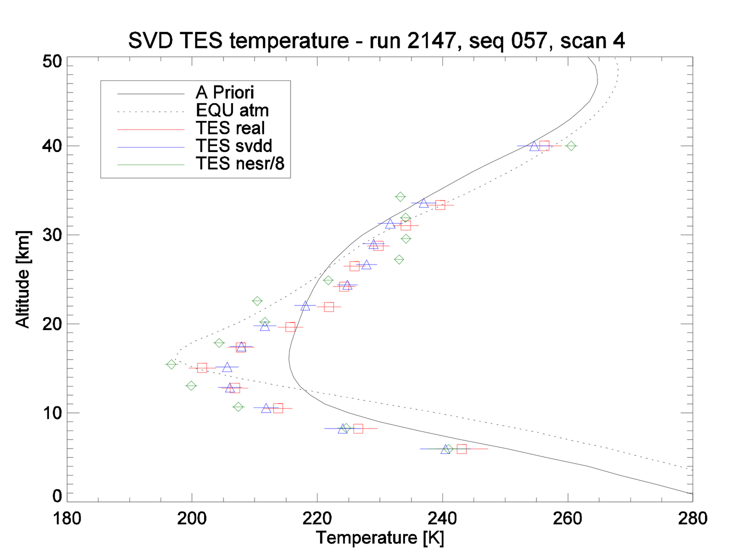

Fig.5: Temperature Retrieval using SVD analysis, using original spectra (red), reconstructed spectra with nominal nesr (blue) and with nesr/8 (green).

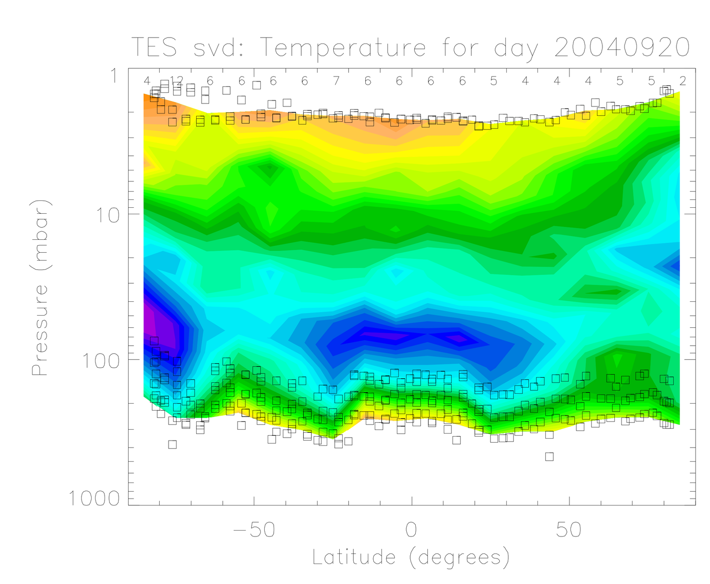

Fig.6: Latitudinal variation of Temperature for run 2147, scan 4, using 100 reconstructed sequences with nesr/8. Squares: measurements not used (e.g. clouds).

Results of the Singular Value Decomposition

Fig. 5 and Fig. 6 present an example of temperature retrievals using the SVD approach.
Fig. 5 shows a comparison between the temperature profile retrieved using TES original spectra (in red) and the spectra reconstructed from the first 20 singular vectors obtained from a sample of 100 TES limb sequences. In blue the temperature profiles was retrieved using the TES nominal nesr and in green using nesr/8, corresponding approximately to the error on the SVD (1600 spectra averaged / 20 singular vectors used for the reconstruction).
Fig. 6 shows the latitudinal variation of temperature retrieved from the reconstructed spectra with a nesr/8 (first 100 sequences of run 2147, scan 4). This temperature zonal mean shows finer structure than the temperature zonal mean of Fig. 3.

Further work

- Selection of more microwindows for water vapor or of new microwindows dedicated to TES
- Application of the SVD analysis to a bigger sample of spectra (averaged altitude by altitude)