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GLORIA – AN AIRBORNE IMAGING FTS

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I. Introduction

The Gimballed Limb Observer for Radiance Imaging of the Atmosphere (GLORIA) is an imaging Fourier Transform Spectrometer (FTS) which is capable of operating on various airborne platforms. The main scientific focus is on the dynamics and chemistry of the Upper Troposphere and Lower Stratosphere (UTLS) region. The instrument is capable of measuring in limb and nadir geometry and has flexibility in terms of spatial and spectral sampling. The limb sounding mode is used to explore transport processes between different compartments of the atmosphere that takes place on scales satellite instruments are not able to resolve. GLORIA will provide vertical sampling in the order of few hundreds of meters vertically and a few tens of kilometers horizontally. The nadir mode is designed for enhancing the horizontal sampling density in the lower and middle troposphere to support research on e.g. biomass burning, pollution, methane sources and sinks. The instrument is a joint development of the research centers Karlsruher Institut für Technologie and Forschungszentrum Jülich. The first measurement campaign (ESA Sounder Campaign – ESSenCe) was conducted in December 2011 in Kiruna (Sweden). Two flights were performed during the campaign with the Russian research aircraft Geophysica M55. The second campaign was done in April 2012 for test, certification and performance flights with the new German High Altitude and LOng range (HALO) research aircraft. Presently GLORIA is deployed on HALO for the first mission dedicated to atmospheric science scheduled for July to September 2012 during the TACTS and ESMVAL campaigns. On HALO the instrument is mounted in a belly pod, while on Geophysica it was deployed to bay No. 1; in both cases the instrument is exposed to ambient pressure and temperature.

Fig 1: GLORIA mounted in bay no. 1 of Geophysica M55

Fig 2: GLORIA mounted in the bellypod of HALO

II. Instrument Description

The heart of the instrument is a Michelson interferometer with a maximum optical path difference of +/- 8 cm. The interferometer is a single linear slide design with hollow cube corners. The interferometer is cooled to 215 K with the help of solid carbon dioxide. The infrared signal coming through the interferometer is imaged with an infrared lens system on the Mercury Cadmium Telluride (MCT) focal plane array (FPA). The detector is cooled to 60 K or less with a Stirling cooler. The detector has 256 x 256 elements. Depending on the scientific needs only a subset of the full array is used for performing the measurements. The field of view is freely configurable from 8 x 8 to 128 x 128 pixels; typically 48 (horizontal) x 128 (vertical) pixels corresponding to 1.5° x 4° field of view are used. The spectral coverage of the instrument in its current configuration is from 780 cm^{-1} to 1400 cm^{-1}. The spectrometer is mounted inside a gimballed frame which ensures agility to move the instrument in three axes (elevation, azimuth and image rotation). The scene can be stabilized on the focal place array by compensating the aircraft roll, pitch and yaw movements. In limb mode the horizontal viewing direction can be chosen freely within an angle range from 45° to 132° to the flight direction to allow tomographic sampling of the atmosphere (so-called dynamics mode). The necessary altitude information for the system is generated by a dedicated high precision inertial navigation system (INS). Two large blackbodies with very high emissivity and thermoelectric temperature control are used for radiometric calibration. The blackbodies are operated in the range from 15 K below and at least 30 K above ambient temperature. The instrument can be operated autonomously on the aircraft. A satellite link (Iridium) to a supervising ground station has been implemented for reacting to unforeseen problems and adapting the measurement plan. Alternatively, an instrument operator onboard takes care of the instrument operations.

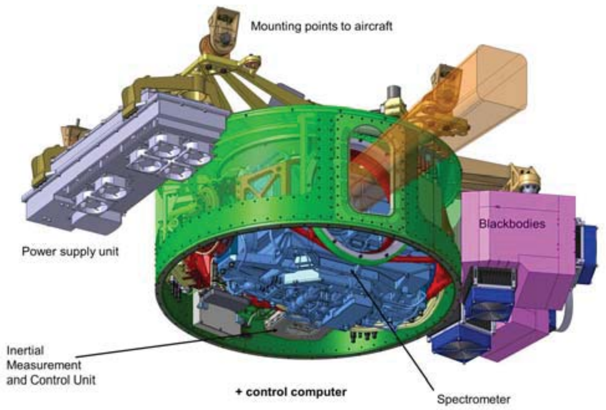

Fig 3: 3D CAD modelof GLORIA

III. Preliminary Results From First Campaign

Analysis of the data measured during the ESSenCe campaign is ongoing; some preliminary results are presented in this section. Both flights were focused on the instrument performance as well as on data quality checks. The flight was made with detector configuration of 48 (horizontal) x 128 (vertical) pixels. Figure 4 shows the interferogram DC plot with the instrument looking at the atmosphere. The data has been rescaled on a value of 0 to 1. The plot shows structures which comprises of clouds and aerosols (red to bluish colors). The dark blue color corresponds to clear sky condition. Figure 5 shows the interferogram maximum position plotted for each pixel over the detector array. The maximum position is plotted relative to the on axis pixel. The interferogram's maximum position represents the static shear. The static shear was adjusted on-ground before takeoff. The plot was done with a dataset measured during flight where the temperature of the interferometer drifted from the initial value by 15 K. A very small maximum shear of +/- 1 micrometer has been determined.

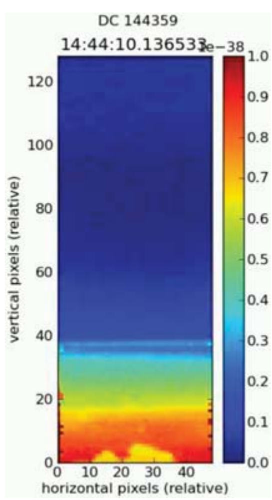

Fig 4: DC values plotted over pixels

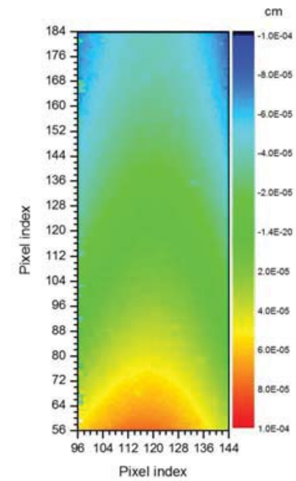

Fig 5: Interferogram maximum plotted over pixels

Figure 6 shows the calibrated spectra from measurements sampled with the chemistry mode. The pixels of each row are co-added after removing the bad pixels. The 128 co-added pixels are shown in this plot spreading over lower troposphere tangent altitudes (highest radiance values) up to viewing angles sampling radiation from above the airplane.

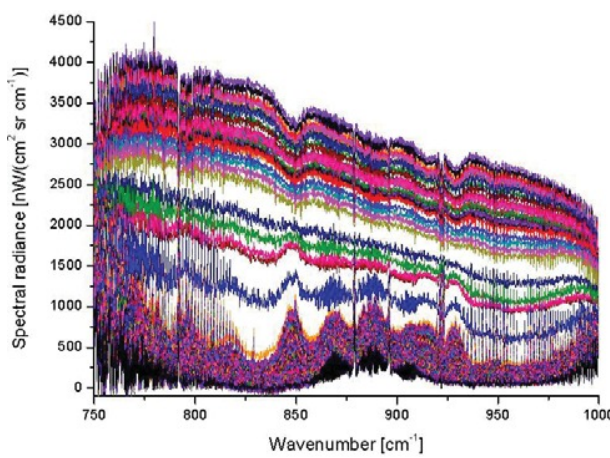

Fig 6: Chemistry mode calibrated spectra in the range of 750 cm^{-1} – 1400 cm^{-1}, 128 (v) spectra are plotted; these spectra are the mean of the 48 (h) pixels.

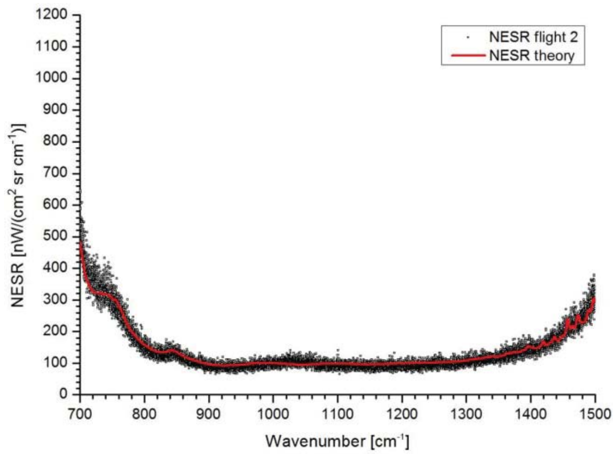

Fig 7: Chemistry mode NESR plot. Black dots represent the measurement and the red line the theoretical expectation.

Figure 7 shows the noise equivalent spectral radiance (NESR) plot for a single pixel of GLORIA. The black points are derived from the measurements. The NESR value has been calculated by taking the standard deviation of the imaginary part of the calibrated spectra of different measurements. The red line is the theoretically expected NESR. The theoretical value of NESR is calculated using the modeled instrument noise and the measured detector response. The values are then put in the NESR model as described in the paper from Villemaire and Giroux [3].

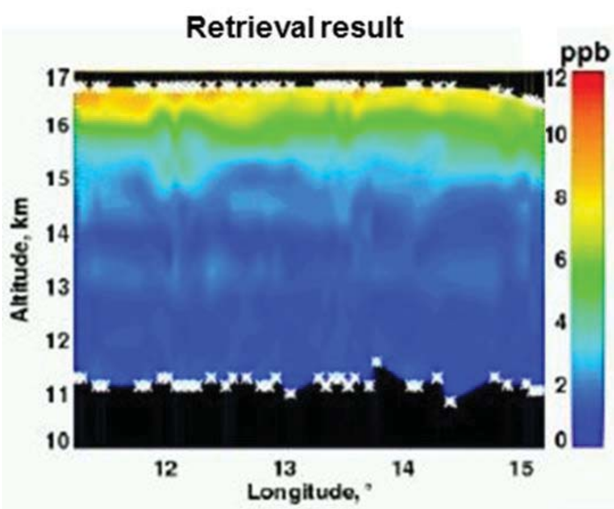

Fig 8: HNO_3 retrieval results from the Chemistry mode measurement

Figure 8 shows an exemplary retrieval result of Nitric acid (HNO3) plotted against longitude from ESSenCe campaign. The retrieval was done for the micro-window in the range of 876-880 cm-1.

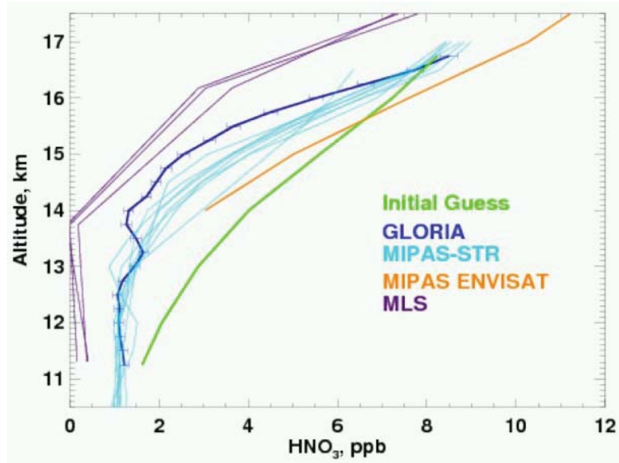

Fig 9: GLORIA HNO_3 profile (blue) compared to results from other instruments

Figure 9 shows the HNO_3 vertical profile plotted along with the profile from other infrared (MIPAS-STR and MIPAS ENVISAT) and microwave (MLS) instruments. GLORIA data are in good agreement with the MIPAS-STR profiles (measured at the same flight) below 13.5 km and above 16 km. In the altitude range of 13.5 km to 16 km GLORIA data show a low bias when compared to MIPAS-STR which still needs to be explored. The MLS data set provides smaller mixing ratios than the GLORIA results, whereas the MIPAS ENIVSAT results are larger than any of the profiles available for the inter-comparison. The measurement locations of MLS and MIPAS ENVISAT do not coincide in time and space and have a poorer vertical resolution than GLORIA and MIPAS-STR which might explain most of the differences.

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