Limb Sounding of the Atmosphere with the GLORIA Airborne Hyperspectral Imaging Spectrometer

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The *Gimballed Limb Observer for Radiance Imaging of the Atmosphere* (GLORIA) is an airborne imaging Fourier transform spectrometer (iFTS) which is able to operate on the German HALO and the Russian M55 Geophysica aircraft. It sounds the atmosphere in limb geometry and can execute complex measurement patterns enabling 3D tomography studies. The instrument is designed by joint teams of the KIT and the FZJ to answer questions both about the atmosphere's chemical processes and about its dynamics and transport mechanisms.

Limb Sounding of the Atmosphere

The limb observation geometry is the main geometry used by GLORIA. The different vertical tangent points (TP) are observed all at once, making use of the imaging capability of the spectrometer large focal plane array (LFPA). This is a notable advantage of imaging instrument in contrast to limb-scanning instruments.

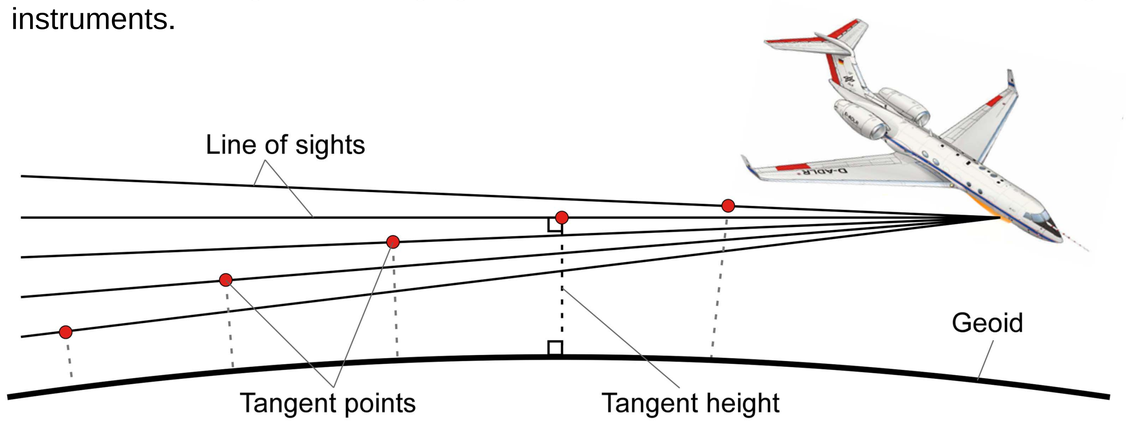

Fig. 1 *Schematic view of the limb observation geometry, showing the line of sight and the tangent points.*

In the limb geometry, the emission of the atmosphere is sounded with the cold space as background. The largest atmospheric emission contribution arises from the tangent point of each line of sight.

Instrument Design Overview

GLORIA is an imaging Fourier transform Spectrometer based on a linear-slide Michelson interferometer. The classical FTIR instrument is coupled to a 256 x 256 pixel high-speed IR camera covering the spectral range from 7 to 13 µm. A region of interest (ROI) of 128 x 48 pixel is used for the measurements. The whole spectrometer is mounted in a gimbal, providing the agility pointing orientation and stabilization. The spectrometer can operate in two modes: the chemistry mode (CM) for study of chemical processes and the dynamics mode (DM) for study of dynamic structures.

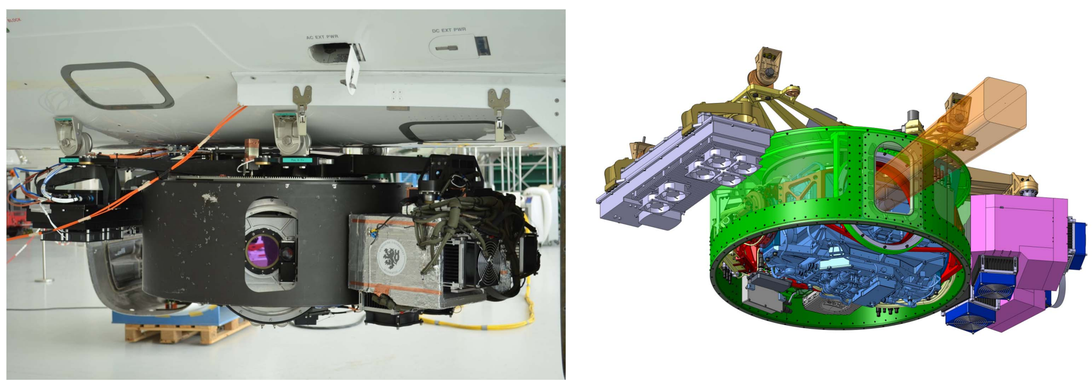

Fig. 2 *GLORIA on HALO and Illustration of GLORIA showing in green, red and blue respectively the gimbal azimuth, roll and pitch frames. The spectrometer is integrated to the blue pitch frame.*

The complex pointing system along with the flexibility of the spectrometer requires advanced automation in parallel to constant operator monitoring. The automation system integrates the information provided by over 1000 sensors and executes measurements. This includes the computation of TP according to the aircraft attitude.

Tab. 1 *Main characteristics of GLORIA in DM and CM for a flight altitude of 15 km and a tangent height of 10 km.*

	Dynamics mode	Chemistry mode
Vertical coverage	4 km to 0.8°	4 km to 0.8°
Vertical sampling	140 m	140 m
Horizontal coverage	6.7 km	6.7 km
Spectral sampling	0.625 cm^{-1}	0.0625 cm^{-1}
MOPD	0.8 cm	8 cm
Temporal sampling	2 s	12.8 s
Spectral coverage	780 – 1400 cm^{-1}	780 – 1400 cm^{-1}
NESR-0 (apod.)	< 5 nW/(cm² sr cm^{-1})	< 15 nW/(cm² sr cm^{-1})

Measured Spectra

The following figure shows details of the measured CM spectra after calibration taken in a single 12 s measurement. It was taken during the TACTS-ESMVal campaign on 2012-09-26. Each spectrum is for a selected horizontal line, with the index given in the legend. 48 pixels of each lines are co-added. Among H_2O lines, the signature of F-11 and HNO_3 are clearly discernable.

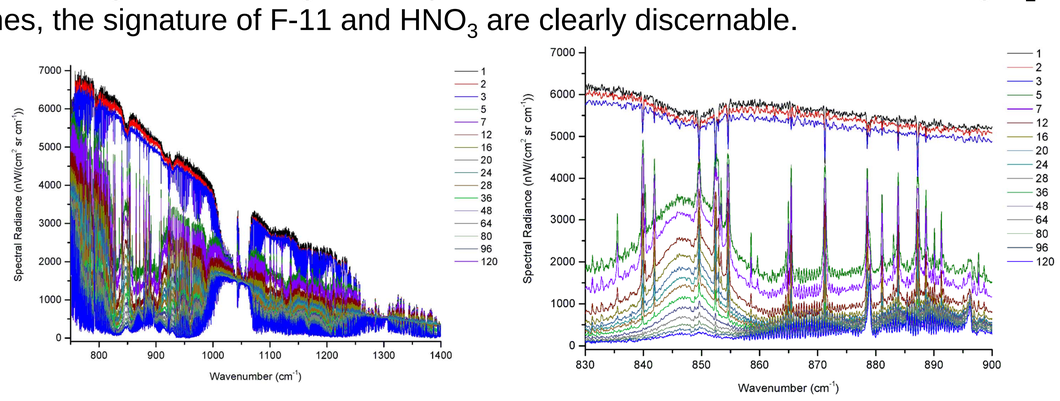

Fig. 3 *Spectra issuing from a single simultaneous measurement of all tangent point with GLORIA. Each line give the spectrum for the co-added pixels of a line of the LFPA (48 pixels). A selected number of lines, given in legend, are shown for the full spectral band (left) and detail (right) (Friedl-Vallon et al., 2014).*

The spectral sampling, given in Tab. 1, is defined by the maximum optical path difference (MOPD) of the Michelson interferometer. The actual spectral resolution, described by the instrument line shape (ILS) is driven by this sampling, but also by optical effects (integrated field angles) and numerical apodization applied in the processing. Achieved resolutions are about 1.25 cm^{-1} for DM and 0.125 cm^{-1} for CM with 10 ppm accuracy.

Retrieved Atmospheric Species

The following graphics show retrieval results for temperature, HNO_3, O_3 and H_2O from a TACTS-ESMVal flight on 2012-09-26 over the North Atlantic.

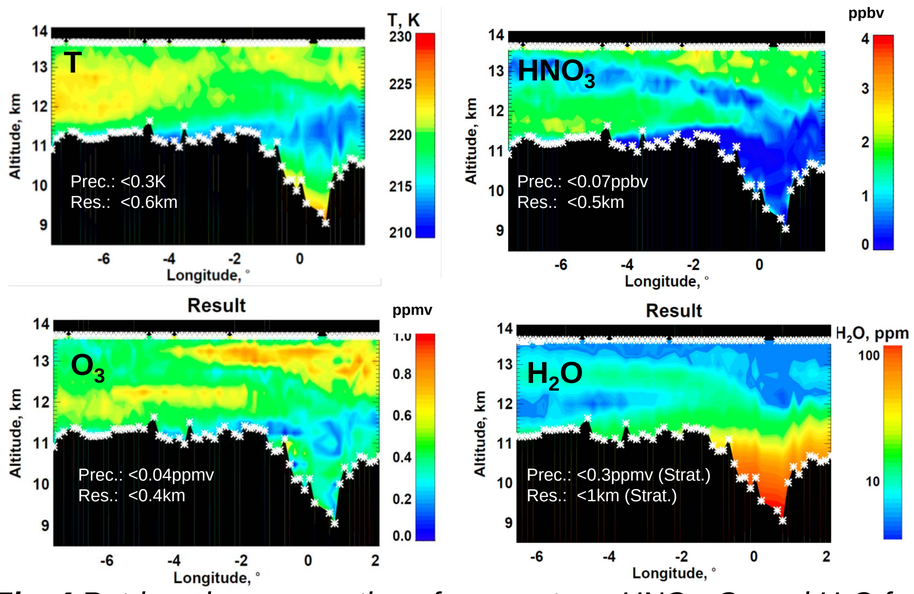

Fig. 4 *Retrieved cross-section of emperature, HNO_3, O_3 and H_2O for a flight leg of ~1h. The upper part of the cross-section is limited by the flight altitude (white crosses) and the lower part by tropospheric clouds. Filamentation is clearly visible. (Suminska-Ebersoldt, 2012)*

Other than temperature, vertical profiles can be retrieved for the following species: H_2O, HDO, O_3, CH_4, N_2O, CFC-11, CFC-12, HCFC-12, SF_6, HNO_3, N_2O_5, $ClONO_2$, HO_2NO_2, PAN, C_2H_6, H_2CO, NH_3. Furthermore, clouds, including thin cirrus clouds, and ice water content can be identified.

For more information: http://gloria.helmholtz.de

Friedl-Vallon et al.: Instrument concept of the imaging Fourier transform spectrometer GLORIA, Atmos. Meas. Tech., 7, 3565-3577, doi:10.5194/amt-7-3565-2014, 2014..

Riese et al.: Gimballed Limb Observer for Radiance Imaging of the Atmosphere (GLORIA) scientific objectives, Atmos. Meas. Tech., 7, 1915–1928, doi:10.5194/amt-7-1915-2014, 2014.