

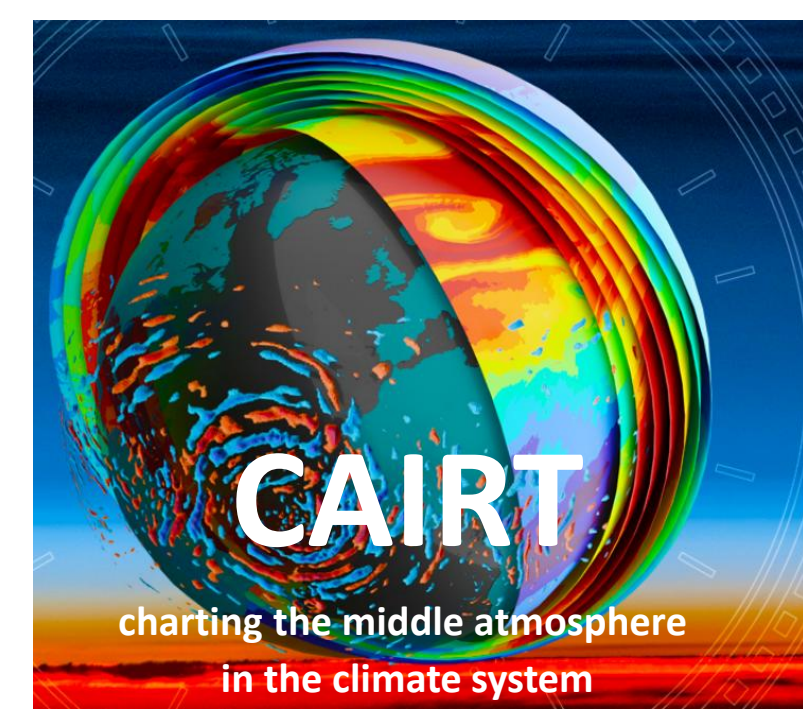
Validating the CAIRT tomographic limb-sounding concept with airborne GLORIA and WALES

J. Ungermann¹, S. Johansson², P. Preusse¹, E. Kretschmer², M. Wirth³, B.-M. Sinnhuber² and the GLORIA-Team

¹Institut für Energie und Klimaforschung (ICE-4), Forschungszentrum Jülich, Germany

²Institut für Meteorologie und Klimaforschung (IMK ASF), Karlsruher Institut für Technologie, Karlsruhe, Germany

³Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany



Introduction. The Gimbalbed Limb Observer for Radiance Imaging of the Atmosphere (GLORIA) is an infrared imaging FTS with a 2-D detector operated on high flying research aircraft, and, most recently, stratospheric balloons. It has collected two- and three-dimensional data of infrared radiance on eight scientific campaigns, leading to derived vertical profiles of temperature, water vapor, ozone, (H)-CFCs, biomass burning tracers, cirrus clouds, etc., along more than 300 000 km of flight track in its lifetime. GLORIA also serves as a demonstrator for the finally not selected ESA Earth Explorer 11 mission CAIRT. In this project, we use GLORIA to replicate the 3-D tomographic measurement pattern of a CAIRT-like instrument to provide a realistic data set for demonstration and testing purposes of the involved tomographic algorithms and retrievals.

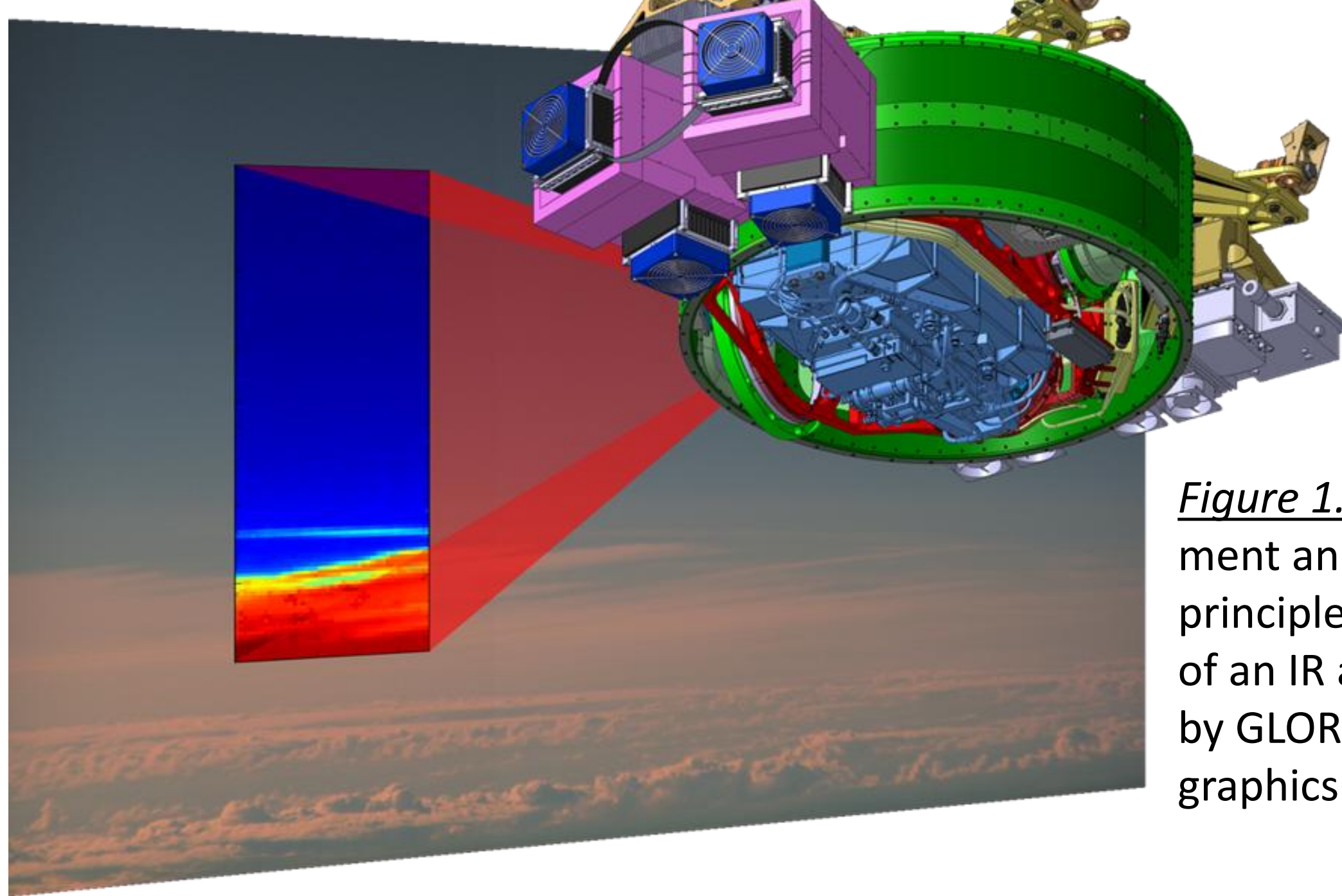


Figure 1. Schematic of the instrument and the measurement principle. Depicted is an overlay of an IR and a visual image taken by GLORIA together with a CAD graphics of the instrument.

The Arctic Springtime Chemistry-Climate Investigations campaign

- Inter-annual variability of Arctic lower stratospheric ozone depletion
- High latitude stratosphere-troposphere exchange and the structure of the high latitude tropopause
- Short-lived climate pollutants (ozone, aerosols) and their precursors in the Arctic upper troposphere
- 3 remote sensing and 9 in-situ instruments



Figure 2. (a) The German HALO research aircraft. The GLORIA instrument (circled) is mounted in the belly pod and observes to the right. (b) HALO in front of the hangar in Kiruna.

Experimental design

Due to the slow speed of the aircraft and the pointing of GLORIA, we typically perform tomographic measurements similar to a computer-tomography machine in circular flight patterns. To simulate the CAIRT geometry, a slow, dedicated flight pattern was designed that alternates between „limb“ legs measuring in the CAIRT geometry and „nadir“ legs to provide MetOp-like measurements for combined limb/nadir retrievals. Having a flight with no high and ideally no low clouds was a strong secondary requirement.

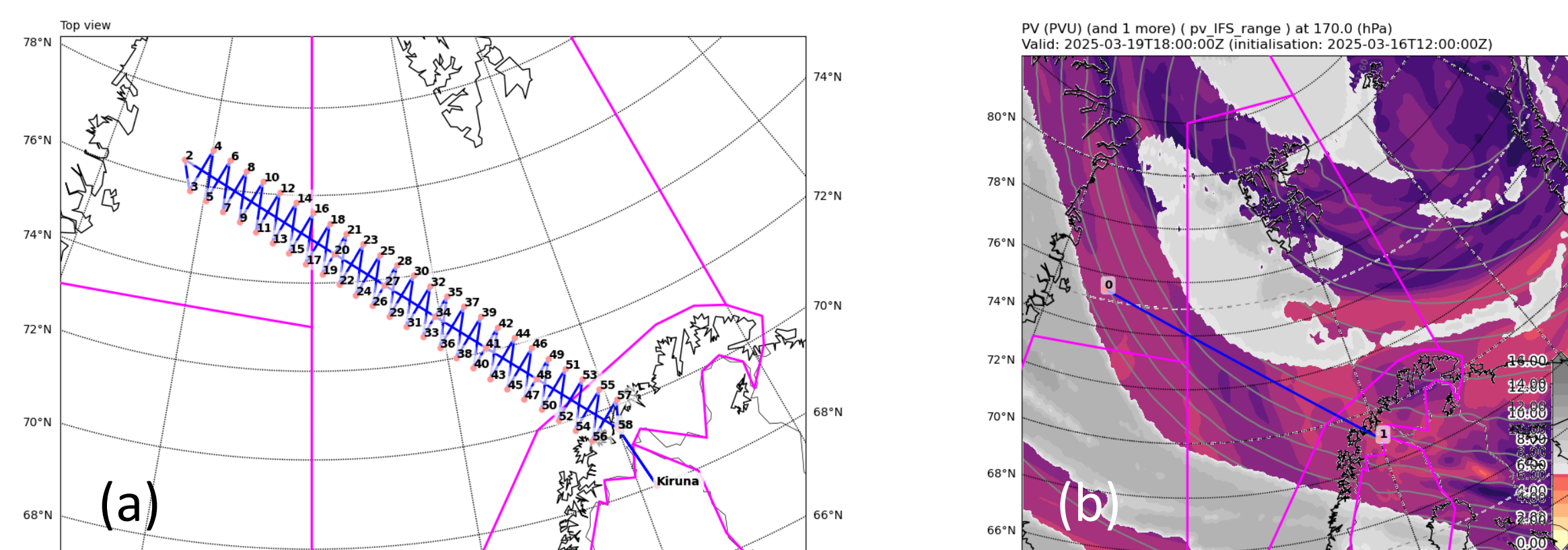


Figure 3. (a) The zig-zag pattern provides CAIRT-like measurements and allows for expected deviations by the aircraft from the planned track. (b) The ECMWF and ICON-ART forecasts showed a mostly cloud free region with only very low clouds, with some trace gas filaments.

Conventional retrieval

In a first step, conventional retrievals were employed on the individually retrieved profiles. In particular, both, the trans-sect and the „CAIRT“ measurements were derived. Several hours passed between the first and last measurements, still the agreement is good around the turn-around point.

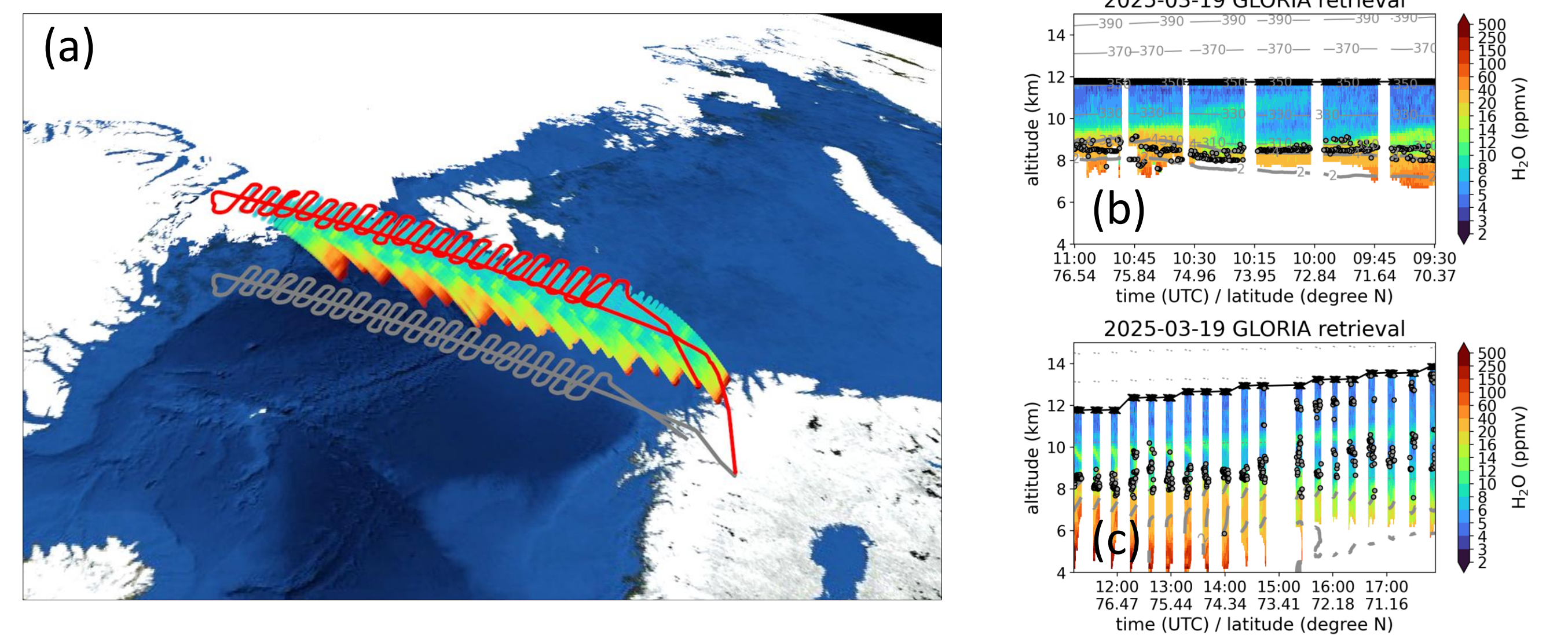


Figure 3. (a) 1-D retrieval results of the CAIRT measurements at the location of the tangent points. (b) cross section of 1-D retrieval results acquired during the transect. (c) results of the 1-D retrieval during the „CAIRT-like“ measurements.

3-D tomographic retrieval

In a second step, the „CAIRT-like“ measurements were co-added in two separate 25km across-track bins, allowing for two measurement tracks. These were separately evaluated using the JURASSIC2 tomographic processor and assembled back to a 3-D field. The results can be compared against ECMWF model data and Lagrangian-interpolated WALES lidar data, which also measured ozone and water vapour. Due to the differing measurement geometries and advection, only part of the cross-section is available.

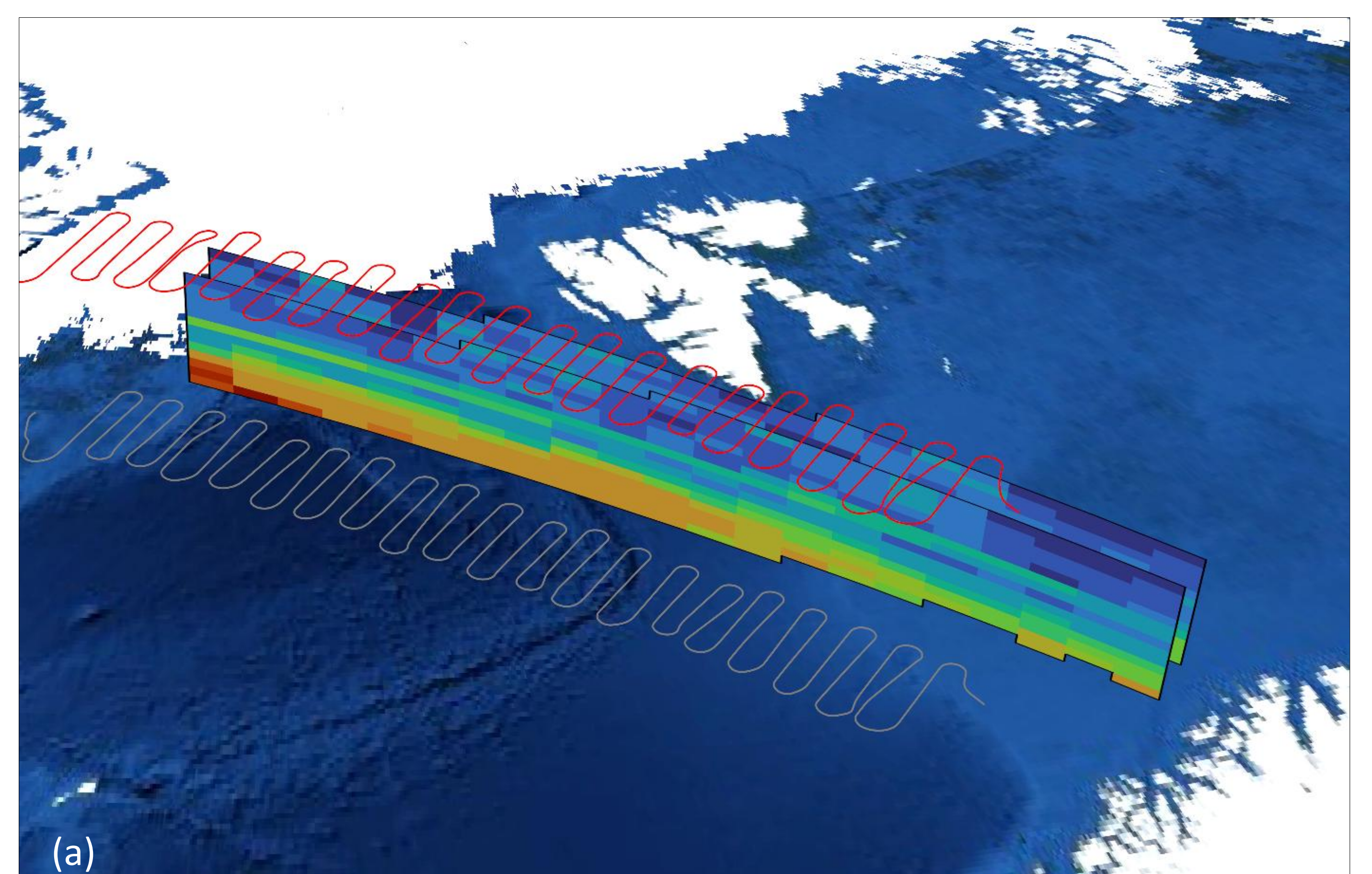


Figure 4. (a) two tomographic 2-D tracks. Even with 25km distance, the two track exhibit differences in the small-scale filament. (b) the southward GLORIA 2-D cross-section. (c) The corresponding ECMWF analysis model data. (d) The corresponding WALES lidar measurements.

Friedl-Vallon, F., 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.

Ungermann, J., et al.: A 3-D tomographic retrieval approach with advection compensation for the air-borne limb-imager GLORIA, Atmos. Meas. Tech., 4, 2509–2529, doi:10.5194/amt-4-2509-2011, 2011.

Ungermann, J., et al.: Quantification and mitigation of the instrument effects and uncertainties of the airborne limb imaging FTIR GLORIA, Atmos. Meas. Tech., 15, 2503–2530, doi:10.5194/amt-15-2503-2022, 2022.

Tirelli, C., et al.: Extension of the Complete Data Fusion algorithm to tomographic retrieval products, Atmos. Meas. Tech., 18, 5619–5636, doi:10.5194/amt-18-5619-2025, 2025.

This study called (Project CAREVALAB, ESA Contract No. 4000147015/25/NL/IB/ar) was carried out under a programme of, and funded by, the European Space Agency. The views expressed in here can in no way be taken to reflect the official opinion of the European Space Agency.

