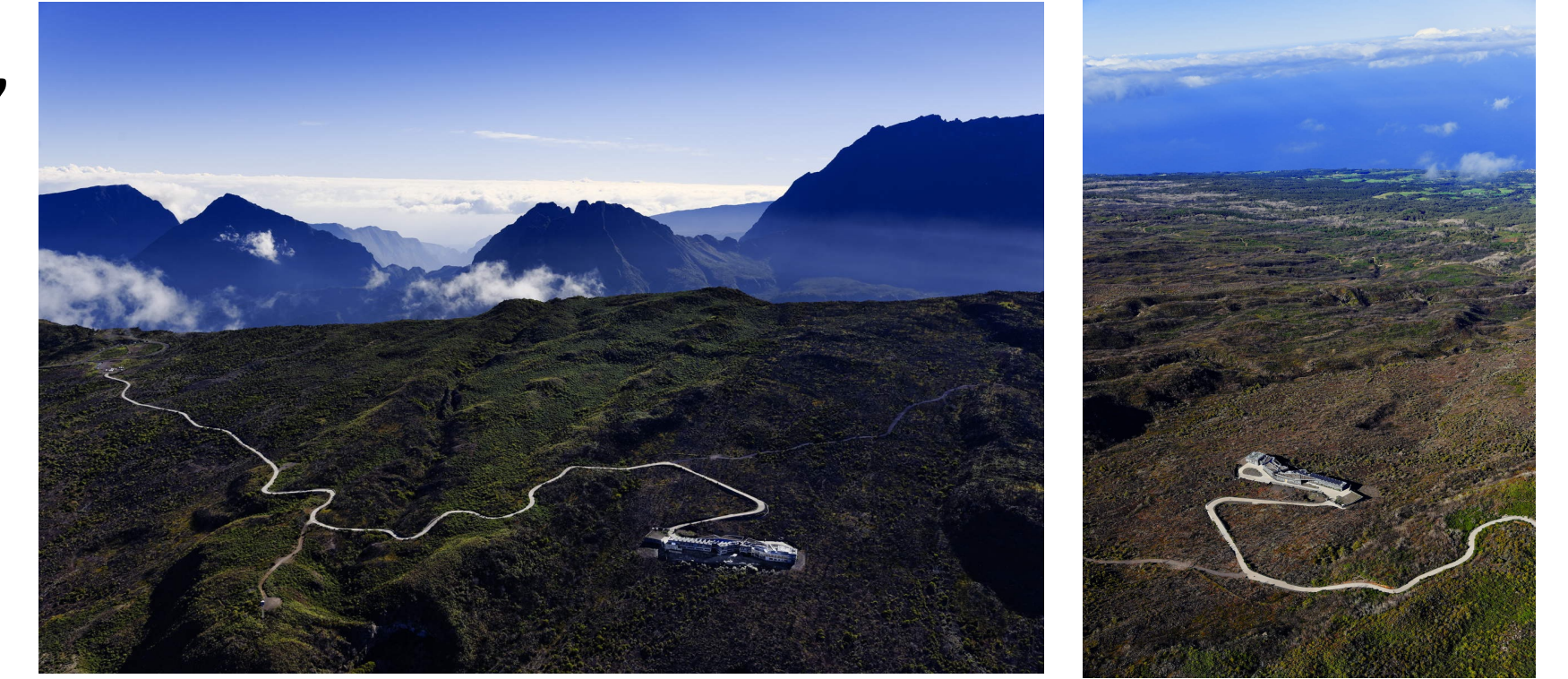


Ozone profiles obtained by DIAL technique at Maïdo Observatory in La Reunion Island comparisons with ECC ozone-sondes, ground-based FTIR spectrometer and microwave radiometer measurements.

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Maïdo Facility at 2153 m asl - 21.079°S - 55.383°E

Abstract : A DIAL (Differential Absorption Lidar) system performing stratospheric ozone profile measurements from 15 to 45 km is installed at Reunion Island. The purpose of this communication is to present this LIDAR mounted now at the new Maïdo Observatory since February 2013, and the ozone profile retrieval. The stratospheric ozone profiles obtained during 2013 and 2014 are presented. Some inter-comparison and differences observed with other vertical ozone profiles performed on the same site.

Maïdo facility: Reunion Island is situated in the Southwest of Indian Ocean (55° East, 21° South). This location is particularly well suited for monitoring stratospheric ozone in the tropical belt of the southern hemisphere. A new high-altitude observatory was built on the west coast of the island at 2153 m asl (Baray et al. 2013). The main objective of this station consists in observing the long-term chemical composition of the tropical atmosphere. This facility called Maïdo Observatory hosts many instruments for monitoring the atmosphere by various techniques: in-situ measurements, radiosoundings, active and passive remote sensing experiments... Stratospheric ozone measurements are routinely performed with:

- a DIAL system to perform high-resolution vertical profiles of ozone in the 15-45km altitude range
- a high spectral resolution Fourier- Transform infrared spectrometer (FTIR) operated by the Belgian Institute for Space Aeronomy ozone (10-40km)
- balloonborn soundings with ECC component to measure ozone profiles from ground to 30km

In addition, a microwave radiometer of University of Bern, has operated between late 2013 and early 2015.

Stratospheric DIAL System at Maïdo Observatory :

- Laser sources are a tripled Nd:Yag laser (Spectra-Physics Lab 150) and a XeCl excimer laser (Lumonics PM 844). The Nd:Yag provides the non-absorbed beam at 355 nm with a pulse rate of 30 Hz and a power of 5W, and the excimer provides the absorbed beam at 308 nm with a pulse rate of 40 Hz and a power larger than 9W. An afocal optical system is used to reduce the divergence of the beam to 0.5 mrad.
- The receiving telescope is composed of 4 parabolic mirrors (diameter: 500 mm). The backscattered signal is collected by 4 optical fibers located at the focal point of each mirror. The spectrometer used for the separation of the wavelengths is a Jobin Yvon holographic grating (3600 lines.mm⁻¹, resolution 3 Å.mm⁻¹, efficiency >25 %).
- The optical signals are detected by 6 Hamamatsu non-cooled photomultipliers (PM). A mechanical chopper is used to cadence the laser shots and cut the signal in the lower altitude range where PM are saturated. This chopper consists of a steel blade rotating at 24 000 rpm in primary vacuum. 6 acquisition channels are recorded simultaneously: 2 channels at 355 nm corresponding to the lower and upper parts of the profile, 2 channels at 308 nm (lower and upper parts) and 2 Nitrogen Raman channels at 332 and 387 nm. In addition to the mechanical gating, both upper Rayleigh channels at 355 nm and 308 nm, are equipped with an electronic gating in order to cut the signals for the altitudes below 16 km and prevent signal-induced noise.
- The lidar signals are recorded in a 3 min time file but averaged over the whole night acquisition (2 to 3h time integration per night) to increase the signal-to-noise ratio.
- The ozone number density is retrieved from the slope of signals after derivation (Godin-Beekmann et al., 2003).

Correction: The background signal is removed using an average or a linear regression in the high altitude range (over 80 km). Correction of photomultiplier saturation is also required and applied. The lidar signals are corrected the Rayleigh extinction using a composite pressure temperature profile computed from nearby meteorological soundings performed daily at Reunion Airport and the Arletty model (based on ECMWF)

Filtering: (low-pass filter) The logarithm of each signal is fitted to a 2nd order polynomial and the ozone number density is computed from the difference of the derivative of the fitted polynomial. Varying the number of points on which the signals are fitted completes the filtering.

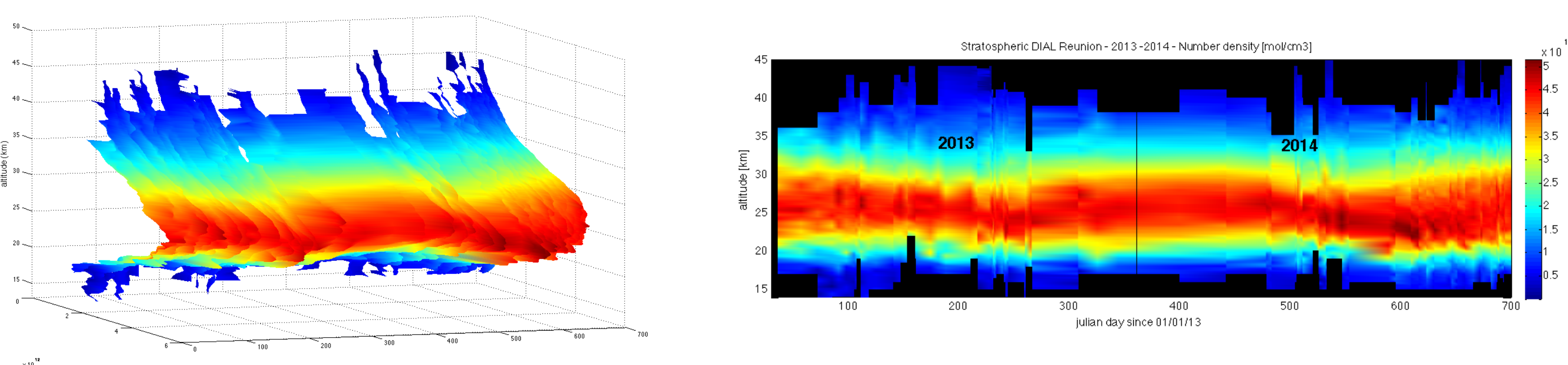


Figure 1 : 104 ozone profiles between February 2013 and November 2014, between 15 and 45 km altitude. The instrument operates between 1 and 4 times per week.

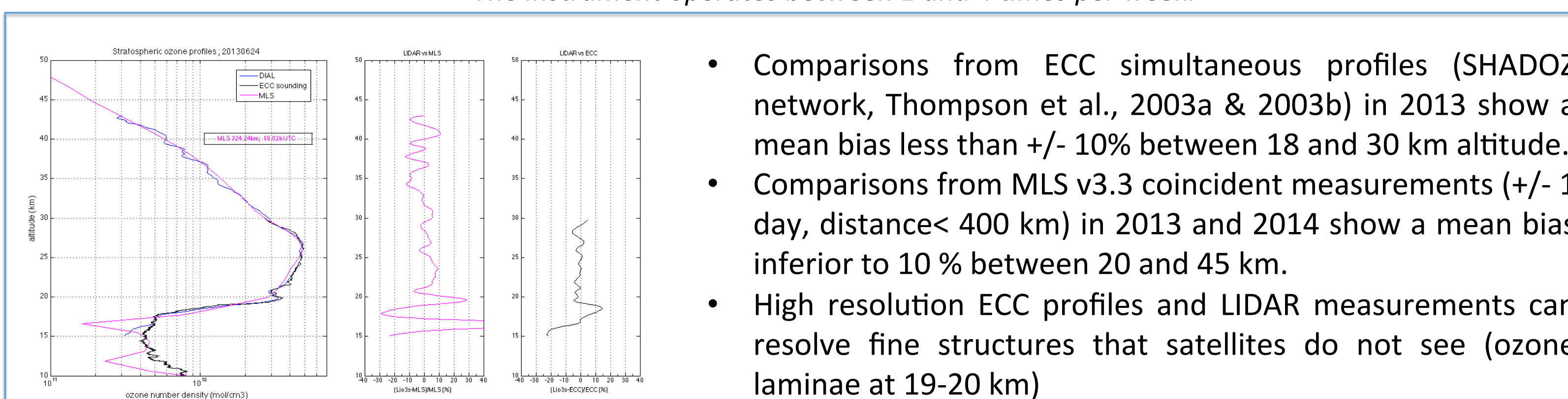


Figure 2: example of profiles and bias calculated on measurements in coincidence (23 June 2013).

Comparisons with FTIR measurements

Instrument description and method in

http://nors.aeronomie.be/projectdir/PDF/NORS_D4.2_DUG.pdf.

- FTIR measurement is coupled to the closest LIDAR measurement in time if it is within a 12h window
- For each pair (14 in total), the LIDAR profile is regridded (with mass conservation) to the FTIR height grid
- this regridded LIDAR profile is then smoothed with the FTIR AVK matrix
- from this smoothed LIDAR profile a partial column is calculated between 20km and 35km (this region is the maximum column within the validity range of the consolidated LIDAR profiles)
- the LIDAR uncertainty is propagated to the smoothed profile and to the smoothed partial column between 20-35km.
- the bias between these 14 pairs LIDAR - FTIR is ~ 5DU, or ~2%.
- This bias lies within the combined uncertainty budgets for the LIDAR and FTIR. As a consequence, we can not conclude that there is a bias in the comparison
- There are only a limited number of simultaneous measurements

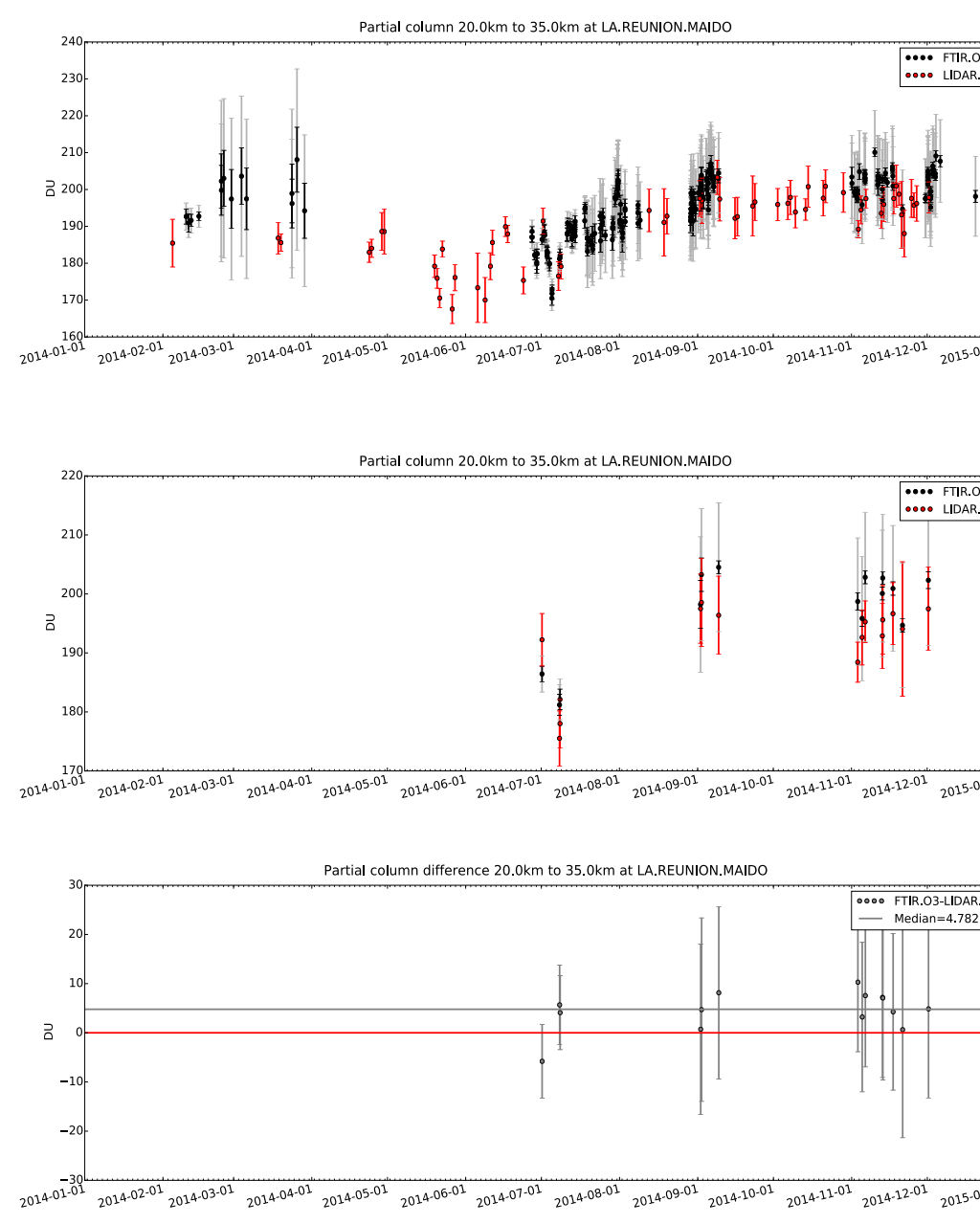


Figure 3: time series of FTIR and DIAL partial column

Comparisons with GROMOS-C microwave radiometer (GROUND based Ozone MONitoring System for Campaigns)

- GROMOS-C is designed to measure the vertical profile of ozone distribution in the middle atmosphere, by observing ozone emission spectra at a frequency of 110.836 GHz. It is a total power radiometer which uses a preamplified single sideband heterodyne receiver, and a digital Fast Fourier Transform spectrometer for the spectral analysis.
- the vertical resolution of GROMOS-C is between 10-15 km
- MLS data has been convolved with the averaging kernels
- see Fernandez et al., 2015 for details on GROMOS-C and method

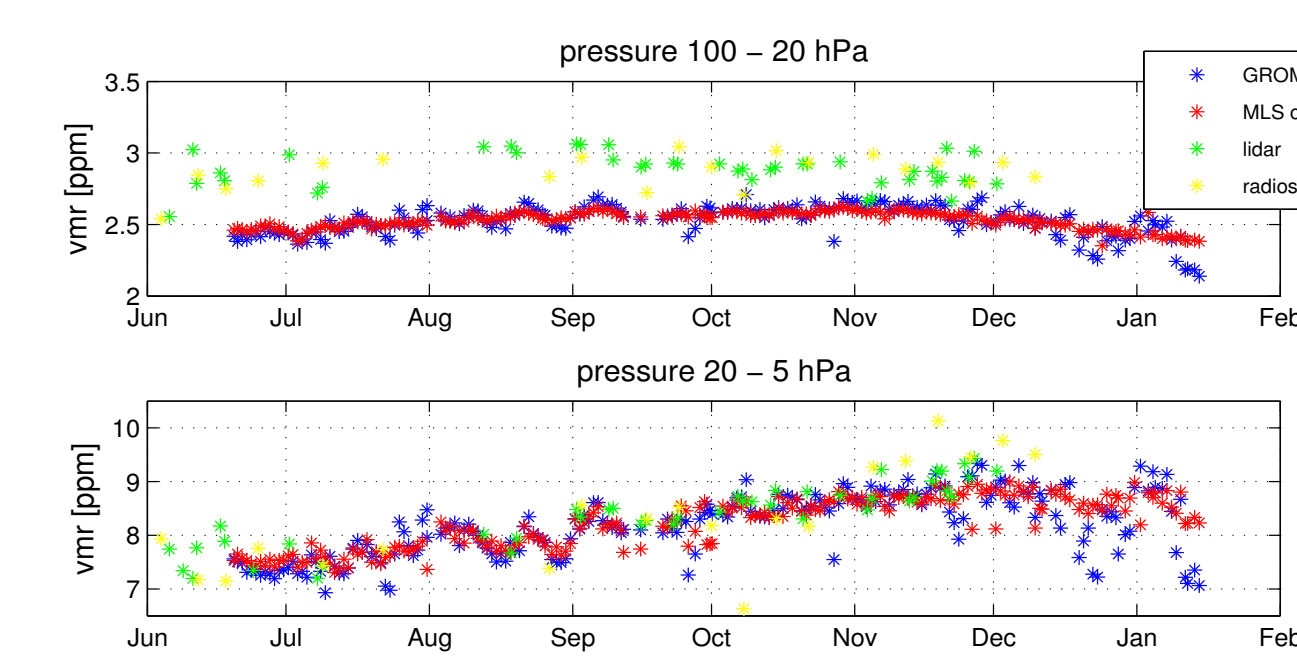


Figure 4: Comparisons of 2 Partial columns (20-5 hPa/26-36 km and 100-20 hPa/16-26 km) for the GROMOS-C radiometer

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References :

- [1] Baray, J.-L., Courcoux, Y., Keckhut, P., Portafaix, T., Tulet, P., Cammas, J.-P., Hauchecorne, A., Godin Beekmann, S., De Mazière, M., Hermans, C., Desmet, F., Sellegri, K., Colomb, A., Ramonet, M., Sciaré, J., Vuillemin, C., Hoareau, C., Dionisi, D., Duflot, V., Vérémes, H., Porteneuve, J., Gabarro, F., Gaudo, T., Metzger, J.-M., Payen, G., Leclair de Belleuve, J., Barthe, C., Posny, F., Ricaud, P., Abchiche, A., and Delmas, R.: Maïdo observatory: a new high-altitude station facility at Reunion Island (21° S, 55° E) for long-term atmospheric remote sensing and in situ measurements, Atmos. Meas. Tech., 6, 2865-2877, doi:10.5194/amt-6-2865-2013, 2013.
- [2] Fernandez, S., A. Murk, and N. Kämpfer, GROMOS-C, a novel ground based microwave radiometer for ozone measurement campaigns, Atmos. Meas. Tech. Discuss., 8, 3001-3048, 2015, doi:10.5194/amt-8-3001-2015
- [3] Froidevaux, L., Y.B. Jiang, A. Lambert, N.J. Livesey, W.G. Read, J.W. Waters, E.V. Browell, J.W. Hair, M.A. Avery, T.J. McGee, L.W. Twigg, G.K. Sumnicht, K.W. Jucks, J.J. Margitan, B. Sen, R.A. Stachnik, G.C. Toon, et al., Validation of Aura Microwave Limb Sounder stratospheric ozone measurements, Journal of Geophysical Research 113, D15520, doi:10.1029/2007JD008771, 2008.
- [4] Godin-Beekmann, S., J. Porteneuve, A. Garnier, Systematic DIAL ozone measurements at Observatoire de Haute-Provence, J. Env. Monitoring, 5, 57-67, 2003
- [5] Thompson, A. M., et al. (2003a & b), Southern Hemisphere Additional Ozone sondes (SHADOZ) 1998-2000 tropical ozone climatology: 1. Comparison with Total Ozone Mapping Spectrometer (TOMS) and ground-based measurements, J. Geophys. Res., 108(D2), 8238, doi:10.1029/2001JD000967 & doi: 10.1029/2002JD002241.
- [6] Vigouroux, C., De Mazière, M., Demoulin, P., Servais, C., Hase, F., Blumenstock, T., Kramer, I., Schneider, M., Mellqvist, J., Strand-berg, A., Velasco, V., Notholt, J., Sussmann, R., Stremme, W., Rockmann, A., Gardiner, T., Coleman, M., and Woods, P.: Evaluation of tropospheric and stratospheric ozone trends over Western Europe from ground-based FTIR network observations, Atmos. Chem. Phys., 8, 6865-6886, acp-8-6865-2008, 2008.