CRISTA-NF observations of filamentary structures of different origin in the vicinity of the polar vortex

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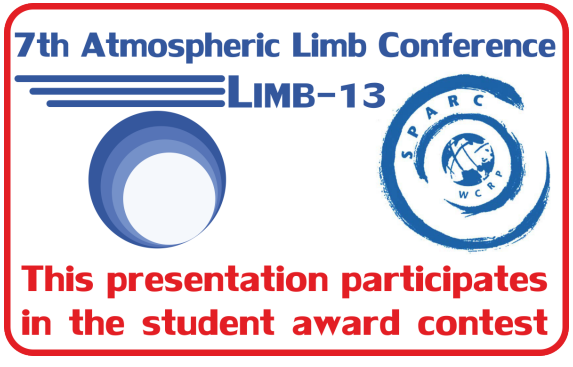

7th Atmospheric Limb Conference
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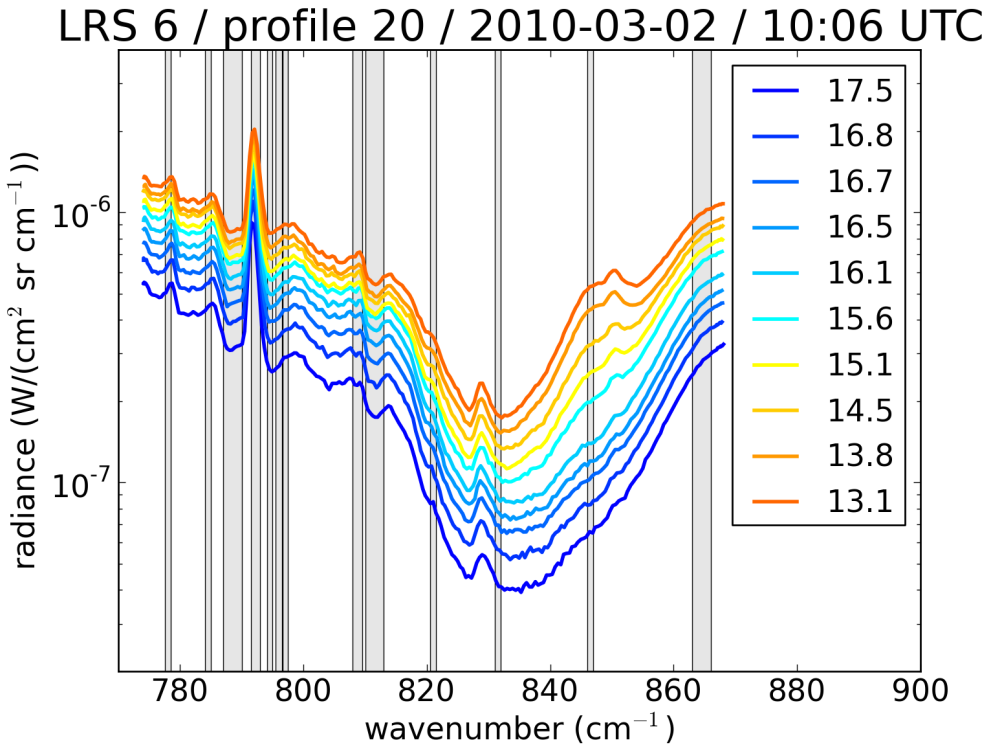
CRISTA-NF Instrument

- CRISTA-NF (Cryogenic Infrared Spectrometers and Telescope for the Atmosphere - New Frontiers)
- aircraft: M-55 Geophysica
  max. flight altitude: $\approx 20\,\mathrm{km}$

- viewing direction: perpendicular to flight direction to right side
- grating spectrometers: mid-infrared ($\lambda \approx 4 - 15\,\mu\mathrm{m}$)
- spatial resolution: $\approx 1.5\,\mathrm{cm}^{-1}$
- sampling: $250\,\mathrm{m}$ vertical and $15\,\mathrm{km}$ horizontal along flight track
- altitude range: $20\,\mathrm{km} - 5\,\mathrm{km}$

CRISTA-NF Retrieval

- multi-target retrieval using JURASSIC (version 2)
- main targets: CFC-11, O_3, $ClONO_2$, HNO_3, H_2O, CCl_4
- 13 IMWs, mostly dominated by emissions of one trace gas
- unprecedented vertical resolution: e.g. CFC-11 $<$ 500 m and ozone 500–600 m for several km below flight altitude



RECONCILE aircraft campaign

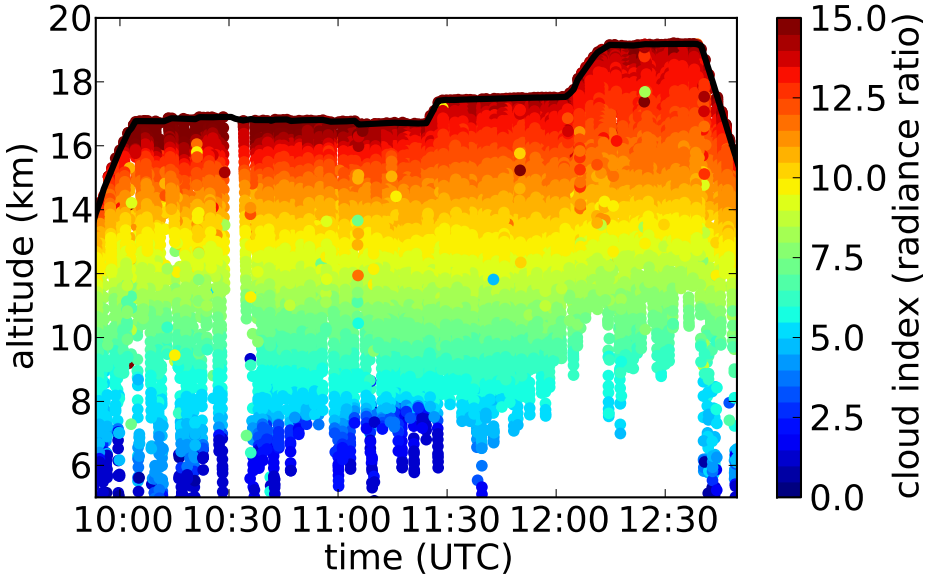
- 12 scientific flights (17.01.2010 - 10.03.2010) in Kiruna (Sweden)
- more than 20 instruments from different groups: FZJ, KIT, BUW, DLR, MPI Mainz, CSEM, CNR, Uni Heidelberg, CAO
- EU-FP7 project : https://www.fp7-reconcile.eu/

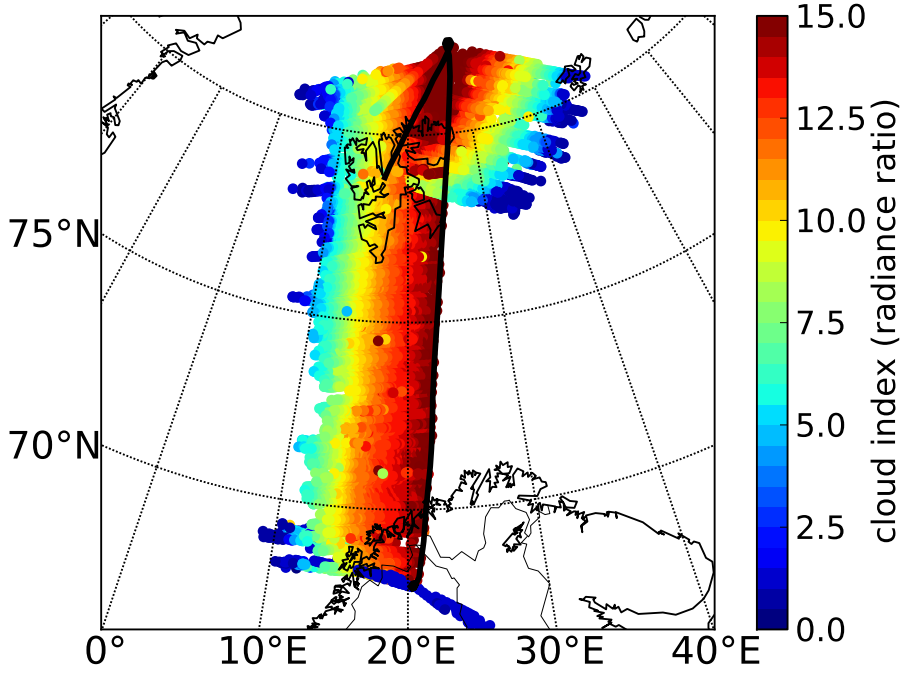
- scientific objectives:
  - PSC microphysics
  - ozone chemistry
  - dynamics in the region of the polar vortex
- CRISTA-NF contributes to the last objective

photographer: F. Stroh

Measurement conditions during flight 11

- Spitsbergen - Kiruna (March 2, 2010)

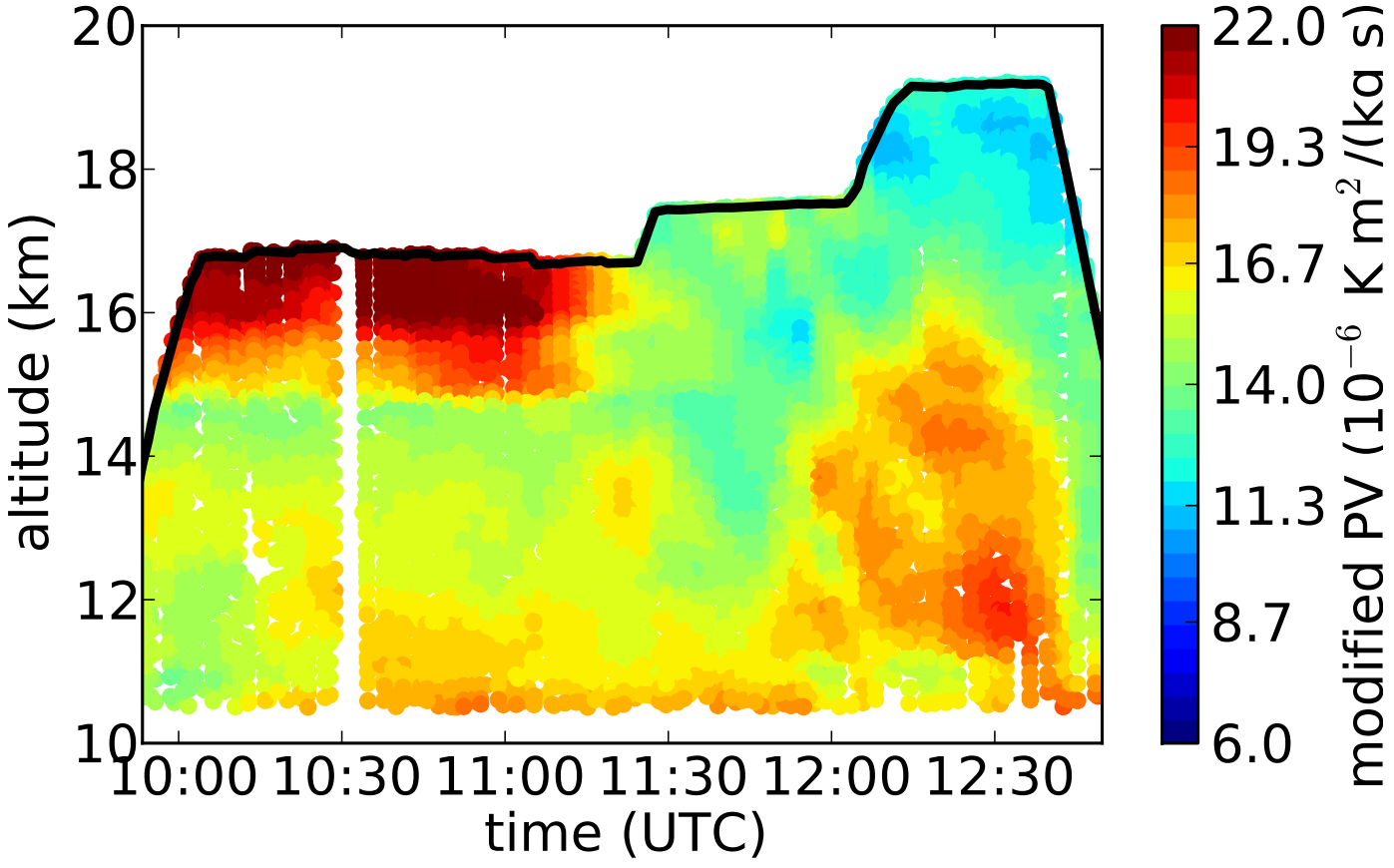




- cloud index: radiance ratio $\frac{IMW1}{IMW2}$
- IMW1: dominated by CO_2, IMW2: atmospheric window (aerosol)
- favourable measurement conditions

Cloud Index: e.g. Spang et al.,JGR,2002; Spang et al.,ASR,2008

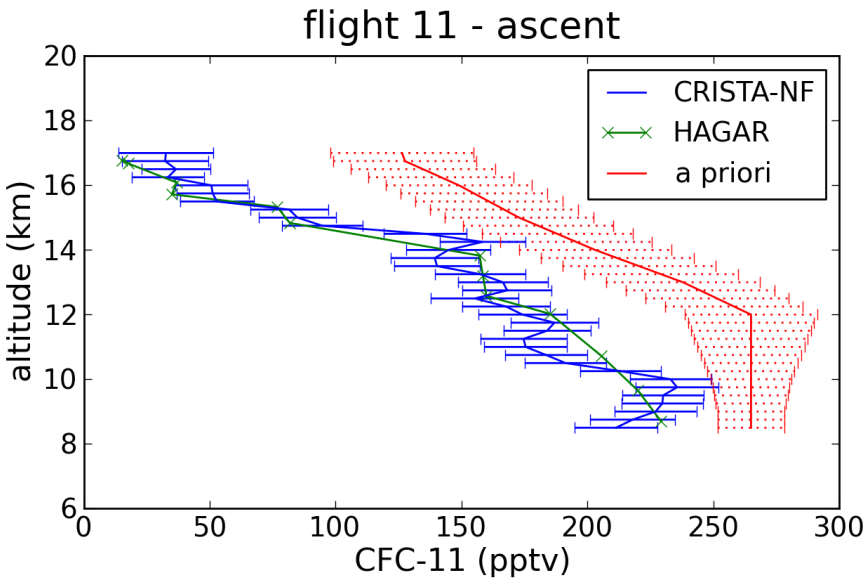
Meteorological situation during flight 11

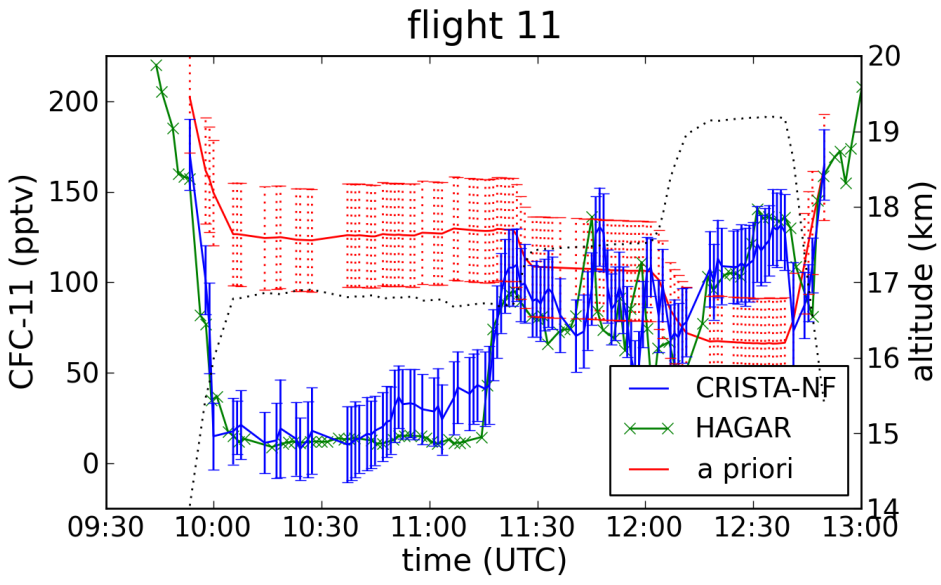


- high values of modified PV $\rightarrow$ vortex air masses
- low values of modified PV $\rightarrow$ air masses of mid- to low-latitude origin

modified PV: Lait,J. Atmos. Sci.,1994; Müller and Günther,J. Atmos. Sci.,2003

Comparison with HAGAR in-situ measurements: CFC-11

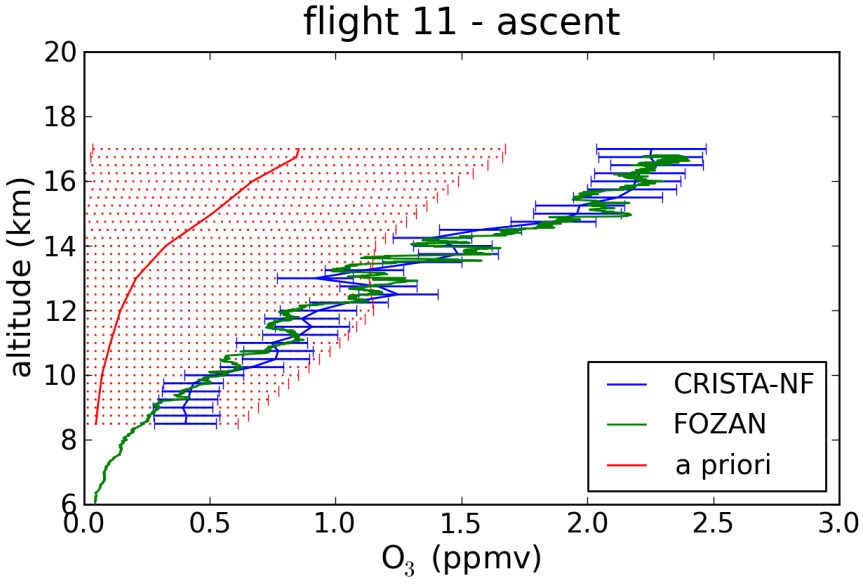


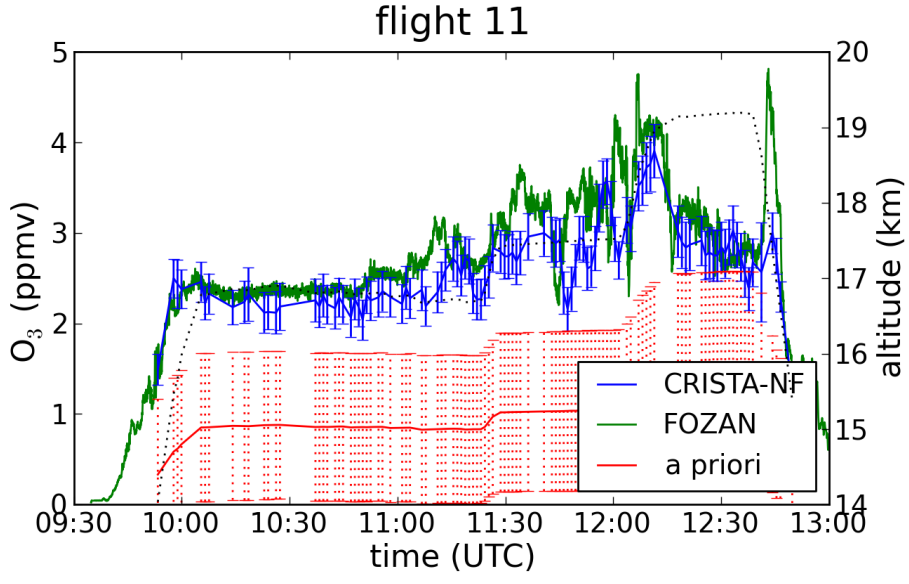


HAGAR data: courtesy of E. Hösen and C. M. Volk

- very good agreement between the two measurements
- differences can be explained by the viewing geometry and the orientation of the crossed filaments

Comparison with FOZAN in-situ measurements: O_3



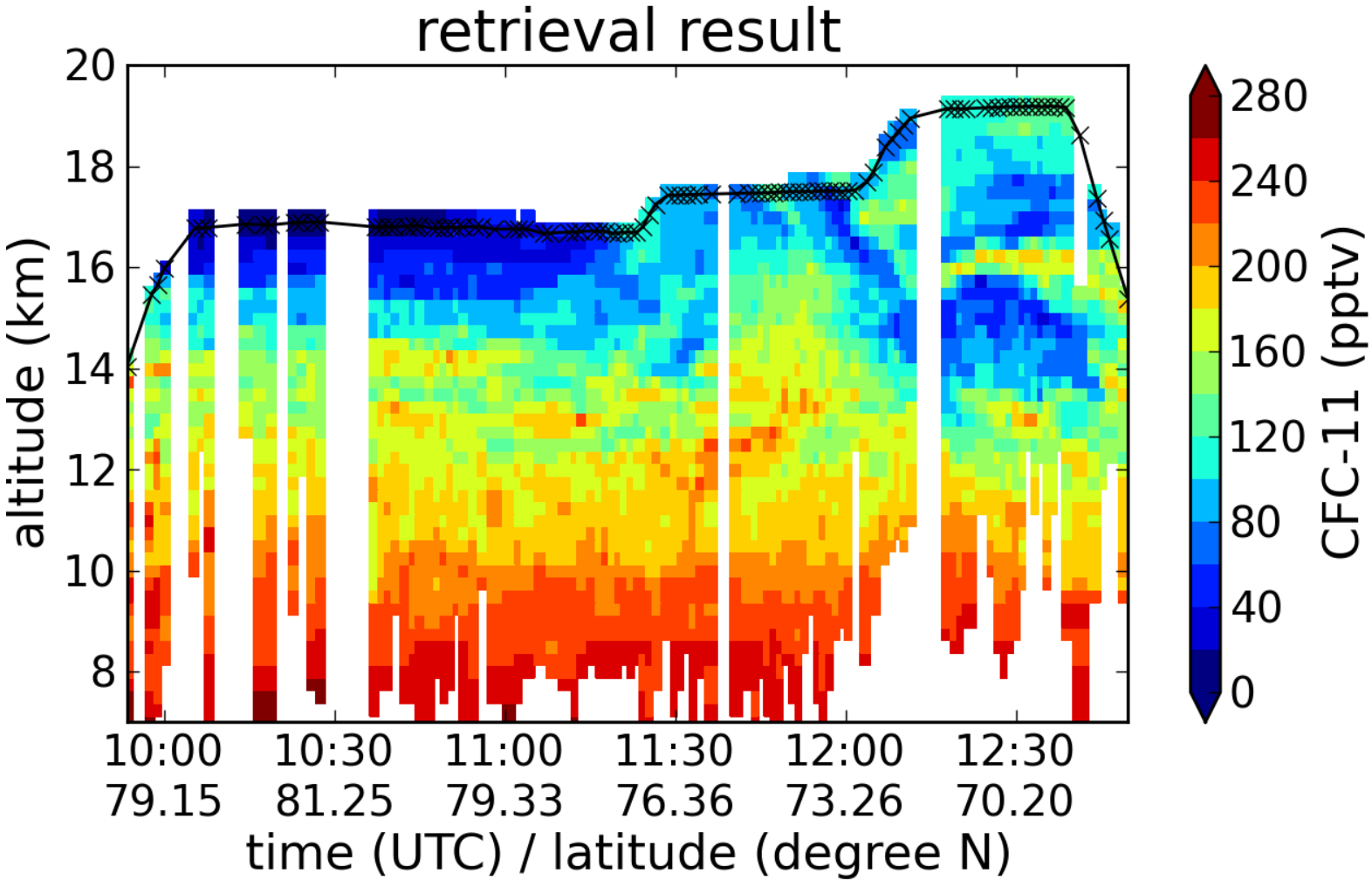


FOZAN data: courtesy of A. Ulanovsky and. F. Ravegnani

- very good agreement between the two measurements
- differences can be explained by the viewing geometry and the orientation of the crossed filaments

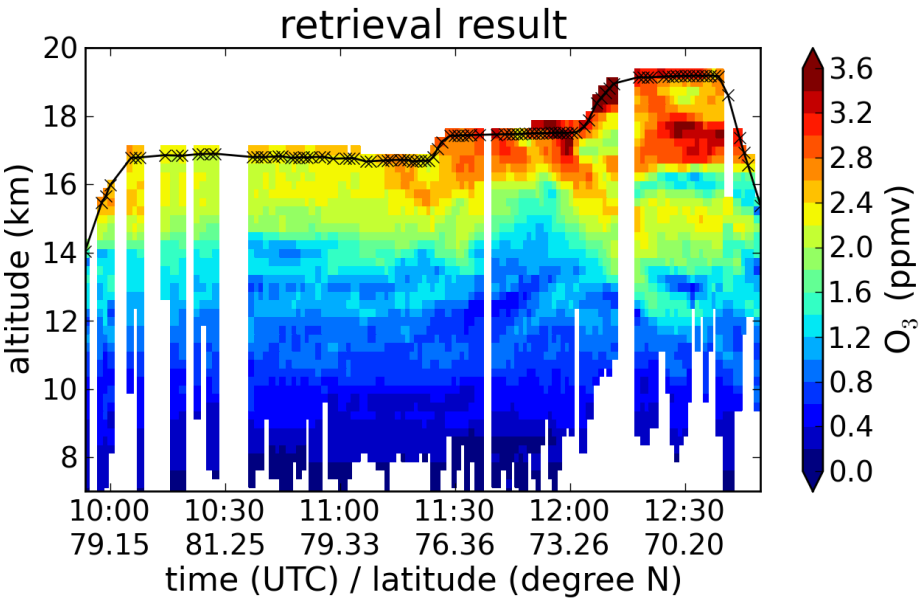
description of retrieval scheme and comparisons: Ungermann et al.,AMT,2012

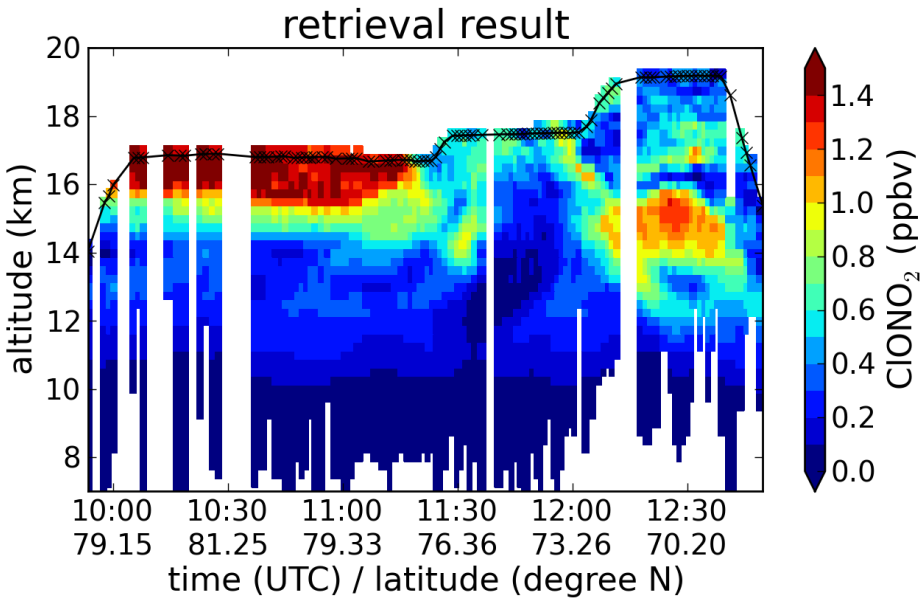
CRISTA-NF retrieval result: CFC-11



- polar vortex and two filaments with low CFC-11 VMRs

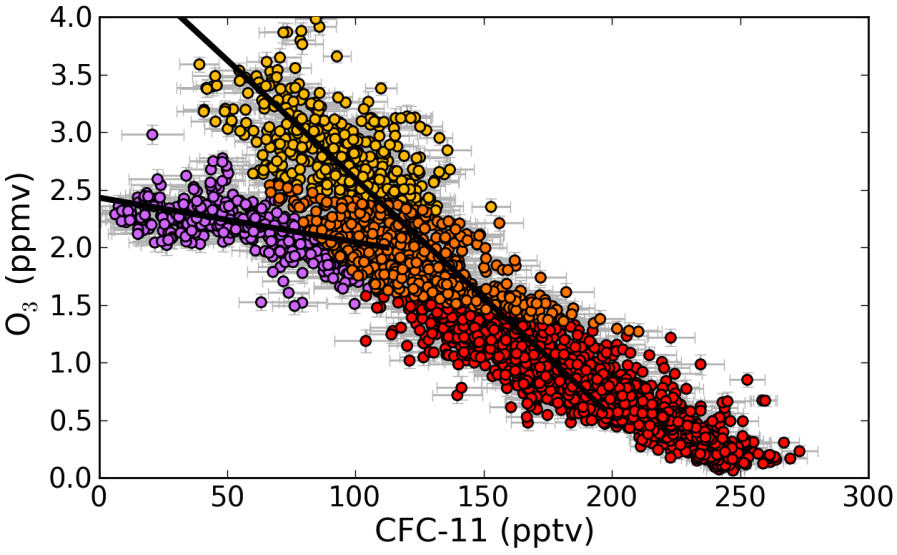
CRISTA-NF retrieval result: O_3 and $ClONO_2$

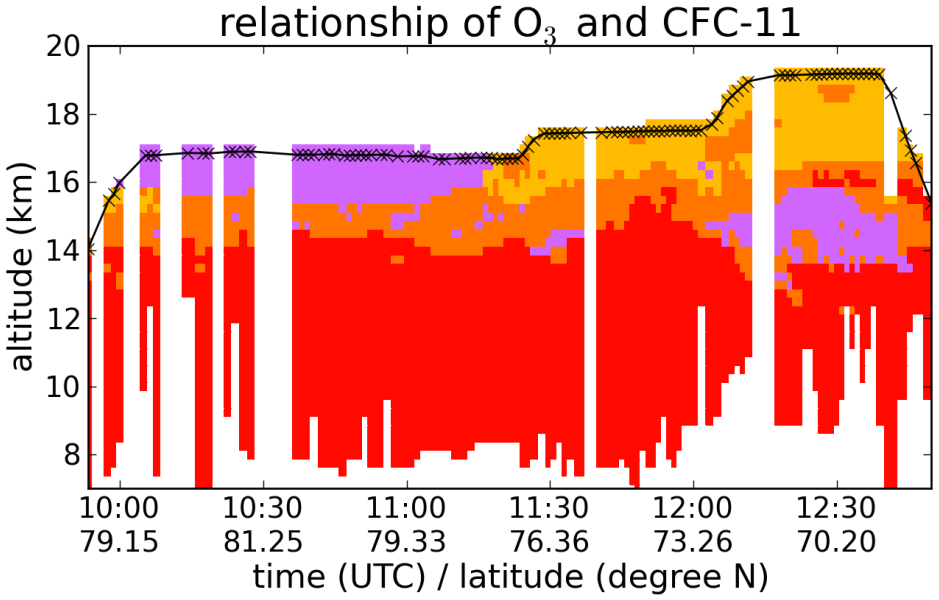




- ozone loss and chlorine deactivation inside the polar vortex
- differences in the two filaments:
  - only lower filament influenced by ozone depletion and chlorine deactivation

CRISTA-NF air mass discrimination





- CFC-11-ozone-relation allows for discrimination of vortex air masses
- polar vortex located at beginning of flight down to 15.5 km
- lower filament is a vortex filament, upper filament is of other origin

Chemistry and Transport Model CLaMS

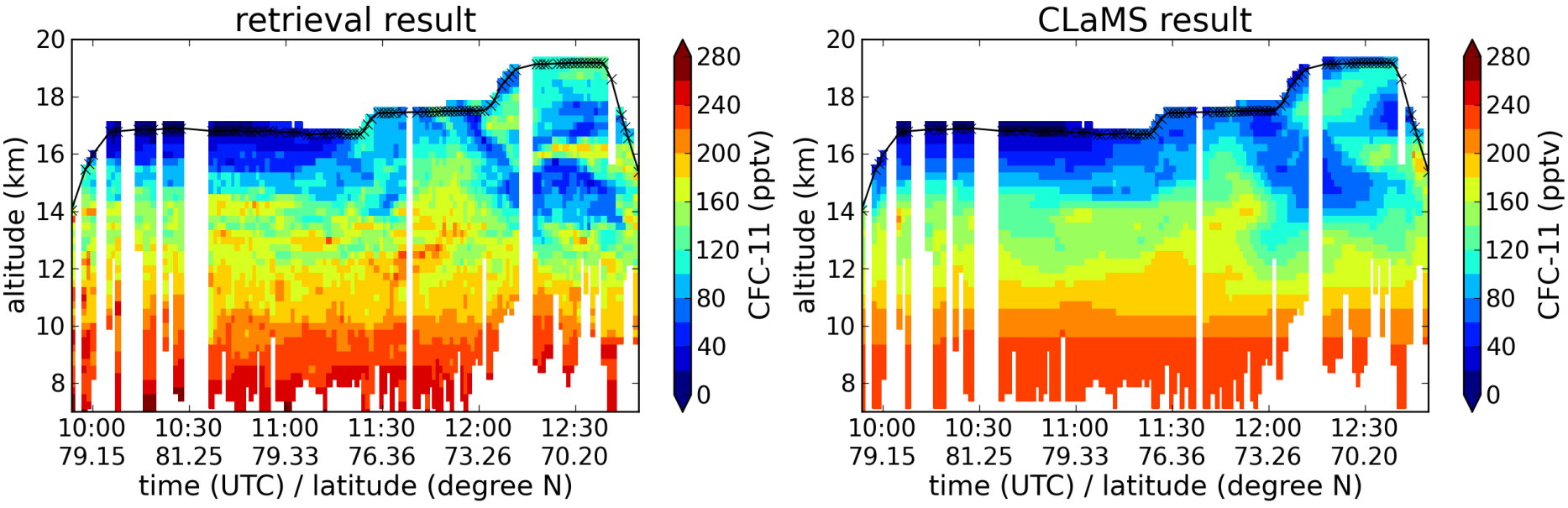
- **C**hemical **La**grangian **M**odel of the **S**tratosphere
- air parcels instead of fixed grid boxes ($\neq$ Eulerian)

- transport driven by ECMWF wind fields and cooling/heating rates
- horizontal resolution: 70 km; vertical resolution: 500 m
- 144 chemical reactions and 48 species

- initialization and simulation start: December 1, 2009
- passive tracer (e.g. vortex, low-latitude):
  initialized according to mPV values on January 15, 2010

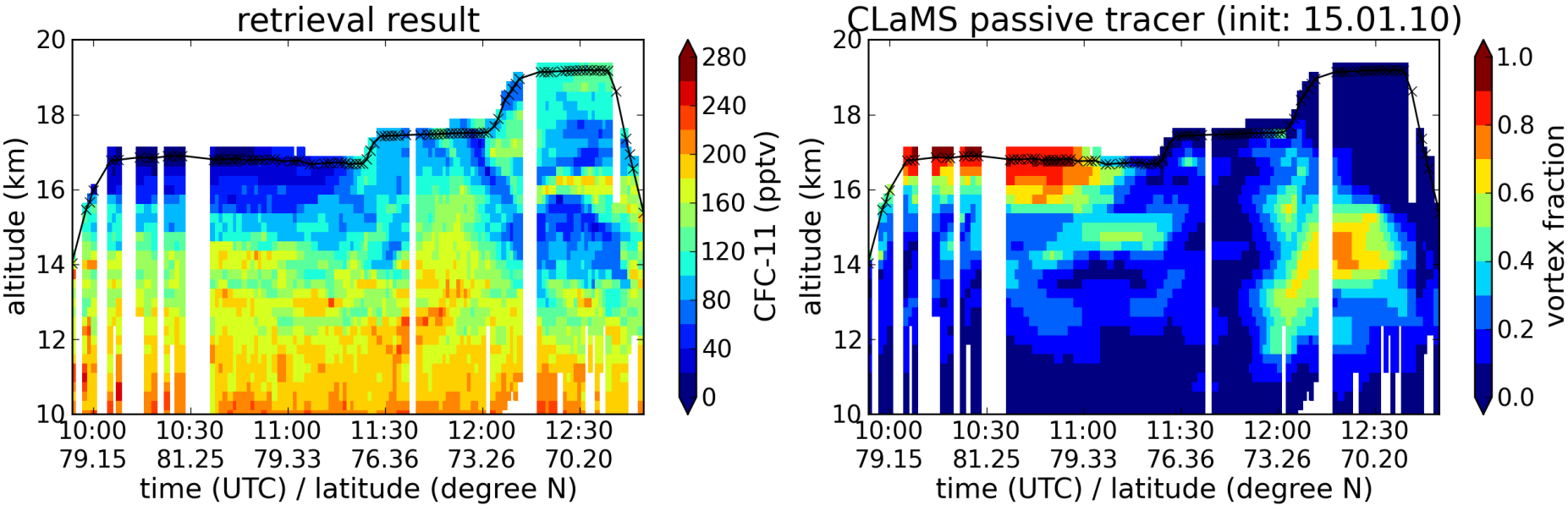
CLaMS description: McKenna et al.,JGR,2002a,b; Konopka et al.,JGR,2004; Grooß et al.,ACP,2005; Konopka et al.,ACP,2007

Comparison for CFC-11



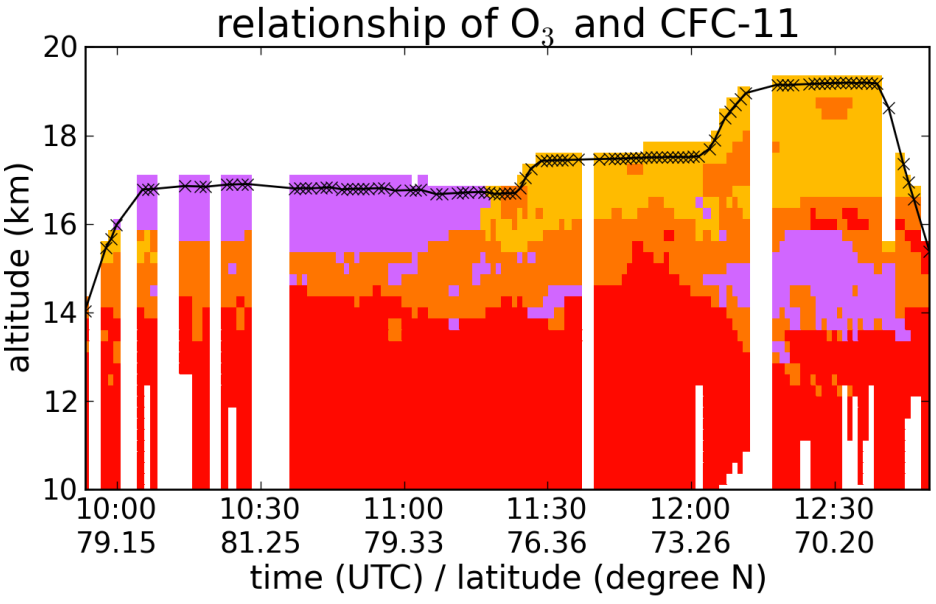
- both results are in a good agreement
- advection and mixing processes well simulated by CLaMS

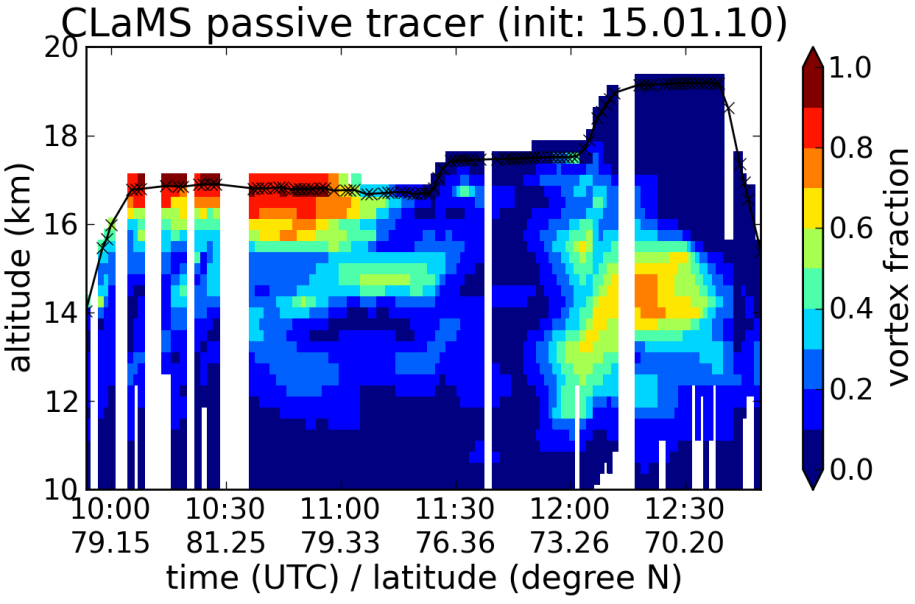
Origin of air masses: vortex air masses



- very high vortex fraction inside polar vortex (partly larger 90%)
- lower filament: $>$ 70 % vortex air masses
- very good agreement with CRISTA-NF observations

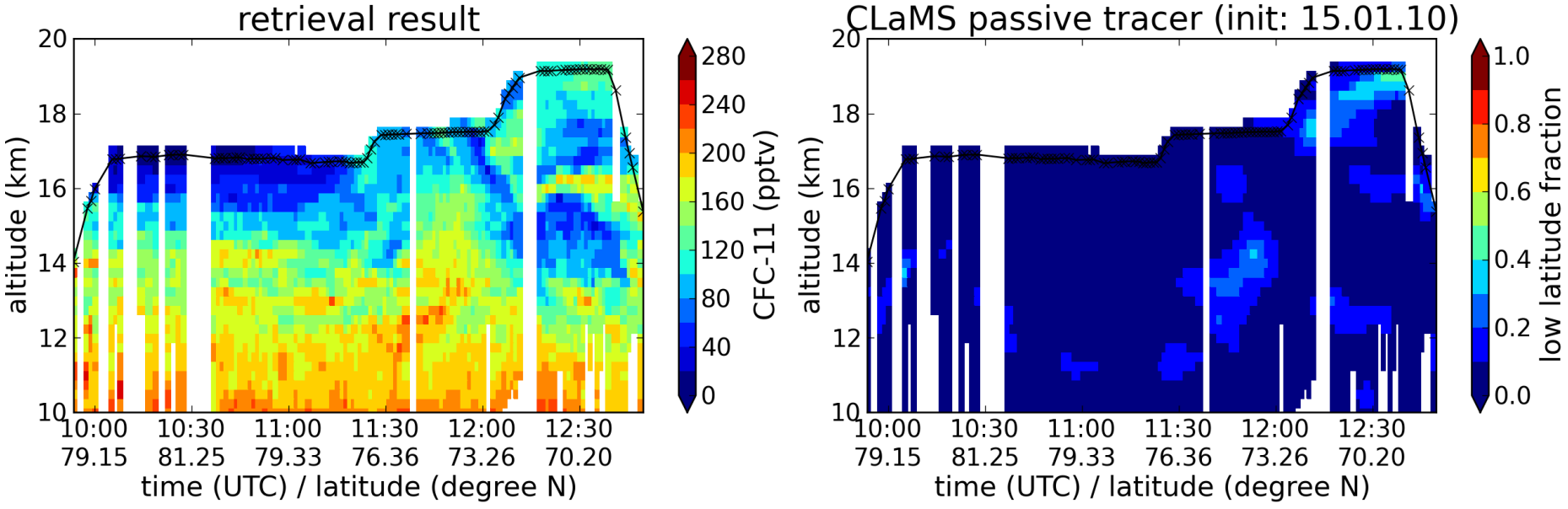
Origin of air masses: vortex air masses





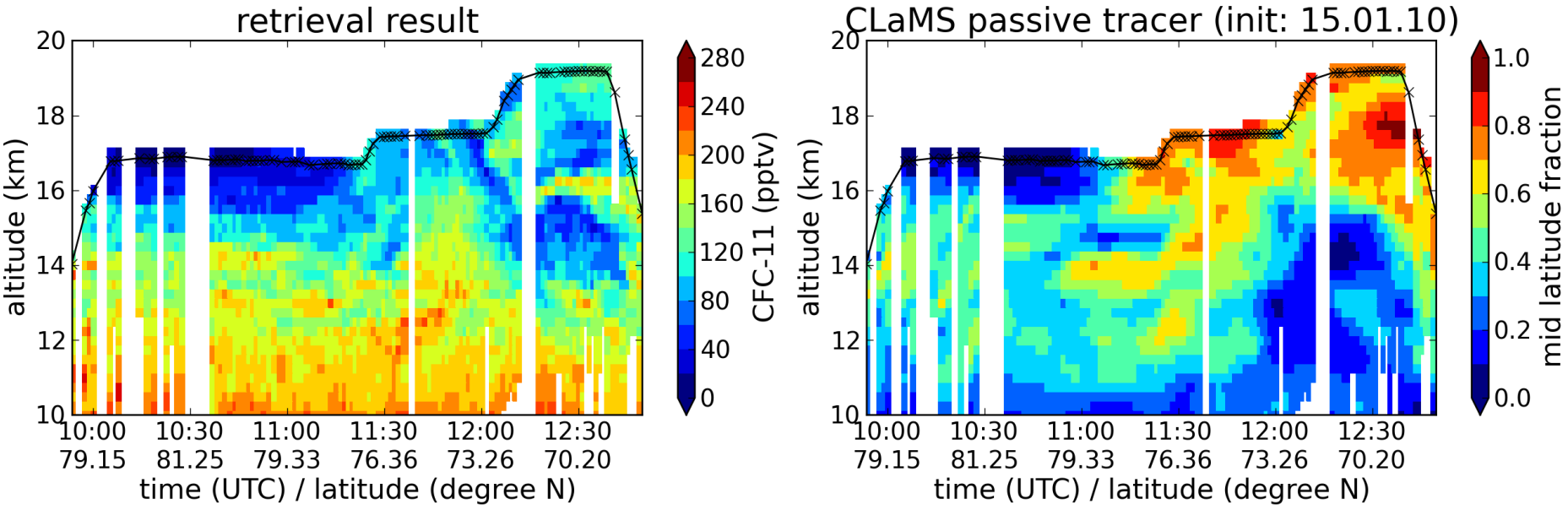
- very high vortex fraction inside polar vortex (partly larger 90%)
- lower filament: $>$ 70 % vortex air masses
- very good agreement with CRISTA-NF observations

Origin of air masses: low-latitude air masses



- high CFC-11 VMRs in region around the upper filament caused by transport of low-latitude air masses towards the pole
- structure of high CFC-11 VMRs in middle of flight (11–15 km) shows influence of low-latitude air

Origin of air masses: mid-latitude air masses



- upper filament consists of mid-latitude air; similar to large parts outside the vortex
- low-latitude air masses surrounding this mid-latitude air masses are the real filament

Summary

- CRISTA-NF retrieval results for CFC-11, O_3, and $ClONO_2$ with very high vertical resolution and horizontal sampling
- measurements allow for discrimination of vortex air masses by means of CFC-11-ozone-relation
  - observation of polar vortex and vortex filament
- CLaMS trace gas results in good agreement with observations
  - CFC-11: advection and mixing well simulated by CLaMS
- CLaMS passive tracers provide consistent picture to observations
  - vortex tracer is in perfect agreement with discrimination of vortex air masses by CRISTA-NF
  - several structures showing low-latitude influence