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Stirring and mixing of stratospheric filaments around the subtropical jet

as observed by the CRISTA-NF infrared limb sounder

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CRISTA-NF

An instrument realises its potential

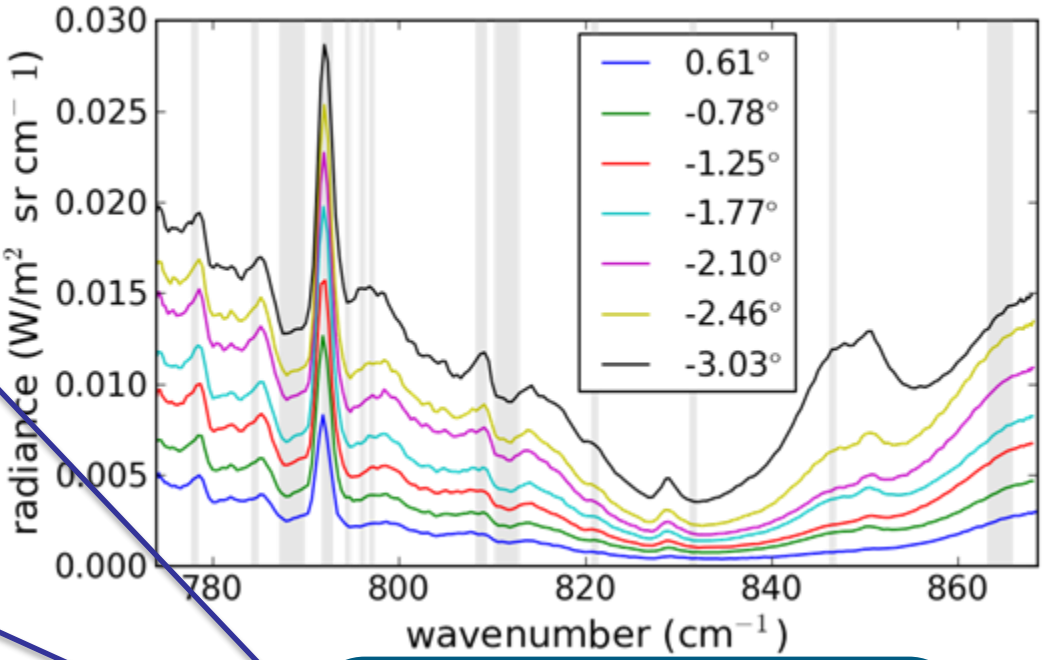
CRISTA-NF
Instrument

- CRISTA-NF: Cryogenic Infrared Spectrometers and Telescope for the Atmosphere – New Frontiers
- Platform: M55-Geophysica (max. flight altitude: ~21 km)
- Method: Passive mid-infrared limb sounding (4 – 15 µm)
- Profile acquisition time: ~70 s (60 · 1.2 s)
- Vert. Sampling: ~0.25 km
- Hor. Sampling: ~15 km

photograph: F.Stroh

CRISTA-NF
Cross-section retrieval setup

- Based on 13 ISW
- EGA, CGA + regression
- Retrieval objectives:
  - aerosol, temperature, CCl_4, CFC−11, CFC−113, $ClONO_2$, HCFC-22, HNO_3, H_2O, O_3, PAN
- Vert. retrieval grid: 0.25 km
- Regularisation: climatological Tikhon
- Apriori: ECMWF , Remedios climatol



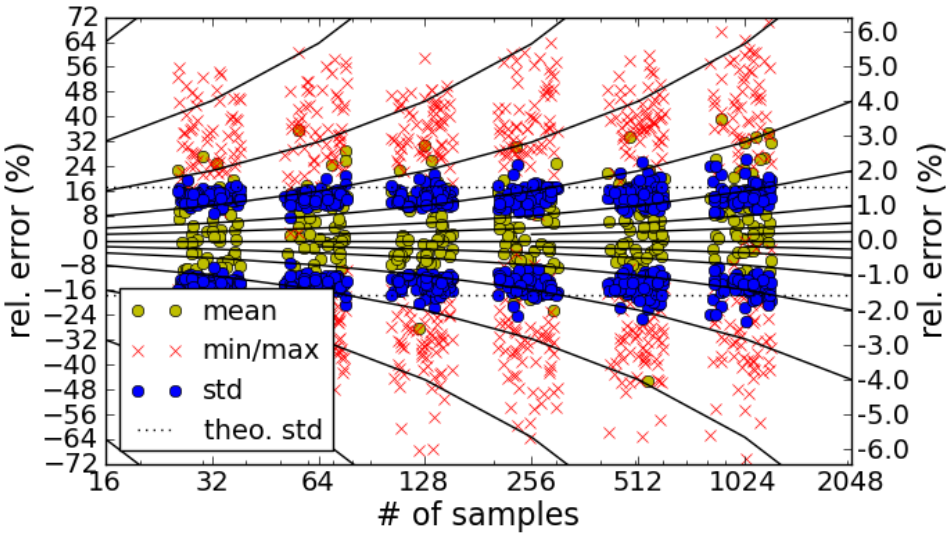
27 000 measurements
32 000 unknowns
18 minutes on 8 cores

Retrieval for large-scale inverse problems
Linearised diagnostics

$$\boldsymbol{x}_i^{\mathrm{mc}} = \boldsymbol{x}_{\mathrm{f}} - \left(\mathbf{S}_{\mathrm{a}}^{-1} + \mathbf{F}'(\boldsymbol{x}_{\mathrm{f}})^T\, \mathbf{S}_{\epsilon}^{-1}\, \mathbf{F}'(\boldsymbol{x}_{\mathrm{f}})\right)^{-1} \cdot \left(\mathbf{F}'(\boldsymbol{x}_{\mathrm{f}})^T\, \mathbf{S}_{\epsilon}^{-1}\, \boldsymbol{\epsilon}_i^{\mathrm{mc}}\right).$$

„Monte carlo“ diagnostics:

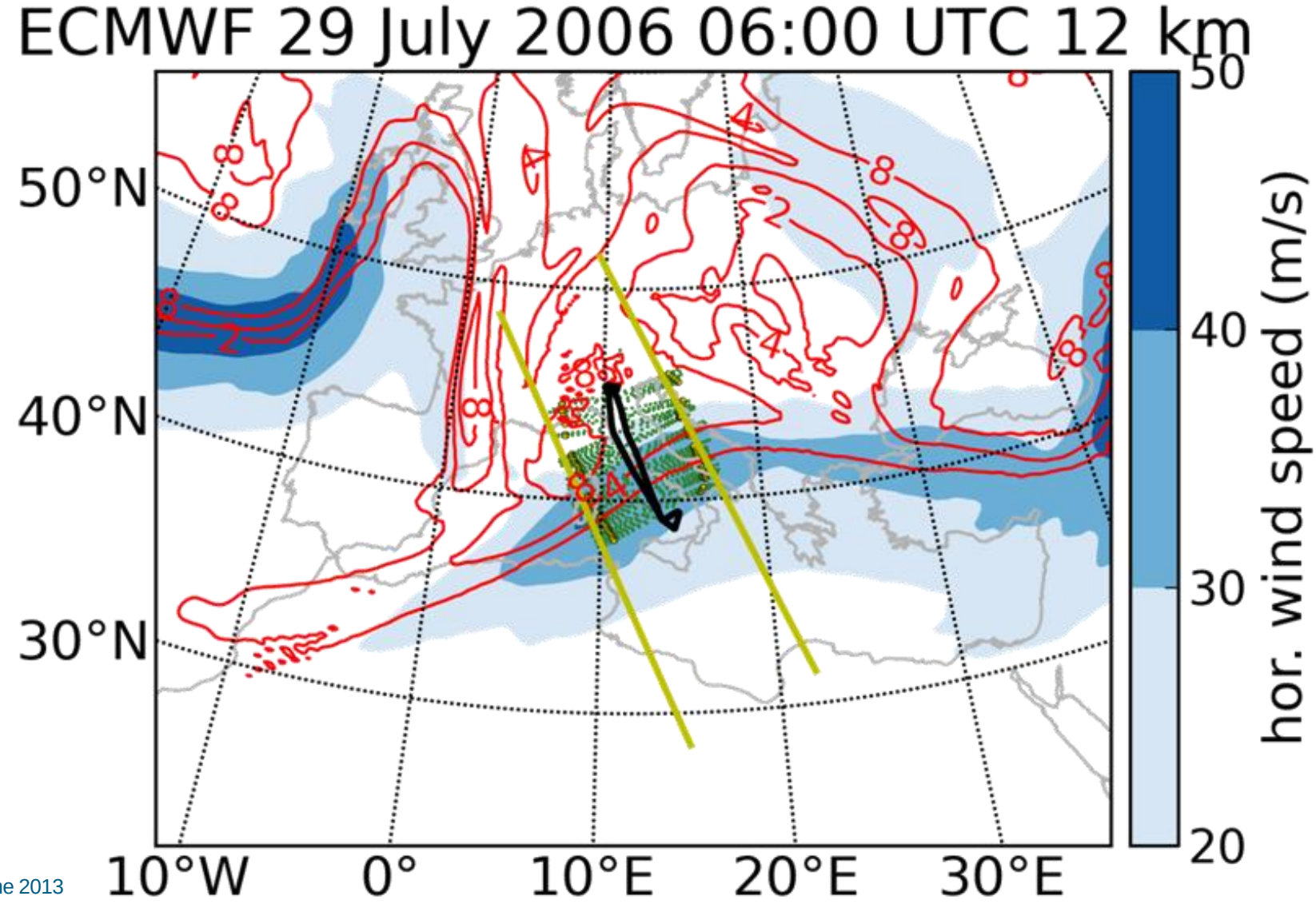
1) Determine Error vectors according to known or assumed Gaussian distributions.
2) Derive perturbed solutions.
3) Determine effect on result by calculating the variance of the perturbed solutions.
4) Repeat for every important error source.



METEOROLOGICAL SETTING

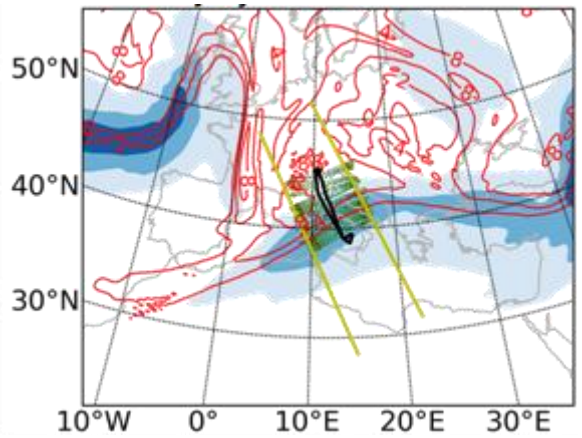
ECMWF T799 2006-07-29 at 12 km

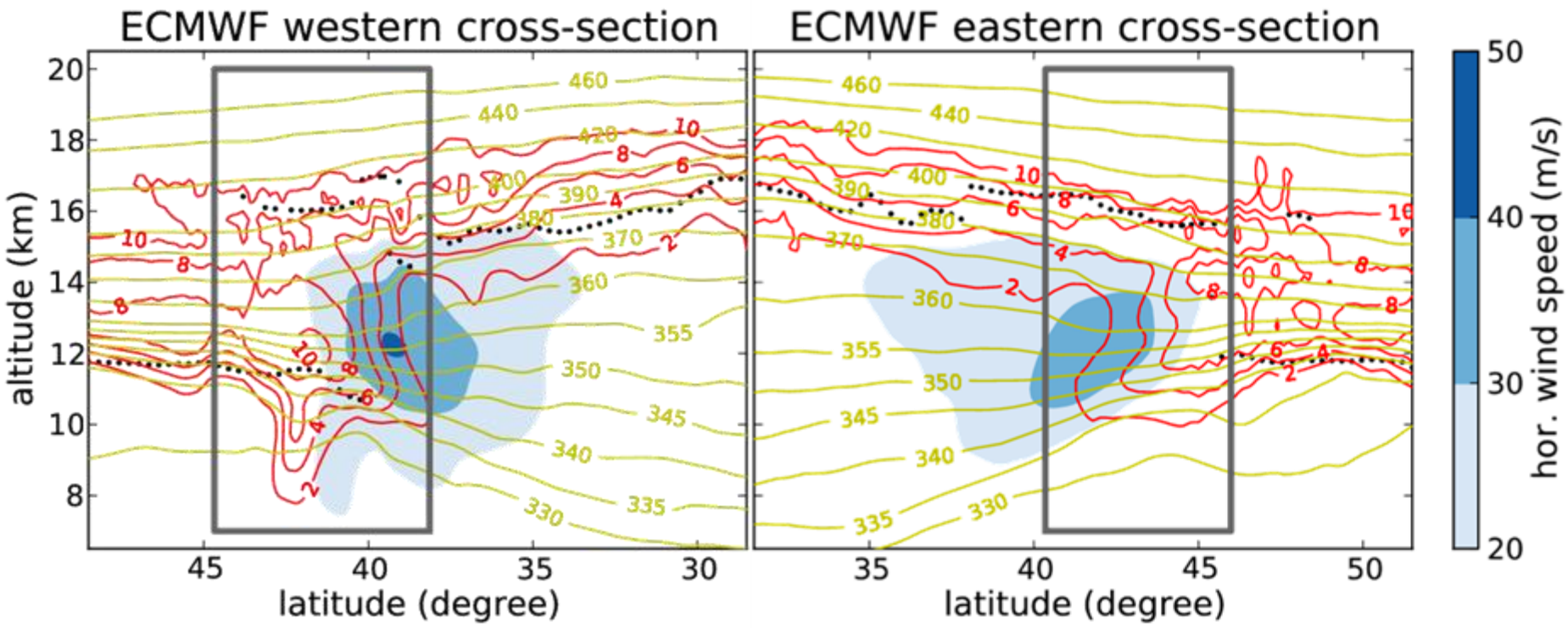
red: PV, black: flight path, green: tangent points



ECMWF T799 2006-07-29

Vertical cross-sections





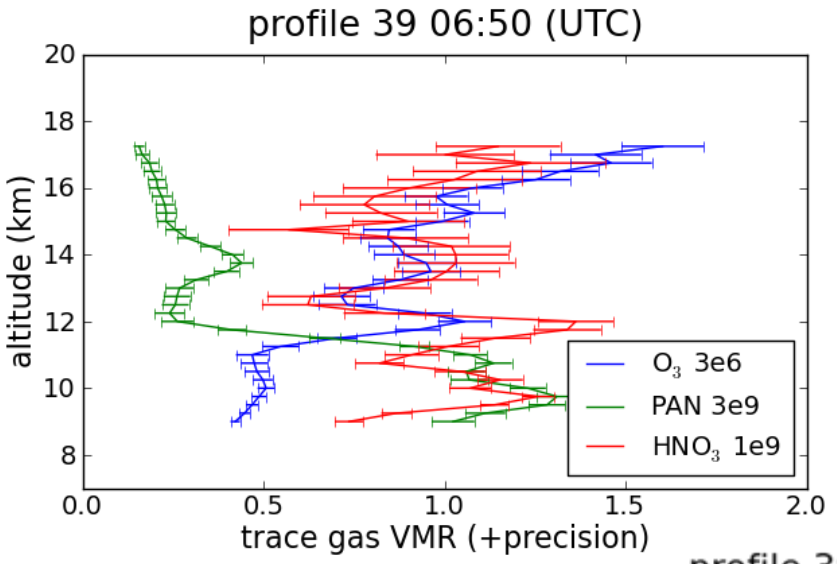
red: PV (PVU), yellow: Theta (K), blue: hor. wind speed (m/s),
black dots: thermal lapse-rate tropopause, gray square: measured area

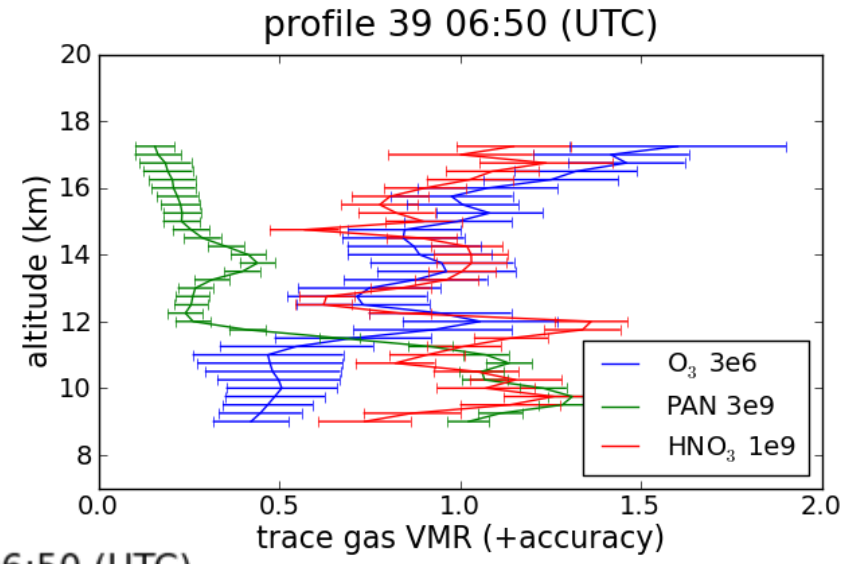
VALIDATION

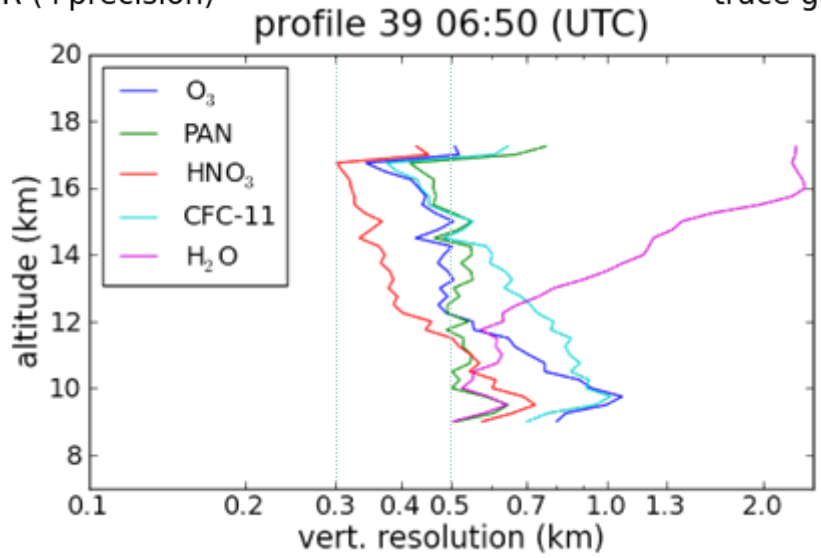
Quality of retrieved trace gases

Retrieval quality

Precision, accuracy, and vertical resolution

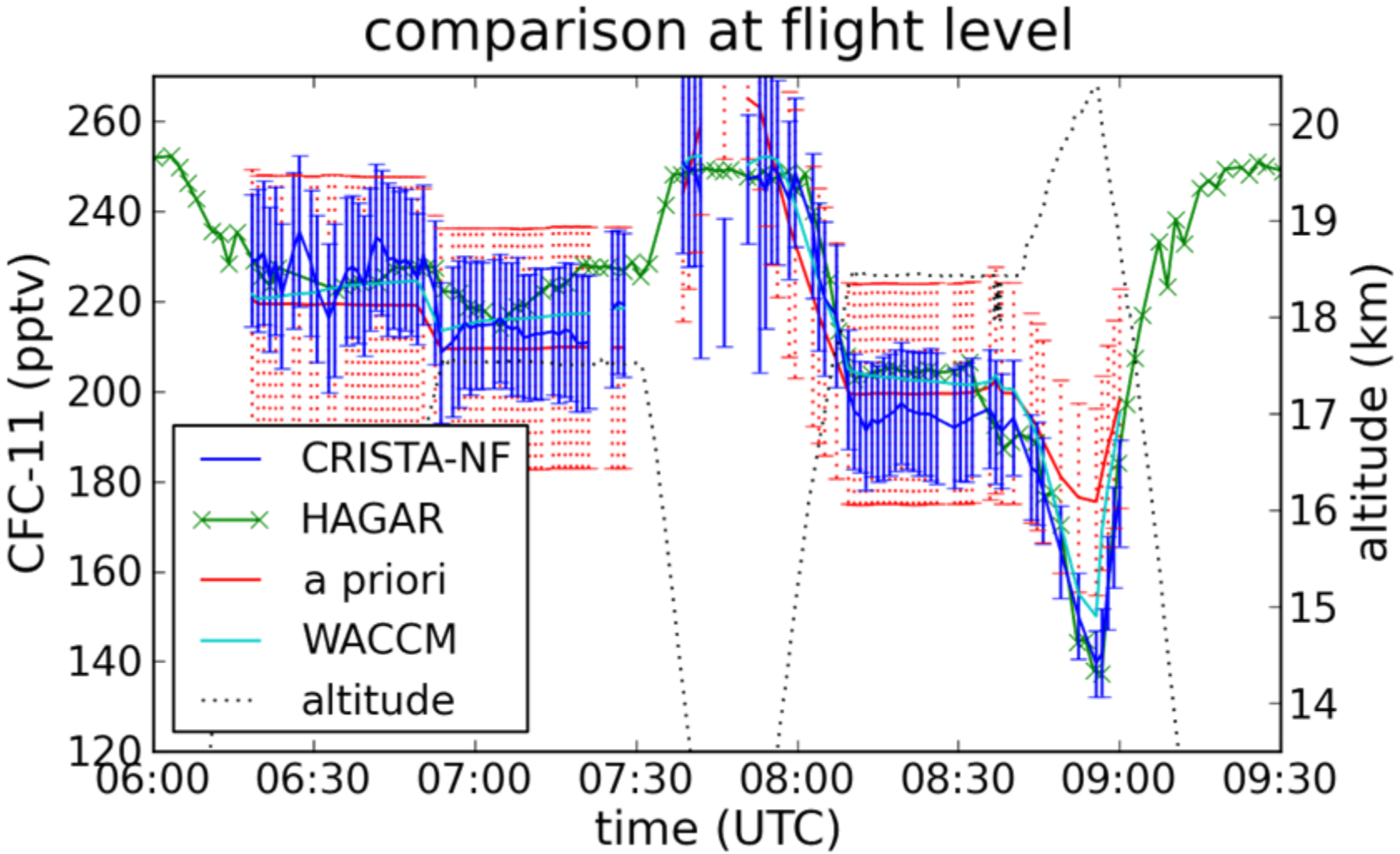






Retrieval quality

„Validation“



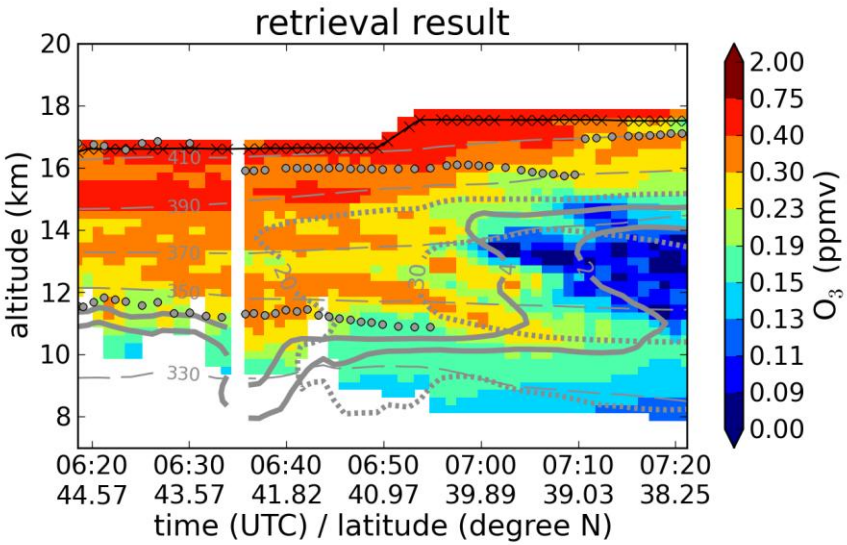
HAGAR CFC-11 data provided by M. Volk. WACCM data provided by D. Kinnison.

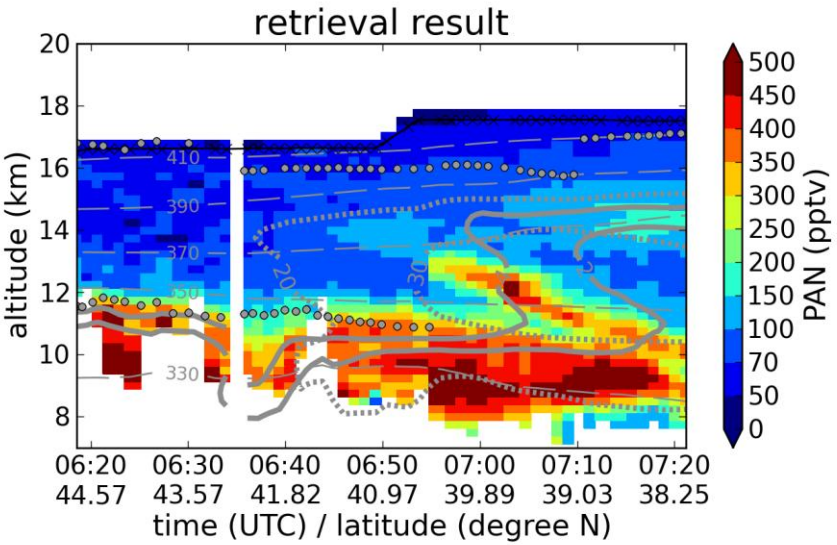
SMALL SCALE FILAMENTS

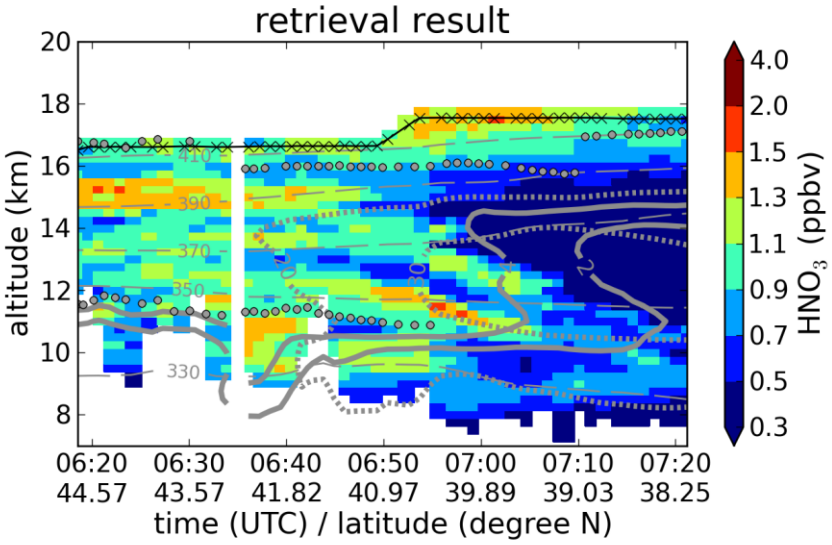
Exploiting the resolution of CRISTA-NF

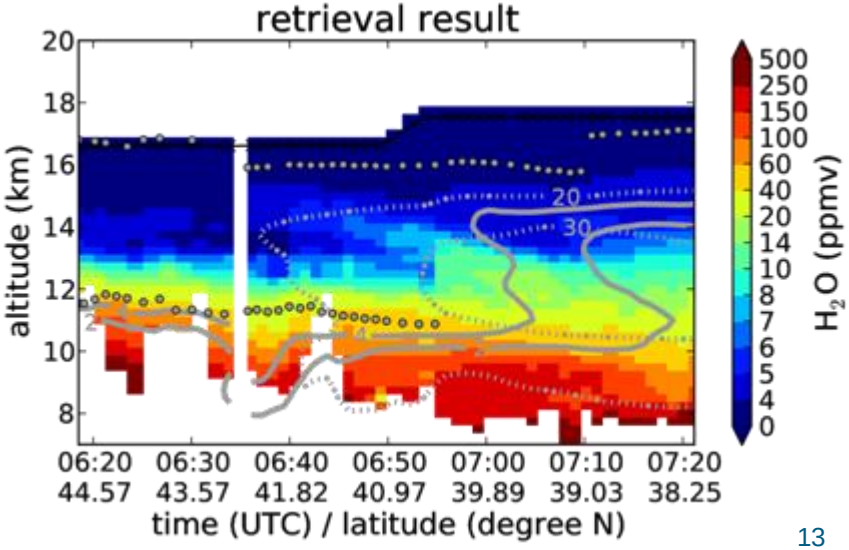
AMMA/CRISTA-NF retrieval results 2006-07-29

Western cross-sections







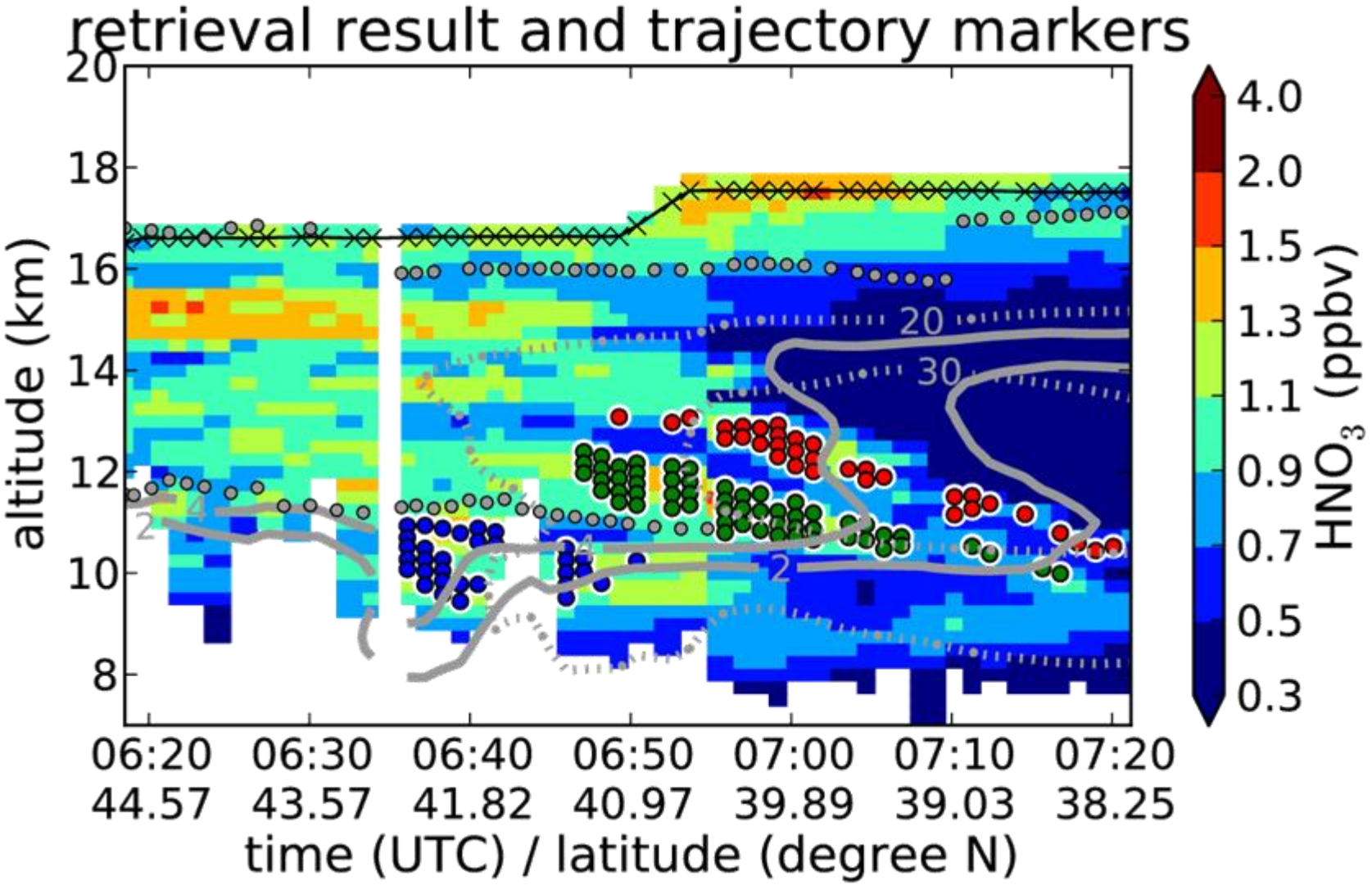


STIRRING

How one breaking Rossby-wave produces the imaged situation

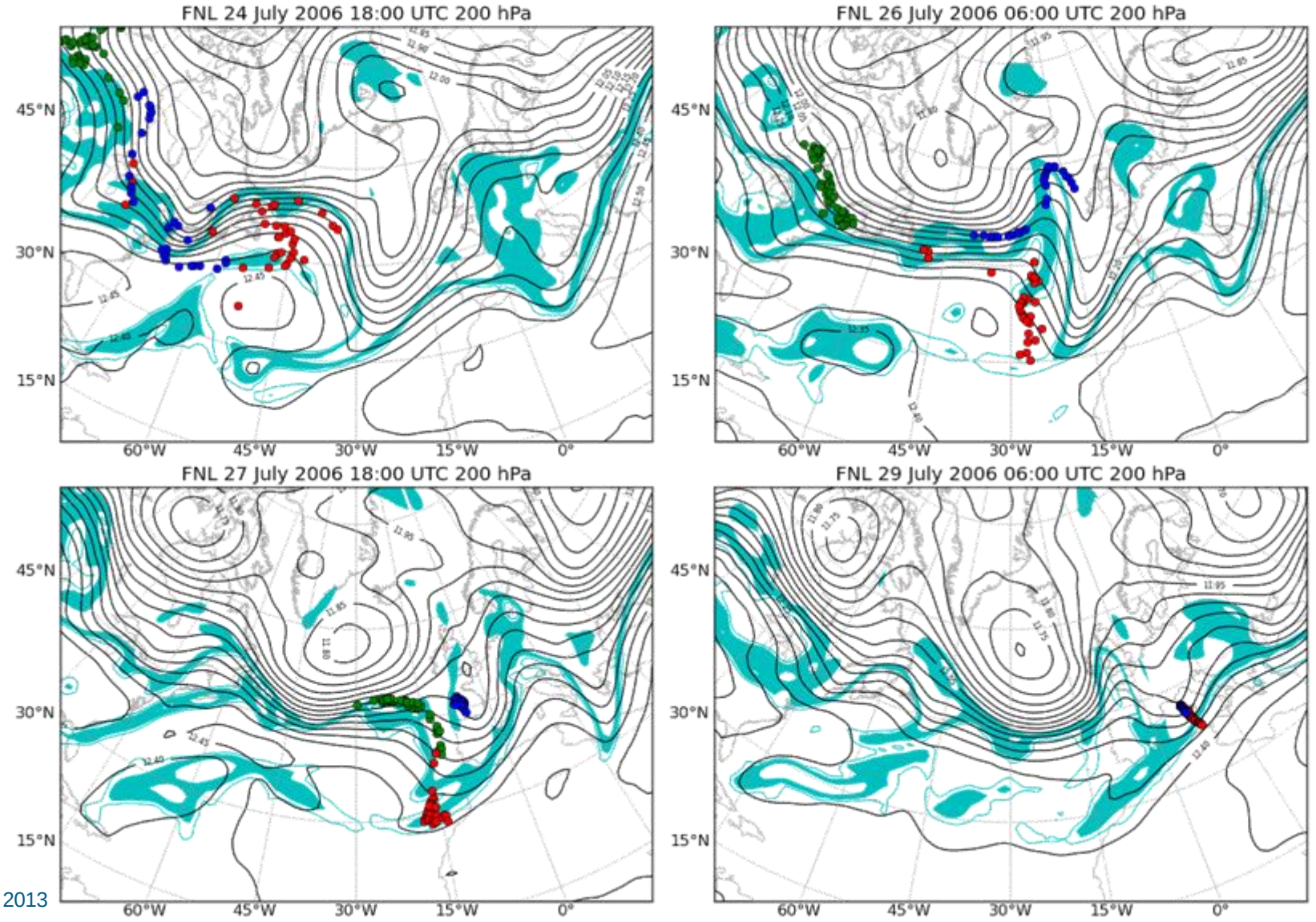
AMMA/CRISTA-NF retrieval result 2006-07-29

red, green, and blue dots mark stratospheric filaments



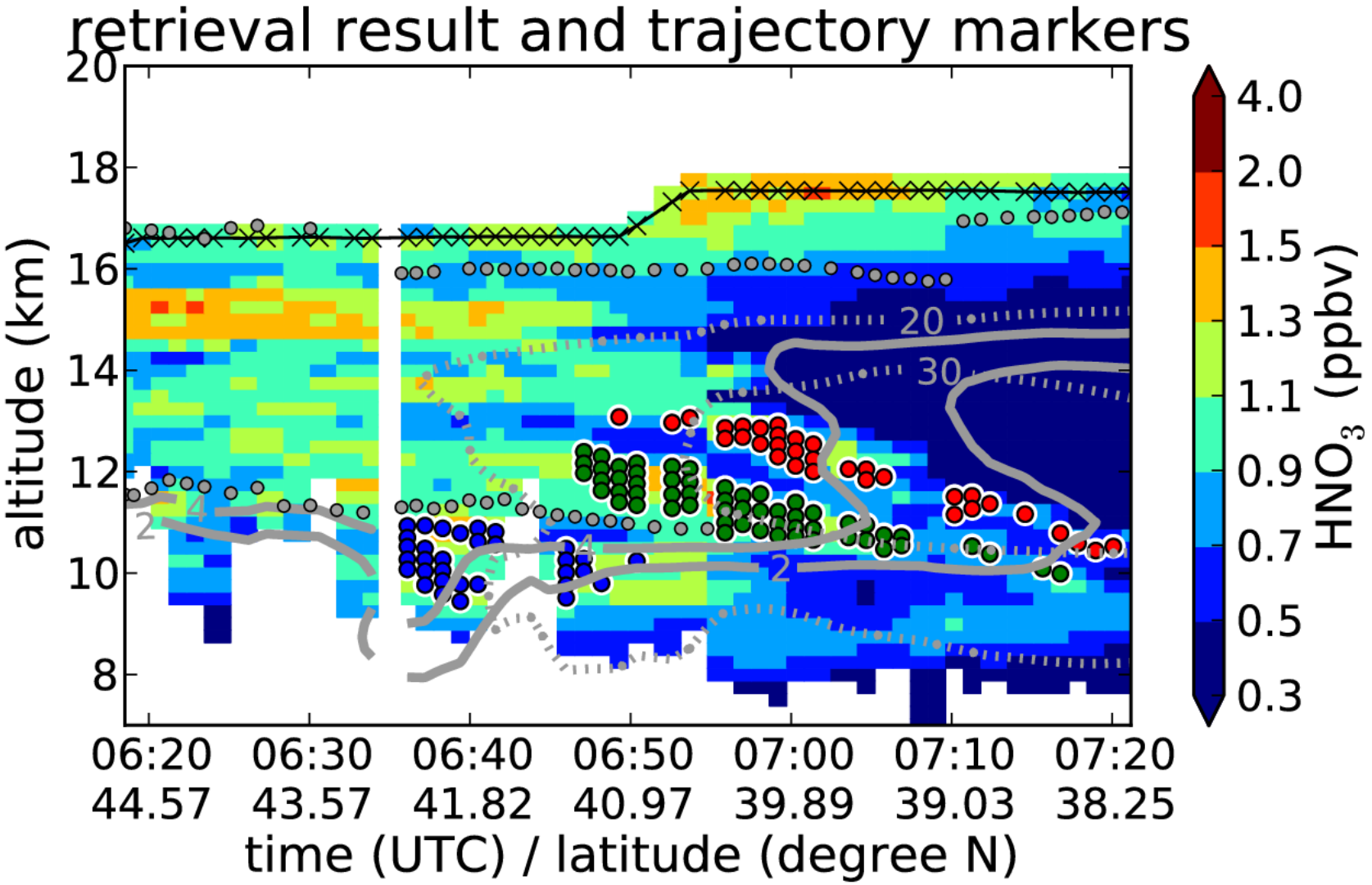
FNL 2006-07-24 to 2006-07-29 at 200 hPa

black: GPH, turquois line: 1.5 PVU, turquois area: 2 to 4 PVU



AMMA/CRISTA-NF retrieval result 2006-07-29

red, green, and blue dots mark stratospheric filaments

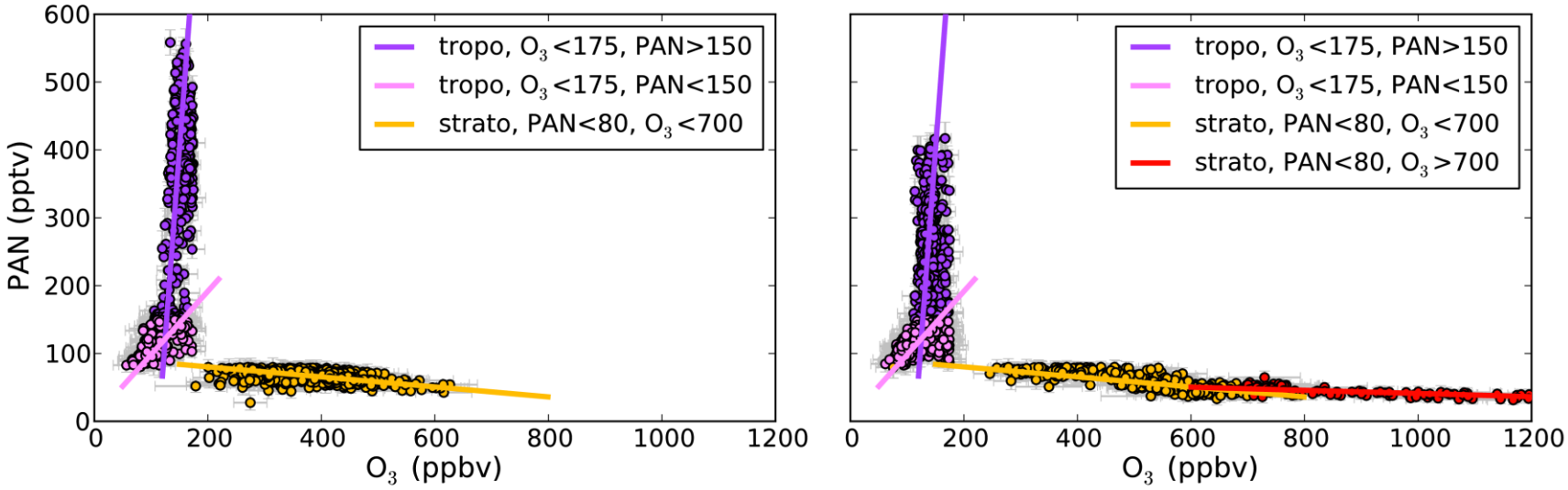


MIXING

Connecting tracer-tracer space and geophysical space

AMMA/CRISTA-NF retrieval result 2006-07-29

Relationship between PAN and O_3 in tracer / geospatial space

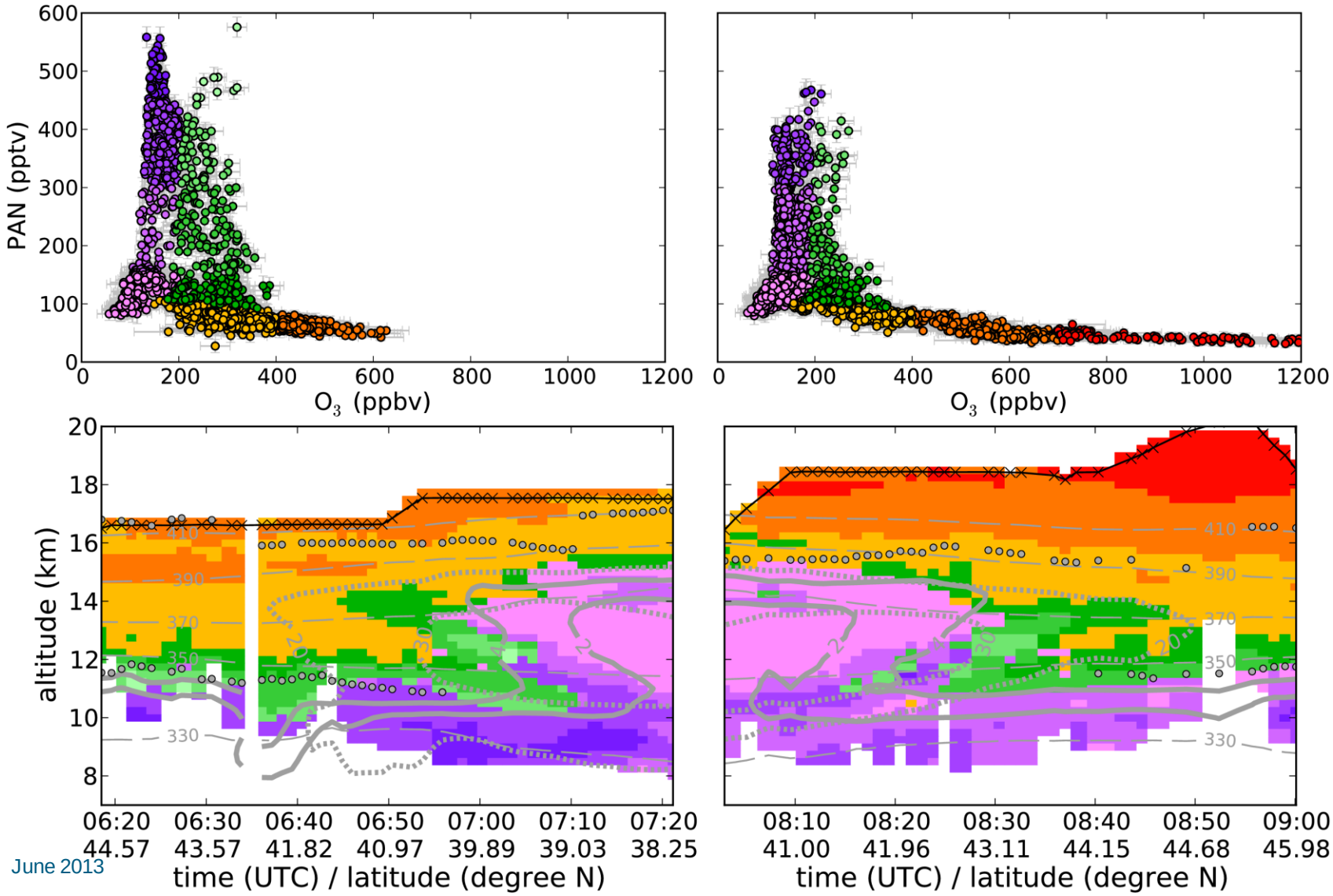


$$O_3\ (\text{pptv}) = a \cdot \text{PAN}\ (\text{pptv}) + b\ (\text{pptv})$$

O_3 (ppbv)	PAN (ppbv)	n	a	b (pptv)
< 175	≥ 0.15	600	$1.114(79)\cdot 10^{-2}$	$-1.27(11)\cdot 10^{3}$
< 175	< 0.15	447	$9.33(65)\cdot 10^{-4}$	$5.1(74)\cdot 10^{0}$
< 700	< 0.08	914	$-7.38(23)\cdot 10^{-5}$	$9.51(11)\cdot 10^{1}$
≥ 700	< 0.08	105	$-2.34(28)\cdot 10^{-5}$	$6.45(28)\cdot 10^{1}$

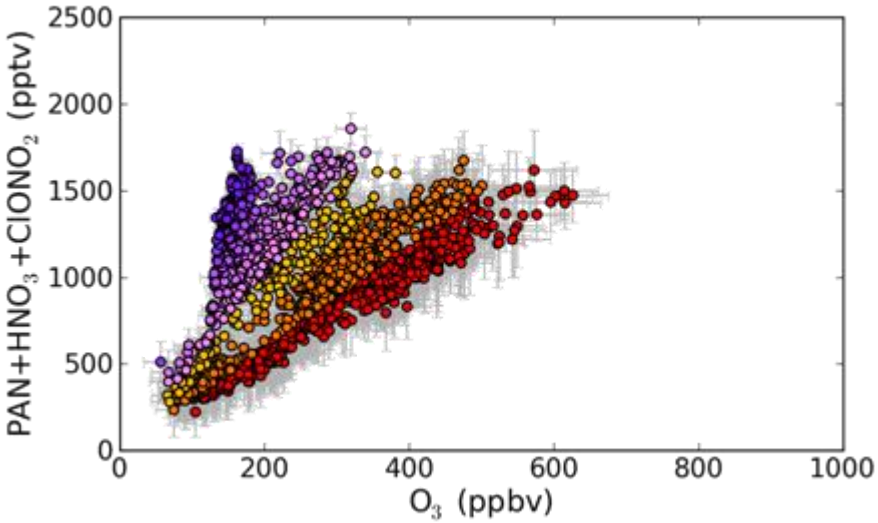
AMMA/CRISTA-NF retrieval result 2006-07-29

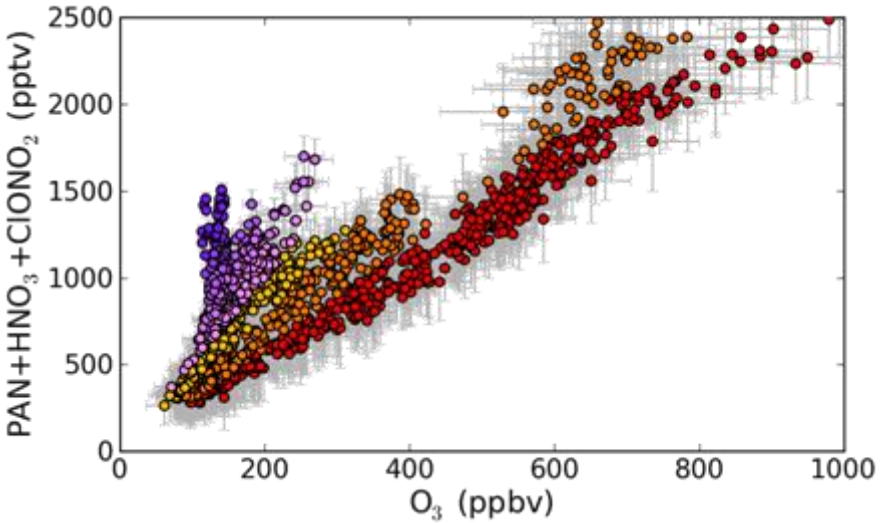
Relationship between PAN and O_3 in tracer / geospatial space

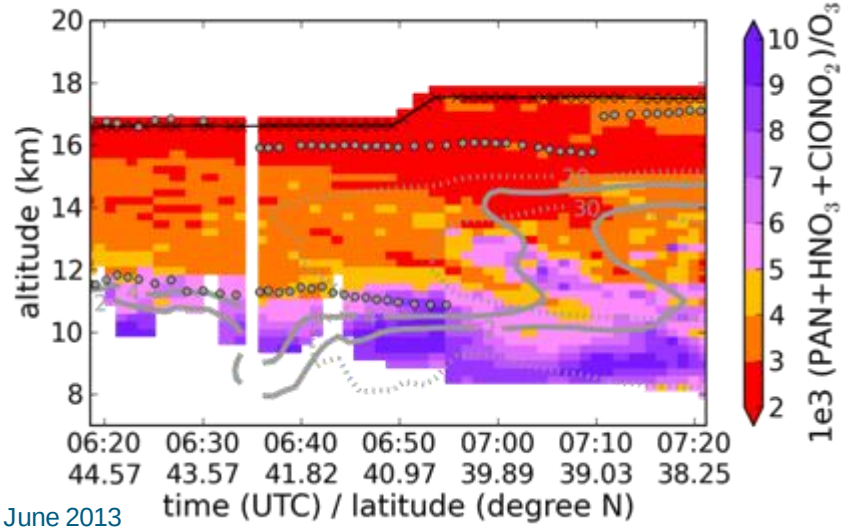


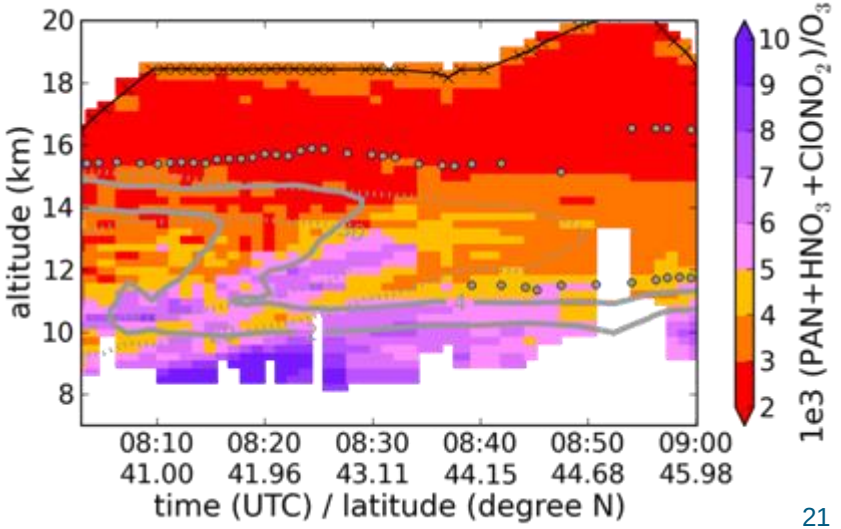
AMMA/CRISTA-NF retrieval result 2006-07-29

Relationship between $PAN+HNO_3+ClONO_2$ and O_3 and ratio









Stirring and mixing in the UTLS
Conclusions

- Fine-scale filaments with a vertical extent of less than 0.8 km could be observed. The originating breaking wave could be identified using trajectory calculations
- Vertical resolution is sufficient but also necessary to map the mixing zone between UT and LS
- Available trace gases (nearly) allow a derivation of NO_y and a classification of air as pristine or polluted
- Analysis lacks in several (in principle retrievable!) trace gases and also temporal and spatial coverage:
  - GLORIA offers much higher spectral resolution at better spatial resolution
  - PREMIER or a similar instrument would provide global coverage at comparable quality