Ice particles observed in the tropical lower stratosphere: Unambiguous evidence for transport by convective overshooting

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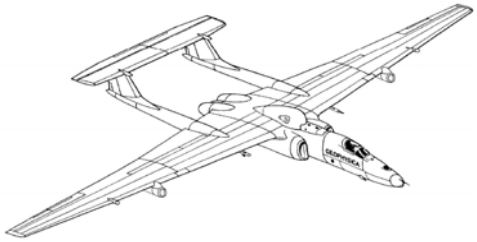
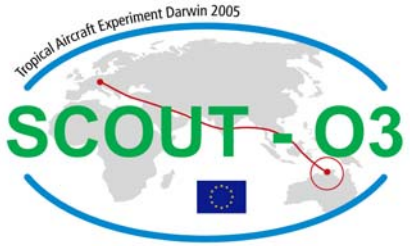




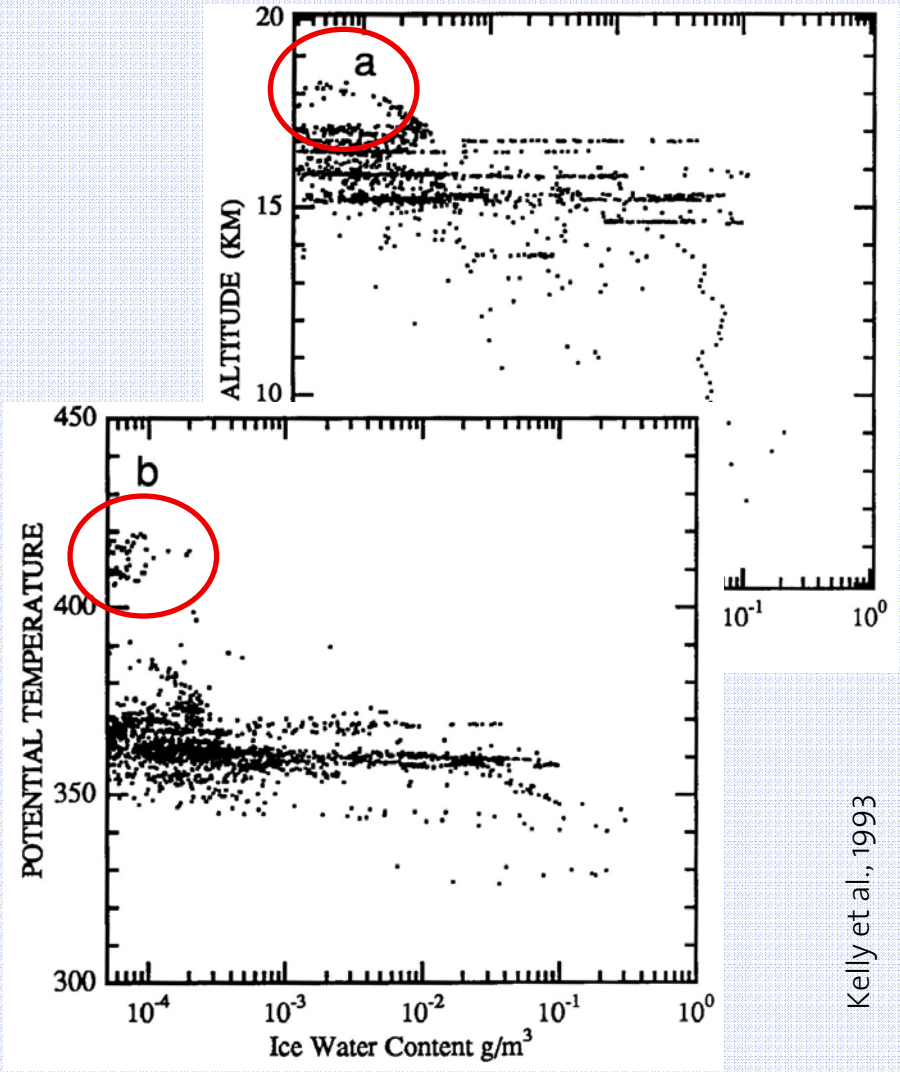
Content

- Observations from 2 recent campaigns
- 3 Hypotheses
- Some arguments

Observations

Ice particles close to deep convection above the tropical tropopause (380 K) have been observed during aircraft campaigns

STEP in Darwin (1987)
TROCCINOX in Araçatuba (2005)
SCOUT-O3 in Darwin (2005)



Kelly et al., 1993

Observations from 2 campaigns in 2005

2 campaigns involving (among others) the aircraft "Geophysica"

TROCCINOX (Tropical Convection, Cirrus and Nitrogen Oxides Experiment)

- Campaign in January / February 2005 in Araçatuba, Brazil
- 2 flights with probing in and above very deep convection

SCOUT-O3 (Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere)

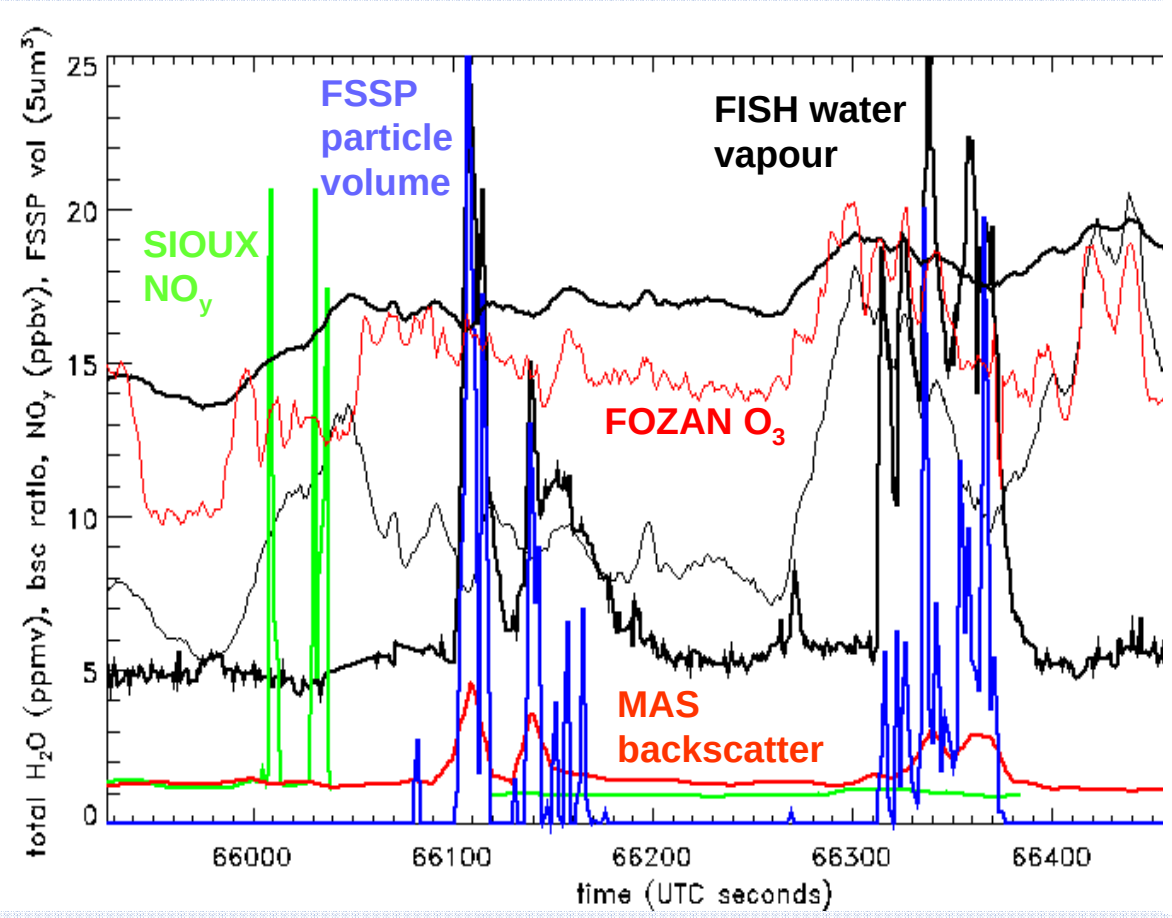
- Campaign in November / December 2005 in Darwin, Australia
- 4 flights with probing in and above very deep convection

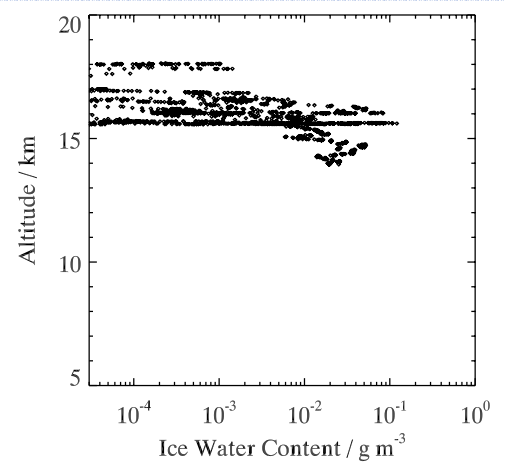
Geophysica payload (excerpt)

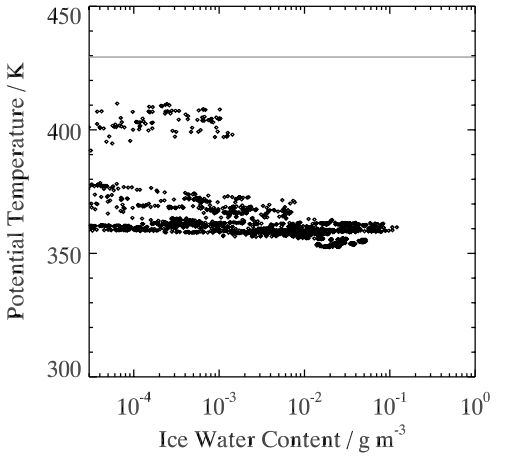
Instrument	Measured parameter	Technique
FISH	H_2O (total)	Lyman-α
FLASH	H_2O (gas phase)	Lyman-α
ACH	H_2O (gas phase)	Mirror hygrometer
FSSP 100 or 300	Particle size distribution	Laser-particle spectrometer
MAS	Aerosol/cloud optical prop.	Multi-wavelength scattering
MAL (down)	Remote aerosol/cloud profile	Microjoule-lidar
…		

TROCCINOX, 4 Feb 2005

„Golden day of thunderstorm chasing“. Geophysica overflying a very deep convective system.

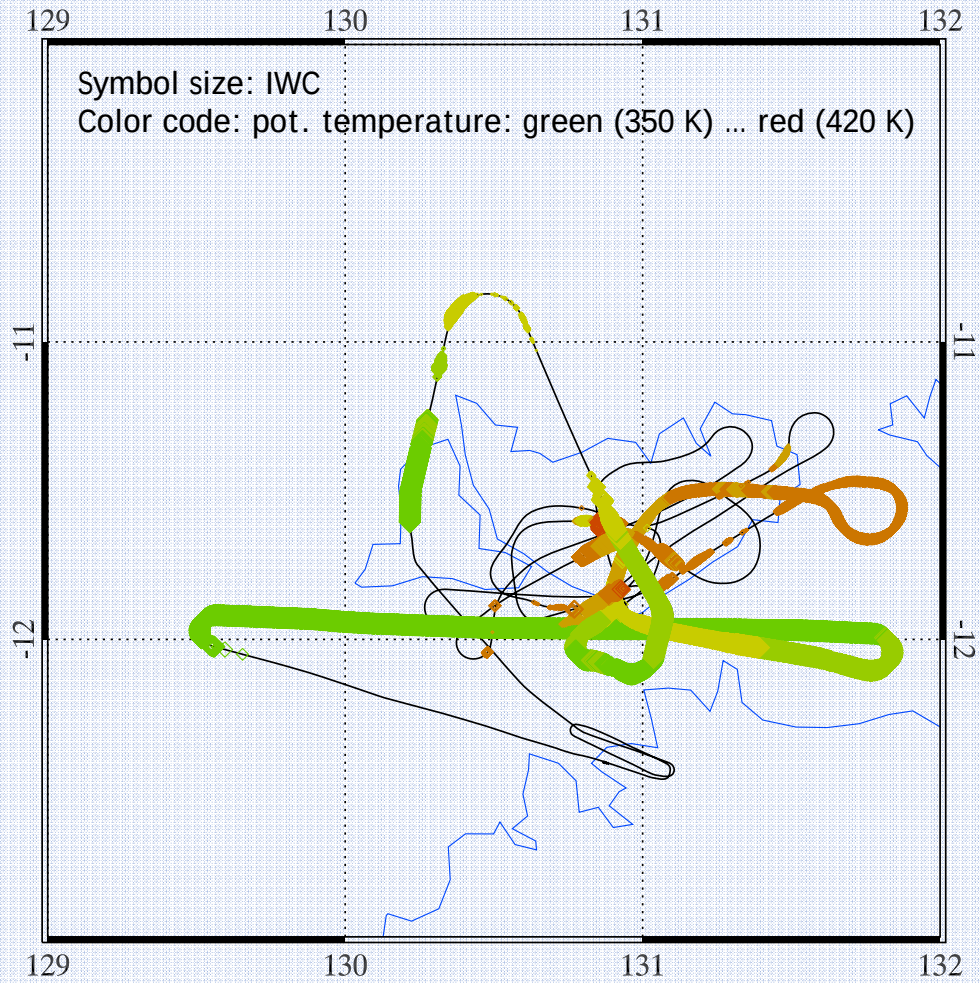


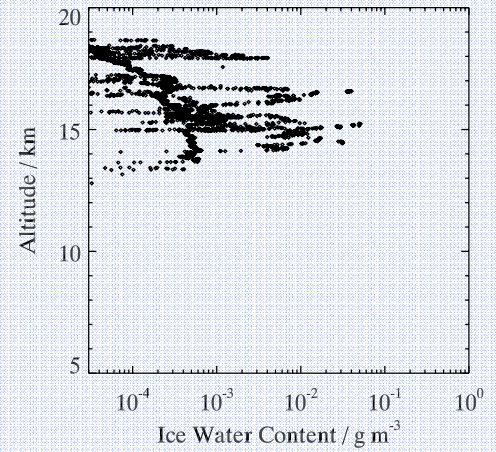


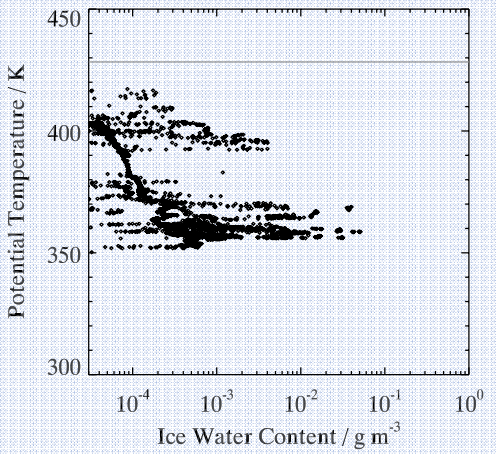


SCOUT-O3, flight #7, 30 Nov 2005

„Golden Hector day“. Geophysica circling above Hector







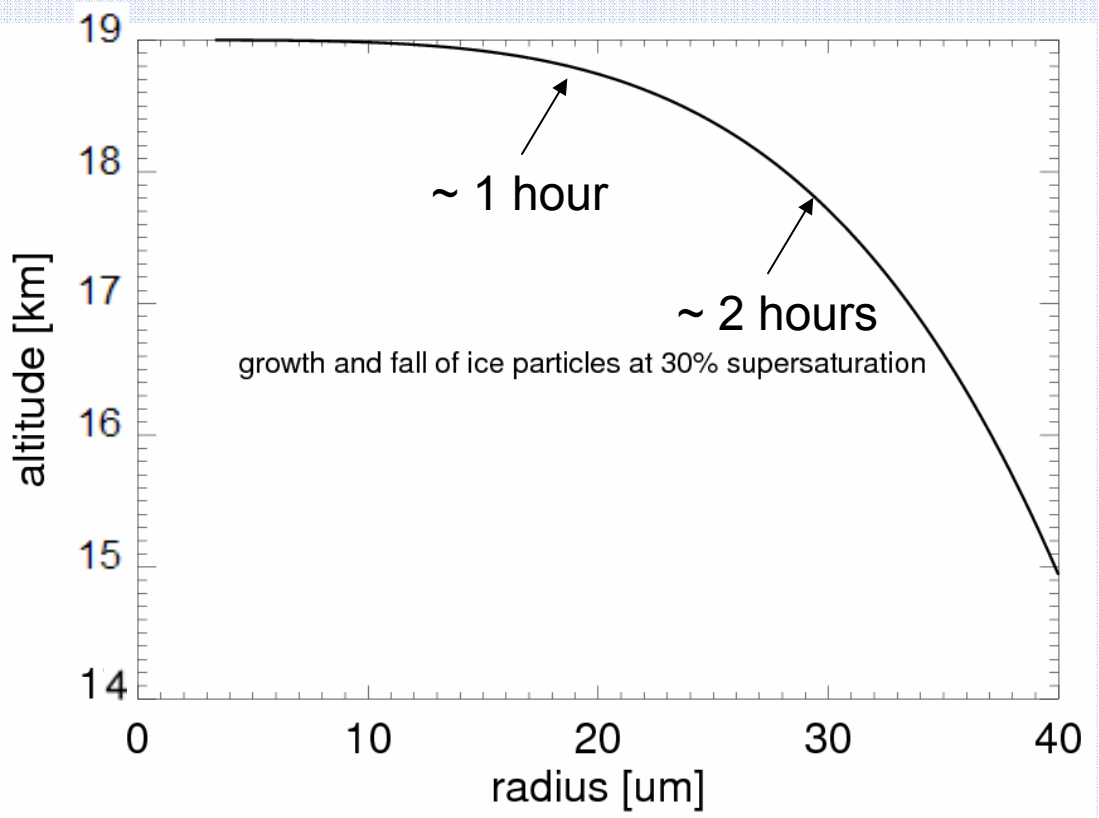
3 hypotheses

- In situ formation
- Contrail sampling
- Convective transport, overshooting and mixing

In situ formation?

Hypothesis:
Ice particles have formed in supersaturated air above the deep convection.

Arguments
- supersaturation unrealistic (strong undersaturation observed)
- In situ formation too slow



Contrail sampling?

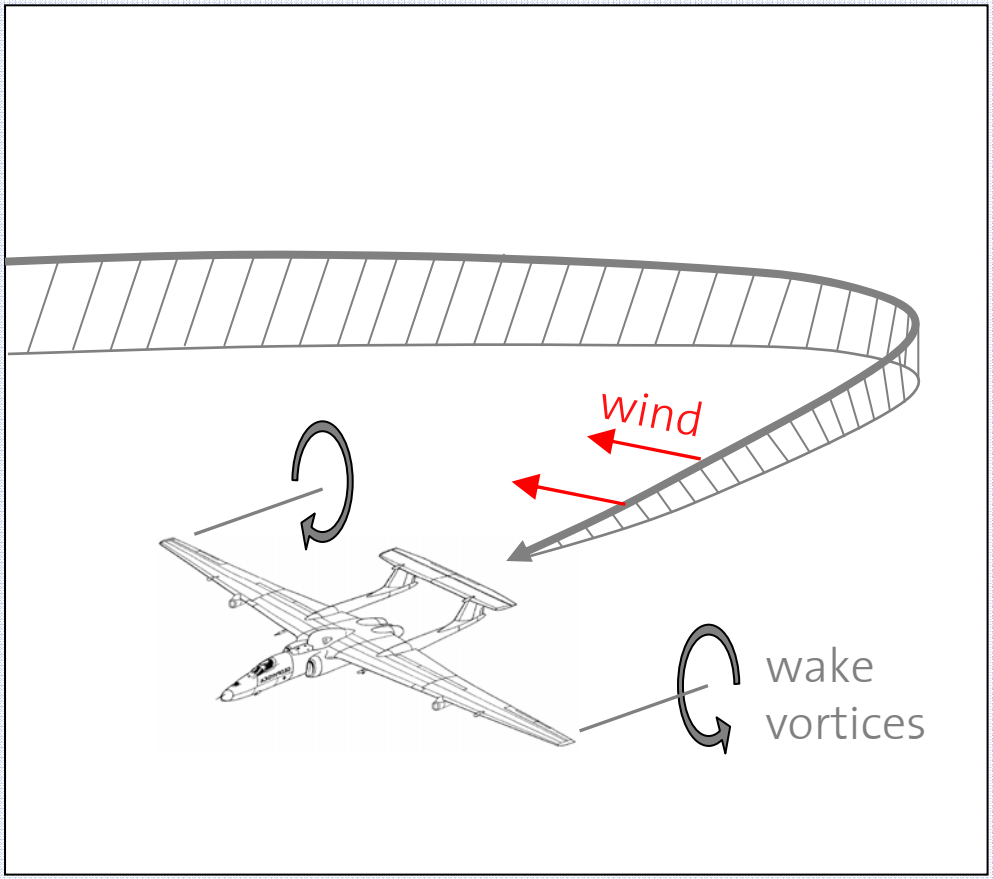
Hypothesis:
Ice particles originate from Geophysica contrail.

Arguments

— During TROCCINOX and some flights during SCOUT-O3, particles have been observed where Geophysica has not flown before.

\+ In some cases, contrail sampling appears probable.

Contrail tracking using aircraft wind measurements and ECMWF trajectories



Convective transport

Hypothesis:

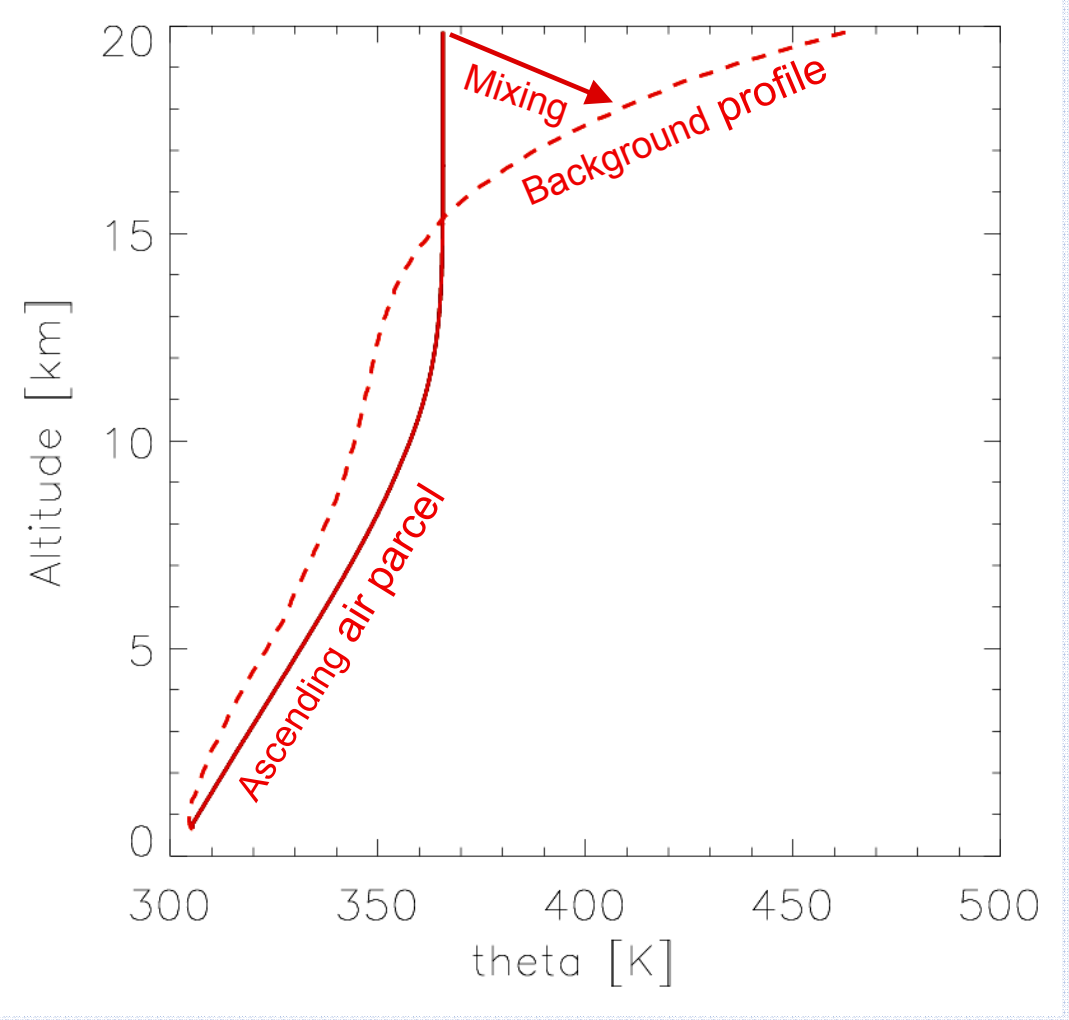
Transport in overshooting convection with subsequent mixing

Ascent of an air parcel in deep convection (moist adiabat) assuming no friction.

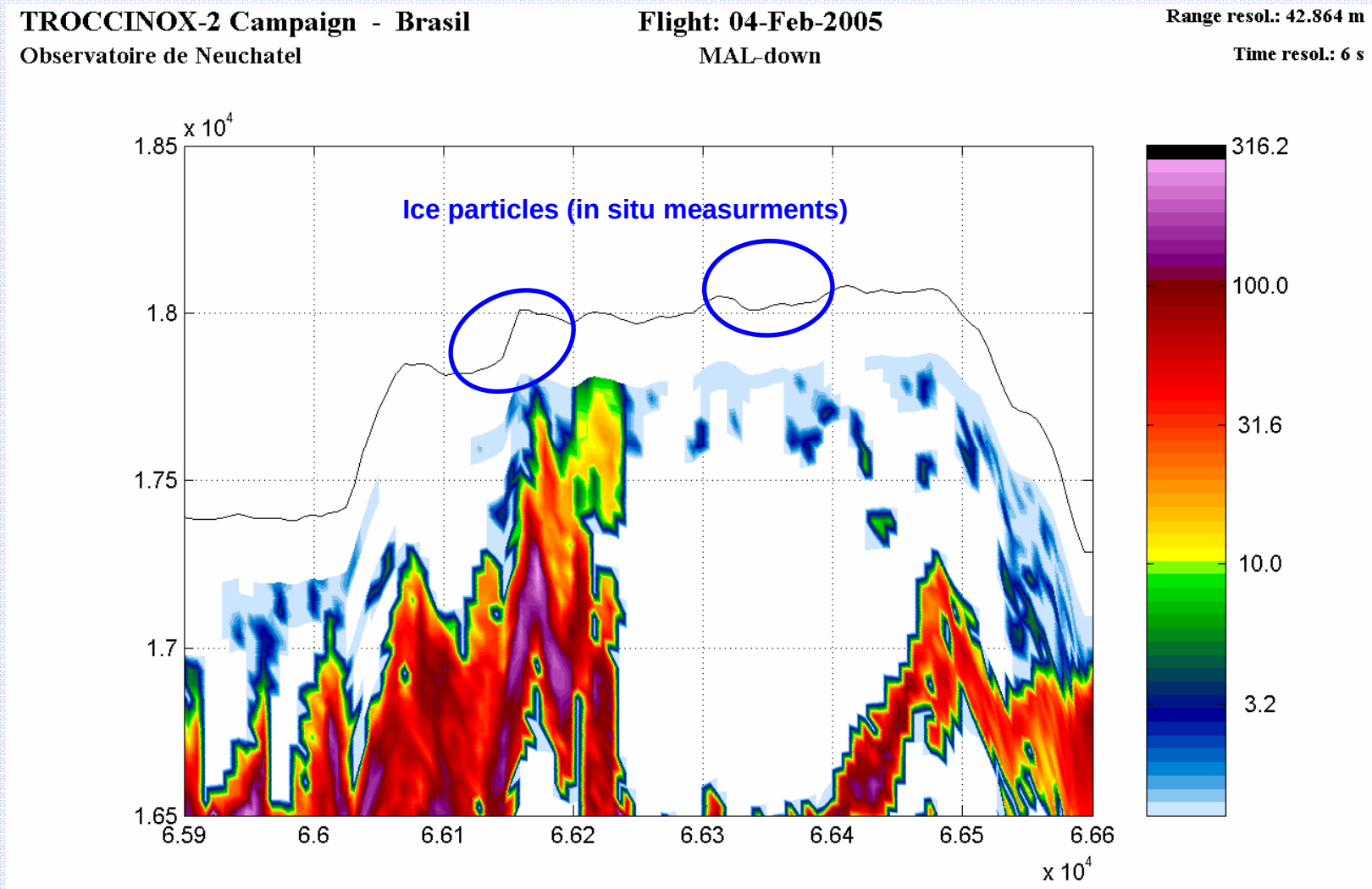
Overshooting up to ~20 km

Argument

+ Atmospheric conditions favourable to overshooting



Convective transport. Evidence from LIDAR

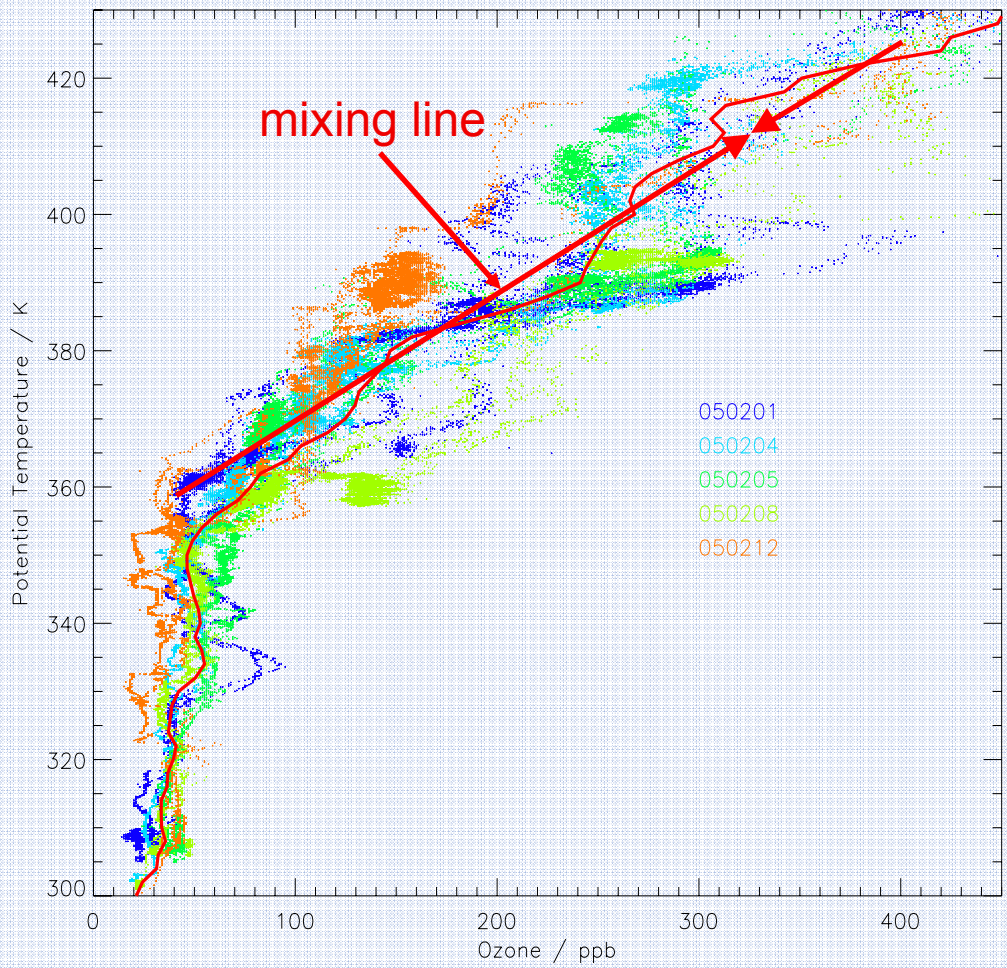


Convective transport

Why don't we find any signature in ozone?

Argument

± Linear change in ozone with potential temperature leads to an unobtrusive ozone signal.



Conclusions

- Ice particles have been observed close to deep convection above the tropical tropopause (380 K) during TROCCINOX and SCOUT-O3
- Transport by convective overshooting appears to be the only plausible explanation for most observations.
- These events are moistening the lower stratosphere.
- An upscaling of the contribution of convective overshooting to troposphere-to-stratosphere transport (TST) remains a challenge and will require further studies.

Upscaling?

E.g., combine results from detailed modelling with climatological observations

Detailed modelling:

Correlate mass fluxes or water vapor transport (e.g., at 380K) with:

- Brightness temperature
- Storm top height
- Rainfall
- …

Global observations:

Establish PDFs for the same variables from:

- High-resolution satellite imagery
- precipitation and cloud radar
- space borne lidar
- …

Combination → Set of estimates of convective mass flux and water vapor transport across the tropopause