

# A numerical study of cross-tropopause transport by convective overshoots during the TROCCINOX golden day

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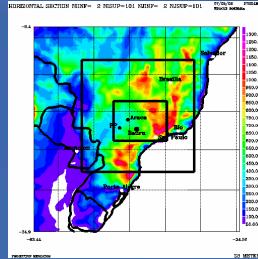
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## Summary

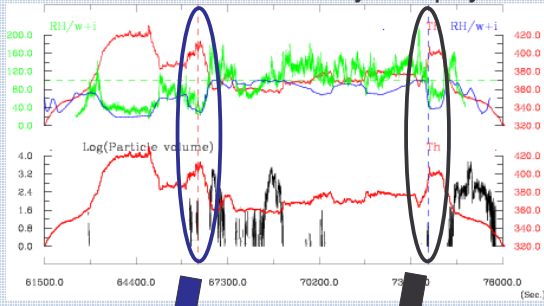
Observations during the Tropical Convection, Cirrus and Nitrogen Oxides (TROCCINOX) golden day (4 February 2005) have revealed the presence of particles up to 410 K (19 km). The case is investigated using a three-dimensional triply nested non-hydrostatic simulation starting from standard analyses. The simulation fairly well reproduces the relative humidity measurements along the flight track. A reasonable agreement with Meteosat Second Generation observations is also achieved. The simulation produces an overshooting plume up to 410 K yielding an upward transport of water vapour of a few tons per second across the tropical tropopause.



## Model set-up

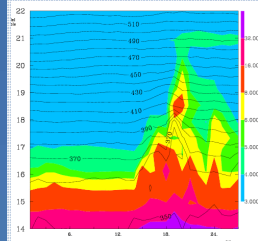
- Non-hydrostatic mesoscale model Méso-NH (Lafore et al. 1998)
- 3 domains (30, 10, and 3.3 km) with 2-way interaction.
- 72 vertical levels up to 27 km with  $\Delta z = 600$  m (free troposphere)
- Initial and coupling fields with ECMWF operational analysis
- Parameterization schemes: 1-D turbulence scheme, ECMWF radiation package, ISBA surface scheme, mixed-phase bulk microphysics (Pinty and Jabouille 1998), and deep and shallow convection scheme for the 30 and 10 km models only (Bechtold et al. 2001)
- Evaluation by model-to-satellite approach

## Particles at 410 K seen by Geophysica



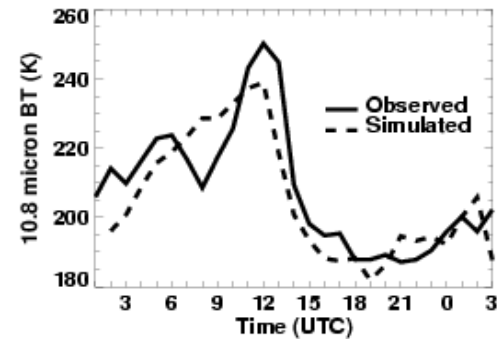
Top: observed potential temperature (red line, K), relative humidity (green line, %) and simulated relative humidity (blue line, %) during the Geophysica flight. Bottom: observed potential temperature (red line, K) and total particle concentration (black line,  $\text{cm}^{-3}$ ) as measured by the FSSP-100 instrument. The horizontal axis is the time in s.

## Water vapor maximum



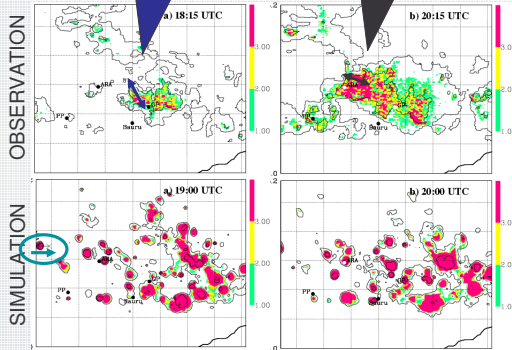
Time evolution of the water vapor mixing ratio maximum (color, ppmv) and of the potential temperature minimum (isolines, K). The vertical axis range is 14-22 km and horizontal axis range 0-27 UTC.

## Overview of the convective event



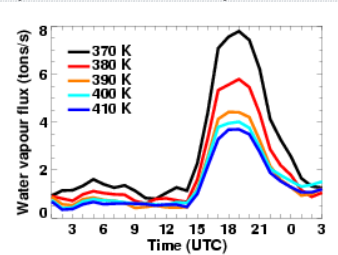
Time evolution of observed and simulated minimum brightness temperature (BT, K) at 10.8  $\mu\text{m}$  in the inner domain. The temporal resolution is 1 h.

## Convective Overshoots



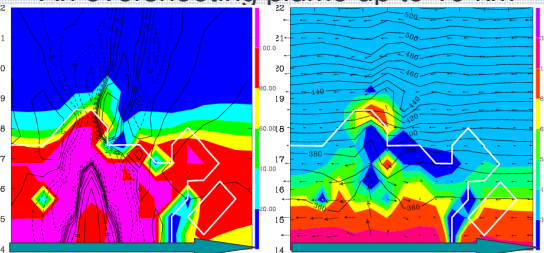
BT difference (K) between 6.2- and 10.8- $\mu\text{m}$  band. Top: MSG observation, bottom: Méso-NH simulation. The 200-K and 220-K isolines of the 10.8  $\mu\text{m}$  BT are superimposed.

## Upward water vapor flux



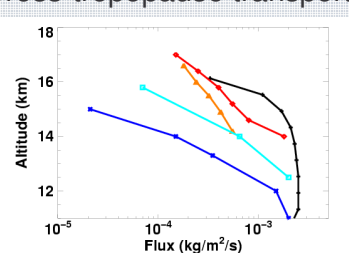
Times series of upward water vapour flux through isentropic surface of 370, 380, 390, 400, and 410 K.

## An overshooting plume up to 19 km



Vertical cross section at 19:00 UTC 4 February 2005. Left: relative humidity w. resp. ice (%) Solid (dotted) contours represent positive (negative) vertical velocity ( $\text{m s}^{-1}$ ). Right: water vapor mixing ratio (color, ppmv), potential temperature (isolines, K), and wind vectors. The maximum vector length is  $25 \text{ m s}^{-1}$ . The white line delineates the cloud limit.

## Cross-tropopause transport



Mass flux estimation based on  $\text{O}_3$  (red diamonds) and CO (orange triangles) budgets (Dessler, 2002), imagery (cyan squares; Gettelman et al., 2002), and CRM from Küpper et al. (2004, blue asterisks) and this work (black crosses).