Transport across the tropical tropopause by convection, mixing, and slow upwelling:

Insights from recent in situ observations with the Geophysica aircraft

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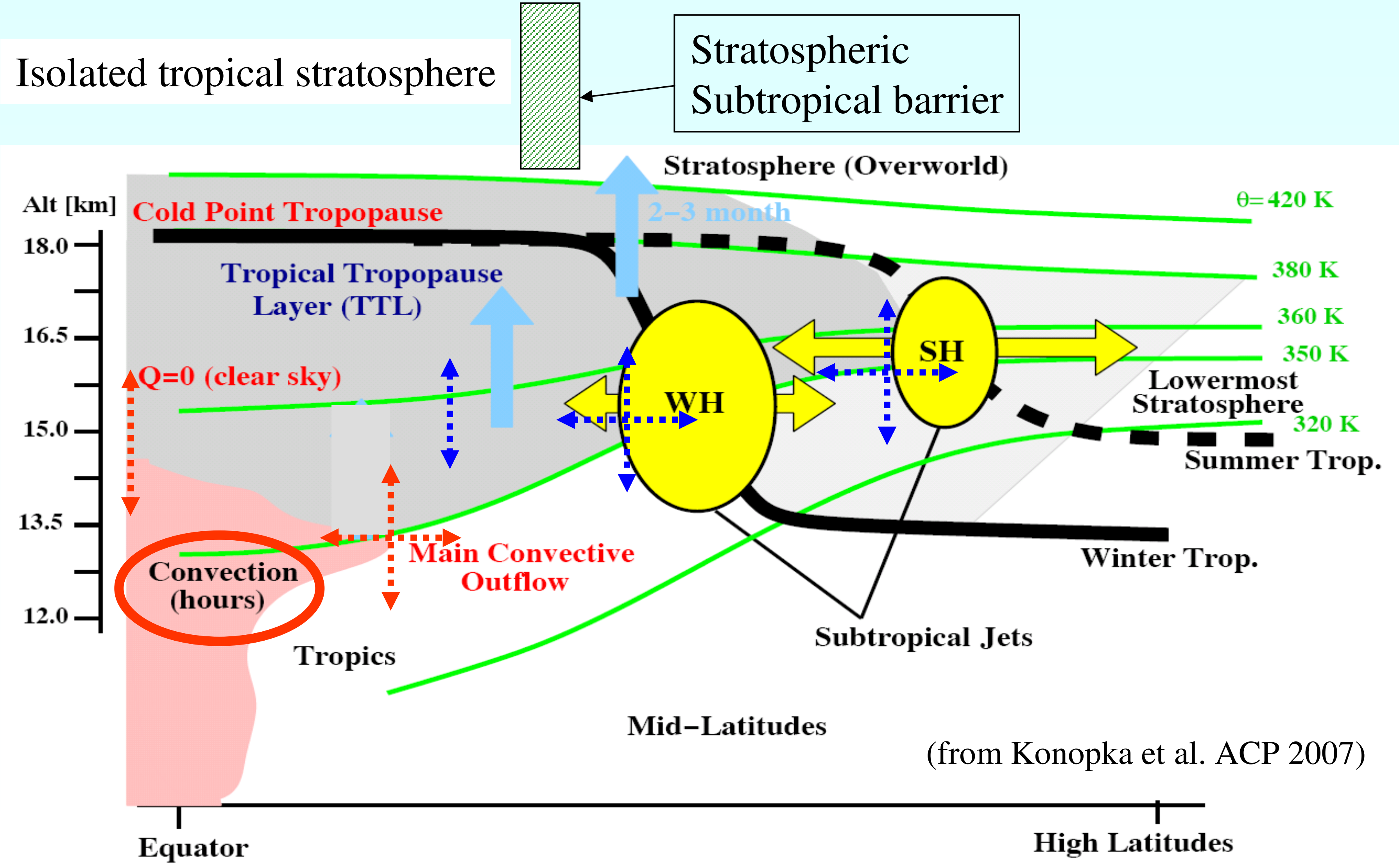
Transport Processes in the Tropical Tropopause Region



Goal: *Quantitative understanding of the balance between the dominant transport processes as function of time and space*

M55 In situ Tracer Measurements

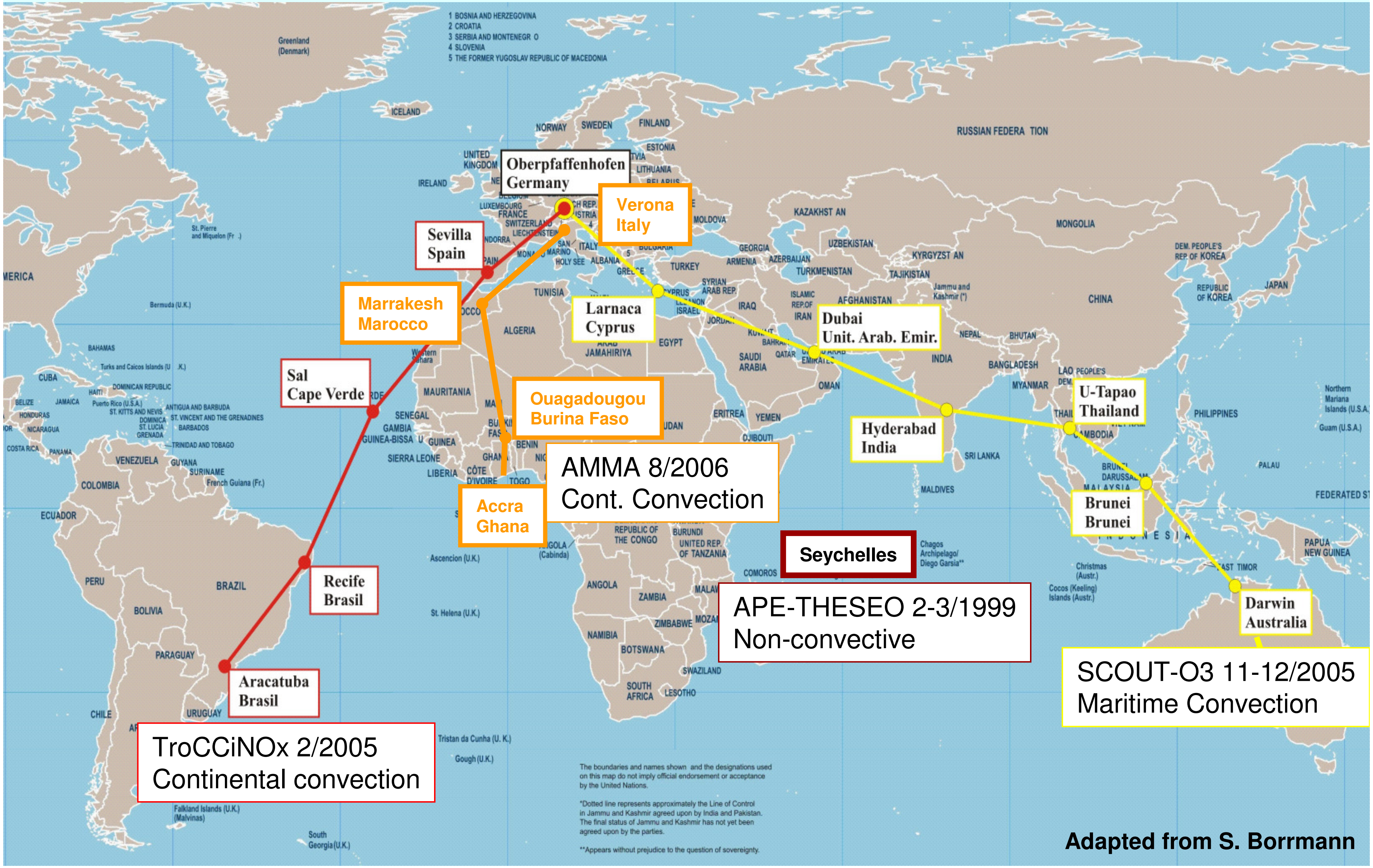
FOZAN (CAO, Russia): O_3

COLD (INOA, Italy): CO

HAGAR (Univ. Frankfurt)

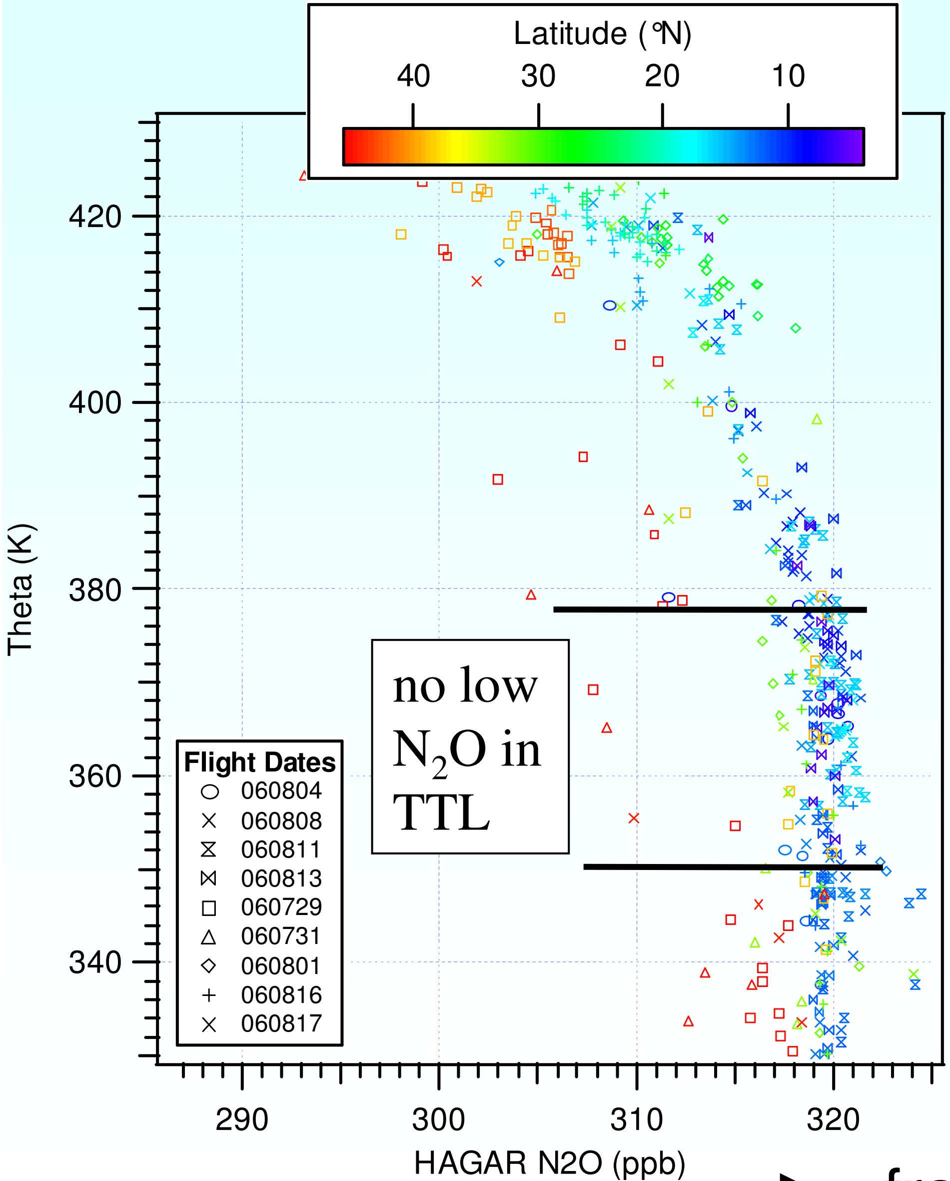
N_2O, F11, F12, H1211, SF_6, CO_2
(CH_4, CO, H_2)

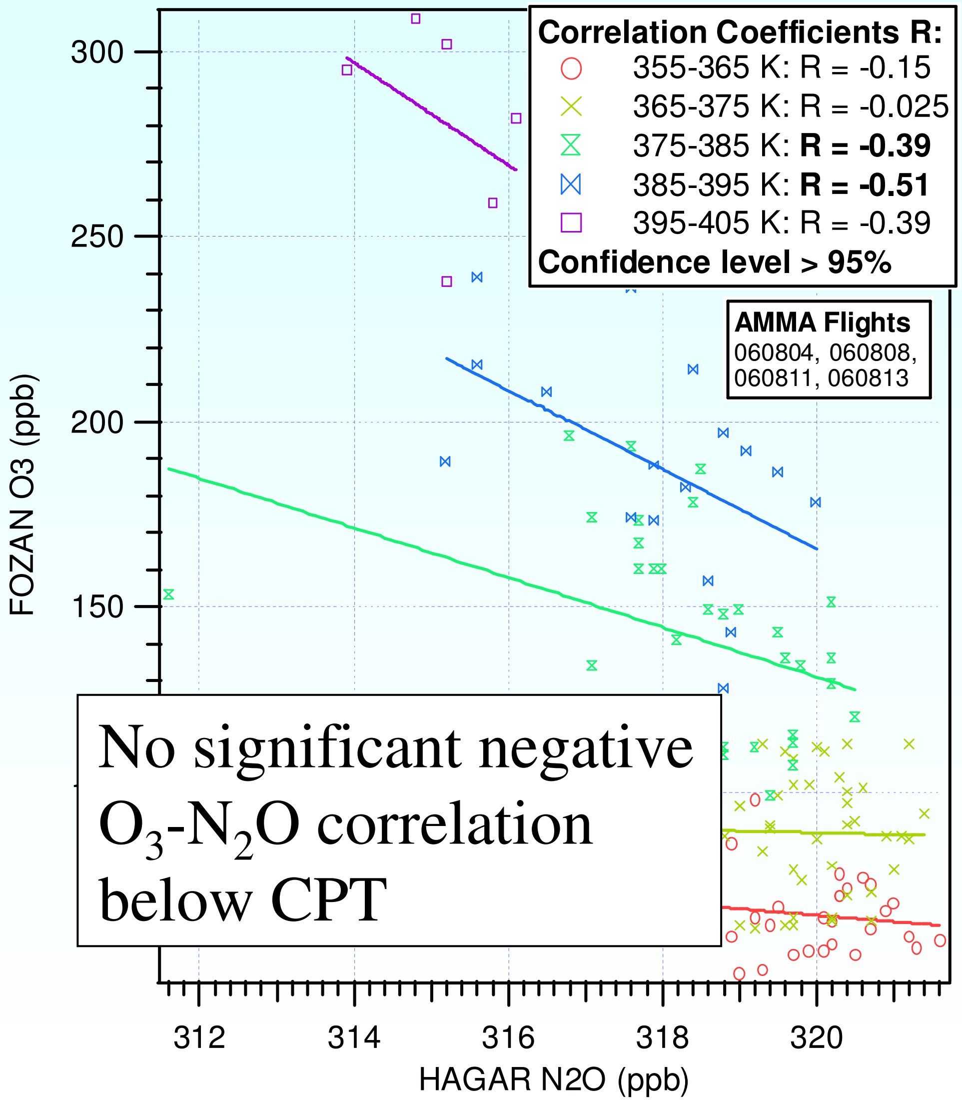
Campaign locations 1999-2006 (incl. transfer flights)



Total # of tropical flights: 44

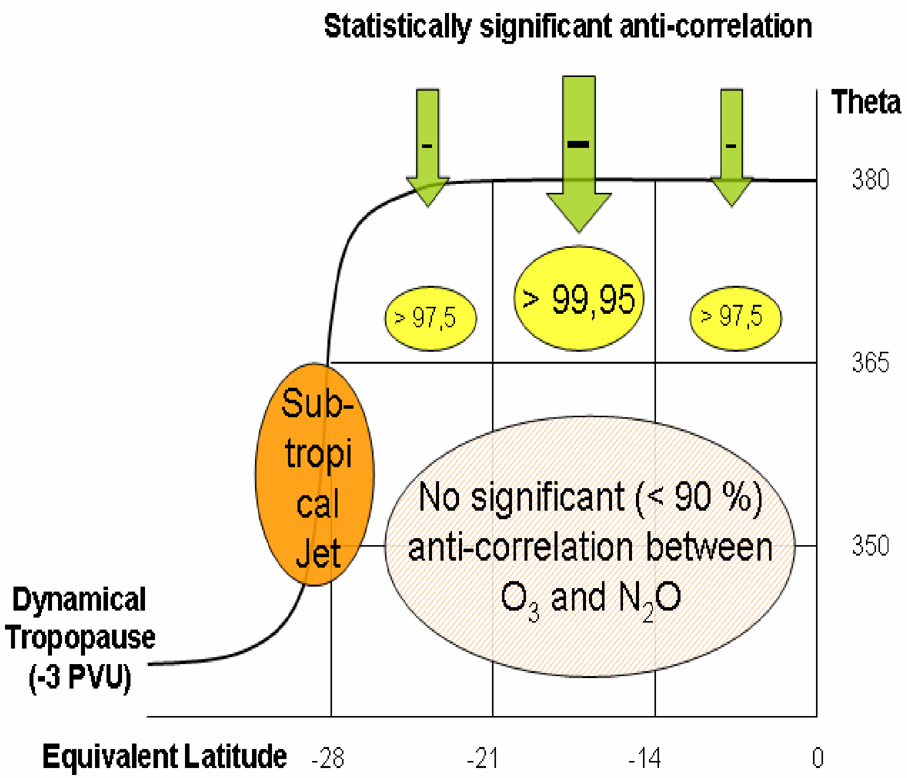
TTL: Stratospheric (horizontal) inmixing above W. Africa 2006?

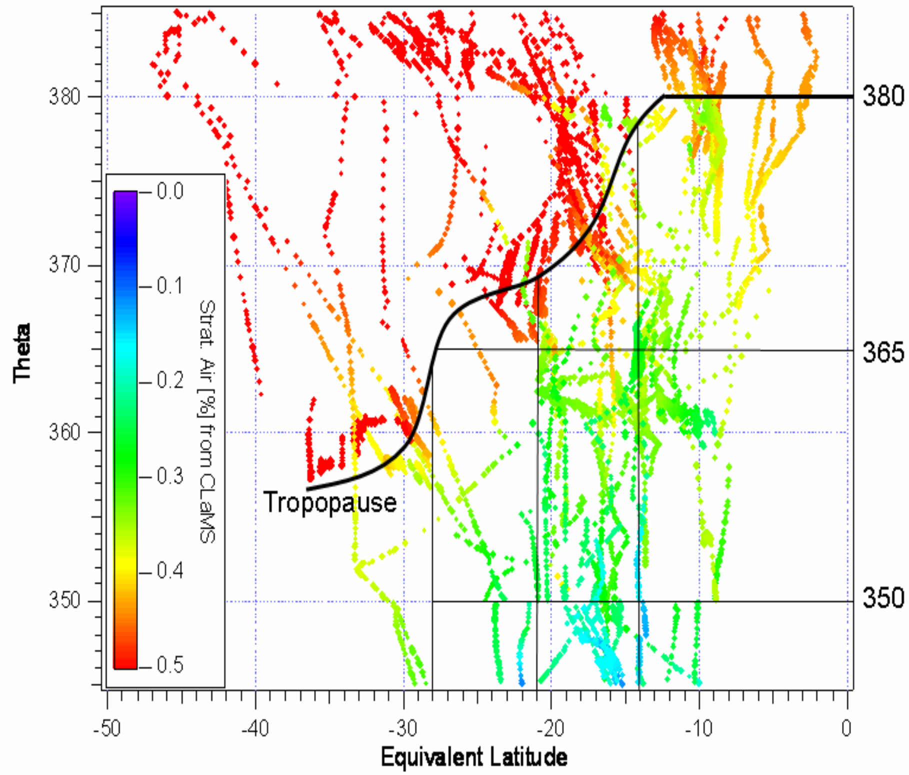




→ fraction of aged air small (<~10%)

TTL: Stratospheric inmixing above Brazil 2005?





Significant anti-correlations between O_3 and F12 found everywhere between 365 K and 380 K indicate significant stratospheric influence.

The CLaMS model calculates a fraction of **30-40%** of TTL air over subtropical Brazil originating from the stratosphere

(see poster by A.C. Kuhn et al.)

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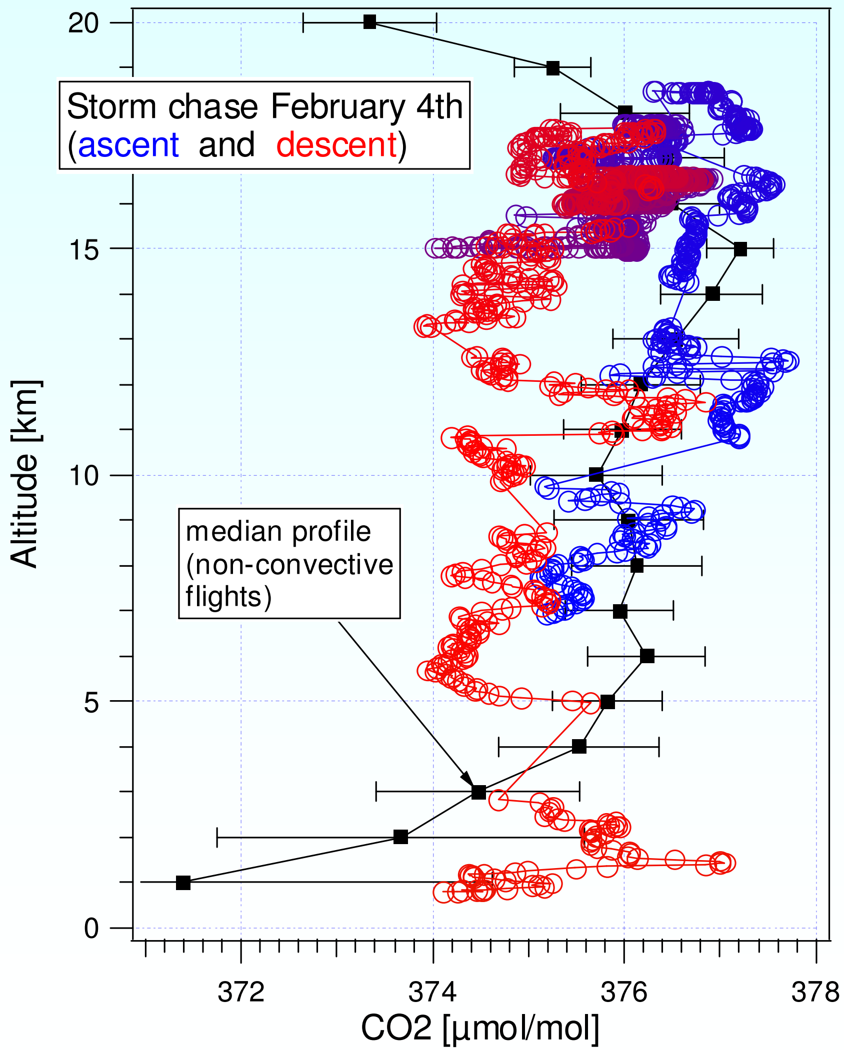
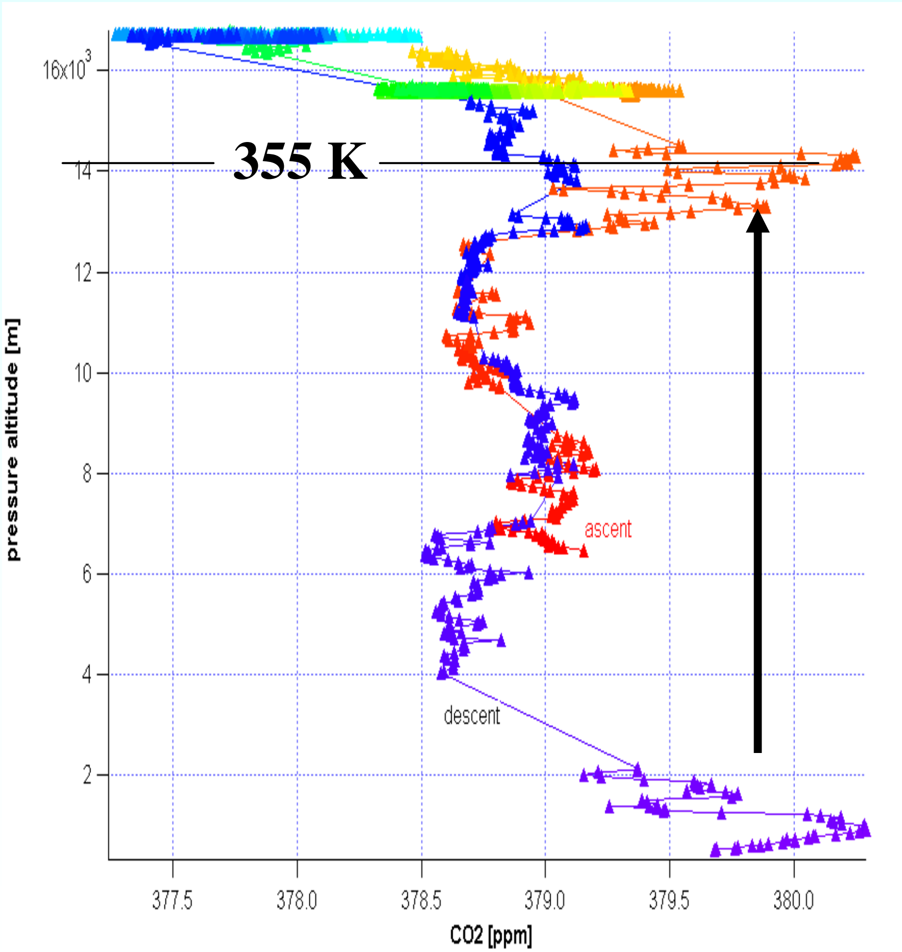
Convective uplift of boundary layer air into the TTL: CO_2

Brazil 2005



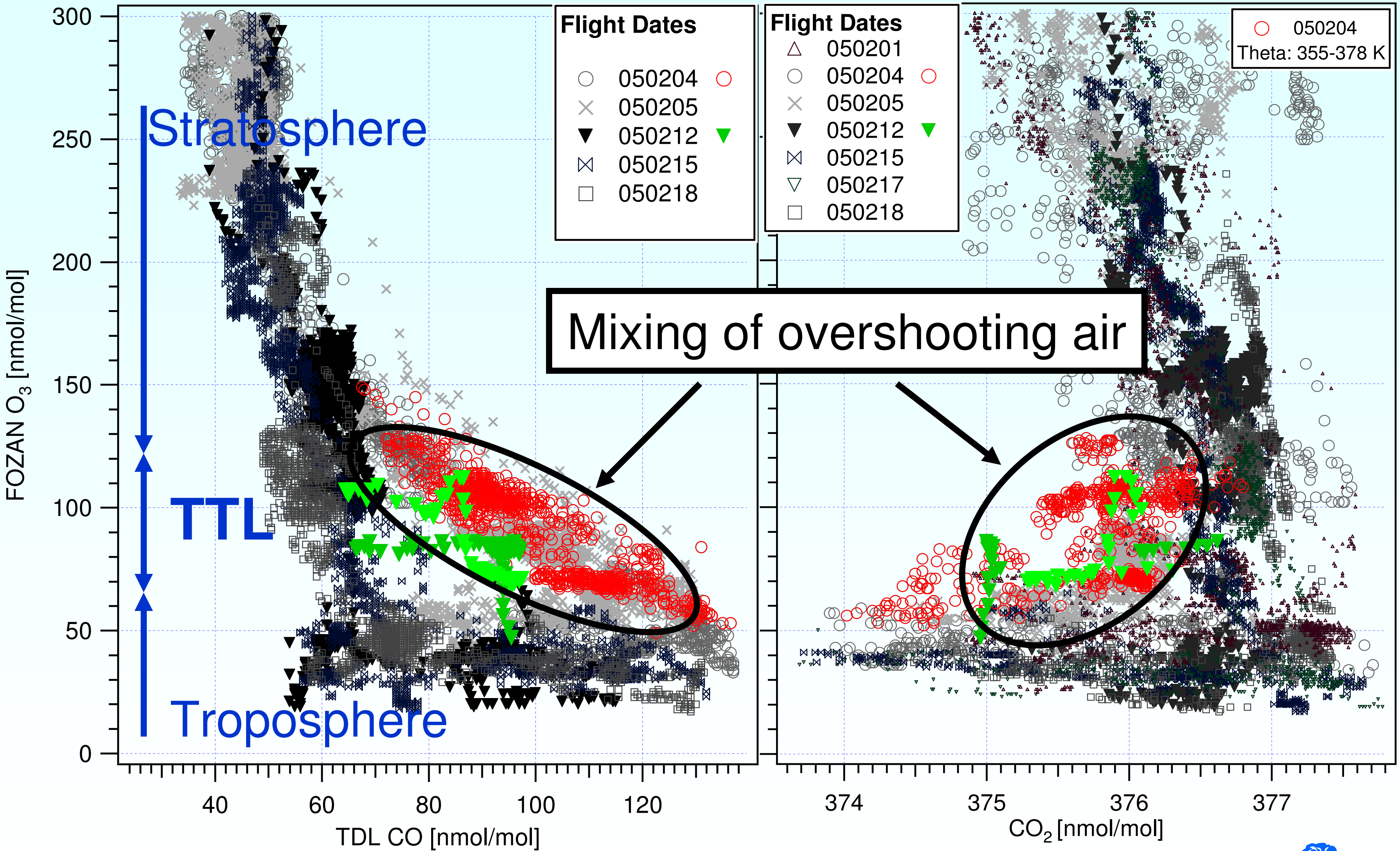
convective influence up to 17 km

Darwin 2005
051130b



Max. outflow level ~ 355 K

Mixing of overshooting air in the TTL: Brazil 2005 correlations



vertical transport of convectively detraining air to the upper TTL by mixing

(see poster by J. Baehr et al.)

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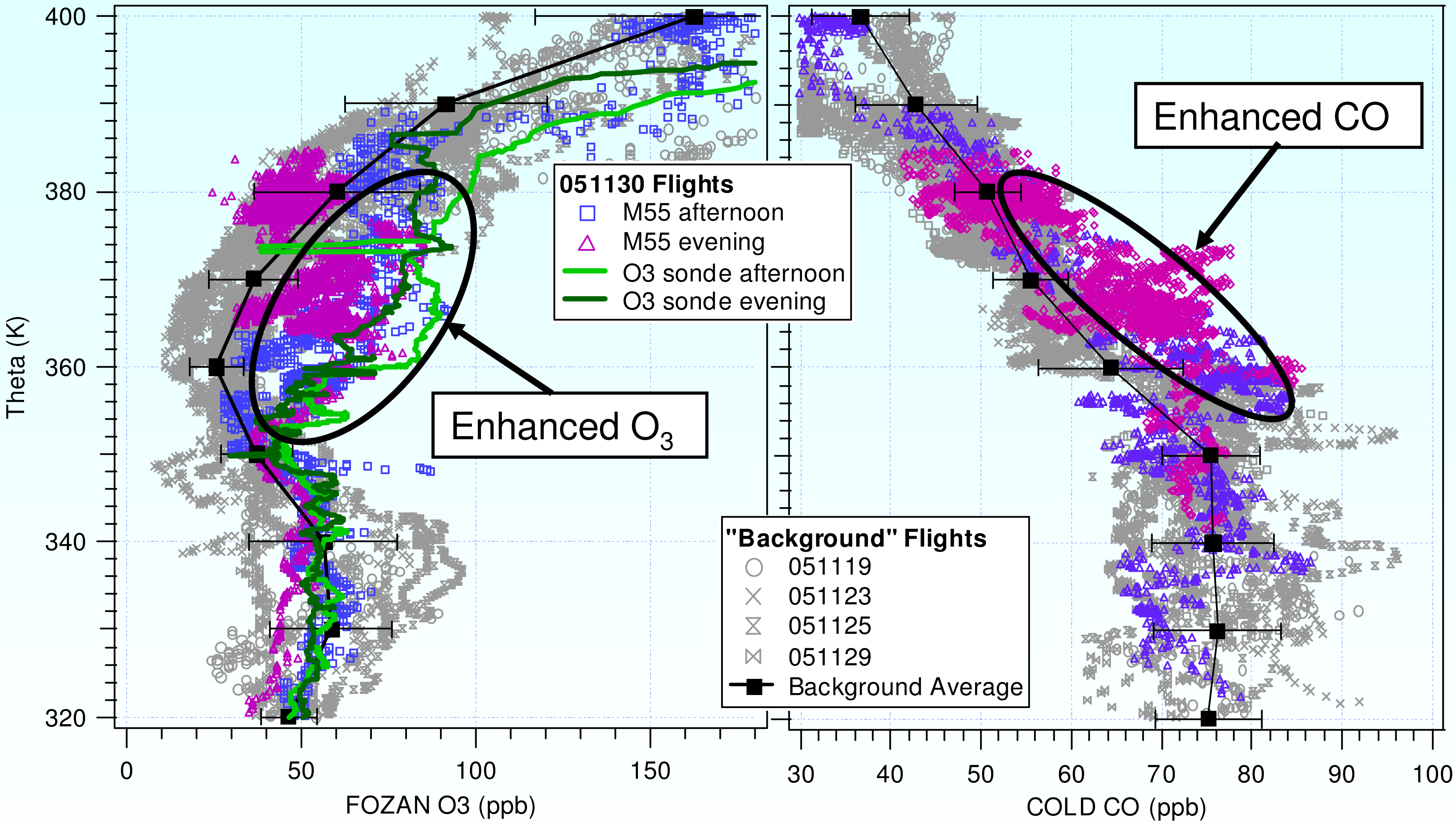
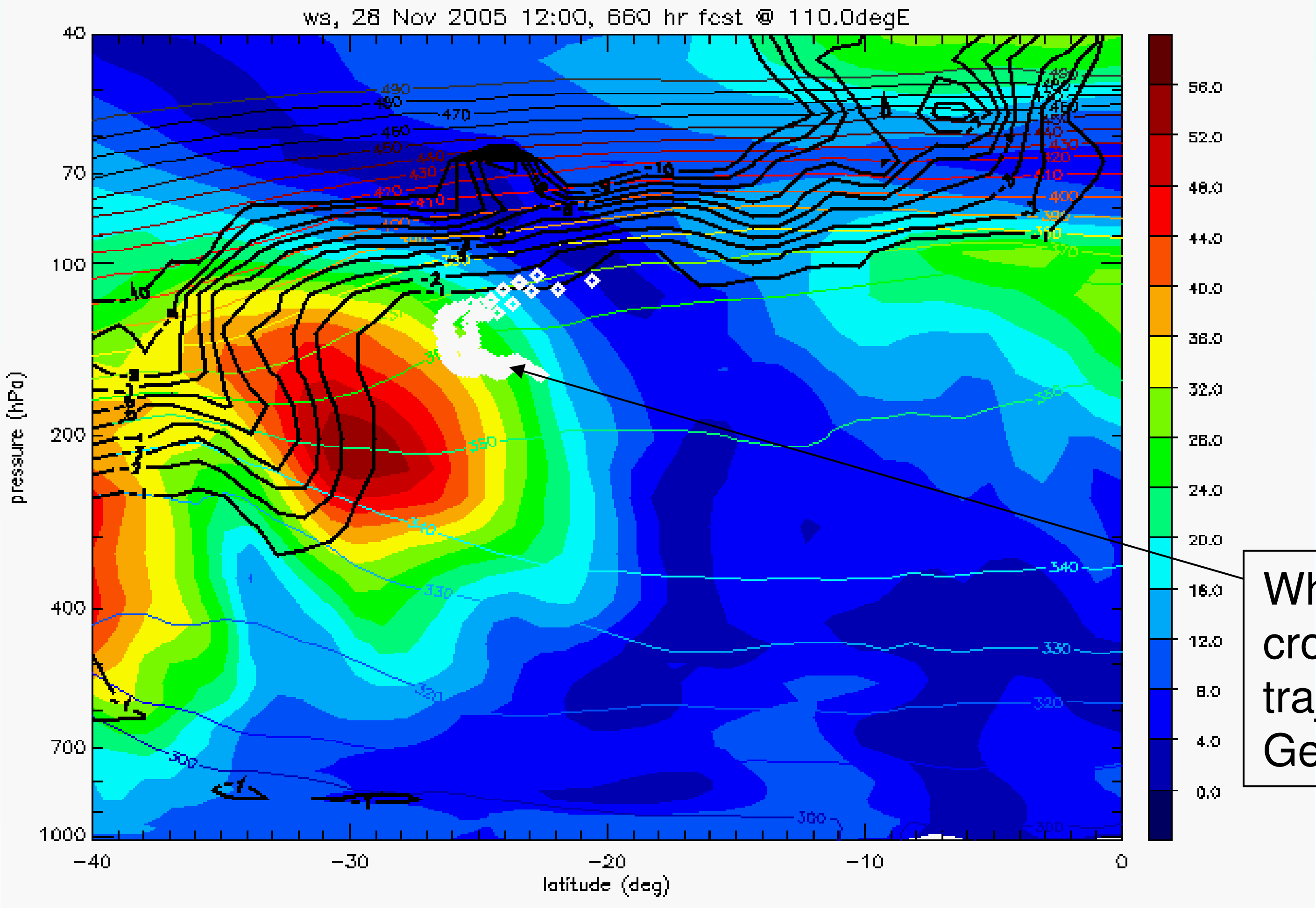
Vertical mixing in the TTL over Darwin 11/2005



Enhanced O3 and CO levels on 051130 consistent with vertical mixing (not consistent with horizontal stratospheric inmixing into TTL)

Most likely explanation for high O3 and CO levels:

Vertical mixing in the vicinity of the subtropical jet



=> air travels along the edge of the subtropical jet

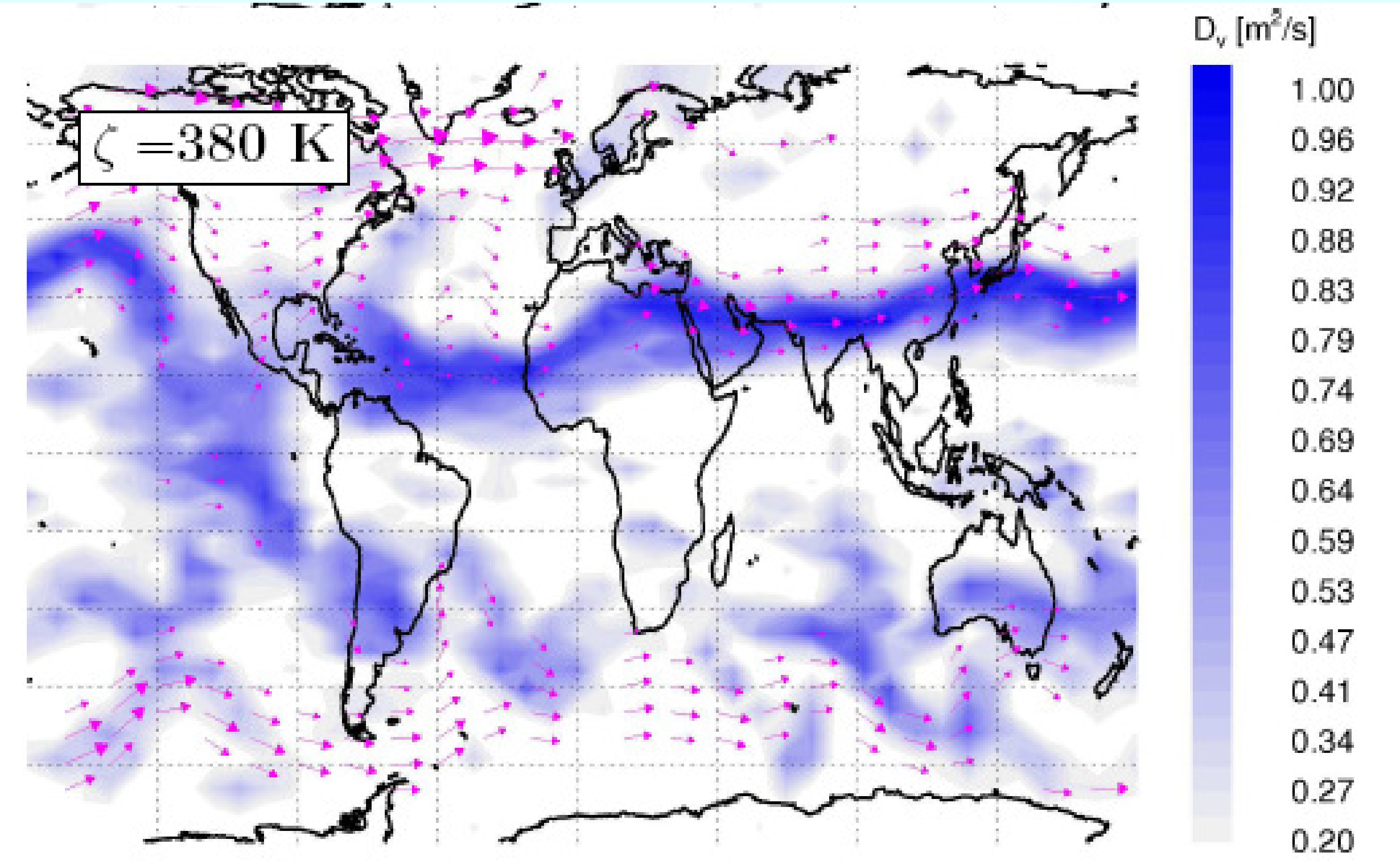
=> vertical wind shear facilitates small-scale mixing

White squares: crossing of backward trajectories from Geophysica flight track

Vertical cross section at 110°E of the wind speed (color contours) and PV (black contours).

The subtropical jet as a major agent for vertical mixing

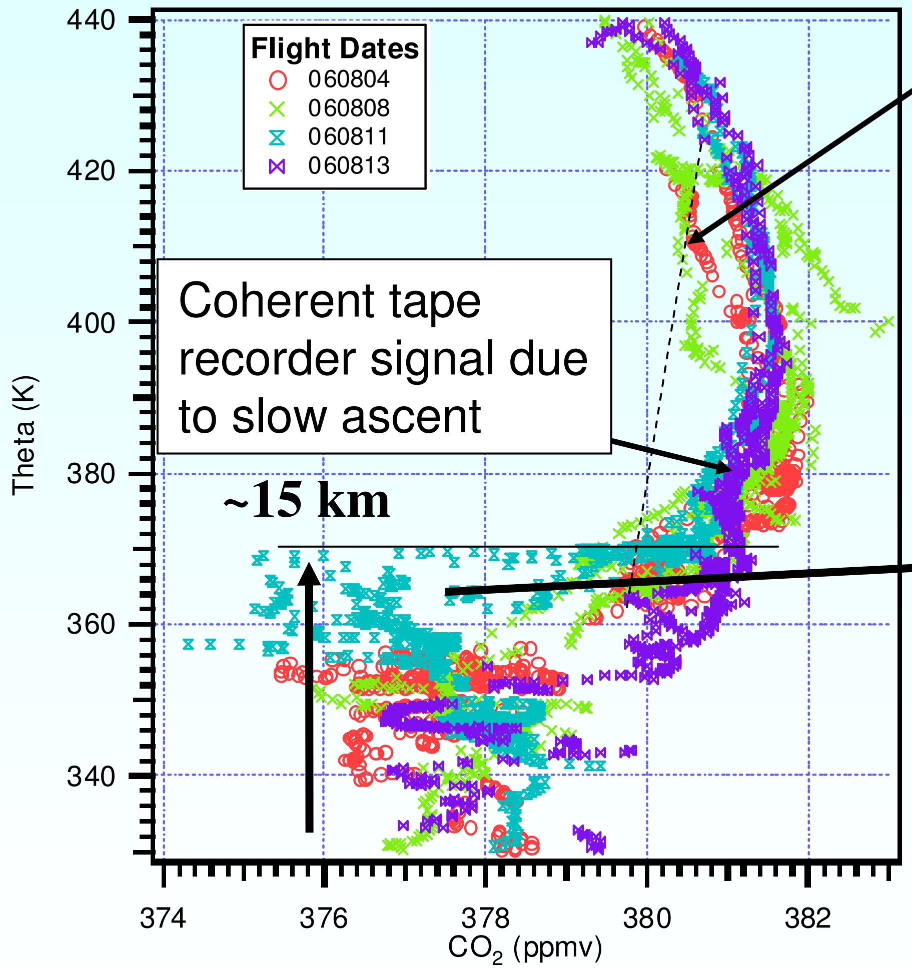
CLaMS: Chemical Langrangian Model of the Stratosphere



(Konopka et al., 2007)

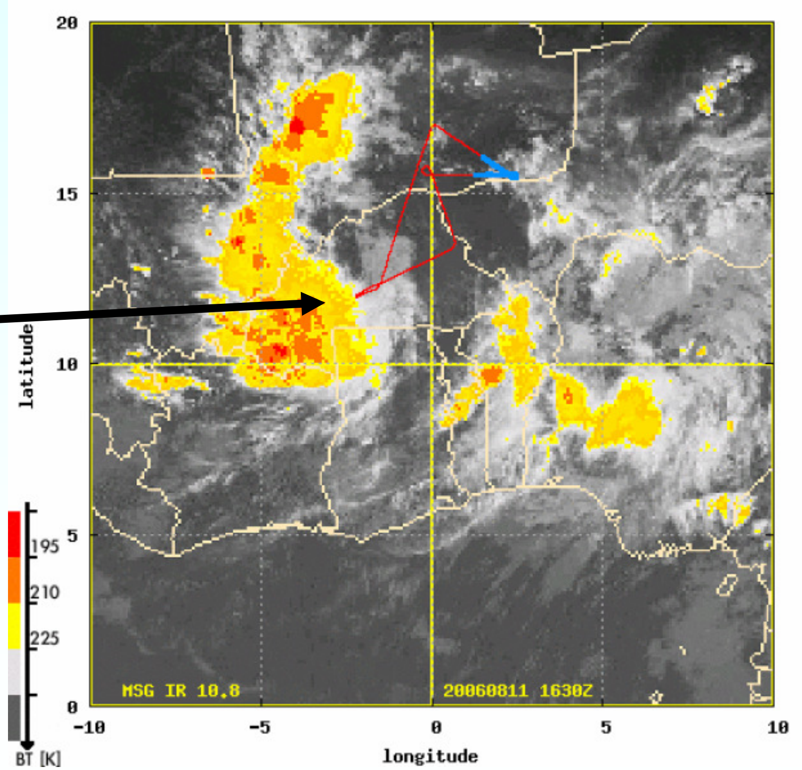
Vertical diffusivity at 380 K (February)

Convection versus slow ascent: CO_2 profiles West Africa



Max. convective outflow ~ 14-15 km

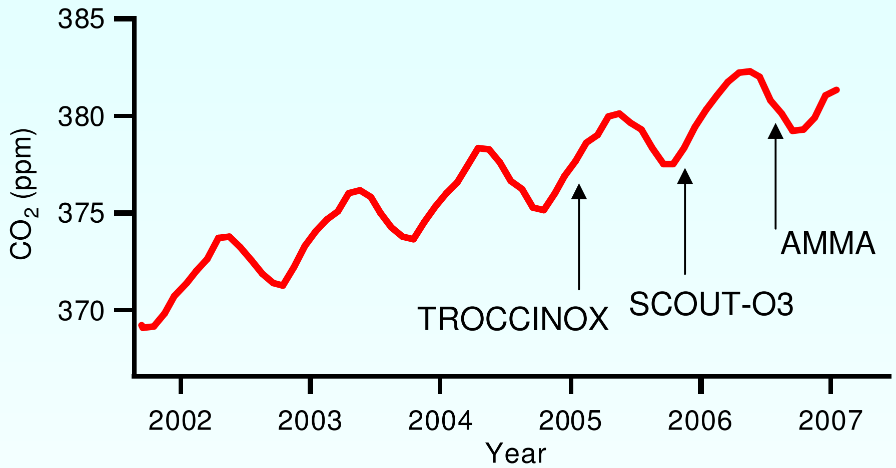
Small features at 08-08-2006 due to overshooting convection ?



Satellite picture flight 11th Aug.

CO_2 tracer clock to quantify slow ascent

Define mean $CO_{2surface}$ = average Mauna Loa +Samoa



NOAA ESRL (Conway et al.)

CO_2 tape recorder

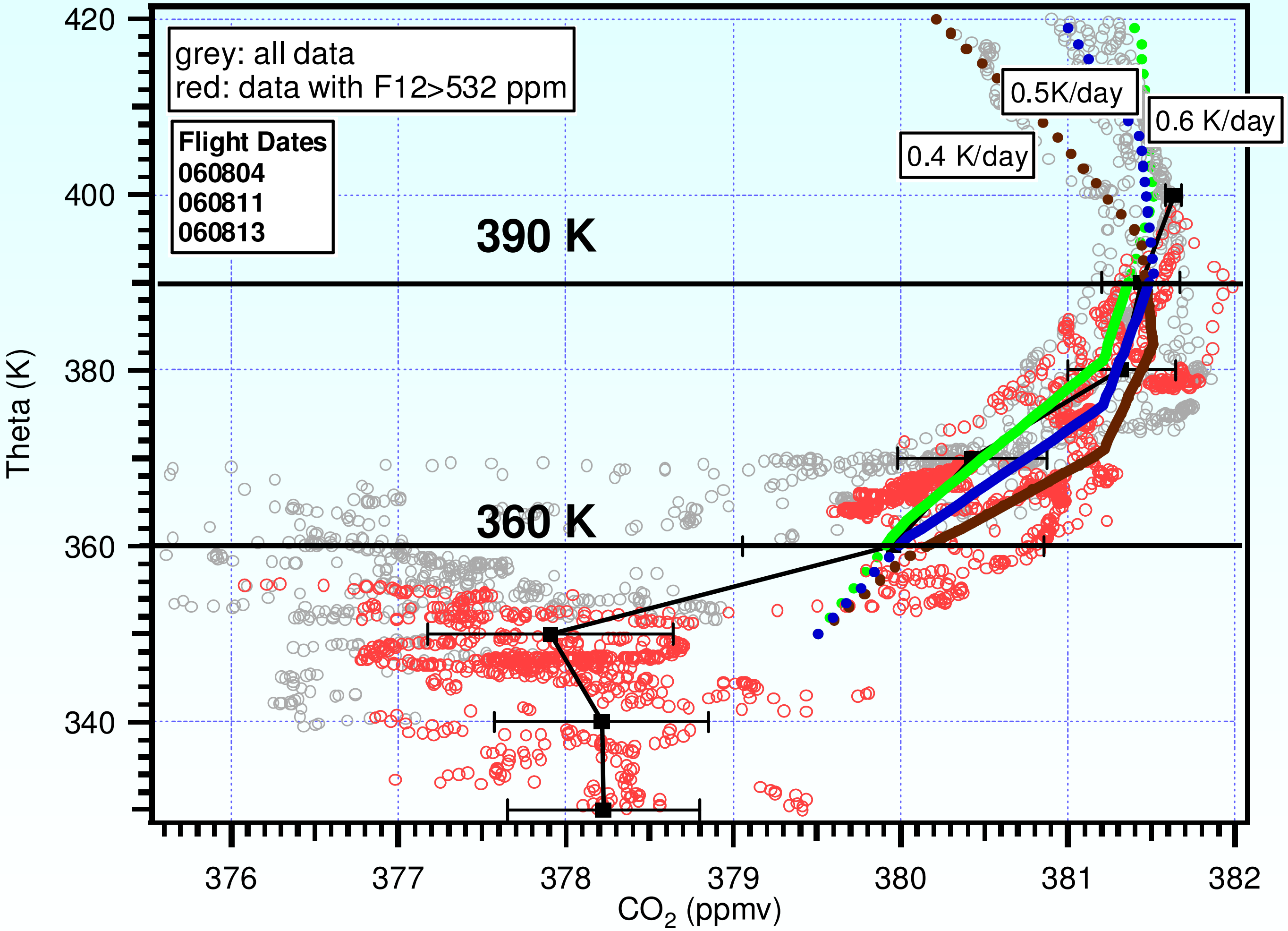
Use seasonal change of CO_2 to measure mean age since entering the TTL

Assumptions:

- At TTL bottom (~350 K): $CO2(t) = CO2_{surface}(t)$
- Uniform ascent rate in the TTL $w = d\theta/dt$
- => match "model" profile in region dominated by slow ascent

(360 < θ < 390 K): $CO2(\theta, t) = CO2_{surface}(t - [\theta\text{-}350K]/w)$

AMMA – August 2006

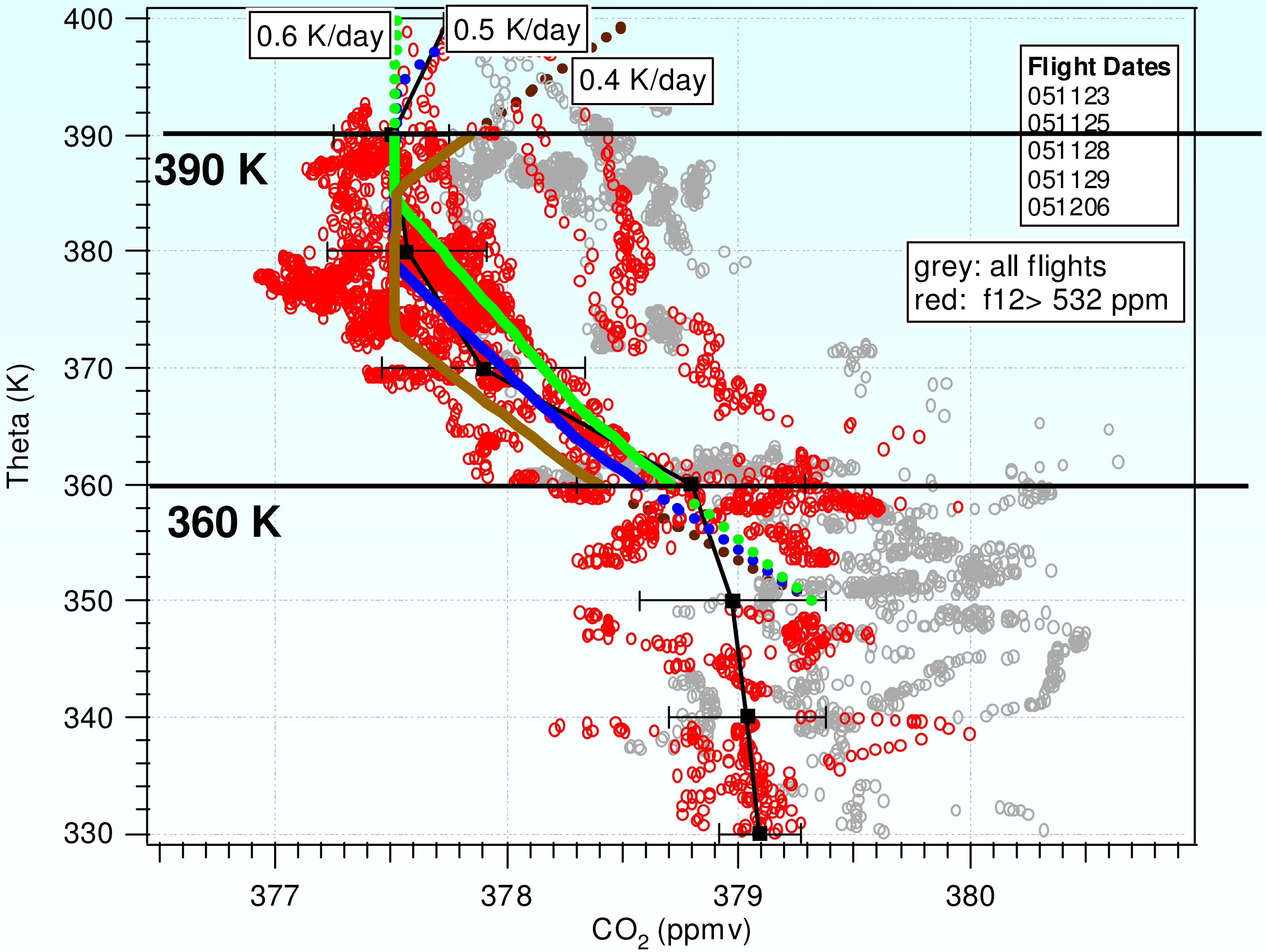


Mean ascent rate in the TTL:

0.5 +/-0.1 K/day

=> Air ascended since mid June

SCOUT-O3- November/December 2005

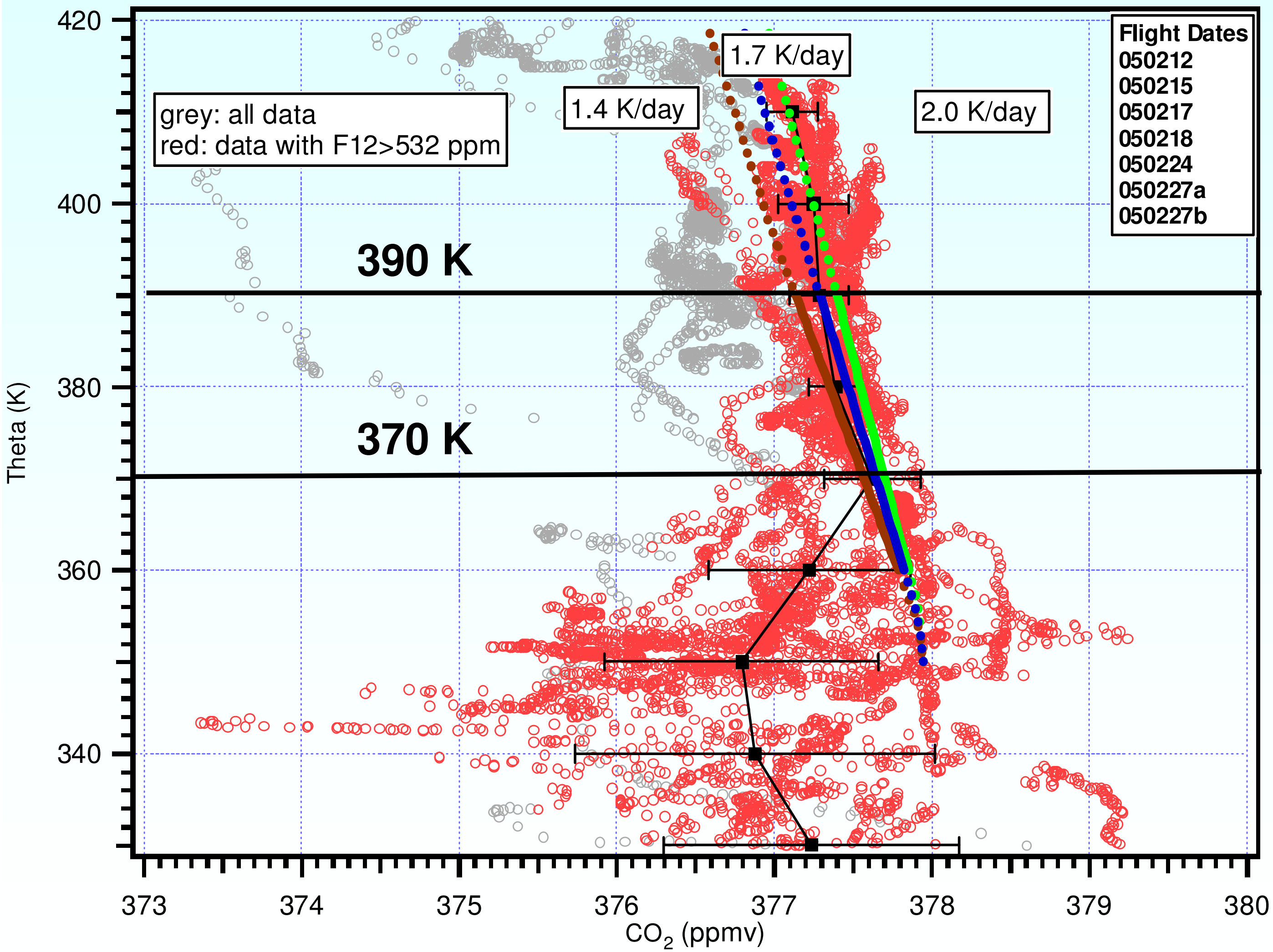


Mean ascent rate in the TTL:

0.5 +/-0.1 K/day

=> Air ascended since early October

TROCCINOX- February 2005



Mean ascent rate in the TTL:

1.7 +/-0.6 K/day

=> Air ascended since late January

Conclusions

- **Horizontal inmixing of aged stratospheric air into TTL:** appears to be common close to the subtropical jets, but not in inner tropics
- **Convection**: Max. outflow levels @ ~365 K or ~15 km, max. in Darwin
- **Vertical mixing** following convective overshooting:

  can effect much higher levels (~ 390K or 17 km observed over Brazil 2005) => causes strat.-trop. exchange

  W. Africa: possibly influence of overshooting up to 420 K
- **Vertical mixing along subtropical jets:**

  likely a major agent for tropical stratosphere-troposphere exchange !
- **Mean diabatic ascent (360-390K) derived from CO_2 clock:**

June/July 2006:	0.5 +/- 0.1 K/day
Oct./Nov. 2005:	0.5 +/- 0.1 K/day
Jan./Feb. 2005:	1.7 +/- 0.6 K/day