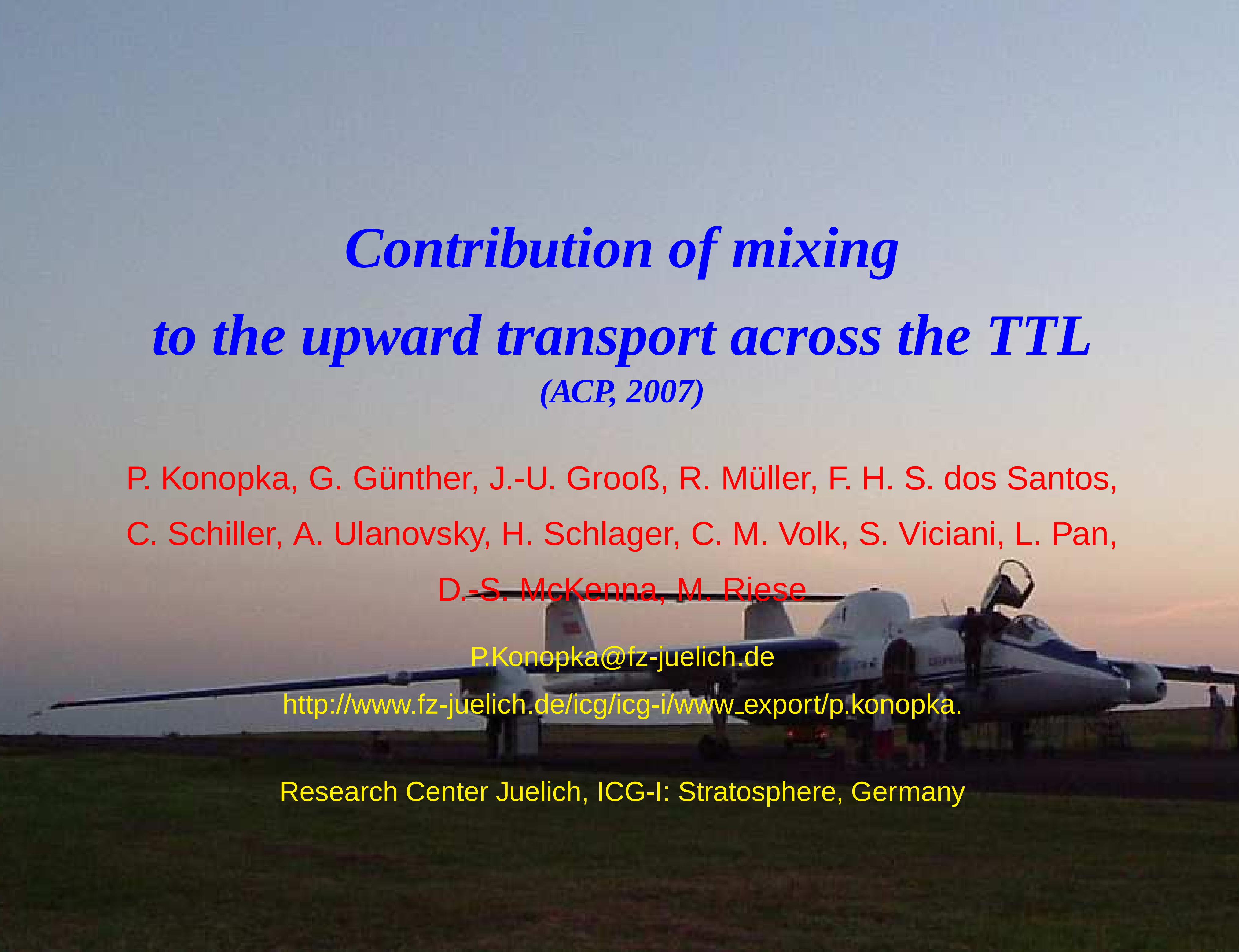


Contribution of mixing to the upward transport across the TTL

(ACP, 2007)

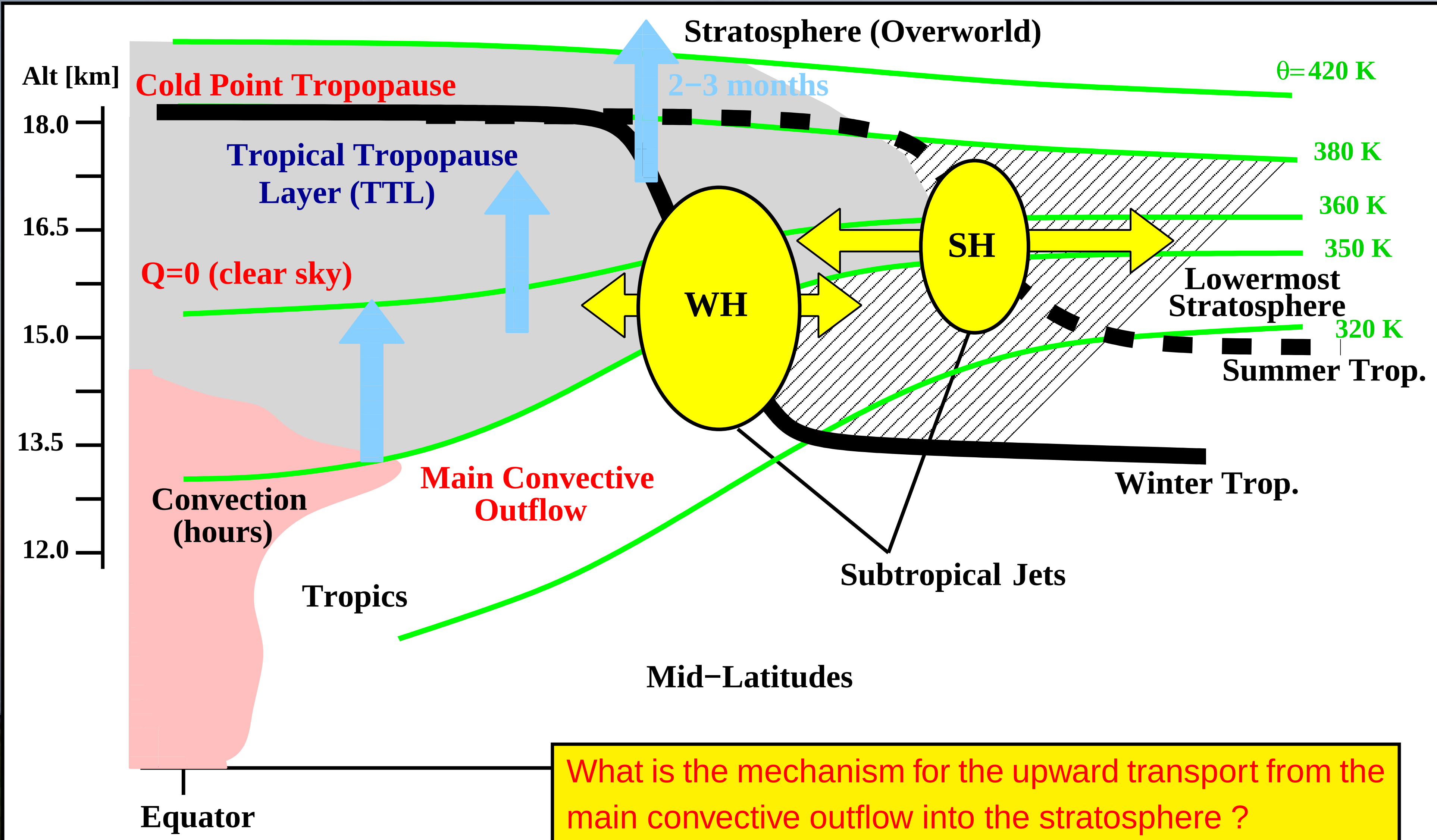
P. Konopka, G. Günther, J.-U. Grooß, R. Müller, F. H. S. dos Santos,
C. Schiller, A. Ulanovsky, H. Schlager, C. M. Volk, S. Viciani, L. Pan,
D.-S. McKenna, M. Riese

P.Konopka@fz-juelich.de

http://www.fz-juelich.de/icg/icg-i/www_export/p.konopka.

Research Center Juelich, ICG-I: Stratosphere, Germany

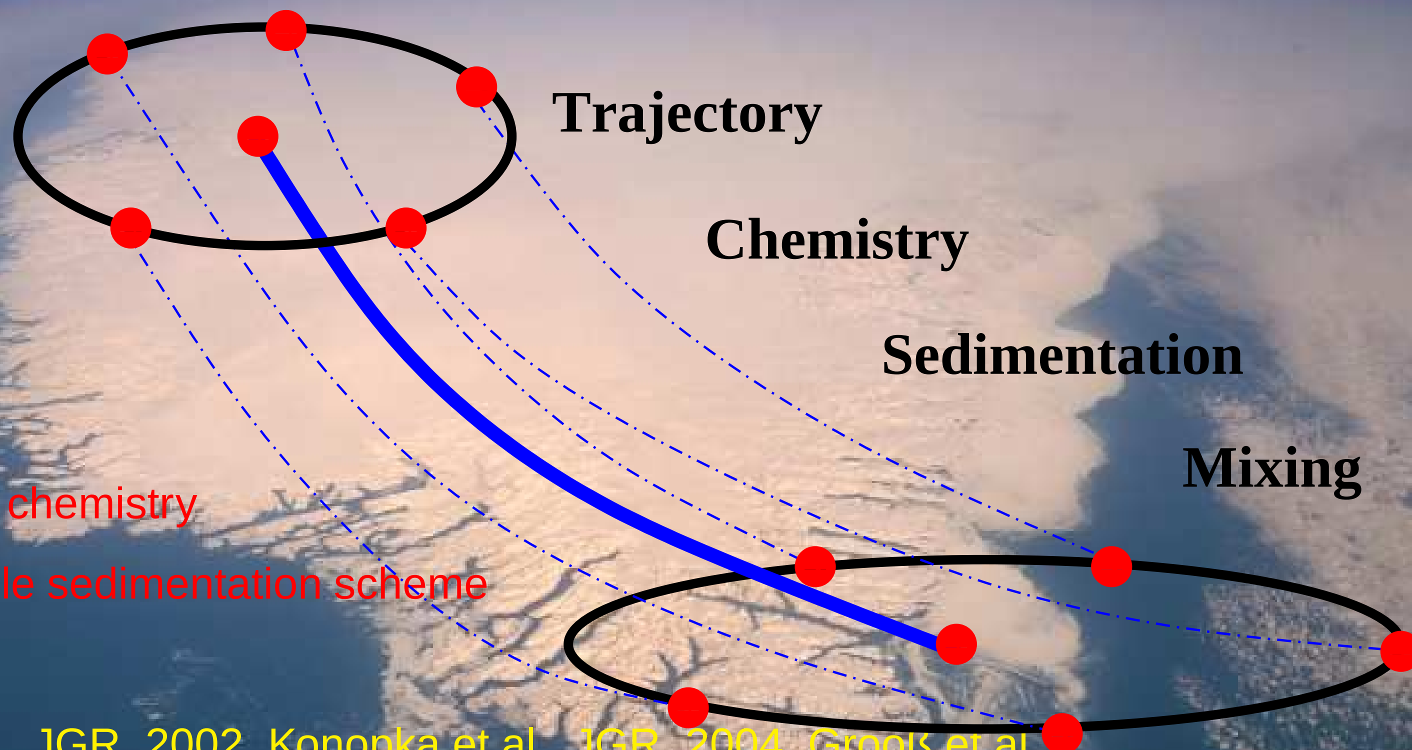
Upward transport across the TTL



What is the mechanism for the upward transport from the main convective outflow into the stratosphere ?

CLaMS-Model

- CLaMS - Lagrangian Chemistry Transport Model
- Potential temperature as vertical coordinate in the stratosphere
- Horizontal and vertical velocities from meteor. winds (ECMWF) and/or a radiation scheme
- Lagrangian mixing



- Full stratospheric chemistry
- Lagrangian particle sedimentation scheme
- parallelized code

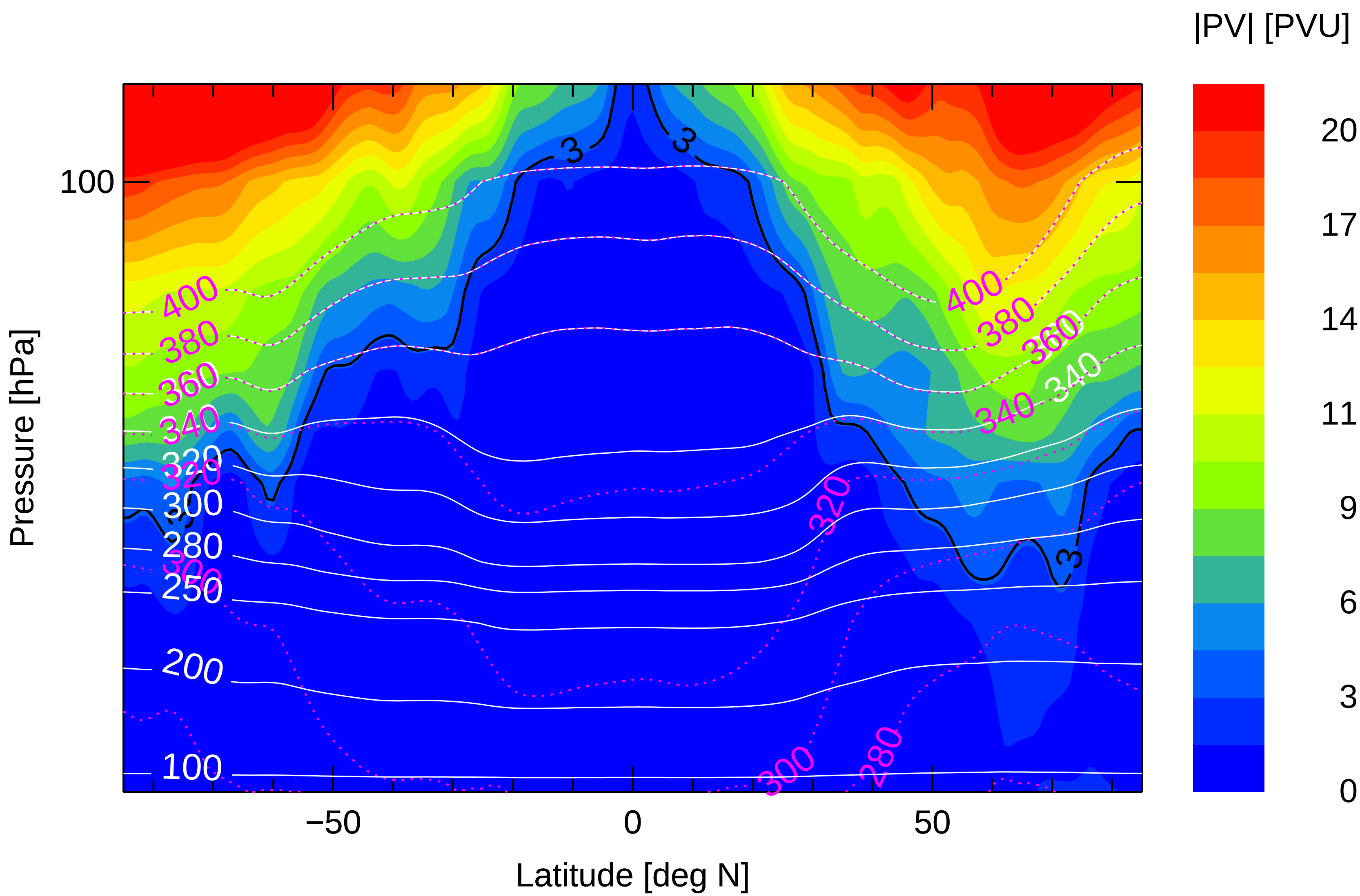
McKenna et al., JGR, 2002, Konopka et al., JGR, 2004, Grooß et al., 2005, ACP

- Extension for the troposphere - hybride coordinates

Greenland from space shuttle (NASA)

CLaMS with stratosphere and troposphere

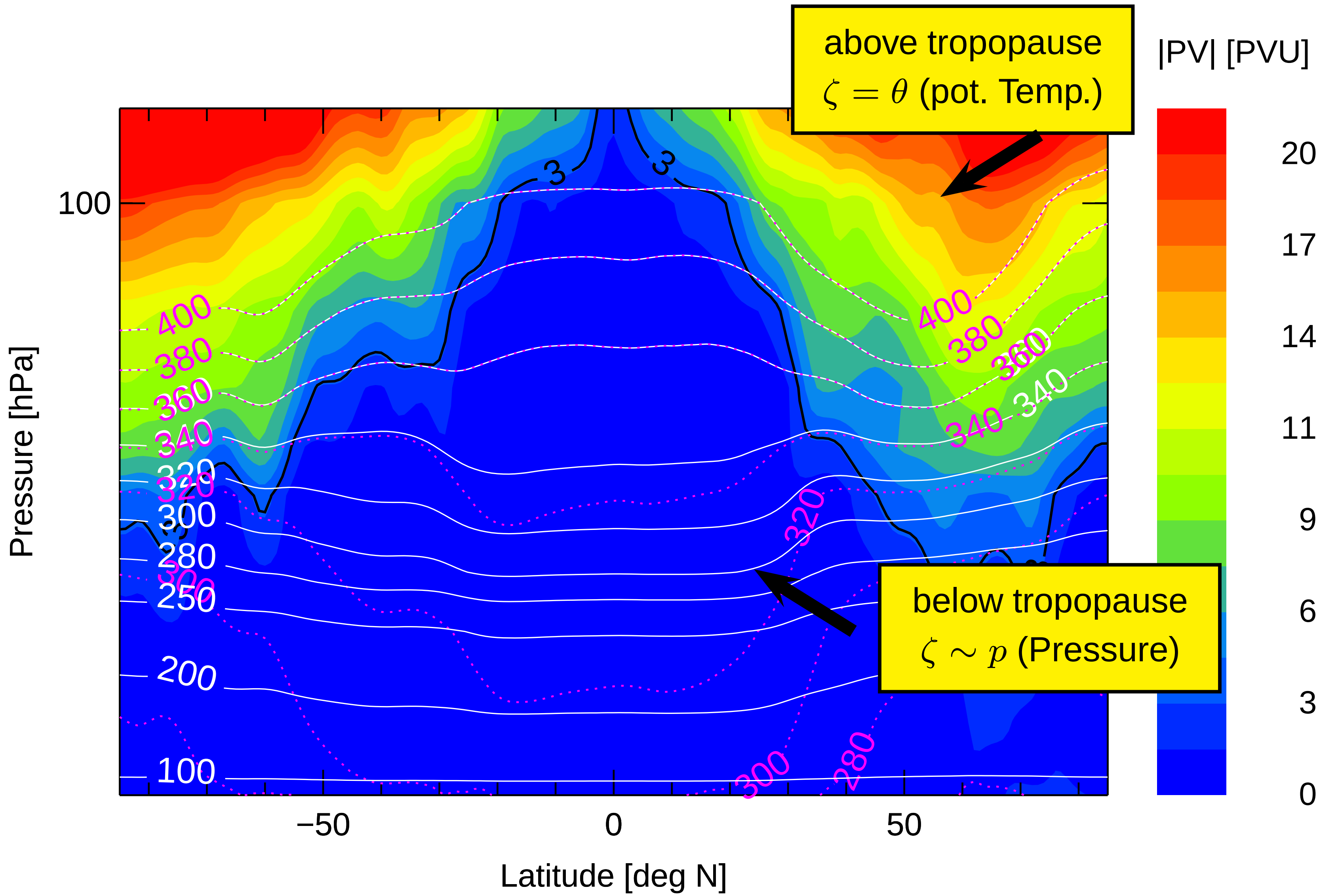
Convection AND radiative forcing ⇒ Hybride ζ-coordinates, Mahowald et al., JGR, 2002



Vertical cross section of PV (ECMWF)

CLaMS with stratosphere and troposphere

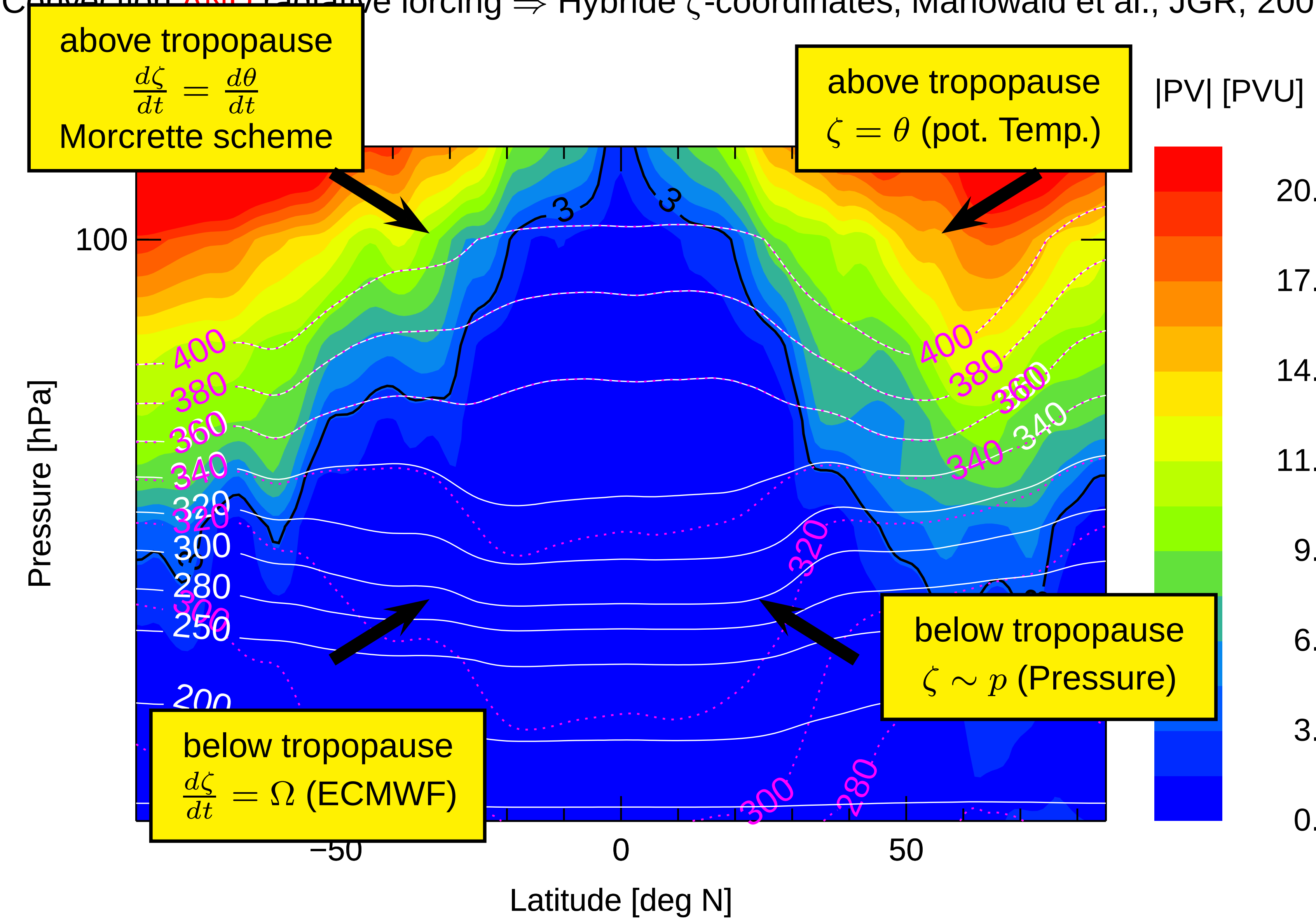
Convection AND radiative forcing $\Rightarrow$ Hybride ζ-coordinates, Mahowald et al., JGR, 2002



Vertical cross section of PV (ECMWF)

CLaMS with stratosphere and troposphere

Convection AND radiative forcing $\Rightarrow$ Hybride ζ-coordinates, Mahowald et al., JGR, 2002



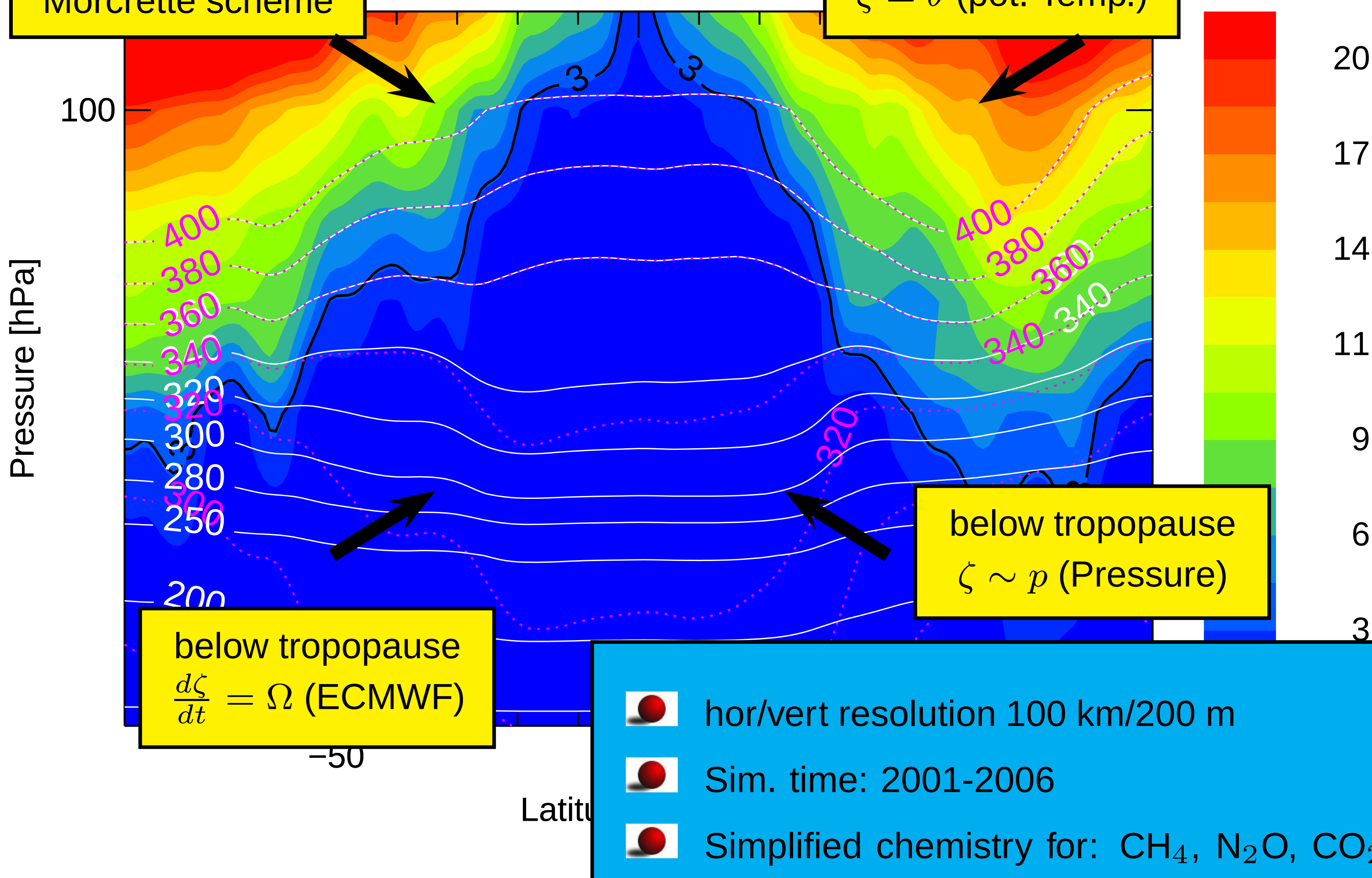
Vertical cross section of PV (ECMWF)

CLaMS with stratosphere and troposphere

Convection AND radiative forcing $\Rightarrow$ Hybride ζ-coordinates, Mahowald et al., JGR, 2002

above tropopause
$\frac{d\zeta}{dt} = \frac{d\theta}{dt}$
Morcrette scheme

above tropopause
$\zeta = \theta$ (pot. Temp.)

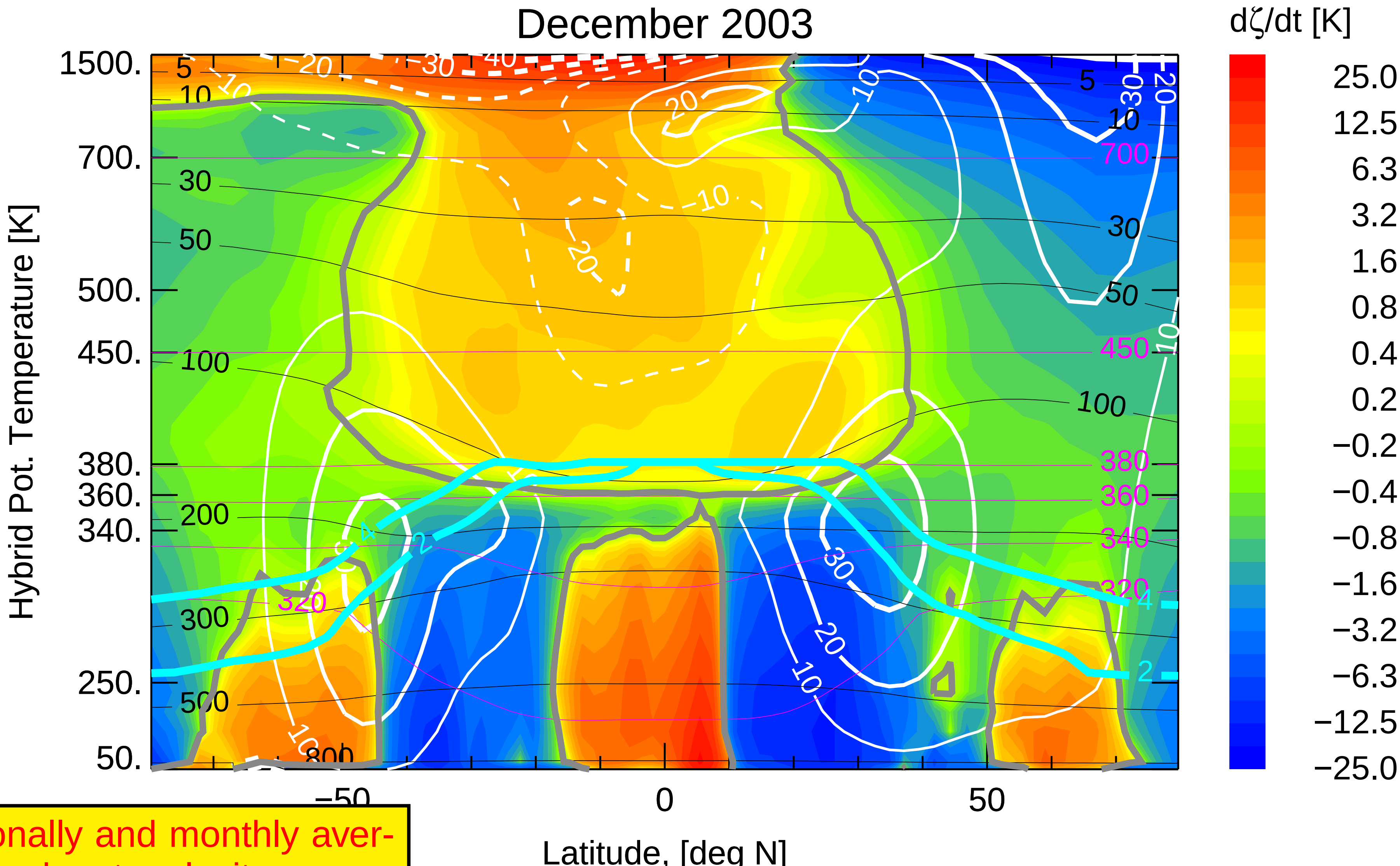


below tropopause
$\zeta \sim p$ (Pressure)

below tropopause
$\frac{d\zeta}{dt} = \Omega$ (ECMWF)

- hor/vert resolution 100 km/200 m
- Sim. time: 2001-2006
- Simplified chemistry for: CH_4, N_2O, CO_2, CO, O_3 (passive), In addition: H_2O, Ice, Age of air

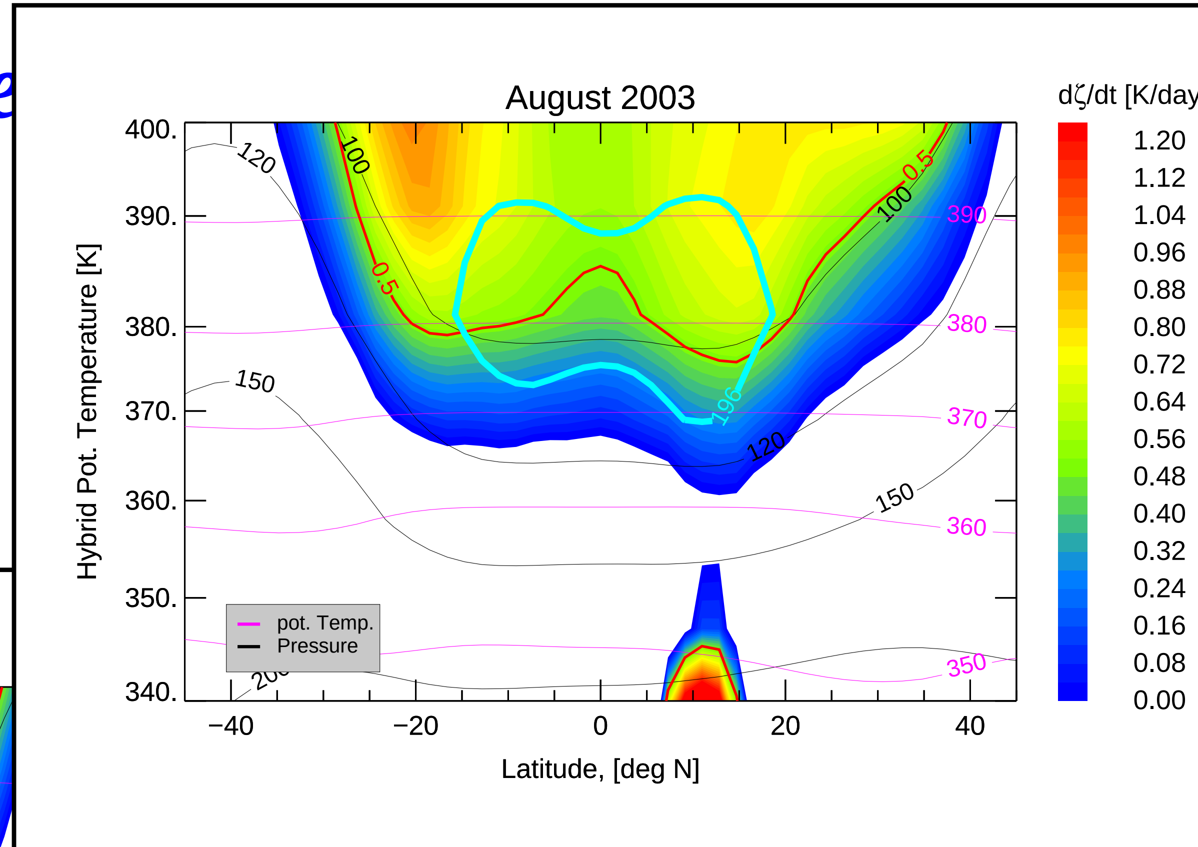
Vertical velocities in the TTL

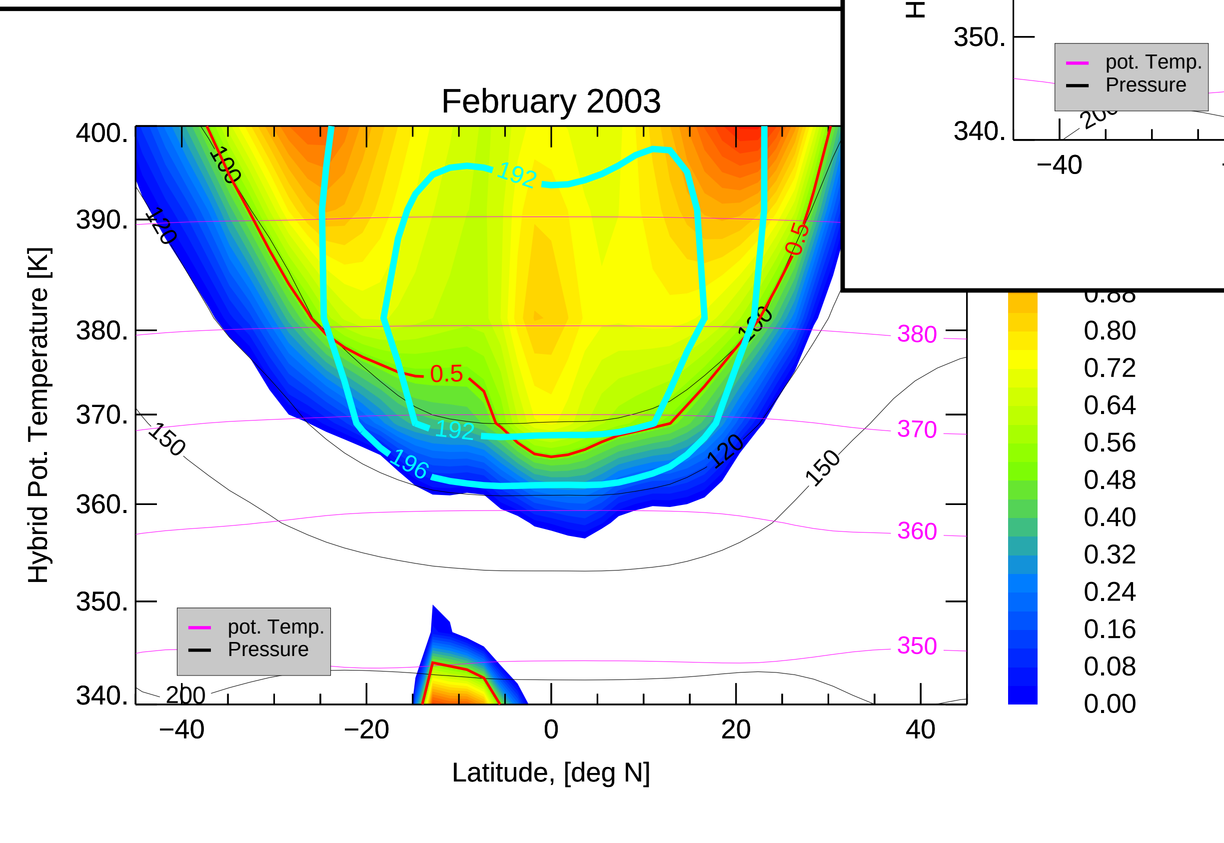


zonally and monthly averaged vert. velocity, Konopka et al., ACP, 2007

Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

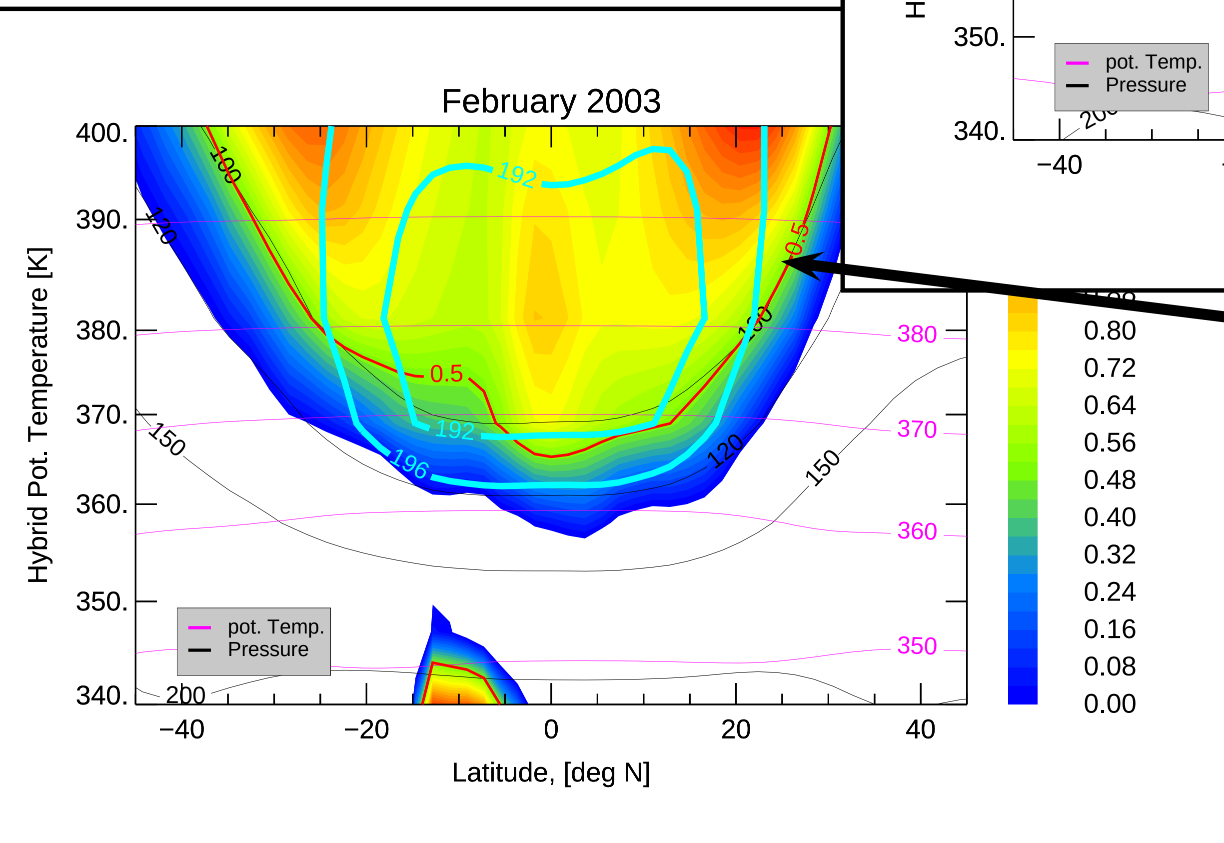
Vertical ve

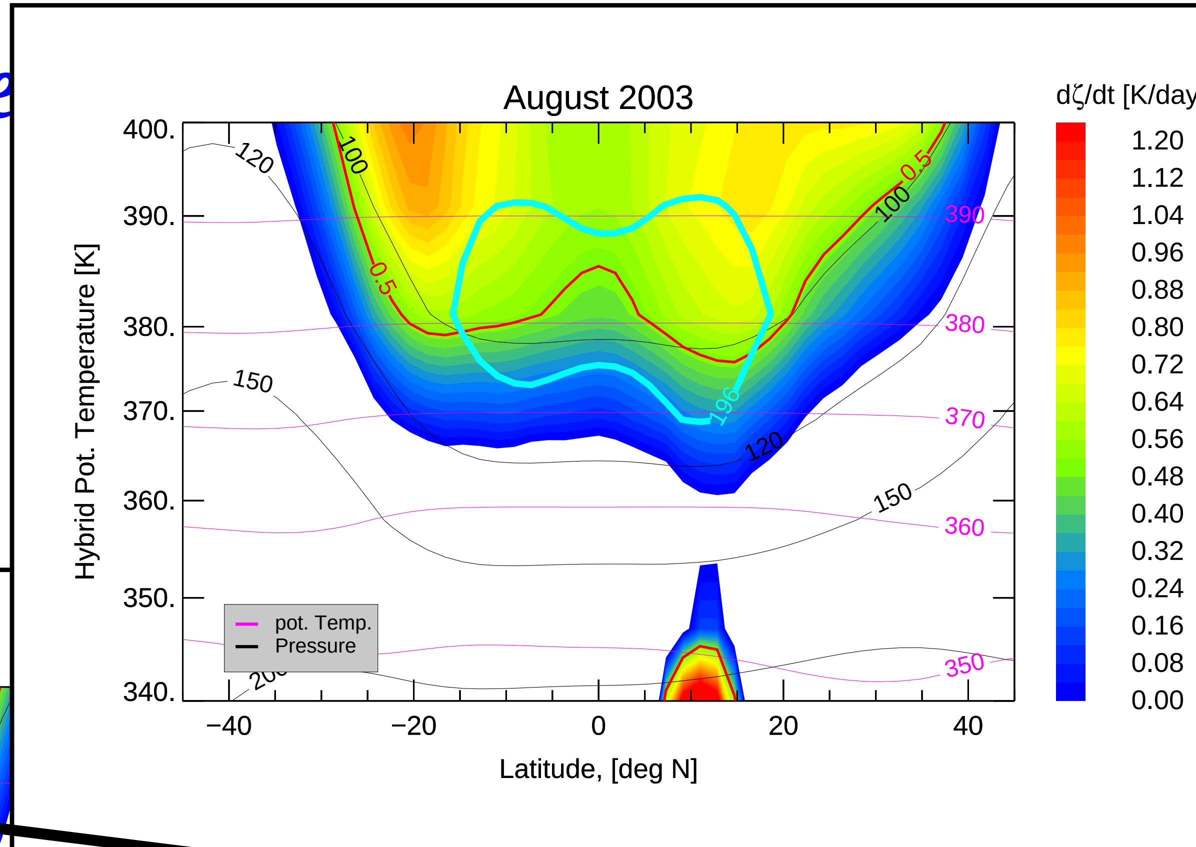




Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

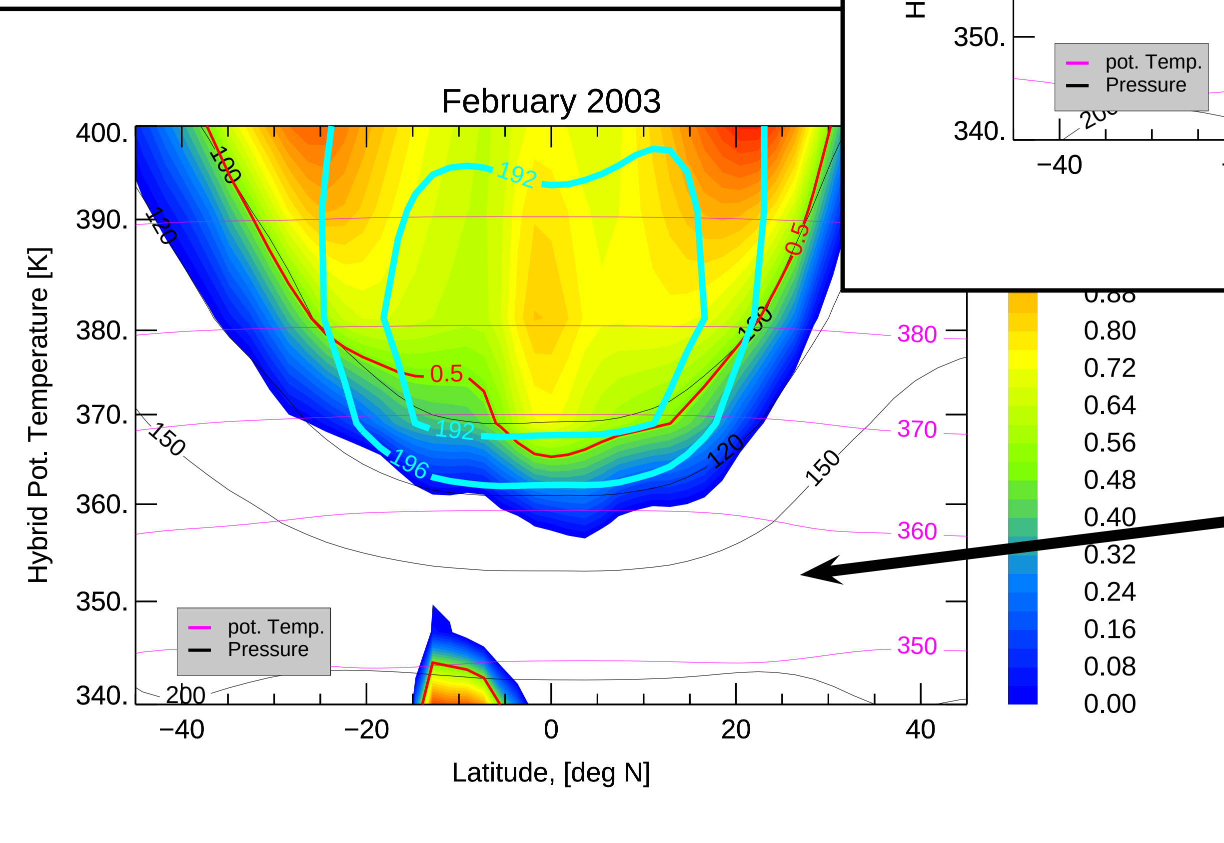
Vertical ve

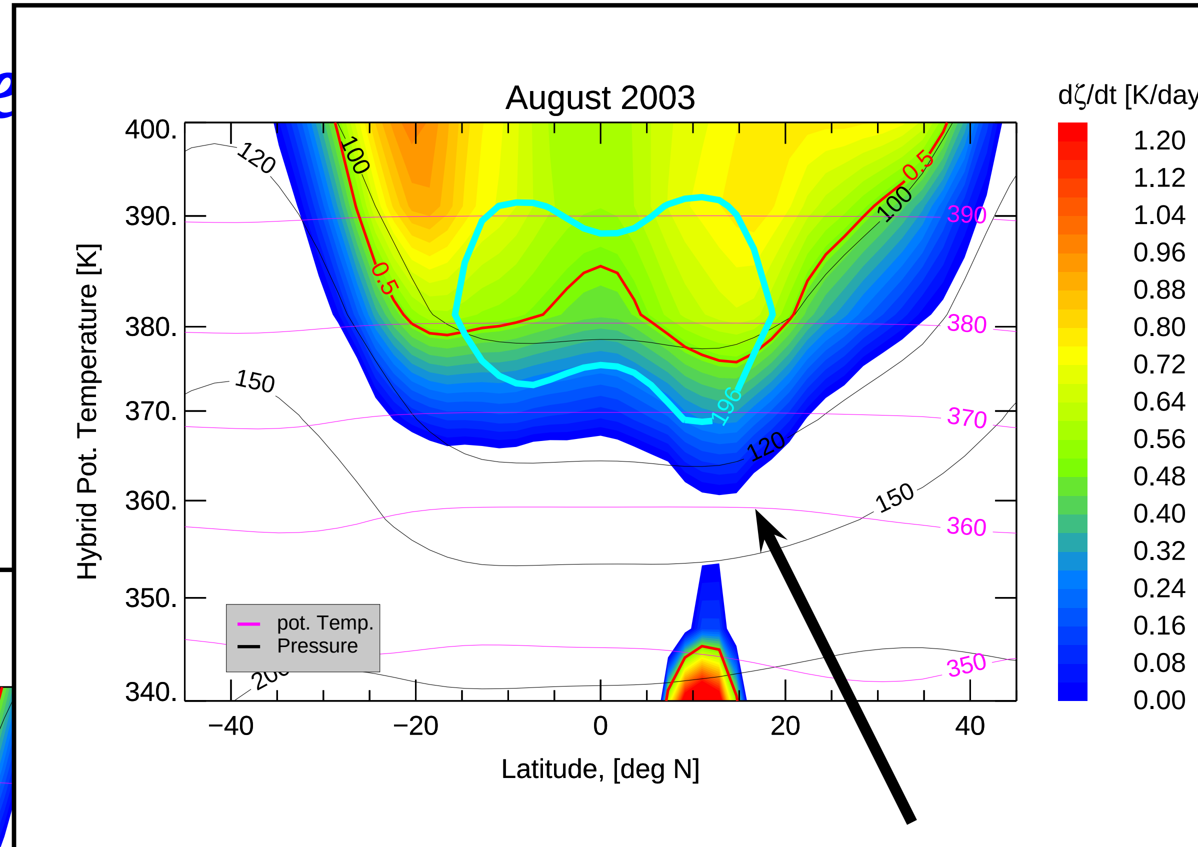




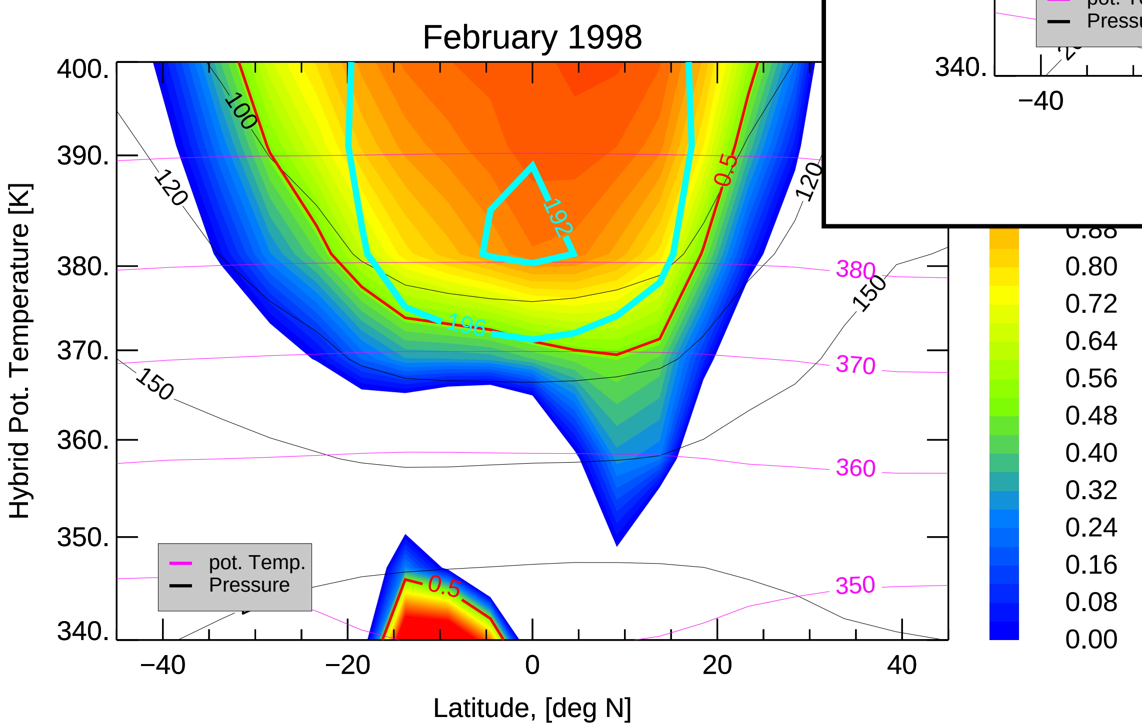
low temperatures, $\dot{\theta} > 0$
$\Rightarrow$ upwelling
“downward control”
(Haynes et al., JAS, 1991)

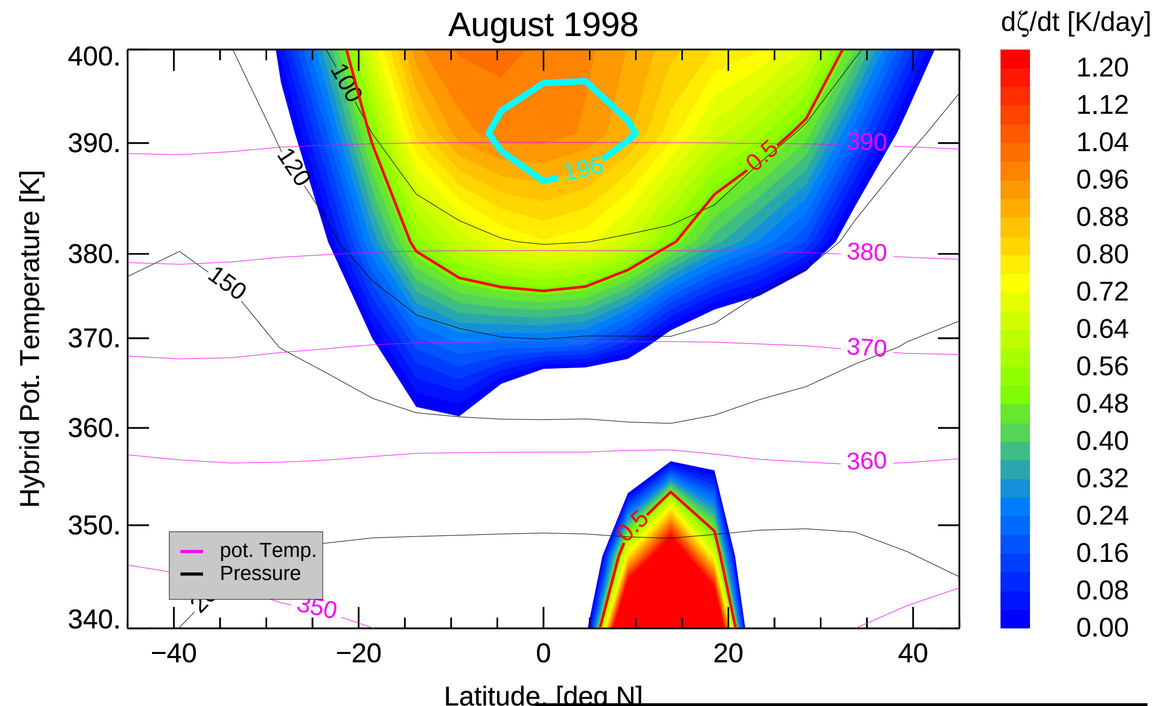
Vertical ve



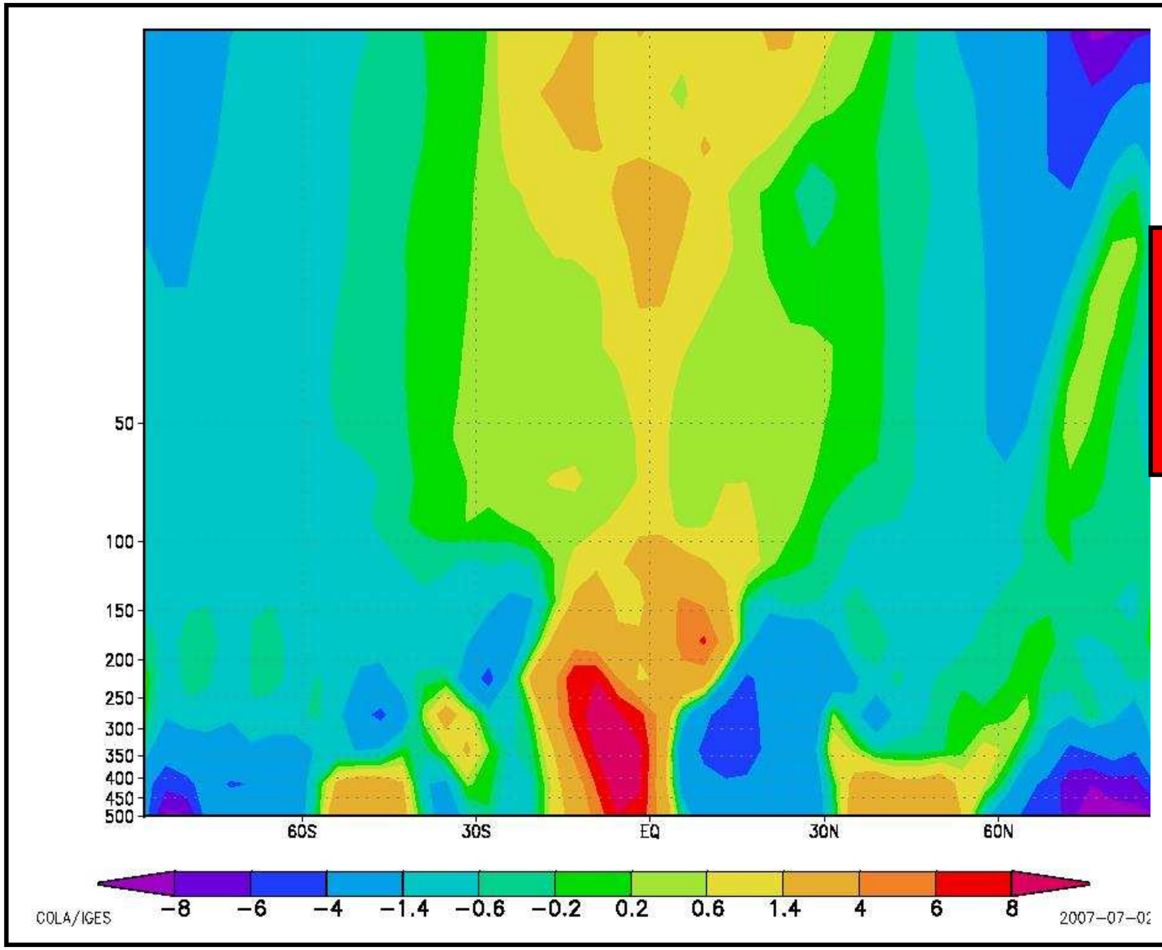


...but still a large gap between the main convective outflow and the stratosphere !

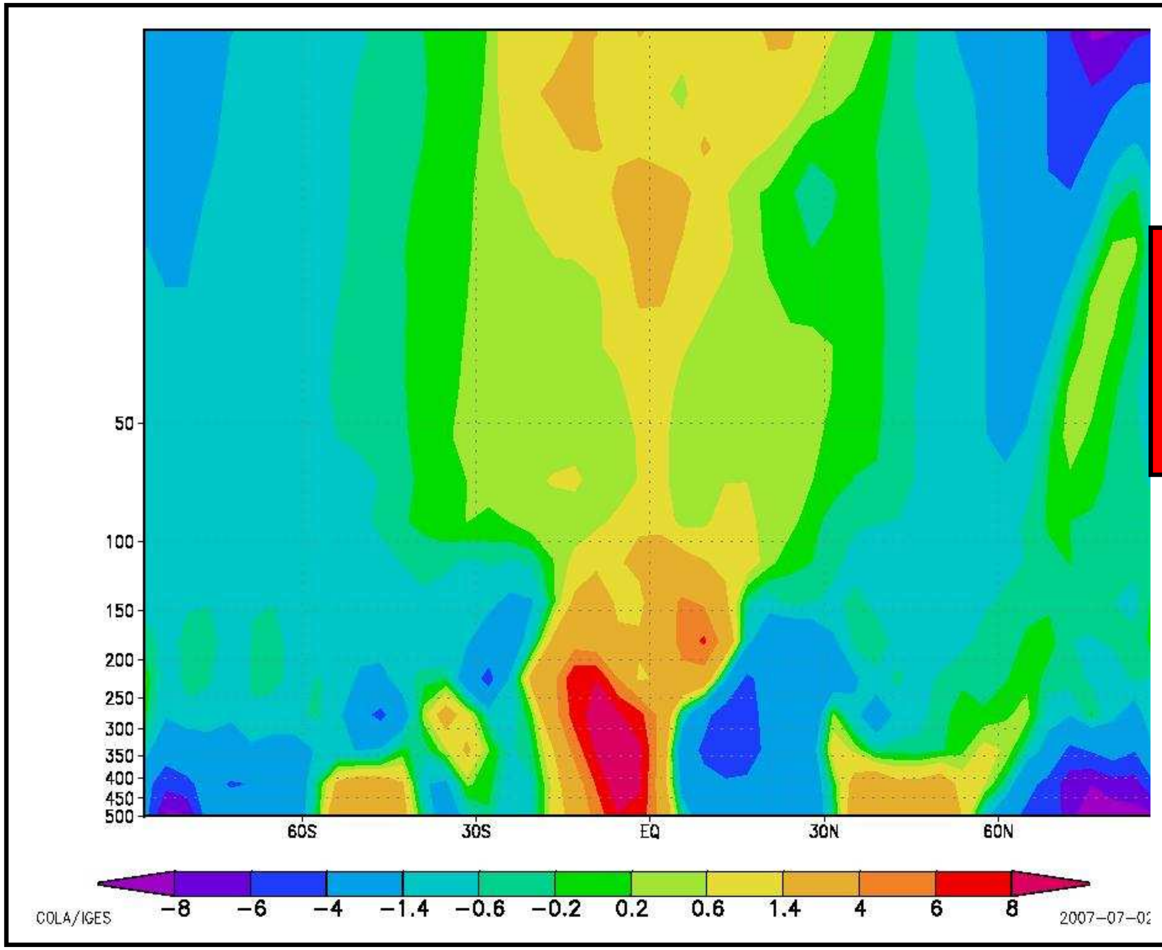




A similar picture derived from MAECHAM4-CHEM experiment (radiation with clouds !, courtesy of H.-J. Punge and M Giorgetta)



But, there is no gap by using $\Omega = \dot{p}$! (derived from the continuity equation, courtesy of H.-J. Punge and M Giorgetta)



But, there is no gap by using $\Omega = \dot{p}$! (derived from the continuity equation, courtesy of H.-J. Punge and M Giorgetta)

Vertical velocities derived from $\dot{\theta}$:
SLIMCAT, CLaMS,
Trajectory calculations (Schoeberl et al., Rex et al.,...)

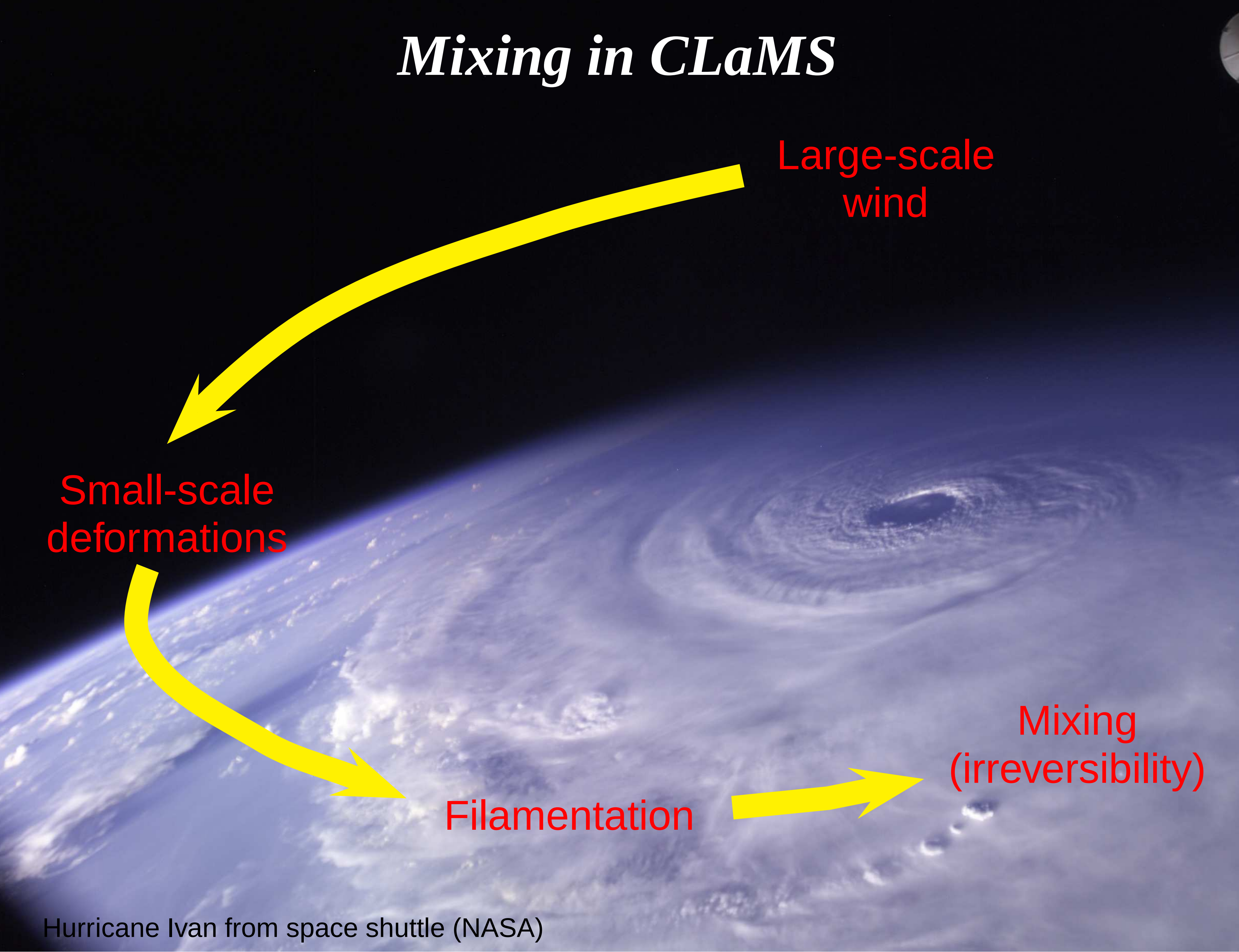
Vertical velocities derived from Ω:
ECHAM, REPROBUS...
Trajectory calculations (Fueglistaler et al., Wernli et al., Stohl et al.,...)

Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

Possible options to close this gap ?

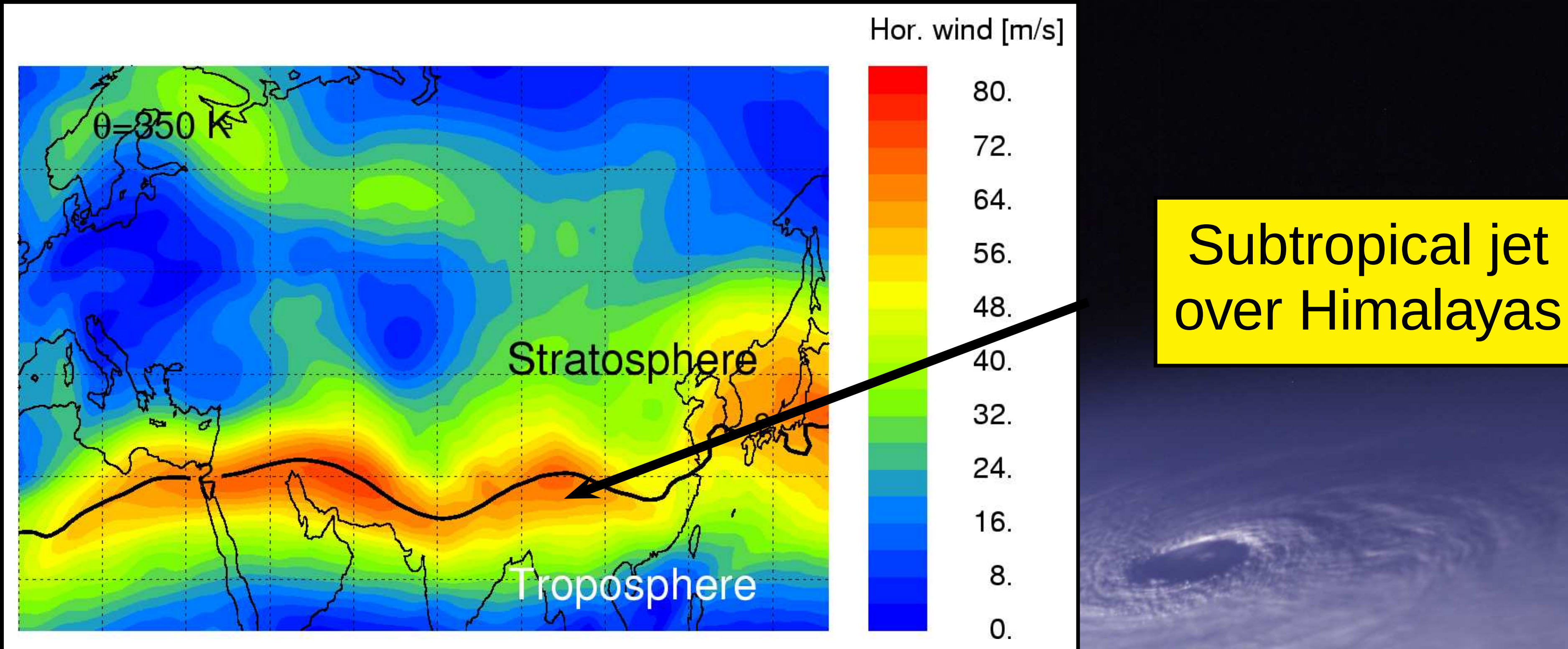
1. radiative lofting via cirrus clouds
   (Corti et al., ACP, 2006)
2. overshooting convection dominates transport across the TTL ?
   “It is found (TRMM) that 1.3% of tropical convection systems reach 14 km and 0.1% of them may even penetrate the 380 K potential temperature level.” (Liu et al., JGR, 2005)
3. CLaMS, deformation-induced mixing parameterizes the unresolved small-scale dynamics in the TTL (gravity-waves, etc..)

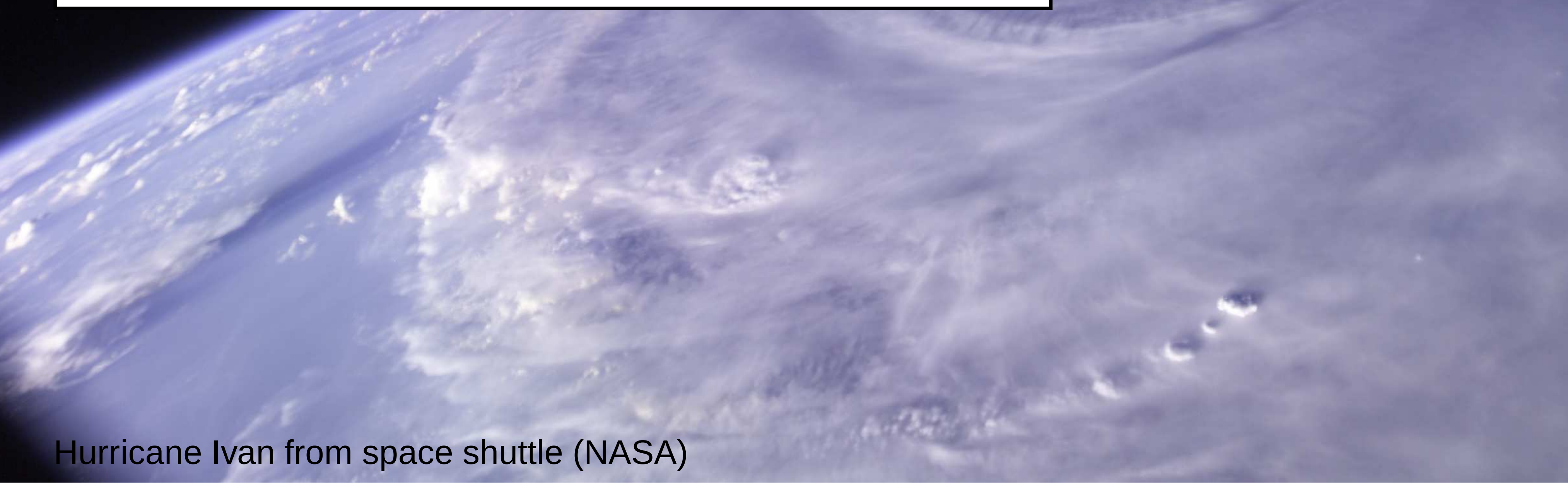
Mixing in CLaMS



Hurricane Ivan from space shuttle (NASA)

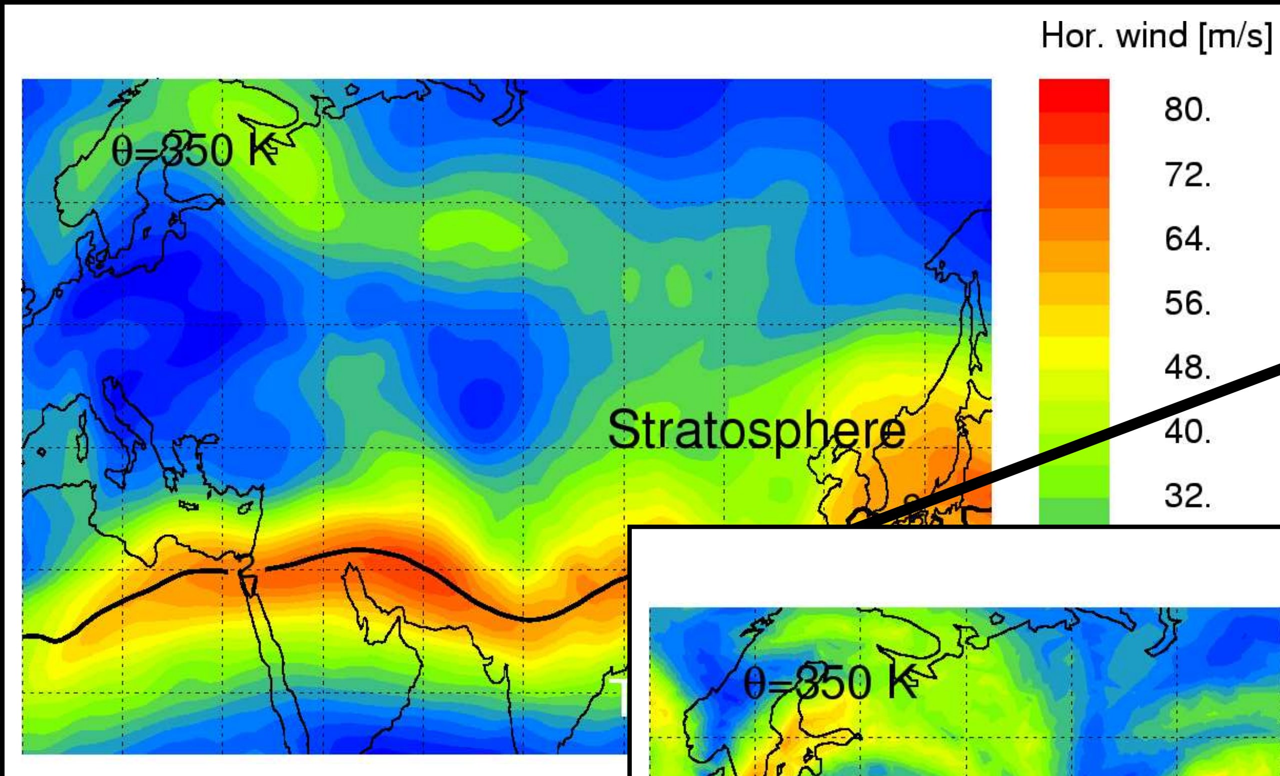
Mixing in the vicinity of the subtropical jet



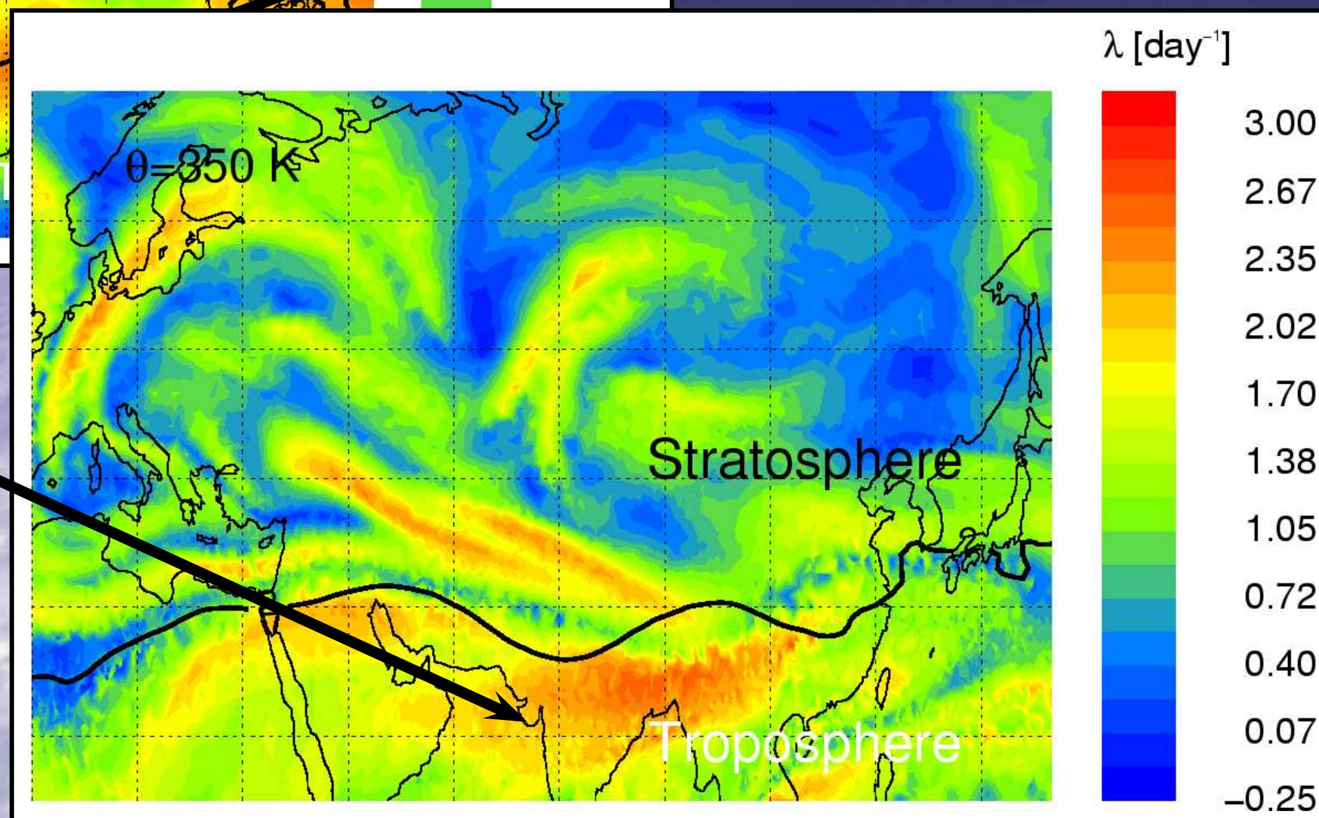


Hurricane Ivan from space shuttle (NASA)

Mixing in the vicinity of the subtropical jet



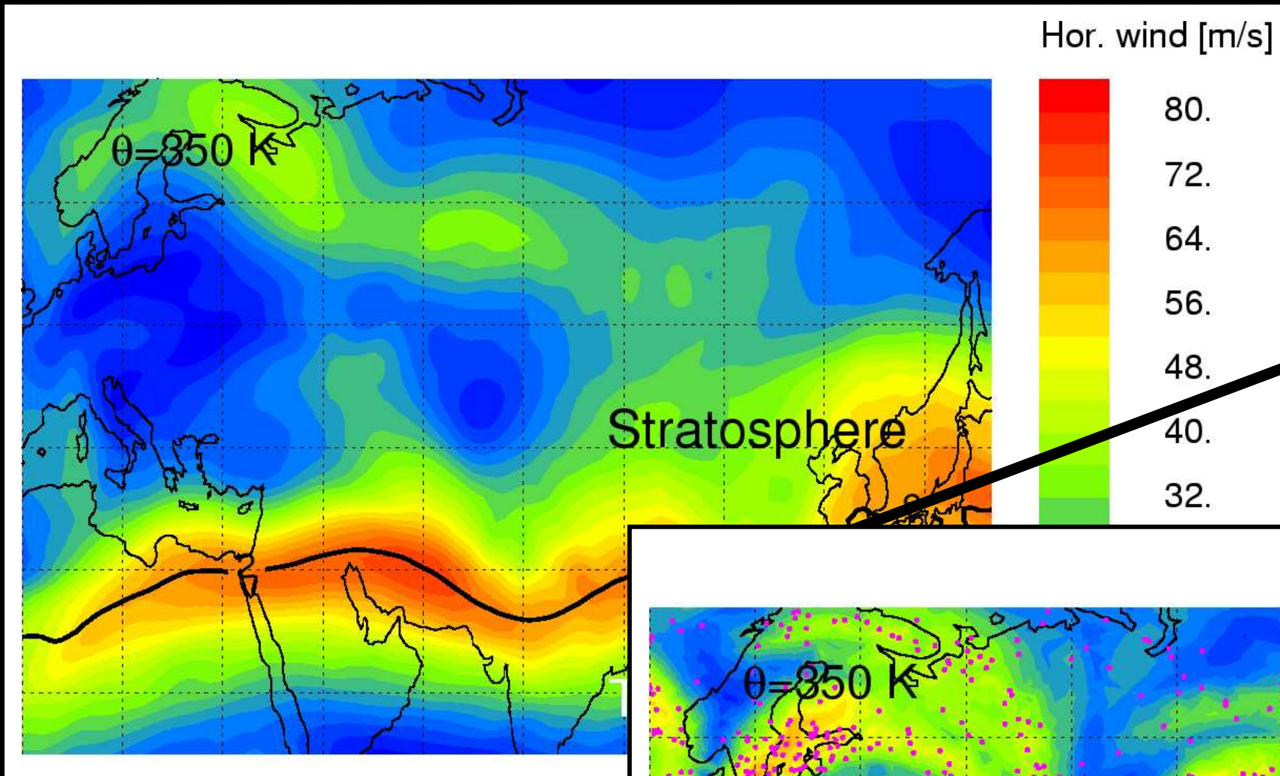
Subtropical jet over Himalayas



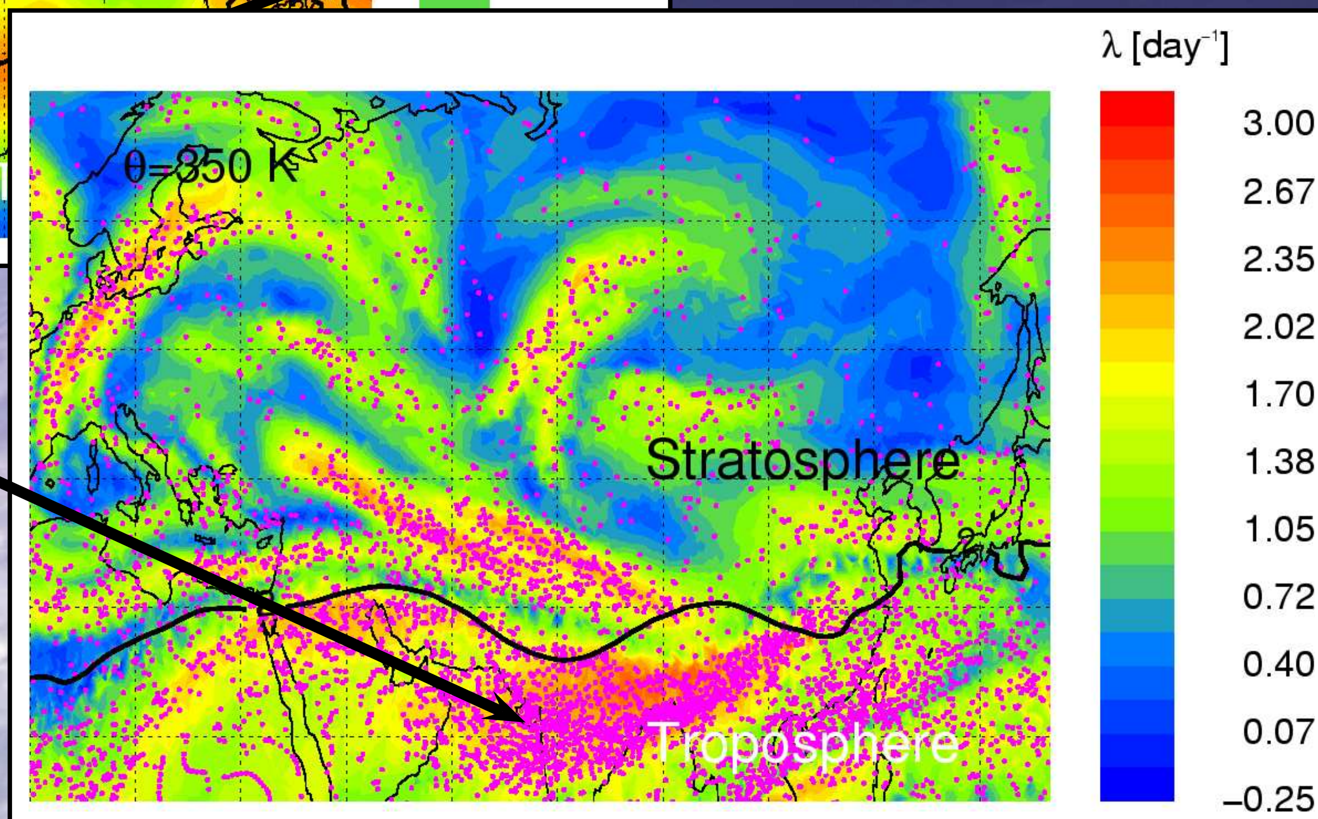
Strong deformations ...

Hurricane Ivan from space shuttle (NASA)

Mixing in the vicinity of the subtropical jet



Subtropical jet over Himalayas

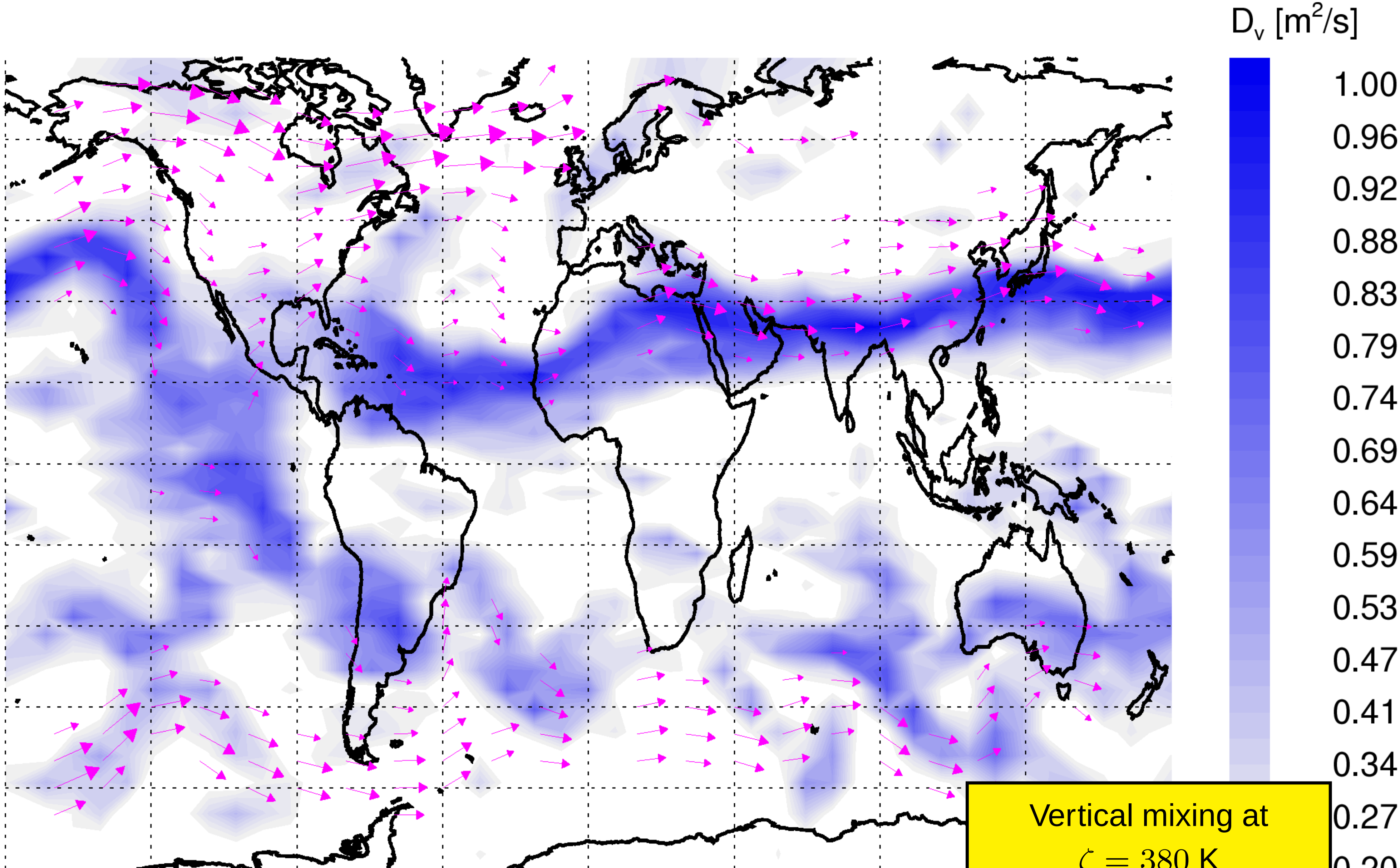


... and mixing !

Pan et al., 2006, JGR

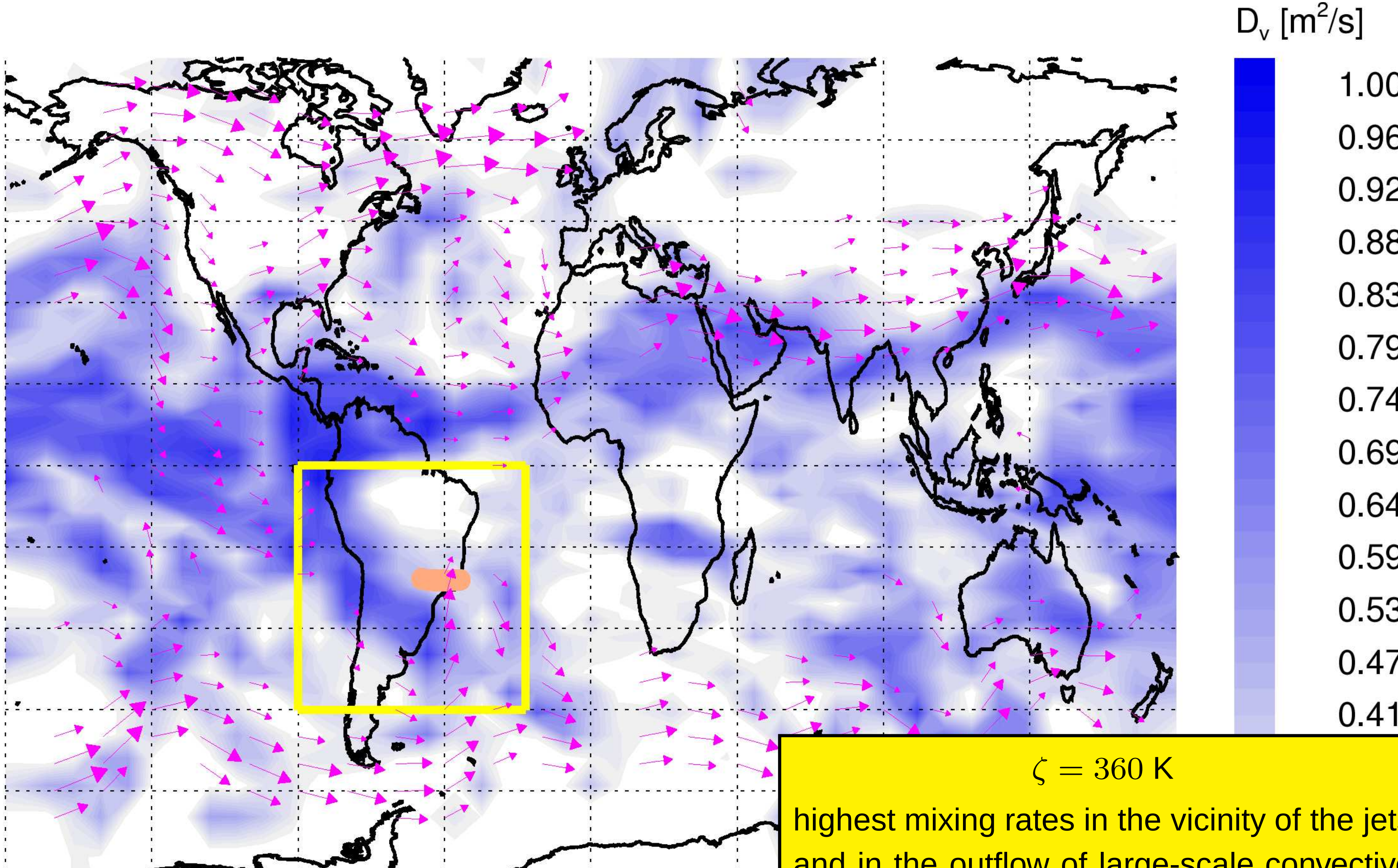
Hurricane Ivan from space shuttle (NASA)

Deformation-induced mixing



Vertical mixing at
$\zeta = 380$ K
08.02.2005

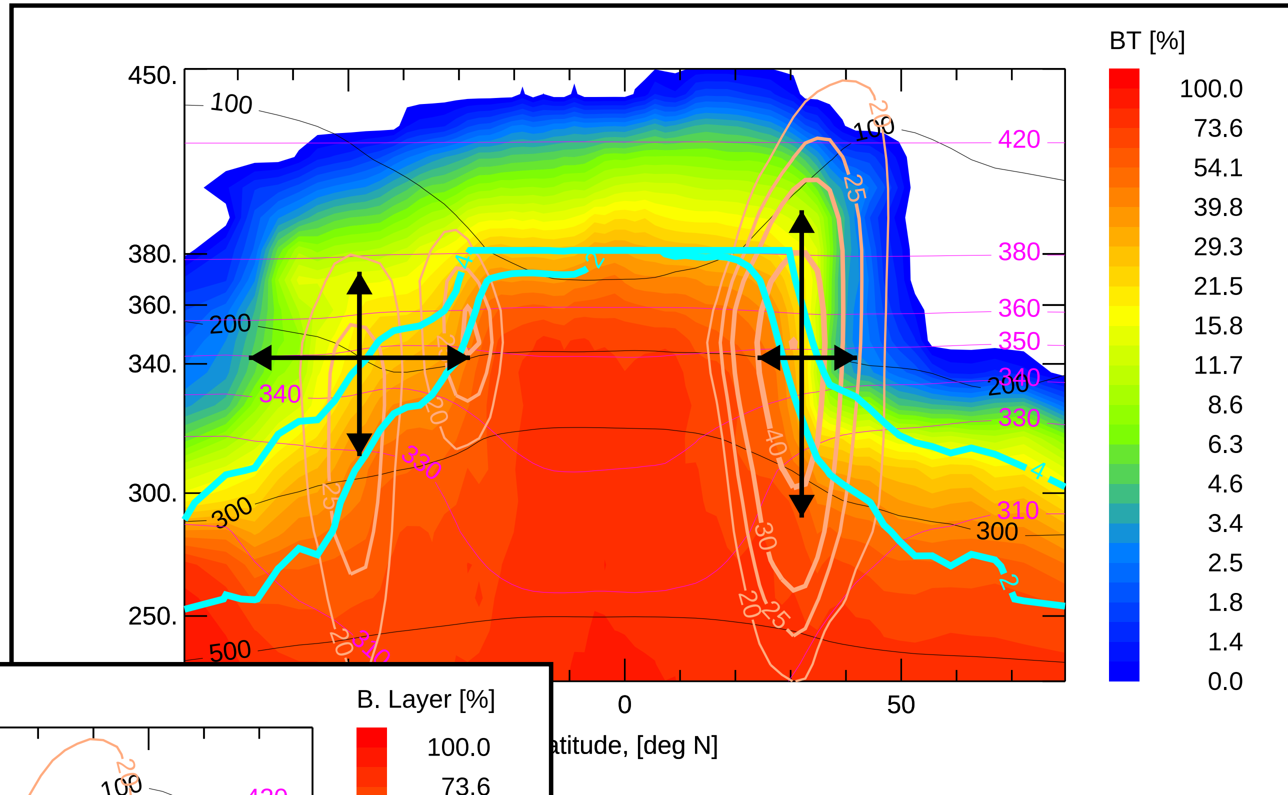
Deformation-induced mixing

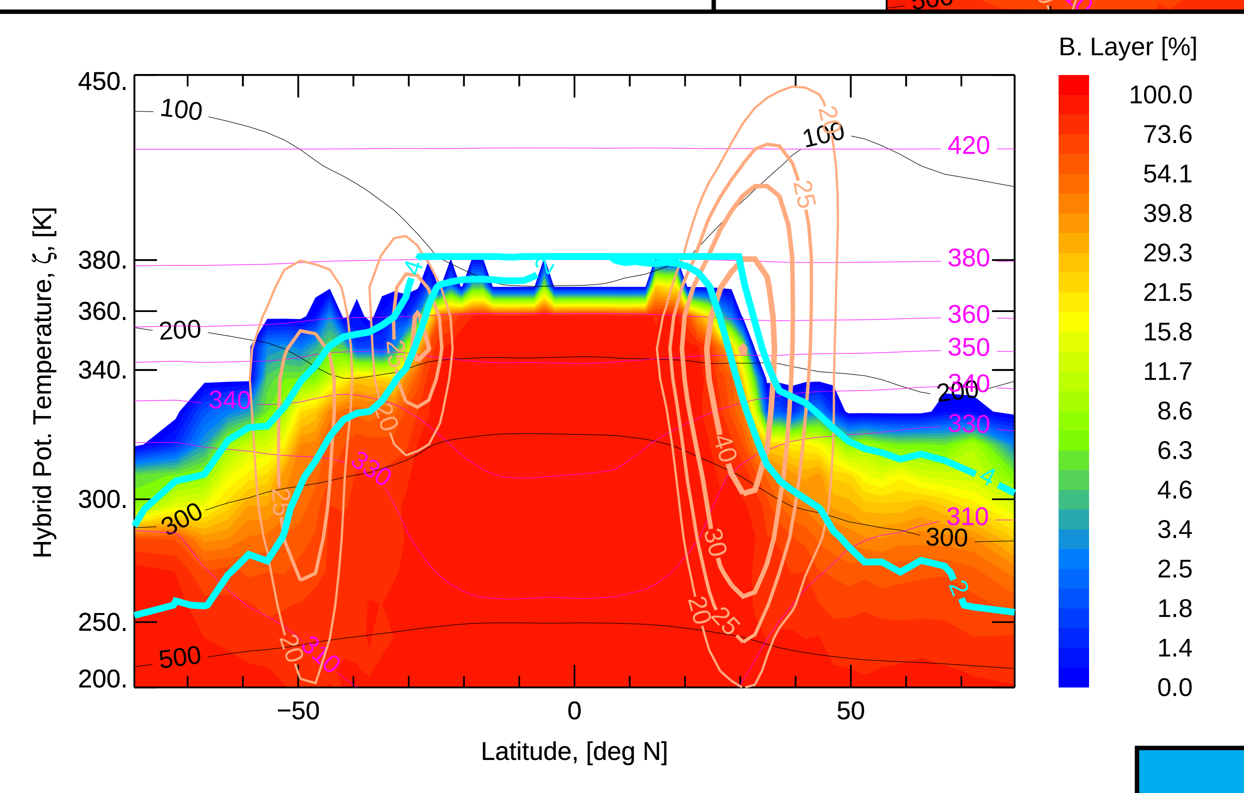


$\zeta = 360$ K

highest mixing rates in the vicinity of the jets and in the outflow of large-scale convective systems

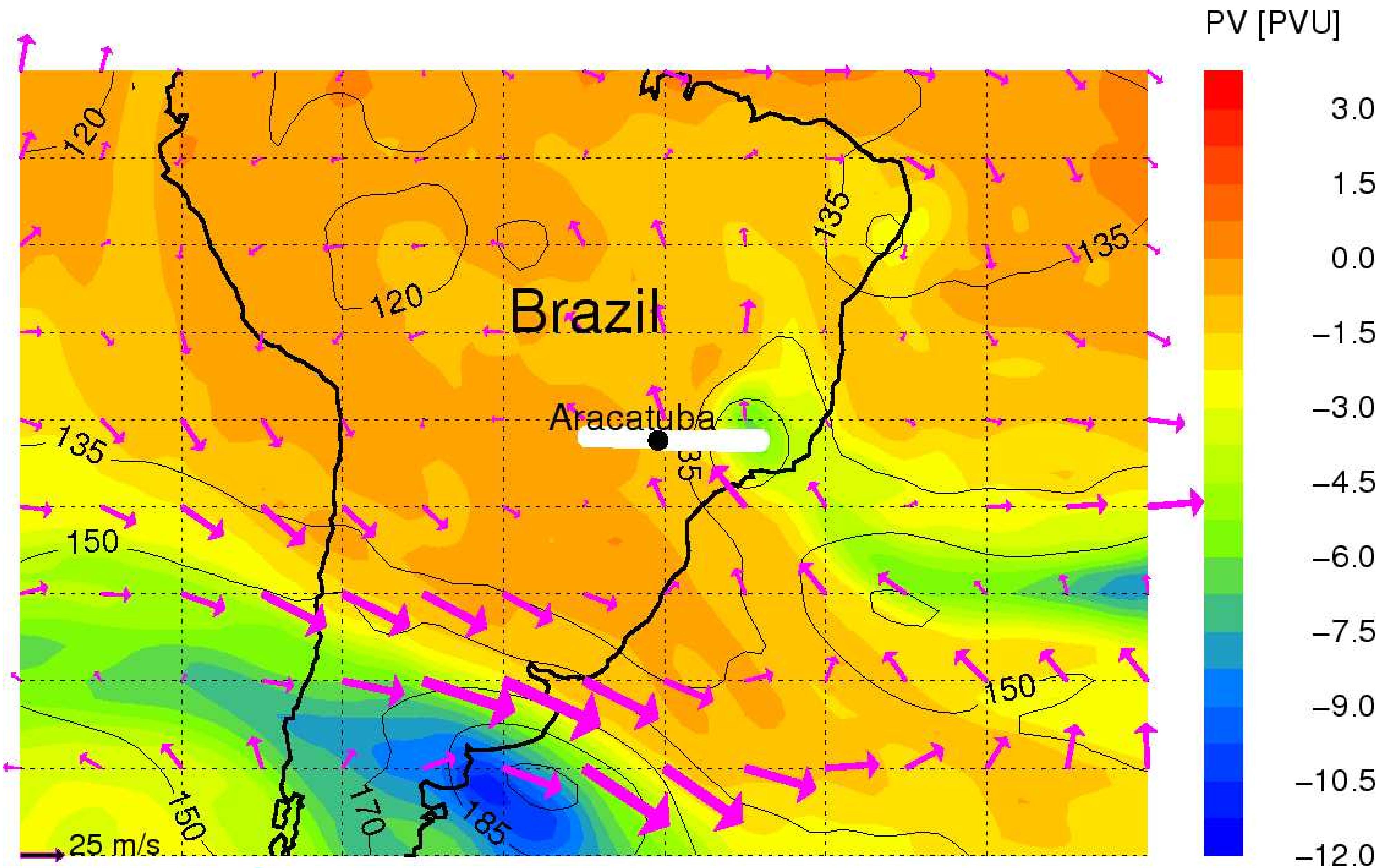
Zonally averaged signature of boundary layer tracer after ≈4 month of transport
Dec - Mar



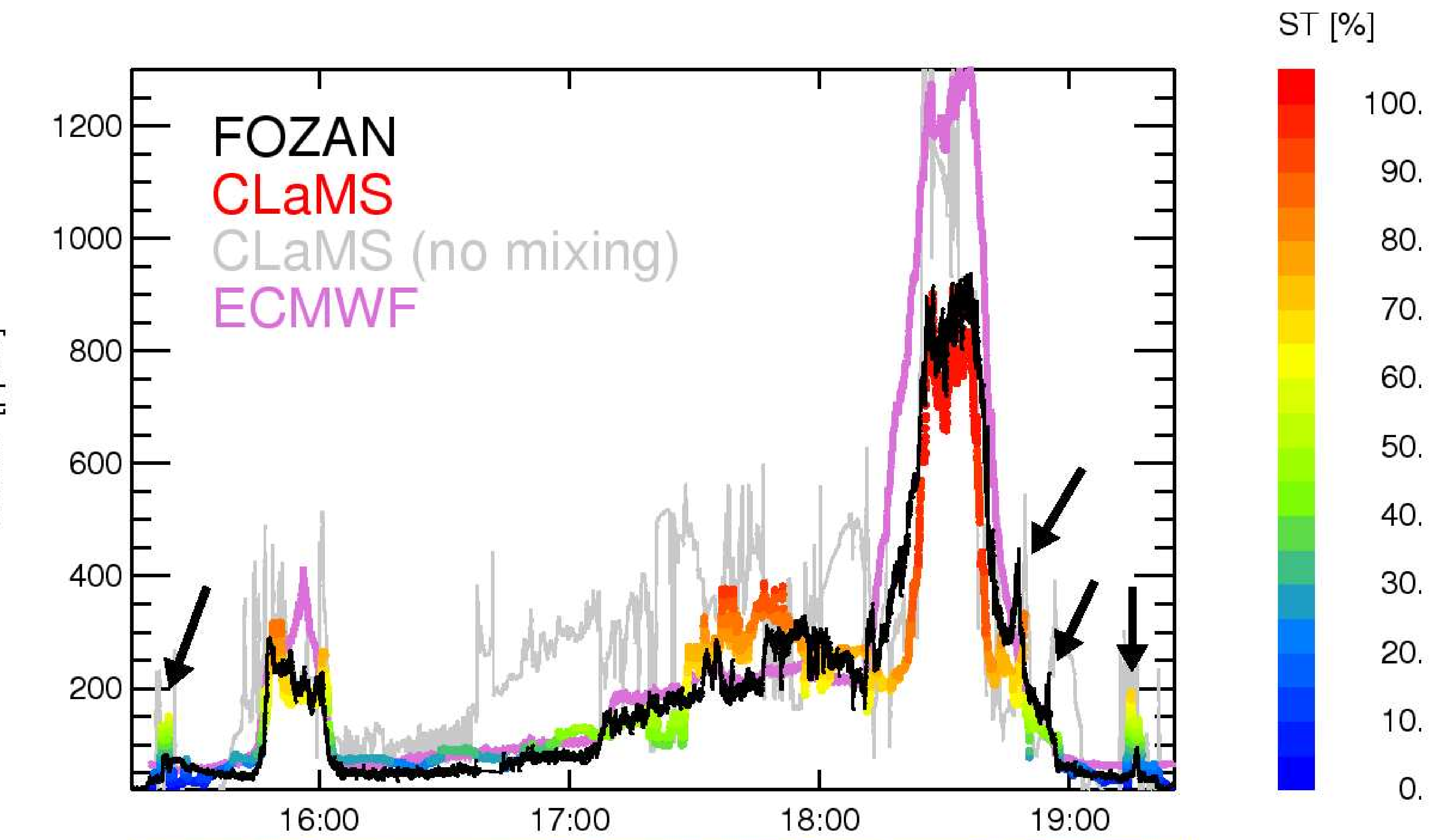


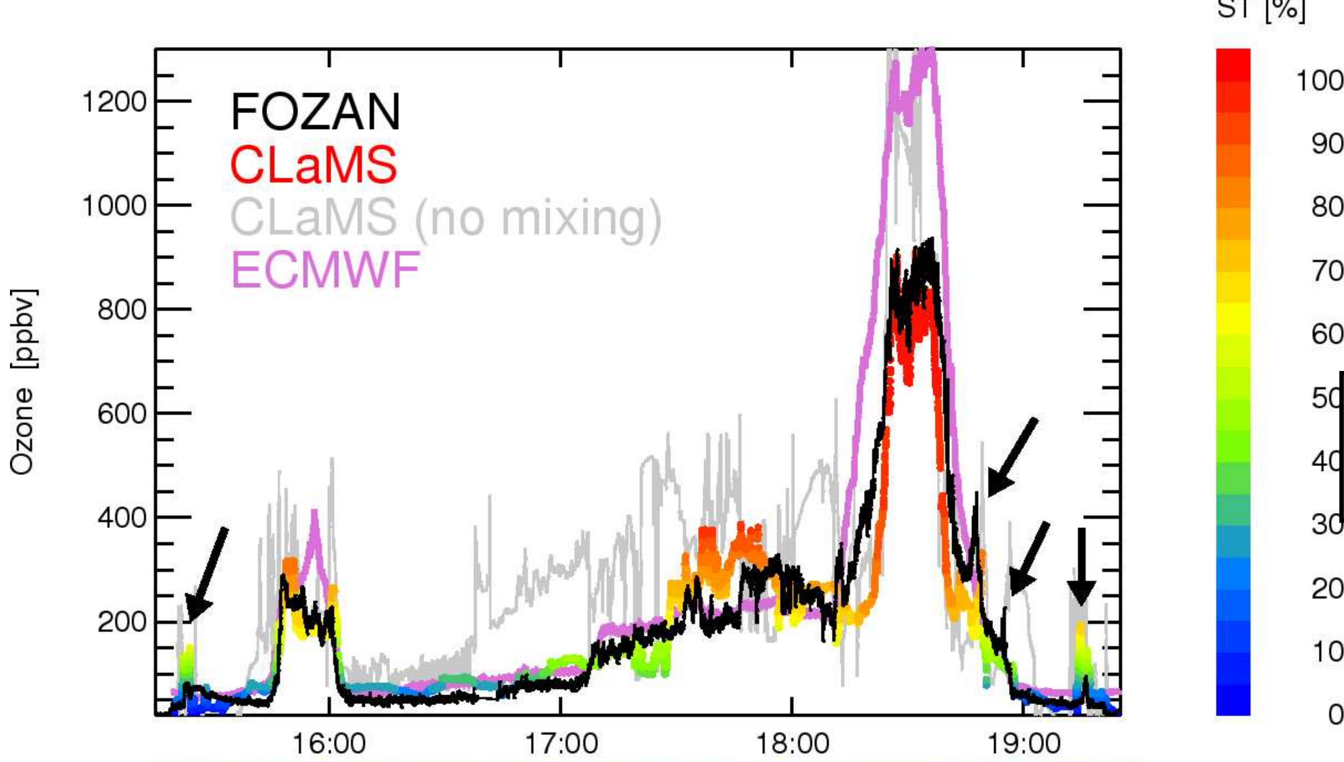
No mixing !!

A case study

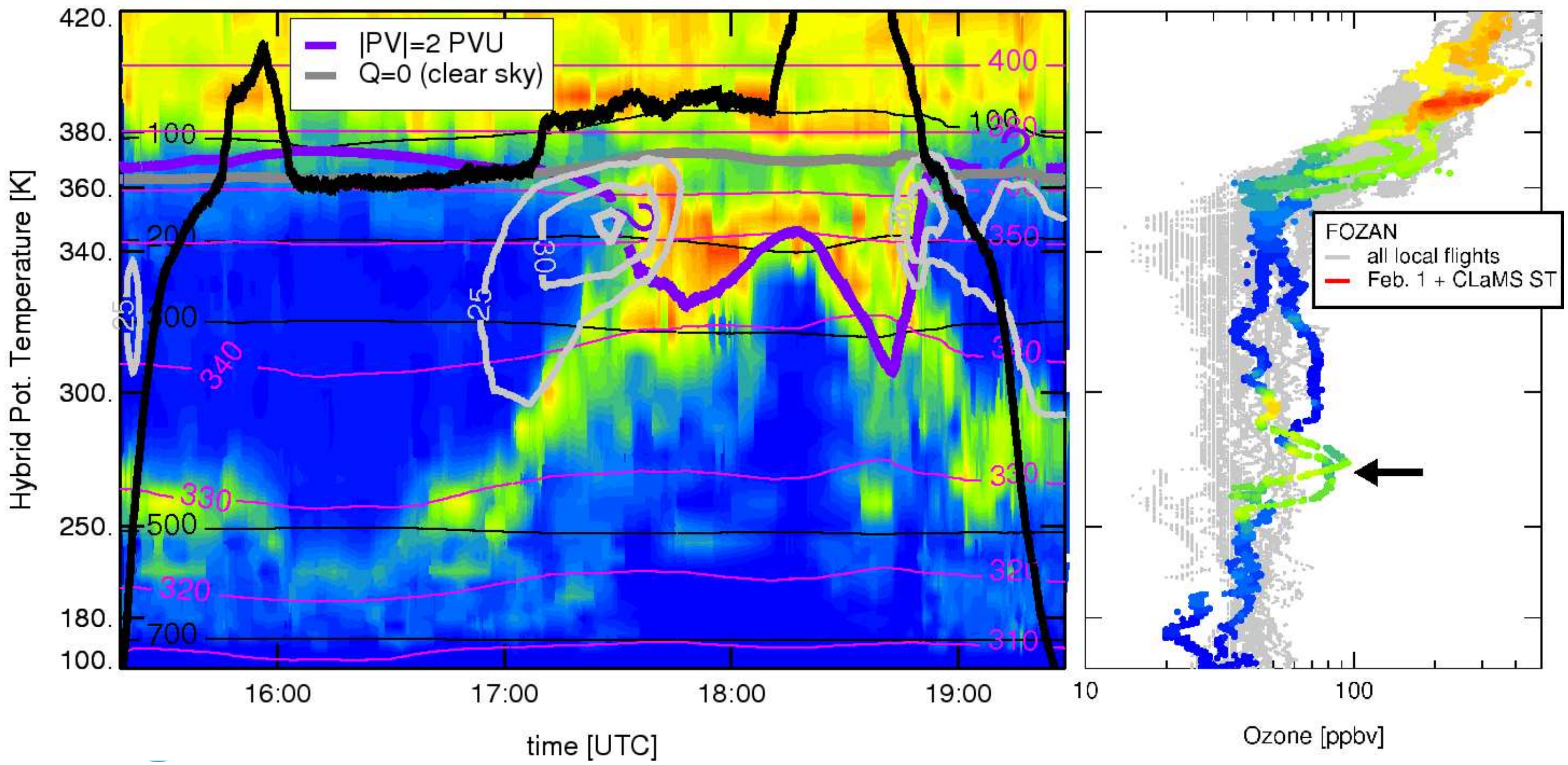

PV [PVU]
3.0
1.5
0.0
−1.5
−3.0
−4.5
−6.0
−7.5
−9.0
−10.5
−12.0
Brazil
Aracatuba
120
120
135
135
135
150
150
150
170
185
25 m/s

A case study

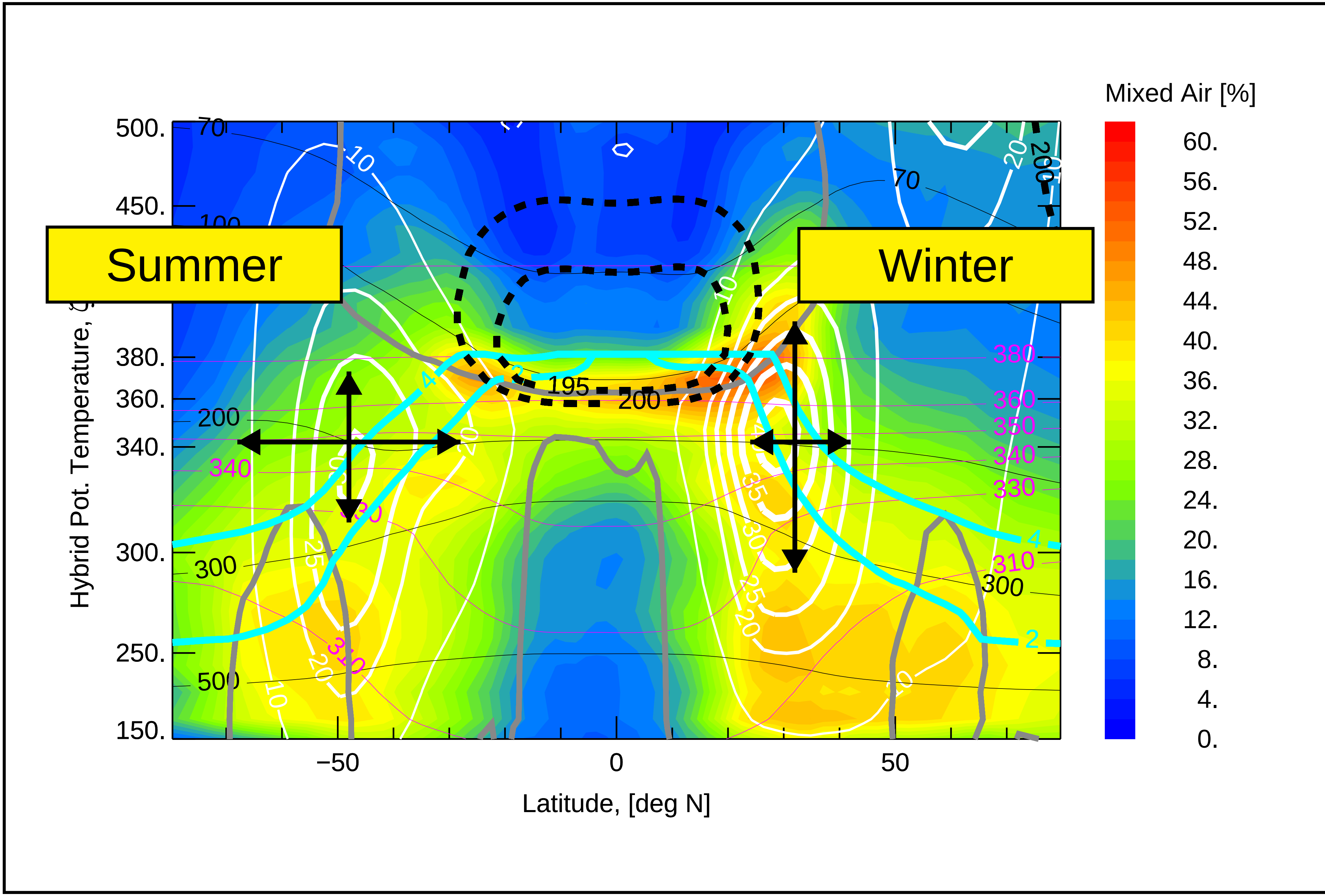

FOZAN
CLaMS
CLaMS (no mixing)
ECMWF
1200
1000
800
600
400
200
16:00
17:00
18:00
19:00
ST [%]
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.



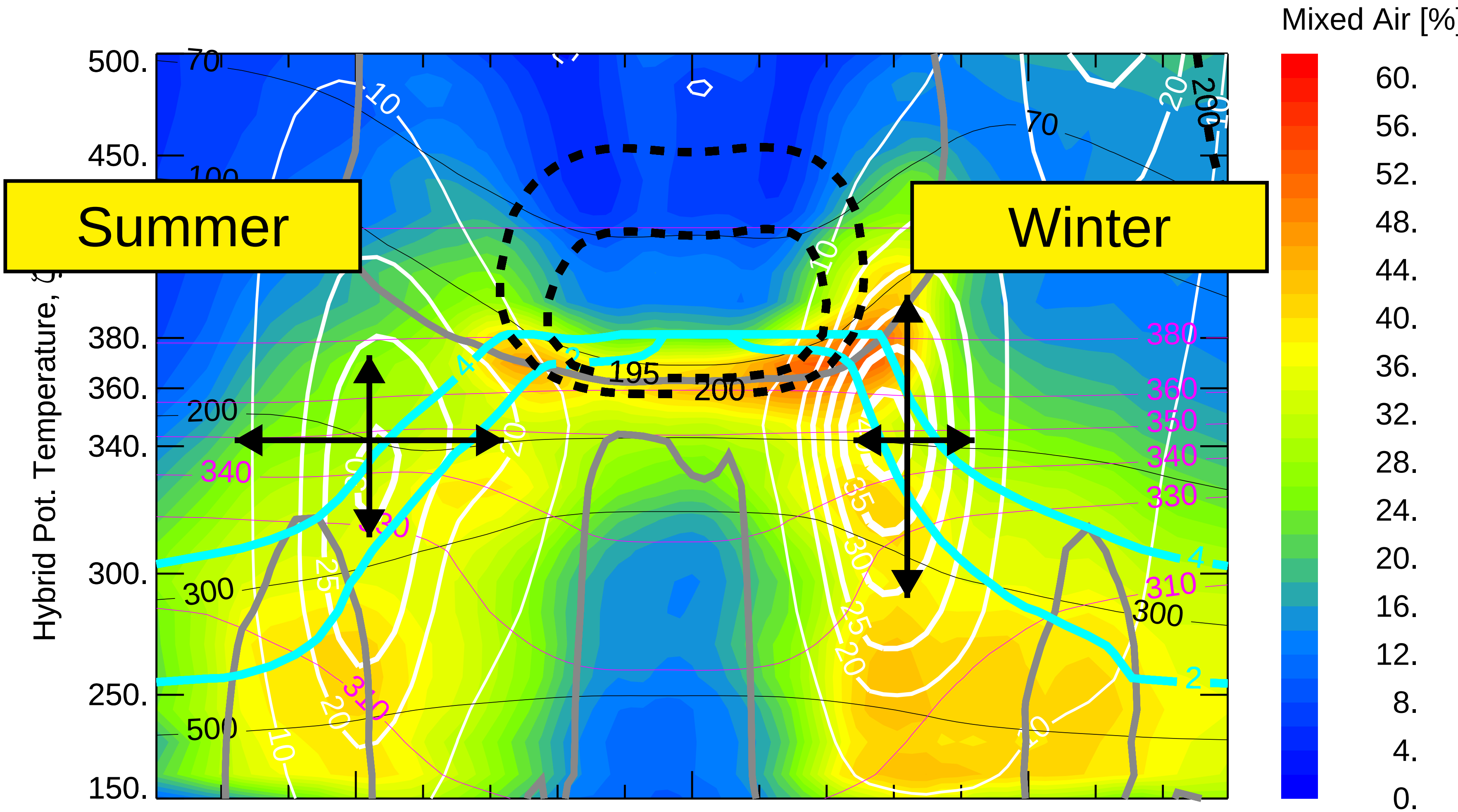
Konopka et al., ACP, 2007



Mixing intensity (Dec - Jan - Feb - Mar)

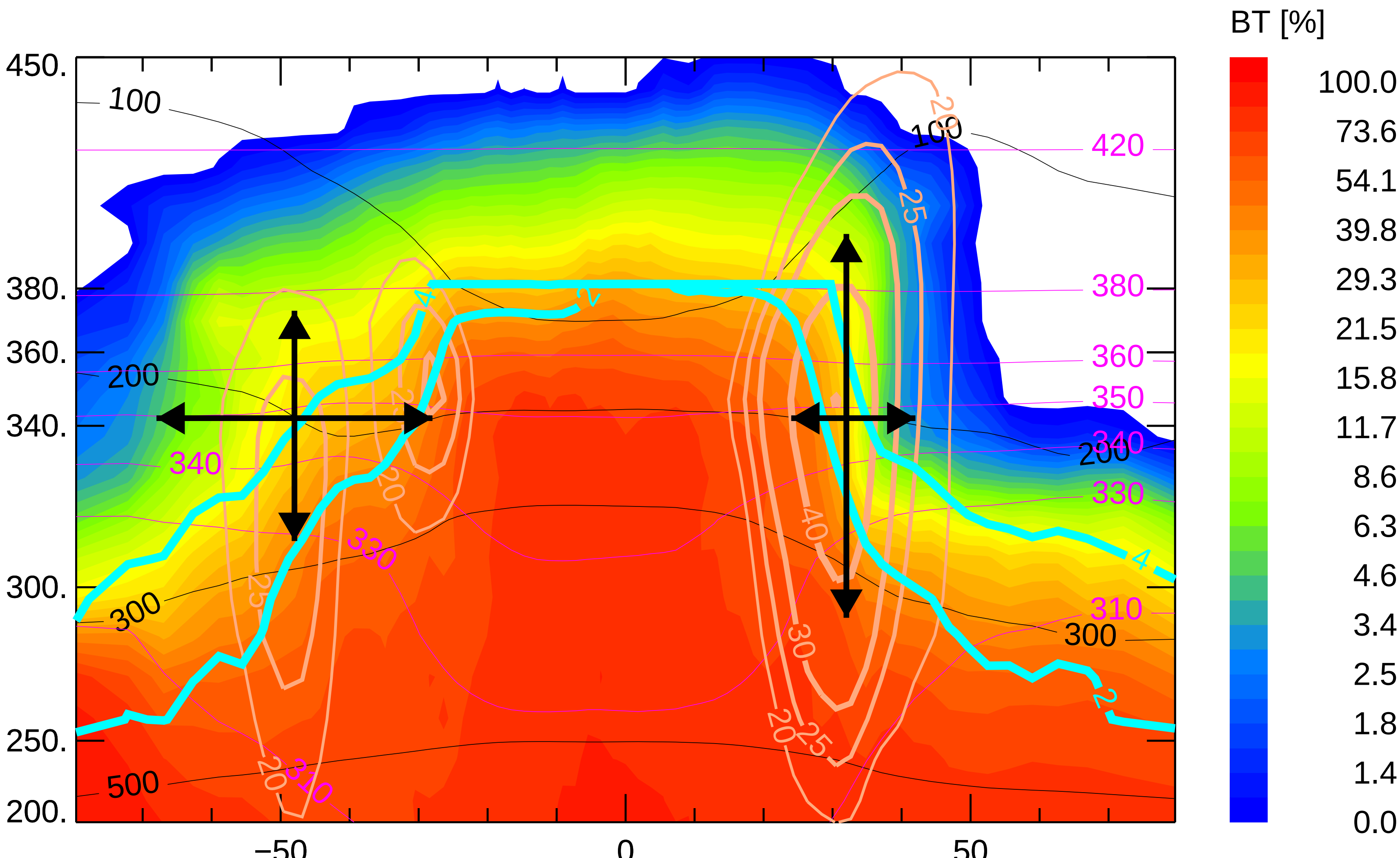


Mixing intensity (Dec - Jan - Feb - Mar)

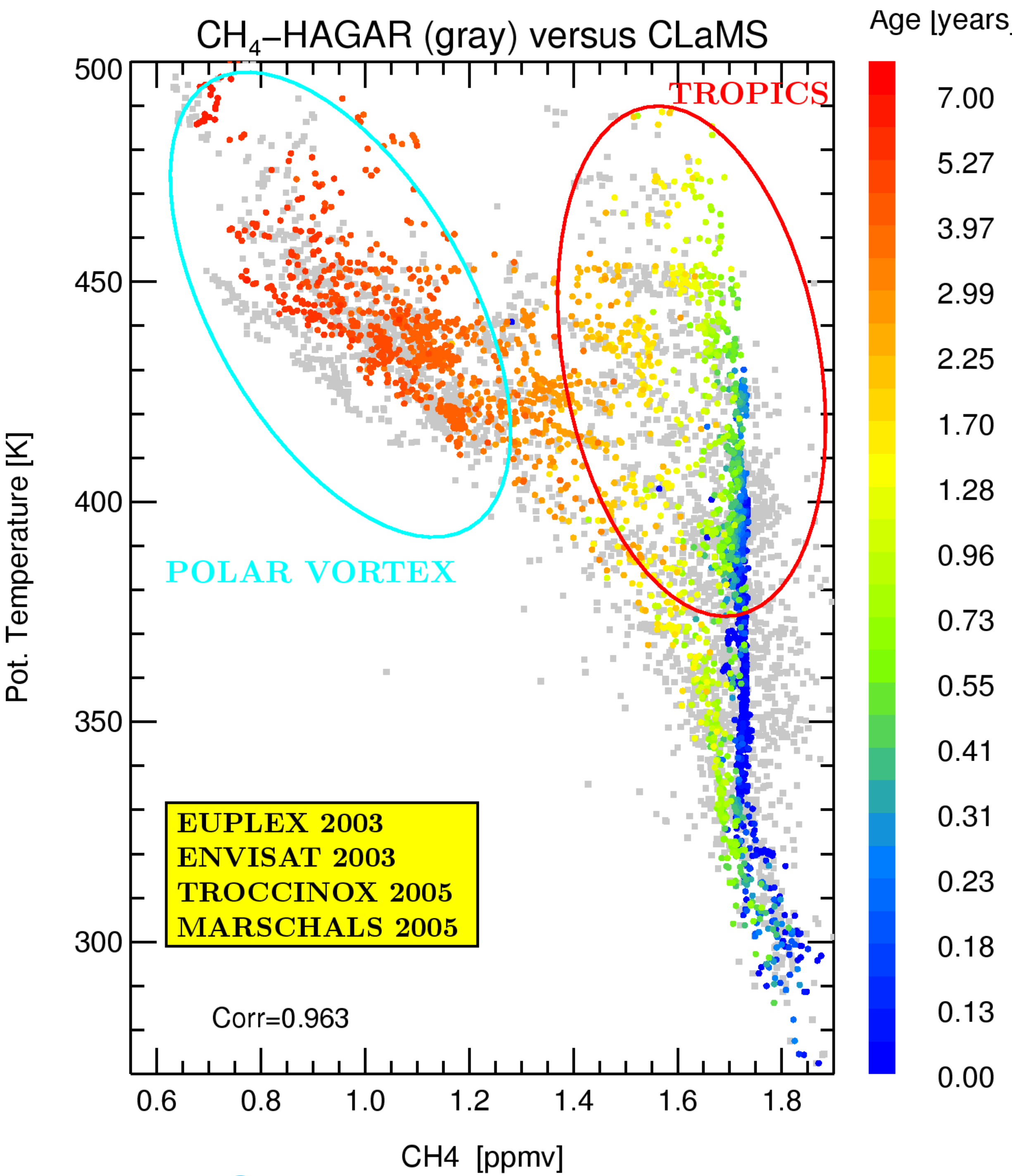


High local mixing intensity in CLaMS does not necessarily implicate a permeable transport barrier

Mixing intensity (Dec - Jan - Feb - Mar)



Zonally averaged signature of boundary layer tracer after ≈4 month of transport: Dec - Jan - Feb - Mar

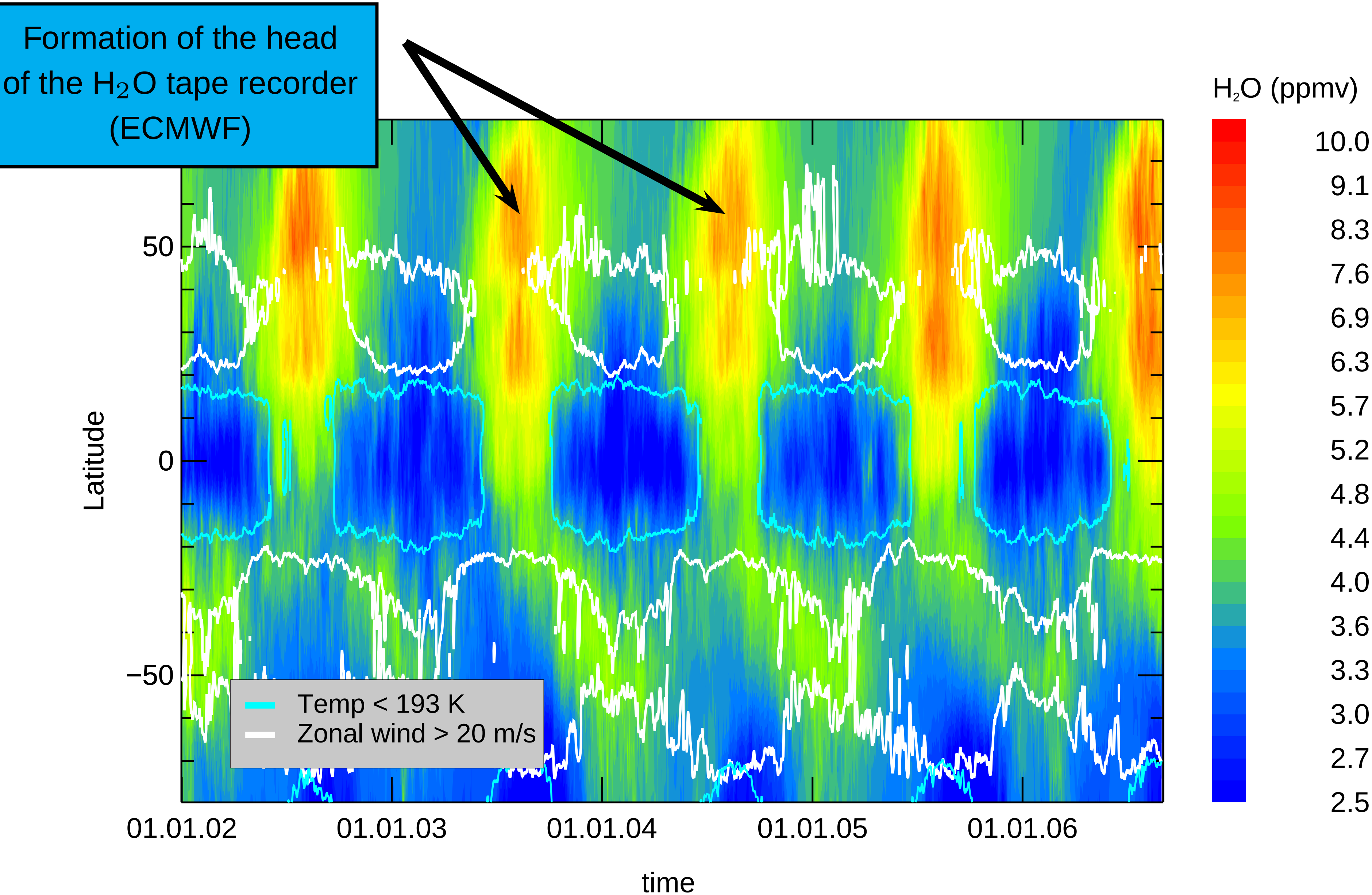


CLaMS versus all Geophysica flights (2003-2006)

Conclusions

- Mixing (in CLaMS) is the main driving force for the upward transport across the TTL between 350 and 380 K (Konopka et al., ACP, 2007)
  (highest vertical mixing in the TTL in in the vicinity of the subtropical jets and in the outflow regions of convection)
- Other options are still possible:
  - radiative lofting via cirrus clouds (Corti et al., 2006)
  - unresolved subgrid convection (Tiedtke at al., 1998)
  - overshooting convection
- First 5-years CLaMS simulations with CO_2, CH_4 produce reliable transport (tracer distributions, age of air, tape-recorder signatures...).
- This indicates that mainly diffusive (and not advective) fluxes effectively transport the tracer gases across the TTL

Implications for the tape-recorder effect

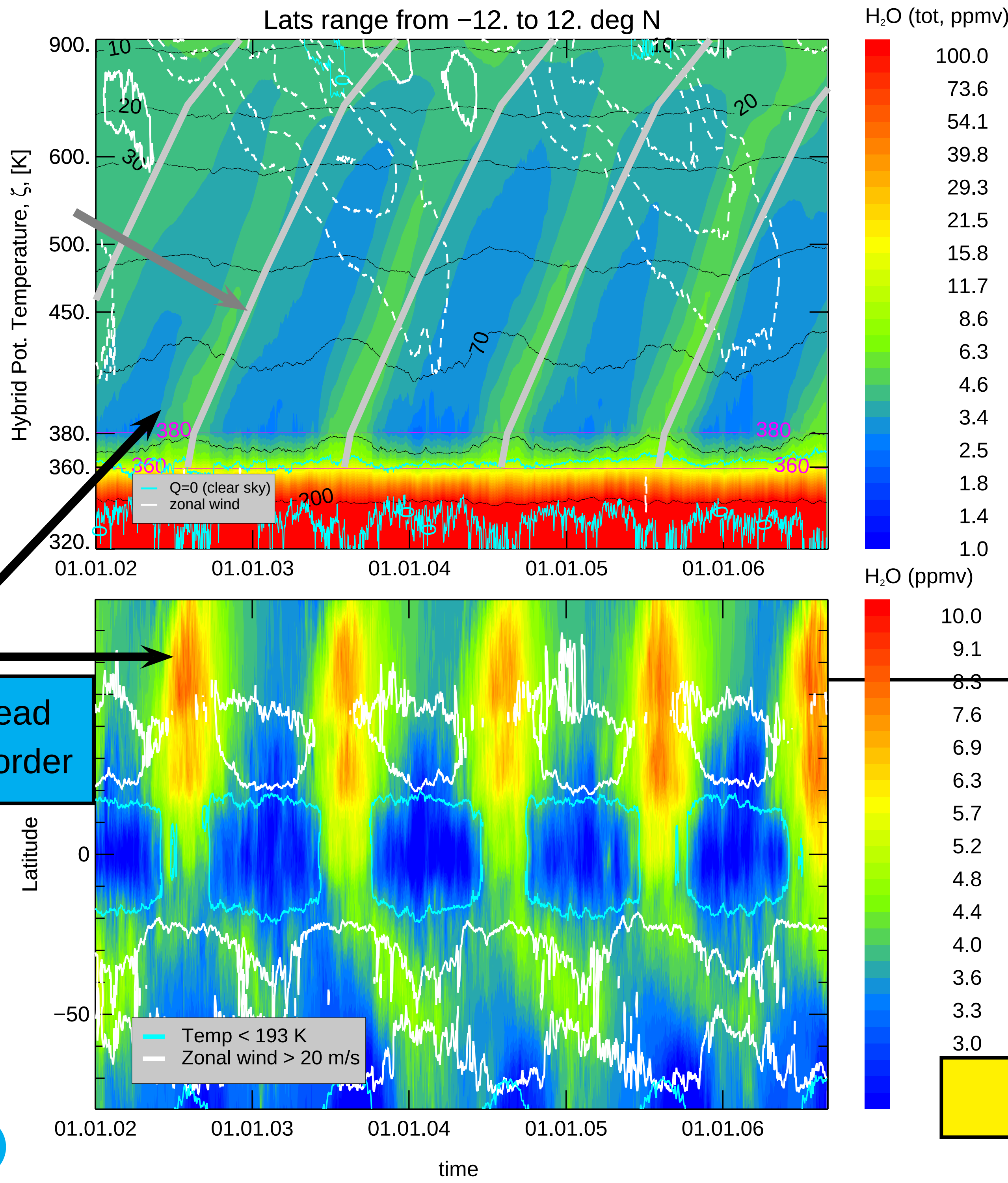


θ =380 K

Imp… t

Mean tape recorder signal in the 90’s (HALOE)

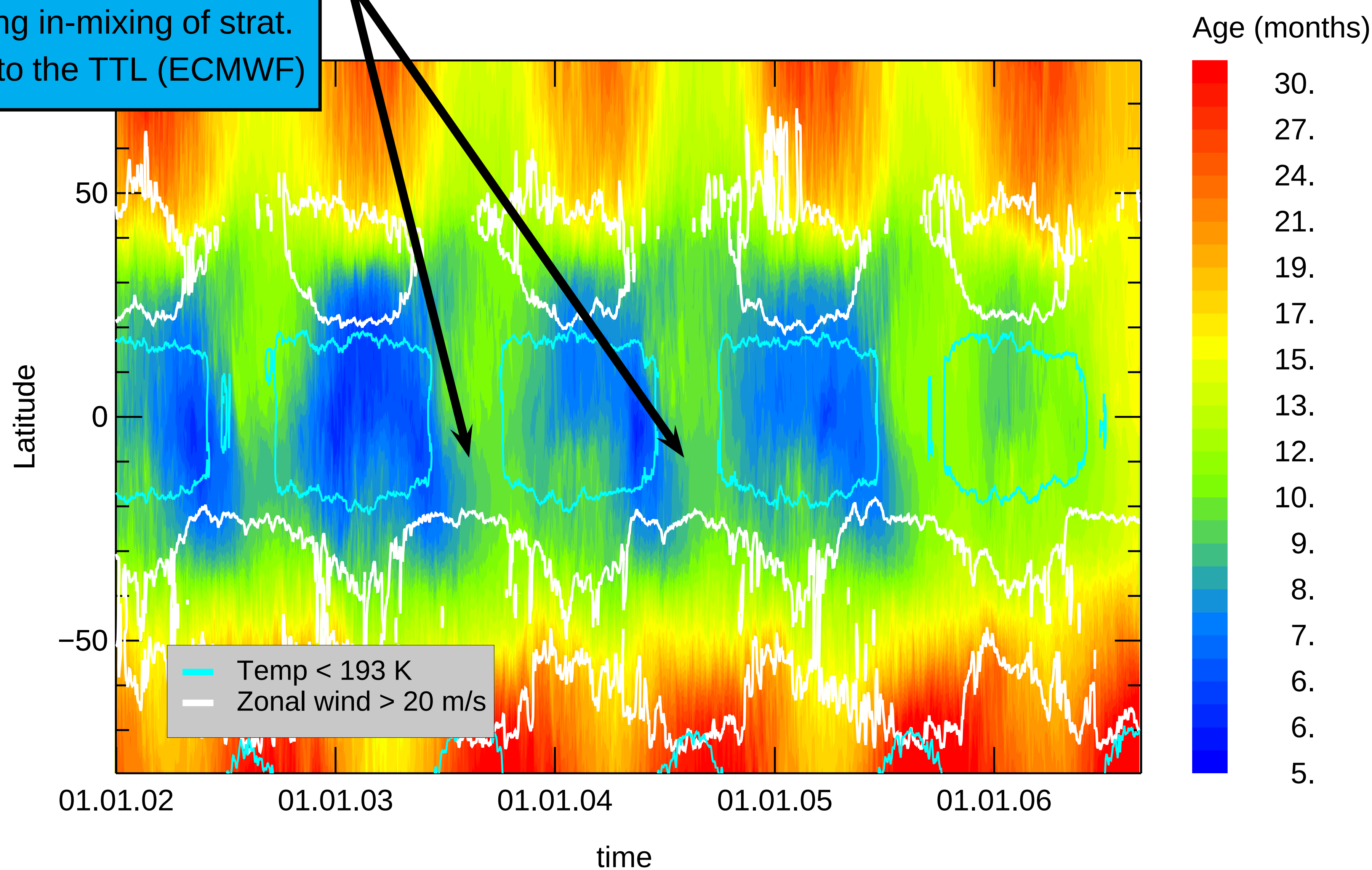
Formation of the head of the H_2O tape recorder



$\theta = 380$ K

Seasonality of the permeability through the STJ

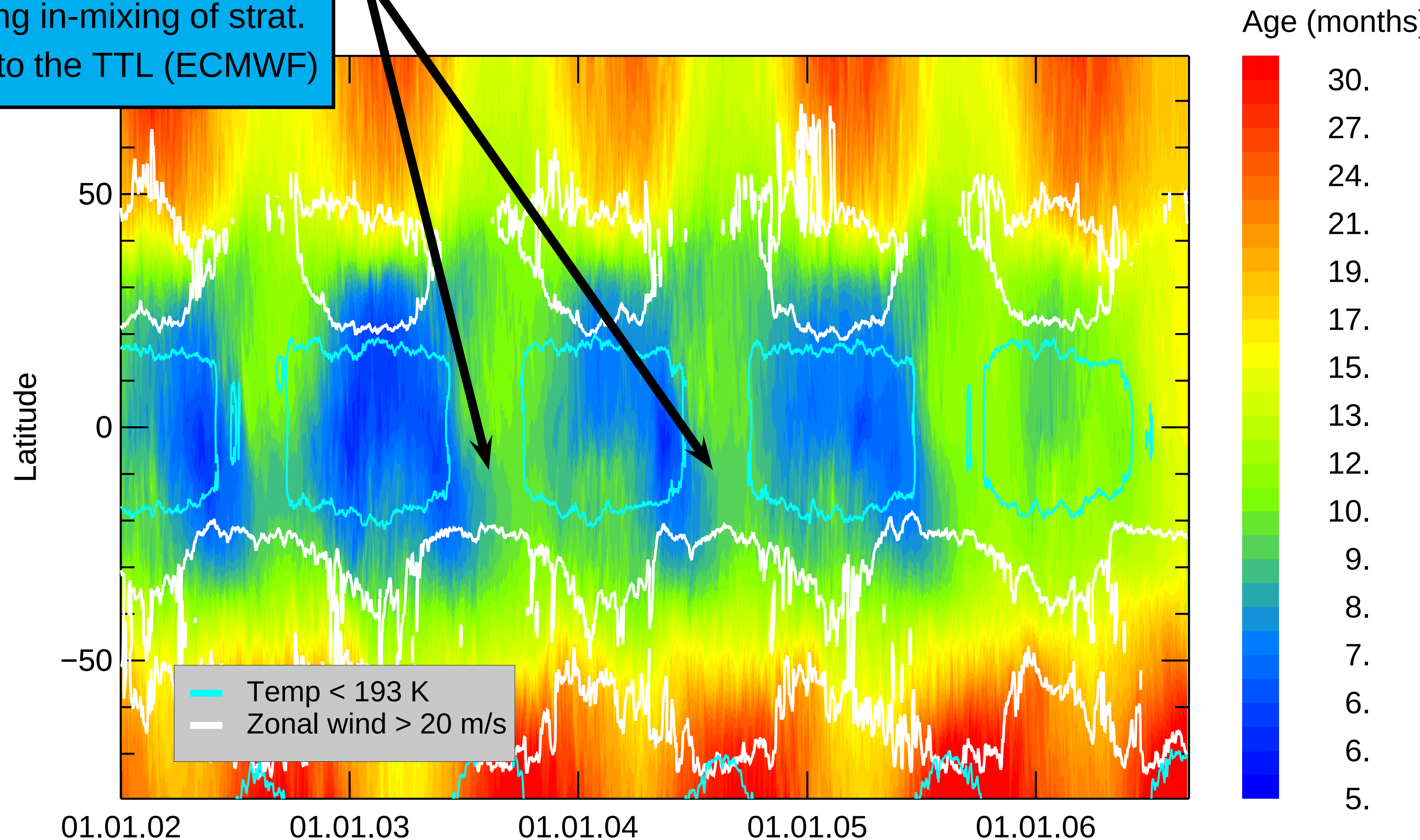
NH summer:
strong in-mixing of strat.
air into the TTL (ECMWF)



θ =380 K

Seasonality of the permeability through the STJ

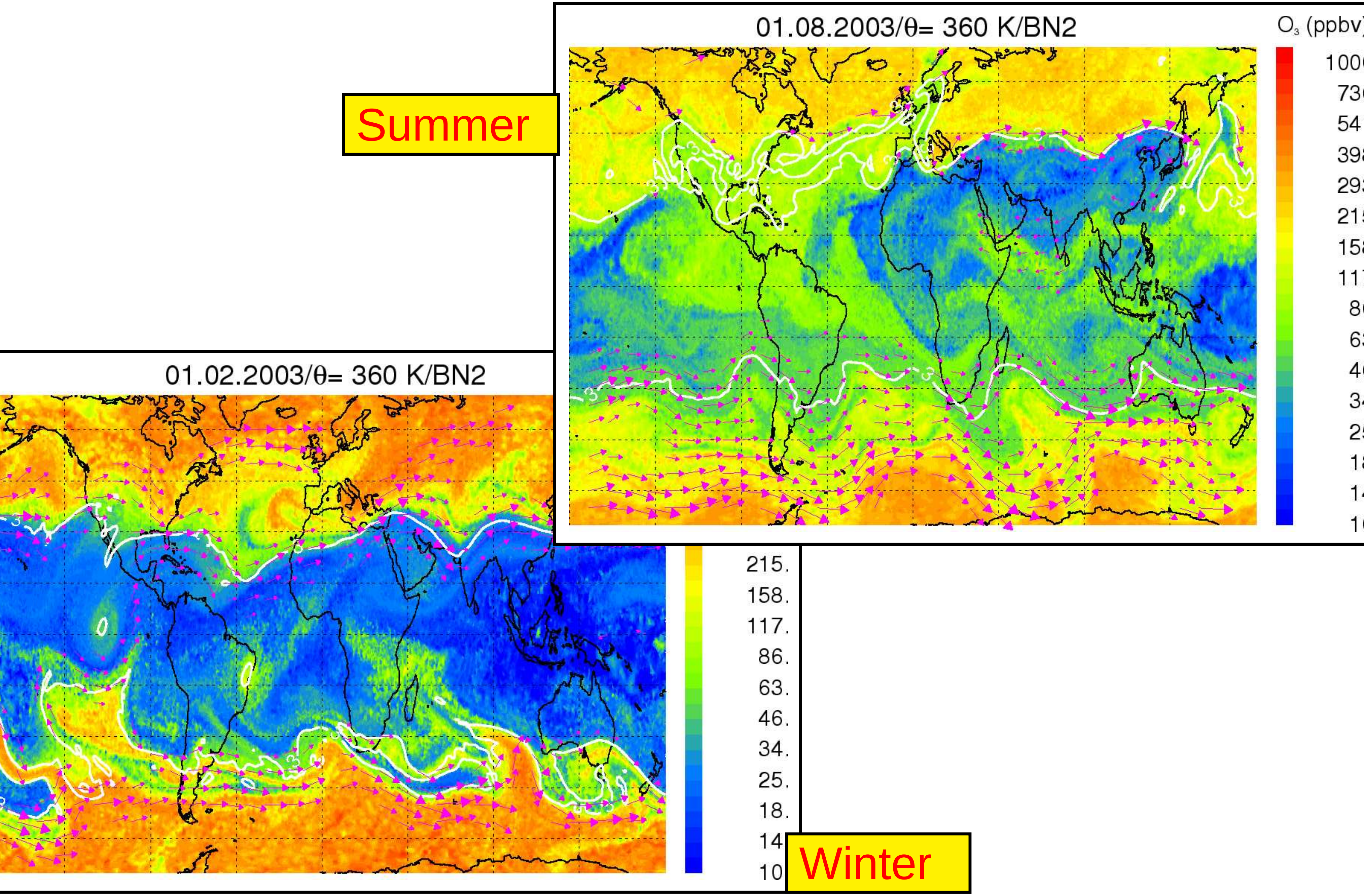
NH summer:
strong in-mixing of strat.
air into the TTL (ECMWF)



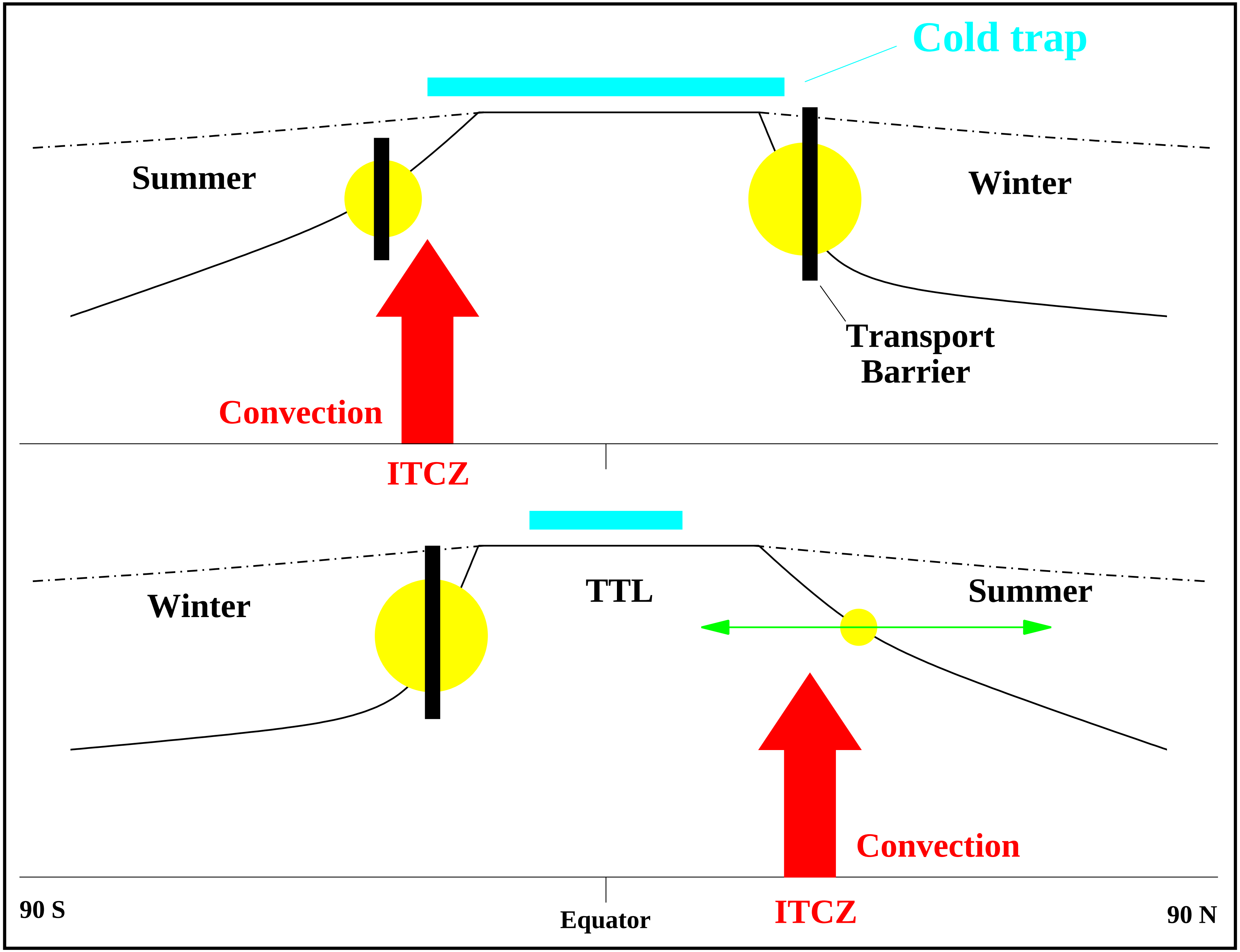
Low CO values (enhanced age), CO anticorelated with H_2O, Schoeberl et al., GRL, 2006

$\theta = 380$ K

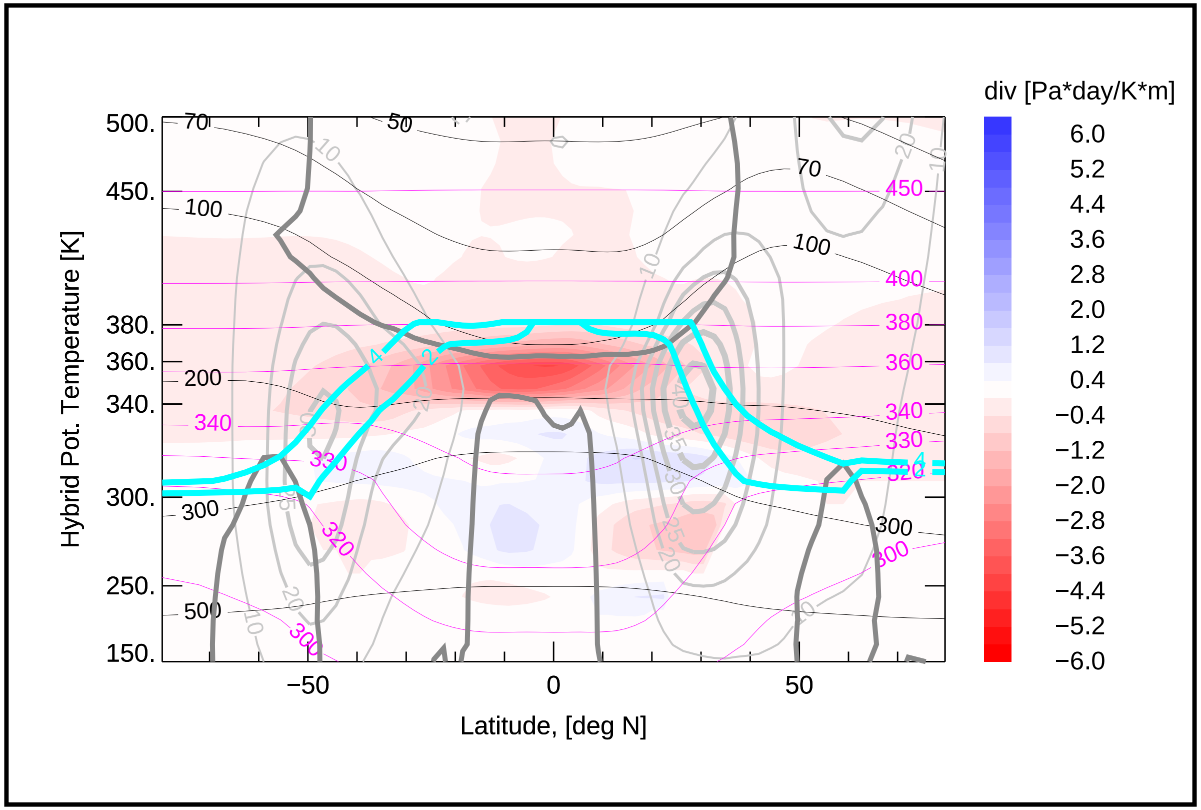
Summer versus winter



Summer versus winter



Mass conservation



- Mass conservation not valid in $\zeta-$coordinates
- “empty" regions in pure trajectory calculations
- removing these regions does not (significantly) reduce the mixing in CLaMS
- ECMWF mean meridional (polewards) velocities are probably too strong
- ECMWF mean vertical tropical updraft between 360 and 380 K also probably too strong