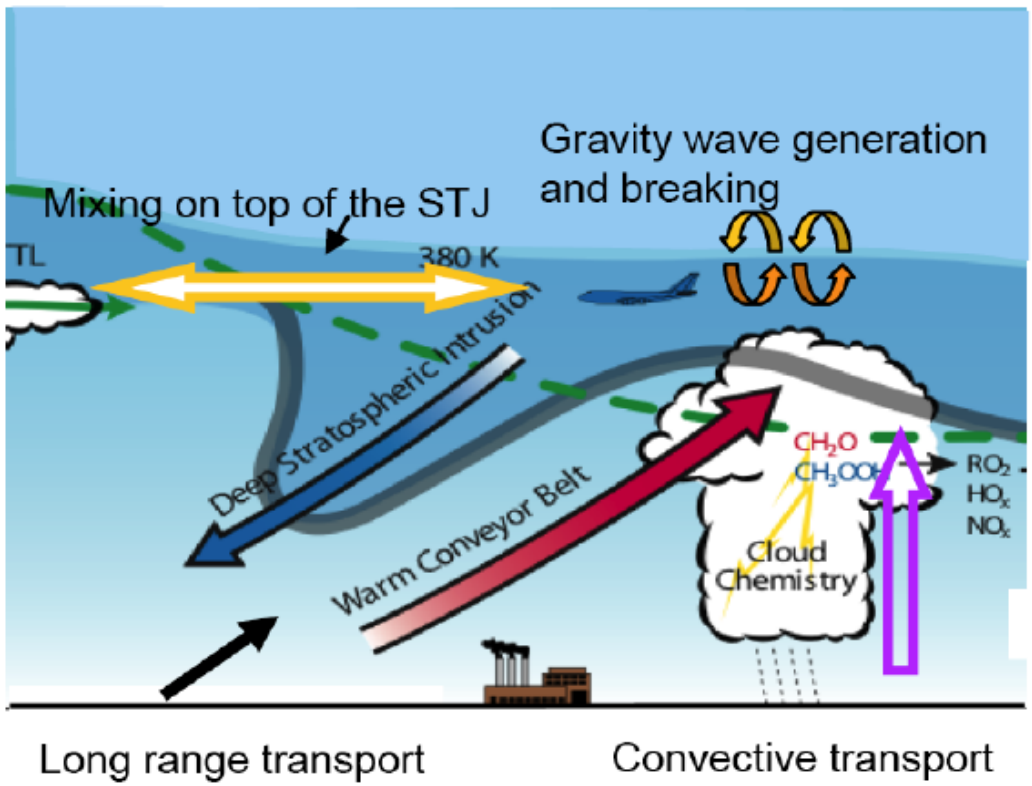
Identification of transport pathways using CO-O3 correlations in Lagrangian model simulations

B. Vogel[1], L. Pan[2], P. Konopka[1],
G. Günther[1], R. Müller[1], W. Hall[2],
T. Campos[2], I. Pollack[2], A. Weinheimer[2],
J. Wei[3], E. Atlas[4], K. P. Bowman[5]

[1] Forschungszentrum Jülich, ICG-1: Stratosphere, Jülich, Germany
[2] National Center for Atmopheric Research (NCAR), Boulder, USA
[3] National Oceanic and Atmospheric Administration (NOAA), Boulder USA
[4] University of Miami, USA
[5] Texas A&M University, USA

Motivation

What can we learn from Lagrangian simulations about transport pathways and the preferred location of mixing in the Ex-UTLS?



1. **Extratropical UT/LS Survey (including cirrus clouds) (RF 03, 09, 14, 17, 18)**
2. **Stratospheric Intrusion (Tropopause Fold) (RF 04, 06, 11, 12)**
3. **Tropospheric Intrusion (RF 01, 07, 08, 09, 14)**
4. **Convective Influence (RF 08, 13, 14, 18)**
5. **Gravity Wave (RF 02)**
6. **HIPPO (RF 05, 07, 08, 10, 13, 15, 16)**

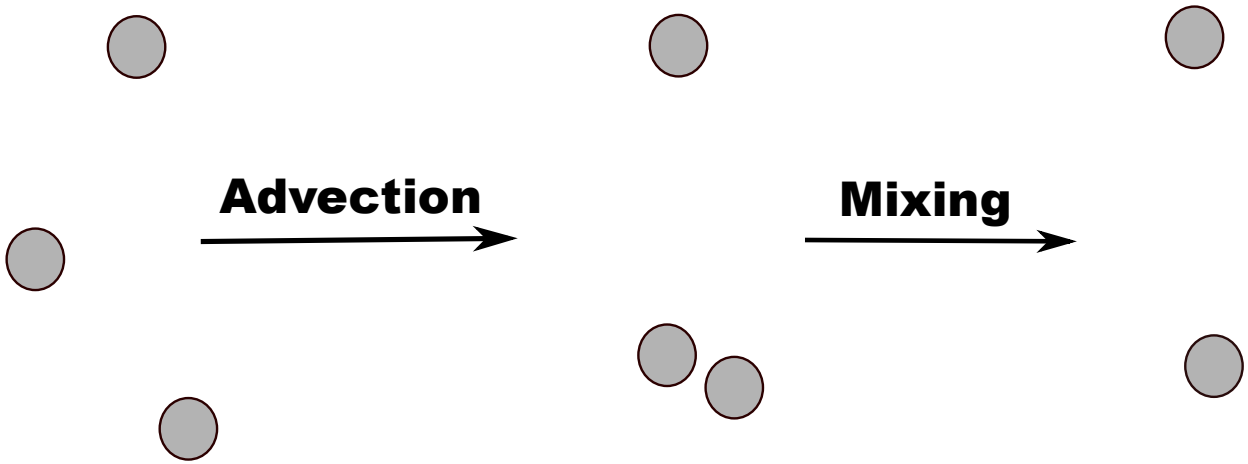
Chemical **La**grangian **M**odel of the **S**tratosphere (CLaMS)

JÜLICH FORSCHUNGSZENTRUM

- NH 3D simulation from 1 April 2008 - 16 May 2008
- altitude range: surface until 500 K pot. Temp.
- horizontal / vertical resolution: 50 km / 35 levels
- horizontal winds: NCEP (every 6 hours)
- vertical winds [*Konopka et al. 2007*]:
  < 100 hPa: ω = vertical velocity in pressure coordinates
  > 100 hPa: radiation calculations
- using simplified chemistry (O_3 and CO)
- mixing is driven by strain and shear rates of the horizontal wind [*Konopka et al. 2004*]

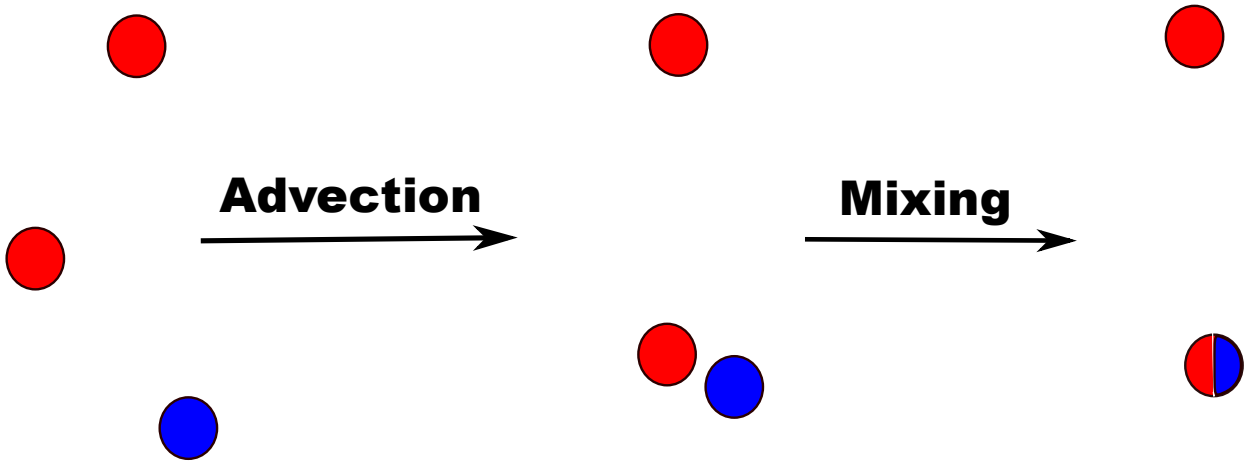
Using tracers of air mass origin in CLaMS

Transport = Advection (reversible) + Mixing (irreversible)



Using tracers of air mass origin in CLaMS

Transport = Advection (reversible) + Mixing (irreversible)

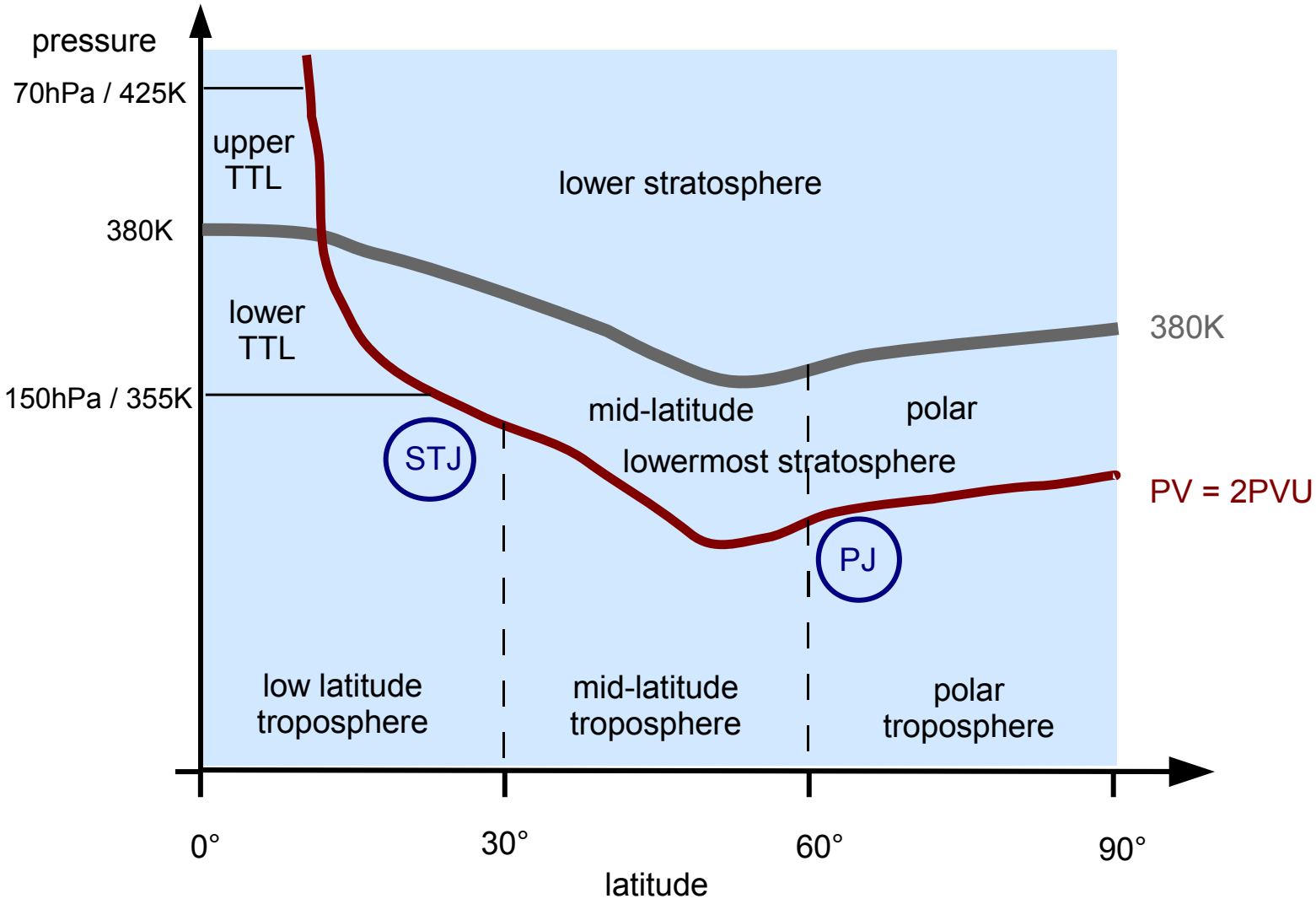


Using artificial tracers that mark particular regions in the atmosphere yields [*Günther et al., 2008*]:

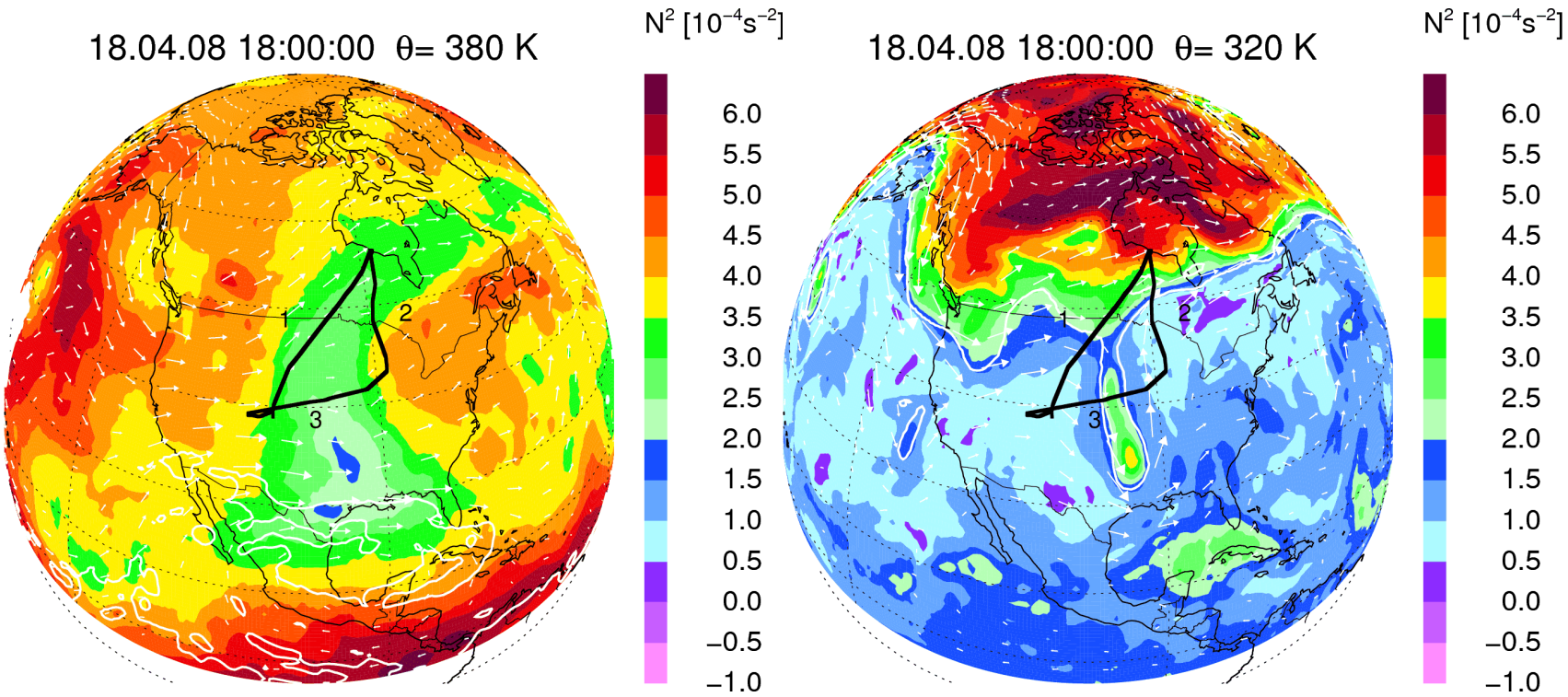
- identification of the origin of air masses
- the contribution of air mass origin in every air parcel

Definition of tracers of air mass origin

at the beginning of the simulation at April 1, 2008

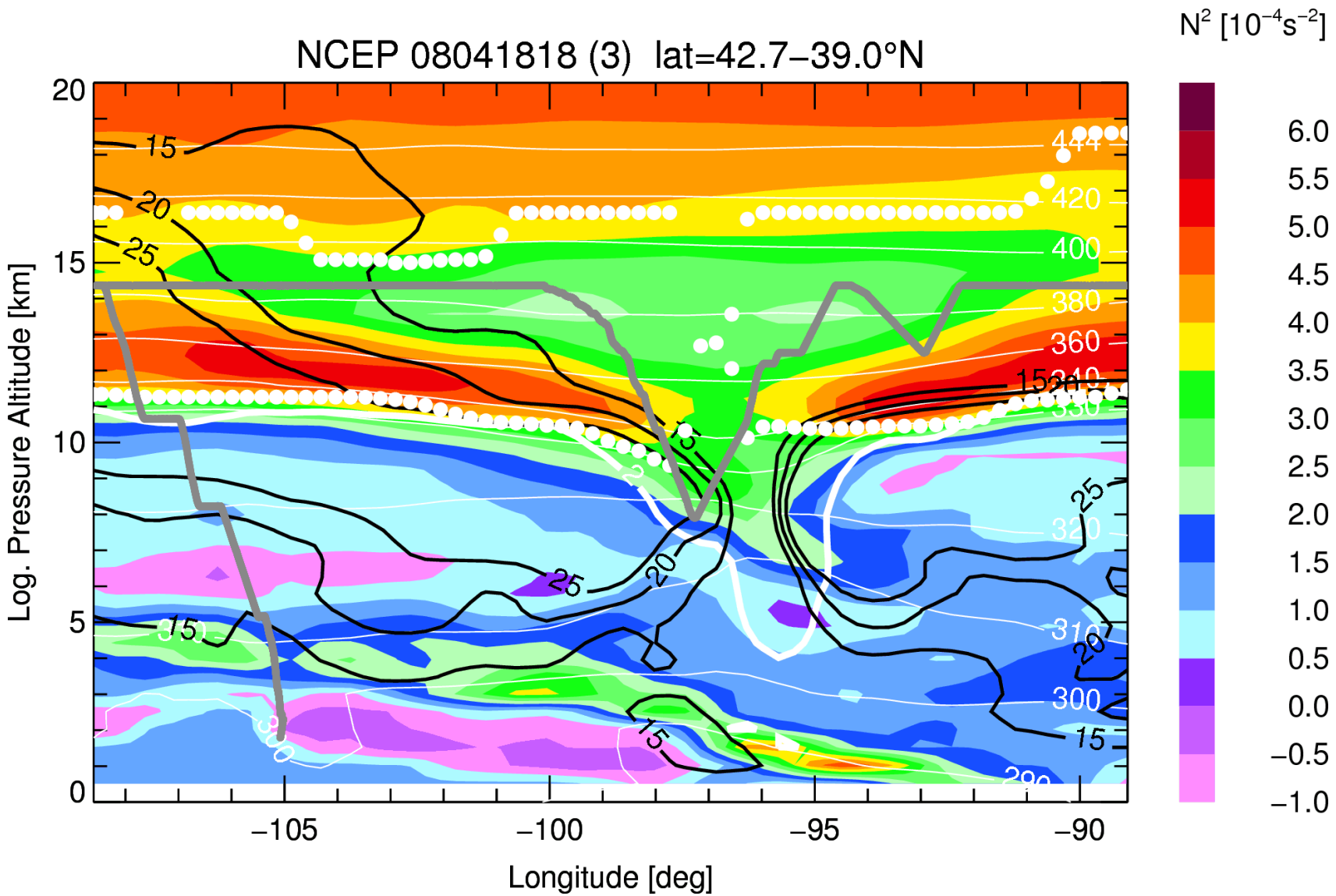


Research Flight 1: Tropospheric intrusion

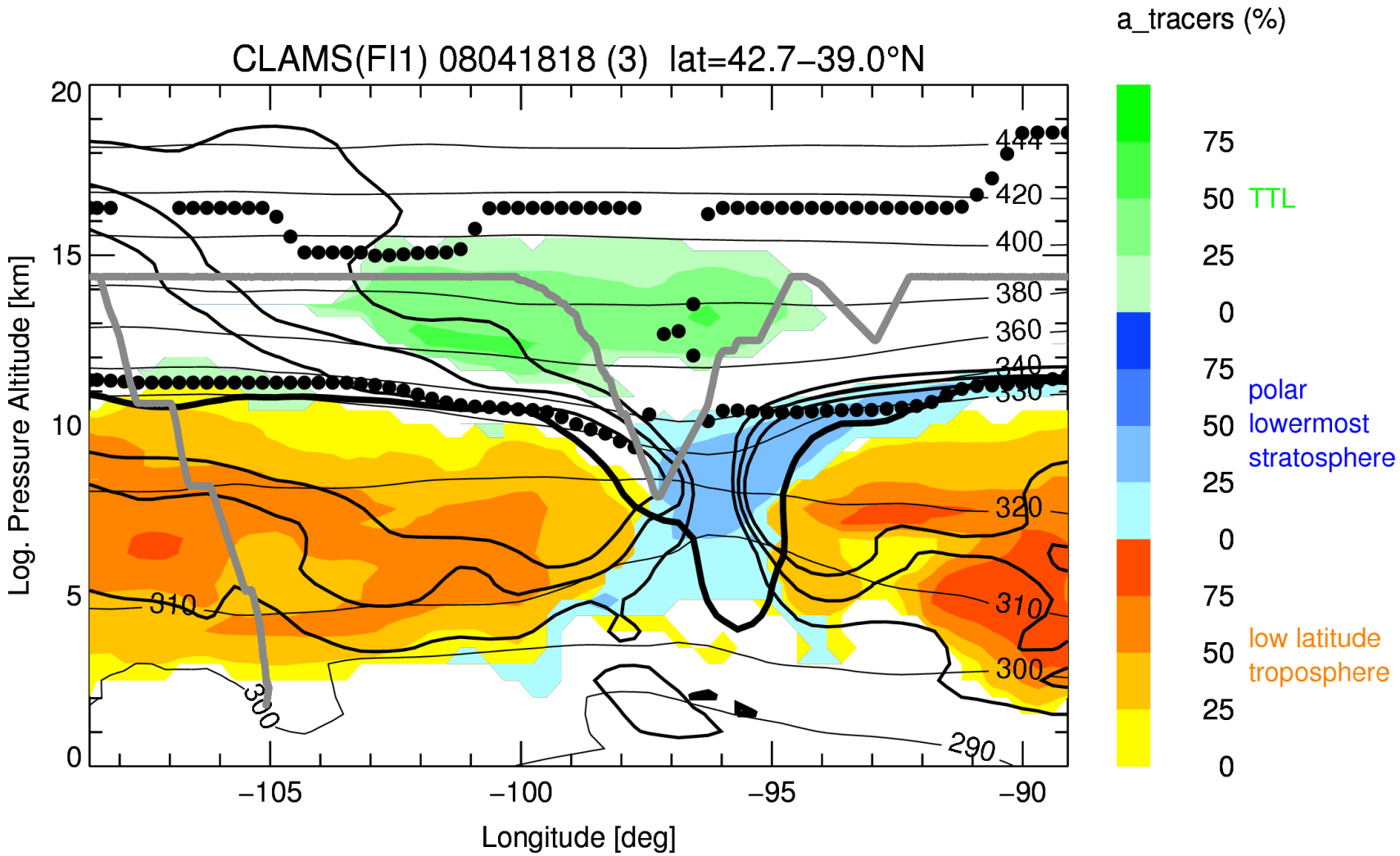


RF01: Deep tropospheric intrusion

vertical curtain along the flight path



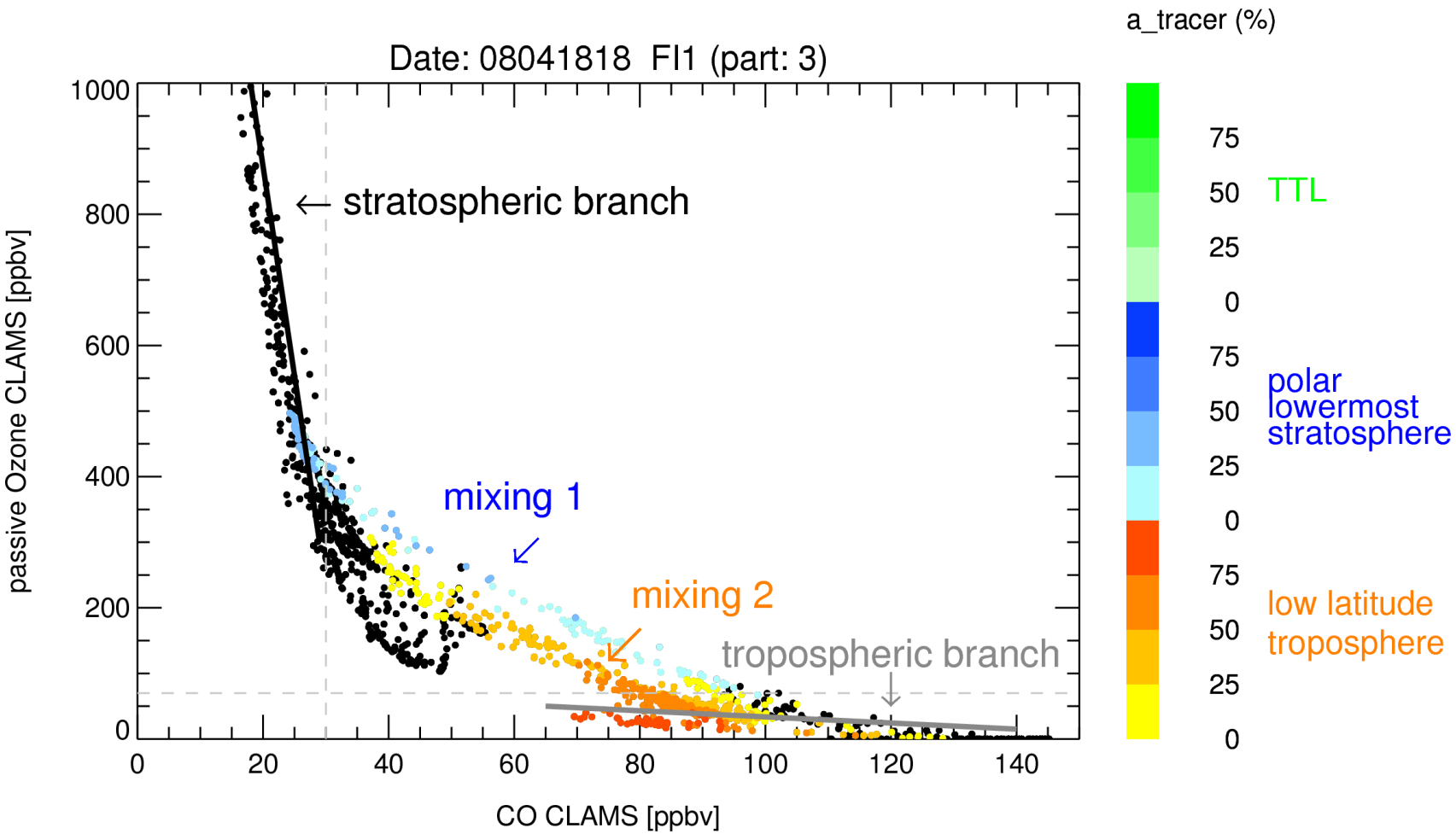
RF01 CLaMS Results: Artificial Tracers



artificial tracers shown here are $> 10\%$

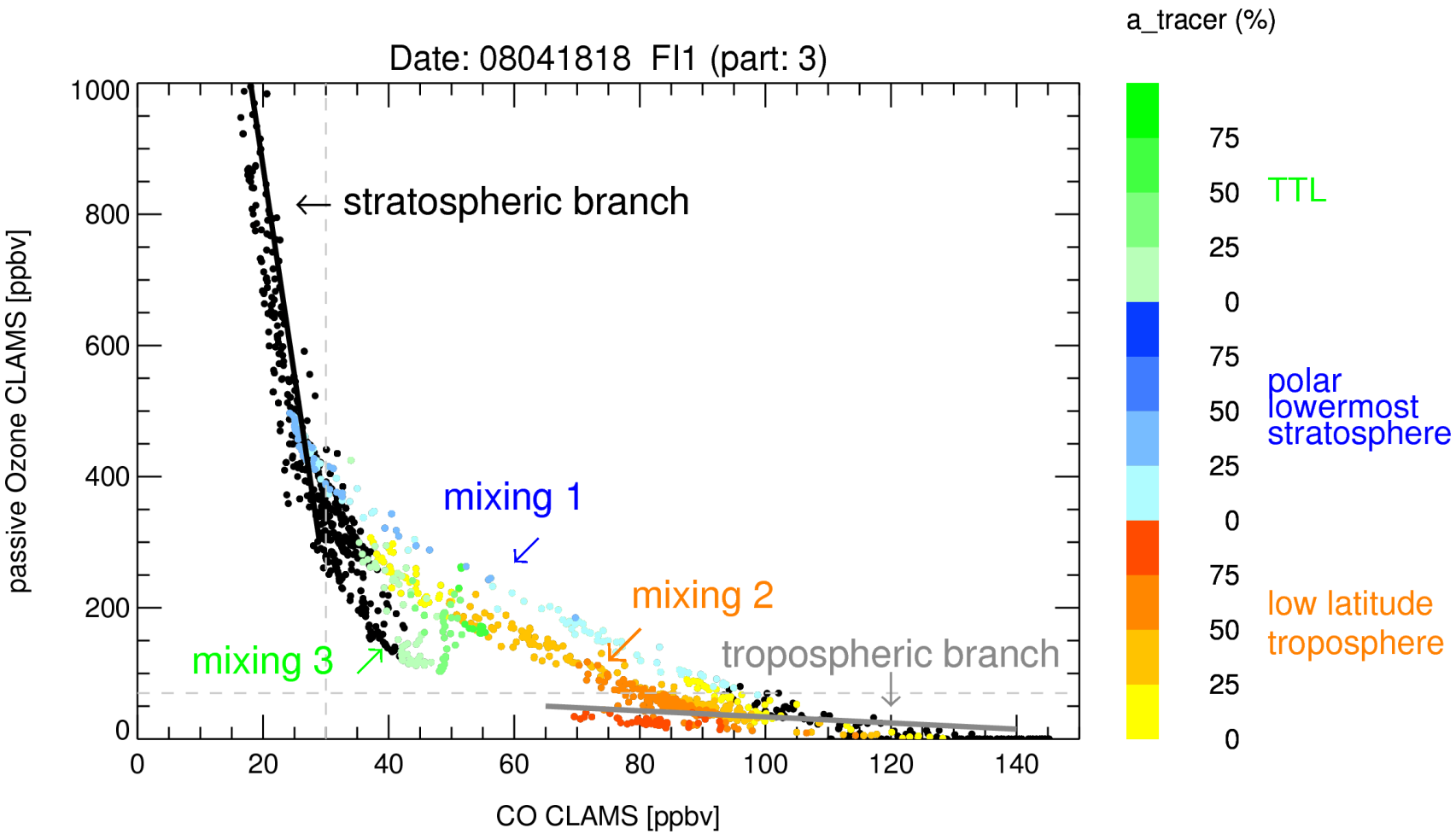
CLaMS Results RF01: $CO - O_3$ Correlation

all CLaMS points within the vertical curtain along the flight path

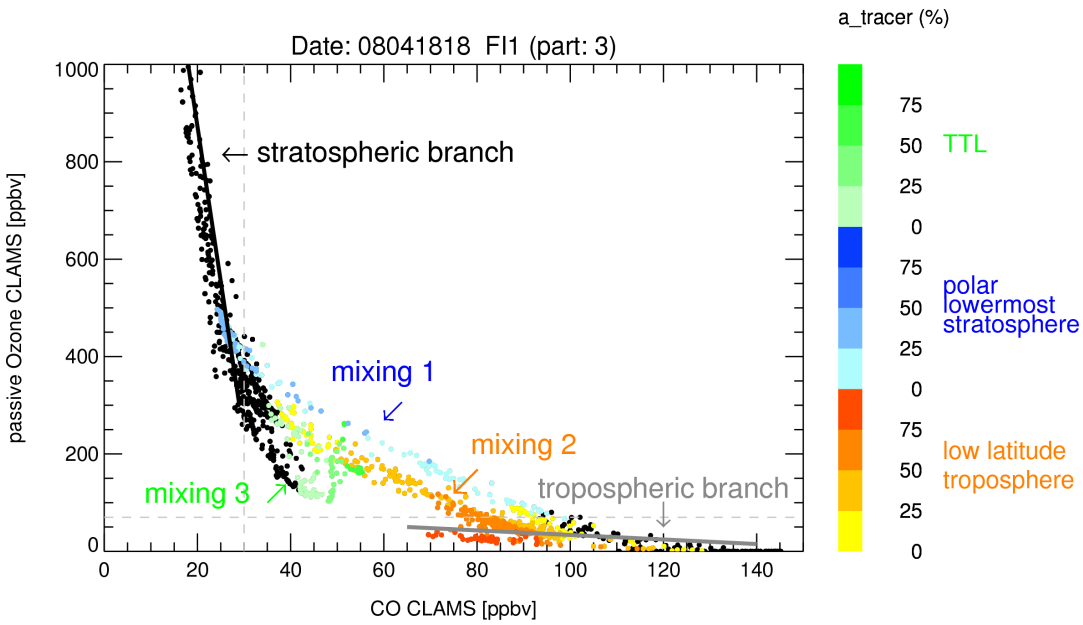


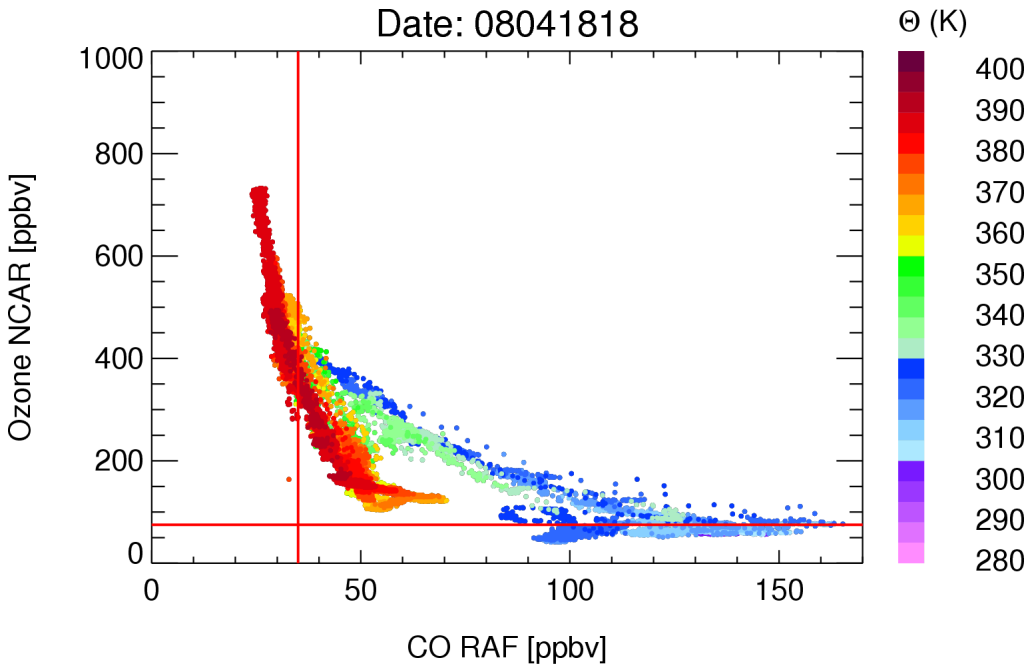
CLaMS Results RF01: $CO - O_3$ Correlation

all CLaMS points within the vertical curtain along the flight path



artificial tracers shown here are $>$ 10%, except of TTL ($>$ 5%)

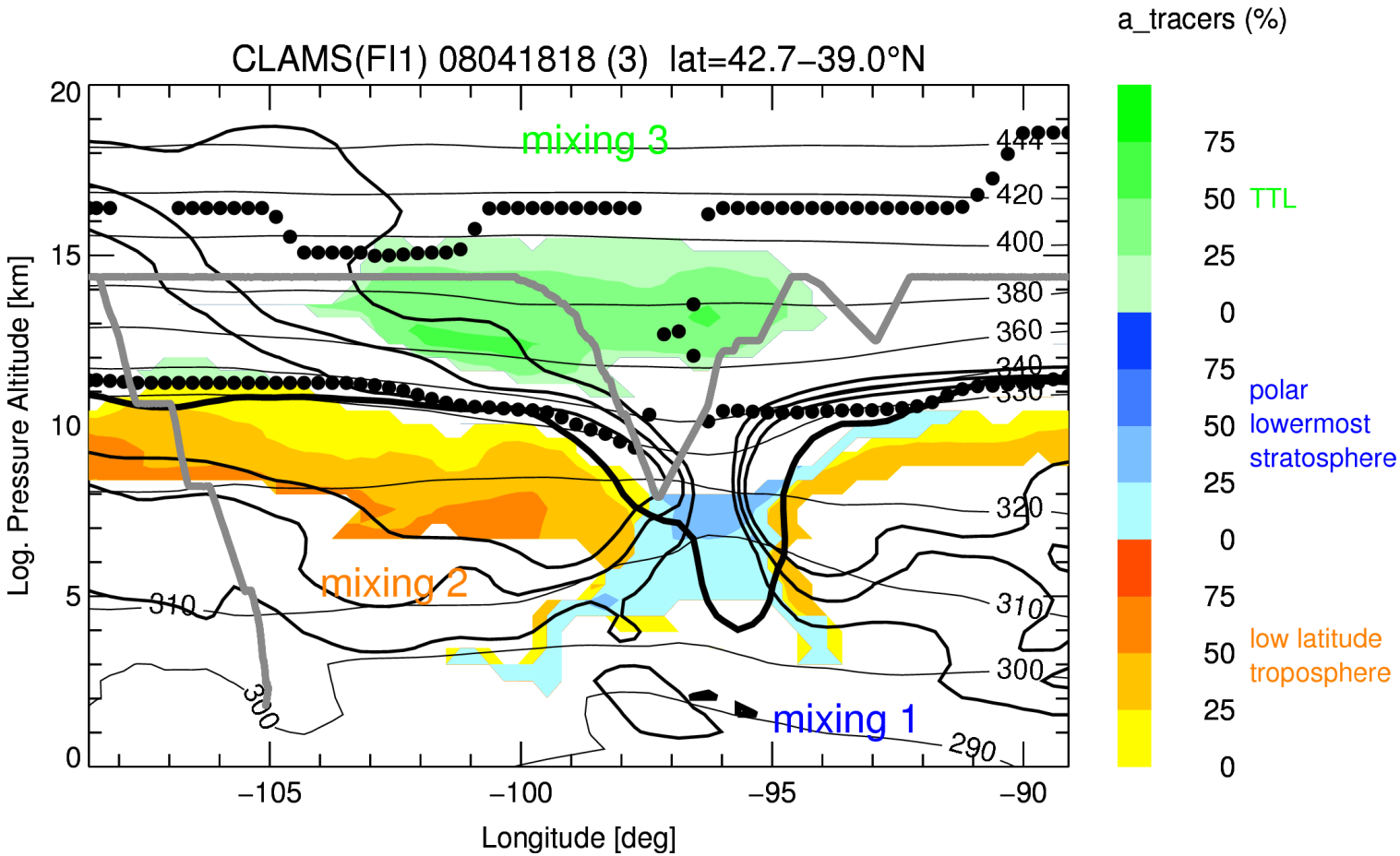




RF01: $CO - O_3$ Correlation CLaMS vs. measurements

- very good qualitative overall agreement
- tropospheric branch in CLaMS is too low
- CLaMS over-interprets the separation between mixing region 1 and 2

Location of mixing regions in physical space

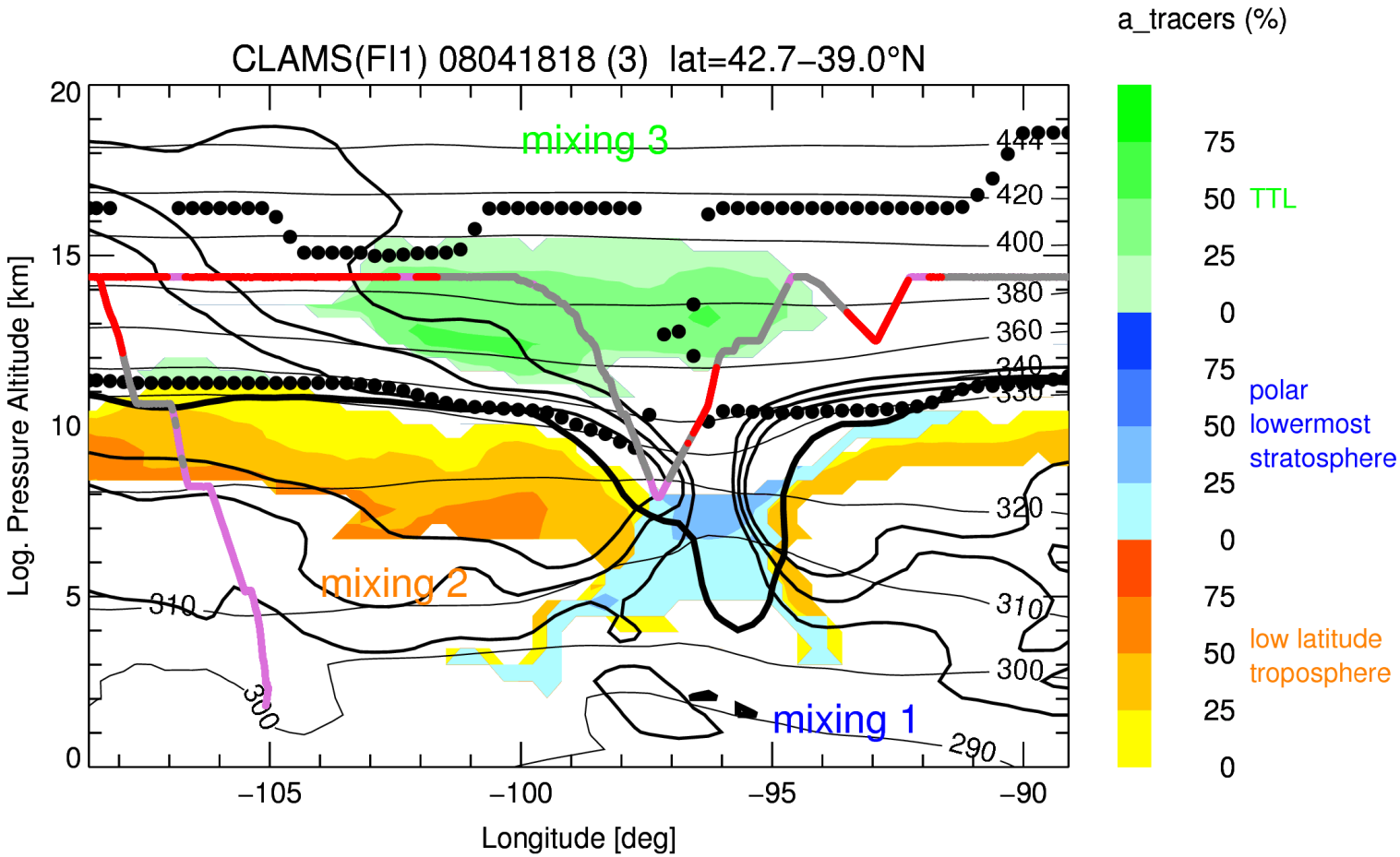


Mixing 1 occurred within the tropopause fold

Mixing 2 occurred just below the tropopause

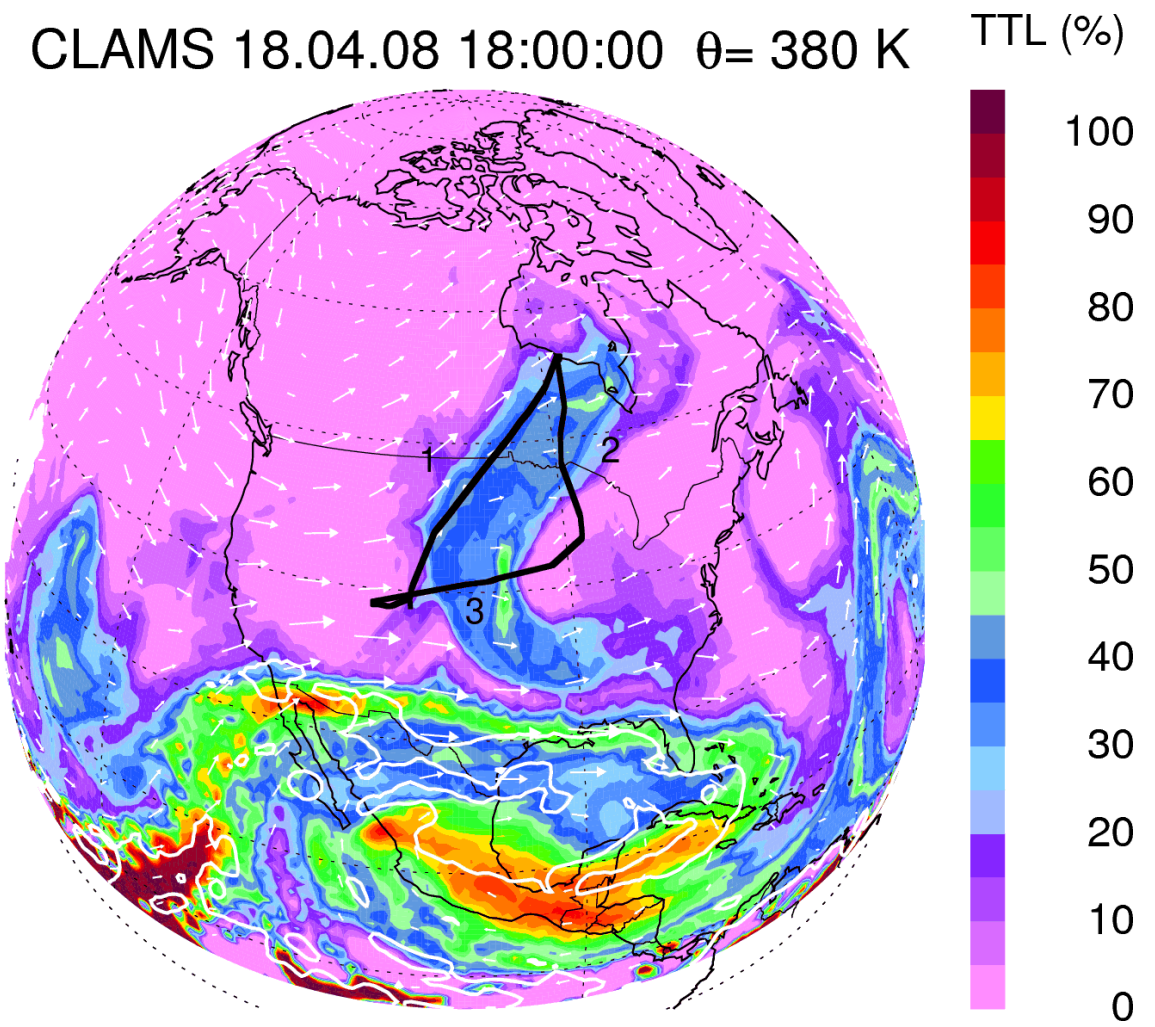
Mixing 3 occurred in air masses transported from the TTL into the stratosphere

Location of mixing regions in physical space



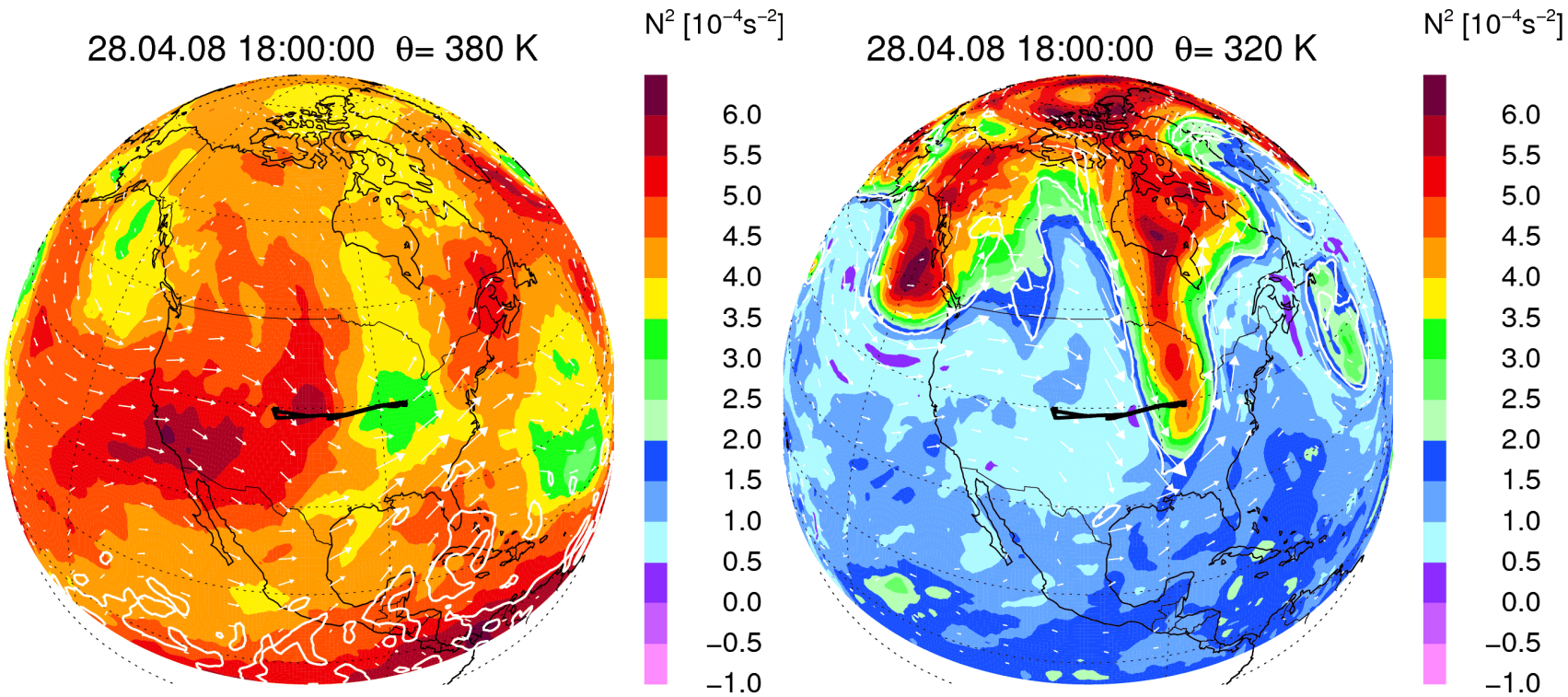
→ Most mixing regions in CLaMS and observations agree

Fraction of air masses originate in the TTL



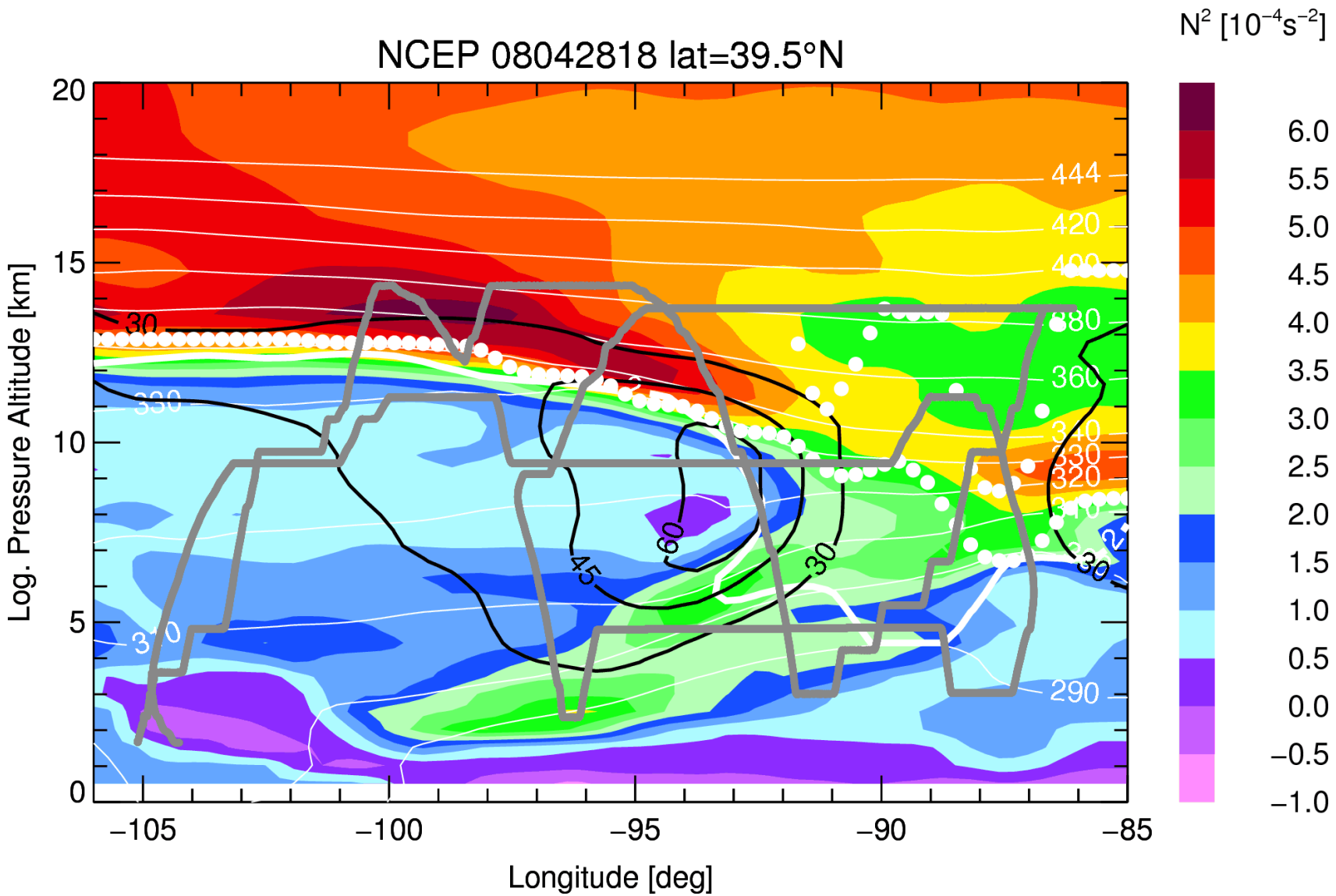
In CLaMS the tropospheric intrusion has a life time of $\approx$ 20 days

Research Flight 4: 2008-04-28
Stratospheric intrusion

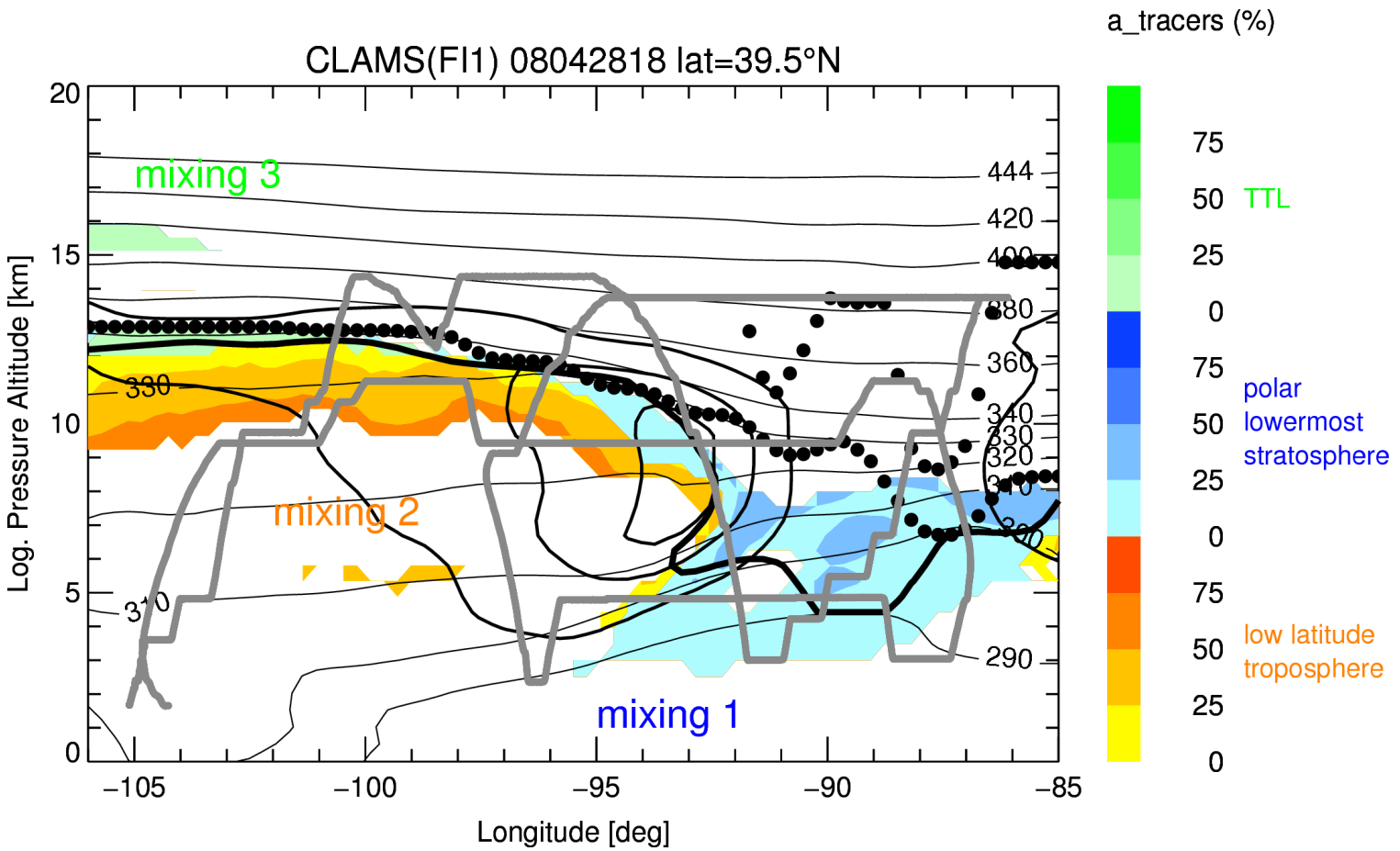


RF04: Stratospheric Intrusion

vertical curtain along the flight path



Location of mixing regions in physical space

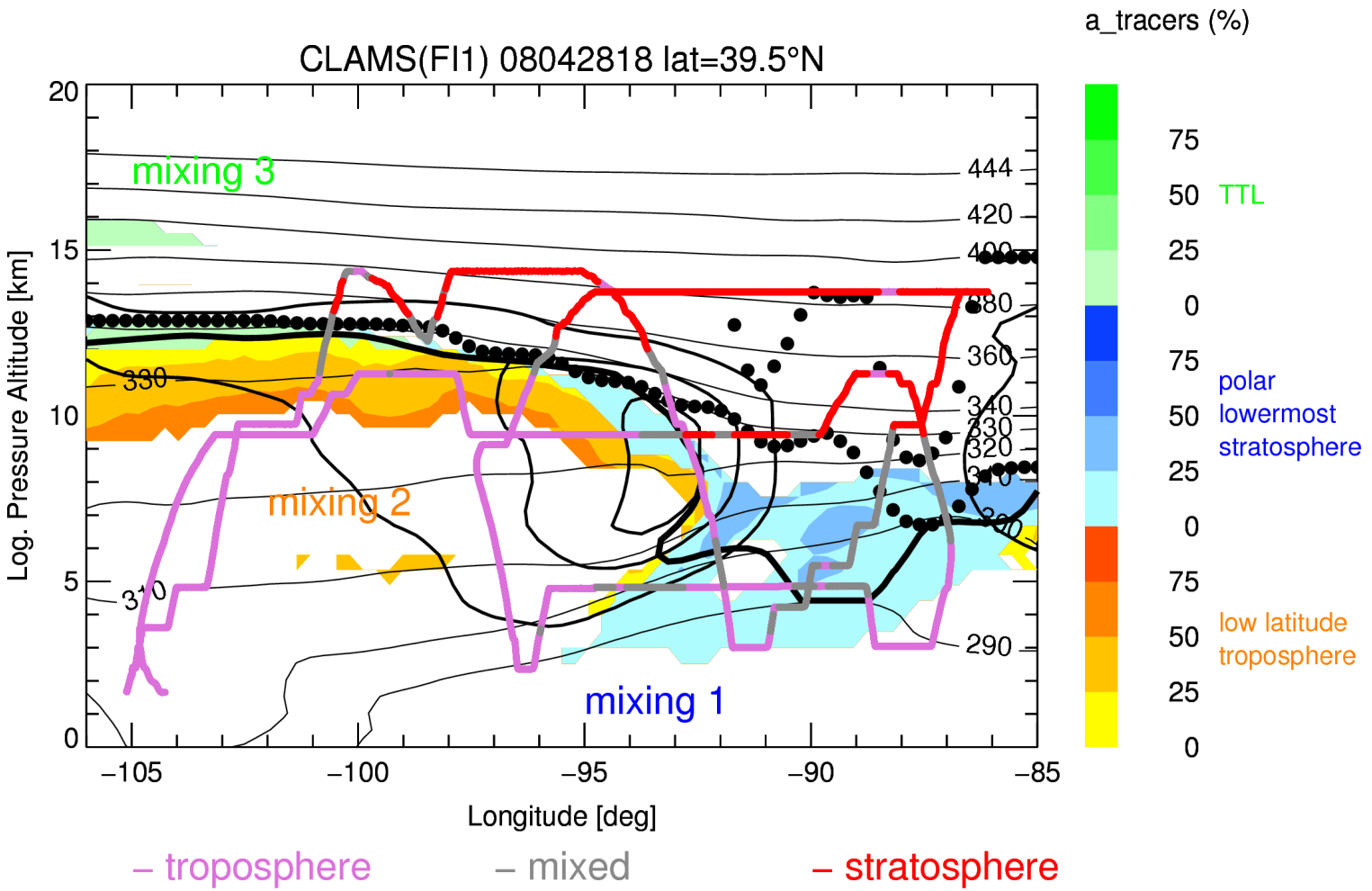


Mixing 1 occurred within the tropopause fold

Mixing 2 occurred below the tropopause

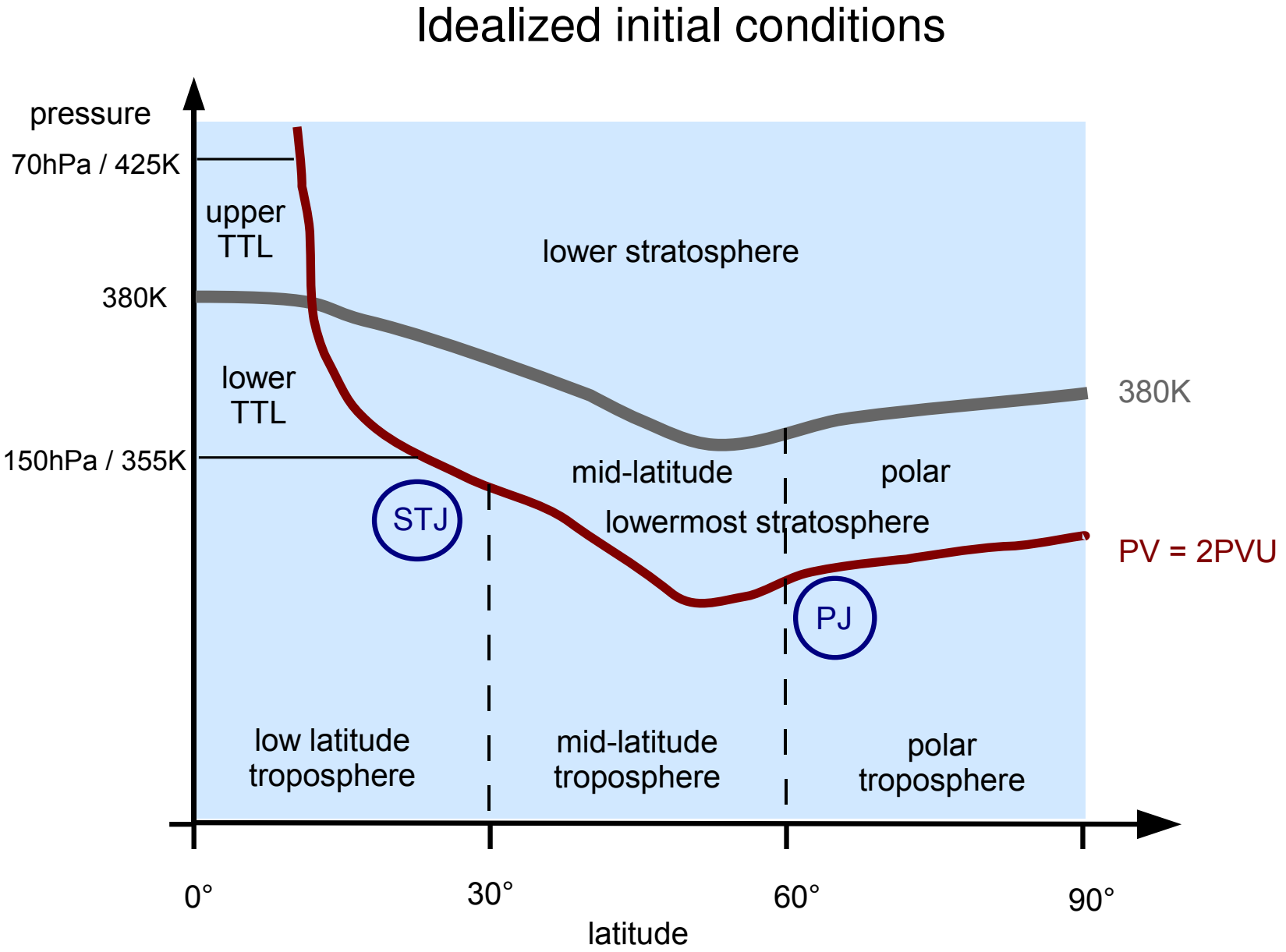
Mixing 3 occurred in air masses transported from the TTL into the stratosphere

Location of mixing regions in physical space

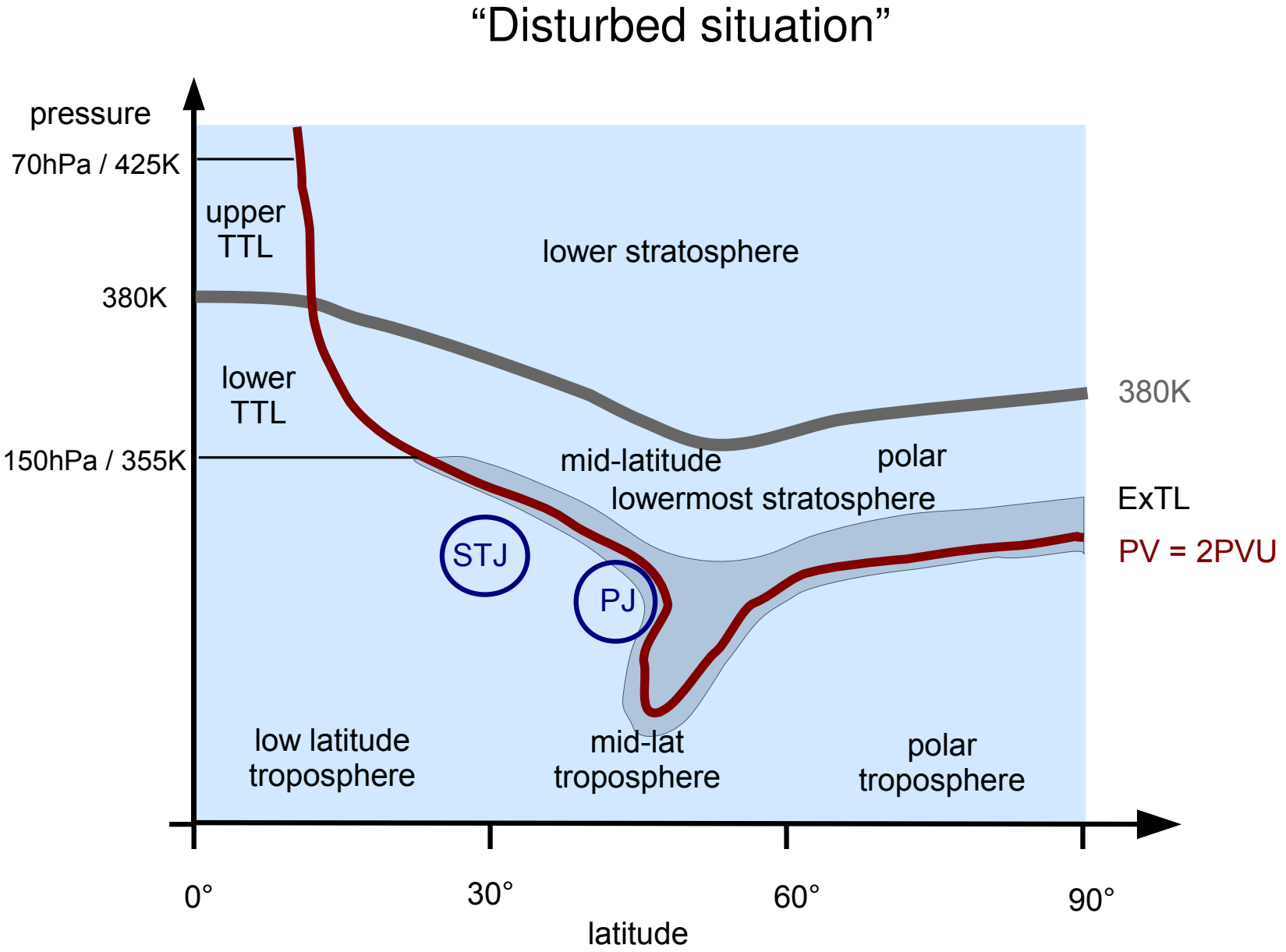


- Most mixing regions in CLaMS and observations agree
- mixing region 1 and 2 in CLaMS are at slight lower altitudes compared to observations

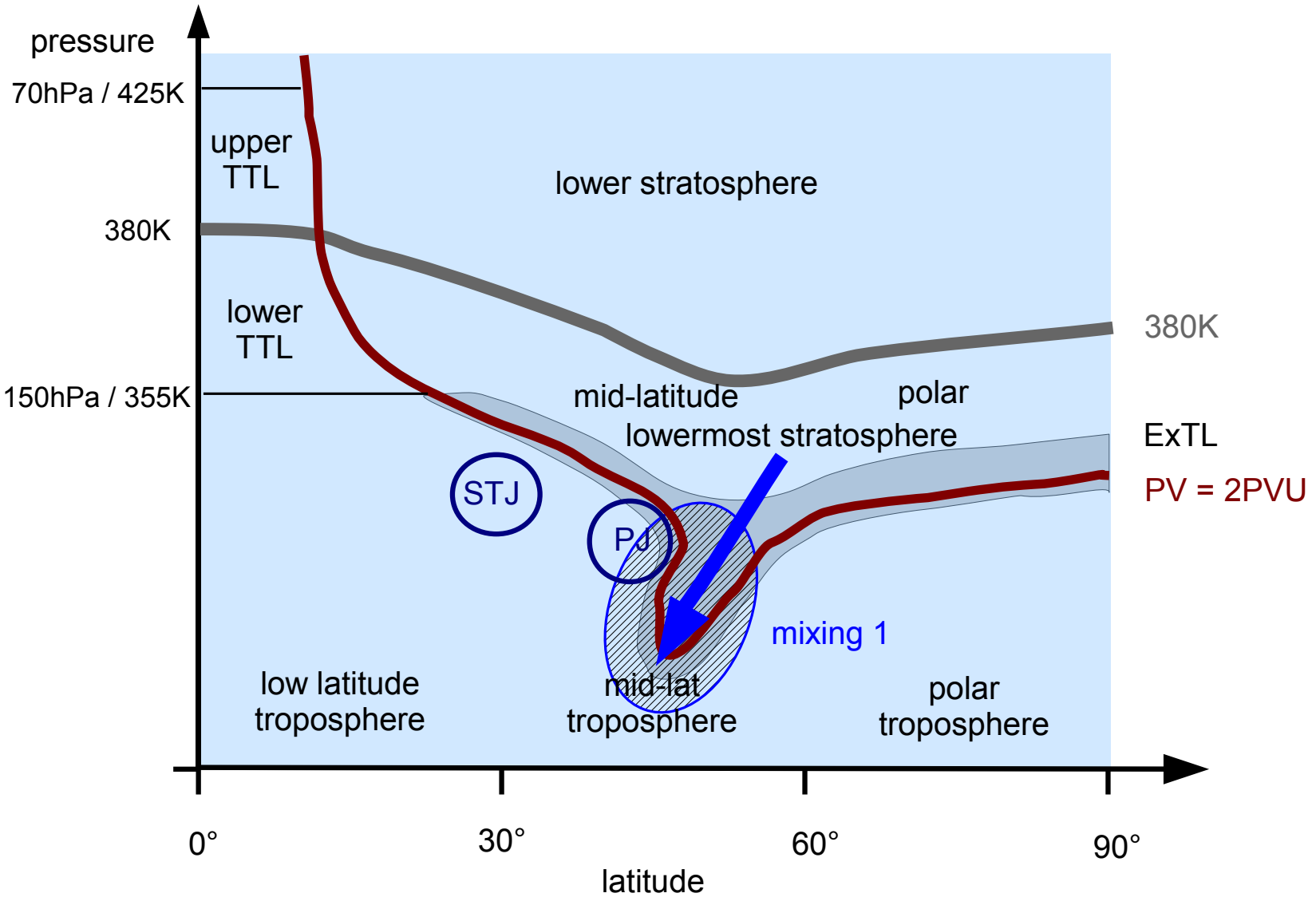
Results: transport pathways



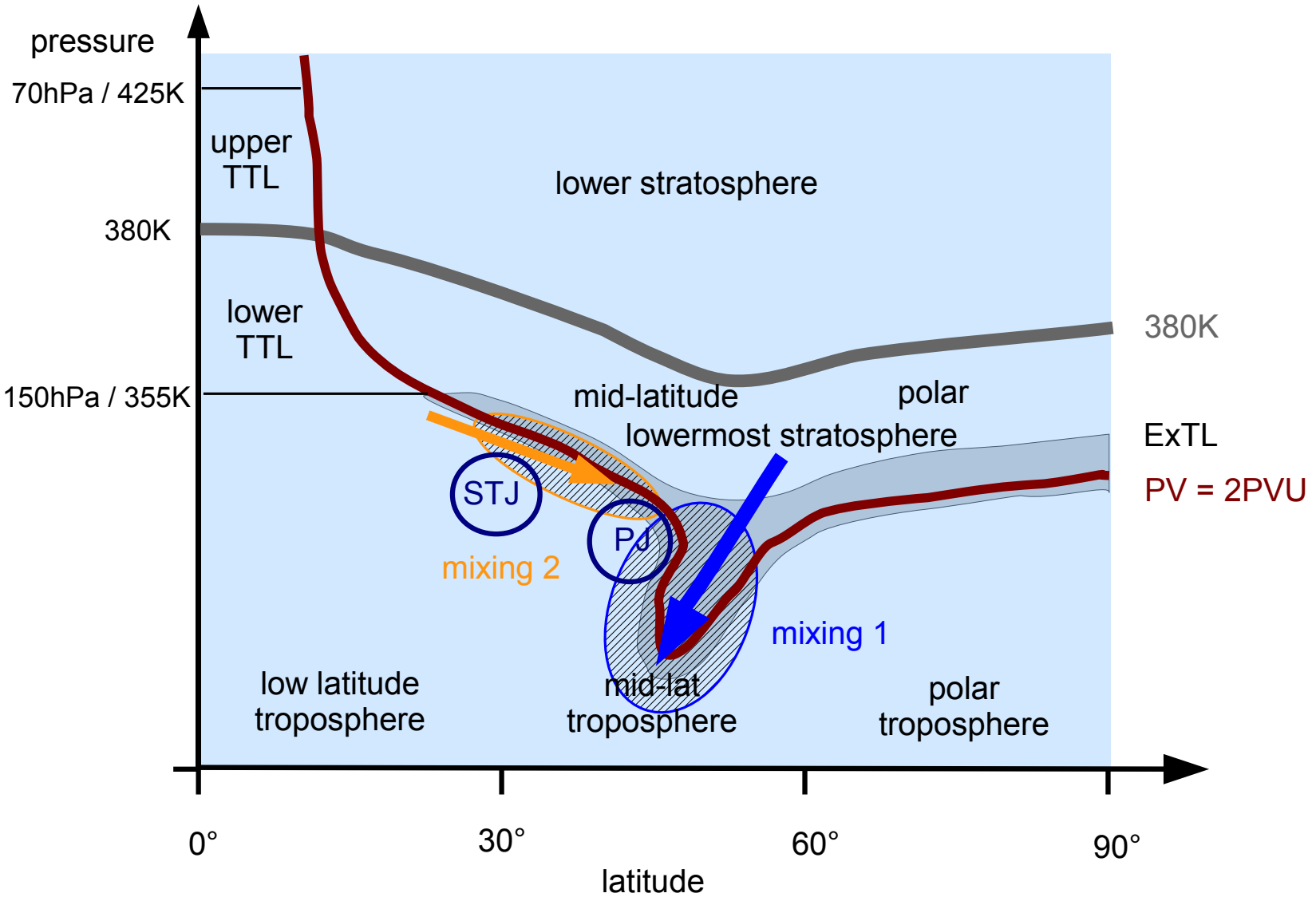
Results: transport pathways



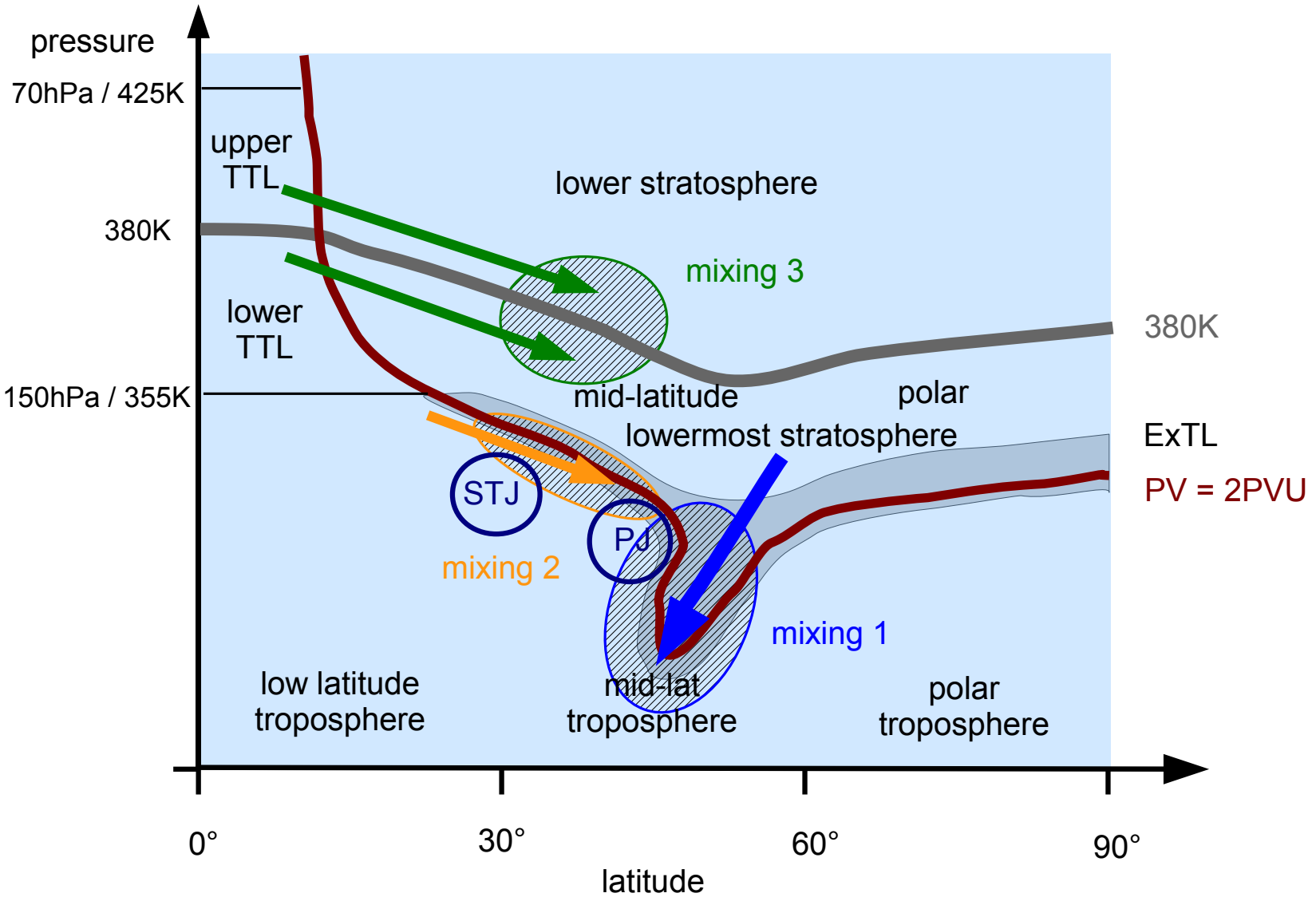
Results: transport pathways



Results: transport pathways



Results: transport pathways



Conclusions

Using tracers of air mass origin CLaMS gives information about

- fraction of air mass origin
- transport pathways
- time scales of mixing

- mixing processes within stratospheric intrusions (mixing 1) are influenced by air masses from the polar lowermost stratosphere and occurred within the last days
- mixing occurred at the dynamical tropopause (mixing 2) between air masses from the low latitude troposphere and the mid-latitude lowermost stratosphere
- deep tropospheric intrusions (mixing 3) originate in the TTL and mixing processes occurred with stratospheric air masses within the last 10 – 20 days