The tropopause inversion layer and its link to the mixing layer

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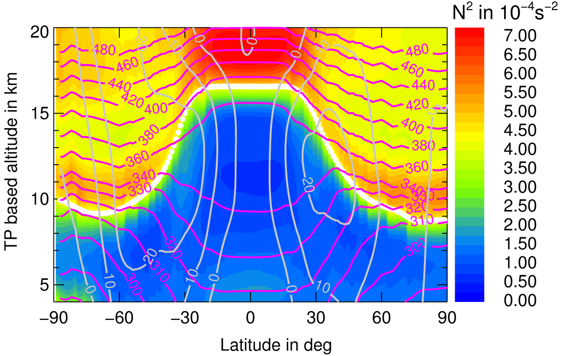
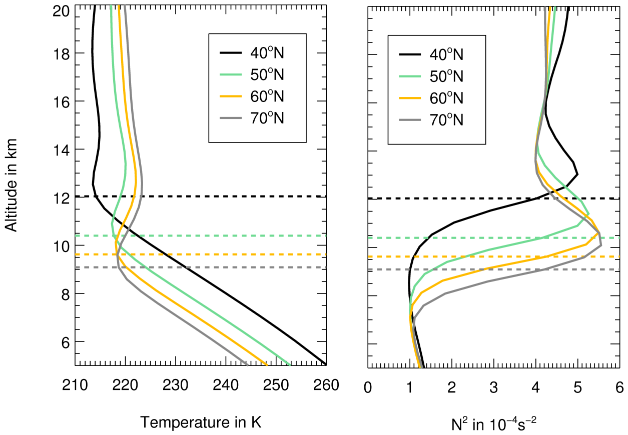
Zonal and time mean static stability N^2



- Brunt-Vaisala Frequency squared: $N^2 = \frac{g}{\theta} \cdot \partial_z \theta$
- ECMWF operational data ($\Delta_z^{TP} \sim 0.8 - 1.4\,\mathrm{km}$) at SPURT flight days

Zonal and time mean temperature and static stability



- Poleward intensification of the TIL

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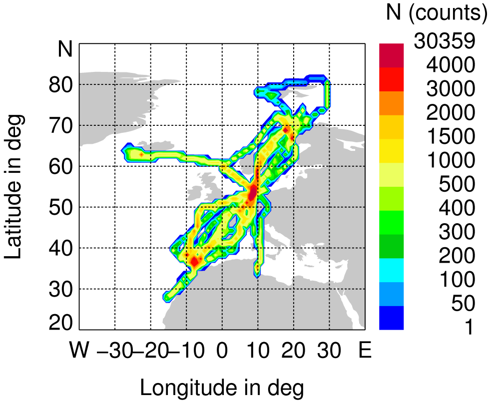
- Is there any relationship between the mixing and the high static stability above the extratropical tropopause?

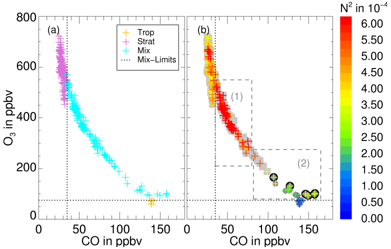
SPURT

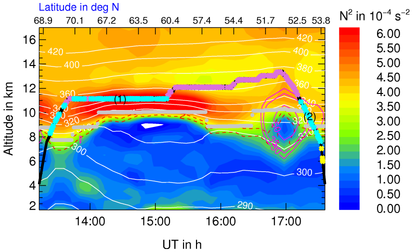
Trace gas transport in the tropopause region



- 8 campaigns: 11/2001–07/2003
- 36 flights
- 28°N – 80°N
- Ceiling altitude: 13.5 km

SPURT case study: Kiruna – Hohn (27.04.2003)

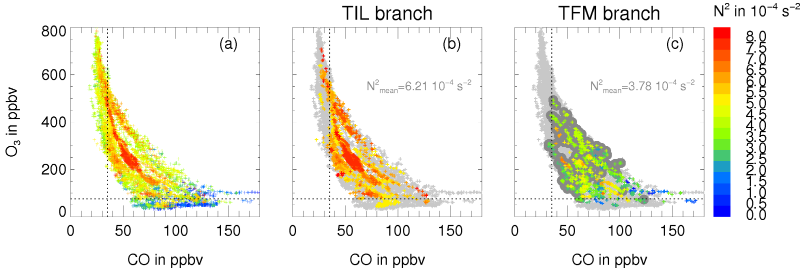




Two types of mixed air masses:

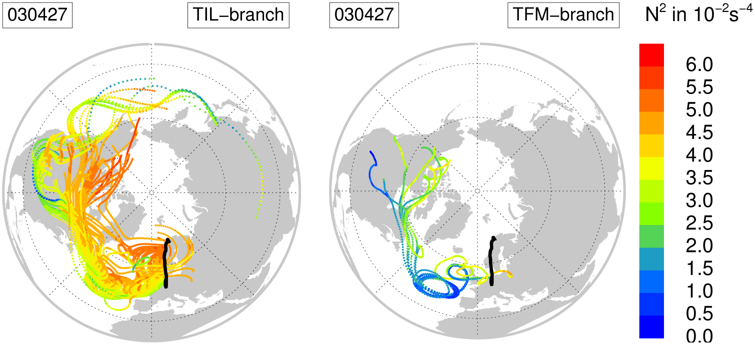
1. Above the thermal tropopause within the TIL with enhanced N^2
2. In the vicinity of the jet with little enhanced N^2 compared to tropospheric values

O_3–CO correlation of all SPURT data



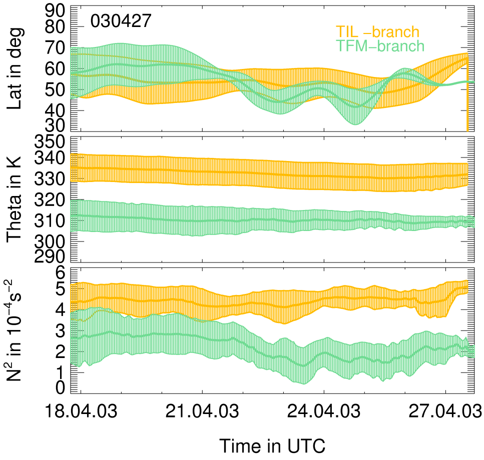
1. TIL branch:
   - Above thermal tropopause $\mathrm{TP_{th}}$
   - High static stability ($N^2 > 5 \cdot 10^{-4}\,\mathrm{s^{-2}}$)
   - Tropopause vicinity ($\mathrm{DTP} < 30\mathrm{K}$)
2. TFM branch:
   - Fresh mixing events (air from the Troposphere)
   - Between dynamical $\mathrm{TP_{dyn}}$ and thermal tropopause $\mathrm{TP_{th}}$

SPURT case study (27.04.2003): CLaMS 10 day backward trajectories



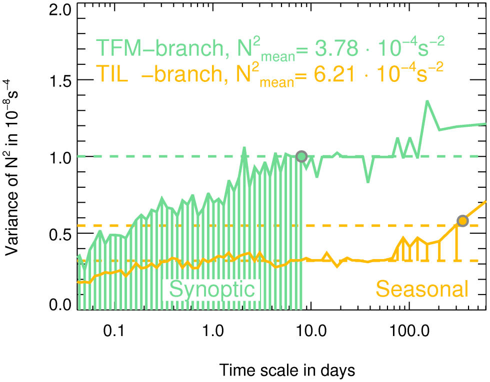
- 10 day trajectories of the TFM and TIL branches are within the midlatitudes

Mean 10 day backward trajectories from the TIL and TFM branch



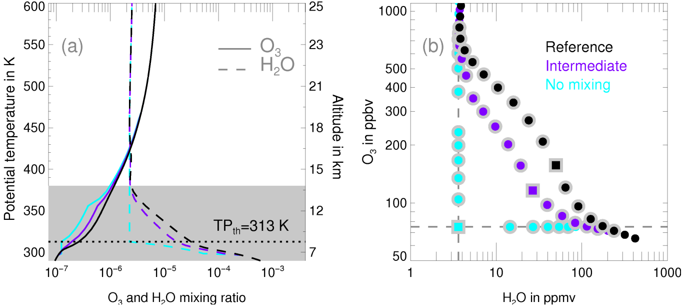
- Trajectories in the midlatitudes between 35–70°N
- Nearly isentropic transport: TIL branch ≈ 330–340K, TFM branch ≈ 310–320K
- N^2: TIL branch ≈ $3.5–5.5 \cdot 10^{-4} s^{-2}$, TFM branch ≈ $1.0–4.0 \cdot 10^{-4} s^{-2}$

Temporal variance analysis of N^2 during SPURT



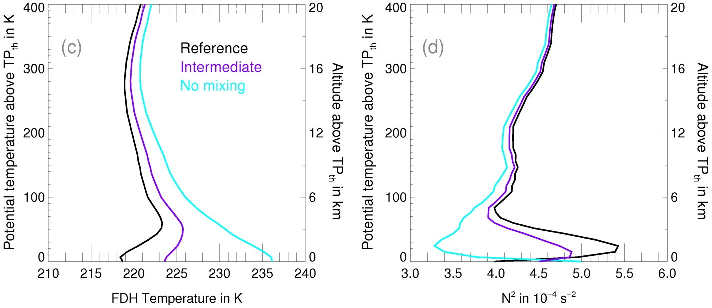
- TFM branch: Synoptic time scale (up to 8 days)
- TIL branch: Seasonal time scale (around 90 to 360 days)

ECMWF mean H_2O and O_3 at 60°N



- Consistent perturbation of H_2O and O_3 in the same altitude region by taking into account their correlation in the UT/LS.
- What is the impact of the perturbation on the temperature and N^2 above the tropopause?

FDH temperature and N^2



Mixing near the tropopause leads to:

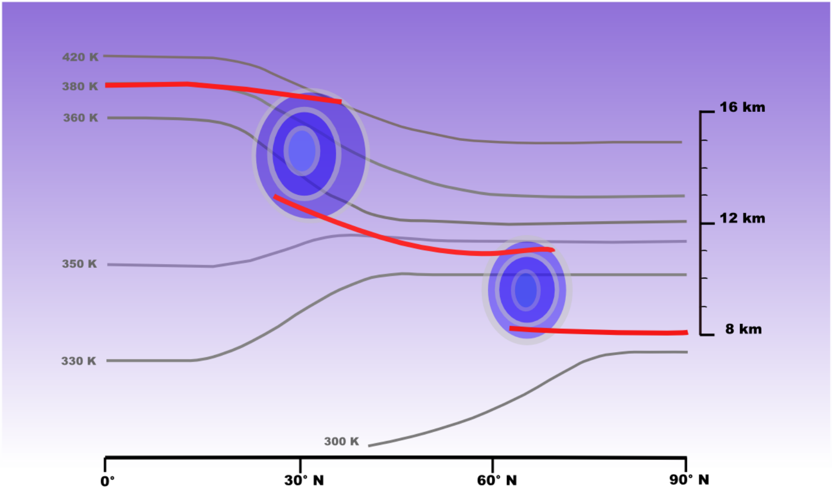
- Temperature reduction $(18\,\mathrm{K})$ and development of an inversion
- N^2 enhancement $(2.1 \cdot 10^{-4}\,\mathrm{s}^{-2})$ and development of the TIL

In case of non–mixed profiles the TIL vanishes

Results

- SPURT observations suggest a link between the TIL and the mixing layer in the extratropics. (Kunz et al. 2009, JGR)
- The mixing layer contains two types of air masses: TIL branch and TFM branch.
- Processes playing a role within the TIL may be on a seasonal rather than a synoptic time scale.
- FDH calculations substantiate the enhancement of N^2 with strengthened mixing. Radiative forcing may contribute to the maintenance of the TIL.

Conclusions



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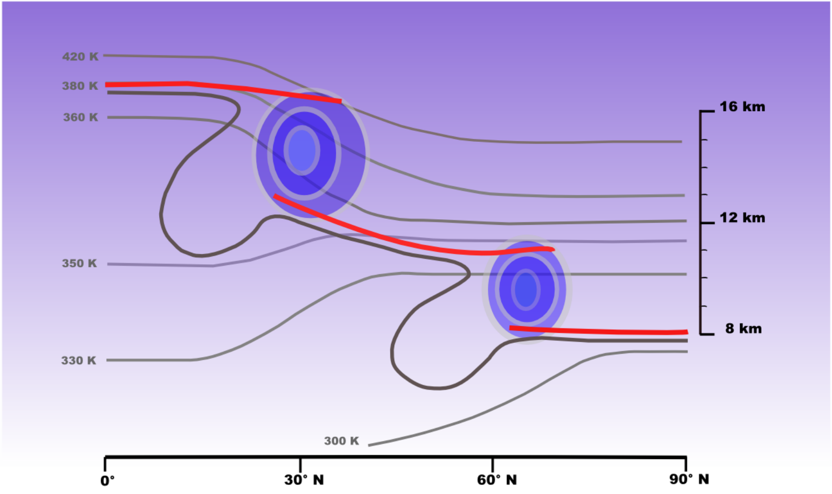

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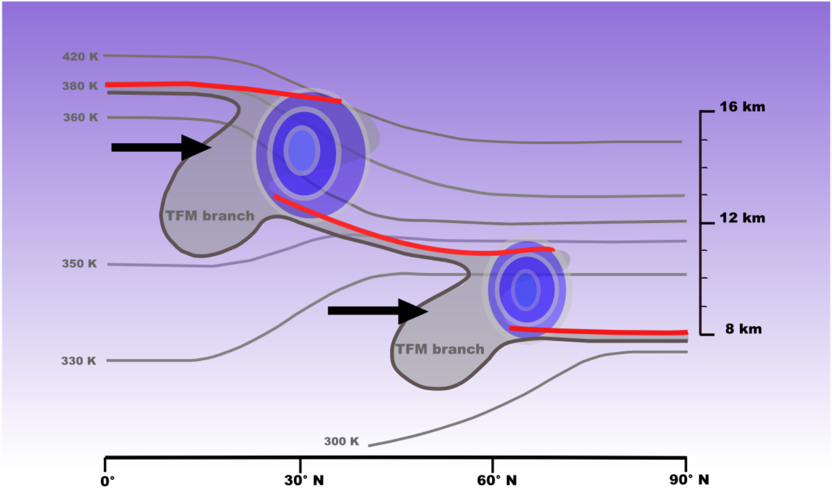

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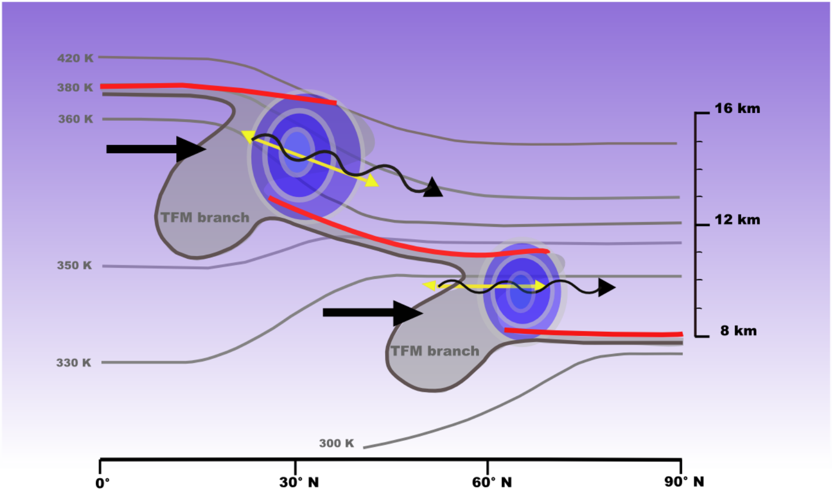

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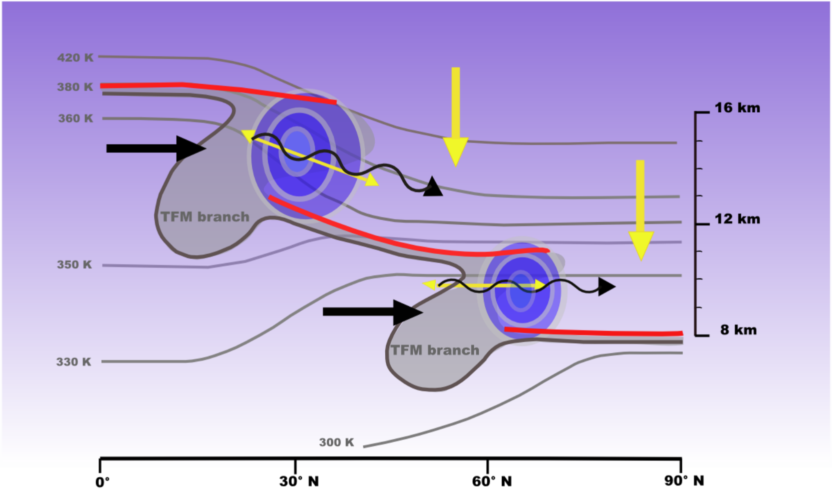

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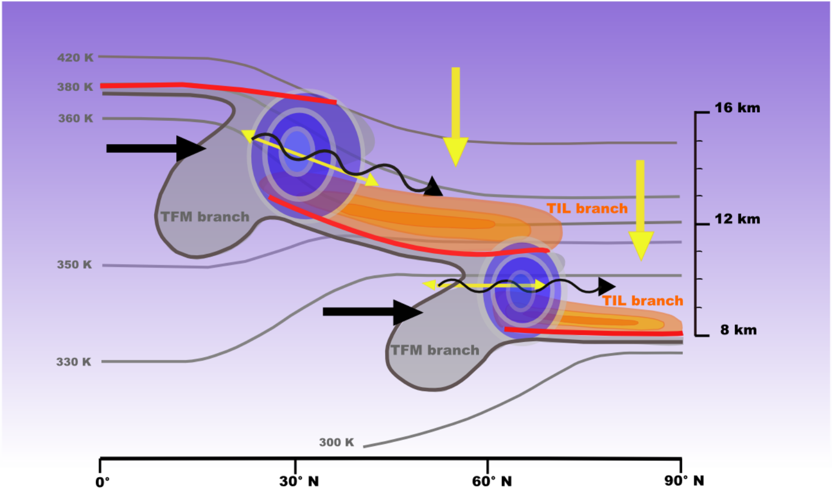

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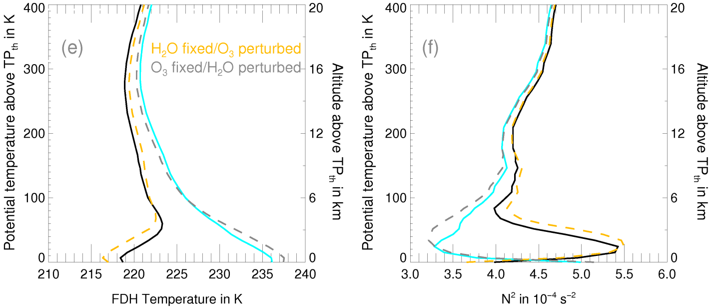
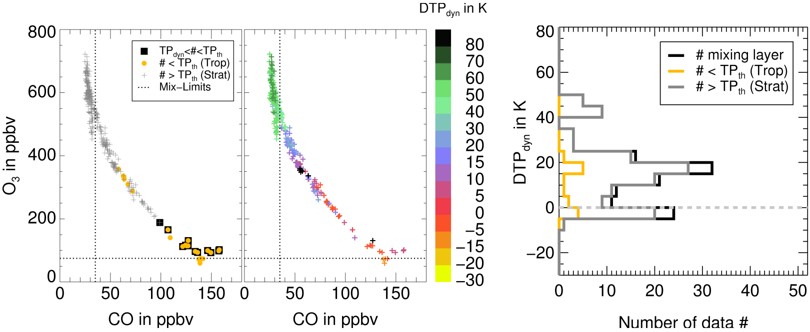


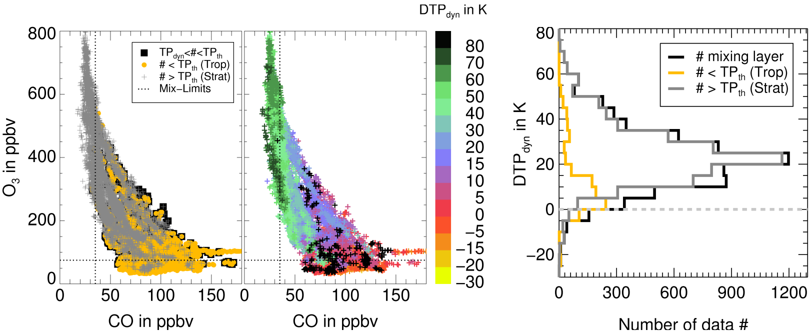
- H_2O is the major parameter in maintaining the temperature inversion and the TIL compared to O_3

SPURT case study (27.04.2003): Mixing layer relative to thermal and dynamical tropopause



- Mixed air masses in the vicinity of the jet stream are mainly above the dynamical and below the thermal tropopause

All SPURT data: Mixing layer relative to the thermal and dynamical tropopause



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