B01 Fine scale composition gradients and mixing at the tropopause region

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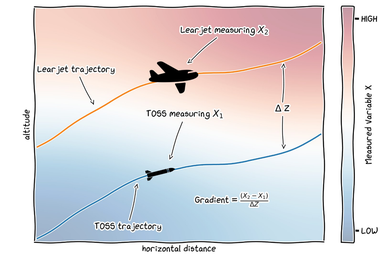
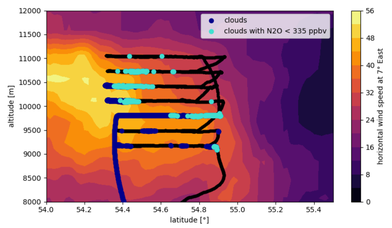
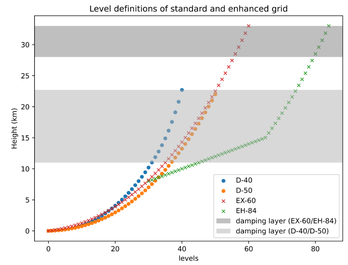
Motivation

Small-scale diabatic (i.e. **radiative** and/or **turbulent**) processes in the UTLS region may play a critical role in atmospheric transport and mixing and potential cross tropopause exchange, since they are not subject to the restrictions for adiabatic flow. This dynamical influence impacts the composition of the UTLS and shapes the **distribution of atmospheric constituents** such as ozone, water vapor and aerosol in this region.

The approach of B01 is to identify the driving processes via in situ measurements (TPC-TOSS, **Bozem et al., 2025**) as well as high resolution model simulations (MECO(n) and ICON).







Collaborations within TPChange

General contribution: Campaign data TPEx
– LEARJET: O_3, N_2O, CO, GPS and pressure
– TPC-TOSS: O_3, GPS and pressure

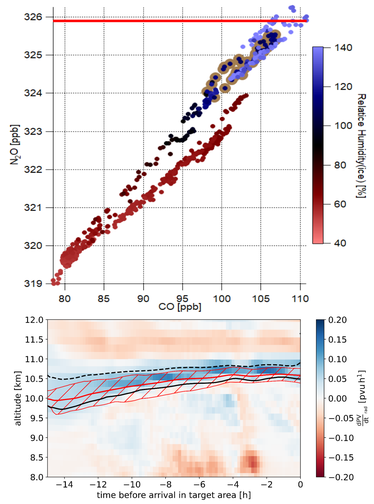
- **A04** Determination of chemical N_2O tropopause, linking aerosol observations with B01 analysis
- **A05** Organic aerosol fraction and identification of stratospheric air via TPEx O_3 data
- **A06** Aerosol morphology and cross tropopause exchange
- **B02** Comparison of gas phase and Aerosol composition
- **B08** ICON model simulations and analysis for TPC-TOSS case studies
- **Z01** TPEx observational data and positional data for interpolation
- **Z03** CAT mixing comparison between ICON and MECO(n), Representation of gradients and parameter evaluation

Results from phase I

Impact of cirrus on extratropical tropopause structure

Emig et al., 2025 (accepted for ACP)

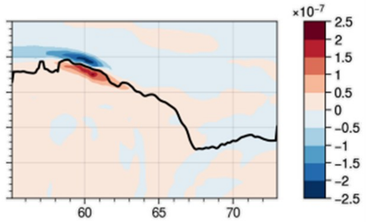
– Unique measurement technique: TOSS (Airtoss ICE campaign)
– Cirrus in chemically stratospheric air, supersaturated with respect to ice
– **Diabatic impact on dynamical structure: Weakening of the stratification**
– Lagrangian Analysis (ICON) in collaboration with project B08
  – Long residence times of cirrus particles, high humidity in UTLS airmass
  – PV production through radiative cooling



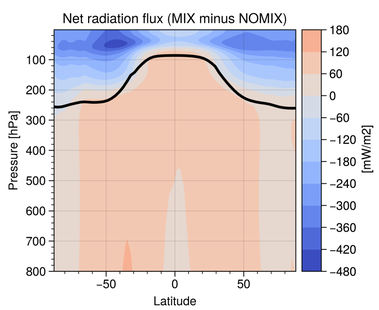
Simulated mixing by small-scale turbulence using multi-scale climate chemistry model MECO(n)

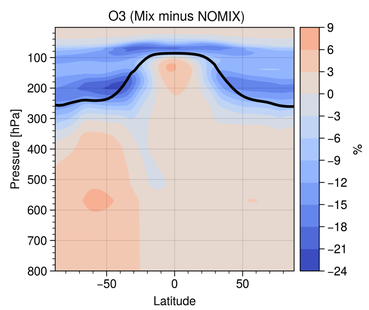
Chau et al., 2025 (accepted for ACP)

– Designed an enhanced vertical resolution setup for UTLS studies in MECO(n), with 200 m resolution between 8 to 15 km
– Novel diagnostic (delta tracer-tracer correlation) to determine the direction of the vertical mixing



– Development of new CAT (clear air turbulence) submodel to parameterize the vertical tracer mixing in EMAC
– Parameterizing CAT mixing using turbulence diagnostics
– **By applying the CAT submodel in a QCTM simulation, CAT mixing modifies UTLS radiative fluxes, mainly driven by ozone**





Research plan phase II

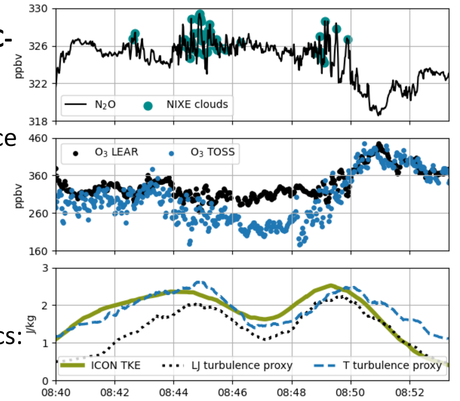
Main Goal: Quantify the impact of small-scale diabatics and turbulent mixing on chemical processing and composition of the tropopause region in synoptic-scale systems

B01 objectives

O1 **Measurements:** Composition modification by mixing events downwind of turbulence, shear, or cirrus close to the tropopause
O2 **Lagrangian** identification of **dynamical** processes and diabatics leading to mixing based on high resolution ICON data
O3 Evaluation of **chemical impact** and aerosol processing using **Eulerian** model system MECO(n) (→ phase III: ICON/MESSy)

High resolution double platform measurements (TPC-TOSS) and meteorological analysis (ICON):

- Measurements of turbulence and mixing effect on ozone
- Cross-TP transport of cirrus particles into subsaturated stratospheric air
- ICON analysis: Possible to analyze small-scale dynamics: consistent turbulence location and mixing



Lagrangian analysis tools as in phase I (see left results phase I)
Dynamical processes and PV budget (as in **Emig et al., 2025**)

Eulerian simulation by applying the novel MECO(n) development from phase I: Chemical processing from the case base and potential impact on global UTLS