C05 Large-Scale Structure & Variability of Lowermost Stratospheric Water Vapour

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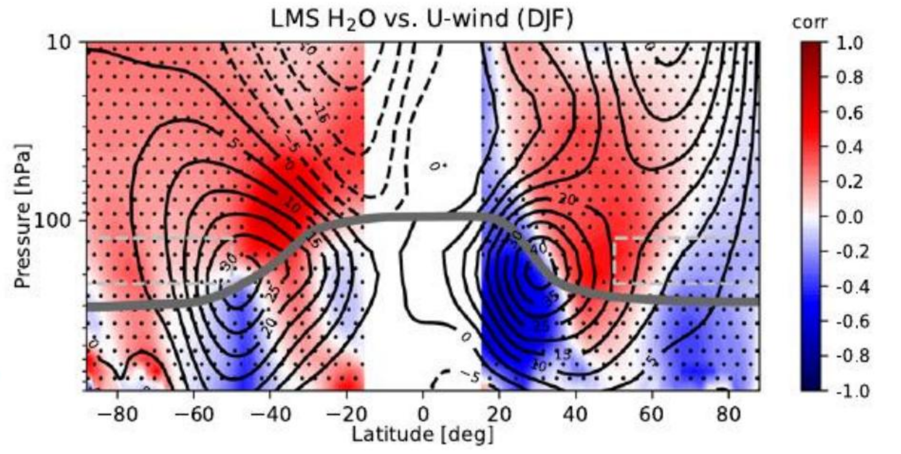
Motivation

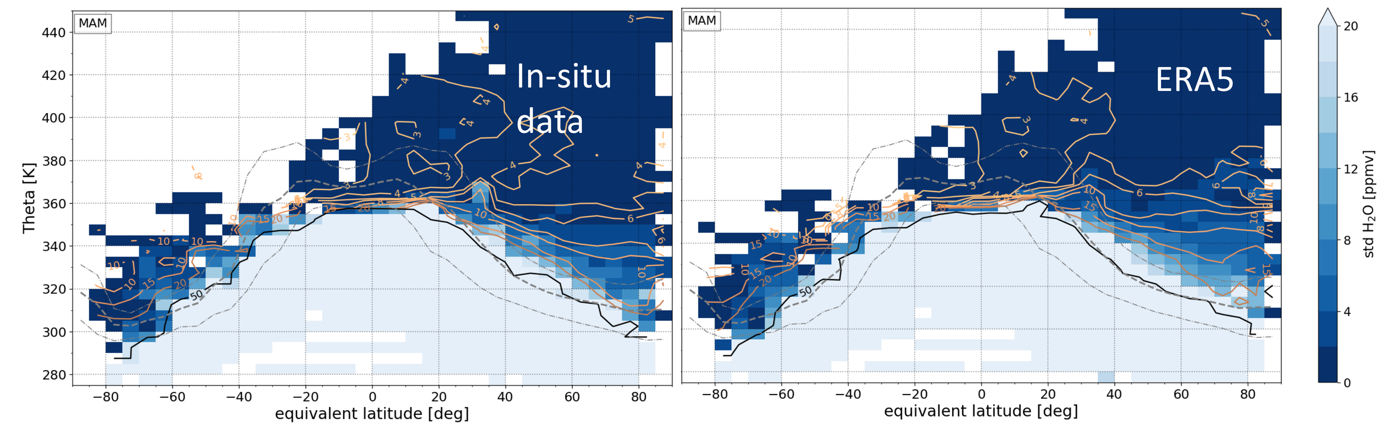
LowerMost Stratospheric (LMS) Water Vapour (WV):

- strong radiative effects, important but highly uncertain positive climate feedback with significant circulation feedbacks
- current climate models simulate large moist bias in LMS with corresponding circulation response (Charlesworth et al., 2023):



→ LMS-WV–zonal wind correlation map showing correlation coefficients between WV averaged over grey box and zonal mean zonal wind at each latitude-pressure grid point across climate models (for each hemisphere separately)

- in part controlled by transport, in part by temperature and microphysics → uncertainties & large sensitivities due to strong horizontal and vertical gradients near tropopause



LMS-WV–from multi campaign observations (left) and ERA5 along the flight tracks (right) for Northern Spring (March-April-May): bin variability (shading) and mean (contour lines)

➡ **Need for improved characterisation of large-scale structure & variability of LMS-WV**

Role within TPChange

Collaborations

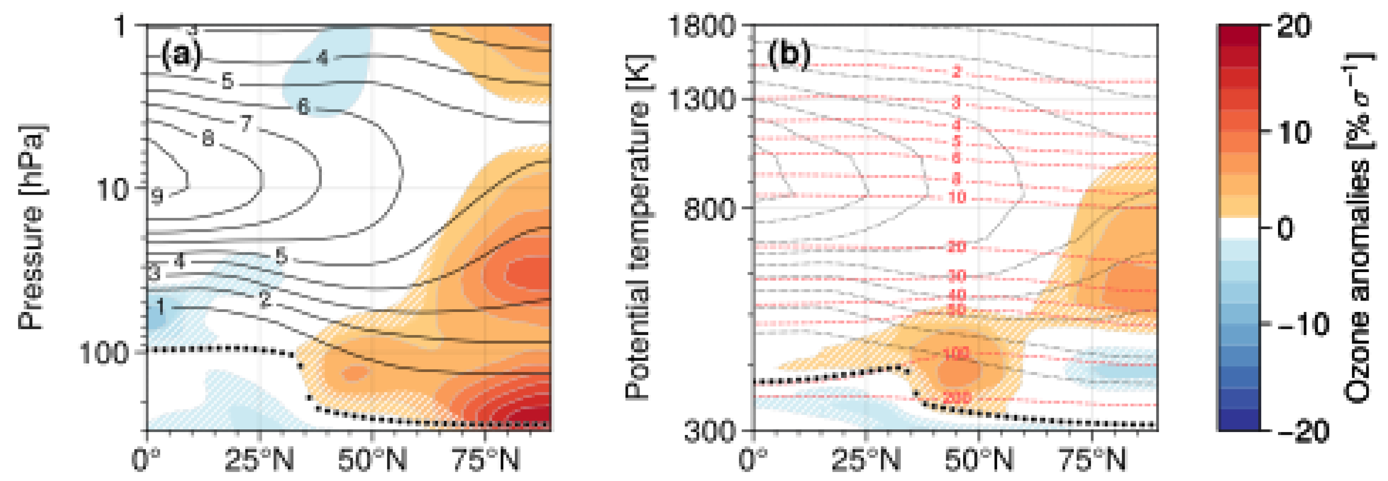
- **B09** Transport terms of model runs, interpretation of our results
- **C01** IAGOS-Core water vapour climatologies
- **C02** downwelling into LMS, source due to methane oxidation
- **C03** CLaMS transport evaluation, joint interpretation of results
- **C07** EMAC MECO(n), ICON-MESSy: H2O variability evaluation
- **C08** Convective transport and UTLS H2O in EMAC/ICON-MESSy

Contribution to TPChange synthesis

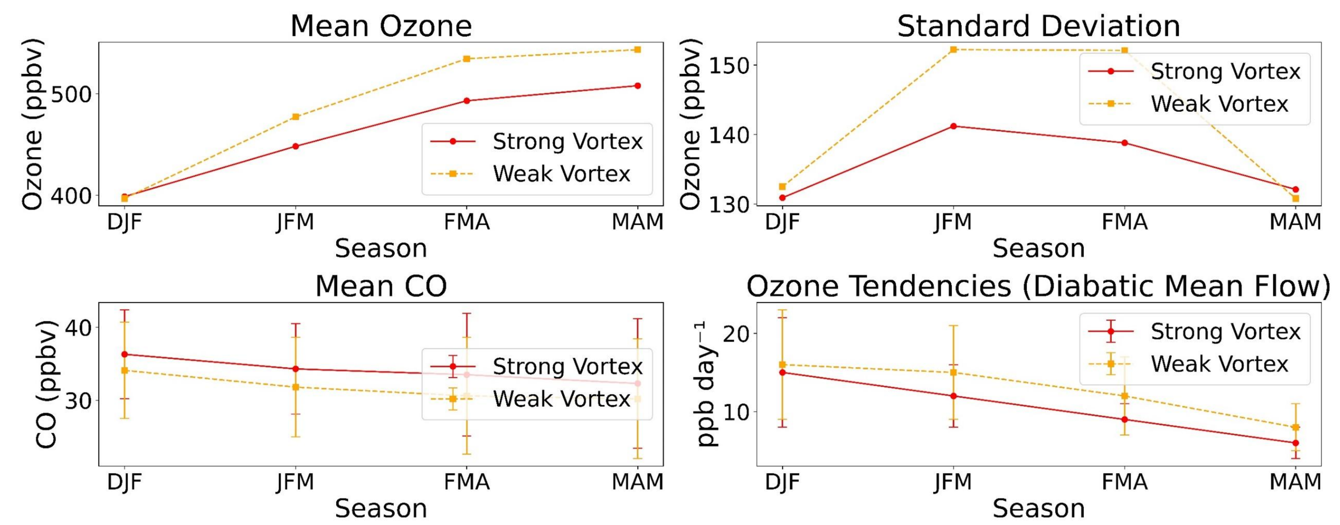
- **Z03** diagnostics/metrics for model evaluation & potential future water vapour bias correction
- **Z01** use of TPC data base for H2O and hygropause diagnostics

Results from phase I

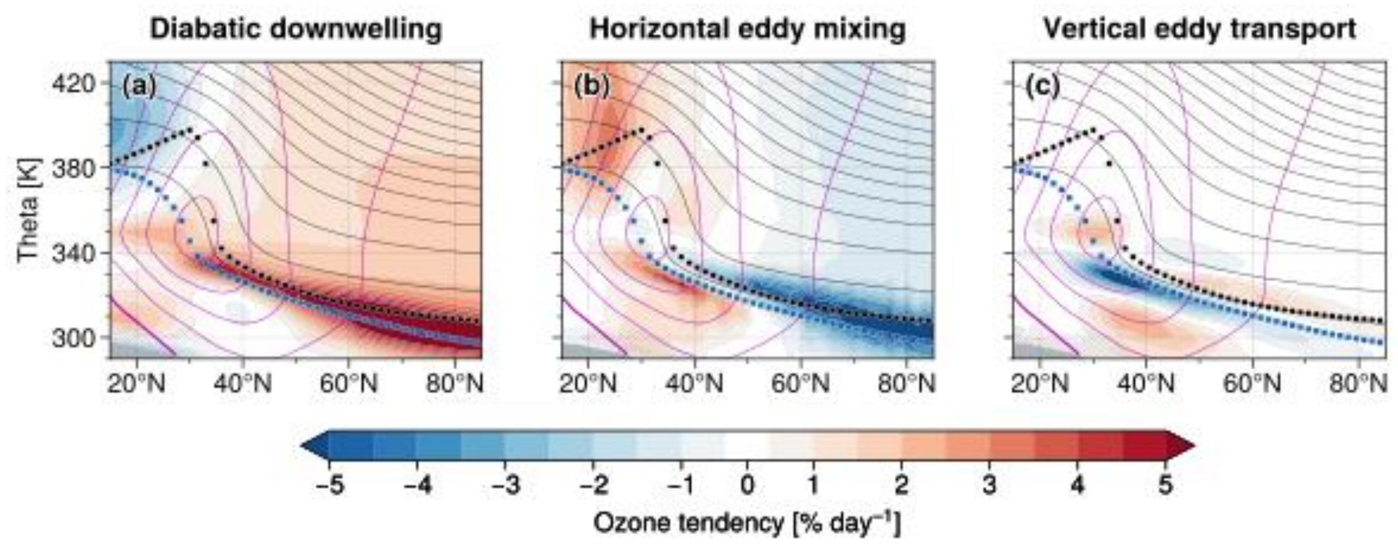
- Improved characterisation of large-scale LMS-Ozone structure and interannual variability in observations, reanalyses, models:
  - interannual co-variability of ozone with polar vortex strength shows complex response pattern (Harzer et al., 2023):



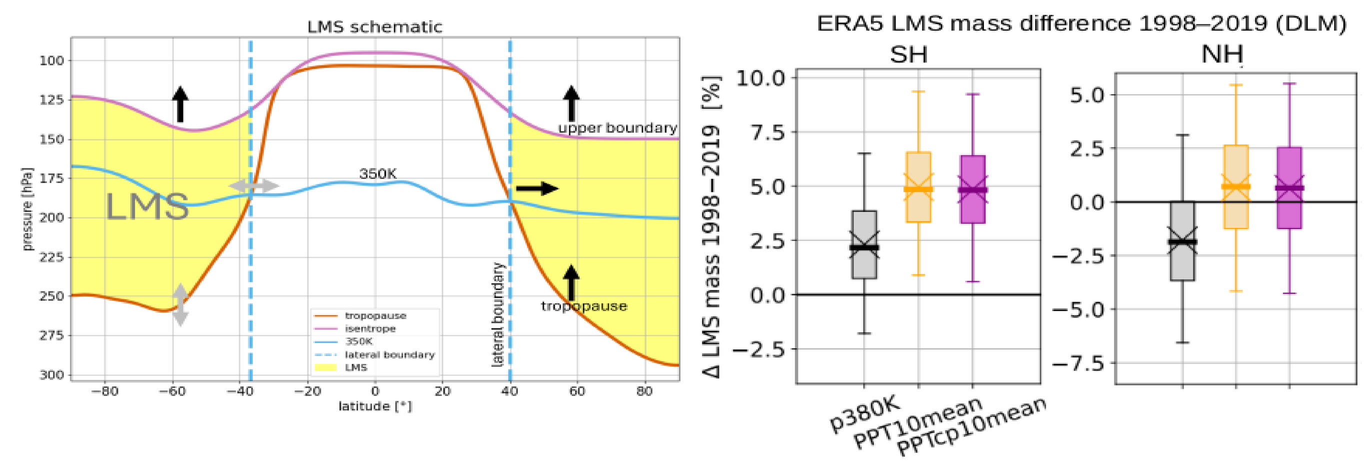
  - Observed impact of polar vortex variability and associated downwelling on LMS composition from IAGOS-CARIBIC data:



  - Interannual co-variability of position & strength of subtropical jet and subtropical ozone gradients (Harzer et al., 2025a)
  - Transport contributions to ozone budget in isentropic coordinates (Harzer et al., 2025b):



  - Recent LMS mass trends from ERA5 (Weyland et al., 2025):



Research plan phase II

Research Goal:

Reveal the physical drivers of the large scale structure and variability of LMS-WV from a combined observational, reanalysis and climate modelling approach

- Specific research questions:
  - Q1) What are the relative contributions of various transport processes to the LMS-WV budget in reanalyses and climate models?
  - Q2) How does LMS-WV vary spatially at synoptic to planetary scales, and temporally at seasonal to interannual scales and what are the driving processes of these variations?
  - Q3) How can we identify and diagnose the distribution ov LMS-WV in observations, reanalyses and models?
  - Q4) Can we identify potential drivers of LMS-WV biases in observations, reanalyses and models related to transport variability?
- Strategy:
  - Combined analyses of aircraft measurements, ERA5, models in quasi-conservative coordinates (potential temperature, equivalent latitude)
  - Leverage tracer budget framework in isentropic coordinates (phase 1)

Workpackages

- WP1: Climatological-mean aspects in observations, reanalysis aand models
- WP2: Regional, seasonal and Interannual variability of LMS-WV
- WP3: Toward identifying causes of model biases & their variability