C09(N) Role of the representation of gravity waves for downward transport into the UTLS

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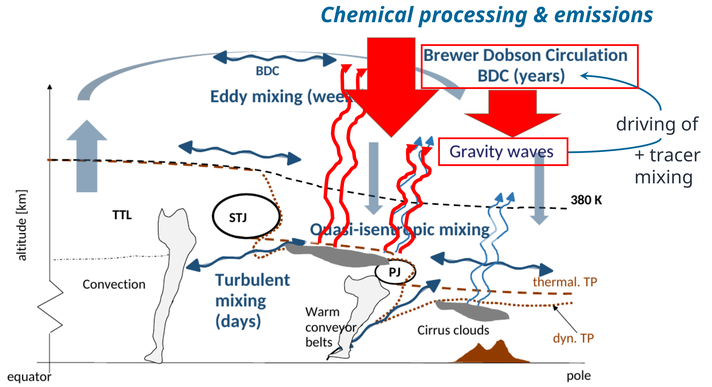
Motivation



– **UTLS air mass is mixture** of air from troposphere, from tropical stratosphere and **from deep stratosphere**. The latter **is chemically processed** and thus has a **distinct composition** (e.g. methane oxidation -> water vapour source). It also carries emissions from natural (e.g. meteoric dust) and anthropogenic sources (e.g., ablation of space debris).

– Downward transport from deep stratosphere is **wave-driven**, with a large contribution by **gravity waves**. Those are represented in global models in parameterizations with simplified assumptions, posing a **large uncertainty**

-> Here: How sensitive is UTLS composition to downward transport from the deep stratosphere / mesosphere?

Collaborations within TPChange

- **B06** Joint use of MS-GWaM gravity wave parameterization in the UA-ICON model
- **C02** Comparison to observations of methane fractional release and age-of-air compiled by project C02
- **C03** Comparison of transport times to model simulations conducted by C03 with different transport schemes (Eulerian vs. Lagrangian), and joint interpretation of H2O in the LS
- **Z03** Synthesize different model components (tracer utilities in MESSy, MS-GWaM param.) in one ICON/MESSy model set-up

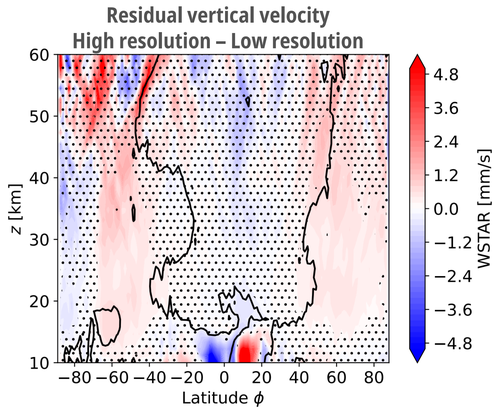
Preliminary work

– Recently**, progress in the representation of gravity waves** in global models through

A) models resolving part of the gravity wave spectrum

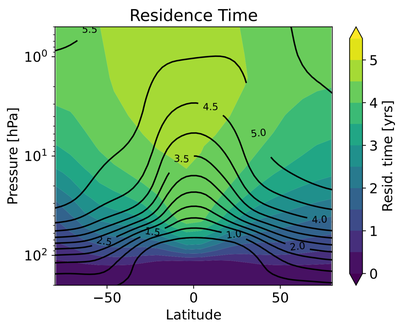
B) advanced gravity wave parameterizations (MS-GWAM, see B06)

-> Impact on the simulation of high-latitude downwelling



Difference in residual vertical velocity w^* between UA-ICON simulation with high- and low-resolution for mid-August to September (stippling: non-significant).
Data from Garny (2025)

– Metrics to asses and evaluate **impact on UTLS composition?**
-> Transport times and fractional release

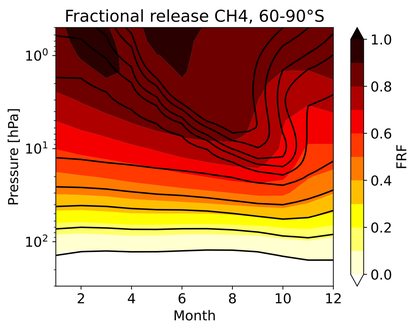


Integrated transport times from troposphere to stratosphere measured by „age-of-air“ (black contours), and from stratosphere to tropopause by „residence time“ (colors; data from EMAC simulations).

Age-of-air can be observationally constrained, but not residence times -> explore their non-trivial relation

Chemical processing is measured by „fractional release factor“ -> FRF of CH4 gives amount of water vapor stemming from deep stratosphere

Downward transport maximizes in winter high-latitudes, imprinted in FRF of CH4 (colors; data from EMAC simulation), and in relative difference of age-of-air derived from SF6 to ideal age-of-air (black contours, ranging from 0.01 to 1)



Research plan phase II

Main goal: Testing whether an advanced representation of gravity waves leads to improvements in the simulation of UTLS composition through more realistic simulation of downwelling from the deep stratosphere

Question 1: How sensitive is the middle atmospheric circulation to the representation of gravity waves?

Dedicated sensitivity simulations with UA-ICON with three different set-ups:

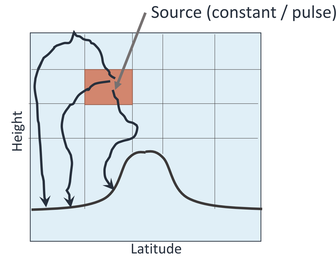
Low-resolution model	High-resolution model	Low-resolution model + advanced param. MS-GWAM
dx = 160 km, 120 vertical levels to top of 150 km	dx = 20 km, 250 vertical levels to top of 150 km	as on left (low-resolution)

-> analysis of residual circulation and its wave-driving

Question 2: What are the transport times from the deep stratosphere / mesosphere to the UTLS?

-> analysis of species-dependent (mean) residence time for sources in the middle atmosphere by implementing idealized tracers (with gas / particle properties) in the three set-ups

-> Additionally, set-up to include mixing by gravity waves (in MS-GWaM, see B06)



Question 3: How does the different representation of downwelling impact UTLS composition?

-> implement realistic tracers H2O / CH4 and SF6 (with simplified chemistry, e.g. methane oxidation, SF6 depletion)

-> Quantify contribution of UTLS water vapor from methane oxidation via fractional release factors

-> Evaluation by comparison to observations of CH4 FRF, and of age-of-air from SF6 versus CO2 (from C02 project)