Mountain wave induced transport of water vapor across the tropopause (DEEPWAVE campaign)

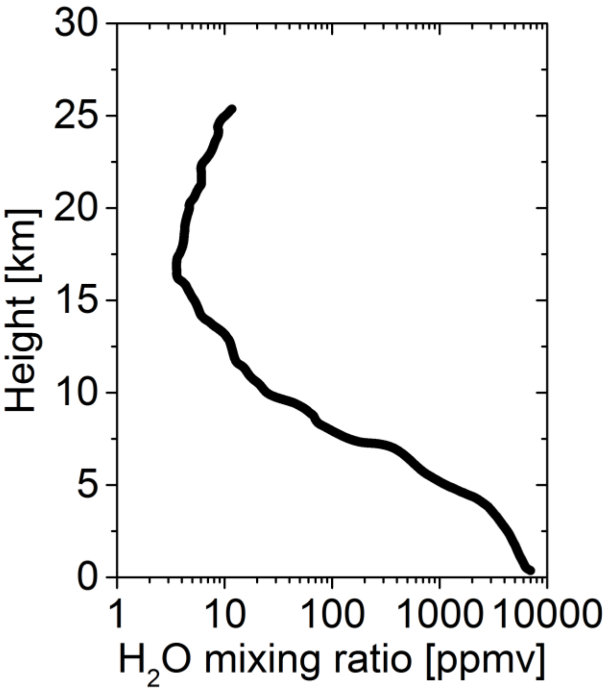
SPARC Gravity Wave Symposium 2016
18th May 2016

Romy Schlage[1], Stuart Beaton[2], Andreas Dörnbrack[1], Stefan Kaufmann[1], Markus Rapp[1], Johannes Wagner[1], Christiane Voigt[1]

[1] DLR, Germany
[2] NCAR, USA

Why looking into gravity wave induced water vapor transport?

Changes in the distribution of climate sensitive gases have a strong impact on radiation budget of the UTLS and on surface temperatures



Water vapor profile in the atmosphere

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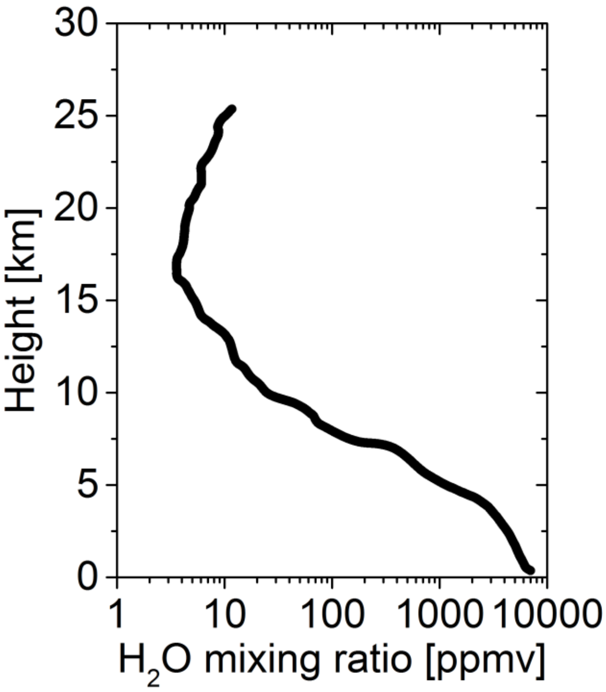
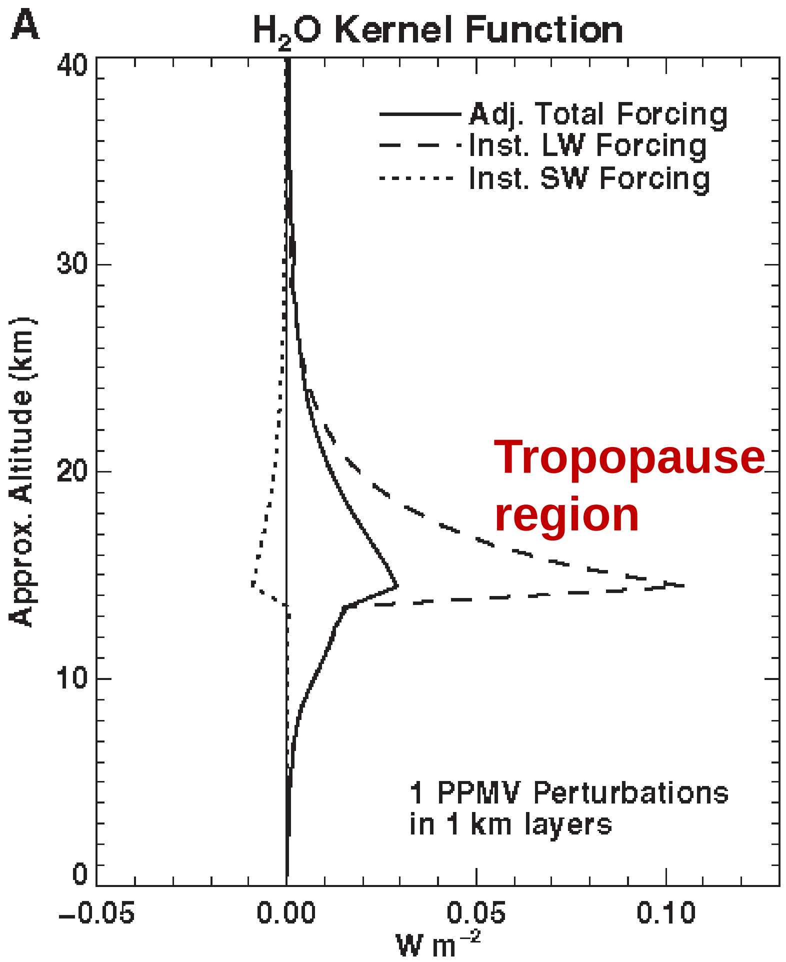


Water vapor profile in the atmosphere



Solomon et al., 2010

Measurements during DEEPWAVE

Meteo data

Gas phase H_2O:
CR-2 dewpoint mirror

DLR Falcon-20

NSF/NCAR GV Hiaper

Gas phase H_2O:
VCSEL
Vertical-cavity surface-emitting laser (open path)

VCSEL data by Stuart Beaton

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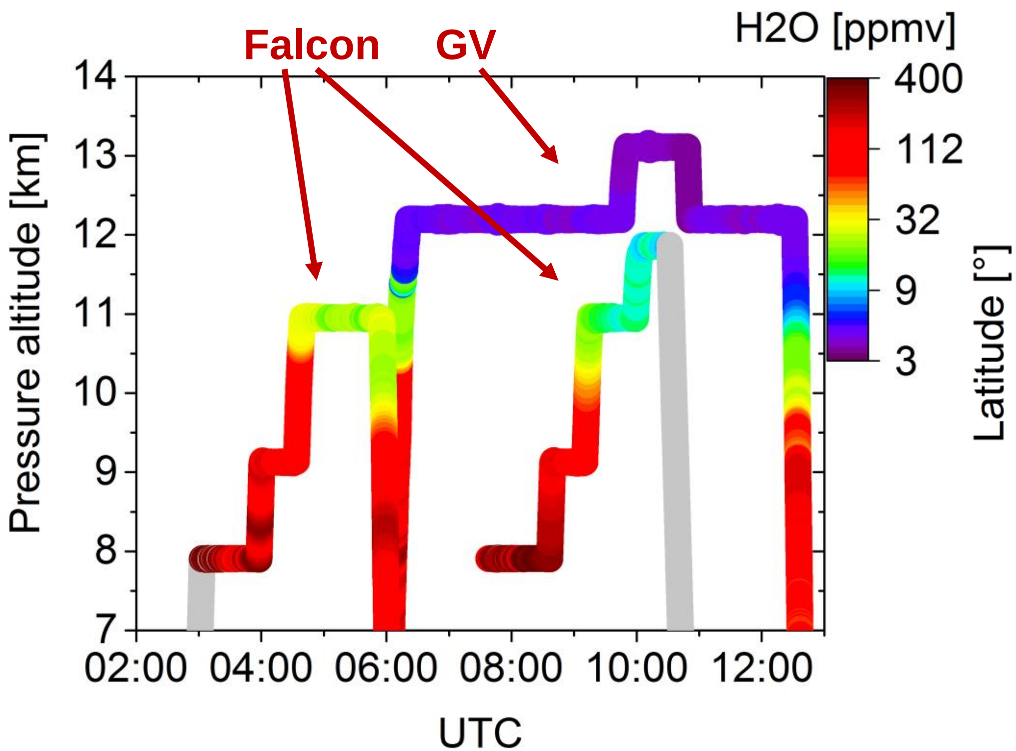
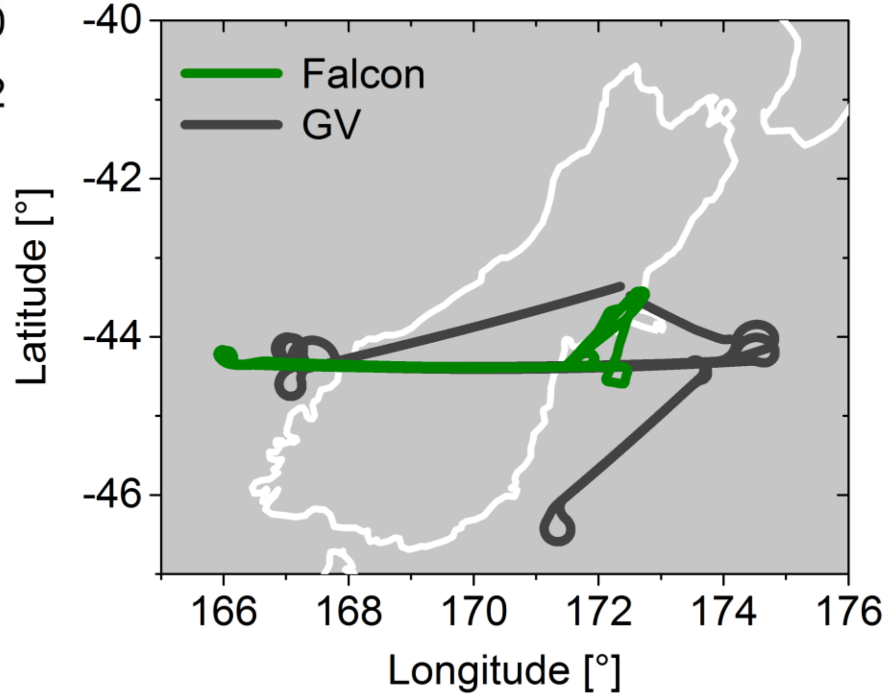
Case study on 4th July 2014

- GW event with strongest energy fluxes during the DEEPWAVE campaign
- Coordinated flights of Falcon & GV

Water vapor distribution: CR-2 (Falcon) and VCSEL (GV)





Vertical water vapor flux

Fluctuation $q'(t) = q(t) - \bar{q}$ $q(t)$ … measurement, $\bar{q}$ … running mean

Vertical flux $\overline{w'q'} = \frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} q'(t) \cdot w'(t) dt$

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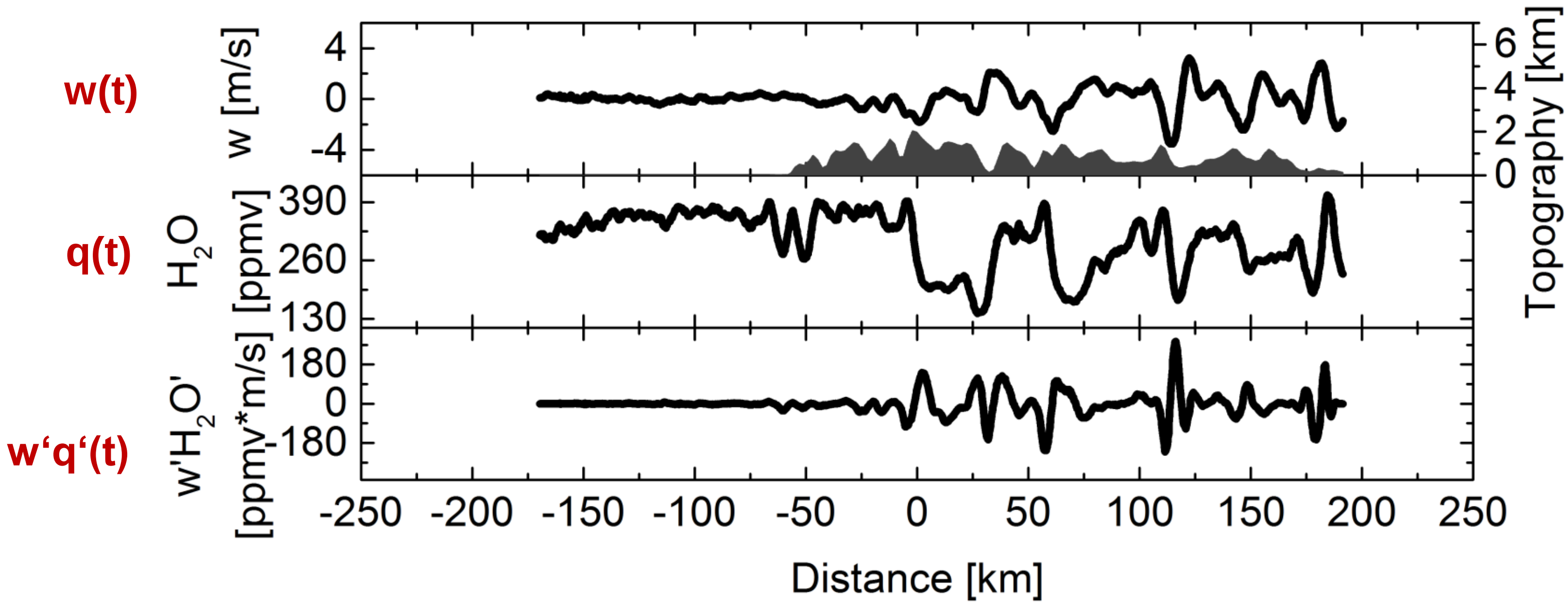
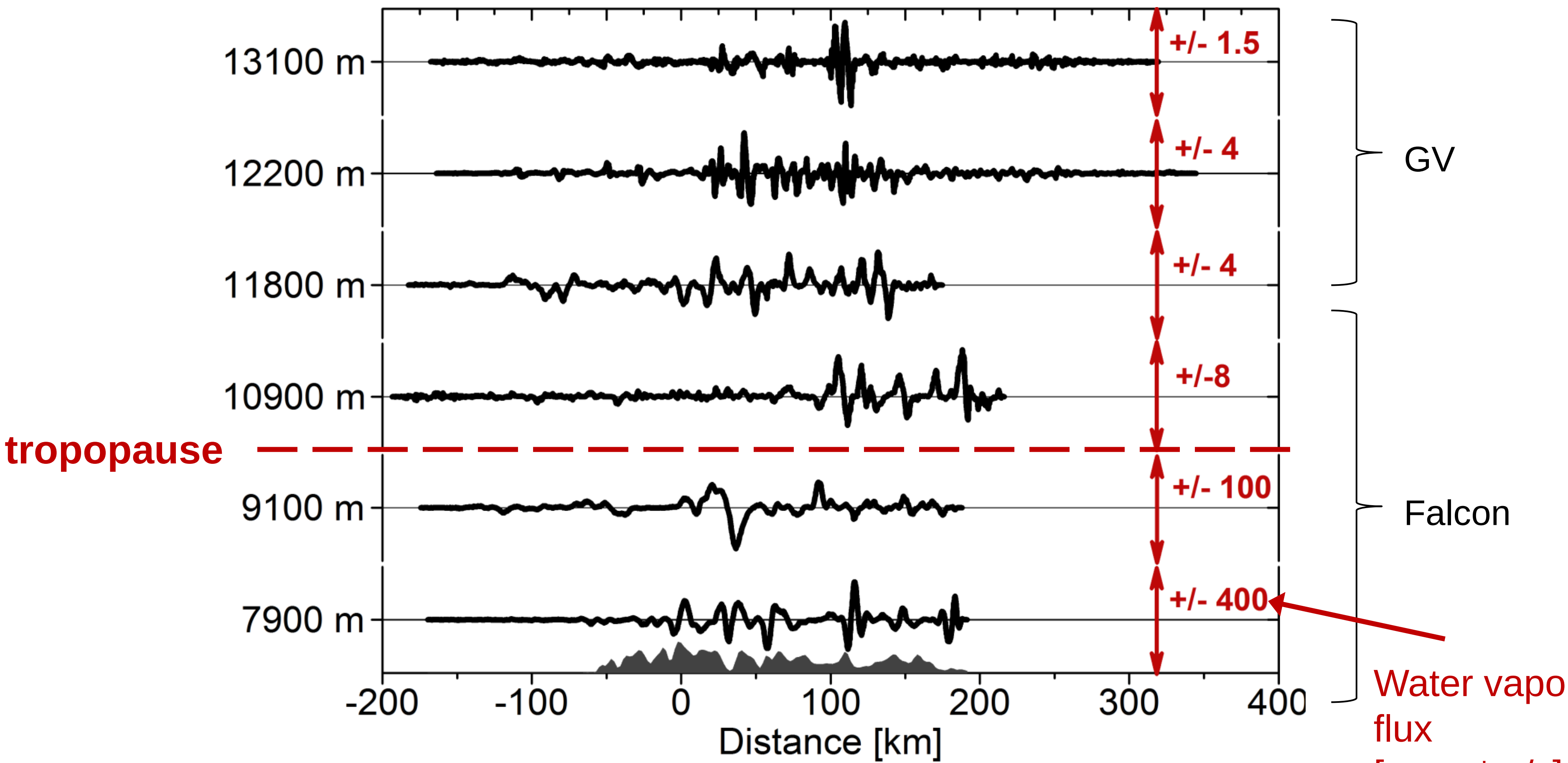
Example for FF05: Leg 1 @ ~ 8 km



Water vapor fluxes from Falcon FF05 and GV RF16



- Up- and downstream region: no significant water vapor flux
- waves are propagating through tropopause

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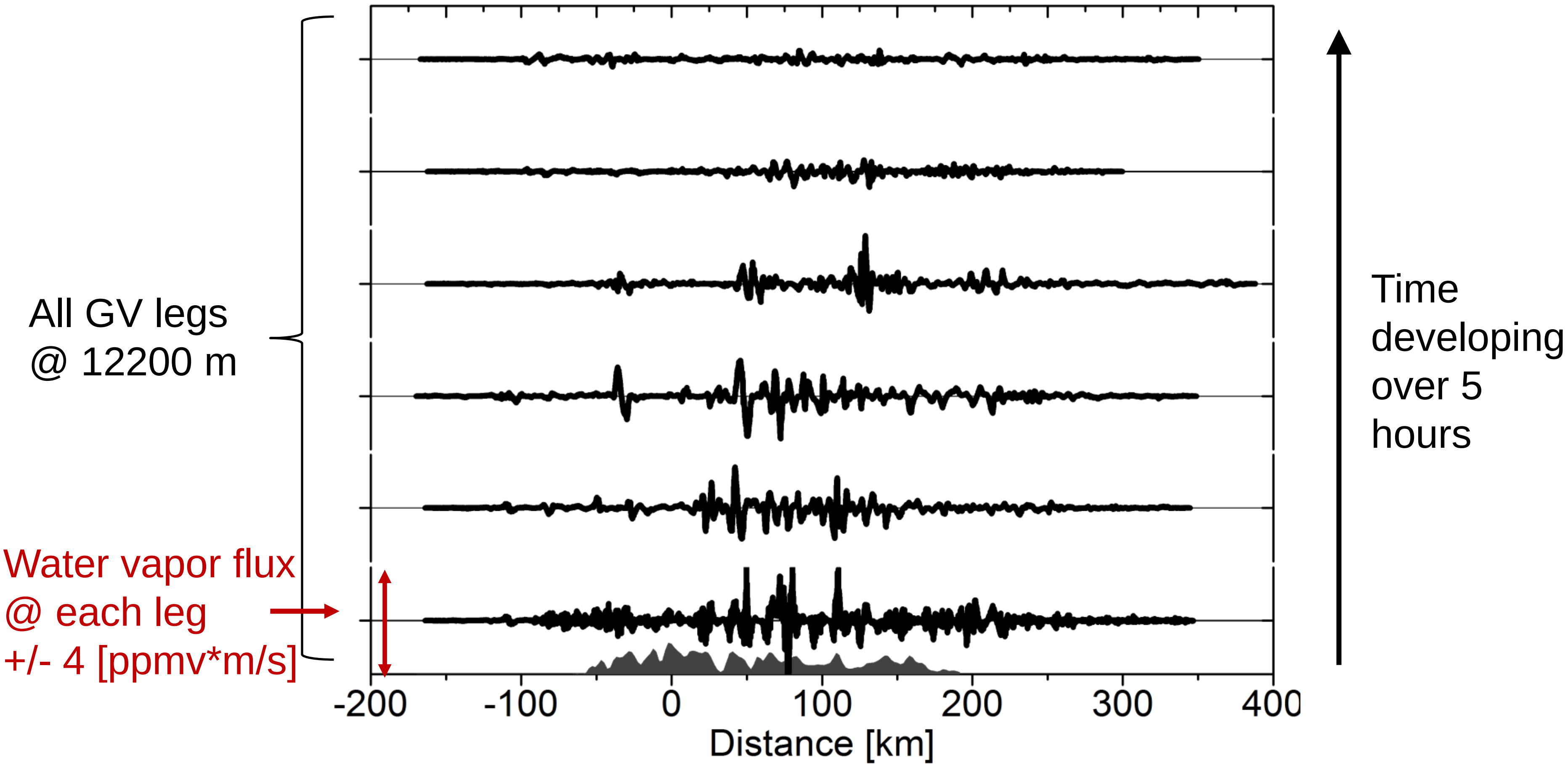
Water vapor fluxes from Falcon FF05 and GV RF16



- Amplitude decreases with time → gravity wave event weakened

Mean water vapor fluxes

- Vertical mean flux over whole legs is small but high local max. and min. values show significant transport
- Tendency indicates mixing processes but scale cannot be resolved by the measurements

FF05	**Mean vertical H_2O flux [ppmv*m/s]**
Leg1	-3.19
Leg2	0.78
Leg3	0.17
Leg4	(-0.002)

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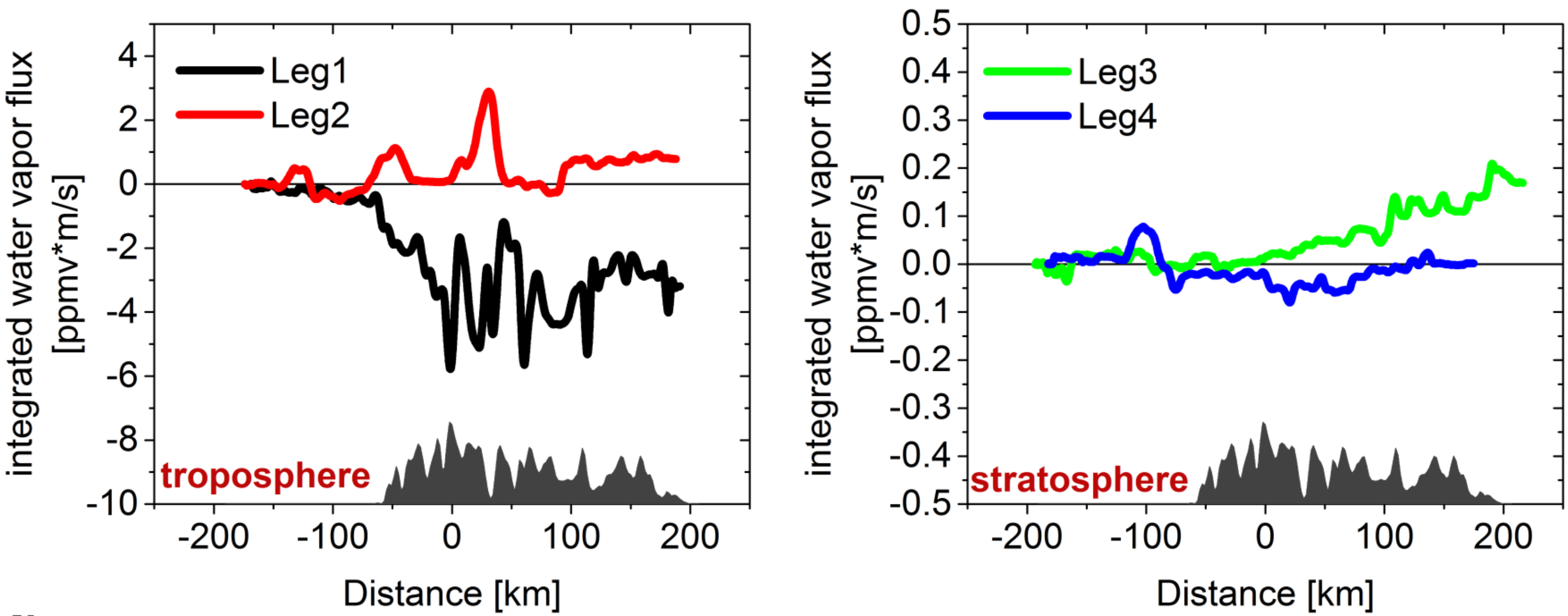
Integrated water vapor flux for FF05



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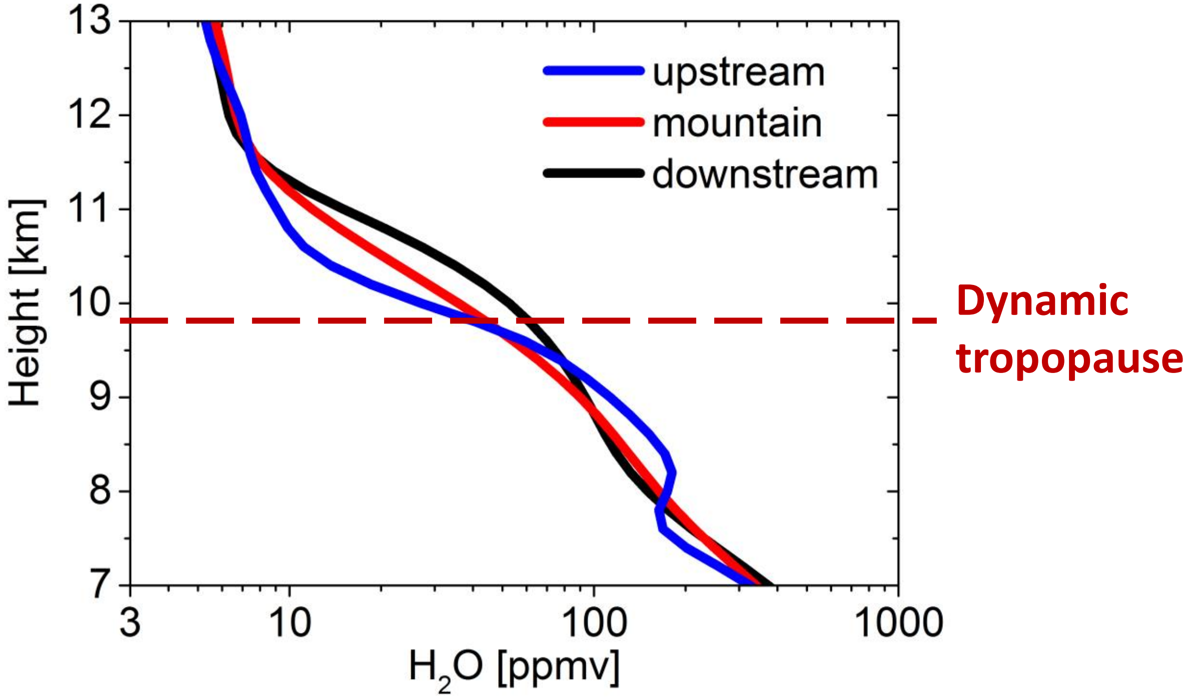
Can models help to answer the question of irreversible trace gas transport?

- WRF simulations: Δx = 2km, Δz = 80 – 600 m
- Comparison of vertical profiles from 3 different sections of a flight: upstream, mountain, downstream

WRF cross section along FF05: mean profiles of humidity mixing ratio

Tropopause region: differences in the profiles → explained by mixing



WRF simulations by Johannes Wagner

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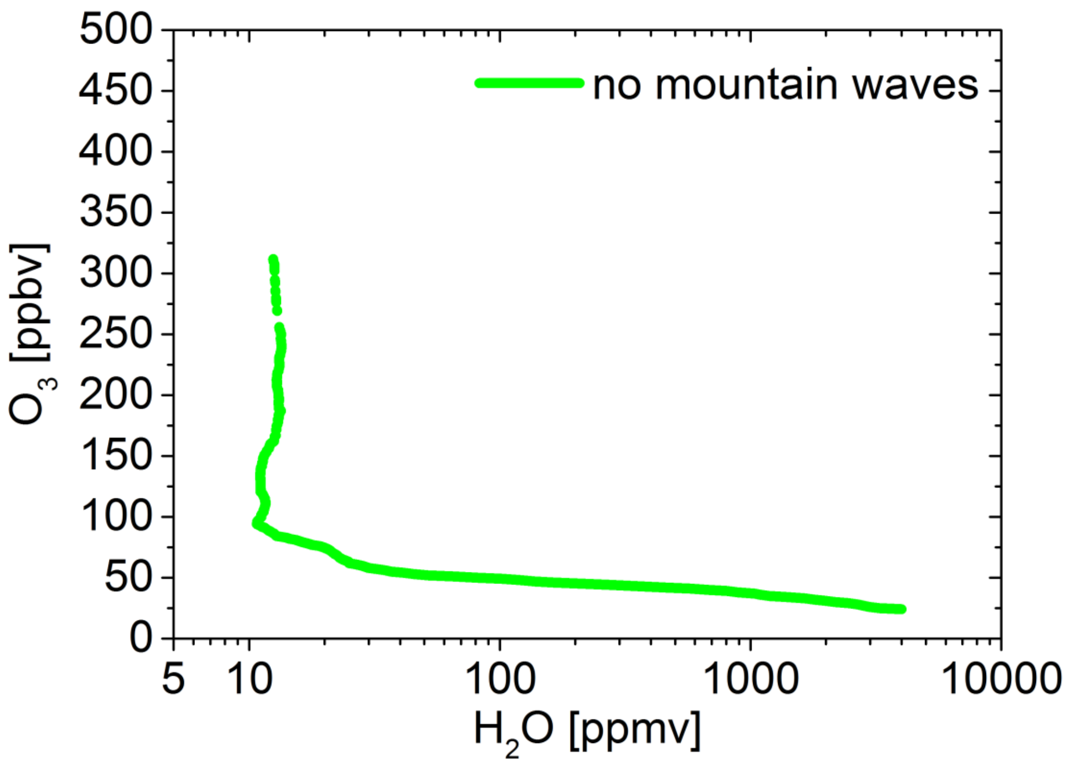
Tracer-tracer correlation for all Falcon flights

Shape of the correlation:

- Non-GW flights: ideal L-shape → indicates no (less) mixing in the tropopause region

H_2O
strong gradient
in troposphere

O_3
strong gradient
in stratosphere



Ozone data by Hans Schlager

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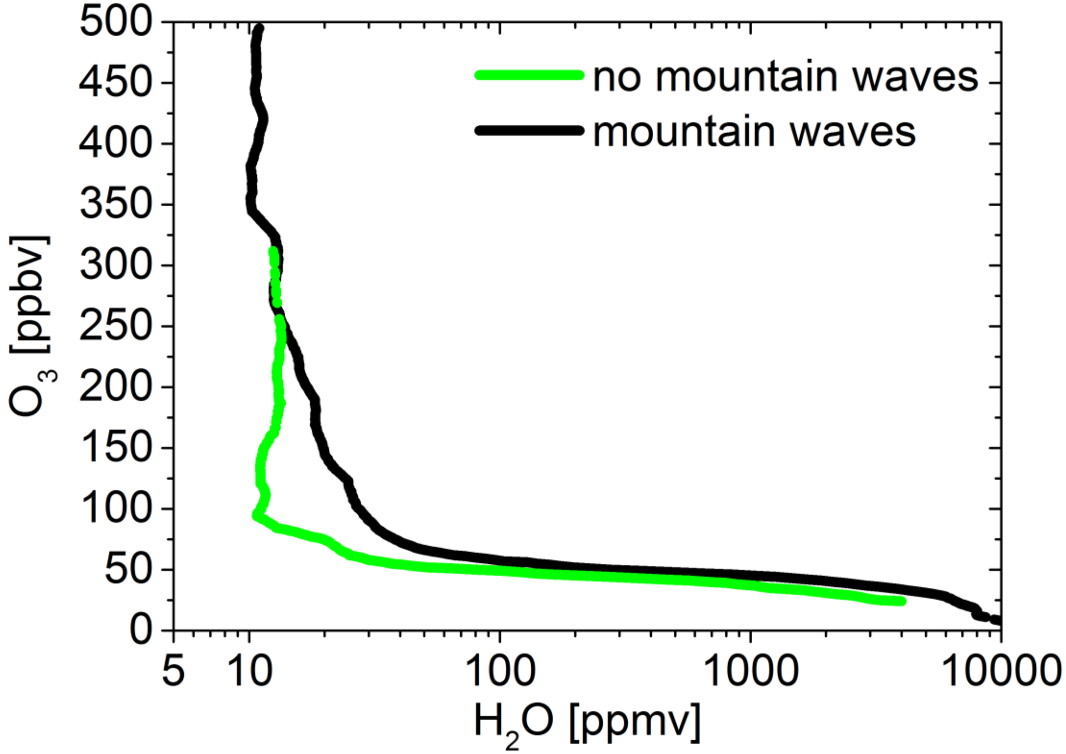
Tracer-tracer correlation for all Falcon flights

Shape of the correlation:

- Non-GW flights: ideal L-shape → indicates no (less) mixing in the tropopause region
- GW flights: smoothed profiles → indicate mixing processes

Mixing is induced by processes connected to mountain waves (turbulence, …)



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Summary

- Transport of water vapor in the UTLS region induced by mountain waves
- WRF vertical profiles indicate mixing over the mountains
- Campaign tracer-tracer-correlation also suggest mixing in the tropopause region
- Additionally, turbulence analysis is needed to investigate the small-scale mixing

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