



Airborne Water Vapour and Wind Lidars to Estimate Latent Heat Fluxes over Complex Terrain



*Doppler lidar:
vertical windspeed*

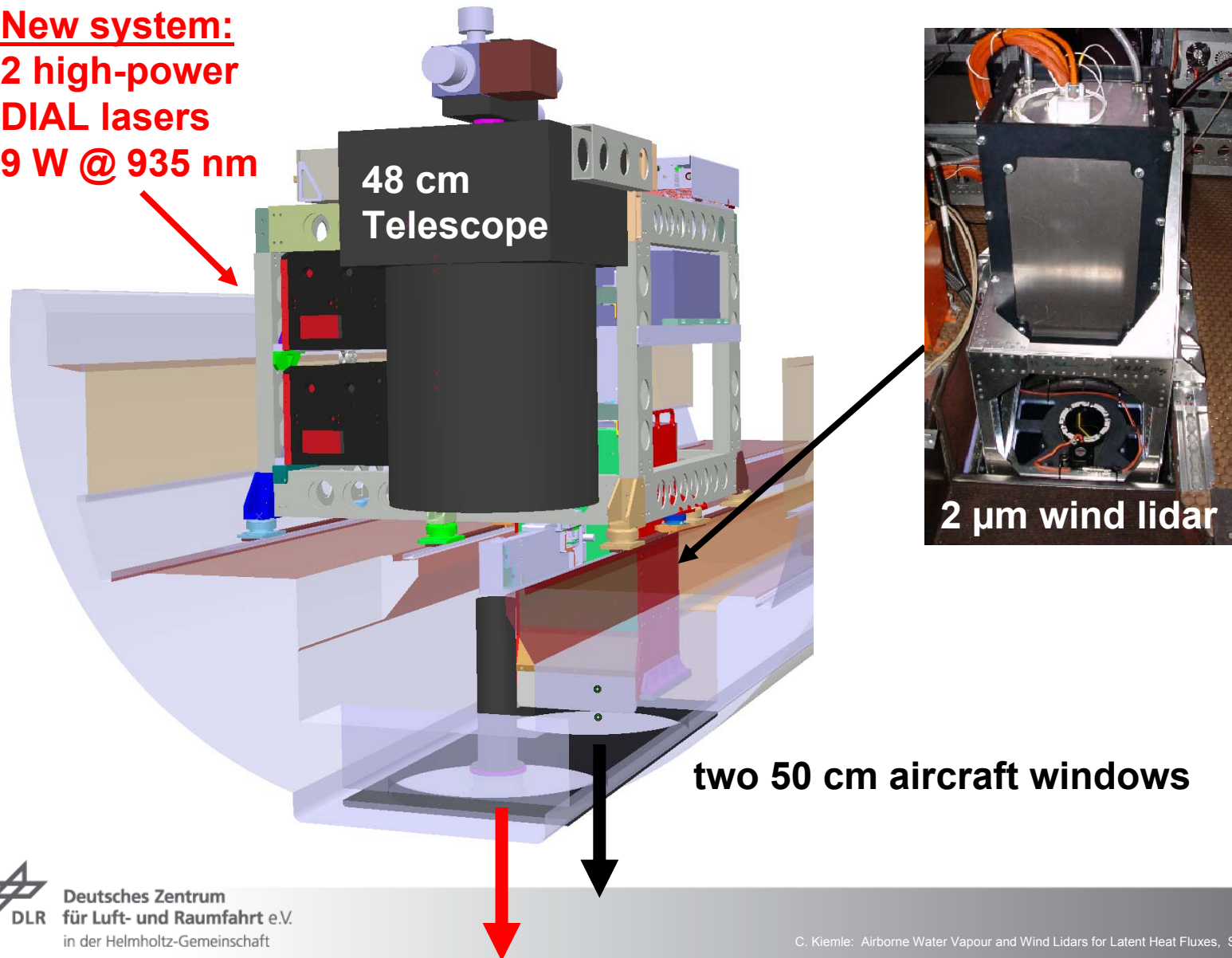
*DIAL:
H₂O, aerosols*

Christoph Kiemle,

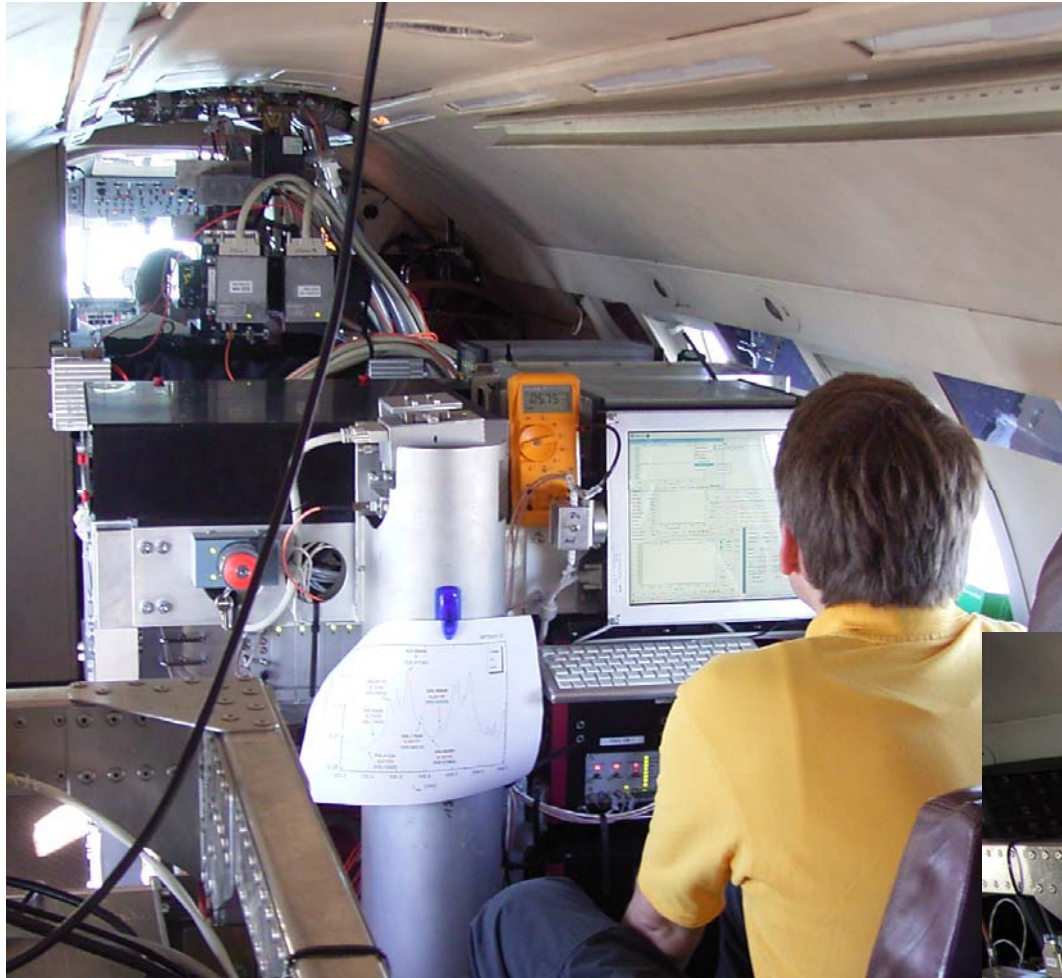
M. Wirth, A. Fix, A. Schäfler, A. Dörnbrack, S. Rahm and G. Ehret

Water Vapour and Wind Lidar on board the Falcon

**New system:
2 high-power
DIAL lasers
9 W @ 935 nm**



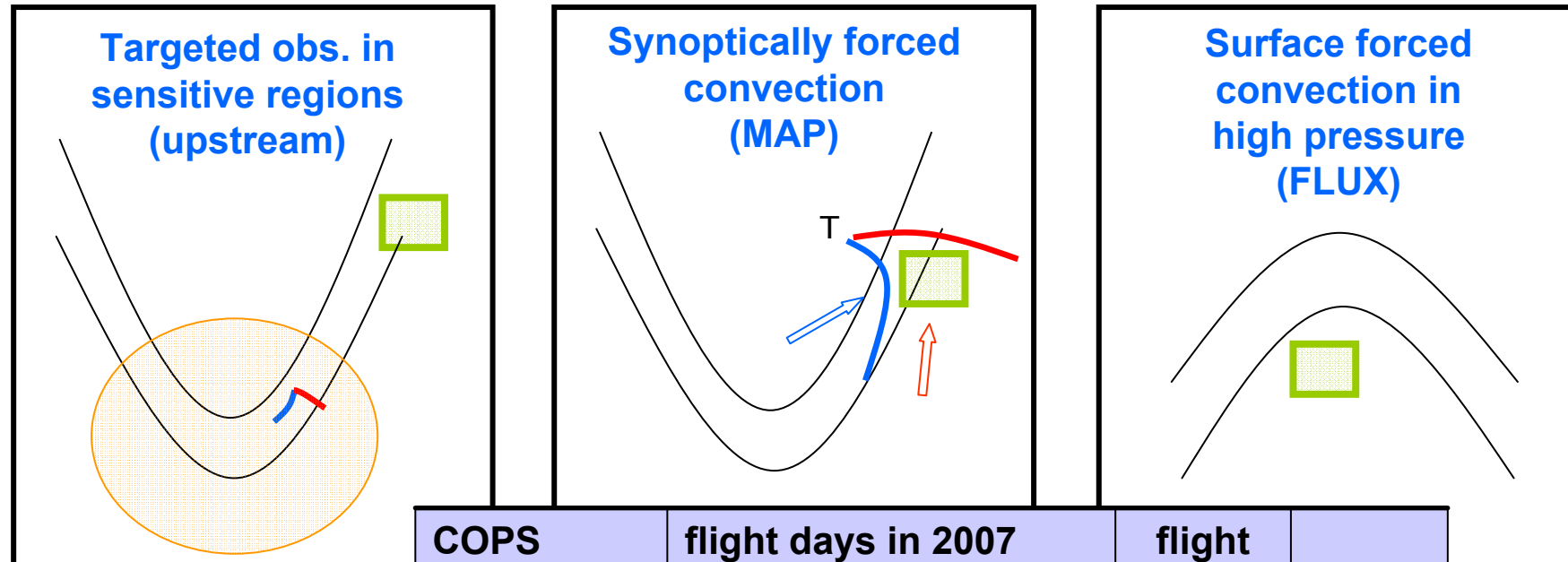
Water Vapour and Wind Lidar on board: Falcon full!



Displays for system
control and quicklooks



DLR Falcon Missions during COPS 2007

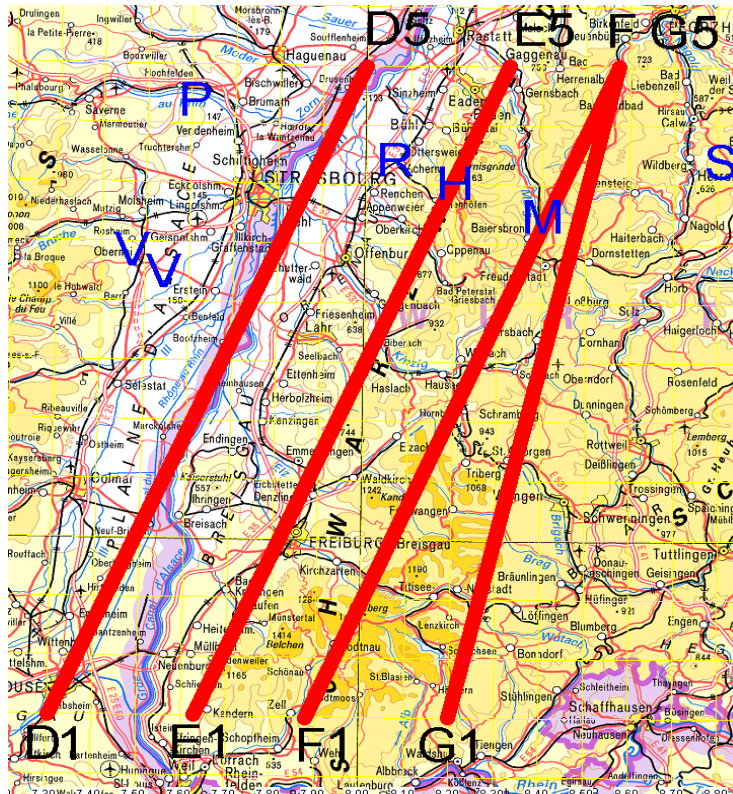
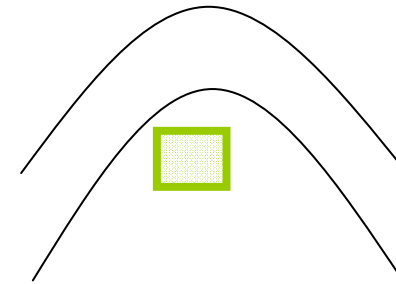


COPS Mission	flight days in 2007	flight time	
UPSTREAM	2 · 8.7., 2 · 19.7., 2 · 1.8.	21.7 h	44%
MAP	18.7., 2 · 20.7., 1.8.	12.9 h	26%
FLUX	15.7., 25.7., 26.7., 30.7.	14.8 h	30%
Total	14 flights	49.4 h	100%

FLUX Mission Objectives

1. Characterise initiation of convection with **high resolution wind and water vapour** lidar profiles.
2. Investigate the spatial variability of humidity, wind and **latent heat fluxes**.
3. Verify model skills **in complex terrain**.

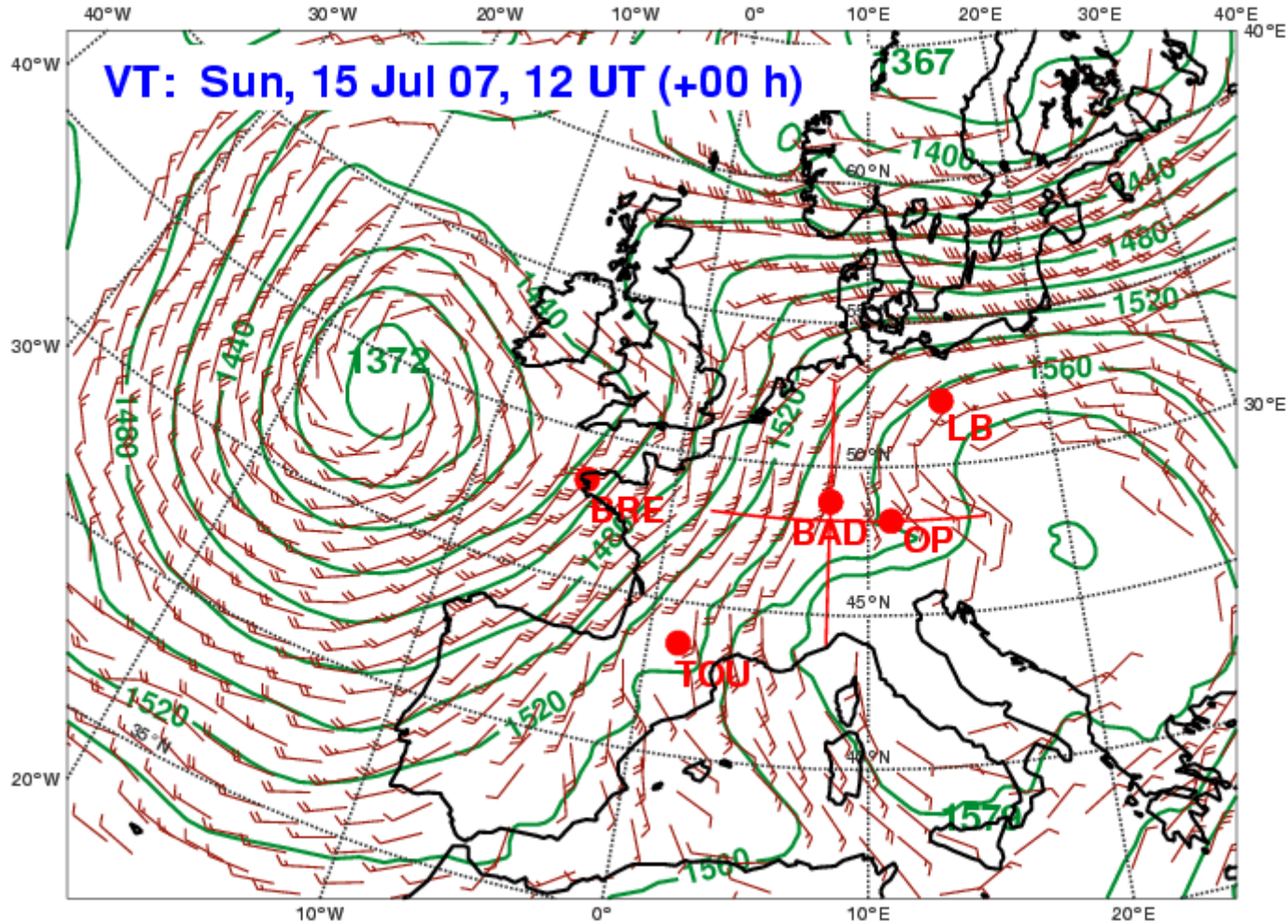
Surface forced convection in high pressure (FLUX)

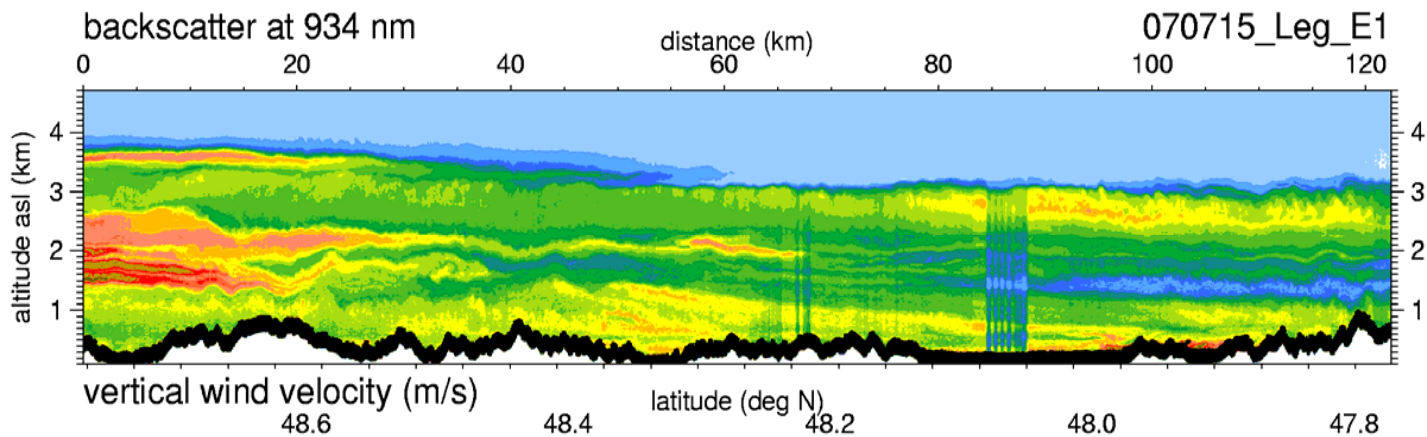


2 examples:

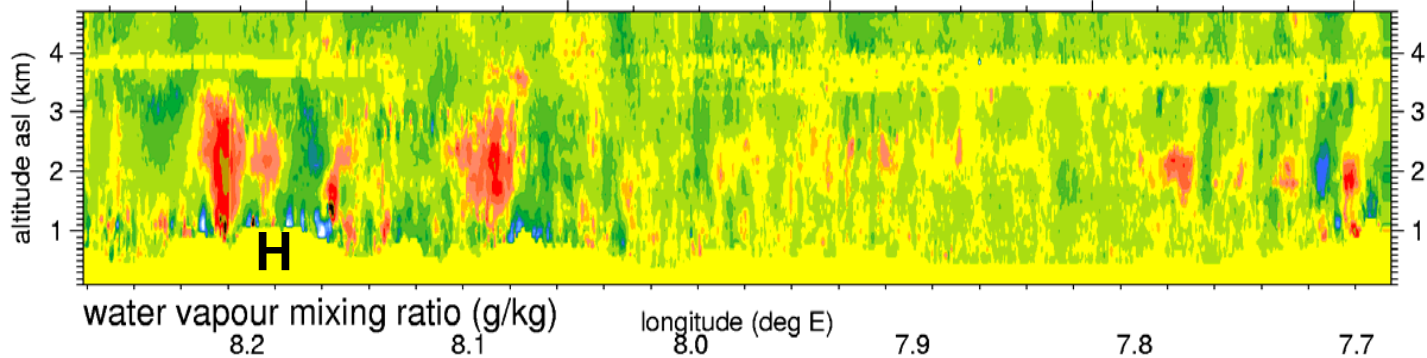
15.7. + 30.7.07

IOP 8b: Ridge, no clouds in morning, S-wind

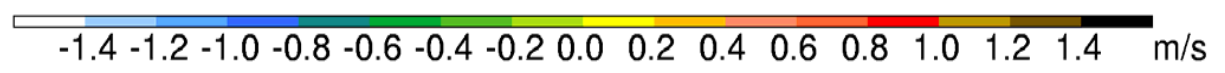
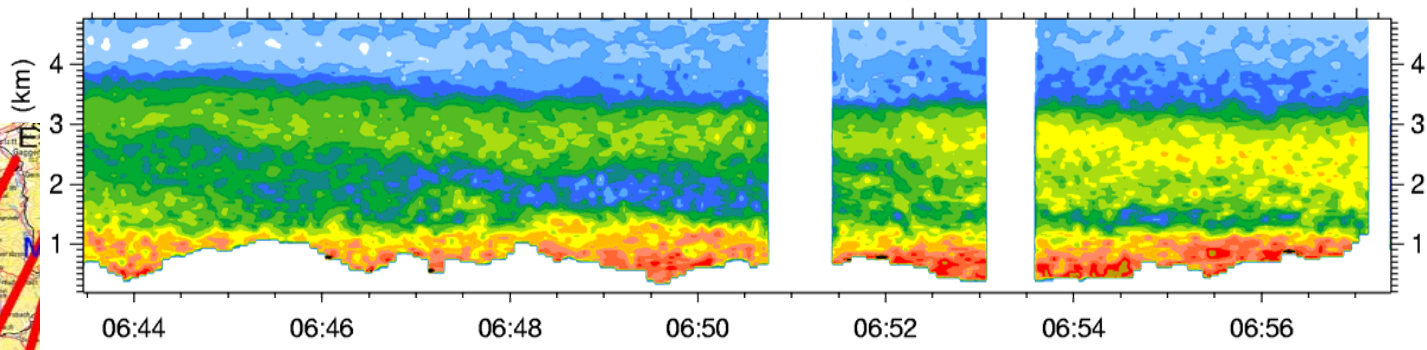


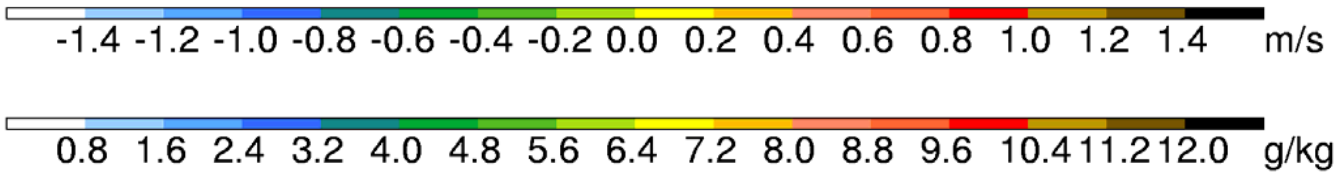
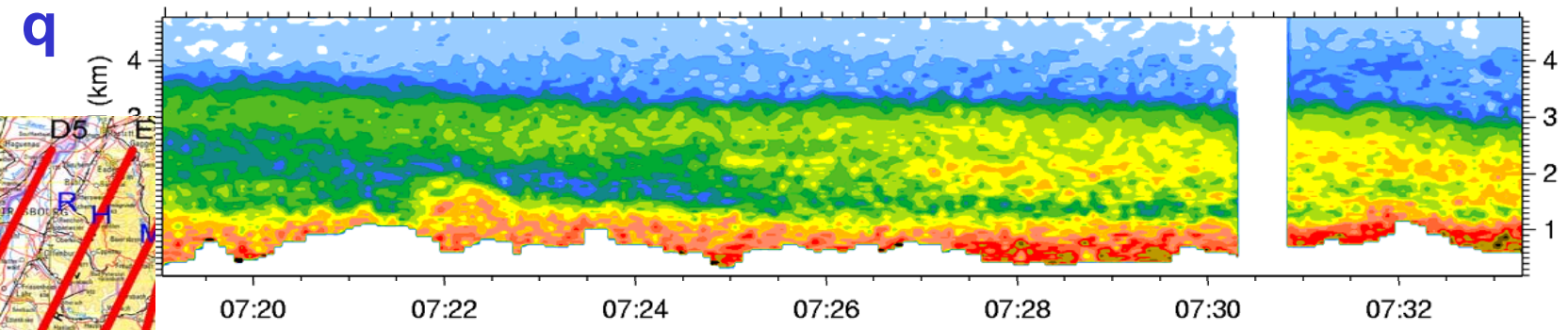
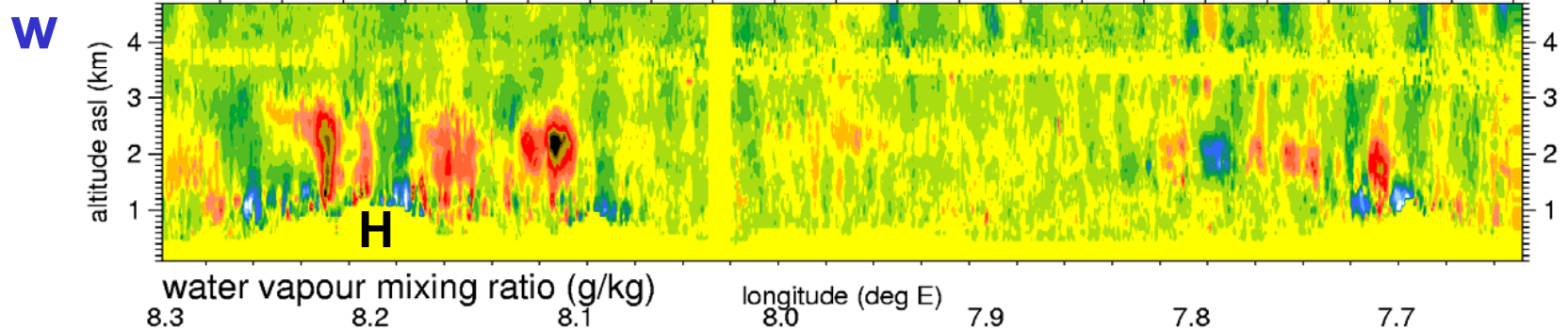
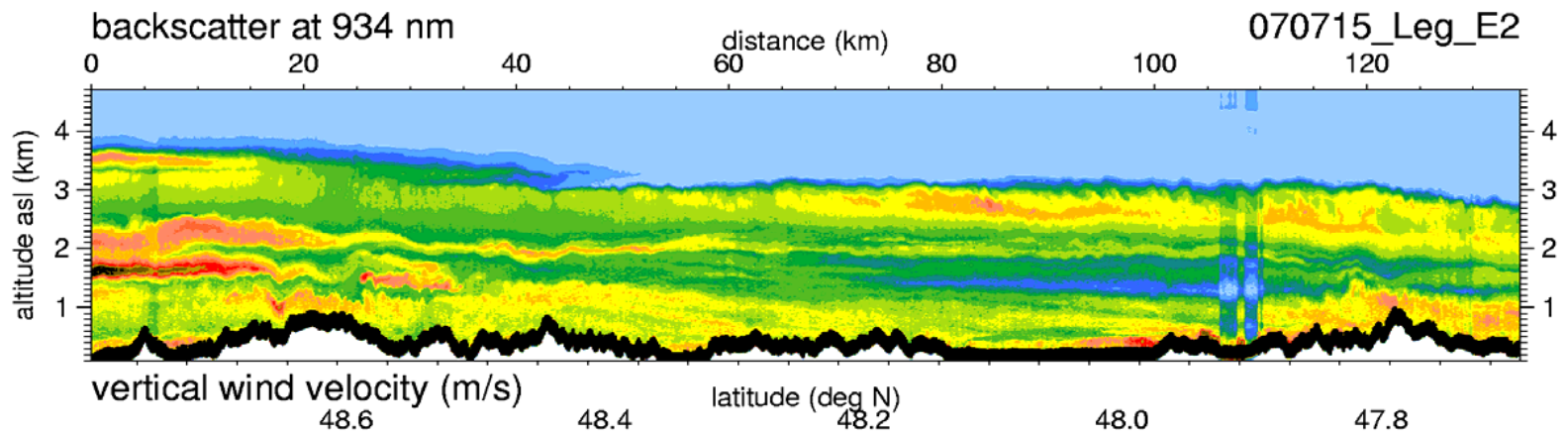


W



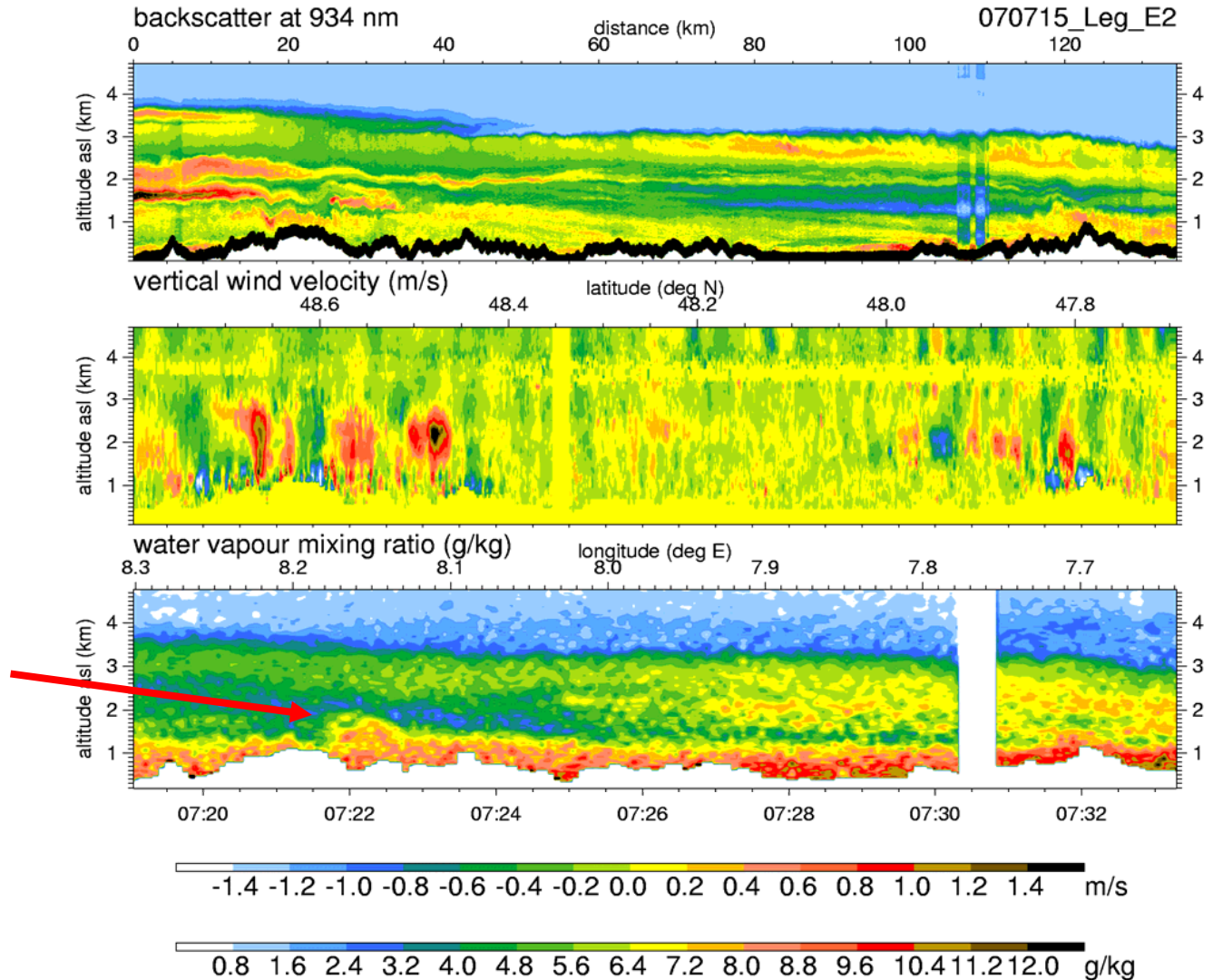
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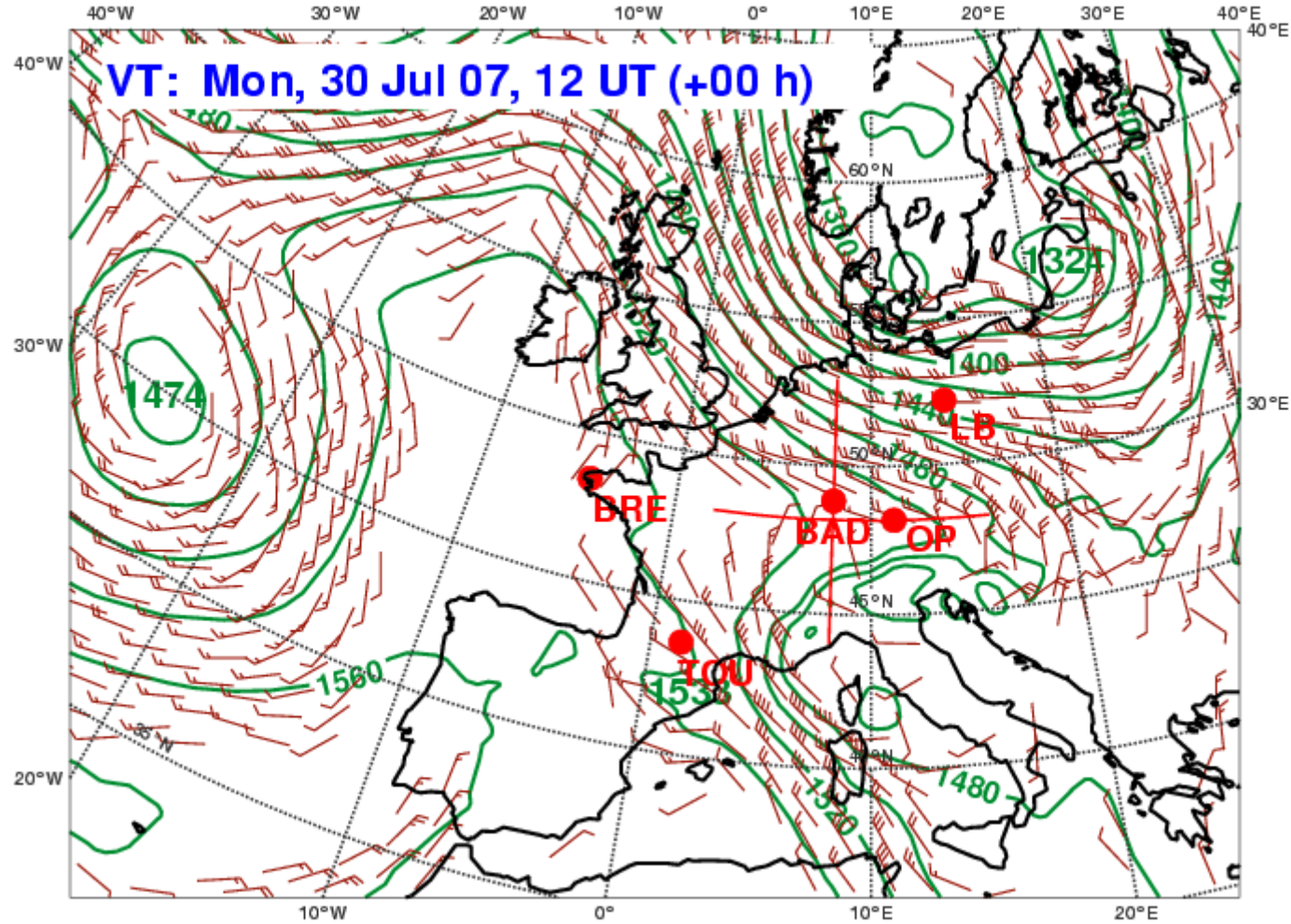


15.7. 7 UT: Falcon Lidar Observations

- 9 m/s wind generates lee waves
- stationary waves above H
- BL hum. lifted 500m in 36min = 0.23 m/s



IOP 12: Trough rear side: adv. of cold, clean, dry air



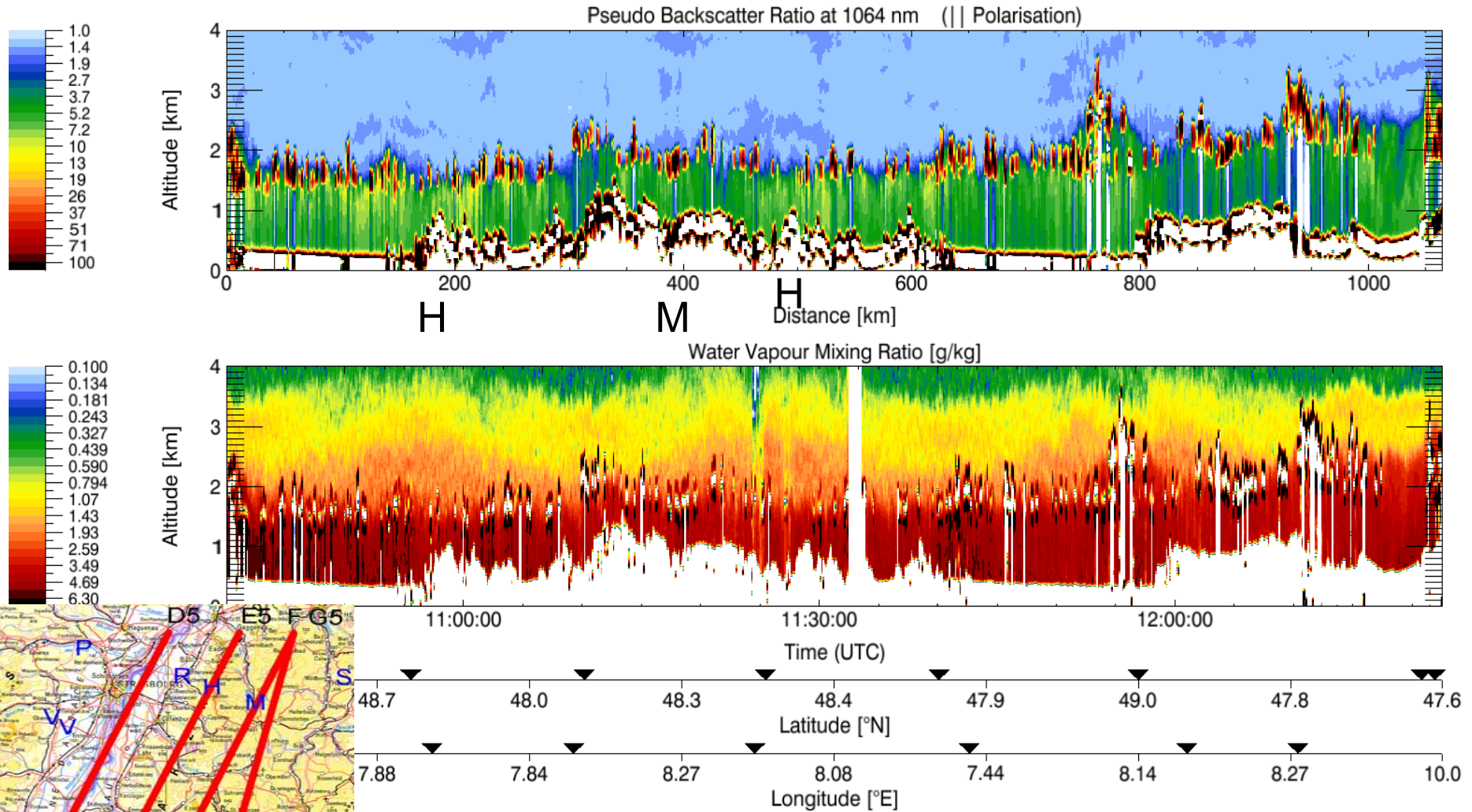


IOP 12

COPS 30-07-2007



D1-----D5 E5-----E1 F1-----F5 E5-----E1 D1-----D5 G5-----G1



e.V.
st

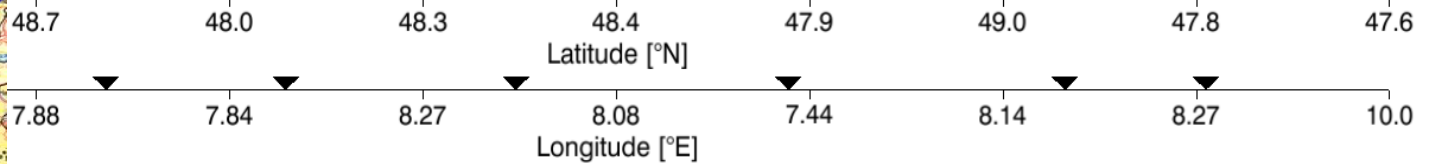
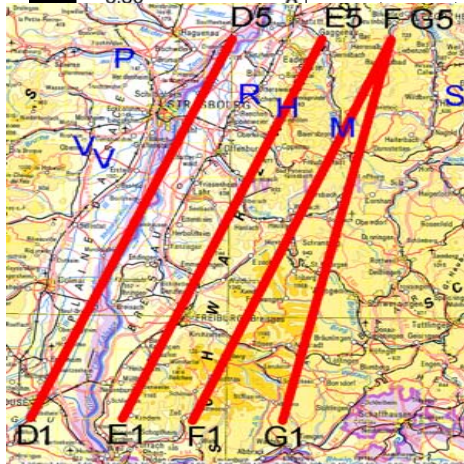
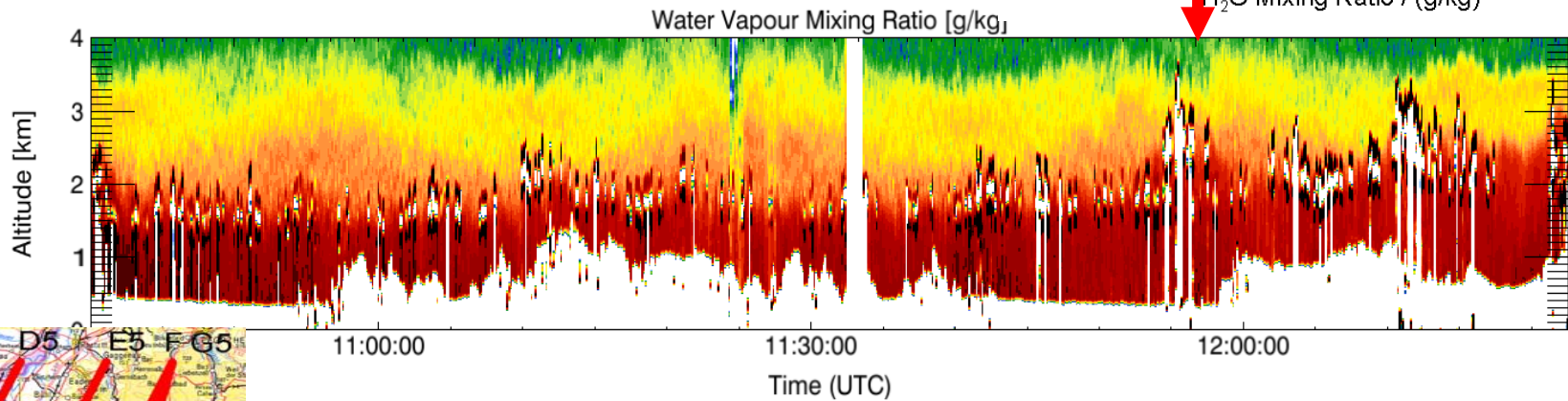
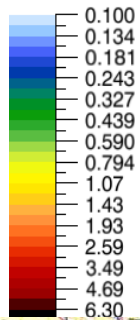
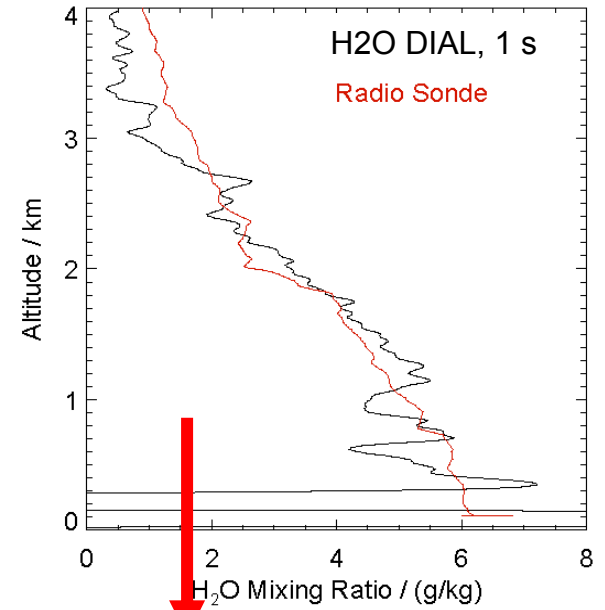
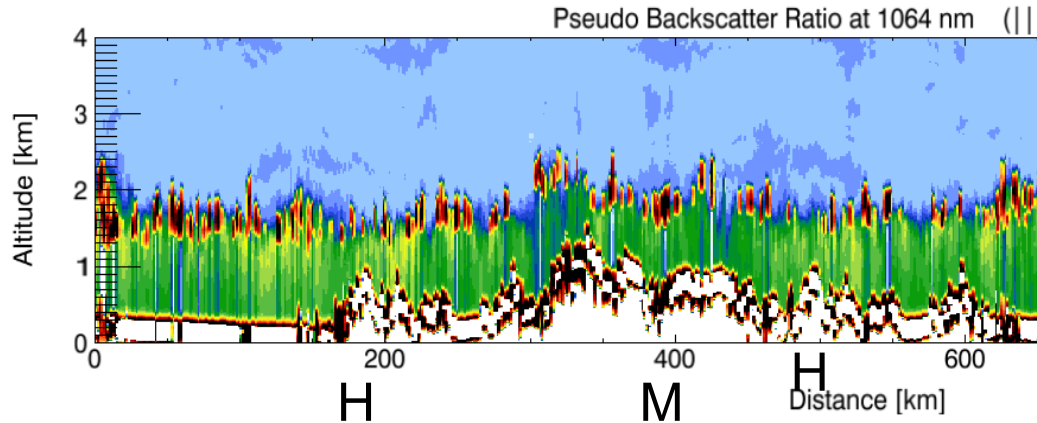
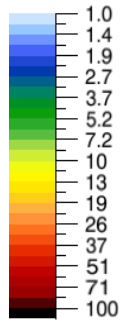


IOP 12

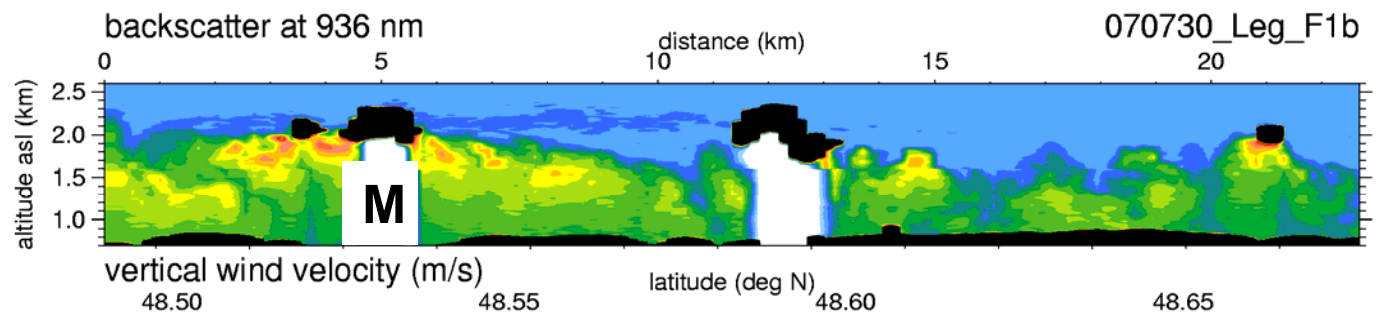
COPS 30-07-

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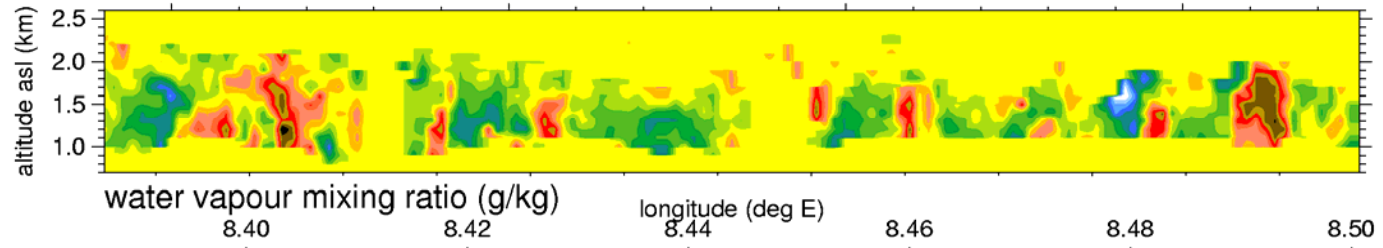
D1-----D5 E5-----E1 F1-----F5 E5-----E1 D



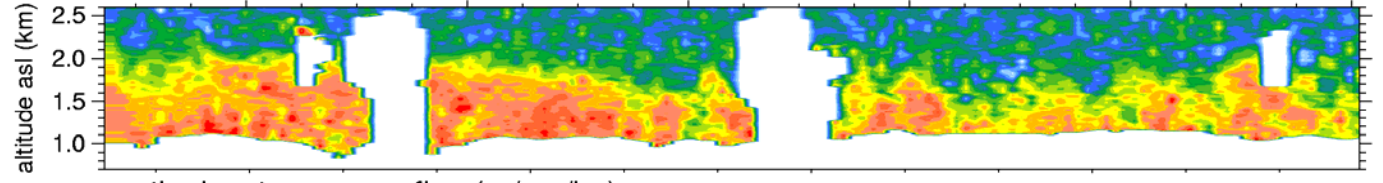
180 m
hor. (1 s),
200 m
vert. res.



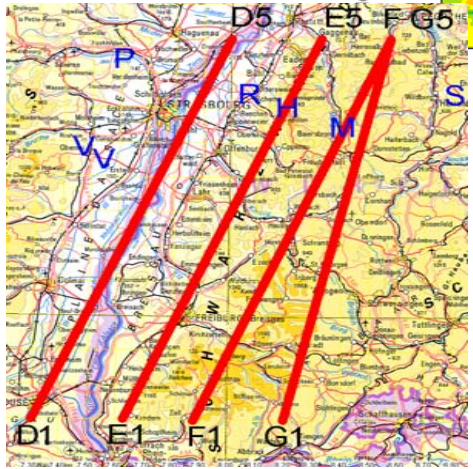
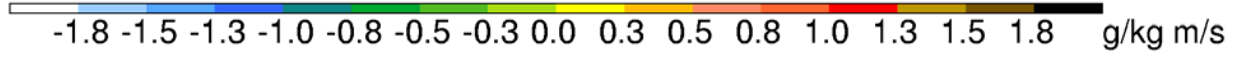
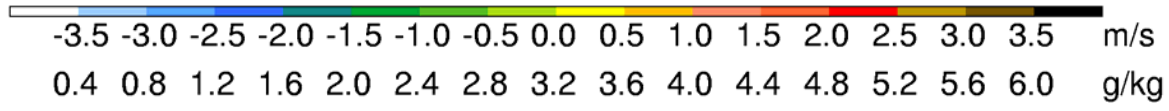
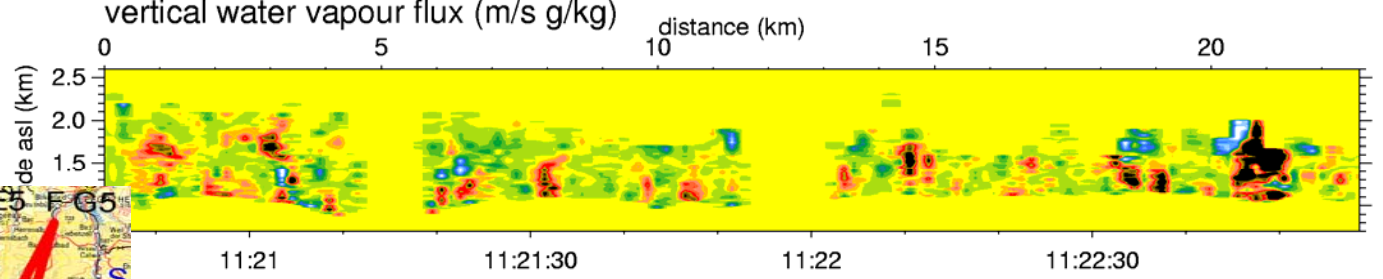
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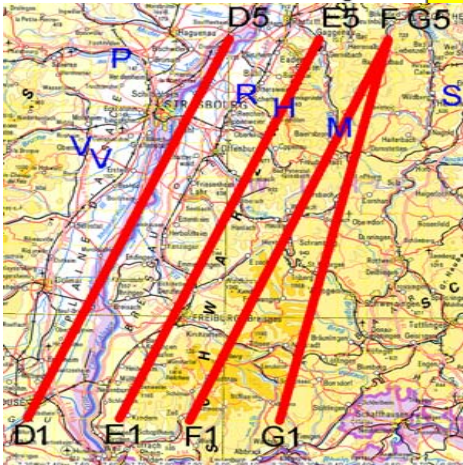
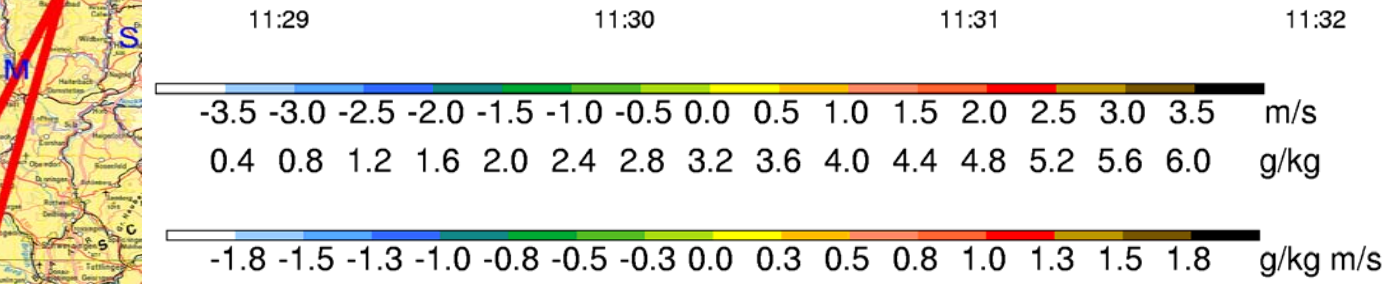
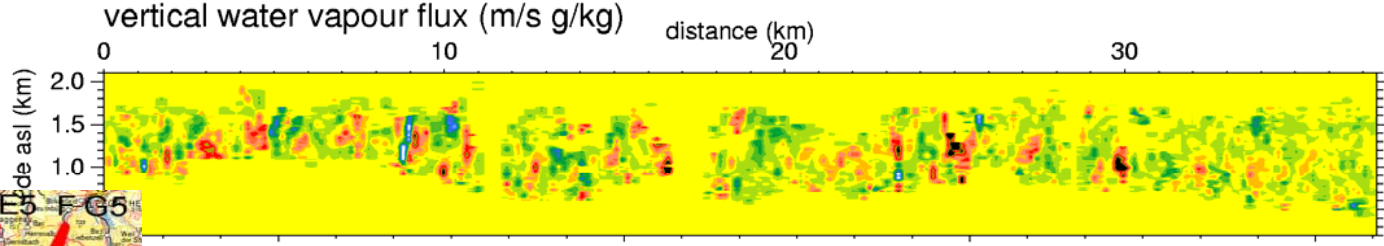
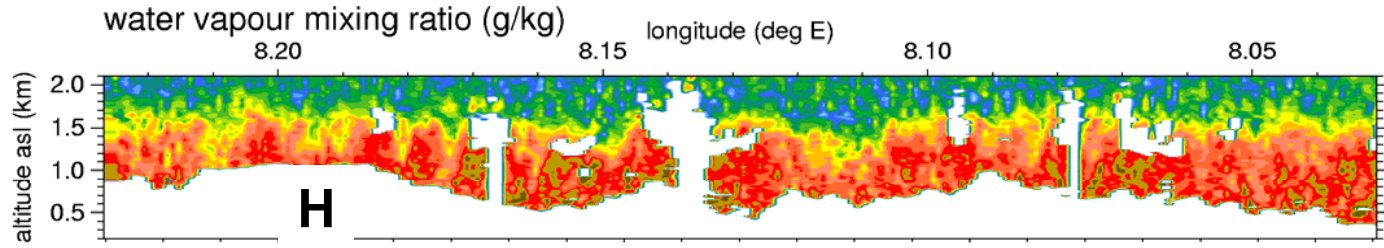
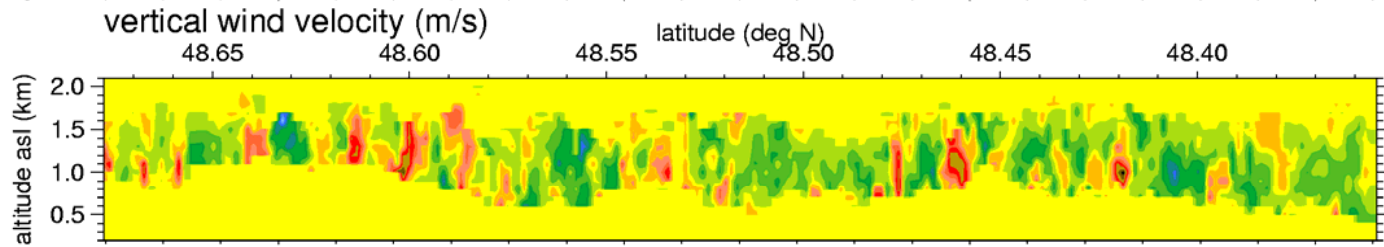
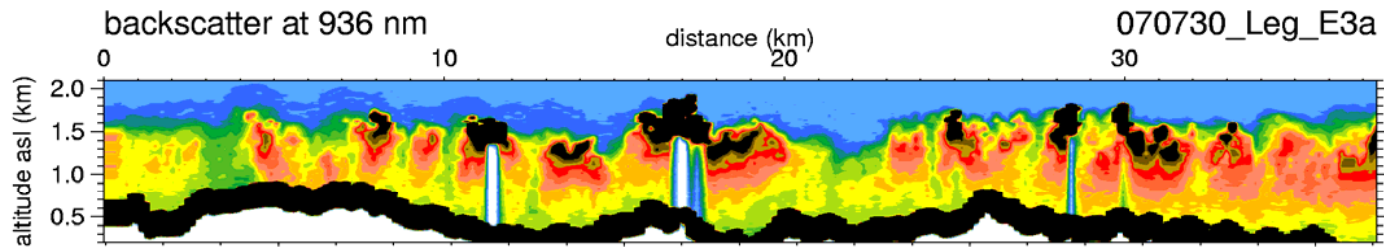
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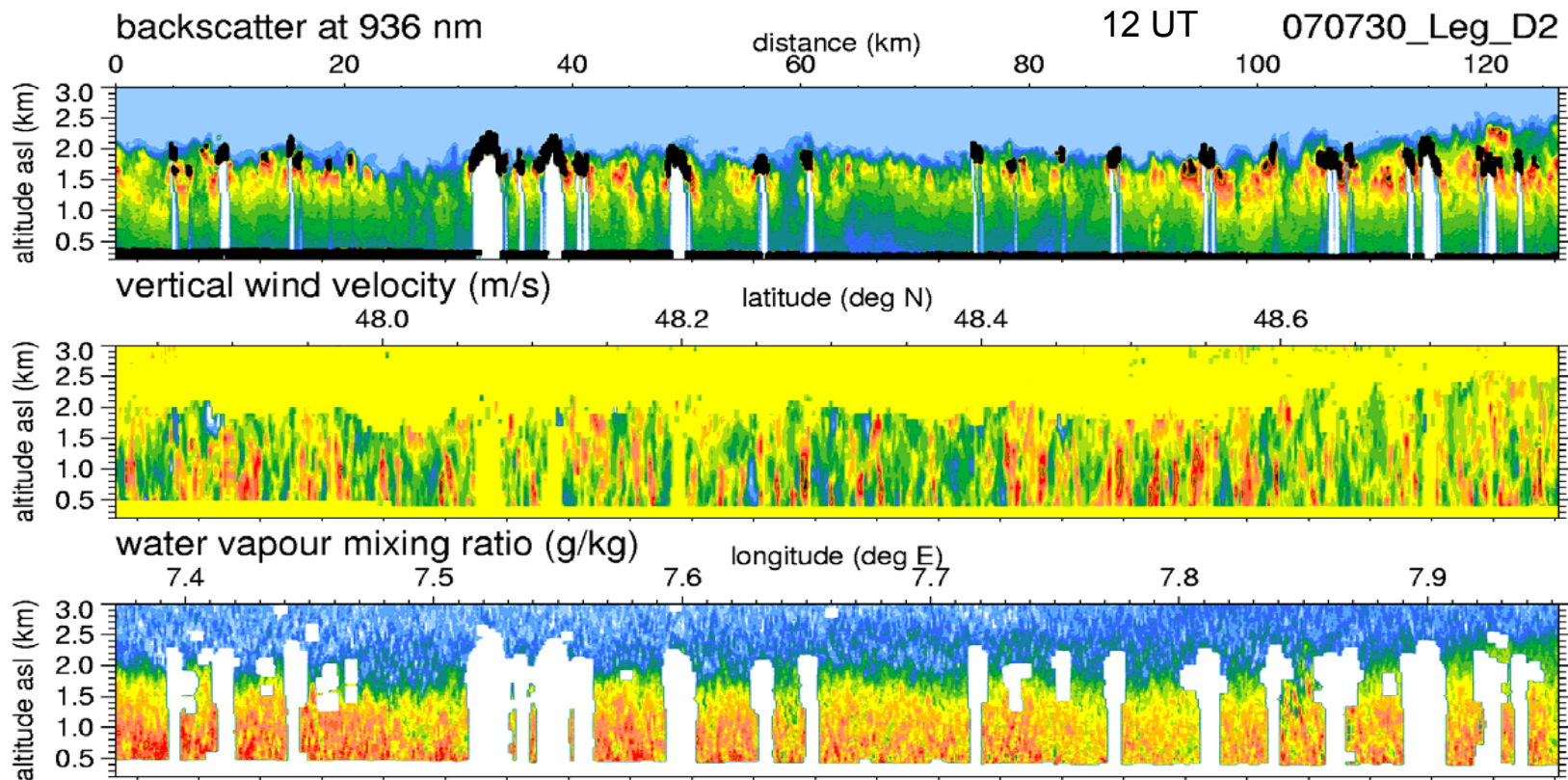
w'q'



w'q' is turbulent flux, $q' = q - \overline{q}_{10km}$ and $w' \approx w$



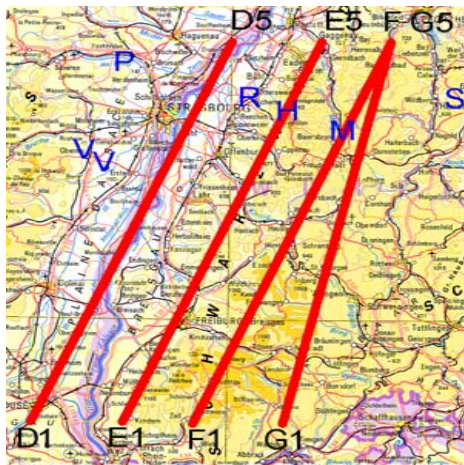
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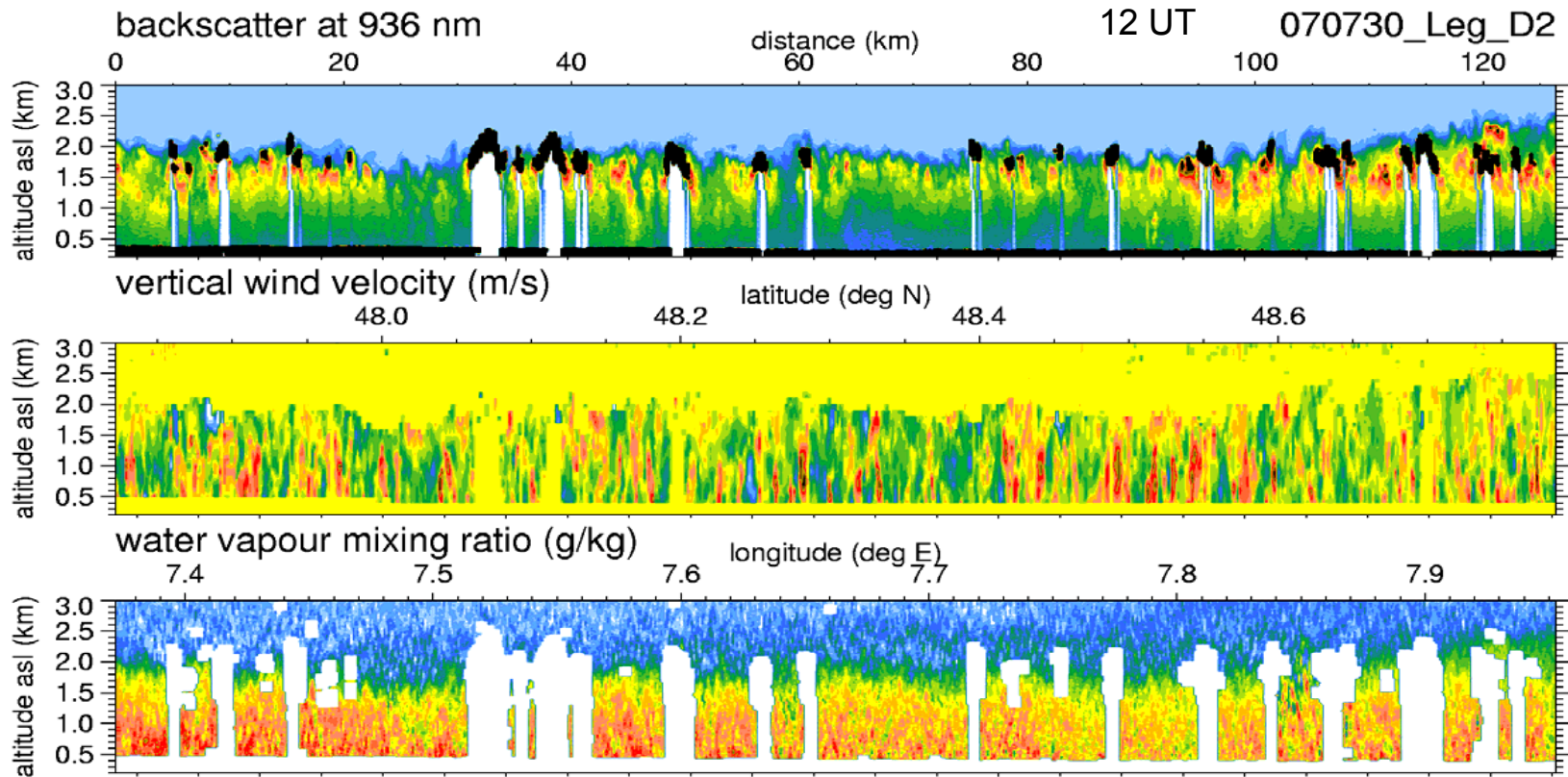


Rhine valley:

flat-terrain reference for statistics and fluxes.

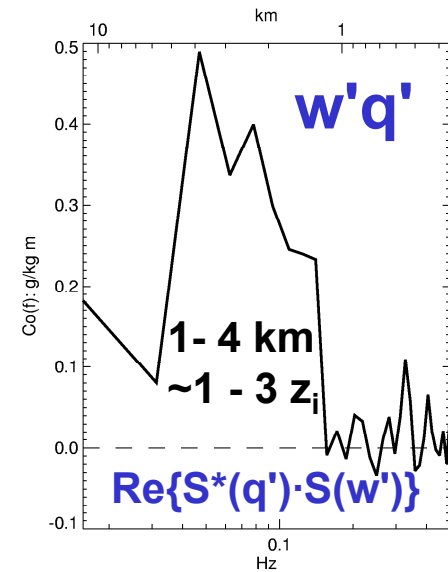
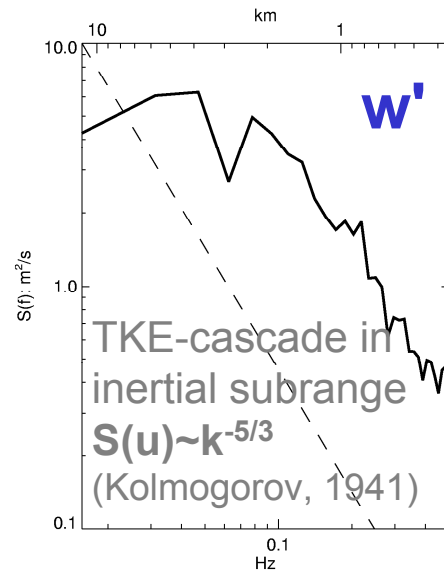
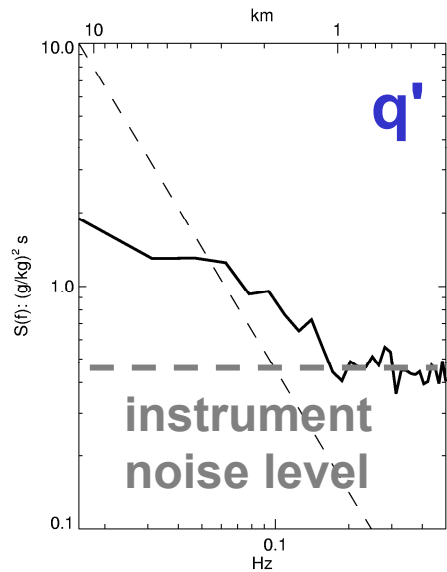
High spatial res.: 180 m hor. (1 s), 200 m vert.





Fourier spectra in mid-CBL:

Kiemle et al.,
JTECH 2007



30.7.07: Eddy-correlation and Latent Heat Flux Profile

Kinematic turb. flux:

$$F = \overline{w'q'} \quad [\text{g/kg m/s}]$$

$F = \text{integral (cospec.)}$

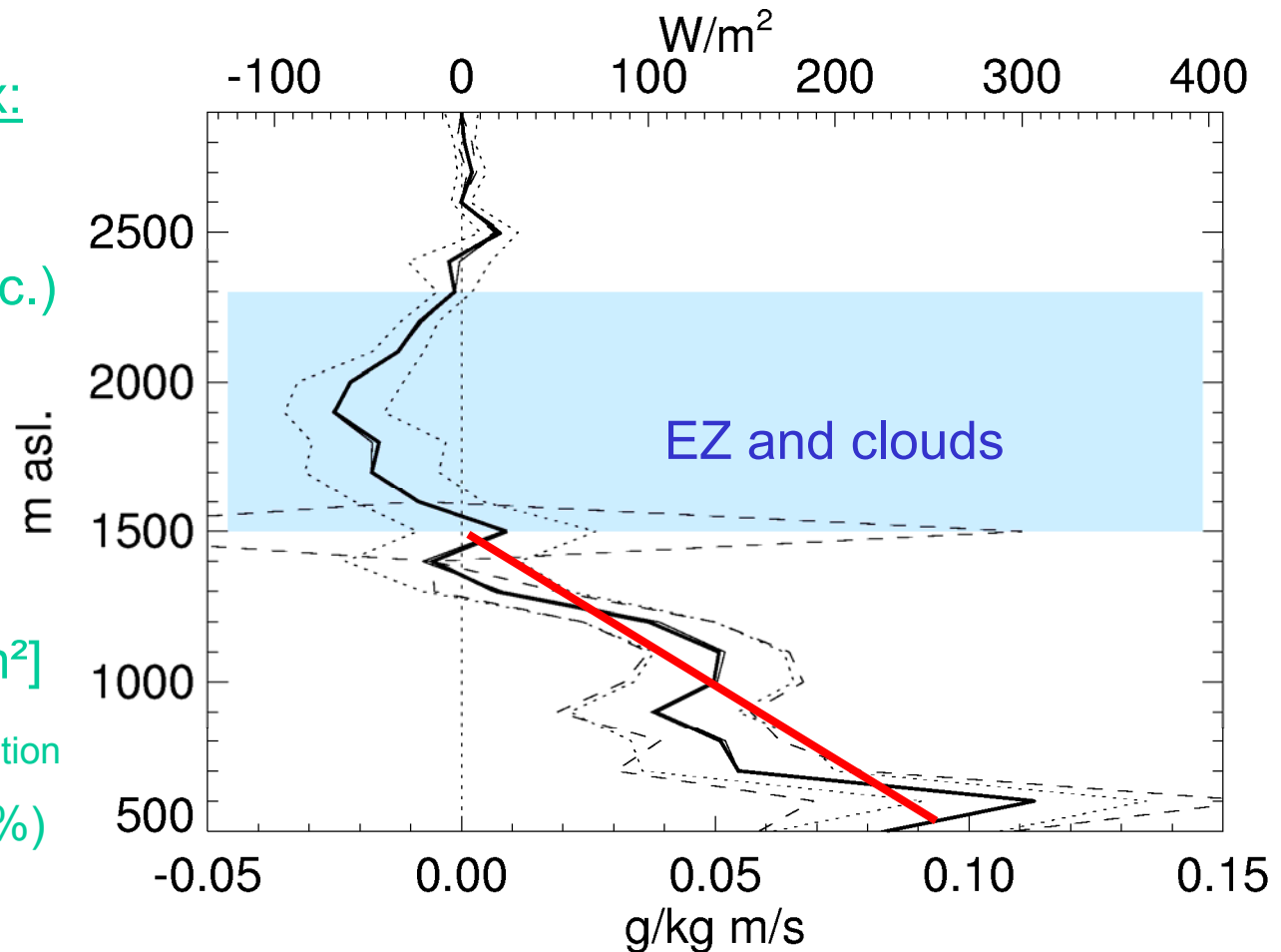
$$F = \text{CCF}_0 (w', q')$$

Latent heat flux:

$$W = \rho_{\text{air}} L_v F \quad [\text{W/m}^2]$$

L_v is latent heat of vaporisation

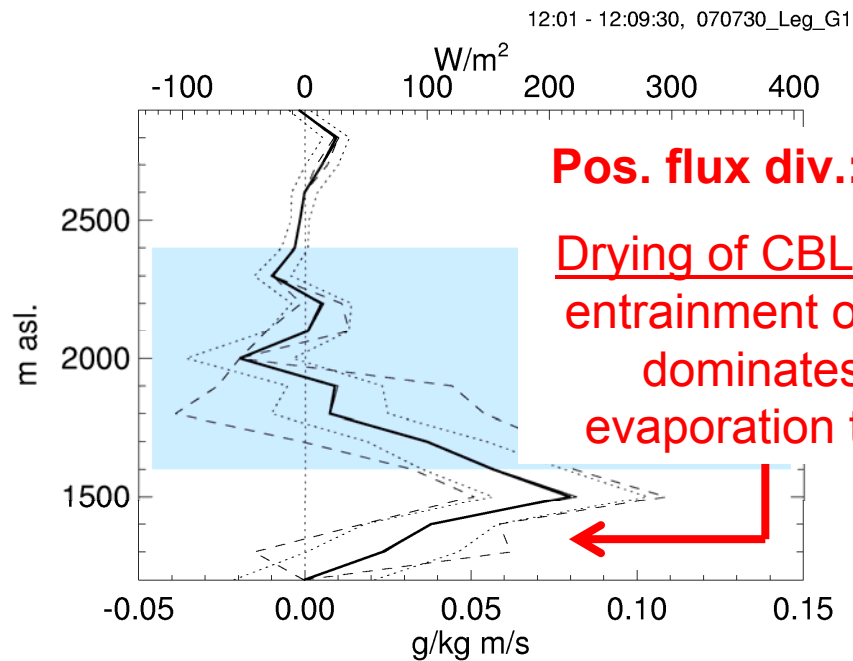
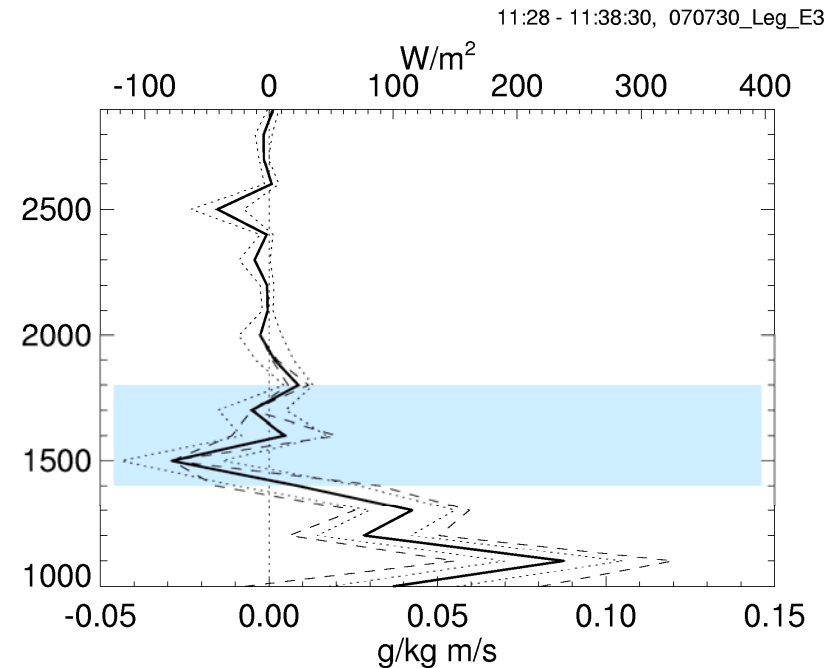
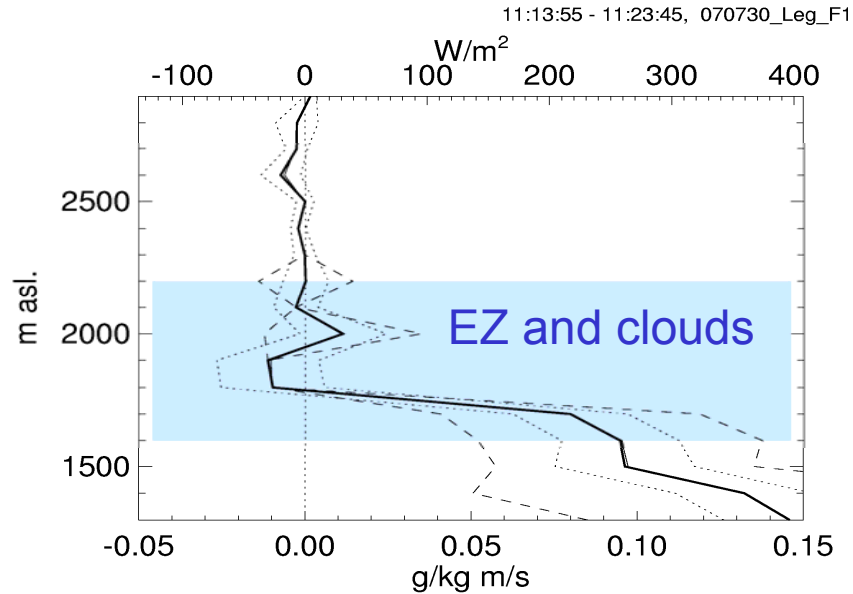
$$\rho \cdot L_v \approx 2.8 \text{ MJ/m}^3 (\pm 4\%)$$



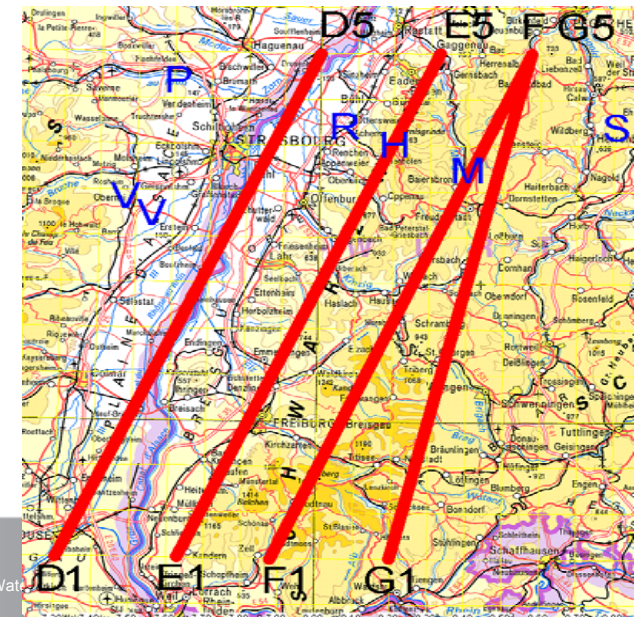
CBL flux divergence $\partial \overline{w'q'}/\partial z \approx -0.09 \text{ g/kg m/s km}^{-1} \approx -0.3 \text{ g/kg h}^{-1}$

accuracy: $\pm 30\%$ due to instrument noise and sampling uncertainty.

30.7.07: Latent Heat Fluxes above Black Forest



Pos. flux div.: 0.5 g/kg h⁻¹
Drying of CBL likely due to
 entrainment of dry air that
 dominates surface
 evaporation to the East.



Conclusions and Outlook

- **Successful operation of wind and water vapour lidars on aircraft with high spatial resolution (200 m);**
- **unique instrumentation to characterise BL variability and fluxes over complex terrain, essential to CI;**
- **4 flux missions currently under investigation.**

- **Next steps:**
 - **explore methods other than eddy-correlation for latent heat fluxes in mountains and valleys: conditional sampling, ...**
 - **compare with insitu fluxes from D-IBUF and Hornisgrinde lidars, for validation and more comprehensive case studies.**