Potential of Airborne Lidar Observations of Water Vapour Transport

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HALO: The New German Research Aircraft

- maximum altitude 15.5 km
- maximum range 10000 km
- flight duration 8-10 hours
- maximum payload 3 tons
- 6 viewports for lidar instruments

DIAL: $\text{H}_2\text{O}$, aerosols

Doppler lidar:
- nadir: vertical wind
- scanning: hor. wind

dropsondes: p, T profiles
Water Vapour and Wind Lidars: Own Developments

New Diff. Abs. Lidar (DIAL): 4 wavelengths, 8 W @ 935 nm

48 cm Telescope

Kiemle et al., JTech, 2007
Schäfler et al., JTech, 2010
Kiemle et al., QJRMS, 2011
Schäfler et al., QJRMS, 2011
Full tropospheric profile by three line combination

![Graph showing full tropospheric profile](image)

- Altitude / km
- H₂O Mixing Ratio / 10⁶
- Reference: weak, medium, strong
E-TReC 2007: European Thorpex Regional Campaign

Mission Objectives

Perform targeted measurements across upstream sensitive regions over SW-Europe and quantify humidity advection into the COPS area.
E-TReC 2007: Pre-convective Water Vapour Transport

q·|v_h| in g/kg · m/s

Lidar obs: colors, ECMWF analysis: lines

Where are the lidar WCB observations?
When did the air ascend?
→ Calculate forward and back trajectories starting at each measurement point.

Δp_{max} in 48 h
COPS Case Study 19. 7. 2007: WCB Structure

WV mixing ratio

0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 g/kg
COPS Case Study 19.7.07: ECMWF Overestimates WCB Humidity Inflow

ECMWF - Lidar obs:

→ mean bias in WCB inflow: 
~ 1 g kg\(^{-1}\) (14 %)

→ max. bias: 7 g/kg (100 %)

Tropical Deep Convection Outflow, Brazil, 2005

Res.: 2 km hor., 100 - 300 m vert.
Hypotheses:

- Specific humidity is a conserved tracer in absence of clouds
- Humidity structures related to transport and mixing processes
- Distribution is non-stationary, non-Gaussian, multi-fractal
- Fourier spectra not adequate to characterize intermittency
- Structure functions of higher order needed (Davis et al, 1994)
Water Vapour Variability in the Free Troposphere

Smoothness and intermittency quantifiable in bi-fractal parameter space: comparisons with COSMO-DE in hope to improve model parameterisations (Lucas Fischer, PhD student, Univ. Munich)
COPS 2007: Convective and Orographically-induced Precipitation Study

Measure latent heat fluxes over complex terrain
Aerosol, vertical wind and water vapour in the Rhine Valley CBL
COPS 30.7.07: Fourier Spectra from Horizontal Series

- Successful comparison with insitu fluxes (Kiemle et al, QJ 2011)
- Lidar spatial resolution of ~200 m resolves flux dominating eddies

TKE-cascade in inertial subrange
$S(f) \sim k^{-5/3}$
(Kolmogorov, 1941)
TKE Dissipation Rate Estimation from Wind Lidar

\[ \varepsilon \approx 2.5 \cdot 10^{-5} \text{ m}^2 \text{ s}^{-3} \]

Kolmogorov:

\[ S(k) \approx 0.5 \varepsilon^{2/3} k^{-5/3} \]

- Successful comparison with insitu fluxes (Kiemle et al, QJ 2011)
- Lidar spatial resolution of ~200 m resolves flux dominating eddies
COPS 30.7.07, 14 LT: CBL Latent Heat Flux Divergence

w'q' cospectrum:

CBL flux divergence: $\approx -0.3 \, \text{g/kg h}^{-1}$ (± 50 %); advection negligible:

humidity increase by surface evaporation due to previous days' rain.
Institut für Physik der Atmosphäre

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THORPEX-IPY 1.3.2008: cold air convection over Barents sea

latent heat flux profile:

H₂O-DIAL

Backscatter Intensity at 936nm 1. 3.2008

cold air

over Barents sea
Conclusions

Airborne wind and water vapor lidar obs for:

- Quantification of humidity transport in WCB / cyclone inflow and outflow regions,
- Characterisation of latent heat fluxes near WCB inflow regions, also over sea,
- Parameterisation of humidity variability in free atmosphere.