Meteorologisches Institut
der Universität München

HALO-LIDAR:
A short introduction to high resolution airborne measurements of moisture in the troposphere

METEOROLOGISCHES INSTITUT UNIVERSITÄT MÜNCHEN (MIM)
QUEST Final Meeting 21. Oktober 2010, Lucas Fischer

www.meteo.physik.uni-muenchen.de

1 OVERVIEW

- Introduction - HALO
- DIAL Method (Differential Absorption Lidar)
- Data Analysis Method – Power Spectrum Estimation
- First Results
- Conclusion and Outlook

2. INTRODUCTION

QUEST

Quantitative Evaluation of Regional Precipitation Forecasts using Multi-Dimensional Remote Sensing Observations

- **Evaluate quantitative precipitation forecasts**
  - Spatial-temporal structure of water
  - Sub-grid variability
- **Data base of ground-based and satellite remote sensing observations**
- **Investigate the process chain from water vapour to precipitation at the ground**

HALO-LIDAR

High Altitude and Long Range Research Aircraft

- **Cooperation between DLR and MIM**
  - DLR: Christoph Kiemle, Post Doc
  - MIM: Prof. Dr. G. Craig, L. Fischer (PhD)
  - Duration 36 month (2nd period of the SPP 1294)
- **Why LIDAR?**
  - Direct measurement of model variables
  - High resolution, high accuracy
- **Topic**
  - Combined airborne lidar measurements of moisture transport and cirrus properties
- **Aims**
  - Develop methods for analysing physically relevant quantities based on data from lidars
  - Model data will be exploited to quantify uncertainties due to atmospheric variability

2. INTRODUCTION

Overview of planned HALO campaigns with the DLR lidars as key instruments

ML-CIRRUS	Investigation of microphysical properties of natural cirrus clouds and cirrus modified by aviation
T-NAWDEX	Quantify the inflow of humidity into extratropical cyclones; Measure latent heat fluxes in humidity source regions relevant fpr extratropical cyclones
NARVAL	Investigate convective mesoscale postfrontal precipitation; Investigate mesoscale disturbances exploiting the synergy between radar and lidar
NEPTUN	Improve the prediction of rainfall caused by embedded pre-frontal rain bands and convective cells triggered by orography and air-sea interactions

3. Differential-Absorption-Lidar (DIAL) in the DLR Falcon aircraft

Emit spectrally narrow and short light pulses into the atmosphere at two distinct wavelengths

↓

Online wavelength: tuned to the center of an absorption line of water vapor
Offline wavelength: serves as reference

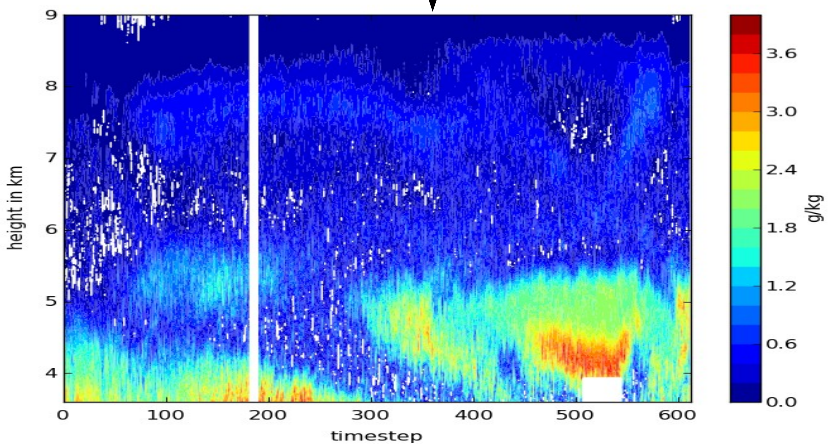
↓

Ratio of on- and offline return signals: Water vapor number density

↓

By using the ideal gas law: Specific humidity

↓



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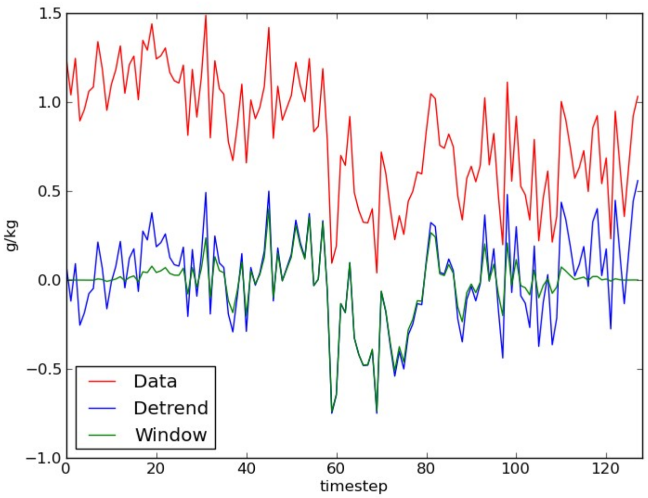
4. Data Analysis Method
Water Vapor Energy Spectra



- *One segment with n = 128 data points*
- *Data gaps: fill with zeroes*
- *Segmentation: n must be a power of 2 (p.654)*
- *Overlapping: overlap segments by one-half of their length (p.660)*

Raw data over finite time → Removal of mean value and linear trend

↓

Data window:

→ Hanning window: $W(k) = 0.5 * (1 - \cos(2\pi * k / n))$

→ Reduce leakage

↓

FFT-Routine: $S_{FFT}(f) = \sum_{n=0}^{N-1} W(k) * x(n) \, e^{2\pi * n * k / N}$

↓

Energy Spectrum: $(S_x(f) = \frac{2}{df} \frac{n}{n_{valid}} \frac{n}{\sum_{k=0}^{n} W(k)^2} |S_{FFT}|^2)$

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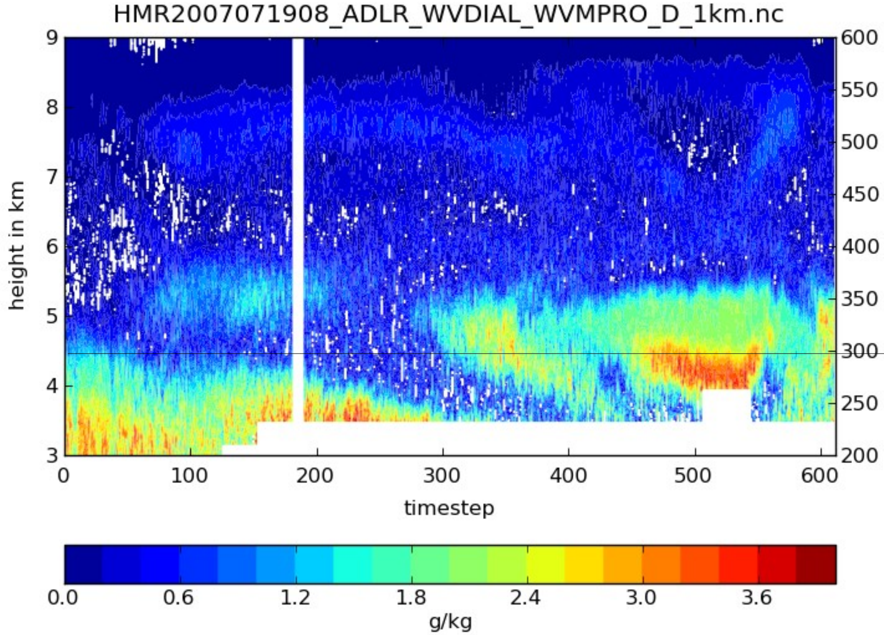
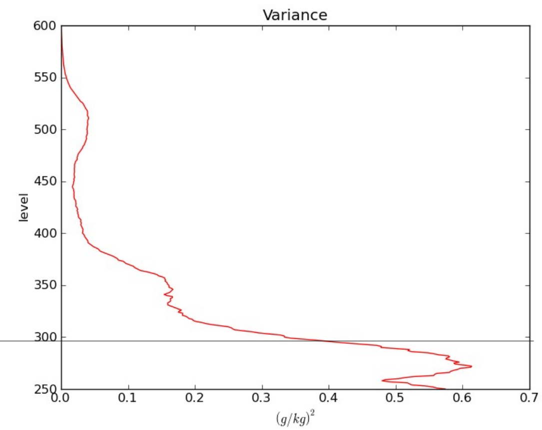
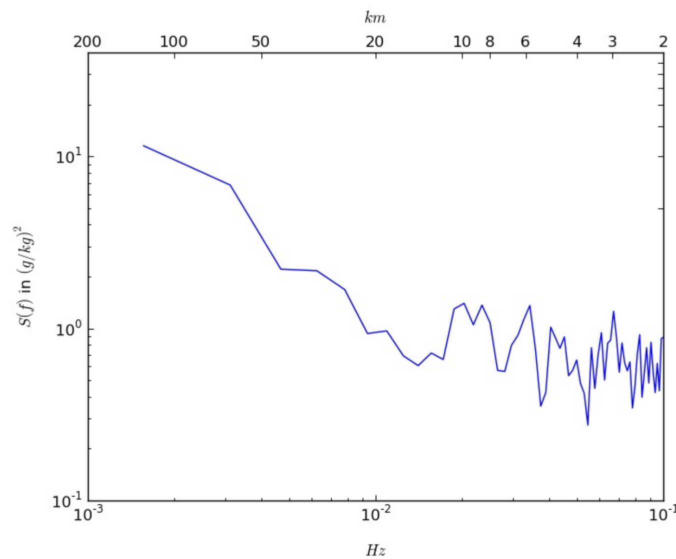
5. FIRST RESULTS







Level 300:

- Cross section: High variability, dry and humid region from left to right
- Energy spectra: High variability, long scales are well defined, min. near 15 km → spectral gap means scale break?

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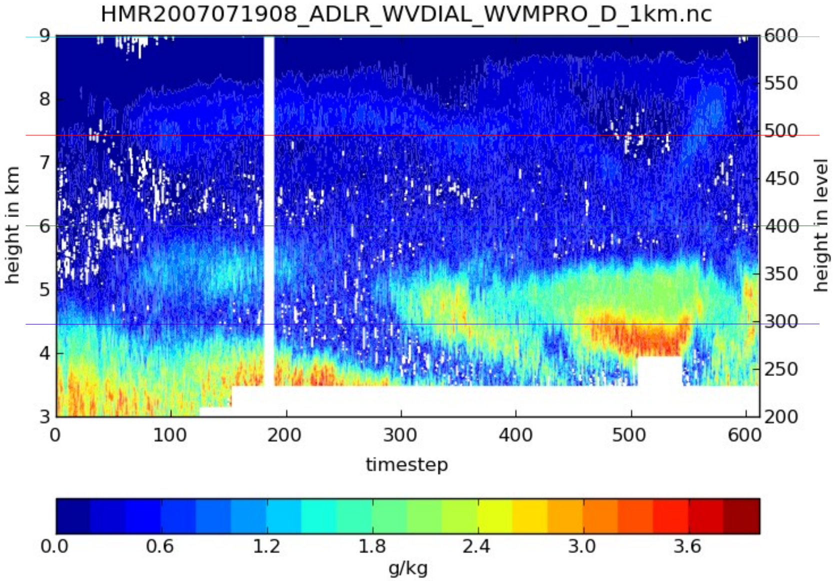
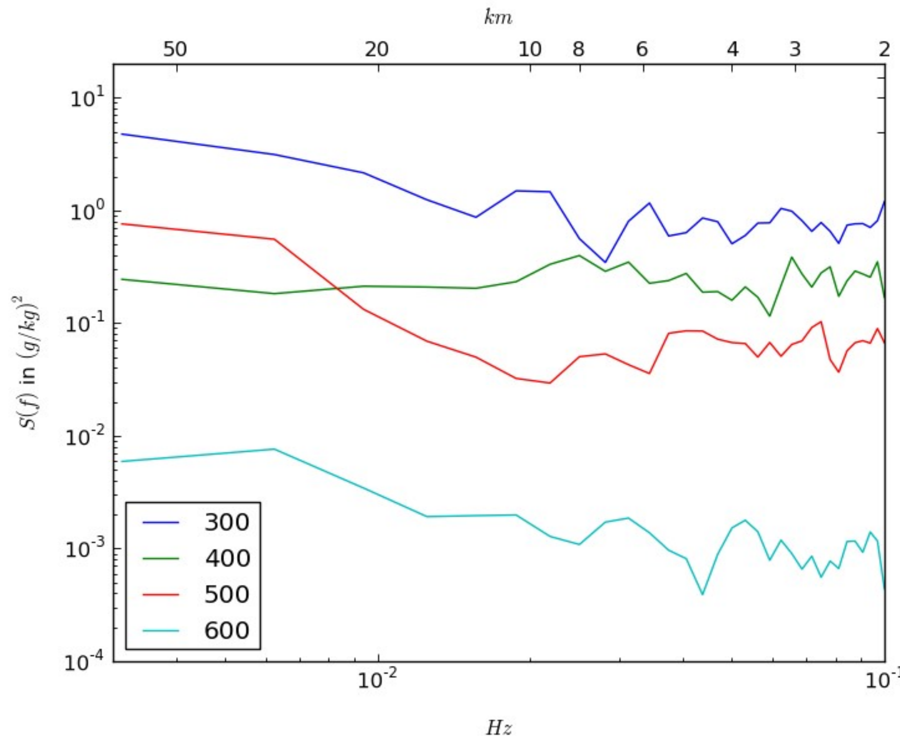
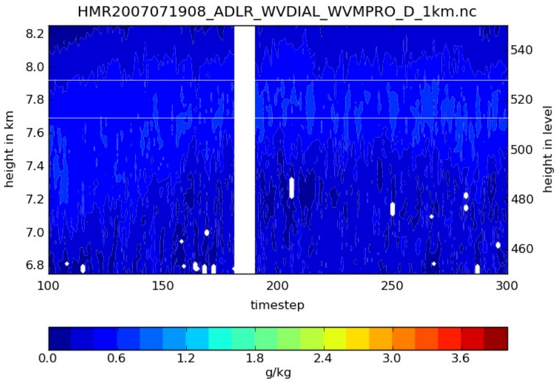
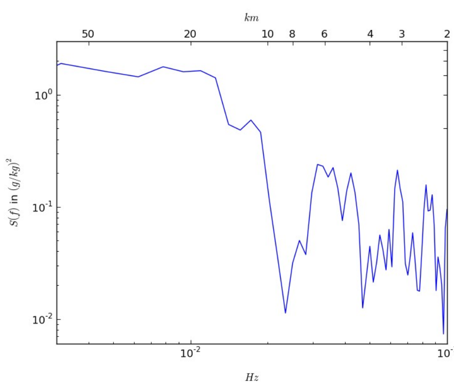
5. FIRST RESULTS









- Noise decreases with smaller range
- Spectra of a dry region is flat (Level 400)
- Small scale spectra (6 – 2 km) is always flat
- Large scale spectra more variable (Level 500)

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CONCLUSION AND OUTLOOK

CONCLUSION:

- The Spectra-Method possibly shows the variability of water vapor in the middle and upper troposphere.
- The total variance of the spectras is dependent on height.
- Technical problems: Differentiation of the noise from signal.
- Hypothesis: a scale break near 15 km.
- Homogeneous data results in a small variance, i.e. there are only few scales that dominate.

OUTLOOK:

- Use Autocorrelationfunction, to test if random noise or coherent structures.
- Develop more scientific lidar analysis methods to characterise magnitude and spatial scales of variability.
- Comparison between Simulation and Observation taking into account the smallest resolved scales and the subgrid (for stochastic parameterisation).
- Develop methods that combine statistical descriptions of the measurements with dynamical measures of atmospheric predictability to enable more precise comparisons with theory and numerical models.