Assessment of integrated water vapour and its variability inferred by satellite, ground-based measurements and atmospheric models

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1. Goals

- Asses accuracy of various techniques to measure interpolated integrated water vapour (IWV).
- Exploit continous ground-based measurements at the Jülich Observatory of Cloud Evolution (JOYCE) and two month field campaign
- Investigate the variability of IWV on small scales

2. HD(CP)² Observational Prototype Experiment (HOPE)

Within the project High Definition Clouds and Precipitation for advancing Climate Prediction (HD(CP)²) HOPE took place in the vicinity of JOYCE

- April and May 2013
- Measurements of integrated water vapour (IWV) with microwave radiometers (MWR), Global Positioning System (GPS), sunphotometer, and radiosoundings
- Standard infrared (IR) and near infrared (NIR) and NIR Freie Universität Berlin (NIRFUB) Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals from Aqua and Terra overflights

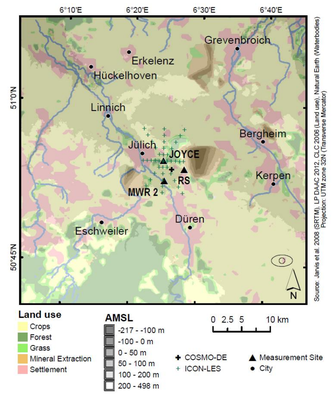


Fig.1 : *GPS and MWR are located at JOYCE. ICON grid points and MWR2 are used in Fig. 4.*

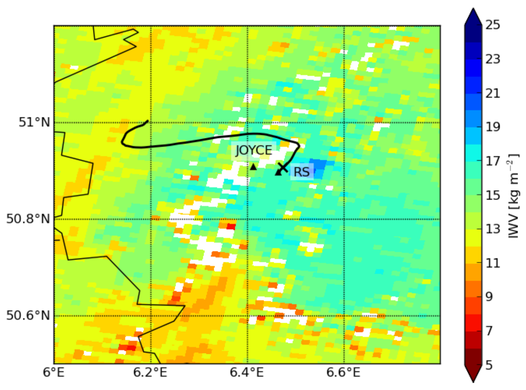
3. MODIS-NIRFUB retrieval

- Reduction of forward operator uncertainty due to sdaption of temperature and water vapour profiles for atmospheric transmittance calculations
- Consideration of scattering processes on aerosols
- Iterative inverse modeling scheme using Newton method exploiting three absorption bands
- Uncertainty estimates considering all error influences on a pixel by pixel basis

4. Can measurements capture small-scale IWV variability?

MODIS can show spatial variability, …

Fig. 2: MODIS-NIR IWV for 5 May 2013 at 10:25 UTC. Cloudy pixels are displayed in white. The black line indicates the track of the radiosonde launched at 11:00 UTC (IWV = 13.2 kg/m²) with a cross at the location where it leaves the planetary boundary layer.



…but no temporal small-scale variability. These can be captured by continuous measurements from the ground:

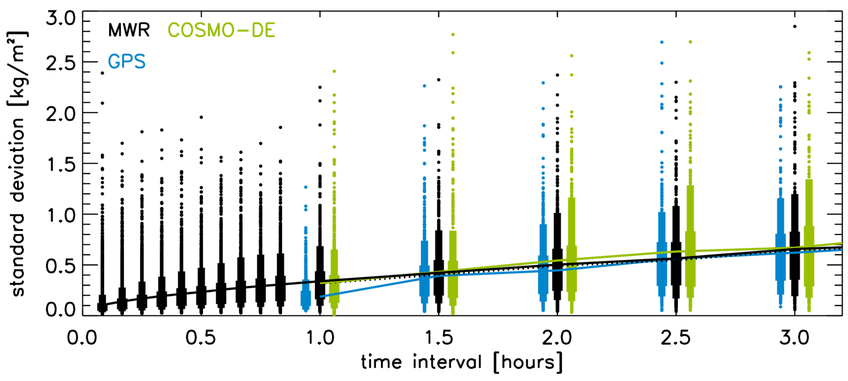


Fig.3 : *Lines: Mean standard deviation of IWV during HOPE computed for varying intervals. Displayed are: MWR with 15 min resolution (dotted black), MWR with 5 s resolution (solid black), GPS (blue), and COSMO-DE (green). For the 5 s MWR measurements, the GPS measurements, and the COSMO-DE simulation the vertical bars indicate the 10%, 25%, 75%, and 90%-percentiles of the standard deviation for varying intervals. The single dots indicate the outliers.*

- Standard deviations of 2 kg m^{-2} occur even at time intervals of less than 1 h
- MWR: Mean standard deviation of 15 min averaged data are only slightly smaller than mean standard deviation of 5 s averaged data

→For time scales of a few hours a resolution of 15 min is sufficient for resolving mean IWV variability

5. Which error can occur due to temporal/spatial mismatch?

Use of high resolution (156 m) ICOsahedral Non-hydrostatic (ICON) weather prediction model run to investigate temporal and spatial mismatch simultaneously

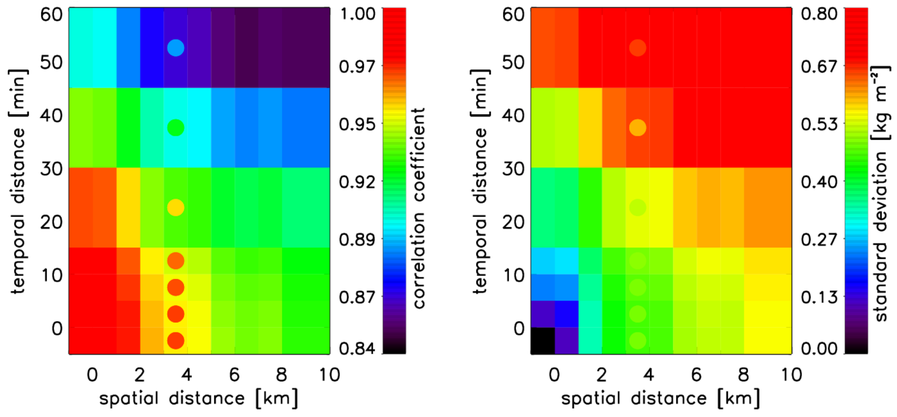


Fig. 4: *Correlation coefficients (left) and standard deviations (right) of IWV from ICON model grid points (simulation for 5 May 2013) as a function of temporal and spatial distance. The circles represent the correlation coefficients and standard deviations from 2MWRs positioned 3.3 km apart.*

- **ICON model** shows that correlation (standard deviation) decreases (increases) distinctly with temporal and spatial mismatch
- **2 MWRs** 3.3 km apart from each other confirm ICON results

6. Multi-instrument comparison

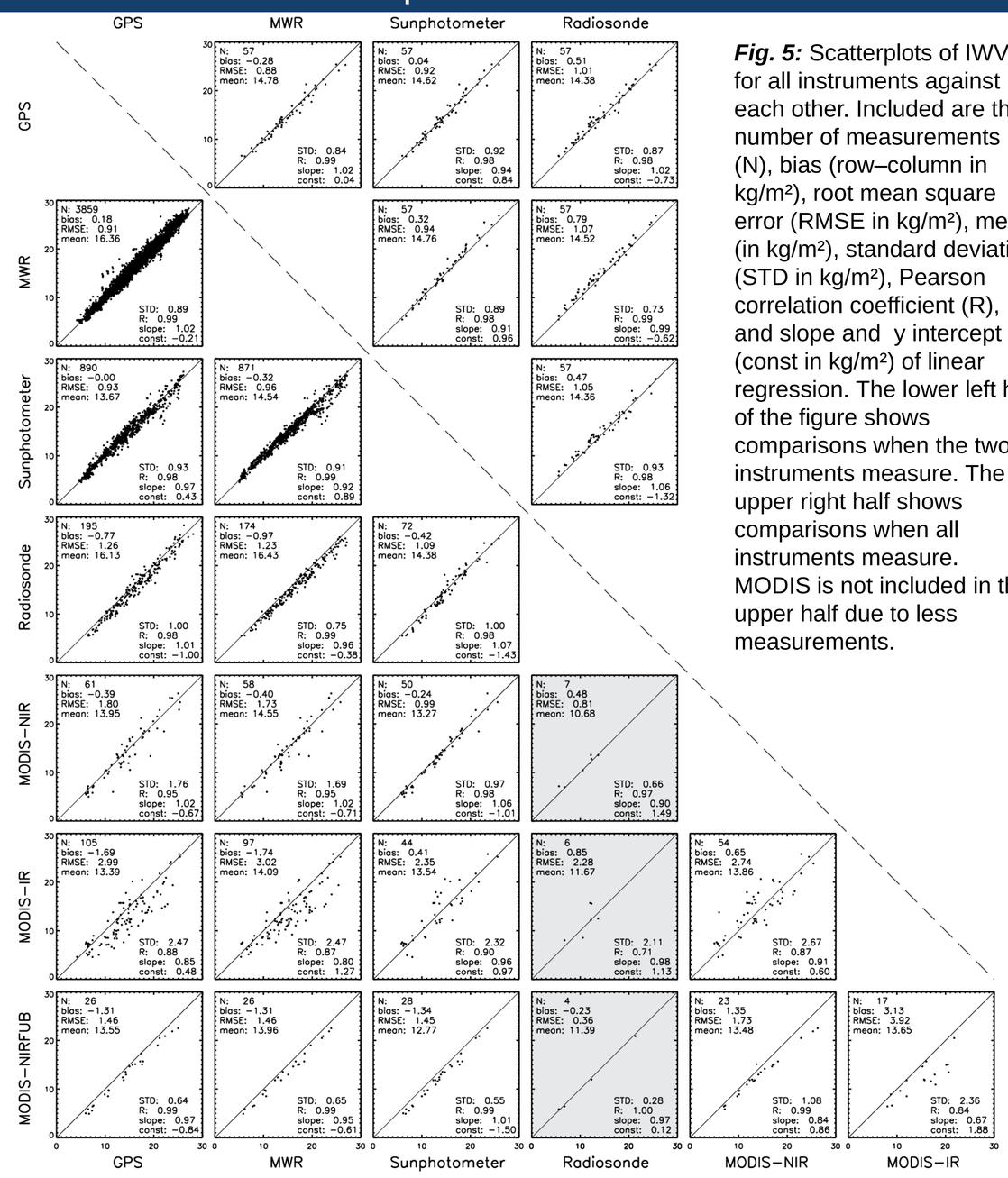


Fig. 5: Scatterplots of IWV for all instruments against each other. Included are the number of measurements (N), bias (row–column in kg/m²), root mean square error (RMSE in kg/m²), mean (in kg/m²), standard deviation (STD in kg/m²), Pearson correlation coefficient (R), and slope and y intercept (const in kg/m²) of linear regression. The lower left half of the figure shows comparisons when the two instruments measure. The upper right half shows comparisons when all instruments measure. MODIS is not included in the upper half due to less measurements.

- GPS: offset at beginning of the day due to near real time processing
- MODIS-NIR: Insufficient cloudmask, cloudy pixels not included in sunphotometer comparison
- MODIS-NIRFUB: to dry, better detection of clouds
- If only coincident measurements of MWR, sunphotometer, GPS and radiosounding are compared → reduction of random error due to mostly clearsky and not raining events

Instrument set of JOYCE is applicable to evaluate satellite measurements

Reference:

Diedrich, H., Preusker, R., Lindstrot, R., and Fischer, J.: Retrieval of daytime total columnar water vapour from MODIS measurements over land surfaces, Atmos. Meas. Tech. Discuss., 7, 7753-7792, 2014.

Steinke, S., Eikenberg, S., Löhnert, U., Dick, G., Klocke, D., Di Girolamo, P., and Crewell, S.: Assessment of small-scale integrated water vapour variability during HOPE, Atmos. Chem. Phys. Discuss., 14, 22837-22879, 2014.

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