A new atmospheric observatory: The Jülich ObservatorY for Cloud Evolution

http://www.geomet.uni-koeln.de/joyce

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JOYCE central questions

Boundary layer

➢ What is the role of the heterogeneous land surface for spatial water vapor inhomogeneities and cloud formation?

Cloud development

➢ What is the relative importance of local and synoptic forcing?

Formation of precipitation

➢ Under which circumstances do clouds begin to precipitate?

Cloud radiation interaction

➢ Can current radiation transfer models accurately simulate 3D radiation fields based on available measurements?

JOYCE instruments

JOYCE is a unique platform of **instruments for atmospheric remote sensing and radiation measurements** jointly operated by the University of Cologne and Forschungszentrum Jülich

- Scanning 35 GHz cloud radar MIRA[1]
- Scanning 14 channel microwave radiometer MWR[2] with IR pyrometer[3]
- Scanning Doppler wind lidar[4]
- Atm. emitted radiance interferometer[5]
- Total Sky Imager TSI[6]
- Laser ceilometer CT25K[7]
- Micro Rain Radar[8], sodar[9]
- Max-DOAS[10]
- Radiation sensors[11]
- 120 m meteorological mast[12] including eddy covariance station

Retrieval methodology

On the basis of the Cloudnet target categorization product, a 1DVAR retrieval schemes combines multiple measurements with a priori information to provide physically consistent atmospheric profiles and corresponding uncertainty estimates.

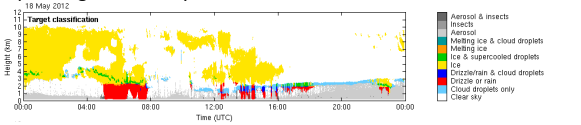


Figure above: Categorization of backscatter objects detected by cloud radar and ceilometer on May 18, 2012. The categorization is based on radar moments, ceilometer backscatter gradient, microwave-derived liquid water path and temperature and humidity from model analyses. Quantitative cloud property retrieval is constrained by the categorization.

Input
- cloud boundaries
- cloud phase
- measurement vector $\mathbf{y}$:=
  - radar moments
  - microwave TB
  - IR radiances
  - a priori information

$$\mathbf{x}_{i+1} = \mathbf{x}_i + \left(\mathbf{K}_i^T \mathbf{S}_\varepsilon^{-1} \mathbf{K}_i + \mathbf{S}_a^{-1}\right)^{-1} \times \left[\mathbf{K}_i^T \mathbf{S}_\varepsilon^{-1} \left(\mathbf{y} - \mathbf{y}_i\right) + \mathbf{S}_a^{-1} \left(\mathbf{x}_a - \mathbf{x}_i\right)\right]$$

$\mathbf{F}$: forward model (radiative transfer)

$\mathbf{K}_i = \frac{\partial \mathbf{F}(\mathbf{x}_i)}{\partial \mathbf{x}_i} = \frac{\partial \mathbf{y}_i}{\partial \mathbf{x}_i}$: Jacobian

$\mathbf{S}_a$: a priori covariance

$\mathbf{S}_\varepsilon$: measurement error covariance

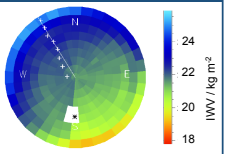
1D-VAR scheme

Output
- state vector $\mathbf{x}$:=
  - temperature & humidity profile
  - ice and liquid cloud effective radius
  - ice and liquid cloud water content
- error estimate of $\mathbf{x}$

Water vapor investigation with MWR

Strength and direction of spatial gradient

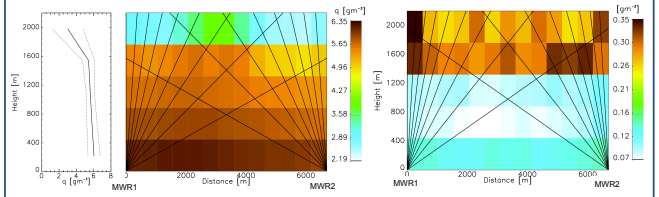
- hemispheric MWR scan during a frontal passage: attribute 88% of spatial IWV variance to advection → 12% to turbulence



Above: Spatial distribution and gradient of air-mass corrected Integrated Water Vapor (IWV) on Sept 09, 2009. Zenith angle of the outermost ring is 76.8° (Schween et al., 2011)

2D water vapor fields

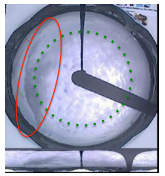
- two elevation scanning MWR: enhanced water vapor accuracy in the boundary layer → evaluate model



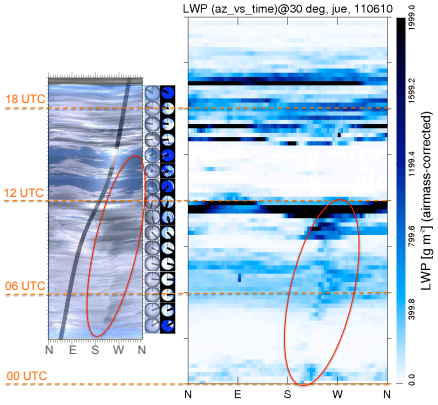
Left: mean water vapor profile (and standard deviation) from an LES simulation over the JOYCE area. Center: a retrieved 2D water vapor cross-section using the "LES truth" to simulate MWR measurements in the K-Band along the shown propagation directions. Right: derived water vapor accuracy using all LES time steps (N=360).

Cloud investigations

During southward flow, JOYCE observations are influenced by emissions from the lignite power plant Weisweiler located about 10 km to the south west.



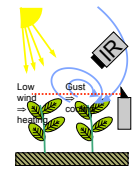
Left: TSI at 8:30 UTC on 11 June 2011. The green circle indicates sky observations at 30° elevation. Right: Temporal development of clouds from TSI and MWR LWP at 30° elevation as function of azimuth angle. Red ovals indicate the cloud from the power plant cooling tower.



Upcoming campaigns

In spring/summer 2012 and 2013 additional instrumentation by external partners will supplement the JOYCE observations :

- High resolution observations at m-scale with IR thermography, wind and water vapor lidar in order to study **surface exchange processes**
- Multiple scanning cloud radar, radiometer and lidar (IfT Leipzig, KIT Karlsruhe, MPI Hamburg, University of Hohenheim) together with TSI and pyranometer network in order to study **cloud radiative effects**



Left: 360° azimuth scan of cloud radar MIRA at 30° elevation angle. Right: Water vapor field derived from elevation scan of Differential Absorption Lidar (University of Hohenheim).