Horizontal humidity gradient from a single scanning microwave radiometer

Jan H. Schween, Susanne Crewell, and Ulricht Löhnert
Universität zu Köln, Institut für Geophysik und Meteorologie,Germany,
jschween@uni-koeln.de

Introduction

Water vapour variations in the boundary layer (BL) reflect convective activity and are important for the development of clouds and precipitation. We present a new approach to derive horizontal gradients of water vapour from a single microwave radiometer (MWR) in volume scanning mode. An approaching frontal system (Sept. 9, 2009) is analysed.

Method

We are interested in how an inhomogeneous water vapour field appears in measured integrated water vapour. We assume for the **water vapour density** ρ_V in the horizontal:

$$\rho_{V0}(x) = A_0 + A_1 \cdot x \qquad (1)$$

With **A_0 the average in the BL** and **A_1 the horizontal gradient**. In the vertical:

$$\rho_V(x,z) = \begin{cases} \rho_{V0}(x) & z \le h \\ \rho_{V0}(x)\cdot \exp\left(-\frac{z-h}{L}\right) & z > h \end{cases} \qquad (2)$$

with **BL-height h** and **scaling height L**. Integration along a line of sight yields the air mass corrected **integrated water vapour W**:

$$W(\alpha,\theta) = W_1 \tan(\theta)\cos(\alpha+\varphi) + W_0 \qquad (3)$$

with θ and α zenith and azimuth angle respectively, and φ the direction of the gradient. The offset or **vertical column W_0** and **amplitude W_1** are related to h and L:

$$W_0 = A_0 \cdot (h + L) \qquad (4)$$

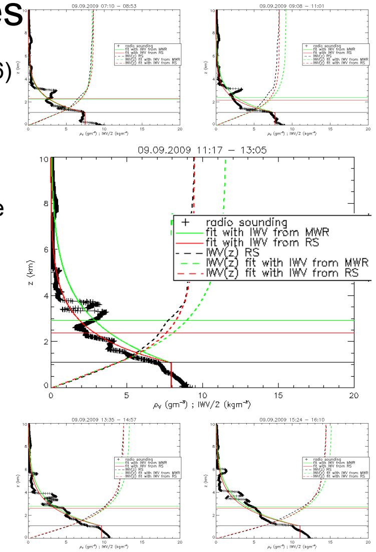
$$W_1 = A_1 \cdot \left(\tfrac{1}{2}h^2 + h\cdot L + L^2\right) \qquad (5)$$

Parameters W_0 and W_1 and φ can be determined by means of a least square fit to data from a scanning microwave radiometer. Parameters A_0 and h must be derived from water vapour density profiles and L can be inferred from W_0.

Water vapour profiles

Five radio soundings (Graw DFM06) between 7 and 16 UTC. ρ_V profiles (+), fitted profile (solid lines), fit parameters h and L (horizontal lines), and bottom up integral ($W(z)$ dashed lines). Green lines mark the fit with L from radiometer, red lines with L from sonde.

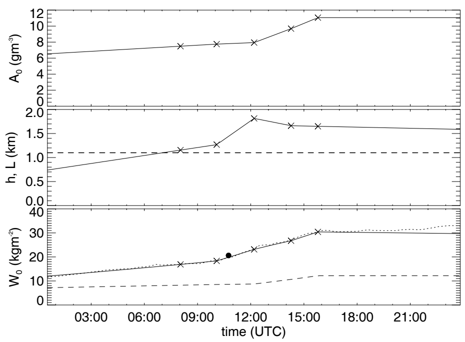
- **BL height h** = 1100 m from temperature profiles and ceilometer
- **Average BL water vapour density A_0** from of radio sonde ρ_V for $z < h$
- **Scaling length L** from radio-meter vertical W_0 via eq.4



Profile parameters

Derived profile parameters interpolated into time. Top: ρ_V in the BL (A_1), middle: scaling lengths h (dashed) and L (solid), bottom: vertical water column W_0 from profile parameters for the whole column (solid), for the BL only (dashed) and from radiometer (dotted). Dot marks value from MERIS satellite instrument.

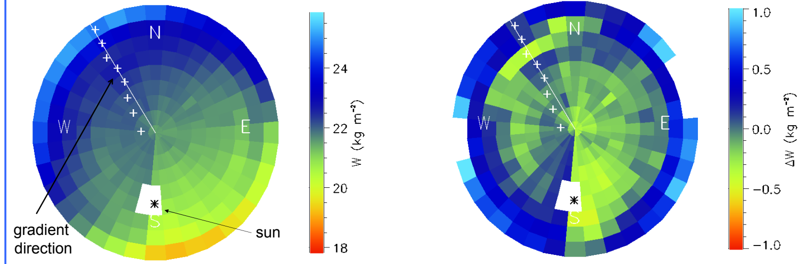
- strongest increase of A_1 (i.e. water vapour in the BL) after 12UTC
- strongest increase of L (i.e. water vapour above BL) in the hour before 12UTC



References:
Rose, T., S. Crewell, U. Löhnert, and C. Simmer, 2005: A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere. *Atmos. Res.* **75**, 183-200

Water vapour scans

Humidity and Temperature Profiler (HATPRO, Rose et al. 2005) scans upper hemisphere with about 10 ° resolution every 18 min within 8.25minutes.

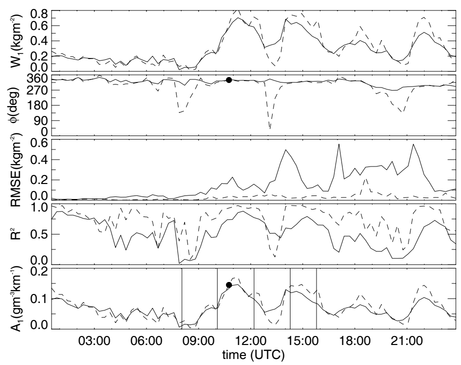


Hemispherical scan of airmass corrected integrated water vapour W from 11:30-11:38: Smooth field with highest values in the NW and lowest in the SE.

Residuum after fit of eq. 3. No clear pattern except for step in the south which is due to increase during first minute of scan. Fourier analysis gives no higher order components. ⇒ spatial and temporal **variability** must be due to local **convective activity**.

Results and outlook

Amplitude (W_1) of the fit to the full scan (solid) and a single elevation (dashed), derived direction of the gradient (φ), RMSE of the fit, explained variance (R^2) and derived gradient A_1. Dot marks value derived from MERIS satellite data.



- two distinct **maxima in W_1** before and after 12UTC coincide with strongest increase of water vapour in BL and above.
- good agreement between full scan fit and single elevation fit except for times with low R^2
  - ⇒ **scan at one or two elevations** could be sufficient
  - ⇒ option for **faster scanning** to reduce influence of temporal fluctuations
- large RMSE values during the day indicate **convective activity**
- good agreement with satellite
- **retrieval of ρ_V profile-parameters** from radiometer will make the method independent from radio soundings.