WRF humidity profile simulations in PBL: Sensitivity studies and comparisons with scanning water vapor DIAL measurements

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INTRODUCTION

- ❑ Correct simulation of initiation and organization of convection is a prerequisite for accurate cloud and precipitation simulation. This is heavily dependent on PBL dynamics, thermodynamics and land-surface-atmosphere feedback processes.
- ❑ In this case study, an ensemble of WRF version 3.4.1 simulations is utilized for examining the sensitivity of humidity profiles to PBL parameterizations and land-surface model (LSM) options over the area of Germany.
- ❑ Simulated profiles are compared with water-vapor profile measurements performed with the differential absorption lidar (DIAL) of the University of Hohenheim (UHOH).
- ❑ DIAL provides high quality and continuous data set with very high accuracy and the highest spatial/temporal resolution of all existing water-vapor remote sensing systems (*Behrendt et al., 2009*).

EXPERIMENTAL DESIGN

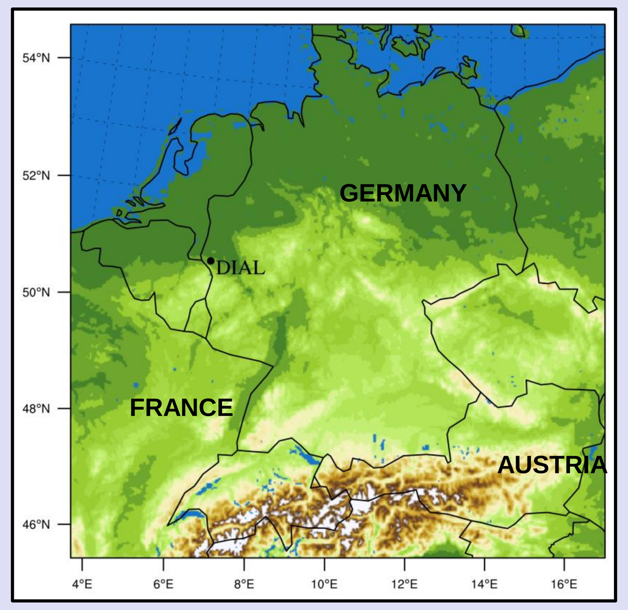
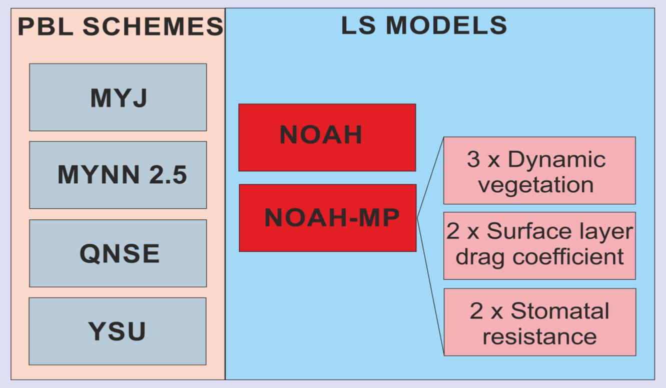


Figure 1. *WRF Domain: Germany with neighbouring countries.*

Figure 2. *44 simulations of* ***WRF-ARW version 3.4.1*** *configured with various combinations of 4 PBL schemes:* ***MYJ*** *(Mellor and Yamada, 1982),* ***YSU*** *(Hong at al., 2006),* ***MYNN 2.5*** *(Nakanishi and Niino, 2006),* ***QNSE*** *(Sukoriansky et al., 2006), and 2 LSMs:* ***NOAH*** *and* ***NOAH-MP****, together with different options in NOAH-MP.*



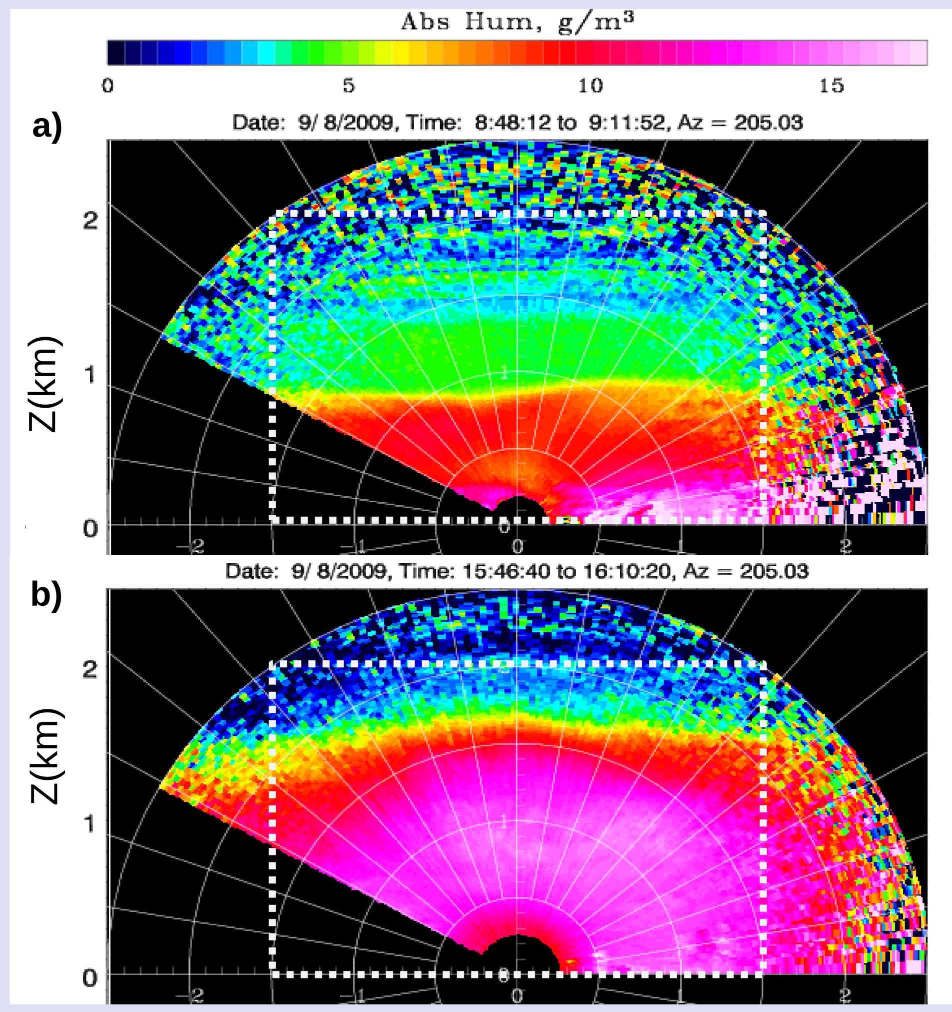
- Δx=Δy=2km
- 49 eta levels
- Forcing: ECMWF analysis (0.125° resolution, 6 hourly)
- Simulation period: 00 UTC 07.09. - 18 UTC 13.09. 2009.

Fixed setup:
- Microphysics: Morrison 2-moment
- SW & LW radiation: RRTMG

UHOH DIAL MEASUREMENTS

Figure 3. *DIAL measurement site, September 2009.*

- ❑ Remote sensing system with pulsed laser that can scan the water-vapor field in any direction.
- ❑ Located between Düren and Jülich, west Germany.
- ❑ Measurements performed under clear and calm weather conditions.



- ❑ DIAL data set allows much better identification of the structures within the PBL and the lower troposphere than e.g. radiosonde measurements.
- ❑ Vertical profiles obtained by averaging over a range of 1.5 km in horizontal directions (white dashed rectangle).

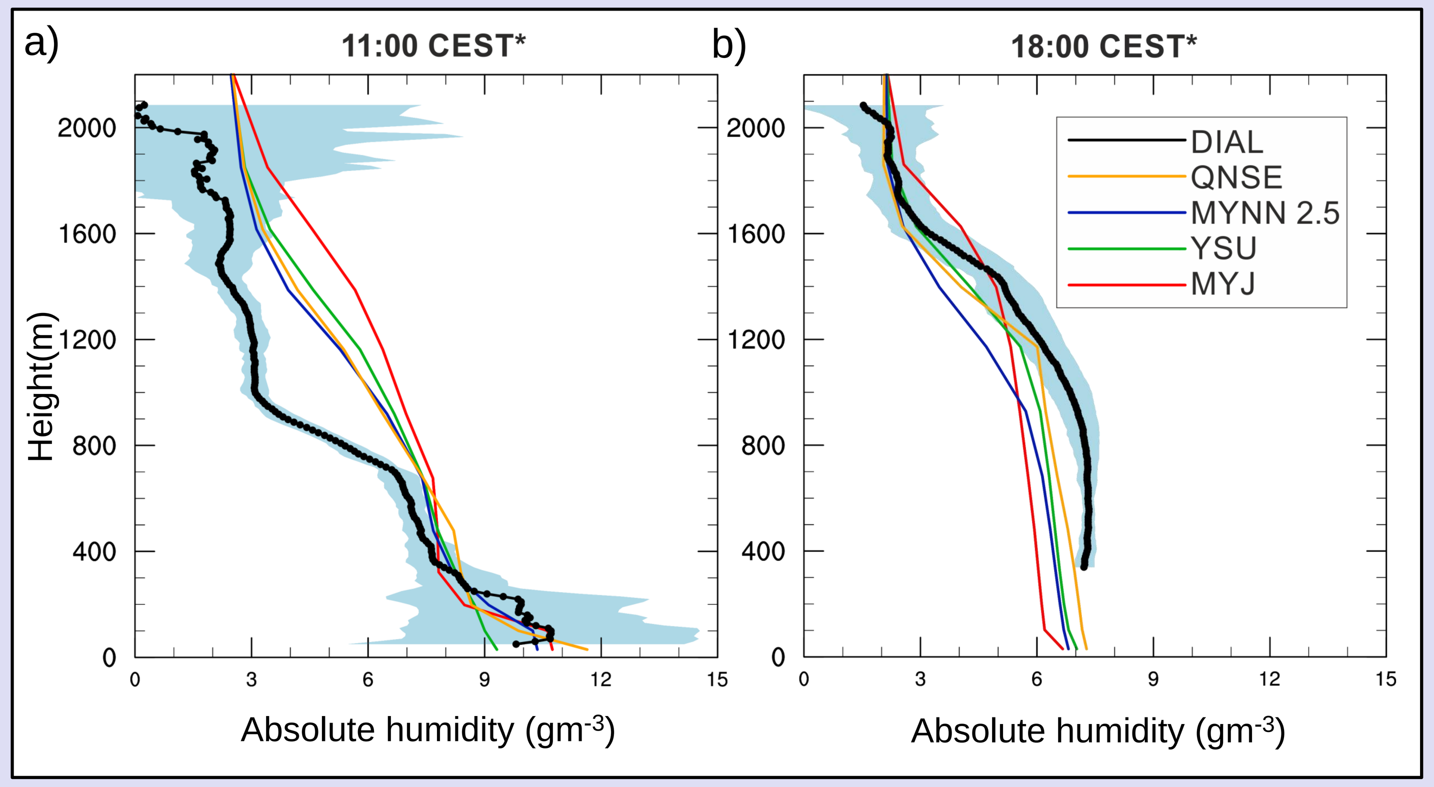
- Horizontal range ~ 2 km
- El = 30 - 180°
- Scan Speed = 0.1°/s
- Δr = 150 m

Errors:
- Systematic: < 5%
- Noise: ~10%

Figure 4.*Scans for September 8th, started at 8:48 UTC (a) and at 15:46 UTC (b).*

SENSITIVITY TO PBL SCHEMES

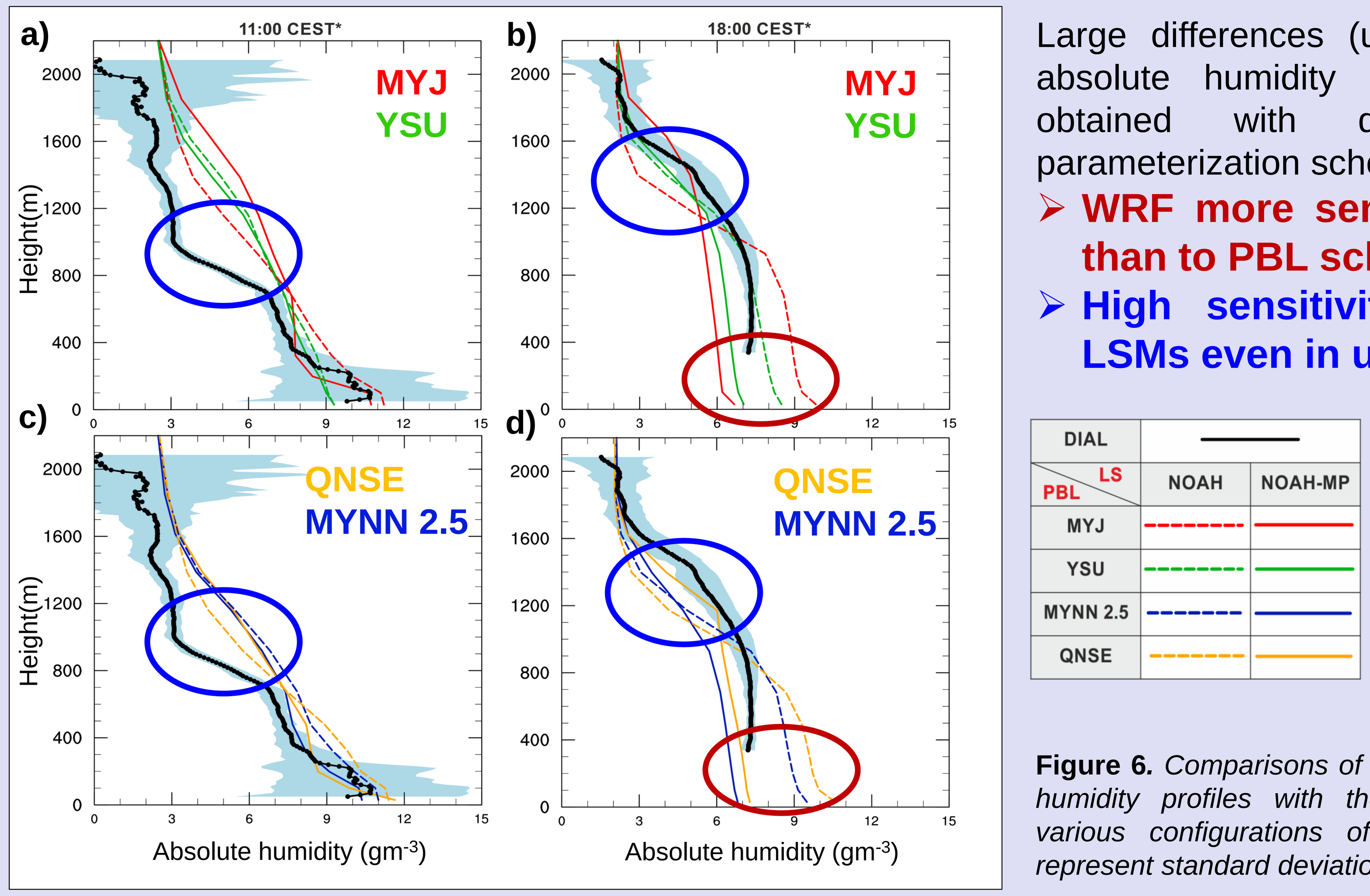
Figure 5. *Measured absolute humidity profiles compared with the ones simulated by WRF with Noah-MP LSM and with 4 different PBL options.*



- ➢ In the upper PBL, large deviations from measurements, especially with MYJ PBL scheme: all simulations do not reproduce the strong gradient of absolute humidity at 11 CEST that was observed.

**Central European Summer Time (CEST) = UTC+2h*

SENSITIVITY TO LSMs AND PBL SCHEMES



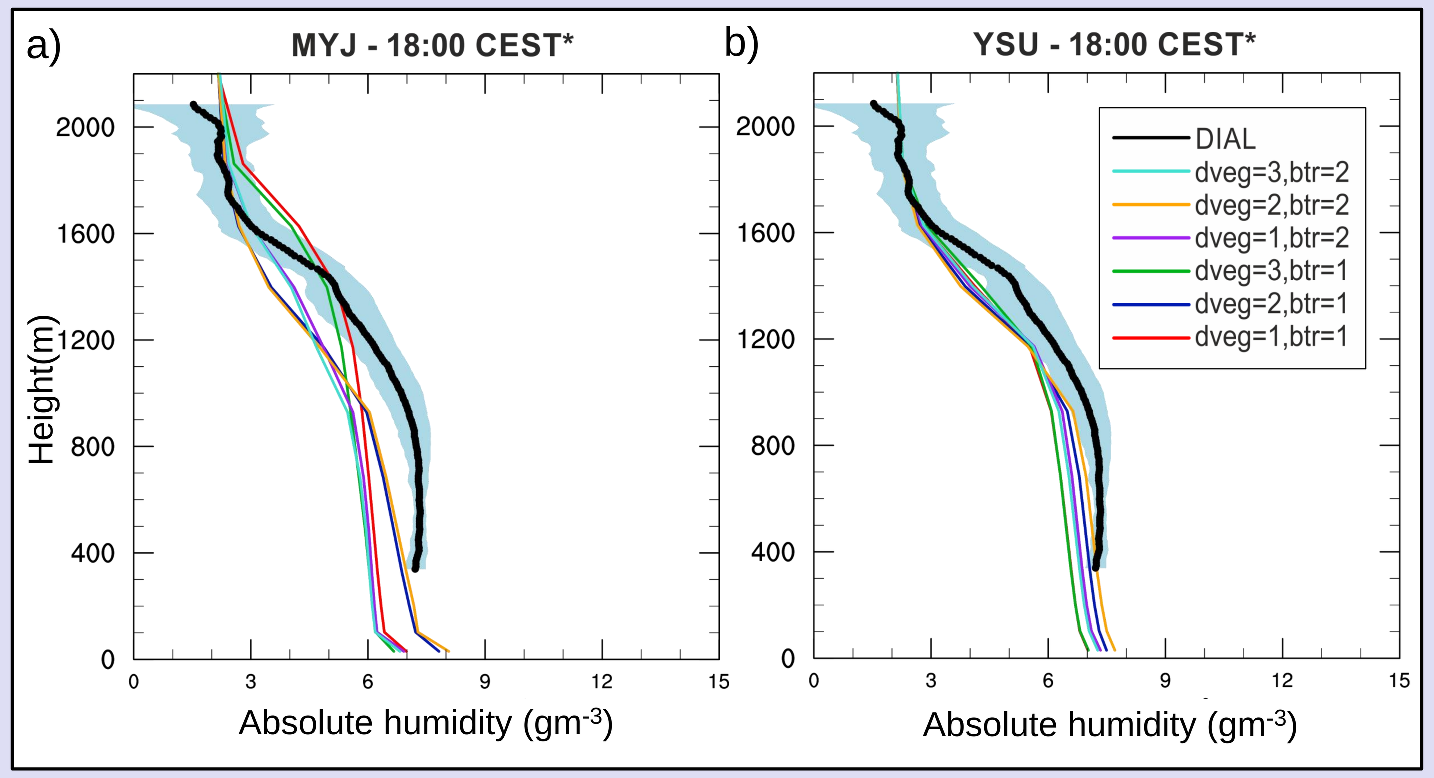
Large differences (up to ~3 gm^{-3}) in absolute humidity profiles could be obtained with different physical parameterization schemes:

- ➢ **WRF more sensitive to LSMs than to PBL schemes**
- ➢ **High sensitivity of WRF to LSMs even in upper PBL**

Figure 6. *Comparisons of the measured absolute humidity profiles with the ones simulated by various configurations of WRF. Shaded area represent standard deviation of the scan.*

SENSITIVITY TO NOAH-MP SWITCHES

Figure 7. *Absolute humidity profiles simulated by WRF configured with (a) MYJ and (b) YSU PBL scheme, both with various combination of the switches in Noah-MP LSM (3 options for dynamic vegetation –* ***dveg****, 2 options for calculation of surface drag coefficient -* ***btr****) compared with measured profiles.*



- ➢ WRF with the MYJ PBL scheme is sensitive to the various switches in Noah-MP LSM.

SUMMARY

DIAL measurements shows great potential in the investigation of the PBL state simulated with WRF:

- ➢ Much higher sensitivity of WRF to LSMs than to PBL schemes - not only in the lower, but also in the upper PBL, often including the whole of the lower troposphere.
- ➢ WRF fails to simulate the observed strong gradients of absolute humidity in upper PBL and lower troposphere – possibly to be improved by higher vertical resolution.
- ➢ MYJ, compared to the other 3 PBL options, is the most sensitive to the LSM choices and exhibits different performance, especially in the residual layer and in the entrainment zone.

OUTLOOK

- ❑ Simulations with longer spin up, higher number of vertical levels and eventually higher horizontal resolution.
- ❑ For verification and evaluation: include eddy-covariance station and soil-moisture network data located at the same sites as DIAL measurements.
- ❑ To analyze more and longer experimental periods with more situations in PBL (stable, unstable).

OPEN QUESTIONS

- ❑ How long must the spin up period be in order to optimize the model hydrological cycle?
- ❑ When manually adjusting vertical resolution in WRF, what would be the optimal height of the lowest vertical level in order to avoid cfl violation?
- ❑ Is this height/selection dependent on PBL parameterization options?

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