Validation of WRF simulated PBL height and soil moisture in dry summer conditions

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Presented at the 13th Annual Meeting of the European Meteorological Society (EMS), 11th European Conference on Applications of Meteorology (ECAM), 9th September to 13th September 2013, Reading, United Kingdom

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Abstract

Using the WRF model, simulations with the WRF-SCM and WRF-ARW are performed over Hungary for the late summer in 2012, in order to analyze the effect of soil moisture on planetary boundary layer (PBL). Derived PBL height from radiometer and windprofiler measurements at one station was compared to the simulations. Alongside the PBL sensitivity, the reliability of the Noah scheme for simulating soil moisture is also tested. Soil moisture measurements took place around the upper air measurement site at five locations within a 4 km^2 area, with 5 different cultivations and 2 different soil types. The weather conditions during the measurement period proved to be dry, as there was no precipitation for at least a month as opposed to the average 40 mm/month. Precipitation events were mostly local convective storms. The soil moisture measurements indicated below wilting point water content, as a result most of the cultivated vegetation (corn, maize) dried out. In these conditions it was in our interest to investigate the modeling capabilities of the WRF model. Simulations with the WRF-ARW were nested around the measurement area using about 2 km grid resolution. Since in this case the surface information for the WRF-ARW is of importance, the CORINE land cover and the Digital Kreybig Soil Information System provided soil texture was used over Hungary, both with 30" resolution.

Model

WRF-ARW v3.4.1 (Skamarock et al., 2008)
ARW modeling features:
- resolution: 36:9:1.875 km one way nested domains, 44 levels
- mother domain size: 1872 x 1872 km,
- simulation time: 24 hours, from 00 UTC; 90s step
- GFS FNL initial and boundary conditions

SCM modeling features:
- resolution: 1000 km, 60 levels
- simulation time: 48 hours, from 00 UTC; 5s step,
- atmospheric initial conditions: 00 UTC radiosonde,
- soil initial conditions: moisture – measurement, temperature – GFS

parameterizations
- RRTM (Mlawer et al., 1997);
- Thompson (2005) & WSM5;
- NOAH (Chen & Dudhia, 2001);
- Kain-Fritsch (Kain, 2004).

PBL schemes

- Yonsei University (YSU) (Hong et al., 2006): 1st order, non-local, K-profile, bulk Ri dependent PBL height;
- Mellor-Yamada-Janjic (MYJ) (Janjic, 1994): 1.5th order, local, TKE prediction, critical TKE defines PBL top;
- Quasi-Normal Scale Elimination (QNSE) (Sukoriansky et al., 2005): 1.5th order, local, TKE prediction, differentiates stable/unstable, PBL top similar to MYJ;
- Asymmetrical Convective Model v2 (ACM2) (Pleim, 2007): Blackadar type, stable – local, unstable – non-local attributes, critical bulk Ri defines PBL height;
- Bougeault-Lacarrére (1989) (BouLac): 1.5th order, local, TKE prediction, PBL height defined by particle method.

Surface properties

- FAO 12 type soil texture;
- over Hungary: Digital Kreybig Soil Information System (Pásztor et al., 2010), 1:25000 resolution; spatial interpolation of soil particle size distribution with FAO classification to 30" resolution grid used by the WRF model (Pásztor et al., 2011; Bakacsi et al., 2010);
- FAO-STATSGO distribution (5') in surrounding countries.
- MARTHA soil data base for soil parameters (Fodor and Pásztor, 2010; Makó and Tóth, 2008).
- CORINE 2000 land use, recategorized for WRF.

Measurements

Measurement site

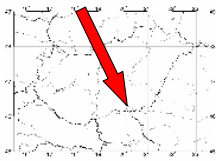
Vertical profiling measurements for this study were conducted at the observatory of the Hungarian Meteorological Service in Szeged (46.25572N, 20.09023E). The site is surrounded by agricultural cultivations outside the city.
Measurement period: July 6 – October 8, 2012.

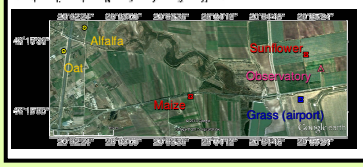
Instruments

Radiometrics MP-3000A, ground-based microwave radiometer:
- continuous temperature, humidity, liquid water profiling to 10 km height,
- 21 calibrated channels in 22–30 GHz (K-band) and 14 in 51–59 GHz (V-band),
- sensors for surface temperature, relative humidity, and pressure.

Vaisala LAP-3000, lower atmosphere windprofiler with radio acoustic sounding system (RASS):
- vertical profiles of horizontal wind speed and direction, and vertical wind velocity up to an altitude of 4 km,
- operating frequency: 1290 MHz,
- time step: every 15 minutes, the average of preceding 30 minutes,
- range resolution: ≈ 220m.

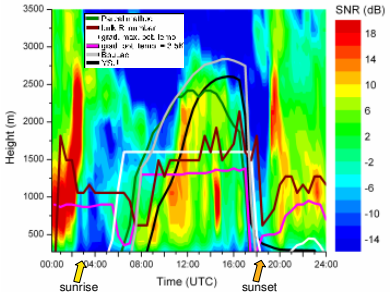
CS616 Soil moisture sensor,
- calibrated with direct measurements,
- hourly,
- 10–40 cm and 40–70 depth,
- 5 locations.





Case study

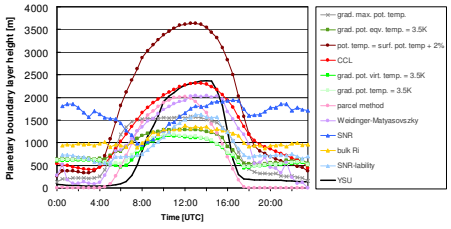
July 14, 2012
- 15ºC – 33ºC;
- 14h sunshine duration, barely cloudy, no precipitation;
- before cold front, maximum wind gust 11 m/s.



Windprofiler signal to noise ratio (SNR) profile, estimated and simulated PBL heights on July 14, 2012.

Estimation of PBL height from measurements

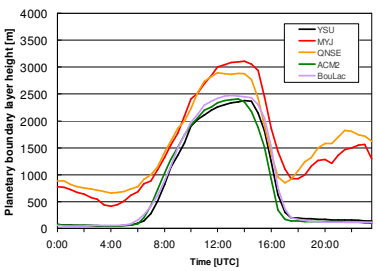
- Different methods have too big variability,
- Daily comparisons show that around 12 UTC the spread is low => comparing simulations to radiosondes is not enough,
- Gradient methods generally show a quick increase in PBL height, then a constant „plateau" until sunset,
- Compared to parcel method, the model shows slower mixing after sunrise (about 1–2 hours).



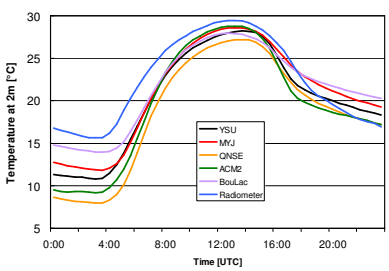
Average (July–September, 2012) daily course of PBL height derived from windprofiler and radiometer.

Results

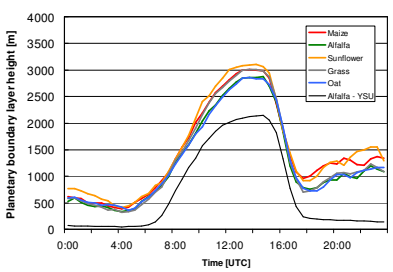
- TKE local and non-local PBL schemes result significantly different PBL top;
- TKE prediction seems to show residual layer during night;
- 2m temperature differences with PBL scheme varies around 3 degrees during daytime and 5 during nighttime with SCM and about half with ARW;
- when the soil moisture in near wilting point a small difference in soil moisture can result 200-500 m difference in PBL height on average.



Average (July–September, 2012) daily course of PBL height using different SCM-PBL schemes.



Average (July–September, 2012) daily course of 2m temperature using different SCM-PBL schemes.



Average (July–September, 2012) daily course of SCM MYJ PBL height over different cultivations.

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Acknowledgements

The project is supported by the Hungarian Scientific Research Found (OTKA K-81432). The authors also thank the help of István Aszalos with the radiometric data.

Centre for Agricultural Research
Hungarian Academy of Sciences