WRF simulations of the atmospheric boundary layer evening transitions during the BLLAST field campaign

M. Sastre [(1)], G.-J. Steeneveld [(2)], C. Yagüe [(1)], C. Román-Cascón [(1)], G. Maqueda [(3)] and A. van de Boer [(2, 4)]

(1) Universidad Complutense de Madrid, Dep. Geofísica y Meteorología, Spain (msastrem@fis.ucm.es); (2) Wageningen University, Meteorology and Air Quality Section, The Netherlands; (3) Universidad Complutense de Madrid, Dep. Astrofísica y Ciencias de la Atmósfera, Spain; (4) Meteorological Institute University Bonn, Germany.

1. INTRODUCTION

- Evening transitions in the Planetary Boundary Layer (PBL) [1]:
  - change from convective to stable conditions
  - confluence of different forcing
  - importance for exchange processes
  - land-atmosphere interaction
  - not very well understood
- Modelling evening transition in the PBL
  - difficult to properly perform
  - importance for air quality forecasting [2]
  - numerical weather prediction (NWP) improvements
  - discrepancies with observations [3]

Goals of this work:

- Study how the WRF model performs for evening transitions by comparing simulations and observations, both at surface and vertical profiles.
- Test the model sensitivity to changes in:
  - Land Surface Model (LSM)
  - PBL scheme

2. BLLAST PROJECT

- Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST) project: aims to study the turbulence decay happening in the PBL during the afternoon and evening.
- Field campaign [4]: between 14th June and 8th July 2011, in Lannemezan (43.12 N, 0.36 E), France.
- Experimental site: plateau in an heterogeneous terrain and close to the Pyrenees (mountains).
- Combine observations and numerical simulations of the PBL transition.
- Instrumentation here employed for comparison with simulations:
  - Radiometers, sonic anemometers, humidity and temperature sensors.
  - Soundings.
  - Further information: http://boc.sedoo.fr/

3. MODELLING SETUP

MODEL	WRF-ARW version 3.4.1
INITIAL AND BOUNDARY CONDITIONS	ECMWF data (pressure levels) 0.15º resolution; every 6 h
HORIZONTAL RESOLUTION	3 nested domains Grids of: 9 km, 3 km, 1 km
VERTICAL RESOLUTION	50 eta vertical levels (28 between ground and1000 m)
TIME STEP	30 s
SPIN UP	12 h

TESTS

- PBL parameterizations: YSU [5], MYJ [6], QNSE [7].
- LSM schemes: 5-layers, NOAH, RUC.

Figure 1: 500 hPa geopotential (gpdm) and surface pressure (hPa) for the two selected transitions.

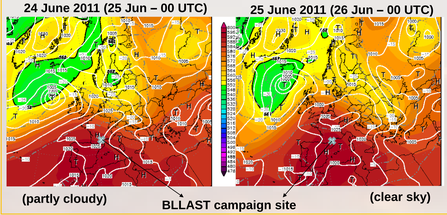


Figure 2: LSM tests with a fixed PBL scheme (YSU). Time series of: net radiation (a), soil heat flux (b), sensible heat flux (c), latent heat flux (d), temperature (e), specific humidity (f), and vertical profiles of potential temperature from 24th Jun. at 1700 UTC (g) and 2300 UTC (h).

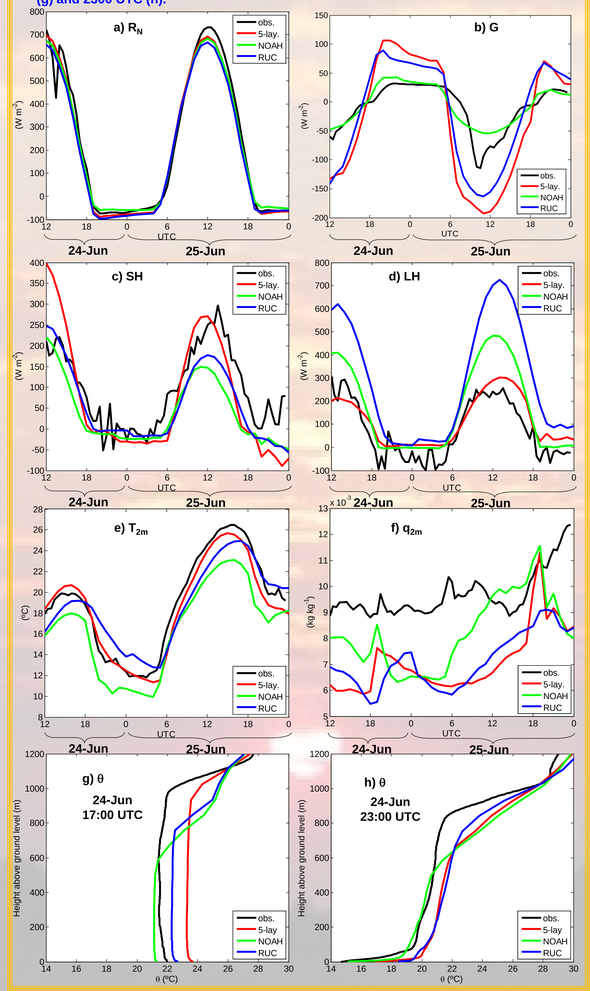
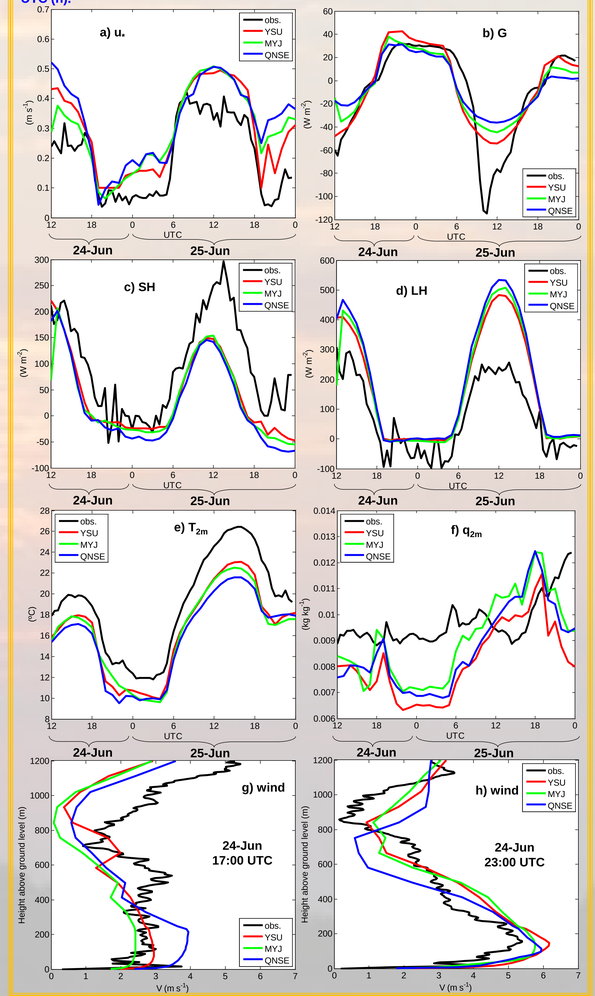


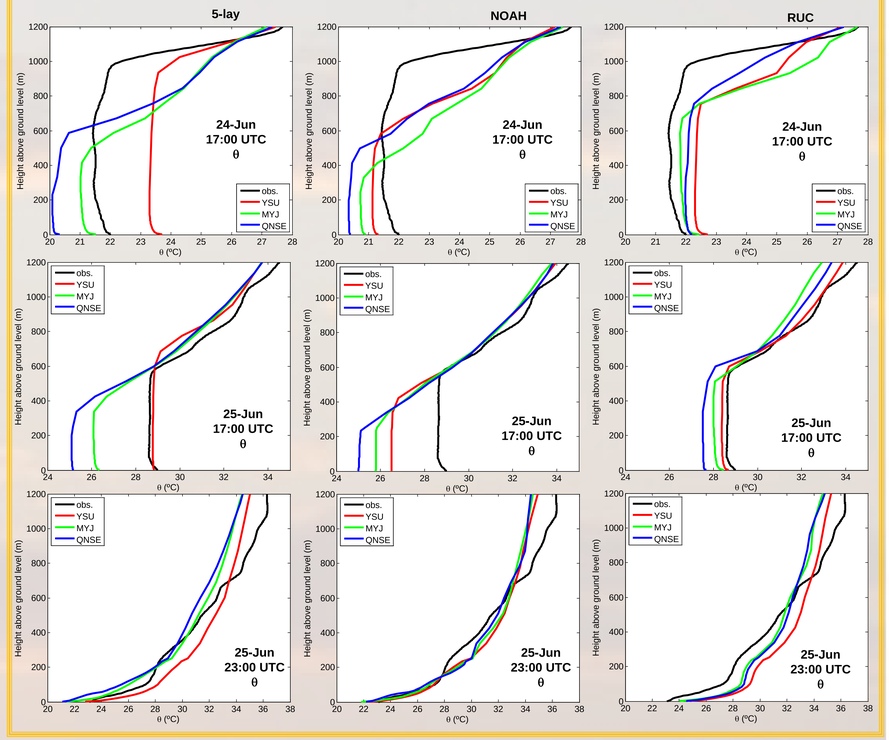
Figure 3: PBL tests with a fixed LSM scheme (NOAH). Time series of: friction velocity (a), soil heat flux (b), sensible heat flux (c), latent heat flux (d), temperature (e), specific humidity (f), and vertical profiles of wind speed from 24th Jun. at 1700 UTC (g) and 2300 UTC (h).



4. RESULTS

- Synoptic situations of the studied transitions (24 and 25 June) can be found in Fig. 1.
- Tests of LSM (Fig. 2) and PBL (Fig. 3) are presented, using respectively the default schemes of PBL (YSU) and LSM (NOAH).
- There is a systematic underestimation of 2m-humidity (Figs. 2f and 3f) and a generalized (wrong) decreasing trend during the transition period. This disagreement with observations may be due to poorly soil moisture representation in the model and could be improved by forcing it to be higher.
- Simulations of sensible heat flux and 2m-temperature provide very consistent results.
- A sensitivity test to both LSM and PBL for potential temperature vertical profiles is shown in Fig. 4. In the night-time profile (23 UTC) there are not big differences among the simulation schemes. In the 17 UTC profiles (both days) the better PBL scheme is very dependent on the LSM chosen.

Figure 4: Comparison of PBL schemes with observations considering 5-lay (left), NOAH (center) and RUC (right) LSM, for three potential temperature vertical profiles: 24-June 1700 UTC (up), 25-June 1700 UTC (middle) and 25-June 2300 UTC (down).



5. SUMMARY AND CONCLUSIONS

- ❖ WRF simulations of evening transitions during BLLAST campaign have been analysed by testing LSM and PBL parameterizations.
- ❖ The simplest configurations (YSU and 5-lay) need less calculation resources and sometimes provide better results than more complex schemes.
- ❖ RUC seems to simulate the potential temperature profiles better than the other LSM.
- ❖ Some schemes present better agreement during the 25th June, which suggests that they may require a longer spin-up.

ACKNOWLEDGEMENTS

The authors thank the BLLAST project and especially all the people participating in the 2011 field campaign in Lannemezan (France).

This research has been funded by the Spanish Government (projects CGL2009-12797-C03-03, CGL2011-13477-E and CGL2012-37416-C04-02). M. Sastre is supported by a FPI-UCM fellowship (BE45/10) and part of this work was developed during a short research stay with UCM fundings (code EB47/11).

The contribution by G.J. Steeneveld has been sponsored by NWO contract 863.10.010 (Lifting the fog).

6. REFERENCES

[1] Angevine, W.M. (2008): Transitional, entraining, cloudy, and coastal boundary layers, *Acta Geophys*., 56, 2-20.

[2] Baklanov, A., Grisogono, B., Bornstein, R., Mahrt, L., Zilitinkevich, S., Taylor, P., Larsen, S., Rotach, M. and Fernando, H.J.S. (2010): On the nature, theory, and modelling of atmospheric planetary boundary layers, *Bull. Amer. Met. Soc*., 92, 123–128.

[3] Svensson, G., and co-authors (2011): Evaluation of the diurnal cycle in the atmospheric boundary layer over land as represented by a variety of single-column models: the second GABLS experiment. *Bound.-Layer Meteorol.*, 140, 177–206.

[4] Lothon, M. and co-authors (2012): The Boundary Layer Late Afternoon and Sunset Turbulence 2011 field experiment, in: Proceedings of the 20th symposium on boundary layers and turbulence, Boston, MA, USA, 9-13 July 2012, 14B.1.

[5] Hong, S.-Y., Noh, Y. and Dudhia, J. (2006): A new vertical diffusion package with an explicit treatment of entrainment processes, *Mon. Weather Rev.,* 134, 2318–2341.

[6] Janjić, Z.I. (1994): The step-mountain eta coordinate model: further developments of the convection, viscous sublayer, and turbulence closure schemes, *Mon. Weather Rev*., 122, 927–945.

[7] Sukoriansky S., Galperin B. and Perov V. (2005): Application of a new spectral theory of stable stratified turbulence to the atmospheric boundary layer over sea ice, *Bound.-Layer Meteorol.*, 117, 231–257.