WRF simulations of the Atmospheric Boundary Layer over homogeneous terrain: representation of nocturnal processes

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1. INTRODUCTION AND OBJECTIVES

- This work analyses the ability of the WRF 3.1 regional model in reproducing phenomena and processes typical of the Planetary Boundary Layer (PBL) in different synoptic situations (Anticyclonic situation and more unstable days), with emphasis on very stable anticyclonic nights over Valladolid, Spain (see Fig. 1).
- Special enphasys on the simulation of nocturnal processes such as Low Level Jets (LLJs) or the occurrence of intermittent turbulence in situations of high stability will be underlined.
- Three different PBL parameterizations have been used in the simulations in order to evaluate the sensitivity to the selection of the physics involved in the PBL: Mellor –Yamada- Janjic (MYJ), Mellor – Yamada – Nakanishi-Niino (MYNN) and Quasi – Normal – Scale- Elimination (QNSE), which is especially designed for stable stratification situations. All the schemes allow the evaluation of the Turbulent Kinetic Energy (TKE).

2. OBSERVATIONAL DATASET

- The validation of the simulations was done with data from an extensive field campaign (SABLES98: *Stable Atmospheric Boundary Layer Experiment in Spain*) developed at the Research Center for the Lower Atmosphere (CIBA) in Valladolid (Spain)[1]. Tethered balloon soundings and a 100m tower equipped with different meteorological instrumentation, including sonic anemometers at different levels, were available.

3. REGIONAL MODEL CONFIGURATION: WRF 3.1

- Initial and Boundary conditions from ERA- Interim Reanalysis (0.75ºx0.75º)[2].
- 4 domains (two- way nesting) are used (Fig. 1).
- 41 sigma vertical levels: 27 below 1 km (7 levels < 100m).
- Time step: 3 minutes.
- Standard physical options[3] (Radiation, Microphysics, Convection, Land Use Model, etc) are used. 3 simulations with different SL/PBL parameterizations have been run.
- Simulation period: 01/09- 30/09/1998 (spin- up of 14 days).

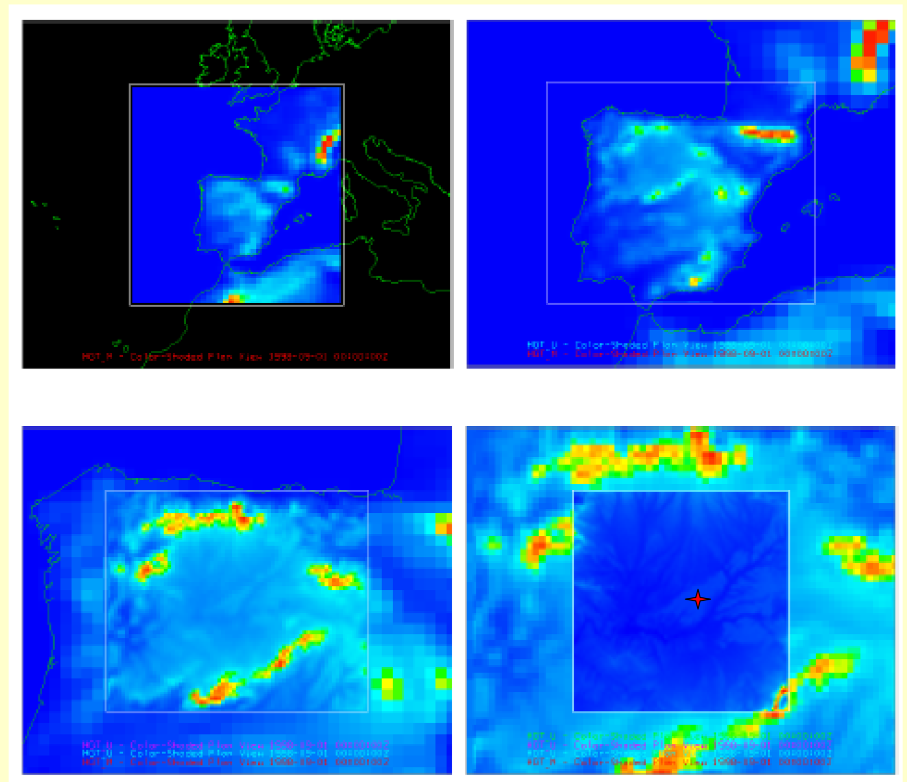

Figure 1: The Four nested domains used in the simulations. The horizontal resolution is respectively 54, 18, 6 and 2 km. The position of the CIBA is indicated by the red star in the higher resolution domain.

4. RESULTS.

4A) Comparison of the observed and simulated time series for the 3 parameterizations

- **T2m:** the amplitude of the diurnal cycle is underestimated by WRF (Fig. 2). MYNN shows the lowest bias (-) (all period and A situation). The best representation of the entrainment in MYNN could be responsible for its better performance[4]. For the stable nights period the bias is + and significantly reduced for the 3 parameterizations (Table I). The underestimation during the day is larger than the overestimation at night.
- **V10m:** wind speed is relatively well simulated by WRF (Fig. 3), with some problems at the transition of the PBL. Mean bias is generally + and small. MYNN shows the lowest bias (all period and A situation), while for the stable nights the parameterization especially designed for stable situations (QNSE) gives the lowest bias (See Table II).
- **TKE14m:** All the simulations underestimate the peaks in Turbulent Kinetic Energy (Fig. 4). The diurnal turbulence is better captured by MYNN during all the period analyzed. However QNSE can be considered the best parameterization for the A period and stable nights. Although the bias of MYJ during the stable nights is low (see Table III), it should be underlined that this parameterization has a lower limit of TKE=0.1 m^2s^{-2}, and the observations can be much lower than this value. During the nights all parameterizations overestimate TKE (sometimes 2 orders of magnitude).

4. RESULTS.

4B) Comparison of the observed and simulated vertical profiles for the 3 parameterizations

- In this section only nocturnal periods (from 18 UTC to 06 UTC) have been analyzed since tethered balloon soundings were only available for this period.
- **θ Profiles:** Fig 5a shows the mean vertical profile of potential temperature in the first 1000m agl. The largest cooling and gradients, near to the surface, is obtained with QNSE, which is generally closer to the reality. The highest discrepancies between simulations and observations are found for the nocturnal transition times (especially for MYJ and MYNN, see Fig. 5c). This could be partially attributed to the bad representation of the TKE at lower levels during nighttime . The best representation of horizontal and vertical transfer during stable conditions allows QNSE[5] to provide the best results.
- **Wind Profiles:** Fig 5b shows the mean vertical wind profile in the first 1000m agl. All the parameterizations are able to reproduce the Low Level Jet, although at higher levels and stronger than observed. The more intense (around 10 m/s) the LLJ is the higher accuracy to capture the Jet is obtained. Again QNSE is more effective to capture the temporal evolution of the wind profile along the transition from the evening PBL to the stable PBL (Fig. 5d).

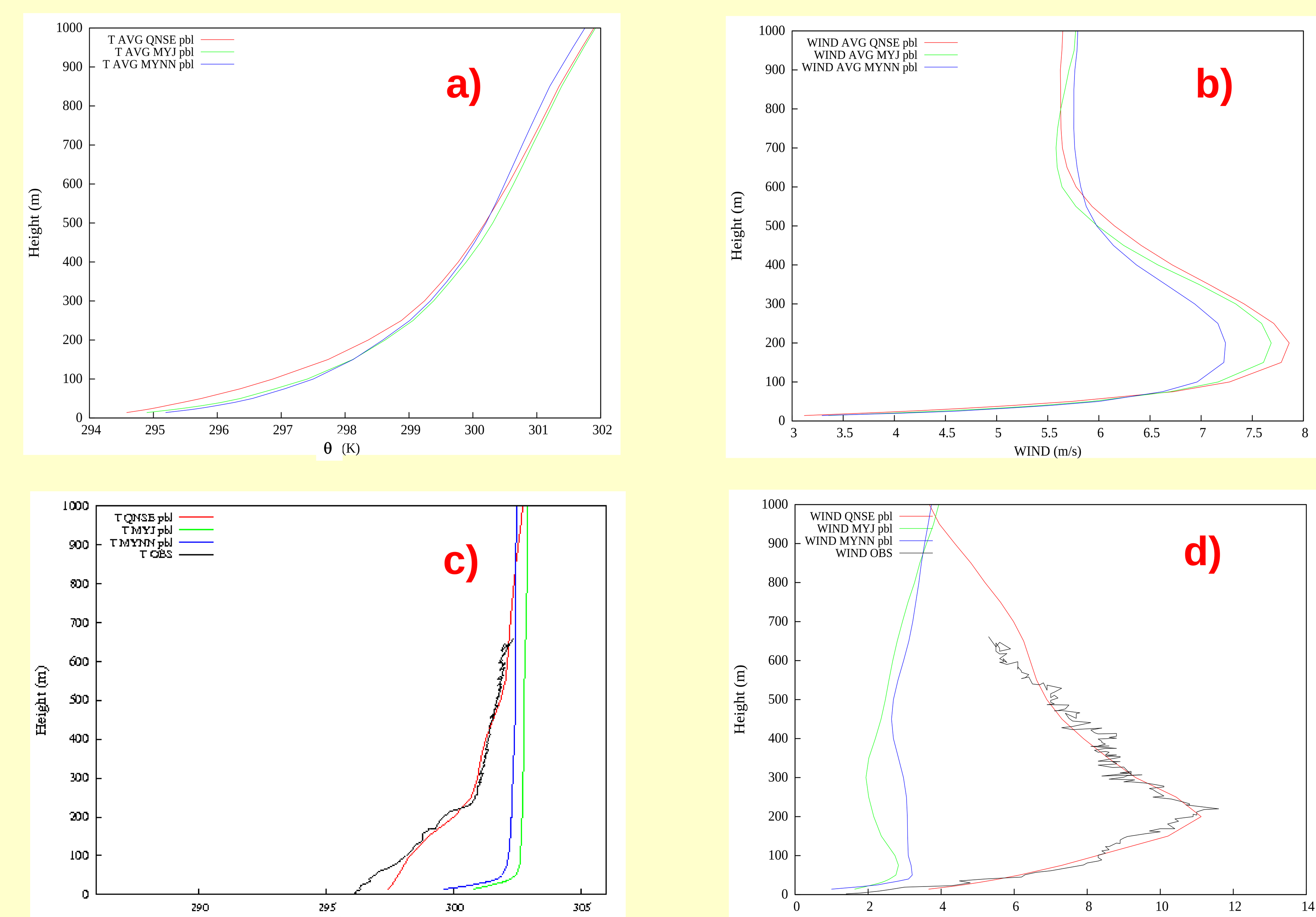

Figure 5: A) Mean potential temperature profile for the nights (18 to 06 UTC) of the Stable Period (14-15 to 21-22 nights). B) As A) but for wind speed profiles. C) Potential temperature profiles for 21 September at 20:00 UTC. D) Wind speed profiles for 21 September at 20:00 UTC.

5. SUMMARY AND CONCLUSIONS

- The diurnal cycle (wind and temperature) during SABLES98 field experiment is relatively well simulated by WRF.
- MYNN parameterization provides better representation of T2m. QNSE reproduces better the cooling along nocturnal boundary layers.
- TKE (Turbulent Kinetic Energy) is better simulated during the day with MYNN (entrainment is more real). Nocturnal TKE is overestimated by QNSE, but this parameterization shows a more realistic behavior than MYNN and MYJ.
- WRF reproduces the Low Level Jets (*LLJs*) which are often present at night in the low atmosphere at CIBA. QNSE parameterization is especially accurate. However MYNN underestimates 10m winds and provides worse location of the *LLJs*.
- QNSE, especially designed for stable stratification situations, produces lower bias for 10m wind, giving more realistic wind profiles, and often captures better the surface cooling.

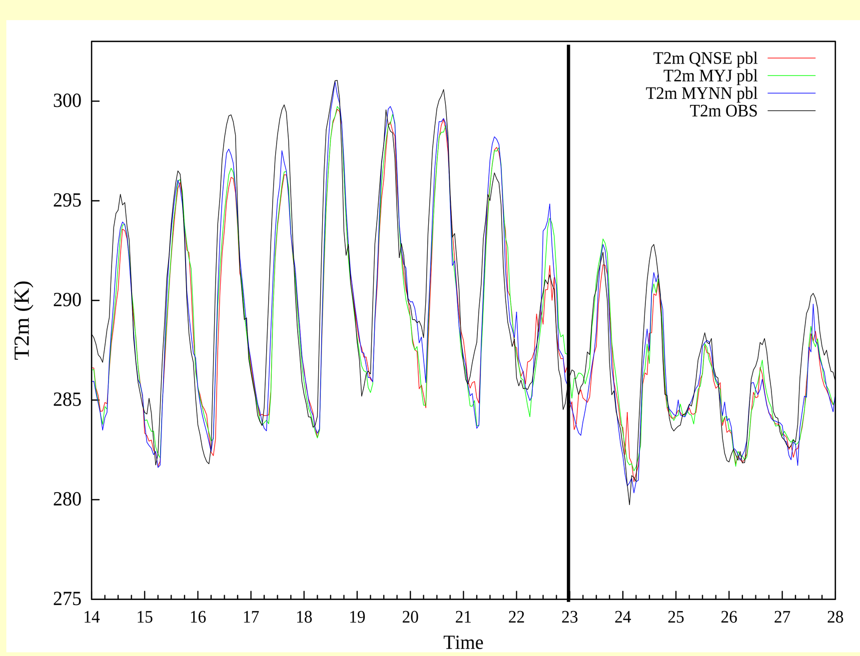

Figure 2: Observed and simulated temperatures at 2m from 14 September 1998 at 00 UTC to 28 September 1998 at 00 UTC. Three different simulations have been run changing the PBL parameterization. The vertical black line indicates the beginning of a change in the synoptic situation from an antyciclonic period (14-22 Sep) to a more unstable period.

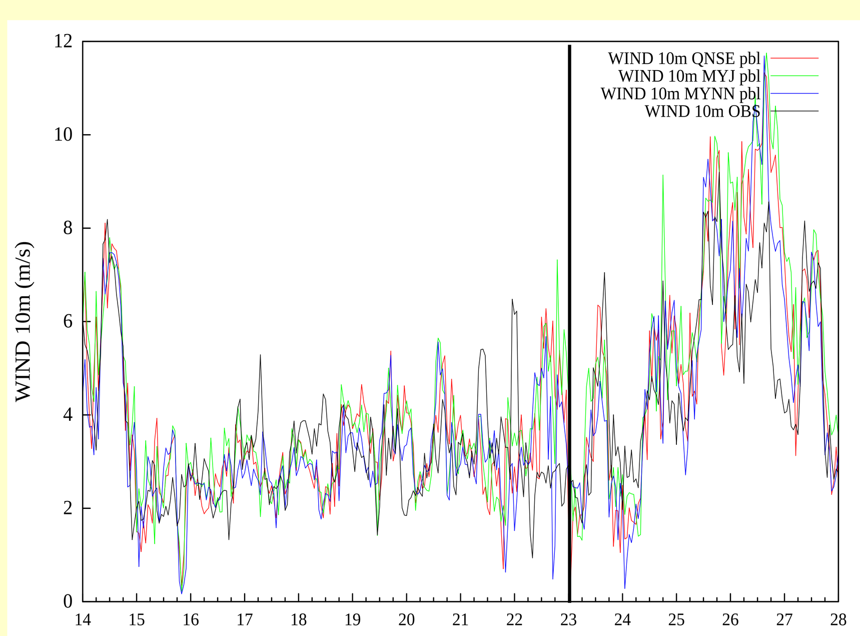

Figure 3: As Fig. 2 but for 10m wind speed 10m.

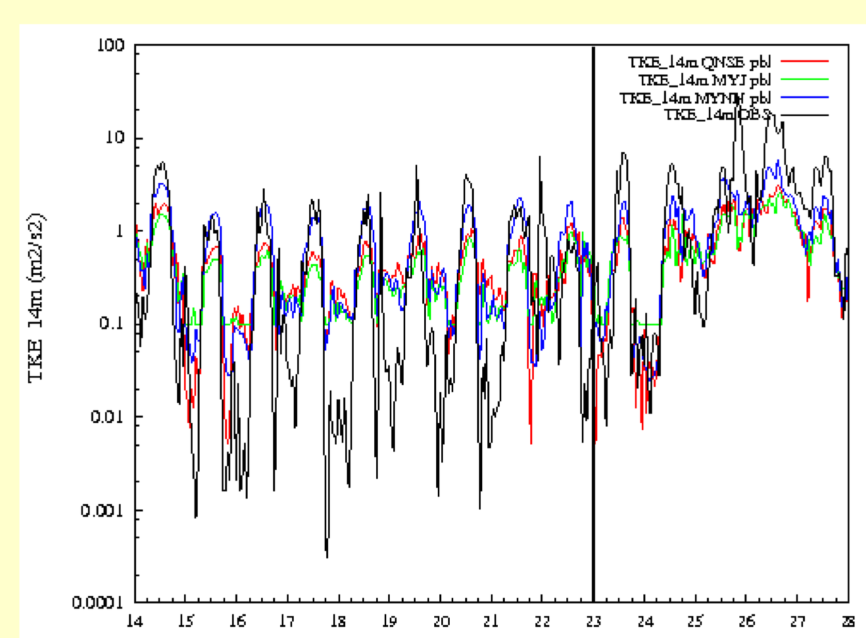

Figure 4: As Fig. 2 but for 14m Turbulent Kinetic Energy (TKE).

	All period		Anticyclonic Situation		Stable nights (14-15 a 21-22)	
	BIAS	RMSE	BIAS	RMSE	BIAS	RMSE
MYJ	-0.70	2.07	-0.84	2.33	0.13	1.63
MYNN	-0.57	1.81	-0.53	1.96	0.16	1.41
QNSE	-0.87	2.17	-0.92	2.40	0.24	1.48

Table I: 2m Temperature Bias (ºC) (Model-Observation) and RMSE (ºC) for the different PBL parameterizations. All simulated period, 14- 22 Sep (A Situation) and Nights from the A situation have been evaluated.

	All period		Anticyclonic Situation		Stable nights (14-15 a 21-22)	
	BIAS	RMSE	BIAS	RMSE	BIAS	RMSE
MYJ	0.52	1.60	0.23	1.28	0.28	1.23
MYNN	**0.06**	1.34	**-0.07**	1.19	-0.30	1.16
QNSE	0.28	1.47	0.11	1.25	**0.07**	1.19

Table II: As Table I but for 10m wind speed (m/s).

	All period		Anticyclonic Situation		Stable nights (14-15 a 21-22)	
	BIAS	RMSE	BIAS	RMSE	BIAS	RMSE
MYJ	-1.16	3.38	-0.32	1.04	**0.035**	0.70
MYNN	**0.19**	2.55	0.68	1.22	0.22	0.79
QNSE	-1.07	3.30	**- 0.24**	0.97	0.06	0.71

Table III: As Table I but for 14m Turbulent Kinetic Energy (TKE) (m^2/s^2).

6. ACKNOWLEDGMENTS

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