P4.4 ONE-COLUMN SIMULATIONS OF THE STABLE BOUNDARY LAYER OBSERVED DURING SABLES-98: IMPORTANCE OF THE SURFACE FLUXES AND THE DYNAMIC FORCINGS.

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1. INTRODUCTION

During September 1998, an experimental campaign (SABLES 98) aimed to study the Stable Boundary Layer (SBL) at mid-latitudes was held in the Northern Spanish Plateau. The experimental set-up consisted of a 10 and a 100-meter tower, a mini-sodar and a tethered balloon (see more details in Cuxart et al., 2000a).
The best conditions were observed during the week 14-21 September. The 7 nights are simulated with a 1D boundary layer model that uses the turbulent kinetic energy (TKE) as the forecasting magnitude. The column is initialised and the results validated from the tethered balloon soundings. The dynamic forcings are obtained from HIRLAM, the operational short-range forecasting model in Spain. A module that allows the introduction of local flows, derived from climatological considerations, has been developed and introduced in the 1D model and it is used here to evaluate the effects of drainage flows.
Special emphasis is devoted to analysing the vertical structure of the turbulence. Sonic anemometers set up on the towers provide useful measures for validation. An important feature of the turbulence profiles, that the model is able to reproduce, is its frequent increase with height that suggests an elevated origin, probably related to the presence of a low-level jet (LLJ).
The adjustment of the current similarity theory proposals for the SBL is also checked.

2. METEOROLOGICAL CONDITIONS

From 14 to 21 September the nocturnal boundary layer was stably stratified, the horizontal pressure gradient and, therefore, the synoptic wind were weak. There was a subsidence inversion at about 2000 m height and predominance of local effects.
Some of the main features of the observational records were: the LLJ formation below 200 m, a stable stratification during all the night and changes in the wind direction associated to local effects.
Fig. 1 shows an example of this behaviour: the potential temperature and wind speed evolution during the night 15-16 September.

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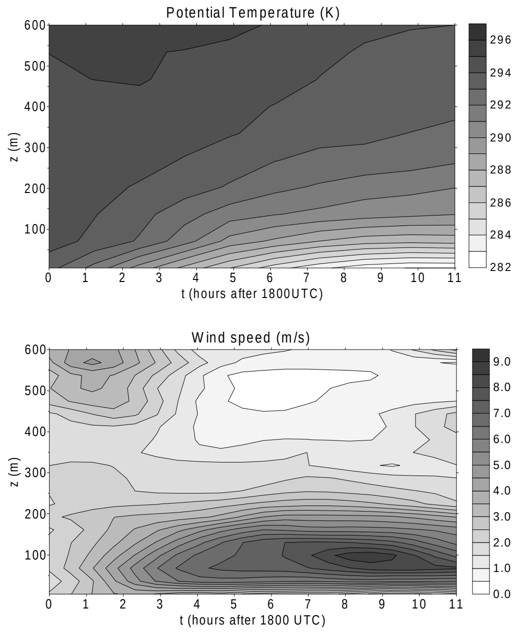

Fig. 1: Evolution of potential temperature and wind speed profiles during the night 15-16 September 1998 calculated from balloon soundings.

3. 1D SIMULATION OF THE SBL

The 1D model uses a 1.5-order turbulence scheme, with a prognostic equation for the TKE (Cuxart et al., 2000b). The scheme uses the Bougeault-Lacarrere mixing length. The model allows the choice between different schemes for calculation of superficial forcings (observed flows, Monin-Obukhov similarity theory). The horizontal structure of the boundary layer is considered through the introduction of dynamic forcings (pressure gradient, advections and mass divergence, which allows the diagnosis of the vertical wind velocity). The model is initialised with potential temperature and wind profiles.

4. RESULTS

The seven nights have been simulated and validated with observations. A quite good agreement between simulations and observations is achieved.
Some results from the simulation of the night 15-16 September, when the analysed phenomena appear in the clearest way, are shown here.
The model is initialised with the 1800 UTC profile obtained from the balloon sounding. The initial

column presents neither a ground temperature inversion nor a LLJ. The imposed dynamic forcings are a horizontal pressure gradient and a very slight horizontal cold advection, both estimated from the HIRLAM analysis. The 1D model simulates the evolution of the SBL during 11 hours.

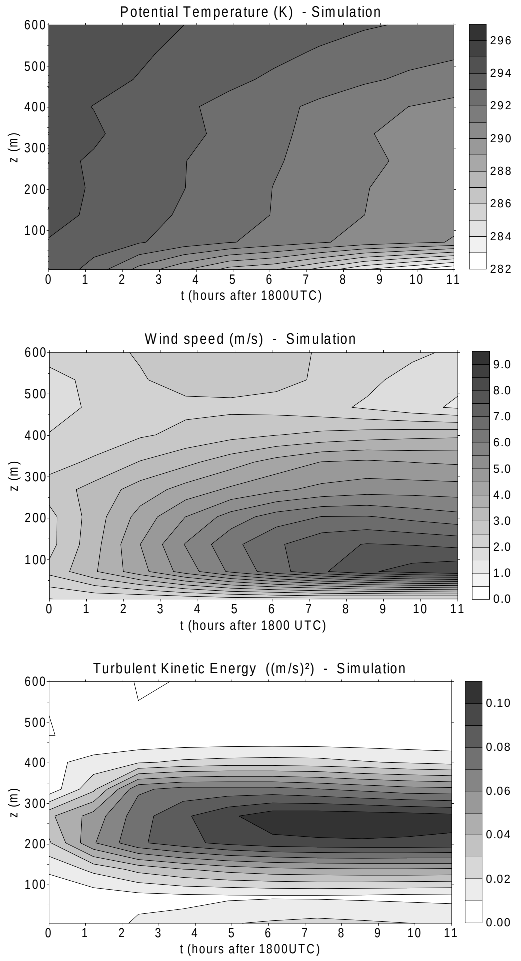

Fig. 2: Simulation of the evolution of potential temperature, wind speed and TKE profiles the night 15-16 September 1998.

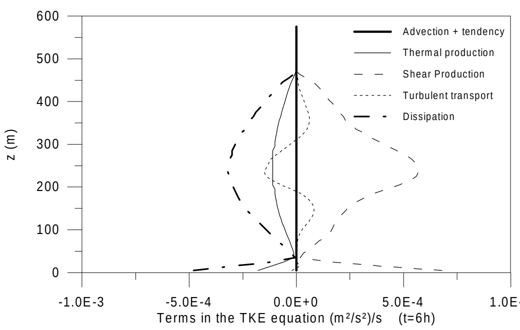

Fig. 3: Terms in the TKE equation (t = 6h simulation time)

The results (Figs. 2 and 3) show a similar behaviour as observations:

- The vertical temperature gradient is quite large close to ground with a similar cooling rate than the observed one.
- The LLJ develops around the top of the ground inversion, near 100 m.
- A change in the wind direction is observed.
- There is weak turbulence close to ground.
- There is intense turbulence in the upper part of the LLJ, a layer with a weaker stability and a stronger wind shear than the subjacent one.
- The momentum flux is perfectly correlated with the TKE.
- The heat flux is always negative.
- During the first steps of the LLJ formation, the dominant terms in the equation of TKE evolution are the dynamic production and the turbulent transport, achieving the highest values over the nose of the LLJ.
- The thermal production and dissipation are always consumption terms.
- During the first two hours, the evolution of the TKE near the ground and in the upper part of the SBL are independent. Nevertheless, a smooth connection can be appreciated later.
- Under a strong stable stratification, the surface forcings only affect the lower layer of the SBL, especially its cooling rate.
- Dynamic forcings are essential in the evolution of the whole SBL.

5. CONCLUSIONS

The model is able to simulate the main characteristics of the SBL vertical structure as the temperature inversion or the development of the LLJ, with a good agreement with observations. The turbulence scheme provides the evolution of the different terms of the TKE budget equation; the analysis of the evolution of these terms allows some theoretical considerations on the physical processes involved. Especially relevant seems to be the different evolution of the turbulence near the ground and in upper levels, sometimes without a clear connection between them.

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