P4.13 CLASSIFYING OBSERVATIONS OF STABLE BOUNDARY LAYERS FOR MODEL VALIDATION.

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1. Introduction

The stable boundary layer (SBL) is a common structure type of the lower atmosphere over land when potential temperature increases with height. The development of the SBL directly influences surface temperature, which in turn feeds back on the surface radiation balance. The large wind shear including turning of the wind with height in the SBL causes synoptical scale convergence and divergence. The height to which the SBL develops is of importance in environmental applications like dispersion of atmospheric contaminants. A correct representation of the SBL in atmospheric models is of great importance both for short term weather forecast as for climate change studies.

The atmospheric modellers community is interested in evaluating atmospheric boundary layer schemes with observations not only for more or less ideal SBL cases, but for all the important boundary conditions encountered over the globe. Model evaluation is often done on a per case basis. Such an evaluation appears to be quite difficult for all but the most ideal cases because important SBL processes may not be incorporated in the model or may not be measured in the observational data set at hand. Here we investigate ways to present observations from non-ideal sites to the model community. Several interesting observational sites with different boundary conditions are identified within the GEWEX GABLS initiative. The current pilot study is based on long term SBL observations from the Cabauw 200 m meteorological tower, The Netherlands. An attempt is made to classify SBL's in a statistical manner exploiting the existing long time series. Observations of the structure of the SBL like temperature, humidity, wind speed and wind direction over the height of the SBL are linked to classes of the relevant forcing variables, e.g. long wave cooling and geostrophic wind.

By applying in future the same methodology to observations at other observational sites valuable information may be gathered about the relation between site specific boundary conditions and SBL behaviour which can be used as input for model evaluation.

2. Observations and model

11 years (1986-1996) of observations of profiles of wind speed and direction, temperature and humidity are taken from the Cabauw 200 m meteorological tower, the Netherlands. This data set is quality checked and gap-filled as described by Beljaars and Bosveld (1997). Observational levels are 200, 140, 80, 40 ,20, 10 and 2 m. At the 2 m level only temperature and humidity is measured.

For the evaluation we use the ECMWF 40 year re-analysis (Simmons and Gibson, 2000). ERA40 data are archived on an hourly basis for special selected locations like Cabauw. In this study we use model data for the same period as the observations (1986-1996). The lowest model levels are at 190, 120, 70, 30 and 10 m. For temperature and humidity also a 2 m value is. Grid spacing is approximately 125 km. The 12 to 36 hour forecast is used starting from 12 UTC of the previous day. Note that at Cabauw mean solar time is 20 minutes ahead of UTC.

3. Methodology

Here we try to separate the local induced factors that influence the SBL-development from the large scale weather induced influence. From an atmospheric point of view the forcings are the geo-strophic wind speed and the long wave cooling. However, long wave cooling exhibits also an influence from the local conditions related to the thermal characteristics of the surface. Therefore we prefer to use the iso-thermal net radiation (Monteith, 1981) with reference temperature for the upward long wave radiation chosen at the top of the stable boundary layer. Since temperature at the top of the SBL is not readily available we here use the observed temperature at 200 m height. In near future we will derive geostrophic winds from surface pressure observation collected in the synoptical network surrounding Cabauw. For the time being we use the 200 m wind speed instead.

We focus on the development of the SBL 6 hours after sunset. Nine classes are defined. Three wind speed classes with average wind speed over the first 6 hours: $F< 5$ m/s, $5<F<10$ m/s and $F> 10$ m/s. Also three classes of isothermal net long wave cooling are defined with $Q < 3$ K, $3<Q<6$ K and $Q>6$ K. Here Q is defined as the temperature drop that the net iso-thermal long wave cooling (no short wave radiation present at night) acting over the period of 6 hours would produce in a 200 m high column of air. Of the 3919 nights 3867 fell into one of the defined classes. The number of nights in each class combination are listed in Table 1.

Table 1 *Number of nights for each class combination.*

	F (m/s)	< 5	<10	> 10	total
Q (K)					
< 3		166	483	543	1192
< 6		158	448	445	1051
> 6		315	716	593	1624
total		639	1647	1581	3867

4. Results

For each class combination mean profiles are calculated for potential temperature, humidity, wind speed and wind direction. Figure 1 shows the profiles of potential temperature for the nine classes for both the observations and the model. To highlight the development of the potential temperature during the 6 hours into the night , differences are taken with the 200 m potential temperature for the observations and the 190 m potential temperature for the model at the moment of sunset. This then serves as an approximation of the potential temperature profile at the moment of stability change. In reality this stability change occurs 1 to 2 hours before sunset. Changes in the temperature (and humidity) over the 6 hour period results from the advection of air masses with different properties and from the SBL development when boundary layer height is large enough.

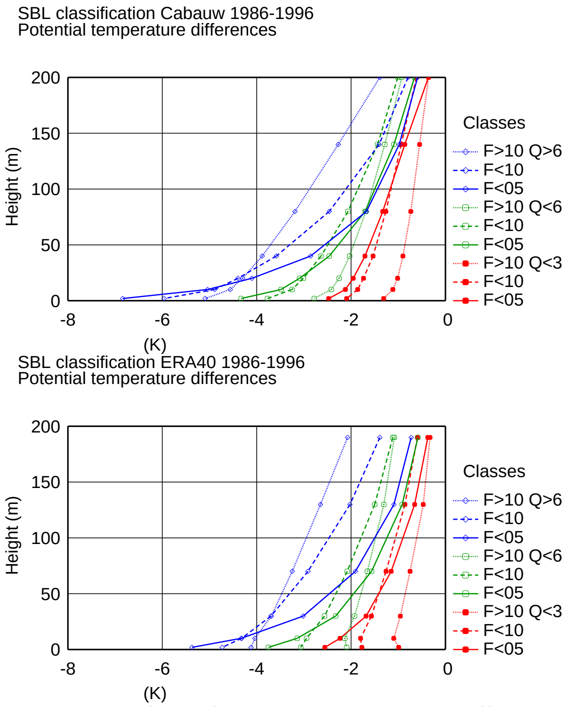

Figure 1 *Profiles of potential temperature difference relative to 200 m sunset value for 9 classes and for observation and model.*

Different colours discriminate between classes of iso-thermal long wave cooling. Different line types differentiate between classes of wind speed. It is observed that there is a general tendency for the 200 level to cool during the night even for the most stable cases were the SBL height is expected to stay below the 200 m level. With increasing Q steeper temperature profiles are observed. The model captures most of the observed features although vertical gradients tend to be somewhat weaker.

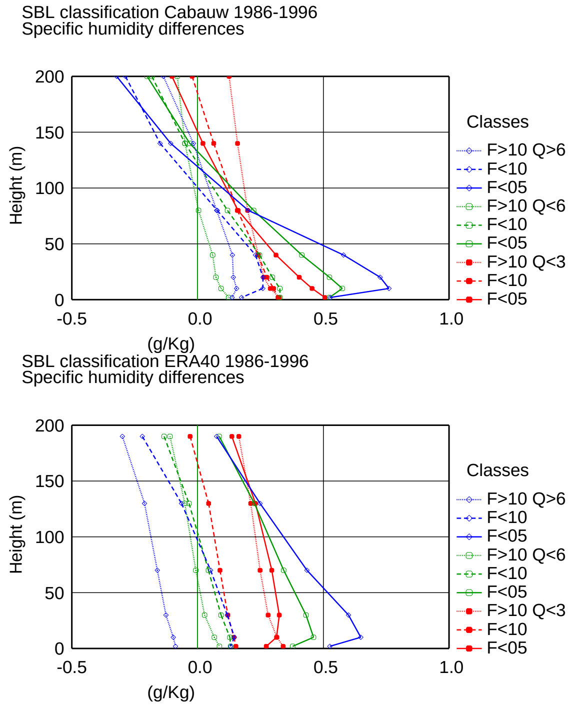

Figure 2 *Profiles of specific humidity difference relative to 200 m sunset value for 9 classes and for observation and model.*

Humidity profiles are shown in Figure 2. Again the differences are taken with the sunset values at 200 and 190 m respectively. Observed 200 m values are in general drying during the night, whereas in the model this depends on the class. Low wind speed cases tends to moisten a bit. Profiles are again somewhat less steep in the model.

Wind speeds are in general somewhat larger then the model values as is observed in Figure 3. For the classes with high values of Q (more stable cases) the observed wind profile is significantly steeper then the model profiles.

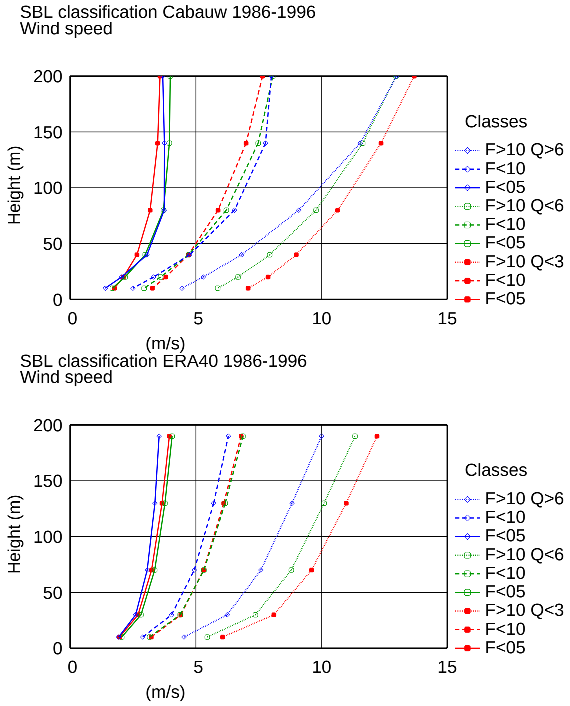

Figure 3 *Profiles of wind speed for 9 classes and for observation and model.*

Wind direction difference profiles are shown in Figure 4. Here differences with the 200 and 190 m values at the same time (6 hours after sunset) are taken. Wind veering is much stronger in the observations then in the model.

5. Summary and conclusions

At a number of observational sites over the world valuable long time series exists of atmospheric parameters under stable conditions. Bringing together this information in a suitable form may contribute to the evaluation and improvement of stable boundary layer representation in atmospheric models. Such an exercise would be especially valuable because it would give insight into the effect the reaction of the SBL on different boundary conditions at the various sites. In this pilot study a first attempt is made for one of these sites, Cabauw. To condense the large data set into a manageable amount of information a statistical approach is chosen by calculating mean profiles for nine classes of SBL forcing. To be independent of the local boundary conditions the chosen forcing variables are geostrophic wind and isothermal net long wave cooling. Distinct profile forms are found for the 9 forcing classes at 6 hours after sunset. Comparison with the ECMWF ERA40 model for the same period shows that the model captures the potential temperature drop over the depth of the SBL reasonable well, but the veering of the wind with height is grossly underestimated.

6. References

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7. Acknowledgement

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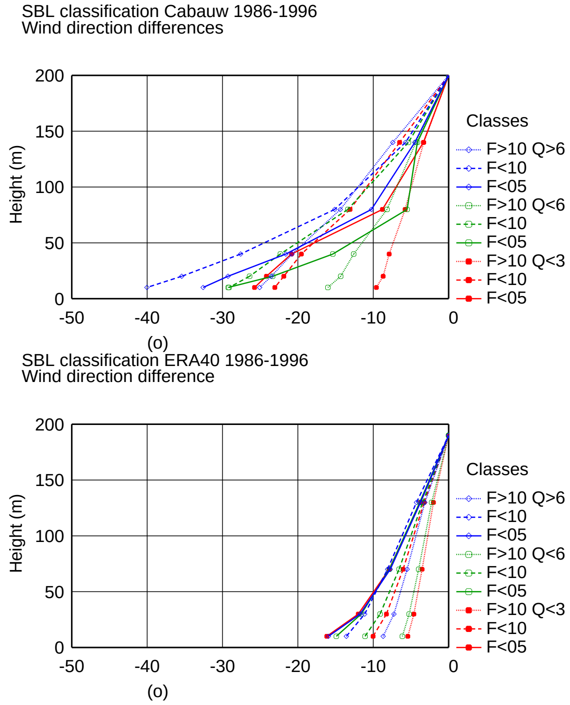

Figure 4 *Profiles of wind direction difference relative to 200 m (190 m) for 9 classes and for observation and model.*