6 Model Evaluation III - Radiosonde and radar wind profiler cluster analysis

This section describes some of the cluster by cluster comparisons between the WRFb simulations and the radiosonde and radar wind profiler clusters. The clusters and the method used to obtain them are described in detail in de Foy et al., 2008.

6.2 Radiosonde clusters

Figure 13 shows the median vertical profile for each of the 5 clusters for both the radiosonde observations and the WRFb simulations at 18:00 UTC (note that there was no occurrence of the sixth cluster, BasinFlush, during MILAGRO). We expect to see the cold and moist bias detected by the statistical metrics and the extent of the slight slow bias in the winds.

The Wet cluster is too cold in the boundary layer but has the correct temperature aloft. It is also too moist by 1 g/kg for most of the boundary layer but then slightly too dry aloft. This is the cluster with some of the strongest winds with northwesterlies aloft veering to southwesterly at the surface. The simulated winds are too weak for the entire profile but especially in the mid-height range from 1000 to 2500 m a.g.l.. The wind direction however is well captured for both layers with some expected variation in the transition layer.

The Hot cluster is the hottest and driest with the weakest winds. For temperature there is the same cold bias in the mixing layer as for the other clusters. The main discrepancy is the considerably stronger moist bias in the simulations and the relatively strong surface winds. The easterly flows are well captured, which suggests that the moist bias may be due to excess humidity transport from the Gulf of Mexico.

The NCool cluster is well represented with a smaller than average temperature bias. The northerly flows are well characterised, suggesting that the cool Mexican Plateau winds are represented in the model.

Likewise the WCool cluster is in good agreement with the data. This the coldest cluster, especially at the surface with humid westerly flows and stronger winds aloft. The model representation suggests that the humidity transport from the Pacific is in better agreement than that from the Gulf for March 2006.

The SWarm cluster has humid southerly flows. The structure of the temperature and humidity biases are similar to that of the other clusters. The wind speed is particularly well simulated, although the wind direction has some of the strongest discrepancy near the surface. Southerly flows aloft turn to more easterly in the observations but more westerly in the model. Because the wind direction is more variable within this cluster (not shown in the figure) the greater discrepancies may be expected.

Overall, we see that the cold bias is a feature of the boundary layer that is relatively constant across all cluster types. The variability of the data is well represented by the variability in the model results. The moist bias is also a relatively constant feature although two clusters have a stronger bias suggesting excess moisture transport from the Gulf of Mexico.

For wind speed, the most striking feature is that the model clusters have very similar profiles with stronger winds near the surface, decreasing wind speeds to a height of around 2000 m and then increasing speeds aloft. This is in contrast to the observations that have less vertical structure in the individual profiles, but more variation between the clusters. This suggests that there is too much shear in the model with too strong winds in the surface layer. There also seems to be insufficient variability aloft which would be due to the boundary and initial conditions from the GFS model.

The wind directions are well characterised given the complexity of the flows. This gives confidence in the wind transport in the model despite the large size of errors for individual profiles and further suggests that the poor statistical metrics are a result of errors in short time scale variations rather than systematic errors in the longer term transport. This is particularly noticeable for the cluster with the variable surface winds where there are large discrepancies at the low levels but better agreement aloft.

6.3 Radar wind profiler clusters

A wealth of data is available from the radar wind profilers. As discussed in de Foy et al., 2008, the reader interested in detailed comparisons will find it most useful to look at the day-by-day comparisons of wind vectors at each of the three sites. This shows that the model is able to capture many of the detailed flow features, even in cases of rapid wind shifts and high vertical shear.

Figure 17 shows wind rose comparisons at T0 for 4 clusters: Northeast, H-Shear, V-Shear and West-Shear. As for the surface sites, the other cluster types were well characterised (see supplementary and it was decided to focus on the clusters with the greatest discrepancy between simulations and observations.

The Northeast cluster has a surface layer from the northeast and southeast flow aloft. The observations show a rapid shift in wind direction at 2500 m. The model has more gradual veering, and much stronger winds in the upper layer. This effect is strongest at T0 but continues to T1 and T2 in weaker form.

The H-Shear cluster has easterlies up to 1000 m and northwesterlies aloft. The winds aloft are well characterised, but the low level layer is southeasterly rather than northeasterly. These tend to be mid-afternoon flows and suggest that there is some channelling around Pico Tres Padres that is not represented in the model.

The V-Shear cluster has a shallow layer from the north with flow aloft from the south. This is represented in the model, although with a much thicker layer extending up to 1250 m rather than the 500 m in the measurements. The weak surface winds are represented, but the simulated winds aloft are considerably stronger than the observations. These flows are associated with the first Cold Surge event and with O3-South days, suggesting that in these cases the model will lead to too much surface transport from the north.

Finally, the West-Shear cluster has northerly surface flows backing to westerly and southwesterly aloft. The surface layer is well simulated, especially with the stronger surface winds. The wind shear is overdone in the model however, with a rapid change in direction at 1000 m to southerly winds. In contrast to the V-Shear cluster, these late afternoon winds would cause stronger transport aloft from the south rather than from the west. Nevertheless, the surface transport is in the right direction and at the right speed.

6.4 Discussion

The advantage of a cluster by cluster comparison is that it is able to evaluate the performance of the model in terms of the representation of different wind patterns. Overall, the results support the statistical and trajectory analyses showing that the model correctly represents wind transport. The strength of these comparisons is to highlight potential model weaknesses in process terms that have more statistical validity than individual hour-by-hour comparisons.

From the comparisons of vertical profiles, it can be seen that the model has a warm and moist bias that persists in the whole boundary layer. Some of the Hot radiosonde clusters in particular were too moist. The NCool clusters however had a smaller moist bias. The model also fails to capture some of the variability in wind speeds between the clusters and has too much wind shear. This is supported by the radar wind profiler comparisons that show stronger wind shear and stronger winds aloft.

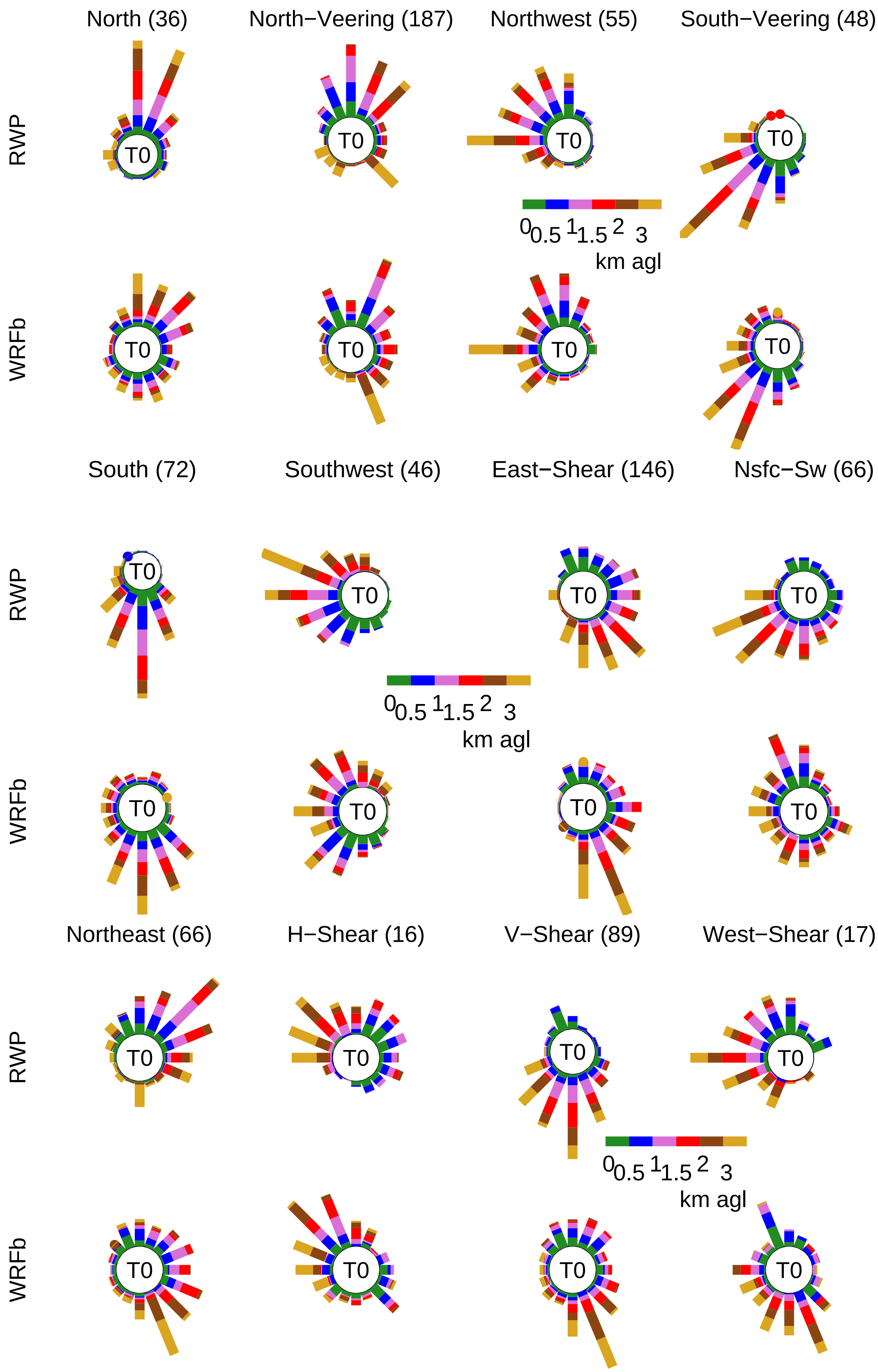

Figure 17: Comparison of wind roses of the vertical wind profiles at T0 from the Radar Wind Profiler and from the WRFb case for all 12 clusters. Wind rose categories by height above ground level. Number of profiles in each cluster in parentheses.