Draft Boundary Layer Research and Findings Report

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DOCUMENT HISTORY

Issue	Date	Summary
A	December 7, 2005	Draft Report

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1.0 Identify Poorly Simulated Cases Associated with Boundary Layer Model Problems

The first step in this subtask was to identify the typical model biases and problems. The next step was to identify those problems that were likely related to the boundary layer. The final step was to identify the meteorological cases that were representative of a given boundary layer related problem in order to perform model experiments in an attempt to identify the source of and solutions to the problems.

Two approaches were used to help identify the model problems relevant to the boundary layer. One approach was an objective statistical analysis of the model output of many cases with observations from various sources to determine where the model was having problems simulating the boundary layer winds. The other approach was a subjective point comparison of model soundings with observed soundings for individual cases. The analysis involved comparing observed wind speed data from sodar, towers, rawinsonde and standard METAR observations with the model output.

The following were three categories of problems identified from the observations that were most likely related to boundary layer problems: (1) atmospheric stability related, (2) terrain complexity related, and (3) problems related to the surface energy budget formulation.

1.1 Problems Related to Atmospheric Stability

There were three model related problems identified that seemed to relate to atmospheric stability:

(a) A general high wind bias in the simulations within the first few hundred meters of the surface. Figure 1 shows a typical example of the low-level high wind speed bias of the model. This is most noticeable during the nighttime when the simulated winds near the surface are too high as noted in Figure 2. The high bias would seem to be related to the thermal structure and stability of the boundary layer during the nighttime hours and lack of model resolution. Figure 3 shows an idealized vertical profile of the wind and temperature that is typically associated with a nocturnal stable layer. Figure 4 gives the mean observation versus the mean model wind speed changes from 00 - 06 local. The sodar and tower measurement were particularly helpful in understanding the nature of the wind speed bias in the lower 200 meters.

(b) The simulated winds show too much vertical shear within the boundary layer when the atmosphere is stable. The sodar data was of great help helpful in identifying this problem. Figure 5 shows an idealized comparison of the model versus observed structure of the shear in the lower part of the boundary layer. Figure 6 shows a comparison of the sodar and model generated wind speeds.

(c) Difficulty in simulating winds transitioning from nocturnal to daytime boundary layer winds.

Problems related to atmospheric stability generally seem to be the result of the model not being able to resolve or properly handle the energy transfer within the boundary layer during periods when the boundary layer is stable. This problem is most noted during the late evening and early morning hours during periods of clear skies. The surface, rawinsonde, tower and sodar observations all indicate that during these stable periods, there is a tendency of the simulated winds to be higher than observed.

1.2 Problems Related to Terrain Complexity

Any atmospheric model will have difficulty simulating low-level airflow in complex terrain when important terrain variations are on the same scale or a smaller scale than the model's grid resolution. All of the active wind energy areas in California are in areas of complex terrain. Tower and sodar observations were used to help identify several terrain-related issues that involved horizontal resolution and non-hydrostatic forcing.

An example of the resolution problems can be seen in the San Gorgonio Pass area. The width of the San Gorgonio Pass is only a few kilometers, so a mesoscale model required grid spacing smaller than about 5 km to have a chance to fully resolve the relevant circulations of the Pass. Several experiments were performed to test the sensitivity of model results to the spacing of the finest nested grid. Figure 7 demonstrates the resolution issue that can result in either an over or underestimation of wind speeds in complex terrain.

Hydrostatic flow is one where the upward vertical pressure gradient force is balanced by the downward force of gravity. Typically mesoscale flow is largely hydrostatic, because we observe vertical accelerations to be much smaller than horizontal accelerations. In areas of steep terrain however, vertical accelerations may be large and a non-hydrostatic model may be essential. Experiments were performed to test whether the use of non-hydrostatic physics in the MASS model would improve the simulation of wind speeds in California. The general results indicated that there are two consequences of running hydrostatically in steep mountainous areas. The first is that model generated wind speeds tend to be a little high at the peak of the mountains (Figure 8) and the high wind bias will extend out into the plains for about 100 km during conditions of strong downslope conditions as shown in Figure 9.

Each mesoscale model handles terrain somewhat differently. In an attempt to determine if there is any significant sensitivity to the model formulation, different models were tested to see if they produced significantly different results in areas of complex terrain.

1.3 Problems Related to Surface Energy Budget Formulation

The surface, tower and sodar observations were used to identify two model-related problems that seem to be related to the surface energy budget. At times the model is unable to properly resolve or develop observed mesoscale circulations. This results in either missing, misplacing or mistiming the circulations. Figure 10 shows an idealization of the problem.

Proper formulation of the surface energy budget is critical to simulating the boundary winds correctly. There are several components to the surface energy budget. First, there is the short and long wave radiation physics that must be handled correctly. Second, there is the soil dynamics and hydrology including evaporation and transpiration. Finally, there is the input data for components such as surface roughness, soil type, and soil moisture that play a critical role in the surface energy budget. If any of these components of the surface energy budget are not modeled correctly, mesoscale circulations that are driven by thermal differences will not be properly simulated.

1.4 Summary of Problems

To consistently simulate the winds correctly within the boundary layer in very complex terrain areas such as California, the model must handle the stability, terrain and surface energy budget correctly. However, it is useful to divide the problems into three categories: (1) stability, (2) terrain and (3) surface energy budget because there seems to be situations where one of the problems dominates the other two.

2.0 Results of Model Experiments

A series of model experiments were conducted in an attempt to find the actual cause of the noted problems and to find solutions if possible.

2.1 Atmospheric Stability Experiments

The following experiments were performed in an attempt to find better ways to handle the stable boundary layer.

(1) Resolution experiments

(2) Boundary layer stability regimes experiments

(3) Boundary layer formulation experiments

2.1.1 Results from Resolution Experiments

Simulations were made with a horizontal grid spacing 30 km, 8 km, and 2 km. The results did show some improvement with higher resolutions, however, it may take a resolution higher than 1 km to fully resolve the boundary layer. One result of increasing the model resolution is to increase the relative impact of friction because of the smaller grid cells. Thus, there is a natural tendency to lower the near-surface wind speeds as model resolution is increased.

Table 1: Comparison of the performance of the models ability to produce accurate 50 m mean wind speed information based upon the horizontal grid resolution.

Location	Observed Speed	Modeled Speed		
		30 km Resolution	8 km Resolution	2 km Resolution
San Gorgonio	5.2 m/s	7.3 m/s	7.1 m/s	6.5 m/s
Mayacamas	6.9 m/s	8.5 m/s	7.6 m/s	7.4 m/s
Shasta	7.8 m/s	9.6 m/s	8.8 m/s	8.2 m/s

2.1.2 Results from PBL Stability Regime Experiments

Various sites were examined in order to examine the performance of the model based upon which of three stability regimes were activated: **stable**, **damped mechanical turbulence** and **forced convection**. A comparison of the absolute value of the difference between the modeled speeds versus observed speeds (model minus observation) was made for the PBL stability regimes for 730 hours of output. The results showed that there was a significantly larger mean wind speed error for the stable regime as compared to the unstable regimes. This further reinforces the idea that the problem with the high wind speed bias is associated with the stable boundary layer conditions.

Table 2: Comparison of the performance of model based upon the activated stability regime.

Stability Regime	Observed Speed	Modeled Speed	Mean Speed Error	Mean Direction Error
Stable regime	5.2 m/s	7.3 m/s	2.1 m/s	71.5 deg
Damped mechanical turbulence	6.9 m/s	8.5 m/s	1.6 m/s	83.9 deg
Forced Convection	7.8 m/s	9.6 m/s	1.8 m/s	68.2 deg

2.1.3 Boundary Layer Formulation Factors

As noted, observations from meteorological towers and sodar in various locations have shown that the MASS model tends to predict wind speeds that are systematically too high in the lowest 100 meters above the ground. Other research that has been done for various locations outside of California, have noted this same problem. This current and past research has also revealed that nearly all of the high bias occurs during the nighttime hours. An example of this problem occurred for a set of October 1999 30 km MASS simulations. When compared to observations at an instrumented tower near Wichita, KS (part of the CASES-99 project), MASS showed a positive bias of 1.1 m/s at 55 m above ground level, about 15% above the observed wind speed.

It was hypothesized that this high wind speed bias results from the inability of a traditional PBL scheme to correctly represent the mixing below nocturnal low-level jets. A traditional PBL scheme assumes that mixing is surface-based, missing the shear-driven turbulence at the top of the boundary layer. In contrast, at night, an "upside-down boundary layer" below the jet maximum is created, which sometimes penetrates downward into the shallow, stable nocturnal boundary layer.

A series of papers by Mahrt and collaborators (Ha and Mahrt 2001; Mahrt and Vickers 2005) proposed a planetary boundary layer formulation that is independent of a z (vertical) coordinate ("z-less"). In this formulation, mixing can be parameterized as a function of local shear and stability that is unrelated to the state of the surface-based boundary layer, and thus could improve upon the traditional approach. A portion of the Mahrt and Vickers (2005) scheme was merged into the MASS Turbulence Kinetic Energy (TKE) scheme. The essential change is that an additional mixing length is calculated which depends entirely on local values of vertical stability and wind shear (it is therefore independent of the z coordinate or "z-less"). If this local mixing length is greater than the original mixing length (which is a function of height within the boundary layer), then the local value is used, resulting in increased mixing. This can help to correct situations where the model often tends to under predict mixing, as in the common case of a nocturnal low-level jet developing above a shallow stable boundary layer.

The z-less scheme was tested in a California simulation and it produced a modest decrease in low-level wind speeds during the nighttime hours. Figure 11 shows the differences in 50 m wind speed caused by use of the z-less scheme over a 24 hr simulation on an 8 km grid beginning at 1200 UTC (0500 PDT) 15 July 2002. The wind speed decreases about 0.15 m/s at the beginning of the simulation under stable nighttime conditions, changes very little during the day, and then decreases again as the next night begins. Figure 12 shows spatial differences at 0600 UTC 16 July (2300 PDT 15 July); it can be seen that the z-less scheme reduces the wind speed in most areas in California by less than 0.5 m/s, although there are locations where the decreases are larger than 1 m/s. Some of the larger decreases appear to be in significant wind energy areas such as the Altamont Pass and the Tehachapi Pass. Figure 13 shows a profile of the wind speed differences created by the z-less scheme over a three month set (March-May 2005) of California simulations (all times of day averaged together). It is believed that these changes due to the use of the z-less scheme occur at the correct time of day and at the correct vertical levels, but the magnitude of the change only partially corrects the general low-level wind speed bias. Further "tweaking" of the scheme may correct more of the problem, or another part of the scheme may need additional attention.

2.2 Terrain Complexity Experiments

The following experiments were performed in an effort to find better ways to simulate the winds in complex terrain areas:

(1) Non-hydrostatic versus hydrostatic experiments

(2) Resolution experiments

(3) Sensitivity to mesoscale model

2.2.1 Non-hydrostatic versus Hydrostatic Experiments

To save computational resources, it can be reasonably assumed that there is a vertical balance between the pressure gradient force that is directed upwards and the force of gravity that is directed downwards. This assumption of balance is called the hydrostatic assumption. For relatively large areas (5 km grid spacing or larger) this assumption is very reasonable. However, for systems with strong forcing over small distances, such as thunderstorms and steep drainage winds, this assumption is not a good one because the vertical forces will not remain balanced and stronger vertical accelerations will occur, at least for short time periods. A variety of model experiments were performed comparing both the hydrostatic and non-hydrostatic versions of MASS with tower, sodar and surface observations in an attempt to examine the importance of non-hydrostatic forcing on wind climate.

Using the MASS Model over the San Gorgonio Pass in Southern California, simulations were made with a configuration of 30 km, 8 km, 2 km and 1 km hydrostatic, and 2 km and 1 km non-hydrostatic simulations. This allowed us to test both the sensitivity to resolution and running non-hydrostatically. The results of these experiments showed very little sensitivity to running non-hydrostatically. There are likely cases where the non-hydrostatic MASS does a better job, especially for extreme down slope conditions. But in most cases there is very little difference between the hydrostatic and non-hydrostatic wind speeds. The number of times there is a significant difference would not be significant when creating a long-term climatology of the wind speeds. Below are some specifics on each set of experiments.

2.2.1.1 Resolution

In order to examine the impact of running non-hydrostatically, resolution experiments were first run hydrostatically using 8 km, 4 km, 2 km and 1 km grid spacing. By comparing the model output to the tower, sodar and surface observations, we found that model resolution had a major impact on the quality of the simulations. In general, the simulations were not very representative until the resolution reached 2 km. The 1 km hydrostatic run did a little better than 2 km. The San Gorgonio Pass is quite narrow, so it seems clear that a grid resolution of less than 8 km and preferably 2 km or less is necessary to resolve it properly.

2.2.1.2 Hydrostatic versus Non-hydrostatic

In theory, we should see some improvement in the results when running non-hydrostatically. But there was very little difference; in fact, at 2 km grid spacing non-hydrostatic runs produced a slightly poorer comparison with observations than a corresponding 2 km hydrostatic run. The conclusion is that running non-hydrostatically is not a major factor for improving wind maps. It is likely that the non-hydrostatic forcing is relatively important for specific situations such as extreme Santa Ana conditions. Since we wanted to improve the climate statistics for wind, we were not looking for cases with extreme wind event problems. The cases we used were more typical of ones that give the model problems on a day-to-day basis. So these cases are not ones where non-hydrostatic forcing is significant.

Table 3: Comparison of the mean wind speed of model when in hydrostatic and non-hydrostatic mode.

Model Mode	Observed Speed	Modeled Speed			
		8 km Resolution	4 km Resolution	2 km Resolution	1 km Resolution
Hydrostatic	5.2 m/s	7.2 m/s	6.8 m/s	6.1 m/s	6.2 m/s
Non-Hydrostatic	5.2 m/s	7.2 m/s	6.7 m/s	5.9 m/s	5.8 m/s

2.2.2 Sensitivity to Mesoscale Model

In addition to the resolution experiments, experiments were run comparing two other mesoscale models with MASS to the tower, sodar and surface observations to see if the other models could handle the complex terrain and other problems better. The models used were (1) OMEGA, which is unique in that it uses an adaptive grid that can in theory resolve complex terrain areas more accurately, and (2) WRF, which is the new community mesoscale model being developed at the National Centers for Atmospheric Research.

2.2.2.1 OMEGA Results

A large OMEGA grid was set up over approximately the same region as the MASS grid that had been used to produce the output for San Gorgonio Pass. The size of the grid cells ranged from 35 to 70 km on the outer part of the grid, decreasing to 4 km in the vicinity of San Gorgonio Pass at the center of the grid.

On the encouraging side, the OMEGA run has westerly winds through the San Gorgonio Pass for the entire simulation that matched well with the observations. On the negative side, the wind speeds were lower than observed and some aspects of the OMEGA simulation did not appear to be realistic. The temperatures seemed too cool on the eastern side of the Pass, and the skin temperature varied greatly between adjacent cells.

The other major negative was the speed of the simulation when using OMEGA. MASS ran the 24-hour simulation for the domain in 18 hours, but OMEGA on the same machine took 87 hours to complete. Even though OMEGA demonstrated some hope of producing superior results, given the slowness of OMEGA, we have not spent time to investigate the further use of OMEGA.

2.2.2.2 WRF Results

A large WRF grid was set up over approximately the same region as the MASS grid that had been used to produce the output for San Gorgonio Pass. The grid spacing for WRF was 4 km; identical to the OMEGA and MASS simulations.

A comparison of the output from the WRF with standard soundings, tower and sodar data revealed the following. The MASS and WRF 4 km results are strikingly similar in this complex terrain region. Both show westerly flow through the Pass for the first part of the day, a reversal to easterly for a few hours in the afternoon, then a resumption of westerly flow. The low-level temperature fields on the eastern side of the Pass appear to be similar for the two models, and both seem to be several degrees cooler than observed temperatures in Palm Springs and Thermal.

Observations, MASS and WRF each showed a mean sea level pressure gradient across the Pass (Riverside to Thermal), with higher pressure all day on the western side. But the pressures on the eastern side seem to be higher in MASS than WRF, with the pressure at Thermal rising to within 2 mb of Riverside late in the day. Observations show a 5-6 mb difference between Riverside and Thermal all day.

Table 4: Comparison of the mean wind speed of model produced by MASS, WRF and OMEGA.

Level	Observed Speed	Modeled Speed		
		MASS	OMEGA km	WRF
10 m	5.2 m/s	6.8 m/s	6.1 m/s	7.2 m/s
50 m	5.2 m/s	6.7 m/s	5.9 m/s	7.2 m/s

2.3 Surface Energy Budget Formulation Experiments

The following experiments were performed in an attempt to find better ways to simulate the winds in complex terrain areas:

(1) Non-hydrostatic versus hydrostatic experiments

(2) Resolution experiments

(3) Sensitivity to mesoscale model and surface energy budget formulation

(4) Sensitivity to input data surface and atmospheric data

2.3.1 Non-hydrostatic versus Hydrostatic experiments and Resolution Experiments

Resolution experiments investigating the surface energy budget problems revealed that neither resolution nor non-hydrostatic forcing were primary factors. For example, the reversal of wind flow appears in all of the MASS and WRF simulations for the Tehachapi locations (Oak Creek and Rosamond) regardless of the grid spacing or running non-hydrostatically. The wind reversal in the simulations does not show up in the observations.

2.3.2 Sensitivity to mesoscale model and surface energy budget formulation

A comparison of the surface energy budget generated by the WRF was made with the surface energy budget generated by MASS. We looked at the various upward and downward radiation fluxes to try to gain a better understanding of how the formulation of the radiation scheme as part of the boundary layer energy budget impacts the simulation of wind features in steep, complex terrain associated with the California passes. The net result of the study is that MASS and WRF energy schemes are very similar and produce similar results.

2.3.3 Sensitivity to Atmospheric Input Data

2.3.3.1 Atmospheric Data Sensitivity

The model experiment showed there was some sensitivity to the atmospheric input data. The atmospheric data that is ingested by the model comes in two forms: (1) gridded and (2) point observations. There was slight sensitivity to the gridded data source and there was significant sensitivity to the availability or non-availability of the point data. The following model experiments were run for the San Gorgonio 11 June 2002 case during March using MASS with a cold start:

1. 2 km hydrostatic 125x125x25, AVN gridded data only
2. 2 km hydrostatic 125x125x25, AVN, rawinsonde and surface,
3. 2 km hydrostatic 125x125x25, Eta, rawinsonde and surface
4. 1 km hydrostatic 125x125x35, AVN, rawinsonde and surface
5. 2 km non-hydrostatic 125x125x35, AVN, rawinsonde and surface,
6. 2 km hydrostatic 125x125x25, AVN, rawinsonde and surface, 24-hr spin-up

2.3.3.2 Source of Initial/BC Conditions

The runs using Eta (NAM) gridded data produced slightly better simulation results than the simulation that used data from the AVN (GFS) model.

2.3.3.3 Availability or Non-Availability of Observational Point

There was significant improvement in the accuracy of the output for those simulations that used both rawinsonde and surface data as part of the initial conditions.

2.3.3.4 Spin-up Time

When the beginning of the run was moved back 24 hours to allow more "spin-up" time, the San Gorgonio wind speed forecast improved somewhat.

2.3.4 Sensitivity to Surface Input Data

2.3.4.1 Soil Moisture

As the research progressed, it became apparent that the irrigation in the Coachella Valley (Palm Springs down to the Salton Sea) is a key factor in the simulated wind direction reversal problem in the simulations for the Tehachapi locations (Oak Creek and Rosamond). It seems that the irrigation significantly increases the soil moisture and causes a localized thermal and pressure gradient that reduces the up-valley daytime flow. Experiments with MASS, using modified surface moisture data, strongly indicate that the increase in soil moisture resulting from inferred irrigation can produce what is called "an inland sea breeze effect", which can significantly modify the direction of the surface winds. Because the irrigation information is not part of the typical input data in either the MASS or WRF, the simulated up-valley flow is much stronger than the observed up-valley flow. Figure 14 shows the improvement made to the wind direction simulation when the irrigation information is added into the soil database.

2.3.4.2 Sea Surface Temperatures

During the course of this research, as well as research for other projects, it became apparent that the sea surface temperature (SST) distribution can have a significant impact on the winds in California. It also became apparent that the SST database should include information on inland lake surface temperatures. The MASS model previously used one of two sources for the initialization of sea surface temperature: (1) A global database of monthly climatological SST at 0.2 deg (about 20 km) resolution; or (2) an NCEP global database of historical SST at 1 deg (about 110 km) resolution covering 1981 to the present at weekly intervals. We have found that both of these datasets have significant problems. The 1 deg historical data is extremely coarse, and even the 0.2 deg climatological data is too coarse to properly resolve important gradients of SST's in inland lakes and coastal oceans. The result is that the water surface temperature for lakes as large as the Salton Sea in Southern California are poorly known and the model may make an assumption which differs significantly from reality.

After searching for better, higher-resolution sources of SST data, we evaluated two different types of satellite-derived data from NASA: (1) AVHRR Pathfinder global data at 4 km resolution, which is available from the mid-1980's to the present; and (2) Aqua MODIS global data at 4 km resolution, which is available from July 2002 to the present. The use of these high-resolution datasets improve the SST fields in California runs, especially close to the coast and in places such as San Francisco Bay and the Salton Sea. The results have been more accurate simulations.

Figure 15 gives an example of the difference in temperatures using the courser data as compared with the higher resolution SST data. Figure 16 shows the improvements made in the wind speed when using the improved SST data.

3.0 Conclusions

The availability of the tower and sodar data enabled model versus observation comparison possible that lead to the identification of several model problems. The data also helped us determine the cause, and in some cases, the solution to the various problems.

The following are the key conclusions drawn from this research:

1. Model resolution is important in improving results for the stable boundary layer and in complex terrain regions. It is not important in resolving the surface energy budget problems.

2. The "z-less" boundary scheme improved the result for the stable layer cases.

3. Running non-hydrostatically may not make a significant difference when producing climate statistics for most areas.

4. There was little difference between the performance of MASS and WRF in terms of quality and timing. OMEGA did somewhat better in some aspects but is much slower to run than either WRF or MASS.

5. WRF PBL and radiative scheme comparisons with MASS results show that the schemes are quite similar in formulation and performance.

6. The use of higher resolution gridded data (ETA) for initial and lateral boundary conditions improved the results slightly.

7. The inclusion of point surface and rawinsonde observations as part of the initial conditions substantially improved the quality of the simulations.

8. Changes in soil moisture content made a difference in simulation. When the soil moisture was corrected to more accurately reflect irrigation patterns, the result of the test cases improved.

9. Sea surface temperatures have an effect on the winds in California. The more accurate the input data, the more accurate the results from the simulations.

Appendix

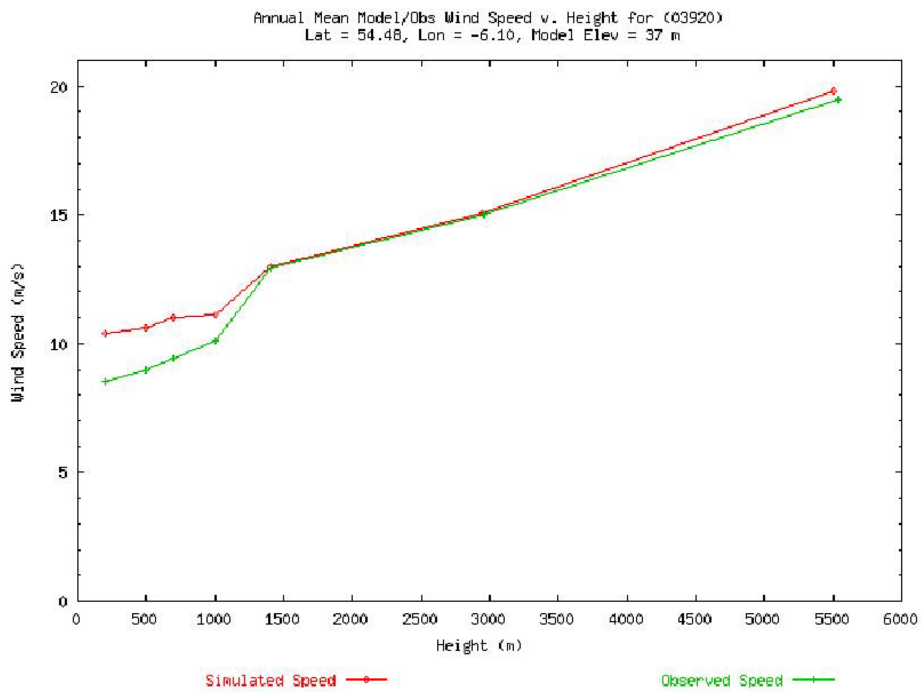

Figure 1: Example of observed versus model results, demonstrating high wind model bias

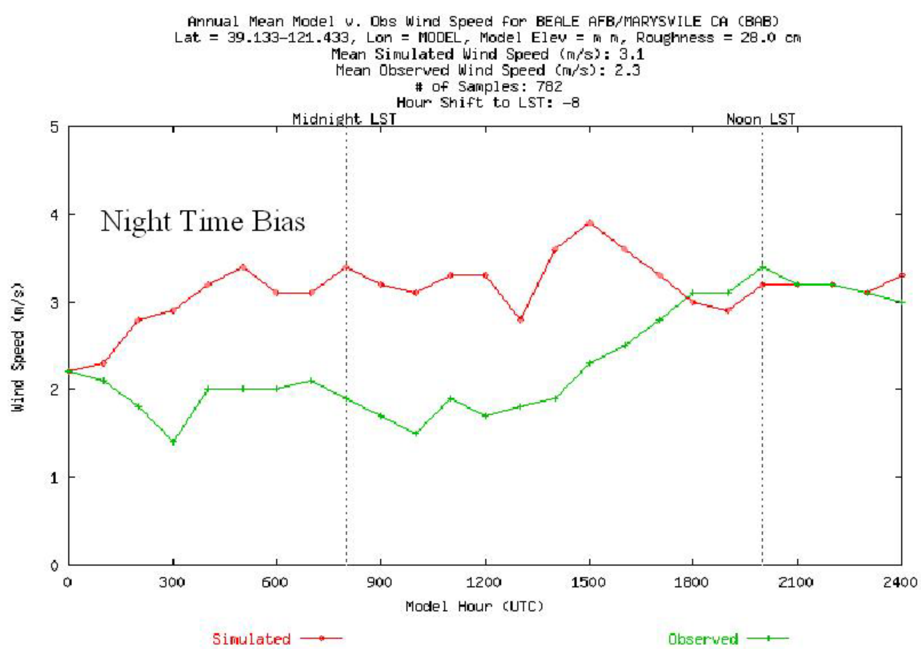

Figure 2: Example of the primarily nocturnal model wind speed bias

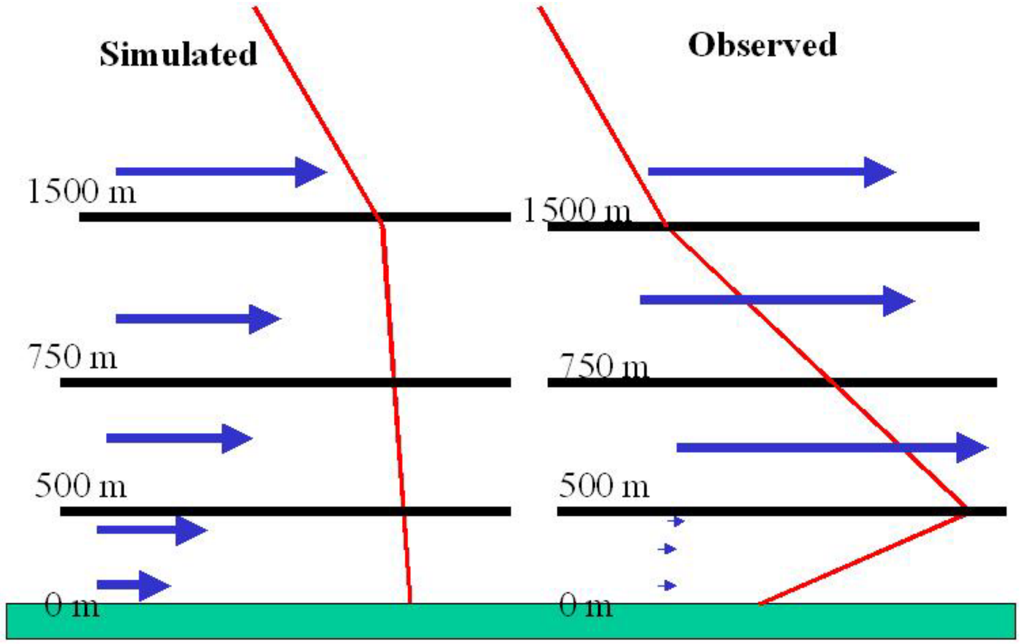

Figure 3: Over estimation of wind speeds near the surface due to coarse model resolution

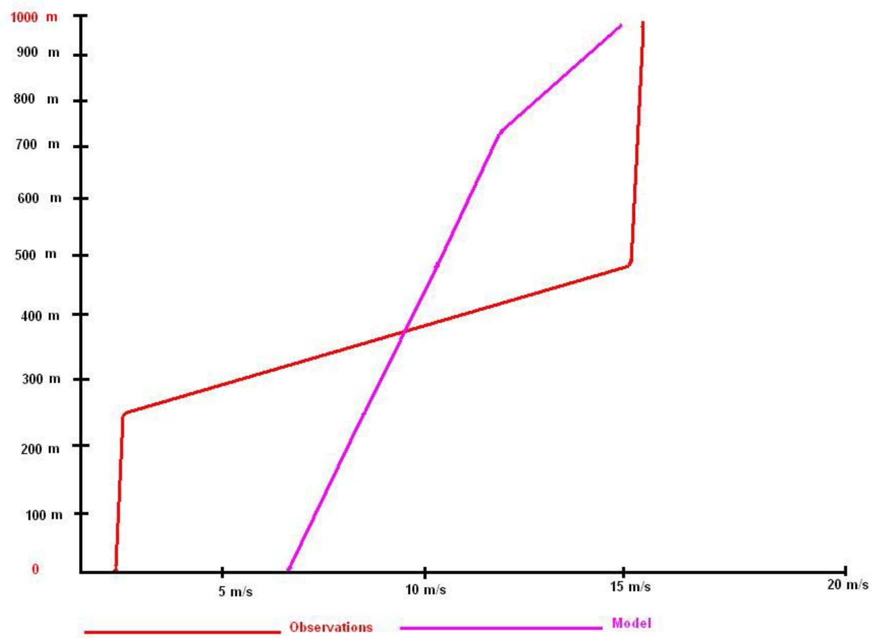

Figure 4: Observed and modeled wind speed changes from 00 - 06 local Time

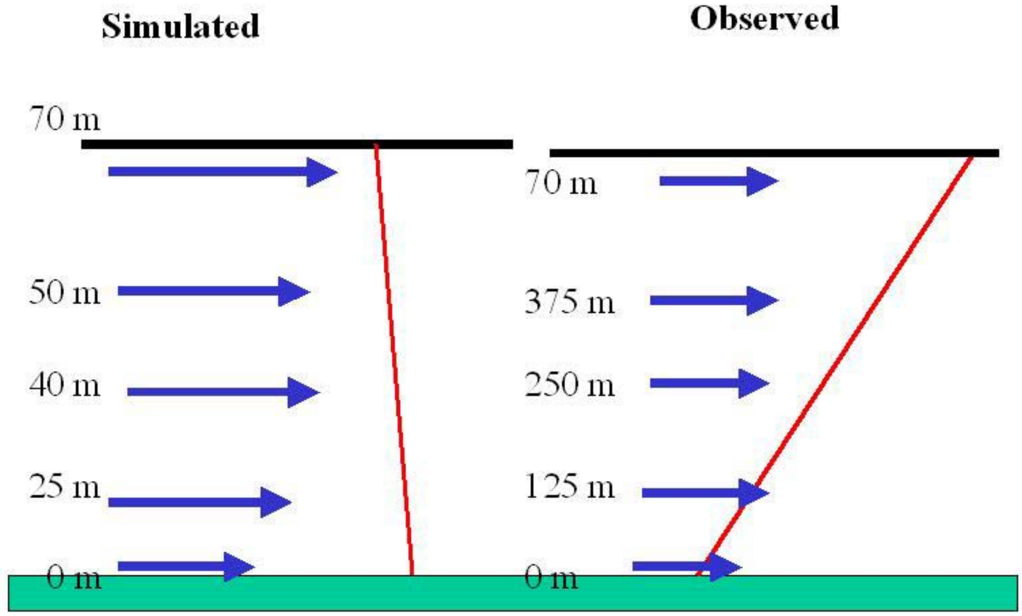

Figure 5: Over estimation of windshear near the surface due during in a stable boundary layer due to limited model resolution

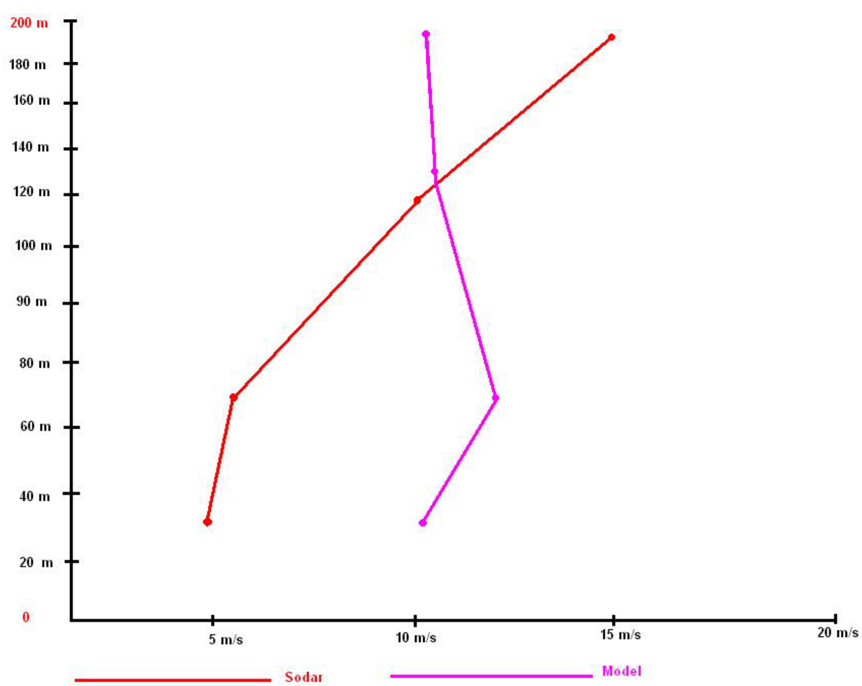

Figure 6: Observed sodar and model speeds from 00 - 06 local time.

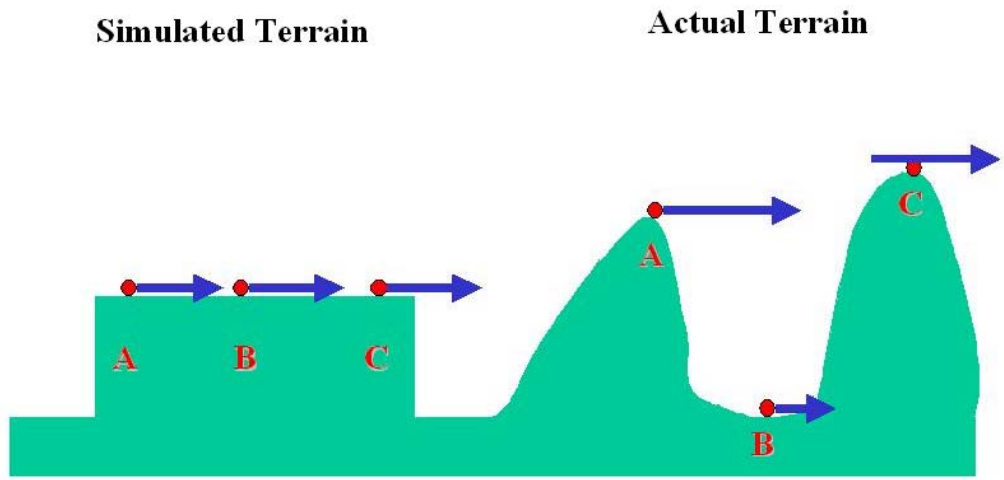

Figure 7: Result of limited model resolution in complex terrain, producing an over estimation of the winds at elevations higher than the model (A and C) and a lower estimation at elevations lower than the model (B)

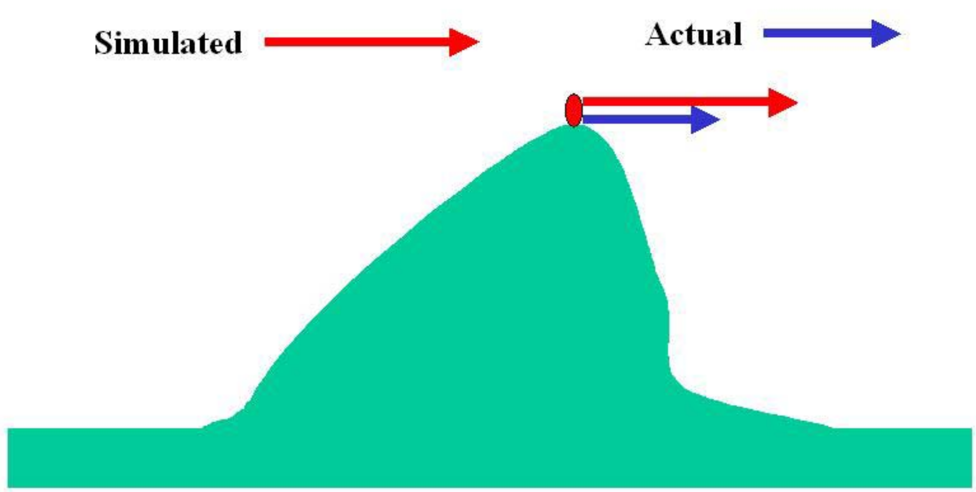

Figure 8: Example of overestimation of wind speeds at mountaintop using a hydrostatic model

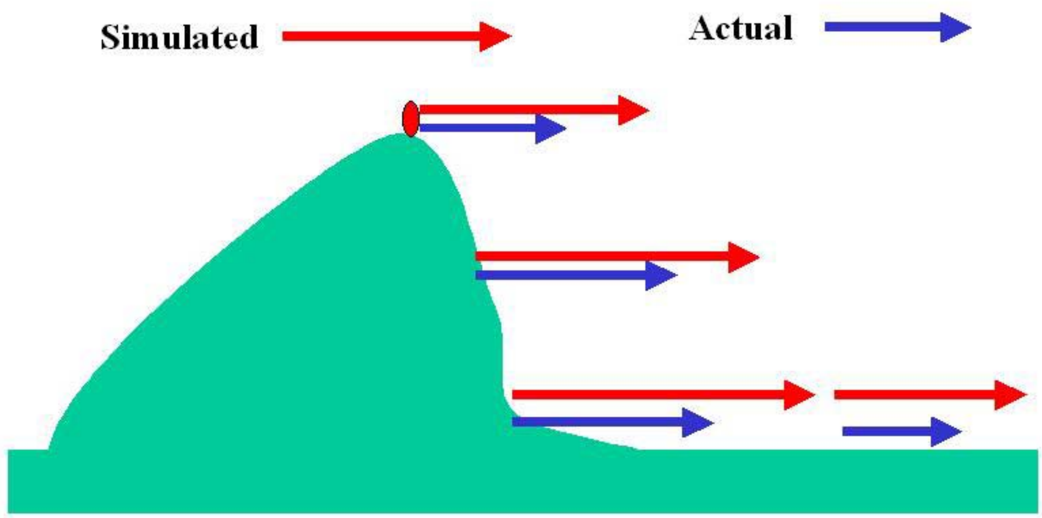

Figure 9: Example of overestimation of downslope flow with a hydrostatic model

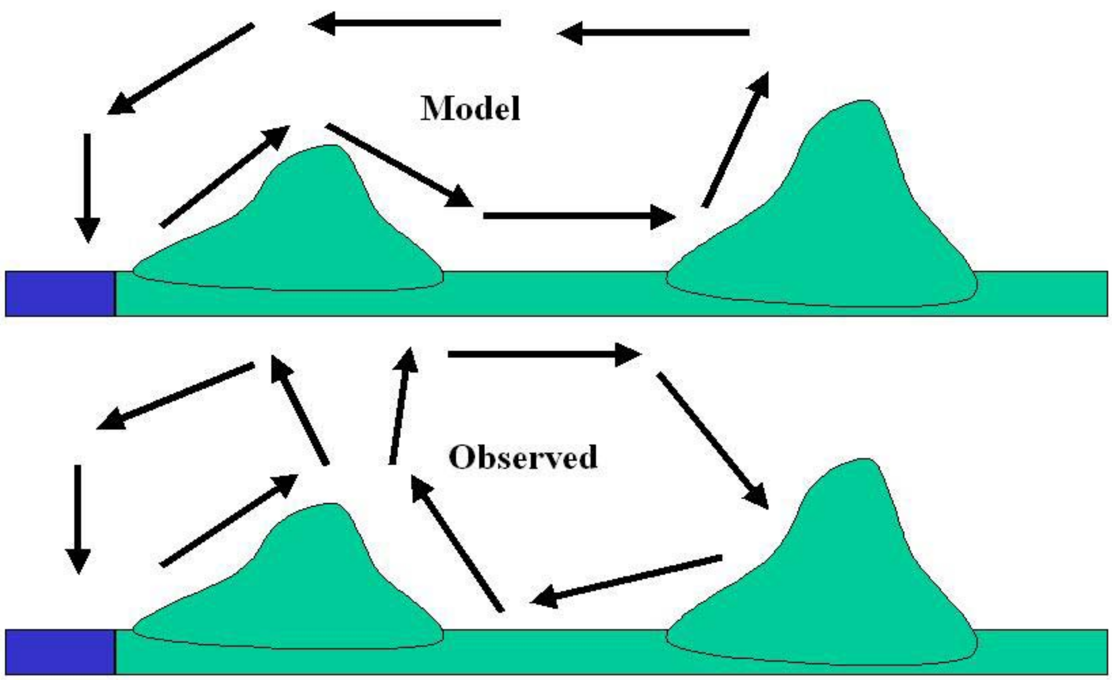

Figure 10: Errors in surface energy budgeting can lead to a poorly resolved or timed mesoscale circulations

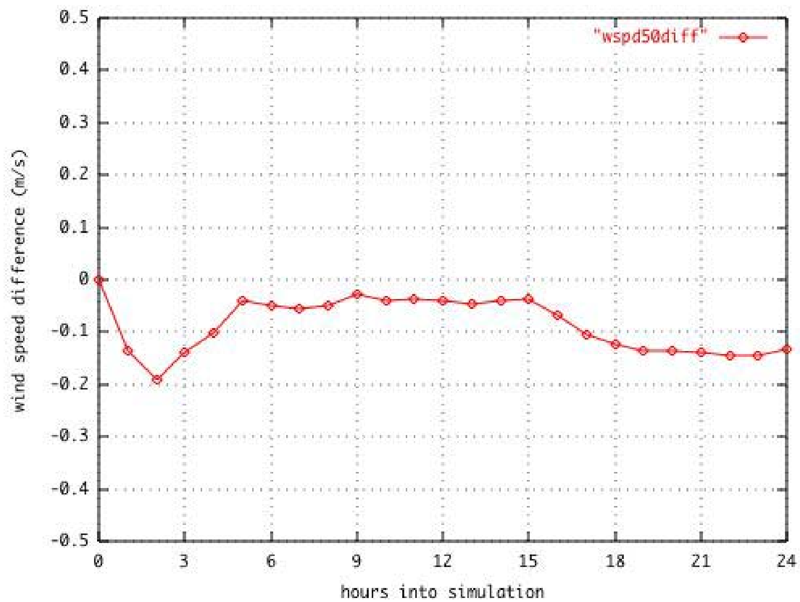

Figure 11: Comparison of 50 m modeled wind speeds using the traditional and z-less scheme, for an 8 km grid

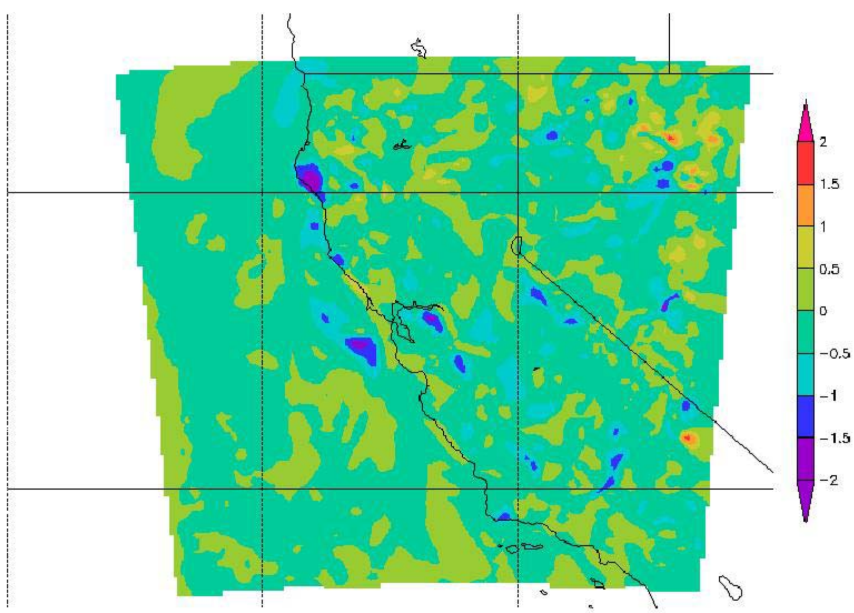

Figure 12: Spatial speed differences at 2300 PDT 15 July.
The z-less scheme reduces the wind speed in most areas in California by less than 0.5 m/s, although there are locations where the decreases are larger than 1 m/s.

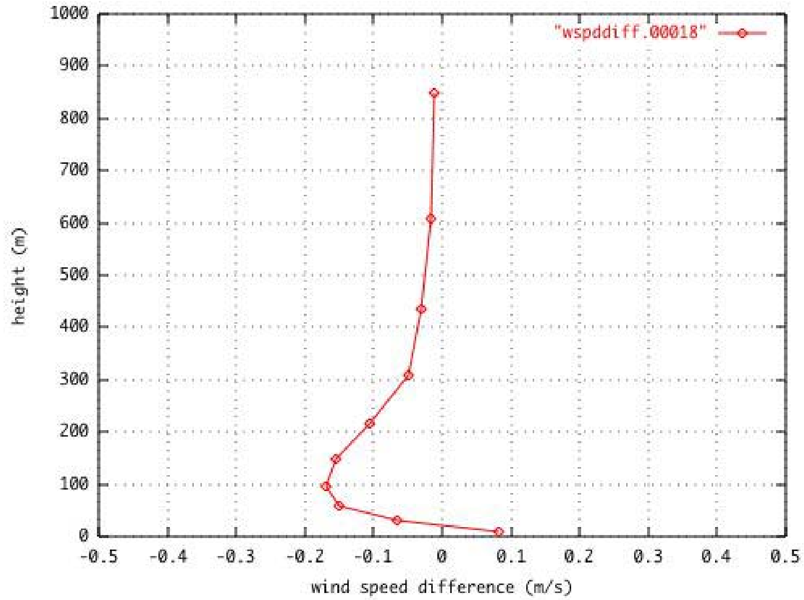

Figure 13: Profile of wind speed differences using the z-less scheme, for a three-month period (March-May 2005)

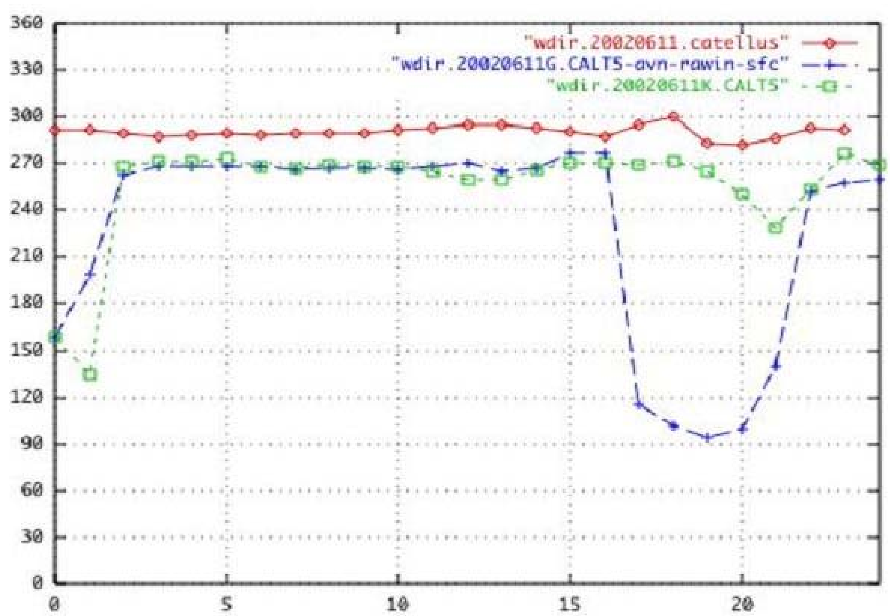

Figure 14: Comparison of the observed (red line) and modeled wind direction (green and blue lines).
The green line incorporates additional irrigation information in the soil database.

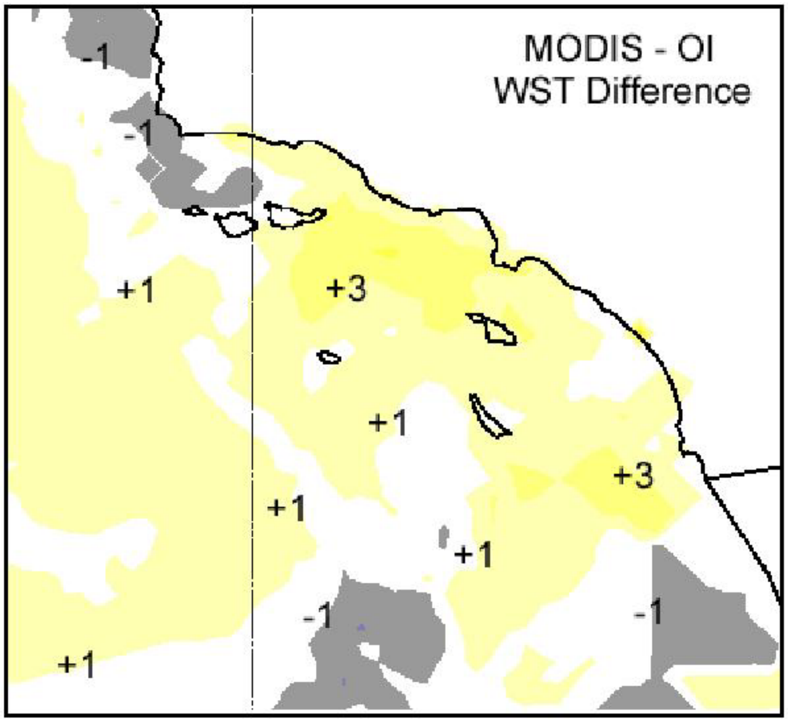

Figure 15: Differences in the initial skin temperature (degrees F) between the NCEP OI and MODIS WST for the 23 August 2002 forecast simulation

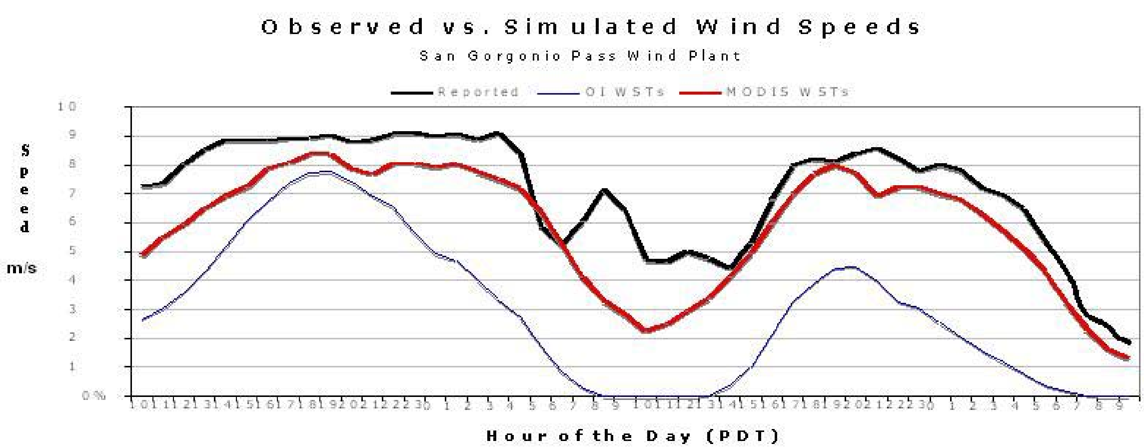

Figure 16: Simulated and observed wind speeds for the Mountain View wind plant for the period beginning at 9 AM PDT 23 August 2002