Recent Performances of the High-Resolution Rapid Refresh (HRRR) Model in Southern California

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Introduction

The large variations in terrain features in Southern California (mountain areas to over 11,000 feet MSL, desert areas below -200 feet MSL, and its proximity to the Pacific Ocean) creates significant difficulty for forecast models to accurately resolve weather features in Southern California (fig. 1). The High-Resolution Rapid Refresh (HRRR) model, NOAA's real-time 3-km resolution, hourly updated, cloud-resolving atmospheric model, (initialized by 3-km grids with 3-km radar assimilation over a 1-h period) has been incorporated into the National Weather Service San Diego warning/forecast process in order to address this challenge. We have had some recent opportunities to examine the HRRR in action. One case was a cold front event with strong winds, which makes timing the front through the area a very critical part of an aviation forecaster's "problem of the day". Another case was a surge of southeast winds in the desert, which can easily produce strong winds for hundreds of miles, reduce visibility, and sometimes creating additional thunderstorms when it encounters high terrain, terrain related flows, or the sea breeze flows. An event involving low elevation snowfall was also captured by the model in 2014. These events will be examined, and will illustrate that the 3-km HRRR has shown promise for significant forecasting improvements in Southern California.

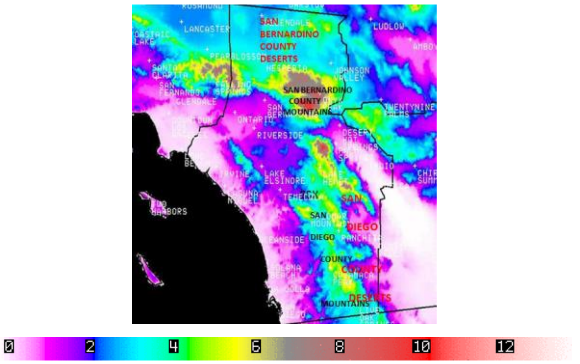

Fig. 1. Terrain map of the WFO SGX CWFA. Color coding in the legend is in thousands of feet MSL.

Strong Cold Frontal Passage Case

During the morning of 12 December 2014 a strong cold front moved through Southern California. It brought strong winds associated with the front. The winds were from the south ahead of the front, which creates wind shear and crosswind issues as the runway orientations of the major airports are often east-west. When the crosswinds reach about 25 knots (29 mph), issues develop concerning landing of aircrafts. Also an airport weather warning is issued for events when wind gusts reach or exceed 30 knots (35 mph). The 0000 UTC 12 December 2014 run of the 3-km HRRR (fig. 2) did a fine job of showing the frontal position and wind strength, with 30 knot (35 mph) wind gusts in table 1, reasonably consistent with the 30 knot southerly wind in the model.

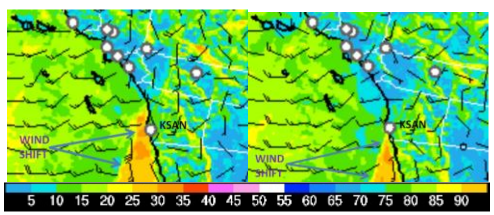

Fig. 2. The image shown on the left is the 14 hour forecast of the 3-km HRRR 10 meter winds (in knots) valid at 1400 UTC 12 December 2014 (6 am local time). The image shown on the right is the 15 hour forecast of the 3-km HRRR 10 meter winds (in knots) valid an hour later, at 1500 UTC 12 December 2014 (7 am local time). Both are from the 0000 UTC 12 December 2014 HRRR run (Legend speeds in knots).

Time (GMT)	Temperature (Deg F)	Dew Point (Deg F)	Relative Humidity (%)	Wind Speed (mph)	Wind Gust (mph)	Wind Direction (Deg)	Weather Conditions	Vis (miles)	Precip (1 hr)	Precip (3 hr)	Precip (6 hr)	Ceiling (Feet)
15:56	57.2	53.6	88	8		W	light rain, fog	4	0.00			2200
15:51	57	53.1	87	9		W	light rain, fog	2.5	0.46			1300
15:30	57.2	53.6	88	20	30	W	moderate rain, fog	1.75	0.43			800
15:22	57.2	55.4	94	24	30	W	moderate rain, fog	1.5	0.42			800
15:13	57.2	55.4	94	13		SW	heavy rain, fog	1	0.33			800
15:06	59	55.4	88	10	22	SW	heavy rain, fog	0.75	0.17			800
15:00	59	55.4	88	15	31	SW	heavy rain, fog	0.75	0.05			1900
14:51	62.1	55	78	25	35	SSW	moderate rain	2	0.01	0.01		2600
14:44	64.4	53.6	68	26	35	S	light rain, fog	2	0.00			2800
13:51	64	51.1	63	22	35	SSE	overcast	10				3000
12:51	64.9	50	58	18	28	SSE	overcast	10				3400
11:51	64.9	52	63	20	28	SSE	overcast	10			0.00	4100
10:51	64.9	53.1	65	17	24	SE	overcast	10				4900

Table 1. Table 1 is a snapshot of the MESOWEST surface observations for Lindbergh Field (KSAN). The weather elements of note are in red (strong wind gusts, crosswinds, low ceilings, and low visibilities). Note the wind shift from a southerly crosswind at 14:44 UTC to westerly winds (with little crosswind component remaining) by 15:22 UTC (7:22 am local time).

With such strong winds, not only is an aviation weather warning needed for San Diego International Airport, Lindbergh Field (KSAN), there is also enough crosswind to disrupt landing operations. Table 1 shows the winds gusting to over the threshold for an Airport Weather Warning, (the winds are strong crosswinds), and the ceiling/visibility falls to under 1000 feet/3 miles (actually down to 800 feet and ¾ of a mile in heavy rain and fog as the front passes by). As can be seen, at least in this case, the HRRR was able to accurately forecast the timing and wind strength of the frontal passage; hence the forecaster can determine when the crosswinds are likely to develop as well as the potential drop in ceiling/visibilities in heavy rain and fog.

Thunderstorm Outflow/Gulf Surge Case

During the evening of 24 August 2015 through the morning hours of 25 August 2015 southeast winds increased and moved into Southern California. Convection along with surface pressure gradients allow for outflows and southerly winds to reach Palm Springs International Airport (KPSP) and Thermal Airport [also known as Jacqueline Cochran Regional Airport (KTRM)]. The winds reached Thermal at around 1552 UTC on 25 August 2015 (Typically a late night and early morning phenomena). The model was able to capture this event (fig. 2 and Table 2).

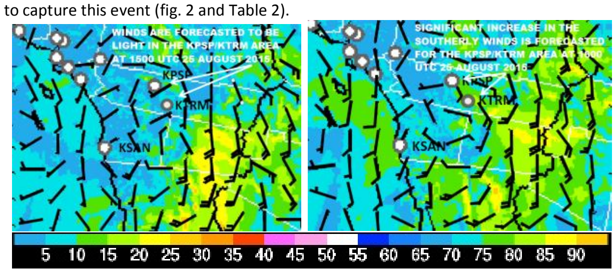

Fig.2. The above graphics are the 10 meter wind forecasts from the 3-km HRRR. The 3 hour forecast is valid at 1500 UTC 25 August 2015 (left). The 4 hour forecast is valid an hour later at 1600 UTC 25 August 2015 (right). Legend speeds in knots.

The 30-31 December 2014 Low Elevation Snow Event

On 30-31 December 2014 a very cold low moved into southern California. The 3-km HRRR 15 hour forecast of the Run-Total Accumulated Snow/Sleet using the 10:1 ratio (inches) valid the following morning at 1500 UTC 31 December 2014 (from the 0000 UTC 31 December 2014 run) indicated snow would develop across most of the southern portion of the Inland Empire [most of western Riverside County (fig. 3 and Table 3)]. This event had many characteristics of low elevation snowstorms in Southern California, for example, it occurred during the "low elevation snow prone" time of the day [the night through morning period when downslope winds typically maximize, temperatures are more likely to be near their minimums, and more advection of cold air, thus there is a higher probability of a low snow event during those times. Also, precipitation falling into the cold, downslope wind can result in wet bulb cooling effects to lower the snow level in Southern California (Small et al, 2009)].

Time (GMT)	Temperature (Deg F)	Dew Point (Deg F)	Relative Humidity (%)	Wind Speed (mph)	Wind Gust (mph)	Wind Direction (Deg)	Weather Conditions	Vis (miles)
19:52	97	70	42	8		SSE	clear	10
18:52	97	71.1	44	10	21	SE	clear	10
17:52	95	71.1	46	15	22	SSE	clear	10
16:52	95	69.1	43	9	20	SSE	clear	10
15:52	91	71.1	52	6		S	clear	10
14:52	88	70	55	3		S	clear	10
13:52	84.9	69.1	59	5		S	clear	10
12:52	87.1	64.9	48	9		SE	clear	10
11:52	90	55.9	32	7		E	clear	10

Table 2. Table of observations for Thermal Airport (KTRM).

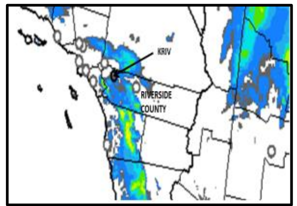

Fig. 3. 3-km HRRR 15 hour forecast of the Run-Total Accumulated Snow/Sleet using the 10:1 ratio (inches) valid the following morning at 1500 UTC 31 December 2014 (from the 0000 UTC 31 December 2014 run) shows snow/sleet across western Riverside County (including the valleys). Legend amounts in inches.

Time (GMT)	Temperature (Deg F)	Dew Point (Deg F)	Relative Humidity (%)	Wind Speed (mph)	Wind Gust (mph)	Wind Direction (Deg)	Weather Conditions	Vis (miles)	Precip (1 hr)	Precip (3 hr)	Precip (6 hr)	Precip (24 hr)	Ceiling (Feet)
6:28	37.4	35.6	93	17		N	light rain, fog	5					2700
5:58	35.8	35.6	99	22		N	light rain, light snow, fog	3	0.04		0.11		2000
5:39	39.2	37.4	93	24		N	light rain, fog	3					2000

Table 3. Table of observations for Riverside March Air Reserve Base (KRIV). The field is only at about 1536 feet MSL.

Summary and Conclusions

Although some of the biggest winter storms, most unstable episodes, and the highest frequency of heavy rain events was shown to peak in February for the 1998-2005 period, [strongly skewed by the very strong El Niño Event of 1997-1998 (Small, 2007)], some fairly sizable events have already occurred during the early part of the 2015-2016 very strong El Niño (including flash flooding and severe weather). With February 2016 closing in, there is the potential for a similar pattern to set up over the Southwest. Although the 12 December 2014 event was only one frontal case, it is anticipated that similar events will be caught by the 3-km HRRR during the 2015-2016 El Niño that will result in timely forecasts of frontal impacts in Southern California. Outflow boundary and gulf surge events have been tricky at best in the past when attempting to determine their impact in Southern California using the lower resolution models. Based on the 25 August 2015 case, this higher resolution 3-km HRRR model can indeed catch some of the subtle details surrounding such events, and should help to improve forecasts of blowing dust, shifting winds, and thunderstorms generated by "topographical updrafts" (outflows flowing up mountain slopes) in the future. In the 30-31 December 2014 low elevation snowfall case the HRRR showed that it can handle rare events, (for example, in this case when snow covered the valley areas). There was also snow west of the mountains in what was at the time a "coastal area forecast zone" (snow was accumulating below 1500 feet MSL just east of Irvine).

References

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