Early Wind Forecasting Results from the 1.5 km WRF-ARW in Extreme Southwestern California

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Introduction

Wind flow into Southern California interacting with rugged terrain results in very complex wind patterns. To examine these winds, NWS San Diego utilizes a 1.5 km nest inside of our 3.7 km local WRF-EMS ARW. It has helped in both analyzing and predicting the strength, location, onset, and cessation of a variety of phenomena driven by local wind flows as seen in the following cases.

Sea Breeze/Upvalley Flow Case

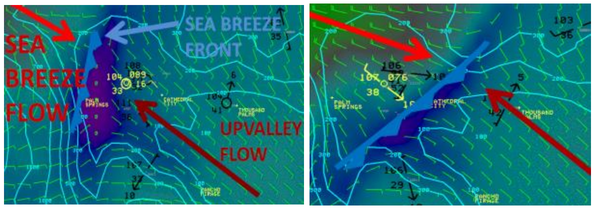


Fig. 1. The image on the left is the 15 hour forecast 1.5 km WRF-EMS ARW surface winds (green barbs), wind speed (shading), and surface observations valid at 2100 UTC 12 August 2013. The leading edge of the sea breeze front is indicated (blue line with barbs) and is seen quite well in the shading. Note the calm winds at Palm Springs (yellow METAR observation). Two hours later (at 2300 UTC 12 August 2013) the image on the right shows the sea breeze front has passed Palm Springs based on the model forecast and the observation, with gusts to 18 knots.

Convergence Pattern Schematics and Convection Case

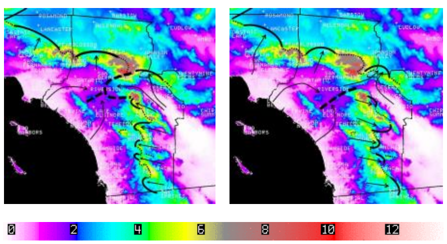


Fig. 2. Idealized schematic patterns for dominant offshore flow (left) and dominant onshore flow (right). The arrows are low-level cross-barrier (or gap) wind components. The thin dashed lines are convergence lines generated on/near mountain ridges, and the thick solid lines are convergence "arcs" downwind of passes and canyons. The thick dashed lines are the "Modified Elsinore Convergence Zone" (left) and the "Standard Elsinore Convergence Zone" (right). The legend is in thousands of feet MSL.

Convergence patterns can effect convection location and strength (fig. 2). In the following case study (a deep offshore flow case), convergence develops west of the mountain crestlines and below canyons and passes. The model reflects this pattern. East winds at the stations on the mountain crests in the satellite imagery in fig. 3 shows convergence, displaced to the leeside (western) slopes. Weak 700-500 mb winds also helps generate an offshore flow surface convergence pattern (convergence is seen via the tight gradients in the black isotachs where velocities approach zero). The westerly sea breeze flow eventually nudges the convergence boundaries eastward during the afternoon, moving past the mountain crest. The dashed ridgeline convergence zones (fig. 2 and 3) near the mountains, (possibly beginning an event displaced off the mountain crest on the lee side), typically develops convection before the arcs downwind of the passes during very moist and unstable days, but convection may be confined to the ridgelines on relatively dry days when the LCL/LFC is high and mid-level relative humidity is rather modest. The 2200 UTC image (lower left image in fig. 3.) shows convergence lines associated with the crest of the mountains and the convergence arcs associated with the gap flow. They have been displaced to the east (typical afternoon movement). Enhanced convection (especially near Warner Springs in the north in fig. 3), develops on the convergence lines as they move eastward.

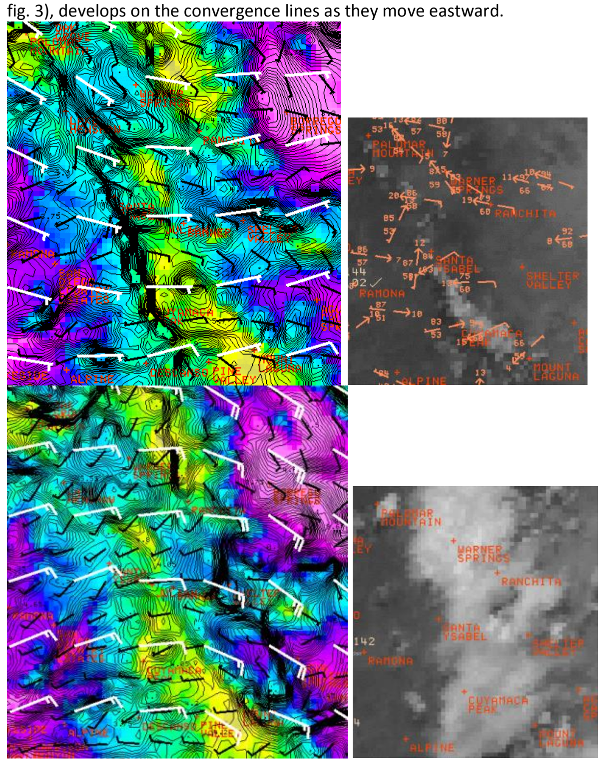


Fig. 3. The top left panel is the 30 hour 1.5 km WRF-EMS ARW surface winds (black barbs), 700-500 mb winds (white barbs), and surface wind speed (black contours) overlaid on a terrain background (shaded) valid at 1800 UTC 4 July 2014. The bottom left panel is the same, except it is the 34 hour forecast valid at 2200 UTC 4 July 2014. The visible satellite imagery and surface observations on the right corresponds to the times of the images on left (surface observations not available at 2200 UTC). Yellow areas are the higher mountains and the dark blues and purples are the lower elevations.

Mountain Wave Case at Burns Canyon

On 30 January 2014 during strong onshore flow, a strong mountain wave and rotor hit Burns Canyon (BCNC1) gusting to over 80 mph (fig. 4 and 5). The 1200 UTC 30 January 2014 KNKX sounding shows a stable layer (inversion) near 5,000 feet MSL and 10,000 feet MSL, with moderate-strong westerly flow. The observations in fig. 5 show southeasterly rotor winds in blue text, which brackets the much stronger, westerly wind phase of the event (red text). The model forecasted a wave surfacing very close to the sensor at 1700 UTC, and the wave and strong west winds arrived at 1700 UTC. So In this case, the surfacing strong west winds were still a bit west of Burns Canyon in the model when the winds actually surfaced. The 10 hour forecast indicated 40-50 knot sustained winds at Burns Canyon (fig. 5, lower left), similar to the 45-55 mph winds seen in the observation data during the peak of the windstorm.

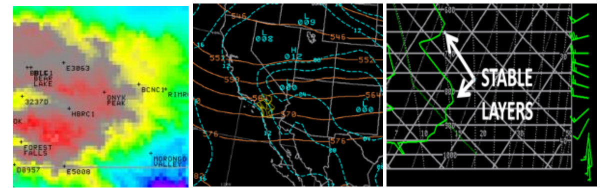
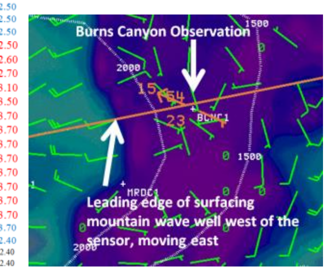


Fig. 4. The image on the left is a high resolution terrain map of Southern California showing the location of Burns Canyon (BCNC1). The middle image is the NAM80 500 mb height and mean sea level pressure for 0000 UTC 31 January 2014. On the right is the 1200 UTC 30 January 2014 KNKX sounding (just north of KSAN).

Tabular Listing: January 30, 2014 - 12:00 through January 31, 2014 - 13:00 GMT

Time(GMT)	Temperature °F	Dew Point °F	Relative Humidity %	Wind Speed mph	Wind Gust mph	Wind Direction	Quality check	Solar Radiation W/m*m	Precipitation accumulated in	Battery voltage volt
12:51	36.0	19.2	50	3	20	E	OK	0.0	0.27	12.40
11:51	38.0	14.1	37	10	21	NW	OK	0.0	0.27	12.40
10:51	39.0	16.2	39	6	27	SE	OK	0.0	0.27	12.50
9:51	41.0	18.0	39	13	24	W	OK	0.0	0.27	12.50
8:51	42.0	12.8	30	9	22	NNW	Caution	0.0	0.27	12.50
7:51	40.0	19.9	44	4	20	E	Caution	0.0	0.27	12.50
6:51	39.0	17.3	41	2	12	S	Caution	0.0	0.27	12.50
5:51	41.0	19.1	41	3	31	SE	Caution	0.0	0.27	12.50
4:51	48.0	7.7	19	21	42	W	Caution	0.0	0.27	12.50
3:51	49.0	-12.4	7	23	66	W	OK	0.0	0.27	12.60
2:51	50.0	-9.0	8	51	85	WSW	OK	0.0	0.27	12.70
1:51	52.0	9.8	18	54	84	WSW	OK	5.0	0.27	13.10
0:51	51.0	26.3	38	49	83	WSW	OK	88.0	0.27	13.50
23:51	51.0	28.7	42	46	74	WSW	OK	199.0	0.27	13.70
22:51	51.0	25.0	36	44	81	WSW	OK	311.0	0.27	13.70
21:51	51.0	22.2	32	43	83	WSW	OK	415.0	0.27	13.70
20:51	56.0	27.3	33	45	79	WSW	OK	640.0	0.27	13.70
19:51	57.0	28.2	33	42	69	WSW	OK	675.0	0.27	13.70
18:51	57.0	28.2	33	39	65	WSW	OK	446.0	0.27	13.70
17:51	57.0	30.3	36	39	63	WSW	OK	343.0	0.27	13.70
16:51	58.0	27.5	31	23	50	WSW	OK	266.0	0.27	13.70
15:51	54.0	23.3	30	7	17	ESE	OK	63.0	0.27	13.70
14:51	50.0	23.4	35	1	13	S	OK	0.0	0.27	12.40
13:51	53.0	23.9	32	5	22	NNW	OK	0.0	0.27	12.40
12:51	52.0	25.2	35	4	14	E	OK	0.0	0.27	12.40



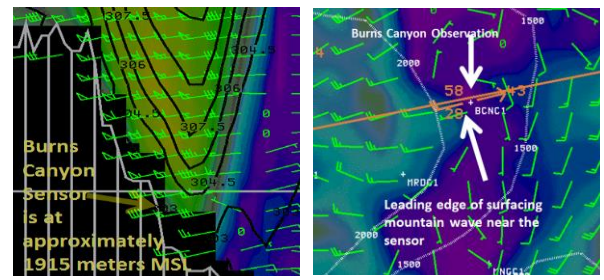


Fig. 5. The upper left panel is a snapshot of the Mesowest observations for BCNC1. The local 1.5 km WRF-EMS ARW nest surface maps are the 4 hour forecast valid at 1600 UTC 30 January 2014 (upper right) and the 5 hour forecast valid at 1700 UTC 30 January 2014 (lower right) when the wave arrived. The images include wind barbs, wind isotachs (shaded) and model terrain (thin white lines, in meters MSL). The 10 hour forecast cross section valid at 2200 UTC 30 January 2014 (taken along the orange line) is shown in the lower left. The wind speed (shaded), the wind barbs (green, in knots), and the potential temperatures (black contours) are shown.

Summary and Conclusions

The 1.5 km resolution data has allowed us to take a closer look at several local phenomena and implement the findings operationally (Special thanks to Brian D'Agostino and Steven Vanderburg for their support on this project). We see that it can accurately forecast the sea breeze (at least in this case) in the Palm Springs area. For the mountain wave case, it captured the rotor flow at Burns Canyon and was close on the timing of the surfacing wave. The model also seems to have a good idea on the locations of convergence boundaries. We can now have more confidence in the model wind patterns for timing and intensity, from mountain waves to sea breezes, as well as for convergence zones.