Ambient High Elevation Coastal Weather and the Thermal Trough

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Introduction and Motivation

Wildfires are a common occurrence in the mountains of northwest California during the summer and early autumn months. Given the unique combination of weather influences, topography and remoteness, wildfires are often quite difficult to contain and control. In particular, the ridges along Cape Mendocino typify these characteristics, as the interaction between strong surface heating of interior California and adjacent cold sea surface temperatures sets up a seasonally pronounced isobaric gradient. While the intensity of this gradient oscillates diurnally due to a variety of synoptic and mesoscale factors, the most principal of which are the position and strength of the subtropical Pacific high pressure and location of the inverted thermal trough, the result is a very challenging fire weather forecast which presents unique challenges for meteorologists and land management agencies. The Paradise and Panther wildfires, occurring in June 2008 and July 2009, respectively, heightened awareness as to the weather-related difficulties surrounding fire suppression in the higher terrain along Cape Mendocino’s coast.

Meteorology and Data

While the marine layer is a nearly ever-present feature along the California coast, its depth varies significantly in response to transient synoptic features. In particular, strong high pressure aloft results in subsidence which helps compress the relatively cool and moist air and confine it to elevations below the ridges along Cape Mendocino, whose highest peaks range from 2,500 to just over 4,000 feet elevation. Conversely, approaching shortwaves or low pressure systems have the effect of inducing boundary layer lift which often allows the marine layer to expand to heights which reach mid-slope or higher locations. Even in the absence of passing disturbances, mechanical mixing during the afternoons typically allows some marine influence in the form of cooler and more moist conditions to permeate lower elevation ridge tops. While there were some differences in the overall upper level pattern between the two cases subsequently presented, ridging was present over the area and the minor inconsistencies noted were not believed to be material. A topographic map of the region, delineated by National Weather Service County Warning and Forecast Area (CWFA) and the area of consideration (circled) is presented in Figure 1.

The two cases examined herein are superficially similar, although modeled data were unavailable in the second case. In the initial case, NAM data were archived using the Weather Event Simulator (WES) in order to assess predictability and model performance in comparison to subsequent observations.

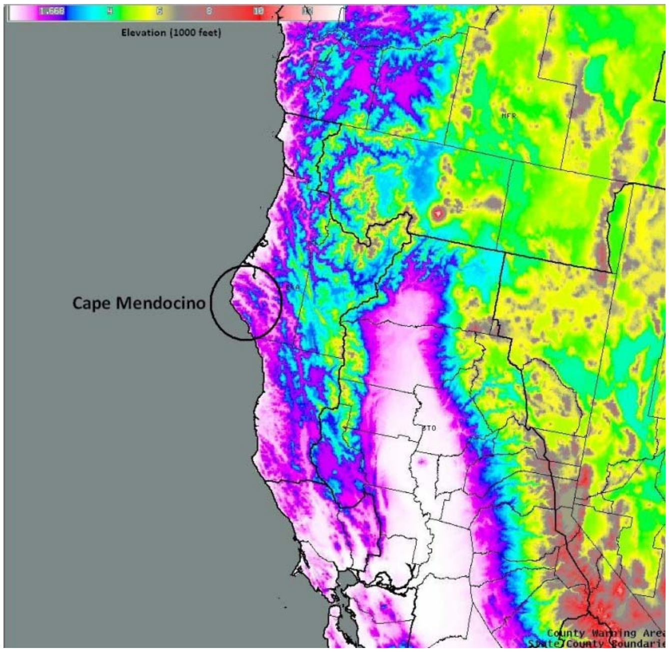

Figure 1. Topographic map of northwest California, divided by NWS area of responsibility. The circled area around Cape Mendocino represents the focus area for the study.

Case: July 19-20, 2009

Figure 2 indicates the NAM80 initialization of mean sea level pressure (MSLP) at 12 UTC July 19. At this time, Cooskie Mountain RAWS, an automated ridgetop station located at 2,950 feet MSL along Cape Mendocino, indicated sustained north winds of 23 MPH and gusts of 34 MPH, along with a relative humidity of 38%. These predawn conditions are quite typical under such pressure gradient circumstances and orientation. At the same time, a neighboring fire RAWS, located at an elevation of 2,399 feet MSL registered gusts of 23 MPH and a relative humidity of 34%.

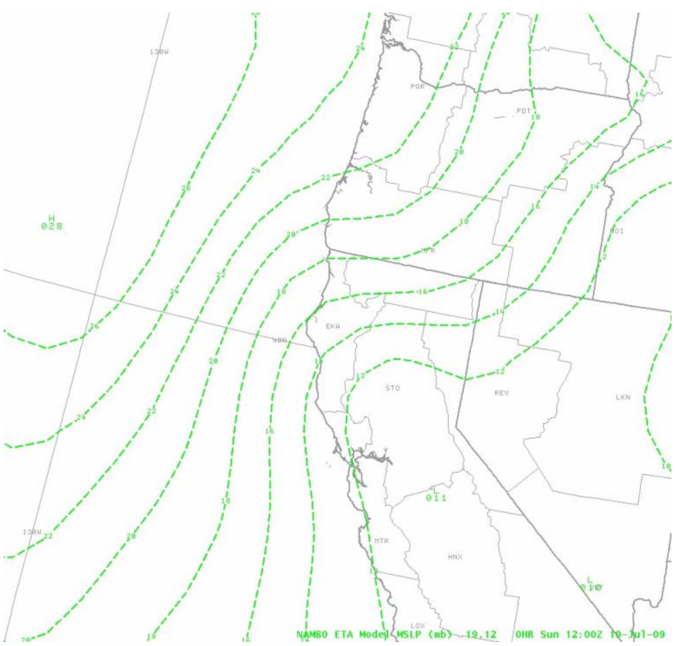

Figure 2. 12 UTC initialization of MSLP from the NAM80 on July 19, 2009.

Using this particular run of the NAM, it should be readily apparent to the forecaster that significant changes to the MSLP pattern were suggested for coastal northern California over the next 24 hours, as shown in Figure 3.

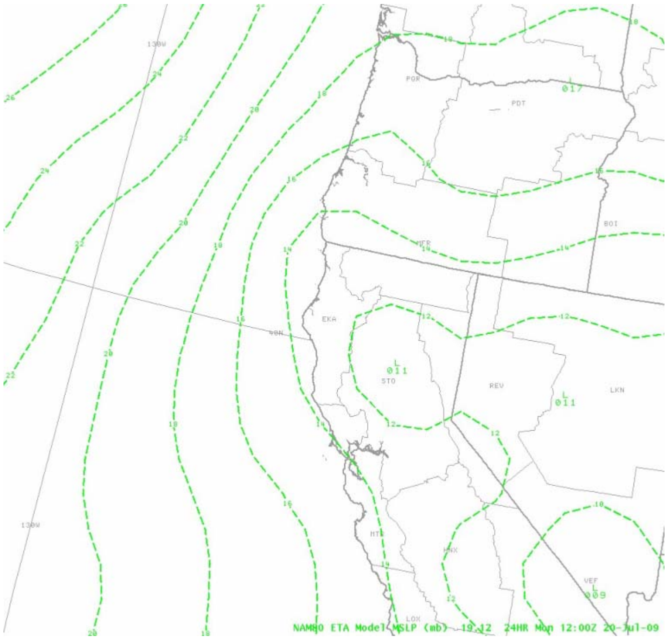

Figure 3. 24-hour forecast of MSLP from the 12 UTC July 19, 2009 run of the NAM80.

From a forecasting standpoint, the obvious change is an expectation for much lighter winds along the ridges of Cape Mendocino, which under normal circumstances would be a positive factor in the suppression of wildfires. However, an often overlooked consequence of the thermal trough shifting north in this manner is a substantial *decrease* in relative humidity, along with some *increase* in temperatures at the ridges. These changes typically occur during the late night and early morning hours, which not only contradicts the expected diurnal behavior, but also can prove potentially devastating for fire crews planning burnout or other containment operations as these conditions will exacerbate nighttime fire behavior. Thus, from a decision-support perspective, it is extremely important to be able to convey and emphasize these characteristics, as changes in fire weather, especially those which are counterintuitive to basic firefighter meteorological training, represent a definite safety threat.

By the morning of July 20, significant changes in sensible weather did indeed occur, not only over the course of several hours that night, but also in comparison to the previous night. At the Cooskie Mountain RAWS, relative humidity fell after sunset, achieving a minimum of just 9% at 6 a.m. The 24-hour reduction in humidity was as great as 30% when comparing the two mornings. It is important to note that while a reduction in relative humidity from 100% to 70%, for example, means little in terms of an expected increase in fire behavior, the same absolute decrease in humidity from 40% to 10%, as in this case, infers a change from “moderate” burning conditions to “critical” or “extreme” ones (NWCG Fireline Handbook 1993). In addition, ambient air temperatures rose several degrees during the night, with the 24-hour change in temperature as great as 12 degrees Fahrenheit. In accordance with the NAM solution, winds dropped to just a few MPH on the morning of the 20th in response to the much weaker pressure gradient. Table 1 presents selected meteorological data at the Cooskie Mountain RAWS for trend comparison.

Date	Time (PDT)	Temp (F)	Rel Hum	Wind (MPH)	Direction	Gust (MPH)	Date	Time (PDT)	Temp (F)	Rel Hum	Wind (MPH)	Direction	Gust (MPH)
18-Jul	21:00	65	34%	30	002	45	19-Jul	21:00	72	27%	13	351	22
	22:00	67	36%	31	004	47		22:00	72	21%	14	353	18
	23:00	67	38%	28	358	48		23:00	75	17%	16	000	18
19-Jul	0:00	64	41%	27	357	42	20-Jul	0:00	76	14%	12	006	19
	1:00	66	36%	25	356	40		1:00	75	11%	9	006	18
	2:00	67	40%	27	001	38		2:00	77	10%	9	000	13
	3:00	70	41%	23	358	36		3:00	77	12%	7	344	11
	4:00	69	41%	24	355	32		4:00	75	17%	5	327	10
	5:00	69	38%	23	352	34		5:00	76	20%	5	299	8
	6:00	68	36%	21	349	32		6:00	75	9%	2	308	6
	7:00	70	34%	23	349	28		7:00	79	17%	3	289	5

Table 1. Selected meteorological data at Cooskie Mountain RAWS from July 18-20, 2009.

These data from Cooskie Mountain are well corroborated with those available from the neighboring fire RAWS site referenced earlier; the morning of the 19th registered a minimum relative humidity of 34%, while on the subsequent morning this reading fell to just 12%. Similarly, sharp reductions in wind speed and a moderate increase in surface temperatures were realized upon comparing 24-hour change data.

Case: June 26-27, 2008

The overall synoptic and mesoscale patterns were roughly similar to the 2009 case, although no archived WES data were available. The surface pattern on the morning of June 26 is presented in Figure 4.

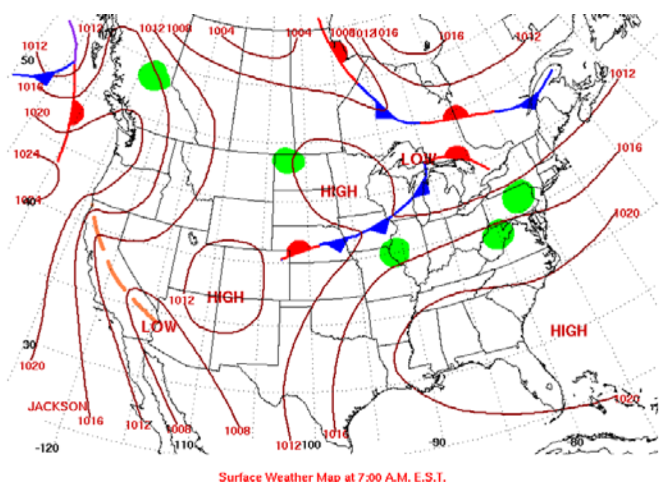

Figure 4. NCEP surface map for 12 UTC June 26, 2008.

The packing of isobars across northwest California in association with the thermal trough produced primarily southeast winds at Cooskie Mountain, gusting to as high as 48 MPH during the predawn hours. Relative humidity was quite high, falling to a reading of 50% during the early morning hours, while temperatures ranged from the upper 40s to lower 50s Fahrenheit. On the following morning, the surface pattern (as shown in Figure 5) featured the thermal trough shifting north and west of the area.

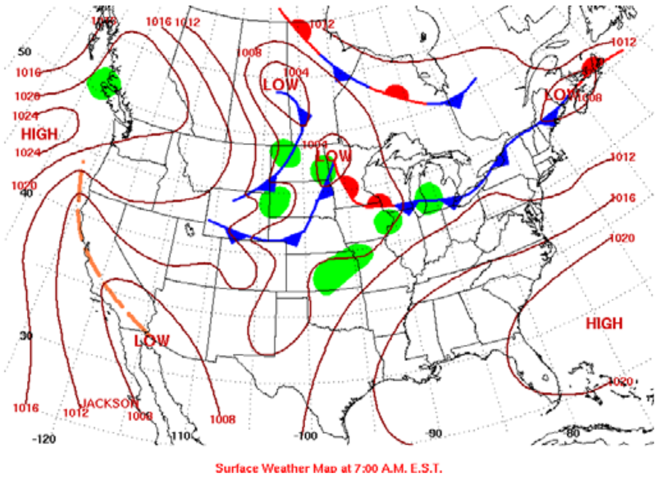

Figure 5. NCEP surface map for 12 UTC June 27, 2008.

Consistent with the previous case, winds fell significantly, with gusts less than 10 MPH in the predawn hours. Similarly, relative humidity fell quite dramatically versus 24 hours earlier, with predawn readings around 30%. Perhaps most notable was the dramatic rise in temperature, with measurements in the mid to upper 70s being recorded (or as much as 30 degrees warmer than the previous night). Unlike the earlier case, however, these much warmer early morning temperatures set the stage for an afternoon that was some 30 degrees warmer than the previous day at the RAWS site. A principal contributing factor appears to be that winds maintained an easterly component for much of the afternoon in the 2008 case, whereas they retained a westerly component in the 2009 case; despite the difference in wind direction, speeds remained relatively light during the afternoon in both cases once the thermal trough expanded over the region.

Forecasting Considerations

While the main driver of rapid day-to-day meteorological changes discussed in this paper is the strength and orientation of the thermal trough, it is by no means the only determinant of significant weather change along the ridges of Cape Mendocino. As briefly discussed earlier, forecasters must constantly evaluate the synoptic scale for the presence of disturbances or ridges which help enhance or suppress the marine layer, respectively. Failure to take these factors into consideration will likewise result in poor forecasts which ultimately may prove frustrating or life-threatening for land managers in a wildland fire situation.

With respect to the analysis and forecasting of pressure patterns, it should be recognized that while this study specifically examines the performance of the NAM80, this is more as a result of archived data limitations rather than any implied performance improvement over competing models, such as the GFS or ECMWF. Other coarse models, including the GFS40, have proven equally as effective in forecasting subtle position shifts in the thermal trough. However, the use of higher resolution models may introduce considerable noise in the interpretation of the thermal trough due to mesoscale influences between land and sea, as well as terrain, and thus should be used with caution. Meteorologists must be mindful of the northward shift and subsequent weakening of the thermal trough in their predictions, and fully expect a substantial day-over-day change towards lighter winds, lower humidities, and warmer temperatures as a result. The presence of a weak westerly component during the following afternoon will likely restrict the potential for warmer mornings to translate into equally warmer afternoons. That is, the 24-hour change experienced in morning temperatures between successive days is unlikely to persist to an equal magnitude later in the day. Conversely, a weak easterly flow will tend to carry over a similar magnitude change in 24-hour morning temperatures into the afternoon.

Summary

The position and strength of the thermal trough influences a wide range of weather conditions along the coast. Although the best known of these is the coastally-trapped wind reversal (also known as “southerly surge”) present at low elevations, often overlooked is the impact of the northward progression of the thermal trough at elevations typically above the marine layer. The two cases presented herein demonstrate the drastic day-to-day changes governed by the presence and position of the thermal trough along the ridges of Cape Mendocino. Given the difficulty in suppressing wildfires in this area due to unfavorable and changing weather conditions and the potential for long-lasting incidents, forecasters should be very mindful of subtle shifts in the synoptic pattern (such as the position of the subtropical high pressure offshore) and mesoscale features, including the thermal trough.

Acknowledgements

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Reference

National Wildfire Coordinating Group, 1993: NWCG Fireline Handbook Appendix B, National Interagency Fire Center. p.56.