# Low Elevation and Coastal Snow in Southwest Oregon:

# Analysis of a High-Impact Event on March 12th, 2012

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## Introduction

A high-impact winter weather event affected populated areas of Medford Weather Forecast Office's (WFO) County Warning Area (CWA) on the evening of March $12^{th}$ into the early morning hours of March $13^{th}$, 2012.

Normally snow-free coastal towns north of Cape Blanco, such as Bandon, OR, measured 3.5 inches of wet snow in about 6 hours, dwarfing the previous March daily record of 0.6 inches. Additionally, Sexton Summit on Interstate 5 got about 8 inches of snow in 6 hours, while isolated locations near the Rogue Valley received up to 9 inches at elevations as low as 2500 feet, 1000 feet above the valley floor.

The major impacts to Interstate 5 were forecast well ahead of time, and were more climatologically favored. Lead time was significantly less for the coastal snow and heavier Rogue Valley Hills snow, and this paper will address methods that could provide more lead time during similar situations in the future.

A combination of conceptual and meteorological challenges surrounded this event, and the purpose of this document is to provide lessons learned that can be applied, not only to other winter storms in the region, but also to forecasting in general. A brief summary of antecedent synoptic conditions will follow, with the focus of the paper being model output analysis, the forecast and warning process, situational awareness, and realistic potential improvements to these areas.

## Impacts

One of the authors of this paper traveled along the southern Oregon coast several weeks after the event, and the destruction was impressive. Widespread tree damage was evident along highway 42 all through Coos County and along much of highway 101 northward. DOT crews had evidently piled the downed trees and litter in parking lots along the way that residents were still cutting for firewood weeks later. There were hundreds of places where trees had fallen across guardrails and either bent or destroyed them. Entire groves of leafy trees had been stripped bare. Social Media was very active during the coastal snow, with citizens reporting multiple auto accidents and power outages. According to Pacific Power, more than 8,500 Coos County residents lost power due to the coastal snow.

# Part 1 - Forecasting the Event

## Synoptic Pattern before Low Elevation Snow

On the evening of March 12th, a deep 979mb occluding low pressure system was over the British Columbia coastline.  A cold front was draped along the Oregon coast, and a cold, unstable air mass was evident behind the cold front per open-cell cumulus depicted on IR imagery. (Fig. 1)

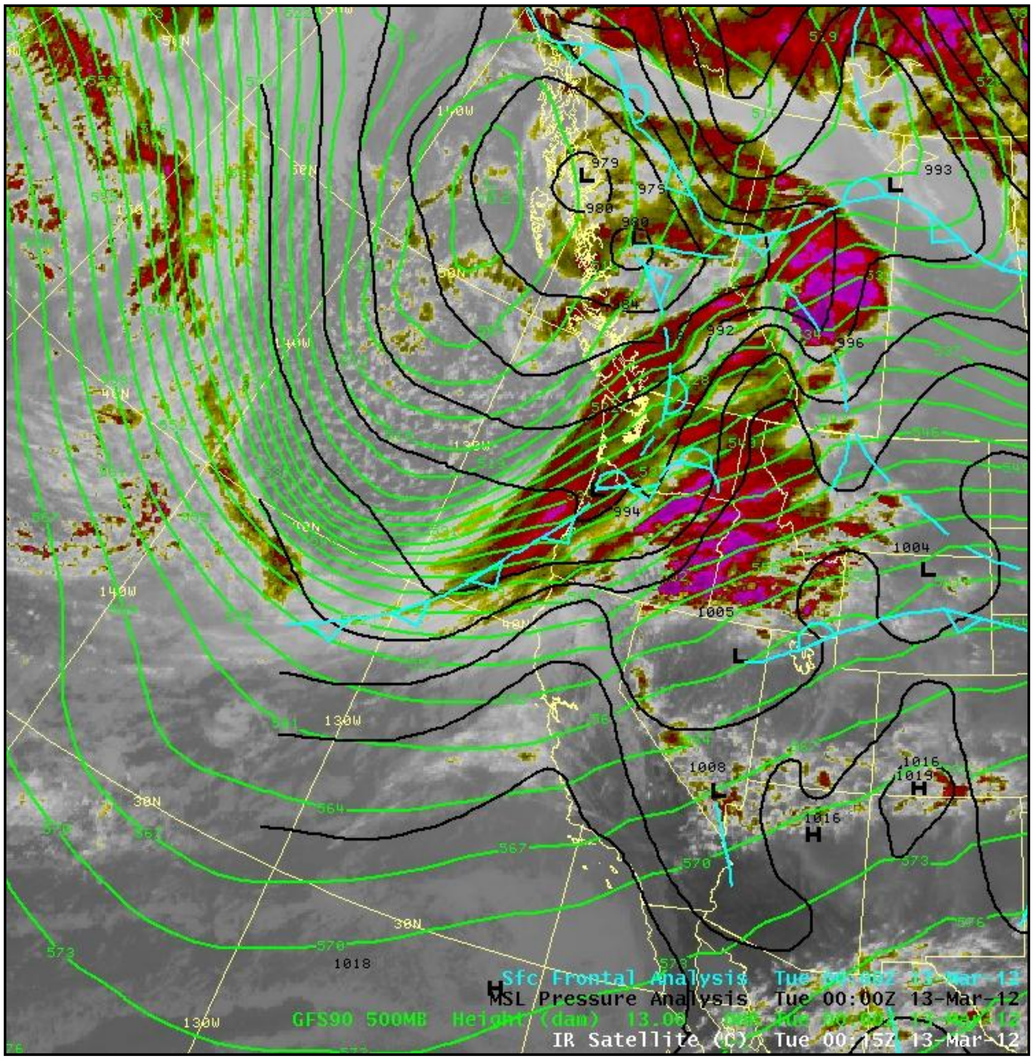


**Figure 1. IR Imagery, Surface Frontal Analysis, 500mb Height, MSL Pressure Analysis for 20120313/0000Z.**

## Model Data 24 Hours Prior to the Event

The 12Z model data that was available March 12th will be featured here, and the focus will be on a 6-hour period of expected significant weather, between 06Z and 12Z on March 13th.  The model data essentially represents an 18 to 24 hour outlook. Model output valid at 06Z corresponds to the period of heavy coastal snow, while output valid at 12Z will align with the heavy inland snow in the hills surrounding the Rogue Valley. Model time-height cross-sections and model soundings will be highlighted for their utility in this situation. Time-height cross-sections provide valuable insight into the timing of the strongest upward vertical velocities (UVVs) and details regarding the dendritic growth zone. Model soundings provide a quick glimpse of the entire atmospheric column, highlighting snow levels, and allowing for easy comparison amongst different models. Model data is discussed below for both the coast and the Rogue Valley.

***- Coast –***

The NAM12 time-height cross-section for North Bend, OR is shown in figure 2:

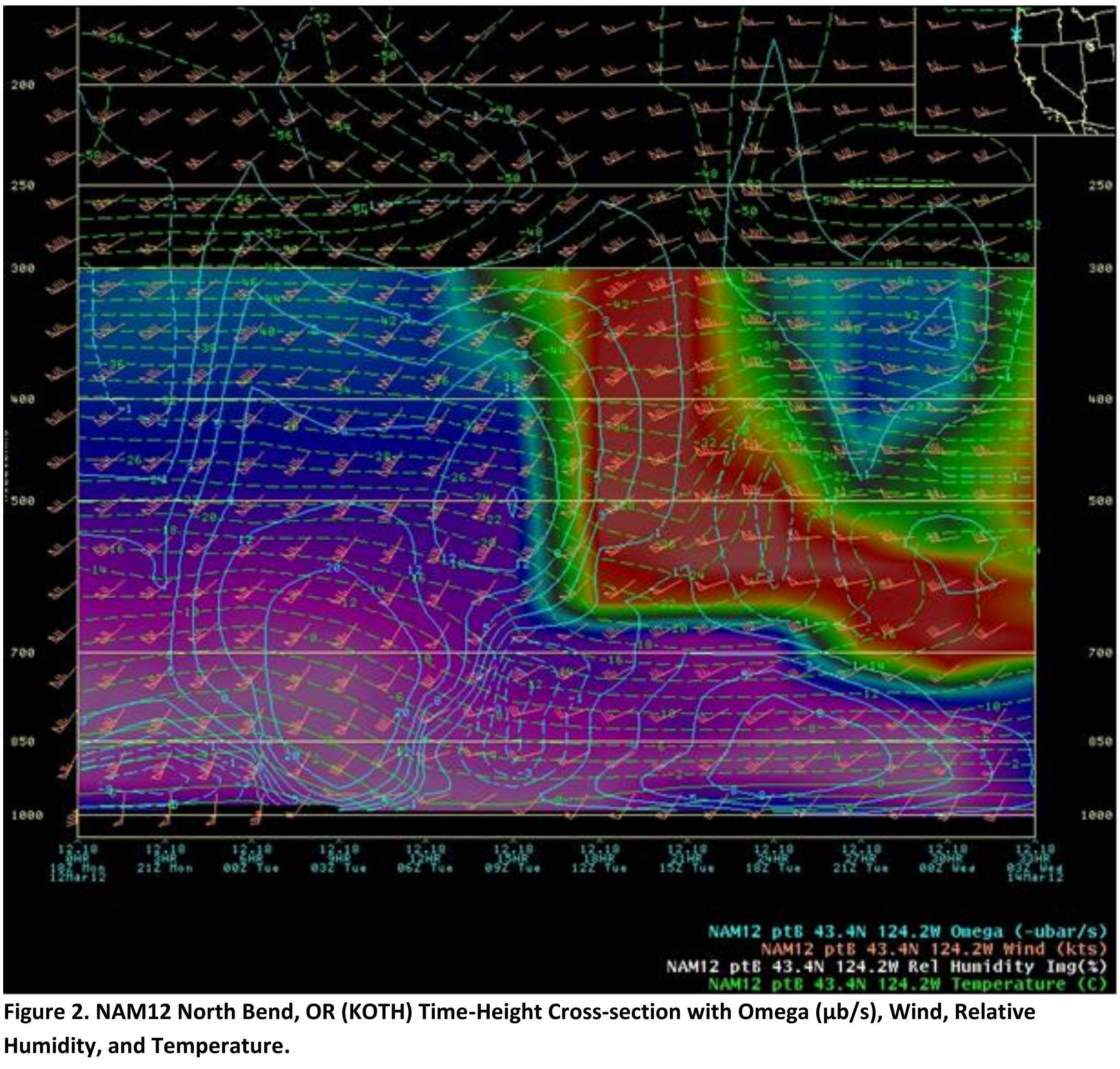


**Figure 2. NAM12 North Bend, OR (KOTH) Time-Height Cross-section with Omega (µb/s), Wind, Relative Humidity, and Temperature.**

It's important for forecasters to prioritize tasks during the shift to allow for proper attention to the portion of the forecast with the greatest impacts. This usually translates into focusing on a brief period of the forecast - the high-impact portion - and this could include a short duration of 6 to 12 hours. The key to the time-height cross-sections during this analysis was that the omega values provided a good idea of when the most significant precipitation and impacts would occur. Time-height cross-sections for KOTH North Bend, OR in this snow event honed in on a period between 06Z and 12Z on March 13th, where heavy precipitation and the arrival of a cold air mass coincided, suggesting a potential for low elevation snow across the beaches of SW Oregon. Also supporting the potential for low elevation snow were very strong UVVs of 20µb/s that implied lower snow levels per heavy precipitation rates. Lastly, a portion of the strong UVVs and high relative humidities in the dendritic growth zone of -12C to -18C highlighted the potential for above normal snow-to-water ratios. Model soundings for North Bend, OR (KOTH) valid at 06Z on March 13th are shown in figure 3:

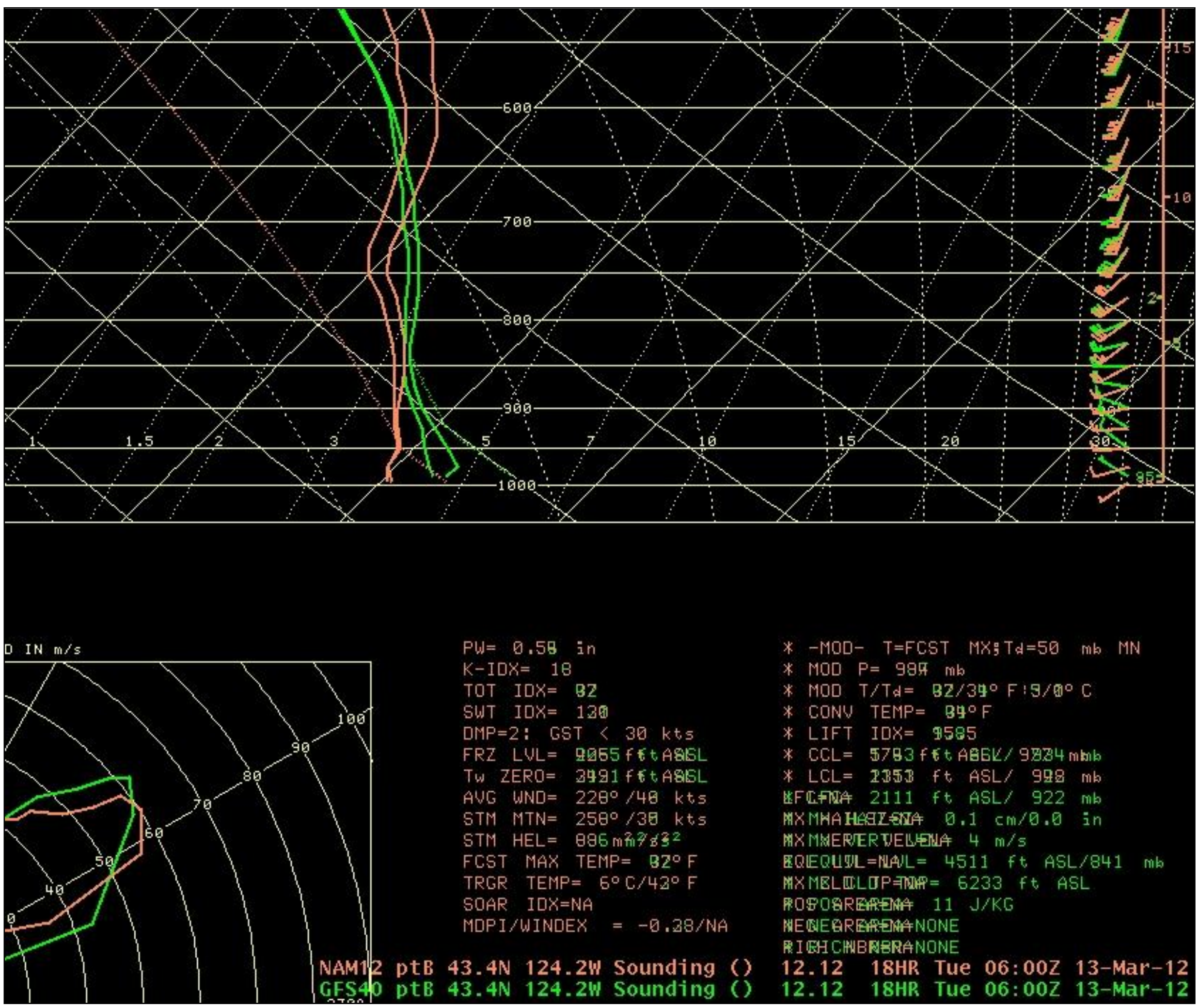


**Figure 3. NAM12 (Green) and GFS40 (Orange) Model Soundings for North Bend, OR (KOTH) Valid 20120313/0600Z.**

Forecast soundings differed on how cool the atmosphere would be near the surface, but the GFS and NAM were very similar in terms of 850mb temperature. This is typically a much more reliable element of the forecast sounding compared to the highly variable near-surface layer. This likely was the most critical element of the sounding because the precipitation rates were high enough to entrain air from 850mb to the surface, helping nudge the transition from rain to snow.

***- Rogue Valley -***

The time-height cross-section from the 12Z NAM on March 12th for Medford, OR is shown in figure 4:

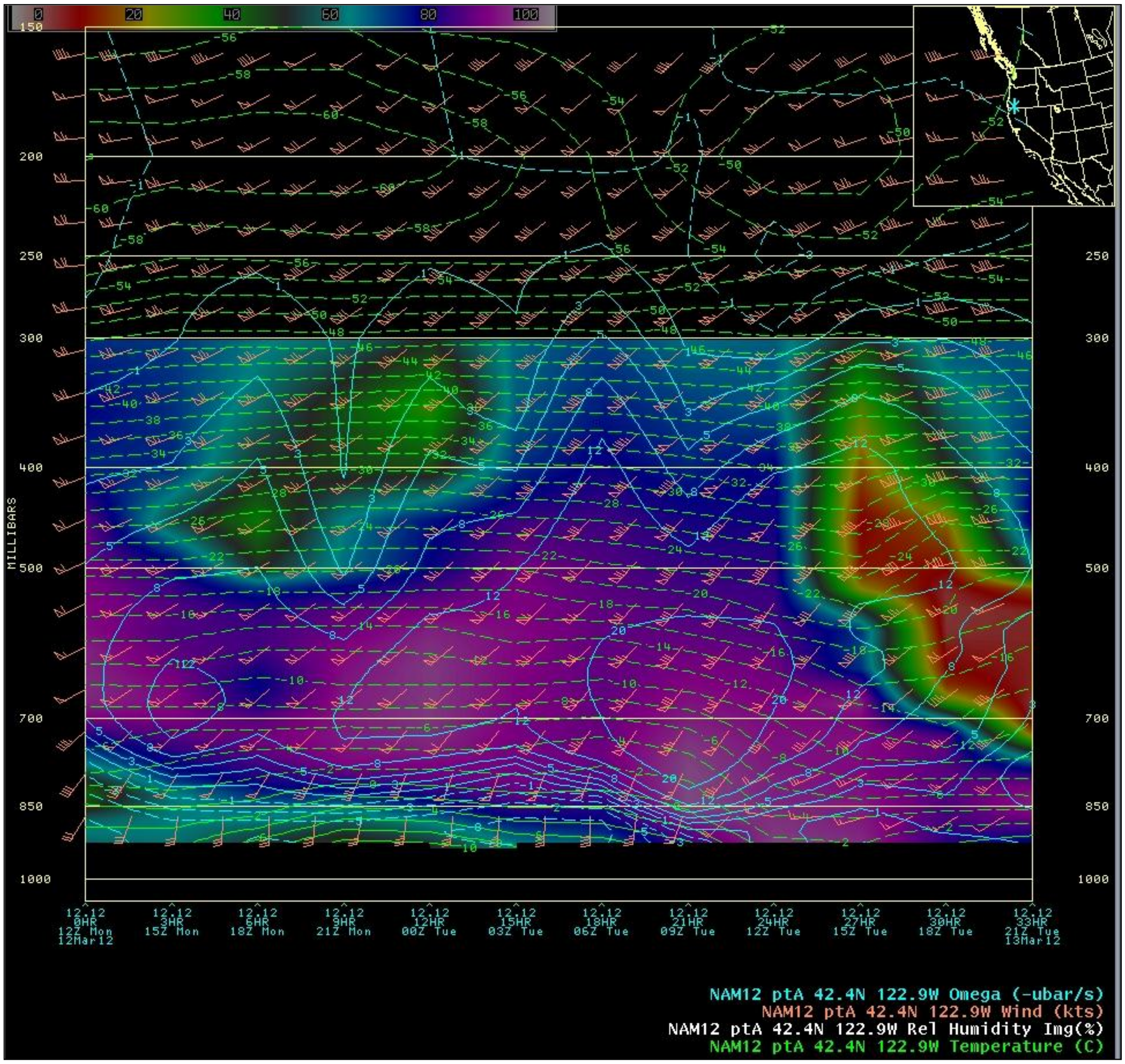


**Figure 4. NAM12 Medford, OR (KMFR) Time-Height Cross-section with Omega (µb/s), Wind, Relative Humidity, and Temperature.**

One aspect of this cross-section that really stands out is the bulls-eye of 20 µb/s UVVs centered at 09Z. This verified nicely, with heavy rain reported at KMFR at 0844Z. Similar to the coastal cross-section, a good portion of strongest UVVs lay inside the dendritic growth zone of -12C to -18C. The cross-section was key to highlighting the period of heaviest precipitation and the potential for enhanced snowfall. The observed and 24-hour model forecast soundings for Medford, OR valid at 12Z on March 13th are shown in figure 5:

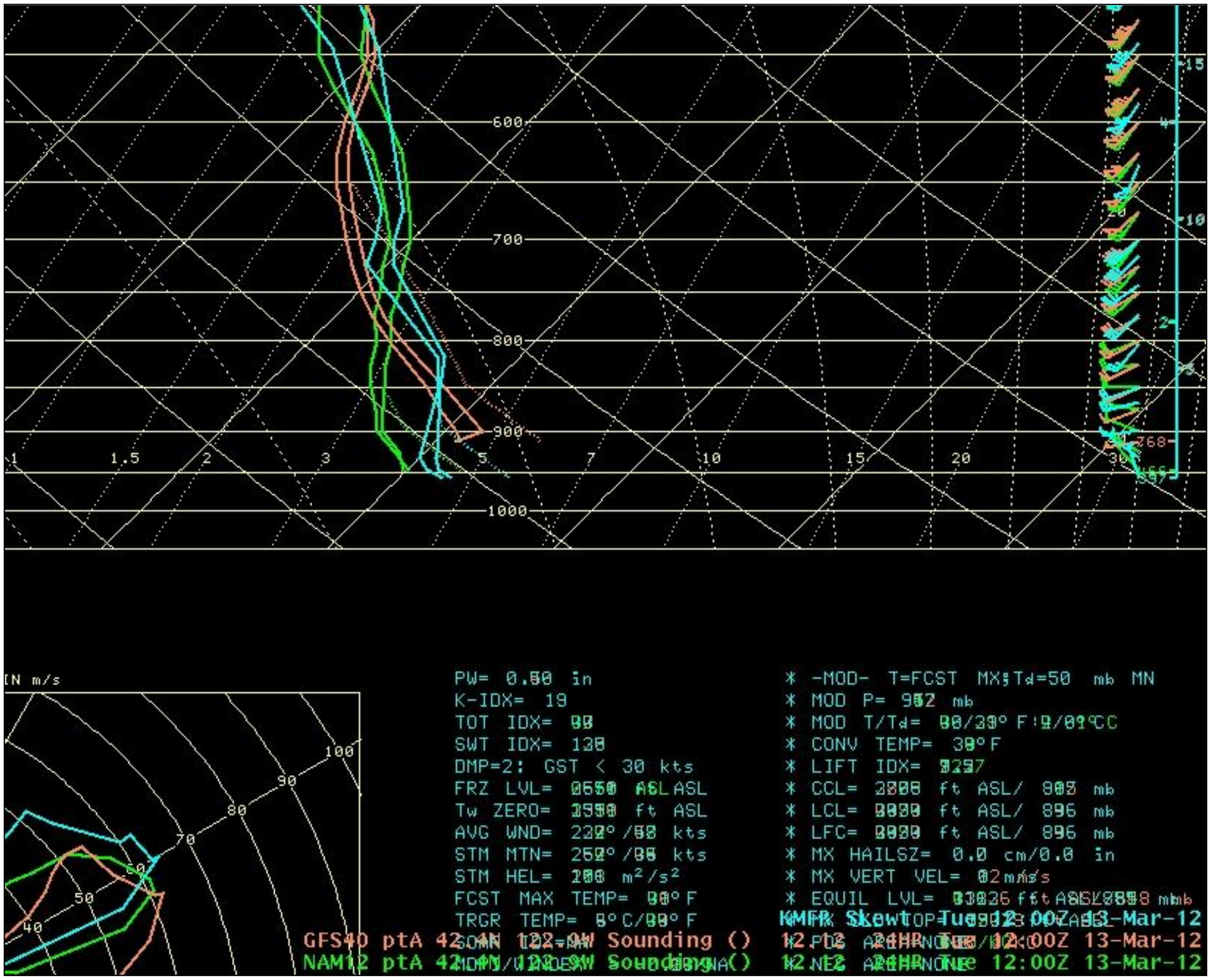


**Figure 5. NAM12 (Green) and GFS40 (Orange) Model Soundings and Observed Sounding (Blue) for Medford, OR (MFR) Valid 20120313/1200Z.**

On this image, the observed MFR 12Z sounding, which coincided with a brief period of light snow at MFR and heavier snow in the nearby higher elevations, is shown along with the GFS and NAM 24-hour forecast soundings valid at 12Z. The NAM12 forecast sounding was the coldest and suggested snow down to the valley floor. This, if supported by other data, should warrant a winter weather advisory issuance despite being climatologically unlikely. One can infer, despite the elevation difference of the GFS sounding, that the actual sounding verified in between the two forecasts in the lowest levels.

According to a local study (*Gettman*) correlating thickness values, 850mb temperatures, and observed weather at Medford, the 850mb temperature of -2C that was observed the morning of the 13th is warmer than the normal values that support Rogue Valley snowfall. However, given the favorable UVVs and precipitation rates, entrainment of cold air aloft resulted in snow levels that were well below what was expected. It's likely that the significant precipitation rates and dynamic cooling resulted in smaller scale processes that the model did not resolve.

# Part 2 - Working the Event

As the evening shift arrived, it was clear that a snow event was forecast to occur across Southwest Oregon and Northern California. Initially, the primary concerns were to develop and maintain situational awareness and attempt to improve the forecast if possible. The purpose in Part 2 is to show how the event unfolded in real time, what actually caused the unusually heavy snow, and what could have been done better.

Snow along the south Oregon coast is climatologically very unlikely. The models did a fairly good job at indicating the potential for significant snow at low elevations, and previous shifts issued a myriad of winter weather headlines. This certainly heightened the awareness of subsequent shifts, but moreover, situational awareness proved to be a very important factor – perhaps *the* factor – in overcoming the climatological bias against coastal snow and deciding to issue additional products and upgrades to existing products. Figure 6 is an IR satellite overlaid with surface observations from 23Z on March 12th:

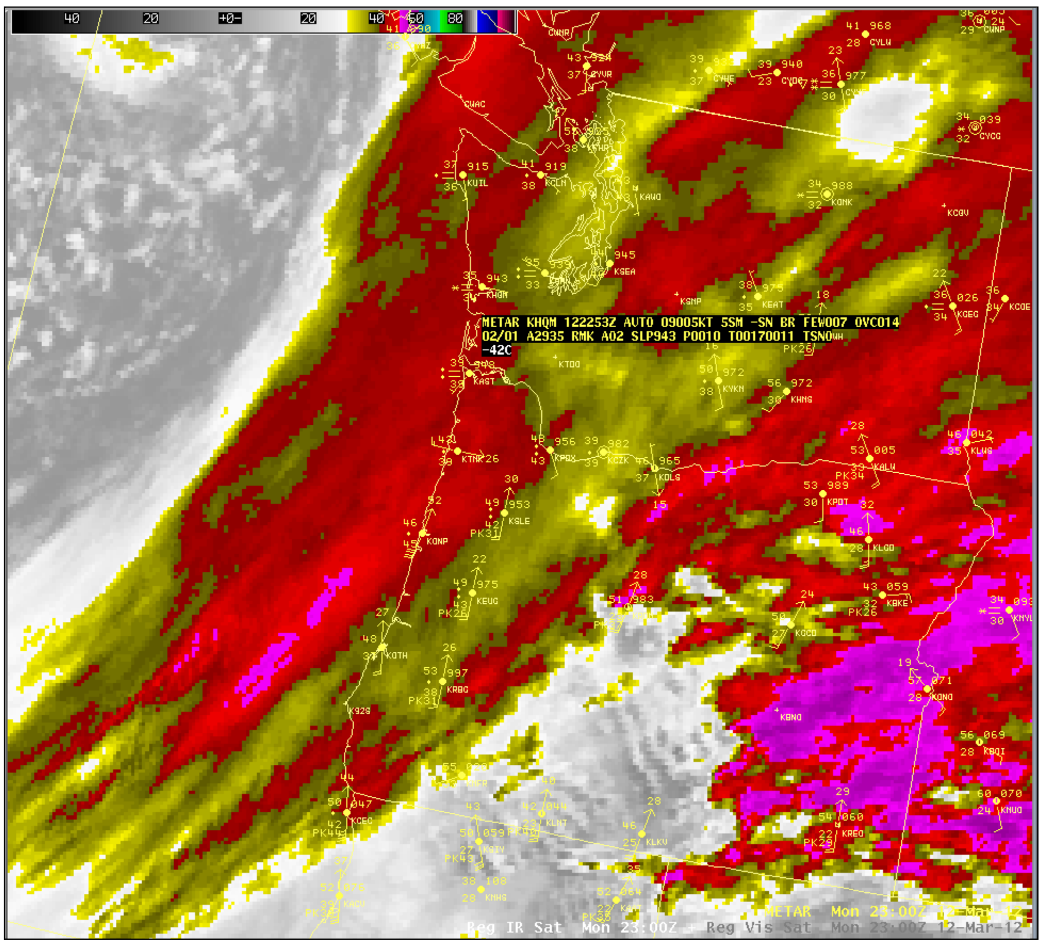


**Figure 6. Infrared Satellite image and METARs, valid 20120312/2300Z.**

There are a number of things to note on this image. First are the waves along the back (western) edge of the coldest cloud tops. A number of these waves could be seen riding along this back edge throughout the day, which seemed to be slowing the progression of the entire system. Second is that the rain had changed to snow at Hoquiam, WA (KHQM) just as a wave passed. Snow is also climatologically rare at KHQM, and this lent credence to the NAM12 forecast of snow further south as well. Also of note is that the cool low level air had started to move onto the north Oregon coast, well in advance of the back edge of the coldest cloud tops. Lastly, one can see in the image a brightening of the cloud tops extending southwest from Newport, OR (KONP). This region was undergoing frontogenesis, as will be discussed.

As in earlier runs, the 00Z NAM from the 13th continued to show the potential for snow down to the coast. The 00Z runs of the GFS and RUC also remained consistent in their solutions - showing it remaining too warm for snow at the coast. Of course, the big question was: which one was right? In assessing model initialization, the 00Z run was compared with surface observations in figure 7:

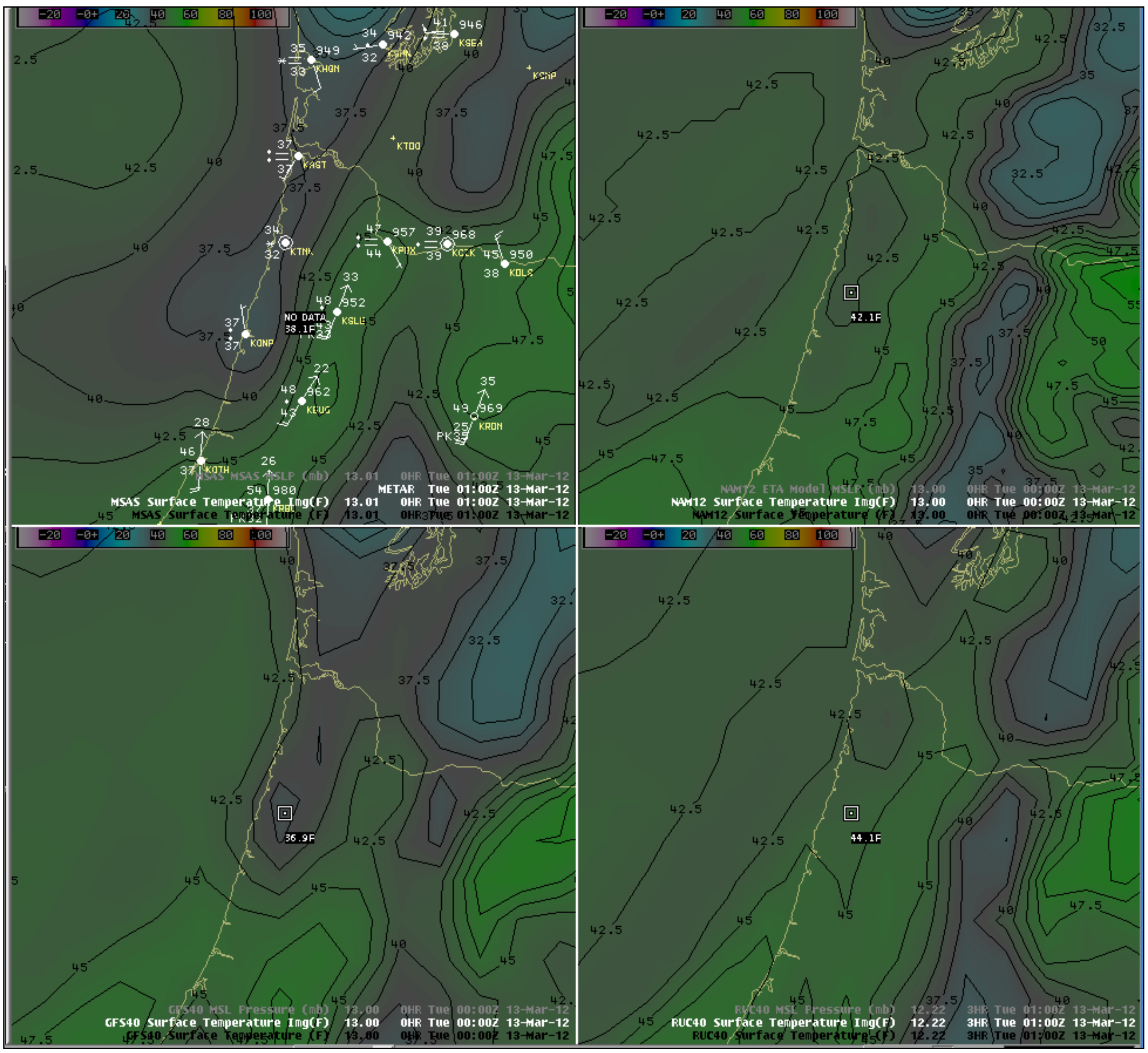


**Figure 7. 13/01Z observations and MSAS surface T analysis (top left), 13/00Z NAM12 surface T initialization (top right), 13/00Z GFS40 surface T initialization (bottom left), 12/22Z RUC40 surface T initialization (bottom right).**

Compared to surface observations, the NAM12 actually had one of the warmer initializations, whereas the GFS was much closer to reality in bringing the cool air down the coast into northwest Oregon. Another ominous sign in figure 7 is that rain had changed to snow at Tillamook (KTMK) as of 01Z on March 13th.

The only model which showed KOTH cold enough for snow by 06Z on the 13th was the NAM. The others showed the cold air coming, but as usual, only after much of the precip had already fallen. At this point, there was still much uncertainty. However, despite its poorer initialization, the NAM12 surface temperature forecast for 06Z on the 13th (Fig. 7) was the only one that seemed reasonable given the current conditions and the likelihood of the cold air surging down the coast. The 3-hour NAM QPF forecast ending 06Z March 13th was particularly disturbing because these amounts translated in snowfall would be highly significant for the coast (Image in Fig. 8):

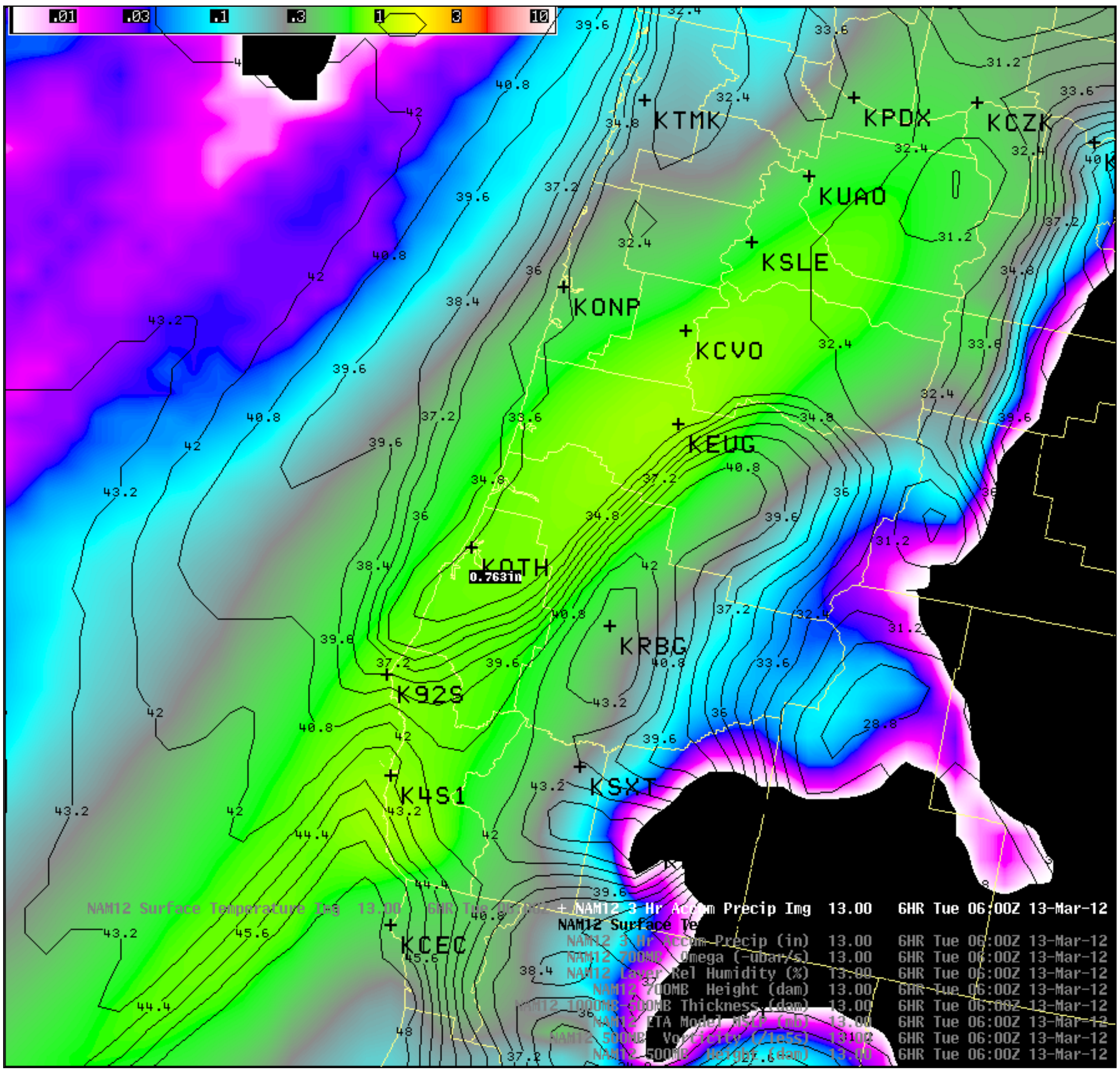


**Figure 8. NAM12 3 hour QPF (image) and surface temperature forecast (black lines), valid 13/06Z.**

Of course, the ¾ inch QPF forecast at KOTH wasn't likely to be all snow, but even half of that in the form of snow would have been expected to cause major problems. The following cross-section normal to the central Oregon coast from the 00Z NAM on the 13th shows what was going on within the front as it neared the coast:

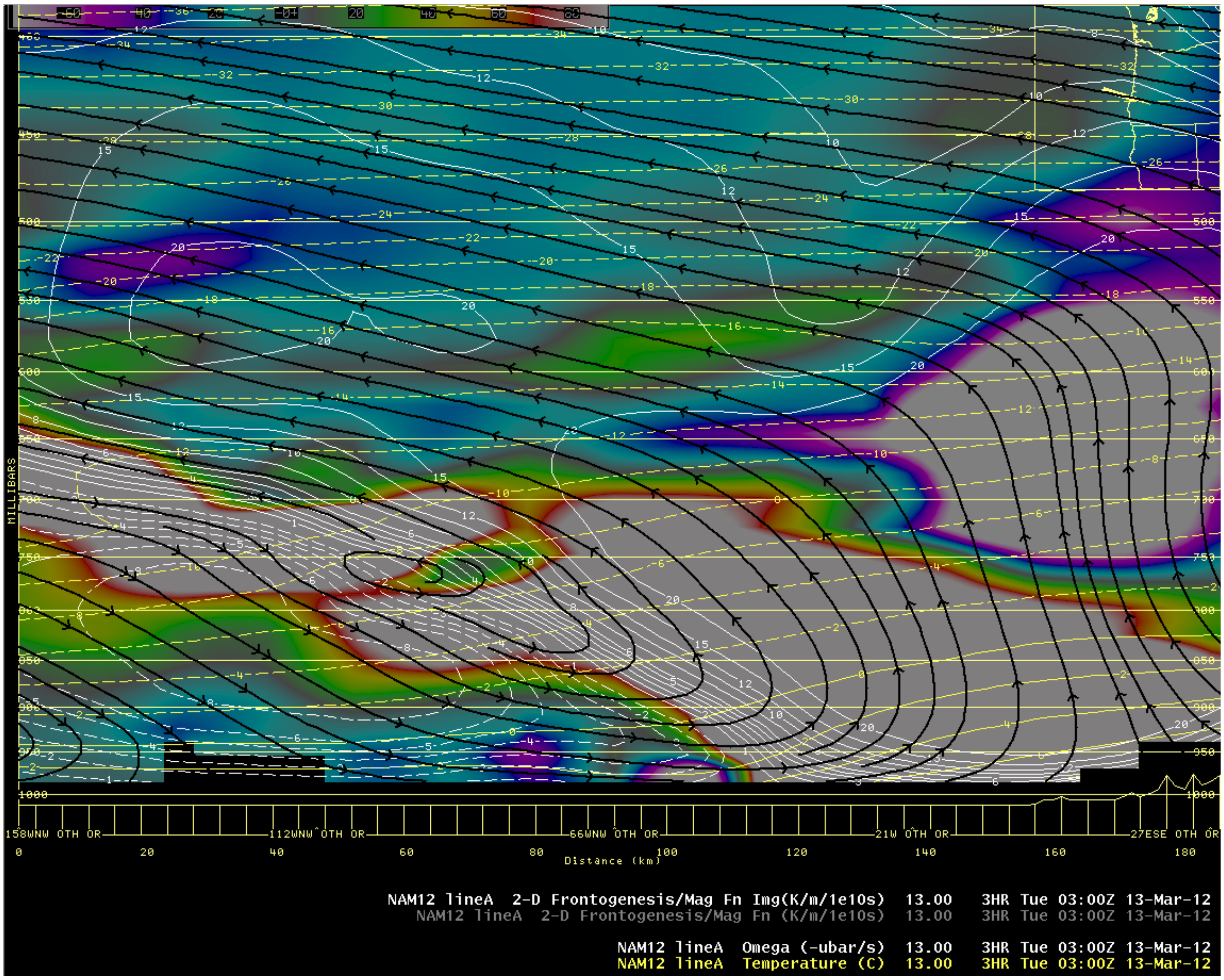


**Figure 9. NAM12 cross-section of 2-D frontogenesis (image), omega (white lines), and ageostrophic circulation streamlines (black lines), valid 20120313/03Z.**

Very strong, deep frontogenesis was evident along the cold front as it approached the coast. Strong downward motion is seen behind the front with a large area of strong upward motion and omegas of 20µb/s extending inland. Large values of 2-D frontogenesis (indicated in the red to pink portion of the image in figure 9) clearly indicated the front was strengthening which lead to a strong ageostrophic circulation and enhanced vertical motion along and ahead of the front at the Oregon coast. The impressive dynamics associated with this front along with cold air entrainment via heavy precipitation processes were believed to be driving the snow level to the surface along the coast.

The forecaster continued to monitor the situation, but as cold air continued to advance down the coast with rain changing to snow at each coastal station, it became obvious that the NAM was correct. By mid-evening, live webcams showed snow accumulating on the beaches and on the dock at the Hatfield Marine

Science Center in Newport, OR.  At this time (approximately 0430Z), the decision was made to issue a winter weather advisory for snow down to sea level of Coos County, and also to lower the rest of the advisories and warnings across Southwest Oregon to the valley floors.

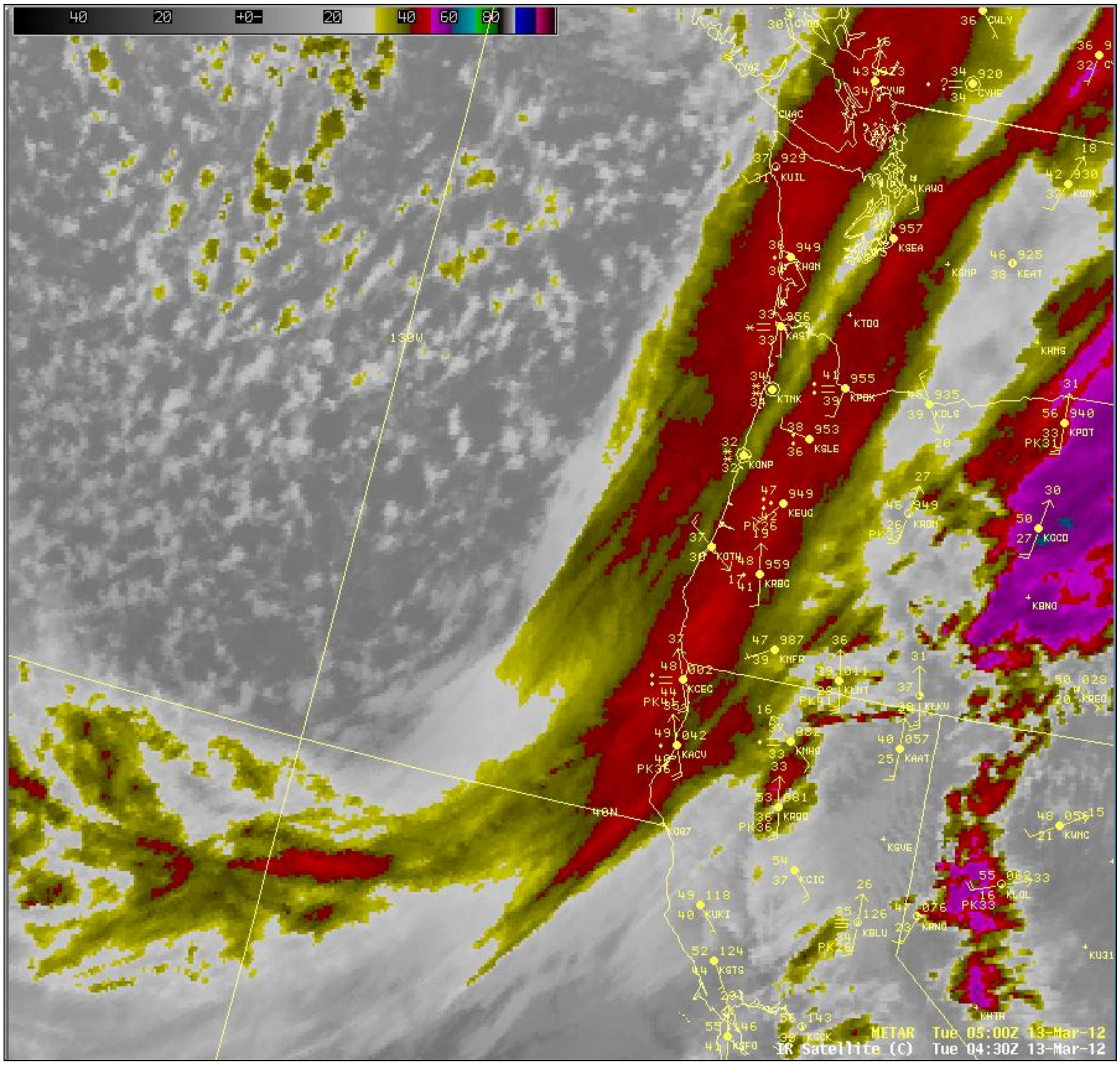


**Figure 10. Infrared Satellite image and surface observations, valid 20120313/04Z and 20120313/05Z, respectively.**

By 05Z on the 13th (Fig. 10), the wind shifted at North Bend, OR (KOTH), cold air poured in, and rain began to mix with snow (note that KOTH only reports weather in remarks so it doesn't plot in AWIPS). The forecast was then updated and a new winter weather advisory was issued which was intended to cover all of Coos County to sea level.

Shortly after the product was issued, snow began falling heavily all along the Coos County coast.  It snowed heavily for several hours until the back edge of the cold cloud tops arrived and turned the snow to back to mixed rain and snow showers.

*- Lessons Learned –*

## Emphasize the IDSS

A couple of items were addressed in the gridded forecast update process whereby an inadvertent elevation qualifier was assigned to Coos County. During the quickly unfolding scenario, the evening forecaster was also challenged in producing representative QPF, snow, and snow level grids. Lastly, uncertainties were high throughout. In light of these operational challenges, it became apparent that forecasters need to consider opportunities, even during short term updates, to shift the focus to the most effective Impact-based Decision Support Services. Forecasters will often be faced with uncertainties that can be communicated through multiple avenues. In the process, though always emphasizing high quality grids and products, forecasters may increasingly need to consider approaches such as email messages and phone calls to customer groups who could receive the highest impacts. Social media continues to emerge as an effective channel for this information as well as Facebook, Twitter, and NWSChat.

## Make Room in Conceptual Model for Anomalies

Forecaster experience shapes expectations during a weather event. Recent weather events or a forecaster's collective experience can drive how a forecaster conceptually models a particular weather event. Categorizing storms helps focus energy and time on certain aspects and impacts of a storm. However, if these models are too rigid, observations and model data can be overlooked or not addressed appropriately. Ample forecast discussion, openly reassessing the conceptual model during shift, and being open to rare events are ways to create a flexible outlook for a particular storm.

## Consider Precipitation Rate and Frontogenesis Influence on Snow Levels

High precipitation rates can entrain cold air, bringing snow levels below what are expected. This occurs frequently on the tail end of frontal systems in the vicinity of Siskiyou Summit. Time-height cross-sections with temperature, relative humidity, and UVV are important tools in identifying high precipitation rate potential and dendritic growth potential. Experience and this case in particular, show that 20μb/s is a significant value for upward motion. In addition, strong frontogenesis should be monitored in tightening baroclinic zones approaching the coast as these can lead to enhanced vertical motions through ageostrophic circulations.

## Focus on Short, High-Impact Periods of the Forecast

During a busy weather pattern, dedicating a significant amount of energy to the highest impact portion of the forecast is a good practice for the lead forecaster. It's important for the lead to delegate some lower impact portions of the forecast, freeing up time for the lead forecaster or multiple forecasters on duty to identify and address the high-impact time frames and areas in the forecast. *A video that highlights this lesson learned can be found here.*

## Advisories Can Be a Good Product if Unsure of Potential Impact

In addition to the IDSS methodologies discussed, when there is high uncertainty in the forecast, or a small potential for an anomalous event, an advisory can also be a good option. It alerts the public to potentially significant weather without carrying the weight or confidence level of a warning.

## Consider GOES Sounding Data for Ocean Air Mass Analysis

It's more difficult to gauge the temperature characteristics of an upstream air mass for coastal locations than inland areas. GOES Soundings can help assess an air mass over the ocean, providing another tool to forecast snow levels with an approaching storm system. They are located here.

## All Events are Different

Don't let a previous forecast experiences overshadow current data and possibilities. Always step into the forecasting position with a fresh perspective, drawing from previous forecast experiences but not allowing them to bias the forecast.

## Be Aware of Forecasting Biases

It is natural for forecasters to be biased against climatologically unlikely events. Heavy snow along the Oregon coast is certainly such a phenomenon. Forecasters had to fight against this bias even as events unfolded in real time. The authors do not expect these biases to go away as they are reasonable and probably prevent a lot of false alarms. This simply serves as an example that we need to be aware of them.

## Situational Awareness

This is a great example of the importance of situational awareness. It is believed that situational awareness was the main factor which allowed the evening forecaster to overcome model performance and preexisting biases and issue an advisory for the coast before the snow occurred. Forecasters are frequently faced with poor, inconsistent, or ambiguous model information, and yet, they have to make decisions. Had conditions and trends up the coast not been noticed early in the shift and continuously monitored over subsequent hours, they may not have recognized this event until it was too late.

## GFE Issues

Excessive time was spent tweaking snow levels and QPF in order to get the tool to produce the desired snow grids. In retrospect, the forecaster should have produced the desired snow grid and then backed the other parameters out of it later on. The most important element in this portion of the process was the decision support. The best practice for the future will be to take action to get the word out to the customers in the most effective means possible and worry about producing a corresponding set of grids later. By prioritizing IDSS over the grids, it is estimated that quality decision support information could have been provided up to an hour earlier as the front made its way south along the coast.

## The Models

Sometimes the models can be right, even with poor initializations.  The NAM surface temperature initialization was poor, yet probably due to its advantage with higher resolution, it produced the best forecast just 4-6 hours later.  Despite difficulties at the surface, the NAM forecast model soundings and cross-sections for the subsequent 3 to 9 hour period clearly (and correctly) indicated the potential for heavy snow due to dynamical forcing.