Using Standard Anomaly and Ensemble Data to Support Forecast Confidence of an Extreme Wind Event in the Pacific Northwest on December 14th-15th 2006

Mike Stavish
National Weather Service Medford, Oregon

1. Introduction

The difference of any meteorological variable from its climatological mean is the anomaly. Divide this anomaly value by the standard deviation and you've got a standard or "normalized" anomaly (Hart and Grumm). Model forecast anomalies of this type are provided by NCEP on their website and referred to as "standard anomalies". Forecasters can use this normalized or standard anomaly data to help gauge the magnitude of an advertised weather event with respect to historical occurrence. This paper provides an example of using normalized anomaly and ensemble data to assist in forecasting a strong wind event that occurred across Oregon and Washington and the adjacent coastal waters on December 14th-15th, 2006.

2. Background

The normalized anomaly for a given parameter for any given day is the departure from the climatological mean, divided by the standard deviation from the daily mean. For instance, the mean 500 mb height can be calculated from NCEP reanalysis data for each day of the year for a period of years. This provides a daily mean climatology, and the difference of any 500 mb daily height field from this mean is simply the anomaly. The standard deviation value for each day can then be computed, which is a measure of the spread of the heights through the climatology period. To calculate a standard deviation (σ) for 500 mb heights, NCEP utilizes the following equation:

$$\sigma = \sqrt{\text{(the average of heights}^2\text{) - (average height)}^2}$$

Dividing the daily anomaly by the standard deviation (σ) provides the "normalized" or "standard" anomaly, or simply the number of standard deviations:

$$\text{Total Standard Deviations} = \text{(forecast height - average height)} \div \sigma$$

A 500 mb height normalized anomaly value of -3 would be 3 standard deviations below normal for the given location and day, which should imply a significant but not extreme departure from normal. (Hart and Grumm) NCEP literature indicates a value of more than 3 is suggesting of a significant or record breaking event. As the normalized anomaly approaches 5, event occurrence escalates to extreme. Notice in the following table how the probability of any event decreases as the number of standard deviations increases:

Table 1. Standard Deviation versus Probability of Occurrence Based on Climatology.

# of Standard Deviations	Probability of Occurrence Based on Climatology
1σ	0.6826895
2σ	0.2718076
3σ	0.0428032
4σ	0.0026364
5σ	0.0000628

NCEP

Since the standardized anomalies include effects from latitudinal and seasonal variances, the greatest standard deviations are found over higher latitudes. This means it's "more normal" for larger deviations to occur over the northern latitudes versus the mid and lower latitudes. (NCEP)

Current operational and ensemble model solutions are compared to climatological means, and normalized (standard) anomalies are calculated and provided on the NCEP web site. Forecasters can make use of this data, which includes anomalies of several different fields, to quickly gauge the rarity of model-advertised events; however, caution should be used since the data provided assumes a "perfect prog" model solution. Using ensemble spread is a good way to assess the likelihood that a given model solution will occur.

3. Forecast Standard Anomalies of the 850 Mb Jet for the December 14^{th}-15^{th} Event

Available from the Hydrometeorological Prediction Center website at NCEP are standard anomalies for several fields from the operational runs of the GFS, NAM, SREF, CMC, UKMET, and ECMWF. As of this writing the site is not operational, but NCEP claims that intentions are to get the package supported operationally on the NCEP compute farm in the near future. The following data was gathered prior to the onset of the December 14^{th}-15^{th} Pacific Northwest wind storm. For our purposes, it is implied that the 850 low level jet correlates effectively to low level pressure gradient near the strong surface low advertised off the Washington coast.

a. GFS Standard Anomaly. Figure 1 below is the standard anomaly of the GFS 36-hour forecast 850 mb jet valid 00Z Friday December 15th, 2006 (zoomed on the right). Note the forecast standard anomaly for the Oregon coast exceeds 6.5 on the anomaly scale, which indicates potential for a rare and extreme wind event. Notice also that a large portion of western Oregon and Washington show values exceeding 3 (green shading), which should imply where the event is forecast to become significant. Confidence here should be assessed through an analysis of the ensemble spread.

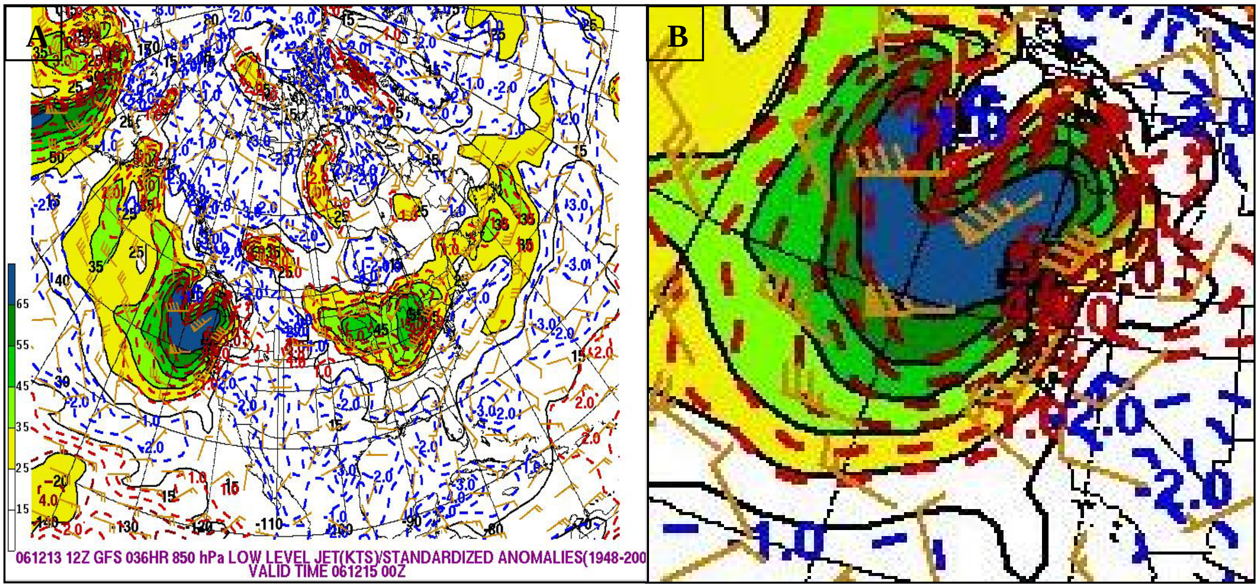

Figure 1. GFS initialization 12Z 13 Dec 2006. A. 36-hr 850 hPa Low Level Jet (kts; brown) and standardized anomalies (1948-2005; contoured 1.5, 2.5, 3.5, 4.5, 5.5, and 6.5; black and shaded) valid 00Z 15 Dec 2006. B. As in A, but zoomed into the West.

b. SREF Mean Standard Anomaly. From the same web site as above, Figure 2 below is the SREF 39-hour mean 850 mb jet standard anomaly valid also 00Z Friday December 15th, 2006. The SREF mean is fairly consistent with the GFS, showing extreme wind potential for portions of western Oregon and Washington, though with a slightly smaller area of extreme winds. Due to the higher skill of the ensemble mean, in addition to the agreement with the GFS, this should elicit higher confidence in the magnitude of the event.

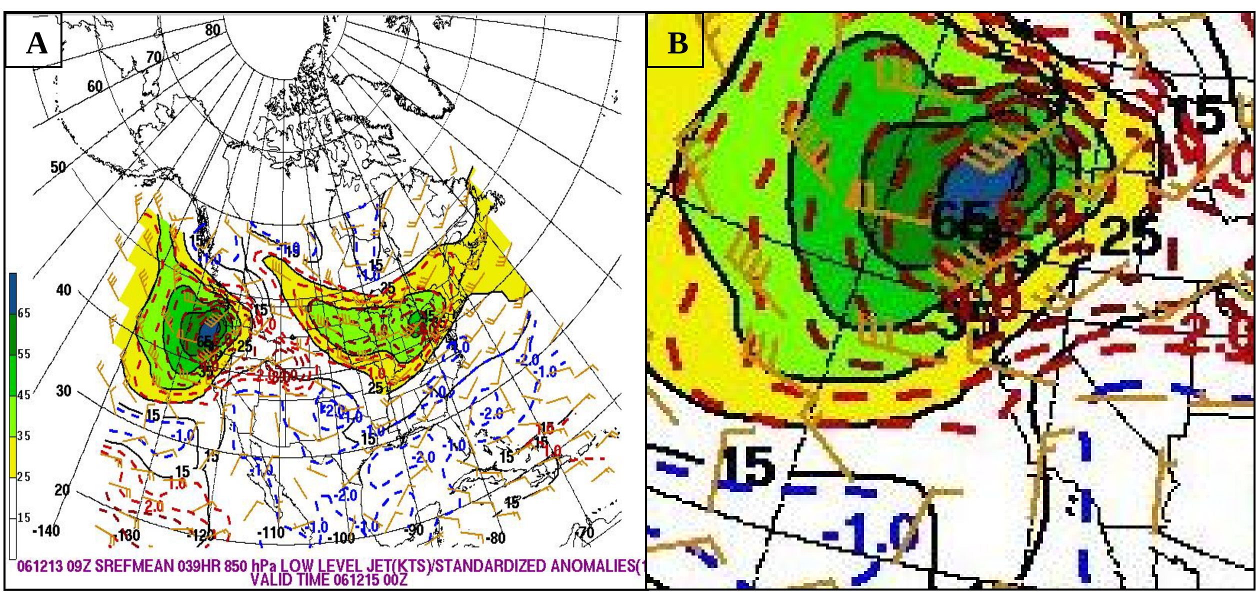

Figure 2. As in Figure 1, but with SREF Initialization valid 13 Dec 2006, 39-hr forecast.

4. Investigating Spread

The forecast anomaly data should be used in conjunction with a method to assess confidence in the forecast data used to create the anomalies. Ensemble spread is a measure of the differences between the members in the ensemble forecast and can be used for this purpose. There are a couple of different sources for retrieving ensemble spread.

a. GFS Ensemble Mean and Normalized Spread. Taken from the NCEP Ensemble Home Page, figure 3 below shows the 36-hour forecast of the GFS ensemble mean MSLP and spread valid 00Z Friday December 15th, 2006. The spread indicates ensemble variance ranging from only 2 to 4 mb within the coastal gradient south of the low, while the mean MSLP forecast indicates 20 mb of gradient along the Washington and Oregon coasts. The ensemble forecast here should provide increased confidence in the standard anomaly forecast of the GFS in figure 1.

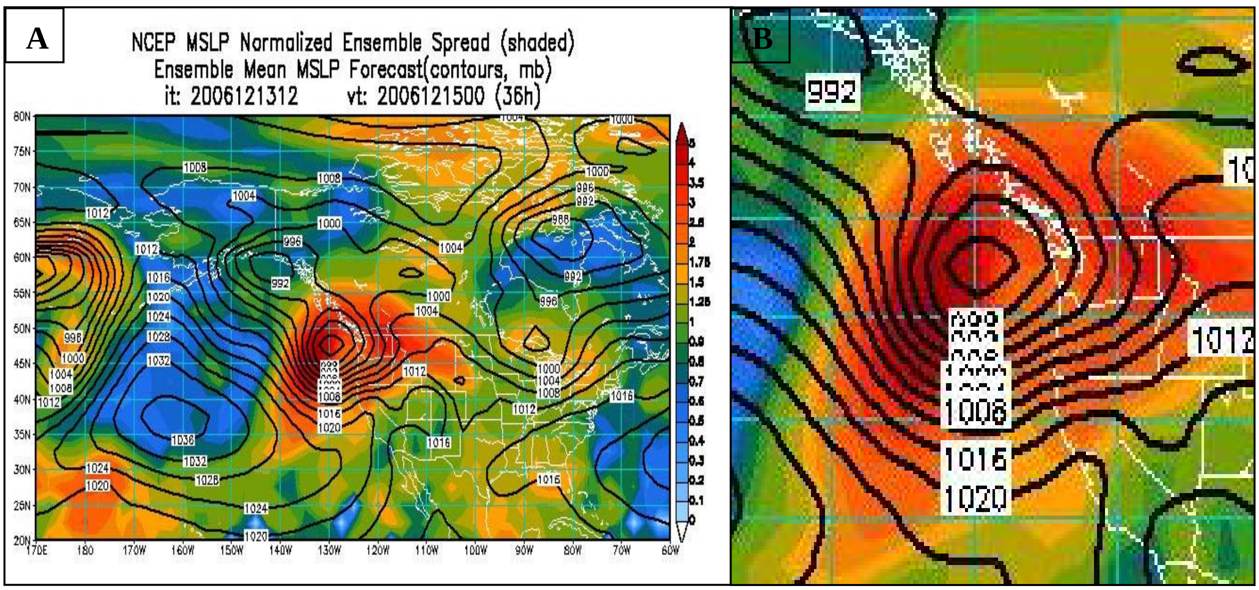

Figure 3. GFS Ensemble initialization 12Z Dec 13 2006. A. 36-hour forecast GFS MSLP Normalized Spread (shaded, mb) and GFS Ensemble Mean MSLP (contoured mb, black) valid 00 UTC 12/15/2006. B. As in A, but zoomed into the west.

b. SREF Mean and Spread. From the NCEP Central Operations Model Analysis and Forecasts Page, one can view the SREF forecasts with spread. Figure 4 below is the SREF 33-hour forecast MSLP and spread valid 00Z Friday December 15th, 2006. Note the SREF mean was fairly consistent with the GFS ensemble mean in forecasting a 980 mb low, with a spread of 2.5 to 4.5 mb within a gradient of 24 mb along the Washington and Oregon coast. Other sources for SREF data are the Mesoscale Modeling Branch of NCEP's Environmental Modeling Center, or the Ensemble Page from Penn State's Meteorology Department.

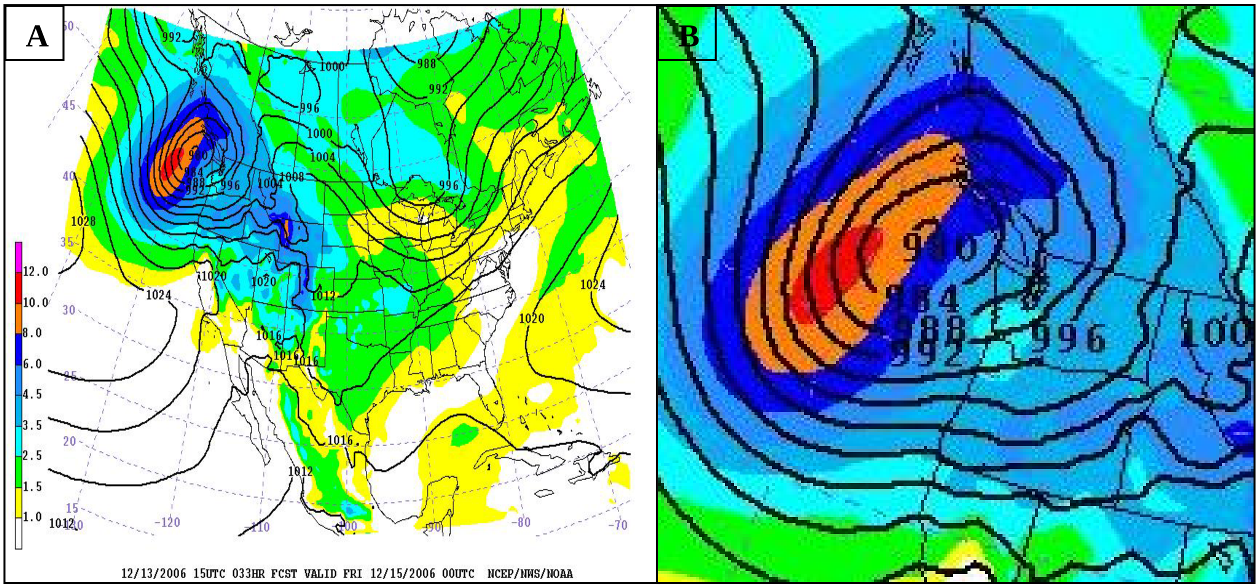

Figure 4. SREF Initialization 15Z Dec 13 2006. A. 33-hour SREF MSLP (contoured mb, black) and Spread (percent, shaded) valid 00 UTC 12/15/2006. B. As in A, but zoomed into the Northwest.

5. What Happened?

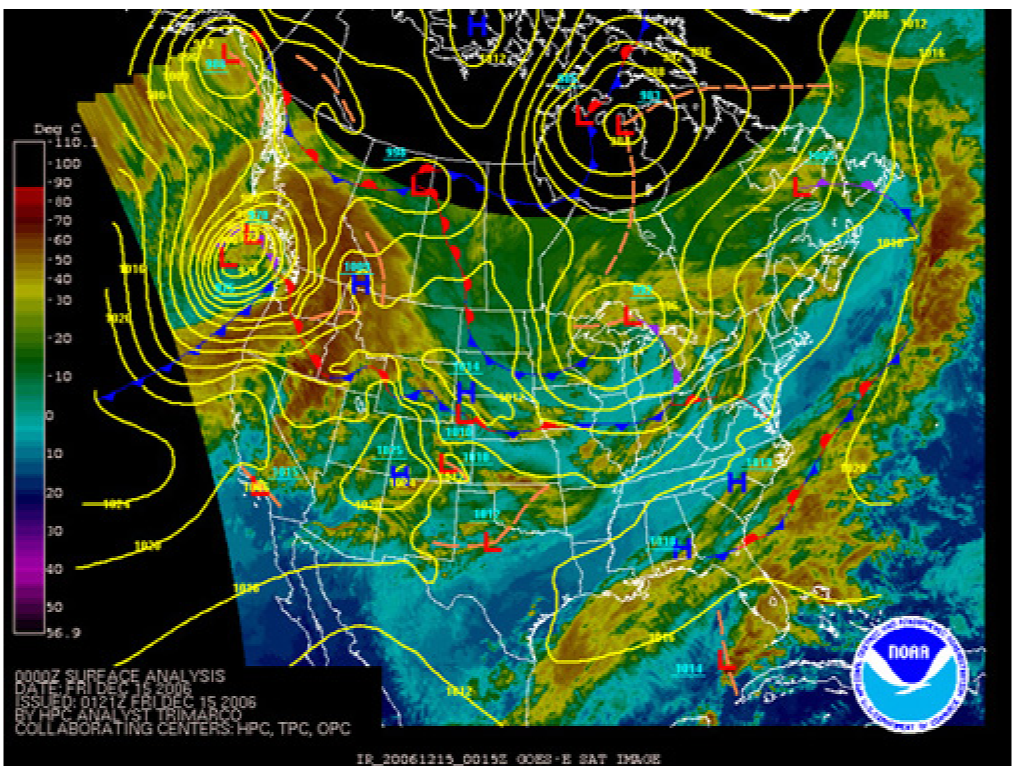

Figure 5. NOAA surface analysis valid 00Z Dec 15 2006.

Figure 5 shows the HPC analysis valid 00Z Friday December 15. This graphic illustrates a 976 mb low off the Washington coast and 24 mb of gradient along the Washington and Oregon coasts – fairly consistent with the GFS and SREF ensemble forecasts. The storm produced extreme wind damage throughout western portions of Oregon and Washington beginning early Thursday afternoon and continuing into early Friday. Gusts of 60-80 mph were fairly common across west-central and northwest Oregon and across much of western Washington. The strongest gust reports ranged from 90 mph to 115 mph across the north Oregon and Washington coasts and Cascades. The greatest damage came from downed trees and powers lines, which also caused several fires. Heavy rain accompanied the storm with flooding resulting in some areas. The saturated soil was likely a factor in the excessive number of downed trees.

Due to countless trees down, estimates were that 1.5 million people lost power. A state of emergency was declared for several Washington counties. Numerous storm-related deaths were also reported with causes including being crushed by falling trees, drowning, electrocution, and carbon monoxide poisoning. It was quite cold in the wake of the storm and some residents without power resorted to using portable propane heaters and gas grills indoors. Lack of appropriate ventilation led to asphyxiation. A detailed summary of the storm impacts in Washington can be found courtesy of Historylink.org.

6. Conclusion

Using standard anomalies allows one to place a weather event in perspective with regard to its climatological occurrence. Large magnitudes of standard anomalies indicate the potential for a weather event of historic proportion. Since the anomalies are computed from forecast model data, SREF and GFS Ensemble data should be examined to assess the confidence one can have in the occurrence of the event as forecast.

In this case, the forecast standard anomaly of the low level jet from both the SREF and the GFS exceeded 6.5, indicating a very low probability strong wind event. However, the standardized anomalies were assessed through investigation of the SREF and GFS ensemble mean and spread forecasts. Due to spreads of only 2 to 4 mb within a gradient of 20 to 24 mb along the coast, in addition to consistency among the models, it was reasonable to have had above average confidence in forecasting an extreme wind event across portions of western Oregon and Washington.

Another important application in the use of standard anomaly data is the wording of public watches, warnings, and advisories. The forecast staff should utilize effective and innovative communication of the events magnitude and rarity. In the developing age of NWS operations, the high impact weather events need to be effectively communicated to our customers.

An example of this is going beyond what may sound like the “normal scope” of written word in our watch/warning products and statements. This includes using creative and emphatic wording in calls-to-action to identify rare and high-impact events. Also, forecasters should be triggered to “above and beyond the call of duty” actions, such as volunteering for overtime efforts, preparing for potential backup, and utilizing extra personnel in operations. Other things to consider are placing extra effort in communicating the forecast to our stakeholders, including emergency management, and enhancing internal collaboration with neighboring offices and regional and national centers.

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