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THE USE OF ANALOG GUIDANCE IN FORECASTING SOUTHERN PLAINS WILDFIRE OUTBREAKS

Jeffrey D. Vitale* and T. Todd Lindley
NOAA/National Weather Service Lubbock, Texas

Chad M. Gravelle and Charles E. Graves
Saint Louis University, St. Louis, Missouri

1. INTRODUCTION

Wind-driven grass fires and regional outbreaks of destructive Southern Plains wildfires have increased in frequency across New Mexico, Texas, and Oklahoma since 2005 (Lindley et al. 2011a and Lindley et al. 2011b). During recent years, many Southern Plains wildfires have become extremely large and destructive and have taken lives, destroyed property and devastated millions of acres (Storm Data 2005-2010). Thus, fire weather research and the development of new prediction methods for extreme wildland fire events has become a priority for the meteorological community in the region.

Weather is the most dynamic factor to influence wildland fire behavior (Heilman 1995). Violent Southern Plains wildfire outbreaks have been linked to the passage of mid-latitude cyclones and associated strong mid and upper-tropospheric wind maxima during periods of dry vegetative fuels. Usually, fire outbreaks develop within the passing cyclone's warm and dry sector where deep boundary layer mixing occurs to the west of a surface dryline and south of an advancing cold front extending from a deepening surface low over Kansas (Lindley et al. 2007). Understanding how to better forecast fire weather conditions would be greatly beneficial for fire meteorologists and fire managers due to the influence of weather on wildland fire behavior.

Meteorological analogs have been shown to provide useful operational forecast guidance in identifying historically similar events (Gravelle et al. 2009). The purpose of historical analogs is to provide forecast guidance for several types of hazardous weather such as winter precipitation, severe local storms, and anomalous temperatures. Historical analogs, like composite maps, can educate operational forecasters on favorable meteorological patterns associated with specific types of weather. Thus, forecasters can gain valuable insight towards pattern recognition with the use of historical analog guidance.

Analog guidance produced by Saint Louis University's (SLU) Cooperative Institute for Precipitation Systems (CIPS) (http://www.eas.slu.edu/CIPS/ANALOG/COLD/analog.php) allowed fire meteorologists in west Texas to communicate risks and convey potential impacts to decision makers and fire analysts by referencing past fire events during the historic 2011 Texas fire season. The Southern Plains wildfire composite chart (Fig. 1), a valuable tool used in pattern recognition forecasts for extreme fire episodes in the region, is derived from synoptic-scale analyses of ten wildfire outbreaks from 2005-2009. The CIPS analog guidance quantitatively identified the dates of past southern plains wildfire outbreaks used in the development of this conceptual model prior to destructive wildfire outbreaks on 27 February, 22 March, and 3 April 2011. Similarities were statistically determined between numerical weather prediction (NWP) output and North American Regional Reanalysis (NARR; Mesinger et al. 2006) data for multiple dates which comprise the 2005-2009 outbreak dataset. This output from the CIPS analog guidance led to increased confidence for operational fire meteorologists in their successful predictions and warnings prior to these rare and destructive wildfire episodes.

2. METHODOLOGY

The CIPS analog guidance produced by SLU was utilized for this study. The analog system is comprised of the NARR dataset over a 30-year period during the cool season (October-March). The NARR data is analyzed at six-hour intervals, similar to the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS)

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* *Corresponding author address:* Jeffrey D. Vitale, National Weather Service, 2579 S. Loop 289, Suite 100, Lubbock, TX 79423; email: jeffrey.vitale@noaa.gov

model. This gives a potential of approximately 21,800 analogs in the database. Statistical techniques determine analog cases including pattern correlation, mean absolute error, root mean square error, and anomalies. If specific statistical thresholds of selected weather parameters are not exceeded, the date/time is dropped from analog consideration. Each potential analog is scored based on a pattern correlation and mean absolute error calculation. Higher scores indicate greater confidence in historically similar events. For potential analogs the system determined to be statistically significant, standard weather forecast charts, similar to parameters identified in the wildfire composite outbreak, are generated for use in the operational forecast process. Here, forecasters then determined if any of the analog dates matched dates (±1 day) of the previous ten 2005-2009 wildfire outbreaks. The use of analog guidance prior to outbreaks on 27 February, 22 March, and 2-3 April 2011 were chosen for this study because the CIPS analog guidance determined previous historic wildfire outbreak days as analogs for these events.

3. CASES

3.1 *27 February 2011*

Portions of eastern New Mexico, West Texas and western Oklahoma experienced high winds, blowing dust with very low visibilities and numerous destructive wildfires on 27 February 2011. This day became one of the largest wildfire outbreak days in Texas state history ranking fourth in area burned relative to previously documented wildfire outbreaks. Several wildfires in particular prompted evacuations of Matador in Motley County, Texas, Canyon in Randall County, Texas and portions of Amarillo in Potter County, Texas. By the end of the day, 39 major wildfires had burned 284,911 acres (115,299 ha), destroyed 210 structures, killed one person with four injured, and caused $17 million in damages.

A strong closed upper-air low pressure system ejected from southern California towards the region beginning early on the 27th. As this upper-air low moved toward the region, it became an open wave trough. The upper-air trough axis remained west of the Southern Plains, generally over New Mexico and Colorado by 2100 UTC, and west of the ideal location per the Southern Plains wildfire outbreak composite. The strongest upper level winds did not move over the region until late in the afternoon hours from 2100 UTC to 0600 UTC. However, the trough was moving rapidly eastward and was accompanied by broad and intense mid-upper tropospheric wind fields. Observed upper-level winds at 300hPa, 500hPa, and 700hPa were between 35% and 50% higher than those depicted in the outbreak composite chart. A dryline rapidly moved through the area from 1600 UTC through 1800 UTC, followed by a Pacific cold front from 1800 UTC through 0000 UTC. Despite the cold front which advected higher surface dew points into the region, relative humidity values dropped into the single digits area wide. These factors combined to result in a dangerous wildfire outbreak.

In the forecast process for this event, analog guidance was first used five days prior to the outbreak. CIPS analog guidance began to identify historic wildfire outbreaks at forecast hour 120. Between forecast hours 72 and 36, an increasing number of historic wildfire outbreak days were determined to be analogs. Additionally, many of these analogs ranked within the top 15 analogs identified. Past Southern Plains wildfire outbreaks identified included 12 March 2006 (8 hits), 1 January 2006 (4 hits), 2 February 2008 (2 hits), and 14 March 2008 (1 hit). The 1200 UTC GFS212 model output at forecast hour 96 on 24 February 2011 (Fig. 2) had the highest analog correlation to past wildfire outbreaks on 12 March 2006 (Fig. 3) and 1 January 2006 (Fig. 4) with total analog scores of 9.680 and 9.331 respectively. Three days before the event, the Area Forecast Discussion (AFD) from the Lubbock, Texas Weather Forecast Office (WFO) stated:

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"ANALOG GUIDANCE INDICATED A FEW HISTORICALLY WINDY DAYS AS HIGH RANKING ANALOGS TO THE CURRENT EVENT."
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The increased confidence gained by forecasters from the analog guidance lead to this statement issued in the Fire Weather Forecast (FWF) from WFO Lubbock, Texas at 2356 UTC 26 February 2011:

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"HIGH WINDS /SUSTAINED SOUTHWEST-WEST 20 FT WINDS 25-35 MPH/ WILL COMBINE WITH VERY DRY AIR /DAYTIME RH 5-15 PERCENT/ AND TEMPERATURES UPWARDS OF 20 DEGREES ABOVE SEASONAL NORM WILL PRESENT A THREAT OF DAMAGING/LIFE THREATENING WILDFIRES SUNDAY AFTERNOON/EVENING."
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Forecaster confidence increased each successive day leading up to the event due to historical wildfire outbreak days continually being determined as analogs. At 1600 UTC on 25 February 2011 the following statement was communicated to the Texas Forest Service (TFS) and other local firefighting agencies:

`"NOW IS THE TIME TO HIT THIS EVENT VERY HARD AS A POTENTIALLY DAMAGING/LIFE THREATENING EVENT. ESPECIALLY GIVEN QUANTITATIVE ANALOG QUIDANCE HITS PREVIOUS HISTORIC WILDFIRE OUTBREAK DATES"`

3.2 *22 March 2011*

A wildfire outbreak impacted west Texas and the Oklahoma Panhandle on 22 March 2011. Twenty major wildfires burned 69,903 acres (28,288 ha), destroyed 10 structures, injured two persons and caused $320,000 in damages.

A large upper-level negatively tilted trough extended from the Great Basin through northern Mexico, with the trough moving over the Southern Plains from about 1800 UTC to 0000 UTC. Similarly to the previous case, upper-level winds were observed to be higher than those depicted in the wildfire outbreak composite. A dryline quickly moved east of the region by 1800 UTC, with afternoon minimum relative humidity values in the single digits. The fire weather pattern parameters were not as pronounced as those seen during the 27 February 2011 event, but were within expected ranges to support a significant wildfire outbreak.

CIPS analog guidance identified five historical wildfire outbreak days as analogs as early as forecast hour 120. Past Southern Plains wildfire outbreaks noted in the analog guidance included 1 January 2006 (10 hits), 27 December 2005 (6 hits), 12 March 2006 (5 hits), 25 February 2008 (2 hits), and 12 January 2006 (2 hits) with scores between 2.840 and 7.075. Most of these scores, however, did not rank in the top 15 analogs. The GFS212 model run at 18 March 2011 1200 UTC (Fig. 5) showed similarities to the 1 January 2006 wildfire outbreak as seen in the previous case (Fig. 4). Three days prior to the event, the AFD from WFO Lubbock, Texas mentioned:

`"ON TUESDAY...THE UPPER WAVE LIFTS NEWD INTO THE CENTRAL PLAINS SENDING THE DRYLINE EAST OF THE AREA AND SETTING THE STAGE FOR CRITICAL FIRE WEATHER CONDITIONS."`

Forecasters recognized that the weather pattern was similar to the wildfire outbreak composite. This increased forecaster confidence led to the following statement one day prior to the event:

`"THE PATTERN DISCUSSED AMOUNTS TO A LOW AMPLITUDE VERSION THE SOUTHERN PLAINS WILDFIRE OUTBREAK COMPOSITE."`

3.3 *3 April 2011*

Another day that proved to be a destructive wildfire outbreak across the Southern Plains was 3 April 2011. Though not as widespread as the previously discussed events, 14 major wildfires burned a total of 25,615 acres (10,366 ha). These fires, however, combined to destroy a total of 351 structures, injured 13 people and caused $3.4 million in damages

A strong but broad mid and upper-air trough moved across the Rockies during the local daytime hours. Even though the trough largely stayed west of the region, a surface low deepened over Kansas and strong mid and upper-level wind fields overspread the region in a manner similar to the Southern Plains wildfire outbreak composite. An extreme wildfire event resulted south of an advancing cold front which moved through the area early on 4 April 2011.

Although all of the analog scores ranked outside the top 15 matches for the event, a total of four past Southern Plains wildfire outbreak dates were noted in the guidance between forecast hours 120 and 48. Historical dates identified included 25 February 2008 (5 hits), 25 February 2008 (3 hits), 1 January 2006 (2 hits), and 12 January 2006 (1 hit) with analog scores that ranged from 4.802 to 7.389. The 25 February 2008 outbreak was most commonly determined to be an analog to 3 April 2011. The GFS212 run from 1 April 2011 0000 UTC (Fig. 6) showed similarities to the 25 February 2008 pattern (Fig. 7). With consistent analog guidance hits for historical Southern Plains wildfire outbreaks, the following statements were including in forecast products from WFO Lubbock prior to the event:

`"THIS PATTERN APPEARS TO PROMOTE STRONG DOWNSLOPE WINDS AND UNUSUALLY WARM/DRY AIR...WHICH MAY SUPPORT A SOLID FIRE WEATHER THREAT."`

"WEATHER CONDITIONS WILL BE SUPPORTIVE OF DANGEROUS WIND-DRIVEN GRASSLAND WILDFIRES."

Additionally, the following information was communicated to the TFS and other local officials at 1700 UTC 1 April 2011:

"SLU ANALOG GUIDANCE IS HITTING UPON WILDFIRE OUTBREAK DAYS IN OUR WILDFIRE OUTBREAK DATABASE FOR THE UPCOMING EVENT. THIS MODEL DATA IS FROM THE 00Z RUN YESTERDAY EVENING AND IS VALID FOR 00Z MONDAY. THE PARTICULAR DAYS IT IS CHOOSING AS ANALOGS *(include)* 25 FEB 2008."

4. SUMMARY

CIPS cool-season analog guidance quantitatively identified three 2011 Southern Plains wildfire outbreaks as analogs to numerous past historic wildfire events. A common theme in all three cases was the fact that analog guidance identified historic wildfire cases 120 hours in advance of each 2011 outbreak. Forecaster confidence in predictions of rare and high-end wildfire episodes was greatly improved due to the analog guidance output. As a result, forecasters were able to convey a high confidence in forecasts and warnings to local and state-level decision makers. Although multiple past Southern Plains wildfire outbreaks were identified by the analog guidance prior to similar fire events in 2011, the eventual occurrence of fires did not correspond geographically to fire during those past events. The use of analog guidance, however, is now known to be advantageous in the forecasting of extreme wildfire episodes in the Southern Plains. Because of this, an automated system at WFO Lubbock checks each analog run to determine if the dates of past historical wildfire outbreaks have been determined to be analogs. Operational forecasters at WFO Lubbock are alerted if a match is made.

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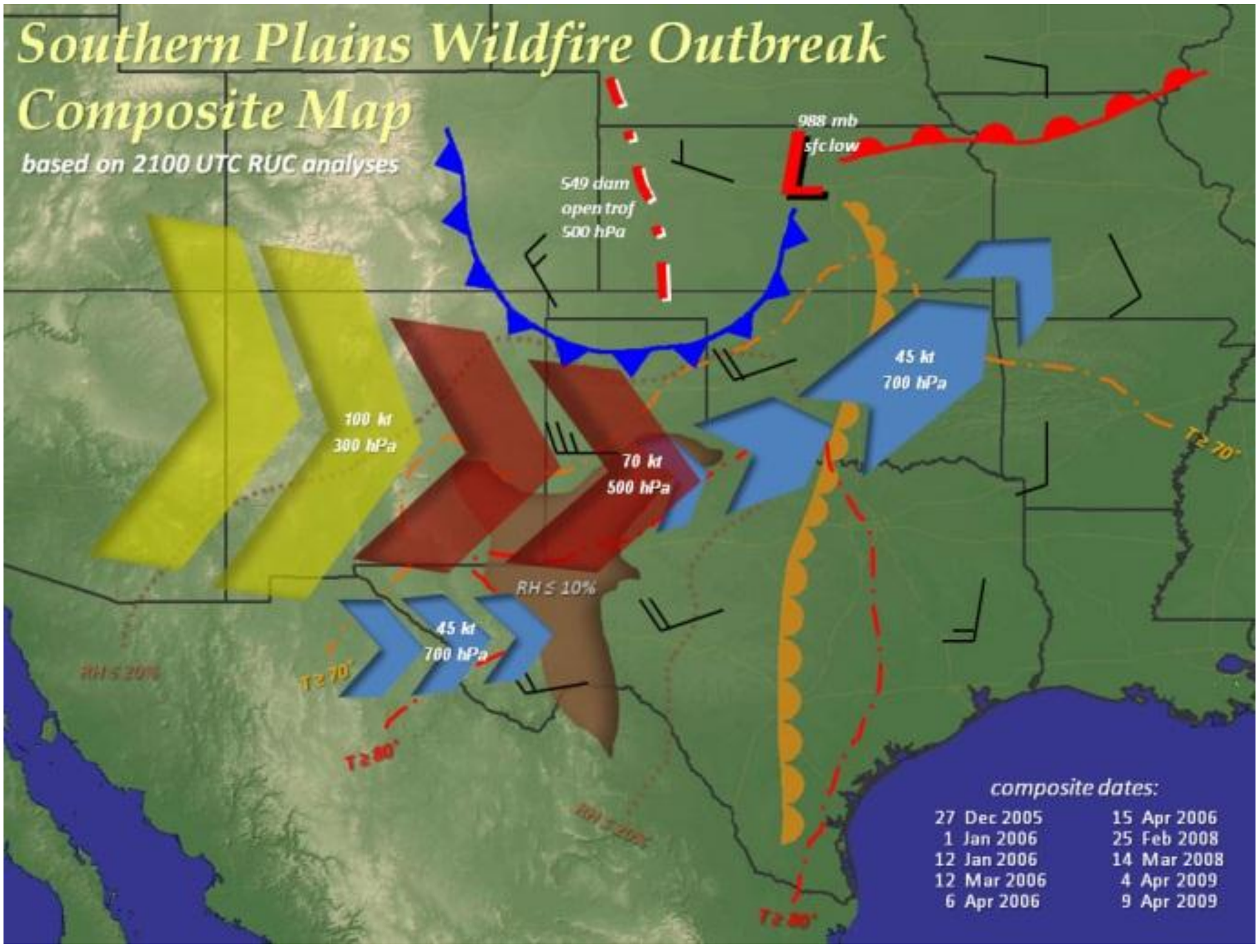

Fig. 1: Composite weather pattern associated with extreme fire events in the Southern Plains (from: http://www.srh.noaa.gov/lub/?n=science-wtefirewx).

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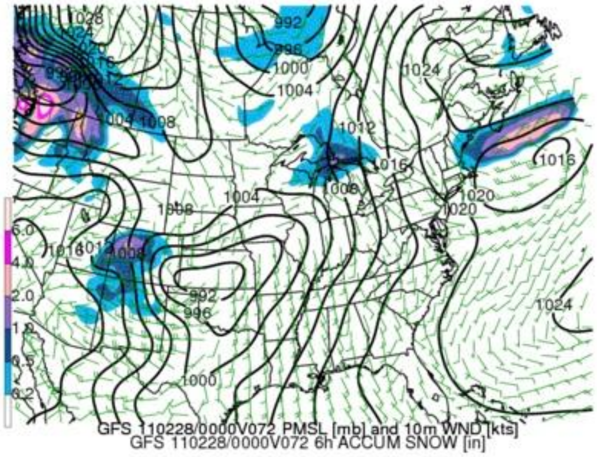

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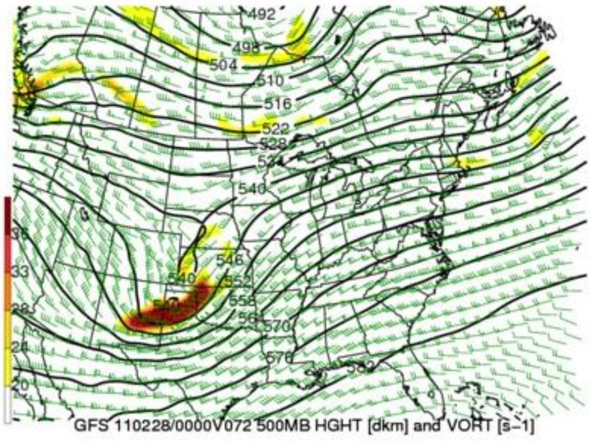
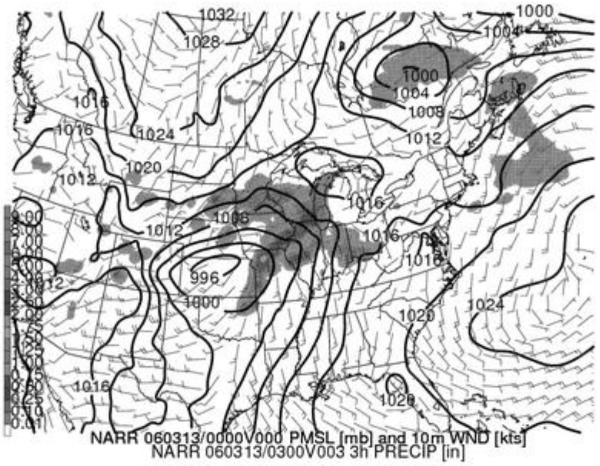


Fig. 2a: GFS212 24 February 2011 F072h MSLP, 10m wind, and 6h snow accumulation.
Fig. 2b: Same as 2a, except for 500 hPa height and vorticity.

A



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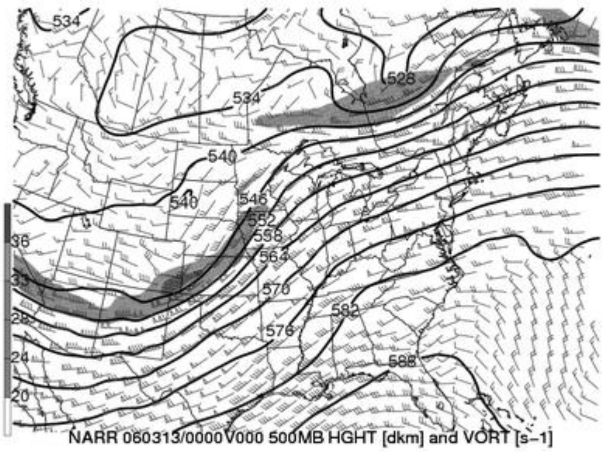

Fig. 3a: NARR 13 March 2006 0000 UTC MSLP, 10m wind, and 3h precipitation accumulation.
Fig. 3b: Same as 3a, except for 500 hPa height and vorticity.

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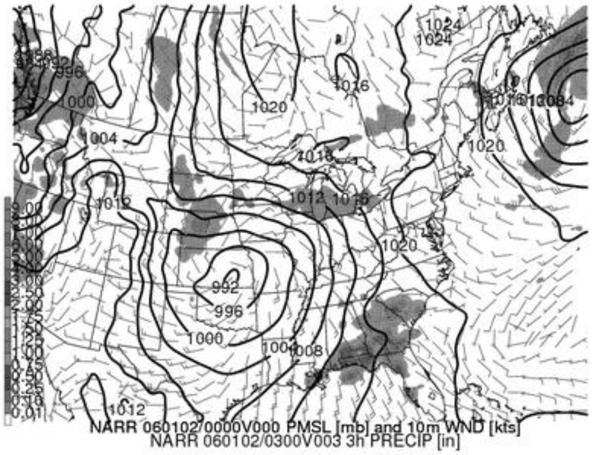

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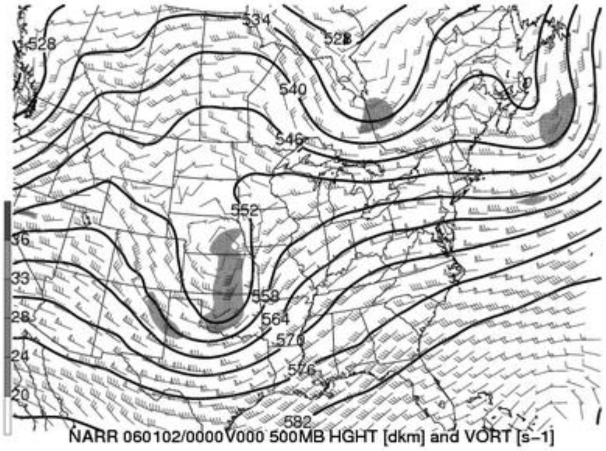

Fig. 4a: NARR 02 January 2006 0000 UTC MSLP, 10m wind, and 3h precipitation accumulation.
Fig. 4b: Same as 3a, except for 500 hPa height and vorticity.

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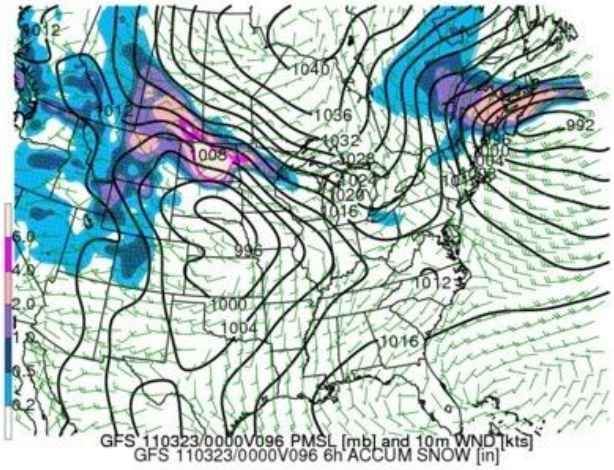

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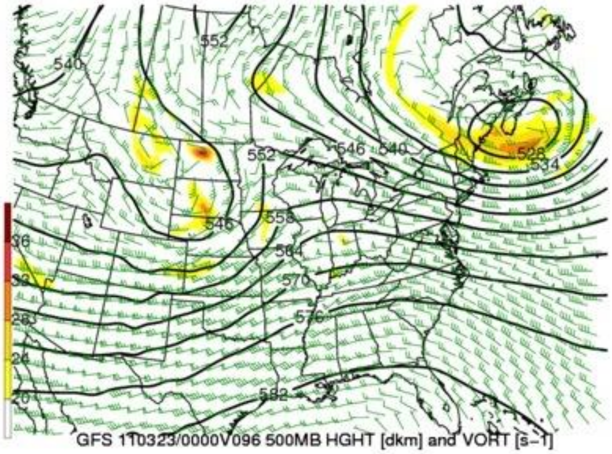

Fig. 5a: GFS212 18 March 2011 F096h MSLP, 10m wind, and 6h snow accumulation.
Fig. 5b: Same as 5a, except for 500 hPa height and vorticity.

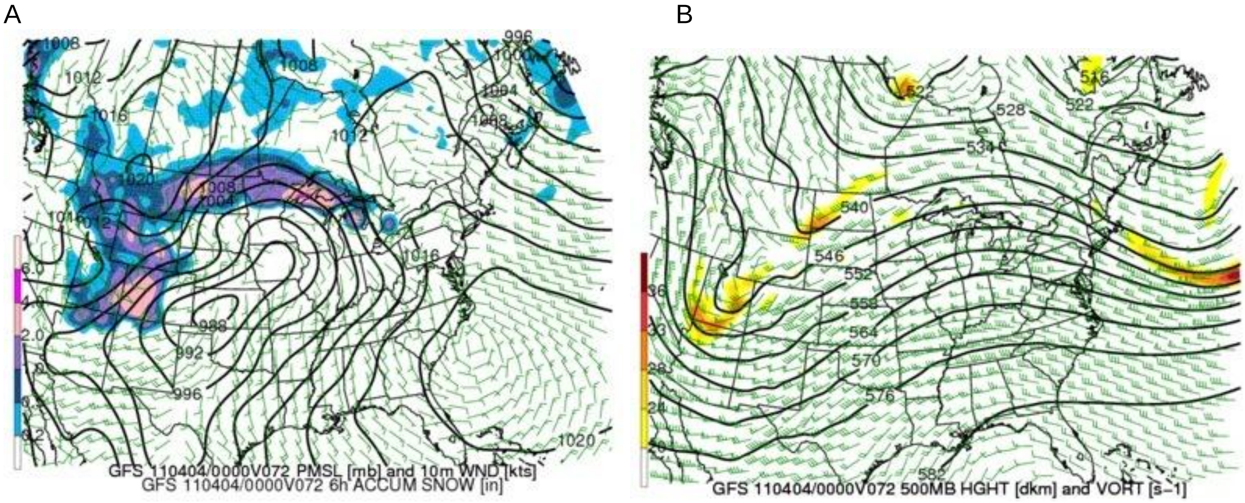

Fig. 6a: GFS212 1 April 2011 F072h MSLP, 10m wind, and 6h snow accumulation.
Fig. 6b: Same as 6a, except for 500 hPa height and vorticity.

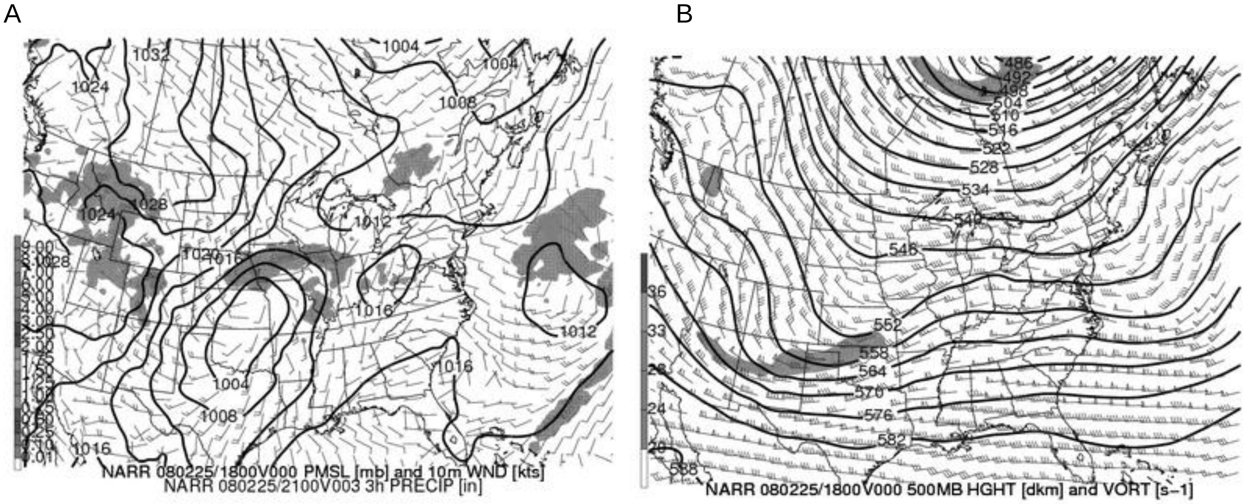

Fig. 7a: NARR 25 February 2008 1800 UTC MSLP, 10m wind, and 3h precipitation accumulation.
Fig. 7b: Same as 7a, except for 500 hPa height and vorticity.