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A METEOROLOGICAL COMPOSITE OF THE 2005/06 WILDFIRE OUTBREAKS IN THE SOUTHERN PLAINS

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1. INTRODUCTION

The 2005/06 cold season was characterized by an intensifying long-term drought across the southern Great Plains (U.S. Drought Monitor 2005 and 2006). Enhanced curing of vegetation during the extended period of dry weather contributed to unprecedented wildfire activity over portions of New Mexico, Oklahoma, and Texas between December 2005 and April 2006 (Texas Forest Service 2006a and Van Speybroeck et al. 2007).

Particularly dangerous wildfires threatened life and property in the Southern Plains during six widespread and destructive fire weather episodes, or *"outbreaks"* (Table 1). On 27 December 2005, 1 January 2006, 12 January 2006, 12 March 2006, 6 April 2006, and 15 April 2006, numerous massive wildfires evolved suddenly within meteorological environments that favored extreme fire behavior (National Interagency Fire Center 2006). Wildfires during each of these events scorched tens of thousands to over a million acres of prairie across multiple states (Fig. 1). A total of 616 structures were destroyed, and combined damages were estimated near $150 million in economic loss. Five of the six outbreaks resulted in human casualties (NOAA 2005, NOAA 2006a, NOAA 2006b, and NOAA 2006c).

These catastrophic fire weather episodes occurred in synoptic scale weather patterns that featured: 1) the passage of progressive middle latitude cyclones and associated wind maxima over the Southern Plains, 2) intense cyclogenesis over Kansas, and 3) deep mixing of the planetary boundary layer coincident with volatile fuels and antecedent drought conditions west of a surface dryline. This study utilizes 2100 UTC Rapid Update Cycle (RUC) (Benjamin et al. 2004) analyses of middle and upper tropospheric geopotential heights and winds, mean sea level pressure (mslp), 10 m winds, and 2 m relative humidity from each case to produce a meteorological composite of the 2005/06 Southern Plains wildfire outbreaks.

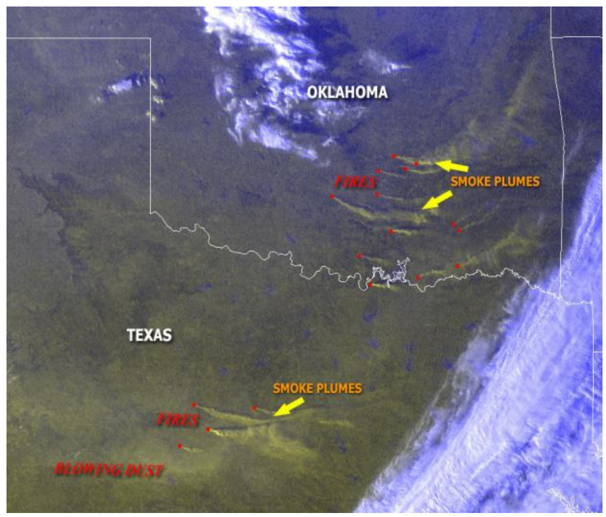

Figure 1: NOAA GOES-12 satellite imagery of a wildfire outbreak in the Southern Plains. Numerous large wildfires over Oklahoma and Texas are depicted as red dots and smoke plumes are clearly evident. Image from 2215 UTC 27 December 2005.

2. METHODOLOGY

In order to summarize the synoptic patterns associated with the historical 2005/06 wildfire outbreaks in the Southern Plains, meteorological composites were derived using RUC analysis post-processed at 20 km resolution. These composites were comprised of 2100 UTC initial hour data for 27 December 2005, 1 January 2006, 12 January 2006, 12 March 2006, 6 April 2006, and 15 April 2006, and used the 20 km grid point mean of various meteorological fields for each of the six cases. After the mean grid values were computed, General Meteorological Package (GEMPAK) (Unidata 2002) applications were utilized to plot composite graphics of mslp, 10 m winds, and 2 m relative

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humidity. Relative humidity and winds, along with atmospheric stability, are the most critical meteorological parameters used to predict fire behavior and spread, and have long been recognized as the primary variable factors to influence wildfire severity (Heilman 1995, Anderson 1998, and U.S. Department of Commerce 1998). In addition, to understand the large scale weather patterns that contributed to widespread conditions favorable for extreme fire behavior, geopotential heights, winds, and isotachs for the 700 hPa, 500 hPa, and 300 hPa pressure levels were generated. The resulting GEMPAK composite graphics are presented below as Fig. 8 through Fig. 11.

Table 1: The 2005/06 Southern Plains Wildfire Outbreaks

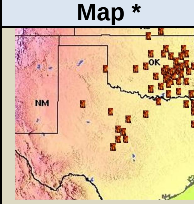
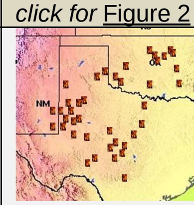
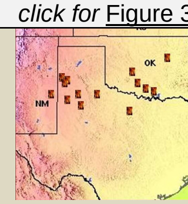
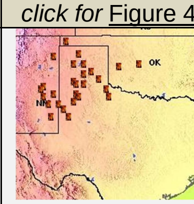
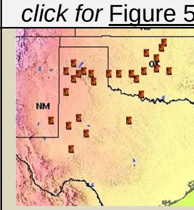
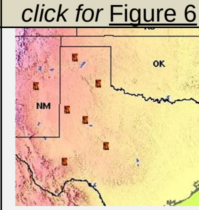
Event Date	Major Wildfires	Acreage Burned	Economic Damages	Structures Destroyed	Reported Deaths	Reported Injuries	Outbreak Map *
27 Dec 2005	52	60,823	$19 M	341	4	28	 *click for* Figure 2
1 Jan 2006	40	303,570	$25 M	115	2	19	 *click for* Figure 3
12 Jan 2006	14	39,173	$600 K	48	0	0	 *click for* Figure 4
12 Mar 2006	27	1,102,044	$96 M	102	12	11	 *click for* Figure 5
6 Apr 2006	26	119,846	$3 M	42	0	2	 *click for* Figure 6
15 Apr 2006	7	23,135	$290 K	7	0	3	 *click for* Figure 7

Table 1: The impacts of six 2005/06 wildfire outbreaks in the Southern Plains are presented. Maps that depict the location of major fires associated with each outbreak are embedded as Fig. 2 through Fig. 7. Click *thumbnail map images to view full resolution figures. * Major wildfire maps based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2005, NOAA 2006a, NOAA 2006b, and NOAA 2006c) and by state agencies (Texas Forest Service 2005 and 2006b, Oklahoma Department of Agriculture 2005 and 2006, and New Mexico State Forestry 2006).*

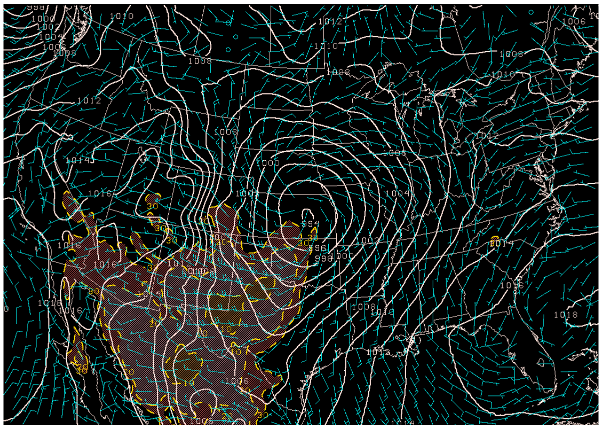


Figure 8: 2100 UTC RUC composite for mslp (white contours), 10 m winds (blue barbs in kt), and 2 m relative humidity less than 30% (yellow dashed contours and image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

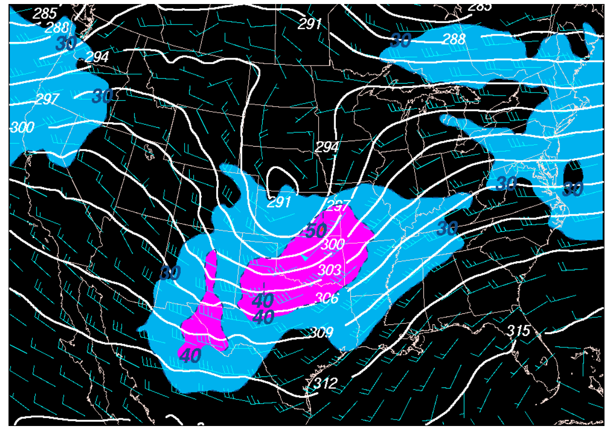


Figure 9: 2100 UTC RUC composite for 700 hPa heights (white contours), winds (blue barbs in kt), and isotachs greater than 30 kt (15 m s^{-1}) (image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

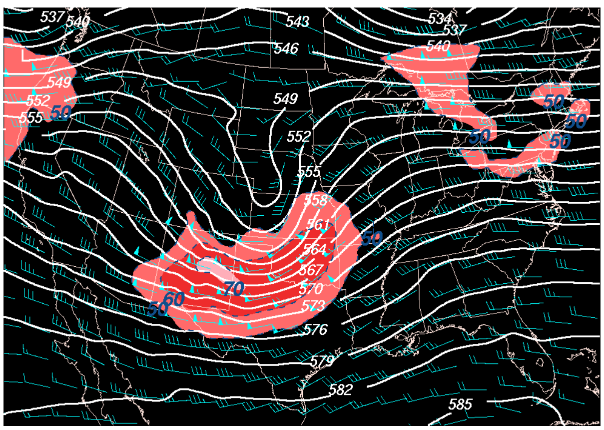


Figure 10: 2100 UTC RUC composite for 500 hPa heights (white contours), winds (blue barbs in kt), and isotachs greater than 50 kt (26 m s^{-1}) (image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

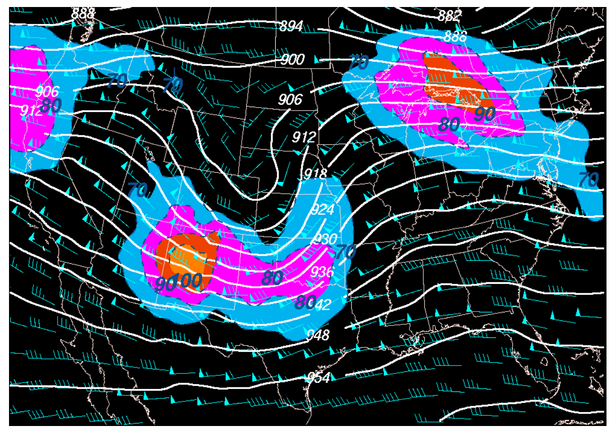


Figure 11: 2100 UTC RUC composite for 300 hPa heights (white contours), winds (blue barbs in kt), and isotachs greater than 70 kt (36 m s^{-1}) (image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

3. METEOROLOGICAL COMPOSITE

The six devastating Southern Plains wildfire outbreaks examined here were associated with the passage of intense middle latitude cyclones. This signal is strongly evident in the surface and pressure level composites generated using 2100 UTC RUC initializations. Schroeder (1964) identified similar synoptic scale situations as a "Chinook-Type" critical fire weather pattern for the Southern Plains.

Significant meteorological features that contributed to the widespread nature and severity of wildfires during the 2005/06 cool season, and that were reflected in the 2100 UTC RUC GEMPAK graphics, were combined as to derive a single graphical atmospheric composite for the Southern Plains wildfire outbreaks (Fig. 12). The composite highlights synoptic and mesoscale commonalities of these extreme fire weather episodes.

The Southern Plains wildfire composite depicts a negatively tilted open trough in the middle and upper levels of the atmosphere over the Plains. Average minimum 500 hPa heights of 549 dam were characteristic of the trough axis from western Kansas to eastern Wyoming. In addition, intense wind fields were highlighted in the composite, propagating through the base of the middle and upper tropospheric troughs. Averaged winds at the 300 hPa level of 70 kt (36 m s^{-1}) overspread an expansive area of the Southern Plains, and an averaged jet max surpassing 100 kt (51 m s^{-1}) over western and central New Mexico. The averaged wind maximum at 500 hPa exceeded 70 kt (36 m s^{-1}) over eastern New Mexico and west Texas, with a broad area greater than 50 kt (26 m s^{-1}) over most of the Southern Plains.

The 2100 UTC RUC composites depicted a deepening lower tropospheric cyclone over the Southern Plains.

At 700 hPa, the composite analysis indicated a 291 dam closed low centered over northwestern Kansas into south-central Nebraska, with a broad area of south to southwest winds in excess of 40 kt (21 m s^{-1}) from portions of eastern New Mexico and far west Texas eastward over Oklahoma, southeastern Kansas, and western Missouri.

The averaged surface map also was consistent with strong cyclonegensis over the Southern Plains. The surface composite indicated a 994 hPa surface low centered near Salina, Kansas in mslp plots. Extremely dry air was noted west of a dryline that extended southward from the low across central Oklahoma and central Texas, where abnormally warm temperatures and strong downsloping winds occurred in association with deep mixing of the planetary boundary layer. Relative humidity values at the 2 m level fell below 10% over a large portion of southeastern New Mexico, west Texas, and southwestern Oklahoma. A broader area of 2 m relative humidities of less than 30% encompassed all of the Southern Plains west of the dryline feature.

A cold front was depicted in the composites pushing southward into the dry air over western Oklahoma, the Texas and Oklahoma Panhandles, and northeastern New Mexico. During at least two of the 2005/06 wildfire outbreaks, sudden wind shifts associated with frontal passages led to dangerously adverse conditions for firefighting operations (Lindley et al. 2006a and 2006b). This is particularly notable given that changes it wind speed and direction are a reoccurring element common to many wildfire-related fatalities (National Wildfire Coordinating Group 1997). Low-level winds (10 m) were generally sustained at speeds between 20 kt (10 m s^{-1}) and 30 kt (15 m s^{-1}) within the dry air south of the cold front, and shifted to the northwest at around 15 kt (8m s^{-1}) north of the front.

As previously noted, the synoptic and mesoscale weather features depicted in the atmospheric composite for a Southern Plains wildfire outbreak were coincident with moderate (D2) to severe (D4) long term drought conditions (U.S. Drought Monitor 2005 and 2006). It is noteworthy that numerous wildfires also were observed over eastern Oklahoma, and to a lesser extent in extreme western Arkansas, where relatively higher humidities and lower sustained wind speeds occurred on average east of the composite dryline location. This area is characterized by more rugged terrain and heavier vegetation compared to the geographical areas that experienced the most devastating impacts from the Southern Plains wildfire outbreaks, and was experiencing extreme (D4) drought at that time.

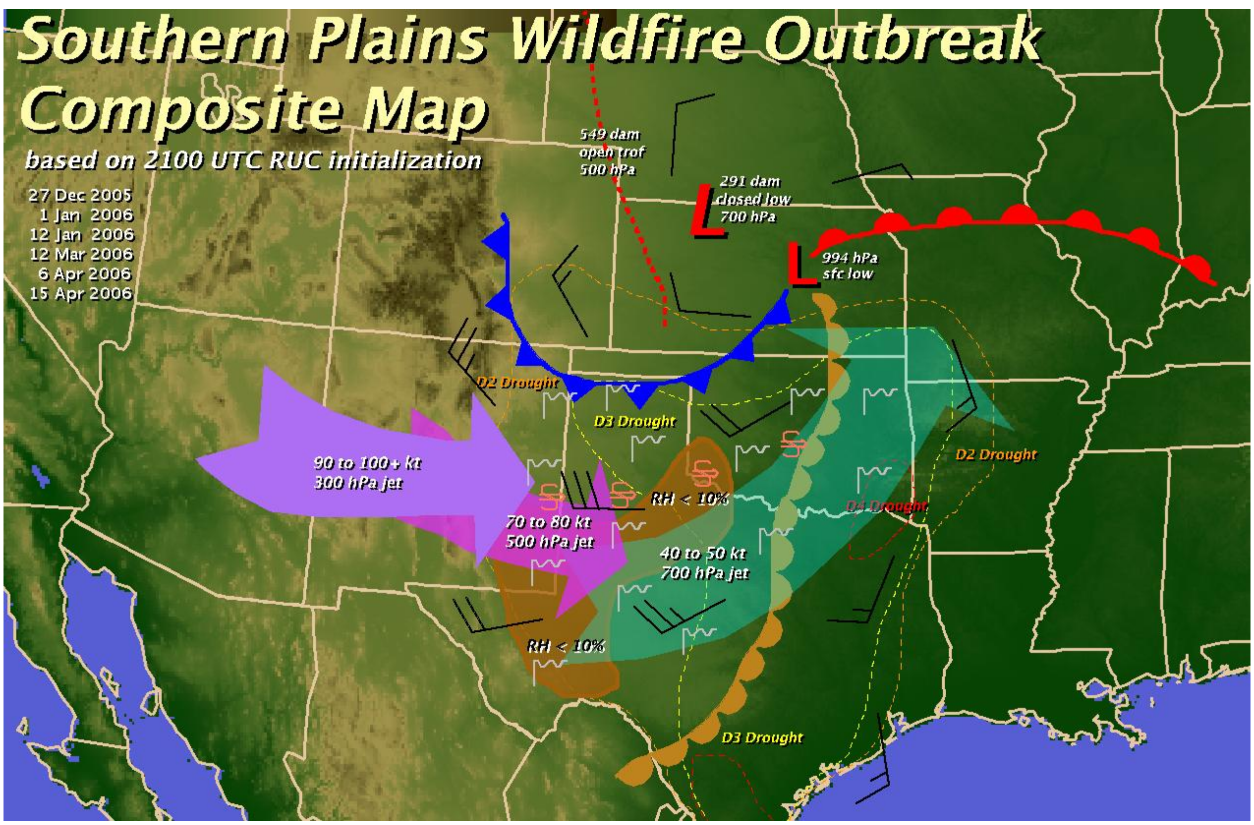


Figure 12: An operationally useful meteorological composite derived from 2100 UTC RUC initializations during six 2005/06 wildfire outbreaks in the Southern Plains. Key meteorological features at the surface and at varying atmospheric pressure levels aloft that contributed to the wildfire outbreaks are denoted. Drought conditions observed near the midpoint of the unprecedented fire weather episodes, in March 2006, are also noted. The meteorological smoke symbol "" marks the geographical distribution of fire activity in the Southern Plains, and the meteorological symbol for blowing dust "" indicates the location of a pronounced dust plume during five of the six outbreaks.

4. CONCLUSIONS

The destructive 2005/06 cool season fire weather episodes in the Southern Plains occurred within synoptic weather patterns consistent with previously documented "Chinook-Type" critical fire weather patterns and featured: 1) the passage of progressive middle latitude cyclones and associated wind maxima, 2) intense cyclogenesis over Kansas, and 3) deep mixing of the planetary boundary layer coincident with volatile fuels and antecedent drought conditions west of a surface dryline. With multiple wildfire occurrences that evolved on spatial and temporal scales associated with a particular synoptic scale feature, the events were analogous to *"outbreaks"* of other hazardous meteorological phenomenon as defined by the American Meteorological Society (2007).

Meteorological composites generated using 2100 UTC RUC initializations during six of the most widespread and damaging outbreak events (27 December 2005, 1 January 2006, 12 January 2006, 12 March 2006, 6 April 2006, and 15 April 2006) depicted an open negatively tilted upper and middle tropospheric trough axis from the northern Texas Panhandle and northwestern Oklahoma to eastern Wyoming and western South Dakota. The composite middle latitude cyclone deepened to a closed low below the 700 hPa pressure level, as intense low-level cyclogenesis occurred over Kansas. A cold front, that extended southwestward from a surface low near Salina, Kansas, was depicted in the composite advancing southward over western Oklahoma, the Texas and Oklahoma Panhandles, and northeastern New Mexico. During several of the outbreak events, wind shifts and the resultant change in fire propagation associated with frontal passages, created dangerous conditions for firefighting operations at ongoing wildfire burn sites. In addition, intense wind fields were depicted in the composites at all levels, as wind maxima in the base of the middle latitude cyclone overspread the Southern Plains. Deep mixing of the planetary boundary layer west of a surface dryline contributed to average sustained 10 m winds as high as 30 kt (15 m s^{-1}) and 2 m relative humidity values below 10% over portions of the Southern Plains, where moderate (D2) to severe (D3) drought conditions were ongoing.

The 2005/06 Southern Plains wildfire outbreaks will continue to be documented in meteorological literature. Plans exist to elaborate upon the composite presented here with information regarding the antecedent drought conditions that contributed to these unprecedented outbreaks and their societal impacts in a peer-reviewed electronic journal article. It is hoped that the meteorological composite presented here will ultimately enhance the awareness of operational meteorologists for weather conditions related to devastating wildfire activity over the Southern Plains, and improve operational fire weather forecast and warning capabilities prior to similar future events.

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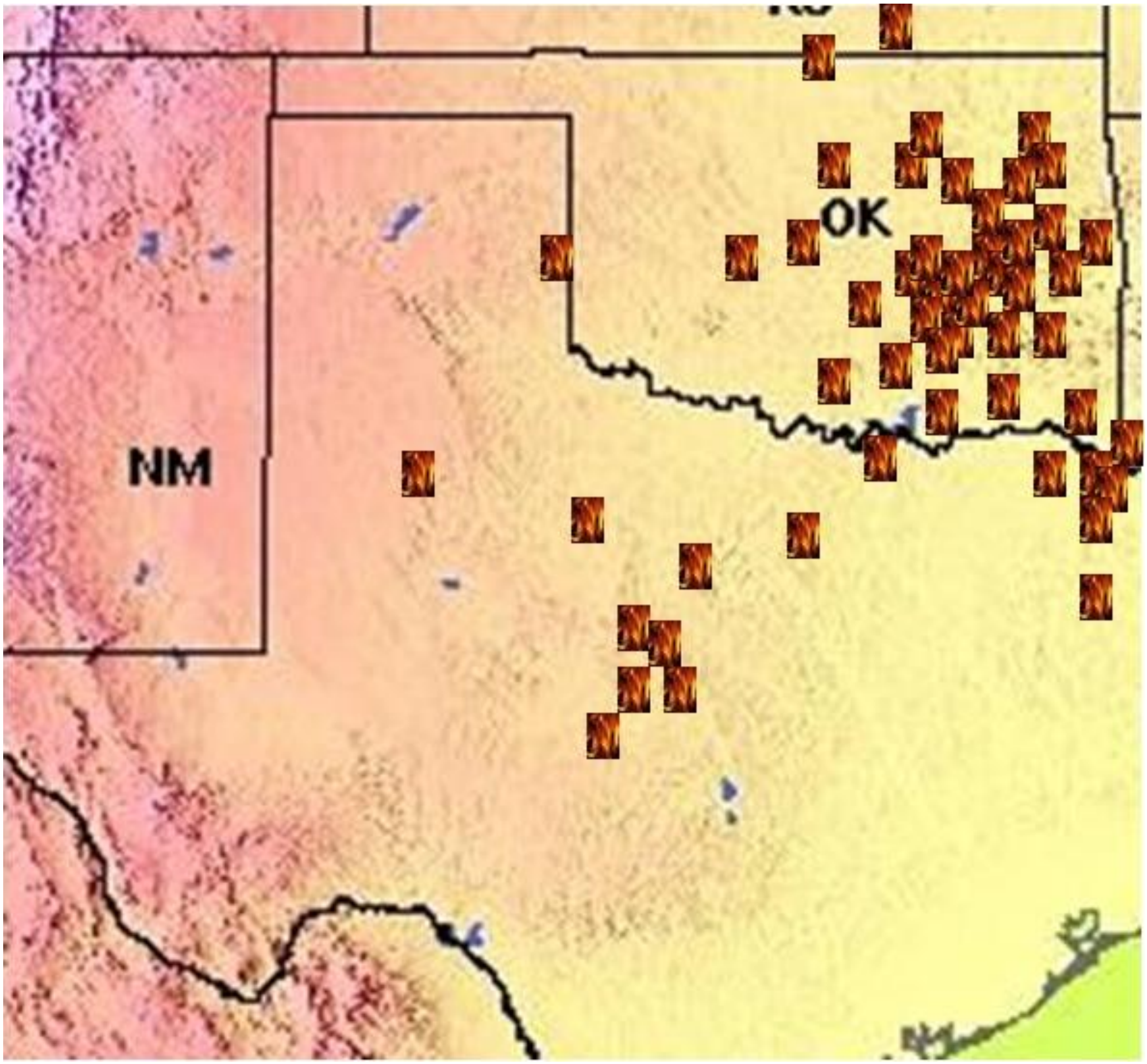


Figure 2: Major wildfire map for the 27 December 2005 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2005) and by state agencies (Texas Forest Service 2005, and Oklahoma Department of Agriculture 2005. *Click the figure to return to the main manuscript.*

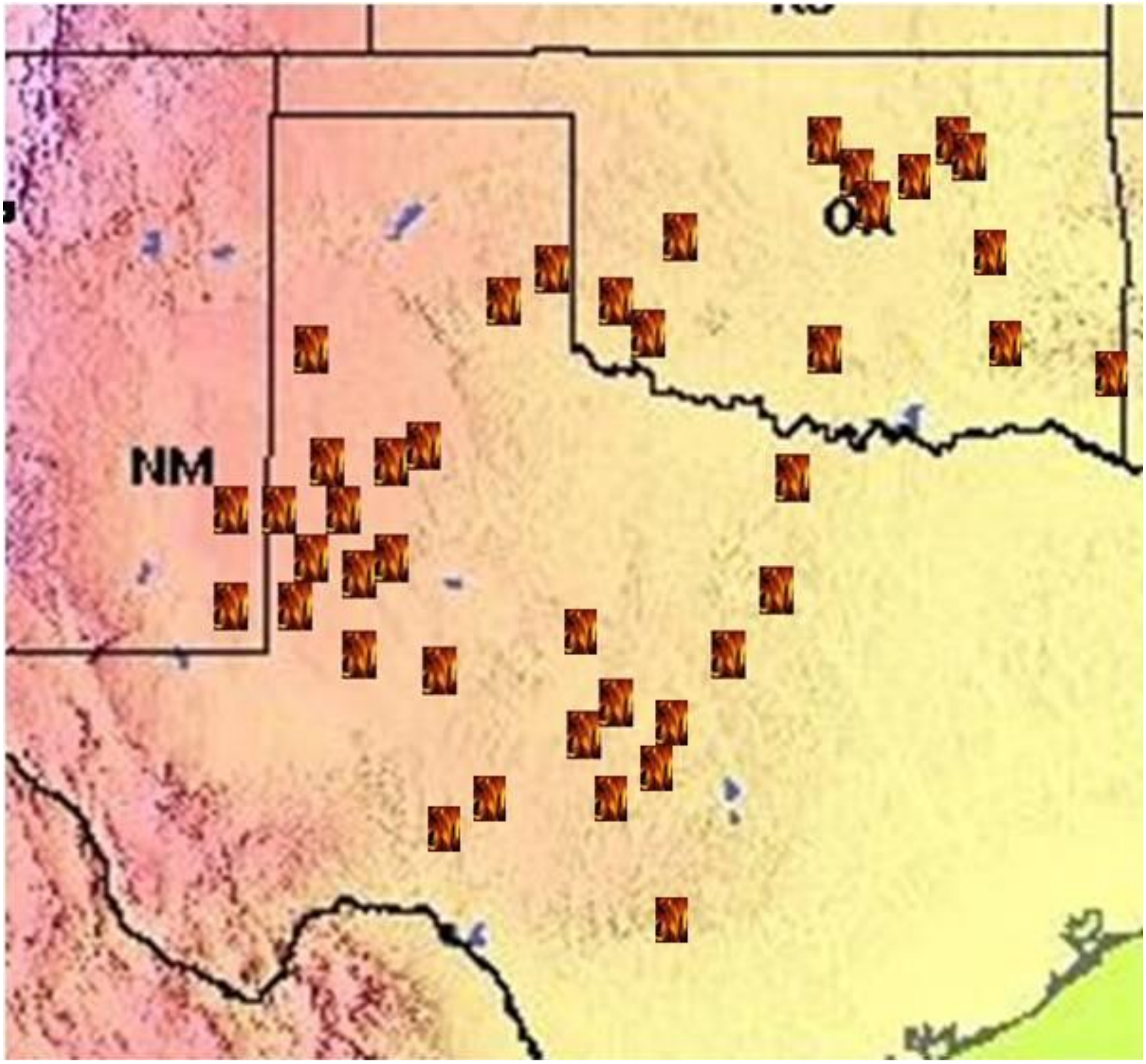


Figure 3: Major wildfire map for the 1 January 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006a) and by state agencies (Texas Forest Service 2006b, Oklahoma Department of Agriculture 2006, and New Mexico State Forestry 2006). *Click the figure to return to the main manuscript.*

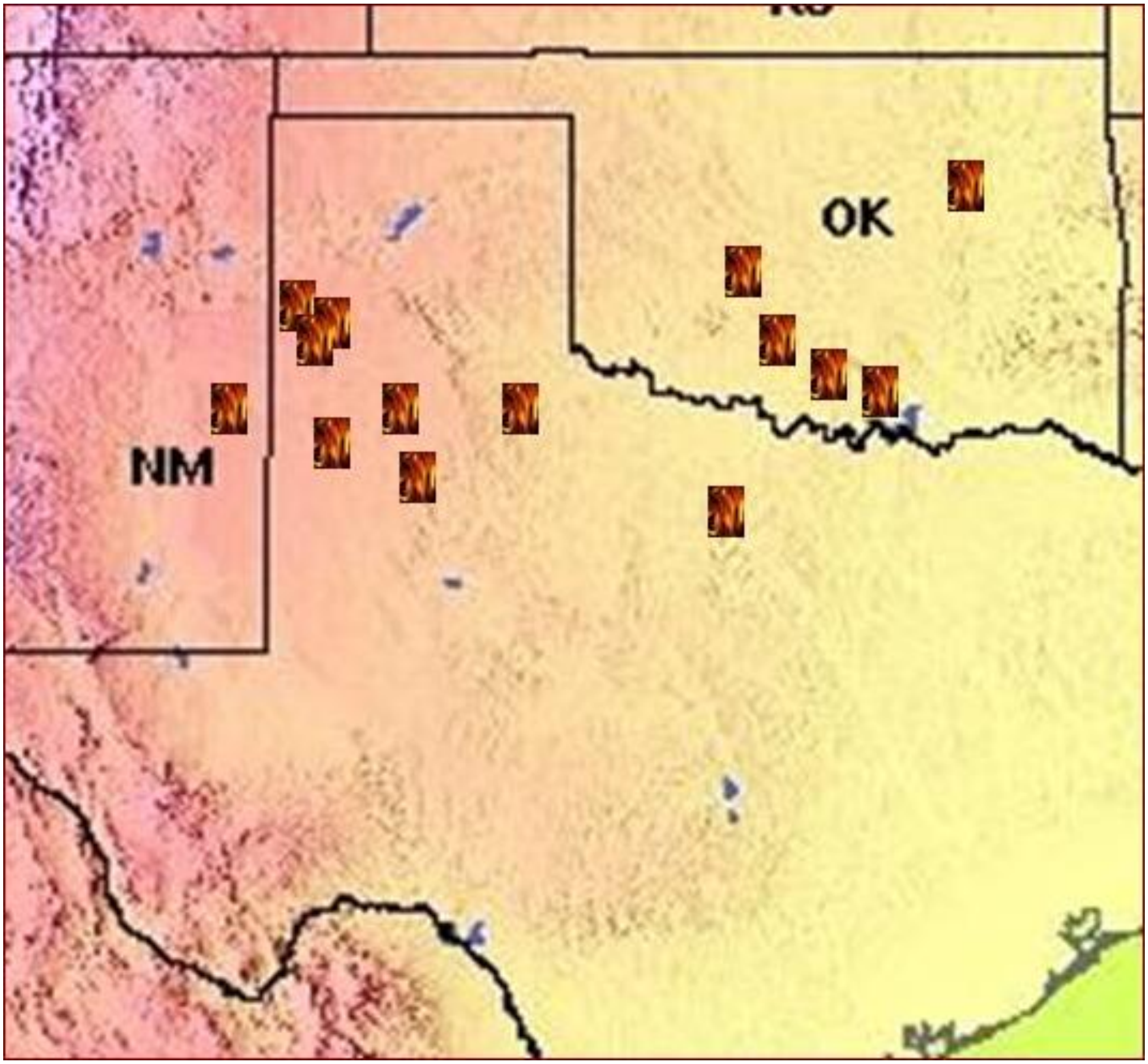


Figure 4: Major wildfire map for the 12 January 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006a) and by state agencies (Texas Forest Service 2006b, Oklahoma Department of Agriculture 2006, and New Mexico State Forestry 2006). *Click the figure to return to the main manuscript.*

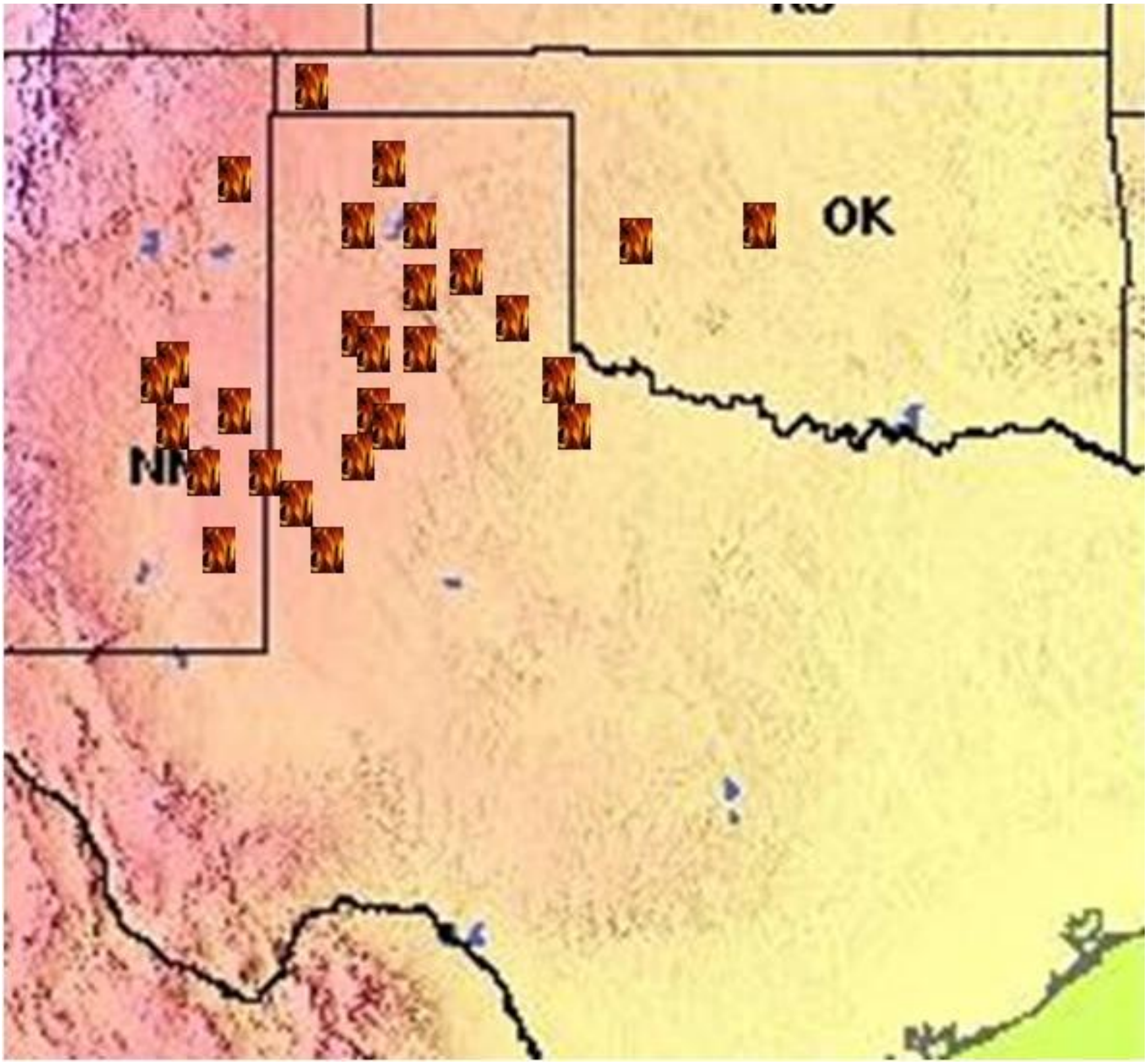


Figure 5: Major wildfire map for the 12 March 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006b) and by state agencies (Texas Forest Service 2006b, Oklahoma Department of Agriculture 2006, and New Mexico State Forestry 2006). *Click the figure to return to the main manuscript.*

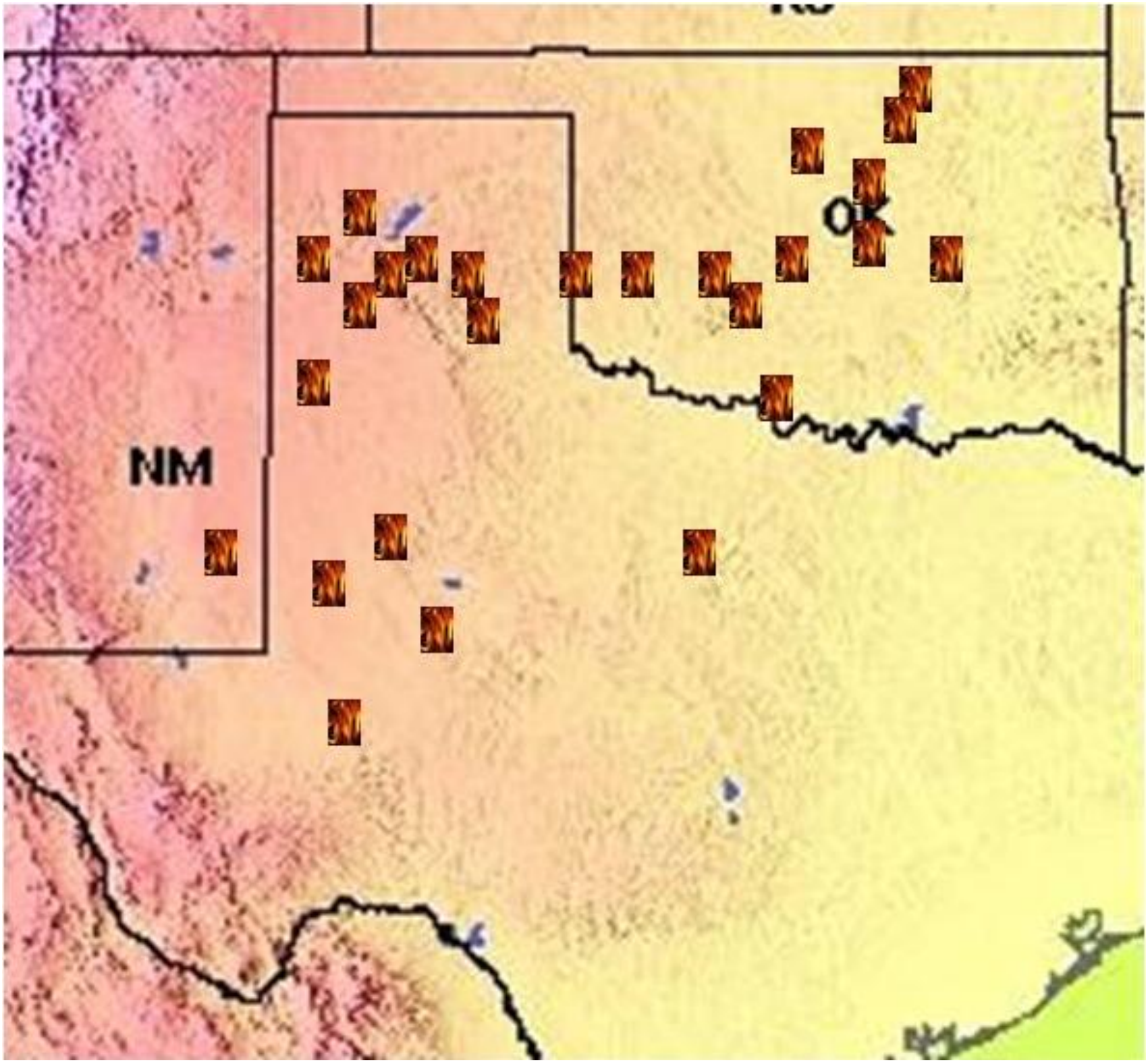


Figure 6: Major wildfire map for the 6 April 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006c) and by state agencies (Texas Forest Service 2006b, Oklahoma Department of Agriculture 2006, and New Mexico State Forestry 2006). *Click the figure to return to the main manuscript.*

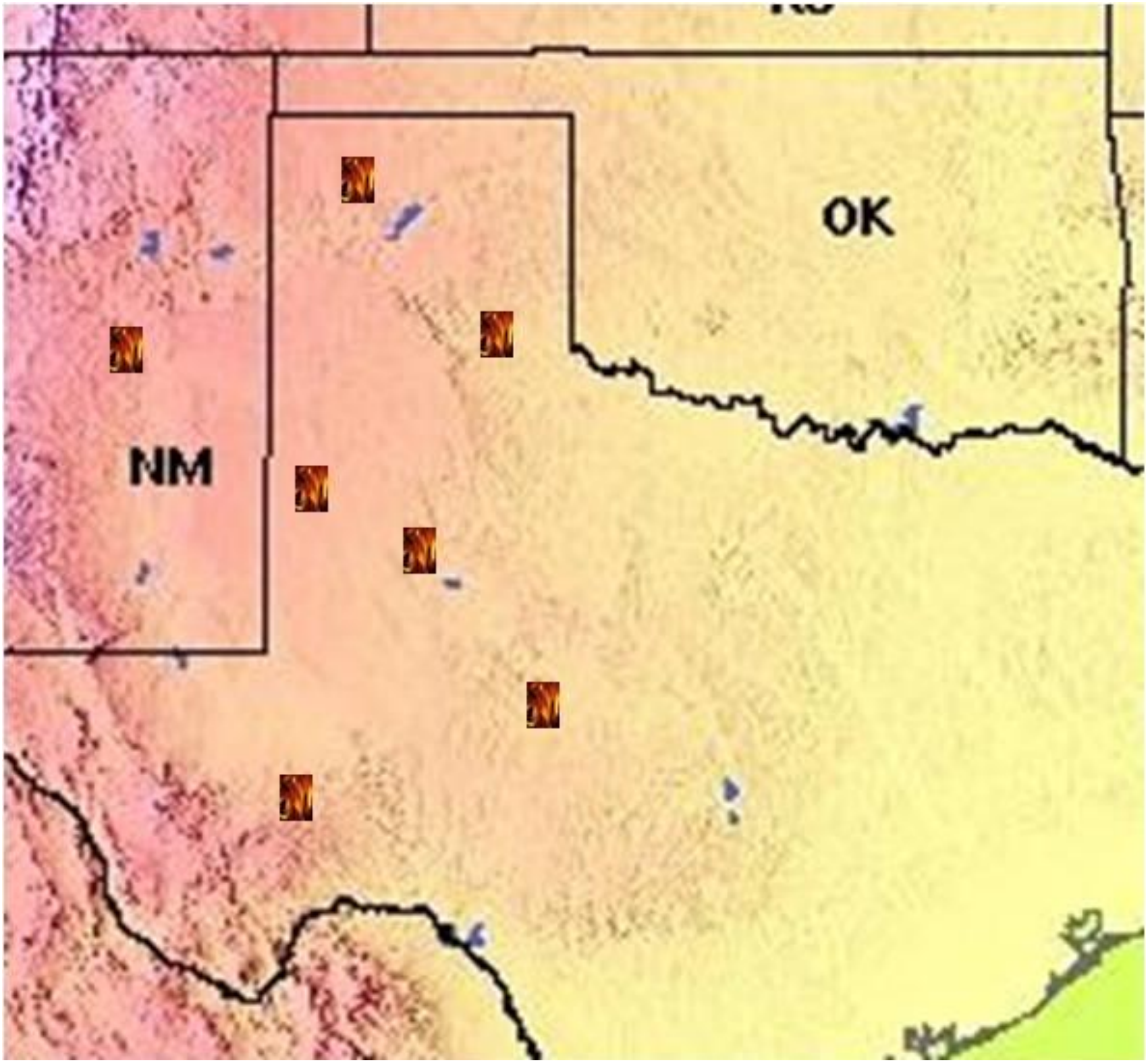
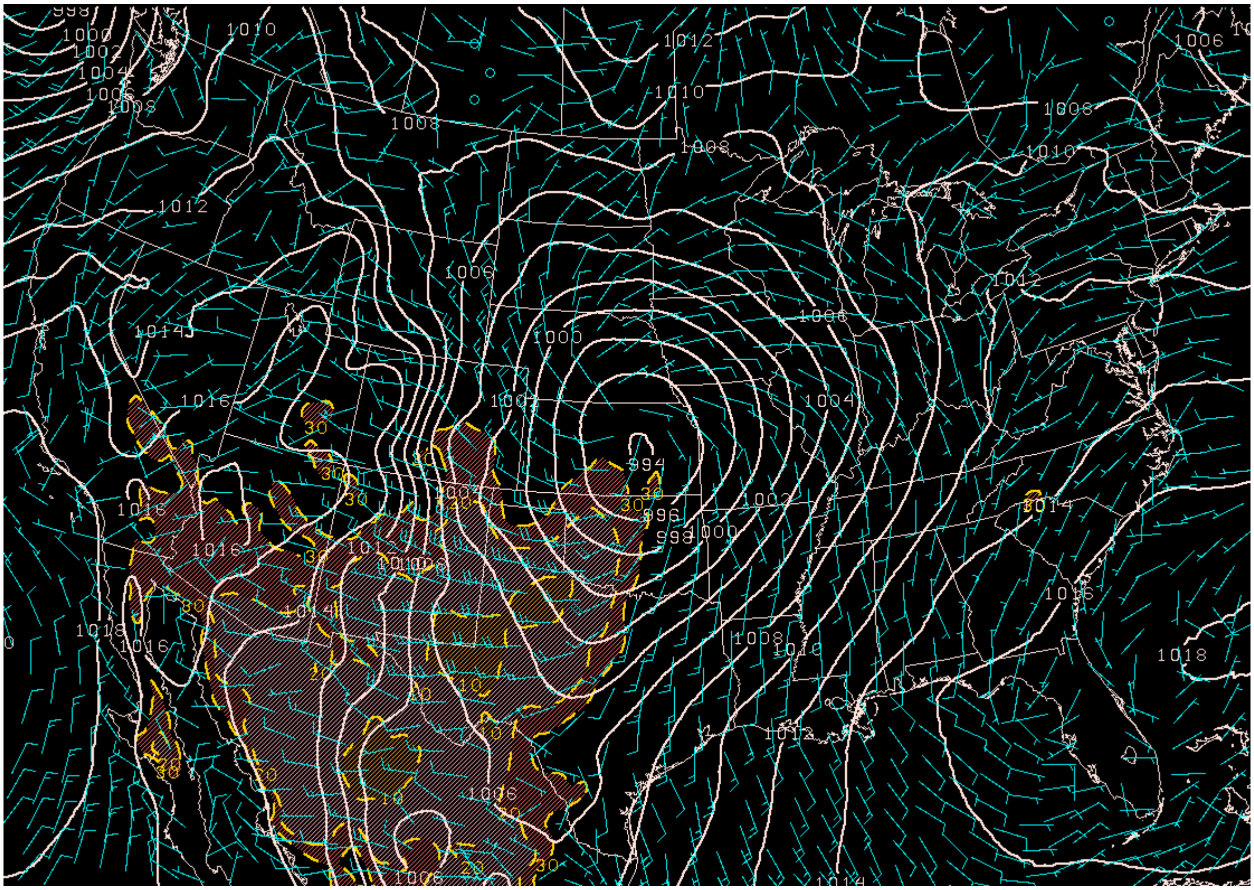


Figure 7: Major wildfire map for the 6 April 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006c) and by state agencies (Texas Forest Service 2006b, Oklahoma Department of Agriculture 2006, and New Mexico State Forestry 2006). *Click the figure to return to the main manuscript.*



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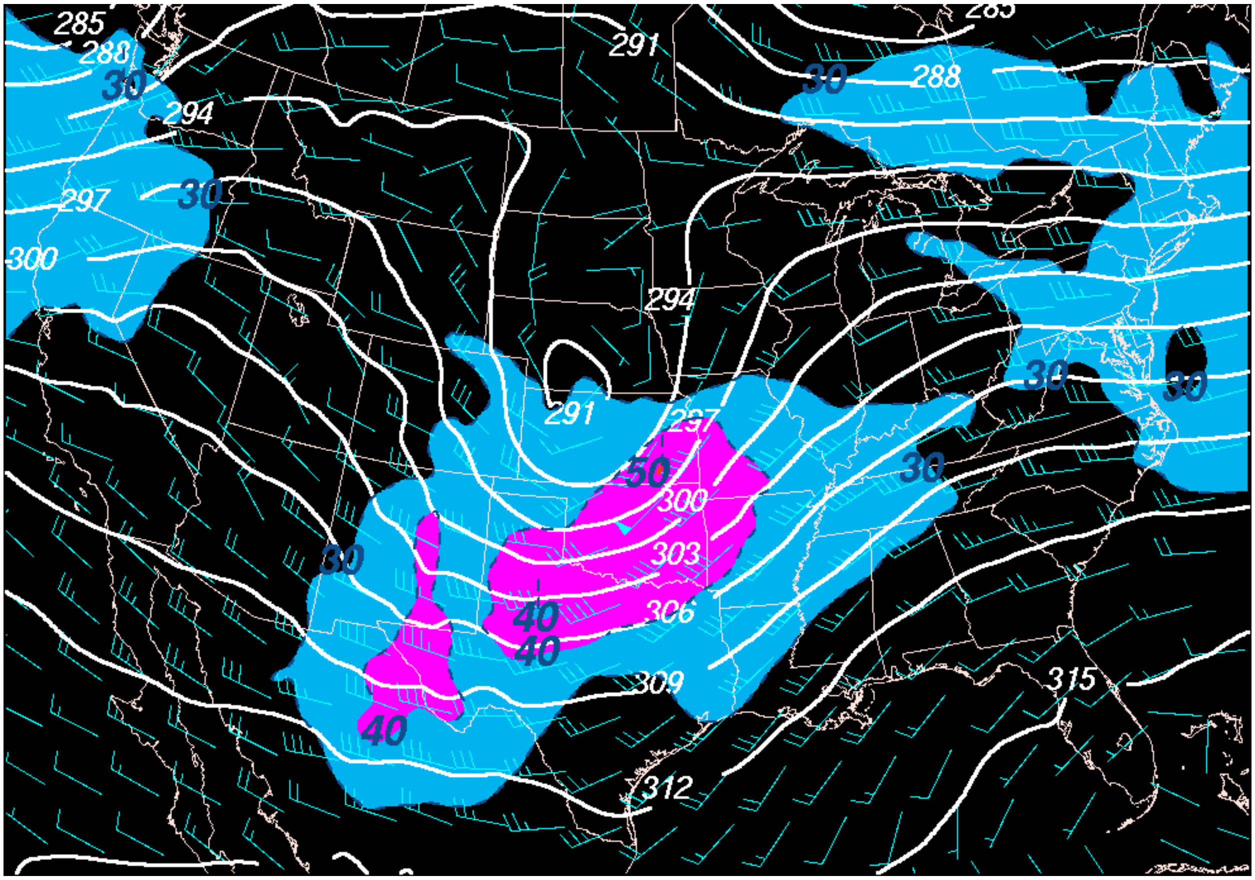

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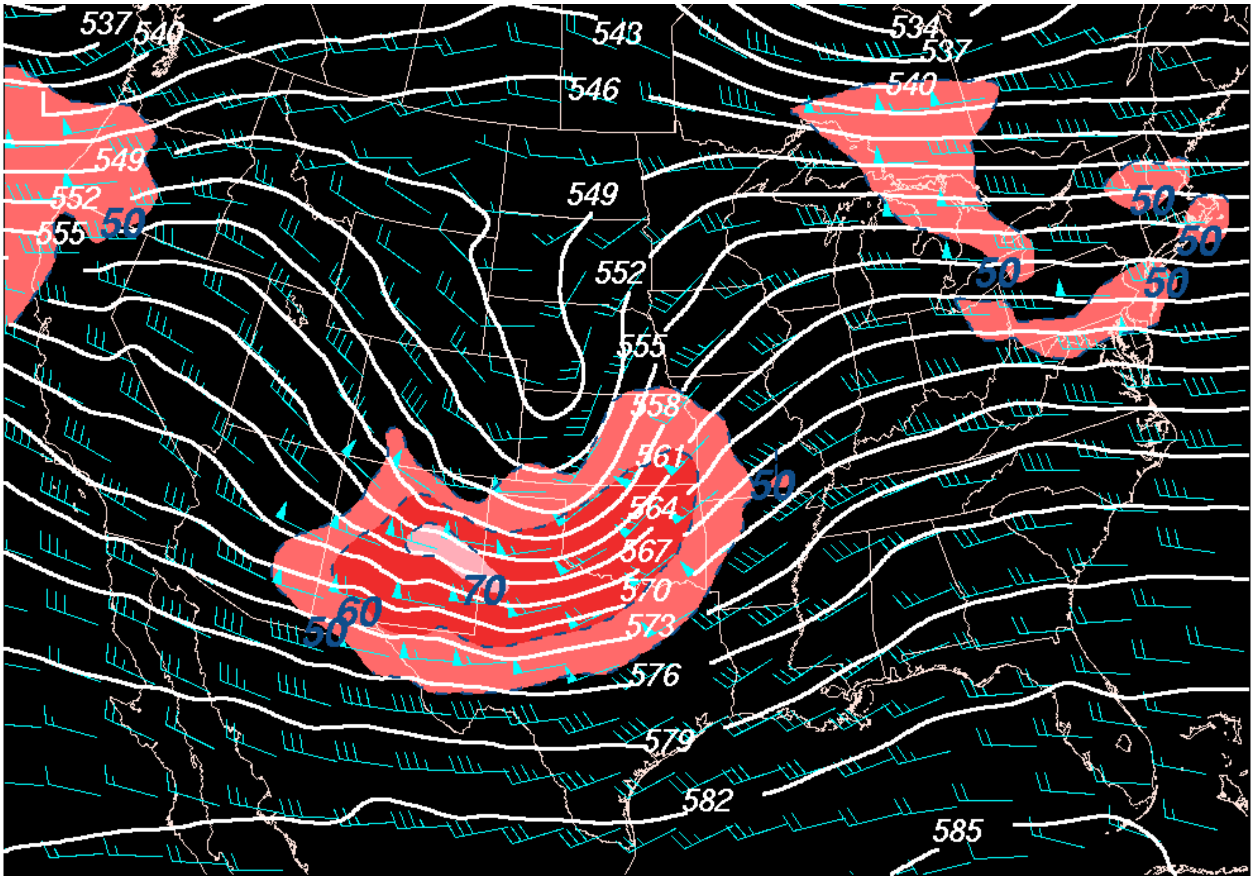

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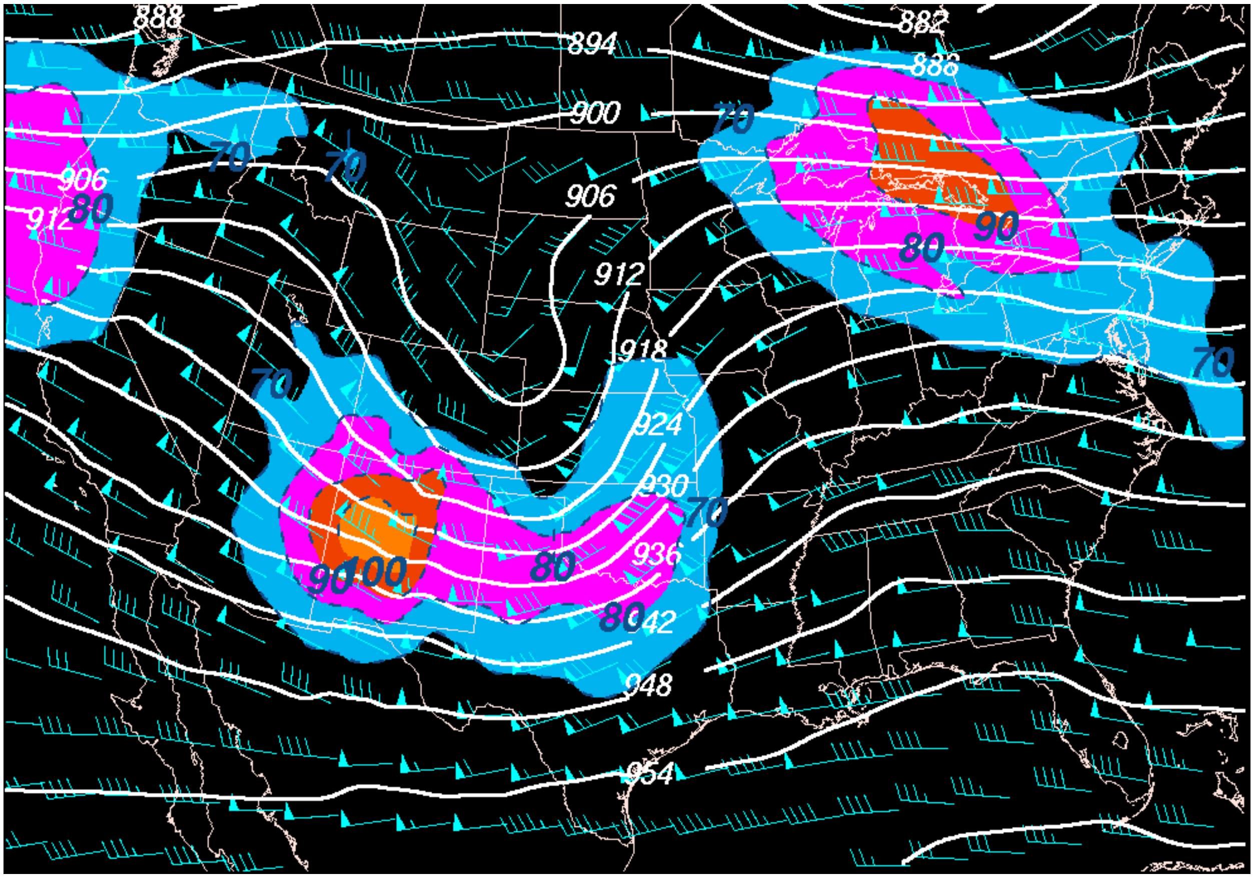

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