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

T. Todd Lindley[1]*, Jared L. Guyer[2], Gregory P. Murdoch[3],
Seth R. Nagle[4], Kenneth J. Schneider[5], and Gary D. Skwira[1]

[1]NOAA/National Weather Service - Lubbock, Texas
[2]NOAA/Storm Prediction Center – Norman, Oklahoma
[3]NOAA/National Weather Service - Midland, Texas
[4]NOAA/National Weather Service – San Angelo, Texas
[5]NOAA/National Weather Service – Amarillo, Texas

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 dry period contributed to unprecedented wildfire activity over portions of New Mexico, Oklahoma, and Texas between December 2005 and April 2006 (Texas Forest Service 2006).

Particularly dangerous wildfires threatened life and property in the Southern Plains during six widespread and destructive fire weather episodes on 27 December 2005, 1 January 2006, 12 January 2006, 12 March 2006, 6 April 2006, and 15 April 2006. These Southern Plains *"wildfire outbreaks",* were characterized by the sudden evolution of numerous severe wildfires (> 1000 acres per NCRS 2006) within meteorological environments that favored extreme fire behavior (NIFC 2006a) on temporal and spatial scales related to a particular synoptic scale weather feature. During each of these outbreak events, wildfires scorched tens of thousands to over a million acres of prairie across multiple states. At least 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). A summary of the 2005/06 Southern Plains wildfire outbreaks is found in Table 1, and a satellite image of the 27 December 2005 event is presented in Fig. 1.

Despite favorable fuel moisture conditions brought on by climatic variations (Van Speybroeck et al. 2007), Brotak and Reifsnyder (1977) noted that certain infrequent combinations of weather conditions are also a prerequisite for major wildfire activity. The catastrophic Southern Plains fire weather events of 2005/06 were quickly recognized by operational forecasters to occur in association with: 1) the passage of progressive middle latitude cyclones and associated wind maxima, 2) intense low-level cyclogenesis over Kansas, and 3) deep mixing of the planetary boundary layer coincident with volatile vegetative fuels in 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 the aforementioned cases to produce a meteorological composite of the 2005/06 Southern Plains wildfire outbreaks.

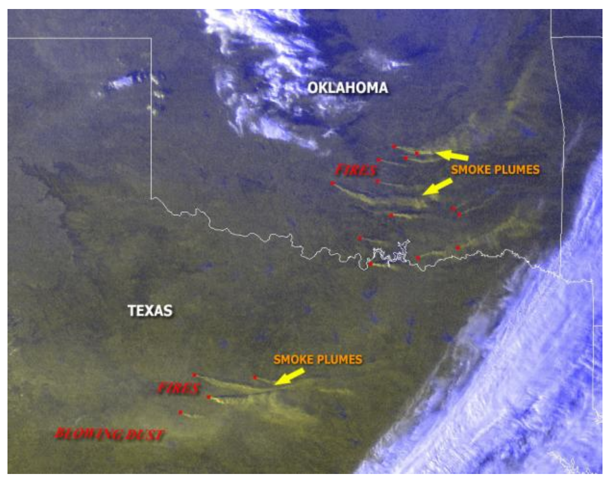


Figure 1: NOAA GOES-12 satellite imagery of a wildfire outbreak in the Southern Plains. Numerous large wildfires over Oklahoma and Texas are depicted (red dots) and smoke plumes are clearly evident. Image from 2215 UTC 27 December 2005.

2. METHODOLOGY

In order to summarize the critical fire weather patterns associated with the historical 2005/06 wildfire outbreaks in the Southern Plains, meteorological composites were created using RUC analyses post-processed on a 20 km grid. These composites were based on mean fields comprised of 2100 UTC initial hour data analyses for the cases of 27 December 2005, 1 January 2006, 12 January 2006, 12 March 2006, 6 April 2006, and 15 April 2006. After the mean grid values were computed,

* *Corresponding author address:* T. Todd Lindley, National Weather Service, 2579 S. Loop 289 #100 Lubbock, TX 79423. e-mail: Todd.Lindley@noaa.gov

GEneral Meteorological PAcKage (GEMPAK) (Unidata 2002) applications were utilized to plot a variety of composite graphics, including MSLP, 10 m winds, and 2 m relative humidity. These fields were deemed relevant since 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 synoptic scale patterns that contributed to widespread conditions favorable for extreme fire behavior, composite analyses of geopotential heights, winds, and isotachs for the 700 hPa, 500 hPa, and 300 hPa pressure levels also 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

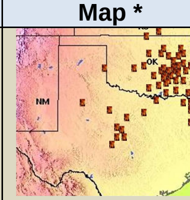
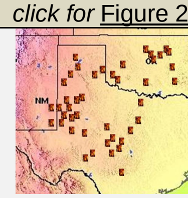
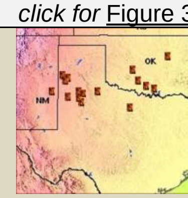
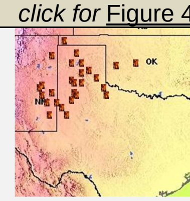
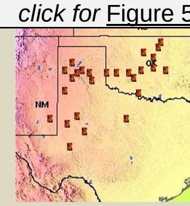
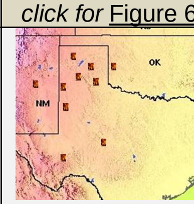
Event Date	Major Wildfires	Acreage Burned	Economic Damages	Structures Destroyed	Reported Deaths	Reported Injuries	Outbreak Map *
27 Dec 2005	52	60,823	$19 M	341	4	28	 *click for* Figure 2
1 Jan 2006	43	303,570	$25 M	115	2	19	 *click for* Figure 3
12 Jan 2006	16	39,173	$600 K	48	0	0	 *click for* Figure 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	10	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 maps to view full resolution figures*. ** 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 the National Interagency Fire Center (NIFC 2005 and 2006b).*

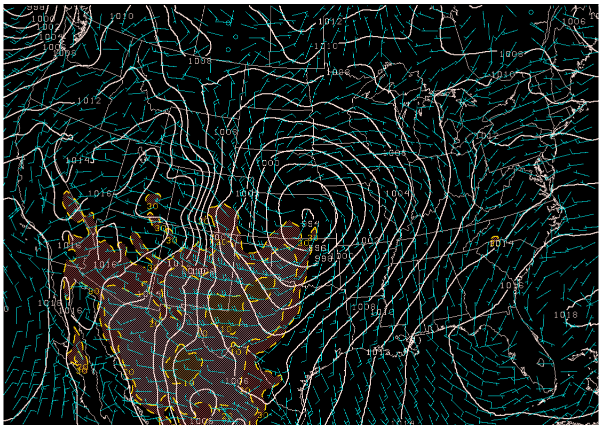


Figure 8: 2100 UTC RUC composite for MSLP (white contours in hPa), 10 m winds (blue barbs in kt), and 2 m relative humidity less than 30% (yellow dashed contours and image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

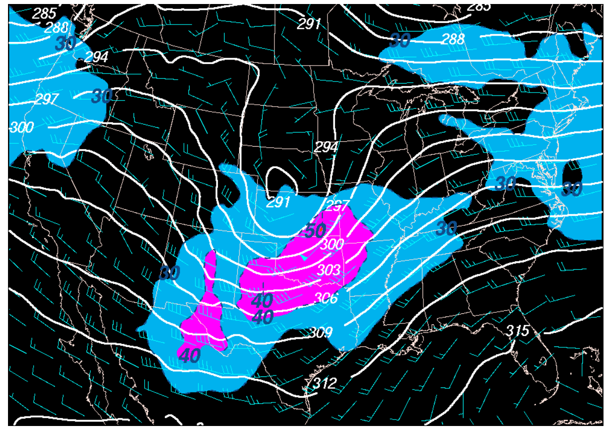


Figure 9: 2100 UTC RUC composite for 700 hPa heights (white contours in dam), winds (blue barbs in kt), and isotachs greater than 30 kt (15 m s^{-1}) (image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

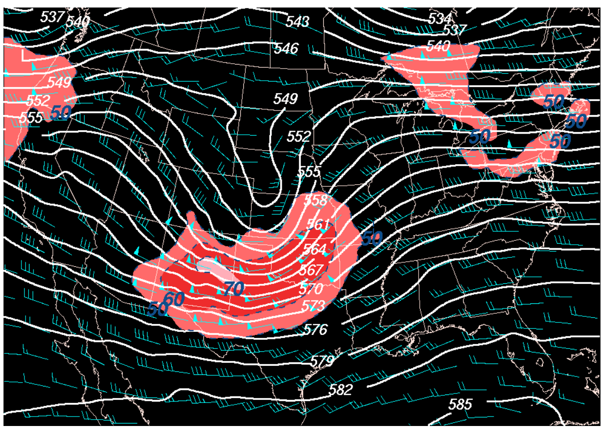


Figure 10: 2100 UTC RUC composite for 500 hPa heights (white contours in dam), winds (blue barbs in kt), and isotachs greater than 50 kt (26 m s^{-1}) (image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

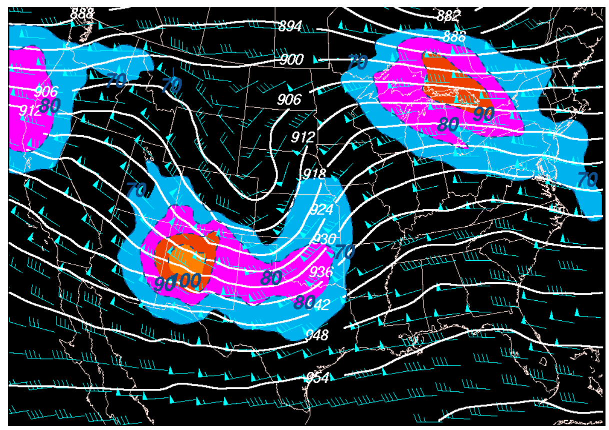


Figure 11: 2100 UTC RUC composite for 300 hPa heights (white contours in dam), winds (blue barbs in kt), and isotachs greater than 70 kt (36 m s^{-1}) (image) from six 2005/06 Southern Plains wildfire outbreaks. *Click the above image to see the full resolution figure.*

3. METEOROLOGICAL COMPOSITE

The six devastating Southern Plains wildfire outbreaks in 2005/06 occurred in association with the passage of intense middle latitude cyclones. This signal is strongly evident in the surface and constant pressure level composites. Schroeder et al. (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 these events were combined to derive a single graphical atmospheric composite chart for the 2005/06 Southern Plains wildfire outbreaks (Fig. 12). The composite highlights synoptic and mesoscale commonalities of these extreme fire weather episodes.

The Southern Plains wildfire outbreak composite analysis depicted 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. Mean winds at the 300 hPa level of 70 kt (36 m s^{-1}) overspread an expansive area of the Southern Plains, and a mean upper level jet maximum surpassing 100 kt (51 m s^{-1}) was noted over western and central New Mexico. The mean 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 composite analysis also depicted a closed lower tropospheric cyclone over the Southern Plains. A 291 dam low was located over northwestern Kansas and south-central Nebraska at the 700 hPa level, along with a broad area of south to southwest winds in excess of 40 kt (21 m s^{-1}) from eastern New Mexico and far west Texas eastward over Oklahoma, southeastern Kansas, and western Missouri.

The composite map was consistent with strong surface cyclogenesis over the Southern Plains, with a 994 hPa low centered near Salina, Kansas. 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 composite analysis progressing 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 in wind speed and direction are a recurring element common to many wildfire-related fatalities (NWCG 1997). Surface 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 (8 m s^{-1}) north of the front.

As previously noted, the synoptic and mesoscale weather features depicted in the atmospheric composite chart for a Southern Plains wildfire outbreak were coincident with severe (D2) to extreme (D3) long term drought conditions (U.S. Drought Monitor 2005 and 2006). It is noteworthy that numerous wildfires also burned across eastern Oklahoma, northeastern Texas, and to a lesser extent in extreme western Arkansas, where higher relative humidities and lower sustained wind speeds occurred east of the composite dryline location. This area is characterized by more rugged terrain and heavier vegetation compared to the grassy plains which experienced the most devastating impacts from the Southern Plains wildfire outbreaks. In addition, the thicker vegetative fuels in eastern Oklahoma, northeastern Texas, and western Arkansas also were subject to exceptional (D4) drought during the 2005/06 cool season.

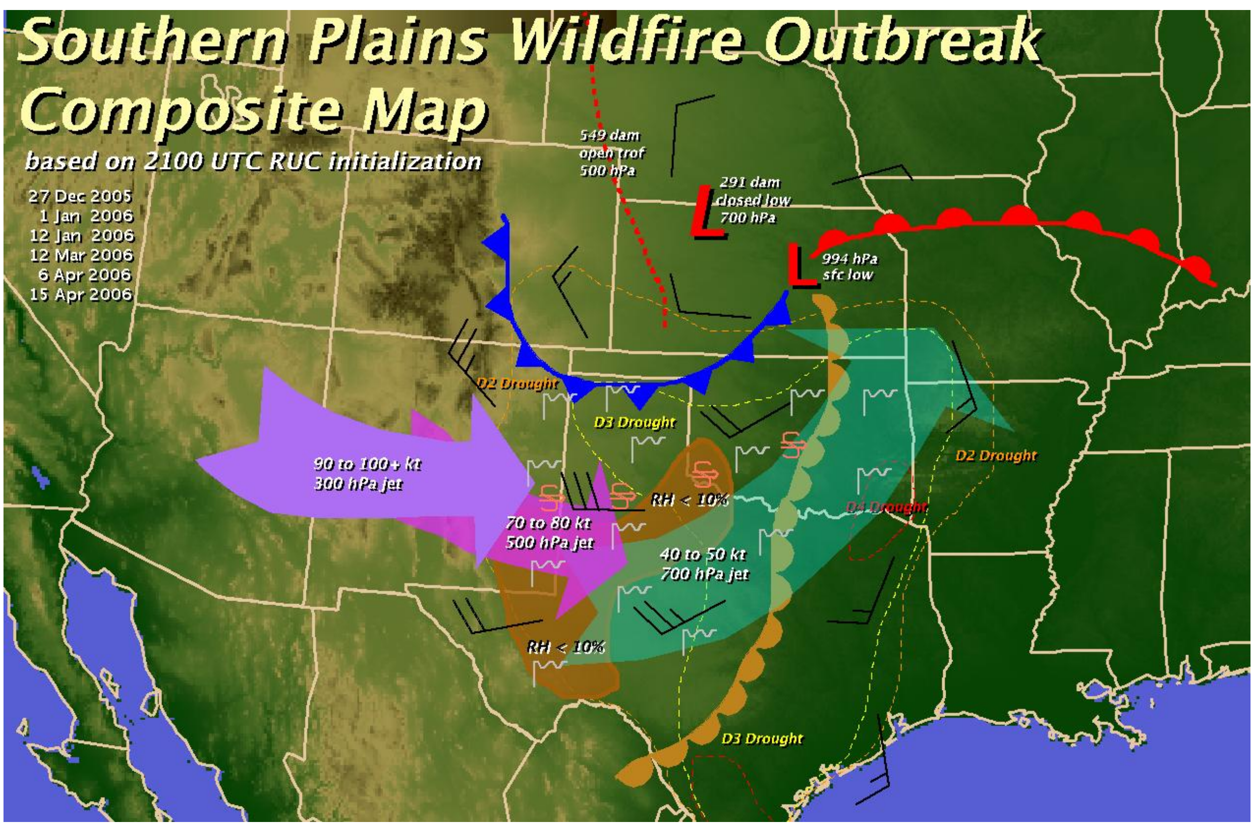


Figure 12: An operationally useful meteorological composite derived from 2100 UTC RUC analyses during six 2005/06 wildfire outbreaks in the Southern Plains. Key meteorological features at the surface and at varying atmospheric pressure levels aloft that contributed to the wildfire outbreaks are denoted. 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 surface 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, such as tornadoes, as defined by the American Meteorological Society (2007).

Meteorological composites generated using 2100 UTC RUC analyses 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 was depicted as a closed low at and below the 700 hPa pressure level, as intense surface cyclogenesis occurred over Kansas. A cold front, that extended southwestward from a low near Salina, Kansas, was depicted in the composite advancing southward over western Oklahoma, the Texas and Oklahoma Panhandles, and northeastern New Mexico. During at least two 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 severe (D2) to extreme (D3) drought conditions were ongoing.

The 2005/06 Southern Plains wildfire outbreaks will continue to be documented in meteorological literature. The authors plan to elaborate upon the composite presented here with information regarding the ambient climatic 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 in the Southern Plains, and improve operational fire weather forecast and warning capabilities prior to similar future events.

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Acknowledgments: The authors would like to thank Steve Cobb, Justin Weaver, Jose Valdez, Mark Conder, and John Holsenbeck of the National Weather Service Forecast Office in Lubbock, Texas, Amy McCullough of the National Weather Service Forecast Office in San Angelo, Texas, and Jeff Cupo of the National Weather Service Forecast Office in San Juan, Puerto Rico, for their technical and editorial contributions. Thanks to Steve Weiss at the Storm Prediction Center in Norman, Oklahoma, for his review of the manuscript, and a special thanks to David Bright for assistance in the processing of archived RUC data. Sharon Tarbet assisted in the editorial process.

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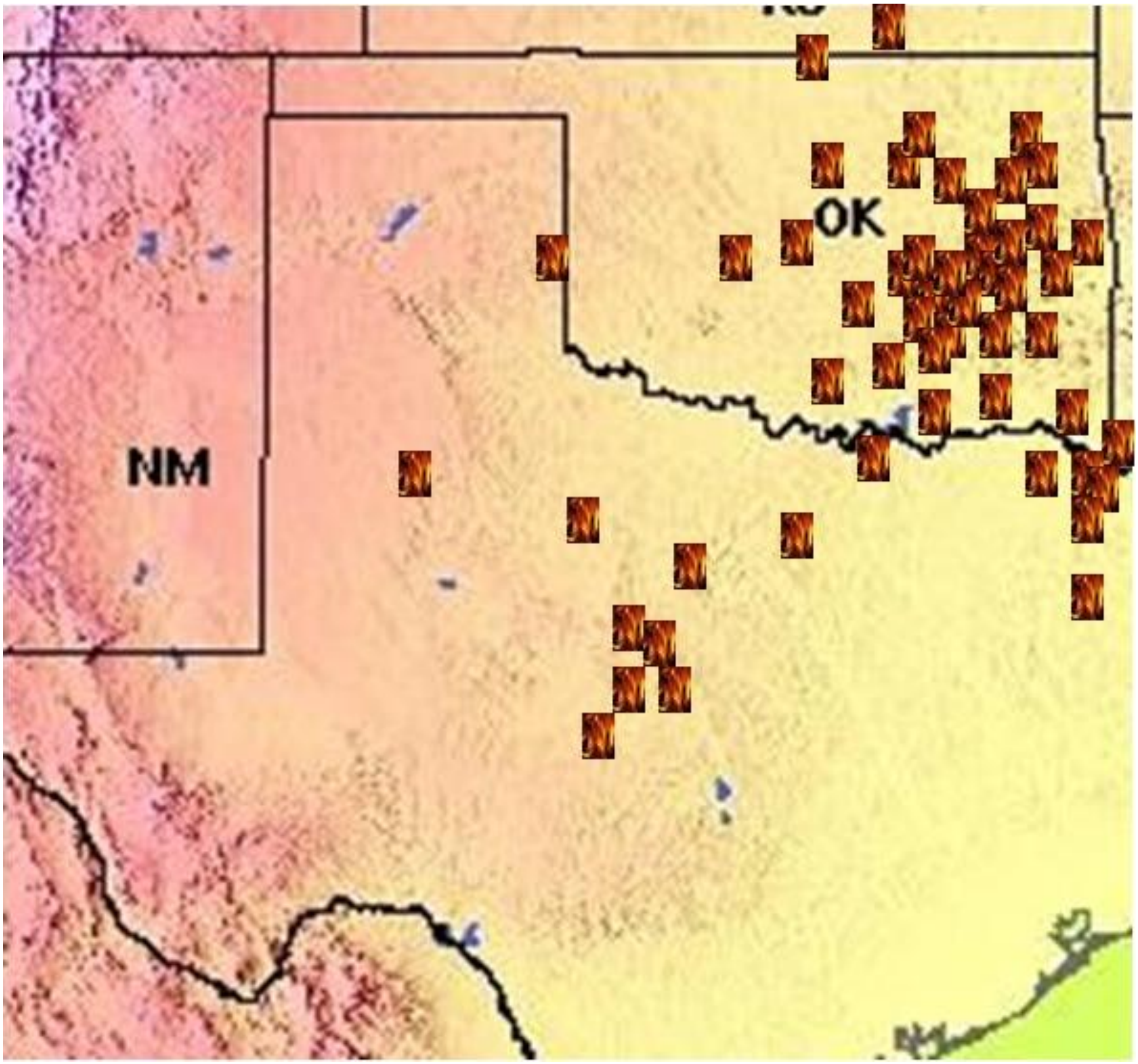


Figure 2: Major wildfire map for the 27 December 2005 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2005) and by the National Interagency Fire Center (NIFC 2005 and 2006b). *Click the figure to return to the main manuscript.*

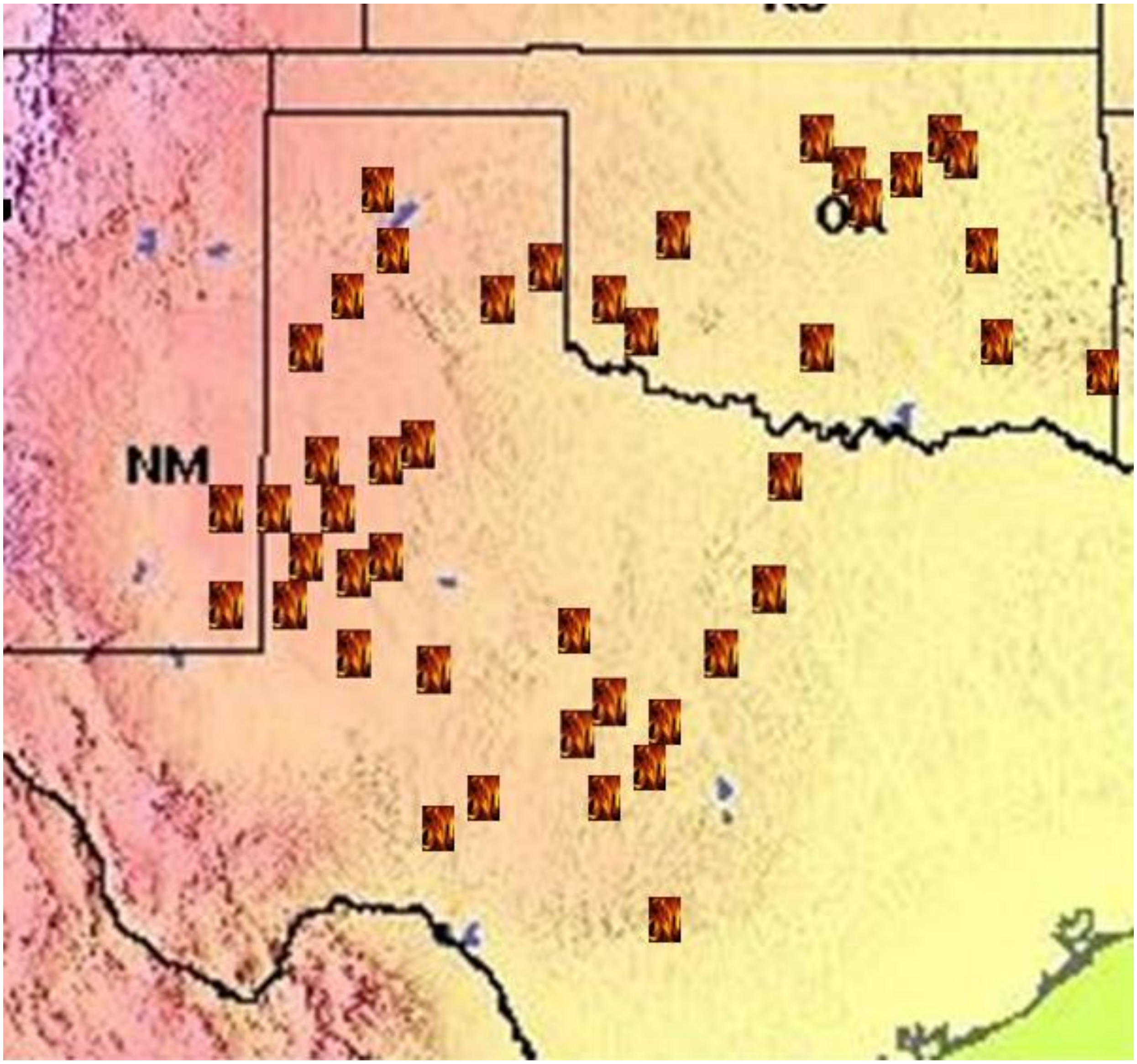


Figure 3: Major wildfire map for the 1 January 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006a) and by the National Interagency Fire Center (NIFC 2005 and 2006b). *Click the figure to return to the main manuscript.*

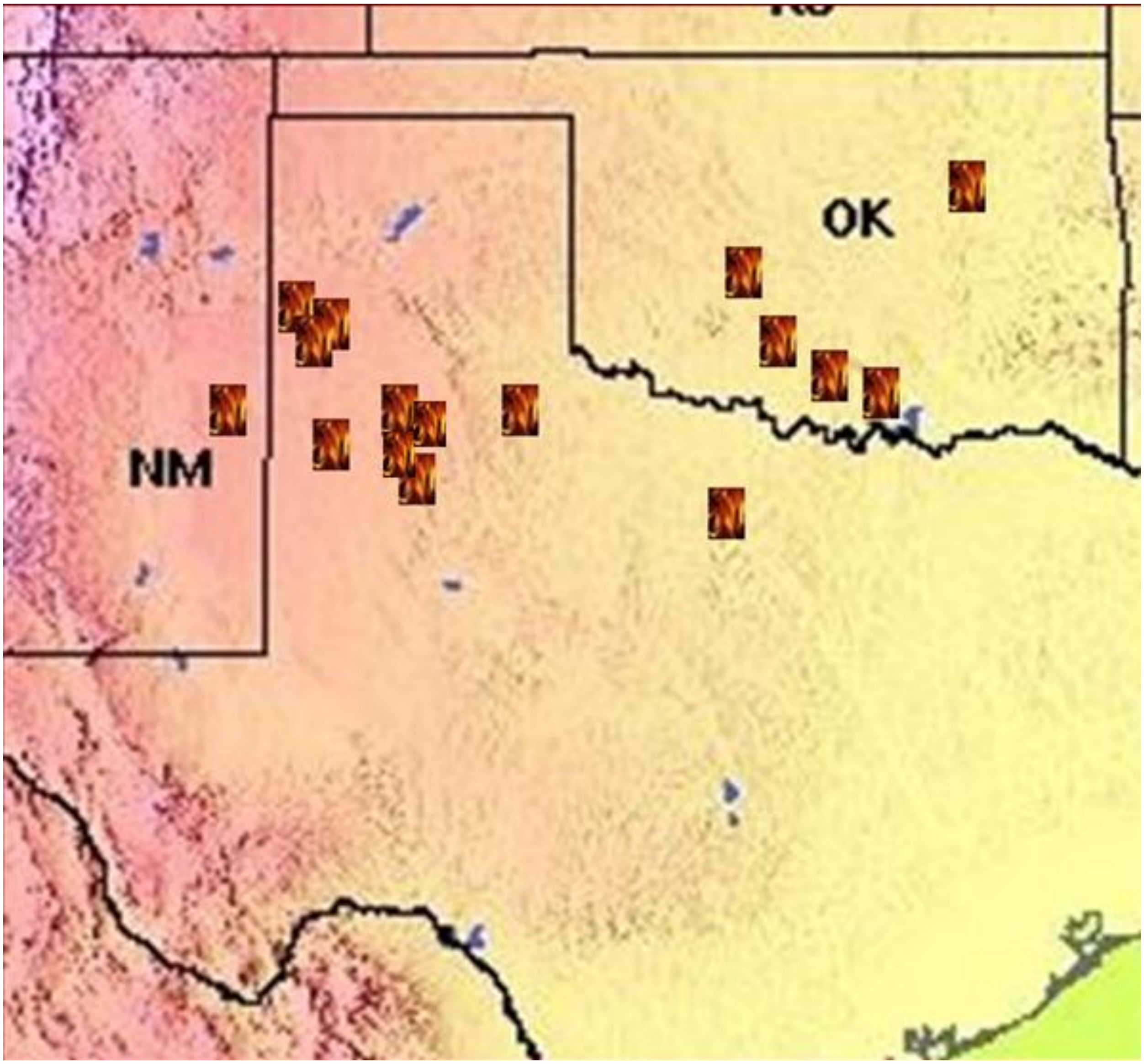
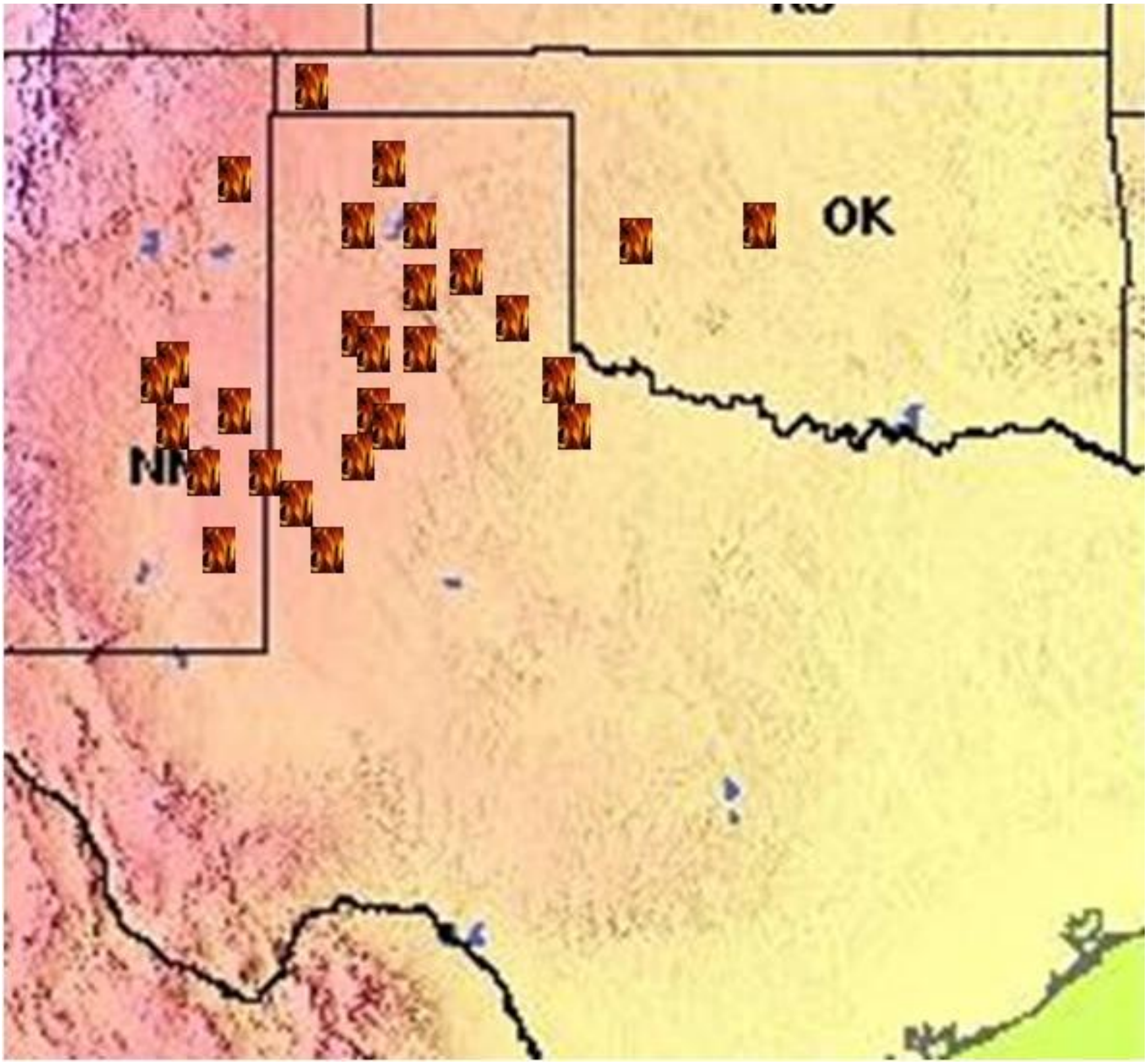


Figure 4: Major wildfire map for the 12 January 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006a) and by the National Interagency Fire Center (NIFC 2005 and 2006b). *Click the figure to return to the main manuscript.*



<u>Figure 5:</u> 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 the National Interagency Fire Center (NIFC 2005 and 2006b). *Click the figure to return to the main manuscript.*

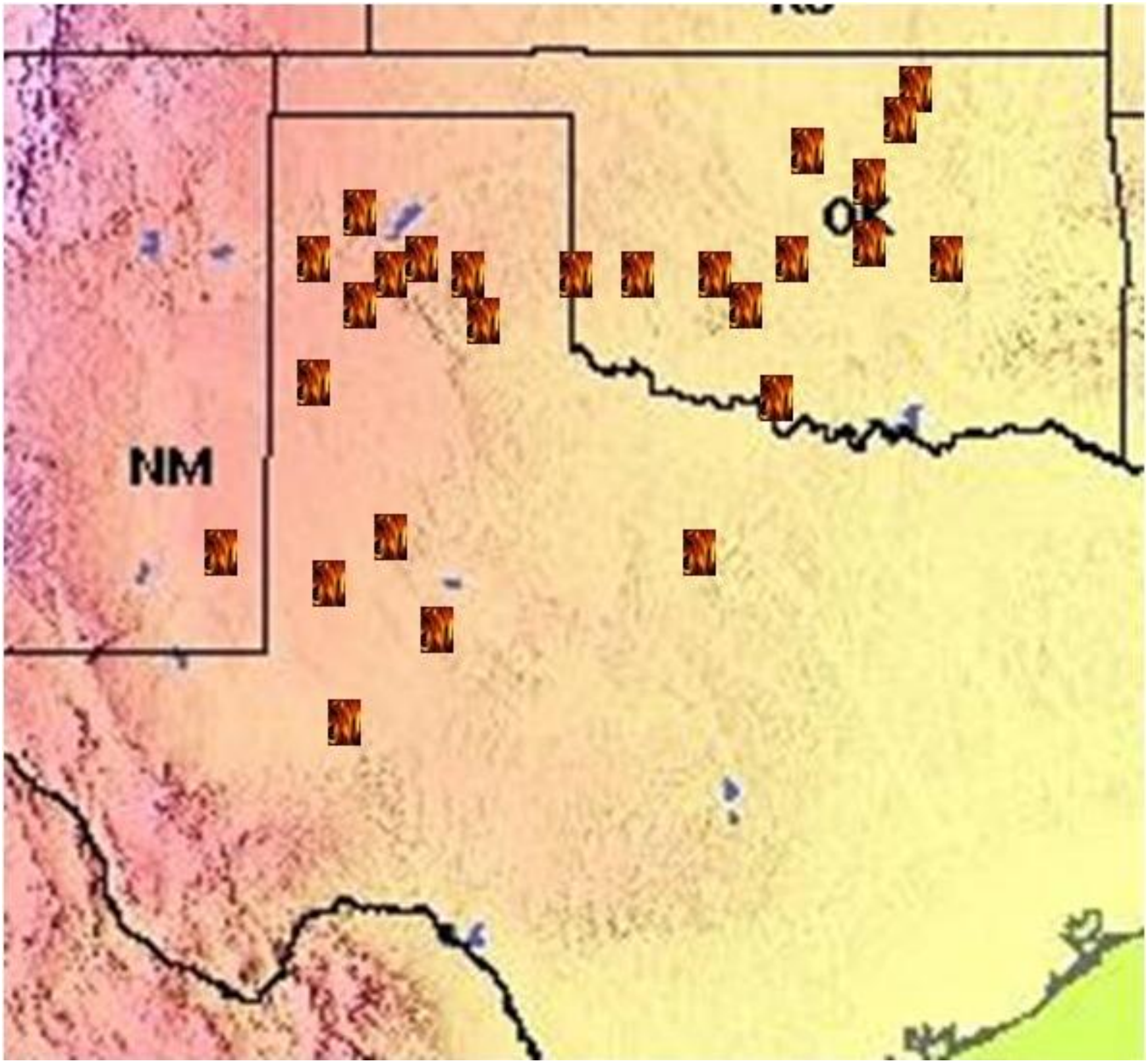


Figure 6: Major wildfire map for the 6 April 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006c) and by the National Interagency Fire Center (NIFC 2005 and 2006b). *Click the figure to return to the main manuscript.*

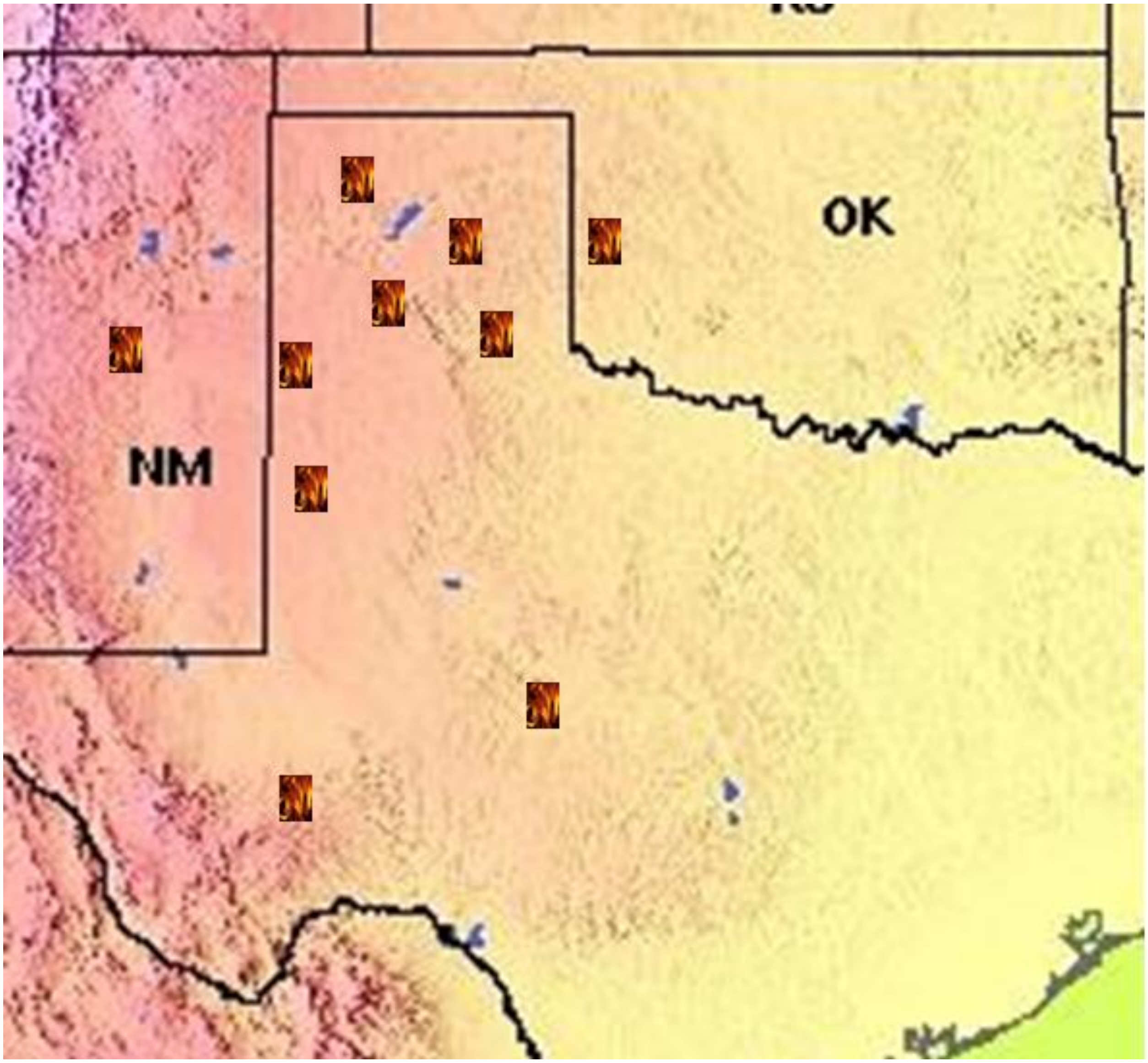


Figure 7: Major wildfire map for the 15 April 2006 wildfire outbreak. Wildfire locations based on fire detections per meteorological remote sensing and/or as reported in Storm Data (NOAA 2006c) and by the National Interagency Fire Center (NIFC 2005 and 2006b). *Click the figure to return to the main manuscript.*

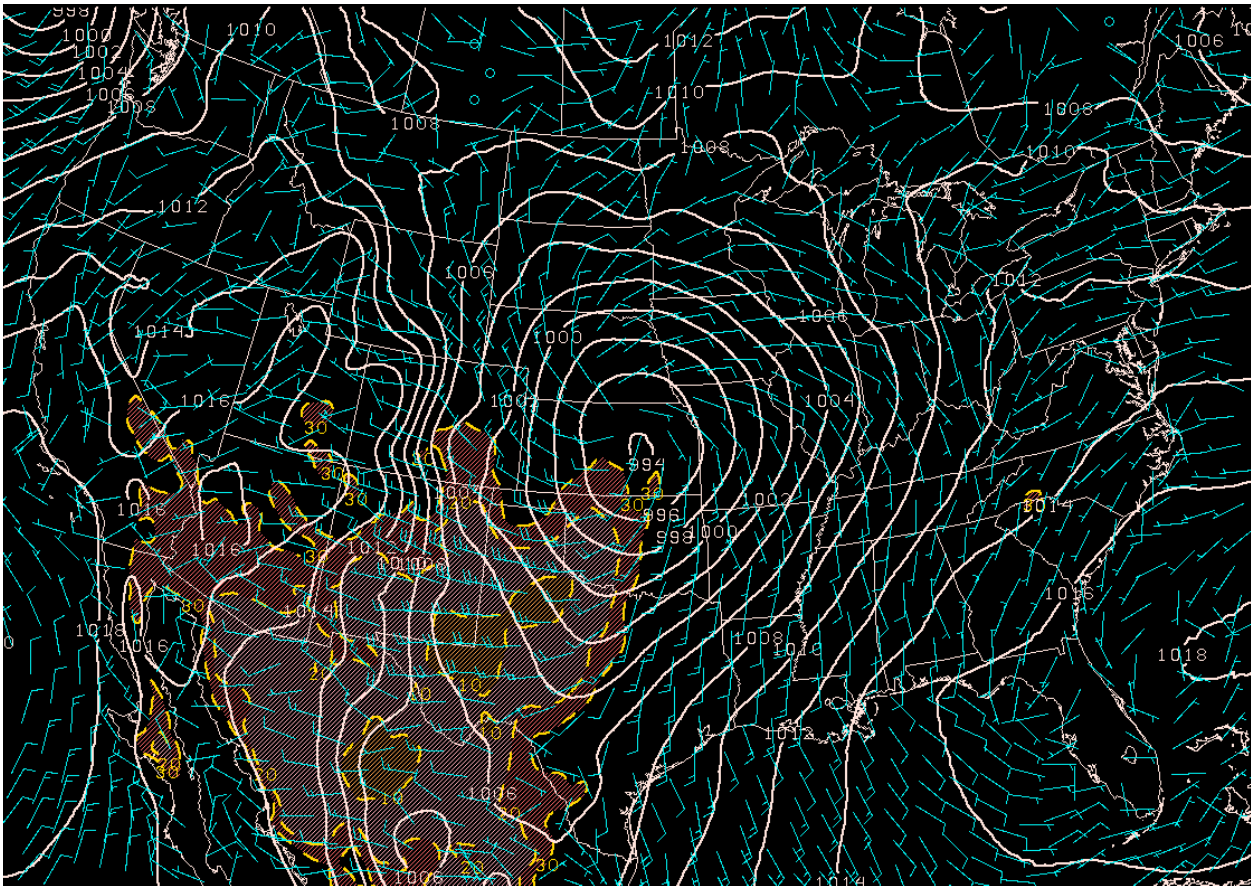
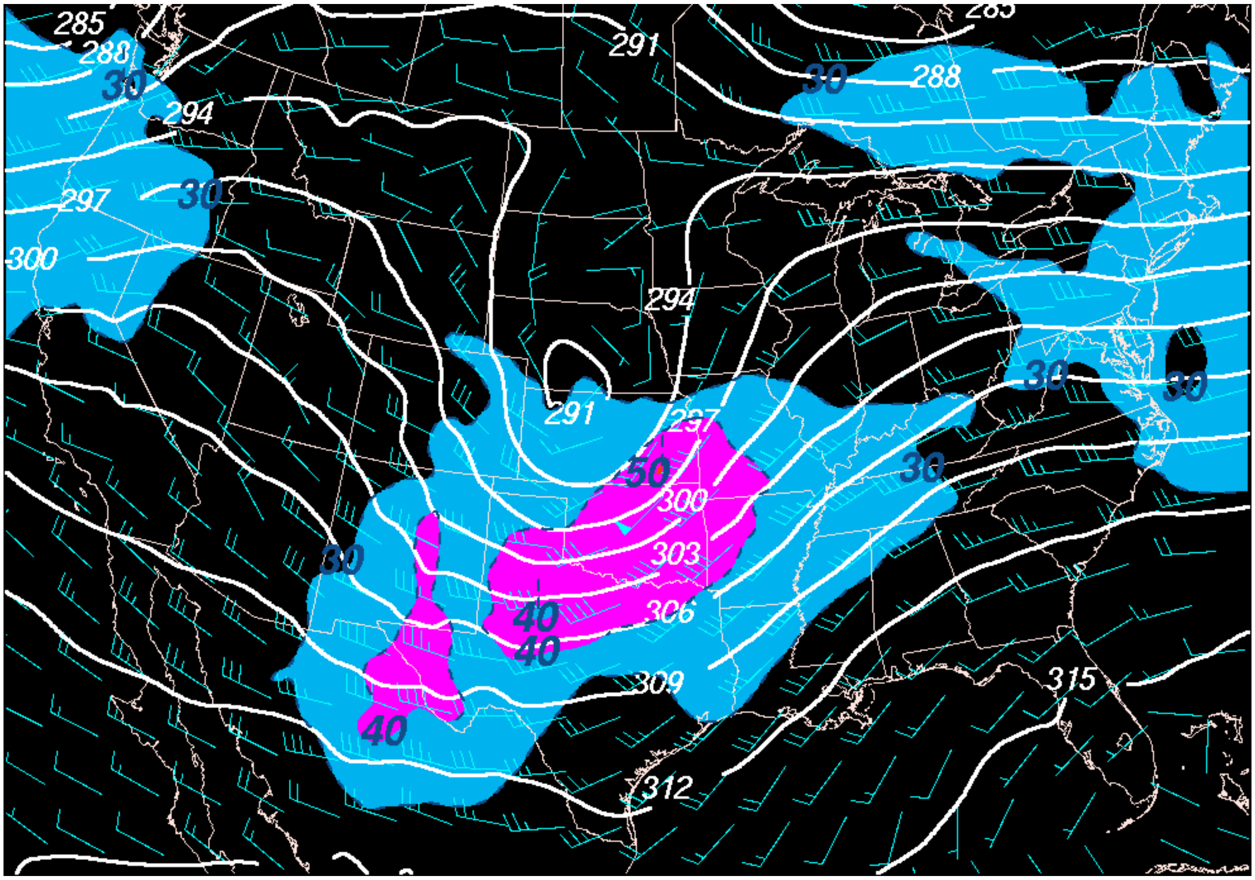


Figure 8: 2100 UTC RUC composite created in GEMPAK for the six 2005/06 Southern Plains wildfire outbreaks: 27 December 2005, 1 January 2006, 12 January 2006, 12 March 2006, 6 April 2006, and 15 April 2006. The meteorological fields are: MSLP (white contours in hPa), 10 m winds (blue barbs in kt), and 2 m relative humidity less than 30% (yellow dashed contours and image). *Click the figure to return to the main manuscript.*



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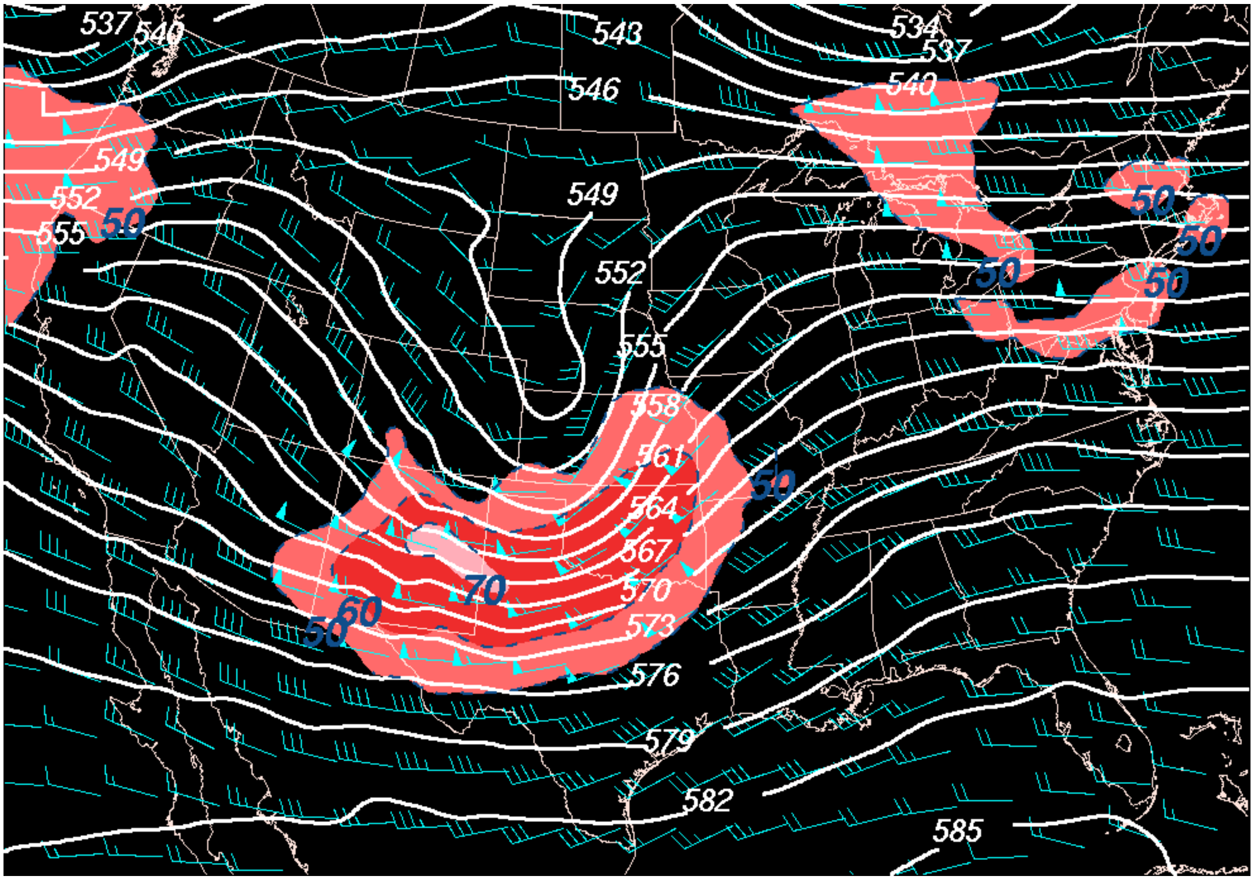

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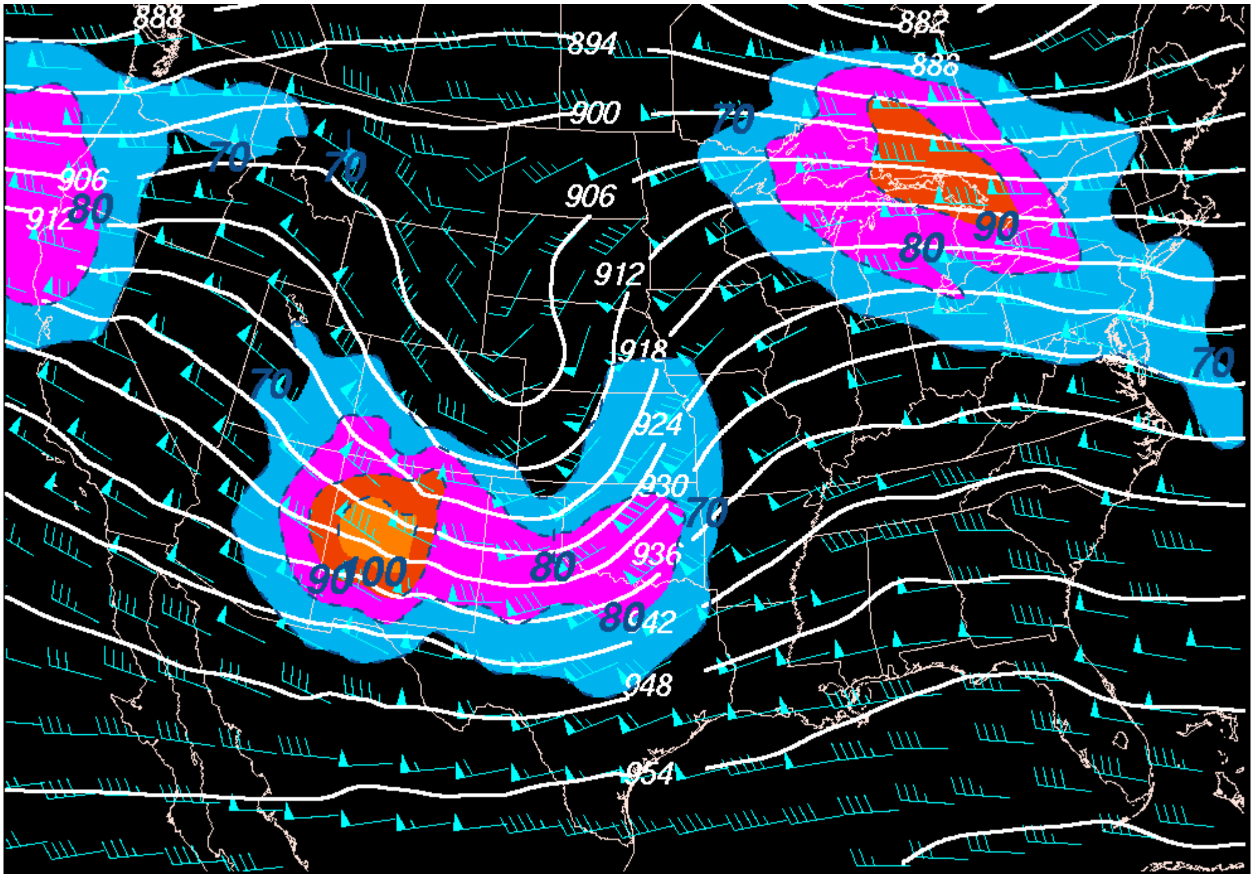

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