Using Teleconnections to Predict Wildfires in Mississippi

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(Manuscript received 28 June 2007, in final form 14 November 2007)

ABSTRACT

Previous wildfire research in the United States has been focused primarily on the western states. Much of this research has discovered relationships between wildfire variability and atmospheric teleconnections. Thus far, few published projects have addressed the effects of various teleconnections on wildfire in the southeastern United States. Index values for the El Niño–Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific decadal oscillation (PDO), and Pacific–North American (PNA) pattern are all tested for relationships with fire variables in the state of Mississippi. Each of the indices displays significant correlations with wildfire occurrence and/or size in Mississippi. The findings of this research suggest that it might be feasible to create predictive fire-risk models for the southeastern United States based on the combination of these teleconnection indices.

1. Introduction

Forest fires, both natural and human-induced, play an important role in determining the type, distribution, and evolution of forest landscapes. This is true even in the southeastern United States, as Waldrop et al. (1992) point out that fire has been a major ecological force in the evolution and distribution of forest types in the region. The seasonality and interannual variation of forest fires can play important roles in determining whether pine and grassland communities eventually transition into hardwood stands, thus affecting land management practices (Komarek 1965; Abrams 1992; Waldrop et al. 1992; Whitlock 2004). Therefore, it is important to understand the relationships between seasonal, annual, and decadal climate variables, and forest fires. Most forest fire research literature is dominated by studies on the western United States, and some clear relationships have been established between western fires and various climate patterns. There are not nearly as many studies of climatic effects on wildfires in the southeastern United States (Simard et al. 1985; Brenner 1991; Goodrick and Hanley 2005), but there is a respectable body of research literature that addresses the typical effects of those same climate patterns on the regional weather of the southeastern United States. Therefore, the purpose of this study is to merge two previously separate groups of research in order to gain a better understanding of the impacts that climate variability has, if any, on forest fires across the normally humid Southeast.

Western wildfires have been shown to be increasing over the last few decades and much research implies that these trends will continue (Covington 2000; Pierce et al. 2004; Westerling et al. 2006). Much of the research on western United States forest fires has focused on fire-suppressing land-use changes rather than climatic effects (Westerling et al. 2006). However, Westerling et al. (2006) argue that climate variability is the primary driver of wildfire risk, while some land uses may simply increase sensitivity to climatic effects. Unusually warm and/or early springs and longer, drier summers lead to extended fire seasons, but it is unclear if these are because of global climate change or regular cyclic climate teleconnections (Westerling et al. 2003, 2006).

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DOI: 10.1175/2007MWR2297.1

Because wildfires tend to occur during periods of drought, climatic moisture variables appear to be the most logical predictors of wildfire dependence upon climate. This is why the Palmer drought severity index (PDSI) and the Keetch–Byram drought index (KBDI) are commonly used in wildfire research and operational forecasting. According to some previous studies, PDSI is so strongly correlated with the occurrence of large fires that it can be used to make wildfire risk predictions up to a year in advance (Westerling et al. 2003; Keeley 2004). Conversely, Collins et al. (2006) suggest that PDSI is a good predictor of wildfires only during certain climatic phases (warm phases of the Atlantic Multidecadal Oscillation and Pacific decadal oscillation) and only for certain regions of the western United States. KBDI, which was developed for forested areas in the eastern United States, has been implemented into the U.S. National Fire Danger Rating System, and it is used primarily by fire managers (Keetch and Byram 1968; Andrews and Bradshaw 1997; Heim 2002). Unfortunately, both of these drought measures provide little help for predicting fire seasons as they are both based on current conditions that could change dramatically in the near future. It is imperative that relationships between climate teleconnections and wildfires be studied specifically for each region of interest in order to maximize predictive capabilities.

Climatic effects on western fires

Past research on fire–climate relationships have revealed numerous complex correlations that often depend on the constructive or destructive combinations of several teleconnection indices (Swetnam and Betancourt 1998; Kitzberger et al. 2001; Norman and Taylor 2003; Collins et al. 2006; Sibold and Veblen 2006). It has been shown that wildfire risk tends to increase in the western United States when dry years are preceded immediately by abnormally wet years, when vegetation is anomalously prevalent (Swetnam and Betancourt 1998; Kitzberger et al. 2001; Norman and Taylor 2003). Swetnam and Betancourt (1998) found the highest decadal fire–climate correlations in the southwestern United States during periods when the Southern Oscillation illustrated high amplitude and switched from extreme wet to dry years. Kitzberger et al. (2001) found that major southwestern fires tend to follow the switching from positive to negative El Niño–Southern Oscillation (ENSO) conditions. The increased moisture during positive ENSO conditions enhances the production of fuels, and then the drought conditions associated with a negative ENSO enhance the likelihood of sustained fires.

Unfortunately, assessing fire risk is not as simple as identifying the phase of ENSO. Norman and Taylor (2003) also found that fires are more widespread during warm, dry years that followed cool, wet years. However, the effect of ENSO appears to be modulated by the Pacific decadal oscillation (PDO), such that fires are more widespread when the PDO is in a warm or normal phase (Norman and Taylor 2003). It has also been suggested that the Atlantic multidecadal oscillation (AMO) may be the most dominant teleconnection index with respect to forest fire probability in the western United States (Sibold and Veblen 2006). It appears that no single teleconnection index is sufficient for assessing and/or predicting fire risk. A combination of negative ENSO (La Niña), negative PDO, and positive AMO seems to be the most reliable method for predicting wildfires in the western United States (Sibold and Veblen 2006).

2. Teleconnection relationships to climate in the Southeast

a. ENSO

ENSO appears to have a significant effect on the climate of the southeastern United States with respect to precipitation and, to some extent, temperature. Research shows increased precipitation during positive ENSO periods and decreased precipitation during negative ENSO periods, with both results being most pronounced during October–March (Ropelewski and Halpert 1986). Multiple studies have found that parts of the southeastern United States display cooler temperatures during most positive ENSO events (Ropelewski and Halpert 1986; Wu et al. 2005).

Supporting the ENSO generalizations above, previous studies of satellite-derived normalized difference vegetation index (NDVI) showed that positive sea surface temperature (SST) anomalies in the equatorial Pacific Ocean (associated with positive ENSO events) tend to be associated with summer droughts, increased winter precipitation, and decreased vegetation during both seasons in the southeastern United States (Mennis 2001; Peters et al. 2003). Peters et al. (2003) suggest that locations along the Gulf Coast and Florida experience increased vegetation during positive ENSO winters. The relationships between vegetation and negative ENSO periods seem less clear as Peters et al. (2003) found some decreases in vegetation while Mennis (2001) showed increases. This discrepancy is likely because of significant differences in the study areas of each project (three states versus nine states). Neutral ENSO events are shown to result in above-average vegetation in the Southeast (Peters et al. 2003).

Mennis (2001) points out that variations in deciduous forest vegetation, because of climatic anomalies, appear to be more pronounced than those in evergreen forests and croplands. For deeply rooted vegetation types (evergreen forest), groundwater provides a buffer against soil-water deficits during the growing season (Webb et al. 1978; Woodward 1987; Stephenson 1990; Jobbágy and Sala 2000). Findings by Xiao and Moody (2004) reinforce the importance of water balance as a primary determinant of spatial gradients in productivity. This suggests that climatic variability is reflected more quickly and has a greater impact on deciduous vegetation because of the shallower rooting characteristics. Despite significant correlations from studies conducted at various locations around the Southeast, effects of ENSO on Southeast vegetation are spatially inconsistent because of local factors such as land cover change, elevation, proximity to coastlines, pests, and diseases (Mennis 2001). However, there has been some research showing that Southeastern wildfires, especially in Florida, are significantly affected by variations in ENSO (Simard et al. 1985; Brenner 1991; Goodrick and Hanley 2005).

b. North Atlantic Oscillation (NAO)

The positive phase of the NAO reflects below-normal heights and pressure across the high latitudes of the North Atlantic, and above-normal heights and pressure over the central North Atlantic, the eastern United States, and western Europe. The negative phase reflects an opposite pattern of height and pressure anomalies over these regions. Both phases of the NAO are associated with basinwide changes in the intensity and location of the North Atlantic jet stream and storm track, and in large-scale modulations of the normal patterns of zonal and meridional heat and moisture transport (Hurrell 1995). Positive NAO, or an expanded subtropical ridge, is associated with above-normal temperature in the eastern United States (Greenland 2001) and dry spring seasons (Stahle and Cleaveland 1992).

c. PDO

The PDO represents low-frequency variability in extratropical SSTs in the North Pacific with a period of approximately 50 yr (Mantua et al. 1997). The warm phase of the PDO is associated with cooler than normal SSTs in the north-central Pacific and warmer than normal SSTs along the west coast of North America, while the cold phase is associated with the opposite SST patterns. Kurtzman and Scanlon (2006) found that the PDO's effects on the Southeastern climate are most detectable when phases are combined with those of ENSO. Then, positive PDO events tend to enhance positive ENSO anomalies from Louisiana to Florida (Kurtzman and Scanlon 2006).

d. Pacific–North American (PNA)

The positive phase of the PNA pattern features above-average heights in the vicinity of Hawaii and over the intermountain region of North America, and below-average heights located south of the Aleutian Islands and over the southeastern United States. The positive phase is most commonly associated with a more active and expanded jet stream over eastern Asia and the Pacific Ocean.

The positive phase of the PNA pattern is associated with above-average temperatures over western Canada and the extreme western United States, and below-average temperatures across the south-central and southeastern United States. The PNA tends to have little impact on surface temperature variability over North America during summer. The positive phase of the PNA pattern tends to be associated with Pacific warm episodes (positive ENSO), and the negative phase tends to be associated with Pacific cold episodes (negative ENSO; Climate Prediction Center 2007).

3. Data

Fire data were obtained from the Mississippi Forestry Commission and include all nonstructure fires in the state of Mississippi that required the activation of at least one fire department crew during the period of July 1990–June 2006. Small fires were documented by digitizing coordinates from field maps to digital maps (digital orthoimagery quarter quadrangles), while the approximate centroids of larger fires were recorded using GPS equipment aboard aircraft. All fire occurrences were aggregated into monthly totals for the purpose of this study.

According to the Climate Prediction Center (CPC), the operational definitions of El Niño (positive ENSO) and La Niña (negative ENSO) used by the National Oceanic and Atmospheric Administration (NOAA) require that the 3-month running-mean values of SST anomalies in the Niño-3.4 region be greater than ±0.5°C (positive anomalies being associated with El Niño events) for at least 5 consecutive months (details available online at http://www.cpc.noaa.gov/index.php). The Niño-3.4 region spans 5°N–5°S, 120°–170°W in the tropical Pacific Ocean (Trenberth 1997). Therefore, analyses for this study use monthly SST values from the Niño-3.4 region, obtained from the CPC.

The PDO index is defined as the leading principal component of monthly SST variability in the northern Pacific Ocean, poleward of 20°N latitude (Mantua et al.

1997; Zhang et al. 1997; Mantua and Hare 2002). Monthly PDO index data were obtained from the University of Washington's Joint Institute for the Study of the Atmosphere and Ocean (available online at http://jisao.washington.edu/pdo/PDO.latest).

Both the NAO and PNA indices are based on the leading rotated (varimax) principal component analyses of mean 500-mb heights in the Northern Hemisphere (20°–90°N latitude). [Please see Richman (1986) for more information regarding rotated principal components.] NAO values are based on observations over the Atlantic Ocean, while PNA values are based on observations over the Pacific Ocean (Barnston and Livezey 1987). Monthly data for both indices are obtained from CPC (available online at http://www.cpc.noaa.gov/index.php).

4. Methods

Monthly fire data for each month during the study period (192 total months) were aggregated into three categories: total fire events, average acres per fire event, and total acres burned. These categories are used as the dependent variables throughout the rest of the study. Pearson correlation coefficients (*r*) were then calculated for the relationships between each teleconnection index and each fire variable for each month of the year. The Pearson correlation coefficient (also called the Pearson product-moment coefficient of linear correlation) is used to measure the linear correlation between two variables (Wilks 2006). Such a relationship is considered significant if the probability of the observed test statistic (*p* value) is equal to or less than the test level, so smaller *p* values allude to more consistent correlations (Wilks 2006).

It is possible that variations in the teleconnection indices may not affect Mississippi fires until a few months later and/or the effects may last several months. Fire variables were also correlated with teleconnection index values from each of the 6 previous months in order to identify any lagging relationships. Unlike some western fire research, this project does not attempt to qualify fire risk based on conditions of the previous year (i.e., dry year following a wet year). It is assumed that fire fuels are always available in the region, and fire risk will usually be limited by soil moisture.

5. Results

During the study period, June 1990–July 2006, the state of Mississippi experienced 63 905 wildfires. By far, the months of February and March experienced the greatest number of fires while June and July saw the fewest (Fig. 1a). February, March, and April also experienced the largest fires, on average. The increased size and number of fires during February and March cause these months to experience the most acres burned each year (Figs. 1b,c).

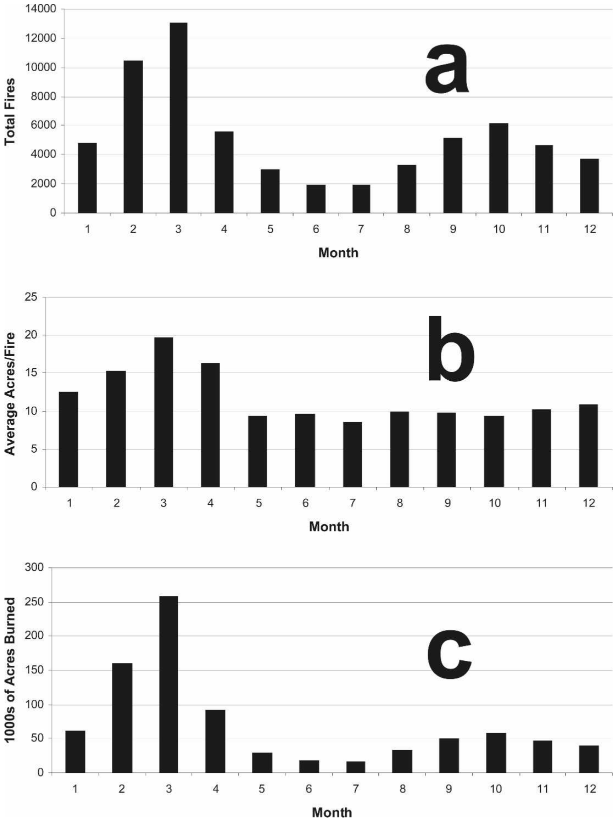

FIG. 1. (a) Total number of wildfires, (b) average number of acres burned per fire, and (c) total acres (×1000) burned by month for the study period from July 1990 to June 2006.

a. ENSO

The month of February appears to be consistently affected by ENSO values in preceding months, especially late summer and early autumn (Table 1). August fire variables display stronger and more consistent relationships with ENSO values for each of the preceding 6 months (Table 1). The month of September displays more sporadic ENSO–fire relationships, with only the ENSO values during the preceding June and July showing notable effects on fire size and total acres burned (Table 1).

All of these ENSO–fire relationships are negative (i.e., positive ENSO anomalies lead to decreased fire risk). This is most likely due to the annual minimum in precipitation that typically occurs in late summer. During these dry conditions, antecedent soil moisture becomes a primary factor controlling the fire occurrence and extent. Because positive ENSO anomalies usually

TABLE 1. Pearson correlation values (r) comparing fire variables for the months of February, August, and September to ENSO values 0–6 months earlier. Relationships with p values ≤0.10 are in boldface and those ≤0.05 are in italic.

		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
					Fire events			
Feb	r	−0.23	−0.26	−0.29	−0.38	**−0.43**	*−0.50*	**−0.43**
	p	0.39	0.34	0.28	0.15	**0.10**	*0.05*	**0.10**
Aug	r	−0.35	**−0.46**	*−0.53*	**−0.47**	*−0.49*	**−0.45**	**−0.44**
	p	0.18	**0.08**	*0.04*	**0.07**	*0.05*	**0.08**	**0.09**
Sep	r	−0.29	−0.28	−0.33	−0.37	−0.35	−0.37	−0.30
	p	0.27	0.29	0.22	0.16	0.19	0.16	0.26
					Acres per fire			
Feb	r	−0.24	−0.27	−0.26	−0.24	−0.18	−0.17	−0.11
	p	0.36	0.32	0.33	0.37	0.51	0.54	0.69
Aug	r	−0.31	**−0.44**	**−0.46**	**−0.46**	*−0.51*	**−0.44**	**−0.43**
	p	0.25	**0.09**	**0.08**	**0.08**	*0.05*	**0.09**	**0.10**
Sep	r	−0.33	−0.39	*−0.51*	**−0.47**	−0.14	−0.19	−0.17
	p	0.21	0.13	*0.04*	**0.07**	0.62	0.48	0.54
					Total acres			
Feb	r	−0.29	−0.32	−0.34	−0.42	**−0.45**	*−0.50*	**−0.44**
	p	0.28	0.23	0.20	0.11	**0.08**	*0.05*	**0.09**
Aug	r	−0.31	**−0.43**	*−0.50*	**−0.48**	*−0.51*	**−0.48**	**−0.47**
	p	0.24	**0.10**	*0.05*	**0.06**	*0.05*	**0.06**	**0.07**
Sep	r	−0.36	−0.37	**−0.43**	**−0.48**	−0.42	**−0.44**	−0.37
	p	0.17	0.16	**0.10**	**0.06**	0.11	**0.09**	0.16

TABLE 2. Pearson correlation values (r) comparing fire variables from the months of March, April, October, November, and December to NAO values 0–6 months earlier. Relationships with p values ≤0.10 are in boldface and those ≤0.05 are in italic.

		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
					Fire events			
Mar	r	0.00	−0.26	0.12	0.12	0.16	0.11	*0.56*
	p	0.99	0.34	0.66	0.65	0.57	0.69	*0.03*
Apr	r	0.27	−0.10	**-0.45**	−0.23	−0.22	−0.28	0.04
	p	0.31	0.72	**0.08**	0.39	0.41	0.30	0.89
Oct	r	*0.55*	*0.52*	0.20	−0.29	−0.23	−0.20	−0.18
	p	*0.03*	*0.04*	0.46	0.28	0.39	0.45	0.51
Nov	r	0.09	0.42	**0.48**	**0.45**	−0.20	−0.01	−0.21
	p	0.75	0.10	**0.06**	**0.08**	0.45	0.98	0.44
Dec	r	0.12	0.09	0.38	*0.59*	**0.44**	−0.36	0.19
	p	0.65	0.75	0.15	*0.02*	**0.09**	0.17	0.48
					Acres per fire			
Mar	r	*−0.59*	*−0.69*	0.41	−0.04	0.00	−0.16	0.38
	p	*0.02*	*0.00*	0.12	0.89	0.99	0.56	0.15
Apr	r	−0.04	−0.38	**-0.44**	−0.21	**-0.48**	*−0.58*	0.24
	p	0.88	0.14	**0.09**	0.44	**0.06**	*0.02*	0.38
Oct	r	*0.60*	**0.44**	−0.21	−0.29	−0.13	−0.08	−0.36
	p	*0.01*	**0.09**	0.44	0.27	0.63	0.77	0.17
Nov	r	−0.27	0.36	0.20	0.38	**-0.48**	−0.35	−0.38
	p	0.31	0.17	0.46	0.14	**0.06**	0.18	0.15
Dec	r	−0.15	−0.22	−0.04	0.38	0.41	0.29	0.06
	p	0.58	0.42	0.89	0.15	0.11	0.27	0.81
					Total acres			
Mar	r	−0.30	*−0.52*	0.25	−0.02	0.03	−0.03	**0.49**
	p	0.26	*0.04*	0.35	0.93	0.92	0.92	**0.06**
Apr	r	0.13	−0.29	*−0.53*	−0.17	−0.36	**-0.44**	0.12
	p	0.63	0.27	*0.04*	0.53	0.17	**0.09**	0.65
Oct	r	*0.62*	**0.48**	0.04	−0.26	−0.12	−0.13	−0.18
	p	*0.01*	**0.06**	0.89	0.32	0.67	0.63	0.51
Nov	r	0.04	0.41	*0.50*	**0.48**	−0.21	−0.07	−0.25
	p	0.89	0.12	*0.05*	**0.06**	0.45	0.79	0.36
Dec	r	0.06	0.01	0.33	*0.60*	**0.47**	−0.23	0.19
	p	0.81	0.98	0.21	*0.01*	**0.06**	0.38	0.48

result in increased precipitation across the Southeast, soil moisture remains high.

b. NAO

The relationships between fire variables and the NAO appear to be driven by NAO values in early spring and autumn. Unlike the ENSO–fire relationships, which appear to show that a few particular fire months are directly related to multiple preceding months of climate variation, NAO–fire correlations suggest that a few months of NAO values tend to have direct effects on fires during several of the following months. March and April fires display notable correlations with the previous February NAO values (Table 2). Likewise, fire variables during the months of October, November, and December all depend on NAO variations during August, September, and October (Table 2).

During some months, the NAO–fire relationship is positive, while it is negative during other months or lag times. During winter, negative NAO is associated with a cool, dry northwesterly flow that decreases winter and spring precipitation and leads to diminished soil moisture and increased fire risk for late spring and early summer. During autumn, positive NAO is associated with a dry zonal flow in the southeast United States. This zonal flow is more likely to be accompanied by nonconvective precipitation and lighter winds. More analyses focusing on smaller-scale variables (local precipitation, wind, lightning, etc.) are required to gain a better understanding of these relationships.

c. PDO

PDO–fire correlations are similar to those for ENSO such that a few fire months are consistently affected by teleconnection anomalies during several preceding months. The fire variables for February show consistent correlations with PDO values during the months of November, December, and January (Table 3). July fire events display strong correlations only with January PDO values, but the relationships are quite impressive (Table 3). PDO values from six months earlier (February) also appear to modulate fires in August. All three fire variables for the month of August display notable

TABLE 3. Pearson correlation values (*r*) comparing fire variables from the months of February, July, and August to PDO values 0–6 months earlier. Relationships with *p* values ≤0.10 are in boldface and those ≤0.05 are in italic.

		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
					Fire events			
Feb	*r*	**−0.43**	*−0.55*	**−0.46**	−0.36	−0.22	−0.16	−0.28
	p	**0.10**	*0.03*	**0.07**	0.17	0.42	0.56	0.29
Jul	*r*	−0.24	−0.16	−0.14	0.00	−0.08	−0.32	*−0.58*
	p	0.37	0.55	0.59	1.00	0.77	0.23	*0.02*
Aug	*r*	**−0.48**	−0.38	−0.38	−0.41	−0.29	−0.42	*−0.55*
	p	**0.06**	0.15	0.15	0.11	0.29	0.11	*0.03*
					Acres per fire			
Feb	*r*	−0.08	−0.03	−0.24	*−0.52*	−0.39	−0.32	−0.30
	p	0.76	0.92	0.37	*0.04*	0.14	0.23	0.27
Jul	*r*	−0.26	−0.10	0.03	0.04	0.30	0.14	−0.06
	p	0.32	0.70	0.90	0.89	0.25	0.60	0.83
Aug	*r*	**−0.48**	**−0.43**	−0.26	−0.32	−0.09	−0.14	−0.33
	p	**0.06**	**0.10**	0.33	0.23	0.73	0.59	0.21
					Total acres			
Feb	*r*	−0.40	*−0.51*	**−0.46**	**−0.43**	−0.29	−0.23	−0.35
	p	0.12	*0.05*	**0.07**	**0.10**	0.27	0.38	0.19
Jul	*r*	−0.30	−0.20	−0.18	−0.01	0.01	−0.26	*−0.55*
	p	0.26	0.45	0.50	0.98	0.99	0.34	*0.03*
Aug	*r*	**−0.48**	−0.38	−0.34	−0.38	−0.22	−0.32	*−0.50*
	p	**0.06**	0.14	0.20	0.15	0.42	0.22	*0.05*

correlations with August PDO values (Table 3). Of course, such a relationship provides little in the way of predictive ability.

Much like ENSO, there is a negative relationship between PDO and fire events in Mississippi. Positive PDO periods are also accompanied by increased precipitation across the southeast United States, so soil moisture is able to remain above normal.

d. PNA

PNA values illustrate the most impressive and consistent relationships with fire variables, as at least two of the three fire variables in each of the months from July to October display statistically significant correlations with July PNA values (Table 4). This leaves little doubt about the importance of July PNA values to the upcoming fire season of late summer and autumn. There are also some interesting PNA–fire relationships between late winter fires and autumn PNA anomalies, but they are somewhat inconsistent and require further research before being presented.

Only slightly more than half of the presented relationships display negative PNA–fire relationships, but only one of the statistically significant ($\alpha = 0.10$) relationships has a positive value (Table 4). All of the important relationships between July PNA values and the following fire months are negative. Below-average heights associated with the positive PNA usually lead to lower temperatures across the Southeast, which should yield less evaporation, above-average soil moisture, and fewer fires.

TABLE 4. Pearson correlation values (*r*) comparing fire variables from the months of July, August, September, and October to PNA values 0–6 months earlier. Relationships with *p* values ≤0.10 are in boldface and those ≤0.05 are in italic.

		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
					Fire events			
Jul	*r*	*−0.67*	−0.29	−0.01	−0.09	0.37	0.15	**−0.47**
	p	*0.01*	0.28	0.96	0.75	0.16	0.59	**0.06**
Aug	*r*	0.34	*−0.68*	−0.30	−0.06	−0.14	0.34	−0.17
	p	0.20	*0.00*	0.26	0.83	0.60	0.19	0.53
Sep	*r*	0.09	**0.47**	*−0.50*	0.06	0.07	−0.03	0.18
	p	0.75	**0.07**	*0.05*	0.81	0.79	0.92	0.51
Oct	*r*	0.13	0.13	0.24	−0.35	−0.10	0.20	0.30
	p	0.64	0.62	0.37	0.18	0.71	0.45	0.26
					Acres per fire			
Jul	*r*	0.02	0.17	0.16	0.21	0.36	0.06	−0.07
	p	0.94	0.53	0.55	0.44	0.17	0.82	0.79
Aug	*r*	0.17	**−0.46**	−0.27	−0.08	−0.19	0.18	−0.06
	p	0.54	**0.07**	0.31	0.78	0.49	0.52	0.81
Sep	*r*	−0.20	0.02	−0.40	0.03	−0.04	0.17	*0.52*
	p	0.45	0.93	0.13	0.90	0.88	0.54	*0.04*
Oct	*r*	0.30	0.09	0.14	*−0.51*	0.08	−0.05	0.36
	p	0.25	0.73	0.61	*0.04*	0.78	0.86	0.18
					Total acres			
Jul	*r*	*−0.63*	−0.26	−0.08	−0.07	0.40	0.26	**−0.42**
	p	*0.01*	0.34	0.78	0.78	0.12	0.34	**0.10**
Aug	*r*	0.21	*−0.73*	−0.32	−0.06	−0.17	0.36	−0.05
	p	0.44	*0.00*	0.22	0.83	0.53	0.16	0.85
Sep	*r*	0.01	0.39	*−0.59*	0.05	0.03	−0.01	0.28
	p	0.97	0.13	*0.02*	0.85	0.92	0.96	0.30
Oct	*r*	0.19	0.06	0.21	*−0.55*	−0.11	0.13	0.13
	p	0.49	0.83	0.43	*0.03*	0.69	0.64	0.63

6. Conclusions

This paper is the result of some preliminary studies of the relationships between a few widely used teleconnection indices and forest fires across the state of Mississippi. Now that some consistent significant correlations have been established, future work will focus on the development of predictive fire-risk models for individual regions of the state during each month. It is anticipated that certain regions of the state will yield different results from predictive models based on these teleconnections due to variations in forest density, forest type, agriculture distribution, soil type, and presence of population centers.

It is already evident that fires across the entire state during the winter months are related to variations in ENSO and NAO values during late summer and autumn. Some of the fires during late winter months show

TABLE 5. Actual July PNA values and numbers of August wildfires for the years 1991–2005. Columns are sorted from lowest to highest PNA value. Last column shows the relative rank of that year based on the number of wildfires in August (15 = most fires).

Yr	Jul PNA	Aug fires	Rank
2000	−2.28	911	15
1999	−0.54	555	14
1995	−0.34	215	13
2001	0.06	26	2
2004	0.09	83	9
1993	0.15	75	8
1994	0.38	89	10
2005	0.43	70	7
1997	0.56	63	6
1996	0.64	63	5
1991	0.75	171	11
1992	0.85	46	4
2002	0.88	44	3
2003	1.23	19	1
1998	2.24	189	12

some correlations with PDO and PNA anomalies just a couple months prior. This is important because the late winter encompasses the two most active fire months in Mississippi (February and March). Late summer fire variables can be predicted by anomalies in ENSO values of the preceding 6 months, and fire variables during late summer and early autumn (July–October) are strongly dependent upon PNA variation in July. This is important as these are the months leading up to the secondary maximum that occurs in October.

There appear to be fewer reliable connections between transitional-season fires (spring and autumn) and teleconnection values several months in advance. Spring fires show some relationships to NAO variability during late winter, but this does not provide much lead time. Likewise, autumn fires seem to depend somewhat on NAO values during the late summer and early autumn months, with as much as 4-months lead time.

Given the strength of the relationships between monthly fires and some of these teleconnection anomalies for the entire state of Mississippi, there is little doubt that regional analyses of the state will yield even stronger correlations for some portions of the state. For these areas, it is anticipated that a predictive fire-risk model can be quite accurate and useful. Table 5 shows the success of July PNA values predicting August wildfires. During 1991–2005, only three years (1991, 1998, 2001) stand out with relatively large or small values for both July PNA and August wildfires. The use of teleconnection indices, in conjunction with ambient conditions of moisture, temperature, wind, and ongoing drought, should provide better forecasts of coming months as opposed to just a measure of previous months. While ambient conditions can be used to assess real-time fire risk, as is commonly done throughout the country, these results show that it is feasible to create a fire-risk model capable of 6-month forecasts for at least a few months of each year.

Acknowledgments. The authors acknowledge Patrick Glass and Randel Romedy of of the Mississippi Forestry Commission. Their help with the fire data was invaluable. Also, part of this research was funded by a grant from NASA.

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