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# USING CLIMATIC ANOMALIES TO FORECAST WILDFIRES IN PENNSYLVANIA

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## 1. INTRODUCTION

Hundreds of wildfires (WF) occur across Pennsylvania each year. The majority of these WFs are small and affect only a few acres. The spring WF season is the most active with the majority of WFs occurring between March and May. A secondary WF peak appears in the autumn (October-December). Occasionally, the combination of high temperatures, and extended periods of dry weather create active WF period during the summer months.

The average annual extinction expense for Pennsylvania's Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (BOF) in the form of staffing, equipment rental (aircraft and bulldozers), and other miscellaneous items such as food, amounts to around $500,000. Much greater damage from each fire can be attributed to the loss of valuable timber, watershed, and recreational land. Large fires (> 100 acres) that impact Pennsylvania are the most costly to the DCNR BOF, and to private and public landowners. The total monetary loss associated with each of the most common variety of large fires (those burning 100 to 150 acres) averages between $15,000 and $30,000.

This paper will focus on 153 large wildfires (> 100 acres) that occurred across Pennsylvania during the 19-year period 1983-2001. Favorable weather parameters for the creation of large WFs, along with their anomalies from 30-year climatology, will be examined with the goal of finding distinct weather patterns leading to active periods of large WFs. Additional emphasis will be placed on factors relating to seasonal and geographical variability of fire size and frequency.

## 2. METHOD AND DATA

Data for individual fire size and location was obtained from the BOF Division of Forest Fire Protection's Wildfire Reports. Information contained within this data set includes: fire location by county, township, and landmark or town, extinctions costs pertaining to employees and equipment along with estimated damage to timber, recreation, wildlife, and public or personal property. Latitude and longitude for each fire was derived from the locations listed on the reports.

Climatic anomalies based on departure from 30-year climatology were extracted from the NCDC reanalysis data as described in Hart and Grumm (2001). Climatic anomalies were computed for dates with WFs > 100 acres. The anomalies were used to analyze important fire weather parameters such as 850 hPa temperature, 850 hPa U and V wind components, and precipitable water (PW). Anomalously strong 850hPa wind combined with low PW values imply a dry, well mixed lower atmosphere. The presence of anomalously warm 850 hPa temperatures would infer greater instability and combined with the above conditions would be conducive for fire growth. Additional parameters that help to distinguish favorable patterns for WFs are 250hPa U and V wind components, 500hPa geopotential heights, and mean sea level pressure (MSLP).

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## 3. RESULTS

3.1 *Fire Sizes*

A high percentage (90%) of the 153 cases of WFs examined fell into the range of 100-499 acres. Pennsylvania WFs of 500-999 acres, and those burning an area > 1000 acres each comprised only 5% of the total (Fig. 1).

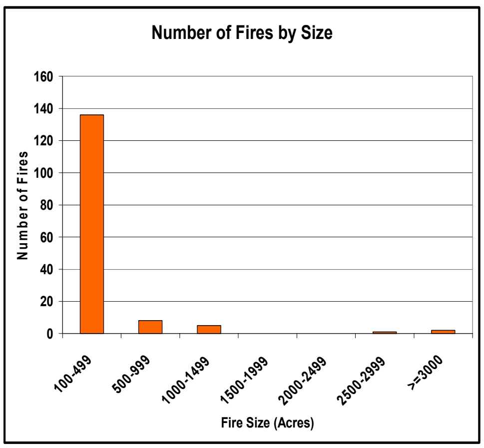


**Figure 1. The number of fires grouped by acreage burned.**

An extended period of heat, drought, and relatively high winds are the primary factors that allow fires to grow larger than 100 acres. However, heat appears to be the least important meteorological factors for fire occurrence and growth in Pennsylvania. Terrain slope and accessibility to the fire also play a major role in the ultimate size of the fire. Fire size increases rapidly on steep terrain as fuels upslope from the fire are heated. Rapid fire growth also occurs in remote locations (even in the absence of steep terrain) which are not easily accessible by fire fighting personnel and equipment via logging roads or recreational trails

3.2 *Monthly and Seasonal Distribution*

A distinct peak in fire occurrence and the size of individual fires occurs from late March through May (Fig. 2 and 3) suggesting a spring fire season with April as the single most active WF month. There were 4 unusually active WF periods. All of these events fell within about a 6 week period from late March into early May (not shown). Each of these periods contained 2 or more consecutive days with WFs, including at least one day with 4 or more WFs. Several fires >1000 acres also occurred during these periods.

A secondary WF season is observed in the autumn with November being the single most active month. The autumn WF season accounted for 27 cases (18%) of all fires > 100 acres. Limiting autumn WF factors are:

1) *The relatively short period of anomalously strong gradient winds coinciding with dry leaf litter on the ground.*
2) *Significant and widespread rainfall from the remnants of Tropical Storms or Hurricanes.*
3) *Extensive fog in the valleys until the late morning on an otherwise clear day during the month of October.*
4) *A lower mean sun angle compared to the Spring when fuel is available.*

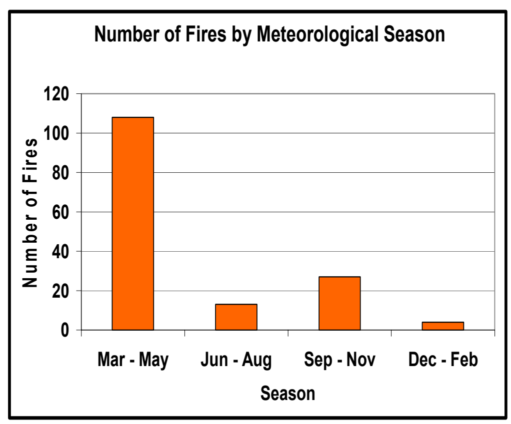


**Figure 2. Number of fires that burned 100 or more acres occurring in each 3 month meteorological season.**

3.3 *Geographical Distribution*

The majority of Pennsylvania WFs occur in the western Pocono Mountain region and along the Allegheny Front in central Pennsylvania (Figure 4).

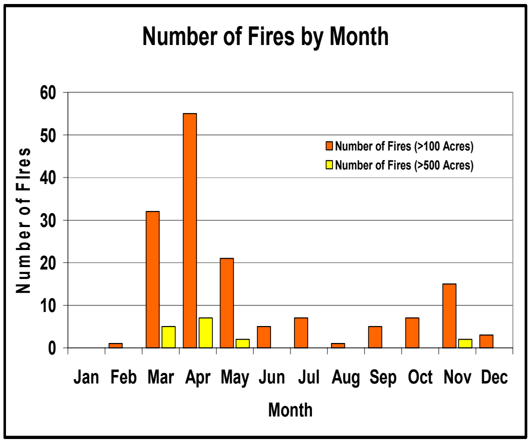


**Figure 3. Number of wildfires >= 100 acres by month (orange bars) and wildfires >= 500 acres (yellow bars).**

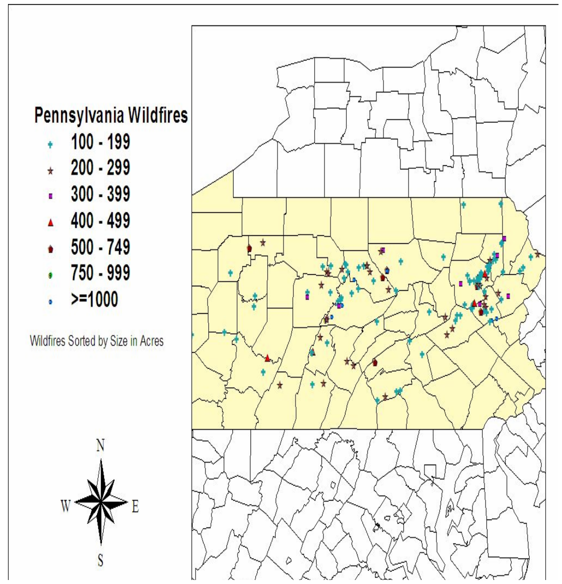


**Figure 4.** The distribution of wildfires across Pennsylvania with fire size is indicated.

Factors that affect this clustering may include: the population distribution, the proximity to active railroad lines, and the presence of arsonists. The Allegheny Front of central Pennsylvania and Pocono Mountain region in the northeast contain some of the greatest topographic relief in the state, and are noted for heavy recreational usage. In close proximity to these areas are numerous large towns and several cities, such as Wilkes-Barre and Scranton (Pocono Mountains), and Lock Haven (Allegheny Front). These larger population centers increase the chance for arson and/or accidental ignition by trash burning and campfires. In addition, each region contains one heavily used railroad line. Conrail tracks snake their way through the western Poconos, while trains on the Penn Central line pass through areas adjacent to the Allegheny Front. The friction of train wheels on the tracks can cause sparks to ignite grass or other fine fuels. This occasionally is the ignition mechanism for large WFs in Pennsylvania.

3.4 *Climatological Pattern Anomalies*

Several key meteorological factors are required to generate large wildfires in Pennsylvania. These include extended periods of anomalously high temperatures and dry conditions reflected by low PW anomalies, in addition to anomalously strong winds.

Occasionally, a precursor to the development of large WFs in Pennsylvania is an extended period of anomalously warm weather (positive 850 hPa temperature anomalies) shown by the +1-2 Standard Deviation (SD) and dry antecedent conditions as noted by low PWs (Fig. 5). The predominant number of large WFs occurs with anomalously strong north to northwesterly flow (850 hPa through 250 hPa) associated with a deep 500-250 hPa trough or surface low pressure area just off the coast of the Mid-Atlantic region or southern New England (Fig. 6d, and 8a,c). This is in stark contrast to fires found in the Western and Southeastern U.S. where either persistent hot, dry weather, or increasing low-level gradient wind during the breakdown of an upper level ridge, are the primary ingredients for fire occurrence and growth (Brotak and Reifsnyder 1977).

The most reliable and notable forecast parameter associated with these fires is the presence of anomalous northwest winds on the order of -1 to -2 SD normal, implying strong northerly winds (Hart and Grumm 2001). Less frequently, summertime WFs appear to be associated with deep, and typically, northeast to northwesterly flow at both 850 hPa and 250hPa

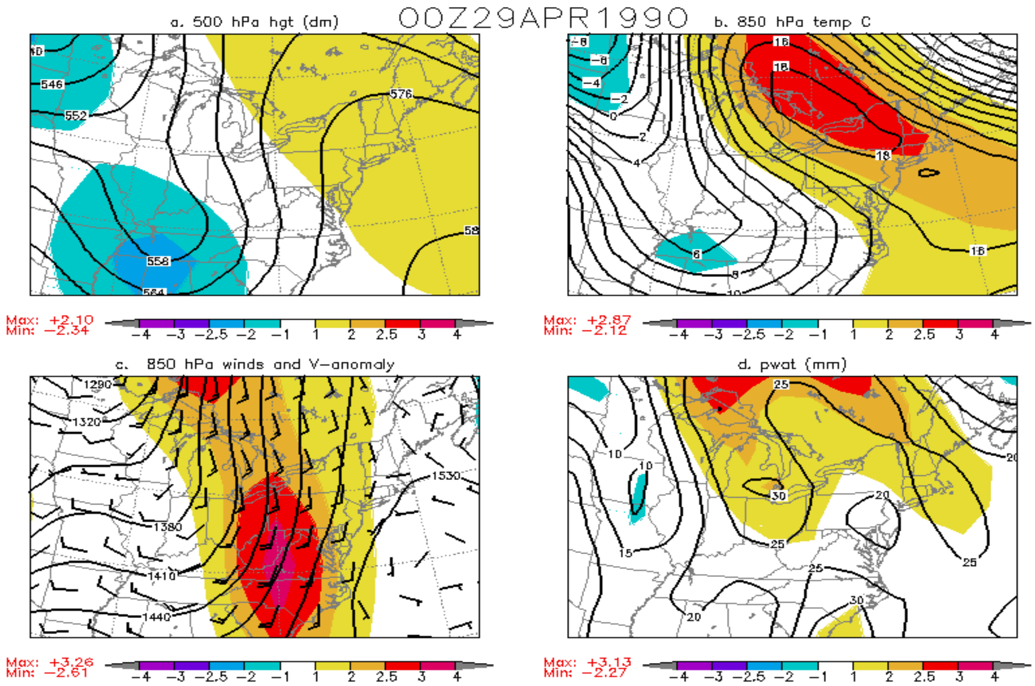


**Figure 5.** NCEP reanalysis data valid at 0000 UTC 29 April 1990 showing a) 500 hPa heights (dm) and anomalies, b) 850 hPa temperatures and anomalies, c) 850 hPa heights (dm), winds, and V-wind anomalies, and d) precipitable water (mm) and anomalies. All anomalies are shown in standard deviations from the 30-year mean.

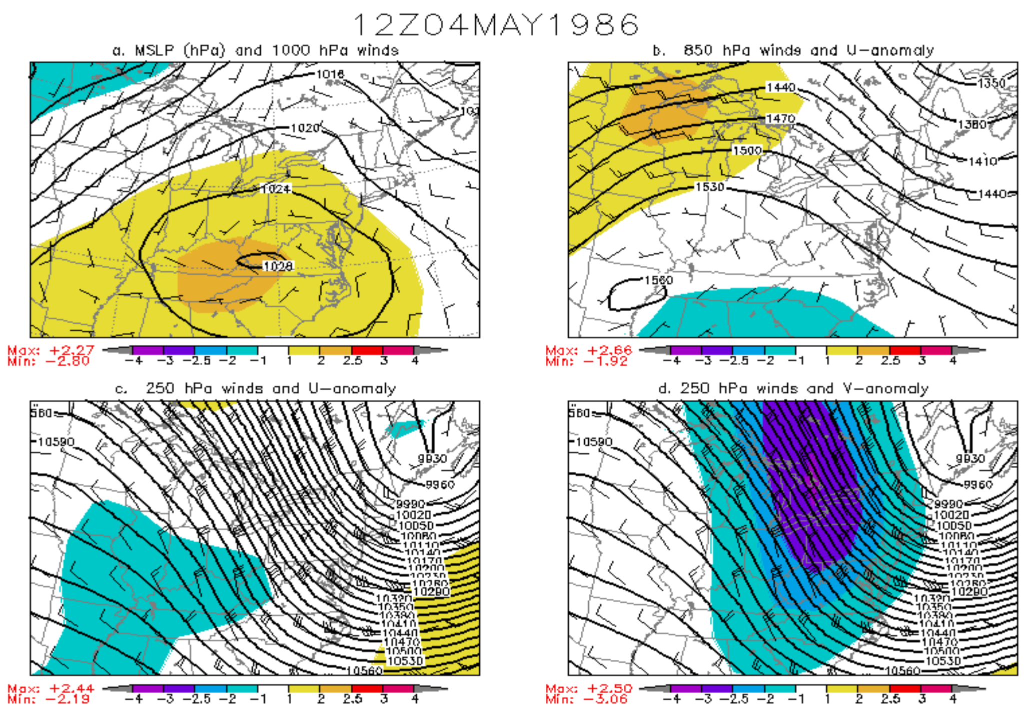


**Figure 6.** As in Figure 5, except valid at 1200 UTC 4 May 1986 showing a) MSLP and anomalies, b) 850 heights, winds, and U-wind anomalies, c) 250 hPa heights, winds and U-wind anomalies, and d) 250 heights, winds, and V-wind anomalies.

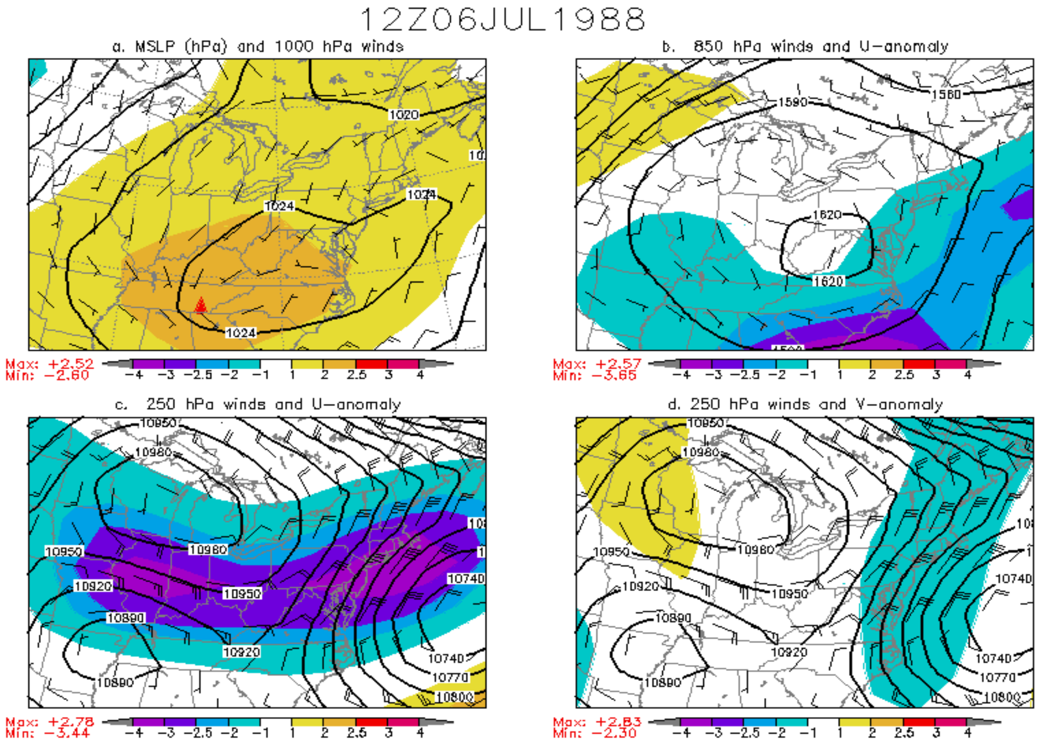


**Figure 7.** As in Figure 6, except valid at 1200 UTC 6 July 1988.

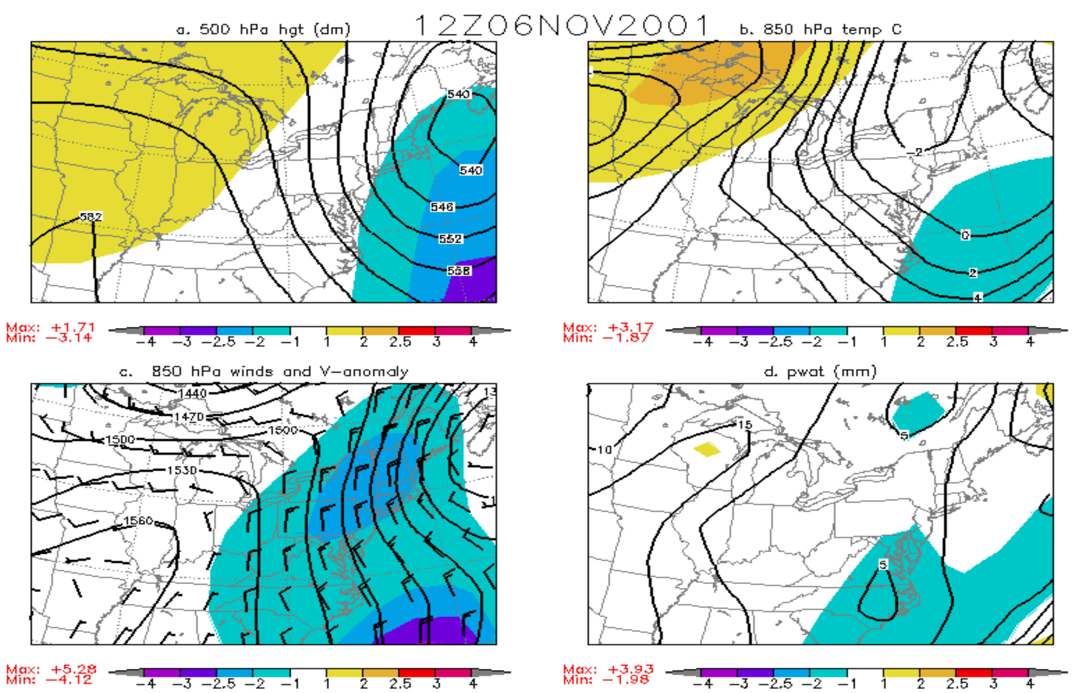


**Figure 8.** As in Figure 5, except valid at 1200 UTC 6 November 2001.

following a period of anomalously dry and warm weather. The WFs of 6 July 1988 (Fig. 7) is an example of a summer event conducive for WFs.

3.5 *WF Events*

A rare southerly flow event that occurred on 28 April 1990 (Fig. 5) produced the largest and most costly WF in the state of Pennsylvania. The “Two Rock Run” fire began in extreme northern Centre County during the morning of 28 April 1990 and destroyed almost 10,000 acres within 24 hours as it raced to the north-northwest. Damage from this fire (mostly in the form of timber loss) amounted to almost 1.9 million dollars. This event occurred under anomalously strong southerly flow with the 250 hPa southerly jet (not shown) +3.45 SD and the 850 hPa southerly jet +3.26 SD normal (Fig. 5). The 850 hPa temperatures of +2 SD showed an unusually warm air mass over the northeastern United States (Fig. 5b).

A strong northwesterly WF flow event is represented by the 6 Nov 2001 event (Fig. 8). In this event, a deep 500-250 hPa trough developed off the East Coast. Unseasonably dry air moved over the region behind the cyclone, as indicated by the PW anomalies (Fig. 8d). A strong low-level northerly jet developed, as depicted by the 850hPa jet (Fig. 8c). The 850 hPa V-component wind anomalies were over 2 SD below normal. Though not shown, the strong northwesterly flow was deep and a strong northwesterly wind maximum was present at 250hPa. At 250hPa, the V-component winds were greater than 2 SD below normal and centered across Pennsylvania.

## 4. CONCLUSION

The DCNR BOF wildfire data from 1983-2001 revealed the character of Pennsylvania WFs. These data showed a distinct springtime maximum in WF activity and a secondary maximum of WFs in the autumn. The majority of these fires were 100-499 acres in size. The availability of fuels appears to be a critical issue, limiting the autumn fire season. The summer fire season is less pronounced with only one distinctly active summer WF season in 1988.

Using the NCEP re-analysis data it appeared that some meteorological parameters might be useful in identifying active periods for WFs. Many Pennsylvania WFs appear to be associated with anomalously strong northwesterly flow, and antecedent conditions that include dry weather (represented by low PW values) and above normal temperatures at 850 hPa prior to large WFs. Unlike the primary WF conditions characteristic of the Western and the Southeastern U.S., persistent hot weather followed by the breakdown of an upper ridge is *not* a typical prerequisite condition for large WFs.

Synoptic patterns exhibiting anomalous (<= -1 SD) northwest flow aloft (850 hPa to 250 hPa), with a deep 500-250 hPa trough located off the Mid-Atlantic or New England coast, were the most favorable for producing large and unusually active WF periods in Pennsylvania. This type of flow pattern is typically associated with an extended period of dry weather, gusty surface winds, and near or below normal temperatures. Examples of these patterns are shown in Fig. 6 and 8, and to a lesser extent Fig. 7, where the surface and 500-250hPa low position were further southeast and created an anomalously strong north to northeast flow.

The less frequent summer WFs appear to be associated with prolonged dry periods and weakly anomalous northwest flow, represented by U and V wind component SD between –1 and +1 at 850 hPa and 250 hPa. These conditions imply a transport of dry (low PW) air southward from Canada, which would serve to dry out fine fuels and leaf litter. Additionally, this set of conditions may weaken the evapotranspiration and make the fully leaved trees easier to burn. The hot, dry weather may make the leaf litter more combustible. It is beyond the scope to of this paper to determine which effects are more important.

The April 1990 fire was unique in many respects. In addition to the meteorological conditions (anomalous southerly flow >+2.5 SD) associated with this fire, there was an unusual high amount of fuel available. This fire developed rapidly and raced through areas of downed and decaying trees, which were left behind from the May 1985 tornado outbreak in the same region.

Applying the climatic anomaly approach to numerical weather output may be highly beneficial in forecasting large wildfires (>100 acres) in Pennsylvania, and the rare cases of very active fire periods (including extremely large wildfires of >5000 acres) that create the most damage. Forecasters must know the optimal time of year for WFs. During these times, forecasters must recognize the patterns that favor the development of and movement of fires: abnormally warm periods (850hPa temperatures >1 SD above normal) with strong north to northwesterly winds from 850-250 hPa.

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**REFERENCES**

Brotak, Edward A., Reifsnyder, William E. 1977: An Investigation of the Synoptic Situations Associated with Major Wildland Fires. *Journal of Applied Meteorology*: **16**, 867–870.

Grumm, Richard H., and R. Hart, 2001a: Standardized Anomalies Applied to Significant Cold Season Weather Events: Preliminary Findings. *Wea. And Forecasting*, **16**, 736-754.

Grumm, Richard H., and R. Hart, 2001b: Anticipating Heavy Rains: Forecast Aspects. *Preprints Symposium on Precipitation Extremes: Prediction Impacts and Responses*, Albuquerque, NM, Amer. Meteo. Soc., 66-70.

Hart, Robert E., Richard H. Grumm, 2001: Using Normalized Climatological Anomalies to Rank Synoptic-Scale Events Objectively, *Mon. Wea. Rev*. **129**, 2426-2442.