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What are the most fire-dangerous atmospheric circulations in the Eastern-Mediterranean? Analysis of the synoptic wildfire climatology

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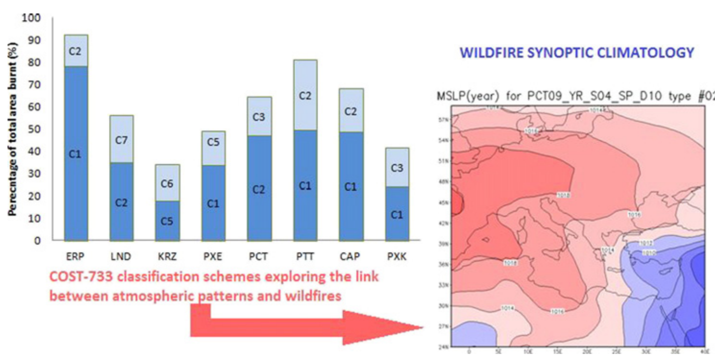
HIGHLIGHTS

- The Greek wildfires' synoptic climatology was studied through classification schemes.
- Significant link among certain COST-733 synoptic types and fire occurrence was found.
- The Etesian winds were associated with the most fire-hazardous days.
- Anomalously low 500 hPa geopotential heights and total water columns were observed.
- Anomalously high atmospheric pressure patterns were also observed during wildfires.

GRAPHICAL ABSTRACT



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ABSTRACT

Wildfire management is closely linked to robust forecasts of changes in wildfire risk related to meteorological conditions. This link can be bridged either through fire weather indices or through statistical techniques that directly relate atmospheric patterns to wildfire activity. In the present work the COST-733 classification schemes are applied in order to link wildfires in Greece with synoptic circulation patterns. The analysis reveals that the majority of wildfire events can be explained by a small number of specific synoptic circulations, hence reflecting the synoptic climatology of wildfires. All 8 classification schemes used, prove that the most fire-dangerous conditions in Greece are characterized by a combination of high atmospheric pressure systems located N to NW of Greece, coupled with lower pressures located over the very Eastern part of the Mediterranean, an atmospheric pressure pattern closely linked to the local Etesian winds over the Aegean Sea. During these events, the atmospheric pressure has been reported to be anomalously high, while anomalously low 500 hPa geopotential heights and negative total water column anomalies were also observed. Among the various classification schemes used, the 2 Principal Component Analysis-based classifications, namely the PCT and the PXE, as well as the Leader Algorithm classification LND proved to be the best options, in terms of being capable to isolate the vast amount of fire events in a small number of classes with increased frequency of occurrence. It is estimated that these 3 schemes, in combination with medium-range

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to seasonal climate forecasts, could be used by wildfire risk managers to provide increased wildfire prediction accuracy.

1. Introduction

Although wildfires are known as natural phenomena and important features of many ecosystems (Pausas et al., 2008, Bowman et al., 2009), the significant increase in the number of fires and area burnt during the 2nd half of the 20th century has confirmed the perception that wildfires are a serious environmental and socioeconomic hazard for most Mediterranean-type ecosystems.

The total area burnt during wildfires depends on a number of geographical parameters, such as the topography, as well as temporal (e.g. the season), and fuel-related (e.g. the fuel loading) parameters. Various contingency factors, namely the fire suppression and the site accessibility, are also known to play an important role on the wildfire occurrence (Papadopoulos et al., 2013). On the other hand, meteorological and climatological parameters are widely known for their impact on wildfires (e.g. Gorski and Farnsworth, 2000; Thompson and Calkin, 2011). Very often it is the synergy of a combination of parameters (for instance a combination between fuel loading and weather conditions, Koutsias et al. (2012)) that explains wildfire activity.

During the last decades, wildfires in the Mediterranean region have been linked to (a) fuel accumulation, as a consequence of the abandonment of cultivated fields and afforestation policies, (b) climate change and (c) increased ignition sources (Moreira and Russo, 2007), while concerns have grown about how climate change and human activities might impact future fire regimes. However, it is still unsettled whether climate or direct anthropogenic influences (fire ignition and suppression, as well as fuel management) are more important in determining global fire trends (Pechony and Shindell, 2010).

In the present work we focus on Greece, a typical Mediterranean environment, which is well-known for its disastrous wildfires since the early 1970s. In the recent past, a number of researchers focused their studies on Greek forest fires, especially in the context of fire management. Specifically, Kalabokidis et al. (2002) proposed an analytical and operational inventory procedure aimed at appraising forest fire potential. Bonazountas et al. (2005) studied forest fires from a risk-analysis point of view, while Bonazountas et al. (2007) introduced a decision support system for managing forest fire casualties. Kassomenos (2010) linked the synoptic weather types with wildfires during a 20-year period and concluded that 70–90% of the total wildfires were associated with three discrete synoptic classification categories. Specifically, the first category consisted of wildfires that occurred when a low-pressure system prevailing over the Greek area intensified and the pressure gradient increased in the Aegean Sea. The second synoptic type was associated with the gradual replacement of a low pressure system by a high-pressure system. Finally, anticyclonic conditions associated with high temperatures, low humidity, and moderate winds were also found to be responsible for the onset and the persistence of wildfires.

Recently, Papadopoulos et al. (2013) studied the relationship between the meteorological/climatological conditions and wildfires on a variety of temporal and spatial scales at 26 meteorological stations, covering both maritime and land environments in the Greek domain, and concluded that positive surface temperature, absolute/specific humidity, 500-hPa geopotential height, and vector wind anomalies were observed during wildfires, while sea level pressures were found to be anomalously negative. Gudmundsson et al. (2014) used logistic regression and showed that the probability of above normal summer wildfire activity in the 1985–2010 time-period in Southern Europe (Greece included) can be forecasted as a function of meteorological drought with significant predictability several months in advance. Finally, Papadopoulos et al. (2014) performed cluster analysis of 2-month air mass back-trajectories for three contrasting fire and non-fire events in Greece and showed that the large fire event displayed an air mass history dissimilar to other events whereby a 39-day period of warm and dry chiefly northerly anticyclonic conditions was evident, before a week of warmer predominantly southwesterly cyclonic activity, immediately prior to ignition.

Given the need to bring different perspectives and apply a range of methodologies to comprehending wildfires, the objective of this paper is to investigate the possibility of using synoptic classifications to derive information on the occurrence and severity of wildfires in Greece and to explore the possible link between certain atmospheric patterns and wildfires, so that the most fire-dangerous conditions can be recognized. Such understanding is expected to permit appropriate steps to be undertaken including reliable prediction and improved fire-suppression strategy.

2. Data and methods

2.1. Area description

Greece is located in SE Europe and covers an area of approximately 131,000 km^2, of which 80% is mountainous. The country is surrounded by sea, with the Aegean Sea located to the east of the Greek mainland, the Ionian Sea to the west, and the Mediterranean to the south. Greece is well-known for its typical Mediterranean climate. Specifically, during wintertime, traveling depressions and blocking anticyclones prevail, bringing in moist and low temperatures. Hence, precipitation can be high, although significantly dependent upon location. In summertime, much more stable weather conditions prevail, due to the invariant effect of the subtropical anticyclone of the Atlantic and the SW Asian thermal low.

The Pindus mountain range (with maximum elevation at 2637 m) strongly affects the climate of the country, as areas to the west of the range are considerably wetter on average than the areas lying at the east of the range, due to the rain shadow effect. The complex relief, the proximity to the sea and the height above sea level in combination with local (such as the sea/land breezes) and seasonal (such as the Etesians) wind patterns strongly affect the Greek climate and the development of wildfires.

2.2. Data sources

Forest-fire data corresponding to the 18-year period between 1985 and 2002 and reflecting the fire-season in Greece (April 1st to October 30th) were provided by the Hellenic Fire Service and the archives of the National Forest Inventory. For the needs of the study, only "large fire events" (i.e., >200 ha total burnt area) were taken under consideration. This filtering was performed to allow comparisons with previous research conducted for the same area (Kassomenos, 2010; Papadopoulos et al., 2013, 2014). It is noted that no distinction between naturally and anthropogenically (traditional burning practices or arson) induced events was made, as regardless of cause, specific environmental and atmospheric thresholds are required for a wildfire to develop and progress.

2.3. Methodology

For the needs of the study, the 'COST-733 Action of the European Science Foundation' (http://www.cost733.eu) classification software (version 2.0) was used to associate wildfires and prevailing weather