Atmospheric Circulation Characteristics associated with wildfires occurrence in the Mediterranean Basin

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1. INTRODUCTION

Wildfires have been recognized as an intrinsic factor of the Earth system affecting vegetation functioning, structure and distribution with consequent impacts on terrestrial ecosystems, biogeochemical cycle, atmospheric composition, surface albedo and climate. However, large uncontrolled fires are an environmental hazard due to their adverse effects on natural systems, the economy and human health. Wildfires regime is controlled by both, natural and human factors, such as vegetation type and cover, climate, weather, land management practices including human ignitions. Weather plays a key role in fire ignition and behavior affecting its spreading, severity and suppression. Frequently, large fire events are the synergistic result of fuel load and anomalous atmospheric conditions.

2. DATA

Fire Data: wildfire ignition date and circumference of burned area at a spatial resolution of 500 m for the region 33°N - 60°N and 11°W - 35°E obtained from the MCD64monthly Collection 6 MODIS database.

Time period: 2002 – 2016 (warm season of the year, May - September)

Atmospheric Circulation Data: gridded values at 1200 UTC on 2.5° x 2.5° spatial resolution derived from the NOAA NCEP/NCAR Reanalysis database

- 500 hPa geopotential height (Z500)
- 1000hPa geopotential height (Z1000)
- 1000hPa temperature (T1000)

for the domain 25°N - 60°N and 30°W - 50°E (495 grid points)

- 850hPa relative humidity (Rh850) for the domain 32.5°N - 60°N and 10°W - 35°E (228 grid points)

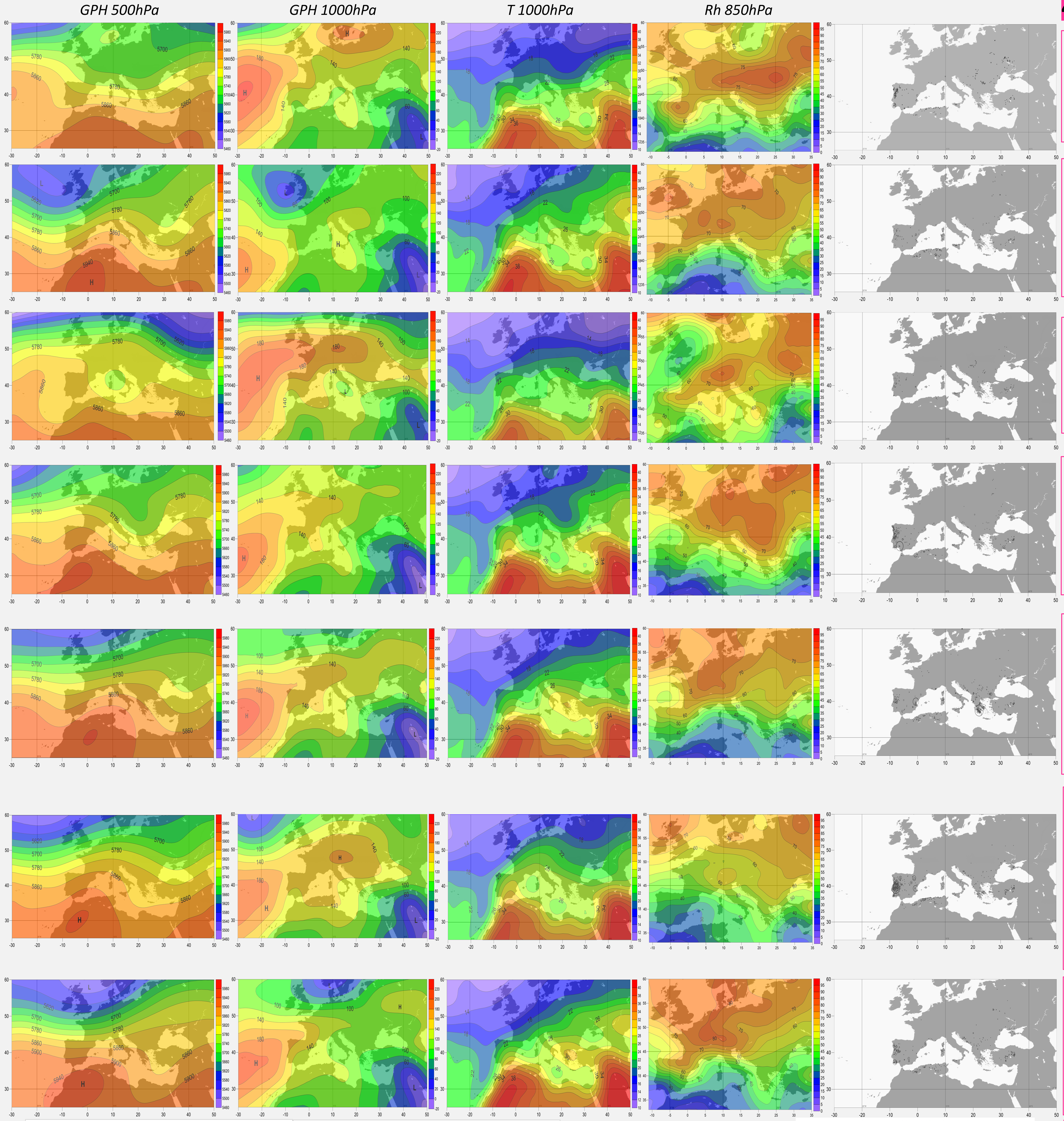
3. METHODOLOGY

- Total burned area estimation for each wildfire
- Only wildfires with at least 500ha burned area (2533 events taking place in 871 days) are considered
- For each of the meteorological parameters Z500, Z1000 and T1000 a matrix with 871 rows (wildfire days) and 495 columns (grid points) was constructed
- A respective matrix (871 x 228) was constructed for Rh850

➡ These matrices were merged into one (871 x 1713) whose each row represents the three-dimensional structure of the atmosphere at 1200UTC of a specific wildfire day

➡
- Factor Analysis was applied to this matrix to reduce the data dimensionality resulting in a 871 x 17 matrix
- Now, atmospheric circulation is represented by the 17 factor scores values only
- Only factors with physical meaning were retained

➡
- Cluster Analysis was applied to the new 871 x 17 matrix to objectively group the atmospheric circulation characteristics of 871 wildfires days into **7 clusters** as much as possible homogenous and distinct to each other



4. RESULTS

Cluster 1: 293 fire events (108 fire days, 12.4% of the total fire days) mostly occurring in September, in Portugal, north Africa, central Balkans and Ukraine

- *500 hPa level*: zonal western flow dominates over the Mediterranean favoring fair weather conditions at surface
- *1000 hPa / surface level*: combination of the extended Subtropical Anticyclone over western and northern Europe with the low pressure field over the northwestern Africa and the extension of the Asian thermal low towards Turkey and Black Sea creates strengthened northeastern winds over Portugal and eastern-northeastern flow over Ukraine respectively
- In Portugal, the eastern-northeastern flow bringing dry air masses from inland along with low relative humidity values (< 45%) creates favorable conditions to fire

Cluster 2: 261 fire events (111 fire days, 12.7% of totals) mostly occurring in North Africa, southern Italy and central-western Iberia peninsula, distributed over all months of the warm period

- *500 hPa*: A ridge dominates over the central Mediterranean with a strong vertical structure down to surface causing air subsidence and thus warm and dry conditions at surface (e.g. Sardine and Sicily isles) that favor fire ignition
- *1000 hPa*: a pressure gradient between the subtropical anticyclone extended to southwestern Europe and the low pressure system centered over Ireland creates a western-northwestern flow over the fire areas of Iberia peninsula
- High surface temperatures along with extremely low relative humidity (20-25%) over Algeria are favorable conditions for fires ignition and persistence

Cluster 3 : 134 fire events (55 fire days, 6.3% of totals) with a relative small mean burned area (898 ha), exclusively taking place in September

- *1000 hPa*: The main feature of atmospheric circulation is the dominance and the wide extension of the Subtropical anticyclone over the North Atlantic covering the west, central and part of northern Europe. The weaken due to the season, Middle East thermal low combined with the central Europe high pressures creates a strong gradient and enhanced eastern flow over Anatolia. The resulted strong winds carry dry air masses (Rh850 < 40%) from inland explaining the fire events in Turkey
- The Portugal fire events are also associated with eastern and dry winds generated from the pressure gradient between the Azores anticyclone and the south Spain-north Africa thermal low

Cluster 4: 384 fire events (139 fire days, 16% of totals) with most of them taking place in the Iberian Peninsula and primarily in Portugal including a mega-fire event (07/2004) with a burned area of 20861 ha in south Spain. Increased frequency of wildfires has been recorded in Algeria and Turkey. August presents greater fire activity with more events in fewer days

- *500 hPa*: a trough with its axis lying along the Balkan Peninsula followed by a ridge over the western Mediterranean largely determine the Rh850 and T1000 patterns
- *1000 hPa*: the greatly extended Azores anticyclone over western, northwestern and central Europe including central Mediterranean combined with the thermal low developed over the southern Iberian Peninsula creates a pressure gradient and an eastern flow over the north-northwestern part of the peninsula, assisted by the high temperatures and RH (<45%) favors fires ignition and spreading
- A strengthened NE flow over the Aegean Sea, Black Sea and Turkey results from the pressure gradient between the eastern Mediterranean thermal low and the high pressures over the central Europe

Cluster 5: 487 fire events (152 fire days, 17.2% of totals) with 1235 ha mean burned area. The catastrophic event with human losses and 24841 ha burned area, in Peloponnese-Greece in August 2007 is classified in this cluster, making August the month with greater mean burned area (1597 ha) while July presents the most events

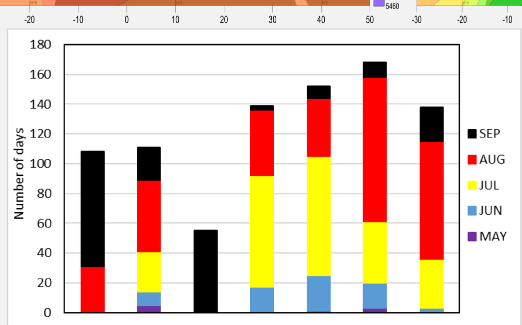
- *500 hPa*: an extended ridge over the western and central part of the Basin with a SW to NE axis lying over Tunisia – south Italy – western Greece bringing to affected areas warm and dry air masses from Africa. This circulation causes the highest temperatures compared to other clusters, over Greece and southern Italy and low RH (25 - 45%), favorable conditions for fires ignition and persistence
- *1000 hPa*: the widely extended Subtropical anticyclone over North Africa and almost all Europe in combination with the extension of Asian thermal low to Middle-East, creates an intense northeasterly flow over Balkans manifested through strong NE winds (known as Etesian winds). This flow is mostly responsible for fire ignition and spreading in Greek area, reinforced in some cases by a local circulation like katabatic winds as in the case of Peloponnese fires

Cluster 6: the most numerous cluster with 580 fire events (168 fire days, 19.3% of totals) and the largest mean burned area (1371 ha) including the multiple disastrous wildfires in August 2003 in Portugal. High density of fires in Portugal and high frequency in August

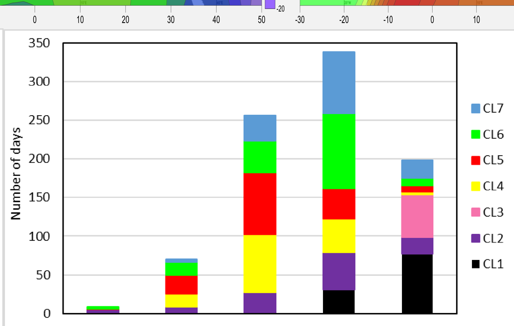
- *500 hPa:* an extended ridge over the western Mediterranean carries to the region warm and dry air masses from Africa
- *1000 hPa:* a widespread high pressure field covers all the continental Europe and the subsequent air masses subsidence further heats and dries air results in extremely high temperatures and very low RH over western Europe, being favorable conditions for fire ignition, spreading and persistence
- Those conditions are assisted by an easterly flow over Portugal induced by a pressure gradient between the enhanced anticyclonic circulation and the thermal low over the southern Iberian Peninsula
- The extended anticyclone over central Europe and Balkans along with the extended Asian thermal low over the eastern Mediterranean results in strong E–NE winds over Turkey and Balkan peninsula explaining fires ignition in this area

Cluster 7: 394 wildfire events (138 fire days, 15.8% of totals) with the highest frequency in August but the more disastrous events occurred in July with a mean burned area 1381 ha

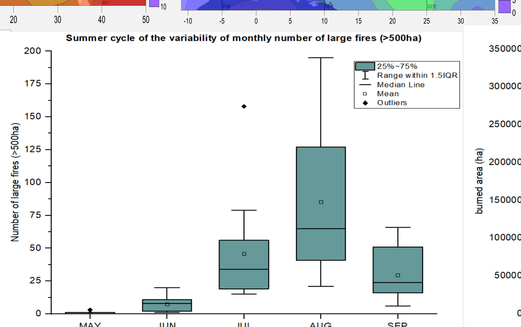
- *500 hPa*: almost zonal flow over the western Mediterranean with a strong anticyclonic circulation over the NW Africa and a trough over the eastern Mediterranean
- *1000 hPa*: a strong northeasterly flow over Portugal and Spain due to the Azores anticyclone extension over the northwestern Iberia peninsula and the low pressures in the southern of peninsula and Northern Africa
- The combination of high pressure field over Balkans and central Mediterranean and the Caspian anticyclone with the extension of Asian thermal low to Middle-East produces a strong eastern flow over Turkey and E-NE flow over Balkan Peninsula



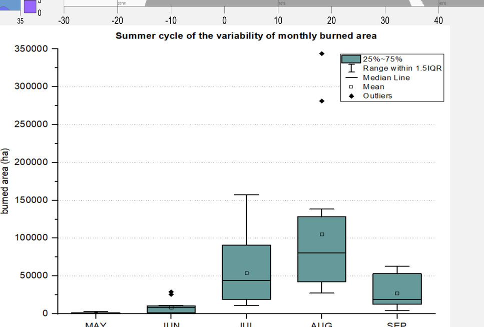
Distribution of wildfire days per month for each cluster



Monthly distribution of wildfire days for each cluster



Monthly variability of wildfire events number



Monthly variability of wildfire events burned area

5. CONCLUSIONS

- Position, extension and strength of the Subtropical Azores' Anticyclone hold the key role in the atmospheric circulation related to wildfire events in the broader region of the Mediterranean Basin.
- The associated air subsidence results in high temperatures and dry conditions at surface, favoring fire ignition. Moreover,
- In the western Mediterranean the pressure gradient, caused by the combination of the Subtropical Anticyclone and a thermal low over the southern Iberian Peninsula and North Africa, induces strong northeastern winds assisting in the wildfires spreading, particularly in Portugal.
- Likewise, the pressure gradient, resulted from the extensions of the Subtropical Anticyclone and the Asian thermal low towards the eastern Mediterranean, causes strong north-northeastern winds (the so called Etesians) over the Balkans and Anatolia, favoring the occurrence of intense wildfires in these regions.
- Often, circulation in the middle troposphere (500 hPa) is associated with warm advection over parts of Mediterranean, contributing to the formation of favorable conditions for fire ignition and spreading

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Acknowledgments

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