MINISTRY OF RECONSTRUCTION OF PRODUCTION, ENVIRONMENT & ENERGY
HELLENIC AGRICULTURAL ORGANISATION «DEMETER»

Understanding fire weather: a basic need for successful and safe fire management

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The Abdus Salam International Centre for Theoretical Physics

IAEA

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Definitions

- **Meteorology:** The interdisciplinary scientific study of the atmosphere and its phenomena. It mainly concentrates the changes in temperature, air pressure, moisture, and wind direction in the troposphere.
- **Weather:** The current state of the atmosphere at any time. Weather is what is happening now, or happened in the past, but only at one given moment.

Wildfires and weather are interrelated

- **Fire meteorology:** The branch of meteorology that deals with the relationship of weather and climate to wildfires.
- **Fire weather:** Weather characteristics and parameters as related to their influence on wildfires (fire ignition, behavior, and suppression)
  - Air Temperature
  - Wind speed & direction
  - Relative humidity
  - Solar radiation
  - Rain / Drought
  - Weather fronts
  - Thunderstorms
  - Lightning
  - Atmospheric instability
  - Inversion

Fire weather forecasting

- Up-to-date weather forecasts are crucial for determining fire danger and fire behaviour.
- Need to consider
  - Values of fire separate fire weather parameters
  - Fire weather indices (they try to capture the combined effect off the various weather parameters)
  - Local conditions (Diurnal changes, topography, fuels and their condition)

Meteorologists in support of fire management (USA)

- Weather Forecast Office (WFO) Forecaster (emphasizes events based on mesoscale to synoptic-scale features)
- Incident Meteorologist (IMET) (deployed to support wildfire management activities - extends the WFO capabilities to the incident, tailoring a WFO forecast to the area of concern)
- IMETs provide a personal level of service to the incident that the WFO cannot. When deployed to a fire, the IMET becomes the weather expert for the fire, while the WFO is the source of information for the zone or region.
- When an IMET is not deployed, the WFO may make spot forecasts to support decision-making at an incident.

Info Source: University Corporation for Atmospheric Research (UCAR), COMET Program, on-line course on "Fire Weather Forecasting"

Meteorological information communication flow

On a large fire (indicative):

1. WFO
2. IMET
3. FIRE BEHAVIOR OFFICER/ANALYST
4. INCIDENT COMMANDER
5. DIVISION BOSSES
6. SECTOR BOSSES
7. CREW BOSSES

Communication of information is of paramount importance. However, the content may vary

Understanding fire weather

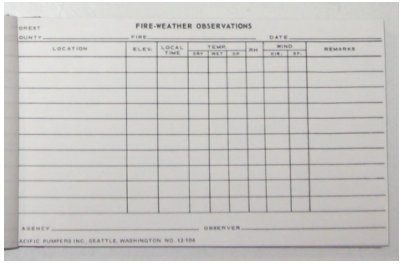
- Theoretical training
- Learn your local weather (identify patterns)
- Develop experience on what parameter or index values mean in regard to fire behavior
- Integrate this knowledge and experience into decision making, fire management actions, and safety considerations
- Stay current with weather at all times (observations & predictions) and adjust operations accordingly, increasing firefighting effectiveness and improving firefighter safety

Portable weather station

Belt Weather Kit

- Belt-mounted case with pockets fitted for anemometer, compass, sling psychrometer, slide rule, water bottle, pencils, and book of weather report forms.
- Used to take weather observations to provide on-site conditions to the fire weather forecaster or fire behavior analyst. Observations include air temperature, wind speed and direction, and relative humidity.

Belt Weather Kit



KESTREL 3000

The Kestrel hand-held weather instrument (left) and a standard sling psychrometer (right).

White, G. L. 2011. How Accurate Is Your Kestrel®?. Fire Management Today, 71(1) 33.

Fire Weather considerations on the line

- Receive information from meteorologists
- Measure weather parameters locally
- Observe signs of weather and fire behavior
- Sense, feel, smell, hear
- Identify weather patterns of interest
- Recognize critical conditions, including weather, fuels, topography and access
- Decide and act with effectiveness and safety in mind
- Monitor weather and fire evolution
- Adjust operations as needed

Examples

Wind dominated fire
(Yellowstone 1988)

Wind dominated fire

- In a wind-driven event, the power of the wind is greater than the power of the fire.
- Predicting probable fire behavior, which is a function of the wind speed and direction, is somewhat simplified.
- The direction of spread and the anticipated fuel bed can be evaluated.
- Predicting changes in wind is critical since wind shifts can pose serious threats to safety.
- Spotting almost always occurs downwind and is a major contributor to spread rates.

Plume dominated fire

- A fire that develops an immense convection column capable of producing its own mini weather system.
- These convection columns are called pyrocummulus and reach heights in excess of 6000 m
- The power of the fire is greater than the power of the wind
- An unstable atmospheric profile makes such behavior likely

Plume dominated fire

- A developing pyrocumulus cloud above the Oregon Gulch fire, a part of the Beaver Complex fire. Taken from an Oregon Air National Guard F-15C by James Haseltine on July 31, 2014, at 8:20 PM Pacific Daylight Time.

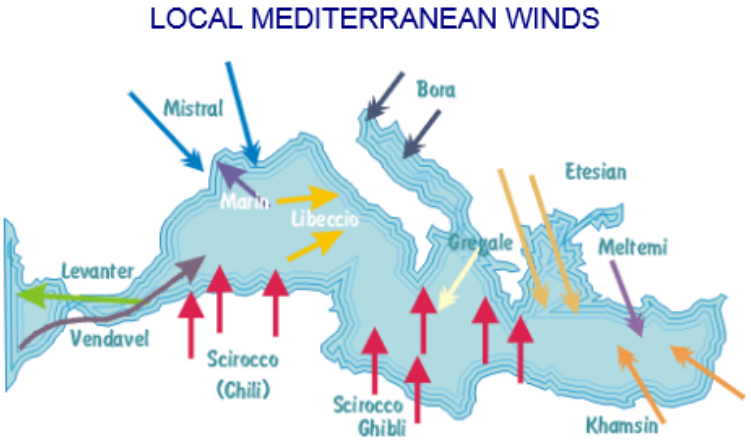
Main characteristic: Unpredictability

- All convective columns have updrafts and downdrafts. Associated with these are indrafts, which is the flow of air into the column, and downdrafts or downbursts of air out of the convective column.
- There can be spotting in any direction around the perimeter of the column and there can be short distance rapid fire runs.
- If relative humidity is very low (<20%) firefighting can be extremely dangerous

Plume dominated fire: Collapsing of the column

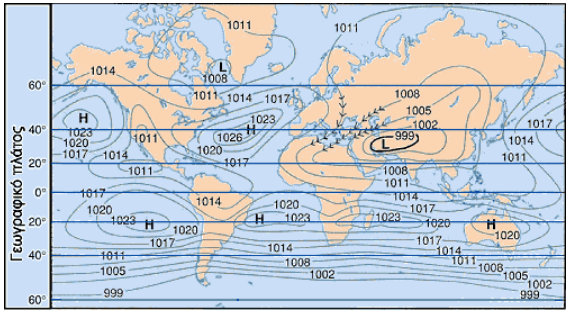
- When the fire runs into lighter fuels the column can collapse, causing a downward rushing of air in every direction and spreading fire rapidly outward.
- The downward rush of air from a collapsing column can break off large trees and create hazardous turbulence for aircraft.

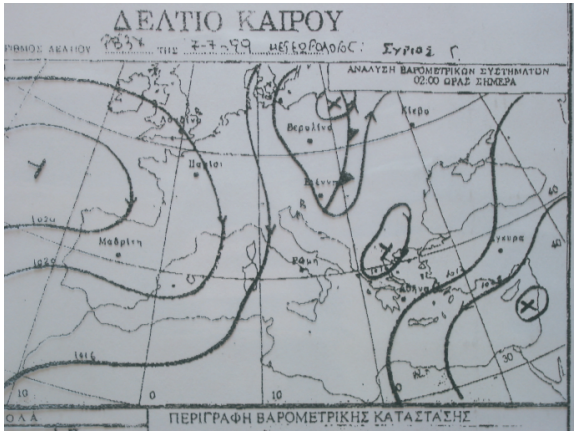
Strong Steady Winds

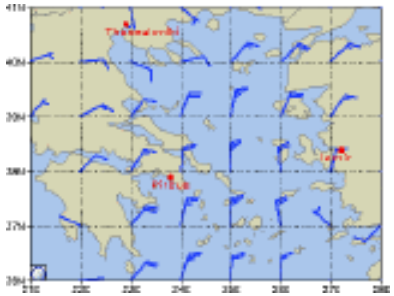


- **Mistral**: A strong northerly wind in the Gulf of Lions and Rhone Valley. The air is usually dry, bringing bright and clear weather with freezing temperatures to the south of France. The Mistral often reaches gale force especially in winter and is capable of raising a heavy sea in a short space of time.
- **Meltemi (Etesians)**: A wind that blows during the summer in the Aegean Sea, known as meltemi by the Turks and etesians by the Greeks. Direction may be from north-east to north-west but remains steady. Meltemi weather is ordinarily fine and clear, the northerly winds tempering the fierce summer heat of the region.

Etesians / Meltemi







The **Etesians/Meltemi** winds are the result of air flow between a HIGH over the Balkans and a LOW over the Eastern Mediterranean

These are at the borders of the HIGH of the Azores, and the deep continental depression (LOW) centered over the north-west of India

Etesians/Meltemi Characteristics

- Can occur from May to October
- More pronounced and strongest in July-August
- Typically it is accompanied by a sudden drop in humidity, improved visibility and a raise in atmospheric pressure
- Usually it reaches 7 Beaufort scale velocities but 8-9 BF is not uncommon in the Aegean sea
- Usually, the wind remains strong for 3-4 days. As a rule it picks-up in the morning (07:00 to 09:00) and calms by dusk.
- On the first day (onset) it is not uncommon to continue blowing through the night.

Etesians/Meltemi Characteristics (2)

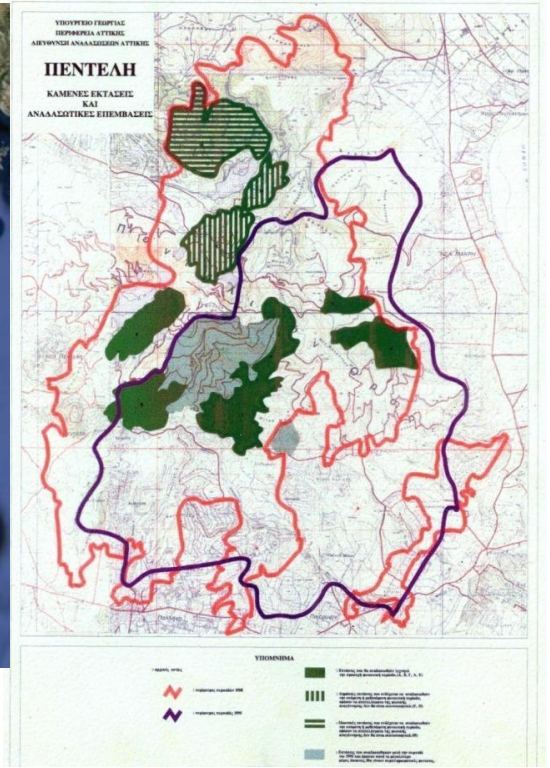
- Wind direction remains steady
- The numerous Aegean Islands and mountain gaps are channeling the wind causing gusty, vigorous jet-effects and **lee eddies** as well as local katabatic winds.
- The latter is especially pronounced in the south part of the island of Crete.

Historic fires with meltemi wind

The fires of Penteli mountain

Source: Newspaper “Eleftherotypia”

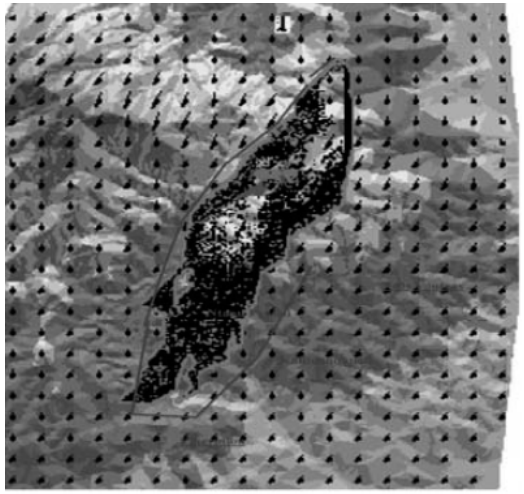
Penteli mountain fires (1995 & 1998)



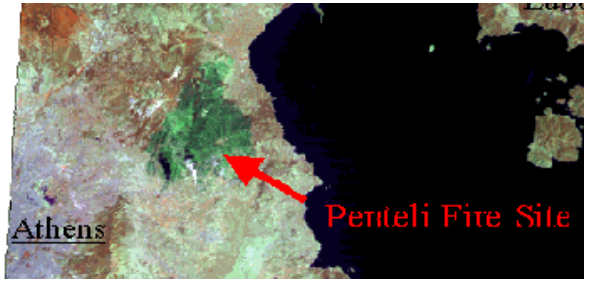
The Mt. Penteli fire of July 21-24, 1995

- Fire started at 07:50 under:
  - 9 BF meltemi wind (gusts reaching 75 km/hr)
  - Temperature at 25^{o}C
  - Relative humidity >35%
- Canadairs unable to operate
- 6200 ha burned, mainly Aleppo pine forest
- 105 homes destroyed or heavily damaged
- Final fire suppression at the north end of the fire

Fire perimeter



The outline of the 1995 fire on Penteli on July 21st at 13:30, and the simulated fire spread by a fire management information system (FMIS) developed by ALGOSYSTEMS S.A. (Varela et al. 1999).



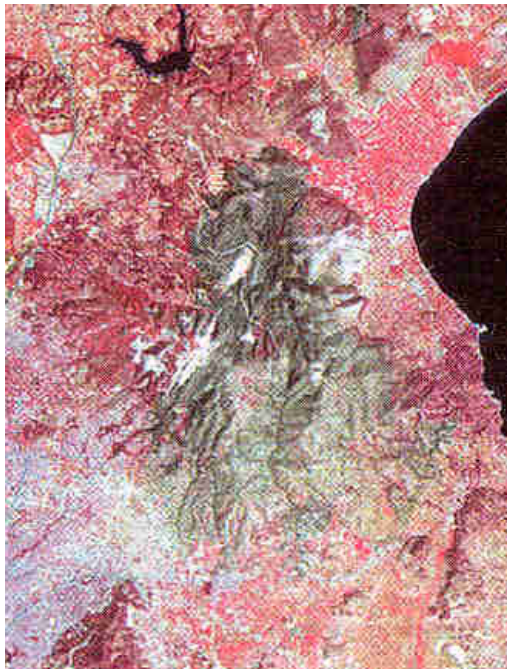
The final burned area of the 1995 fire.

Image Source: “Land Use Change Interactions with Fire in Mediterranean Landscapes” (LUCIFER) project.

Key points

- Extremely strong wind – aerial resources unable to operate due to extreme wind
- Delayed initial attack due to pre-existing other fires in Attica
- High frontal fire intensity, high ROS, medium spotting.
- Poor planning and management of resources (efforts to control the front, no efforts at the heel)
- Involvement of politicians

The Mt. Penteli fire of August 2-5, 1998



- The fire started at 22:00 on August 2, under light NE wind at less than 2 BF, air temperature at 27 ^{o}C, and relative humidity around 30%
- Little initial attack effort at night and delay in the morning although the meteorological forecast predicted strong meltemi wind for the next day

The Mt. Penteli fire of 1998 (2)

- Early in the morning of August 3rd, the meltemi wind picked-up to roughly 7 BF. Initially, the fire burned in Pinus halepensis forest that had not been burned in 1995 and it crowned quickly.
- Then it entered in the previously burned area which was covered by regenerating shrubs and grasses.
- Relative humidity dropped to less than 15% during the day and the fire soon started producing heavy medium and some long-range spotting.
- The wind speed did not preclude aerial firefighting as in 1995, but the spotting made all efforts to stop the fire along roads in its path, ineffective.

The Mt. Penteli fire of 1998 (3)

- The final burned area reached 7,500 ha.
- Hundreds of homes were destroyed or seriously damaged.
- One citizen fatality.
- Firefighting proved unable to stop the front but also neglected the heel of the fire. Widening at the flanks on August 5th the fire entered WUI areas near Athens causing serious damage.

Key points

- Delayed initial attack (poor consideration of weather forecast, lack of experience)
- Medium to high frontal fire intensity, high ROS, heavy spotting.
- Poor planning and management of resources (efforts to control the front, no efforts at the heel)
- Poor coordination of ground and aerial resources
- Aerial resources able to operate but ineffective

The Mt. Penteli fire of August 16, 2007

- Started at 10:30. Initial attack failed
- Quickly became plume dominated. Wind at 25 km/h. Aerial resources unable to act due to turbulence.
- About 12:30 wind increased to 35 km/h. The fire became wind dominated. Within the next three hours the aerial resources helped put it under control.
- The photo at the left was taken at 12:06.
- The photo at the right was taken at 12:47: the fire changes from plume to wind dominated.

Penteli fire, August 16, 2007 (from NET TV)

The fire burned 900 ha and destroyed many homes

NE Attica fire of August 21-23, 2009

- The fire started at 20:46 near the town of Grammatikos
- Initial attack: 14 fire trucks, 42 firefighters
- Until 07:00 there was no feeling of urgency at the Fire Service coordination center
- There was a delay in aerial resources intervention next morning (> 07:00)
- By then the meltemi wind which had been blowing through the night picked-up, reaching 40 km/h, accelerating the fire
- Wind direction: steady at 30^{o}

Meteorological conditions for 22-8-2009

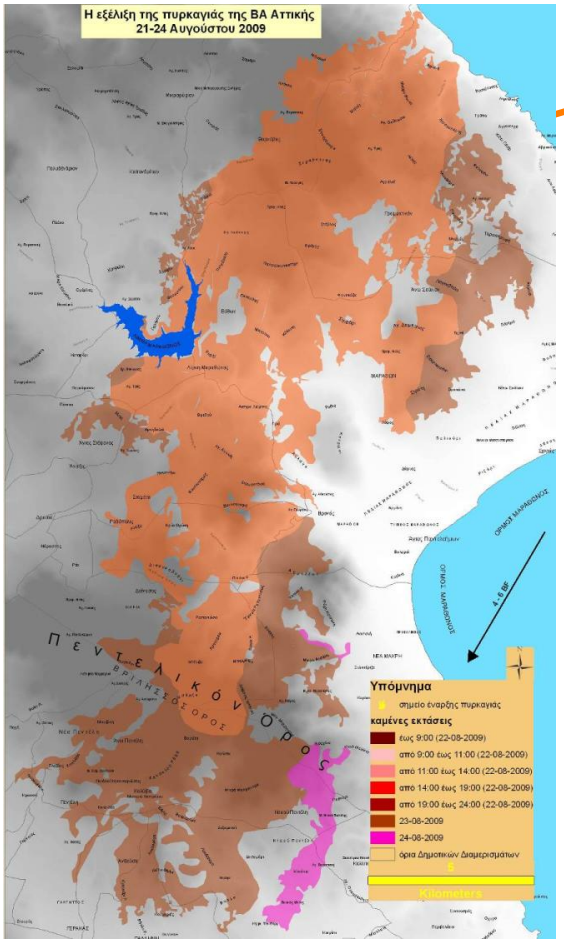
Parmater	**Mean**	**Maximum**	**Minimum**
Temperature	26 ^{o}C	28 ^{o}C	24 ^{o}C
Relative humidity	33%	41%	24%
Wind speed	26 km/h	41 km/h (6 BF)	---
Wind gusts	---	57 km/h (7 BF)	---

Fire Danger Index (Scale 1-5): **4** (Very high)

The wind dominated fire at 14:48 (22/8/2009)

Rate of Spread

- Initial ROS about 2 km/h
- Later in the day it, close to Marathon lake, it exceeded 2 km/h
- ROS at times reached 3.8 km/h, especially in light fuels, in spite of firefighting efforts
- Main fire behavior characteristic was high rate of spread. Intensity was medium.
- It became an active crown fire only at places where there was tall shrub understory under thick overstory.



22-08-2009

Xanthopoulos & Athanasiou, 2013

Spotting in early afternoon 22-8-2009

Damages

- Burned area: 21,000 ha
- 15 towns and settlements hit
- 60 homes destroyed, 150 damaged

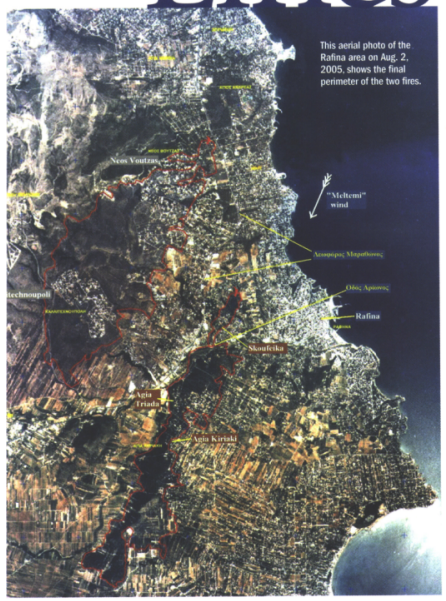
Key points

- Failed initial attack / underestimation
- Medium to high frontal fire intensity, high ROS, some spotting in the afternoon.
- Poor planning and management of resources (efforts to control the front, no efforts at the heel)
- Missed opportunities (e.g. Marathon lake)
- Useless efforts in some cases (dozer line without anchoring).
- Poor coordination of ground and aerial resources
- Aerial resources able to operate but ineffective

Parallel Lines

Why would two fires that burned at the same time in the same area under the same conditions produce very different results?

By Gavriil Xanthopoulos



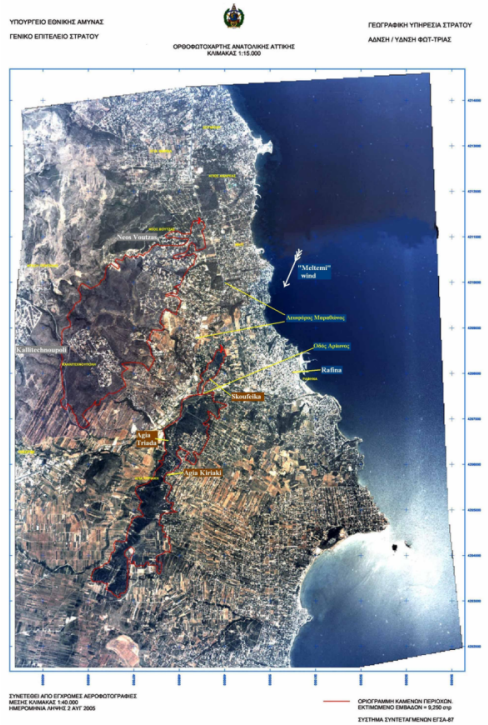
This aerial photo of the Rafina area on Aug. 2, 2005, shows the final perimeter of the two fires.

Greece faces a serious forest fire problem. The climate is typically Mediterranean with mild, rainy winters and warm, dry summers. The fire problem is more pronounced in the south part of the country, which is drier and hotter in the summer than the north part and which faces a strong north-east wind called meltemi. This wind blows in the Aegean Sea and the coasts around it during the summer months.

The capital of Greece is the historic city of Athens, which lies in Attica, a peninsula surrounded by the Aegean Sea to the east, the Saronic Gulf to the south and the Corinthian Gulf to the west. Athens has grown rapidly since the 1950s and currently has a population of more than 4 million. In the 1980s, many people built vacation houses along the coastline and in the forests to escape city congestion and summer heat. In the 1990s, people also started building expensive houses in these areas for year-round occupancy.

Olive groves and vineyards comprise a large part of Attica's agricultural areas. Natural vegetation includes scrub vegetation called phrygana. At elevations up to 800 meters, most of the forest area is covered by Aleppo

The fires of July 28, 2005 in the area of Rafina, East Attica



- Two fires
  1. The fire of Rafina- Agia Triada (start: 10:40)
  2. The fire of Neos Voutzas – Kallitechnoupoli (start: 12:30)
- They run in parallel under the same conditions:
  - NE “meltemi” wind at 30-45 km/h, gusts up to 60 km/h
  - Relative humidity ~30%
  - Maximum temperature 30 ^{o}C

Agia Triada and Kallitechnoupoli

Neos Voutzas

Fire of Chios island August 17-21, 2012

Fire at Lithi, Chios Source: APE

View of the fire from Lesvos (18-8-2012, 13:00

Day

Aug: 23 24 25 26

Daily Modis

Wednesday 22nd of August 2012

Hot Spots

24 Hrs | 7 Days | 90 Days

Burnt Areas

24 Hrs | 7 Days | 30 Days | All

Burnt Area Disclaimer!

Burnt Area Locator

Country:

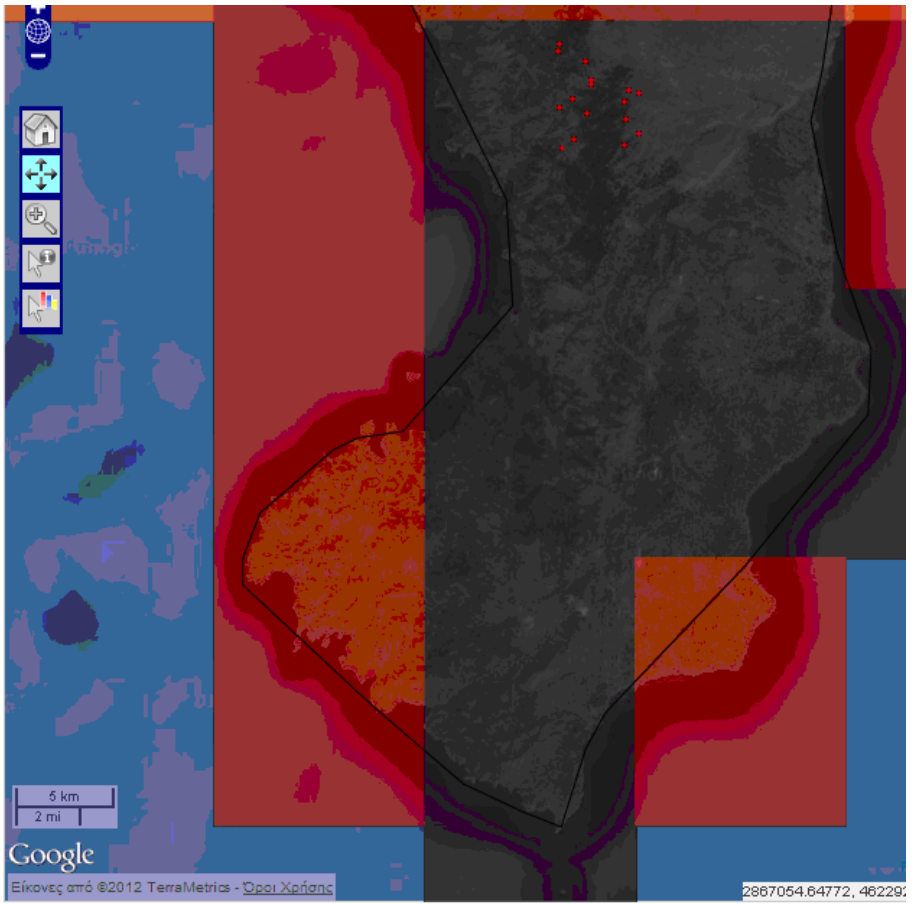
All

Province: ...Select...

Last Update: 2012-08-22
Start Date: 2012-08-20
Location: **Not Available**
Province : Not Available(Montenegr
Size of Burnt Area: 826 (ha)

Last Update: 2012-08-22
Start Date: 2012-08-18
Location: **Dimos Mastichochorio**
Province : Chios(Greece)
Size of Burnt Area: 14909 (ha)

Last Update: 2012-08-22
Start Date: 2012-08-17
Location: **Not Available**
Province : Not Available(Bosnia)
Size of Burnt Area: 1030 (ha)



Key points

- Burned area: 14,800 ha (including large area of masticha producing trees)
- Up to 9 BF winds
- Canadair CL-415 ineffective (had to pick water from Kalloni lagoon in Lesvos)
- Erickson S-64 contributed significantly
- More than 100 firetrucks (Fire Service & volunteers)
- Strong resources, poor management (no suppression efforts at the heel).

The extreme fires of August 2007

- On August 21-23 the third heat wave (temperatures above 39 ^{o}C for three days) hit the country.
- It was followed by a day of 7-8 Beaufort scale winds (50-70 km/hr) and extremely low relative humidity (8-20%).
- The vegetation was severely water stressed. There had been no rain in southern Greece for the whole summer.

The chronicle of the disaster (23-08-2007)

Fires starting on August 23 on Parnon mountain (morning) and Taygetos mountain (afternoon). Initial attack failed.

Image: NASA Aqua sensor

24-08-2007

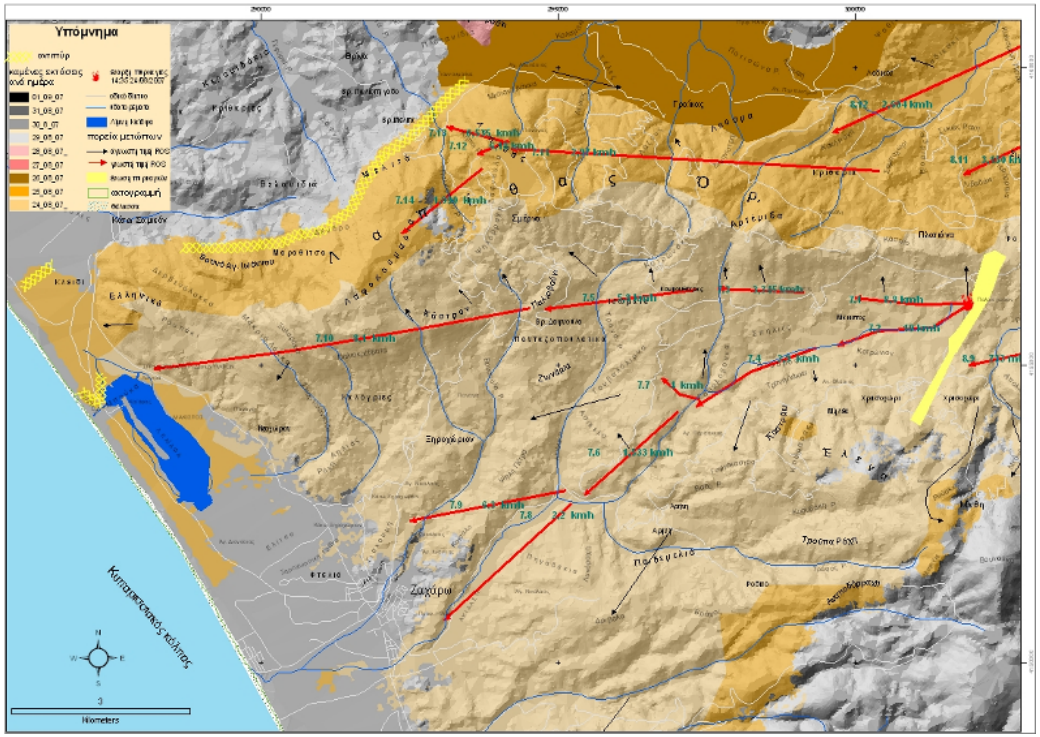
Late morning

Early afternoon

Image: NASA Terra sensor

Aqua sensor

Fire of Paleohori-Makistos-Artemida-Zaharo (Aug. 24th) (from M. Athanasiou)



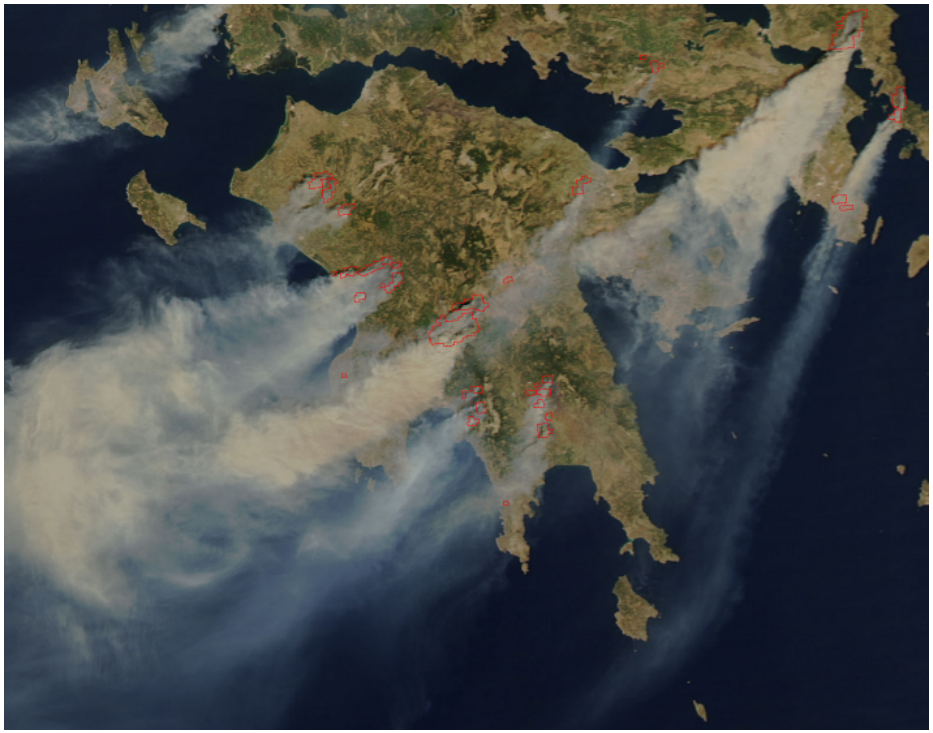
More than thirty
dead on
24-8-2009
(twenty three near
Artemida, Ilia,
Peloponnese)

Spotting during the fire that 10 minutes before this moment killed 23 people in Artemida

(Source: a video in www.YouTube.com)

Spotting during that fire

25-08-2007



(NASA image, captured by the MODIS aqua sensor)

Ilia, 25-8-2007

Photo: M. Athanasiou

Ilia, 25-8-2007

Photos: M. Athanasiou

Explosive fire behavior in Arcadia

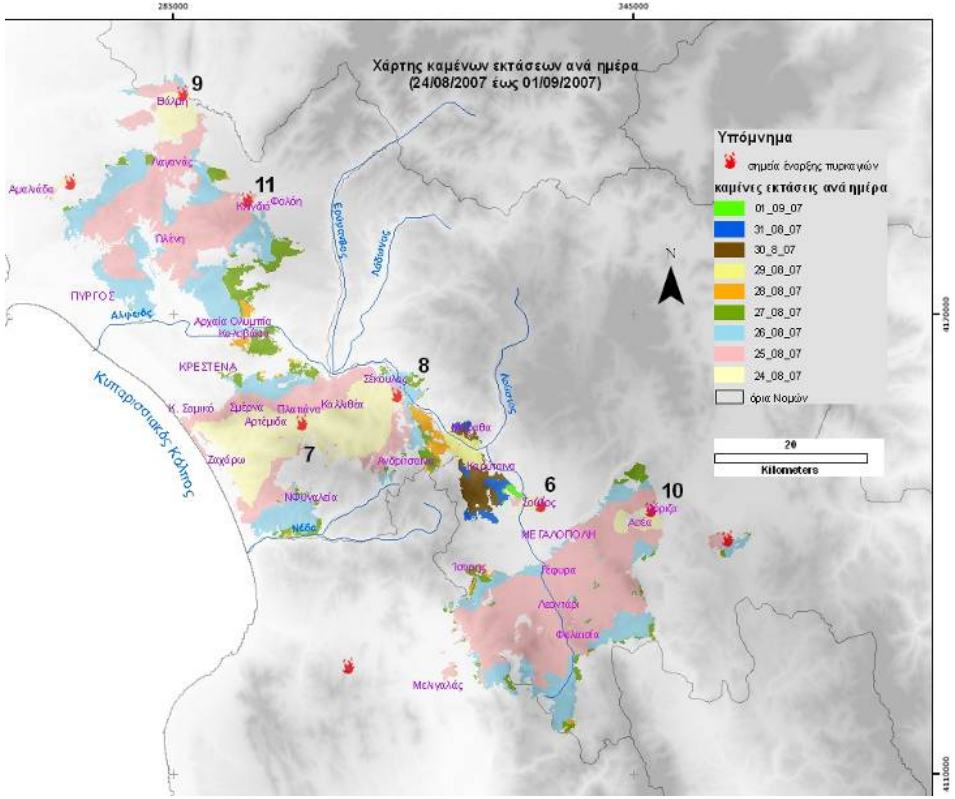
Photo: M. Athanasiou

26-08-2007

Late morning

Early afternoon

Burned area per day map in Western Peloponnese (from M. Athanasiou)



Fire approaching Olympia, 26-8-2007

Firefighting in Ancient Olympia

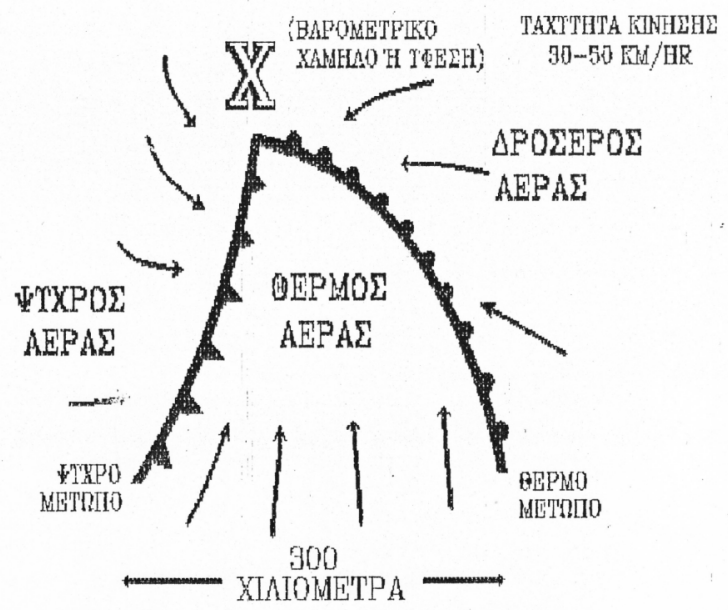
Photos from the Mass Media

Fire at Ancient Olympia (Aug. 26th)

Photos from the Mass Media

Cold Front Fires

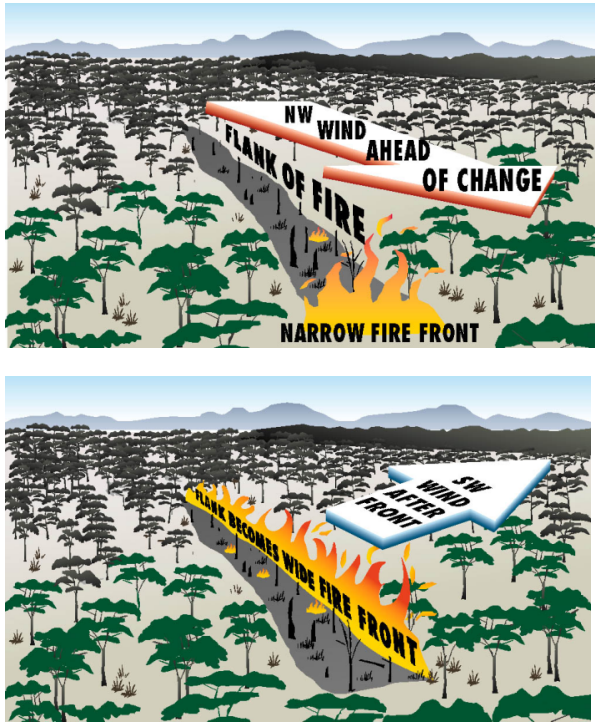
ΜΕΤΑΒΟΛΕΣ ΑΝΕΜΩΝ ΜΕ ΤΗΝ ΕΛΕΥΣΗ ΜΕΤΩΠΩΝ



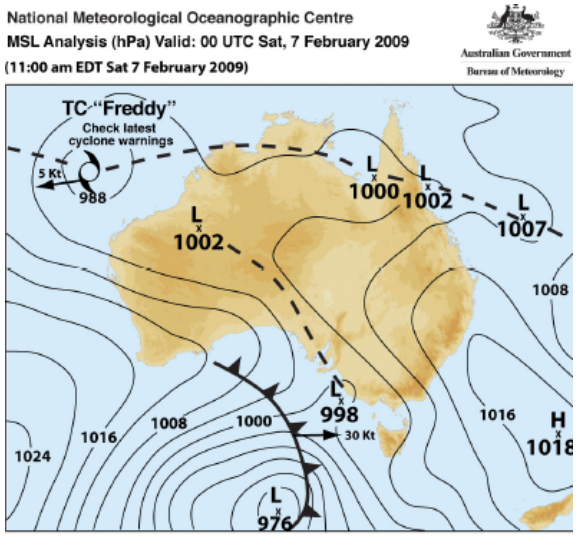
ΜΕ ΤΗΝ ΕΛΕΥΣΗ ΕΝΟΣ ΜΕΤΩΠΟΥ ΟΙ ΑΝΕΜΟΙ:

- ΑΛΛΑΖΟΥΝ ΚΑΤΕΥΘΥΝΣΗ ΚΑΤΑ ΤΗ ΦΟΡΑ ΤΩΝ ΔΕΙΚΤΩΝ ΤΟΥ ΩΡΟΛΟΓΙΟΥ
- ΑΥΞΑΝΟΥΝ ΣΕ ΕΝΤΑΣΗ ΚΑΘΩΣ ΠΕΡΝΑΕΙ ΤΟ ΜΕΤΩΠΟ

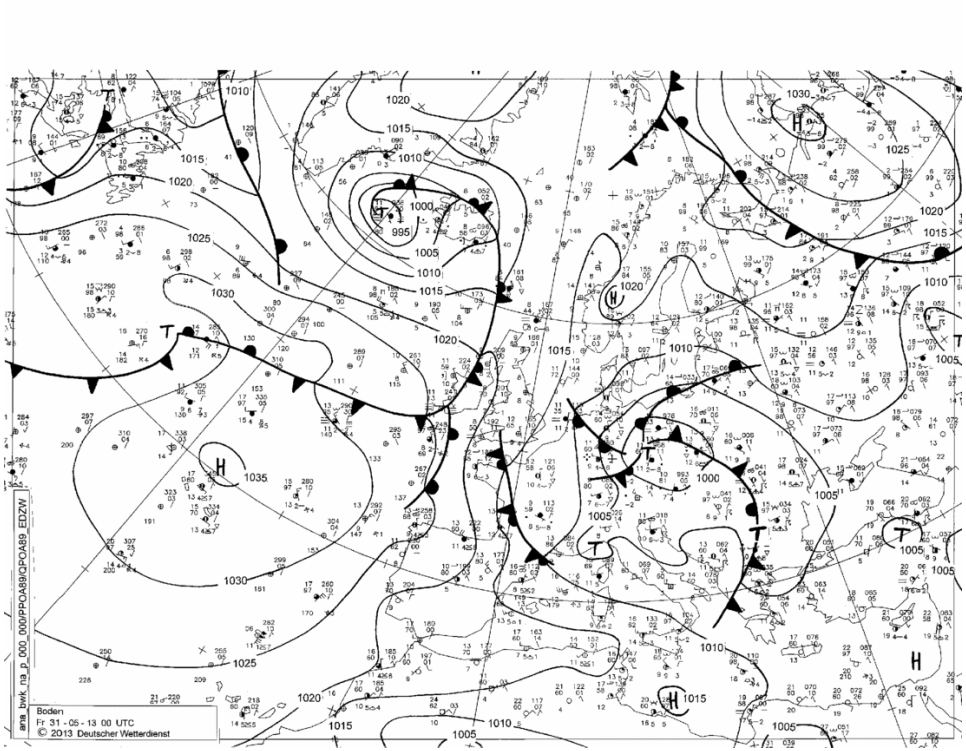
Cold front (Australia)



“Black Saturday” fires
in Victoria Australia (February 7, 2009)



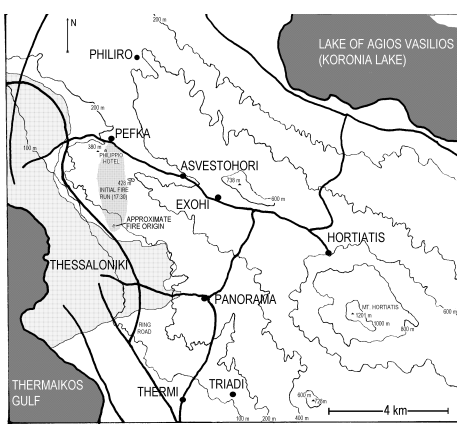
Cold fronts over Europe 31-5-2013

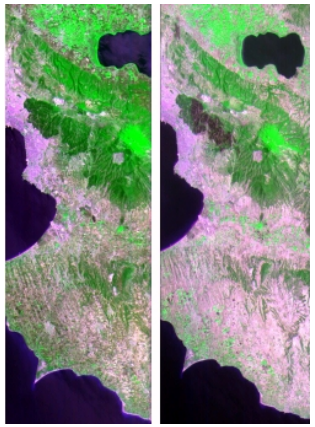


Fire of Avlonas (September 5, 1992)

- Started from a burning open garbage dump with increasing SW wind, preceding the passage of a cold front.
- Burned area:
  - 2,500 ha in 5 hours
  - Total 5,500 ha until next morning

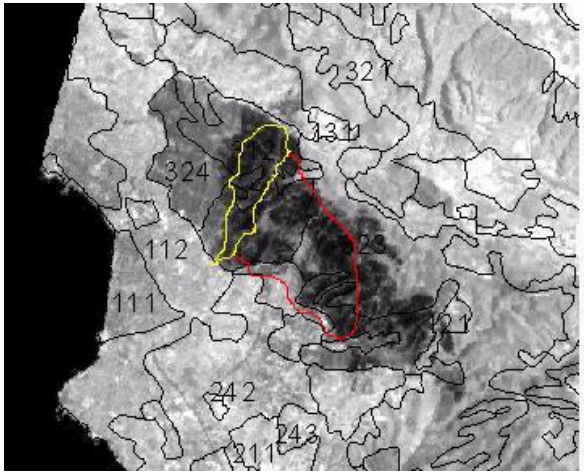
The fire of the forest-park of Thessaloniki, Greece, July 6-8, 1997





- The fire erupted around 16:10, under a 35 km/h S to SW wind preceding a dry cold front.
- Temperature at 37^{o}C, RH quite high
- Cold front passage around 19:30
- Then, the wind turned to NW in a few minutes.

The fire of the forest-park of Thessaloniki, July 6-8, 1997

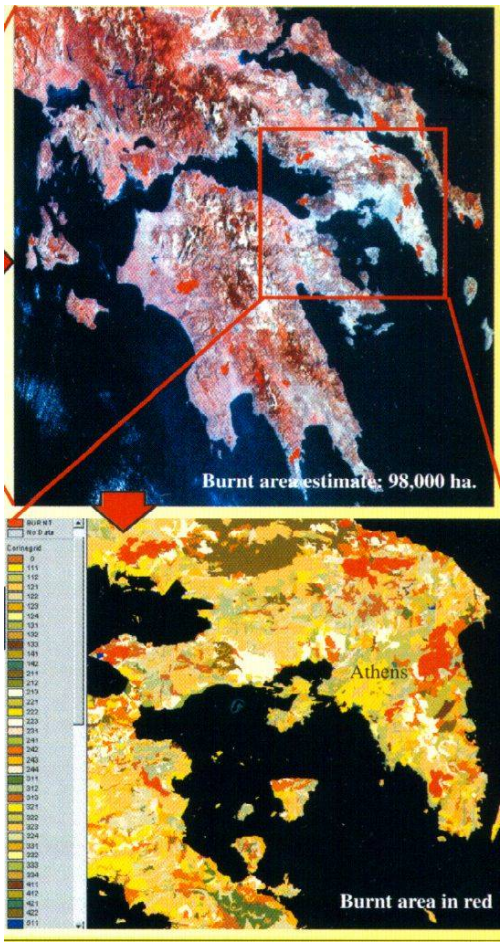


CORINE Code	Description	Burned area (ha)
111	Continuous urban fabric	0,00
112	Discontinuous urban fabric	0,12
121	Industrial or commercial units	7,74
131	Mineral extraction site	0,00
211	Non irrigated arable land	0,00
242	Complex cultivation patterns	0,75
243	Land principally occupied by agriculture,with significant areas of natural vegetation	0,00
312	Coniferous forest	842,91
321	Natural grassland	46,18
323	Sclerophylous vegetation	541,60
324	Burnt areas	59,79
Total		**1499,09**

- Yellow: Approximate fire perimeter at 19:30
- Red: Approximate fire perimeter at 24:00

Key points

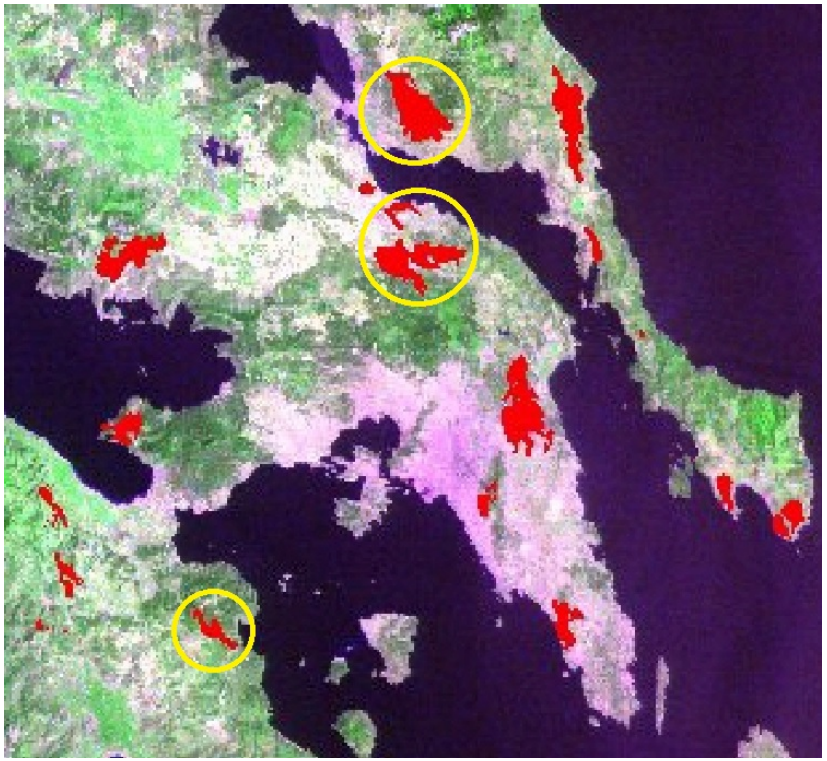
- The firefighting resources were caught by surprise by the wind shift
- The fire spread vigorously until the wind calmed down (around 02:00 in the night)
- However, it picked up again in the afternoon of July 7th and threatened the city suburb of Panorama
- The total burned area reached 1,700 ha



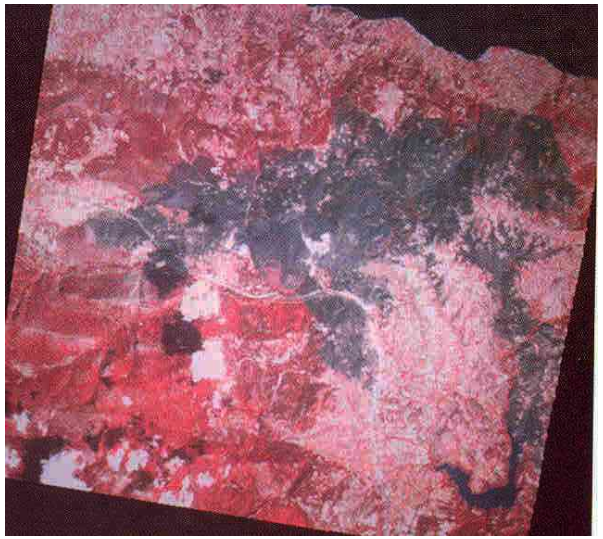
Burned area in Greece in 1998

- Total: 98,000 ha
- About 20,000 ha burned on July 4-5th 1998, in 12 hours, with the passage of a dry cold front around 13:00
- 180 fires erupted in the area around Athens mostly between 12:00 and 14:00

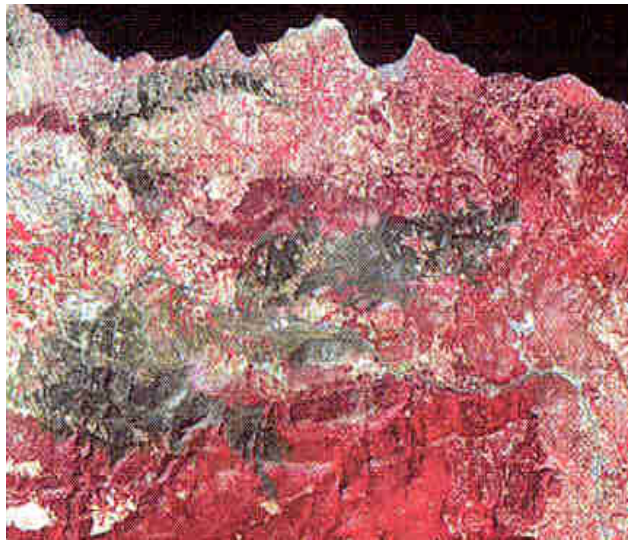
Fires of July 4-5, 1998

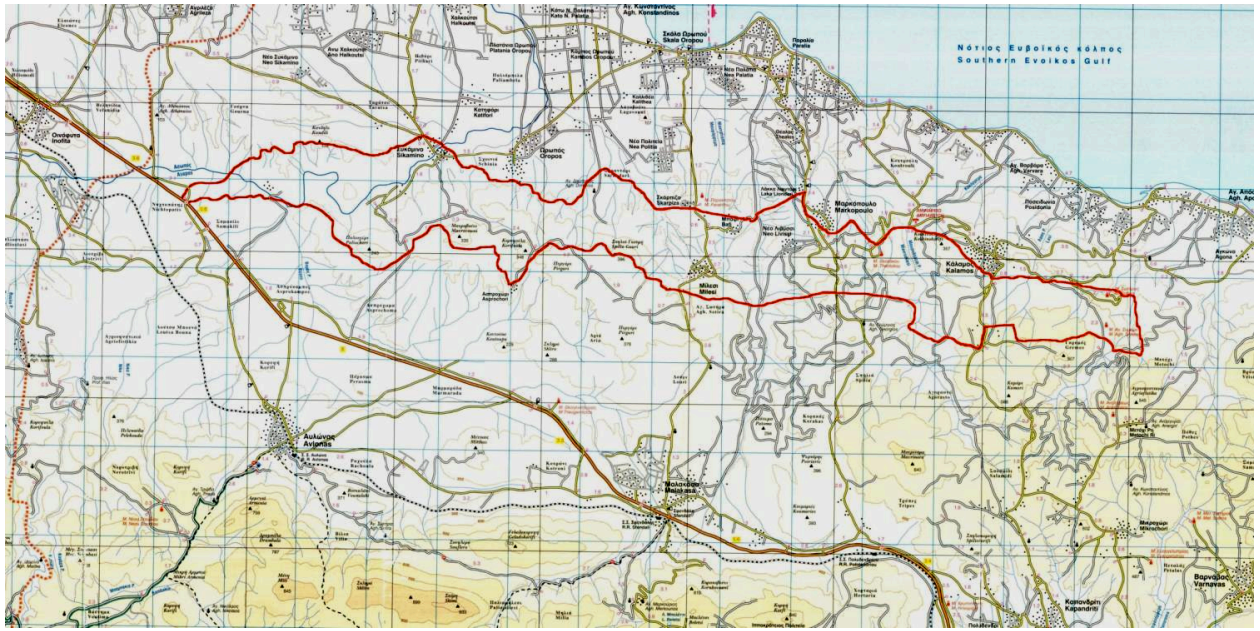


September 1992

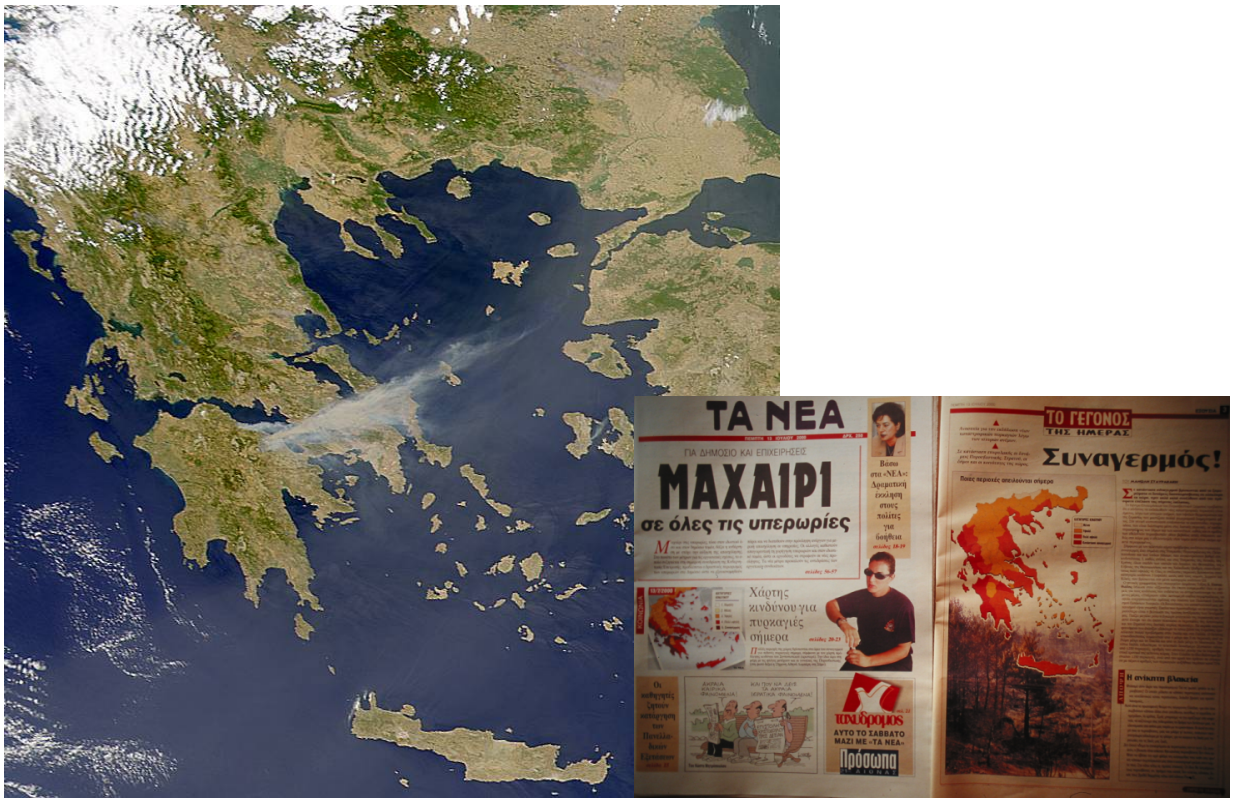


July 1998



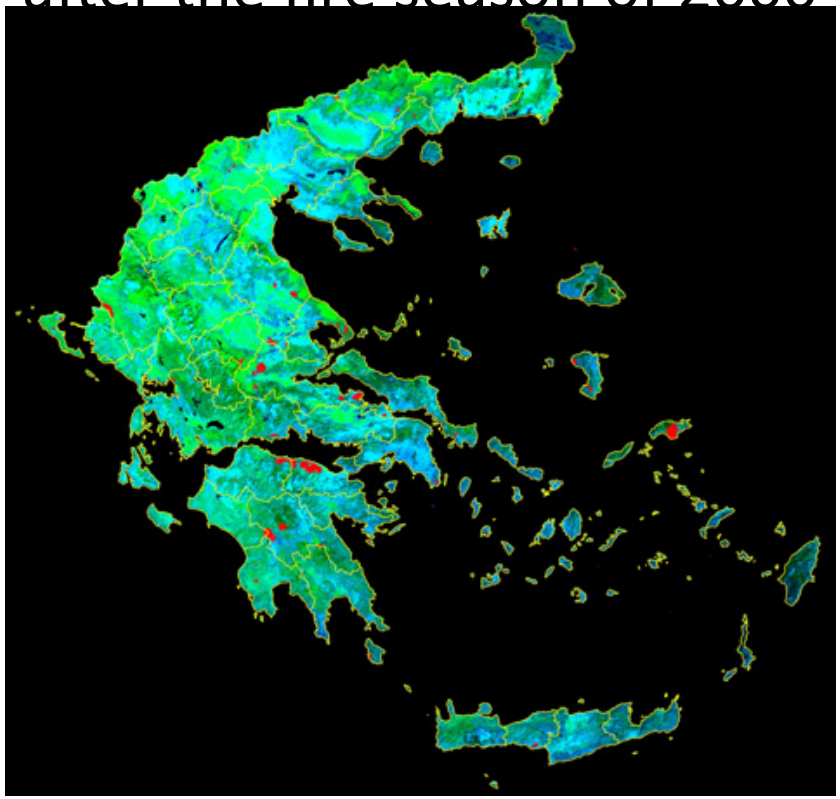

Νότιος Ευβοϊκός κόλπος
Southern Evoikos Gulf

North Peloponnese fires (July 13, 2000)

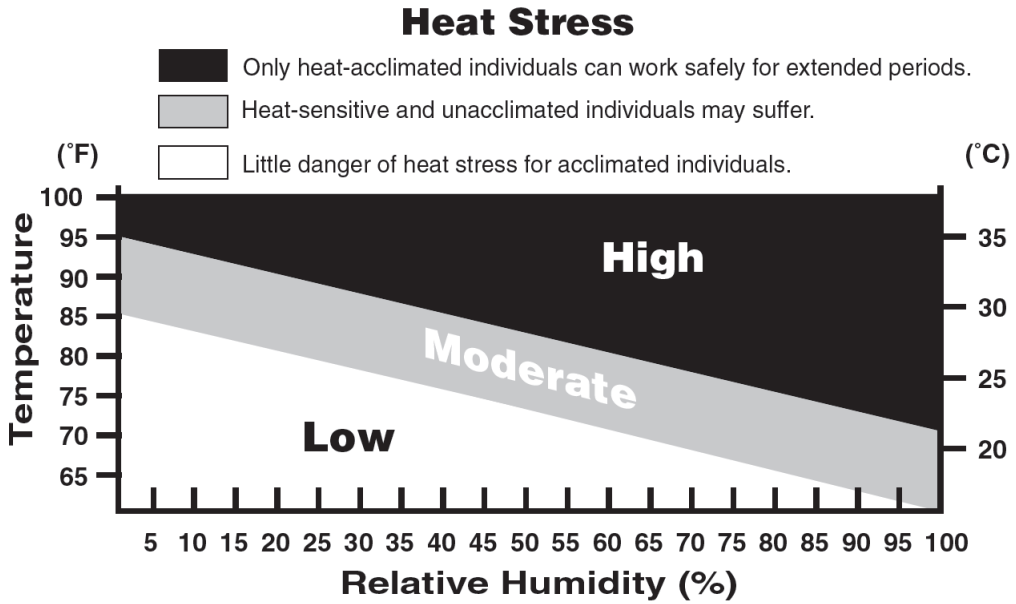


Fire danger prediction for July 13, 2000

Large fire scars in Greece
after the fire season of 2000



Weather effects on humans



Domitrovich and Sharkey, 2010

In conclusion

- Deep knowledge and continuous attention on fire weather are absolutely necessary for managing forest fires effectively and safely.
- A good understanding of the basics of fire weather and the situations that shout “watch-out” is of paramount importance even for the simple firefighter.

Thank you