Probabilistic fire spread prediction
The case of the deadly wildfire in Mati, Greece

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Using ECMWF’s Forecasts (UEF2019), June 6 2019, ECMWF, Reading, UK
Background

The wildfire broke up in the **early afternoon** (13:45 UTC) on **Monday July 23, 2018**, at the foothill of the Penteli Mountain, **20 km NE** of the city of **Athens** and **5 km off** the eastern Attica coast.

Assisted by the prevailing meteorological conditions, it spread **erratically**, literally **wiping out** the residential settlement of **Mati** in **less than 2 h**.
Aftermath

- ~12.8 km² were burnt (1276 ha).
- >1,000 buildings were totally destroyed.
- 305 vehicles were burnt.
- 101 civilian fatalities.

The Mati wildfire is the 2nd deadliest natural disaster in Greece’s modern history.
July 23, 2018

Ridge breakdown due to approaching upper-level trough.

Shallow (1004 hPa) low-pressure system over NE Aegean Sea.

Subtropical ridge.
Overview: Synoptic environment

July 23, 2018
Subtropical jet stream extending from S Italy to Greece.

25-30 m s\(^{-1}\) peak winds.
Overview: AWS observations

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6 AWS of NOA, recording T, RH, WS and WD at 10min intervals
W/NW winds >15 m s\(^{-1}\) prior to fire ignition, peaking at ~18 m s\(^{-1}\) (~65 km h\(^{-1}\)) during active fire spread.
Rapid dry-out of fine fuels prior to fire ignition. Winds 8-10 m s⁻¹ during active fire spread.
Overview: Fire spread

Based on evidence collected by the National and Kapodistrian University of Athens (https://edcm.edu.gr/images/docs/2018/Newsletter_Attica_Fires_2018_v11.pdf)

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Objectives

**IRIS**: rapid Response fire Spread forecasting system for Greece, based on the coupled fire-atmosphere WRF-Fire modelling system (Munoz-Esparza et al., 2018) and supported by a prototype fuel models’ map derived from products of the Copernicus Land Monitoring Service.

Pre-operational implementation during 2018 fire season; Fully operational during 2019 fire season.

Two-way coupling between the fire and the atmosphere (via heat/vapour fluxes); Rapid-response

Could *ECMWF’s EPS* be used (and how?) for providing an early warning?

Does driving *IRIS* with *ECMWF’s EPS* provide added-value for fire spread forecasting?
The **key ingredients** for potentially **extreme fire behaviour** are present in the deterministic forecast:

- **Ridge break-down.**
- Approaching **upper-level trough.**
- Mid-level subtropical **jet stream** (~30 m s\(^{-1}\)) over S Greece.
Deterministic outlook: T0+48

Deterministic forecast guidance for **conditions highly conducive** for **extreme fire behaviour** in **Attica**.

**Trigger alarm** for **potentially dangerous** conditions in Attica; Employ **ECMWF EPS** for gaining further insight.

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IRIS: Configuration - Atmospheric model (WRF)

Three **2-way nested** modelling domains, **centred** around fire **ignition**: 15 - 5 - 1 km.

**Initialisation:** ECMWF EPS of 21/07/2018, ~16km resolution (T0+48).

**Simulations:** 50 (EPS members) + 1 (EPS control) + 1 (IFS CY45R1)
IRIS: Configuration - Fire spread model (Fire)

Ultra-high-resolution domain (100m) embedded as sub-grid within the 1km atmospheric domain:
- 90m SRTM topography.
- 100m fuel models (based on Copernicus Land Monitoring Service products).

Fire spread simulated with the level-set method (Munoz-Esparza et al., 2018).

~10min integration time per 6h of forecast
Burn probability

IRIS: Mati Wildfire - 100m
ECMWF EPS init.: 21/07/2018 12Z
Burn probability (shaded, %)
Green (contour): Deterministic | Blue (contour): Control
Valid: 23/07/2018 15:30Z

15:30 UTC

EPS fails to provide added-value guidance.
- **Limited** fire spread.
- **NE movement** of the fire front.
**IRIS: Results - T0+48**

**CY45R1**: 3 m s\(^{-1}\), 42.5°  
**EPS**: 4.2 m s\(^{-1}\), 50.9°
**IRIS: Results - T0+48**

**CY45R1**: 3.3 m s\(^{-1}\), 71.4°

**EPS**: 1.5 m s\(^{-1}\), 56.3°

Using ECMWF’s Forecasts (UEF2019), June 6 2019, ECMWF, Reading, UK
The key ingredients for potentially extreme fire behaviour are present in the deterministic forecast:

- Ridge break-down.
- Approaching upper-level trough.
- Mid-level subtropical jet stream (~30 m s\(^{-1}\)) over S Greece.

Critical fire weather pattern
Deterministic forecast guidance for **conditions highly conducive** for extreme fire behaviour in **Eastern Attica**.

**Trigger alarm** for potentially dangerous conditions in **Eastern Attica**; Employ **ECMWF EPS** for gaining further insight.

Using ECMWF’s Forecasts (UEF2019), June 6 2019, ECMWF, Reading, UK
EPS shows **larger lateral spread** along the **north flank** of the fire front, while it also **enhances the credibility** of the deterministic forecast.
IRIS: Results - T0+24

Using ECMWF’s Forecasts (UEF2019), June 6 2019, ECMWF, Reading, UK

**CY45R1**: 3.3 m s\(^{-1}\), 27.3\(^\circ\)

**EPS**: 3.5 m s\(^{-1}\), 39.2\(^\circ\)
**IRIS: Results - T0+24**

**CY45R1**: 2.6 m s⁻¹, 47.9°

**EPS**: 1.4 m s⁻¹, 47.8°

Using ECMWF’s Forecasts (UEF2019), June 6 2019, ECMWF, Reading, UK
EPS: Alarm bells

Extreme Forecast Index for Model Gust Factors

Reference (D) Day 23 July 2018

Values greater than +0.5

First alarm bells six days prior the event

Saturated values of GF as approaching D day

 usando ECMWF’s Forecasts (UEF2019), 3-6 June 2019, ECMWF, Reading, UK
Extreme Forecast Index (EFI) T0-T24 Values (based on 00utc model run) of ECMWF EPS for Gust Factors (GF) of winds at 10-meter height that could be available to Fire Managers during morning hours for assessing the anticipated gusty behaviour of atmosphere flow.

Using ECMWF’s Forecasts (UEF2019), 3-6 June 2019, ECMWF, Reading, UK
Summary - Conclusions - Future work

The coupled fire-atmosphere IRIS forecasting system was used for retrospectively forecasting the deadly Mati wildfire, driven by ECMWF deterministic and EPS data.

Preliminary results show that:
• The deterministic forecast outperformed EPS at both lead times: T0+48, T0+24.
• At T0+48, the EPS guidance is misleading (NE movement of fire front).
• At T0+24, the EPS is in line with the deterministic forecast, enhancing credibility.
• Extreme forecast index for gust factors could be used for early warning.

Overall, the present study shows no significant added-value provided by the use of EPS for driving a fire spread forecasting system. This is particularly true, considering the computational cost for running the probabilistic fire spread forecasts.

Preliminary results should be revisited by expanding the current study:
• More wildfires, covering a wide range of meteorological/fuel conditions.
• Include fire ignition location uncertainty in the ensemble forecasting.

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Thank you for attention!

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