Wildfire danger forecasting at different spatio-temoral scales

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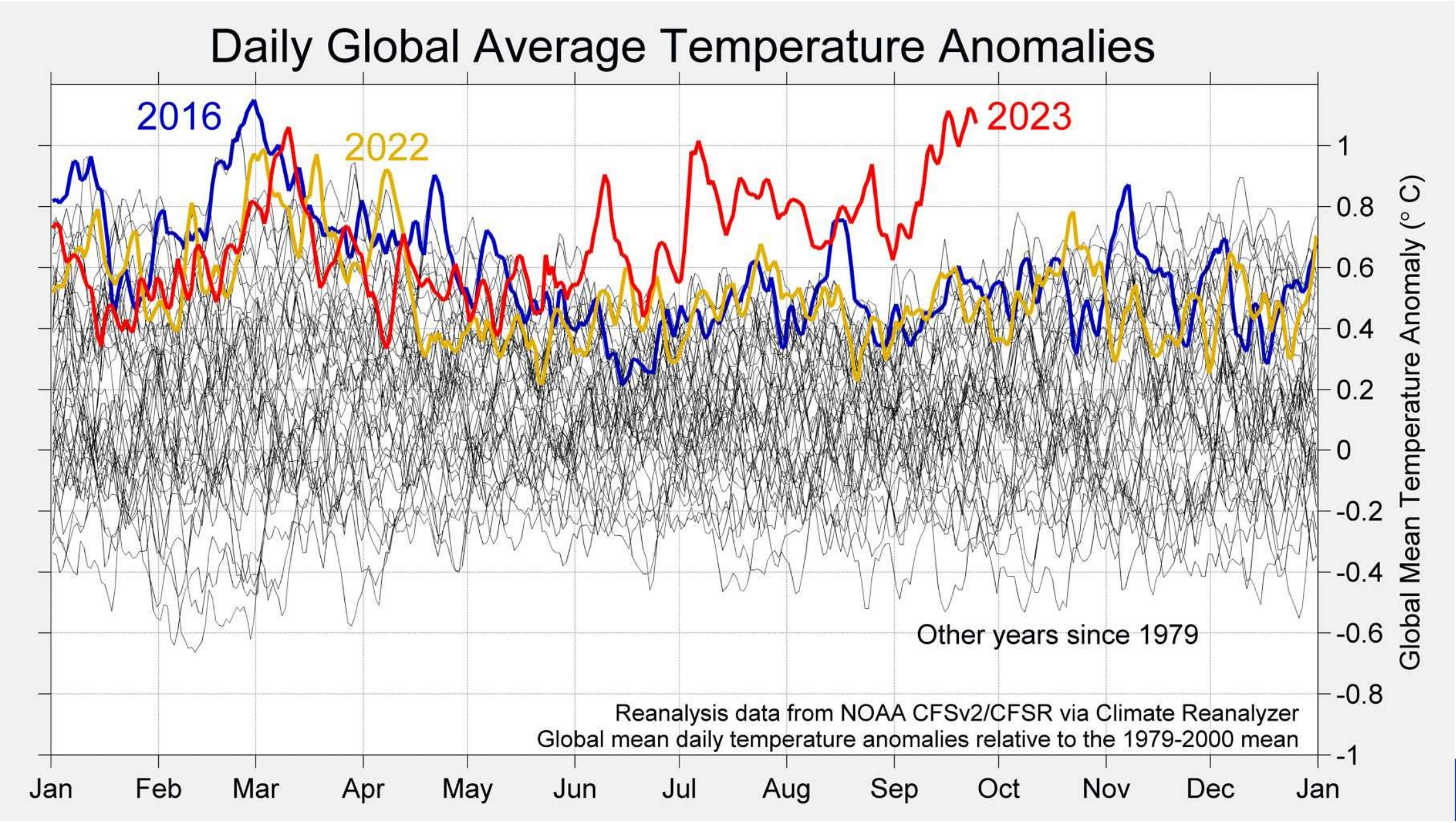
Integrating Disaster Risk Data in Policy: the Copernicus Emergency Management Service Annual Conference 2023


Daily Global Average Temperature Anomalies
2016
2022
2023
Other years since 1979
Reanalysis data from NOAA CFSv2/CFSR via Climate Reanalyzer
Global mean daily temperature anomalies relative to the 1979-2000 mean
Global Mean Temperature Anomaly (° C)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

What happened in Greece in 2023

- Difference from the Fire Season 2021– No Warning !!!!
- Heatwaves – High Fire Risks – Two waves of forest fires– July and August
- 3 Big Forest Fires at the same day in the 17th of July and 3 Big Forest fires at the same day in the 23rd of July
- The biggest forest fire in Europe – Alexandroupolis Fire
- Affected WUI, Touristic facilities, Military basis, Critical infrastructures, etc.
- 22 countries came to support us – working together and learn from each other is the only way
- At the same day extreme forest fire and extreme floods
- Extreme floods in central Greece – 3.576 rescues (807 of them by air)
- 5 Losses due to forest fires and 16 Losses + 1 Missing due to the floods
- More than 7.120 forest fires– 162.000 ha until now from January 2023

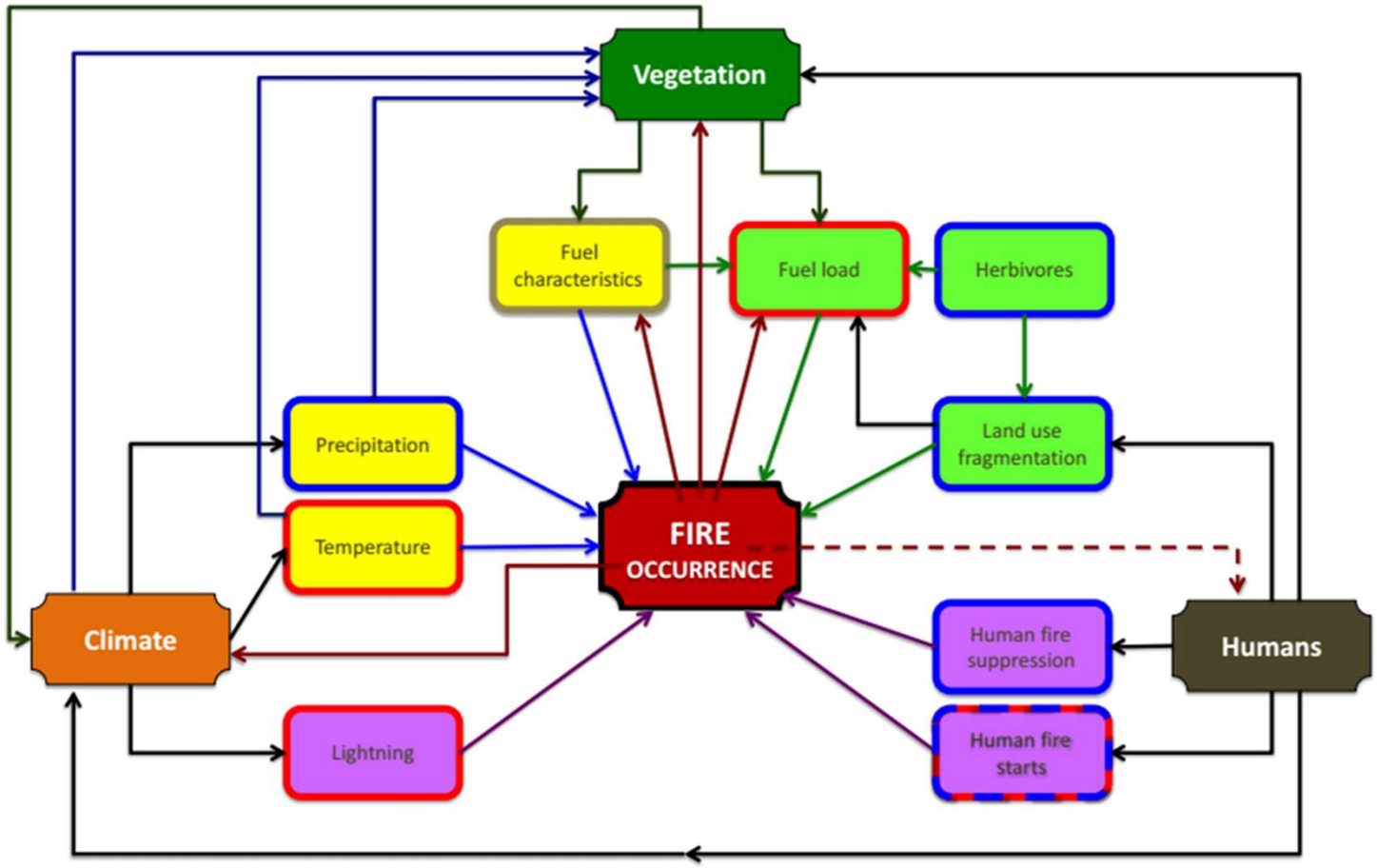
Challenges

Fires are the result of **complex interactions** between humans, climate, vegetation

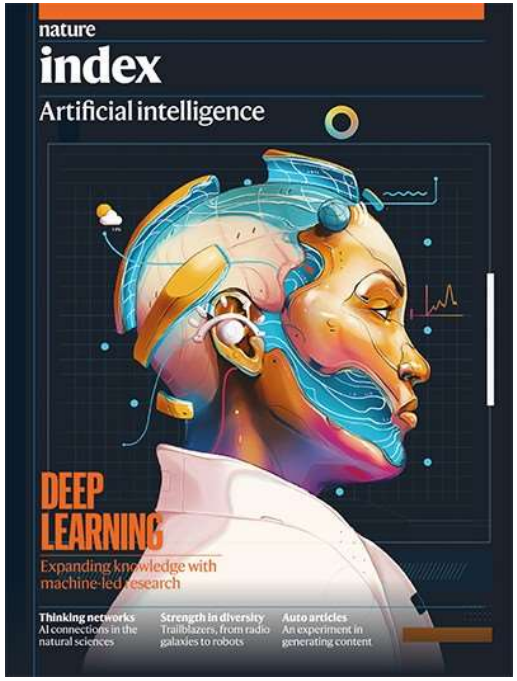
Proposed solution

Use **Machine Learning** on historical Earth Observation data

Associate conditions of fire drivers with past **burned areas**



Fire Drivers. *Source: Hantson et al. "The status and challenge of global fire modelling" (2016)*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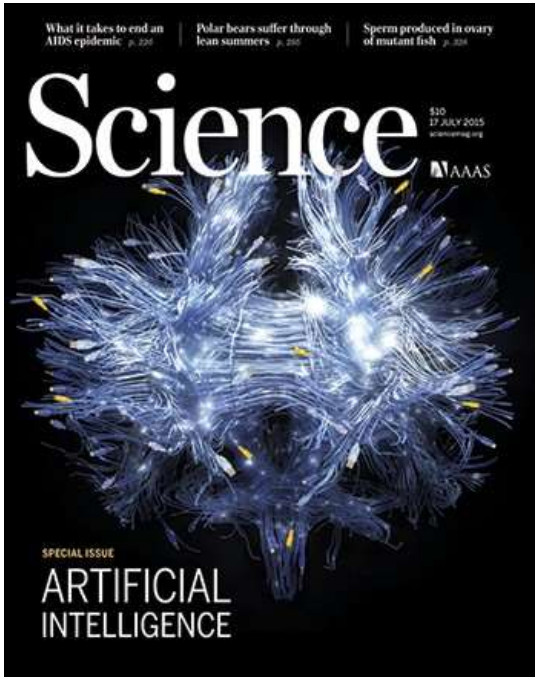
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FireCube - Data collection & harmonization

Variables

Meteo (ERA5-Land): Temperature, Wind speed & directic Precipitation, Relative Humidity (9km)

Satellite (MODIS): Land Temperature, NDVI/EVI, LAI/FPAR, Evapotranspiration

Soil moisture (European Drought Observatory)

Topography (EU-DEM): Elevation, Slope, Aspect

Land Cover (Corine)

Population Density (WorldPop)

Roads Density (OpenStreetMap)

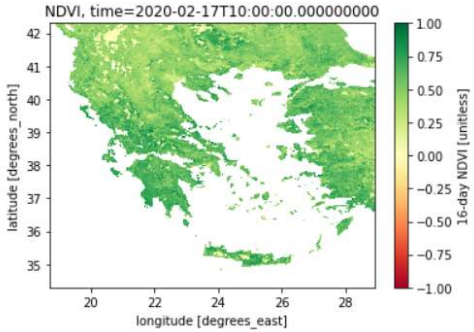
Burned areas (EFFIS)

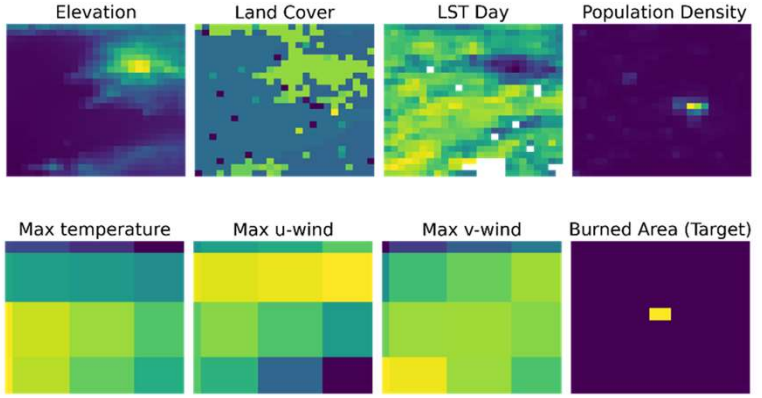
Harmonization

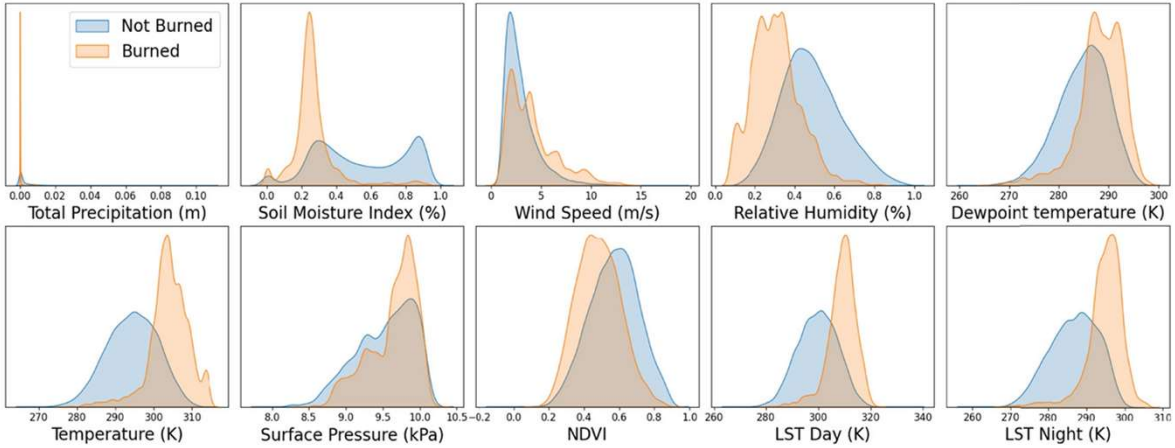
Resolution: 1km x 1km x 1day

Spatial Extent: Greece and eastern Mediterranean

Temporal Extent: 2009-2021







FireCube: A Daily Datacube for the Modeling and Analysis of Wildfires in Greece (1.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.6475592

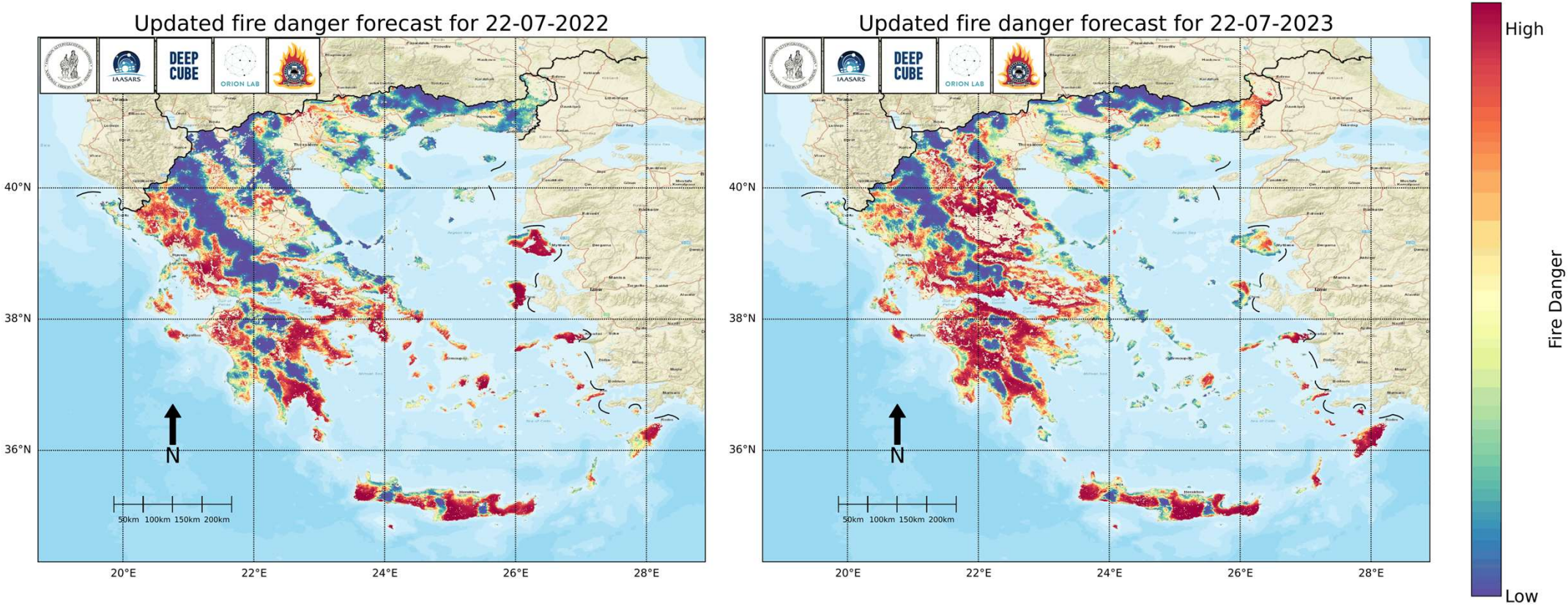
Daily maps delivered to the Hellenic Fire Service

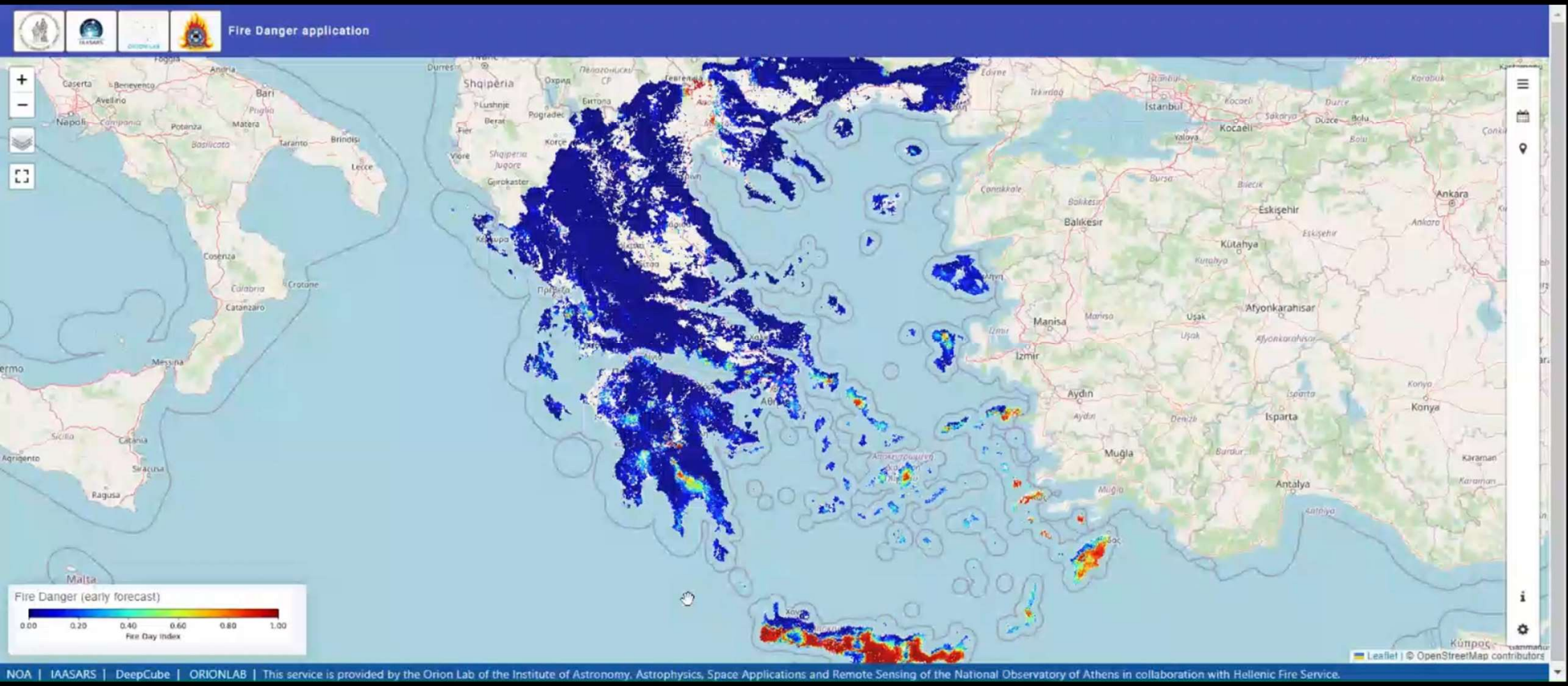
Geophysical Research Letters

Research Letter | Open Access

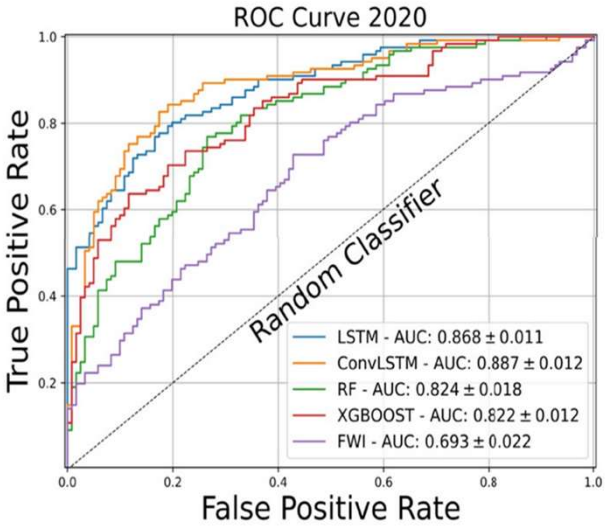
Wildfire Danger Prediction and Understanding With Deep Learning

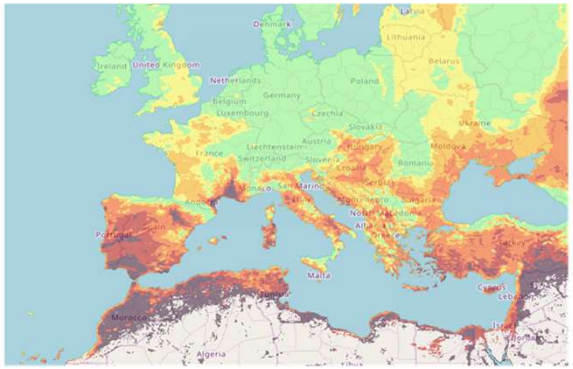
Spyros Kondylatos, Ioannis Prapas, Michele Ronco, Ioannis Papoutsis, Gustau Camps-Valls, María Piles, Miguel-Ángel Fernández-Torres, Nuno Carvalhais



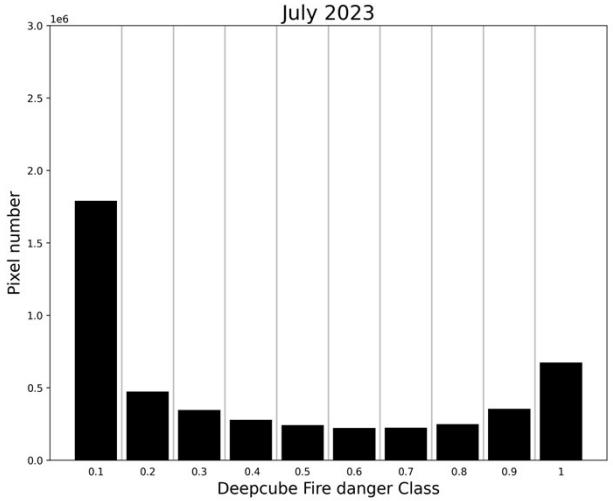

Fire Danger application
Fire Danger (early forecast)
0.00
0.20
0.40
0.60
0.80
1.00
Fire Day Index
Leaflet | © OpenStreetMap contributors
NOA | IAASARS | DeepCube | ORIONLAB | This service is provided by the Orion Lab of the Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing of the National Observatory of Athens in collaboration with Hellenic Fire Service.

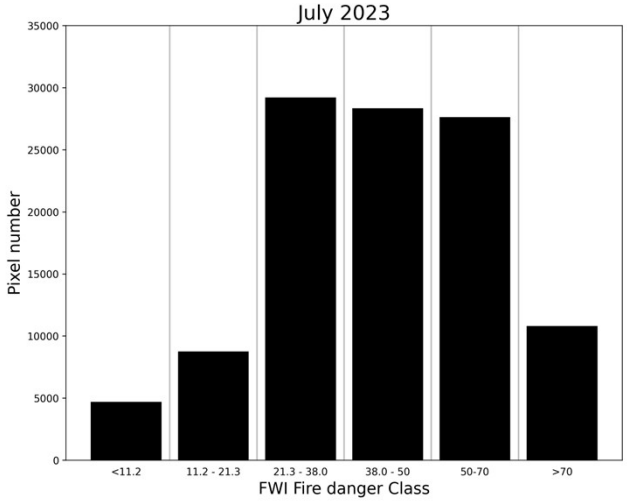
Evaluation

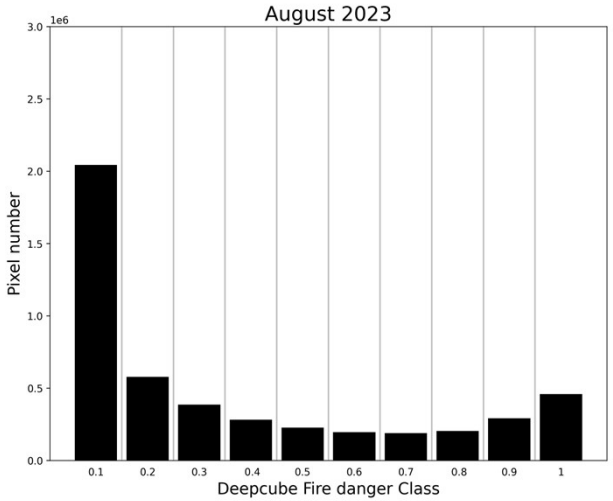


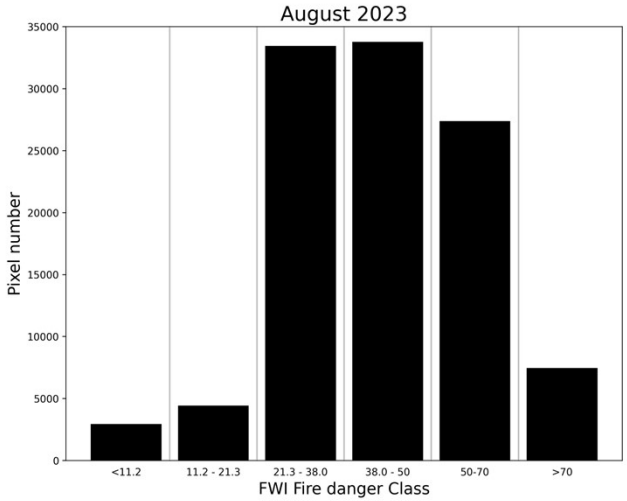


Source: EFFIS fire danger forecast for July 16th 2020
https://effis.jrc.ec.europa.eu/about-effis/









Scaling up to the Mediterranean

Specifications

- Resolution: 1km x 1km x 1-day
- Temporal extent: 2006 - 2022
- 28 variables related to wildfires

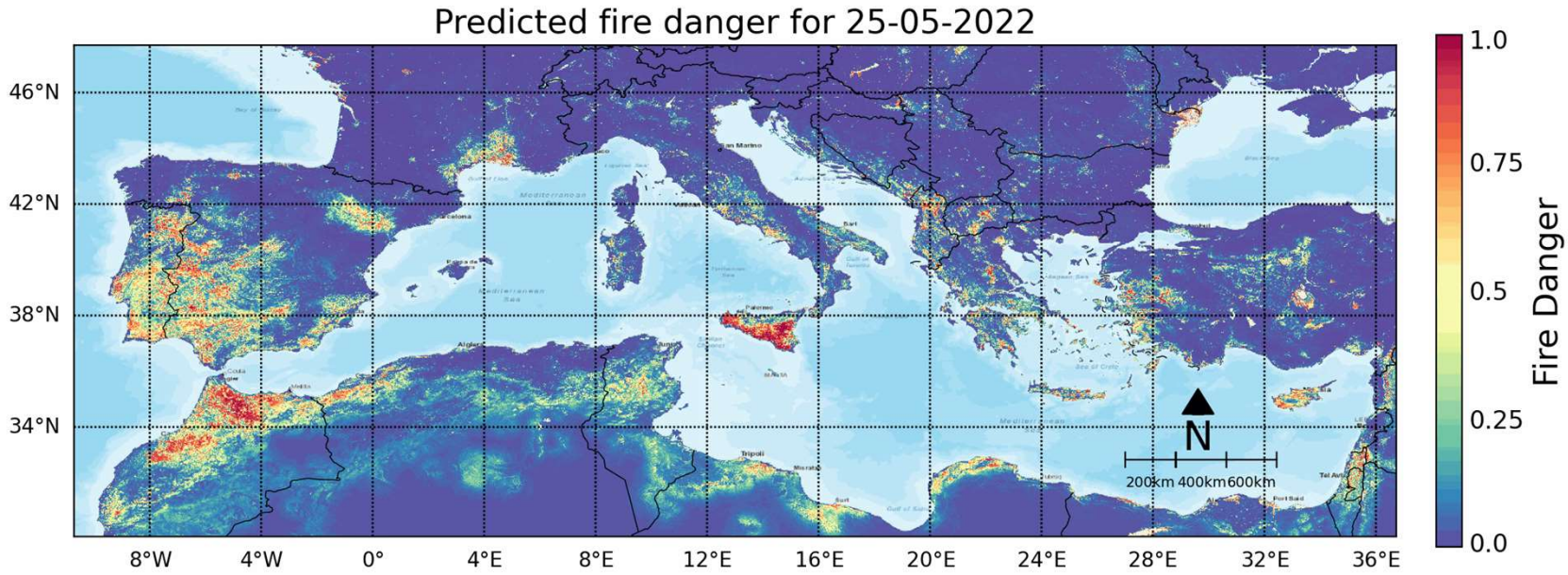
Mesogeos: A multi-purpose dataset for data-driven wildfire modeling in the Mediterranean

Spyros Kondylatos (1, 2), Ioannis Prapas (1, 2), Gustau Camps-Valls (2), Ioannis Papoutsis (1)
(1) Orion Lab, IAASARS, National Observatory of Athens
(2) Image & Signal Processing Group, Universitat de València

Paper | Dataset | Code | arXiv

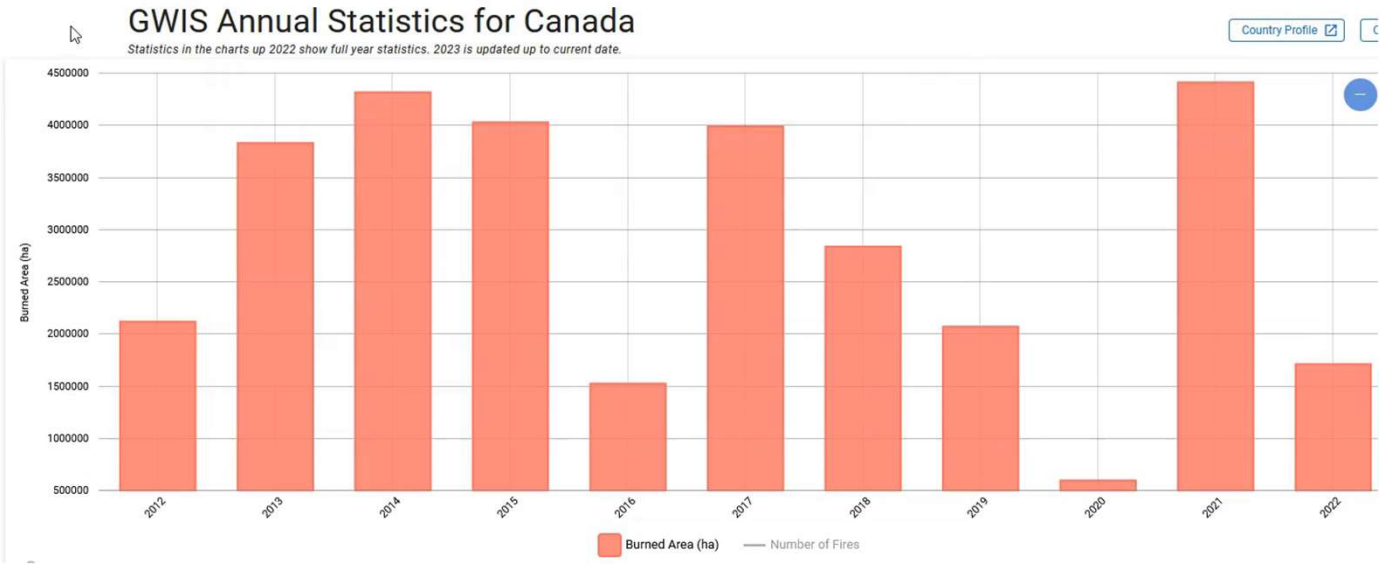
NEURAL INFORMATION PROCESSING SYSTEMS

orion-ai-lab.github.io/mesogeos/

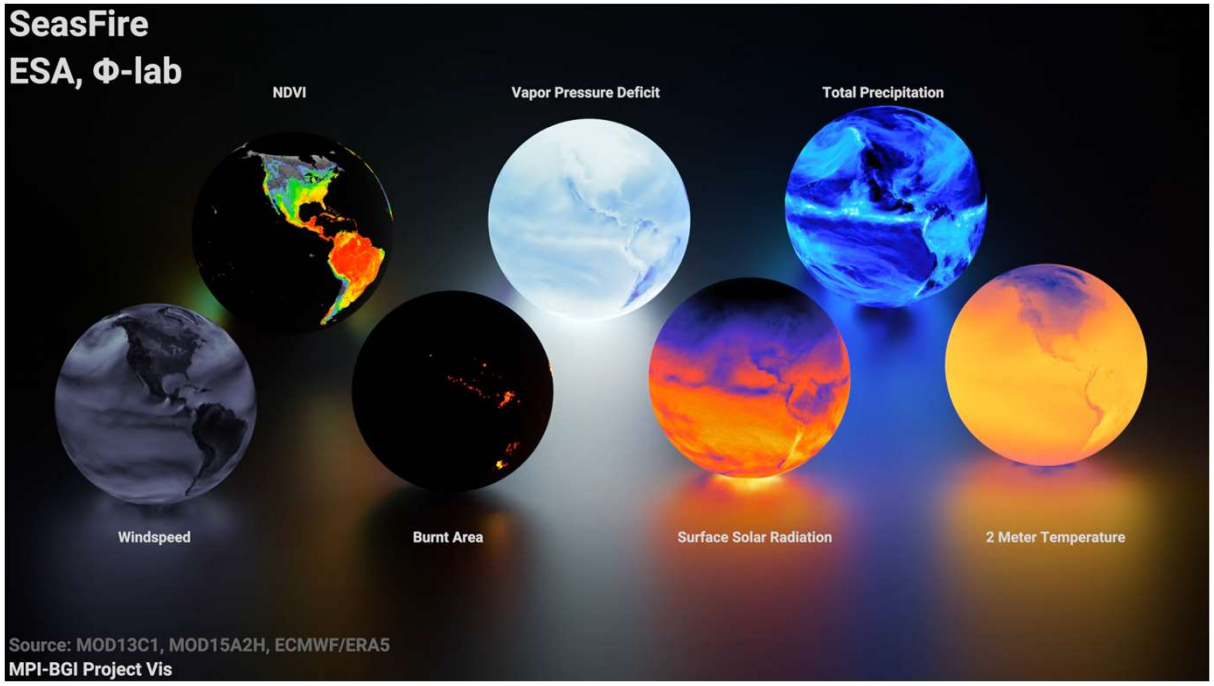


Subseasonal to seasonal wildfire forecasting

- High variability between fire seasons
- Climate change fosters extreme fire conditions



SeasFire Datacube



SeasFire Cube: A Global Dataset for Seasonal Fire Modeling in the Earth System [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7108392

Resolution: 8days x 0.25° x 0.25°

Extent: Global, 2001 - 2021

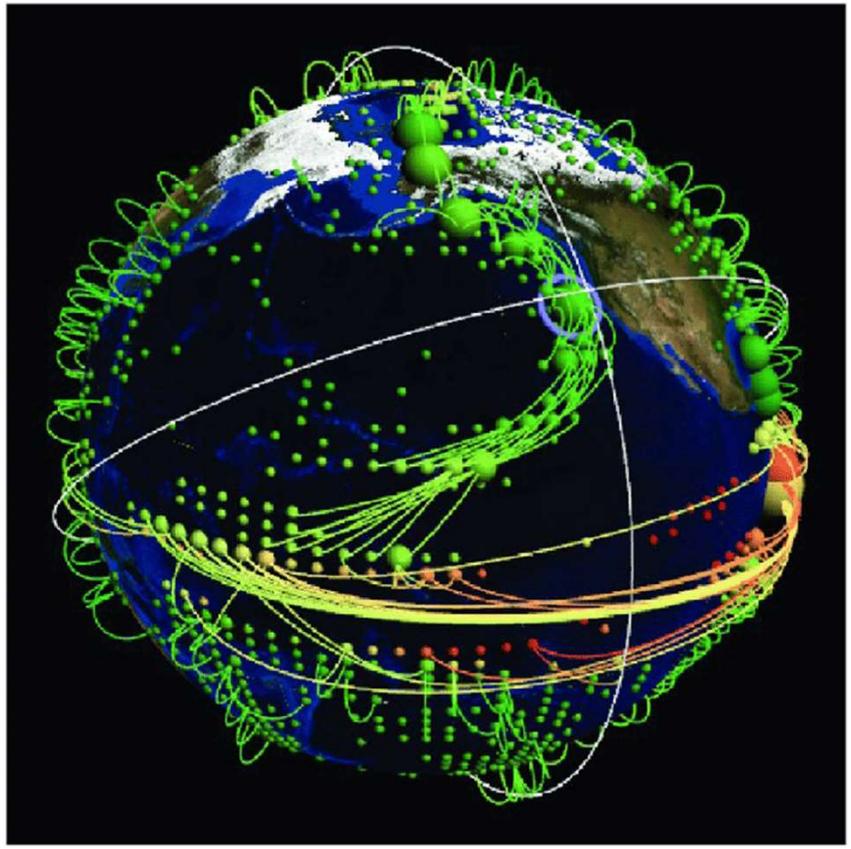
Wildfire drivers

- Meteorology (ERA5)
- Satellite Observations (MODIS)
- Vegetation, Surface Temperature
- Oceanic Indices (NOAA)
- Population Density (NASA SEDAC), Land Cover (ESA CCI)

Wildfire variables

- Burned Areas (GFED, FireCCI, GWIS)
- Fire Emissions (GFAS)

Earth is a complex inter-connected system



Source: Statistical physics approaches to the complex Earth system

Teleconnections are long-range spatiotemporal connections in the earth system. “Arctic oscillation anomalies linked to extreme wildfires in Siberia” Kim et al. (2020)

Memory effects refer to the influence of past events on current and future states of the Earth system. How past events such as fuel accumulation, drought conditions, and weather patterns can impact future wildfires. E.g. state of vegetation after previous year sustained drought.

Teleconnections modulate global wildfires

npj climate and atmospheric science

www.nature.com/npjclimatsci

ARTICLE OPEN

Check for updates

Arctic Oscillation and Pacific-North American pattern dominated-modulation of fire danger and wildfire occurrence

Flavio Justino[1✉], David H. Bromwich[2], Vanucia Schumacher[3], Alex daSilva[4] and Sheng-Hung Wang[2]

nature communications

Article

https://doi.org/10.1038/s41467-023-3605

Climate teleconnections modulate global burned area

Received: 31 March 2022

Accepted: 12 January 2023

Adrián Cardil[1,2,3], Marcos Rodrigues[4,5], Mario Tapia[2], Renaud Barbero[6], Joaquin Ramírez[2], Cathelijne R. Stoof[7], Carlos Alberto Silva[8], Midhun Mohan[9] & Sergio de-Miguel[1,3]

RESEARCH ARTICLE | CLIMATOLOGY

Extensive fires in southeastern Siberian permafrost linked to preceding Arctic Oscillation

Jin-Soo Kim[1,2], Jong-Seong Kug[3,*], Su-Jong Jeong[4,5], Hotaek Park[6] and Gabriela Schaepman-Strub[7]

+ See all authors and affiliations

Science Advances 08 Jan 2020:
Vol. 6, no. 2, eaax3308
DOI: 10.1126/sciadv.aax3308

Environmental Research Letters

PAPER

How much global burned area can be forecast on seasonal time scales using sea surface temperatures?

Yang Chen[1], Douglas C Morton[2], Niels Andela[2], Louis Giglio[3] and James T Randerson[1]

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[2] Biospheric Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[3] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA

E-mail: yang.chen@uci.edu

TeleViT architecture

TeleViT: Teleconnection-driven Transformers Improve Subseasonal to Seasonal Wildfire Forecasting

Ioannis Prapas (1, 3), Nikolaos-Ioannis Bountos (1, 2), Spyros Kondylatos (1, 3), Dimitrios Michail (2), Gustau Camps-Valls(3), Ioannis Papoutsis (1)
(1) Orion Lab, IAASARS, National Observatory of Athens
(2) Department of Informatics and Telematics, Harokopio University of Athens
(3) Image & Signal Processing Group, Universitat de València
Best Paper Award at ICCV 2023, AI+HADR workshop

Paper | Code | arXiv

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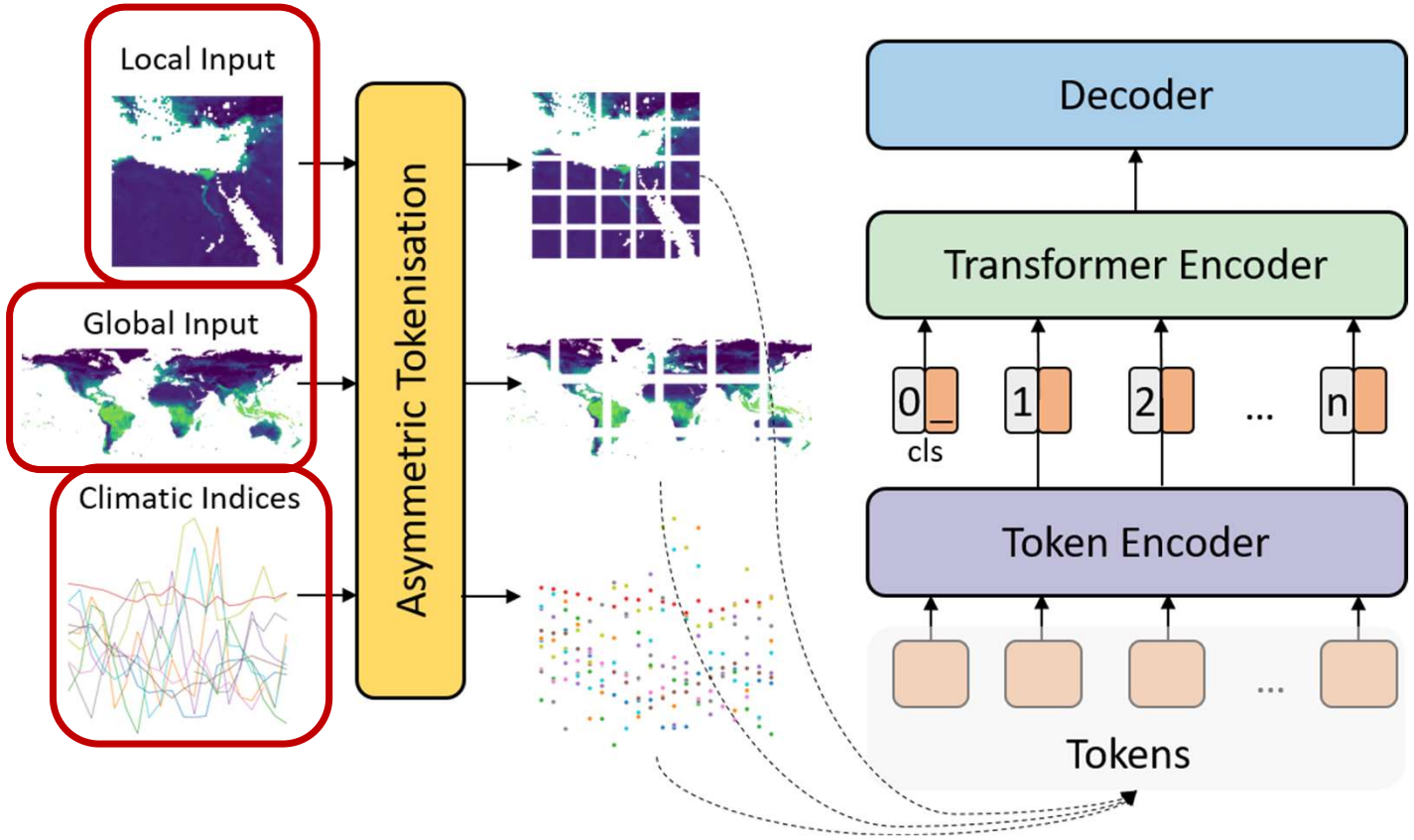


Results

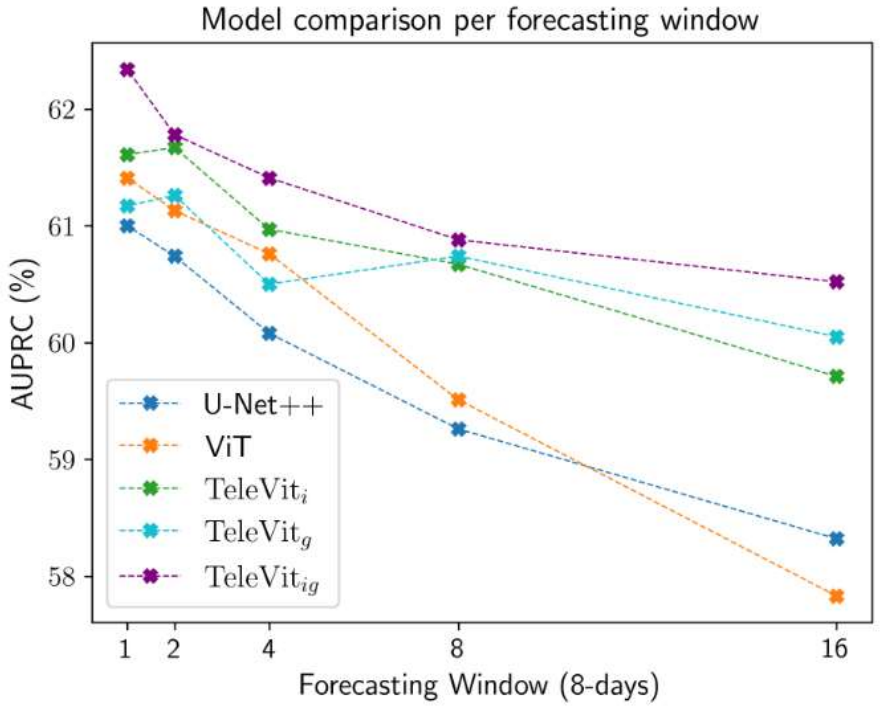
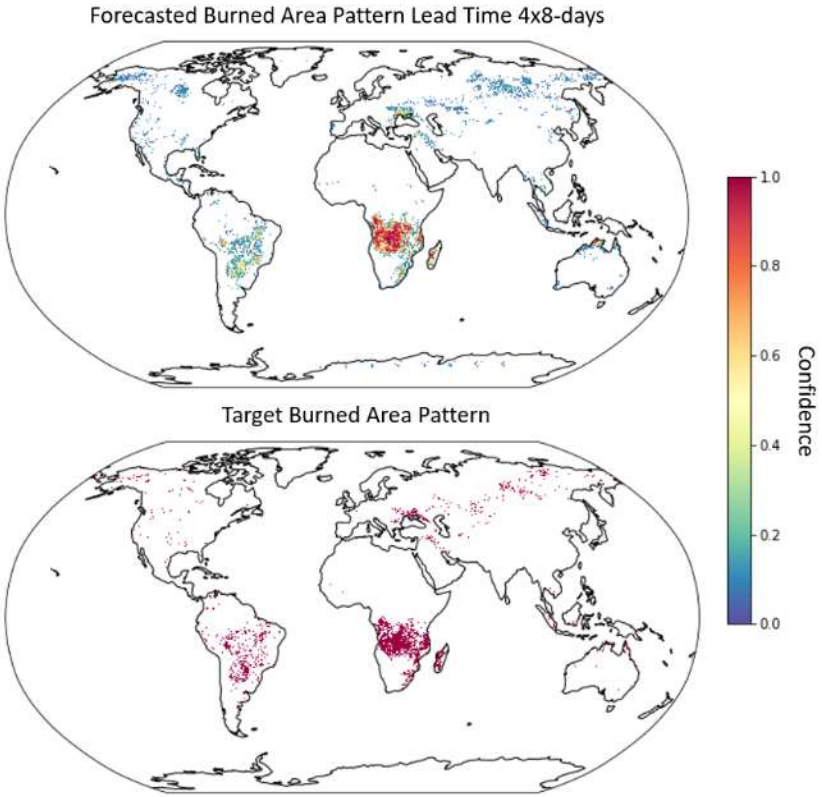


Figure 2. AUPRC performance of the different models for forecasting windows of 1, 2, 4, 8 and 16×8-days in advance.



Main Takeaways – R&D

- Machine Learning can increase the skill of wildfire danger predictions
- Short-term versus Long-term forecasting
  - In the **short-term** (days), **temporal context** is mostly enough
  - In the **long-term** (weeks, months), **spatial context** becomes important
  - **Teleconnection-informed** models can improve long-term forecasting capabilities
- Exciting future work!
  - Understand performance gain. Explainability & interpretability
  - Forecast extreme events

Lessons learned 2023 - Operations

- Extreme Forest fires – Extreme fire behaviour
- Forest fires inside WUI
- Very high fire severity in an expand burned area
- Fire fighting by night was impossible
- Protection, preparedness, firefighting and restoration must work more closely together
- Forest management is the key to manage the fuel, even in protected areas
- Use prescribed burning as a prevention tool
- Train and educate the communities about natural disasters
- Legislation issues in Greece regarding the decision making in operations
- Use of new technologies and artificial intelligence in the forecasting of dangerous weather phenomena and concerns both forest fires and floods, for better preparation and immediate response of the operational mechanism. Time is a crucial factor.

Thank you!

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