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Copernicus

European Commission

Machine-Learning for Supporting Drought Risk Management

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European Commission – Joint Research Centre (EC-JRC)

Webinar – Land Reborn: Digital Solutions for Combating Desertification and Drought Resilience

Session 1: Greening the Future: Navigating Digital Transformation for Land Restoration

05/06, 14:00 - 15:00 CEST

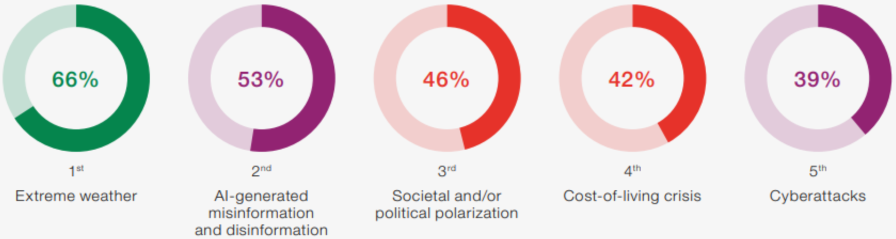
COPERNICUS EMERGENCY MANAGEMENT SERVICE

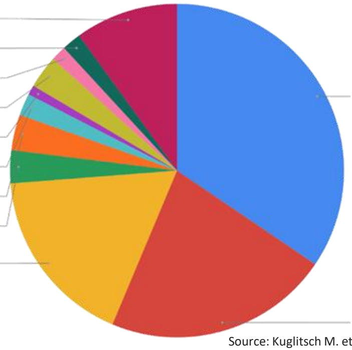
WORLD ECONOMIC FORUM

ML applications in DRR

Risk categories		2 years		10 years
Economic	1st	Misinformation and disinformation	1st	Extreme weather events
Environmental	2nd	Extreme weather events	2nd	Critical change to Earth systems
Geopolitical	3rd	Societal polarization	3rd	Biodiversity loss and ecosystem collapse
Societal	4th	Cyber insecurity	4th	Natural resource shortages
Technological	5th	Interstate armed conflict	5th	Misinformation and disinformation
	6th	Lack of economic opportunity	6th	Adverse outcomes of AI technologies
	7th	Inflation	7th	Involuntary migration
	8th	Involuntary migration	8th	Cyber insecurity
	9th	Economic downturn	9th	Societal polarization
	10th	Pollution	10th	Pollution

Source
World Economic Forum Global Risks Perception Survey 2023-2024.

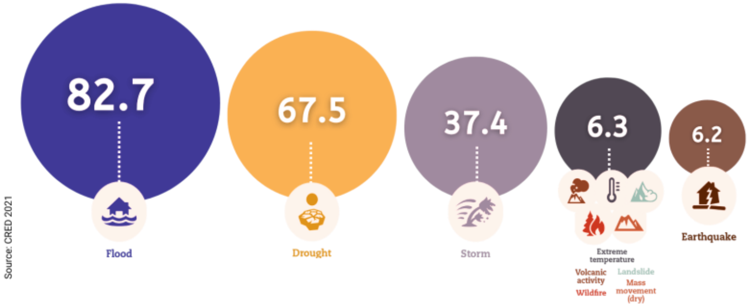




Source: Kuglitsch M. et al., 2022.

Annual average number of (millions) affected by disaster type (2001 - 2020)

UNDRR
UN Office for Disaster Risk Reduction



AI for Natural Disaster Management
ITU Focus Group

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NOAA
CENTER FOR ARTIFICIAL INTELLIGENCE

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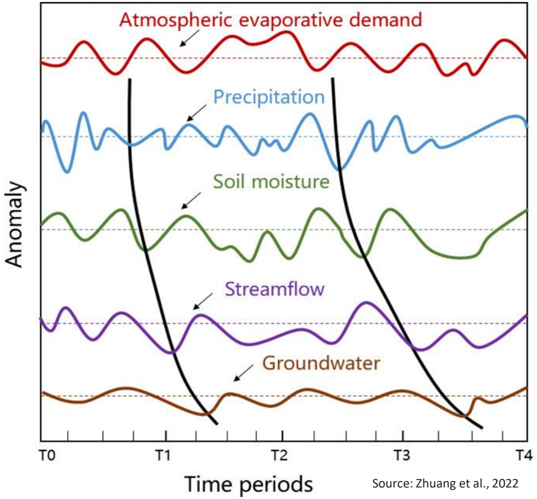
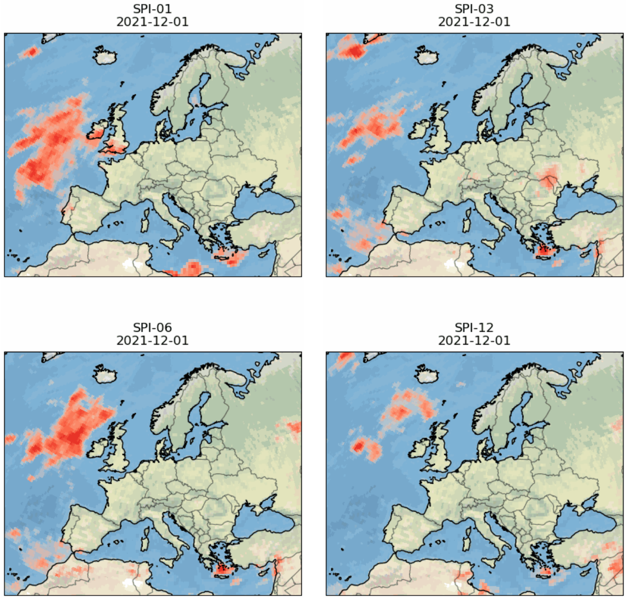
Challenges in Drought Risk Management

Drought Characterisation and Forecasting

- Why extreme events, such as droughts, matter?
  - 'High-impact, low-probability' (HILP) events (e.g. Summer of 2022)
- To prepare for such events, one must:
  1. Observe trends;
  2. Forecast outcomes, and
  3. Evaluate scenarios for better mitigating any potential threat
- Yet, droughts are not trivial to define in time and space



Source: Zhuang et al., 2022

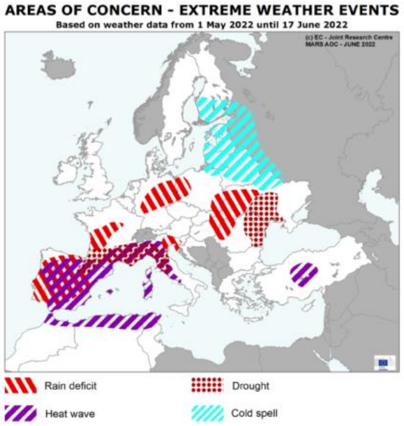


Data source: ERA5 reanalysis

Expertise from the JRC

Areas of Concern

- Each month the JRC issues the MARS Bulletin on the assessment of European crops’ status and yield forecasts.
- Synthetic maps called **Areas of Concern (AOC)** are produced in each Bulletin depicting extreme weather events and their impact during the analysis period.
- AOC are defined based on a range of quantitative and qualitative agro-meteorological data and heavily relying on expert analysis.



Source: JRC MARS Bulletin Vol. 30, no 6, June 2022

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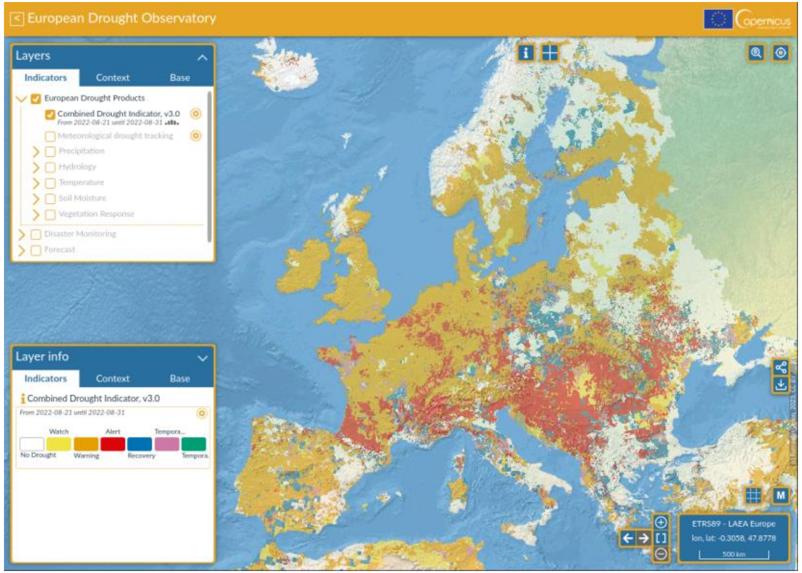
European (EDO) and Global (GDO) Drought Observatories



Climate Change
Land Monitoring
Emergency Management

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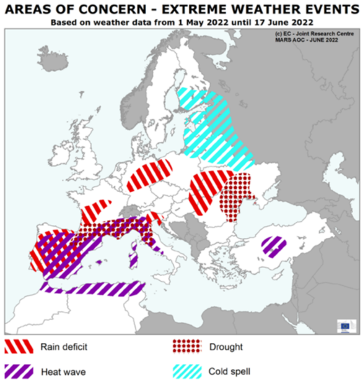
AI-based first guess of Areas of Concerns

Gradient Boosted Trees Model

- We build an ensemble of Gradient Boosted Decision Tree models to produce a first-guess of AOC, which can then be more easily digested by an expert.
- We use both ERA5 and CEMS data for detecting and analysing various meteorological AOC
- Data is passed as mean, anomalies and standardized-anomalies (where applicable) for the specific period of analysis
- A class-balanced approach based on a simple proportion between the positive and negative classes is implemented to adjust for the importance of each class during training
- The model uses a logistic regression objective function for the binary classification of a cell as an AOC or not
- A collection of 1,000-folded individually-trained models for each AOC type is implemented.

Meteorological event	Definition
Rain excess or rain deficit	*Cumulated rainfall* *RA: ± 25% observed in two or more analysis period* *RA: ± 50% over the analysis period* *One or more days with daily precipitation > 50 mm*
Radiation deficit	*Cumulated radiation* *RA: ± 25% observed in two or more analysis* *RA: ± 50% over the analysis period*
Heat wave	*Three or more days with Tmax > 30 °C and no precipitation*
Cold spell	*One day with Tmin < −18 °C or* *Two or more days with Tmin < −10°C or* *Three or more days with Tmin < 0 °C* *Average Tmin has RA < −50%*
Hot and dry conditions	*Three or more days with 25 °C < Tmax < 30 °C and no precipitation* *Average Tmax has RA > 0%*
Drought	*Rain deficit event observed for at least two or more analysis* *Evidence of effect on crops from remote sensing observation*
Temperature accumulation surplus or deficit	*Sum of average temperatures (Tsum)* *RA: ± 50% over the analysis period*



DATASET	Dataset Description	VARIABLE	Variable Description	SI Unit
CEMS	Copernicus Emergency Management Service (CEMS) European Drought Observatory (EDO)	spi01	SPI (1-month accumulation)	-
		spi03	SPI (3-months accumulation)	-
		spi06	SPI (6-months accumulation)	-
		spi09	SPI (9-months accumulation)	-
		spi12	SPI (12-months accumulation)	-
		sma	ensemble soil moisture anomaly	-
		fapar	fAPAR anomaly	-
ERA5-derived	Variables derived from the ERA5 database (frequency of days)	daystmax25a30C	number of days when tmax is between 25 and 30°C	days
		daystmax30C	number of days when tmax is larger than 30°C	days
		daystmin0C	number of days when tmin is lower than 0°C	days
		daystminm10C	number of days when tmin is lower than 10°C	days
		daystminm18C	number of days when tmin is lower than 18°C	days
		daystp01mm	number of days when tp is over 1mm	days
		daystp30mm	number of days when tp is over 30mm	days
	Variables derived from the ERA5 database (mean and anomalies)	msla	air pressure at sea level	Pa
		spa	surface air pressure	Pa
		t2ma	near-surface air temperature	K
		tmaxa	maximum near-surface temperature in period	K
		tmina	minimum near-surface temperature in period	K
		z500a	geopotential height	$m^2 s^{-2}$

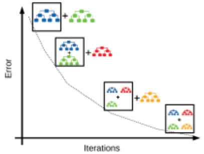


Image source: medium.com/

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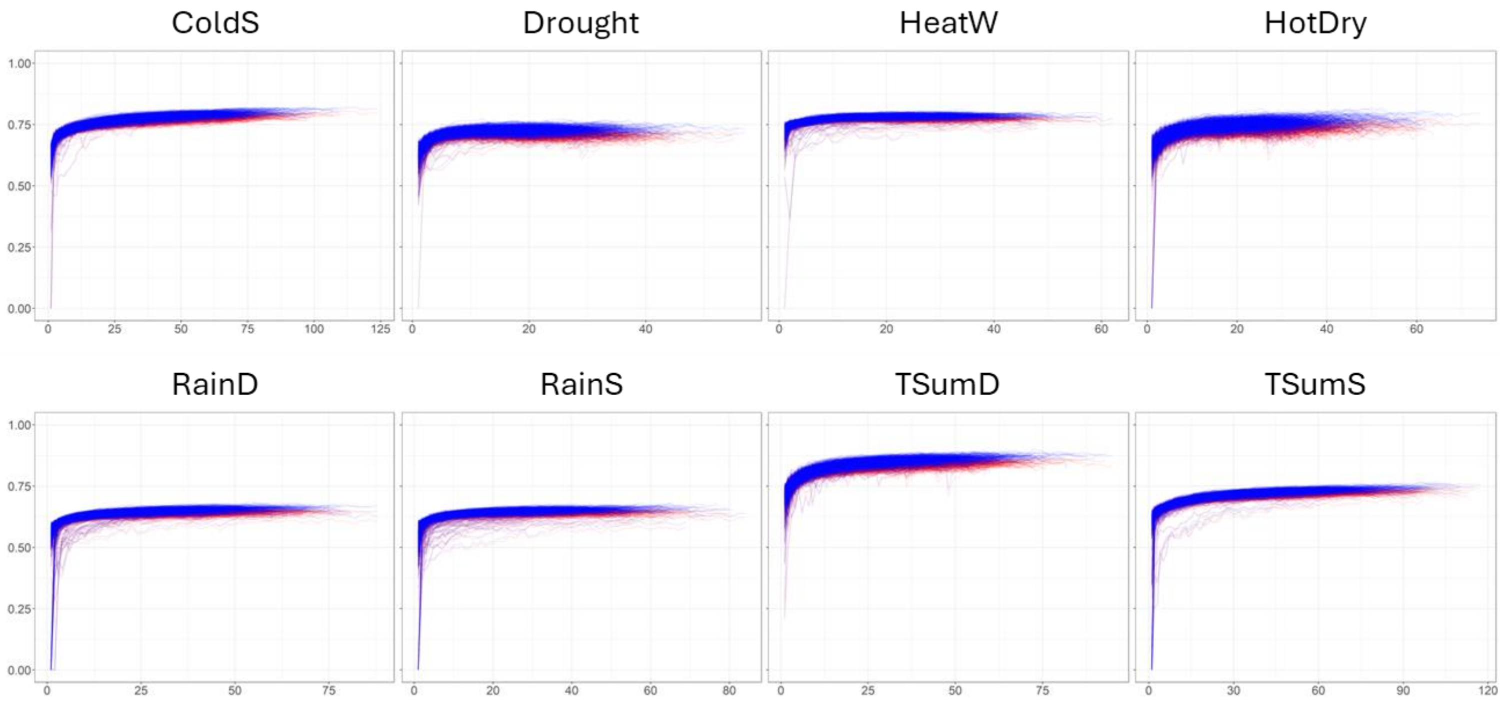
Results – Evolution Log (boosting rounds)



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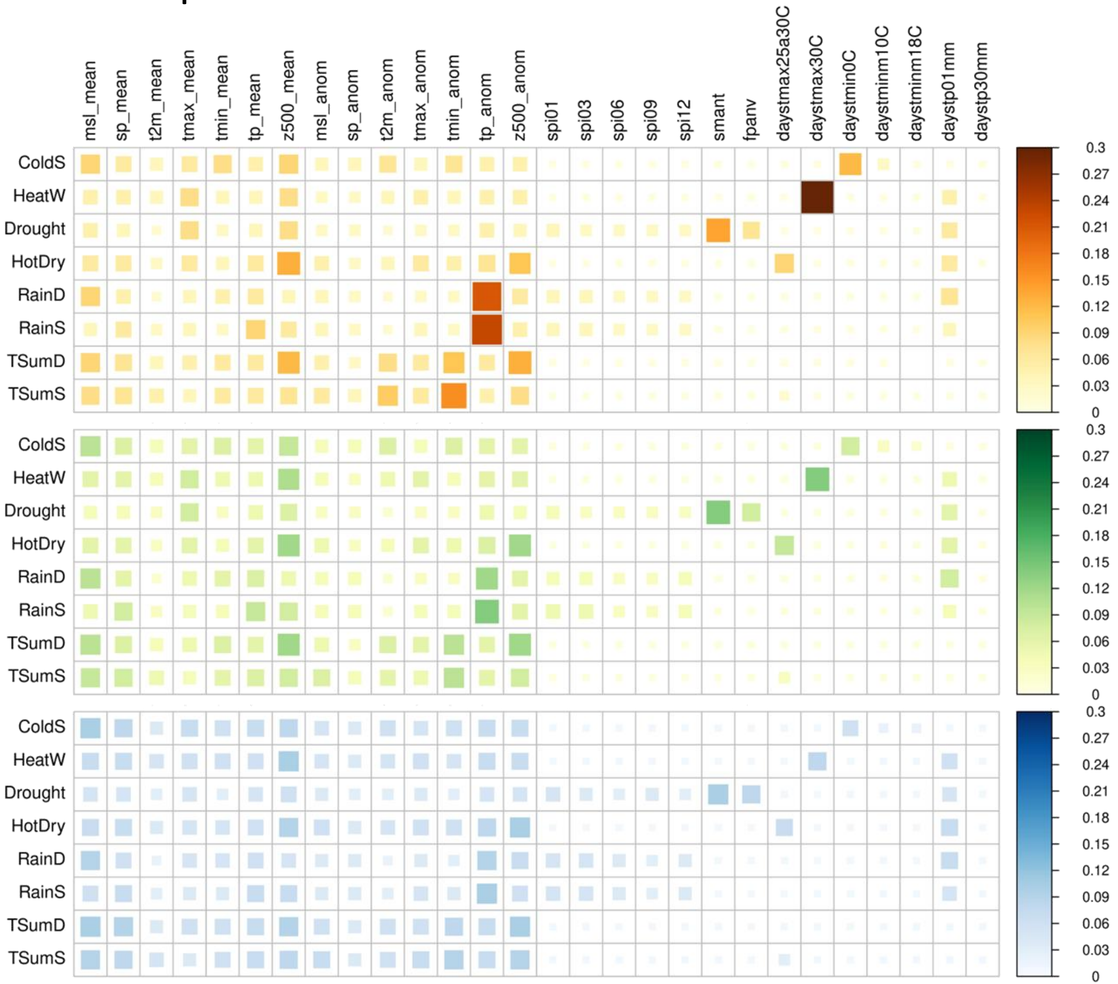
Results – Variable Importance Matrix

- **Gain**: higher values indicate that a variable is more important for generating a prediction.
- **Cover**: measures the relative number of observations related to this feature. It is related to the second order derivative (or Hessian) of the loss function with respect to a particular variable.
- **Frequency**: relative number of times a particular feature occurs in the trees of the model.



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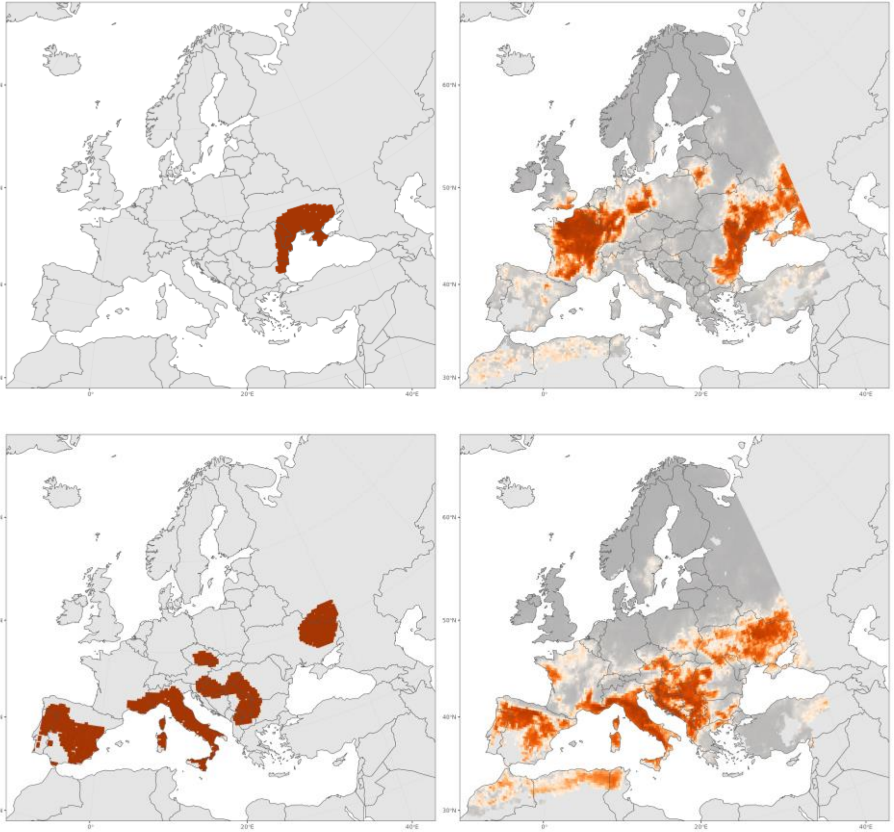
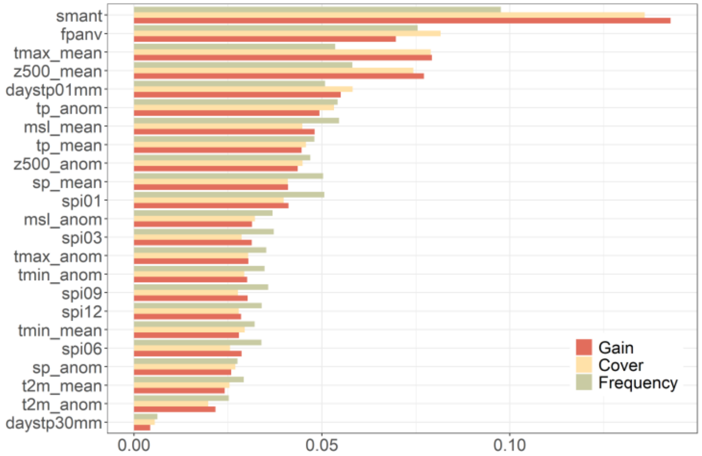
AI-based first guess of Areas of Concerns – Droughts

Training dataset

Test dataset





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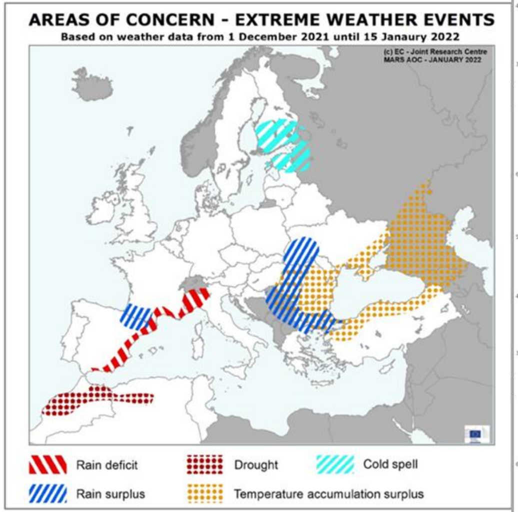
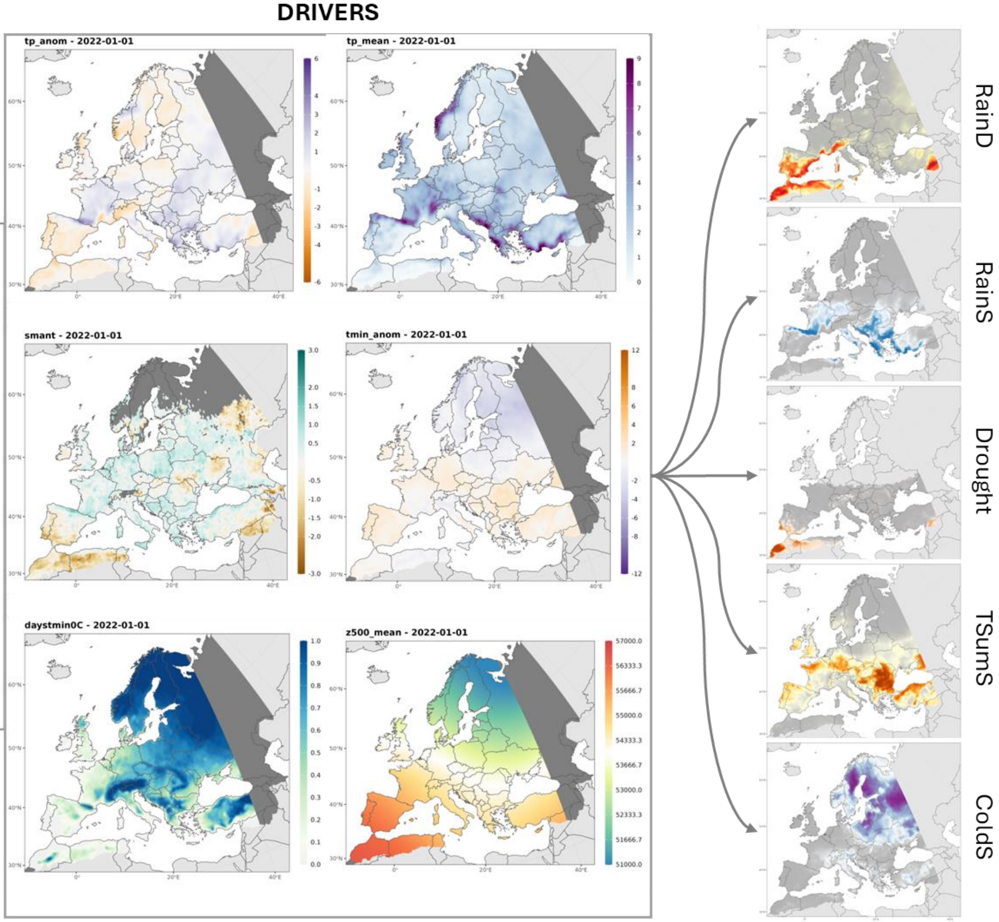
ERA5 Drivers of 2022 First-Guess





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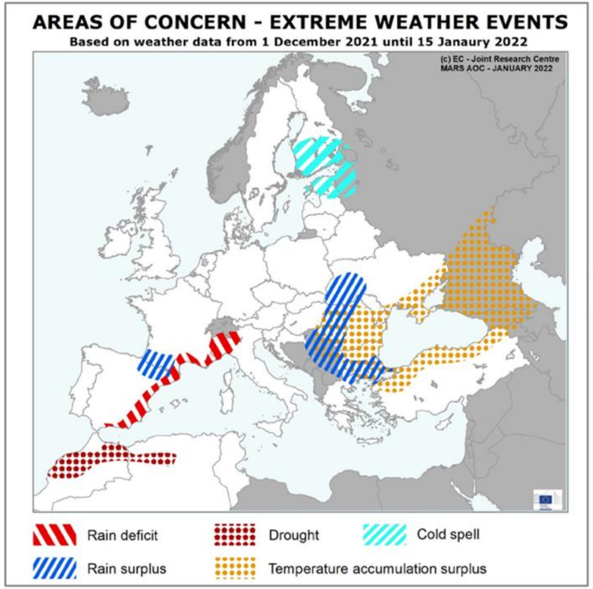
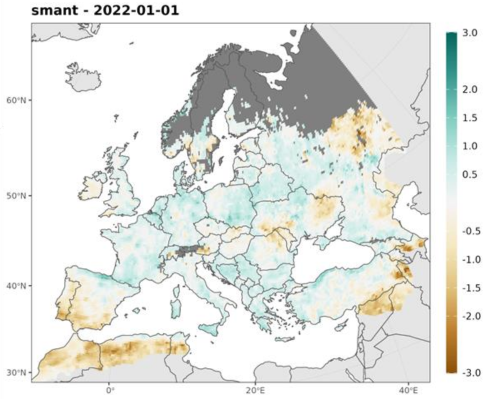
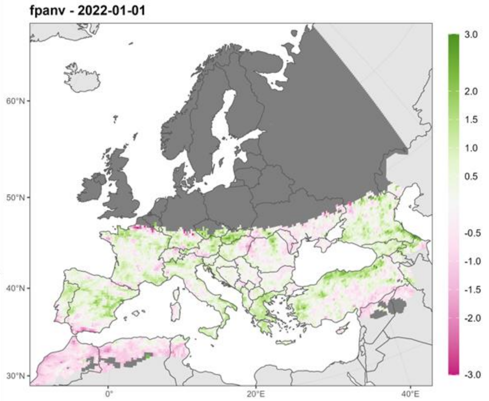
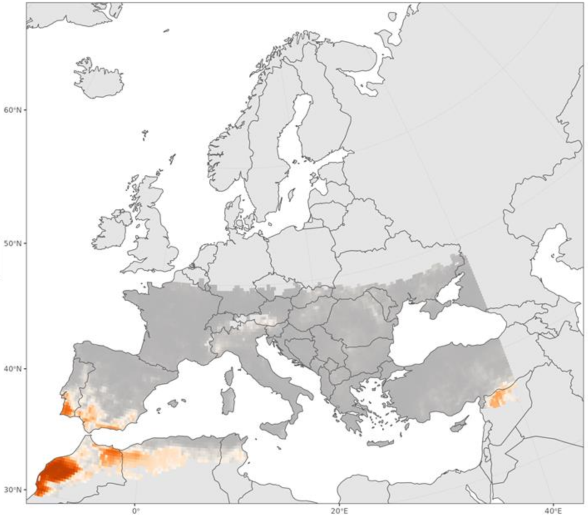
ERA5 Drivers of 2022 First-Guess – Droughts









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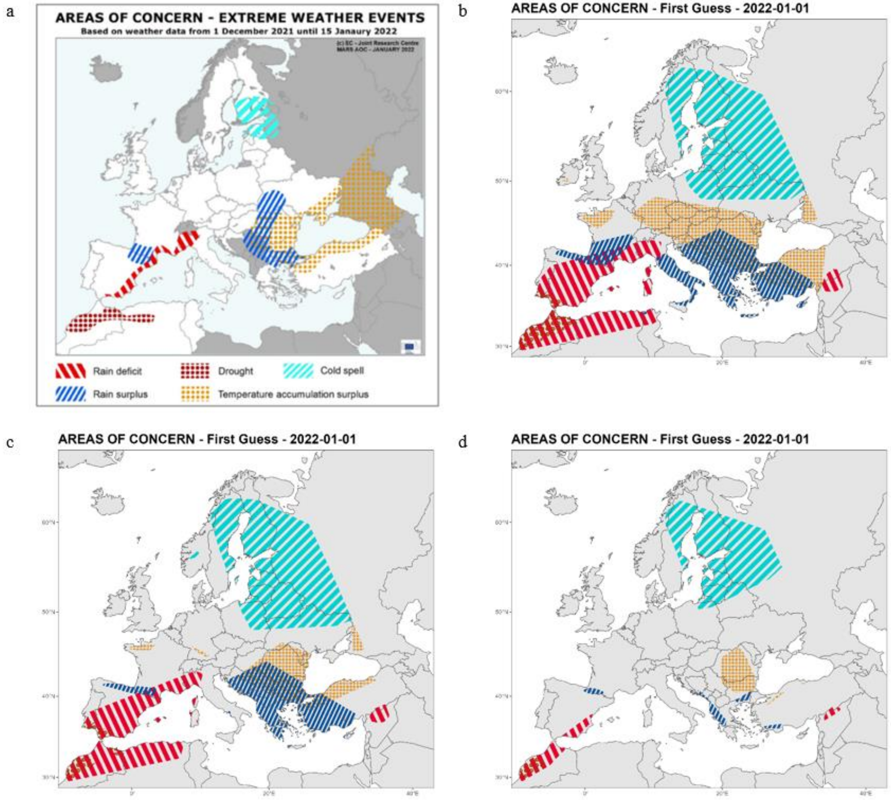
ERA5 Drivers of 2022 First-Guess – AOCs



Example of the first-guess identification of AOC over Europe during the period of analysis covered in the MARS Bulletin of January 2022; a) Actual meteorological AOC in the MARS Bulletin. The AOC first-guess when about: b) two-thirds; c) 90%, and d) 95% of the XGBoost models agree on the detection of a certain AOC type.

Conclusions

- We have developed a **hybrid xAI-based model** that results from the combination of **data-driven xAI methods** with the **expert-based knowledge** produced in JRC to provide a first-guess of meteorological extremes as AOCs in Europe

- The proposed solution tackles two currently frontiers in science:
  1. A system for the detection, in space and time, of multi-hazard extreme events
  2. The application of (x)AI-based methods in a context of DRR for droughts

- The developed model/solution is **xAI-based** as it is both **interpretable** (i.e. the results given and decision taken by the AI system is understandable) and **transparent** (i.e. capable of understanding which kind of data it uses, how the system works, and how it takes decisions).

- Potential future **policy relevance**: Water Resilience Initiative; Climate Adaptation Strategy; EU Civil Protection Mechanism; Common Agriculture Policy (CAP); Early Warning for All (WMO)

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