

SeasFire

Earth System Deep Learning towards a Global Digital Twin of Wildfires

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Vision - A digital twin of wildfires

Monitoring

• Detection, nowcasting

Causality

• Effect of the human activities, climate change

Anticipation

- Extreme Events
- Interannual variability

Simulation (What-if scenarios)

- Assessing the impact of land use changes
- Assessment of wildfire practices, policies

Impact Quantification

- Interaction with other twins
- Ecosystem damage and recovery



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Earth is a complex interconnected system



Fan, Jingfang, et al. "Statistical physics approaches to the complex Earth system." *Physics reports* 896 (2021): 1-84.

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

Memory effects refer to the temporal dynamics of earth system variables. Vegetation drought response after previous year drought.

Why Deep Learning?

(a) Non-Linear Interactions: Hard to capture relationships on seasonal and sub-seasonal scales.

(b) ML works well with large-scale datasets

(c) Modern ML methods like Transformers and Graph Neural Networks learn from non-local variable interactions









SeasFire DataCube as a test-bed for wildfire twinning



MPI-BGI DataVis Team

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Funded by

esa

(GFED, FireCCI, GWIS) Fire Emissions (GFAS)

Resolution: 8dx0.25°x0.25°

(Sub-seasonal to Seasonal)

Extent: Global. 2001 - 2020

Fire drivers

Meteorology (ERA5) Satellite Observations (MODIS) - NDVI, LST Oceanic Indices (NOAA)

Population Density Land Cover (ESA CCI)

Fire products Burned Areas

Datacube Demonstration

Cloud-optimized zarr dataset

Rapid analytics without downloading the dataset

Can associate fire drivers to wildfires around the world



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D	V Os	D	ds			
		C⇒	xarray.Dataset			
			► Dimensions:	(latitude: 720, longitude: 1440, time: 966)		
			► Coordinates: (3)			
			► Data variables: (54)	i)		
			►Indexes: (3)			
				EPSG:4326 The SeasFire Cube is a scientific datacube for seasonal fire forecasting around the do		
				be. It has been created for the SeasFire project, that adresses 'Earth System Deep Lea ming for Seasonal Fire Forecasting' and is funded by the European Space Agency (ES A) in the context of ESA Future EO-1 Science for Society Call. It contains almost 20 ye ars of data (2001-2021) in an 8-days time resolution and 0.25 degrees grid resolution. I		
				t has a diverse range of seasonal fire drivers. It expands from atmospheric and climatol ogical ones to vegetation variables, socioeconomic and the target variables related to wildfires such as burned areas, fire radiative power, and wildfire-related CO2 emission s		
<>			title :	SeasFire Cube: A Global Dataset for Seasonal Fire Modeling in the Earth System		

Plot the NDVI of a particular 8-day period

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Causal Analysis



Runge, Jakob, et al. "Detecting and quantifying causal associations in large nonlinear time series datasets." *Science advances* 5.11 (2019): eaau4996.



Mediterranean Forests, Woodlands & Scrub of Europe



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Burned Area Forecasting

- Input: 8 fire driver variables at time *t*.
 Stacked 128x128 patches
- Target: Presence of burned area at time *t+h* (h=8, 16, 32, 64 days)
- A separate **UNET++** model is trained for each *h*
- Data split temporally: Training (2001 to 2017) Validation (2018) Testing (2019)

Presented in NeurIPS 2022 Workshop on Tackling Climate Change with AI

https://www.climatechange.ai/papers/neurips2022/52

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Global Prediction Maps

Captured change of fire activity in eastern Europe and south-east Asia, shift from the southern to the northern African savanna.

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Earth System DL: Leveraging non-local interactions



Graph Neural Networks

Learned edges of GNN hints into model's inner workings

Y. Wang, Y. Sun, Z. Liu, S. E. Sarma, M. M. Bronstein, and J. M. Solomon, 'Dynamic Graph CNN for Learning on Point Clouds'. (2019).



Better performance when adding info from oceanic indices.

Dosovitskiy, Alexey, et al. "An image is worth 16x16 words: Transformers for image recognition at scale." (2020).

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Main Takeaways

- SeasFire cube can serve as a test bed for digital twin models of wildfires (for sub-seasonal to seasonal scales)
- Deep Learning can increase our ability to forecast and simulate wildfires
- Modeling the earth as a system can enhance our understanding of largescale processes

Links

SeasFire Project: <u>https://seasfire.hua.gr</u> Preprint: <u>https://arxiv.org/abs/2211.00534</u> SeasFire Cube: <u>https://zenodo.org/record/7108392</u> Tutorials: <u>https://github.com/SeasFire/seasfire-datacube</u>

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