

# AI 4 Science - “Deep Extremes”



Multi -Hazards, Compounds and Cascade Events



UNIVERSITÄT  
LEIPZIG

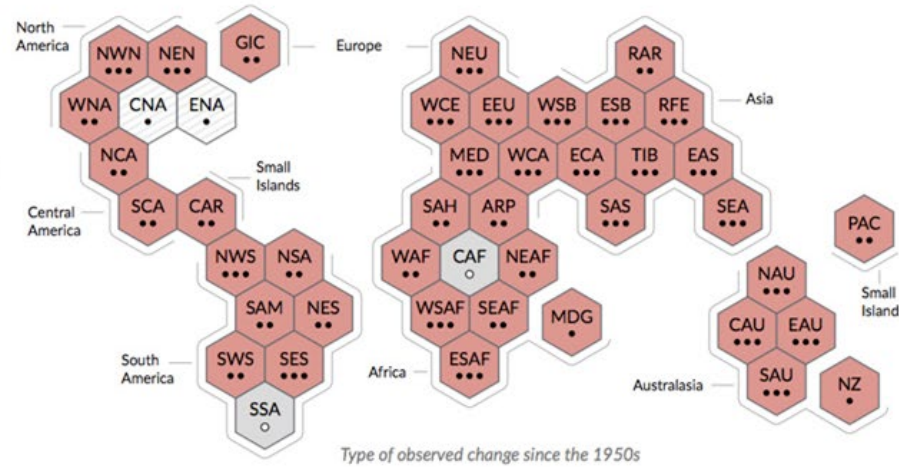
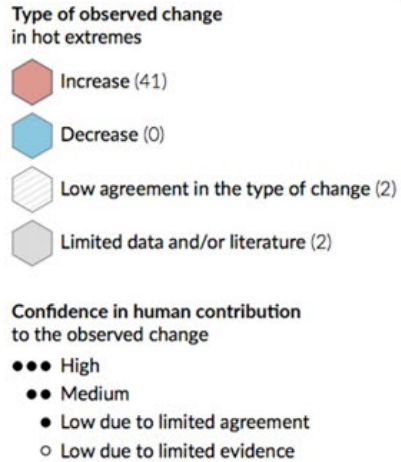


UNIVERSITAT  
DE VALÈNCIA

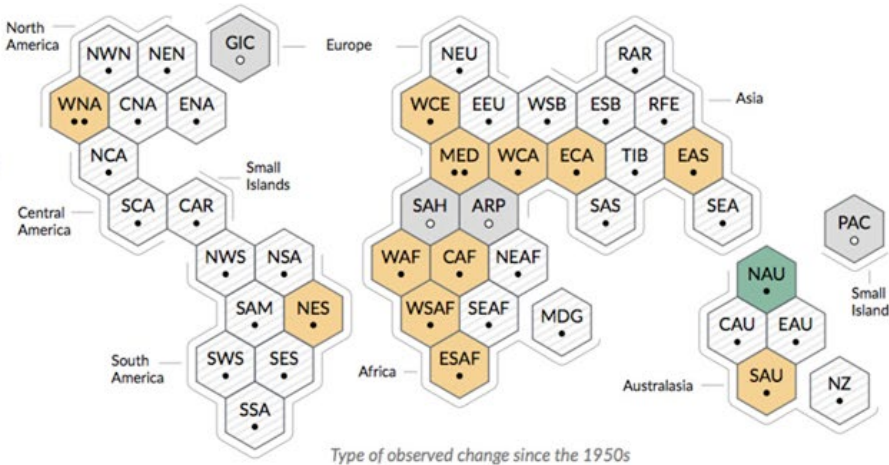
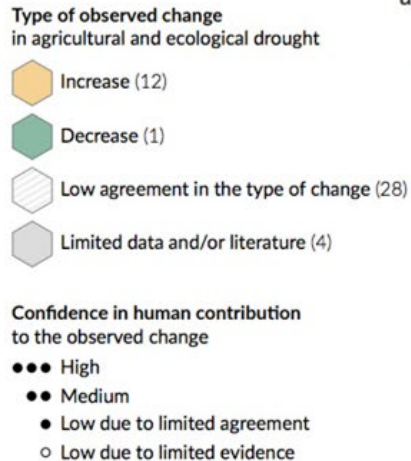


# Scientific Relevance: Climate extremes are on the rise

a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions

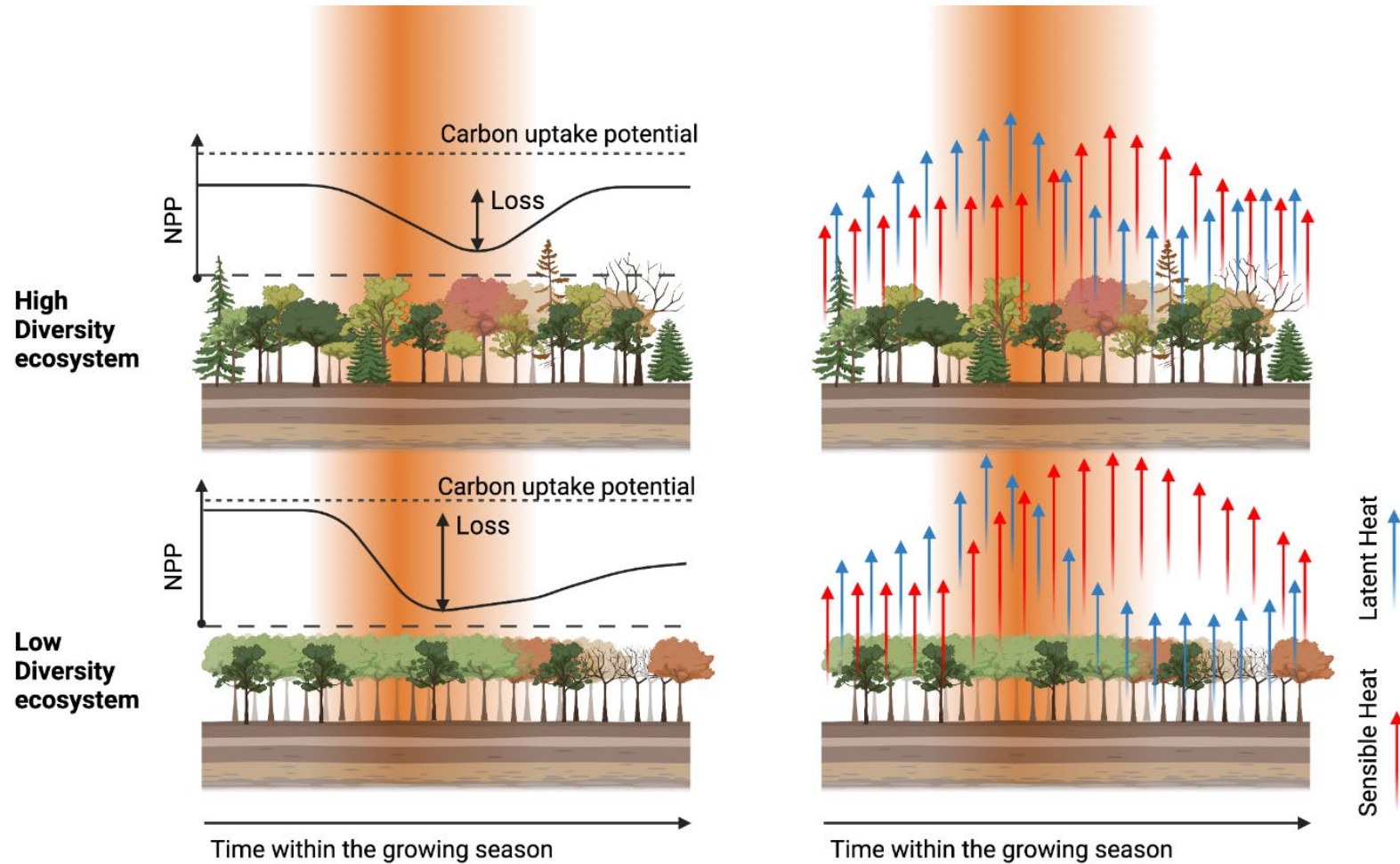


c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions



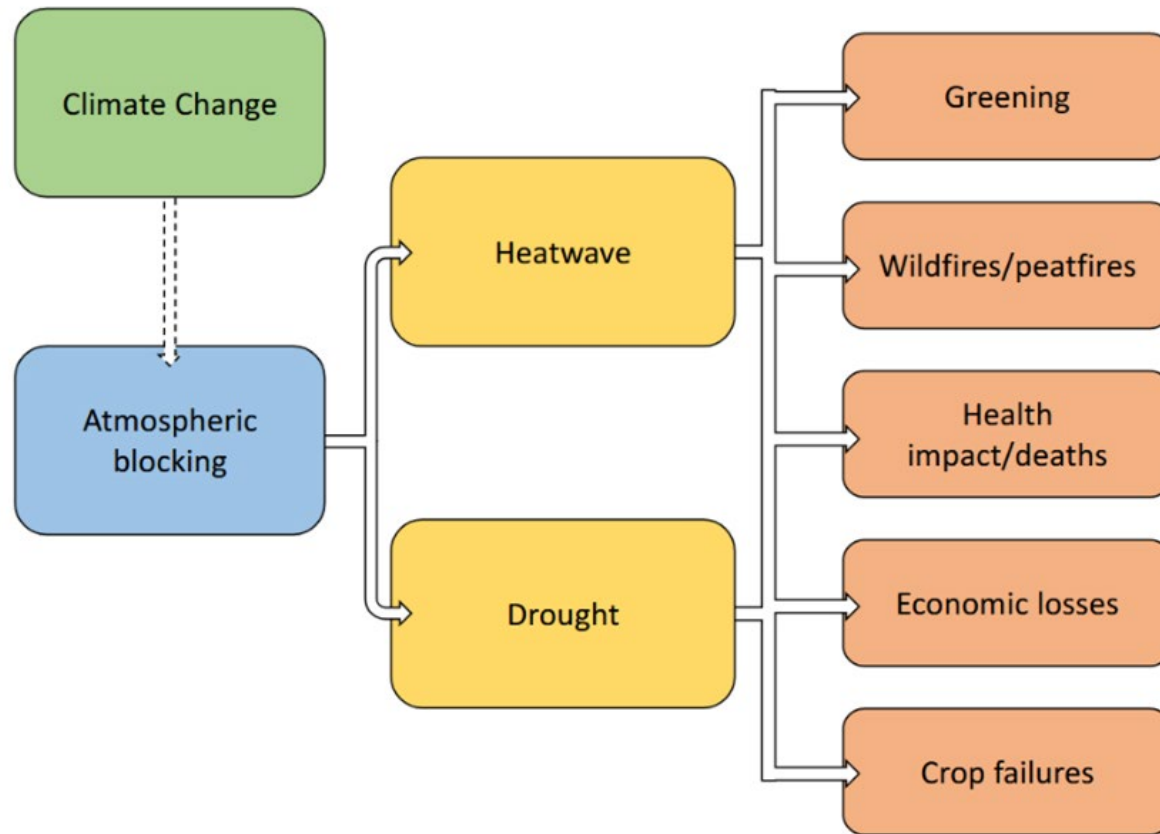
IPCC AR6 WGI reference regions: North America: NWN (North-Western North America), NEN (North-Eastern North America), WNA (Western North America), CNA (Central North America), ENA (Eastern North America), Central America: NCA (Northern Central America), SCA (Southern Central America), Caribbean: CAR (Caribbean), South America: NWS (North-Western South America), NSA (Northern South America), NES (North-Eastern South America), SAM (South American Monsoon), SWS (South-Western South America), SES (South-Eastern South America), SSA (Southern South America), Europe: GIC (Greenland/Iceland), NEU (Northern Europe), WCE (Western and Central Europe), EEU (Eastern Europe), MED (Mediterranean), Africa: MED (Mediterranean), SAH (Sahara), WAF (Western Africa), CAF (Central Africa), NEAF (North Eastern Africa), SEAF (South Eastern Africa), WSAF (West Southern Africa), ESAF (East Southern Africa), MDG (Madagascar), Asia: RAR (Russian Arctic), WSB (West Siberia), ESB (East Siberia), RFE (Russian Far East), WCA (West Central Asia), ECA (East Central Asia), TIB (Tibetan Plateau), EAS (East Asia), ARP (Arabian Peninsula), SAS (South Asia), SEA (South East Asia), Australasia: NAU (Northern Australia), CAU (Central Australia), EAU (Eastern Australia), SAU (Southern Australia), NZ (New Zealand), Small Islands: CAR (Caribbean), PAC (Pacific Small Islands) Figure SPM.3a from AR6 WGI Summary of Policymakers, IPCC.

# Scientific Relevance: Land-surface structure controls impacts



- Climate extremes can lead to **multiple responses** depending on ecosystem structure

# Scientific Relevance: Compounding event → $n$ -dimensional impacts

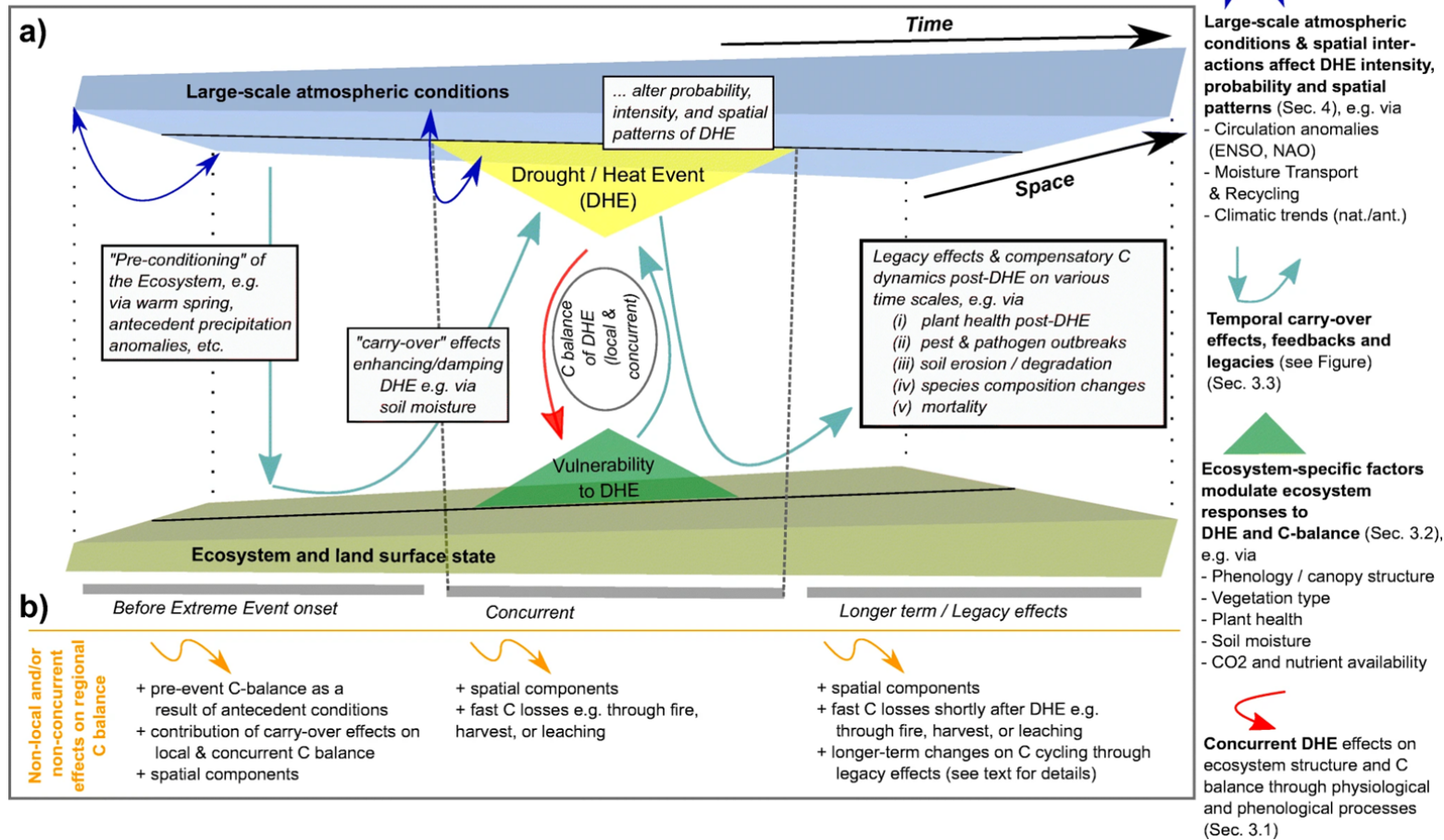


- Climate extremes can lead to **multiple responses** depending on ecosystem structure
- **Compound events** max exacerbate the impacts on multiple sectors

Fig. courtesy Karin Mora based on concept presented in Zscheischler et al. (2020) Nature Reviews Earth & Environment 1, 333–347

# Scientific Relevance: Timing of extremes is crucial

C balance of DHEs in a spatio-temporal continuum



- Climate extremes can lead to multiple responses depending on ecosystem structure
- Compound events max exacerbate the impacts on multiple sectors
- Timing matters and can change impact dynamics

Sippel et al. (2018) *Current Climate Change Reports* 4, 266-286

# Detecting large-scale $n$ -dimensional extremes

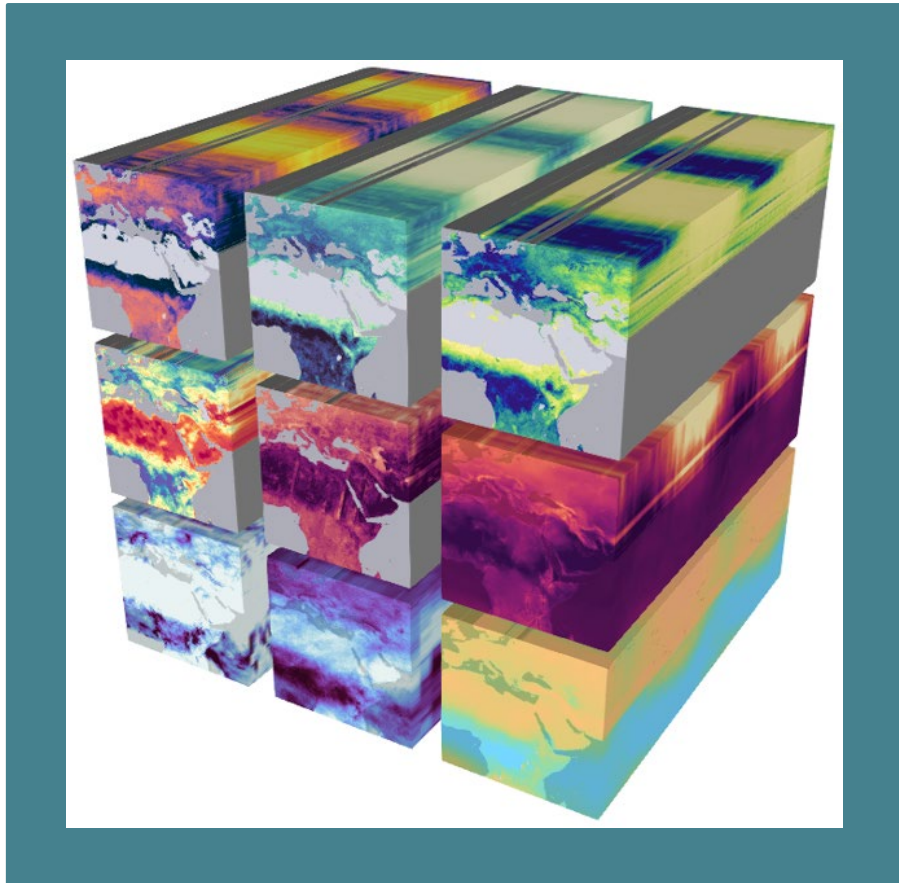


Fig. Mahecha, Gans et al. (2020) *Earth System Dynamics* 11, 20-234

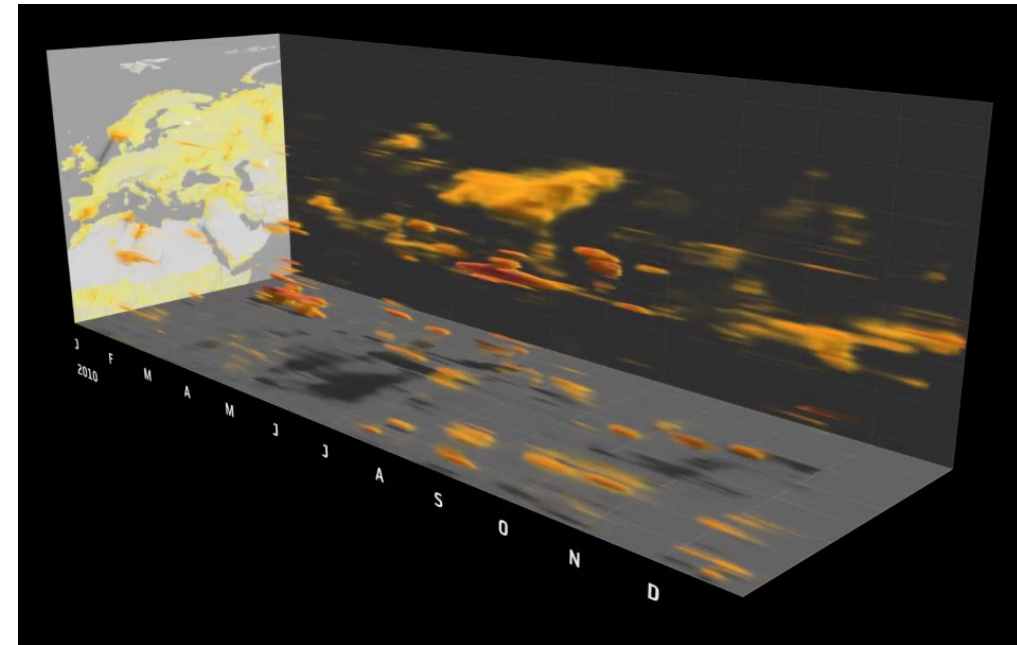
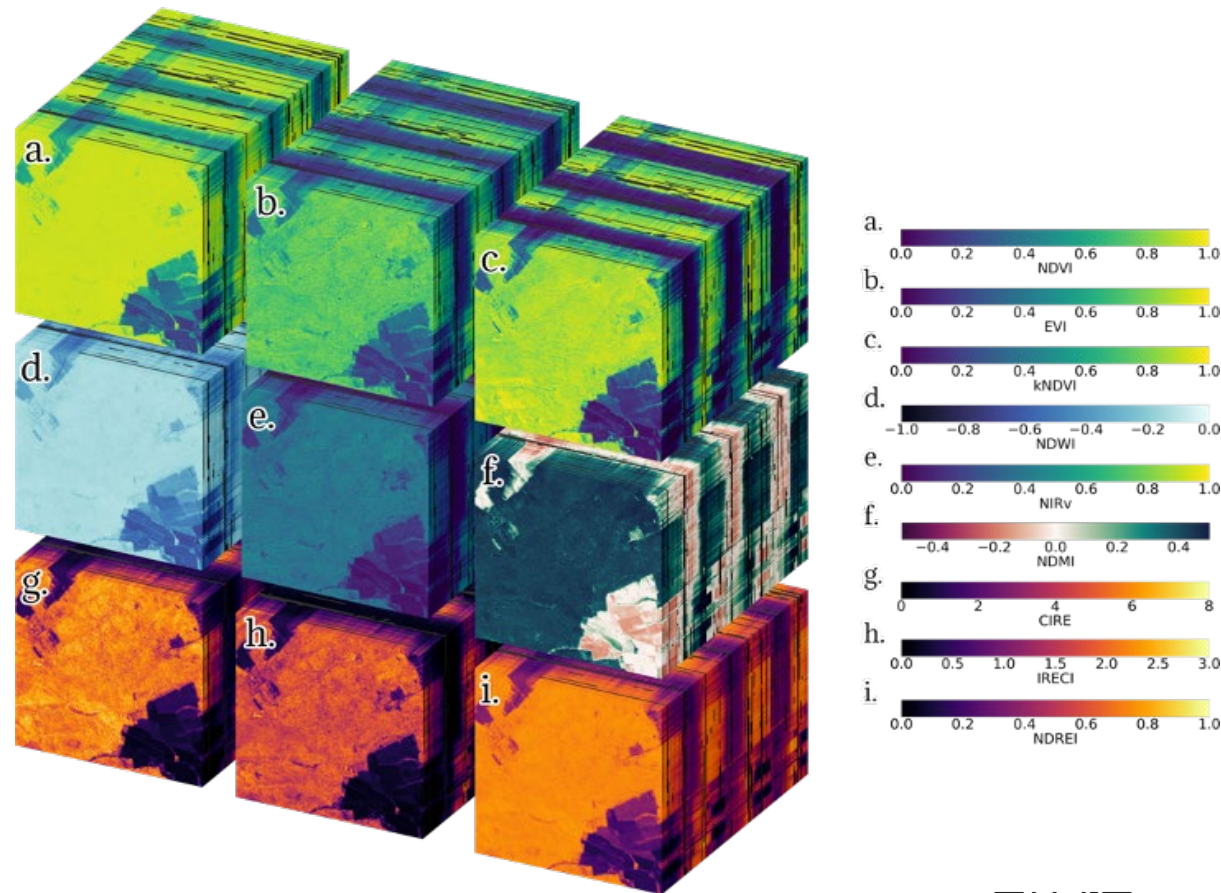


Fig. <https://www.earthsystemdatalab.net/movie> from Planetary Vision based on the analysis in Flach et al. (2018) *Biogeosciences* 15, 6067-6085

# The devil is in the details! Can optical remote sensing data save us?

- Sentinel-2 data bring us the required detail and information
- But event detection is not enough, **impact prediction capacity** is what matters.

You like these visualizations?  
Try them interactively on [lexcube.org](http://lexcube.org)



Montero et al. (in prep)  
Poster C1.07 on Thursday



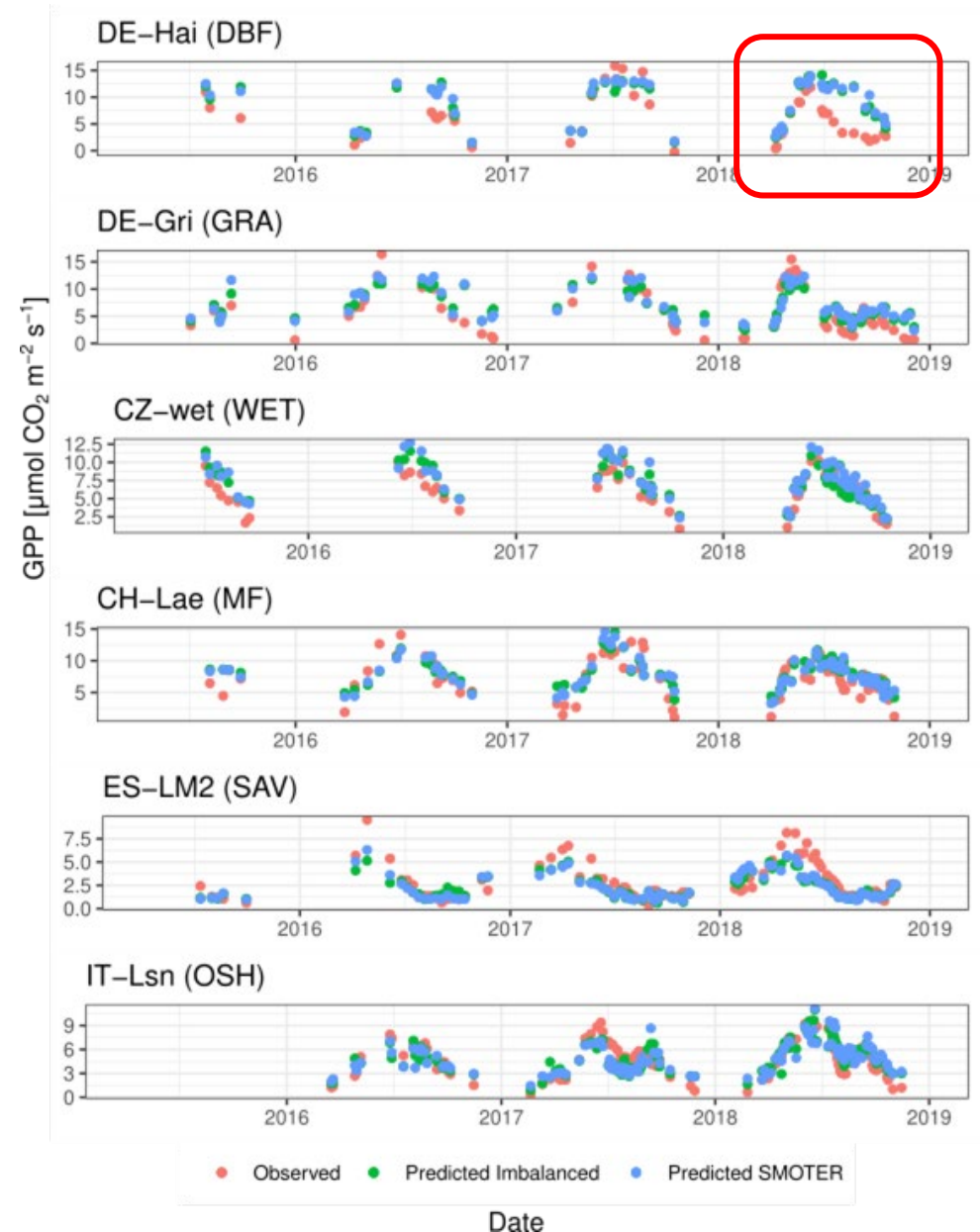
Poster: C1.07  
ML4Earth 7

# The devil is in the details, so can optical remote sensing save us?

- Sentinel-2 data bring us the required detail and information
- But event detection is not enough, **impact prediction capacity** is what matters.



Pabon et al. (2022) *IEEE Transactions on Geoscience and Remote Sensing* →





# Project idea: Subsampling

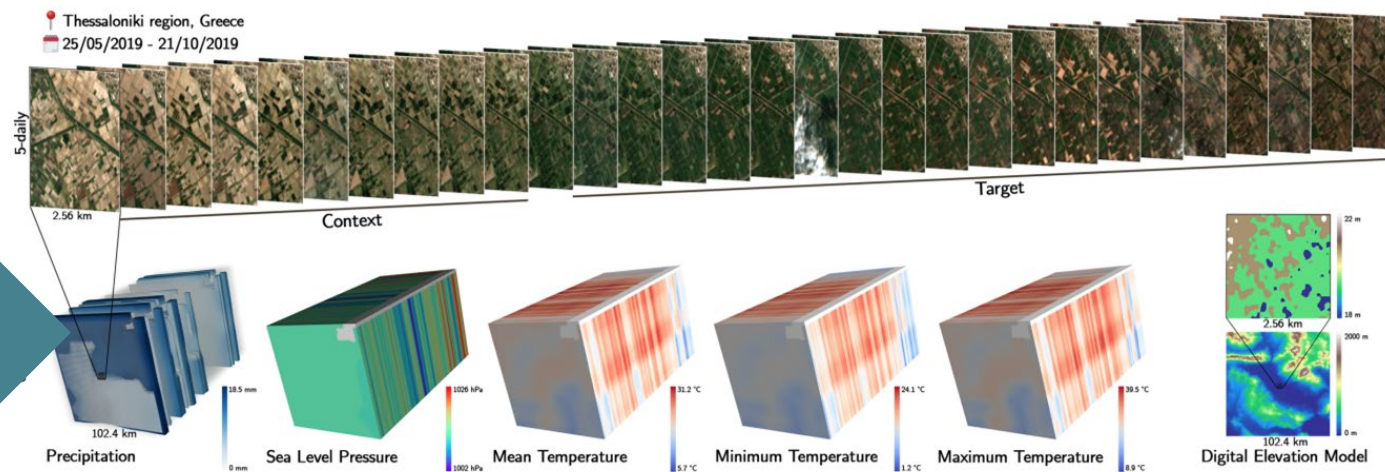
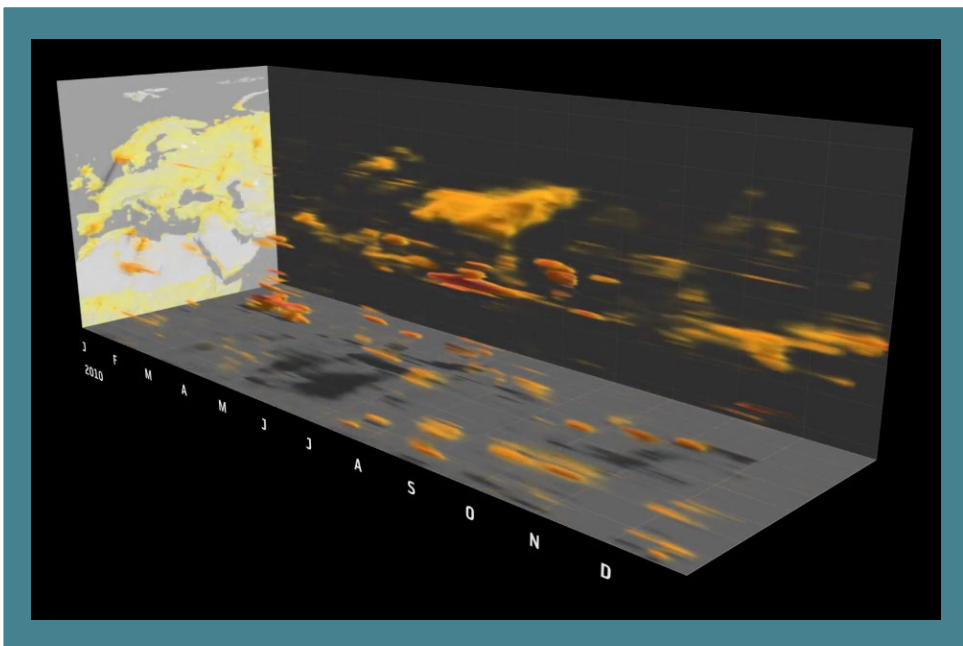
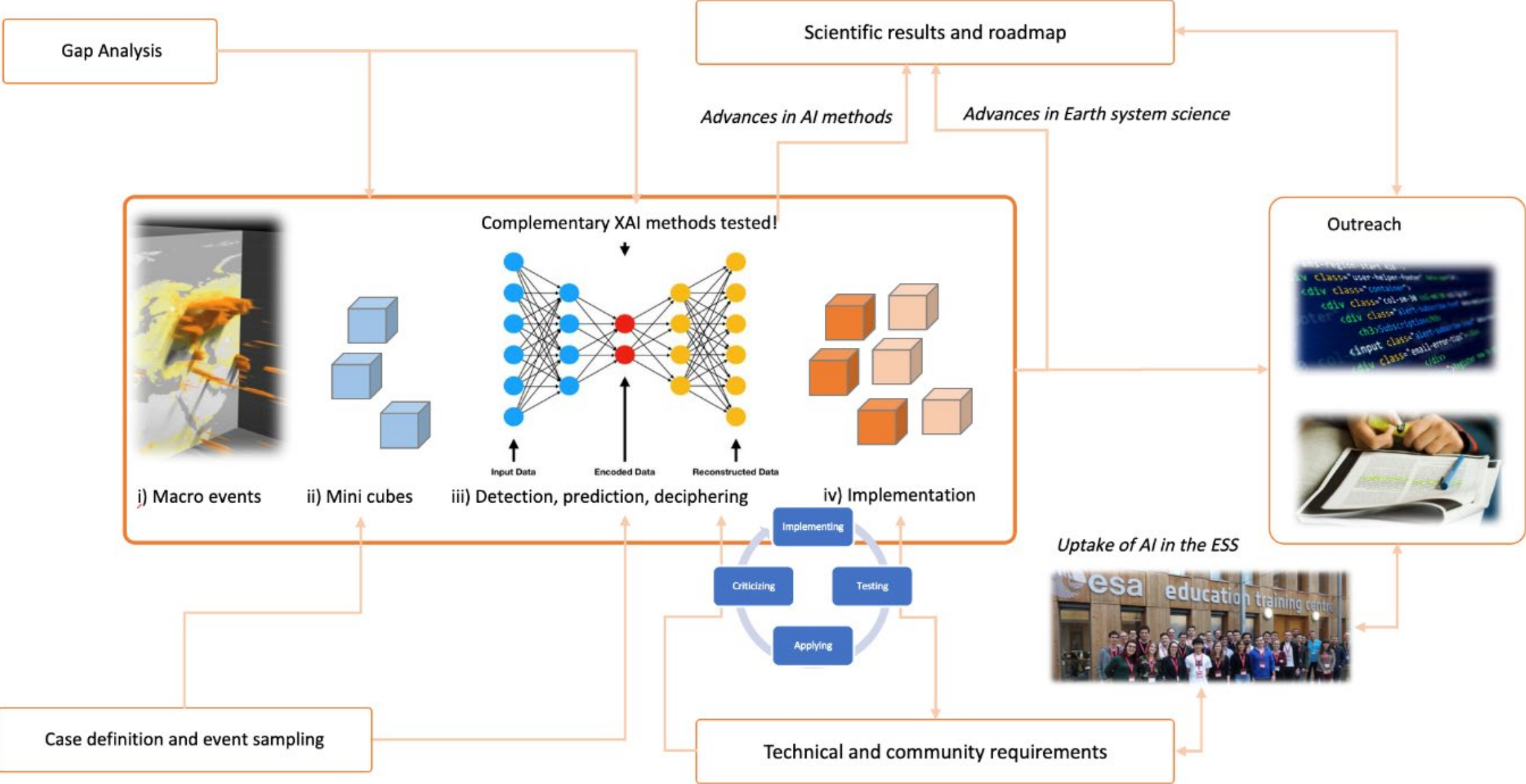


Fig. top  
Requena-Mesa et al. (2021) EarthNet21: A novel large-scale dataset and challenge for forecasting localized climate imatcs. arXiv:2012.06246

# DeepExtremes in a nutshell



# A nice example of the work in the consortium

## Explaining Deep Learning Models for Earth Surface Forecasting

Miguel-Ángel Fernández-Torres<sup>1</sup>, Michele Ronco<sup>1</sup>, Vitus Benson<sup>2</sup>, Christian Requena-Mesa<sup>2</sup>, Miguel Mahecha<sup>3</sup> and Gustau Camps-Valls<sup>1</sup>

<sup>1</sup> Universitat de València, Image Processing Laboratory, València, Spain

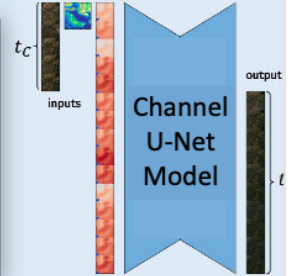
<sup>2</sup> Max-Planck-Institute for Biogeochemistry, Jena, Germany; <sup>3</sup> Remote Sensing Centre for Earth System Research, Leipzig University, Leipzig, Germany

### Motivation and objectives

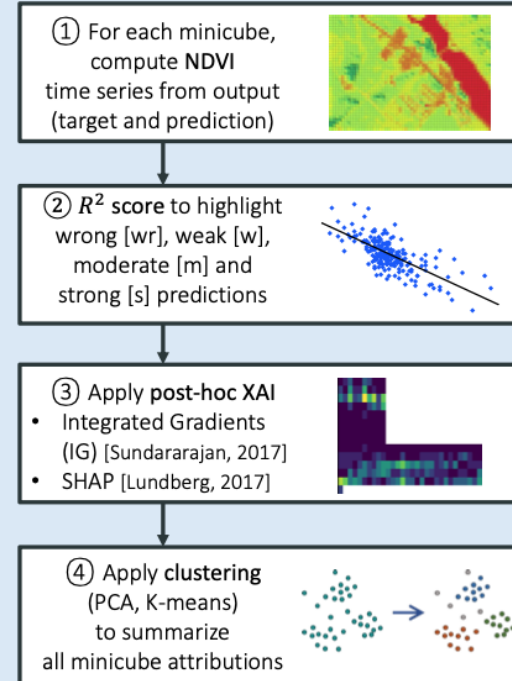
- Understanding rather than fitting Earth Surface Forecasting (ESF) models
  - 1) Model evaluation and improvement
  - 2) Illustrate outputs in a more intelligible way for climate and Earth science researchers
- Apply eXplainable AI (XAI) methods to ESF

### Earth surface forecasting as a video prediction task

- Channel-U-Net encoder-decoder, using EfficientNet-B5 as backbone [Requena-Mesa, 2021]
- Inputs (stacked, 191 channels):
  - 1) Satellite [RGB+NIR] (10 context time steps; s: HR; t: 5-daily)
  - 2) 5 meteo predictors: Prec. [RR], sea press. [PP],  $\mu$ /min/max temp. [TG,TN,TX] (10 context + 20 target time steps; s: LR, up.; t: 1-daily)
  - 3) Digital Elevation Model [DEM] (HR)
- Output (stacked, 80 channels): Satellite [RGB+NIR] (20 target ts.)

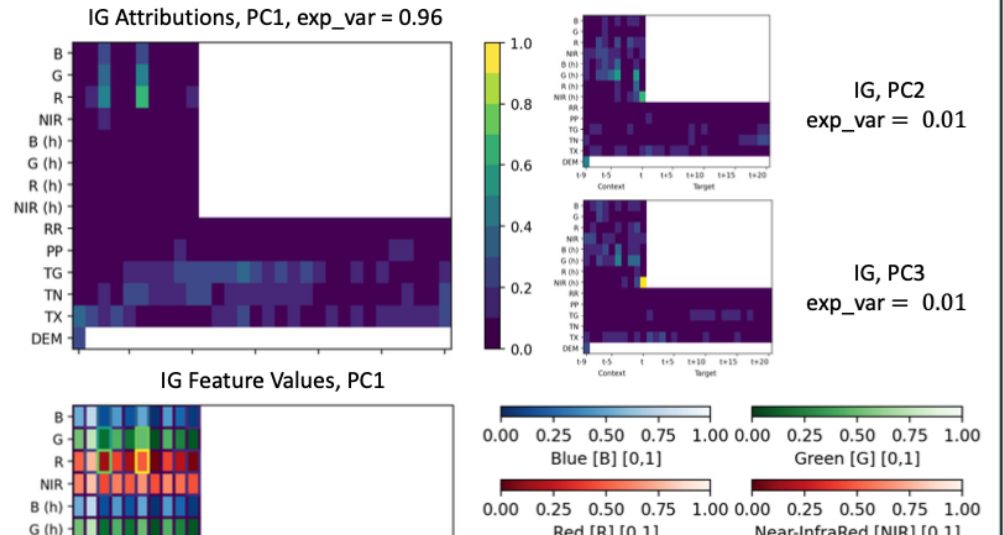


### Methodology for eXplainable AI (XAI)



### Understanding In-Domain (IID) predictions from EarthNet2021 database: First PCs for attributions obtained using IG and SHAP

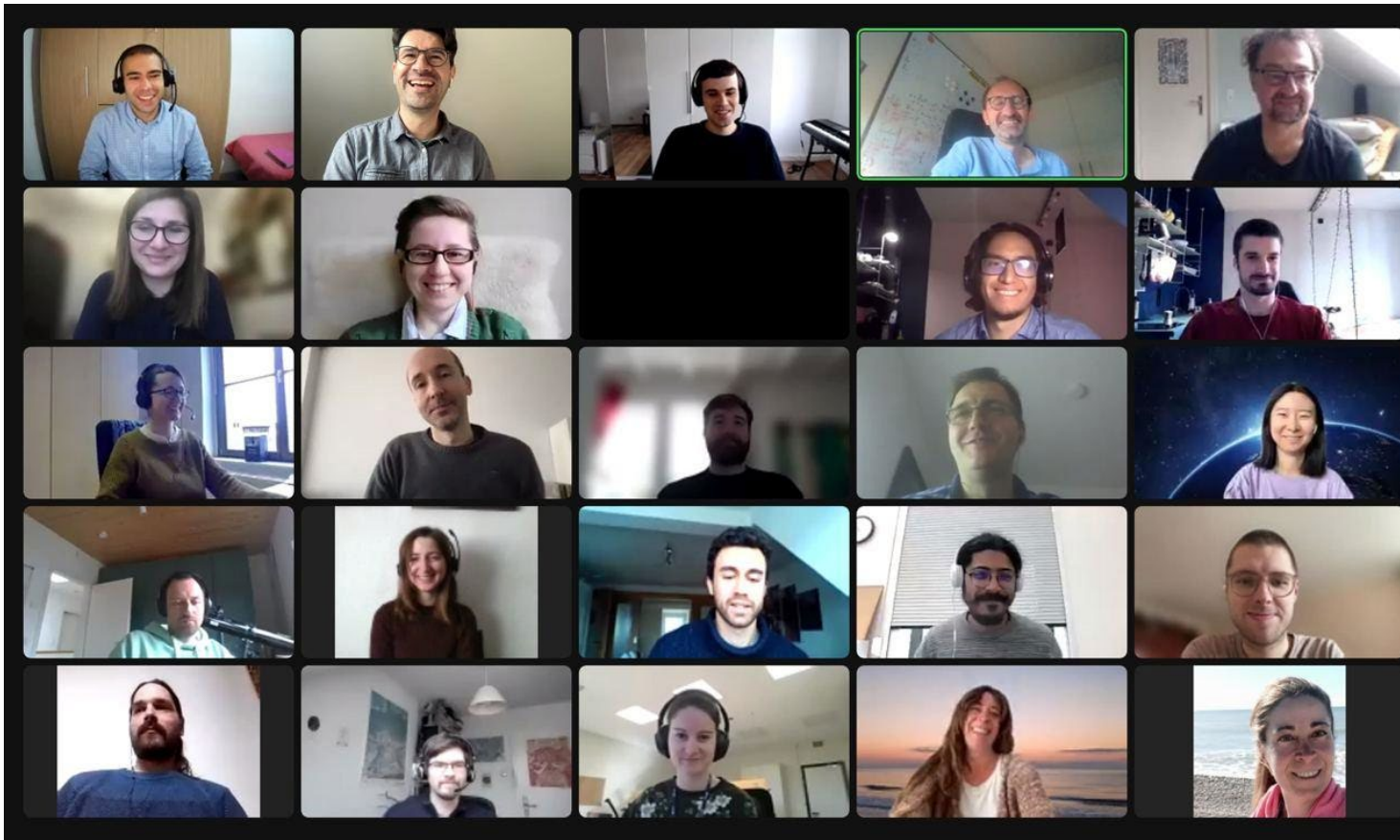
- Analysis limited to minicubes in France and going from May to September, approximately
- Still not enough [s] ( $R^2 > 0.6$ ) predictions for XAI  $\rightarrow$  Analysis over [m] ( $0.3 < R^2 < 0.6$ )
- Attributions based on IG: First principal component PC1, exp\_var = 0.96
- Average feature values obtained by clustering minicubes according to PCs (weighted mean)



Take-home messages and future work

# “Deep Extremes” → MultiHazards, Compounds, Cascade Events

Thank you for your attention



**Leipzig University**  
**Brockmann Consult**  
**Max Planck Institute for**  
**Biogeochemistry**  
**Valencia University**



MAX-PLANCK-GESELLSCHAFT



Thank you! Some preliminary  
information is here;  
[rsc4earth.de/project/deepextremes/](https://rsc4earth.de/project/deepextremes/)

...

AI 4 Science- “Deep Extremes” rsc



UNIVERSITÄT  
LEIPZIG



UNIVERSITAT  
ID VALÈNCIA

