Using Machine-Learning to Evaluate and Understand our Capability to Model Tropical Wetland Methane Emissions

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UNIVERSITY OF LEICESTER
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL
Space Park Leicester
esa
UKRI
Natural Environment Research Council

Project Details/Updates

Work initially funded via CMUG has now grown into a wider research project:

- "The First Environmental Digital Twin Dedicated to Understanding Tropical Wetland Methane Emissions for Improved Predictions of Climate Change"
- Funded as part of my 4-year UKRI Future Leaders Fellowship

As part of CMUG project:

- Focused on Africa
- We're developing an emulator for JULES wetland methane
- Will use it's explainability to show which factors matter in the model
- Will drive the emulator with CCI EO data to generate wetland fluxes
- Compare those to a CH_4 inversions performed on GOSAT/TROPOMI ESA-CCI data

As part of FLF:

- Focused on whole Tropics
- We'll extend emulator to other models from Global Carbon Project
- Develop EO ML-based wetland extent datasets
- Combine hydrological models with our land surface models to better represent wetland dynamics
- Improve methane wetland emissions in UK Earth System Model for climate predictions (including ESMValTool recipes for evaluation)
- Develop "climate services" around this capability, providing decision support to stakeholders

Complex

Unexplained Increases

Alarming and Urgent

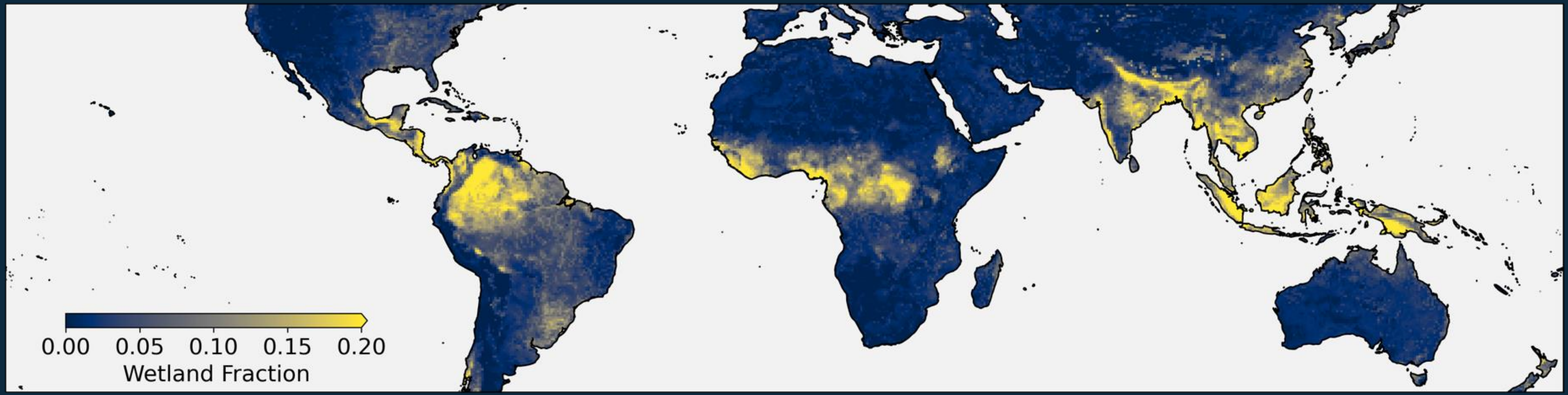
Tropical Wetlands?

Missing Knowledge

The Problems

The First Problem.
Significant differences between the methane from models

The Second Problem.
Models fail at correctly simulating the size and location of wetlands



Parker et al., Biogeosciences, 2022

The key research questions that I will address:

1) ***How are tropical wetland methane emissions responding to climate change?***
2) ***How will they continue to do so under future climate scenarios?***

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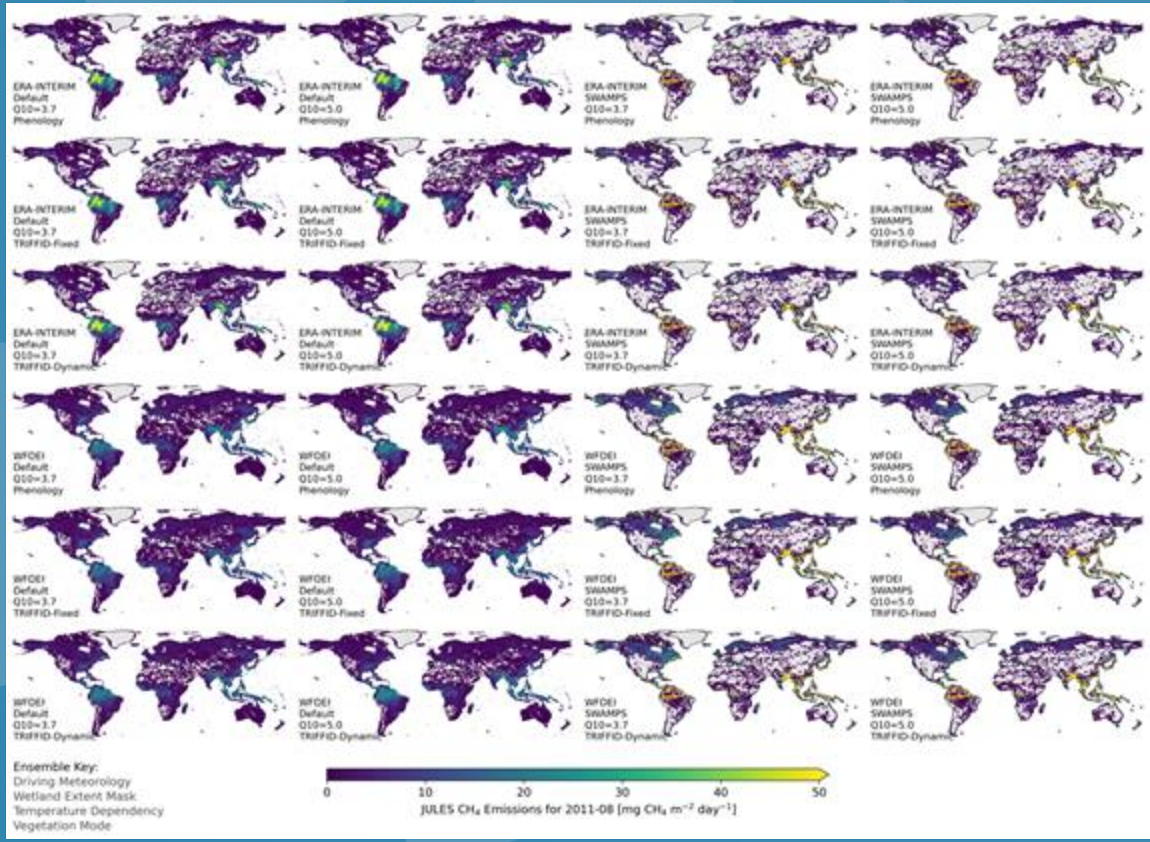
- Models disagree

"Models demonstrate extensive disagreement in their simulations of wetland areal extent and CH_4 emissions, in both space and time" – Melton et al., 2013

- Intercomparisons are challenging

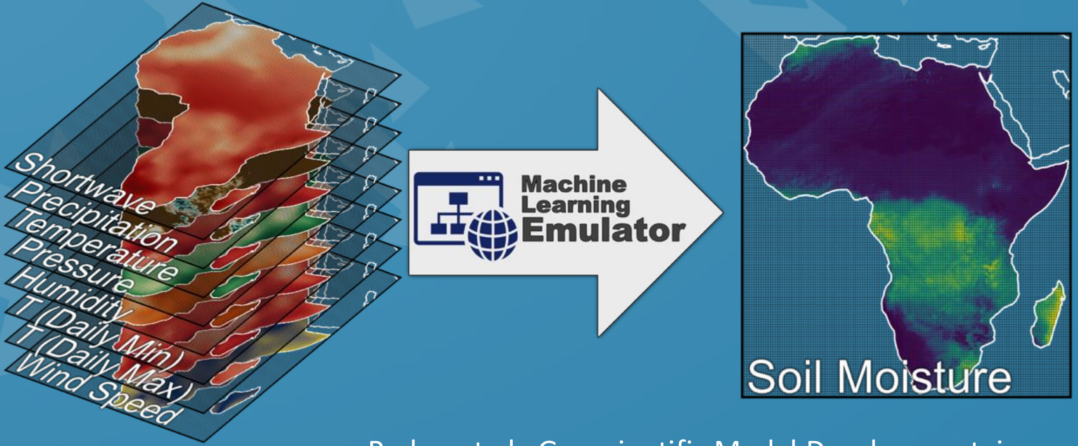


Parker et al., Biogeosciences, 2022

WP 1 – Emulating and Explaining Wetland Models (Years 1-2)

Results in new capabilities to model and explain wetland methane emissions

- Emulators allow novel comparisons
- Explainable AI can be powerful
- => New understanding!

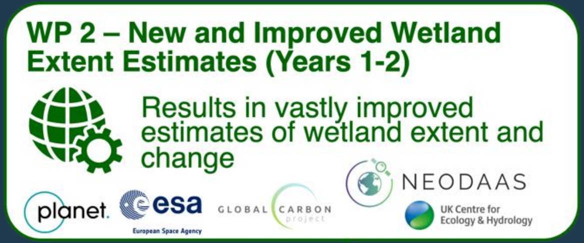


Parker et al., Geoscientific Model Development, in prep

- Wetland extent = huge uncertainty

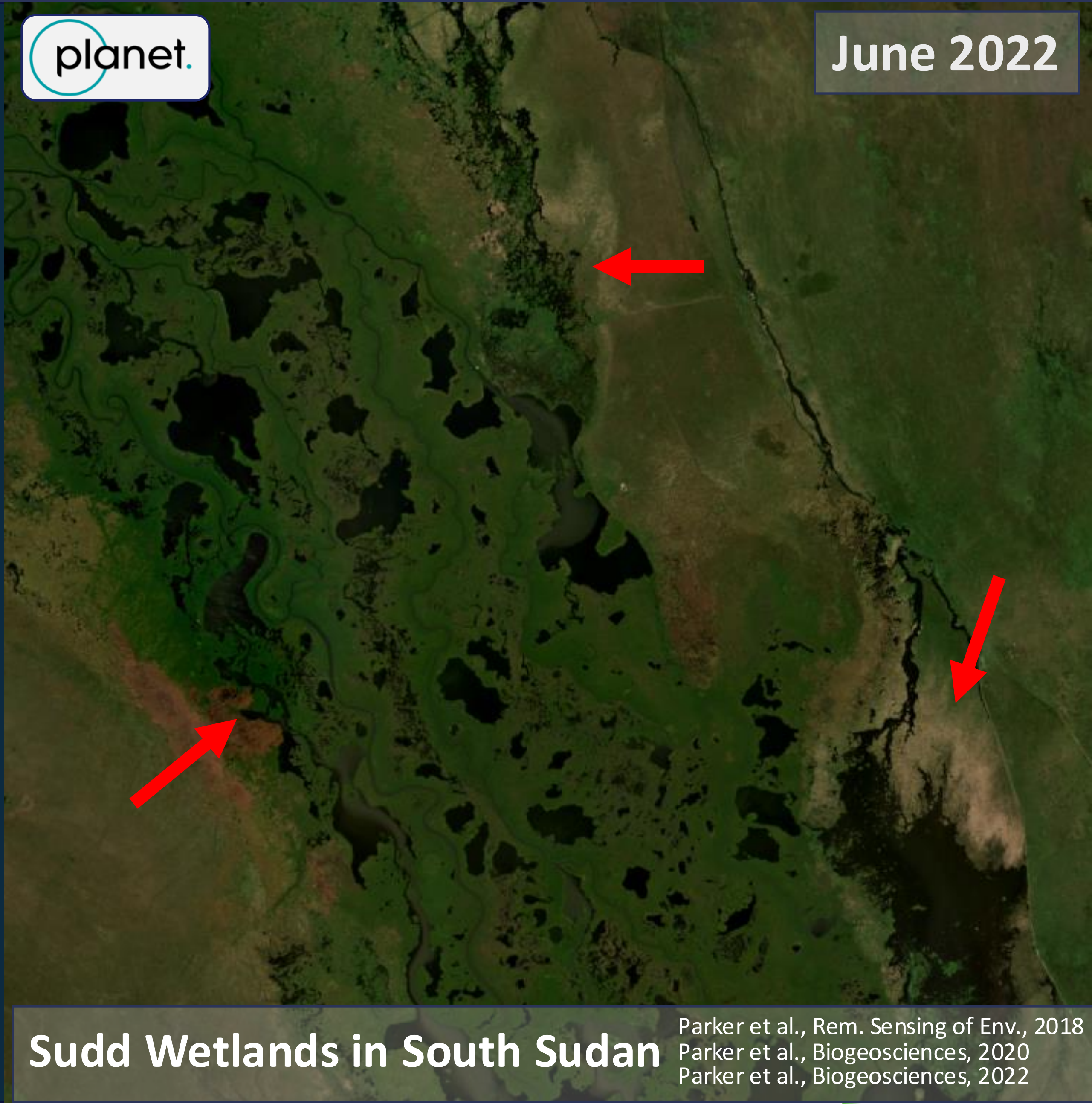
"Our simulated wetland extents are also difficult to evaluate due to extensive disagreements between wetland mapping and remotely sensed inundation datasets." – Melton 2013

- Partnering with Planet



- New ML-based wetland extent dataset

- Improve estimates of wetland extent



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Vision

We will develop a **new world-class capability in Environmental Digital Twins**, enabling cutting-edge science and truly impacting on climate policy decision-making.

Host Institute

University of Leicester

National Centre for Earth Observation – Natural Environment Research Council

Space Park Leicester

Project Partners

Met Office

esa – European Space Agency

planet.

Global Carbon project

CGI

UK Centre for Ecology & Hydrology

Stakeholders

WCRP – World Climate Research Programme

ICPAC – IGAD Climate Prediction & Applications Centre

UN environment programme

WMO

Ramsar – Convention on Wetlands

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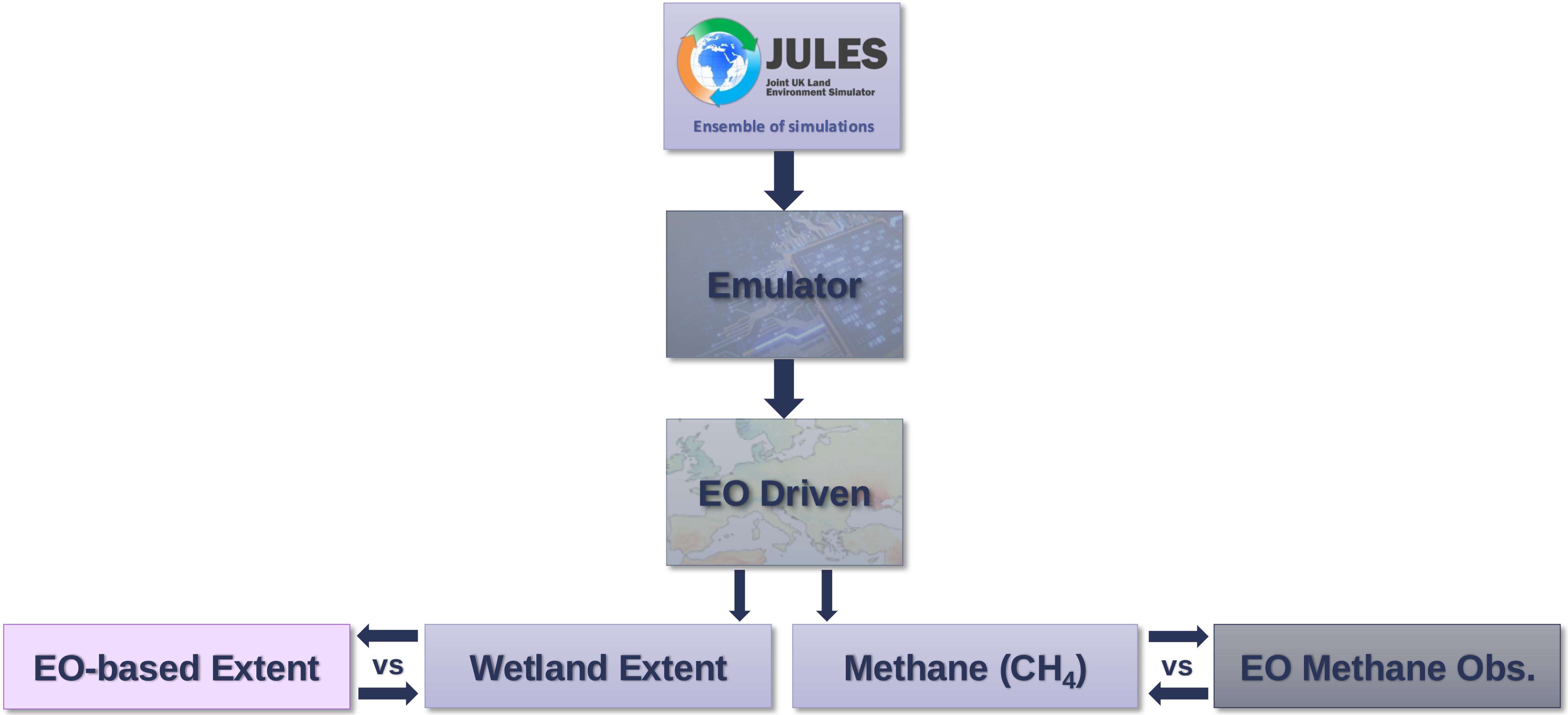
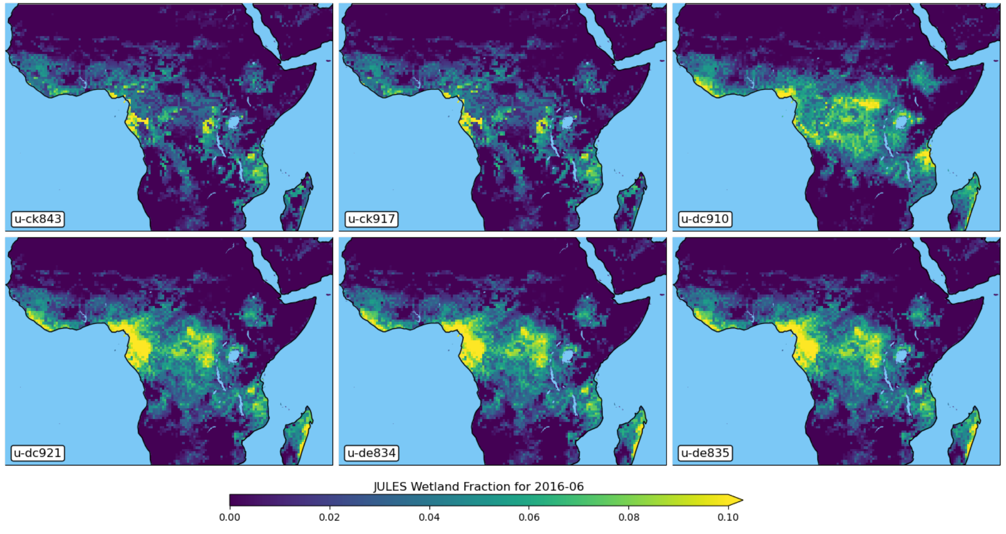
Methodology

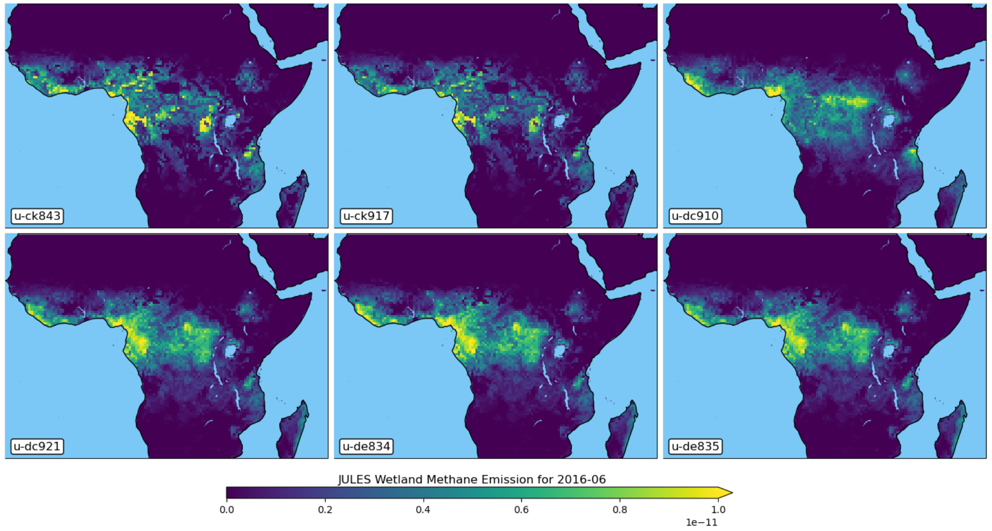


Methodology



Wetland Extent

JULES
Joint UK Land Environment Simulator
Ensemble of simulations



Wetland Methane

- Ensemble of simulations
- Currently 6 members but work ongoing
- Different forcing meteorology
- Different temperature dependencies
- Different soil types

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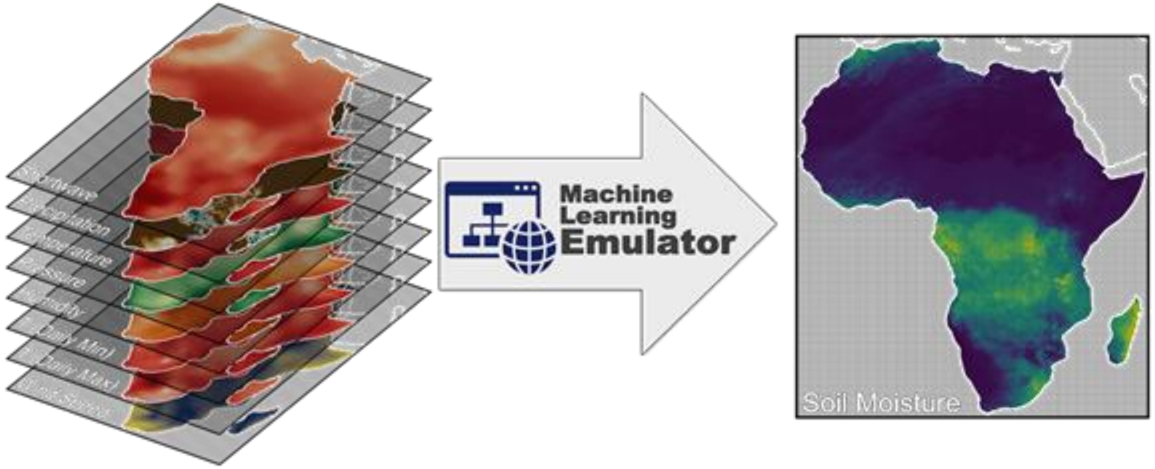
Methodology

We train a **machine-learning** decision-tree model (*emulator*) using JULES data to reproduce wetland extent and methane emissions.



Advantages

- ✓ We can run many simulations **very fast**
- ✓ **No** need for **expert** knowledge
- ✓ **No** need for expensive **supercomputers**
- ✓ We can derive **useful metrics** for users
- ✓ They can be deployed on **web platforms**
- ✓ They can integrate **many types of data**
- ✓ **Explainable AI.**

Methodology

Model-data fusion

We will **drive the emulator** with input based on **ESA-CCI data** to produce new wetland CH_4 emissions, consistent with observed LST and soil moisture.

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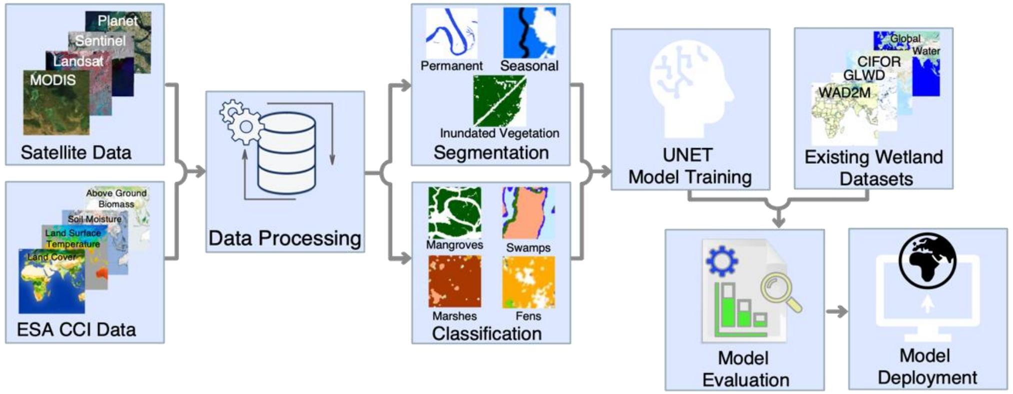
Methodology

ML-based Architecture for Segmentation and Classification



JULES
Joint UK Land Environment Simulator
Ensemble of simulations

↓

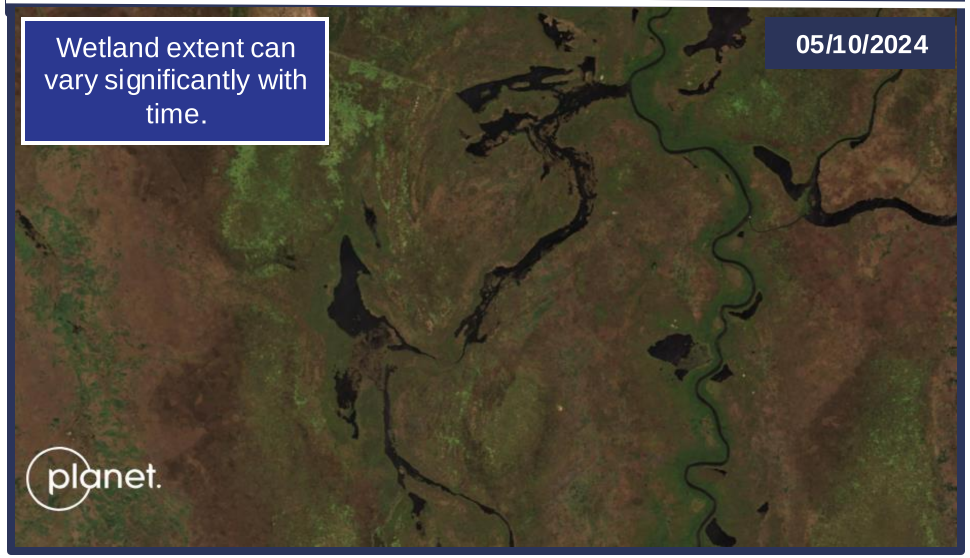
Emulator

↓

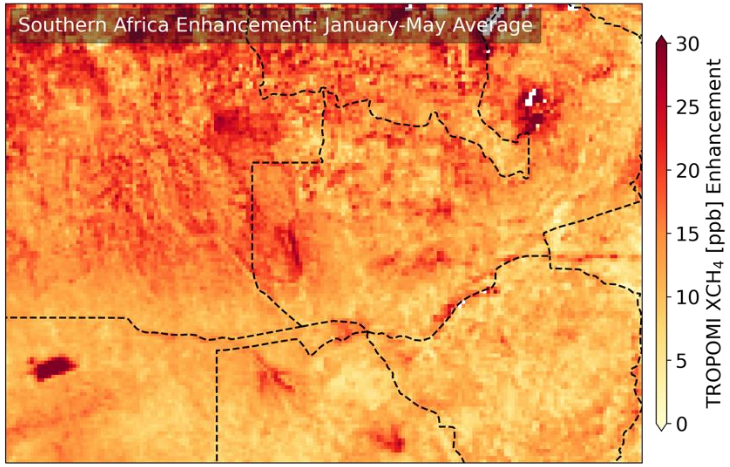
EO Driven

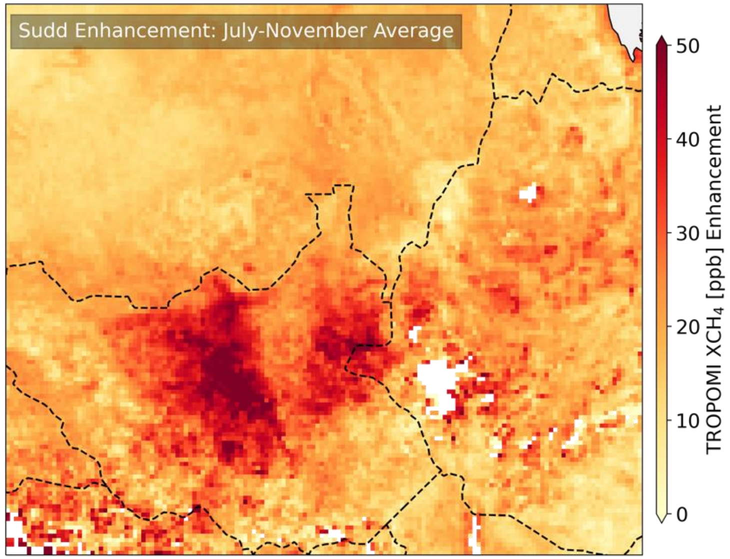
↓

EO-based Extent ⇄ vs ⇄ Wetland Extent

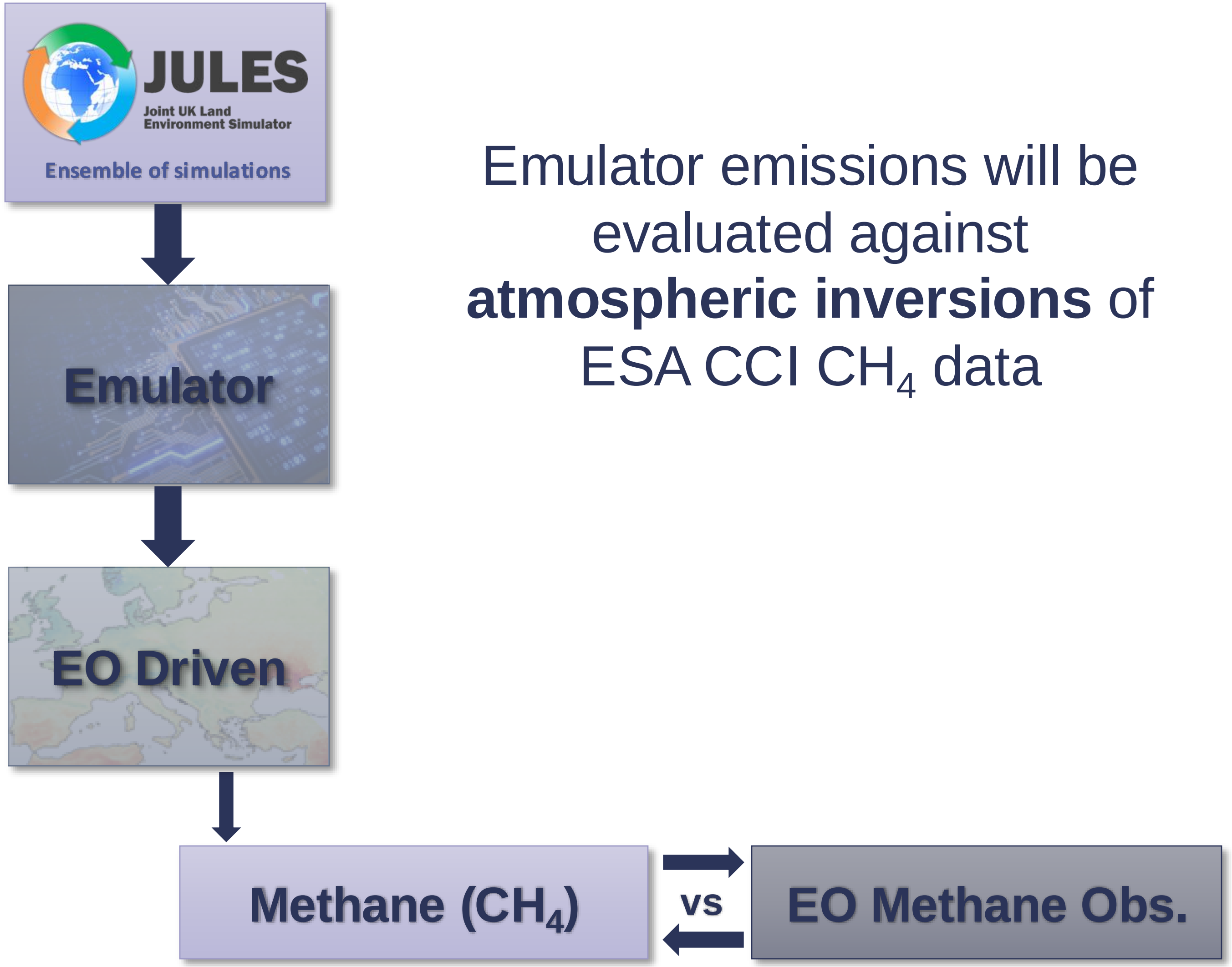


Methodology





Parker et al. (2022)



Emulator emissions will be evaluated against **atmospheric inversions** of ESA CCI CH_4 data

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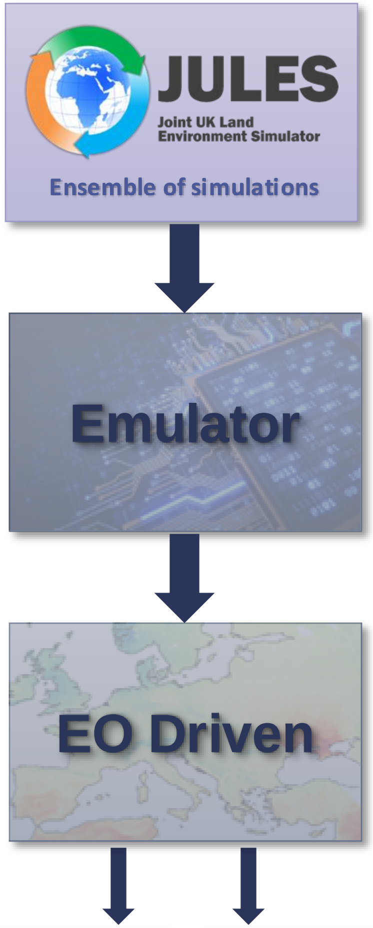
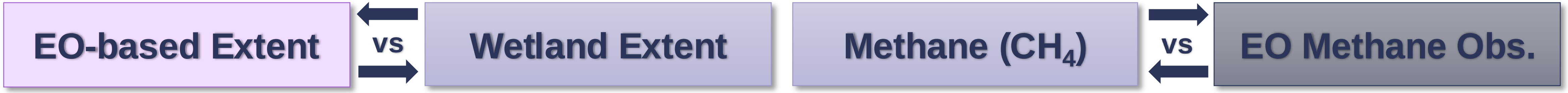
Next Steps

- Continue with additional JULES simulations to extend ensemble
- Discuss with CCI teams (LST, soil moisture) on most appropriate datasets to use to drive emulator
- Develop wetland extent datasets and make use of CCI land cover



- Continue to develop emulator
  - Fairly slow process as lots of potential combinations of input features
- Evaluate against GHG-CCI CH_4 data
  - Perform regional flux inversions



For more details, please see poster and talk to Cristina, Khunsa and Chandana ☺