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

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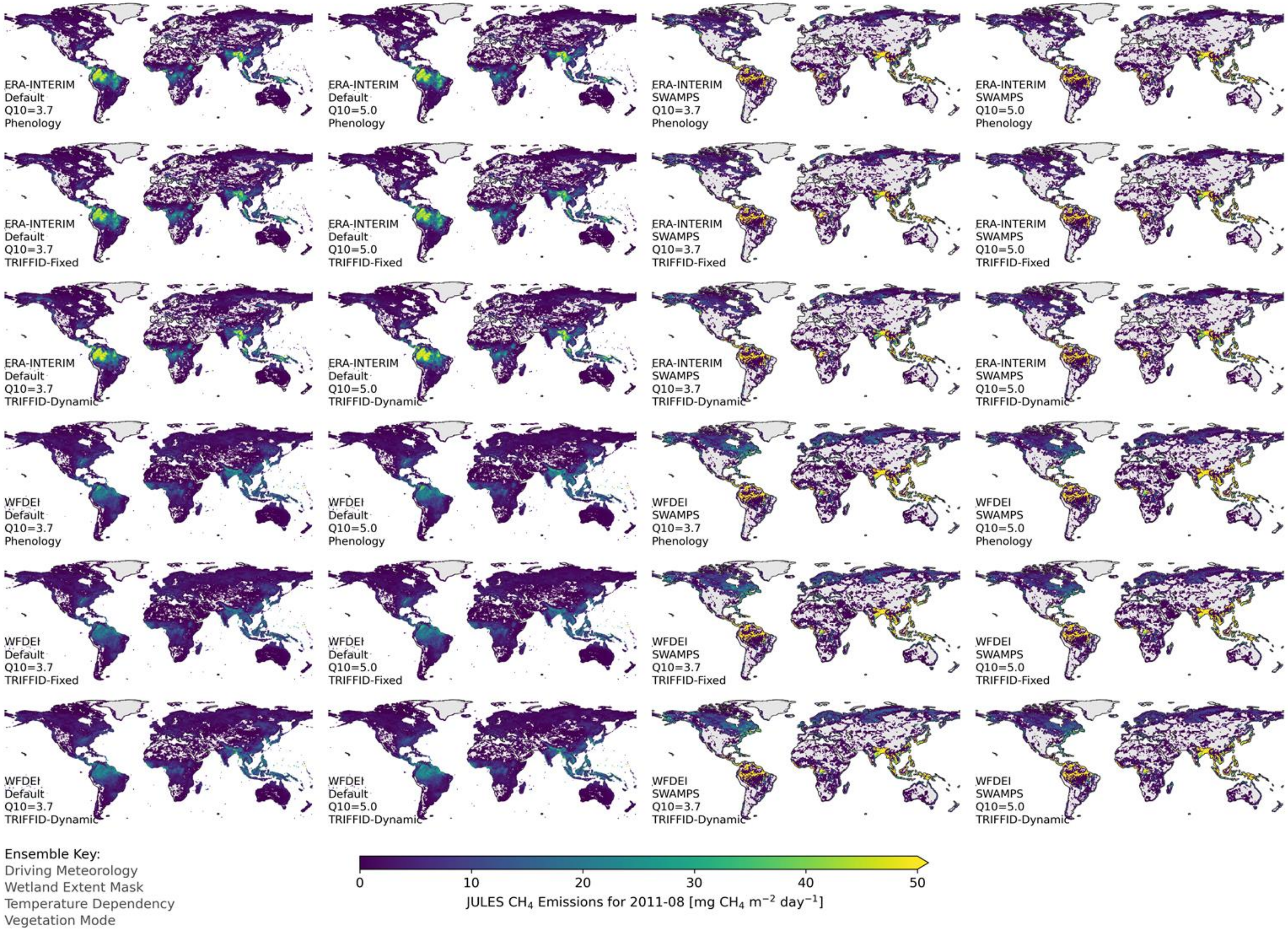
- Duration: 18 months

- In short: We'll develop an emulator for JULES wetland methane, use it's explainability to show which factors matter in the model, drive the emulator with CCI EO data to generate wetland fluxes and compare those to a CH_4 inversions performed on GOSAT/TROPOMI ESA-CCI data.

- Details:
  - Generate JULES wetland simulations across an ensemble of settings (Gedney, MO)
  - Train emulator based on JULES simulations (Parker, UoL)
  - Explainability of simulations using explainable AI methods and other CCI data (soil moisture, LST, etc) (Parker, UoL)
  - Drive emulator with EO data (e.g. CCI land surface temperature, soil moisture, WAD2M wetland extent data, etc) to produce EO-based wetland emission dataset (Parker, UoL)
  - Compare to existing wetland emission datasets (e.g. WetCHARTS) (Parker, UoL)
  - Perform wetland flux inversions using CCI CH_4 (Palmer, Edinburgh)
  - Evaluate both JULES and new EO-based dataset against wetland flux inversions (Palmer, Edinburgh)

Figure: Ensemble of JULES simulations with different driving data, temperature dependency, vegetation and wetland mask show massively different methane fluxes!



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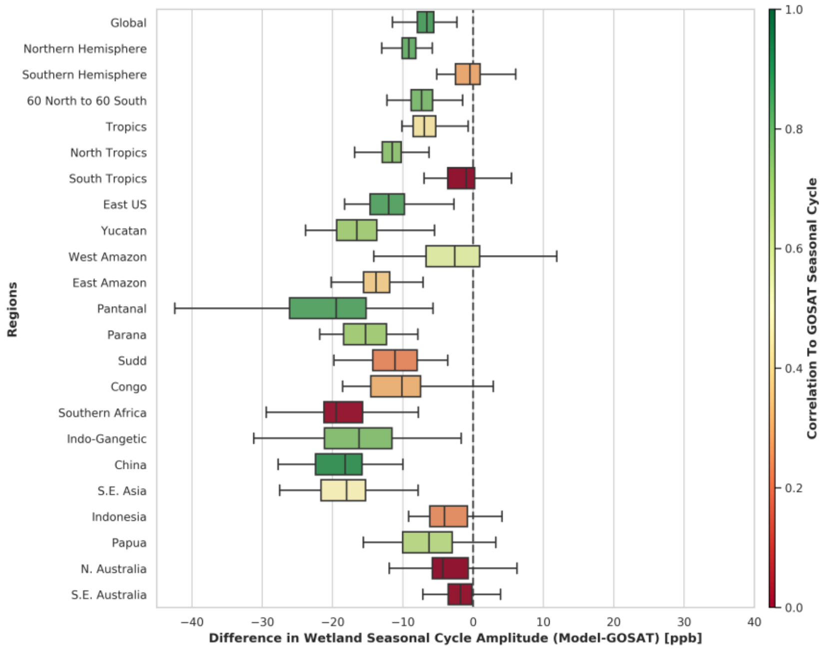

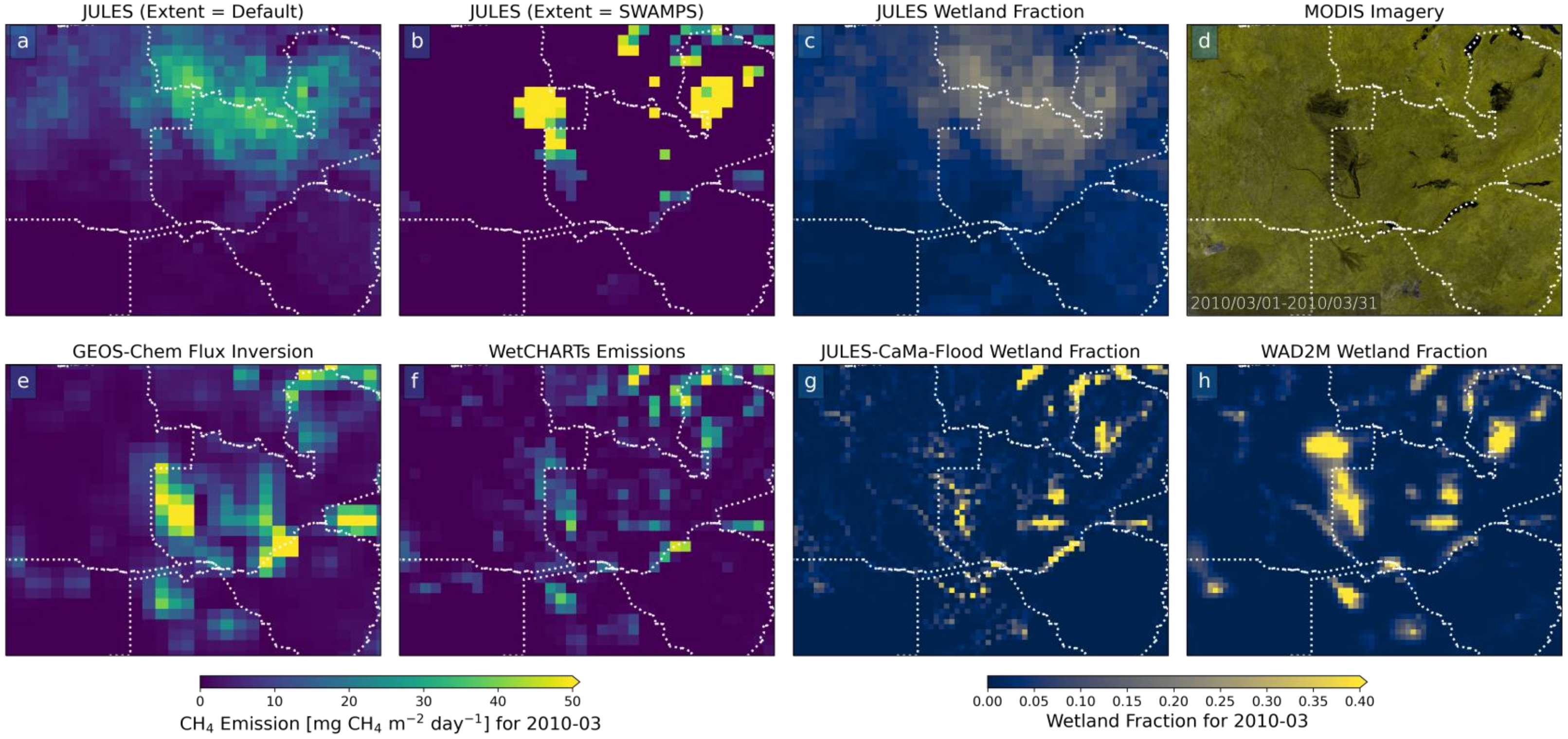

- Recent JULES evaluation - *Parker et al. (including Gedney and Palmer), 2022, Biogeosciences,* - shows that JULES does a good job reproducing the observed wetland methane seasonal cycle but some areas are problematic (especially several African regions).
- JULES is the land surface model in UKESM and recently an interactive-methane version of UKESM has been produced - *Folberth et al. (including Parker and Gedney), 2022* – which makes use of JULES wetland emissions. It is therefore vital for future climate simulations that the performance of the JULES wetland methane emissions is well-understood and characterised.
- To understand the behaviour better and to direct future JULES developments/improvements, we will use machine-learning emulation to explore the wide potential feature space of the JULES configurations and use Explainable AI methods to highlight the most important features and relationship.

- After developing this emulator, we can swap out the standard JULES inputs (typically meteorological driving data based on ERA) and instead drive the emulator with **observed data** from CCI, for example land surface temperature.
- This means that, the emulator will benefit from having both learnt the relevant physical relationships from the original JULES simulations but at the same time be constrained to the observational (EO-based) input data (such as land surface temperature and soil moisture).
- We will generate new observationally-based but physically-consistent estimates of wetland CH4 emissions

CCI Datasets

- GHG (methane)
- Land Surface Temperature
- Soil Moisture
- Land Cover
- + Vegetation (?)

Models

- JULES (land surface)
- GEOS-Chem (atmospheric)

Previous work using same concept – European GPP

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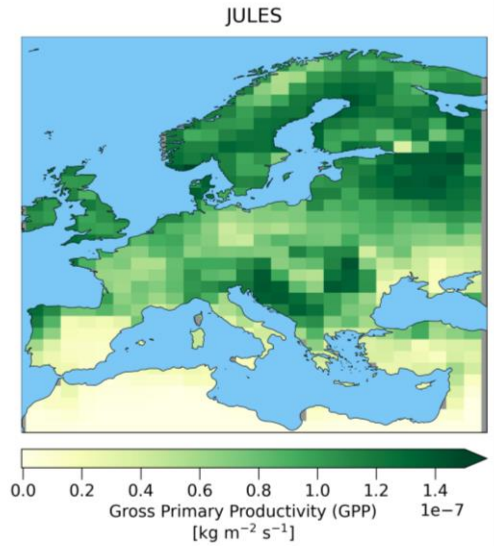
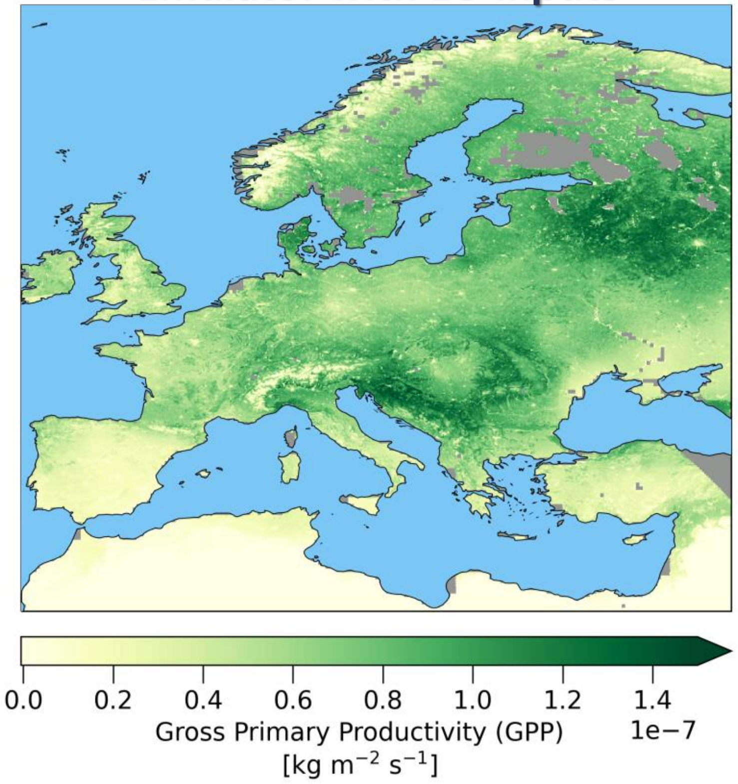
Our data compares well with existing satellite GPP products

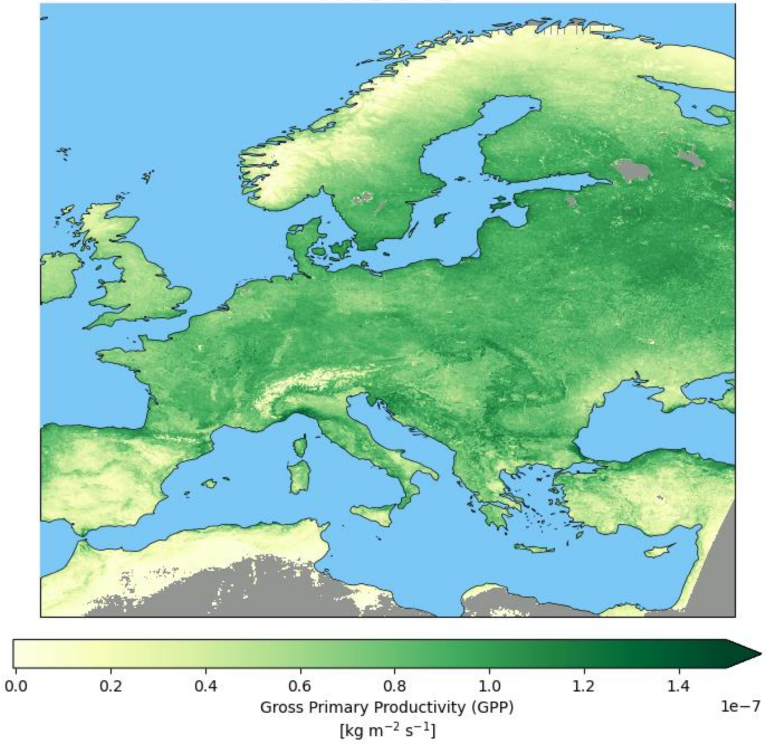
GPP monthly average 06-2019



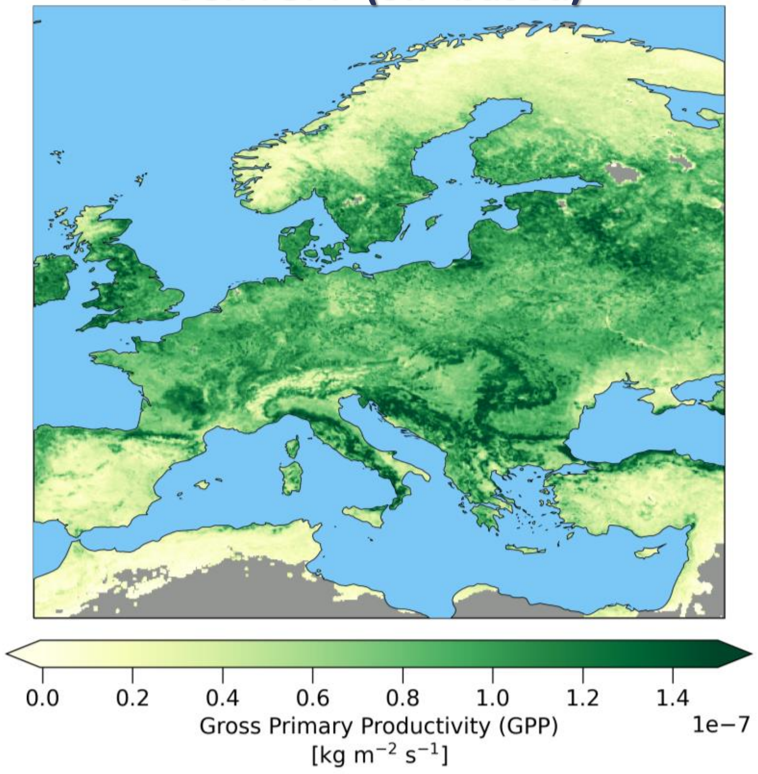
Emulator with EO inputs



MODIS



Sen4GPP (SIF-based)



- The estimated uncertainties on the ESA-CCI data will be used to perturb the inputs and produce an uncertainty estimate on the generated data products.
- This propagation of uncertainty is both challenging and computationally expensive when performed on the full JULES land surface model but the speed and efficiency of the emulator allows a much wider uncertainty-space to be more fully characterised.
- Finally, we will compare these new wetland emission estimates to those derived directly from atmospheric inversions of the observed GHG-CCI CH_4 measurements.