European Biogenic Volatile Organic Compound Emissions Based on Land Surface Modelling and Satellite Data Assimilation

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What is the SEEDS project?

Funded by the European Union

SEEDS - Sentinel EO-based Emission and Deposition Service

- EU funded H2020 project for further development of CAMS (3 years, Jan. 2021 to Dec. 2023).
- The project aimed to use satellite observations, data assimilations and land surface modelling to:
  - Improve emissions
  - Improve dry deposition fluxes
  - Improve the air quality modelling component of CAMS
  - Expand the number of use cases for CAMS in policy relevant areas

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A Focus on the Land Surface

A simple theoretical framework:

1. Use a state of the art land surface model
2. Improve the model using data assimilation of leaf area index observations
3. Leverage these improvements to advance
    a. Biogenic emission modelling
    b. Dry deposition modelling
4. Test these advancements in one of the operational CAMS models

Land Surface Modelling Setup

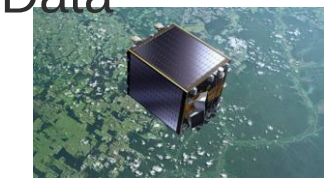
ECMWF IFS HRES Meteorology

ECOCLIMAP-II Land Cover

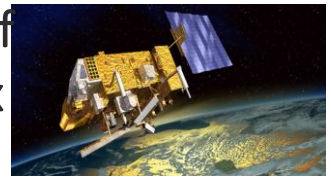
Satellite Observations

Copernicus CGLS Data

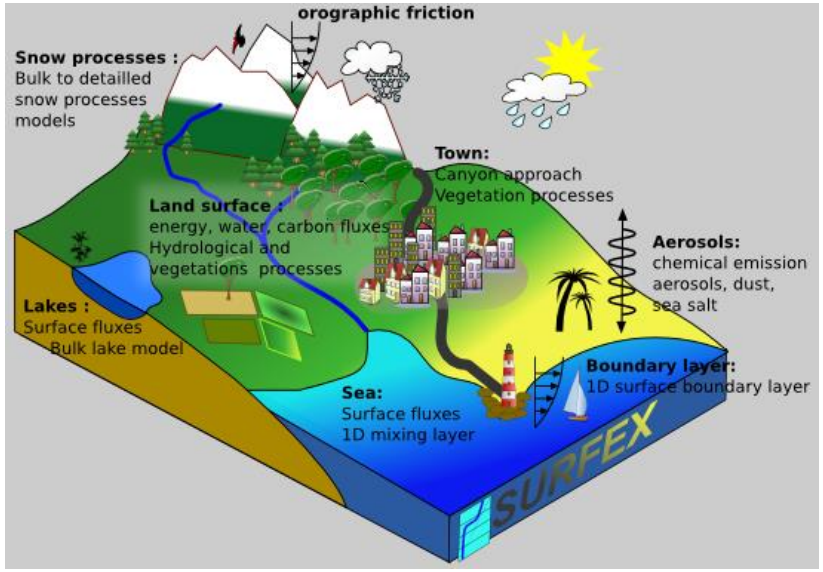
PROBA-V Leaf Area Index



AVHRR Leaf Area Index



SURFEX LDAS-MONDE Data Assimilation

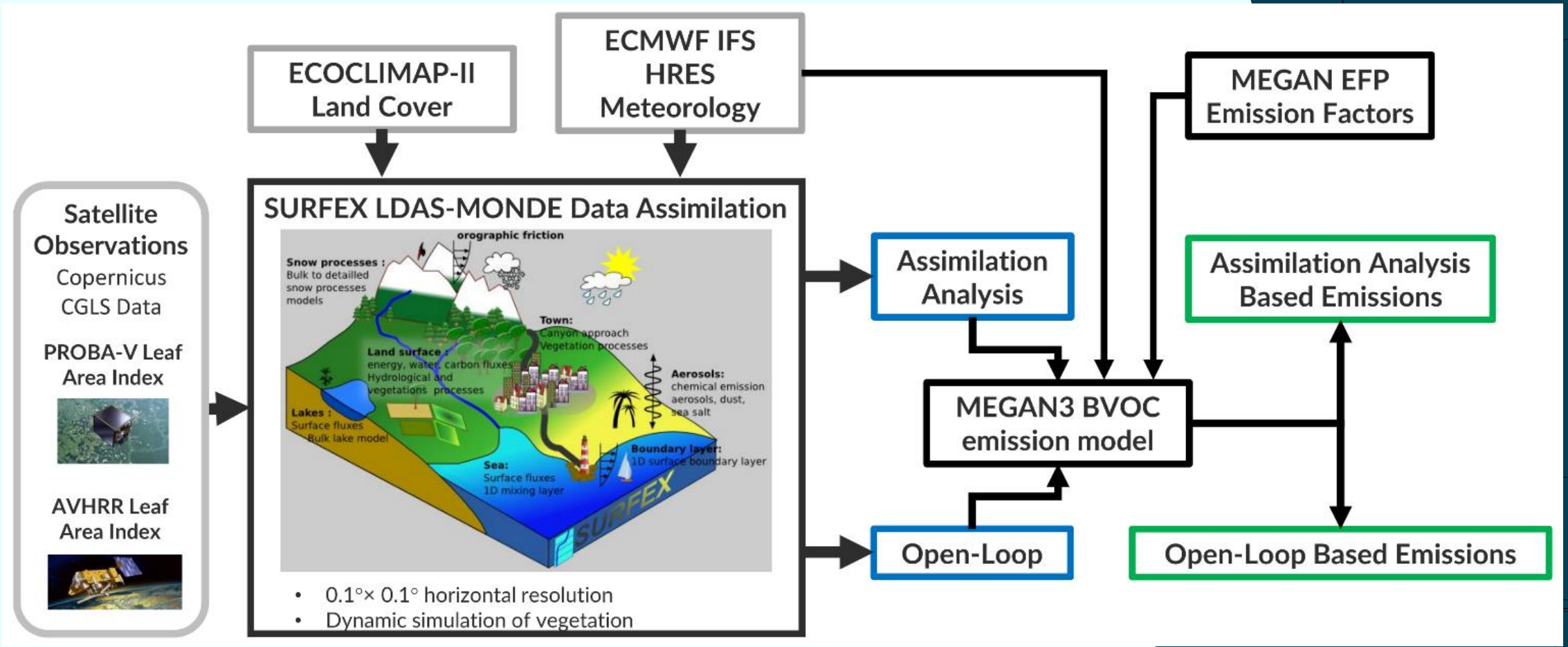


- CAMS European domain
- 0.1°× 0.1° horizontal resolution
- Dynamic simulation of vegetation
- 14 soil layers in diffusion based scheme
- 12 natural land cover types
- Sequential Kalman Filter

Open-Loop (No data assimilation)

Assimilation analysis

Biogenic VOC Emission Methodology



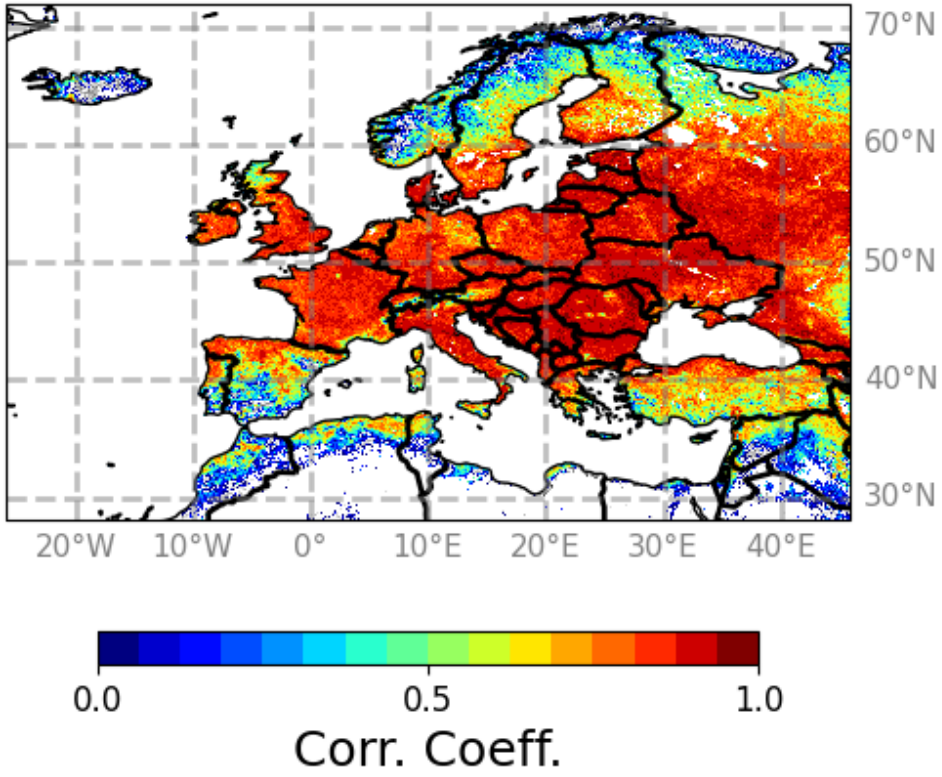
Biogenic VOC Emission Methodology

- We coupled MEGANv3.0 offline with SURFEX via these variables
  - LAI
  - Root-zone soil moisture
  - Root-zone soil temperature
  - Identical meteorological input data
- SURFEX will soon have MEGANv2.1 coupled online in the open source version – this was not available during SEEDS

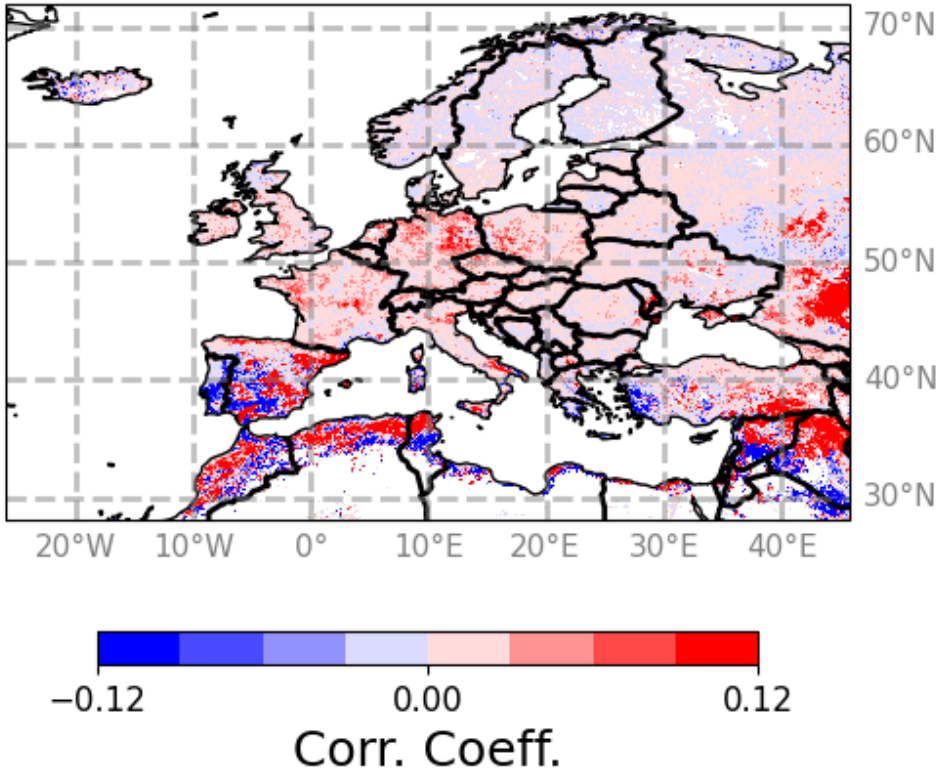
Evaluation of SURFEX LAI

SURFEX LAI correlations with TROPOMI SIF observations

(a) Correlation (Analysis,Obs)



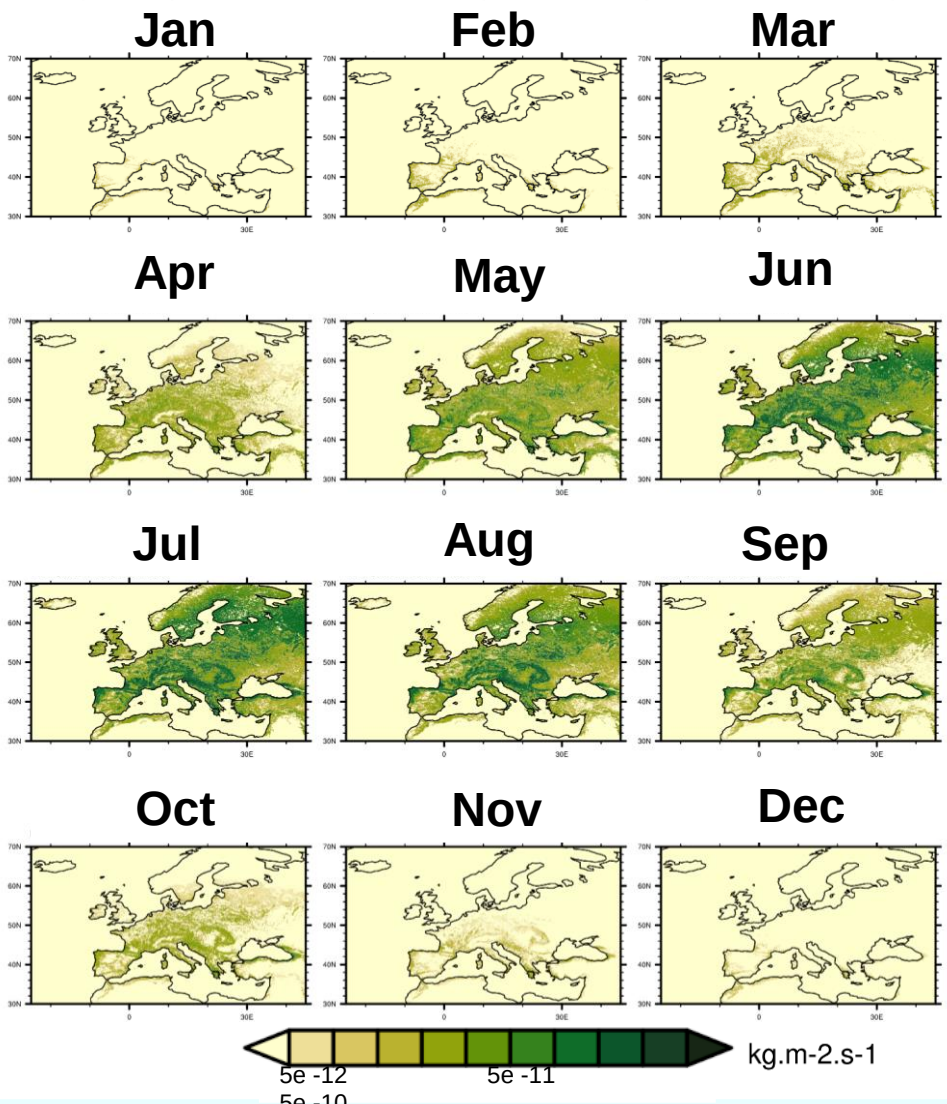
(b) Correlation (Analysis,Obs) - Correlation (Model,Obs)



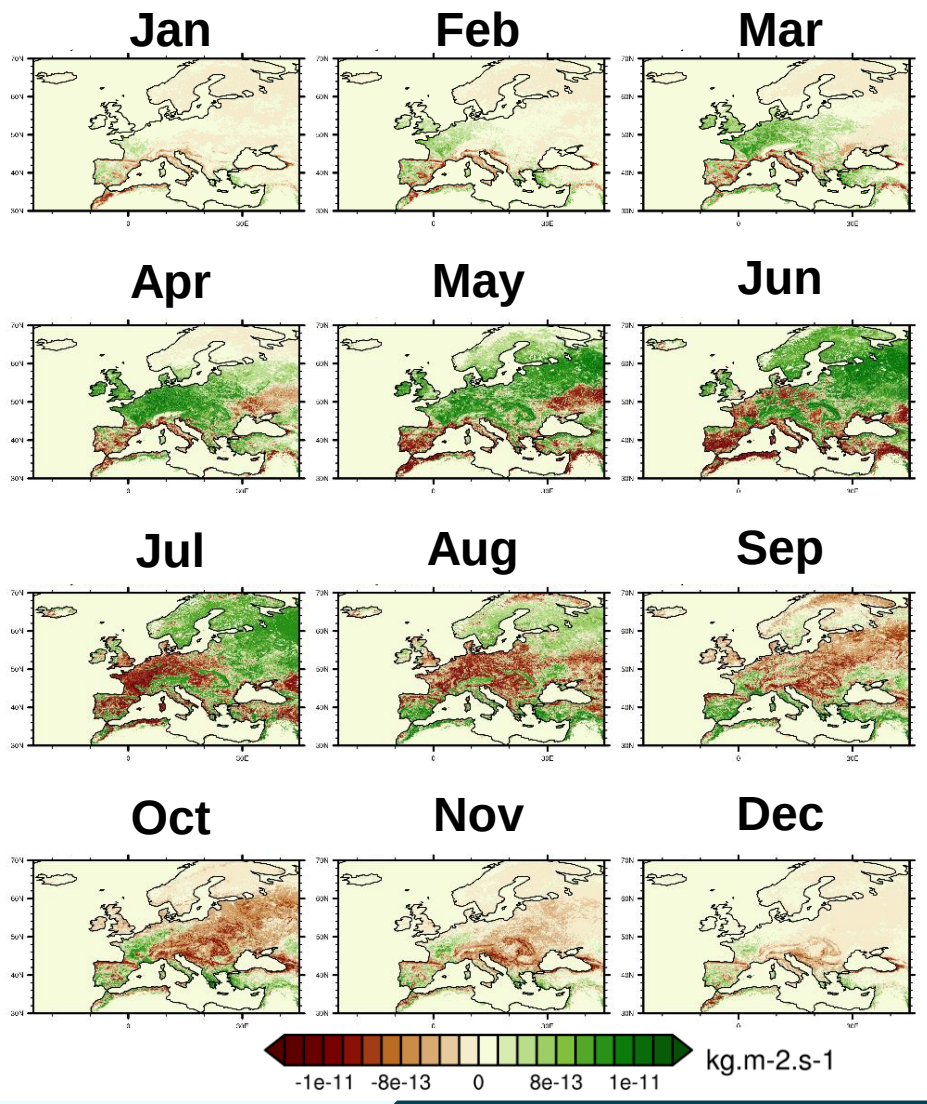
- The LAI analysis has improved correlation with solar induced fluorescence observations.
- Correlations are very good over most areas of Europe. Clear weaknesses over very arid or cold regions.

Monthly Mean Isoprene Emissions

LAI Analysis Based Emissions Averaged over 2018-2020

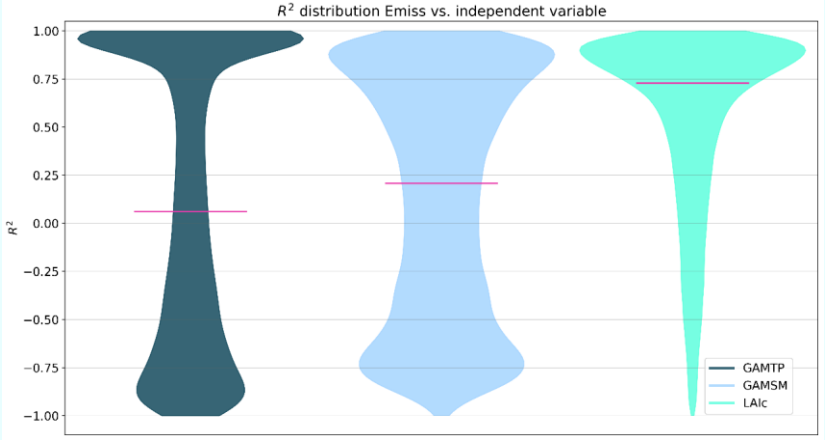


LAI Analysis Minus Open-Loop Emissions Averaged over 2018-2020



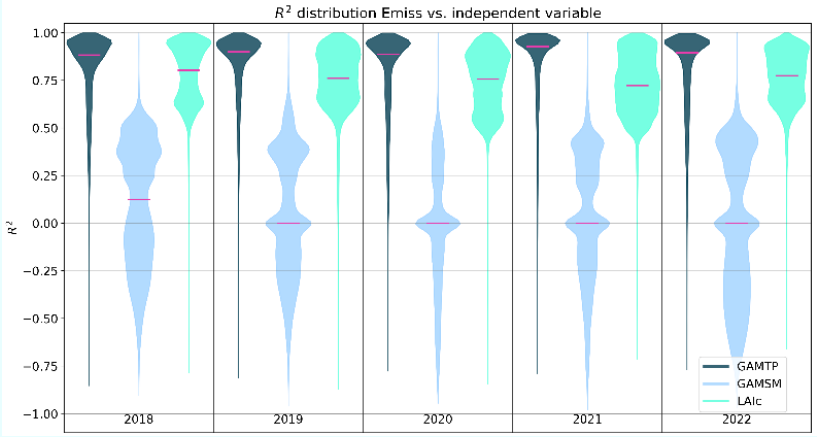
What is driving isoprene emission variability on different timescales?

Annual Correlations

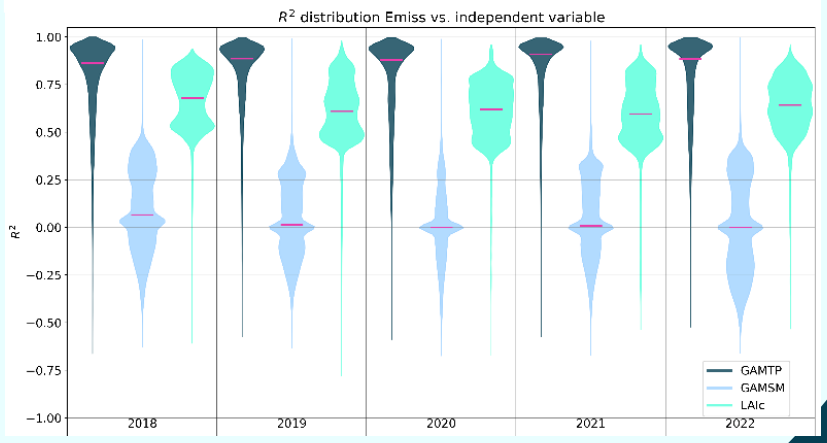


- LAI correlates the most with isoprene emissions on annual timescales
- LAI correlation is still strong on monthly timescales.
- LAI correlation weakens at daily and hourly timescales.
- Temperature and radiation control isoprene emissions on shortest timescales

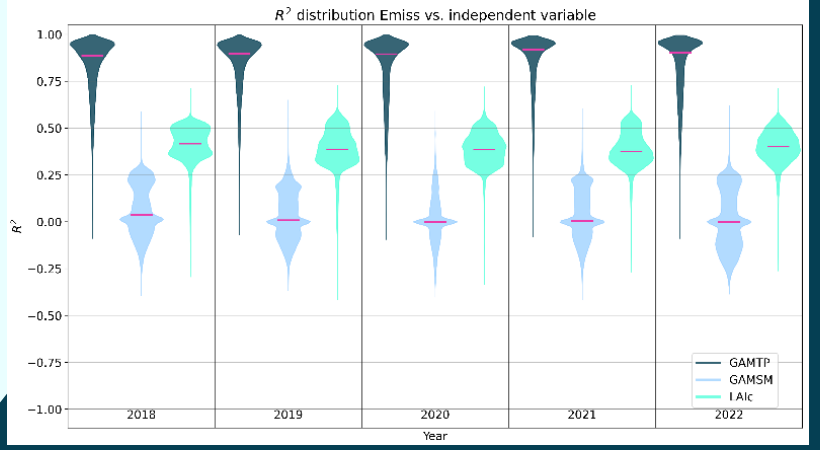
Monthly Correlations



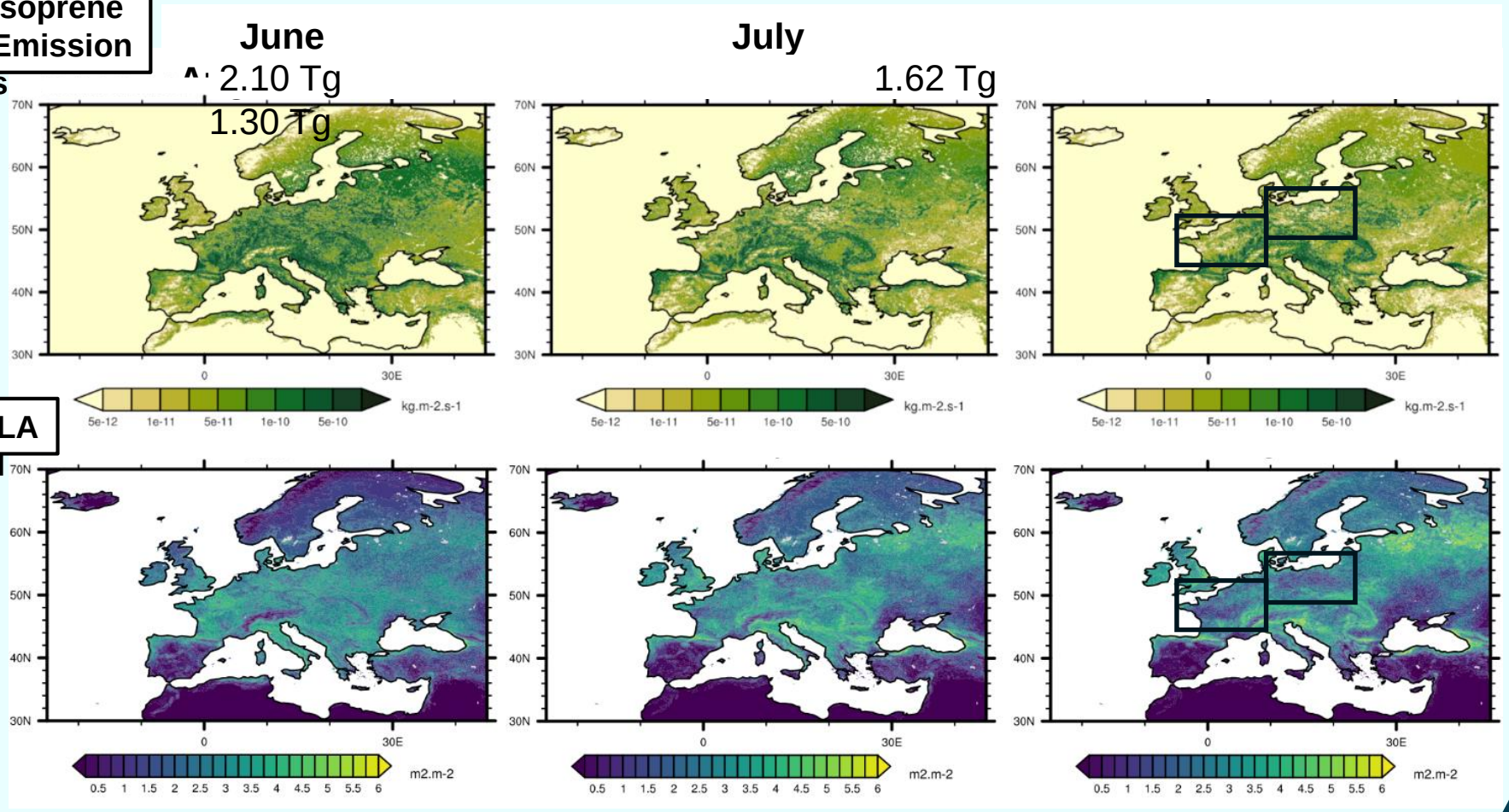
Daily Correlations



Hourly Correlations

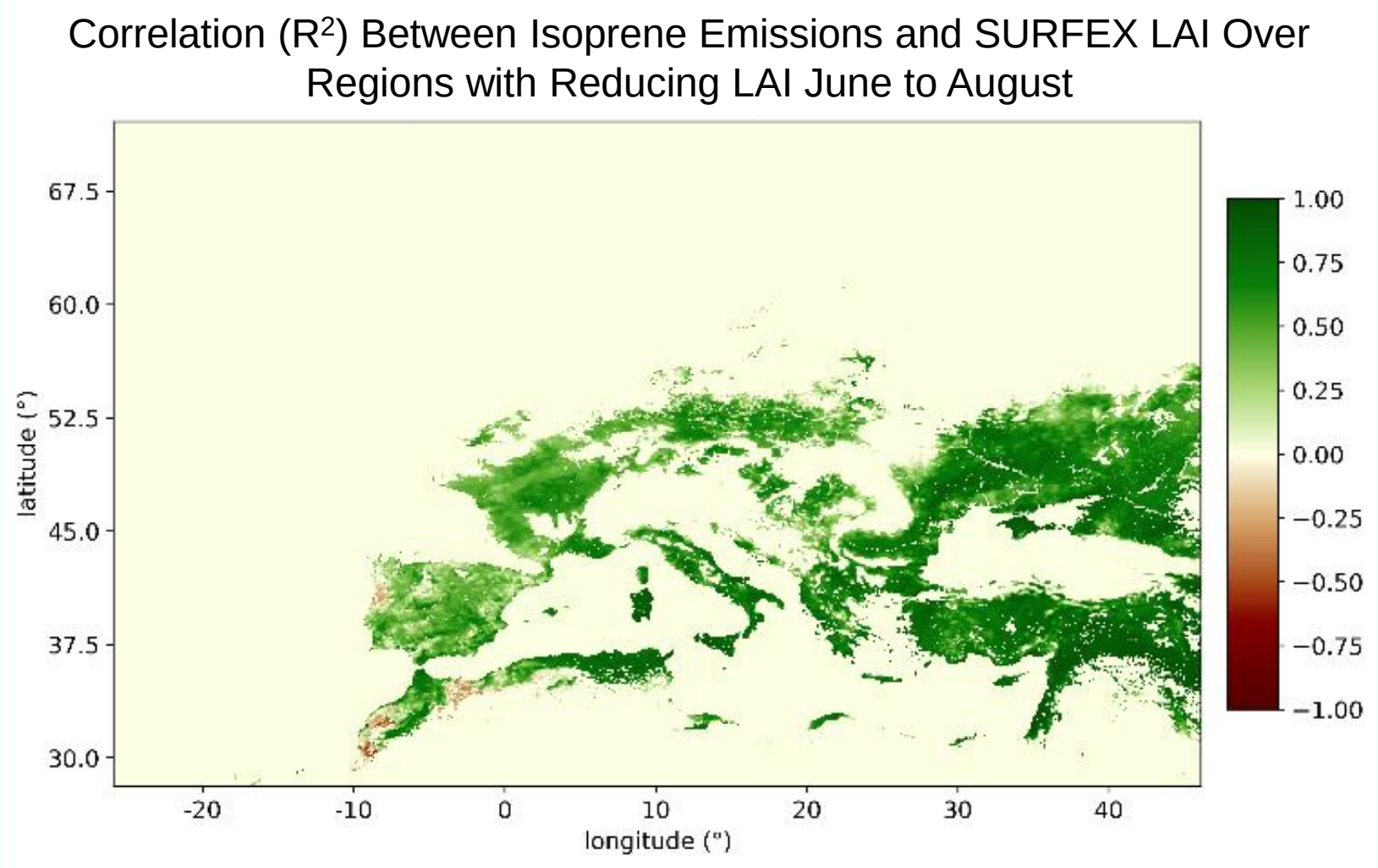


Summer 2019: The influence of LAI



- Isoprene emissions peaked early in 2019 in June
- Isoprene emissions decreased in July and August in several regions.
- LAI decreased at the same time in these locations due to drought and heatwave effects.

Summer 2019: The influence of LAI

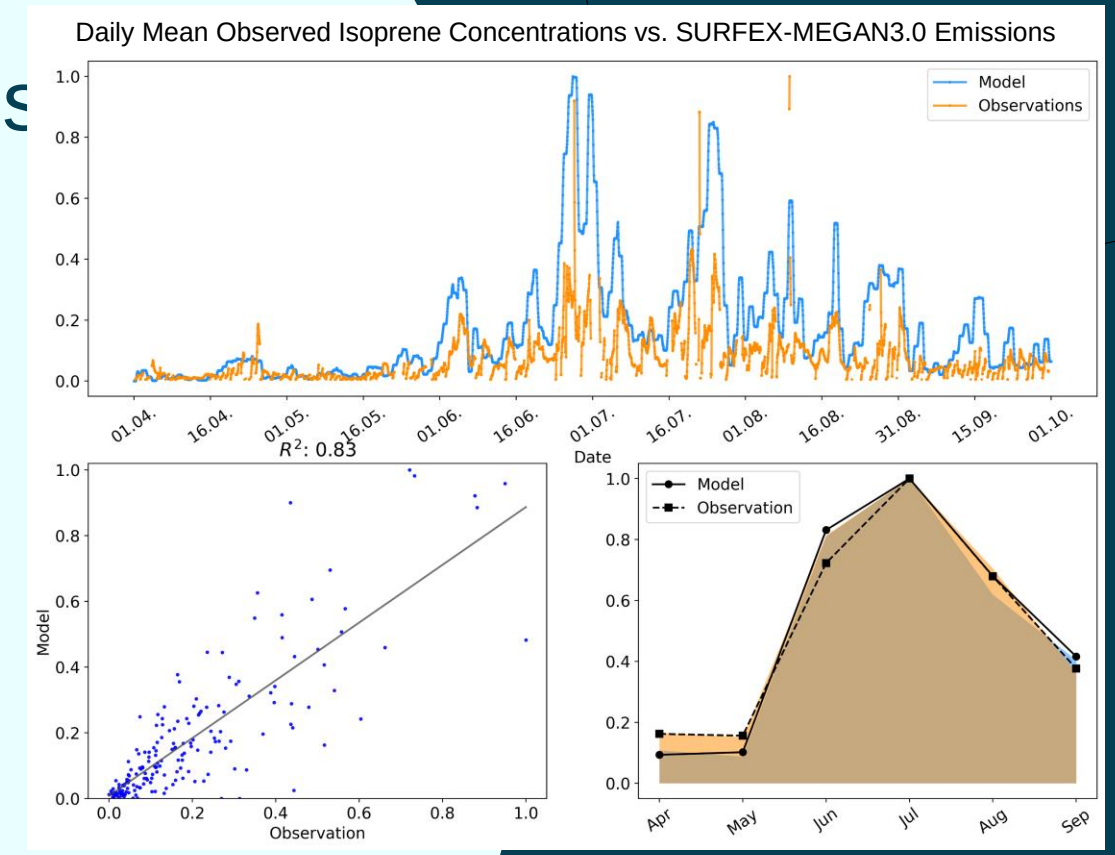


- Regions where LAI declined between June and September are highlighted.
- Isoprene emissions declined in nearly all of these locations.
- High correlation between LAI and isoprene emissions implies strong influence of LAI on emissions.
- Drought → reduced LAI → reduced isoprene emissions.

Evaluation of Isoprene Emissions:

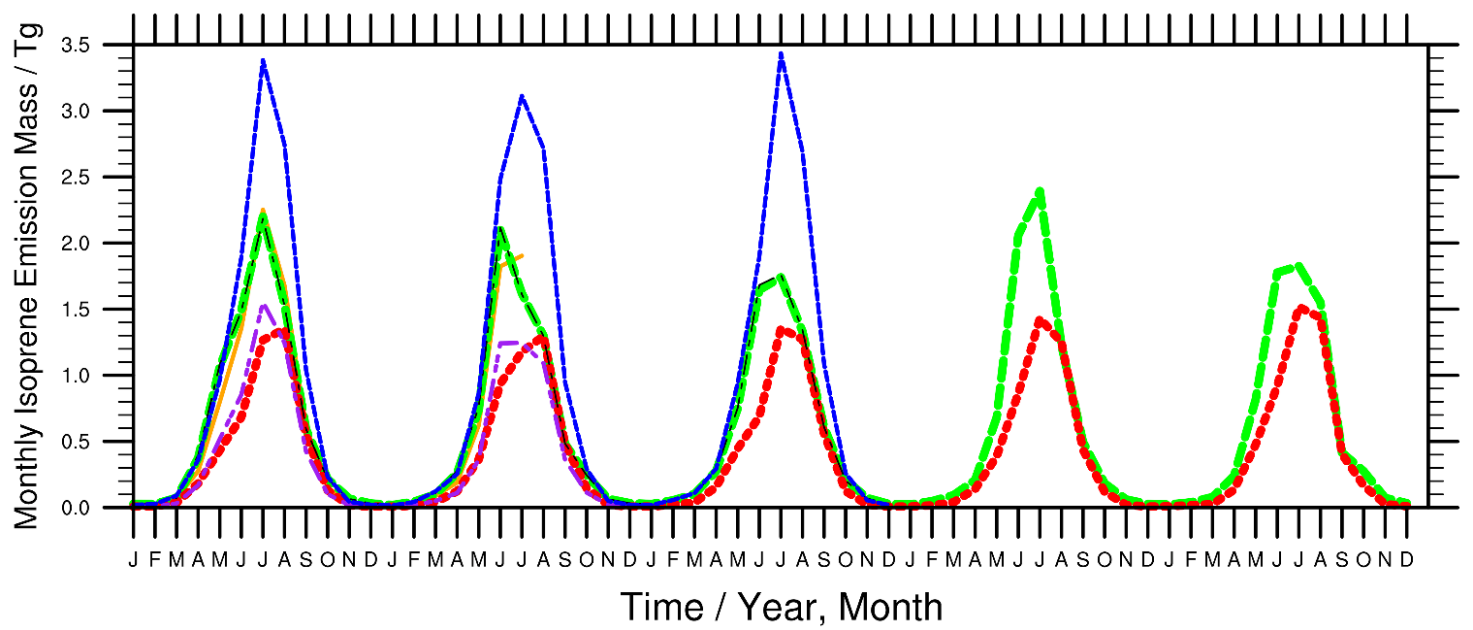
Isoprene Concentrations vs. Emiss

- Evaluation using online-gas chromatograph observations from 8 sites across Europe.
- Daily mean emissions correlate extremely well with daily mean isoprene concentrations.
- Only the Eltham site provided consistent challenges.
- Scores from the open-loop similar to the analysis.



	France				United Kingdom				Switzerland				Germany		Finland	
Year	FEY		VER		ELT		AUC		BER		ZÜR		HOH		PAL	
	O	A	O	A	O	A	O	A	O	A	O	A	O	A	O	A
2018	0.56	0.54	0.73	0.72	0.36	0.26	0.80	0.80	0.80		-		0.79	0.80	0.76	0.75
2019	0.74	0.73	0.81	0.80	0.85	0.81	++		0.83		-		0.81	0.81	0.70	0.70
2020	0.63	0.66	0.63	0.65	0.51	0.44	0.72	0.72	0.72		-		0.88	0.88	0.39	0.38
2021	0.72	-	0.88	-	0.87	-	++	-	0.78	-	-	-	0.81	-		-
2022	0.36	-	0.63	-	0.17	-	++	-	0.64	-	0.89	-	0.76	-		-

Evaluation Against Other Emission Inventories



- Magnitude of SEEDS isoprene emissions falls midway between the MEGAN-MACC and CAMS-GLOB-BIOv3/3.1.
- The SEEDS emissions have notably different temporal variability in the summer from CAMS-GLOB-BIOv3.1.
- Overall, the open-loop and analysis have very similar total annual emissions.

Year	SURFEX-MEGAN3.0 OL	SURFEX-MEGAN3.0 Analysis	MEGAN-MACC	CAMS-GLOB-BIOv1.2	CAMS-GLOB-BIOv3.0	CAMS-GLOB-BIOv3.1
2018	7.70	7.71	10.81	7.27	4.94	4.67
2019	7.01	7.07	10.92	4.67*	4.63	4.61
2020	6.84	6.91	10.87			4.70
2021	7.50					4.72

*Only calculated over January through to July 2019

Differences between inventories

- SURFEX-MEGAN3.0 is likely lower than MEGAN-MACC because of differences in meteorological input, i.e., ECMWF HRES vs MERRA/MERRA-2.
- SURFEX-MEGAN3.0 is likely higher than CAMS-GLOB-BIOv3.1 because of differences in the emission factors, i.e., MEGAN vs EMEP emission factors.
- The CAMS-GLOB-BIOv3.1 LAI is about 20% lower than the SURFEX-MEGAN3.0 LAI.
- The CAMS-GLOB-BIOv3.1 LAI typically peaks earlier than the MODIS based LAI climatology.

Conclusions on Isoprene Emissions

- SURFEX LAI analysis shown to have high skill over most of Europe.
- Inter-annual variability and seasonality of isoprene emissions from SURFEX-MEGANv3.0 linked to variability of LAI and drought effects.
- The isoprene emissions correlate extremely well on daily timescales with high quality in-situ observations.
- The isoprene emissions sit in the middle of the pack compared to other inventories and have a noticeable difference in seasonality linked to LAI input data
- Overall, this shows the strength of adopting an Earth System type approach.

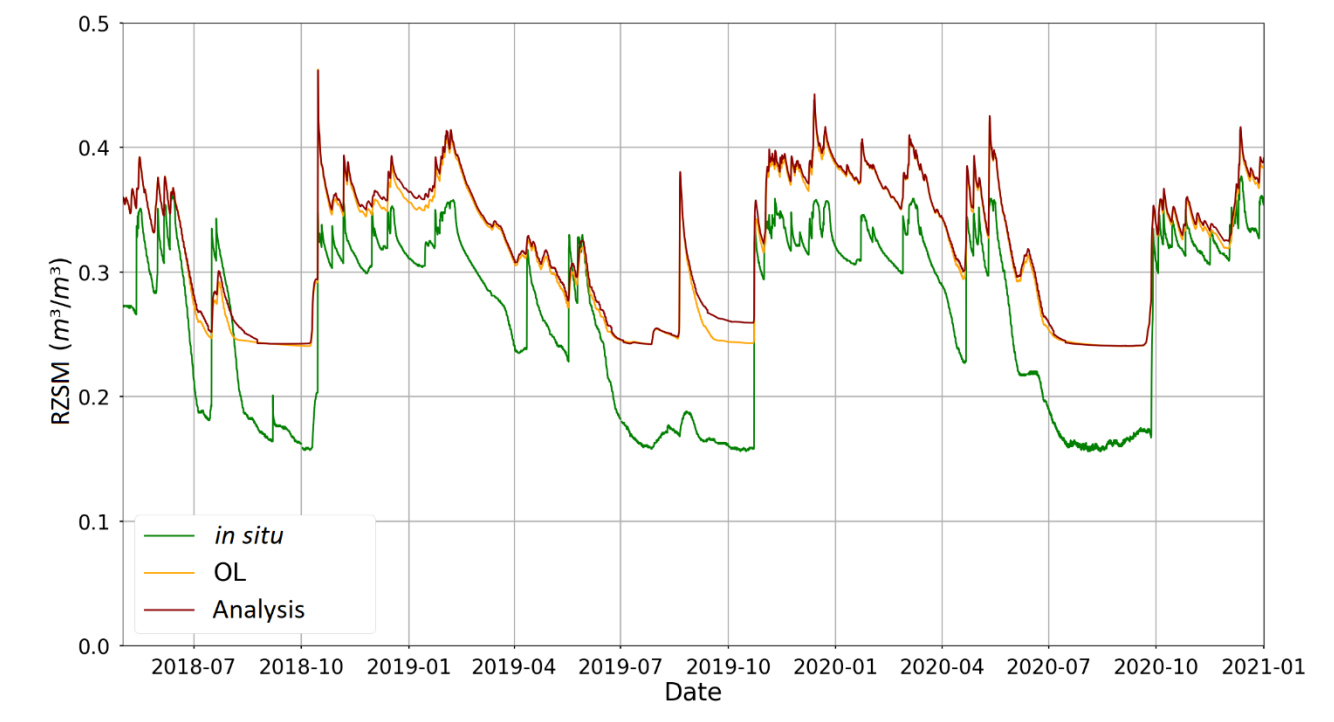
Two Biogenic Volatile Organic Carbon Emission Datasets over Europe Based on Land Surface Modelling and Satellite Data Assimilation In final preparations for submission to Earth System Science Data

Thank you for listening

Land Surface Modelling Setup

- Simulations run without any data assimilation termed the «open-loop» were used as a reference for evaluating impacts of data assimilation.
- SURFEX used the sequential Kalman filter for the data assimilation.
- SEEDS produced open-loop data for 2018-2022
- SEEDS produced assimilation analysis data for 2018-2020

Biogenic VOC Results



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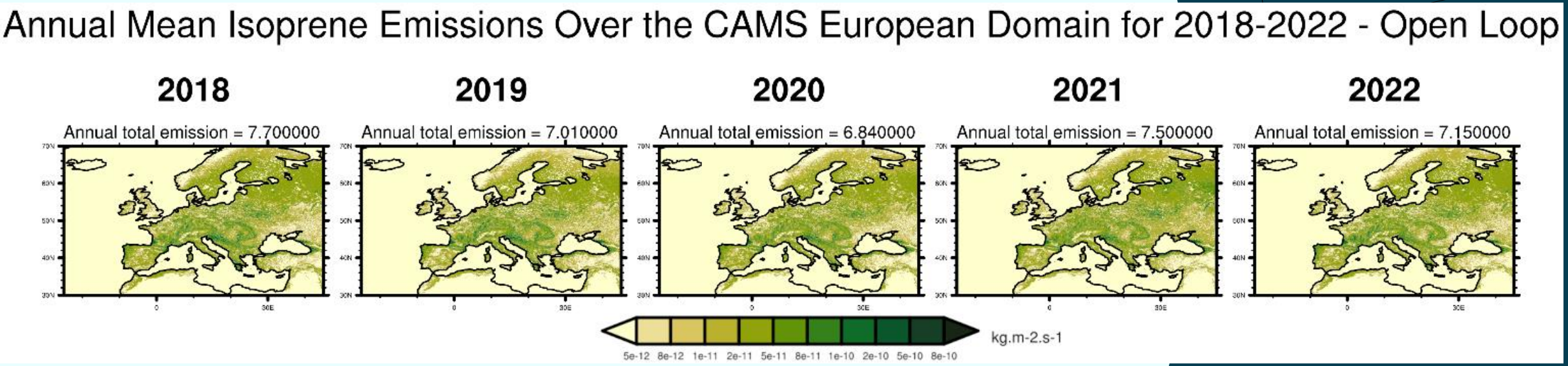

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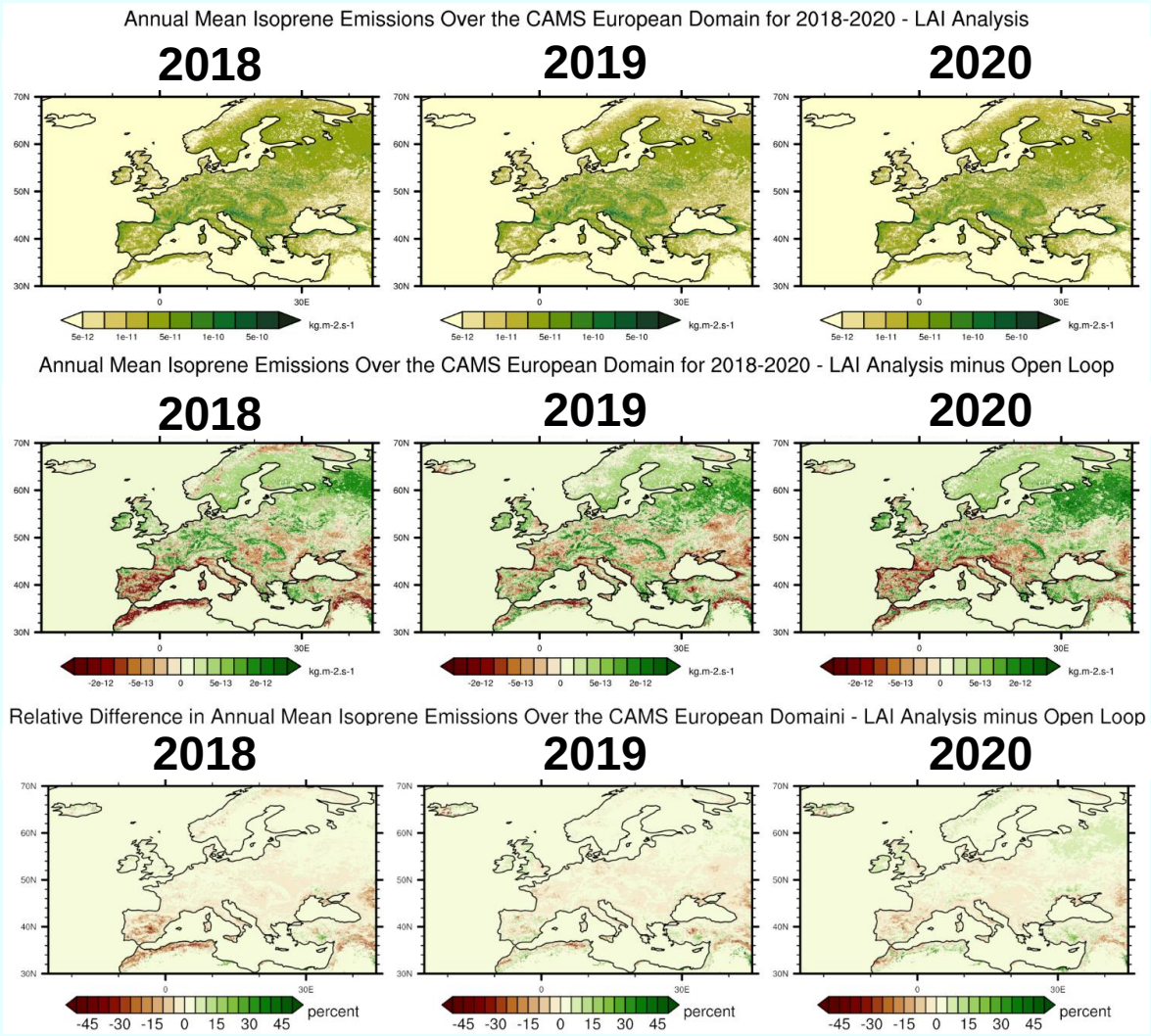

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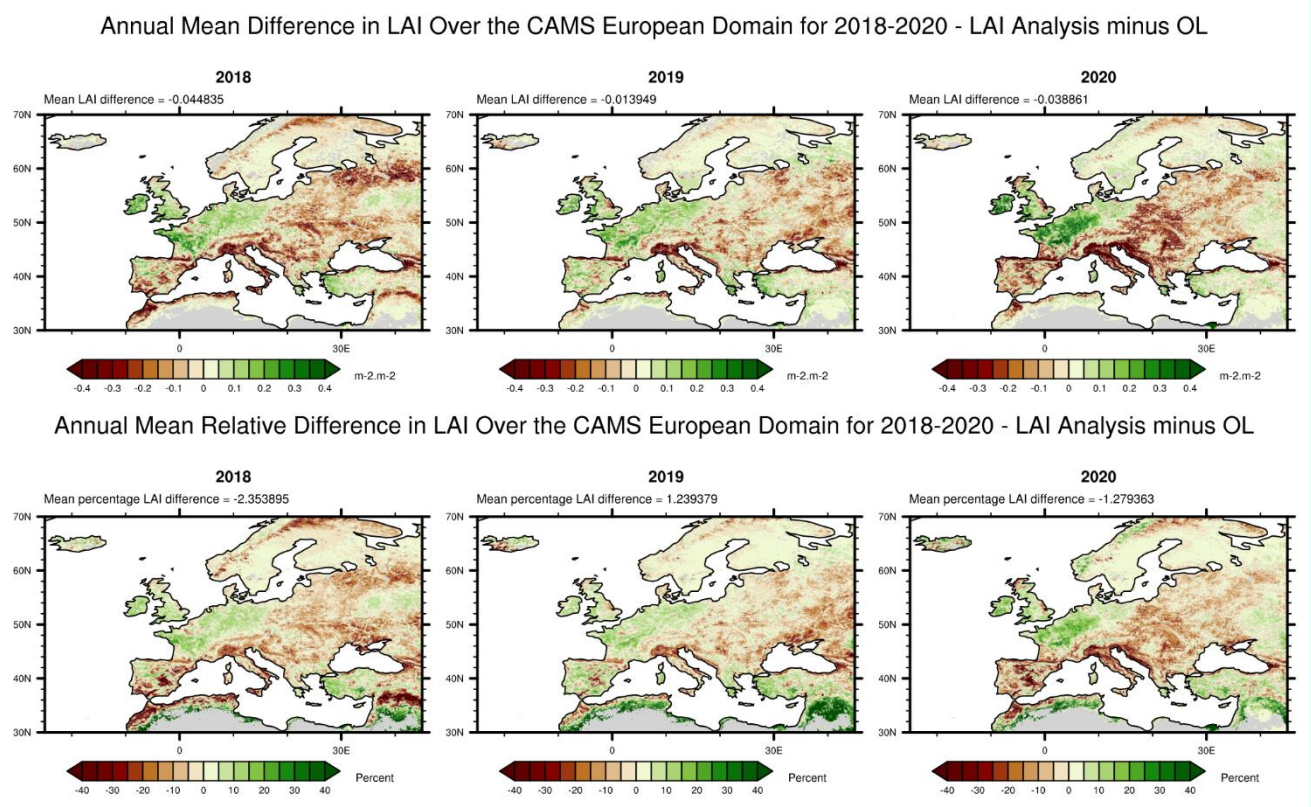

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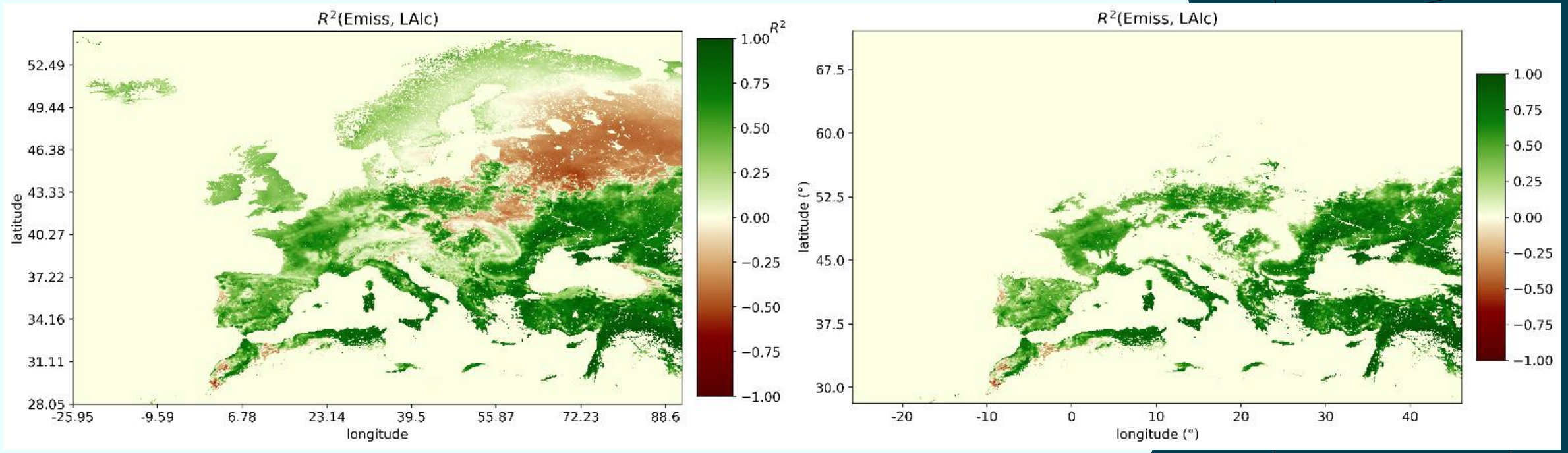

Funded by the European Union

2019: An example of an extreme year in Europe

SEEDS
Sentinel EO-based Emission and Deposition Service

Hari et al., 2020: ***Increased future occurrences of the exceptional 2018–2019 Central European drought under global warming***