Fire emissions in SEEDS

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Uncertainties in fire inventories

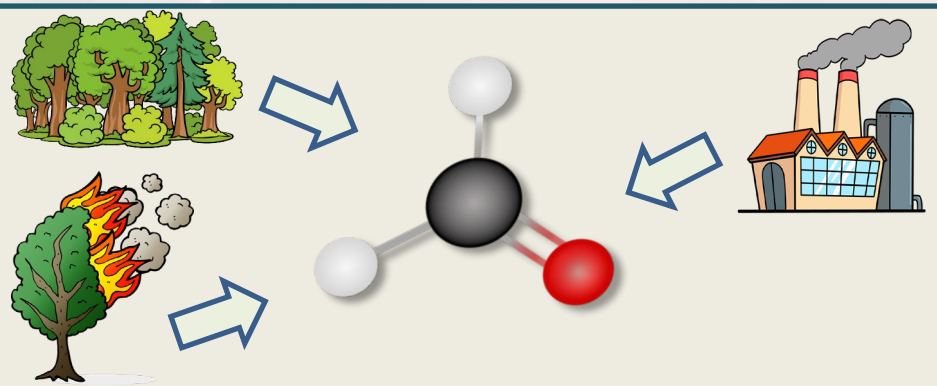
- Uncertainties due to detection of burnt area, FRP, emission factors, biome types, fuel consumption + difficulty to account for understory fires, peatland fires → hampers our understanding of fire impacts

BB datasets	Relies on
GFED4s	MODIS burnt area + active fires
FINN	MODIS active fire counts + active fires
GFAS	Assimilated MODIS FRP
FEER	As in GFAS, constrained by MODIS AOD
QFED	MODIS FRP + AOD
SEEDS	Top-down, based on HCHO chemical data

- Factor of ~4 between the global estimates, larger differences at regional scale
- Inventories perform differently depending on species, season, location

HCHO:

Short-lived product in the oxidation of the majority of VOCs



Satellite HCHO data offer an alternative way to constrain biomass burning emissions

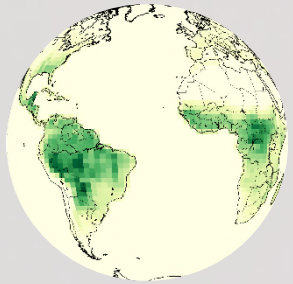
Formaldehyde observations from Sentinel-5p

Sentinel-5p

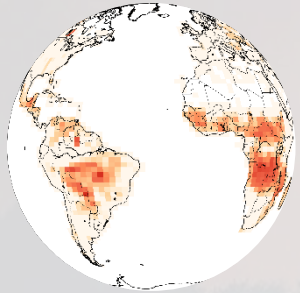
- Daily global coverage
- 3.5 × 5.5 km² resolution

- HCHO is a weak absorber
- With past sounders, there was a need to average HCHO columns over a month ro reduce data noise
- TROPOMI high S/N and more data allow to increase temporal resolution, e.g. weekly. Daily observations over Europe are too noisy.

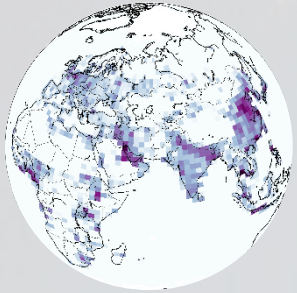
From bottom-up to top-down emissions through MAGRITTE



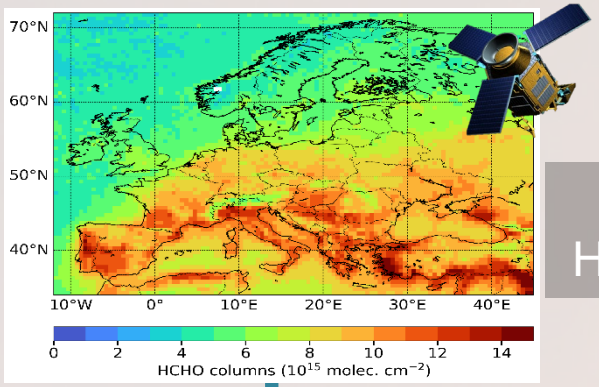
biogenic emissions



fire emissions



anthropogenic emissions



TROPOMI HCHO columns

Inversion constrained by weekly-averages

MAGRITTE chemistry-transport model and its adjoint

Iterative minimization algorithm

Top-down biogenic isoprene fluxes

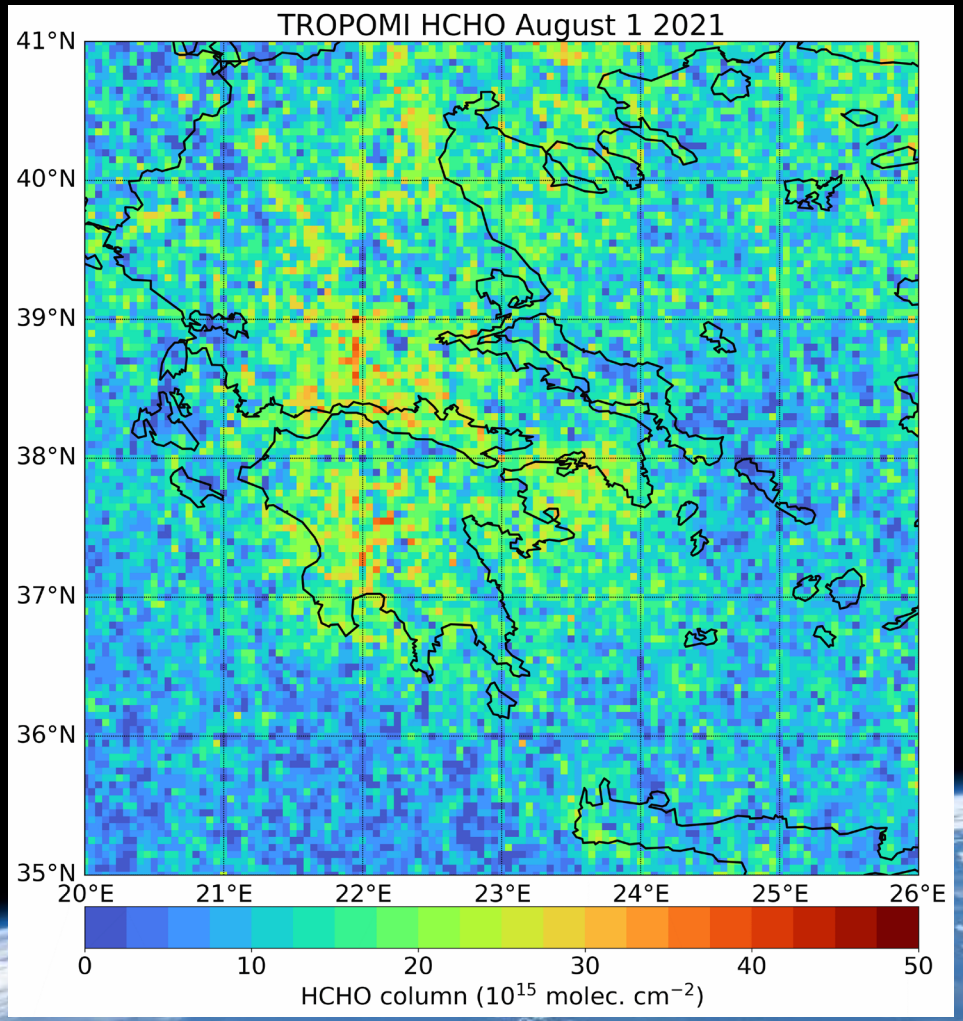
Top-down biomass burning fluxes

Top-down anthropogenic fluxes

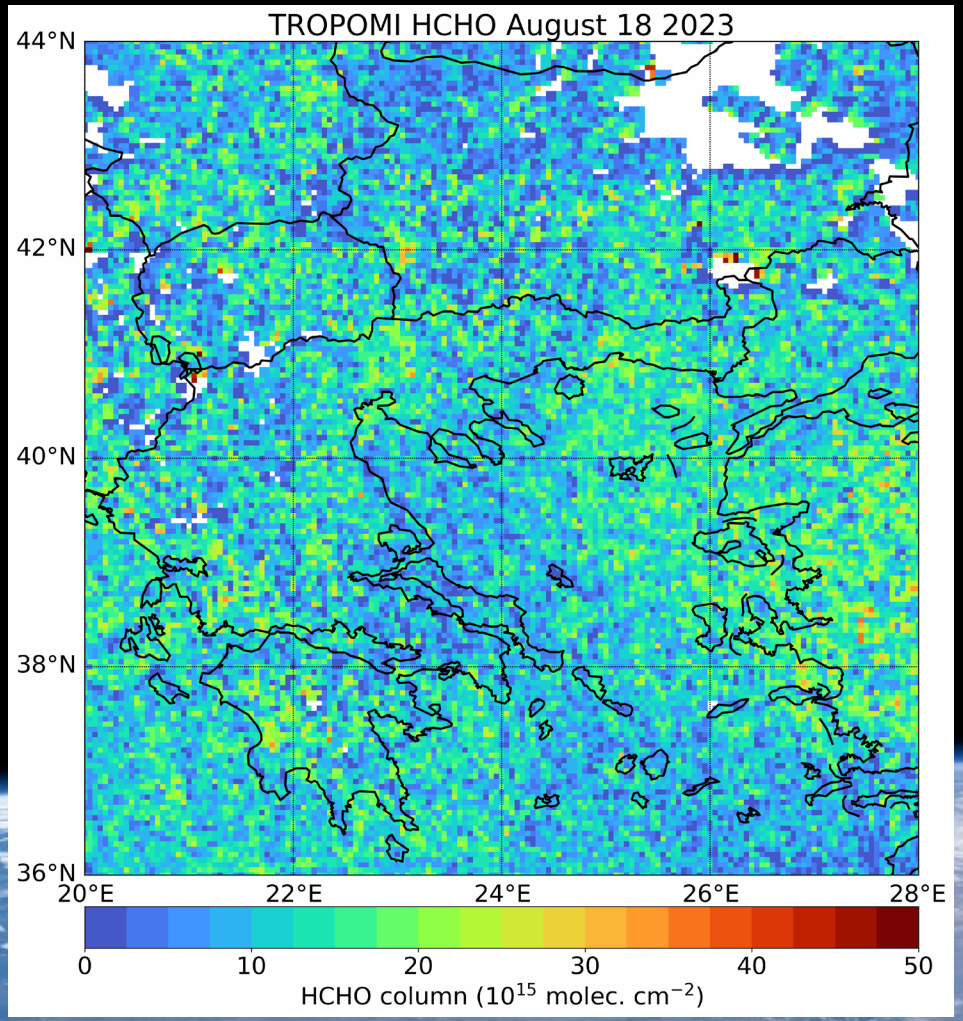
- ❑ 40 VOCs emitted by fires and their chemical oxidation mechanism
- ❑ QFED a priori fires, emission factors from Andreae (2019)

Illustration of TROPOMI HCHO columns during fires

Evia fires in August 2021

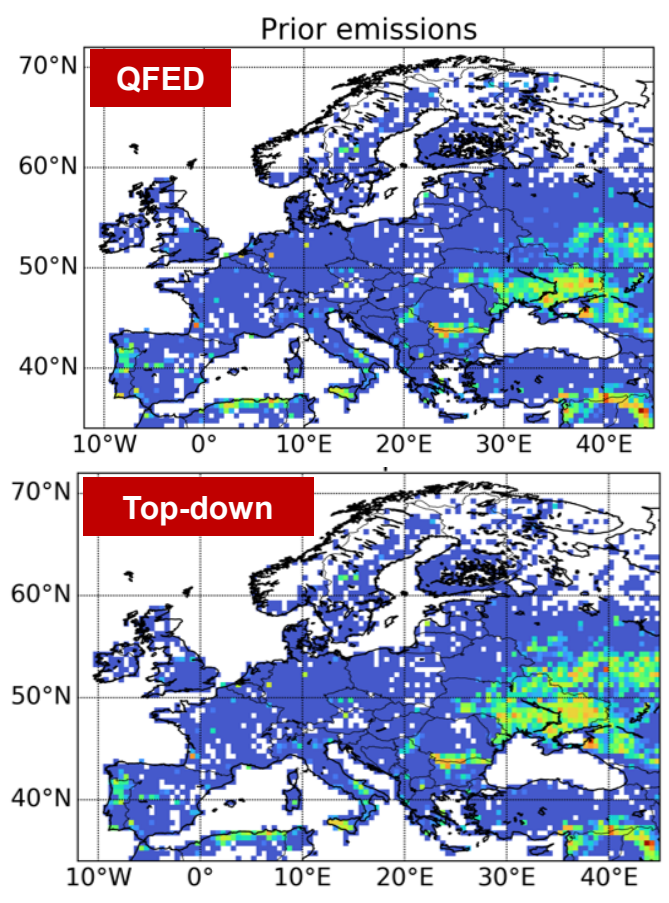


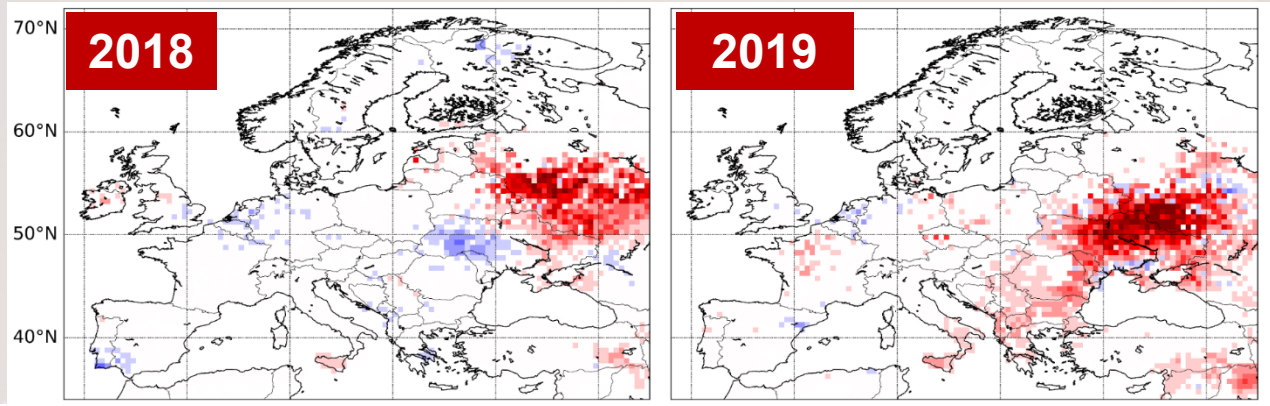
Thrace fires in August 2023

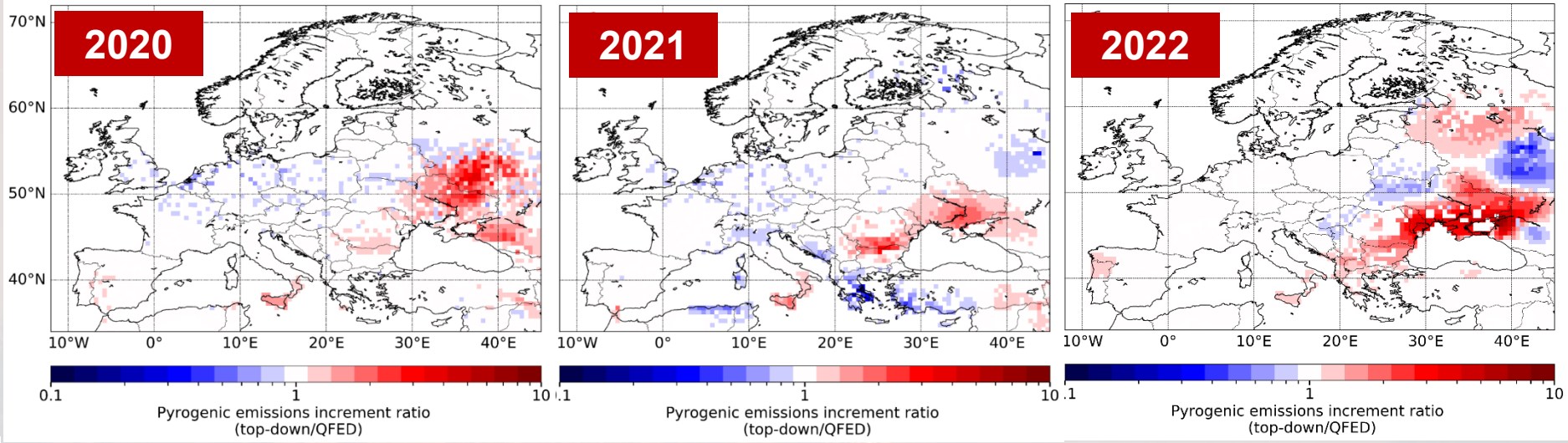


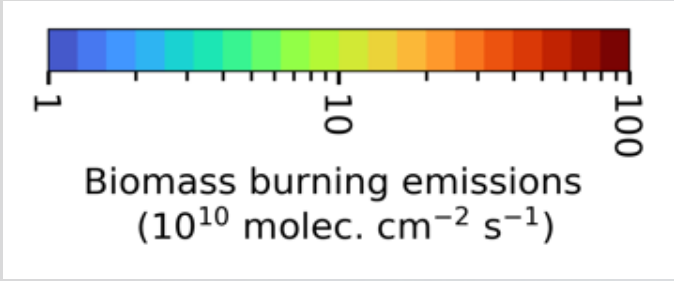
- ✓ 2023 heatwave was the longest in history (16–17d), largest recorded fire in the EU
- ✓ High HCHO columns recorded due to massive emission of pyrogenic VOCs

Emission enhancements : average May-September



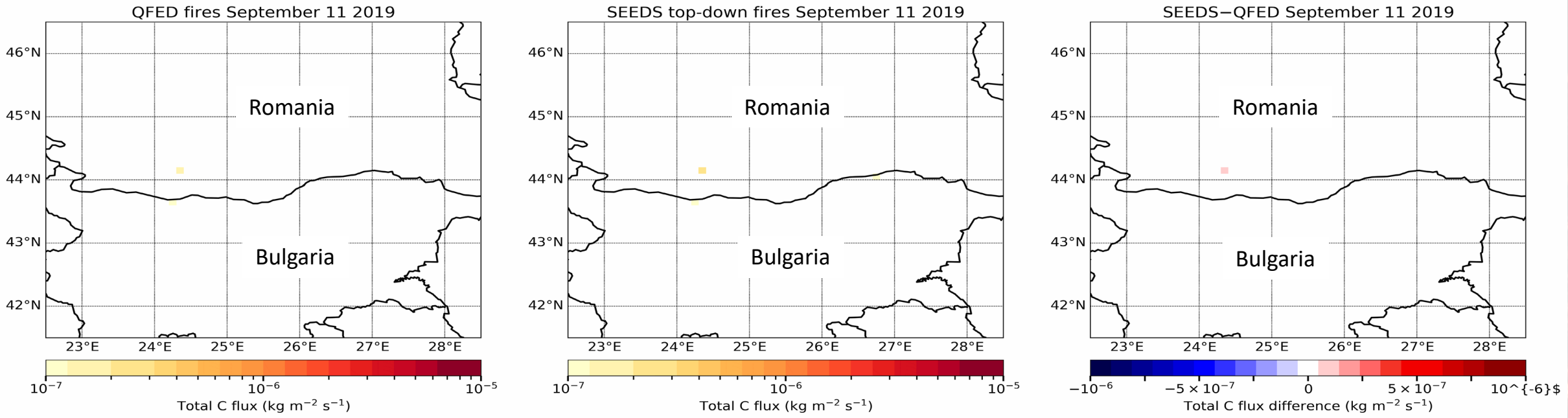




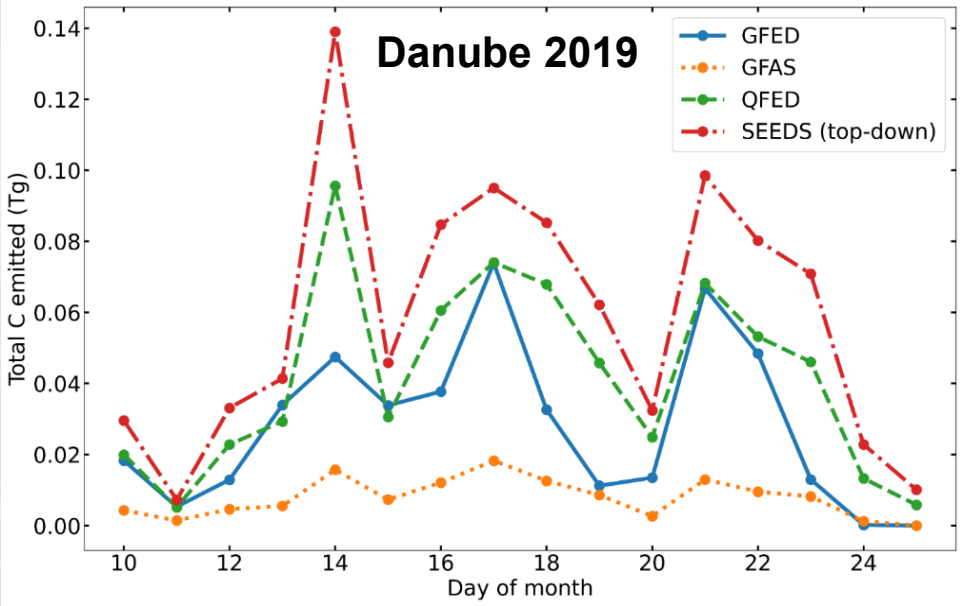


Fire emissions (Tg/yr)	2018	2019	2020	2021	2022
A priori	1.6	2.5	2.6	1.7	2.0
Top-down	2.1	3.5	2.9	1.7	1.8

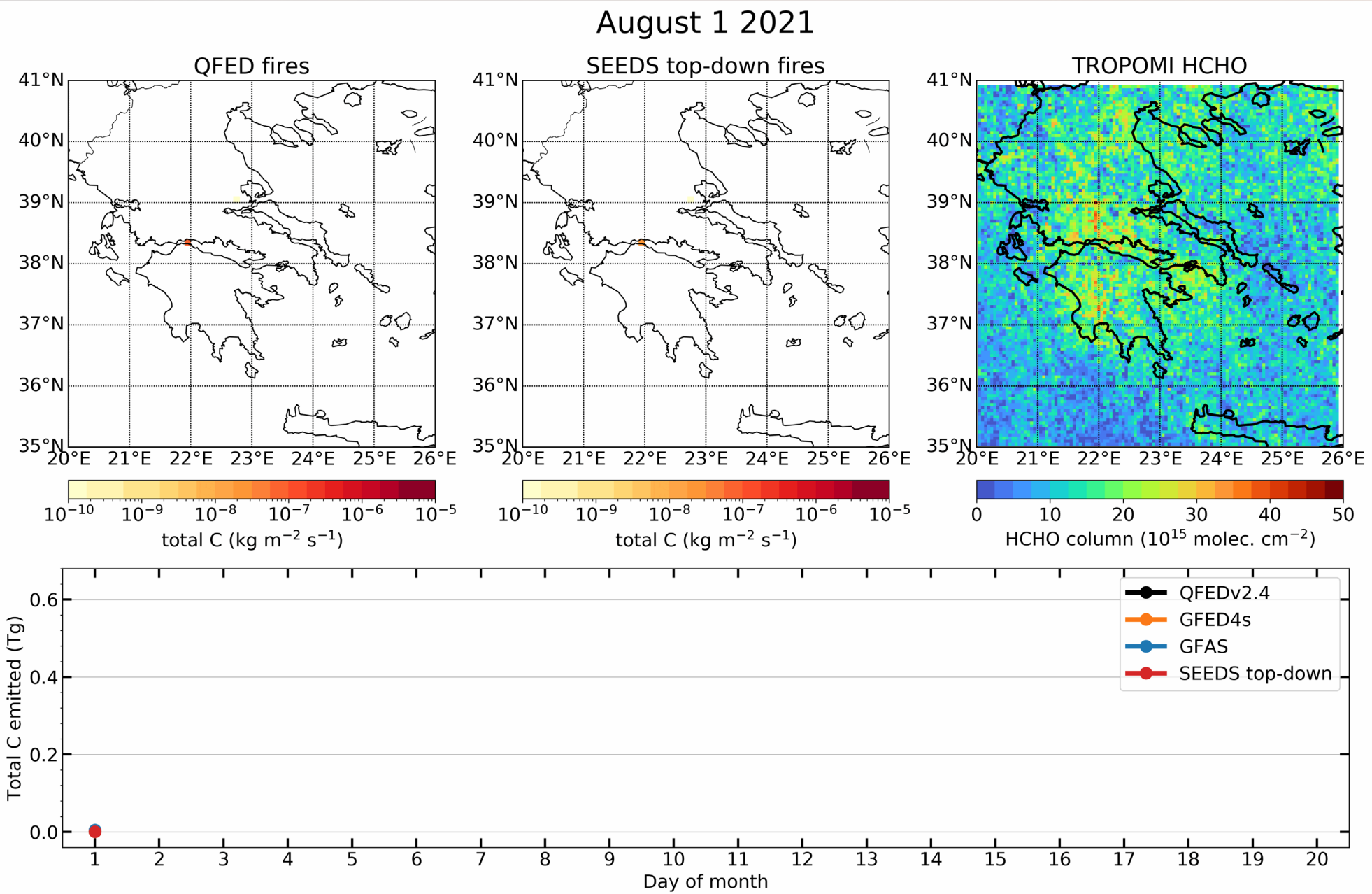
Danube fires in 2019: bottom-up vs top-down



- TROPOMI data suggest increased emissions relative to QFED
- All datasets agree on the peaks on 14, 17, 21 Sep but large differences in the emission strength (up to x10)

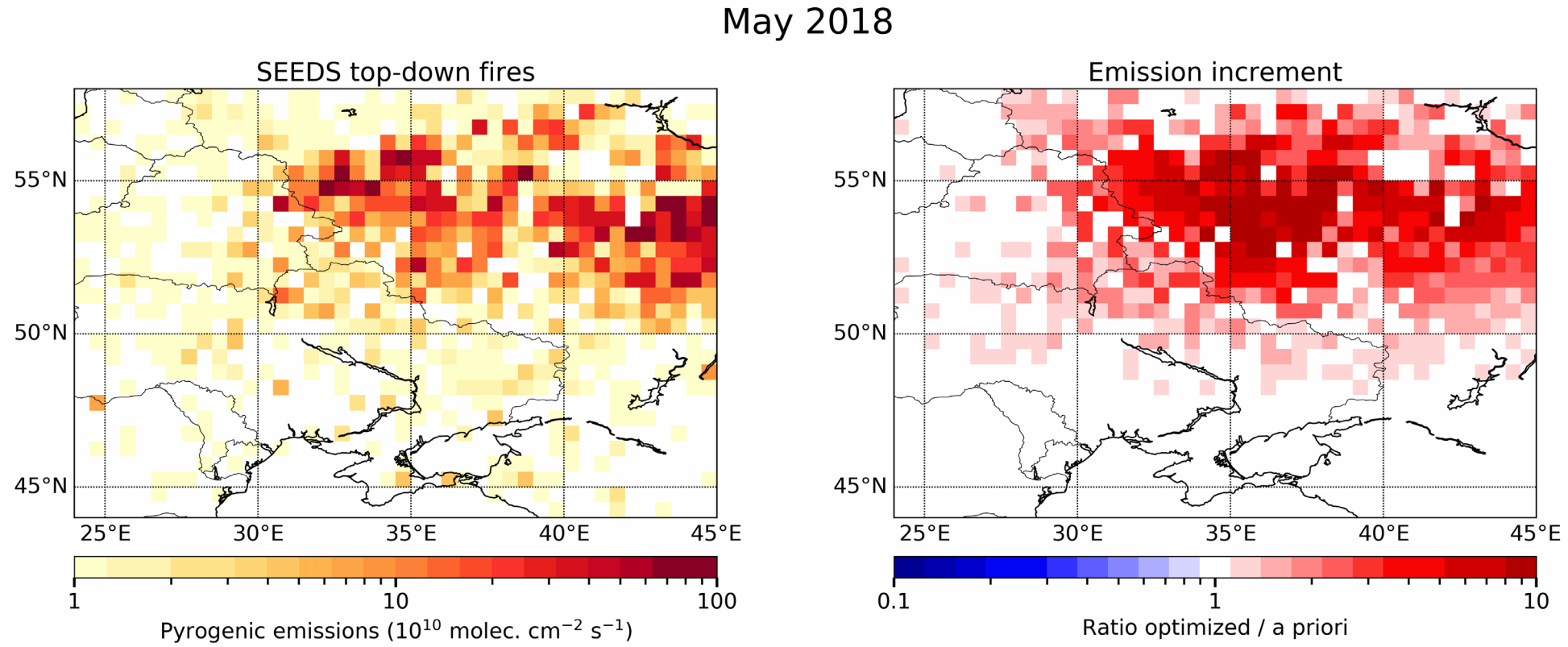


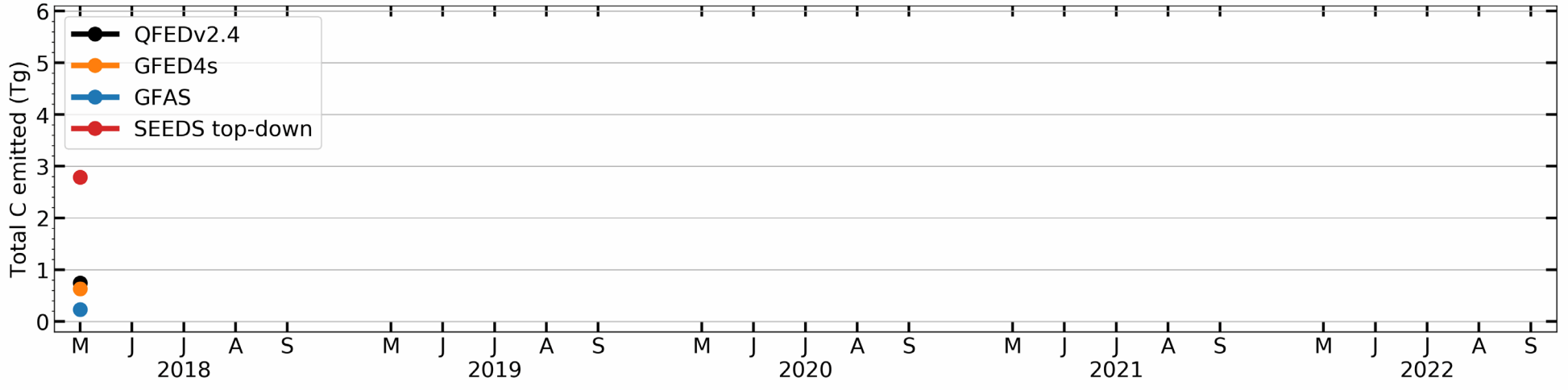
An example of extreme weather caused by climate change



- Top-down emissions are lower than all inventories
- The peak on 6 Aug is well captured in all datasets, except for GFED
- The SEEDS peak is x2-3 lower than QFED/GFAS, could be due to the export of pollution due to strong winds

Underestimated cropland burning in Ukraine/Russia

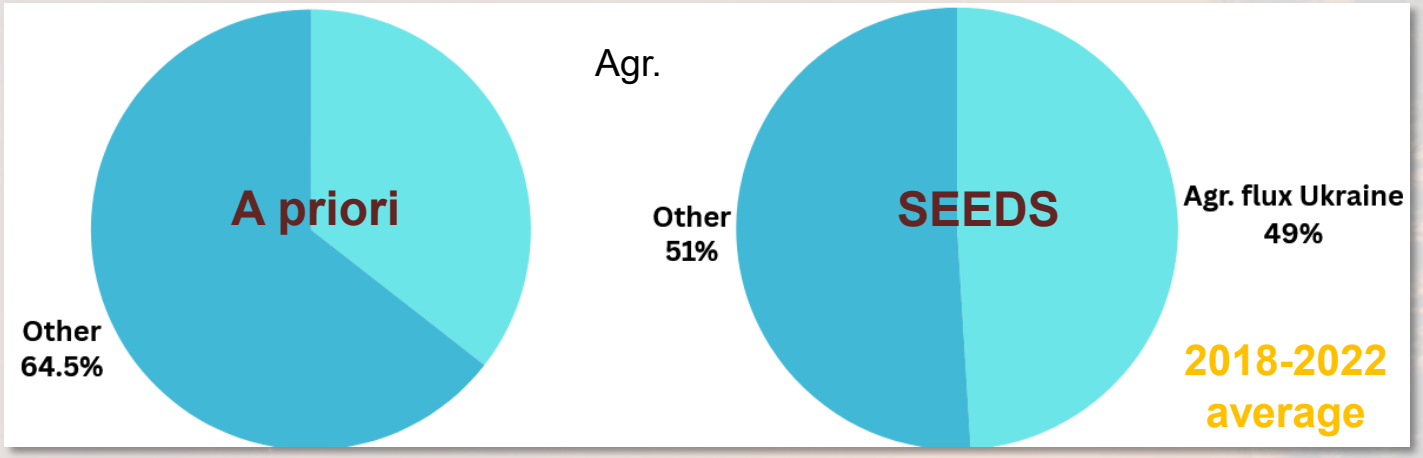




- ✓ ~Half of Ukraine is cultivated area, 70% of land area is dedicated to agricultural use
- ✓ Due to the small size of cropland fires, satellite burnt area is often underestimated
- ✓ SEEDS estimates are factor of 1.5-2 higher on average than QFED, GFAS estimates are the lowest

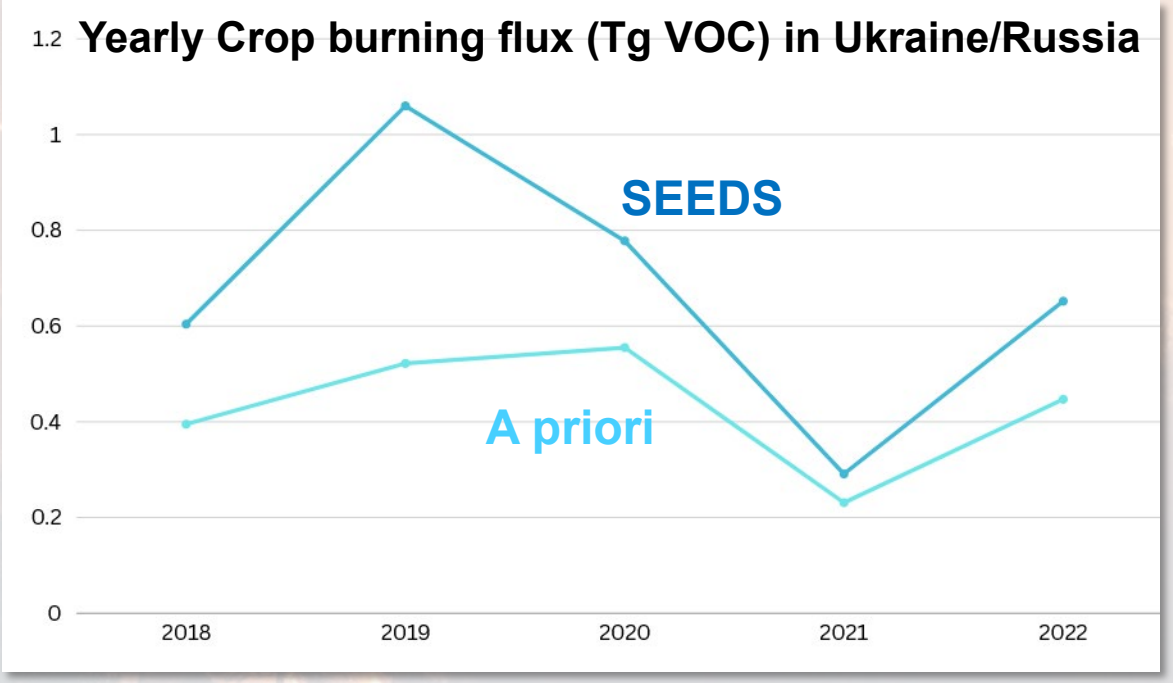
Share of cropland burning in Ukraine

The share of top-down crop residue burning in Ukraine accounts for half of the total flux estimate in the European domain, increased wrt to the a priori



Ukraine/Russia fires	TgC (5-yr average)
A priori (QFED)	5.9
GFED	*3.7*
GFAS	*2.5*
SEEDS	11.2

Evia fire event	TgC
A priori	1.68
GFED	*1.6*
GFAS	*2.51*
SEEDS	0.60



- ✓ Small fires are underrepresented in inventories, due to difficulties to map burnt area from satellites
- ✓ The SEEDS products offer an alternative approach, independent of fire proxies

Conclusions and perspectives

- The inversion is able to infer changes in emission strengths and spatial distribution, but not in localization of fires (which relies on a priori biomass burning dataset)
- Uncertainties in the chemical degradation of BB VOCs in the model → *need to update representation of pyrogenic VOCs in the model*
- Inherent difficulty: Co-occurrence of sources (fires and enhanced vegetation emissions) during summertime makes it difficult to separate the sources
- TROPOMI HCHO suggest increased fire fluxes from crop residue burning and decreased emissions over forested areas wrt bottom-up inventories → *geostationary observations offer promise*
- SEEDS top-down emissions publicly available at 0.1°x0.1° for 2018-2022

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