Effects of Extreme Meteorological Conditions in 2018 on European Methane Emissions

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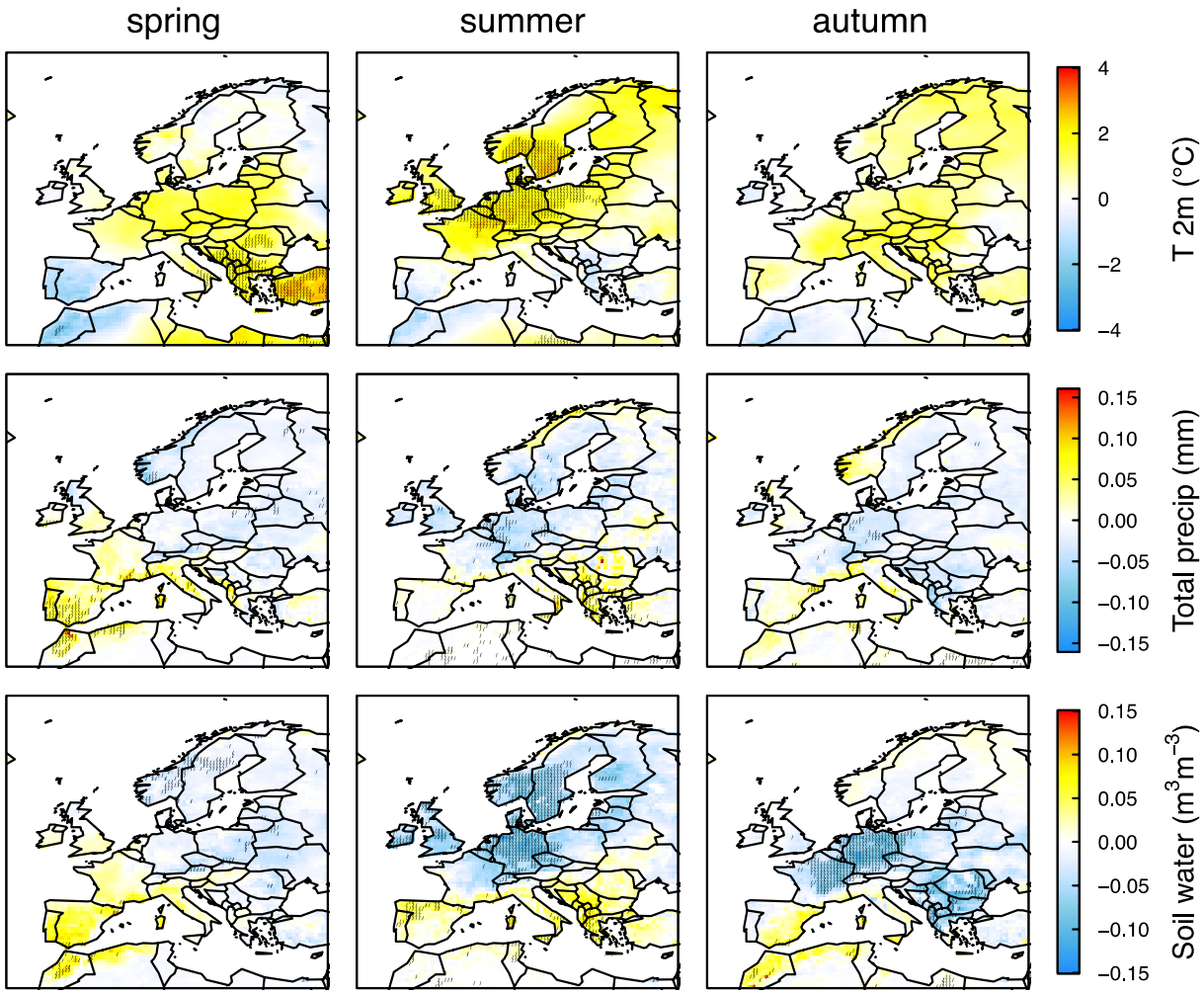
Introduction

- Large regions of Europe affected by heatwave and drought in 2018
- Heatwave and drought impacted CO_2 land-biosphere fluxes (NEE)
- Considerable portion of CH_4 emissions is biogenic and potentially sensitive to meteorological conditions
- IPCC Tier 1 methods do not account for temporal variations in CH_4 emissions due to meteorological conditions
- Used four atmospheric inversions to estimate CH_4 emissions 2005-2018 and to determine if there was any anomaly in 2018

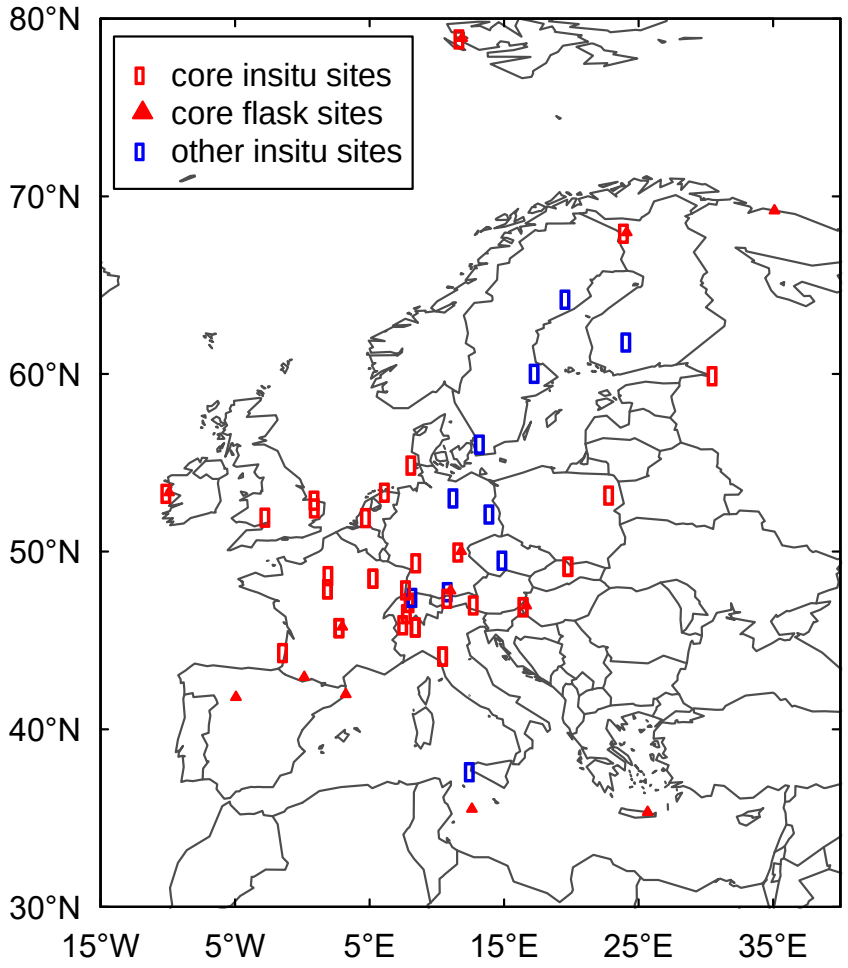
Meteorological situation in 2018

- Anomalies in temperature, precipitation and soil moisture from ECMWF ERA5 data relative to 2005-2018
- North of Alps warmer spring-autumn and soil moisture deficit summer-autumn
- South of alps (Balkans) wetter than usual summer



Atmospheric observations

- Core dataset: sites with at least 9 years of data between 2005-2018
- Core dataset included 31 timeseries at 26 locations with 20 in-situ measurement sites
- In-situ sites circa hourly frequency
- Flask sites circa weekly frequency



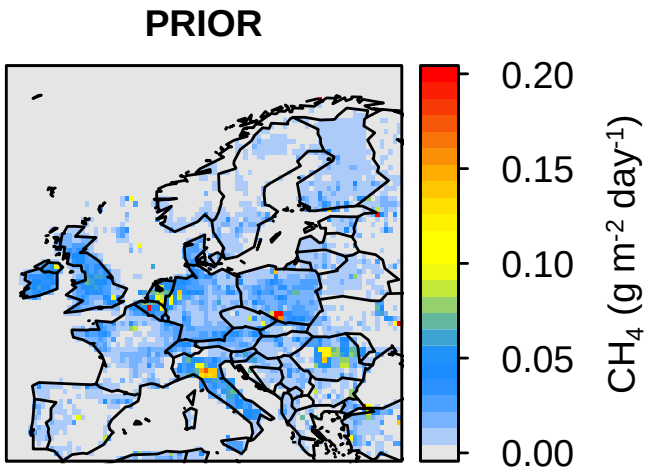
Inversion frameworks

	FLEXINVERT	FLEXKF	TM5-4DVAR	CTE
Full name	FLEXINVERT	FLEXPART-ExKF	TM5-4DVar	Carbon-Tracker Europe CH4
Resolution Europe	0.25° × 0.25°	0.5° × 0.5°	1° × 1°	1° × 1°
Temporal resolution	Monthly	Monthly	Monthly	Monthly
Transport model	FLEXPART-v10.3	FLEXPART-v9.1	TM5	TM5
Model domain	Europe	Europe	Global	Global
Algorithm	Analytical	ExKF	4D-Var	EnKF
Observation dataset	Core	Core	Core	Inclusive
Background	Flexpart-CTM	TM5-4DVAR	N/A	N/A

Prior fluxes used in inversions

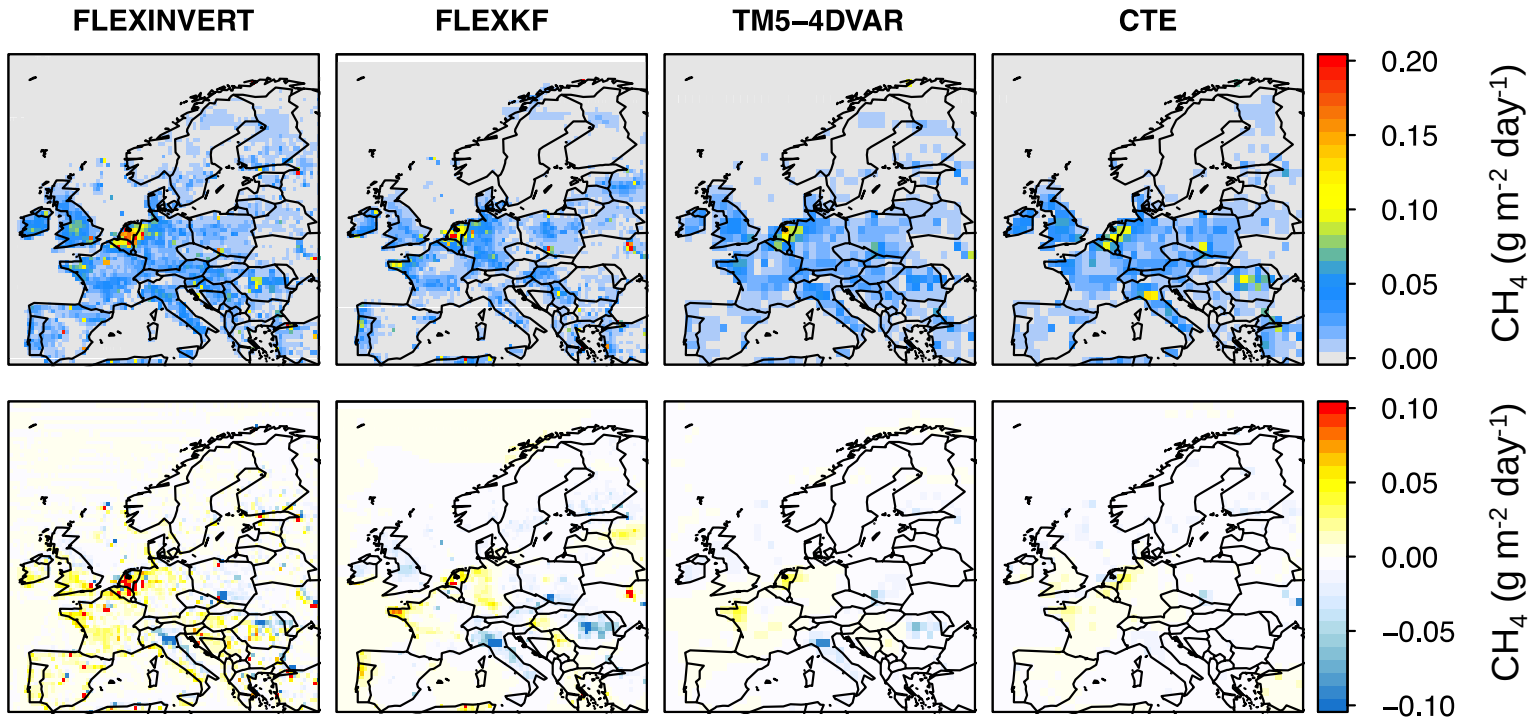
Annual mean estimates given for 2018

Source category	Model/Reference	EU27+UK (Tg/y)
Anthropogenic		
Agriculture & Waste	EDGAR-v6	14.7
Fossil fuels	EDGAR-v6	4.1
Biofuel and biomass burning	EDGAR-v6	0.8
Natural		
Lakes	ULB model	2.4
Peatlands & mineral soil	JSBACH	3.4
Geological	Etiope 2015	6.6
Total		32.3



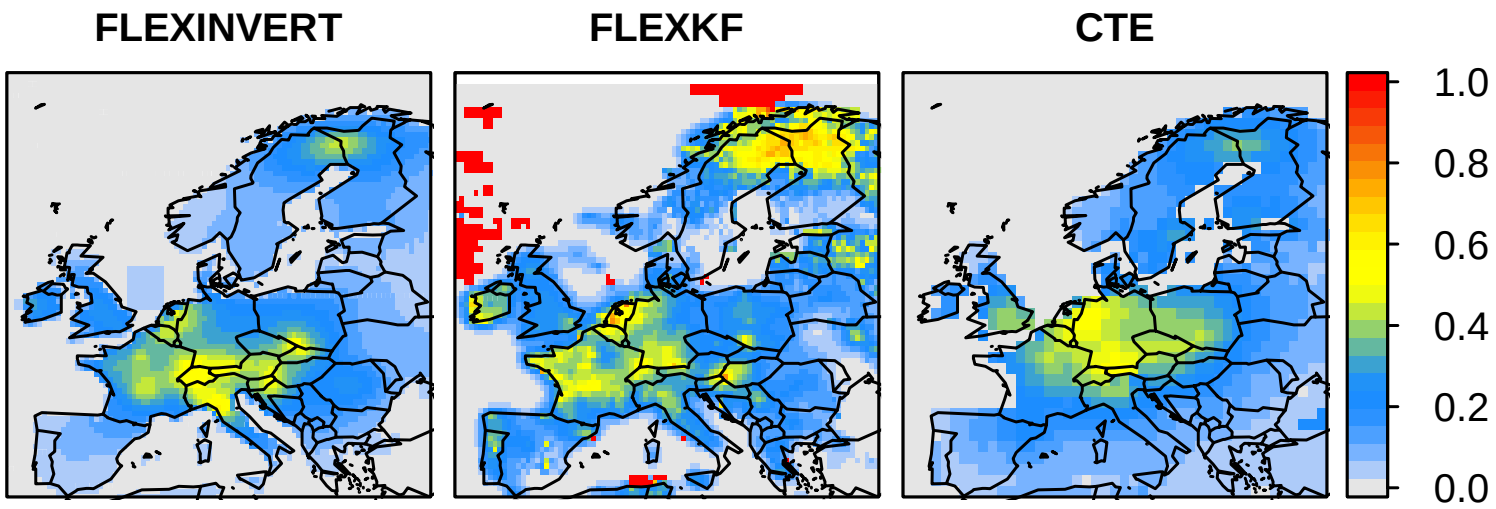
Posterior fluxes

- Annual mean fluxes for 2018 (top row) quite consistent across inversions
- Annual mean flux increments (bottom row) also quite consistent



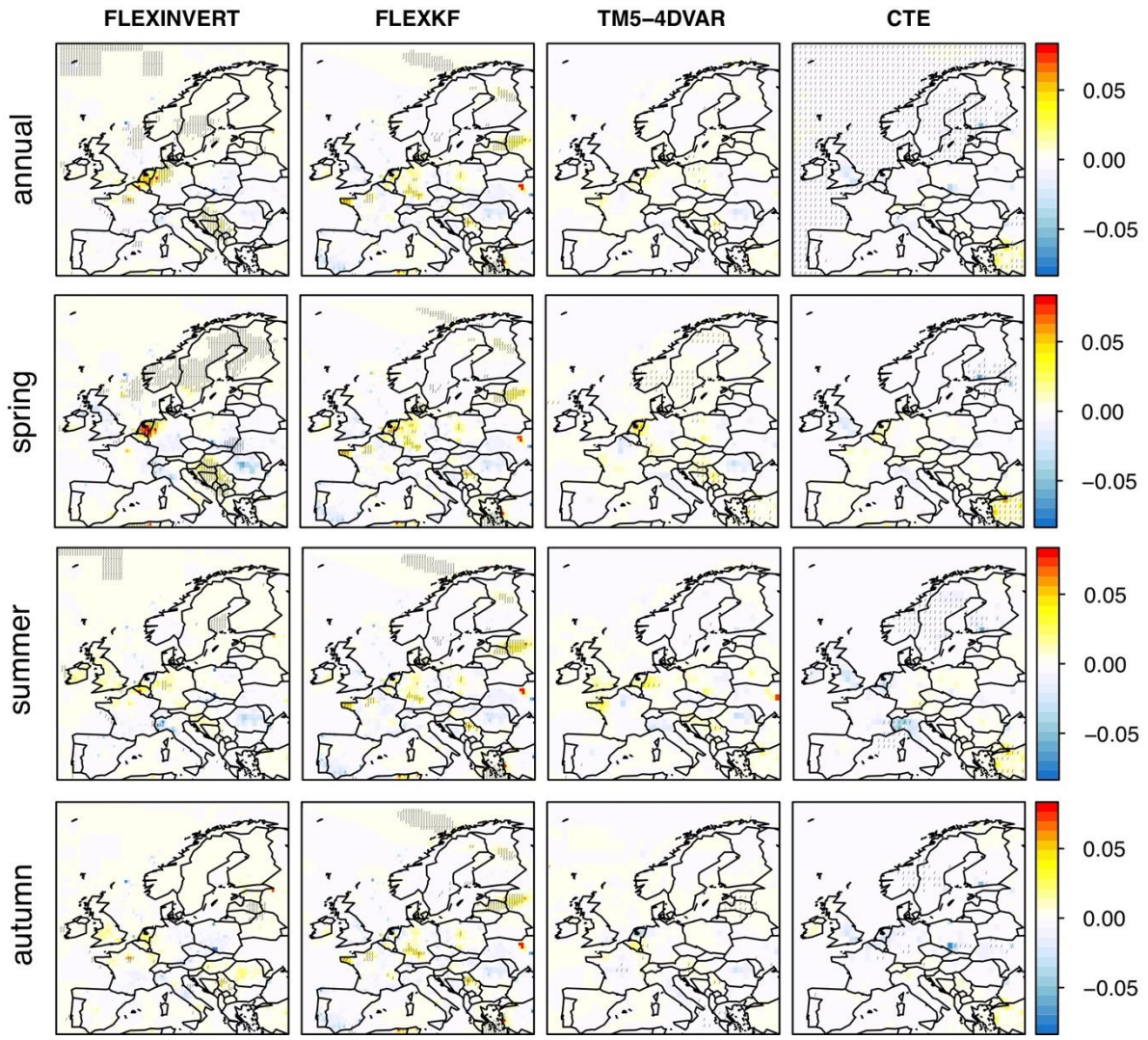
Uncertainty reduction

- Annual uncertainty reduction calculated as $1 - \sigma_{post}/\sigma_{prior}$



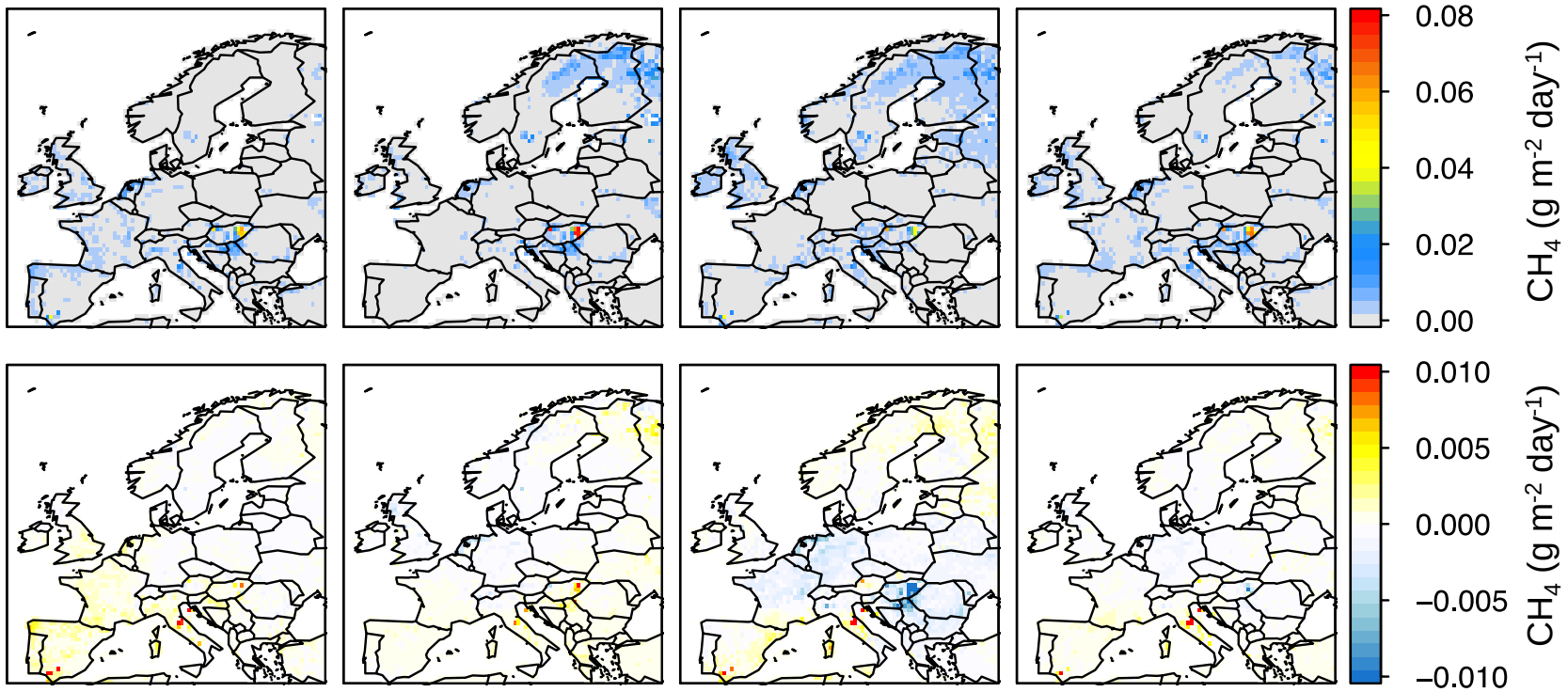
Posterior flux anomalies 2018

- Annual anomalies weak or not consistent across all inversions
- Netherlands positive anomaly in spring and weak negative anomaly in autumn
- Serbia positive anomaly spring, summer and autumn



Soil fluxes from LPX-Bern

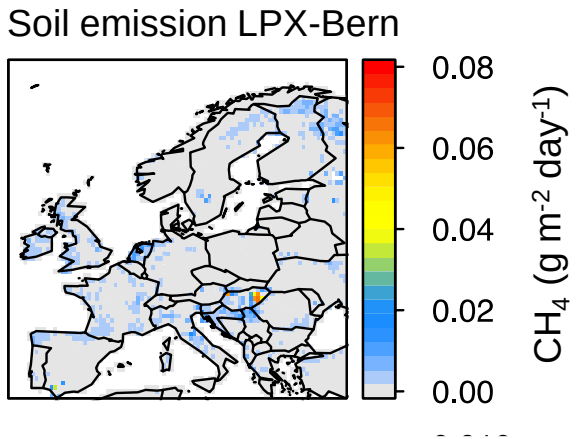
Peatland, wet and inundated soil fluxes for 2018 (top) and the anomaly (bottom) from the land surface model LPX-Bern

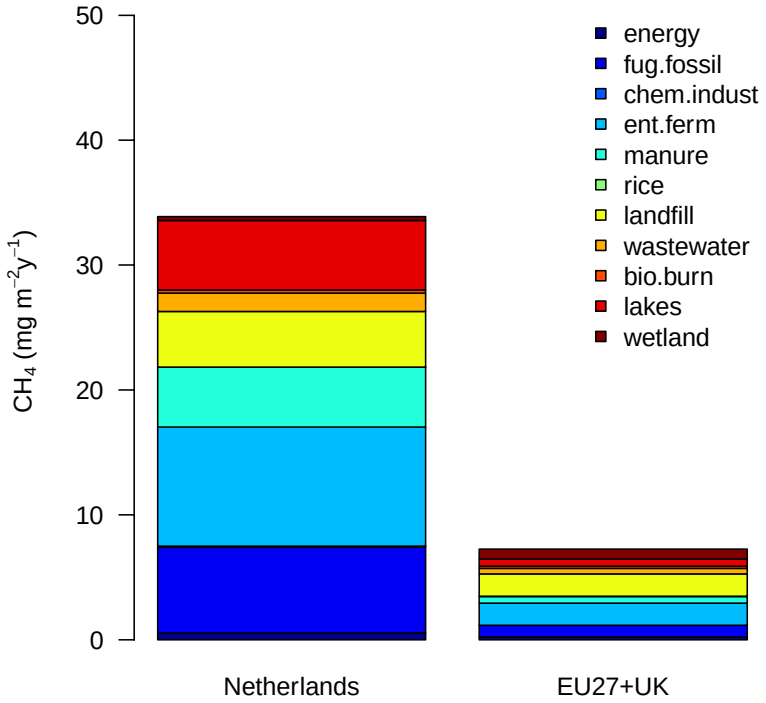


The Netherlands

Why an anomaly for the Netherlands but not other regions?

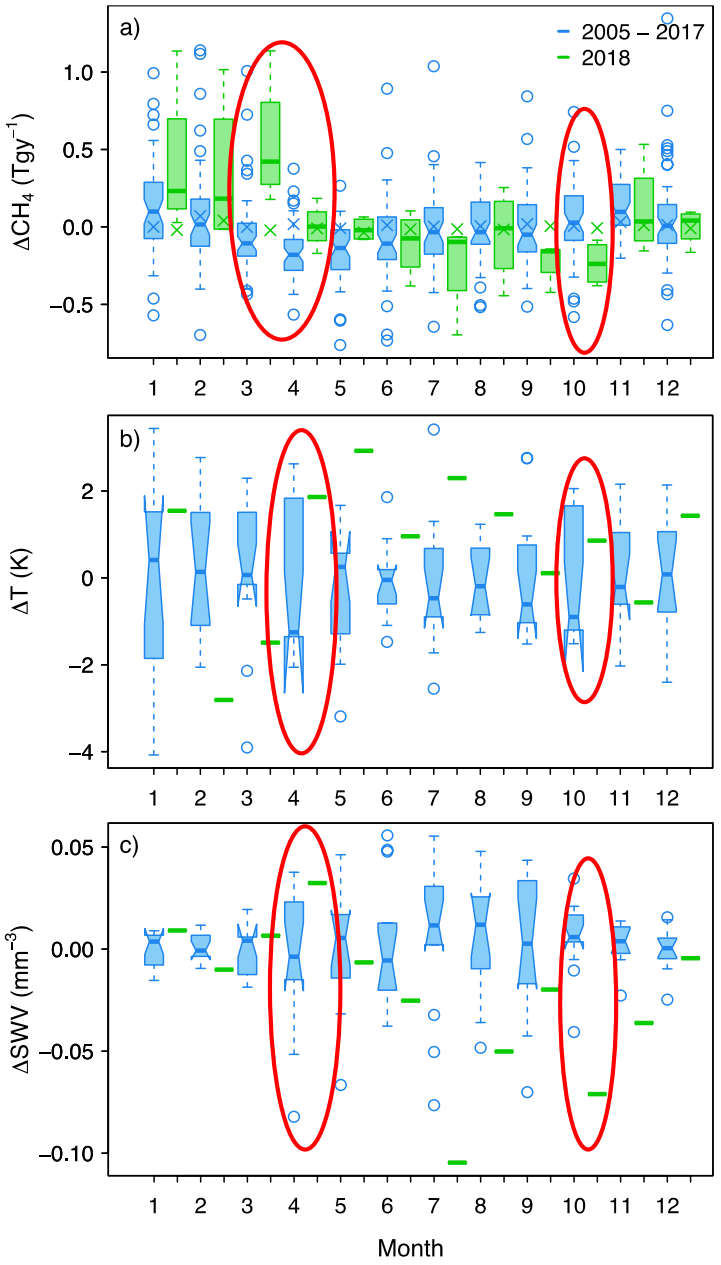
- Largest per area CH_4 fluxes
- Important contributions from biogenic sources (manure, landfills, lakes)
- According to LPX-Bern, also important contribution from mineral soils





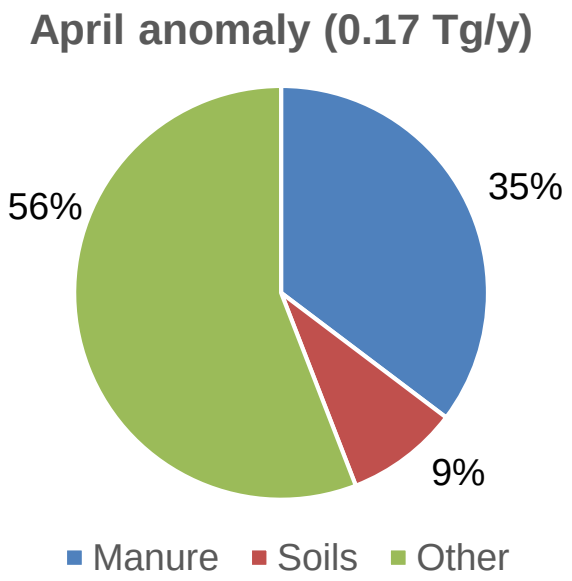
The Netherlands

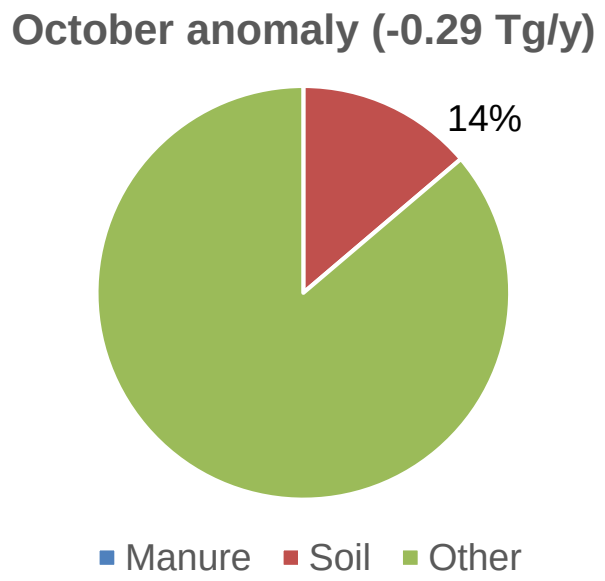
- Differences between 2005-2017 and 2018 CH_4 emissions were significant at 95% confidence level for March, April and October
- April anomaly coincided with warmer temperature and higher soil moisture
- October anomaly coincided with lower soil moisture



The Netherlands

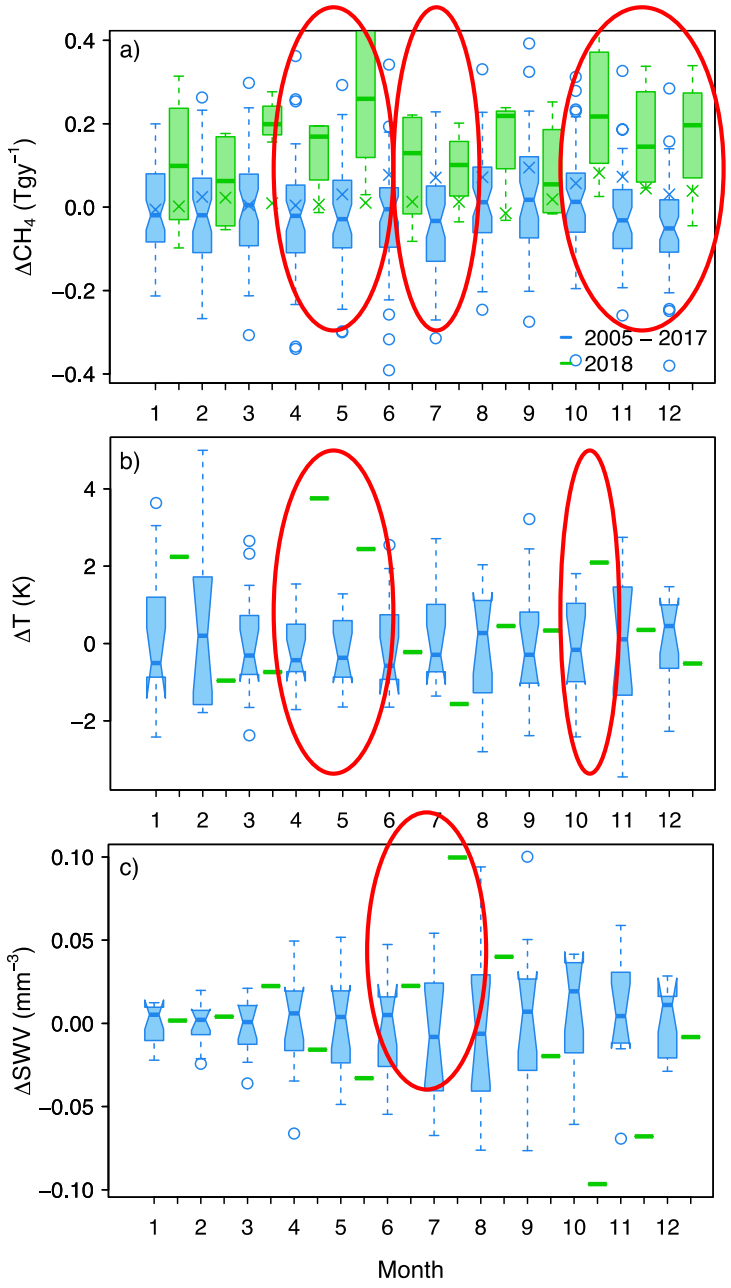
- Manure emissions have Q10 of 3.4 (similar to wetlands) and account for ~14% of total source
- Calculated anomaly in manure emission ~35% of spring anomaly
- Summer no anomaly – possible compensating effects of temperature and soil moisture
- October coincided with soil moisture deficit, reduction in mineral soil fluxes may account for ~14% of anomaly





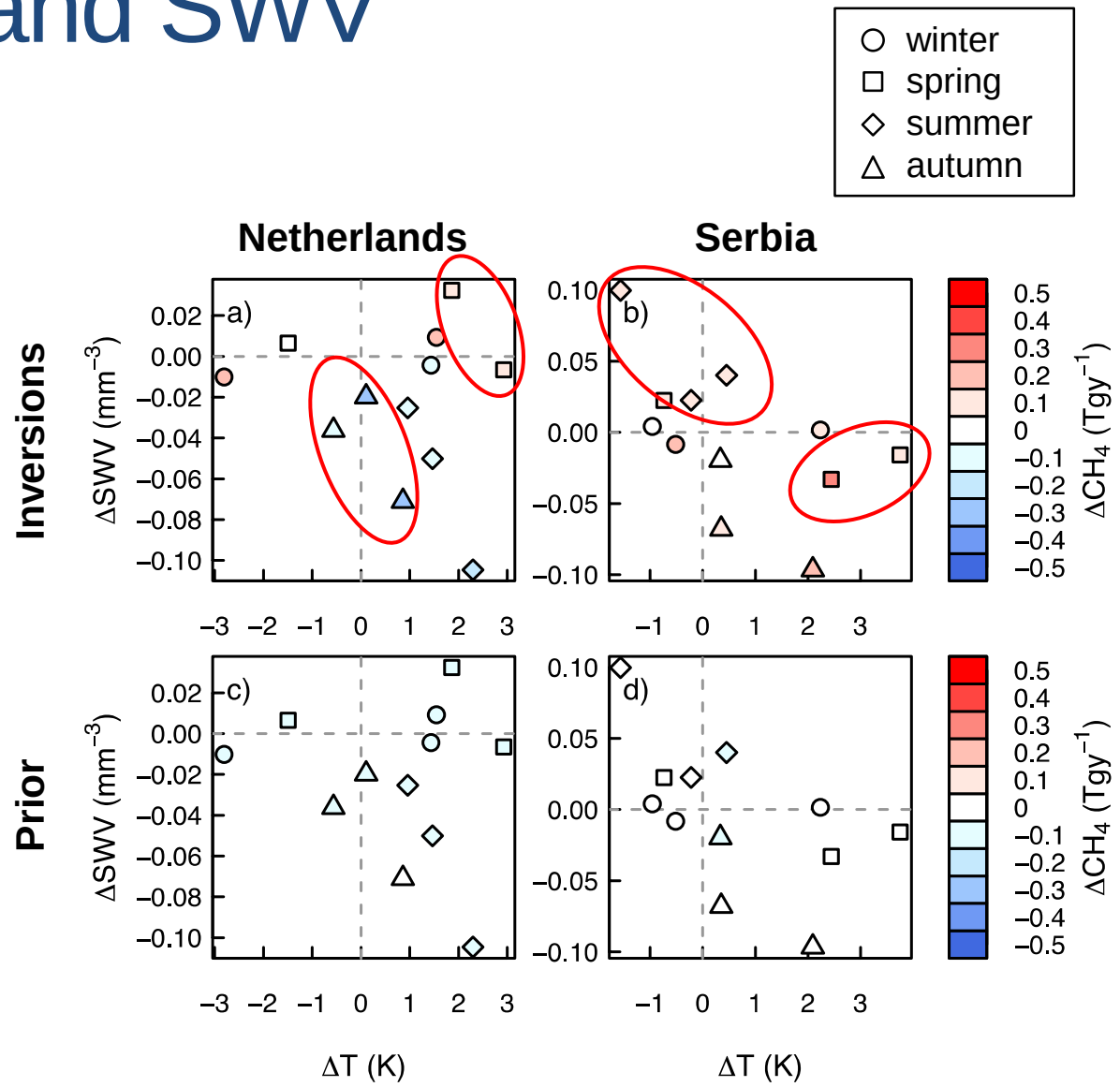
Serbia

- Differences between 2005-2017 and 2018 CH_4 emissions were significant at 95% confidence level for March-May, June-July and October-December
- Spring anomaly coincided with warmer temperature
- Summer anomaly coincided with higher soil moisture
- October anomaly coincided with warmer temperature but unclear cause for November-December



Sensitivity of fluxes to T and SWV

- Netherlands
  - spring CH_4 anomaly appears largely driven by warmer temperature
  - autumn negative CH_4 anomaly appears largely driven by reduced soil moisture
- Serbia
  - spring CH_4 anomaly appears largely driven by warmer temperature
  - summer CH_4 anomaly appears largely driven by wetter soils
  - autumn CH_4 anomaly appears driven by warmer temperature



Conclusions

- Despite the heatwave and drought in 2018 (north of the Alps) the effect on CH_4 emissions was small
- Anomalies found for the Netherlands (positive in spring and negative in autumn) associated with temperature and soil moisture anomalies suggesting changes in biogenic sources
- Anomalies in spring, summer and autumn found for Serbia again associated with temperature and soil moisture anomalies and may indicate increase in mineral soil emissions
- Although CH_4 emissions in Europe have only small sensitivity to meteorological conditions this could be important when reconciling TD and BU estimates

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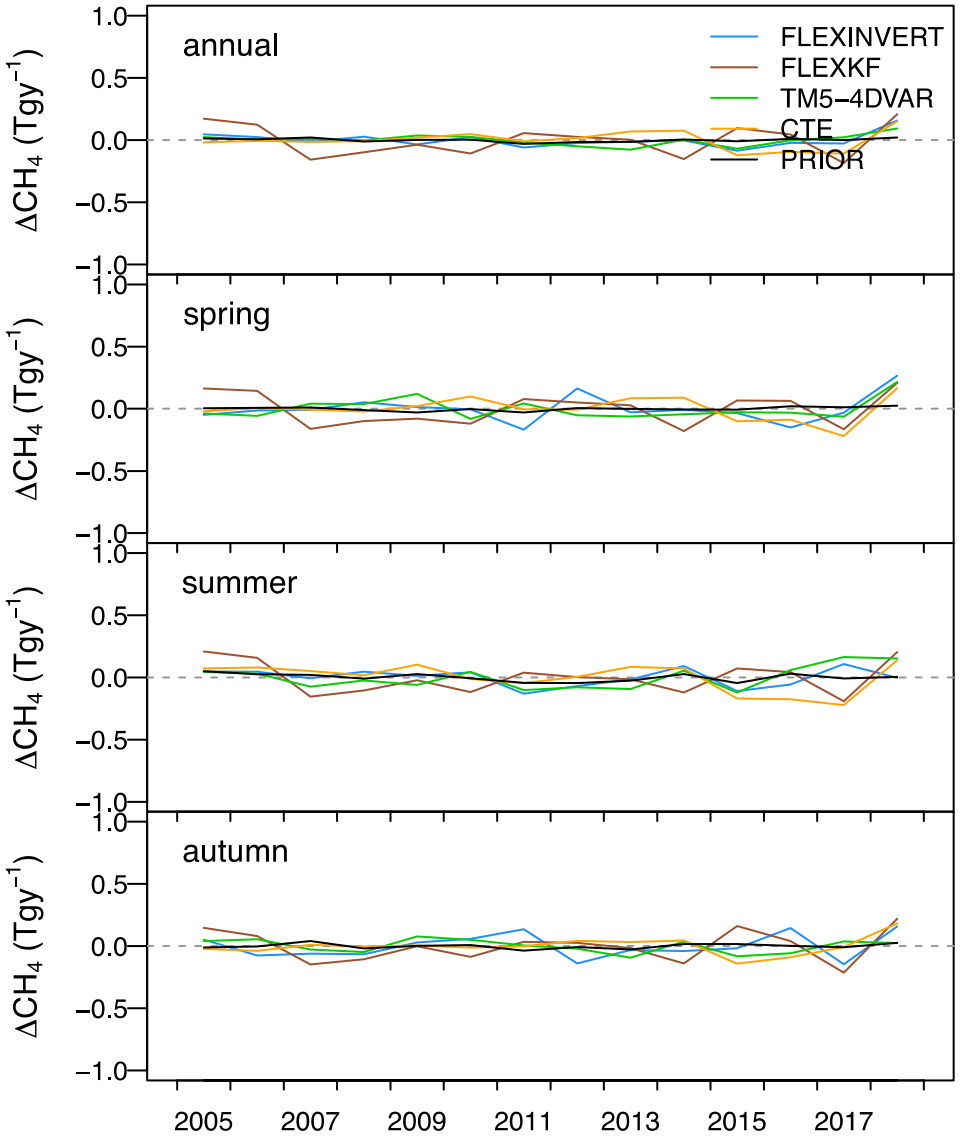
Posterior budget EU27+UK

Estimate	2018 (Tg/y)	Mean (min – max) (Tg/y)
Prior	32.3	33.0 (31.9 – 34.2)
FLEXINVERT	36.8	36.0 (30.9 – 39.1)
FLEXPART-ExKF	24.6	27.3 (23.1 – 34.3)
TM5-4DVAR	26.4	26.8 (25.7 – 28.7)
CTE-CH4	28.3	31.7 (27.3 – 36.4)
Bergamaschi et al. 2018	*26.8 (mean for 2006-2012)*	
Petrescu et al. 2020	*28.8 (mean for 2011-2015)*	

Serbia

- Positive annual anomaly of 0.16 Tg/y (36% higher than prior mean of 2005-2017)
- All inversions find positive anomaly in spring
- Three of four inversions find positive anomalies for summer and autumn



The Netherlands

- All inversions find a positive anomaly for spring and a negative anomaly for autumn in 2018
- No summer anomaly in 2018
- No annual anomaly in 2018