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# TM5-4DVAR inverse modelling system for atmospheric $CH_4$: Sensitivity of derived European emissions on observational network


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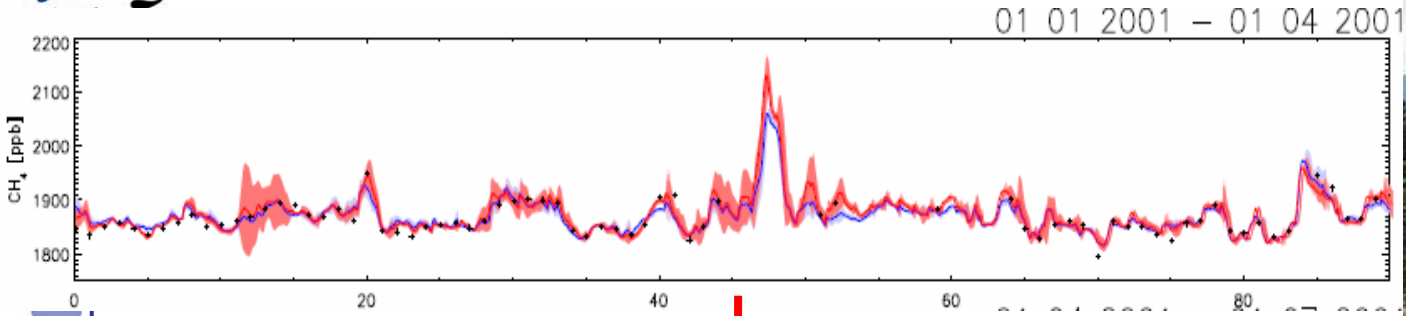
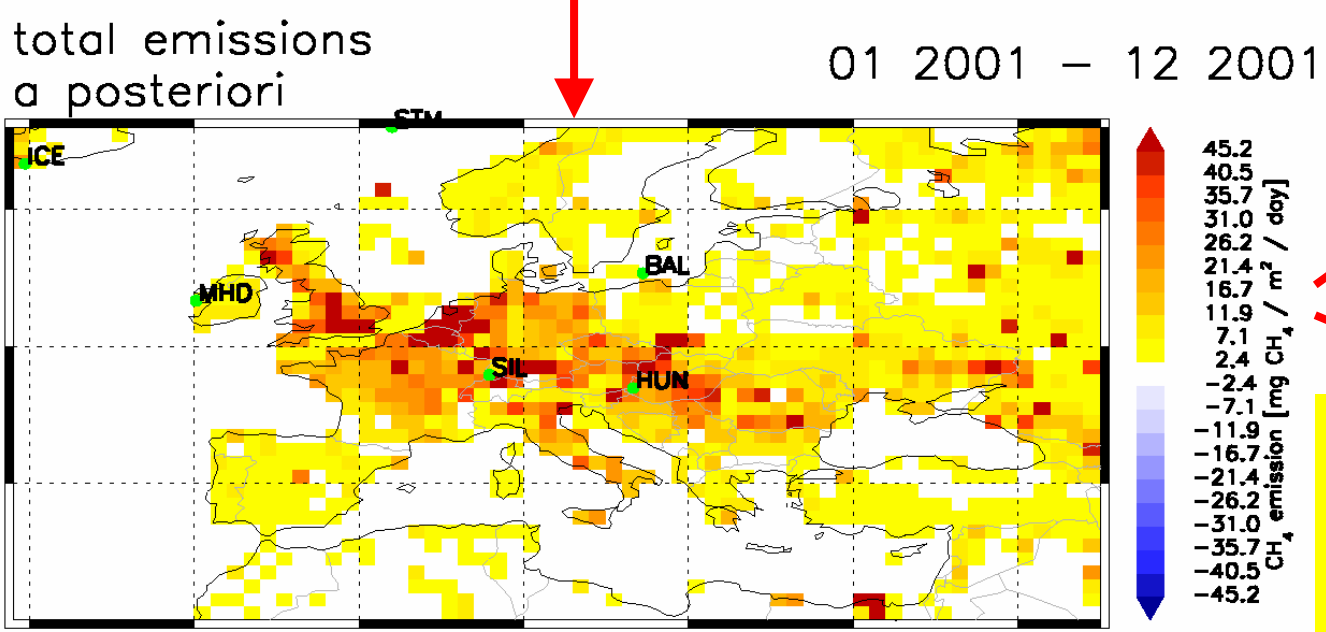
# basic principle + objective of inverse modelling




**top down estimate of emissions**




**verification**

UNFCCC

**Kyoto protocol**

**monitoring of global $CH_4$ cycle**

**natural sources and their feedback to climate change (wetlands, permafrost, $CH_4$ hydrates,...)**

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# Motivation



**Objective:**

Influence of ground based network on retrieved emissions:

- almost (no) knowledge of the apriori distribution (*uniform spatial* and *temporal distribution* of a priori emissions)
- sets of ground based observations: *sites locations*; *sampling frequency, network density*

# Methodology: Sensitivity Experiments

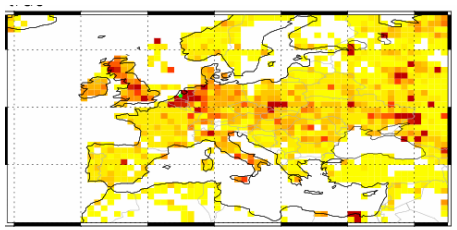


## Sensitivity experiments use synthetic observations

**FIRST STEP** : Ground-based observations generated by model forward run

*$CH_4$ emissions inventories = 'true' emissions*

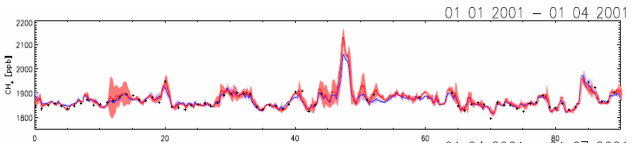
INPUT:



**'true' $CH_4$ emissions**

TM5-4DVAR
forward mode

OUTPUT:




**$CH_4$ concentrations**

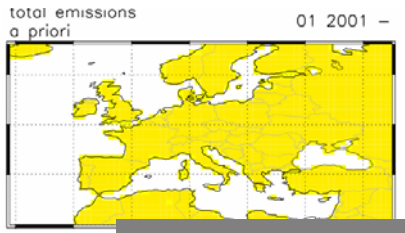
# Methodology: Sensitivity Experiments



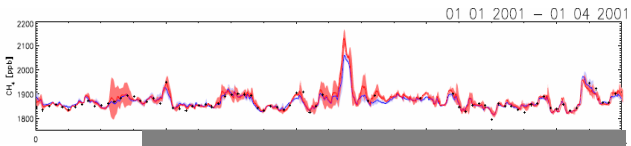
**SECOND STEP**: measurements are assimilated in model run

*$CH_4$ a-priori emissions = spatially and temporally constant*

INPUT:



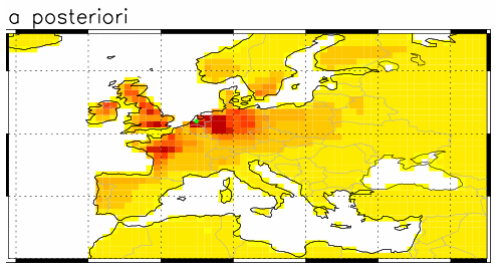

**apriori/unknown $CH_4$ emissions**




**$CH_4$ concentrations**

TM5-4DVAR
Inverse mode

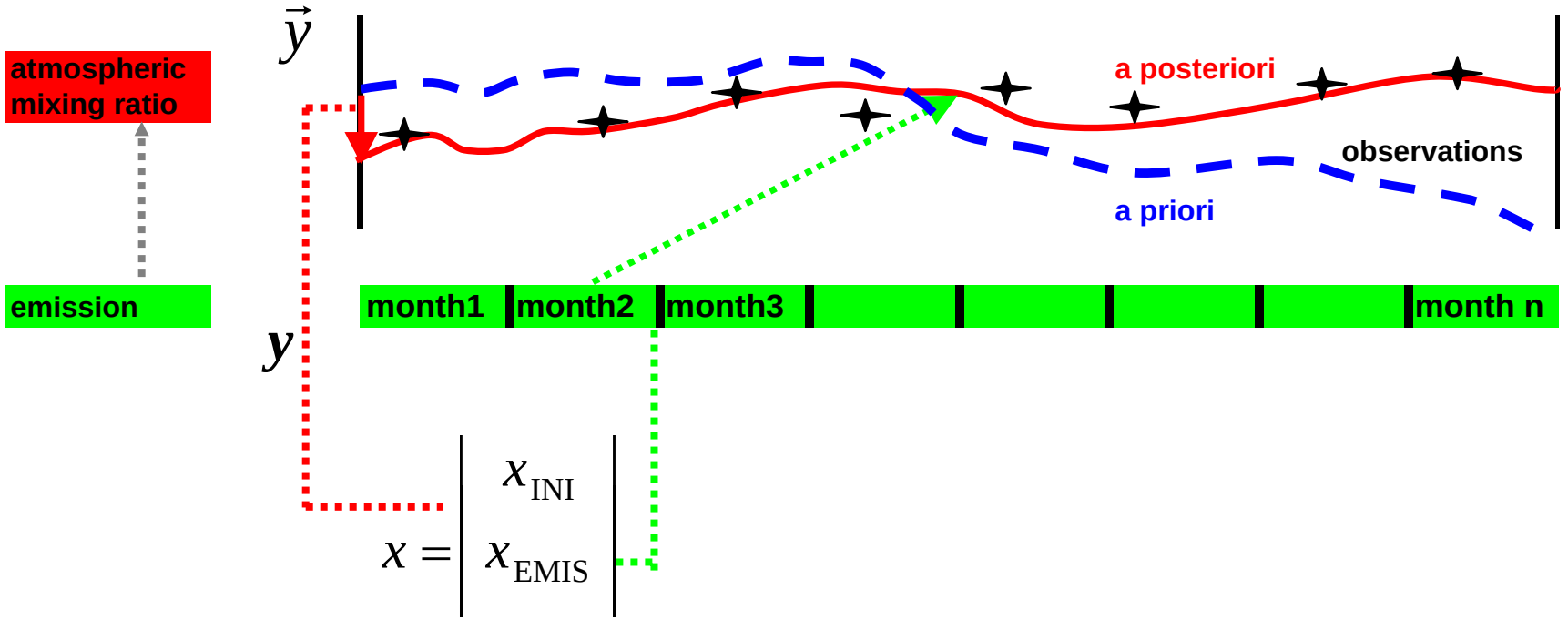
OUTPUT:




**derived/optimized $CH_4$ emissions**

# TM5-4DVar inverse modeling system





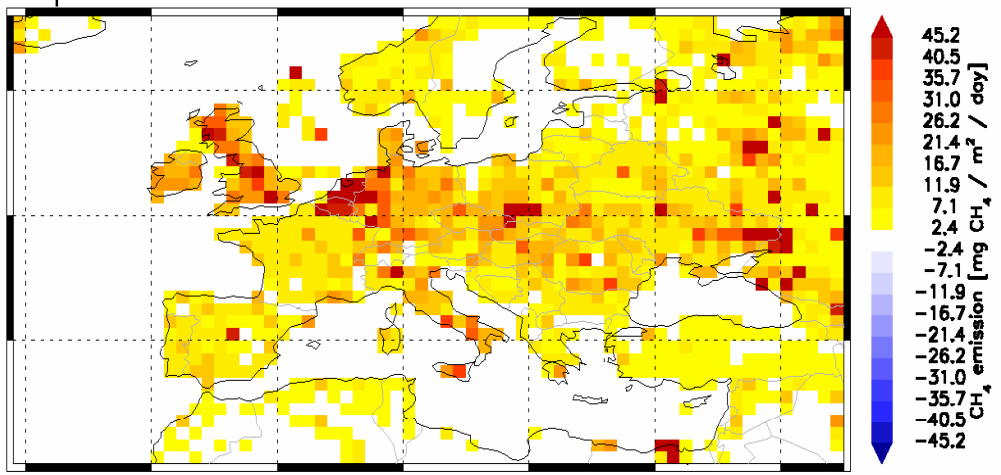

Here we use the semi-linear version of the TM5-4DVAR system

# linear vs. non-linear: emissions

VAR_T30_25L60_tmppod_eur. **linear 4DVAR** 0201

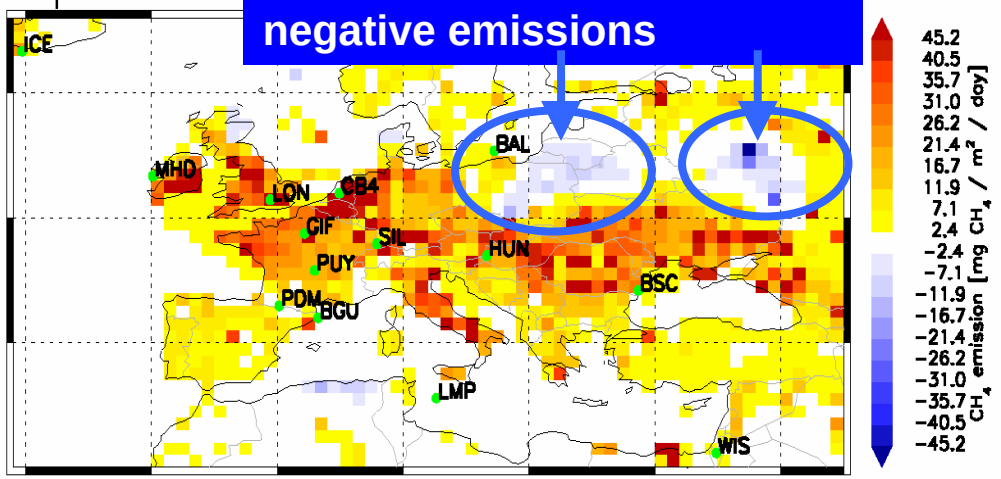
total emissions
a priori

01 2001 – 12 2001




a posteriori

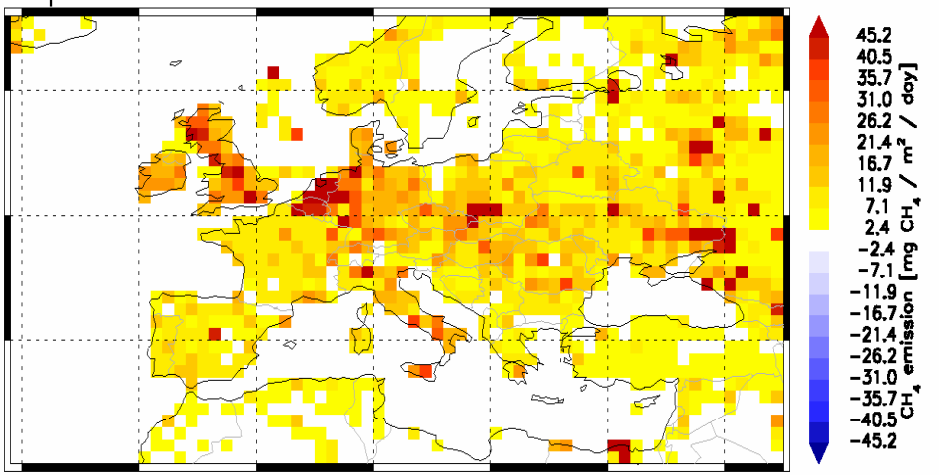
**negative emissions**



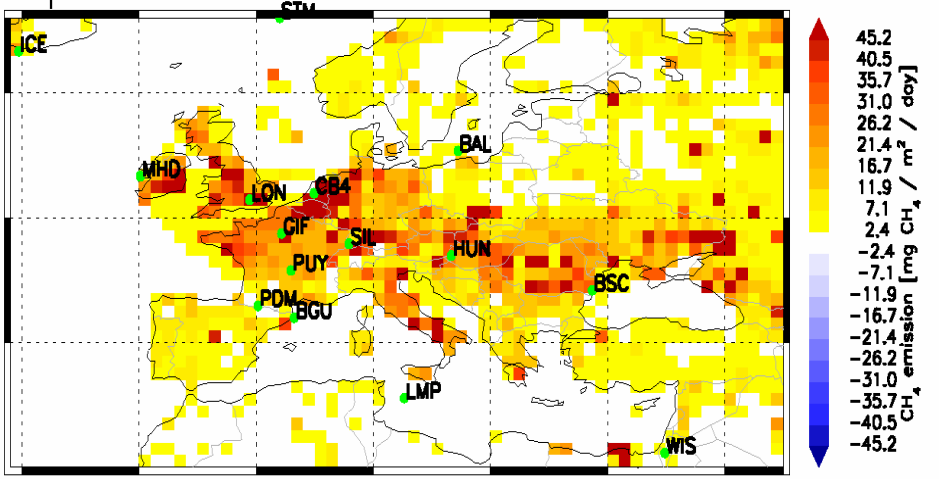

VAR_T30_25L60_tmppod_ **non-linear 4DVAR** 20201

total emissions
a priori

01 2001 – 12 2001

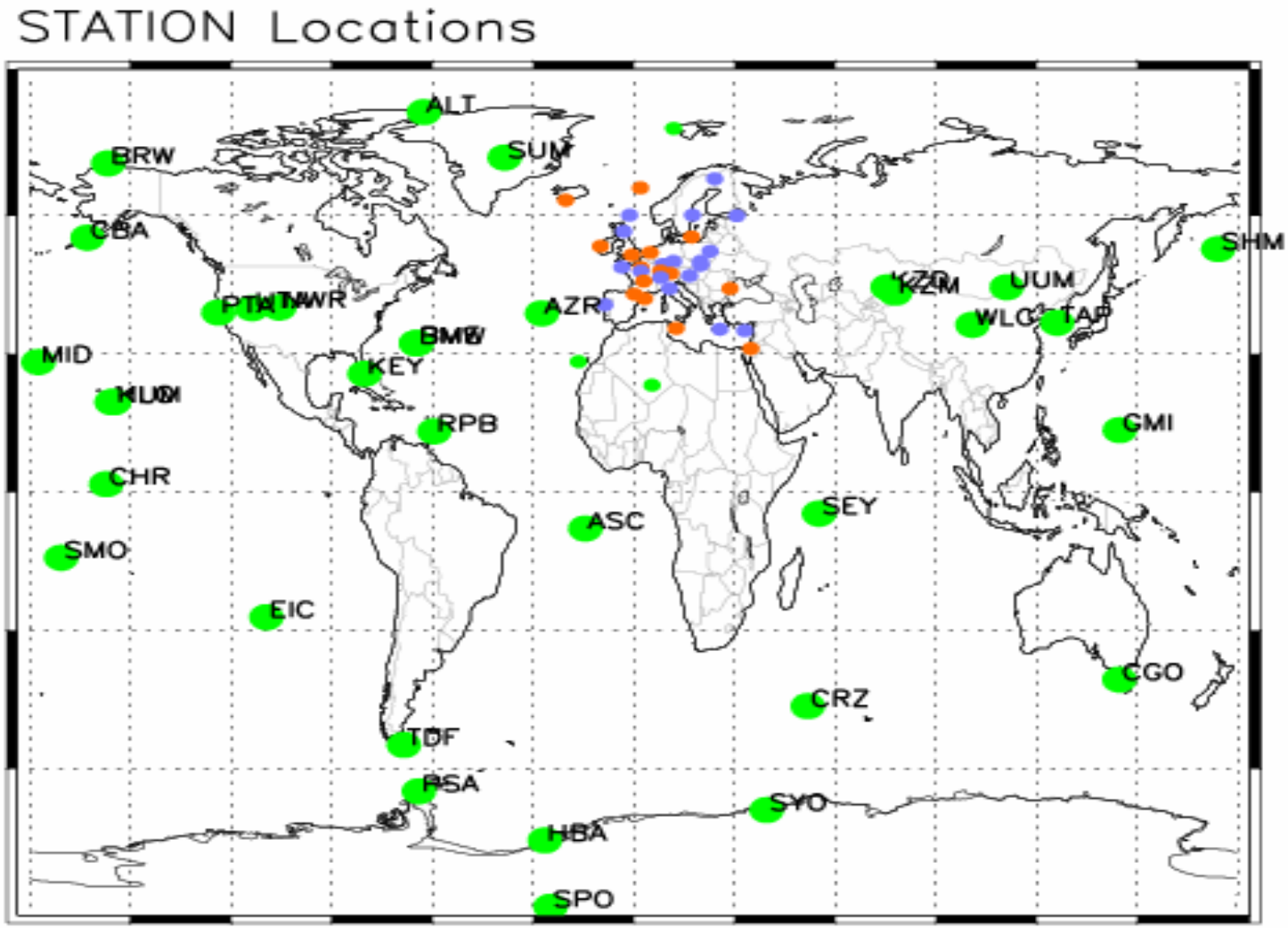



a posteriori



# World-wide Observational network



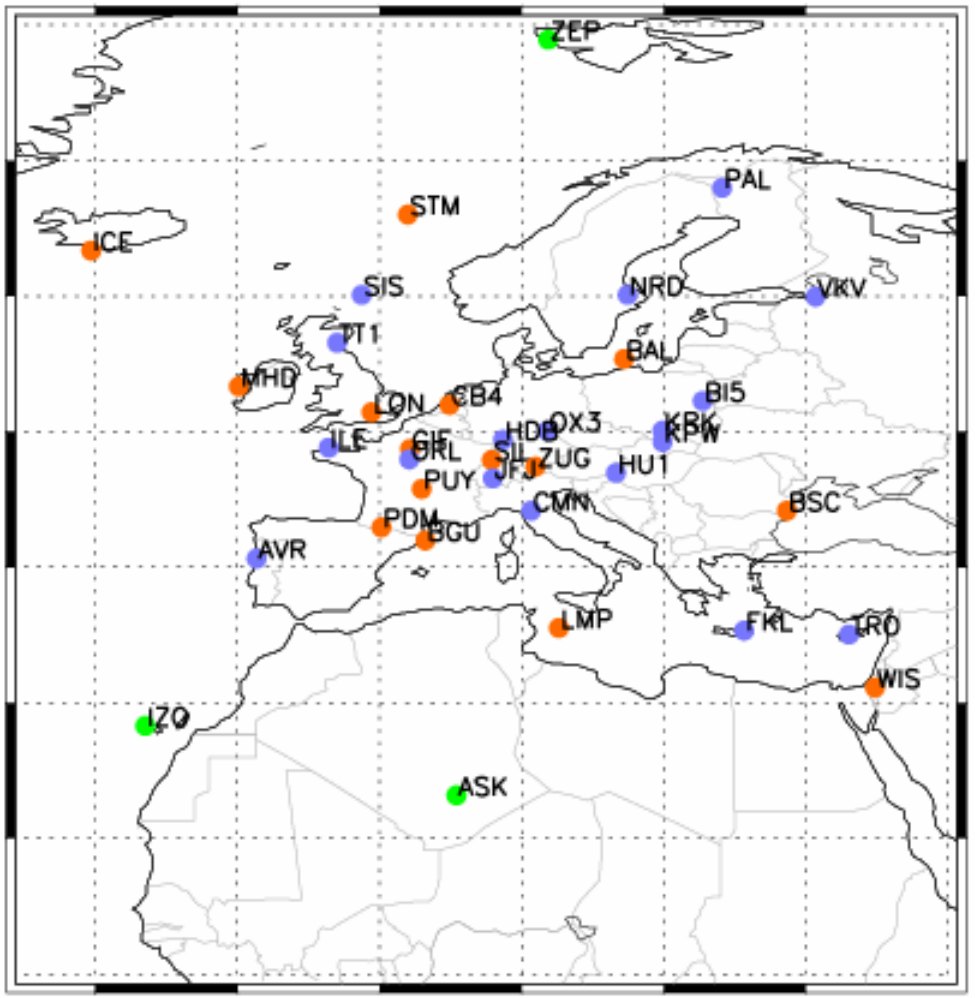



## Legend:

- Global background (flask)
- CS (current stations)
- "Manometer"

# EU Observational Networks

## European map with the EU stations




## Legend:

- Global background (flask)
- CS (current stations)
- "Manometer"

# Synthetic measurements



**Sample frequency**:

Continuous and flask measurements (once per day; per week)

- Sampling:
  - at daytime [12:00-15:00 local time]- DY
  - at nighttime [00:00-03:00 local time]- NI
- Stations: Mountain stations (NI), Boundary layer (DY)

Errors in Observations:

- “standard error” [3ppb $CH_4$]

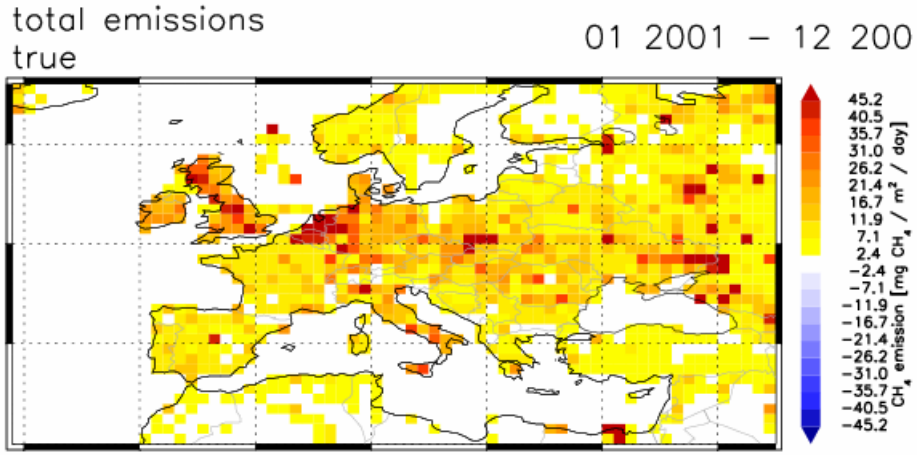
Model errors:

- “representativeness” error

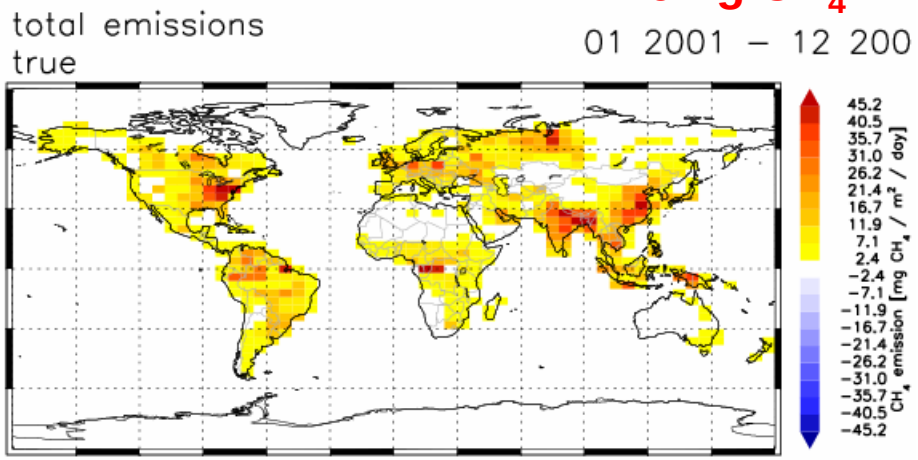
# $CH_4$ Emissions



## True emissions [forward run]

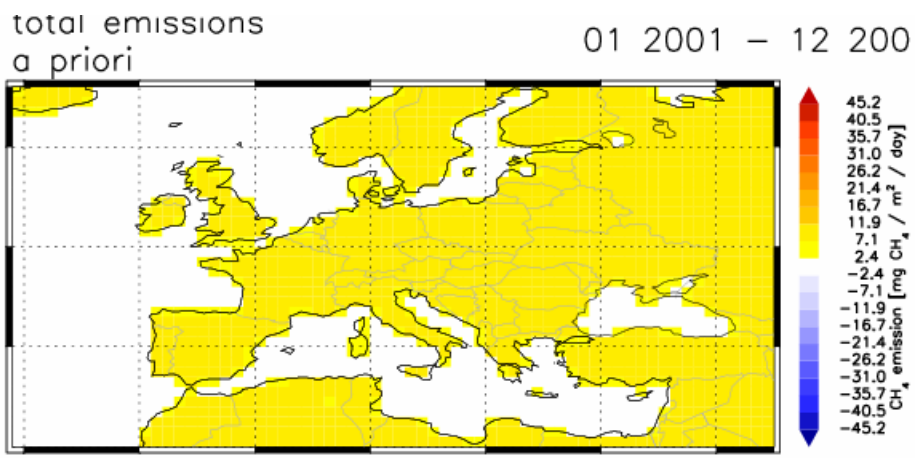



**44.6 Tg $CH_4$**

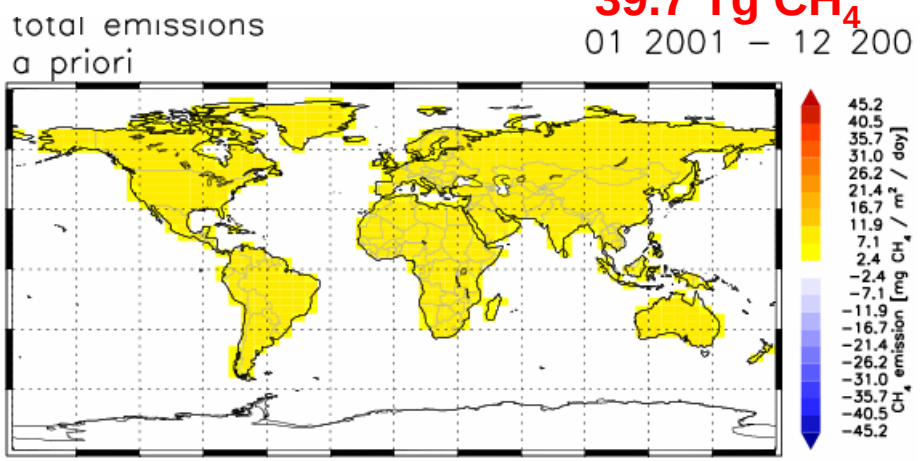



**512.5 Tg $CH_4$**

## A priori emissions [4D-Var]

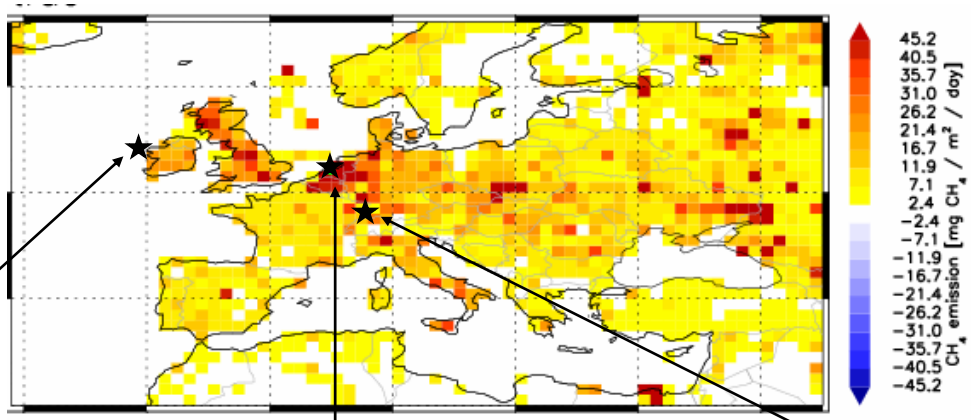



**39.7 Tg $CH_4$**




**517.0 Tg $CH_4$**

# Influence of Station Locations




Mace Head, 25m asl:
boundary layer /
marine background

Cabauw, 200m asl:
boundary layer

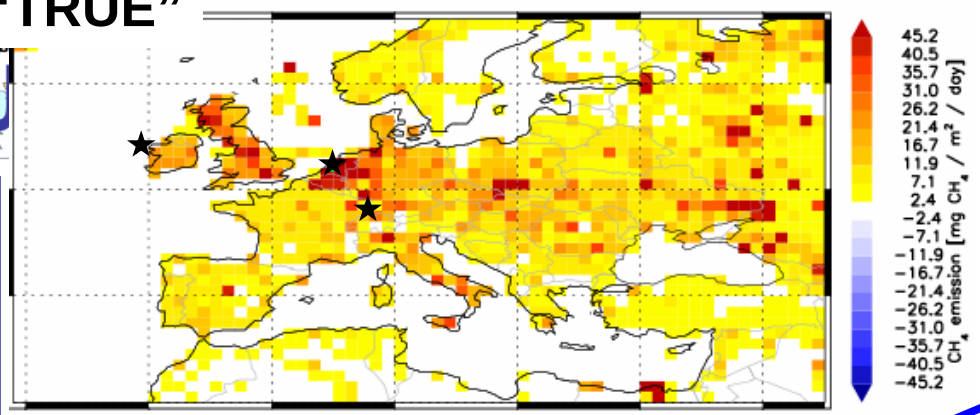
Schauinsland, 1205m asl:
mountain station

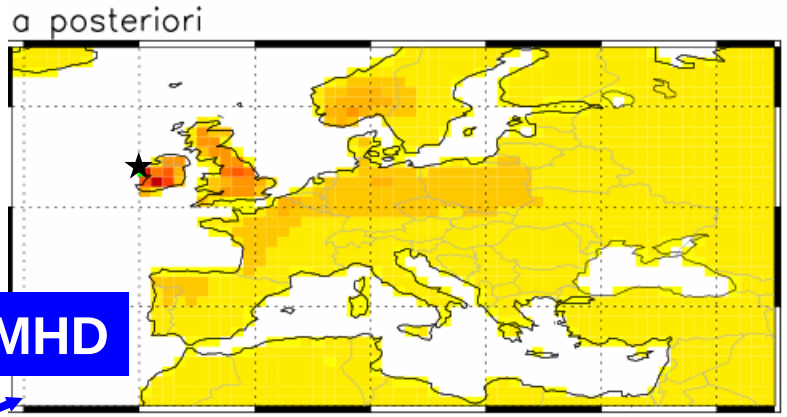
MHD

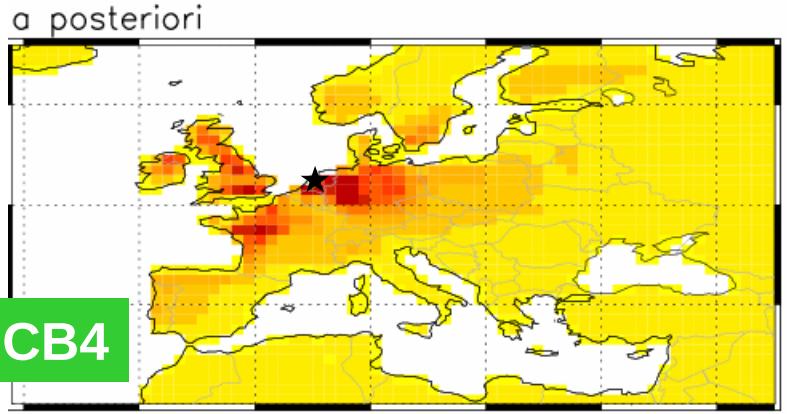
CB4

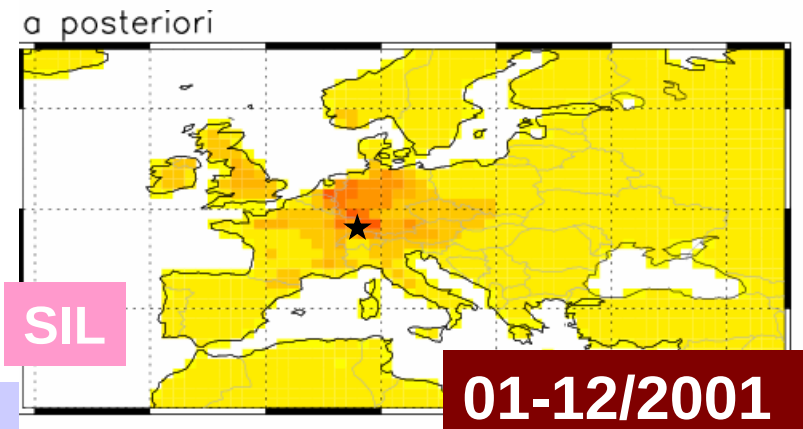
SIL

# Influence of Station Locations




Mace Head:
boundary layer / marine background

Cabauw:
boundary layer

Schauinsland:
mountain station

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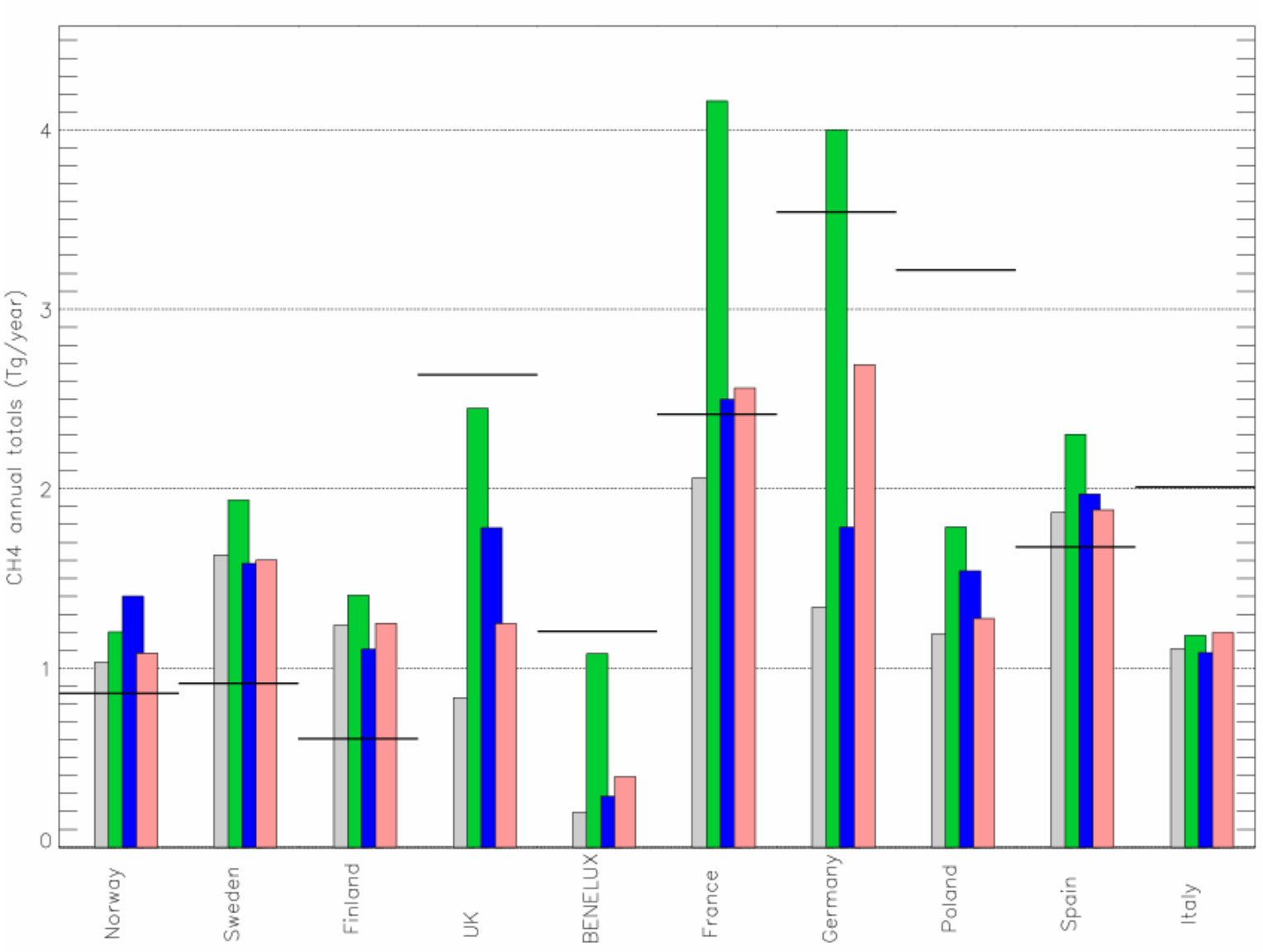
# Influence of Station Locations at EU scale




"TRUE"

CB4

MHD

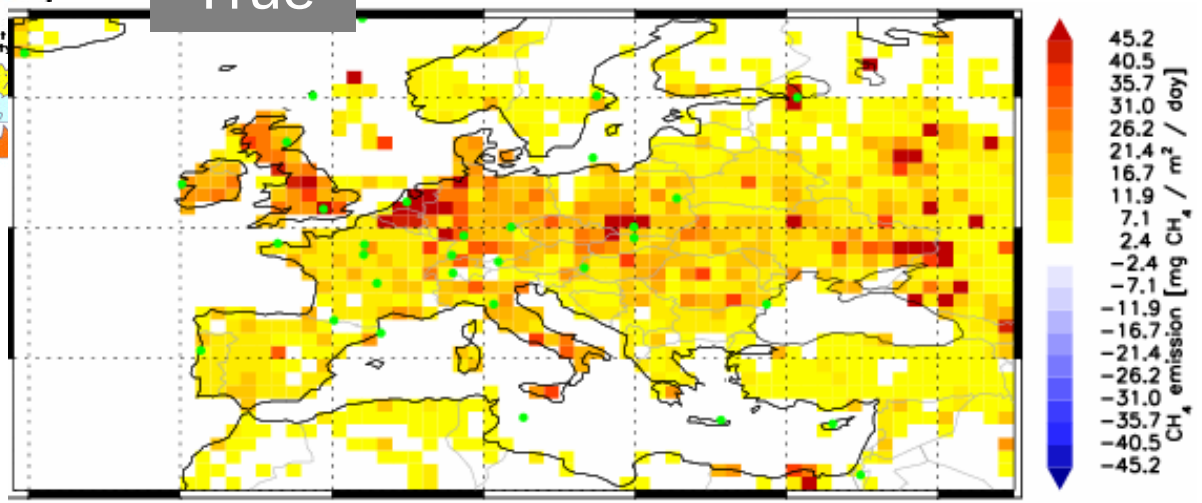
SIL

apriori

# Derived $CH_4$ emissions with observational network

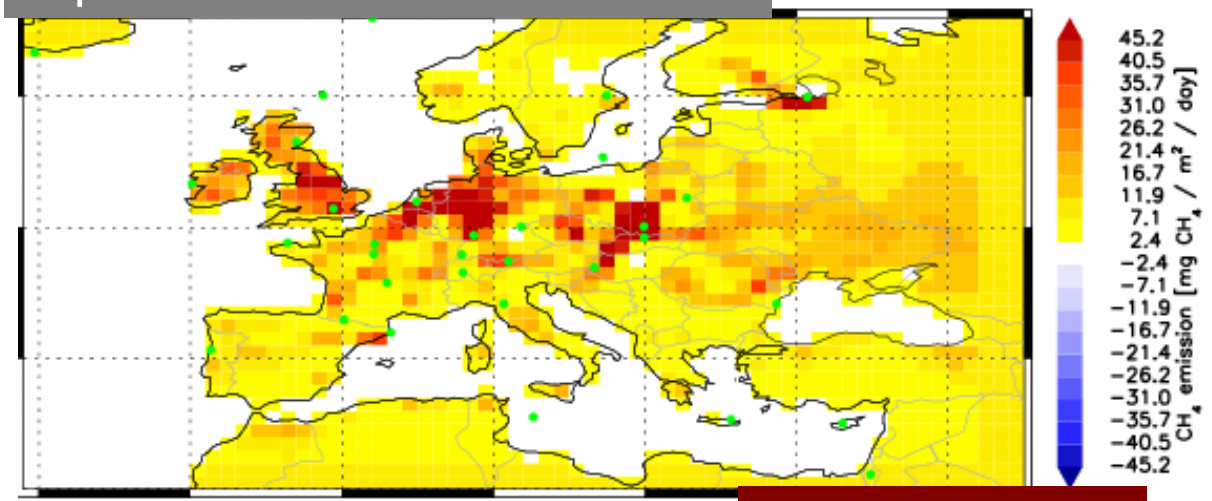


"True"






A posteriori- derived emissions

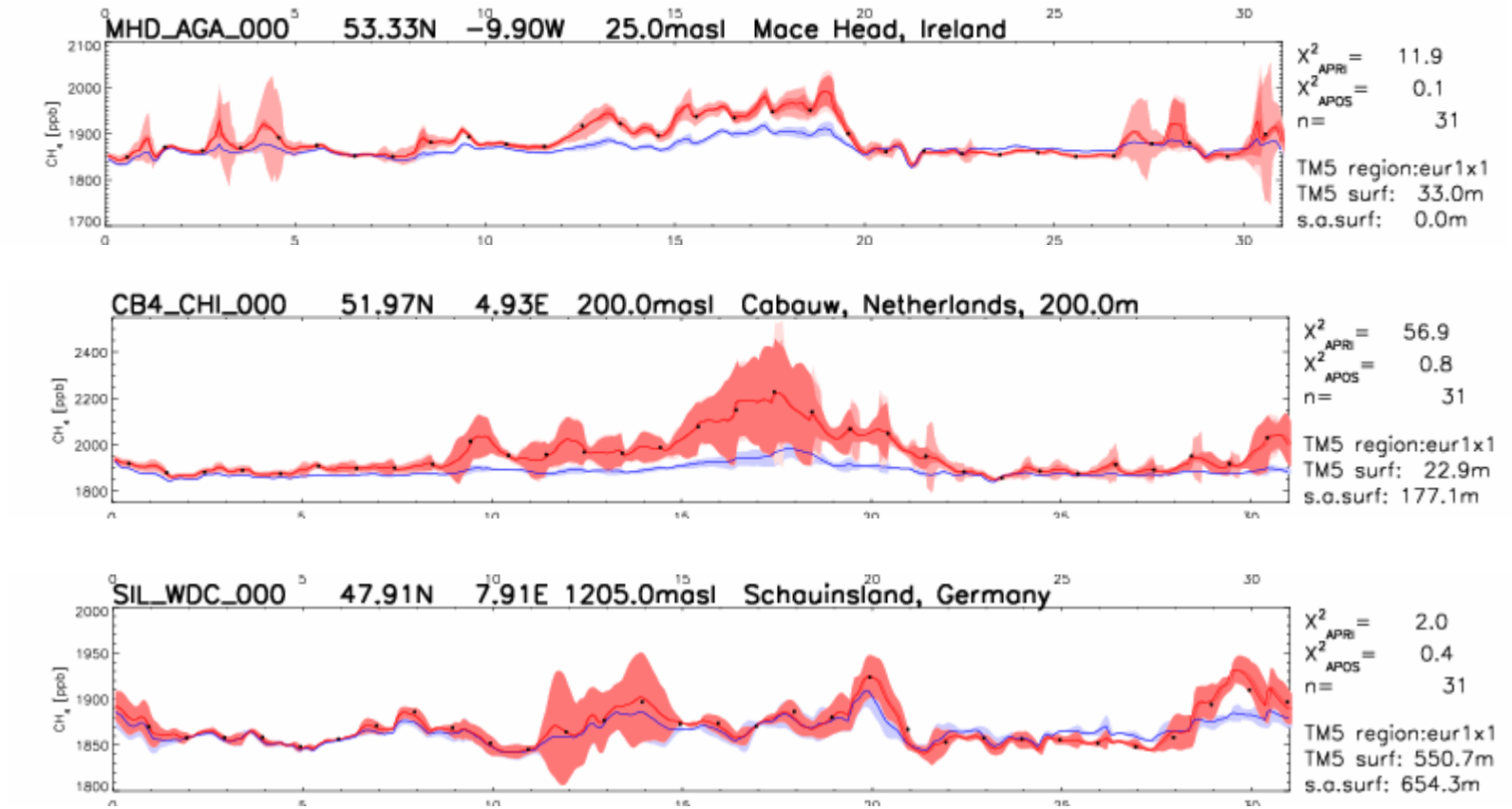





**01-2001**

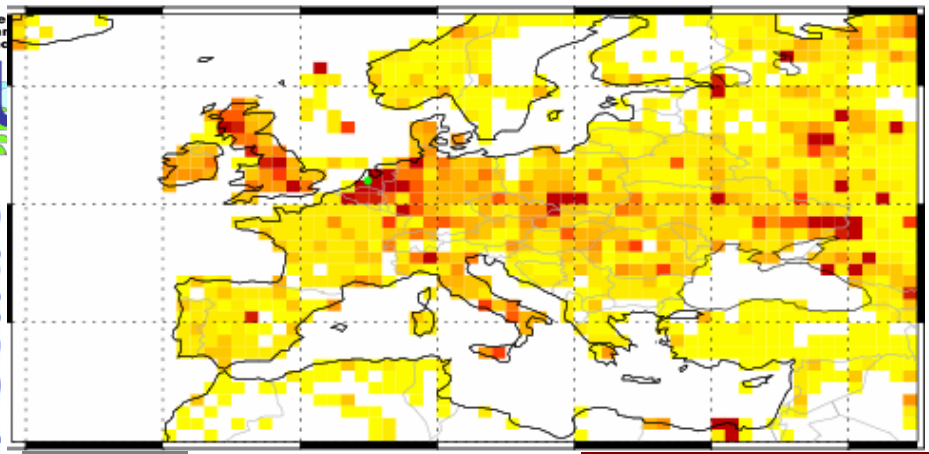
Larger-scale regional $CH_4$ emissions close to station locations satisfactorily retrieved

# $CH_4$ concentration at selected stations: MHD, CB4, SIL




- observations
- a priori run
- a posteriori run

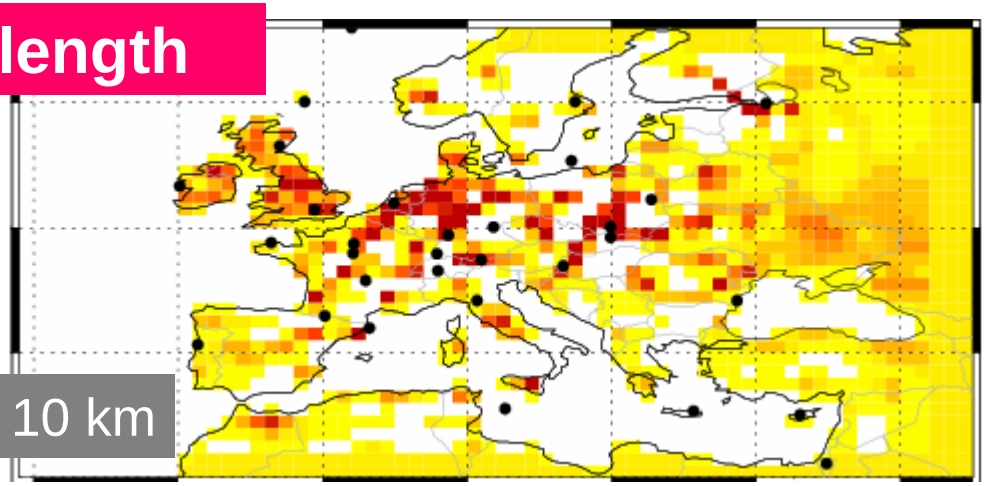
# Sensitivity spatial correlation length



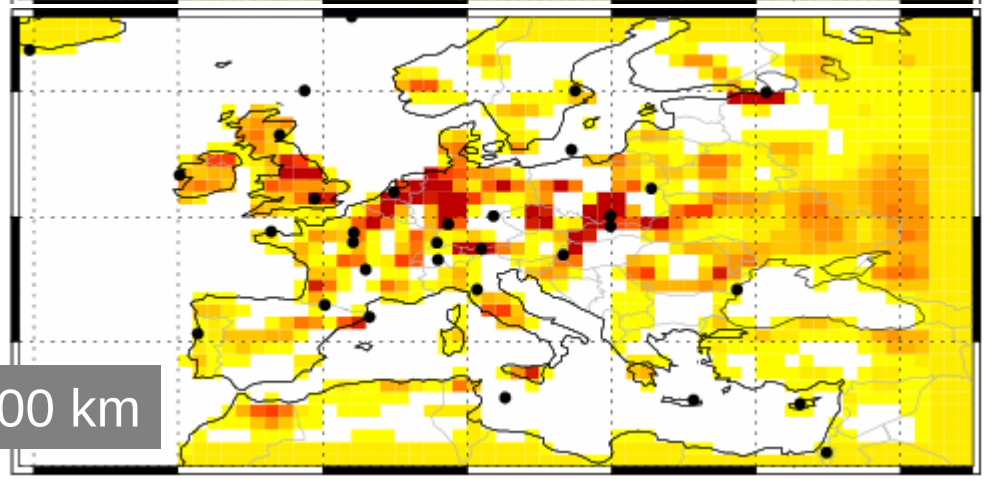
"true"

**01-2001**

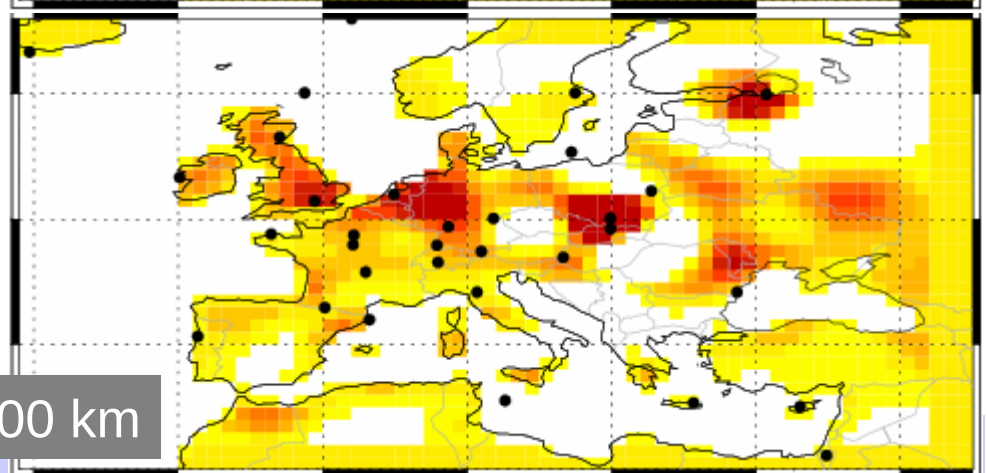
"Smoothing" effect due to increasing correlation length



10 km



100 km



300 km

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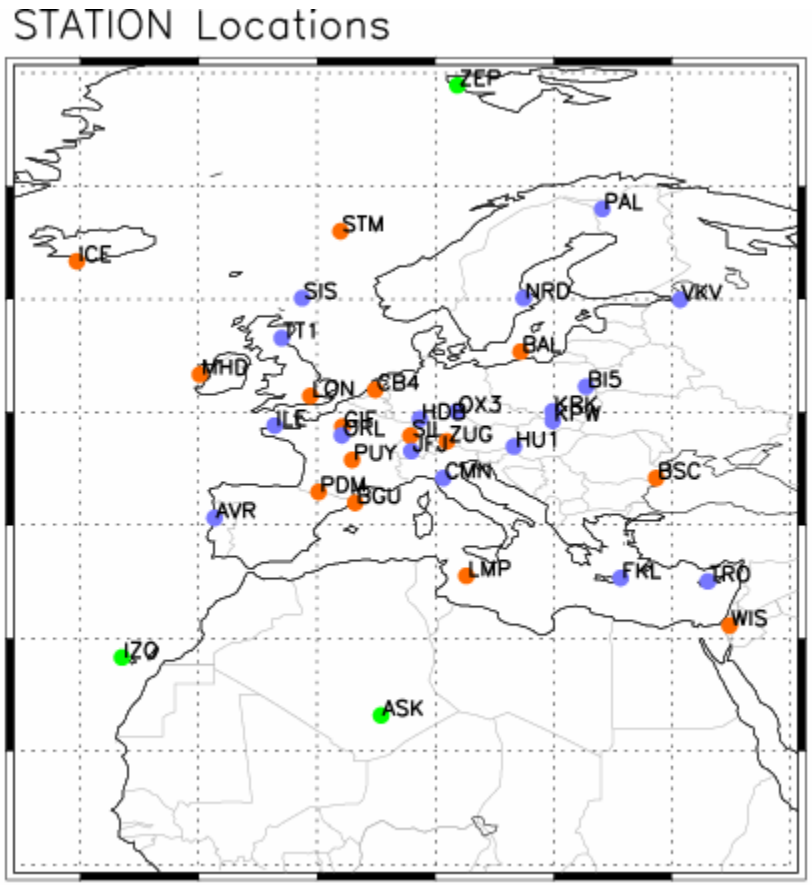
# EU-Observational Networks

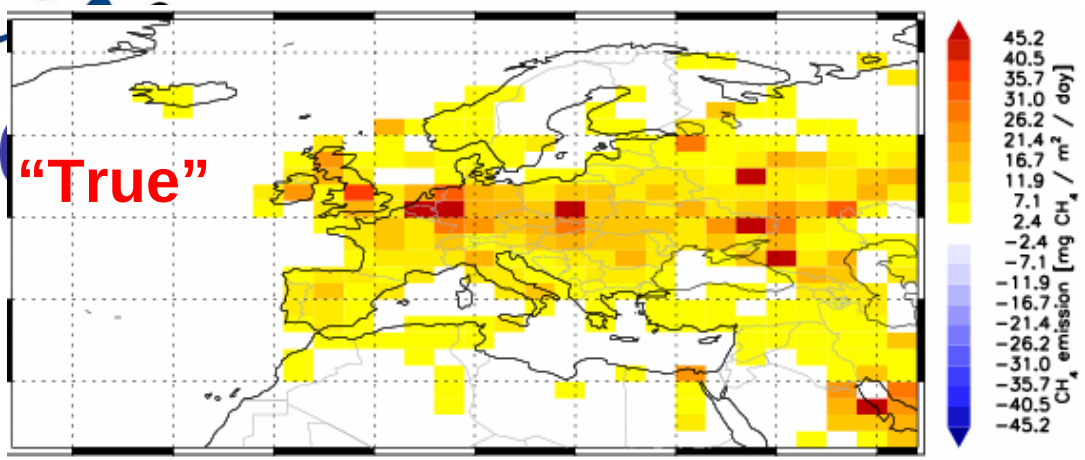


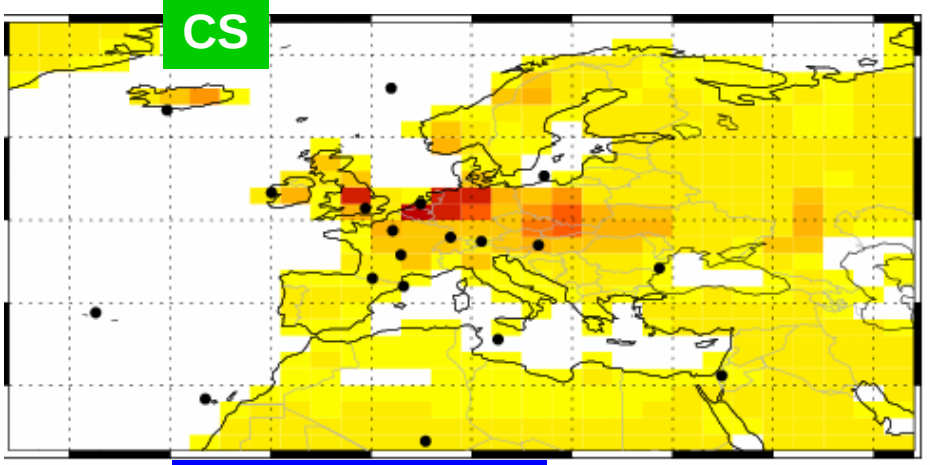
## Datasets shown here:

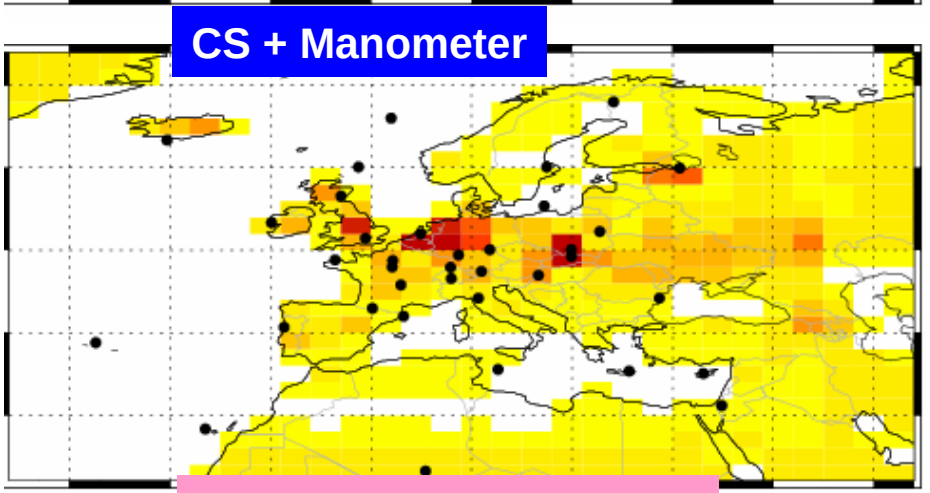
| Synthetic Observations | ID | symbol |
|---|---|---|
| Global background (flask) | Global background | |
| CS (current network) | "CS" | |
| CS+Manometer | "CSMAN" | |
| CS+Manometer EU all CM | "CSMANCM" | |

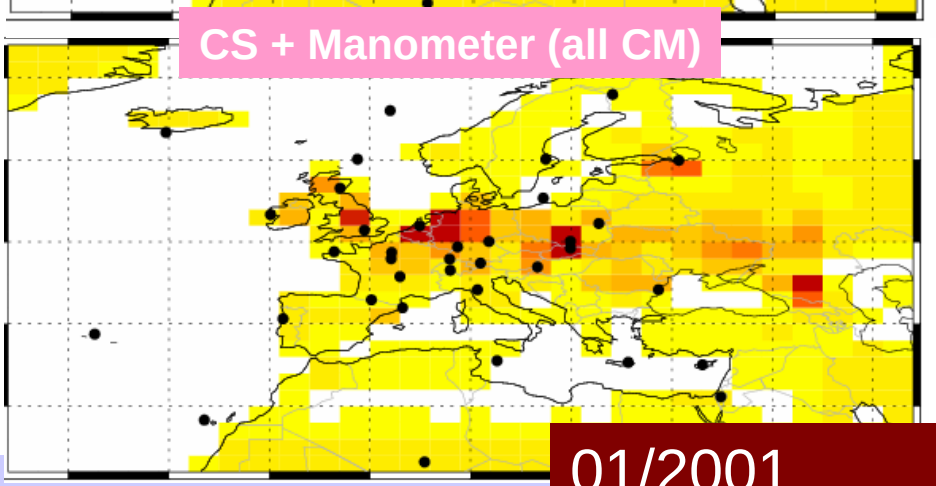


# Derived $CH_4$ emissions

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**Increasing number of stations and sampling frequency:**

**retrieved $CH_4$ emissions closer to true values and better resolved in NWE countries**

01/2001

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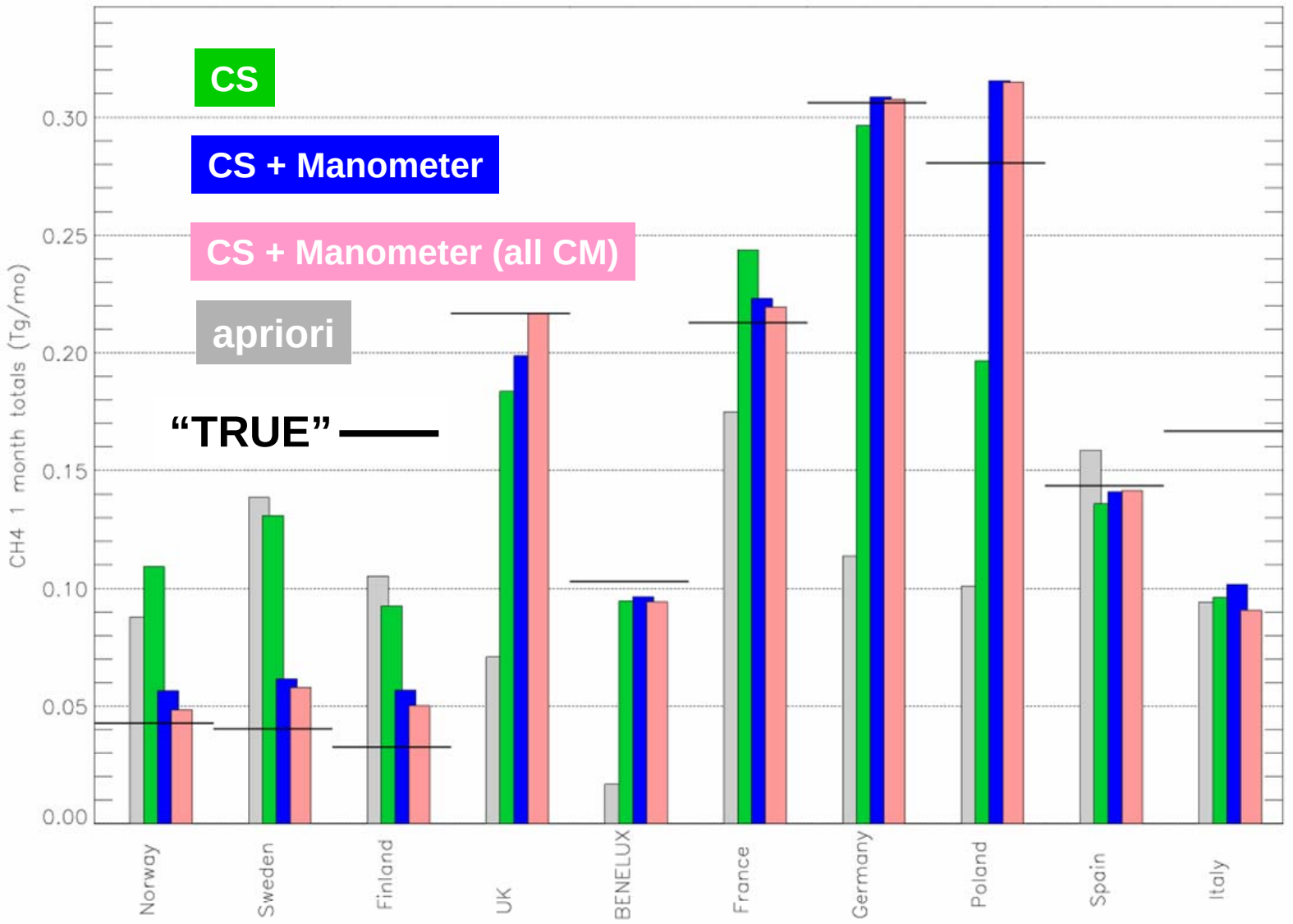
# Derived $CH_4$ Emissions at EU countries base



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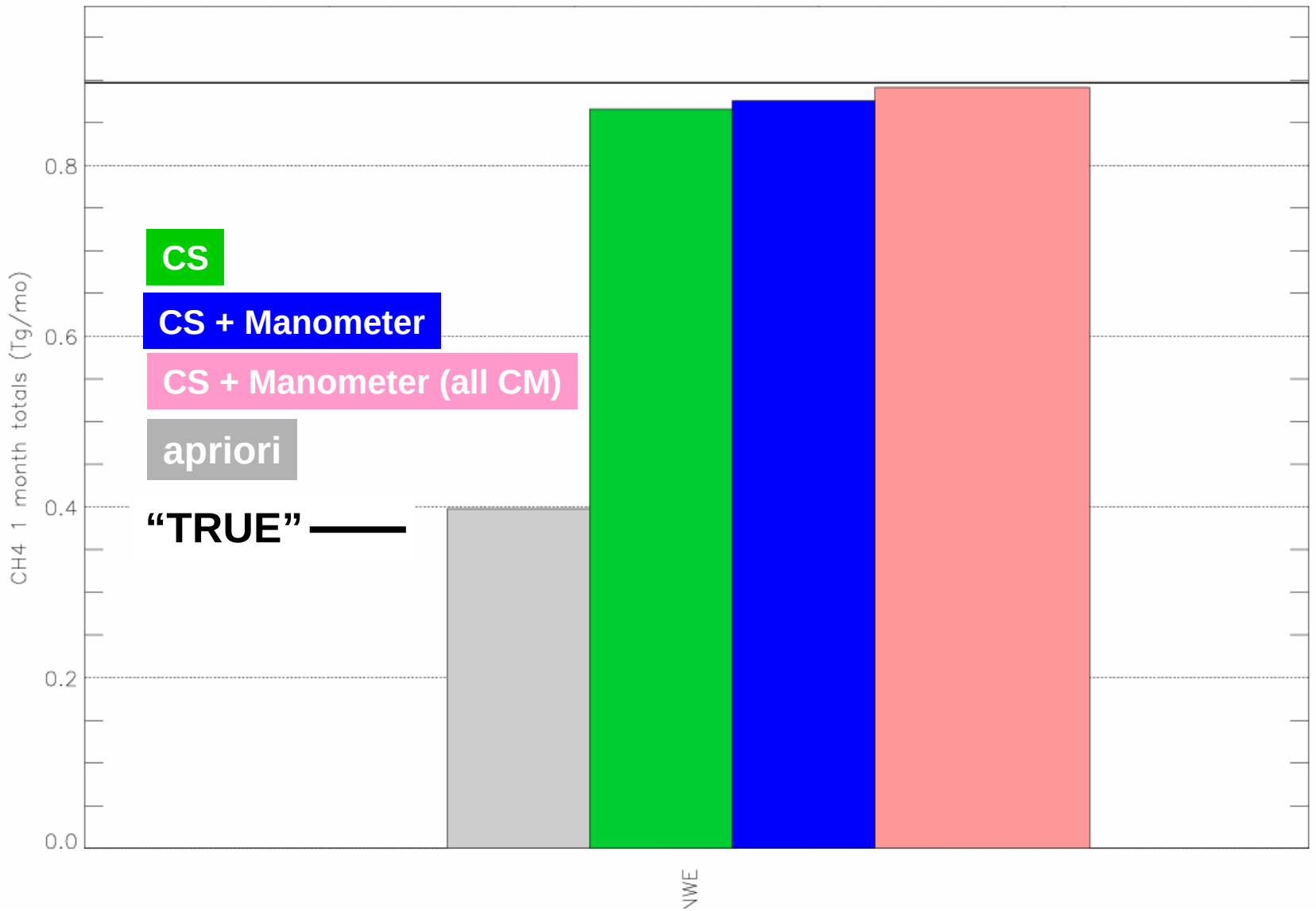
# Derived $CH_4$ Emissions on EU countries base: NWE



# Conclusions

- Current observational network constrain the NWE sector satisfactorily

- Increased network density -> better top-down $CH_4$ emission estimates

-Extended network:

-> Significant improvement over Scandinavia

-> Major signals from Southern and Eastern Europe cannot be resolved

# Limitations / outlook



-Analyses limited to one month

-Synthetic Observations calculated by assuming no errors in:

- measurements
- transport model

-Further experiments with additional stations in poorly resolved regions (e.g. Southern and Eastern Europe)

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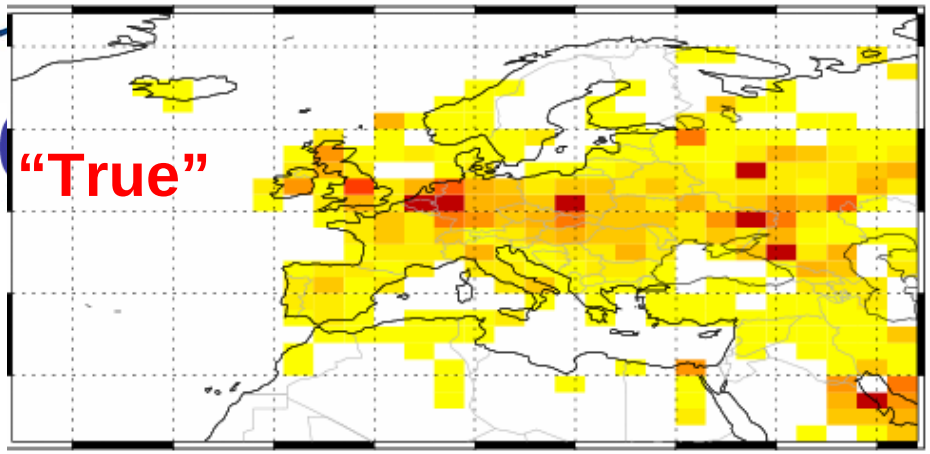
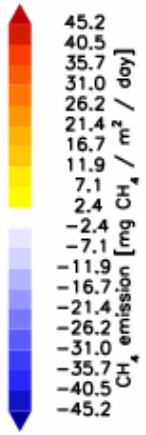
# End of the presentation

# Derived $CH_4$ emissions

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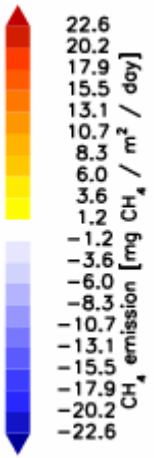
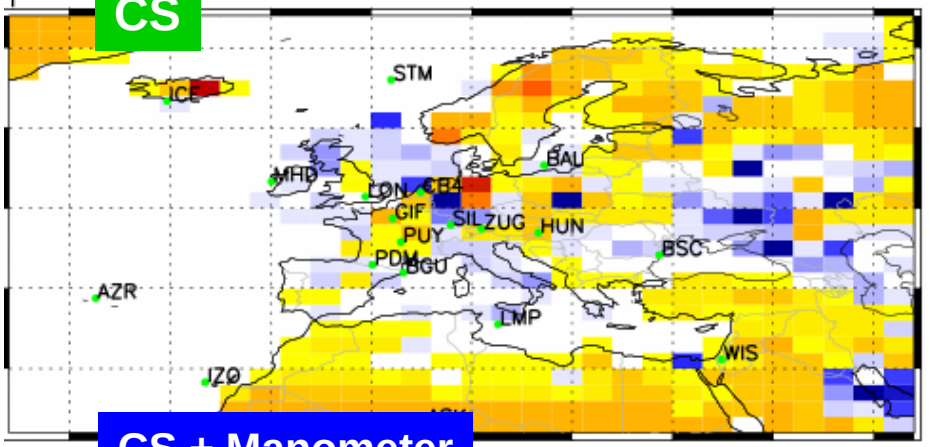
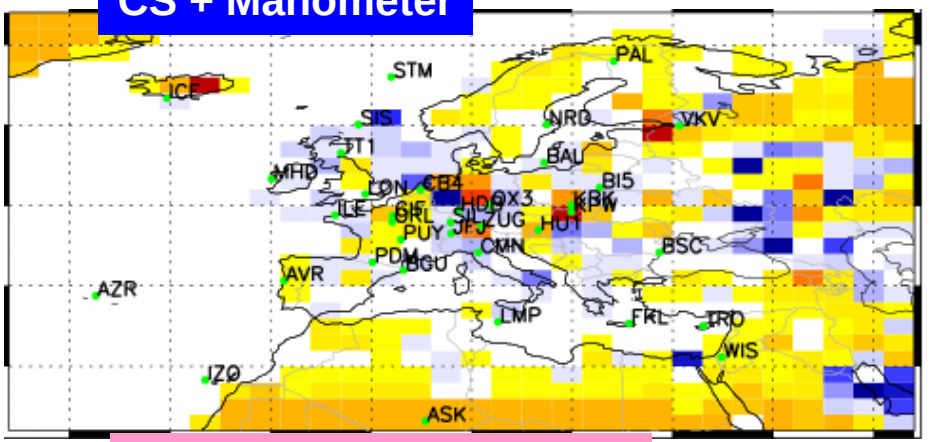
**A posteriori - true :**



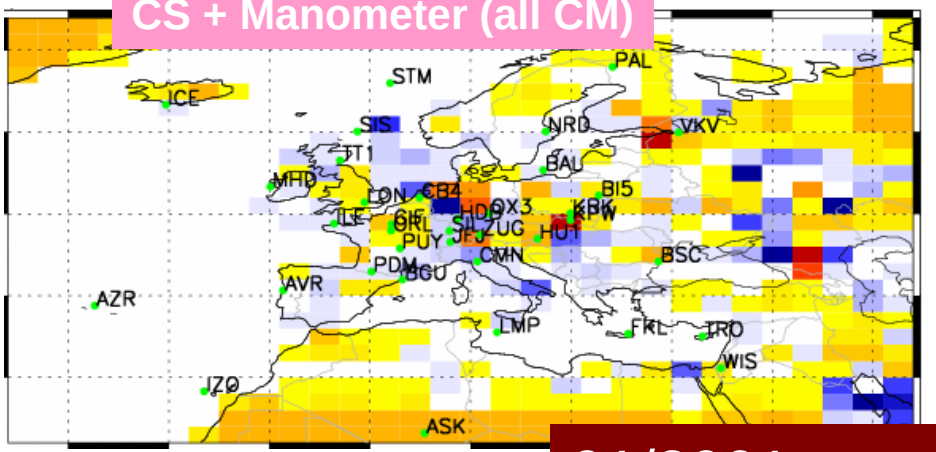

CS




CS + Manometer




CS + Manometer (all CM)

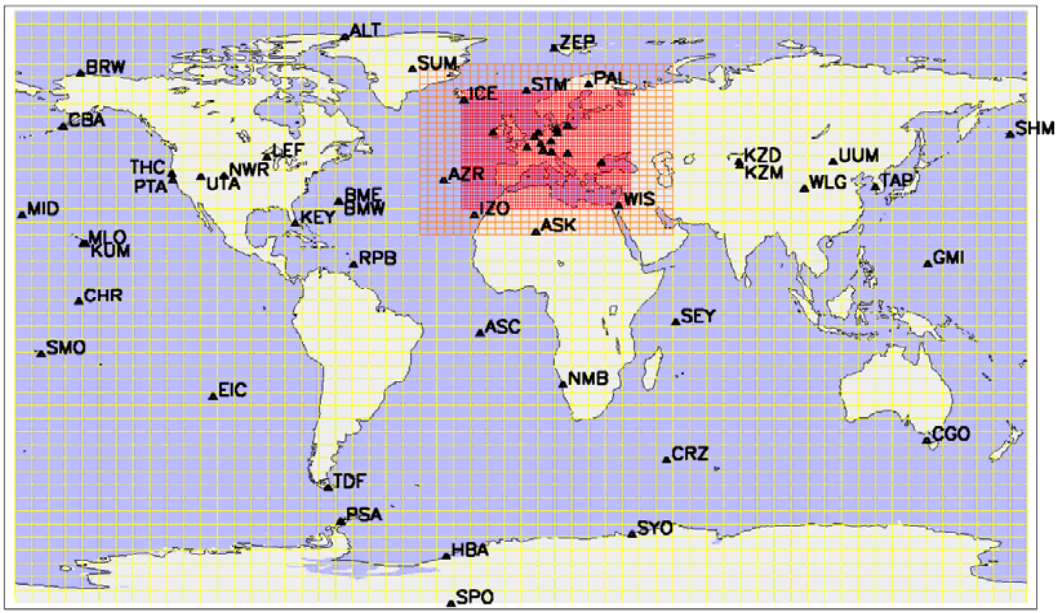


# Methodology: runs-planning



**TM5 runs :**

- year 2001
- ECMWF meteorology
- TM5 25 out of 60 vertical layers
- Global domain 6x4 deg + zoom over Europe (3x2 and 1x1 deg)
- one total source category



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# Methodology: TM5