EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

Institute for Environment and Sustainability

Joint Research Centre

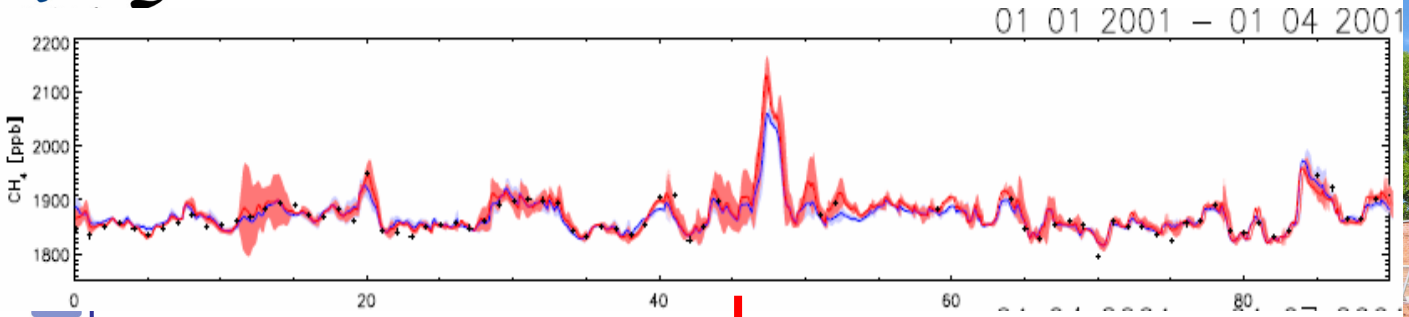
TM5-4DVAR inverse modelling system for atmospheric CH_4: Sensitivity of derived European emissions to observational network

UPDATE

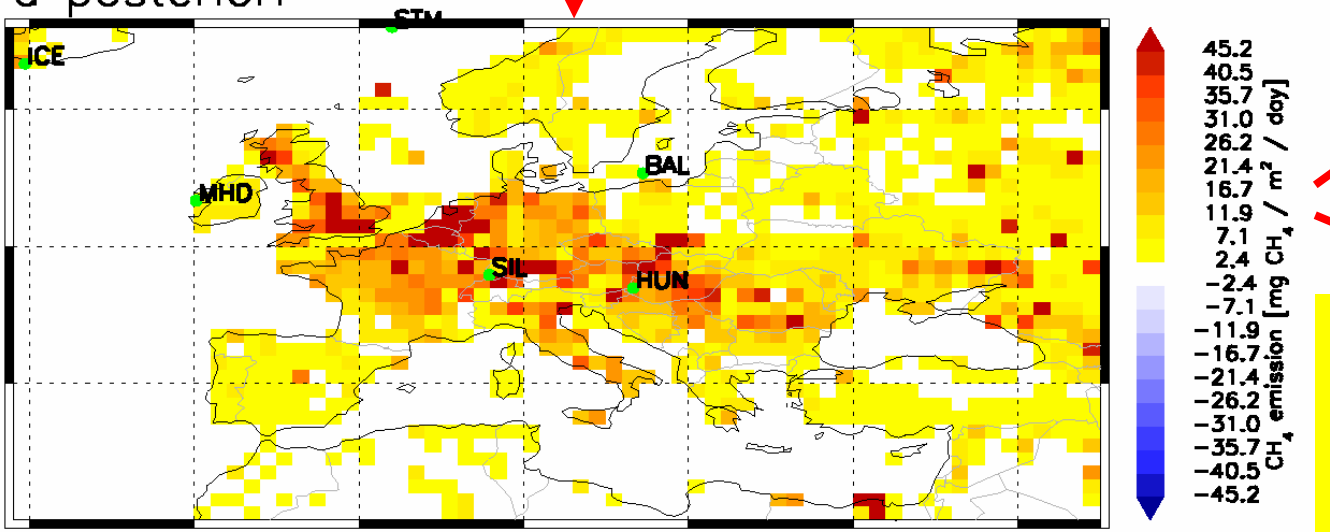
Maria Gabriella Villani[1]
Peter Bergamaschi[1]
Maarten Krol[3,4]
Jan Fokke Meirink[2]
Frank Dentener[1]

[1] European Commission Joint Research Centre, Institute for Environment and Sustainability, I-21027 Ispra (VA), Italy
[2] KNMI, The Netherlands
[3] Wageningen University and Research Centre, Wageningen, The Netherlands
[4] Netherlands Institute for Space Research, Utrecht, The Netherlands

basic principle + objective of inverse modelling



top down estimate of emissions



verification

Kyoto protocol

monitoring of global CH_4 cycle

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

Joint Research Cel

Objectives

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*

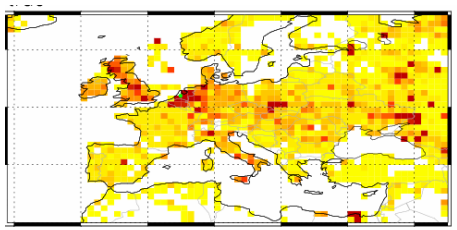
Methodology: Sensitivity Experiments

Sensitivity experiments use synthetic observations

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

CH_4 emissions inventories = 'true' emissions

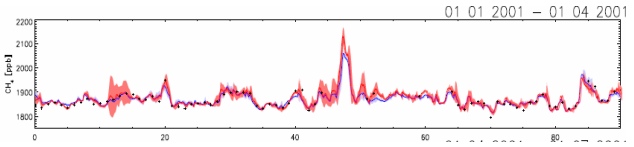
INPUT:



'true' CH_4 emissions

TM5-4DVAR
forward mode

OUTPUT:



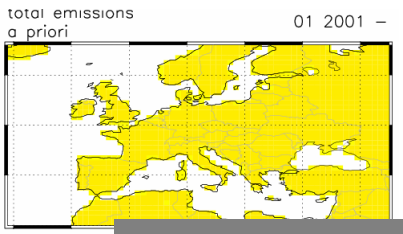
CH_4 concentrations

Methodology: Sensitivity Experiments

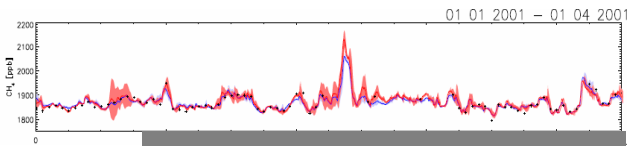
SECOND STEP: measurements are assimilated in model run

CH_4 a-priori emissions = spatially and temporally constant

INPUT:



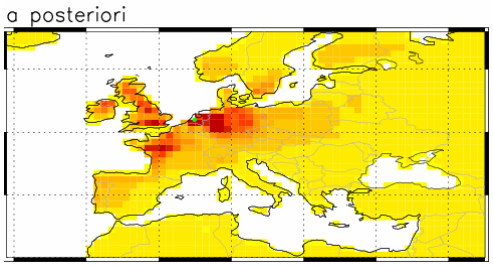
apriori/unknown CH_4 emissions



CH_4 concentrations

TM5-4DVAR
Inverse mode

OUTPUT:



derived/optimized CH_4 emissions

Experiments settings

Semi-linear version for TM5-4DVAR system (5 outer loops, 10 inner loops)

Year 2001: 01.01.2001-01.01.2002

CH_4 mixing ratios: initialized from previous inversion (based on real observations)

CH_4 monthly emissions: EDGAR3.2FT, GFEDv2..
One total source category (about 516 Tg CH_4/yr)

Spatial correlation for emissions: 50km
A priori uncertainty: 300%

Inversions performed in two cycles (<10% rejection)

Observational networks

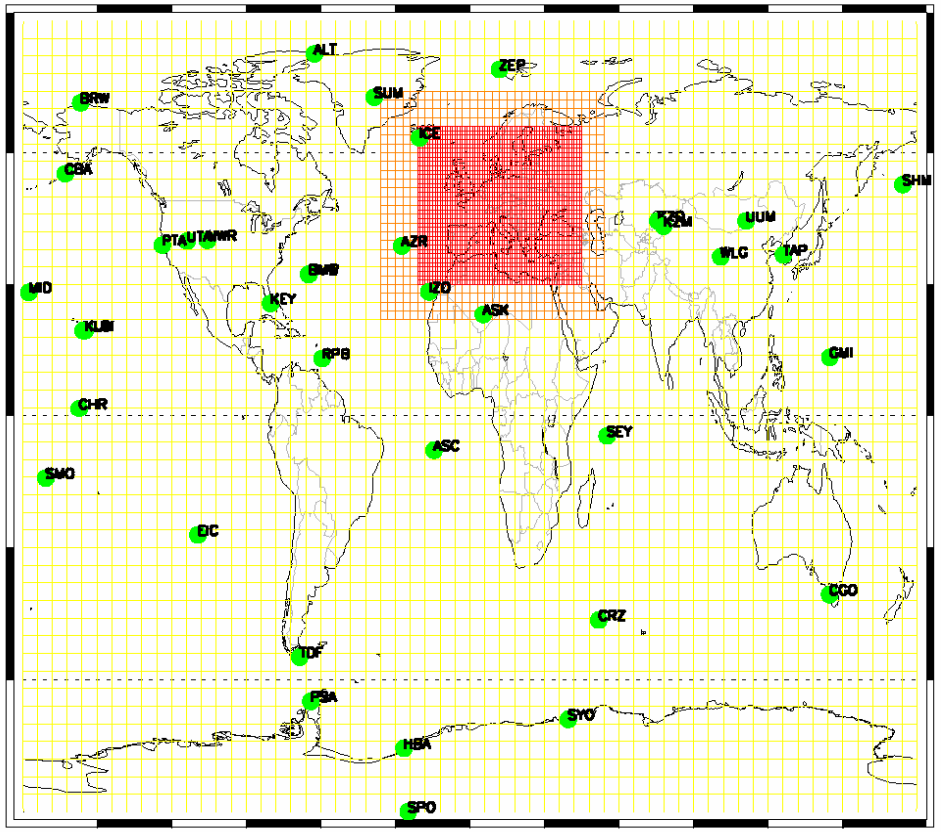
Institute for Environment and Sustainability

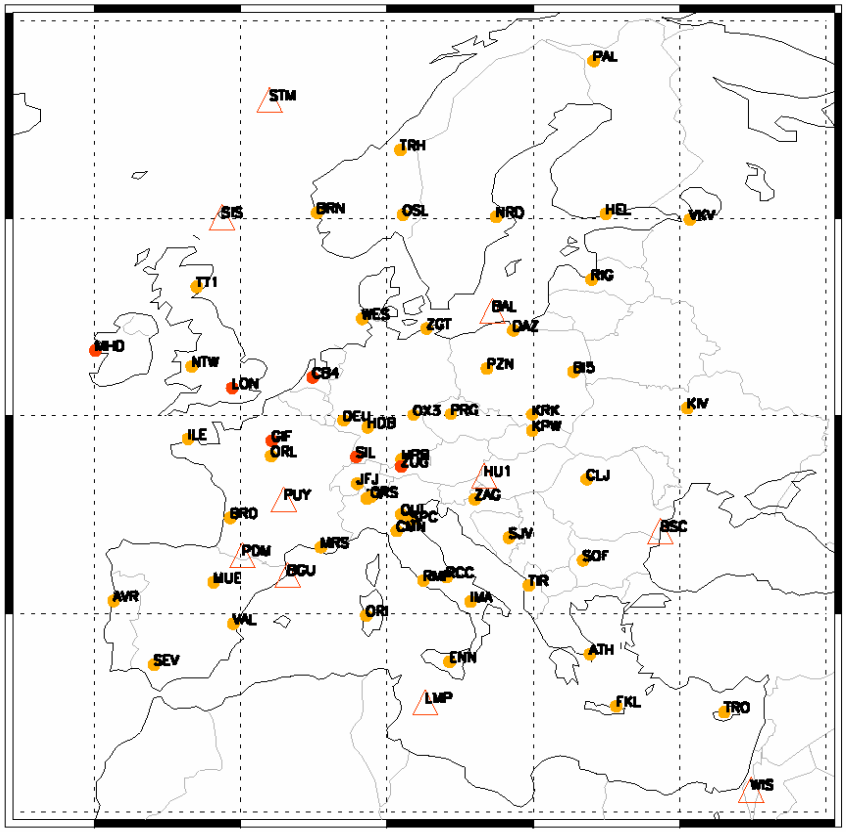
CCU

Joint Research Centre

Legend:

- Global background (flask)
- CS CM
- CS Flask
- EXTENDED (about 60 EU-sites)





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

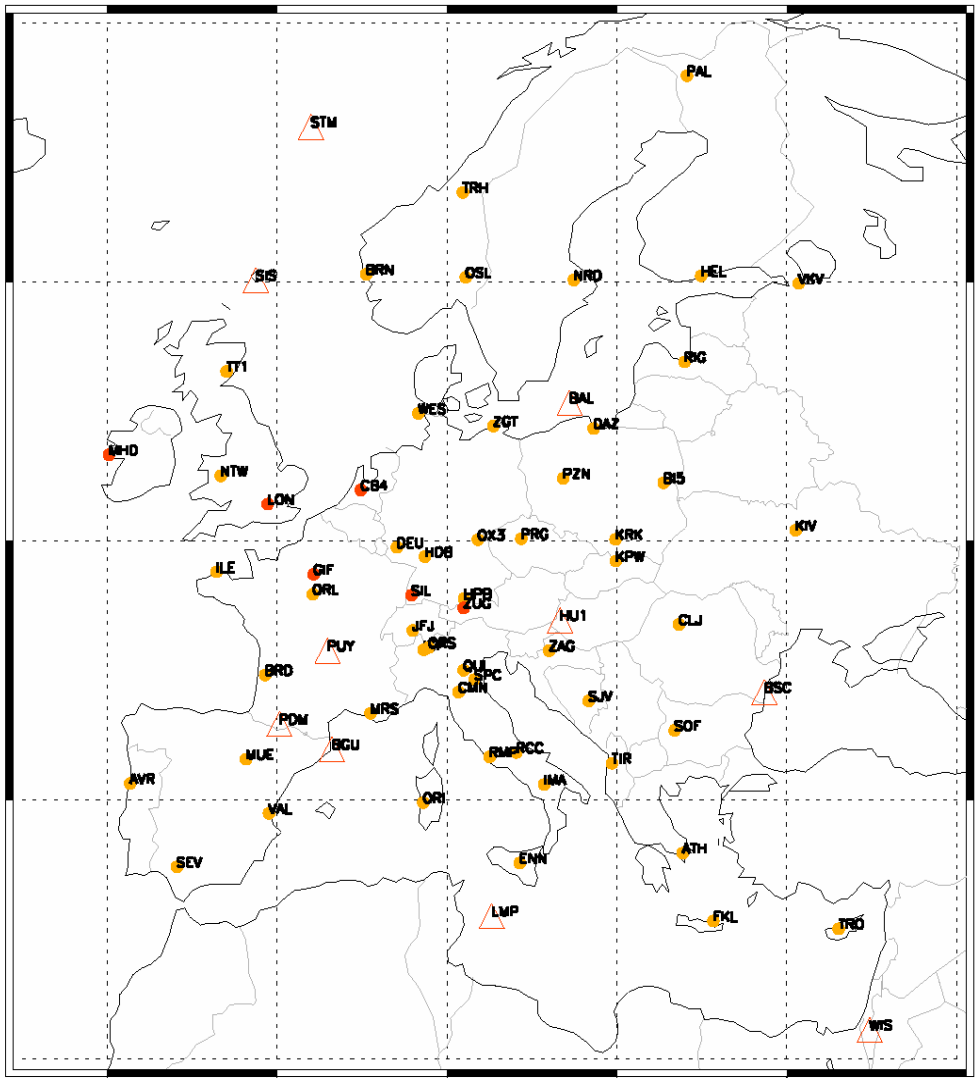
Perturbations:

- 0.5 "representativeness" error

EU-Observational Networks

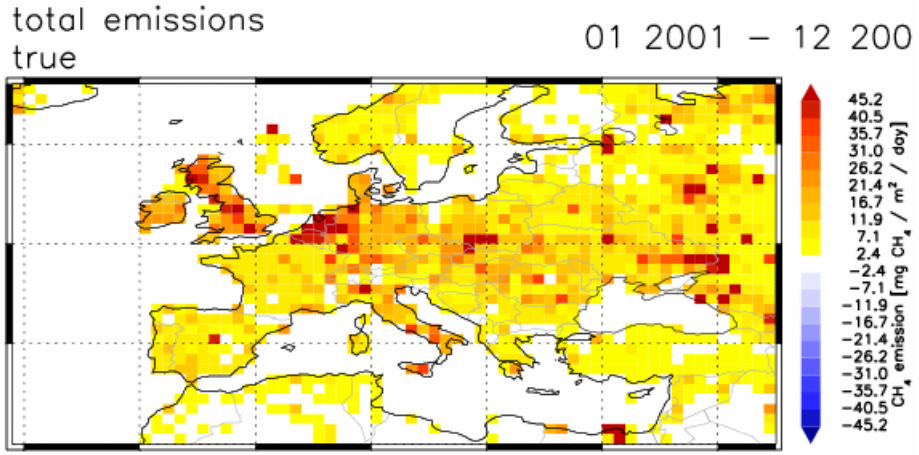
Datasets :

ID	Synth. Obs.	Name	symbol
S1	CS	“CS”	
S2	CS cont.	“CS-CM”	
S3	EXTENDED	“EXTENDED”	

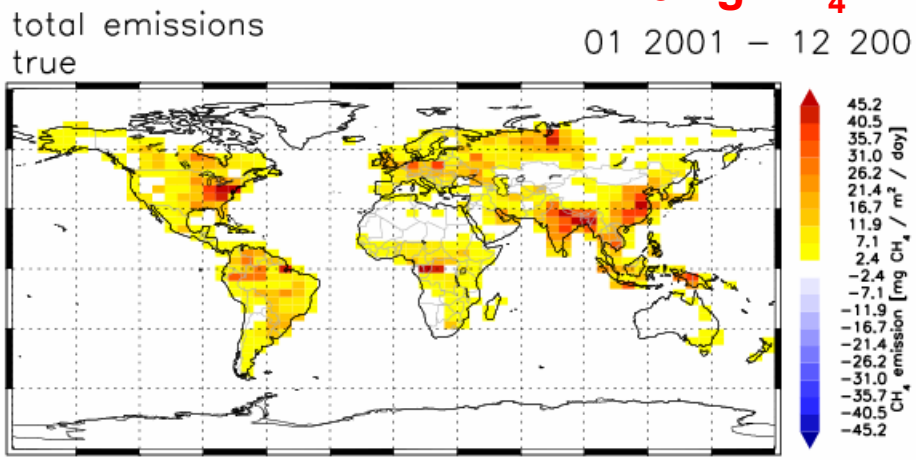


CH_4 Emissions

True emissions [forward run]

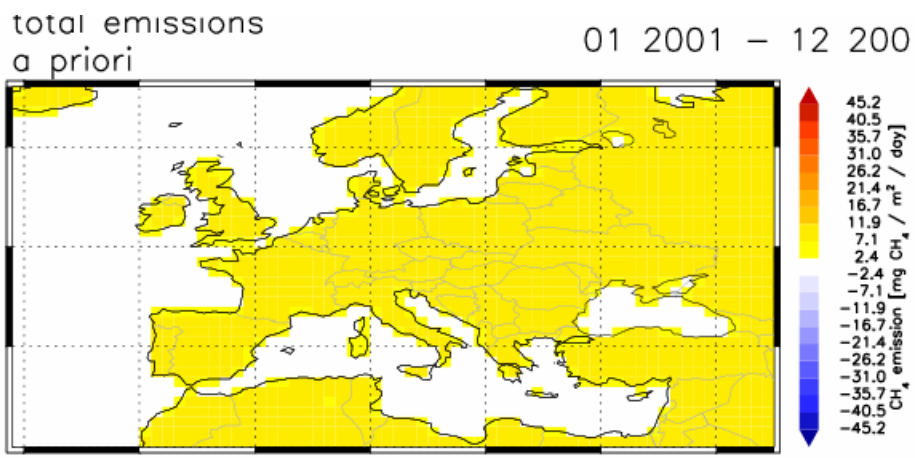


44.6 Tg CH_4

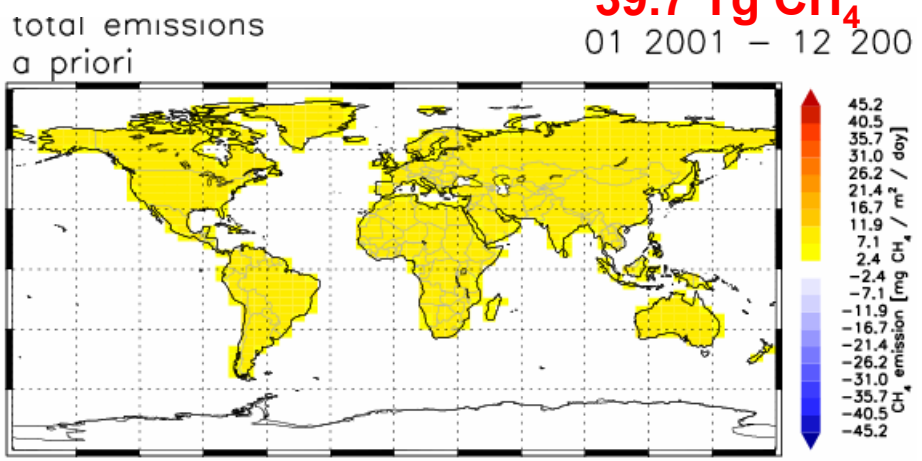


512.5 Tg CH_4

A priori emissions [4D-Var]



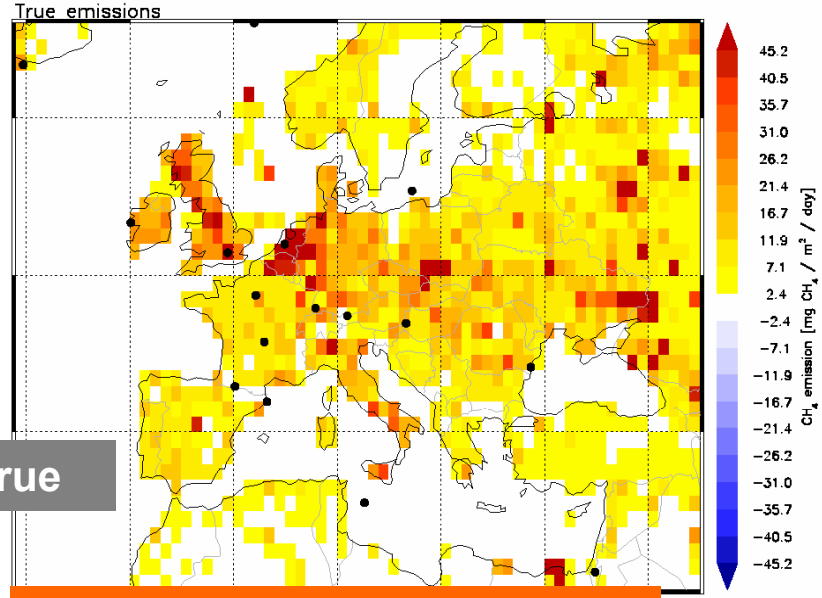
39.7 Tg CH_4



517.0 Tg CH_4

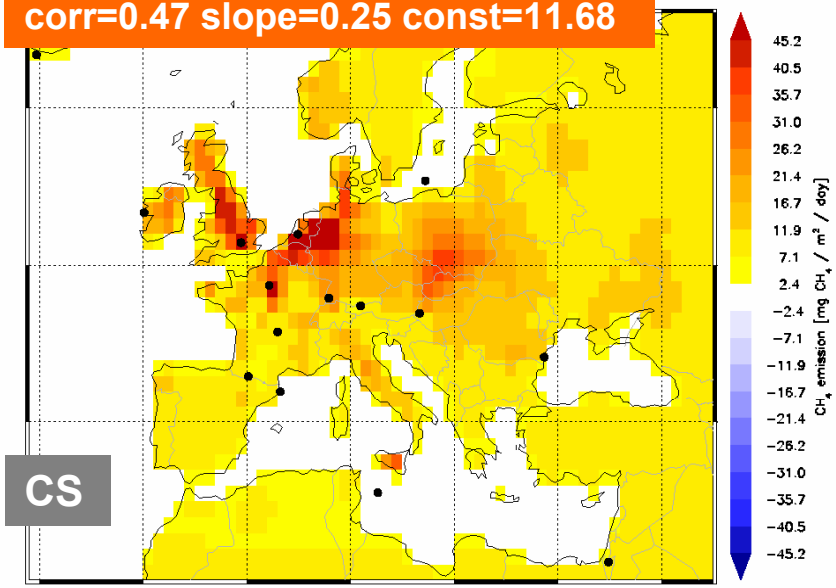
Derived CH_4 Emissions

True emissions



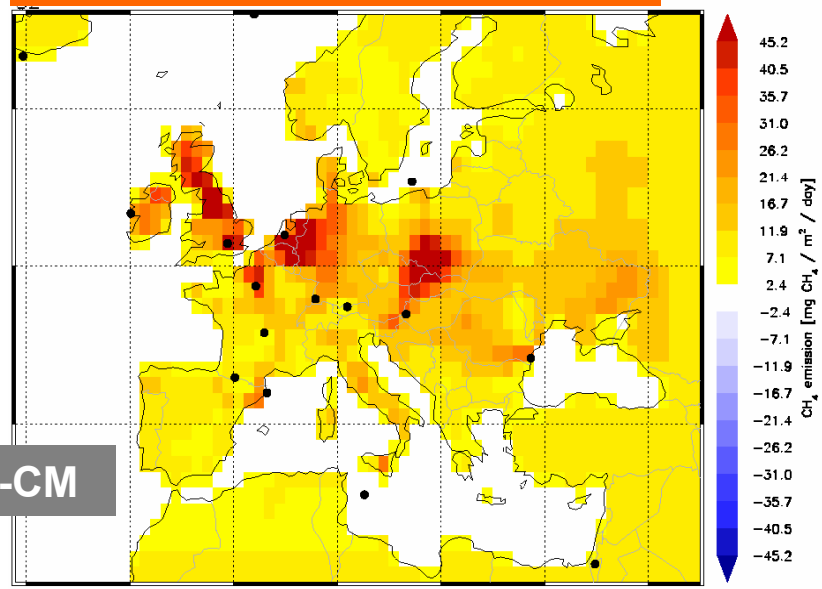
True

corr=0.47 slope=0.25 const=11.68



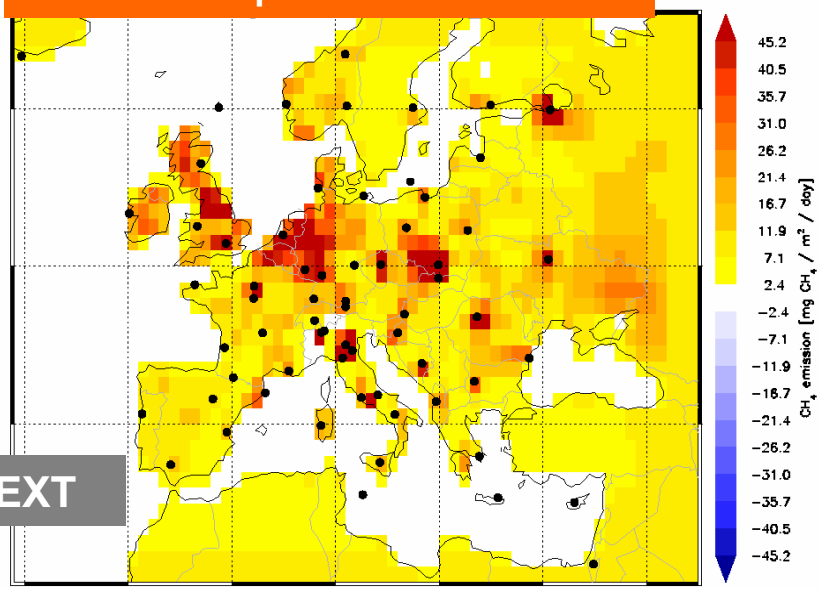
CS

corr=0.57 slope=0.33 const=10.01



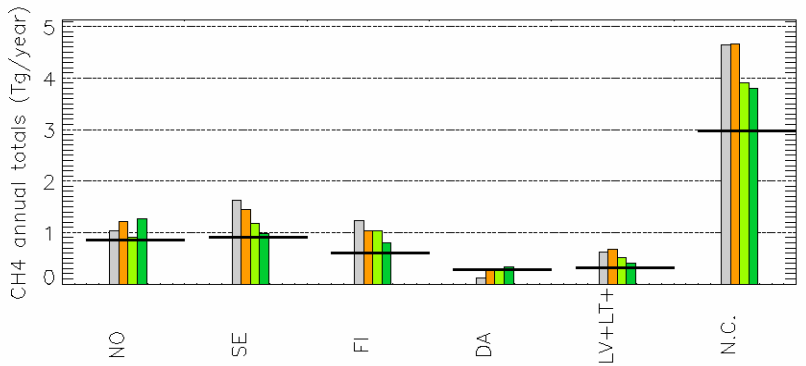
CS-CM

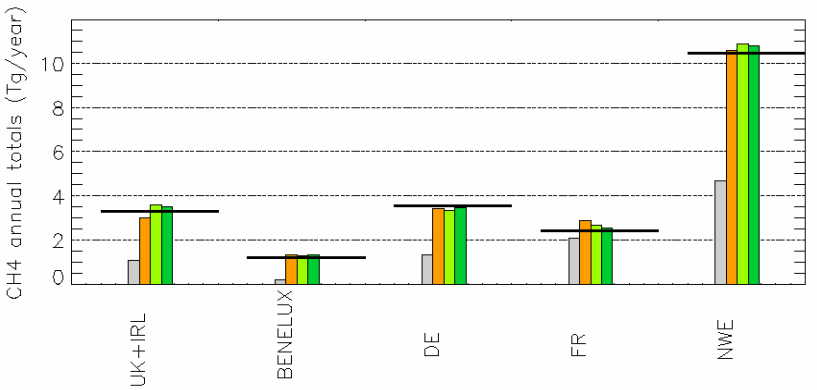
corr=0.74 slope=0.74 const=5.54

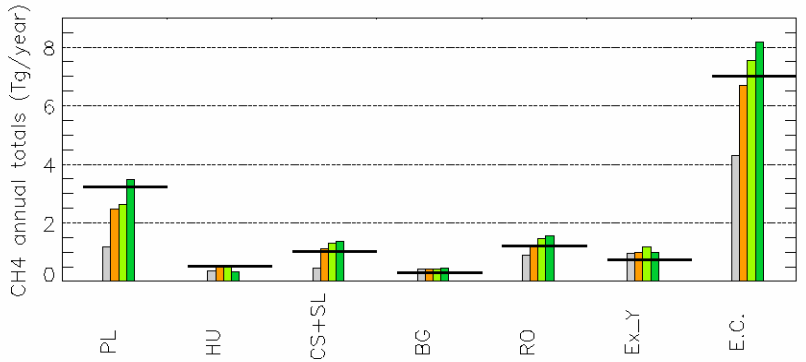


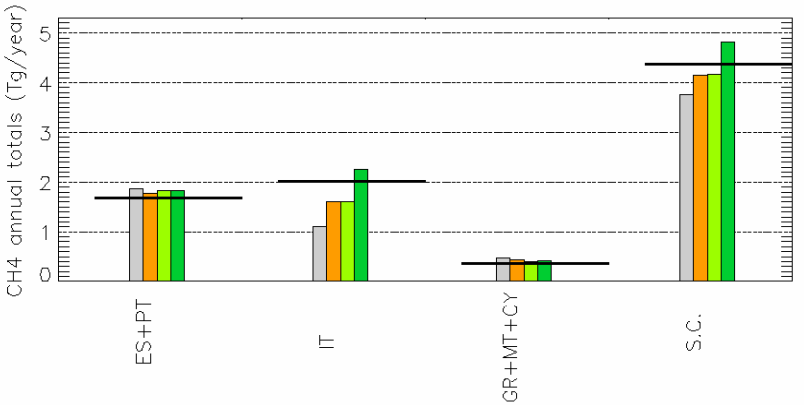
EXT

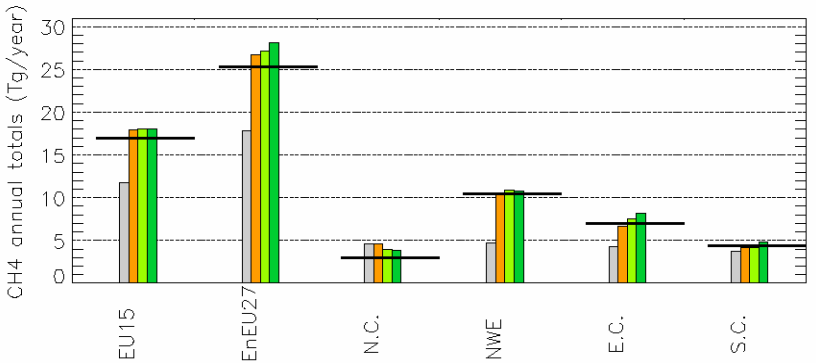
Derived CH_4 Emissions: Annual totals





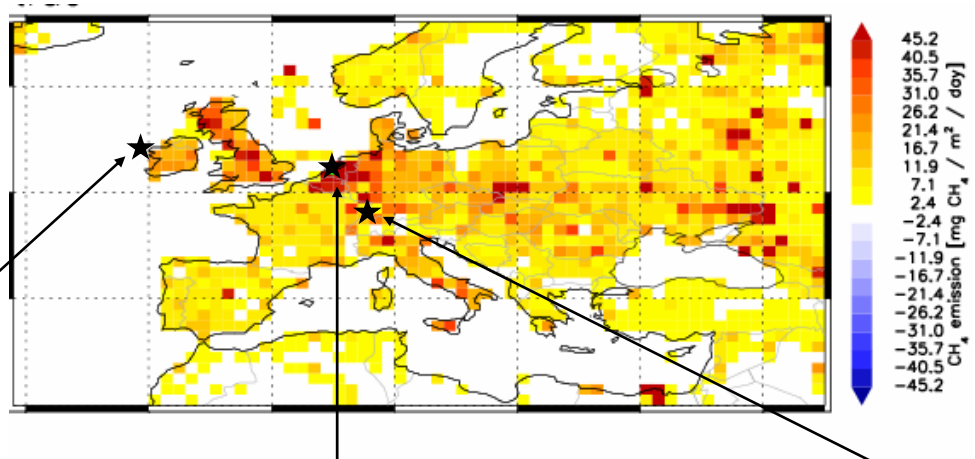






true:
apriori:
CS:
CS-CM:
EXT:

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

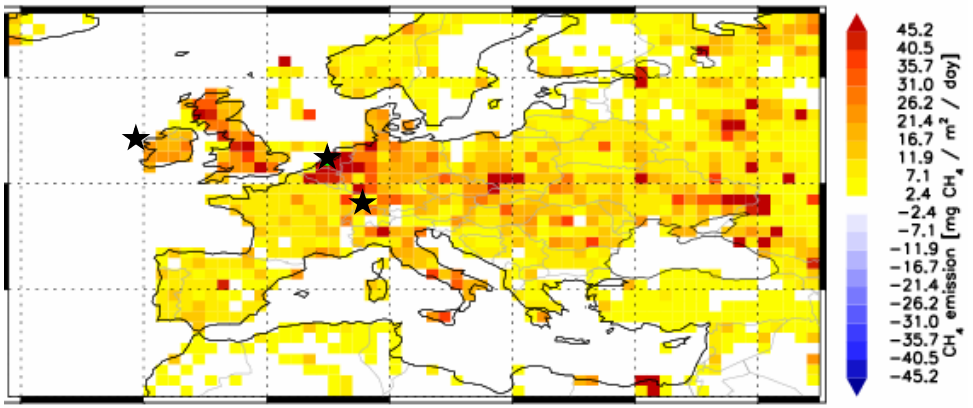
EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

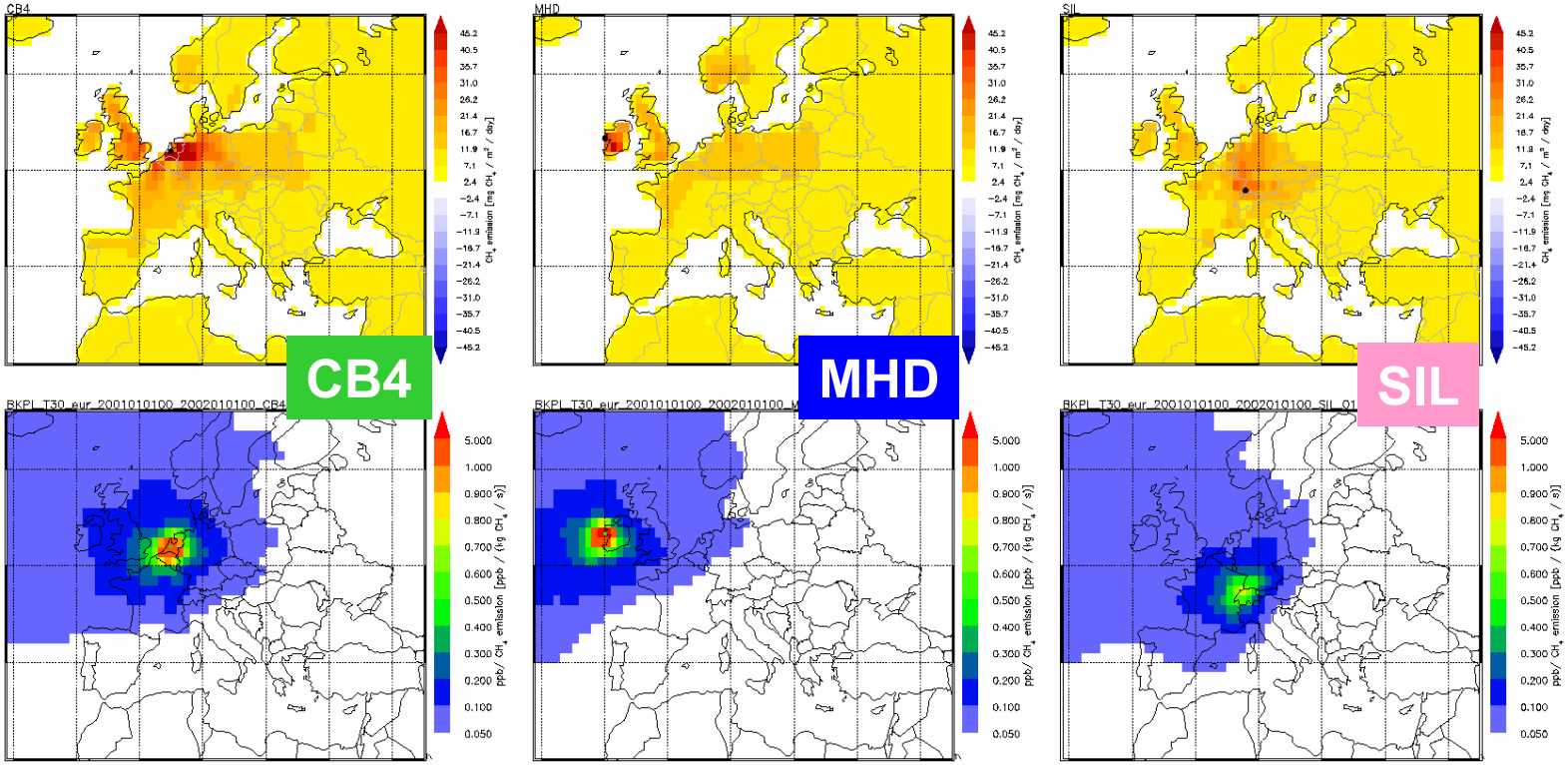
Institute for Environment and Sustainability

CCU

Joint Research Centre

Influence of Station Locations





Conclusions

-CS network constrain the NWE sector satisfactorily:

-UK, the BENELUX, France, and Germany (<20%)

-Scandinavian regions , Southern Europe and Eastern Europe not adequately captured.

-CS-CM network:

-Better regional pattern retrieved for Northern and Central Europe

-Better representation for Scandinavian Countries

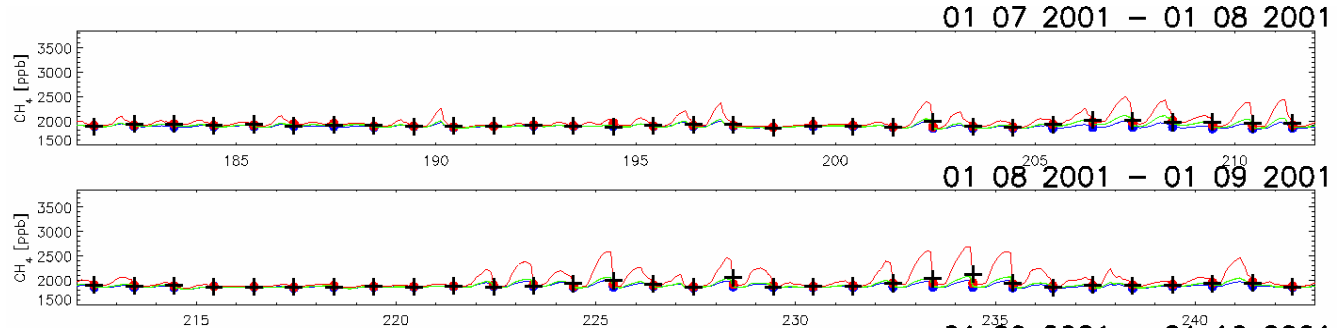
-Extended network:

-Major improvement for emission patterns in Southern and Eastern Europe (e.g. for Italy and Poland)

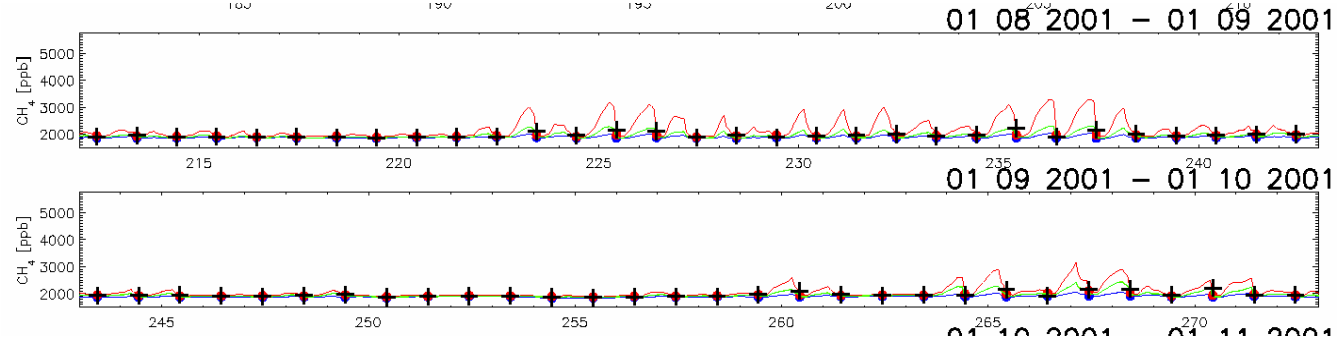
-For some countries derived total emissions worse than in CS-CM scenario

-> ***Need to investigate on this....***

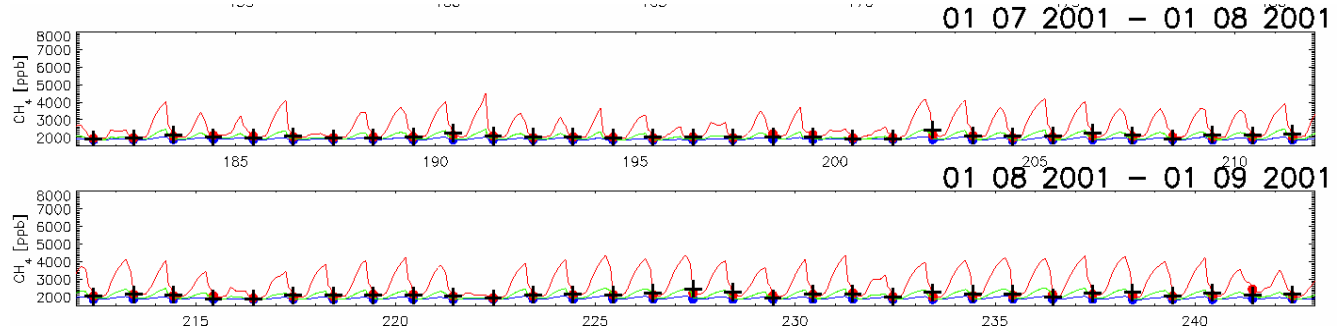
.... Suggestions .. 4DVAR semilinear version?



Saclay

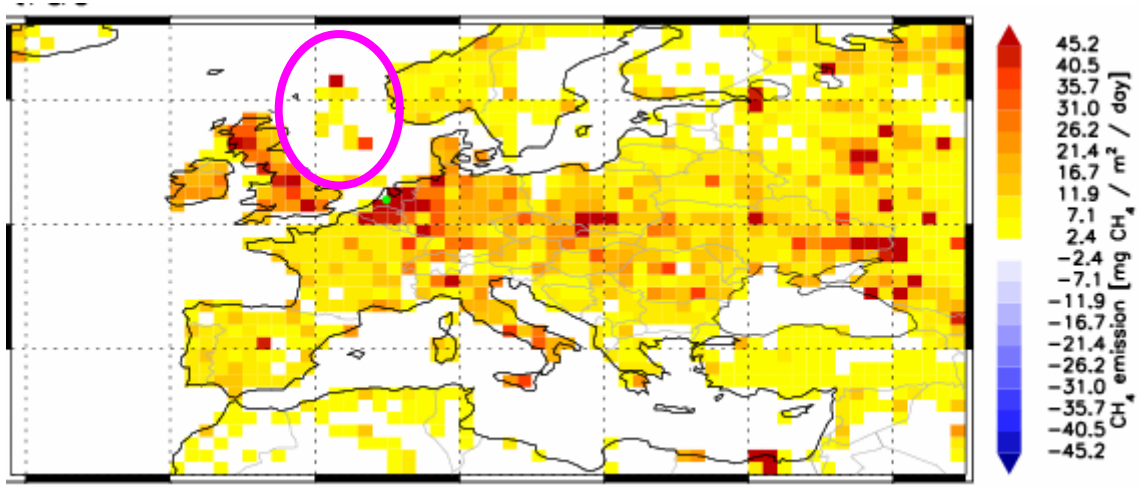


Heidelberg



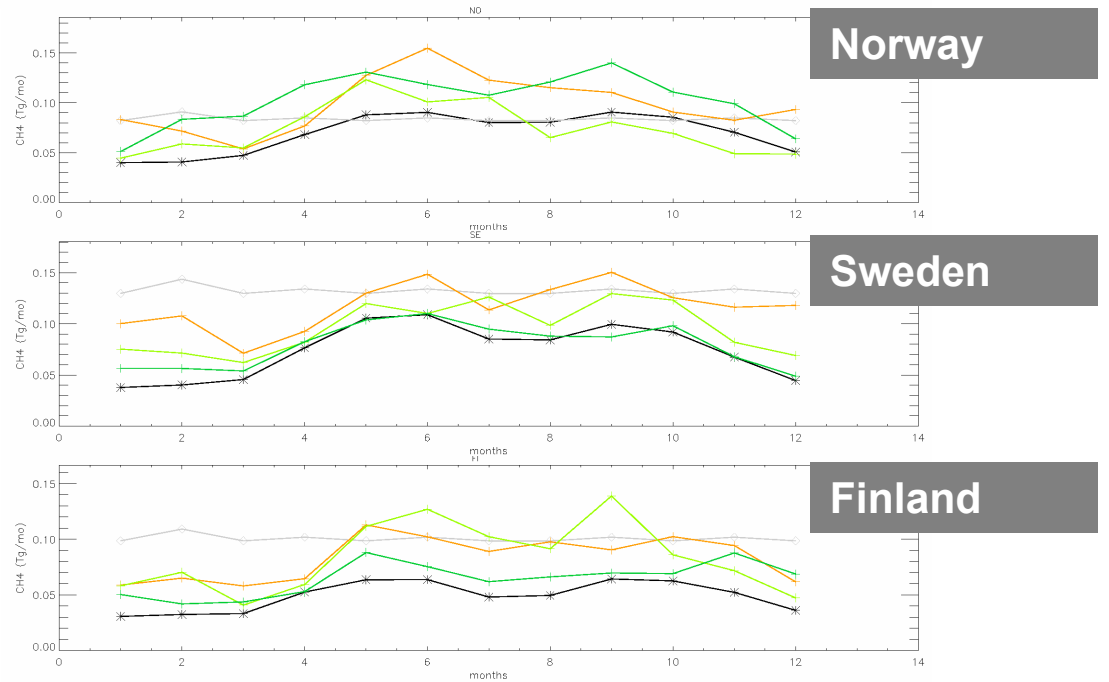
Ispra

... Suggestions .. Emissions over Sea?



Emissions over Sea

true:
apriori:
CS:
CS-CM:
EXT:



End of the presentation

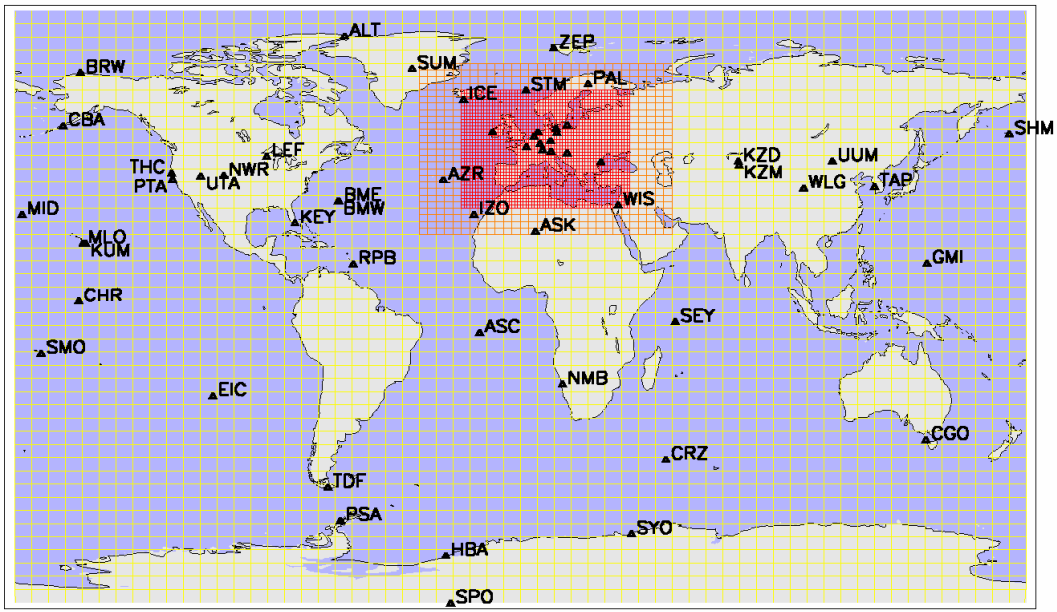
Experiments settings: source categories

source category	Reference	emission [Tg CH_4/yr]
'wetlands and rice'		
wetlands	'JK' inventory [*Bergamaschi et al.*, 2007] [b]	174.9
rice	GISS [*Matthews et al.*, 1991]	59.7
'biomass burning'		
biomass burning	GFEDv2 [*van der Werf et al.*, 2004]	20.1
'remaining sources'		
coal mining	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	33.2
oil production, transmission and handling	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	10.4
gas production and transmission	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	48.7
fossil fuel use	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	3.4
industrial processes	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	0.9
bio fuel	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	14.9
enteric fermentation	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	80.4
animal waste management	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	8.5
waste handling	EDGARV3.2FT [*Olivier and Berdowski*, 2001] [a]	58.1
wild animals	[*Houweling et al.*, 1999]	5.0
termites	[*Sanderson*, 1996]	19.4
ocean	[*Houweling et al.*, 1999; *Lambert and Schmidt*, 1993]	17.0
soil sink	[*Ridgwell et al.*, 1999]	-38.0
total		**516.5**

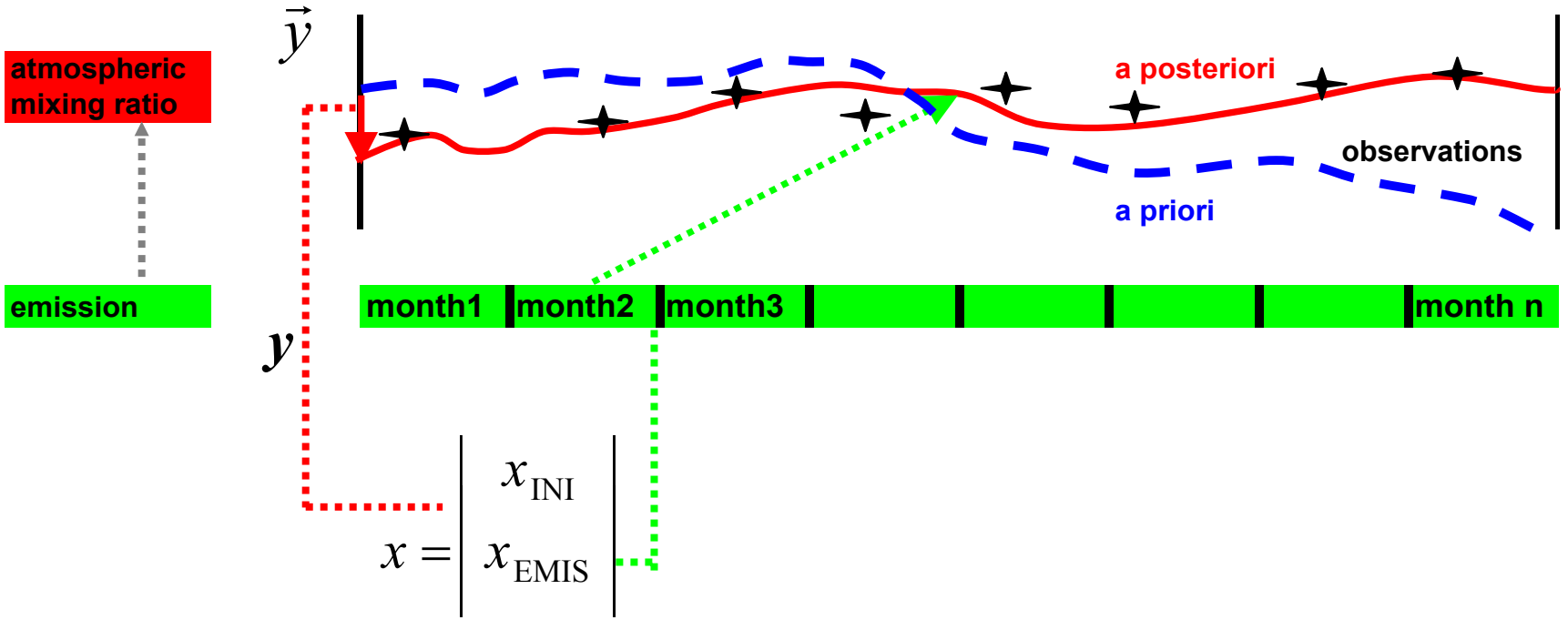
Methodology: runs-planning

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



TM5-4DVar inverse modeling system



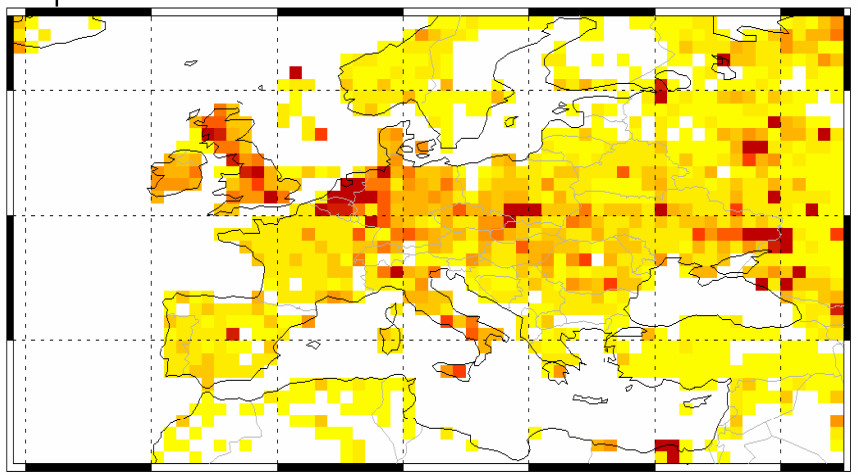
Here we use the semi-linear version of the TM5-4DVAR system

linear vs. non-linear: emissions

VAR_T30_25L60_tmppod_eur. **linear 4DVAR** 0201

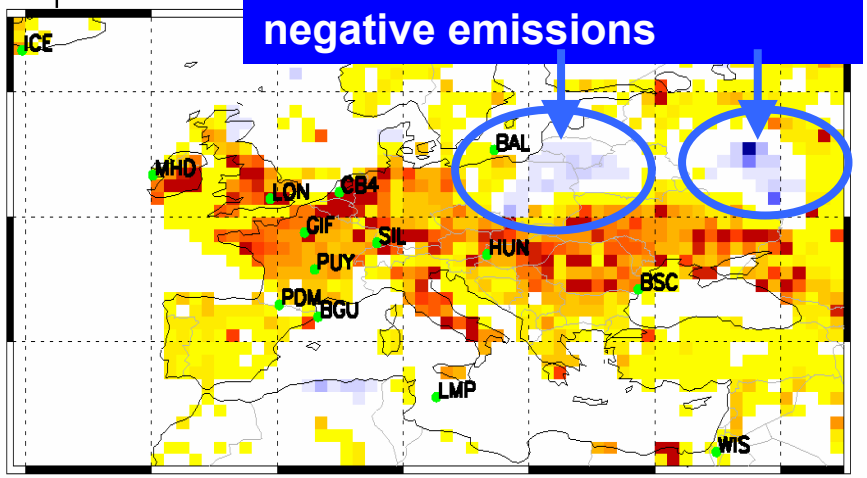
total emissions
a priori

01 2001 – 12 2001



a posteriori

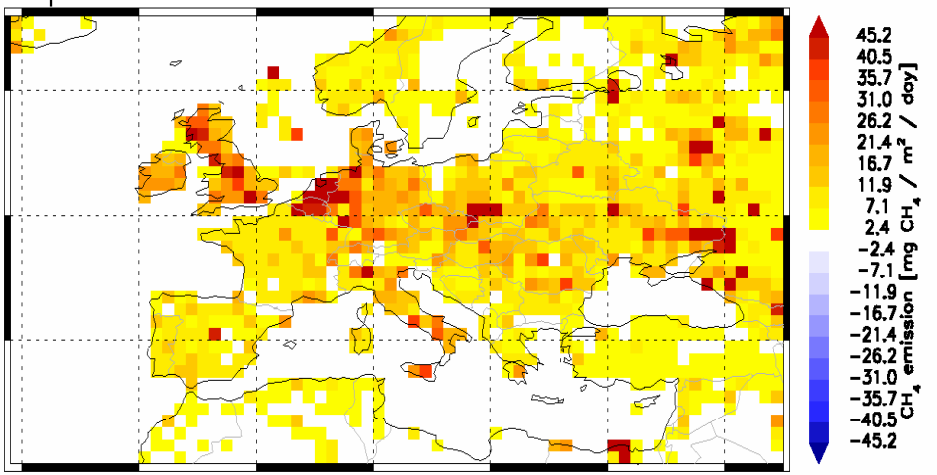
negative emissions



VAR_T30_25L60_tmppod_ **non-linear 4DVAR** 20201

total emissions
a priori

01 2001 – 12 2001



a posteriori