InGOS

Integrated non-$CO_2$ Greenhouse gas Observing System

# Verification of non-$CO_2$ greenhouse gas emissions of Europe

## Capabilities of the current and future surface network

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InGOS modellers, InGOS station PI's

Lund University

ICOS Carbon Portal

ECN

# InGOS network and project

- EU FP7 Integrating Activity 2012-2015
- Focus on non-$CO_2$ Greenhouse Gases
  - Networking activities: historic and nrt time series
  - Access to facilities: visits, campaigns, database, analysis services, airborne facility
  - Research activities: instruments, model improvement
- 38 institutes, 15 countries, 24 observatories
- Strong links with ICOS
- Work in progress…

http://www.ingos-infrastructure.eu

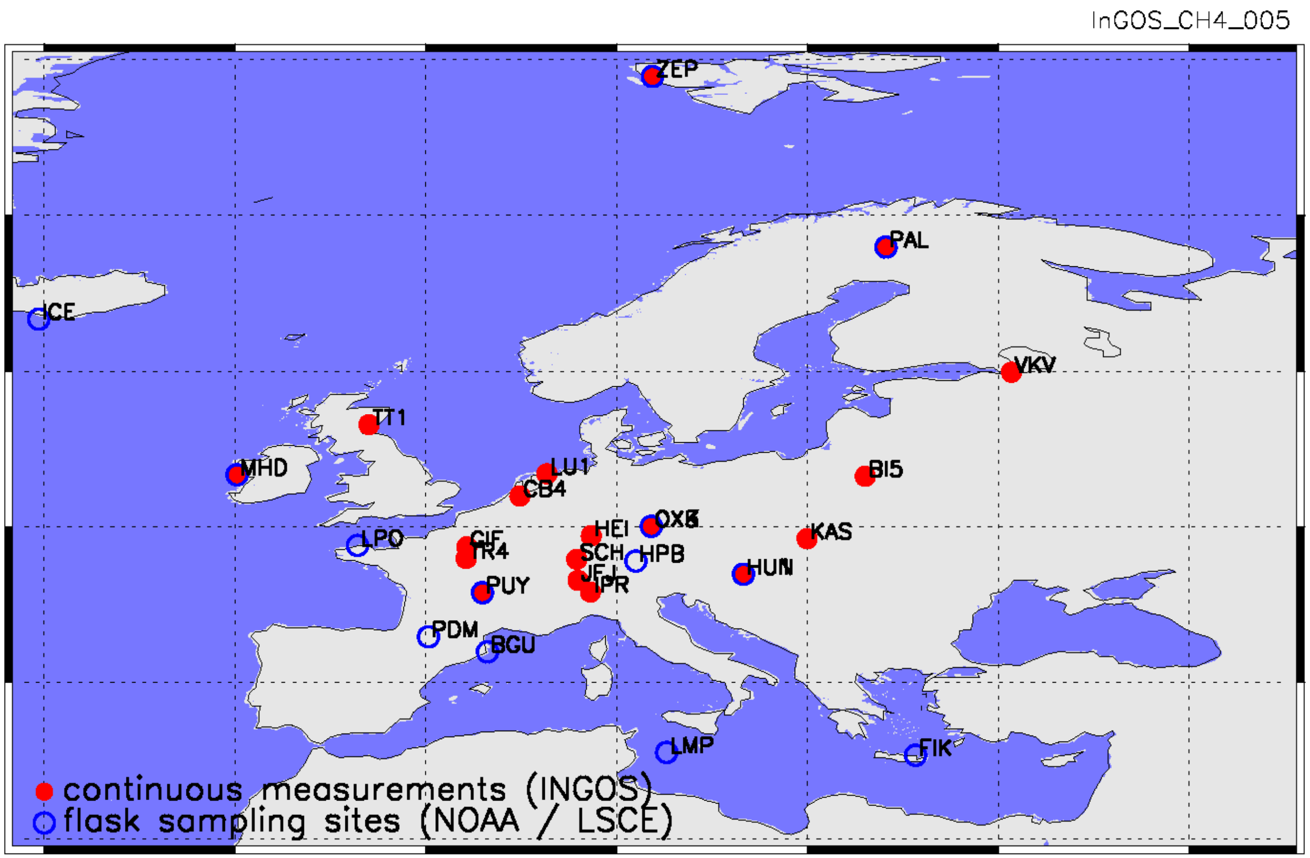
# Emission verification potential

- Climate change is real and does not go away
- GHG emission reductions needed
  - 100% by 2100
  - 30-70% by 2050
- Independent emission verification at country/state scale needed to check progress
- We cannot manage what we do not measure…
- Baseline observations needed now
- Model+Network development until 2020-2030
- Commitment period 2030-2050: systems ready

# Start with $CH_4$ and $N_2O$; $CO_2$ later

- Easier case for EV: Emission less variable in time and space than for $CO_2$
- Variation above background comparable to $CO_2$ (5-10%)
- Dense European network of continuous surface observations
- Long time series starting early '90s
- Also important for GHG reductions, $CH_4$ fast effect, $N_2O$ also major ODS
- 'Ideal' tests for (systematic) model transport errors

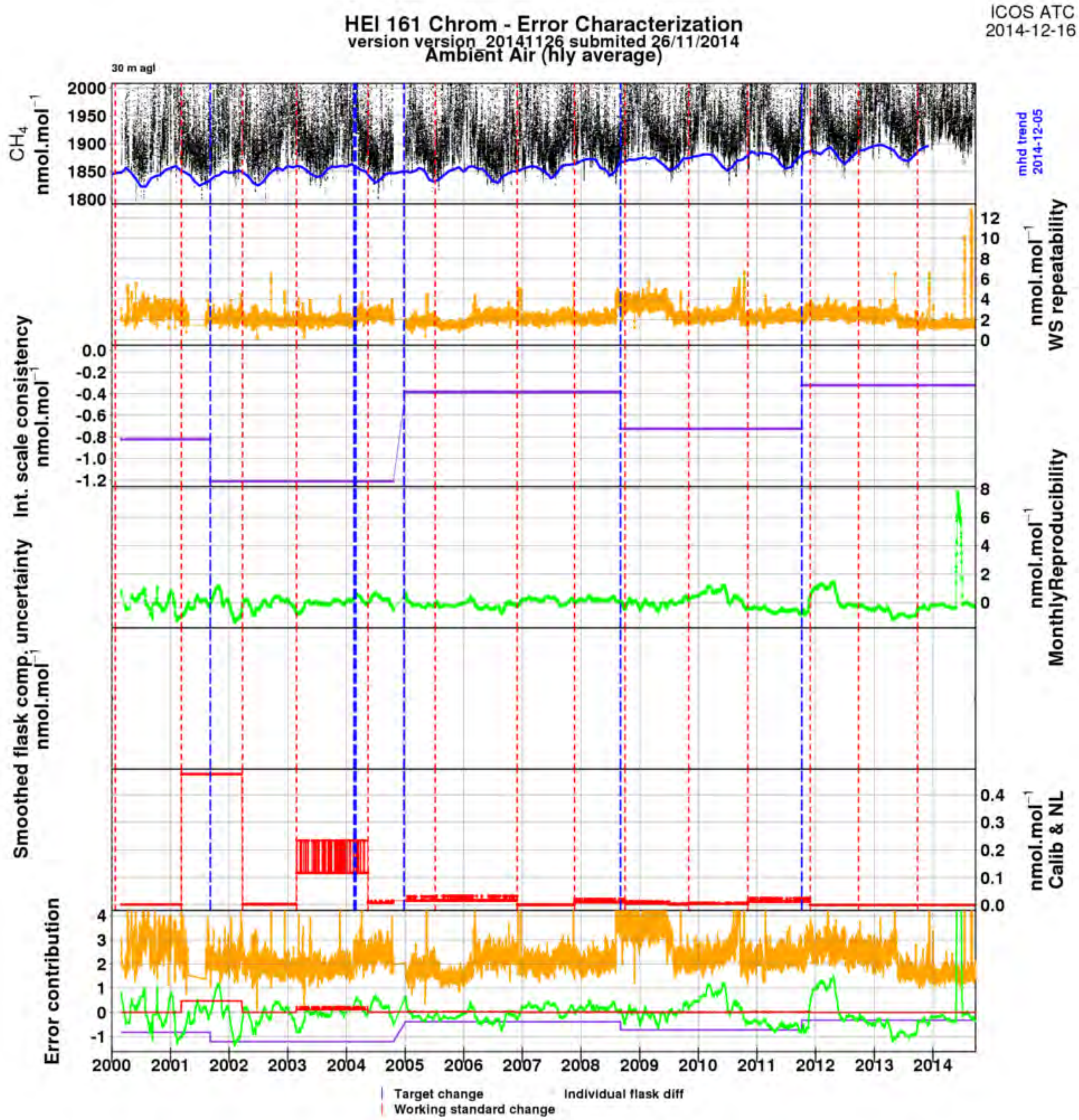
# Historic Data




- 24 stations, some co-located with NOAA flasks

# Re-analysis of observation data

- GC-data: check/reprocess chromatograms
- Fix to current WMO calibration scale
- Re-assess precision with target measurements
- (Re)do drift corrections with surveillance target
- Assess scale transfer errors, uncertainty associated with non-linearity


HEI 161 Chrom - Error Characterization
version version_20141126 submited 26/11/2014
Ambient Air (hly average)
ICOS ATC
2014-12-16
30 m agl
CH4 nmol.mol-1
mhd trend 2014-12-05
nmol.mol-1 WS repeatability
Int. scale consistency nmol.mol-1
nmol.mol-1 MonthlyReproducibility
Smoothed flask comp. uncertainty nmol.mol-1
nmol.mol-1 Calib & NL
Error contribution
Target change
Working standard change
Individual flask diff
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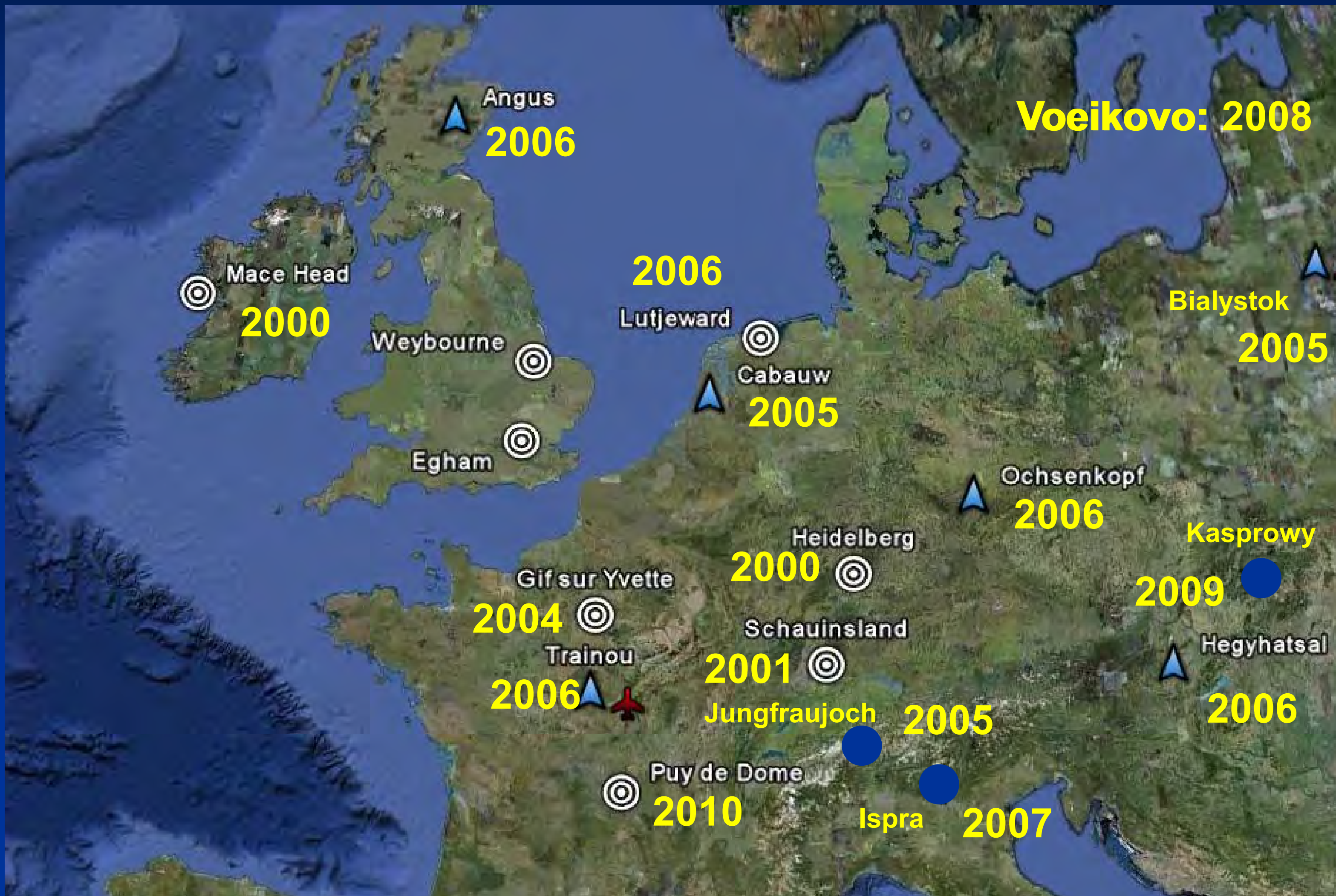
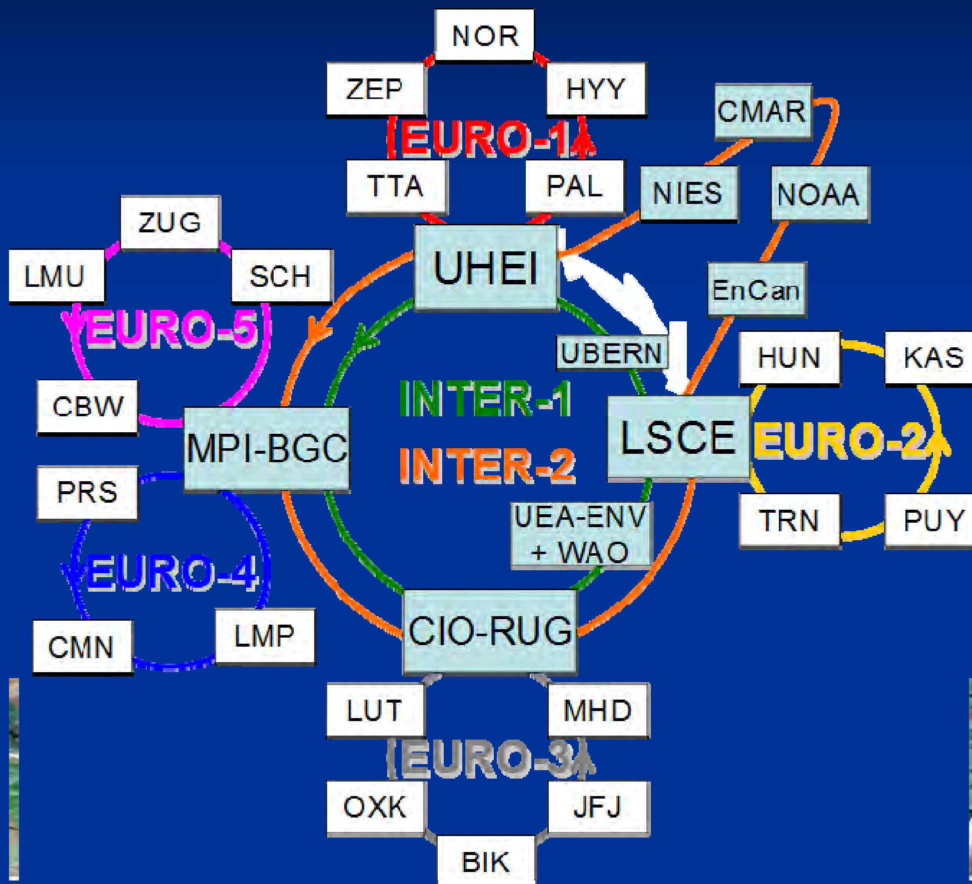
# Current availability of continuous $CH_4$ observations in Europe

**Zeppelin: 2001** **Pallas: 2004**




**Lampedusa: 2006**

# QC: intercomparisons




- **66** authors (on the AMT paper)
- **23** *in situ* atmospheric field stations in Europe.
- **11** measurement laboratories.
- **34** organisations.
- **16** countries.
- **9** atmospheric species' compatibility assessed.
- **9+** years of intercomparison measurements.
- **21** high pressure cylinders (Cucumbers) in **7** loops of **3** Cucumbers each.
- **405** graphs on the website.

Manning et al, AMTD, in preparation

Dedicated website: http://cucumbers.uea.ac.uk/

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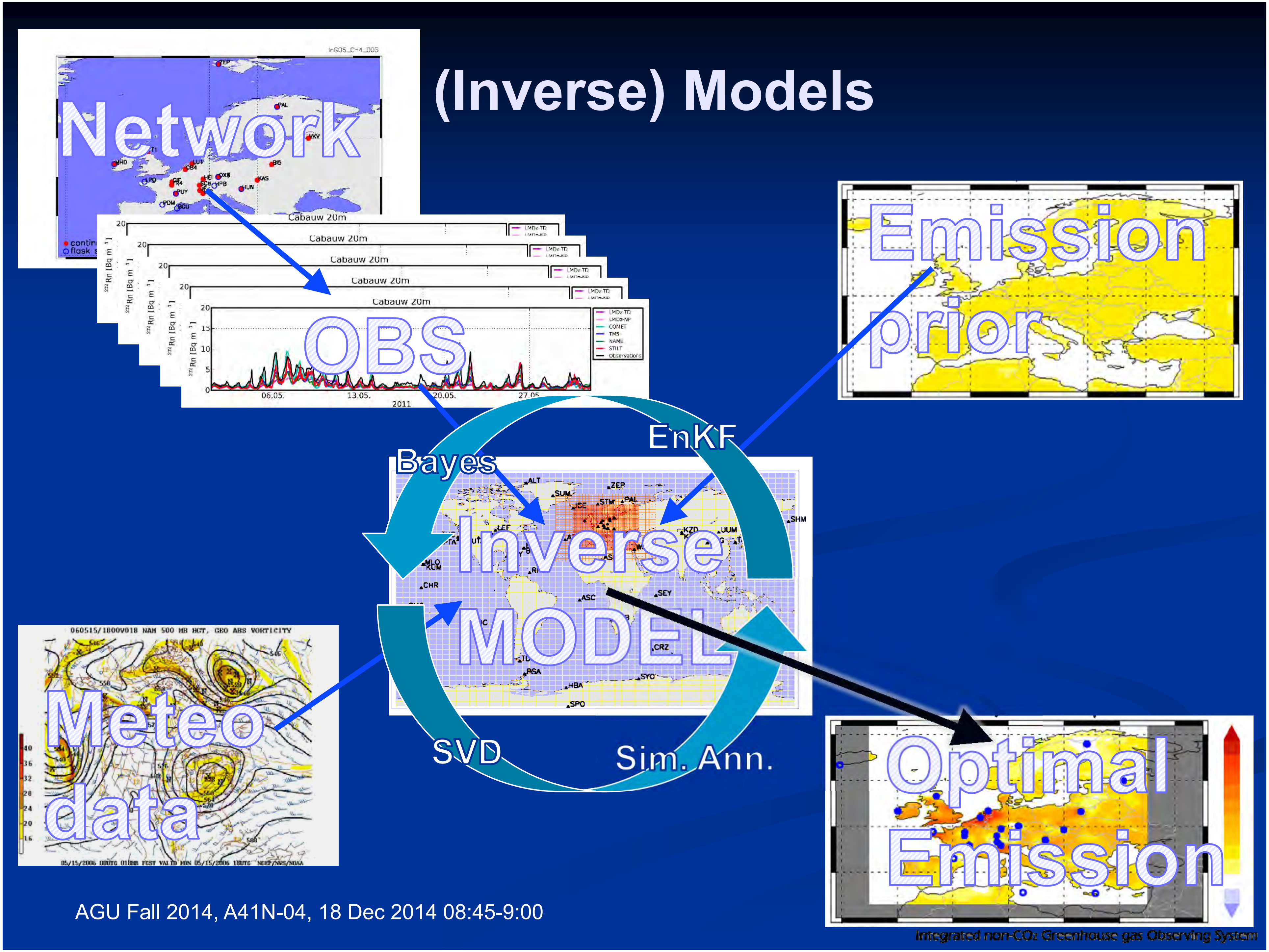
(Inverse) Models
Network
OBS
Cabauw 20m
Emission prior
EnKF
Bayes
Inverse MODEL
Meteo data
SVD
Sim. Ann.
Optimal Emission
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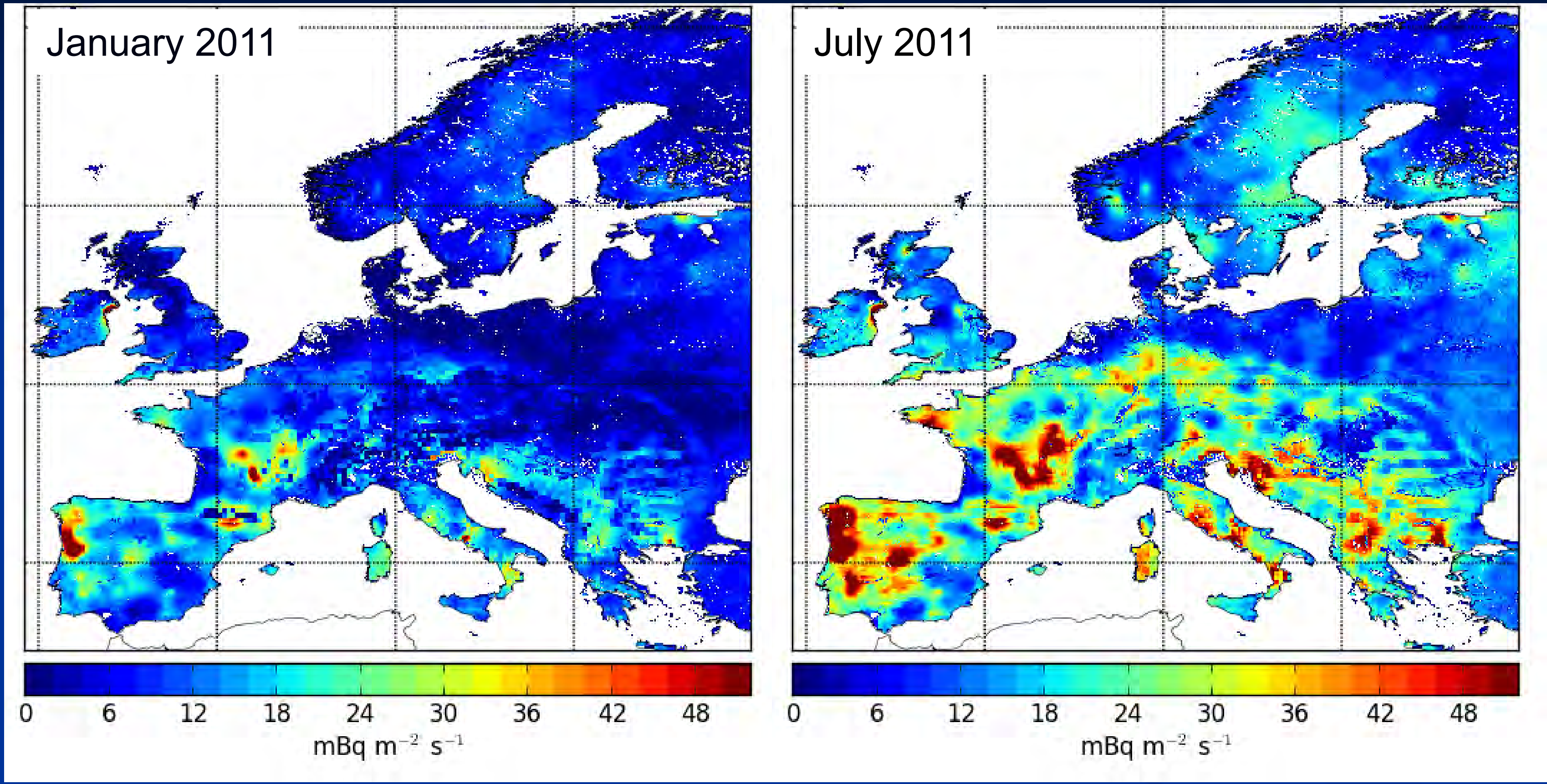
# InGOS model simulations

| Model | Institute | Resolution horizontal | Resolution vertical | Meteo. Re-analysis | $^{222}$Radon Time range | $^{222}$Radon res. | Mixing Height Time range | Mixing Height res. | |
|---|---|---|---|---|---|---|---|---|---|
| STILT | MPI-BGC | 0.25° x 0.25° | 20 lev. < 5km | ECMWF | 2007-2011 | 1 hr | 2006-2011 | 1 hr | Europe |
| NAME | MET | 0.35° x 0.23° | 34 lev. < 8km | Unified Model | 2011 | 2 hrs | 2006-2011 | 1 hr | Europe |
| COMET | ECN | 1° x 1° | 2 in dyn.PBL | ERA-Interim | 2006-2012 | 1 hr | 2006-2012 | 1 hr | Europe |
| TM5 | JRC-IES | 1° x 1° (Europe) | 25 lev. | ERA-Interim | 2006-2011 | 1 hr | 2006-2011 | 3 hrs | Europe |
| LMDz-TD<br>LMDz-NP | LSCE | 3.75° x 1.875° | 39 lev. | ERA-I (nudged) | 2006-2011 | 1 hr | 2006-2011 | 3 hrs | global |

- Eulerian and Lagrangian transport models
- Mixing height inferred from meteorological reanalysis or computed online

# InGOS $^{222}$Radon flux map

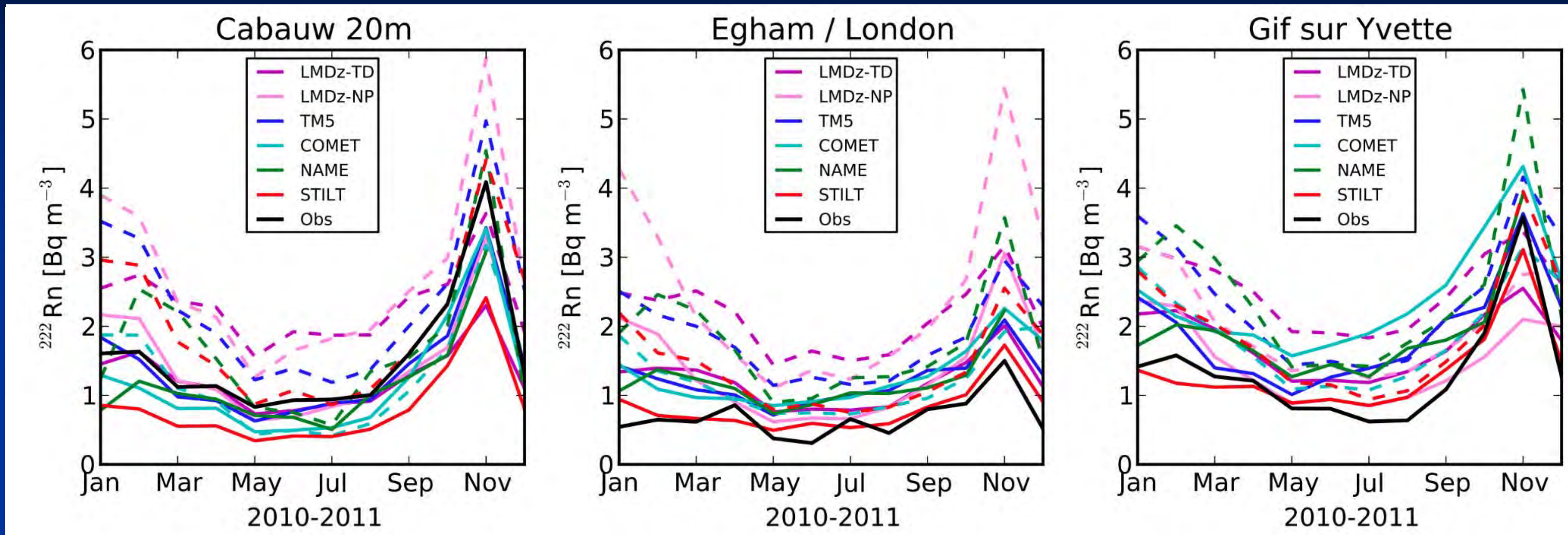


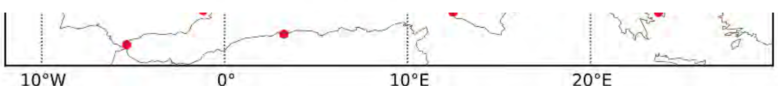

- Radon source ~ Uranium content
  Geochemical Atlas of Europe (2005)
- Soil texture, porosity (Reynolds et al., 2000)
- Soil moisture
  (Noah LSM, GLDAS Land Data Assimilation (Rodell et al., 2004)

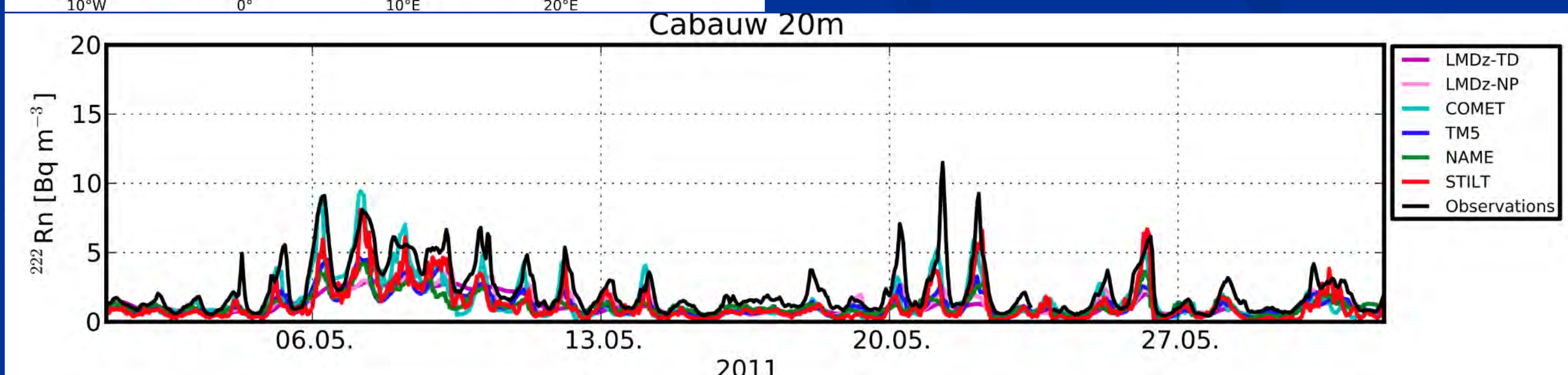
spatial variations

temporal variations

# $^{222}Rn$ measurement network

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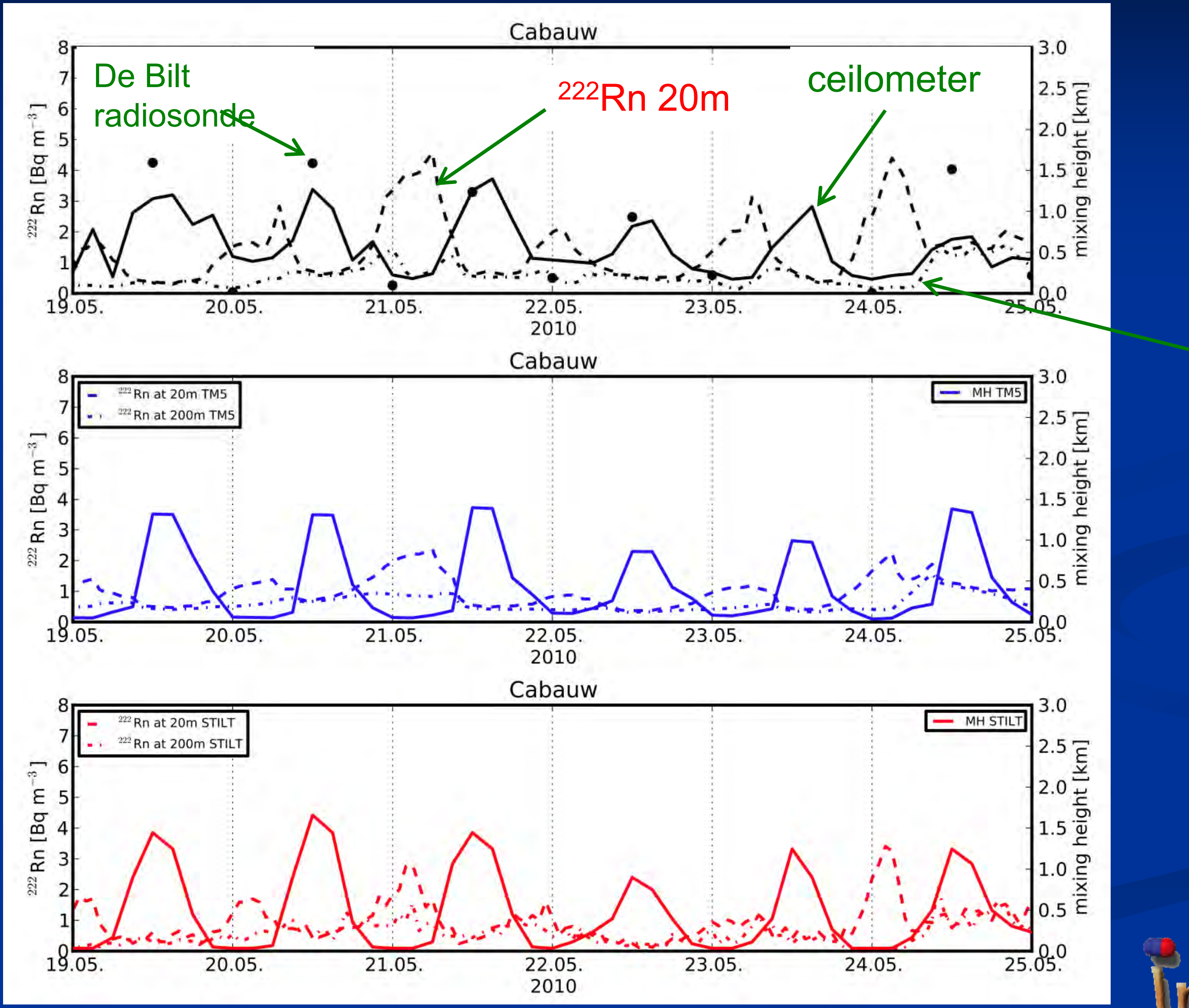
# Diurnal cycle of $^{222}$Radon and mixing height

Obs.

TM5

STILT

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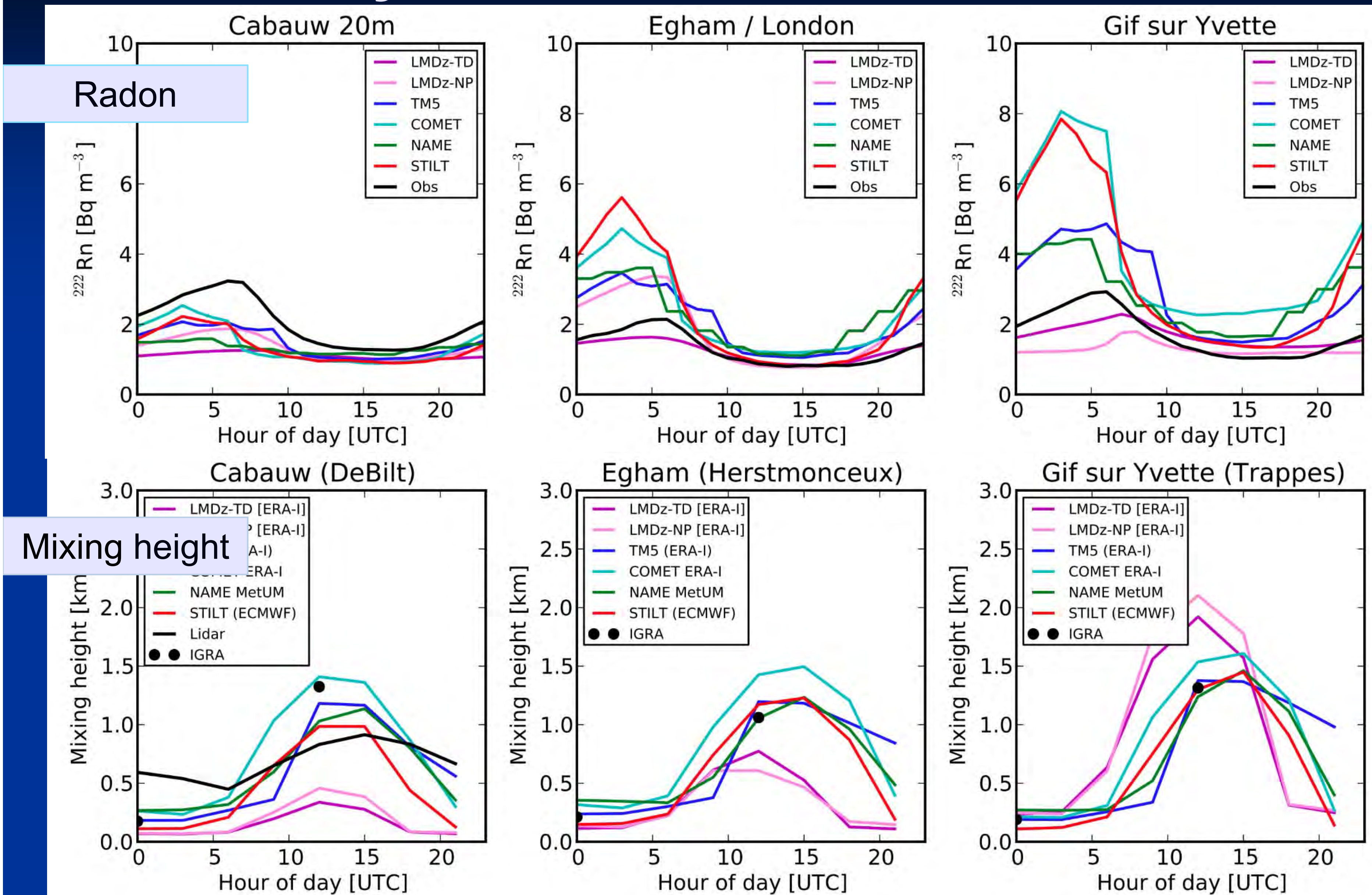
# Diurnal cycle of $^{222}$Rn and MH in summer

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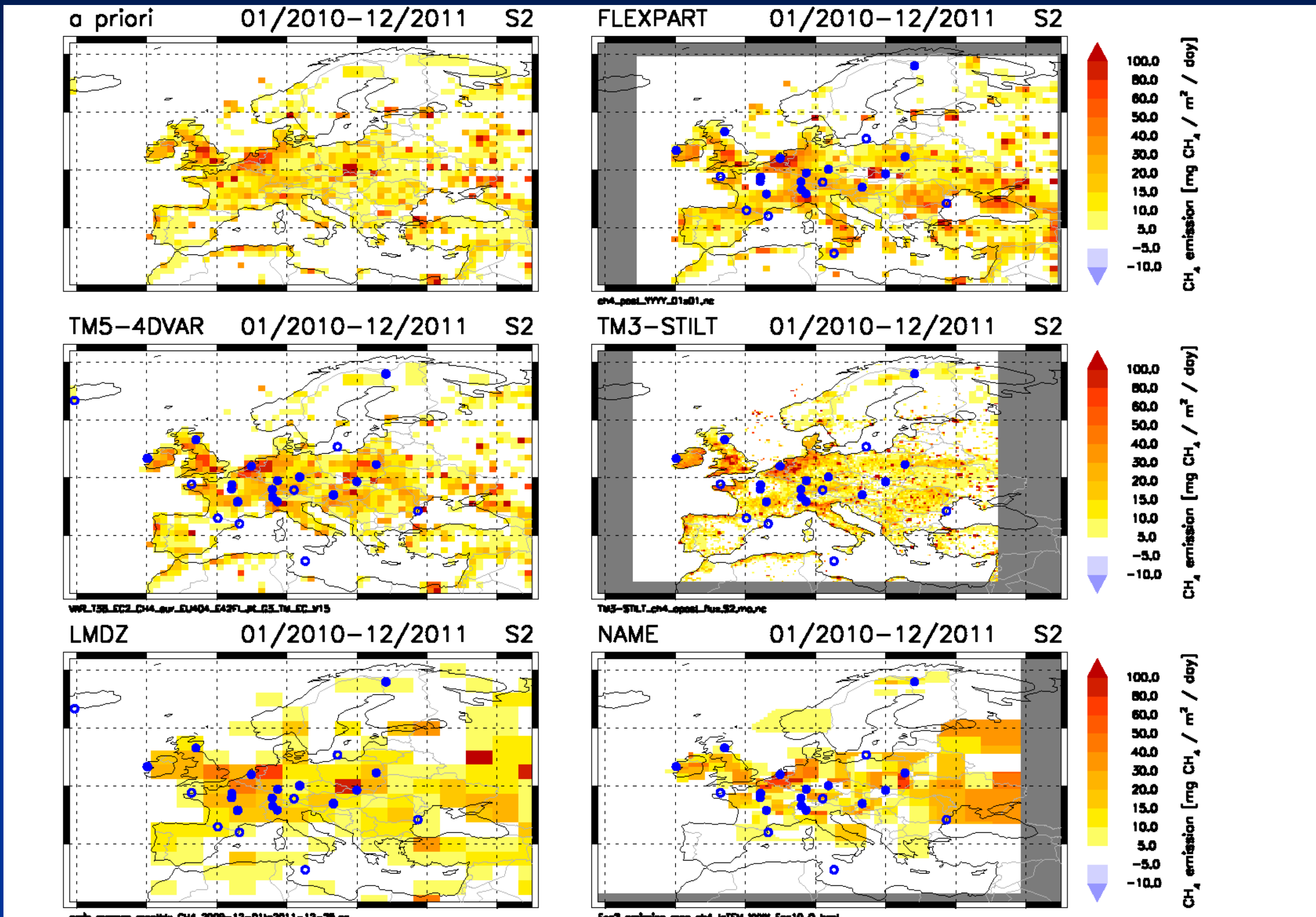
# Inversion "scenarios"

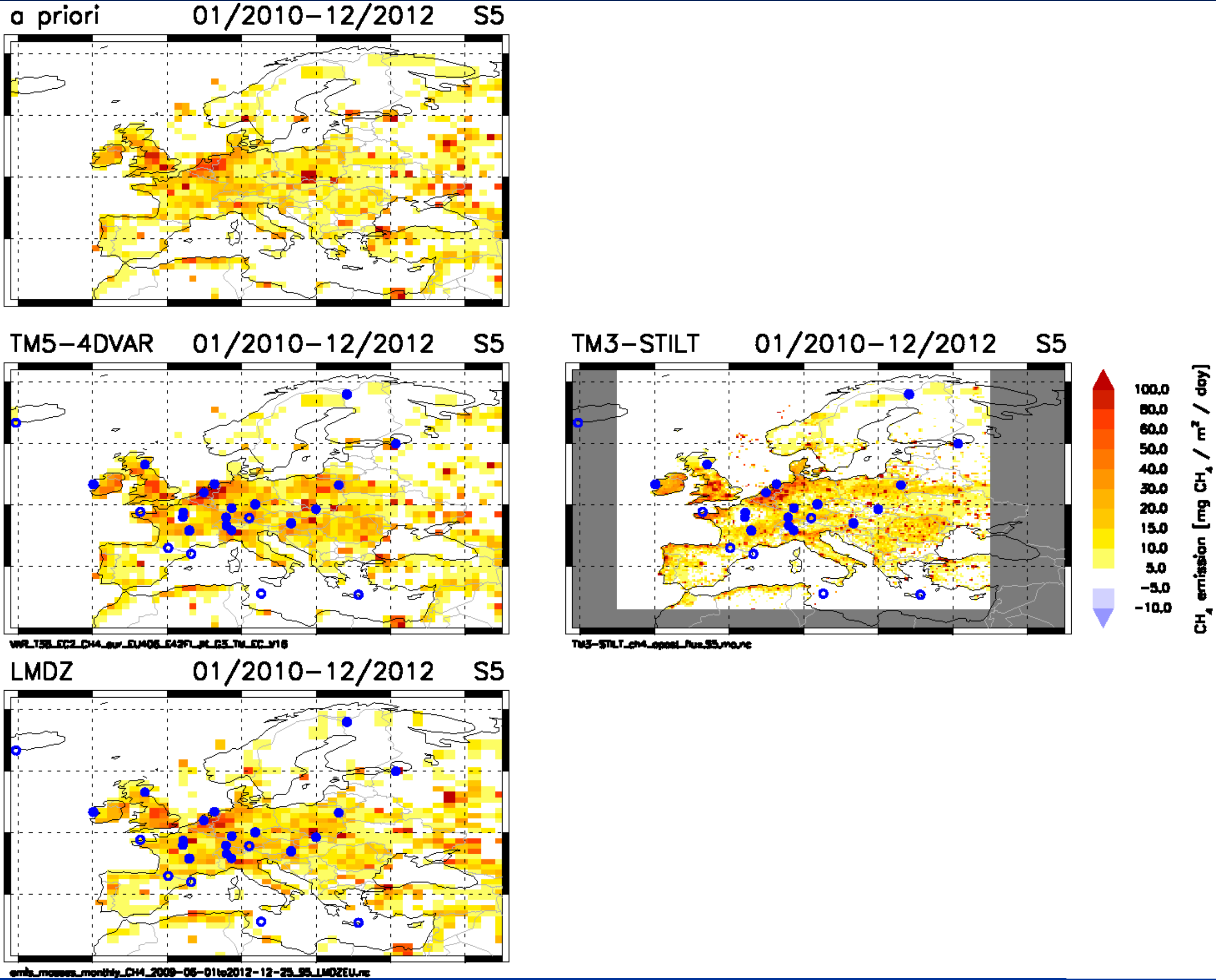
| | station list | a priori inventory | period | InGOS data | NOAA+LSCE flask |
|---|---|---|---|---|---|
| S1-CH4 | CH4_001B | EDGARv4.2FT-InGOS | 2007-2011 | preliminary | x |
| S2-CH4 | CH4_002B | EDGARv4.2FT-InGOS | 2010-2011 | preliminary | x |
| S3-CH4 | CH4_002B | no a priori | 2010-2011 | preliminary | x |
| S4-CH4 | CH4_004 | EDGARv4.2FT-InGOS | 2006-2012 | 2014 release | x |
| S5-CH4 | CH4_005 | EDGARv4.2FT-InGOS | 2010-2012 | 2014 release | x |
| S6-CH4 | CH4_005 | no a priori | 2010-2012 | 2014 release | x |
| S7-CH4 | CH4_007 | EDGARv4.2FT-InGOS | 2010-2012 | 2014 release | - |

# S2 $CH_4$

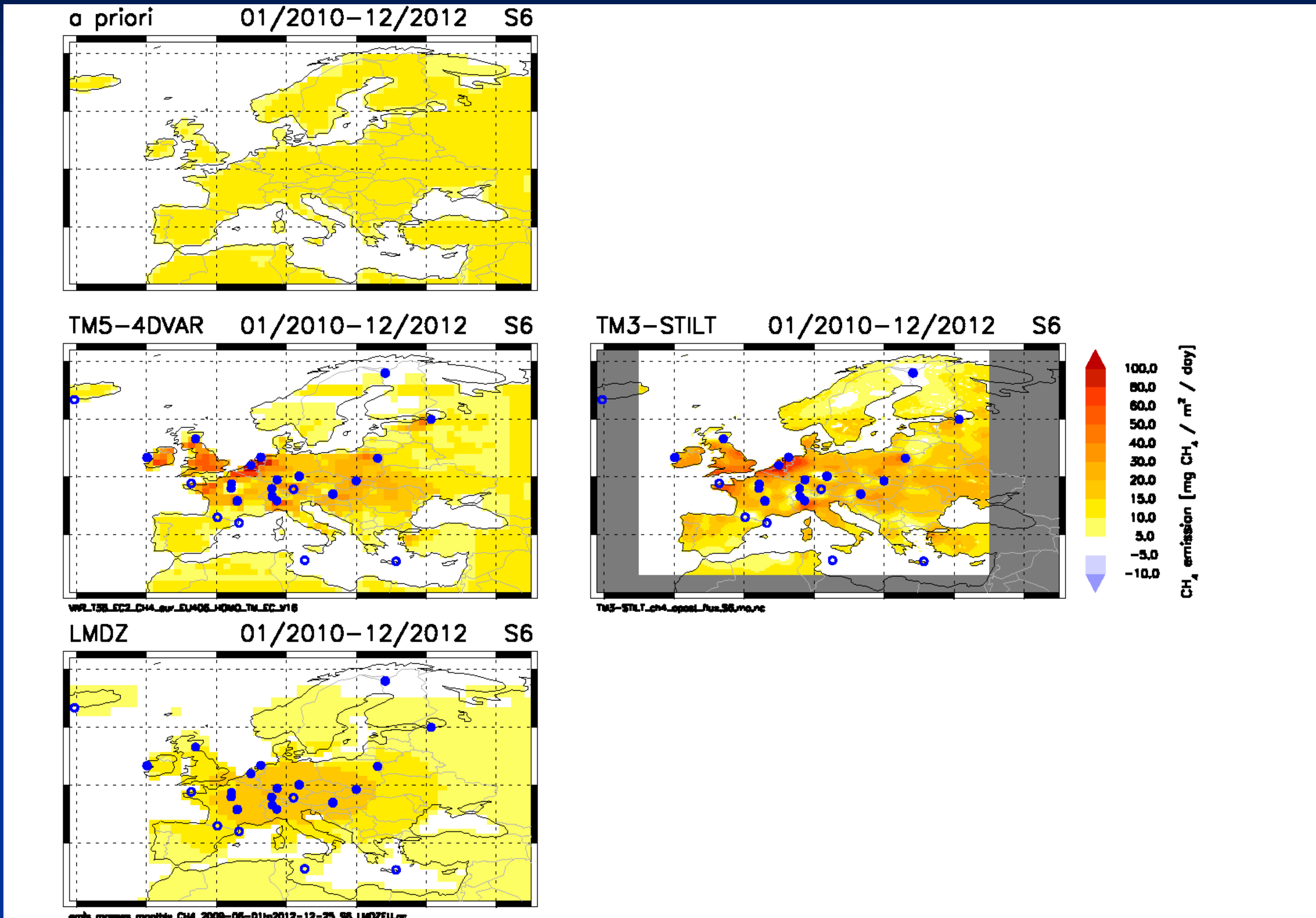


a priori 01/2010-12/2011 S2
FLEXPART 01/2010-12/2011 S2
TM5-4DVAR 01/2010-12/2011 S2
TM3-STILT 01/2010-12/2011 S2
LMDZ 01/2010-12/2011 S2
NAME 01/2010-12/2011 S2
100.0
80.0
60.0
50.0
40.0
30.0
20.0
15.0
10.0
5.0
-5.0
-10.0
CH4 emission [mg CH4 / m² / day]

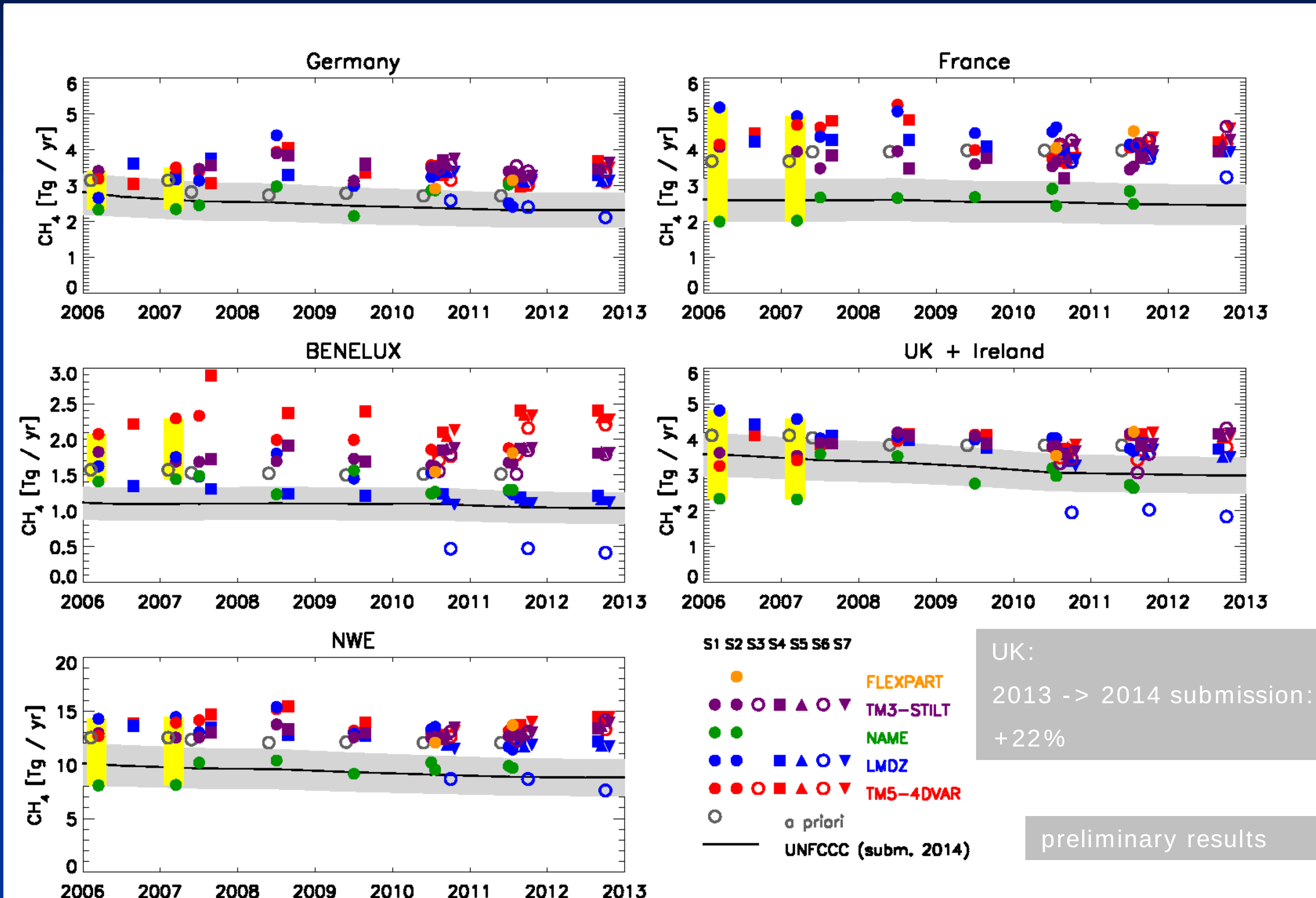
# S5 $CH_4$


a priori 01/2010–12/2012 S5
TM5–4DVAR 01/2010–12/2012 S5
TM3–STILT 01/2010–12/2012 S5
LMDZ 01/2010–12/2012 S5
100.0
80.0
60.0
50.0
40.0
30.0
20.0
15.0
10.0
5.0
–5.0
–10.0
CH4 emission [mg CH4 / m2 / day]

# S6 $CH_4$


a priori 01/2010–12/2012 S6
TM5–4DVAR 01/2010–12/2012 S6
TM3–STILT 01/2010–12/2012 S6
LMDZ 01/2010–12/2012 S6
100.0
80.0
60.0
50.0
40.0
30.0
20.0
15.0
10.0
5.0
–5.0
–10.0
CH4 emission [mg CH4 / m2 / day]

# Country aggregate emissions $CH_4$



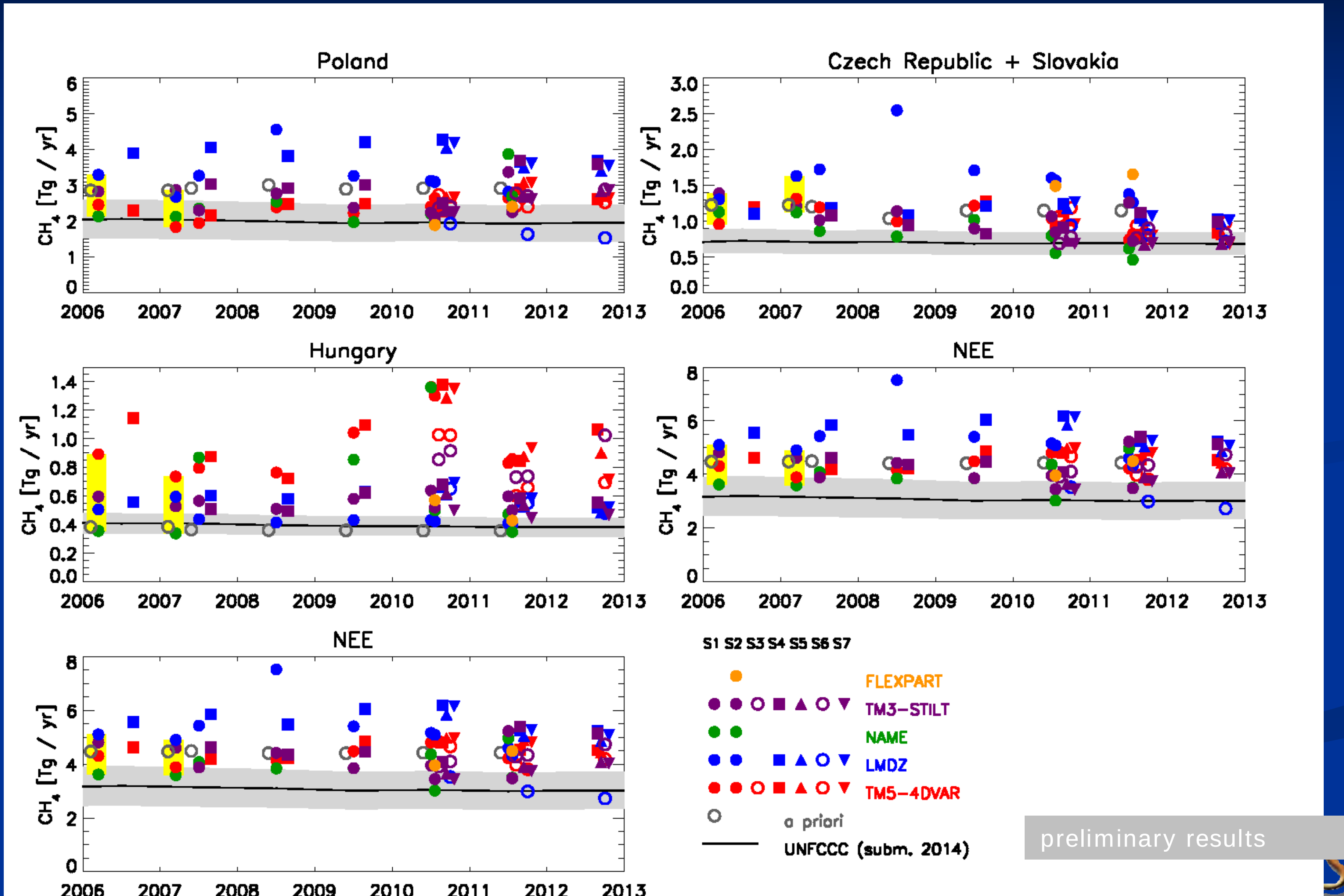

UK:

2013 -> 2014 submission:

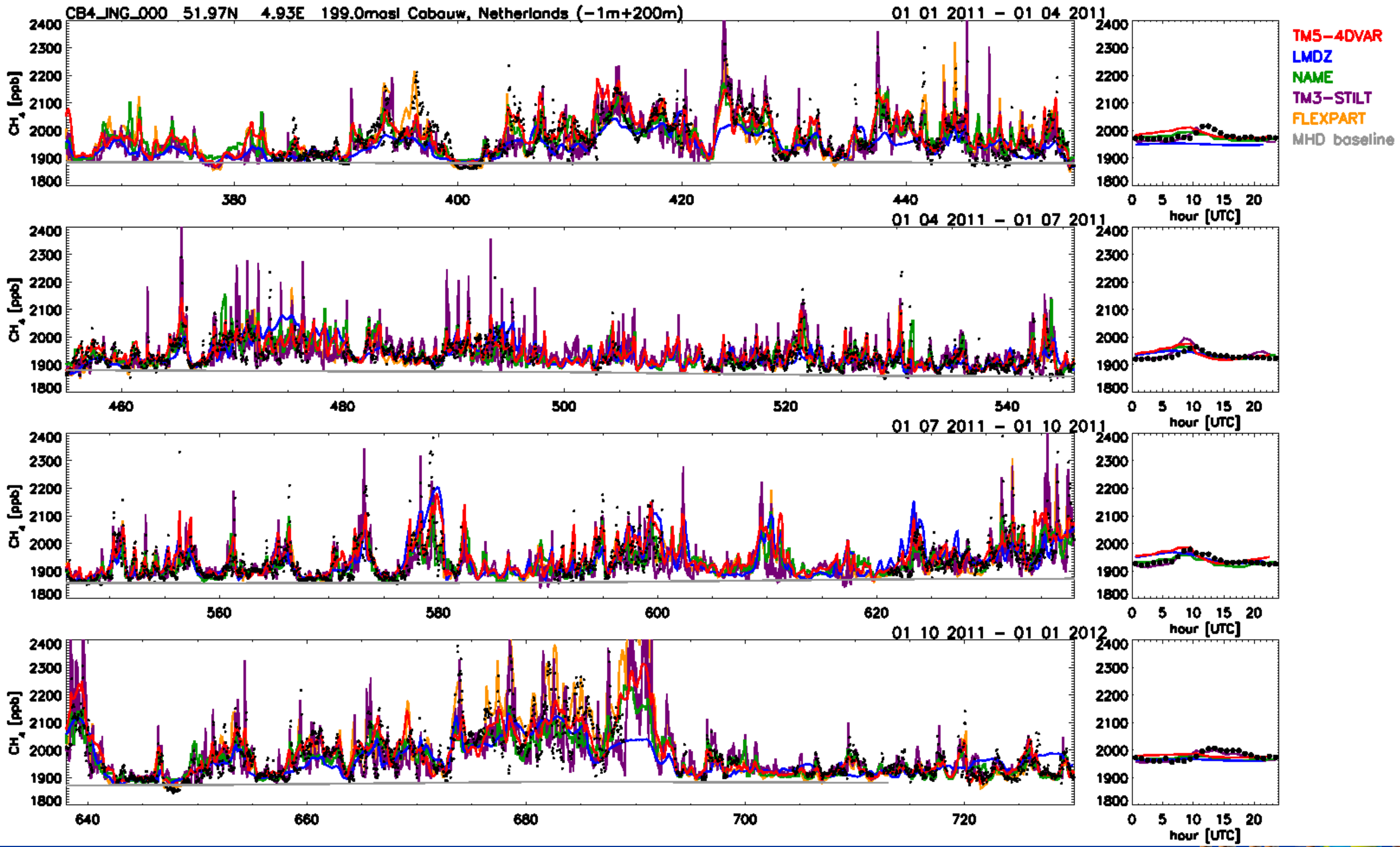
+22%

preliminary results

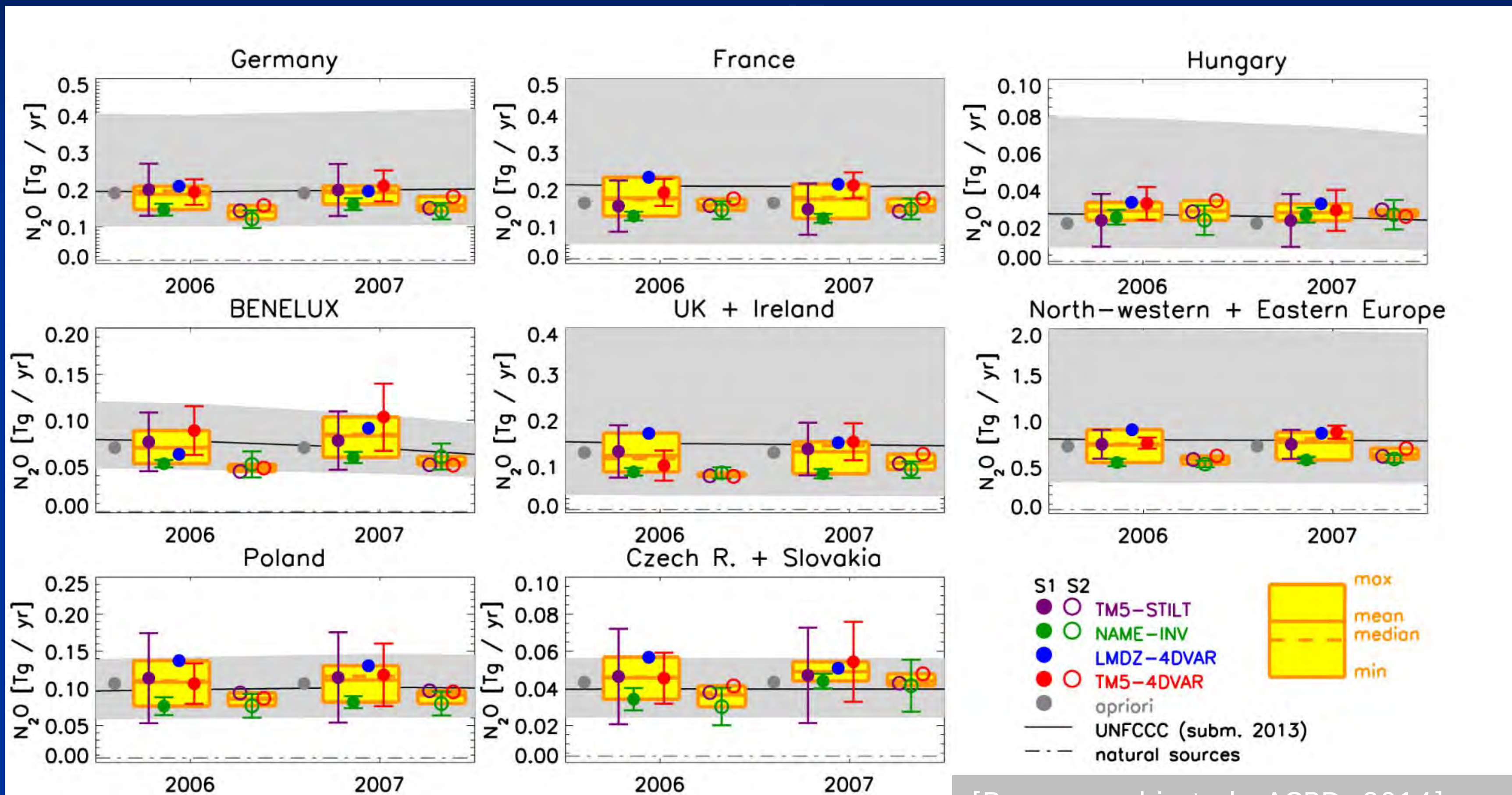
# Country aggregate emissions $CH_4$



# $CH_4$ station timeseries Cabauw 200m 2011



# European $N_2O$ emissions - country totals




[Bergamaschi et al., ACPD, 2014]

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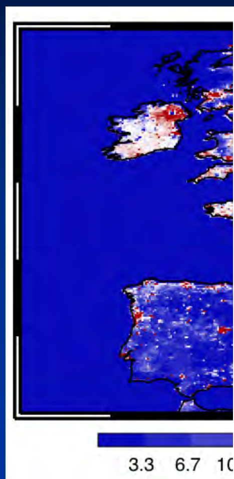
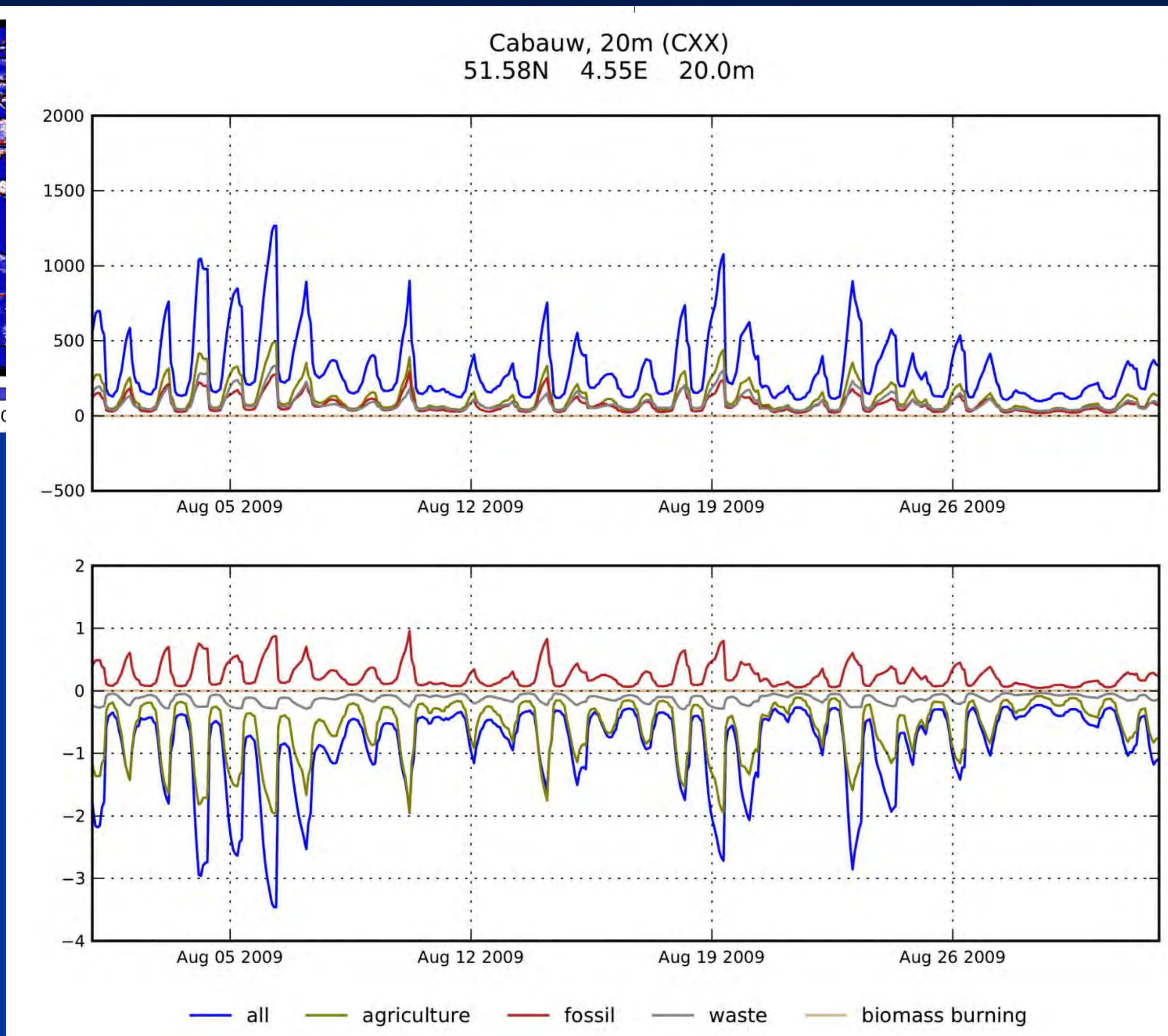
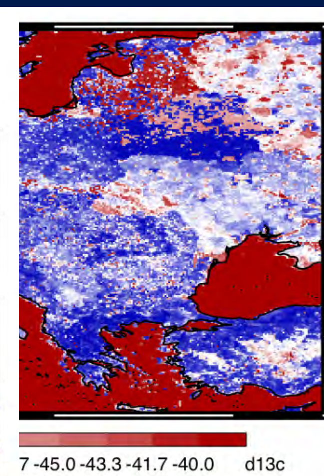
# $^{13}CH_4$

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# Conclusions I

- Synoptic variability of tracer mixing ratios is well represented in models
- Tall towers: model performance improves with increasing height
- Deficiencies to simulate diurnal cycle, especially at continental surface stations
- Model-data differences largest in nocturnal boundary layer
- Further evaluation of simulation of BLH dynamics and vertical gradients essential
- Continuous mixing height data (lidar/ceilometer) valuable tool for evaluation of model performance
- European sources of $CH_4$ should produce detecteable signals in $^{13}CH_4$ measurements

- Transport model errors are still an important source of uncertainty in inversion studies
  - ⇒ Selection of tracers at times of well-mixed boundary layer, i.e. afternoon at surface stations and night time at mountain sites
  - ⇒ Include uncertainty estimates from $^{222}Rn$ comparison in specification of model representation error in inversions

# Conclusions II

- These preliminary results show the potential of top-down emission verification
  - ⇒ Provided availability of a dense network of long-term continuous high quality observations
  - ⇒ Reproduces both temporal and spatial variability of emissions from just the atmospheric observations
  - ⇒ Results consistent with previous analyses (Bergamaschi et al, 2014)
  - ⇒ Indication top down uncertainty lower than bottom-up uncertainties for $CH_4$, even more so for $N_2O$
- More potential can be unleashed
  - ⇒ Improvement of BLH dynamics and vertical mixing in ATM’s: enable use of night time obs
  - ⇒ Increase network coverage and density, using tall towers

# THANK YOU!

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