# The Met Office NAME-Inversion Method in the Nitro-Europe project

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# Nitro-Europe: FP6 EU project (2005-2011)

www.nitroeurope.eu

- Derive estimates of $N_2O$ and $CH_4$ over Europe
- WP6.2 (Modelling component): Verify European emissions and evaluate independently $N_2O$ and $CH_4$ inventories from bottom-up methods
  - Considerable uncertainties in the bottom-up inventories
  - Uncertainty in the estimates reported to UNFCCC:
  - $CH_4$: ~ 25%; $N_2O$ > 100% (for annual country totals)
- 5 partners – 5 different methods
- Different: Meteorology, Transport models & Inversion methods
- Common: Observations & Bottom-up inventories

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# The NAME-Inversion Method

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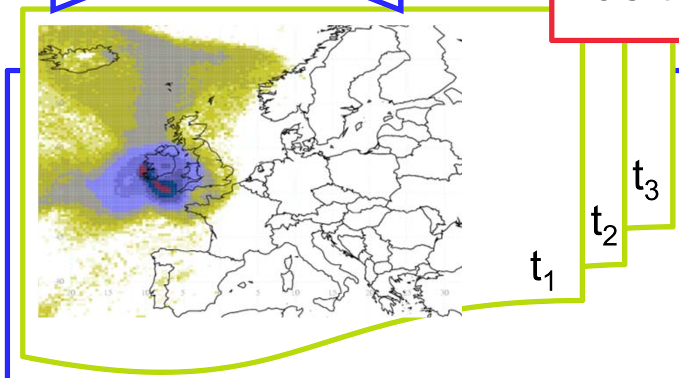
$$\mathbf{M}\ [t \times m]\ ¤\ \mathbf{E}\ [m \times 1] = \mathbf{O'}\ [t \times 1] = \mathbf{O} - \mathbf{b}$$

Transport matrix

Emission map to be obtained as the solution

Time series of observations

Baseline




- Air history maps from each observation station are generated using NAME model
- Relative contribution of surface sources at observation stations

- Solve equation iteratively using a best-fit approach, in a limited area domain
- First guess for E from a random map or known emission map (*a priori*)
- Suitable baseline
  - Air representative of NH background
  - Air concentrations entering the domain

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# The Method in Nitro Europe

- Domain: 14.6°W - 39.1°E, 33.8°N – 72.7°N at 0.42° × 0.27° resolution
- Observations (O) from 21 stations across Europe (2006 – 2007)
  - $CH_4$: 11 high frequency (1hr) + 10 flask type (~1 wk)
  - $N_2O$: 9 high frequency (1hr) + 6 flask type (~1 wk)

    Apply bias correction from TM5 model
- Baselines (b)
  - Mace Head (MH) from MH observations (Manning *et al* 2011)
  - Site specific from TM5 model (based on method of Roedenbeck *et al* 2009)
- 52 realisations to obtain mean solution and a measure of uncertainty
- Noise was applied to the observations (from log-normal distribution)

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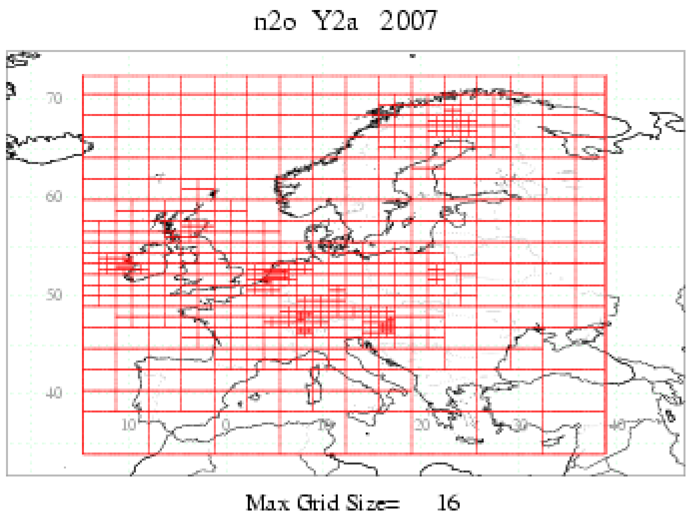
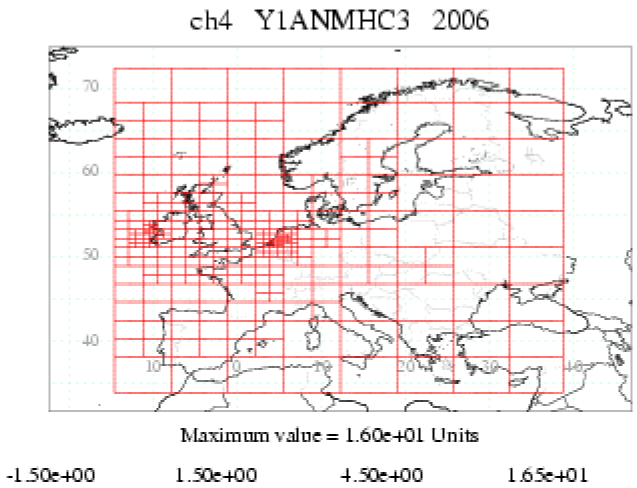
# Grid examples

$N_2O$ Y2a using 15 stations




$CH_4$ using 3 stations




Grid-boxes aggregated in 2x2, 4x4 etc depending on amount of available information

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# $CH_4$ Inversion - 21 stations

High Frequency: AN BK C3 EG HY MH OK PA SL SY JJ (11)
Flask: BS BR CO HB LM IG PM PU SI OS (10)

- MH-baseline
- Stations where MH-baseline deemed suitable (representative)
- All stations except JJ & PM
- Two experiments
  - Y1: random start
  - Y1b: *a priori* constraint
  - Use data at all times

- TM5-baseline
- Six experiments in total
- Using all stations except JJ & PM
  - Y2: same as Y1
  - Y3a: like Y2 but with time window
- Using all stations
  - Y2a: random start, all data
  - Y2b: *a priori*, all data
  - Y3: random start with time window
  - Y4: *a priori* with time window

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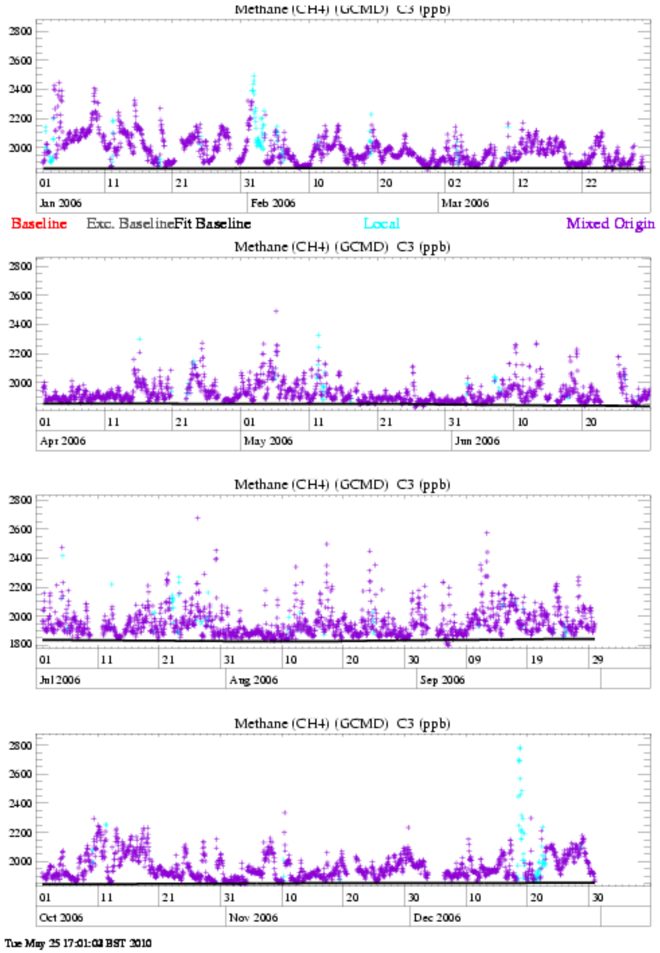
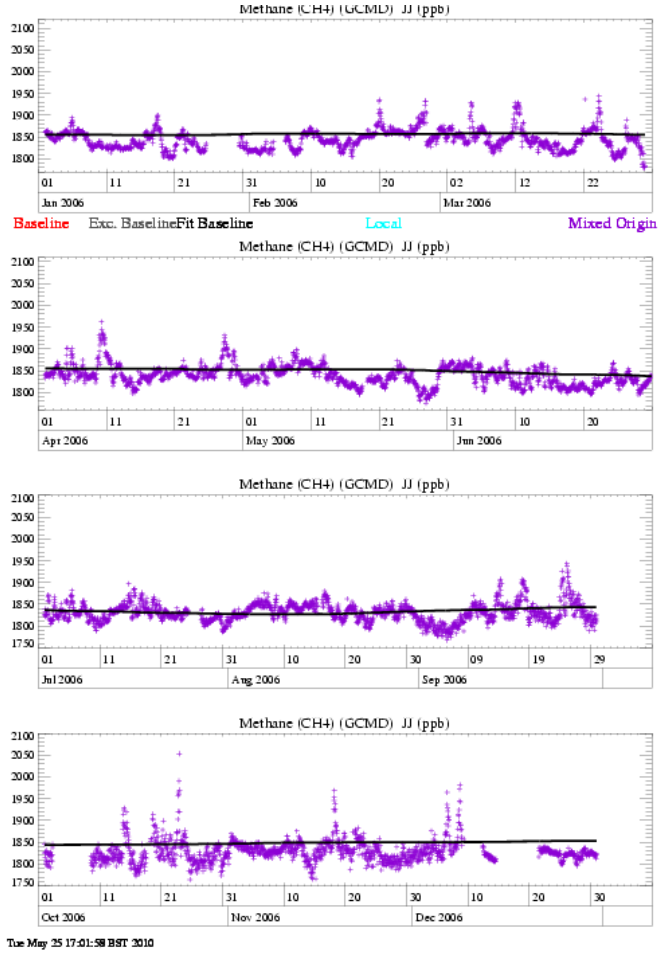
# MH-baseline at Cabauw & Jungfrau

Representative

Not representative




CH4

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# $CH_4$ Inversion - 21 stations

| | | |
|---|---|---|
| <u>High Frequency</u>: | AN BK C3 EG HY MH OK PA SL SY JJ | (11) |
| <u>Flask</u>: | BS BR CO HB LM IG PM PU SI OS | (10) |

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- Using all stations
  - Y2a: random start, all data
  - Y2b: *a priori*, all data
  - Y3: random start with time window
  - Y4: *a priori* with time window

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# $N_2O$ Inversion - 15 stations

| | | |
|---|---|---|
| High Frequency: | AN BK C3 HY MH OK PA SL JJ | (9) |
| Flask: | BS CO HB LM SI OS | (6) |

- MH-baseline
- Stations where MH-baseline deemed suitable (representative)
- All stations except AN & JJ
- Two experiments
  - Y1: random start
  - Y1b: *a priori* constraint
  - Use data at all times

- TM5-baseline
- Five experiments in total
- Using all stations except AN & JJ
  - Y2: same as Y1
- Using all stations
  - Y2a: random start, all data
  - Y2b: *a priori* start, all data
  - Y3: random start with time window
  - Y4: *a priori* with time window

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# Results:

## Summary of influence of various parameters

- ❑ Y1 and Y2 (choice of baseline to otherwise identical simulations) have shown differences in the obtained solution
- ❑ Y2 and Y2a (exclusion of JJ and PM observations) does not make any significant difference to the results
- ❑ Using time windows (Y3, Y3a, Y4) to select observations proved somewhat detrimental to the inversion
  - Significantly reduced number of data used
  - Affects (makes coarser) the inversion grid
- ❑ Use of *a priori* emission maps (Y1b, Y2b, Y4) to constrain the inversion:
  - Does not allow the solution to diverge strongly from the *a priori* emissions
  - Any errors or bias in the *a priori* will influence the solution
  - Loss of independence
- ❑ Now focus on Y1 and Y2a (influence of baseline)
  - Y1: MH-baseline to all stations that MH-baseline is suitable
  - Y2a: TM5-baseline to all stations

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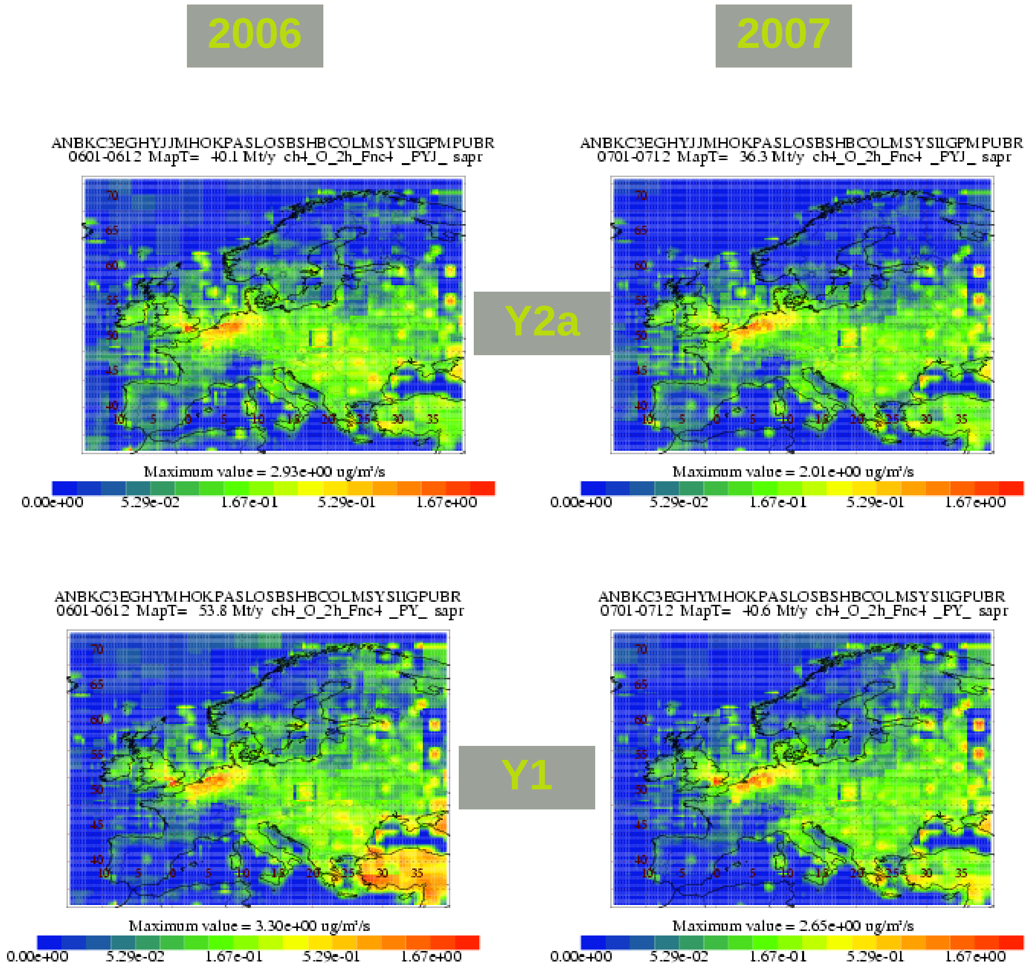
# Results: emission maps $CH_4$

- Random start initialisation
- Re-distribute emissions (inversion solution) on the grid-box based on *a priori* (EDGAR)
  - No change in inversion solution
  - More realistic distribution
  - No difference in well resolved areas
  - Positive impacts in certain areas (Iberian Peninsula, Mediterranean)
- Similar overall picture
- More pronounced differences are observed along the southern part of the domain where there are few observations and the MH-baseline is less suitable

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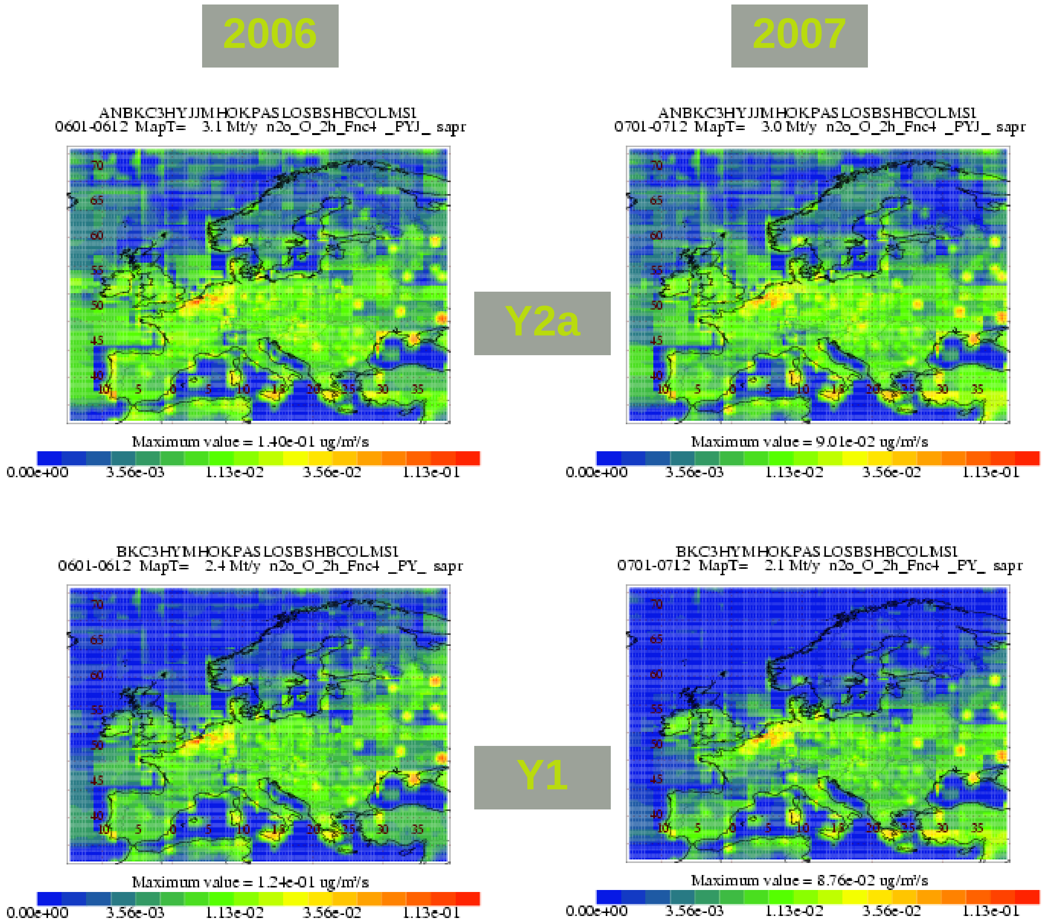
# Results: emission maps $N_2O$

- Random start initialisation
- Re-distribute emissions (inversion solution) on the grid-box based on *a priori* (EDGAR)
- Comparison of Y1 and Y2a
    - More overall differences than was for $CH_4$
    - All over the domain
    - TM5-baseline solution has higher emissions than solution using MH-baseline

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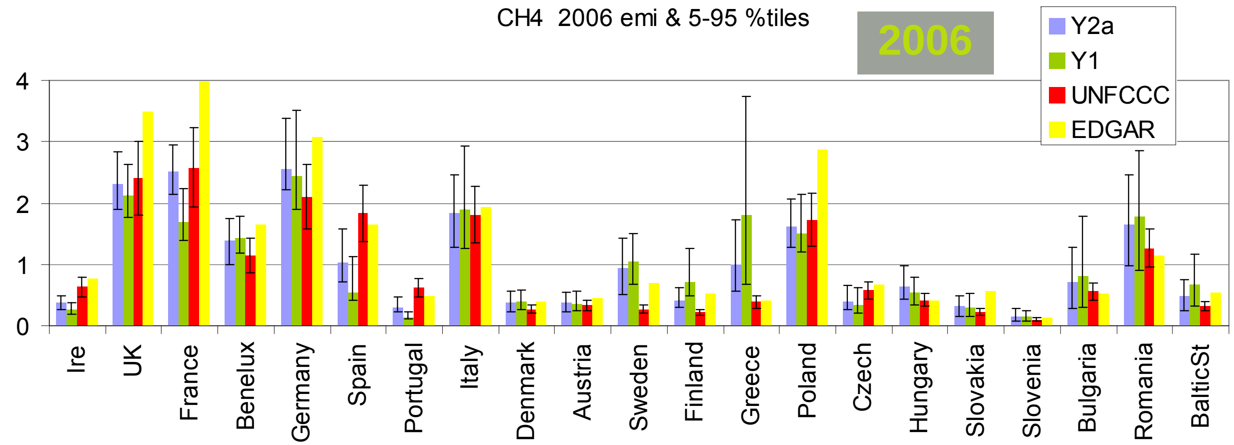
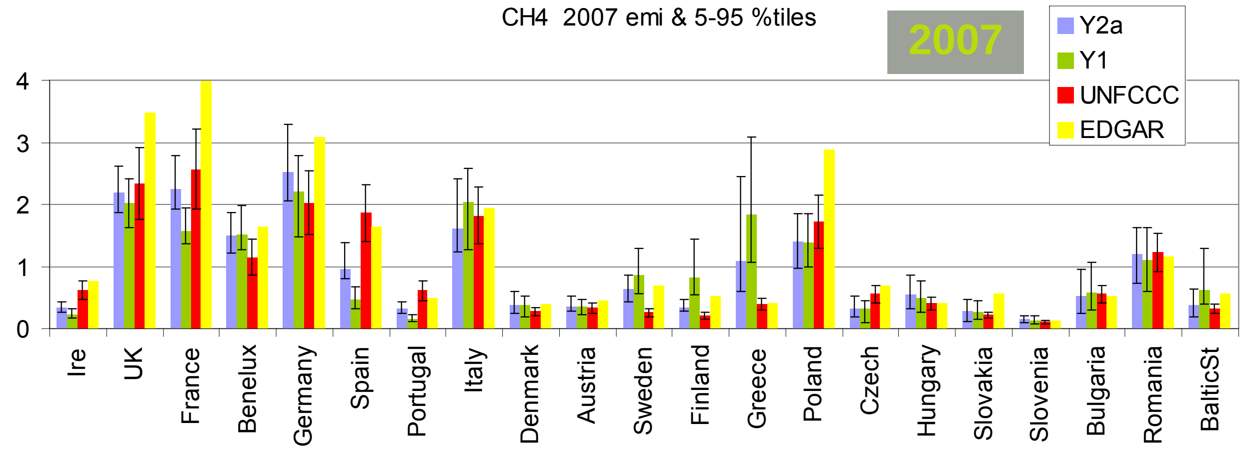
# Results: Individual Country Totals $CH_4$

- Bars represent the uncertainty of mean solution defined from the 5 – 95 percentiles of 52 individual solutions
- 25 % uncertainty in UNFCCC
- Big differences between UNFCCC and EDGAR in certain countries
- Y2a & Y1 solutions give rather similar values for most countries
- Emissions from each solution within uncertainty of solution

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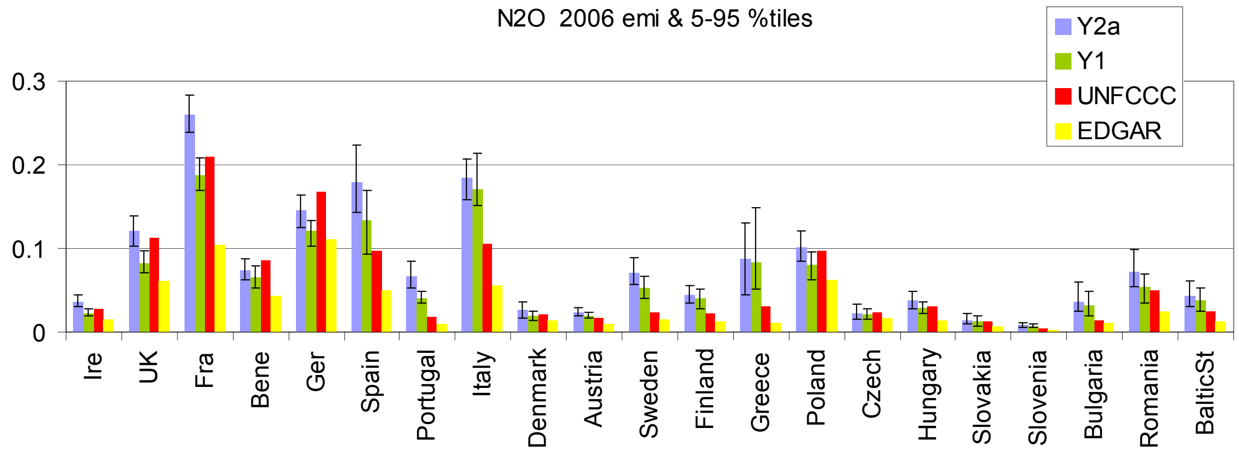
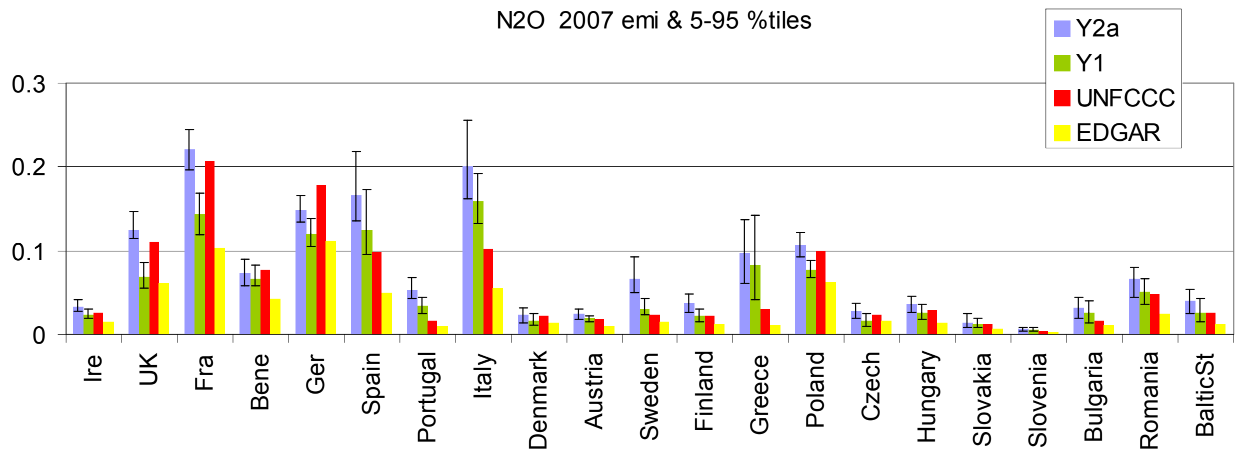
# Results: Individual Country Totals N2O

- Big differences between UNFCCC and EDGAR in certain countries
- Uncertainty in UNFCCC is considerable (>100%)
- Y2a has consistently higher values than Y1 for all countries
- In a few cases, the difference between Y2a and Y1 is outside the uncertainty of the solution i.e., France

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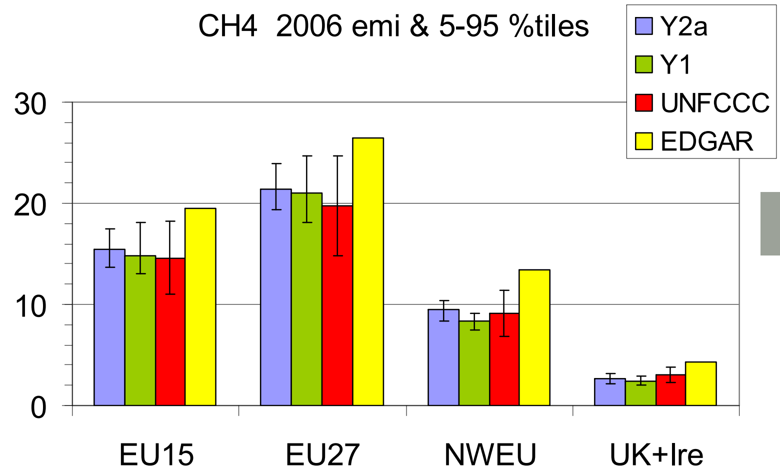
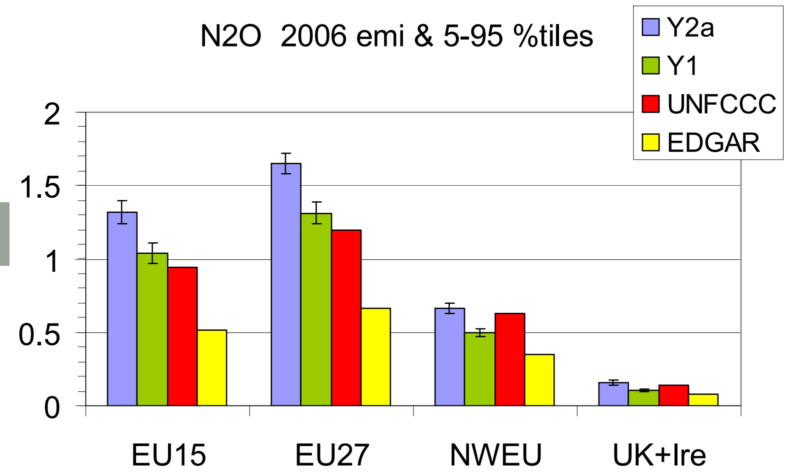
# Results: Aggregated totals

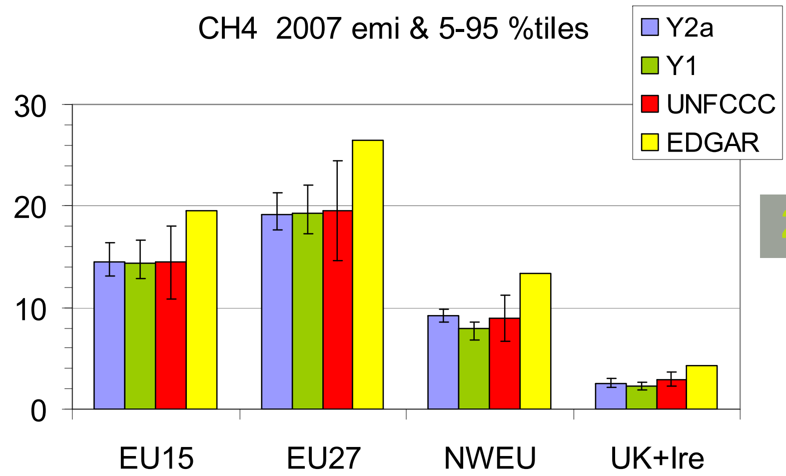
CH4

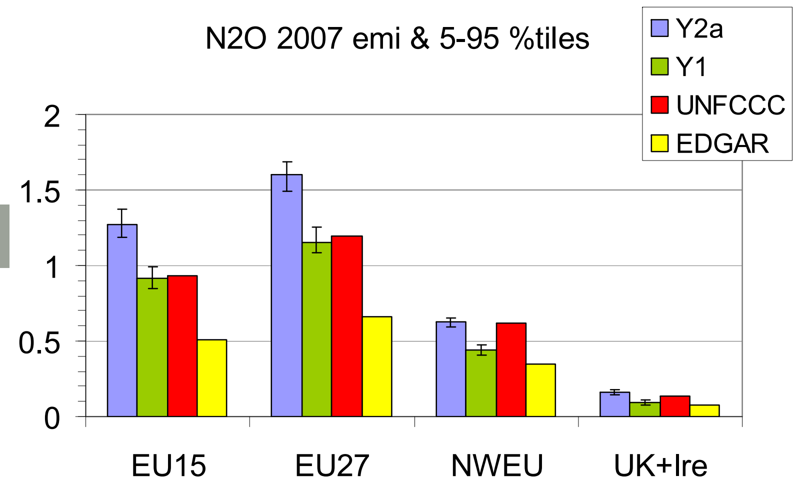
N2O




2006




2007

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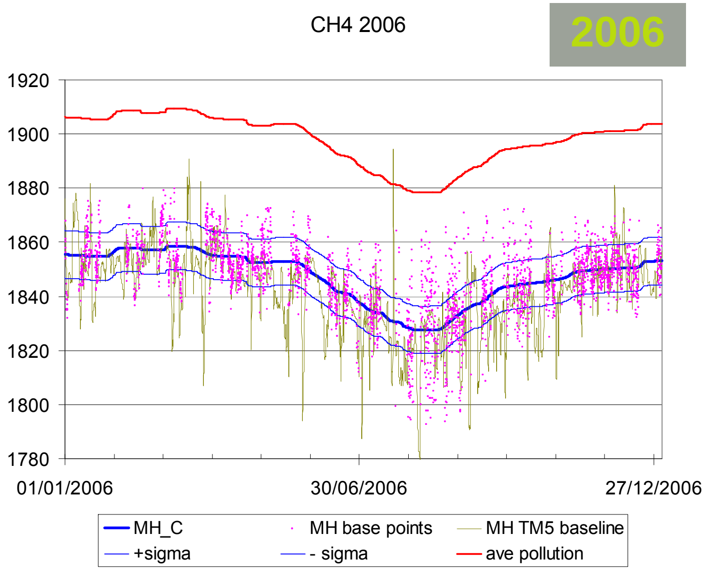
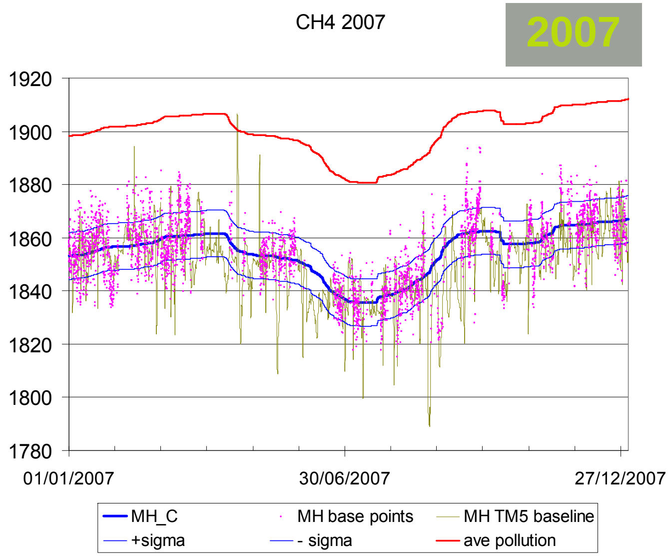
# Baselines: Influence on solution

CH4

2006




2007




- APE = average pollution event (red line)
- MHB = MH-baseline (**thick blue line**) ±σ (thin blue line)
- Pink dots are the observations used in the calculation of MH-baseline
- TM5B = TM5-baseline
- R = (MHB – TM5B) / (APE – MHB) = 8%
  - Difference between the baselines compared to the difference between the MH-baseline and the pollution event
- R small → not much difference in solutions Y1 & Y2a

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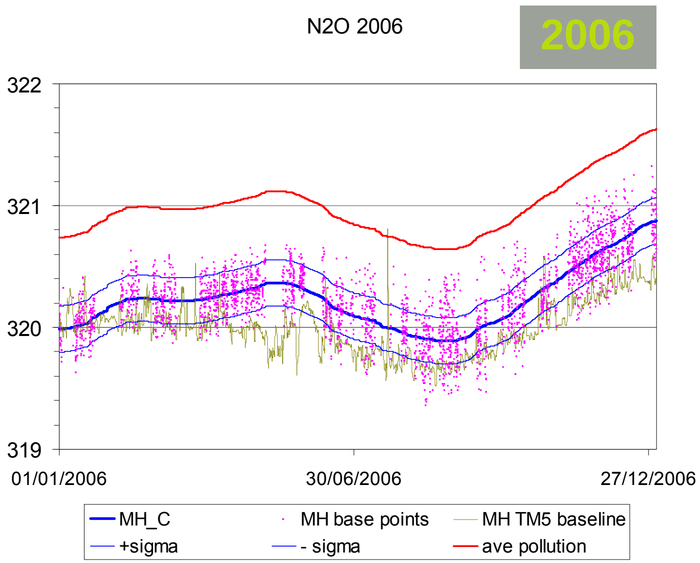
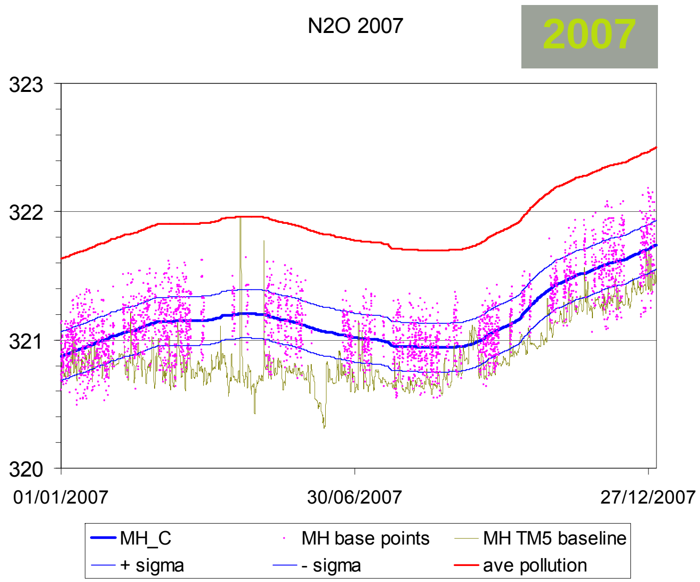
# Baselines: Influence on solution

N2O




- APE = average pollution event (red line)
- MHB = MH-baseline (**thick blue line**) ±σ (thin blue line)
- TM5B = TM5-baseline
- R = (MHB – TM5) / (APE – MHB) = 33%
- R large → discernible difference between solutions Y1 & Y2a
- In this case, the TM5-baseline is consistently below observations (pink dots) that classed as baseline (i.e. from Atlantic) according to the MH-baseline analysis

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# Summary: Influence of baseline

- Baseline a key parameter to the inversion
- Relates to the 'distance' between the baseline points and pollution values
  - M x E = O' = O – b
  - Smaller baseline values → higher O' → larger emissions
- Demonstrated in the comparison between MH-baseline and TM5-baseline
- Results from all models (not shown) proved top-down modelling to be a very useful tool in the estimation of emissions.
- The ability of the NAME-Inversion method to converge to realistic solutions starting from random emissions makes the method truly independent from *apriori* information (bottom-up inventories).
- MH-baseline can be applied to stations across Europe with at least as good results as site specific baselines.

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Questions ?

Thank you for your attention

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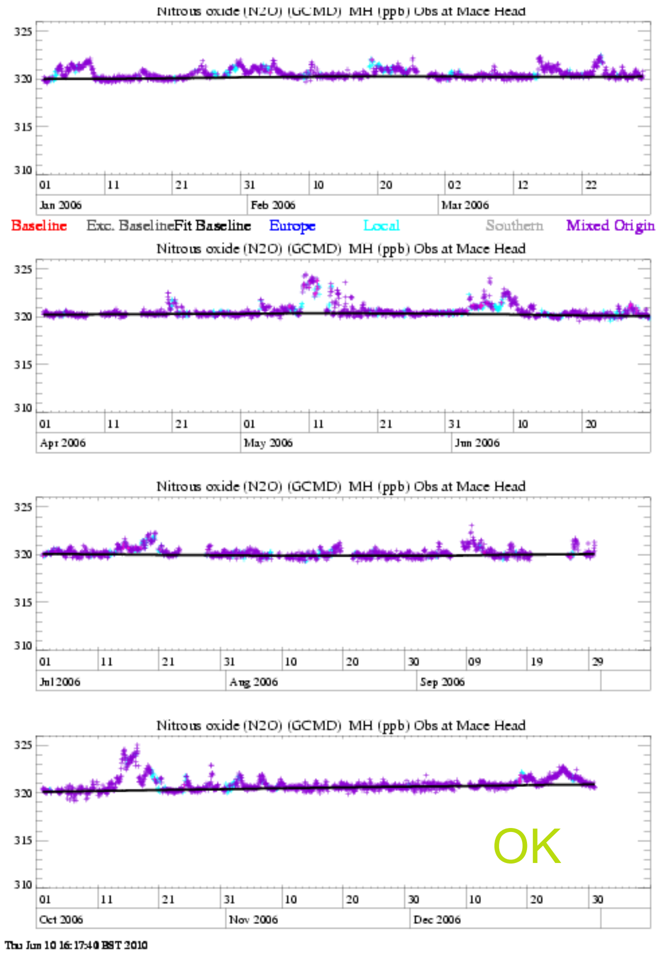
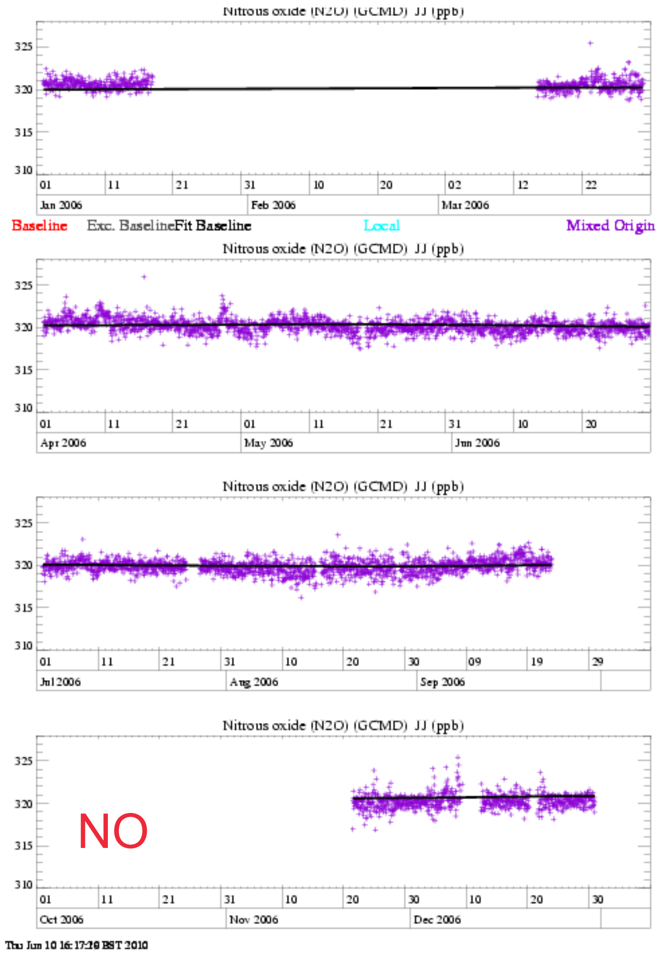
# MH-baseline at MH & JJ

N2O

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