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
The NAME-Inversion Method

- 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 (priori)
- Suitable baseline
  - Air representative of NH background
  - Air concentrations entering the domain

\[ M_{[t \times m]} \otimes E_{[m \times 1]} = O'_{[t \times 1]} = O - b \]

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

Baseline

Time series of observations

Transport matrix

Emission map to be obtained as the solution
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)
  - CH₄: 11 high frequency (1hr) + 10 flask type (~1 wk)
  - N₂O: 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)
Grid examples

N$_2$O Y2a using 15 stations

CH$_4$ using 3 stations

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

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### CH₄ Inversion - 21 stations

#### High Frequency:
- AN
- BK
- C3
- EG
- HY
- MH
- OK
- PA
- SL
- SY
- JJ

#### Flask:
- BS
- BR
- CO
- HB
- LM
- IG
- PM
- PU
- SI
- OS

- **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
MH-baseline at Cabauw & Jungfrau

Representative

Not representative

CH4
CH₄ 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
N$_2$O 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
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
Results: emission maps CH₄

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- 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
Results: emission maps N$_2$O

- 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
Results: Individual Country Totals CH₄

- 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.
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
Results: Aggregated totals

CH4 2006 emi & 5-95 %tiles

N2O 2006 emi & 5-95 %tiles

CH4 2007 emi & 5-95 %tiles

N2O 2007 emi & 5-95 %tiles

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Baselines: Influence on solution

- **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** = \( \frac{\text{MHB} - \text{TM5B}}{\text{APE} - \text{MHB}} \) = 8%
  - Difference between the baselines compared to the difference between the MH-baseline and the pollution event
- **R** small \( \rightarrow \) not much difference in solutions Y1 & Y2a

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Baselines: Influence on solution

- **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
Summary: Influence of baseline

• Baseline a key parameter to the inversion

• Relates to the ‘distance’ between the baseline points and pollution values
  • \( M \times E = O' = O - b \)
  • Smaller baseline values \( \rightarrow \) higher \( O' \) \( \rightarrow \) 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.
Questions?

Thank you for your attention
MH-baseline at MH & JJ

N2O

Graphs showing N2O levels over time with labels for baseline, region, and local origins.