Verifying the Emissions of non-CO$_2$ GHG of NW Europe Using the European Network of Tall Towers


$^1$ ECN  $^2$ JRC ISPRA  $^3$ LSCE  $^4$ MPI-BGC  $^5$ CIO-RUG  $^6$ UEDIN  $^7$ HMS  $^8$ UK Metoffice
• Expansion of the surface network in Europe
• Measurement results
• Model setup (NEU 6.2)
• Model results: emissions of methane
• Challenges & Outlook
The European Atmospheric Network

- 3 laboratories for air sample analysis
- Background CO$_2$ observing sites around the world
- Regionally dense stations network in Western Europe
- Transect of aircraft sites across Eurasia
- New network of tall towers
The tall tower network (CHIOTTO)

- 8 continuous monitoring stations
- 4 new stations, 4 upgraded
- High precision CO₂, CH₄, SF₆, N₂O
- Tall towers (>100 m AGL)
- Common equipment set
- Common sample treatment (drying etc)
- Common scale, calibration gases, archive standards
- Vertical gradient where possible
- Ancillary tracers: CO, ²²²Rn, H₂, FTIR
- Flask observations
- Intercomparisons
The observational (tall) tower network

<table>
<thead>
<tr>
<th>Name</th>
<th>Hght (m)</th>
<th>Lon</th>
<th>Lat</th>
<th>CO₂</th>
<th>CH₄</th>
<th>N₂O</th>
<th>SF₆</th>
<th>CO</th>
<th>²²²Rn</th>
<th>Flux</th>
<th>CO₂</th>
<th>CH₄</th>
<th>Operator</th>
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<td>Cabauw</td>
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<td>04°56'</td>
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<td>46°57'</td>
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<td>46°58'</td>
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<td>Norunda</td>
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<td>43°49'</td>
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<td>50°03'</td>
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<td>Bialystok</td>
<td>PL 300</td>
<td>22°45'</td>
<td>52°15'</td>
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15th WMO expert meeting on GHG+ tracers measurement techniques
Jena, 7 Sept 2009
Measurement results: CH$_4$ in the network

CH$_4$ observations from Tall Towers Nov 2006

15th WMO expert meeting on GHG+related tracers measurement techniques
Jena, 7 Sept 2009
Measurement results: $N_2O$

N2O Tall Tower observations

- 1 CBW_200
- 5 TTA_222
- 6 LUT_60
- 7 HUN
- 10 OXK_183
- 16 BIK_300
Measurement results: CH$_4$ emission trend CBW

- Seasonal trend fit 1993-2008: $0.8 \pm 0.6$ ppb/yr
- 2000-2008: $4.7 \pm 1.2$ ppb/yr
<table>
<thead>
<tr>
<th>partner</th>
<th>model</th>
<th>short description</th>
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<tbody>
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<td>JRC</td>
<td>TM5-4DVAR model</td>
<td>Eulerian two-way nested zoom model [Krol et al., 2005]; 4DVAR optimization (individual grid cells) [Bergamaschi et al., 2007; Meirink et al., 2008]</td>
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<tr>
<td>MPI</td>
<td>TM3-STILT</td>
<td>TM3: global Eulerian model [Heimann and Koerner, 2003] STILT: nested regional model (0.25x0.25)</td>
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<td>CEA</td>
<td>LMDZ model</td>
<td>Eulerian model with flexible grid size, high resolution over Europe [Bousquet et al., 2007] 4DVAR multi-species optimization (individual grid cells)</td>
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<td>UKM</td>
<td>NAME model</td>
<td>Lagrangian particle dispersion model [Manning et al., 2003, Manning, 2007] Baseline detection and Simulated annealing inversion technique</td>
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10th WMO expert meeting on GHG-related tracers measurement techniques
Jena, 7 Sept 2009

**CH₄ forward results: CBW**

**CB1_CHL_000  51.97°N  4.93°E  52.0masl [ 12.0 – 15.0 LT ]**

Cobauw, Netherlands, base: -2m, tower level: 20.0m

01 01 2006 – 01 05 2006

01 05 2006 – 01 09 2006

01 09 2006 – 01 01 2007

<table>
<thead>
<tr>
<th>Model</th>
<th>r</th>
<th>sd(m-o)</th>
<th>bias</th>
<th>n</th>
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<td>TM5</td>
<td>0.70</td>
<td>83.96ppb</td>
<td>-30.49ppb</td>
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<td>95.65ppb</td>
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<td>COMET</td>
<td>0.79</td>
<td>78.06ppb</td>
<td>-14.45ppb</td>
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</table>

sd(m)/sd(o): 0.63  sd(m)/sd(o): 0.46  sd(m)/sd(o): 0.52  sd(m)/sd(o): 1.12
N$_2$O forward results: MHD

MHD_AGAD_000  53.33N  -9.90W  53.3masl
Mace Head, Ireland

01 01 2006 – 01 05 2006

01 05 2006 – 01 09 2006

01 09 2006 – 01 01 2007

r  : 0.67
sd(m-o): 0.53ppb
bias    : -0.07ppb
n       : 6826

r  : 0.52
sd(m-o): 0.67ppb
bias    : -0.56ppb
n       : 6826

r  : 0.67
sd(m-o): 0.54ppb
bias    : -0.12ppb
n       : 6826

r  : 0.58
sd(m-o): 0.56ppb
bias    : -0.35ppb
n       : 6719

sd(m): 0.38ppb
sd(o): 0.70ppb
sd(m)/sd(o): 0.54

ds(m): 0.68ppb
sd(o): 0.70ppb
sd(m)/sd(o): 0.97

sd(m): 0.34ppb
sd(o): 0.70ppb
sd(m)/sd(o): 0.48

sd(m): 0.30ppb
sd(o): 0.71ppb
sd(m)/sd(o): 0.43

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N$_2$O Forward results: BIK

BI5_chi_000  52.25N  22.75E  52.3masl
Bialystok, Poland, base: 160m, tower level:300m

01 01 2006 – 01 05 2006

01 05 2006 – 01 09 2006

01 09 2006 – 01 01 2007

TMS
LMDZ
NAME
COMET
Transport model COMET

- Lagrangian model
- ECMWF meteorology
  - 2° to 0.2° resolution
  - timestep 3 hr, interpolated into 1 hr
- Hourly trajectories (FLEXTRA)
- Moving two layered box:
  - Mixing layer
  - Reservoir layer
- Mixing layer height: critical Richardson number

*Previous results for CH₄: R=0.9, bias =0 ppb*

Vermeulen et al., Env. Sci. & Pol., 2, 1999
Vermeulen et al., ACPD, 6, 2006
(Inverse) Model setup

• Source receptor matrix resol. 6 minutes (0.1°)
• Domain: Western Europe
• Matrix inversion using weighted SVD
• Linear system, SRM produced using COMET
• SRM is regularized based on maximum contributions by joining adjacent gridboxes 2 by 2
• Method allows emission determination for about 200 gridboxes
• Uses full hourly concentration data
• Dipole removal
• Variance criterium (30-50%).
• TM5 background concentrations
• Prior emissions: METDAT, Edgar 3.2/4, NEU
SVD inversion + recursive Source area aggregation

High res emission map

High res SRM = emission sensitivity

SVD

Dipoles removal

Improve uncertainty

Medium resol. aggregated emission

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CH₄ Inversion 2006 (prelim!)

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Energy research Centre of the Netherlands

www.ecn.nl
One station can make a difference

- Inversion is robust, adding TRN (3 months 2006) allows to resolve France better
Increasing model emissions+resolution

- WRF V3 mesoscale
- Resolution 15+5 km
- Passive tracers
- ECMWF 0.2 meteo
  - Constant Rn
  - Szegvary Rn
  - 5 km res CH4 IER

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High resolution forward model results

R=correlation coefficients
Rn observed/modelled:
- Comet_20_cnst 0.74
- Comet_20_Conen 0.72
- Comet_200_cnst 0.74
- Comet_200_Conen 0.36
- WRF_10_cnst 0.63
- WRF_10_szeg 0.66
- WRF_40_cnst 0.59
- WRF_40_szeg 0.61
- WRF_190_cnst 0.63
- WRF_190_szeg 0.48
Conclusions, outlook

- Network is working, delivering data (still)
- Measurement are consistent, but more intercomparisons are needed
- Continuous data looks noisy at first sight, but is full of valuable information
- Potential can be exploited using high resol. models
- First regional inversions on basis of data promising and consistent
- Measurements are now under severe threat
- **Support for infrastructure is critical!**

**Outlook:**
- Inversion for emissions CH4 2007 (NEU)
- Inversions for emissions N2O (NEU)
- Including Edgar V4 prior emissions at 0.1° res.
- Implement SVD inversions based on WRF SRM’s (2 km res)
Acknowledgements

- EU FP5/6:
  - CHIOTTO
  - CarboEurope-IP
  - NitroEurope-IP
  - IMECC
  - Geomon

- Klimaat voor Ruimte:
  - ME-2

ECN crew:
- Pim van den Bulk, Piet Jongejan, Gerben Pieterse, Rob Rodink, Bart Verheggen, Elena Popa