Are methane concentration trends in line with methane emissions?

TNO | Knowledge for business

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Question

Methane emissions in many European countries and in the US are reported to have decreased considerably since the 1990s.

Do we see a signal of emission reduction in the time series of observations?

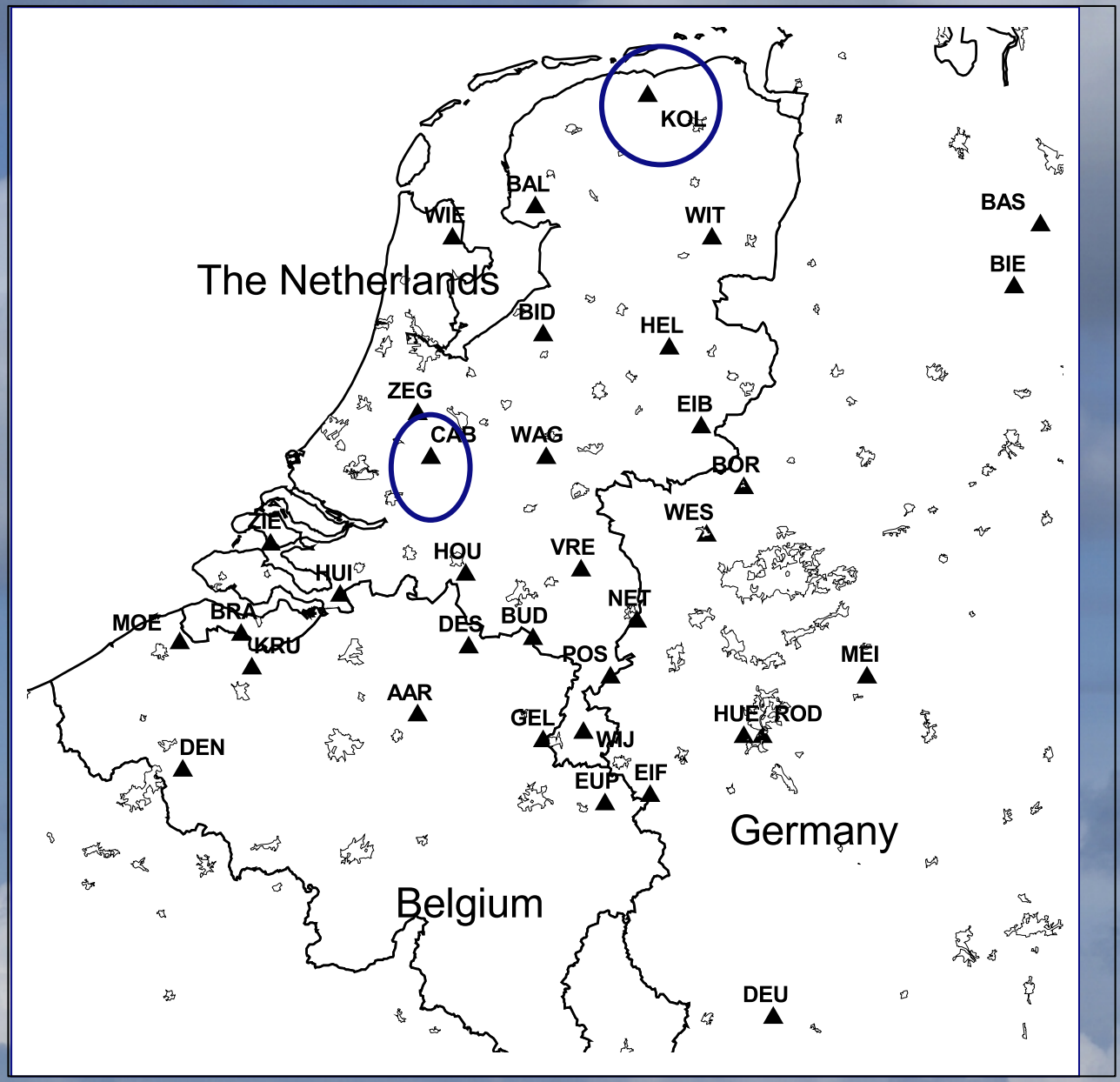
Objective

1. To split the time series of observations into global, regional and local contributions.

2. To perform a trend analysis on the filtered time series, taking into account meteorological fluctuations.

3. The resulting trends in the filtered (regional) observations should be indicative of changes in regional emissions.

4. To compare trends in the observations with reported national emission trends.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ROD
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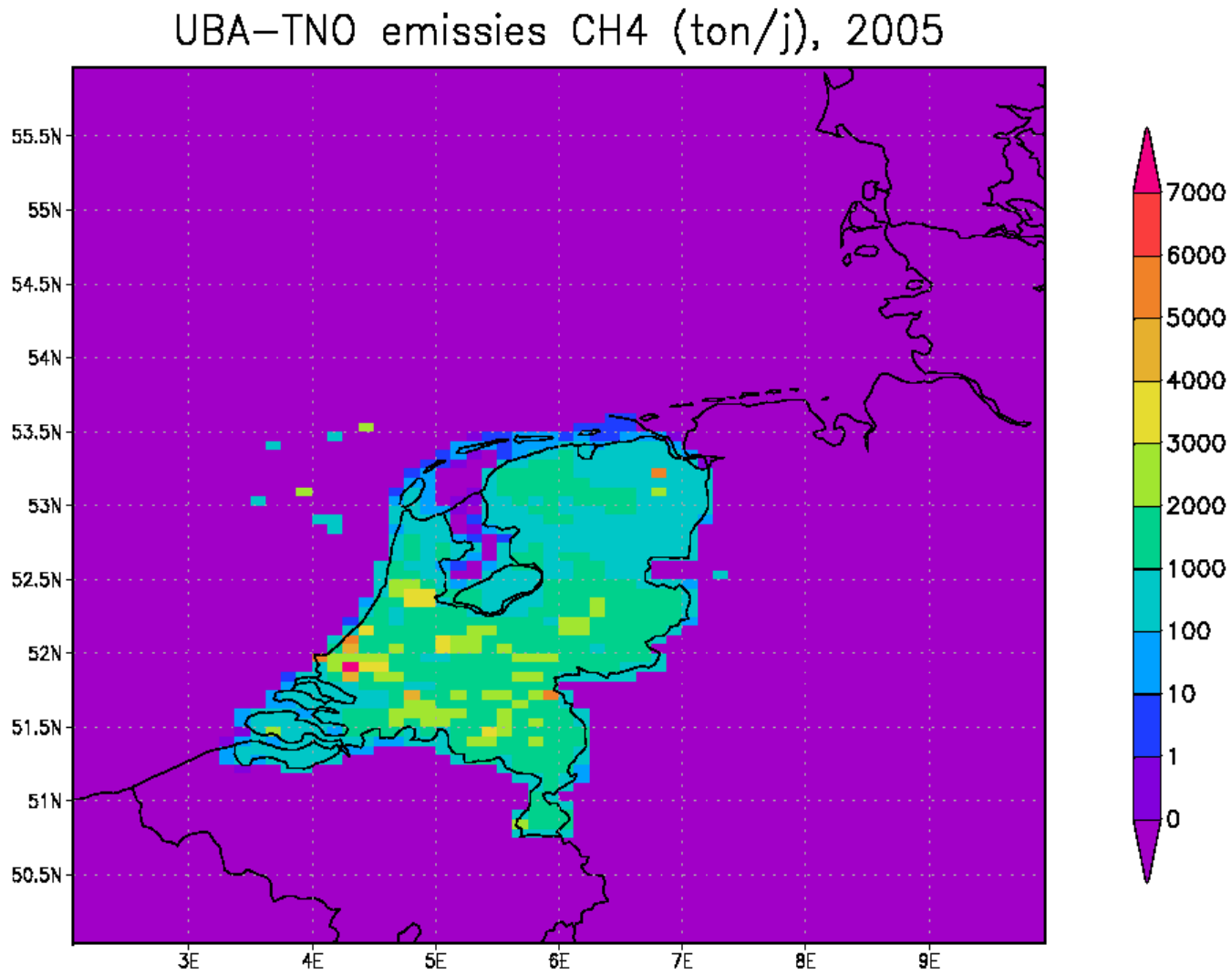
WIJ
EUP
EIF
Germany
Belgium
DEU

A few characteristics of Kollumerwaard

- Background values (NW winds) ~ 1800 ppb
- Contribution from European sources ~100-200 ppb


UBA–TNO emissies CH4 (ton/j), 2005
55.5N
55N
54.5N
54N
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53N
52.5N
52N
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Approach

1. Model simulations with:
    1. TM5 (assimilation mode) for global scale,
    2. LOTOS-EUROS for European scale
    3. Plume model for local scale (30-60 km)

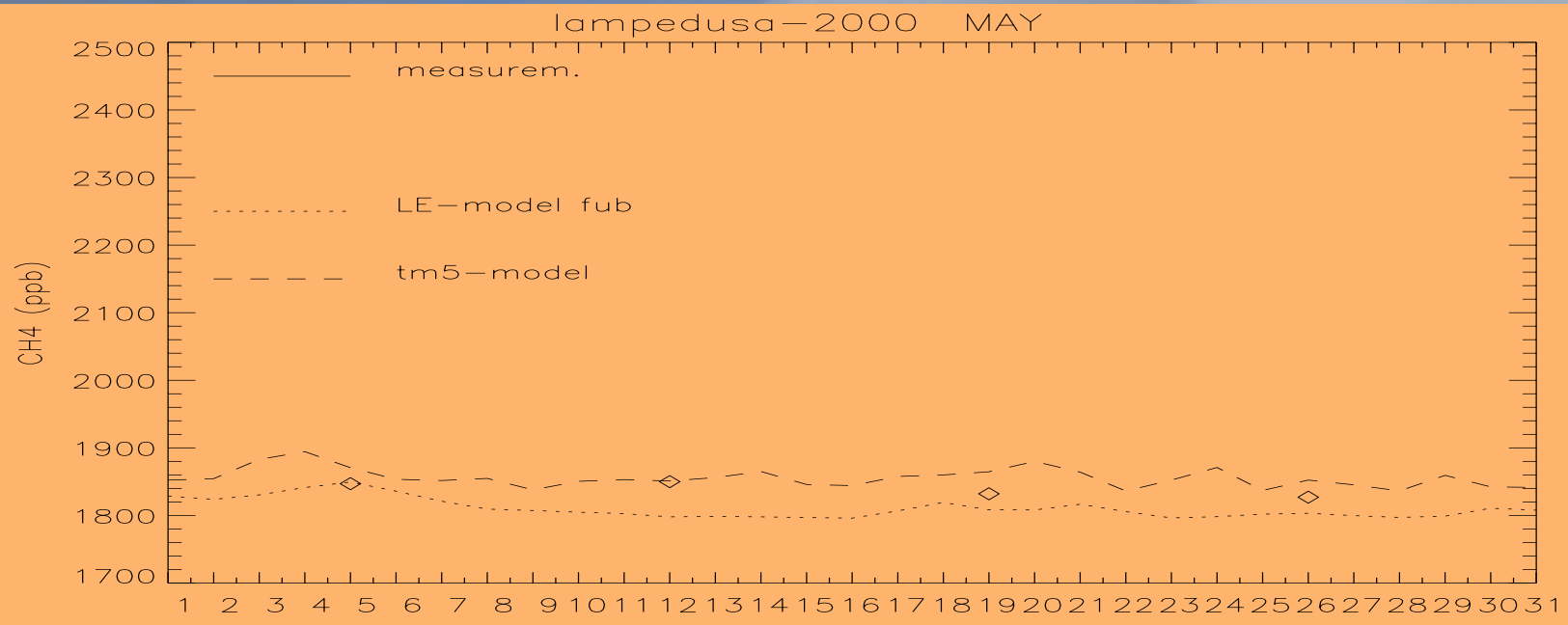
2. Compare with observations and identify contributions from:
    1. Background,
    2. A few nearby countries,
    3. Rest of Europe
    4. Grid cells (30-60 km) at and near measurement sites

3. Identify in the time series (modelled and measured) features that are characteristic of global and local contributions

4. Apply criteria for global and local contributions to time series of observations to separate local and global from regional contributions

Models

- TM5 (assimilation mode) results available, and to provide boundary conditions to LOTOS-EUROS model
- LOTOS-EUROS model: European scale, 0-2/3 km, 0.25lat*0.50lon resolution
- A Gaussian plume model (Nieuw Nationaal Model) using same emissions as LOTOS-EUROS in corresponding grids
- In LOTOS-EUROS CH4 contributions from boundaries, from a few countries, and from grid cells near Kollumerwaard and Cabauw were marked


lampedusa—2000 MAY
measurem.
LE—model fub
tm5—model
CH4 (ppb)
2500
2400
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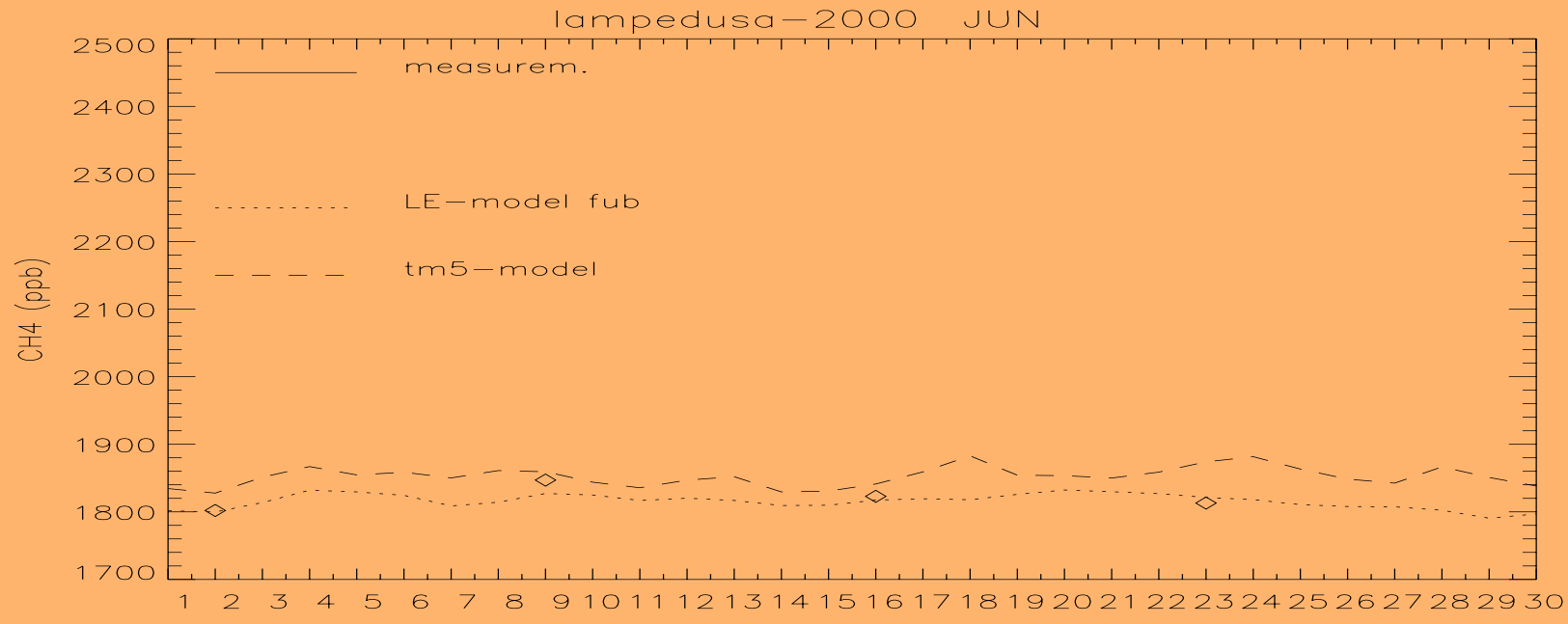
lampedusa—2000 JUN
measurem.
LE—model fub
tm5—model
CH4 (ppb)
2500
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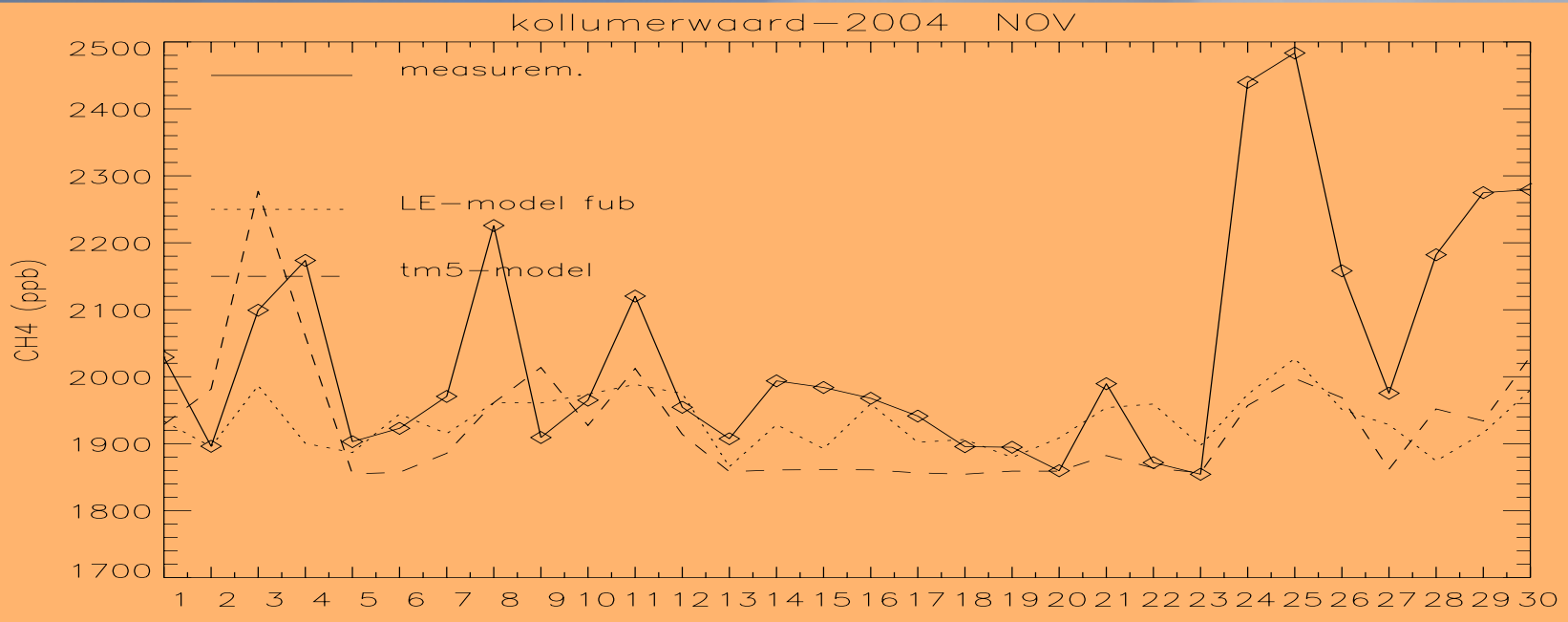
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


kollumerwaard—2004 NOV
measurem.
LE—model fub
tm5—model
CH4 (ppb)
2500
2400
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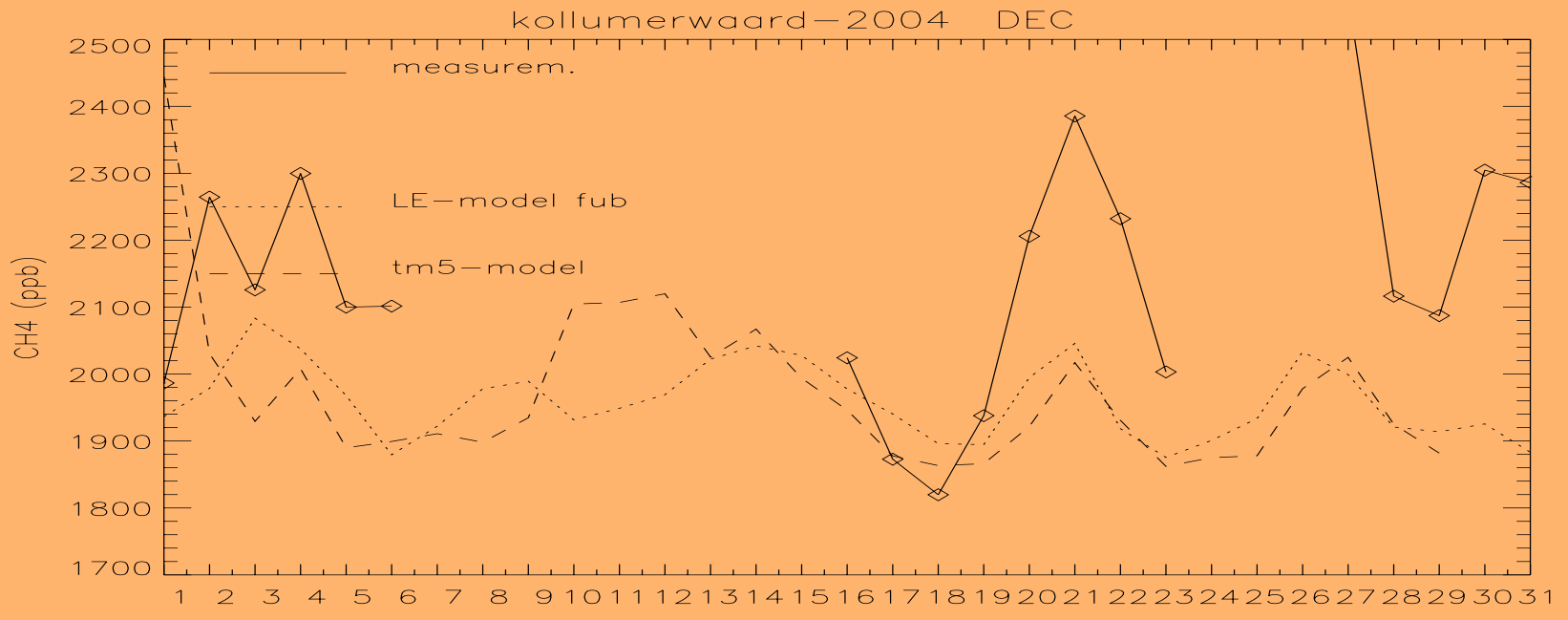
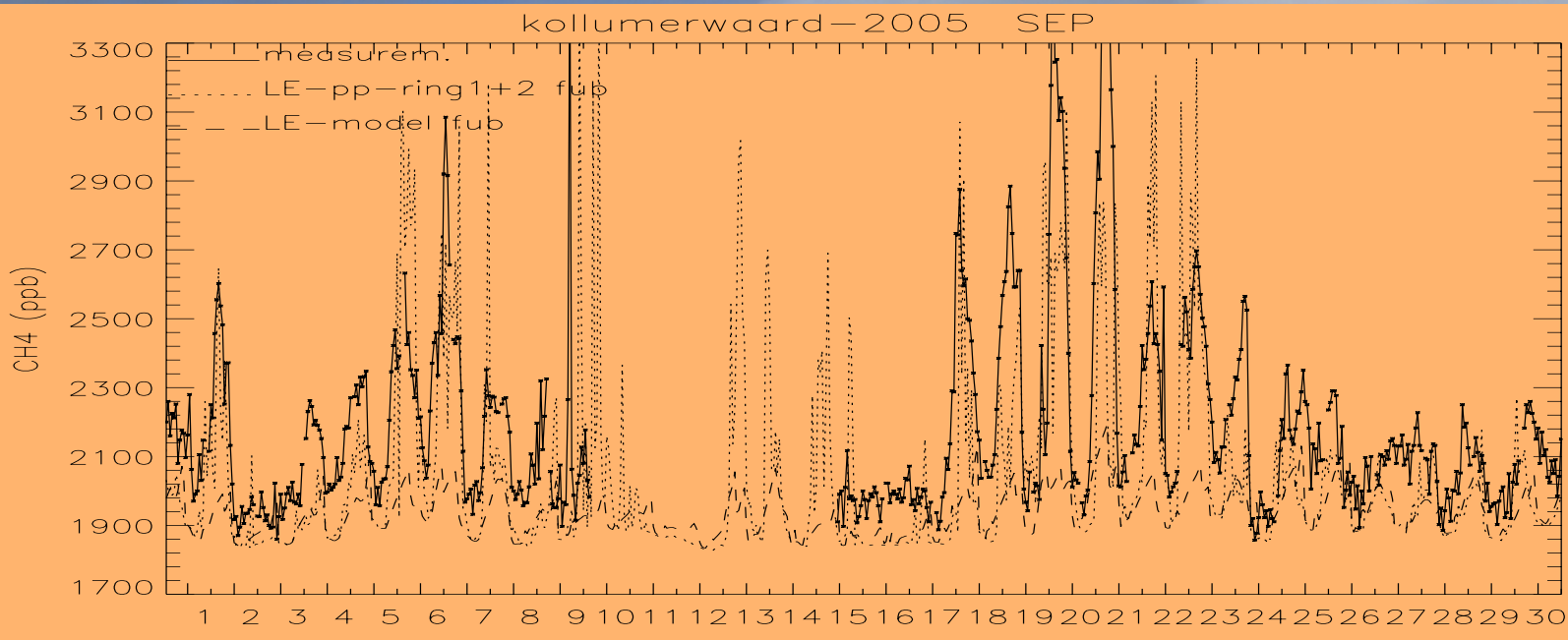

kollumerwaard—2004 DEC
measurem.
LE—model fub
tm5—model
CH4 (ppb)
2500
2400
2300
2200
2100
2000
1900
1800
1700
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Background

- Modelled background value at Kollumerwaard:~1830 ppb
  - (contribution of TM5 boundary conditions)
- Measurements (2000):
  - Lowest values: 1780-1800 ppb
  - 01-percentile: 1840 ppb
  - 10-percentile: 1880 ppb
  - 25-percentile: 1920 ppb
- 01-percentile (on a monthly basis) of observations seems good indicator of background conditions
- Substract 01-percentile (monthly) from data to obtain European contributions (regional+local)


kollumerwaard—2005 SEP
measurem.
LE—pp—ring1+2 fub
LE—model fub
CH4 (ppb)
3300
3100
2900
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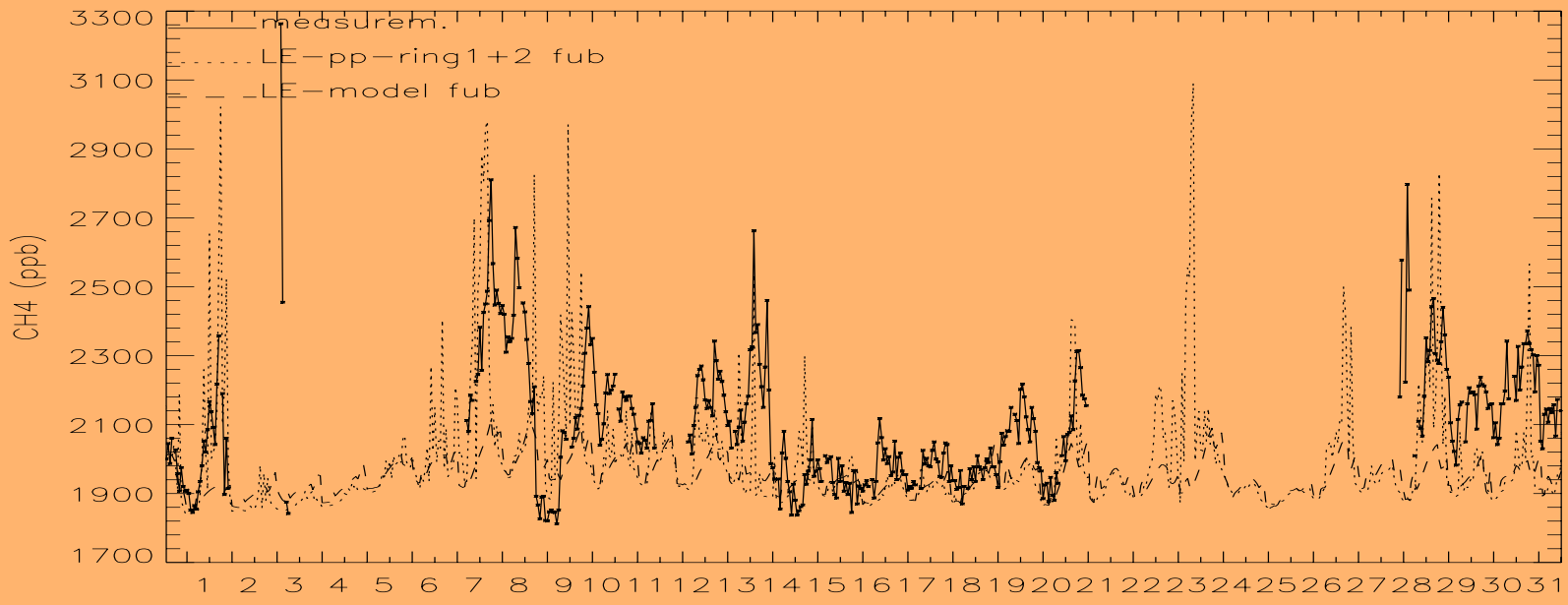
2500
2300
2100
1900
1700
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


kollumerwaard—2005 OCT
measurem.
LE—pp—ring1+2 fub
LE—model fub
CH4 (ppb)
3300
3100
2900
2700
2500
2300
2100
1900
1700
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Conclusions (1)

- TM5 and TM5/LOTOS-EUROS perform quite well compared to observations in rural areas
- TM5 and TM5/LOTOS-EUROS have a problem in simulating peak values of CH4 in areas with strong sources
- Adding of a plume model for the local scale improves peak simulation a lot, although timing of peak is not always correct
- Use characteristics in modelled time series to identify local contributions

Country contributions at Kollumerwaard

- Netherlands: 37%
- Germany: 35%
- Belgium: 5%
- France: 5%
- UK: 13%
- Rest of Europe: 5%

Characteristics of local contribution in polluted areas

- Contributions from regional sources never exceed certain levels,O(500-800 ppb). If more, then contribution is from nearby sources

- Contributions from regional sources manifest themselves usually by gradual changes (dc/dt: low)
- Contributions from local sources can manifest themselves by rapid changes (dc/dt: occasionally high)

- From the model simulations criteria emerge (level of contribution, dc/dt) to detect local contributions

Dc/dt

	1/c*Dc/dt (min) (/h)	1/c*Dc/dt (max) (/h)	1/c*Dc/dt (avg(abs)) (/h)
Modelled background	-0.0	0.0	0.0003
Modelled regional	*-2.4*	*0.8*	*0.1*
Modelled plume	-14.1	13.9	0.6
Modelled regional+plume	-9.3	9.0	0.4
Measurements-p01P	-3.3	5.9	2.0

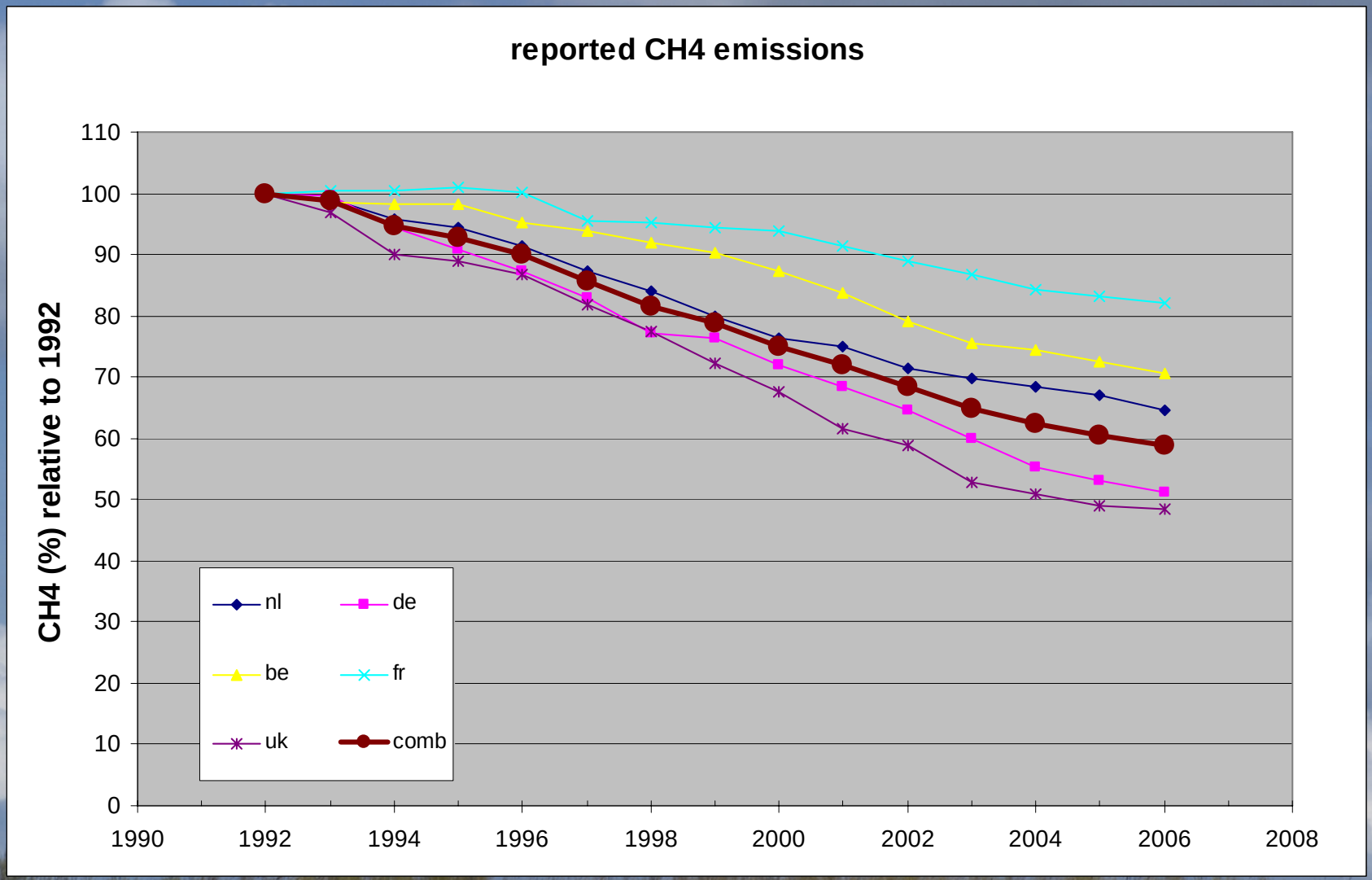
Criteria Kollumerwaard

- Contributions above 800 ppb: local
- Data points with 1/c*dc/dt > 2.4/h considered as local
- Apply this to observations – 01percentile: → regional and local time series

Trends 1992-2000

- Background (p01-percentile): 4-5 ppb/yr
- Regional: application of regression model with variables such as:
  - Wind direction
  - 1/wind speed
  - Kzz (from the model)
  - Trend
- Result: regional contribution has dropped at 3.5%/yr, equalling a reduction of 28% in 2000 compared to 1992.

Emissions


reported CH4 emissions
CH4 (%) relative to 1992
110
100
90
80
70
60
50
40
30
20
10
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
nl
de
be
fr
uk
comb

Conclusions

- A combination of models at 3 different scales gave reasonable results of simulating CH4 observations in areas with strong sources.
- Background was removed from observations by subtracting monthly 01-percentile.
- Over 1992-2000 interval background increased by 4-5 ppb/yr.
- Local contributions were removed by application of criteria on dc/dt and absolute levels
- Over 1992-2000 interval resulting regional time series showed a downward trend of 3.5%/yr, implying a drop by 28%.
- Over 1992-2000 interval the reported emissions (combined) of NL, Be, Ger, UK, Fr show a reduction of 25%.