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Department of Environmental Science

High-resolution modelling of health impacts and related external cost from air pollution using the integrated model system EVA

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Denmark

WHO report 25/3-2014

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7 million deaths annually linked to air pollution

In new estimates released, WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

Read the news release on air pollution

Read the feature story on air pollution

FAQs on air pollution
pdf, 169kb

Air pollution estimates
pdf, 1.16Mb

3.7 million deaths
attributable to ambient air pollution

4.3 million deaths
attributable to household air pollution

7 million deaths
caused by air pollution in 2012, covering

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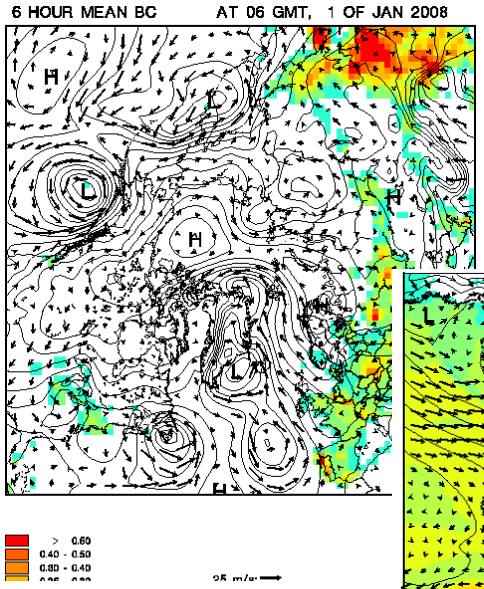
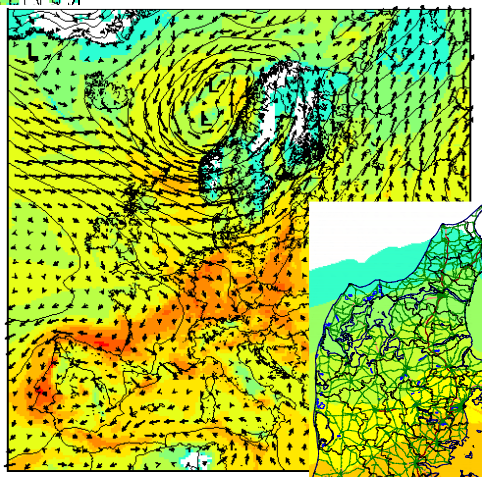
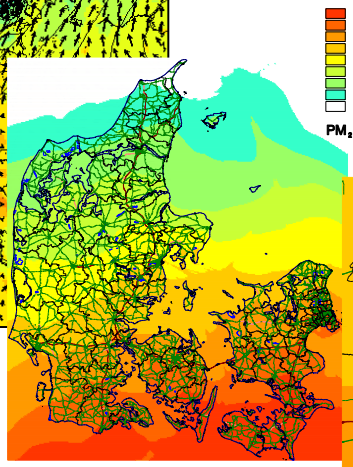
The integrated THOR system

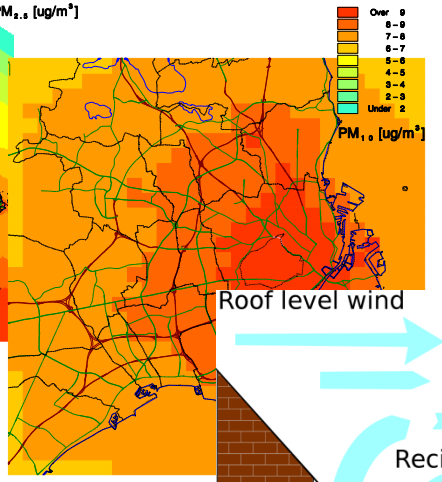


DEHM





UBM



50%

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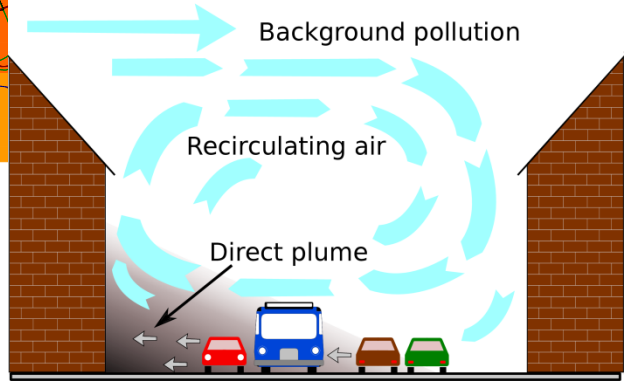
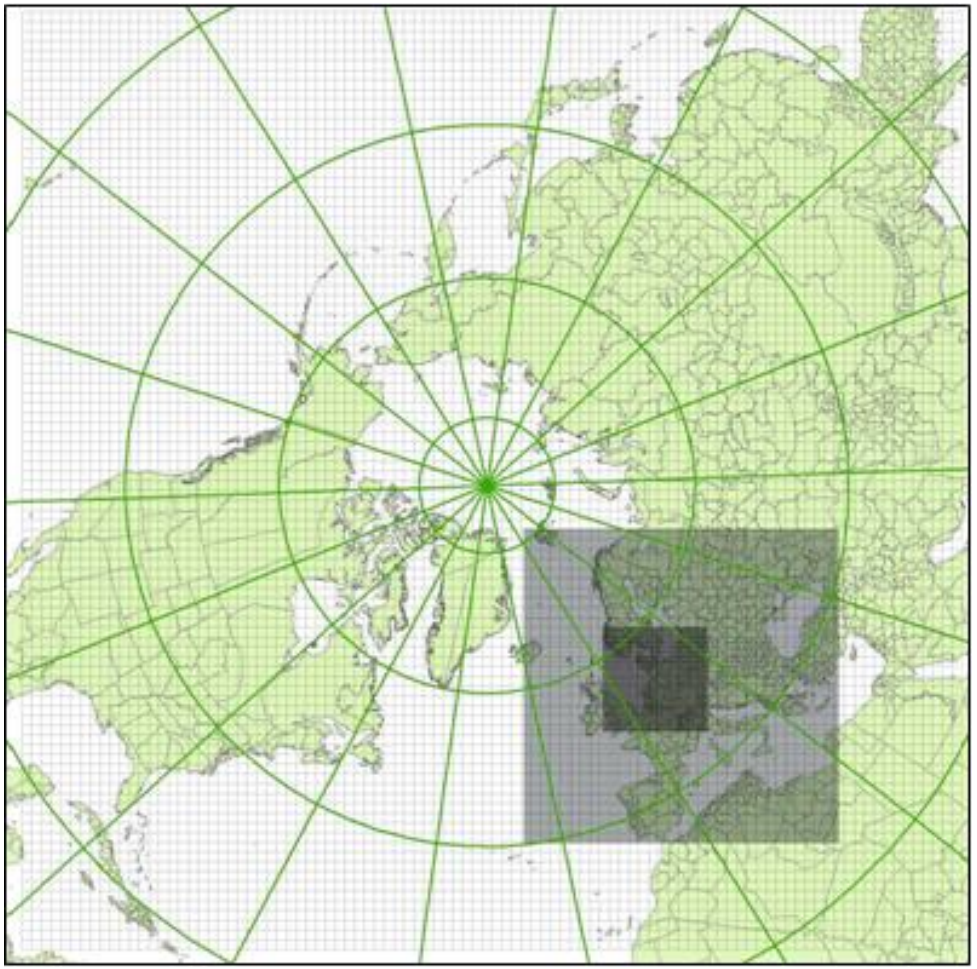
OSPM



The Danish Eulerian Hemispheric Model, DEHM

- Long-range transport of air pollution in the Northern Hemisphere and/or Europe
- Species: photo-chemistry and particles (67 species), POPs, (PCBs, HCHs, PAHs and dioxins - 15 species), mercury (7 species), pollen, CO_2, etc.
- Two-way nesting capability
- 150 / 50 / 16,67 / 5,56 km grid resolutions
- 29 vertical levels up to ~16 km
- Model run and validation for a period of 25 years (1989 to 2013)
- Emission tagging capability
- Can be run on climate data
- DA – OI, 3D-var or EKF



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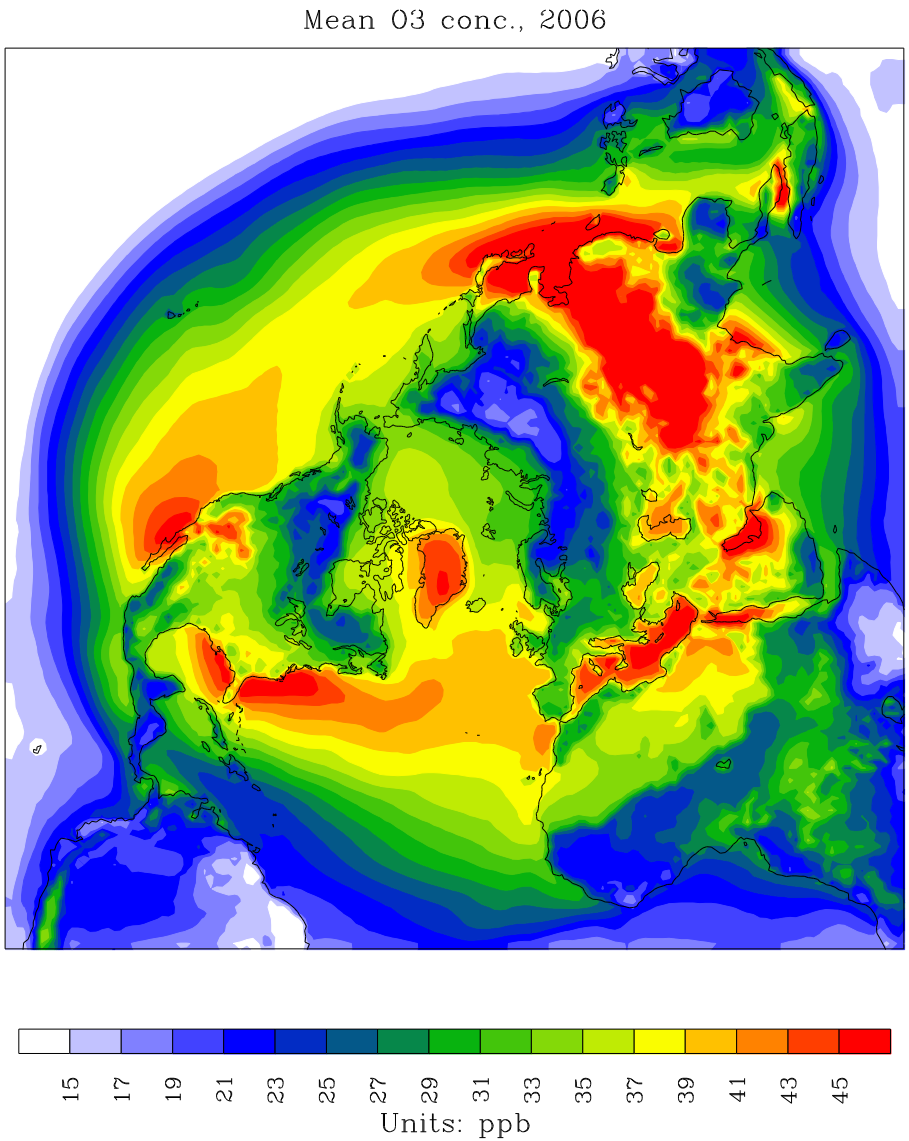
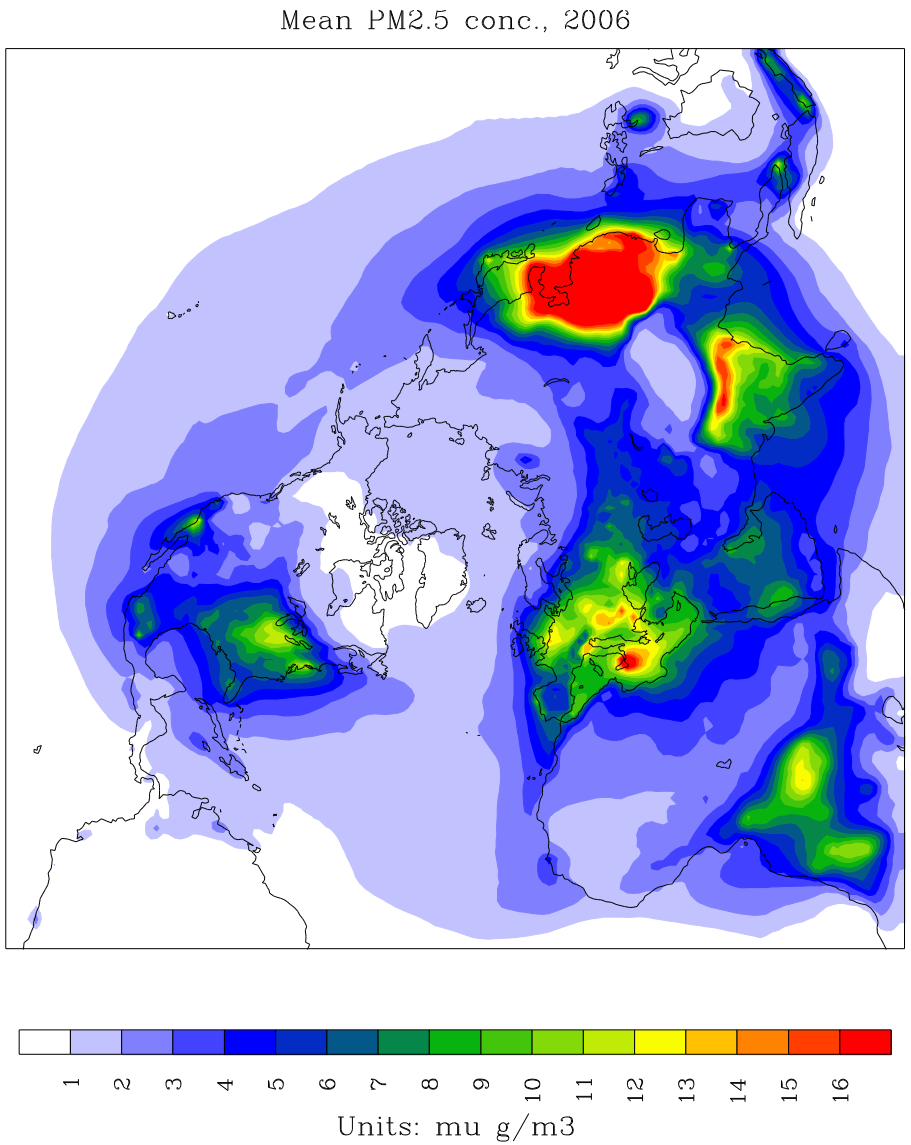
The Danish Eulerian Hemispheric Model, DEHM





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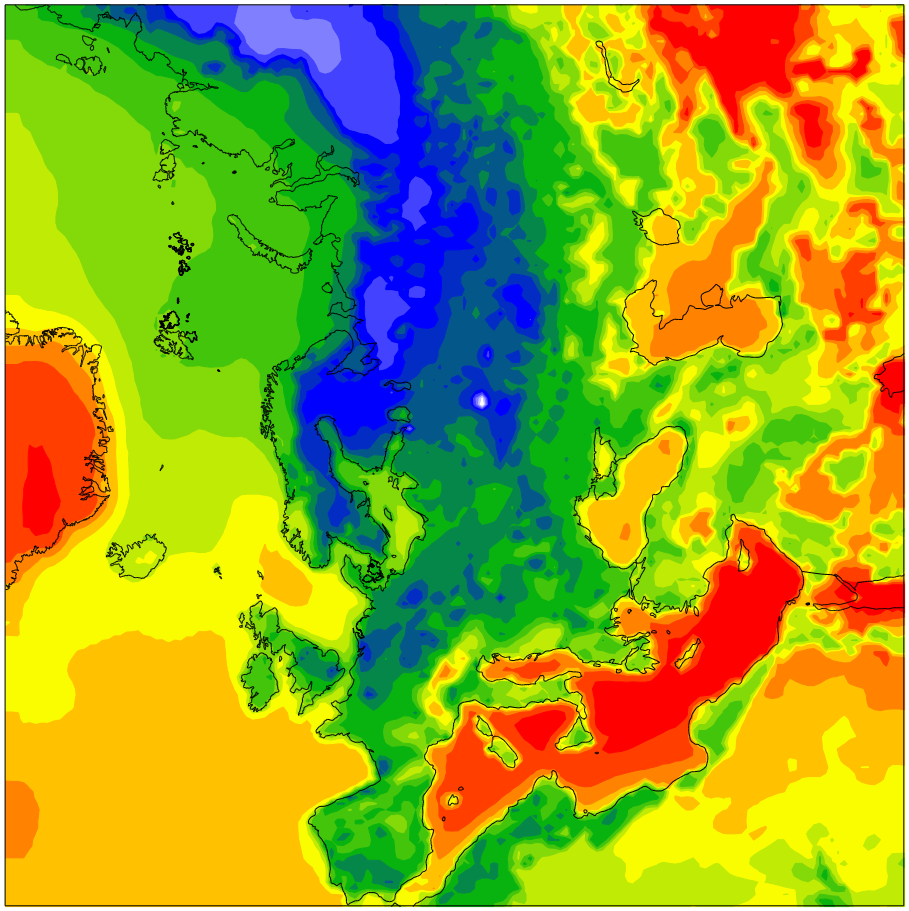
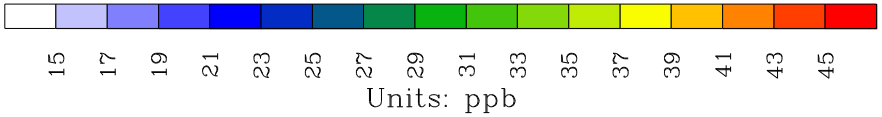
November 2014,

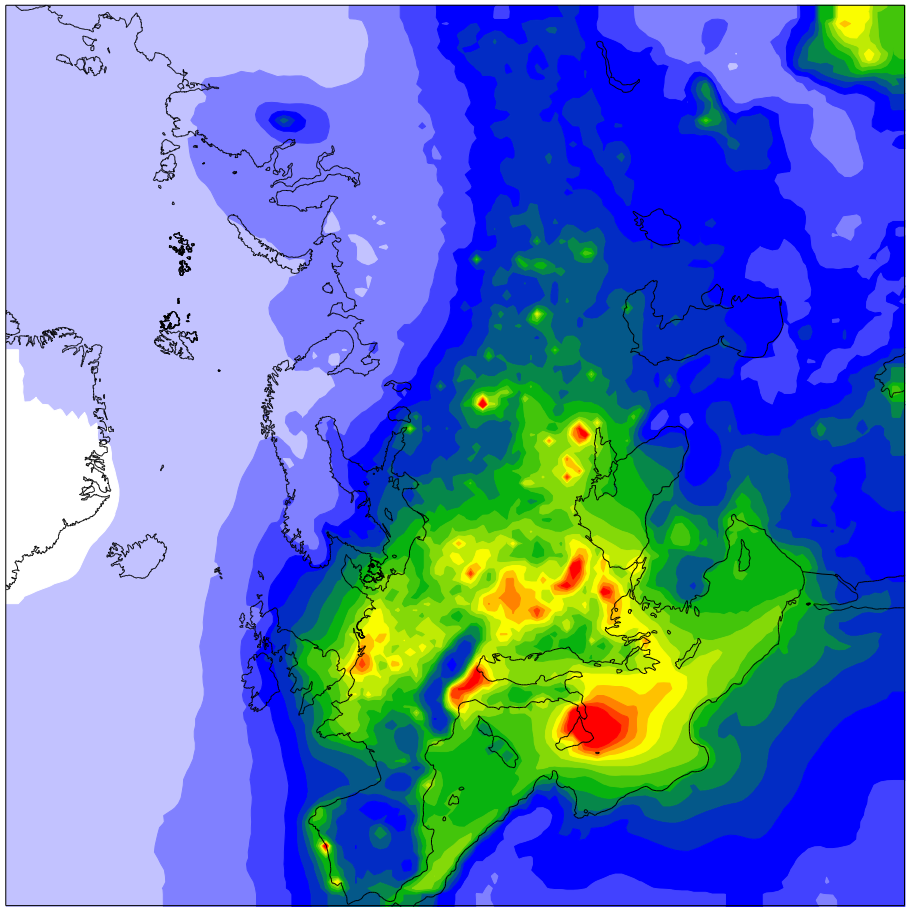
The Danish Eulerian Hemispheric Model, DEHM

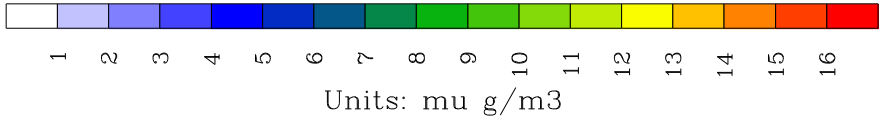
Mean O3 conc., 2006





Mean PM2.5 conc., 2006





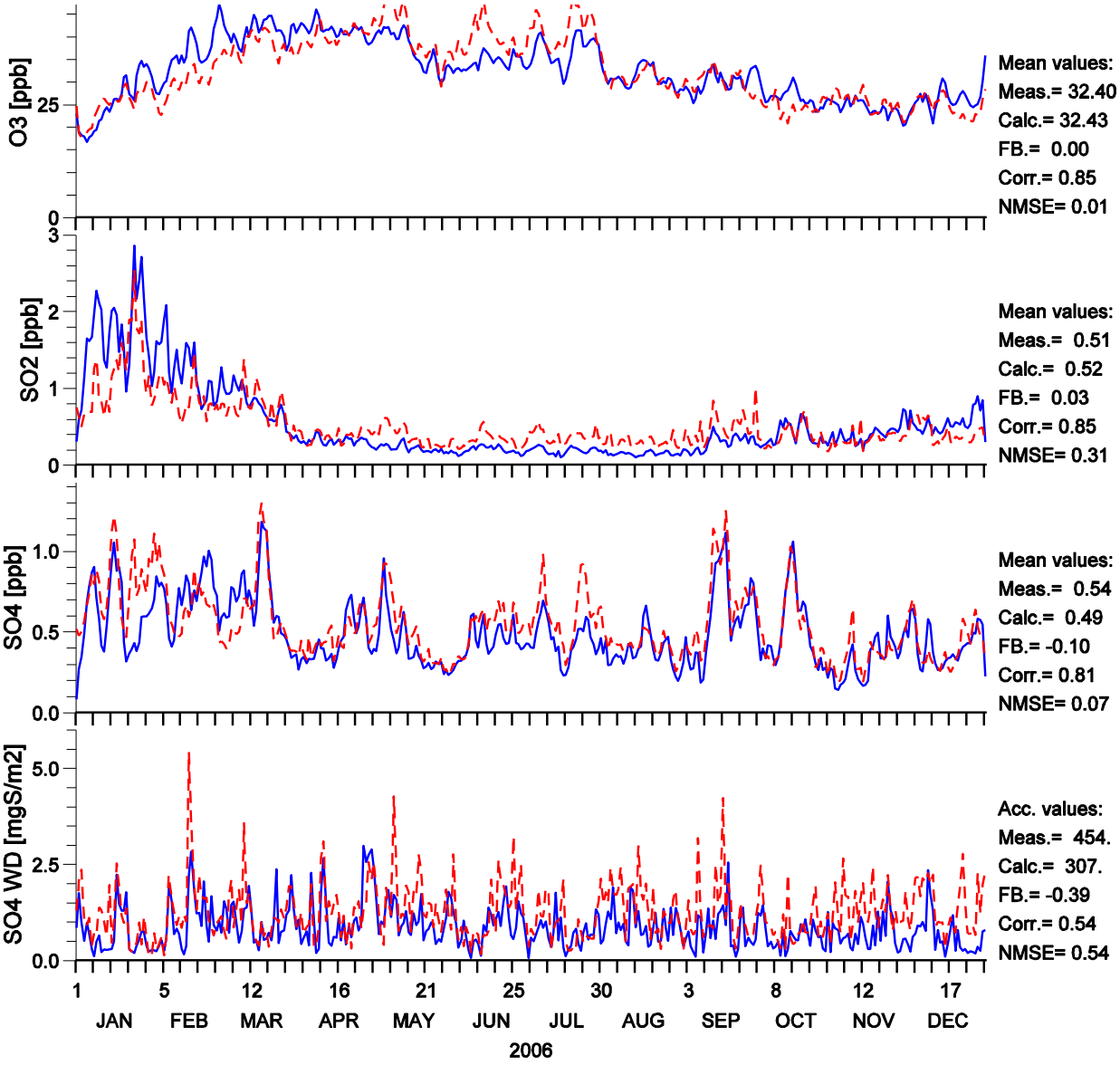
The Danish Eulerian Hemispheric Model, DEHM

O_3

SO_2

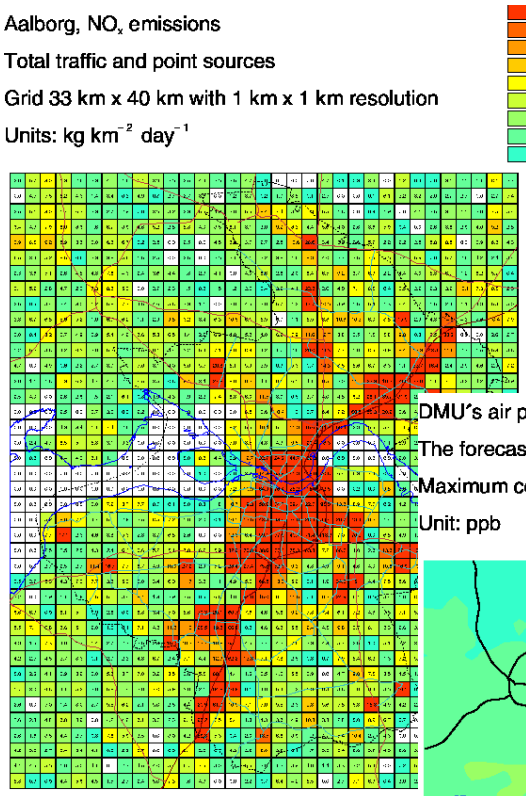
SO_4^{2-}

SO_4 Wet Dep.

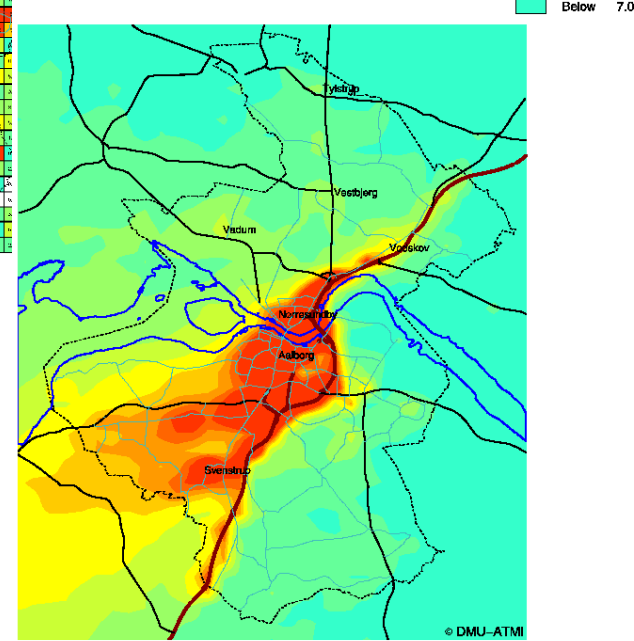


Urban Background Model, UBM

- Gaussian multiple plume model (horizontal) and linear dispersion to H_{mix} (vertical)
- Input data:
  - Meteorological forecast from the Eta/MM5 model
  - Regional air pollution forecast from DEHM
  - Emissions of e.g. NO_x, CO and PM, etc.
- Output: Hourly values of O_3, NO, NO_2, NO_x , CO and PM
- Resolution 1 km x 1 km

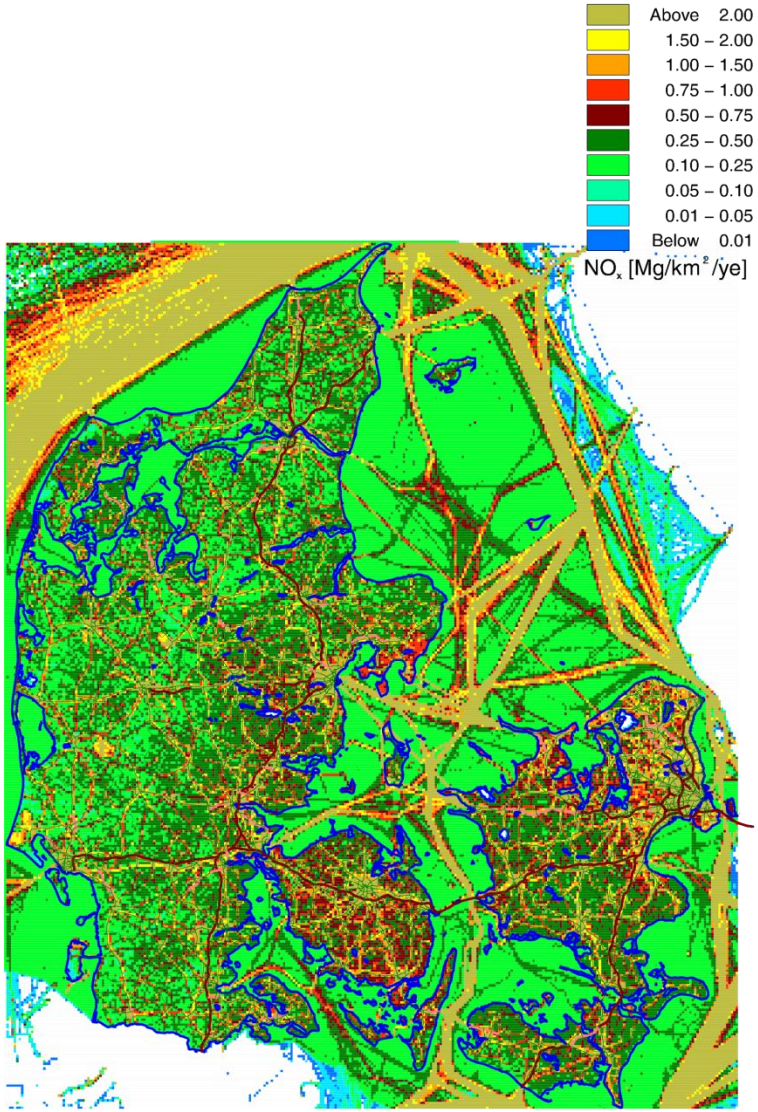


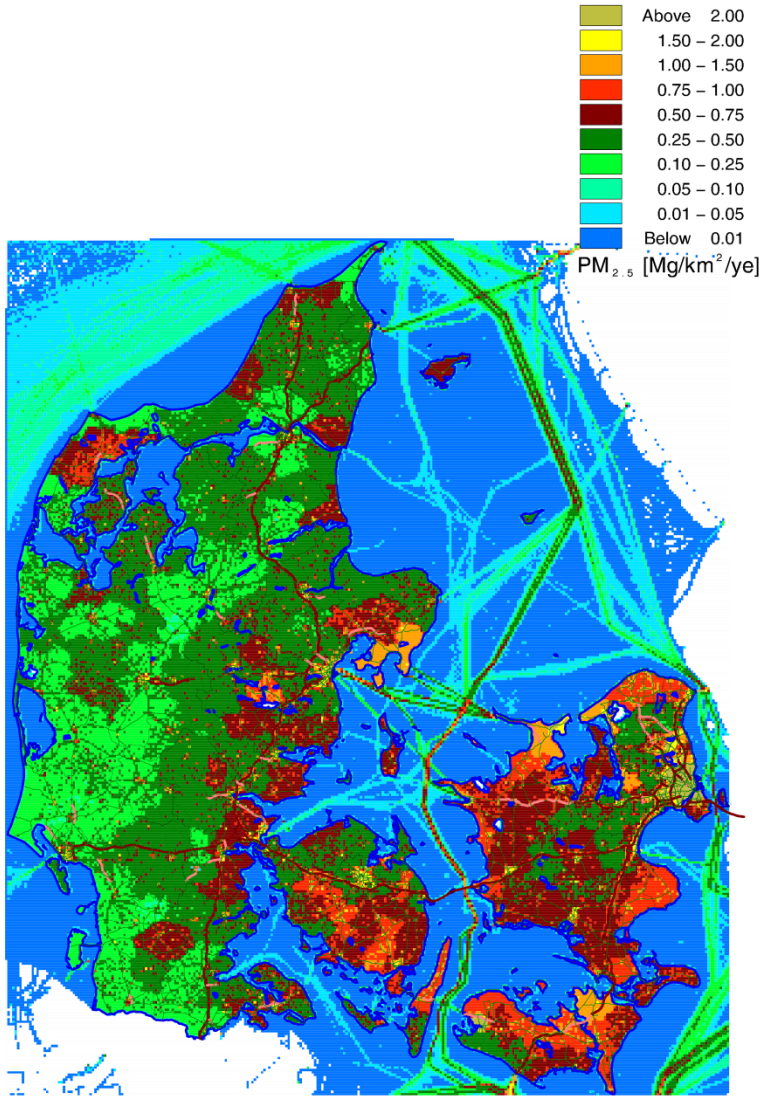
NO_x emissions [kg/km^2/day]



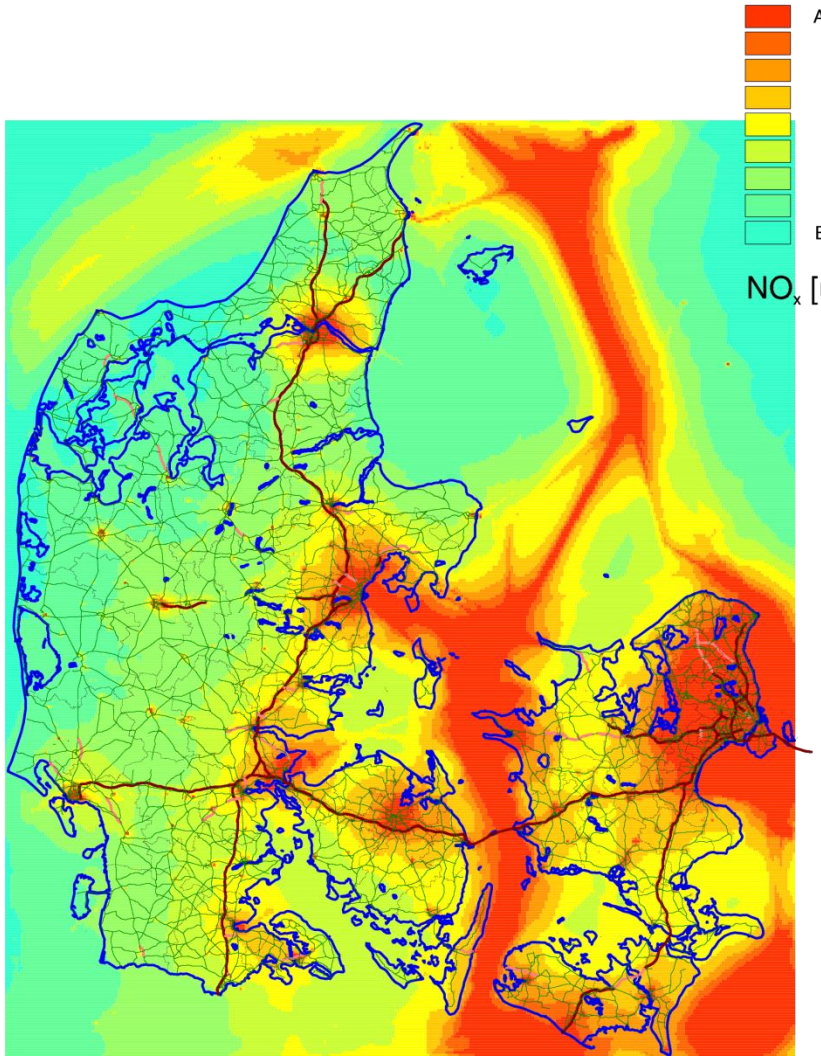
NO_2 conc. [ppb]

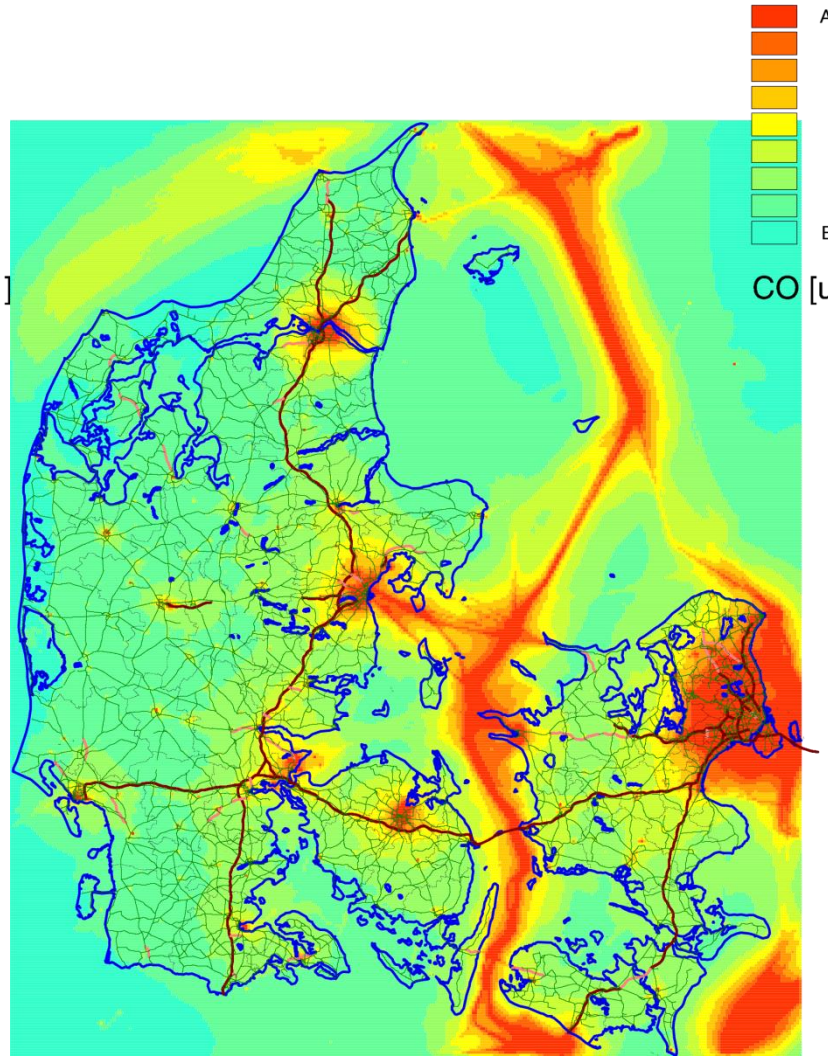
Emissions from SPREAD



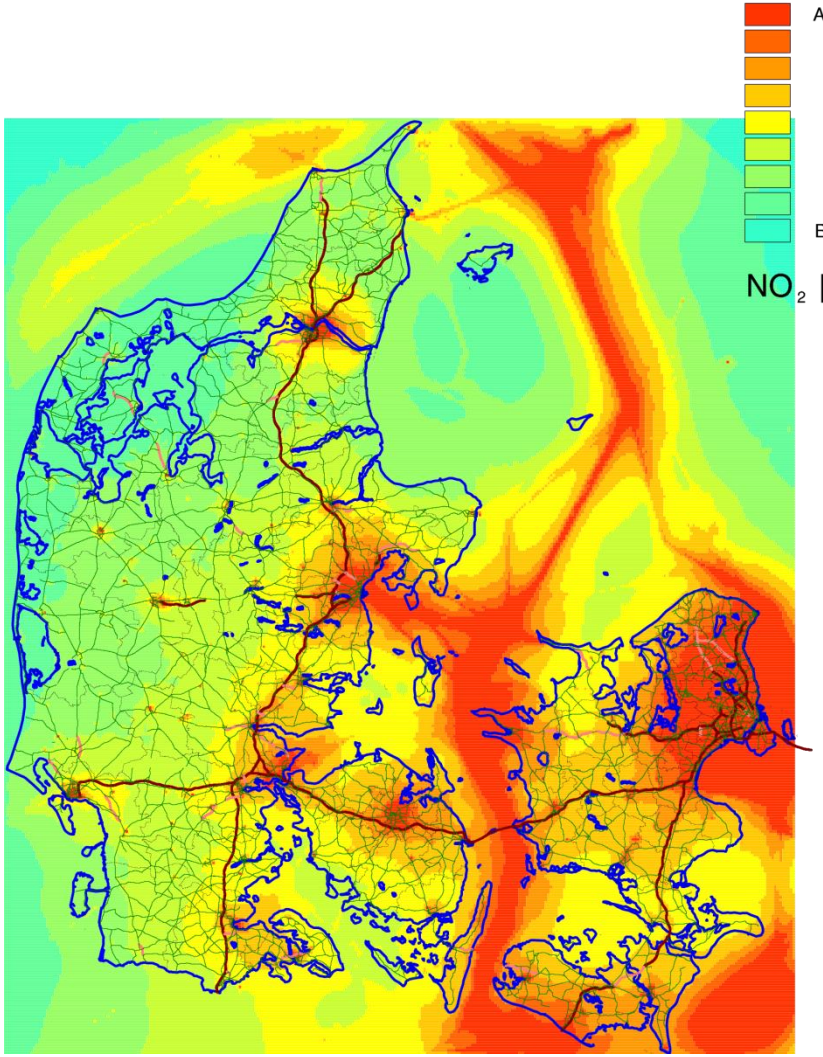


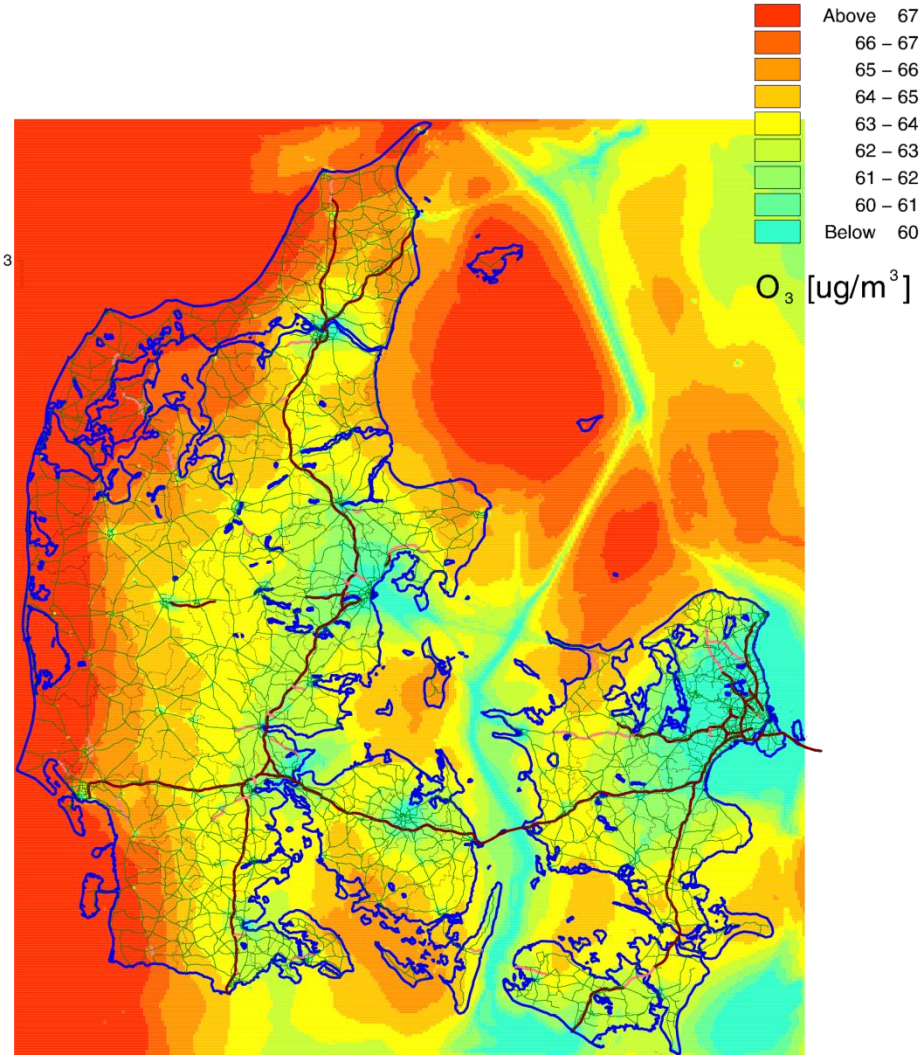
Urban Background Model, UBM



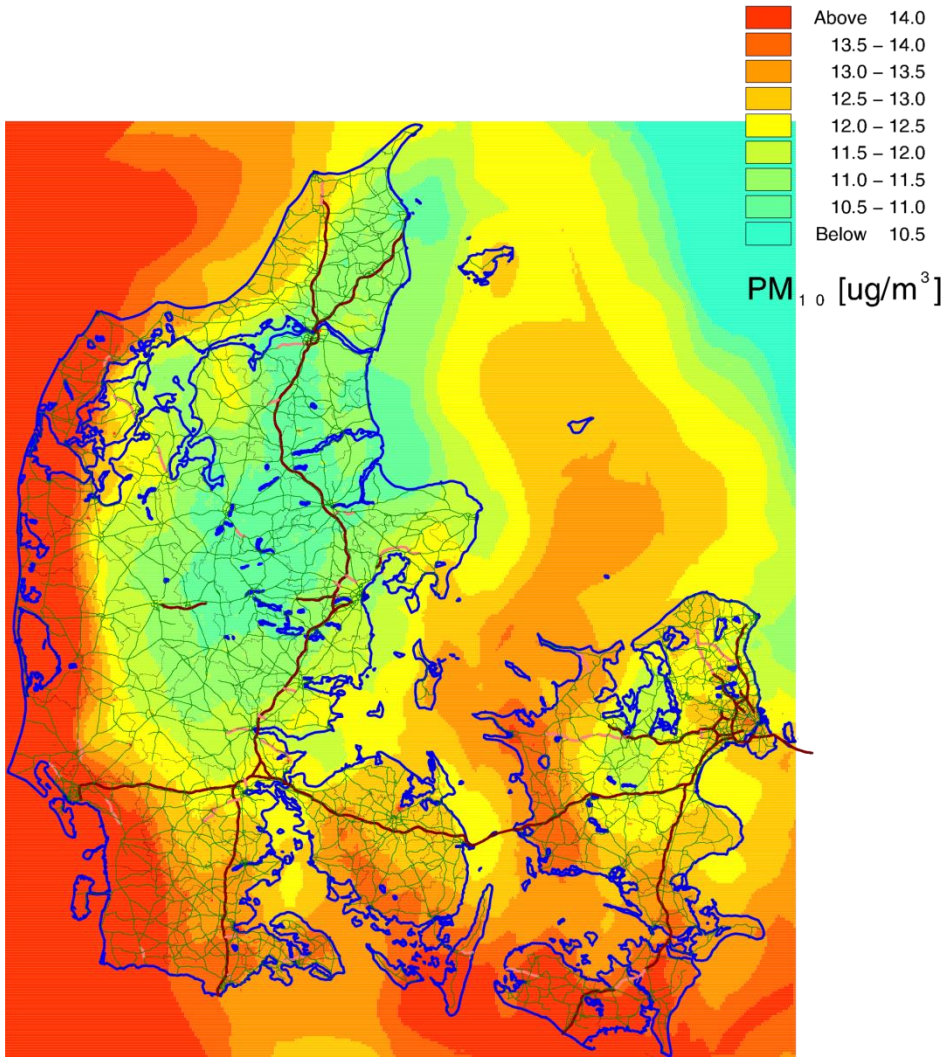


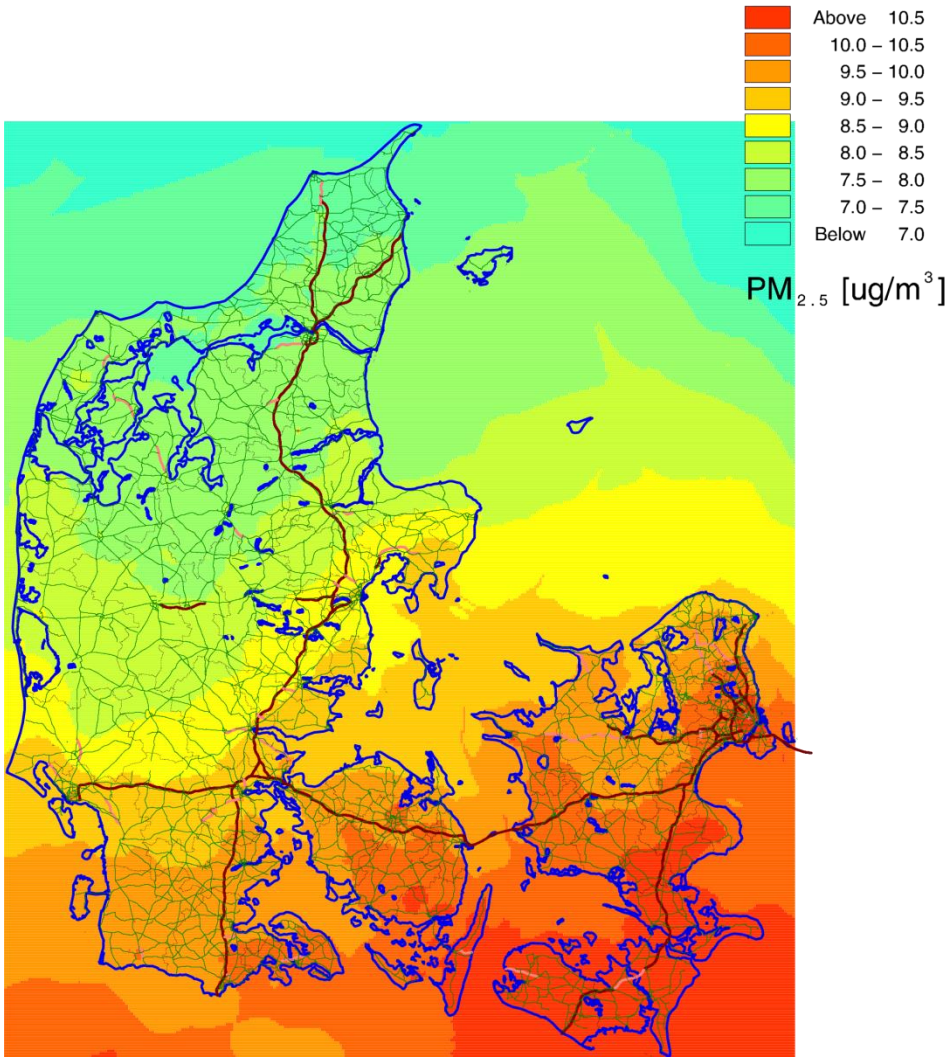
Urban Background Model, UBM



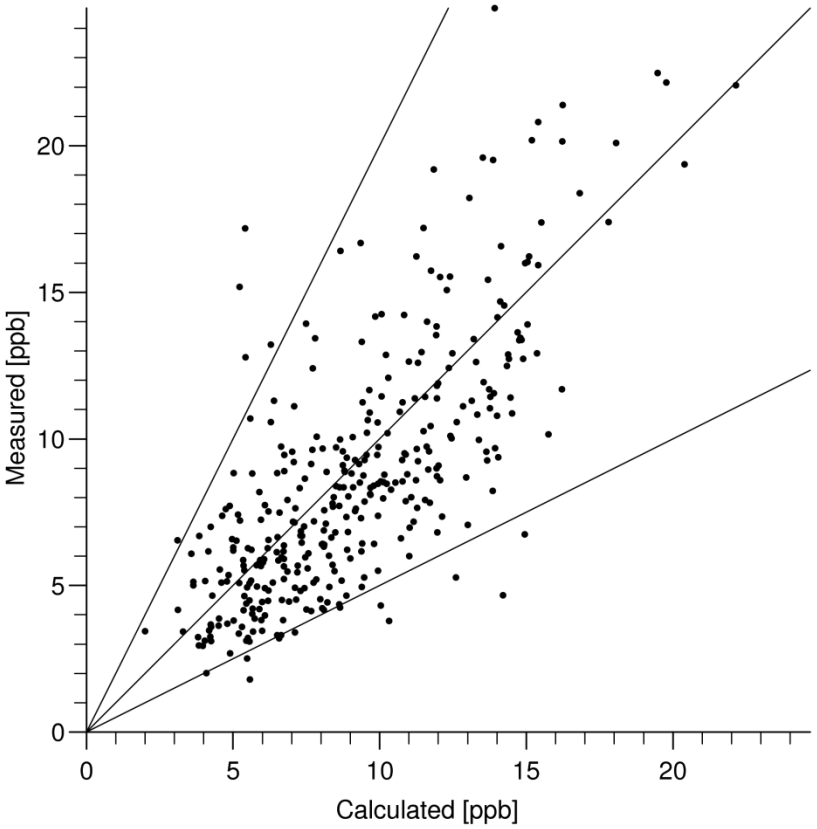


Urban Background Model, UBM



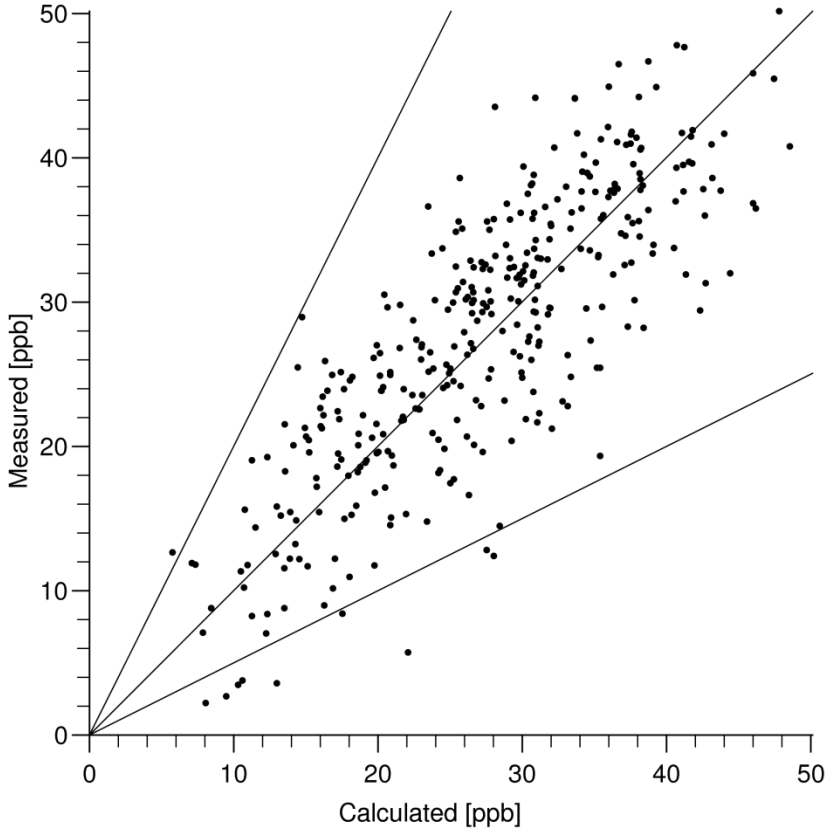


NO_2, DAILY MEAN VALUES



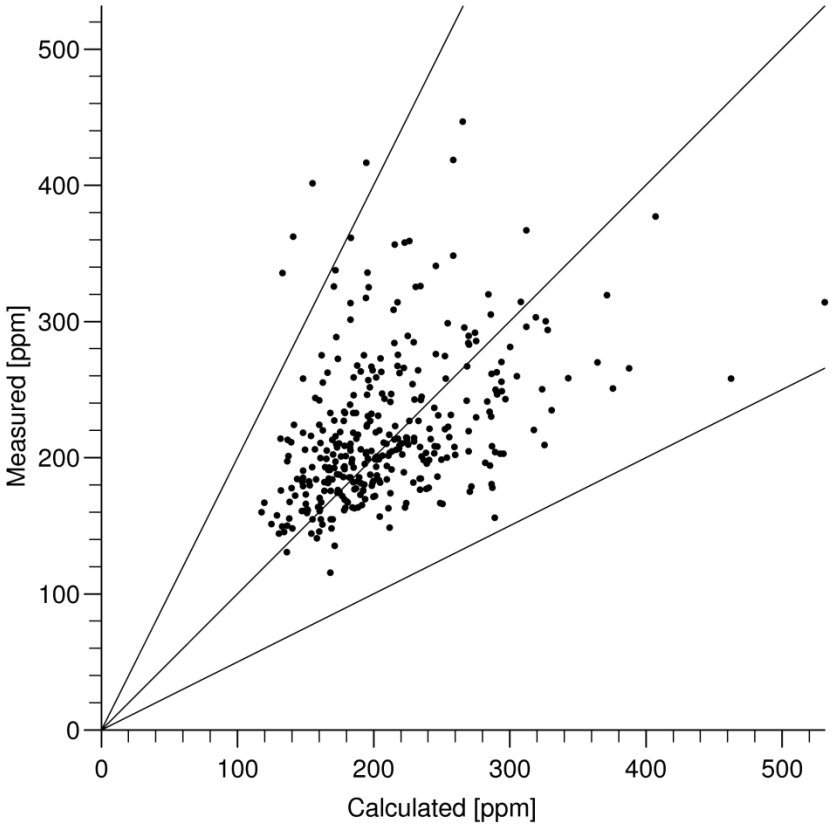
N = 358, means: calculated = 9.11, measured = 8.68
Standard deviations: calculated = 3.51, measured = 4.24
correlation = 0.75, test (H: corr=0) = 21.26, FM = 78.05%
bias = 0.427, ci_{bias}(95%) = +/- 0.294, FB = 0.048, FSD = -0.373
NMSE = 0.104, ci_{NMSE}(95%) = +/- 0.000

O_3, DAILY MEAN VALUES



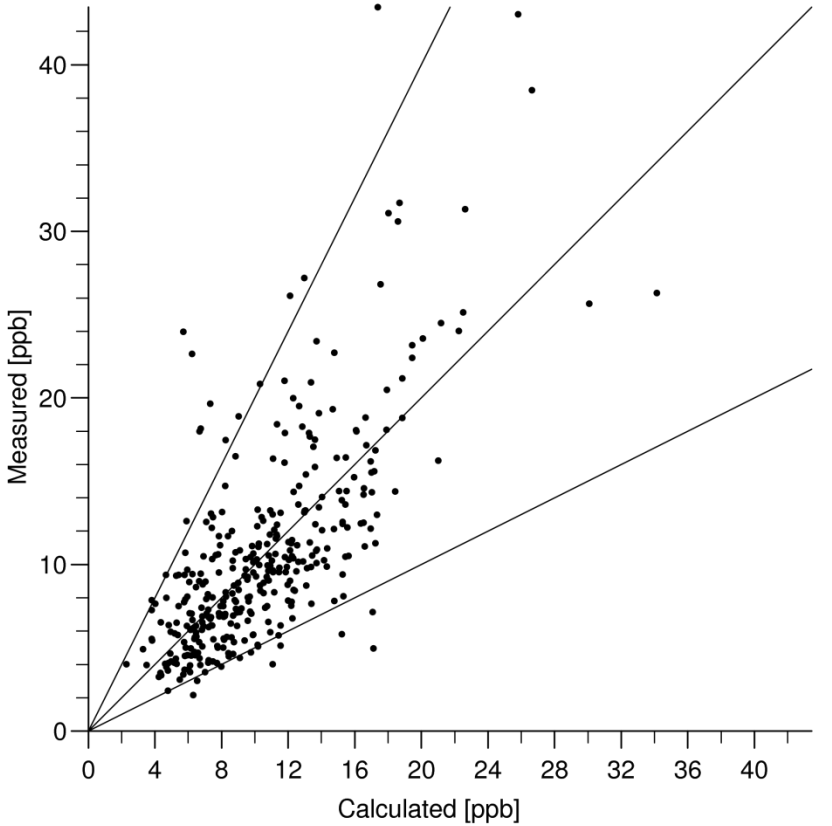
N = 358, means: calculated = 27.23, measured = 27.82
Standard deviations: calculated = 8.94, measured = 9.61
correlation = 0.82, test (H: corr=0) = 27.13, FM = 84.85%
bias = -0.584, ci_{bias}(95%) = +/- 0.580, FB = -0.021, FSD = -0.144
NMSE = 0.042, ci_{NMSE}(95%) = +/- 0.000

CO, DAILY MEAN VALUES



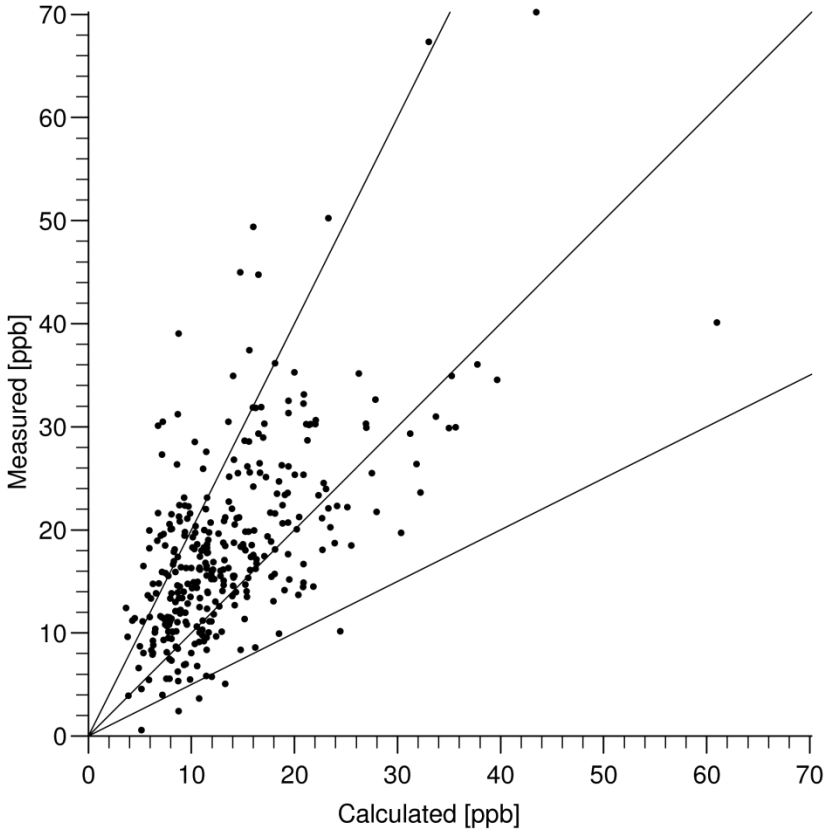
N = 348, means: calculated = 209.86, measured = 219.74
Standard deviations: calculated = 55.98, measured = 54.08
correlation = 0.42, test (H: corr=0) = 8.51, FM = 81.69%
bias = -9.880, ci_{bias}(95%) = +/- 6.260, FB = -0.046, FSD = 0.069
NMSE = 0.079, ci_{NMSE}(95%) = +/- 0.000

NO_x, DAILY MEAN VALUES



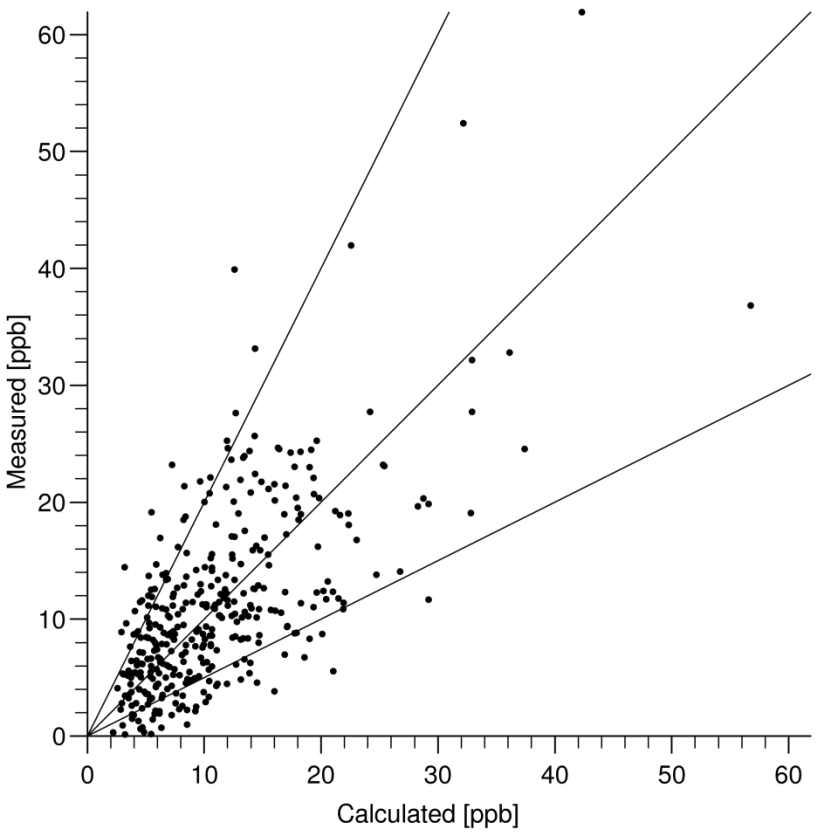
N = 358, means: calculated = 10.41, measured = 10.61
Standard deviations: calculated = 4.48, measured = 6.25
correlation = 0.71, test (H: corr=0) = 19.10, FM = 74.87%
bias = -0.201, ci_{bias}(95%) = +/- 0.456, FB = -0.019, FSD = -0.642
NMSE = 0.175, ci_{NMSE}(95%) = +/- 0.000

PM10, DAILY MEAN VALUES



N = 333, means: calculated = 13.62, measured = 18.24
Standard deviations: calculated = 7.12, measured = 9.06
correlation = 0.61, test (H: corr=0) = 14.18, FM = 66.60%
bias = -4.620, ci_{bias}(95%) = +/- 0.787, FB = -0.290, FSD = -0.472
NMSE = 0.301, ci_{NMSE}(95%) = +/- 0.000

PM25, DAILY MEAN VALUES



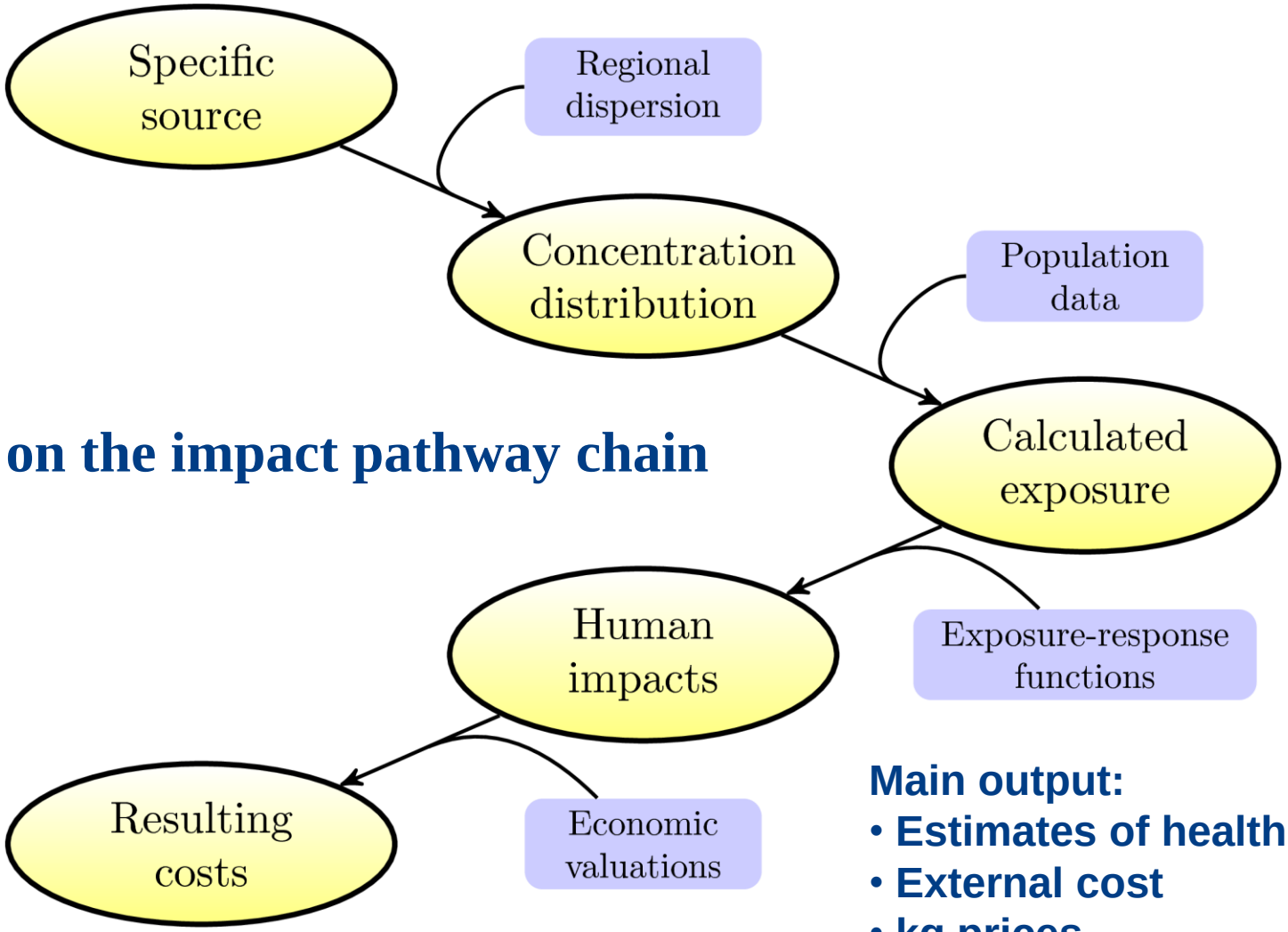
N = 360, means: calculated = 11.07, measured = 11.25
Standard deviations: calculated = 6.94, measured = 7.90
correlation = 0.67, test (H: corr=0) = 17.14, FM = 66.18%
bias = -0.186, ci_{bias}(95%) = +/- 0.629, FB = -0.017, FSD = -0.258
NMSE = 0.297, ci_{NMSE}(95%) = +/- 0.000

The integrated model system

EVA

Economic Valuation of Air pollution

The EVA system – Economic Valuation of Air pollution



Based on the impact pathway chain

Main output:

- **Estimates of health impacts**
- **External cost**
- **kg prices**

Health effects (species)	Exposure-response coefficient	Valuation, Euros
Morbidity		
Chronic Bronchitis (PM)	8.2E-5 cases/μgm^{-3} (adults)	52,962 per case
Restricted activity days (PM)	8.4E-4 days/ μgm^{-3} (adults)	131 per day
Congestive heart failure (PM)	3.09E-5 cases/ μgm^{-3}	16,409 per case
Congestive heart failure (CO)	5.64E-7 cases/ μgm^{-3}	
Lung cancer (PM)	1.26E-5 cases/ μgm^{-3}	21,152 per case
Hospital admissions		
Respiratory (PM)	3.46E-6 cases/ μgm^{-3}	7,931 per case
Respiratory (SO_2)	2.04E-6 cases/ μgm^{-3}	
Cerebrovascular (PM)	8.42E-6 cases/ μgm^{-3}	10,047 per case
Asthma children (7.6 % < 16 years)		
Bronchodilator use (PM)	1.29E-1 cases/ μgm^{-3}	23 per case
Cough (PM)	4.46E-1 days/ μgm^{-3}	59 per day
Lower respiratory symptoms (PM)	1.72E-1 days/ μgm^{-3}	16 per day
Asthma adults (5.9 % > 15 years)		
Bronchodilator use (PM)	2.72E-1 cases/ μgm^{-3}	23 per case
Cough (PM)	2.8E-1 days/ μgm^{-3}	59 per day
Lower respiratory symptoms (PM)	1.01E-1 days/ μgm^{-3}	16 per day
Mortality		
Acute mortality (SO_2)	7.85E-6 cases/ μgm^{-3}	2,111,888 per case
Acute mortality (O_3)	3.27E-6*SOMO35 cases/ μgm^{-3}	
Chronic mortality (PM)	1.138E-3 YOLL/ μgm^{-3} (>30 years)	77,199 per YOLL
Infant mortality (PM)	6.68E-6 cases/ μgm^{-3} (> 9 months)	3,167,832 per case

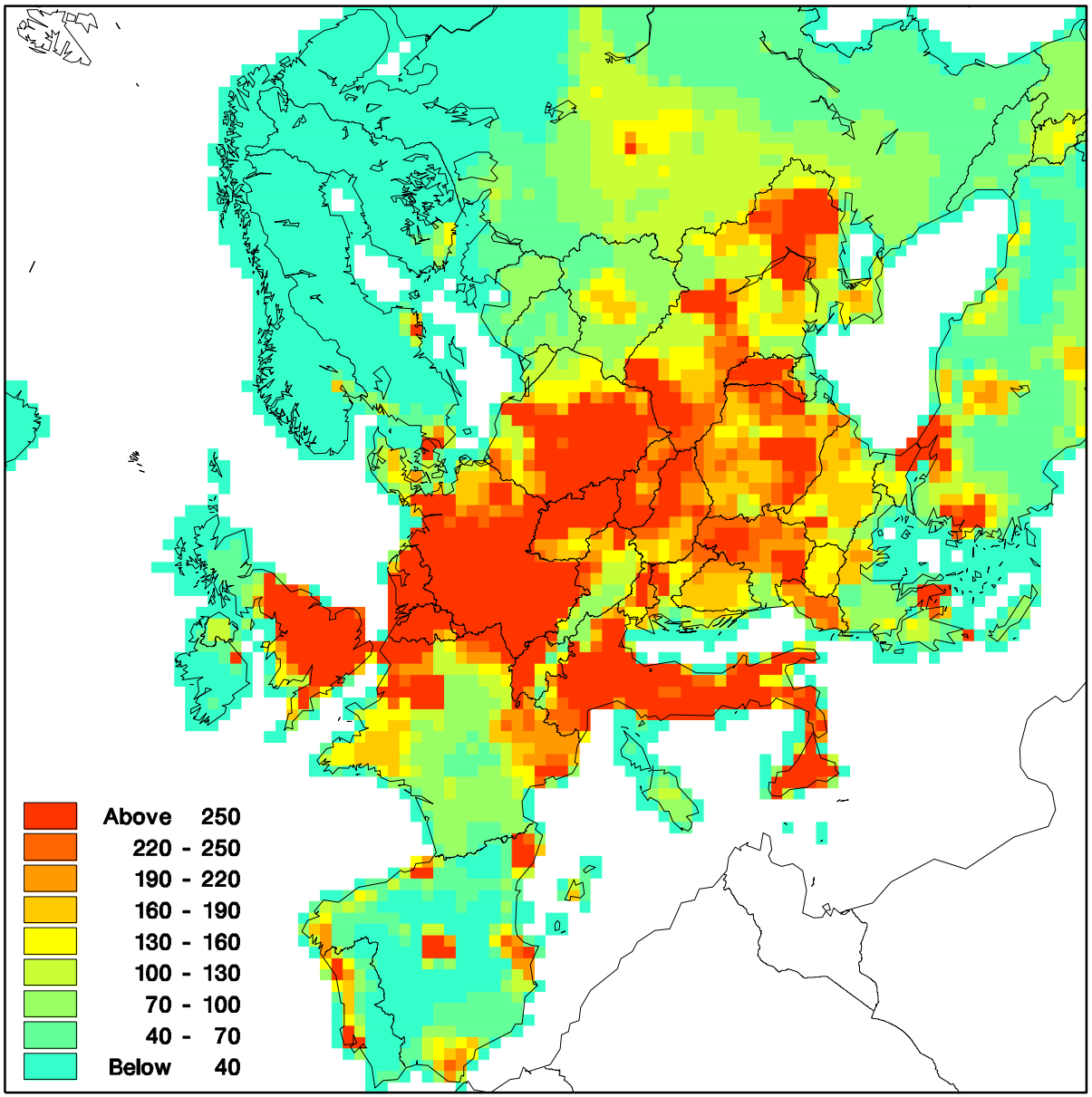
Total number of cases of premature deaths in Europe

Calculated using EVA for the year 2000 for the total air pollution levels

A total of 680000 cases decreasing to 450000 in the year 2020

IIASA estimates 310000 cases of premature deaths in year 2000 (EU25).

For Denmark:
Year 2000: 4000,
Year 2011: 3300
Year 2020: 2200



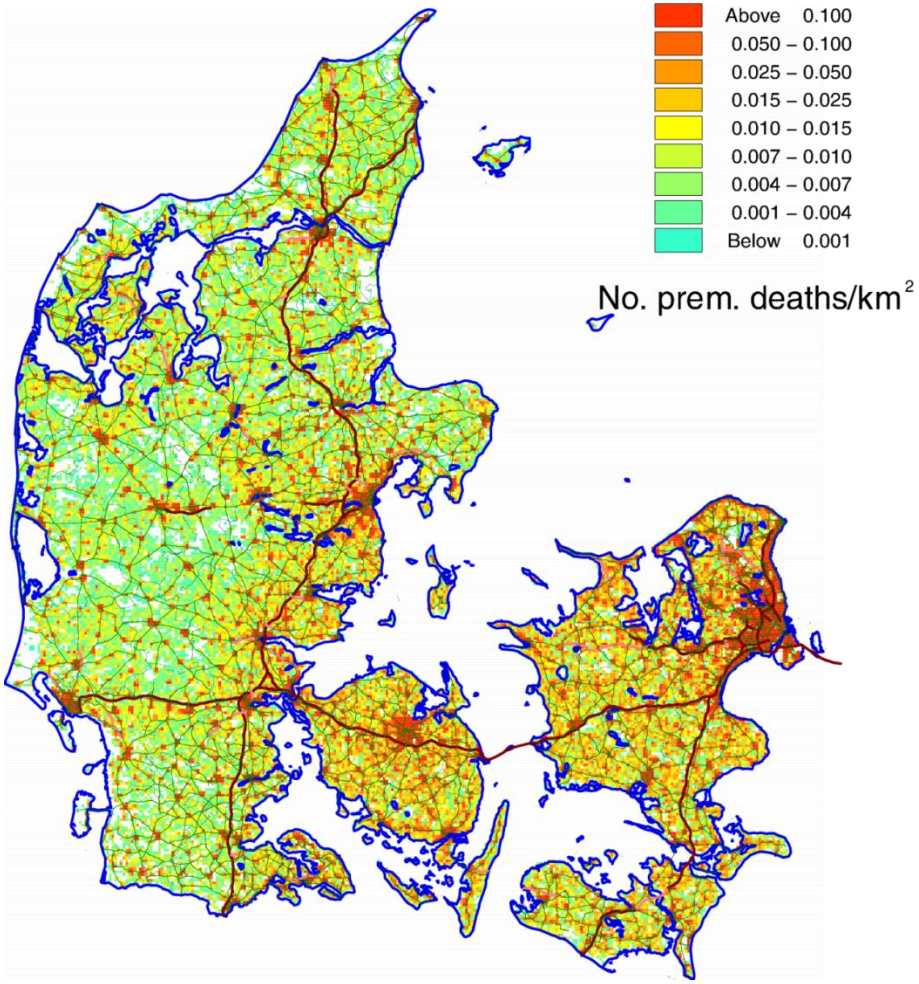
Contributions in % from European emission sectors to the total cost related to health impacts in Europe and Denmark, year 2000

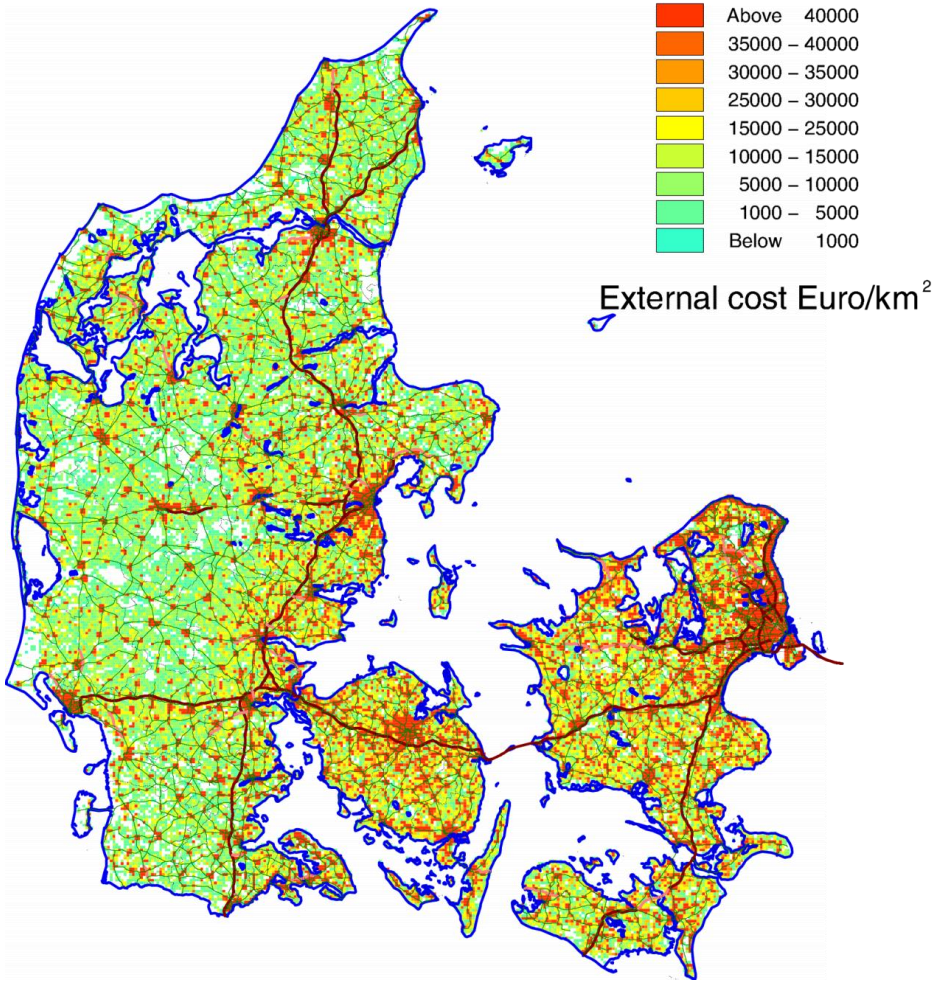
	Europe		Denmark	
SNAP category	bn Euros	%	Mio Euros	%
SNAP 1 (Power plants)	185	24.1	698	18.6
SNAP 2 (Domestic heating - wood stoves)	73	9.5	362	9.7
SNAP 3 (Industrial combustion)	60	7.9	258	6.9
SNAP 4 (Production processes)	50	6.5	193	5.2
SNAP 5 (Fossil fuels extraction/distr.)	10	1.3	50	1.3
SNAP 6 (Solvents and other products use)	13	1.7	84	2.2
SNAP 7 (Road traffic)	138	18.0	857	22.9
SNAP 8 (Other mobile sources)	50	6.5	255	6.8
SNAP 9 (Waste treatment)	7.8	1.0	29	0.8
SNAP 10 (Agriculture)	180	23.5	957	25.6
Sum 1-10	766	100.0	3740	100.0

Contributions in % from Danish emission sectors to the total cost related to health impacts in Europe and Denmark

Emission year	2000		2008	
Region/SNAP	Europe	Denmark	Europe	Denmark
DK/1 (Power plants)	10.3	5.7	8.5	4.4 (3.4)
DK/2 (Domestic heating - wood stoves)	9.3	16.3	17.6	29.9 (39.1)
DK/3 (Industrial combustion)	5.3	4.3	6.7	4.3 (3.6)
DK/4 (Production processes)	1.9	3.1	1.8	2.4 (1.9)
DK/5 (Fossil fuels extraction/distr.)	1.7	2.3	1.4	1.8 (1.4)
DK/6 (Solvents and other products use)	2.6	2.5	2.0	2.0 (1.5)
DK/7 (Road traffic)	17.6	19.3	17.4	16.3 (17.7)
DK/8 (Other mobile sources)	7.9	7.2	7.9	5.4 (5.6)
DK/9 (Waste treatment)	0.6	0.1	0.5	0.4 (0.3)
DK/10 (Agriculture)	42.8	39.4	36.2	33.2 (25.5)
DK/sum 1-10	100.0	100.0	100.0	100.0 (100.0)

No. of premature deaths/km^2 and related external cost/km^2





Total number of cases in Denmark

Health impact	Number of cases in Denmark
Year	2012
Chronic Bronchitis	3355
Restricted Activity Days	3430338
Respiratory Hospital Admissions	173
Cerebrovascular Hospital Admissions	422
Congestive Heart Failure	306
Lung Cancer	514
Bronchodilator Use Children	90090
Bronchodilator Use Adults	656636
Cough Children	311264
Cough Adults	675950
Lower Respiratory Symptoms Children	120120
Lower Respiratory Symptoms Adults	243824
Acute YOLL	98
Chronic YOLL	35745
No. of premature deaths	3470
Infant mortality	4

Source allocation for $PM_{2.5}$ in Denmark and Copenhagen - contribution to the health related external costs

	Rural background (DK)	Urban background (Cph)	Street Level (Cph)
International ship traffic (**2**)	18%	15%	13%
Europe (**10**)	57%	48%	40%
Denmark (**10**)	25%	21%	17%
Neighbouring municipalities (**1**)		3,4%	2,8%
Urban background (**16**)		12%	10%
Street (**5**)			18%
Sum	100%	100%	100%

= a total of 44 different source allocations at street level

Overall conclusions

- **Air pollution constitutes a serious problem to human health and the related external costs are considerable.**
- **Air pollution can only be understood by coupling of models at all scales taking into account local, regional and remote sources.**
- **Air pollution can only be understood by integrating information from models and measurements.**
- **The integrated THOR and EVA systems has been developed for understanding air pollution levels, and source allocations as a basis for policy making with respect to both air pollution levels, exposure and impacts.**

Current research questions

- **In order to regulate air pollution optimally, the vital questions are:**
  - **How to obtain mass-closure in the models – including all kind of particles?**
  - **Which kind of air pollution/atmospheric particles causes the health effects?**
  - **Are there some chemical components of particles that are more harmful than others (e.g. BC vs. NH_4NO_3 vs. sea salt)**
  - **Is it the chemical species attached to the surface of the particles that are harmful (e.g. metals, PAHs, dioxines, POPs in general)?**
  - **Is it really the ultrafine particles that causes health effects or is it total $PM_{2.5}$?**
  - **Can we assign different air pollutants to short term and long term health effects?**

Thanks for your attention!

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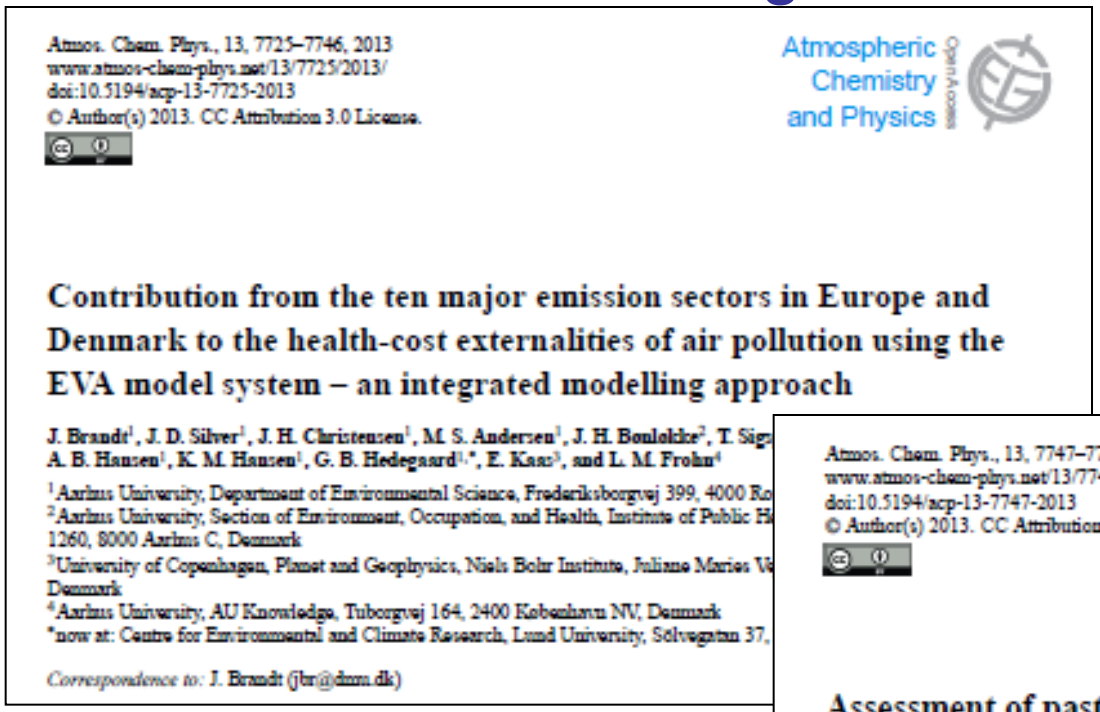

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Atmospheric Chemistry and Physics

Contribution from the ten major emission sectors in Europe and Denmark to the health-cost externalities of air pollution using the EVA model system – an integrated modelling approach

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Atmospheric Chemistry and Physics

Assessment of past, present and future health-cost externalities of air pollution in Europe and the contribution from international ship traffic using the EVA model system

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