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F 33/2012

Downscaling Emission Data from a Global Emission Inventory Database for use in an Air Dispersion Model

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Presented at
Better Air Quality Conference
Hongkong
5-7 December 2012

Scientific report

DOWNSCALING EMISSION DATA FROM A GLOBAL EMISSION INVENTORY DATABASE FOR USE IN AN AIR DISPERSION MODEL

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Abstract:

Implementation of an air dispersion model requires emission data at the model domain level. Since no local emission inventory with gridded emission data exist for many city areas, a downscaling methodology has been developed to use data from a global coarse-resolution emission inventory database. Areal emissions over a region were produced by spatially downscaling data from existing global emission inventories such as the EMEP (European Monitoring and Evaluation Programme) or the RETRO (REanalysis of the TROpospheric chemical composition over the past 40 years) data sets depending on their individual suitability to provide regional emission data for the various components over the area.

This coarse-resolution (0.5^o x 0.5^o) information was downscaled to higher spatial resolution using land cover data derived from multispectral Landsat satellite data using maximum-likelihood classification techniques combined with source allocation using satellite images. The satellite data provides a spatial resolution of approximately 30 m and is well suited for deriving detailed spatial information on general land cover classes. Primary land cover classes used for the purpose of down-scaling the emission data were urban/built-up area, agricultural area, natural vegetation, and water surfaces.
Geoprocessing, which combines land cover layers and global scale gridded emissions was handled by Geographic Information System (GIS) tools to distribute emissions according to emission source sectors and spatially distributed land cover information.

All regional emissions of components such as NO_x, NO_2, CO, SO_2, O_3, PM_{10} and $PM_{2.5}$ were imported into the emission database as part of the input data for the air dispersion calculation. The method is applicable for many cities in Asia where emission databases are still in an early stage of development. The method was applied in areas like Abu Dhabi (United Arab Emirates) as well as several cities in Norway, and will further be applied in Dhaka, Bangladesh and Hubei, China, in the near future.

Keywords: Emission inventories, Modeling, Urban Development

Tag: Air Quality and GHG Management

1. INTRODUCTION

Gridded emission data were required as input data for the air dispersion calculations. Since no such data exist for the many areas like Drammen, Norway and Khalifa Port and Industrial Zone (KPIZ), Abu Dhabi, the necessary emission data for those areas have been produced by extracting available emission information from the global emission database such as the EMEP or the RETRO (Schultz et al., 2007) data sets, order respectively, depending on their individual suitability to provide regional emission data for the various components over the area.

The emission information from EMEP and RETRO was downscaled to higher spatial resolution using land cover data. Two ways of deriving land cover data had been applied for the two different areas. That was to show the different ways of deriving land cover data. Any of the ways can be applied depending on complicated of the area geography. For Drammen, Norway land cover information were derived from satellite data acquired by the Landsat program. For Khalifa Port and Industrial Zone (KPIZ), Abu Dhabi, the land cover data were derived by the aid of Google Earth and available information of the specific location of some of the larger industries and power plants.

Gridded emission data for NOx, PM10 and PM2.5 from 04 sectors, Residence, Industry, Agriculture and Mobile Sources and Machinery were calculated as input for dispersion calculation over 23x22km model domain in Drammen area.

With different study purposes, emission data of twenty species include NO, NO2, NOx, SO2, Acetone, Benzene, Butane, Formaldehyde (CH2O), Ethane, Ethene, Propane, Propene, Toluene, Xylene, CO, Pentanes, Lumped_Alkenes, Lumped_Alkanes_And_Aromatics, Hexanes_Plus_Higher_Alkanes, Alkanals from seven sectors: Industrial Combustion, Power generation, Residence, Commercial combustion, Road transport, Solvent Use, Waste Treatment and Disposal and Shipping were built as input for a photochemical model simulations performed for a 100 km x 100 km model domain surrounding the Khalifa Port and Industrial Zone (KPIZ).

The downscaling data were compared with and reinforced by bottom-up emission data where it is available.

2. METHODOLOGY

The coarse-resolution (0.5^o x 0.5^o) emission information from EMEP and RETRO was downscaled to higher spatial resolution using land cover data. Two ways of deriving land cover data had been applied for the two different areas.

For Drammen, Norway land cover information were derived from multispectral Landsat satellite data using maximum-likelihood classification techniques. The satellite data provides a spatial resolution of approximately 30 m and is well suited for deriving detailed spatial information on general land cover classes. Primary land cover classes used for the purpose of down-scaling the emission data were urban/built-up area, agricultural area, natural vegetation, and water surfaces.

For Khalifa Port and Industrial Zone (KPIZ), Abu Dhabi, the land cover data were derived by the aid of Google Earth and available information of the specific location of some of the larger industries and power plants.

Geoprocessing, which combines land cover layers and global scale gridded emissions was handled by Geographic Information System (GIS) tools to distribute emissions according to emission source sectors and spatially distributed land cover information.

3. EMISSION DATA

Two emission datasets were used for different areas Drammen and Khalifa Port & Industrial Zone depending on their individual suitability to provide regional emission data for the various components over the area

3.1. EMEP

Figure 3.1: The locations of the 02 applied EMEP grid cells (Red), in relation to the Drammen model domain (Light Blue).

The first was a continental-scale gridded emission inventory available for Europe, EMEP (European Monitoring and Evaluation Programme) (Mareckova et al., 2009). Two versions of the EMEP emissions inventory exist: 1) The officially reported emissions from the member countries and 2) the gap-filled and corrected emissions to be used for modelling purposes. The latter version was used here as a base dataset for downscaling. This gridded EMEP emission inventory has a spatial resolution of 50 km x 50 km and provides emission information over a total of 11 SNAP sectors. For the Drammen area, 02 EMEP grid cells data which cover the area were used as shown in Figure 3.1.

The way of grouping emission into sectors is different in comparison to land use classifications. Emission from different sectors could come from same land use source. Therefore, the 11 SNAP sectors of EMEP were grouped into 05 land cover sectors, which were shown in Table 1.0. Emission data of NOx, PM10 and PM2.5 were also summed accordingly. Since the bottom-up emission was available for traffic, this sector was not included in the downscaling emission for Drammen.

Table 1.0: EMEP sector in relation to Land cover sector

EMEP Sector	Land Cover Sector
Group 2: Non-industrial combustion plants	Residence
Group 1: Combustion in energy and transformation industries	Industry
Group 3: Combustion in manufacturing industry	
Group 4: Production processes	
Group 5: Extraction & distribution of fossil fuels and geothermal energy	
Group 6: Solvent and other product use	
Group 9: Waste treatment and disposal	
Group 10: Agriculture	Agriculture
Group 11: Other sources and sinks	Mobile
Group 8: Other mobile sources and machinery	
Group 7: Road transport	Traffic

3.2. RETRO

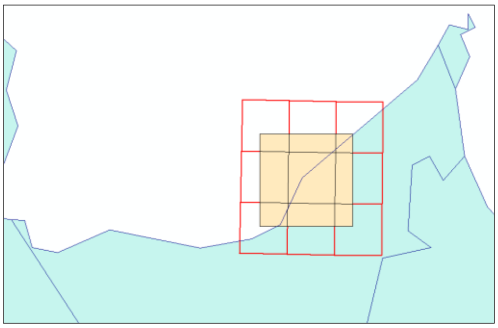


Figure 3.2: Illustration showing the locations of the 9 applied RETRO grid cells (Red), in relation to the KPIZ photochemical model domain (Light Yellow).

The second emission dataset was data from the RETRO (REanalysis of the TROpospheric chemical composition over the past 40 years) emission inventory (Schultz et al., 2007). This global database contains emissions for a large number of atmospheric compounds, from various emission sectors (shipping, traffic, etc...) (Schultz et al., 2007). The RETRO data is defined on a global grid with 0.5° x 0.5° grid spacing. For the Khalifa Port and Industrial Zone area, 09 grid cells RETRO data which cover Khalifa Port and Industrial Zone (KPIZ) model domain were used as shown in Figure 3.2.

Table 2.0: RETRO species in sectors

	Ships	Inc	Pow	Res	Tra	Sol	Was	Agr
Acetone (CH3COCH3)	-	x	x	x	x	x	x	0
Alkanals	-	x	x	x	x	-	x	-
Benzene (C6H6)	-	x	x	x	x	-	x	0
Butanes	x	x	x	x	x	-	x	0
CO	x	x	x	x	x	-	-	-
Ethane (C2H6)	x	0	0	x	x	-	x	0
Ethene (C2H4)	x	0	0	x	x	-	x	0
Formaldehyde (CH2O)	-	x	x	x	x	-	x	0
Hexanes_plus_higher_alkanes	x	x	x	x	x	x	x	-
Lumped_alkanes_and_aromatics	x	x	x	x	x	x	x	-
Lumped_alkenes	x	x	x	x	x	-	x	-
NO	x	x	x	x	x	-	-	-
NO2	x	x	x	x	x	-	-	-
NOx	x	x	x	x	x	-	-	-
Pentanes	-	x	x	x	x	-	x	-
Propane (C3H8)	x	x	x	x	x	-	x	0
Propene (C3H6)	x	0	0	x	x	-	x	0
Toluene(C7H8)	-	x	x	x	x	x	x	0
Xylene (C8H10)	x	x	x	x	x	x	x	0

Inc: Industrial combustion
Pow: Power generation
Res: Residential, commercial and other combustion
Tra: Road transport
Sol: Solvent use
Exf: Extraction distribution of fossil fuels
Was: Waste treatment and disposal
Agr: Agriculture and landuse change
LOTOS categorization scheme (Schaap et al., 2005)

(x): data available
(-): no contribution from the sector
(0): Zero emission in project area's grid cells

The 07 RETRO sectors were grouped into 05 land cover sectors: Power plants, Shipping, Industry and Solvent use, Residence and Waste, the last one was Traffic.

4. DATA TO DERIVE LAND COVER

4.1. Landsat data

Satellite data acquired by the Landsat program were used for deriving land cover information for the areas of interest. The Landsat program consists of a series of satellite missions that are jointly managed by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS). The Landsat instruments provide multispectral repetitive coverage of the Earth surface, going back in time all the way until 1972. The Landsat 7 satellite used for the Drammen study has the Enhanced Thematic Mapper PLus (ETM+) as its main instrument. It has 8 spectral channels ranging from the visible part of the spectrum all the way to thermal infrared (a wavelength range of 0.5 to 12.5 um). The ETM+ instrument acquires imagery at a spatial resolution of 30 m and is therefore well suited for providing detailed information on land cover.

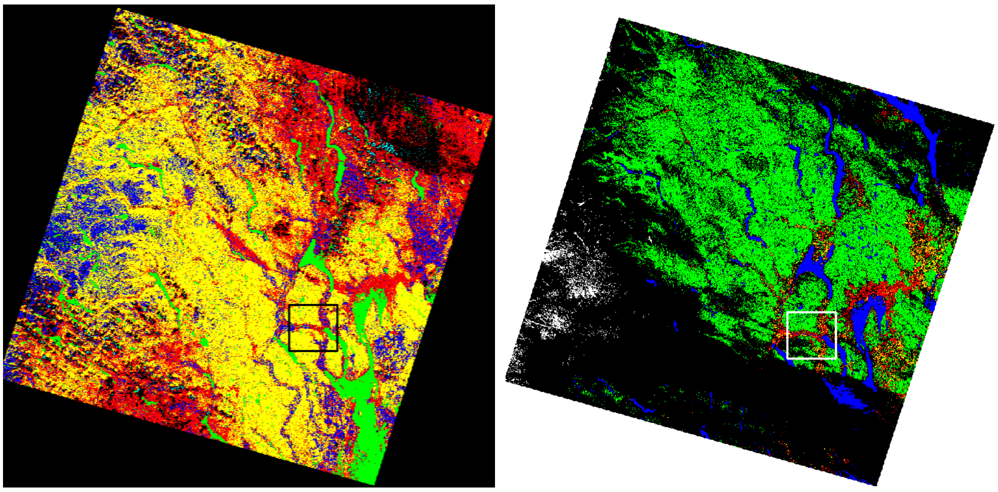


Figure 4.1: Landsat satellite data focusing on Drammen (to the left) and Oslo (to the right)

As shown in figure 3.1, the Drammen model domain, which was also shown as black/white square in figure 4.1, is covered by 02 EMEP emission grid cells, so same as emission data we need to derive land cover data using 02 satellite images focusing on different areas.

The Landsat images were processed using a supervised maximum likelihood classification. Four classes were considered: Vegetated areas, built-up/urban areas, water surfaces, and agricultural areas. These four classes can be separated reasonably well even with sensors of coarse spectral sampling such as ETM+. Suitable, homogeneous training areas were selected within the image for each of the four classes.

The land covers were derived from Landsat images (figure 4.2) included: 1-Residential sector, which is part of the built-up/urban areas from the satellite data, except the industrial areas; the 2-Industrial sector was separated out from built-up/urban information from satellite manually; the Agriculture sector was derived from agriculture areas from satellite; while, the 4-Mobile Sources and Machinery was a combination of water surfaces from satellite plus residential and agriculture sectors.

The Mobile sector, therefore, has emission of the group 11 plus 8 from EMPE which are “Other sources and sinks” and “Other mobile sources and machinery” but the emission will be distributed on the larger land use area.

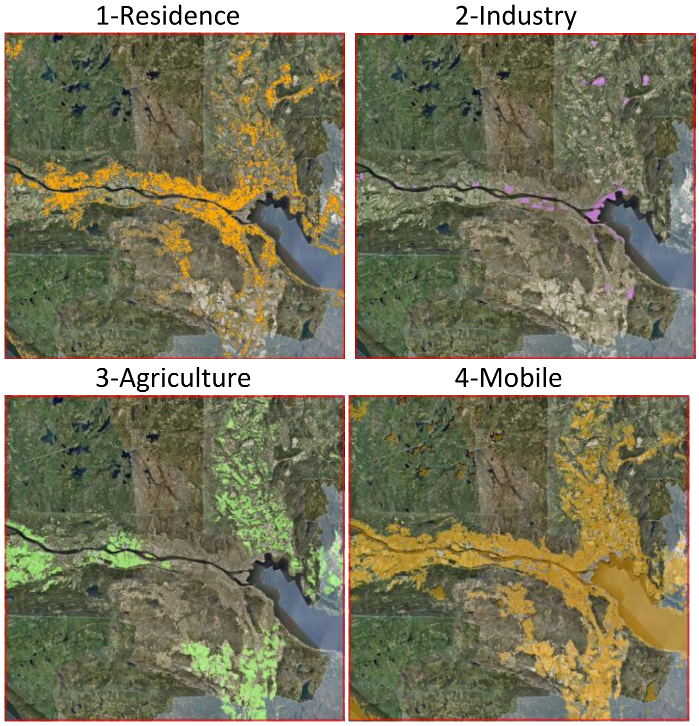


Figure 4.2: Land cover for various source sectors deriving from Landsat images.

4.2. By the aid Google Earth

By the aid of Google Earth and available information of the specific location of some of the larger industries and power plants, the land cover for KPIZ area were derived for seven source sectors: Sector 1: Residence, Sector 2: Industry, Sector 3: Power plants, Sector 4: Solvent use, Sector 5: Shipping, Sector 6: Waste treatment, and Sector 7: Traffic, which are shown in Figure 4.3a-e.

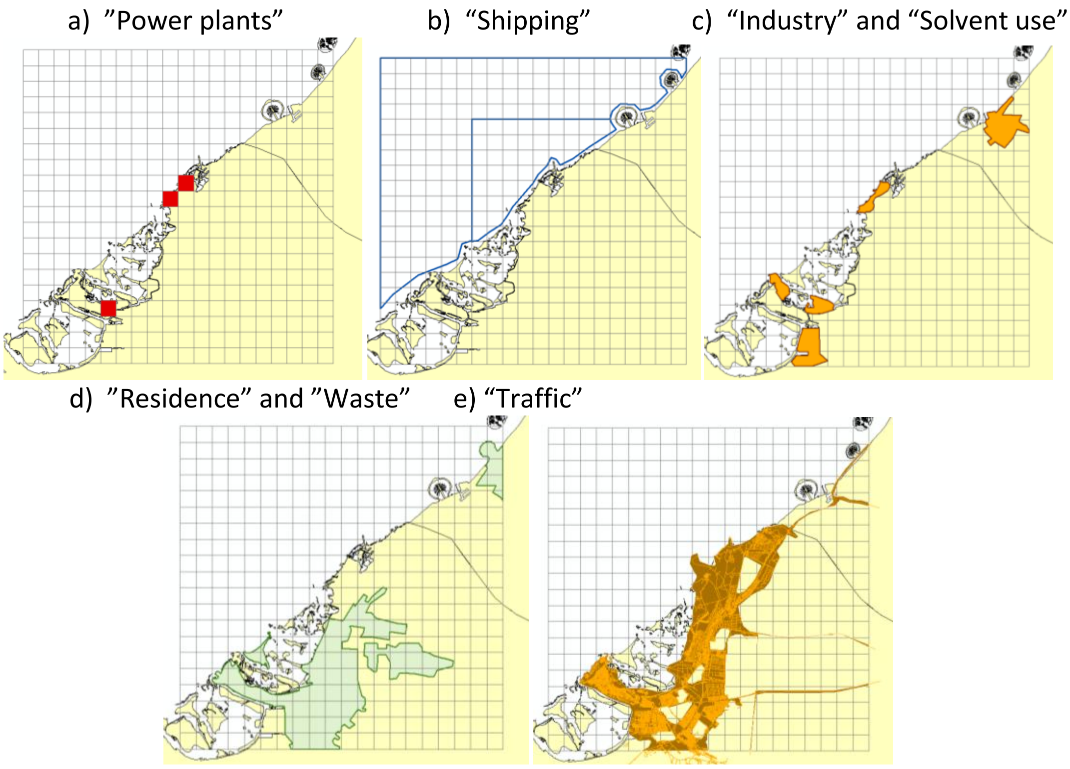


Figure 4.3: Horizontal distribution of the emissions from the various source sectors.

5. DOWNSCALING DATA PROCESSING

5.1. Drammen area

The EMEP grid for the year 2009 was acquired for the species NOx, PM10, and PM2.5 from the EMEP Centre on Emission Inventories and Projections (CEIP) hosted by the Umweltbundesamt Vienna (UBA-V). The EMEP grid cells covering the study area were subsequently extracted from the gridded EMEP dataset and written out in the shape file format for further processing.

Geoprocessing, which combines land cover layers and global scale gridded emissions was handled by Geographic Information System (GIS) tools to distribute emissions according to emission source sectors and spatially distributed land cover information.

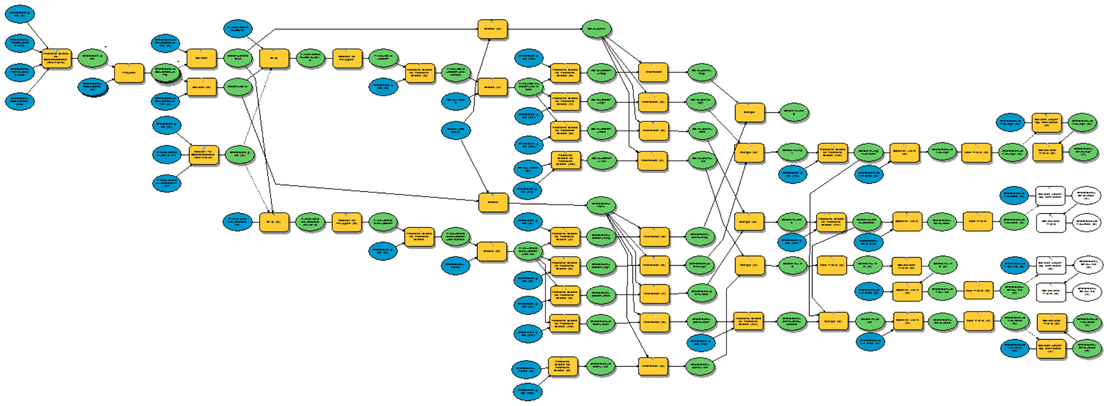


Figure 5.1: Geoprocessing model was built using ArcGIS as a tool

The total emission of the whole model domain is the sum emission of the parts which are covered by two different EMEP grid cells. The summing calculation was base on the ratio of area weight of each land cover sector within model domain and the total area of the same land cover layer area of the EMEP grid.
The total amount emission of each sector (Table 3.0) within the model domain will then be distribute evenly on the grid cells which have intersection with the land cover layer of that sector.

Table 3.0: Total emission amount from different source sectors for Drammen Model domain (Unit: ton/year)

	Residence	**Industry**	**Agriculture**	**Mobile**
NOx	13.28	112.86	0.77	220.44
PM10	0.52	78.96	0.10	29.47
PM2.5	343.25	25.91	1.76	27.74

The gridded spatial distribution of emission data from different source sectors are shown in figure 5.2. The emission data were prepared in templates and then imported into AirQUIS (Air Quality Information System) developed by NILU as input data for dispersion calculations.

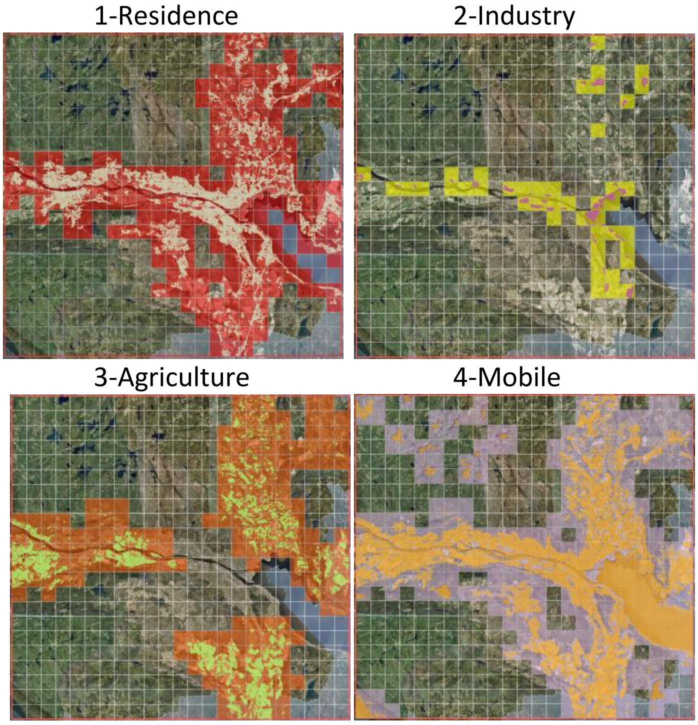


Figure 5.2: Gridded emission data from different sector for Drammen model domain.

5.2. KPIZ area

A similar geoprocessing for KPIZ area was applied to distribute the emission data. By the aid of Google Earth and available information of the specific location of some of the larger industries and power plants, the emissions from the various emissions sectors has been distributed horizontally within the modeling domain. Because of the poor detail in the present data, some of the sectors have been identically distributed horizontally. This is the case for sector 2 (Industry) and 4 (Solvent use), and sector 1 (Residence) and 6 (Waste treatment). The applied sector distributions are shown in Figure 5.3 a - e.

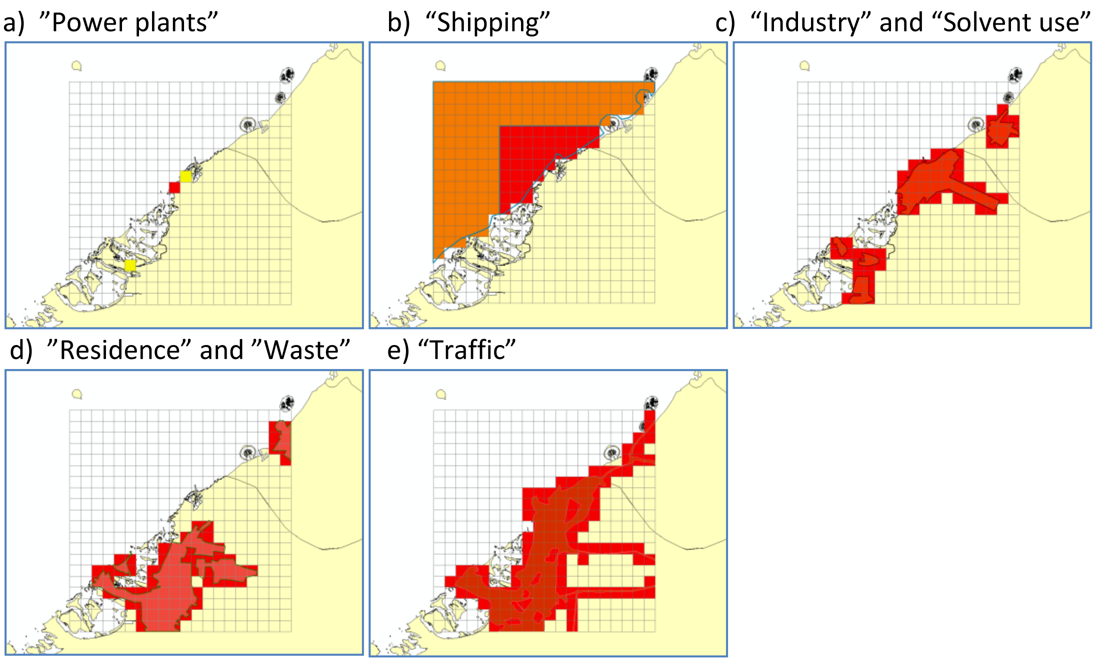


Figure 5.3: Horizontal distribution of the emissions from the various source sectors.

For the Power Sector three main sources have been identified in the three grid cells shown in Figure 5.3a (from south-west to north-east): Umm Al Nar, Taweelah, and EMAL, and the total Power sector emissions have been split between these three sites as 10 %, 80 % and 10 %, respectively. For the Shipping sector the emissions have simply been specified with 50 % evenly distributed within a triangle closest to the KPIZ area (Red area in Figure 5.3b) and the rest evenly distributed over the remaining ocean area. The emissions from the "Industry" and "Solvent use" sectors have been distributed manually by the aid of Google Earth, and the emissions from these sectors have been specified evenly to the grid cells of the orange color in Figure 5.3c. The Google Earth method has also been applied for distributing the emissions from the "Residential" and "Waste treatment" sectors, as illustrated with the light-blue areas in Figure 5.3d. The distribution of the "Traffic" sector has been made by the help of available shape files of the road system. By utilizing this information these emissions has been specified in the relevant grid squares as indicated in Figure 5.3e.

The emission data were used as model input for dispersion calculations. Examples of model generated hourly NO2 and O3 fields are presented. These fields are showing the spatial concentration distribution in the lowermost model layer. The fields are valid for September 4 2010 at 15:00. For this hour northerly winds are transporting the NO2 concentrations southward and create rather strong concentration gradients downwind of the major emission areas along the coastline, and maximum O3 levels of 125 – 130 µg/m3 are calculated west- southwest of the Taweelah power plant during this particular hour (Slørdal, 2011).

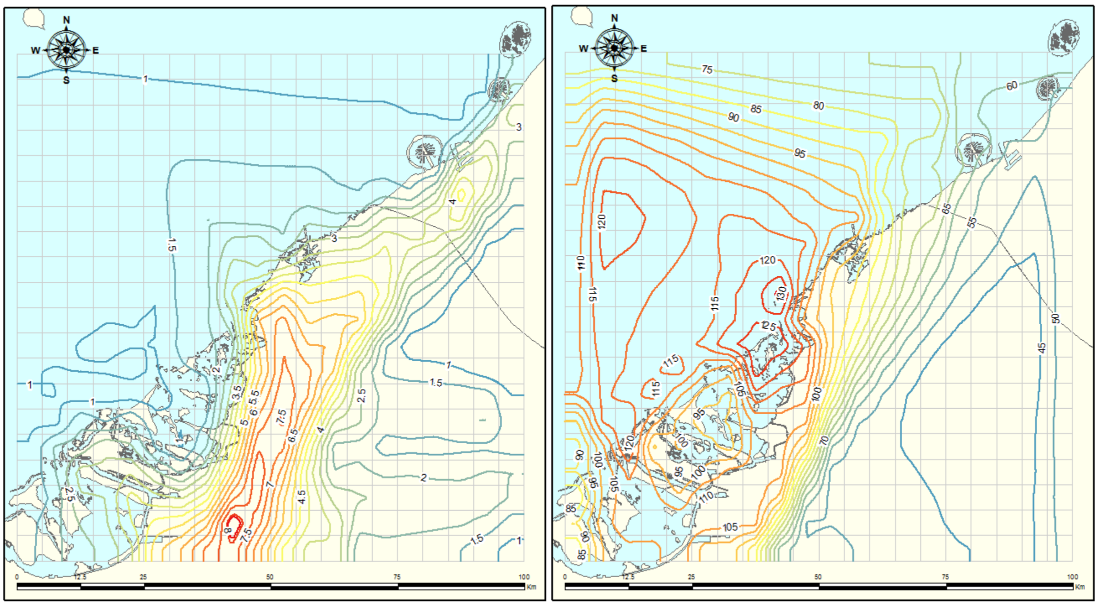


Figure 5.4: Examples of hourly concentration fields of NO2 (left panel) and O3 (right panel) valid for September 4, 2010 at 15:00. The computed fields are given in units of µg/m3

6. CONCLUSION

The method is applicable for many cities in Asia where emission databases are still in an early stage of development.

Which emission data set will be selected as the source for downscaling process depends on its individual suitability to provide regional emission data for the various components over the area. EMEP database is widely used in Europe, while global database RETRO can be used for any region, especially areas like Asia, Middle East or Africa.

More reliable and higher resolution emission databases are under developing. As primary input data for the downscaling process, those database will have give useful contribution to improve the quality of the results.

NILU is presently applying a combination of a top-down emission inventory using downscaling emission method and a more detailed bottom-up inventory for 02 cities Dhaka, and Chittagong in Bangladesh. The emission data will be prepared for modeling purposes.

REFERENCES

Mareckova, K., Wankmueller, R., Anderl, M., Poupa, S., Wieser, M., 2009. Inventory Review 2009 - Emission Data reported under the LRTAP Convention and NEC Directive: Stage 1 and 2 review. Status of gridded data and LPS data. CEIP Technical Report 1/2009), Technical Report CEIP 1/2009.

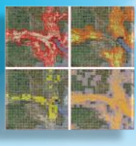
Schultz, M., S. Rast, M. van het Bolscher, T. Pulles, R. Brand, J. Pereira, B. Mota, A. Spessa, S. Dalsøren, T. van Nojie, S. Szopa, Emission data sets and methodologies for estimating emissions, RETRO project report D1-6, Hamburg, 26 Feb 2007

Slørdal; Leiv Håvard (2011) - Photochemical air quality scenario simulations for the khalifa port & industrial zone (KPIZ) - NILU Deliverables Report 2.5.

J.F. Lamarque et al., 2010 Historical (1850-2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application, Atmospheric Chemistry and Physics, 2010 (ACP-2010-67)

Smith, S. J., Steven, J., Pitcher, H., and Wigley, T. M. L.: Global and Regional Anthropogenic Sulfur Dioxide Emissions, Global Planet. Change, 29(1–2), 99–119, 2001 (http://www.sciencedirect.com/science/article/pii/S0921818100000576)

DOWNSCALING EMISSION DATA FROM A GLOBAL EMISSION INVENTORY DATABASE FOR USE IN AN AIR DISPERSION MODEL



BAQ Conference - December 2012

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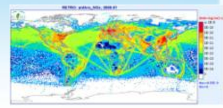
NILU

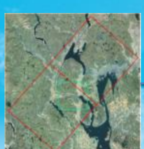
Introduction

- In air quality modeling, gridded emission data as input is a key issue.
- Bottom-up data - difficult to collect and data reliability.
- Global emission databases are developed and easy to access.
- More and more satellite data is available.
- Combination of Top-Down and Bottom-Up to fill in the gaps.
- Globally applicable.

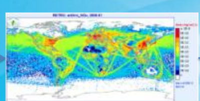


NILU

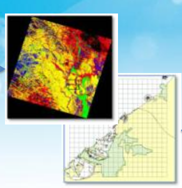
Methodology



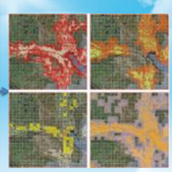
Area of interest



Emission database



Land cover data



Gridded emisson from Source Sectors

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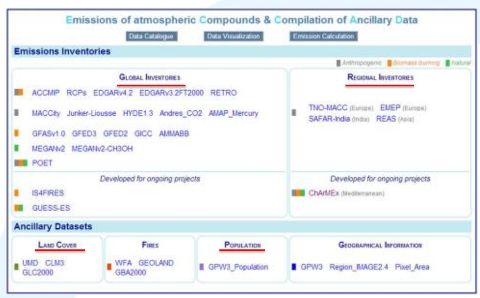
Emission databases



http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_login.jsf

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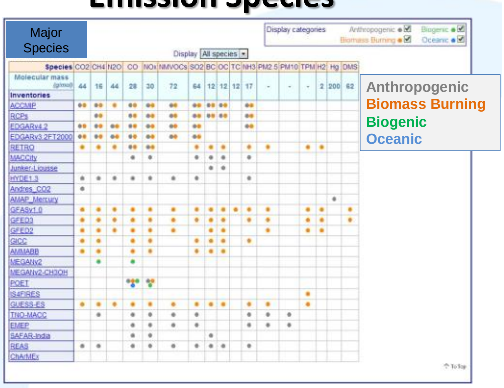
Emission Species



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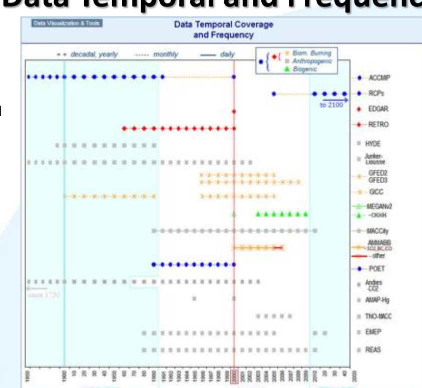
Data Temporal and Frequency

- Decadal
- Yearly
- Monthly
- Daily**



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Emission Sectors

Species			CO	NOx	SO2	BC	OC	NH3
Category	Sectors	Molecular mass (g/mol)	28	30	64	12	12	17
		IPCC code						
Anthropogenic	Transportation	1A3b_c_e	●	●	●	●	●	●
	Energy	1A1_1B	●	●	●	●	●	●
	Solvents	2F_3	●	●	●	●	●	●
	Waste	6A_B_C_D	●	●	●	●	●	●
	Industries	1A2_2A_B_C_D_E	●	●	●	●	●	●
	Residential	1A4	●	●	●	●	●	●
	Agric. waste	4F	●	●	●	●	●	●
	Agriculture	4A_B_C_D_G	●	●	●	●	●	●
	Ships	1A3d	●	●	●	●	●	●

MACCity

EMEP

EMEP Sector (SNAP)
Group 1: Combustion in energy and transformation industries
Group 2: Non-industrial combustion plants
Group 3: Combustion in manufacturing industry
Group 4: Production processes
Group 5: Extraction & distribution of fossil fuels and geothermal energy
Group 6: Solvent and other product use
Group 7: Road transport
Group 8: Other mobile sources and machinery
Group 9: Waste treatment and disposal
Group 10: Agriculture
Group 11: Other sources and sinks

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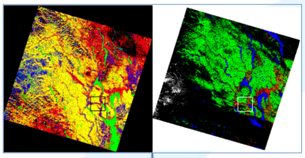
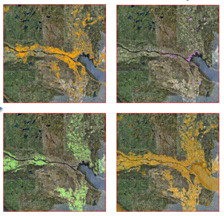
Land Cover Data - Satellite



Satellite data - Landsat

Supervised maximum likelihood
&
Spatial classification

Residence Industry



Agriculture Mobile

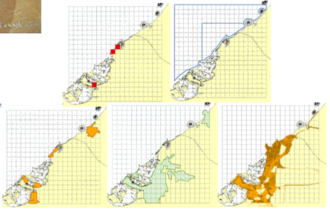
NILU

Land Cover Data – Google Earth

Google Earth

Digitize manually

Power/Shipping
Industy/Residence/Traffic



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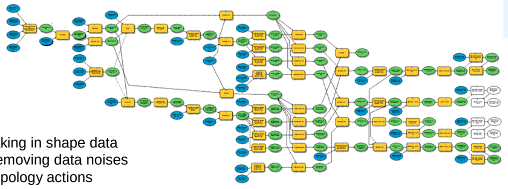
Geoprocessing



- Taking in shape data
- Removing data noises
- Topology actions
- Filtering
- Area weight calculations
- Spatial distribution
- Etc…

EMEP Sector	Land Cover Sector
Group 2: Non-industrial combustion plants	Residence
Group 1: Combustion in energy and transformation industries	Industry
Group 3: Combustion in manufacturing industry	
Group 4: Production processes	
Group 5: Extraction & distribution of fossil fuels and geothermal energy	
Group 6: Solvent and other product use	
Group 9: Waste treatment and disposal	
Group 10: Agriculture	Agriculture
Group 11: Other sources and sinks	Mobile
Group 8: Other mobile sources and machinery	
Group 7: Road transport	Traffic

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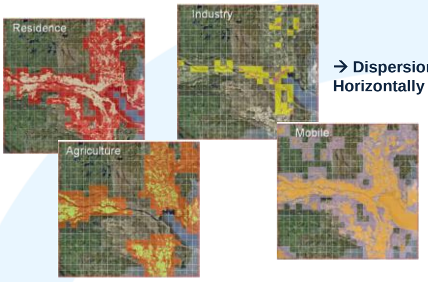
Gridded Emission – Drammen, Norway



→ Dispersion Model
Horizontally - Vertically

ton/year	Residence	Industry	Agriculture	Mobile
NOx	13.28	112.86	0.77	220.44
PM10	0.52	78.96	0.10	29.47
PM2.5	343.25	25.91	1.76	27.74

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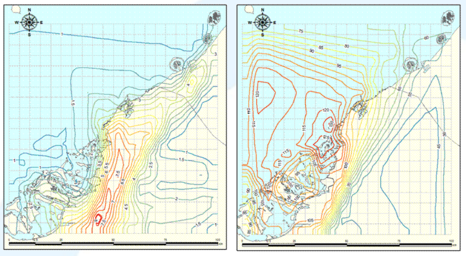
Input to dispersion model



NO2 (μg/m³) O_3 μg/m³

Hourly concentration fields
September 4, 2010 at 15:00

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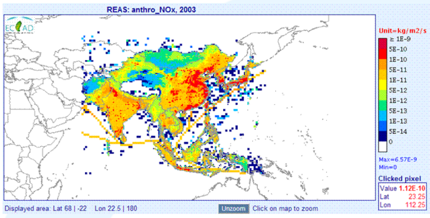
Relevance for Asia



Regional **E**mission inventory in **A**sia

REAS

1980:2020

Japan institutes

NILU on going projects

•**Dhaka & Chittagong , Bangladesh**

•**Hubei, China**

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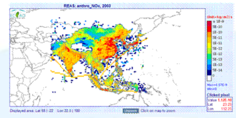
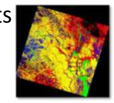
Conclusion



- Applicable in Asia
- Dependent on the quality of emission databases
- Database resolution (0.5x0.5°)
- Evenly distribution (except main point sources)
- Higher resolution and more info databases are under developing (0.1x0.1°)
- Availability of landuse digital maps and population distribution are good inputs
- Reinfore by bottom-up information



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THANK YOU FOR YOUR ATTENTION!!!!

For more information, www.nilu.no

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