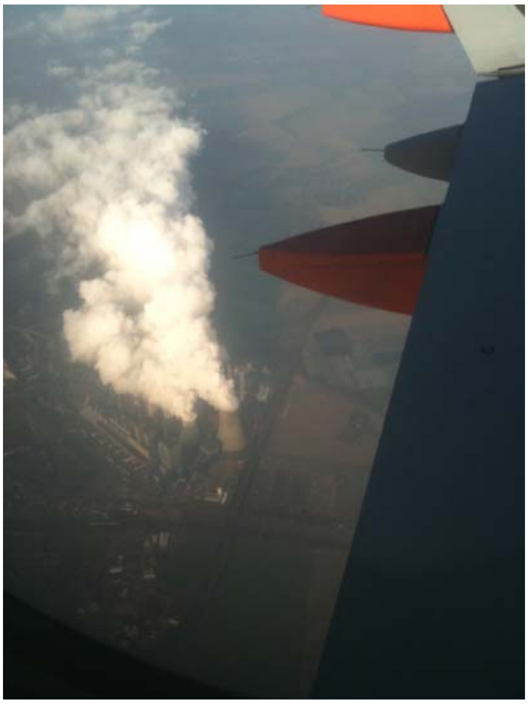
GMES Services and Emission Inventories

workshop October 2011



ETC/ACM Technical Paper 2011/13

December 2011

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European Topic Centre on Air Pollution and Climate Change Mitigation

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is a consortium of European institutes under contract of the European Environment Agency
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Front page picture:
Aerial picture of emissions from a European power station in 2011. (by Justin Goodwin)

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Acknowledgements

This report was prepared by the European Environment Agency's Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACM). The authors of the report were Justin Goodwin (Aether, UK), Peter de Smet (RIVM, NL), Laurence Rouïl (INERIS, FR) and John van Aardenne (EEA, DK).

The EEA project manager was John van Aardenne.

EEA acknowledges the support provided by the workshop attendees in providing their presentations and insights and to the FP7 MACC project Grant Agreement no. 218793 for contributing to many of the studies presented.

Executive Summary

The workshop on GMES and Emission Inventories was held on the 10-11 October 2011, in the EEA building in Copenhagen, Denmark. With about 45 participants, this workshop brought together the emission inventory, satellite observation, in-situ observation and atmospheric modelling communities. This with the aim to showcase existing collaboration and activities as well as to highlight options where in the near future inventories could support GMES services and where GMES services and other observational datasets could improve emission inventory information for science and policy.

The aim of the report is to synthesise the conclusions and discussions that where held during the workshop and to present insights in data and data flows to improve understanding, assessment and decision making on atmospheric emissions (air pollutants and greenhouse gases) and to list requirements on how to improve the linkages between datasets and emission and modelling communities. An important feedback from the participants was the usefulness of exchanging methodological views, insight in applied data sources, and especially to put GMES in perspective of European and national scientific and regulatory activities when it comes to emissions of air pollutant of greenhouse gases, also in relation to Climate and Air Quality legislation.

It was clarified on a number of occasions that there are two different perspectives on emissions inventory data. ***Scientific emissions*** data strives to characterise emissions as accurately and completely as possible utilising the most up-to-date methods and data sources wherever possible. Scientific inventories are driven by research projects where requirements often are set by atmospheric chemistry modelling activity and that is often limited by funding. It should be noted that sometimes scientific studies indirectly support legislation by providing datasets as input to models that then provide legislation relevant data (e.g. Air pollutant inventories provide inputs to models which support Air Quality Directive activities). ***Official and regulatory emission*** inventories are issued from nationally reported inventories conform to agreed standards and methods valuing consistency and transparency over accuracy and detail. National inventories are driven by EU legislation where the EU national/EU legislation set requirements on contents and quality of the inventory data.

There are new requirements arising from the development of operational products and services from the GMES initiatives. They are related to a number of issues among which:

- **Spatial resolution of emission inventories**: that are more and more widely developed at the country level as a tool for reporting according to the AQ Directives, to check compliance and to identify the most sensitive emission sectors on which emission control strategies should apply, are an appropriate source of high resolution information for GMES services development. This can be an alternative to some European-wide emission datasets. Unfortunately, the discussion did not lead to a conclusion on whether the current level of data provided by Countries (50x50km^2 every 5 years, E-PRTR, LPS etc) was sufficient for GMES services.

- **Consistency between available European datasets**: following the development of the GMES services and their crucial need for more spatially resolved emission data, several European emission datasets are now available (EMEP, MACC, E-PRTR). They are likely to be used in modelling systems to provide air quality reference maps. Differences in emission data will induce differences in those assessment maps which can lead to different insights in policy effectiveness or compliance by countries with, for example air quality standards. Therefore more insights to the methodologies, independent verification of emission data and the setting up of a dialogue between emission providers and air quality modellers will be required to improve consistency, robustness and accuracy of emission datasets. Some key bodies like the EEA or the CEIP/TFEIP and FAIRMODE have a major role to play in that perspective.

- **Temporal resolution of emission inventories**: new observation datasets available in near real time allow assessment of the impact of the temporal variability of emission data on concentration fields. The lack of temporal resolution can create a systematic biases and result in the failures of current air quality forecasting systems based on annual total of emissions as taken from national emission inventories. The emission peak values (due for instance to heating, accidental releases, natural emissions, non-standard meteorological conditions) are often not well considered leading to underestimation when comparing modelled with monitored data at the hourly or daily scales. The establishment of an expert group on near-real time emission data has been proposed during the meeting.

- **Speciation of the chemical compounds**: improved speciation is needed by source category for PM, NMVOC, PAH and HMs in order to make better use of the chemical schemes implemented in the air quality models.

On the other side, there are three areas where GMES services can directly provide support to emissions inventories. These are in:

- **Providing independent verification** issuing in-situ or Earth Observation data. While these approaches are showing promising signs they are still relatively new and need further refinement and application. A number rely on priori emission inventory data as input and all are heavily reliant on high quality measurement and meteorological data as well as significant computing capacity.

- **Providing more spatially or temporally detailed proxies** for emissions mapping through the development of land cover maps, column/temperature measurement and GPS datasets. Many of these datasets support rapid and consistent “dissagregation” of emissions at administrative boundaries to more detailed scales and provide some real-time inputs to spatial and temporal trends in emissions.

- **Providing techniques for natural and international emissions sources of estimation**. In many cases (particularly for natural sources of emissions) there are no reliable statistical data sources and emissions can occur aver large remote areas. GMES/Satellite services can be used to estimate these emission sources and fill gaps in emissions inventory. A number of projects are showing potential to estimate emissions for forest fires, dust, volcanoes and from international shipping lanes.

Based on the presentations and discussion held at the workshop, the following recommendations have been made:

1. ***Develop Guidance*** for estimating emissions estimates with high **Spatial** (1x1km – 5x5km areas with vertical detail), **Temporal** (hourly, daily, monthly) and **Species** (PMs, NMVOC, PAHs & HMs) resolution.
2. ***Improve consistency between EIs and E-PRTR/EU-ETS/LCPD*** and other industrial data reported under national or EU legislation.
3. ***Investigate feasibilities of data exchange between national high resolution data and GMES services***.
4. ***Investigate the ability of countries that don't have highly detailed data, to gather and report it***.
5. ***Develop centralised Emissions Inventory Datasets such as speciation profiles, temporal profiles and EU wide spatial proxies (e.g. roads, agriculture, residential, industrial areas))***
6. ***Development of validation and verification (independent checking*** on accuracy and uncertainty***) techniques*** for national inventories and large point sources using inverse modelling and satellite EO data. Validation needed to find missing sources and provide independent information on non-EU emission trends.
7. Continued development of **In-Situ data** provisions and metadata catalogue with reference to datasets that would support emissions inventory development (e.g. traffic monitoring).
8. Continue to develop ***proxy datasets of value for mapping national emissions inventories at 5x5km and below.***
9. ***Continue to evaluate and utilise methods to estimate emissions from natural and international source (e.g. shipping, forest fires, dust and volcano emissions).***
10. ***Inverse modelling to improve the accuracy of EU level modelling*** (e.g. better attribution of air quality exceedances)

All the presentations proposed during the workshop are available in the Meeting section of the ETC/ACM web site:
http://acm.eionet.europa.eu/docs/meetings/111010_gmes-emissinv_ws/meeting111010.html

Glossary

AOT	Aerosol Optical Thickness
AP	Air Pollutant
AQ	Air Quality
BC	Black Carbon
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CEIP	Center on Emission Inventories and Projections
CH4	Methane
CLRTAP	Convention on Long Range Transboundary Air Pollution
CO	Carbon Monoxide
DEFRA	Department for Environment, Food, and Rural Affairs (UK)
EC	European Commission
ECMWF	uropean Centre for medium-range Weather Forecasts
EEA	European Environment Agency
EI	Emission Inventory
EMEP	Cooperative program for monitoring and evaluation of the LRTAP in Europe
EPER	European Pollutant Emissions Register
ETC/ACM	European Topic Center on Air Pollution and Climate Change Mitigation
E-PRTR	European Pollutant Release and Transfer Register
EO	Earth Observation
ESA	European Space Agency
EU	European Union
EUMM	EU Monitoring Mission
EU-ETS	EU Emission Trading System
F-gases	Fluorinated gases
FP	EU Framework Program
GHG	Green House Gases
GISC	GMES In-Situ Coordination
GMES	Global Monitoring for Environment and Security
GOME-2	Global Ozone Monitoring Experiment
HM	Heavy Metals
IIASA	International Institute on Applied Systems Analysis
IPCC	International Panel on Climate Change
LPS	Large Point Sources
LRTAP	Long range transmission of air pollutants (Convention of the UNECE)
MACC	Monitoring Atmospheric Composition and Climate Change
MSG	Meteosat Second Generation
NFR	Nomenclature For Reporting
NMVOC	Non-Methanic Volatile Organic Compounds
NO2	Nitrogen dioxyde
NOx	Nitrogen oxydes
N2O	Nitrous Oxyde
NRT	Near Real Time
OECD	Organisation for Economic Cooperation and Development
OMI	Ozone Monitoring Instrument
PAH	Polycyclic Aromatic Hydrocarbons

PM	**Particulate Matter**
SO2	**Sulfur Dioxide**
TFEIP	**Task Force on Emission Inventories and Projections**
TFMM	**Task Force on Measurement and Modelling**
TROPOMI	**Tropospheric Monitoring Instrument**
UNECE	**United Nations Economic Commission for Europe**
UNFCCC	**United Nations Framework Convention on Climate Change**

1. Introduction

On Monday 10 and Tuesday 11 October, 2011, the European Environment Agency (EEA) in collaboration with the European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM) organized a workshop entitled “GMES services and emissions inventories”.

The meeting was held in the EEA building in Copenhagen, Denmark. With about 45 participants, this workshop brought together the emission inventory, satellite observation, in-situ observation and atmospheric modelling communities. This with the aim to showcase existing collaboration and activities as well as to highlight options where in the near future inventories could support GMES services and where GMES services and other observational datasets could improve emission inventory information for science and policy.

The workshop and report presented here is drawing on expertise in emissions inventory and GMES communities. The aim of the report is to support enhancing insights in data and data flows to improve understanding, assessment and decision making on atmospheric emissions (AP and CC) and to list requirements how to improve the linkages between datasets and communities.

The workshop programme can be found in Annex I.

1.1 Background and aim of the workshop

GMES (Global Monitoring for Environment and Security) is the European Earth Observation Program for the implementation of information services set up to support EU environmental policy and security. The workshop aims to explore current and potential links between GMES services and emission inventory compilation from two perspectives:

Emission inventory as input to GMES services:

Because many GMES services are based on atmospheric chemistry and dispersion modelling, emission inventory data are used as basic input for their development. For example the GMES MACC atmosphere service developed its own high resolution emission inventory at the European scale (see section 2.2.1) for atmospheric composition and air quality forecasts, near real time (NRT) analyses and re-analyses. Besides the MACC inventory, there is a large variety of scientific and policy emission inventory data available. Operational use of these data are hampered by disparate and inconsistent datasets, long production times (+2 years for regulatory reported data), insufficient spatial and temporal resolution and limited connectivity between emission inventory datasets. Moreover, limited reporting requirements make it difficult to fully utilize “officially” reported emissions data (UNFCCC/EU GHG Monitoring Mechanism., UNECE-LRTAP Convention, NECD, E-PRTR, ETS) for high resolution modelling applications, such as national or local evaluation which could be used for air quality reporting according to the EU legislation or for air pollution episodes analysis. Dealing with these issues needs to link those officially data accurately with spatial/temporal intensities or compound speciation data as required by atmospheric dispersion models.

Using GMES data in emission inventory compilation

To date, limited use is made of GMES data in emission inventory compilation. This is because methods and data sources are well established for mandatory emission inventory reporting. The use of GMES services to date can be found for estimating emissions for land use change and forestry (including wildfires). There is potential to improve spatial and temporal emission inventory data and verification of emission inventories using GMES related products and services via near-real-time data collection (e.g. traffic/energy use), earth observation images (land cover/use) and in-situ/satellite concentration measurements (verification).

1.2 Information from session 1 (introduction)

Session 1 provided an introduction to the workshop highlighting its objectives: to highlight existing and potential linkages between inventory data, GMES services and observational datasets. Presentations were made by Justin Goodwin (Aether, ETC/ACM), Michael Rohn (DG Enterprise and Industry, GMES Bureau), Tim Haigh (EEA) and John van Aardenne (EEA) showing the contribution from Claus Zehner (ESA) who had to cancel participation at the last minute.

1.2.1 Introduction to the workshop

Justin Goodwin (Aether, ETC/ACM), presented the workshop objectives and current challenges for GMES and emissions inventory communities focussing on the opportunities and weaknesses in relation to GMES application as well as opportunities and weaknesses in relation to GMES.

To date, limited use is made of GMES data in emission inventory compilation. This is because methods and data sources are well established for mandatory emissions inventory reporting. Emissions inventories utilise national statistics and other ground based datasets to deliver estimates of emissions on an annual basis. Other emissions compilation (e.g. for region, city and street) are done as needed and not regularly updated or supported by standards and methodologies. The use of GMES services to date can be found for estimating emissions for emissions/removals and biomass from forest growth and deforestation (LULUCF) and natural sources (Volcanoes, forest fires) where large scale physical/visual monitoring is possible using earth observation techniques. There is however, potential to improve spatial and temporal emissions inventory data using GMES related products and services including the use of near-real-time data collected via satellites (e.g. traffic and energy use for estimating emissions) as well as the use of earth observation (for land cover) and measurements (of column concentrations for verification). Finally, products issued from inverse modelling approaches based on the use of available in-situ and earth observation data that constrain atmospheric chemistry-transport models could be used to verify or improve air pollutants, and greenhouse gases emission inventories. A number of these solutions are presented in this report.

Inventory data used as input for GMES based services (e.g. concentration modelling) is often based on European or national inventory data supplemented with additional information to increase the spatial or temporal resolution. There are a number of models using European inventory datasets “enhanced” with national information or high resolution proxies (population densities, road maps...) to derive estimates of atmospheric concentrations. However, results are hampered by disparate and inconsistent datasets and standards, long production times (+ 2 years) and limited connectivity between emissions inventory datasets (e.g. linking of national emissions estimates under EUMM and NRECD to regulated process reporting such as E-PRTR). In addition, rather limited reporting requirements, especially on temporal intensities or compound speciation make it difficult to fully utilise "officially" reported emissions data for the development of high resolution air quality modelling services. A number of options for improving the generation and management of emissions inventory data are presented for further discussion and include improved/increased national reporting, gathering of near-real-time in-situ datasets (e.g. continuous emission measurement, energy consumption, traffic counts), development of standards and requirements for existing regulations that involve emissions reporting.

Recommendations relating to the development of emissions inventory datasets and GMES services are presented in section 5 below. For further details of the points from the introductory presentation see Annex III.

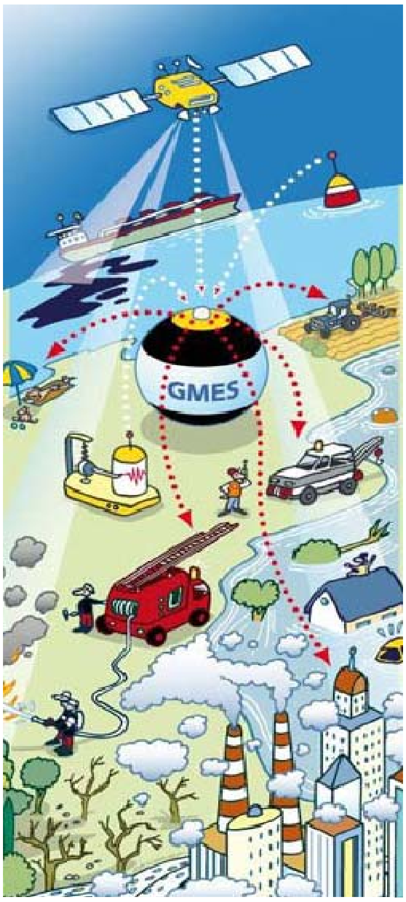

Figure 1. GMES services

1.2.2 Overview of GMES activities

Michael Rohn (DG Enterprise and Industry, GMES Bureau) provided details of the regulation on the European Earth Monitoring Programme (GMES) and its initial operations (2011-2013) bringing GMES into a new governance and operational regime. The GMES regulation includes 19 articles describing rules for work covering 6 areas (Atmosphere, Climate Change, Emergency, Land, Marine, Security) and establishes a Committee, User forum and Security Board.

The User forum consists of public sector users appointed by MS to support a transparent consultation mechanism. It provides users with the forum to express needs and give feedback on the fitness-for-purpose and needs for new GMES services (Figure 1) and products. The User Forum has extensive consultation at two levels: national level: linking with the appropriate user communities in each MS and providing the national view into GMES User Forum; European level: existing links to stakeholders to build consultation process (DG-ENV, EEA, DG-CLIMA,). It was pointed out that further work on user needs and feedback on the fitness-for- purpose of GMES services and products is needed. Also to ensure investment and user interest, clarity is needed on future GMES requirements (in terms of legislation, reporting and monitoring).

GMES's transition to operational regime should include: (i) defined stable service scope to initiate operational services; (ii) "Quick-Wins" to pilot & demonstrate services; (iii) service evolution (break through into main stream). The presentation highlighted existing information on requirements related to emissions inventory data as described by the Implementation Group Report for GMES Atmosphere monitoring (April 2009) and from user consultation within the pilot service (MACC). In order to help stabilizing service scope definition as mentioned above it was recommended to carefully distinguish between requirements needed to start an operational service from those which will help to further improve quality in the long term during service evolution. In order to validate user requirements in general consultation through workshops and the GMES User Forum will be needed. This is planned through EIONET and will be communicated through EEA.

1.2.3 GMES in-situ data

Tim Haigh (EEA) highlighted the GMES in-situ data services. The goal is to develop an initial framework and secure sustainable provision of in-situ data in support of GMES products and according to end user requirements. The development of a metadata catalogue of in-situ data services (Living catalogue of data needs and requirements) was highlighted. Work is on-going at the EEA to ensure coordination of in-situ data collection and in-situ data access for GMES services (via the so-called GISC project). Implementation and operation of GMES shall be based on partnerships between the Union and Member States. For this to work bilateral exchange need to be common with shared value and investment in data flows. The EEA plans to continue to finalise agreements and build partnerships through country visits and provide additional analysis and prioritisation of in-situ requirements.

Note that availability of in-situ data from dense monitoring networks, delivering near real time information on observations, could help in improving or at least verifying emission information that is provided as models input.

1.2.4 GMES satellite data: The possible usage of satellite measurements to improve emission inventories - the ESA Globemission project

Unfortunately Claus Zehner (ESA) had to cancel participation to the workshop. The organizing committee presented a selection of the ESA presentation slides. ESA is working on the development and use of regional and global emissions estimates based on satellite observations and using inversion techniques. The focus to date has been on a limited number of species (NOx, CH4, CO, NMVOC, SO2, PM). There are four different types of emission estimates involved in the GLOBEMISSION project:

- Global: Inversion of HCHO, CHOCHO on a global domain. CO inventory assessment
- Regional: NO2 (and O3) and SO2 over South Africa, China, India (high resolution)
- European: Inversion of NOx in Europe, Verification of SO2 and CO inventories in Europe (and O3)
- Aerosol-related: Aerosol inversion over Europe, South Africa, China and Japan. Forest Fire emissions.

The approach claims to be able to provide near real time emissions estimates with monthly temporal resolution but with limitations on source apportionment and some dependency on priori emissions inventory datasets.

2. Theme 1: Priorities for emission inventories to improve their input to the GMES services and modelling activities

Theme 1 provided opportunities for discussion and exchange of ideas for improvement of emission inventories so that they can provide an improved service to GMES (and the modelling community) including:

- The mismatch between available emission inventory data and the GMES requirements.
- Options for improvements to these mismatches (scientific, legal/reporting requirement, technology)
- The role that could be played by national inventory reporting under the EU Monitoring Mechanism, National Emissions Ceiling Directive and UNECE.
- Other scientific projects (R&D) and dissemination of relevant knowledge.

2.1 Session 2: GMES applications, atmospheric model communities and their requirements for emission inventory data.

2.1.1 MACC project and the GMES atmosphere services

Demonstration of achievement: Vincent Henri Peuch (Meteo France) highlighted plans for increased effort into developing MACC II emissions inventories and a focus on the EU level data. MACC II offers a host of modelling techniques and expertise on atmospheric physics and chemical modelling using an ensemble of models to estimate air quality impacts including: Air Forecasts (Figure 3), Stratospheric Ozone, UV index, Aerosol Forecasts, background on the sequence of projects from GEMS to MACC and MACC-II (Figure 2). MACC data collection activities. Currently MACC uses national totals, data reported under EMEP with additional spatial enhancements (such as population, road networks etc) to derive its spatially resolved emissions estimates. MACC II will reduce support for in-situ data infrastructure & downscaling approaches ==> these will be GISC now.

Barriers: MACC inventories require further enhancement in terms of temporal profile and update frequency to take account of emission peaks that can cause situations where the regulatory air quality limit values are exceeded, and recent economic trends.

Opportunities/Improvements: these involve an increased effort on emission estimation drawing in more national country specific data for point sources, temporal trends including data used by countries for their own AQ modelling and assessments related to the Daughter Directive on AQ. etc. Improve operational focus of current datasets in MACC and MACC II including web design, product dissemination, improved documentation & user support.

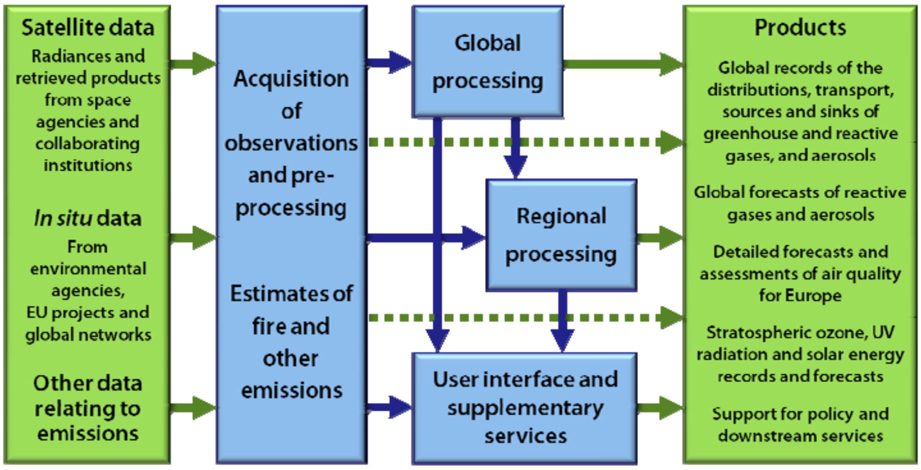

Figure 2. GMES/MACC project structure

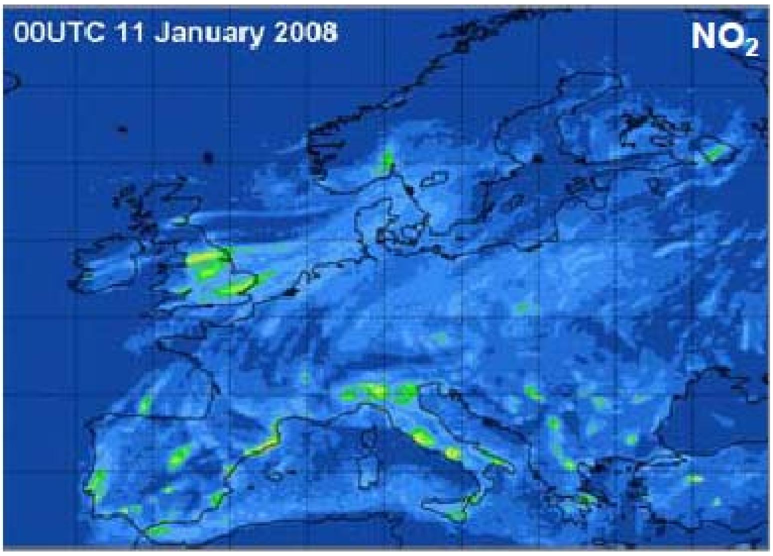

Figure 3. 2008 Air Quality Forecasts using ensemble GMES modelling services

2.1.2 Use and development of emission inventory for research projects

Demonstration of achievement: Claire Granier (LATMOS, France) provided a summary of the different global and regional inventories and the differences in emissions estimates. These covered different type of emissions needed according to the various objectives of the project: forecasts and scenarios including data linking historical estimates to forecasts ("handshaking"), global scale long-range, climate change (climate impacts on emissions; emissions impacts on climate);

Opportunities/improvements: Recommendations concentrated on improvements needed for MACCII inventory including better categorisation to enable linking between datasets (e.g. Transport vs Road transport), VOC and PM speciation, temporal profiles (daily, weekly, monthly), emission estimates for shipping not covered by national inventories and improved documentation and transparency on reported datasets. Figure 4 provides an overview of issues that limit emission research according to Granier.

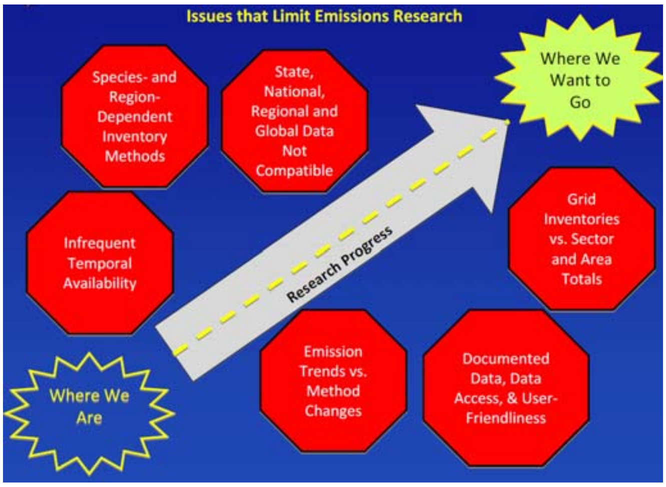

Figure 4. Issues that limit emissions research.

2.1.3 How has GMES services implementation changed the work on emission inventories

Achievements: Leonor Tarrason (NILU, Norway) presented some examples of GMES type activities that provide improved analysis and insights to emissions and emissions reduction. These included the use of OMI observations to show the Day-to-day Variability inNO2 concentrations over Beijing for a known period with reduced traffic flow. Also presented were the GMES capabilities to provide near real time data on natural events (e.g. Sea Salt Episodes, Saharan Dust Episodes, Forest Fires, Volcanic Eruptions). Specific analysis of the differences between inventories used for national reporting and policy support from those used for scientific analysis where highlighted..

Opportunities/improvements: A number of improvements needed of emissions inventories for GMES were highlighted including: 10x10km data with stronger links to urban scale data, refined temporal and species (PM, VOC, PNC) resolution, natural and accidental source episodes when available in case of episode or environmental crisis and improved validation. The establishment of an EXPERT GROUP ON NRT EMISSION data was proposed by the speaker.

Finally the GEIA (Global Emission Inventory activity) initiative was presented as a forum “for exchange of expertise and information that unites the scientific, regulatory, and operational emission communities”. Such initiatives can help in achieving the needs for consistency of available emission inventories and wider use of observations to improve them.

2.2 Session 3: Emission inventories in GMES projects

This session looked at the different uses of Emissions Inventory data in the GMES projects focussing on the data flows, challenges and successes. Presentations looked at whether there was a mismatch between available emission inventory data and application of these in GMES and atmospheric modelling projects.

2.2.1 MACC inventory

Demonstration of achievements: Hugo Denier van der Gon (TNO, The Netherlands) presented the anthropogenic high-resolution emission inventory database (e.g. Figure 5) developed within and for MACC. Data consists of national emissions submitted to EMEP under the CLRTAP process

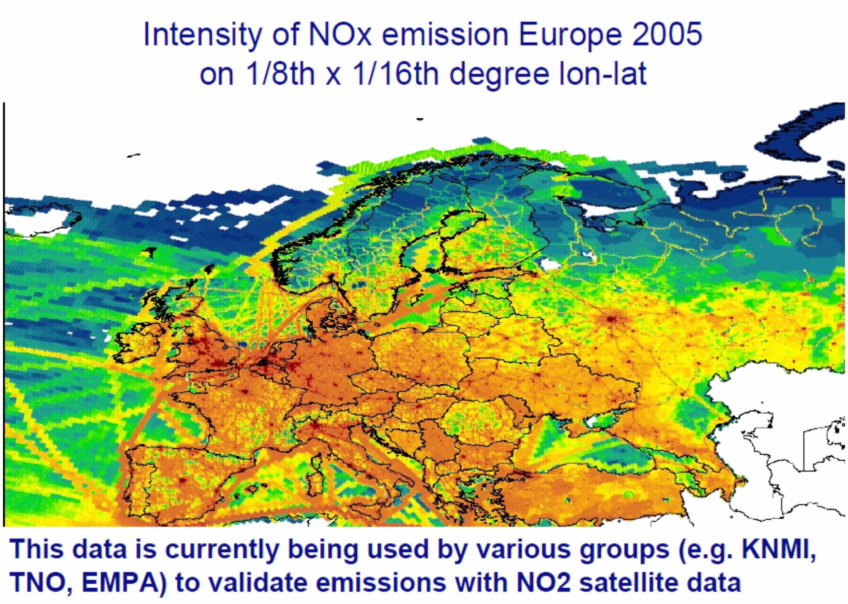

Figure 5. TNO MACC emissions Inventory

which is then distributed spatially using a number of surrogates/proxies or spatial statistics including population, road transport networks supplemented with EPER and LPS datasets for large facilities. MACC emissions data also split emissions into PM and NMVOC species ready for use by the air quality modelling community.

The success of the dataset is the use of consistent high–resolution data across the modelling domain- providing speciation, spatial, temporal consistency and a helpdesk for users.

Barriers: Extensive efforts were involved with intensive consistency checking, correction and gap filling by country, by sector, by year. More detailed country specific data is not available in usable forms and appear to be time consuming to integrate.

Opportunities/improvements: Incorporate country level gridded (geographical e.g. road transport traffic, domestic energy consumption, employment, port and aircraft movements) and point source (e.g. E-PRTR) data. Investigate possible double counting between agricultural waste burning in anthropogenic emissions and fire emissions (GFED). Improve the speciated PM gridded map for PM10 and PM2.5 data when possible (including elemental carbon (EC), organic carbon (OC), mineral dust, heavy metals). Intercompare model outputs using different input data to assess sensitivities (e.g. data from EMEP, TNO_GEMS, TNO_MACC). Major improvements can be made by using local data (e.g., FP7 MEGAPOLI) or inverse modelling to assess regional source strengths.

2.2.2 Downscaling issues: City modelling/city inventories.

Demonstration of achievements: Julio Lumbreras Martín (Universidad Politécnica de Madrid) highlighted complex and multi scale modelling requirements for cities (from street canyon to regional background data and modelling needs). These approaches are needed to determine whether air quality limit values are exceeded in some locations where people live. They require different scales of emissions inventory data (detailed street traffic flows to area wide emissions from different sources and point sources, as illustrated by Figure 6). In many cases down-scaling regional emissions to urban areas does not provide the detail needed to identify and model exceedences accurately.

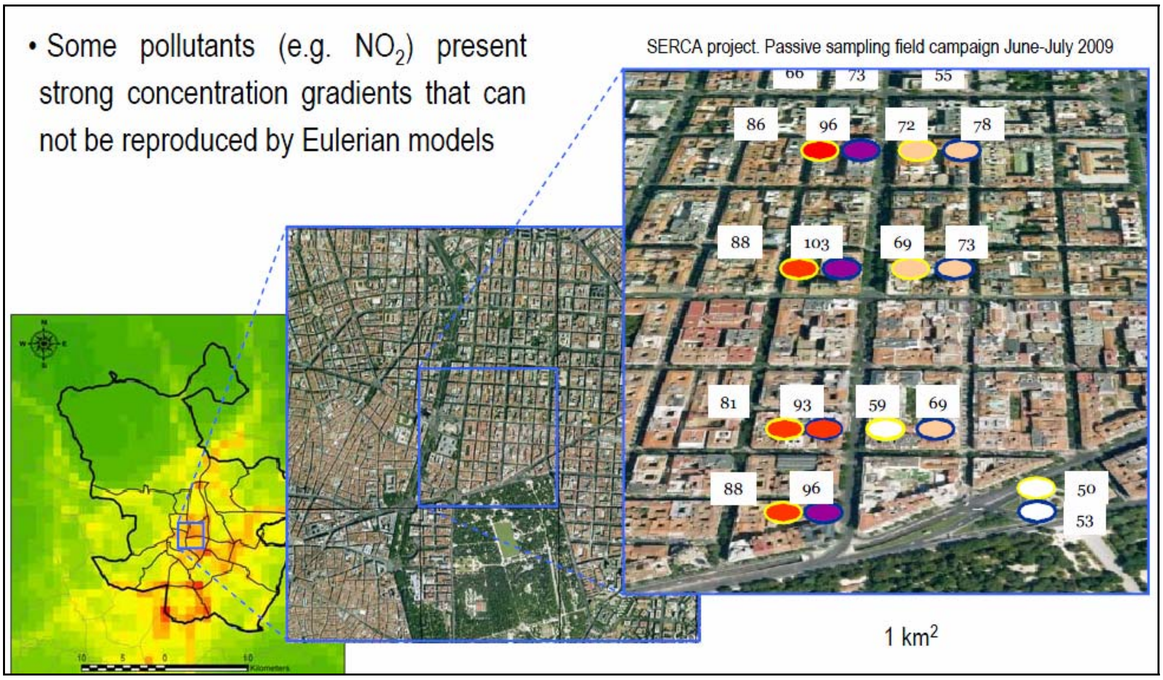

Figure 6. Illustration of detailed variation in city level emissions.

Barriers: Because urban air quality depends on dynamical and chemical phenomena that hold at various spatial scale, a unique model cannot fit all the requirements of city level analysis which needs to assess street as well as background area exceedences. Nested models, from the regional to the local scale, fed by appropriate datasets are required which implies a high level of consistency between data, and computational methods.

Opportunities/improvements: .In addition the need for detailed temporal, chemical (speciation) and spatial (horizontal and vertical) resolution was demonstrated, both for emissions and concentrations. Another important issue for policy purposes is the possibility to run emission reduction scenarios. To have plans and measures simulated as well as possible, emissions inventory data needs to be complete and to reflect as far as possible the scale at which the emission control strategies hold.

2.2.3 Atmospheric Emission Modelling: From Inventories to Air Quality Model Grids

Nele Veldeman (Vito, Belgium) presented details of the development of a spatial emissions model (E-MAP) that can derive gridded maps of emissions for use by air quality models for various areas and at different resolutions, Figure 7 illustrates spatial mapping of shipping emissions. E-MAP is used to grid gaseous air pollutants and particulate matter. It has been used for projects in Europe, Africa and Asia using land and satellite based information to map national emissions totals.

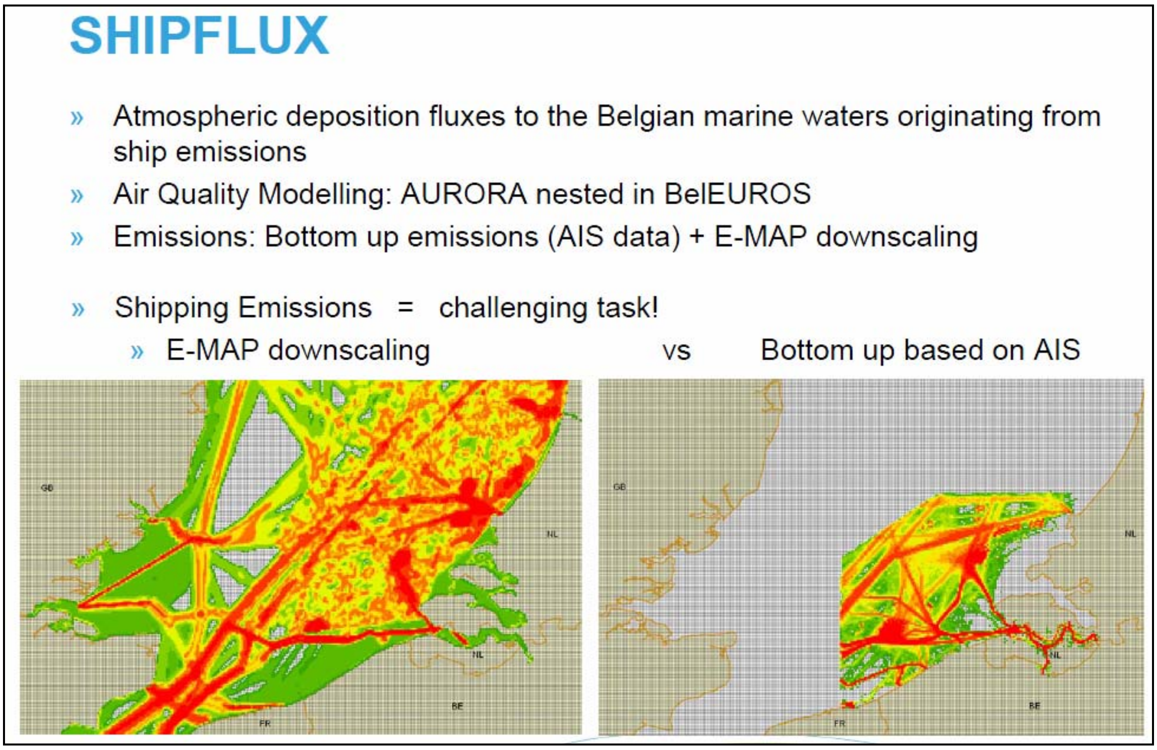

Figure 7. Comparison between EMEP and VITO ship-flux emissions estimates.

Barriers: The tool is only as good as the input data. It currently has difficulty dealing with data at different scales and reconciling detailed bottom up with top down datasets.

Future Opportunities/Improvements: Improve integration of bottom up and top down approaches is needed so that detail can be included where detail is available (e.g. shipping data). There is a need for more standards in nomenclature for sources to help in improving integration of scales.

Improve the usability of point source data (e.g. E-PRTR needs more complete data, to be on a national inventory nomenclature (CRF/NFR) and to include emission characteristics such as stack height, temporal emissions profiles etc).

2.2.4. Impact of various emission inventories on modelling results; impact on the use of the GMES products

Laurence Rouïl (INERIS, FR; ETC/ACM) highlighted key elements that affect the accuracy of models and the sensitivity for model results to different spatial scales of input emissions data. Key elements affecting modelling accuracy include: Wildfires (60% of the total PM10 emissions in Europe including a part of Russia) (emission episodes), Domestic wood burning in wintertime (temporal trends), Road traffic resuspension (~30% of traffic emissions for PM10) (Missing source), Resuspension from soil erosion (Missing source), Emission vertical profiles (vertical spatial scale). Needs and goals of GMES Services have been reiterated as: AQ forecasts, AQ field mapping, (nowcasting for public and policy makers); source allocation and analysis goals, exceedance and exposure assessments and hotspot qualifications.

It was highlighted that highly detailed spatial data are becoming available at the national or local levels for some countries and are used as input data to their modelling activities (Figure 8 provides an examples for French data). Whether this data should be channelled more consistently and regularly into GMES services for a global improvement of European-wide emission inventories and air quality model results has been discussed.

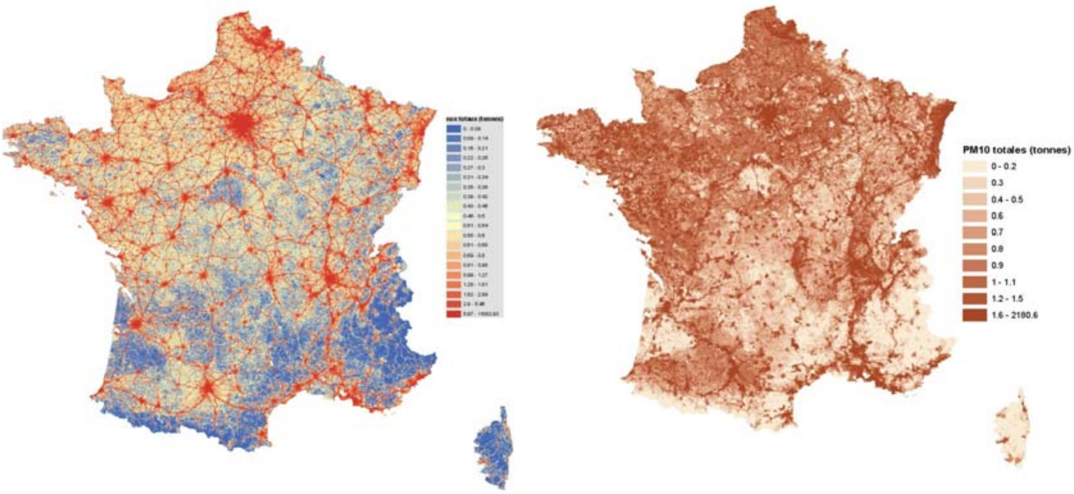

Figure 8. High resolution emissions estimates for France from the National Emission Inventory (INS); NOx (2004) on the left and PM10 (2004) on the right.

2.3 Session 4: What role could be played by official national inventories and what steps are needed to make this information available on suitable spatial and temporal scale?

This session looked at the current drivers for national inventories, the scope of data that “Should” and “Shall” be reported and the important data flows (including any from Earth Observations) used in national reporting. Mechanisms to ensure quality of national inventories were also presented (e.g. Review activities) and how could GMES services help with this.

Presenters and attendees explored plans for improved/increased national reporting and opportunities to influence future reporting requirements (e.g. streamlining, EUMM, NECD, Gothenburg Protocol, OECD, UNFCCC/IPCC).

2.3.1 Overview of official national inventory data and requirements on spatial and temporal allocation

Martin Adams (EEA, co-chair TFEIP) provided a general overview of CLRTAP, NECD, UNFCCC reporting cycle processes, datasets and its data (including 50x50km gridded, LPS data and annual national inventory reporting). How checking/ verification and validation (stage 1-3 reviews) activities are routinely realised according to the mandatory processes was presented as well.

The accepted difference between “scientific” (physico-chemical process oriented) inventories and emissions inventories designed for compliance purposes was highlighted and how this could create inconsistencies between datasets used for GMES services.

- Scientific emissions estimates are needed for modelling impacts and need to consider all sources (anthropogenic and biogenic) at an appropriate spatio-temporal scale estimated using the most accurate methods for the impact being assessed.
- Compliance Emissions Inventories, on the other hand, prioritise an agreed scope (usually anthropogenic sources) attributable to an administrative boundary compiled to agreed standardized methods and reporting formats.

The main point source datasets available for GMES services through official reporting requirements include UNECE LPS, EUETS, LCPD and E-PRTR and the limitations of each of these datasets. No single dataset provides all the necessary information for GMES modelling services (e.g. temporal, vertical resolution, activity data, and consistent nomenclature).

Details of the EU’s E-PRTR data service were presented including its diffuse component which delivers 5x5km emissions estimates for Europe based on nationally reported data (UNECE/EMEP) and surrogate/proxy datasets for transport (Figure 9), agriculture and residential emissions. Current limitations in the E-PRTR dataset includes missing sources for non-combustion road transport, off road vehicles, railways, field burning and agricultural N2O.

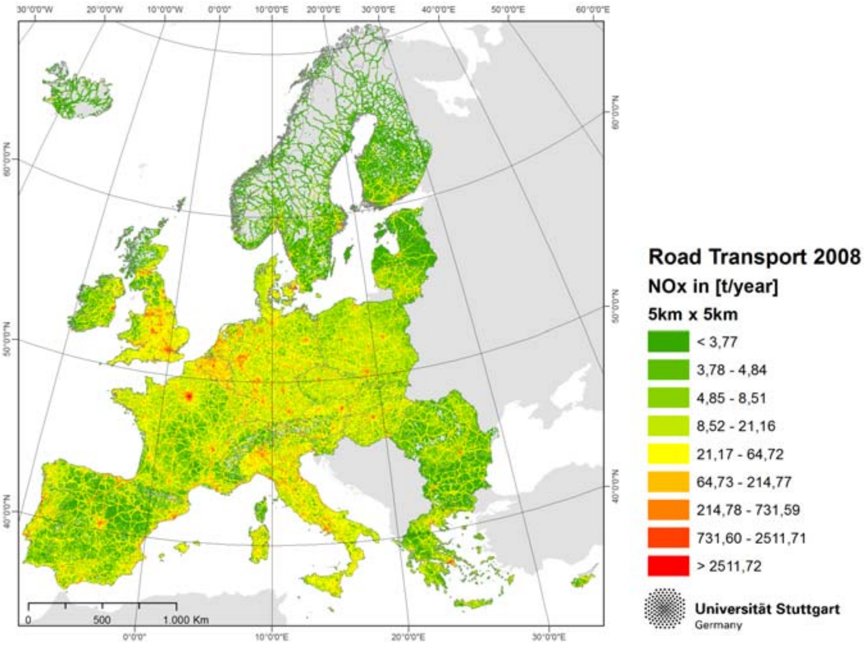

Figure 9. Road transport NOx emissions (2008) from 5km*5km resolution E-PRTR datasets.

2.3.2 How official national inventory data is used as input to EMEP is models (gridded, temporal, speciation)

Robert Wankmueller (EMEP CEIP) showed that Emission inventory delivery EMEP compiles a pan-European map of emissions which feeds into the EMEP modelling work each year to provide background air quality assessments. This draws together nationally reported estimates of emissions for national total by sector point source and gridded data (50x50km). Where national data is unavailable gap filling is undertaken by the CEIP to complete the picture. Gap filling currently uses a number of data sources including data from centrally derived EU wide emission estimates (e.g. TNO, Genemis). International shipping data from IIASA/ENTEC are used to compliment the national estimates reported by countries. An online tool (RepDab) is used for checking national inventory submissions before submission (checks on format and completeness and consistency).

Reported emissions data is critical to the underlying modelling and gap filling is undertaken to distribute national total emissions where reported gridded and LPS data is not provided. Reporting of Gridded and LPS data by the Parties is generally limited but within requirements (5 yearly reporting) 35 Parties provided gridded data for the 2005 inventory year with only 6, 4, 4 and 3 parties providing data for the years 2006 – 2009 respectively.

Future Opportunities/Improvements: A new EMEP grid will help to improve the reliability of the modelling. The new EMEP grid will go to longitude/latitude (i.e. geographical coordinates instead Polar Stereographic) to meet better compatibility with other spatial oriented activities (especially modelling) and to facilitate comparison with other emission datasets. Resolution will be increased from 50x50 km^2 to 0.1 x.01 decimal degrees (approximately 10x10 km^2 at equator). Revised guidance planned for mapping of emissions will also help improve reported spatial data.

2.3.3 Comparison of E-PRTR spatial allocation of diffuse emissions sources with high resolution national emission inventories, example The Netherlands

Wim van der Maas (RIVM, The Netherlands), provided an overview of the Netherlands PRTR and the motivation for its detailed 500mx 500m emissions data. Spatial estimates are consistent with the national inventory and utilise the E-PRTR data for NL. Constraints on development (driven by a desire to minimise environmental impact) created the need to “prove” that new infrastructure and buildings would not impose un-due environmental impacts and thus the need for a detailed spatial emissions inventory to support modelling. NL has difficulty in meeting AQ standards and deposition limits, therefore a high level of detail related to spatial allocation of emissions is needed to be able fine-tune its policies and actions.

Comparisons with EU E-PRTR maps showed that: 80% of the grids differ more than 20% for CO emission and 20% of the grids differ more than 80% for CO. (Figure 10 demonstrates a similar comparison result for NOx). This shows that consistency is hard to reach since each approach used different proxies. It was inconclusive as to which was correct.

The Netherlands invests considerable effort in improve the level of detail and accuracy in spatialized emission inventories. Methodologies and databases to geographically allocate emissions were detailed in the presentation. However, uncertainties are still high (due to the spatial proxies used) and further integration of consistent local inventories, new GMES based datasets and standardisation in inventory datasets should be considered.

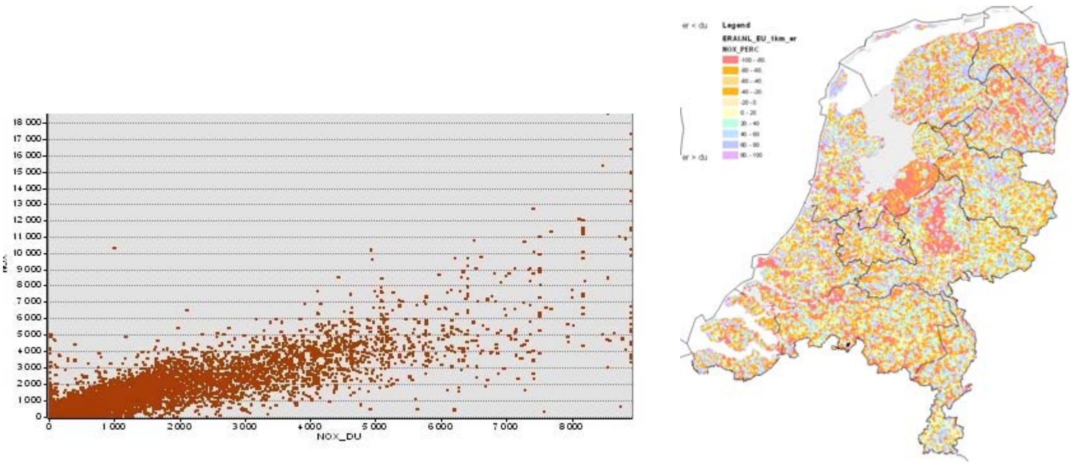

Figure 10. Dutch residential emissions of NOx modelled in its PRTR system and comparison with EU data.

2.3.4. High resolution emission mapping in the UK linked to national reporting.

Ioannis Tsagatakis (AEA, United Kingdom) presented the UK 1x1km emission mapping system used to serve national air quality modelling and international reporting requirements (Figure 11 for NOx). The datasets cover Air pollutants and greenhouse gases and serve to provide the UK with detailed data for national, regional and local purposes. Projections are also provided for specific modelling exercised.

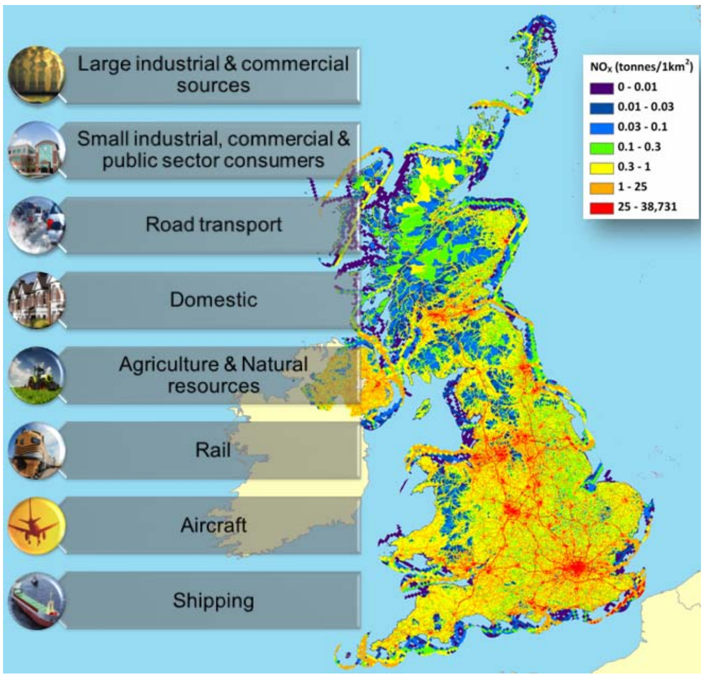

Figure 11. The UK's high resolution NOx emissions inventory supporting national modelling of Air quality.

Estimates are based on national emission totals, point source data (from regulatory reporting underpinning UK emissions legislation) and detailed spatial statistical data collected from a number of different sources (e.g. road and rail traffic by route, shipping data for ports and shipping lanes, information on business types and location, postcode sector level gas and electricity consumption, agricultural census data and population census data). Currently the UK's $1x1km^2$ inventory does not make use of earth observation data.

The UKs $1x1km^2$ maps are input into the UKs Pollution Climate Mapping (PCM) model which provides strategic policy analysis to DEFRA, helping build an understanding of the current AQ situation, provides source apportionment analysis, projections of future air quality and modelling potential AQ impacts of possible policy measures.

The UK 1x1km2 mapping is labour intensive and relies on detailed spatial datasets. As a result of the time taken to collect, QA and prepare the data, the modelling delivery time is reasonably long (data for 2010 will be available by July 1012).

Improving the timeliness of data provision of these detailed spatial datasets would help to provide more up-to-date data to the UK modelling community. Also development of speciation and temporal profiles would enhance the modelling accuracy.

3. Theme 2: GMES services for verification and quantification of emissions inventories.

Under this theme presentations were given on existing and potential application of GMES satellite and in-situ monitoring data to improve emission inventory (and air quality) information for science and policy application focussing on:

- Identifying GMES observational datasets that can be immediately applied to improve emission inventory (and air quality) information for science and policy application
- Evaluation of existing and forthcoming GMES observational datasets that are not yet mature or existing but that can potentially be applied by the emission inventory community and policy makers.

3.1 Session 5: Verification of emissions inventories

This session assessed the extent to which experts are we able to verify or provide independent national emission inventory data through combining GMES observational datasets and atmospheric chemistry modelling. It looked at identifying the pollutants and sectors that can be determined using techniques such as inverse modelling as a means of providing an independent check of reported national emission inventory data. Questions asked included:

- What EO/GMES techniques have been used to verify emissions inventories?
- What key data is needed for this verification?
- What are the levels of uncertainty in datasets?
- What future developments/enhancements are possible?
- Can EO/GMES techniques replace traditional emissions inventory estimates (which use statistical data)?

3.1.1 F-gases emissions through inverse modelling

Stefan Reimann (EMPA) demonstrated that continuous ground-based measurements have been used with inverse modelling to estimate national emission of F-gases for verification against UNFCCC reports and to pinpoint high emitters. Earth Observation (EO) products have not been used until now, because no satellite observations exist for F-gases in the troposphere.

Within the Kyoto Protocol individual Annex-1 countries submit greenhouse gas emission to the inventory on a yearly basis. These inventories are the basis for checking the compliance of the countries for the agreed emission reductions within the first commitment period of the Protocol.

A new approach was presented by Stefan Reimann, which uses data of fluorinated greenhouse gases (F-gases) from several continuous measurement sites in Europe. The measurements are combined with information from atmospheric transport models and a Kalman-filter approach is used to optimize the calculated numbers. In this way it was possible to estimate emissions from several European countries individually (Figure 12). For HFC-125 (mostly used in stationary air conditioner mixtures), the agreement between the inventory and the emissions estimated by Empa was very good. However, agreement for HFC-152a (mostly used in foam blowing) was far from excellent and needs further research. In a second approach, where the Empa model was tuned for periodically occurring emissions from point sources, emissions of HFC-23 from the HCFC-22 manufacture process were estimated to be higher than those provided by the individual countries. While for most countries for HFC-23 there was generally good agreement with most national inventories, the Italian emissions estimated by Empa were at least 10 times higher than those listed in the inventory.

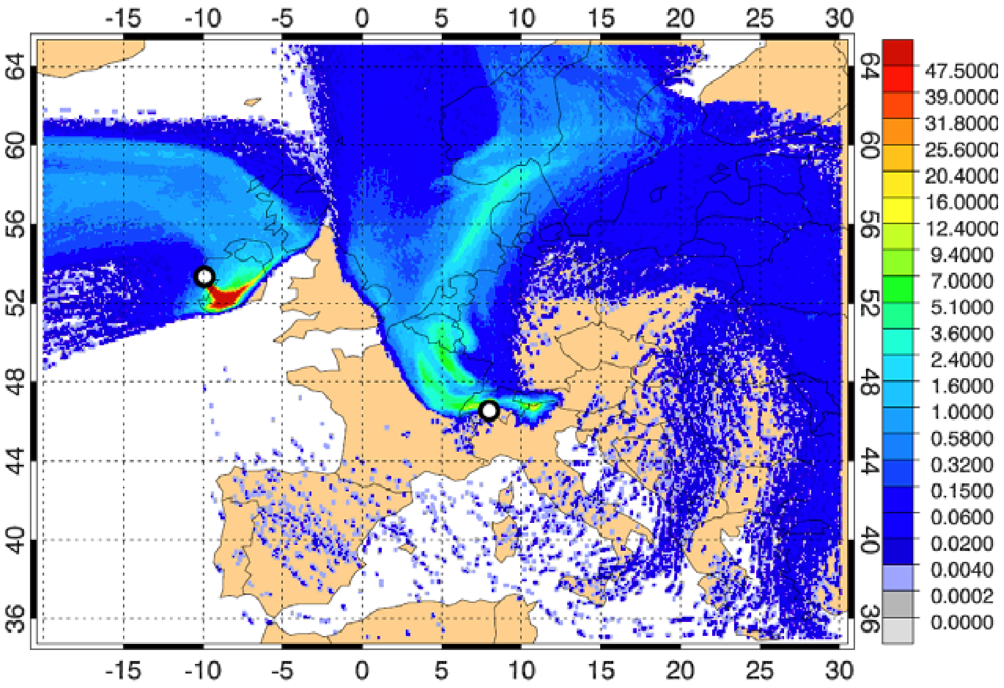

Figure 12. Modelled emissions using inverse modelling from measurement station data.

Barriers: Emission inventories are used as a-priori information and therefore results are not truly independent.

*Future Opportunities/Improvements***:** High-resolution inventories (spatial/temporal) will provide better resolution to the modelling activities. CO measurements from satellites could allow better independent source allocation for tracer-tracer ratios (F-gases vs. CO). Direct measurements of F-gases from satellites are likely to develop with the appropriate instrumentation.

3.1.2 Anthropogenic CO2 emissions through inverse modelling

Frédéric Chevallier (ISCE/IPSL, FR) demonstrated that anthropogenic CO2 emission totals can be estimated through inverse modelling of CO2 measurements from known locations. The approach makes use of CO2 surface measurement stations, satellite CO2 partial column (EO), satellite CO2 total column (EO). Key to the approach is the numerical weather prediction data assimilation systems and carbon fluxes information. The approach provides uncertainty estimates, near-real-time possibilities and enhancements to prior inventories.

Barriers: Although CO2 inversion is a mature field it relies heavily on sophisticated numerical technology (complex chemistry-transport models) and data processing, potentially expensive measurement network deployment, prior information (inventory data), . Moreover itdoes not characterise emissions from different sources easily.

Future Opportunities/Improvements: Developments in satellite measurement technology could provide higher resolution measurement fields for inverse modelling and improve accuracy. High resolution wind data is also needed to model dispersion of emissions.

The method could be used for independent verification of nationally reported emissions although it could be costly and involve high uncertainties. Those could be reduced by use of higher observation density with some focus on specific targeted regions. Those opportunities are scientifically evaluated within the GMES/MACC project and other initiatives dedicated to the "regionalisation" of CO2 fluxes (over Paris and Indianapolis).

3.1.3 Air Pollutant and greenhouse emissions via inverse modelling, the UK experience

Alistair Manning (UK Metoffice) demonstrated the NAME-Inversion method used to estimate UK and NW European emissions of N2O and CH4 from 1990 until 2010 from an observation station on west coast of Ireland. N2O estimates broadly agree (lower by 10-20% but trend agrees) with UNFCCC inventory. CH4 estimates for UK show slow decline (10-20%) markedly different to UNFCCC trend which shows a 50% reduction over the 20 years- but the last 5 years agree well (Figure 13). CH4 estimate for NW Europe broadly agrees with UNFCCC but with a slightly slower decline.

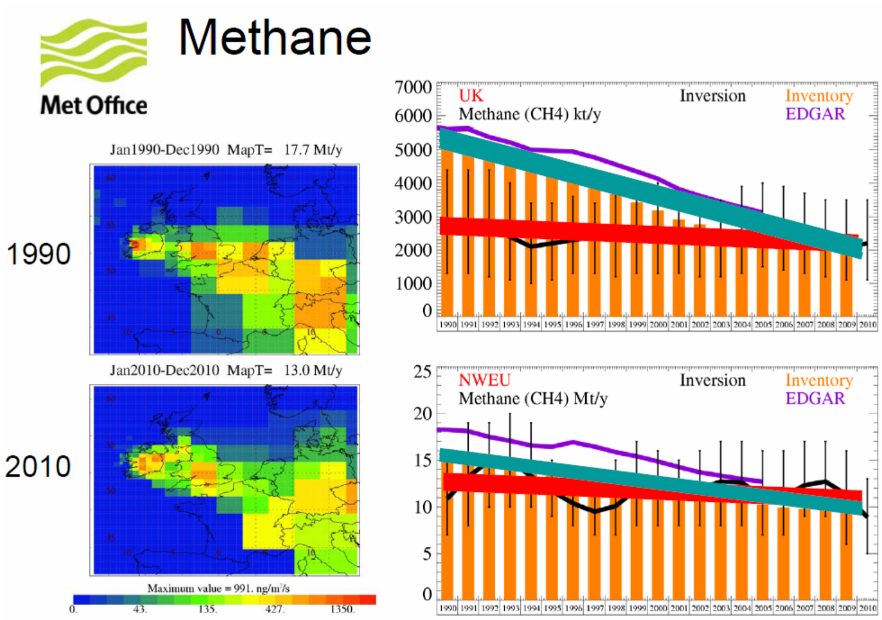

Figure 13. Inverse modelling without priori data.

This inverse modelling technique uses weather data and reliable measurement data (Mace Head). It does not use satellite or priori data (emissions inventories). It is therefore completely independent of inventory data and can be used for verification of national totals and in assessment of inventory components such as activity data and emission factors. Current techniques are best for N2O and CH4 best (stable compounds with diffuse constant source profiles). Critical components of the approach include location and reliability of measurement stations.

Barriers: Estimates are not sectorally resolved and accuracy is dependent on quality of measurements, the location of monitoring stations and proximity of the monitoring station to national boundaries. Therefore the approach is not suitable for all locations and countries yet.

Future Opportunities/Improvements: Increasing the number of representative observation sites will increase resolution of the inversion emission estimates. Improved meteorological models will improve the ability of models to calculate the recent history and dilution of the air.

Satellites – Need to be able to 'see' the boundary layer better before they are used more widely as a basis for wider measurements.

3.2 Session 6: Quantification of emissions sources

Session 6 investigated the extent to which experts are able to use observation to quantify emissions from sources that are superior to traditional survey/census and statistical based methods, for example, natural emissions and emissions in countries where inventory data is out-dated or incomplete.

3.2.1 Forest fire NRT emissions

Johannes Kaiser (ECMWF, UK) demonstrated that GFASv1.0 provides Forest Fire NRT emissions and is a GMES service provided by MACC. It provides 0.5 degree gridded daily forest fire emission estimates (Figure 14) for 40 species including PMs and NMVOCs. It has been successfully validated against the 2010 Russian forest fires. It uses earth observation to detect the infrared and burnt scar signals of forest fires. It then links these to the type of land cover to estimate emissions.

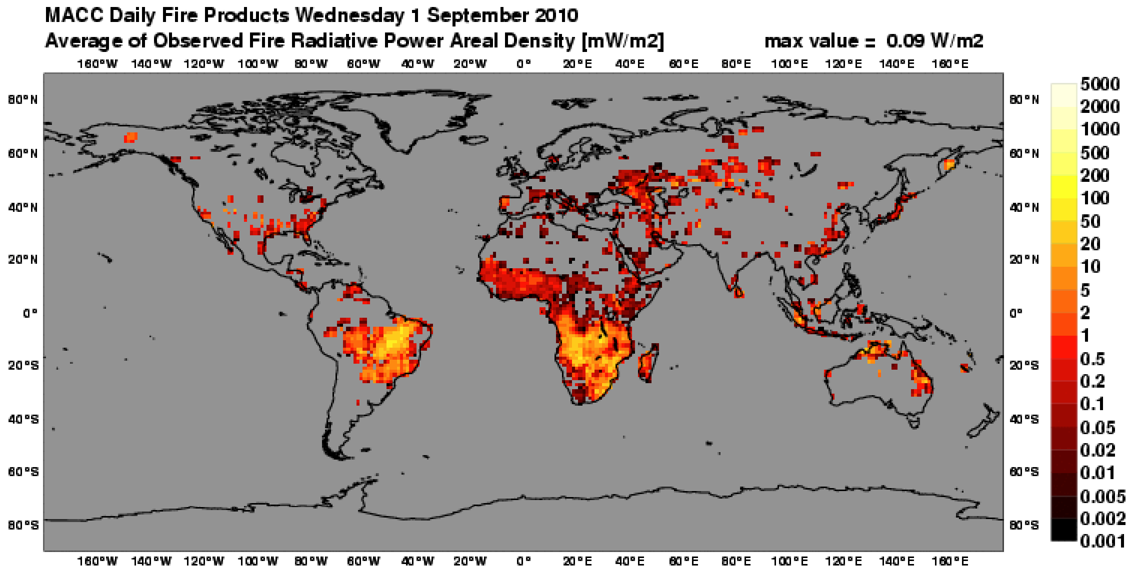

Figure 14. Daily fire radiative power maps from forest fires available on http/gmes-atmosphere.eu/fire available from September 2010.

Barriers: Gas flaring and cloud cover need adjustment information and correction. The current resolution is 1 day and 0.5 decimal degrees. Geostationary satellites are needed for suitable data capture and global coverage.

Future Opportunities/Improvements: GFAS will soon go to 1hr and 0.1 decimal degree resolution with new Satellite technology. This service based on satellite imagery is considered as well mature and reliable enough, despite clouds and overcast.

3.2.2 Emissions of crustal material in air quality forecast systems; use of satellite observations.

Laurent Menut (IPSL/LMD, FR) presented research into the development of a mineral dust emissions database for Europe. This included the same dust production scheme used in Africa and takes into account vegetation, forest, soil humidity (after rain), and different soil mineralogies (e.g Chernozemic soils) as well as modelled wind biases (different in Africa and Europe). Satellite data is used for identify soil and surface properties (mineralogy, vegetation), major dust events location and long-range transport (AOT, with OMI,MSG) and vertical layers identification (CALIOP) (see Figure 15 as illustration).

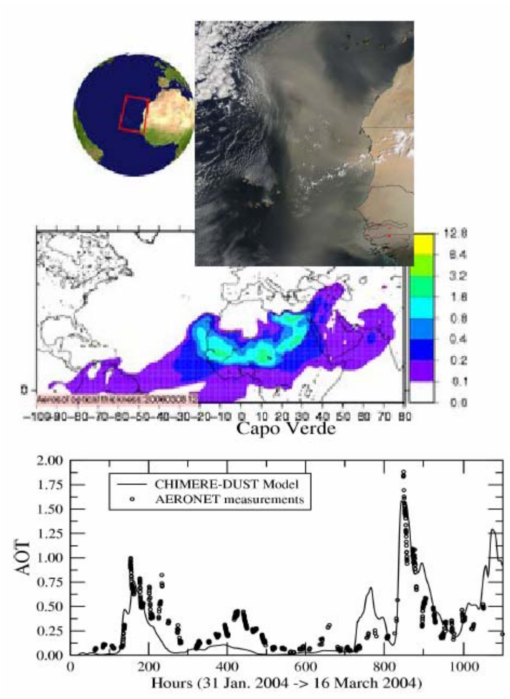

Figure 15. Modelling dust.

Barriers: The approach is difficult to use for local dust sources because of the high variability with large orders of magnitude of the vertically emitted flux, a lack of information on size distribution and composition of this flux, limited data on wind speed linked to the dust flux, and limited ability to model the effects of clouds and precipitation. Currently cannot be used for Air Quality forecasting because of too high uncertainties to develop a full operational system based on this approach

Future Opportunities/Improvements: Need to develop model-2-obs systems with both clouds and aerosols included to produce modelled lidar profiles. Coupling NRT satellite data and CHIMERE model will improve the short-term forecast (i.e 1 to 3 days). Development of statistical budgets to optimize mineral dust vertical fluxes. Comparing model and NRT satellite data and updating existing plumes (location, altitude, concentration). Updates to surface characteristics (u*T versus forecasted wind) are needed. Further testing and research required to tune system for Air Quality Forecasting.

3.2.3 Trends in ship NOx emissions observed from space.

Folkert Boersma (KNMI, NL) demonstrated that high spatial resolution satellite measurements (SCIAMACHY, OMI, GOME-2) allows tracking of changes in NOx emissions from major shipping routes.

Barriers: Improved model description of physical and chemical mechanisms is needed before being able to reliably derive top-down estimates of NOx emissions using atmospheric chemistry modelling. Identifying shipping lane concentrations of SO2 is much more difficult as concentrations cannot be retrieved down to the marine boundary layer. Also needs better understanding of physical and chemical mechanisms in plumes. For SO2 it is more difficult to retrieve info from the boundary layer.

Future Opportunities/Improvements: TROPOMI (7 x 7 km2) or geostationary satellites could incorporate up-to-date information on ship emissions in models. Development of SAMBA could provide an approach to verify shipping emissions of NOx by correlating AIS ship tracking data with OMI/TROPOMI column NO2 measurements to assess compliance and to provide air quality information (Figure 16). In the future it will allow for tracking changes in NOx emissions and as such contribute an (independent) check on national reporting and/or contribute in national reporting.

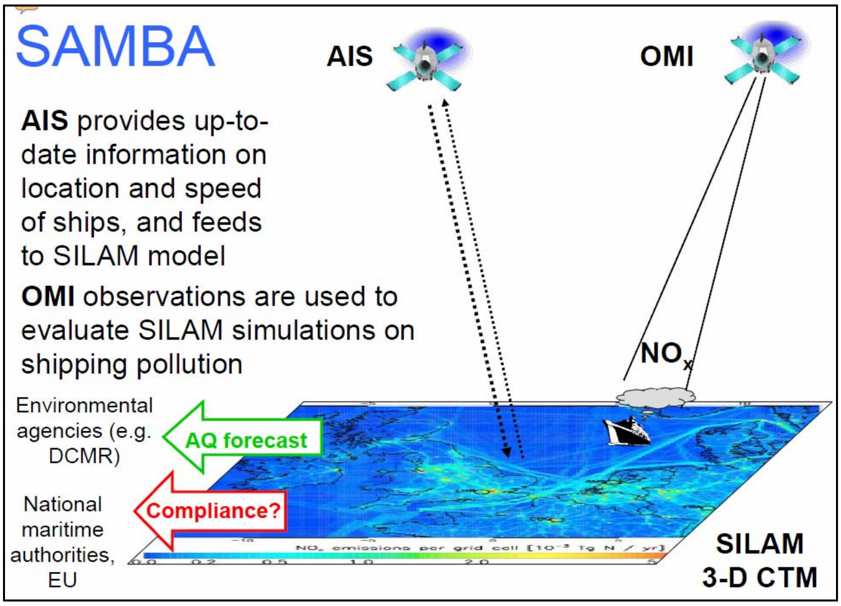

Figure 16. Future ship emission tracking using AIS and satellite column measurement.

4. Discussion and conclusion

The discussion following each session highlighted a number of opportunities to improve both Emissions Inventories and GMES services.

Based on the presentations and discussions, the organizing committee summarized the existing and possible future interactions between GMES services and emissions inventories as summarized in Figure 17 below. The workshop participants showed consensus on this schematic overview which shows the central role held by countries in data flows and decision making assuming that in a number of countries this data was already compiled in support of AQ modelling used to assess countries own progress in meeting Daughter Directive requirements. Figure 17 also outlines proposals (see below for more detail) for improved data flows of high resolution (spatial, temporal and species) “Scientific” inventory data from Countries to GMES services in exchange for GMES model outputs, verification, AQ forecasting and background data services. It also shows the “Back-UP” process of using officially reported data to EMEP/CLRTAP and “Gap filling” by experts where data is unavailable (currently employed by MACC to deliver primary emissions inventory data fields).

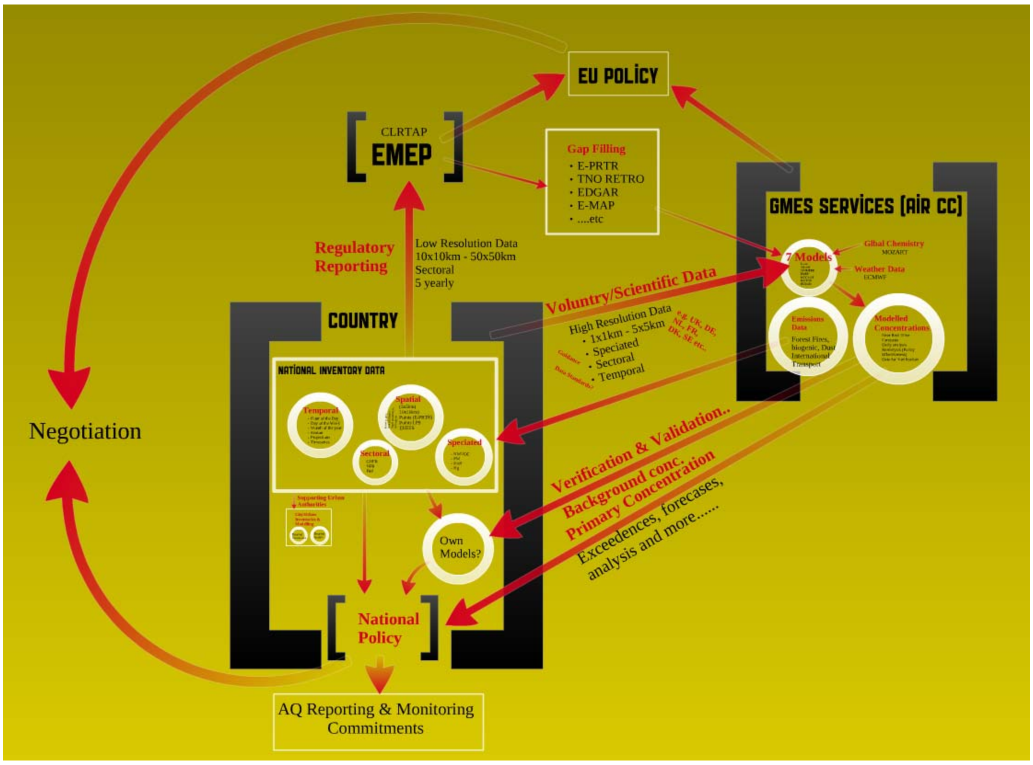

Figure 17. Emissions Inventories and GMES service interactions. A online version of this figure can be found at http://prezi.com/tsit2xkz06-4/gmes-and-emissions-inventories-conclusions/

4.1 Priorities for emissions inventories to improve their input to the GMES services and modelling activities (Theme 1)

Discussions on the need for and availability of emissions inventory data for GMES.

Two different concepts of Emissions Inventory: It was clarified on a number of occasions that there are two different perspectives on Emissions Inventory data. Scientific emissions data strives to characterise emissions as accurately as possible utilising the most up-to-date methods and data sources wherever possible. Scientific inventories are driven by research projects where requirements often are set by atmospheric chemistry modelling activity and that is often limited by funding. It should be noted that sometimes scientific studies are supporting indirectly legislation (e.g. Air Quality Directive). Nationally reported inventories conform to agreed standards and methods valuing consistency and transparency over accuracy and detail. National inventories are driven by EU legislation where the EU national/EU legislation set requirements on contents and quality of the inventory data.

The challenge is how to connect these different inventory activities and sometimes different requirements that are set upon them. A clear example of such a connection is the use of emission inventory data for the forecasting or now-casting of regulatory thresholds exceedances under the daughter directive. For this situation high spatial /temporal resolved emission inventories are needed. However, they need to relate to official national reported data so that improvement actions and future limits can be related to national emissions reduction activities.

Emissions Inventory data availability and transparency is important for GMES services. Improved data flows and communication between modellers and inventory developers will contribute to improved understanding of data and needs and improve the flow of and consistency between emissions inventory datasets (e.g. National Inventories and E-PRTR/EUETS). Bodies such as CEIP and EMEP should facilitate communication (e.g. install FAQ + transparency info on their communication platform web site + helpdesk); Develop central living library of data from different studies and databases (e.g. speciation, temporal profiles etc).

Current methods for GMES inventories: There are a number of “Centralised” approaches to compiling emissions inventory data at the required level of detail for GMES services. These include the approach currently used for MACC (see section 2.2.1) and the E-PRTR point and diffuse datasets (see section 2.3.1) both of which start with nationally reported emissions inventory data from EMEP, E-PRTR point sources datasets provide detailed high resolution data on emissions.

Including and working with National Projections is a problem for scenario modelling activities in GMES. A lack of detail and transparency in projected emissions inventory data could be addressed by improved reporting requirements.

Future approaches for GMES emissions inventories: Countries can and do produce (see sections 2.2.4, 2.3.3 and 2.3.4) more detailed 1x1km^2 inventories, point source data etc (UK, FR, DE, NL). Drivers are the AQ Daughter Directive for modelling of concentrations and the political need to minimise environmental impacts for road and building developments. DK also has 100mx100m NH3 for farm management modelling.

Although it was generally concluded that detailed spatial (e.g. 1x1km + Point sources and temporal detail) inventories (such as those presented by the Netherlands and UK) would enhance GMES services it was unclear how delivery of this data could be motivated for all Countries in a timely and consistent manner. Unfortunately, the discussion did not lead to a conclusion on whether the current level of data provided by Countries (50x50km every 5 years, E-PRTR, LPS etc) was sufficient for GMES services. In particular the MACC community did not “bridge the gap” by providing definitive user requirements of Countries for providing data. In addition there was reflection on the lack of general feedback from the “modelling community” back to the National Inventory community and that this should be addressed more specifically by EMEP and TFEIP.

GMES services and the modelling community generally called for the ”best available estimate” for emissions inventory data (e.g; 1hr time, 1x1 km spatial resolution, high vertical resolution especially in the boundary layer; Speciation for PMs (+ Aerosols), NMVOCs). Although a number of Countries presented their capability to provide this information for their own national modelling, there are currently no legal requirements (and thus no resources) or reporting formats established to provide this more detailed information internationally. It was concluded that the best spatial, temporal resolution data will come from Countries and that, as part of their response to the Daughter Directive Air Quality limits and monitoring requirements a number of European Countries (France, UK, Netherlands, Denmark etc) already compile the required information and input it into national models. However, it was also concluded that considerable resources are needed to put a more detailed reporting framework in place and to up-skill many EU countries in providing detailed spatial and temporal datasets. Nevertheless there is a space for European bodies (EEA, CEIP, EMEP) to gather and facilitate access, if possible, to this high resolved data. Exchange of national detailed emission information should be encouraged to improve in fine operational GMES atmosphere services.

Summary of GMES needs:

1. *Species : better speciation needed by source category for PM, NMVOC, PAH and HMs*
2. *Spatial: Improved 5x5km reported inventories including point sources with emission height is needed. Africa is under-represented in the regional inventories*
3. *Temporal: More recent emission estimates needed. Higher temporal resolution needed is monthly or daily to catch with the models episodes due to non standard emissions (natural events, forest fires).*

4.2 GMES services for verification and quantification of emissions inventories (Theme 2)

GMES services focus on EU and Global level services. GMES services are not targeted at Urban/City scale but can provide background and other support to more detailed services (downstream services) and inventories. Anyway when reporting on their air quality situation at the European Commission Member states need to assess correctly their background concentrations which corresponds to a scale well-covered by the GMES services. There are three areas where GMES services can directly provide support to emissions inventories. These are in :

- providing independent verification issuing in-situ or Earth Observation data,
- providing more spatially or temporally detailed proxies for emissions mapping,
- providing estimation techniques for natural and international emissions sources of emission.

Verification of Inventories: The presentations during the verification session (session 5) showed a variation in maturity and methods. It was concluded that in general inverse model studies can be used to identify large gaps in inventories and to trace large episodes in emissions for some gases and point sources. Some specific cases illustrated that there are still a rather large gap in understanding / appreciation between inventory and inverse modelling communities and that some of the approaches and findings of inverse studies are not entirely welcomed by countries (e.g. F-gases results).

Improving Detail: A number of examples throughout the workshop showed that GMES services (EO data) can and do provide enhancements to emissions inventory data by providing proxies for spatial distribution e.g. Land cover and land use (urban, industrial, transport networks) and temporal profiling (identifying daily, monthly trends in concentrations, surface air temperature and in carrying GPS data for traffic flow estimates etc).

Quantification of emissions sources: Presentations showed that emission sources not easily quantified with traditional emission inventory methods can be quantified, such as shown for biogenic/natural sources such using satellite datasets to quantify Saharan dust, forest fires or emission from international transport. Methods are currently being tested and promise to provide quantified spatial estimates of emissions. Currently it is not yet possible to attribute exceedance of air quality due to Saharan dust events or emission trends of shipping but general spatial quantification can be made.

Summary of Emission Inventory needs:

1. *Reliable verification, validation techniques for national inventories and point source emissions.*
2. *Accurate proxies for distributing area based emissions sources (e.g. residential, transport, small industry) and for deriving temporal emissions resolution (hourly, monthly etc).*
3. *Accurate approaches for estimating emissions of natural emissions (fires, volcanoes, dust) and international emissions (shipping, aviation) that are not included in national statistics based inventories.*

5. Recommendations

Recommendations for improving the national emissions data and the emerging GMES services are presented below in three sections. The first is for general cross cutting recommendations bringing the communities together and improving understanding of needs. The second is for Theme 1 Emissions Inventories and improving those for GMES and the third Theme 2 for GMES services and improving those for EIs.

General cross cutting recommendations

1. Recommendations for the development of a common understanding/perception of user needs and benefits of EI and GMES improvements came from a number of different discussions and presentations in theme 1 sessions 2 and 3. Proposals focussed on improved communication between CEIP/EMEP/E-PRTR/EU-ETS/GMES that could help to improve the flow of data into GMES from Countries and an understanding of GMES services (see 2.1.1 – 2.1.3). Key components proposed include:
   - Understanding of terminology on areas, sectors, temporal sectoral etc. scales.
   - User needs (policy questions) linked to data and data flows, consistency with IPCC AR5 (Handshake process). Links with Integrated assessment models. Highlighting priorities for EI in GMES (e.g. what (sectoral, spatial, temporal, species, characteristics) are important and why. Develop clear mapping of data needs based on GMES services and EIs providing answers to policy questions.
   - Funding sources for further development work,
   - Understanding methodologies and data sources used for EIs and GMES
   - Feedback on existing reported/gathered EI data and uses in GMES,
   - Library of datasets containing speciation, temporal profiles and EU wide mapping datasets (e.g. CORINE, Population, road network etc).
   - Standards, interoperability of data between GMES and EIs

A proposal to introduce a “Near Real Time” expert group was welcomed by some participants as a means of getting different EI and GMES communities together and of promoting new approaches and technologies. However some viewed this as “another group” and not something that would provide effective interactions. No conclusion was formally reached.

Theme 1 recommendations

Theme 1 recommendations following Theme 1 presentations and discussions include development of guidance (see session 4 2.3.2), a focussed study on improving the consistency of National EIs and point source data, developments to the EMEP grid based on discussions following presentations in session 4.

2. ***Develop Guidance*** for estimating emissions estimates with high **Spatial** (1x1km – 5x5km areas with vertical detail), **Temporal** (hourly, daily, monthly) and **Species** (PMs, NMVOC, PAHs & HMs) resolution.
   - Standards for preparing high resolution national inventory data as input to GMES/EMEP/atmospheric modelling studies (e.g. via TFEIP activities/guidebook updates)

- Downscaling from national inventories (top-down). What data is available, uncertainties/limitations and how to process it.
- How to adapt/optimise existing inventories and national spatial data.
- What's done in EMEP post-processing --> to get consistent modelling input data
- Dealing with issues with nomenclature for Global Scale models (different sectors) for different datasets and inputs and output needs

3. ***Improving consistency between EIs and E-PRTR/EU-ETS/LCPD*** and other industrial data reported under national or EU legislation.
   - Clarify the role of E-PRTR in providing the useful information to the GMES community (via National emissions inventories) and how can consistency between CEIPs EI and E-PRTR be improved. This to be achieved via consultation with modelling groups on the existing E-PRTR data available and interaction with leads on E-PRTR legislation.
4. ***Change the EMEP GRID to 10x10km*** including gridded area data + point sources with temporal and species detail and to include , natural and accidental emissions.
5. ***Pilot 1: Investigate feasibilities of data exchange between national high resolution data and GMES services.*** Work with countries that have spatial/temporal resolved inventories (determine what can they provide, what is coming back to them in return).
   - Agree / develop data exchange formats for national AQ Daughter Directive modelling inventory data flow to GMES services: What data could be provided by Countries, what data exchange formats would be needed and how could these improve GMES service accuracy? (e.g. high-res MACC EI comparison with natl high-res EIs. Conclude on discrepancies and commonalities and determinate way forward.)
6. ***Pilot 2: Investigating the ability of MS that don't have highly detailed data to gather and report it***.
   - EEA and countries could support in this with 3-5 countries needing development (e.g. Twining projects and Daughter Directive support)
7. ***Improve centralised Emissions Inventory Datasets (emission speciation and proxy data)***
   - Improvement to speciation (PMs, NMVOC, PAHs & HMs) by collating data from countries that compile it. In MACC temporal resolution is identified as the highest priority
     - NMVOC (UK, NL etc)
     - Collate data on BC: UK will develop BC in next 12 month, MACC could help in this too. (Same is the case in many other countries is assumed). MACC provide as starting point PM-split table as default (=standardisation).
   - Gather together libraries of proxy data to use for distributing national total emissions.

Theme 2 Recommendations

Theme 2 recommendations are focussed on GMES services improving Emissions Inventories following theme 2 presentations and discussions (see above session 5 presentations). Recommendations from presentations and associated discussions include further development of validation and verification techniques, development and refinement of proxy datasets for mapping national emissions and development of estimation techniques for natural sources and emission events.

8. ***Development of validation and verification (independent checking*** on accuracy and uncertainty***) techniques*** for national inventories and large point sources using inverse

modelling and satellite EO data. Validation needed to find missing sources and provide independent information on non-EU emission trends.

- Develop the maturity of methods using and not using priori datasets.
- Improve EO measurement techniques to provide data for validation and verification studies.
- Improvement of in-situ data and knowledge going into inverse studies
- Development of library of validation and verification techniques for national inventories and large point sources using inverse modelling and satellite EO data.

9. Continued development of **In-Situ data** provisions and metadata catalogue with reference to datasets that would support emissions inventory development (e.g. traffic monitoring).
10. Continue to develop ***proxy datasets of value for mapping national emissions inventories at 5x5km and below.***
    - Develop and improve timeliness of spatial proxies for distribution e.g. Land cover and land use (urban, industrial, transport networks) and temporal profiling (identifying daily, monthly trends and episodes in concentrations, surface air temperature and in carrying GPS data for traffic flow estimates etc.).
11. ***Continue to evaluate and utilise methods to estimate emissions from natural and international source (e.g. shipping, forest fires, dust and volcano emissions).***
12. ***Inverse modelling to improve the accuracy of EU level modelling*** (e.g. better attribution of air quality exceedances)
    - Continue to develop inverse modelling techniques that provide real/near-real time information on Air Quality or inputs to AQ modelling that are difficult from traditional emission inventories.

Annex I. Workshop Programme

Day 1	**Monday 10 October 2011**	
08:30-09:00	**Registration**	
Session 1: Introduction (09:00-10:30)		
Welcome and introduction to the workshop (purpose)		John van Aardenne (EEA) and Justin Goodwin (AETHER, UK; ETC/ACM)
Overview of GMES activities		Michael Rohn (DG Enterprise and Industry, GMES Bureau)
GMES in-situ data		Tim Haigh (EEA)
GMES satellite data: The possible usage of satellite measurements to improve emission inventories - the ESA Globemission project		Claus Zehner (ESA)
Session 2: GMES applications, atmospheric model community activities and their requirements for emission inventory data (10:30-13:00)		
MACC project and the GMES atmosphere services		Vincent Henri Peuch (Meteo France)
How has GMES services implementation changed the work on emission inventories (Requirements on emission inventory data)		Leonor Tarrason (NILU, NO)
Use and development of emission inventory for research projects		Claire Granier (LATMOS, FR)
Summary of and discussion around highlighted successes and improvement needs.		
Session 3: Emissions inventories in GMES projects. Challenges and successes. (14.00-17.00)		
MACC inventory		Hugo Denier van der Gon (TNO, NL)
Downscaling issues: City modelling/city inventories		Julio Lumbreras Martín(Universidad Politécnica de Madrid)
Atmospheric Emission Modelling: From Inventories to Air Quality Model Grids		Nele Veldeman (Vito, BE)
Impact of various emission inventories on modelling results; impact on the use of the GMES products		Laurence Rouïl (INERIS, FR; ETC/ACM)
Summary of and discussion around highlighted successes and improvement needs.		

Day 2	Tuesday 11 October 2011	
Session 4: What role could be played by official national inventories and what steps are needed to make this information available on suitable spatial and temporal scale? How to be sure about consistency between regulatory emission inventories and research or operational ones. (09:00-11:00)		
Overview of official national inventory data and requirements on spatial and temporal allocation		Martin Adams (EEA, co-chair TFEIP)
How official national inventory data is used as input to EMEP is models (gridded, temporal, speciation).		Katarina Mareckova (EMEP CEIP)
Comparison of E-PRTR spatial allocation of diffuse emissions sources with high resolution national emission inventories, example The Netherlands		Wim van der Maas (RIVM, NL)
High resolution emissions mapping in the United Kingdom linked to national reporting		Ioannis Tsagatakis (AEA, UK)
Summary of and discussion around highlighted successes and improvement needs.		
Session 5: Verification of emissions inventories (11:00-13:00):		
F-gases emissions through inverse modelling		Stefan Reimann (EMPA)
Anthropogenic CO2 emissions through inverse modelling		Frédéric Chevallier (ISCE/IPSL, FR)
Air Pollutant and greenhouse emissions via inverse modelling, the UK experience		Alistair Manning (UK Metoffice)
Summary of and discussion around highlighted successes and improvement needs.		
Session 6: Quantification of emissions sources (14:00-16:00): To what extend are we able to use observational dataset to quantify emissions from sources where traditional emission factor approaches have not been able to quantify these well or where (up-to-date) national inventory data is missing? For example, natural vs. anthropogenic emissions, emissions in countries where inventory data is out-dated or incomplete?		
Forest fire NRT emissions		Johannes Kaiser (ECMWF, UK)
Emissions of crustal material in air quality forecast systems: Use of satellite observations		Laurent Menut (IPSL/LMD, FR)
'Trends in ship NOx emissions observed from space		Folkert Boersma (KNMI, NL)
Summary of and discussion around highlighted successes and improvement needs		
Closure of the meeting (16:00)		

Annex II. Participants list.

Name	Role
Alistair James Manning	Attendee
Bertrand Bessagnet	Attendee
CRISTINA MIHAELA NEGULESCU	Attendee
Ceren UNCU AGACDIKEN	Attendee
Csaba Bán	Attendee
Damian Zasina	Attendee
Elo Mandel	Attendee
FULYA YAYCILI	Attendee
Gaia Righini	Attendee
Gird Bogdan	Attendee
Hilde Fagerli	Attendee
Irimescu Anisoara	Attendee
Jacek Skoskiewicz	Attendee
Jean-Pierre CHANG	Attendee
Jean-Pierre FONTELLE	Attendee
Johannes Kaiser	Attendee
Klaas Folkert Boersma	Attendee
Louise Refalo	Attendee
Marlene Plejdrup	Attendee
Michael Rohn	Attendee
Nele Veldeman	Attendee
Ole-Kenneth Nielsen	Attendee
Paul Ruyssenaars	Attendee
Paunescu Aurora	Attendee

Philipp Schneider	Attendee
Robert Wankmueller	Attendee
Slavko Kostoski	Attendee
Theloke Jochen	Attendee
Zoran Velickov	Attendee
Zorana Komar	Attendee
Catherine Brytygier	Organiser
John Van Aardenne	Organiser
Justin Goodwin	Organiser
Laurence Rouil	Organiser
Peter de Smet	Organiser
Claire GRANIER	Speaker
Claus Zehner	Speaker
Frederic Chevallier	Speaker
Hugo Denier van der Gon	Speaker
Katarina Mareckova	Speaker
Laurent MENUT	Speaker
Leonor Tarrason	Speaker
Stefan Reimann	Speaker
Tim Haigh	Speaker
Vincent-Henri Peuch	Speaker
Wim van der Maas	Speaker

Annex III Mutual weaknesses and opportunities

A summary of the 2010 paper and main areas of interest from the 2011 workshop (Figure A.III).

Weaknesses in Emissions Inventories for GMES

Annual National Inventories:

- National inventories lack a regularly updated spatial dataset. Only national totals with 50x50km + Large Point Sources data are reported for some air pollutants every 5 years.
- Time-lag: it takes ~2 years to prepare and report national inventories.
- There are very limited details of monthly, daily or hourly variation in emissions which inhibits the modelling of episodes of exceedence of air quality.

Regulated installation inventories (Data reported by industrial facility operators):

- Installation reporting has limited detail of source categories, stack height, activity data (fuel use), temporal (only annual totals: not monthly, daily or hourly) variations.
- Thresholds and threshold reporting limits the usability and integration of the data into national inventories and the comparability with real emissions.
- Time-lag (~2 years).
- No projections information is provided.

City Inventories:

- Irregular update frequency (data are often out of date)
- Time consuming and bespoke, involving lots of data suppliers without long term data flows or strong institutional arrangements.
- Lack of standards and consistent/comparable emissions datasets to generate comparable estimates between cities.
- Difficult to integrate/compare with national inventories/statistics.
- Time-lag in production (> 2 years).

Global Inventories:

- Time-lag in production (>5 years).
- Large dataset to maintain with many inconsistencies between country boundaries with other smaller scale data to resolve.
- Irregular update frequency (data are often out of date)
- Limited accuracy through use of “generic” global datasets (e.g. population, employment etc)

Opportunities for improvement to Emissions Inventories for GMES:

Annual National Inventories:

- More survey/census data (e.g. Domestic wood, cities, fuel type)

- Methods to use proxy data indicators (e.g. temperature, traffic flows, electricity/gas demand) to improve timeliness of emissions inventories.
- Improved collection of temporal variations (e.g. monthly, daily and hourly traffic, energy demand and production, agricultural activity etc).
- Speciation of pollutants (e.g. NMVOC, Heavy Metals, and POPs).PM characteristics EC, OC, BC, PM size distribution and particle number. Aircraft flight data from ICAO.
- Shipping route and traffic data from AIS.
- Real time energy supply data (e.g. http://www.nationalgrid.com/uk/Electricity/Data/Realtime/Demand/).

Regulated installation inventories (Data reported by industrial facility operators):

- Integration & Data from facility reporting (energy consumption, stack height and temporal variation) (IPPC/E-PRTR/EUETS).
- Improved collection of temporal variations (e.g. monthly, daily and hourly emissions from industrial plant).
- Continuous emissions monitoring networks OGC –Sensor Observation Services

City Inventories:

- Automatic Number Plate Recognition for road traffic in LEZs.
- City/urban inventory Standards

Global Inventories:

- Better integration of National Inventory data used for national modelling (e.g. 1x1km, speciated, temporal data)

Weaknesses in GMES for Emissions Inventories

National Inventory Compilation:

- Methods and data sources are well established and utilise national statistics and other ground based datasets. There are few opportunities for GMES services to add value to emissions inventory compilation.
- Limited “intensity” information available from GMES services and therefore GMES services unable to “Quantify” national emissions for energy, waste and industrial process emissions. E.g. Fuel use, traffic density, numbers of cars, fuel type.
- Cloud cover and/or instrument failure may prohibit a continuous operation and quality may vary between countries depending on climatic conditions.
- Limitation on consistent historic datasets for analysis of trends with no data available before GMES services datastet established and likelihood of changes in techniques in the future.

Spatial emissions distribution:

- Limited intensity information, (better for area based source/removal categories)
- Limitation on historic datasets and timeseries mapping.

Inventory verification:

- Verification approaches are promising but currently limited and most require some level of emissions (Priori data). Some questions about update frequency and availability of up-to-date data (e.g. EAS GlobCover dataset is becoming available in 2010 showing 2005 data).

Opportunities for improvement to Emissions Inventories for GMES:

National Inventory Compilation:

- Emissions/removals and biomass from forest growth and deforestation (LULUCF) and natural sources (Volcanoes, forest fires) could be improved using GMES services.
- Note there are no other satellite based datasets known that are viable replacements or enhancements to established statistics (energy, waste, agriculture and industrial process) based inventory accounting.

Spatial & temporal emissions distribution:

- GPS tracking of transport movements & type to estimate traffic intensity (Road vehicles and Shipping) to improve spatial and temporal details.
- Inverse near-real-time modelling of atmospheric concentrations and emissions based on high resolution column measurement data to provide details of emissions based on observed column concentration measurements.
- spatial distribution of forest growth and deforestation from landcover images and analysis
- spatial distribution of statistics based agriculture Crop types and areas, fertilizer applications and management practice surveys based on from landcover images and analysis.
- A number of these techniques are quite well advanced and have been tested in a number of EU projects (APMOSPHERE, IMPRESARIO, GEMs, PROMOTE)

Inventory Verification: This is a relatively new solution to independent verification of reported emissions inventory data. Approaches still have high uncertainties and methods need streamlining and developing.

- Inverse near-real-time modelling of atmospheric concentrations and emissions based on high resolution column measurement data to validate spatial emissions inventories..
- Verification of emissions from and location of Large Emission Sources based on their stack plumes.
- verifying Landuse, Land Use Change and Forestry (LULUCF) inventories reported under UNFCCC/EUMM by providing detailed maps of forest change.
- Verification based on inverse modelling of column measurement.

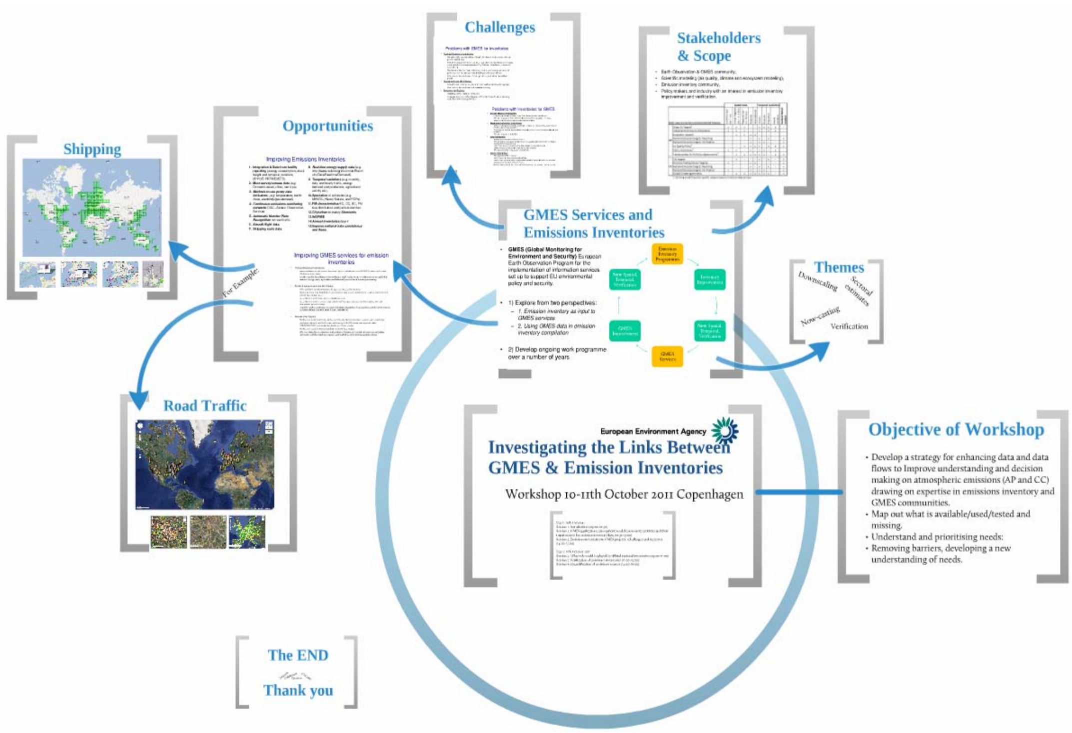

Figure A.III. Chart summarising main areas of interest of the GMES Services and Emission Inventories workshop.