NILU: F 4/2008

NILU: F 4/2008
REFERANSE: M-814
DATO: JANUAR 2008

The AirQUIS management system

Application for Singapore

Bjarne Sivertsen

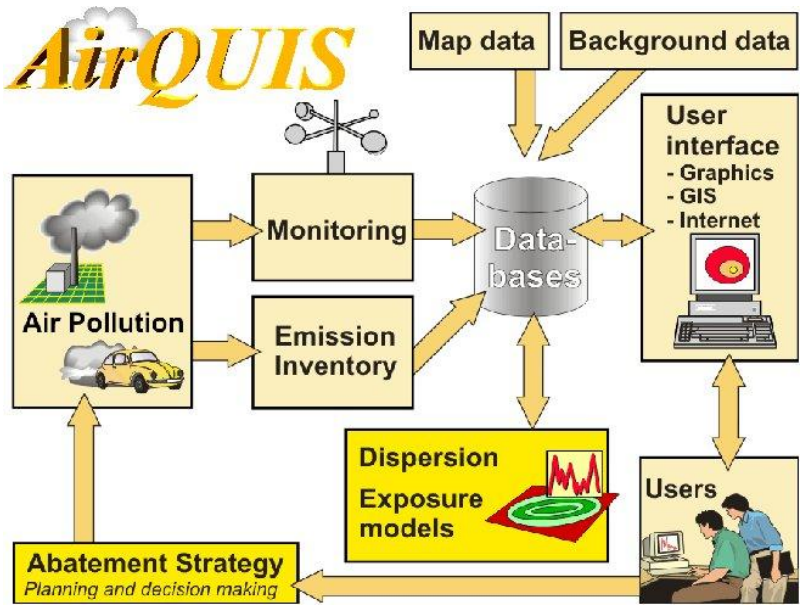


Table of Contents

1 Introduction 2
2 The air quality management concept 2
3 AirQUIS functionalities 3
4 The measurement module; data statistics and presentations 4
5 The emission inventory database 4
6 Air pollution dispersion module 4
7 Air pollution exposure models 5
8 Air quality projections and forecast 5
9 Information through Web pages 6
10 AirQUIS for Singapore? 6
11 References 7
Vedlegg A Slide presentation AirQUIS managment system 8

The AirQUIS management system

Application for Singapore

1 Introduction

AirQUIS has been developed by NILU to handle a number of air pollution tasks and challenges. It is based on a Geographical Information System (GIS). The main objective of a modern environmental surveillance platform like AirQUIS is to enable direct data and information transfer and obtain a remote quality control of the data collection.

The system combine monitoring, data presentation and modelling in one package, which enable the user not only to present and evaluate the present situation, but also to undertake environmental planning for a sustainable future. The GIS platform, on which the system is operated, provides easy access to the data and gives a perfect and easily understandable data presentation tool.

2 The air quality management concept

NILU has been working with the development of a complete Air Quality Management System (AQMS) for several years. During the last few years NILU developed and applied the system in several urban areas in Asia, Africa, The middle East and Europe.

The first application was in the URBAIR project undertaken by NILU for the World Bank. The Air Quality Management Strategy (AQMS) system consisted of two main components, which were **assessment and control**. In parallel with the AQMS development, and to facilitate checking the effectiveness of the air pollution control actions, a third component is necessary, which is **surveillance**.

The basic concept for an Air Quality Management Strategy contains the following main components:

- Air Quality Assessment
- Environmental Damage Assessment
- Abatement Options Assessment
- Cost Benefit Analysis or Cost Effectiveness Analysis
- Abatement Measures
- Optimum Control Strategy

The Air Quality Assessment, Environmental Damage Assessment and Abatement Options Assessment provide input to the **Cost Benefit or Cost Effectiveness**

Analysis, which is also based on established Air Quality Objectives (i.e. guidelines, standards) and Economic Objectives (i.e. reduction of damage costs). The final result of this analysis is **Optimum Control Strategy**.

A system for air quality management requires continuing activities on the urban scale in the following fields:

- Inventorying of air pollution activities and emissions
- Monitoring of air pollution and dispersion parameters
- Calculation of air pollution concentrations, by dispersion models
- Inventorying of population, materials and urban development
- Calculation of the effect of abatement/control measures
- Establishing/improving air pollution regulations.

In order to facilitate a tool and a system for undertaking air quality management in urban areas NILU developed the AirQUIS system.

3 AirQUIS functionalities

Objectives behind the development of AirQUIS were to combine the needed functionalities related to:

- on-line monitoring data collection and presentation
- assessment of present-day air pollution and its distribution
- projections of future air quality for various control and abatement options and scenarios

AirQUIS has been developed into one integrated system which can be operated on a PC platform. The AirQUIS system contains the following modules:

- Geographical Information System (GIS)
- Automatic Data Acquisition System (ADACS)
- Measurement database (air quality and meteorology)
- Statistical and Graphical Presentation Tools
- Emission Inventory Database
- Emission Model
- Wind Field Model
- Pollution Dispersion Models
- Exposure Models
- Abatement module (under development)

Data quality control is performed at different levels in the data collection process; in field during automatic and manual calibrations and controls, at the central data collection base, and in the approvals of the final storage database, where statistics and data graphics are used to check the validity and representativity of the data.

4 The measurement module; data statistics and presentations

All measured data can be viewed in graphs. The components can be viewed separately or as different lines in the same graph window. It is possible to add mean, minimum and maximum values to the graph as well as regression lines. There are several options for editing the appearance of the graph, for example line width, colours, markers, axes etc.

The tools for performing statistical calculations include:

- Mean, maximum and minimum values
- Percentiles
- Frequency distributions
- Counting values above or below bounds
- Linear regression
- Average diurnal variations
- Wind roses (for wind speed and wind direction registrations)
- Stability statistics (for measurements of atmospheric stability)
- Wind and stability frequency matrixes

Statistical calculation results may be shown as a table or by different options of graphical presentations.

5 The emission inventory database

The emission module is a flexible system containing a user friendly map oriented inter phase to treat the main sources for emission to air such as industry, traffic, energy (consumption of fossil fuels) and emissions related to other mobile sources such as airport and harbour activities.

The industry emission module allows the user to select sources related to specific activities or areas. The time variation of emissions can be entered specific for each source or for groups of sources. Based on emission factors, emissions can be calculated from consumption data.

The traffic module is the most complex part of the emission module, includes road types, vehicle type distribution, traffic time variation and emission factors dependent on parameters such as vehicle type, traffic speed and road type.

6 Air pollution dispersion module

This module contains a series of dispersion models, integrated within a framework suitable for calculation of air pollution concentration distribution fields in urban and metropolitan areas. The framework, as it is built into the AirQUIS platform, enables calculation of concentrations in any point within the modelling area, whether representative for the average concentration in each of the grid elements of the model area (typically 1x1 or 2x2 $km^{2,}$ or whether it is specific, freely selected points close to specific sources (e.g. stacks, roads), representing "hot-spots", areas of high concentrations.

The set of models include:

- Wind field model: the Mathew model
- Urban airshed dispersion model: the NILU EPISODE model
- Industrial / point source models:
- Road and road network dispersion models:

7 Air pollution exposure models

Calculation of the population exposure to air pollution provides the real basis for assessing an important part of the costs of the damage caused by air pollution, and further the basis for optimizing the control scenarios based upon cost analysis.

Other parts of the damage of air pollution concerns materials (in buildings and monuments) and ecosystems. AirQUIS also includes a module for assessing damage to materials.

In the population exposure module, the population exposure is calculated by combining the air concentration fields with the population distribution fields. Various schemes are used for these calculations.

8 Air quality projections and forecast

One main application of the AirQUIS system has been as an effective tool for air quality abatement strategy. The contribution of air pollution from different source categories such as traffic, household and industry to the population exposure in an urban area can be calculated based upon data on emissions, dispersion and population distribution. Different recommended measures to reduce air pollution can be evaluated due to population exposure and cost-benefit or cost-efficiency analyses. A priority list of the selected measures can be developed, taking into account air pollution exposure, health aspects and related costs.

Air quality forecasts and early warning systems have been developed for the largest urban areas of Norway. A direct interface between the MM5 weather prediction model, which estimates wind and turbulence fields, and the numerical air pollution dispersion models in AirQUIS, has been developed. This allows air quality forecast to be carried out automatically for the coming 24 and 48 hour periods.

The system is currently in place for 6 cities in Norway and results from the forecast are transferred directly to the health authorities for assessment. Based on this assessment health warnings may be distributed to high risk groups in affected areas. The forecast are also published by the health authorities on the Internet pages www.luftkvalitet.info on a daily basis

9 Information through Web pages

Information produced by the air quality monitoring and management system should be disseminated to decision makers, stakeholders to support decisions and to the public in order to increase awareness of air pollution in general.

To simplify the daily on-line information reported to the public an air quality index (AQI) is often produced. The measured results for the potential harmful species NO_2, CO, SO_2, O_3 and PM_{10} are included for determination of the AQI. Further both hourly and daily averages are included to take into account that the health deterioration may be initiated both of short time exposure to high concentrations and long time exposure to lower levels. This fact is also reflected in the Air Quality Standards.

A web-portal may be developed for Singapore showing on-line air quality data as well as historical air quality data and emissions. Status of air quality compared to standards and guidelines will be shown. Functionality to include written reports will also be provided.

The work contains the following activities:

- Defining the content of the web-portal
- Adjusting the web portal to Singapore
- Operational and editorial procedures

10 AirQUIS for Singapore?

NEA through ARC Engineering & Services Pte monitors the ambient air quality through the Telemetric Air Quality Monitoring and Management System. The system comprises remote air monitoring stations linked to a Central Control System via dial-up telephone lines, provides an efficient means of obtaining air quality data.

The monitoring stations monitor both ambient and roadside air quality. The automatic analysers and equipment at the stations measure the concentrations of major pollutants such as sulphur dioxide, oxides of nitrogen, carbon monoxide, ozone, hydrocarbons and respirable suspended particles (PM_{10}).

A request has been placed in order to exchange some of the elements of the data retrieval system, the QA/QC system and the databases with AirQUIS/NILU technology.

The first part of the project, including an evaluation and assessment of the existing system as well as a study of the QA/QC applications should be undertaken as soon as possible. This may also include the design of the monitoring system taking into account the already existing automatic monitors...

Evaluation of additional equipment as well as the preparations for the development of the database and planning tool AirQUIS will follow after the initiation of the project. As part of the mobilisation phase NILU will offer a kick-

off seminar, where all parts of a complete Air Quality Management programme will be presented.

11 References

Gryning, S.E., Holtslag, A.A.M., Irwin, J.S., and Sivertsen, B. (1987) Applied Dispersion Modelling Based on Meteorological Scaling Parameters. *Atmos. Environ., 21,* 79-89.

Grønskei, K.E., Walker S.E. and Gram F. (1993) Evaluation of a model for hourly spatial concentrations distributions, *Atmos. Environ.* **27B**, 105-120.

Irwin, J.S. (1983) Estimating plume dispersion - a comparison of several sigma schemes. *J. Climate Appl. Meteor.* ***22****, 92-114.*

Larssen, S. et al. URBAIR - Urban Air Quality Management Strategy in Asia, Metro Manila City Specific Report. Kjeller (NILU OR 57/95), 1995.

Larssen, S., Grønskei K.E., Gram, F., Hagen L.O, Walker S.E. (1994) Verification of urban scale time-dependent dispersion model with sub-grid elements in Oslo, Norway. Air Poll. Modelling and Its Appl. X, Plenum Press, New York.

Sivertsen, B. Air Pollution Monitoring for on-line Warning and Alarm. Presented at the International Emergency Management and Engineering Conference. Florida April 18-21, 1994 Lillestrøm (NILU F 7/94), 1994.

Sivertsen B. and Bøhler T. On-line Air Quality Management System for Urban Areas in Norway. Presented at "The air of our cities – it's everybody's business". Paris 16-18 February 2000. Kjeller (NILU F 4/2000), 2000.

Slørdal L.H., Walker, S.E (1997) Dispersion calculations of NO_X, NO_2 and PM_{10} in Oslo, Drammen, Bergen and Trondheim. Model validation. Kjeller (NILU OR 68/97). (In Norwegian).

Vedlegg A

Slide presentation
AirQUIS managment system

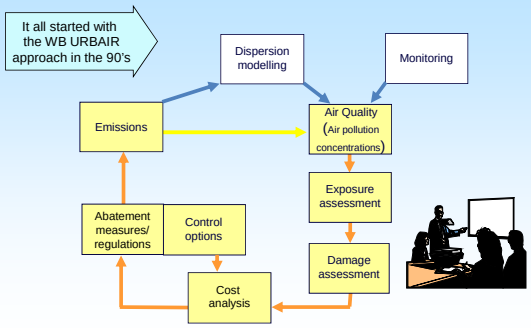
The Air Quality Management System

AirQUIS

Developed by the
Norwegian Institute for Air Research

BS NILU Singapore 29Jan08 www.NILU.no

AQ Management model concept



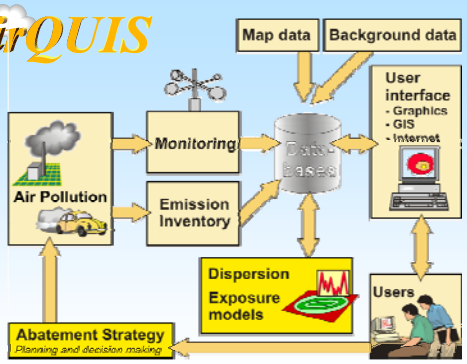
BS NILU Singapore, Jan 2008 www.NILU.no

A complete Air Quality Management System

- Monitoring (Air Qual.)
- Meteorological data !
- Data retrieval
- QA/QC
- Databases (GIS based)
- Dispersion Models
- Assessment tools
- Planning tools
- Forecasts (met+AQ)

BS NILU Singapore 29Jan08 www.NILU.no

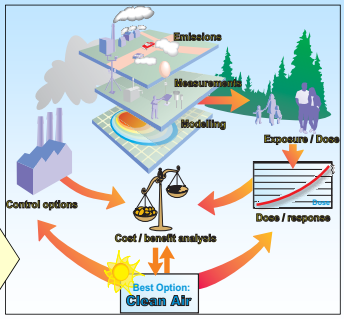
AirQUIS



BS NILU Singapore 29Jan08 www.NILU.no

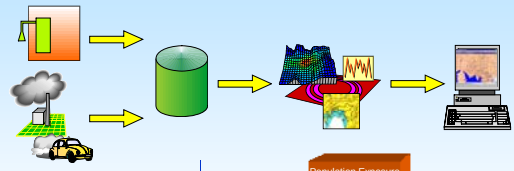
AQMS – main objective:

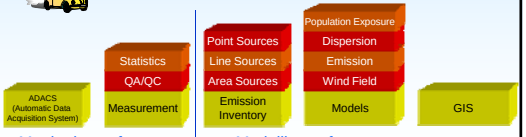
Identify actions to improve air quality



Identify most cost-effective options

AirQUIS Software system





Monitoring software Modelling software

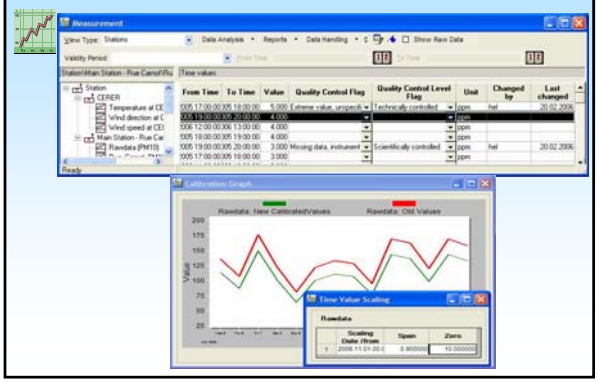
AirQUIS application

BS NILU Singapore, Jan 2008

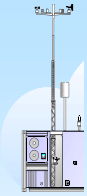
Measurement database

- **Database: Retrieve, organise and store data**
- **Quality control**
- **Data presentation**
- **Graphics and statistics**
- **Data as input for model calculations**

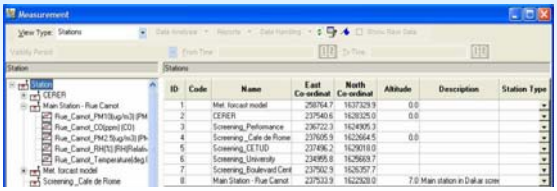
Measurement data – quality control



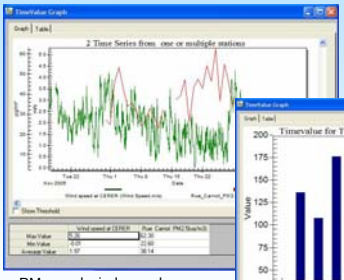
Measurement database



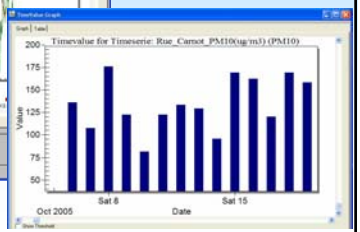
- Stations
- Components
- Time series



Measurements – time series



$PM_{2.5}$ and wind speed

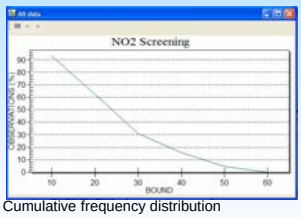


Daily values of PM_{10}

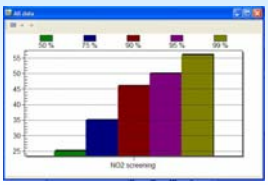
www.NILU.no

BS NILU Singapore, Jan 2008

Measurement - statistics



Cumulative frequency distribution

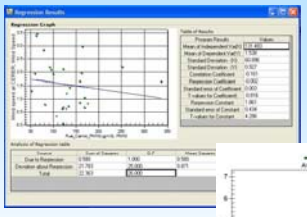


Percentiles

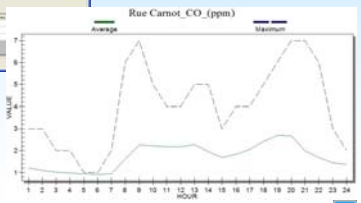
www.NILU.no

BS NILU Singapore, Jan 2008

Measurement - statistics



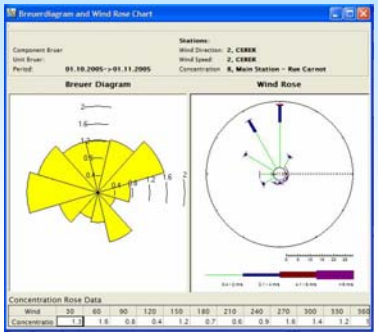
Regression: PM_{10} v.s wind speed



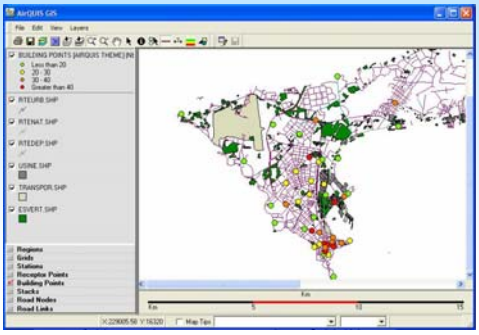
Diurnal variation CO

www.NILU.no

Measurements - air quality statistics



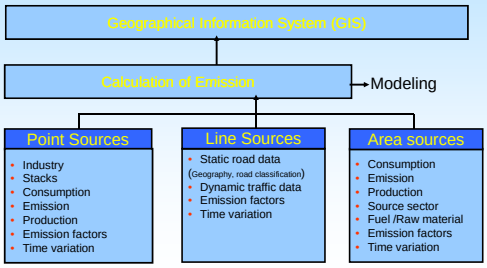
Measurement data presentations



The emission inventory

The atmospheric emissions inventory is a compilation of all sources of air pollution within an area

The emission inventory database

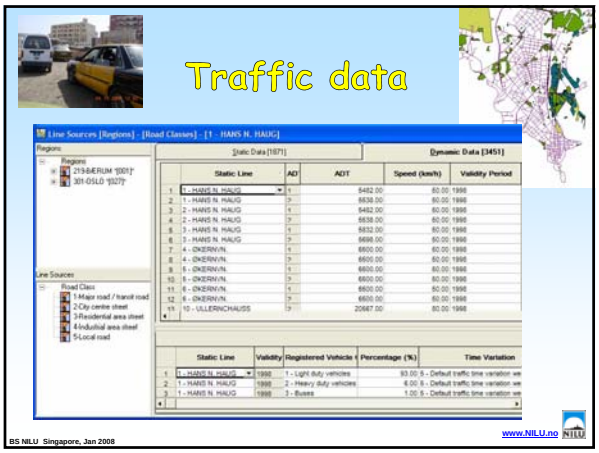


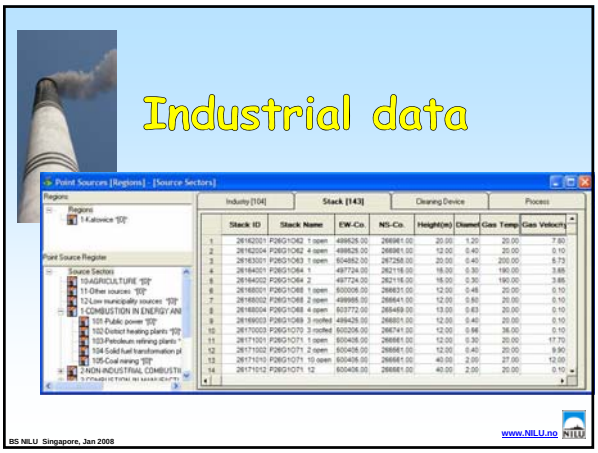
Emission inventory templates

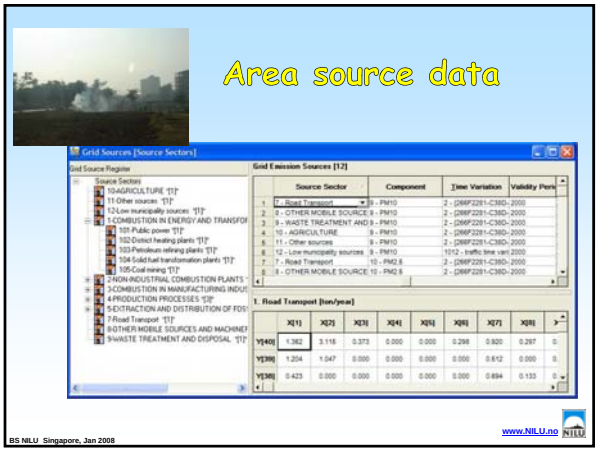
Stack data											
Stack ID	Stack name	X Co-ordinate	Y Co-ordinate	Stack height (m)	Stack Diameter (m)	Gas Temperature (C)	Gas Velocity (m/s)	Gas Flow Rate (m^3/s)	Building Height	Building Width	Industrial Plant Name
30100501	Pipe 301005-1	600669	6645282	10	0.5	130	16.27	3.19	5	10	Industry nr 301005
30100601	Pipe 301006-1	598856	6646044	20	0.5	178	10	2.00	5	10	Industry nr 301006
30101201	Pipe 301012-1	604096	6646518	46	0.9	250	20	6.67	18	28	Industry nr 301012
30101301	Pipe 301013-1	600071	6644966	14	0.4	190	12.6	10.00	6	10	Industry nr 301005
30101502	Pipe 301015-2	598835	6644487	40	3	225	5	35.34	18	40	Industry nr 301006
30101901	Pipe 301019-1	604474	6649890	30	0.8	110	20	10.00	12	18	Industry nr 301012

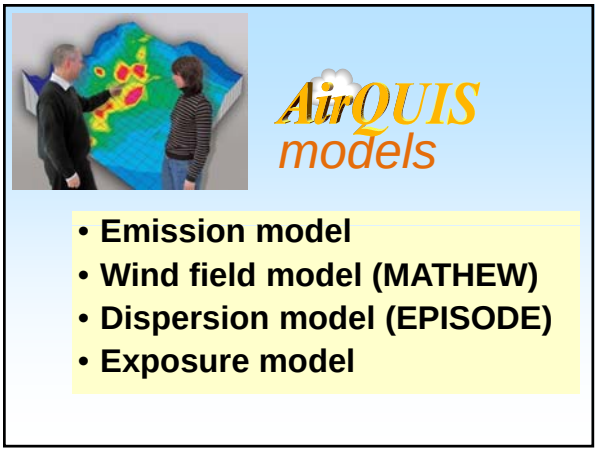
A number of Excel based templates for collecting of input data

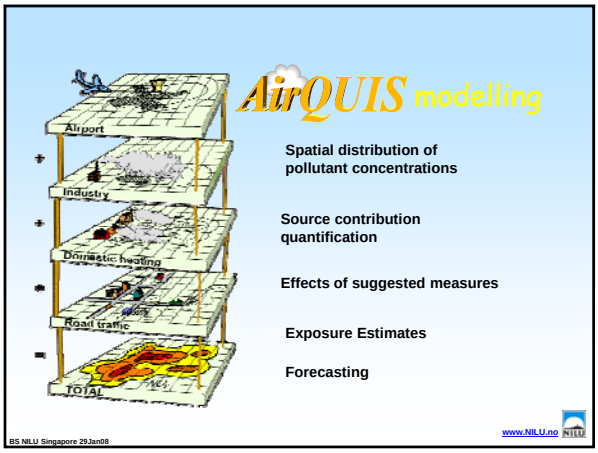
www.NILU.no

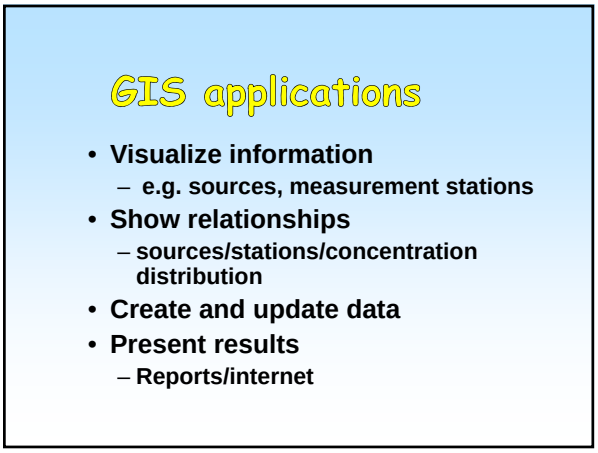

Traffic data
www.NILU.no
BS NILU Singapore, Jan 2008


Industrial data
www.NILU.no
BS NILU Singapore, Jan 2008

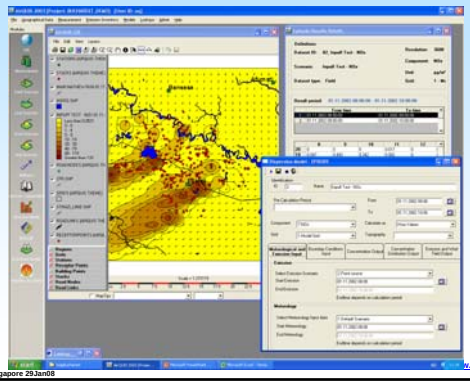

Area source data
www.NILU.no
BS NILU Singapore, Jan 2008


AirQUIS models
• Emission model
• Wind field model (MATHEW)
• Dispersion model (EPISODE)
• Exposure model


AirQUIS modelling
Airport
Industry
Domestic heating
Road traffic
TOTAL
Spatial distribution of pollutant concentrations
Source contribution quantification
Effects of suggested measures
Exposure Estimates
Forecasting
www.NILU.no
BS NILU Singapore 29Jan08

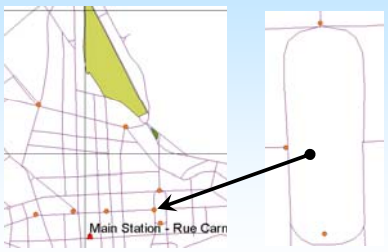

GIS applications
• Visualize information
– e.g. sources, measurement stations
• Show relationships
– sources/stations/concentration distribution
• Create and update data
• Present results
– Reports/internet

Dispersion Models



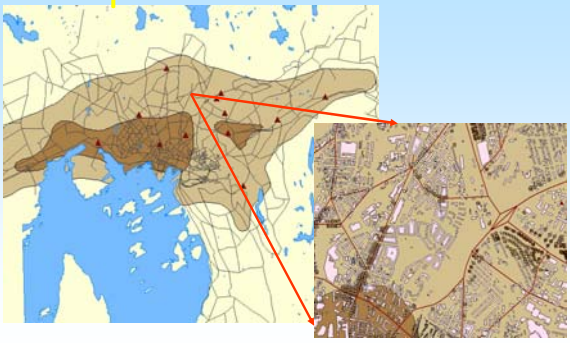
BS NILU Singapore 29Jan08 www.NILU.no

Vizualisation of data



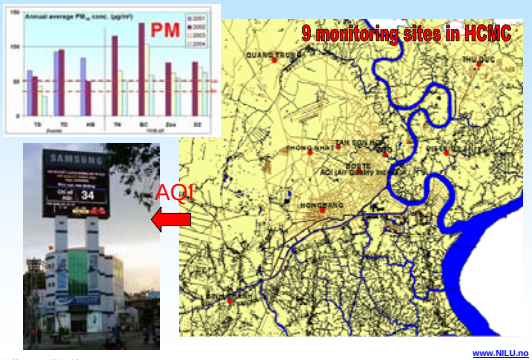
BS NILU Singapore, Jan 2008 www.NILU.no

GIS presentations



BS NILU Singapore, Jan 2008 www.NILU.no

AQM in Ho Chi Minh City



BS NILU Singapore 29Jan08 www.NILU.no

Model development

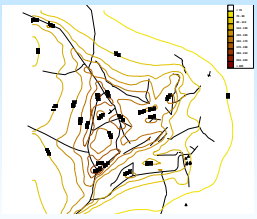

Emissions


Meteorology


Air Quality

118 roads
125 stacks
(70 plants and ind.)
+ all areas

model test evaluation



Operational dispersion model

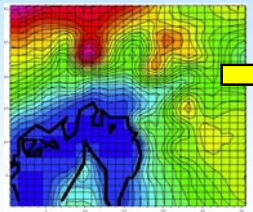
BS NILU Singapore 29Jan08 www.NILU.no

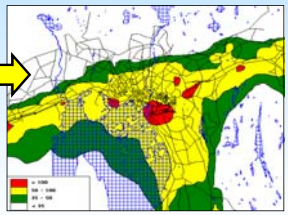
Air Quality Forecast

1. HIRLAM 50 (Atlantic ocean north of 20 deg)
2. HIRLAM 10 (North Western Europe)
3. MM5 (regional scale 3 km res.)
(inner city, local 1 km res.)

48 h prognoses - 1,25 hours at CRAY T3E

"Better city air" -





Important parameters:
- Topographical and surface features
- net radiation - surface temperatures
- clouds and snow cover
Uses NOAA Satellite data

NO_2 (µg/m3) 24h forward

DNMI

BS NILU Singapore 29Jan08 www.NILU.no

Model applications

- Environment impact assessment
- Surveillance and management
- A.Q. forecasting and early warning
- Optimal abatement strategies
- A.Q. information systems

Web solutions AQ data information

Public pages

Admin pages

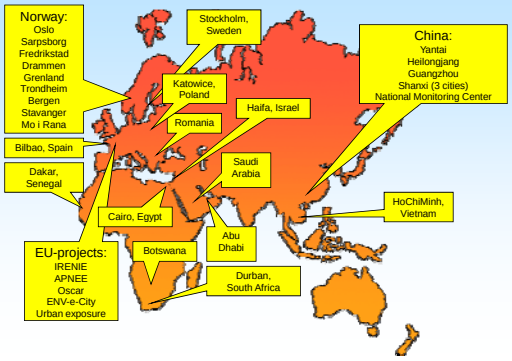
AirOnline

www.luftkvalitet.info

BS NILU Singapore, Jan 2008

www.NILU.no

AirQUIS Installations



www.nilu.no

BS NILU Singapore, Jan 2008

www.NILU.no

Norwegian Institute for Air Research

NILU
POBox 100
No-2027 Kjeller
Norway
Fax: +4763898050
E-mail: nilu@nilu.no

BS NILU Fornybar energi, Jan 2008

www.NILU.no