INTEGRATED SYSTEMS FOR FORECASTING URBAN METEOROLOGY, AIR POLLUTION AND POPULATION EXPOSURE: FUMAPEX ACHIEVEMENTS

Presented by Leiv H. Slørdal

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*** See the affiliations, partners and references on the FUMAPEX web-site:**
http://fumapex.dmi.dk

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17-20 October, 2005
Sissi (Malia), Crete, Greece

FUMAPEX: *Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure*

Project objectives:

(i) **the improvement of meteorological forecasts for urban areas,**

(ii) **the connection of NWP models to urban air quality (UAQ) and population exposure (PE) models,**

(iii) **the building of improved *Urban Air Quality Information and Forecasting Systems* (UAQIFS), and**

(iv) **their application in cities in various European climates.**

Project participants

Danish Meteorological Institute, DMI	**A.Baklanov (co-ordinator), A.Rasmussen**
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Hamburg University, MIHU	**M.Schatzmann**
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Norwegian Traffic Authorities, NTA	***P. Rosland***
Municipality of Oslo, MO	***O.M. Hunnes***

WHY to study it now ?

Meteorological fields constitute a main source of uncertainty in urban air quality (UAQ) forecasting models.

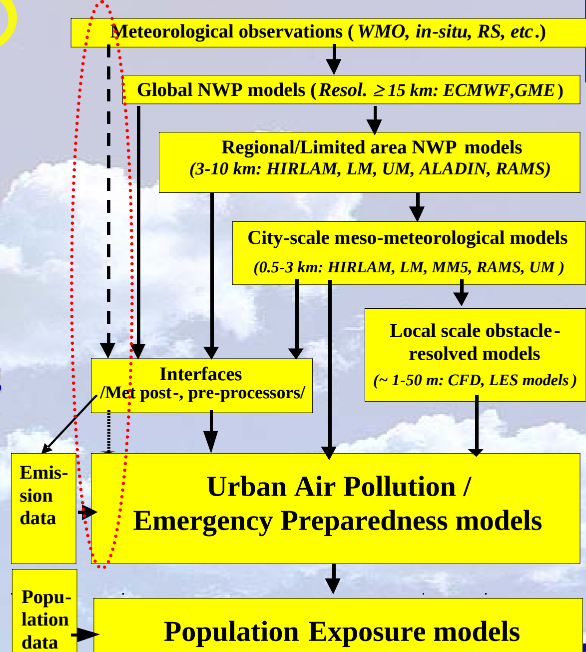
Historically, UAQ forecasting and NWP models were developed separately and there is no tradition for co-operation between the modelling groups.

This was plausible in the previous decades when the resolution of NWP models was too poor for city-scale air pollution forecasting, but the situation has now changed and it is obvious that **a revision of the conventional conception of urban air quality forecasting is required**.

FUMAPEX Work Packages Structure

WP 1	Analysis and evaluation of air pollution episodes in European cities (leaded by J. Kukkonen, FMI)
WP 2	Assessment of different existing approaches to forecast UAP episodes (leaded by R.S. Sokhi, UH)
WP 3	Testing the quality of different operational meteorological forecasting systems for urban areas (leaded by B. Fay, DWD)
WP 4	Improvement of parameterisation of urban atmospheric processes and urban physiographic data classification (leaded by A. Baklanov, DMI)
WP 5	Development of interface between urban-scale NWP and UAP models (leaded by S. Finardi, Arianet)
WP 6	Evaluation of the suggested system (UAQIFS) to uncertainties of input data for UAP episodes (leaded by N. Bjergene, DNMI)
WP 7	Development and evaluation of population exposure models in combination with UAQIFS's (leaded by M. Jantunen, KTL)
WP 8	Implementation and demonstration of improved Urban Air Quality Information and Forecasting Systems (leaded by L.H. Slørdal, NILU)
WP 9	Providing and dissemination of relevant information (leaded by A. Skouloudis, JRC)
WP 10	Project management and quality assurance (leaded by A. Rasmussen, DMI).

Current regulatory (dash line) and suggested (solid and dash lines) ways for systems of forecasting of urban meteorology for UAQIFS



Possibilities of NWP Models for UAP forecasting

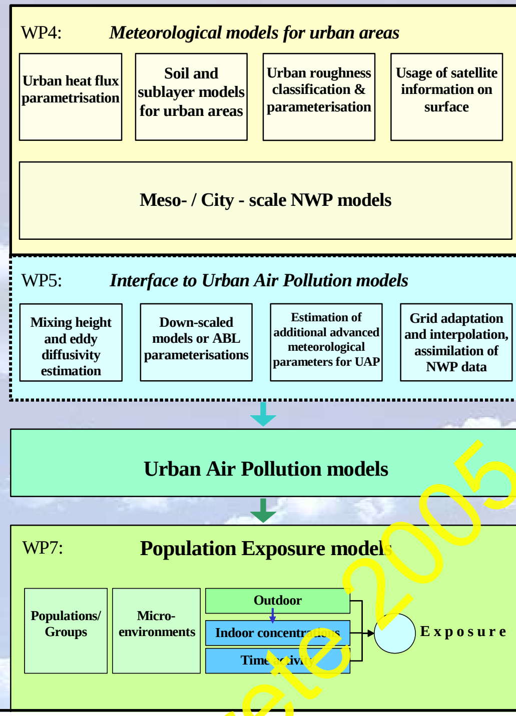
- Modern nested NWP models are approaching the resolution of the meso- and city-scale utilising land-use databases down to 1 km resolution or finer.
- In combination with the recent scientific developments in the field of urban atmospheric physics and the enhanced availability of high-resolution urban surface characteristics, the capability of the NWP models to provide high quality urban meteorological data will therefore increase.
- Existing operational UAP models often employ simple local measurements and meteorological pre-processors with a poor description of the temporal and spatial evolution of meteorological variables on the urban scale.
- Modern UAP models demand a lot more of additional meteorological input data, such as humidity distribution, cloud characteristics, intensity and type of precipitation, radiation characteristics etc.
- Clearly, present UAP models could greatly benefit from utilising meteorological data from NWP models to give a physically consistent basis for urban air quality forecasts.

Shortcomings of existing NWP:

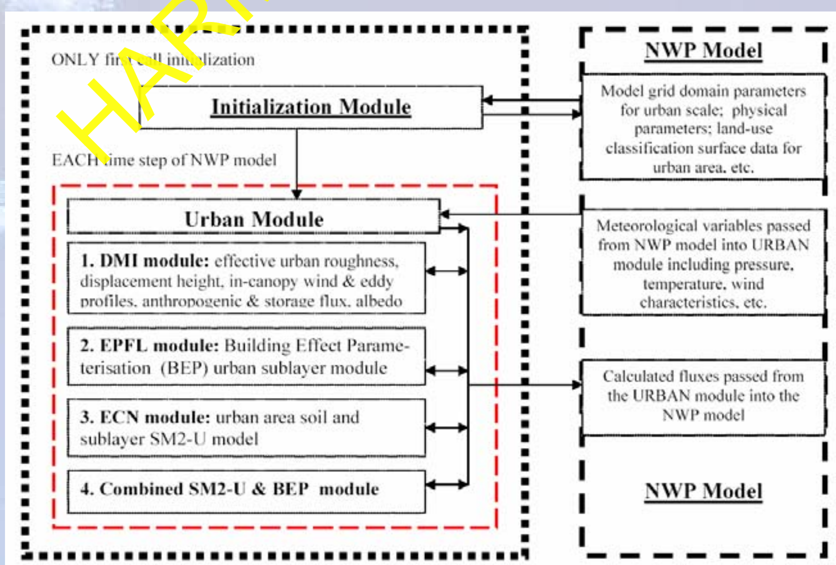
- ❑ Despite the increased resolution of existing operational NWP models, urban and non-urban areas mostly contain similar sub-surface, surface, and boundary layer formulation.
- ❑ These do not account for specifically urban dynamics and energetics and their impact on the numerical simulation of the atmospheric boundary layer and its various characteristics (e.g. internal boundary layers, urban heat island, precipitation patterns).
- ❑ Additionally, NWP models are not primarily developed for air pollution modelling and their results need to be designed as input to urban and mesoscale air pollution models.

UAQIFS:

Scheme of the suggested improvements of meteorological forecasts (NWP) in urban areas, interfaces to and integration with UAP and PE models



Scheme of the FUMAPEX urban module for NWP models

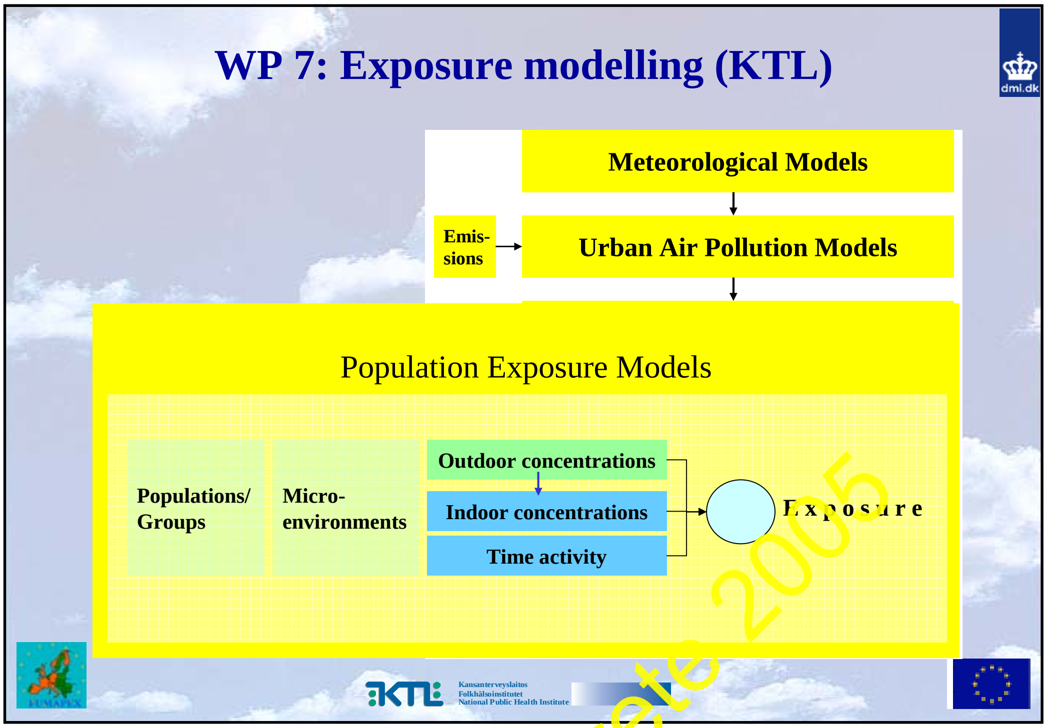


Interface: Urban BL features for MH estimation

(i) internal urban boundary layer (IBL) and blending height,
(ii) elevated nocturnal inversion layer,
(iii) strong horizontal inhomogeneity and temporal non-stationarity,
(iv) so-called 'urban roughness island', zero-level of urban canopy, and $z0u \neq z0T$,
(v) anthropogenic heat fluxes from street to city scale,
(vi) downwind 'urban plume' and scale of urban effects in space and time,
(vii) calm weather situation simulation,
(viii) non-local character of urban MH formation,
(ix) urban soil, effect of the water vapour fluxes.

Applicability of 'rural' methods of the MH estimation for urban areas:

- For estimation of the daytime MH, applicability of common methods is more acceptable than for the nocturnal MH.
- For the convective UBL the simple *slab models* (e.g. Gryning and Batchvarova, 2001) were found to perform quite well.
- The formation of the nocturnal UBL occurs in a counteraction with the negative 'non-urban' surface heat fluxes and positive anthropogenic/urban heat fluxes, so the applicability of the common methods for the SBL estimation is less promising.
- The determination of the SBL height needs further developments and verifications versus urban data. As a variant of the methods for SBL MH estimation the new Zilitinkevich *et al.* (2002) parameterisation can be suggested in combination with a prognostic equation for the horizontal advection and diffusion terms (Zilitinkevich and Baklanov, 2002).
- Meso-meteorological and NWP models with modern high-order non-local turbulence closures give promising results (especially for the CBL), however the urban effects in such models need to be included.


WP 7: Exposure modelling (KTL)
Meteorological Models
Emis-
sions
Urban Air Pollution Models
Population Exposure Models
Populations/
Groups
Micro-
environments
Outdoor concentrations
Indoor concentrations
Time activity
Exposure
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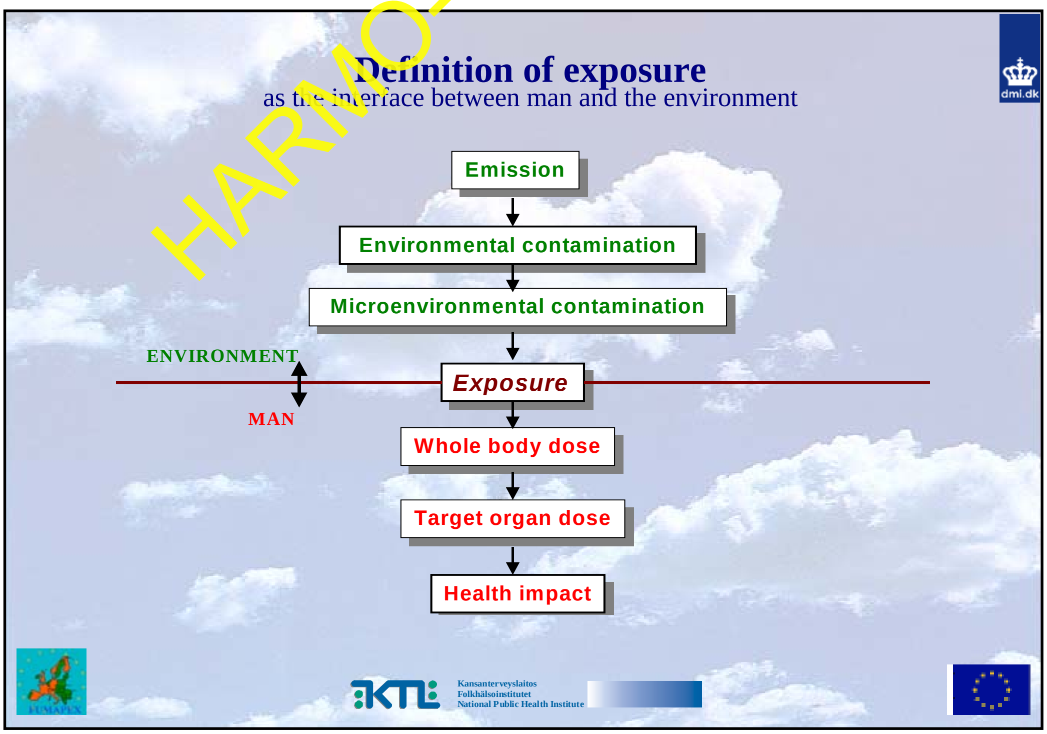
National Public Health Institute


Definition of exposure
as the interface between man and the environment
Emission
Environmental contamination
Microenvironmental contamination
ENVIRONMENT
MAN
Exposure
Whole body dose
Target organ dose
Health impact
dml.dk
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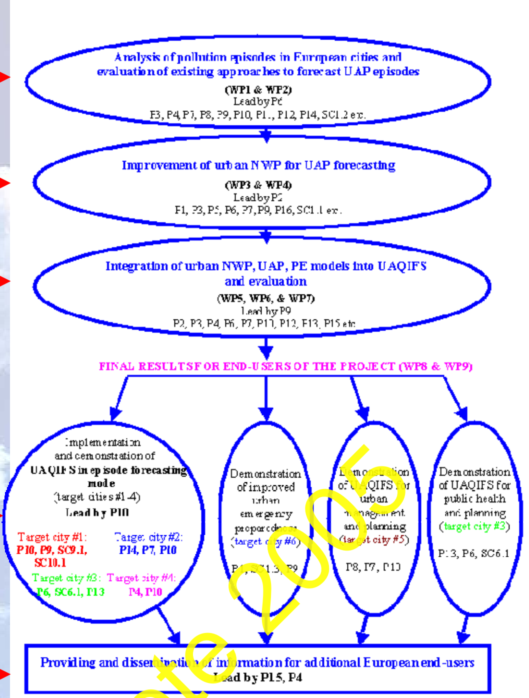
Folkhälsoinstitutet
National Public Health Institute

Graphical presentation of the projects components

FUMAPEX Work Packages, Participants, their interconnection and the horizontal organisation of the consortium, including several WP groups (NWP: Numerical Weather Prediction, UAP: Urban Air Pollution, PE: Population Exposure);

Target city candidates: #1 – Oslo, #2 – Torino, #3 – Helsinki, #4 – Valencia/Castellon, #5 – Bologna, #6 - Copenhagen.

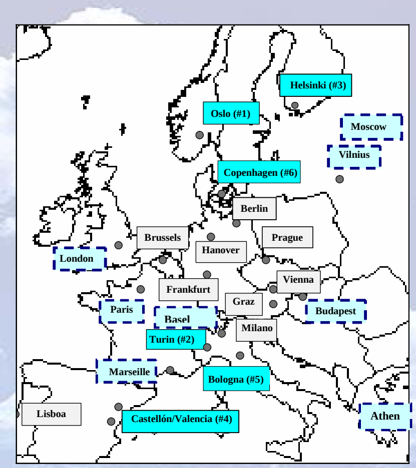


FUMAPEX target cities for improved UAQIFS implementation

#1 – Oslo, Norway
#2 – Turin, Italy
#3 – Helsinki, Finland
#4 – Valencia/Castellon, Spain
#5 – Bologna, Italy
#6 – Copenhagen, Denmark

Different ways of the UAQIFS implementation:

(i) urban air quality forecasting mode,
(ii) urban management and planning mode,
(iii) public health assessment and exposure prediction mode,
(iv) urban emergency preparedness system.

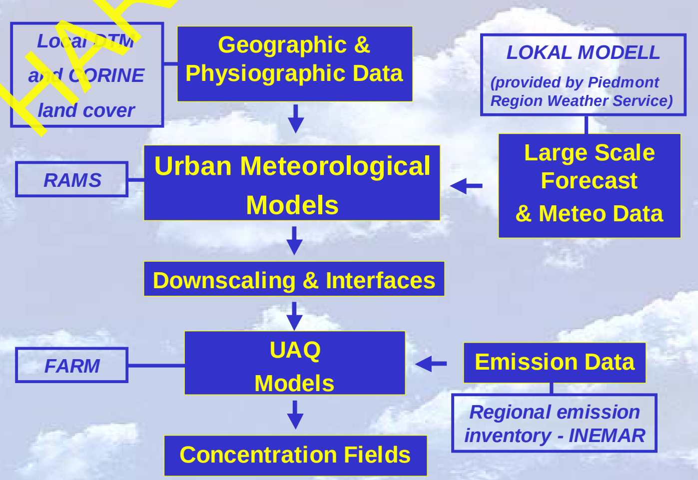


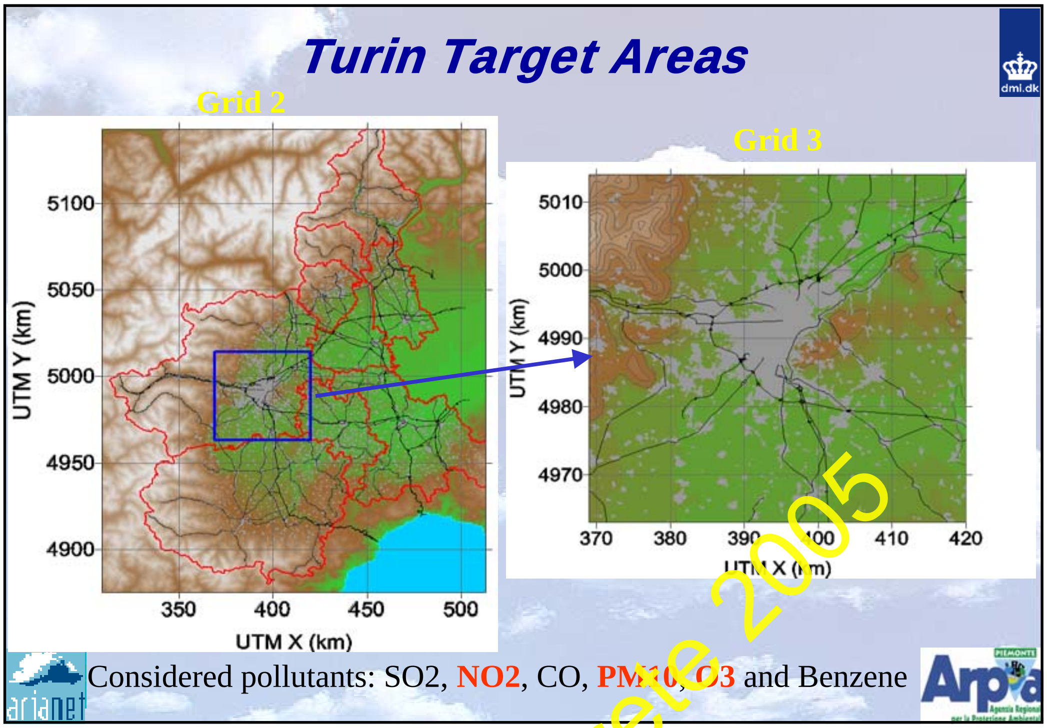
Map of the selected European cities for air pollution episode analysis. The target city candidates for UAQIFS implementation in FUMAPEX are marked by a # and blue background. Potential target cities for applying the FUMAPEX technique in future are marked with a dark-blue shaded border.

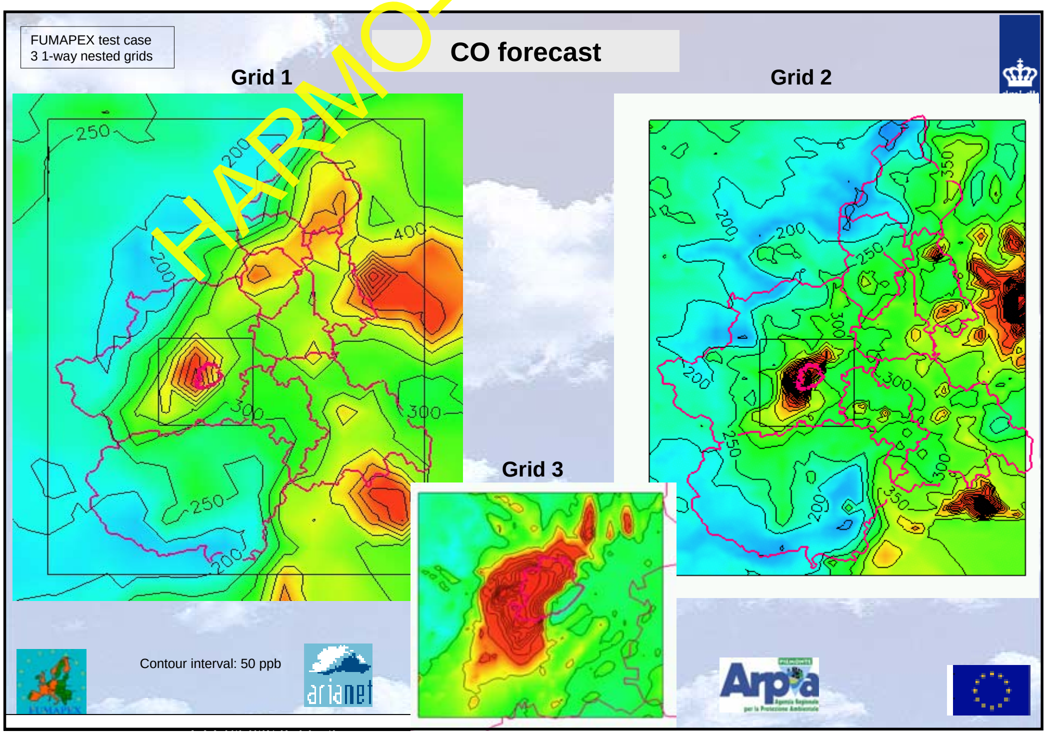
Summary of the UAQIFS applied in the target cities

Target City	*Meteorological Model*	*Met Pre-processors*	*AQ Model*
Oslo, Norway	met.no-HIRLAM (hydrostatic NWP model)/ MM5 (non-hydrostatic mesoscale model)	METPRO (M-O based MPP)	AirQUIS/EPISODE - Urban Air Quality, Episode simulation
Helsinki Metropolitan area, Finland	FMI-HIRLAM (hydrostatic NWP model)	MPP-FMI (M-O based MPP)	CAR-FMI and OSPM - Air Quality (traffic) UDM-FMI - Urban Air Quality
Castellon area, Spain	RAMS (non-hydrostatic mesoscale model)	RAMS generates CAMx input on identical grids	Comprehensive Air Quality Model with Extensions (CAMx) Version 3.1 - Episodes simulation
The city of Turin, Italy	RAMS (non-hydrostatic mesoscale model)	SURFPRO (M-O based MPP)	FARM (Flexible Air quality Regional Model) - Episode simulation
The city of Bologna, Italy	LAMI (non-hydrostatic mesoscale model)	CALMET-SMR (M-O based MPP)	OLMO (Ozone Linear MOdel) - Air Quality Forecast PIOPPO (Pm10 Pollution POlynomial model) - Air Quality Forecast CALGRID - Regional Scale Episode simulations
Copenhagen Metropolitan area, Denmark	DMI-HIRLAM (hydrostatic NWP model)	LSMC pre-processor (a part of the ARGOS system) RODOS met-pre-processor Mixing Height Calculation Library	The Danish Emergency Response Model of the Atmosphere (DERMA)- Emergency response The Accident Reporting and Guidance Operation System (ARGOS) - Emergency response

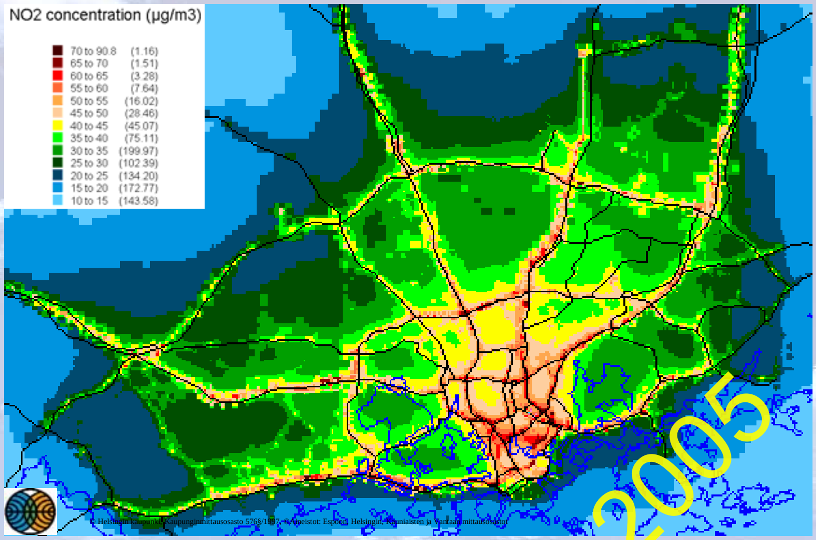
Scheme of the different elements composing the UAQIFS for Turin city




Turin Target Areas
dml.dk
Grid 2
Grid 3
UTM Y (km)
UTM X (km)
Considered pollutants: SO2, NO2, CO, PM10, O3 and Benzene
arianet
Arpa


FUMAPEX test case
3 1-way nested grids
CO forecast
Grid 1
Grid 2
Grid 3
Contour interval: 50 ppb
arianet
Arpa

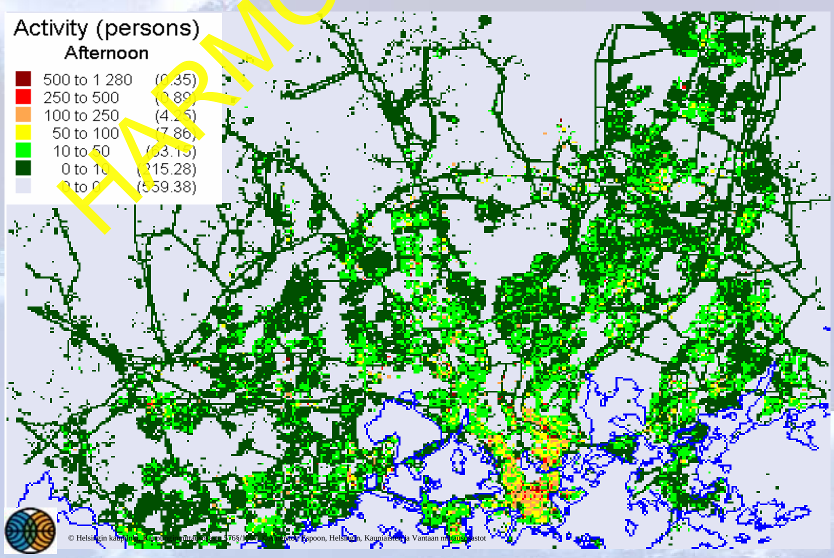
Prediction of population exposure for Helsinki by KTL/FMI/YTV



The predicted concentration of NO_2 in the greater Helsinki area (µg/m^3)

Kansanterveyslaitos
Folkhälsoinstitutet
National Public Health Institute

YTV Environmental Office



The predicted population activity (number of persons).

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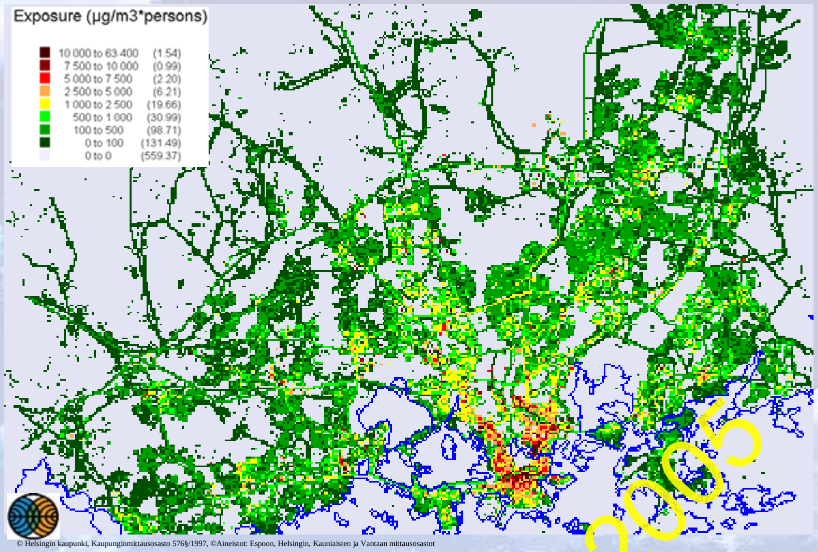
Folkhälsoinstitutet
National Public Health Institute

YTV Environmental Office



The predicted exposure of population to NO_2 (µg/m^3*persons).

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Folkhälsoinstitutet
National Public Health Institute

YTV Environmental Office

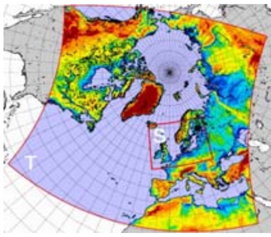
Copenhagen Metropolitan Area

Early warning and emergency preparedness:
The availability of reliable UAQIFS with urban scale weather and pollution forecasts could be of relevant support for emergency management:
(i) fires,
(ii) accidental radioactive or toxic emissions,
(iii) potential terrorist attacks with radioactive, chemical or biological matter releases, etc.

Structure of the Danish nuclear emergency modelling system

DMI-HIRLAM system

- T version: 0.15°
- S version: 0.05°
- L version: 0.014°



ECMWF global model

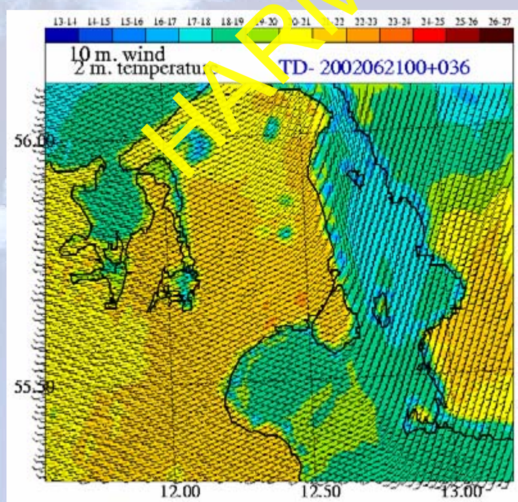
DERMA model

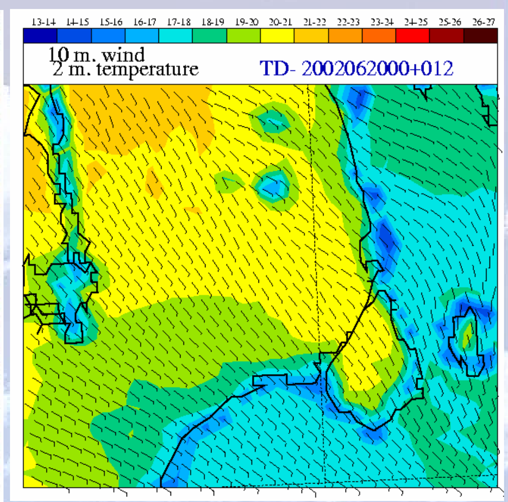
- 3-D trajectory model
- Long-range dispersion
- Deposition of radionuclides
- Radioactive decay

ARGOS system

- Radiological monitoring
- Source term estimation
- Local-Scale Model Chain
- Health effects

High resolution DMI-HIRLAM NWP forecast for Copenhagen area

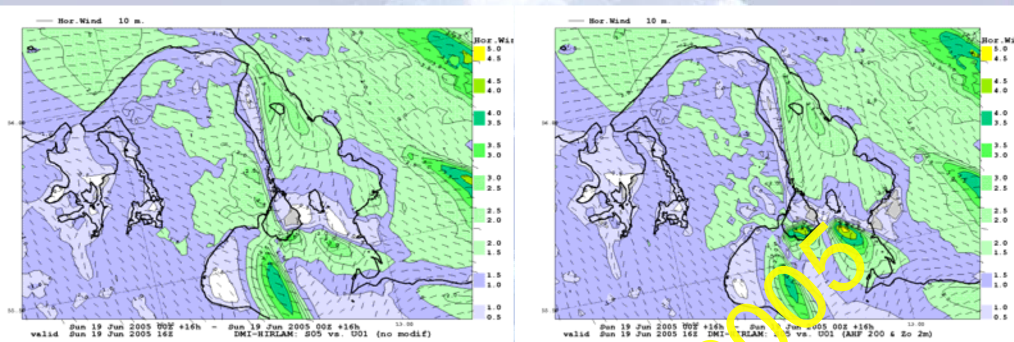




Examples of forecasted wind fields at 10-meter height and of 2-meter air temperature for the Copenhagen metropolitan area by the experimental version of DMI-HIRLAM with the horizontal resolution of 1.4 km.

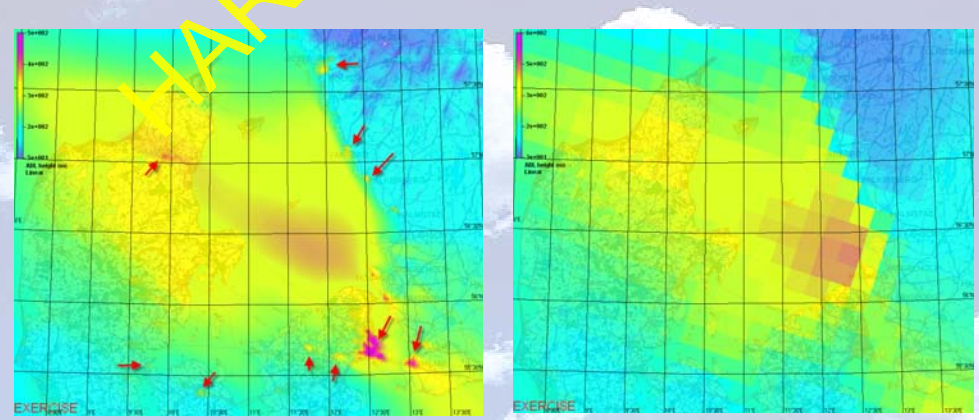
DMI-HIRLAM S05 vs. U01 Modelling

Difference fields for the wind at 10 m simulated
by the DMI-HIRLAM-S05 vs. U01 (urbanized) models
at 16 UTC on 19 June 2005 for the ISBA land surface scheme with:



no modifications | combined effects of roughness and anthropogenic heat flux

The mixing height in ARGOS as calculated from different versions of DMI-HIRLAM

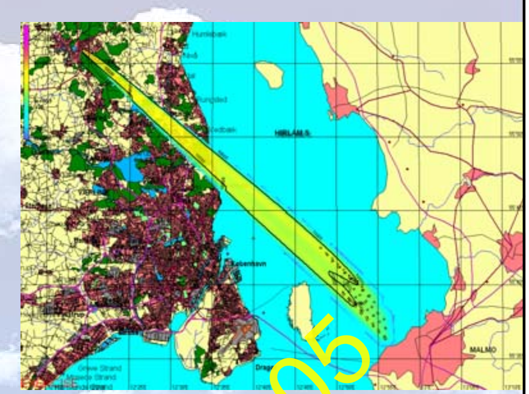


urbanised U01 | **operational T15**

Main cities are shown by arrows

Sensitivity of ARGOS dispersion simulations to urbanized DMI-HIRLAM NWP data

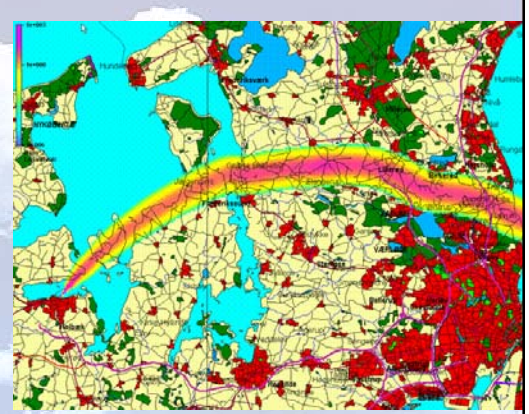
urbanised U01, 1.4 km resolution



operational S05, 5 km resolution

Cs-137 air concentration for different DMI-HIRLAM data
A local-scale plume from the ^{137}Cs hypothetical atmospheric release in Hillerød at 00 UTC, 19 June 2005 as calculated with RIMPUFF using DMI-HIRLAM and visualised in ARGOS for the Copenhagen Metropolitan Area.

Dirty bomb scenario for the Copenhagen Metropolitan Area



A local-scale plume from a hypothetical atmospheric release as calculated by RIMPUFF using DMI-HIRLAM data with 1.4-km resolution and visualised by ARGOS. One-hour hypothetical release of 137Cs with a total activity of 50 TBq for May 6, 2003 took place in the city of Holbæk, close to the Roskilde and Copenhagen cities.

For more information:

FUMAPEX web-site: ***http://fumapex.dmi.dk***

FUMAPEX progress reports:

http://www.dmi.dk/f+u/publikation/vidrap/

Thank you !