Theme 3: Research to operations

Methodology for UAQ information and forecasting systems and Urban multi-hazard early warning systems, contribution to Urban Integrated Services
(Guidelines for UAQIFS/UMHEWS)

Alexander Baklanov, WMO

GURME SAG Meeting, WMO, 7-8 April 2017

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

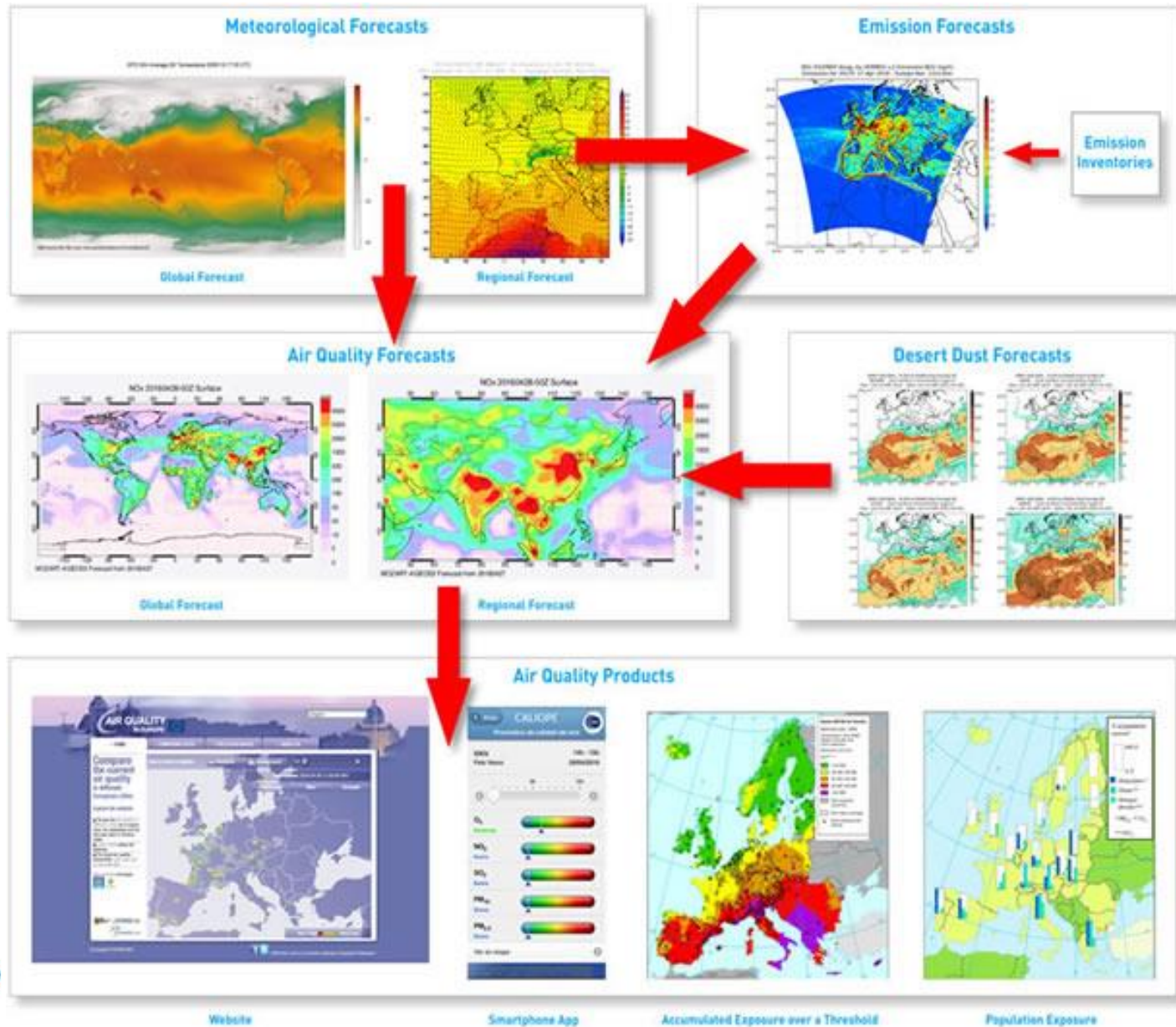# Hazards and Risks in the Urban Environment:

- **Poor air quality**
- ***Extreme heat/cold and human thermal stress***
- ***Hurricanes, typhoons, extreme local winds***
- **Wild fires, sand and dust storms**
- **Urban floods**
- **Sea-level rise due to climate change**
- **Energy and water sustainability**
- **Public health problems caused by the previous**
- **Climate change: 70% of GHG emission - urban**

MALAO@pictzz.blogspot.com

© Adrian Pearman/Caters

© www.thamai.net

© Tommy Hindley/ Professional Sport

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Through a domino effect, a single extreme event can lead to a broad breakdown of a city's infrastructure:

Example of Hazard Domino Effect (Typhoon)

Transmission Line *Street Trees*

Green House

Street Billboards

Traffic Accident

Infrastructure Damage

Severe Convection

Strong Wind

Casualty

Typhoon

Storm Surge

Heavy Rain

Farmland

Riverbanks Destroyed

High Waves

Traffic Accident

Inundation

Water Logging

Marine Accident

Electrocution *Basement Flooding*

Plant Disease

Overflowing

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Solution: Integrated Urban Services

Urban activities are a priority and specific cross-cutting element within the WMO strategy

- **Integrated Urban Weather, Water, Environment and Climate Services**
- **Multi-Hazard Early Warning Systems**
- **Focus on impact based forecast and risk based warnings**


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Schematic overview of potential GAW services

Elements of the GAW Programme

"Nesting" – from the planet to a building

- Global consistency
- Consistency across scales
- standardization
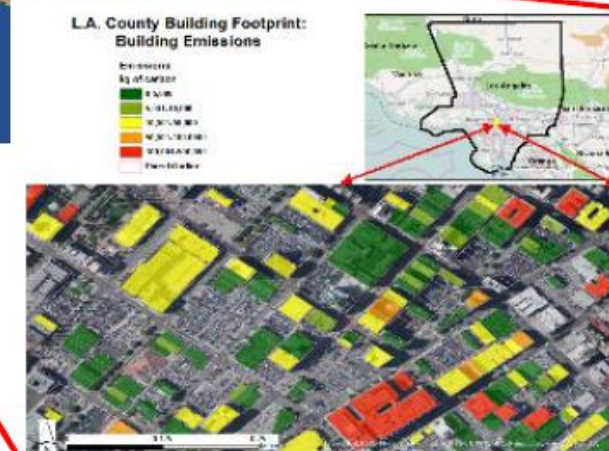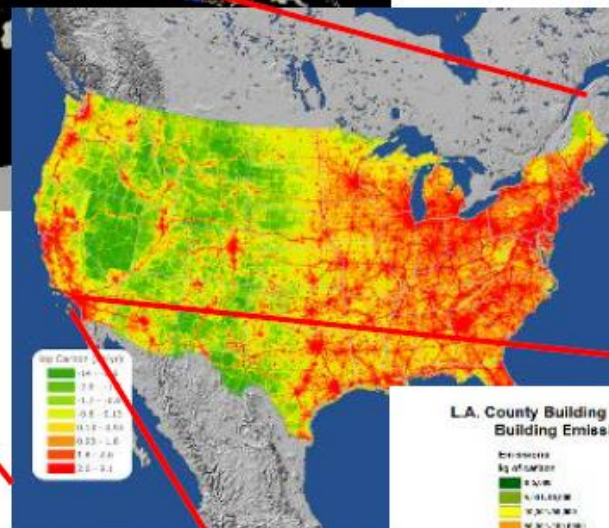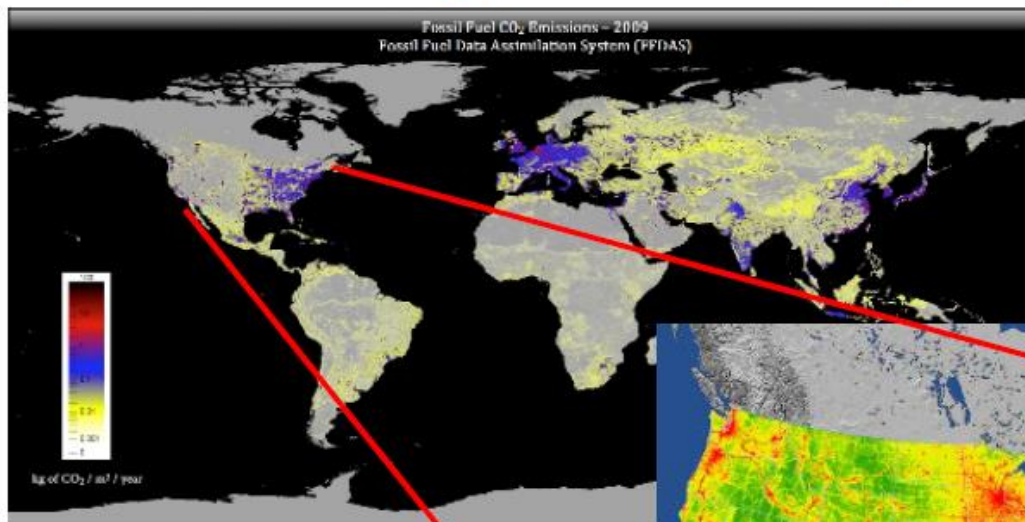
Seamless Methodology and Research Tools
Multi-scale modelling Chain / Framework: from Neighborhood to Global

Megacity, Air quality and Climate: Observations and multi-scale Modelling
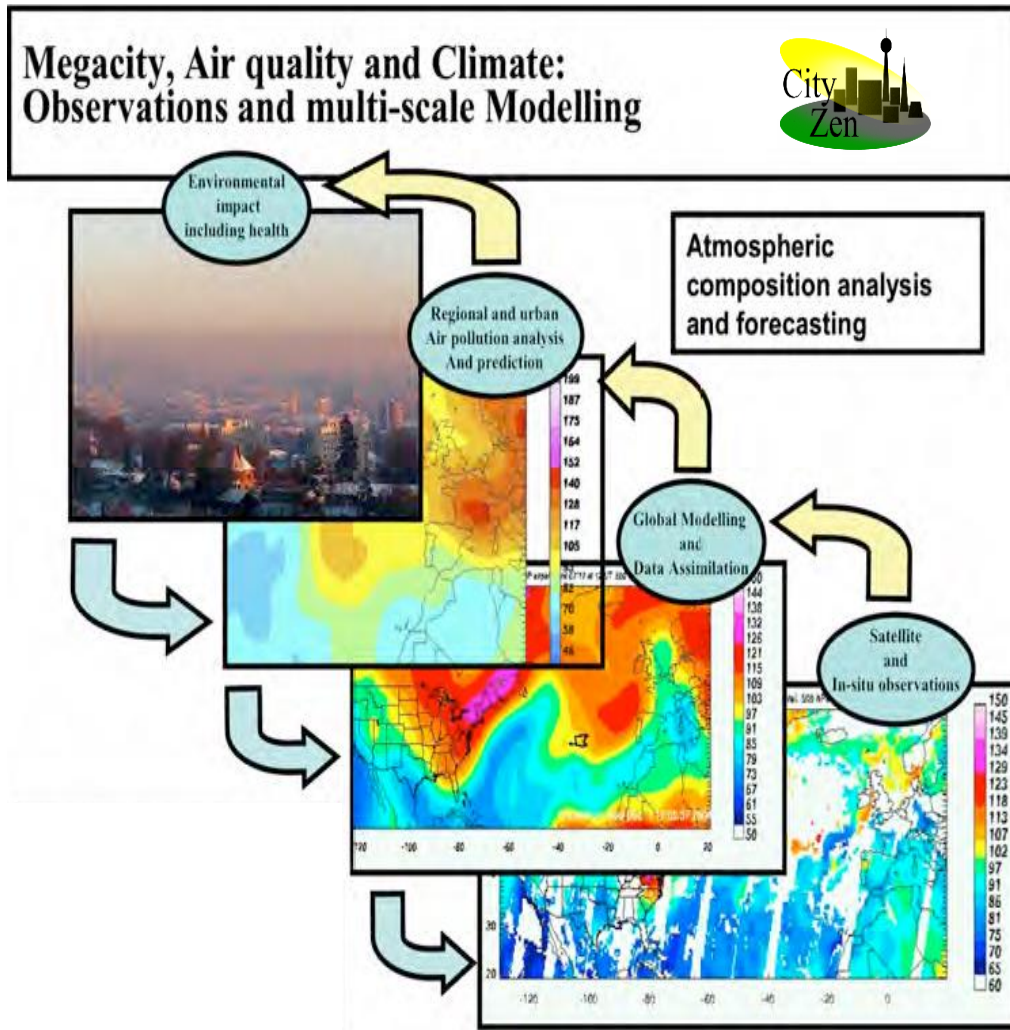
Seamless coupling for:

- Time scales: from nowcasting till decades
- Spatial scales: from street till global
- Processes: physical, chemical, biological, social
- Earth system elements: atmosphere, water, urban soil, ecosystems
- Different types of observations and modelling
- Links with health and social consequences, services and end-users

=> New generation of integrated models

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CAMS SERVICE CHAIN IN A NUTSHELL
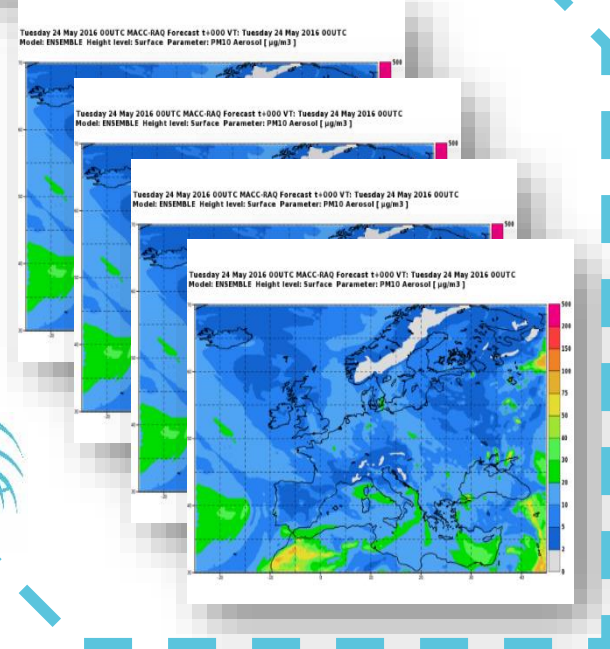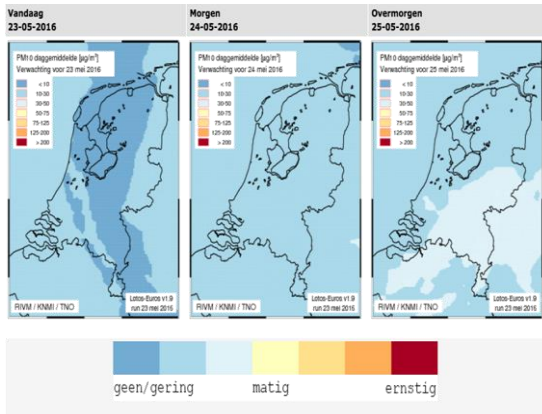

Satellite observations
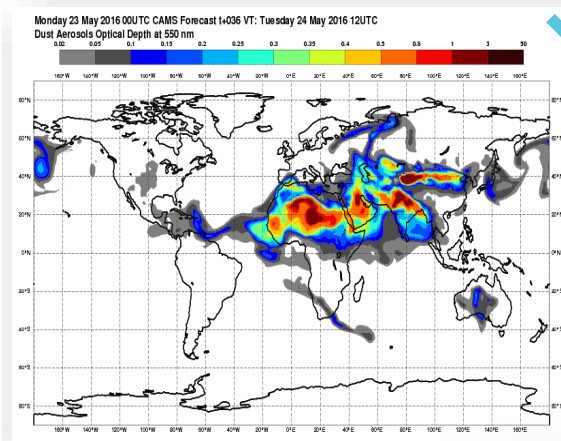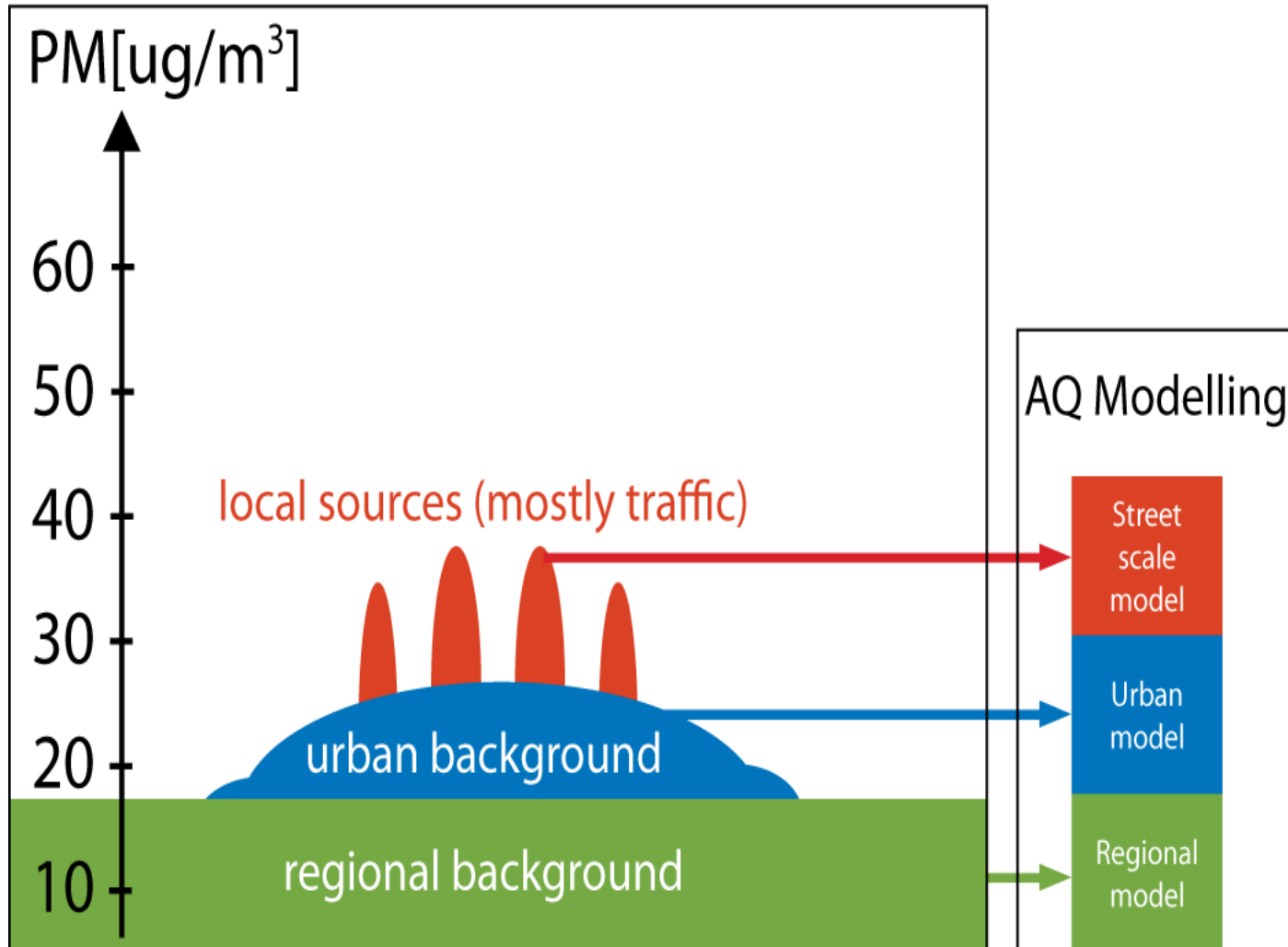
In-situ observations

REGIONAL

GLOBAL

National scale
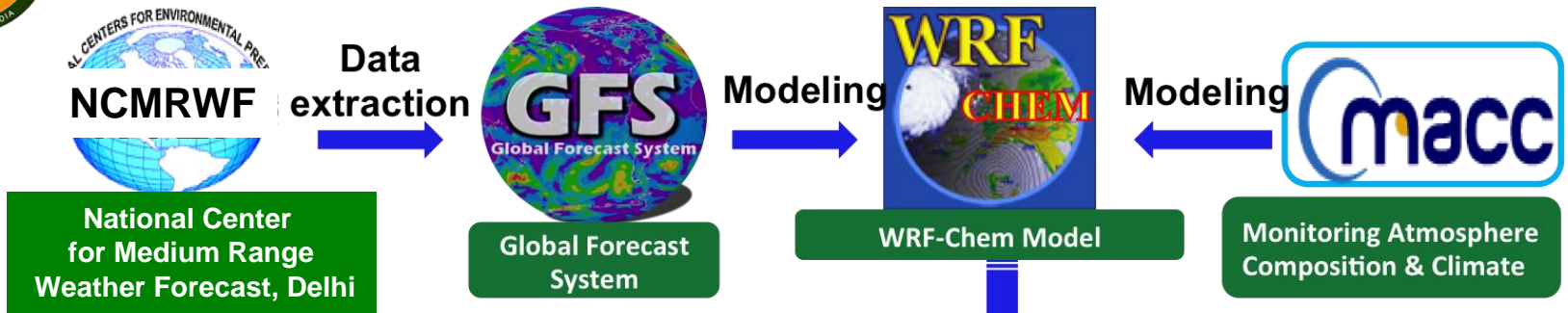
Better estimates of exposure at urban scales

Scientific issues

- Requirements for observations (local stations?: urban-rural couple?)
- Near-real-time data access and analyses
- Assimilation of data in urban areas
- Urban Test Beds that integrate in situ and remote sensing observations with modeling efforts
- High-resolution modelling: 'grey zone', needed resolution?
- Coupling of air quality, meteorological, surface, hydrological processes
- Seamless approach: scale interaction
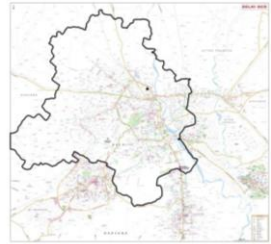- From science to integrated urban services

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SAFAR Modeling Set-up (online) for City Level Forecast

NCMRWF → **Data extraction** → **GFS** Global Forecast System → **Modeling** → **WRF-CHEM** ← **Modeling** — **macc**

National Center for Medium Range Weather Forecast, Delhi

Global Forecast System

WRF-Chem Model

Monitoring Atmosphere Composition & Climate

Meteorological data output

Meteorological forecasting

Domain 1
Horizontal resolution of 45 km

Domain 2
Resolution of 15 km

South Asia

Domain 3
Resolution of 5 km

southern and northern part of India

Domain 4
Resolution of 1.67 km

Pune and its adjacent region

Pune city

Domain Configuration

GLOBAL

45km
↓
15km
↓
5km
↓
1.67km

LOCAL

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SHANGHAI METEOROLOGICAL SERVICES FOR PUBLIC HEALTH

Led by Tang Xu, SMB

Monitoring and Observations

- Meteorological Observations (temperature, wind, humidity, pressure, cloud, etc.)
- Ultra Violet Radiation
- Atmospheric Chemistry Observations (O_3, SO_2, NO_x Aerosols,
- Pollen Measurements (open plate method, microscope filter)
- Integrated Risk Monitoring (bacterial food poisoning, diarrhea diagnostic, trauma, influenza heatstroke)

Observations ⟹ Forecast Models

Climate Services and Products for Health

- Heat wave/cold spell forecasts
- UV Exposure Forecast
- Ozone Forecast
- Haze Forecast
- Pollen Forecast
- Influenza Forecast
- Heat Index, Sunstroke and Diarrhea forecast for EXPO 2010

METROPOLITAN AIR QUALITY AND WEATHER FORECASTING SERVICES

SAFAR project, India   *Beig et al., 2015*

GURME

AIR-Now & AIR-Tomorrow

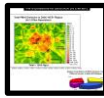**Weather -Now & -Tomorrow**

Health Advisories

City Pollution Maps

UV Index-Skin Advisory

Air Quality Monitoring

Weather Monitoring

Emission inventory Development
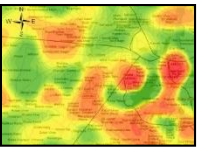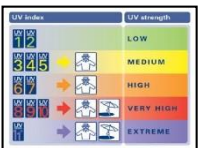
Surface topography & land use study

AIR QUALITY FORECAST MODELING Supercomputer **WEATHER FORECAST**

Translate Science to Public

PRODUCTS   **SERVICES**

Web Portal

E-mail Alerts

SMS Alerts

Digital Display

TV /Radio

BENEFIT TO END -USER

- Protecting Human **Health**
- Agricultural yield Benefits to **Farmers**
- **Awareness** of impact of AQ & Weather
- Basis for **mitigation** strategies

RESEARCH

- Explore **Chemical-Weather**
- Improve Weather & AQ **Forecasting Skill**
- Development of **Emission** scenario
- Short Term **Climate** Change

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High Impact Weather Project

Urban Flood: Reducing mortality, morbidity, damage and disruption from flood inundation by intense rain.

Disruptive Winter Weather: Reducing mortality, morbidity, damage and disruption from snow, ice and fog to transport, power & communications infrastructure.

Wildfire: Reducing mortality, morbidity, damage and disruption from wildfires & their smoke.

Urban Heat Waves & Air Pollution: Reducing mortality, morbidity and disruption from extreme heat & pollution in the megacities of the developing and newly developed world.

Extreme Local Wind: Reducing mortality, morbidity, damage and disruption from wind & wind blown debris in tropical & extra-tropical cyclones, downslope windstorms & convective storms, including tornadoes.

HIW project C0-chair B. Golding, UK MetOffice

Weather · Climate · Water

End-to-end (E2E) Flood Forecasting and Early Warning Initiative
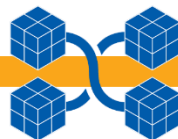
| REAL-TIME DATA COLLECTION	MODELLING & FORECASTING	EARLY WARNING DISSEMINATION	DECISION SUPPORT	RESPONSE TO WARNING
Global Hydrometry Service Facility (GHSF) Meteorological, Climatological and Hydrological (MCH) Database Management System	Flash Flood Guidance System (FFGS) Coastal Inundation Forecasting Demonstration Project (CIFDP) Severe Weather Forecasting Demonstration Project (SWFDP)		Associated Programme on Flood Management (APFM) DEWETRA Platform Preparing for Extreme And Rare events in coastaL regions (PEARL)	

In support of the functions of National Hydrological Services

APFM

Structure of WUDAPT project and current portal tools:
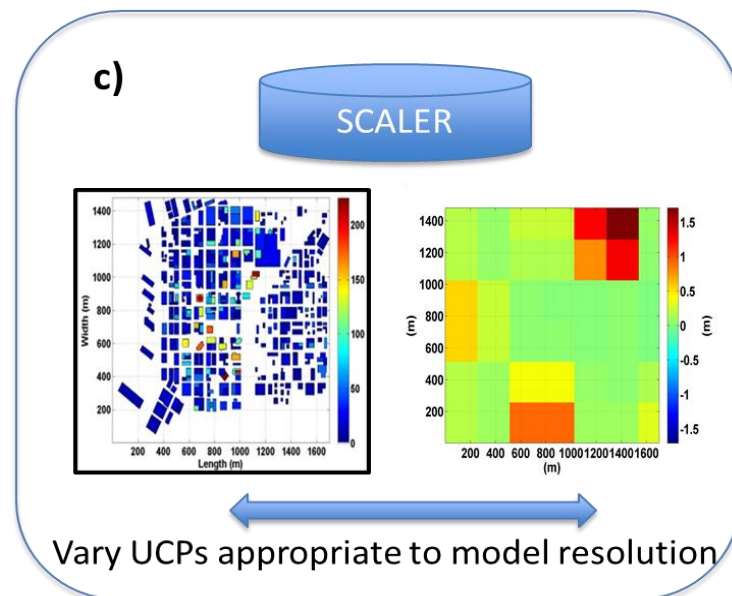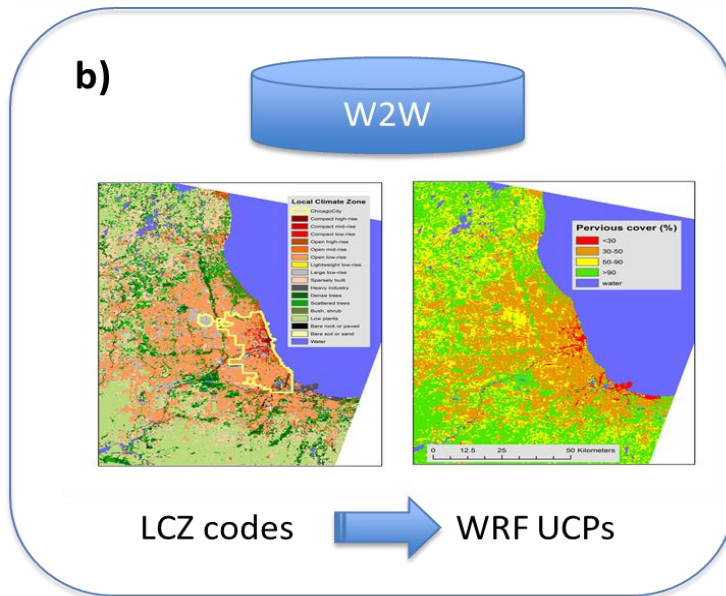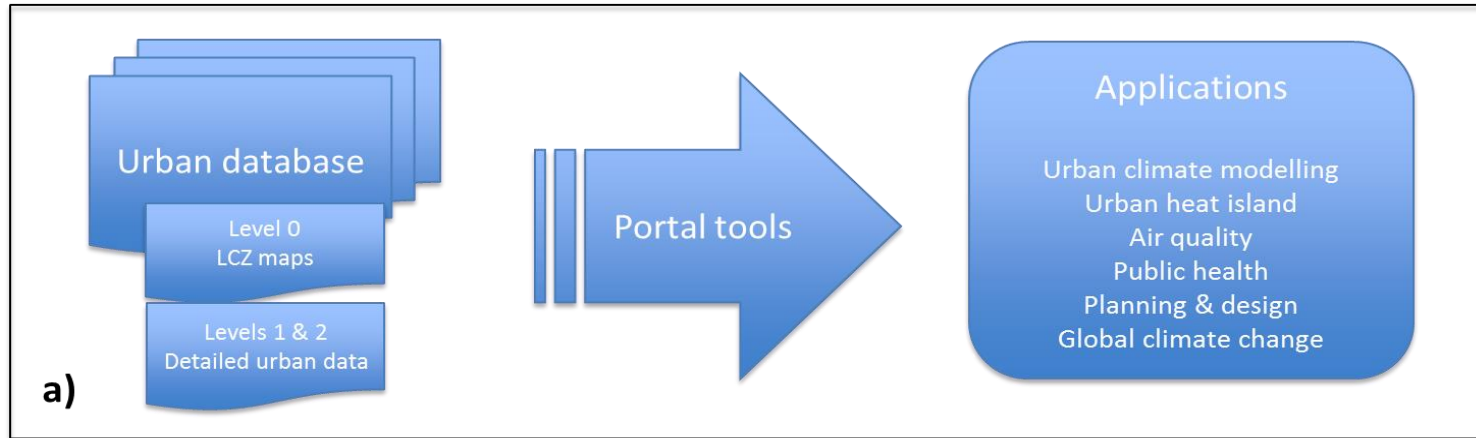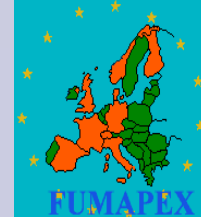

b) W2W which is designed to integrate LCZ data with WRF model
c) SCALER which permits the extraction of data appropriate to model resolution

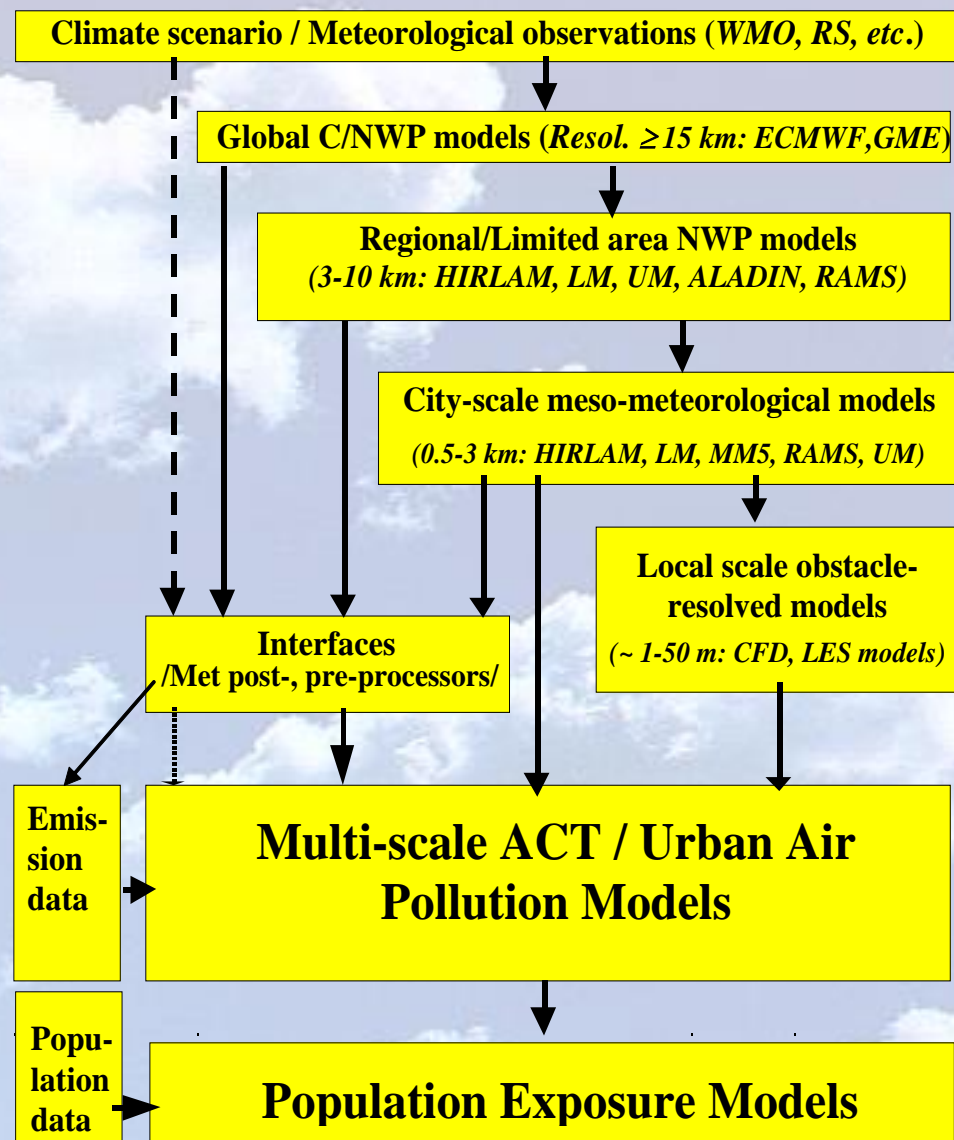WMO OMM

5FP EC project FUMAPEX:

Multi-scale UAQIFS

Integrated Systems for Forecasting Urban Meteorology, Air Pollution & Population Exposure

22 teams from 10 European countries
(Baklanov et al., ACP, 2006)

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.

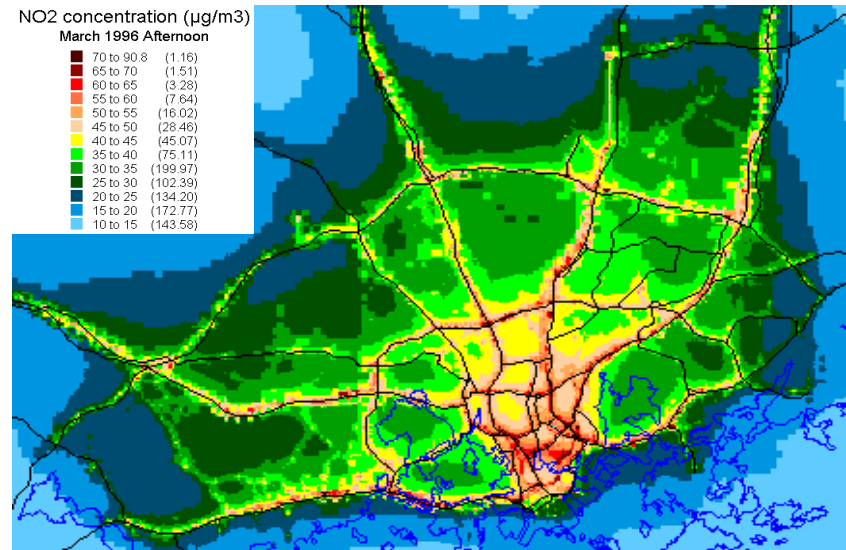Climate scenario / Meteorological observations (*WMO, RS, etc.*)

Global C/NWP models (*Resol. ≥15 km: ECMWF,GME*)

Regional/Limited area NWP models
(3-10 km: HIRLAM, LM, UM, ALADIN, RAMS)

City-scale meso-meteorological models
(0.5-3 km: HIRLAM, LM, MM5, RAMS, UM)

Local scale obstacle-resolved models
(~ 1-50 m: CFD, LES models)

Interfaces
/Met post-, pre-processors/

Emission data

Population data

Multi-scale ACT / Urban Air Pollution Models

Population Exposure Models

FUMAPEX
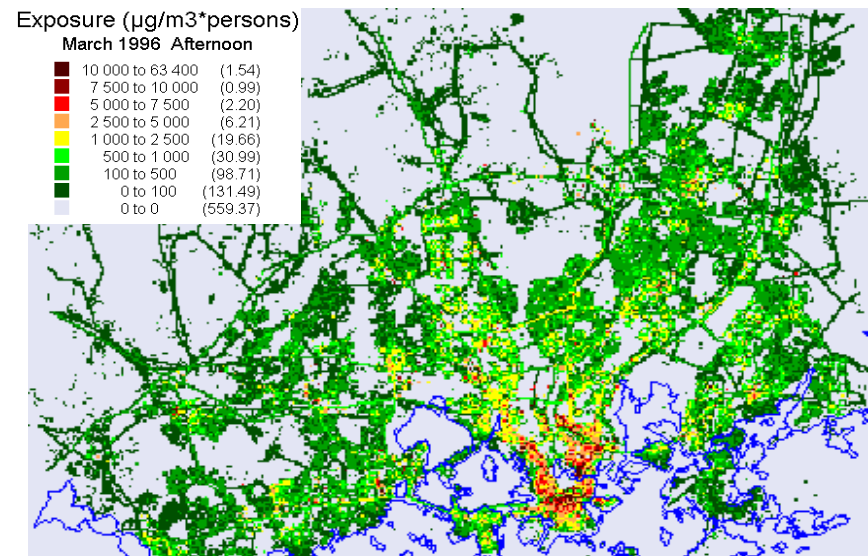
FUMAPEX cities for UAQIFS implementation

#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.

The predicted concentration of NO_2 in the greater Helsinki area ($\mu g/m^3$)

The predicted exposure of population to NO_2 ($\mu g/m^3$ *persons).

Kansanterveyslaitos
Folkhälsoinstitutet
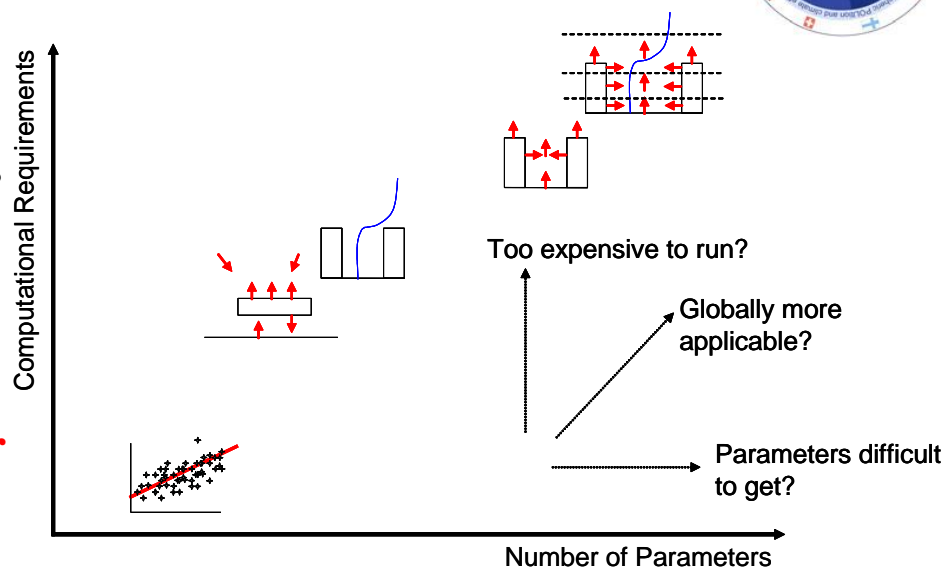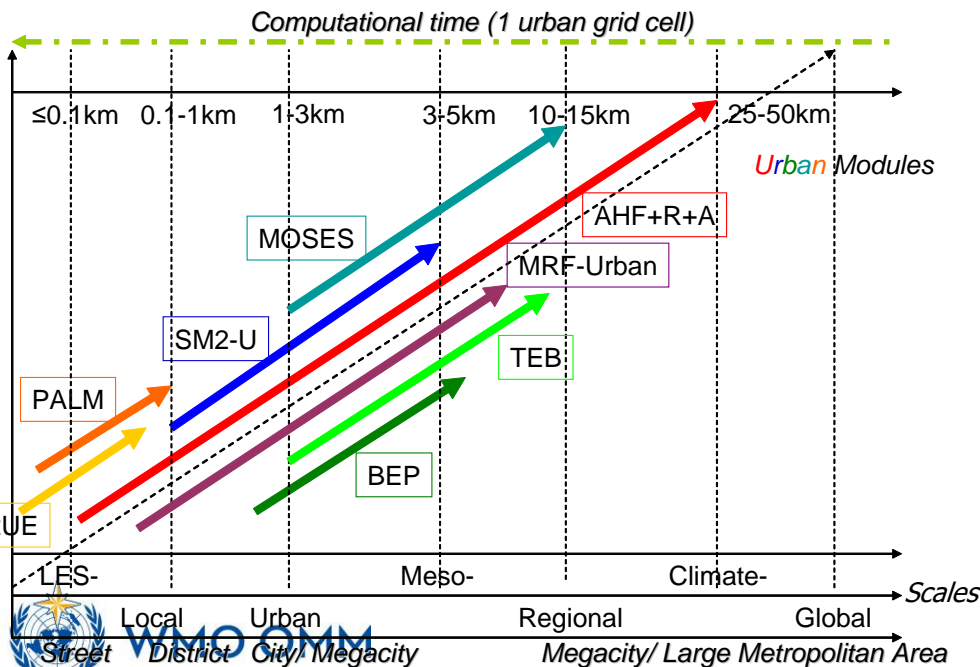National Public Health Institute

YTV

# Strategy to urbanize different models

Main types of UC schemes:

- Single-layer and slab/bulk-type UC schemes,
- Multilayer UC schemes,
- Obstacle-resolved microscale models

MP hierarchy of urban canopy schemes for different type and scale models:


- Simple modification of land surface schemes (AHF+R+A)
- Medium-Range Forecast Urban Scheme (MRF-Urban)
- Building Effect Parameterization (BEP)
- Town Energy Budget (TEB) scheme
- Soil Model for Sub-Meso scales Urbanised version (SM2-U)
- UM Surface Exchange Scheme (MOSES)
- Urbanized Large-Eddy Simulation Model (PALM)
- CFD type Micro-scale model for urban environment (M2UE)
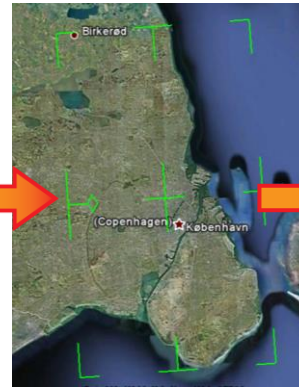
MEGAPOLI, 2011

Suggested core-downstream processing chain for Copenhagen:
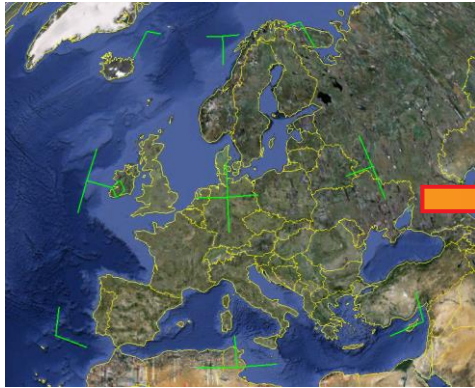
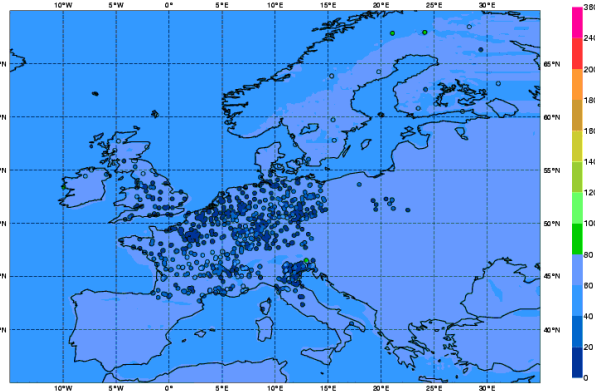GEMS/MACC regional domain (resolution - 20km)
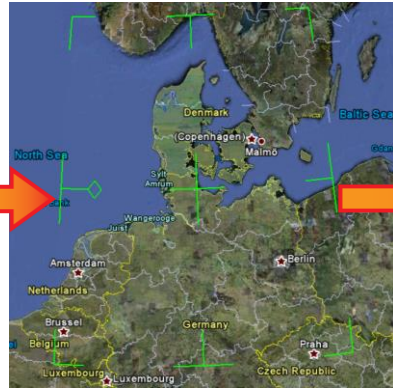
Denmark-scale domain (3km)

City-scale domain (1km)

Street-scale selected domain (Jagtvej) (5m)

Example of regional-scale O_3 forecast by CAC system (GEMS)
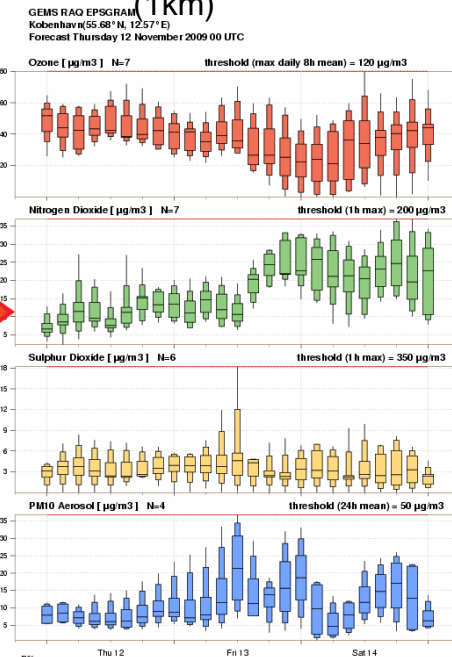
GEMS ensemble forecast for Copenhagen

Example of concentration and velocity fields for street-scale downscaling with CFD-type model M2UE (Jagtvej in Copenhagen)

DMI MACC report by Nuterman et al., 2011

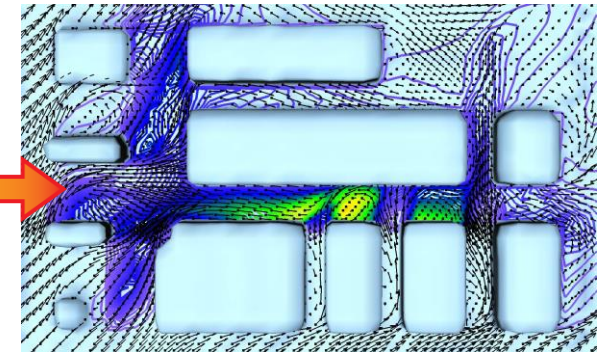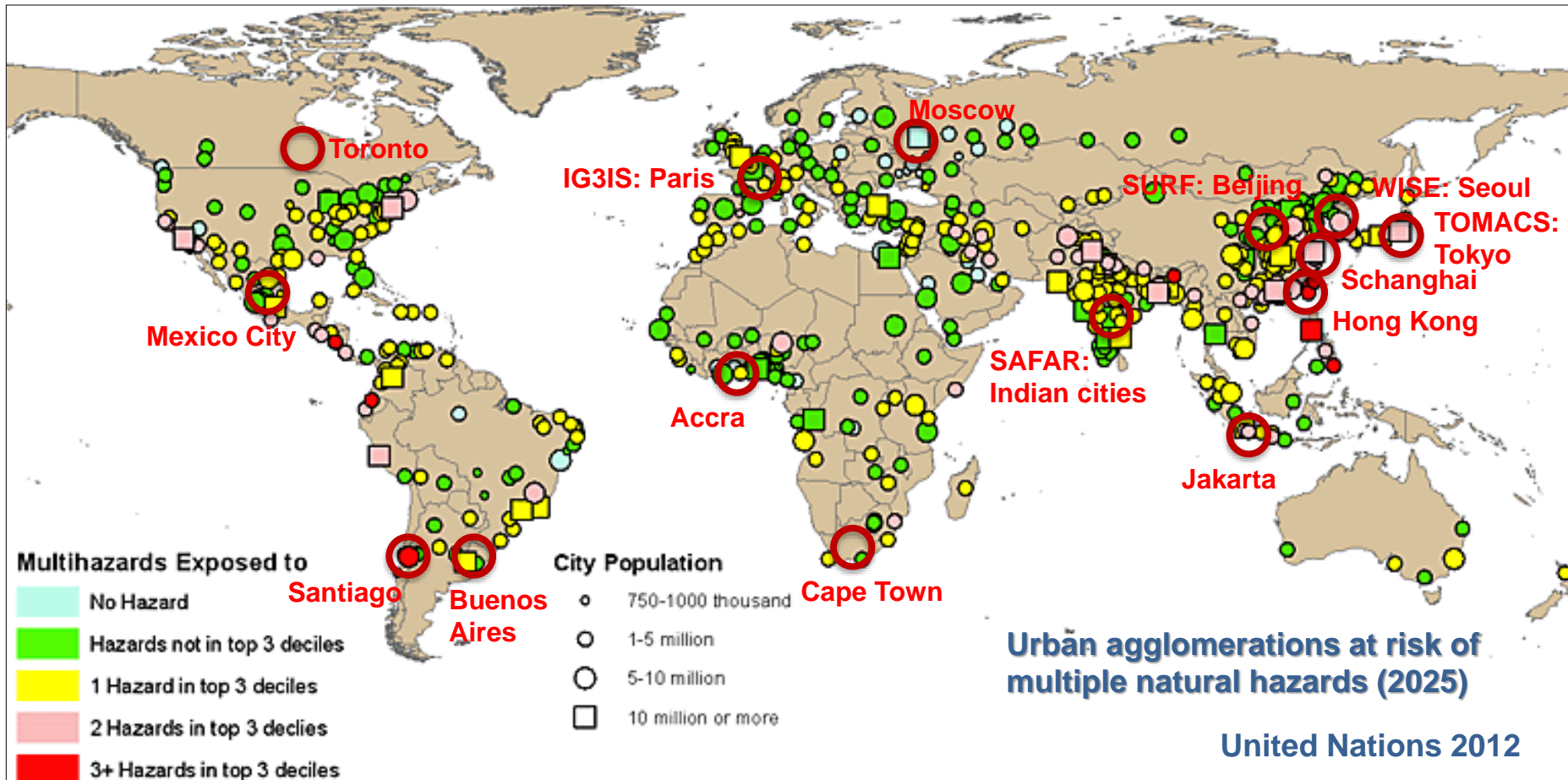# WMO pilot projects and demonstration cities

Moscow

Toronto

IG3IS: Paris

SURF: Beijing

WISE: Seoul

TOMACS: Tokyo

Schanghai

Mexico City

Hong Kong

SAFAR: Indian cities

Accra

Jakarta

Santiago

Buenos Aires

Cape Town

Multihazards Exposed to
- No Hazard
- Hazards not in top 3 deciles
- 1 Hazard in top 3 deciles
- 2 Hazards in top 3 declies
- 3+ Hazards in top 3 deciles

City Population
- 750-1000 thousand
- 1-5 million
- 5-10 million
- 10 million or more

Urban agglomerations at risk of multiple natural hazards (2025)

United Nations 2012

Priorities in development of Gidelines and demonstration for cities:
- Integrated Urban Weather, Water, Environment and Climate Services
- Multi-Hazard Early Warning Systems
- Focus on impact based forecast and risk based warnings

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Guidelines for UAQIFS/UMHEWS

- Urban morphology and input data (WUDAPT?)
- Emission inventories and parameterisations
- Observation system
- Integration with urban NWP
- Downscaling from global to urban (B.C.)
- Data assimilation
- Impact based forecast
- User oriented tools and services

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Specific recommendations:

(1) development of high-resolution coupled environmental prediction models that include realistic city specific processes, boundary conditions, and fluxes of energy and physical properties;

(2) enhanced urban observational systems to determine unknown processes and to force these models to provide high quality forecasts to be used in new urban climate services;

(3) understanding of the critical limit values for meteorological and atmospheric composition variables with respect to human health and environmental protection;

(4) new, targeted and customized delivery platforms using an array of modern communication techniques, developed in close consultation with users to ensure that services, advice and warnings result in appropriate action and in turn inform how best to improve the services;

(5) the development of new skill and capacity to make best use of technologies to produce and deliver new services in complex, challenging and evolving city environments.
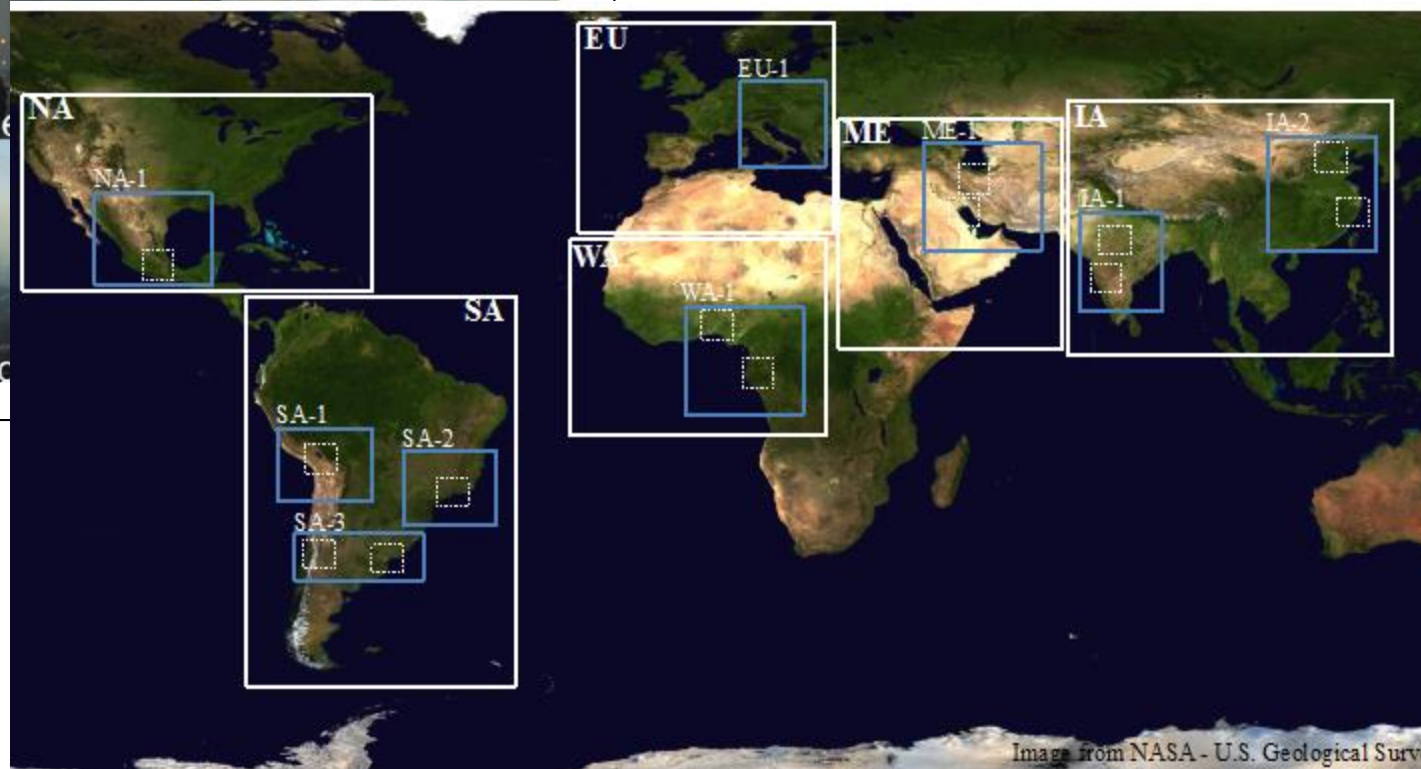
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Agreed to consider MAP-AQ as a key project of WMO GAW SAG-APP

- Malaysia GURME training workshop provides a good example and a step forward to such recommendations to build UAQIFSs and UMHEWSs

Theme 2: Advancing GURME objectives through pilots and demonstrations

- General updates for pilot/demonstrations activities
  - A. Baklanov – 25 min: WMO priorities, HABITAT-III, WB PMEH, CCAC, WHO, World Bank, MacArtur, GCF initiatives,

WMO OMM

Possible contribution to World Bank PMEH Program:
Pollution Management and Environment Health

Possible enhancing the PMEH AQ monitoring program by utilizing equipment that support a forecasting capability.

GURME is asked to prepare a Briefing Note to cover:

1)   What are the elements of such a system and how does it fit into what is currently designed as a monitoring approach as part of the PMEH AQM framework

2)   The modeling required to utilize this capability

3)   The underlying rationale for a forecasting capability particularly as it relates to informing the public and decisions makers.

4)   The necessary equipment that would be required, cost comparisons versus the equipment currently envisioned for the PMEH program.

5)   The likely benefits associated with the reduction in O&M costs over time and any associated QA benefits to the overall process.

Responsible GURME SAG members: Gufran Beig and Luisa Molina

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WMO Priority: Urbanization - Research and services for megacities and large urban complexes

Goal: **Integrated Urban Weather, Water, Environment and Climate Services to address Urban Hazards and Risks.**

- **Focus** on impact-based forecast and risk-based warnings

- **Addressing** key <u>Scientific issues:</u> Requirements for observations; Near-real-time data assimilation; Coupling of air quality, meteorological, surface, hydrological processes; Seamless approach: scale interaction; High-resolution modelling: 'grey zone'

- **Through research** to service actions across WMO (GAW, WWRP, WCRP) and beyond

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Coast, Cities, and Climate

- Example: current & future climate risk in New York [IPCC AR5 WGII, Table. 8-6]

Table 8-6 | Current and indicative future climate risks for Dar es Salaam, Durban, London, and New York City

GC-Extremes
Heavy Precipitation / Draught
Heatwave / Storm

(Regional) Climate Information

Initiative for Comprehensive Planet Data

GC-Snow & Ice

GC-Regional Sea Level

GC-Water Availability

FUMAPEX target cities for 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.**

Shanghai Practice

METEO SHANGHAI
上海气象

上海市气候变化监测公报
SHANGHAI CLIMATE CHANGE BULLETIN
2013

Urban climate service :

- **climate change risk assessment**

Shanghai Climate Change Observation & Monitoring Report

- **climate feasibility studies**

Shanghai Disney resort , Pudong international airport , Shanghai stadium

- **climate environmental effect**

Ecosystem network planning

- **adaptation strategy assessment**
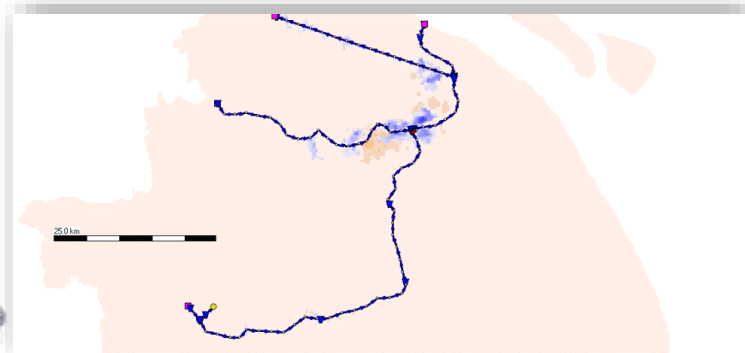
Different scenarios: Barrier built at the mouth of Huangpu River; ~3 km away from the river mouth, with high floodwall in the mouth area, etc.
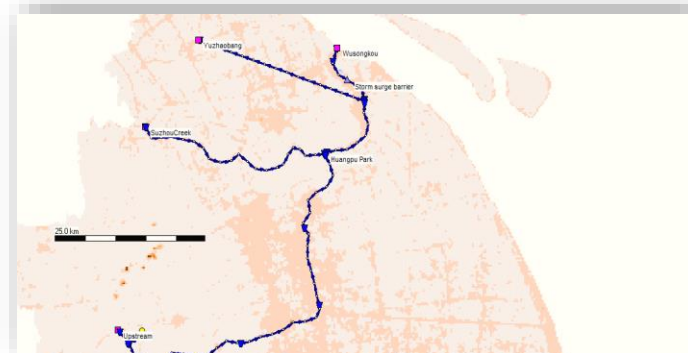

Pudong International Airport

Leader: Dr. Zhenlin Chen, SMS Director-General

Scenario 0: 1000 yr return period flood and river wall breach at the Huangpu River Park

Scenario 2: ~3 km away from the rive mouth, with low floodwall in the mouth area

WMO for Integrated Urban Services

Welcome to WMO Events on HABITAT-III Conference at One UN Pavilion:

- **«Meetings with WMO» on 18 Oct 14:30; 19 Oct 17:00; 20 Oct 12:00, "Talk with the United Nations" Room**
- **Side Event "Climate change and urban disaster resilience" on 20 Oct at 8:30 -11:30, Room B**

  - **Exhibition & Urban Library**
 - **E-Game 'Be an Urban Climate Architect'**

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World Meteorological Organization
Organisation météorologique mondiale

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

CAS-16 priority: Urbanization: Research and services for megacities and large urban complexes

- **Risks in the urban environment**: flooding; poor air quality; sea-level rise; extreme heat/cold and human thermal stress; energy and water sustainability; public health problems caused by the previous.
- GAW Urban Research Meteorology and Environment Project (**GURME**) : **integral part of urban research and services**
- To **enhance the capabilities of NMHSs** in providing the weather and environment service for cities to deal with **weather, climate and environmental problems**
- **Scientific issues**: Requirements for observations; Near-real-time data assimilation; Coupling of air quality, meteorological, surface, hydrological processes; Seamless approach: scale interaction; High-resolution modelling: 'grey zone'.
- **Focus on impact based forecast and risk based warnings**
- **From science to integrated urban services**
- Toward Integrated and user-tailored **Urban Weather, Water, Environment and Climate Services**
- Urban activities shall be a specific **cross-cutting element within WMO** and in collaboration with WHO, UNEP, HABITAT-III, etc.

WMO OMM
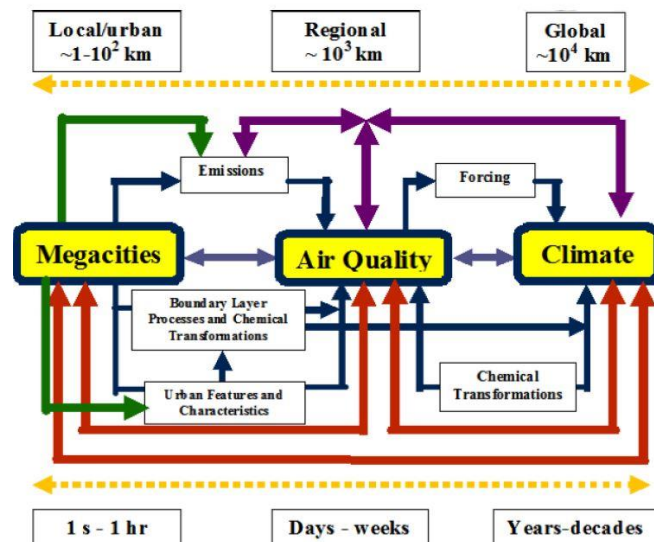
WMO-WHO-UNEP cooperation in AQR

10 work areas identified:

- Acute air pollution episodes: communicating and acting
- Harmonised air quality information (data)
- Estimated/actual economic impacts of air pollution.
- Legislative and regulatory support
- Awareness-raising and Communication e.g. Scale up delivery of the "Breathe life" campaign
- Deployment of sectoral solutions, e.g. transport
- Local government action
- Capacity strengthening activities targeting the environment, health as well as other critical sectors of interventions
- Sand and dust storms
- Biomass burning including peat fires/haze

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Possible role of WMO GAW in PMEH

- GAW observations and requirements: urban vs rural, source apportionment, aerosol chemical composition, calibration, …

- GAW Urban Research Meteorology & Environment (GURME) Program and Modelling Application SAG

- Dust storms and wild fires pollution: SDS-WAS System is available online

- MEGAPOLI and CEEH experience: optimization => min health impact

- Integrated urban servises: cooperation of different agencies

- GURME Pilot studies and demonstrations: realisation of UAQIF/MHEW system for JJJ, other Indian cities, Accra, Lagos, etc.

- Capacity building: join training workshops etc.

- Joint training workshop for urban AQ for African cities, e.g. Lagos, Accra, S.Africa, Cairo

WMO OMM

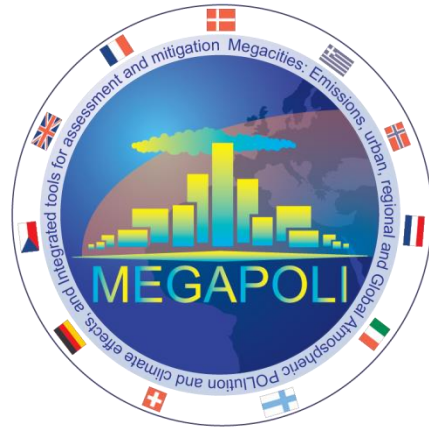# The complexity of the urban setting
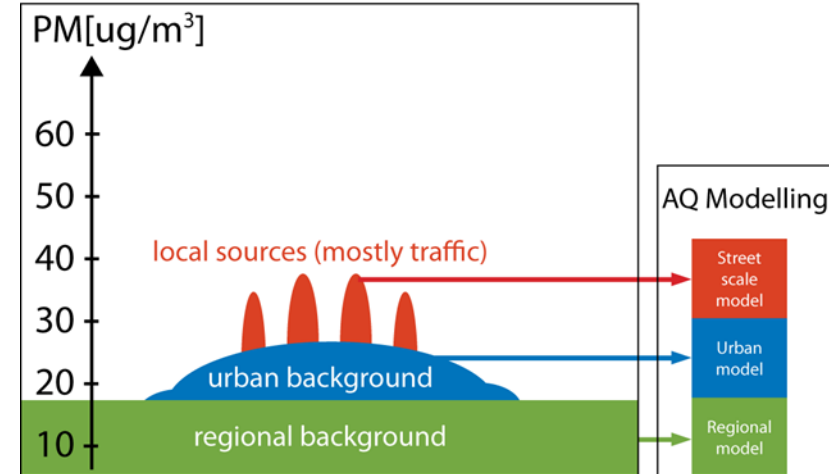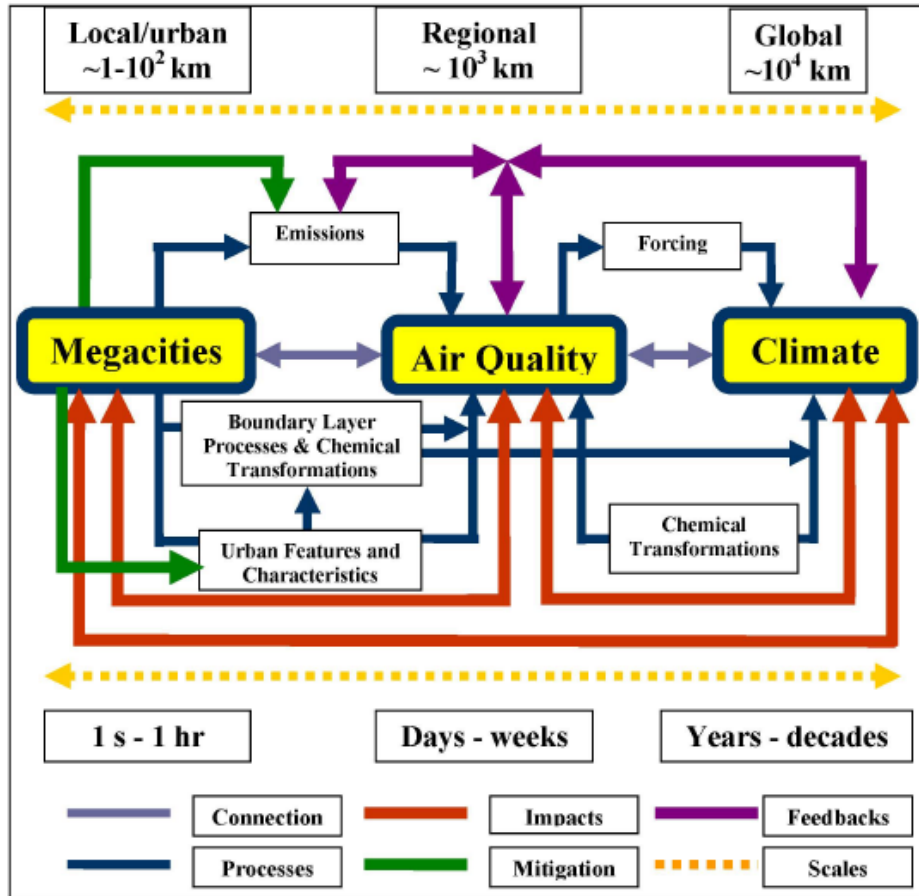
Main Linkages between Megacities, Air Quality and Climate

A. Baklanov et al.: Concept of multi-scale modelling of megacity impact on air quality and climate

What type of modelling tools should be used for the simulation of multi-scale megacity air quality - climate interactions?

WMO OMM

SAFAR: Modeling Set-up (online) for City Level AQ Forecast
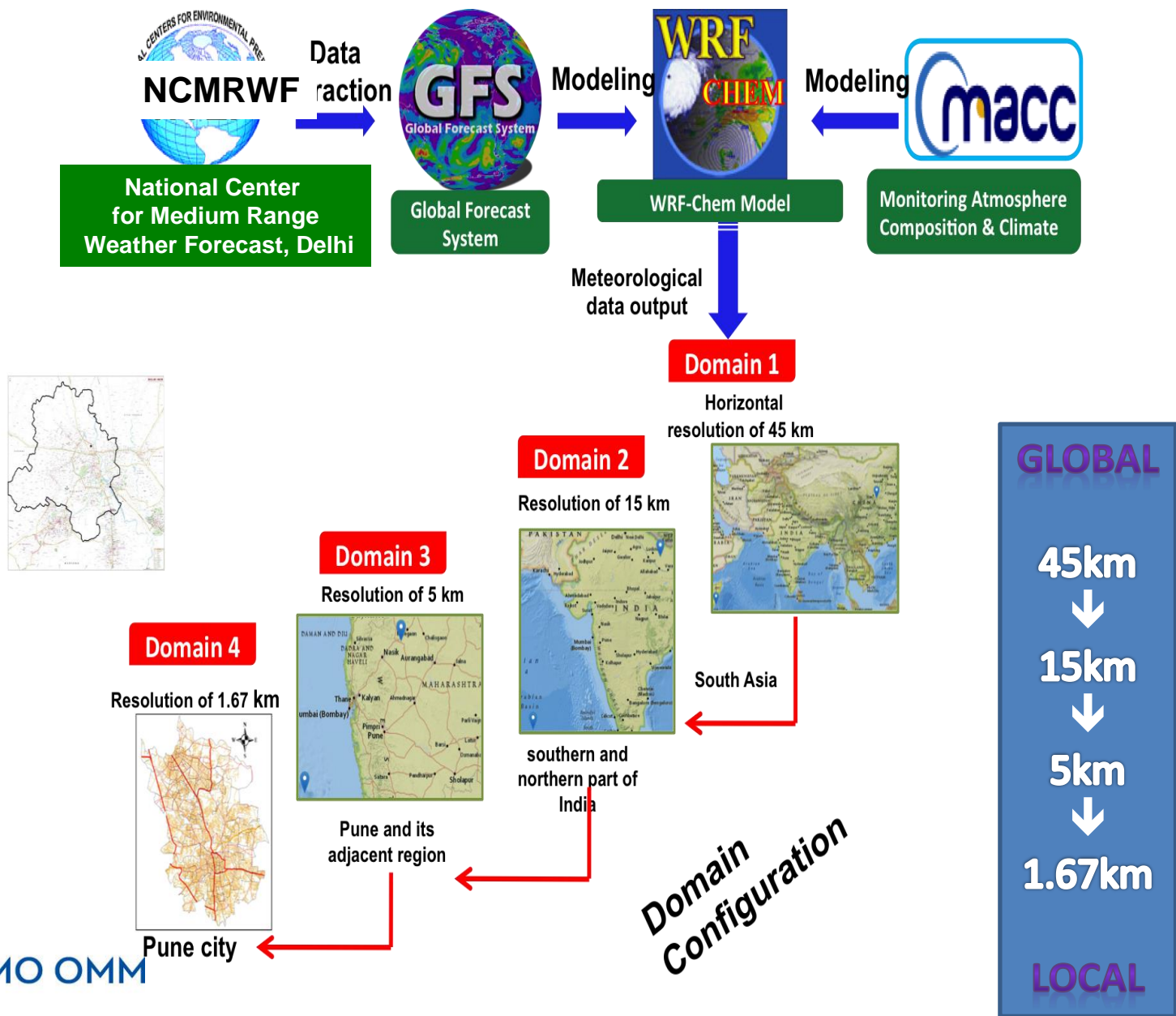
Methodology and Research Tools
Multi-scale modelling Chain / Framework: from Street to Global

- Land-use characteristics and scenarios
- Anthropogenic heat fluxes
- Emission inventories and scenarios
- Atmospheric processes model down- and up-scaling

ACT, Meteorology, Climate Models
Global: ACT: MPIC, MACC; GCM: UKMO;
Regional: ACTM *Ensemble*, RCM: RegCM, ..
Megacity: Enviro-HIRLAM, MEMO, METRAS, PMCAMx, …;
Street: LES, M2UE, MIMO, MITRAS, …

Temporal and spatial scales and ways of integration:
- Level 1 – Spatial: One way (Global -> regional -> urban -> street);
- Level 2 – Spatial: Two way (Global <=> regional <=> urban);
- Level 3 – Time integration: Time-scale and direction; Direct and Inverse modelling.
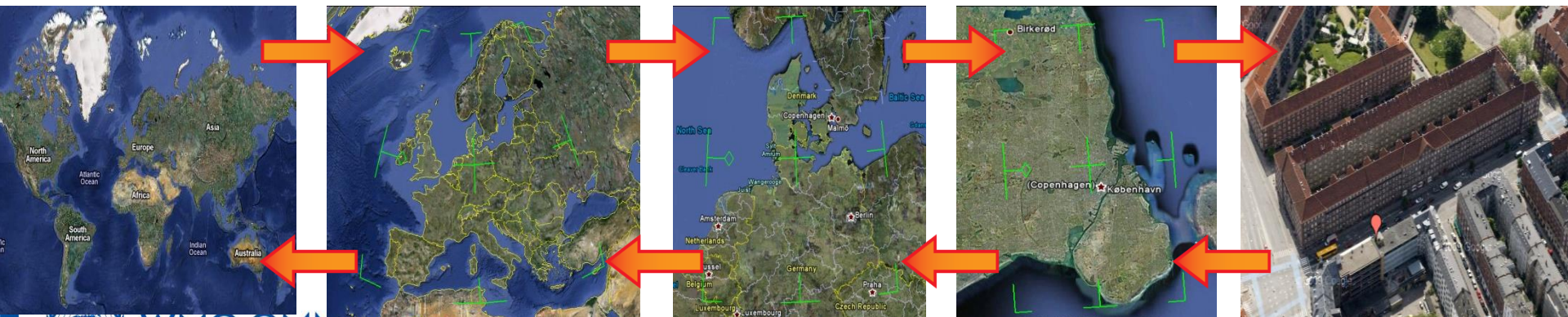
WMO OMM
Two-way Nesting, Zooming, Nudging, Parameterizations, Urban increment methodology (AUTH)

Schematic diagram of the offline and online coupled ACT & NWP/CC modelling approaches

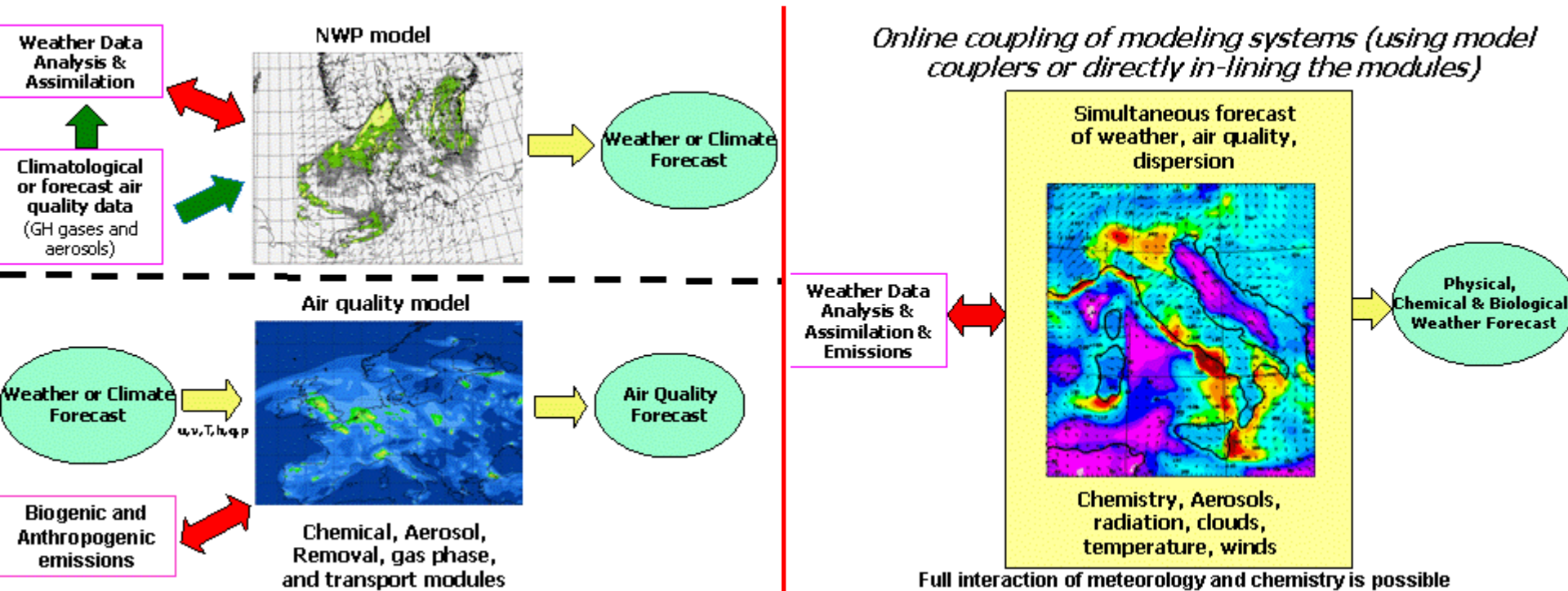*Online coupling can be archived through the use of various available coupling tools or through directly inlining the chemical and aerosol modules into the NWP models.*

Order of integration and complexity:
• Order A – off-line coupling, meteorology / emissions -> chemistry; Models: All.
• Order B – partly online coupling, meteorology -> chemistry & emission; Models: UKCA, M-SYS, UM/WRFChem, SILAM.
• Order C – fully online integrated with two-way feedbacks, meteorology <=> chemistry & emissions; Models: UKCA, WRF-Chem, Enviro-HIRLAM, EMAC (former ECHAM5/MESSy).

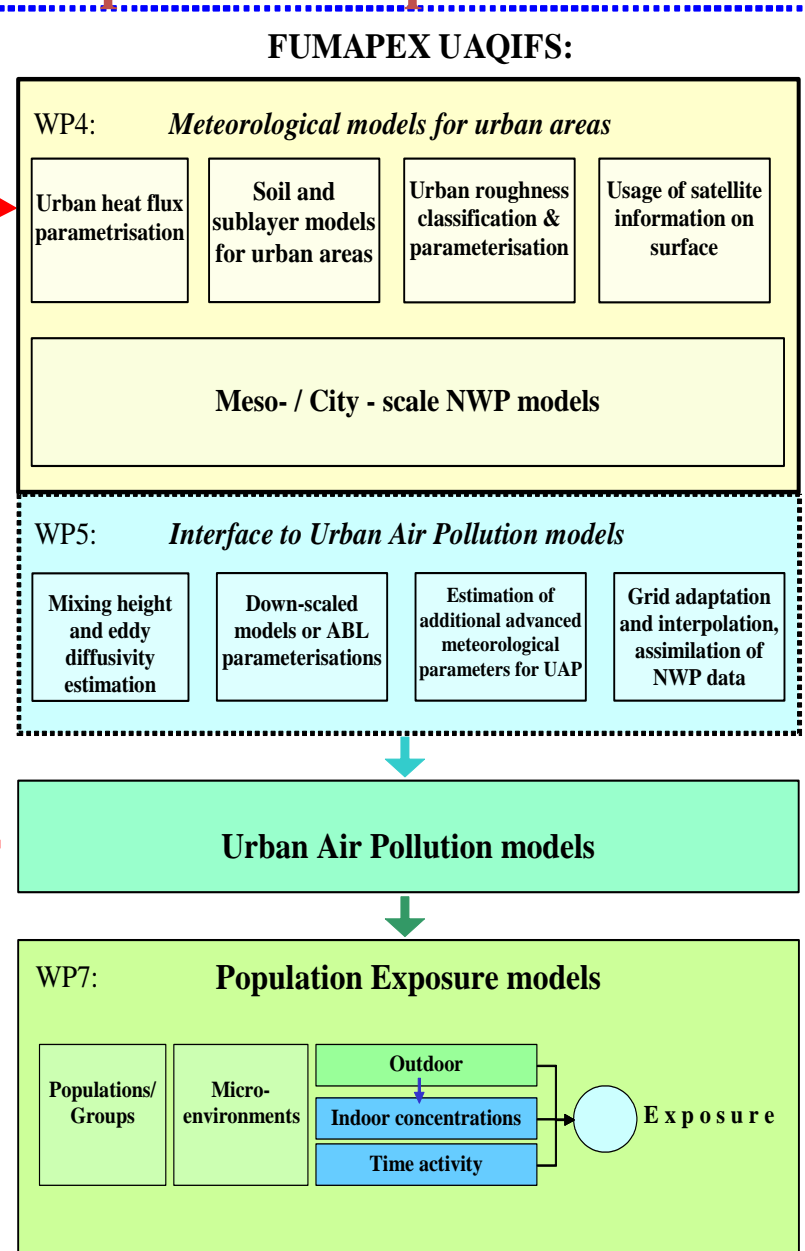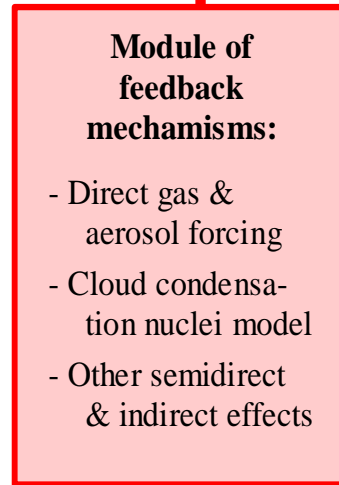# FUMAPEX: Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure

http://fumapex.dmi.dk

Goal: Improvements of meteorological forecasts (NWP) in urban areas, interfaces and integration with UAP and population exposure models following the off-line or on-line integration

Implemented in 6 European cities for operational forecasting:

#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,
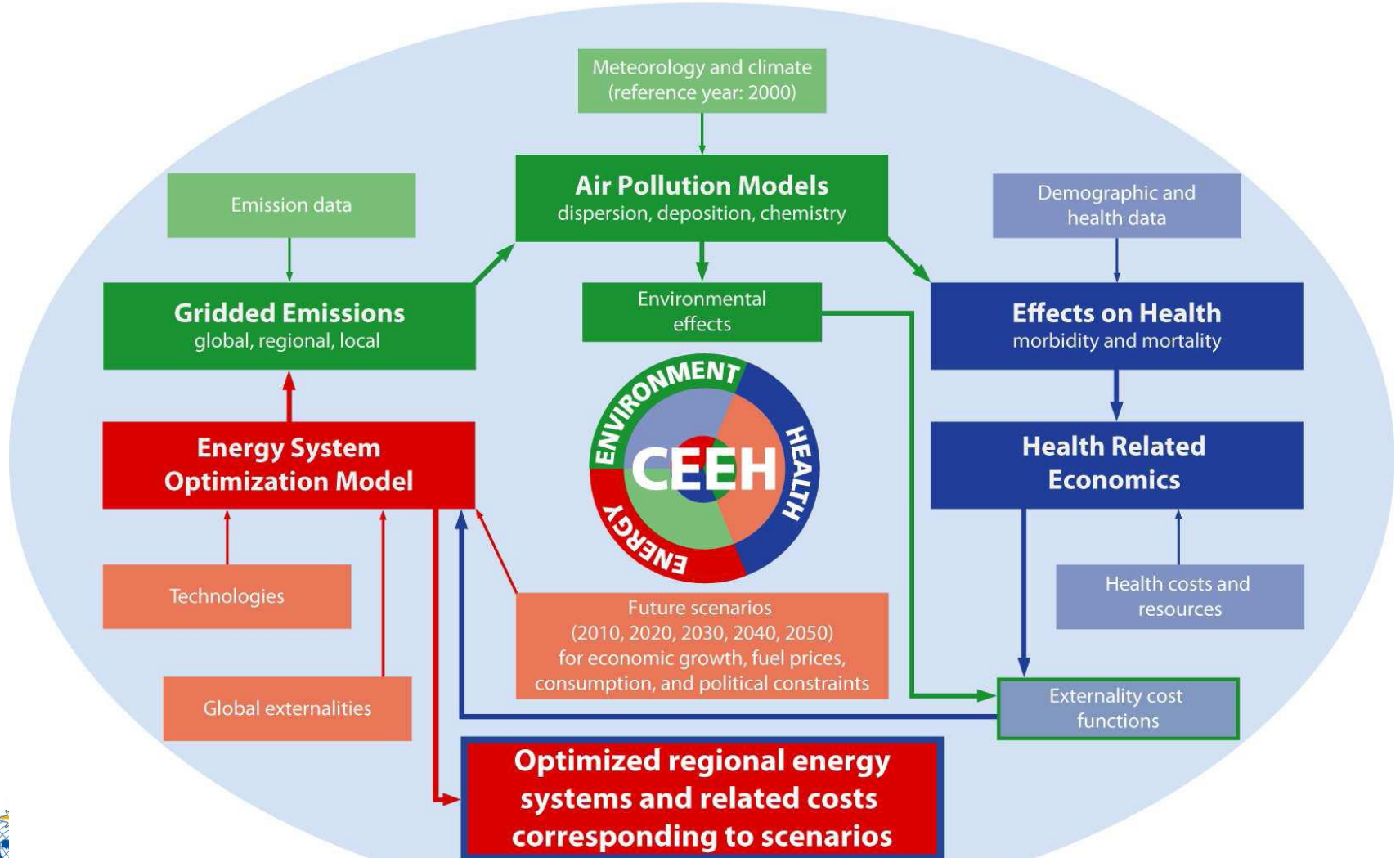(iv) urban emergency preparedness system.

Module of feedback mechamisms:

- Direct gas & aerosol forcing
- Cloud condensation nuclei model
- Other semidirect & indirect effects

FUMAPEX UAQIFS:

WP4: *Meteorological models for urban areas*

Urban heat flux parametrisation	Soil and sublayer models for urban areas	Urban roughness classification & parameterisation	Usage of satellite information on surface

Meso- / City - scale NWP models

WP5: *Interface to Urban Air Pollution models*

Mixing height and eddy diffusivity estimation	Down-scaled models or ABL parameterisations	Estimation of additional advanced meteorological parameters for UAP	Grid adaptation and interpolation, assimilation of NWP data

Urban Air Pollution models

WP7: **Population Exposure models**

Populations/ Groups	Micro-environments	Outdoor
		Indoor concentrations
		Time activity

Exposure

Baklanov & Kaas, 2011, CEEH sci rep #1: ceeh.dk
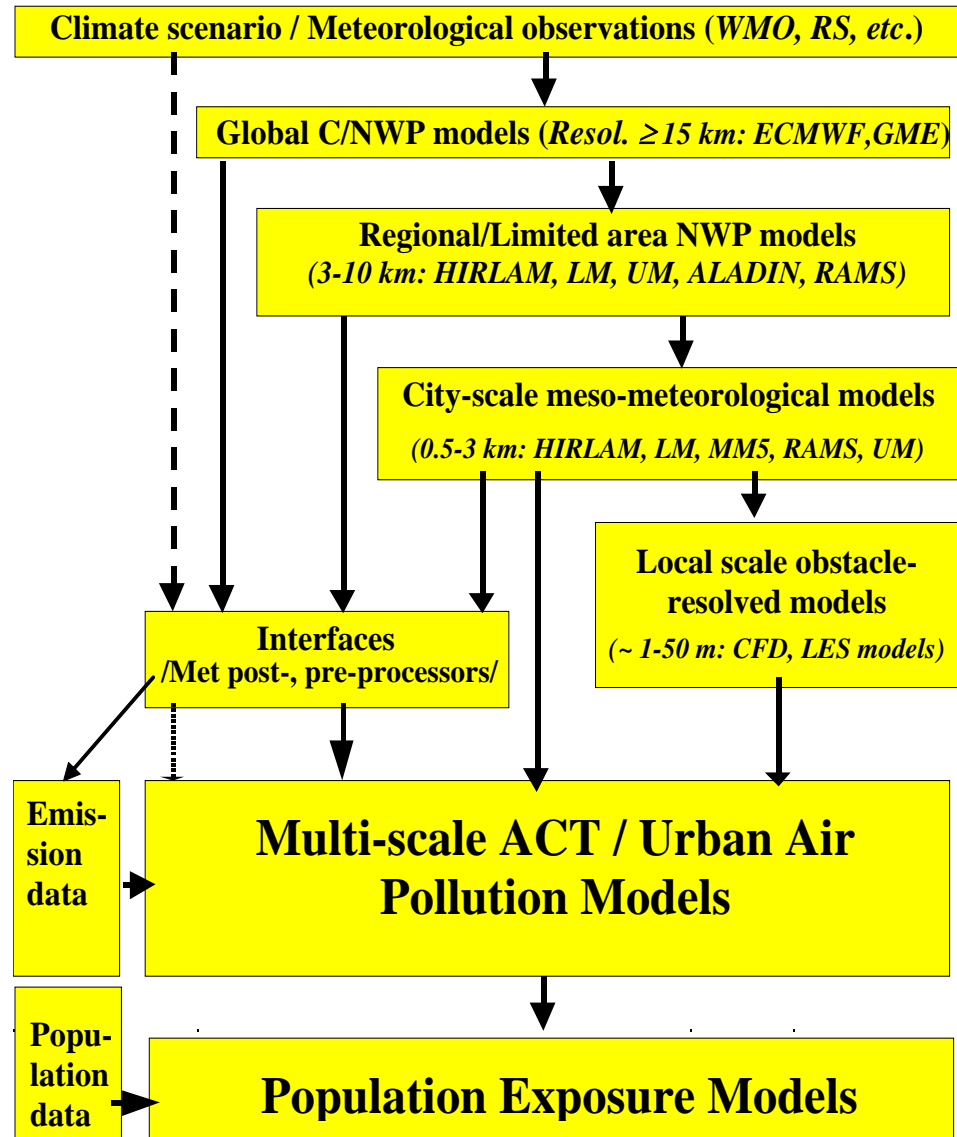
5FP EC project FUMAPEX:

Multi-scale UAQIFS

FUMAPEX

Integrated Systems for Forecasting Urban Meteorology, Air Pollution & Population Exposure

22 teams from 10 European countries
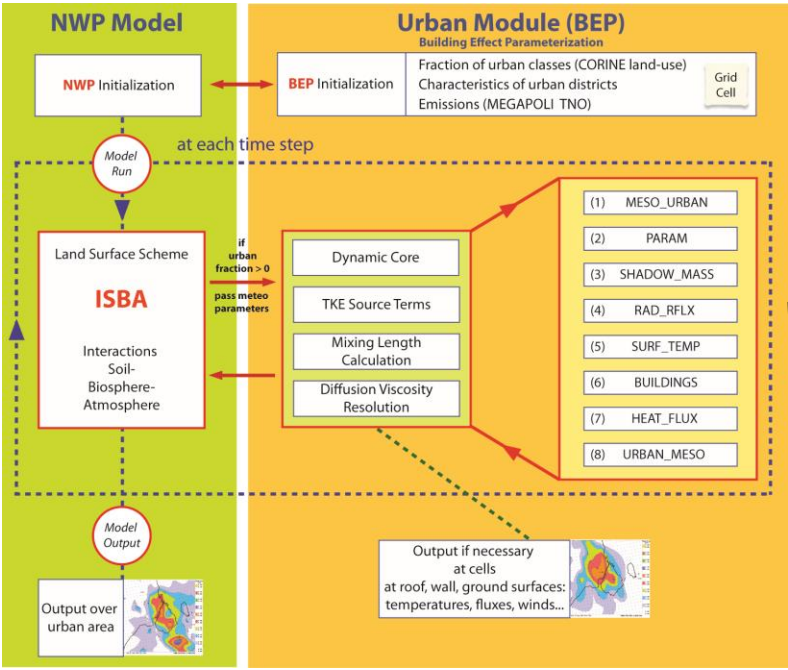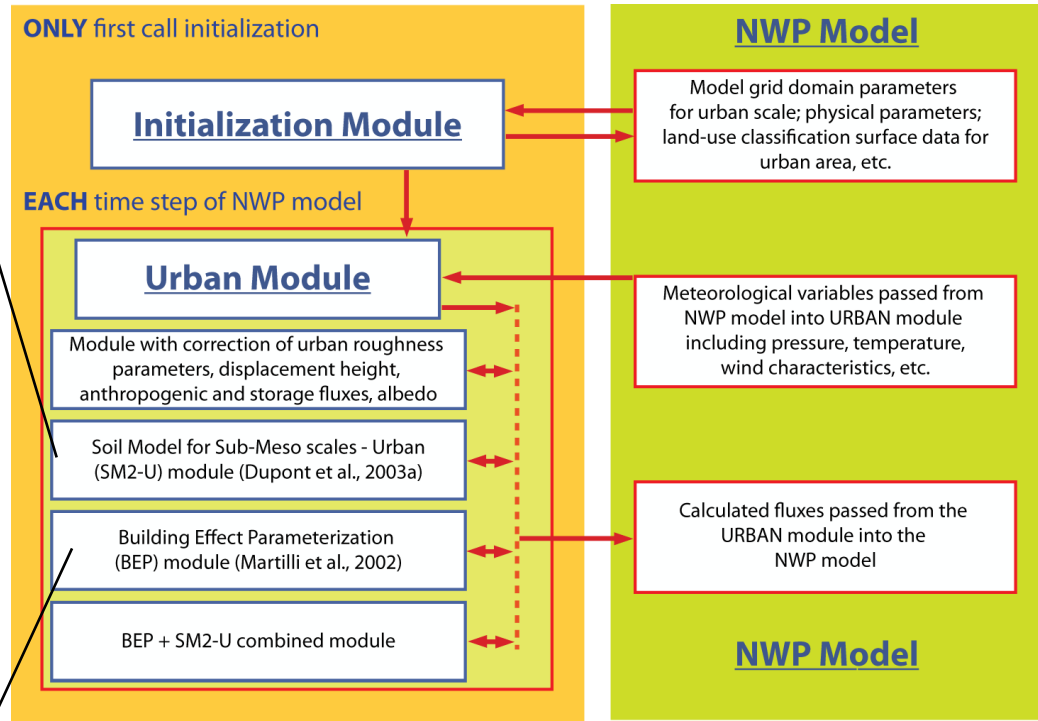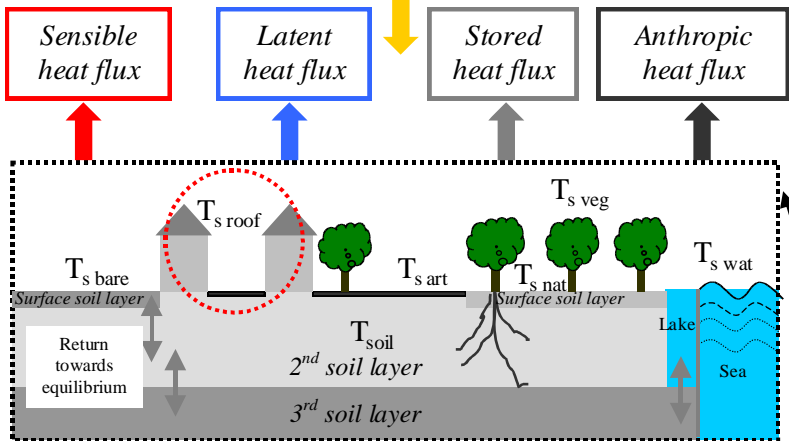
Project objectives:
(i) the improvement of meteorological forecasts for urban areas,
(ii) the connection of NWP models to urban air quality (UAQ) and population exposure (PE) models,
(iii) the building of improved *Urban Air Quality Information and Forecasting Systems* (UAQIFS), and
(iv) their application in cities in various European climates.

Climate scenario / Meteorological observations (*WMO, RS, etc.*)

Global C/NWP models (*Resol. ≥15 km: ECMWF,GME*)

Regional/Limited area NWP models
(3-10 km: HIRLAM, LM, UM, ALADIN, RAMS)

City-scale meso-meteorological models
(0.5-3 km: HIRLAM, LM, MM5, RAMS, UM)

Local scale obstacle-resolved models
(~ 1-50 m: CFD, LES models)

Interfaces
/Met post-, pre-processors/

Emis-sion data

Popu-lation data

Multi-scale ACT / Urban Air Pollution Models

Population Exposure Models

Enviro-HIRLAM Urbanization

MACC operational downscaling chain for Bucharest

Alaro / AROME
10 km. domain D2: country)

Alaro / AROME
2 km. domain D3 – Bucharest area, **TEB surface exchange**)

+

Regional scale (domain D1)

MACC R-ENS

MOCAGE
(domain D2: country)

Urban scale emission

+

MOCAGE
(domain D3: urban Bucharest area)
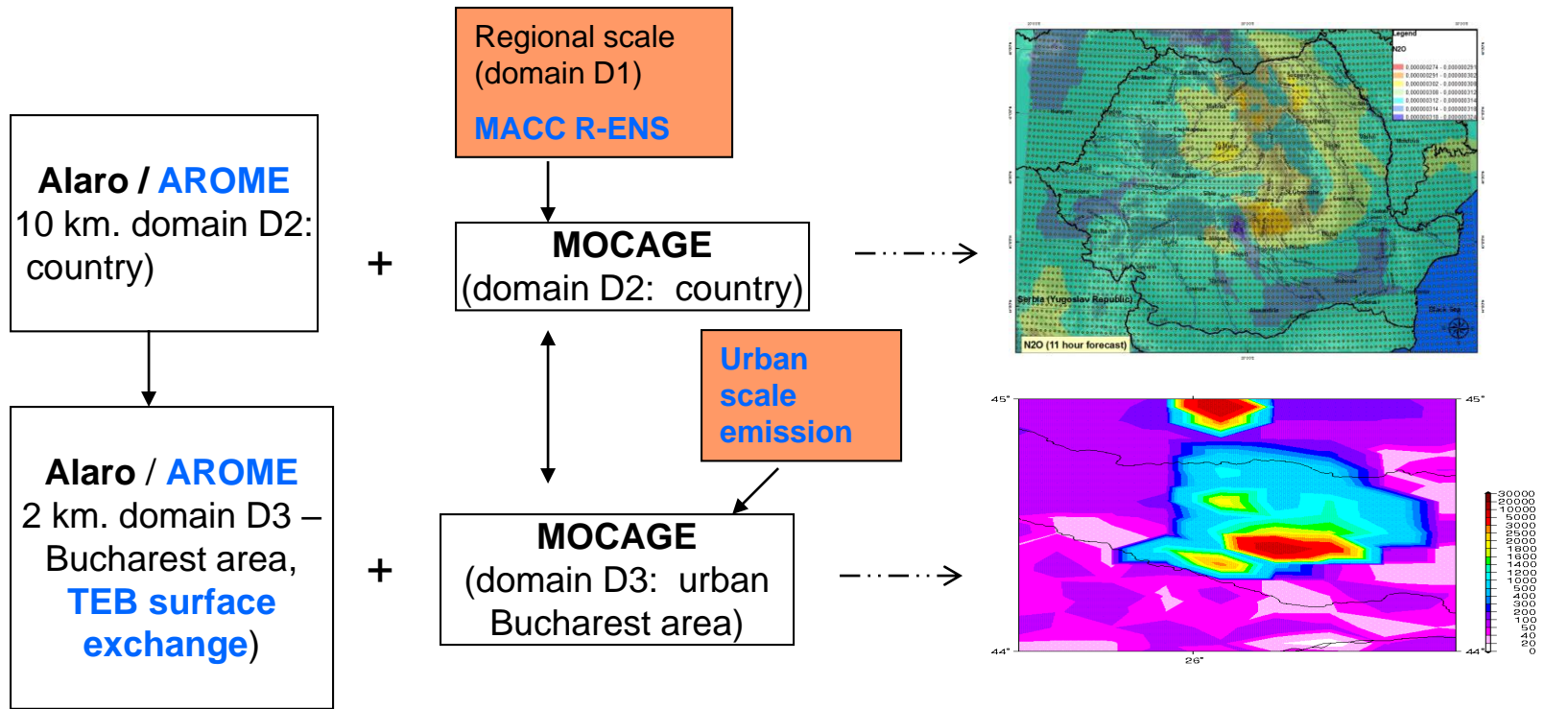
Validation, process analysis for 8 stations and 1 observation site

User requirements processing

National Meteorological Administration, Romania (*Mihaela Caian*)
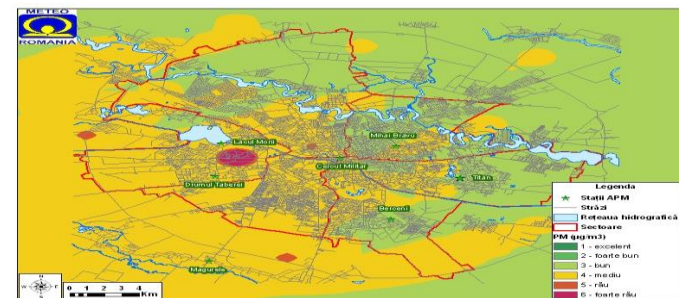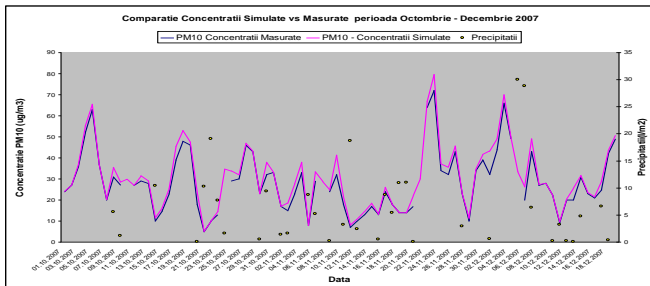
FUMAPEX: Exposure Modelling

Climate scenario → Meteorological Models

Emissions → ACT / Urban Dispersion Models

Population Exposure Models

- Populations / Groups
- Micro-environments
- Outdoor concentrations → Indoor concentrations → Time activity → Exposure

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National Public Health Institute