

Urban Meteorology and GURME Overview

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Geneva, Switzerland*

**WMO WWRP 4th International Symposium on Nowcasting and
Very-short-range Forecast 2016 (WSN16)
25-29 July 2016, Hong Kong**



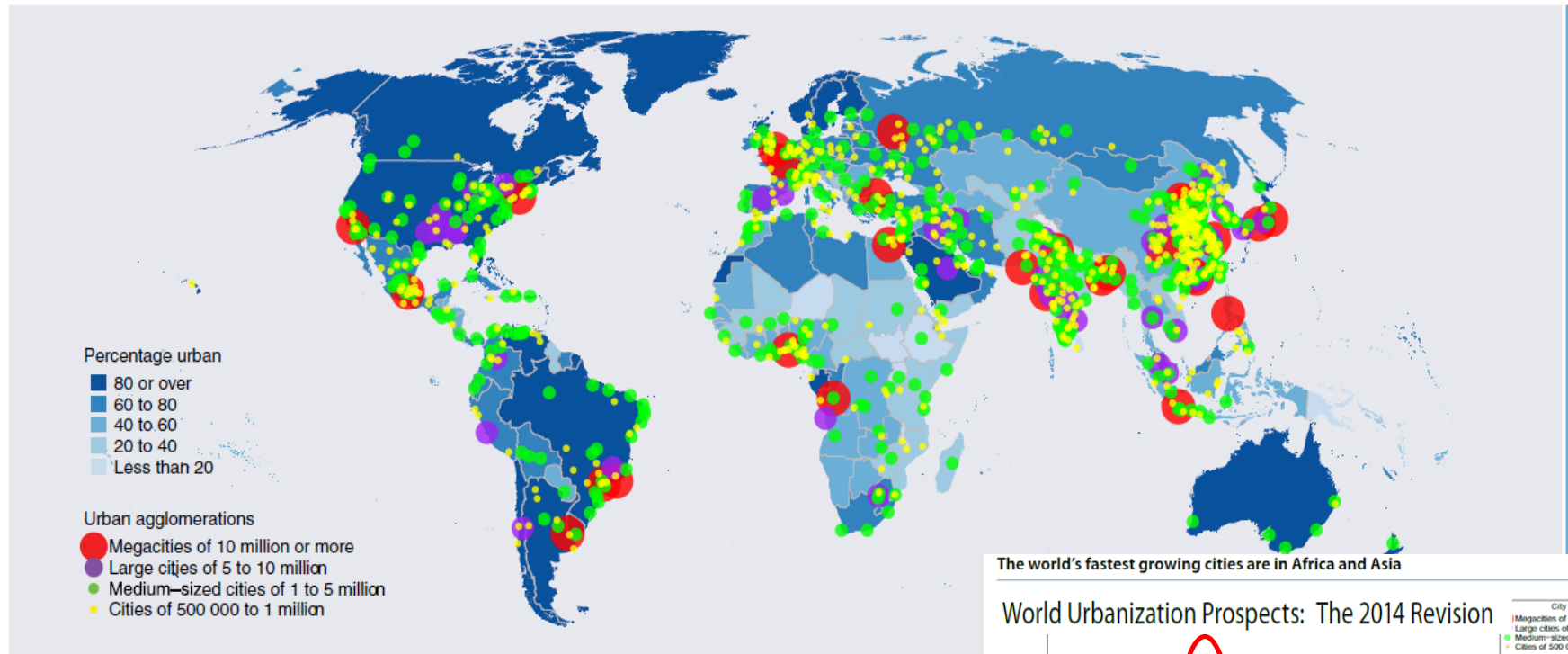
WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

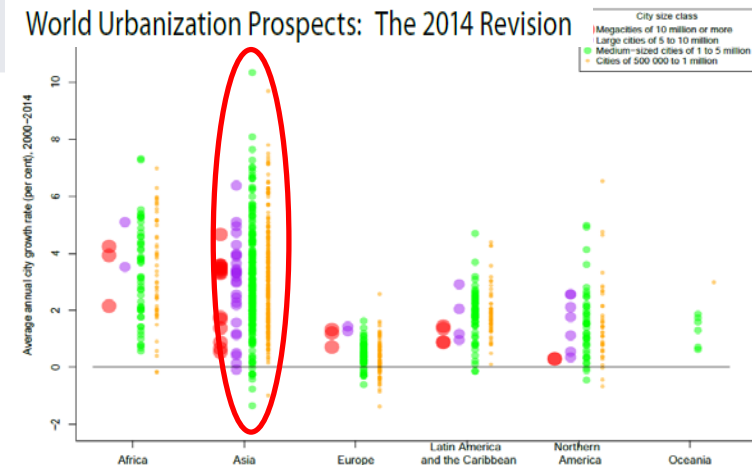


XXI century – a century of urbanization

Percentage urban and location of urban agglomerations with at least 500,000 inhabitants, 2014



The world's fastest growing cities are in Africa and Asia



Risks in the urban environment:

- poor air quality;
- extreme heat/cold & human thermal stress, extreme local winds;
- urban floods;
- sea-level rise;
- energy and water sustainability;
- public health problems caused by the previous
- climate change - 75% GHG emission.



Urban Issues at WMO

- UN-wide new Urban Agenda is being developed (HABITAT-III is planning in October 2016)
- **Urbanization is one of the agreed priorities in the WMO Strategic Plan 2016-2019**
- Resolution 9.8/1 (Cg-17): ESTABLISHING WMO CROSS-CUTTING URBAN FOCUS
- CAS-16 priority: Urbanization: Research and services for megacities and large urban complexes
- **Integrated approach providing weather, climate, water and related environmental services tailored to the urban needs**
- Many other urban related cross-cutting activities to be integrated/coordinated, e.g. GAW (GURME), GFCS, WWRP (HIW), WCRP, WCAS, PWSP, DRR
- **Cg-17: To set priorities and provide guidance on the development of service delivery strategy to address urban needs**

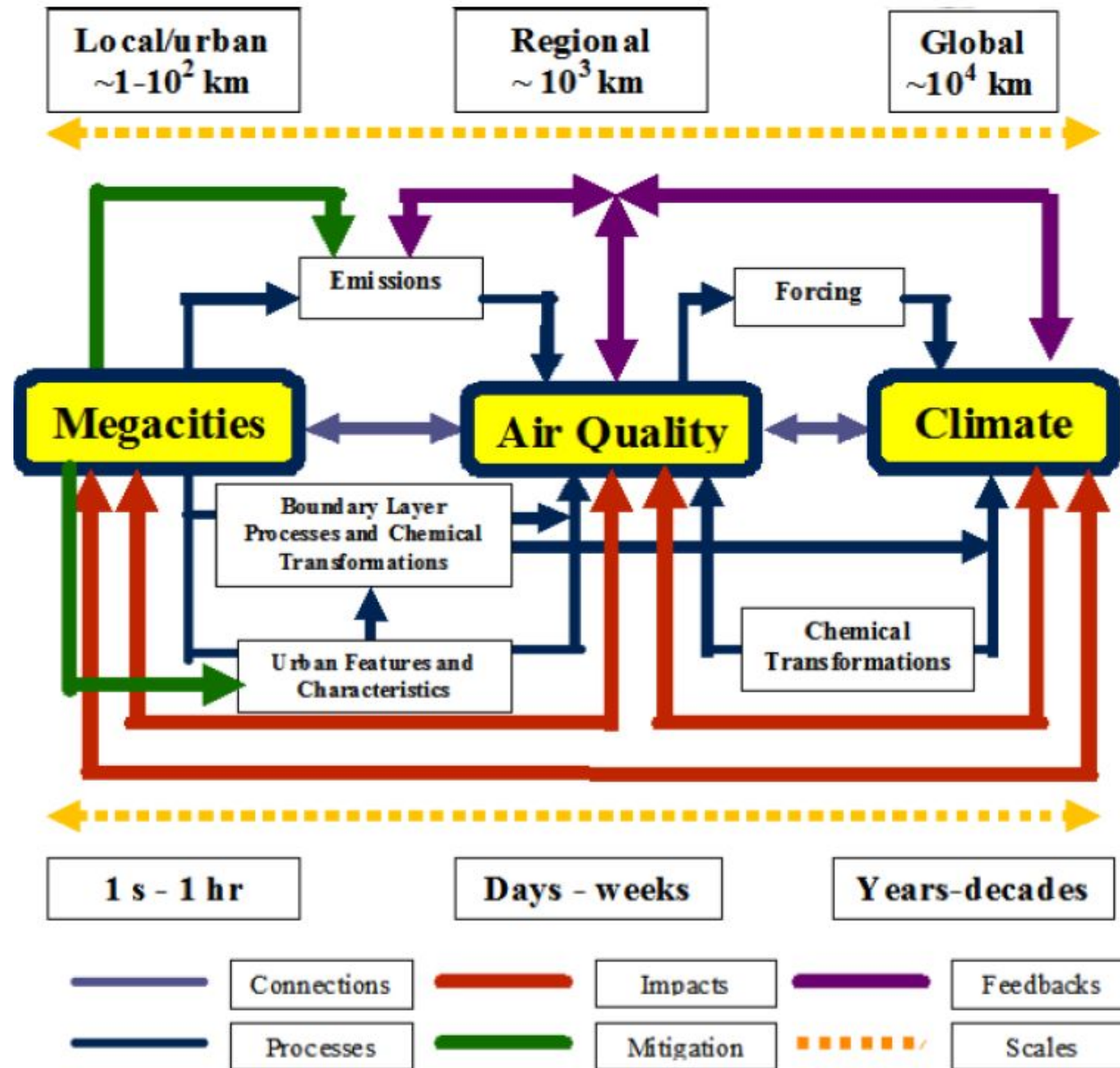




Connections of Cities, AirQuality, Weather & Climate

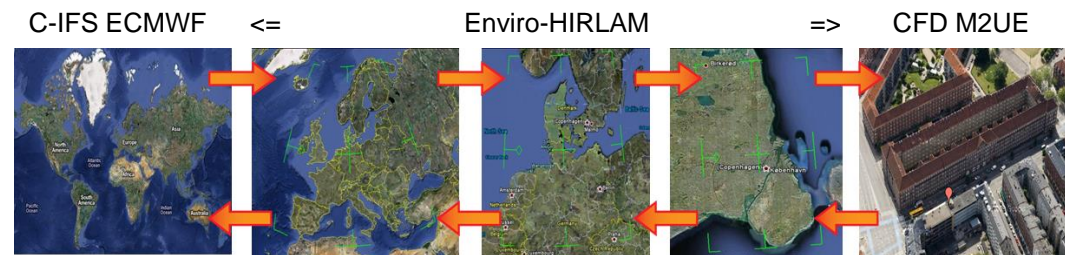
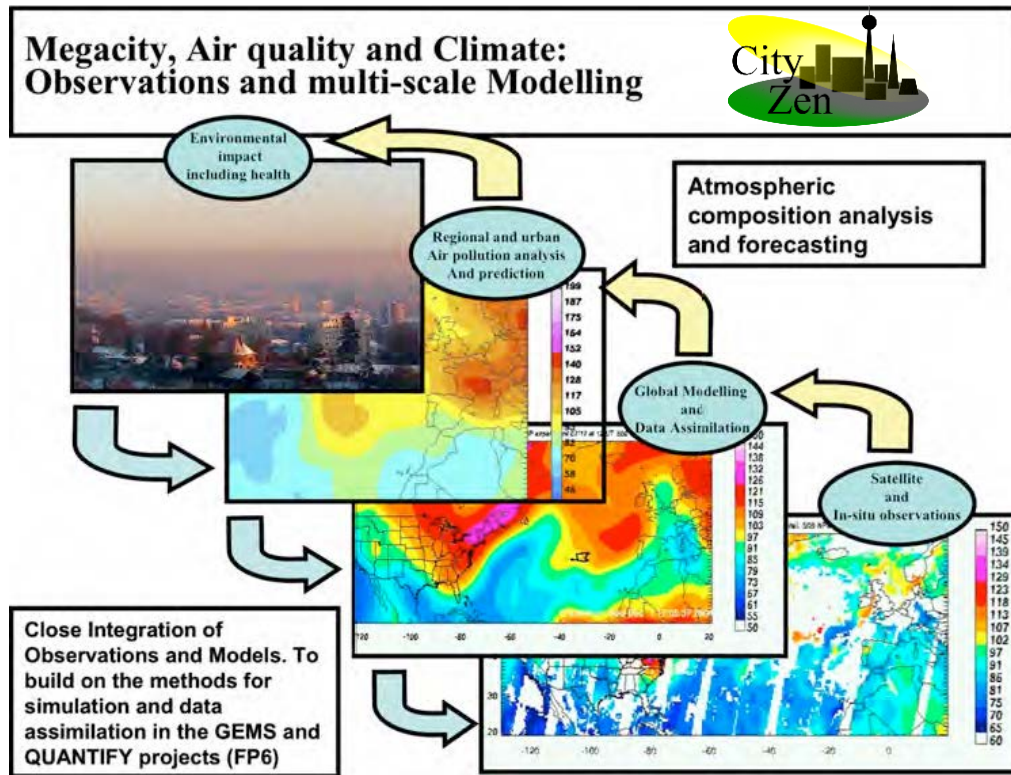
main feedbacks, ecosystem, health & weather impact pathways, mitigations

- Unique challenging environments: very heterogeneous systems
- Science - nonlinear interactions and feedbacks between emissions, chemistry, meteorology and climate
- Multiple spatial and temporal scales
- Interacting effects of urban features and emissions
- Chain of meteo-hazards domino effects on city safety and social activities



Seamless Methodology and Research Tools

Multi-scale modelling Chain / Framework: from Street to Global



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 and canopy, ecosystems
- Different types of observations and modelling
- Links with health and social consequences, services and end-users

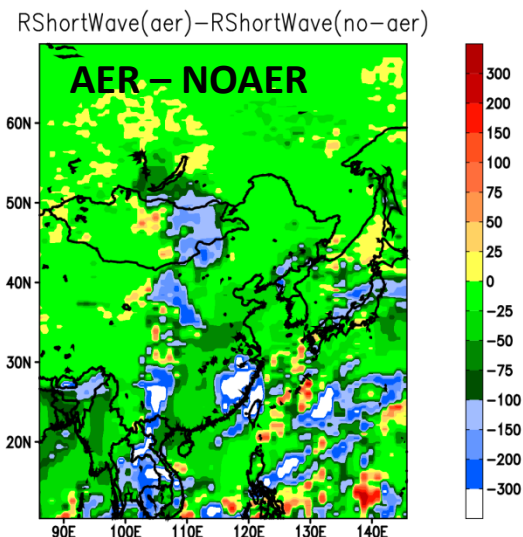
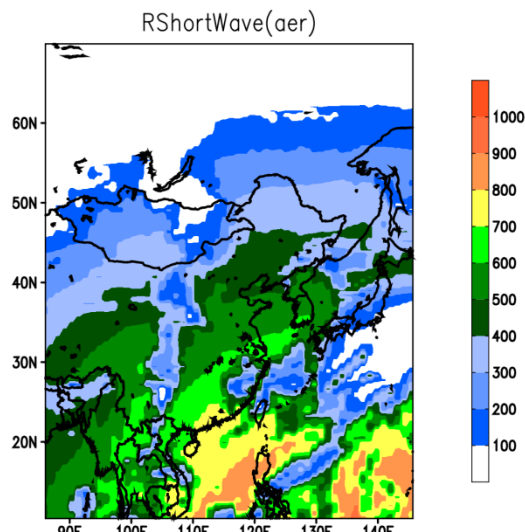
=> New generation of integrated models

← 2-way nesting, Zooming, Nudging, Parameterizations, Urban increment

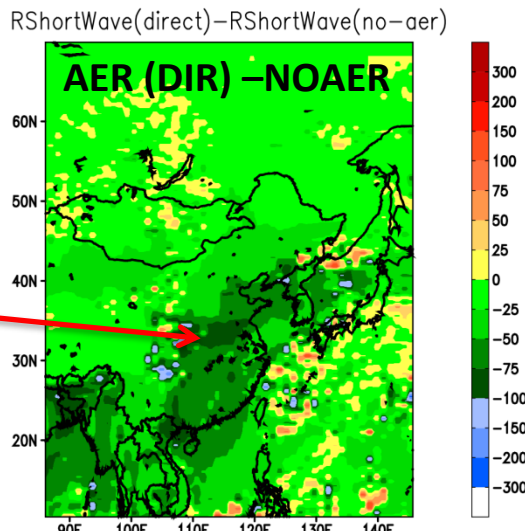


Beijing episode: JMA – Rad shortwave at sfc ($W m^{-2}$)

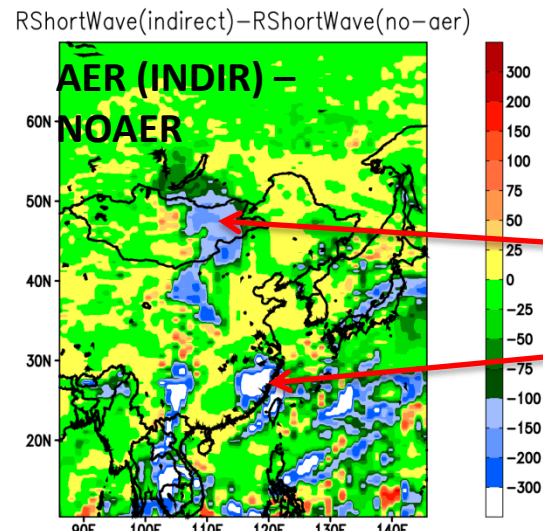
Init 00UTC12JAN FCT: 03UTC14JAN



INDIR effect has more pronounced effect on sfc rsw extinction



DIR effect: -25 to -100 $W m^{-2}$



INDIR effect: -100 to -300 (or less) $W m^{-2}$



Soil-Canopy-Atmosphere Energy Budget Model for Urban Areas (SM2-U)

Thermal budget

$H_{sens\ i}$
Sensible heat flux

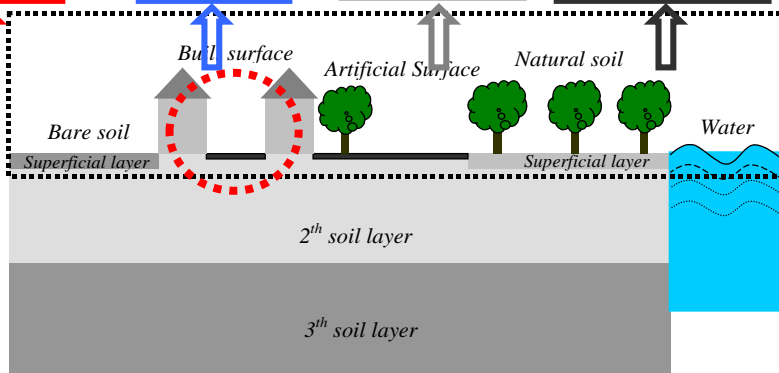
Net radiation: solar, atmospheric, and earth radiations

LE_i
Latent heat flux

$G_{s\ i}$
Heat storage flux

$Q_{anth\ i}$
Anthropogenic heat flux

$R_{n\ i}$

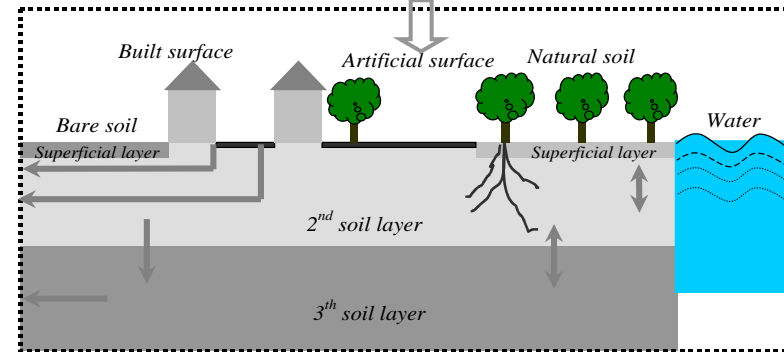


Water budget

Evapotranspiration

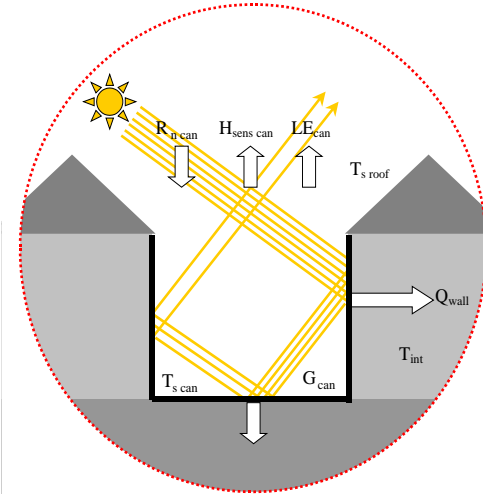
Precipitations

+



+

Canopy



$$Q_H + Q_E + Q_G = Q^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow$$

$$dT_s/dt = C_T Q_G - (2\pi/\tau)(T_s - T_{soil})$$

$$Q_G = \text{Ground flux} ; \tau = 24 \text{ h}$$

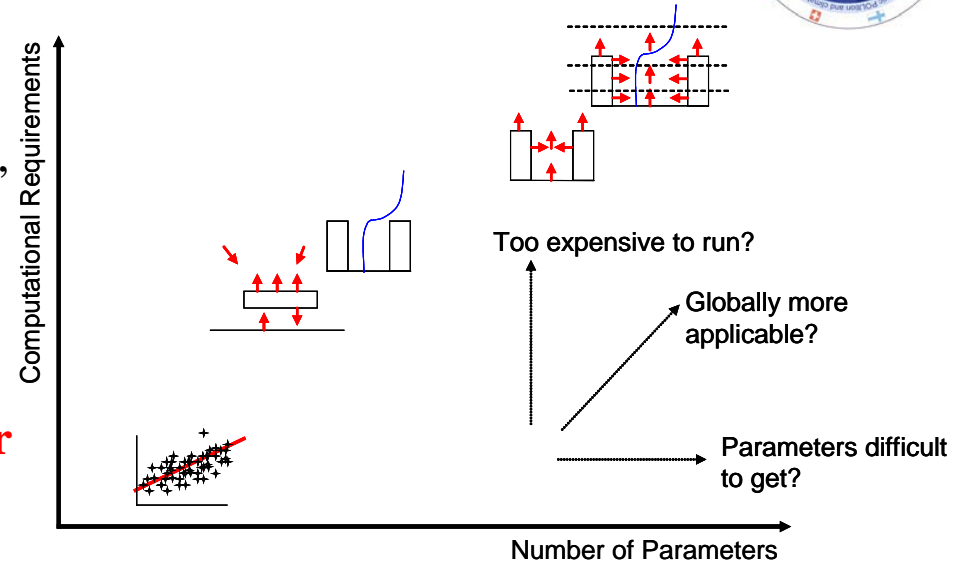
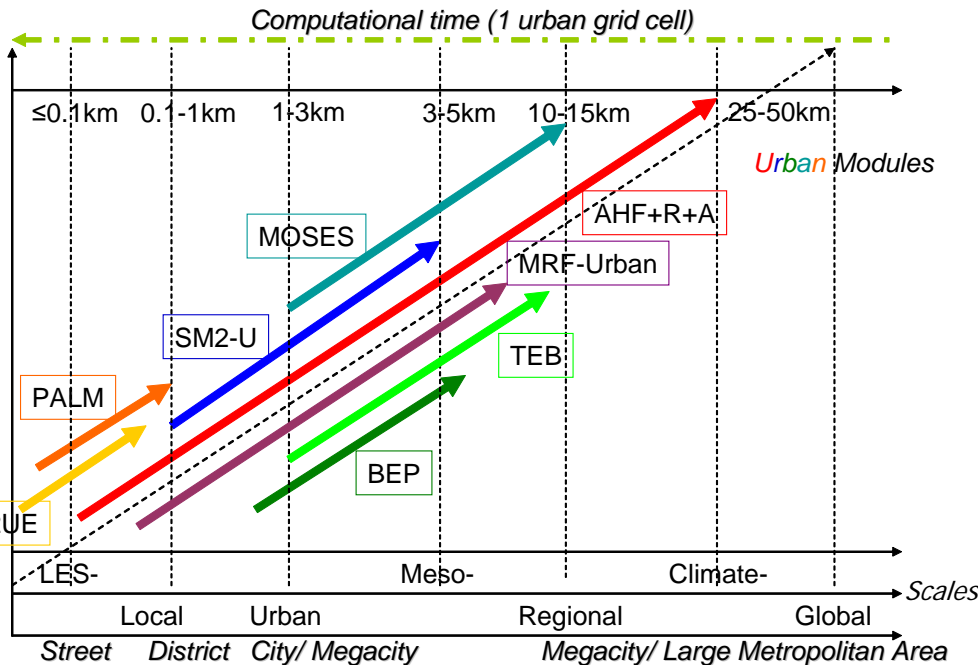
Strategy to urbanize different models



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)

Gaps in knowledge & Research needs:

- Requirements for urban observations, use of crowdsourcing data;
- Near-real-time data access and assimilation for urban areas;
- Coupling of air chemistry, aerosols, meteorological, surface, hydrological processes with chains of feedbacks;
- Formation of SOA, interaction of urban aerosols with UHI and clouds
- Seamless approach: scale interaction;
- High-resolution modelling: 'grey zone' and needed resolution;
- Urban Test Beds that integrate in situ and remote sensing observations with modeling efforts
- Focus on impact based forecast and risk based warnings
- From Research to Services and Society.

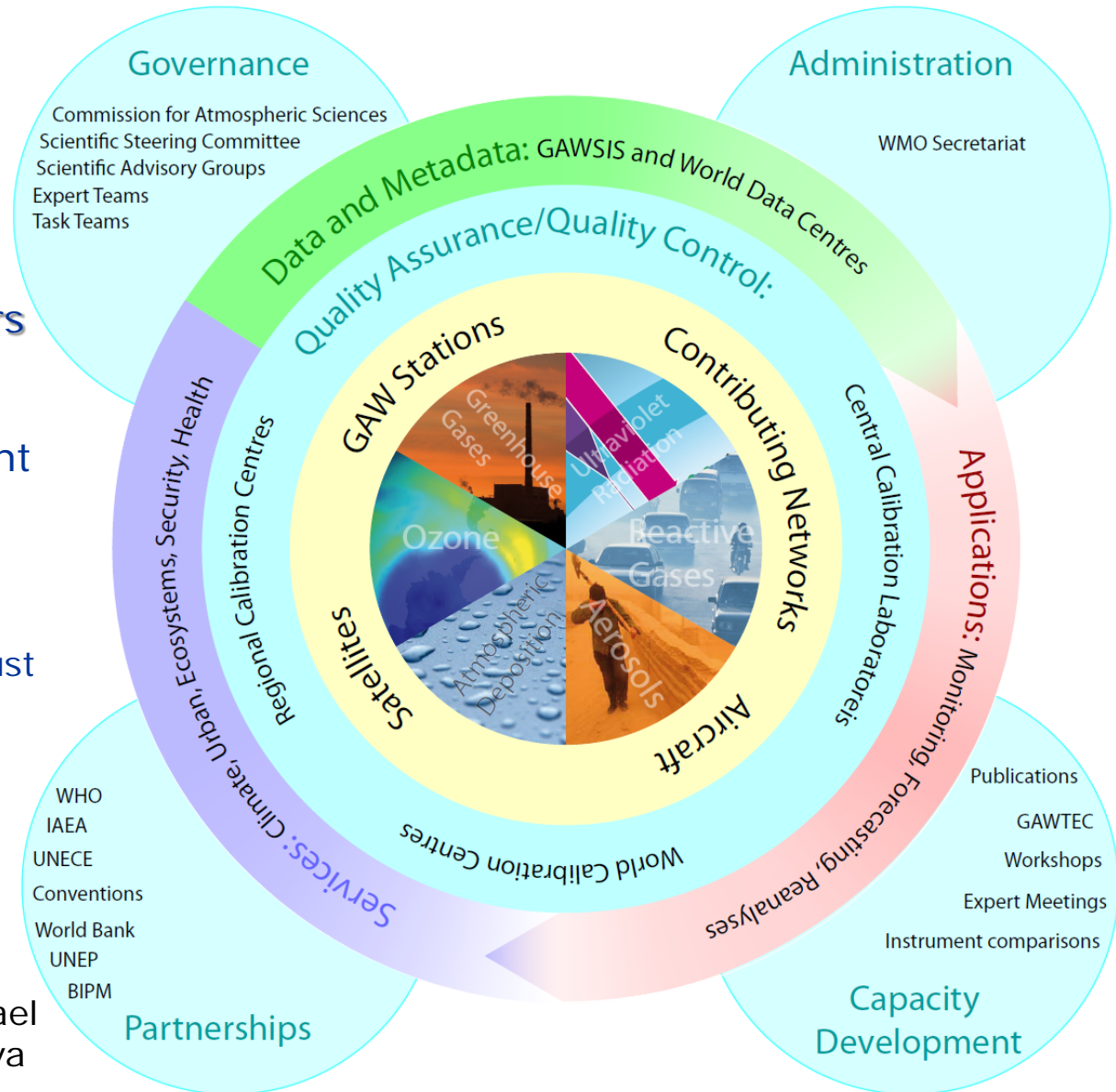
WMO Global Atmosphere Watch Program



GAW Mission:

- Systematic long-term monitoring of atmospheric chemical and physical parameters globally
- Analysis and assessment
- **Development of predictive capability**
(GURME and Sand and Dust Storm Warning System) and now for chemical weather (e.g. incl. volcanic ash, wildfires)

GAW SSC Chair G. Carmichael
WMO AERD Chief O. Tarasova





WMO GAW Urban Research Meteorology and Environment Project (GURME)



- To enhance the capabilities of NMHSs in providing urban-environmental forecasting and air quality services of high quality, illustrating the linkages between meteorology and air quality;
- In collaboration with other WMO programmes, WHO and environmental agencies, to better define meteorological and air quality measurements focusing specifically on those that support urban forecasting;
- To provide NMHSs with easy access to information on measurement and modeling techniques;
- To promote a series of pilot projects to demonstrate how NMHSs can successfully expand their activities into urban environment issues.



GURME- Science Advisory Group



- **Veronique Bouchet (Chair)** – Environment Canada
- **Gufran Beig** - Indian Institute of Tropical Meteorology
- **Sue Grimmond** – Department of Meteorology, University of Reading
- **Louisa Molina** – Molina Center for Energy and Environment
- **Pablo Saide** – National Center for Atmospheric Research
- **Jianguo Tan** – China Meteorological Administration
- **Alexander Baklanov**, WMO Secretariat

- 3 new members are expected

- **Ex-officio:**
 - Greg Carmichael (former Chair)

GURME web-site: mce2.org/wmogurme.org/

GURME Tasks For The Strategic Planning Period 2008-2015

Observational Needs

- Chemical
- Meteorological

(Tasks: 3,6,17)

Assimilation

Modeling Needs

- Weather prediction
- Chemical weather and air quality prediction

(Tasks: 8,11,13,15)

Demonstration

Capacity Building

- Workshops
- Training

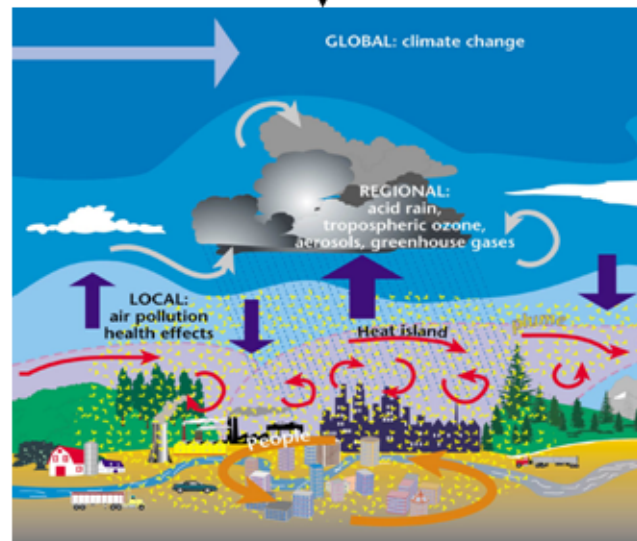
(Tasks: 2,4)

Coordination

Users

- Health
- Agriculture
- Environmental
- Public
- Emergency Response

(Tasks: 9,14,16,18)



Education

Air Quality & Related Products

- Improved Forecasts
- Guidelines
- Pilot Projects

(Tasks: 1,5,7,12)

Dissemination



Example of GURME pilot projects: Latin American Cities



Sao Paulo,
Brazil



Mexico City,
Mexico



Santiago,
Chile



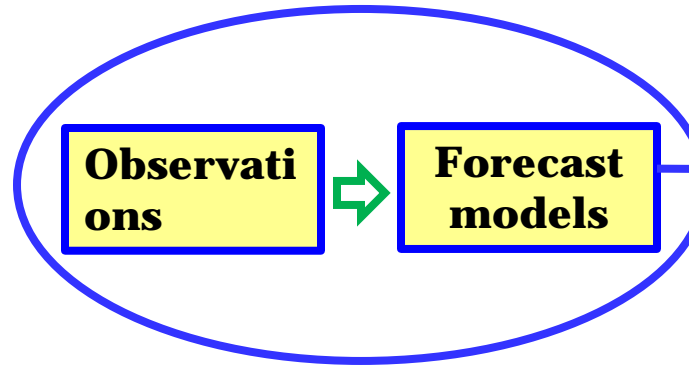
Improvement of AQ forecasting in Latin American cities through capacity building

- Air Quality Forecasting Workshops in 2003 (Chile), 2006 (Brazil, Peru), 2009 (Mexico), 2011 (Costa Rica), 2013 (Chile)
 - Participation from NMHS, Universities & Environmental Agencies
- Signature of MOU between Chilean Meteorological Office and UNAB to transfer AQ forecasting model to the Met Office.
- MoU between Mexico City Administration and WMO GAW Program



GURME Pilot Project (MHEWS Shanghai) (EXPO-2010)

- Enhanced observing system
- Enhanced air quality & weather forecasting (heatwaves, AQ, +)
- Field experiment (jointly with NCAR)
- Workshop activities



Heat wave and cold spell forecast

UV forecast

Ozone forecast

Haze forecast

Pollen forecast

Bacterial Food Poisoning

Influenza forecast

Heat index, Sunstroke, and Diarrhea forecast for EXPO 2010₁₈

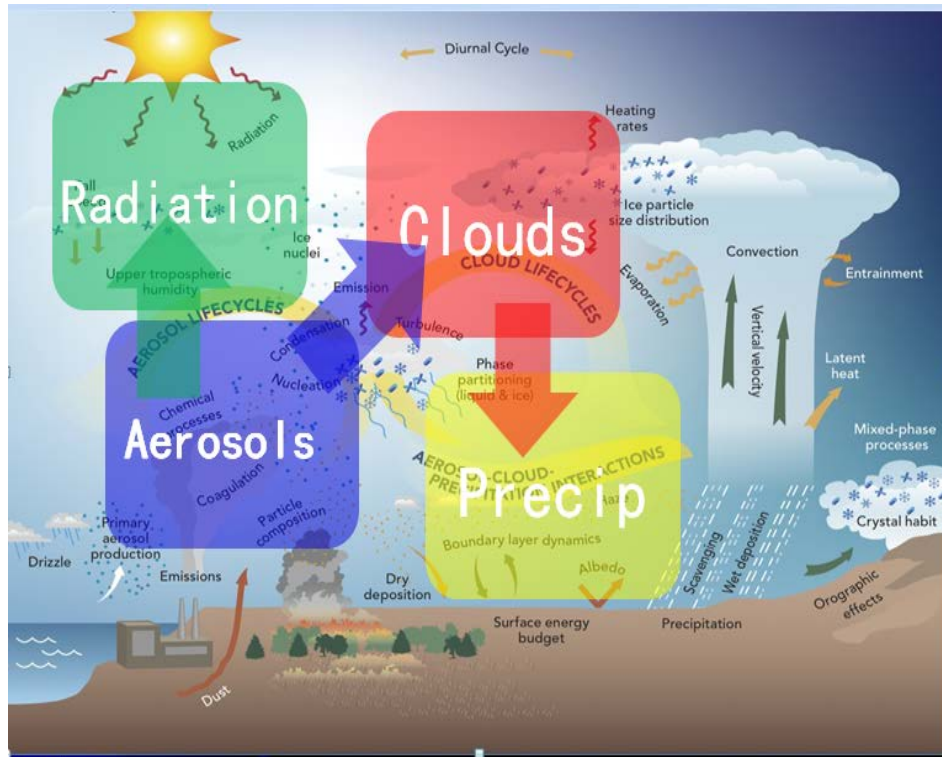
Led by Tang Xu, SMB



中国气象局-国际气象组织 城市气象和环境研究示范项目 A CMA-WMO GURME Pilot Project



NRT Data Application to Air Quality Forecasts Xiaoye Zhang, Sunling Gong, Chunhong Zhou and others



Develop and establish a NRT chemical data transfer system to collect and process both ground based and satellite observations, based on the WMO data transfer protocols for conventional weather data;

Develop an AQ forecasting system and integrate it with the NRT system to illustrate the capacity of NRT data to enhance the accuracy of AQ forecasts in China;

Develop an emission estimating system using the NRT data and inverse modeling methodology;

Exchange and transfer research results with other national and international agencies.

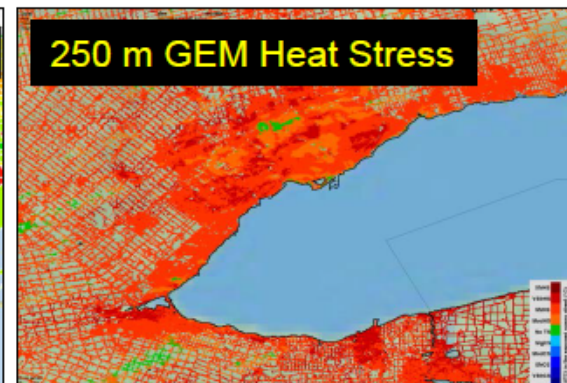
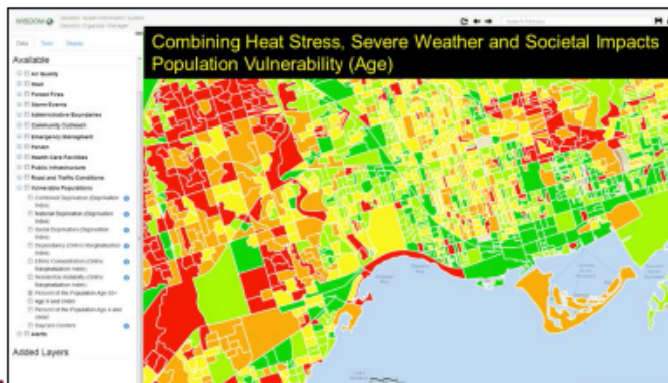
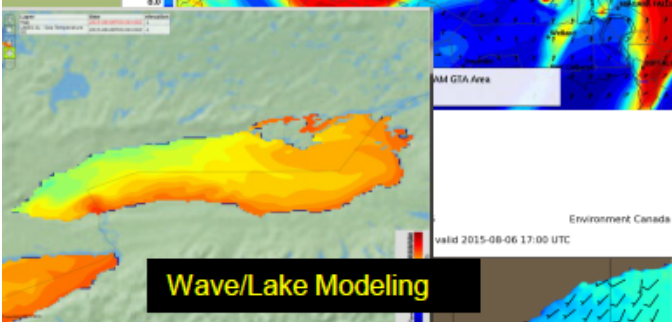
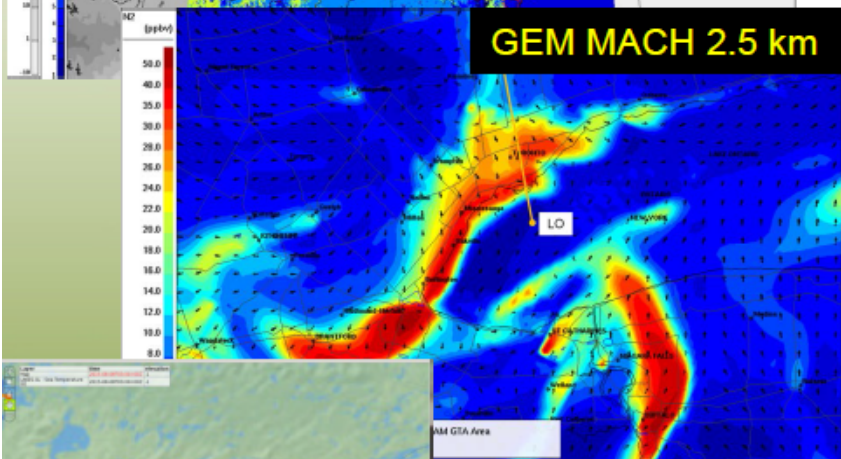
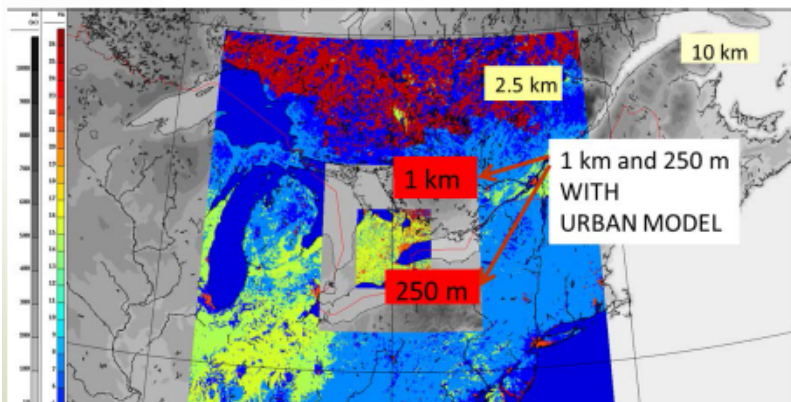


Environment
Canada

Environnement
Canada

Forecast/Nowcast System for Pan-American Games

- Weather: 10km, 2.5km, 1km, 250m
GEM cascade (urbanized <1km)
- AirQuality: 2.5 km GEM MACH AQ
(HPC)
- Lake Model: GEM-NEMO (2km)
- Wave model :WW3 (1km deterministic)
- Heat: GEM heat stress indices
- Health Services & Societal User Impacts
- Dispersion modelling for emergency
preparedness & response





High Impact Weather Project



Co-chairs: Brian Golding, MetOffice
David Johnston, Massey University

- Increasing resilience to Urban Flood, Wildfire, Urban Heat and Air Pollution in Megacities, Localised extreme wind, Disruptive winter weather through improving forecasts for timescales of minutes to two weeks and enhancing their communication and utility in social, economic and environmental applications
- Implementation Plan (2015-2024) approved by WWRP SSC
- Links to WCRP through quantifying vulnerability and risk assessment, and for response to High Impact Weather in a changing climate.



Christof Stache/AFP/Getty Images; Marina Shemesh /publicdomainpictures.net; Alexandros Vlachos/EPA; NOAA NWS; NOAA NWS

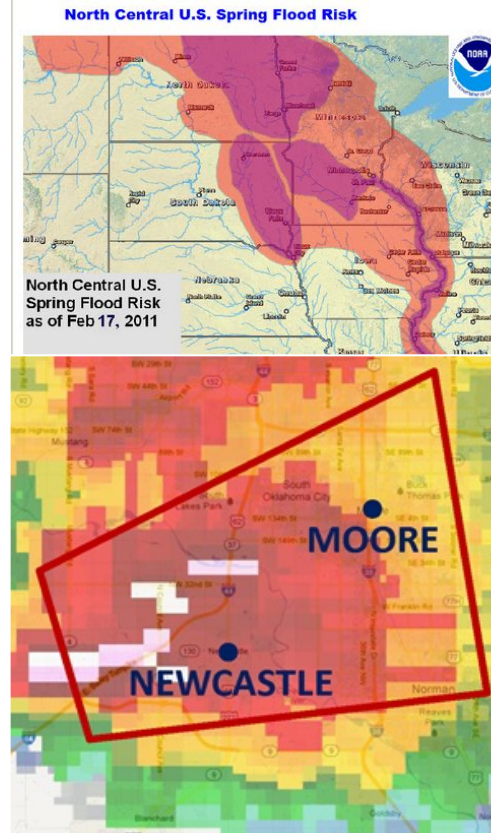
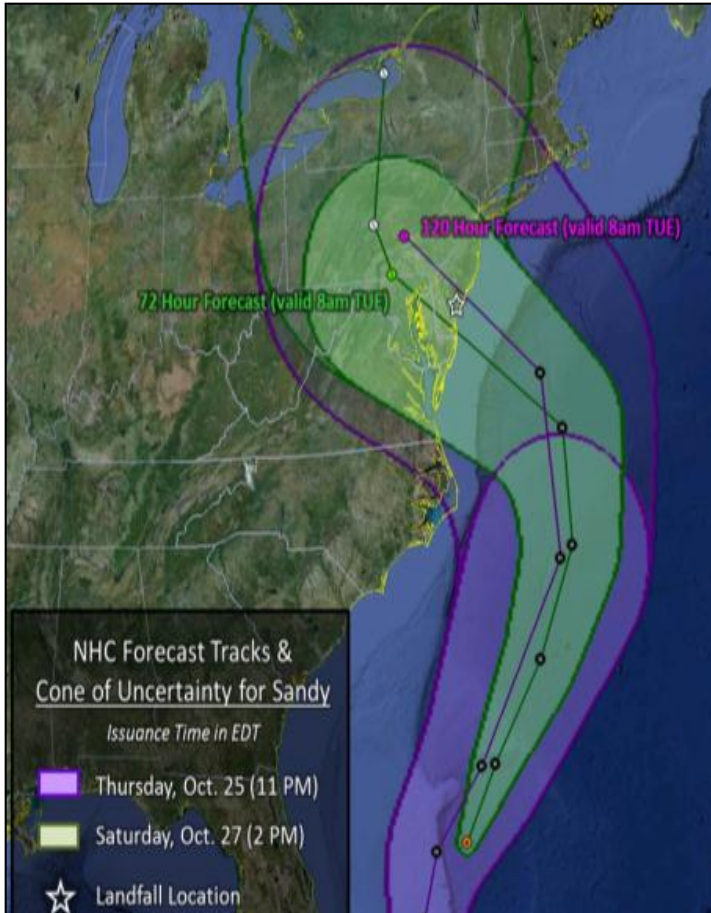




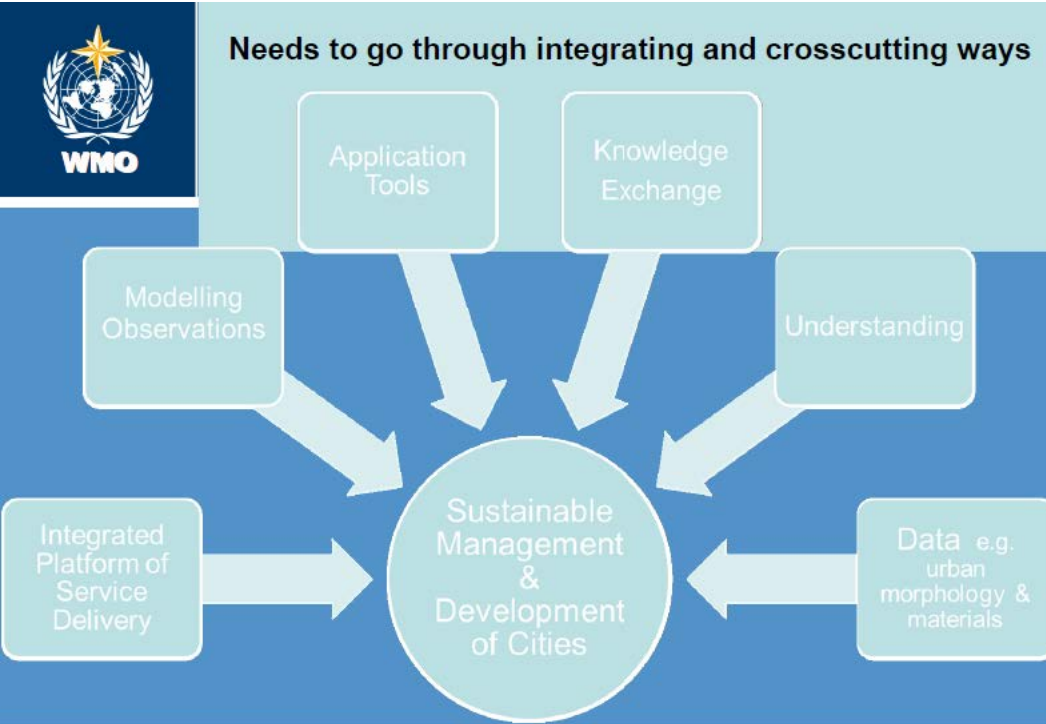
Communication... Case for change



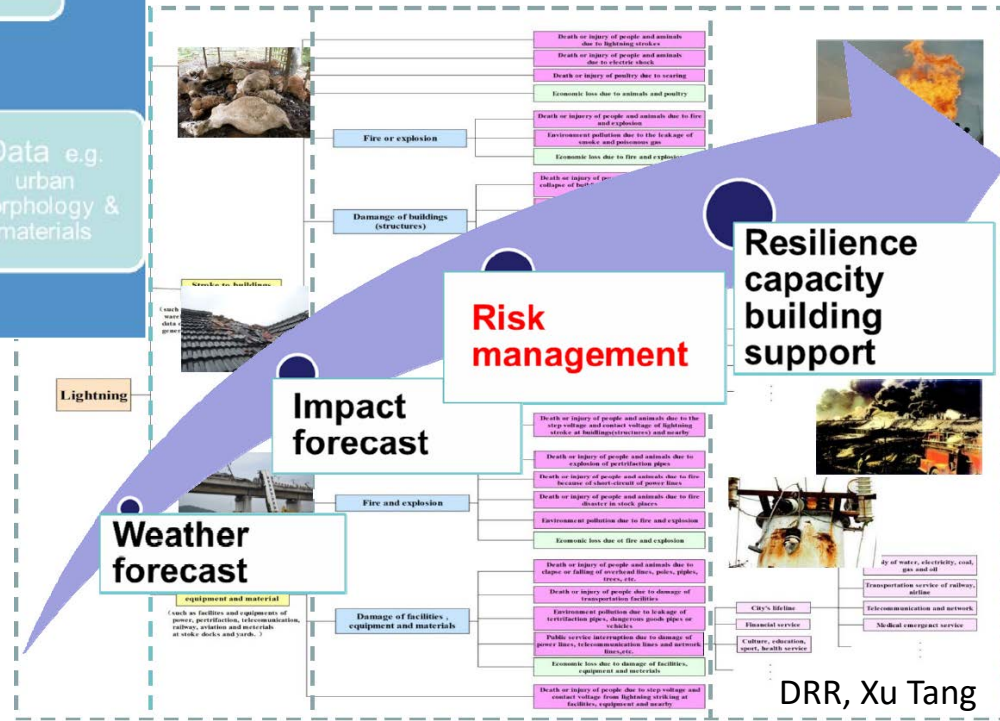
Extreme events well forecast ... but societal impacts?



Integrated Service Delivery on Weather and Climate including Supporting Research for Megacity and in Urban Areas, WMO Priority Area (2016-2019) as a response action to UN New Urban Agenda

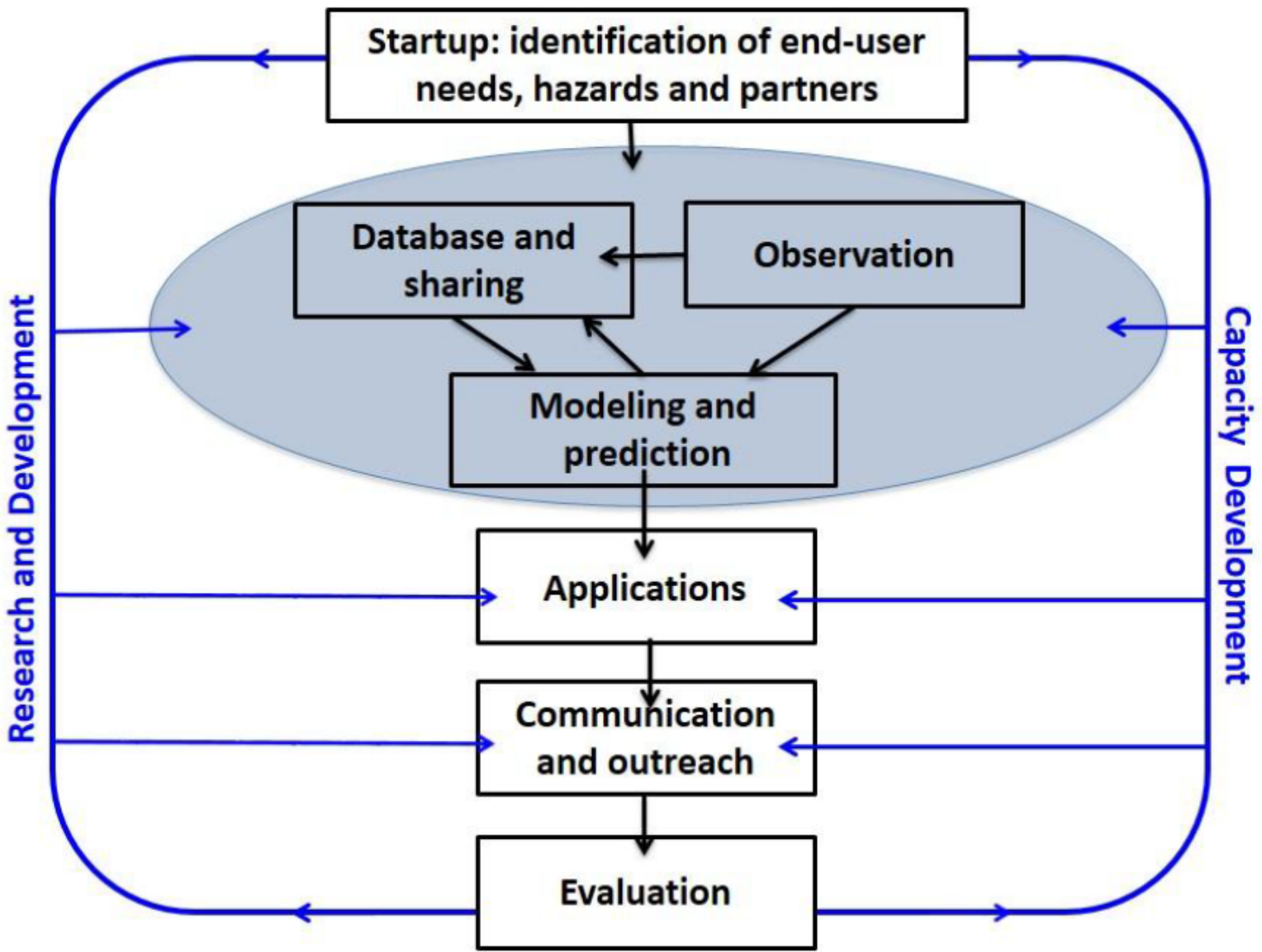


- Cg-17 Resolution 9.8: Establishing WMO Cross-cutting Urban Focus
- WMO GAW APP, GURME SAGs, IGIS
- Guide for Urban Integrated Services
- Input to HABITAT-III conference





Components of to the development an Integrated Urban Weather, Environment and Climate Service (IUWECS)





METROPOLITAN AIR QUALITY AND WEATHER FORECASTING SERVICES

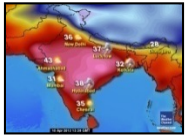


SAFAR project, India

Beig et al., 2015



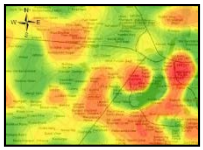
AIR-Now & AIR-Tomorrow



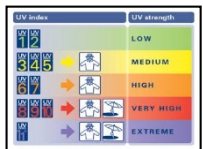
Weather -Now & -Tomorrow



Health Advisories



City Pollution Maps



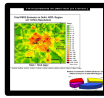
UV Index-Skin Advisory



Air Quality Monitoring



Weather Monitoring



Emission inventory Development



Surface topography & land use study

AIR QUALITY FORECAST MODELING **WEATHER FORECAST**

Supercomputer

PRODUCTS

Translate Science to Public

SERVICES

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



Web Portal



E-mail Alerts



SMS Alerts



Digital Display



TV /Radio

WWOSC 'Seamless Earth System Modelling' Book:

http://library.wmo.int/pmb_ged/wmo_1156_en.pdf



WWOSC 2014
MONTREAL, CANADA

We are entering a new era in technological innovation and in use and integration of different sources of information for improving well-being and the ability to cope with multi-hazards. New predictive tools able to detail weather conditions to neighbourhood level, to provide early warnings a month ahead, and to forecast weather-related impacts such as flooding and energy consumption will be the main outcomes of the next ten years research activities in weather science. A better understanding of small-scale processes and their inherent predictability should go together with a better comprehension of how weather-related information influences decisional processes and with better strategies for communicating this information. Within this perspective, this book is intended to be a valuable resource for anyone dealing with environmental prediction matters, providing new perspectives for planning and guiding future research programmes.



ON OF THE EARTH SYSTEM:
TES TO MONTHS

SEAMLESS PREDICTION OF THE EARTH SYSTEM:
FROM MINUTES TO MONTHS



CHAPTER 18. URBAN-SCALE ENVIRONMENTAL PREDICTION SYSTEMS

C. Sue Grimmond, Greg Carmichael, Humphrey Lean, Alexander Baklanov, Sylvie Leroyer, Valery Masson K. Heinke Schluenzen and Brian Golding

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J/N 15/28



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$$\frac{\partial \psi}{\partial t} + J(\psi, q) + \beta \frac{\partial \psi}{\partial x} = 0$$



WWOSC 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.**

WMO for UN New Urban Agenda

WEATHER CLIMATE WATER



WORLD
METEOROLOGICAL
ORGANIZATION



Building **Urban cross-cutting WG** and elaboration of **Guidelines for Integrated urban services** (for Cg-18)

Welcome to contribute!

Integrated weather, climate, hydrology and related environment services for sustainable cities



World Meteorological Organization



A United Nations Specialized Agency
Working together in Weather, Climate and Water



Thank you for your attention

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