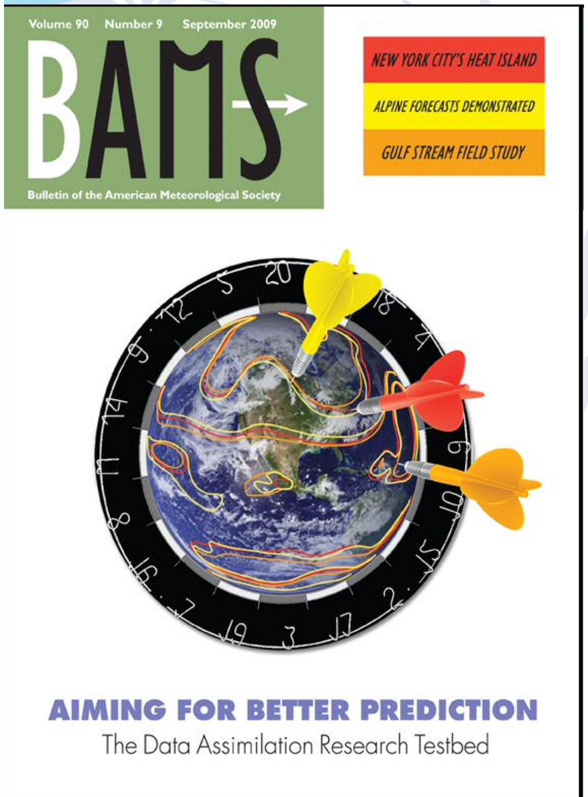
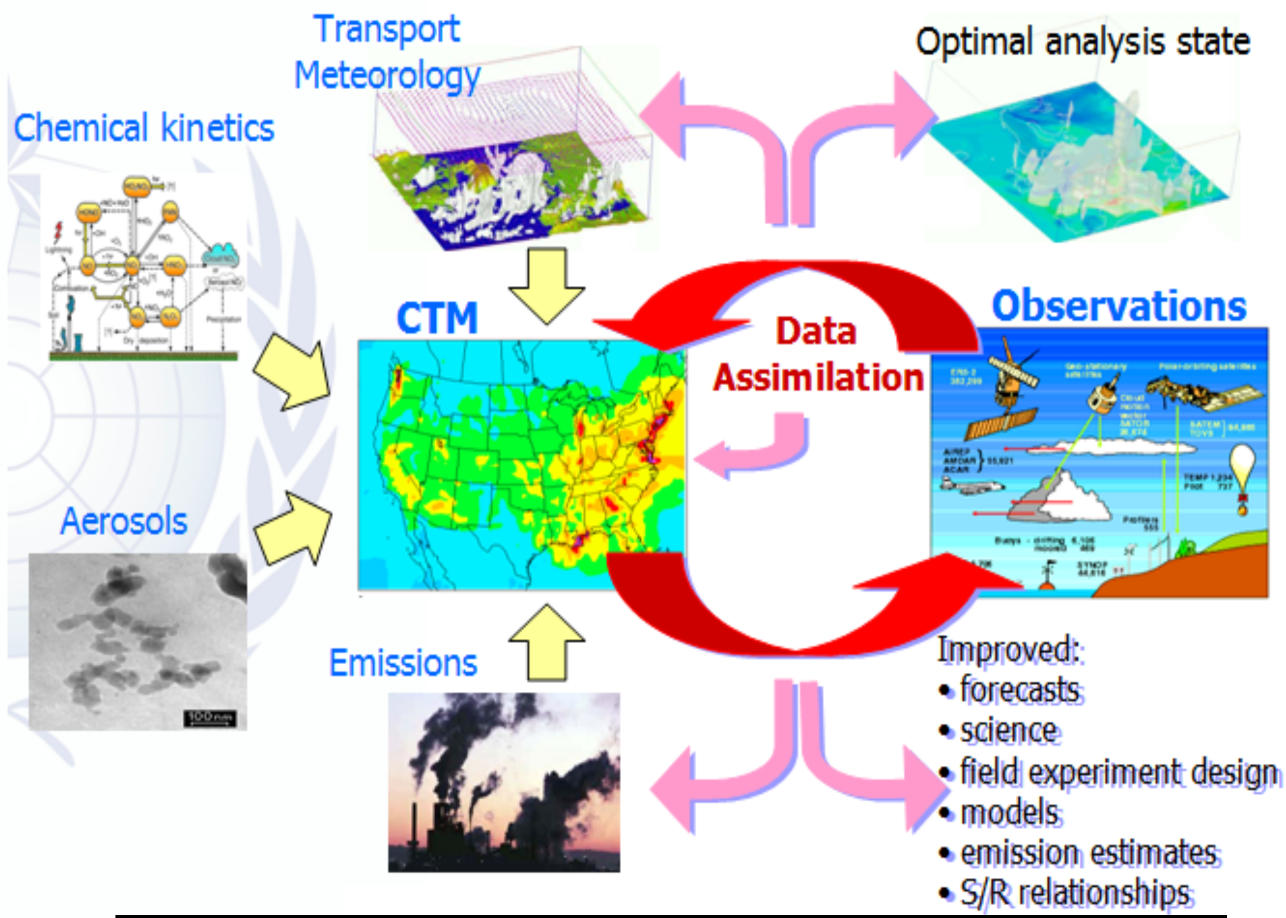
AREP
GAW

Improving AQ Forecasting Through
A Closer Integration Of Observations And Models





New requirements for NRT data, observing systems, and assimilation systems for chemical applications!!

WMO
OMM

AREP
GAW

Research Needs in AQ Data Assimilation

- **Met focused impacts (clouds, soil moisture, etc.)**

- **Chemical Techniques (ensemble, Var, hybrid)**
  - **Diversity of models (and components) with DA capabilities (e.g., Aerosol mod, radiation)**
  - **Control targets: initial, boundary, emissions**
  - **What existing data to assimilate (little experience in multiple species assimilations)**

- **Observing systems**
  - **Observation impact on analysis; quantify "value" of observations**
  - **Spatial, temporal value**

- **Better estimates of:**
  - **background errors (e.g., flow dependent, …)**
  - **observational errors,**
  - **model errors, and**
  - **the impact of error misspecification on analysis**

WMO
OMM

AREP
GAW

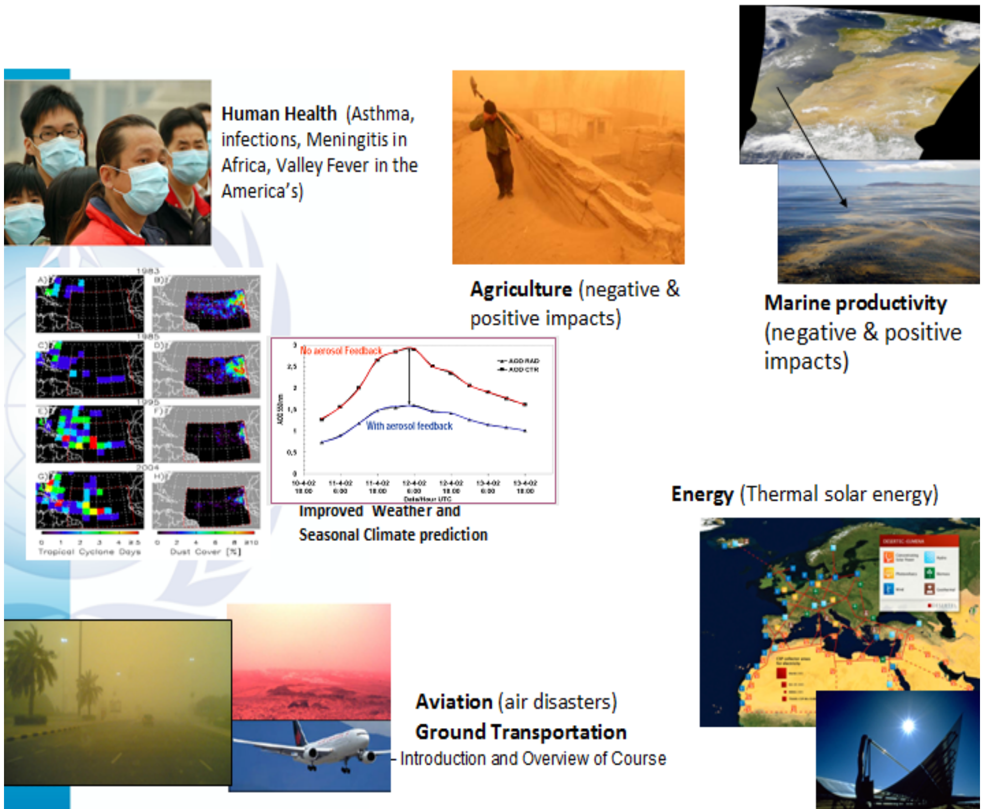
Research Needs in AQ Data Assimilation

- **New algorithmic developments:**
  - **ability to deal with non-Gaussian uncertainty (e.g., particle filters);**
  - **ability to account for model errors (e.g., weakly constrained 4D-Var);**
  - **ability to quantify posterior errors (e.g., second order adjoint)**
  - **ability to integrate the lessons learned so far (e.g., hybrid variational-ensemble methods)**
  - **higher computational efficiency (e.g., reduced order models)**
- **Challenges wrt to scales (resolution, multiscales,…)**
- **"coupled" met strategies (what species, techniques, impacts both ways, etc..)**
- **New computer science developments**
  - **Data management**
  - **Exploit accelerator architectures (e.g., GPUs)**
- **Computational resources/efficiency**
- **Testbeds**
- **Building community efforts – identity, articulation**

WMO
OMM

AREP
GAW

FUTURE DIRECTIONS FOR IMPROVING AIR QUALITY PREDICTIONS -- Summary



Air Quality ↔ Weather ↔ Climate

✓Further improvements will require reductions in key uncertainties (e.g., emissions, better basic understanding of some processes).

✓There remain many observation needs and they need to be better articulated (NRT, 3-d components, geostationary)!

✓Closer integration of observations is needed, including closer integration with AQ and met forecasting elements.

✓A growing set of tools and techniques to assist and apply data assimilation are available (KPP- adjoints, models for background errors, EnKf wrappers, etc.), **BUT** more work on chemical aspects and techniques needed.

✓ Need to continue to build the community and share experiences!

WMO
OMM

AREP
GAW

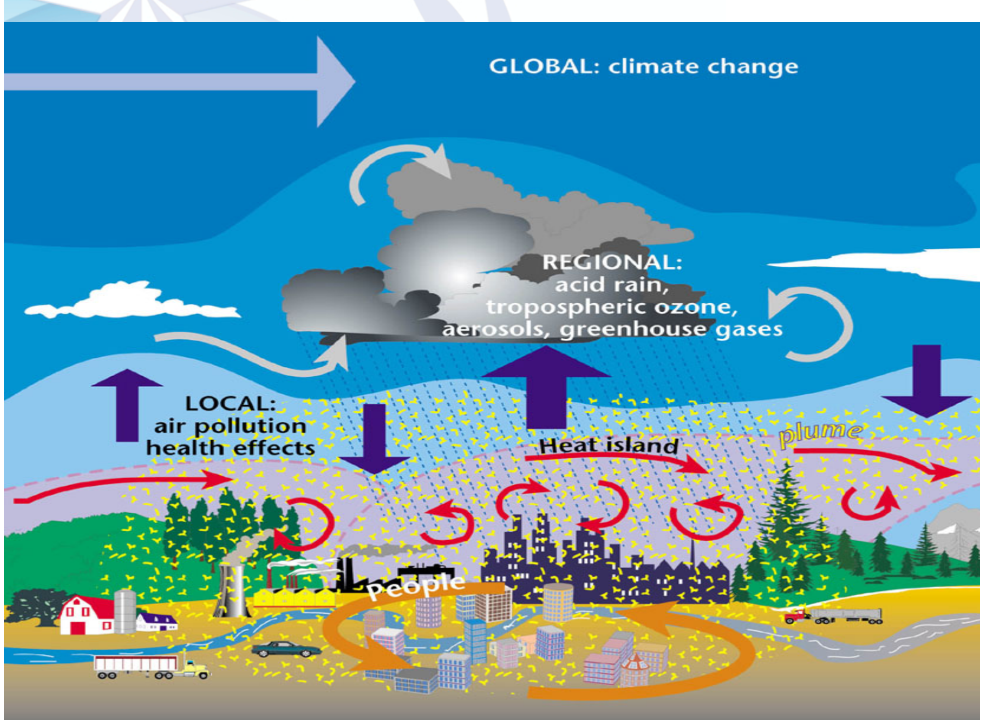
Backup Slides

WMO
OMM

AREP
GAW

Chemical Weather – A New Challenge/ Opportunity For Weather And Other Services

Evolving complexity of observing systems, models, and applications.



Importance of Chemical Weather

- Effects of air quality and chemical exposure on human health.
- Effects of gases and aerosols on ecosystems and agriculture
- Effects of air quality and visibility on tourism
- Effects of UV radiation on ecosystems and humans
- Improvements of numerical weather prediction models

WMO: GAW Urban Research Meteorology and Environment Project -- GURME

WMO
OMM

Major Challenge: Lack of Observations

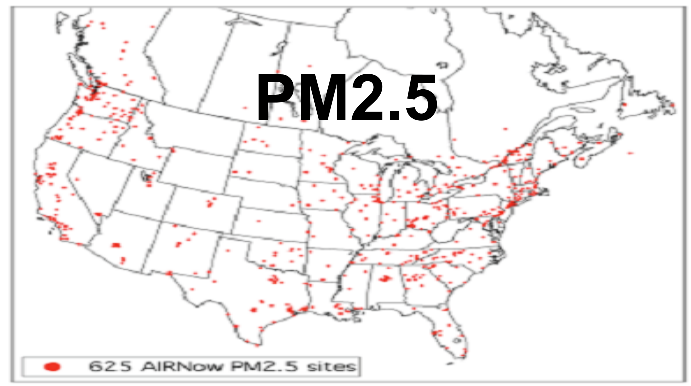
NAS - 2009

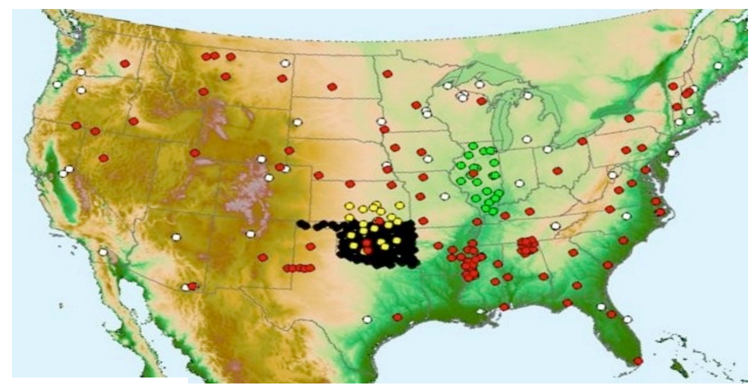
Observing Weather and Climate FROM THE GROUND UP A Nationwide Network of Networks

www.nap.edu/catalog.php?record_id=12540

Focus in CTM-modelling vs NWP (from Ø. Hov)

Parameter	Numerical Weather Prediction	Chemical Transport Modeling
Wind speed	High wind speeds	Stagnant conditions
Wind direction	Not so important	Essential for S-R-relationships
Precipitation	Heavy rain	Length of dry periods; low intensity rain
Temperature	High and low temperatures, freezing	High temperatures – fast reactions and large biogenic emissions
Clouds	Cloud cover	Type, location, lifetime
Convection	Precipitation	BL ventilation
$\tau_{BL,res}$, H_{mix}	Not so important	Important
Specific humidity	Not so important	Important for [OH]
Ground surface	Important for fluxes of heat, momentum, moisture	Important for deposition, biogenic emissions





Soil Moisture Networks

AREP
GAW

Observations Priorities Stemming from Common Threads

MOST NEEDED:

- Height of the planetary boundary layer
- Soil moisture and temperature profiles
- High resolution vertical profiles of humidity
- Measurements of air quality and atmospheric composition above the surface layer

NEEDED:

- Direct and diffuse radiation
- Vertical profiles of wind
- Sub-surface temperature profiles (e.g., under pavement)
- Icing near the surface
- Vertical profiles of temperature
- Surface turbulence parameters

AREP GAW

Assimilation of Key Meteorological Parameters are Needed to Improve AQ Prediction Skill

Design Period Simulations – Satellite Inputs

Retrospective – Data Assimilated for all Integration Period

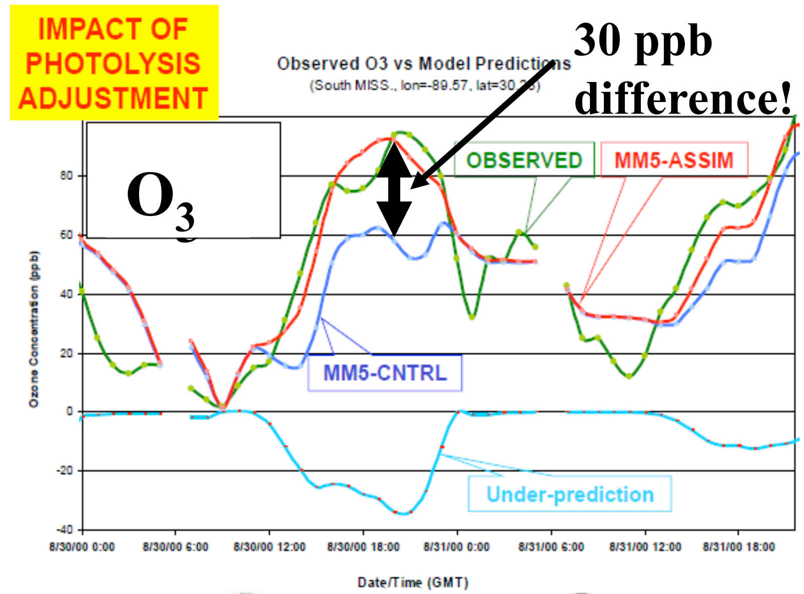
Example: impact of met parameters

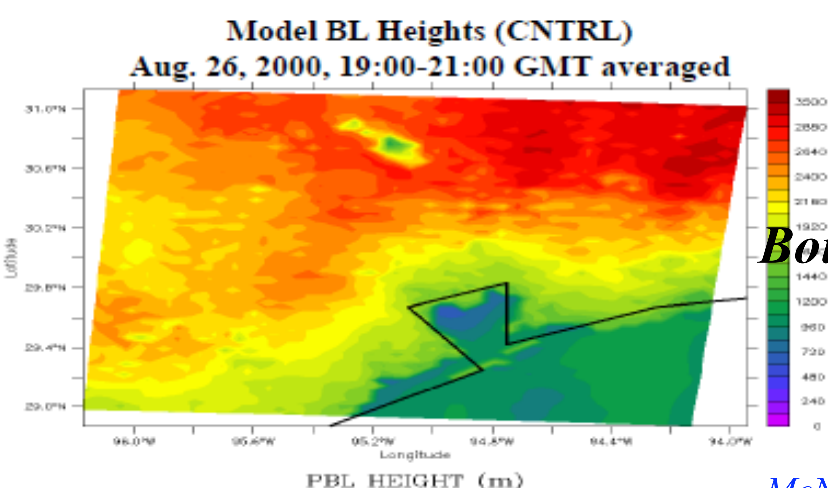
Geostationary Satellite Observations –
- Insolation
- Skin temperatures
- Cloud Properties

MODIS
- Surface emissivity
- Surface albedo
- Skin temperatures

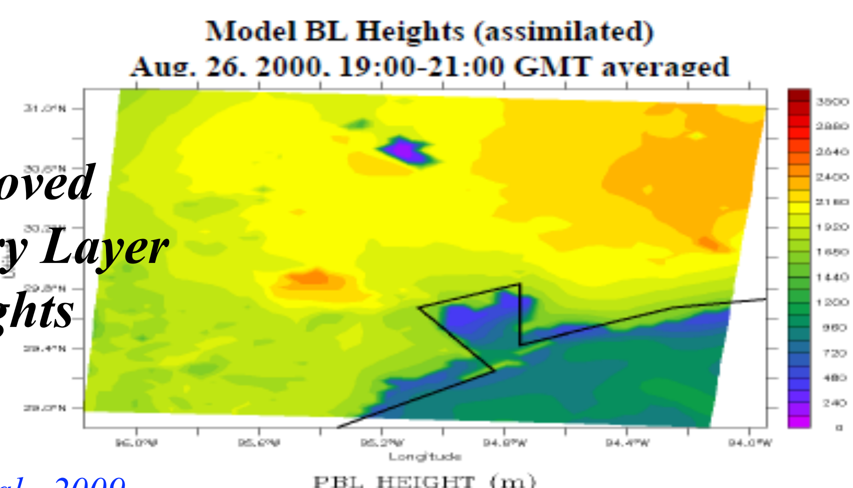
Satellite derived properties for photolysis rates

Physical Model — Recreates Physical Atmosphere → Chemical Model — Recreates Chemical Atmosphere





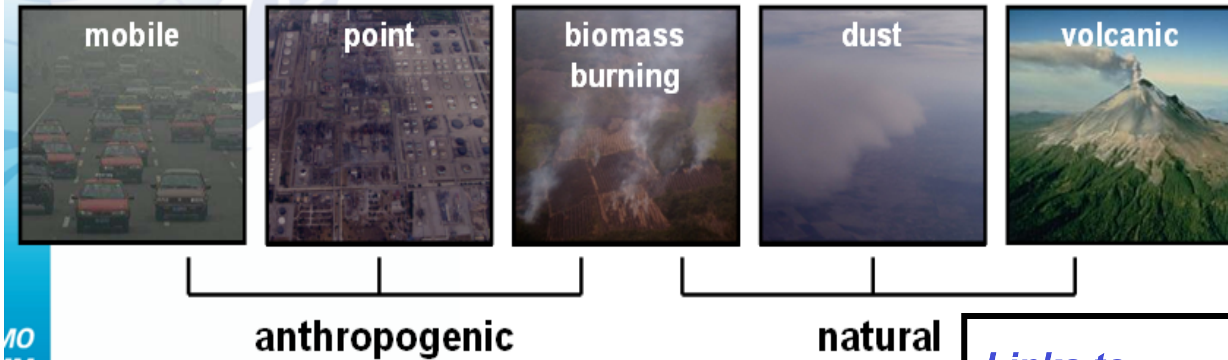
Improved Boundary Layer Heights



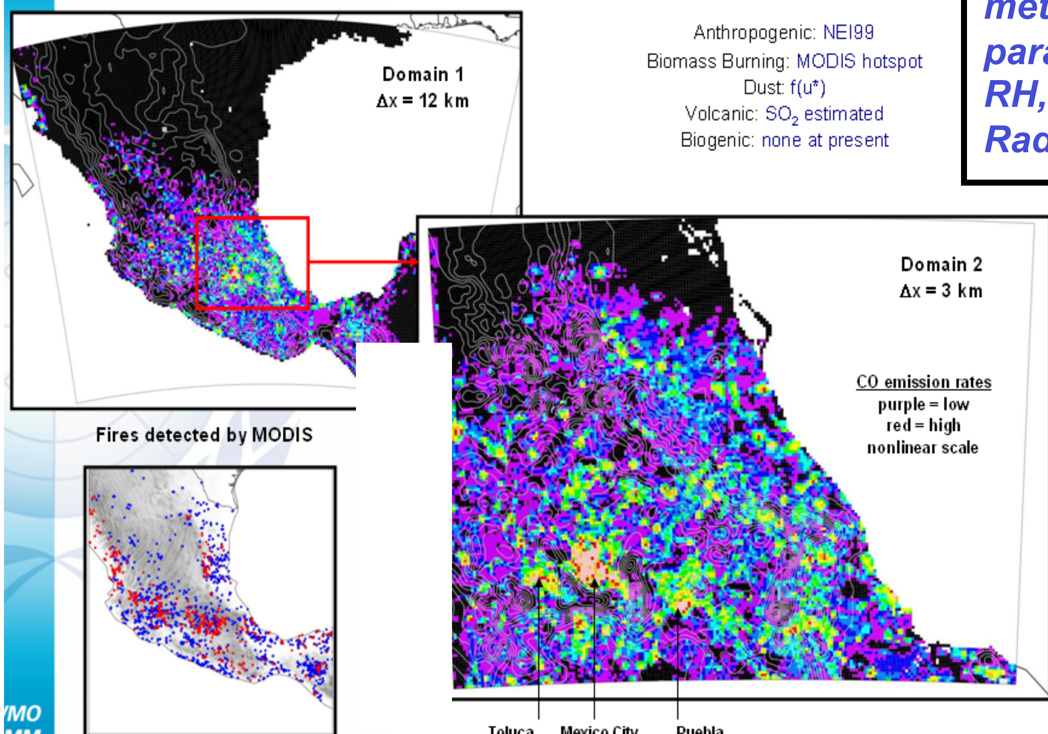
McNider et al., 2009

AREP GAW

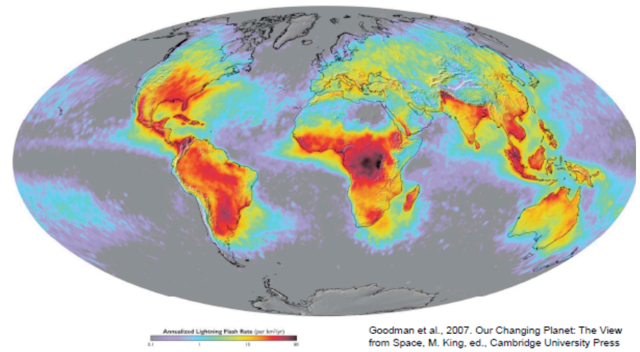
Major Challenge: Need to Estimate ALL Emissions at Appropriate Scales *(places new responsibilities for NMHCs)*



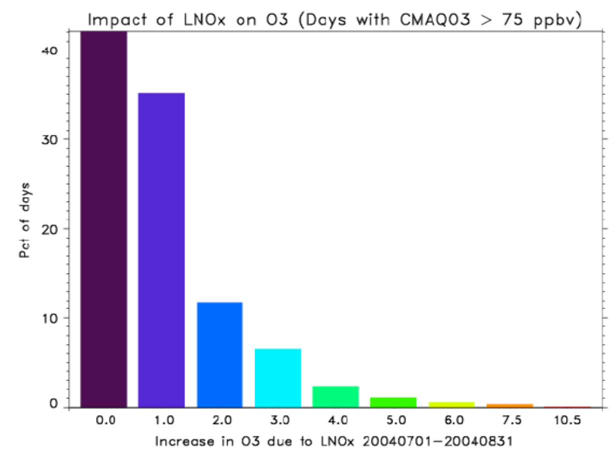
Links to meteorological parameters (T, RH, WS, Radiation, etc.)



Global Distribution of Lightning Activity



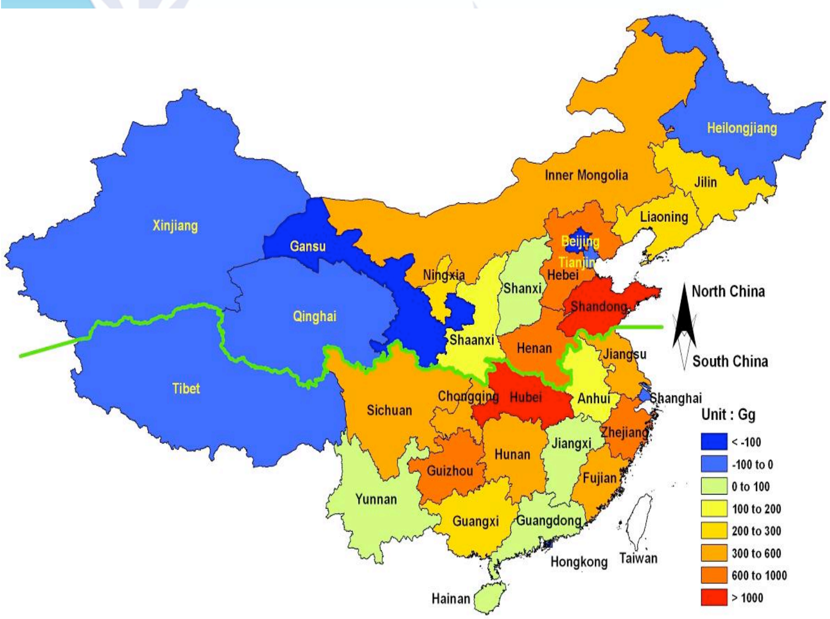
Mean annual global lightning flash rate (flashes km^{-2} yr^{-1}) derived from a combined 8 years from April 1995 to February 2003. (Data from the NASA OTD instrument on the OrbView-1 satellite and the LIS instrument on the TRMM satellite.)



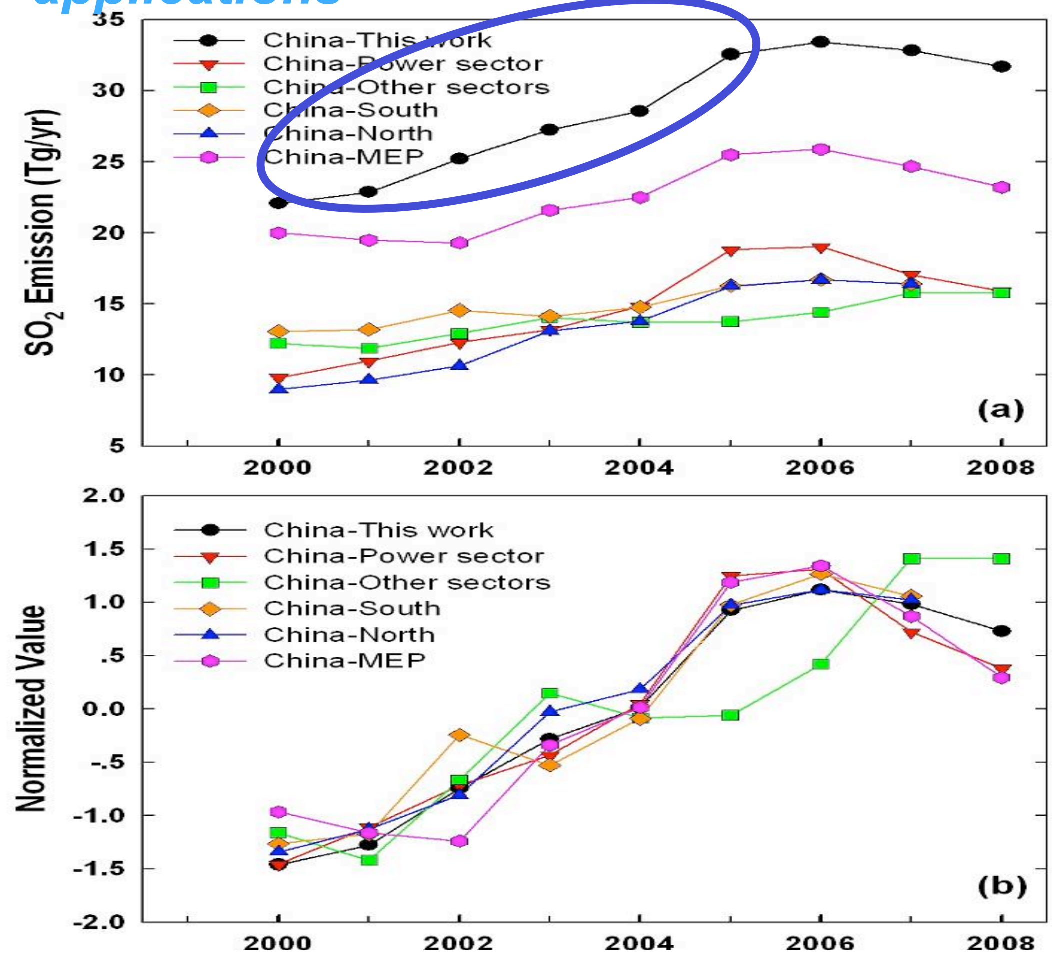
Pickering et al., 2009

AREP
GAW

Major Challenge: Emissions are a large source of uncertainty in AQ Forecasting: ***Emissions change over scales often not captured in current inventories, but updated inventories are needed for many applications***

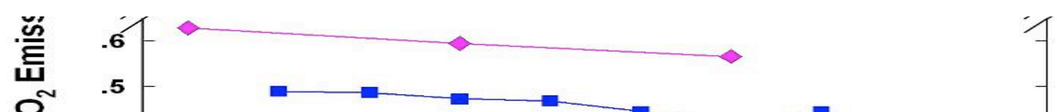


Change of SO2 emission in China between 2000 and 2007



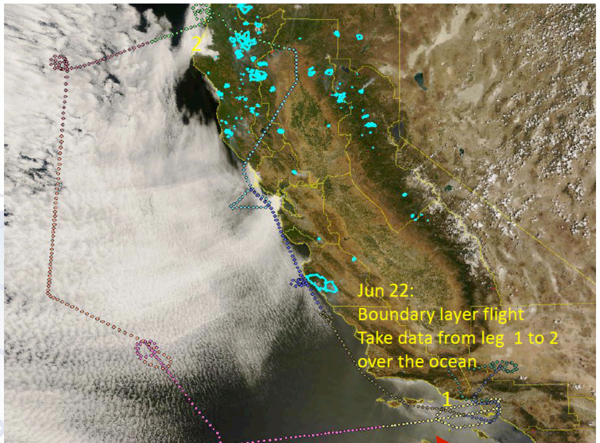
WMO
OMM

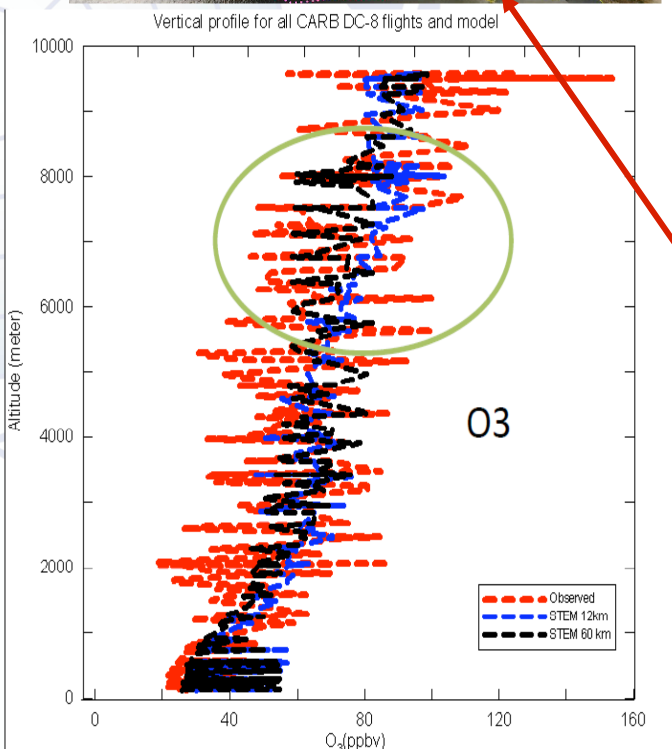
Streets et al., in prep.

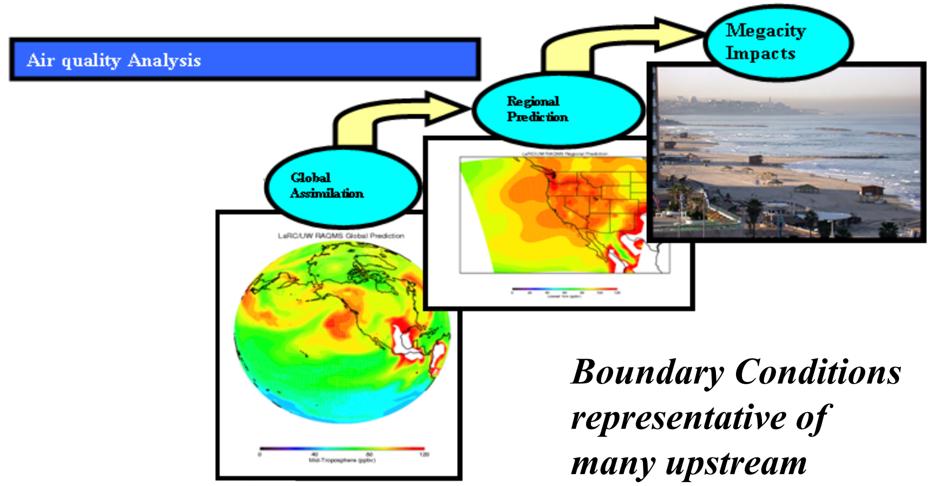


AREP
GAW

Major Challenge: Scales

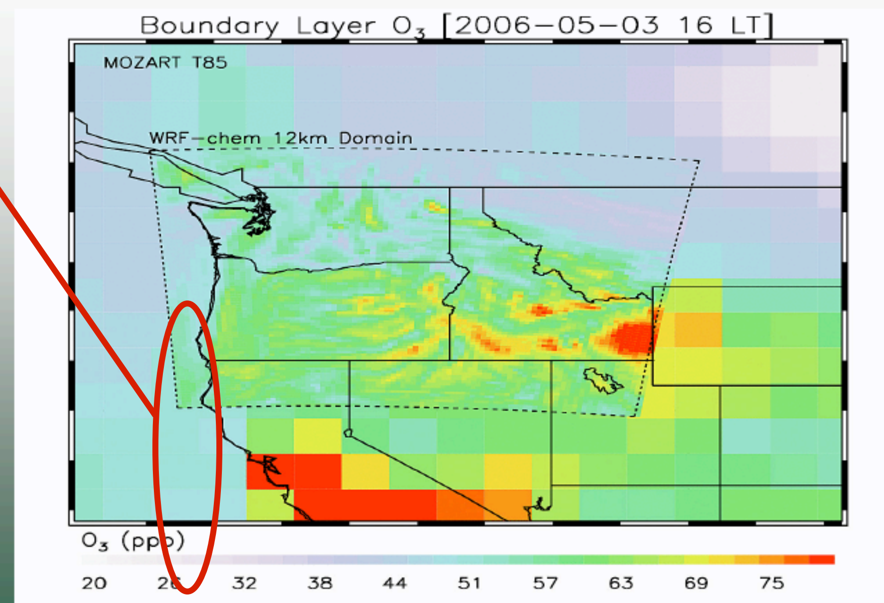






Boundary Conditions representative of many upstream processes are needed in AQ applications

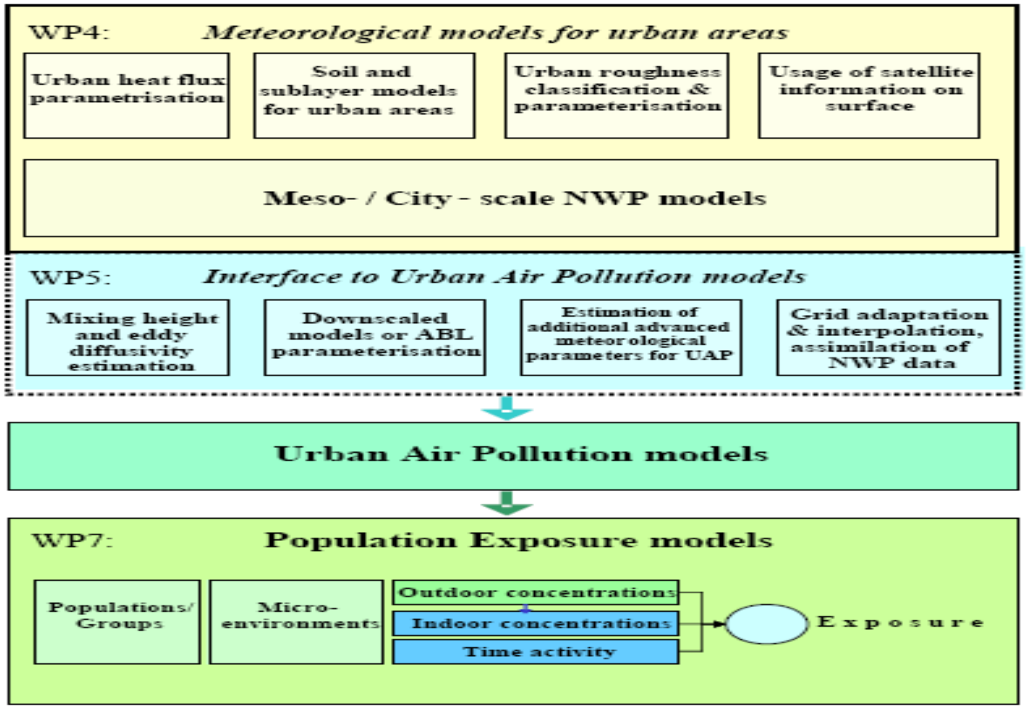
WRF-Chem (12 km) in MOZART (T85)

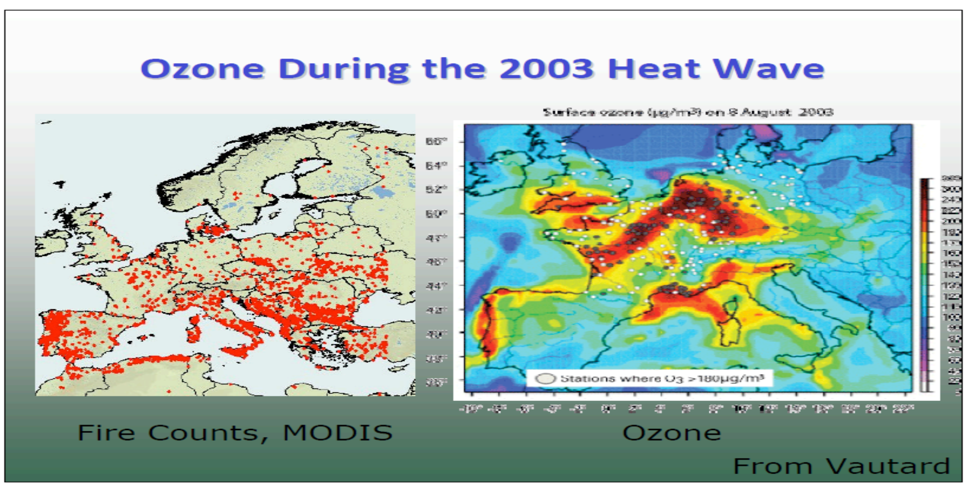


WMO
OMM

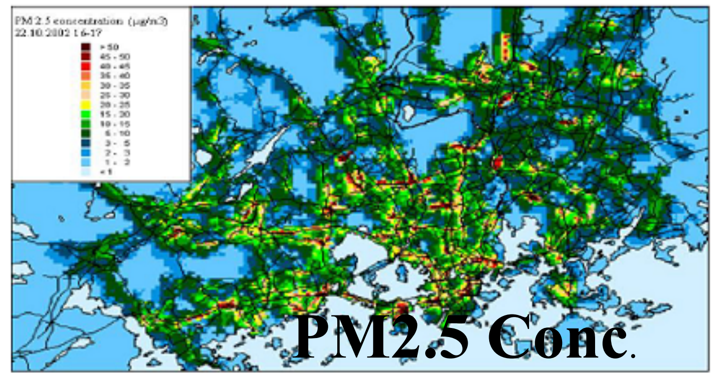
AREP
GAW

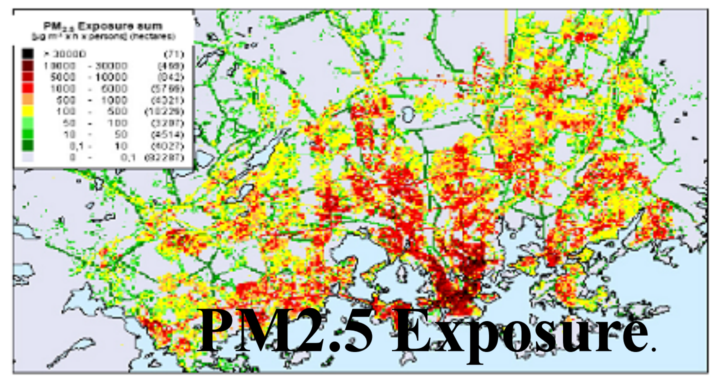
Major Challenge: Linking Meteorology, Air Quality and Human Health





Additional measurement and modeling requirements are needed for urban applications





Baklanov et al., ACP, 2007

COST 728 & MEGAPOLI related

WMO
OMM

AREP
GAW

Environmental Prediction into the Next Decade: Weather, Climate and the Air We Breathe (*Day 2 Summary*)

Weather/Climate services

↕

Environmental Services (Atmosphere)

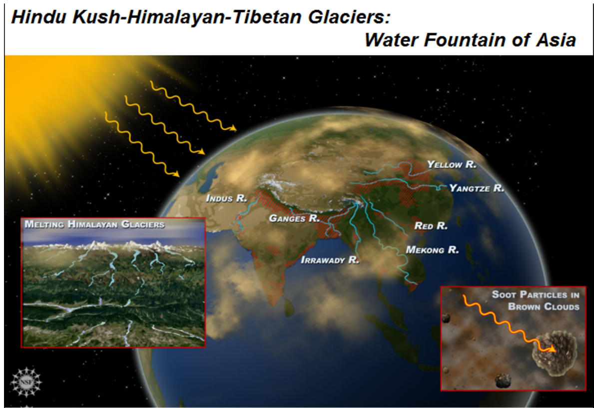
↕

Environmental agencies

provide data & information on →

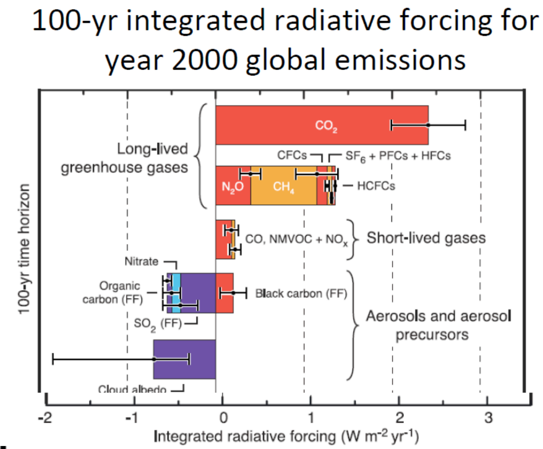
- Climate forcing by gases and aerosols
- Long-range pollutant transport
- Air quality
- Dust outbreaks
- Solar energy
- UV radiation
- Flooding/high impact precip. & connections to water QQ

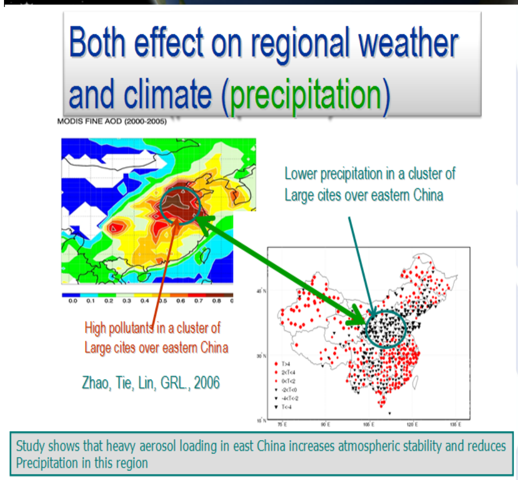
WMO
OMM

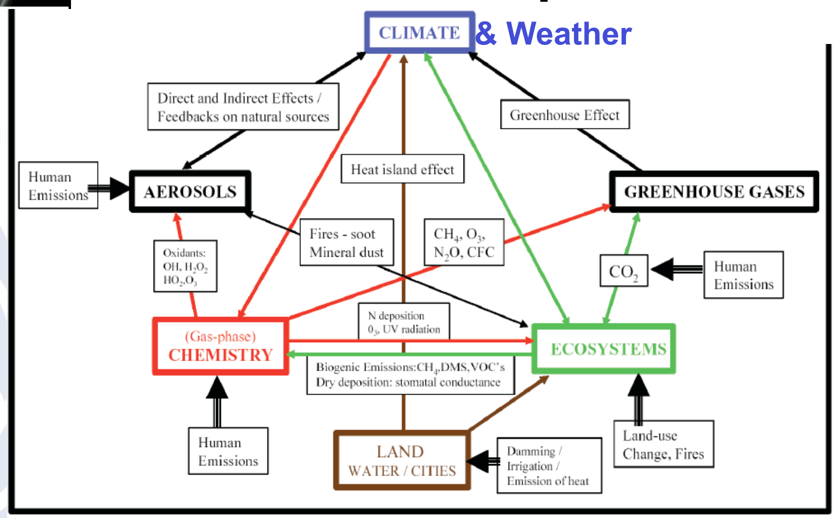


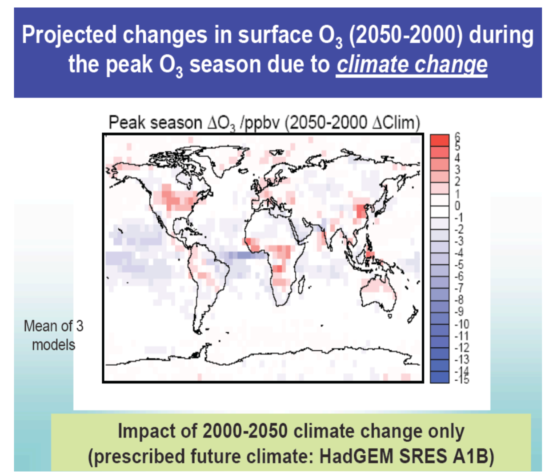
A Major Challenge: Characterizing The Interactions Between Air Pollution, Weather And Climate That Are Many And Complex

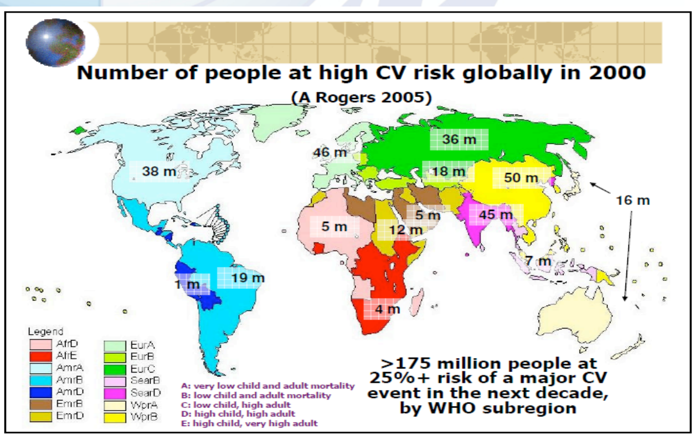
Based on P. Cox, 2004



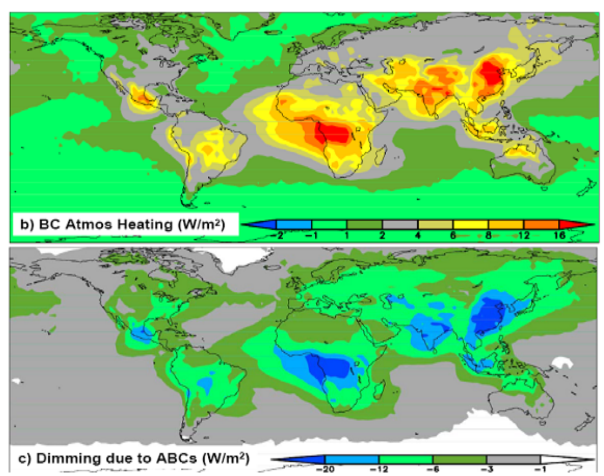


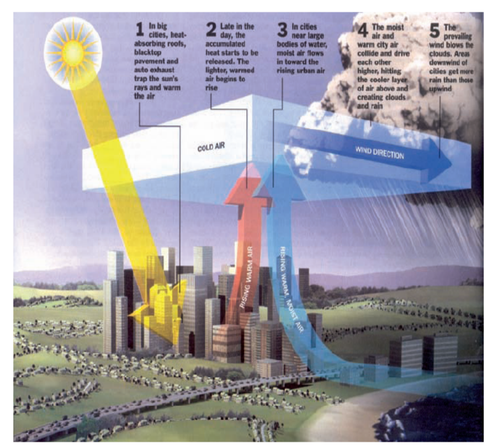






~800,000 excess deaths per year globally
no region immune!

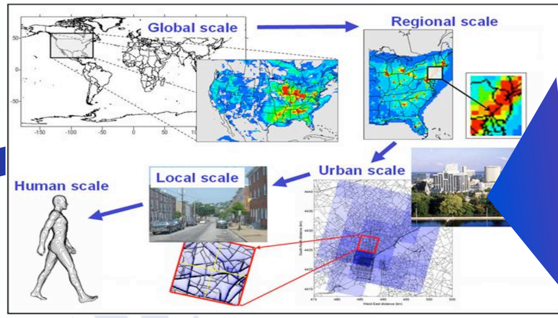


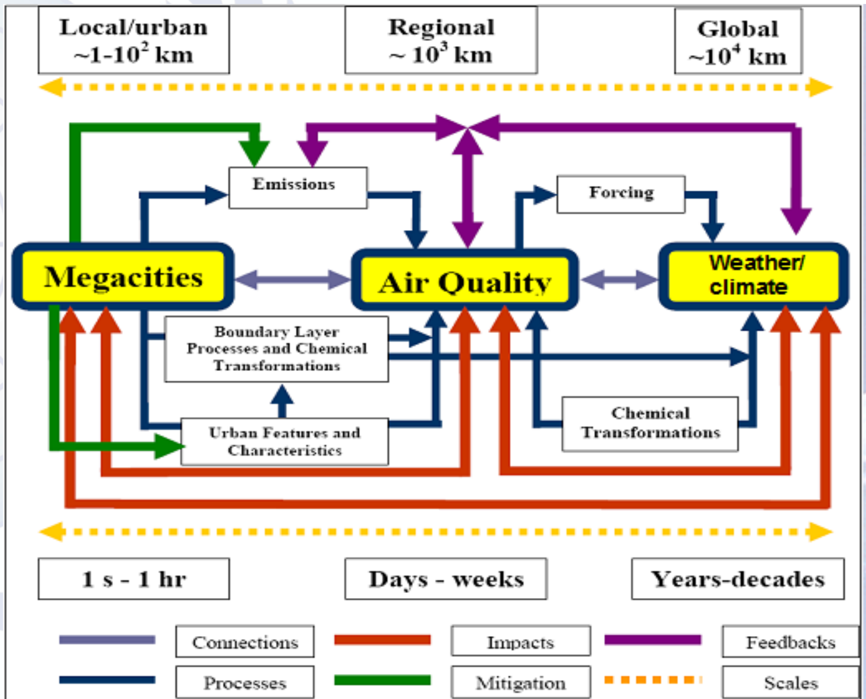


AREP
GAW

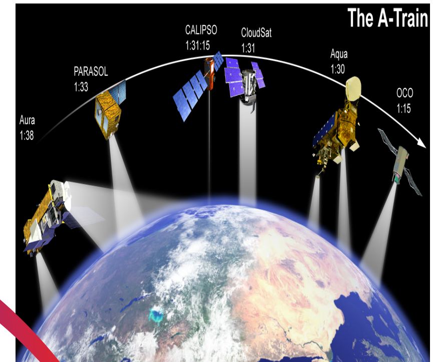
Integrated Air Quality – Weather – Climate Services for the Betterment of Both

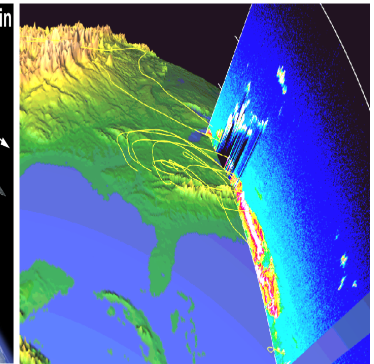
AQ Services



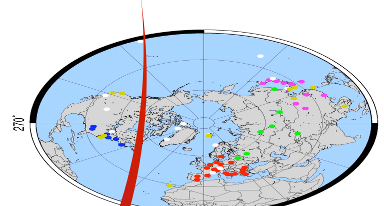


Linkages
GHGs
Air polls.

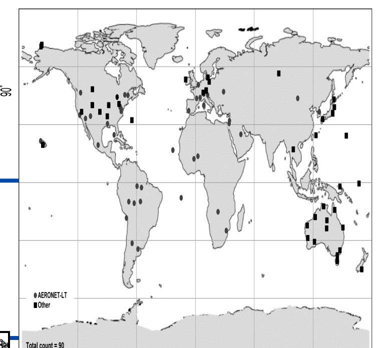




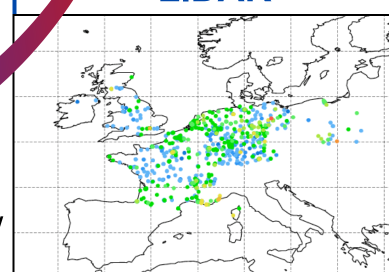
Three dimensional observing systems & Geostationary Satellite Obs



GALION Surface-based LIDAR



GAW/AERONET/ SKYNET Surface-based AOD



PM

Integrated Air Quality Met. Models and assimilation systems

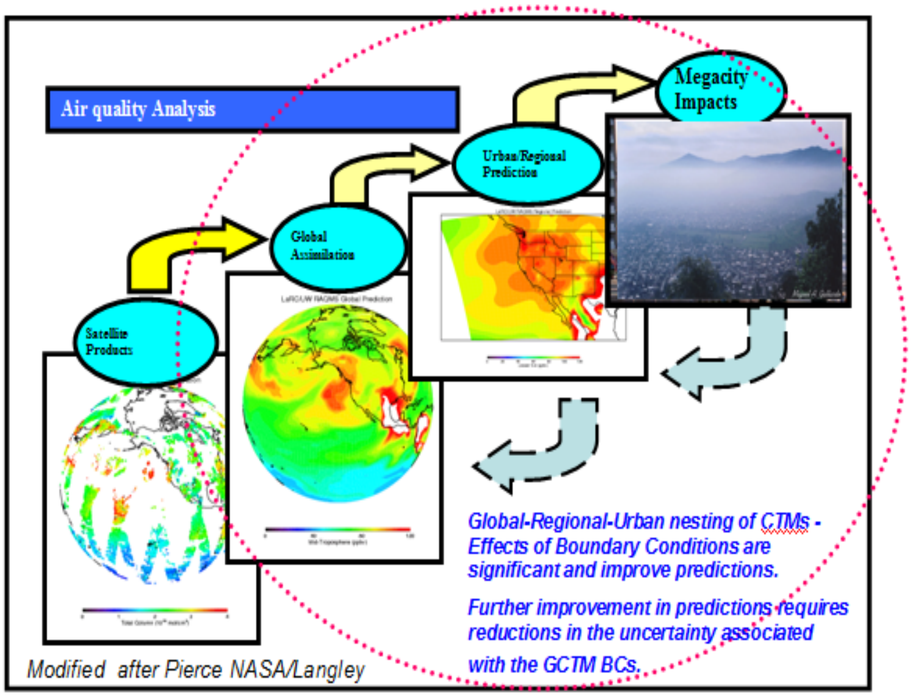
Real & NRT data flows

WMO
OMM

AREP
GAW

Environmental Prediction into the Next Decade: Weather, Climate and the Air We Breathe (*Day 2 Summary*)

Prediction: A Challenge of Scales and Integration



Air Quality ↔ Weather ↔ Climate

Common Challenges

- More Observations (x 10?)
  - Atmosphere
  - Ocean
  - Terrestrial
  - Satellites
  - Improved Instrumentation
- Improved Modeling to Serve Smaller Footprints
  - Transport (÷ 10?)
  - Boundary Layer Understanding
  - Assimilation, Inversion, Diagnosis
  - Prediction
- Enhanced Computing Capacity

QA/QC, Data Management

NRT data flows

But larger geographic extents

WMO
OMM