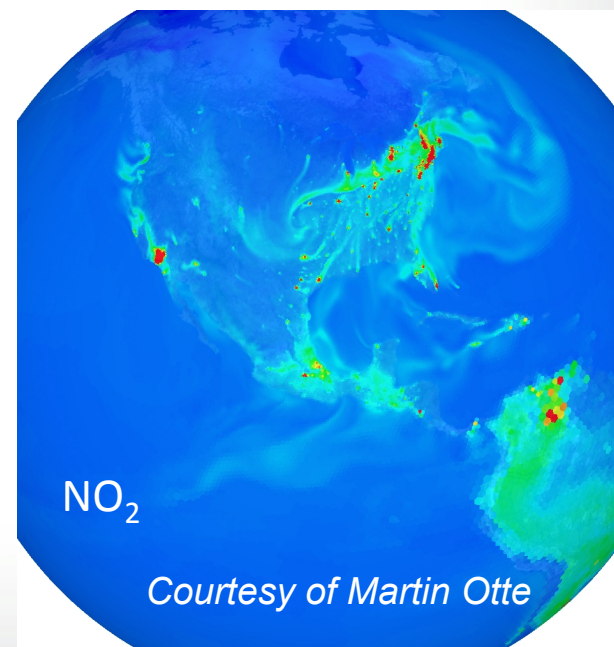




Next Gen AQ model

- **Need AQ modeling at Global to Continental to Regional to Urban scales**
 - Current systems using cascading nests is cumbersome
 - Duplicative modeling in overlap regions
 - Interpolation errors at boundaries
 - Seamless multi-scale grid refinement (e.g. OLAM, MPAS)
 - Minimize interpolation errors in transition from coarse to fine resolution
- **Tighter AQ standards require global modeling:**
 - Inter-continental transport (Ozone and PM)
 - Stratospheric ozone
 - Marine chemistry
- **Earth system Linkages**
 - Greenhouse gases
 - Nitrogen, carbon cycling
 - AQ – Climate interactions
 - Eco, hydro linkages



Courtesy of Martin Otte

OLAM-Chem



Need for online Met-Chem model

- **Growing trend toward integrated Met-Chem modeling**

- Improve NWP – radiative feedbacks and satellite data assimilation
- Regional climate-chemistry modeling including SLCF
- Improve AQ modeling

- **Chem affects Met which affects AQ**

- Aerosol direct effects
 - Reduced SW ground → reduces PBL → greater concentrations
- Aerosol indirect effects
 - Effects cloud cover, COD, radiative forcing, precipitation
 - Effects propagate through AQ
- Gaseous direct effects on LW
 - Ozone, methane, N_2O , etc
- AQ effects on land surface
 - Ozone damages stomatal function which affects:
 - Transpiration, CO_2 uptake, dry deposition
 - CO_2 changes, including regulatory controls, affect stomatal conductance

INTEGRATED METEOROLOGY AND CHEMISTRY MODELING Evaluation and Research Needs

by JONATHAN PAUL, RICHIE MCKINLEY, S. T. RAO, JUDITH EAGLE, AND ALEXANDER DIMITROV

Over the past decade several online integrated atmospheric chemistry, meteorology, and meteorology modeling systems with varying levels of interaction among different atmospheric processes have been developed. A variety of approaches to meteorology, chemistry, and radiation have been developed, and significant progress has been made in the development of these systems. There have been many research efforts for coupling meteorology and chemistry in an integrated modeling system, including the following:

WORKSHOP ON INTEGRATED METEOROLOGY AND CHEMISTRY MODELING

Workshop: Forty scientists from government, academia, and the private sector in the United States, Canada, and Europe discussed issues among different approaches to integrated meteorology and chemistry modeling, such as: numerical weather prediction, air quality modeling, and climate modeling.

Workshop: 18 October 2012

Workshop: Chicago, Illinois, USA

1) Improved numerical weather prediction by including the effects of aerosols and gases on radiative and cloud processes, such as increasing satellite accuracy and data assimilation for NWP operations and providing accurate and reliable data of aerosols and radiative forcing.

2) Regional climate-chemistry modeling, including direct and indirect radiative forcing from short-lived climate forcing (SLCF).

3) Improved air quality modeling for human exposure to chemical and physical processes and the effects of aerosols and gases on health and on radiative forcing, such as temperature, and planetary boundary layer (PBL) processes, and for air quality and climate.

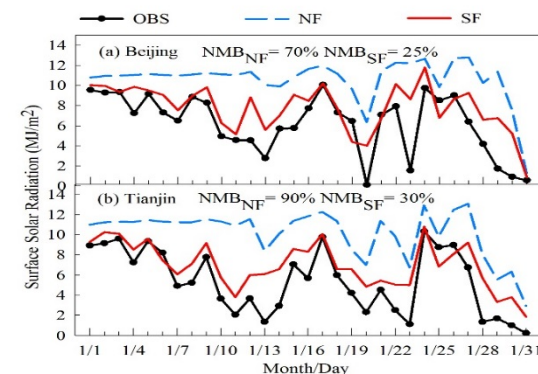
4) Policy assessment of the efficacy of various emission control policies in improving ambient air quality under various conditions.

The benefits of online integrated models over regional meteorology and chemistry transport models are discussed, however, there are still many challenges and many have a significant role of view as well as from a policy perspective. The first

AMERICAN METEOROLOGICAL SOCIETY

AMERICAN METEOROLOGICAL SOCIETY

BAMS 2014

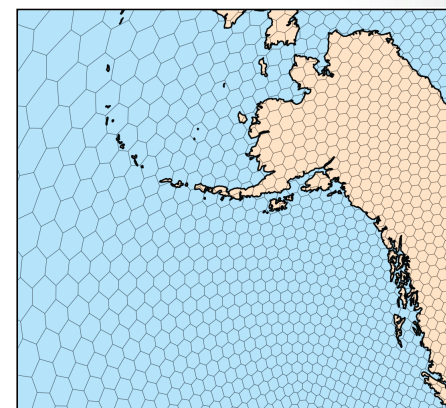
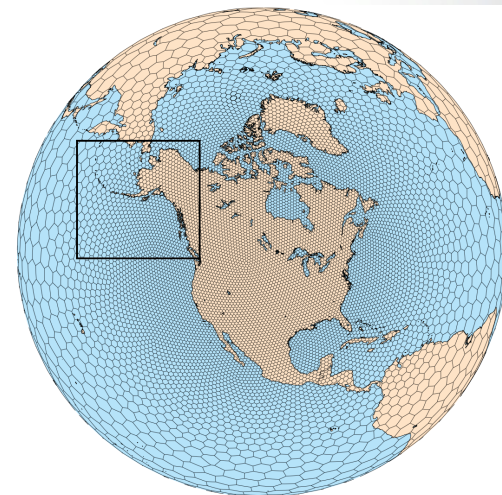


Jiandong Wang et al., 2014, ERL



Vision

- **Extend to global scales**
 - Single global mesh with seamless refinement to local scales
 - Integrated chemistry, dynamics, physics
- **Three configurations of flexible systems:**
 - On-line global variable grid (e.g. MPAS, OLAM)
 - Online regional (WRF-AQ)
 - Offline regional (redesigned CMAQ)
- **Interoperability of as much model code as possible**
 - Gas, aerosol, aqueous in modular box
 - Modules for biogenic emissions, dry dep/bidi, wind-blown dust, photolysis, etc
- **Transport in met models for online systems (adv, diffusion)**
 - Ensure mass conservation
 - Consistency with met parameters
 - Minimize numerical diffusion and dispersion



MPAS



Community development

- **Initial discussions among EPA, NCAR, NOAA, DOE**
 - Leverage diverse expertise across community
- **Multiple purposes:**
 - Air quality policy development and regulation
 - Air quality forecasting
 - Atmospheric chemistry research
 - Climate modeling with short-lived climate forcers
 - Earth system applications: coupled system for air, hydro, eco, ag, energy, etc...
- **Standardize model engineering for coupling chemical components to different dynamics models**
- **Initial steps: add chemistry to existing global models**
 - For example: MPAS-Chem, OLAM-Chem
- **Involve grant programs to foster development**
 - EPA STAR grants
 - DOE Model development grants



Integrated Met-Chem modeling

- **High temporal coupling (data exchange frequency > once per hour)**
 - Better resolve high-frequency meteorological dynamics
 - WS, WD changes, PBL height variations, cloud formation, rainfall
 - Affects chemical transport, transformation, and removal at high spatial resolution
- **More consistent dynamical, physical, and numerical modeling**
 - More constant cloud convective transport of chemistry and met
 - Closer integration of cloud microphysics and aqueous chemistry
 - More consistent advection and diffusion
- **On-line chemistry necessary for global models with non-uniform, refining grid meshes (e.g. OLAM, MPAS)**
 - Advection and horizontal diffusion must be integrated in dynamics solver

Domain config	WRF-CMAQ	WRFadv-CMAQ	Data transfer (min)	Increased time
CA 12 km, 16 cores	1:44:20	2:09:07	2.6	24% (3 run avg)
CA 4 km, 64 cores	9:37:21	15:05:05	46	57% (4 run avg)