Towards an Earth System Model: Chemistry in the FIM and its effect on forecasting weather and air quality

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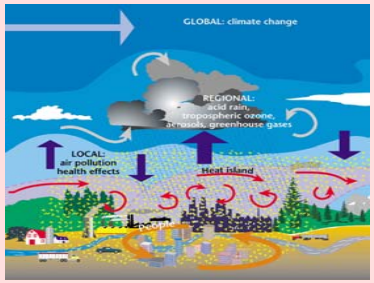
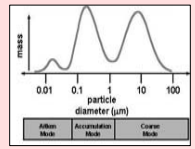
Why do we build Earth System Models?



- Complex interactions of various processes on many scales
- Many different type of models that are only loosely related
- The interactions of these processes can be important for weather and air quality forecasting,
- These interactions are essential for global climate change processes.

Available Aerosol Modules



1. Total aerosol mass transport, emissions, and deposition only
2. Simple aerosol modules from Goddard Chemistry Aerosol Radiation and Transport model (GOCART) (9 variables + dust + seasalt)
3. Modal approach (30 variables + dust + seasalt)

Global Chemistry Module - Based on Kinetic Preprocessor (KPP)

Model for Ozone and Related Chemical Tracers V4 (MOZART V4), widely used in the community, originates at NCAR

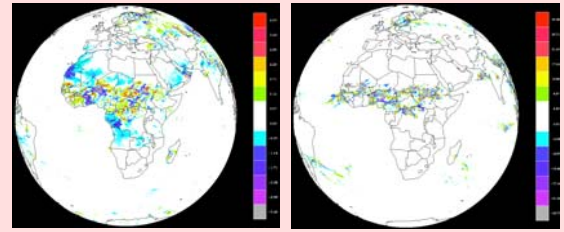
- 85 gas species
- 39 photolysis reactions
- 157 gas phase reactions

Uses climatologies in stratosphere, intended for tropospheric studies

Comparison of differences of two 120hr forecasts: with aerosol direct effect – without aerosol direct effect

Temperature difference (°C) of runs with and without aerosol direct effect (120hr forecast)

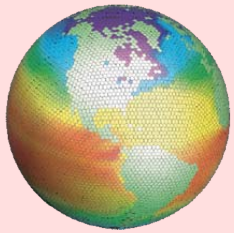
Accumulated rainfall differences (mm) for runs with and without aerosol direct effect (120hr forecast)



Aerosol direct and semi-direct effect: May be important even for forecasting applications!

The Flow-Following Finite-Volume Icosahedral Model (FIM): Improved Conservation Using Quasi-Material Surfaces

In the atmosphere: hybrid (sigma/ isentropic) vertical coordinate



Initial Atmospheric Components

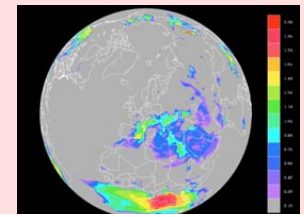
1. Atmosphere – 64 -100 levels, top~0.1 hPa/60km
2. Land-surface/snow/vegetation – 4 levels
3. Chemistry – aerosols, ozone, wildfires, volcanoes, anthropogenic and biogenic emissions

FIM-Chem Simulations with Approximately 30km Horizontal Resolution

- **Initialized with analysis from NCEP's Global Forecast System (GFS)**
- **Anthropogenic emissions from global data base, using EDGAR/RETRO data set as well as global emissions data sets for aerosol species provided by NASA (Mian Chin) and GFDL (Paul Ginoux)**
- **Fires initialized with Satellite data from the Wild Fire Biomass Burning Algorithm (WFABBA) for the Americas and MODIS fire products for the rest of the world**
- **GFS physics, except for the Grell-Devenyi convective parameterization and the two moment Lin et al Microphysics parameterization from the Weather Research and Forecast (WRF) model**

FIM predicted averaged integrated carbon at times of deadly forest fires in Southern Europe (Spain, France, and Sardinia)

72hr prediction valid 24 July 2009, 1200UTC



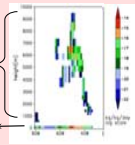
Wildfires influence air quality as well as weather and climate patterns

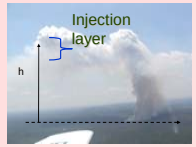
Biogenic Emission Sources

Wildfire emission

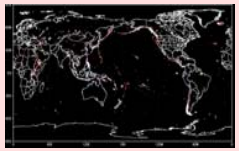
flaming emission

smoldering emissions

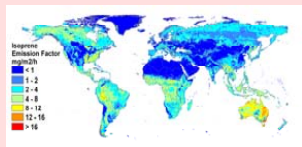




Available volcanoes for FIM

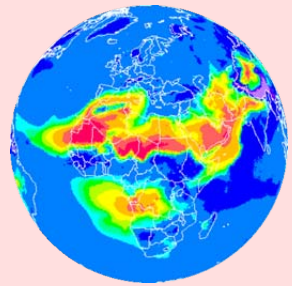


Global biogenic emissions model: Model of Emissions of Gases and Aerosols from Nature (MEGAN)



FIM - 10-Day Prediction of Total Integrated PM2.5:

- Large source of dust over the Sahara and southwest Asia
- Biomass burning sources over Africa and South America
- Anthropogenic carbon sources large over northern India



Total vertically averaged and integrated PM2.5 concentrations are displayed with logarithmic scaling

Conclusions

- Complex FIM-Chem runs with biogenic and anthropogenic emission data sets were successful
- FIM can run coupled with sophisticated as well as simple chemical gas-phase and aerosol modules
- Direct and semi-direct aerosol effect may be significant – even for medium range weather forecasting
- The chemistry modules from WRF-Chem are very modular and can be plugged into any modeling system. This will allow for a direct performance comparison of ESMF implemented code versus inlined code.

Future Work

- Seasonal simulations to look at direct and semi-direct effect
- Aerosol-microphysics interaction (indirect effect) - FIM can run coupled with sophisticated as well as simple chemical gas-phase and aerosol modules
- How does online chemistry influence meteorological data assimilation