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 + sea salt)
3. Modal approach (30 variables + dust + sea salt)

Global Chemistry Module - Based on Kinetic Preprocessor (KPP)
- 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 (%)
- Accumulated rainfall differences (mm) for runs with and without aerosol direct effect (120hr forecast)

Available volcanoes for FIM


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)

Biogenic Emission Sources

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