Coupled modeling systems that allow for aerosol/air quality/weather/climate interactions

Georg Grell (GSD)

Steven Peckham(GSD), Stuart McKeen (CSD), Mariusz Pagowski (GSD)

Many national and international collaborators (PNNL, NCAR,….) for WRF/Chem

And the ESRL FIM group

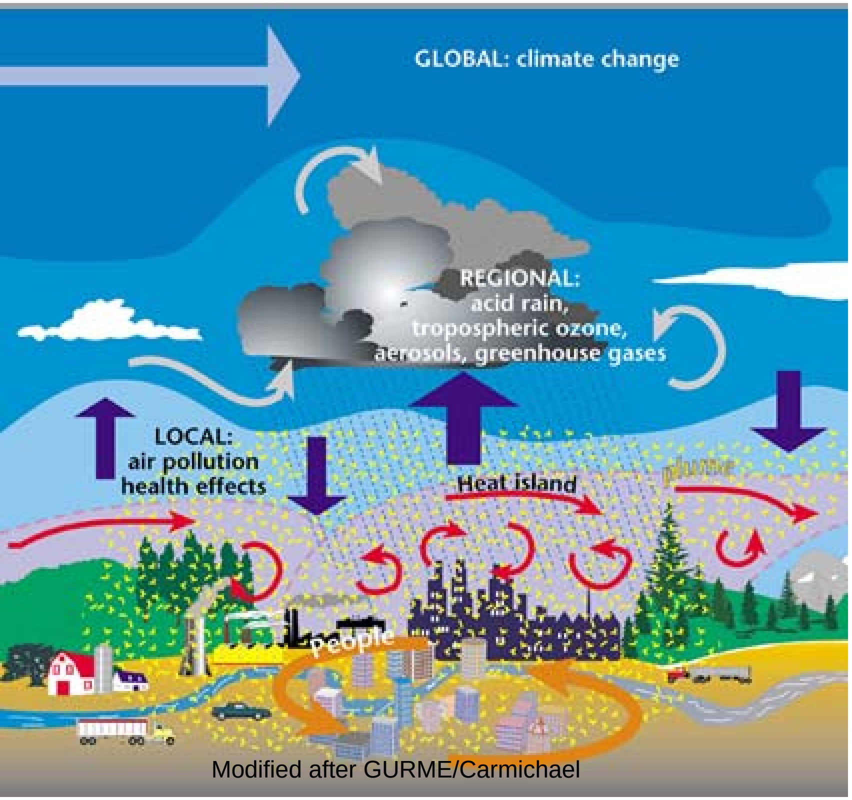
ESRL

Outline

- Sharpening a tool to study aerosol impacts: WRF/Chem and global to cloud scale modeling, aerosol capabilities, wildfires
- A new global ESRL model: FIM/Chem
- Chemical data assimilation

Will not talk much about Large Eddy Simulation (LES) Models

Why do we couple models?



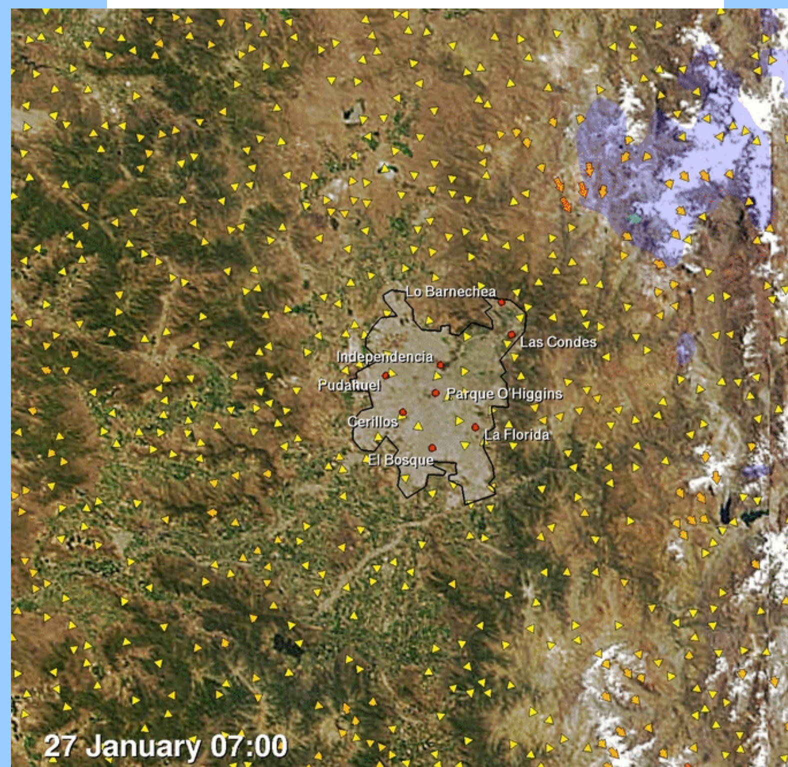
Modified after GURME/Carmichael

- 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 very important

<u>Aerosol processes represent probably the most important link between weather/climate and air quality</u>

WRF/Chem: Online coupling of modeling systems

Simultaneous forecast of weather and air quality



Chemistry, Aerosols, radiation, clouds, temperature, winds

Weather Data Analysis & Assimilation & Emissions

Weather and AQ-Forecast

Full interaction of meteorology and chemistry

WRF/Chem: widely used nationally and internationally, development led by ESRL

- Automatic generation of chemical mechanisms (the part of the model that treats the interactions of the chemical species with each other),
- Multiple aerosol modules (simple to very complex), including direct and indirect effect
- Biogenic emissions, deposition
- Coupled with a sophisticated fire plume rise model
- Global to local scale (**Large Eddy Simulation and cloud resolving**) applications, 1- and 2-way nesting capabilities

Many of the chemistry modules are verified by scientists from CSD and PSD

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Currently available aerosols modules

1. Total aerosol mass transport, emissions, and deposition only
2. Simple aerosol modules from Goddard Chemistry Aerosol Radiation and Transport model (GOCART)
3. Modal approach
4. Sectional approach

Aerosol radiation and microphysics interaction is included for (3) and (4)

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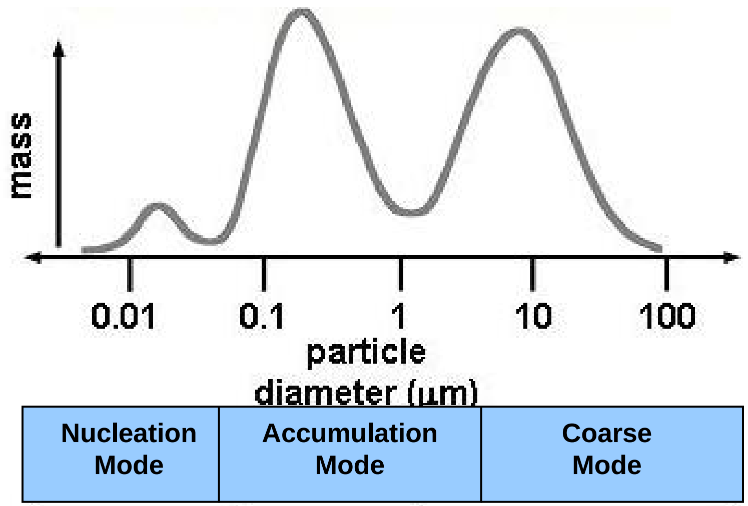
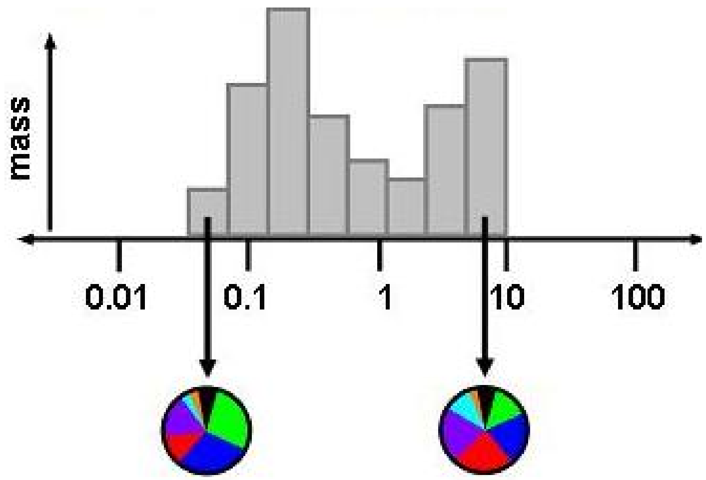
Aerosol modules comparison

(1) Modal



composition
sulfate
nitrate
ammonium
chloride
carbonate
sodium
calcium
other inorganics
organic carbon
elemental carbon

(2) Sectional

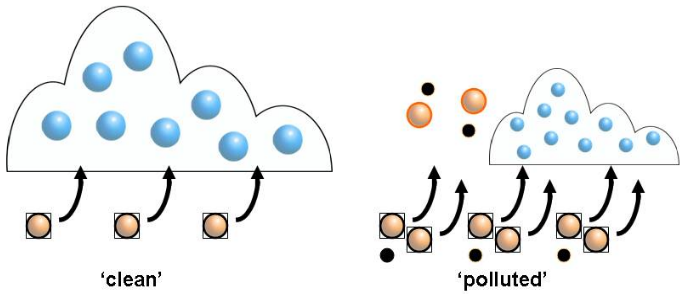


(3) GOCART: Sections for dust and sea salt, otherwise total mass only

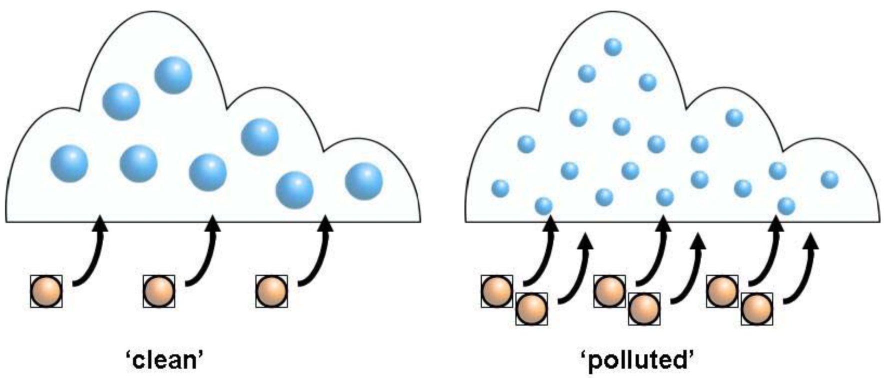
Aerosol effects included in WRF/Chem

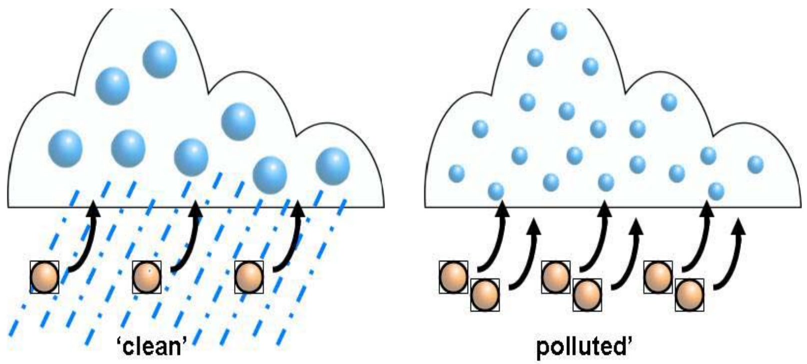
Absorption effect

Direct Interaction with radiation



Direct Interaction with microphysics



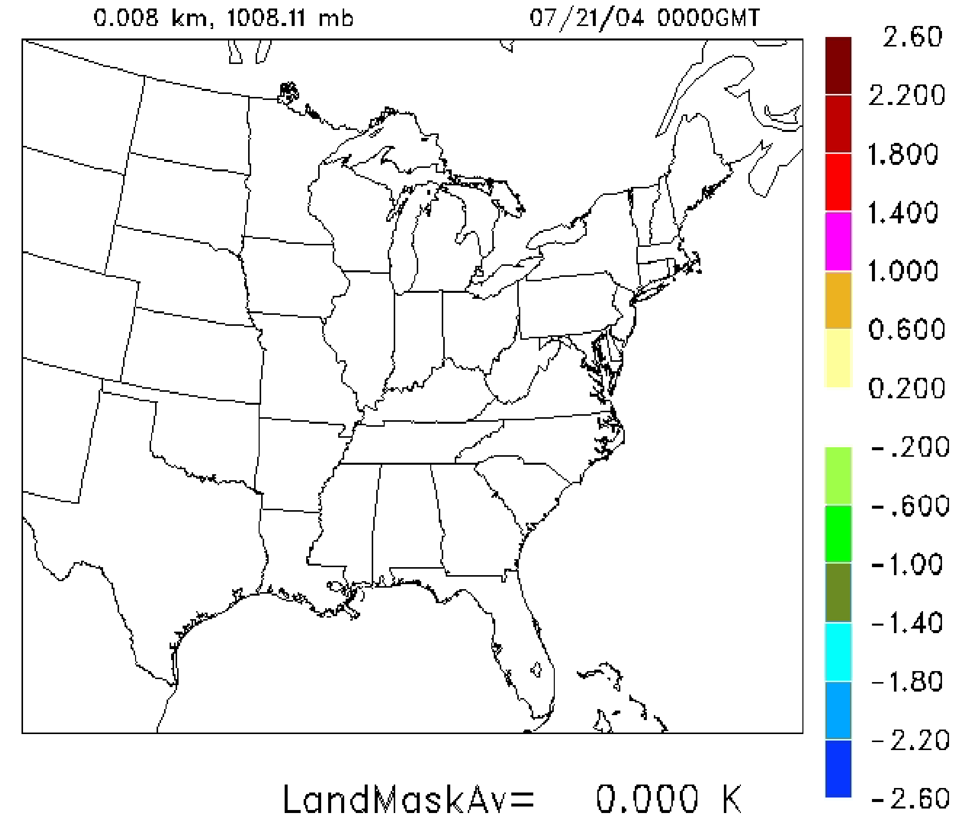


Aerosol feedback effects for modal and sectional approach only

WRF/Chem Aerosol related ongoing development work

- Hailong Wang and Graham Feingold (ESRL/CSD): Implementation of double moment bulk microphysics scheme (Feingold et al. 1998)
- Gordon McFiggans (U of Manchester, UK), implementing their multicomponent aerosol approach
- Karla Longo and Saule Freitas (CPTEC, Brazil) looking at aerosol direct effect
- Mian Chin et al. (NASA) will be looking at GOCART related implementations, including aerosol direct effect
- Graham Feingold and Hailong Wang (ESRL/CSD): Implementation of TelAviv sectional microphysics that includes CCN activation, condensation/evaporation, stochastic collection, and sedimentation
- Mike Kleeman and others from UC Davis: Source oriented approach

Absorption effect – WRF/Chem simulation



T2m differences

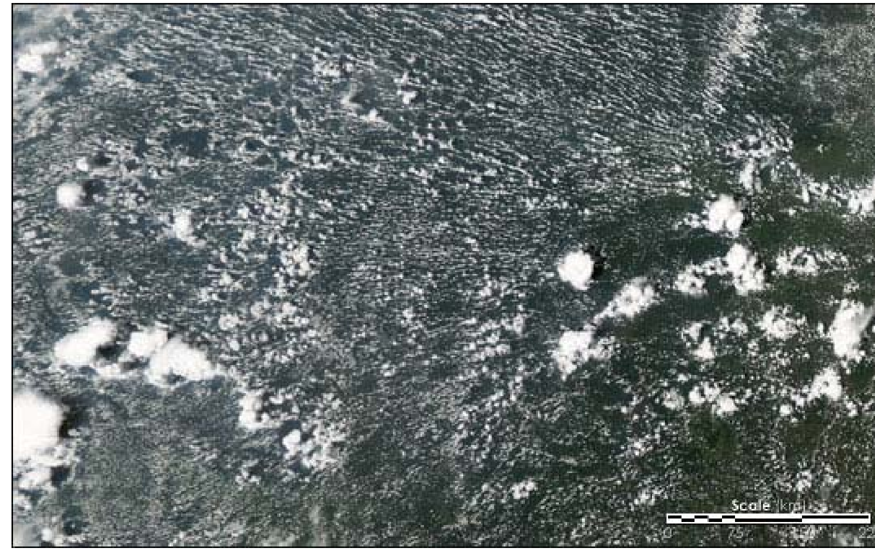
Large uncertainties in representation and estimation of absorption effect

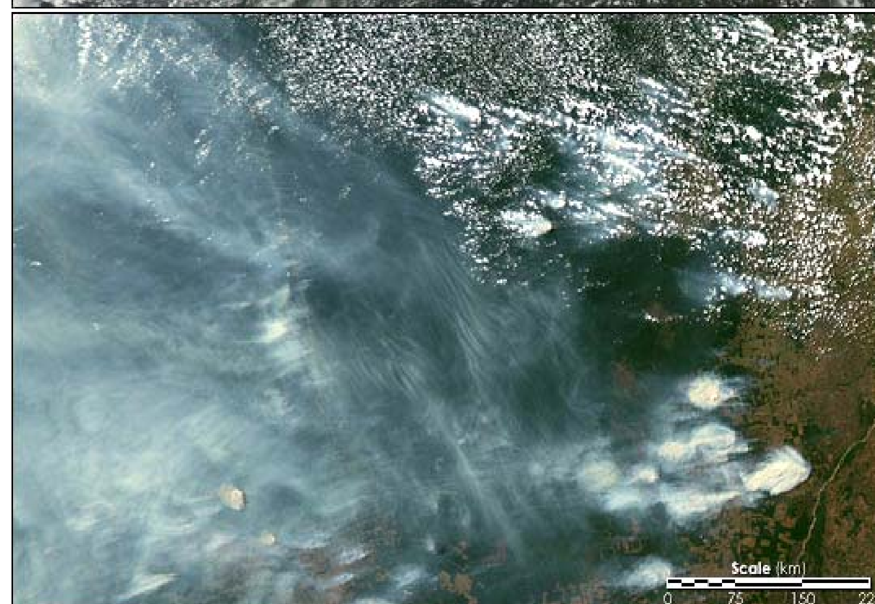
A model within a model : Fire plume rise (Collaboration with Saulo Freitas from CPTEC in Brazil and ARSC in Fairbanks, Alaska)

Wildfires in WRF/Chem initialized with:

- Readily available remote sensing satellite information (real-time or historic, MODIS and WFABBA)

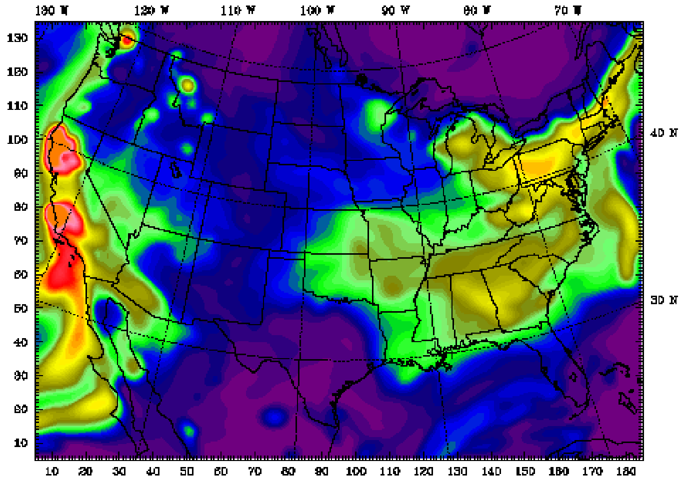
Allows to study the impact of wildfires on clouds/weather and air quality





Prediction of aerosol impacts during fire season in real-time at ESRL

1. GOCART aerosols with ozone chemistry, and no aerosol feedback to meteorology
2. Sectional aerosol scheme with ozone chemistry and full feedback to meteorology (radiation, microphysics, aqueous phase chemistry), 36hr predictions once a day, 27km dx, CONUS domain, 100's of extra varibles!
3. (1) and (2) will run with chemical data assimilation, model output includes visibility, Aerosol Optical Depth (AOD)



July 20, 2008: Fires in California, Idaho, and Montana

24hr prediction from (1)

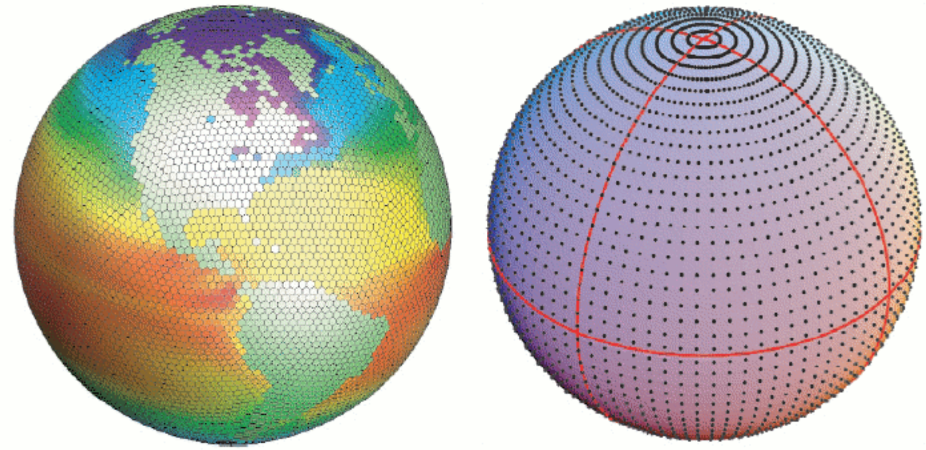
Some news on global model development

Open doors to:

- global chemical data assimilation
- chemical boundary conditions for regional/local modeling
- possibly more climate applications

FIM: A Global Flow-Following Finite-Volume Icosahedral Model with 3 Unique Features

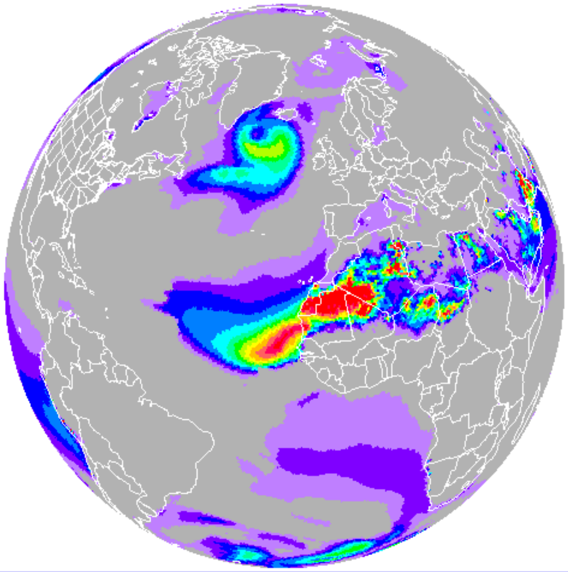
1. Icosahedral grid



2. Adaptive, hybrid-isentropic vertical coordinate
3. Because of the modularity within WRF/Chem a direct link has been established between FIM and WRF/Chem – keeping all WRF/Chem functionality
4. Initial test currently limited to simple aerosol modules (GOCART)

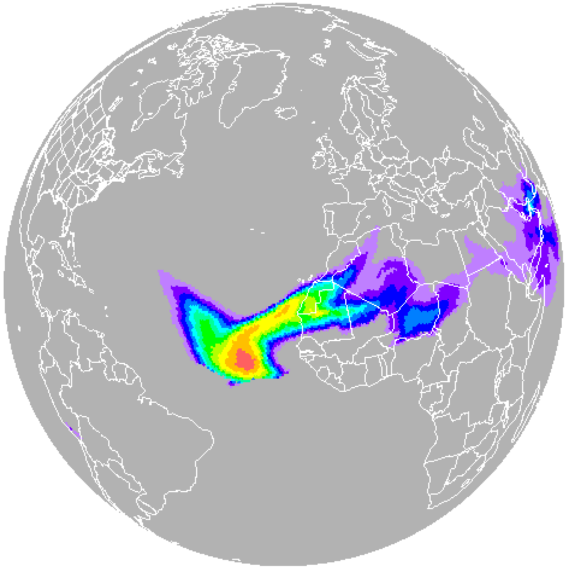
FIM-GOCART Dust and Sea-salt, 10day simulation, no anthropogenic emissions

Near Surface
PM2.5



Saharan Dust

mid-level



Chemical data assimilation

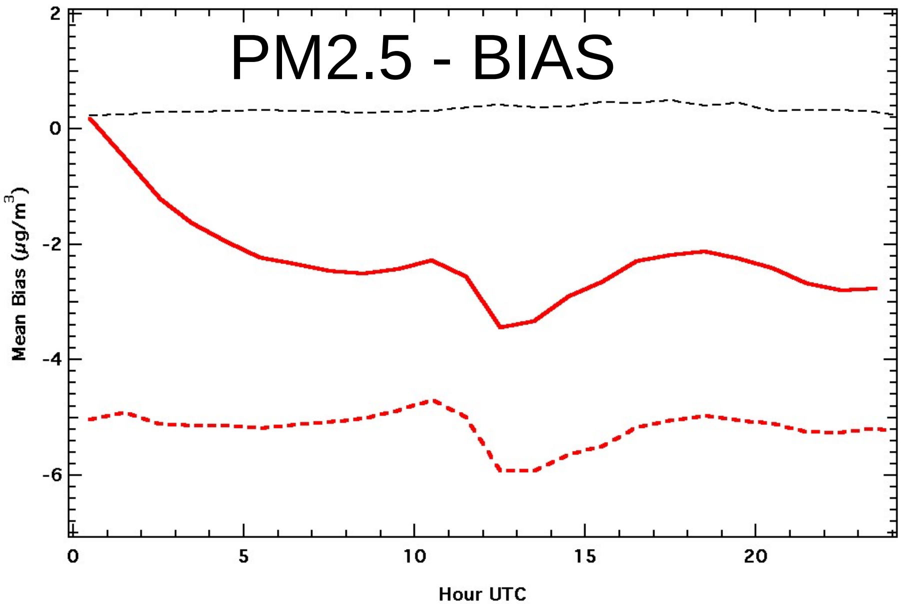
- Incorporation of available observations into modeling system to produce optimal initial state of weather/chemistry
- 3D variational analysis for Ozone and PM2.5 is used within the Grid Point Statistical Interpolation system (GSI) (at ESRL)
- In the future an adjoint of WRF/Chem will be developed for chemical data assimilation and research work

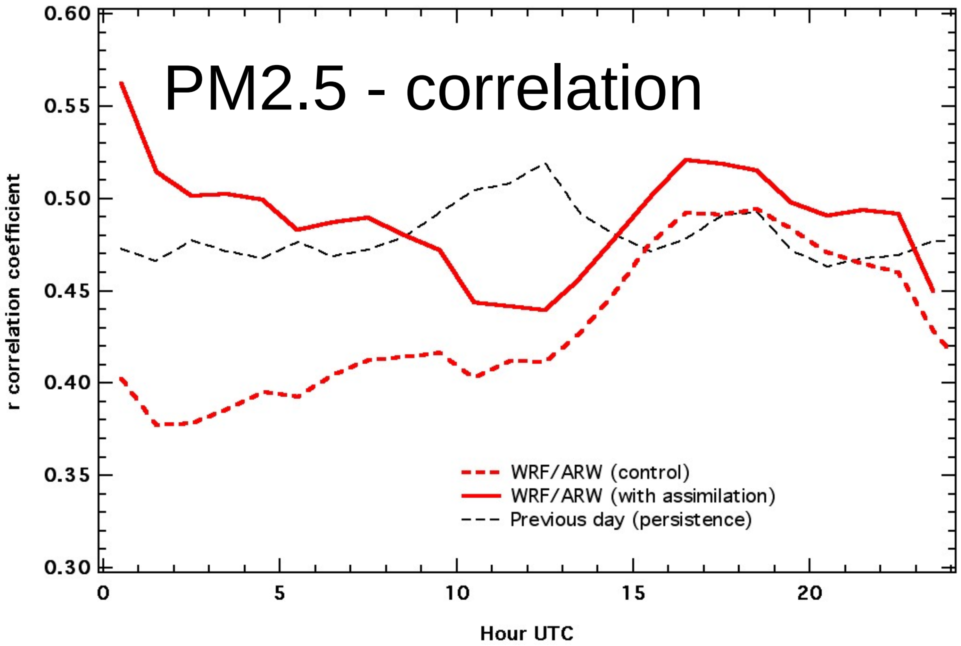
Chemical data assimilation

2 months worth of WRF/Chem runs:

1. New England 2004 to estimate background error covariances and lengthscales

2. Houston 2006 for evaluation





Large improvements in model forecasts of PM2.5, but much work left to do!

From ECMWF: Operational Data Requirements: The Importance of Atmospheric Composition

In addition to reactive and greenhouse gases:

- Aerosols: Modelling and assimilation of aerosols is an emerging issue for accurate NWP. Neglect of aerosol in NWP can lead to errors of
  - - 25W/m**2 in clear-sky radiation calculations
  - - 0.1-0.5K error in forward Radiation Transfer (RT, like CRTM) calculations in assimilation

The prediction and assimilation of aerosol is important for meteorological data assimilation