Global modeling and assimilation – **Earth System Modeling**

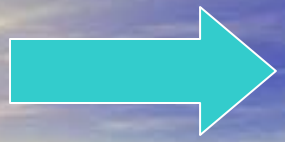
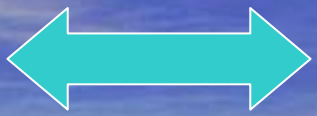
ESRL Theme Presentation

2:00 – 3:30 PM, Wed 7 May 2008

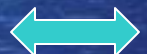
2:00	Intro to Earth System modeling, FIM	– Stan Benjamin
2:15	Icosahedral grid in FIM, NIM	– Jin Lee
2:30	FIM real-data tests	– John Brown
2:40	Global observations for assimilation, NCEP Gridpoint Statistical Interpolation	– Dezso Devenyi
2:55	Global assimilation with ensemble Kalman filter	– Jeff Whitaker
3:10	Panel discussion – presenters, Andy Jacobson, Georg Grell, Tom Schlatter	

An Earth System Model

Or, a Coupled Environmental Model

 Offline OR  Online

Components

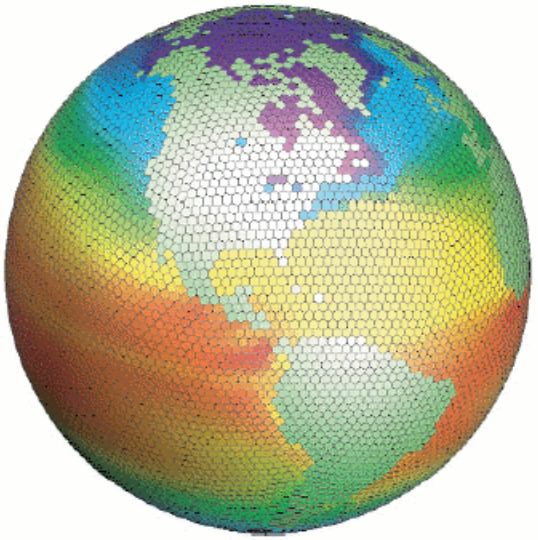
- Atmosphere – 3d – foundation
  - Include interactive treatment for radiation, clouds (resolved, sub-grid-scale (convective)), turbulent mixing
- Land-surface/snow/vegetation
  - Usually  , e.g., in RUC, WRF, NAM, GFS, etc.
- Chemistry (AQ, greenhouse gases), aerosols
  -  (Carbon Tracker, CMAQ/EPA)  (WRF-chem)
- Ocean, lakes (usually  in weather forecast models)
- Cryosphere – sea ice

An Earth System Model
Prognostic variables

Components

- Atmosphere – 20-100+ levels
  - T, p, u, v, qv, q* (hydrometeors), TKE
- Land-surface/snow/vegetation – 1-10+ levels
  - T, soil moisture, snow (water equivalent, density, temp)
- Chemistry (AQ, greenhouse gases), aerosols
  - CO_2, CH_4, SO_2, O_3, biogenic/anthropogenic aerosols, 100s more
- Ocean, lakes (T, p, salinity, ...)
- Cryosphere – (depth, temperature...)

Atmospheric Modeling



solutions to partial differential equations

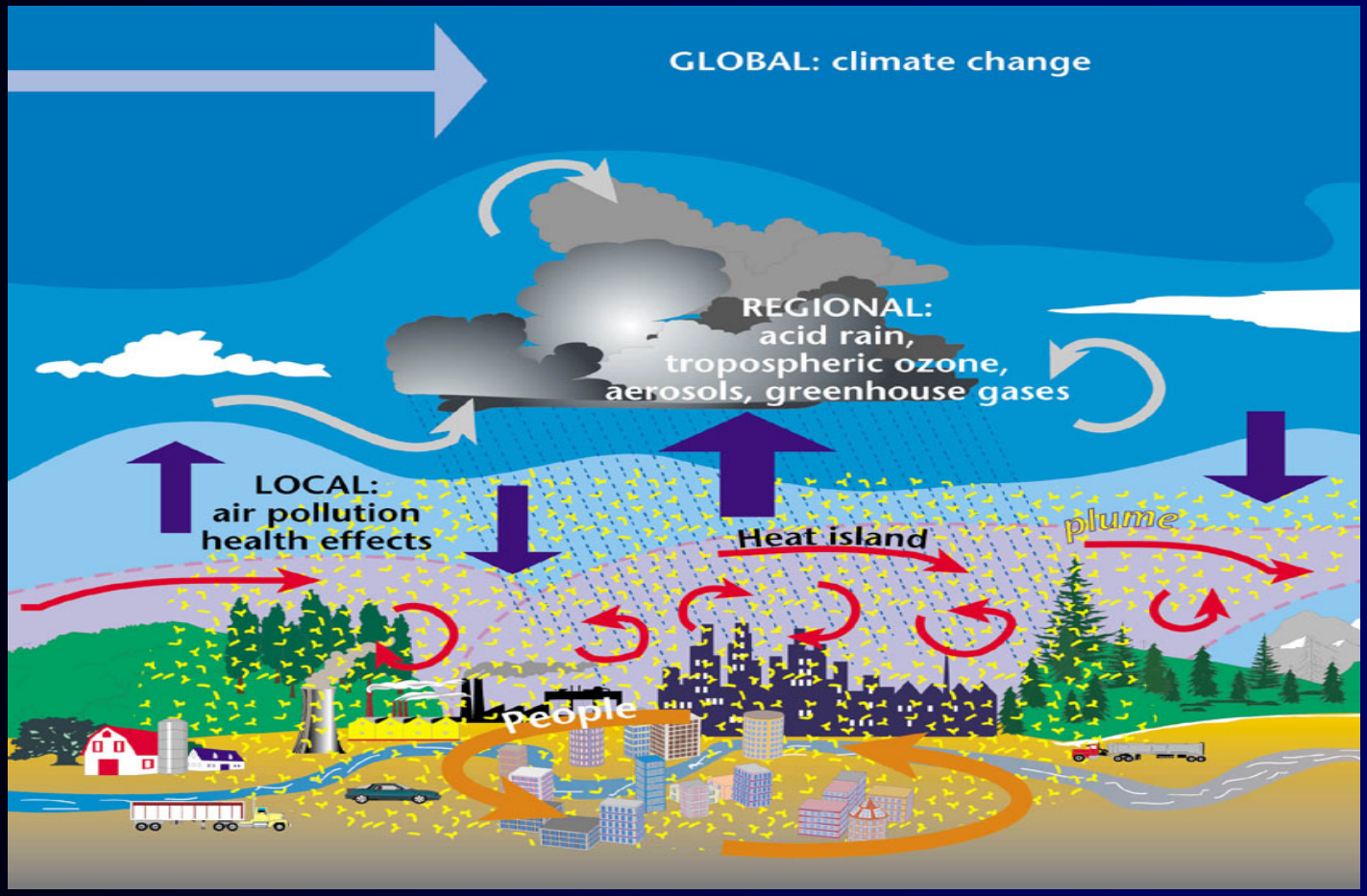
fluid dynamic flow on
unevenly heated rotating sphere

Tendency-in-time equations for
horizontal wind components, pressure, temperature,
moisture variables – e.g., $\frac{\partial u}{\partial t} = \ldots$

Finite difference representation of atmosphere

- cover area to be forecast with 3-d grid of points
at which equations will be solved
- produce short prediction over short time step (0.5 – 5 min)
at each grid point
- repeat process until desired forecast length is complete

Earth systems interactions



Weather, air quality, climate, biology, agriculture, land surface, oceans, lakes

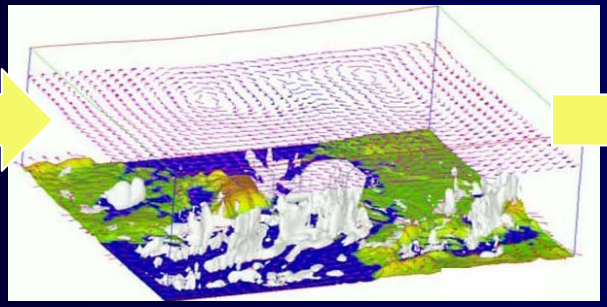
All interact on global to local scales, with various degrees of importance on different scales and for different applications

Modified after Carmichael/GURME

Air Quality Modeling: The commonly used approach ("offline")

Weather Forecast model

Weather Data Analysis & Assimilation

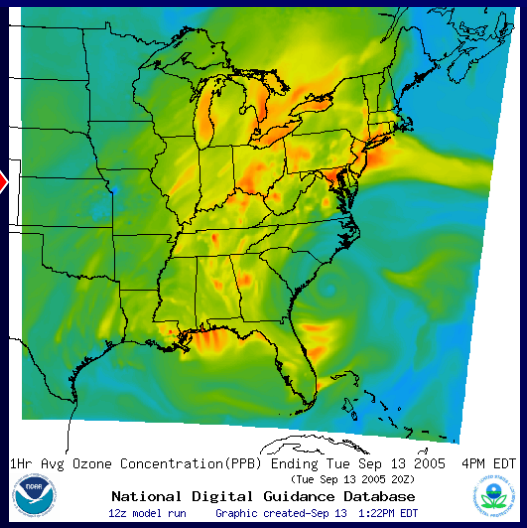


Weather Forecast

Snap shots

Air quality Forecast model

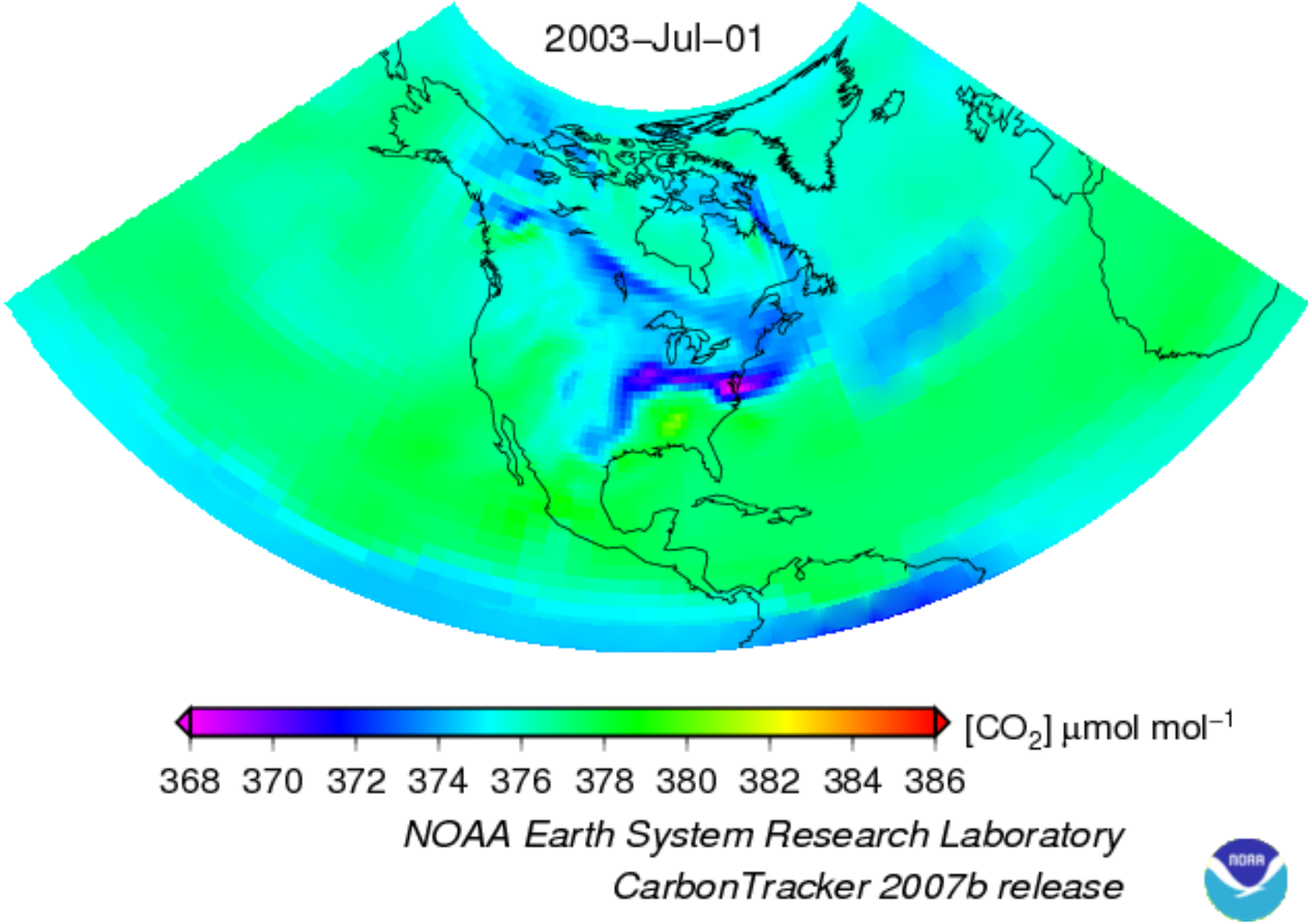
Biogenic and anthropogenic emissions



AQ Forecast

Chemical, aerosol, removal modules

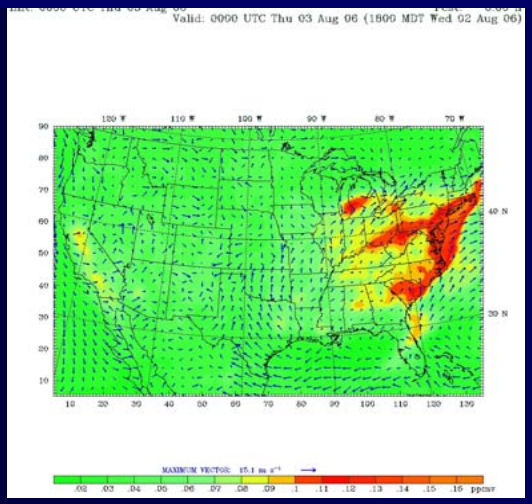
CarbonTracker free troposphere carbon dioxide



Air Quality Modeling: The "online" approach

Weather Data Analysis & Assimilation & Emissions

Simultaneous forecast of weather and air quality



Chemistry, aerosols, radiation, clouds, temperature, winds

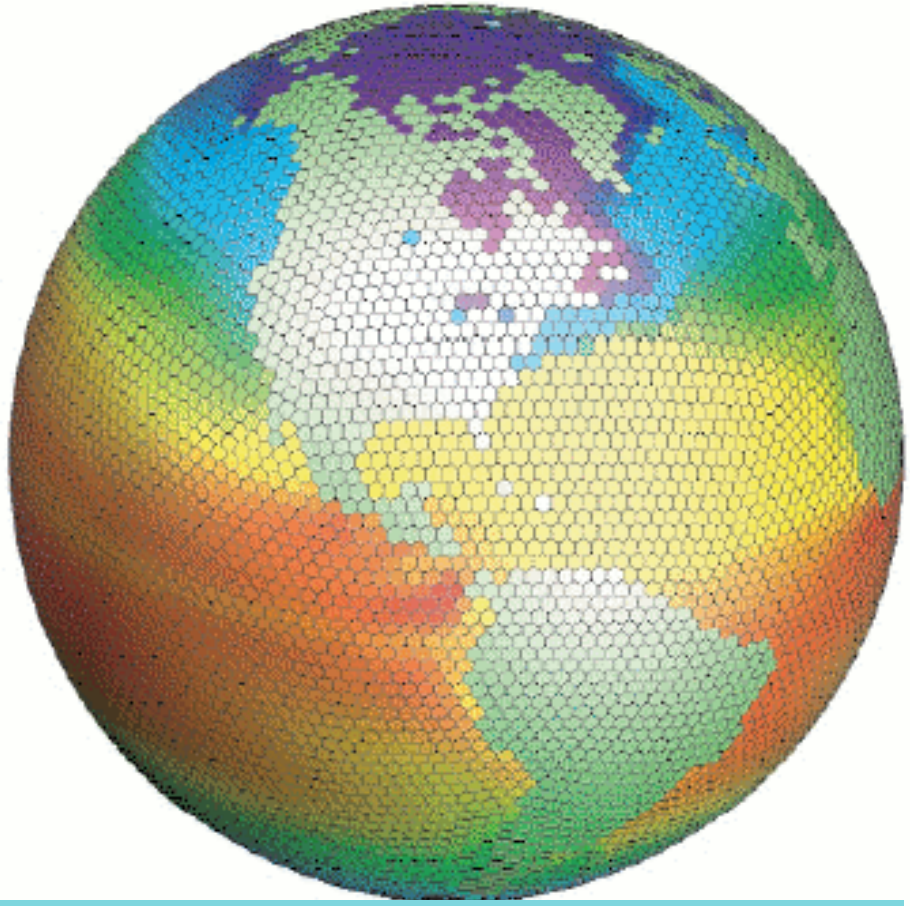
Weather and AQ Forecast

Full interaction of meteorology and chemistry

(WRF/Chem, applicable to other models)

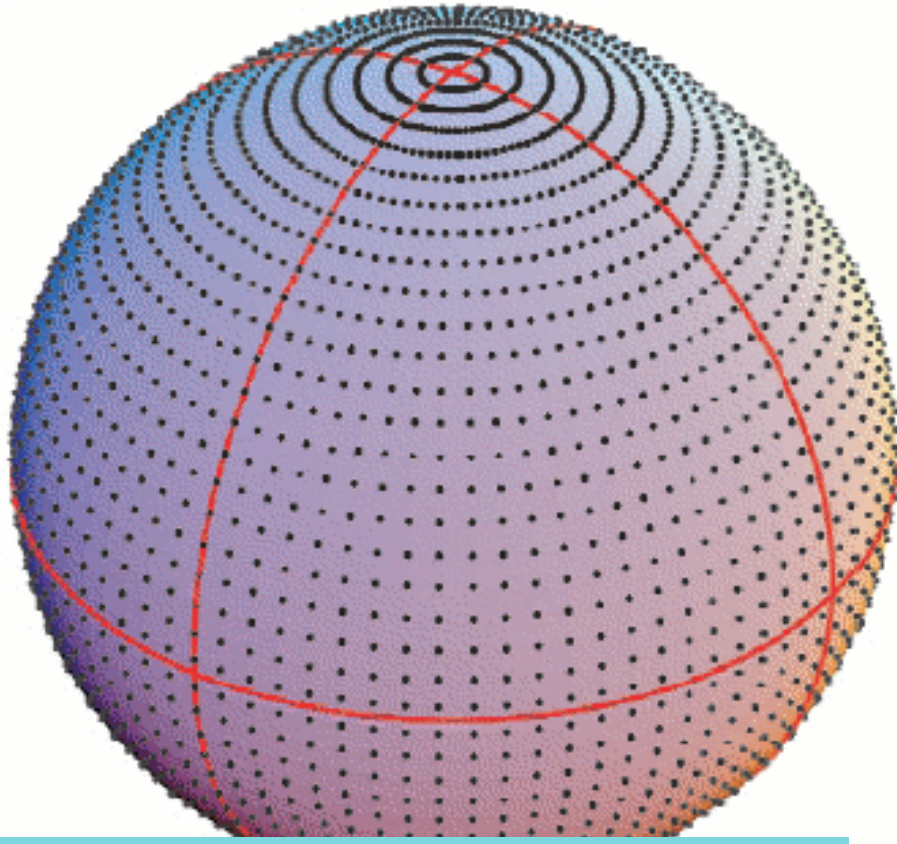
Global discretization for models

Icosahedral grid



Nearly equal size of grid volumes, including near poles

Lat-lon representation
- GFS, ECMWF, etc

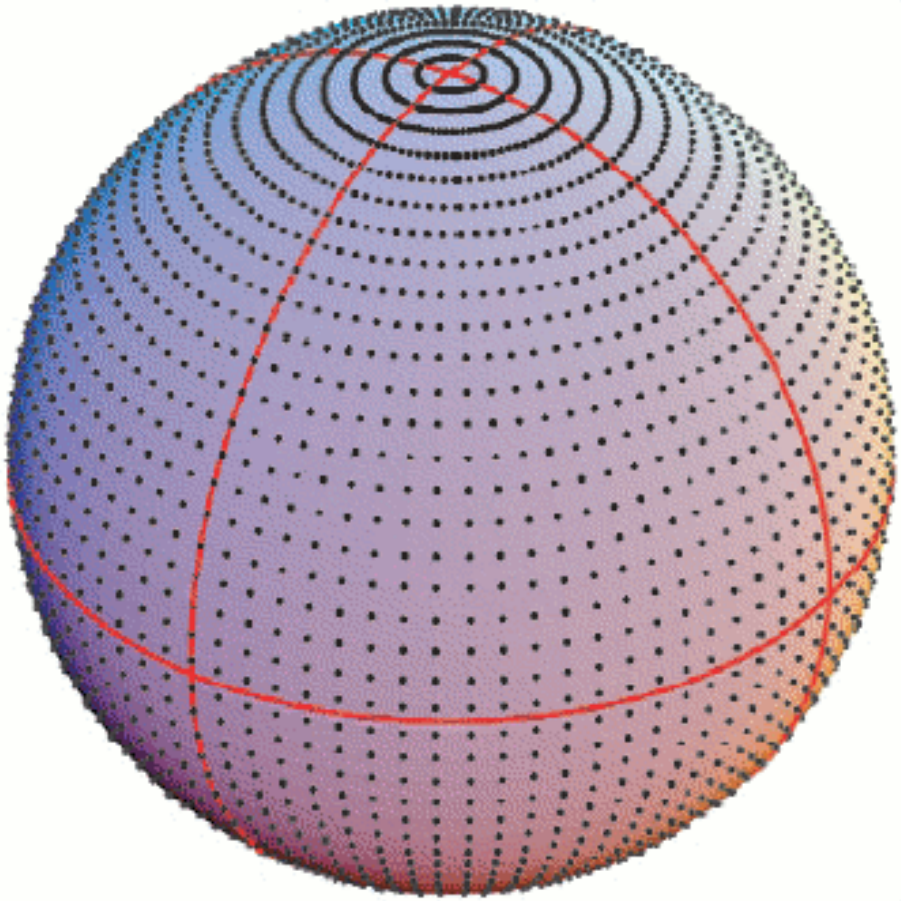


- Singularities near poles
- Requires extra diffusion, longer time steps

NOAA/ESRL

Flow-following- finite-volume
Icosahedral
Model FIM

Lat-lon grid
- GFS, ECMWF, etc



240km icosahedral grid
Level-5 – 10,242 polygons
Real-time FIM forecasts-
30km - G8 -655,362

FIM

Flow-following finite-volume Icosahedral Model

http://fim.noaa.gov

FIM Home
Current and forecast weather
FIM Graphics-
Global - CONUS
FIM GRIB viewer
Soundings:
Interactive (Java)
Other Products:
NCEP Model Products (GFS,etc.)
Organization
RUC home
Rapid Refresh home
FIM Staff
AMB Staff
ESRL/GSD
Description
Manuscript description of FIM model
FIM Poster (powerpoint)
FIM Poster (jpg)
FIM powerpoint - Feb 2007
FIM Documentation
RUC/RR/FIM Pubs
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NCEP obs processing
NCEP status messages
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The FIM Model

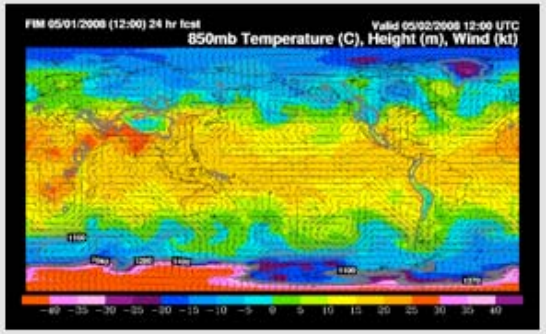
NOAA/ESRL scientists have developed an initial version of a new global model including use of the adaptive isentropic-sigma hybrid vertical coordinate successful with the RUC model, accurate finite-volume horizontal advection, and use of an icosahedral horizontal grid. ESRL is collaborating with NCEP/EMC on development of the FIM model, and was aided by GFDL on its initial design.

3 unique features of the FIM:

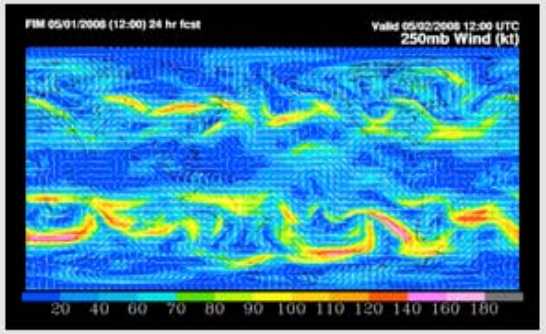
- icosahedral horizontal grid, mostly hexagons except for 12 pentagons ("**I**" in FIM)
- isentropic-sigma hybrid vertical coordinate, adaptive, concentrates around frontal zones, tropopause, similar to RUC model ("**F**" for Flow-following in FIM)
- finite-volume horizontal transport (Also under "**F**", for "finite-volume" in FIM)

News Items

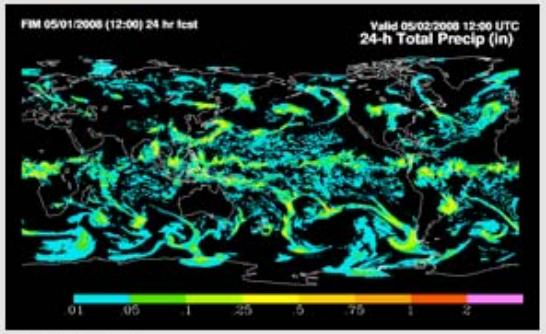
- 17 April 2008 Virtual temperature effect added to calculation of pressure gradient. Prognostic temperature variable is now virtual potential temperature. Average global precipitation and mean zonal wind at jet level increased by about 10% in spring 2008 cases. Change made on 15 April.
- 8 April 2008 Real-data FIM forecasts started in Feb 2008. Graphics here.
  - GFS initial conditions, interpolated from GFS spectral data for analysis
  - 30km horizontal resolution for FIM runs
  - 50 vertical levels
  - Use of GFS physical parameterizations (other options to be added including WRF physics options and WRF-chem as a further option)



850 mb Temperature



250 mb Wind



Total Precip

NOAA/ESRL

Flow-following-finite-volume

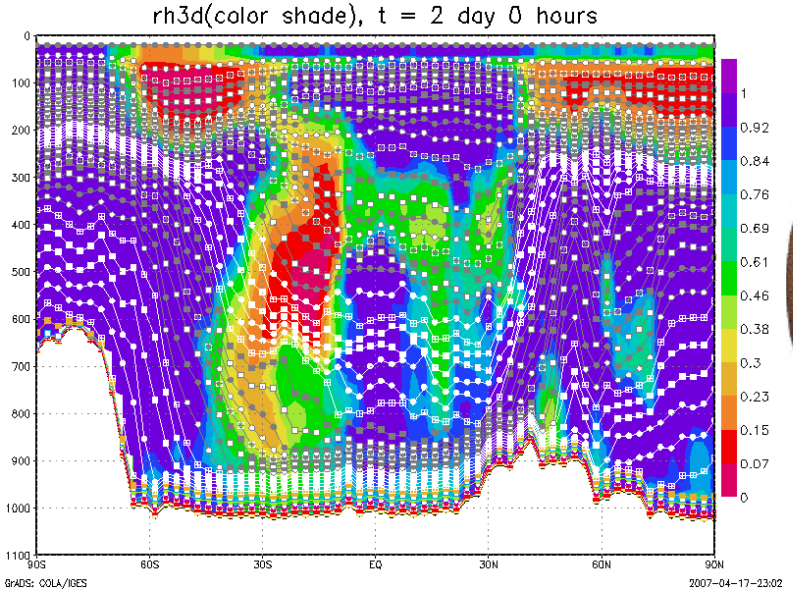
Icosahedral

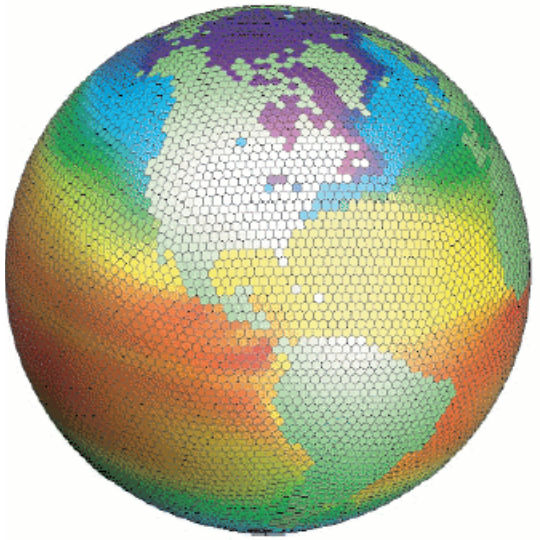
Model

FIM

Jin Lee
Sandy MacDonald
Rainer Bleck
Stan Benjamin
Jian-Wen Bao
John M. Brown
Jacques Middlecoff
Ning Wang

+Tom Henderson, Georg Grell, verif/ITS…





- Applied in real-data cases down to 15km resolution
- MPI implemented with non-structured horizontal grid via ESRL Scalable Modeling System
  - Scaling efficiency from 120→240 procs (98%)
  - 240→480 procs (87%) (for 30km FIM)
- Allows variable number of prognostic tracer variables (suitable for air chemistry)

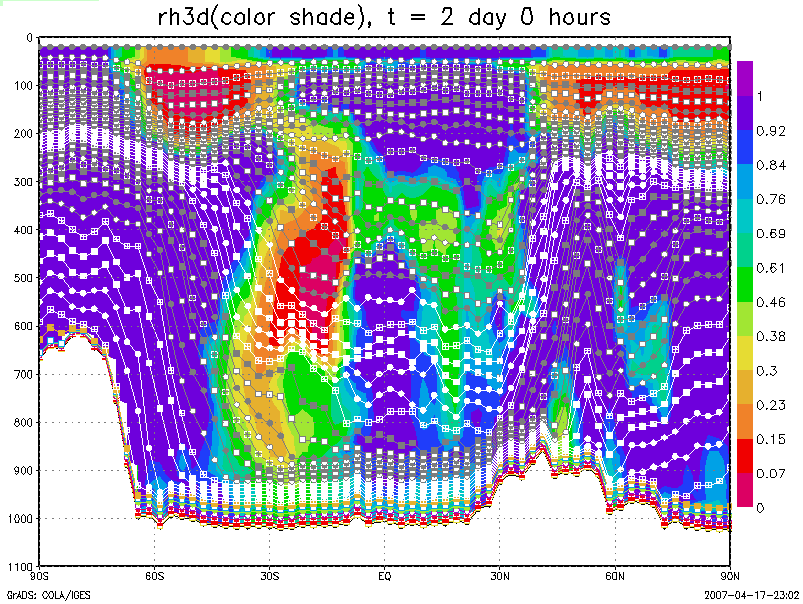
FIM design – vertical coordinate

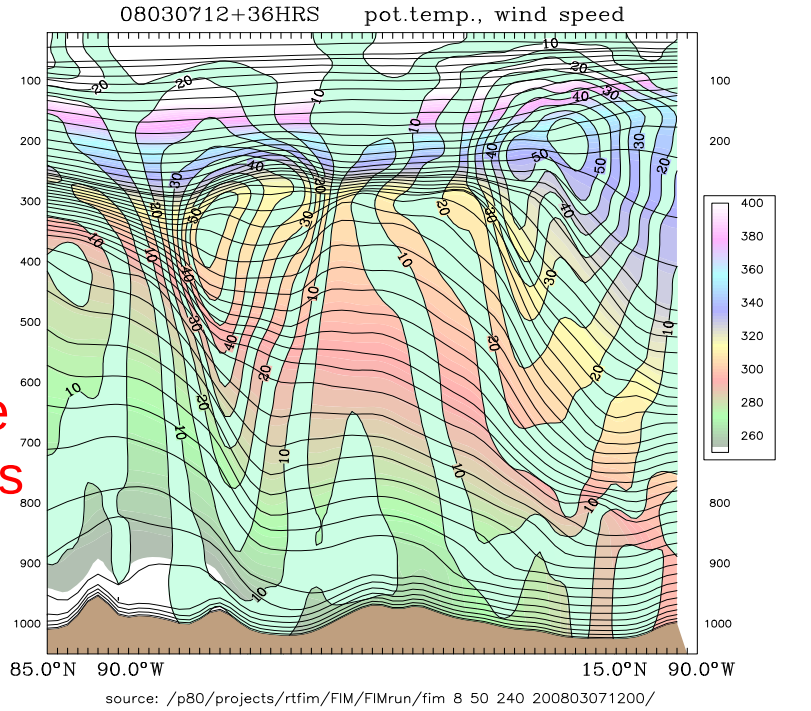
Hybrid (sigma/ isentropic) vertical coordinate

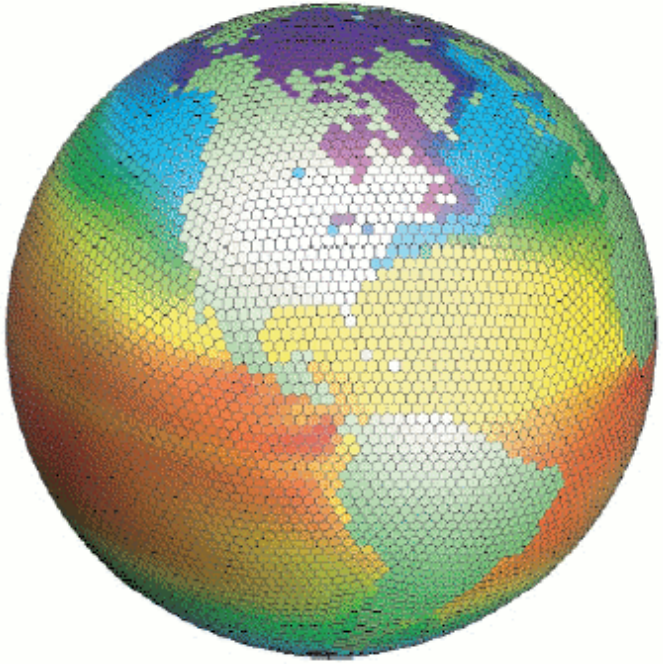
- Adaptive vertical coordinate (θ_v-σ)
- Used in NCEP Rapid Update Cycle (RUC) model (Bleck/Benjamin)
- Used in HYCOM ocean model (Bleck)
- Option in upcoming WRF repository branch (Zangl – NCAR)

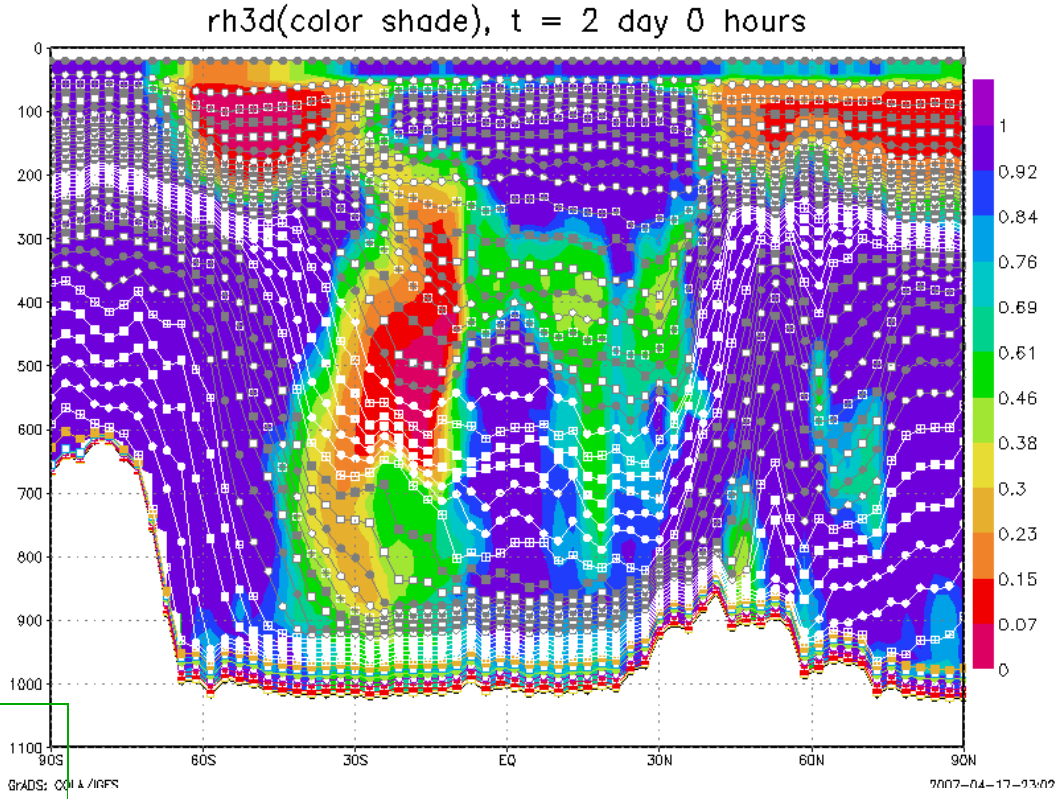
Improved transport by reducing numerical dispersion from vertical cross-coordinate transport, **improved stratospheric/tropospheric exchange.**

Applicable down to 1-km non-hydrostatic scale by using larger-scale 3-d isentropic variation as part of FIM target coordinate definition (e.g, Zangl, 2007 - MWR)





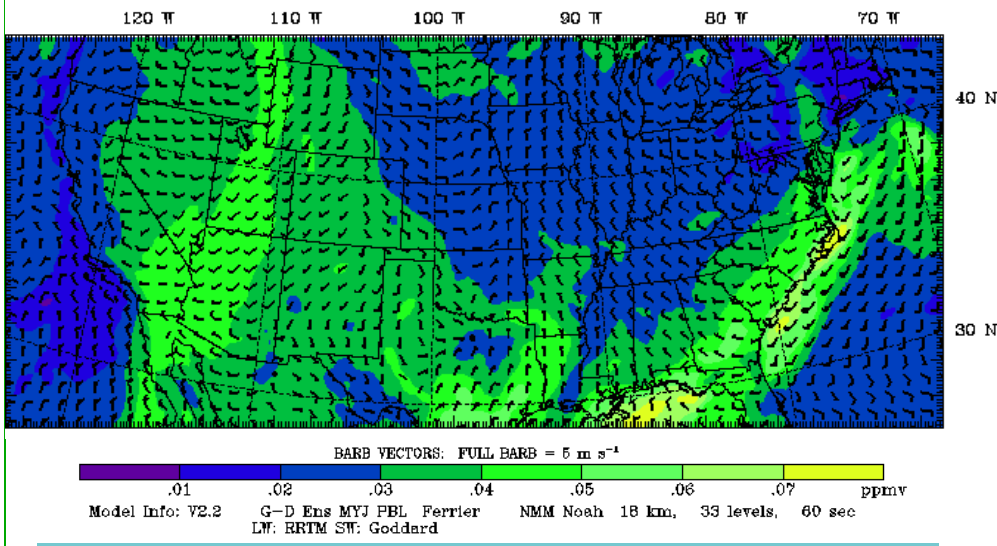




ESRL Global Chemistry/ Atmospheric Model (a work in progress)

Current - Georg Grell, Tom Henderson, FIM team

Future – Andy Jacobson, others

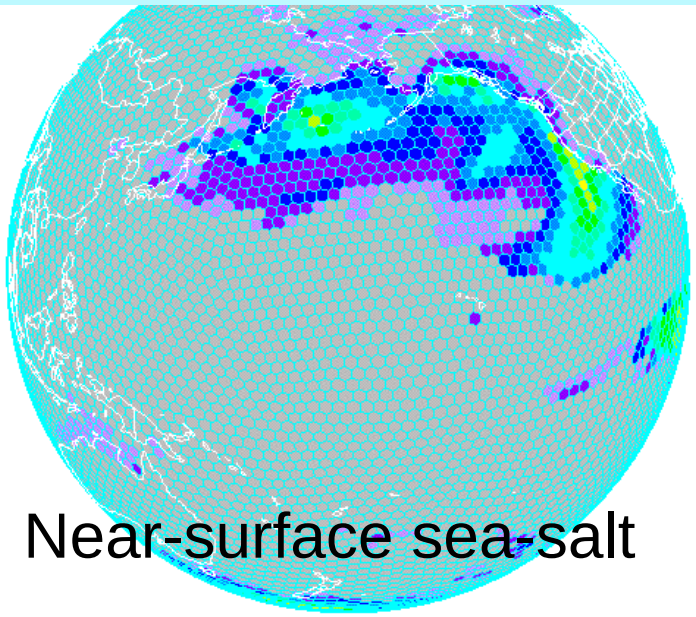


8m O_3 fcst valid 00z 11 Oct 07

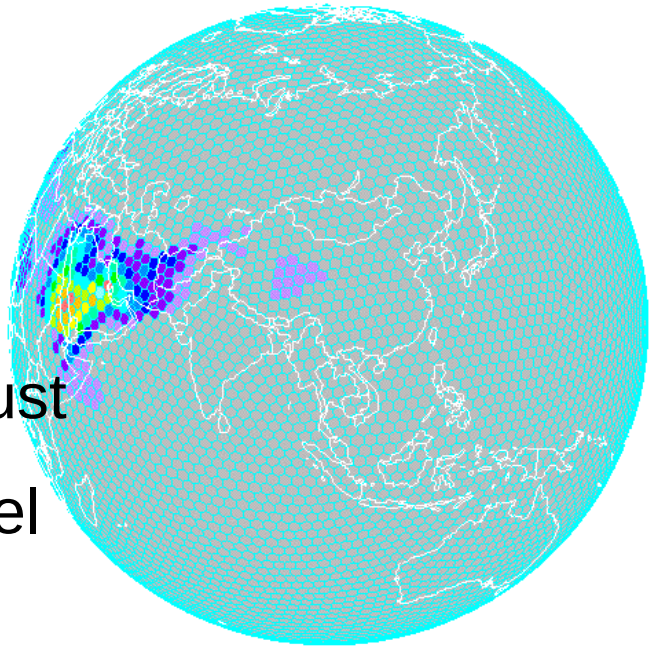
FIM- with GOCART parameterization (18 aerosols) + GFS physics

Dust and Sea-salt, 5-day forecast

G5-240km resolution tests here

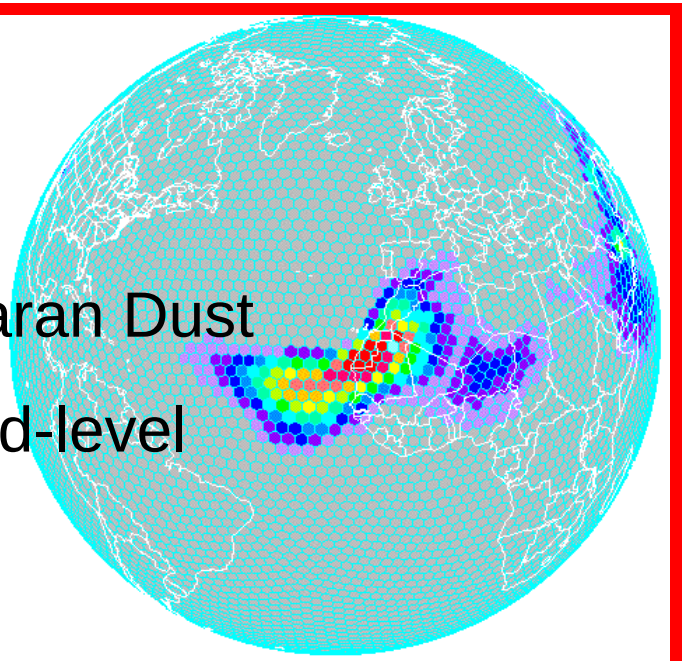


Near-surface sea-salt



Asian Dust

mid-level



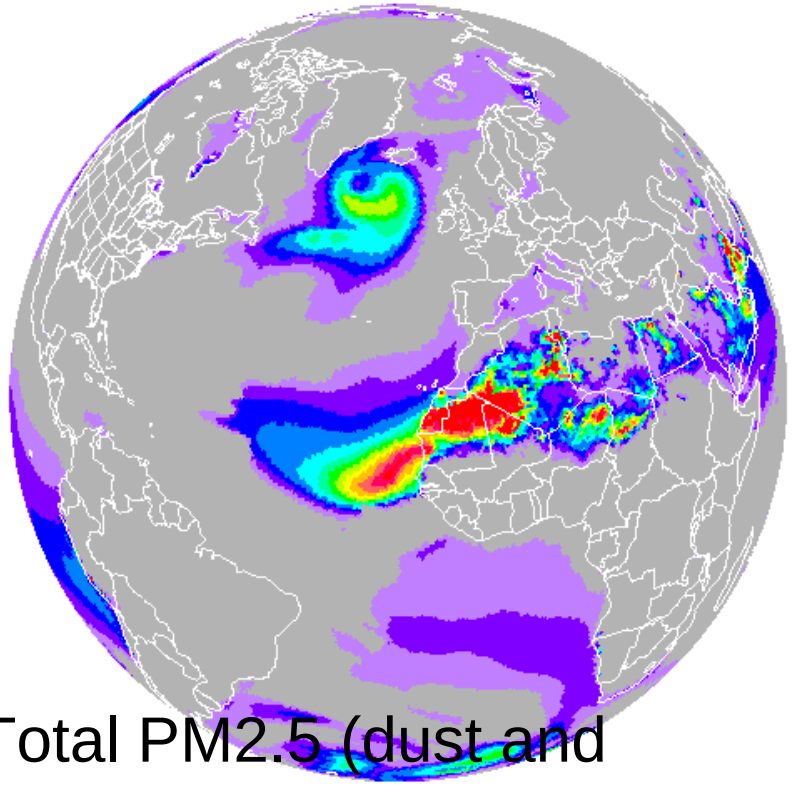
Saharan Dust

mid-level

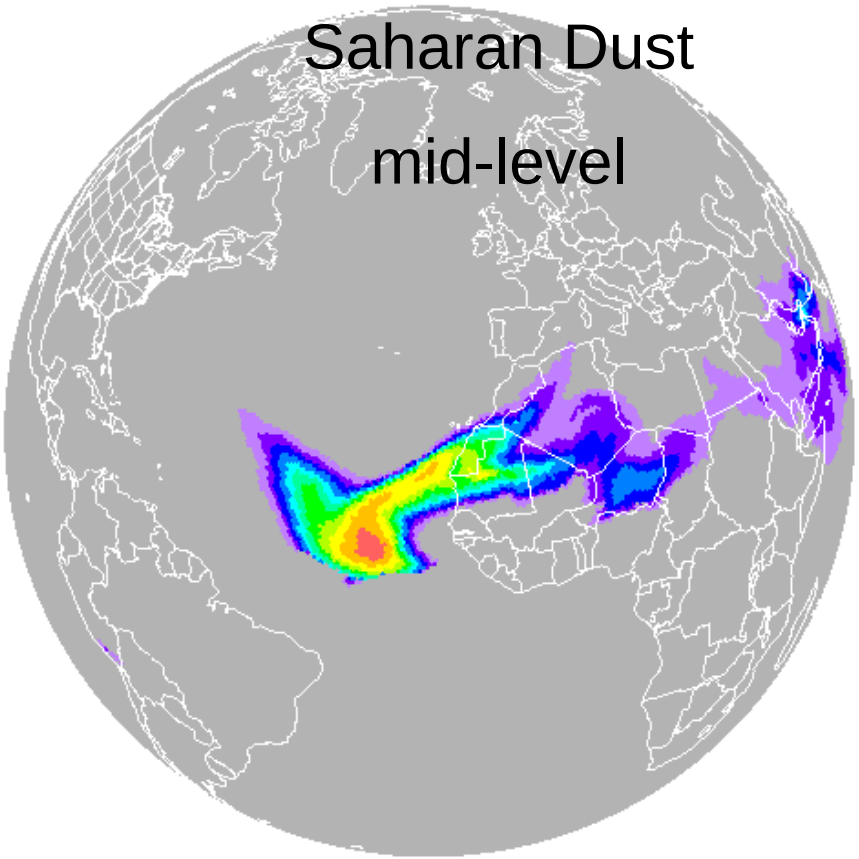
FIM- with GOCART parameterization (18 aerosols) + GFS physics

Dust and Sea-salt, 5-day forecast

G7-60km resolution tests here



Total PM2.5 (dust and sea-salt, some sulfate) at surface



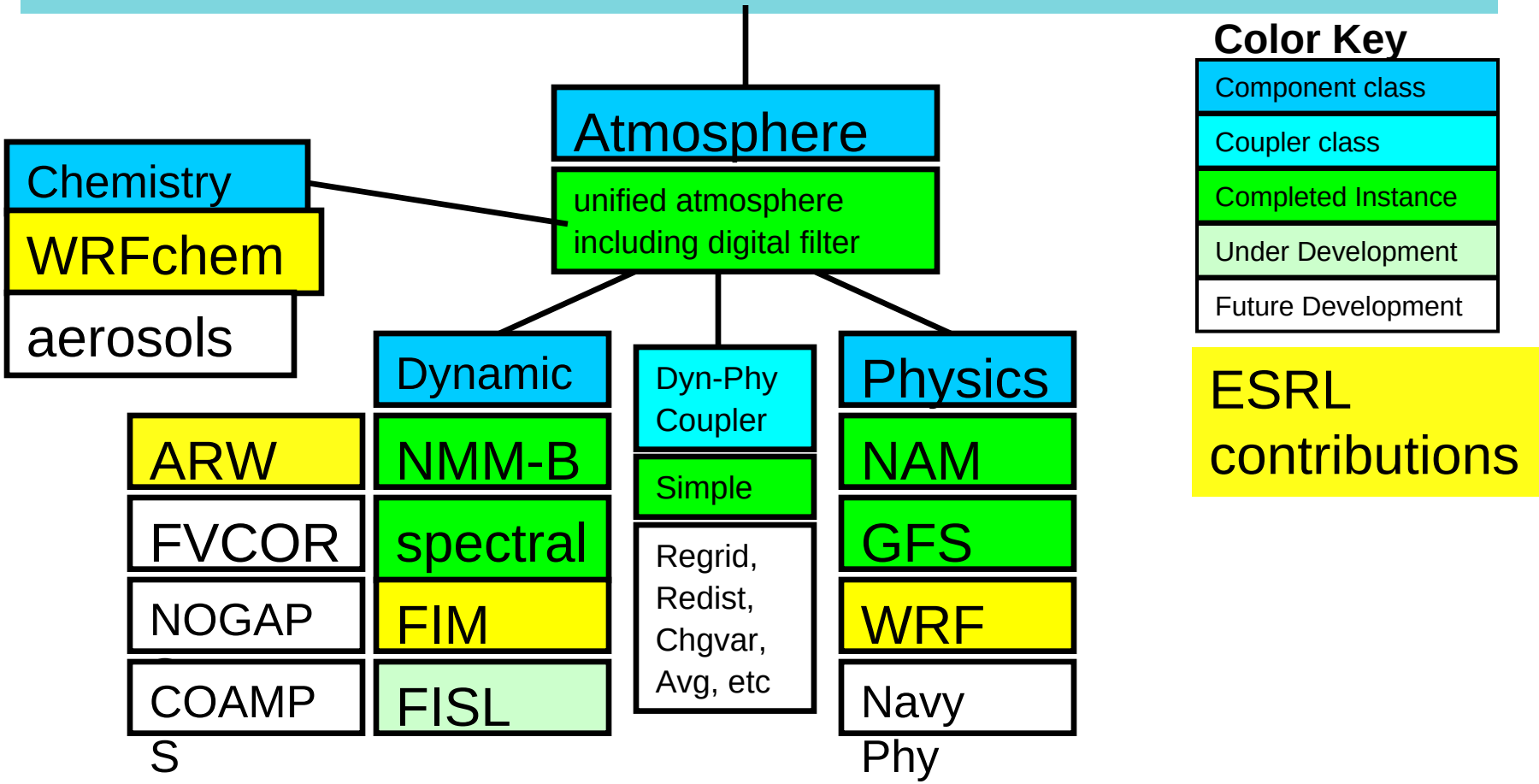
Saharan Dust

mid-level

The bigger picture within NOAA for operational prediction with earth system models - ESMF

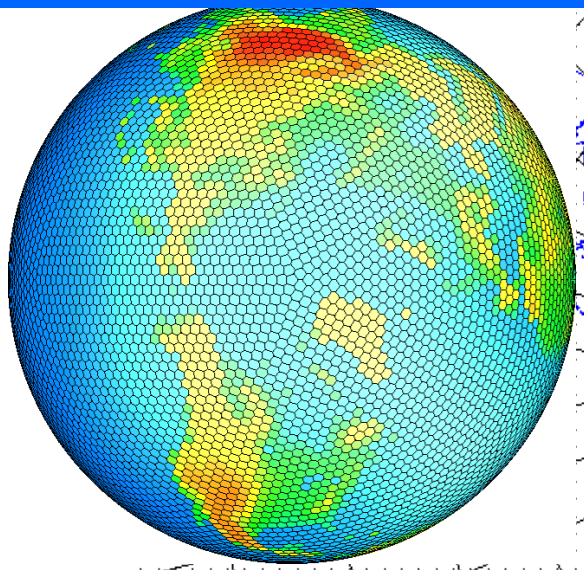
- **Earth System Modeling Framework**
  - Conventions for coupling between earth system model components
- Community effort, partially supported by NOAA (also NCAR, NASA, DoD, etc.)
- ESMF structure used for **NEMS**
  - **NOAA Environmental Modeling System**
  - Earth system coupling framework

NEMS Architecture using ESMF



- The goal is one unified atmospheric component that can invoke multiple dynamics and physics.
- At this time, dynamics and physics run on the same grid in the same decomposition, so the coupler literally is very simple.

Global Rapid Refresh - hourly updated model at NCEP
For aviation, situational awareness
2016- New global satellite ground stations - 40min latency



Global RR = GRR

RapidRefresh = RR

FIM global model

- initial transfer to NCEP – 2010
  - candidate for global ensemble w/i ESMF/NEMS
  - no initial aviation connection
- WRF physics, chem options
- candidate for Global Rapid Refresh

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