Modeling Capabilities during SEAC$^4$RS-NA: Forecasting Support and in-Field Data Analysis

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SEAC4RS-NA Modeling Capabilities at a Glance
NCAR Modeling Support for SEAC4RS

Louisa Emmons
Mary Barth, Gabriele Pfister, Helen Worden, Mijeong Park, Christoph Knote, Christine Wiedinmyer

Atmospheric Chemistry Division, NCAR
Carbon Monoxide Satellite Observations

- MOPITT CO – available within a day of overpass
- IASI CO – about 2-day delay, global coverage 2x/day
- Plots will be available at: [http://www.acd.ucar.edu/acresp/]
Fire Emissions: Fire INventory from NCAR (FINN)

- Daily fire emissions of trace gases and particles are produced
- FINN is run in real-time based on MODIS Rapid Response fire counts [Wiedinmyer, GMD, 2011]
  [http://www.acd.ucar.edu/acresp/forecast/fire-emissions.shtml](http://www.acd.ucar.edu/acresp/forecast/fire-emissions.shtml)
- Plots and data files available each day
**MEGAN**: biogenic emissions model – online in MOZART, CAM-chem/CLM, WRF-chem real-time emissions can be made available.
WRF-Tracers and Flexpart – Example from DC3

*for SEAC4RS, simulations will be chosen to address science questions*

WRF ($\Delta x=3$km) with PBL tracers

Tracers & Flexpart Trajectory Forecast

- PBL tracer from Oklahoma/West Texas at 11 km
- PBL tracer from entire domain in UT

Tracer forecast from Flexpart initialized at ~01 UTC 05-30 at the latitudes, longitudes, and altitudes of the GV anvil passes. Results are valid for 18 UTC 05-30.

Tracer forecast from NCAR WRF initialized at 12 UTC 05-29
MOZART-4 driven by GEOS-5 with assimilation of MOPITT CO

Full chemistry at 1.9°x2.5°

http://www.acd.ucar.edu/acresp/forecast/

5-day forecasts, hourly output, currently operational
MOZART-4 Tracers

Global forecasts of artificial tracers at 0.5°x0.6°

- Isoprene-like tracer based on MEGAN isoprene emissions
- Anthropogenic NOx tracer
- Fire & anthro CO tracers for various regions
- Others can be added as needed
  (based on various sources, lifetimes, soluble/insoluble)
- Similar to forecasts for DC3 (http://www.acd.ucar.edu/acresp/dc3/)

[Map of CO fire surface with isopleth colors]

[Isoprene concentration map with isopleth colors]
Post-Campaign Analysis

CAM-chem and WRF-chem will be run after the campaign and provided to the Science Team for analysis of the observations

• FINN fire emissions will be updated with final MODIS thermal anomalies and regional burn information and used in the model simulations
• CAM-chem (MOZART-4 chemistry) will be driven by GEOS-5 (or MERRA) meteorology
• WRF-chem will be run with MOZART-4 chemistry and aerosols (MAM & SOA)
• Model results will be interpolated to the flight tracks and submitted to the data archive
• Science Team may request other (custom) products
UIOWA Forecasting Capabilities

Pablo Saide, Greg Carmichael, Scott Spak
SEAC4RS science meeting
April 29th, 2013
UIOWA Forecasting Capabilities

- WRF-Chem full chemistry+4 bin MOSAIC aerosol and WRF-tracer for emission regions/sectors
  - 12 or 18km resolution, with a inner moving nest of 4 or 6km
  - 3 day forecasts, NAM or GFS meteorology
  - MOZART or MACC (ECMWF) chemical boundary conditions
  - FINN or QFED fire emissions, MEGAN biogenics, GOCART dust
  - NEI or D. Streets SEAC4RS anthropogenic emissions
  - Radiative feedback on, aerosol activation off (but aerosol number concentration used as proxy)

- AOD assimilation using NASA NNR or NRL-UND products

- Post processing through NCL and/or UPP

- Output on UIOWA webpage and possibly on NASA through OpenDap server

- All flexible depending on this meeting decisions
UIOWA WEBPAGE

SEAC4RS 18km Full Chemistry and Tracer Forecast, 00h = 06UTC, 26/06/2012

Please select pressure [850 mb], START [6] and END time step [72] to see.


Tracers: CO BB, CO THAI, CO CHINA, CO INDIA, CO VIETNAM, CO NEPAL, CO INDONESIA, CO SHIPPING, SO2 VOLCANO.

Meteorology: CAPE, CLD BASE, CLD Incidence, CLD TOP, WP, LWP, LWP+LWP, QV, PBL Height, POT VORT, PRECIP CONV, PRECIP TOT, RH, T, TROP HEIGHT, TROP T, W.

OC = 2.5μm Concentration (μg/kg) at 850 hPa
Wind (kt/s) at 850 hPa

Init: 2012-06-26 06:00:00
Valid: 2012-06-29 06:00:00
SEAC4RS 18km Full Chemistry and Tracer Forecast, 00h = 06UTC, 26/06/2012

Please select Cross-section # 4, START 6 and END time step -72 to see

Full Chemistry: AOD TOT BC
CO ISOP ISOP+PRODS NO3
NUM O3 OC DUST COARSE
DUST FINE PM2.5
SeaSalt COARSE SeaSalt FINE
SO2 SO4

Tracers: CO BB CO THAI
CO CHINA CO INDIA CO VIETNAM
CO NEPAL CO INDONESIA
CO SHIPPING SO2 VOLCANO
GEOS-5 Forecasting Support for SEAC$^4$RS-NA

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(2) Atmospheric Chemistry and Dynamics Branch, NASA/GSFC
(3) Morgan State University/GESTAR
(4) ORAU
(5) SSAI
GEOS-5 Earth-System Model

From weather to seasonal to decadal time scales
# GEOS-5 Atmospheric Data Assimilation System

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>GEOS-5 Earth Modeling System, with GOCART coupled to radiation parameterization</td>
</tr>
<tr>
<td><strong>Fire Emissions</strong></td>
<td>QFED: Daily, NRT, MODIS FRP based</td>
</tr>
<tr>
<td><strong>Met Data Assim</strong></td>
<td>Full NWP observing system (uses GSI)</td>
</tr>
<tr>
<td><strong>Aerosol Data Assimilation</strong></td>
<td>Local Displacement Ensembles (LDE) MODIS reflectances (Aqua &amp; Terra) AERONET Calibrated AOD’s (Neural Net) Stringent cloud screening</td>
</tr>
<tr>
<td><strong>Forecasts</strong></td>
<td>5 day forecasts twice daily: 0Z an 12Z</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>25 km (cubed-sphere), 72 layers, top ~85 km</td>
</tr>
<tr>
<td><strong>Aerosol Species</strong></td>
<td>Dust, sea-salt, sulfates, organic &amp; black carbon</td>
</tr>
<tr>
<td><strong>Carbon Species</strong></td>
<td>CO₂, CO with several tagged tracers</td>
</tr>
</tbody>
</table>
GOCART Component

- Goddard Chemistry, Aerosol, Radiation, and Transport Model [Chin et al. 2002]
- Sources and sinks for 5 non-interactive species

<table>
<thead>
<tr>
<th>Species</th>
<th>Source/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>dust</td>
<td>wind and topographic source, 5 mass bins</td>
</tr>
<tr>
<td>sea salt</td>
<td>wind driven source, 5 mass bins</td>
</tr>
<tr>
<td>black carbon</td>
<td>anthropogenic and wildfire source, mass hydrophobic and hydrophilic</td>
</tr>
<tr>
<td>organic carbon</td>
<td>anthropogenic, biogenic, and wildfire source, mass hydrophobic and hydrophilic</td>
</tr>
<tr>
<td>sulfate</td>
<td>anthropogenic and wildfire source of SO2, oxidation to SO4 mass</td>
</tr>
</tbody>
</table>

- Convective and large scale wet removal
- Dry deposition (and sedimentation for dust and sea salt)
- Optics based primarily on OPAC
QFED: Quick Fire Emission Dataset

- Top-down algorithm based on MODIS Fire Radiative Power (AQUA/TERRA)
- FRP Emission factors tuned by means of inverse calculation based on MODIS AOD data.
- Daily mean emissions, NRT (thanks to LANCE)
- Prescribed diurnal cycle

JCSDA: inclusion of geo-stationary information
QFED Calibrated by MODIS AOD

GEOS-5 Aerosol Optical Depth
- QFED (GFED Calibrated)
- QFED (MODIS Calibrated)
- MODIS Retrievals
Modeling Interannual Variability of Biomass Burning Emissions

- BB emission anomalies respond directly to precipitation and surface humidity conditions.
- The normalized Canadian Fire Weather Index captures the *flammability* conditions as a function of surface meteorology.

Parameterization:

\[
E = \mathcal{E} \left( \frac{I}{I_{clm}} \right)^{\alpha_b} E_{clm}
\]
Aerosol Data Assimilation

- Focus on NASA EOS instruments, MODIS for now
- Global, high resolution (1/4 deg) AOD analysis
- 3D increments by means of Lagrangian Displacement Ensembles (LDE)
- Neural-Net AOD Retrievals
- Simultaneous estimates of background bias (*Dee and da Silva 1998*)
- Adaptive Statistical Quality Control (*Dee et al. 1999*):
  - State dependent (adapts to the error of the day)
  - Background and Buddy checks based on log-transformed AOD innovation
- Error covariance models (*Dee and da Silva 1999*):
  - Innovation based
  - Maximum likelihood
AERONET Validation of Aerosol Assimilation

\[ \eta = \log(\tau + 0.01) \]

Based on 2007-10 data, aerosol assimilated fields.
A possibility: Experimental Global 25 km GEOS-5/GMI Forecasts

(once a day, 3 or 5 day forecasts)

Courtesy: S. Pawson, E. Nielsen
Mission Specific Customization: SEAC4RS-Asia

SEAC4RS Forecast Support

The Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC4RS) will focus specifically on the role of the Asian monsoon circulation and convective redistribution in governing upper atmospheric composition and chemistry in that region. This airborne field campaign will also examine the impact of polluting aerosols on cloud properties and ultimately dynamics.

GMAO will provide GEOS-5 forecast support to aid in aircraft mission planning for SEAC4RS. Field measurements will take place in August and September of 2012.

Supporting Forecasts and Data

http://gmao.gsfc.nasa.gov/projects/SEAC4RS/
GEOS-5 Support for HS3

The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission specifically targeted to investigate the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin. HS3 is motivated by hypotheses related to the relative roles of the large-scale environment and storm-scale internal processes.

Field measurements will take place for one month each during the hurricane seasons of 2012-2014. Test flights will begin in August 2011.

HS3 Deployment Support

Deployment Activities
4 x day, 5-day meteorological and aerosol forecasts with products made available by web pages, web map service, opendap, etc.

Pete Colarco and Ed Nowottnick were deployed during parts of the campaign to help forecasting and flight planning activities
HS3 Customized Maps

GMAO Experimental Forecast Suite
GEOS-5 HS3 Mission Support

Map Regions
HS3

NASA/GMAO – GEOS-5 Forecast initialized on 12z 2012-09-02
300 hPa CO concentration(*1e7)

Valid: Sun 12z 2012-09-02 (\( \tau = 0 \))

GMAO WxMaps
Forecast Initial Time
2012-Sep-02 12z
Forecast Lead Hour
000

Levels
3D CO
3D Aerosols
& Others
80
CO Concentration
Dust Mass
70
CO BB Africa
Black Carbon
60
CO BB Eurasia
Organic Carbon
50
CO BB N. Amer.
SO2
40
CO BB OTHER
SO4
300
CO BB S. Amer.

Map Regions
HS3
DISCOVER-AQ

Aerograms

GEOS-5 Aerograms

<table>
<thead>
<tr>
<th>National</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresno</td>
<td>Select</td>
</tr>
</tbody>
</table>

- OC Organic Carbon Extinction
- BC Black Carbon Extinction
- ALL (OC + BC + SU) Extinction
- SS Sea Salt
- DU Dust
- SU Sulfate Extinction
- CO Concentration
International Cooperative for Aerosol Prediction (ICAP)

- ICAP is an emerging collaboration of “operational” aerosol forecasters and data providers to coordinate and improve aerosol prediction

- ICAP goals
  - Communication and collaboration between operational prediction centers
  - Communication and collaboration between model developers and data providers
  - Develop metrics for evaluating skill of model forecasts (similar to NWP community)
  - Develop techniques for aerosol data assimilation
  - Develop techniques for ensemble model forecasting

Observability, Monterey, CA, April 2010
ICAP Accomplishments

- Participation from all major operational centers: NRL, NCEP, NASA, ECMWF, JMA, UKMO

- Participation from all major data providers: ESA, EUMETSAT, JAXA, NASA, NESDIS

- ICAP workshops
  - Observability, Monterey, CA, April 2010
  - Verification, Oxford, UK, Sept. 2010
  - Ensembles, Boulder, CO, May 2011
  - Sources & Sinks, Frascati, IT, May 2012

- Two workshop write-ups in BAMS

- ICAP Multi-Model Ensemble Dust Forecast
Summary

- SEAC4RS-NA will have a good mix of regional and global models
  - Diversity of emissions
  - Diversity of chemistry/physics
- Much of the forecasting infrastructure that was developed for SEAC4RS-Asia can be re-purposed for SEAC4RS-NA
  - Adapted for the revised science goals/score-cards
- We should leverage the concurrent DISCOVER-AQ/HS3 forecasting activities.
- Need to characterize model skill before deployment
Extra Slides

Useful GEOS-5 URLs, etc
Sample GEOS-5 Aerosol Data Products

2D Datasets
- Hourly, 3-hourly
- Speciated
  - AOT, AAOT, PM2.5, PM10
  - 12 wavelengths
  - 340, 380, 440, 470, 500, 550, 670, 865, 1024, 1240, 1640, 2130
  - Surface & column mass
  - Sources & sinks
- Non-speciated
  - Aerosol radiative forcing
  - UV aerosol Index

3D Datasets
- 3-hourly
- Speciated:
  - Aerosol mixing ratio
- Non-speciated
  - 355nm, 532nm, 1024nm
  - Aerosol Extinction
  - Single Scattering Albedo
  - Asymmetry parameter
  - Backscatter
  - Attenuated Backscatter (TOA & SFC)

In addition to Meteorological Products
GEOS-5 NRT Forecasting - Meteorology

http://gmao.gsfc.nasa.gov/forecasts
NASA Global Modeling and Assimilation Office – GEOS-5 Forecast Initialized on 12z 2011-03-27
SLP [mb], 1000–500mb Thickness [dam] and Sfc Precip [mm/day]

GMAO WxMaps
Forecast Initial Time
2011-Mar-27 12z
Forecast Lead Hour
000

Models
GEOS-5
GFS

Variables
300 Speed
500 Vort
700 RH
850 Stream
Precip & SLP

Animate
All t for Precip & SLP
All Products for t=0

Map Regions
Australia
Europe
Pacific
West Africa
Tropical Atlantic
North America

GMAO Experimental Forecast Suite
Site Developers: Arlindo da Silva / Tommy Owens / Joon Yoon / Austin Conaty, GSFC 610.1
Responsible NASA Official: Michele Rienecker, GSFC 610.1
Privacy Policy and Security Notice
Site Updated: 2009-06-09

http://portal.nccs.nasa.gov/cgi-yotc/e561_fp_wx.cgi
GEOS-5 Forecasting
- Aerosol & Tracers

http://gmao.gsfc.nasa.gov/forecasts
Getting GEOS-5 Data in NRT

http://gmao.gsfc.nasa.gov/forecasts
Getting GEOS-5 Data in NRT

http://gmao.gsfc.nasa.gov/forecasts
Download NetCDF-3, NetCDF-4, HDF-4, HDF-5, GRIB-1 or Binary

3d, 3-Hourly, Instantaneous, Pressure-Level, Forecast Fields (wind, temperature)

Variable Selection

- All
- sea_level_pressure
- ozone_mass_mixing_ratio
- specific_humidity
- surface_geopotential_height
- ertels_potential_vorticity
- relative_humidity_after_moist
- eastward_wind
- edge_heights
- surface_pressure
- vertical_pressure_velocity
- mass_fraction_of_cloud_liquid_water
- northward_wind
- air_temperature
- mass_fraction_of_cloud_ice_water

Date and Time Range

Begin: 2011 - Mar - 27 - 00 - 00 - Z
End: 2011 - Mar - 27 - 00 - 00 - Z

Time Steps: 1

Regridding / Orbital Masking

Choose: none
Method: linear
Format: coads

Geographic Selection

Pan
Draw Box

North: 90
West: -180
East: 180
South: -90
GEOS-5 WMS Server

WMS Server:
http://wms.gsfc.nasa.gov/cgi-bin/wms.cgi

Download NetCDF, GeoTIFF, KML

WMS Viewer: http://http://www.map.nasa.gov/cgi-bin/viewer.cgi?project=geos5-inst2d_hwl_x