Overview of the GFS-GOCART Aerosol Forecasting System

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Project Overview

- Goal: Integration of NASA aerosol modeling and monitoring capabilities into NOAA Decision Support System
- Tasks:
  - Implementation of prognostic aerosols (GOCART) in NEMS GFS
  - Utilization of NASA aerosol data in GFS/GSI system
  - Downstream coupling
    - Regional AQF system (Lateral aerosol boundary conditions)
    - SST analysis system (atmospheric correction)
- Three focus areas:
  - Model development: integration of GOCART into NEMS GFS
  - Emission datasets: explore commonality for global and regional applications
  - Evaluation and verification
- Phased development:
  - Development of prototype GFS-GOCART system
  - Transition to real time system
  - Transition to operational applications
Integration of GOCART into GFS

- GFS-GOCART prototype configuration
  - ESMF architecture (NEMS)
  - On-line coupling
  - Coupling to radiation:
    - GOCART export 3D mixing ratios
    - Optical properties determined by GFS physics component
- Multiple, complementary approaches:
  - On-line systems including GOCART Grid Component:
    - GFS/GOCART: new capability being developed
    - GEOS-5/GOCART: NASA/GMAO real-time system
    - GFS~GEOS-5/GOCART (GEOS-5 dynamics + GFS physics)
      - Research system for sensitivity analysis
      - Nearly ready, good reference implementation
  - Off-line GOCART CTM (NWS AQ project)
    - Driven by GFS meteorology
Aerosol/Trace Gases Emissions Working Group

- Emission datasets common to global and regional AQ efforts
- Leverage from expertise at NOAA, NASA, NRL and Wisconsin
- Initial GFS-GOCART development will use same MODIS biomass as in GEOS-5:
  - Top-down estimates using fire-radiative power from MODIS on AQUA/TERRA
  - Injection layer: Plume Rise model (Freitas et al.)
- WG will examine what is available and draft a recommendation plan for developing an emission subcomponent.
Evaluation and Verification

- Two components:
  - Model inter-comparisons:
    - GEOS-5/GOCART: using the same emissions as GFS/GOCART
    - GFS~GEOS-5/GOCART: effects of dynamics
    - NAAPS
  - Comparison with NASA satellite/insitu observations

- Data sources:
  - EOS satellite data (MODIS, CALIPSO, MISR, OMI, POLDER)
  - NASA insitu observations (AERONET)

- Phases of development:
  - Phase I: Initial model testing and tuning for a sample year
  - Phase II: system runs in real-time, develop specific routine monitoring and evaluation procedures
    - Real time acquisition of NASA satellite data
The Impact of Aerosols on Medium Range Weather Forecasts
Global Forecast System (GFS)

Global spectrum model for operational medium range forecasts

- RESOLUTION
  - T382 horizontal resolution (~ 37 km)
  - 64 vertical levels (from surface to 0.2 mb)

- MODEL PHYSICS AND DYNAMICS
  - Sigma-pressure hybrid coordinate
  - Non-local vertical diffusion
  - Simplified Arakawa-Schubert convection scheme
  - RRTM LW radiation scheme
  - MD Chou SW radiation scheme
  - Explicit cloud microphysics
  - Noah LSM (4 soil layers: 10, 40, 100, 200 cm depth)

- INITIAL CONDITIONS (both atmosphere and land states)
  - NCEP Global Data Assimilation System (GDAS)
Gridpoint Statistical Interpolation (GSI)

Global/regional analysis system for operational weather forecasts

- **NCEP 3DVAR assimilation system**
  - Implemented with WRF-NMM into the NAM system in June, 2006
  - Implemented for replacement of SSI in the GFS system in May, 2007

- **SCIENTIFIC ADVANCES**
  - Grid point definition of background errors
  - Inclusion of new types of data (e.g., AIRS radiance, COSMIC GPS)
  - Advanced data assimilation techniques (e.g., improved balance constraints)
  - New analysis variables (e.g., SST)

- **CODE DEVELOPMENT**
  - GMAO collaboration through JCSDA
  - Evolution to ESMF
GDAS Experiments

- T126 L64
- Sigma-pressure hybrid coordinate
- Initialized from 2006-06-01 00Z GDAS analysis
- 14-week cycling, ending at 2006-09-07 18Z
- Aerosol scheme configuration
  - PRC (climatology): OPAC climatological scheme (5° x 5° monthly climatology)
  - PRG (time varying): Aerosols as passive tracers, updated every 6-hr from GEOS4-GOCART simulations
- The experimental aerosol treatment only impacts the model results via its direct effect on the radiative forcing of the atmosphere
Comparison between forecasts

Sfc Down SW, Day 5, 02 Jun 2006_06 Sep 2006

Precipitation (Prc) 200.78

Precipitation - Reference (Prg-Prc) -4.273

Temperature (T2m) [K], Day 5, 02 Jun 2006_06 Sep 2006

Precipitation (Prc) 239.78

Precipitation - Reference (Prg-Prc) -0.088

Legend:
-2 -1.5 -1.2 -0.8 -0.4 -0.2 0.002 0.006 0.012 0.018 0.024 0.03
Comparison between forecasts and analyses:
Anomaly correlation for 5-day forecasts of 500 mb heights

Northern hemisphere

Southern hemisphere

JCSDA Science Workshop, June 10-11, 2008
Comparison between forecasts and analyses:
RMS errors for 3-day forecasts of tropical winds

RMS Err: WIND P850 G2/TR0 00Z, Day 3

850 mb

RMS Err: WIND P200 G2/TR0 00Z, Day 3

200 mb
Comparison between forecasts and analyses: RMS errors of NH temp for 00Z forecasts

RMS: 20080604-20080607 Mean for T G2/NHX 00Z

Forecast hours
Comparison between forecasts and analyses:
RMS errors of tropical winds for 00Z forecasts

RMS: 20060604–20060607 Mean for WIND G2/TRAN 00Z

Pressure

Forecast hours

JCSDA Science Workshop, June 10-11, 2008
Comparison between forecasts and analyses: RMS errors of NH 850mb Temperature

North America Temperature 850 mb RMS Fit to RAOBS
00z04jun2006 - 00z07sep2006

48-hr fcst

24-hr fcst
Comparison between forecasts and analyses:
Vertical profiles of temperature biases and RMS errors

North America Temp Fits to RAOBS
00z04jun2006 - 00z07sep2006

North America Data Counts

BIAS (F-O) vs RMSE

prec-48hr
prec-24hr
prog-48hr
prog-24hr
Comparison between forecasts and analyses:
Northern American Precip. and Temp. Verification

North America
00Z05JUN2006 – 00Z06SEP2006
12-36 hrs average

Temp 850 mb 48-HR BIAS in Celsius
from 00z04jul2006–00z07sep2006
prc-OBS : Station Count 72 RMSE of mean 1.49

prc-OBS : Station Count 72 RMSE of mean 1.35

Threshold (mm/24 hrs)
Comparison between forecasts and analyses: Downward SW fluxes verification at SURFRAD sites

PRC 6HR SW at SURFRAD Sites 00z02Jun2006–18z07Sep2006

Table Mountain CO

Desert Rock NV

Fort Peck MT

Goodwin Creek MS

Bandville IL

Sioux Fall SD

SURFRAD [Wm⁻²]

PRG 6HR SW at SURFRAD Sites 00z02Jun2006–18z07Sep2006

Table Mountain CO

Desert Rock NV

Fort Peck MT

Goodwin Creek MS

Bandville IL

Sioux Fall SD

SURFRAD [Wm⁻²]
Comparison between forecasts and analyses: Storm track errors for Atlantic hurricanes Alberto & Ernesto

Average track errors (NM) FOR HOMOGENEOUS SAMPLE

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Impact of Aerosols in Global Model
Track Error Comparison, ATLANTIC HURRICANES, 2006
Tracer transport and mass conservation in GFS
GFS Tracer Experiments

- GFS experiment configuration
  - T62 L64
  - Three ICs: 2007-07-01, 2007-10-01, and 2008-01-01 00Z
  - 30-day integration
  - 17 idealized tracers added (ntrac increased from 3 to 20)
  - Control run (CTR)
    - Hybrid general coordinate; enthalpy
    - SAS, Zhao cloud microphysics
    - Digital filter off
  - Sensitivity runs
    - OPR: Sigma-P hybrid coordinate dyn
    - TVD: Flux-limited vertical advection dyn
    - DFS: Vertical/horizontal diffusion turned off phy
    - RAS: relaxed Arakawa-Schubert convection phy
    - CLD: Ferrier cloud microphysics phy
    - ZER: Zerout initial tracer fields ic
The inclusion of 17 idealized (passive) tracers leads to \( \sim 53\% \) increase in wall time
Idealized tracer initialization

Set to 1.0 over specified domain/layers, zero elsewhere
Horizontal: globally and over 4 regions (shown here)
Vertical: SFC (k=1,2); UTLS (k=40-45); ALL (k=1,64)

Q7: EAS_SFC  Q10: WAF_SFC
Q16: NAM_SFC  Q13: SAM_SFC
Time series of normalized global sum change
CTRL run; IC = 2007-10-01

Normalized global sum change = \(100 \times \frac{(\text{glbsum} - \text{glbsum}_i)}{\text{glbsum}_i}\)
Change in normalized global sum
5 spatial domains: GB, EAS, WAF, SAM, NAM
3 vertical levels: SFC, UTLS, ALL

Change in Cksum (CTRL; 2007-10)
3 ICs versus 6 experiments for GB_ALL tracer

0.1-0.2 %, except for OPR
Zonal mean cross section (IC = 2007-10)

CTRL
CTRL; Q4 (GB_SFC)

FLXTVD
FLXTVD; Q4 (GB_SFC)

CTRL; Q5 (GB_UTLS)

FLXTVD; Q5 (GB_UTLS)

SFC

UTLS
Conclusions

- NCEP recently initializes the efforts to develop **global aerosol forecasting and assimilation capability** in GFS/GSI system via the NCEP-GSFC collaborations.
- This project enables the use of **NASA earth science results** (GOCART model and aerosol measurements) to enhance **NOAA environmental forecasting capability**.
- Results of GFS/GSI experiments for the 2006 summer period are presented.
  - Changes in model forecasts arises from the **direct radiative effects**.
  - The impact of aerosols on medium range weather forecasts is examined.
  - The verification against analysis and observation indicates **small and yet positive** forecasts due to realistic time-varying treatment of aerosols.
- Results of GFS idealized tracer experiments are presented.
  - The inclusion of 17 passive tracers leads to 50% increase in wall-time.
  - Mass conservation and tracer transport are examined:
    - Global sum is off by 0.1-0.2% [< 0.04%] for GB_ALL [GB_UTLS] tracer after 30-day integration.
    - Flux-limited vertical advection scheme substantially removes (but not eliminates) negative tracer values.
  - **Needed capabilities**:
    - Convective transport (already available in RAS)
    - Tracer scavenging in moisture processes
    - Positive definite advection with mass conserving and time saving
Initial conditions in NEMS GFS

- Q7: EAS_SFC
- Q10: WAF_SFC
- Q16: NAM_SFC
- Q13: SAM_SFC
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