Overview of the GFS-GOCART Aerosol Forecasting System

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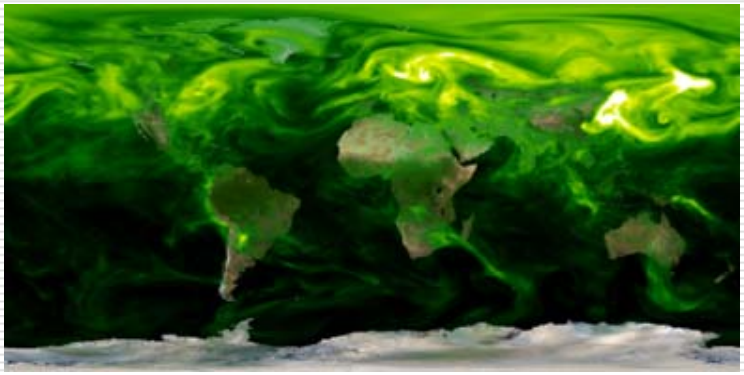
Project Overview

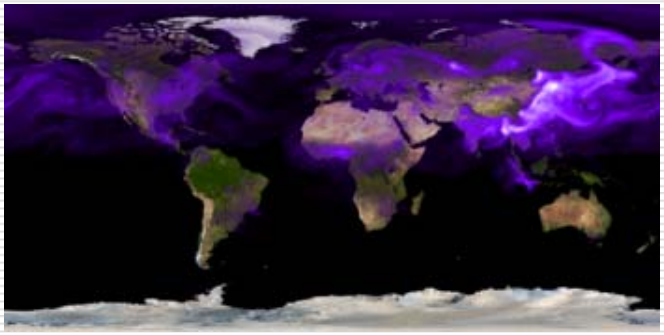
- Goal: Integration of NASA aerosol modeling and monitoring capabilities into NOAA Decision Support System
- Tasks:
  - Implementation of prognostic aerosols (GOCART) in NEMS GFS
  - Utilization of NASA aerosol data in GFS/GSI system
  - Downstream coupling
    - Regional AQF system (Lateral aerosol 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)

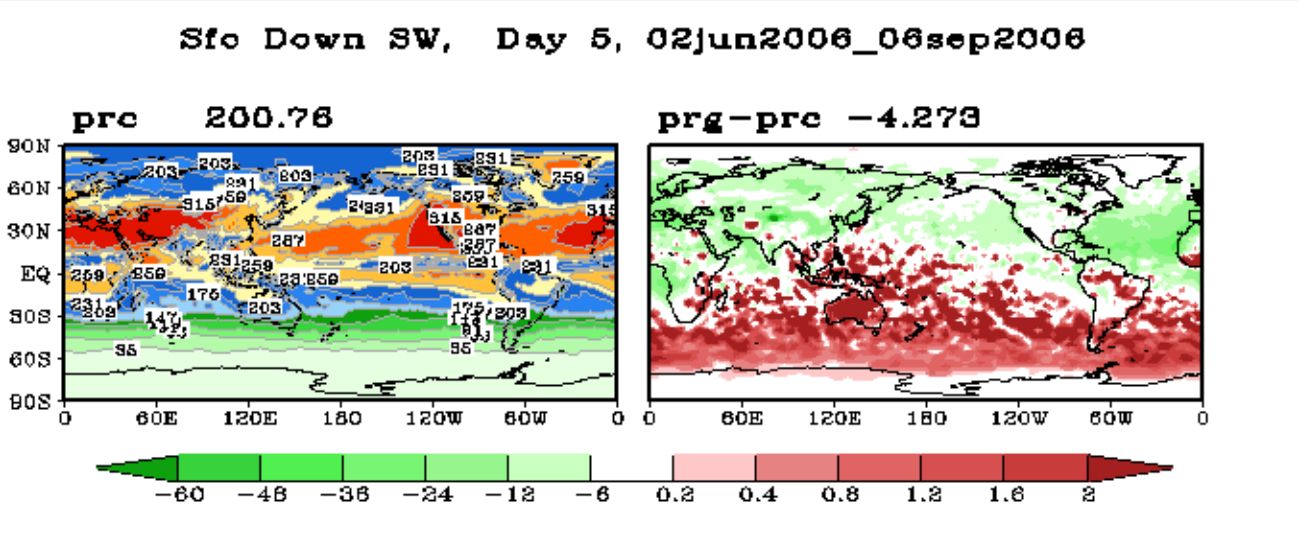
Global/regional analysis system for operational weather forecasts

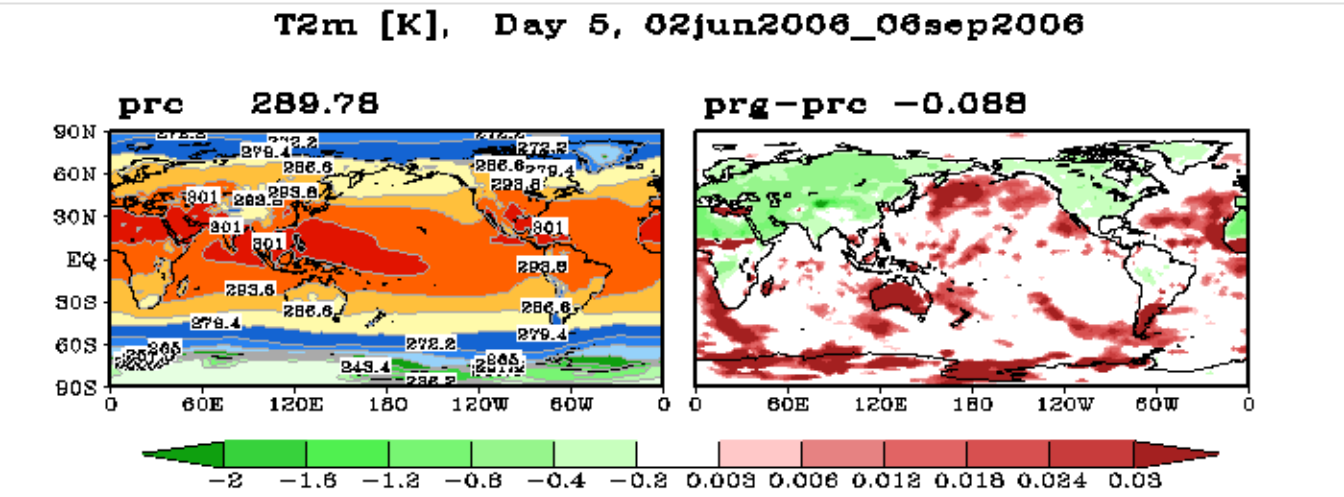
- **NCEP 3DVAR assimilation system**
  - Implemented with WRF-NMM into the NAM system in June, 2006
  - Implemented for replacement of SSI in the GFS system in May, 2007
- **SCIENTIFIC ADVANCES**
  - Grid point definition of background errors
  - Inclusion of new types of data (e.g., AIRS radiance, COSMIC 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

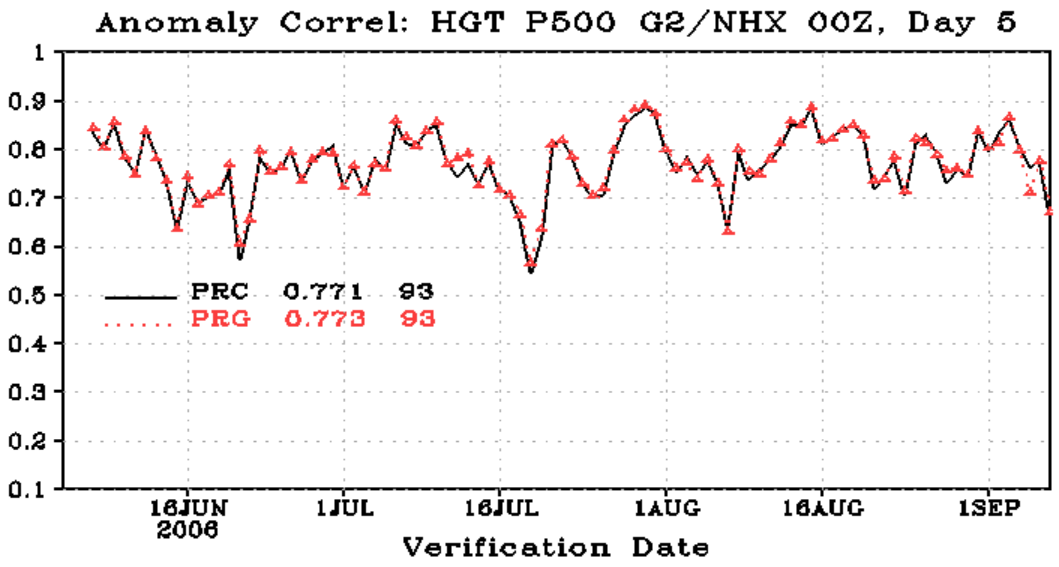
- T126 L64
- Sigma-pressure hybrid coordinate
- Initialized from 2006-06-01 00Z GDAS analysis
- 14-week cycling, ending at 2006-09-07 18Z
- Aerosol scheme configuration
  - PRC (climatology): OPAC climatological scheme (5° x 5° monthly climatology)
  - PRG (time varying): Aerosols as passive tracers, 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

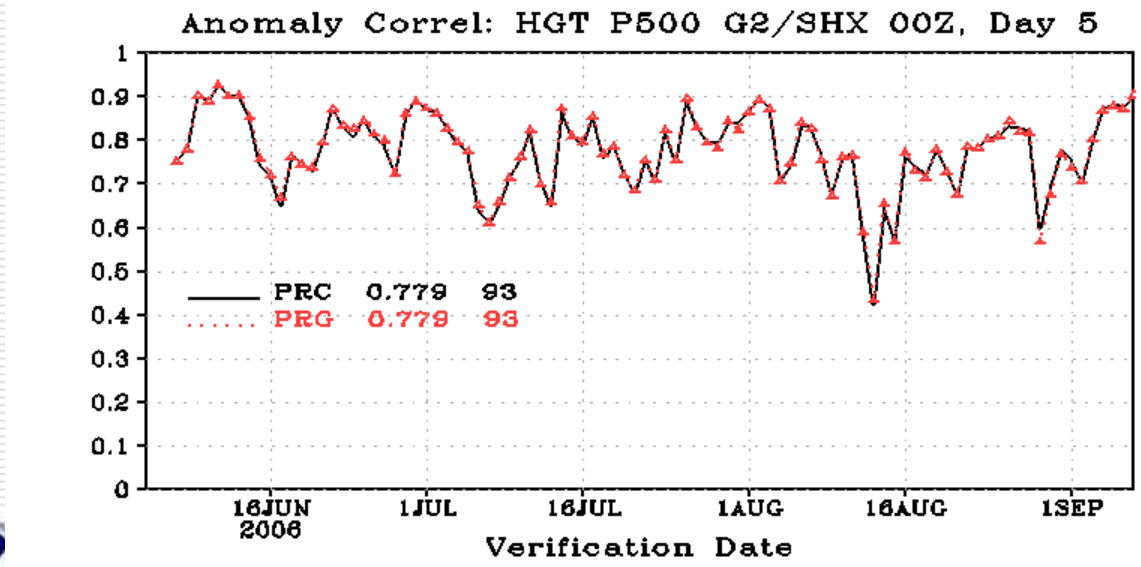




Comparison between forecasts and analyses:
Anomaly correlation for 5-day forecasts of 500 mb heights

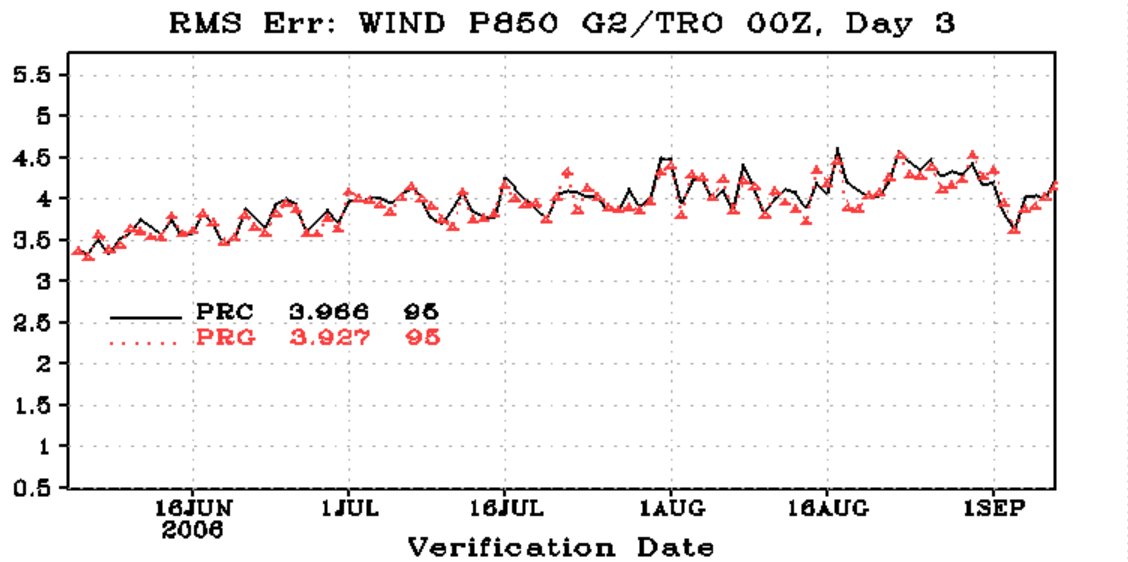


Northern hemisphere

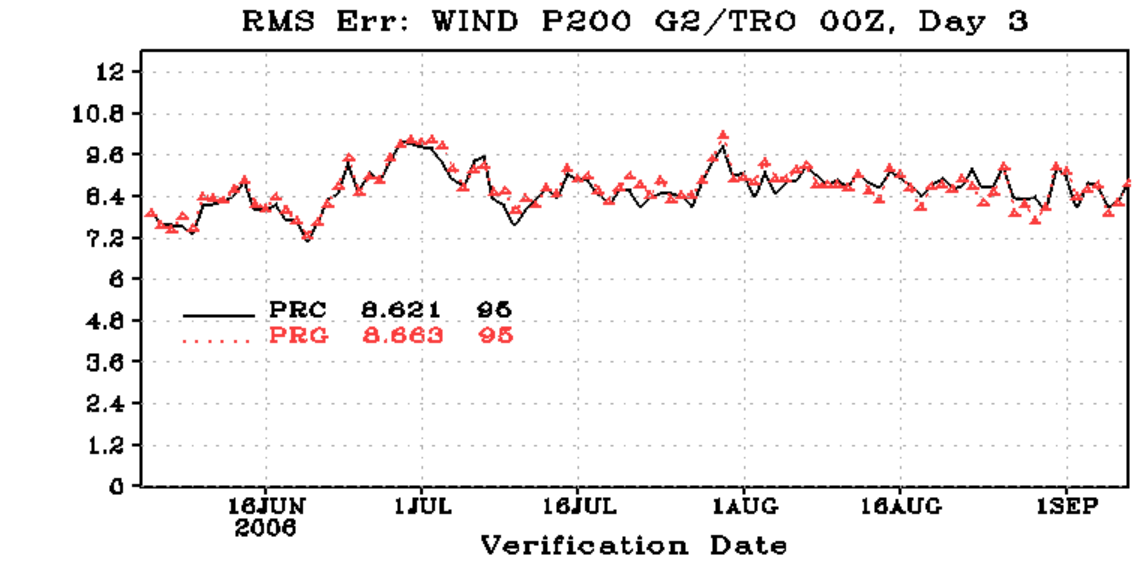


Southern hemisphere

Comparison between forecasts and analyses:
RMS errors for 3-day forecasts of tropical winds

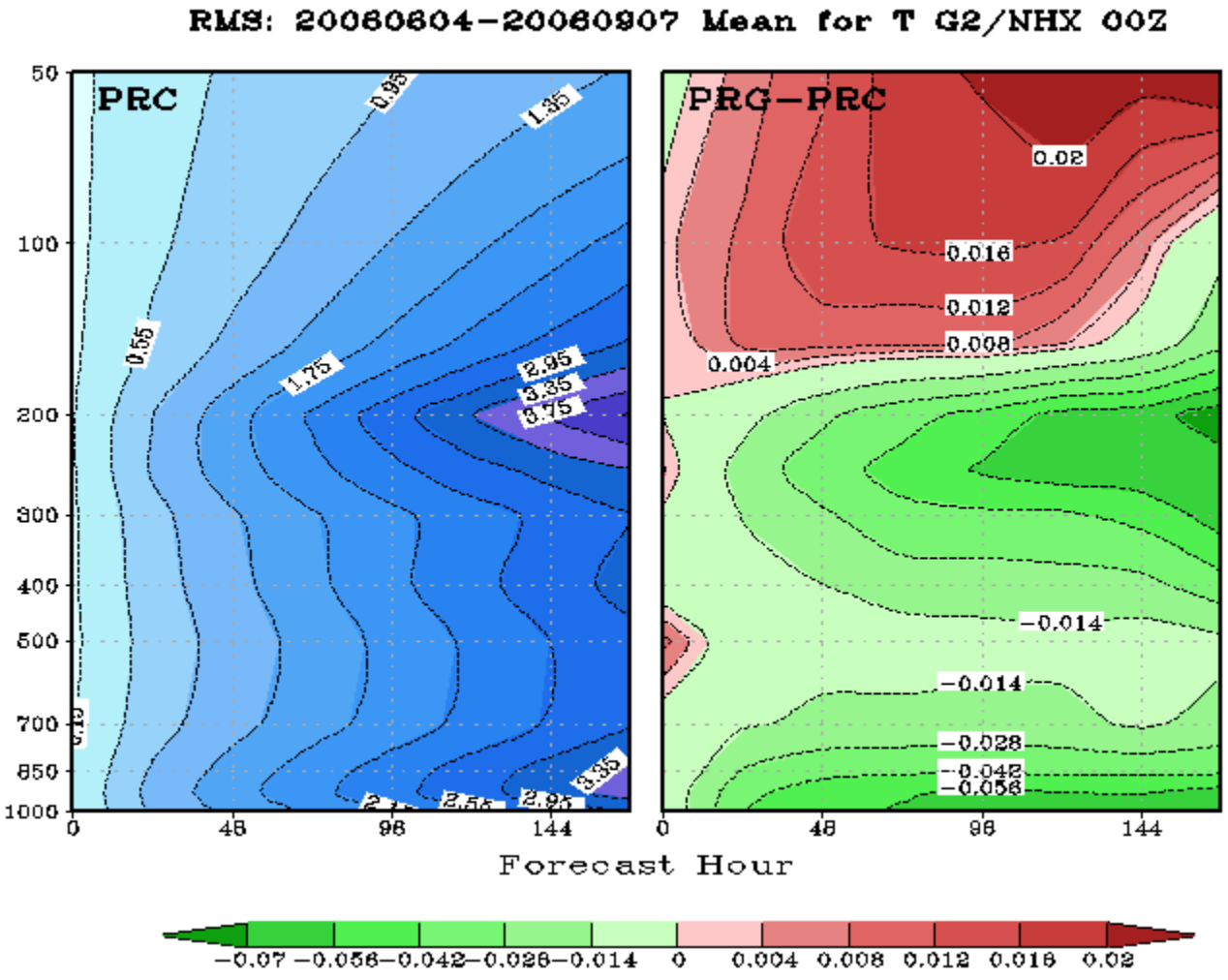


850 mb

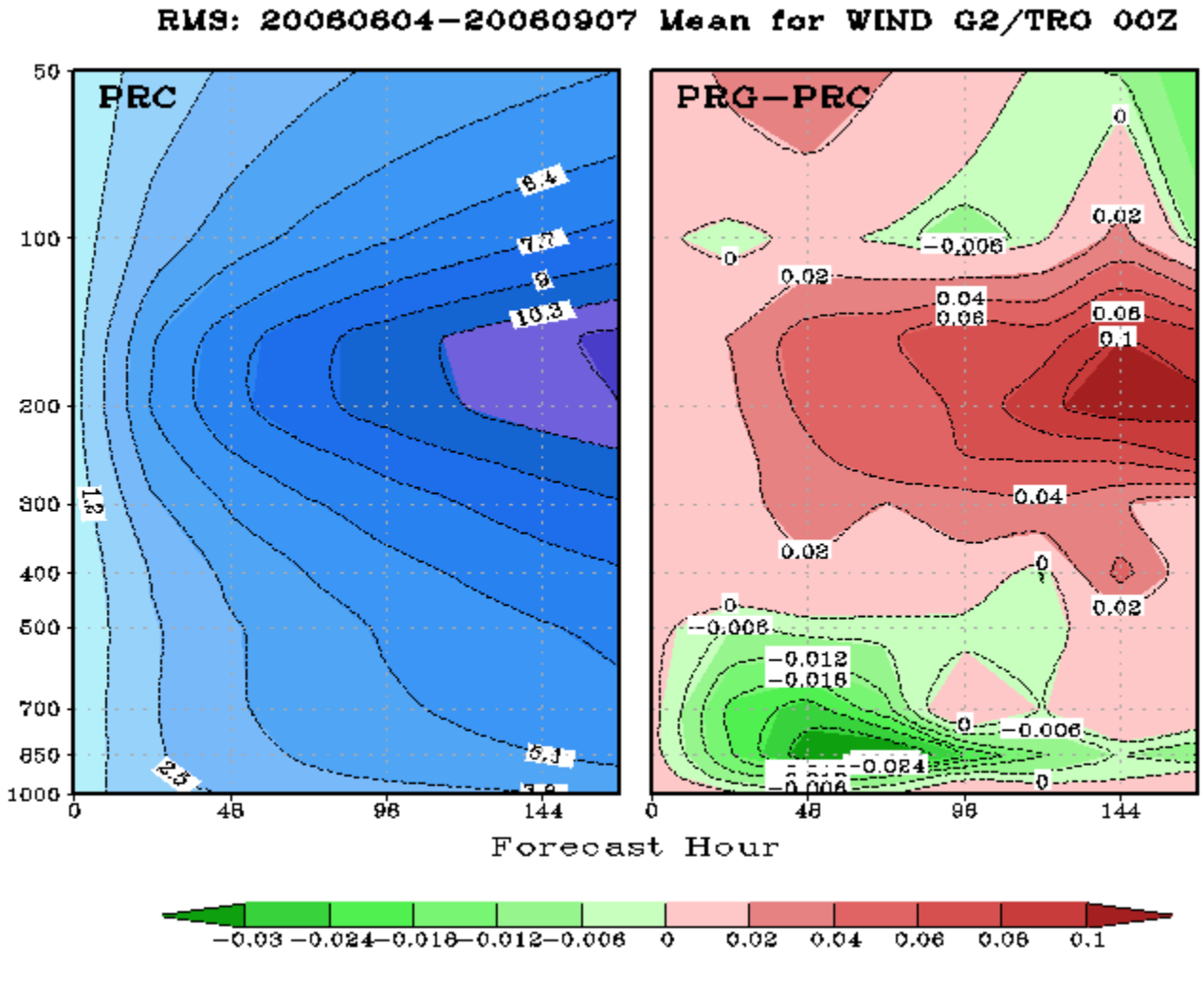


200 mb

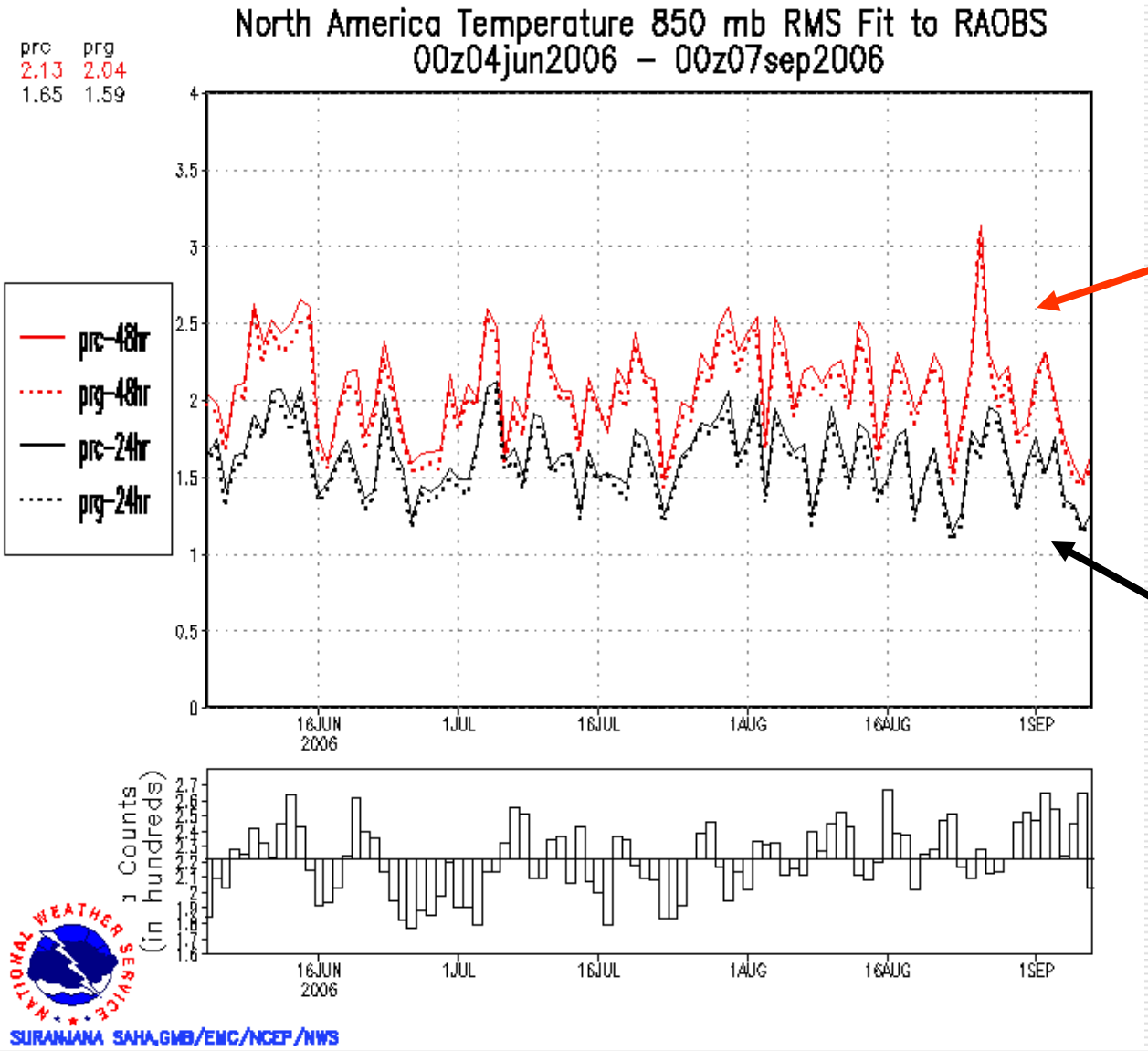
Comparison between forecasts and analyses:
RMS errors of NH temp for 00Z forecasts



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



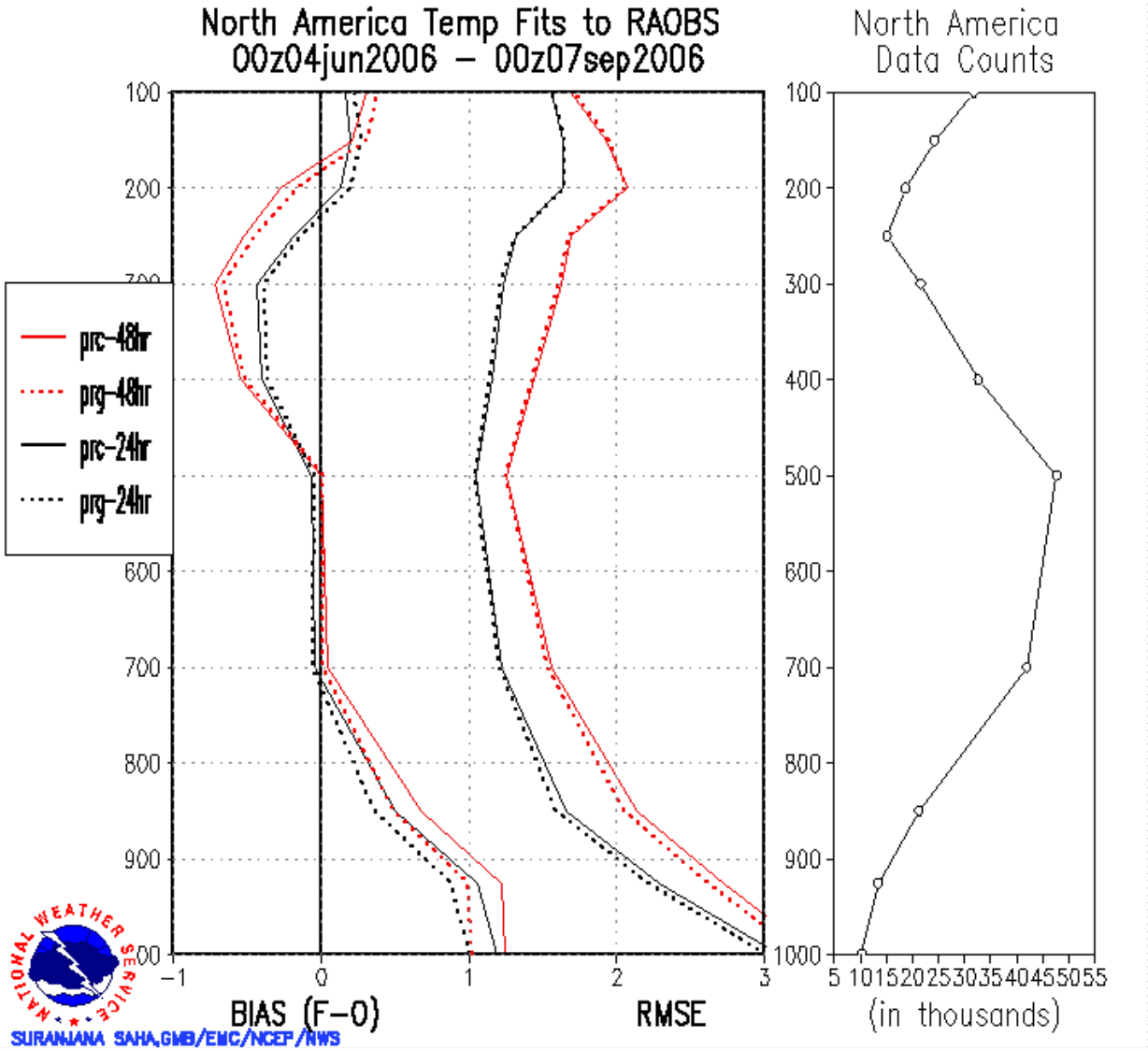
Comparison between forecasts and analyses:
RMS errors of NH 850mb Temperature



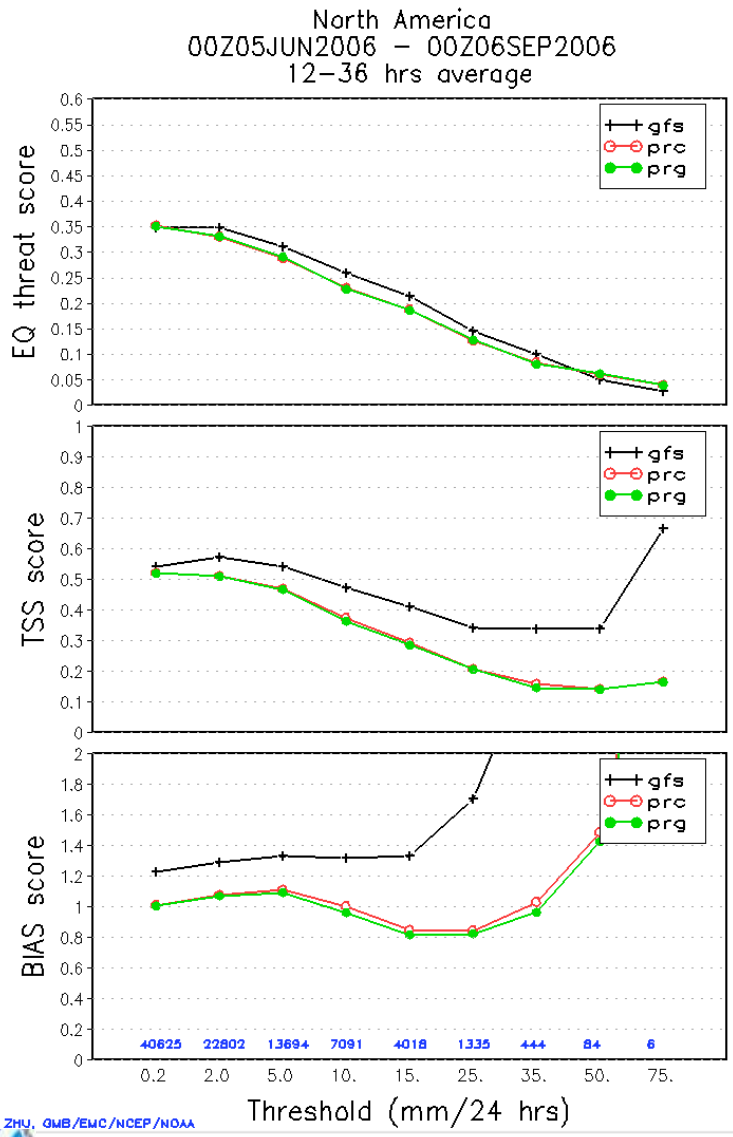
48-hr fcst

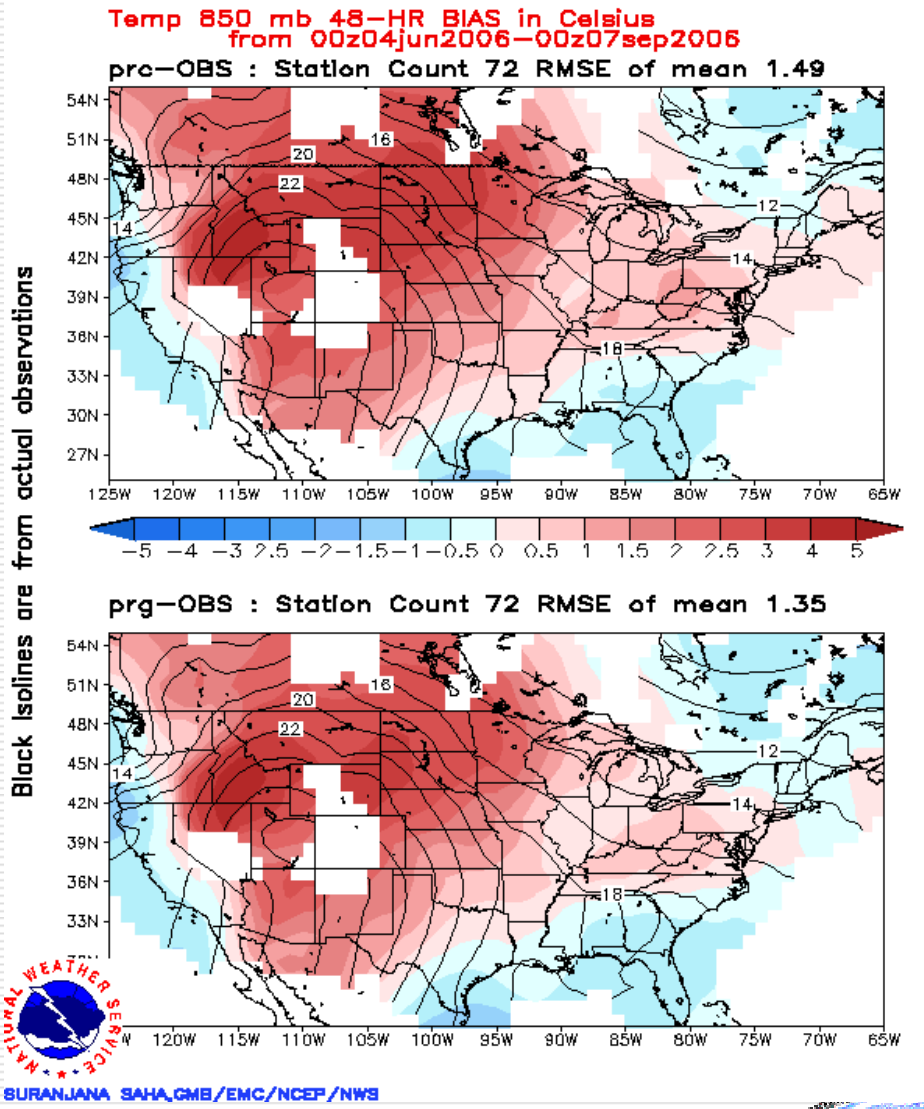
24-hr fcst

Comparison between forecasts and analyses:
Vertical profiles of temperature biases and RMS errors



Comparison between forecasts and analyses:
Northern American Precip. and Temp. Verification





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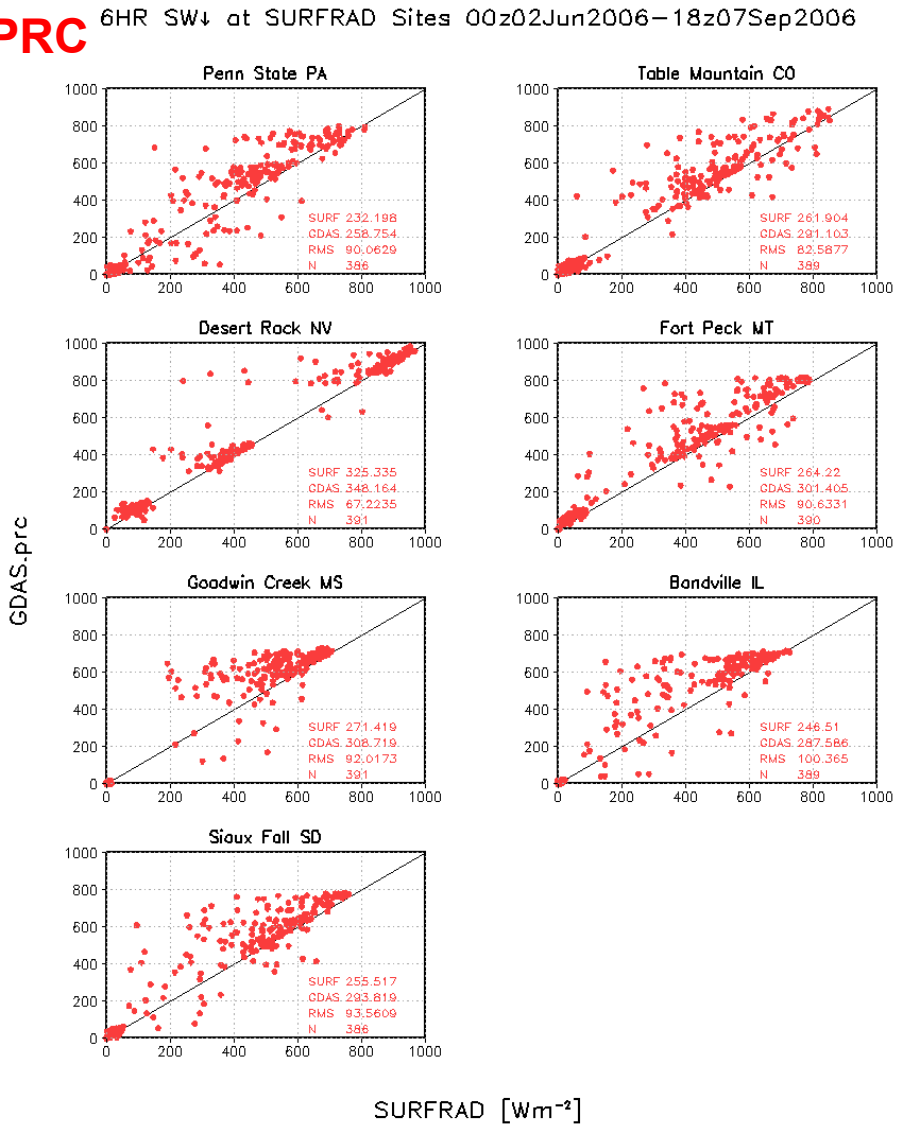
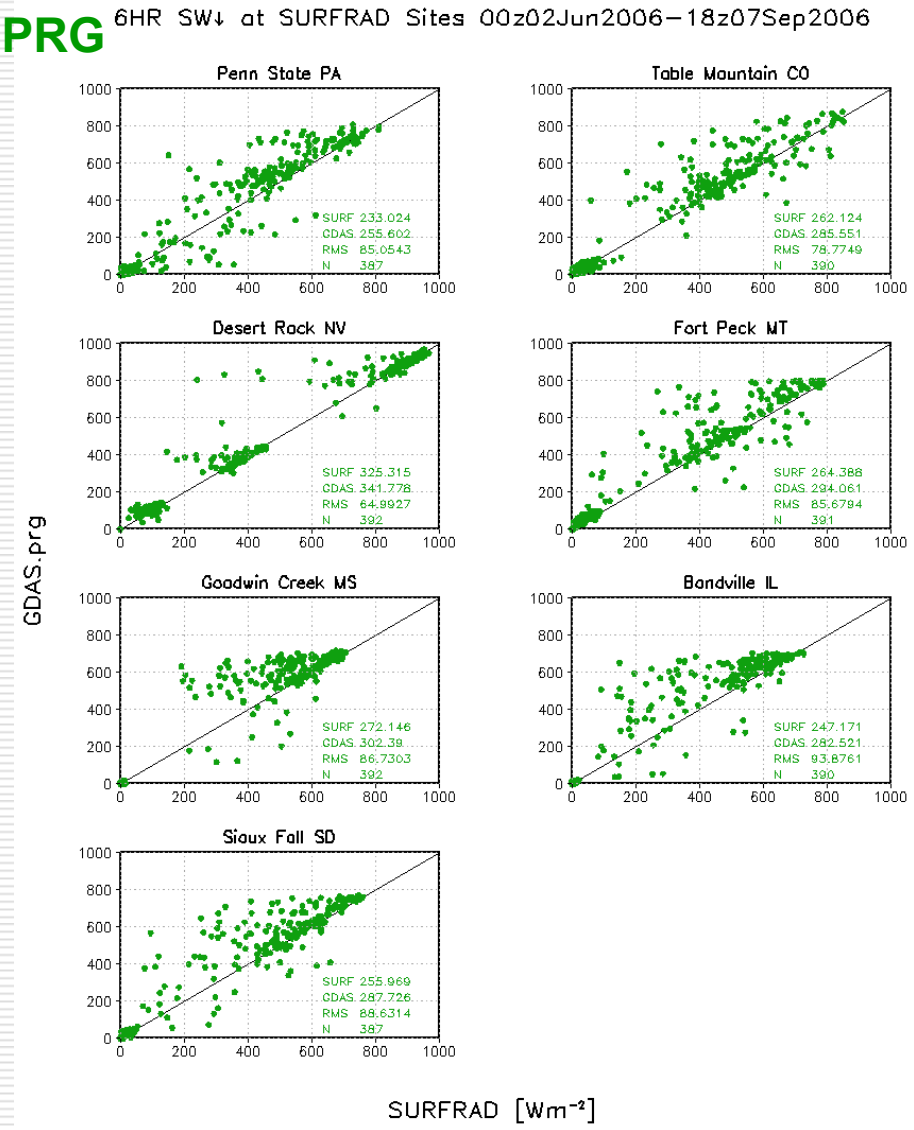
Comparison between forecasts and analyses:
Downward SW fluxes verification at SURFRAD sites

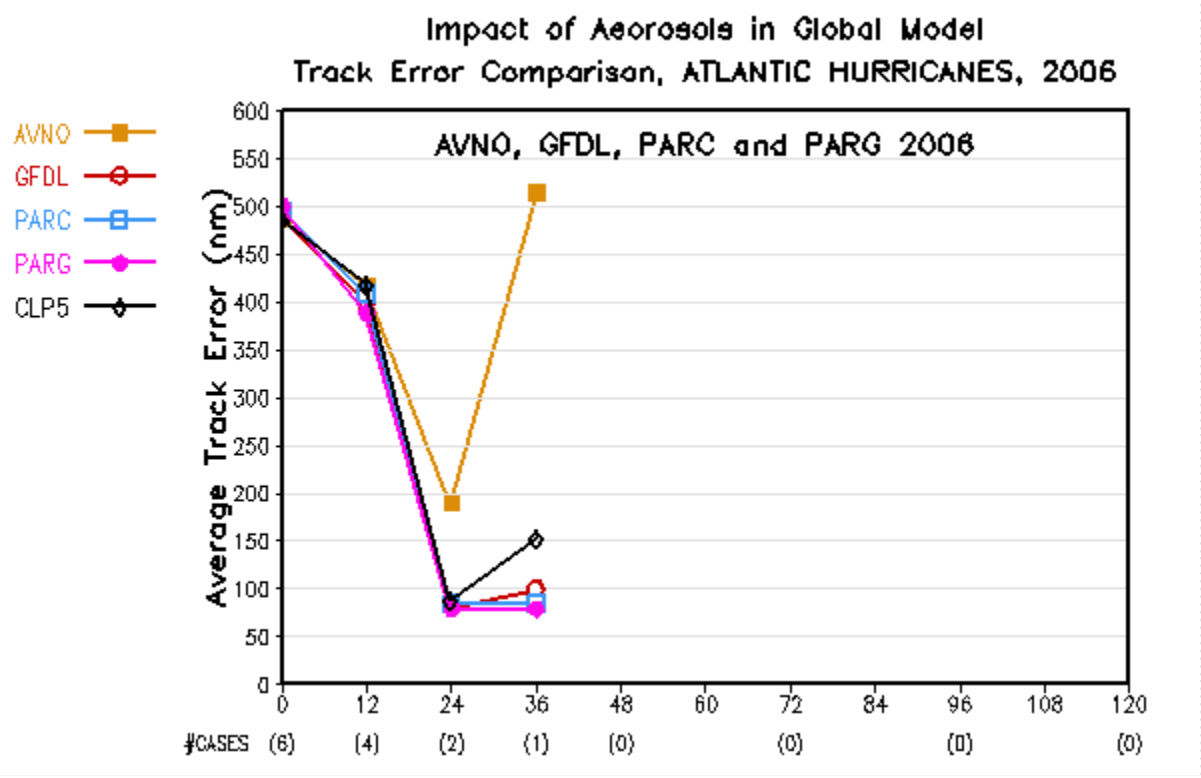
PRC



PRG



Comparison between forecasts and analyses:
Storm track errors for Atlantic hurricanes Alberto & Ernesto



Average track errors (NM) FOR HOMOGENEOUS SAMPLE

	12	24	36	48	72	96	120
PARC	406.9	83.4	83.7				
PARG	388.9	79.5	78.9				
CLP5	417.4	87.9	152.3				
#CASES	4	2	1				

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

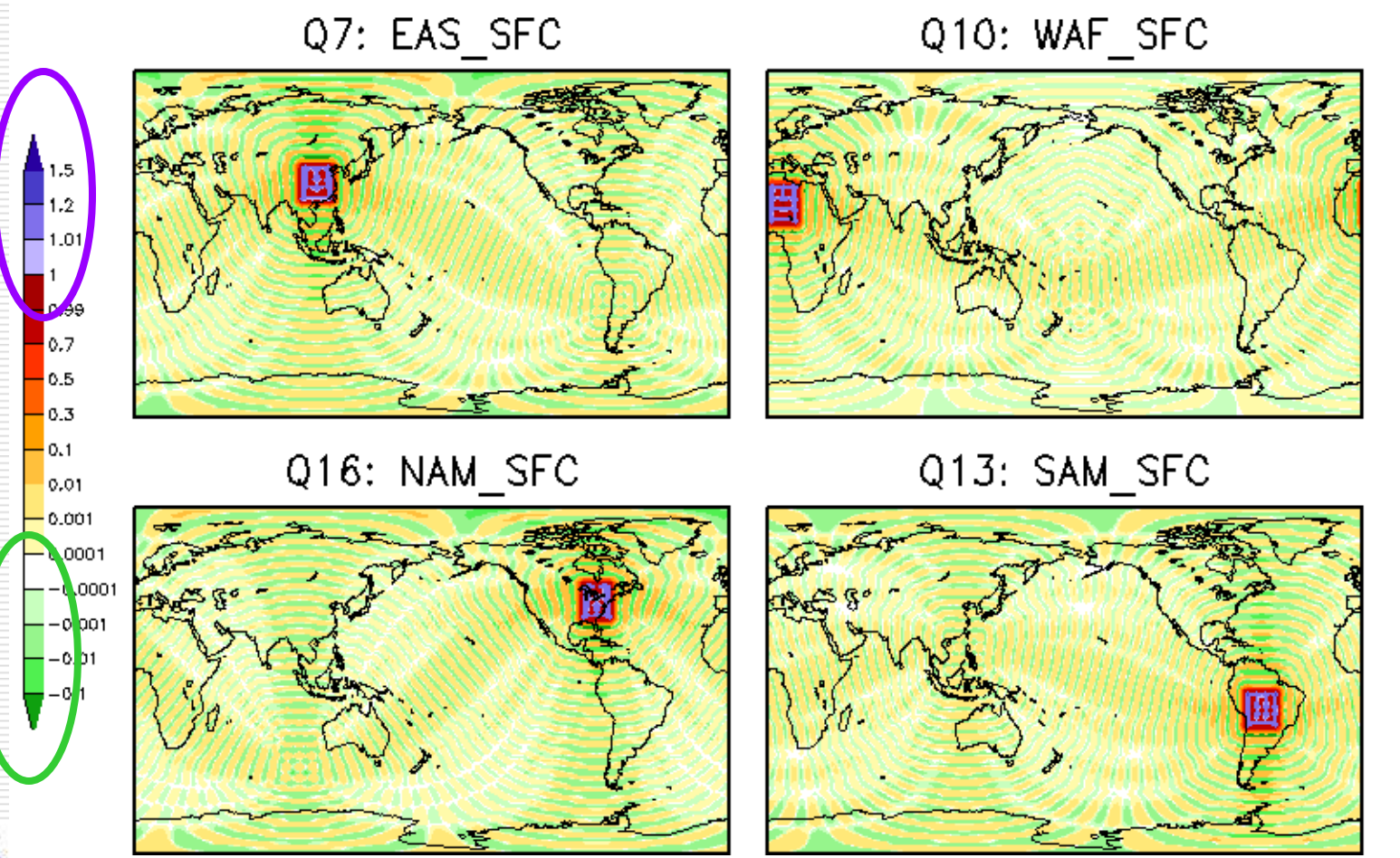
Wall-time

	NTRAC=3	NTRAC=20
2007-07	3023	4604
2007-10	2918	4455
2008-01	2988	4558

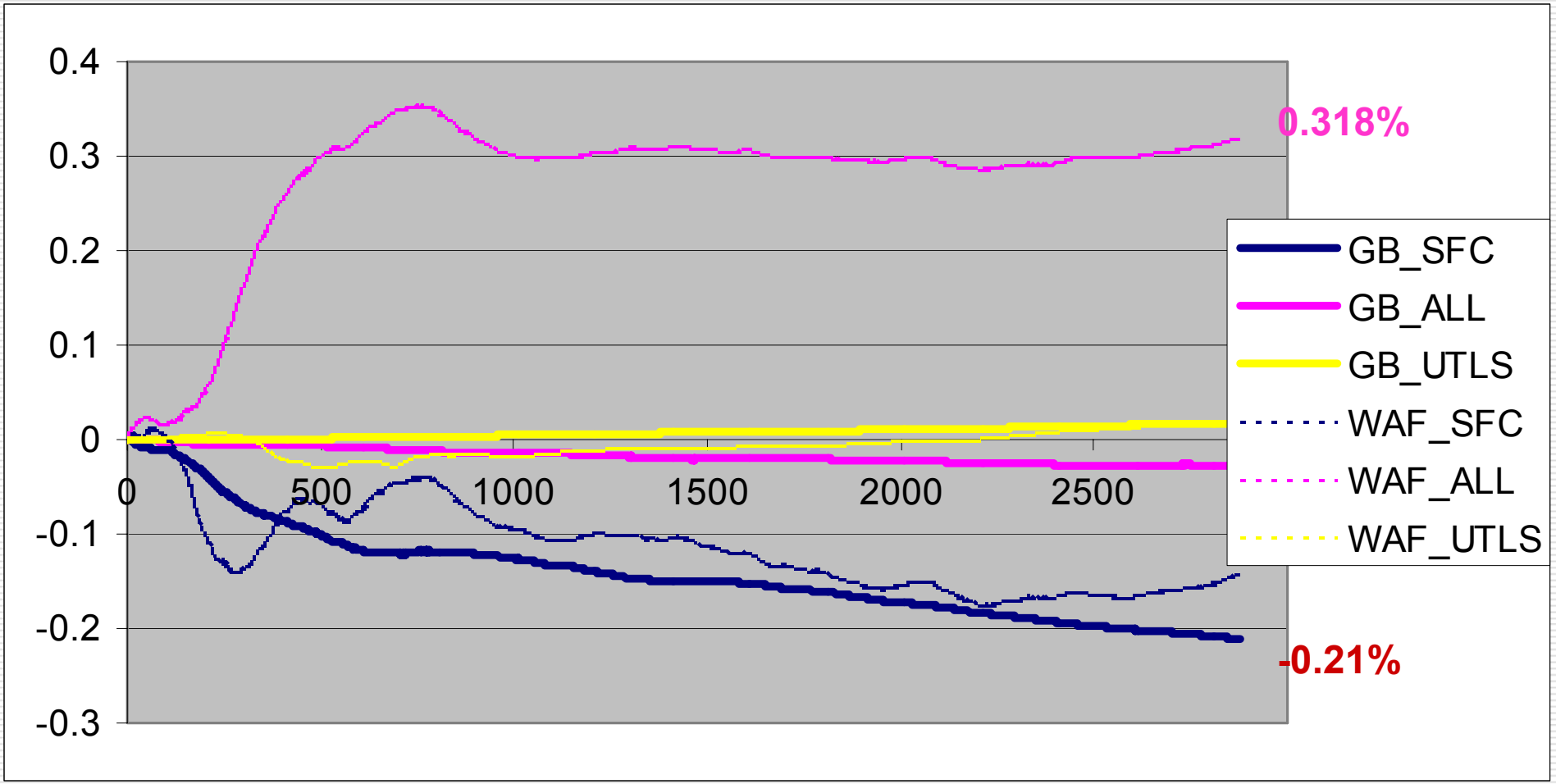
The inclusion of 17 idealized (passive) tracers leads to ~ 53% increase in wall time

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)



Time series of normalized global sum change
CTRL run; IC = 2007-10-01

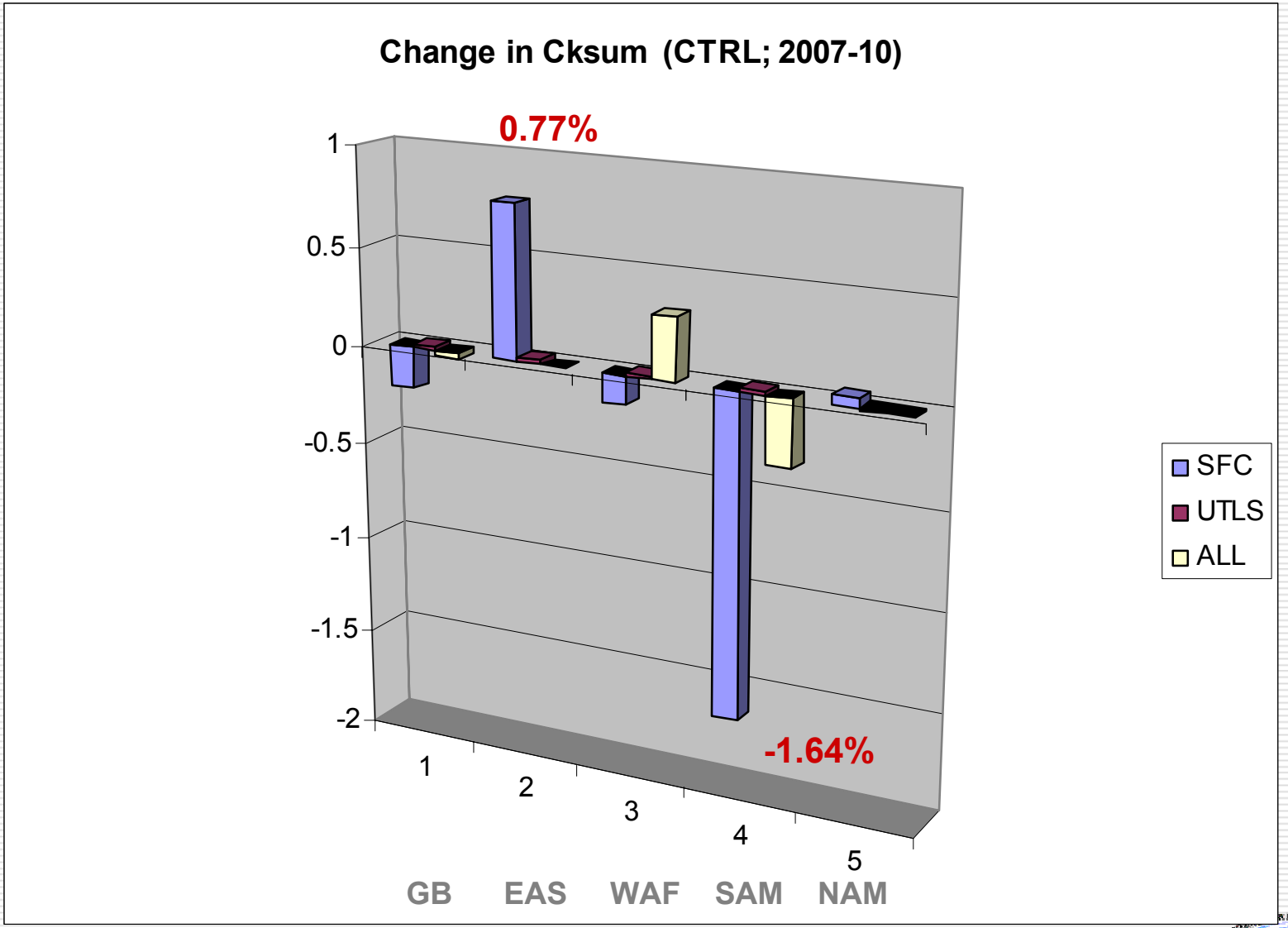


Normalized global sum change = 100. x (glbsum-glbsum$_i$)/ glbsum$_i$

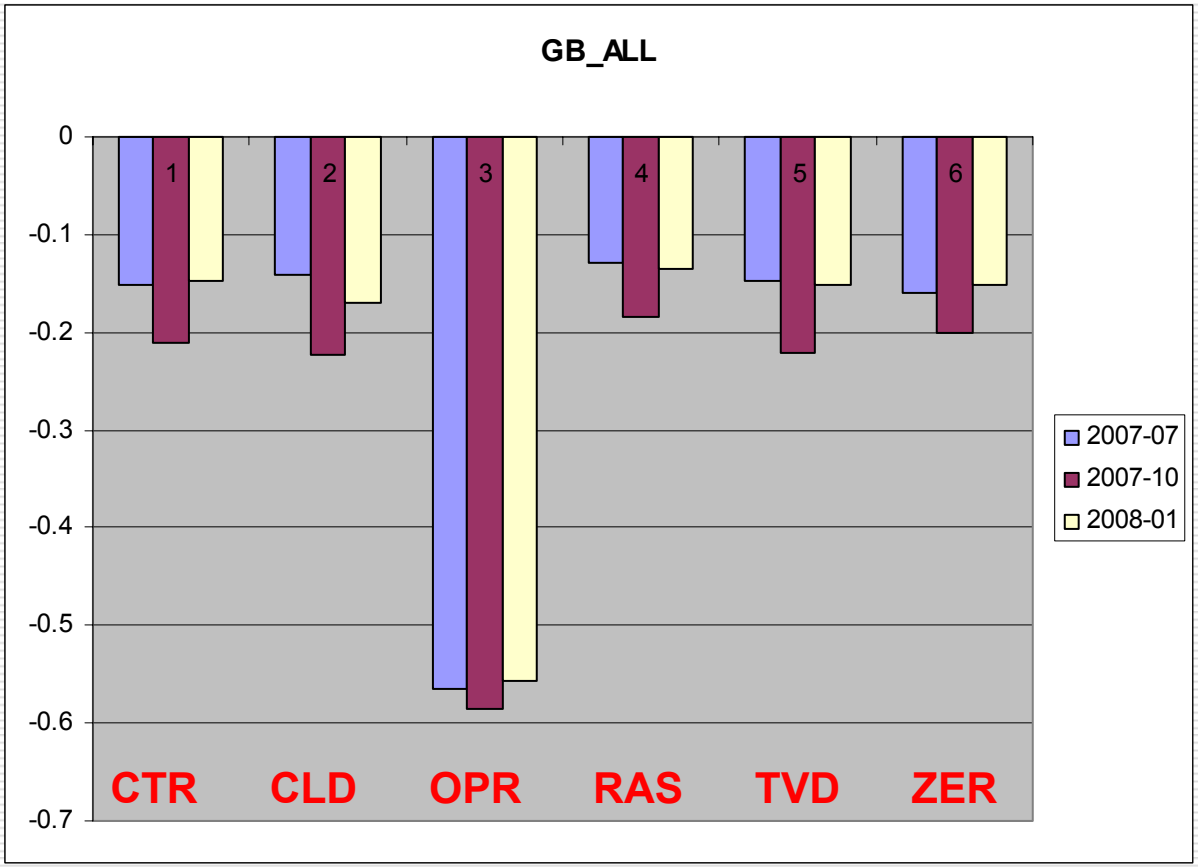
Change in normalized global sum

5 spatial domains: GB, EAS, WAF, SAM, NAM

3 vertical levels: SFC, UTLS, ALL

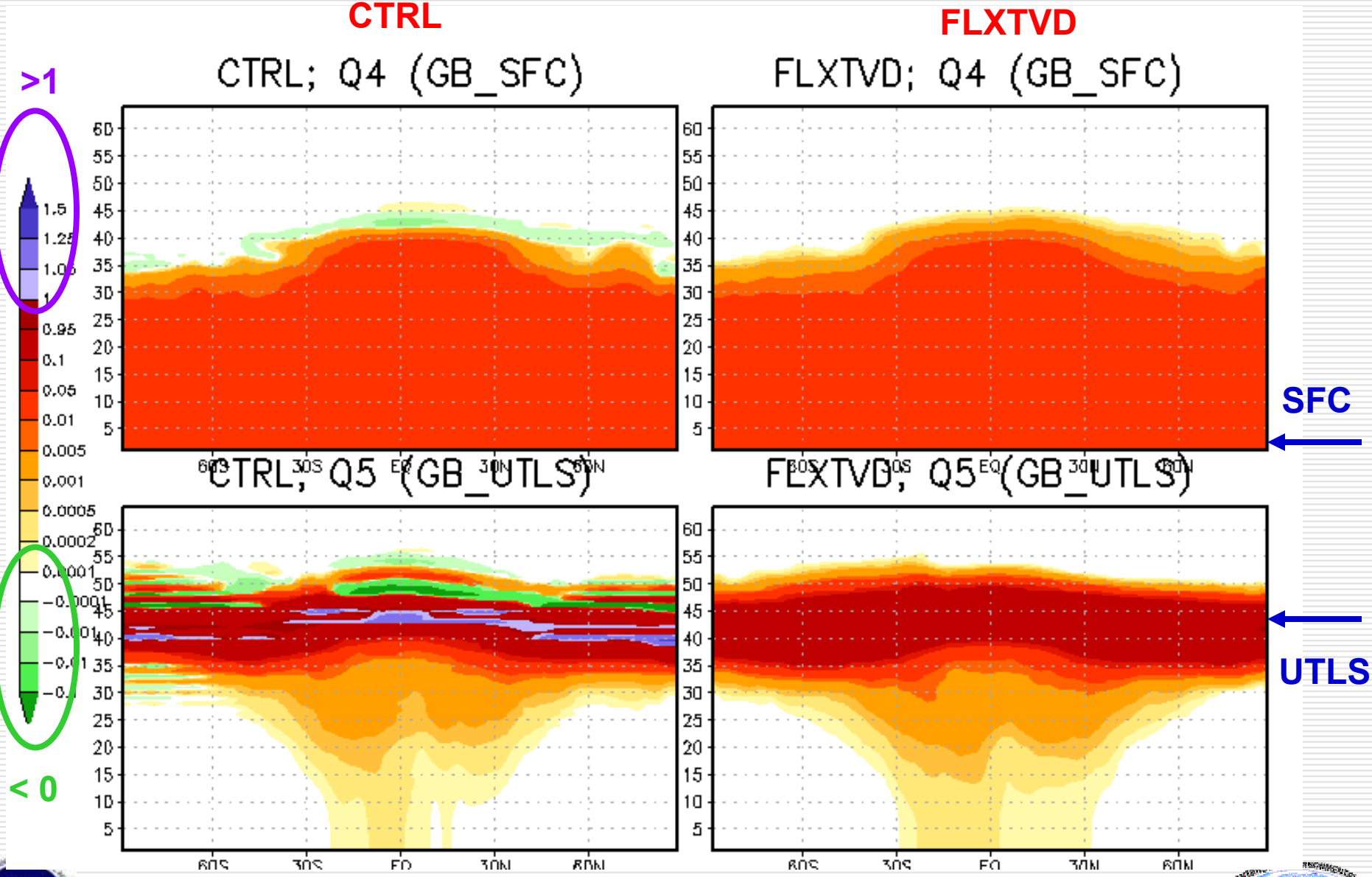


3 ICs versus 6 experiments for GB_ALL tracer



0.1- 0.2 %, except for OPR

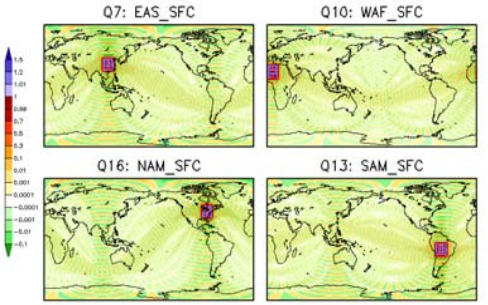
Zonal mean cross section (IC = 2007-10)

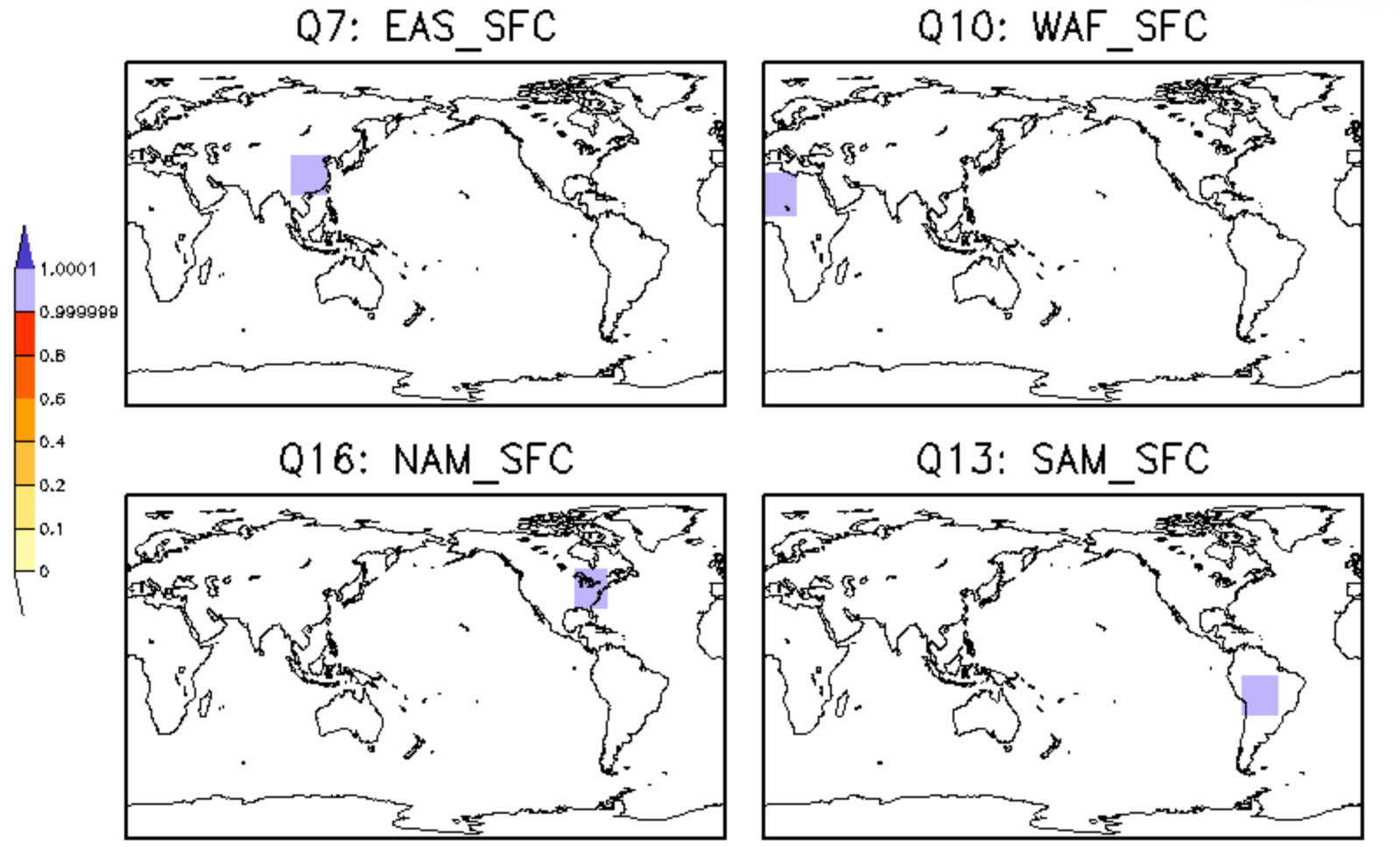


Conclusions

- 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





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Thank You