JCSDA and the NCEP Environmental Modeling Center

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Director
NCEP Environmental Modeling Center

Overview

- **EMC Organization**
- **JCSDA and NCEP/EMC Activity Summary**
- **Summary**

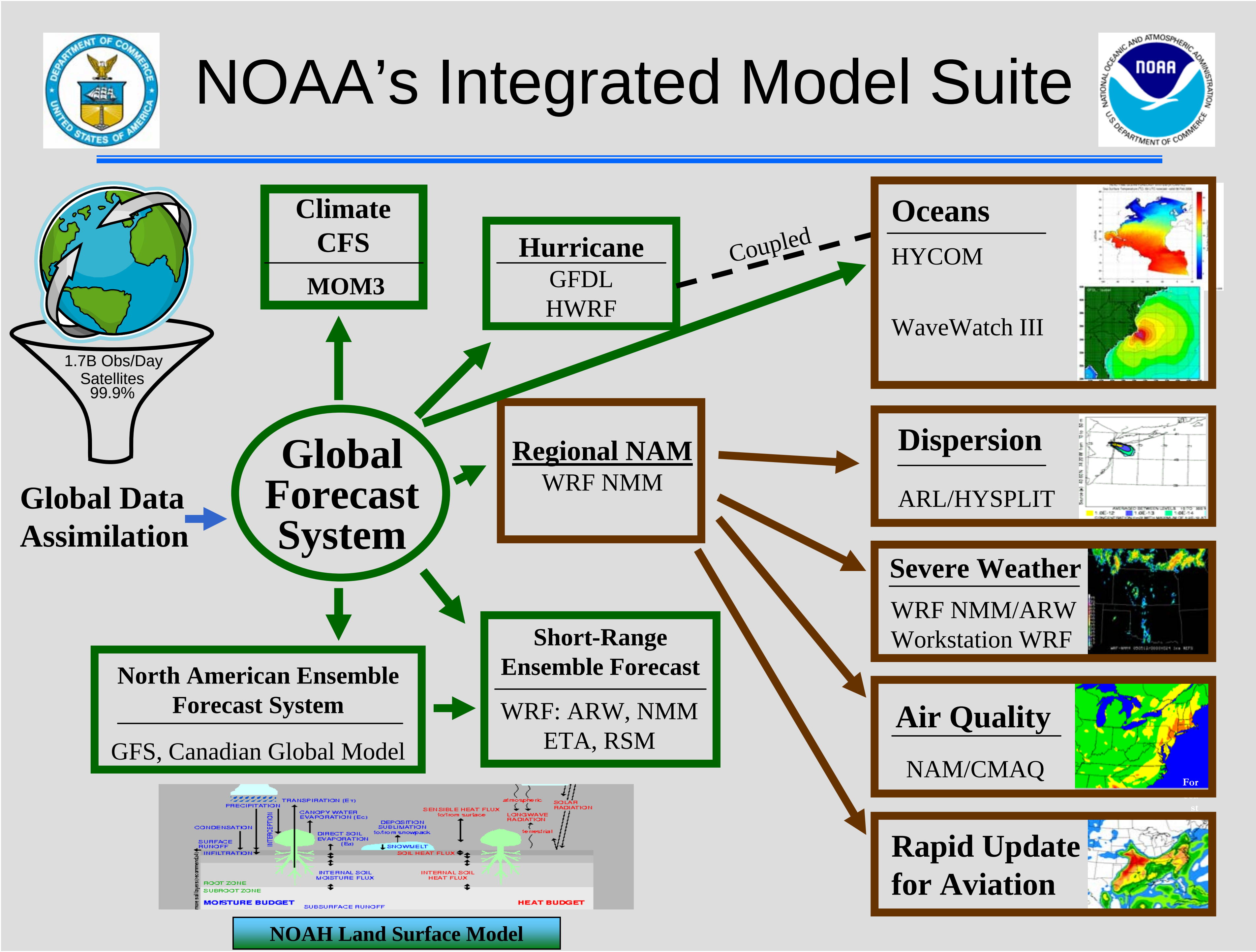
EMC Mission

In response to operational requirements:

- **Maintain**
  - the scientific correctness and integrity of operational forecast systems
  - modify current operational system to adapt to ever-present external changes

- **Enhance** numerical forecasts
  - Test and improve NCEP's numerical forecast systems via
    - Scientific upgrades
    - Tuning
    - Additional observations
- **Transition and Develop o**perational numerical forecast systems
  - **transform & integrate**
    - Code
    - Algorithms
    - Techniques

    from research status to operational status on NCEP computers


NOAA's Integrated Model Suite
1.7B Obs/Day
Satellites
99.9%
Global Data Assimilation
Global Forecast System
Climate CFS
MOM3
Hurricane
GFDL
HWRF
Coupled
Oceans
HYCOM
WaveWatch III
Regional NAM
WRF NMM
Dispersion
ARL/HYSPLIT
Severe Weather
WRF NMM/ARW
Workstation WRF
Air Quality
NAM/CMAQ
Rapid Update for Aviation
North American Ensemble Forecast System
GFS, Canadian Global Model
Short-Range Ensemble Forecast
WRF: ARW, NMM
ETA, RSM
PRECIPITATION
TRANSPIRATION (Et)
CANOPY WATER EVAPORATION (Ec)
CONDENSATION
SURFACE RUNOFF
INFILTRATION
INTERCEPTION
DIRECT SOIL EVAPORATION (Eg)
DEPOSITION SUBLIMATION to/from snowpack
SNOWMELT
SENSIBLE HEAT FLUX to/from surface
SOIL HEAT FLUX
LONGWAVE RADIATION
SOLAR RADIATION
INTERNAL SOIL MOISTURE FLUX
INTERNAL SOIL HEAT FLUX
ROOT ZONE
SUBROOT ZONE
MOISTURE BUDGET
SUBSURFACE RUNOFF
HEAT BUDGET
NOAH Land Surface Model

JCSDA-NCEP/EMC Activity Summary

- **Relevant JCSDA-EMC development and implementations**

- **Note: EMC Data Assimilation and NESDIS-JCSDA personnel are co-located**

NCEP-JCSDA Instrument and Radiative Transfer Development Projects 2007-09

- **New observations implemented operationally at NCEP**
  - **1 May 2007**
    - **COSMIC**
    - **AIRS (all FOV)**
  - **29 May 2007**
    - **METOP AMSU, HSB, HIRS**
    - **GOES 1x1 FOV sounder radiances**
  - **December 2007**
    - **JMA high density winds**
    - **SBUV-8**
  - **September 2008**
    - **Windsat**
  - To be implemented February 2009
    - **IASI**

METOP advanced instruments

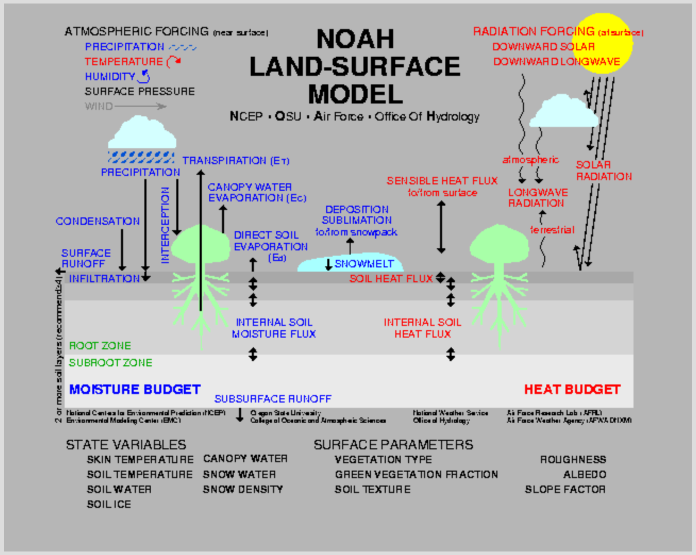
- **Observations under development (CRTM, tested with NCEP systems)**
  - **OMI, GOME, MLS**
  - **ASCAT**
  - **AMSR-E**
  - **SSM/IS**
  - **CHAMP**
  - AIRS (water vapor)
  - **CrIS, ATMS**

NPP, NPOESS advanced instruments

- **New analysis variables (NCEP)**
  - Constituent gas assimilation
  - **Aerosols**
- **Improved radiative transfer (CRTM, tested with NCEP systems)**
  - **Surface emissivity models (MW & IR)**
  - **Cloud absorption & reflection**
- **Data sets tested at NCEP (albedo, vegetation, land type)**
  - **Unified land surface treatment (data assimilation, model)**

Land Information System (LIS)

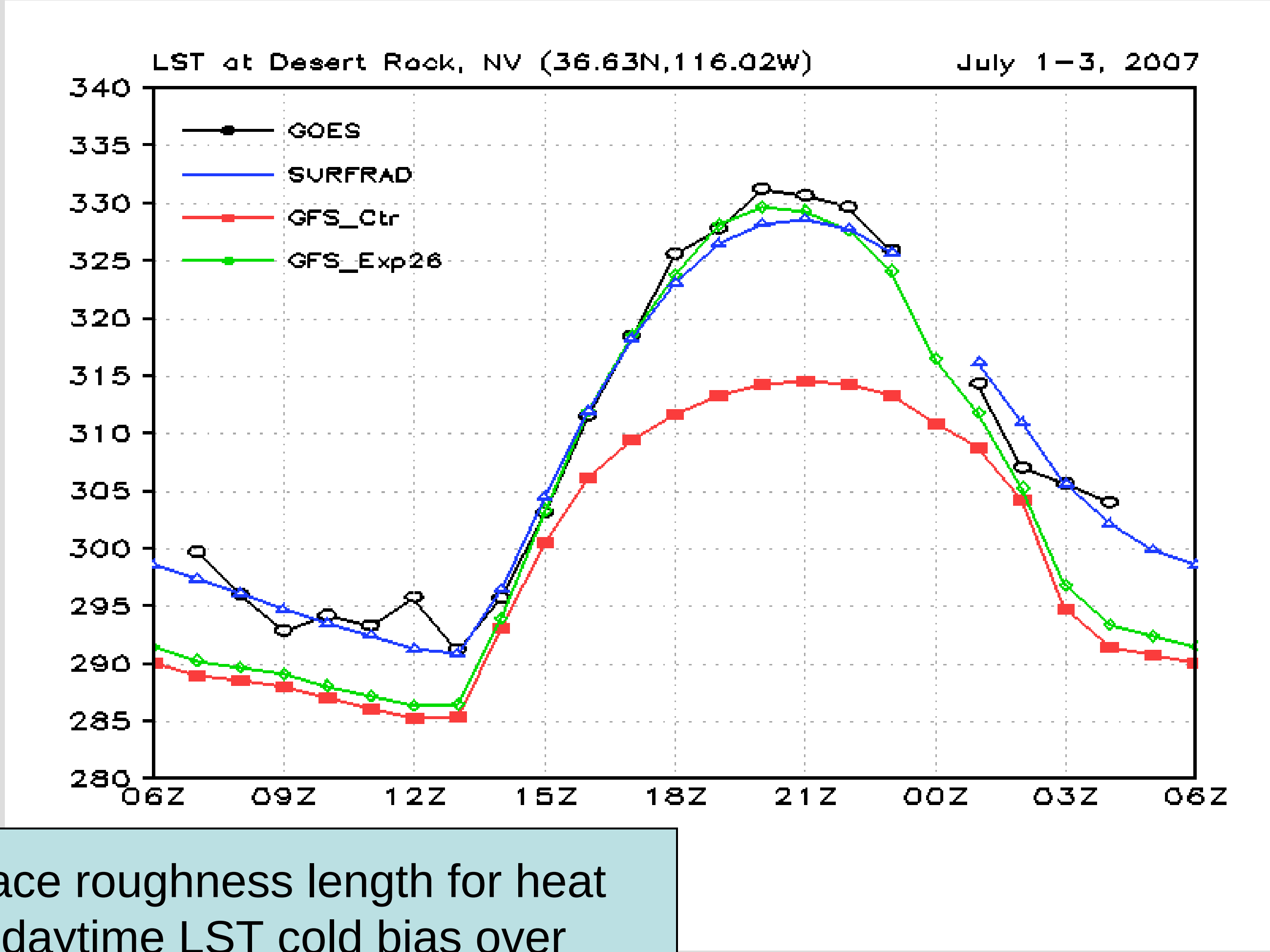
- NOAA-NASA-USAF collaboration
  - K. Mitchell-M. Ek (NOAA)
  - C. Peters-Lidard (NASA)
  - J. Eylander (USAF)



- **LIS** hosts
  - **Land surface models**
  - **Land surface data assimilation**

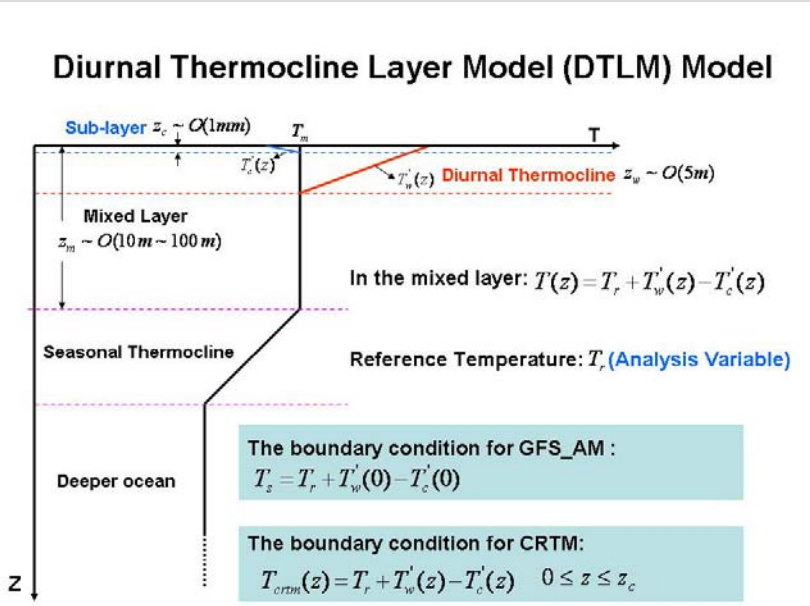
  and provides
  - **Regional or global land surface conditions for use in**
    - **Coupled NWP and Climate models**
    - **Stand-alone land surface applications**

JCSDA sponsored
Land Surface Improvements for NCEP LSM



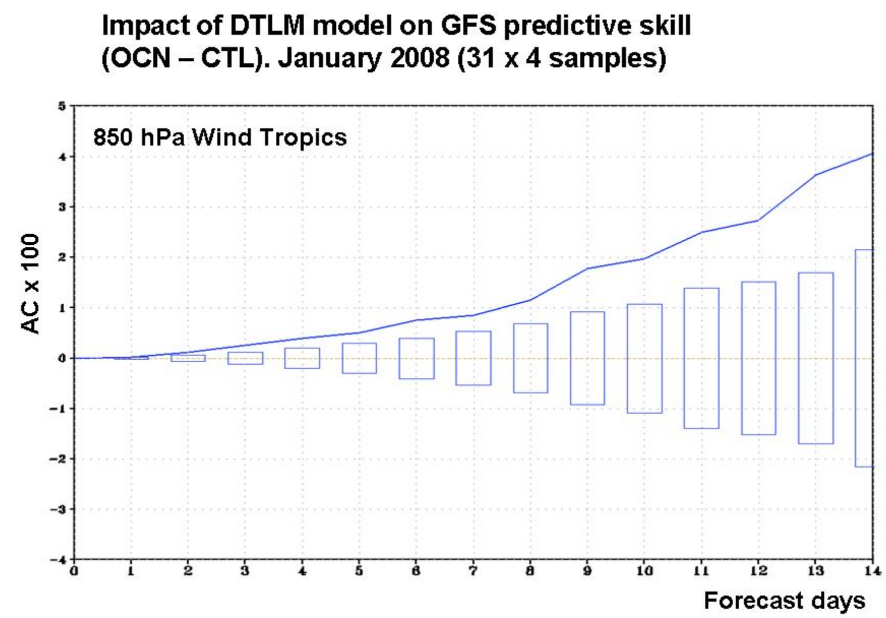
- Reformulation of surface roughness length for heat in GFS PBL reduces daytime LST cold bias over desert and arid regions in the warm season.
- Results in larger amounts of satellite data accepted in the data assimilation over land in the GSI/CRTM.

JCSDA sponsored SST development for NCEP



Diurnal SST variability
Improves tropical wind forecasts

Xu Li



So far, impact on tropical temperature forecasts is negative

NCEP Ocean Data Assimilation development involving JCSDA sponsored work

- Investigate advanced ODA techniques
  - Improved observation representativeness errors (with Bob Miller, OSU-JCSDA)
  - Associated Ocean Data Assimilation activities
    - Experimental Ensemble Data Assimilation system (with GFDL)
    - Reduced Kalman filtering (with JPL)
- JASON-2 data flow (with NAVOCEANO)
- Wave data assimilation proposed
- Future work with GMAO, NRL
  - HYCOM for real-time forecasting (NRL)
  - MOM4 for seasonal climate (GMAO)

Offline NCEP Global Aerosol Modeling System

Ho-Chun Huang, Dongchul Kim, Youhua Tang, **Sarah Lu**, Pius Lee, Marina Tsidulko, Caterina Tassone, Jeff McQueen, Shrinivas Moorthi, Mark Iredell, Geoff DiMego, Paula Davidson[1], Mian Chen[2], Arlindo daSilva[2] and Thomas Diehl[2]

NOAA/NWS/NCEP/EMC [1]NOAA/ARL [2]NASA/GSFC

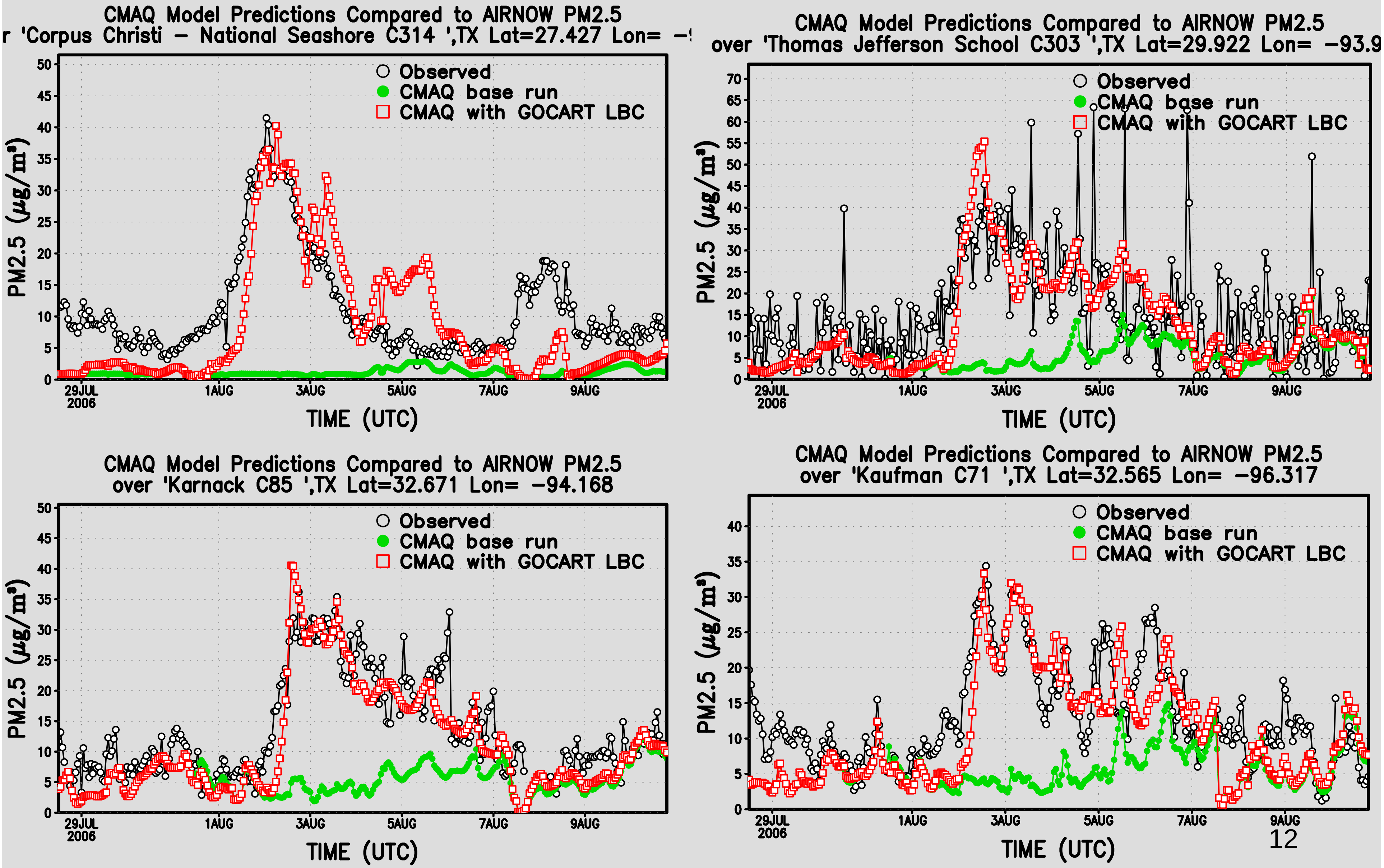
- NCEP GFS
- NASA GOCART (NASA Goddard Global Ozone Chemistry Aerosol Radiation and Transport Model)
- Applications

  (1) dust modeling

  (2) aerosol modeling

JCSDA & NASA ROSES

PM2.5 Regional Forecast Comparison for surface stations over Texas



Other JCSDA-related Development impacting NCEP

- Ozone operational implementations at NCEP
  - SBUV version 8 and quality control (Nov. 2007,Sept. 2008)
  - In progress
    - GOME-2
    - OMI
    - MLS and HIRDLS
- Cloudy radiances (CRTM) tested with NCEP GFS

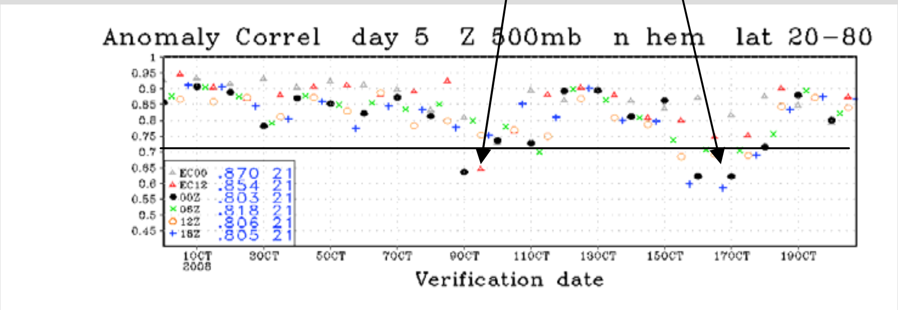
CRTM Development (with NESDIS)

- EMC supporting public server for community code access to
  - CRTM
  - NCEP model and data assimilation code
- CRTM driver for offline development and testing
- IASI longwave temperature channels
- Upper tropospheric moisture
- Spectral response functions for SSM/IS
- Adoption of standard IGBP land classification (add tundra)
- Satellite footprint codes (Gayno) fundamental for NPOESS

GFS Diagnostic Activities (with NRL, GMAO)

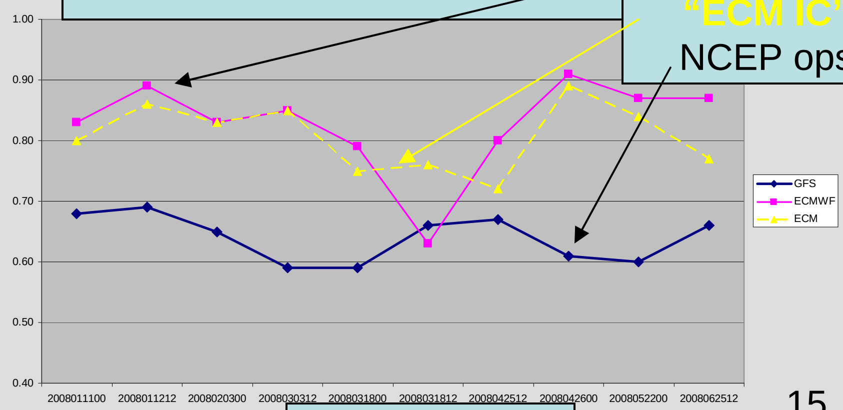
- "Dropouts Team"
  - Reallocated effort from EMC, NCO (4 FTE)
  - Defined "dropout"
  - **Diagnosed cases**
    - **Runs from ECMWF IC ("ECM") improve results often**
    - **Impacts of satellite data show case-dependent impacts**
  - Diagnosed deficiencies
    - Sat wind QC
    - Bias correction and thinning of A/C data
    - Diurnal bias correction
    - Potentially important impact of humidity through satellite data
    - Negative moisture in background model field
    - Augmented and correct observations data base information
- Stimulated many new projects to correct deficiencies

Dropouts



SH 500 hPa AC

ECMWF ops
"ECM IC"
NCEP ops



Cases

The Gridpoint Statistical Interpolation (GSI) System

- Capabilities
  - Currently 3d-var
  - **Future**
    - 4d-var for global, regional and hurricane applications with Situation-Dependent Background Errors (SDBE)

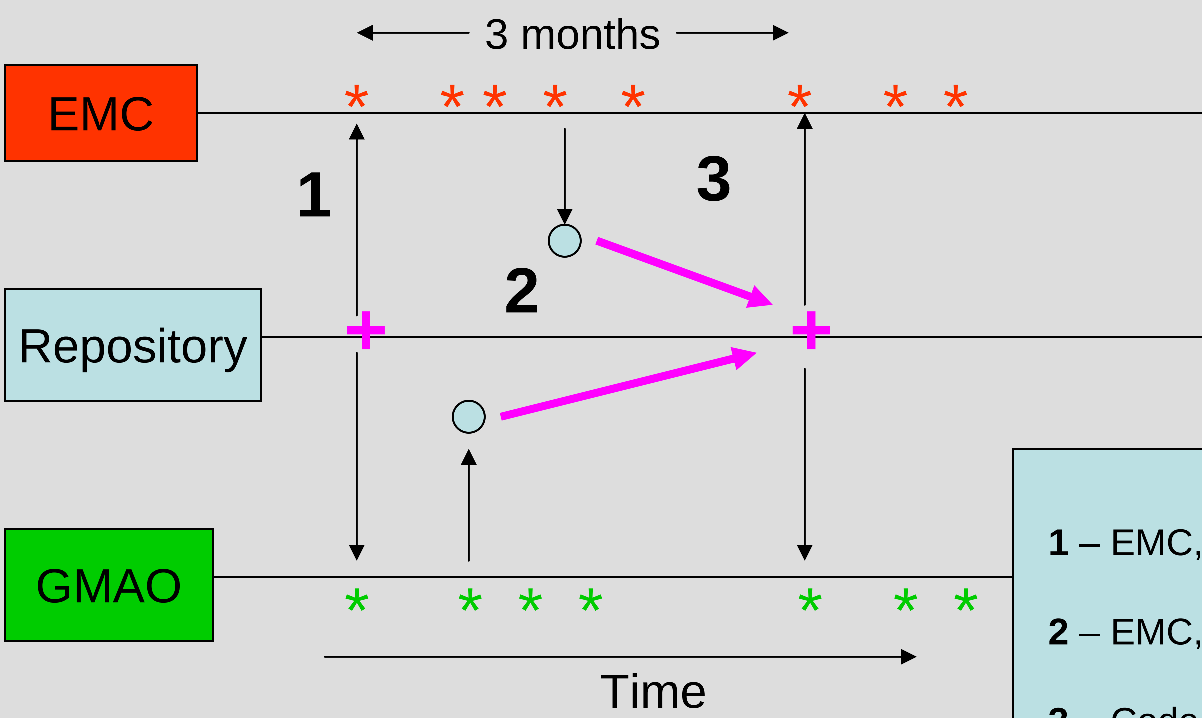
    Or
    - Major component of Ensemble Data Assimilation (EnsDA)

    Or
    - Hybrid system
- Operational for
  - Global Forecast System (GFS)
  - North American Model (NAM)
  - Real-Time Mesoscale Analysis (RTMA)
- Major focus of NCEP/EMC and NASA/GSFC/GMAO collaborative atmospheric analysis development
  - GMAO 4d-var code delivered to NCEP Jan 2009

EMC-GMAO-STAR Code Management for Atmospheric Data Assimilation

Process: similar to ECMWF & Météo-France
who have annual code mergers
Goal is for more frequent mergers (3 months)

GSI & CRTM supported



Accepted changes
EMC, GMAO System change
Repository change
Repository Merger (new tag)

Protocols

1 – EMC, GMAO take (agreed-upon) merged code from repository to begin work
2 – EMC, GMAO incorporate developments into repository
3 – Code mergers, repository changes and timing are NCEP's decision

Summary

- **Satellite development projects in progress**
  - **ASCAT**
  - **SSM/IS**
  - **GOME-2**
  - **OMI**
  - **CHAMP and add'l GPSRO**
  - **CrIS and ATMS**
  - **Cloudy radiances**
  - **Aerosols**
- **JCSDA sponsored development contributes to NCEP forecast skill increases**
- Strong partnership in **core data assimilation activities with NASA/GMAO**
  - **Potential for increased activities with AFWA and NCAR**
  - **Potential research model available with top at 600 km in 2 years**
- **Increased interaction with AFWA through Visiting Scientists at JCSDA**
- **Evaluation plan for EnsDA in progress**

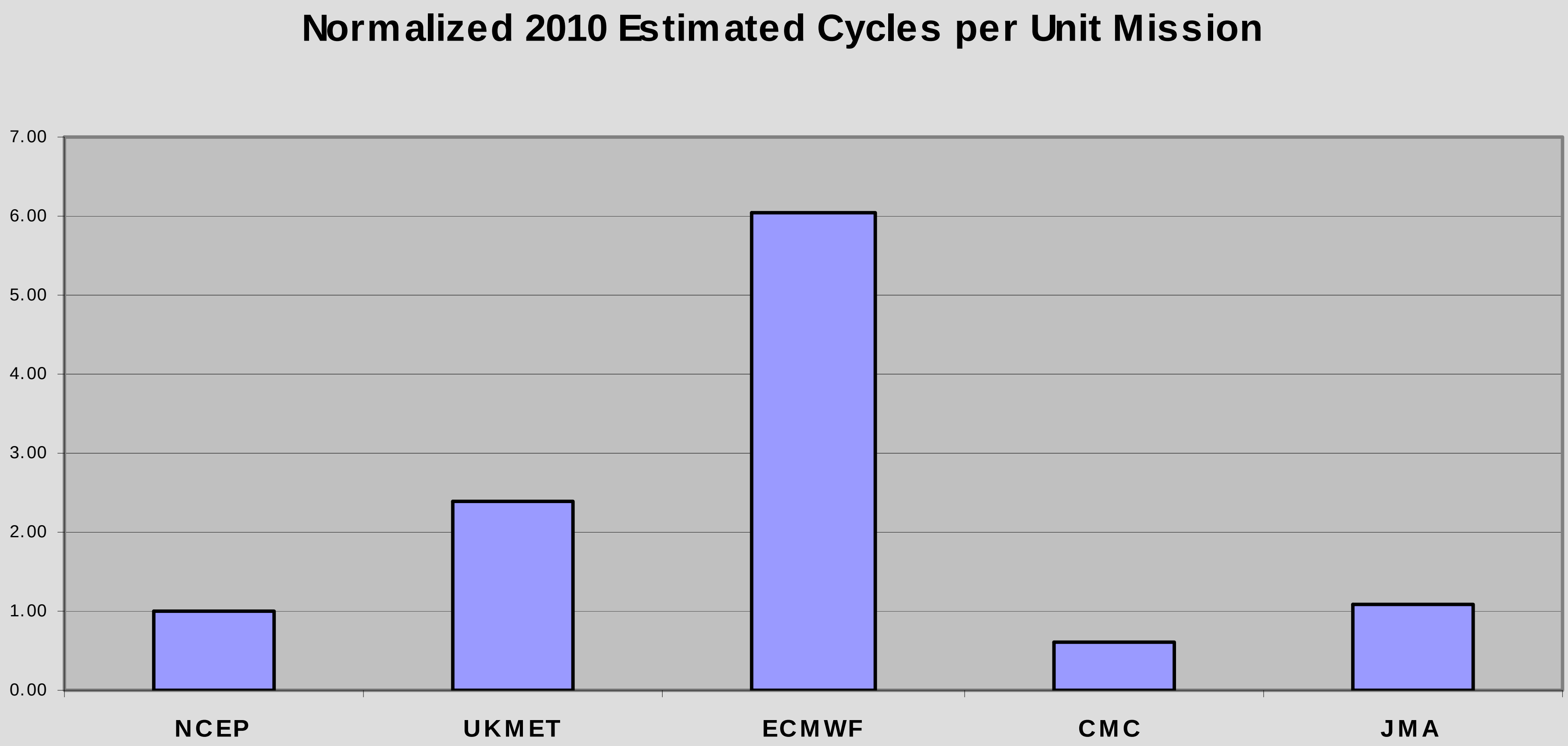
Thanks
Questions?

Resource Gaps (1)
Current Computing Capabilities

	ECMWF	Met Office (Also ECMWF)	NCEP
P6 compute processors (ops)	8192	3295	4608
Disk per cluster	**1800 TB**	**350 TB**	**170 TB**
Sustained performance relative to previous ops	5X	6.5X	3X
Expected computing increase in 2011	2X	3X	2012 – 3X

All systems installed within 6 months of 1/2009

Resource Gaps (2)
Normalized Computing Capabilities



Computing cycles (TFlop) normalized by Mission and by NCEP capability

Resource Gaps (3)
Scientific Personnel (Meteorology)

Function	UK Met Office (global and regional) base	ECMWF (global only) (base + contract)	NCEP/EMC, JCSDA (global and regional) base + contract combined
Processing, Quality Control and Data Assimilation	24	12 (9 + 3)	17
Improve use of satellite data	33	18 (5 + 13)	17.5 [2.5 + 15 (**11**, 4)]
Model dynamics	8	4	6 (NAM & GFS)
Model physical parameterizations	36	11 (8 + 3)	6.3
Convective scale NWP	5	0	0.5
Ensemble forecasting	11	15 (10 + 5)	8
Atmospheric dispersion and composition	7	8.5 (0.5 + 8)	8
Evaluation and diagnostics	14	6 (5 + 1)	6.8
Software infrastructure	19	8 (7 + 1)	6 (WRF, ESMF, NEMS)
Maintainance of operational system (implementations)	24	5	6.4
Postprocessing	9	4 (3 + 1)	4
Total	**183**	**91.5 (56.5 + 35)**	**85.5**

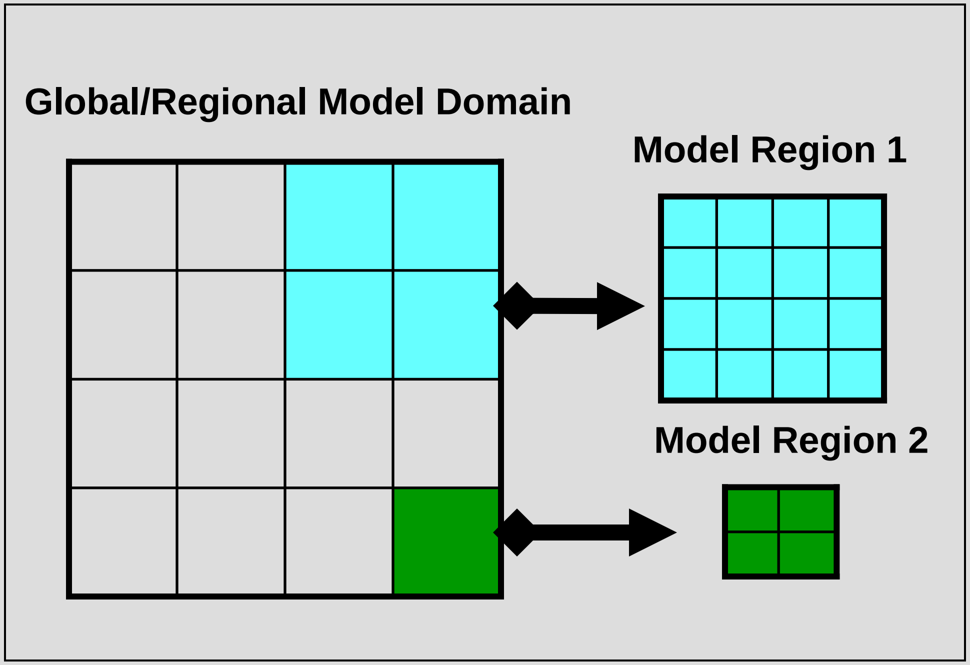
Major deficiencies **"Resources under management" (Managed elsewhere)**

Next generation NOAA Production Suite

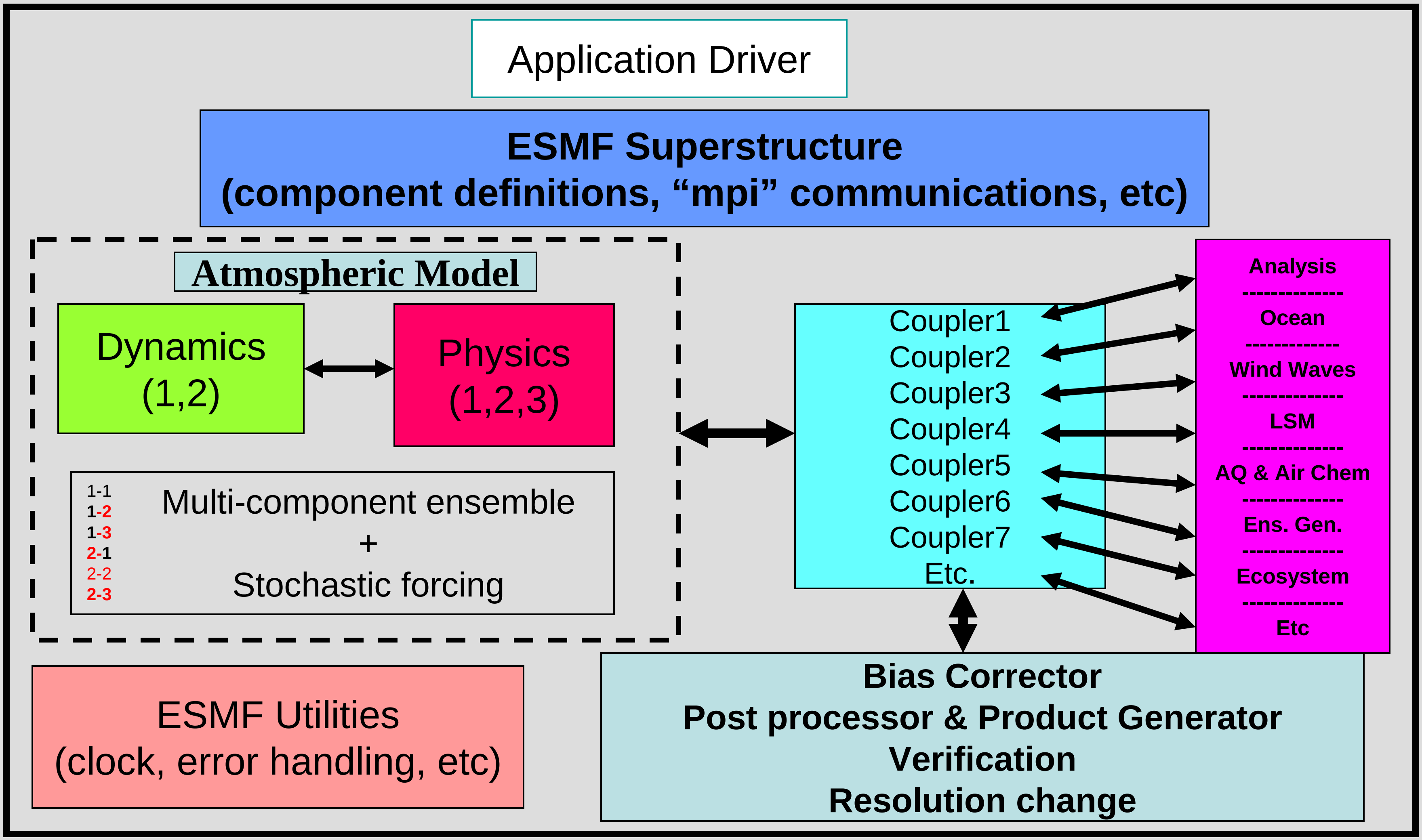
Forces for Change

- Increasing emphasis on multi-model ensemble approaches that build on the NCEP model suite
  - SREF
  - NAEFS
  - Climate Forecast System
- Entering the NPOESS era
  - More rapid access to hyperspectral data
  - GPS soundings
  - Higher resolution surface radiance data
- All models run within ESMF
  - Models run concurrently
  - Coupled
  - Spanning all scales
  - NUOPC/Unified approach
- Operational Earth System model – more explicit hydro, climate and ecosystems applications

ESMF-based System



National Environmental Modeling System (NEMS) (uses standard ESMF compliant software)



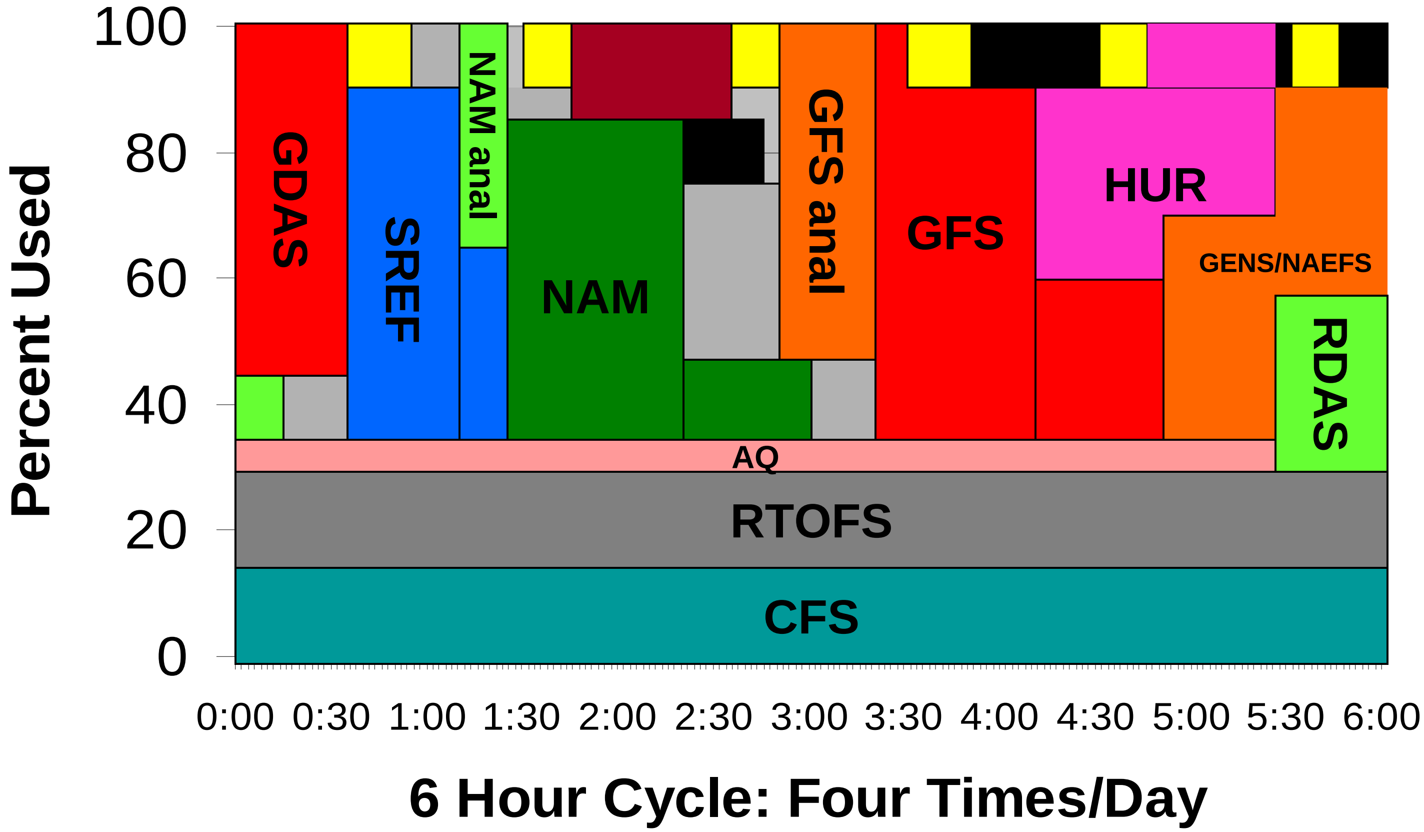
* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC), NOAA/GFDL

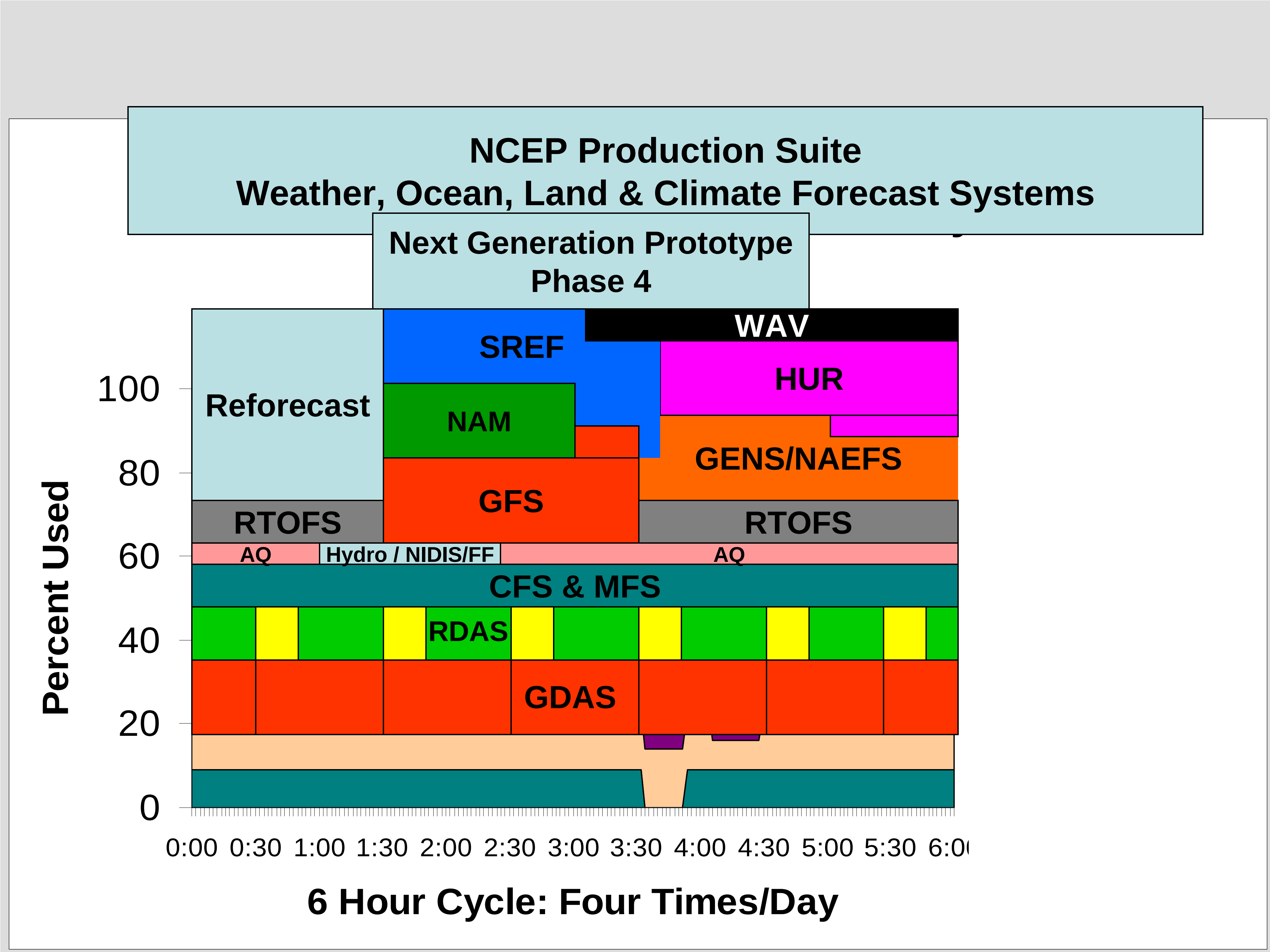
2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments

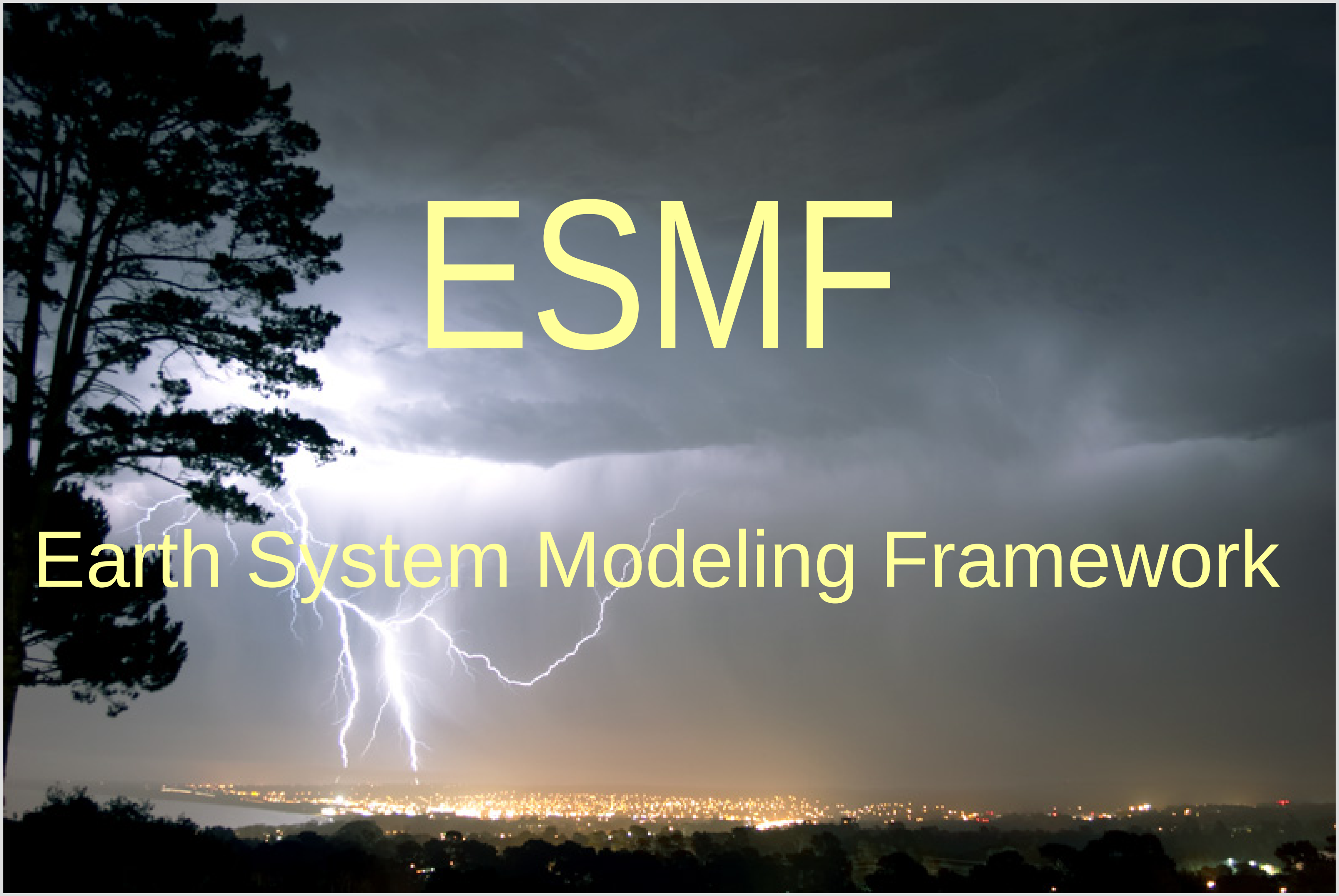
Components are: Dynamics (spectral, FV, NMM, FIM, ARW, FISL, COAMPS…)/Physics (GFS, NRL, NCAR, GMAO, ESRL…)

NCEP Production Suite
Weather, Ocean, Land & Climate Forecast Systems

Current




NCEP Production Suite
Weather, Ocean, Land & Climate Forecast Systems
Next Generation Prototype
Phase 4
Reforecast
SREF
WAV
HUR
NAM
GENS/NAEFS
GFS
RTOFS
RTOFS
AQ
Hydro / NIDIS/FF
AQ
CFS & MFS
RDAS
GDAS
Percent Used
0
20
40
60
80
100
0:00
0:30
1:00
1:30
2:00
2:30
3:00
3:30
4:00
4:30
5:00
5:30
6:00
6 Hour Cycle: Four Times/Day


ESMF
Earth System Modeling Framework

NCEP's Hurricane Forecast Guidance

- GFS
  - T382/64L
  - 3-D var
  - Vortex relocation
  - State of the science physics
- GFDL
  - Movable nested
  - Air-sea coupled
  - Inner nest
    - 9 km/42L
  - Specialized vortex initialization,
  - Upgraded with some GFS physics (2003, 2004)
- **HWRF added to GFDL in 2007**
  - **Same physics as GFDL**
  - **Upgrade to improve intensity, June 2008**

Real Time Ocean Forecasting

- Wave Modeling
  - Global and Regional
  - Unified model approach
  - NOAA Wavewatch III
- Basin-scale Ocean Model
- Sea Surface Temperature & Winds
  - NCEP Ocean Prediction Center support
    - Gulfstream analysis & forecast
- Real-time Sea Ice products
  - Alaska Region support (fishing)

Seasonal to Interannual Prediction at NCEP

Ocean Model
MOMv3
quasi-global
1^{o}x1^{o} ($1/3^{o}$ in tropics)
40 levels

Climate
Forecast
System
(CFS)

Atmospheric Model
GFS (2003)
T62
64 levels

<u>GODAS</u>
3DVAR
XBT
TAO etc
Argo
Salinity (syn.)
(TOPEX/Jason-1)

<u>Reanalysis-2</u>
3DVAR
T62L28
update of the
NCEP-NCAR R1

D. Behringer

Overview

- Evolutionary combination of the global SSI analysis system and the regional ETA 3DVAR
  - Major code re-design
  - New features
- Uses a grid space definition of the background errors
  - Allows use of situation dependent background errors
- Final testing for Global Forecast System (GFS)

GSI analysis system

- Code re-designed for community use
  - F90/95 structures and utilities
  - Improved efficiency
    - Re-designed data distribution
    - Some OpenMP
  - Better documentation
  - Improved portability
    - Less dependency on IBM
- Currently 32 registered groups/users
  - NCEP providing only minimal support for external groups due to lack of resources
- Major focus of NCEP and NASA/GSFC/GMAO atmospheric analysis development
  - To date they have provided the most updates

GSI analysis system

- Incorporated new features
  - Variational QC available
  - Spatial derivatives – allows:
    - non-local operators
    - improved definition of balance operators
    - dynamical balance constraints
    - simplified 4DVAR
  - Improved control over observational errors
  - Improved moisture analysis variable
  - Diagnostic files for background and each outer iteration

GSI analysis system

- Incorporated new features (cont.)
  - Strong and weak dynamical constraints
  - Adjoint and TL of GSI (GMAO)
  - Additional observational data
    - Precipitable water
    - Radar radial winds (w or w/o superobs)
    - GPS RO (COSMIC, CHAMP)
    - Additional satellite radiances

GSI analysis system

- Incorporated new features (cont.)
  - Situation dependent background error available for some modes of operation (RTMA)
  - Available for use in all WRF dynamical cores
  - New version of Community Radiative Transfer Model (CRTM)
  - Improved memory usage and documentation
- Multi-organizational code management

Ongoing work - GSI

- Including
  - Simplified 4DVAR
  - SST analysis by direct use of radiances
    - IR and MW data
  - Variational bias correction for conventional data

- Developing situation dependent background errors for all applications

- Adding new observations
  - AMSR-E
  - Windsat
  - SSM/IS
  - New analysis variables
    - Constituent gas assimilation beginning

- Improved radiative transfer

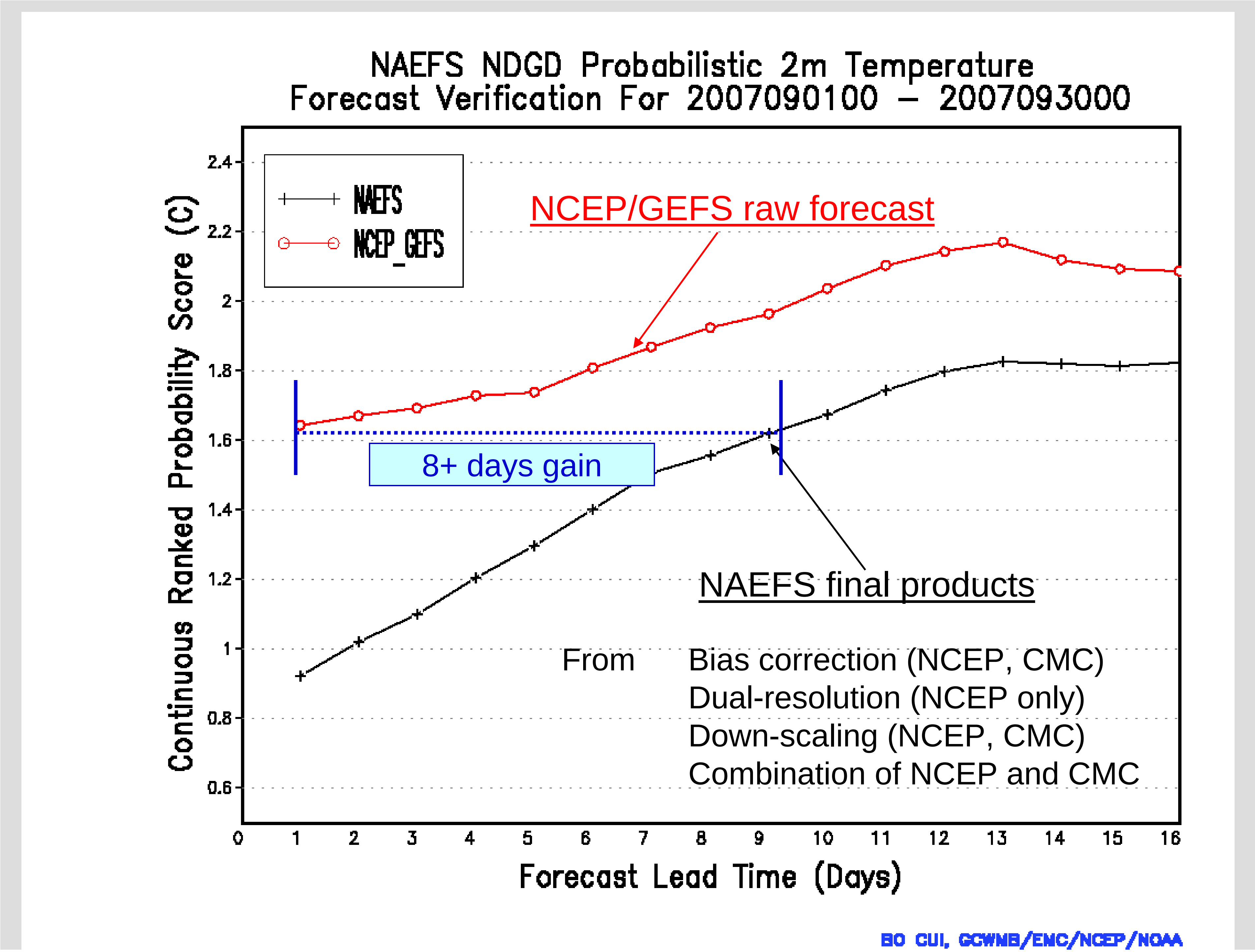
- Re-structuring for ESMF compatibility

Ongoing work – Simplified 4DVAR

- Adiabatic time derivatives
  - Filtered to retain “slow” modes
  - Used to extrapolate state to obs times
  - Captures obs time changes due to slow modes
- No additional cost since calculations already included in constraint term

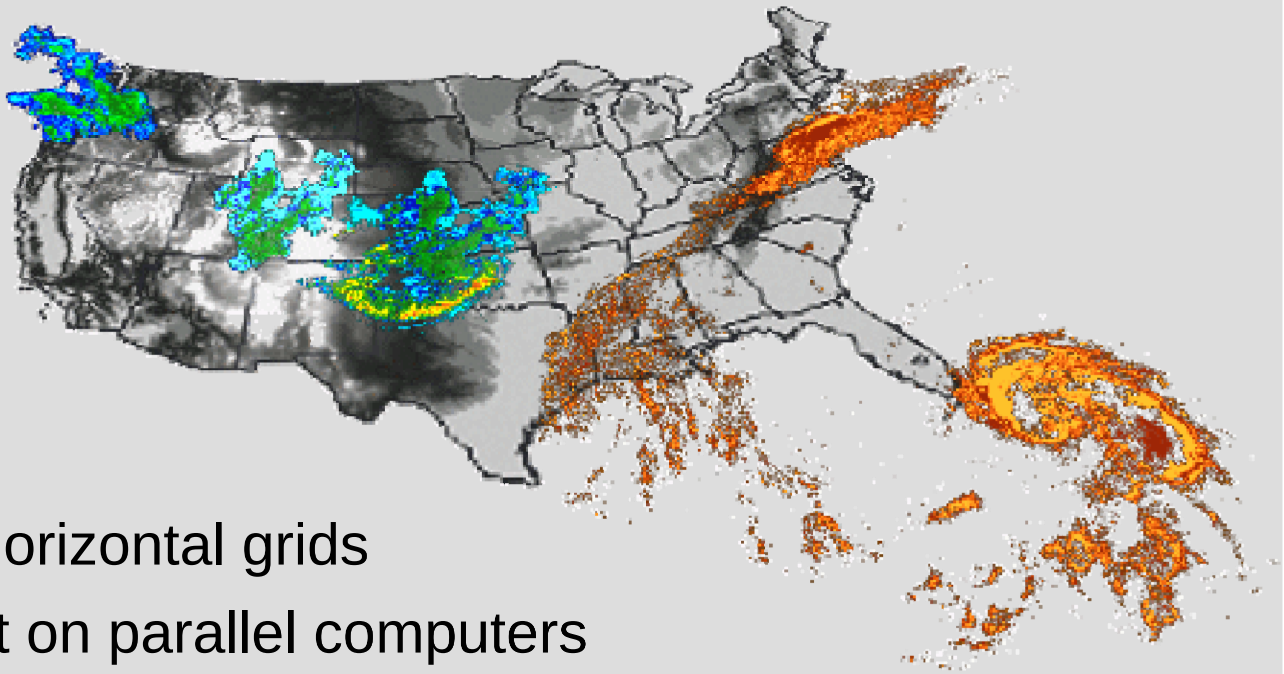
Summary

- GSI analysis system
  - One possibility for NCEP's next-generation data assimilation system
  - Evolutionary path
  - Many new features have not yet been exercised
    - Variational QC
    - New CRTM
  - New observations capability
  - Used by community
    - Global
    - WRF


NAEFS NDGD Probabilistic 2m Temperature
Forecast Verification For 2007090100 – 2007093000
Continuous Ranked Probability Score (C)
Forecast Lead Time (Days)
NAEFS
NCEP_GEFS
NCEP/GEFS raw forecast
8+ days gain
NAEFS final products
From
Bias correction (NCEP, CMC)
Dual-resolution (NCEP only)
Down-scaling (NCEP, CMC)
Combination of NCEP and CMC
BO CUI, GCWMB/EMC/NCEP/NOAA

Weather Research and Forecast (WRF) Modeling System

- Develop an advanced mesoscale forecast and assimilation system
- Promote closer ties between research and operations



Concept:

Design for 1-10 km horizontal grids

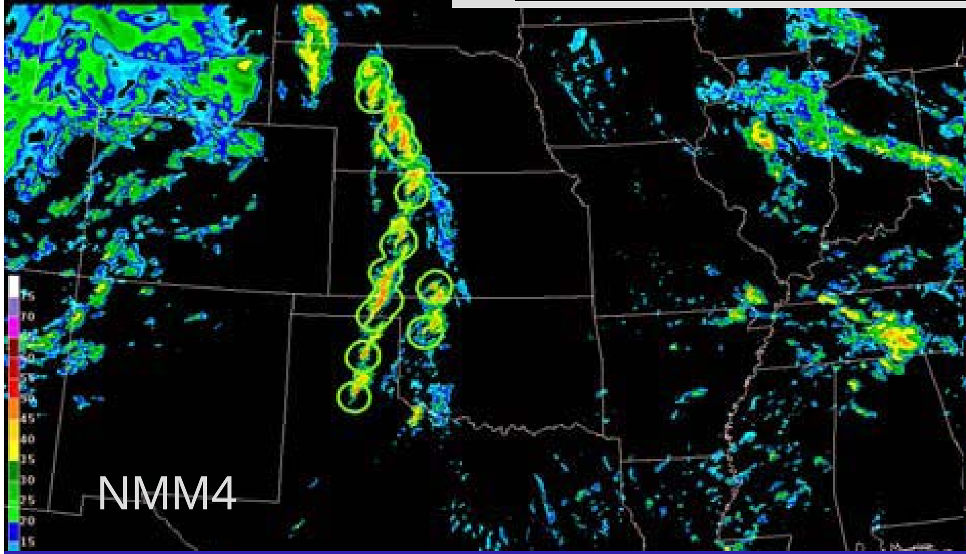
Portable and efficient on parallel computers

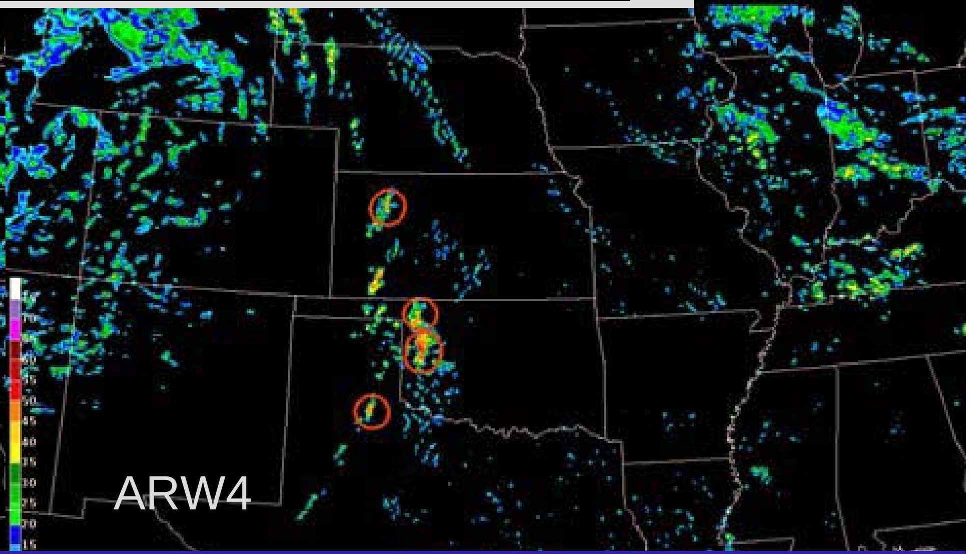
Well suited for a broad range of applications

Community model with direct path to operations

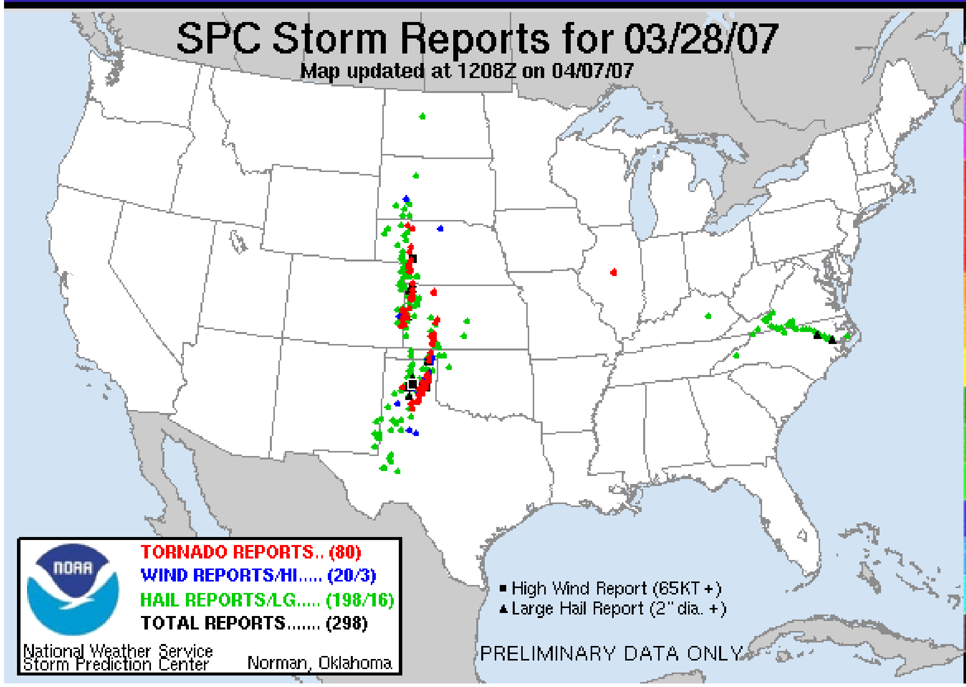
Collaborators: NCEP/EMC, NCAR, AFWA, Navy, NOAA/ESRL, U. Okla.

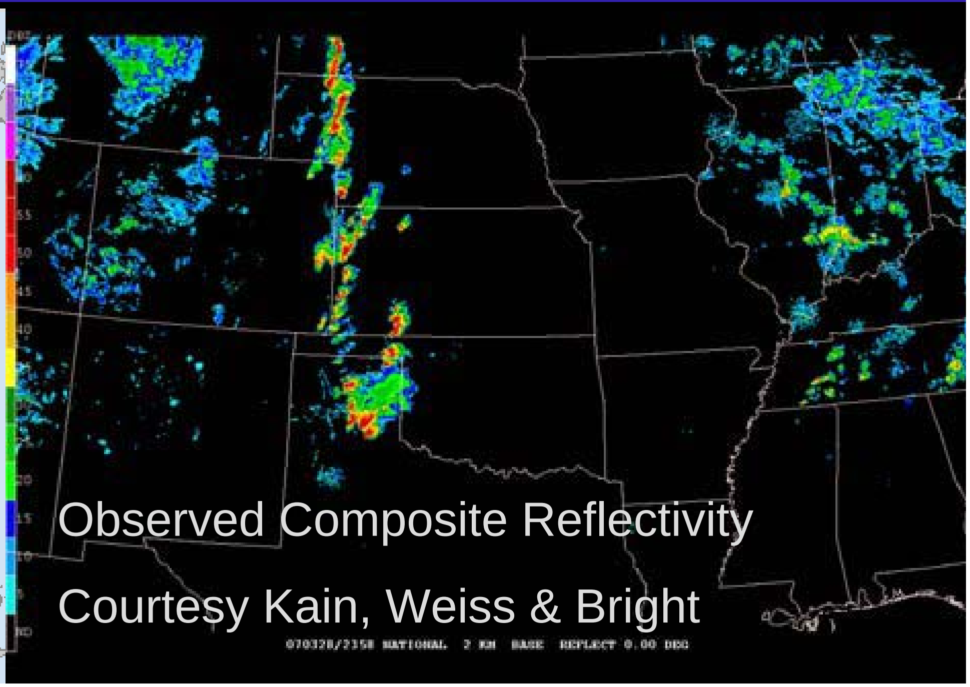
Spring Program 2007

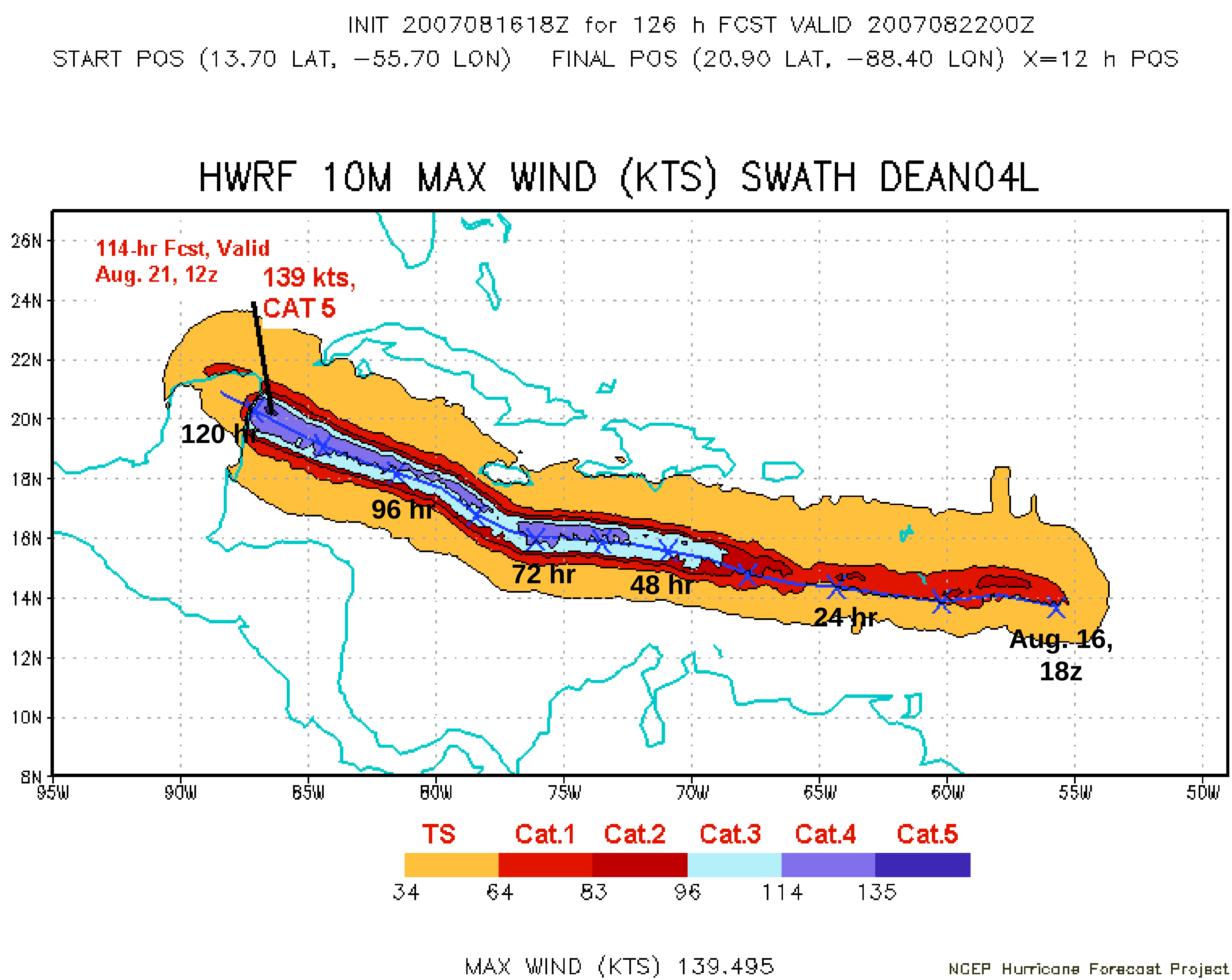




Circles denote locations of rotating updrafts where updraft helicity is at least 50 m^2s^{-2}






INIT 2007081618Z for 126 h FCST VALID 2007082200Z
START POS (13.70 LAT, −55.70 LON) FINAL POS (20.90 LAT, −88.40 LON) X=12 h POS
HWRF 10M MAX WIND (KTS) SWATH DEAN04L
114-hr Fcst, Valid
Aug. 21, 12z
139 kts,
CAT 5
120 hr
96 hr
72 hr
48 hr
24 hr
Aug. 16,
18z
26N
24N
22N
20N
18N
16N
14N
12N
10N
8N
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
TS
Cat.1
Cat.2
Cat.3
Cat.4
Cat.5
34
64
83
96
114
135
MAX WIND (KTS) 139.495
NCEP Hurricane Forecast Project

LIS Capabilities

- **Flexible choice of 7 different land models**
  - Includes Noah LSM used operationally by NCEP and AFWA
  - Includes NASA Catchment model used by GMAO
- **Flexible domain and grid choice**
  - Global: such as NCEP global model Gaussian grid
  - Regional: including very high resolution (~.1-1 km)
- **Data Assimilation**
  - Based on Kalman Filter approaches
- **High performance parallel computing**
  - Scales efficiently across multiple CPUs
- **Interoperable and portable**
  - Executes on several computational platforms
  - NCEP and AFWA computers included
- **Being coupled to NWP & CRTM radiative transfer models**
  - Coupling to WRF model has been demonstrated
  - Coupling to NCEP global GFS model is under development
  - Coupling to JCSDA CRTM radiative transfer model is nearing completion
- **Next-gen AFWA AGRMET model will utilize LIS with Noah**
- **NCEP's Global Land Data Assimilation utilizes LIS**

Collaborative Software Development

- GSI intended for both operations and research applications
  - Community-based code with multi-agency users
- Code Management
  - Minimize redundant development
  - Establish code development standards and procedures
    - Principal Code Manager (EMC)
    - Associate Code Manager (partners)
    - Criteria for accepting code updates
    - Code managed by subversion repository
  - Establish areas of responsibility and milestones among partners
  - Technical oversight group, representatives from
    - EMC
    - GMAO
    - GSD (Boulder)
    - AFWA
- Example: EMC-GMAO collaboration
  - Same code for operations (EMC) and research (GMAO)
  - Bi-weekly progress at group meetings
  - GMAO: 4d-var infrastructure
  - EMC+JCSDA: adding capabilities for new satellite data
  - Quarterly code mergers

Summary

- **Focused** on Multi-disciplinary Environmental Forecasting (atmosphere, ocean, land surface, cryosphere)
- Increased community involvement **(R2O, O2R)**
- Strong partnerships in **core data assimilation activities with NASA/GMAO**
  - **Potential for increased activities with NCAR (July meeting)**
  - **Potential research model available with top at 600 km in 2 years**
- Preparing for future with **next-generation Production Schedule** and **ensemble-based** products