HIWPP Wrap-up

Outline

- Look back at what we planned to do
- For each task or sub-project
  - Look at what has been accomplished
  - Look at what effort remains
- Top ten

HIWPP Goal

Hurricane Sandy Supplemental funding provided an opportunity to bring together the nation's global weather modeling community, and focus them on a common goal:

the development of the world's best medium-range weather forecast model by the end of the decade

HIWPP: Pushing the Limits

- Driving current generation models to their limits
- Reaching for the next generation of models by the end of this decade… Non-Hydrostatic models at 3-4 km
- State-of-the-art data assimilation
- Improve the representation of key physical processes (clouds, radiation, etc.) at finer scales
- Leading the migration into new advanced computing paradigms

HIWPP: Pushing the Limits

- Ability to embed even higher resolution models (<3km) within our global models
- Develop a seamless suite of forecasts that extend beyond 16 days for high impact weather events
- Building a new verification approach
- Distributing massive amounts of data efficiently
- Innovative ways to display, analyze, and compare these large quantities of data
- Enabling real-time research and building partnerships

HIWPP Work Breakdown Structure

Project Manager:
Tim Schneider, ESRL

Business Manager:
Ty Robinson, OWAQ

3.1 Hydrostatic Global Models
POC: S. Benjamin, ESRL

- 3.1.1 DA/Ens/Stoch Physics
- 3.1.2 Parameterization Dev
- 3.1.3 GFS
- 3.1.4 FIM
- 3.1.5 NAVGEM

3.4 NMME Expansion
POC: Jin Huang, NCEP

3.5 Test Program
POC: Bonny Strong, ESRL

- 3.5.1 Statistical Post Processing
- 3.5.2 Visualization via NEIS
- 3.5.3 Verification Methods
- 3.5.4 Real Time IT Operations

3.3 Moving Hurricane Nest
POC: S. Gopalakrishnan, AOML/
V. Tallapragada, NCEP

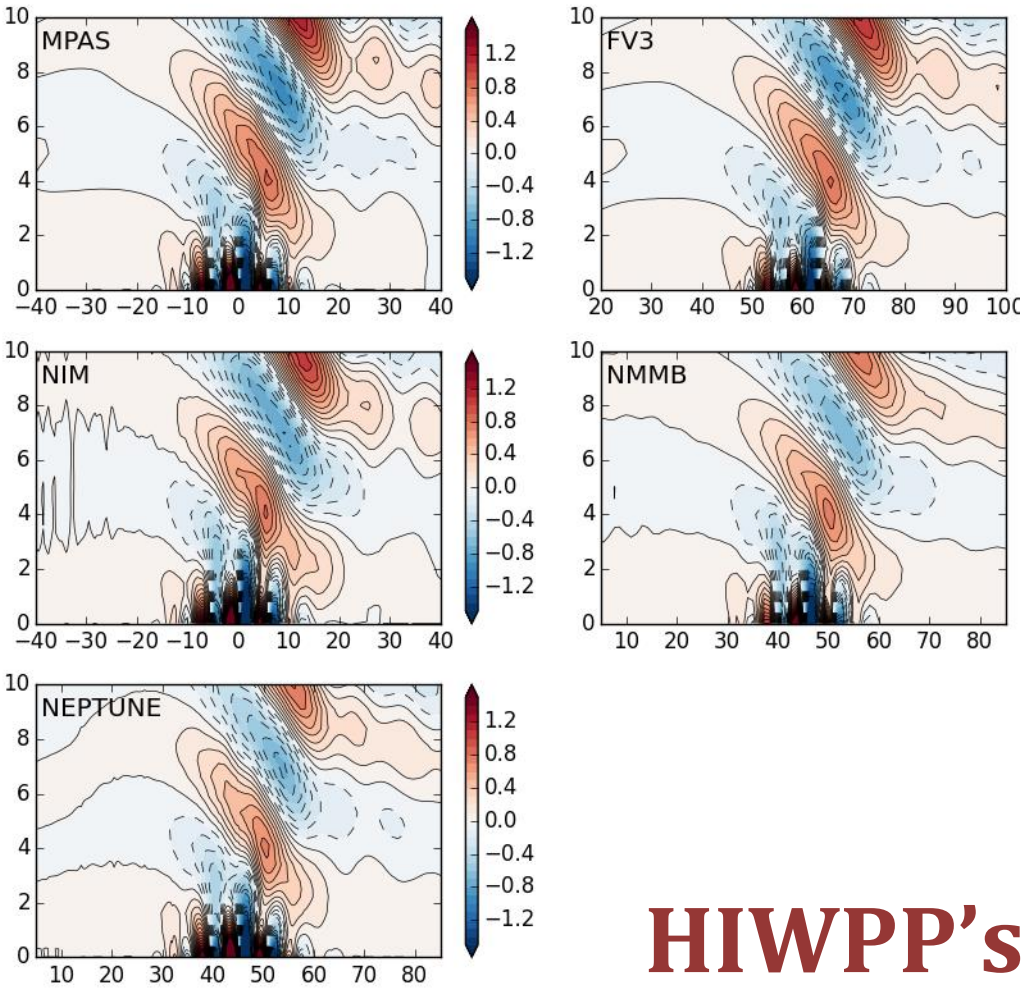
3.2 Non-Hydrostatic Global Models
POC: J.Whitaker, ESRL

- 3.2.1 DA/Ens/Stoch Physics
- 3.2.2 Parameterization Dev
- 3.2.3 MPFG/GPU Optimization
- 3.2.4 NIM
- 3.2.5 MPAS
- 3.2.6 NMMB
- 3.2.7 FV3
- 3.2.8 NEPTUNE

Schedule and Status

- HIWPP planned for 3 years, starting Feb 2014
- Funding to CIs ends June 2017
- Current status:
  - Most tasks have completed
    - Nonhydrostatic models
    - NMME
    - Test Program
  - A few tasks are in final stages of wrapping up
    - Global hydrostatic models – GFS, FIM, NAVGEM
    - Moving Hurricane Nest
  - A few tasks still have significant effort remaining
    - Data Assimilation/Ensembles/Stochastic Physics
    - Aerosol-aware portion of physics parameterizations
    - MPFG

Non-hydrostatic Models



Began with 5 dycores

Testing:

- ❑ Idealized tests
- ❑ Computational efficiency benchmarking
- ❑ Real weather forecasts at 3 km.
  - Hurricane Sandy
  - Moore Ok tornado

HIWPP's top priority

Non-hydrostatic models

- Reduced from 5 candidate dycores down to 2
- Enabled dialog between modelers
- Established structure and foundation for further dycore testing in NGGPS

Massively Parallel Fine Grain High Performance Computing

- **Completed code optimization**
  - critical to using advanced high performance computing needed to run a new non-hydrostatic model at high resolution
- **Supported procurement of first MPFG system**

- **Integrated with the NGGPS AVEC for testing of candidate non-hydrostatic models.**

Data Assimilation

Developed 4D-Ensemble-Variational (4DEnVar)

- With time-varying estimates of the background-error covariance
  - estimated from EnKF ensemble
- Included stochastic physics in GFS model
  - in order to better represent the model uncertainty of the background-error covariance estimated from the ensemble
- Modified GFS to include 4DIAU
  - to more smoothly introduce time-varying analysis increments generated by 4DEnVar.
- Merged EnKF code into GSI project in software repository
- Developed strategy for tropical cyclone relocation within the EnKF system

➢ **Implemented operationally in May 2016**

Data Assimilation – Remaining effort

In progress now:

- Compare effect of increased ensemble size vs. increased resolution
- Add advanced ensemble-based quality control

For new dycore:

- Build interface to 4DEnVar GSI and evaluate impact
- Port stochastic microphysics scheme and evaluate impact

Stochastic Physics

Developed and tested a suite of stochastic physics parameterizations, including the

- SPPT - "stochastically perturbed physical tendencies" (ECMWF)
- SKEB - "stochastic kinetic energy backscatter" (ECMWF, UK Met)
- SHUM - "stochastically perturbed boundary relative humidity" (ESRL/PSD)

- **Provides an unambiguous improvement to the system performance**
  - increasing spread realistically, providing better spread-skill relationship, and improving precipitation reliability.
- **Expected to be implemented in next GEFS operational release, pending approval**

Ensembles/Stochastic Physics

Testing methods for perturbing land and sea surface

1) Perturbing SST
   a) Inclusion of skin-layer SST dynamics, permitting diurnal cycles
   b) Perturbations of initial SST
2) Perturbing land-surface model
   - Expected to be in recommendations for GEFS v12
3) Perturbing soil moisture initial states
   - Evaluating possible inclusion in recommendation for GEFS v12
4) Improving initial estimate of soil moisture and temperature by initializing forecast with GLDAS soil state
   - Initial tests showing marked improvement in 2-m temp bias

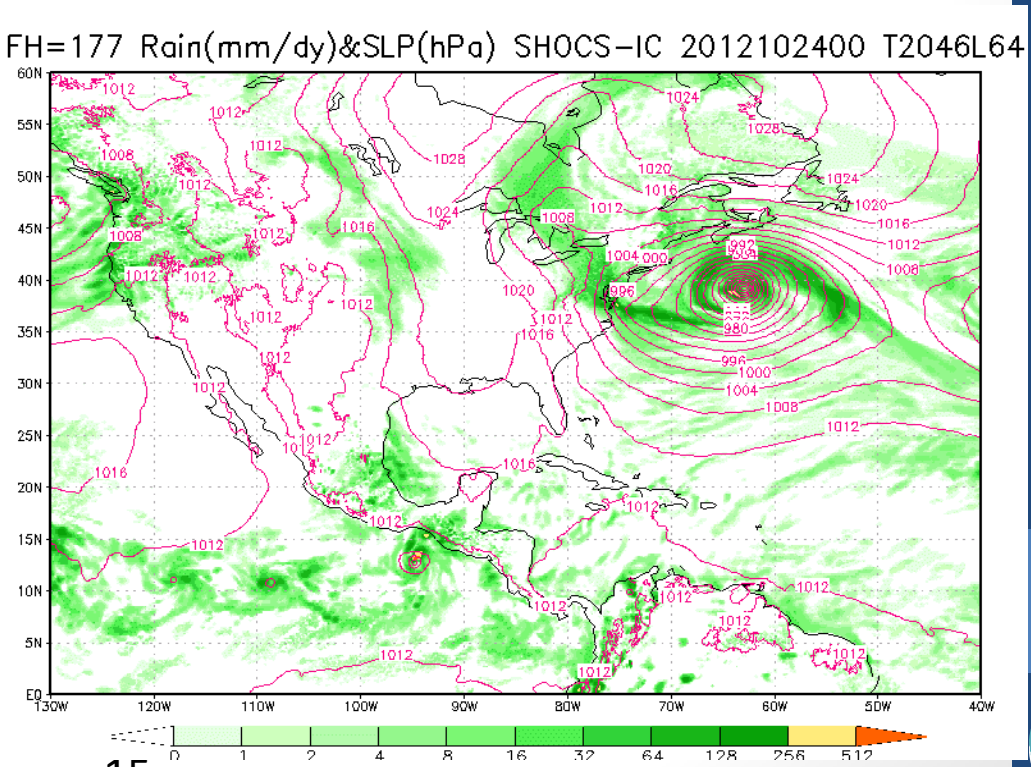
- **Experiments completed and package of recommendations is in preparation for inclusion in operational GEFS v12**

Physics Parameterizations –
Unified representation of turbulence and clouds

- Simplified High Order Closure (SHOC)
  - Implementation of new sub-grid scale turbulence, cloudiness, and shallow convection

➢ **Implemented into non-NEMS version of GFS**

- Goal of having it in operational NEMS implementation by 2018



Physics Parameterizations –

Scale- and aerosol-aware stochastic convective parameterization

Scale-aware parameterizations implemented in GRELL-Freitas Convective Parameterization Scheme

- Momentum transport
- Add'l closure for deep convection: diurnal cycle effect (Bechtold)
- Add'l closures for shallow convection
- Mass conserving transport for shallow scheme
- Mass conserving transport for deep in testing
- PDF approach for normalized mass flux profiles
- Rain evaporation after tendency calculations
- All fully immersed into GFS 2015 physics
  - (replacing call to SAS schemes)

Aerosol-aware parameterizations:

- Ongoing until May, 2017

Global Hydrostatic Models - GFS

Upgraded GFS in January 2015

- ~13-km resolution out to 10 days (increased from 27-km)
- Output at ¼ degree
- Output 1-hr interval to 12 hours, then 3-hr interval to 16 days

Upgrade of GEFS in December 2015

- 33 km resolution 0-8 days; 55 km 8-16 days
- 21 ensemble members
- EnKF DA-generated initial perturbations
- Tropical storm relocation
- Optimum STTP schemes
- Output at ½ degree at 3-hour intervals 0-8 days; 6-hour intervals for 8-16 days

Upgrade of GFS/GDA upgrade in May 2016

- Uses hybrid 4DEnVar for analysis
- Includes modified soil moisture parameter to improve warm bias in summer.
- GFS output at 1-hr interval to 120 hrs; then 3-hr interval to 384 hrs

- Evaluation of multi-model ensemble using GFS and FIM members is ongoing

Global Hydrostatic Models - FIM

Focus on improvements to physics at higher resolution

- **Increased resolution to 14 km** (from 30-km)
  - Output at 1/8-degree hourly to 14 days
- **Implementation and evaluation of GFS 2015 physics**
- **Evaluation of Grell-Freitas scheme**
- **Recommendations provided for:**
  - Gravity Wave Drag, MODIS land use option

- Tested coupled model extensions with FIM
  - WRF-chem/GOCART
  - Ocean with HYCOM
- Evaluation of multi-model ensemble using 10 GFS members with 10 FIM members (ongoing)

Global Hydrostatic Models - NAVGEM

- Model developments under HIWPP:
  - Adapted to be able to read GFS initial conditions
  - Added conversion to GRIB2 output
  - Modified to allow a lower model top
  - Adapted workflow to allow hourly output
- DoD High Performance Modernization Program provided essential HPC support
- Preliminary results:
  - performance improvement that was better than the lower-resolution operational NAVGEM forecast model
  - below the full-resolution GFS model

➢ **New standardized physics interface allows**
  - **Leveraging common set of initial conditions**
  - **Isolating differences in dycore comparisons**

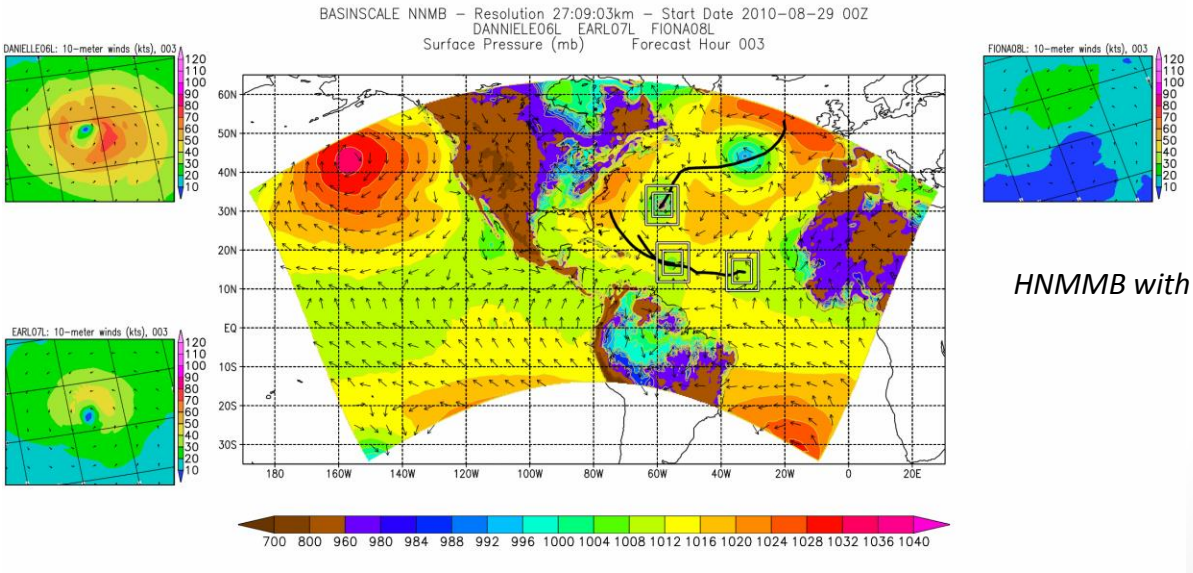
Global Hydrostatic Models - Remaining effort

- GFS and FIM
  - Final evaluation of multi-model ensemble, 10 FIM + 10 GFS members
- FIM - 2 papers:
  - Physics testing and results
  - Multi-model ensembles experiments
- NAVGEM:
  - Completion of retro runs and comparison against GFS, FIM

Moving Hurricane Nest

Goal: Transition all hurricane-specific components from HWRF into the NEMS framework

- Includes:
  - Transition HWRF physics into HNMMB
  - Create an idealized capability framework in NMMB/NEMS
  - Transition vortex initialization into NMMB/NEMS
  - Transition multiple 2-way moving nesting into NMMB/NEMS



HNMMB with 3 nests

Moving Hurricane Nest
Accomplishments and Remaining effort

➢**Developed HNMMB to TR Level 5 and demonstrated proof-of-concept system**

Remaining effort to complete transition to operations:

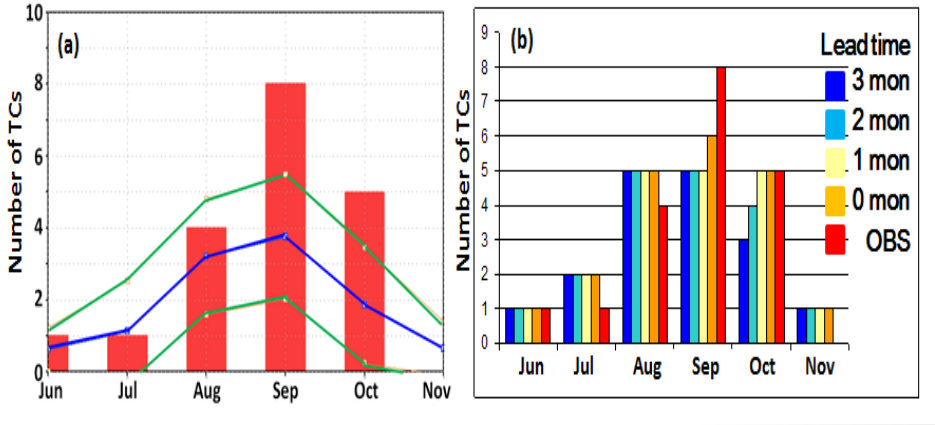
- Comprehensive testing and evaluation for R2O
- Real-time demo
- Large-scale retrospective tests of regional scale HNMMB
- Evaluations of track and intensity skill
- Rainfall and structure evaluation for landfalling storms

Completion expected December 2016

NMME – Task 1

➢ Evaluated and produced NMME-based hurricane outlooks for weeks 1-4

- Developed a hybrid statistical-dynamical prediction system of tropical storm activity for weeks 1-4 over the Atlantic and Pacific basins using the CFSv2 45-day hindcast suite for the 1999-2014 period.
- Performed skill evaluations of the hybrid prediction system for the 1999-2014 period.
- Real-time testing will commence during the 2016 hurricane season and the operational implementation is planned for the 2017 season.

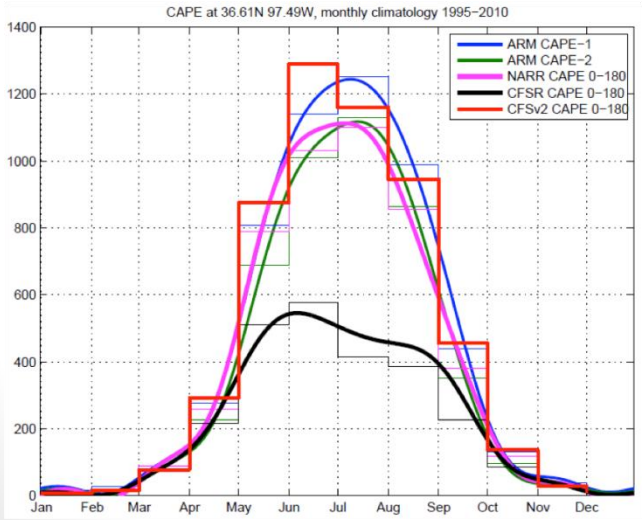


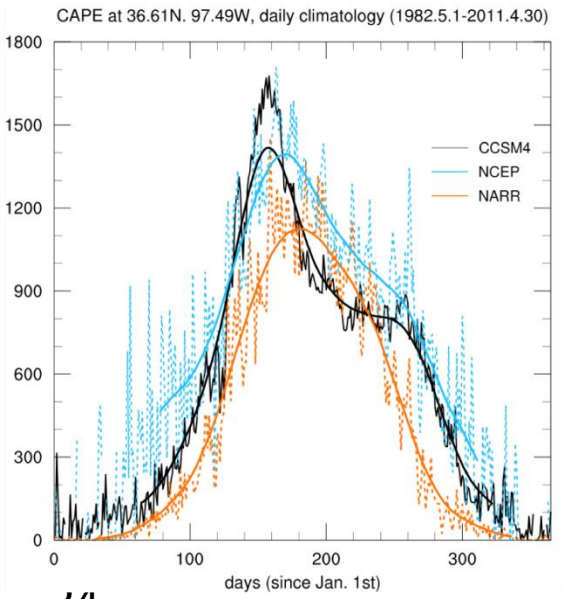
Monthly distribution of tropical cyclones in the 2010 Atlantic hurricane season (a) and forecasts of monthly tropical cyclones for the 2010 hurricane season (b) using the dynamical–statistical model (Wang et al. 2009) with lead time from 3 months to 0 month. Blue line in (a) is the monthly tropical cyclone climatology (1981–2009) and green lines are +/– one-standard-deviation departure from the climatology.

NMME – Task 2

➢ Assessed severe weather environmental factors using NMME data

- Diagnosed CAPE climatology in observational estimates and NMME retrospective forecast experiments
- Identified coupled SST-convective precipitation variability that has potential predictability. Comparison of these coupled modes in nature and the NCAR/CCSM4 retrospective forecasts show substantive spatial similarities.





CAPEs (CCSM4, NARR and NCEP) a) Monthly Climatology and b) Daily Climatology (Solid lines: 30-day running-average; Noisy lines : raw-daily data).

NMME – Task 3

Enhanced the current NMME Phase-II data

- NMME-Phase II data archive contains nearly 9000 datasets and 0.86 million files

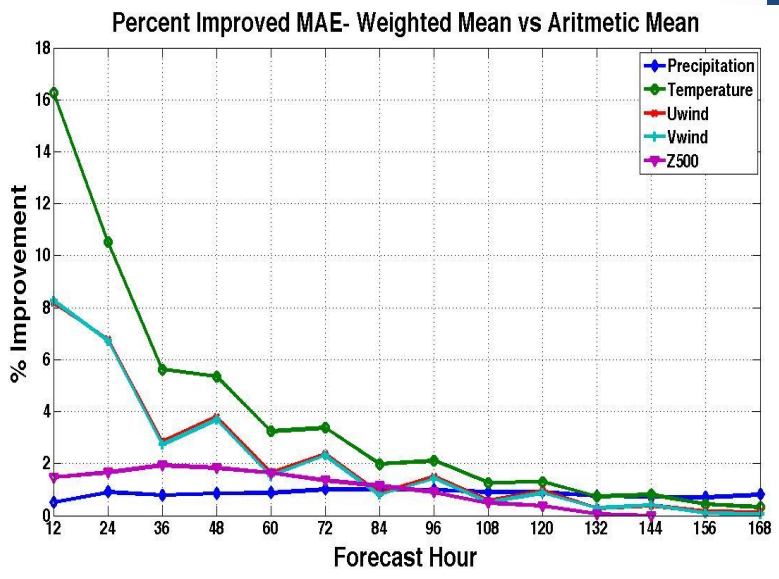
https://www.earthsystemgrid.org/search.html?Project=NMME

Test Program –
Statistical Post-Processing

➢ Completed implementation of Statistical Post-Processing technique for HIWPP models

- Uses model weighting at each grid point that is inversely proportional to the Mean Absolute Error at the point in 30 days of training data.

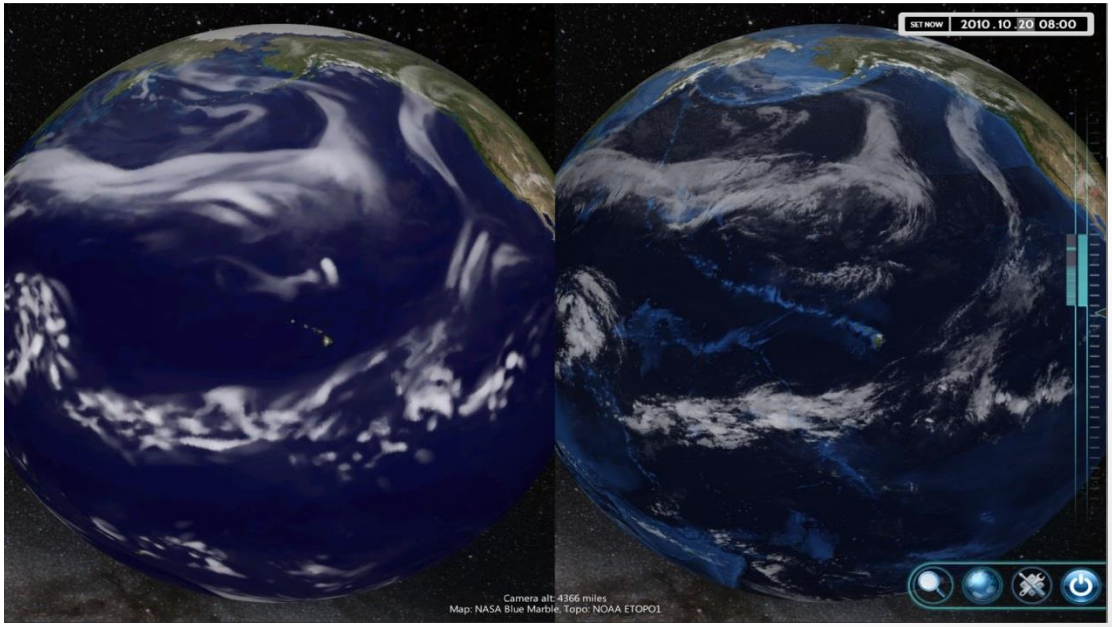
➢ Participated in the development of a precipitation-type (PTYPE) algorithm which yields improved skill for predicted probabilities of 'freezing rain' or 'ice pellets



Test Program - Visualization

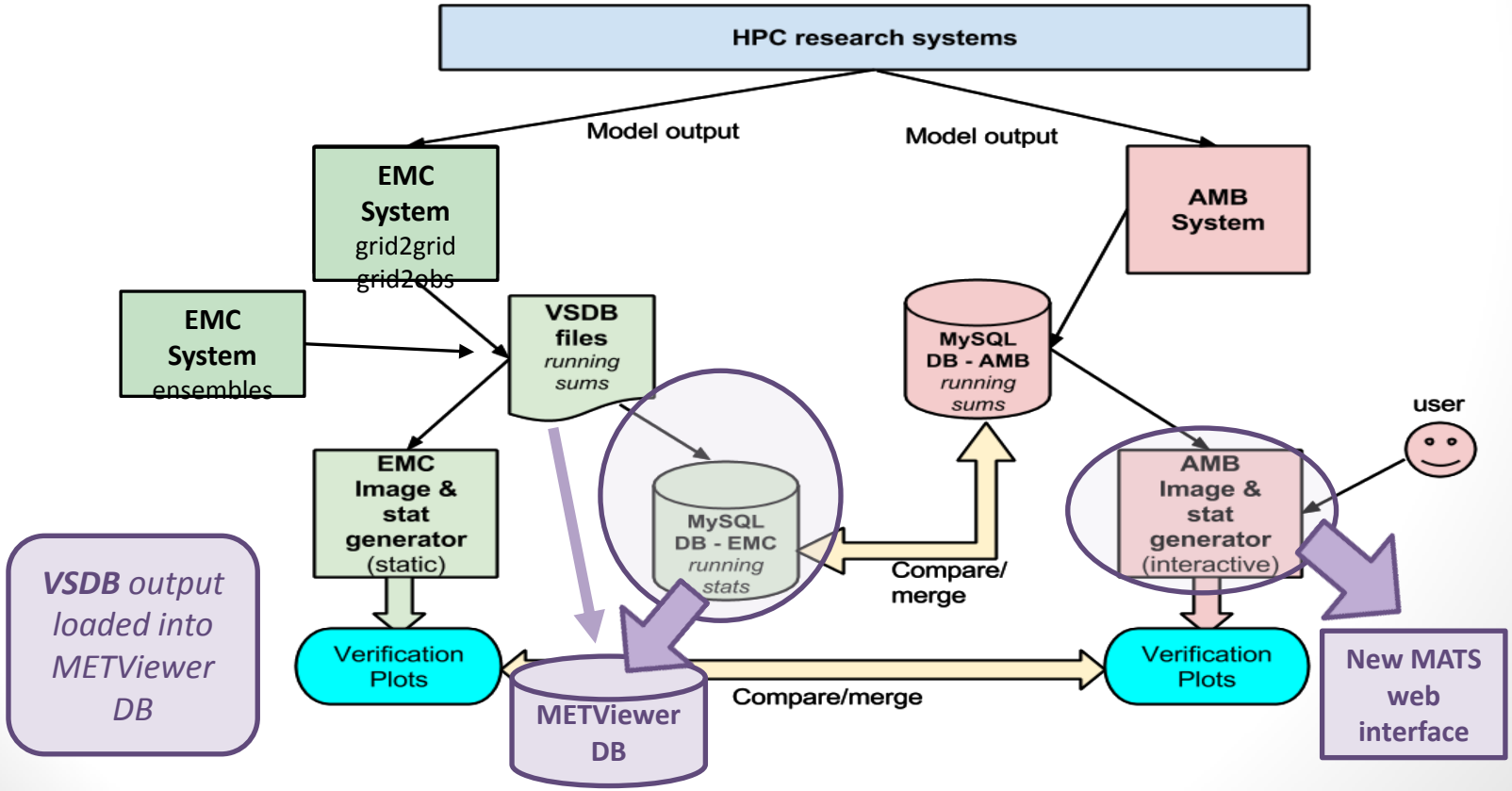
- **Implemented NEIS advanced visualization system**

  - High performance, real-time on-demand access of all HIWPP data
  - Includes cloud images simulated from model data



Test Program - Verification

- Initiated merge of capabilities between EMC and GSD, and added DTC's METViewer
- Built new, advanced MATS web interface



Test Program – Real Time Data

- **Procured hardware to support the large quantities of data exchanged**
- **Implemented faster and more reliable methods of network transfers**
- **Executed the Open Data Initiative**
  - Making real-time research data available to the public

HIWPP Key Accomplishments

1. Phase 1 of dycore testing; reduction to 2 dycores
2. 4D-En-Var transitioned to operations
3. Developed stochastic physics for probable transition to operational GEFS
4. Initial development of SHOC physics parameterization
5. Development of scale-aware physics in GF scheme
6. Ran global hydrostatic models to higher resolutions and produced improvements in physics
7. Developed HNMMB to TR Level 5
8. Pushed NMME forward in 3 areas
9. Implemented NEIS advanced visualization system
10. Initiated unified verification system

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HIWPP
HIGH IMPACT WEATHER PREDICTION PROJECT

FUNDED BY HURRICANE SANDY DISASTER RELIEF SUPPLEMENTAL APPROPRIATIONS

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IMPROVING FORECASTS WITH HIWPP

Announcements

The Open Data Initiative has concluded, but HIWPP research data is still available.

"The goal of HIWPP is to improve time-zero to two-week weather prediction of nature's most dangerous storms such as hurricanes, floods, and blizzards." — Dr. Alexander MacDonald, Director, Earth System Research Laboratory

HIWPP Team Meets in College Park, Maryland

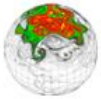
HIWPP IS WORKING TO:

- Improve current global weather models by increasing resolution to 10-13km
- Test next-generation global weather models in a real-time running mode
- Use a nested moving hurricane model that zeroes in on resolution within a global model allowing for more detailed hurricane track and intensity information
- Evaluate the National Multi-Model for Ensembles' ability to improve forecasts out to months and use cutting-edge visualization technology
- Partner with the broader weather community to assess research models in real time

Above: Hurricane Sandy - Ocean Grove Pier, Colorado Flooding 2013, Blizzard Stops Mail, Tacloban Typhoon Haiyan

FOCUS AREAS

Hydrostatic Global Models

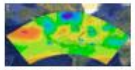


Improve hydrostatic-scale medium-range forecast capability as a benchmark for further model advances.

Non-Hydrostatic Global Models

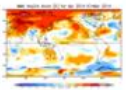
Develop a global cloud-permitting (~3km resolution) forecast capability.

Moving Hurricane Nest



Improve hurricane predictions with development of a high-resolution moving nested HWRF model.

NMME Expansion



Evaluate prediction capabilities of high-impact weather extremes out to several months.

Test Program

Develop advanced capabilities for testing and evaluating global numerical weather prediction systems.

NEXT-GEN HPC

Key to running global non-hydrostatic models at very high resolutions lies in

OPEN DATA INITIATIVE

Engaging with members of the weather and research community is an integral part of the project. Learn more.

PROJECT COLLABORATORS

NOAA is working with a wide community of weather researchers and innovators. Read