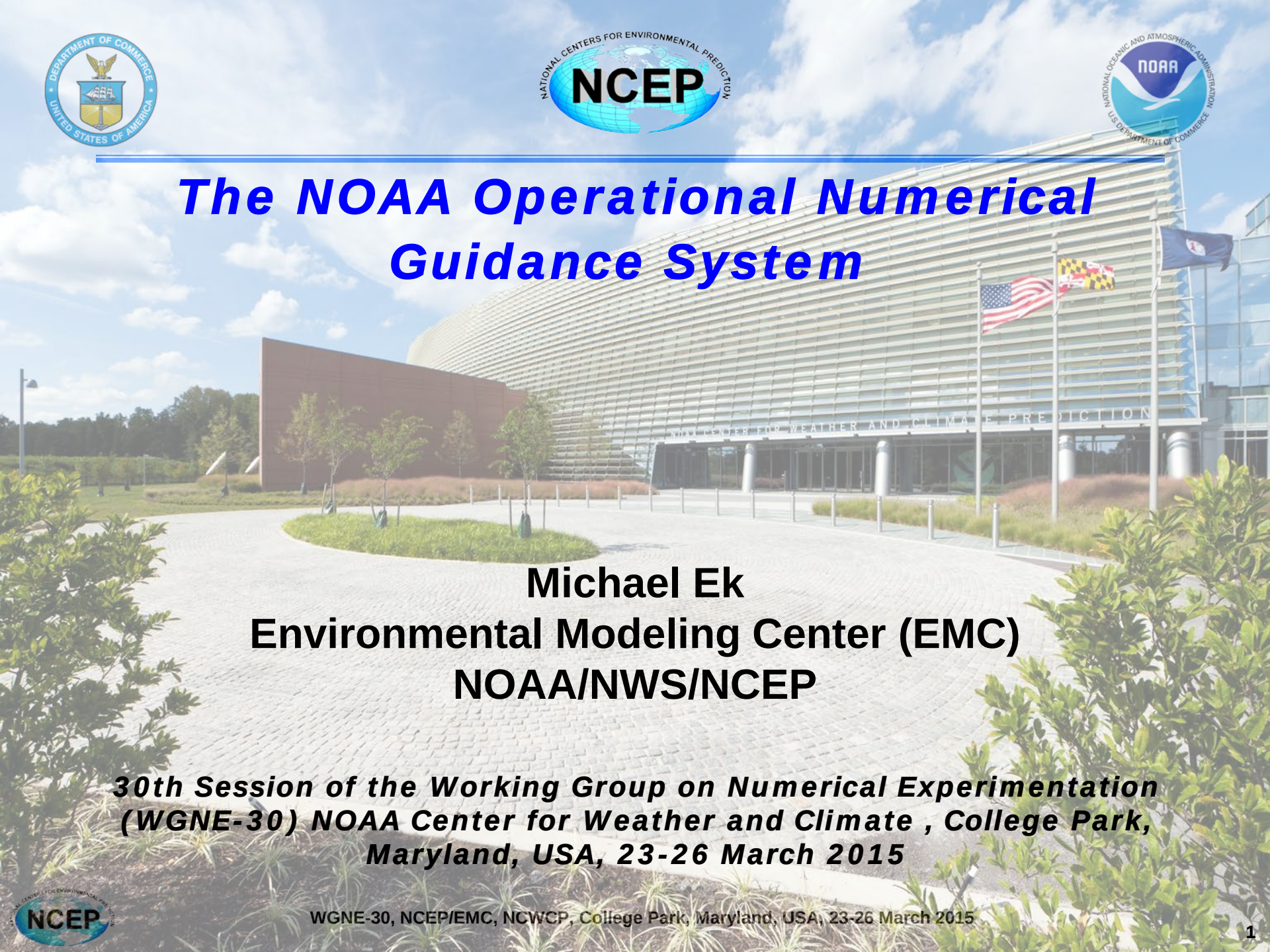


# The NOAA Operational Numerical Guidance System

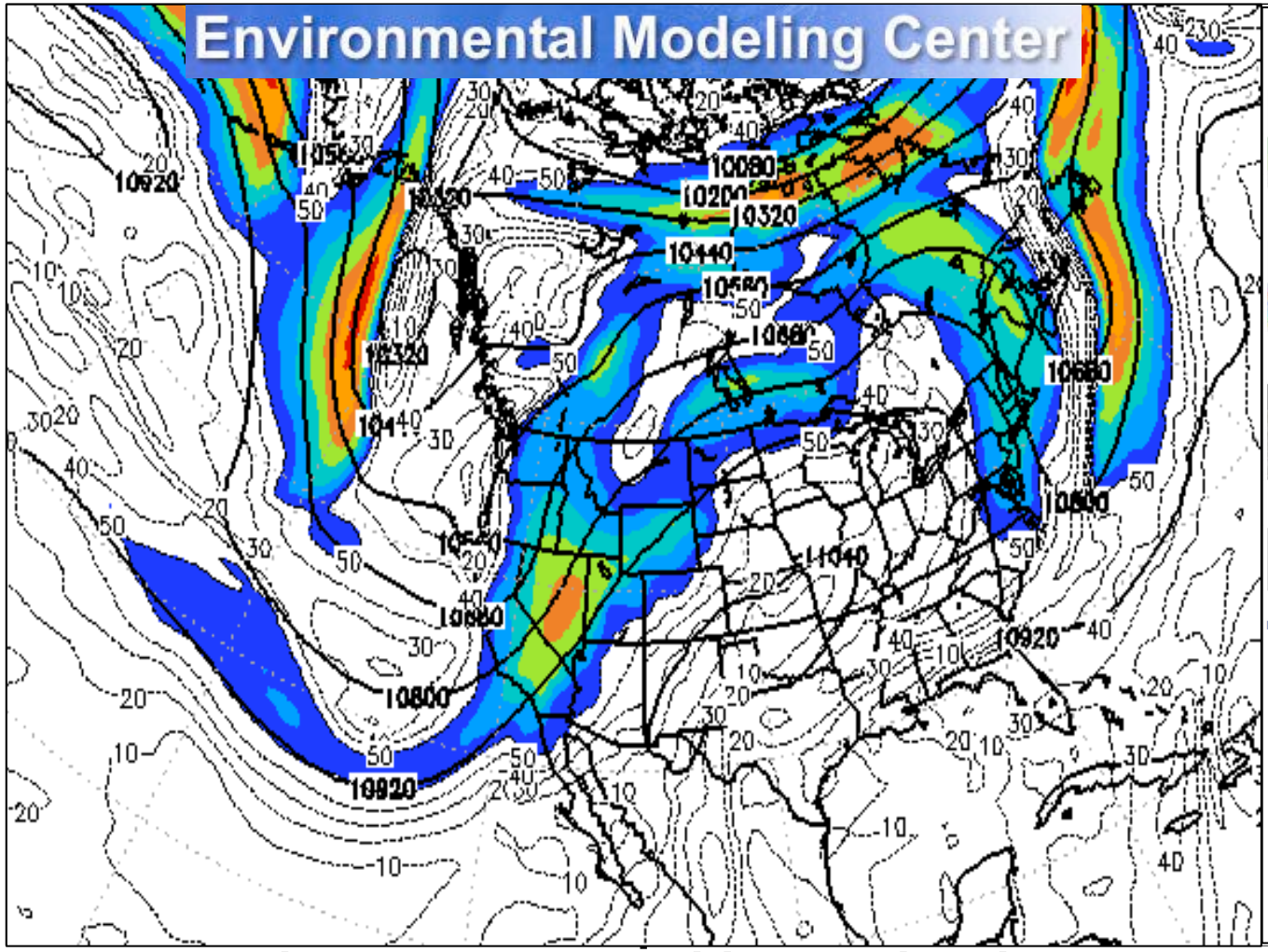
**Michael Ek**
**Environmental Modeling Center (EMC)**
**NOAA/NWS/NCEP**

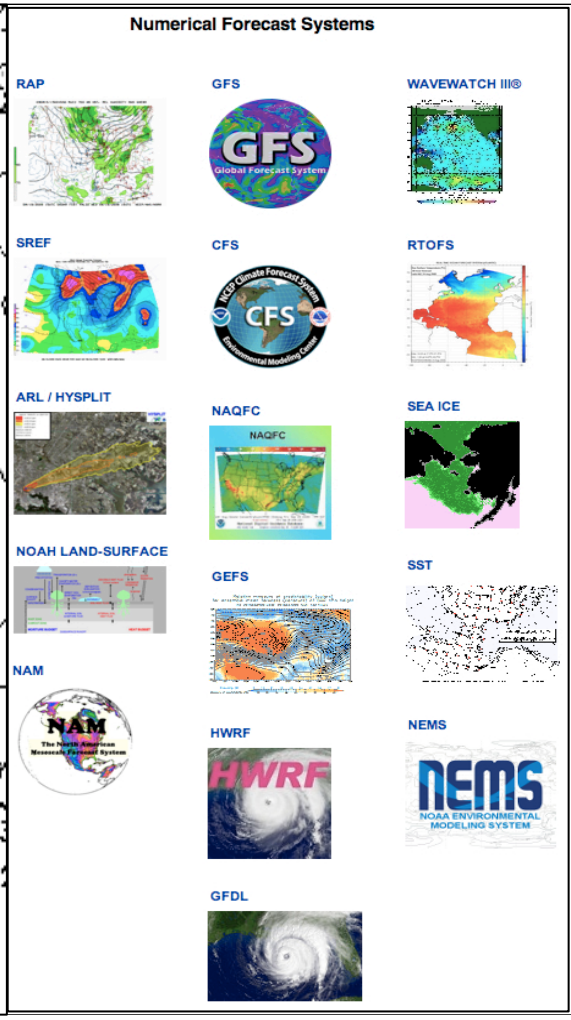
***30th Session of the Working Group on Numerical Experimentation (WGNE-30) NOAA Center for Weather and Climate , College Park, Maryland, USA, 23-26 March 2015***

# Outline

- NCEP and EMC
- Production Suite
- Components:
  - Data Assimilation
  - Global Forecast System (GFS), Global Ensemble (GEFS)
  - Unified Global Coupled System (medium-range to seasonal)
  - North American Multi Model Ensemble (Seasonal)
  - North America Mesoscale (NAM) model, Hurricane (HWRF), Short-range Ensemble Forecast (SREF)
  - Hurricane, Land-Hydrology, Ocean, Sea-ice
  - NOAA Environmental Modeling System (NEMS)
- NCEP/EMC Model Evaluation Group (MEG)

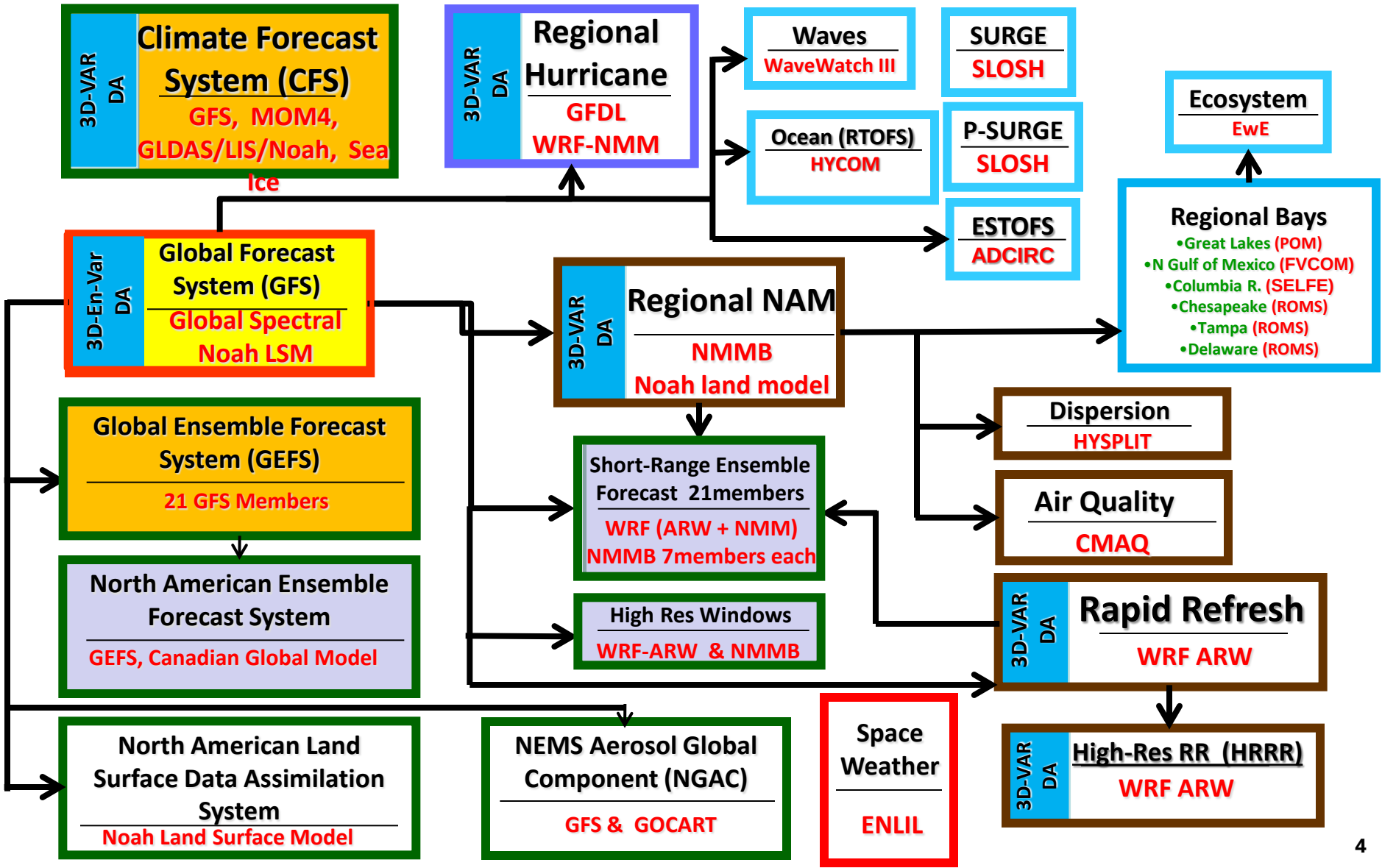
# National Centers for Environmental Prediction
## Specialized Services – Common Mission




**EMC**: Enhancement, transition, and maintenance of numerical mo
that provide operational guidance.

# NOAA's Operational Numerical Guidance Suite (Feb 2015)



# Data Assimil. Plans: Next Global Implementation (~Dec. 2015)

- Hybrid 4D EnVar:
  - Hourly time bins (7 time levels per analysis).
  - 80 ensemble members.
  - T1534L64 deterministic with T574L64 ensembles used for T574 analysis increments
  - Modified thinning of data in time.
- Observation changes:
  - Cloudy Microwave Radiances: Cloud analysis impacted by covariances from Hybrid and cloud impacted microwave radiances.
  - Upgraded CRTM2.2.
  - Additional aircraft and AMV data.
  - Bias correction of aircraft temperature observations.
- NSST:
  - Variation in Near Sea-Surface Temperature of ocean included in both forecast model and analysis.
  - Directly uses radiances and accounts for depth of observations in NSST analysis.
  - Diurnal cycle of Ocean and observations accounted for much better.

# Global Model Plans

**Q2FY15 implementation (January 14, 2015)**

- T1534 Semi-Lagrangian (~13km)
- Use of high resolution daily SST and sea ice analysis
- High resolution until 10 days
- Physics:
  - Radiation modifications
  - Reduced drag coefficient at high wind speeds
  - Stationary convective gravity wave drag
  - Soil Moisture climatology from CFSv2
  - Changes to roughness length calculations

**FY16**

- NEMS
- 4D-Hybrid EnVAR
- Convective upgrade
- Land and surface layer upgrade

**FY17**

- T1534L64 –> T1534L128
- Enhanced physics

Aerosol prediction – initially lower resolution used as forcing in high res.

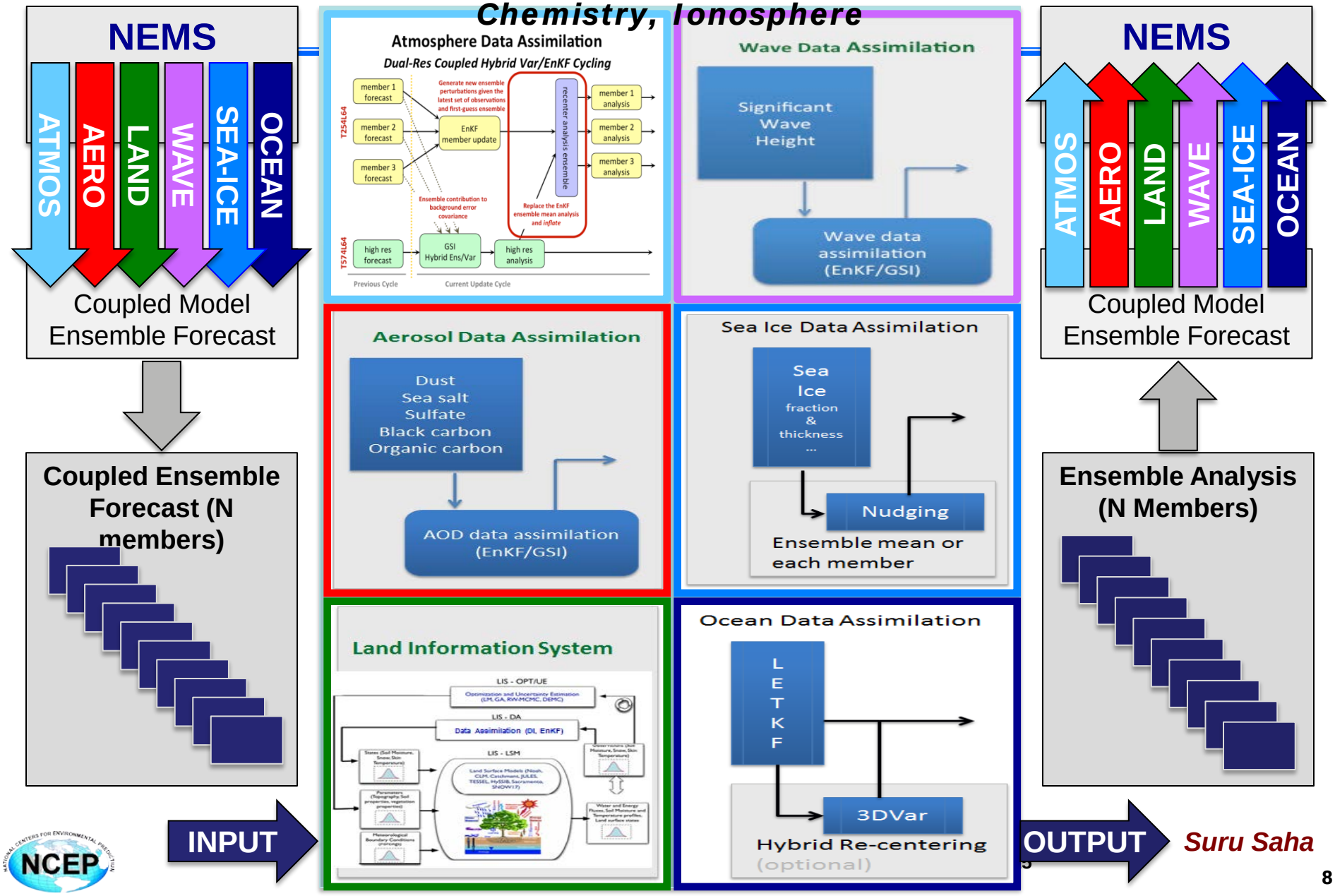
WAM – Whole Atmosphere Model – initially lower resolution up to 600km

# Global Ensemble Plans

| | Current | Next GEFS Configuration (v11.0.0) |
|---|---|---|
| Model | GFS Euler model (V9.0.1) | GFS Semi-Lagrangian model (V10.0.0) |
| Horizontal res. | T254 (~52km) for 0-192 hours, T190 (~70km) for 192-384 hrs | TL574 (~34km) for 0-192 hours, TL382(~52km) for 192-384 hr |
| Vertical res. | L42 hybrid levels | L64 hybrid levels to match GFS and DA |
| Compute | 84 nodes (+ post process) for 55 minutes | 300 nodes (first 35 minutes), 250 nodes (2nd 30 minutes) |
| Output | every 6-hr for 1*1 degree pgrb files | every 3-hr for 0.5*0.5 degree pgrb files |
| Schedule | Feb. 2015 – deliver codes/scripts to NCO | Apr. 2015 – implementation (WCOSS-phase II) |

- **Increase model resolution and membership.**
- **Introduce other stochastic schemes:**
  - Stochastic Kinetic Energy Backscatter (SKEB) represents processes absent from model.
  - Stochastic Perturbed Physics Tendencies (SPPT) designed to represent the structural uncertainty (or random errors) of parameterized physics. Biggest impact for tropics.
  - Stochastically-perturbed boundary layer HUMidity (SHUM) designed to represent influence of sub-grid scale humidity variability on the the triggering of convection.
  - Stochastic perturbed land-surface.
- **Extend GEFS to 35 days: Coupling with ocean/ice model, or alternate method.**

# NCEP Unified Global Coupled Hybrid Data Assimil. and Forecasting Suite: Atmosphere, Land, Ocean, Sea-ice, Wave, Chemistry, Ionosphere




Suru Saha

# NMME = National (or North American) Multi-Model Ensemble for Seasonal Prediction

- **Real-Time definition: Each month a global NMME seasonal forecast of SST, precip and T2m on a global 1X1 grid in support of CPC operations. (This is "phase I")**
- **In early 2014, the SIX real time participants were CFSv2, NCAR-UoFlorida-CCSM3, NASA-GEOSS, GFDL-CM2, Canadian CMC3 and CMC4. (Retired participants include CFSv1, IRI-f and IRI-a)**
- **During 2014, two models were added: NCAR-UoFlorida-CCSM4, and GFDL-Flor-a/b. A third model NCAR-CESM1 is in the pipeline (hindcasts 1982-present to be finished). CCSM3 has been retired by late 2014. Currently SEVEN models, soon EIGHT. Close to 100 ensemble members in hindcasts. More members in real time.**
- **A review of NMME took place Sept 2014 and NMME as a CPU-distributed system will be continued for seasonal prediction and is considered 'operational' .**
- **The phase II R&D effort (*daily* data to study intra-seasonal) has yielded a big archive managed at NCAR.**
- **The IMME carries on each month. IMME at NCEP ~ Eurosip (at ECMWF).**

http://www.cpc.ncep.noaa.gov/products/NMME

# Recent and planned upgrades to North American Mesoscale (NAM) system

## NAM 2014Q4 upgrade

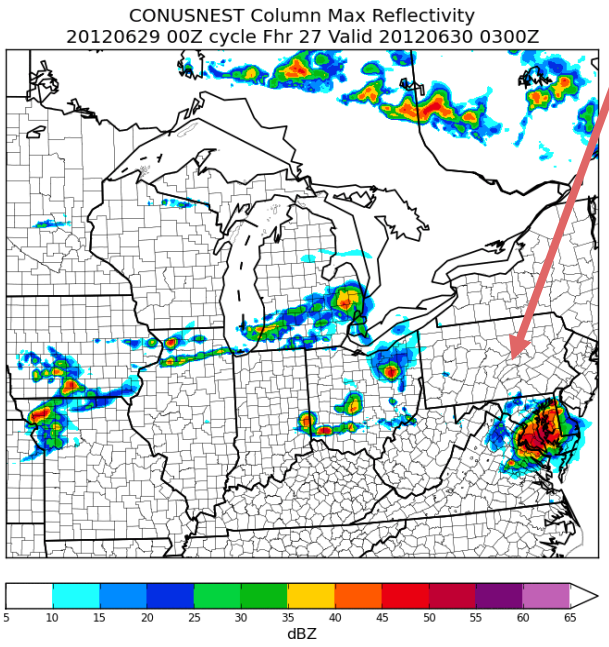
- NAM forecast configuration:
  - 12km parent to 84-hr.
  - 4 fixed nests: 4km CONUS, 6km Alaska, 3km HI/PR to 60-hr.
  - 1.33km relocatable storm scale nest to 36-hr.
- Hybrid variational ensemble analysis; new satellite bias correction algorthim.
- RRTM radiation scheme.
- Ferrier-Aligo microphysics; tuned to improve severe storm structure.
- Convection: Modified BMJ (moister profiles) to improve 12km parent bias; explicit in nests except AK.

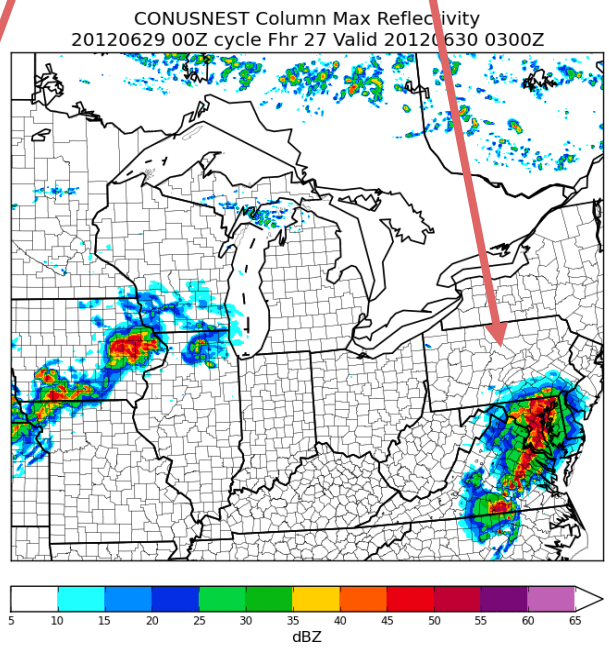
## NAM 2016Q1 upgrade

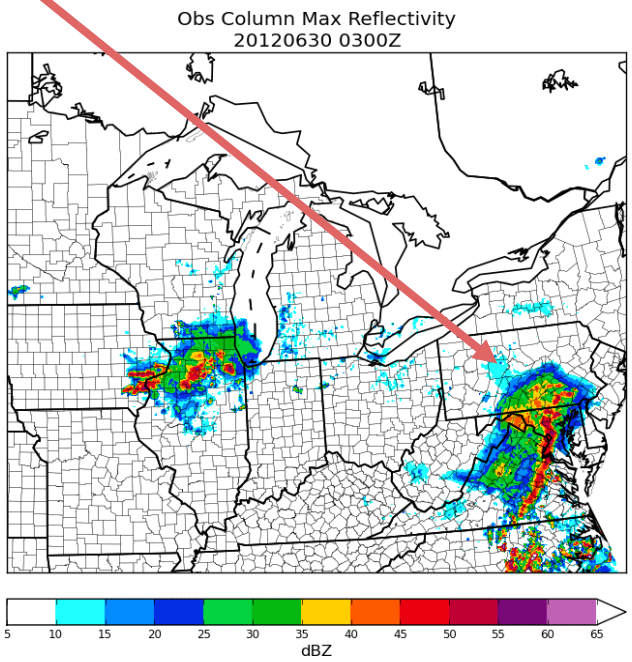
- CONUS/Alaska nest to 3km, explict convection in AK nest.
- New shallow convection scheme in 12km parent NAM; improves cold season QPF bias.
- More frequent calls to radiation/physics.
- Digital filter with radar-derived temperature tendencies.
- 4-d EnKF.
- Rapidly updated hourly assimilation system (NAMRR).
- Others T.B.D.

# June 29-30, 2012 “DC Derecho” - 27hr fcst NAMRR Test with 3km CONUSnest

Significant improvement at longer lead times with 3km NAMRR relative to Operations (at the time)




4 km Ops NAM CONUSnest Fhr=27

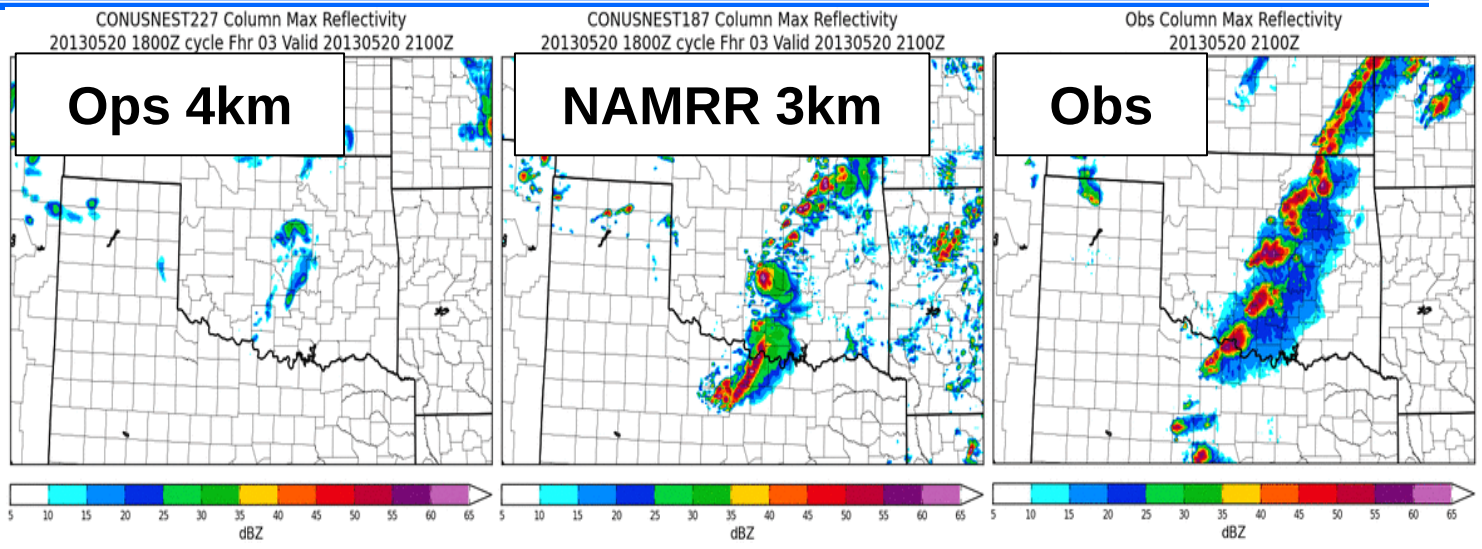
3 km NAMRR CONUSnest Fhr=27

Observations

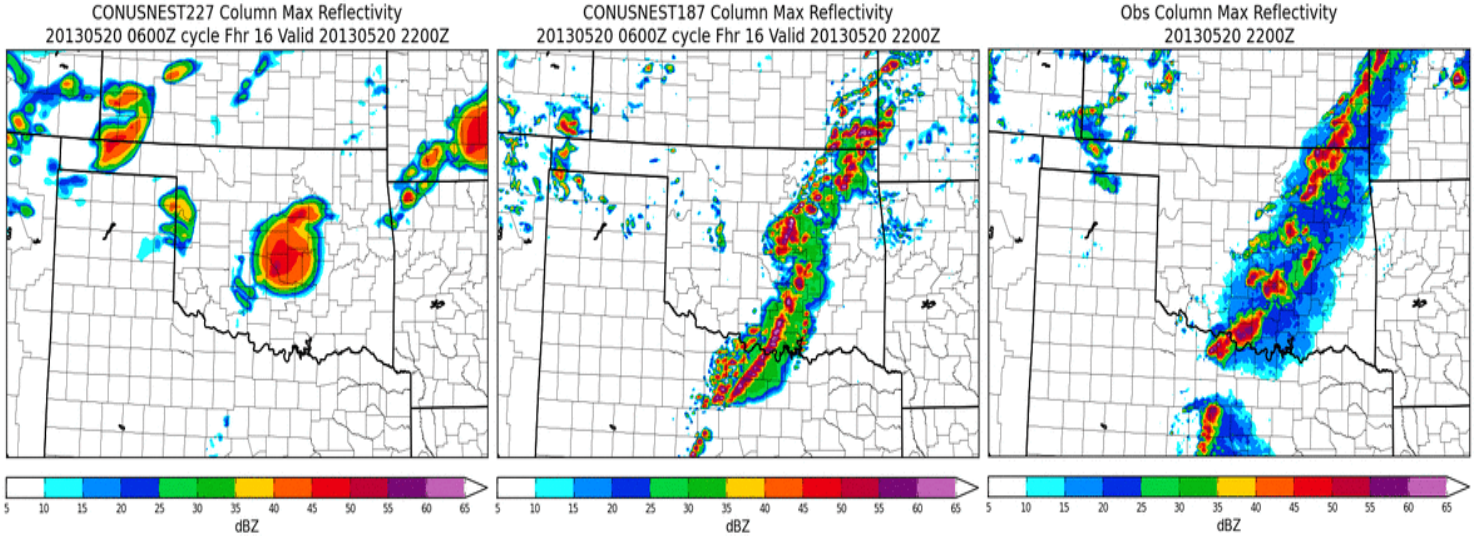
*Eric Rogers*

# Moore OK Severe Weather Event
# 20 May 2013

**Fhr = 03**
**Valid 21Z**




**Fhr = 16**
**Valid 22Z**



# Rapid Refresh and HRRR

## NOAA hourly updated models

**(situational awareness for energy, aviation, severe weather, etc.)**

**13km Rapid Refresh (RAP) (mesoscale)**

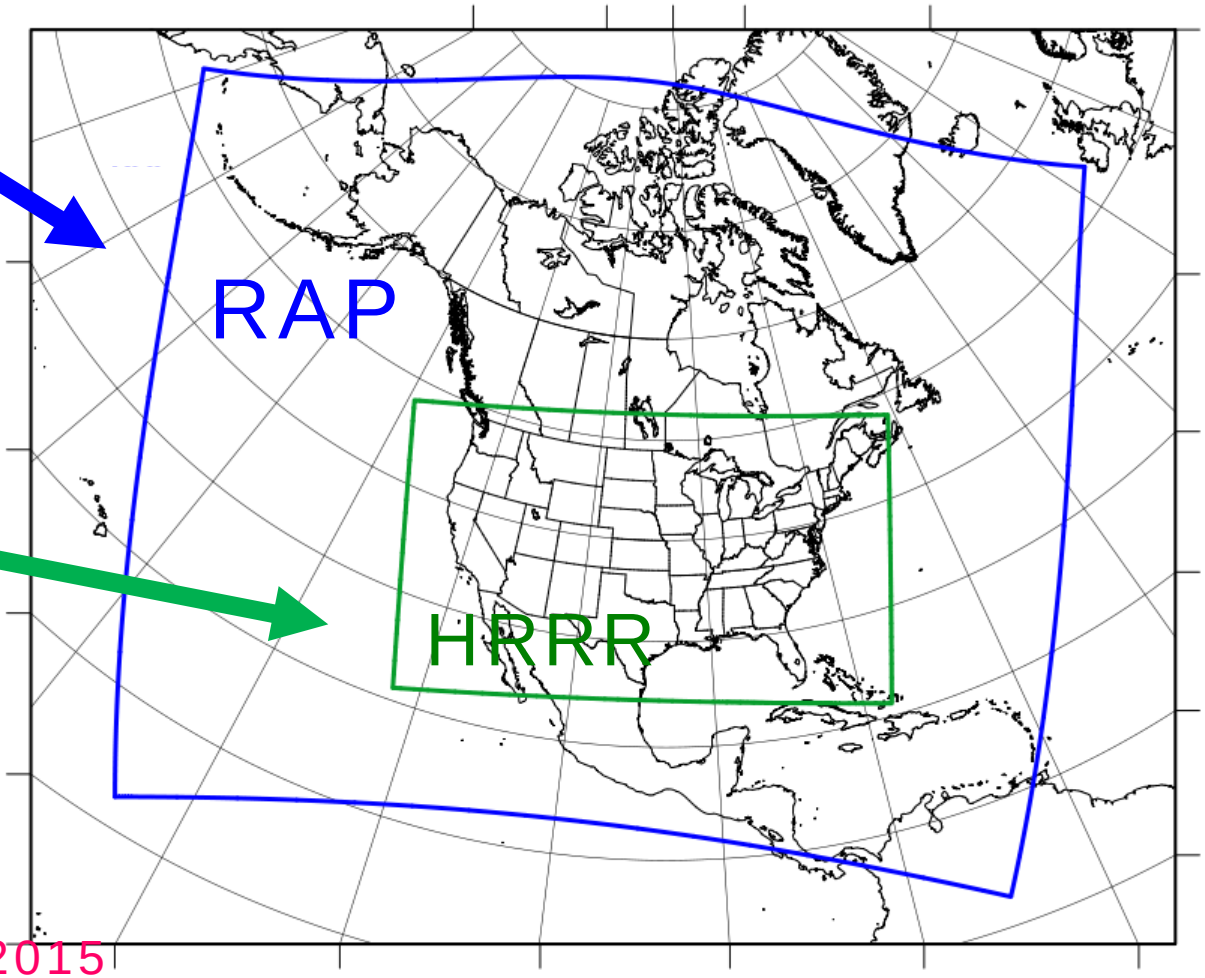
Version 2 -- NCEP implement 25 Feb 2014

Version 3 – GSD Planned NCEP –summer 2015

**3km High Resolution Rapid Refresh (HRRR) (storm-scale)**

Initial -- NCEP implement 30 Sept 2014

Version 2 – GSD Planned NCEP –summer 2015

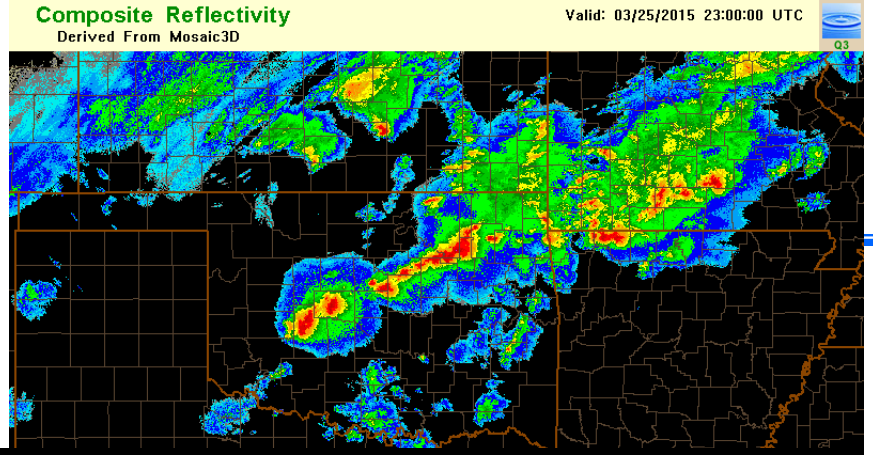


# NCEP RAPv3 and HRRRv2

| Model | Run at: | Domain | Grid Points | Grid Spacing | Vertical Levels | Pressure Top | Boundary Conditions | Initialized |
|---|---|---|---|---|---|---|---|---|
| **RAP** | GSD, NCO | North America | 758 x 567 | 13 km | 50 | 10 mb | GFS | Hourly (cycled) |
| **HRRR** | GSD | CONUS | 1799 x 1059 | 3 km | 50 | 20 mb | RAP | Hourly - RAP (no-cycle) |

| Model | Version | Assimilation | Radar DA | Radiation LW/SW | Microphysics | Cumulus Param | PBL | LSM |
|---|---|---|---|---|---|---|---|---|
| **RAP** | WRF-ARW v3.6+ | GSI Hybrid 3D-VAR/Ensemble | 13-km DFI | RRTMG/RRTMG | Thompson – aerosol v3.6.1 | GF v3.6+ | MYNN v3.6+ | RUC v3.6+ |
| **HRRR** | WRF-ARW v3.6+ | GSI Hybrid 3D-VAR/Ensemble | 3-km 15-min LH | RRTMG/ RRTMG | Thompson – aerosol v3.6.1 | GF shallow | MYNN v3.6+ | RUC v3.6+ |

| Model | Horiz/Vert Advection | Scalar Advection | Upper-Level Damping | 6th Order Diffusion | SW Radiation Update | Land Use | MP Tend Limit | Time-Step |
|---|---|---|---|---|---|---|---|---|
| **RAP** | $5^{th}/5^{th}$ | Positive-Definite | w-Rayleigh 0.2 | Yes 0.12 | 20 min | MODIS Fractional | 0.01 K/s | 60 s |
| **HRRR** | $5^{th}/5^{th}$ | Positive-Definite | w-Rayleigh 0.2 | Yes 0.25 (flat terr) | 15 min with SW-dt (Ruiz-Arias) | MODIS Fractional | 0.07 K/s | 20 s |

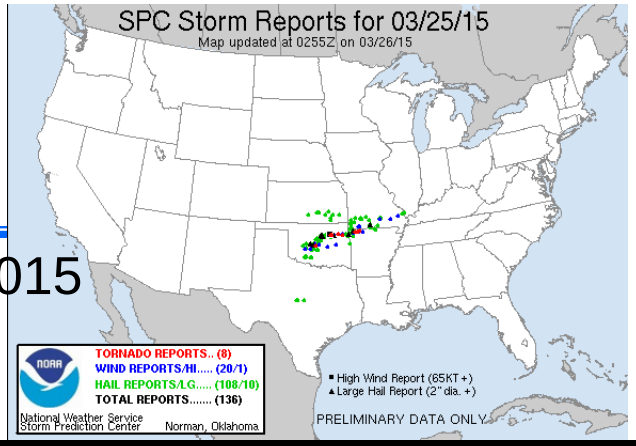


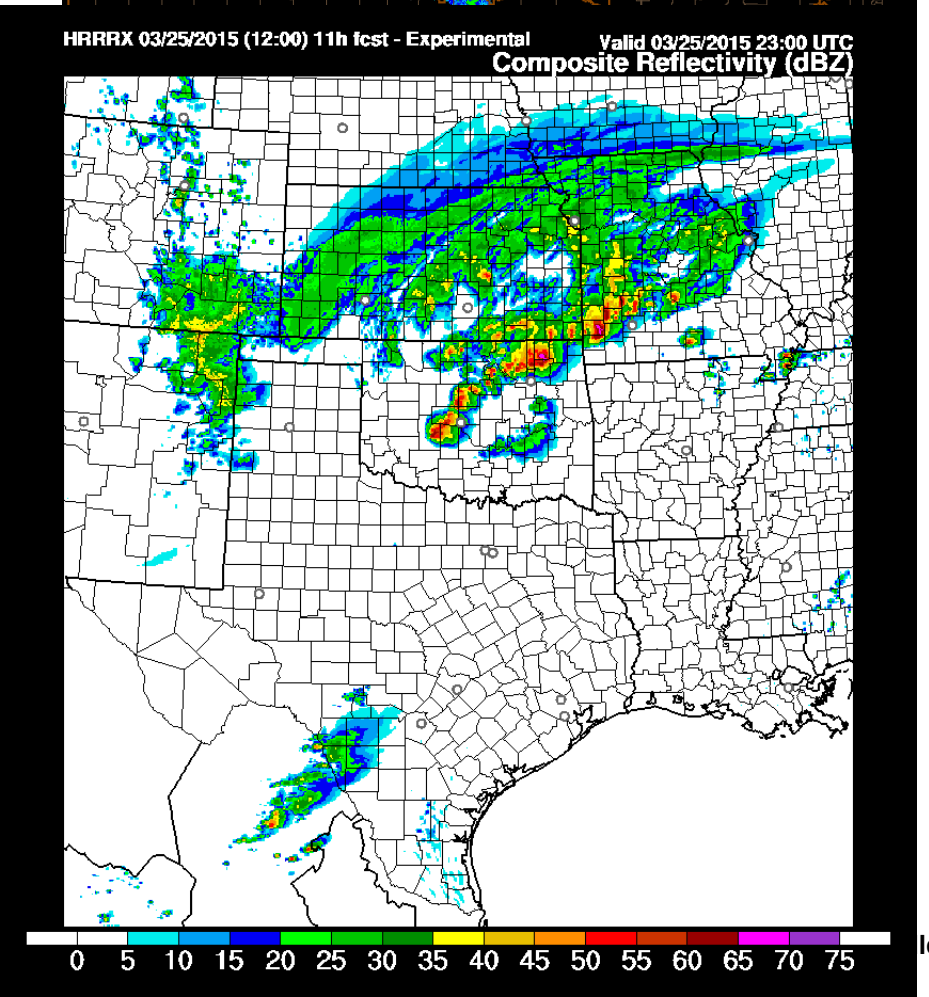

# HRRRv2

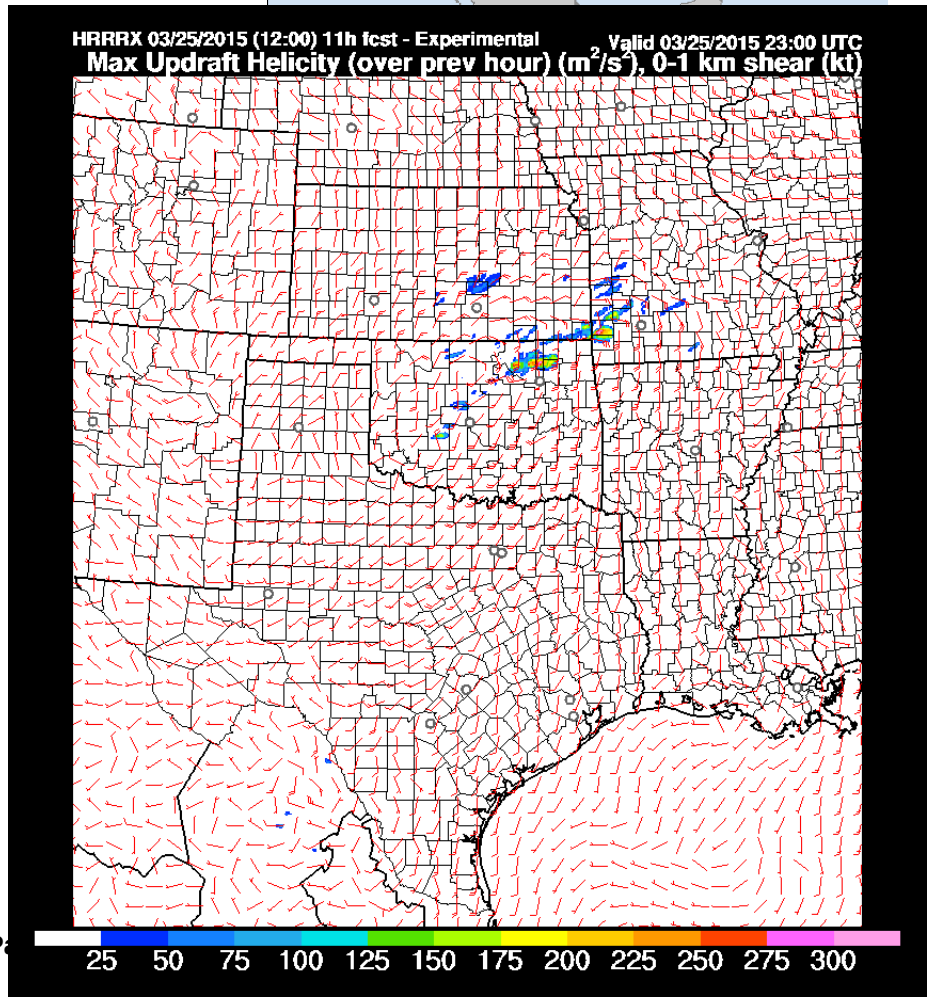
12z 25 Mar 2015

11h fcst

Valid 23z



# NCEP Mesoscale Ensembles Replace Regional Deterministic Guidance: Current and Future

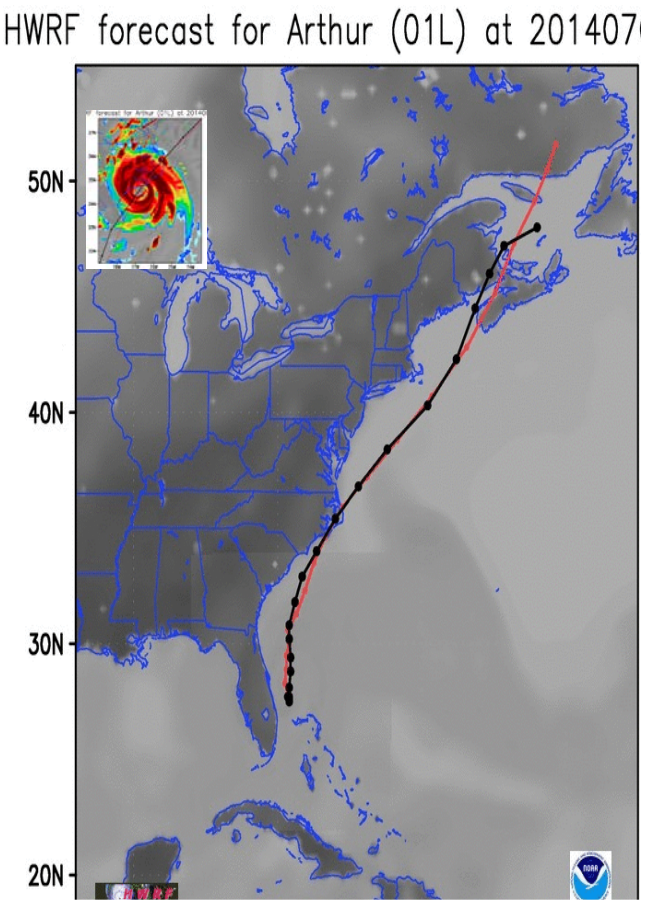
| Current | ~2015 | ~2018 |
|---|---|---|
| **SREF continental scale** | **SREF continental scale** | **SREF continental scale** |
| WRF-ARW, -NMM, NMMB | WRF-ARW & NMMB | WRF-ARW & NMMB |
| 7 each = 21 members<br>16km | 13 each = 26 members<br>~16km | 13 each = 26 members<br>~9km (parent) |
| 35 levels<br>6 hourly to 87 hr | 40 levels<br>6 hourly to 87 hr<br>NARRE-TL run hourly to 18 hr | 50-60 levels<br>6 hourly to 96 hr.<br>SREF_RR run hourly to 24 hr |
| **Convection-Allowing-Scale** | **Convection-Allowing-Scale** | **Convection-Allowing-Scale Ensemble** |
| hrly 3km HRRR & NAM nest run to 15 h for CONUS<br>Irregular suite of guidance 3-6km, ~6 hourly to 48/60 hr for CONUS, Alaska, HI, PR | Upgrade irregular suite (HiResW) to ~3km, 6 hourly to 48/60 hr for CONUS, Alaska, HI, PR | HREF_RR (high-res ensemble fcst): Multiple hourly 3km run to 24 hr; HREF: run 6 hourly extended to 60 hr for CONUS, Alaska, Hi, PR |
| **Storm Scale** | **Storm Scale** | **Storm Scale Ensemble** |
| Single placeable sub-nest [fire weather run]<br>1.33-1.5km<br>Run 6 hourly to 36 hr | Single placeable/movable sub-nest 1-1.5km<br>Run 6 hourly to 36 hr | Storm-scale ensemble (SSE)<br>Multiple placeable/movable sub-nests: ~1km run hourly to 18 hr and run 6 hourly to 36 hr |

# NCEP Operational HWRF Model: NOAA's State-of-the-art Hurricane Prediction System

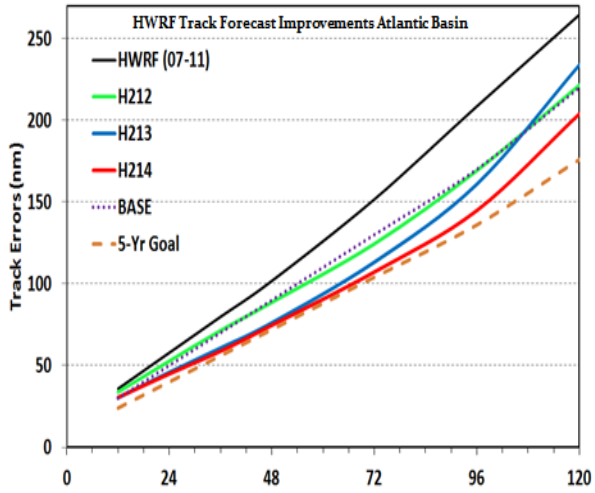
## HWRF Model Configuration:

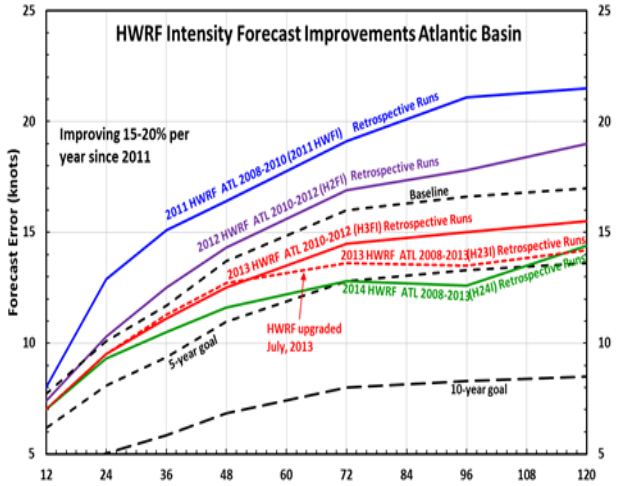
- Three telescopic domains with high resolution storm following nests: 27km/9km/3km; 61L *going to 18km/6km/2km in 2015.*
- Coupled to MPI POM Ocean Model worldwide using NCEP Coupler.
- Sophisticated vortex initialization.
- EnKF/GSI hybrid regional DA system with real-time inner core aircraft data assimilation.
- Advanced physics tailored for hurricane conditions based on observations.
- *Coupled Noah LSM in 2015*
- *Expanding the scope of operational HWRF for all global tropical cyclones in 2015.*

## Accurate and reliable Track, Intensity & Structure Forecasts




## Significant Improvements in the past 5 years, meeting HFIP Goals



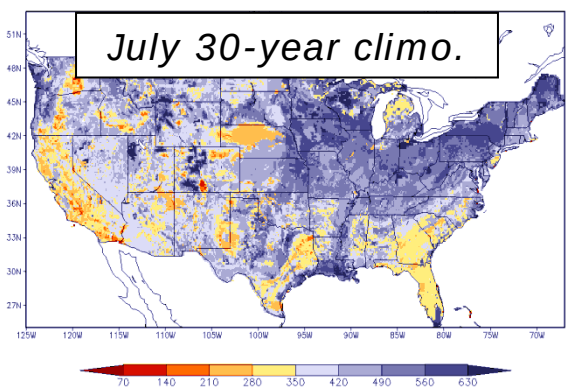



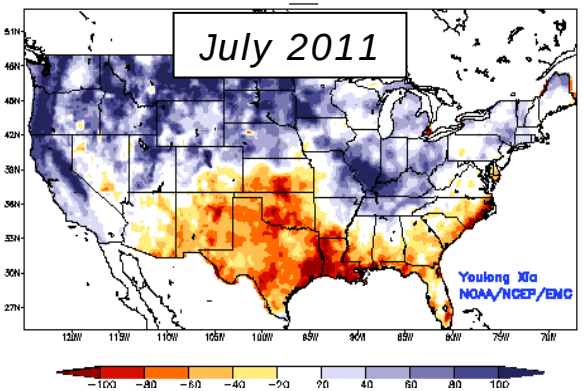

**Real-time HWRF products, all global TCs:**
http://www.emc.ncep.noaa.gov/gc_wmb/vxt

# Land Data Assimilation System (LDAS)

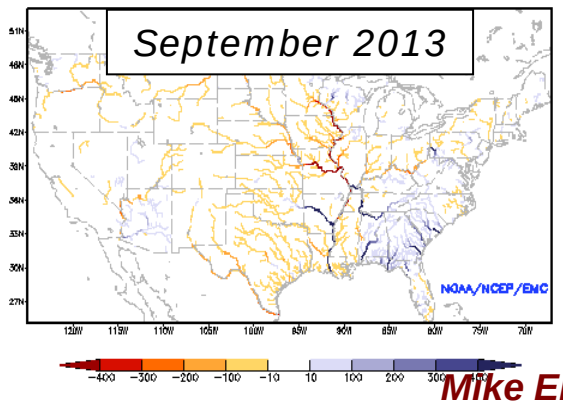
## www.emc.ncep.noaa.gov/mmb/nldas

- 5 Aug 2014: North American LDAS (NLDAS) operational.
- NLDAS: 4 land models run uncoupled, driven by CPC observed precipitation & NCEP R-CDAS atmospheric forcing.
- Output: 1/8-deg. **land** & **soil states**, **surface fluxes**, **runoff** & **streamflow**; anomalies from 30-yr climatology for drought.
- Future: higher res. (~3-4km), extend to N.A./global domains, improved land data sets/data assimil. (soil moisture, snow), land model physics upgrades inc. hydro., initial land states for weather & seasonal climate models; global drought information.



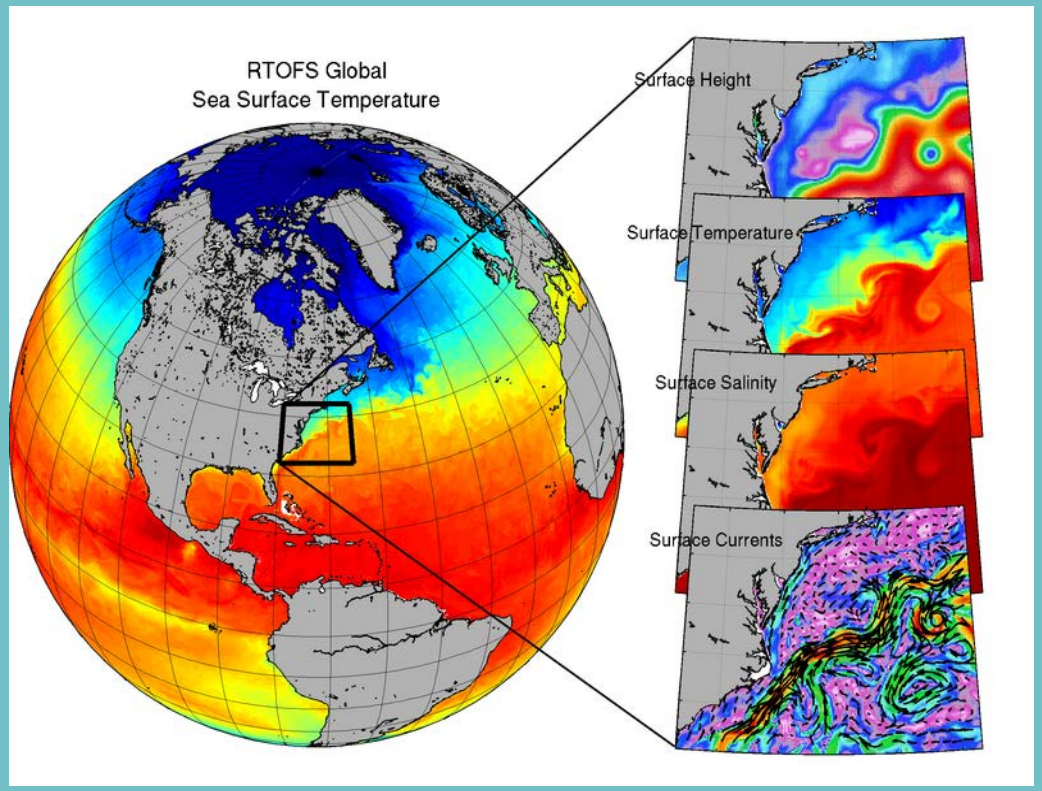

*Ensemble monthly soil moisture anomaly*




*Daily streamflow*

*Mike Ek*

# Global and Basin Scale Ocean Forecast Systems




- Eddy Resolving Ocean Modeling and Initialization
- Coupled Modeling for Hurricanes (Air-Sea-Wave flux interaction, mixing)
- Coupled Modeling for short-term, medium-term and seasonal scales (Air-Sea-Ice-Wave flux interactions, ensembles)
- Coupled Ecosystem Forecasting (Biogeochemical, NPZD, tracers)
- All Ocean Forecast Systems presently based on HYCOM, RTOFS (Real Time Ocean Forecast Systems) represents line of products

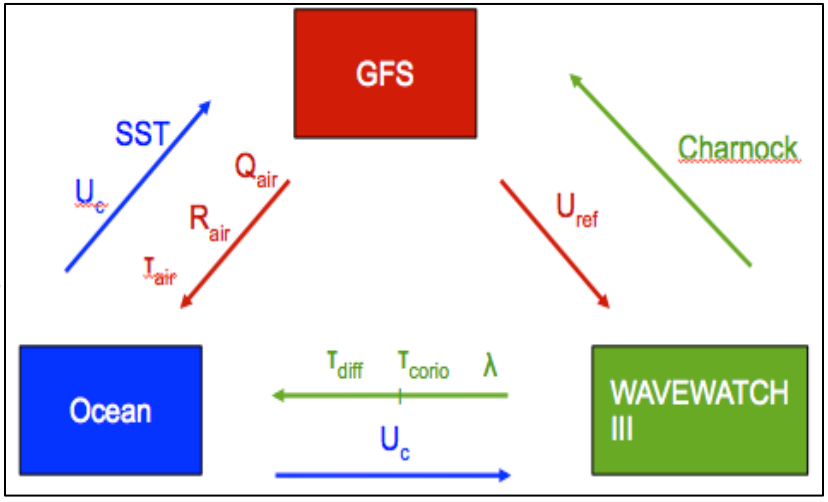
Primary Users:
**NOAA:** NWS, NOS, IOOS, OAR, JCSDA
**External:** DHS, Academia, Japan (JAEA), India (INCOIS)

**Strong collaboration with US Navy, leveraging core HYCOM and data assimilation developments at NRL.**

*Avichal Mehra*

# WAVEWATCH III and Wave Coupling

- **GFS model** air-sea fluxes depend on **sea state** (roughness -> Charnock).
- **WAVEWATCH III model** forced by **wind** from GFS and currents from Ocean**.**
- **Ocean model** forced by **heat flux**, sea state dependent **wind stress** modified by **growing or decaying wave fields and Coriolis-Stokes effect.**
- **Current Status**:
  - o Wave model driven in uncoupled mode with GFS 10m winds for global forecasts (4 cycles a day out to 180 h of forecast).
  - o Hurricane wave model uses blend of GFS and HWRF winds for forecasts (4 cycles a day out to 126 h of forecast).
  - o Use first guess model results from previous cycle as final wave analysis.

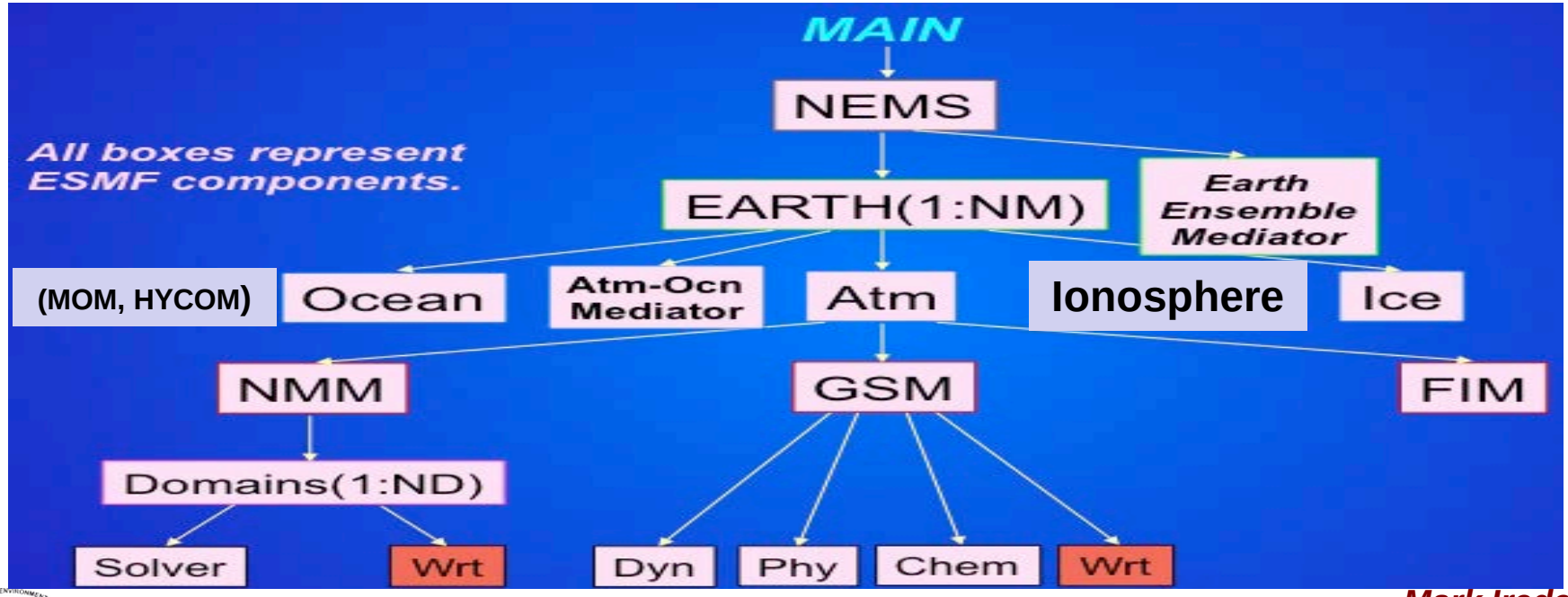



- **Planned Upgrades**:
  - o Drive the wave model in a coupled mode with atmospheric winds (for wave dependent boundary conditions in atmospheric models).
  - o Include wave-ocean coupling (currents from ocean model to wave model, and wave induced langmuir mixing & stokes drift from wave model to ocean).
  - o Data assimilation of significant wave heights to develop a wave analysis: GSI and LETKF approaches.
  - o Planned sources of data: Spectral data from ocean buoys; Satellite data from altimeters.

*Arun Chawla, Henrique Alves, Hendrik Tolman*

# NOAA Environmental Modeling System (NEMS)

- Unify NCEP operational systems under a single framework.
- More easily share common structures/components.
- Expedite interoperability.
- First two systems under NEMS implemented in NCEP ops: NAM, and NEMS Global Aerosol Component (NGAC).




Mark Iredell

# Model Evaluation Group (MEG)

- Verifies and evaluates daily performance of EMC forecast/analysis systems from a synoptic and mesoscale perspective to complement the statistical perspective.
- Conducts weekly EMC map discussion of model performance
  - Audience recently expanded to involve more NWS regional and local forecasters.
- Project benefits:
  - Provides critical feedback to modelers and branch chiefs.
  - Provides streamlined feedback to outside users with model concerns.
  - In first 3 years, several model problems noted, brought to attention of EMC modeling team, and corrected or at least mitigated in operations.
- MEG also to work closely with forecasters to understand and evaluate proposed model upgrades prior to the short formal evaluation period.
- How can MEG best include experience and knowledge of model users?

*Glenn White, Geoff Manikin, Corey Guastini*

# *Thank you!*