Hurricane Forecast Improvement Project (HFIP)

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Boulder, Colorado
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The HFIP Project
Vision/Goals

• Vision
  o Organize the hurricane community to dramatically improve numerical forecast guidance to NHC in 5-10 years

• Goals
  o Reduce numerical forecast errors in track and intensity by 20% in 5 years, 50% in 10 years
  o Extend forecasts to 7 days
  o Increase probability of detecting rapid intensification at day 1 to 90% and 60% at day 5
NHC Official Intensity Errors
HFIP Intensity Baseline and Goals
# Appropriation History
(2009-2013)

<table>
<thead>
<tr>
<th></th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13 PB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HFIP computing</strong></td>
<td>6.000M</td>
<td>3.000M</td>
<td>3.000M</td>
<td>4.000M</td>
<td>2.000M*</td>
</tr>
<tr>
<td>* (OMB increase)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(OMB 1yr reduction)</td>
</tr>
<tr>
<td>* (pending $6.5M NWS reduction)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(OMB restored less 2%)</td>
</tr>
<tr>
<td><strong>OAR Part</strong></td>
<td>6.100M</td>
<td>6.100M</td>
<td>6.100M</td>
<td>6.000M</td>
<td>5.800M</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$27.140M</td>
<td>$23.140M</td>
<td>$23.144M</td>
<td>$24.040M</td>
<td>$21.500M</td>
</tr>
</tbody>
</table>

*Anticipate Restoration in FY14*
HFIP Development Teams

- **Global Model/Physics**  
  *Stan Benjamin (ESRL), John Brown (ESRL),*  
  AOML, NRL, GFDL, EMC, NRL

- **Regional Model/Physics**  
  *Morris Bender (GFDL), Young Kwon (EMC),*  
  AOML, NRL, ESRL URI, Old Dominion Univ, NCAR

- **Ensembles**  
  *Zoltan Toth (ESRL), Carolyn Reynolds (NRL),*  
  AOML, PSU, EMC, NHC, FSU

- **Data Assimilation/Vortex Initialization**  
  *Jeff Whitaker (ESRL), Bill Lapenta (EMC),*  
  AOML, NRL, CIRA, PSU

- **Verification**  
  *Tim Marchok (GFDL), Barb Brown (NCAR),*  
  NRL, NESDIS/STAR, AOML, NHC, EMC, ESRL, NWS/OST

- **Applications Development**  
  *Ed Rappaport (NHC), Mark DeMaria (NESDIS/STAR),*  
  AOML, RAL, ESRL, OU, AOML, FSU, NHC, AOML, NWS/OST

- **Hurricane Observations**  
  *Sim Aberson (AOML), John Knaff (NESDIS/STAR),*  
  NHC, EMC, NESDIS/STAR, ESRL, URI, NRL, AOC, RAL, RSMAS, NCO, NCAR, NWS/OST

- **Ocean/Wave Models**  
  *Hendrik Tolman (EMC), George Halliwell (AOML),*  
  URI, ESRL, NRL, RSMAS

- **Societal Impacts**  
  *Bill Read (NHC), Jennifer Sprague (NWS/OASST),*  
  NWS/SR, NWS/ER, FEMA,CT-EM, TX-EM, NC-EM, FL-EM, Weather Channel
HFIP Baselines and Goals: Intensity

Forecast Error (kt)

Forecast Period (h)

Baseline Error

10 yr Skill Goal

5 yr Error Goal

5 yr Skill Goal

10 yr Error Goal

Baseline Skill

Forecast Skill (%)

0 20 40 60 80

0 12 24 36 48 60 72 84 96 108 120

0 5 10 15 20
HFIP Baselines and Goals: Track
HFIP Overall Strategy

• Use global models at as high a resolution as possible to forecast track out to 7 days

• Use regional models at 1-3 km resolution to predict inner core structure to meet intensity goals out to 5 days including rapid intensification

• Hybrid DA for both regional and global using as much satellite and aircraft data as possible

• Both regional and global models run as an ensemble

• Statistical post processing of model output to further increase forecast skill
Success in Organizing the Community

• External Universities are making significant contributions; Navy/ONR HFIP co-funding external collaborators
  • PSU first to demonstrate the impact of aircraft radar data
  • FSU showing impressive results using a regional multi-model approach
• NCAR/DTC is now the repository for all HWRF codes
  • Both research and operational communities drawing from this repository
  • Greatly streamlines research transitions to operations
• NOAA OAR labs strongly engaged in developing future operational systems
  • ESRL in demonstrating value of advanced data assimilation methods in hurricane track forecasts
  • AOML is working closely with EMC on HWRF development and demonstrating future HWRF DA and model systems
• Strong collaboration with NRL on global/regional model, data assimilation and ensemble development
Reaching Track Goals: Global Models

- Use Global models with advanced Data Assimilation System (Hybrid system eg: 3DVAR+Ensemble background error)

  - Global models outperform regional models on track
  - Forecast problem basically becomes a global problem after a couple of days.
  - Global models are necessary for genesis forecasts particularly at the longer lead times
    - Many storms last less than 5 days so 7 day forecast require skill at forecasting genesis
Track Error of Models (2010-2011) (% Improvement over HFIP baseline)
Atlantic, AL04-16 (08-09/2010); AL01-19(06-12/2011)

- AEMN (red)
- PARA (yellow)
- AVNO (blue)

Track error (NM)

Forecast hours:

0 12 24 36 48 72 96 120 144 168

#CASES:

0 12 24 36 48 72 96 120 144 168

- AEMN---GEFS T190 (operational run)
- PARA---GEFS T254 (parallel run)
- AVNO----GFS T574 (operational run)
Reaching Intensity Goals: Regional Models

• Use Regional models at high resolution (1-3 km)
  – This resolution necessary to capture inner core processes.
  – Won’t be achievable with global models especially when run as ensembles.
  – Need to use high resolution inner core data taken by aircraft and/or satellites
Impact of Aircraft Radar Data
% Improvement over HFIP baseline

All cases with Doppler data 2008-2011
HFIP 5 year goal

AOML PSU
Impact of Aircraft Data
(% improvement over Skill)
HFIP Success to Date

- HFIP recognized for successfully aligning and focusing research efforts within NOAA and its interagency partners

- HFIP has defined a solution for transitioning research into ops
  - Stream 1.5 “experimental operations” products being made available to NHC forecasters in real-time

- HFIP is making significant progress – 5yr performance goals within reach
  - Global ENKF ensembles providing 20% improvement in track guidance
  - Improved hurricane model initialization and higher resolution models – along with inner core data - showing significant (20-40%) improvement in intensity
  - Demonstration of Skill for track at 7 days underway
  - 3-5 day lead-time hurricane genesis potential product with potentially acceptable POD’s and FAR’s in development
  - Still uncertain progress toward goal for POD/FAR of rapid intensification of 90%/10% at day 1 and 60%/40% at day 5.
NCEP Production Suite
Weather, Ocean & Climate Forecast Systems

Current

Percent Used

Total Computing for Hurricane Runs: 26.5%
- GFS analysis and fcst: 15%
- GDAS: 5%
- HWRF: 6.5%

6 Hour Cycle: Four Times/Day
### HFIP dedicated HPC

**NOAA Jet system**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Install Date</th>
<th>Cores</th>
<th>Performance (Tflops)</th>
<th>Storage (Tbytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 (Njet)</td>
<td>Aug 2009</td>
<td>3184</td>
<td>35.6</td>
<td>350</td>
</tr>
<tr>
<td>Phase 2 (Tjet)</td>
<td>Sep 2010</td>
<td>10600</td>
<td>113.0</td>
<td>416</td>
</tr>
<tr>
<td>Phase 3 (Ujet)</td>
<td>Nov 2011</td>
<td>16648</td>
<td>182.0</td>
<td>1166</td>
</tr>
<tr>
<td>Phase 4 (Sjet)</td>
<td>June 2012</td>
<td>est: ~23050</td>
<td>~ 250.0</td>
<td>~1500</td>
</tr>
</tbody>
</table>

- "Jet" system performance in 2011 is estimated at 182 Tflops
- Current Operations Computing peaks at 73.6 Tflops
- Jet system will provide almost 10 times the amount of computing available for hurricanes as compared to ops.
Real-time Forecast System for FY12

- Global Hybrid DA system using GFS at T-574 (80 members)
- Global Ensemble (GFS, FIM) 10 members each, T-382(GFS), 37 km (FIM)
- Global FIM Deterministic model at 15 km
- Multi model Regional ensemble (all 3-5 km)
  - HWRF (9-3) with HEDAS for all aircraft data (WC-130 and P-3), parallel run (6 members)
  - HWRF (27-9-3) multi-physics/multi IC ensembles (6 members)
  - HWRF (27-9-3) operational system run in WPAC
  - ARW (4 km) (EnKF DA on outer domain 10 members)
  - TC-COAMPS (5 km) (navy initialization system 10 members)
  - Wisconsin Model (4 km) (bogus vortex initialization)
  - PSU model (4.5 km) (EnKF DA with aircraft data, 10 members)
  - GFDL ensemble (7.5 km) 16 members
- Basin Scale HWRF (27 km, +multiple 9 km moving nests), 7-day regional model forecasts including genesis
- NESDIS statistical Prediction ensemble (SPICE, using stream 1.5 systems) and FSU MME
- Real-Time storm surge model
The upgrade to the 3km triple-nested HWRF is a result of multi-agency efforts under HFIP support

- EMC - Computational tuning to speed up the model, nest motion algorithm, physics improvements, 3km initialization and pre-implementation T&E
- HRD/AOML - multi-moving nest, nest motion algorithm, PBL upgrades, interpolation routines for initialization and others.
- DTC - code management and maintain subversion repository
- ESRL - Physics sensitivity tests and idealized capability
- NHC - Diagnose the HWRF pre-implementation results
- URI - 1D ocean coupling in Eastern Pacific basin
• Significant Improvements of H212
  – Track/intensity forecast skills for 2011/2010 seasons on Atlantic basin 20-25% improvement against HOPS
  – Track forecast skills of H212 of Eastern Pacific basin maximum 25% over the HOPS in 2011 season, but little degradation at day 4 and 5 in 2010 season mainly due to Hurricane Frank
  – Intensity of 2011 EP basin with over 40% to HOPS. Significant improvements in intensity bias is noted for both Atlantic and Eastern Pacific, for both 2010-2011 seasons.
  – The storm structure in terms of storm size and PBL height significantly improved
  – Much improved wind-pressure relationship in high wind speed regime
Impact of including the operational models (HWRF, GFDL) in the SHIPS statistical intensity model.
Intensity verification statistics from the Various Models for the 2011 season
Questions?
HFIP 5-year Target Numerical Forecast System

- Global model ensemble with Hybrid Data Assimilation
  - 20 members at 20 km
  - Multi Model (at least two—eg: FIM, GFS, NMMB, Cubed Sphere)
  - National Unified Operational Prediction System – multi-Agency multi-model Operational Ensemble system

- Regional model ensemble
  - 20 members at 3 km
  - Multi model (at least two—eg: HWRF, AHW, TC-COAMPS)
  - Using all available aircraft and satellite data in core and near environment of hurricane

- Statistical Post processing
  - Bias correction, CBC, LGEM, SHIPS…
Hurricane Genesis

- Many hurricanes last less than 5 days
  - Genesis is important for forecasting out to 7 days
  - Especially important for hurricanes making landfall toward the end of the forecast period

- Many of the global models are doing well at forecasting Hurricane Genesis
NCEP Operational Ensemble
Initial time: 20 September 2011—7 day forecasts
HFIP Global Ensemble Forecast for Irene Starting at 1200Z August 18, 2011

- Irene declared an investigation area at 1200Z on August 18, 2011
- Irene named at 0000Z August 21, 2011
- Initial indication of the formation of Irene from ensemble at 00Z August 16, 2011
  - 2 days before it was declared an investigation area
  - 5 days before it was named