
Goal:
Advanced global model for improved TC forecasting

Stan Benjamin, John Brown - NOAA/ESRL
+ Mike Fiorino, Jeff Whitaker, Susan Sahm, Ed Szoke,
Rainer Bleck, Susan Sahm, Shan Sun, Jian-Wen Bao,
Georg Grell, Tom Henderson
Fanglin Yang - NCEP/EMC
Jim Ridout (et al.) - NRL

FIM development
Performance in fall 12 for FIM and ESRL global ensembles
FY13 proposed plans and milestones
Areas of FIM development - 2012

- Horizontal diffusion – Rainer Bleck, Shan Sun
  - 4th order diffusion on icosahedral grid now available.
  - 4th order diff somewhat better for TC intensity
  - 2nd order diff better for 500 hPa AC

- May 2012 GFS physics – Jian-wen Bao, Shan Sun
  - Testing underway for 3 months, not working yet
  - Necessary to allow correct CFS physics specification (primarily for cloud-radiation multi-layer specification)

- DCMIP participation – Shan, Rainer, Tanya Smirnova
  - Pressure gradient problem revealed: Janjic PG installed
  - Icos grid approximation issue revealed: Solution (spherical geometry) in development – Ning Wang

- FIM-iHYCOM coupled version – Rainer, Shan

- FIM-EnKF using GSI-EnKF/hybrid structure – Mariusz Pagowski, guidance from Jeff Whitaker
The 2012 Dynamical Core Model Intercomparison Project

The Dynamical Core Model Intercomparison Project (DCMIP) and associated two-week summer school from 7/30/2012-8/10/2012 highlights the newest modeling techniques for global climate and weather models. Special attention is paid to non-hydrostatic global models and their dynamical cores that now emerge in the General Circulation Model (GCM) community. Such future-generation GCMs allow for high-resolution simulations and offer new pathways for embedded variable-resolution meshes.

The objectives of DCMIP and its summer school are (1) to establish an open-access database via the Earth System Grid that hosts DCMIP simulations for community use, (2) to host about 15 dynamical core modeling groups at NCAR in August 2012 for the hands-on student-run DCMIP model intercomparison project, (3) to establish new non-hydrostatic dynamical core test cases in the community that also include simple moisture processes (4) teach a group of about 40 multi-disciplinary students, postdocs and other young researchers how today’s and future atmospheric models are or need to be built, and (5) to hear from keynote speakers who give lectures on modern GCM modeling and evaluation techniques, uncertainty quantification, the lessons-learned from GCM ensembles, the physics-dynamics coupling, innovative computational tools and high-performance aspects. This multidisciplinary two-week summer school and Dynamical Core Model Intercomparison Project (DCMIP) takes place at the National Center for Atmospheric Research (NCAR) in Boulder, CO, USA. The event brings together graduate students, postdocs, atmospheric modelers, expert lecturers and computer specialists to create a stimulating, unique and hands-on driven learning environment.
2011 Tropical wind forecasts – FIM vs GFS, both verified against ECMWF analyses – RMS vector


FIM improvement over GFS in tropical upper-level winds (at 200 hPa) is consistent – occurs in every run

... and little difference in tropical 850 hPa winds

Via collaboration between NCEP/EMC – Fanglin Yang and NOAA/ESRL
2012 Tropical wind forecasts – FIM vs GFS, both verified against ECMWF analyses – RMS vector


200 hPa tropical winds
FIM shows strong improvement over GFS, consistent – occurs in every run

... and slight improvement in tropical 850 hPa winds in 2012

Via collaboration between NCEP/EMC – Fanglin Yang and NOAA/ESRL
<table>
<thead>
<tr>
<th>Versions of FIM in real-time runs – Fall 2012</th>
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<tbody>
<tr>
<td><strong>FIM</strong></td>
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<td><strong>FIM9</strong></td>
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<td><strong>FIM7</strong></td>
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FIM track forecast skill for 60km, 30km, 15km versions

- no other differences

*Improved track skill with higher resolution for LANT and EPAC domains*
WPAC FIM7 v FIM8 v FIM9 track error

FIM track forecast skill for 60km, 30km, 15km versions - WPAC
- no other differences

... but this is not true for the W.Pacific region

60km – GFS IC
30km – GFS IC
15km – GFS IC
Full 2012 track errors – Atlantic + E. Pacific basins

- hwrf - HWRF LAM (Limited-Area-Model) 27:9:3 km
- avno - GFS:GSI(29 km, 0.5deg)
- fim9 - FIM:GSI(T578)/EnKFHybrid(T389)
- edet - ECMWF(det, T1299;15km)

<table>
<thead>
<tr>
<th>Storms</th>
<th>hwrf</th>
<th>avno</th>
<th>fim9</th>
<th>edet</th>
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<td>232[66]</td>
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96h LANT 2012 HWRF v GFS v FIM8 v FIM9 v ECMWF track error by storm

96h Atlantic track error by storm

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<thead>
<tr>
<th>Storms[N]</th>
<th>05L 12 08L 12 09L 12 11L 12 12L 12 13L 12 14L 12 17L 12 18L 12</th>
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<tr>
<td>hwrf</td>
<td>127(7) 62(2) 160(11) 155(2) 182(16) 70(6) 18(129) 335(11) 18(6)</td>
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<tr>
<td>avno</td>
<td>152(7) 64(2) 136(11) 100(2) 131(16) 154(6) 18(129) 419(11) 113(6)</td>
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<td>120(7) 172(2) 160(11) 333(2) 139(16) 103(6) 16(129) 417(1) 65(6)</td>
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### 120h LANT 2012 HWRF v GFS v FIM8 v FIM9 v ECMWF track error by storm

**2 US landfalling storms in Aug-Oct 2012 (Isaac, Sandy)**

**41 of 54 forecasts at 120h from mid-Atlantic storms (Leslie/Michael/Nadine)**

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<thead>
<tr>
<th>Storm</th>
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<th>AVNO</th>
<th>FIM8</th>
<th>FIM9</th>
<th>ECMWF</th>
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**Graphical Representation:**
- Track error by storm for HWRF, AVNO, FIM8, FIM9, ECMWF, and ECMWF with KF Hybrid. The storms include Isaac and Sandy. The error metrics show the deviation from the actual landfall location to the forecasted path at 120h.
Isaac forecasts from HFIP

TCMT All Model Experimental Multi-Model Ensemble Mean (T3MN)

Storm ID: AL092012  Valid: 08/25/2012 00 UTC

FIM9
Sandy – initial time 24 Oct 00z
Sandy – initial time 25 Oct 00z
Sandy – initial time 25 Oct 00z
Sandy – initial time 25 Oct 00z

Valid 2012 10 27 0000 UTC

Observed Best Track (black)
Deterministic FIM9 (brown)
Deterministic FIM9-Hyb (violet)
Deterministic ECMWF EDET (yellow)
Deterministic NCEP AVNO (bright green)
Sandy track forecasts

<table>
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<th>Storms[N][1]: 18L.12</th>
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<tr>
<td>FIM9 – HFIP – Stream 1.5</td>
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<td>FIM9 – ESRL DA</td>
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<th>FE [nm]</th>
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<th>18L.2012 - Sandy fim9(NCEP Hybrid DA) v fim9(ESRL Hybrid DA)</th>
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Global ensemble performance for Sandy

Jeff Whitaker and Phil Pegion

• Track ellipses out to day 7.

• Cumulative probability that the wind will exceed tropical storm force (> 34 kts) at any point during forecast verifying at 2012102912.

• ECMWF, UKMET, Env Canada (CMC), NCEP operational, and HFIP experimental global ensembles are plotted, when available.
2012102212 initialization

UKMO missing
2012102300 initialization
2012102312 initialization
2012102400 initialization
2012102412 initialization
2012102500 initialization
2012102512 initialization
2012102600 initialization

CMC missing
Track forecast skill

**Percent improvement for deterministic forecast over mean ensemble forecast error**
FIM plans for 2013

• Improve accuracy of **FIM numerics** revealed in Dynamic Core Model Intercomparison Project (DCMIP) global model tests
  – Correct pressure gradient
  – Correct grid numerics especially near pentagons including use of spherical geometry rather than plane approximations

• **Data assimilation directly on FIM grid**
  – Builds off GSI-ensemble data assimilation used for GFS
  – Will allow FIM data assimilation cycling

• **Physics**
  – Stochastic physics for FIM ensemble forecasts
  – Test chemistry/aerosol version for TC forecast periods
  – Complete installation of GFS May 2012 physics
  – Perform additional tests of Grell-Freitas convective scheme

• Expand retrospective testing
  – Perform tests for 5-10 year periods, not just 3-12 month periods

• **NCEP** testing for **multi-model ensemble**

• **Single time-step output** for tropical cyclones
### Data Assimilation
- 4D-Var with more Advanced Variational bias correction
- New radiative transfer model CRTM v2 for NPP
- NPP, GPS, SSMIS, UAS, OMPS data sets
- SL/SI scheme
- Cubic interpolation combining with linear interpolation in the vertical
- Improved BC treatment
- T359L50 (Δx=37km, top at 0.04 hPa or ~70 km)
- Time step = 360 sec

### Dynamics
- Simplified Arakawa-Schubert scheme
- Shallow convection
- Prognostic cloud scheme with two species
- RRTMG 4-stream radiation
- Modified cloud fraction scheme
- Modified turbulent mixing scheme
Hurricane Track Forecasts for 2011 TC season
(1 July – 1 October, 2011)

NAVGEM has smaller TC track errors for 2011
Output of TC parameters every time step in FIM - max values within subareas on FIM icosahedral grid (subrhomboids) – Mike Fiorino, Ning Wang [For interaction with Dave Zelinsky – NOAA-HRD]
Conclusions for HFIP global modeling

- **Progress in tropical cyclone skill from NOAA global modeling toward ECMWF global skill**
  - Equal performance from FIM and GFS to ECMWF for 48h-96h
- **Clear improvement in skill from NOAA global models over HWRF**
- **For 2 US landfall storms:**
  - Isaac – best forecasts from FIM
  - Sandy – best forecasts from ECMWF but much improved FIM and GFS forecasting using ESRL higher-resolution hybrid GSI/EnKF data assimilation.
- **Significant global model improvements in pipeline for 2013**
- **Experimental data assimilation gives promise for further improvements in 2013**
  - More work needs to be done to “synchronize” storm positions in control forecast and ensemble with hybrid DA (large initial position errors when relocation turned off, but relocation can degrade TC environment).
  - FIM cycling via ensemble data assimilation
- **Need to expand retrospective testing**
  - Perform tests for 5-10 year periods, not just 3-12 month periods
  - Statistical significance from 1 or even 3 hurricane seasons is limited