Acknowledgements:
Ligia Bernardet, Brian Etherton, Tressa Fowler, Tara Jensen, Hui Shao, Ed Tollerud, Jamie Wolff, and Steve Koch

3rd NOAA Testbed Workshop, May 1, 2012
OUTLINE / SUMMARY

- **What is DTC?**
  - Facility to transition NWP community research into operations

- **Main areas of work**
  - Mesoscale Modeling, Data Assimilation, Ensembles, Hurricane Forecasting, Verification

- **Links with other NOAA testbeds / programs**
  - HMT, HWT, HFIP

- **Outlook**
  - Further integration with NOAA NWP activities
  - DTC’s role in national NWP research, development, transition to operations
WHAT IS DTC?

- DTC is a distributed facility established in 2003 where
  - NWP community can test and evaluate new models & techniques
    - For use in research and operations

Objective

- To serve as a bridge between research and operations
  - To facilitate the activities of both halves of the NWP Community
    - In pursuit of their own objectives

Benefits

- Research community gets an environment functionally similar to operations to test and evaluate new NWP methods
- Operational community benefits from DTC testing and evaluation of strengths and weaknesses of new NWP advances prior to consideration for operational implementation
MULTI-AGENCY EFFORT

The DTC Architecture

- DTC consists of ~45 staff (25 FTE)
  - NCAR/RAL/JNT
  - NOAA/ESRL/GSD
  - In strong partnership with
    - NOAA/NCEP/EMC, NCAR/NESL/MMM, and AFWA
MANAGEMENT

- Executive Committee
  - Principals from NOAA NWS & OAR, AFWA, NSF

- Management Board
  - Two representatives from each sponsoring organization

- Management Team
  - Director: Bill Kuo
  - Assistant Director: Louisa Nance
  - Deputy Director from NCAR/JNT: Barbara Brown
  - Deputy Director from ESRL/GSD: Zoltan Toth (Acting)

- Science Advisory Board
  - Cliff Mass, Chair
WHY ARE WE ENGAGED?

Excerpts from NOAA’s Next Generation Strategic Plan

- Holistic understanding of the Earth system through research
  - NOAA’s strategic progress and future operational capacity will depend upon a strong and vibrant scientific enterprise that draws from NOAA research capabilities and the extended community of public, private, and academic researchers with whom NOAA collaborates routinely

- Integrated environmental modeling system
  - The complexity of NOAA’s modeling requirements and the challenges of transitioning research and development capabilities into operations will require extensive coordination within NOAA and with other Federal Agencies for the optimized use of national investments, and external collaboration with the environmental modeling community in the academic (including academic consortia) and private sectors. To this end, NOAA will develop collaborative strategies involving internal and external partnerships and community-wide standards to ensure interoperability

- Increased development and use of enterprise and community models
Operational Community
- Provide guidance for next generation Operational Configurations

Research Community
- Provide baselines for evaluating impacts of new techniques
- Aid in selecting configurations for research projects
1. DTC activities focused on five key areas

2. HMT, HWT & HFIP are cross-cutting projects
FY12 EXPENDITURES

- NCAR
- ESRL/GSD
- Visitors
DTC ACTIVITIES

OPERATIONS TO RESEARCH (O2R)

- Maintain and support use of community / operational codes
  - Code repository
  - Tutorials / workshops

- Facilitate interactions between research & operations
  - Workshops
  - Visitor program

- Test & evaluation of promising community contributions
  - Transition successful methods to NCEP & AFWA
    - For further testing & possible operational implementation

RESEARCH TO OPERATIONS (R2O)
DTC Community Codes

Philosophy

- Free & shared resource
- Ongoing distributed development by both research & operational communities - maintained under version control
- Periodic releases made available to the community that include latest developments of new capabilities & techniques
- Centralized support (in collaboration w/ developers)
  - Software downloads
  - Documentation
  - Email helpdesk
  - Tutorials

Current Packages

- WRF (model, pre- & post-processors)
- WRF for Hurricanes (HWRF, coupled atmosphere-ocean model + TC post-processing tools)
- Gridpoint Statistical Interpolation (GSI) data assimilation system
- Model Evaluation Tools (MET)
## DTC Community Support

<table>
<thead>
<tr>
<th>Software</th>
<th>Code releases</th>
<th>Registered Users</th>
<th>Helpdesk inquiries (per month)</th>
<th>Onsite Tutorials</th>
<th>Online Tutorial</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRF &amp; UPP</td>
<td>1 major (Apr) 1 minor (Aug)</td>
<td>~13,800</td>
<td>WRF ~400 NMM/WPP/UPP ~5-10%</td>
<td>Bi-annual ~70 students</td>
<td>Yes</td>
</tr>
<tr>
<td>HWRF &amp; GFDL vortex tracker</td>
<td>Annual</td>
<td>HWRF: 340 Tracker: 105</td>
<td>~35</td>
<td>Annual ~30 students</td>
<td>Jan ‘12</td>
</tr>
<tr>
<td>GSI</td>
<td>Annual</td>
<td>482</td>
<td>~20</td>
<td>Annual ~30 students</td>
<td>Yes</td>
</tr>
<tr>
<td>MET</td>
<td>Bi-annual</td>
<td>1,582</td>
<td>~15</td>
<td>Bi-annual ~30 students</td>
<td>Yes</td>
</tr>
</tbody>
</table>
DTC-Sponsored Community Events (2011)

- **Mesoscale Modeling**
  - 12th WRF Users Workshop: 20-24 June 2011
  - NWP Workshop on Model Physics w/ an Emphasis on Short-Range Weather Prediction: 26-28 July 2011

- **Hurricanes**
  - Science day in conjunction w/ WRF for Hurricanes tutorial: 26 April 2011

- **Data Assimilation**
  - 1st GSI Workshop: 28 June 2011
  - BUFR/PrepBUFR Webcast Tutorial: 13 December 2011

- **Ensembles**
  - 5th NCEP Ensemble User Workshop: 10-12 May ‘11
## 2012 DTC Visitor Projects

<table>
<thead>
<tr>
<th>PI</th>
<th>Institution</th>
<th>Type</th>
<th>Project Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan Vigh</td>
<td>NCAR</td>
<td>PI</td>
<td>Development of an HWRF Diagnostics Module to Evaluate Intensity &amp; Structure Using Synthetic Flight Paths Through Tropical Cyclones</td>
</tr>
<tr>
<td>Adam Clark</td>
<td>U. of Oklahoma</td>
<td>PI</td>
<td>Development &amp; Application of 3-Dimensional Object Algorithms to High Resolution Forecasts</td>
</tr>
<tr>
<td>Delia Arnold &amp; Don Morton</td>
<td>Technical University of Catalonia / U. of Alaska –Fairbanks</td>
<td>PI</td>
<td>Moving The NEMS &amp; NMM-B Into a Broader Community Resource Environment</td>
</tr>
<tr>
<td>Travis Wilson</td>
<td>UCLA</td>
<td>GS</td>
<td>Improvements to modeling persistent surface cold pools in WRF</td>
</tr>
<tr>
<td>Sai Ravela</td>
<td>MIT</td>
<td>PI</td>
<td>Deploying the MIT Field Alignment System &amp; Test-bed (FAST) in DTC</td>
</tr>
</tbody>
</table>

200k per year funding
MESOSCALE MODELING - Functionally similar operational environment (WRF-based)

- Community GSI v3.0 integrated into end-to-end workflow
- Conducted observation impact study for two cases
  - Assimilated both prepBufr and satellite radiance datasets
  - Configured similarly to NAM RC
- Further tested system with one-month (noncycled) run
  - Assimilated NDAS prepBufr + GDAS radiance (AMSU-A, AMSU-B, MHS, HIRS3, HIRS4, AIRS)
  - Verification results compared to those from NAM RCT&E
WRF Innovation T&E

- Inter-comparison T&E allows for a quantitative assessment of forecast performance between
  - an operational baseline and community contributed scheme
  - two different versions of WRF using the same physics scheme
SREF Member Testing

- Request from EMC to assist in identifying appropriate configurations for the next implementation of the operational SREF
  - Worked with model developers as necessary to configure namelist settings
  - Ran initial sanity checks for each and adjusted as necessary
  - Ran more extensive testing for ~50 cases distributed throughout one full year
  - Provided temporally aggregated performance results to EMC

<table>
<thead>
<tr>
<th>Physics Parameterization</th>
<th>ARW-NCAR</th>
<th>ARW-RR</th>
<th>ARW-NAM</th>
<th>NMM-NAM</th>
<th>NMM-GFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microphysics</td>
<td>WSM3</td>
<td>Thompson</td>
<td>Ferrier</td>
<td>Ferrier</td>
<td>Ferrier</td>
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<tr>
<td>Surface Layer</td>
<td>M-O Similarity</td>
<td>Eta Similarity</td>
<td>Eta Similarity</td>
<td>Eta Similarity</td>
<td>GFS</td>
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<tr>
<td>PBL</td>
<td>YSU</td>
<td>MYJ</td>
<td>MYJ</td>
<td>MYJ</td>
<td>GFS</td>
</tr>
<tr>
<td>Convection</td>
<td>Kain-Fritsch</td>
<td>Grell-3D</td>
<td>BMJ</td>
<td>BMJ</td>
<td>SAS</td>
</tr>
<tr>
<td>LSM</td>
<td>Noah</td>
<td>RUC</td>
<td>Noah</td>
<td>Noah</td>
<td>Noah</td>
</tr>
<tr>
<td>Radiation</td>
<td>RRTM/Dudhia</td>
<td>RRTM/Goddard</td>
<td>GFDL/GFDL</td>
<td>GFDL/GFDL</td>
<td>GFDL/GFDL</td>
</tr>
</tbody>
</table>

Graph showing Surface Temperature BERMS vs Forecast Lead Time (hours)
DATA ASSIMILATION - Test & Evaluation

- **Observation System**
  - Error Estimation and Tuning
  - Observation System Simulation Experiment (OSSE)

- **Background**
  - DA Based QC
  - DA Technique Testing and Evaluation (Variational, Ensemble, Hybrid)

- **Observation**
  - DA System Maintenance & Community Support
  - DA System Comparison (GSI, WRF-VAR,...)

- **Data Assimilation**
  - System Sensitivity (Cycling vs Cold-start, Frequency, Resolution)

- **Forecast Model**
  - DA Based Validation

- **Forecast**

**Key Points:**
- Provides rational base to operational centers
- Provides feedback to research and development community
Variational vs Hybrid Ens-Var

Analysis increment of T (color) and Streamline

GSI-3DVAR

GSI-Hybrid

Track Error

Glb Ana
Hybrid
3D-Var

Intensity Error
HURRICANE FORECASTING
Goal: Tech Transfer to Hurricane NWP
Current focus on Hurricane WRF model (Weather Research and Forecasting)

1. **Code Management**
   - Create a framework for NCEP and the research community to collaborate

2. **User Support**
   - Support the community in using an operational hurricane model

3. **Testing and Evaluation**
   - Ascertain integrity of the code
   - Conduct diagnostics on operational configuration
   - Evaluate new developments for potential operational implementation
DTC provides developers with access to the centralized research/operations repository. Allows obtaining latest experimental code and adding contributions = clear path to operations.
HWRF Testing, Evaluation, Diagnostics

Comprehensive testing

- Results available at dtcenter.org
- Functionally-equivalent testing suite
- Multi-season tests, thousands of runs
- Benchmarks of community code
  - Inform future development
  - Control to test improvements

Summary Statistics

Average wind radii error for 64 kt threshold (NE):
Inner core too large; contracts during first day

Case Studies / Small tests

4 cumulus schemes:
Inner core size sensitive to cumulus
ENSEMBLE MODULES

Module 1: Configuration

Module 2: Initial Perturbations

Module 3: Model Perturbations

Module 4: Statistical Post-Processing

Module 5: Product Generation

Module 6: Verification

External Input (HMT, HWT, HFIP, etc)
Bias Correction is accomplished by taking the mean forecast of each model core (ARW, NMM, etc.) sub-ensemble of the NCEP SREF and comparing it to the NAM analysis valid at the same time.

Downscale by comparing the RTMA analysis (GRID 259, like GRID 197, 1073x689, 5.079km) with the NAM analysis valid at the same time (10m wind, 2m temperature and humidity).
Implementation of downscaling at EMC

- Downscaling code used in NAEFS ported to DTC in early summer
- Testing/evaluation of the application of this code to the existing NCEP SREF output showed forecast improvement
- DTC code sent to EMC for application to the new NCEP SREF, implemented in approximately 2 days, with downscaled forecasts being produced since December 7th

Raw SREFx, Bias corrected SREFx, and downscaled SREFx forecasts (initialized 2100UTC 12 Jan 2012, valid 1200UTC 16 Jan 2012, 87-hour forecasts)
As implemented at DTC (using archived NCEP SREF ensemble output), downscaling decreased root mean squared error (compared to RTMA) at all lead times.
VERIFICATION

Support and Tools for verification.

- Advice and consulting on all DTC verification activities.
- MET (Model Evaluation Tools).
- New Hurricane Verification Tools coming in June.
Latest MET Enhancements

- Confidence Intervals for MODE attributes in support of Testing & Evaluation.
- MADIS data ingest.
- Investigate ensemble spread vs skill.
- Create vertical MODE objects from CloudSat.
- User contributed TRMM2nc converter posted to MET web page.
Research Objective: Design Verification techniques for QPF During Atmospheric Rivers (ARs) and Extreme Precipitation in the CA Mountains

Research Objectives Require Addressing These issues:

1) Problem of causes (ARs) and effects (extreme precipitation in CA)
2) Impacts Due to:
   ✓ Models of different domains and resolutions
   ✓ Precipitation regimes: Marine and orographic
   ✓ Severe penalties for matched-pair verification
   ✓ Sparse and problematic verification data
3) Ensemble forecasts and MET/MODE: shape ‘averaging’
4) Model comparison and model development (eg., microphysics)

Further details: Two related HMT papers in later sessions
Standard Scores for Inter-model comparisons

- Results for December 2010
- Black, yellow, magenta, purple, blue: HMT ensemble mean, GFS, NAM, NMMP, HRRR
- Dashed – HMT ensemble members

RMSE, inches

Note advantage to higher resolutions

Gilbert Skill Score, 1.0 inch threshold
HWT – DTC COLLABORATION

• **Started collaboration in 2008**
• Introduced **objective evaluation** into the testbed environment; including new verification methods based on
  – Objects
  – Neighborhood
  – Wavelet decomposition
• Provided **automated evaluation** of many contributed models in 2011:
  – 48 member CAPS multi-model ensemble
  – 7 member time-lagged ensemble of current operational 4km models
  – Operational baselines: SREF, NAM, NMM-B parallel, HRRR
  – Research baselines: MMM, LAPS
• Provided **tutorials** with on-site personnel for many of the weeks during the 2009-2011 seasons

➢ **Use of DTC objective evaluation from 2011 highlighted in later talk:**
  **Wed @1:20 Operational Impact of the QPF Component of the 2011 Spring Experiment, Faye Barthold**
Hazardous Weather Testbed (HWT) 2011 SE Probability Fields

SREF 32 km
EMC
CaseAUC = 0.87
MdnAUC = 0.55

HRMOS 4km
MDL
CaseAUC = 0.85
MdnAUC = 0.66

NMQ-Q2 QPE
NSSL
>0.5”

CAPS PR 4km
OU/CAPS
CaseAUC = 0.91
MdnAUC = 0.77

SSEO 4km
SPC
CaseAUC = 0.83
MdnAUC = 0.68

Valid: 20110524 06 UTC
Threshold: 6hr Precip >=0.5”

Area Under the Curve (AUC) – ability to discriminate btw event /non-event – 1 optimal – 0.5 no-skill

SREF – Current Operational Ensemble from EMC
HRMOS - HiRes Model
Output Statistics from MDL
SSEO – 7 HiRes models available to HPC and SPC
CAPS – 4km Multi-Phys Ensemble available for HWT

Courtesy of Tara Jensen and OU/CAPS, SPC, NSSL, EMC, MDL
DTC-RELATED TALKS / POSTER ON WEDNESDAY

1:20-1:40  Operational Impact of the QPF Component of the 2011 Spring Experiment (Faye E. Barthold, I.M Systems Group, Inc., & NWS/HPC)

2:20-3:20  Experimental Regional Ensemble System (ExRES) – Plans for 2012 and Beyond (Brian Etherton, OAR/ESRL/GSD) - Poster

3:40-4:00  Spatial Verification of Atmospheric Rivers (Wallace Clark, Science and Technology Corp. & OAR/ESRL/PSD)

4:20-4:40  Verification and Diagnoses of Ensemble QPF Forecasts during Extreme Events in California during the HMT Winter Exercises (Tara Jensen, NCAR/RAL)
DTC’S ROLE IN NOAA

How to define role of DTC in context of other NOAA testbeds and programs?

- HMT, HWT, ATC, JHT, etc
  - Focus on various application areas

DTC
- National testbed for NWP
- Integrate NWP innovations from other NOAA testbeds / programs into NOAA operations

How to improve efficiency?
- Involve DTC in NWP-related activities at other testbeds?
- Coordinated Announcement of Opportunities
  - Testbeds, DTC, NSF?
EXPECTATIONS OF / CHALLENGES FOR DTC

• National “scorekeeper” for WRF
• Transition NWP community research into operations
  • Who funds community NWP research?
  • Who sets long term plans for NOAA NWP operations?
• Propel US NWP into international leadership position
  • WRF scores do not make it into international comparisons
    • Disconnect between expectations and current activities of DTC
• What is the future of NWP?
  • DTC evolved from WRF modeling to encompass
    • Data assimilation, ensembles, hurricane forecasting
• What is next for DTC?
  • Mesoscale modeling 10 yrs ago meant limited area domain
  • Today, mesoscale research shifting to global domain?
    • MPAS, NIM, Multiscale models with superparameterization, etc.
    • Simplified NWP suite with adaptive resolution global models?
NH 500 Height skill comparison
BEYOND AOP12 & AOP13

- Need vision, mission, & long term plan for DTC
  - In close collaboration with NWS
- What the community expect from DTC?
  - Help US regain leadership in NWP
- What our sponsors expect from DTC?
  - DTC Executive Committee endorsed 20-60-20% effort on
    - Short (<1 year) – medium (2-3 yrs) – long (3+ yrs) term efforts
- How can DTC help US operational NWP regain its leadership?
  - Contribute to development, testing, and transition of
    - Next generation DA, modeling, and ensemble systems
- Current focus on limited area modeling
  - Cost effective to expand effort to global domain?
LOOKING AHEAD

• MISSION
  • Transition cutting edge community research into the nations' operational Numerical Weather Prediction centers

• VISION
  • Become an internationally recognized center to facilitate community development in Numerical Weather Prediction
LONG-TERM PLAN

• Catching up is not going to happen next year
  • Not in next 3 yrs perhaps
  • Aim at next generation systems (3-5+ years)

• Organize & work w. community to facilitate development of
  • Next generation DA, modeling, & ensemble systems

• Develop long-term plan in strong coordination with NWS
  • Hold Community / DTC Strategic Planning Workshop
    • Organize Community Global Modeling summit?
    • Next generation DA Developers meeting?
    • Ensemble Developers Workshop
      • June 27-29, 2012, Boulder
OUTLINE / SUMMARY

• What is DTC?
  • Facility to transition NWP community research into operations

• Main areas of work
  • Mesoscale Modeling, Data Assimilation, Ensembles, Hurricane Forecasting, Verification

• Links with other NOAA testbeds / programs
  • HMT, HWT, HFIP

• Outlook
  • Further integration with NOAA NWP activities
  • DTC’s role in national NWP research, development, transition to operations
BACKGROUND
Challenges in Code Management
NCEP does not have rigorous software development practices

Continuous use of internal EMC repository for development adds overhead
We are working with EMC to make this more efficient
Held at NCEP 26-28 July 2011 with 34 invited participants

Recommended Action Items

- EMC should establish a science advisory board to provide guidance on scientific priorities
- EMC and DTC should work closely to promote R&O collaborations through working group meetings and workshops
- NOAA/NWS should fund a substantial grants program for NWP weather research
- DTC should establish a model evaluation testbed with a variety of datasets
- NWP physics developers should make use of direct physical validation, special observation networks and simplified modeling frameworks
- NOAA/NWS should acquire increased computing resources for developing the next generation high-resolution modeling systems

Summary of the “NWP Workshop on Model Physics with an Emphasis on Short-Range Weather Prediction”

A workshop organized by the DTC and NCEP/EMC was held at the World Weather Building in Camp Springs, Maryland on 26-28 July 2011. The goals of the two and a half day meeting were to find short-term opportunities for improving numerical weather prediction (NWP) models, and to establish a longer-term framework for closer collaboration between research and operations (R&O). ... The final portion of the meeting focused on identifying a path forward for promoting greater coordination of physics development between the R&O modeling communities.
SYSTEMATIC ERRORS

- As implemented at DTC (using archived NCEP SREF ensemble output), downscaling decreased mean error (removed bias)
- Not always statistically significant