# HFIP Verification Team: FY11 Review

*HFIP Team Meeting*
*Miami, FL*
*08 November 2011*

- *OAR / GFDL*
  - Tim Marchok
- *OAR / AOML / HRD*
  - Rob Rogers
- *OAR / ESRL*
  - Mike Fiorino
- *SUNY-Albany*
  - Ryan Torn
- *NRL*
  - Jim Goerss
  - Hao Jin
- *TCMT and DTC*
  - Barb Brown
  - Louisa Nance
  - Ligia Berndardet (DTC)
  - Paul Kucera
- *NESDIS*
  - Mark DeMaria
- *NCEP / NHC*
  - James Franklin
- *NCEP / EMC*
  - Vijay Tallapragada
- *NWS / OST*
  - Tony Eckel

# Verification Team Milestones 2011

- Testing and evaluation of operational models
- Planning and coordination of HFIP hurricane model evaluations for retrospective demonstration tests
- Ongoing model verification analyses for retrospective and demonstration exercises
- Development, testing, and implementation of new tools for evaluation of hurricane forecasts.

# HWRF: Testing and Evaluation

**Testing and evaluation of operational models**

- Pre-implementation testing of HWRF
  - Test plan **(*EMC*, DTC, NHC)** Stream 1 **5.1.1 June 1, 2011**
  - Report on testing activities and results **(*EMC*, DTC, NHC)** Stream 1 **5.1.2 Sept 30, 2011**

## Created (w/ EMC) and conducting DTC HWRF Test Plan

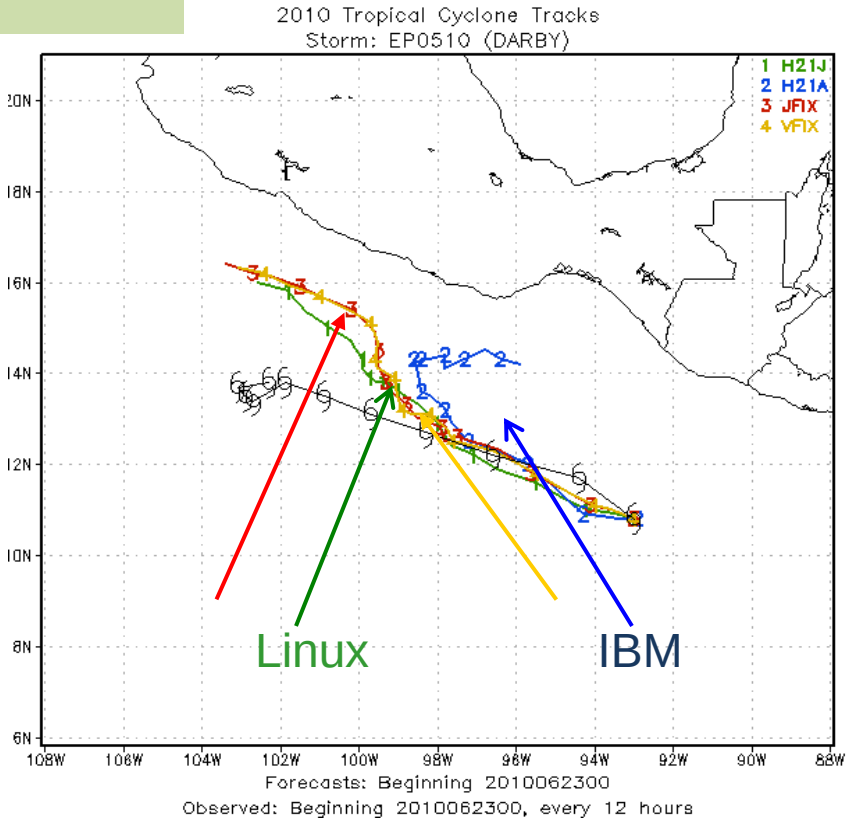
- January: Reference Configuration (benchmark of 27/9 community code using 2011 baseline configuration)
- July: Benchmark of 27/9 code using 2011 operational configuration (Findings led to crisis-RFC fixes)
- November: HWRF Reference Configuration (benchmark of 27/9 community code using 2011 operational configuration)
- December: Benchmark of 27/9/3 code
- December: Test of various cumulus parameterizations in HWRF

# Tests of 2011 Operational HWRF Model

**2011 Operational HWRF model**

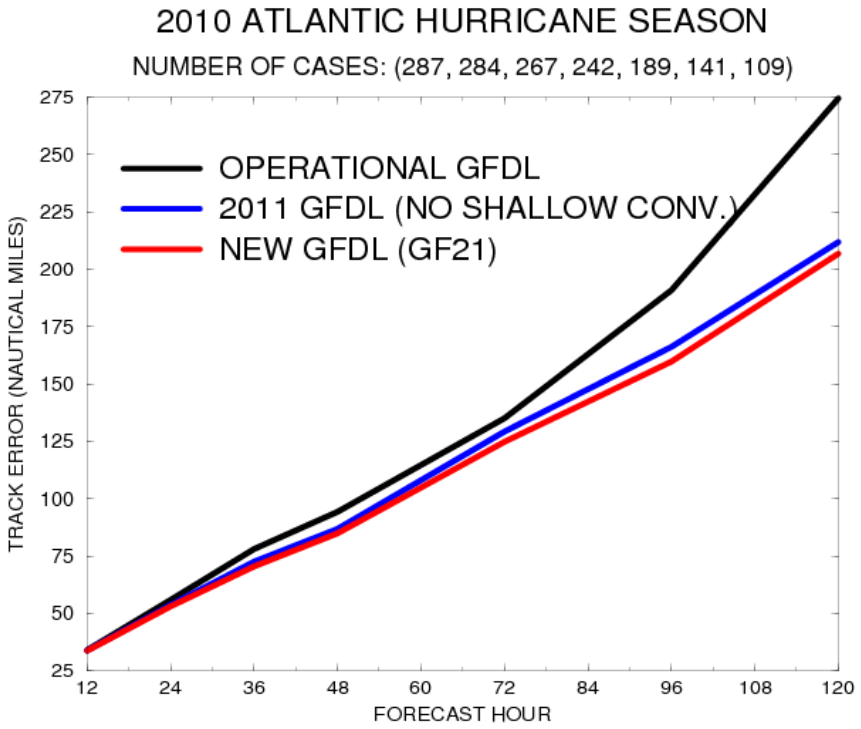
- Testing and evaluation
- Uncovered SAS bug → crisis RFC

- Same code with bug produces different forecast on Linux and IBM.
- Fixed code produces similar forecast on Linux and IBM.



# GFDL: Testing and Evaluation

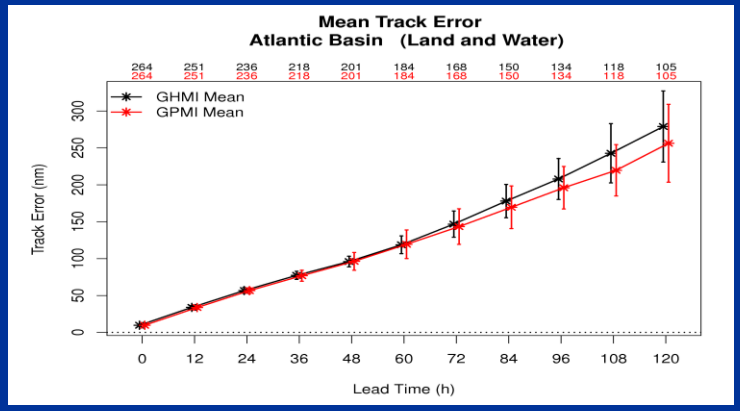
1. **Testing and evaluation of first major upgrade of operational GFDL model since 2006**
   - January: New model configuration frozen.
   - February: Retrospective runs from 2008-2010 completed




2. **Testing and evaluation of GFDL ensemble for potential use as a Stream 1.5 model**

# 2011 Retrospective Planning, Testing, and Evaluation

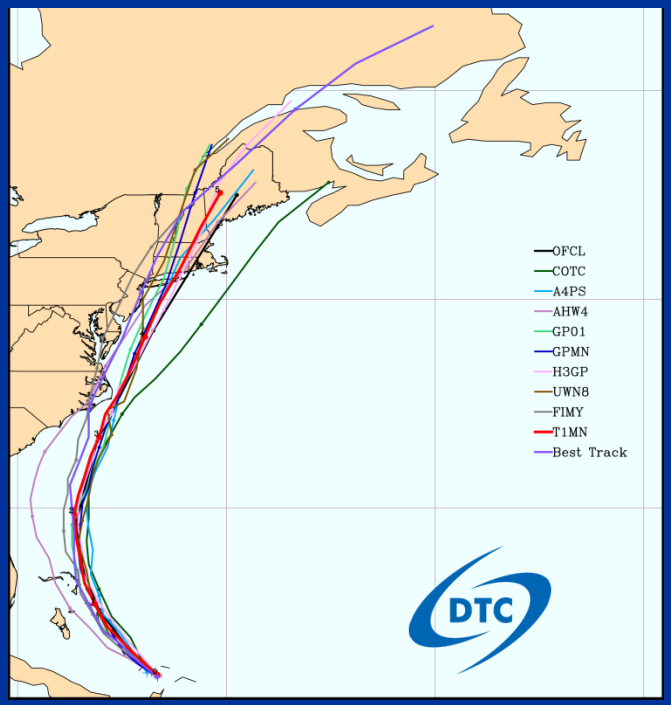
- Verification team and TCMT coordinated 2011 Stream 1.5 Retrospective Evaluation with NHC and modeling groups
- Evaluation activities coordinated with NHC
  - Use of interpolator
  - This year included performance relative to consensus, top-flight models
  - Powerful comparisons with paired tests
  - Identification of "practically" important differences
- Many types of models and groups involved – much more than 2010
- More on this Wed (Nance presentation)

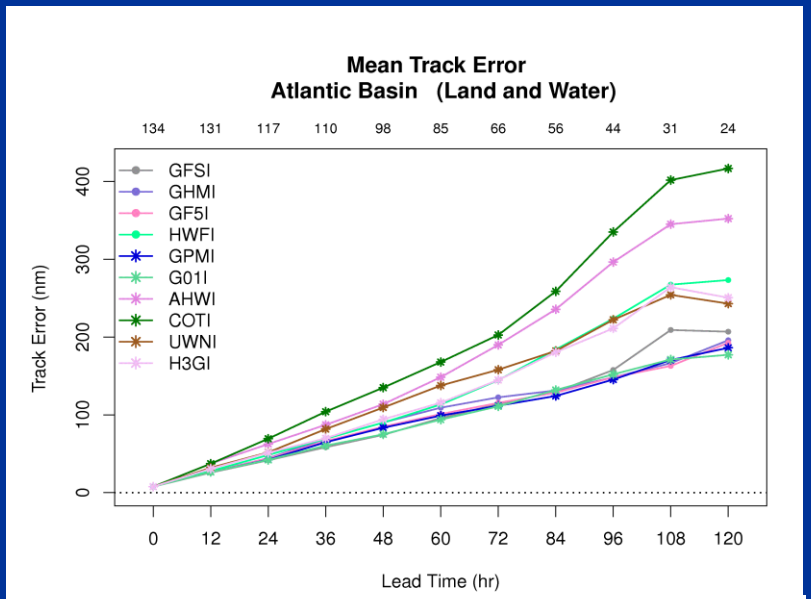


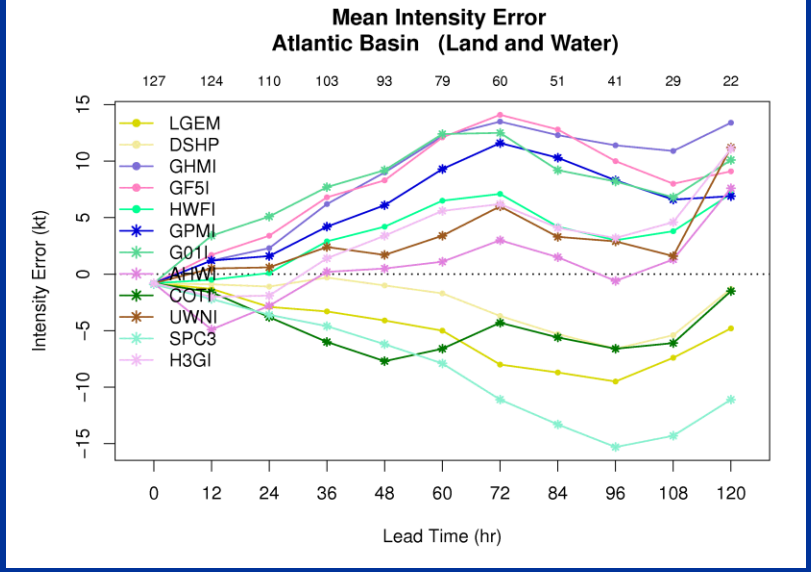

| 0 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 5.6 | 10.9 | 16.6 | 15.2 | 19.2 | 14.7 | 20.2 | 1.1 | 12.8 | 15.6 |
| 0% | 16% | 17% | 20% | 15% | 16% | 11% | 13% | 1% | 6% | 6% |
| - | 0.999 | 0.965 | 0.932 | 0.769 | 0.786 | 0.689 | 0.528 | 0.020 | 0.164 | 0.087 |
| 0.0 | 0.1 | 2.6 | 4.4 | 5.3 | 6.9 | 5.9 | 4.8 | 4.0 | 2.4 | -0.4 |
| 0% | 1% | 16% | 19% | 19% | 22% | 18% | 14% | 12% | 7% | -1% |
| - | 0.132 | 0.995 | 0.998 | 0.97 | 0.98 | 0.987 | 0.966 | 0.883 | 0.602 | 0.095 |
| 0.0 | 2.8 | 5.8 | 16.3 | 11.2 | 9.8 | 11.0 | 1.8 | 17.8 | 109.2 | 74.7 |
| 0% | 9% | 11% | 20% | 12% | 9% | 9% | 1% | 9% | 35% | 23% |
| - | 0.836 | 0.850 | 0.995 | 0.911 | 0.752 | 0.661 | 0.080 | 0.45 | 0.951 | - |
| 0.0 | 0.8 | 0.1 | 4.0 | 4.6 | 9.5 | 17.0 | 15.9 | 2.0 | 1.7 | -17.3 |
| 0% | 3% | 0% | 6% | 5% | 9% | 13% | 10% | 1% | 1% | -8% |
| - | 0.343 | 0.025 | 0.531 | 0.481 | 0.477 | 0.625 | 0.481 | 0.051 | 0.050 | 0.419 |
| 0.0 | -1.3 | -1.4 | -2.9 | -6.4 | -7.6 | -9.9 | -11.9 | -12.9 | -13.0 | -10.5 |
| 0% | -16% | -11% | -18% | -39% | -43% | -54% | -66% | -72% | -64% | -47% |
| - | 0.893 | 0.952 | 0.972 | 0.999 | 0.998 | 0.984 | 0.968 | 0.931 | 0.864 | 0.891 |
| 0.0 | -1.7 | -2.2 | -4.1 | -6.6 | -8.9 | -12.5 | -14.8 | -16.8 | -17.7 | -18.2 |
| 0% | -23% | -19% | -28% | -42% | -56% | -82% | -101% | -123% | -123% | -118% |
| - | 0.999 | 0.993 | 0.999 | 0.999 | 0.999 | 0.999 | 0.998 | 0.992 | 0.979 | 0.968 |

# HFIP 2011 Demonstration

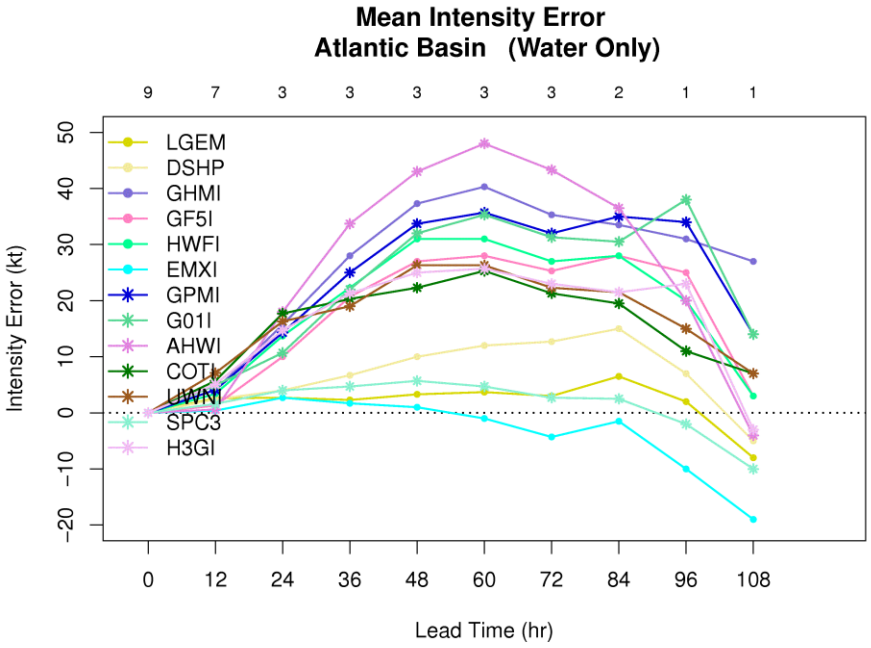
- Real-time track and intensity plots
- Case and full sample evaluations
  - Stream 1, 1.5, 2 + combination

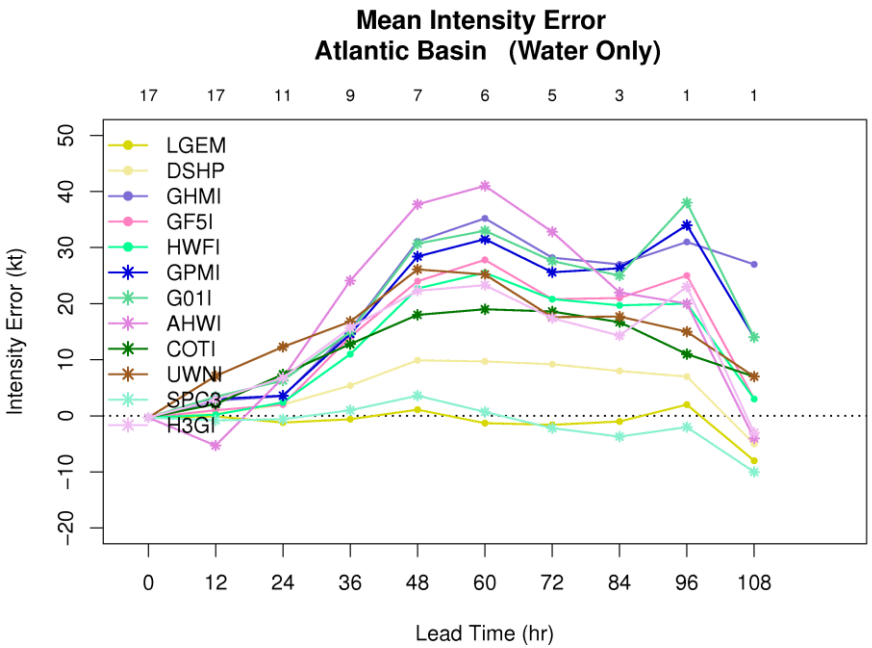


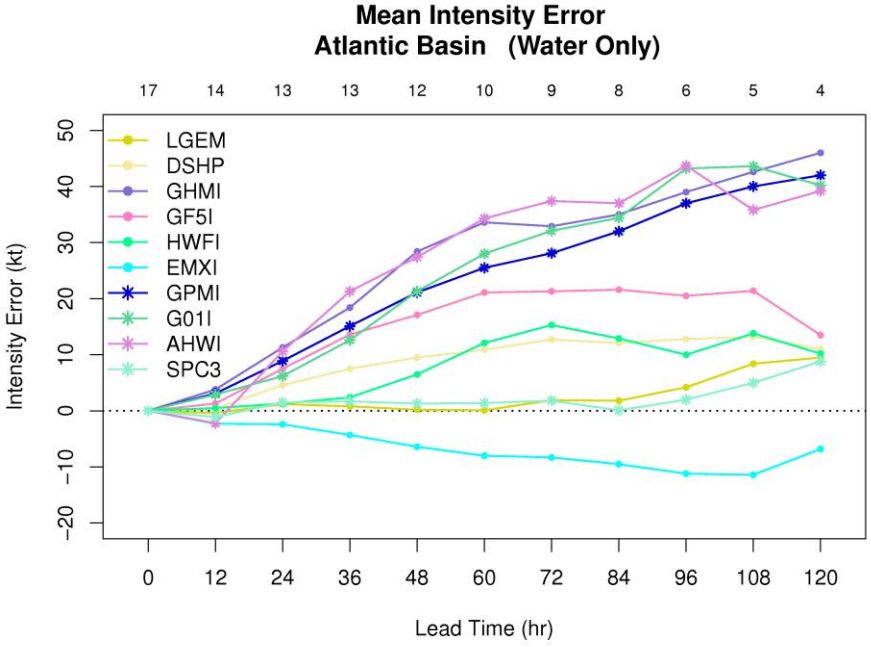



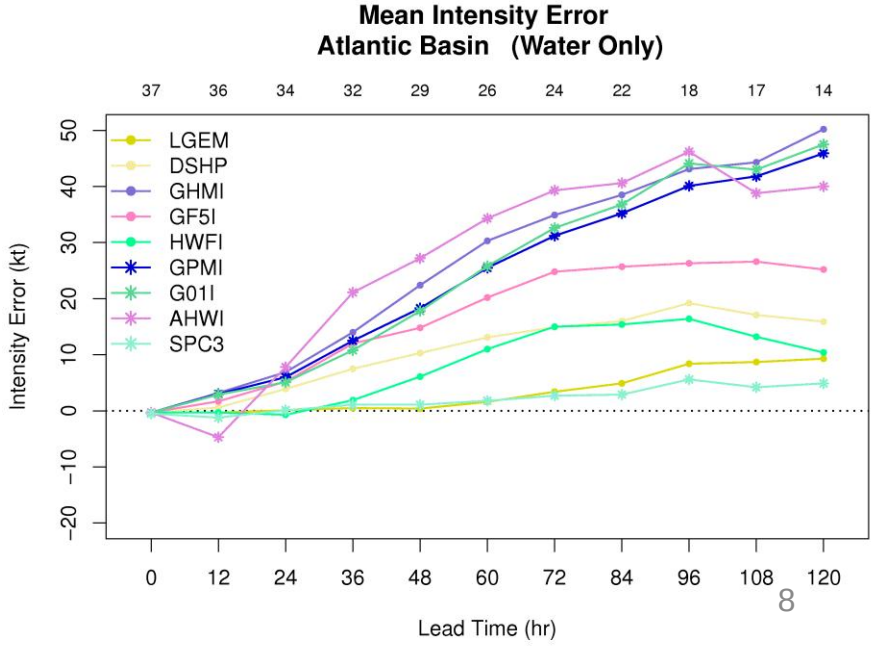



# Homogeneous Comparison of Stream 1.5 Models - Maria



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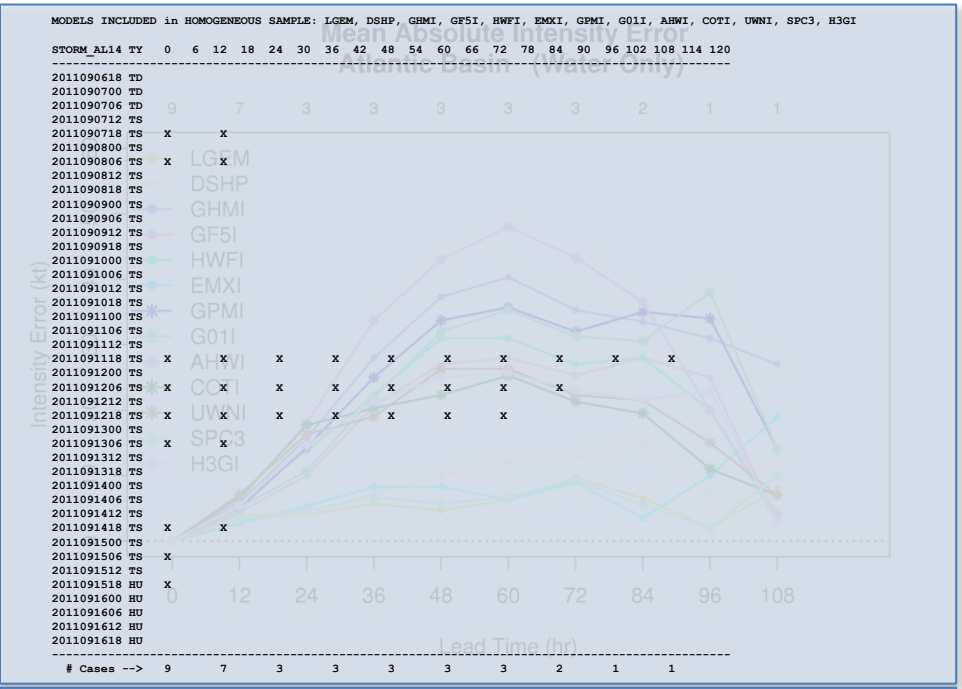
MODELS INCLUDED in HOMOGENEOUS SAMPLE: LGEM, DSHP, GHMI, GF5I, HWFI, EMXI, GPMI, G01I, AHWI, COTI, UWNI, SPC3, H3GI

| STORM_AL14 TY | 0 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 | 102 | 108 | 114 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011090618 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090700 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090706 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090712 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090718 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011090800 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090806 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011090812 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090818 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090900 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090906 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090912 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090918 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091000 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091006 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091012 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091018 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091100 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091106 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091112 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091118 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091200 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091206 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091212 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091218 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091300 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091306 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011091312 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091318 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091400 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091406 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091412 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091418 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011091500 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091506 TS | x | | | | | | | | | | | | | | | | | | | | |
| 2011091512 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091518 HU | x | | | | | | | | | | | | | | | | | | | | |
| 2011091600 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091606 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091612 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091618 HU | | | | | | | | | | | | | | | | | | | | | |
| # Cases --> | 9 | | 7 | | 3 | | 3 | | 3 | | 3 | | 2 | | 1 | | 1 | | | | |

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| 2011090618 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090700 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090706 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090712 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090718 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011090800 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090806 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011090812 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011090818 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090900 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090906 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090912 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090918 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091000 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091006 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091012 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091018 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091100 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091106 TS | x | | x | | x | | x | | x | | x | | x | | x | | | | | | |
| 2011091112 TS | x | | x | | x | | x | | x | | x | | x | | x | | | | | | |
| 2011091118 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091200 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091206 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091212 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091218 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091300 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091306 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091312 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011091318 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011091400 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091406 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091412 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091418 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091500 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091506 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091512 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091518 HU | x | | x | | | | | | | | | | | | | | | | | | |
| 2011091600 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091606 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091612 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091618 HU | | | | | | | | | | | | | | | | | | | | | |
| # Cases --> | 17 | | 17 | | 11 | | 9 | | 7 | | 6 | | 5 | | 3 | | 1 | | | | |


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| 2011090618 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090700 TD | | | | | | | | | | | | | | | | | | | | | |
| 2011090706 TD | x | | x | | x | | x | | x | | x | | x | | x | | | | | | |
| 2011090712 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090718 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090800 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090806 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090812 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090818 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011090900 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090906 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011090912 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011090918 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091000 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091006 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091012 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091018 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091100 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091106 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091112 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091118 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091200 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091206 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091212 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091218 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091300 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091306 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011091312 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091318 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011091400 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091406 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091412 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091418 TS | x | | x | | | | | | | | | | | | | | | | | | |
| 2011091500 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091506 TS | x | | | | | | | | | | | | | | | | | | | | |
| 2011091512 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091518 HU | x | | | | | | | | | | | | | | | | | | | | |
| 2011091600 HU | x | | | | | | | | | | | | | | | | | | | | |
| 2011091606 HU | x | | | | | | | | | | | | | | | | | | | | |
| 2011091612 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091618 HU | | | | | | | | | | | | | | | | | | | | | |
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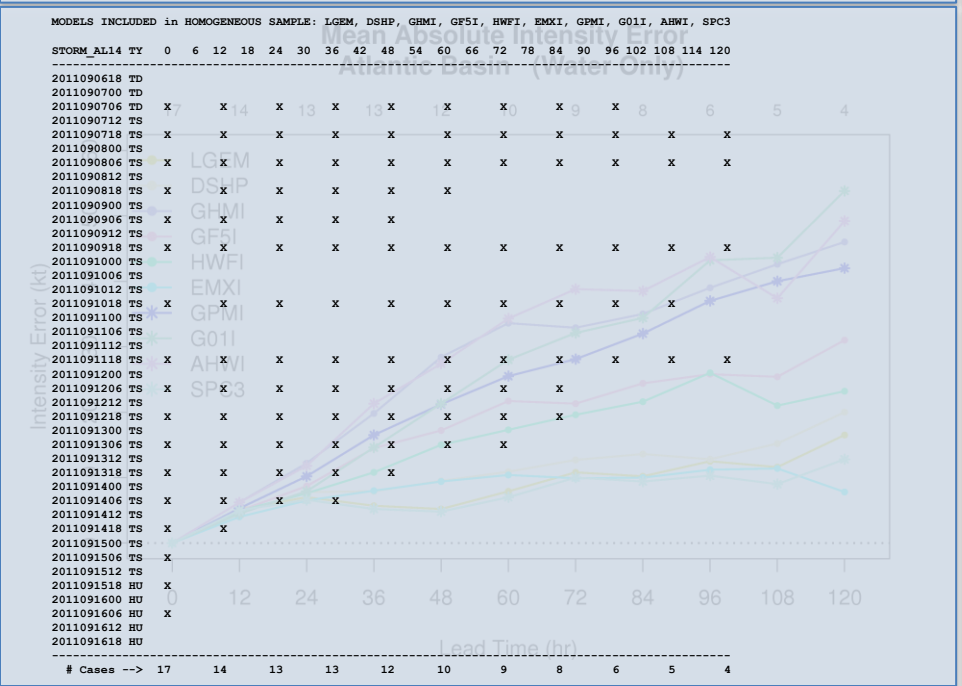


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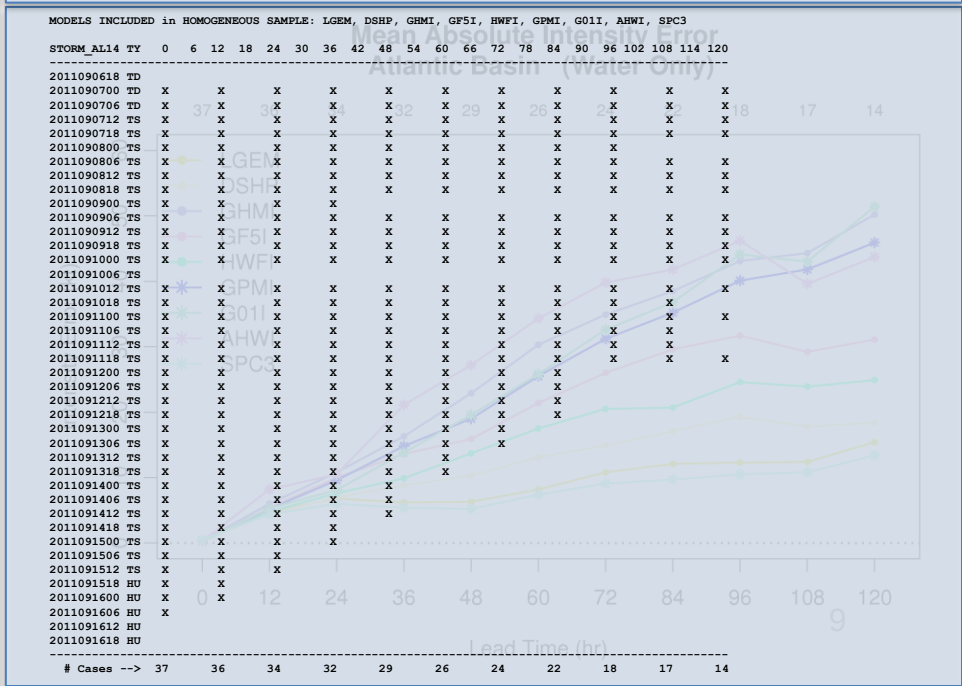
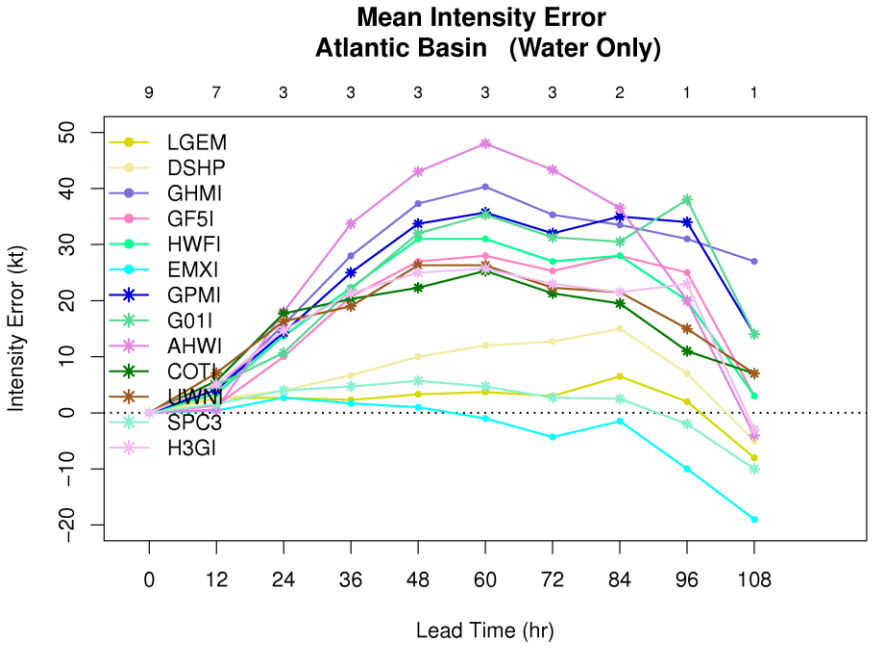
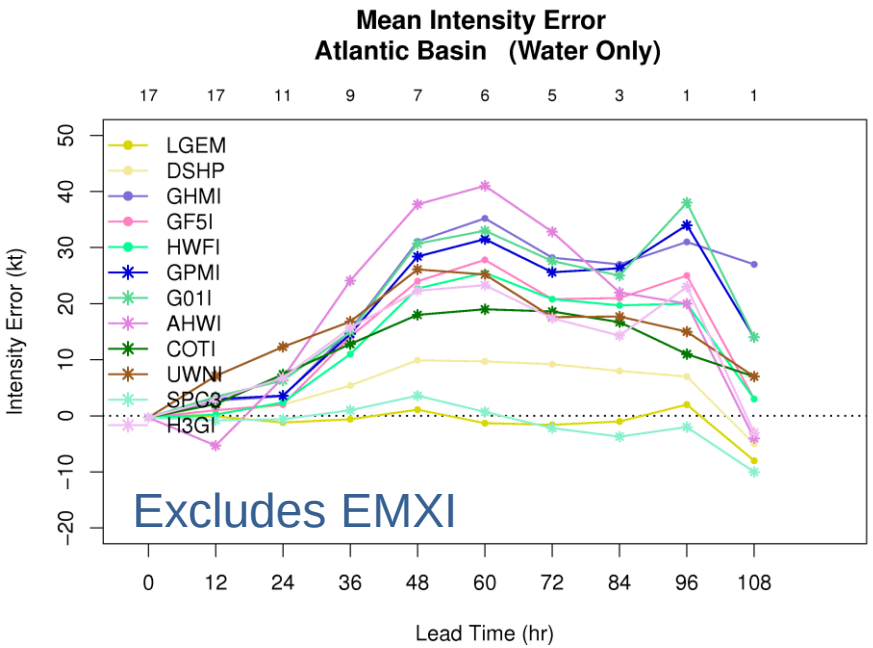
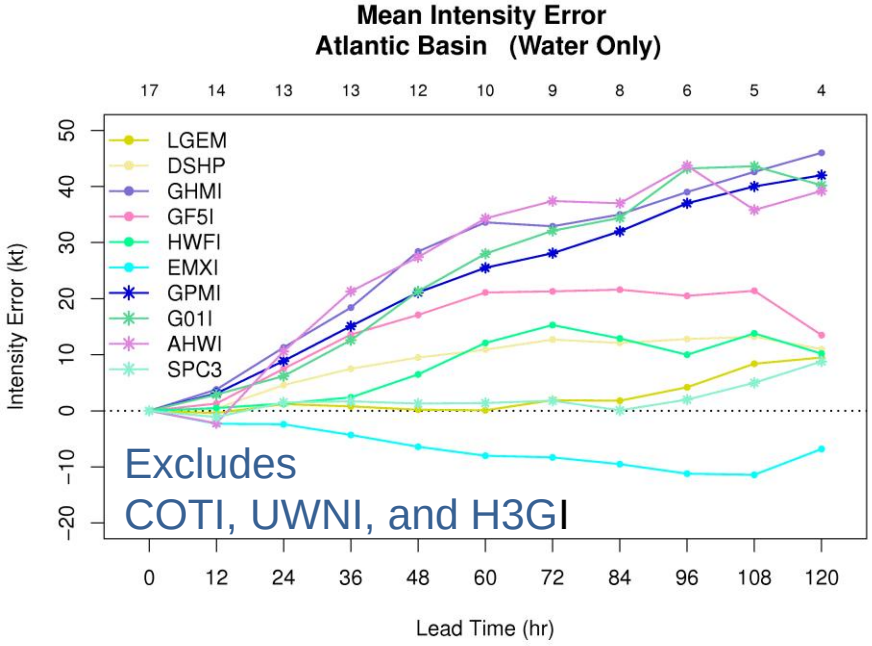
| 2011090700 TD | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090706 TD | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090712 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090718 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090800 TS | x | | x | | x | | x | | x | | x | | x | | x | | | | | | |
| 2011090806 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090812 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090818 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090900 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011090906 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090912 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011090918 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091000 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091006 TS | | | | | | | | | | | | | | | | | | | | | |
| 2011091012 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091018 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091100 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091106 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091112 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091118 TS | x | | x | | x | | x | | x | | x | | x | | x | | x | | | | |
| 2011091200 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091206 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091212 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091218 TS | x | | x | | x | | x | | x | | x | | x | | | | | | | | |
| 2011091300 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091306 TS | x | | x | | x | | x | | x | | x | | | | | | | | | | |
| 2011091312 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011091318 TS | x | | x | | x | | x | | x | | | | | | | | | | | | |
| 2011091400 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091406 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091412 TS | x | | x | | x | | x | | | | | | | | | | | | | | |
| 2011091418 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091500 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091506 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091512 TS | x | | x | | x | | | | | | | | | | | | | | | | |
| 2011091518 HU | x | | x | | | | | | | | | | | | | | | | | | |
| 2011091600 HU | x | 0 | x | | | | | | | | | | | | | | | | | | |
| 2011091606 HU | x | | | | | | | | | | | | | | | | | | | | |
| 2011091612 HU | | | | | | | | | | | | | | | | | | | | | |
| 2011091618 HU | | | | | | | | | | | | | | | | | | | | | |
| # Cases --> | 37 | | 36 | | 34 | | 32 | | 29 | | 26 | | 24 | | 22 | | 18 | | 17 | | 14 |

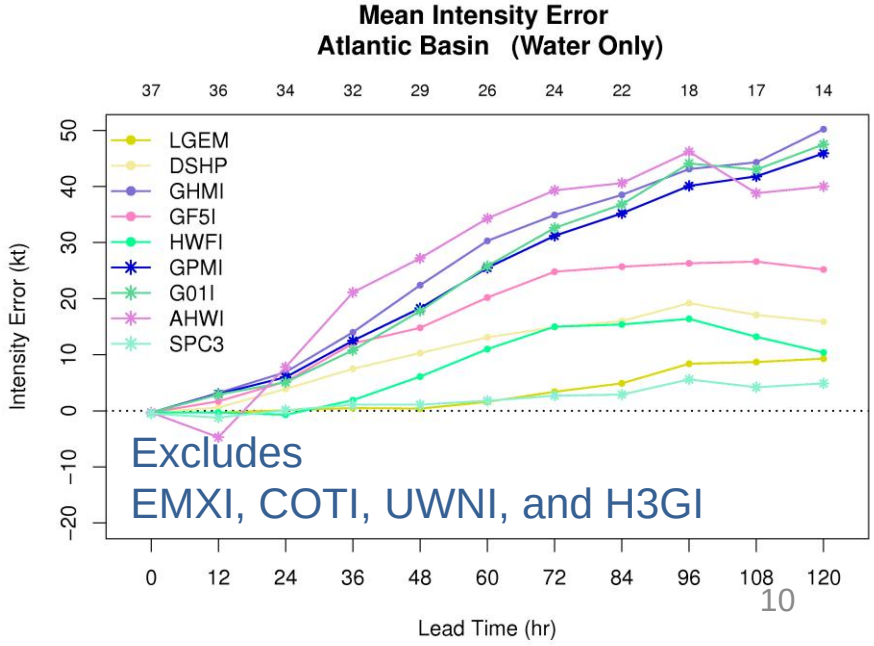


# Homogeneous Comparison of Stream 1.5 Models - Maria

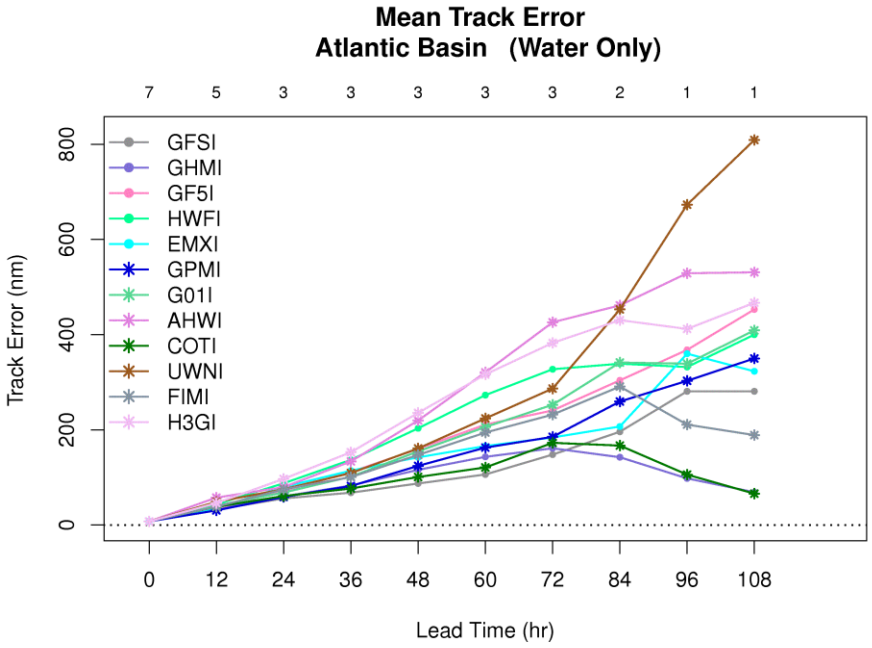


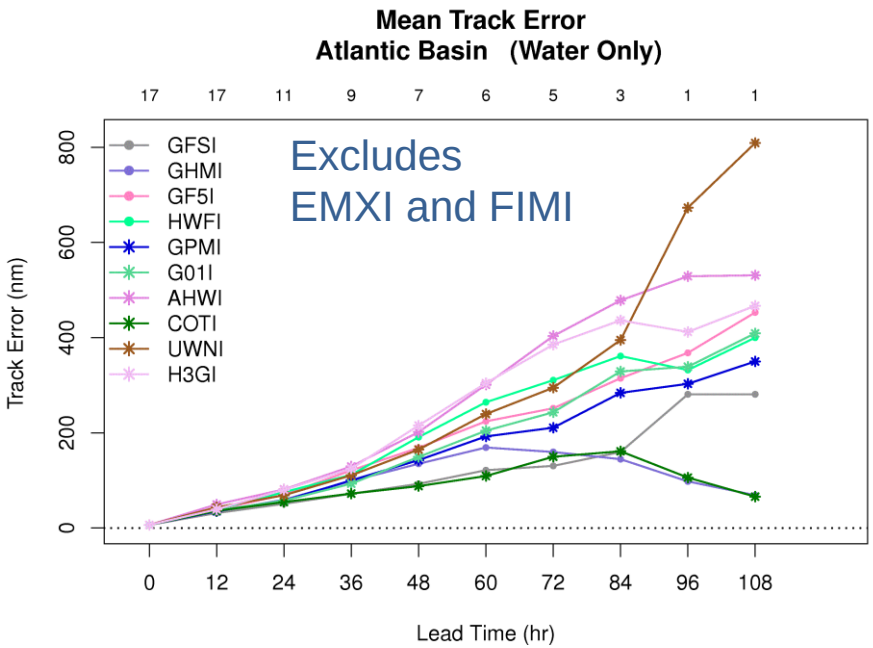



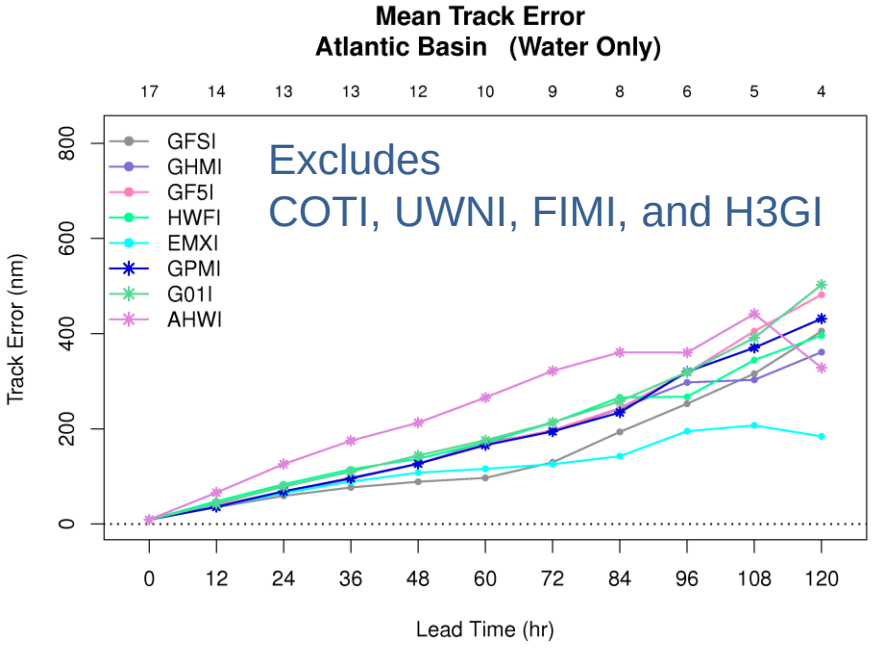



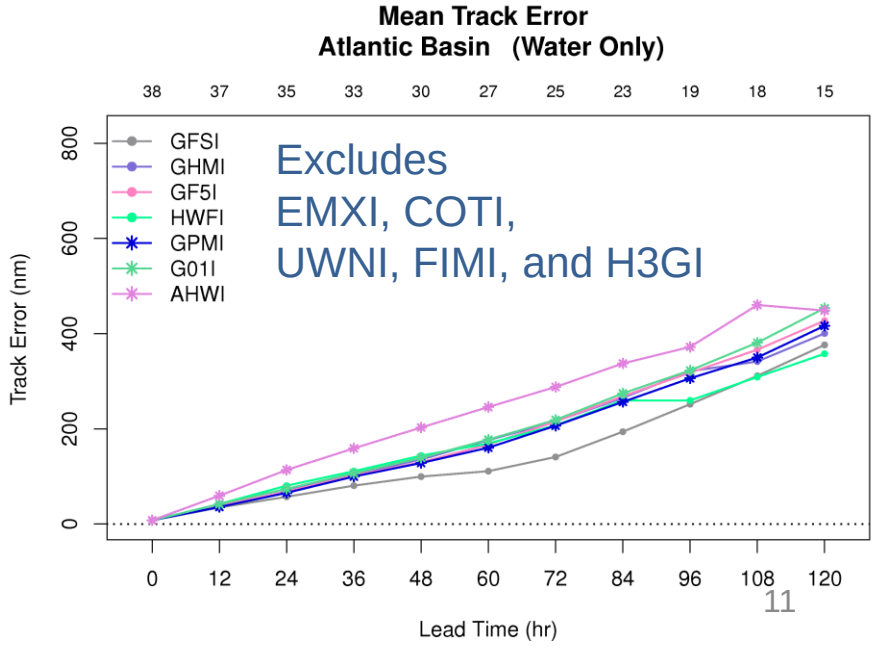



# Homogeneous Comparison of Stream 1.5 Models - Maria



# Verification tools and methods

- Community verification tools
  - Development of community tools to replicate and extend NHC capability is in progress
  - Requirements document ready for review
  - Implementation and testing this winter by DTC
- Interpolator
  - Interpolator code implemented by TCMT
  - Eventually will make available to community
- Verification methods document
  - Summarize current capabilities for track and intensity
  - In progress

    Collaboration with WMO Joint Working Group on Forecast Verification Research

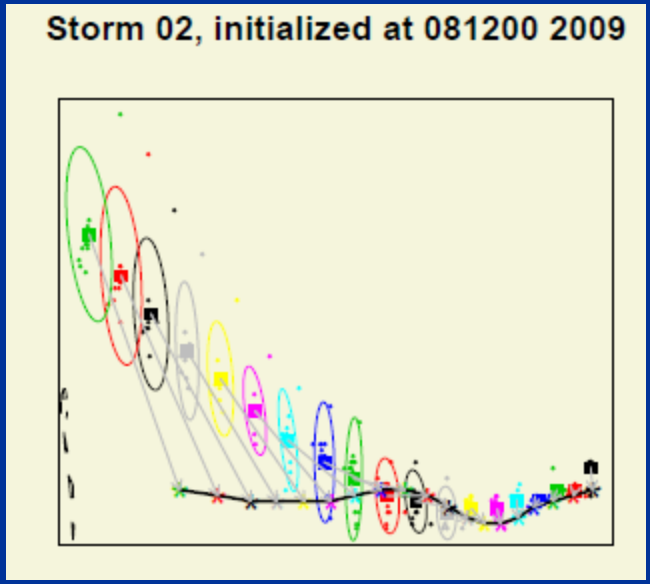
# Verification tools and methods

Additional topics

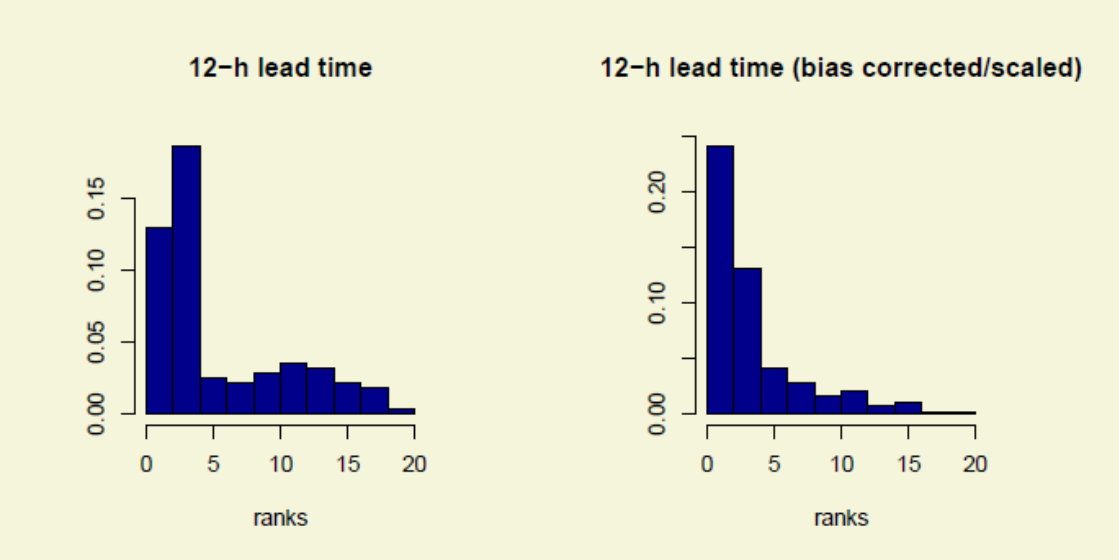
- Ensemble method investigation
- Sample size investigation
- Genesis probabilities
- Tracker implementation in community code

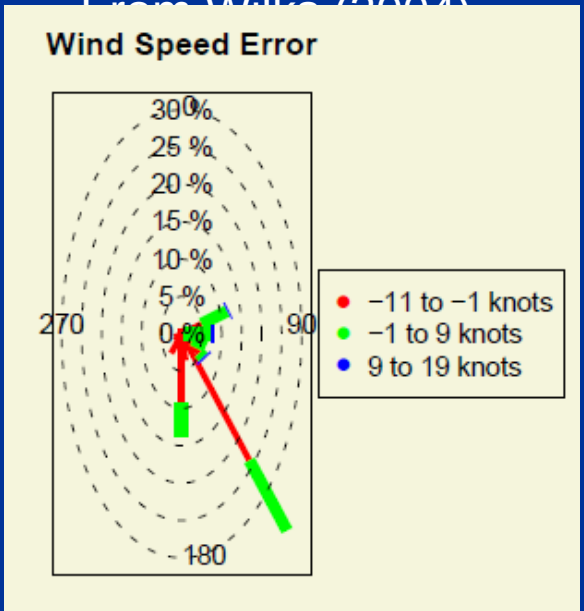
# Ensemble verification methods

- Exploring methods to jointly evaluate ensemble track and intensity forecasts
  - **Minimum Spanning tree** (analogous to rank histogram for multivariate forecasts)
  - **Energy score** (analogous to CRPS for multivariate forecasts)



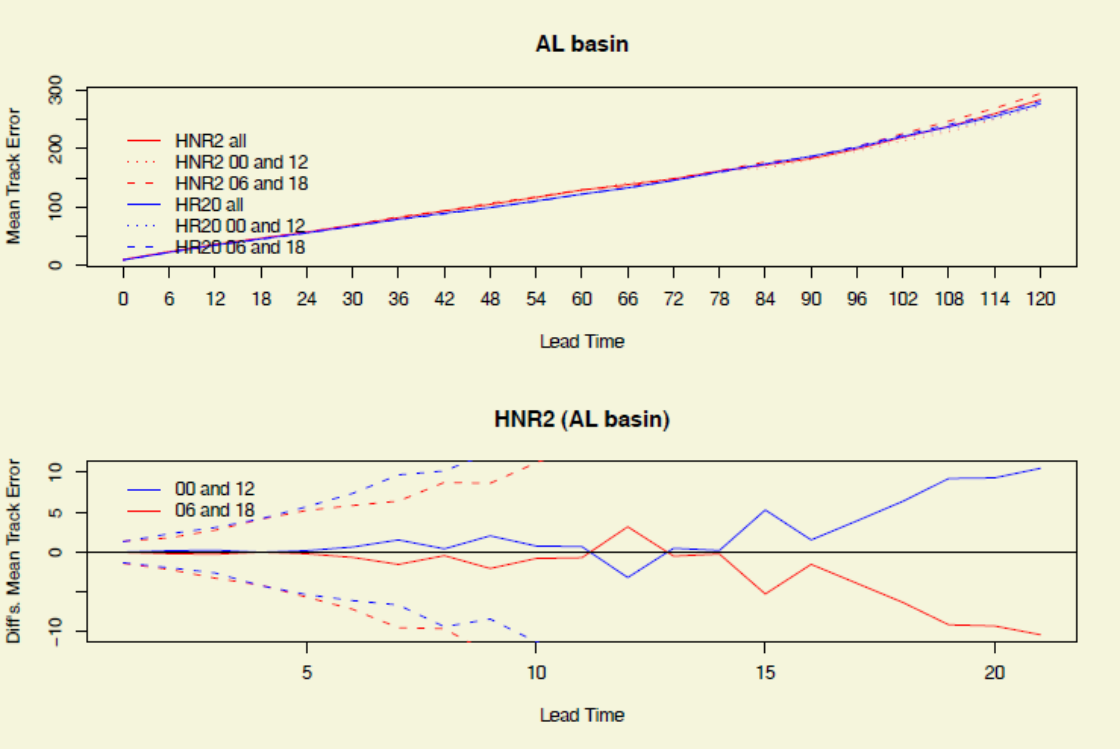

From Wilks (2004)



# Sample size investigations

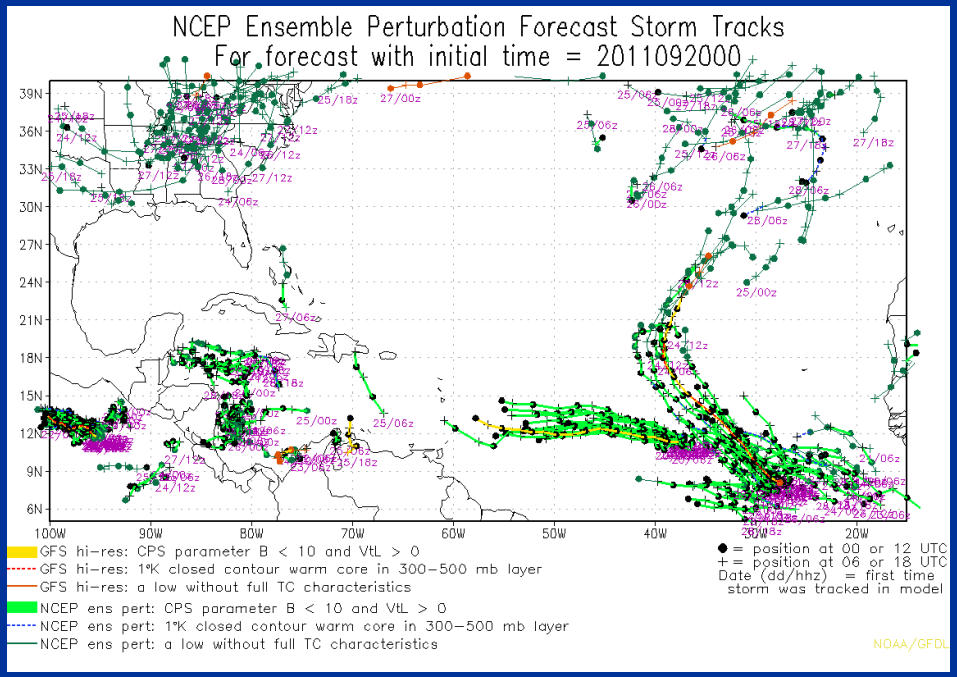
- Exploration of how many samples are needed to obtain stable verification results
  - Ex: What happens if some issue times not included? What are the impacts of autocorrelation on verification analyses?

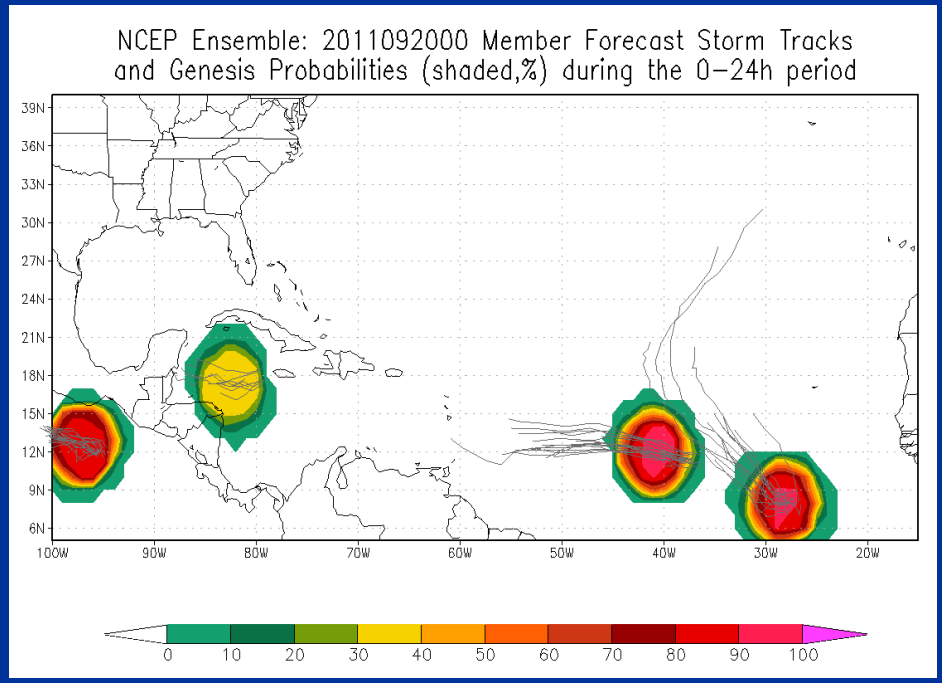


# Verification tools and methods

- Development of model-based tools for forecasting genesis; Perform verification of model genesis forecasts (5.3.3, 5.4.1).

Ensemble products sub-group has begun work to use a combination of statistical / diagnostic methods (Majumdar) as well as tracker-based methods (below) to create a genesis forecast product using global ensembles.



# Upgrades for tracker

- Effort currently underway involving GFDL, EMC, ESRL, DTC to unify versions of the tracker with most recent version. Targeting Spring, 2012 for implementation at NCEP (5.4.1).

- Tracker upgrade at NCEP to include cyclone phase detection, tracking on moveable nests, as well as tracking for additional ensembles such as SREF, FNMOC, NAEFS, and 12Z ECMWF.

# Release of tracker to community

**Continue to improve tracker, release latest version to the Community (*GFDL*, DTC)**

Stream 2 **5.4.2 Sept 30, 2011**

## GFDL tracker releases

- August – component of HWRF v3.3a release
- November– stand alone version (v3.3b) for models other than HWRF

## GFDL tracker upgrades

- Ongoing - Upgraded tracker for all NCEP applications will be transitioned to DTC when ready

# Challenges and Issues

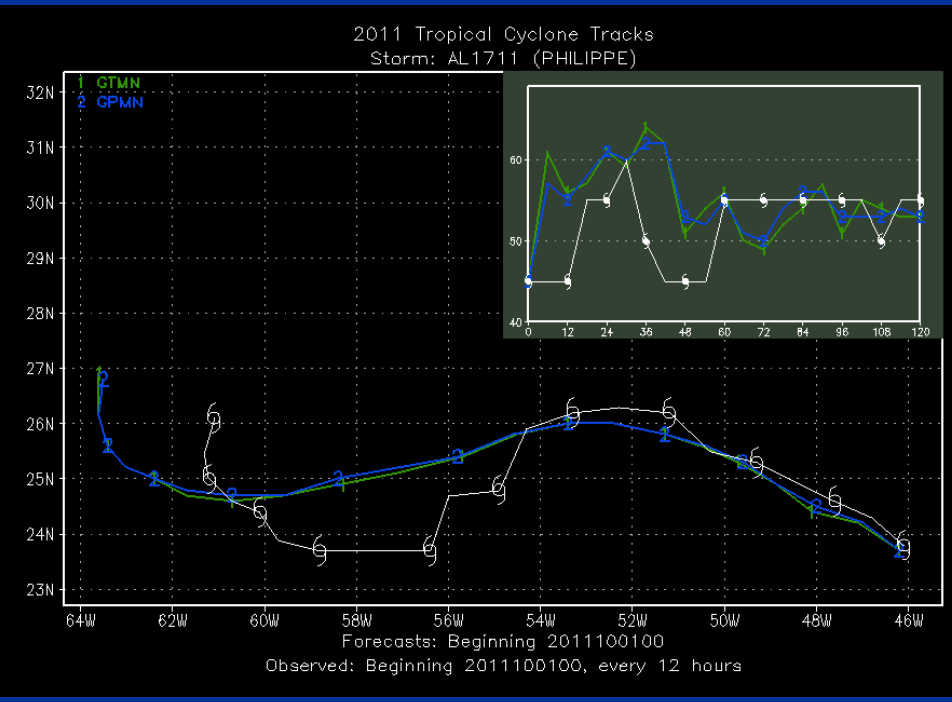
- Use of common tracker
- Estimation of forecast intensity
- Need for central verification activities for consistent model evaluations
- Stratification of results
  - What are appropriate subsamples?
- Evaluation of additional storm attributes
  - What additional storm characteristics should be considered?

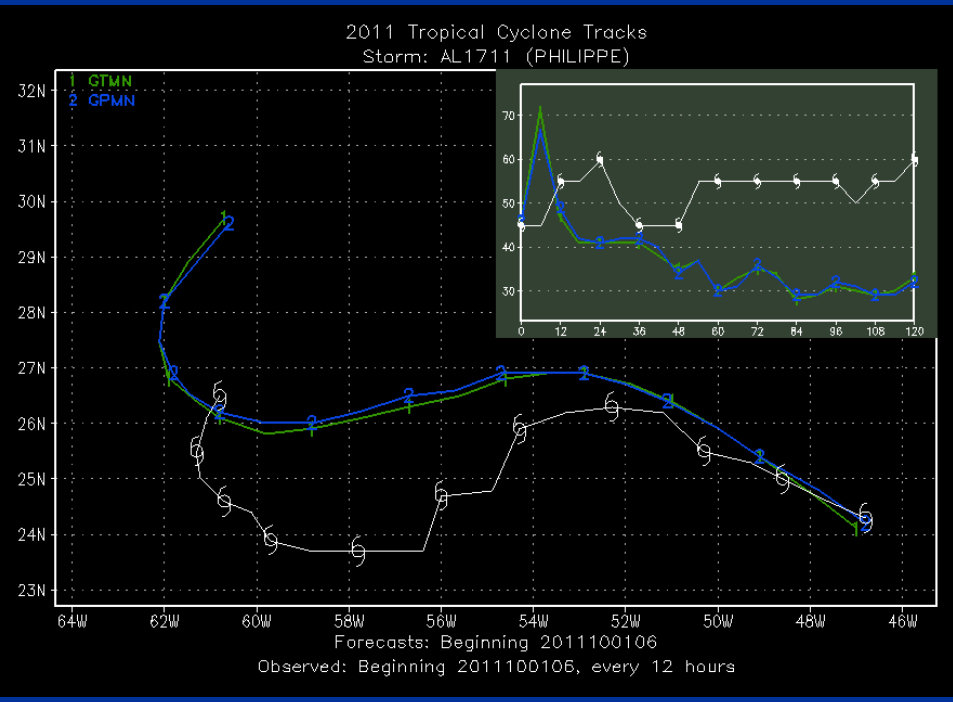
    Precipitation? Storm surge? Storm structure variables? Others?

# Challenges and Issues

## Use of common tracker / Estimation of forecast intensity

Two cases of Philippe from GFDL ensemble: **Green** track uses external tracker (no time averaging), **Blue** track uses internal model tracker (3-h time averaging).




Individual ensemble members all showed similar variability, with mean intensity differences on the order of 1% - 4% at each lead time over the full season (n=350).

# GFDL Tracker vs. COAMPS-TC Built-in Tracker

- **GFDL tracker has been implemented in COAMPS-TC and used for the 2011 real-time forecasts.**
- **Comparison of GFDL tracker with COAMPS-TC built-in tracker shows that they are very close.**