2014 WRF for Hurricanes Tutorial
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Forecast Verification

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Outline

- Introduction to Forecast Verification
  - Introduction
  - Observations
  - Basic verification metrics
  - Uncertainty & Confidence intervals
  - MET overview

- MET-TC
  - What is MET-TC?
  - Getting Started
  - TC-dland
  - TC-pairs
  - TC-stat
  - graphics

Introduction to Forecast Verification

Introduction

- What is Verification?
  - The process of comparing forecasts to relevant observations
  - Measures quality of forecasts
  - Evaluation of a particular model or condition

- Why Verify?
  - Help understand model biases and performance of models under certain conditions
  - Help users interpret forecasts
  - Identify forecast weakness, strengths, differences

Introduction

- Verification goals depend on the questions we want to answer
  - Determines attribute to measure
  - Drives choices in verification statistics, measures, and graphics

- Before starting any verification study:
  1. **Identify multiple verification attributes** that provide answers to the questions of interest
     - ✓ *Position, wind, QPF, RI, landfall …*
  2. **Select measures and graphics** to appropriately measure and represent the attributes of interest
     - ✓ *Track (along/cross) error, Intensity error, Contingency tables …*
  3. **Identify a standard of comparison** that provides a reference level of skill
     - ✓ *CLIPER, SHIFOR, Baseline model …*

Observations

- Observations are an important consideration for TC verification
  - Quality and quantity of observations available
    - Typically sparse or intermittent
    - May infer characteristics from indirect measures (satellite)
- Refer to previous lecture for more detail on observational datasets
- Best track analysis
  - Subjective assessment of TC's center location and intensity (6 hr) using all observations available
  - Includes center position, maximum sfc winds, minimum center pressure, quadrant radii of 34/50/64 kt winds
  - Subjectively smoothed

```
AL, 09, 2011082218,   , BEST,   0, 193N,  680W,  75,  988, HU,  64, NEQ,   25,    0,    0,    0, 1010,  250,  15,  85,   0,   L,   0,    ,   0,   0,     IRENE, D, 12, NEQ,  180,   60,    0,  120
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AL, 09, 2011082312,   , BEST,   0, 204N,  706W,  80,  978, HU,  50, NEQ,   90,   60,   40,   70, 1008,  300,  15, 105,   0,   L,   0,    ,   0,   0,     IRENE, D, 12, NEQ,  180,  120,   35,  150
```
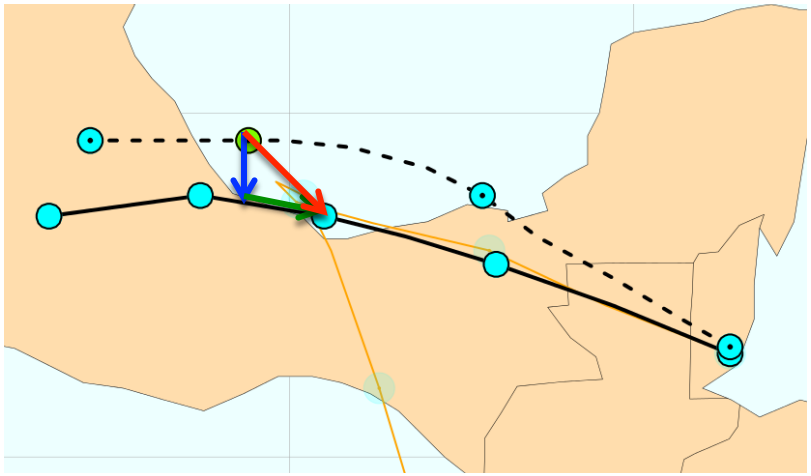
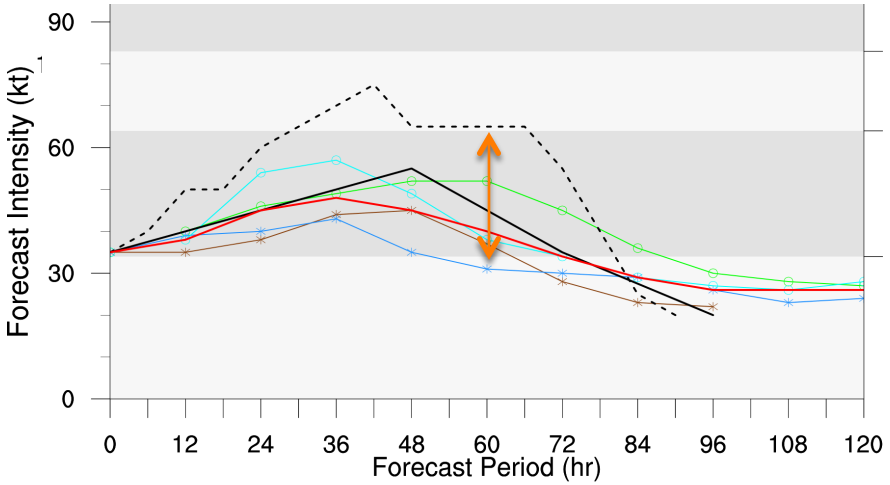

TC Metrics

- **Track Error**: great-circle distance between the forecast location and the actual location of the storm center (nmi)
- **Along-track Error**: indicator of whether a forecasting system is moving a storm too slowly/quickly
- **Cross-track Error**: indicates displacement to the right/left of the observed track
- **Intensity Error**: Difference between forecast and actual intensity (kts)

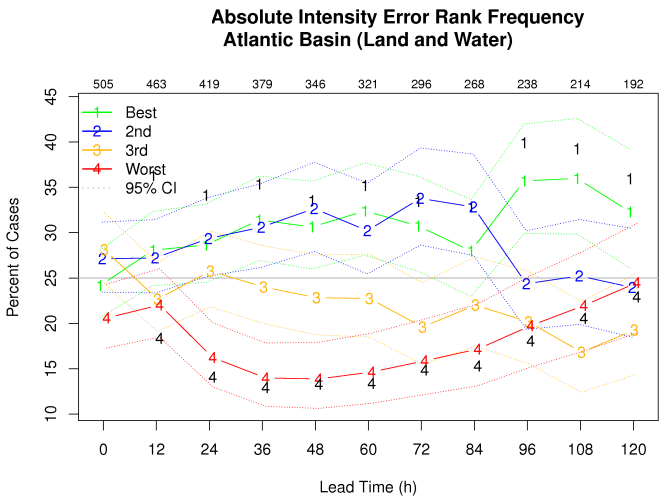


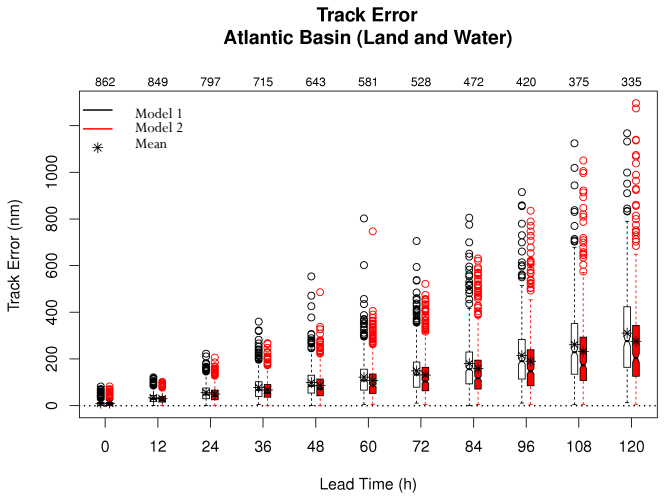


Graphics courtesy of NCAR TCMT

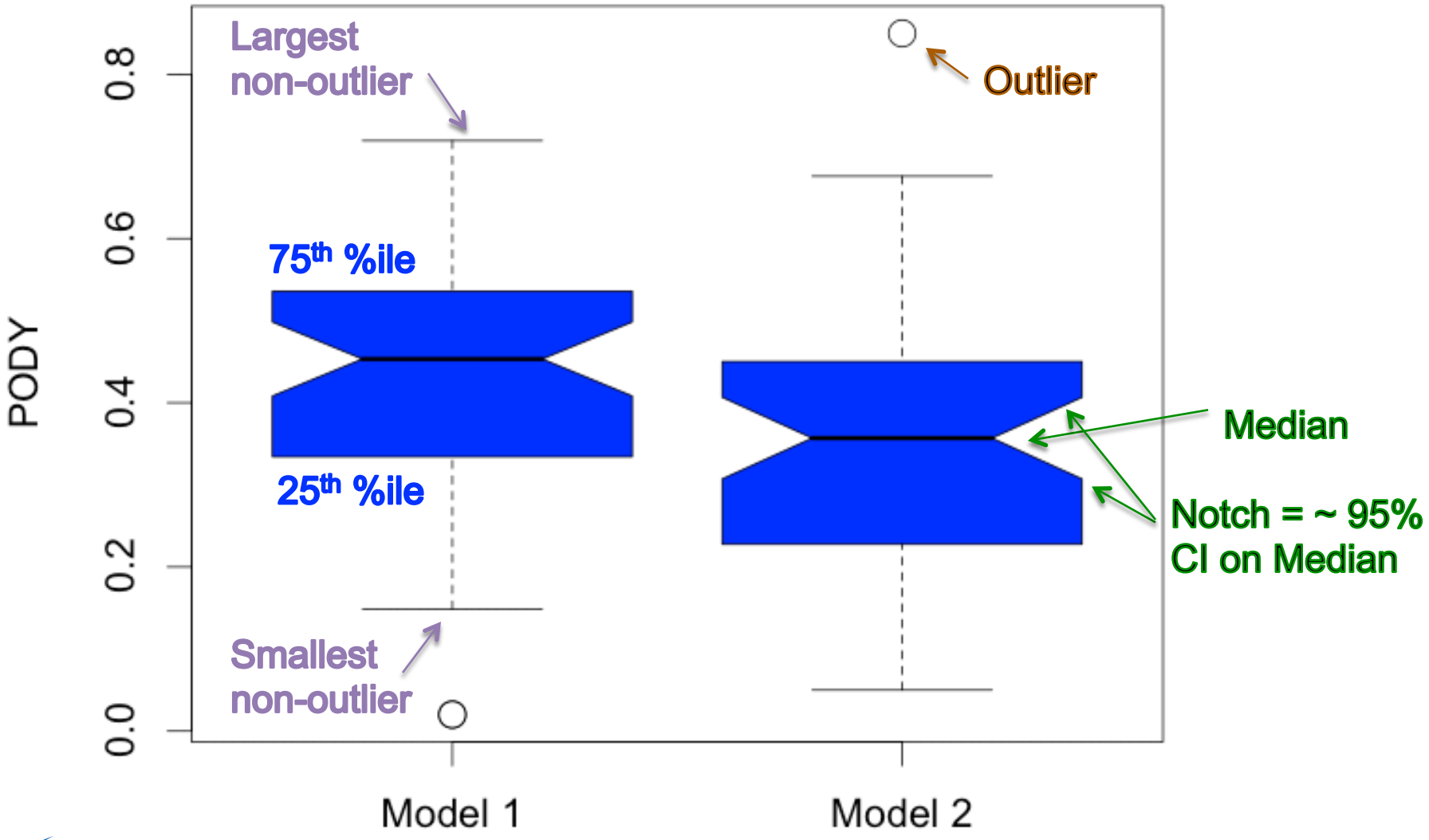
TC metrics

- Skill Scores: Used as a standard of comparison, skill diagrams are often used to compare model skill relative to CLIPER/SHIFOR
- Frequency of Superior Performance: ranking a particular model forecast relative to the performance multiple model forecasts
- Distribution of errors: Box plots can be used to highlight the distributions of the errors in the forecasts





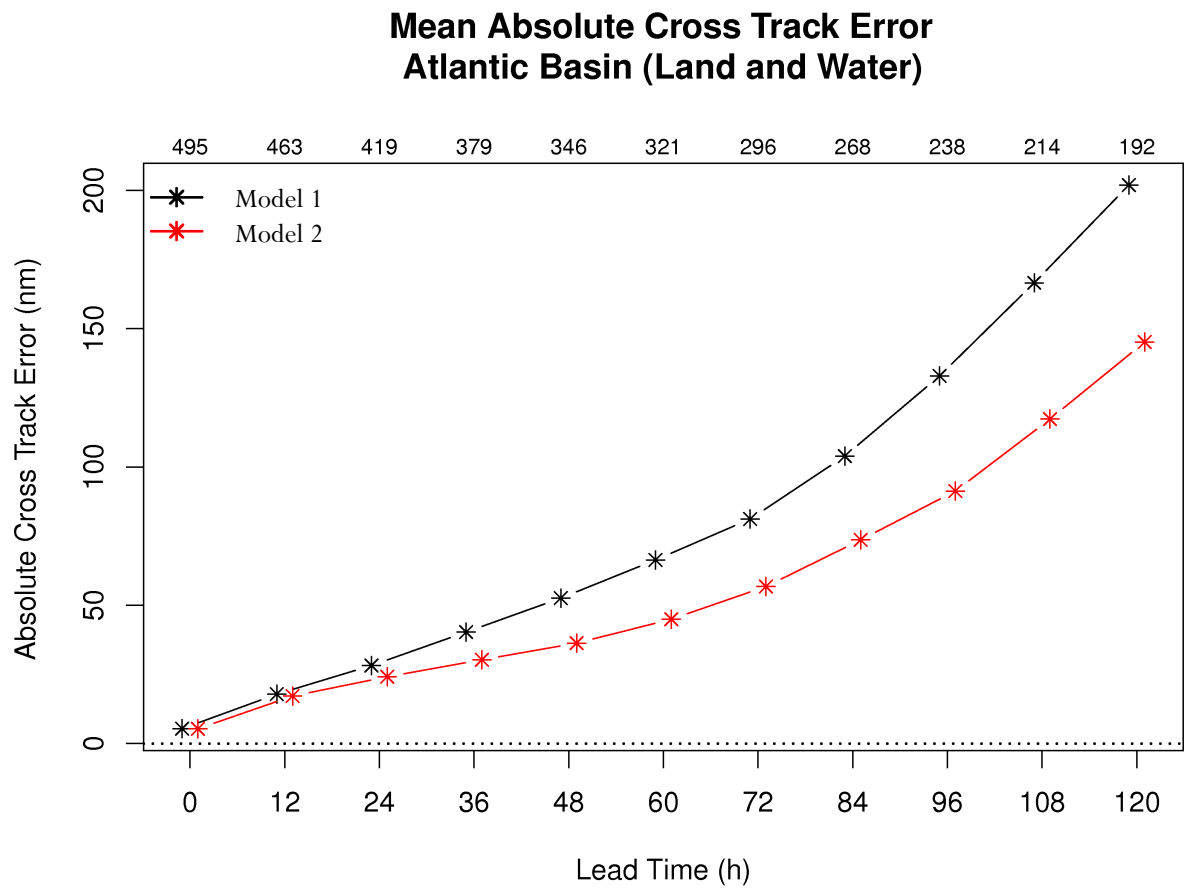
Box (& Whisker) Plot



Uncertainty

- Observations and analysis products as well as models themselves are subject to uncertainty
- Need to be aware of sample size!
  - Typically smaller samples due to lower frequency of occurrence relative to other weather phenomena
- Accounting for sampling uncertainty:
  - Verification statistic is a realization of a random process
  - What if the experiment were re-run under identical conditions? Would you get the same answer?

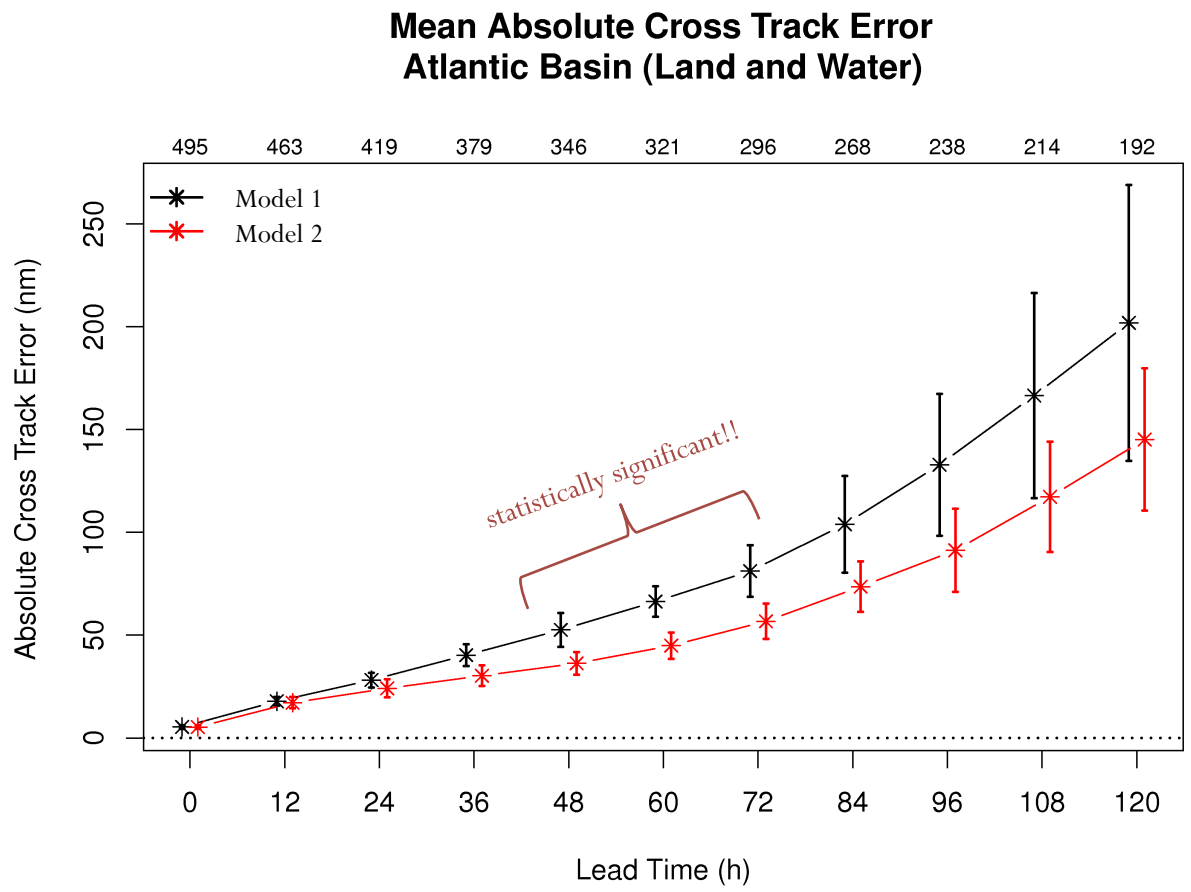
Confidence intervals



Mean absolute cross-track errors for two models.

Scores are very similar at short lead times, but seem to diverge at longer lead times

Confidence intervals

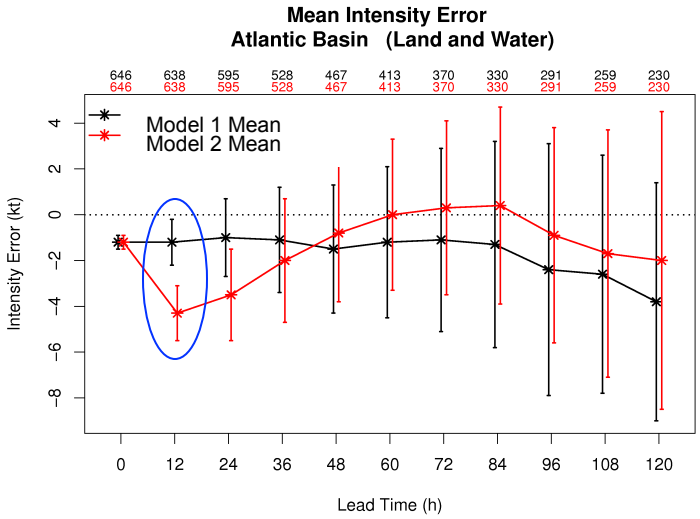


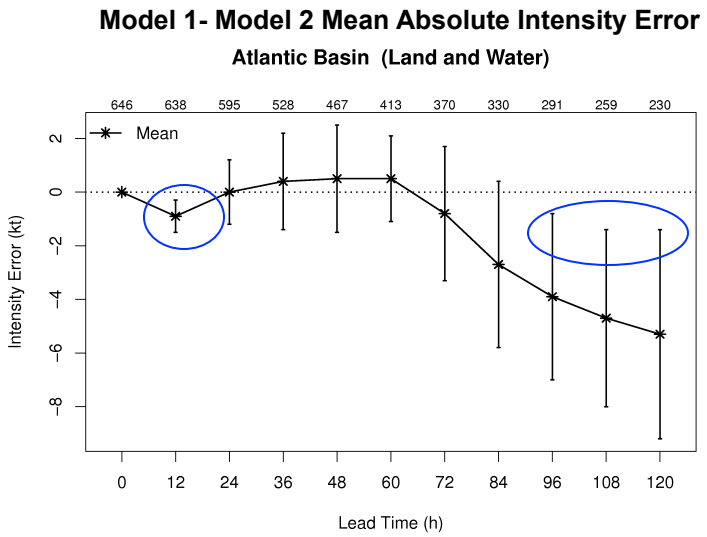
Confidence Intervals (CIs) indicate no significant difference between 0-36 h, after 84 h

Statistical significance indicated where CIs don't overlap

Confidence Intervals

- Two ways to examine scores:
  - CI about absolute scores
    - May be difficult to differentiate model performance differences
    - SS where two model CIs do not intersect
  - CI about Pairwise Differences
    - May allow for differentiation of model performance.
    - SS where CIs do not encompass 0

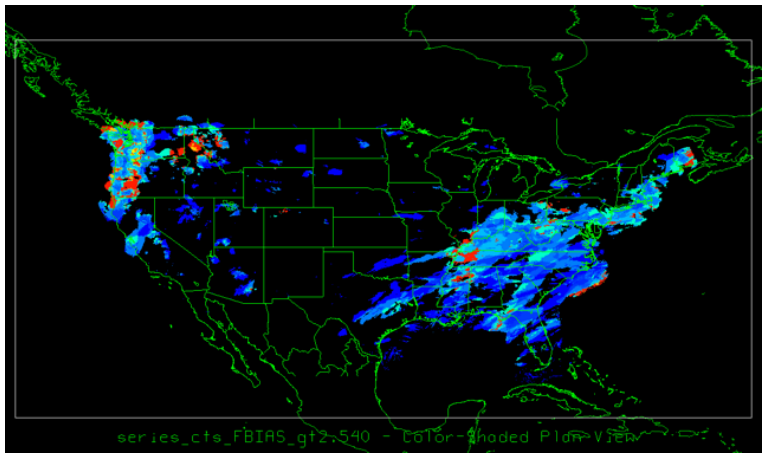




➢ For MET-TC CIs are computed using the assumption of normality for the mean

Model Evaluation Tools

- What is MET?
  - MET is a set of tools for evaluating model forecasts
- A modular set of forecast evaluation tools
  - Freely available, highly configurable, fully documented, supported
- MET includes:
  - Reformatting tools
  - Statistical tools
  - Analysis tools
- MET works directly with post-processed model output to perform a large variety of statistical analyses



Precipitation frequency bias generated from MET output

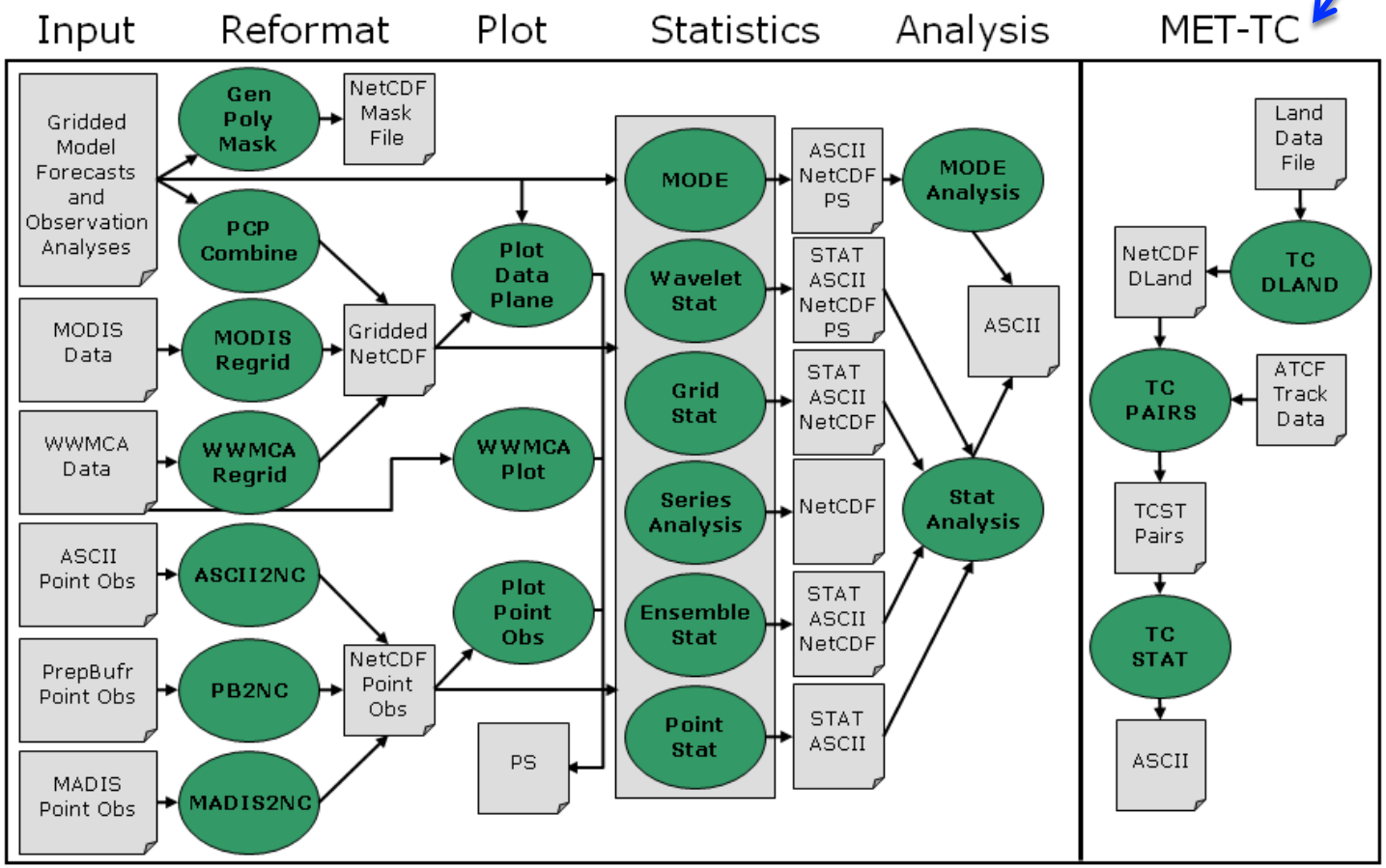
Model Evaluation Tools

- Overview of tools
- MET provides a variety of verification techniques:
  - Gridded model data to point-based observations
  - Gridded model data to gridded observations
  - Ensemble and probabilistic verification methods
  - Aggregating output through time and space

Model Evaluation Tools

MET-TC covered in detail for this talk

- Overview of tools



References & Further Reading

- Gilleland, E., 2010: Confidence intervals for forecast verification. NCAR Technical Note NCAR/TN-479+STR, 71pp. *Available at:* http://nldr.library.ucar.edu/collections/technotes/asset-000-000-000-846.pdf
- Jolliffe and Stephenson (2011): Forecast verification: A practitioner's guide, 2nd Edition, Wiley & sons
- JWGFVR (2009): Recommendation on verification of precipitation forecasts. WMO/TD report, no.1485 WWRP 2009-1
- Nurmi (2003): Recommendations on the verification of local weather forecasts. ECMWF Technical Memorandum, no. 430
- Wilks (2006): Statistical methods in the atmospheric sciences, ch. 7. Academic Press
- See also: http://www.cawcr.gov.au/projects/verification/

Appendix C of MET Documentation: http://www.dtcenter.org/met/users/docs/overview.php

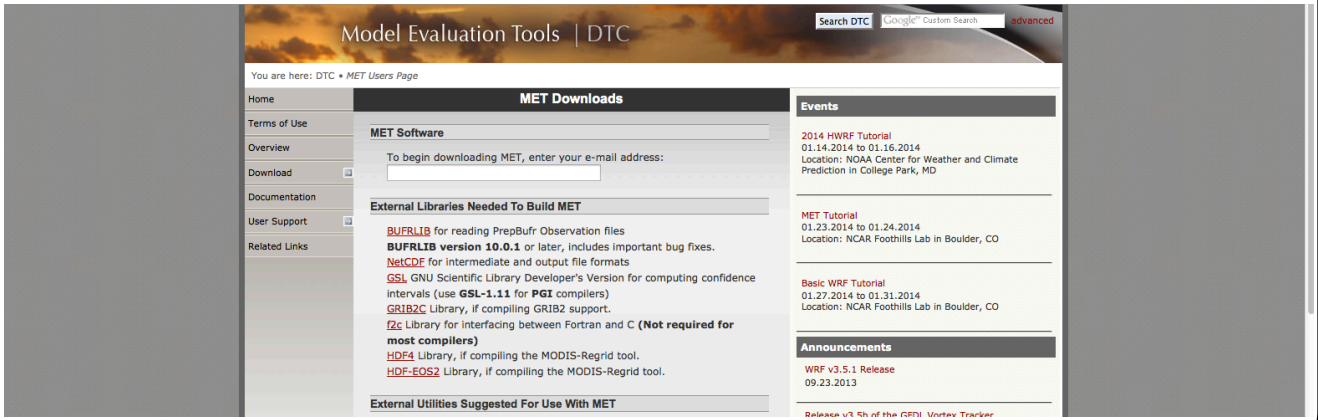
Model Evaluation Tools–Tropical Cyclone

Introduction

- WHAT is MET-TC?
  - A set of tools to aid in TC forecast evaluation and verification
  - Developed to replicate (and add to) the functionality of the NHC verification software
  - Modular set of tools which utilize the MET software framework
    - Allows for additional capabilities and features to be added to future releases
- WHY use MET-TC?
  - Provides a standard set of verification metrics and comprehensive output statistics
  - Available to all users
    - Enables consistent forecast evaluation studies to be undertaken across the community

Compile & Build

- Download MET (must be v4.1) release and compile locally
  - Need to register to download: www.dtcenter.org/met/users
- Supported platforms and compilers
  1. Linux with GNU compilers
  2. Linux with Portland Group (PGI) compilers
  3. Linux with Intel compilers
  4. IBM machines with IBM compilers



Compile & build

- Dependencies
- Required:
  - GNU Make Utility
  - C++/Fortran compilers (GNU, PGI, Intel, or IBM)
  - Unidata's NetCDF Library
  - NCEP's BUFRLIB Library
  - GNU Scientific Library (GSL)
- Optional/Recommended:
  - R statistics and graphics package

Compile & build

- The build will include MET and MET-TC
- MET-TC specific code and tools:
  - **bin/** : executables for each MET-TC module (`tc_dland`, `tc_pairs`, `tc_stat`)
  - **data/config/** : configuration files (`TCPairsConfig_default`, `TCStatConfig_default`)
  - **data/tc_data/** : static files used in MET-TC (`aland.dat`, `wwpts_us.txt`)
  - **doc/** : contains the MET-TC User's Guide
  - **src/tools/tc_utils/** : source code for three MET-TC modules
  - **scripts/Rscripts/** : contains the R script (`plot_tcmpr.R`) which provides graphics tools for MET-TC

Getting Started…

- Model output must be run through an internal/external vortex tracking algorithm *(GFDL vortex tracker – previous lecture)*

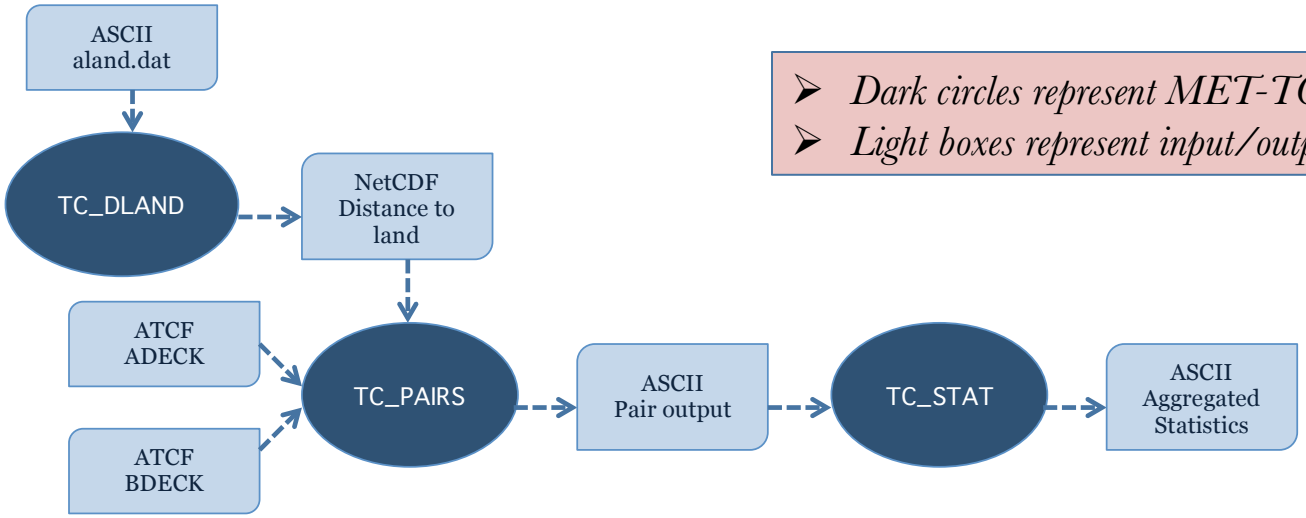
- The input files must be in Automated Tropical Cyclone Forecasting System (ATCF) format.
  - Must adhere to for MET-TC tools to properly parse the input data (first 17 columns required)

For detailed information on ATCF format: `http://www.nrlmry.navy.mil/atcf_web/docs/database/new/abdeck.txt`

- The best track analysis is used primarily used as the observational dataset in MET-TC.

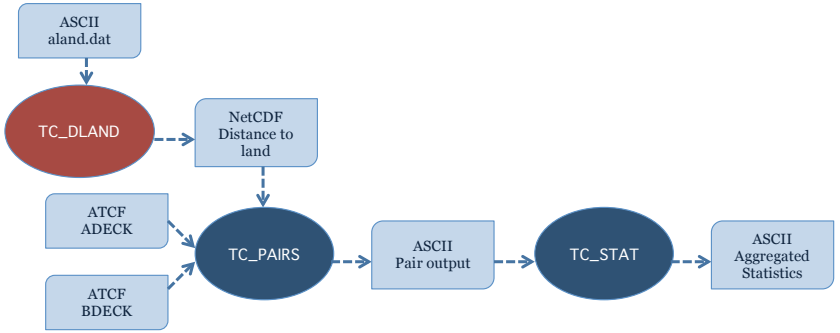
All operational model aids and best track analysis can be found on the NHC ftp server: `ftp://ftp.nhc.noaa.gov/atcf/archive/`

MET-TC components

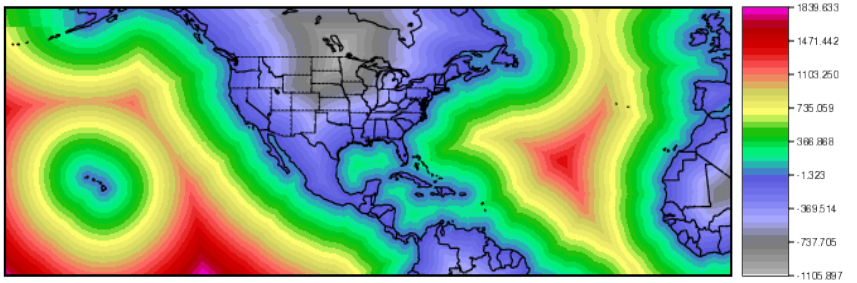


- Primary functions of the code are:
  - Compute pair statistics from ATCF input files
  - Filter pair statistics based on user specifications
  - Compute summary statistics

TC-dland



- Aids in quickly parsing data for filter jobs:
  - Only verify over water
  - Threshold verification based on distance to land
  - Exclusion/inclusion of forecasts within a specified window of landfall
- Input: ASCII file containing Lon/Lat coordinates of all coastlines/islands considered to be a significant landmass. (aland.dat)
- Output: gridded field representing distance to nearest coastline/ island in NetCDF format



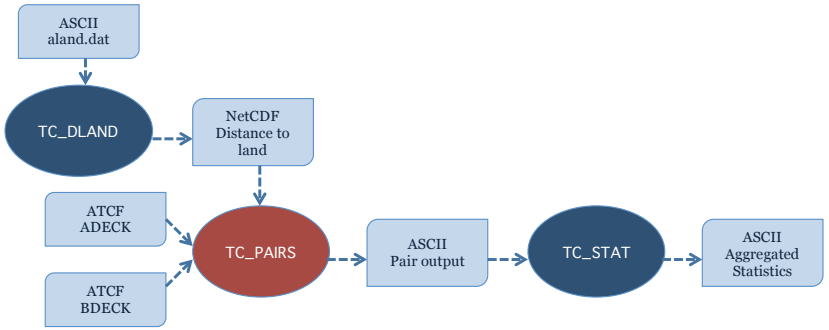
TC-dland

- Usage: **`tc_dland`**
  `out_file`
  `[-grid_spec]`
  `[-noll]`
  `[-land file]`
  `[-log file]`
  `[-v level]`

> - This exe only needs to be run once to establish the NetCDF file.
> - If running over the AL/EP and desire NHC land/water determination: NetCDF file in build

out_file	Indicates NetCDF output file containing the computed distances to land
-grid_spec	Overrides the default 1/10th grid
-noll	Skips writing to reduce size of NetCDF file
-land file	Overwrites the default land data file
-log file	Outputs log messages to the specified file
-v level	Overrides the default level of verbosity (2)

TC-pairs



- Produces pair statistics on independent model input or user-specified consensus forecasts
- Matches forecast with reference TC dataset (most commonly Best Track Analysis)
- Pair generation can be subset based on user-defined filtering criteria
- ASCII pair output allows for new or additional analyses to be completed without performing full verification process

Tc_pairs

- Input: NetCDF gridded distance file, forecast/reference in ATCF format
- Output: TCSTAT format
  - Header, column-based ASCII output
- Usage: **`tc_pairs`**
  `-adeck source`
  `-bdeck source`
  `-config file`
  `[-out base]`
  `[-log file]`
  `[-v level]`

-adeck source	ATCF format file containing TC model forecast
-bdeck source	ATCF format file containing TC reference dataset
-config file	Name of configuration file to be used
-out base	Indicates path of output file base
-log file	Name of log file associated with pairs output
-v level	Indicates desired level of verbosity

Tc_pairs

- Configuration file determines filtering criteria

MODEL	VALID_MASK
STORM_ID	CHECK_DUP
BASIN	INTERP_12
CYCLONE	CONSENSUS
STORM_NAME	LAG_TIME
INIT_BEG/INIT_END	BEST_BASELINE
INIT_INC/INIT_EXC	OPER_BASELINE
VALID_BEG/VALID_END	MATCH_POINTS
INIT_HR	DLAND_FILE
INIT_MASK	VERSION

```
//
// Model initialization time windows to
include or exclude
//
init_beg = "";
init_end = "";
init_inc = [];
init_exc = [];

//
// Valid model time window
//
valid_beg = "";
valid_end = "";

//
// Model initialization hours
//
init_hour = [];

//
// lat/lon polylines defining masking
regions
//
init_mask  = "";
valid_mask = "";

//
// Specify if the code should check for
duplicate ATCF lines
//
check_dup = FALSE;

//
// Specify if special processing should
be performed for interpolated models
with
// 12-hour spacing.
//
interp12 = TRUE;
```

- Take care not to over-subset! Can perform additional filters with tc_stat tool

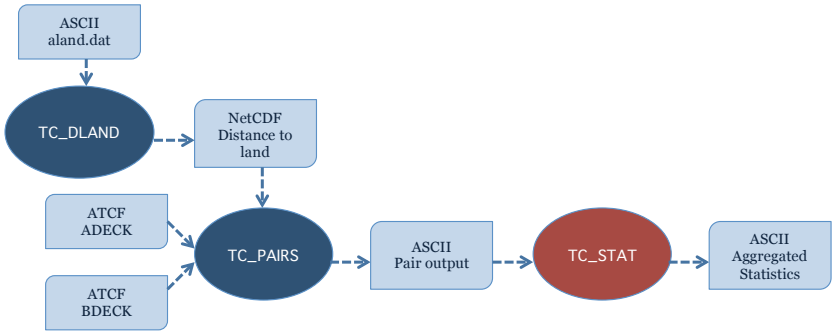
Tc_pairs

- Output in ASCII space delimited columns with header information

HEADER		
Column Number	**Header column Name**	**Description**
1	VERSION	Version number
2	AMODEL	User provided text string designating model name
3	BMODEL	User provided text string designating model name
4	STORM_ID	BBCCYYY designation of storm
5	BASIN	Basin
6	CYCLONE	Cyclone number
7	STORM_NAME	Name of Storm
8	INIT	Initialization time of forecast
9	LEAD	Forecast lead time in HH format
10	VALID	Forecast valid time in YYYYMMDD_HH
11	INIT_MASK	Initialization time masking grid applied
12	VALID_MASK	Valid time masking grid applied
13	LINE_TYPE	Output line type (TCMPR currently only line type)
14	TOTAL	Total number of matched pairs
15	INDEX	Index associated with init time
16	LEVEL	Level of storm classification
17	WATCH_WARN	HU or TS watch or warning in effect
18	INITIALS	Forecaster initials
46, 47	A/BNE_WIND_50	a/bdeck 50-knot radius winds in NE quadrant
48, 49	A/BSE_WIND_50	a/bdeck 50-knot radius winds in SE quadrant

AMODEL	BMODEL	STORM_ID	BASIN	CYCLONE	STORM_NAME	INIT	LEAD	VALID	INIT_MASK	VALID_MASK	LINE_TYPE	TOTAL	INDEX	LEVEL	WATCH_WARN	INITIALS	ALAT	ALON	BLAT	BLON	TK_ERR	X_ERR	Y_ERR	ALTK_ERR	CRTK_ERR
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	000000	20100623_060000	NA	NA	TCMPR	11	1	TS	NA	NA	11.40000	-93.60000	11.30000	-93.70000	8.40263	5.88257	5.99997	-2.87858	7.89256
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	120000	20100623_180000	NA	NA	TCMPR	11	2	TS	NA	NA	11.70000	-95.50000	11.90000	-95.60000	13.36013	5.87311	-11.99999	-8.15483	-10.57959
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	240000	20100624_060000	NA	NA	TCMPR	11	3	HU	NA	NA	11.80000	-97.40000	12.50000	-97.50000	42.40758	5.86551	-41.99999	-19.11107	-37.84869
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	360000	20100624_180000	NA	NA	TCMPR	11	4	HU	NA	NA	12.00000	-98.80000	12.80000	-99.00000	49.41009	11.71989	-48.00001	-18.54863	-45.78675
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	480000	20100625_060000	NA	NA	TCMPR	11	5	HU	NA	NA	12.10000	-99.80000	13.20000	-100.40000	74.76520	35.12605	-65.99997	-44.32520	-60.19218
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	600000	20100625_180000	NA	NA	TCMPR	11	6	HU	NA	NA	12.20000	-100.30000	13.60000	-101.30000	102.35516	58.48567	-84.00003	-90.40811	-47.94976
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	720000	20100626_060000	NA	NA	TCMPR	11	7	HU	NA	NA	12.60000	-100.70000	13.50000	-102.20000	102.97091	87.67560	-53.99998	-53.25324	-88.10950
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	840000	20100626_180000	NA	NA	TCMPR	11	8	HU	NA	NA	12.90000	-101.10000	13.50000	-102.70000	100.15700	93.46349	-36.00002	-93.44622	-35.99469
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	960000	20100627_060000	NA	NA	TCMPR	11	9	TS	NA	NA	13.10000	-101.00000	13.50000	-103.10000	124.94708	122.62045	-23.99998	-122.59808	-23.99716
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	1080000	20100627_180000	NA	NA	TCMPR	11	10	TS	NA	NA	13.20000	-100.30000	13.70000	-102.60000	137.52681	134.21484	-30.00000	122.48569	62.48257
EMXI	BEST	EP052010	EP	05	DARBY	20100623_060000	1200000	20100628_060000	NA	NA	TCMPR	11	11	TS	NA	NA	13.40000	-99.20000	14.10000	-101.30000	129.39545	122.38946	-42.00005	102.09042	79.46509
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	000000	20100623_180000	NA	NA	TCMPR	13	1	TS	NA	NA	11.90000	-95.60000	11.90000	-95.60000	0.00000	0.00000	0.00000	0.00000	0.00000
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	120000	20100624_060000	NA	NA	TCMPR	13	2	HU	NA	NA	12.30000	-97.50000	12.50000	-97.50000	11.99999	0.00000	-11.99999	-3.87452	-11.35500
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	240000	20100624_180000	NA	NA	TCMPR	13	3	HU	NA	NA	12.80000	-99.00000	12.80000	-99.00000	0.00000	0.00000	0.00000	0.00000	0.00000
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	360000	20100625_060000	NA	NA	TCMPR	13	4	HU	NA	NA	13.40000	-100.00000	13.20000	-100.40000	26.25872	23.35638	11.99999	-21.36358	15.26007
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	480000	20100625_180000	NA	NA	TCMPR	13	5	HU	NA	NA	14.10000	-101.00000	13.60000	-101.30000	34.71945	17.47684	30.00000	-1.82367	34.66526
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	600000	20100626_060000	NA	NA	TCMPR	13	6	HU	NA	NA	14.60000	-101.70000	13.50000	-102.20000	72.13155	29.10253	66.00002	-56.06016	45.36899
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	720000	20100626_180000	NA	NA	TCMPR	13	7	HU	NA	NA	14.50000	-102.40000	13.50000	-102.70000	62.49022	17.46506	60.00000	-17.46265	59.98899
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	840000	20100627_060000	NA	NA	TCMPR	13	8	TS	NA	NA	14.20000	-102.70000	13.50000	-103.10000	48.03120	23.30231	41.99999	-23.29863	41.99215
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	960000	20100627_180000	NA	NA	TCMPR	13	9	TS	NA	NA	14.10000	-102.50000	13.70000	-102.60000	24.69662	5.82421	24.00003	11.61810	-21.78814
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	1080000	20100628_060000	NA	NA	TCMPR	13	10	TS	NA	NA	14.50000	-101.40000	14.10000	-101.30000	24.69416	-5.81401	23.99998	2.29705	-24.58263
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	1200000	20100628_180000	NA	NA	TCMPR	13	11	LO	NA	NA	14.80000	-99.80000	14.30000	-98.90000	60.26582	-52.26824	30.00000	-49.49726	-34.36107
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	1320000	20100629_060000	NA	NA	TCMPR	13	12	LO	NA	NA	14.90000	-98.50000	14.90000	-97.10000	81.17568	-81.17568	0.00000	-75.67085	-29.34349
EMXI	BEST	EP052010	EP	05	DARBY	20100623_180000	1440000	20100629_180000	NA	NA	TCMPR	13	13	LO	NA	NA	15.10000	-97.90000	15.30000	-96.10000	104.91052	-104.22196	-11.99999	-98.04120	-37.28503
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	000000	20100624_060000	NA	NA	TCMPR	12	1	HU	NA	NA	12.50000	-97.50000	12.50000	-97.50000	0.00000	0.00000	0.00000	0.00000	0.00000
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	120000	20100624_180000	NA	NA	TCMPR	12	2	HU	NA	NA	12.80000	-98.70000	12.80000	-99.00000	17.55287	17.55287	0.00000	-17.36446	2.54317
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	240000	20100625_060000	NA	NA	TCMPR	12	3	HU	NA	NA	13.00000	-99.70000	13.20000	-100.40000	42.63102	40.90726	-11.99999	-42.20816	-5.93468
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	360000	20100625_180000	NA	NA	TCMPR	12	4	HU	NA	NA	13.20000	-100.70000	13.60000	-101.30000	42.45494	35.02029	-24.00003	-42.11151	-5.32855
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	480000	20100626_060000	NA	NA	TCMPR	12	5	HU	NA	NA	13.20000	-101.60000	13.50000	-102.20000	39.38145	35.02711	-18.00001	-22.90943	-32.02341
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	600000	20100626_180000	NA	NA	TCMPR	12	6	HU	NA	NA	13.10000	-102.30000	13.50000	-102.70000	33.48878	23.35594	-23.99998	-23.35144	-23.99594
EMXI	BEST	EP052010	EP	05	DARBY	20100624_060000	720000	20100627_060000	NA	NA	TCMPR	12	7	TS	NA	NA	12.80000	-102.80000	13.50000	-103.10000	45.51066	17.52773	-41.99999	-17.52406	-41.99264

Tc_stat



- Provides summary statistics and filtering jobs on TCST output
- Filter job:
  - Stratifies pair output by various conditions and thresholds
- Summary job:
  - Produces summary statistics on specific column of interest
- Input: TCST output from tc_pairs
- Output: TCST output file for either filter or summary job

Tc_stat

- Usage: **`tc_stat -lookin source`**

```
[-out file]
[-log file]
[-v level]
[-config file] | [JOB COMMAND LINE]
```

➢ Configuration file options will be applied to every job, unless an individual job specifies a configuration option – joblist options will override

-lookin source	Location of TCST files generated from tc_pairs
-out file	Desired name of output file
-log file	Name of log file associated with tc_stat output
-v level	Verbosity level
-config file	Configuration file to be used
Job command line	specify joblist on command line

Tc_stat

- Configuration file will filter TCST output from tc_pairs to desired subset over which statistics will be computed

AMODEL/BMODEL	INIT_MASK/VALID_MASK	LANDFALL
STORM_ID	LINE_TYPE	LANDFALL_BEG (END)
BASIN	TRACK_WATCH_WARN	MATCH_POINTS
CYCLONE	COLUMN_THRESH_NAME (VAL)	EVENT_EQUAL
STORM_NAME	COLUMN_STR_NAME (VAL)	OUT_INIT_MASK
INIT_BEG/INIT_END	COLUMN_STR_NAME (VAL)	OUT_VALID_MASK
INIT_INC/INIT_EXC	INIT_THRESH_NAME (VAL)	JOBS [ ]
VALID_BEG/VALID_END	INIT_STR_NAME (VAL)	VERSION
VALID_INC/VALID_EXC	WATER_ONLY	
INIT_HR/VALID_HR/LEAD	RAPID_INTEN (THRESH)	

```
//
// Stratify by the ADECK and BDECK
distances to land.
//
water_only = FALSE;

//
// Specify whether only those track
points for which rapid intensification
// occurred in the BDECK track between
the current time and 24-hours prior
// should be retained.
//
rapid_inten        = FALSE;
rapid_inten_thresh = >=30.0;

//
// Specify whether only those track
points occurring near landfall should be
// retained, and define the landfall
retention window as a number of seconds
// offset from the landfall time.
//
landfall     = FALSE;
landfall_beg = -86400;
landfall_end = 0;

//
// Specify whether only those track
points common to both the ADECK and
BDECK
// tracks should be retained.  May
modify using the "-match_points" job
command
// option.
//
match_points = TRUE;

//
// Specify whether only those cases
common to all models in the dataset
should
// be retained.
//
event_equal = TRUE;
```

Tc_stat

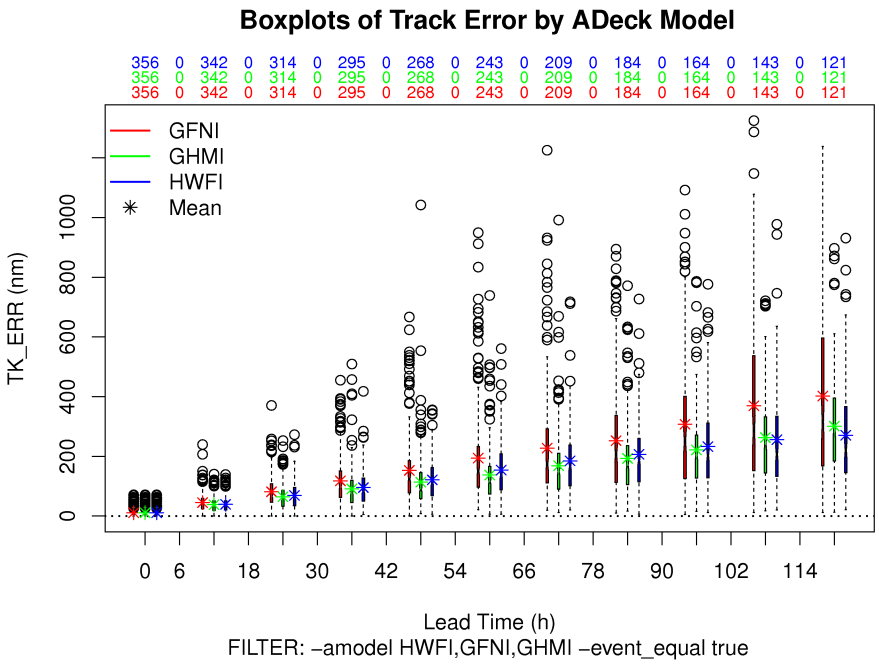
- TC_stat output similar to TC_pairs for filter job (TCSTAT)
- Summary job output
  - "-column" option produces summary statistics for the specified column
  - "-by" option can be used to search each unique entry in selected column

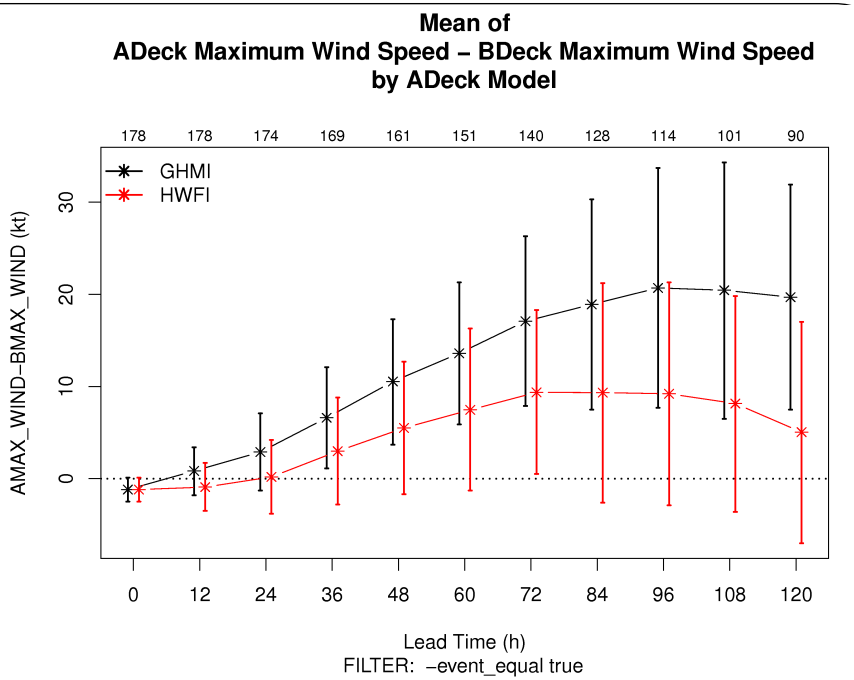
Column number	Description
1	SUMMARY: (job type)
2	Column (dependent parameter)
3	Case (storm + valid time)
4	Total
5	Valid
6-8	Mean including normal upper and lower confidence limits
9	Standard deviation
10	Minimum value
11-15	Percentiles (10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th})
16	Maximum Value
17	Sum
18-19	Independence time
20-23	Frequency of superior performance

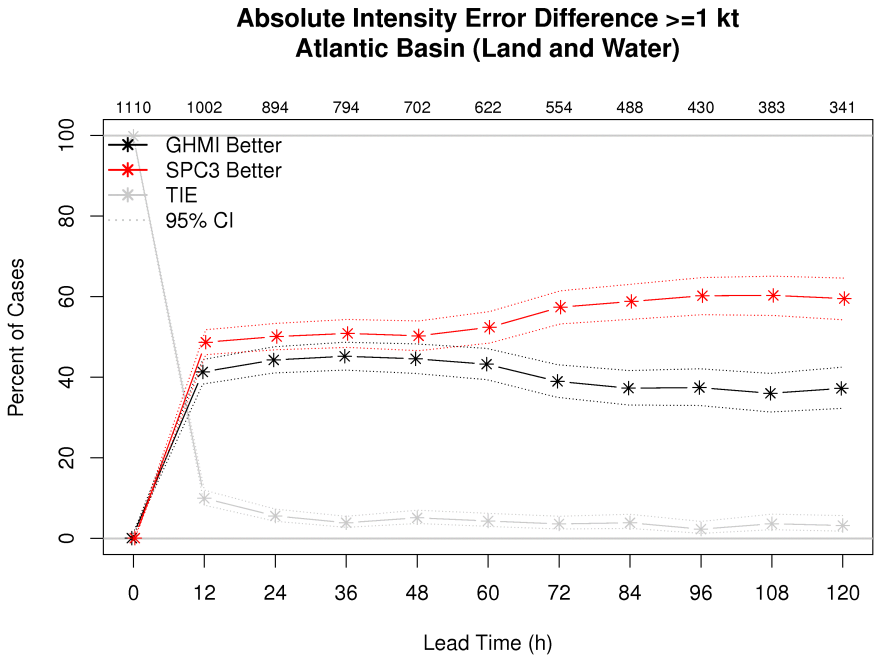
Graphics tools

- Graphical capabilities are included in the MET-TC release
  - `plot_tcmpr.R`
- Input: TCSTAT tc_pairs output
- Output: R graphics, tc_stat logs/filter job TCSTAT (optional)
- Usage: `Rscript plot_tcmpr.R –lookin`
  - -filter (specify filter job)
  - -config (run filter job w/ configuration file)
    - Default Rscript configuration file included in release

Graphics tools







- For code download and user's guide:

  www.dtcenter.org/met/users

- Contact for questions, help, comments:

  met_help@ucar.edu