Improvements in Statistical Tropical Cyclone Forecast Models:
A Year 2 Joint Hurricane Testbed Project Update

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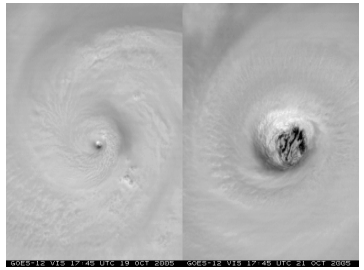
Interdepartmental Hurricane Conference
March 2013



Outline

- Project Tasks
  1. Extended range baseline models for track and intensity
  2. Update of SHIPS/LGEM databases using new NCEP Climate Re-analysis
  3. Extending LGEM to 7 days
  4. SHIPS/LGEM specific for the Gulf of Mexico
- Progress so far
- Plans for 2013 season

1. New Baseline Forecast Models

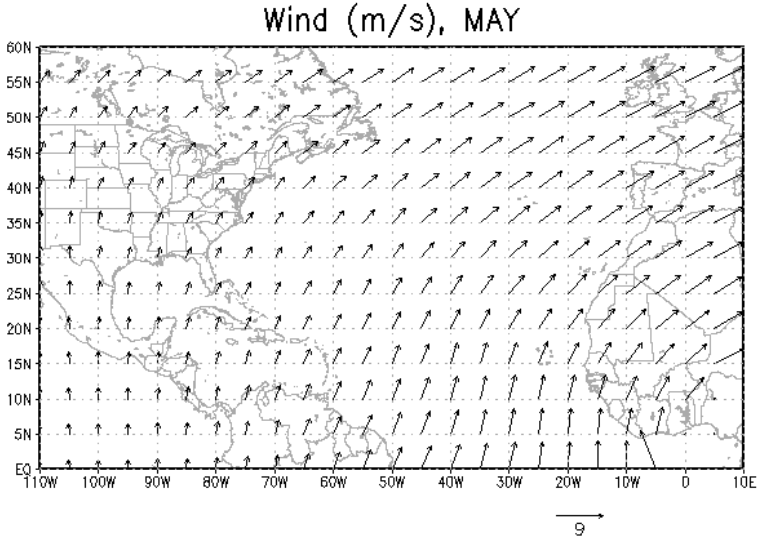
- CLIPER and SHIFOR used as baseline for measuring track and intensity forecast skill
  - Errors provide estimate of forecast difficulty
- Input to linear regression equations
  - t = 0 h max wind, lat, lon, motion vector
  - t =-12h max wind, lat, lon, motion vector
  - Julian Day
- Output
  - 5-day forecast of lat, lon, max wind
- Decay-SHIFOR modifies intensity over land using CLIPER track and climatological decay rate

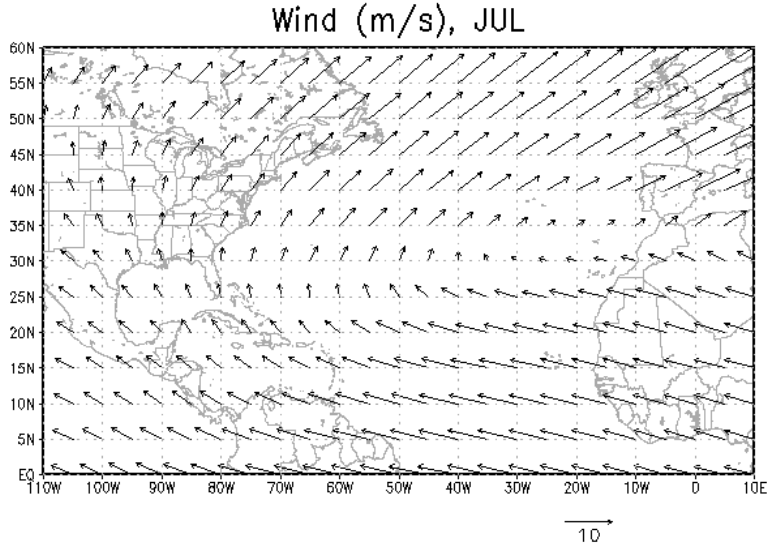
Trajectory Approach for Baseline Models (T-CLIPER)

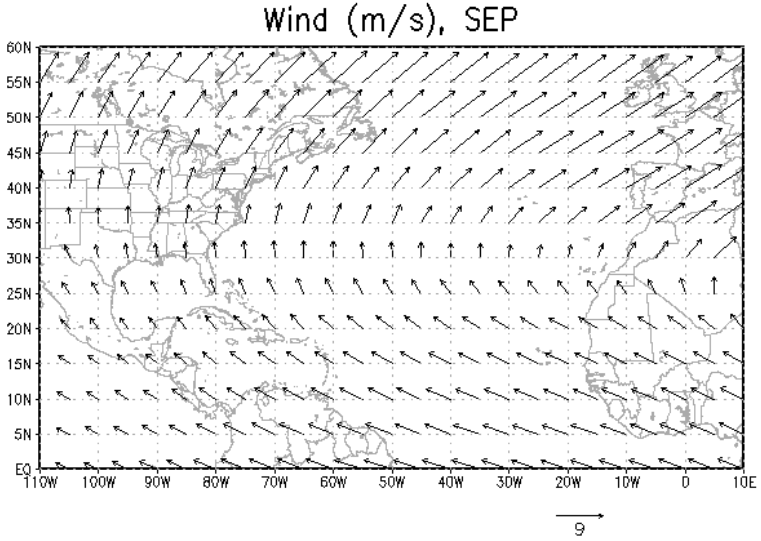
$$dx/dt = u \qquad dy/dt = v \qquad (1)$$

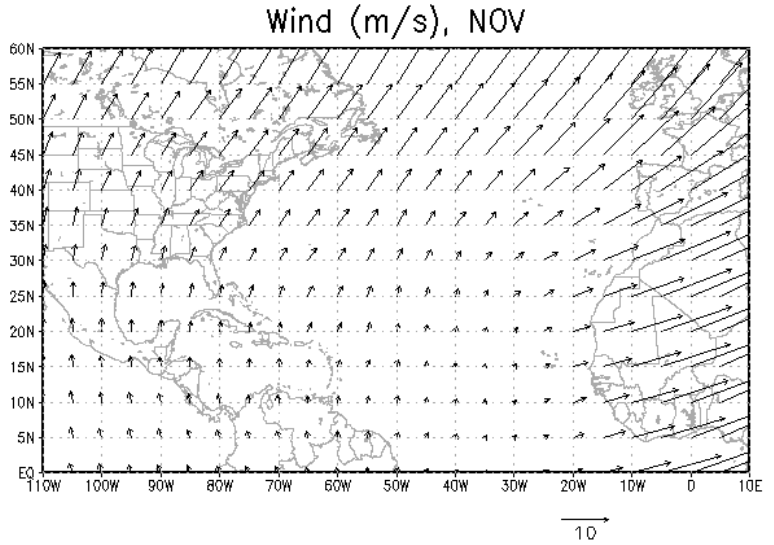
- Estimate u,v from climatological motion vector fields
- Modify u,v at early times using t=0 motion vector
- Integrate (1) to desired time
- Similar approach for intensity using LGEM prediction equation with climatological input and T-CLIPER track
- Can be run to any forecast time until storm leaves model domain

Mean Storm Motion Fields from 1982-2011 Sample





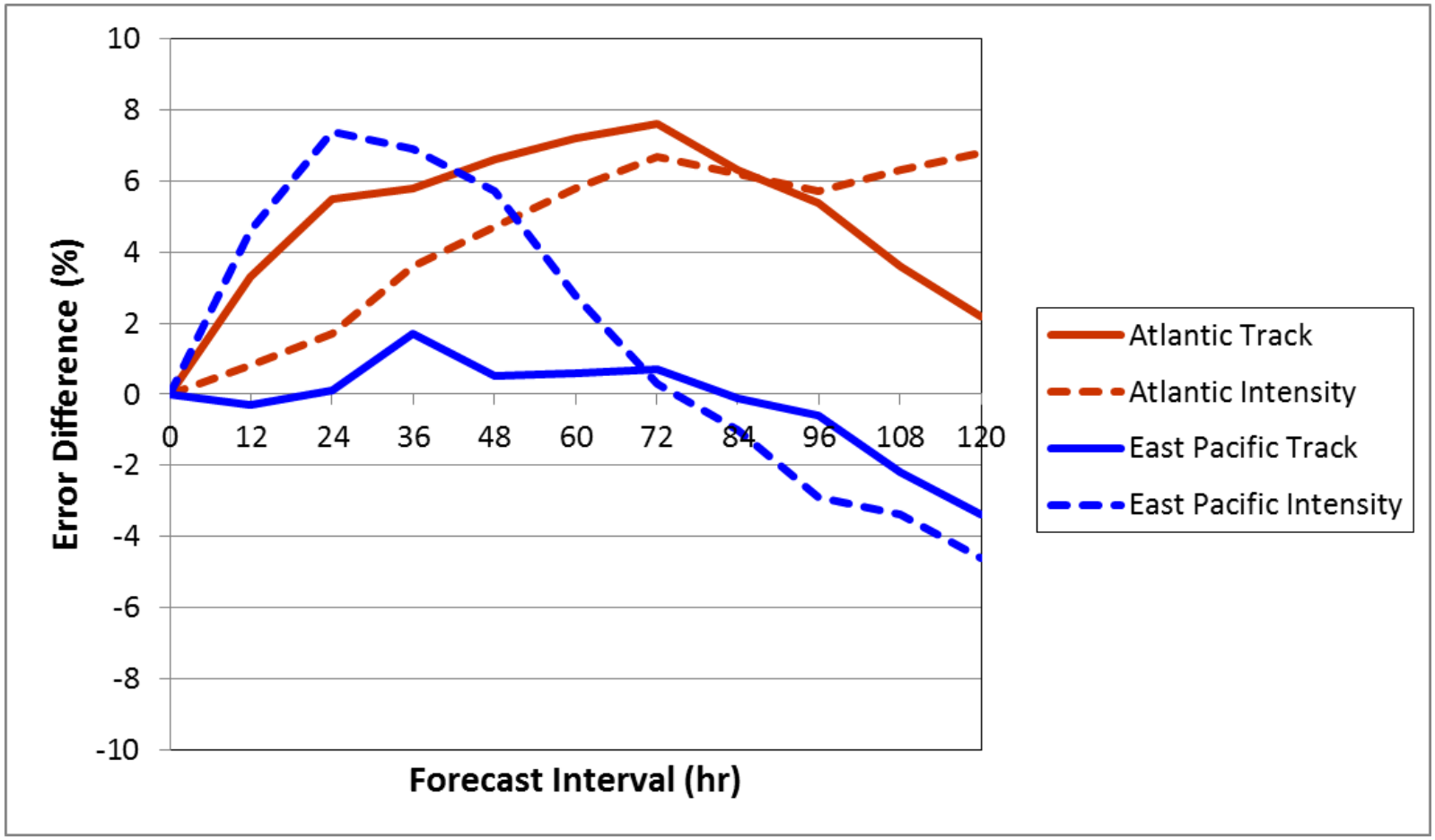




T-CLIPER Tests

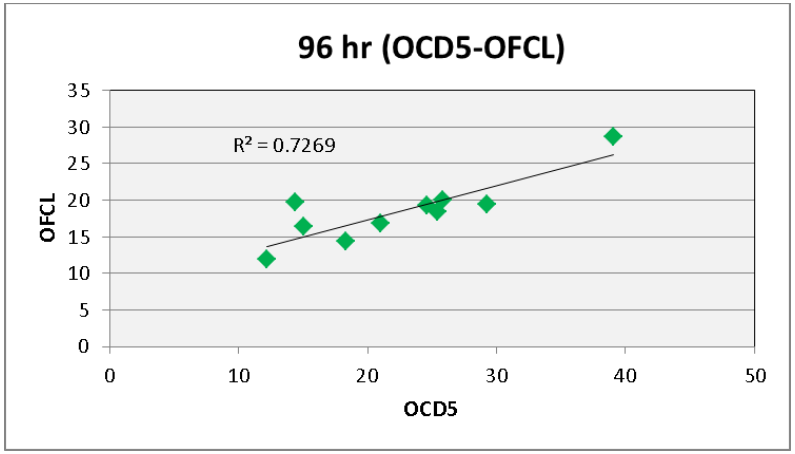
- Run in real time for most of 2012 season
- Re-runs for 2003-2011 using CARQ input
- Evaluation questions
  - How do average errors compare with OCD5 to 5 days?
  - Are annual average T-CLIPER errors correlated with NHC OFCL forecast errors?
  - What is the error behavior beyond 5 days?

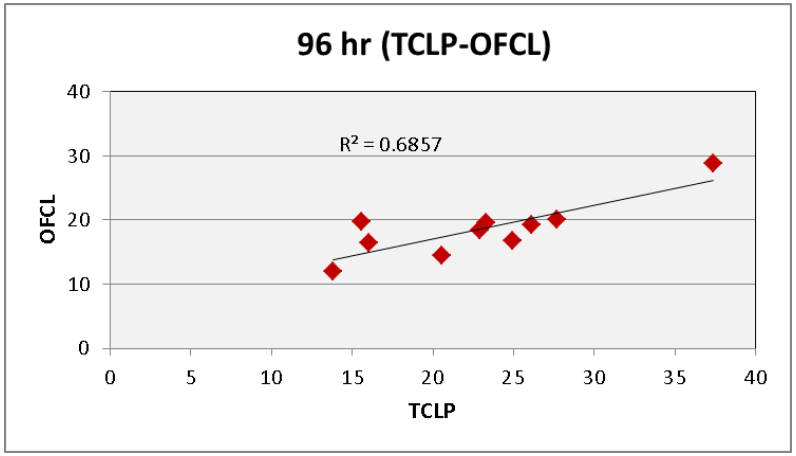
Comparison of T-CLIPER and OCD5 10-year Average Errors



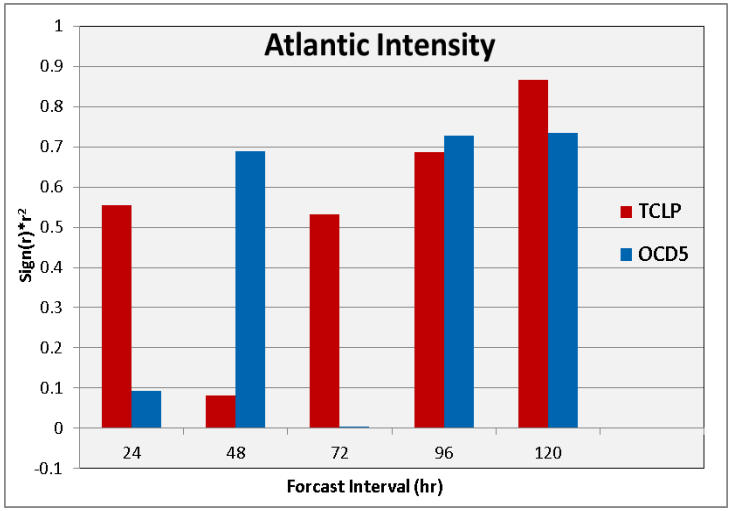
Correlation of Annual OCD5 and T-CLIPER Errors with OFCL

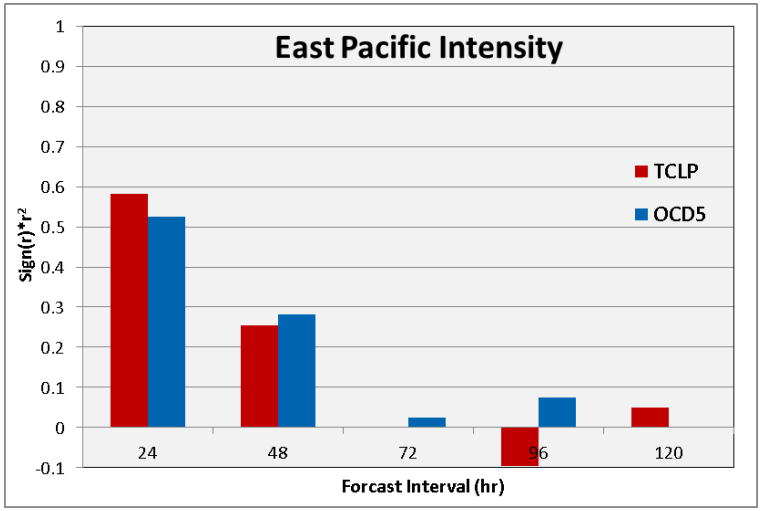
- Correlate OCD5 and OFCL annual errors for 10 year sample
- Repeat for T-CLIPER and OFCL
- Plot r^2 versus forecast interval
  - Plot r^2 as negative if r is negative

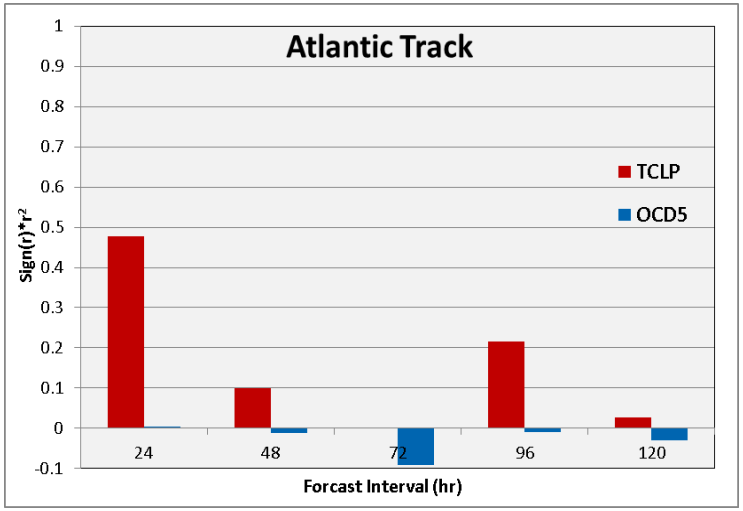


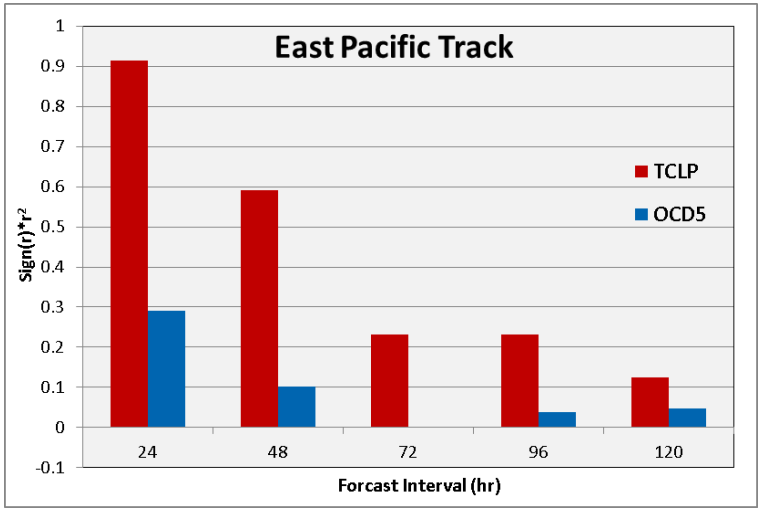


Variance of OFCL Errors Explained by OCD5 and T-CLIPER

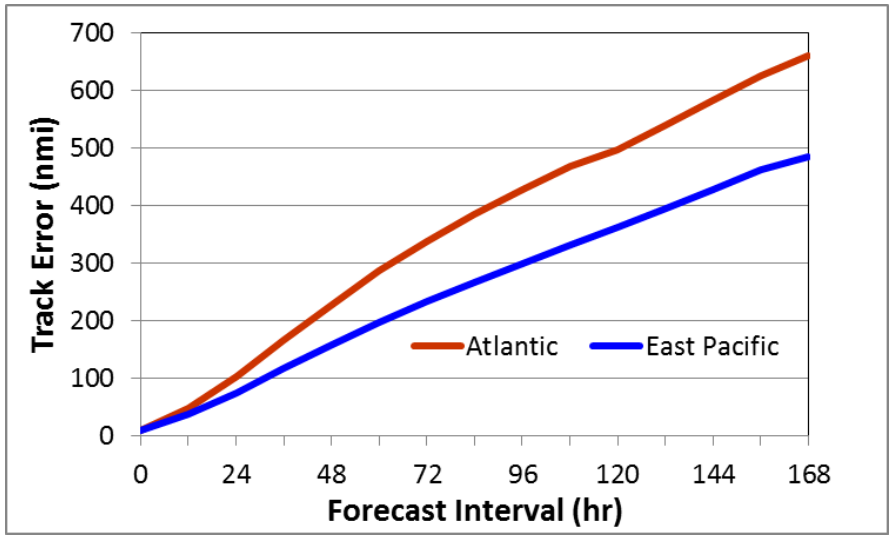




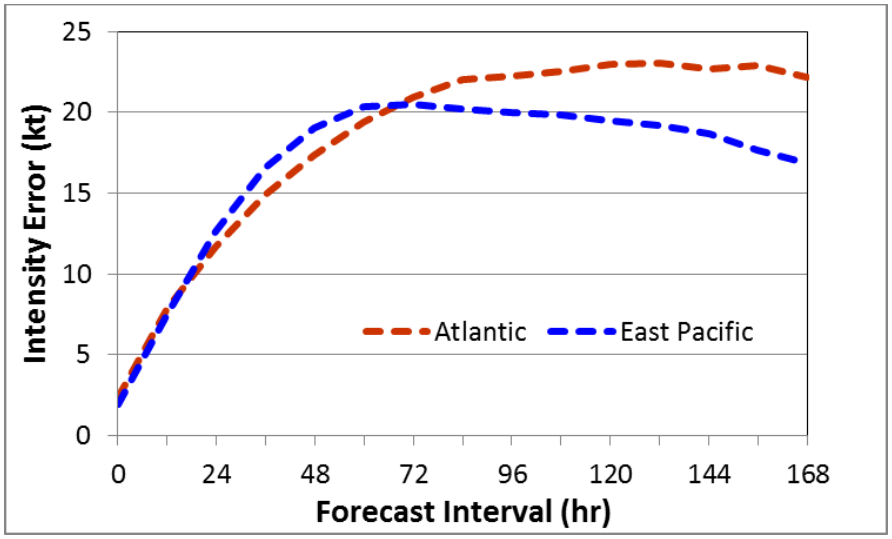




10-Year Average T-CLIPER Errors



Track

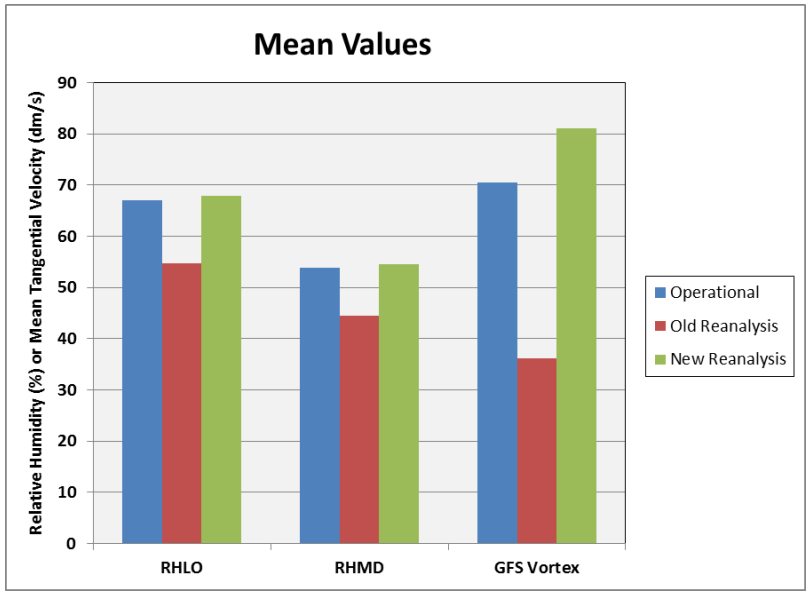


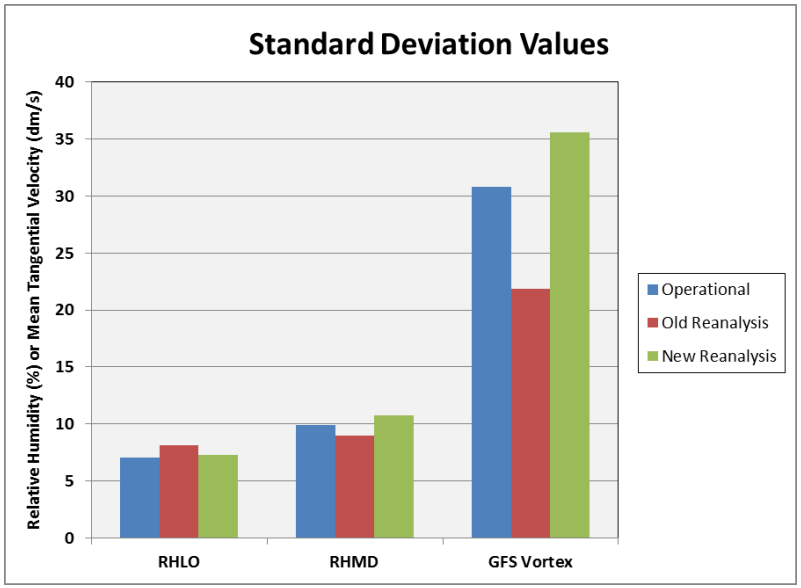
Intensity

2. New Climate Reanalysis Fields

- New NCEP CFSR reanalysis fields obtained for 1979-2009
  - 0.5^{o} lat/lon grib files
- Current SHIPS database
  - 1982-1999 Old NCEP reanalysis (2.5^{o})
  - 2000-2011 Operational GFS analyses (2^{o})
    - Inconsistency of RH and GFS vortex parameters
    - Old reanalysis not used in RII
      - Incomplete operational analyses used for 1989-1999
- 2000-2009 – New, Old reanalysis and Operational analyses all available

Comparison of SHIPS Predictors for Different Analyses (2000-2009 Atlantic Sample)





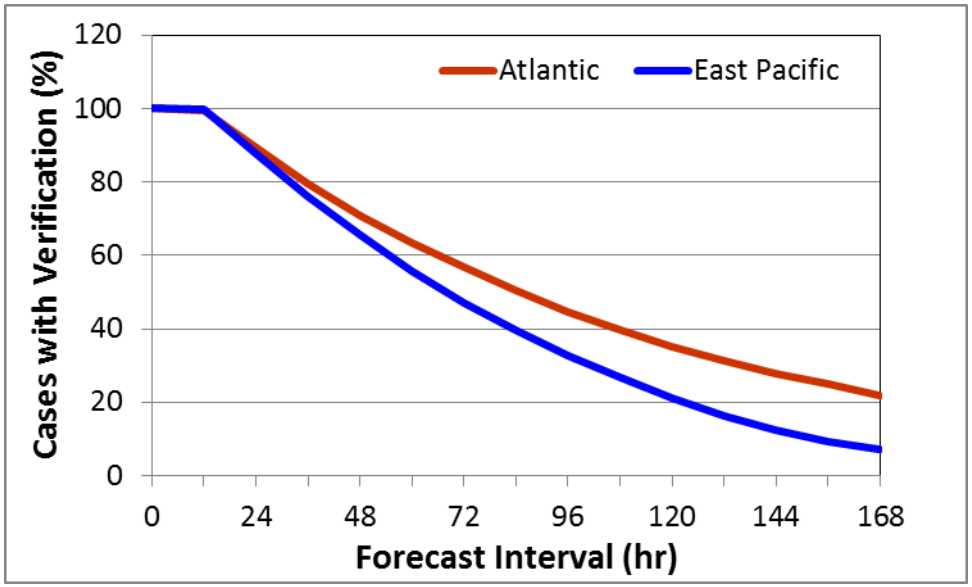
RHLO = 850-700 hPa RH r=200 to 800 km
RHMD = 700-500 hPa RH r=200 to 800 km
GFS Vortex = 850 hPa tangential wind, r= 0 to 600 km

New SHIPS Database

- 1979-2009: New NCEP reanalysis (1^{o})
- 2010-2012: Operational GFS analysis (1^{o})
- 2013 SHIPS, LGEM and RII will all use the same database

3. Seven-Day LGEM

- Small sample size beyond 5 days makes fitting difficult
- Use new formulation of LGEM that fits entire forecast at once



2003-2012 Sample

Comparison of Fitting Methods

- LGEM Equation: $dV/dt = \kappa V - \beta(V/V_{mpi})^n V$

  β, n, V_{mpi} known or specified, need to find κ

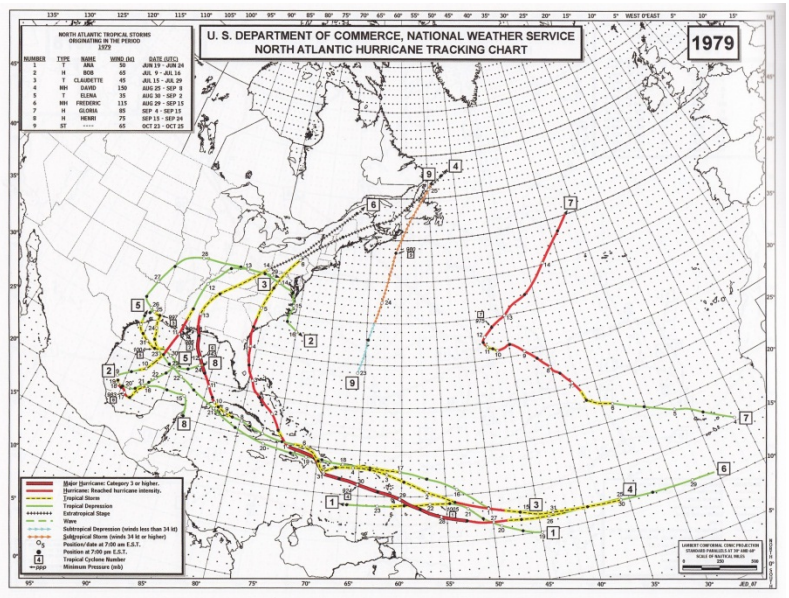
- Old fitting method
  - Solve for κ: $\kappa = (1/V)dV/dt + \beta(V/V_{mpi})^n V$
  - Calculate κ from best track
  - Fit best track κ to predictors using least squares at each forecast period (6, 12 …, 168 h)
- New fitting method
  - Define "cost" function $E = \frac{1}{2}\int(V_{fcst}-V_{obs})dt$
  - Find single set of κ coefficients to minimize E
    - Requires adjoint of LGEM equation for fitting

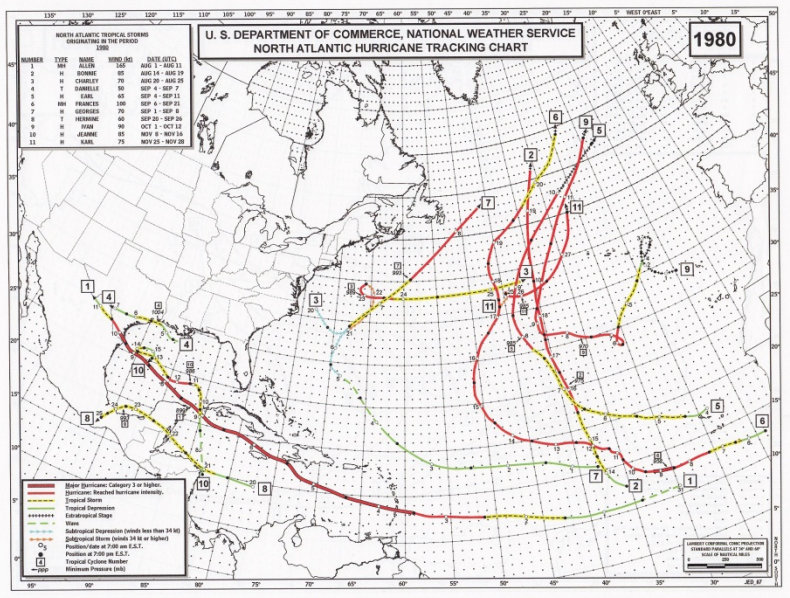
Features of 7-Day LGEM

- Adjoint minimization instead of least squares fit to κ
  - Need to reduce predictor set for efficiency
- Replace simple empirical MPI function with theoretical Bister and Emanuel (2003) formula
  - Can incorporate SST cooling and entrainment in MPI formula
- Include persistence and GOES data through modification of κ at early times
  - Similar to T-CLIPER approach

4. Gulf of Mexico LGEM

- Rappaport et al. (2010) showed Gulf storms have consistent behavior
  - Gulf-specific SHIPS/LGEM may improve skill
- Gulf sample size very small, especially beyond 72 h
  - Use same formulation as 7-Day LGEM
  - Add new Gulf cases from 1979-1980





Plans for 2013 Hurricane Season

- Run standard 5-day SHIPS/LGEM
- Run parallel 7-day LGEM with new formulation
  - Includes Gulf-specific version
- Pre-season tests
  - Run on HFIP stream 1.5 retrospective cases
    - 2010-2012 sample
      - Only 2012 to 7 days since NHC track needed
  - Run for 2008-2009 cases with recon

Summary

- T-CLIPER provides new extended range forecast baseline
  - Errors within +8% to -5% of OCD5 to 5 days
  - Predicts OFCL intensity error similar to OCD5
  - Predicts OFCL track errors better than OCD5
- New NCEP reanalysis provides more consistent and higher resolution developmental sample
- 7-day and Gulf-specific LGEM to be run in parallel in 2013 season
- SHIPS/LGEM/RII being developed for W. Pacific, Indian Ocean and S. Hemisphere
- *Acknowledgement: This NOAA Joint Hurricane Testbed project was funded by the US Weather Research Program in NOAA/OAR's Office of Weather and Air Quality*