A HYBRID STATISTICAL-DYNAMICAL APPROACH TO TROPICAL CYCLONE WIND SPEED PROBABILITIES

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Workshop on Effective Use of Hurricane Ensembles
17 Nov 2015, Miami, FL

Outline

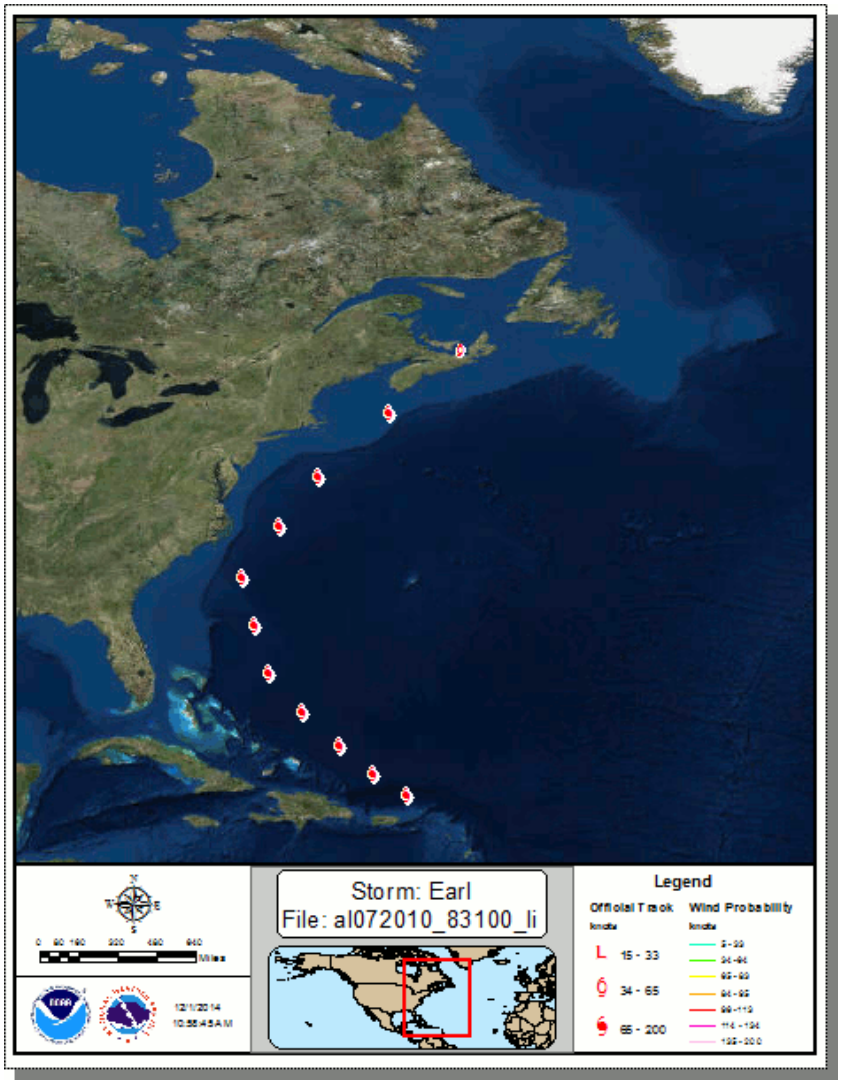
- Overview of the Monte Carlo wind speed probability model (MC Model)
  - How uncertainty is currently incorporated
- Incorporation of global model tracks – hybrid statistical dynamical MC Model
  - Methodology
  - Real-time display
- Verification

Overview of the MC Model

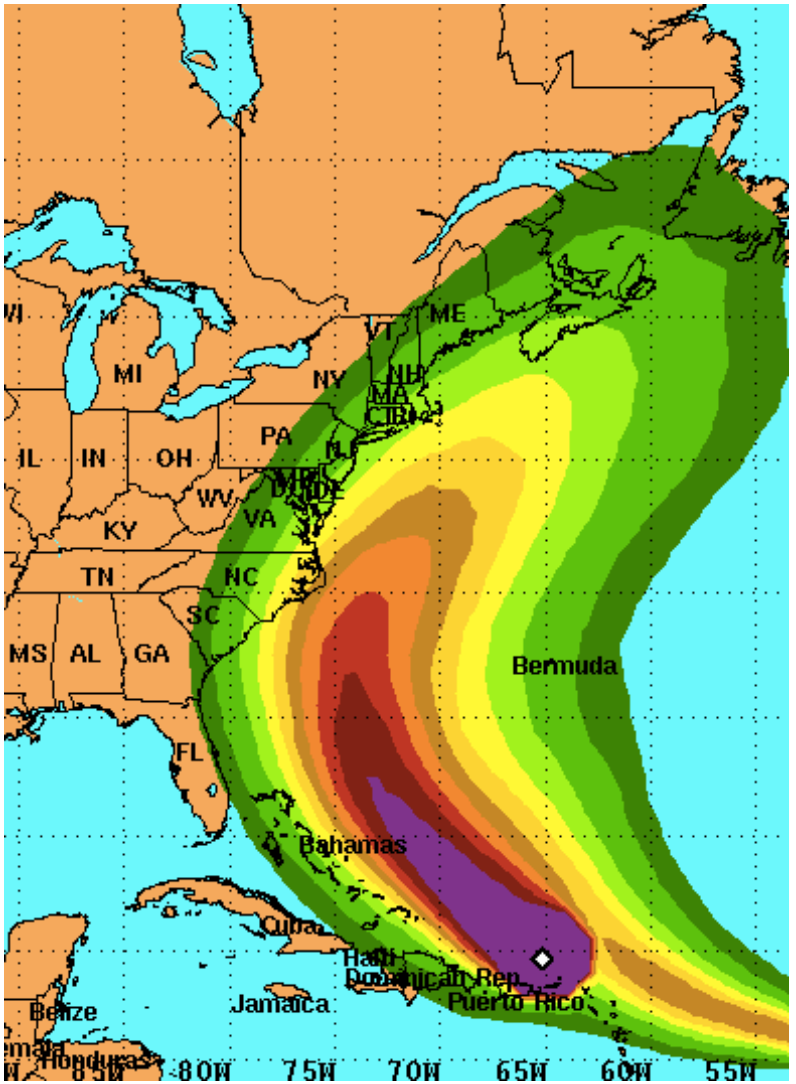
MC Model Basics

- Estimates probability of 34-, 50- and 64-kt winds to 5 days
- 1000 track realizations generated from random sampling NHC track and intensity error distributions
- Wind radii of realizations from radii CLIPER model and its radii error distributions
- Serial correlation of errors included
- Probability at a point computed by counting the number of realizations passing within the wind radii of interest
- Developed under JHT, implemented in 2006, several updates since (incorporation of GPCE)

MC Model Example
Hurricane Earl 31 Aug 2010 00 UTC



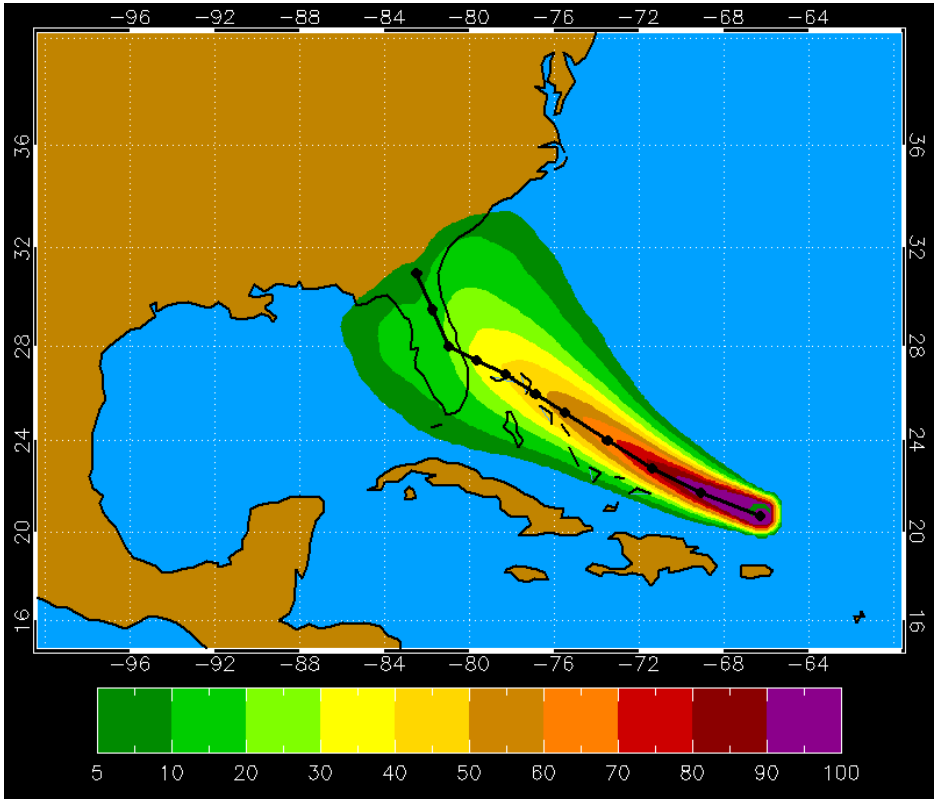
1000 Track Realizations



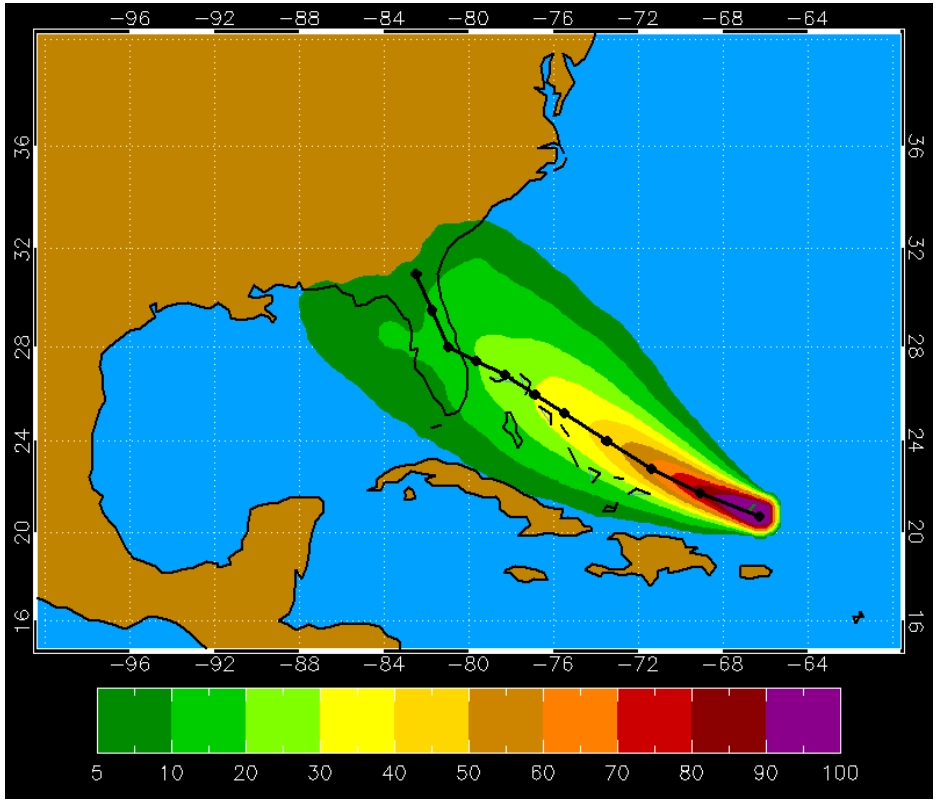
34 kt 0-120 h Cumulative Probabilities

How situation-specific track uncertainty is incorporated now

- Sample different track forecast error distributions based on GPCE tercile (low/avg/high)



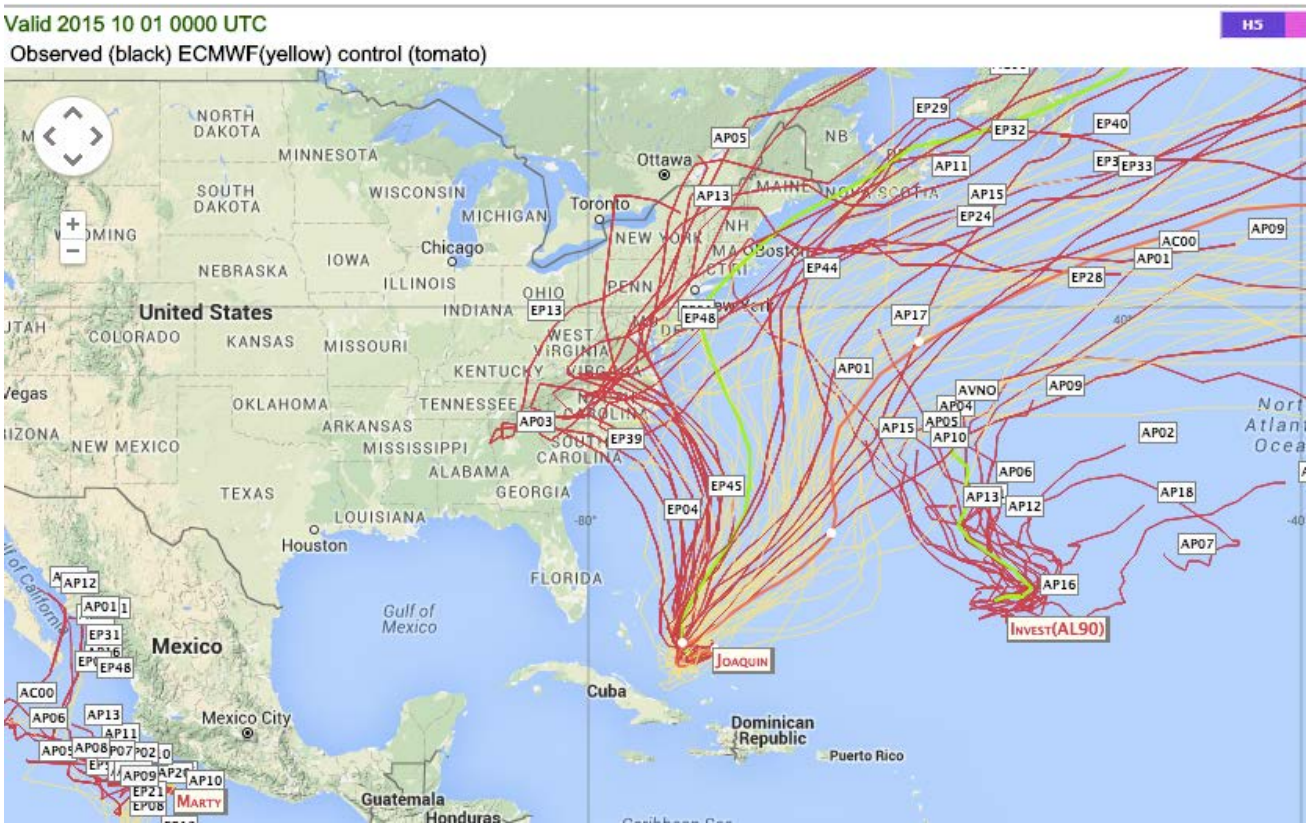
Lower GPCE



Higher GPCE

Incorporating ensembles

- Current method anchored to deterministic NHC forecast
- Unable to represent multiple track scenarios (be design)



Example:

Joaquin (AL112015)
1 Oct 2015 00 UTC

GFS ens (red)
ECMWF ens (yellow)

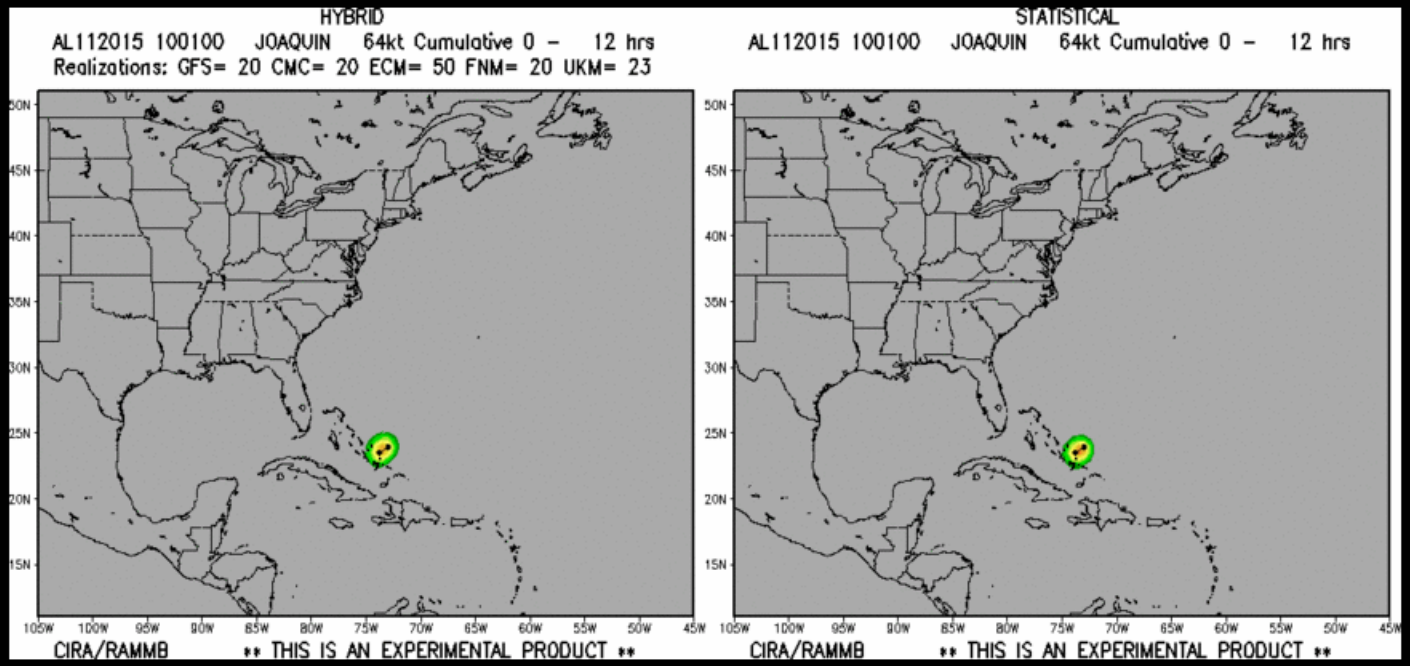
Data

- Tropical cyclone advisories and forecasts
  - a-decks, b-decks and e-decks
- Global numerical model ensemble forecasts
  - GFS (20 members)
  - CMC (20 members)
  - ECMWF (50 members)
  - FNMOC (20 members)
  - UKMET (23 members)
  - 133 model track forecasts total

Methods

- Replaced track realizations with global model ensemble tracks
  - 1000 → 133 realizations
- Intensity and radii same as statistical version
- Atlantic, NE Pacific, NW Pacific basins
- Runs on numbered invests (not verified)
- Latency ~ 6-12 hrs
  - Runs as soon as first ensembles are available
  - Keeps updating until all are available
- Runs at 0 and 12 UTC

Real-time hybrid WSPs



http://www.hfip.org/data/

Display of: Ensemble probability

Select model: Windspeed probability thresholds

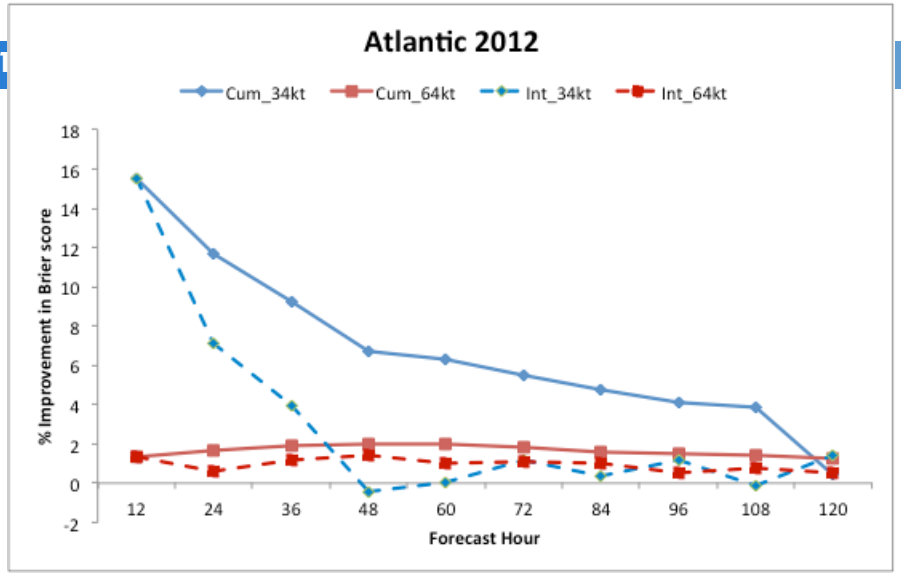
2012-2014 Verification

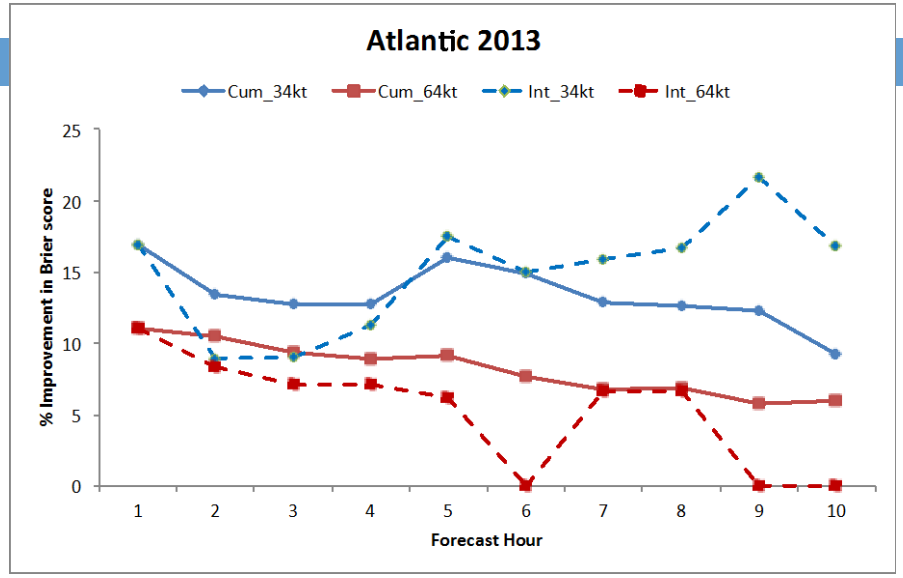
Brier scores

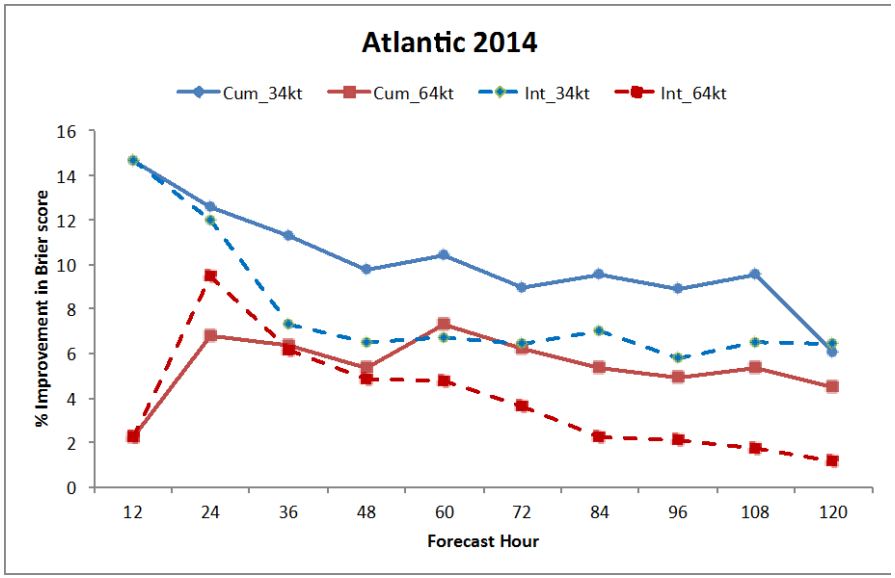
Reliability

Atlantic, NE Pacific, NW Pacific basins

% Reduction in Brier scores - Atlantic

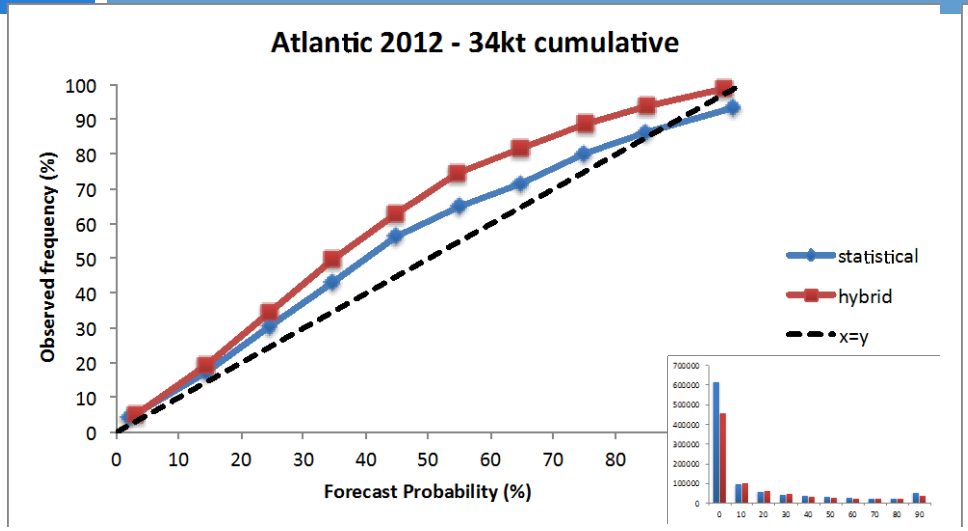


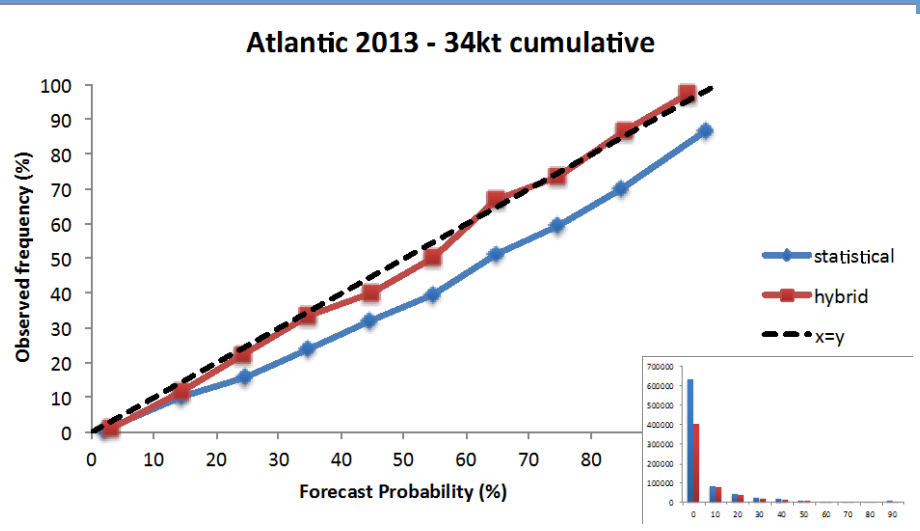


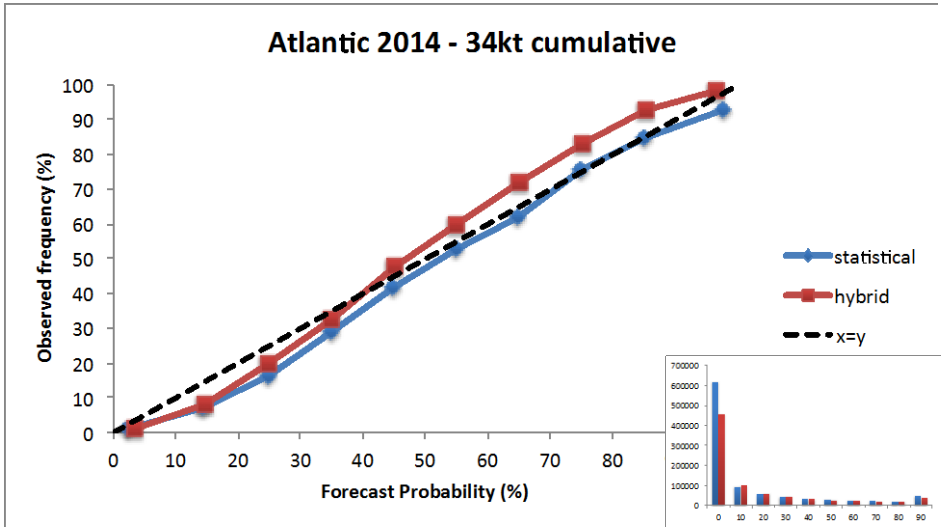


Both 34-kt and 64-kt, all years:
Hybrid Brier scores < statistical Brier scores
(i.e., magnitude of errors is smaller)

Reliability – Atlantic (34kt 0-120h Cum)



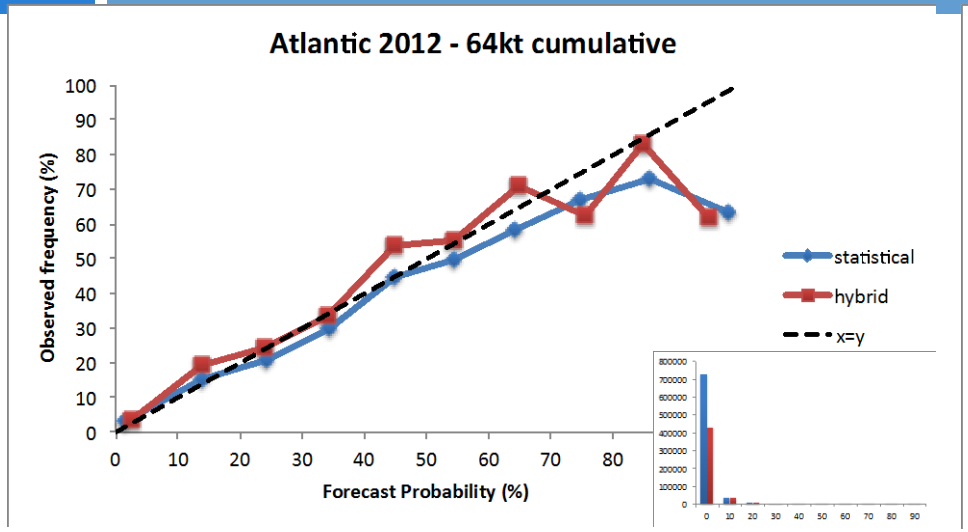


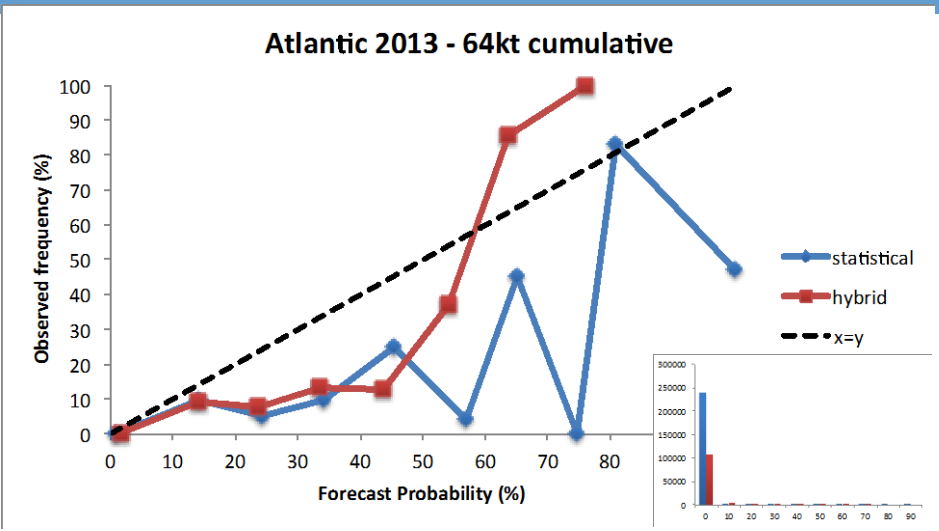


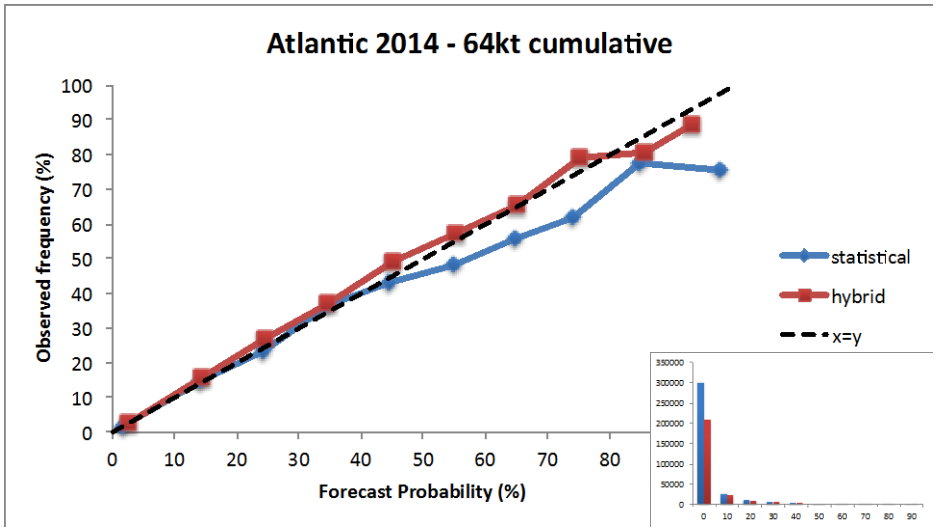
Statistical: tendency to underforecast, especially higher probabilities (although 2013 was almost perfect – lots of weaker Atlantic systems)

Hybrid: underforecasts more than statistical

Reliability – Atlantic (64kt 0-120h Cum)



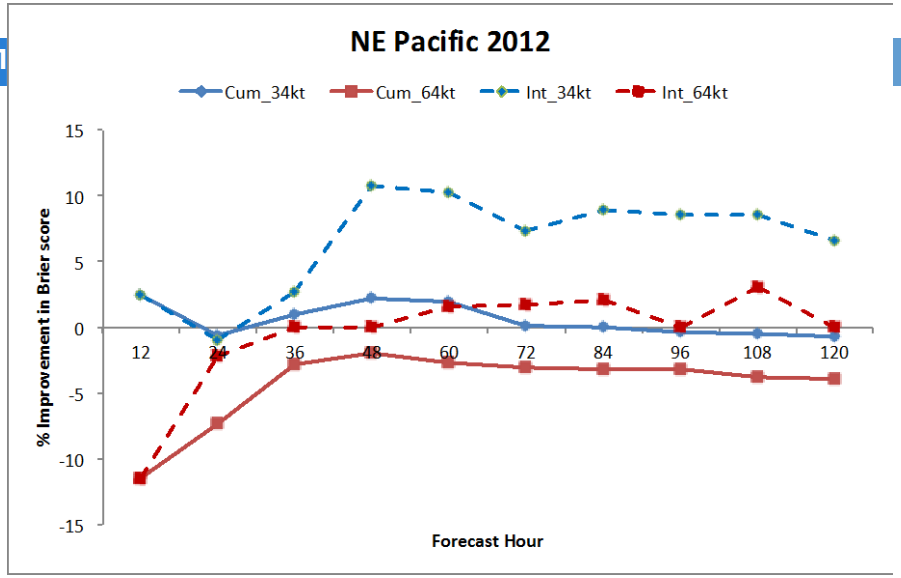


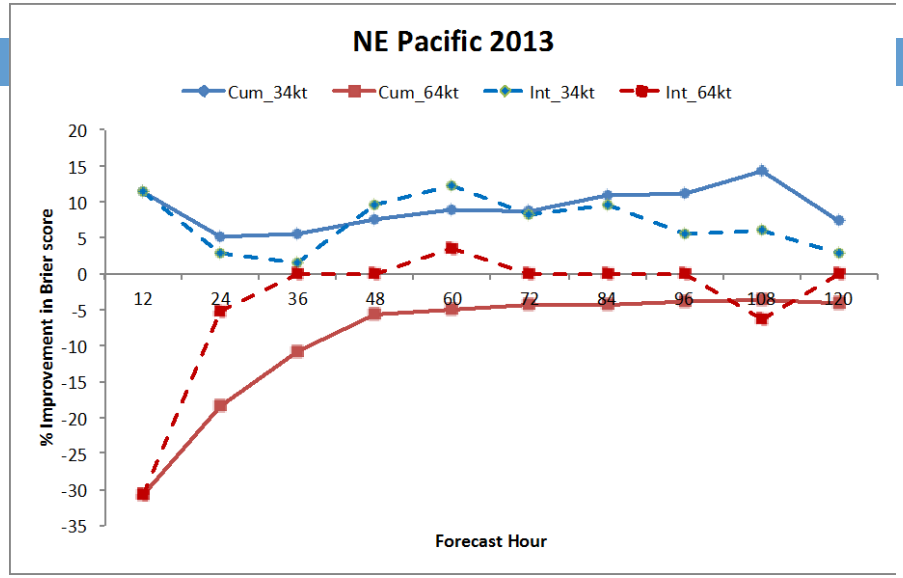


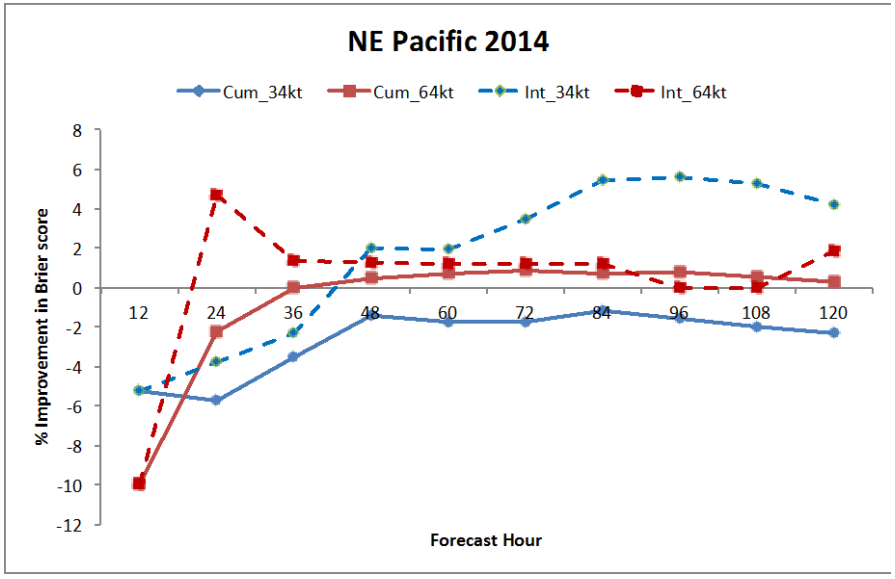
Statistical: tendency to overforecast, especially for higher probabilities

Hybrid: better reliability

% Reduction in Brier scores – NE Pacific



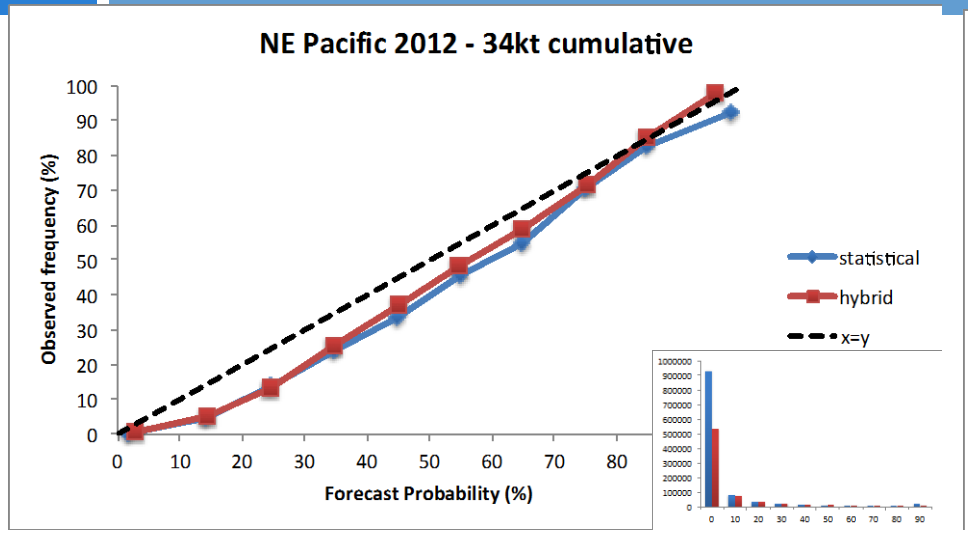


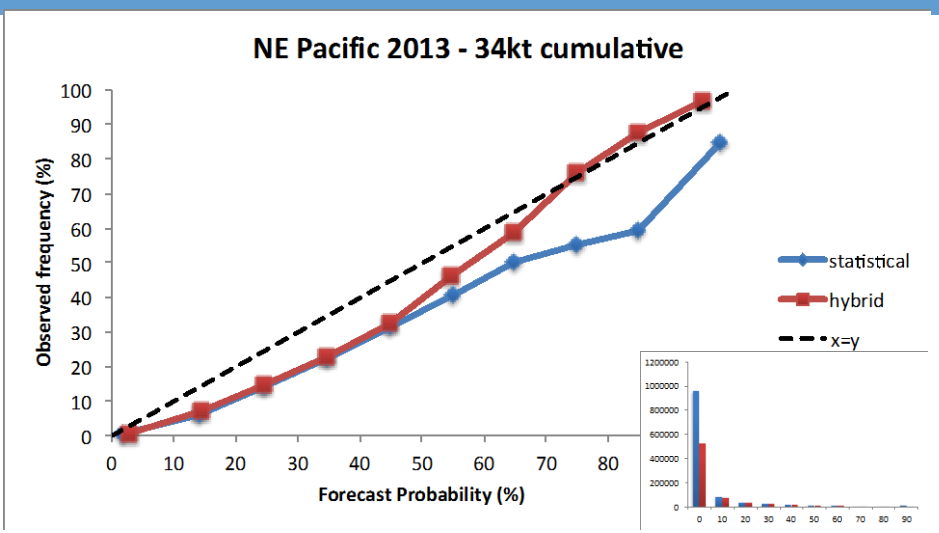


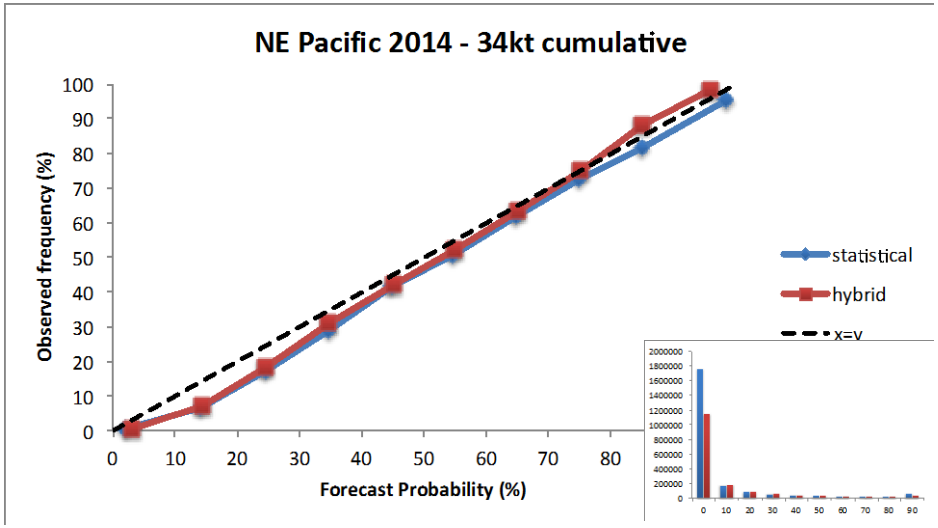
34-kt cumulative and incremental:
Hybrid BS < statistical BS
(i.e., magnitude of errors is smaller)

64-kt cumulative and incremental:
Hybrid BS ≥ statistical BS
(i.e., magnitude of errors is larger)

Reliability – NE Pacific (34kt 0-120h Cum)



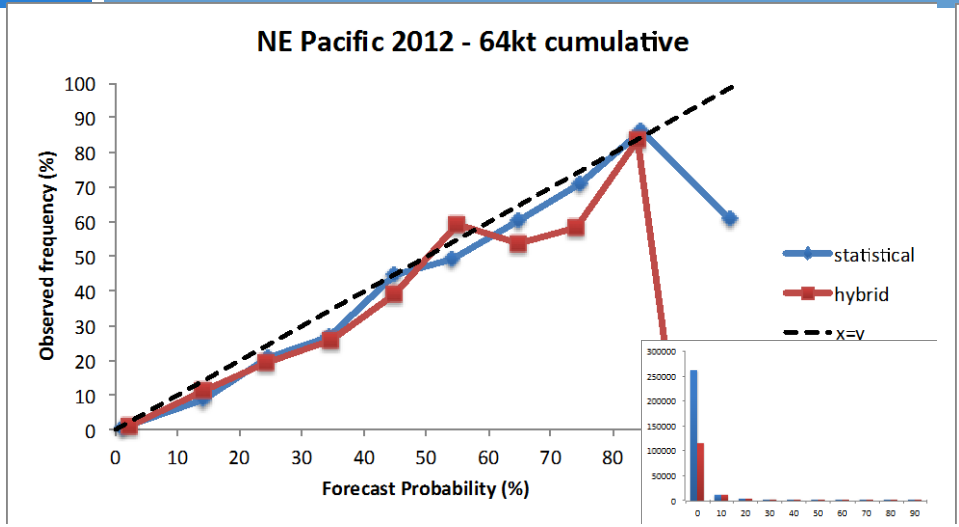


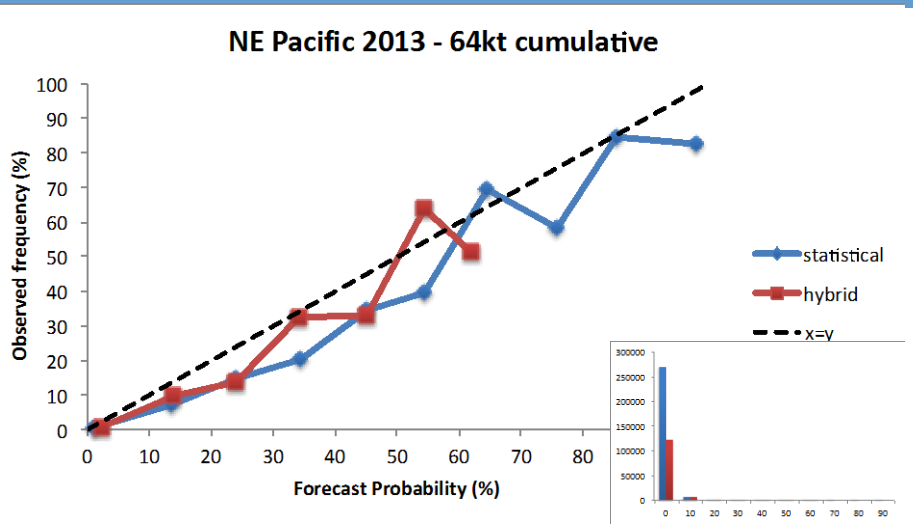


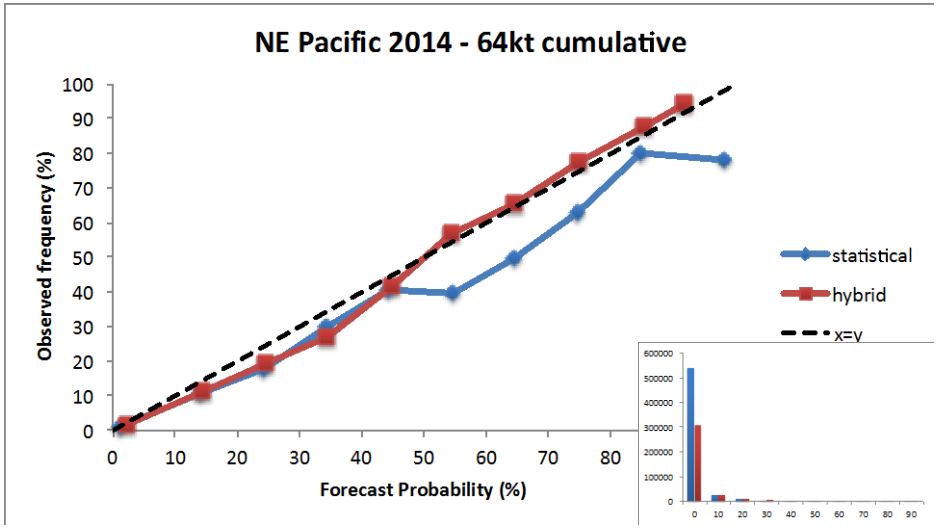
Statistical: consistently overforecasts

Hybrid tendency to underforecast improves reliability

Reliability – NE Pacific (64kt 0-120h Cum)



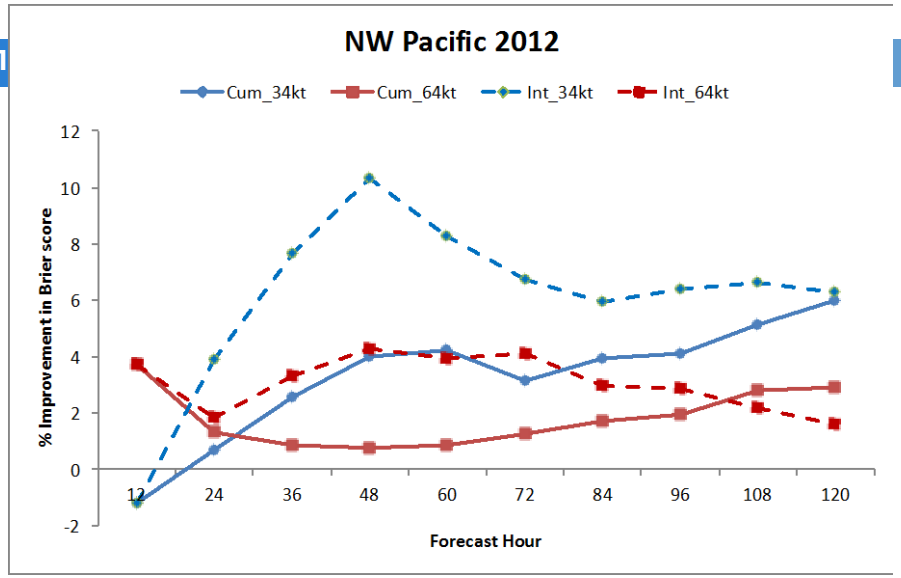


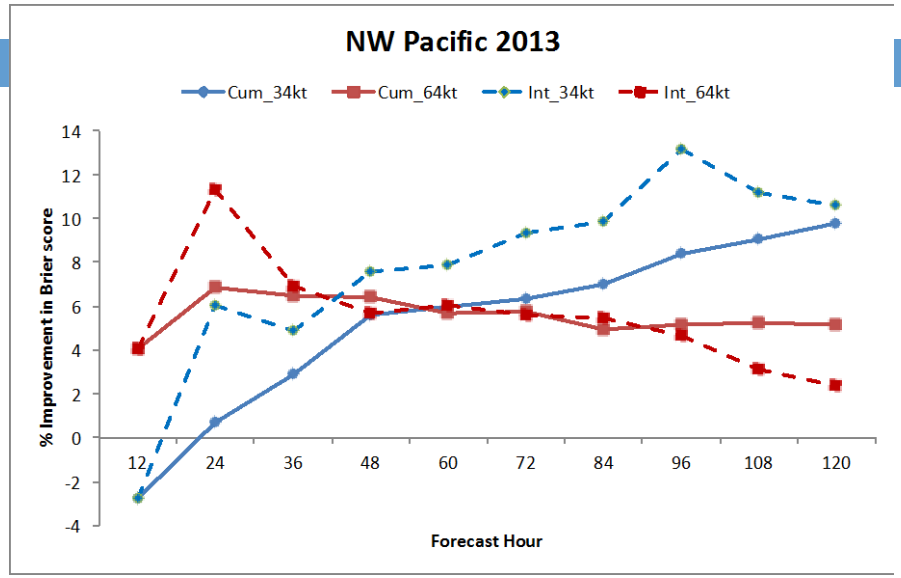


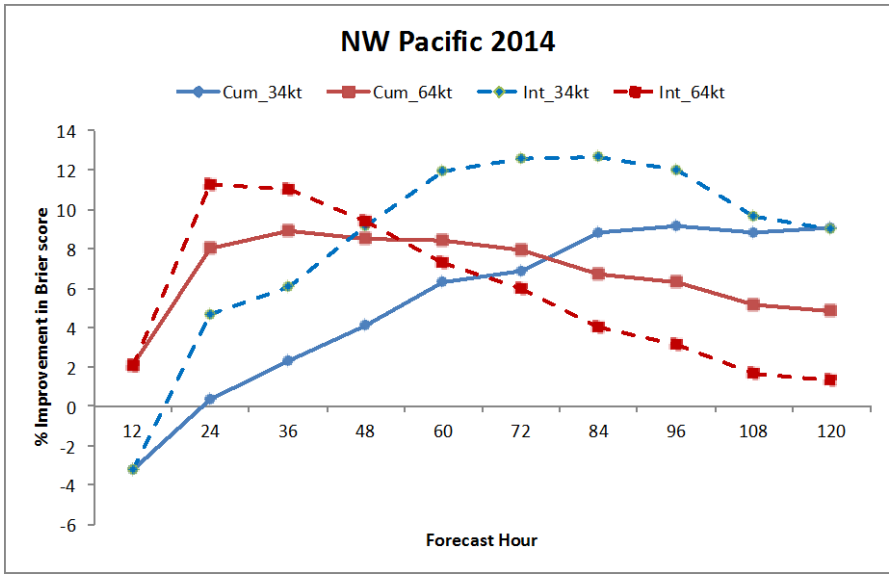
Statistical: slight tendency to overforecast

Hybrid: better reliability

% Reduction in Brier scores – NW Pacific







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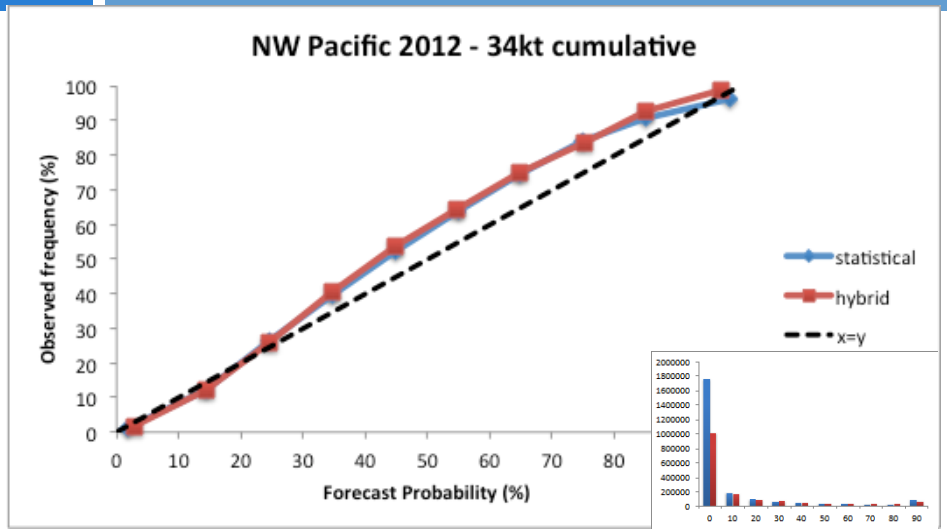
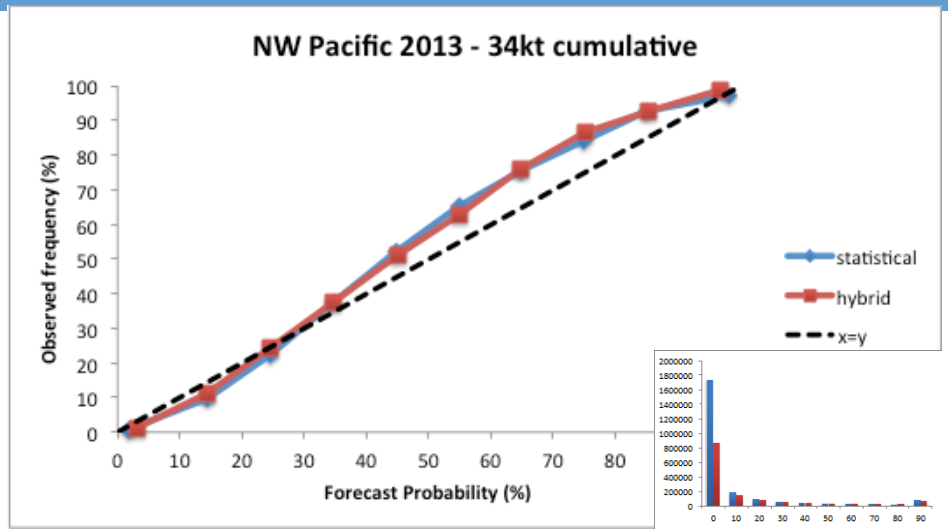
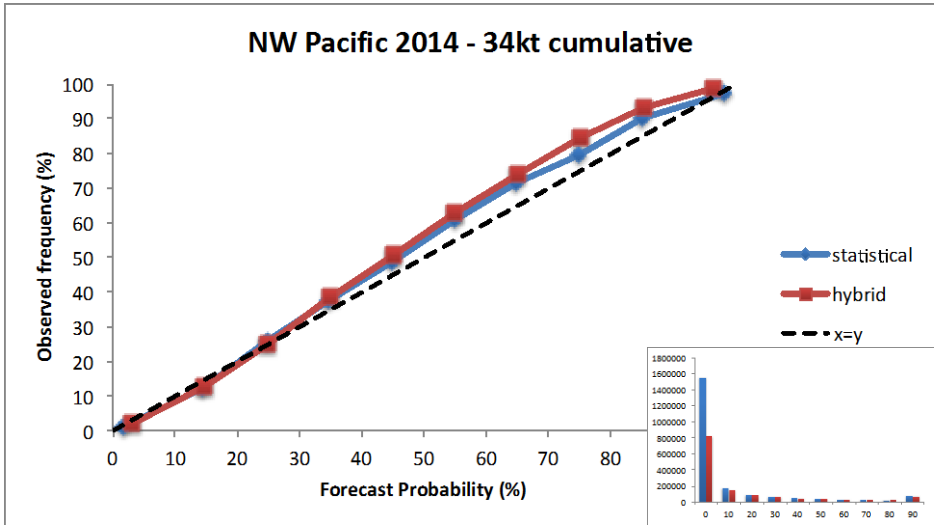
(i.e., magnitude of errors is smaller)

Reliability – NW Pacific (34kt 0-120h Cum)



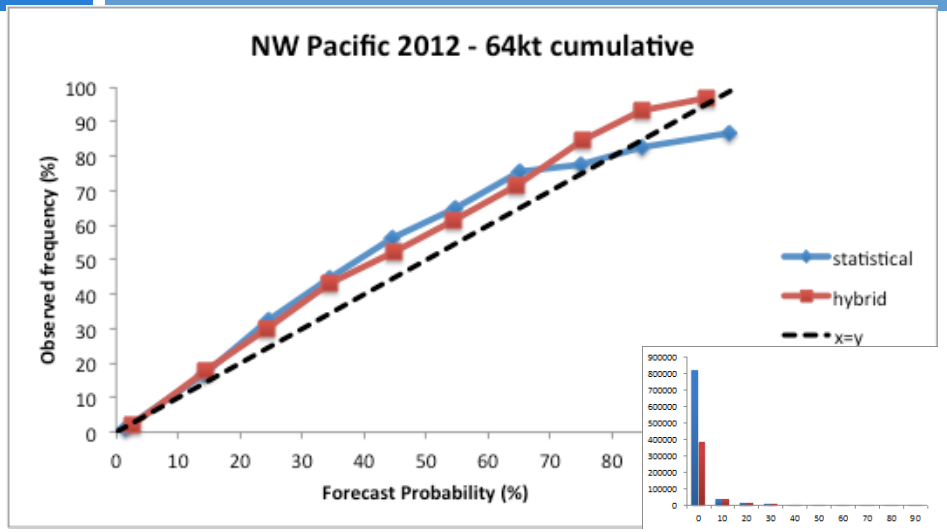


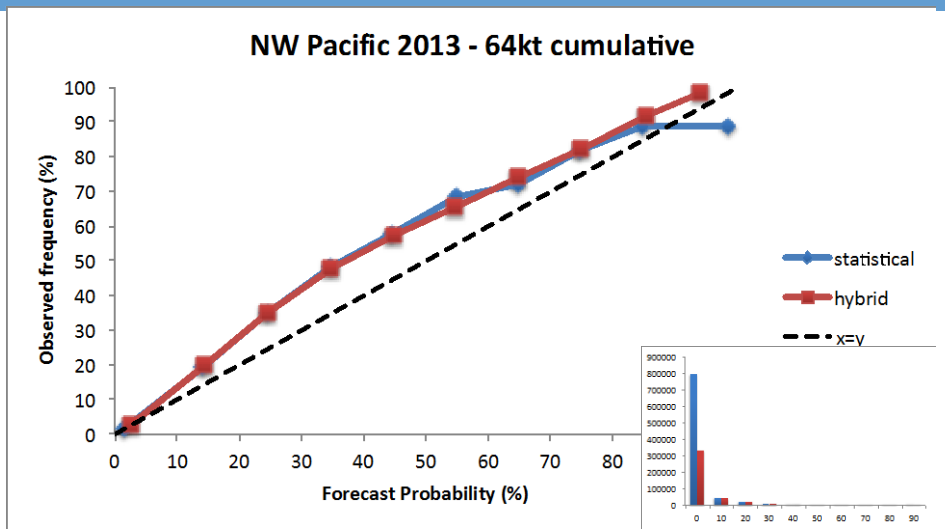


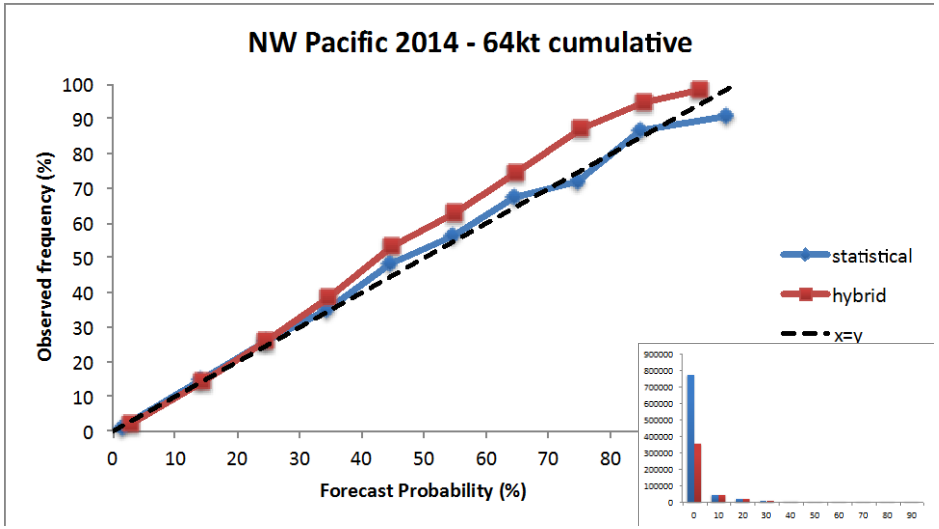
Statistical: tendency to underforecast, especially higher probabilities

Hybrid: very similar to statistical

Reliability – NW Pacific (64kt 0-120h Cum)







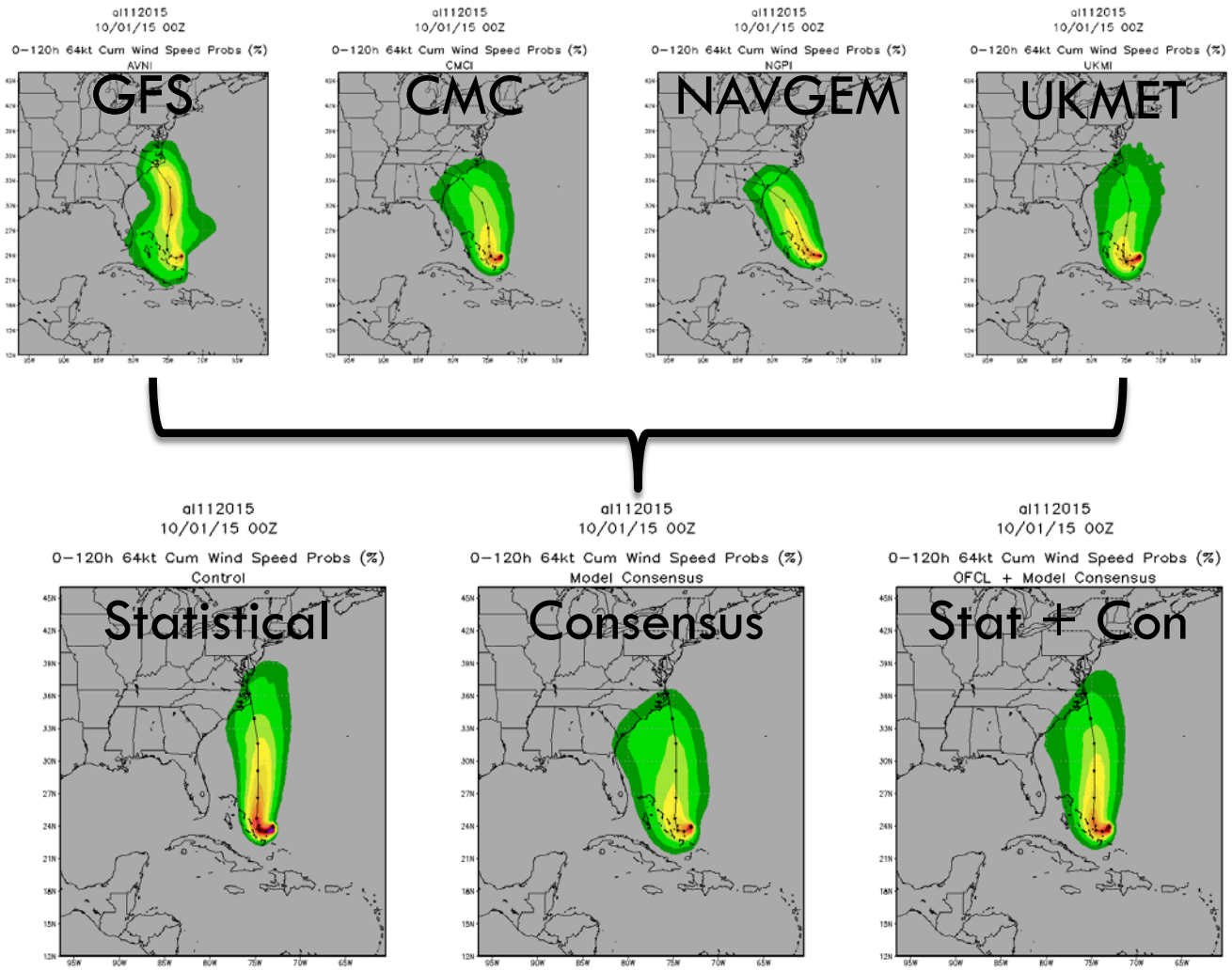
Statistical: tendency to underforecast

Hybrid: same to better reliability

Summary / Future work

- Verification, hybrid vs. statistical
  - Atlantic
    - improves Brier scores
    - worsens conditional bias towards underforecasting probabilities
  - NE Pacific
    - impact on Brier scores mixed
    - improves conditional bias towards overforecasting probabilities
  - NW Pacific
    - improves Brier scores
    - slightly worsens conditional bias towards underforecasting probabilties
- Future work
  - Continue running hybrid WSPs in real time
  - Evaluate hybrid WSPs in applications that use WSPs
    - Application to TCCORs (B. Sampson)

Future work – other hybrid methodologies



Thank you! Questions?

- Goerss, J. S., 2007: Prediction of consensus tropical cyclone track forecast error. *Mon. Wea. Rev.*, 135, 1985–1993.
- Knaff, J. A., C. R. Sampson, M. DeMaria, T. P. Marchok, J. M. Gross, and C. J. McAdie, 2007: Statistical tropical cyclone wind radii prediction using climatology and persistence. *Wea. Forecasting*, 22, 781–791.
- DeMaria, M., J.A. Knaff, R.D. Knabb, C.A. Lauer, C.R. Sampson, and R.T. DeMaria, 2009: A New Method for Estimating Tropical Cyclone Wind Speed Probabilities. *Wea. Forecasting*, 24, 1573–1591.
- DeMaria.M., J.A. Knaff, M.J. Brennan, D. Brown, R.D. Knabb, R.T DeMaria, A. Schumacher, C.A. Lauer, D.P. Roberts, C.R. Sampson, P. Santos, D. Sharp, and K.A. Winters, 2013: Improvements to the operational tropical cyclone wind speed probability model. *Wea. Forecasting*, 28, 586-602.

Extra slides

Impacts of using fewer realizations

In the log-log diagram, errors (*E*) are nearly a linear function of *N*:

$$E = C / N^z \qquad (6)$$

Where C and Z are constants. Taking the natural log of both sides gives

$$y = mx + b \qquad (7)$$

Where $y = ln(E)$, $x = ln(N)$, $b = ln(C)$, and $m = -z$.

Fitting (7) to max. error data yields:

z = 0.485, C = 109.2%

Fitting (7) to avg. error data yields:

z = 0.490, C = 15.8%

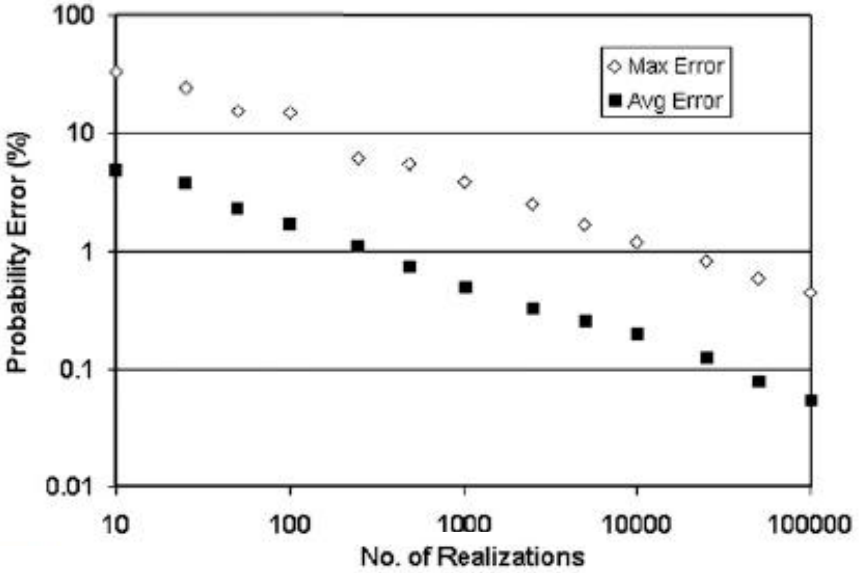


FIG. 5. The maximum and average error of the 64-kt wind probabilities for Hurricane Ike starting at 1200 UTC 7 Sep 2008 as a function of the number of realizations. Note that both axes have log scales.

Maximum and average errors are both inversely proportional to the square root of N:

$$E \sim 1/N^{0.5}$$

For N = 1000, avg E = 0.5%
For N = 100, avg E = 1.6%
i.e., factor of 10 reduction in N
Yields smaller increase in E (~factor of 3)

How situation-specific track uncertainty is incorporated now