Tropical Cyclone Gale Wind Radii Estimates, Forecasts and Forecast Error Estimates for the Western North Pacific

Contributors

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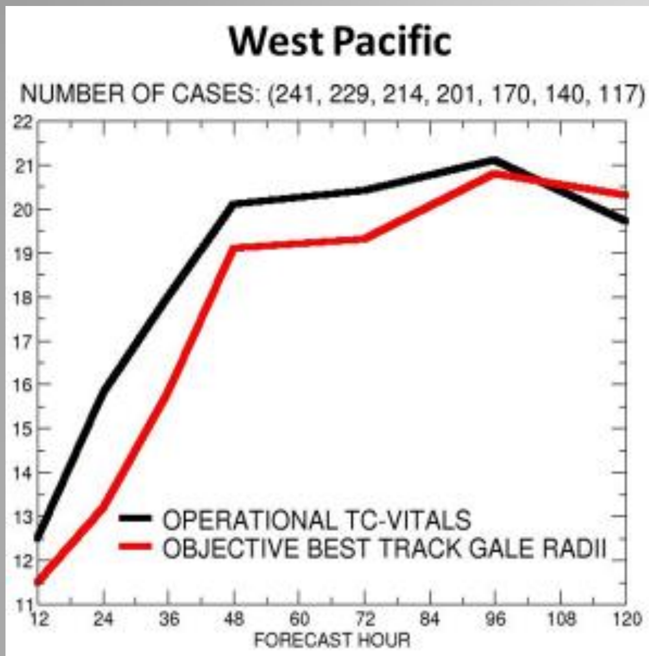
Outline

- Motivation
- Estimating gale wind radii (R34)
  - Satellite-based
  - NWP models
  - Mean (OBTK) and estimated error
- Forecasting R34
  - NWP models and consensus (RVCN)
- Forecasting R34 errors (GPCE)
- Conclusions

Why Specifying/Forecasting Wind Radii Matters



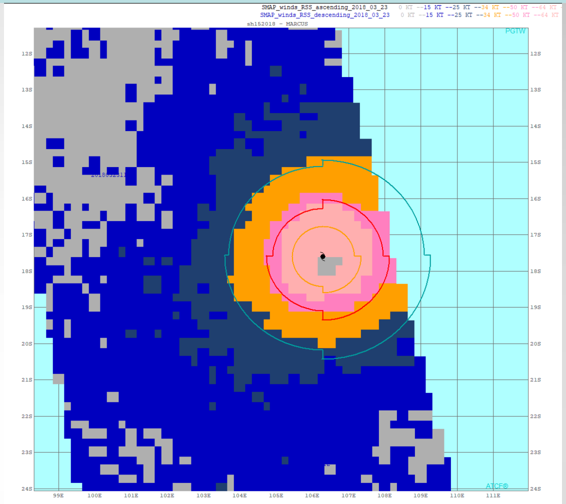
Improved model forecasts

Improved site preparedness

Estimating Gale Wind Radii (R34)

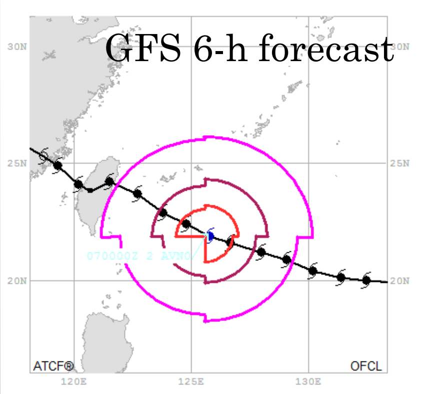
- Satellite-based
  - ASCAT objective fixes
  - Dvorak-based wind radii
  - Soil Moisture Active Passive (SMAP)
  - Multi-platform analysis
  - Sounder based (e.g., AMSU)

SMAP pass for Marcus (SH152018) Mar 22 12Z



34-kt 50-kt 64-kt

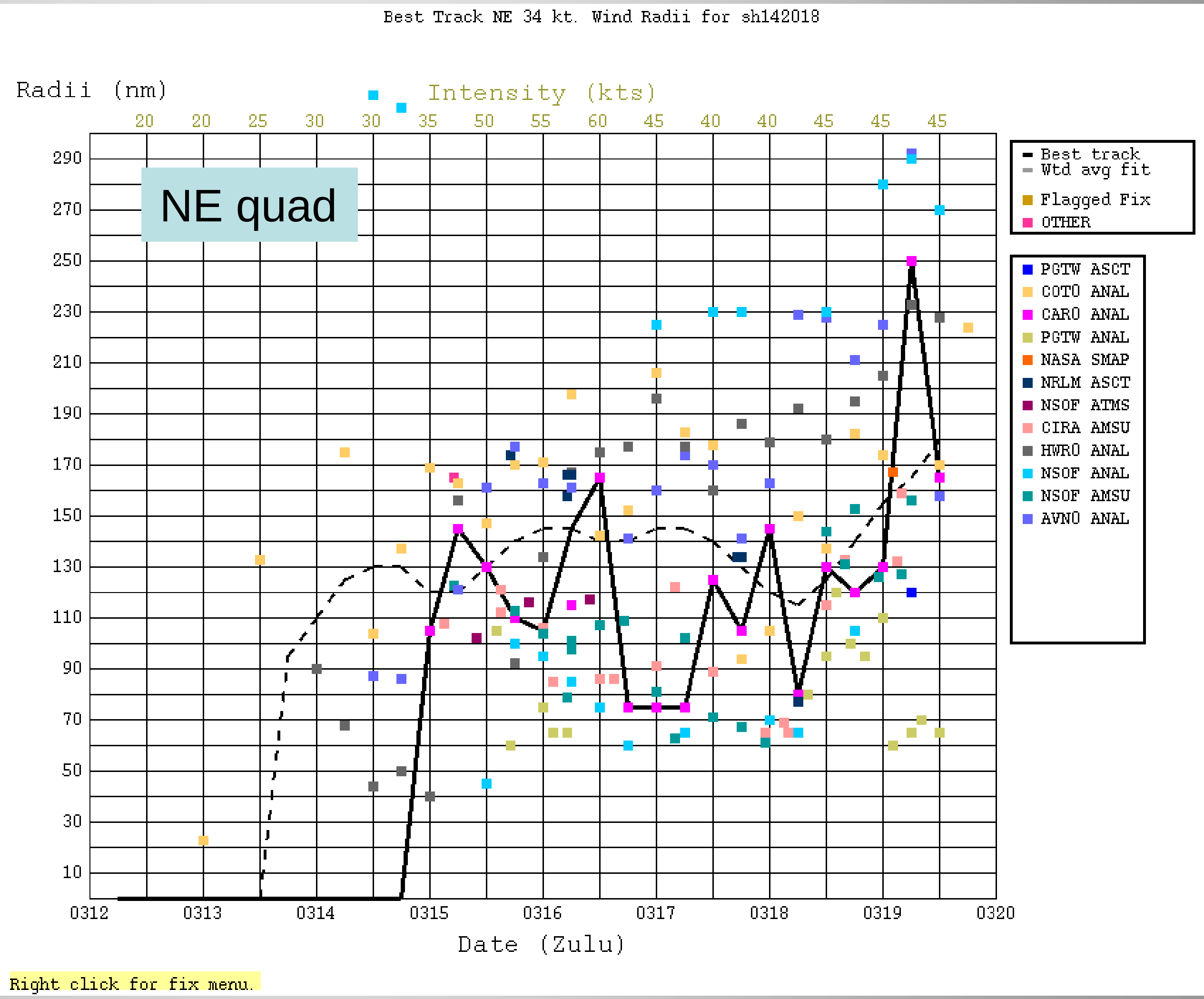
- 6-h NWP model forecasts
  - HWRF
  - GFS
  - GFDL (now defunct!)



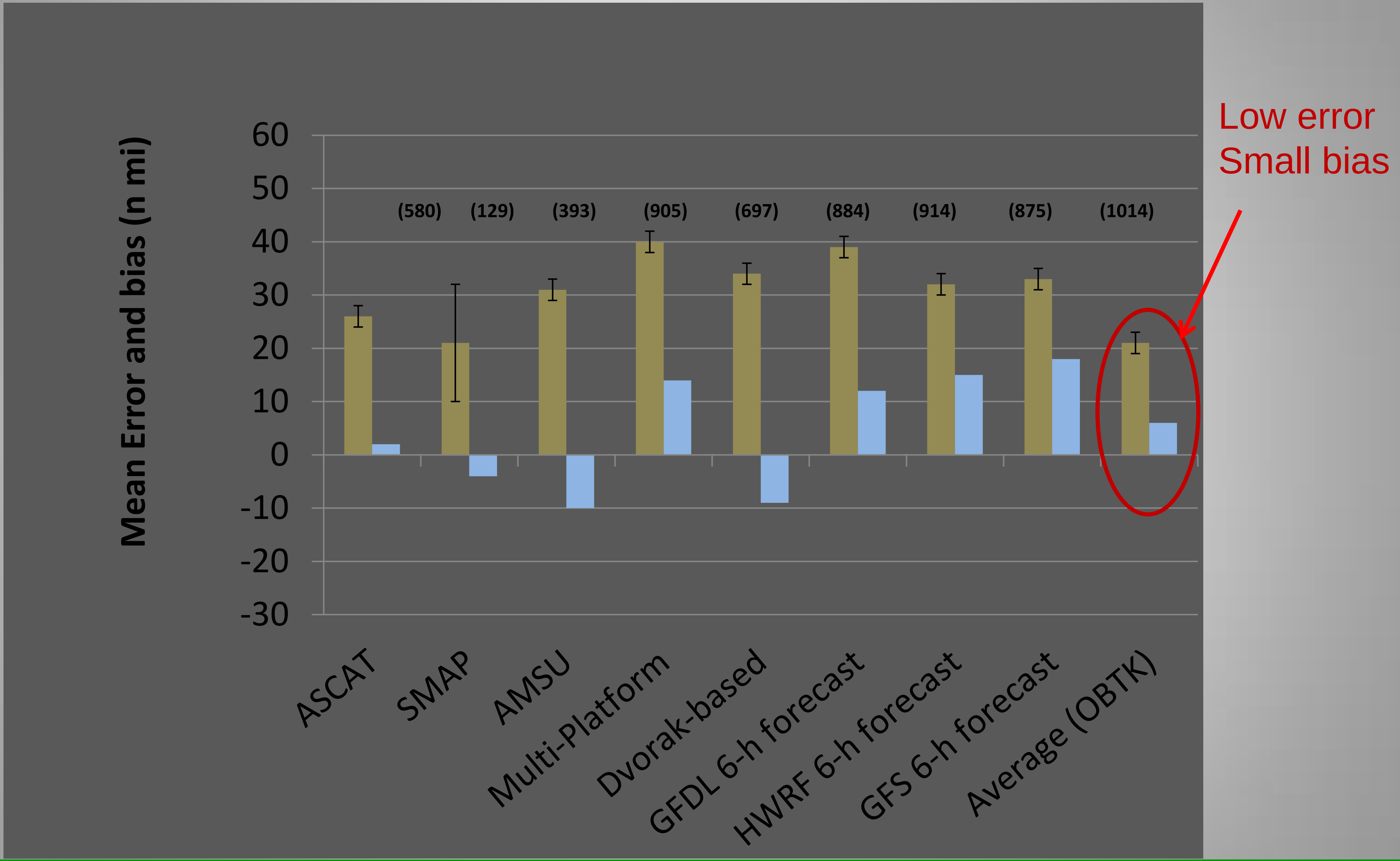
34-kt 50-kt 64-kt

Average of R34 Estimates (OBTK)

- OBTK (dashed line)
  - Average of estimates
  - Mostly equal weights
  - ASCAT*30 (ground truth)
  - 3-point bilinear filter
- Advantages
  - Slowly varying in time
  - Objective
  - Almost always available
  - Similar to best track
  - Good for operators
  - Good for downstream apps
  - And …

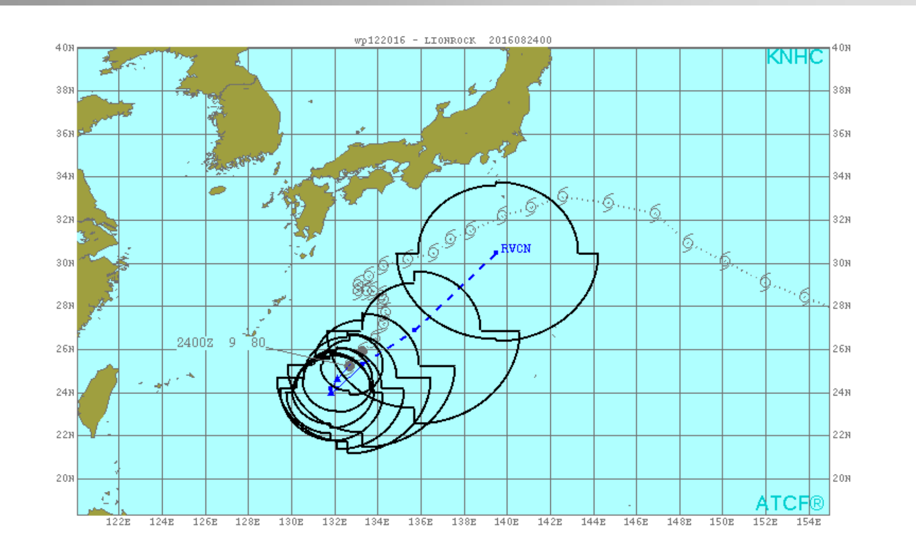


R34 Errors for Coincident with ASCAT Passes

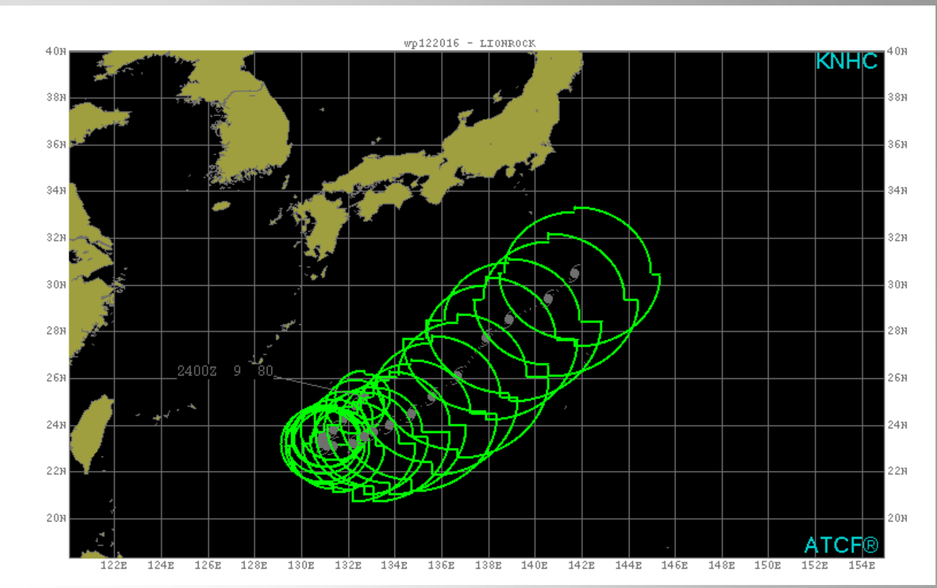


34-kt wind radii fix mean errors (brown) and biases (blue) relative to JTWC 2014-2016 best tracks. Standard error is shown as black bars on means. Mean difference between OBTK and best tracks is about 22 n mi, standard deviation is about 17 n mi. This is one estimate of the R34 error in the best observed TCs in the WP basin.

Forecasting R34 with Consensus (RVCN)



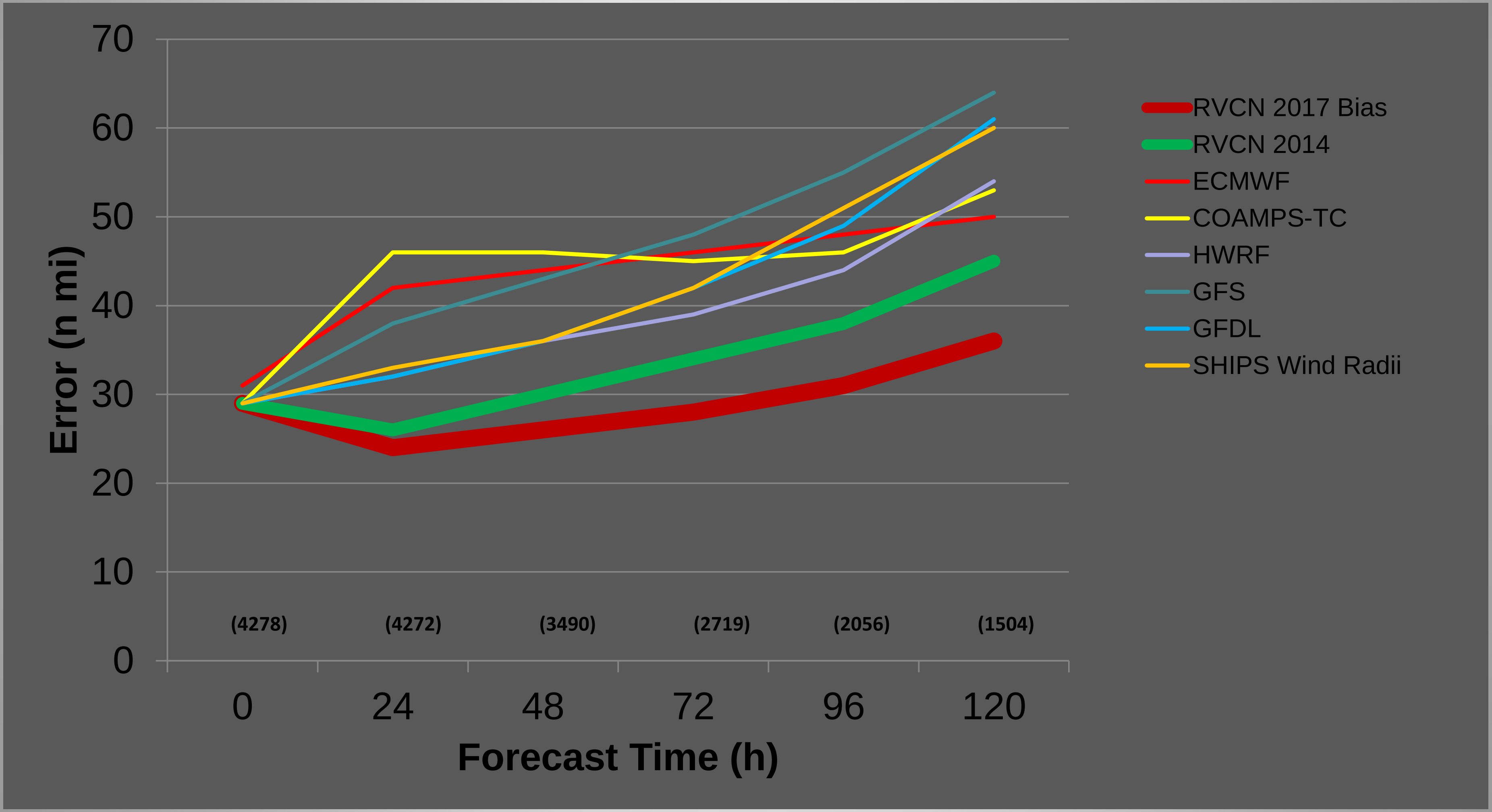
RVCN 5-day R34 forecast for Lionrock (Aug 24 00Z)



R34 best track

RVCN is a consensus of interpolated NWP and statistical-dynamical models
RVCN 2014 = EMXI + HHN I+ AHNI + GFTI
RVCN 2017 = EMXI + HHNI + AHNI + GFTI + CHTI + DSHA

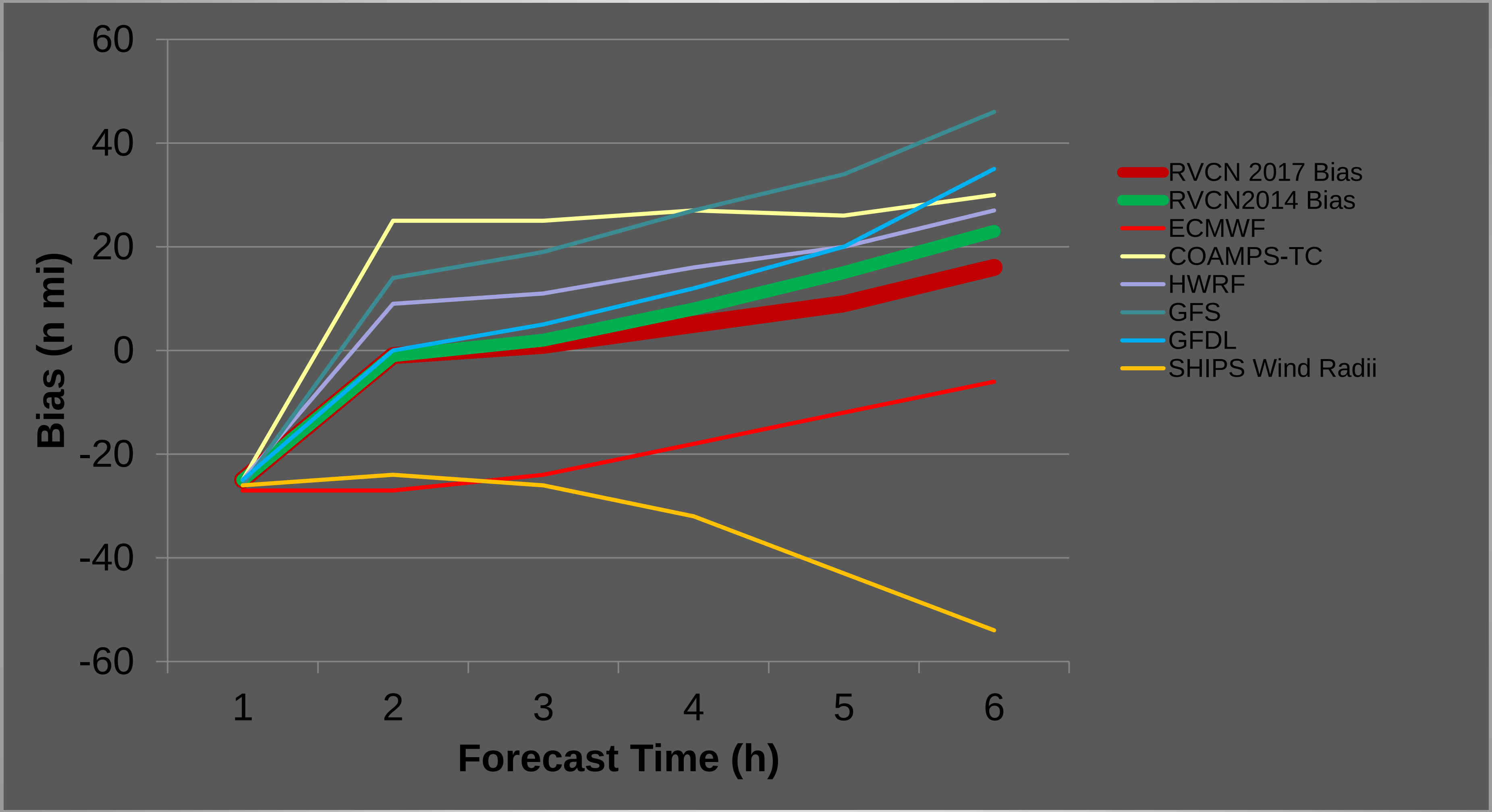
R34 Forecast Mean Error
(WP 2014-2016)



As with track and intensity, the consensus forecasts (RVCN 2014/2017) perform well. Mean error increases from about 20% of mean R34 at 24 h to about 30% of mean R34 at 120 h.

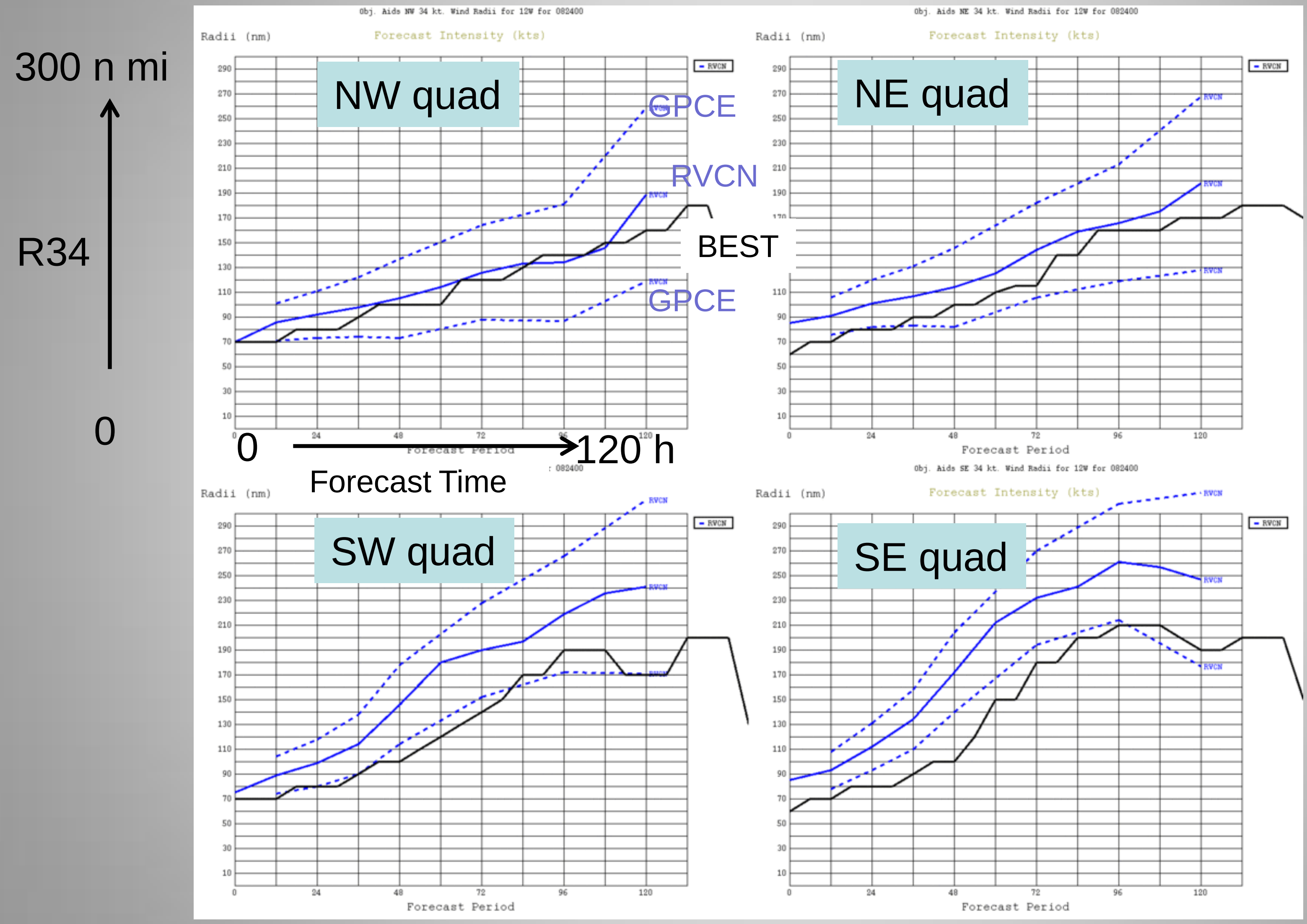
R34 Forecast Bias

(WP 2014-2016)



Biases in individual models offset each other. Not by design, but we still enjoy the benefits.

R34 Forecast Error Estimates (GPCE)



0-120 h RVCN R34 forecast (blue solid) and 67th percentile (blue dashed) for Lionrock (Aug 24 00Z) by quadrant. Best track R34 shown as black solid line. Case shows RVCN forecasts too large in SW and SE quadrants.

R34 GPCE Evaluation

Wind Radii Forecast Error Equation	Cases (2015)	Variance Explained (2015)	Cases (2016)	Variance Explained (2016)
WRE_{12} =0.581*WRCHG + 9	630	.089	372	.171
WRE_{24} =0.307*WRCHG – 0.107*INTF + 2.22*LATC + 22	603	.140	347	.197
WRE_{36} =0.205*WRCHG – 0.161*INTF + 2.09*LATC + 31	569	.137	315	.161
WRE_{48} =0.237*WRCHG – 0.213*INTF + 37	531	.125	278	.118
WRE_{72} =0.441*SPRD + 0.217*WRCHG – 0.238*INTF + 30	443	.236	206	.076
WRE_{96} =0.489*SPRD + 0.223*WRCHG – 0.274*INTF + 29	366	.341	143	.068
WRE_{120} =0.542*SPRD+ 0.249*WRCHG – 0.310*INTF + 31	288	.412	93	.262

Table 2. Regression equations derived for the 2015 western North Pacific season with variance explained for dependent (2015) and independent (2016) data. Variance explained ranges from ~8% to 40%. Need more cases for both development and evaluation. Adding 2016 and 2017 to development set this year.

Summary

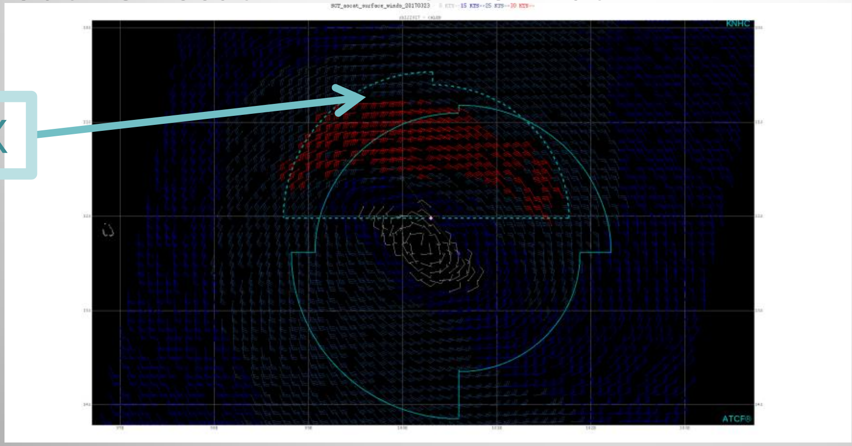
- Analyzing R34
  - Mean (OBTK) works well as initial guess
  - Estimated RMSE with scat data: 17 n mi or 15% of mean R34
  - Estimated RMSE w/o scat data: greater than 17 n mi
- Forecasting R34
  - Consensus (RVCN) one of top aids
  - MAE increases from 25-40 n mi (20%-30% of mean R34) through 120 h
- Forecasting R34 errors (GPCE)
  - GPCE explains 8-40% of variance
  - Model spread leading predictor at 72-120 h
  - Algorithm solid, need more data for development and evaluation
- Future
  - Analysis (OBTK): New estimates (e.g., SMOS, CYGNSS)
  - Forecast (RVCN): Improved/more NWP
  - Forecast Error (GPCE): Add 2016 and 2017 to development set

Extra Material

ASCAT R34 Estimate

1) Read in ascat data for entire day, select +/- 3 h window
2) Adjust scat data to best track time using current TC movement
3) Divide winds up into 8 n mi donuts, then quarter each donut
4) Find maximum wind speed in each quarter donut
5) Start search algorithm
   1) 40 nm < r < 240 nm
   2) Look for R34 , but only where winds drop <34 kt
   3) Other QC
      1) 34-kt winds can't have gaps > 75 n mi going out from center
      2) First wind speed > 33 kt needs to be at r < 120 nm
6) Write out R34 scat fix in ATCF format

ASCAT R34 FIX



Sampson, C. R., J. S. Goerss, J. A. Knaff, B. R. Strahl, E. M. Fukada, E. A. Serra, 2017: Tropical cyclone gale wind radii estimates, forecasts and error forecast for the western North Pacific, **Wea. Forecasting, in press.**

Wind radii from Dvorak fixes

Method:

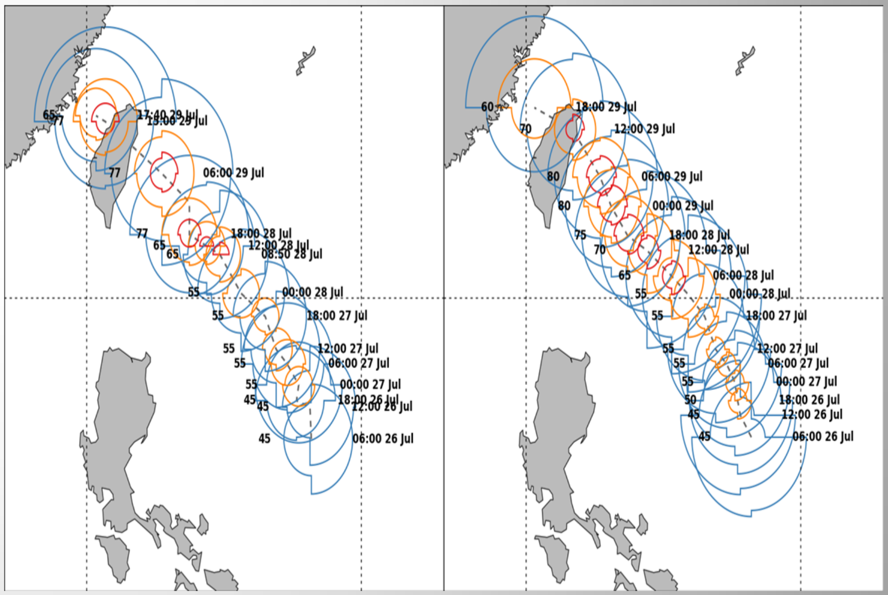
- Relates R5 (zero tangential wind) and intensity to azimuthally averaged wind radii (34-, 50-, 64- knot)
  - Current infrared image
  - Observed/estimated intensity
  - Use observed/estimated or climatological radius of maximum winds, *F(intensity, latitude)*
- Use motion to assign vortex wind asymmetries following Knaff et al. (2007)
  - Observed 6h motion typically used

Available on ATCF… part of the wind radii button

Using this routinely available information provide wind radii estimates to operations (Knaff et al. 2016), where routine information is 1. IR image, 2. TC location, 3. TC Motion, 4. TC Intensity

Estimates based on Dvorak Fixes (PGTW)

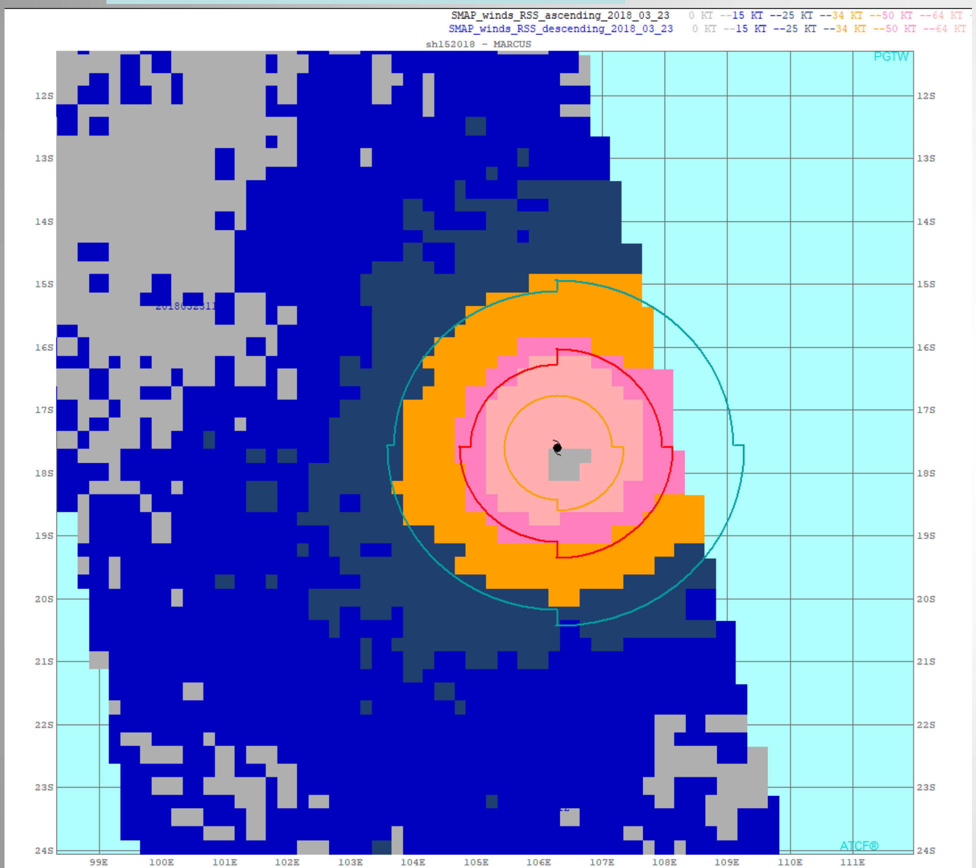
Working Best Track (JTWC)



Knaff, J. A., C. J. Slocum, K. D. Musgrave, C. R. Sampson, and B. Strahl, 2016: Using routinely available information to estimate tropical cyclone wind structure. *Mon. Wea. Rev.*, 144, 1233-1247.

SMAP R34 Estimates

Marcus (SH152018) Mar 22 12Z



34-kt 50-kt 64-kt

- Soil Moisture Active Passive (SMAP),
- L-Band, 1.4 GHz, 40-km footprint
- Sensitive to ocean foam (and thus surface winds)
- Unaffected by precipitation
- Wind speeds do not saturate (Reul et al. 2012, 2016, Meissner et al. 2014)
- Ideal for wind radii and intensity

Meissner, T., L. Ricciardulli, and F. Wentz, 2017: Capability of the SMAP mission to measure ocean surface winds in storms. *Bull. Amer. Meteor. Soc.*, 98, 1660-1677.

Microwave-Sounder-based (AMSU)

Algorithm (Demuth et al. 2004, 2006)

Inputs:

1. Retrieve T(x,y,z) from all AMSU-A channels (statistical or via MIRS)
2. Hydrostatic integration for P(x,y,z)
3. Estimate Gradient wind for V(r,z)

Statistical Prediction

Independent Variables:

Parameters from retrieved T, P, V (right)
Max Wind (Vmax, latest advisory)

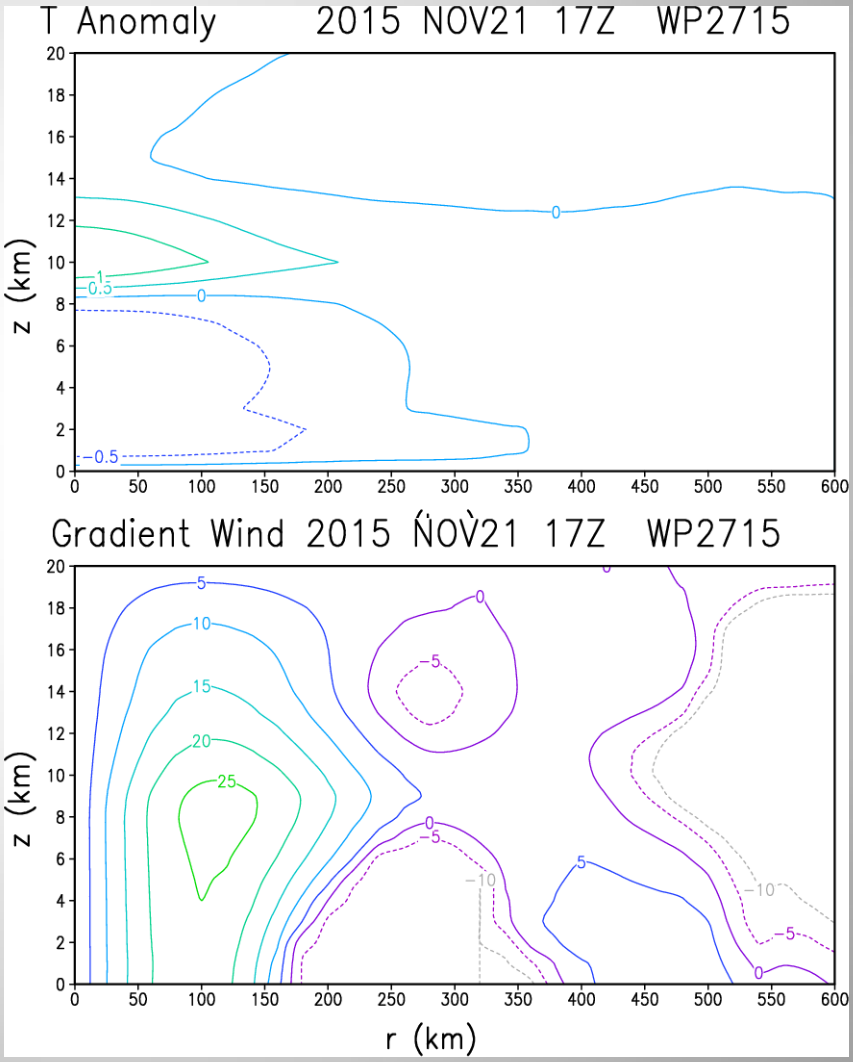
Dependent Variables:

Azimuthally averaged (non-zero) wind radii (r34, r50, r64)

Procedure:

1. Fit parametric wind model to with predicted r34, r50, r64
2. storm speed/direction get asymmetric radii
3. **Output to ATCF fix format**
4. Estimate non-linear balanced winds at standard pressure levels (other uses)

Azimuthally averaged (Ta, Vt) Typhoon In-Fa



R34 101, 69, 61, 87 - Statistical retrieval

Multi-satellite-platform approach

Algorithm (Knaff et al. 2011)

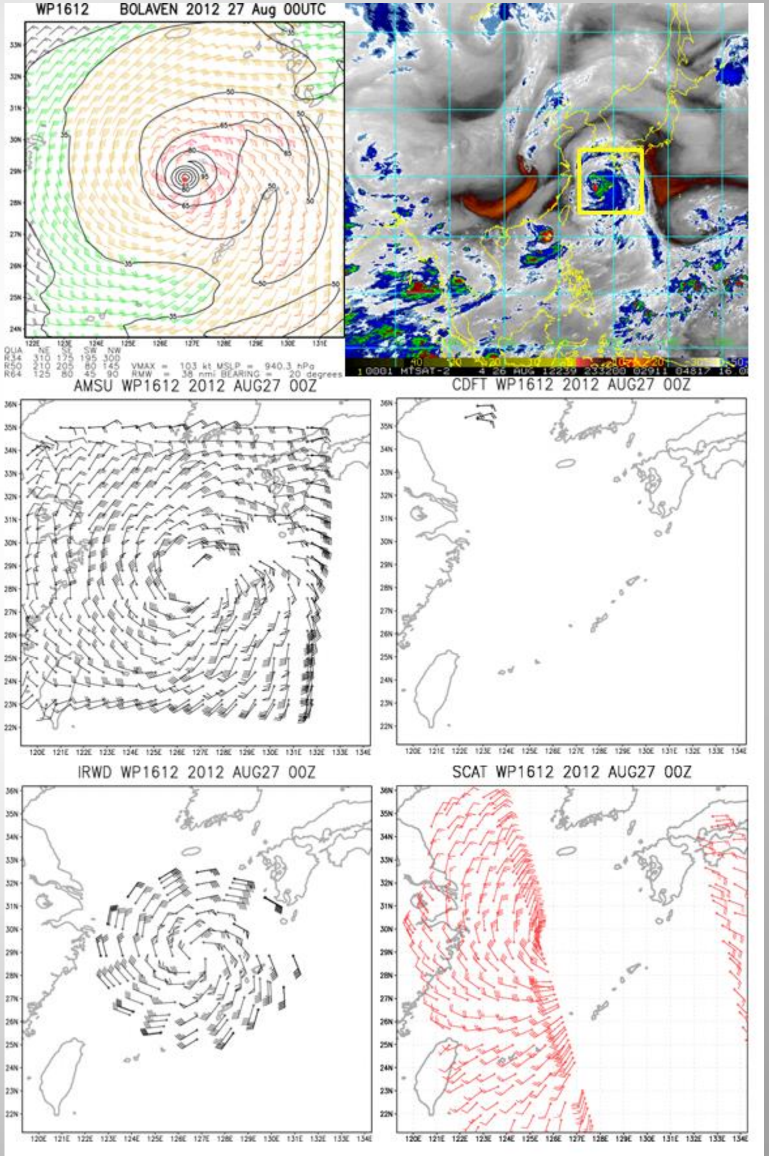
Inputs:

1. TC location
2. TC intensity
3. IR-based flight-level winds at 700 hPa based on Mueller et al. (2006) uses observed intensity
4. Cloud Drift/Feature track winds below 600 hPa
5. MI-Sounder-based non-linear-balanced winds at 700 hPa
6. Scatterometry (A-Scat, two satellites)

Procedure:

1. Compile winds in a storm motion relative framework (9 h window)
2. Adjust winds to a common level (700 hPa)
3. Perform a variational analysis on a polar grid
4. Adjust winds from flight-level to the surface
5. Estimated , MSLP and wind radii
6. **Output to ATCF fix format**

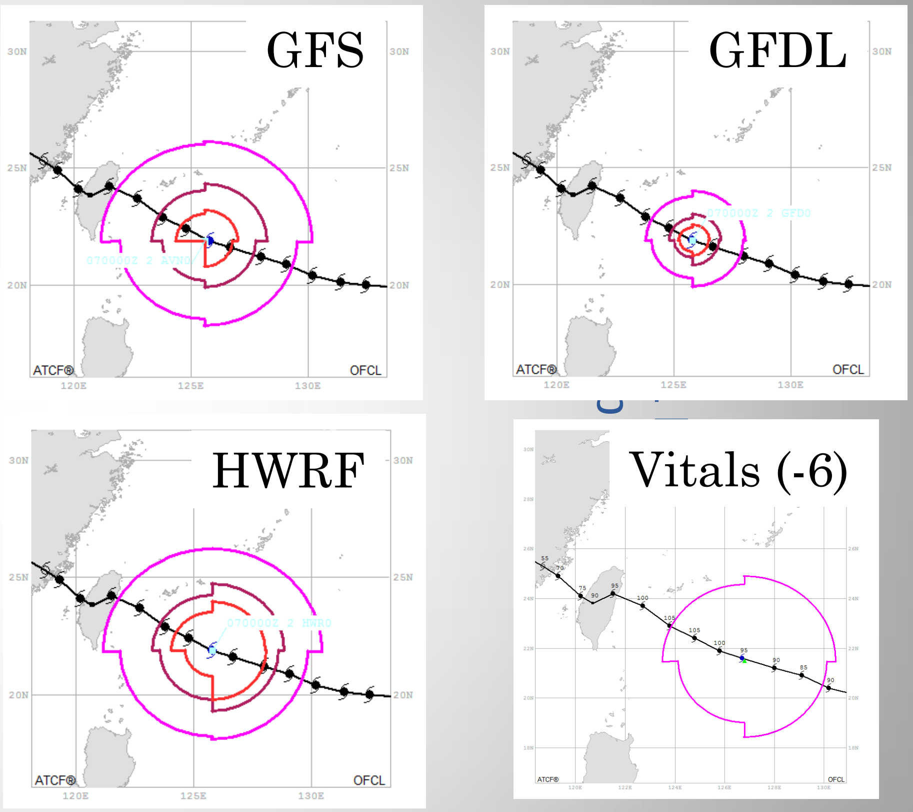
Bolaven (2012)



6-hour Forecasts from NWP

Typhoon Soudelor

2015 7 Aug 00UTC



Marchok Tracker

- NWP model output is typically not available during the forecast cycle
- Six-hour forecast of several NWP models are used as psuedo-fixes in the fdeck
- Positional errors are small (similar to wind radii fixes) an are neglected
- These wind radii psuedo-fixes are used as members of the consensus