18 month report for proposal entitled
TC Dressing: A Probabilistic Approach to Providing State-Dependent, Non-Isotropic Forecast Track Error Guidance

James A. Hansen, NRL
James S. Goerss, NRL
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Summary

The original work plan assumed that extensions to TC Dressing would result in a product superior to GPCE. This result was not realized. In our 6-month report we introduced the concept of bias-corrected GPCE along/across (GPCE-AX) and demonstrated its potential using GUNA over 2002-2005 (dependent) and 2006 (independent). Because GPCE-AX produces a symmetric distribution, our 6-month report presented the idea of attempting to predict situations in which verification is likely to fall to the left or right of consensus and/or is likely to be fast or slow (probability of left/right/fast/slow, P-LRFS).

In our 12-month report we presented results where GPCE-AX and P-LRFS were extended to CONU and to CONW. The CONU results (training over 2002-2007, testing over 2008) indicated that GPCE-AX generally outperforms GPCE in terms of reliability (the fraction of time verification is bound by the 70% uncertainty isopleths) and sharpness (the area bound by the 70% isopleths). The CONW results (training over 2004-2006, testing over 2007) were less conclusive; the sharpness and reliability results for GPCE and GPCE-AX were very similar to one another.

An example of the GPCE and GPCE-AX guidance products for a 72hr forecast of Ike in 2008 is shown in figure 1. An example of GPCE and GPCE-AX for the WestPac is given in figure 2.

We are on schedule according to our Year 2 Timeline. GPCE-AX and P-LRFS have been extended to GPCE domains and validated. We intend to implement GPCE-AX and P-LRFS in the ATCF during the first quarter of calendar year 2009.

GPCE and GPCE-AX statistics

In this section the statistical results for GPCE and GPCE-AX for CONU and CONW are reported. The CONU training set was 2002-2007, with a testing set over 2008. For CONW, the training set was 2004-2006 with a training set over 2007.

Forecast RMS error statistics over the entire 2002-2008 period for CONU and the 2004-2007 period for CONW are given in tables 1 and 2 below. Note that because of the nature of the GPCE-AX problem, the along-track and across-track RMS errors are calculated with respect to the consensus forecast track, not the best track. The along-track direction was calculated by fitting a third order Hermite polynomial to the track, interpolating to hourly values, and using finite differencing. It was found that spline interpolation resulted in misleading across-track and along-track directions. Because across-track and along track directions require an interpolation, the datasets used only considered storms with forecasts out to 24hrs or greater, and only considered storms that were TDs or TSs for the entire forecast periods.

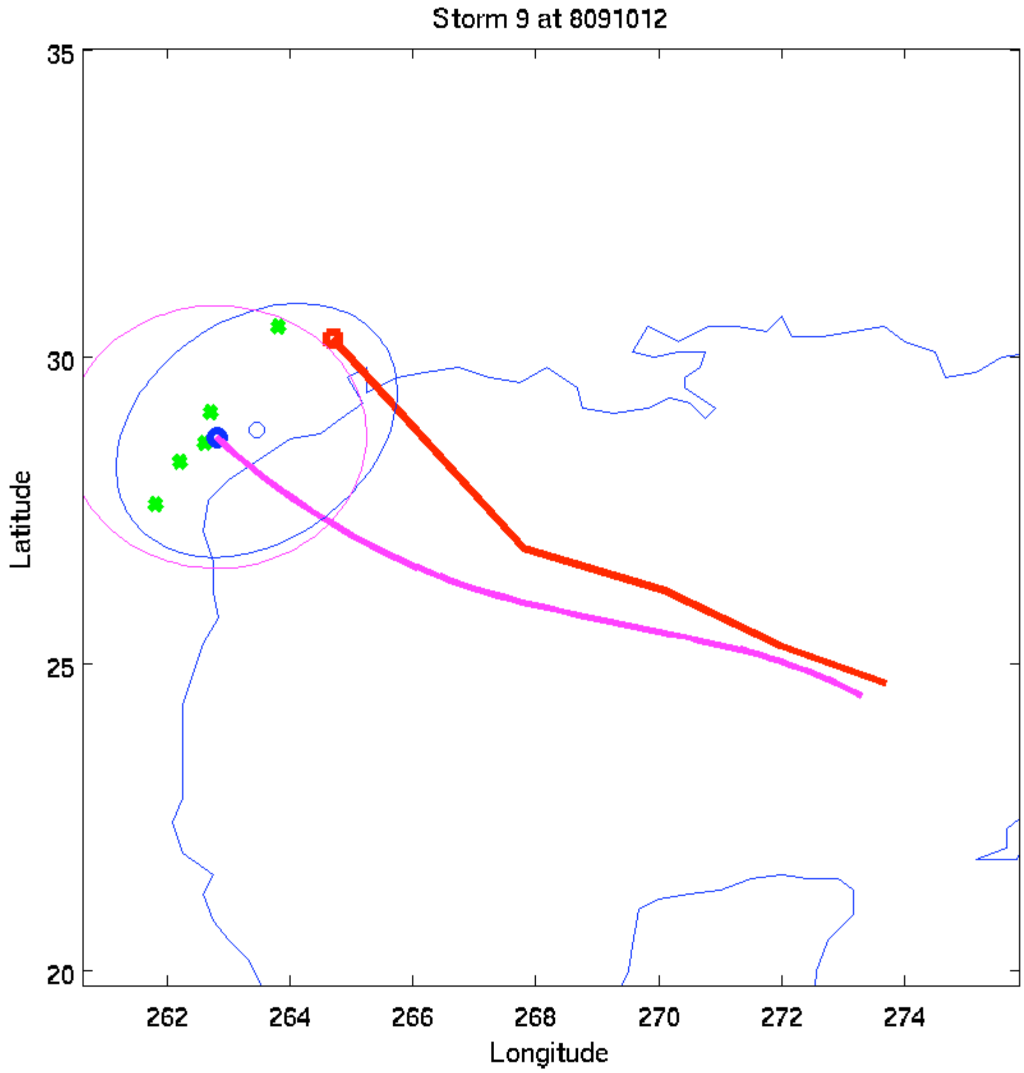

Figure 1: This is a 72hr forecast of Ike in 2008. The red curve shows the best track trajectory and the magenta curve shows the CONU forecast (hours 12, 24, 36, 48, and 72). The 72hr track forecasts from the five models that make up CONU are given as green x's. The 72hr CONU forecast is given by the solid blue circle, the 72hr across-track/along-track bias corrected forecast is given by the open blue circle, and the 72hr verifying location is given by the red square. The GPCE forecast of expected error is given by the magenta circle centered on the CONU forecast, and the GPCE-AX forecast of expected error is given by the blue ellipse centered on the bias corrected CONU forecast.

It is found that the isotropic errors for CONW are slightly higher than those for CONU. Broken into across-track and along-track components, the along-track errors in the two basins are more similar than the across-track errors, which are systematically larger in the WestPac.

Mean absolute errors in the across-track and along-track directions for the two basins are given in tables 3 and 4. CONU is found to have a much stronger bias signal than CONW. The CONU forecasts are found to be consistently to the left of and ahead of the verification.

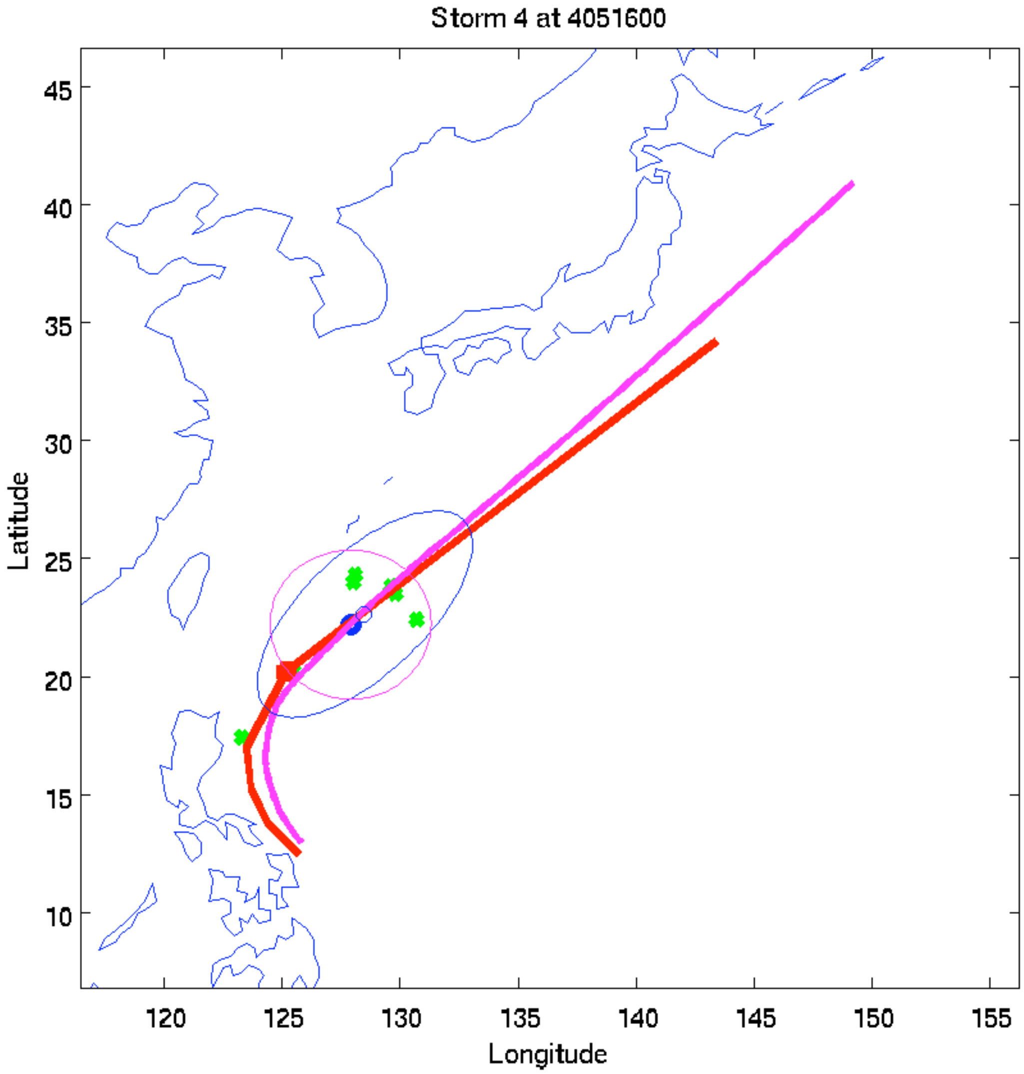

Figure 2: As for figure 1 but for storm 4 in the West Pacific in 2004.

There are two steps behind approach behind generating the GPCE and GPCE-AX radii of the 70% uncertainty isopleths. The first is to build a regression relationship between various predictors (initial intensity of the storm, initial latitude of the storm, predicted longitudinal displacement, etc) and the realized isotropic and/or across-track/along-track error. The second step is to determine a scaling that converts the predicted error into a predicted radius of the 70% probability contour. For the isotropic (GPCE) case all one need do is identify the additive scalar that provides this conversion in-sample. One can take a similar approach in GPCE-AX, but if the same additive scalar is applied to both the along-track and the across-track directions one can destroy the anisotropy of the contour. In the results given here a boost is applied that maintains the ratio between the along-track and across-track directions.

Tau	Across	Along	Isotropic	Sample size
12	19.3	21.6	32.0	1930
24	32.4	37.9	55.3	1930
36	43.3	54.1	76.7	1728
48	55.7	70.4	98.9	1542
72	85.9	102.6	148.7	1246
96	125.8	146.1	213.9	990
120	167.8	195.6	285.5	783

Table 1: Mean absolute errors (in NMI) of across-track, along-track, and isotropic CONU forecasts over 2002-2008. Note that the across-track and along-track directions are defined with respect to the CONU track not the best track.

Tau	Across	Along	Isotropic	Sample size
12	22.3	24.2	36.2	2069
24	38.0	40.4	60.9	2069
36	51.3	54.1	82.3	1884
48	63.2	71.4	105.2	1702
72	93.9	103.6	153.5	1352
96	128.2	148.8	214.4	979
120	163.6	188.3	275.4	681

Table 2: As for table1 but for CONW over the period 2004-2007

Tau	Across	Along	Sample size
12	1.9	-0.5	1930
24	4.8	-1.9	1930
36	8.6	-5.7	1728
48	13.9	-9.7	1542
72	24.1	-20.2	1246
96	23.8	-40.6	990
120	9.8	-74.9	783

Table 3: Mean errors, or bias (in NMI) of across-track and along-track CONU forecasts over 2002-2008. Note that these are biases with respect to the CONU forecast. A positive across-track bias implies that the consensus is consistently to the left of verification and a negative along-track bias implies that the consensus is consistently ahead of verification.

Tau	Across	Along	Sample-size
12	0.9	3.6	2069
24	-1.2	9.5	2069
36	-2.2	15.5	1884
48	-3.8	21.9	1702

72	-3.6	37.1	1352
96	-1.8	-2.5	979
120	4.3	-1.1	681

Table 4: As for table 3 but for CONW over 2004-2007

The GPCE and GPCE-AX results are compared in tables 5 and 6 (CONU and CONW) respectivelvaly. The iso-frac-in column gives the fraction of in-sample forecasts bound by the isotropic (GPCE) 70% contour. Because it is in-sample the values should be very near 0.7. The iso-boost column gives the constant scalar (in NMI) added to the isotropic (GPCE) predicted error to convert it to a prediction of the radius of the 70% probability contour. The xa-frac column gives the fraction of in-sample forecasts bound by the anisotropic (GPCE-AX) 70% contour. The xa-boost column is the scalar added to the along track direction (the across-track direction is scaled in a manner that maintains the ratio between the across-track and along-track directions) to convert the forecasts of across-track and along-track error to forecasts of the 70% probability contour. The in-area column is a measure of the relative sizes of the areas bound by the GPCE and GPCE-AX forecasts of expected error over the in-sample data. Values can be interpreted as the fraction by which the GPCE-AX area is smaller than the GPCE area. Negative values indicate that GPCE has the smaller area. The iso-out-frac, xa-out-frac, and out-area columns contain the same calculations as the iso-in-frac, xa-frac, and in-area columns but for the out-of-sample data.

Tau	iso-in-frac	Iso-boost	xa-frac	xa-boost	in-area	iso-out-frac	Xa-out-frac	out-area
12	0.71	7	0.72	18	-0.076	0.78	0.81	-0.066
24	0.70	11	0.70	29	-0.021	0.79	0.78	-0.020
36	0.70	15	0.71	37	0.038	0.77	0.76	0.038
48	0.71	19	0.70	48	0.010	0.78	0.77	0.0044
72	0.70	30	0.70	71	0.064	0.76	0.69	0.13
96	0.70	40	0.70	104	0.013	0.81	0.76	0.10
120	0.70	54	0.70	141	-0.043	0.84	0.84	0.028

Table 5: Comparison of GPCE and GPCE-AX for CONU. iso-in-frac is the in-sample fraction of verifications bound by the predicted 70% isotropic isopleths of uncertainty given by GPCE, iso-boost is the number of NMI needed to boost the predicted error to obtain a predicted 70% isopleth. xa-frac is the in-sample fraction of verifications bound by the predicted 70% elliptical isopleths of uncertainty given by GPCE-AX, xa-boost is used to translate the predicted error to the 70% ispoleth (it is added to the along-track direction and the across-track direction is modified in a manner than maintains the eccentricity of the ellipse). in-area is the mean fractional difference between the GPCE 70% areas and the GPCE-AX 70% areas. Negative means that the GPCE areas are smaller, while positive means that the GPCE-AX areas are smaller. iso-out-frac, xa-out-frac, and out-area are the out-of-sample versions of iso-in-frac, xa-frac, and in-area. Note that GPCE-AX forecast areas tend to be larger than GPCE areas at short leads, but smaller at longer leads.

For CONU (table 5) we see that GPCE and GPCE-AX have similar out-of-sample reliability (fraction of forecasts bound by the 70% contour), but for leads greater than 24hrs the GPCE-AX forecasts have a smaller area than the GPCE forecasts.

For CONW (table 6), the benefits of GPCE-AX are less clear. Again the out-of-sample reliabilities are similar, but the GPCE-AX areas are larger than the GPCE areas for forecast leads of 24-72hrs. The feeling of the PIs is that even though GPCE and GPCE-AX statistics are similar for CONW, GPCE-AX provides information that is different from GPCE and it is worth pursuing putting GPCE-AX into the ATCF for this basin.

Tau	Iso-in-frac	Iso-boost	xa-frac	xa-boost	in-area	iso-out-frac	xa-out-frac	out-area
12	0.71	8	0.72	20	0.042	0.71	0.73	0.075
24	0.70	12	0.70	31	-0.0093	0.70	0.70	-0.012
36	0.70	16	0.70	44	-0.057	0.73	0.73	-0.062
48	0.70	21	0.70	55	-0.026	0.76	0.73	-0.0085
72	0.70	30	0.70	82	-0.053	0.79	0.78	-0.056
96	0.70	39	0.70	106	0.0061	0.84	0.80	0.023
120	0.70	53	0.70	131	0.057	0.89	0.86	0.054

Table 6: As for table 6 but for CONW.

The information in tables 5 and 6 is broken down a bit further in tables 7-9. These tables show only the GPCE-AX reliability and the fractional difference in GPCE and GPCE-AX areas but for cases where the GPCE-AX area is in the smallest tercile (table 7), the middle tercile (table 8), and the largest tercile (table 9). GPCE-AX reliability is reasonable for both basins for all terciles. We find that GPCE-AX has an area that is systematically larger than GPCE for the smallest tercile of error. Presumably this is because small errors are well modeled by isotropic distributions. The GPCE-AX areas are best in the largest terciles, presumably because the large uncertainties are associated with large along-track or across-track errors that are well modeled by GPCE-AX but require GPCE to produce huge circles to capture those directional errors.

	CONU				**CONW**		
Tau	GPCE-AX frac bound	Frac area difference	Sample size		GPCE-AX frac bound	Frac area difference	Sample size
12	0.86	-0.22	98		0.81	-0.14	133
24	0.86	-0.11	98		0.80	-0.18	118
36	0.85	-0.01	87		0.83	-0.21	102
48	0.82	-0.039	78		0.83	-0.076	87
72	0.73	0.14	63		0.70	0.021	64
96	0.75	0.055	51		0.75	-0.016	36
120	0.76	0.095	42		0.76	0.17	21

Table 7: As for tables 5 and 6, but only out of sample and only for the smallest third GPCE-AX predicted errors.

	CONU				CONW		
Tau	GPCE-AX frac bound	Frac area difference	Sample-size		GPCE-AX frac bound	Frac area difference	Sample-size
12	0.77	-0.011	99		0.78	0.19	134
24	0.75	0.030	99		0.71	0.039	119
36	0.69	0.053	88		0.79	-0.038	103
48	0.71	-0.0077	79		0.76	-0.0092	88
72	0.66	0.098	64		0.86	-0.14	65
96	0.77	0.056	52		0.86	0.033	37
120	0.81	-0.091	43		0.86	0.018	22

Table 8: As for tables 5 and 6, but only out of sample and only for the middle third GPCE-AX predicted errors.

	CONU				CONW		
Tau	GPCE-AX frac bound	Frac area difference	Sample-size		GPCE-AX frac bound	Frac area difference	Sample-size
12	0.80	0.030	100		0.61	0.17	134
24	0.73	0.019	99		0.59	0.11	120
36	0.73	0.071	90		0.56	0.062	105
48	0.78	0.056	81		0.60	0.059	88
72	0.69	0.14	65		0.77	-0.049	66
96	0.77	0.19	52		0.78	0.052	37
120	0.93	0.080	44		0.95	-0.022	22

Table 9: As for tables 5 and 6, but only out of sample and only for the largest third GPCE-AX predicted errors.

Probability of Left/Right/Fast/Slow (P-LRFS)

The GPCE-AX forecast contains information about across-track and along-track expected error, but like GPCE it is symmetric; it provides no information about whether verification is more likely to fall on one side of the consensus or the other. P-LRFS (probability of left/right/fast/slow) was developed to address this shortcoming. P-LRFS is completely independent from GPCE/GPCE-AX. It performs an independent analysis to predict the probability of verification falling to the left, right, front or back of the consensus. Logistic regression was performed using the same potential predictors as GPCE and GPCE-AX, but with predictands that were either a 0 or 1 (e.g. left or right, front or back). Results for the 60% probability of falling to the left/right/fast/slow are given in tables 10 and 11 for CONU, and tables 12 and 13 for CONW. The first number in the column is the in-sample result (we are aiming for 0.6 in this case), while the second is the out-of-sample result. For CONU we find that the approach works best for the probability of verification falling to the left of track and for the probability of verification falling in front of the consensus (although both the fast and slow results are strong). For CONW P-LRFS out-of-sample results do not verify well. It is possible that increasing the training set (a planned activity) will improve the results, but as they stand P-LRFS is not yet ready for the WestPac basin.

Tau	Predictors	60% chance left (in/out)	60% chance right (in/out)
12	init lat, across sprd	0.67/0.48	0.6/0.54
24	init lat, pred dlat	0.68/0.59	0.63/0.47
36	init lat, pred dlat	0.71/0.65	0.65/0.44
48	init lat, pred dlat	0.67/0.68	0.66/0.61
72	init lat, pred dlat	0.63/0.67	0.76/Null
96	init lat, pred dlat	0.58/0.69	0.54/0.54
120	pred dlat, init lat	0.69/Null	0.62/0.53

Table 10: P-LRFS predictors and reliability for CONU across-track errors. init lat is the initial latitude, across sprd is the across-track spread of the aids, and pred dlat is the predicted latitudinal displacement. Both in-sample and out-of-sample results are reported for the probability of falling to the left of the bias corrected forecast and the probability of falling to the right of the bias corrected forecast at the 60% level. The in-sample results for each are reasonable, but the out-of-sample forecasts of falling to the left of consensus are more reliable than those of falling to the right of consensus.

Tau	Predictors	60% chance slow (in/out)	60% chance fast (in/out)
12	speed, pred dlon	0.62/0.67	0.68/0.73
24	speed, for int	0.67/0.72	0.65/0.71
36	speed, for int	0.65/0.56	0.67/0.74
48	speed, for int	0.58/0.41	0.62/0.67
72	init lon, pred dlat	0.55/0.47	0.72/0.45
96	init lon, pred dlon	0.57/0.06	0.62/0.83
120	init long, for int	0.65/0.62	0.73/0.74

Table 11: P-LRFS predictors and reliability for CONU along-track errors. speed is the predicted speed of the storm, pred dlon is the predicted longitudinal displacement of the storm, for int is the forecast intensity, init lon is the initial longitude of the storm, and pred dlat is the predicted latitudinal displacement of the storm. Both in-sample and out-of-sample results are reported for the probability of falling behind the bias corrected forecast and the probability of falling in front of the bias corrected forecast at the 60% level. The in-sample results for each are reasonable, but the out-of-sample forecasts of falling ahead of consensus are more reliable than those of falling behind of consensus.

Tau	Predictors	60% chance slow (in/out)	60% chance fast (in/out)
12	init-lat,pred-dlon	0.6/0.62	0.64/0.53
24	init-lat,pred-dlat	0.64/0.51	0.67/0.42
36	pred-dlat,init-lat	0.63/0.46	0.65/0.34
48	init-lat,pred-dlat	0.64/0.47	0.65/0.27
72	init-lat,pred-dlat	0.62/0.32	0.59/0.13
96	init-lat,for-int	0.61/0.30	0.66/0.06

120	init-lat,init-lon	0.78/Null	0.46/Null

Table 12: Across track CONW P-LRFS results for the 60% level.

12	speed,across-sprd	0.67/0.65	0.7/0.7
24	speed,pred-dlon	0.62/0.56	0.65/0.59
36	speed,pred dlon	0.65/.59	0.70/0.55
48	init-lat,pred-dlat	0.62/0.56	0.71/0.43
72	init-lat,ens-size	0.75/0.65	0.52/0.6
96	init-lat,pred-dlon	0.73/Null	0.59/0.46
120	pred-dlat,for-int	0.63/0.2	0.63/0.67

Table 13: Along-track CONW P-LRFS results for the 60% level

Conclusions

GPCE-AX is an objective improvement over GPCE in the Atlantic and provides results that are nearly identical to GPCE in the WestPac. P-LRFS is found to be reliable for the Atlantic, but unreliable for the West-Pac.

We have identified with Buck Sampson the steps necessary to begin the ATCF modifications necessary to incorporate GPCE-AX and P-LRFS. These modifications will take place in the first quarter of calendar year 2009.