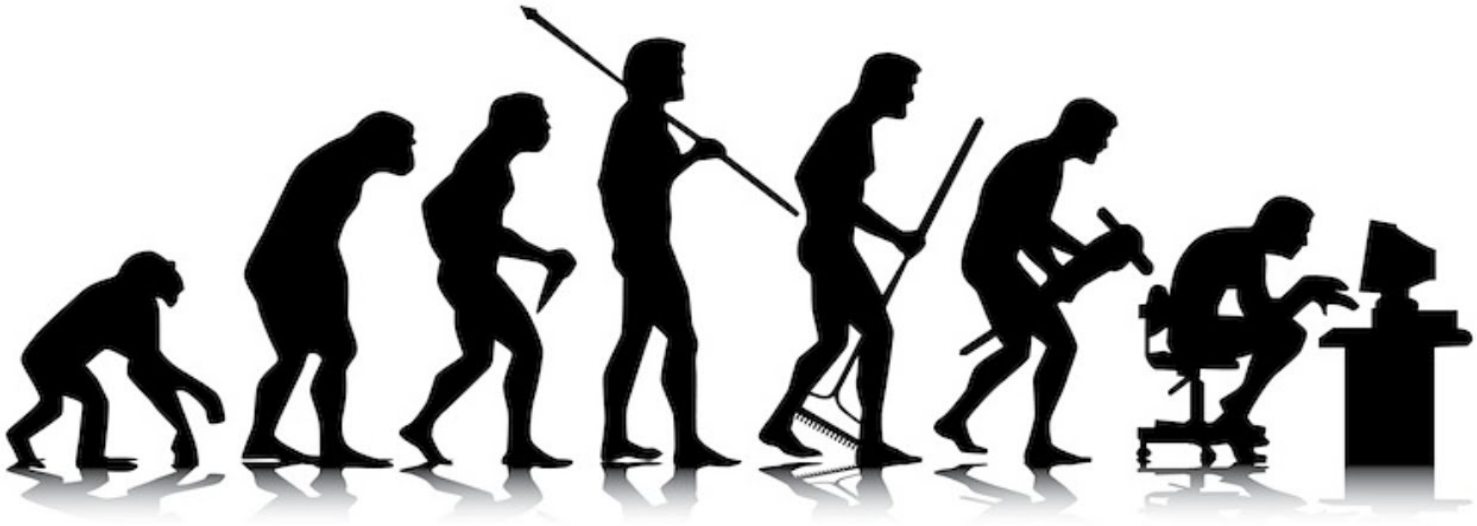
Using Evolutionary Programming for Tropical Cyclone Intensity Forecasts



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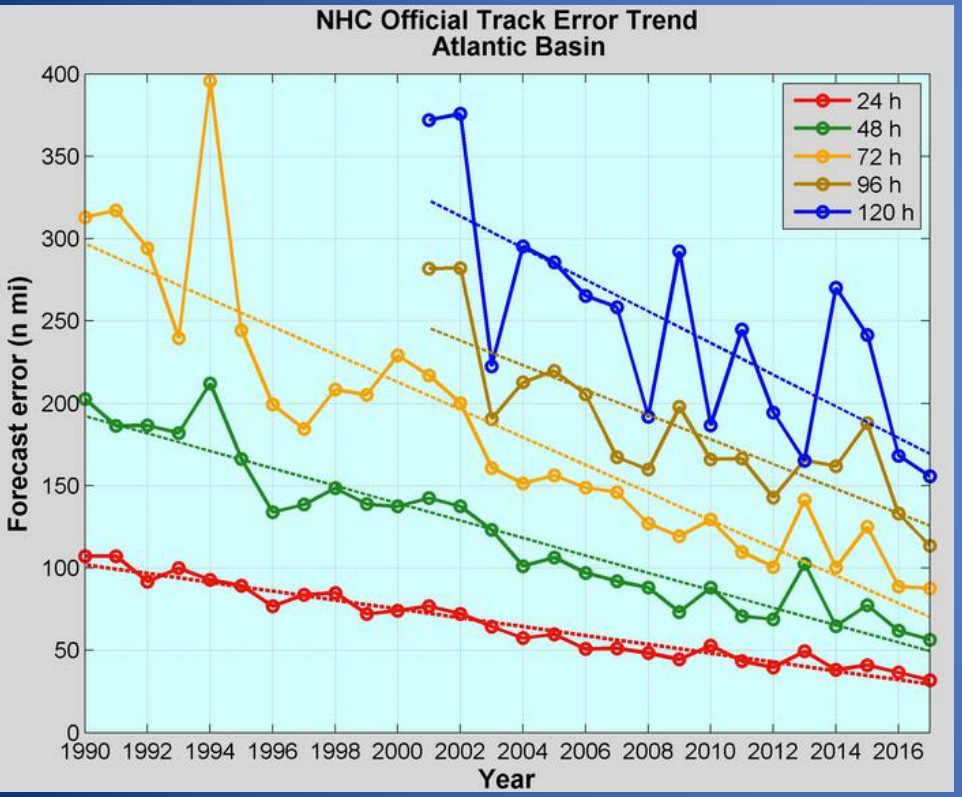
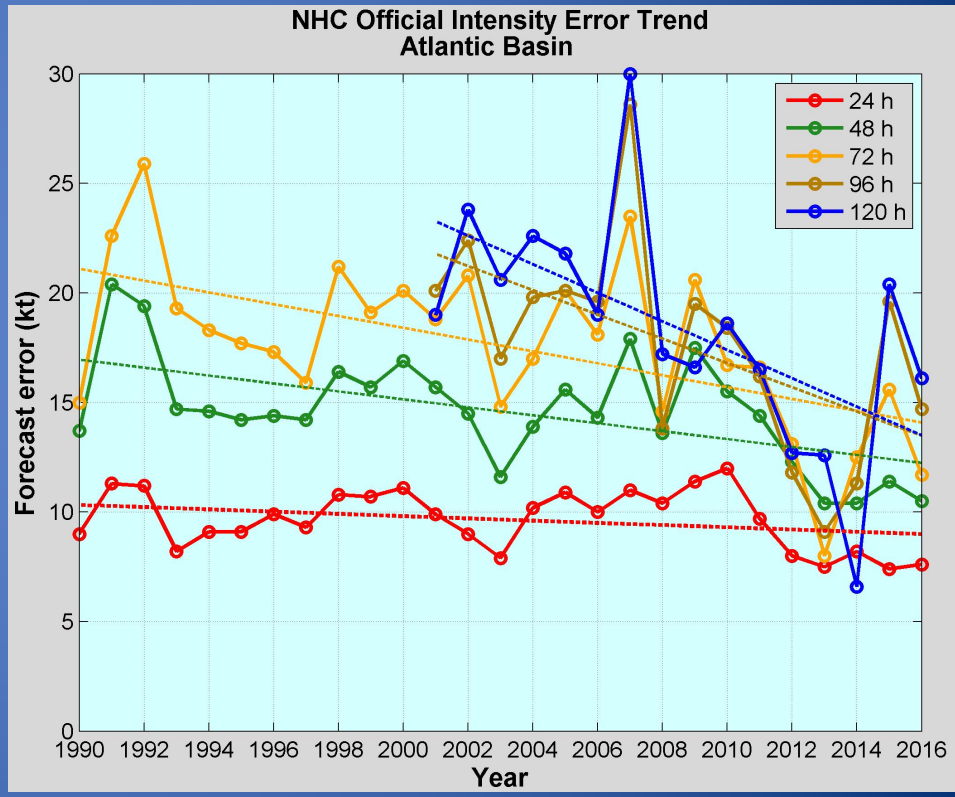
Motivation





https://www.nhc.noaa.gov/verification/verify5.shtml?

Evolutionary Programming (EP)

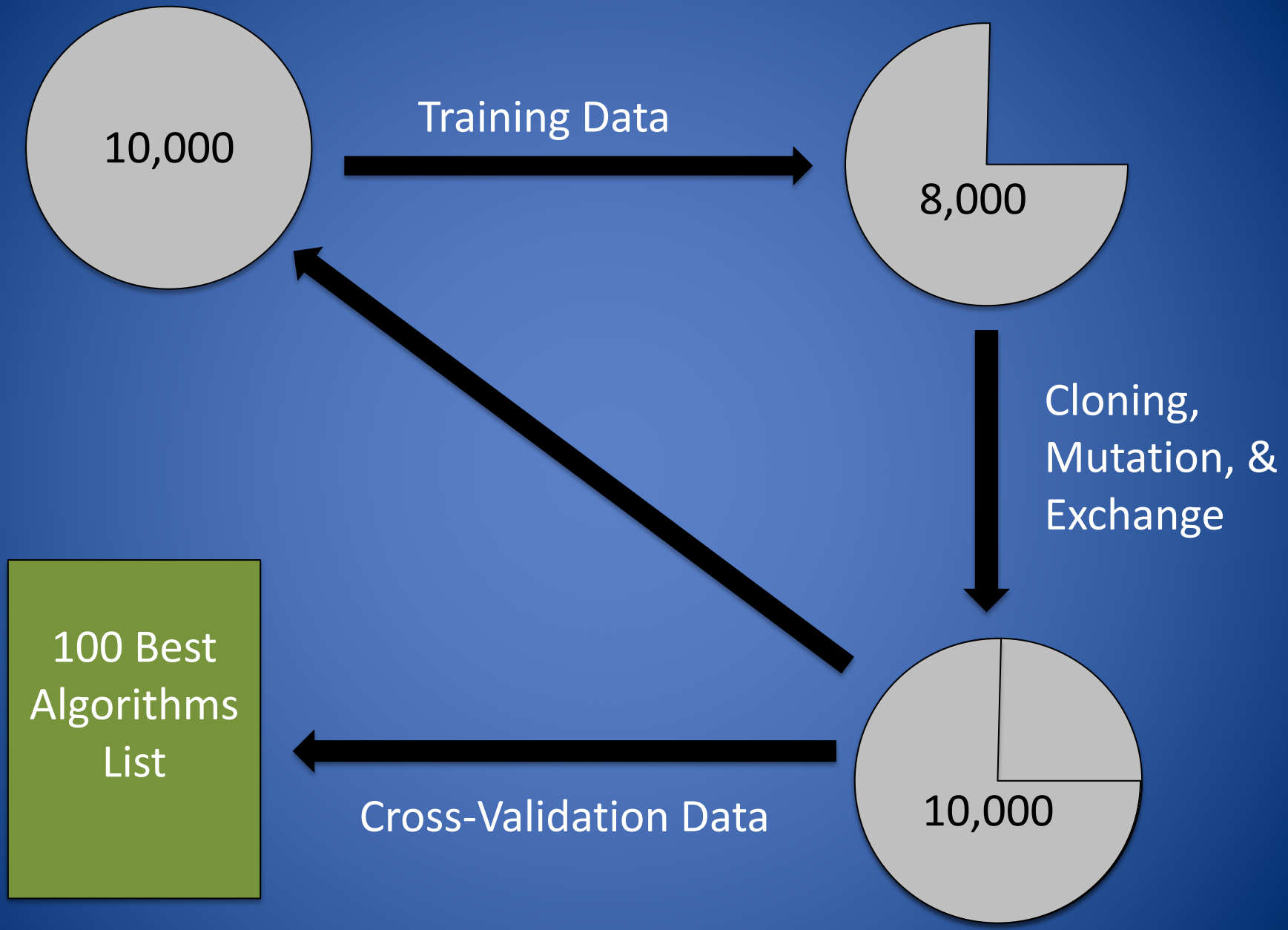
- Developed by Lawrence Fogel in the 1960s to produce large member ensemble forecasts
- Roebber (2014,2015,2016) has demonstrated it's skill over more traditional dynamical models in 500-hPa height forecasts and over statistical dynamical models (e.g. MOS) in minimum temperature forecasts
- Like other machine learning algorithms EP applies to well defined problems with clear measures of success. Yet the algorithms it produces are more easily interpretable

Model Overview / Goals

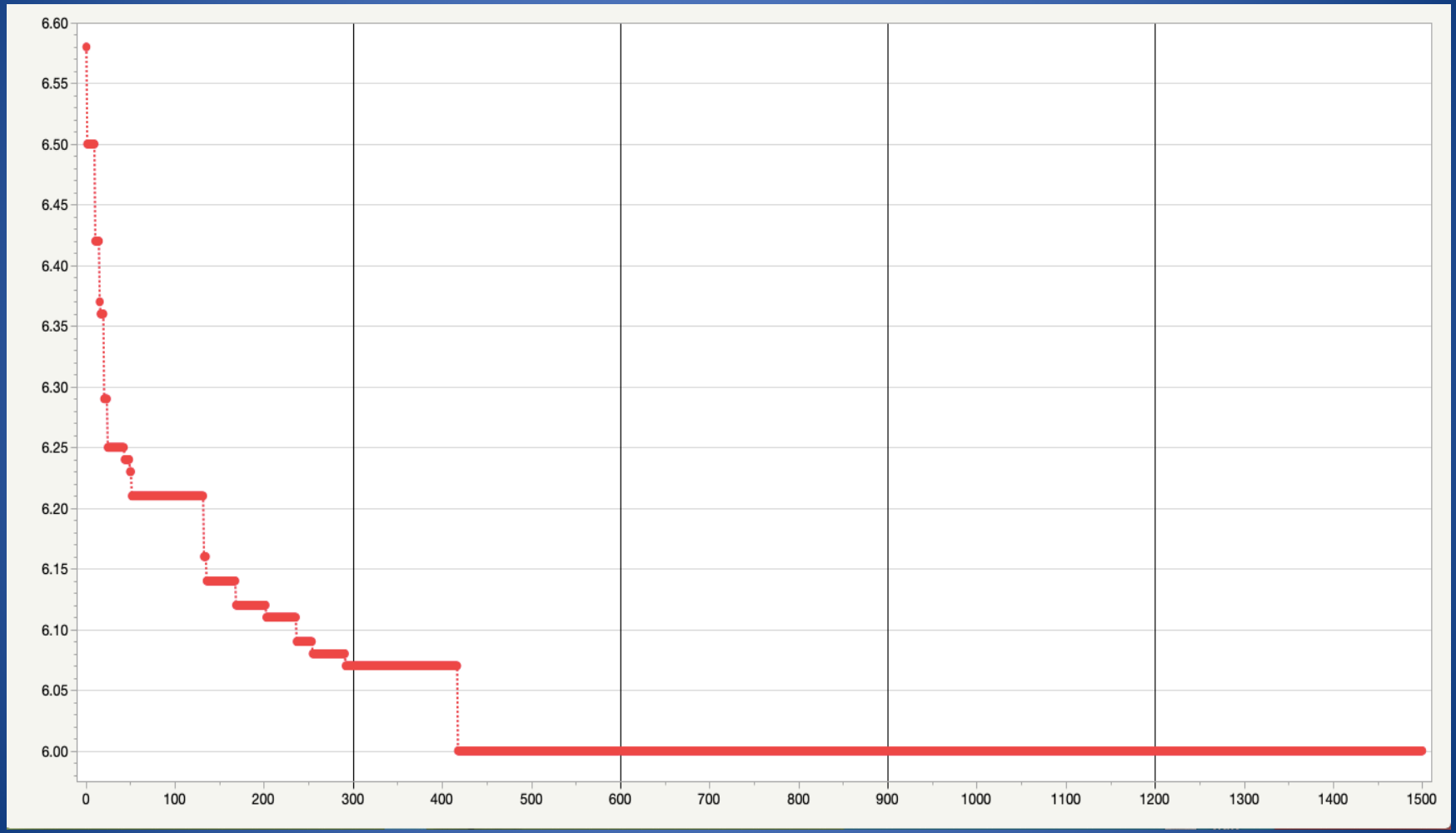
- Develop a Statistical-Dynamical Model using EP to generate improved TC intensity forecasts
- Separate model for the North Atlantic and east/central North Pacific Basins
- Deterministic TC intensity forecasts every 12h out to 120h and probabilistic forecasts for RI and RW every 12h out to 72h

Data

- Utilized SHIPS developmental data for all TCs in the respective basin from 2000-2016 (includes 8 variables converted to standard anomaly, plus a constant)
- TC cases were separated into three categories: TSs, Weak Hurricanes, Major Hurricanes
- Pulled storms evenly from each category to form Training, Cross-Validation, and Testing datasets


10,000
Training Data
8,000
Cloning,
Mutation, &
Exchange
100 Best
Algorithms
List
Cross-Validation Data
10,000

Training Progress of the Best Equation (Atlantic Basin)



Population #1-5 (x300 Generations for each)

Algorithm Structure

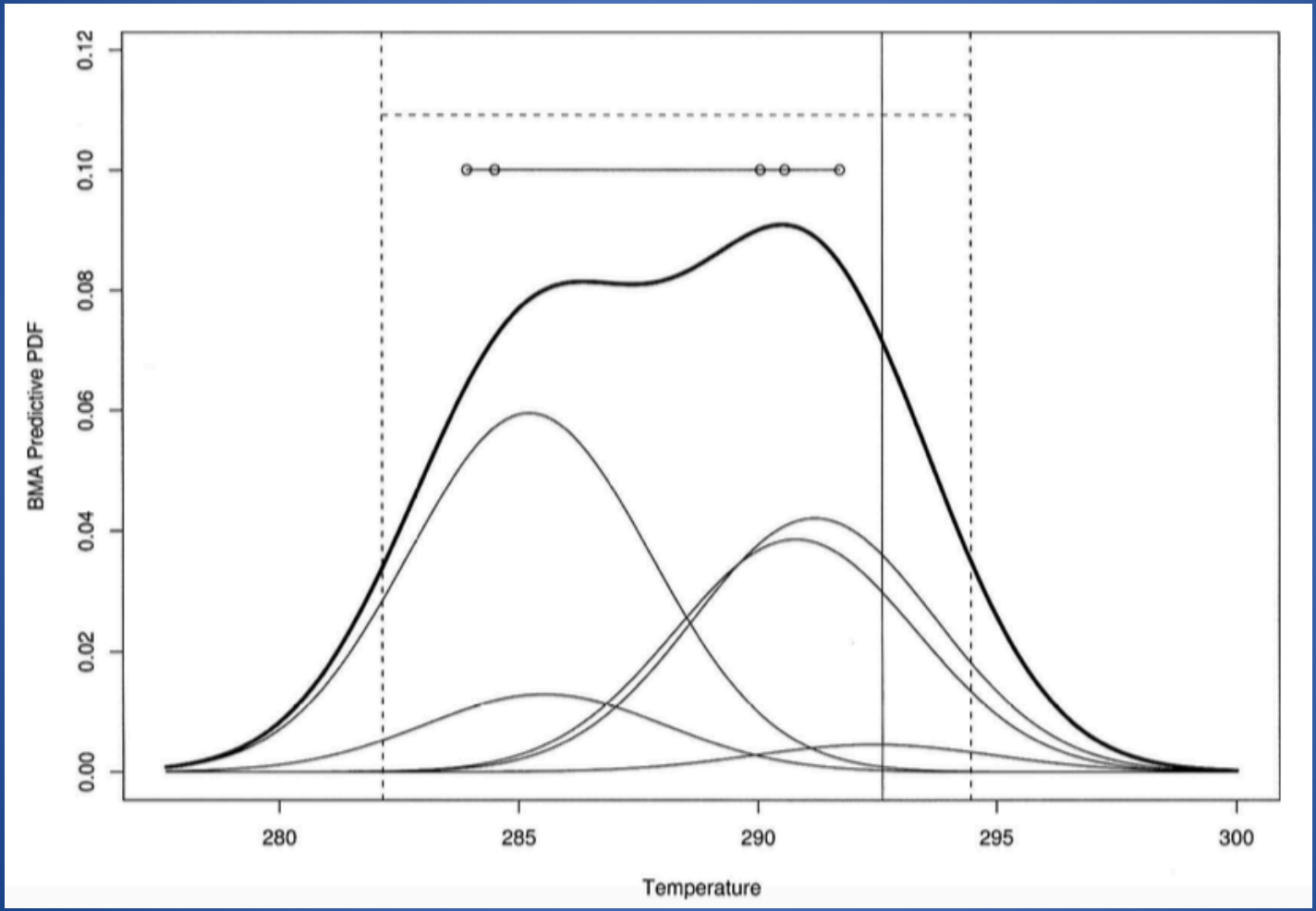
Each algorithm has five IF-THEN statements that sum together to provide forecast change in intensity over 12 h

1	IF	SHDC <= 10	THEN	-0.31846 * CFLX	+	-0.40838 * TWAC	*	0.37035 * CFLX
2	IF	SHDC > D200	THEN	-0.43399 * D200	*	-0.06379 * DELV	+	-0.06141 * SHDC
3	IF	VMPI <= VMPI	THEN	-0.80966 * U20C	*	0.05226 * CD26	+	0.30455 * DELV
4	IF	CD26 > VMPI	THEN	-0.66502 * CFLX	*	0.97804 * U20C	*	-0.09527 * DELV
5	IF	VMPI > U20C	THEN	0.01439 * 10	+	-0.10008 * 10	*	-0.08352 * CD26

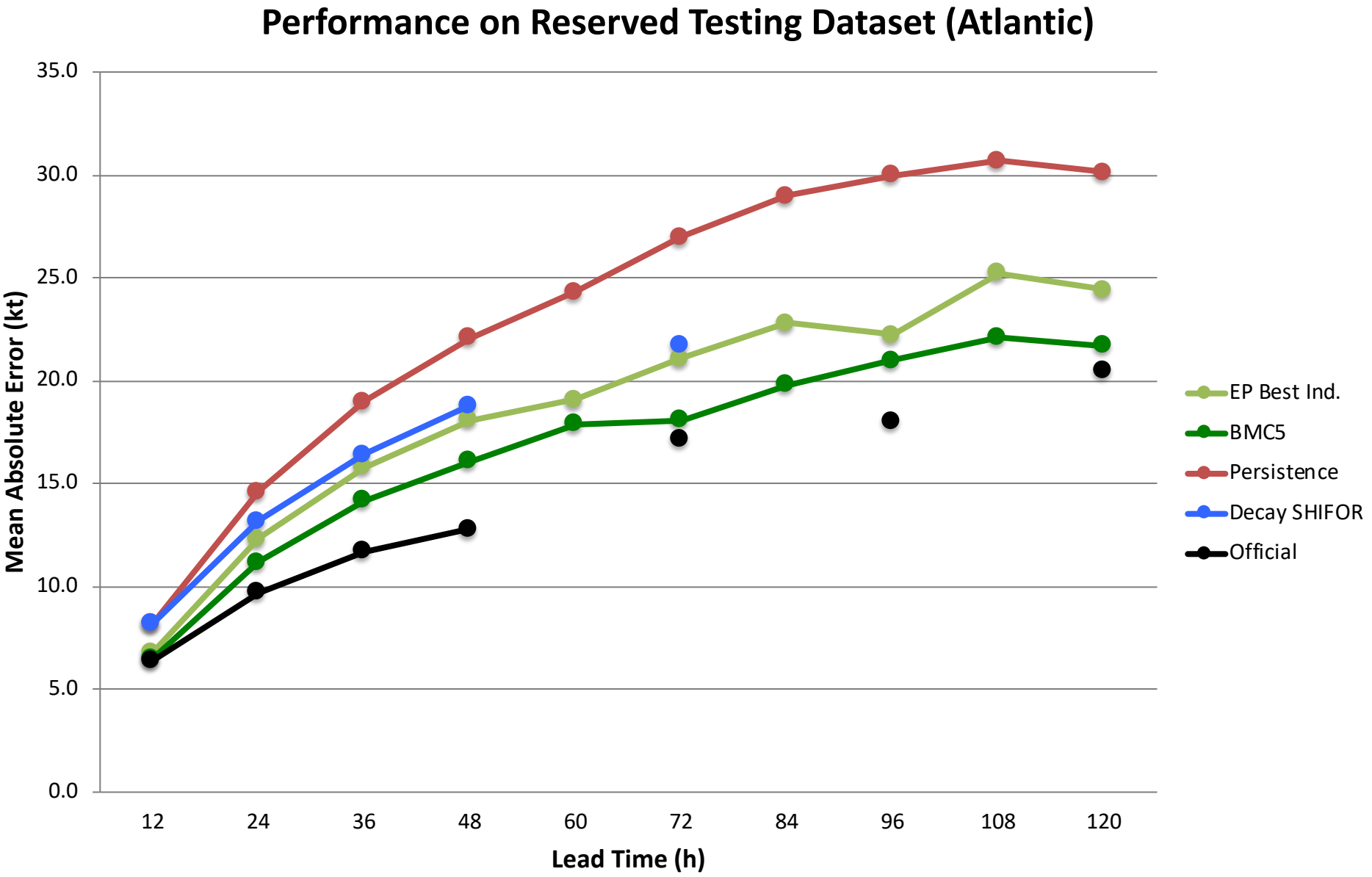
- Blue highlights lines where the if-statement is always true and thus the following adjustment will always be performed.

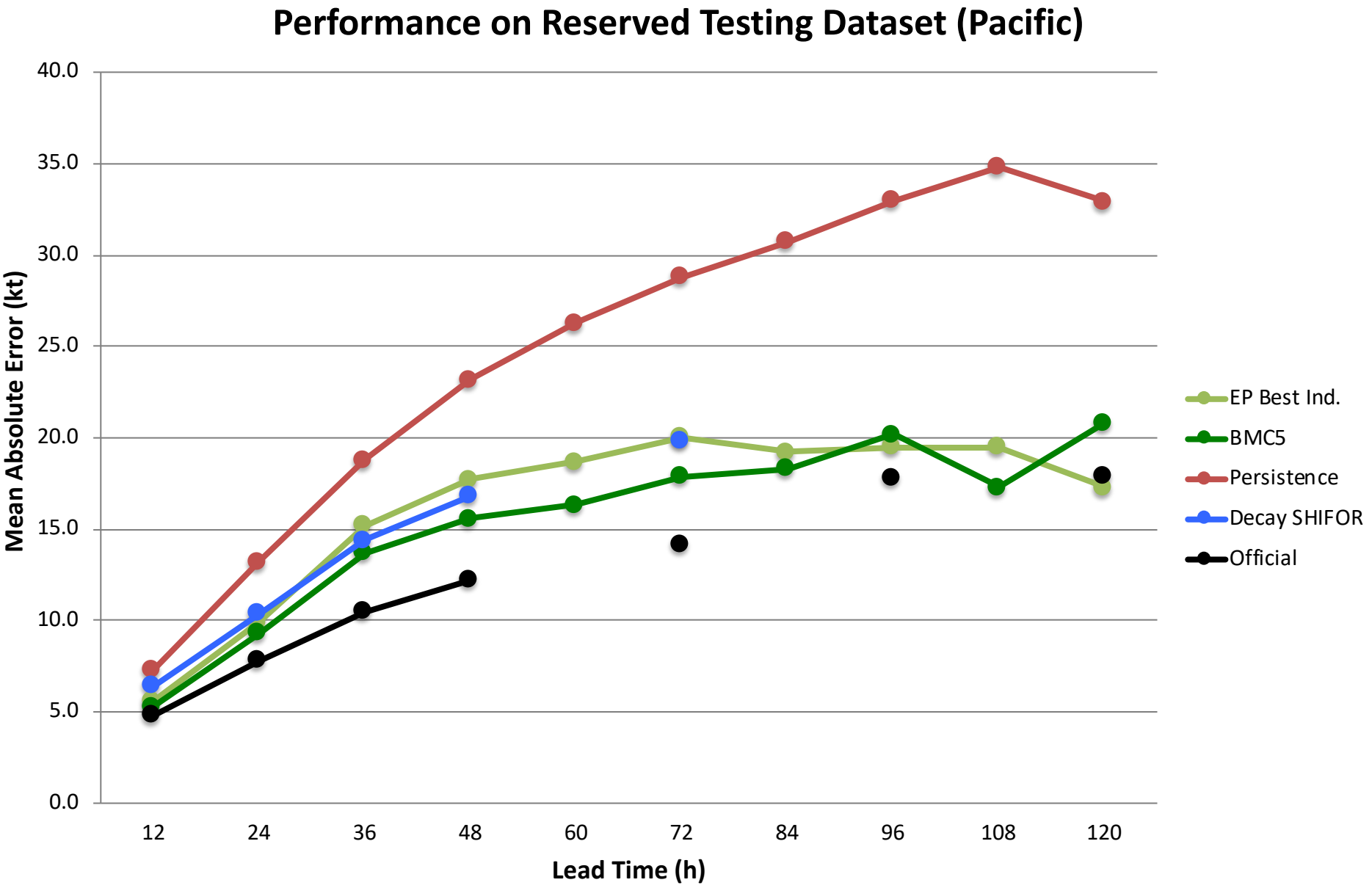
Bayesian Model Combination

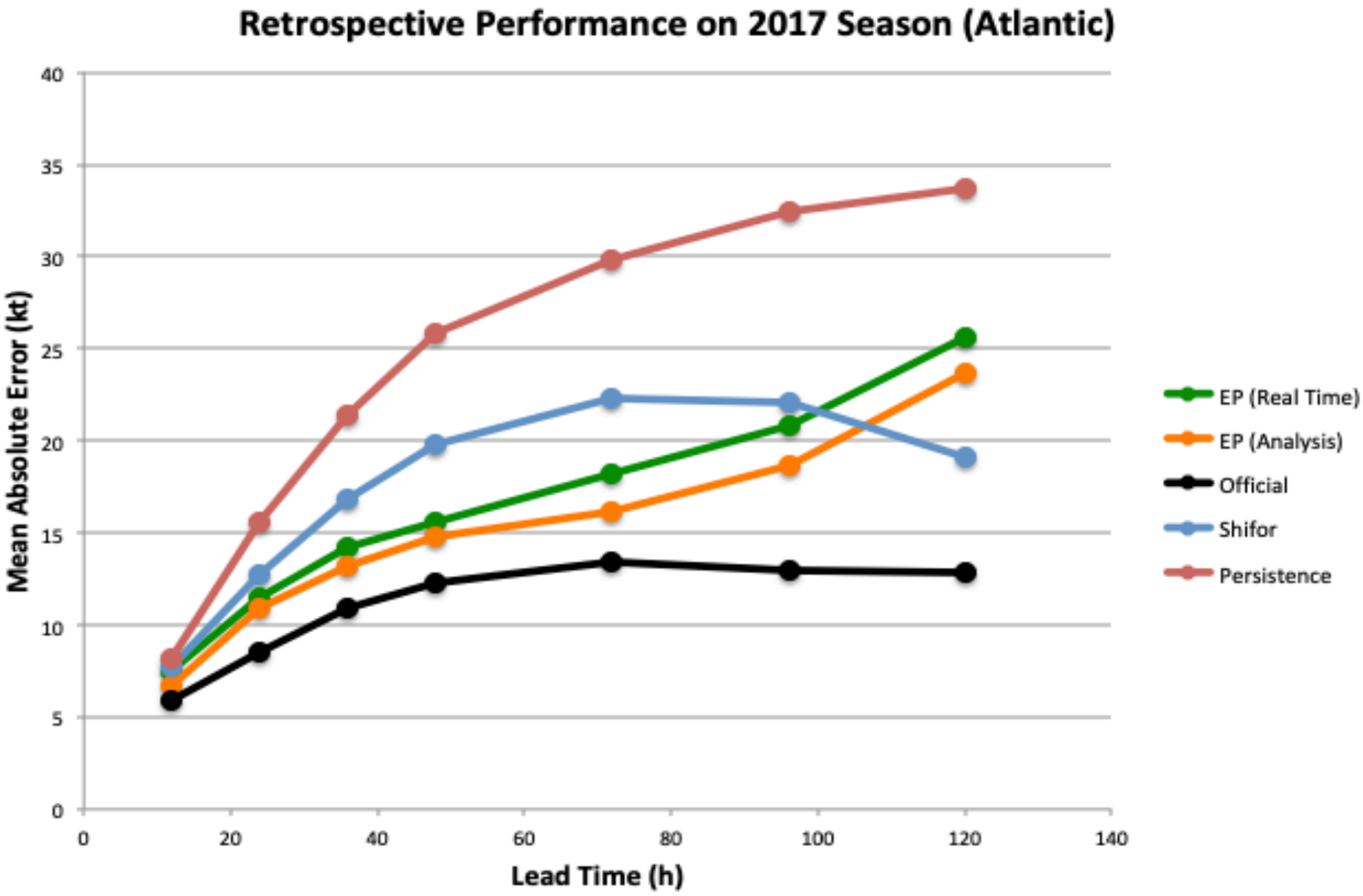
- Process for weighting individual ensemble members together

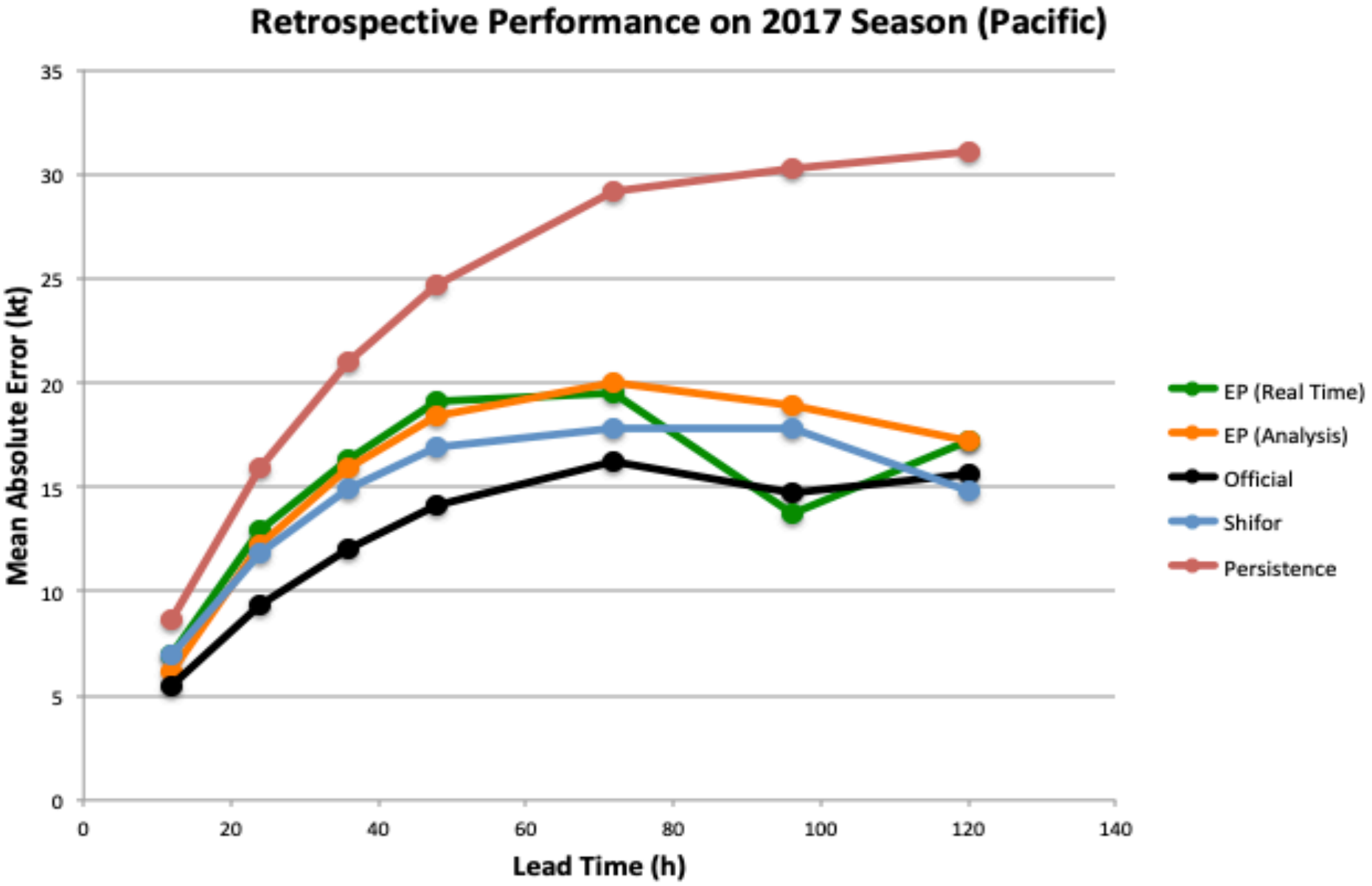


Raftery, A. E., T. Gneiting, F. Balabdaoui, and M. Polakowski, 2005: Using Bayesian model averaging to calibrate forecast ensembles. Mon. Wea. Rev., 133, 1155–1174, doi:10.1175/ MWR2906.1.


Performance on Reserved Testing Dataset (Atlantic)
Mean Absolute Error (kt)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
12
24
36
48
60
72
84
96
108
120
Lead Time (h)
EP Best Ind.
BMC5
Persistence
Decay SHIFOR
Official


Performance on Reserved Testing Dataset (Pacific)
Mean Absolute Error (kt)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
12
24
36
48
60
72
84
96
108
120
Lead Time (h)
EP Best Ind.
BMC5
Persistence
Decay SHIFOR
Official


Retrospective Performance on 2017 Season (Atlantic)
Mean Absolute Error (kt)
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120
140
Lead Time (h)
EP (Real Time)
EP (Analysis)
Official
Shifor
Persistence


Retrospective Performance on 2017 Season (Pacific)
Mean Absolute Error (kt)
0
5
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40
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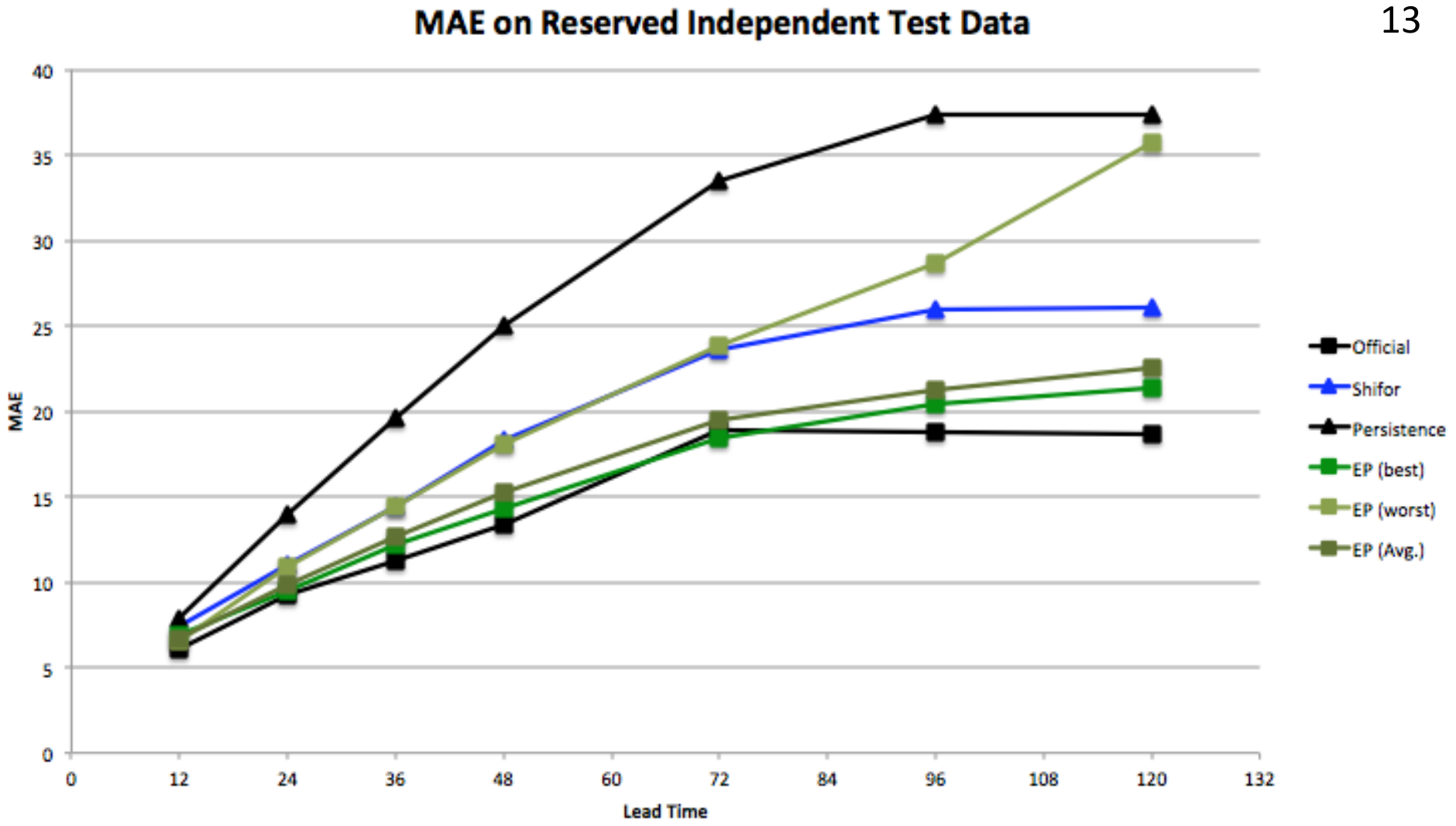
Lead Time (h)
EP (Real Time)
EP (Analysis)
Official
Shifor
Persistence



Performance of Atlantic Model on reserved independent dataset using analysis predictors

- Out of ~6,000 cases for some predictors up to 500 cases featured anomalous data that was on average around 1 unit (0.1 standard deviations) off of what was valid
- TWAC was different for 2692 cases with an average difference of 5.15 ms^{-1} (0.27 std dev)

Conclusion

- We've seen results previously that demonstrate the potential for EP to give competitive TC intensity forecasts in the ATL basin. But in current set up performance drops off towards later lead times.
- Struggling to produce better performance in PAC basin.

Future Work

- Better selecting meaningful variables out of the SHIPS dataset
- Adding future variables representing inner-core processes as well as quadrant-based variables rather than complete radial averages
- Continue to probe how to format EP processes to generate improved skill

Acknowledgments

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