Statistical post-processing work and plans at GSD and DTC

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NOAA/ESRL/FAB (also DTC)

Acknowledgements: Sai Ravela (MIT), Roman Krysztofowicz (UVA), Paula McCaslin (NOAA/ESRL), Tara Jensen (NCAR), Zoltan Toth (NOAA/ESRL)

3 May 2012

Summary of Activities

- NUOPC post-processing toolbox plans
- DTC ensemble stat post and product work and plans
- Bayesian Processor of Ensemble (BPE) plans

NUOPC Post-Processing Toolbox

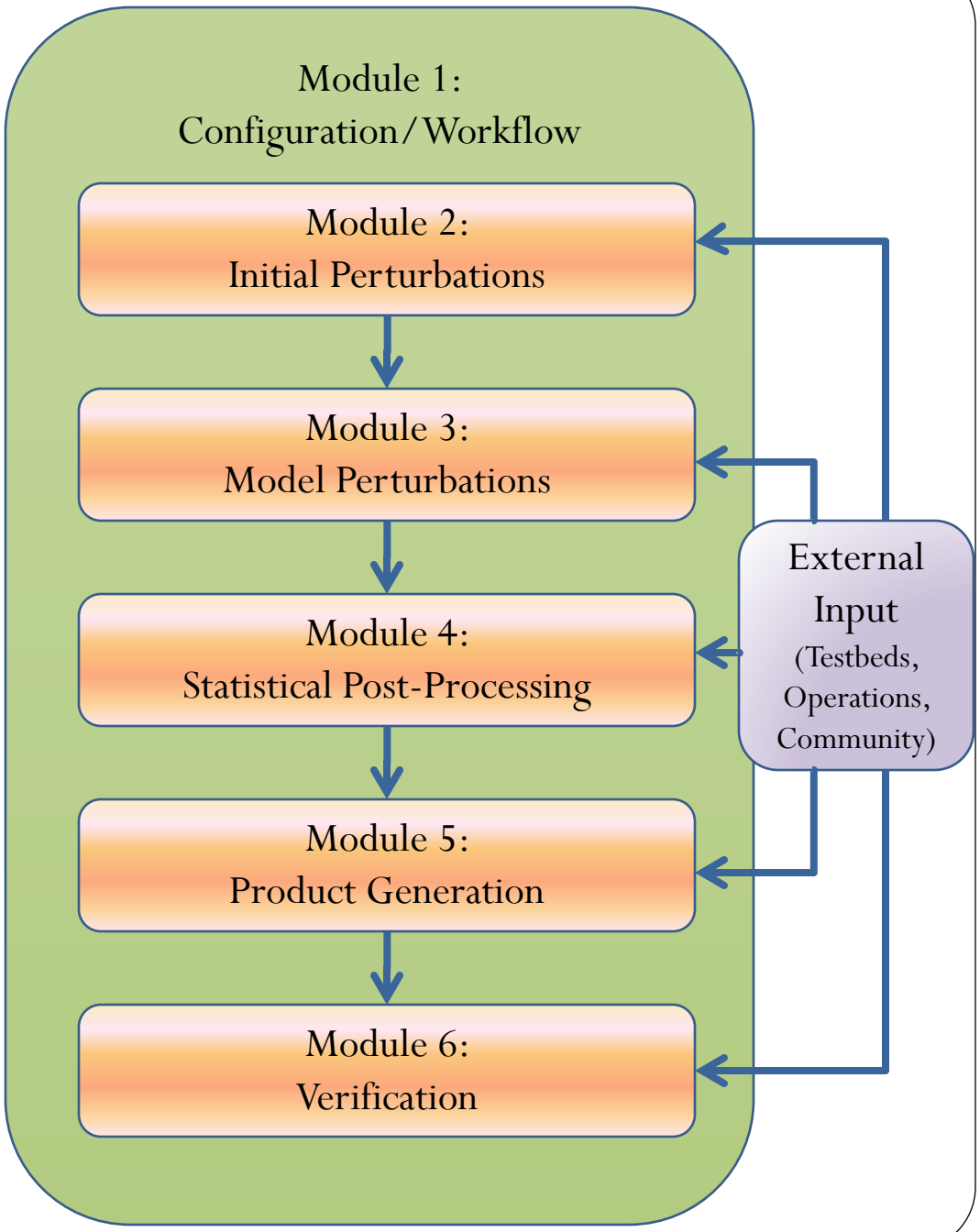
- DTC is already in possession of post-processing codes from AFWA, CAPS, and NCEP/EMC.
- NUOPC wishes these, and other post-processing codes, to be combined into a toolbox at NOAA/ESRL/FAB
  - Toolbox more than a repository – works to connectedness of codes and ensemble systems
- Plans include:
  - Instead of an annotated repository, work will be done to build and end-to-end capacity, where the codes from one agency can work with the ensemble numerical weather prediction output of another agency.
  - Primary focus here will be correction of biases in the mean and spread of the ensemble – the calibration of ensemble output.
  - A number of methods are possible candidates for this toolbox, including BMA, EKDMOS, BPE, Non-Homogeneous Gaussian Regression.

NUOPC Post-Processing Toolbox

- NOAA/ESRL/FAB proposes to do the work of housing the algorithms of different agencies and of investigating how different agencies can use these algorithms. The work to be done in the first year is:
  - Standing up a virtual machine, at NOAA/ESRL, to serve as the repository. This repository will have 'restricted access', so that only NUOPC approved individuals can access it.
  - Committing all codes (NOAA, AFWA, and NAVY) to this repository. While the repository will have the full codes (that is the easiest means of porting), it is the algorithms within that will be the initial focus.
  - Beginning the full evaluation of portability of the algorithms – how different operational systems can hook into them.
  - Beginning the full portability of the algorithms – full end-to-end capability for the use of different algorithms with different ensemble numerical weather prediction output

DTC Ensemble Team

- The DTC is working to enable the infrastructure for testing and evaluation of promising techniques for transition to operations.
- Applications to all the modules shown are invited.



DTC Ensemble Post-Processing

- Enablement of CAPS software required many prerequisite software libraries are required to build the system executables.
- DTC able to run the post-processing product generator successfully on a limited set of data for the initial test.
- Nearest-neighbor probability matching is a candidate to be extracted and ported as a standalone module for use in the DTC with other ensemble systems.

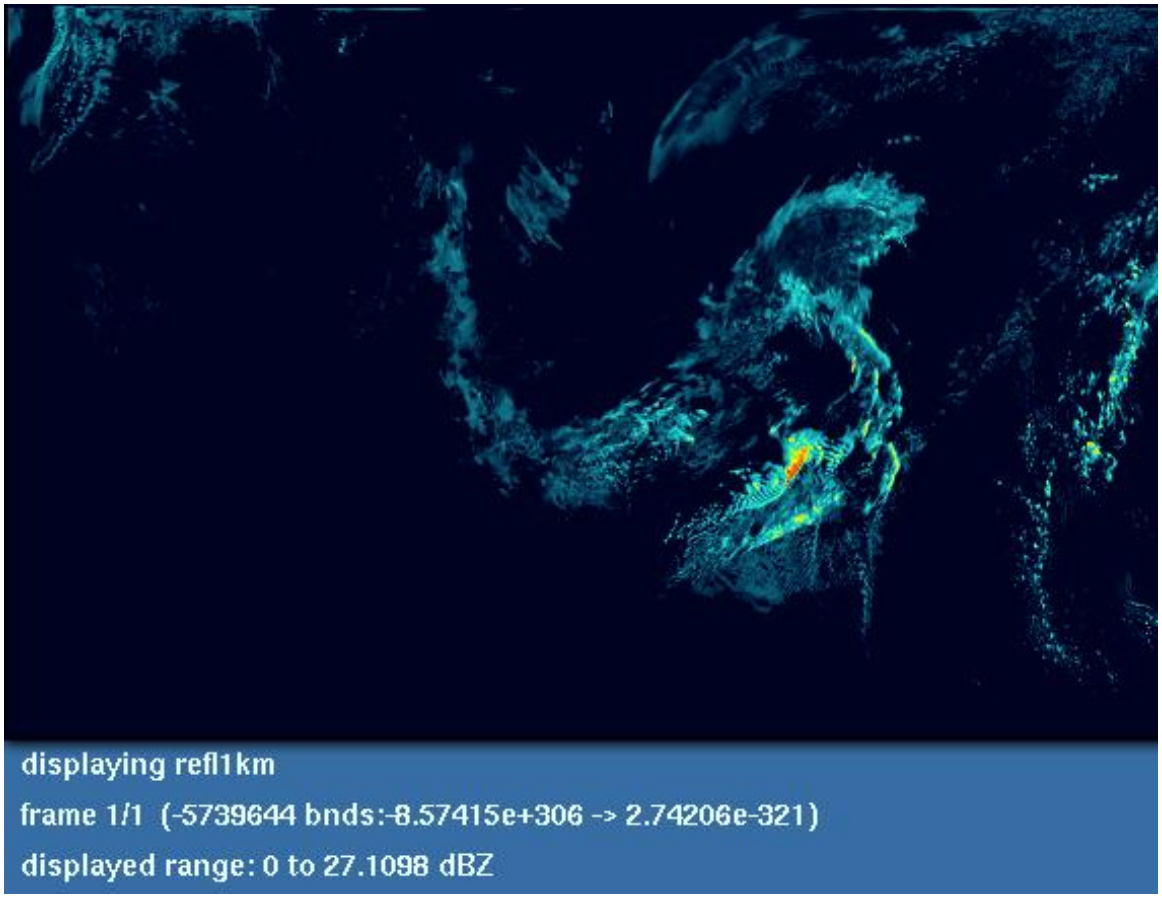


Figure from Paula McCaslin

DTC Ensemble Post-Processing

- In addition to aforementioned products work, DTC visitor program will enable deployment of Field Alignment System and Testbed (FAST).
- Perturbations have a discernible relative position error.
- Ensemble mean in the case of figure 1 would be over smoothed, as would figure 2a/b.
- After field alignment, mean is sharper, more focused (2c/d).

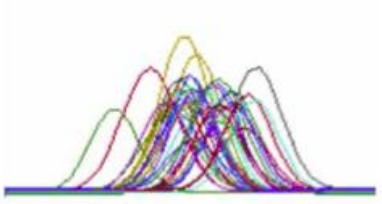
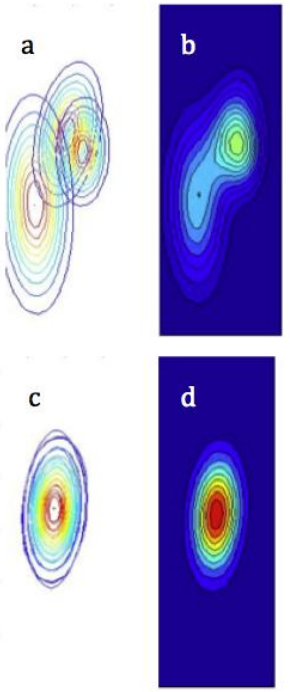


Figure 1: Position errors must be accounted when quantifying uncertainty.



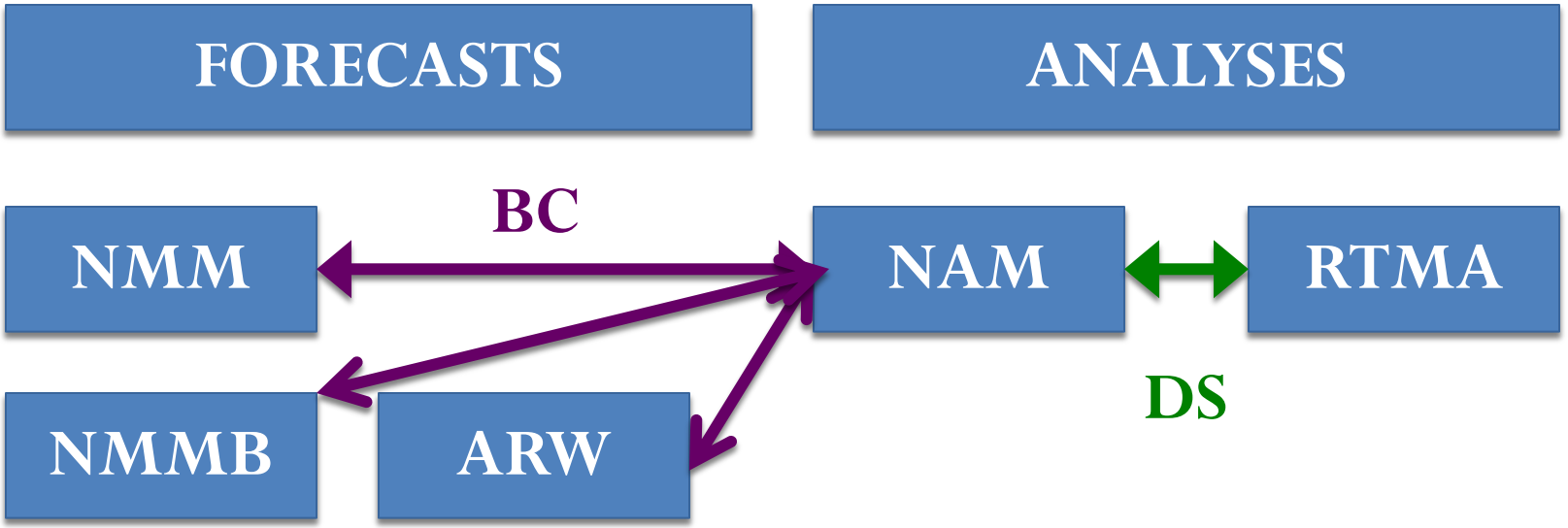
Figures from Sai Ravela

Figure 2: An ensemble with deformation errors (a), their amplitude mean (b), coalesced ensemble (c), amplitude mean after coalescing (d).

DTC Ensemble Post-Processing

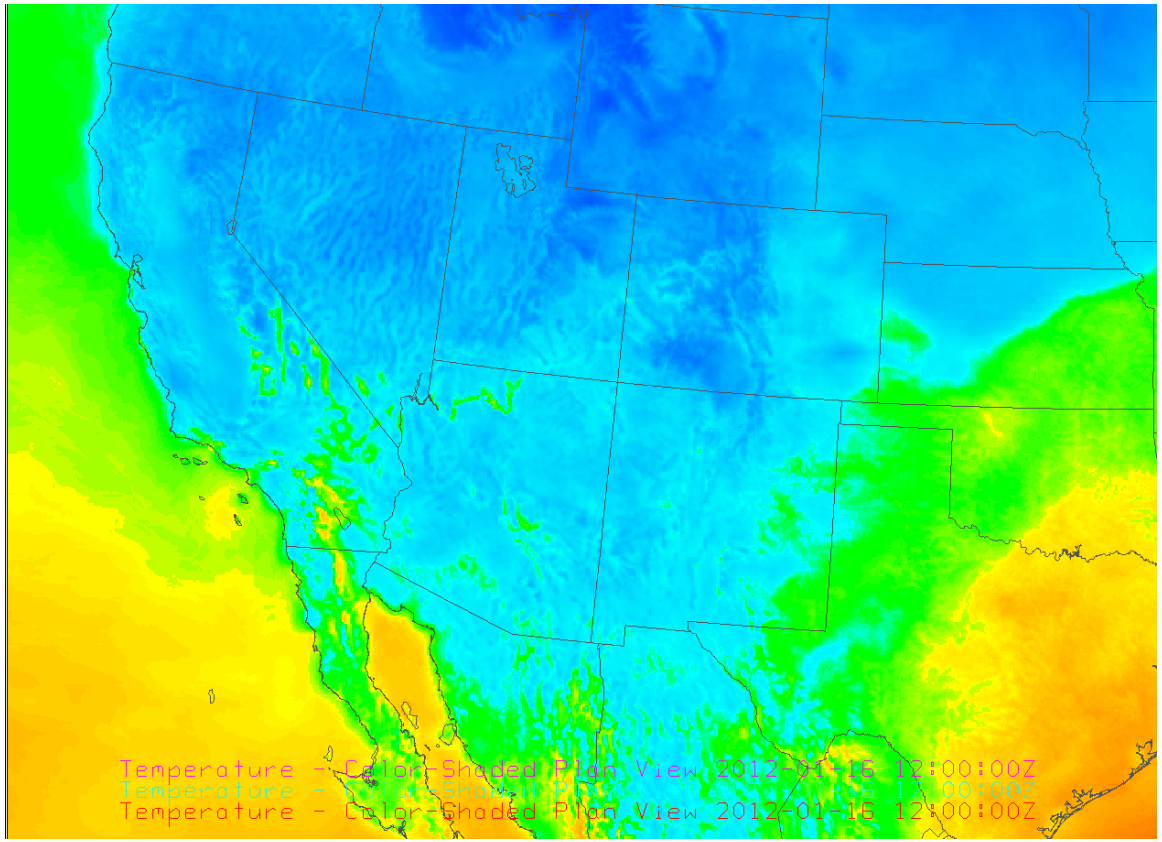
- Deployment of FAST at DTC accomplished by DTC visitor Sai Ravela, over 3 visits to NOAA/ESRL
  - Performance evaluation of algorithms on test cases, and refinements to it.
  - Development of suitable example cases and documentation of those cases.
  - Developing documentation for the system, including support to the community.

DTC implementation of NAEFS Downscaling for NCEP SREF



- Bias Correction is accomplished by taking the mean forecast of each model core (ARW, NMM, etc.) sub-ensemble of the NCEP SREF and comparing it to the NAM analysis valid at the same time.
- Downscale by comparing the RTMA analysis (GRID 259, like GRID 197, 1073x689, 5.079km) with the NAM analysis valid at the same time (10m wind,2m temperature and humidity).

Implementation of downscaling at EMC



Raw SREFx, Bias corrected SREFx, and downscaled SREFx forecasts (initialized 2100UTC 12 Jan 2012, valid 1200UTC 16 Jan 2012, 87-hour forecasts)

- Downscaling code used in NAEFS ported to DTC in early summer
- Testing/evaluation of the application of this code to the existing NCEP SREF output showed forecast improvement
- DTC code sent to EMC for application to the new NCEP SREF, implemented in approximately 2 days, with downscaled forecasts being produced since December 7th

DTC implementation of NAEFS Downscaling for NCEP SREF

- As implemented at DTC (using archived NCEP SREF ensemble output), downscaling decreased mean error (removed bias)
- Not always statistically significant

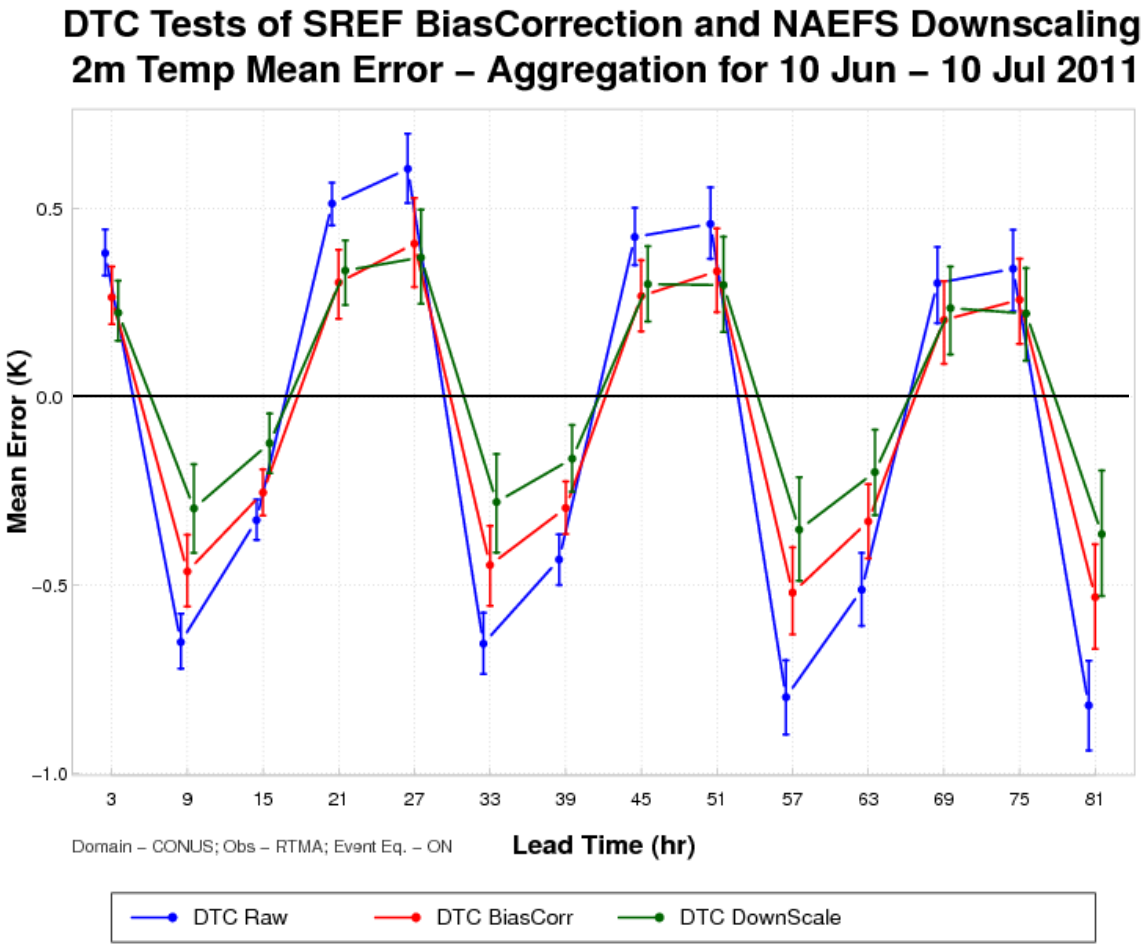


Figure from Tara Jensen

DTC implementation of NAEFS Downscaling for NCEP SREF

- As implemented at DTC (using archived NCEP SREF ensemble output), downscaling decreased root mean squared error (compared to RTMA) at all lead times.

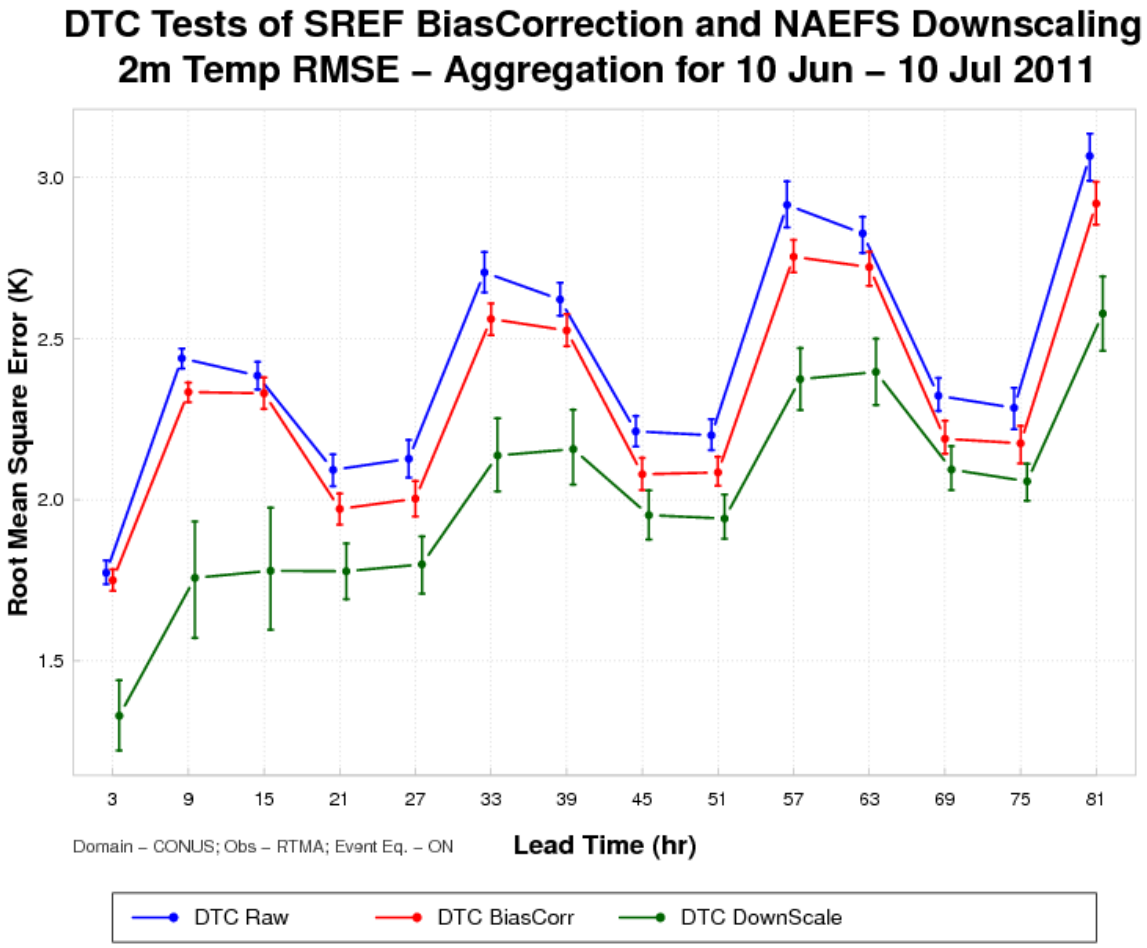


Figure from Tara Jensen

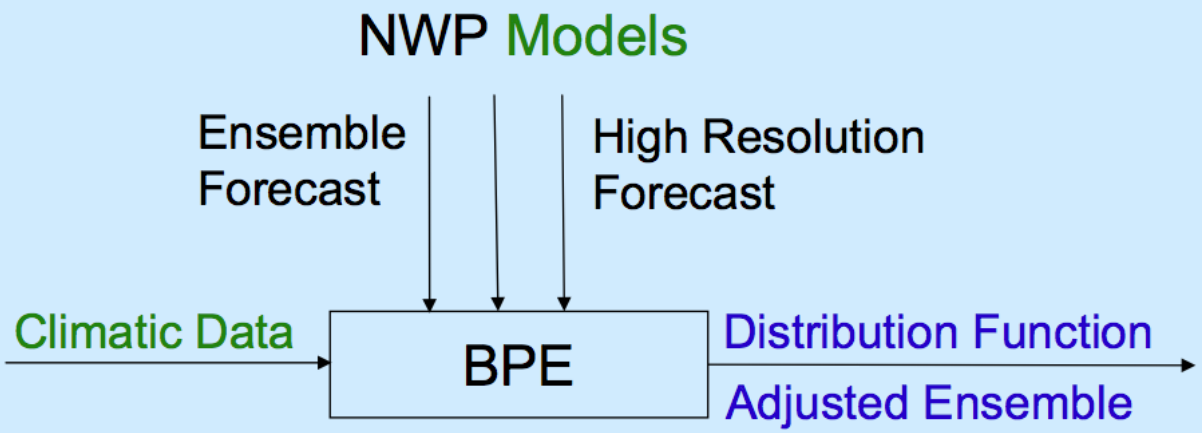
Bayesian Processor of Ensemble

- NOAA and the NWS recognized the importance of digital forecasts both as guidance for NWS forecasters and increasingly as direct input into decision support systems by various users (e.g., NEXTGEN).
- Bias correction and downscaling for NAEFS (and applied to other ensembles) has greatly improved the prediction of the first statistical moment.
- The direct use of NWP forecasts, however, is still limited and often impeded by significant systematic errors (i.e., biases in the higher moments, e.g. the spread) in ensemble forecasts.
- The objective of the BPE work is to develop and test new methods for estimating and then reducing/removing systematic errors from ensemble forecasts, as well as combining NWP and other relevant information into a single high quality ensemble forecast database as an important component of the 4D datacube.

Bayesian Processor of Ensemble

- NAEFS bias correction and down scaling is a first step into the statistical post processing of an ensemble – but this focused on only the first statistical moment
- To move to correction of higher order moments, NOAA/ESRL/FAB will work to implement the Bayesian Processor of Ensemble (BPE).
- Work will be applied to a model grid (as opposed to site specific forecasts).
- Work will be done in collaboration with Roman Krysztofowicz and Yuejian Zhu.

CONCEPT OF BAYESIAN PROCESSOR



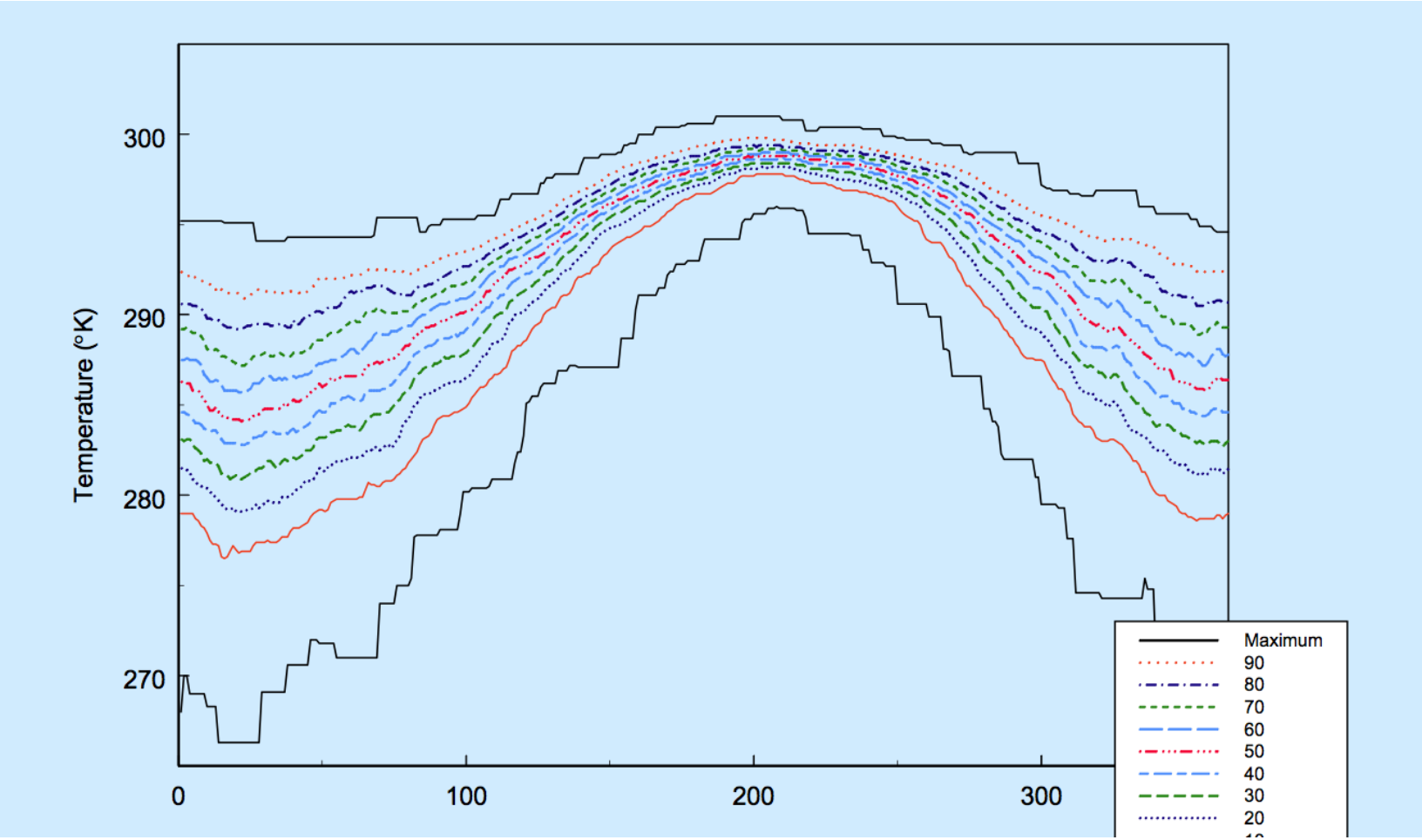
1. Extracts and Fuses Information
   maximizes *informativeness*
2. Quantifies Total Uncertainty
   guarantees *calibration*

Estimated for: predictand, grid point, day, lead time

Versions for: binary, multi-category, continuous predictands

Figure from Roman Krysztofowicz

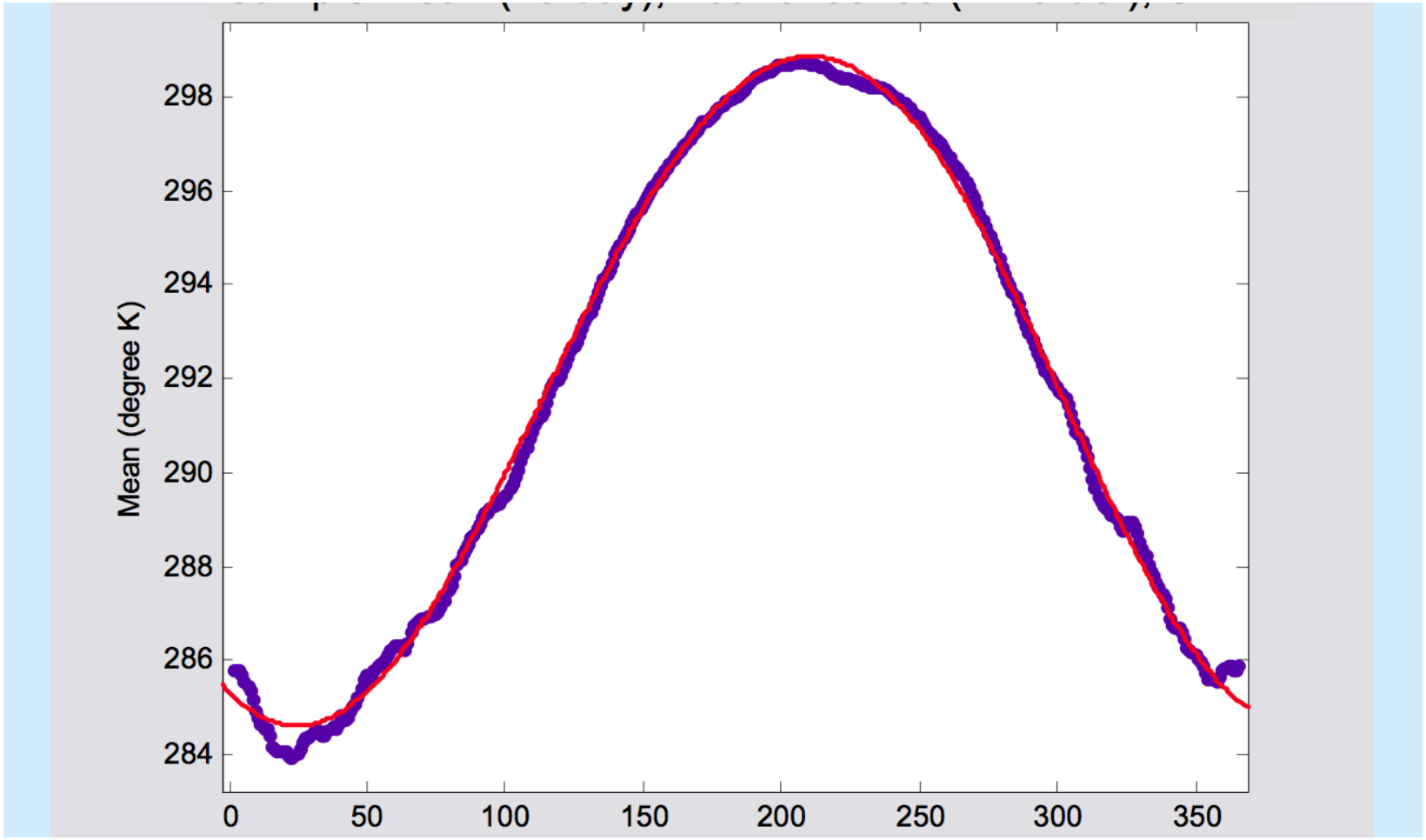
Bayesian Processor of Ensemble



Climatology for analysis gridpoint near Savannah, GA

Figure from Roman Krysztofowicz

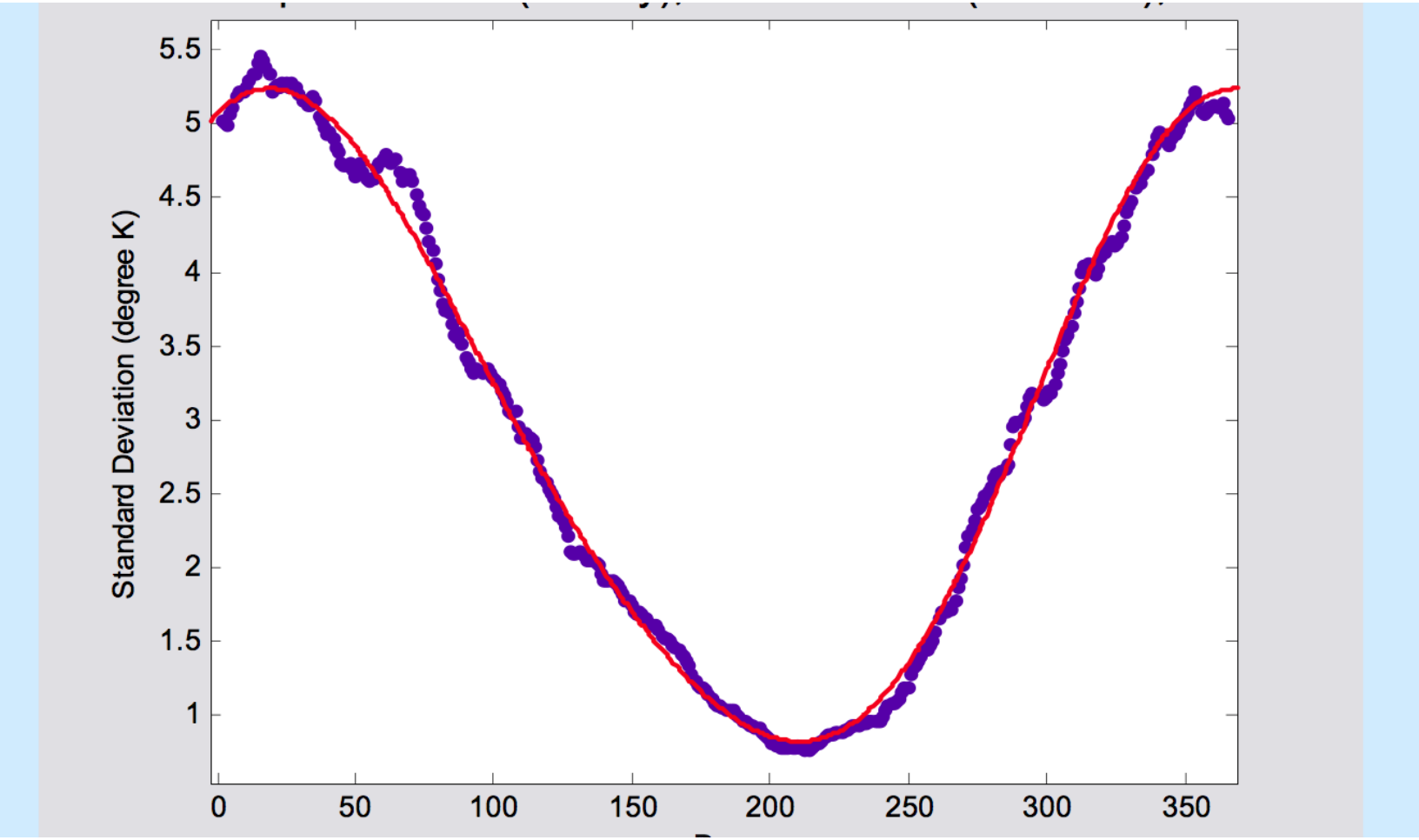
Bayesian Processor of Ensemble



The mean has an annual cycle which can be represented by a curve

Figure from Roman Krysztofowicz

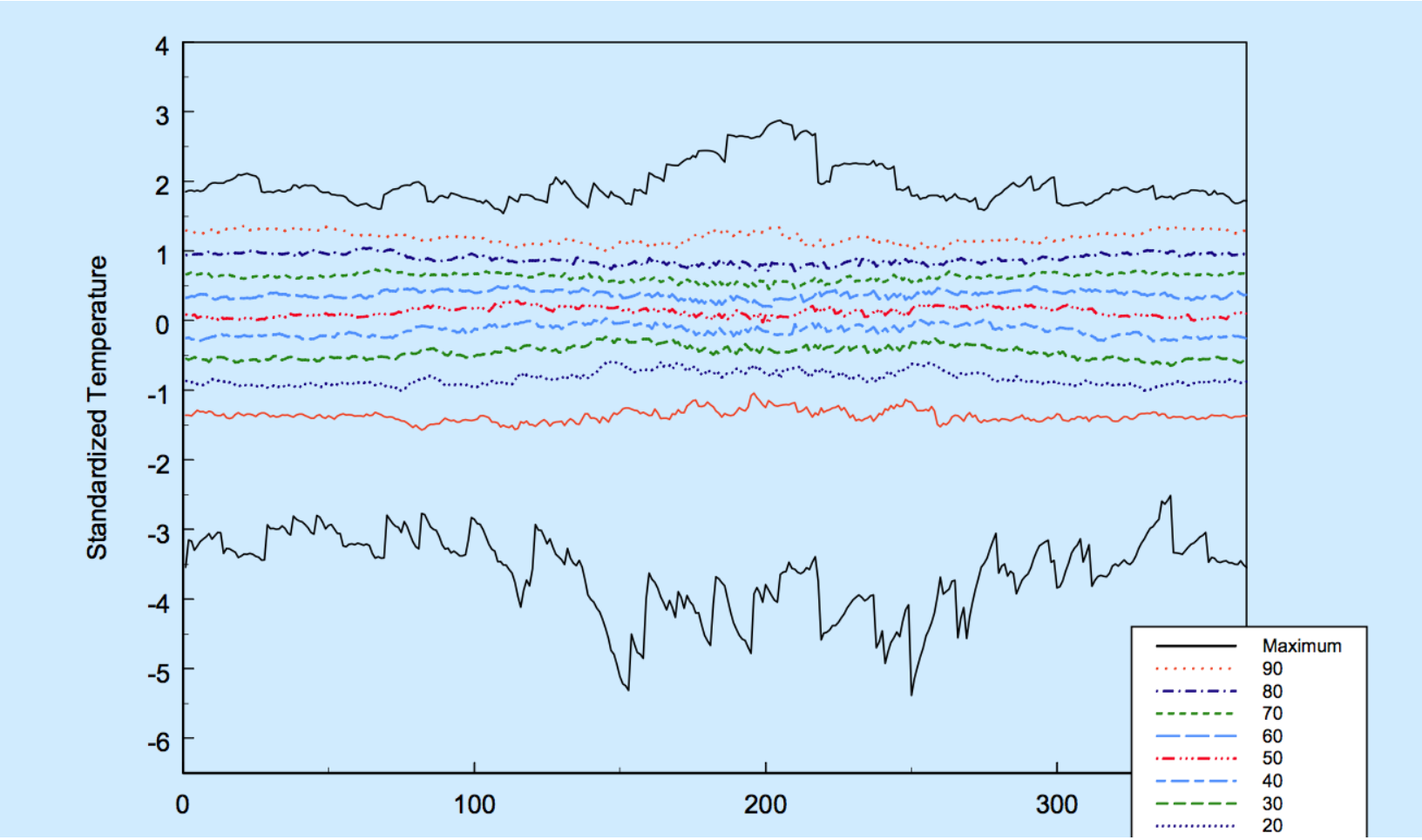
Bayesian Processor of Ensemble



The variance has an annual cycle which can be represented by a curve

Figure from Roman Krysztofowicz

Bayesian Processor of Ensemble



Normalized mean and standard deviation climatology produced

Figure from Roman Krysztofowicz

Bayesian Processor of Ensemble

- Use climatic sample an joint sample of climatology and an ensemble forecast system to produce corrected pdf from ensemble forecasts.
- BPE can be applied to any number of distributions – not only normal/gaussian.
- Output is a posterior density function, posterior distribution function, and posterior ensemble (each member is mapped via the inverse of the posterior distribution function).

Bayesian Processor of Ensemble

- The BPE algorithm will be tested on ensemble forecast data of 2m temperature.
- Operational NCEP Global Ensemble Forecast System (GEFS) data will be used for initial testing. Results will be compared with those from the operational North American Ensemble Forecast System (NAEFS) bias correction algorithm.
- Will assume normal distribution for temperature
- Future work will tackle non-normal variables, such as wind and precipitation