Development of Verification Methodology for Extreme Weather Forecasts

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Highlights

- Definitions of extreme
- Extreme Weather Forecast Methods
  - Anomaly Forecast (ANF) and Extreme Forecast Index (EFI)
- Developments of verification methodology
  - ANF and EFI comparison
  - Verification of extreme cold event forecasts
  - Verification of extreme precipitation forecasts
- Conclusion and future plan

Definition of Extreme Events

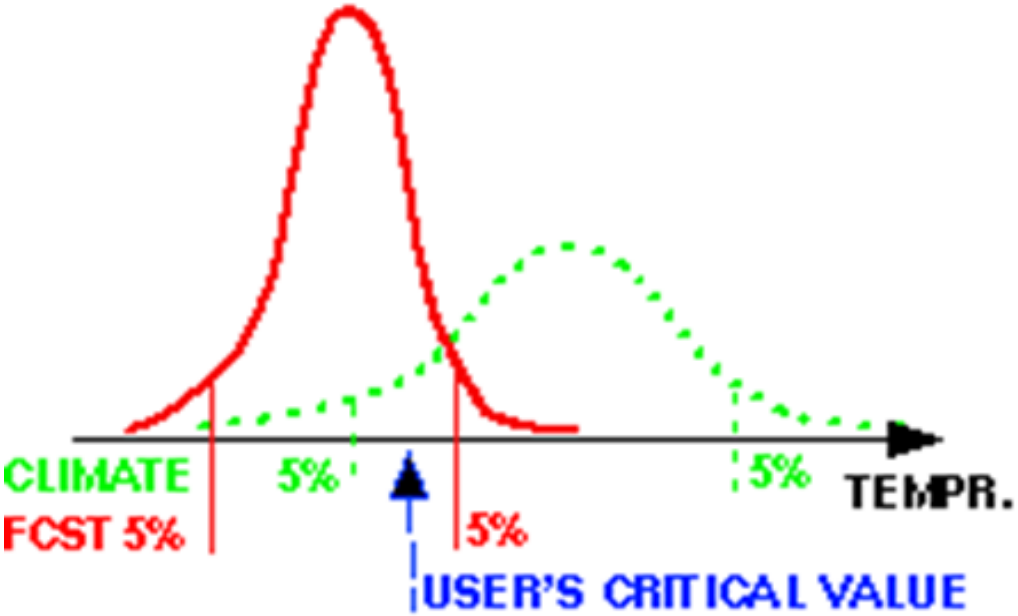


Fig. 1. Schematic indicating climatological (continuous), forecast (dotted) and user specific (dashed) extreme events.

Climatological (forecast) extreme is the tails of corresponding distribution for a particular variable, time, and place.

Extreme Weather Forecast Methods

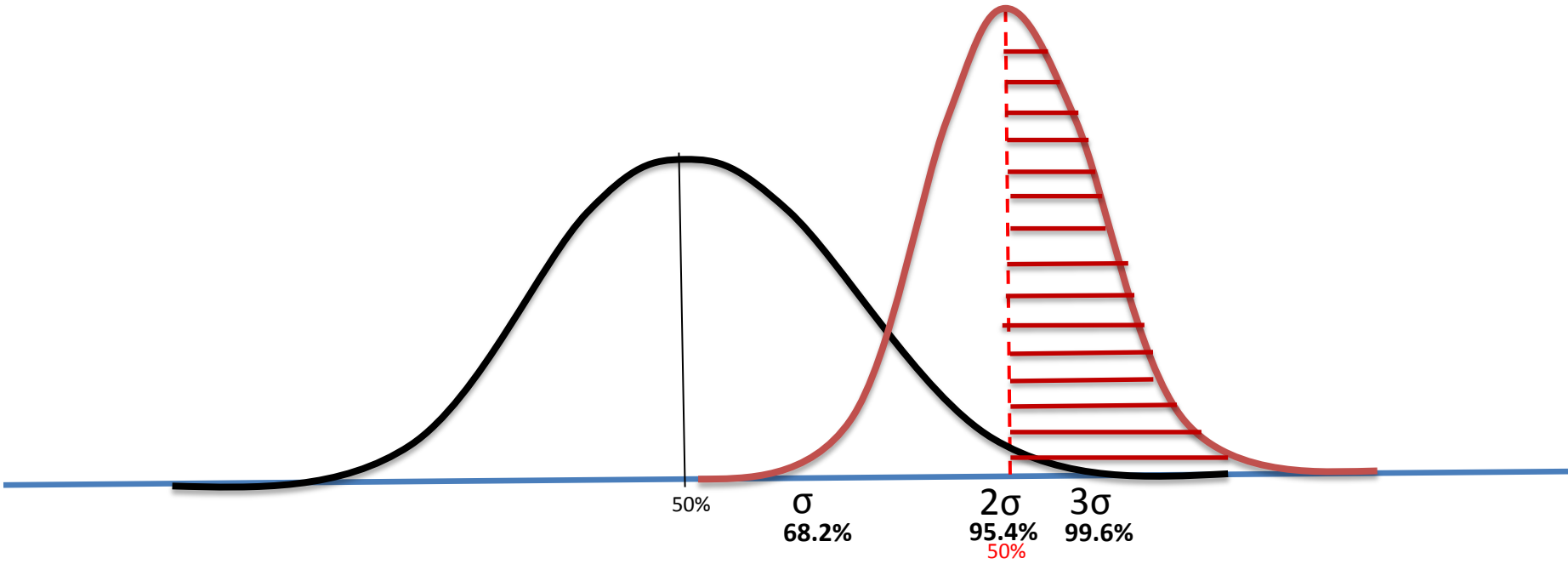
- Anomaly Forecast (ANF)

  EMC/NOAA since 2006

- Extreme Forecast Index (EFI)

  CMC, ECMWF, and ESRL/NOAA

Anomaly Forecast (ANF)



Schematics diagram for anomaly forecast (PDF)

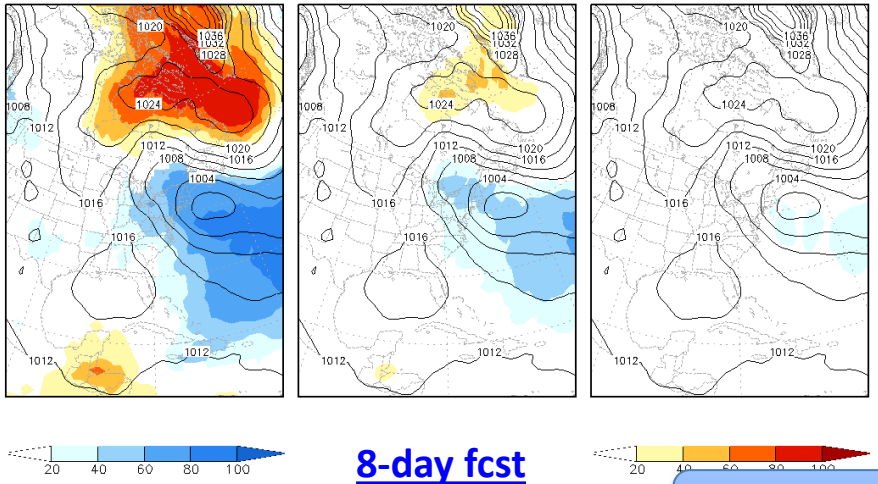
Definitions for Anomaly Forecast

Percentage of ensemble forecast (shaded area) which exceeds climate threshold (for example: 2σ) (NCEP/ NAFES product)

Anomaly forecast

Sea Level Pressure (PRMSL), 192-hour forecast
Ini. time:2012102300 Valid time:2012103100
Contour-mean forecast; Shaded-forecast anomalies

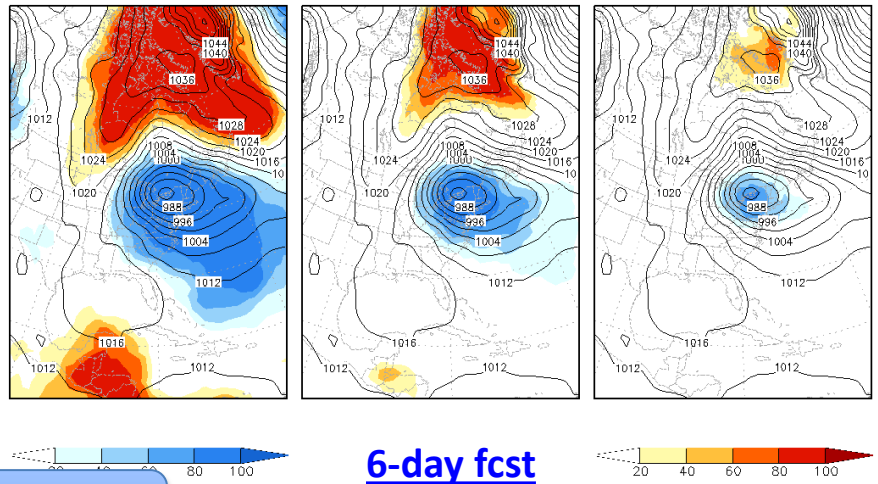
σ 2σ 3σ



8-day fcst

Sea Level Pressure (PRMSL), 144-hour forecast
Ini. time:2012102500 Valid time:2012103100
Contour-mean forecast; Shaded-forecast anomalies

one stdv two stdv three stdv



6-day fcst

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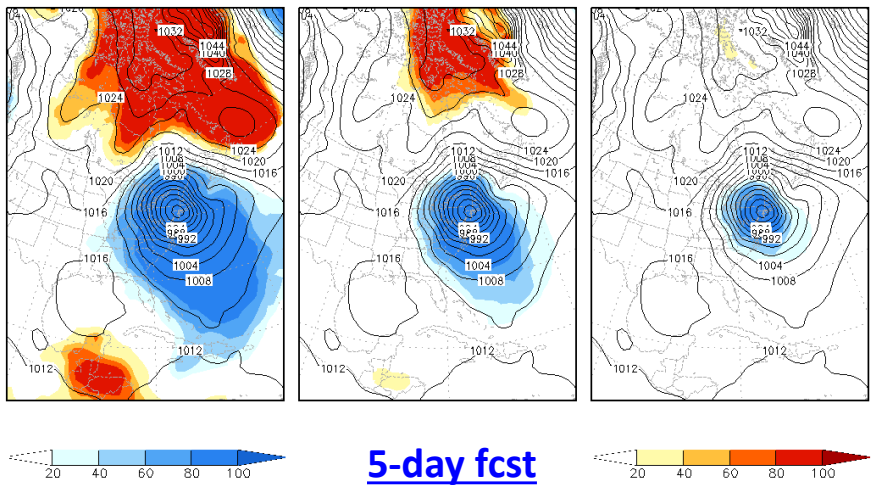
Hurricane Sandy

Sea Level Pressure (PRMSL), 120-hour forecast
Ini. time:2012102600 Valid time:2012103100
Contour-mean forecast; Shaded-forecast anomalies

one stdv two stdv three stdv



5-day fcst

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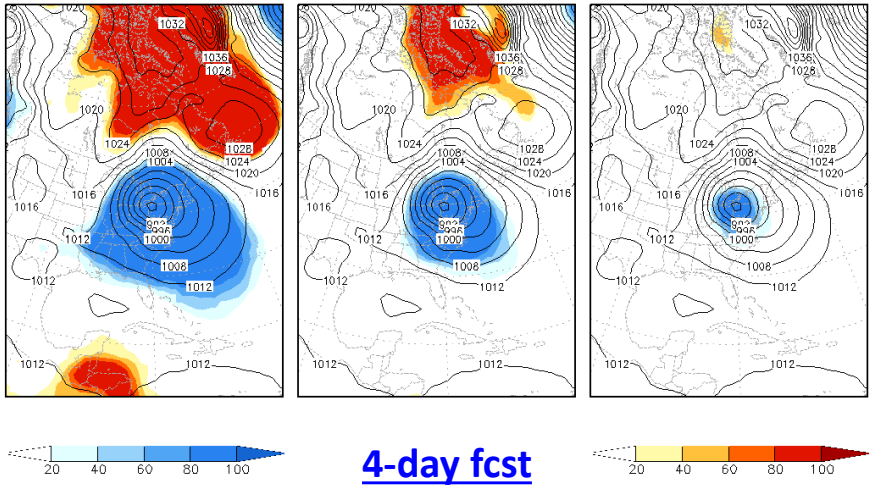
Sea Level Pressure (PRMSL), 96-hour forecast
Ini. time:2012102700 Valid time:2012103100
Contour-mean forecast; Shaded-forecast anomalies

one stdv two stdv three stdv



4-day fcst

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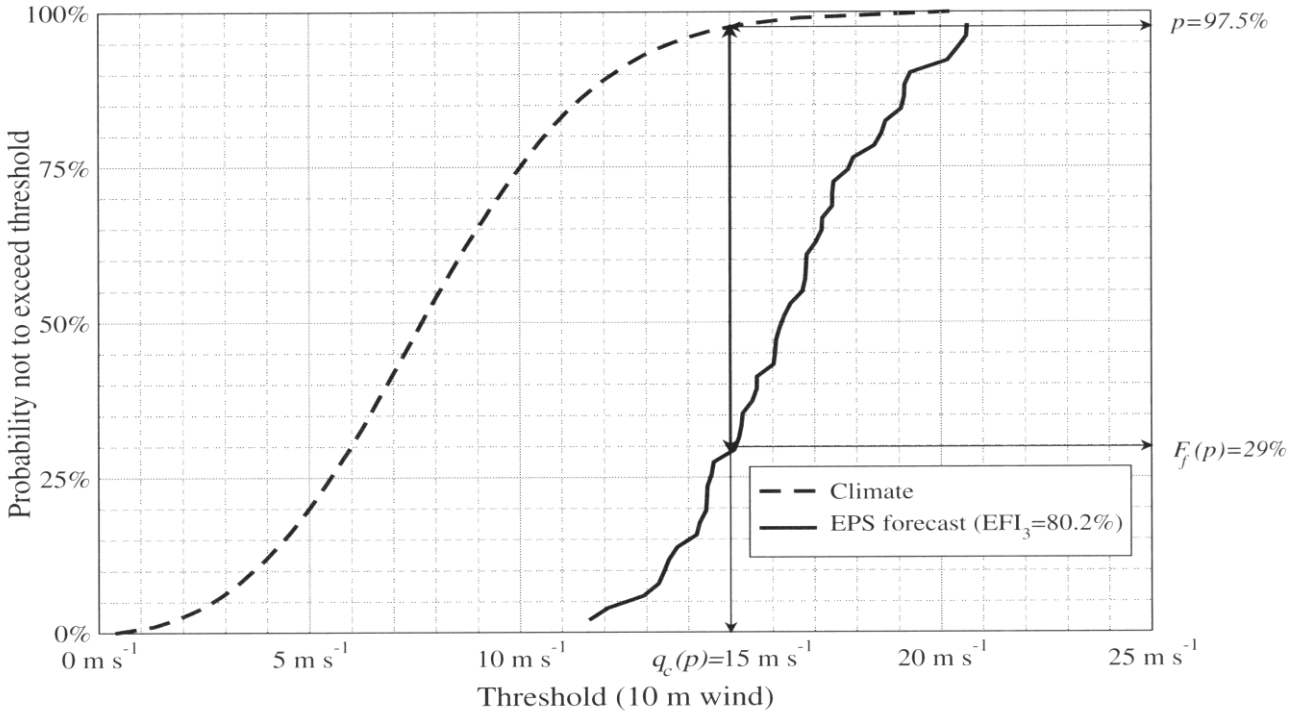
Extreme Forecast Index (EFI)

(Lalaurette, 2003)



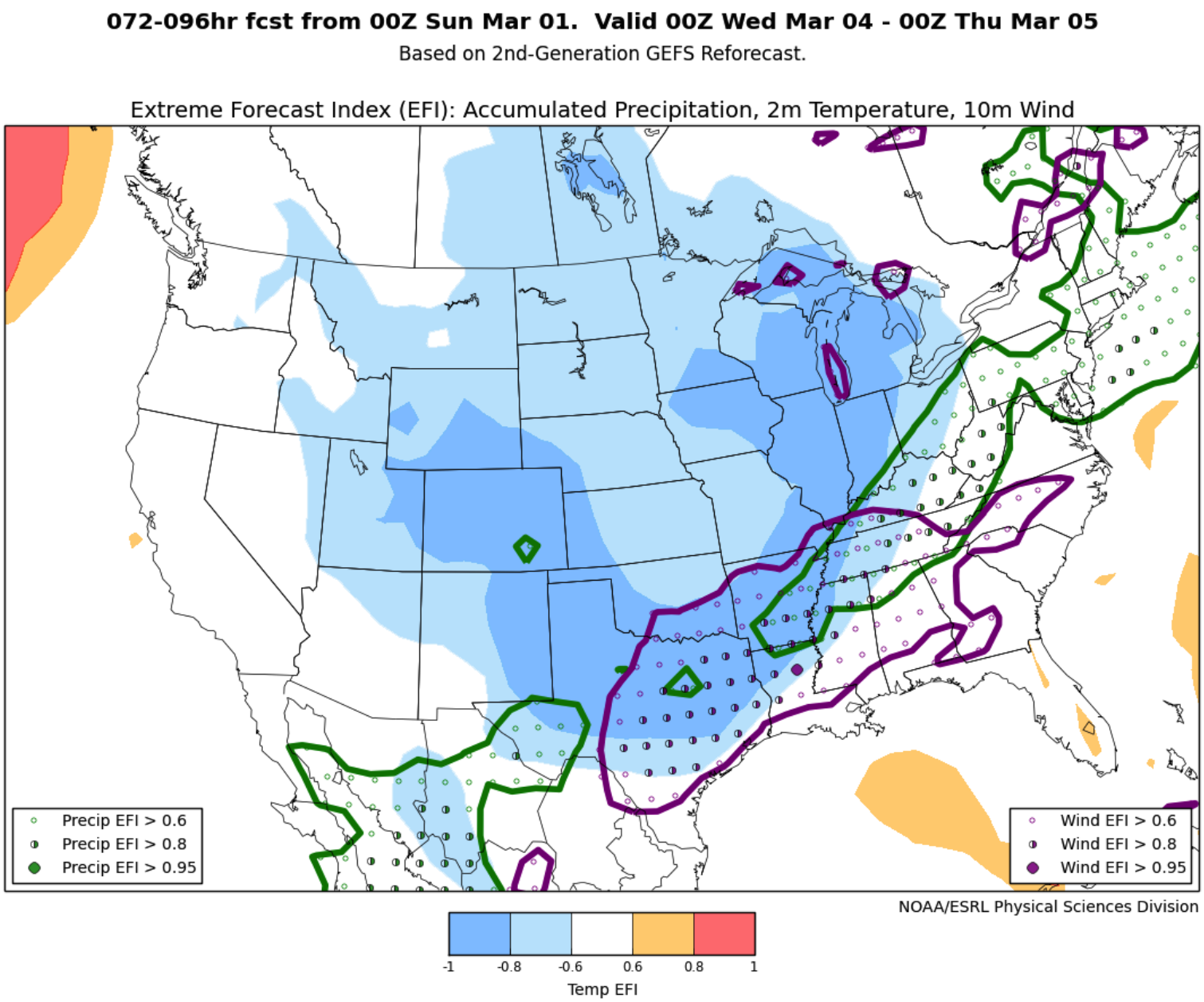
The EFI is a measure of the difference between the model climatological forecast distribution and the current ensemble forecast distribution.

CDF: cumulative distribution function

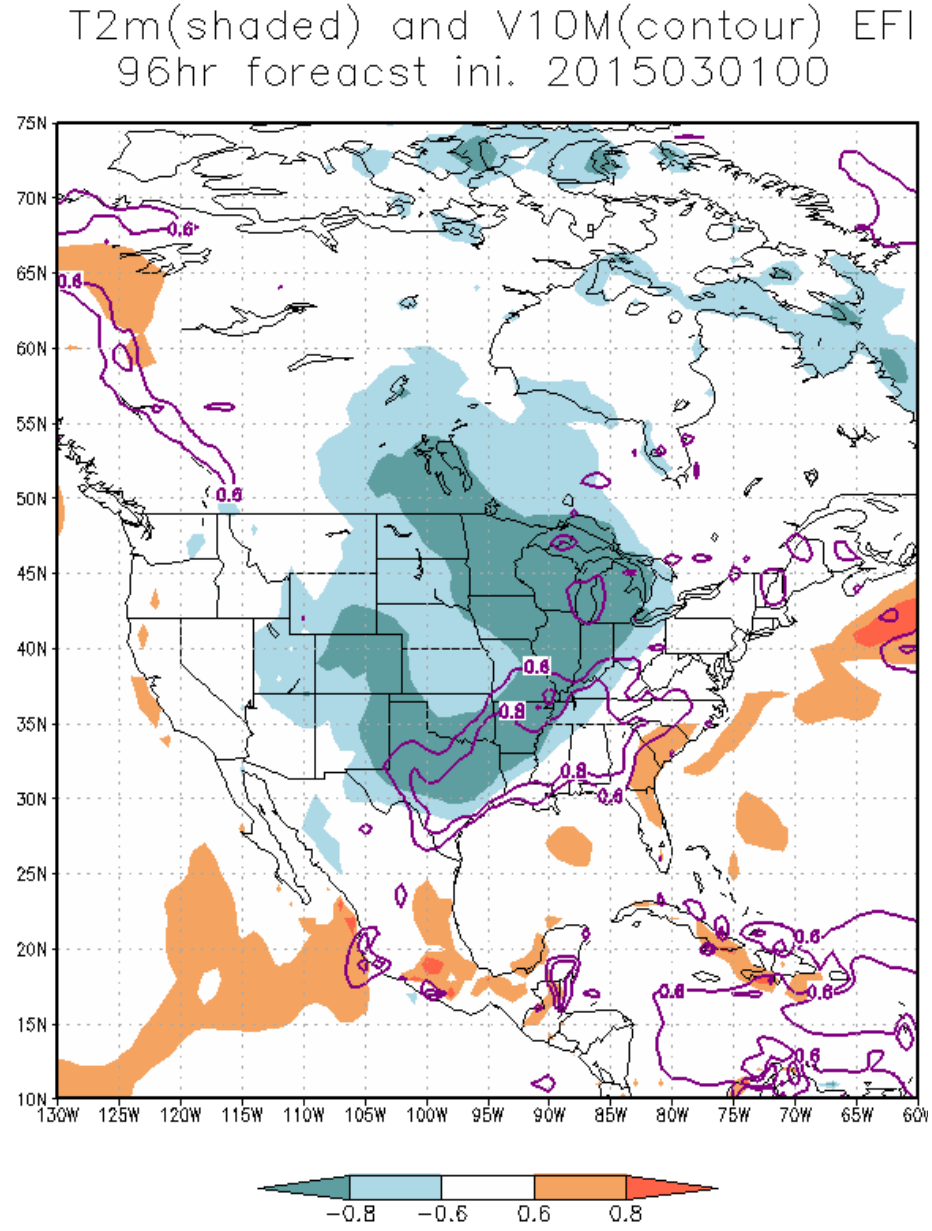
Modified Equation
(Zsooter 2006)

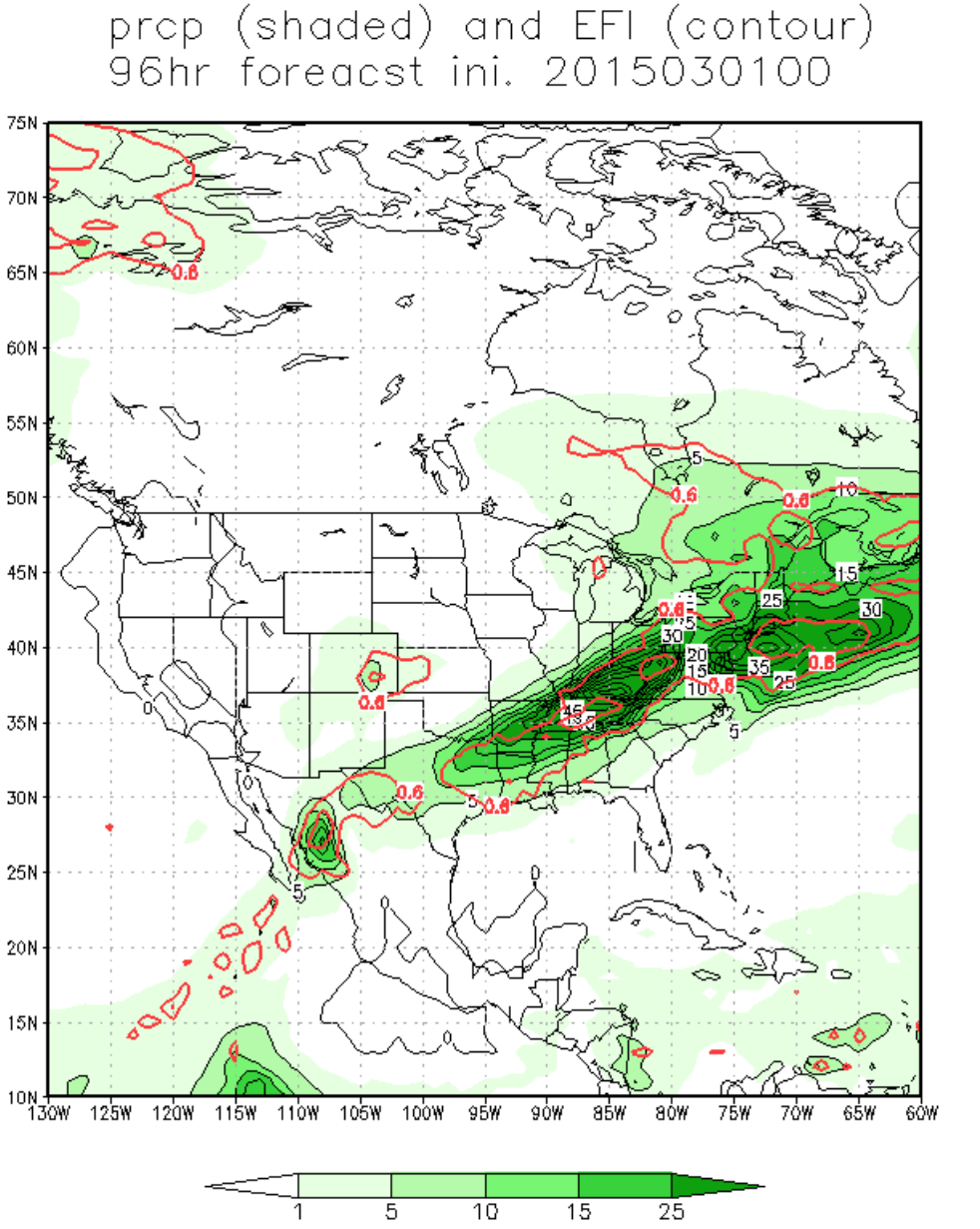
$$EFI = \frac{2}{\pi}\int_0^1 \frac{p - F_f(p)}{\sqrt{p(1-p)}}\,dp$$

Operational GEFS based EFI (ref: 25 years refcst – ESRL)



Parallel GEFS based EFI (ref: 18 years refcst – EMC)





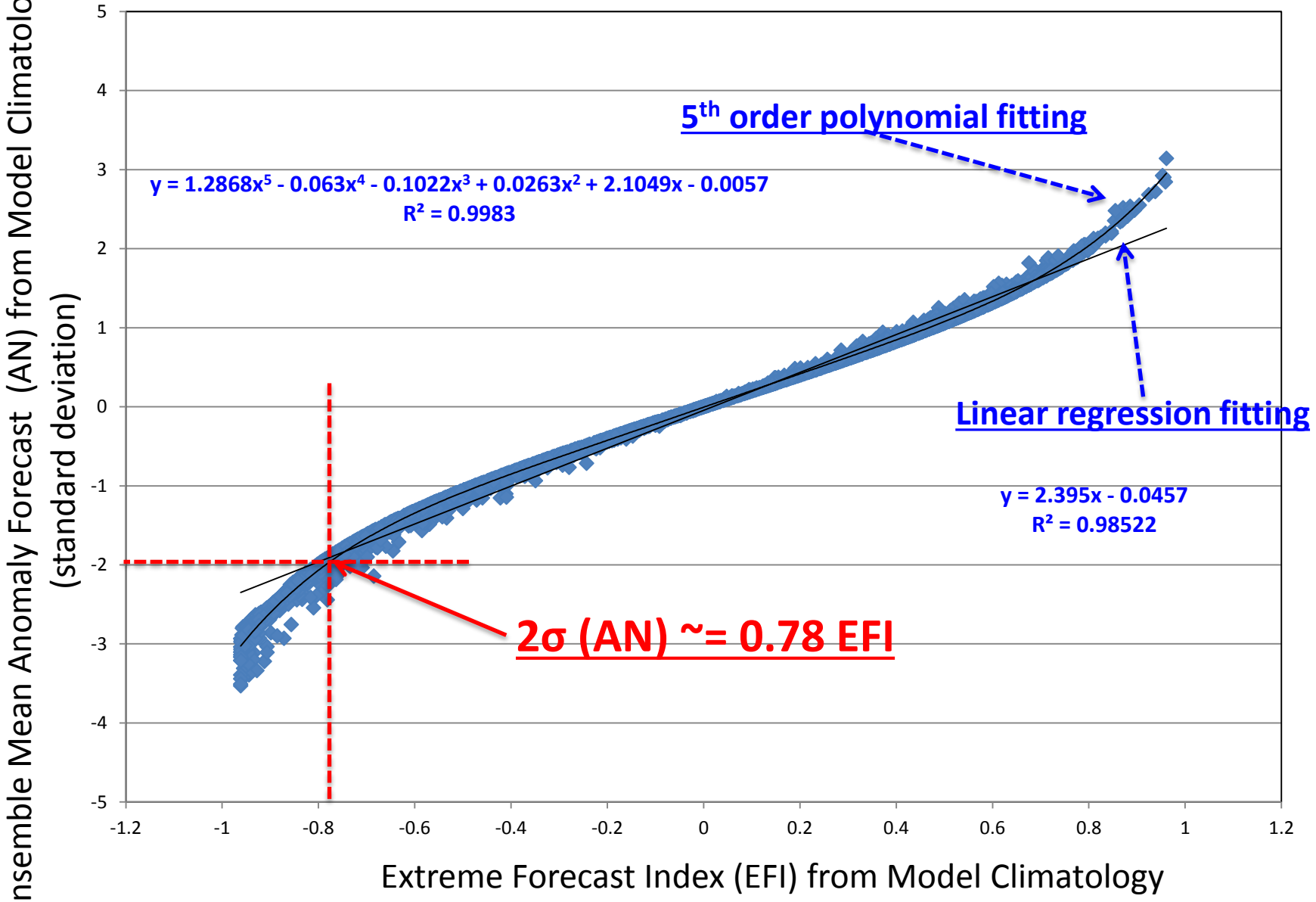
Anomaly Forecast and Extreme Forecast Index

How to compare these two measures?

What EFI value is equivalent to 2σ anomaly?

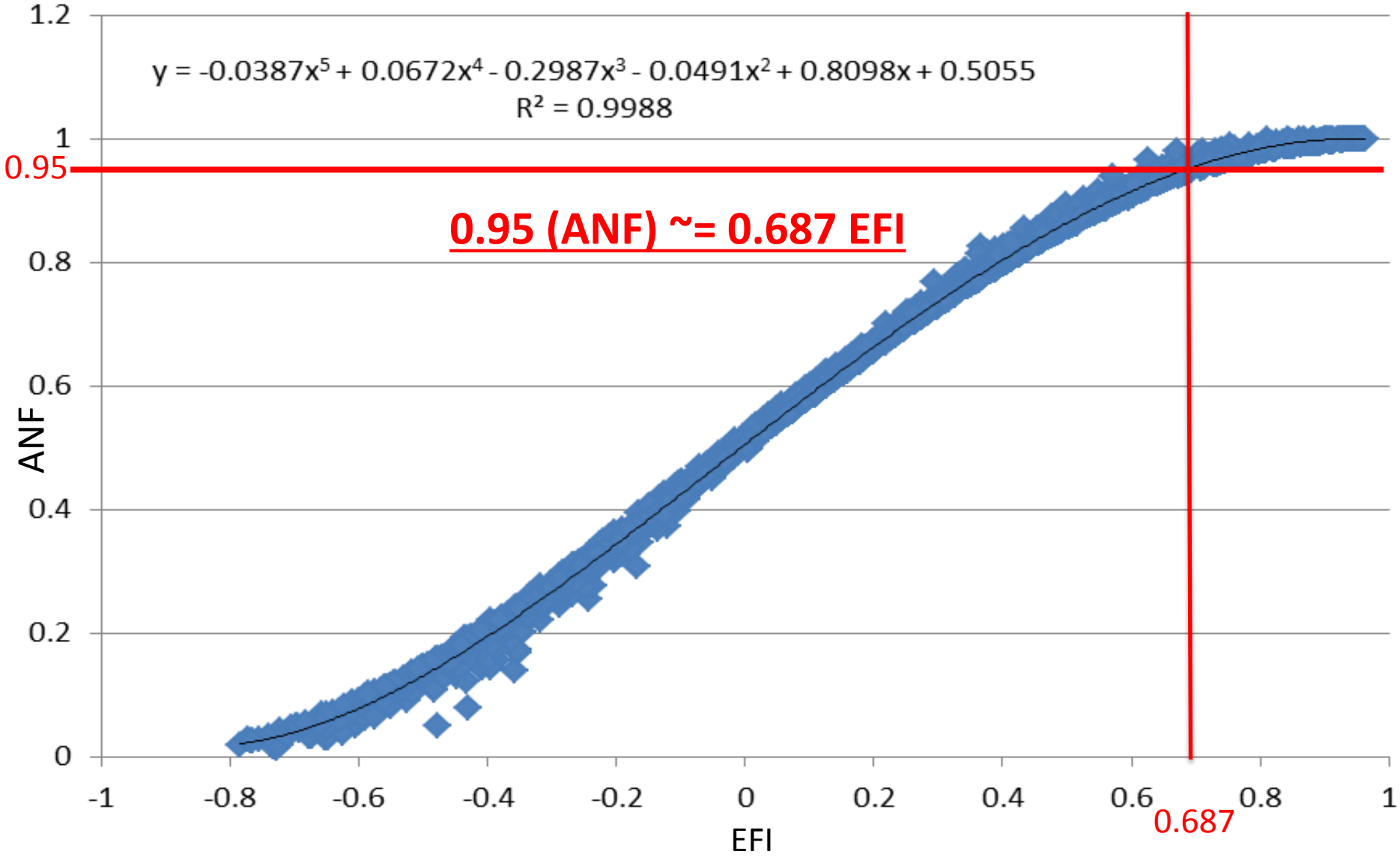
Relationship between ANF and EFI for 2-m temperature

valid 2015030100 (96-hour forecast) – GEFS V11



Relationship between ANF and EFI for Precipitation

Valid 2014010600UTC (96-hour forecast)- GEFS V11



How can we measure the performance?

Thresholds for Extreme Cold Events and Heavy Precipitation

Variable	analysis	ANF	EFI
Extreme cold event	-2σ	-2σ	-0.78
Extreme Precipitation	0.95	0.95	0.687

The Hit Rate (HR),

False Alarm Rate (FAR),

Frequency Bias (FBI),

Equivalent Threat Scores (ETS),

Performance diagram

Extreme cold event forecasts and verification

Input data for extreme cold event forecasts

- Model climatology / raw ensemble forecast
  Climatology: 18-year control-only GEFS v11 reforecast
  Forecast: Raw GEFS v11

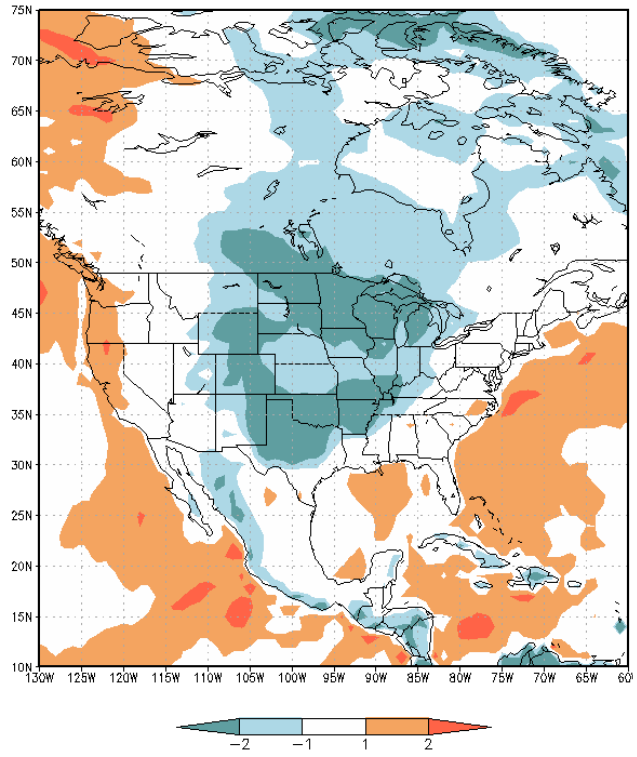
- Analysis climatology / bias-corrected forecast
  Climatology: 40-year reanalysis (1959-1999) and 30-year CFSR (1979-2009)
  Forecast: GEFS v10 and v11

T2m distribution: normal distribution

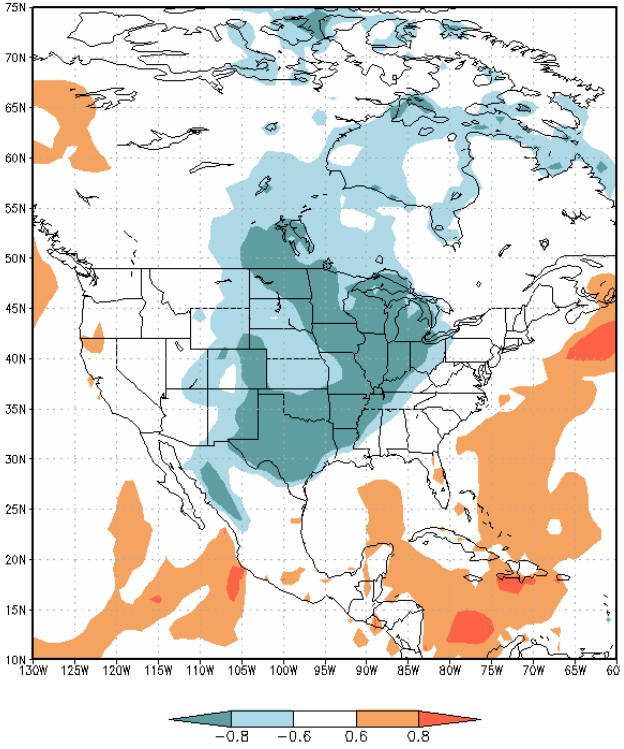
To estimate the relative performance of different methods, model versions, references, and forecasts

Example of extreme cold weather event (Valid: 2015030500)
Comparison between the two methods

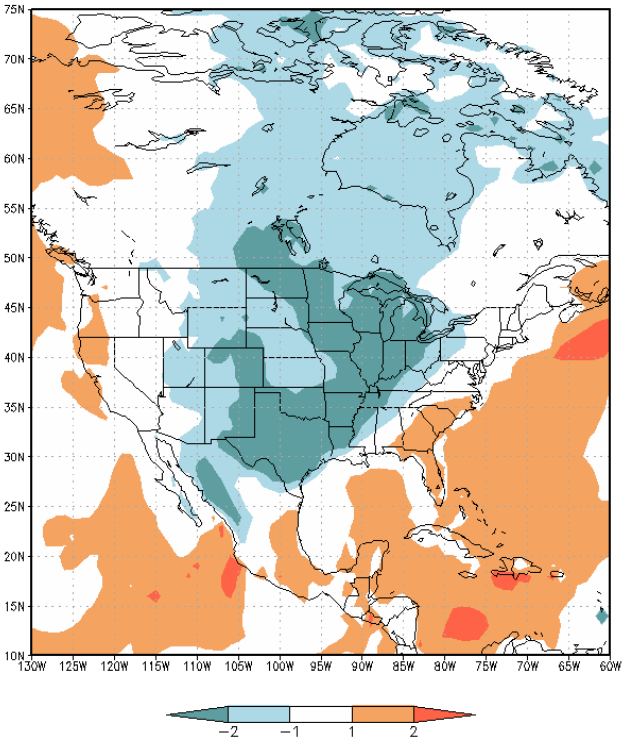
Observed anomaly (analysis)

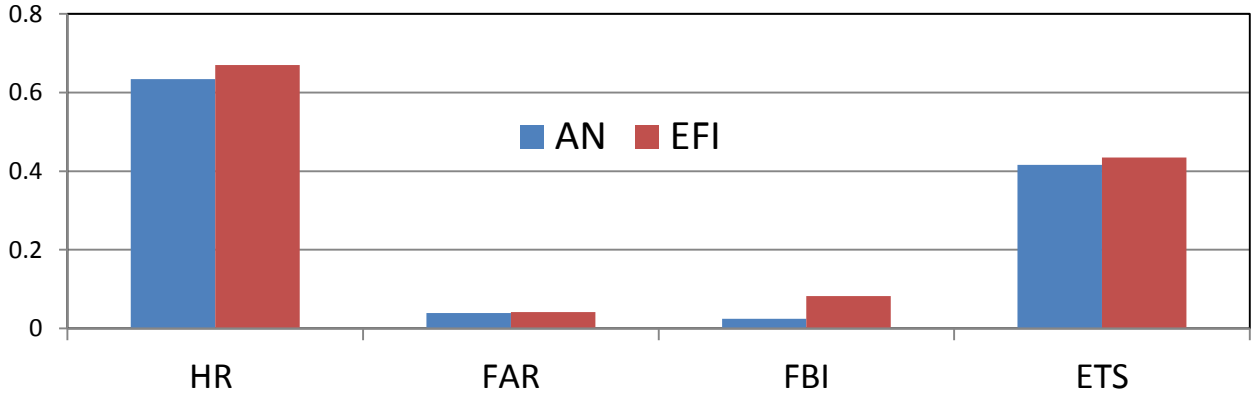


Extreme Forecast Index (EFI)



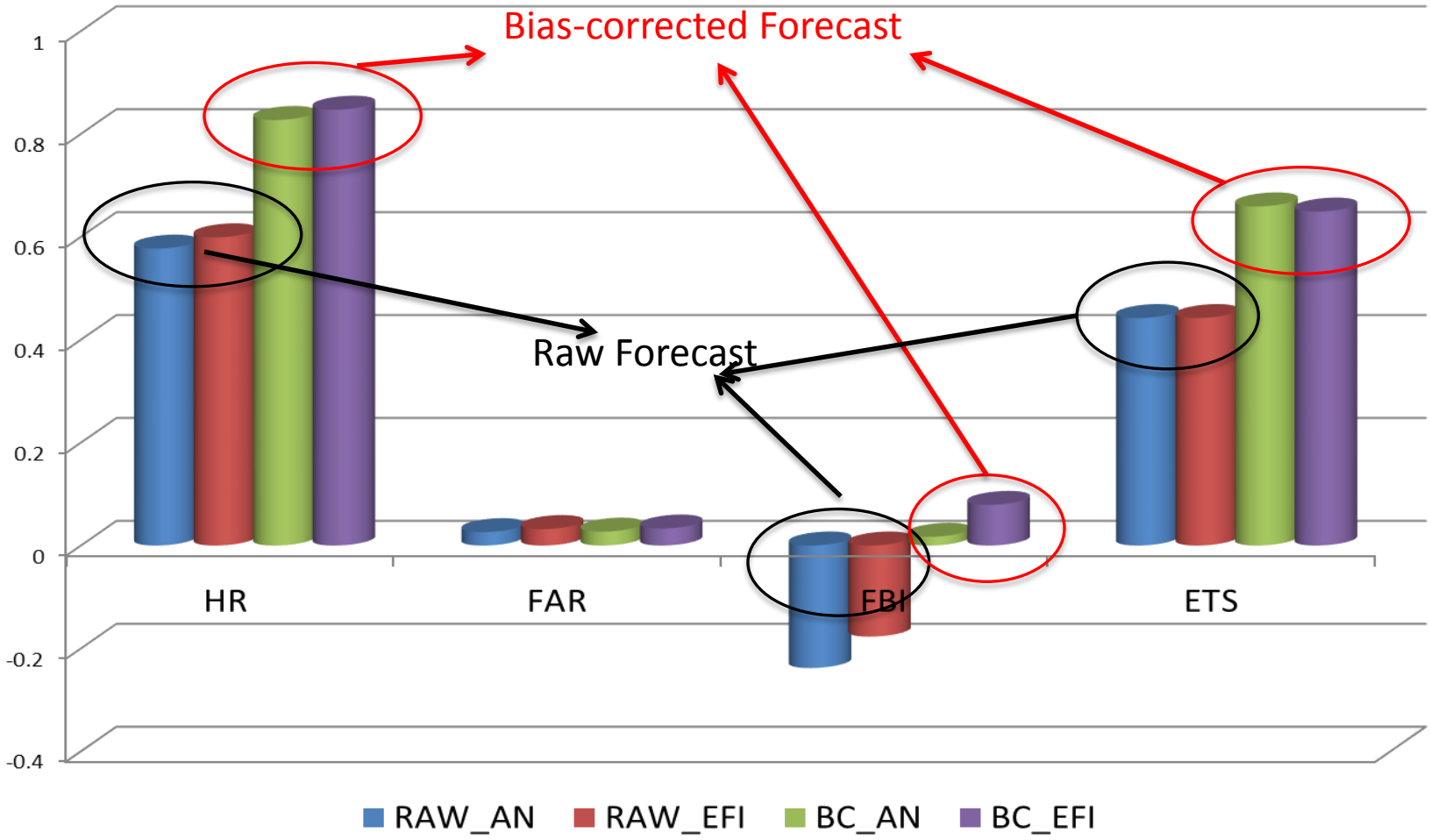
Anomaly Forecast (AN)



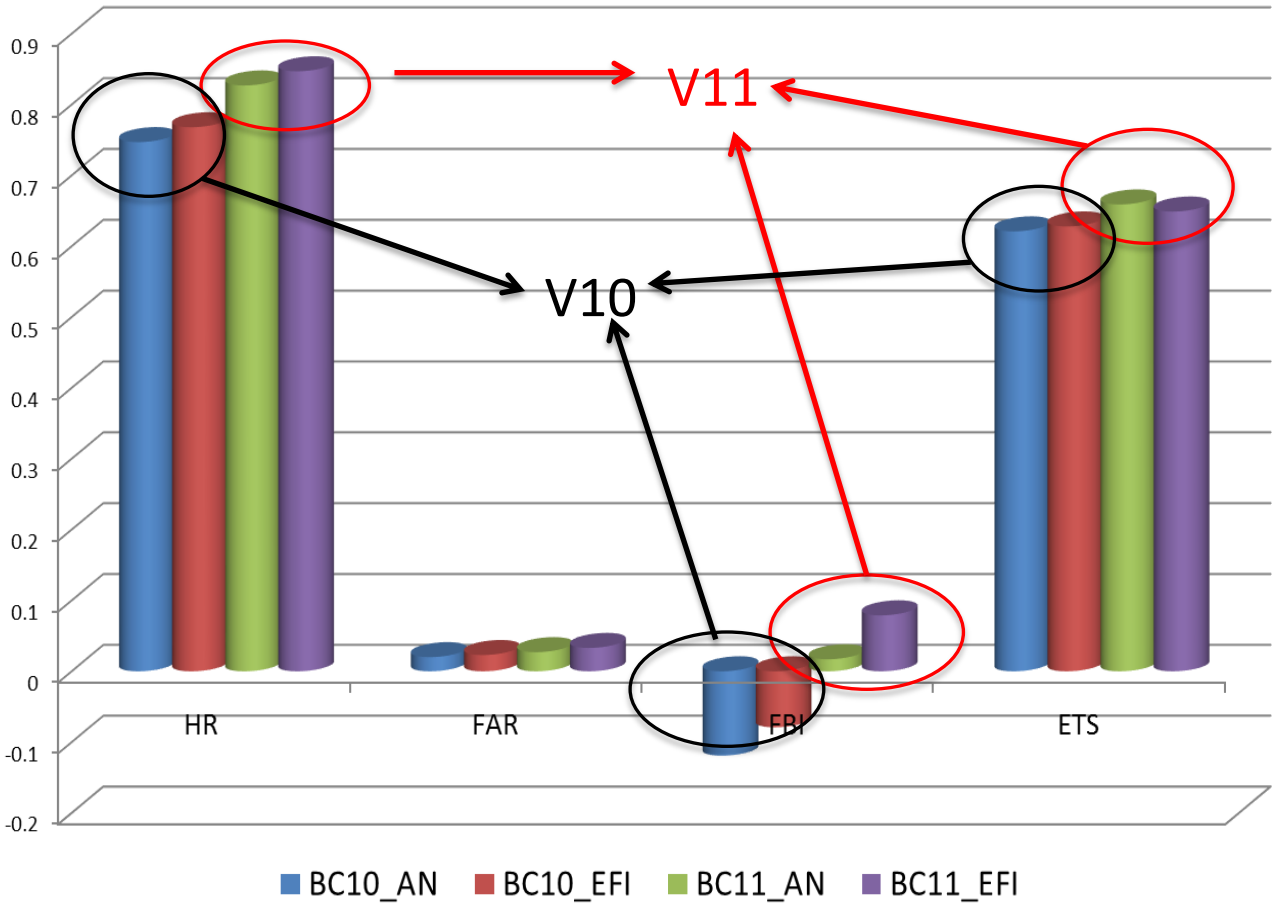


GEFS V11 Raw T2m
Against
Model climatology

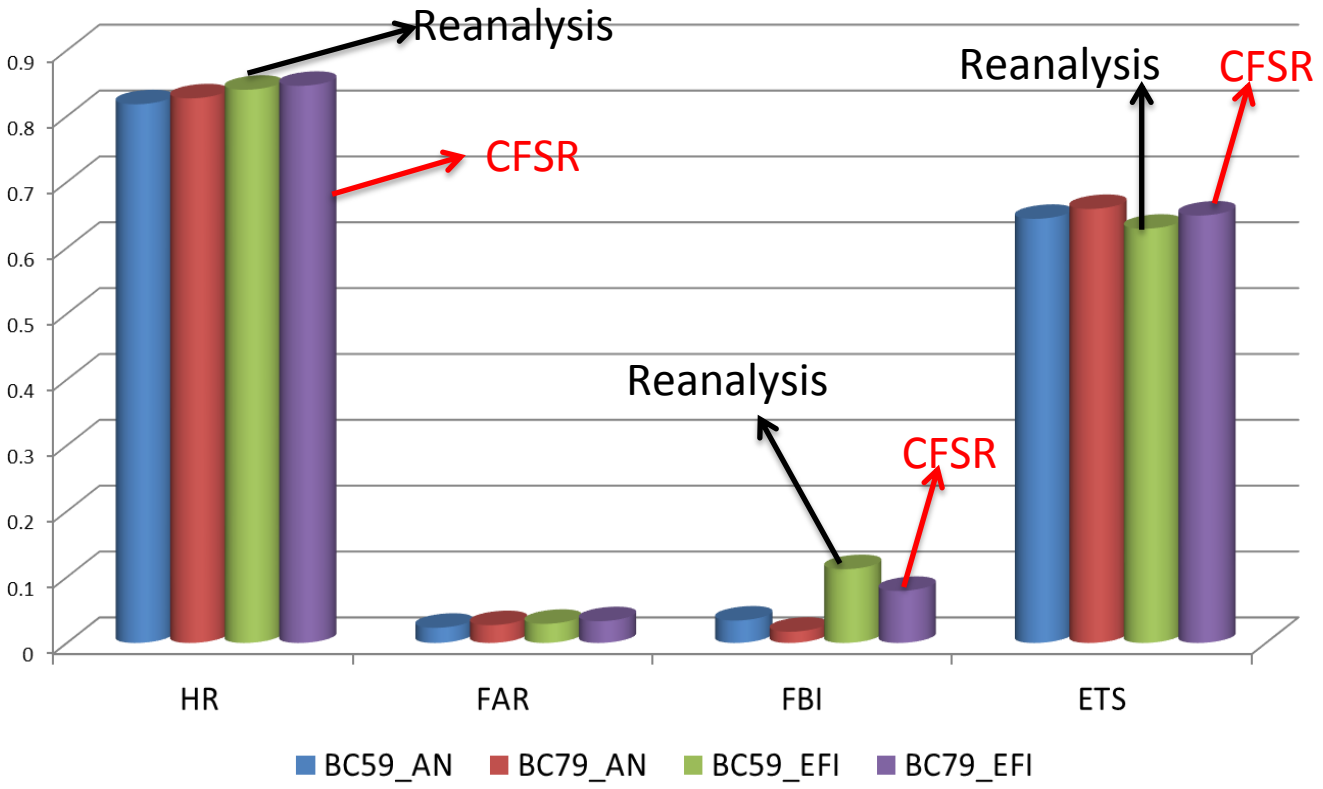
Statistics for extreme cold weather event (11 cases) for 13-14 winter (Raw and bias-corrected forecast (V11))



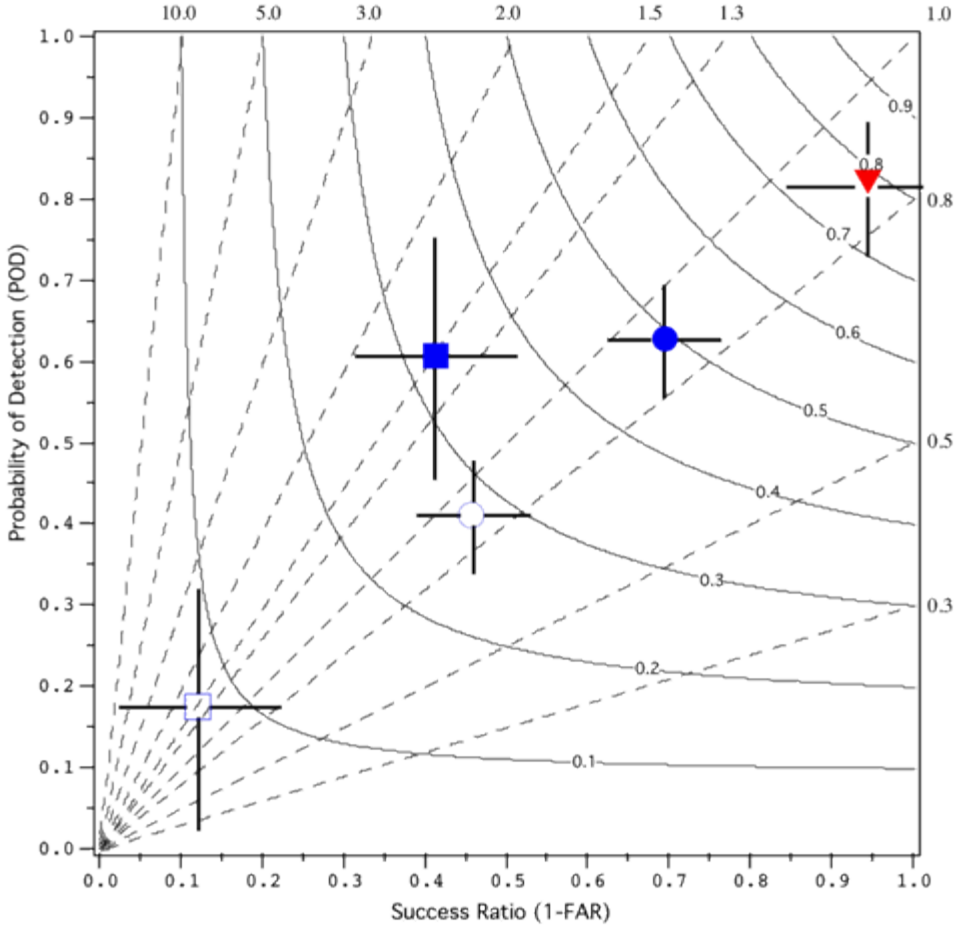
Statistics for extreme cold weather event (11 cases) for 13-14 winter (V10 and V11 bias-corrected forecast)



Statistics for extreme cold weather event (11 cases) for 13-14 winter – bias-corrected V11 forecast for 40yrs reanalysis (from 1959) and 30yrs CFSR (from 1979)



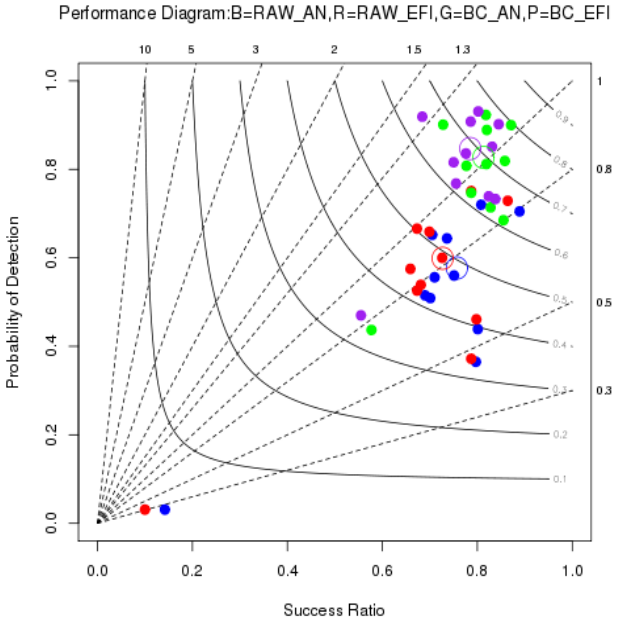
Performance Diagram (Roebber, 2009)



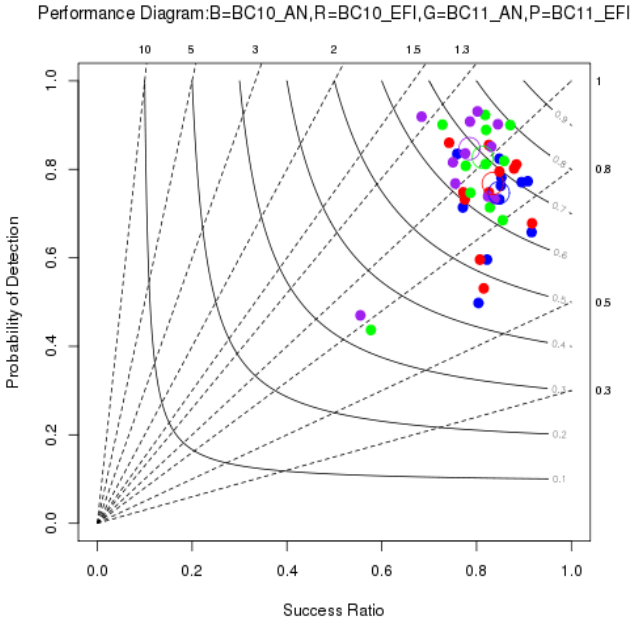
Exploiting the geometric relationship between four measures of dichotomous forecast performance: probability of detection (POD), false alarm ratio or its opposite, the success ratio (SR), bias and critical success index (CSI; also known as the threat score).

Performance Diagram for Extreme Cold Events

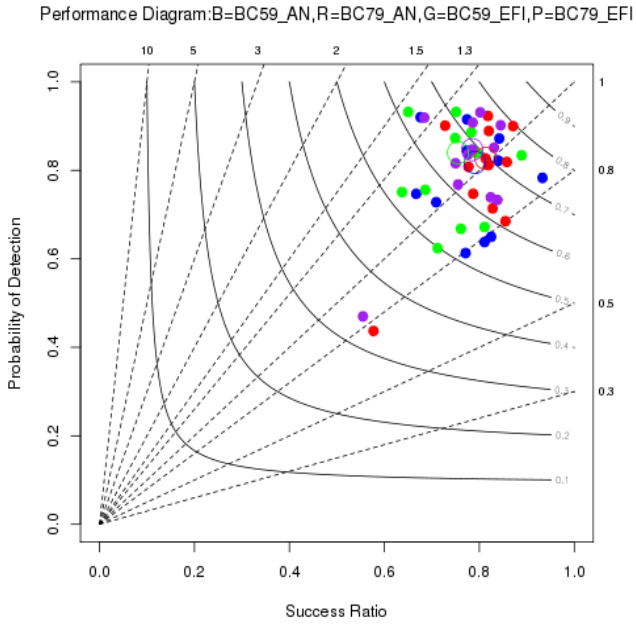
Raw vs. bias-corrected forecasts



v10 vs. v11 forecasts



Reanalysis vs. CFSR



Extreme precipitation forecasts and verification

Input data for extreme precipitation forecasts and verification

– For forecasts
Model climatology / raw ensemble forecast
Climatology : 18-year control-only GEFS v11 reforecast
Forecast: Raw GEFS v11

-- For verification
CCPA data as a true

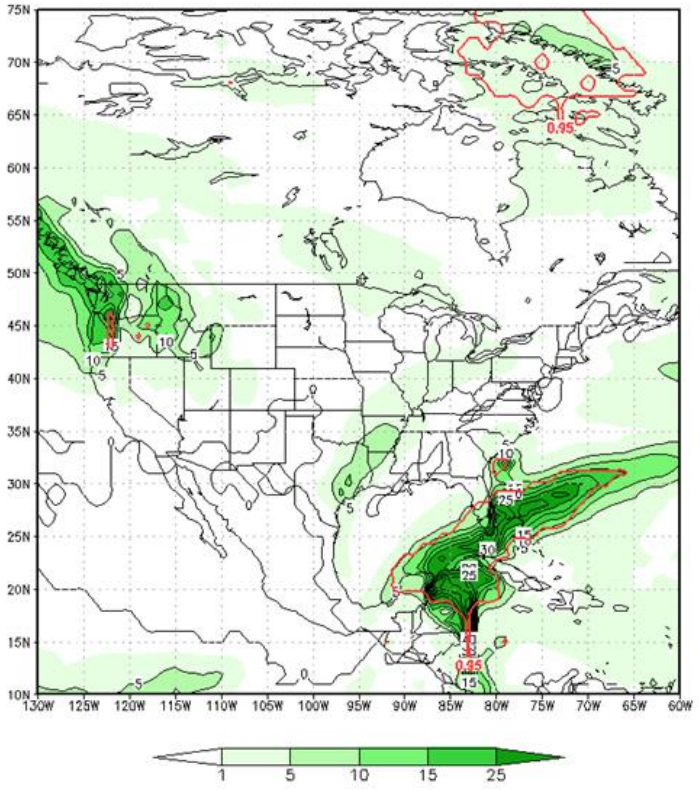
Precipitation distribution: Gamma distribution

To estimate the relative performance of ANF and EFI

Example of Extreme Precipitation Forecast

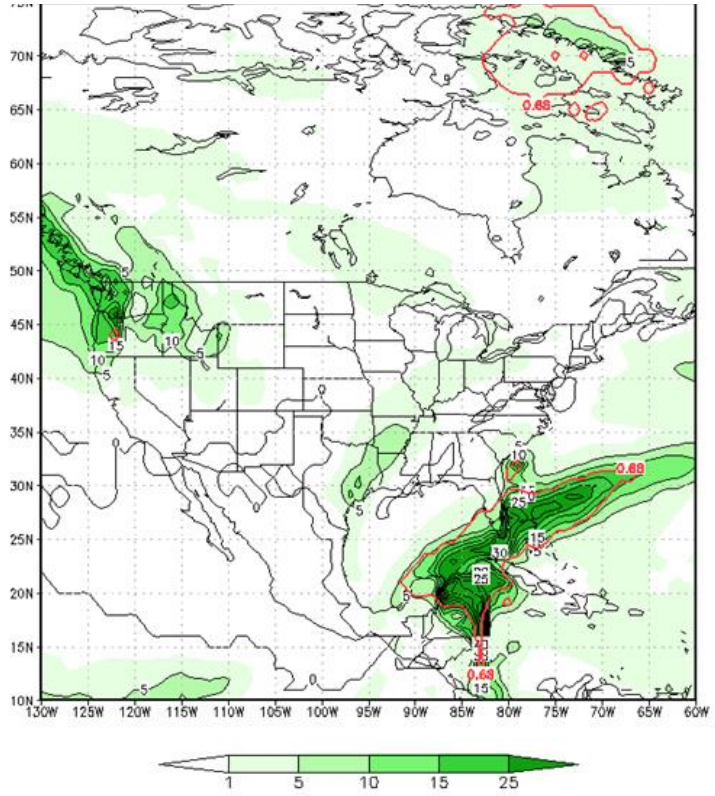
ANF

a. acpr (shaded) and ANOMF=0.95 (contour)
96hr forecast ini. 2014010600



EFI

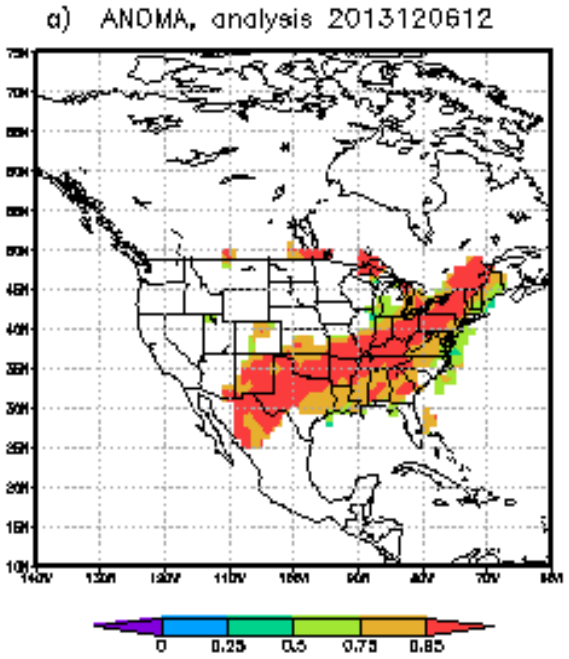
b. acpr (shaded) and EFI=0.687 (contour)
96hr forecast ini. 2014010600



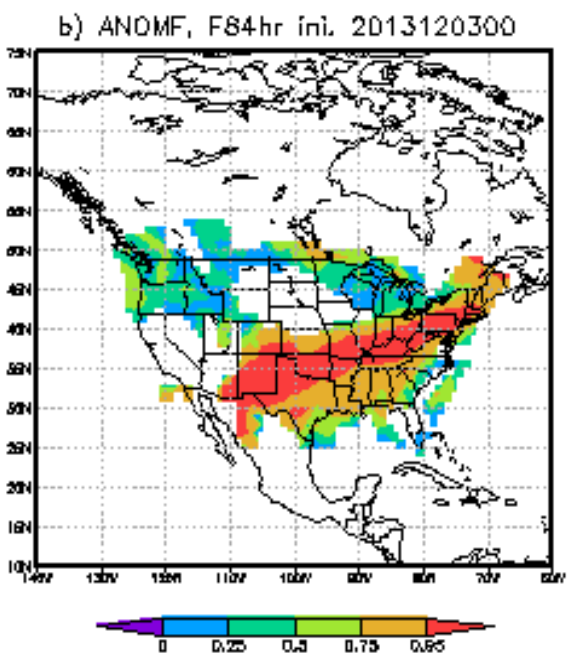
The dependence of the extreme precipitation on the geographic location

Example of Extreme Precipitation Forecast and Verification

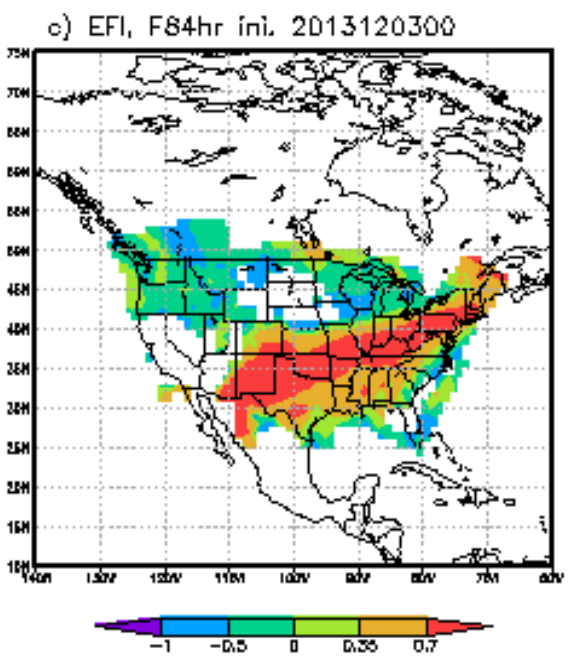
CCPA

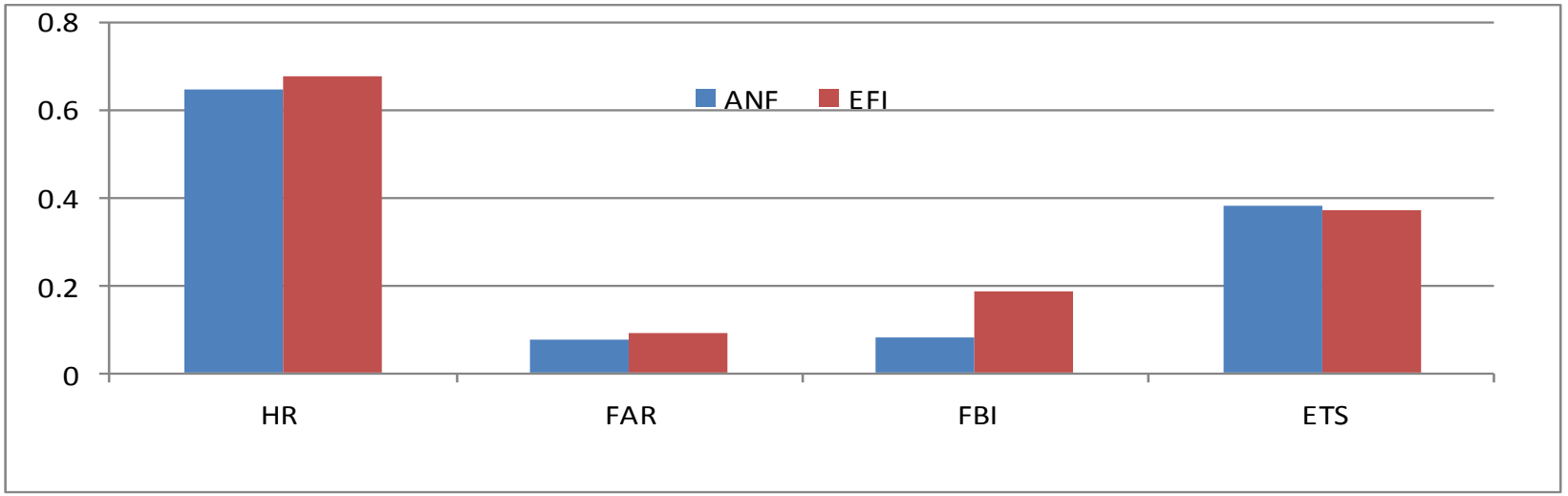


ANF



EFI





Summary and Future Plan

- We have developed the verification methodology for extreme cold weather and extreme precipitation forecast to evaluate the relative performance of different methods, model versions, references, and forecasts.

- Both ANF and EFI could predict extreme cold and precipitation events.

- Verification Stats. for extreme cold events for 2013-2014 winter indicates:

  - GEFSv11 performs better than GEFSv10.
  - EFI forecasts more cold extreme events than ANF
  - Bias corrected forecasts have much better scores than raw forecast.
  - Using CFSR as a reference gives a better performance than using reanalysis.
  - Performance diagram is a useful tool to evaluate the relative performance for the different forecasts.

- In the future, we will have longer period to calculate the statistics for extreme cold and precipitation forecasts. The sensitivity of ANF-EFI relationship on forecast lead-time is also our focus.