

Development of Verification Methodology for Extreme Weather Forecasts

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Highlights

- Definitions of extreme
- Common extreme weather forecast products
 - 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 heavy precipitation forecasts
- Conclusion and future plan
- Reference

Definition of Extreme Events

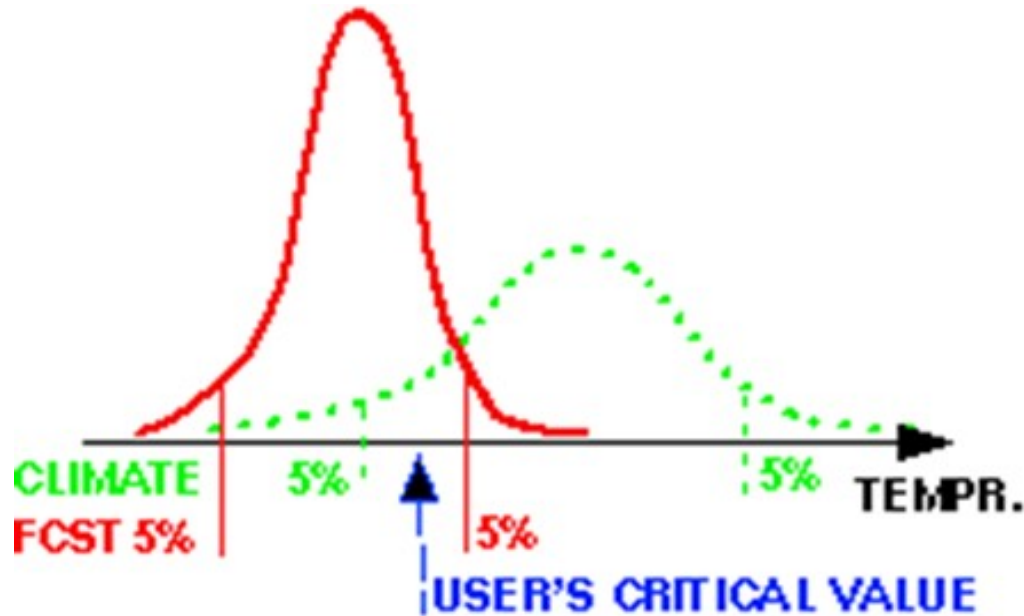


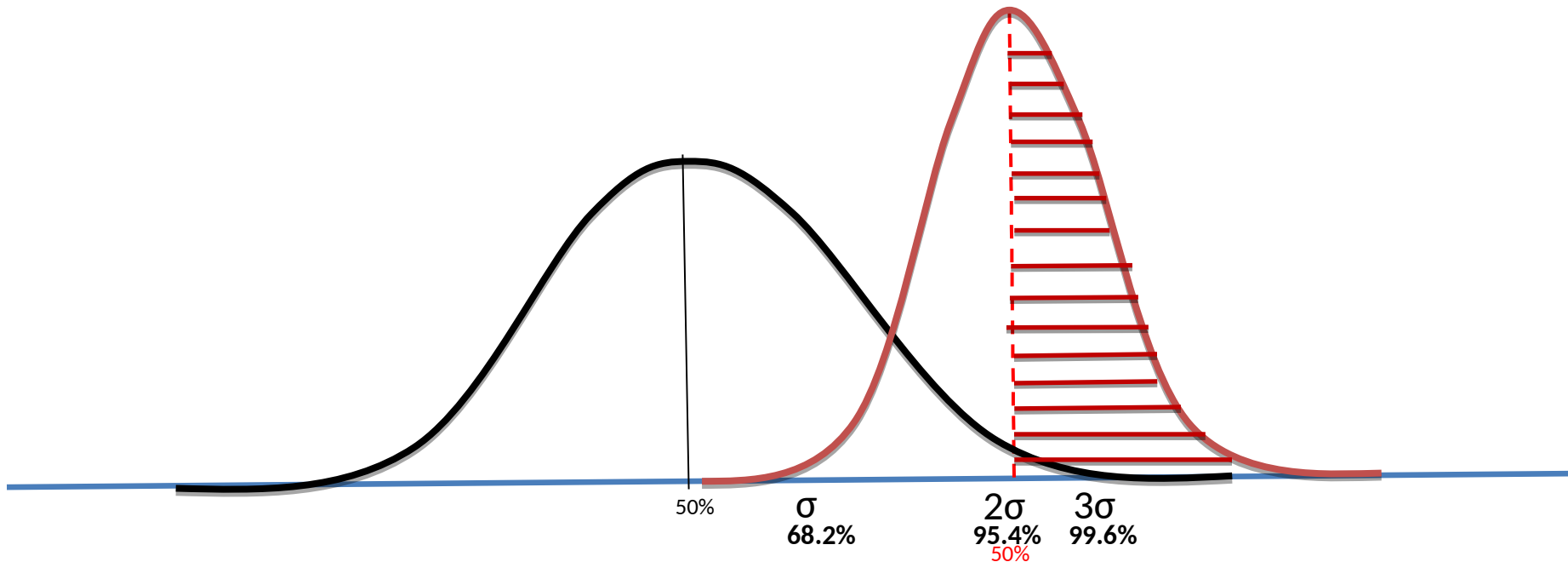
Fig. 1. Schematic indicating climatological (continuous), forecast (dotted) and user specific (dashed) extreme events.

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)

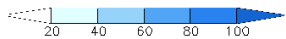
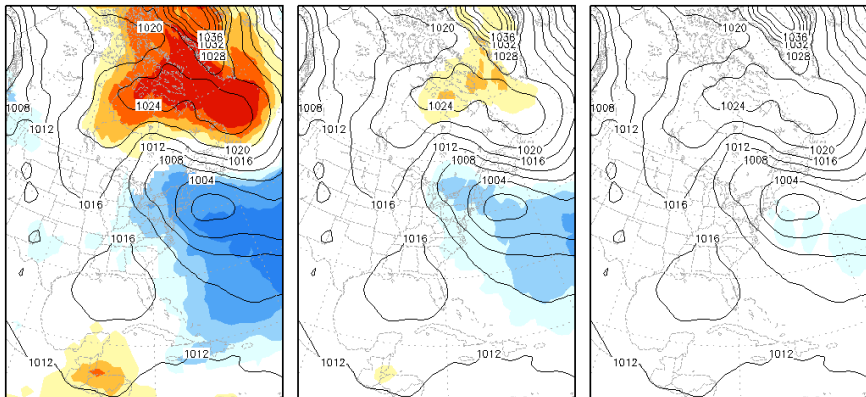
Definitions for Anomaly Forecast

Percentage of ensemble forecast (shaded area) which exceeds climate threshold for example: exceeding 2σ of ensemble mean or exceeding 3σ of 20% ensemble forecast

Sea Level Pressure (PRMSL), 192-hour forecast
 Ini. time:2012102300 Valid time:2012103100

Contour—mean forecast; Shaded—forecast anomalies

σ 2σ 3σ

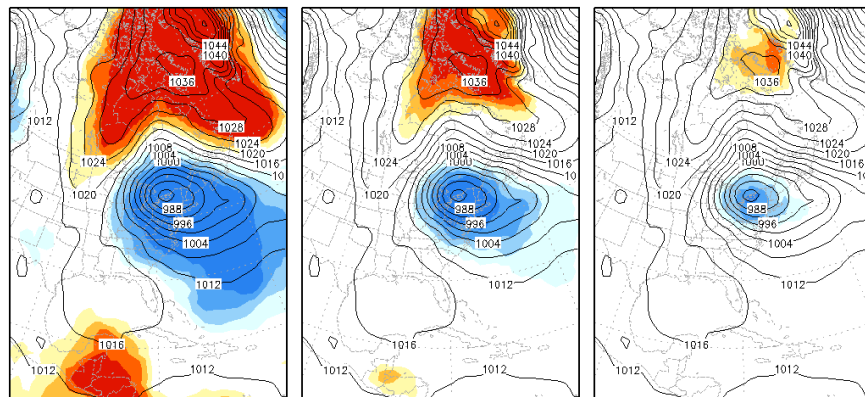


8-day fcst

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

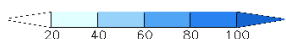
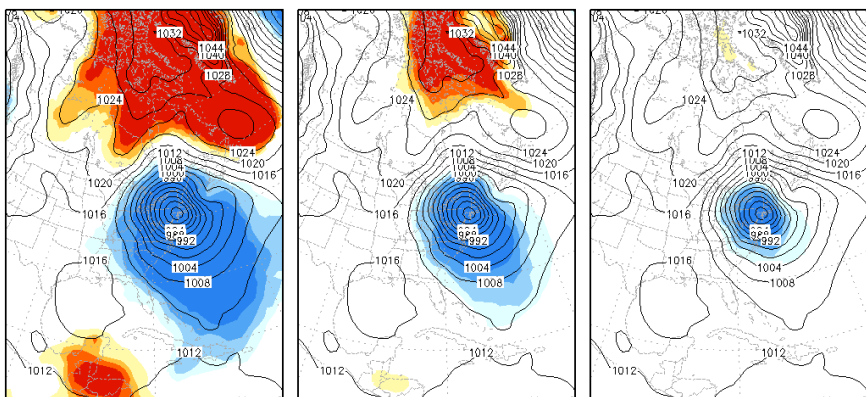
Hurricane Sandy

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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

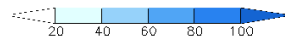
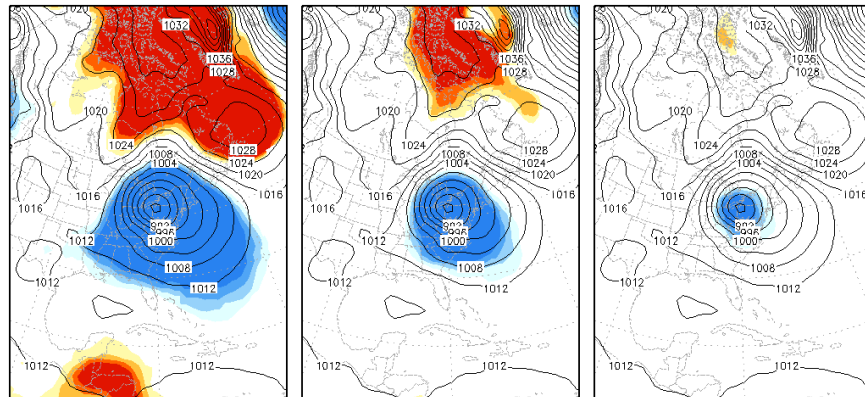


5-day fcst

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



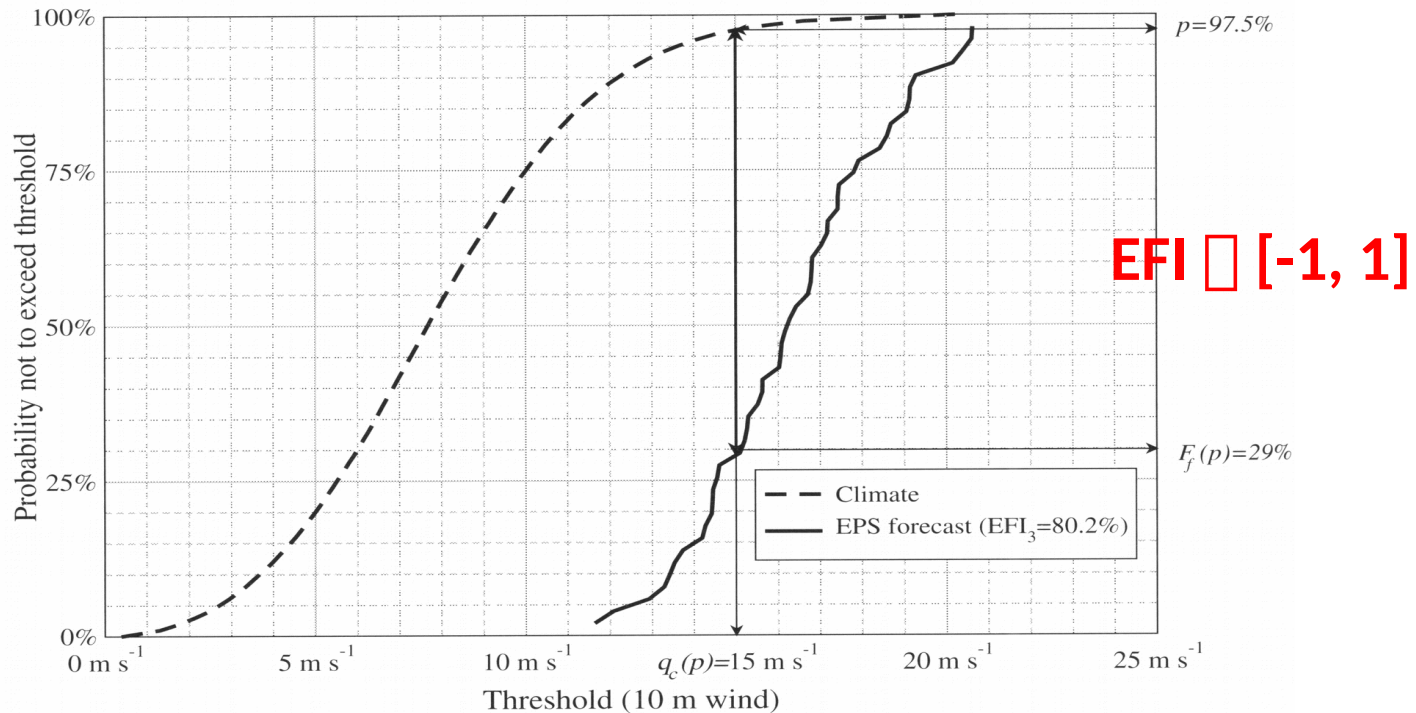
4-day fcst

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Extreme Forecast Index (EFI)

(Lalauette, 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

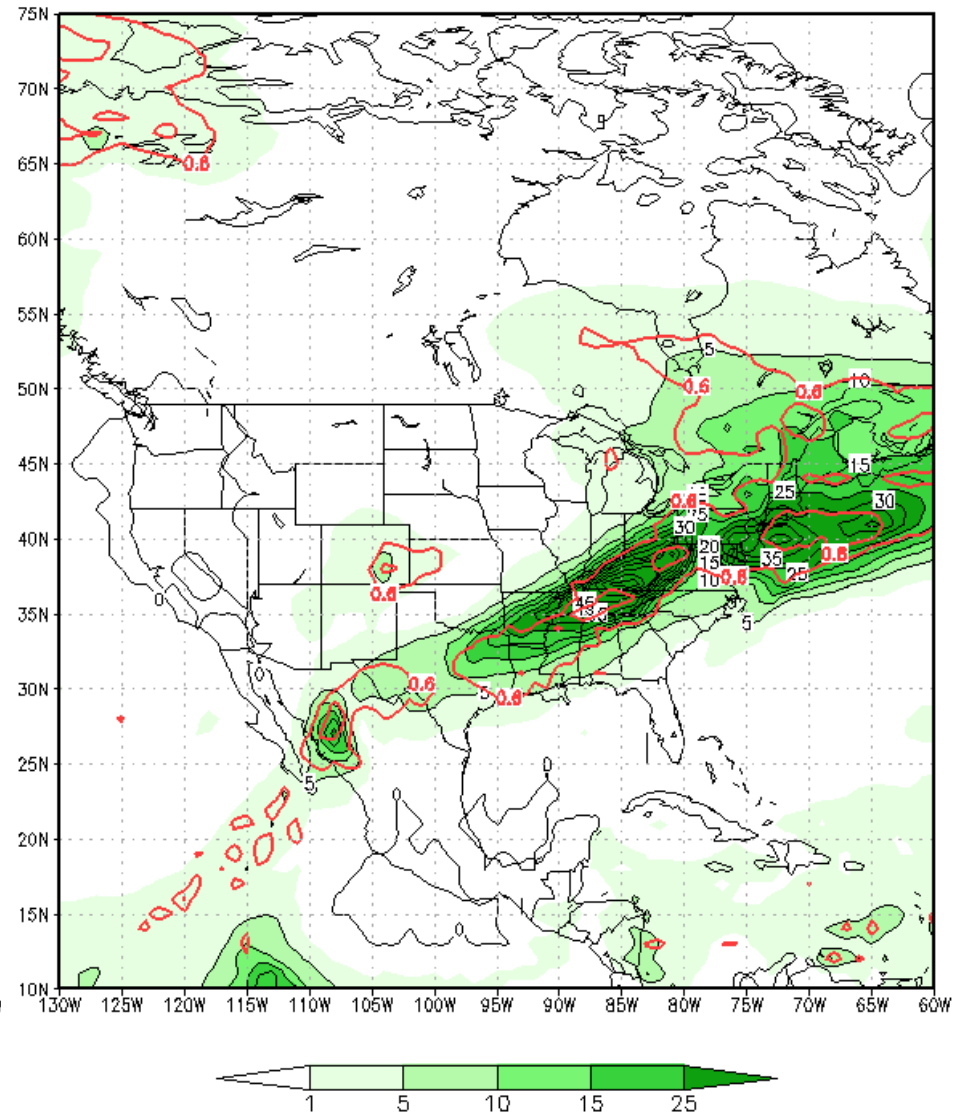
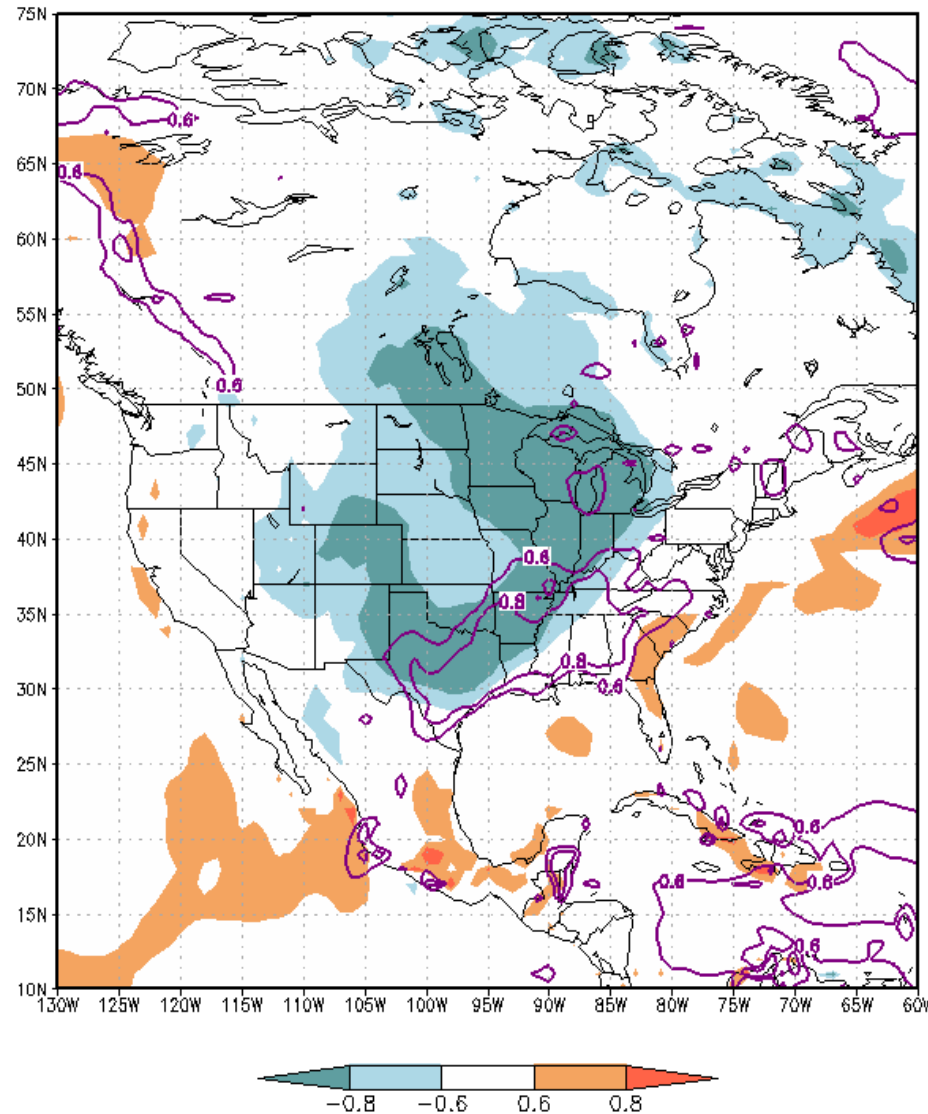
Modified Equation
(Zsoter 2006)

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

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

T2m(shaded) and V10M(contour) EFI
96hr forecast ini. 2015030100

prcp (shaded) and EFI (contour)
96hr forecast ini. 2015030100



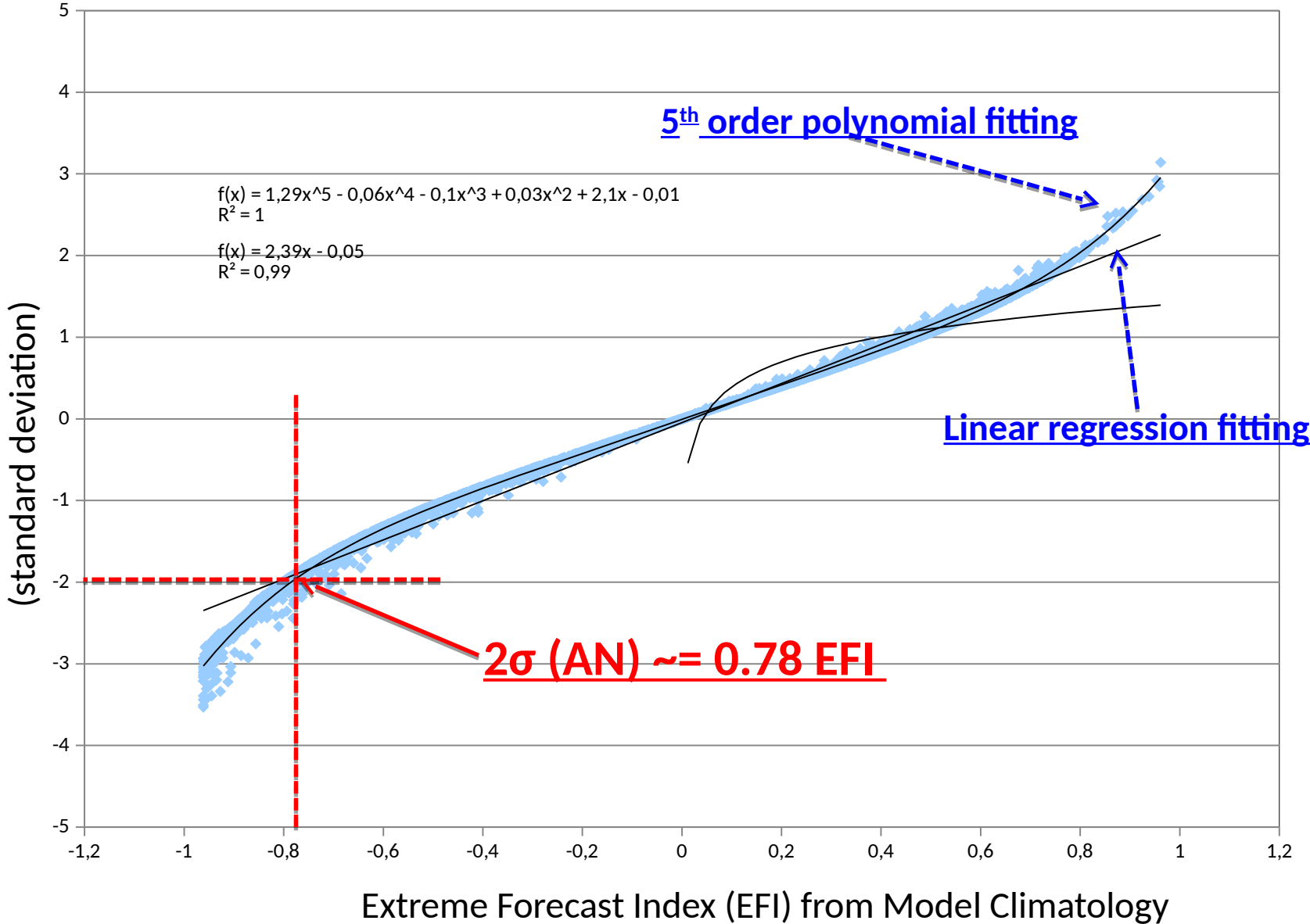
Anomaly Forecast and Extreme Forecast Index

Challenges?

- How to verify extreme forecast?
- How to compare these two measures?
- Relatively, what EFI value is equivalent to standard deviation (e.g. 2σ) anomaly of ensemble mean (as an example)?

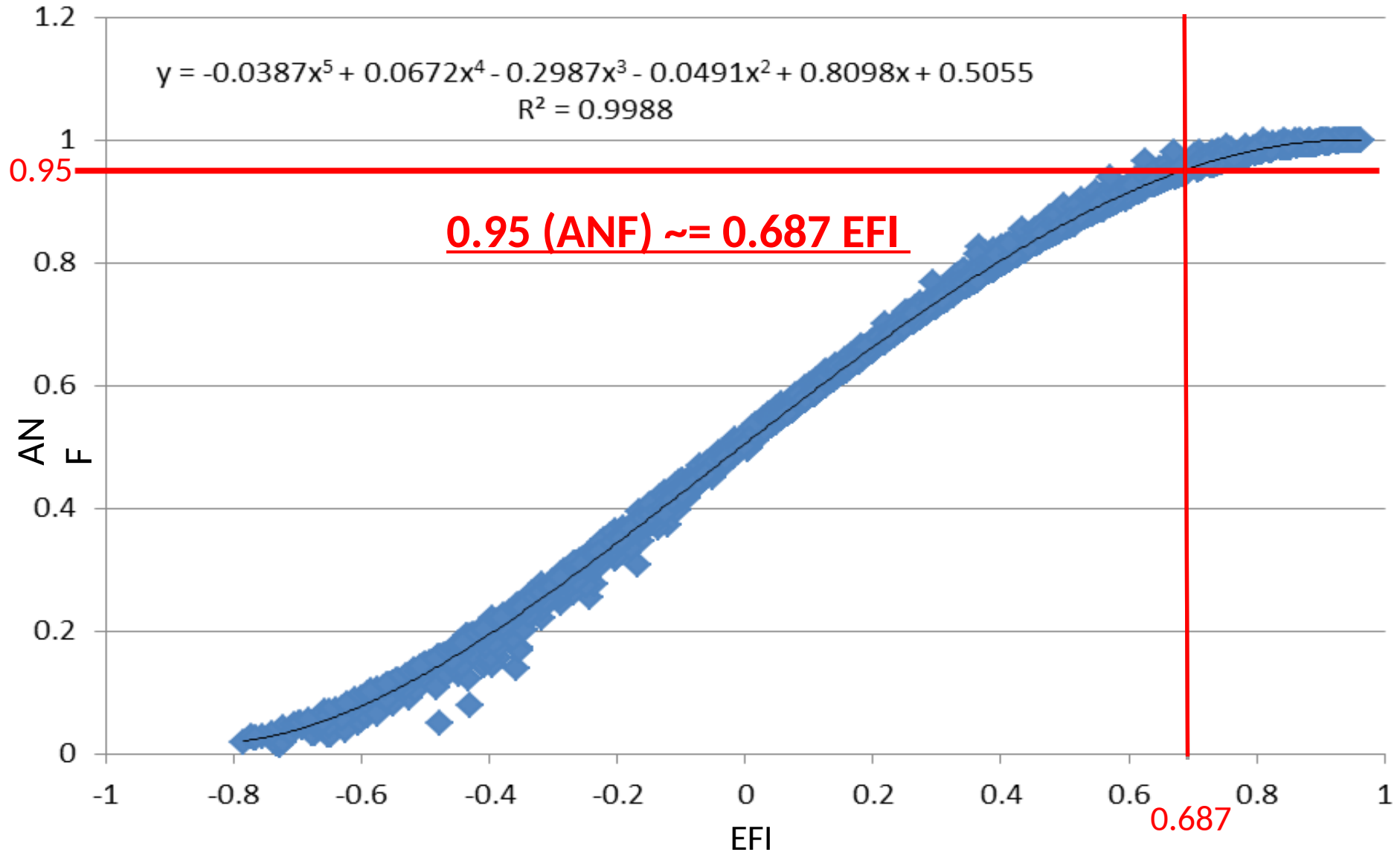
Relationship between ANF and EFI for 2-m temperature valid 2015030100 (96-hour forecast) - GEFS V11

Ensemble Mean Anomaly Forecast (AN) from Model Climatology



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

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

Apply 2*2 contingency table from selected threshold

The Hit Rate (**HR**)

False Alarm Rate (**FAR**)

Frequency Bias (**FBI**)

Equivalent Threat Scores (**ETS**)

Performance diagram

Extreme cold event forecasts and verification

Experiments for extreme cold event forecasts and verifications

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

- Raw GEFS v11 forecast vs. M-climate (18y control-only reforecast)
- Bias-corrected GEFS v10 forecast vs. analysis climatology (30-year CFSR)
- Bias-corrected GEFS v11 forecast vs. analysis climatology (30-year CFSR)
- Bias-corrected GEFS v11 forecast vs. analysis climatology (40-year reanalysis)

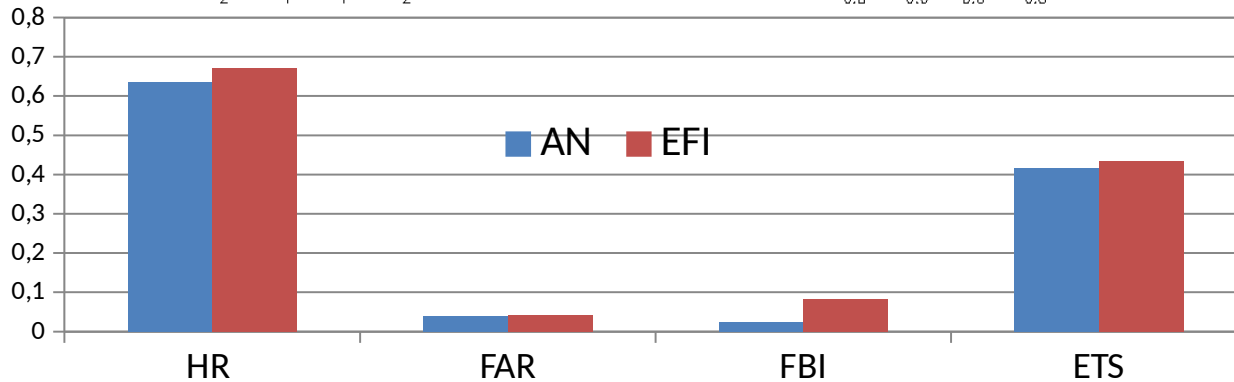
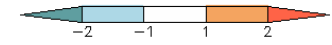
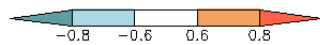
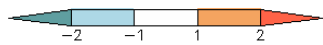
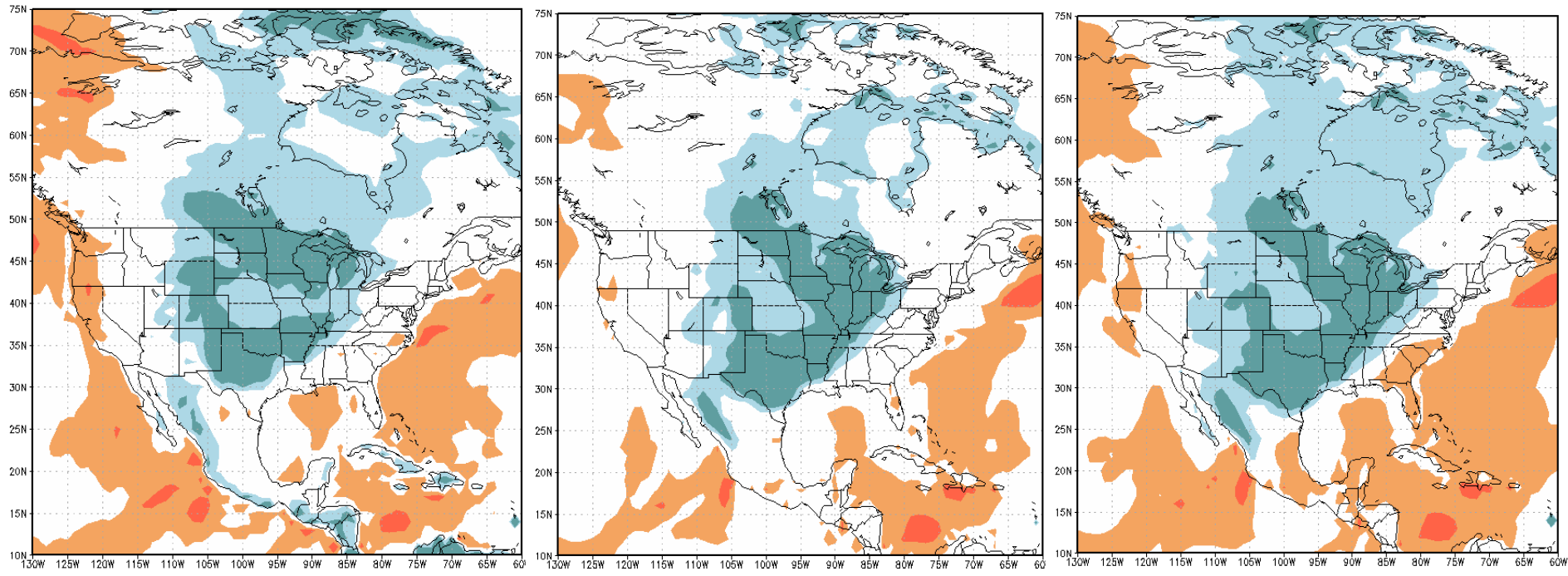
Example of extreme cold weather event (Valid: 2015030500)

Comparison between the two methods

Observed anomaly (analysis)

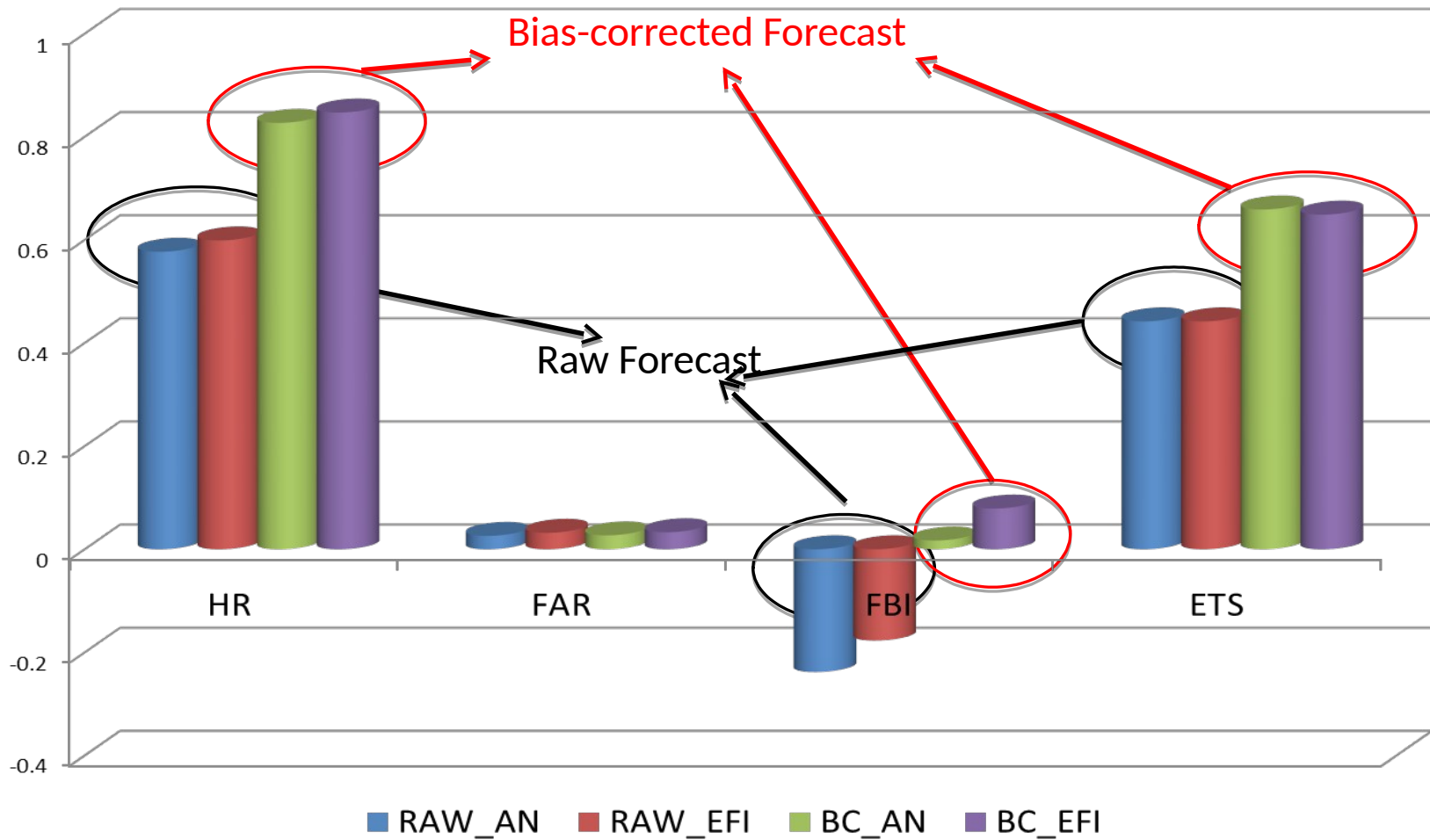
Extreme Forecast Index (EFI)

Anomaly Forecast (AN)

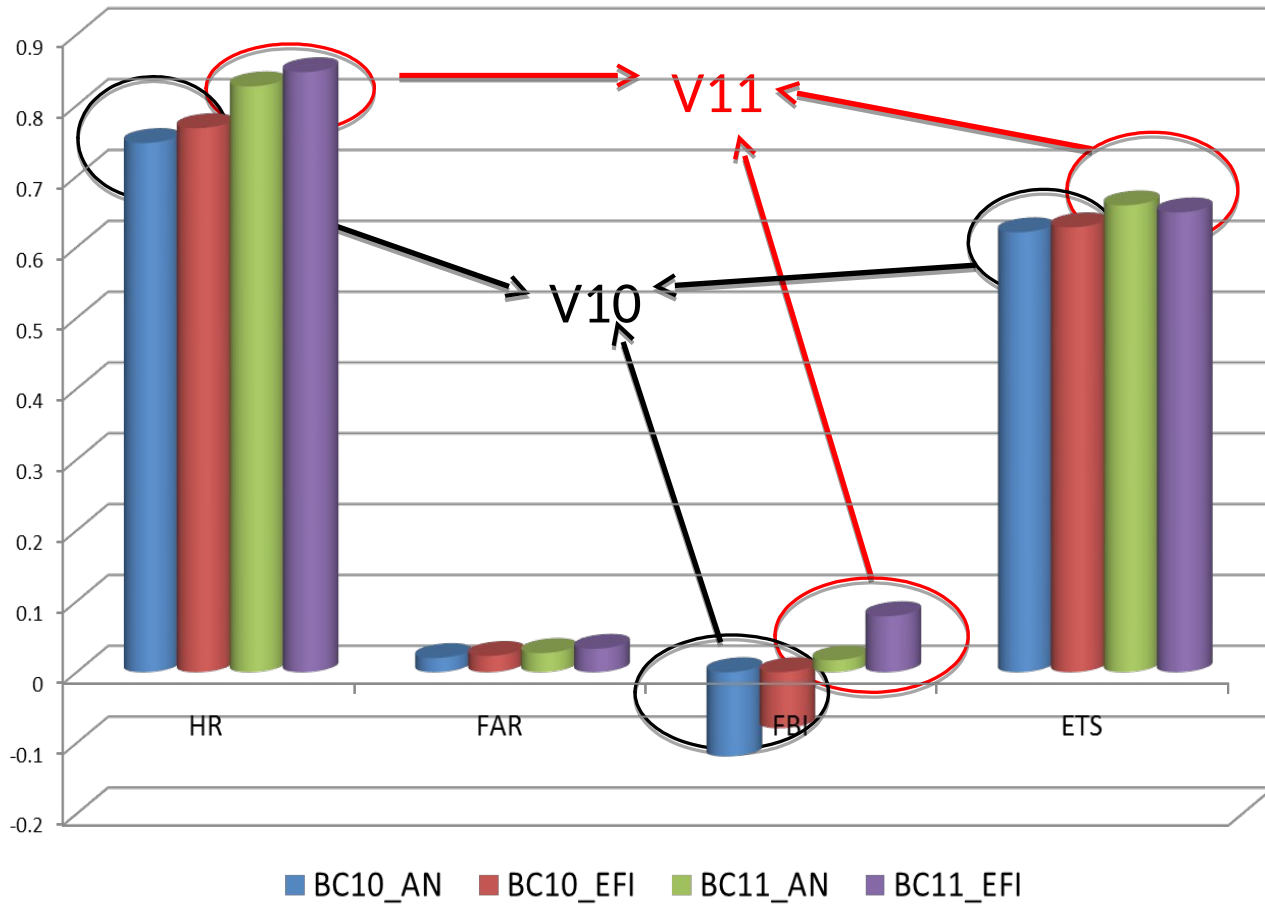


GEFS V11 Raw T2m
Against
Model climatology

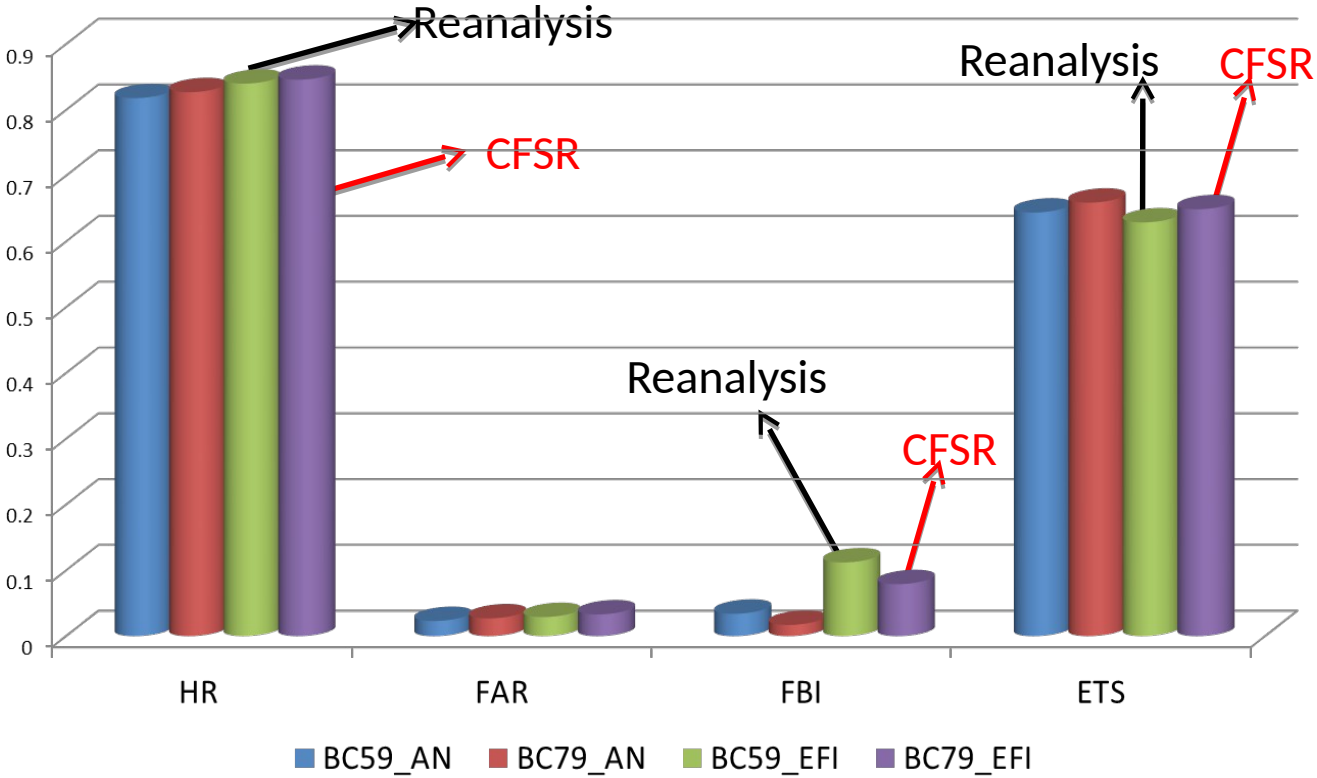
Statistics for extreme cold weather event (11 cases) for 13-14 winter (Raw and bias-corrected forecast (V11))



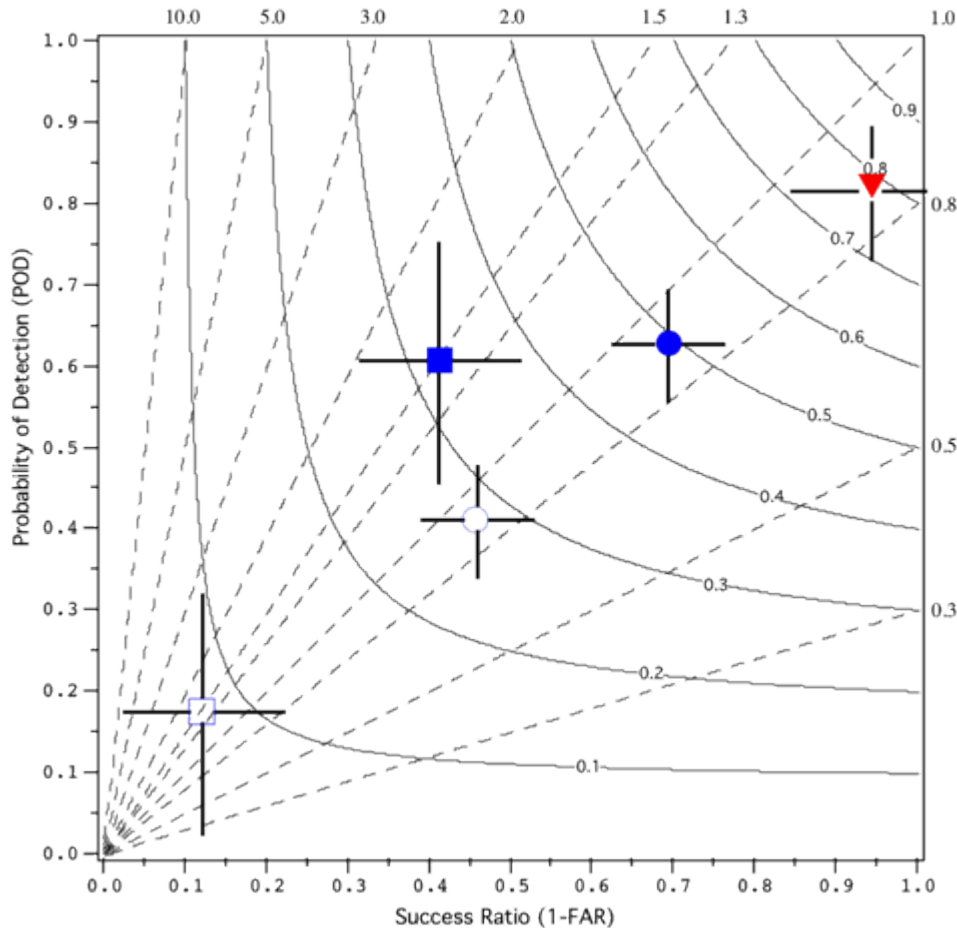
Statistics for extreme cold weather event (11 cases) for 13-14 winter (V10 and V11 bias-corrected forecast)



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)

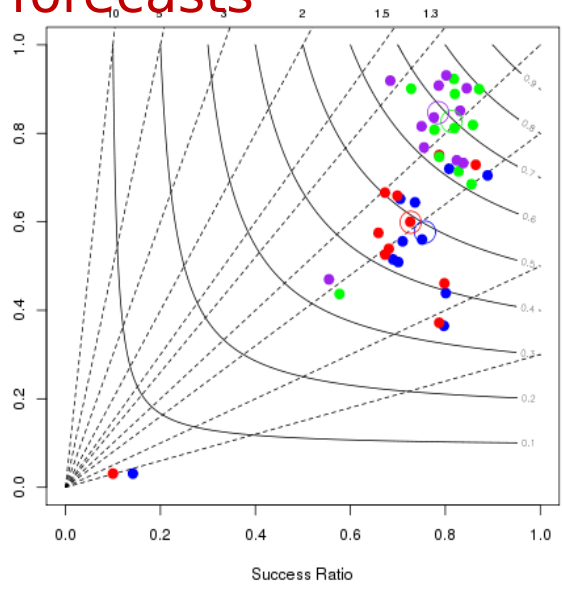


Exploiting the geometric relationship between four measures of dichotomous forecast performance: probability of detection (POD), false alarm ratio or its opposite, the success ratio (SR), bias and critical success index (CSI; also known as the threat score).

Performance Diagram for Extreme Cold Events

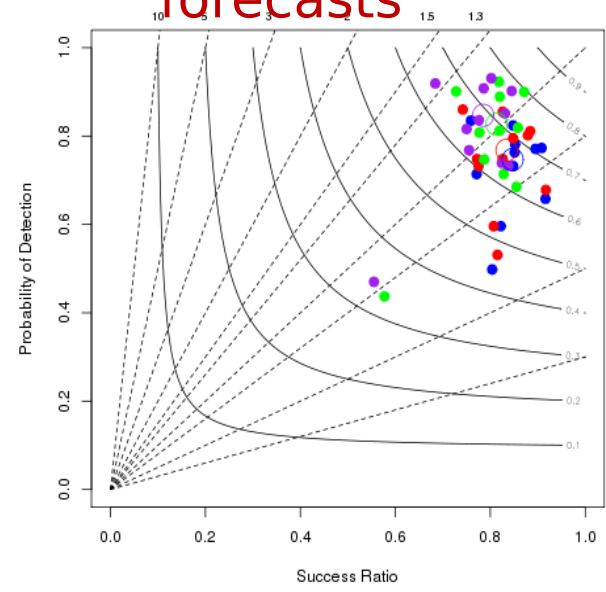
Raw vs. bias-corrected forecasts

Performance Diagram: B=RAW_AN, R=RAW_EFI, G=BC_AN, P=BC_EFI



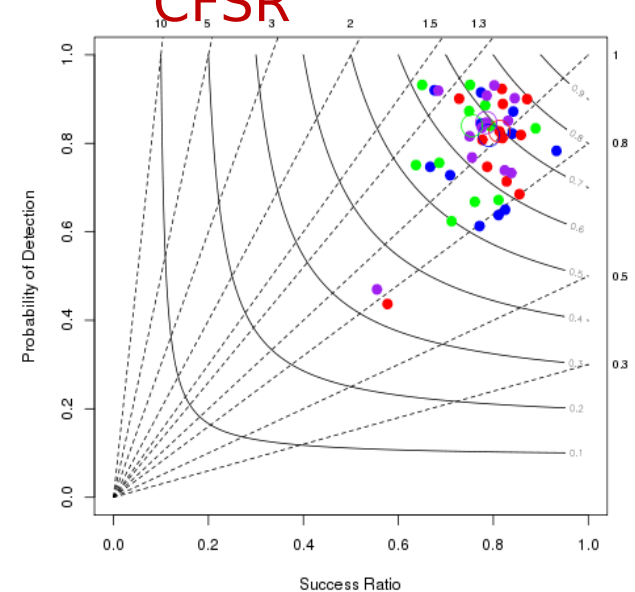
v10 vs. v11 forecasts

Performance Diagram: B=BC10_AN, R=BC10_EFI, G=BC11_AN, P=BC11_EFI



Reanalysis vs. CFSR

Performance Diagram: B=BC59_AN, R=BC79_AN, G=BC59_EFI, P=BC79_EFI



Extreme precipitation forecasts and verification

Experiment for extreme precipitation forecasts and verification

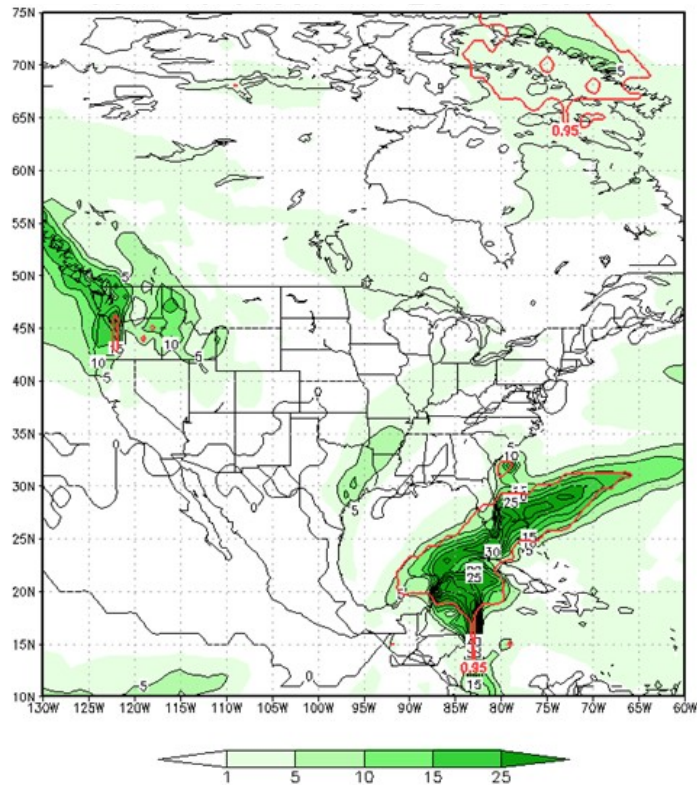
To estimate the relative performance of ANF and EFI:

- Raw GEFS v11 forecast vs. M-climate (18y control-only reforecast)

Example of Extreme Precipitation Forecast

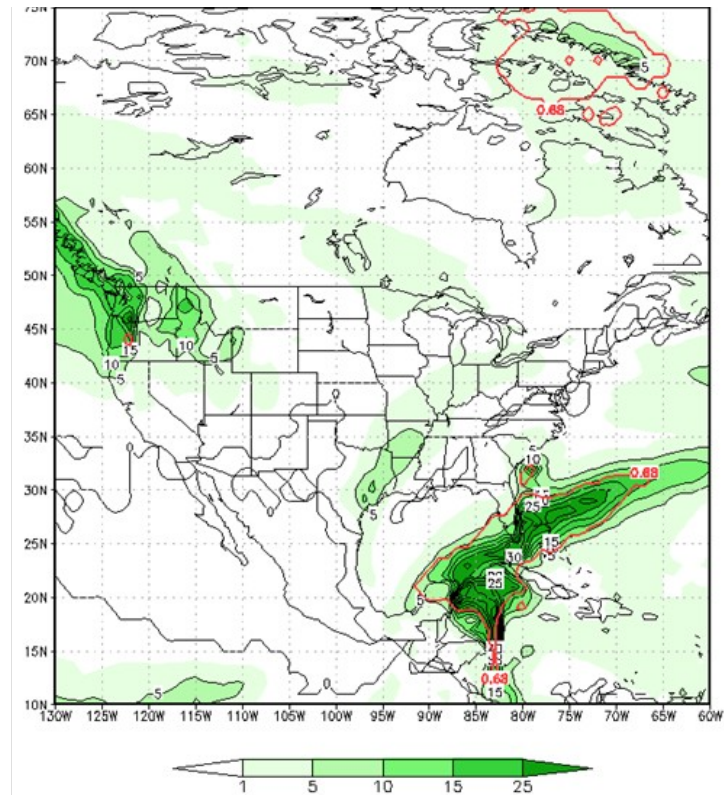
ANF

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



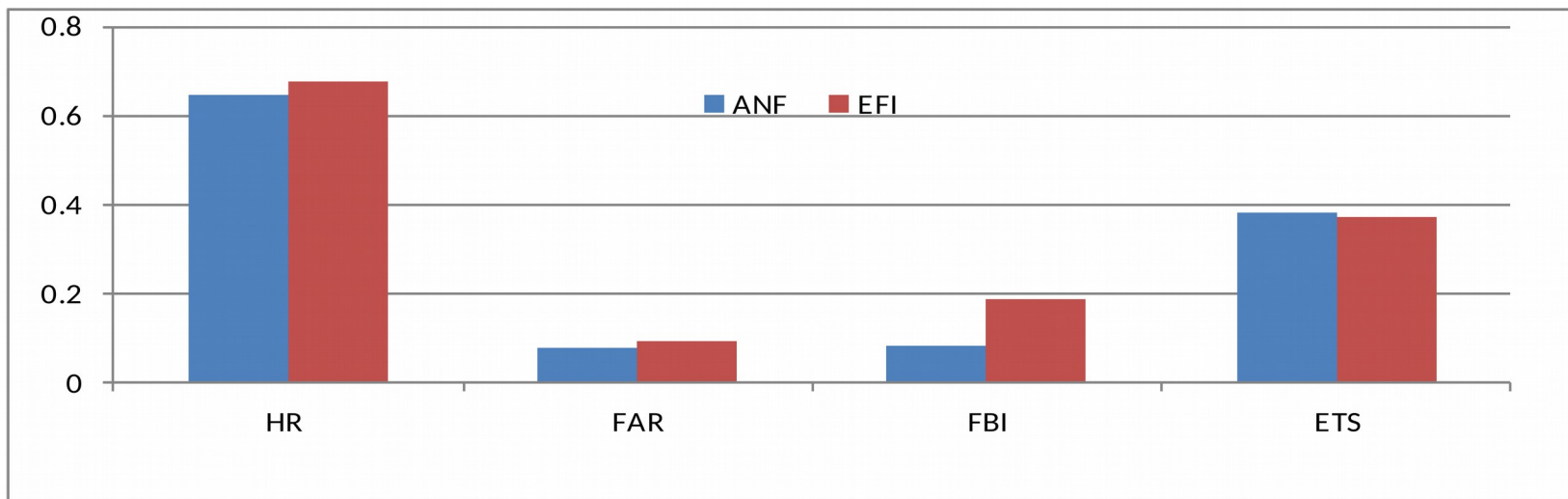
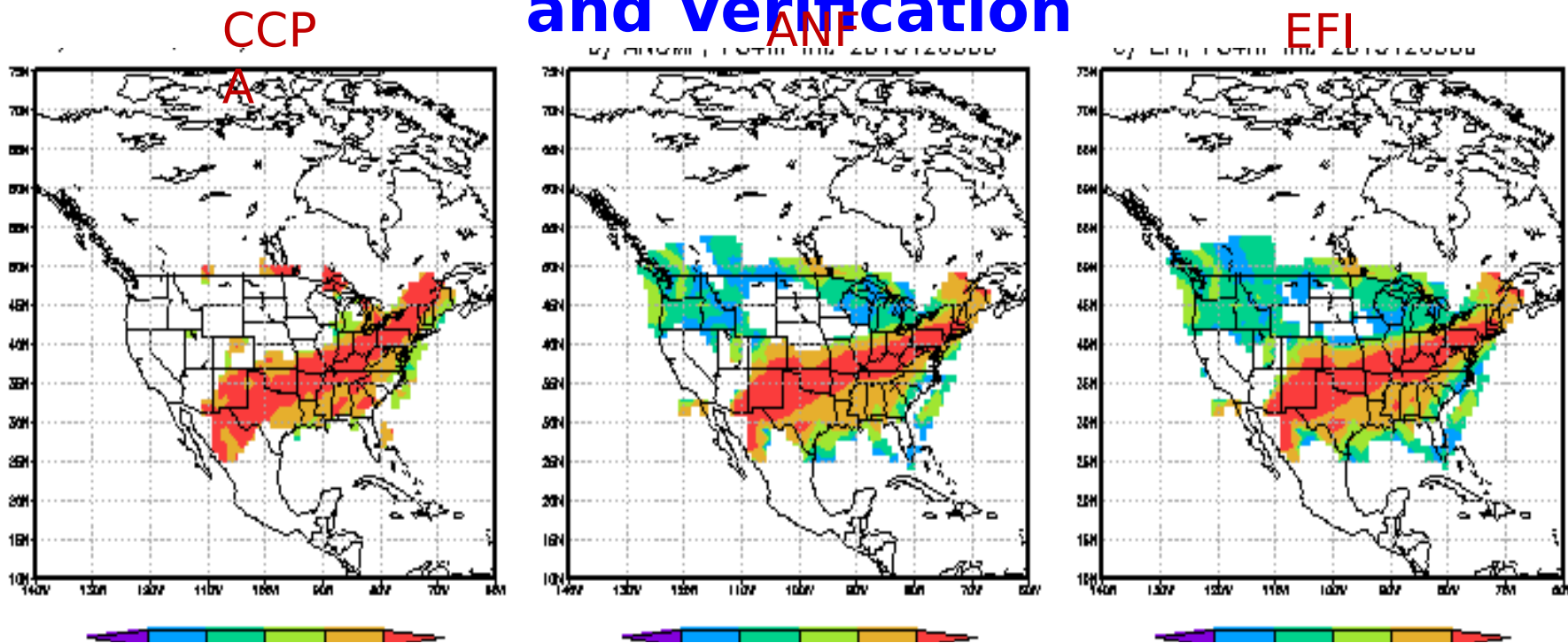
EFI

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



Summary, Future Plan and Reference

- In this study, we have developed the verification methodology for extreme cold event and extreme precipitation forecasts.
 - A highly correlative relationship between the ANF and EFI is found which allows the determination of the equivalent thresholds from both products for extreme event forecast.
 - The equivalent threshold is variable-dependent.
 - For 2-m temperature, -2-sigma ANF \sim -0.78 EFI
 - For 24h accumulated precipitation, 95% ANF \sim 0.687 EFI
 - The methodology has been applied to evaluate the relative performance of different methods, model versions, references, and forecasts.

- “Performance diagram” is a useful visualization tool for validating extreme event forecasts.

- In the future, we will apply the methodology to other variables.

- Reference: Guan, H. and Y. Zhu, 2017:
["Development of verification methodology for extreme weather forecasts"](#)
Weather and Forecasting, Vol. 32, 470-491