

# Using GEFS ensemble forecasts for decision making in reservoir management in California

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# PSD's experimental forecast web product for California

The screenshot shows a web browser window displaying the NOAA Earth System Research Laboratory (ESRL) website. The page is titled "California Medium-Range Precipitation Forecasts, Based on NCEP GEFS Reforecasts and CCPA" and features a sidebar with navigation links and a main content area with a detailed description of the forecasting method and a form for selecting forecast parameters.

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## California Medium-Range Precipitation Forecasts, Based on NCEP GEFS Reforecasts and CCPA

### Censored, Shifted Gamma Distribution (CSGD) Parametric Method

This page presents high resolution (1/8 degree) experimental precipitation forecasts, based on GEFS (Version 10) Reforecasts and Climatology-Calibrated Precipitation Analysis (CCPA, 2002-2013) datasets. A nonhomogeneous regression model that employs censored, shifted gamma distributions (CSGD) is fitted to these data, and then applied to the real-time ensemble forecasts to turn them into probabilistic forecasts. A detailed description of this technique, including an evaluation of its forecast skill, is given in [Scheuerer and Hamill \(2015\)](#).

These forecasts will usually (but not always) be updated by 16 UTC each day. They likely will not be available as consistently as operational products from the National Weather Service. Also please note that this is an experimental forecast product, and is not an official forecast of NOAA or its National Weather Service. Precipitation units are mm (25.4 mm = 1 inch).

We welcome feedback on this product. Email comments to: [esrl.psd.reforecast2@noaa.gov](mailto:esrl.psd.reforecast2@noaa.gov).

**Choose a Forecast Plot Below:**

**Analysis Date** (format: *yyyymmdd*):  Latest: Jan 18 2017 **Forecast Period:**

(Input a date within last 10 days)

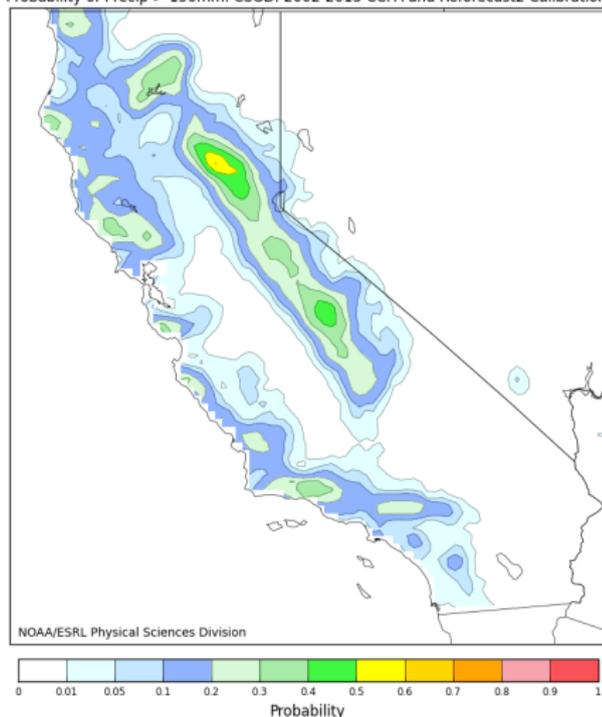
**Plot Field:**

# Probability of $\geq 6''$ precipitation, 00Z Jan 6 - 00Z Jan 11

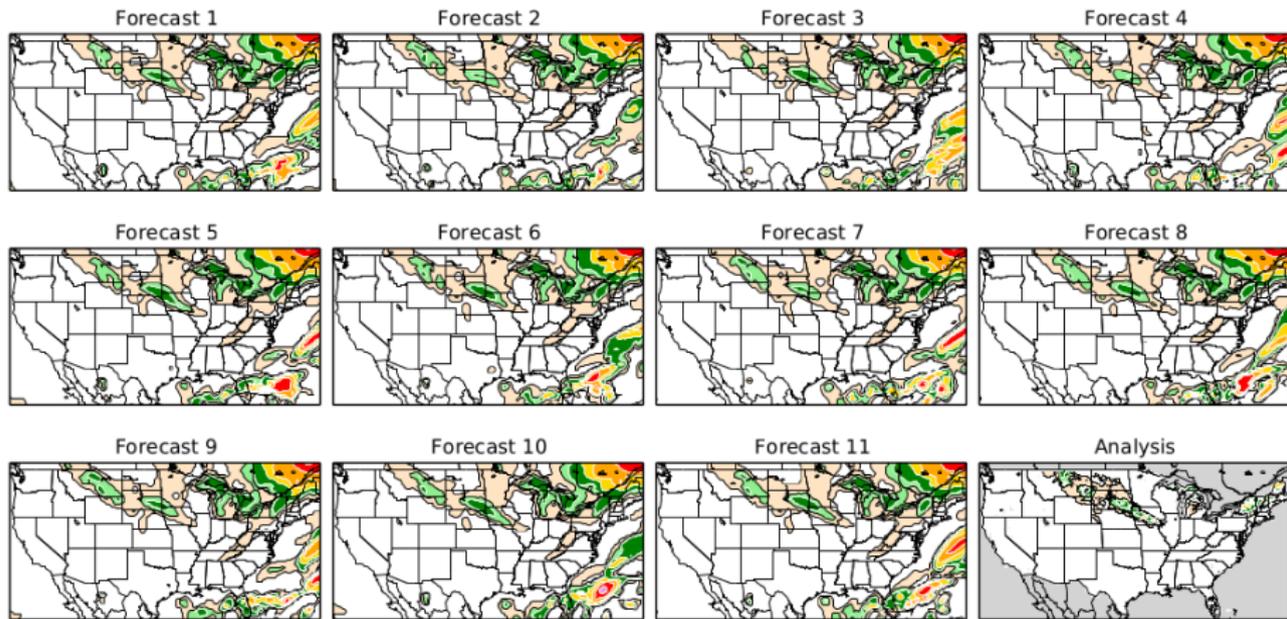
Initialization time 00Z Jan 1,  
day 6-10 precipitation forecast.

This lead time is of particular  
interest in the context of FIRO.

120-240hr fcst from 00Z Sun Jan 01. Valid 00Z Fri Jan 06 - 00Z Wed Jan 11  
Probability of Precip > 150mm. CSGD. 2002-2013 CCPA and Reforecast2 Calibration.



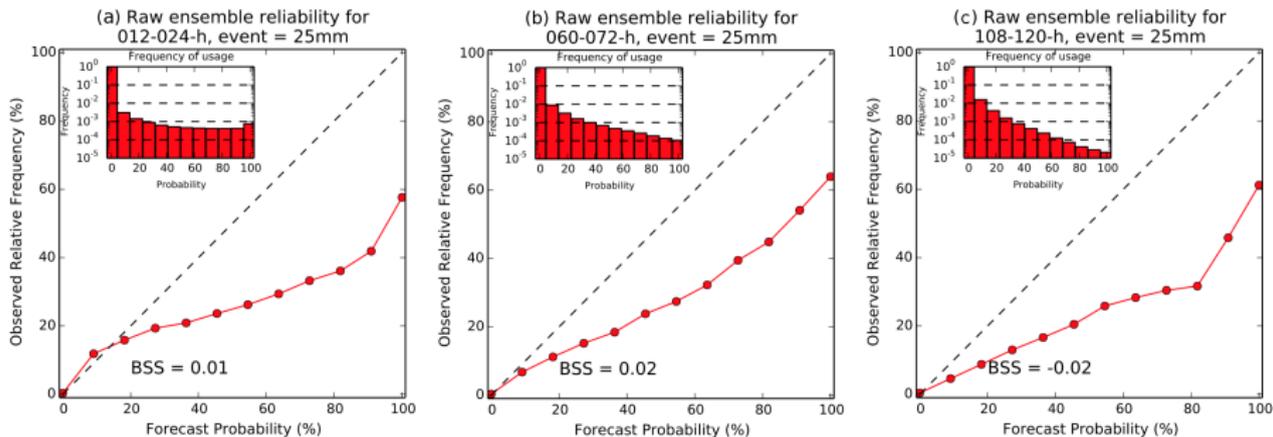
# How do we get there?



GEFS ensemble forecast (lead time 12h - 24h) and climatology corrected analysis of 12h precipitation accumulations on 20 January 2013.

# Post-processing of ensemble forecasts for precipitation

Quantiles and probabilities of threshold exceedance derived from the raw ensemble directly are often unreliable (biases, insufficient representation of uncertainty, etc.)



Statistical post-processing methods use forecast-observation pairs from the past to identify and correct those shortcomings.

## Data used for our experimental web products

The 2nd generation GEFS reforecast data set ([Hamill et al., 2012](#)) is the backbone of our experimental web products and associated research. It contains GEFS version 10 ensemble forecasts for a period from January 1985 to present, initialized at UTC 0000 and consisting of 11 members.

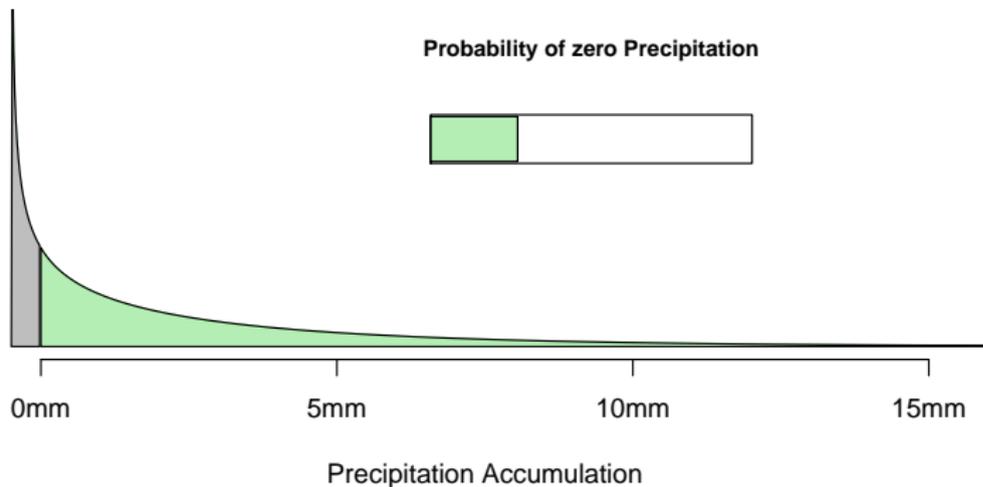
Climatology corrected precipitation analyses ([Hou et al., 2012](#)) over the conterminous U.S. on a grid with  $1/8^\circ$  horizontal resolution are used as the 'truth' against which those forecasts are calibrated and verified.

The probabilistic forecasts made available through our experimental web products are based on the Censored Shifted Gamma Distribution (CSGD) post-processing methodology proposed by ([Scheuerer and Hamill, 2015](#)) and explained on the following slides.

# A distribution family for precipitation

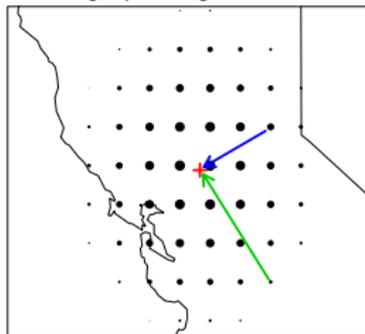
We model precipitation accumulations by censored, shifted gamma distributions (CSGDs):

## Censored shifted gamma distribution

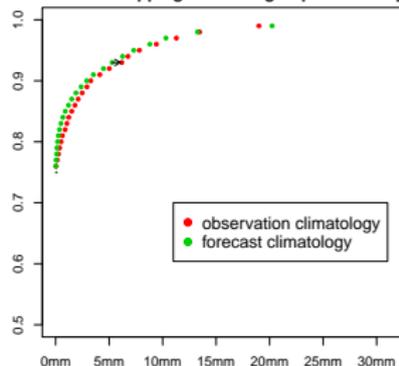


# Accounting for displacement errors

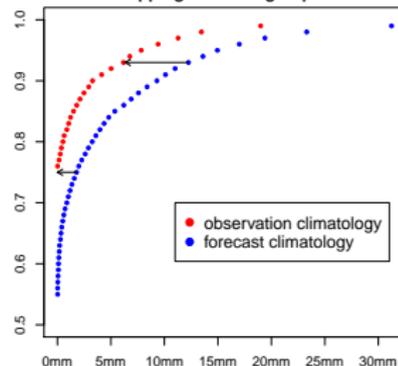
Forecast grid point weights for Sacramento



Quantile mapping: forecast grid point too dry



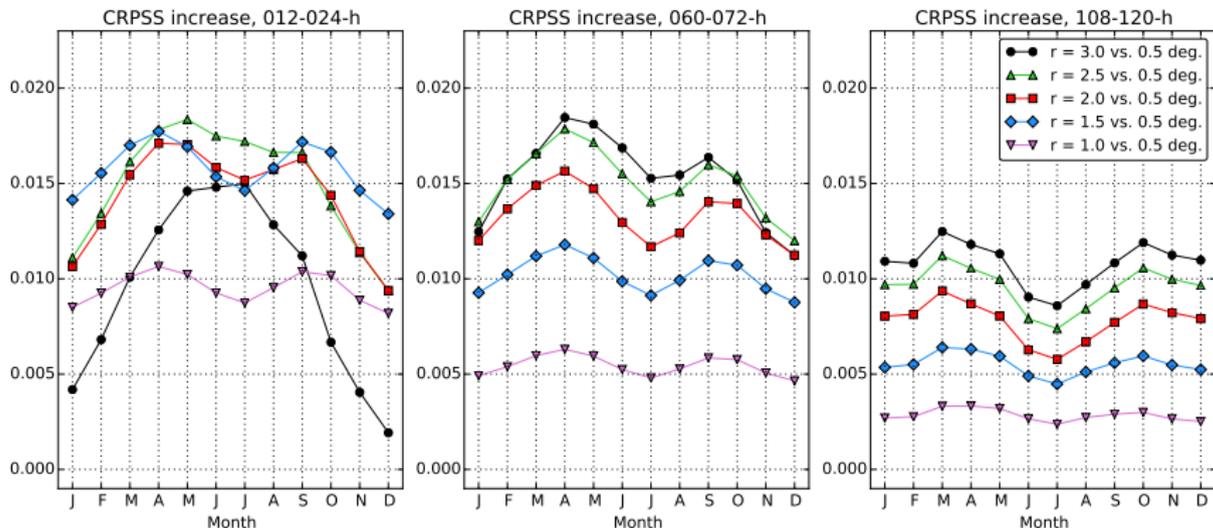
Quantile mapping: forecast grid point too wet



Our method accounts for displacement errors by considering ensemble forecasts in a larger neighborhood of the analysis grid point of interest (here: Sacramento, red cross).

To address the issue of different climatologies within that neighborhood, quantile mapping is used to homogenize the forecasts before further processing them.

# Impact of neighborhood size



Increase of continuous ranked probability skill scores (CRPSSs) for different neighborhood sizes, relative a neighborhood radius of  $r = 0.5$  degrees.

Results are for 12-h precipitation accumulations, cross-validated over the years 2000 to 2013, and averaged over all 1/8 degree CCPA grid points within the CONUS.

## Statistics of quantile-mapped ensemble forecasts

Denote by  $\tilde{f}_{xk}$  the quantile-mapped precipitation forecast of member  $k$  at forecast grid point  $x$ . For prediction at  $s$  we consider the following ensemble statistics:

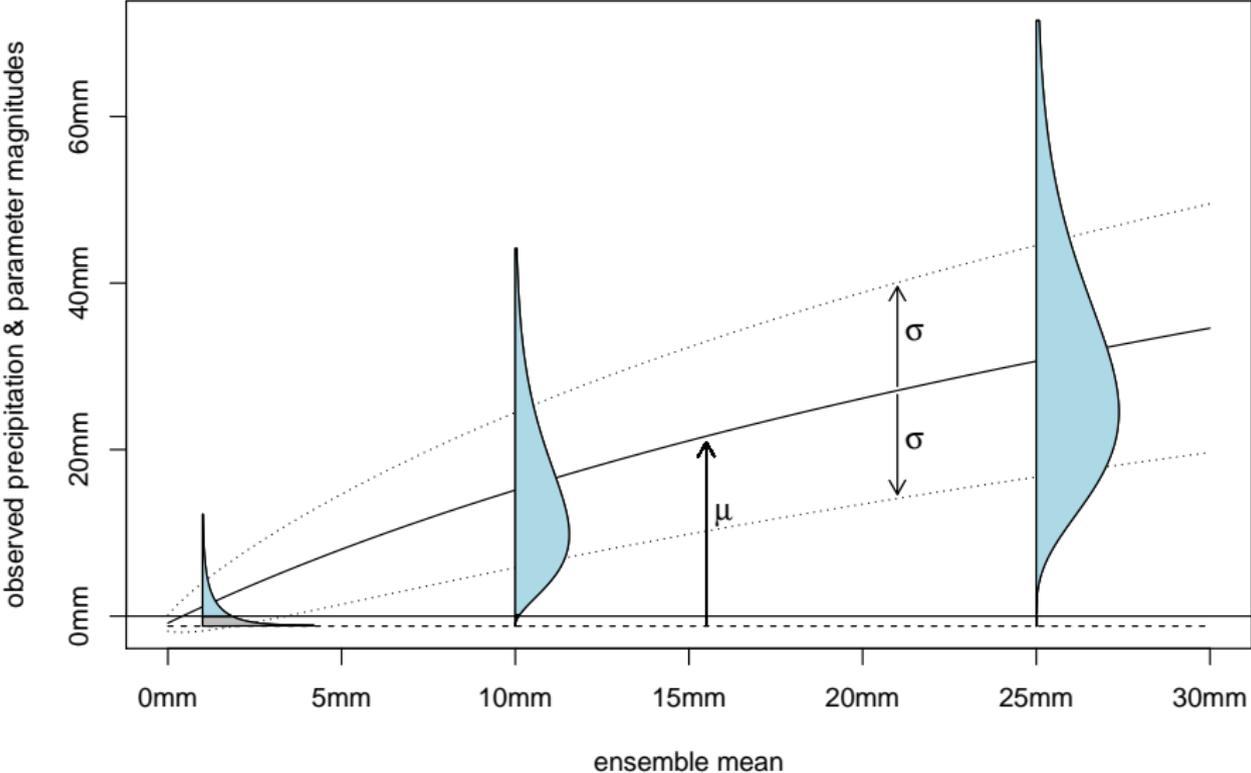
$$\blacktriangleright \text{POP}_{f,s} := \frac{1}{m} \sum_{k=1}^m \sum_{x \in N(s)} w_{sx} \mathbf{1}_{\{\tilde{f}_{xk} > 0\}}$$

$$\blacktriangleright \bar{f}_s := \frac{1}{m} \sum_{k=1}^m \sum_{x \in N(s)} w_{sx} \tilde{f}_{xk}$$

$$\blacktriangleright \text{MD}_{f,s} := \frac{1}{m^2} \sum_{k,k'=1}^m \sum_{x,x' \in N(s)} w_{sx} w_{sx'} |\tilde{f}_{xk} - \tilde{f}_{x'k}|$$

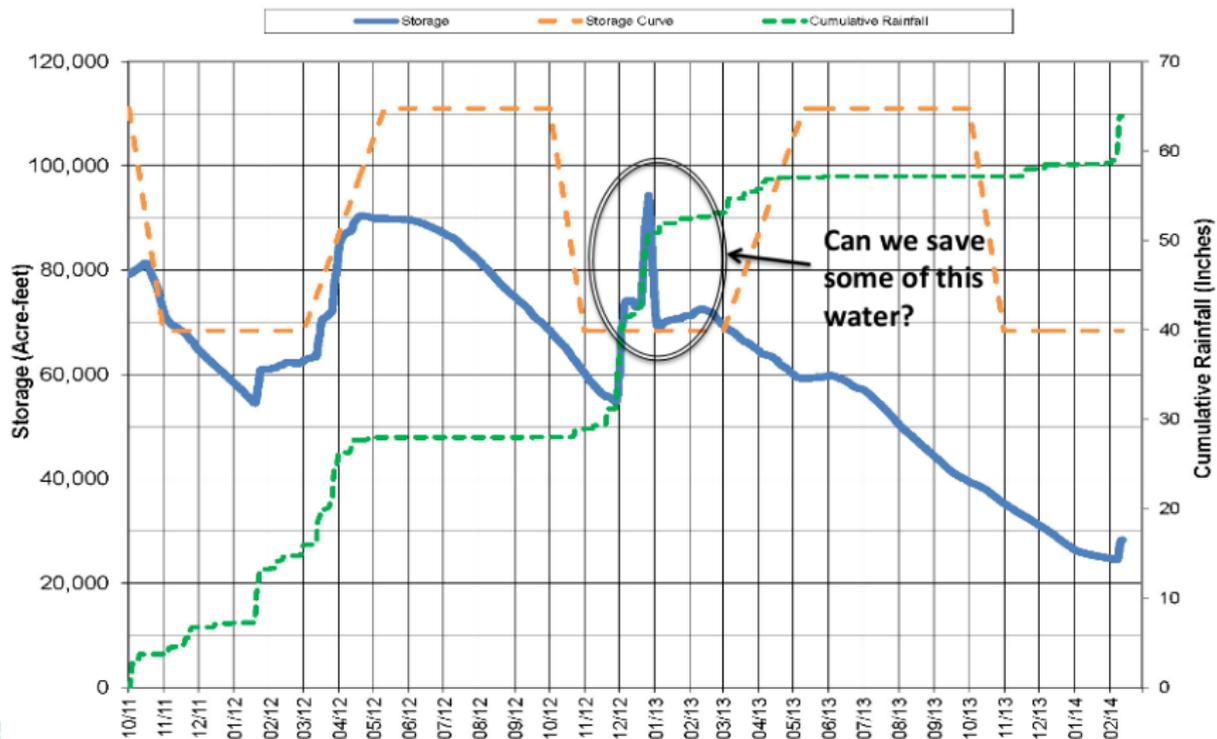
where  $N(s)$  is the set of forecast grid points in the neighborhood of  $s$  and  $w_{sx}$  is the weight associated with this grid point.

# Heteroscedastic regression model



# Application in the FIRO context

## Lake Mendocino Water Years 2012 - 2014



## Application in the FIRO context

Could the probabilistic forecasts of our experimental web product be used to inform reservoir operations?

For example, if a very **low chance of extreme precipitation is forecast**, could **water be kept in the reservoir** even if water levels already exceed the storage curve?

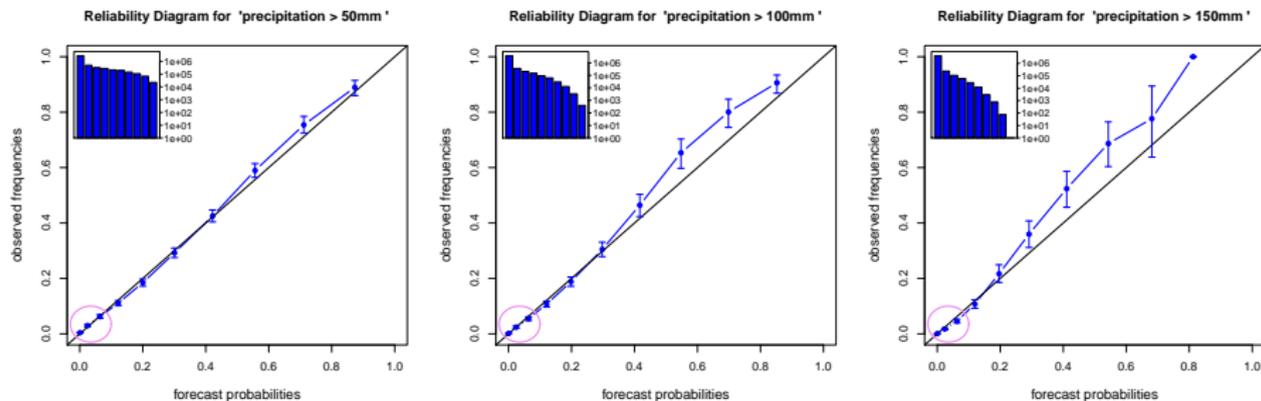
In order to be useful for decision making, probability forecasts must be

- ▶ **reliable**, i.e. if a 10% chance of exceeding a threshold is forecast, the threshold should be exceeded in about 10% of all such forecast cases
- ▶ **sufficiently discriminative**, i.e. if the threshold is exceeded the forecast probability of exceedance should be as high as possible, otherwise as low as possible

# Forecast reliability

A verification study was conducted

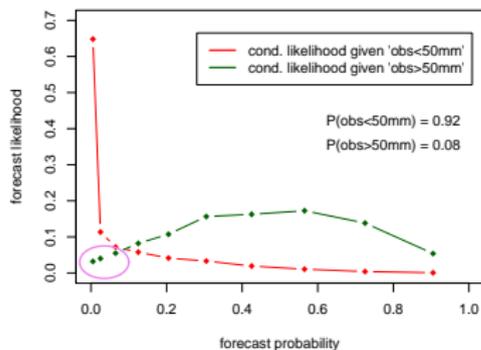
- ▶ using all CCPA grid points within Northern and Central California
- ▶ cross validating the cool seasons 2002/2003 to 2015/2016



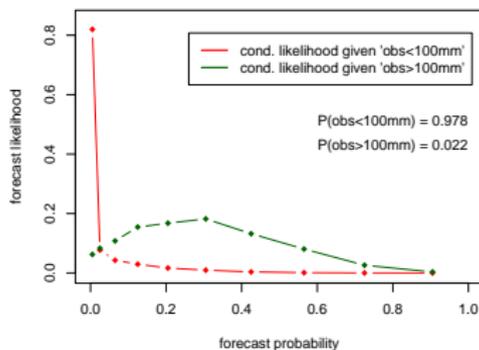
The experimental forecast product has a tendency to underforecast when high probabilities are issued, but is reliable for the low probabilities that are relevant for decision making.

# Discrimination ability

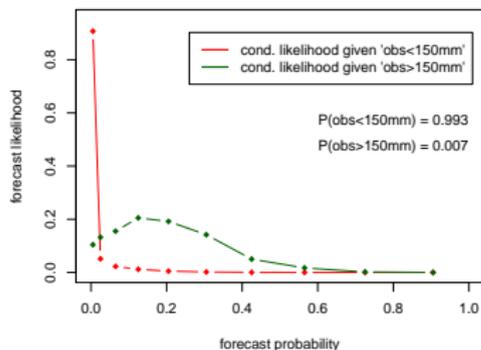
Discrimination Diagram for 'precipitation > 50mm'



Discrimination Diagram for 'precipitation > 100mm'



Discrimination Diagram for 'precipitation > 150mm'

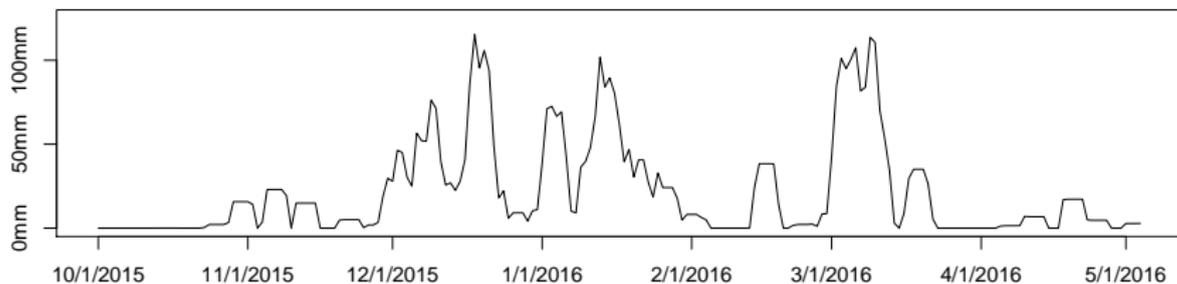


The probability forecasts are able to discriminate exceedance and non-exceedance.

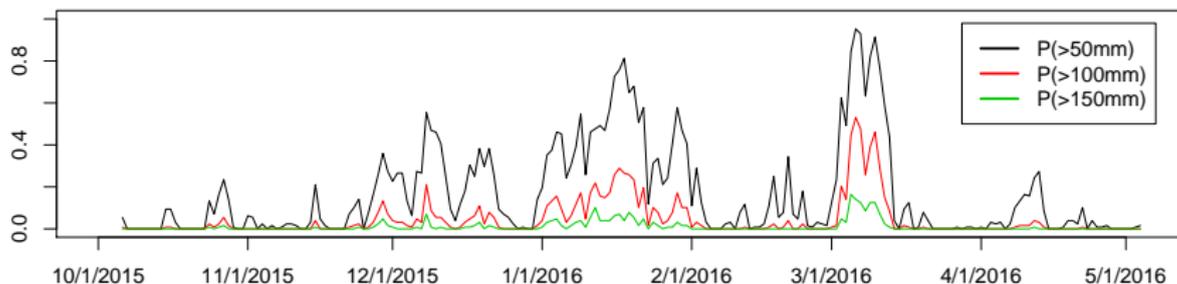
Due to the large uncertainty at lead time 6-10 days, however, there are a number of exceedance cases where low exceedance probabilities are issued.

# Case Study: Lake Mendocino, 2015/2016 cool season

**Analyzed 5-day precipitation accumulations at Lake Mendocino**

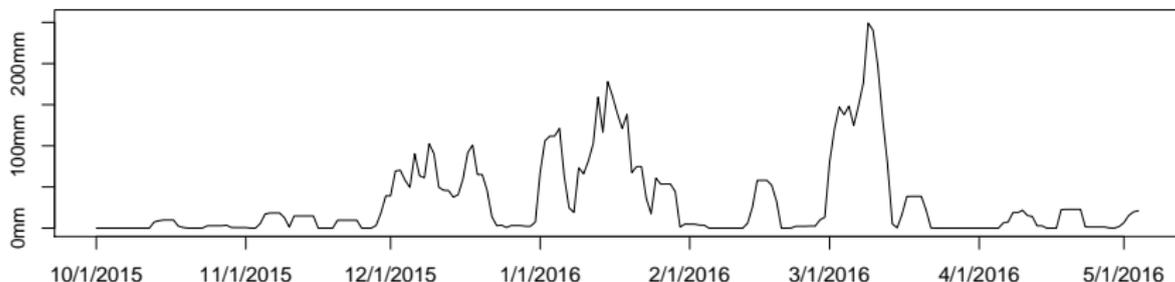


**Corresponding day 6-10 probability forecasts**

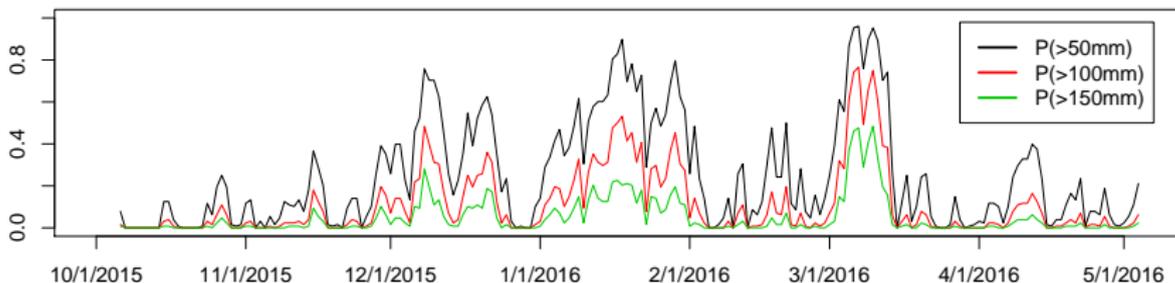


# Case Study: Shasta Lake, 2015/2016 cool season

## Analyzed 5-day precipitation accumulations at Shasta Lake



## Corresponding day 6-10 probability forecasts



## Summary and Discussion

- ▶ Statistical post-processing of the GEFS ensemble forecast can generate probabilistic forecast that can be used for decision making
- ▶ Currently, uncertainty at 6-10 days lead time is still large; as a result, even a reliable probabilistic forecast product will not always issue high exceedance probabilities when an extreme event occurs
- ▶ Probabilistic framework gives decision makers the freedom to manage risks by selecting the probabilities at which action is taken

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- ▶ Probabilistic framework gives decision makers the freedom to manage risks by selecting the probabilities at which action is taken

Thanks for listening!

# References I

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