Precipitation extremes

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- Colorado Front Range
- Generalized Pareto
- Bayesian Heirarchical Model
- Smoothing

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Why precipitation?

Despite the common description of future climate change as "global warming", changes in precipitation can also have a large economic and ecological impact.

Extremes are used to determine flood potential for urban areas and also for dam specifications.
Ecological systems are often sensitive to extreme weather events.

Typically extremes are described by the return period: "A 20 or 100 year event".

100 year return period = the value has a probability of being exceeded in 1 out of 100 years.

Fort Collins Flood, July 1997

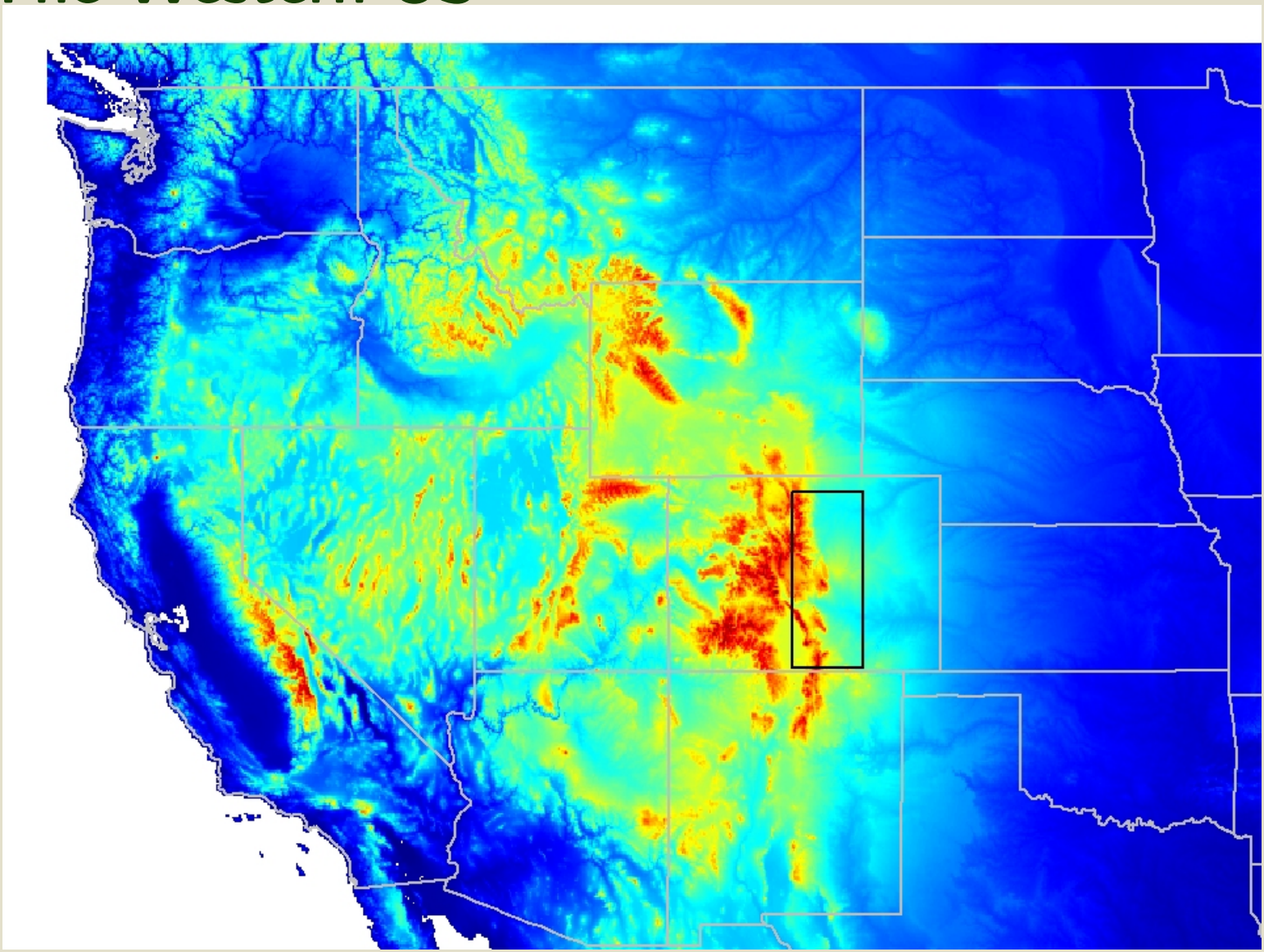
Heaviest rains ever documented over an urbanized area in Colorado (10 inches in 6 hours).

5 dead, 54 injured, 200 homes destroyed, 1,500 structures damaged.

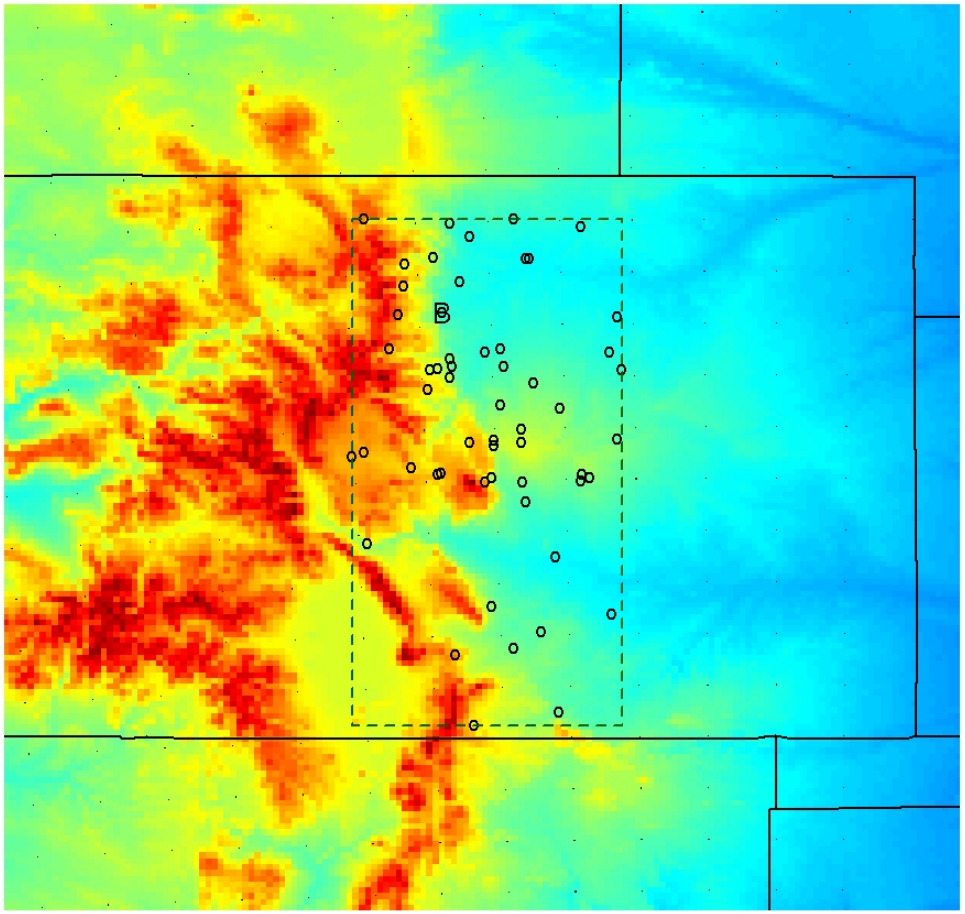
But precipitation extremes are hard to measure ...

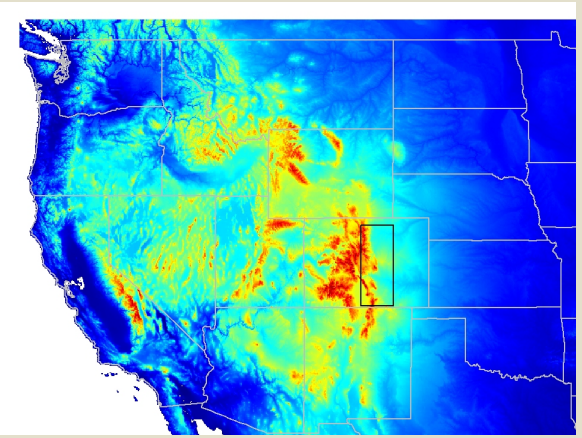
- How does one estimate extremes where no observations are made?
- How does one determine a possible "100 year event" from 50 years worth of data?
- How does one quantify the uncertainty in the estimated return level map?

The Western US



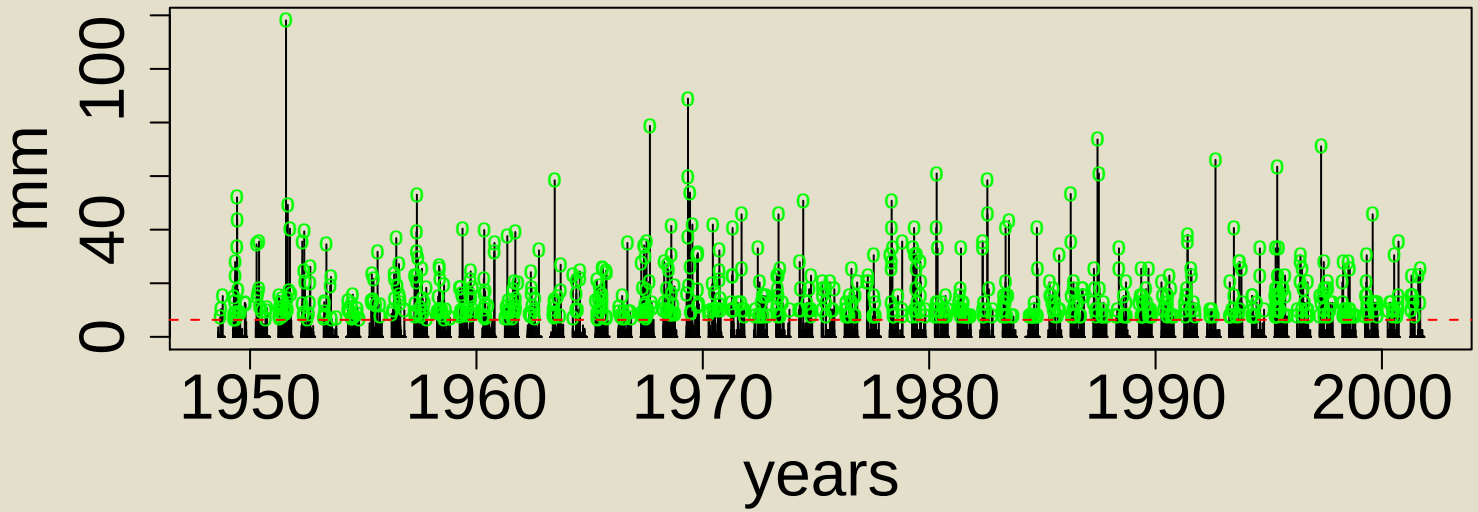
Colorado Front Range





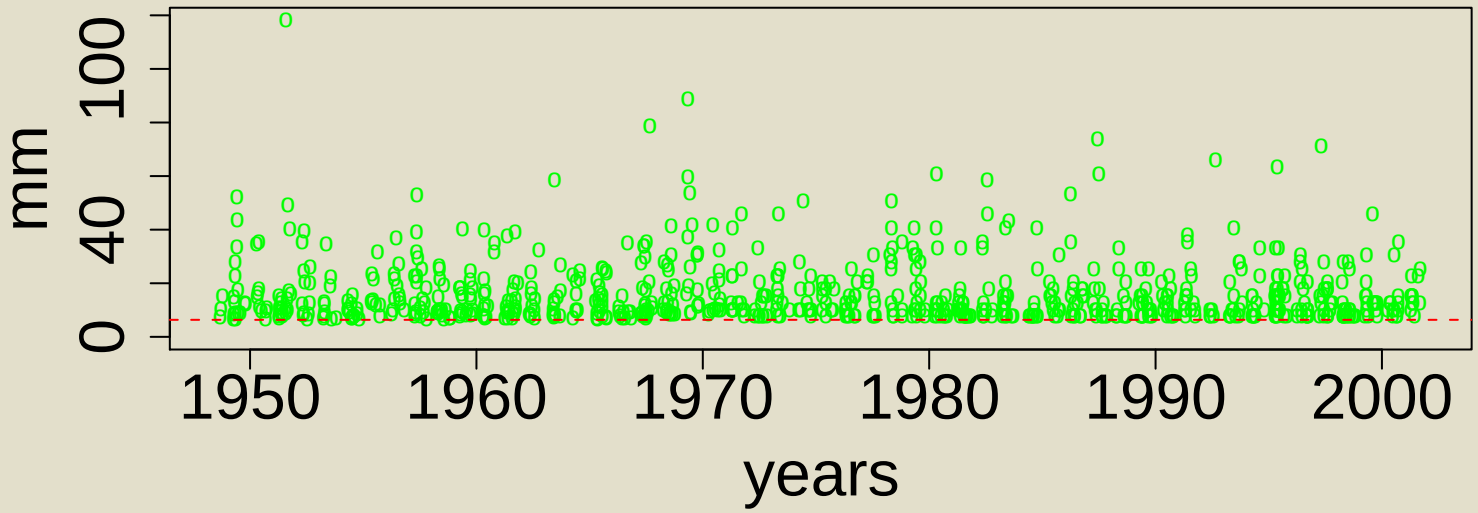
Observed precipitation for Boulder, CO

Daily precipitation amounts

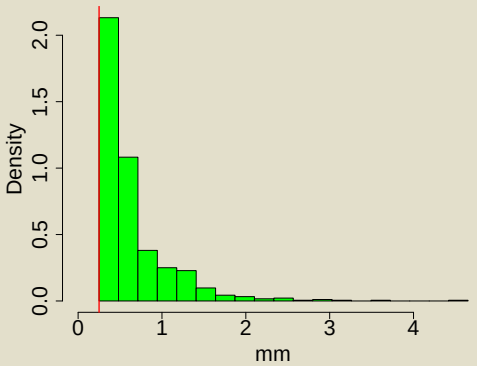


Observed precipitation for Boulder, CO

Daily precipitation amounts thresholded at 2.5 cm



Distribution above threshold:



A spatial model for precipitation extremes

The observed data:

$Y_j(x_i)$ precipitation at location i on day j

The concepts

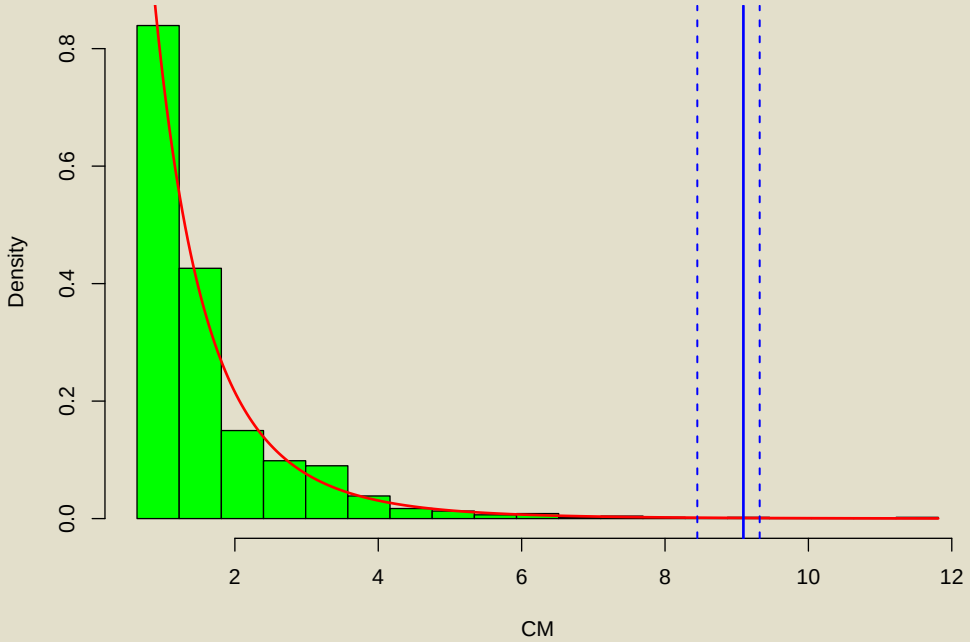
- Use extreme value statistical theory to approximate the distribution of large values $\rightarrow$ three parameters. probability of exceedence, q, shape ξ , log scale ϕ.

$$P\{\mathbf{Y_j(x_i)} - u > y | \mathbf{Y_j(x_i)} > u\} = \left(1 + \frac{\xi_i \, y}{\exp \phi_i}\right)^{-1/\xi_i}$$

- Assume that the parameters of the distribution vary over space according to a spatial process.
- Consider more general "spatial" coordinates besides just longitude and latitude.

Distribution fit to the Boulder exceedances

... and the estimated 25 year event ($\approx 9cm$)



If you know the parameters of the distribution this can easily be converted to any return level

A Bayesian Hierarchical model for precipitation

Goal:

$$[q(\boldsymbol{x}),\ \xi(\boldsymbol{x}),\ \phi(\boldsymbol{x})|Y]$$

Draw inferences about $q(\boldsymbol{x})$, $\xi(\boldsymbol{x})$ and $\phi(\boldsymbol{x})$.

These can be combined to yield posteriors for the return levels.

Model levels:

Data level : $[Y|q(\boldsymbol{x}), \xi(\boldsymbol{x})\phi(\boldsymbol{x}), \omega]$

Use the Gen. Pareto likelihood for exceedences above threshhold ω a vector of all (hyper) parameters.

Process level: $[q(\boldsymbol{x}),\ \xi(\boldsymbol{x}),\ \phi(\boldsymbol{x})|\omega]$

Pareto parameters follow (independent) Gaussian spatial processes with exponential covariance functions.

Priors: $[\omega]$

Choosen to be largely uninformed.

Some details

We assume that $Y_j(\boldsymbol{x}_i)$ are independent conditioned on GPD parameters ...

Posterior approximated by sampling using Markov Chain Monte Carlo.

The sampling steps were broken into logical pieces and a Gibbs sampler was used.

Some interesting points

Connection with smoothing: **Key step in Gibbs sampling is to draw from**

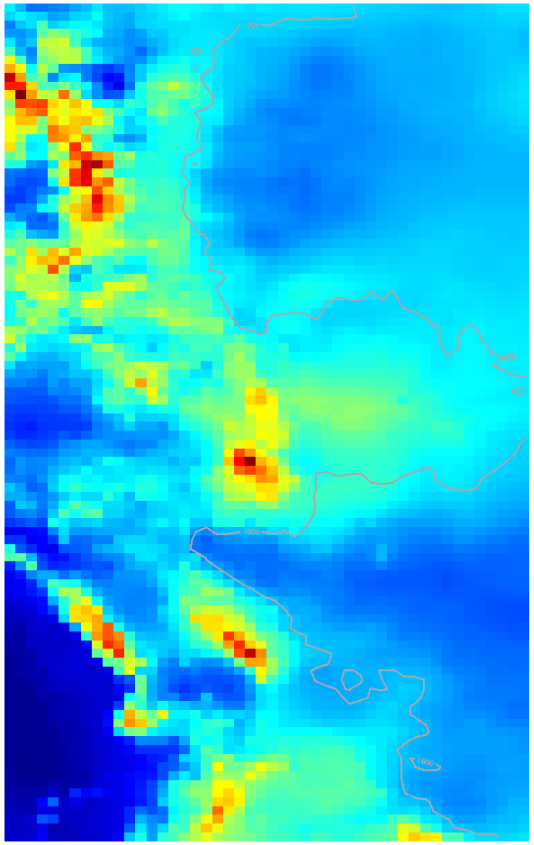
$$[\phi(\boldsymbol{x})|Y, \omega]$$

Metropolis Hasting was used with the proposal distribution based on smoothing the GPD MLEs for $\phi(\boldsymbol{x}_i)$

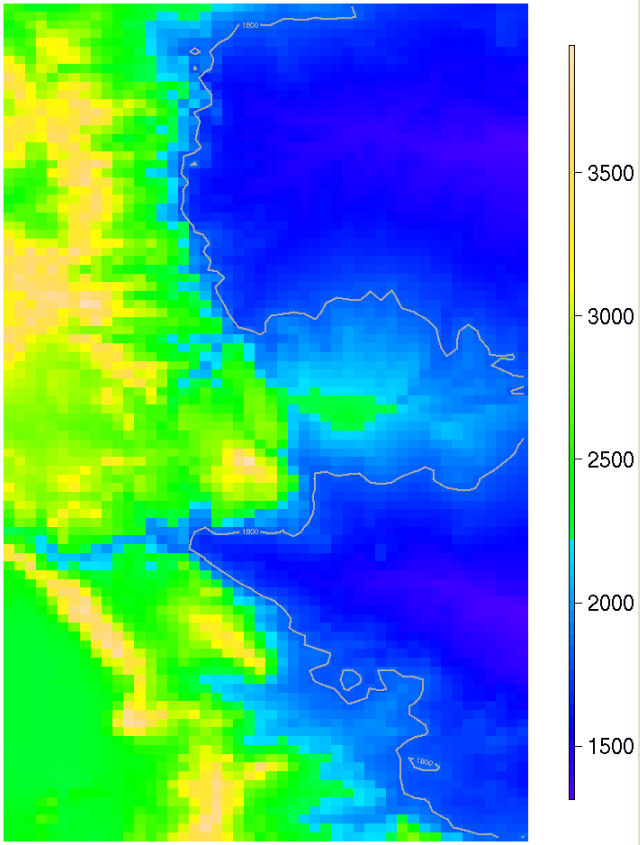
Spatial Coordinates: **Used elevation and summer total precipitatition in plcae of lon/lat.**

PRISM: A Data product for mean precipitation

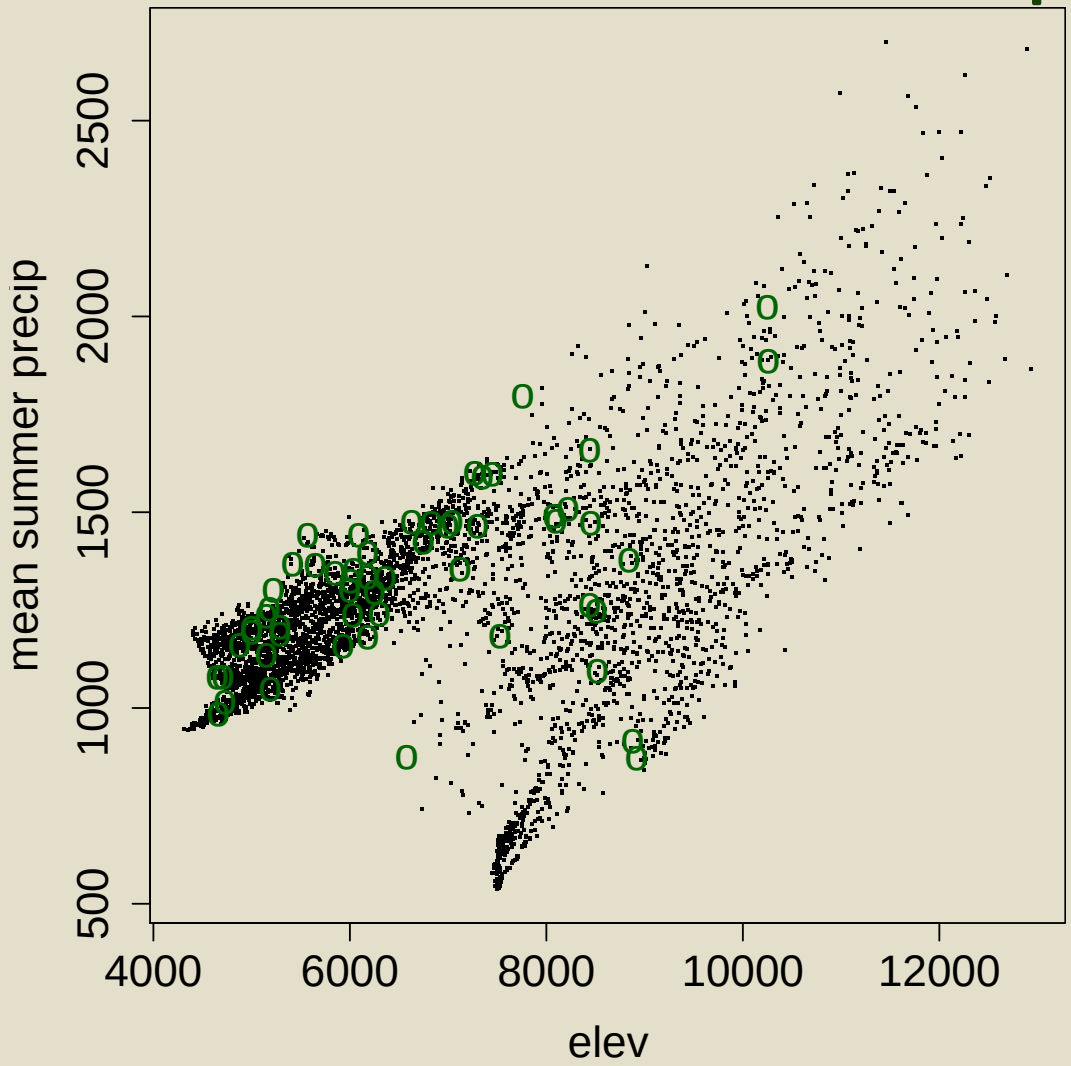
summer precipitation (cm)



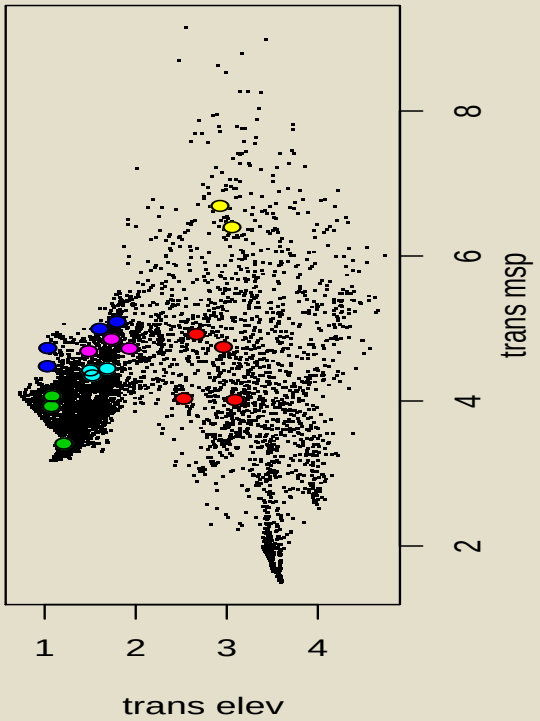
elevation (m)

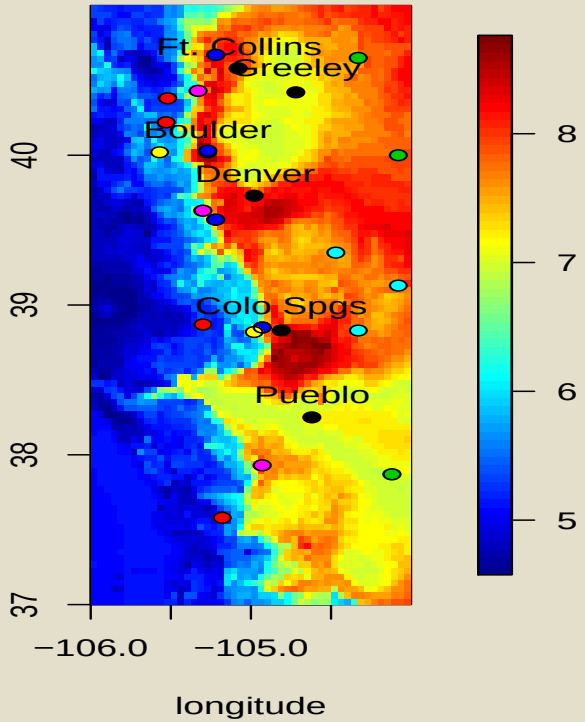


Station locations in climate space



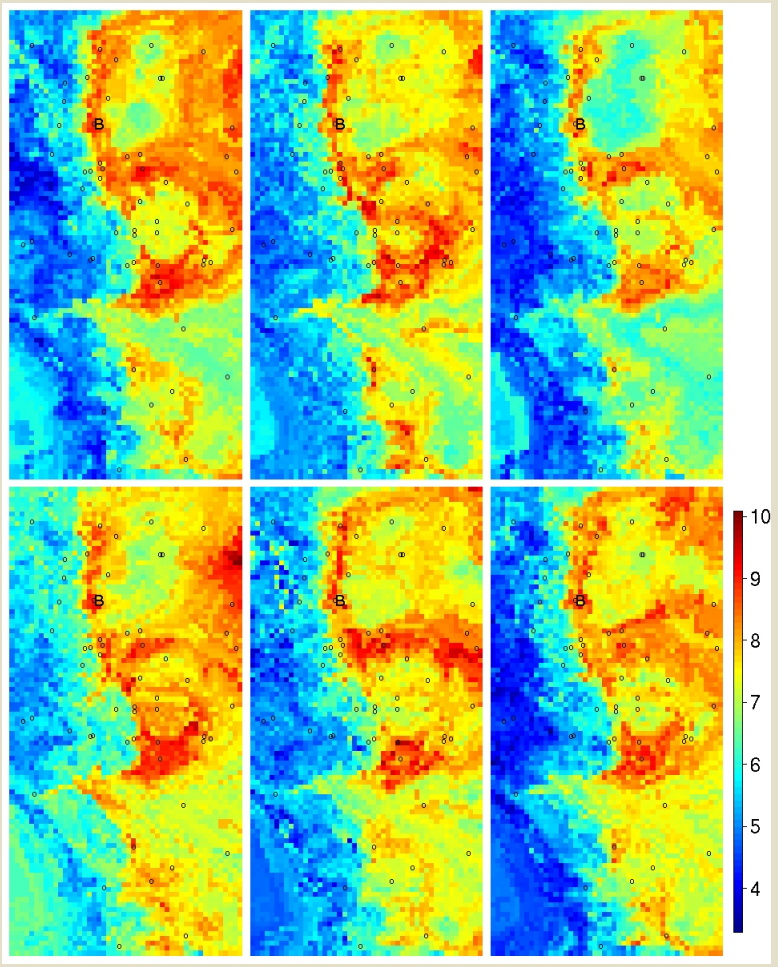
Climate space and geographic space



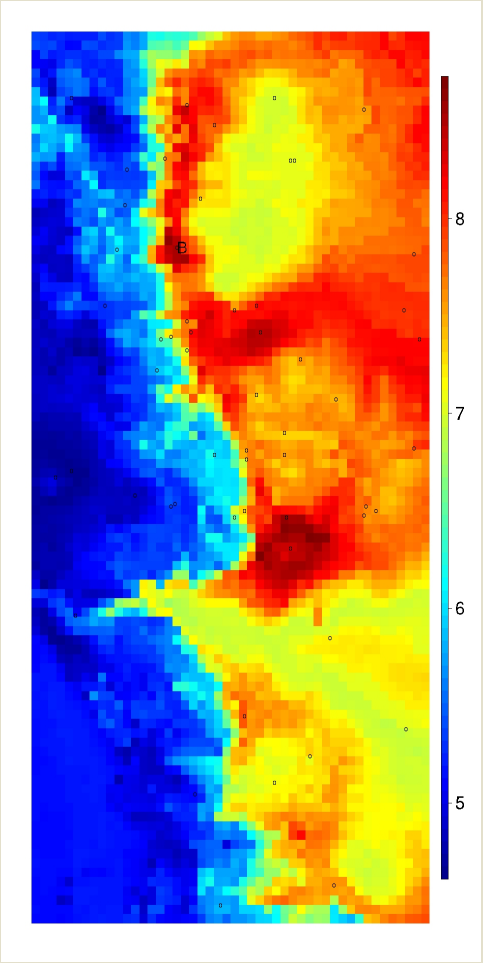


Six ensemble members for 25 year event

25 year return level based on all daily met stations in the Front Range

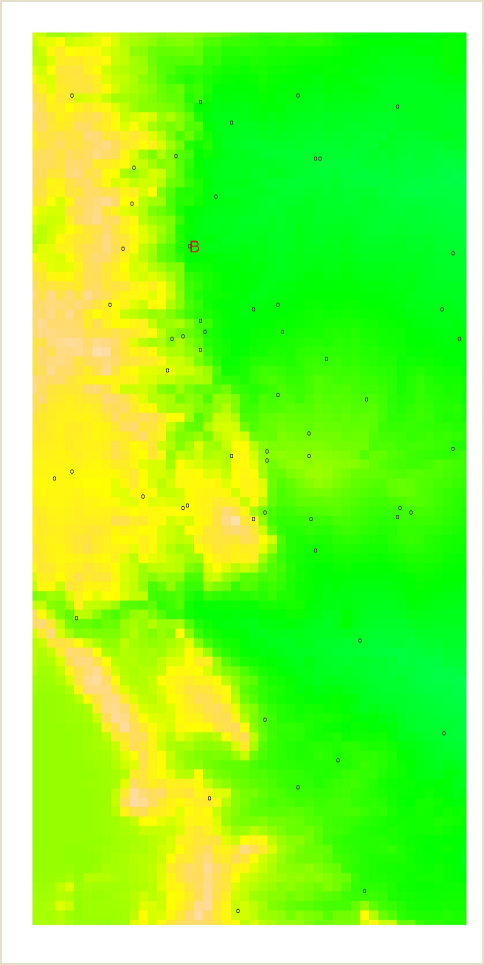


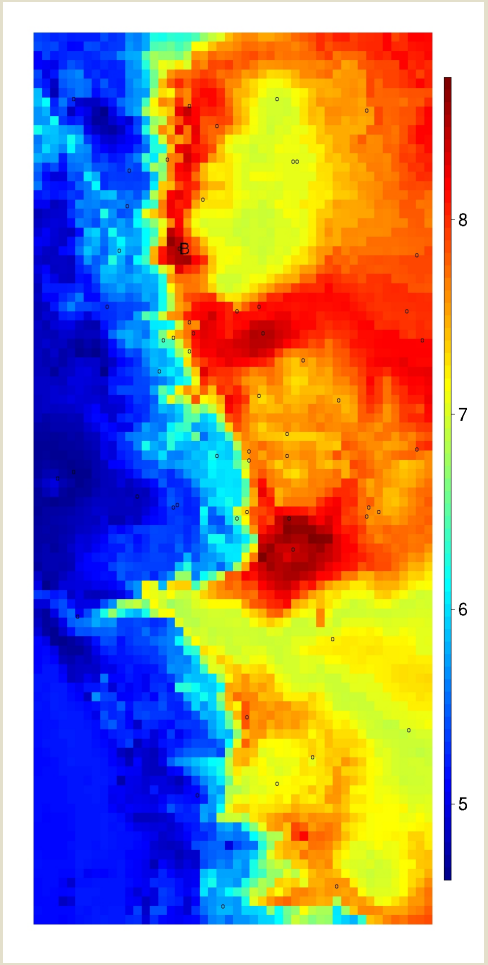
Ensemble mean of the 25 year return level

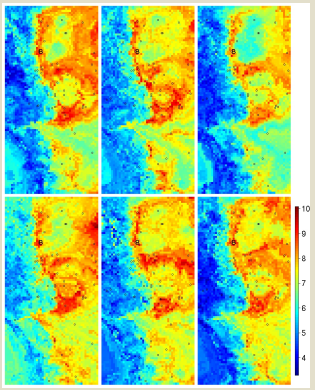


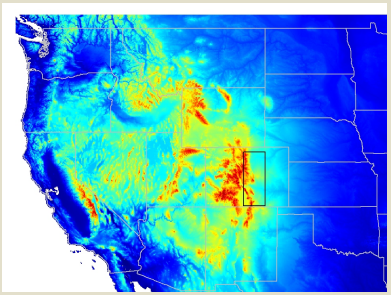
Ensemble mean of the 25 year return level

Elevation and return level (cm)









Future Work

- Extend to other periods besides 24 hours.
- Extend to larger region
- Apply to output from a regional climate model.
- Understand the efficiency of candidate based on smoothing ideas.