Reclamation Review of Stochastic Streamflow Simulation at Interannual and Interdecadal Time Scales and Implications to Water Resources Management

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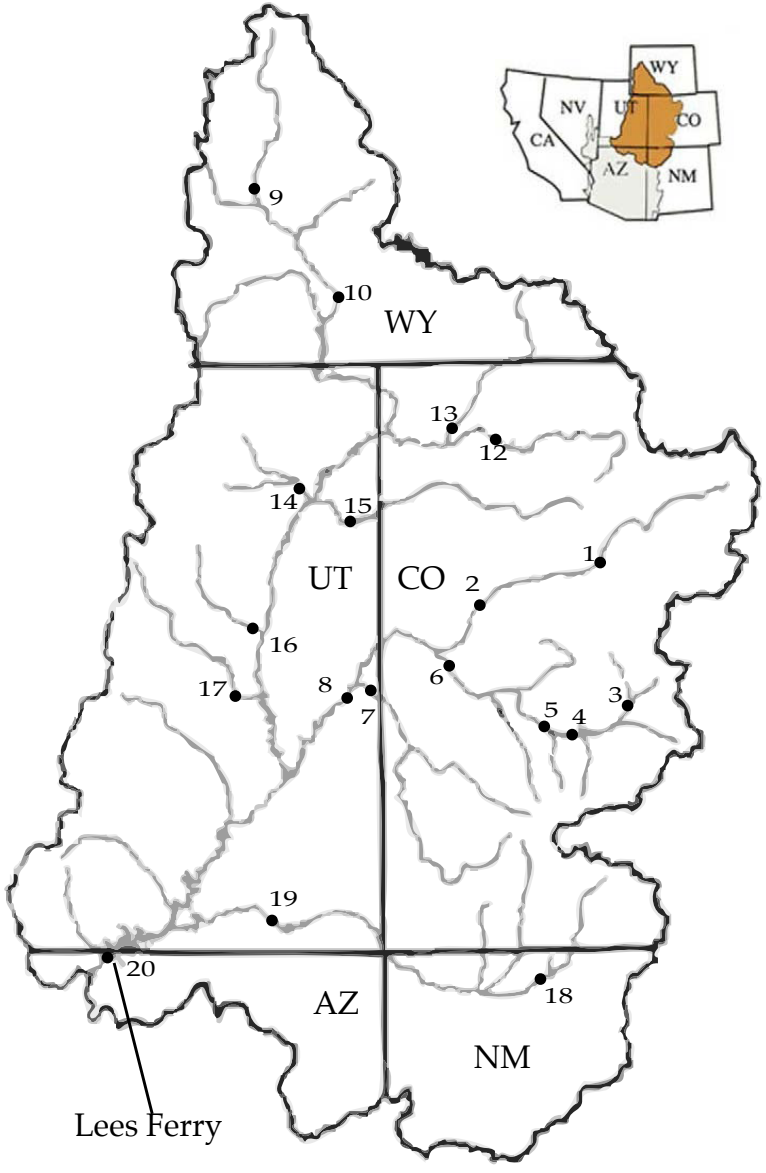
Outline

- Seasonal Forecasts
- Hidden Markov Models
  - Simulations
  - Two Year Forecasts

Study Area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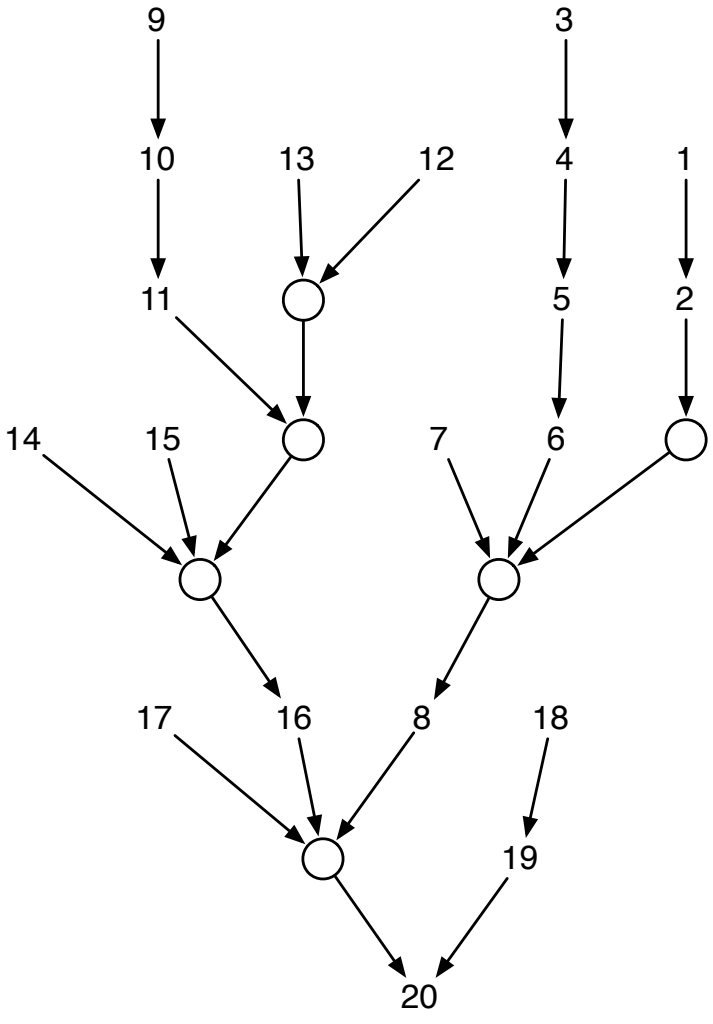
Lees Ferry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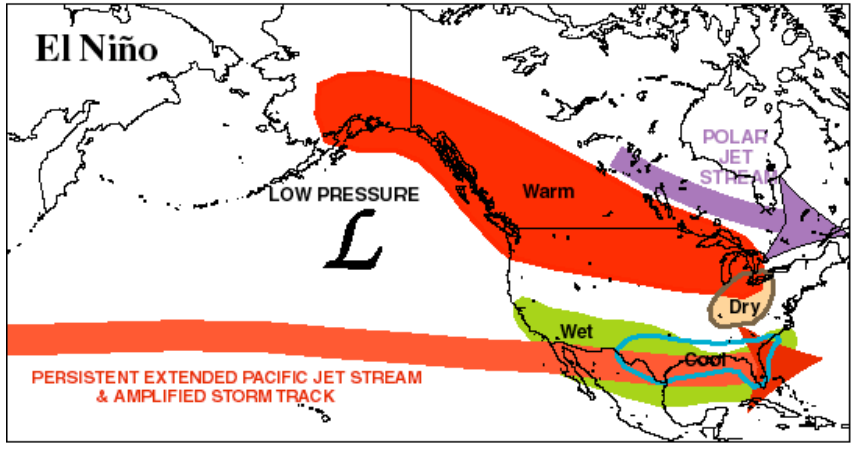
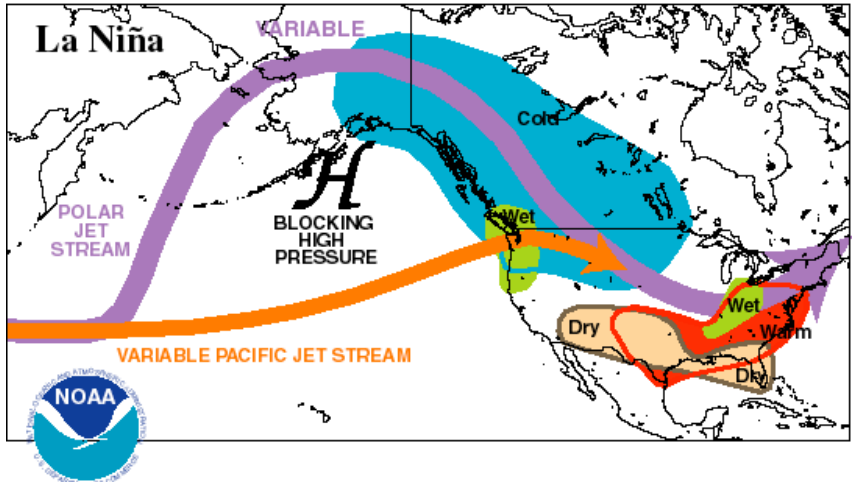
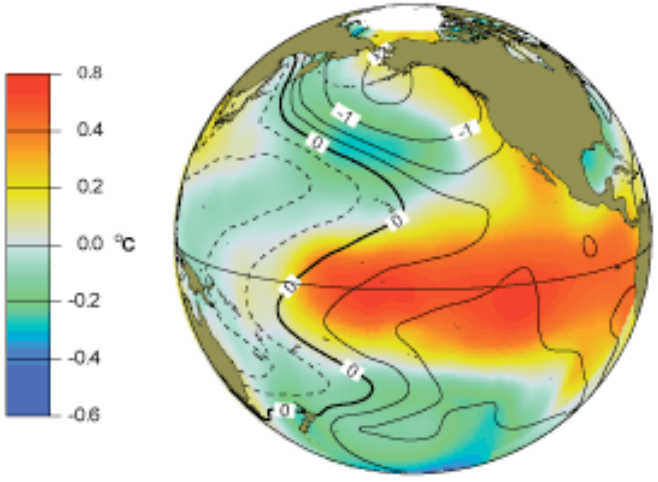
Large-Scale Climate Influence on Basin-Scale Hydrology

How can skillful predictions be made in the earlier in the winter/spring season when snowpack data is unavailable or incomplete?

Large-scale climate variables can be used as predictors of peak season streamflow [Grantz et. al. 2005] [Regonda et. al. 2006].

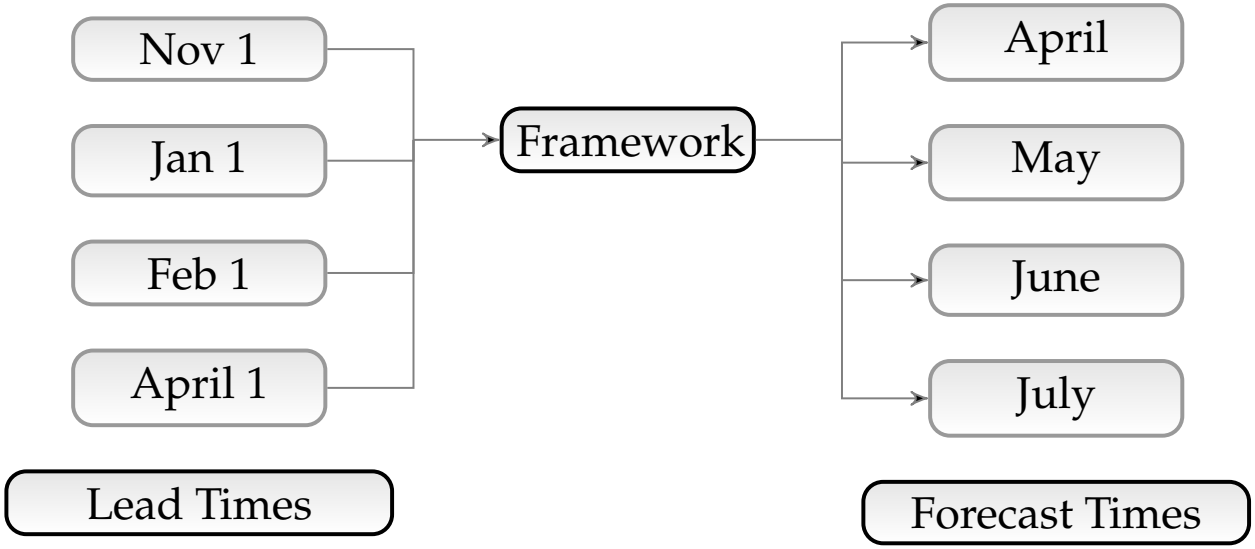






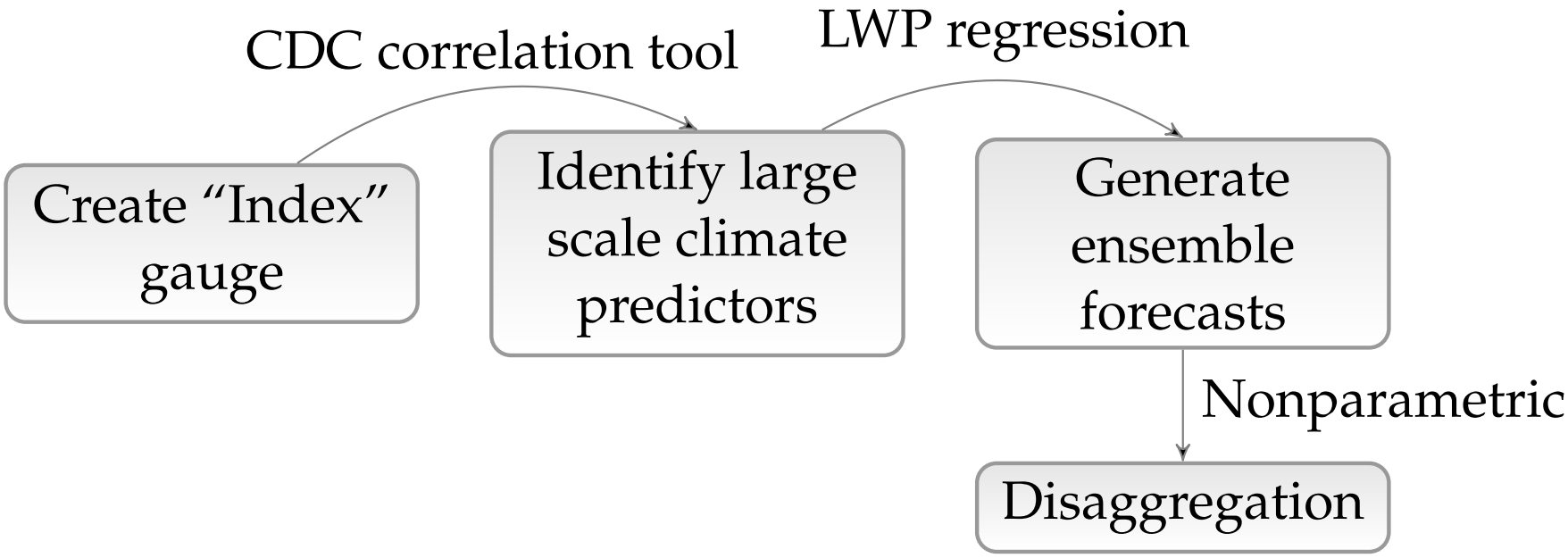
Original Study

Bracken et al. 2010 demonstrated the feasibility of simultaneously forecast many spatial locations while preserving spatial dependencies.

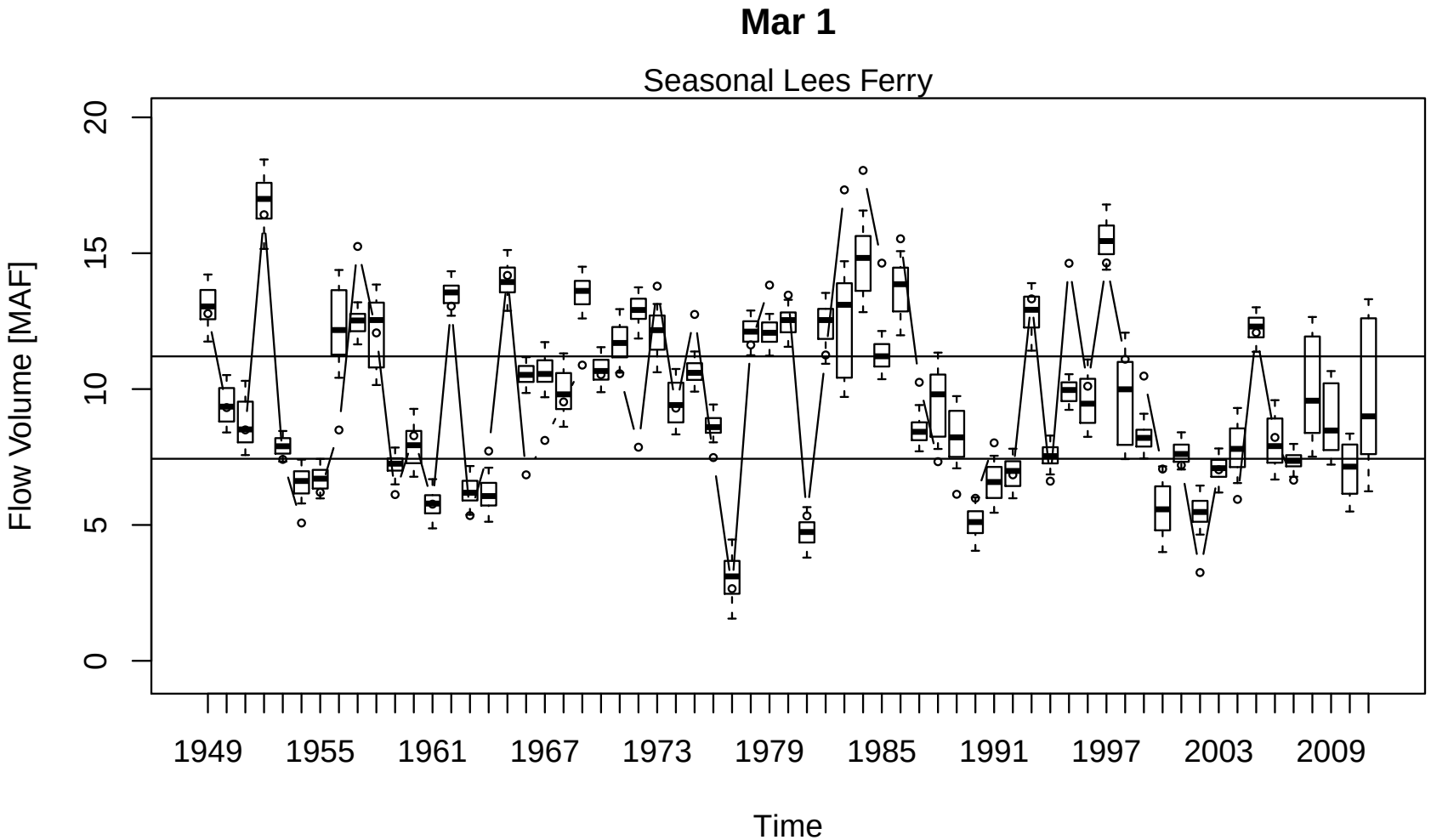


- Predictors are: PDSI, SST, Zonal/Meridional Winds, Geopotential Height, SWE

FRAMEWORK


CDC correlation tool
LWP regression
Create "Index" gauge
Identify large scale climate predictors
Generate ensemble forecasts
Nonparametric
Disaggregation

Seasonal Forecast Results: Drop One Cross-Validation



Seasonal Forecast Results: Drop One Cross-Validation

Validation mode	apr1	mar1	feb1	jan1	nov1
Leave-one	1.00	1.00	0.91	0.66	0.30
Retroactive	0.85	0.42	0.58	0.46	0.66

Table: Lees Ferry total flow forecast skills

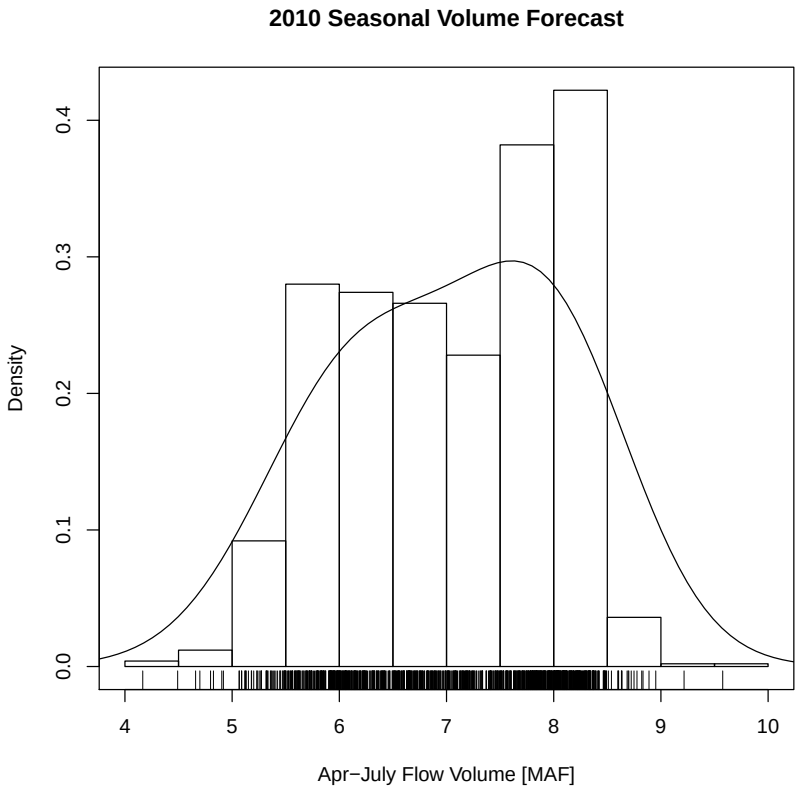
Disaggregation

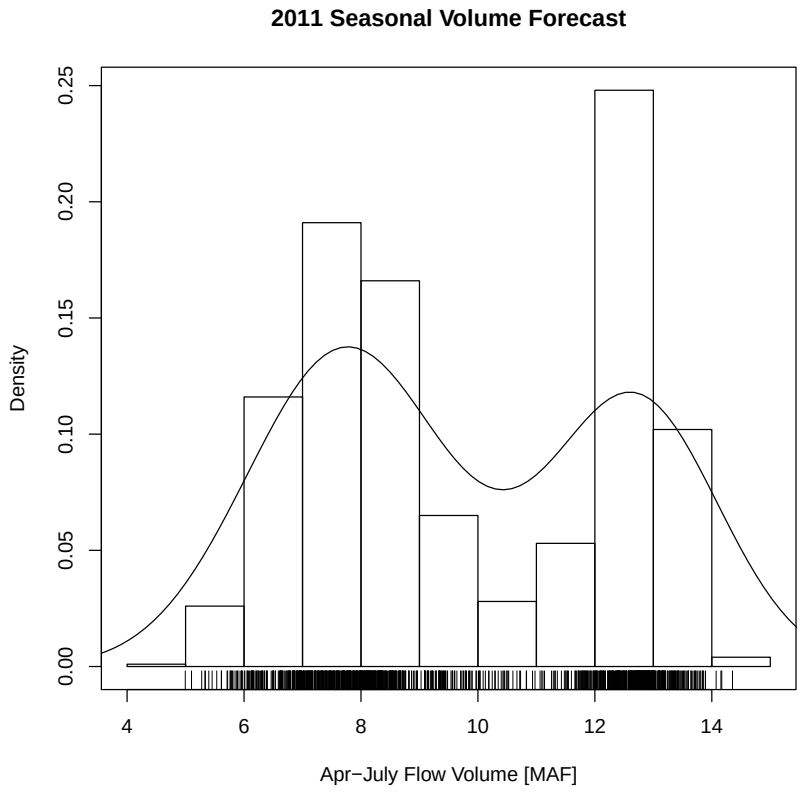
Skills generally translate after disaggregation.

Table: Jan 1 RPSS after disaggregation drop-one

	April	May	June	July
Colorado River At Glenwood Springs, CO	-0.01	0.17	0.44	0.32
Colorado River Near Cameo, CO	-0.04	0.15	0.51	0.48
Taylor River Below Taylor Park Reservoir, CO	0.04	0.10	0.27	0.41
Gunnision River Above Blue Mesa Reservoir, CO	0.07	0.34	0.49	0.47
Gunnison River At Crystal Reservoir, CO	0.13	0.26	0.38	0.08
Gunnison River Near Grand Junction, CO	0.06	0.35	0.48	0.38
Dolores River Near Cisco, UT	0.20	0.26	0.34	0.41
Colorado River Near Cisco, UT	0.08	0.17	0.09	0.11
Green R Bel Fontenelle Res, WY	0.23	0.22	0.14	-0.07
Green R. Nr Green River, WY	0.04	0.12	0.09	0.17
Green River Near Greendale, UT	0.17	0.33	0.25	0.17
Yampa River Near Maybell, CO	0.02	0.32	0.40	0.36
Little Snake River Near Lily, CO	-0.03	0.33	0.31	0.24
Duchesne River Near Randlett, UT	0.23	0.34	0.24	0.32
White River Near Watson, UT	0.13	0.22	0.37	0.46
Green River At Green River, UT	0.05	0.22	0.17	0.25
San Rafael River Near Green River, UT	0.13	0.33	0.42	0.12
San Juan River Near Archuleta, NM	-0.02	0.26	0.16	0.31
San Juan River Near Bluff, UT	0.09	0.31	0.28	0.16
Colorado R At Lees Ferry, AZ	0.17	0.24	0.17	0.35

2011 Forecasts





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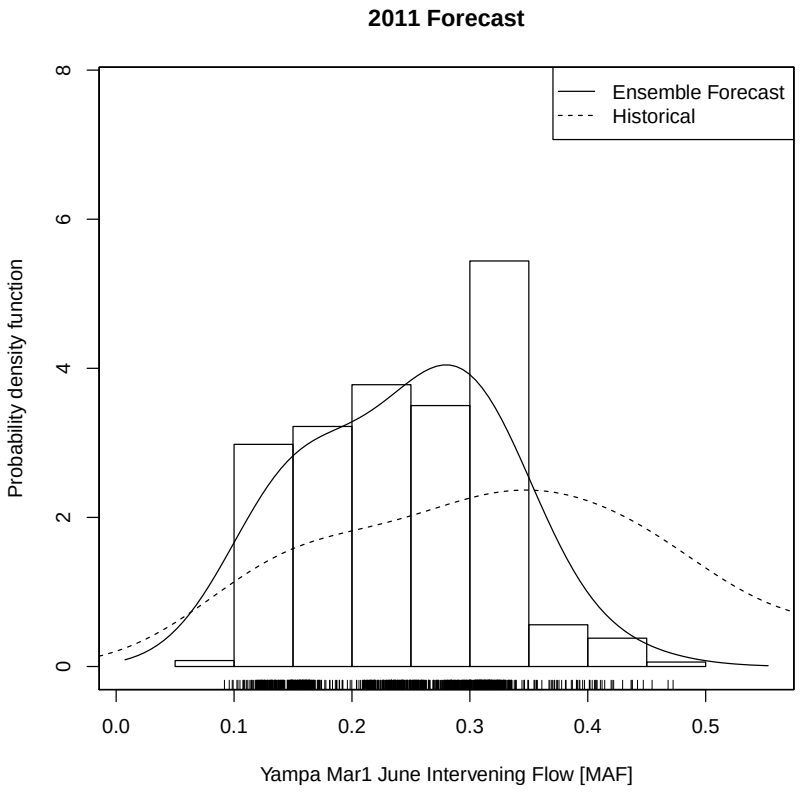
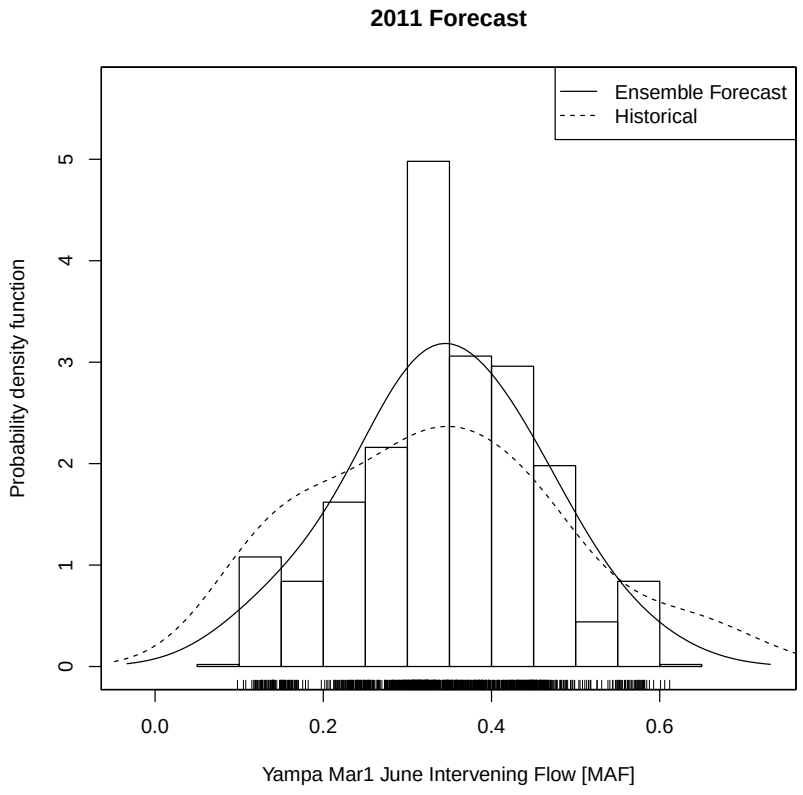
2011 Forecasts





Issued March 1

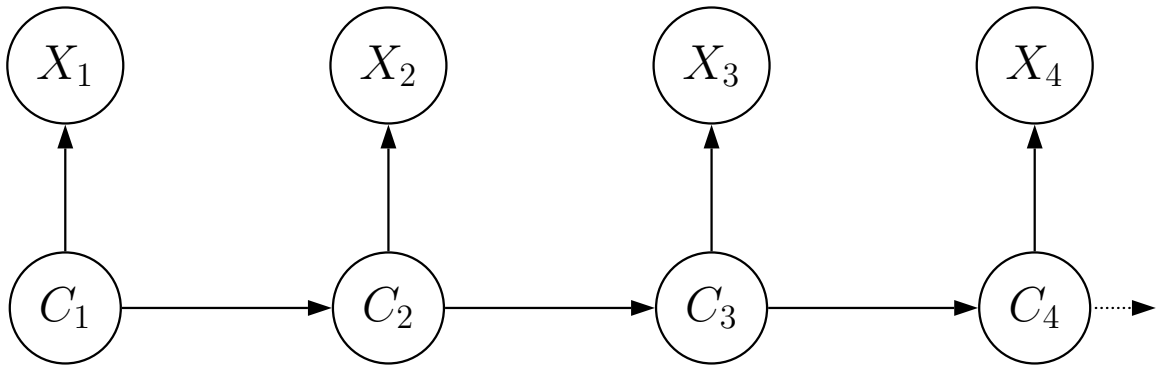
Two Year Forecasts

1. In the second year, climate/snowpack information is not available/poor
2. A logical step is to use time series methods, ARMA, KNN, MC, Time Domain Methods
   2.1 These methods provide little or no predictability over climatology
3. Snow, Climate predictors and seasonal flow timeseries have very low autocorrelation (LF, 0.26)
4. Goal to make predictions from Apr 1 of the following year seasonal flow.

Hidden Markov Models

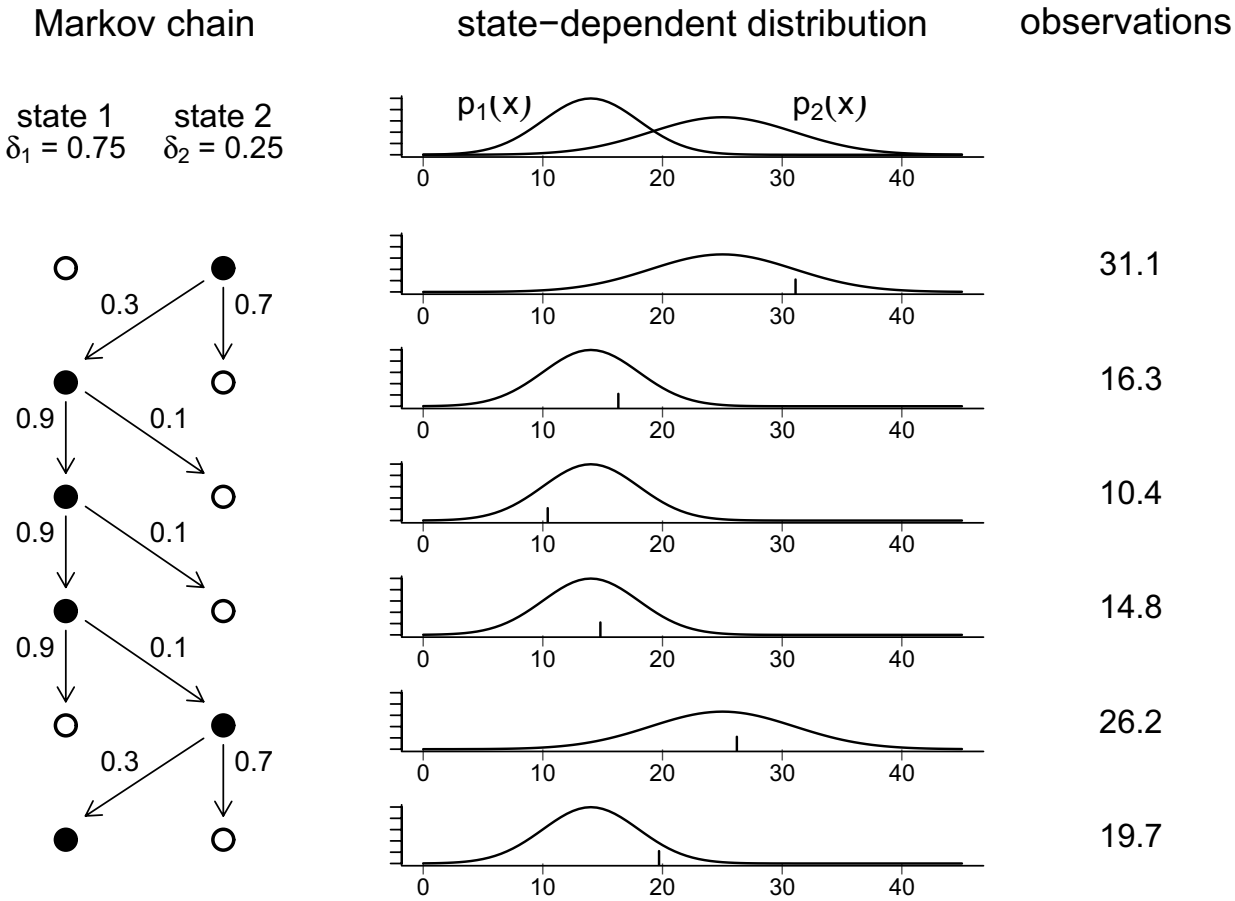
$$\Pr(C_t|\mathbf{C}^{(t-1)}) = \Pr(C_t|C_{t-1}), t = 2, 3, ...$$

$$\Pr(X_t|\mathbf{X}^{(t-1)}, \mathbf{C}^{(t)}) = \Pr(X_t|C_t), t \in \mathbb{N}$$



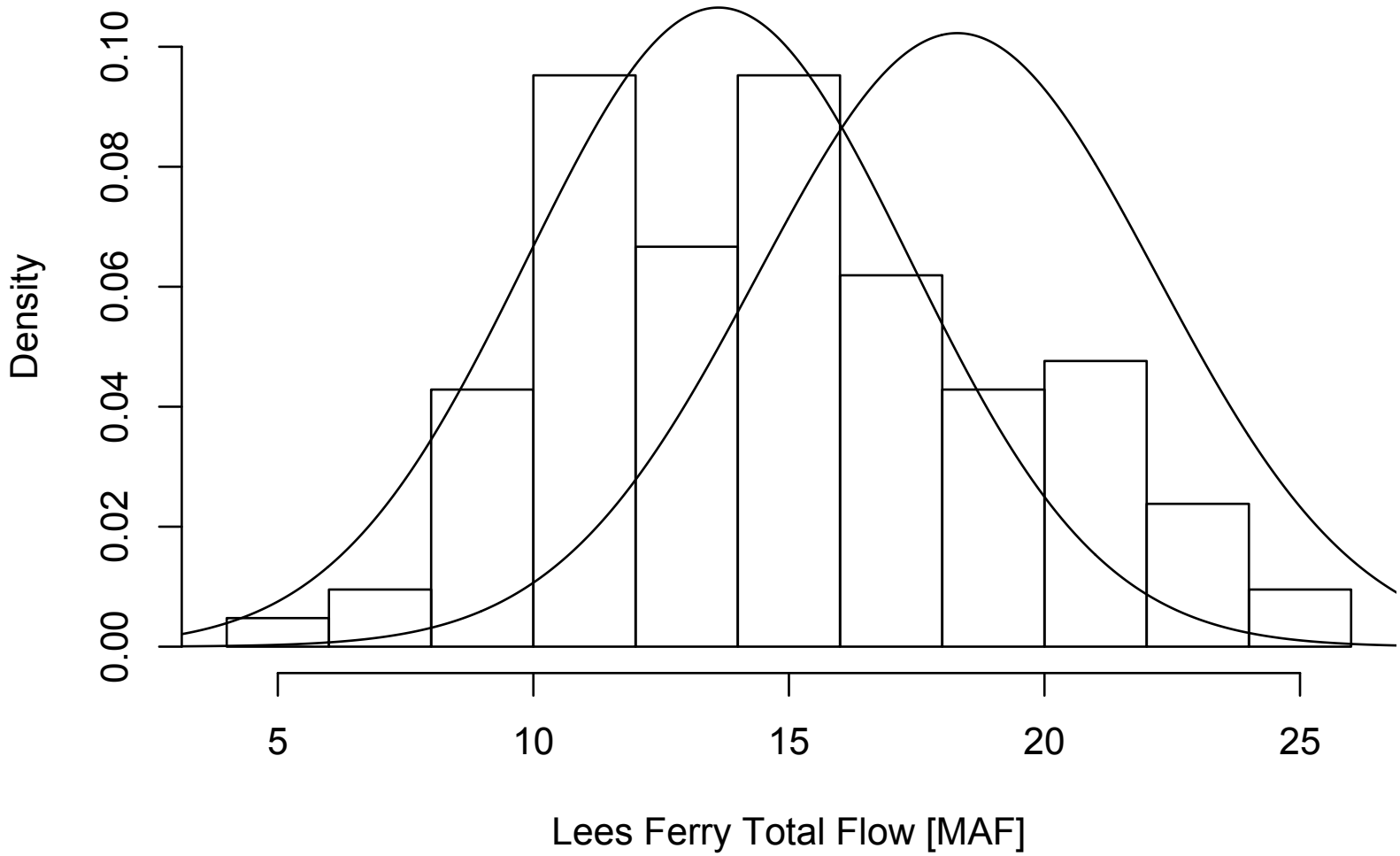
1. General time series model
2. Markov process determines 'hidden' state, state dictates component distribution
3. A model that includes discrete states makes intuitive sense given the concept of climate regimes (such as El Nino)

Hidden Markov Models

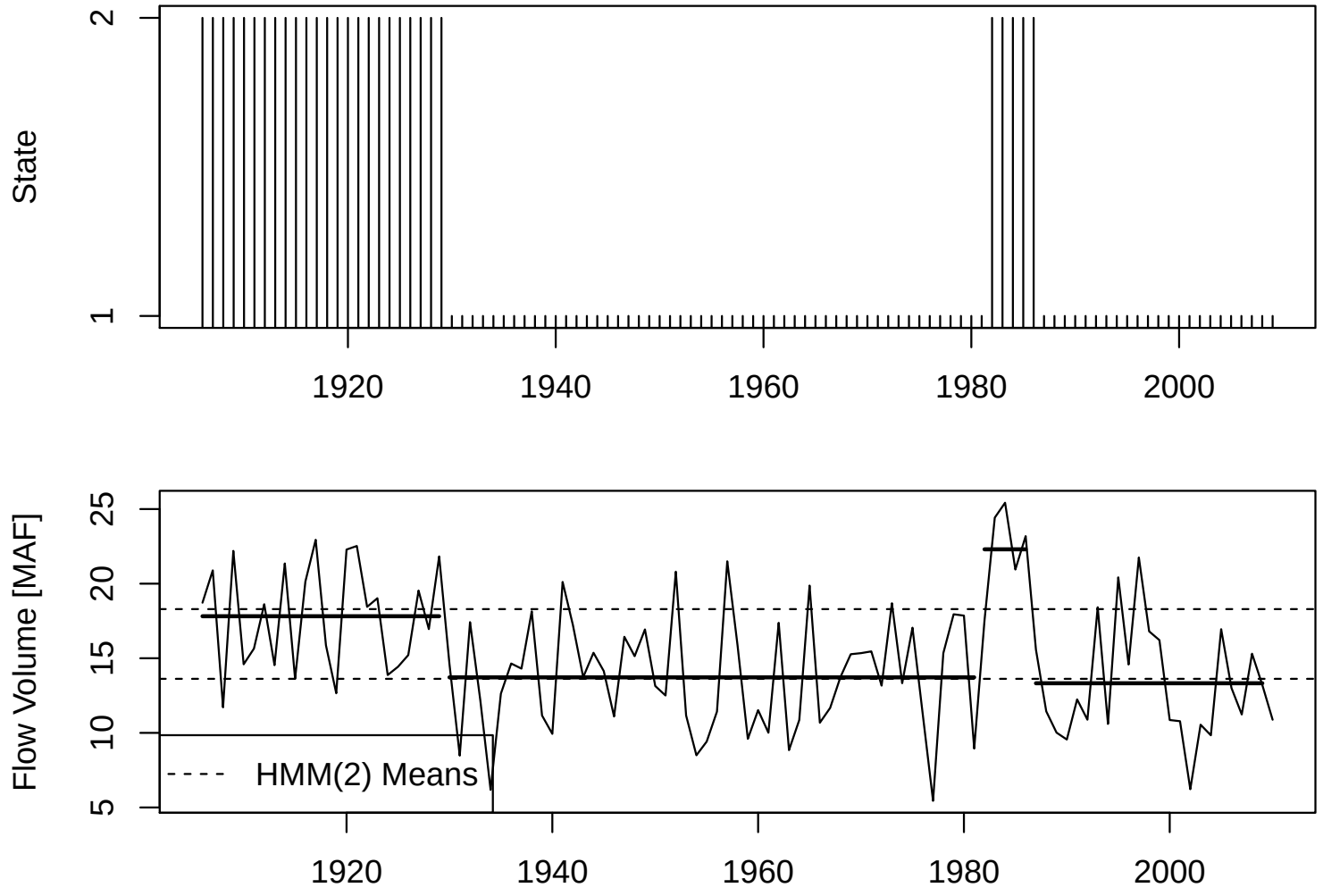


Flexibility over explicit MC states.

Lees Ferry HMM

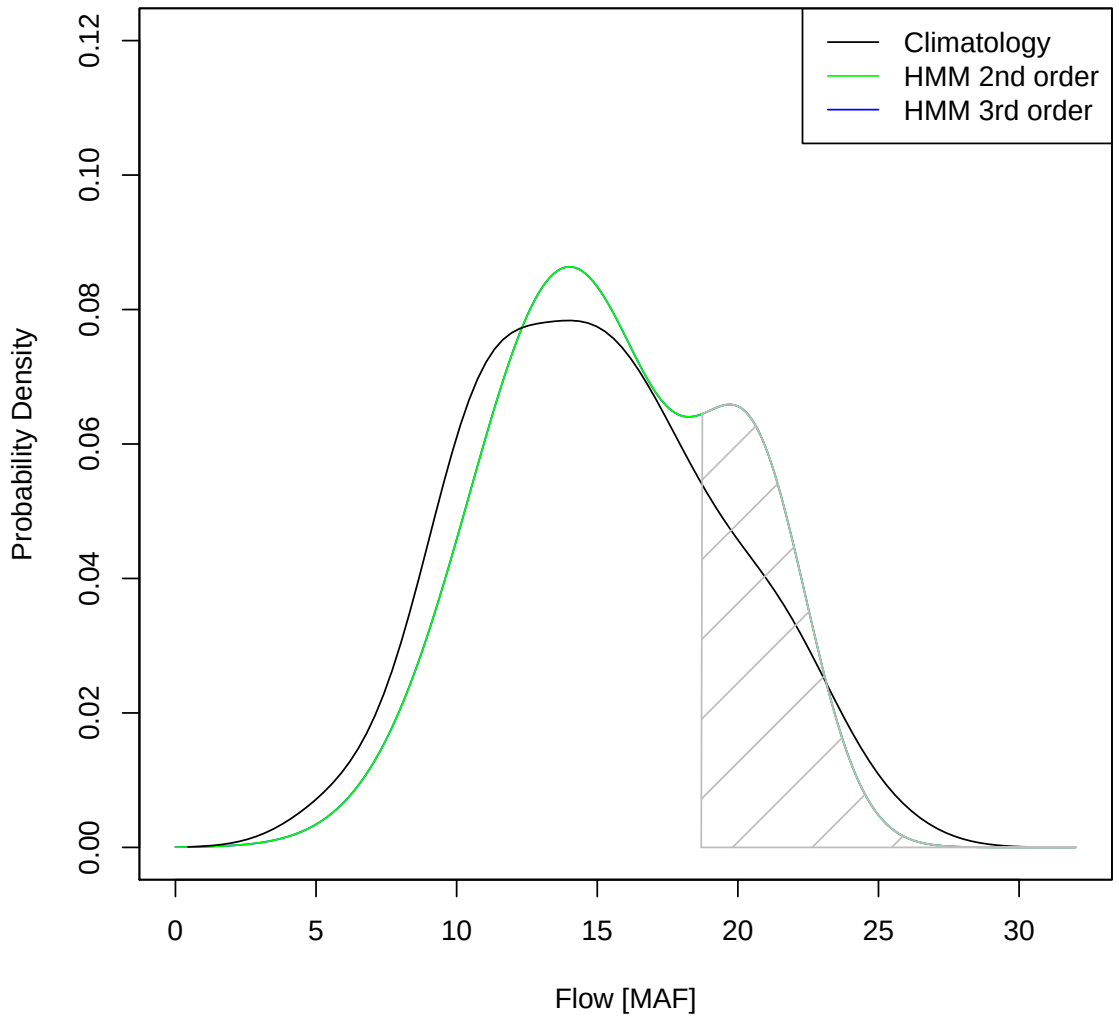


Global Decoding



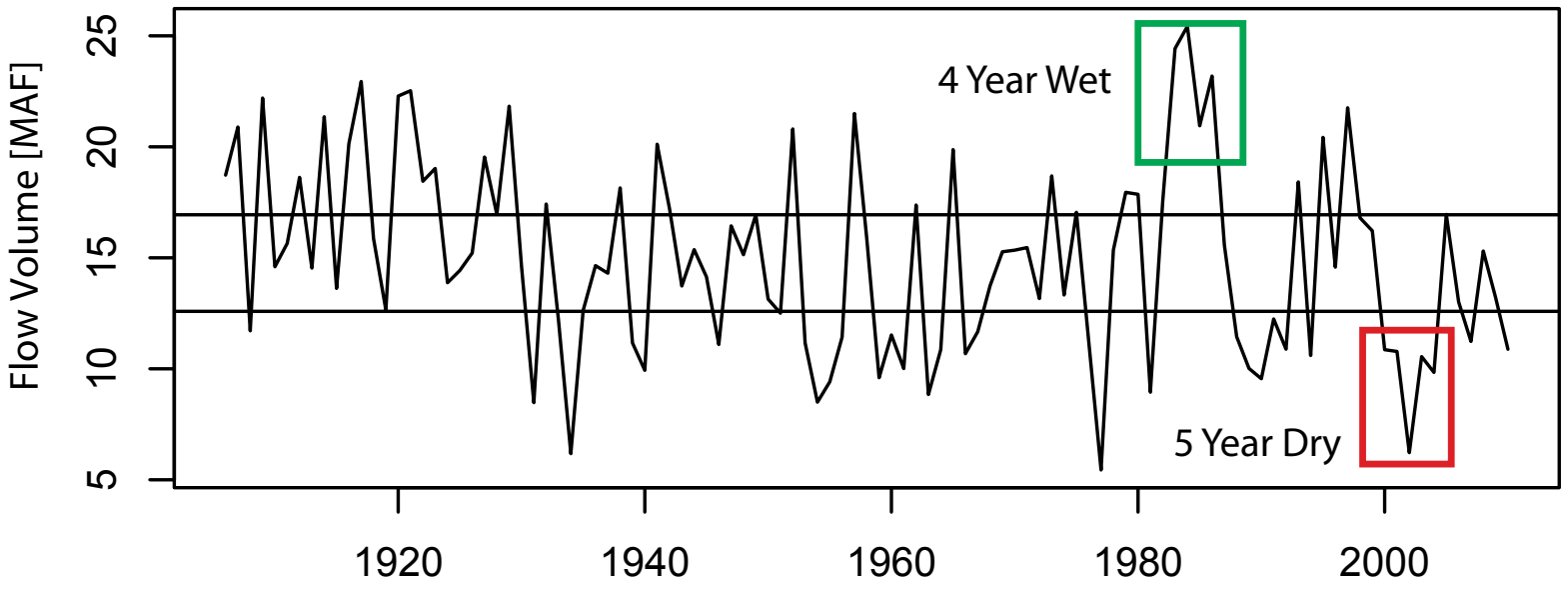
HMM Results (1984)

Climatology, 10%; HMM(2), 14%

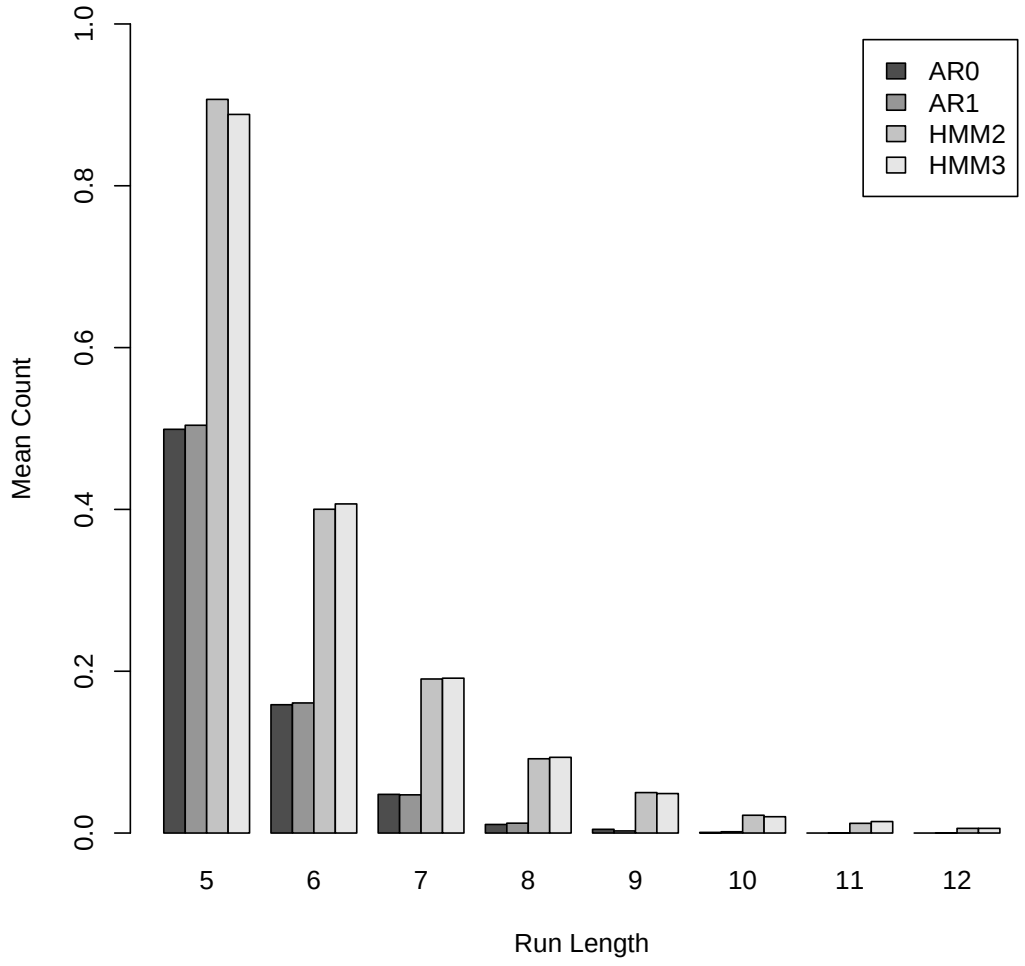


Hidden Markov Models for Simulation

- HMMs are also useful for simulation (used in risk analysis).
- Alternative to AR simulations or
- Can we capture longer period variability?

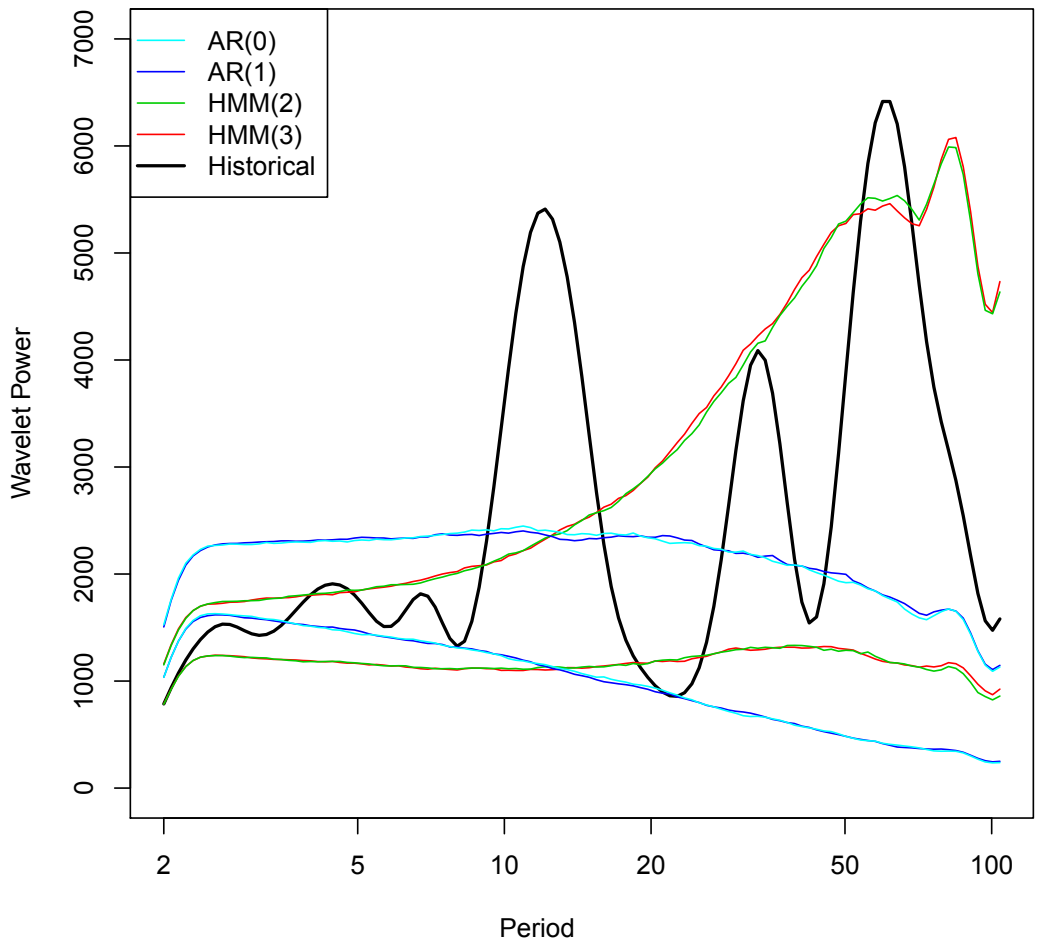


Simulated Spell Lengths



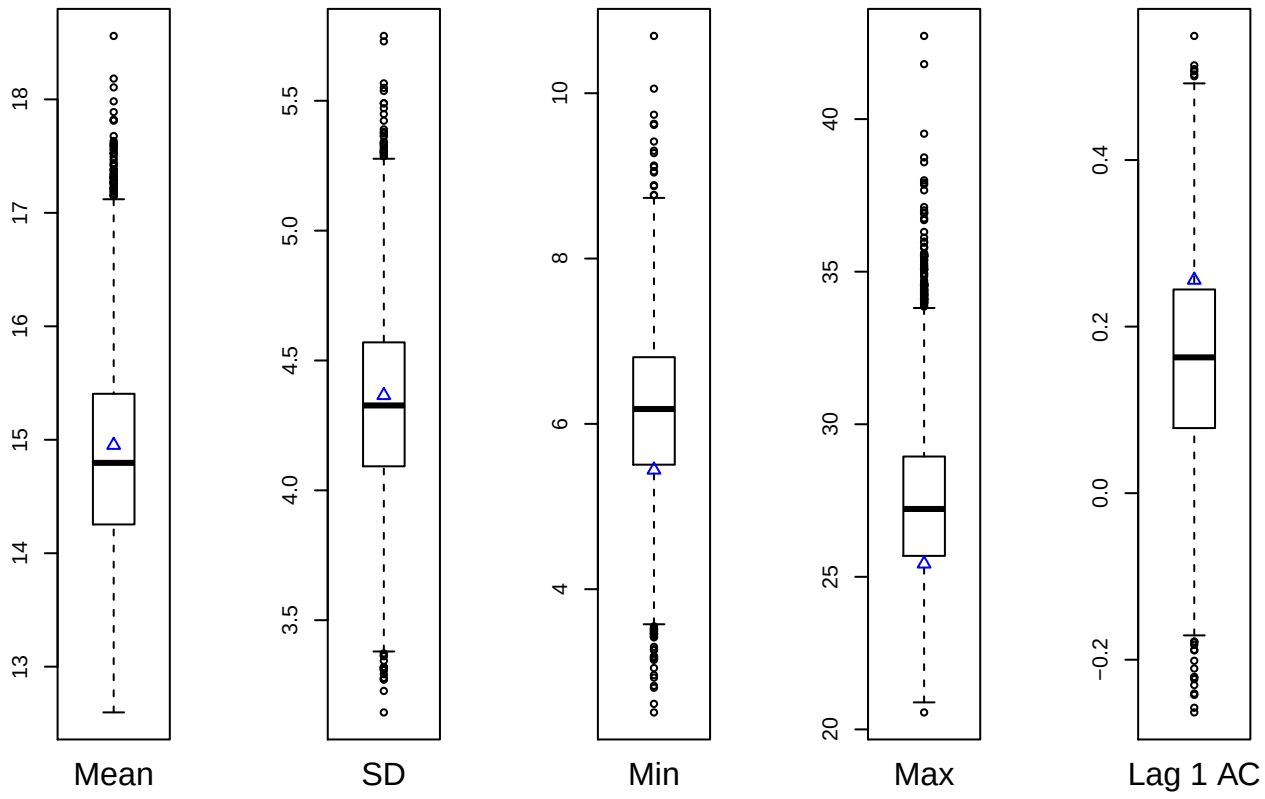
HMMs can capture longer spells than AR models.

Wavelet Spectrum



Ability to capture longer period variability

Simulation statistics



Also capture observed statistics.

Conclusions

- Skillful single year seasonal forecasts at all natural flow nodes starting on Nov1
- Second year forecasts (via HMMs) can be made starting on Apr 1 with overall positive skill.
- HMMs are also useful for simulation.