Real-time Data Assimilation for Operational Ensemble Streamflow Forecasting

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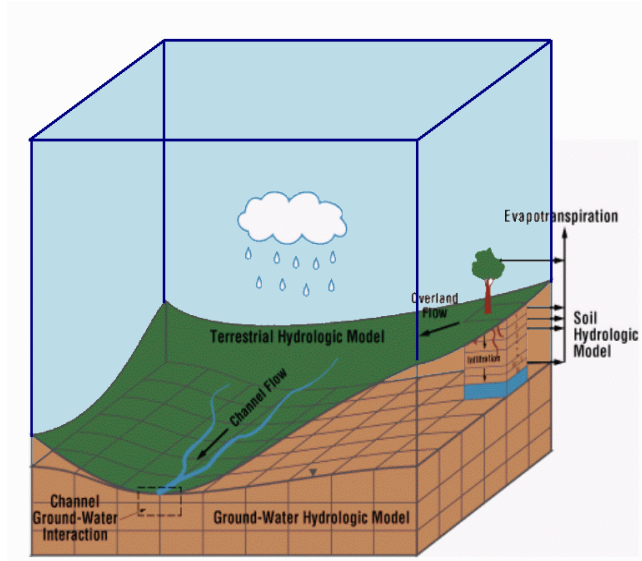
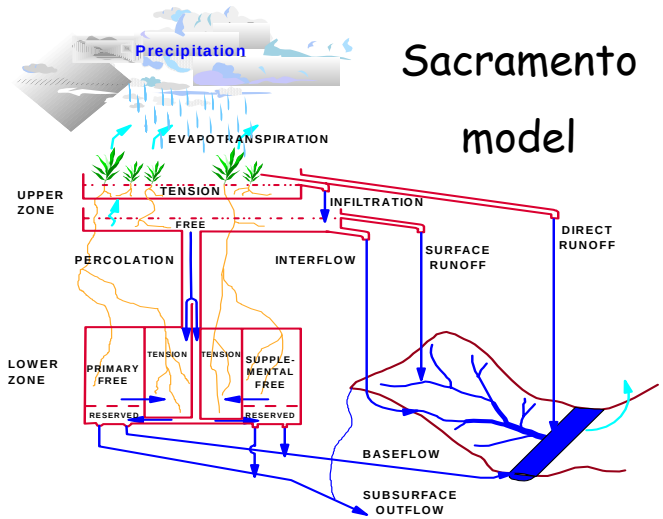
Outline of talk

(1) Introduction
(2) Parameter Estimation
(3) Global Optimization
(4) Sequential Data Assimilation
(5) Improved Flood Forecasting
(6) Conclusions

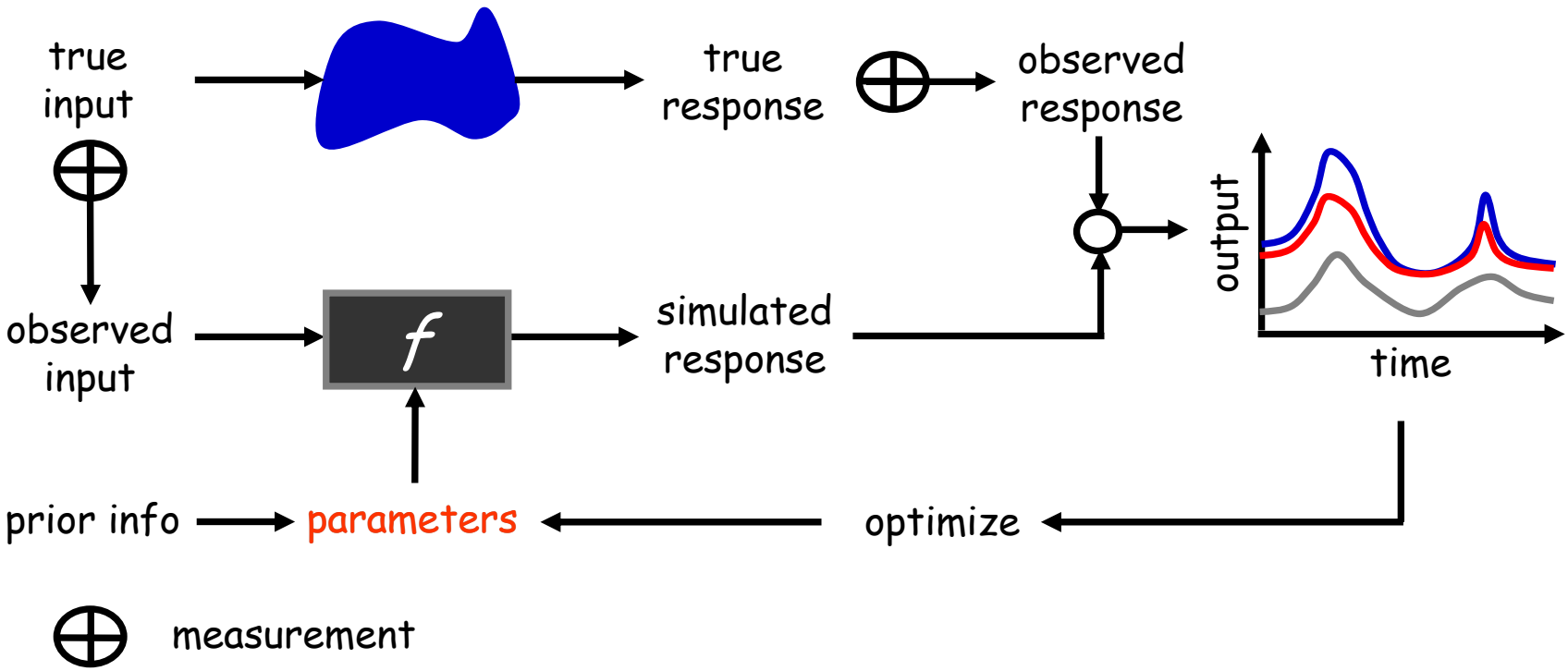
Rainfall – runoff modeling





Sacramento model

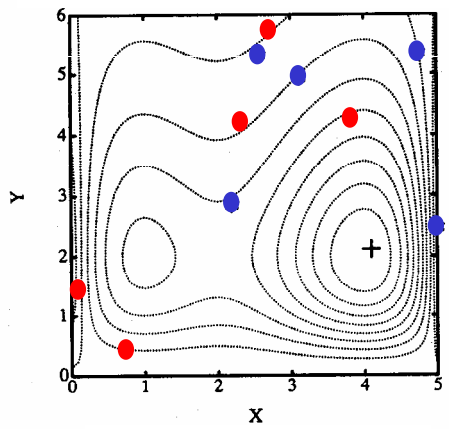
Optimize predictions by tuning parameters …

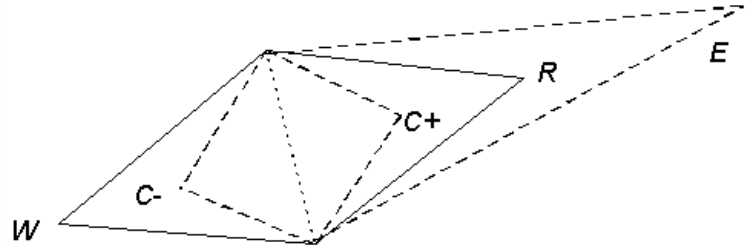


Minimize some measure of length of the residuals

Use global optimization …

Initial population



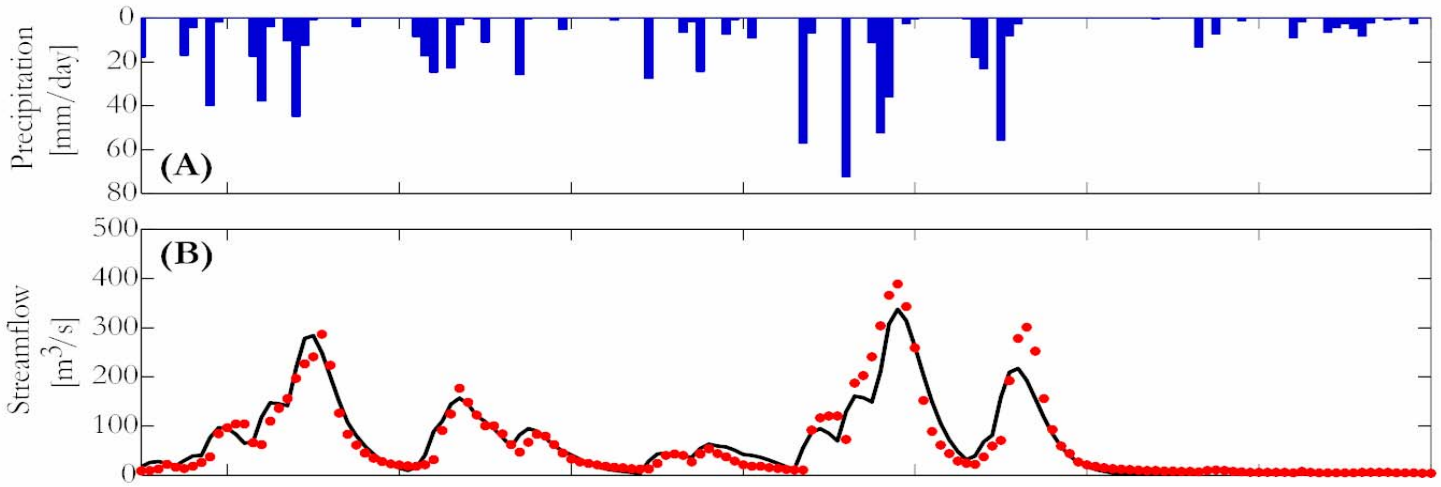


Simplex algorithmic steps

R = reflection
E = expansion
C+ = positive contraction
C- = negative contraction

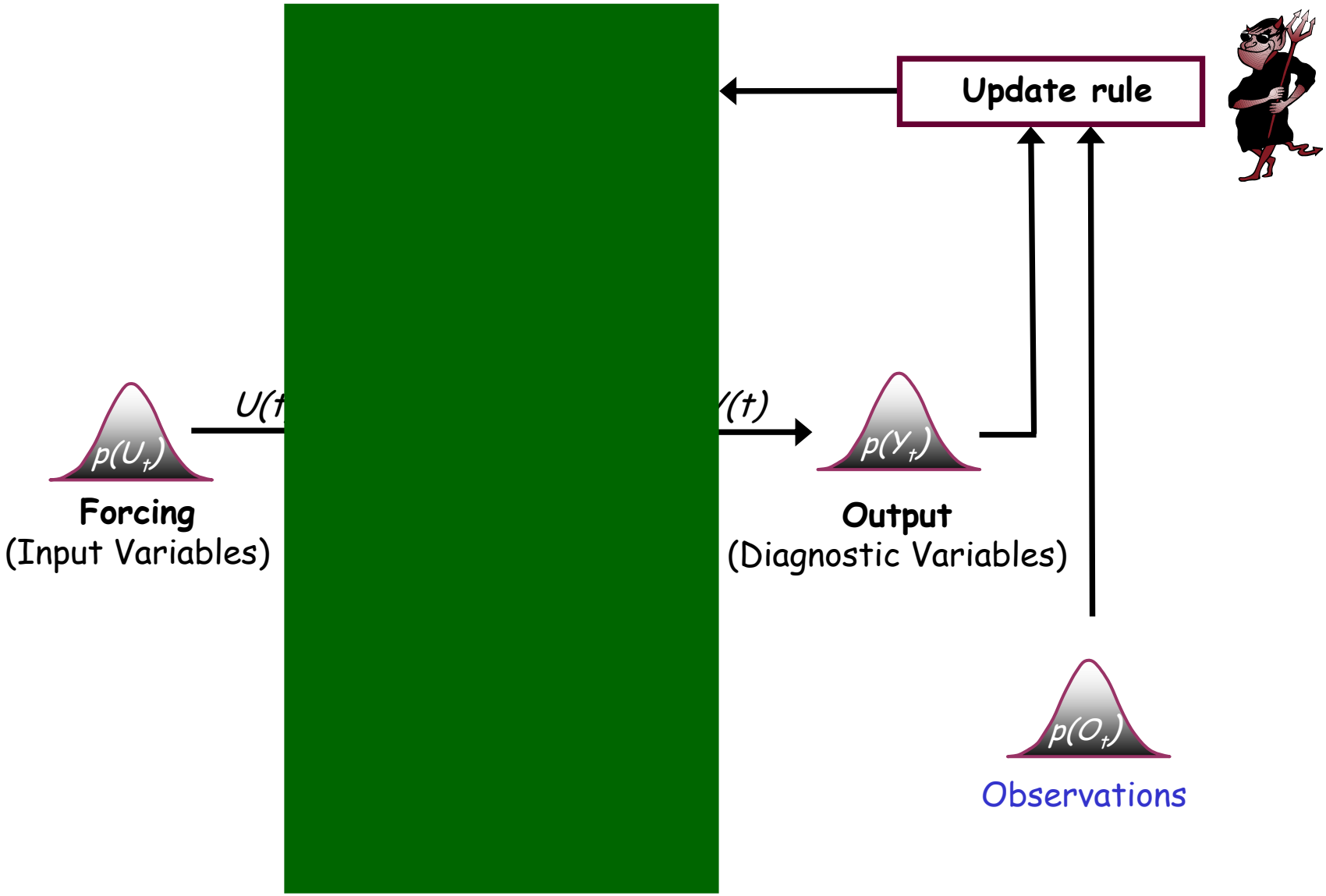
Duan et al. [*WRR* - 1992]

Results classical parameter estimation …



Ignoring uncertainty cannot be justified!

Classical parameter estimation ignores uncertainty …



How to define various error sources?

Output
(Diagnostic Variables)

Non-parametric approach

+

Forcing
(Input Variables)

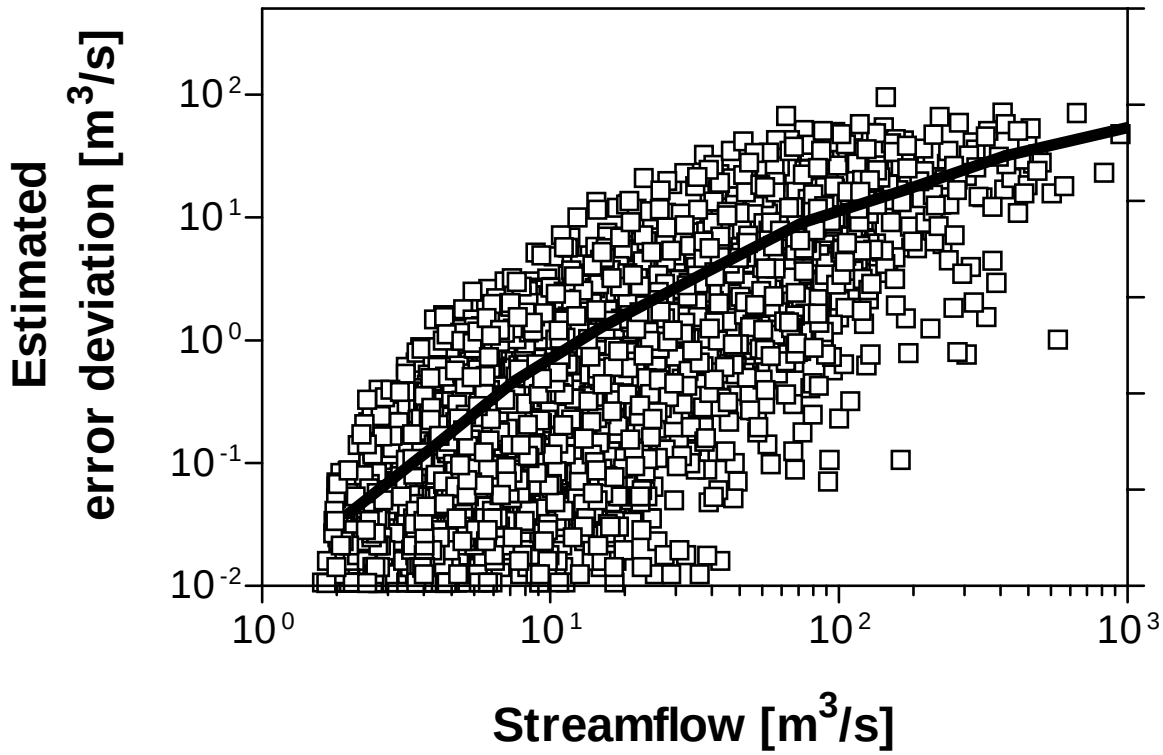
State
(Prognostic Variables)

Total error decomposition

System Invariants
(Parameters)

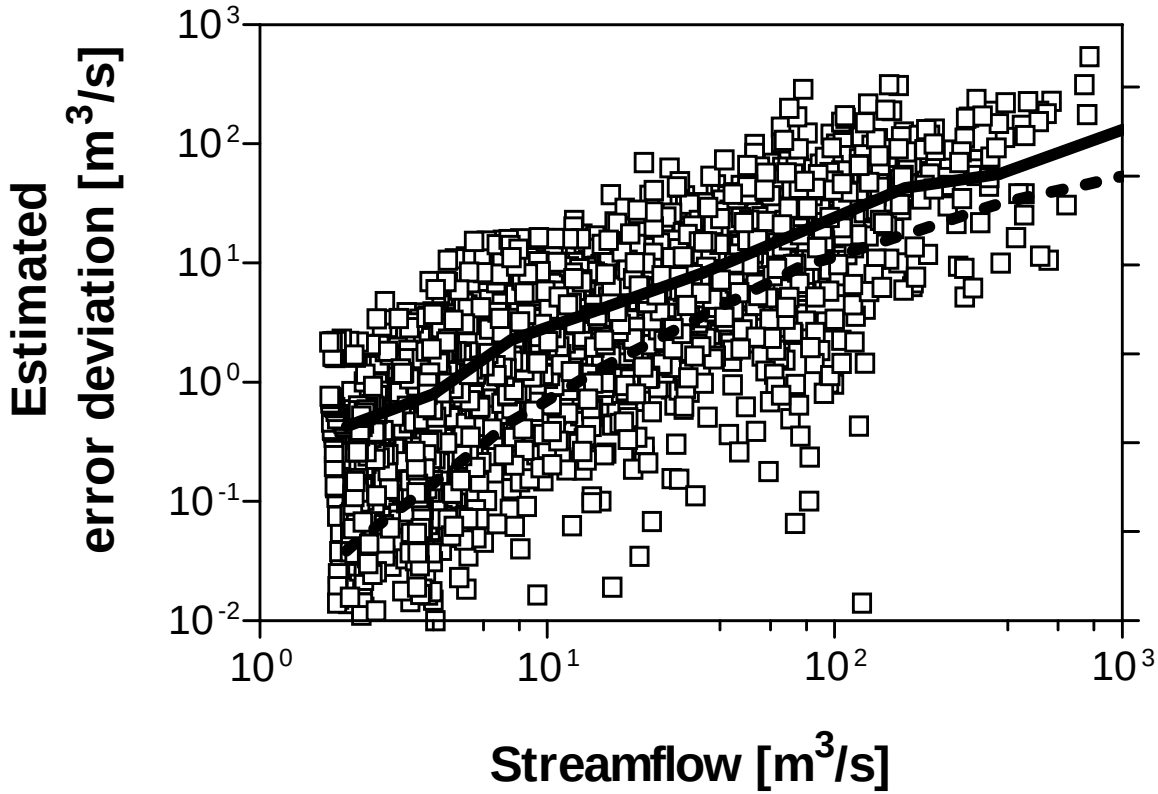
Stochastic optimization

Estimation of measurement error ...

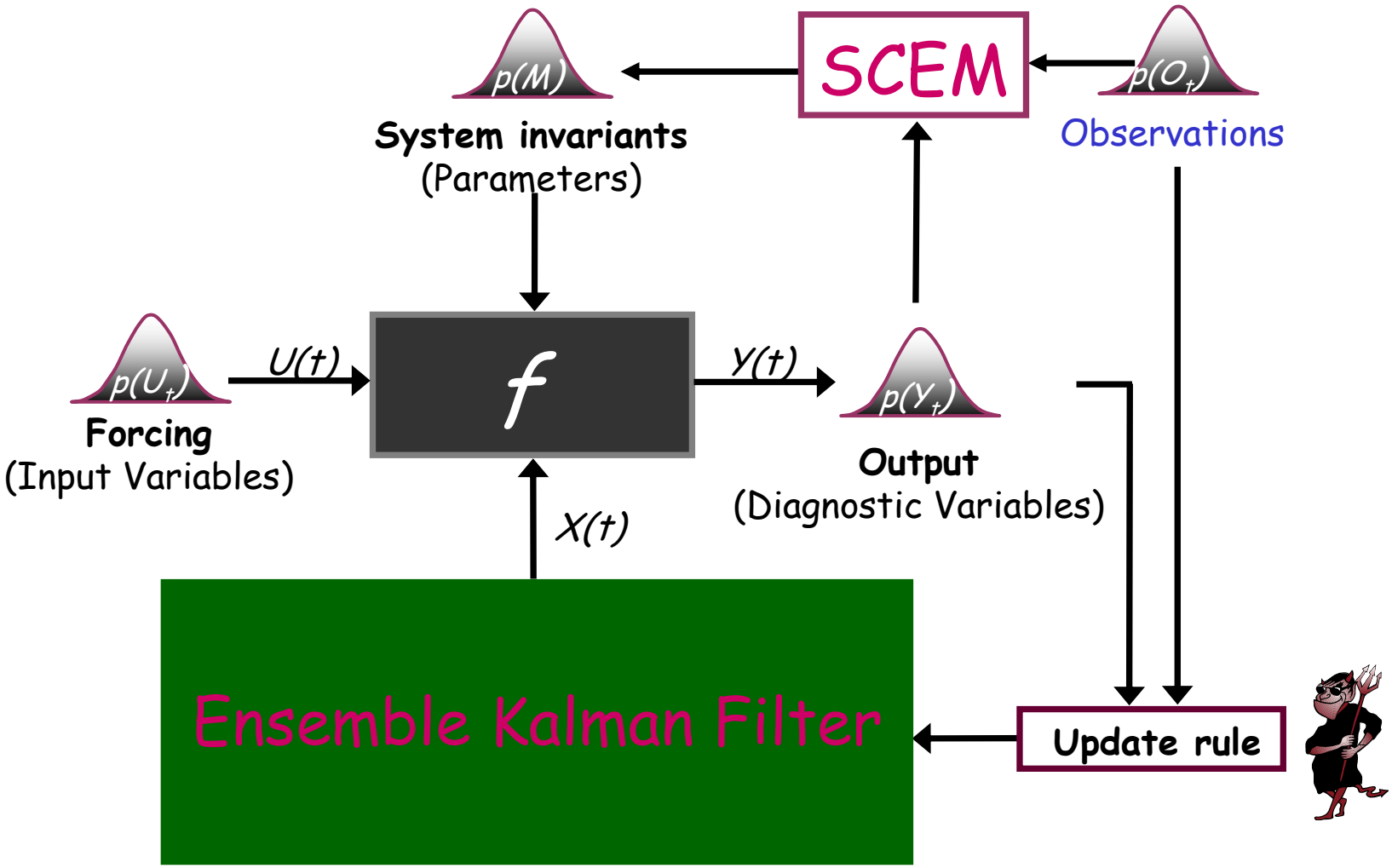


$$\hat{\sigma}_{meas} = \sqrt{\binom{2m}{m}^{-1} (\Delta^m \tilde{y}_t)^2}$$

Estimation of model (+ input) error …

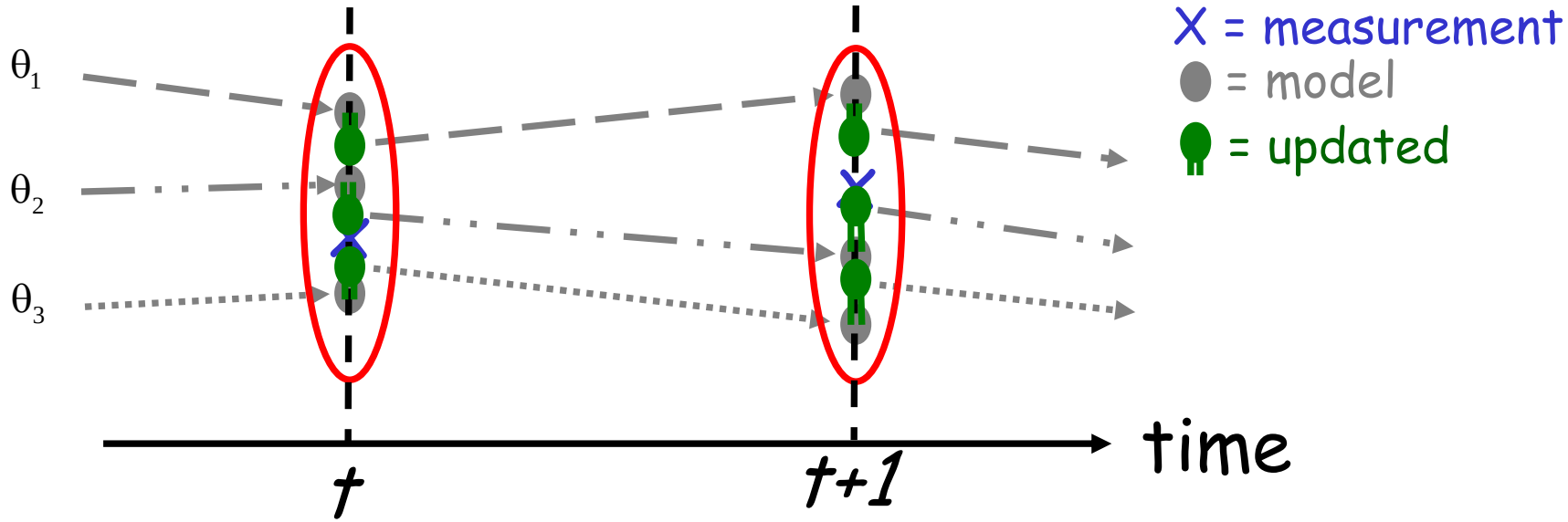


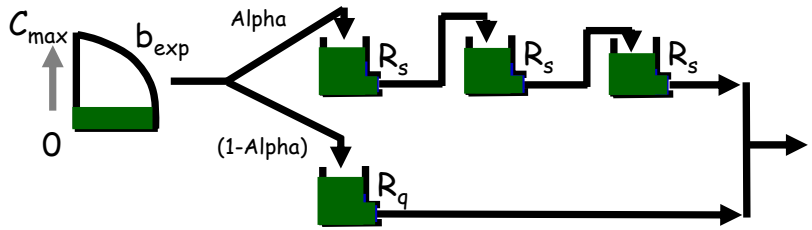
Dual parameter and state estimation (SODA) …



Recursive state estimation …

Recursive state updates – Kalman Filter

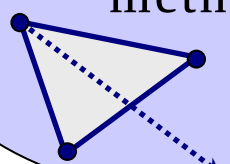




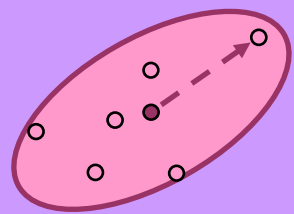
Shuffled Complex Evolution Metropolis (SCEM-UA)

SCE

Downhill Simplex method



Metropolis-annealing-covariance method

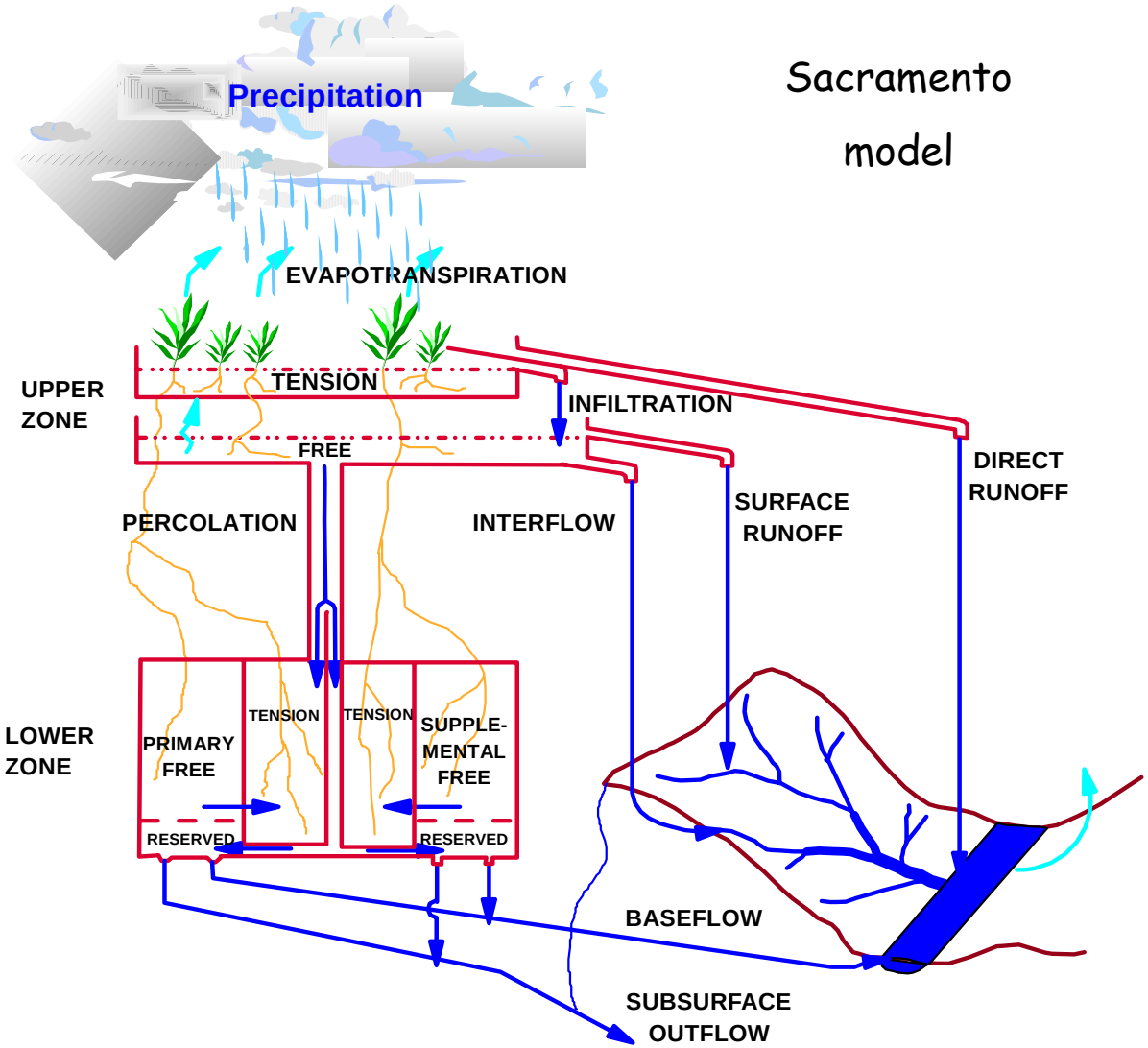


Continuously morph proposal distribution!

Application of SODA to real time flood forecasting

Vrugt et al. [JHM - 2005]

The Sacramento Soil Moisture Accounting model

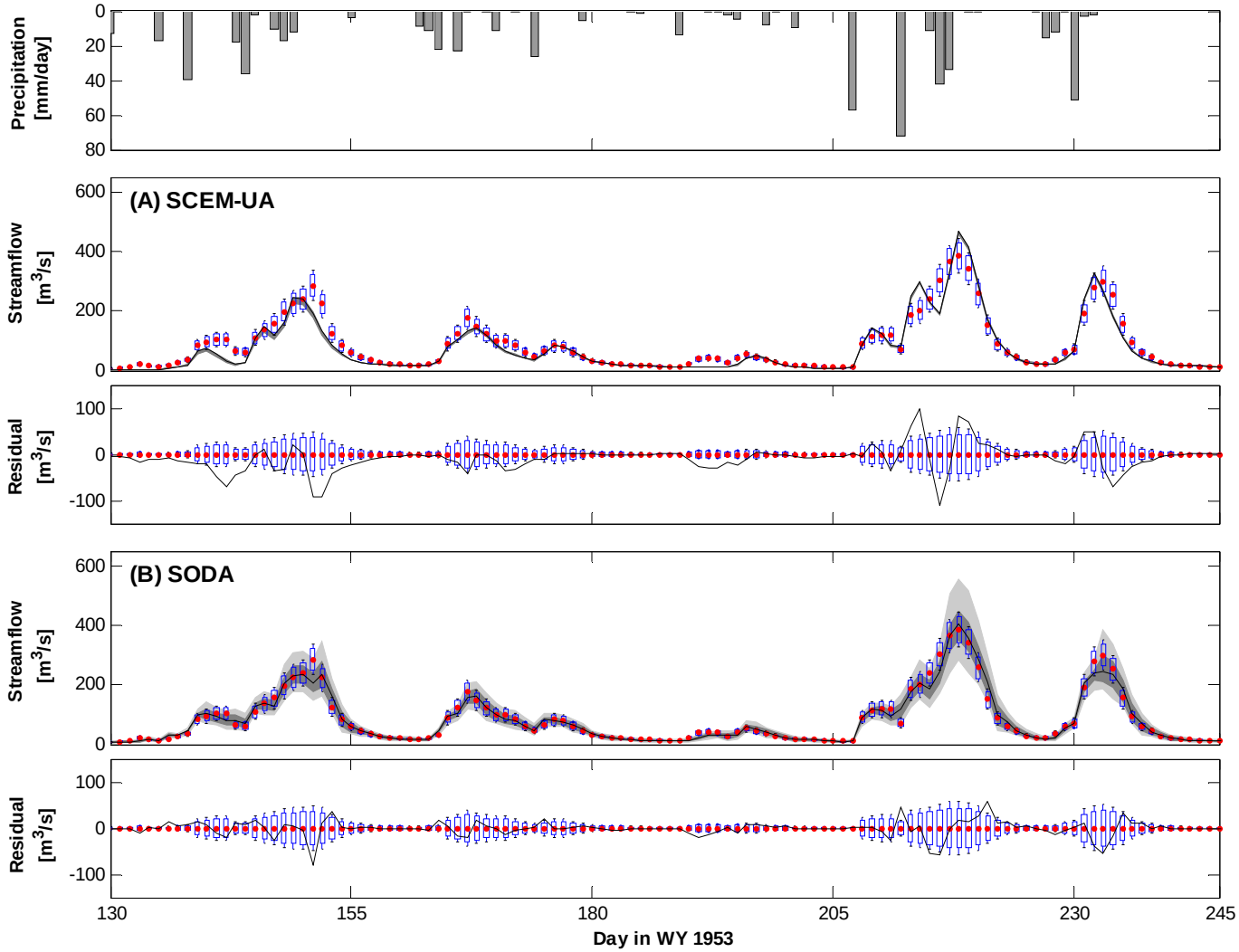


Contains 14 parameters and 9 states…

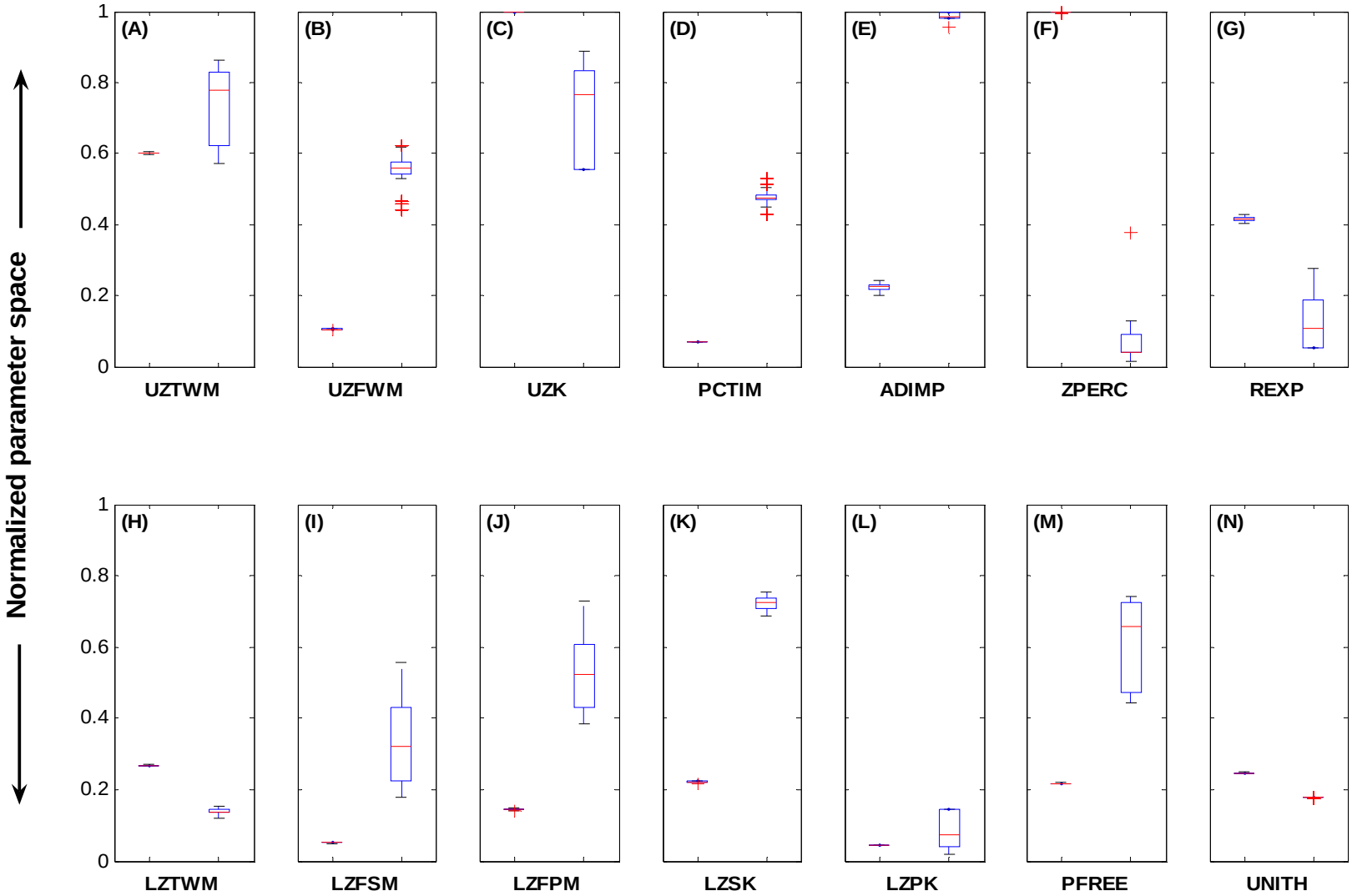
	Capacity thresholds		
UZTWM	upper zone tension water maximum storage	[mm]	1.00 – 150.0
UZFWM	upper zone free water maximum storage	[mm]	1.00 – 150.0
LZTWM	lower zone tension water maximum storage	[mm]	1.0 – 500.0
LZFPM	lower zone free water primary maximum storage	[mm]	1.0 – 1000.0
LZFSM	lower zone free water supplemental maximum storage	[mm]	1.0 – 1000.0
ADIMP	additional impervious area	[-]	0.0 – 0.40
	Recession parameters		
UZK	upper zone free water lateral depletion rate	[d^{-1}]	0.1 - 0.5
LZPK	lower zone primary free water depletion rate	[d^{-1}]	0.0001 – 0.025
LZSK	lower zone supplemental free water depletion rate	[d^{-1}]	0.01 – 0.25
	Percolation and other		
ZPERC	maximum percolation rate	[-]	1.0 – 250.0
REXP	exponent of the percolation equation	[-]	1.0 – 5.0
PCTIM	impervious fraction of the watershed area	[-]	0.0 – 0.1
PFREE	fraction percolating from upper to lower zone free water storage	[-]	0.0 – 0.6
	Not optimized		
RIVA	riparian vegetation area	[-]	0.0
SIDE	ratio of deep recharge to channel base flow	[-]	0.0
RSERV	fraction of lower zone free water not transferable to tension water	[-]	0.3

States	Description	
UZTWC	upper zone tension water storage content	[mm]
UZFWC	upper zone free water storage content	[mm]
LZTWC	lower zone tension water storage content	[mm]
LZFPC	lower zone free primary water storage content	[mm]
LZFSC	lower zone free secondary water storage content	[mm]
ADIMC	additional impervious area content	[mm]

Hydrograph prediction ranges ..

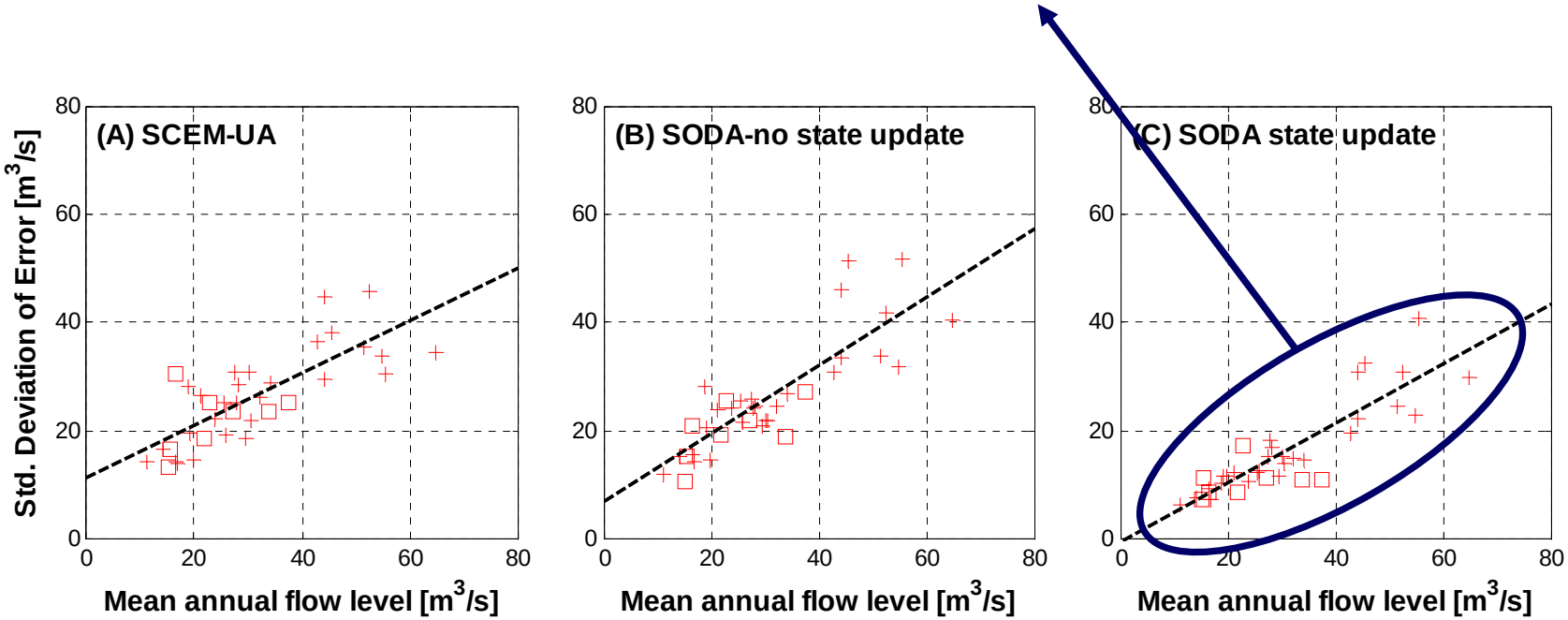


Parameter uncertainties …



Prediction performance…

Consistent better performance with SODA



Conclusions…

(1) Data assimilation significantly improves forecast skills – especially at lower flows.

(2) SODA approach gives reasonable streamflow confidence intervals (neither too narrow nor too wide) that bracket the observations.

(3) Parameter uncertainties with SODA are different and parameters lie in different part of parameter space. This has important consequences for regionalization studies.

Which model states to update…?