

Hydrologic Predictability in Mountainous Terrain

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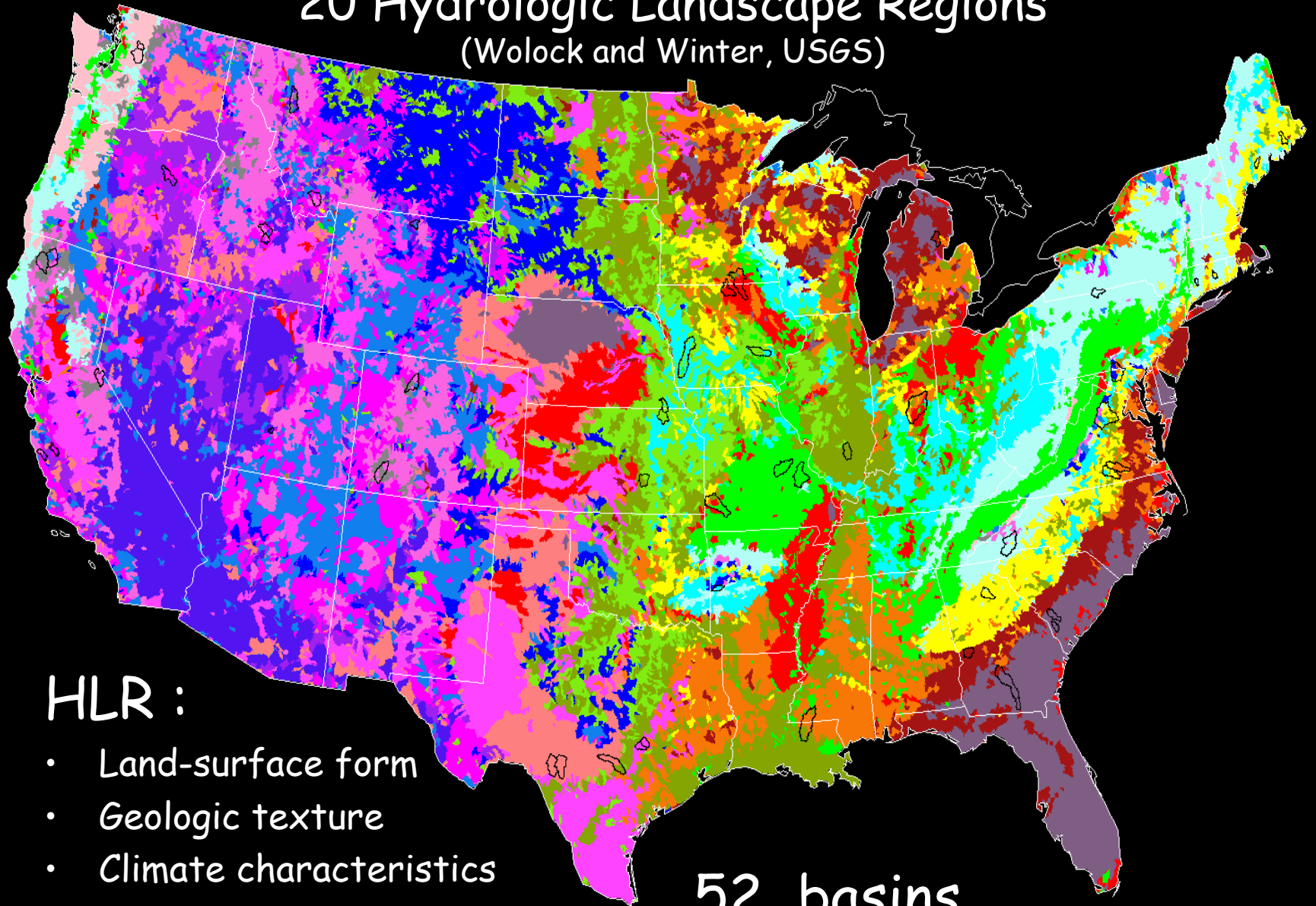
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Background

➤ Hydrologic predictability in the US

20 Hydrologic Landscape Regions

(Wolock and Winter, USGS)



HLR :

- Land-surface form
- Geologic texture
- Climate characteristics

52 basins

Background

- Hydrologic predictability in the US
- Needed to be able to apply a physically-based fully distributed hydrologic models for large number of basins in a timely and efficient manner

Automation in basin setup and parameter estimation

Hydrologic Model Calibration

- Traditional approaches compared observed and simulated runoff at the outlet of the basin.
- Runoff is not sufficient by itself in the evaluation of a hydrologic model.
- While incorporation of spatial data into the calibration and evaluation process is ideal, research in this area has occurred mainly in heavily instrumented research basins.
- In general, the data available for calibration/evaluation of hydrologic models are limited.

Background

- Used **hierarchal approach** to estimate parameters and configure hydrologic model for 52 basins in the US

Precipitation **R**unoff **M**odeling **S**ystem (**PRMS**)

[distributed -parameter, physically-based watershed model]

Implemented in:

Modular **M**odeling **S**ystem (**MMS**)

[A set of modeling tools to enable a user to selectively couple the most appropriate algorithms]

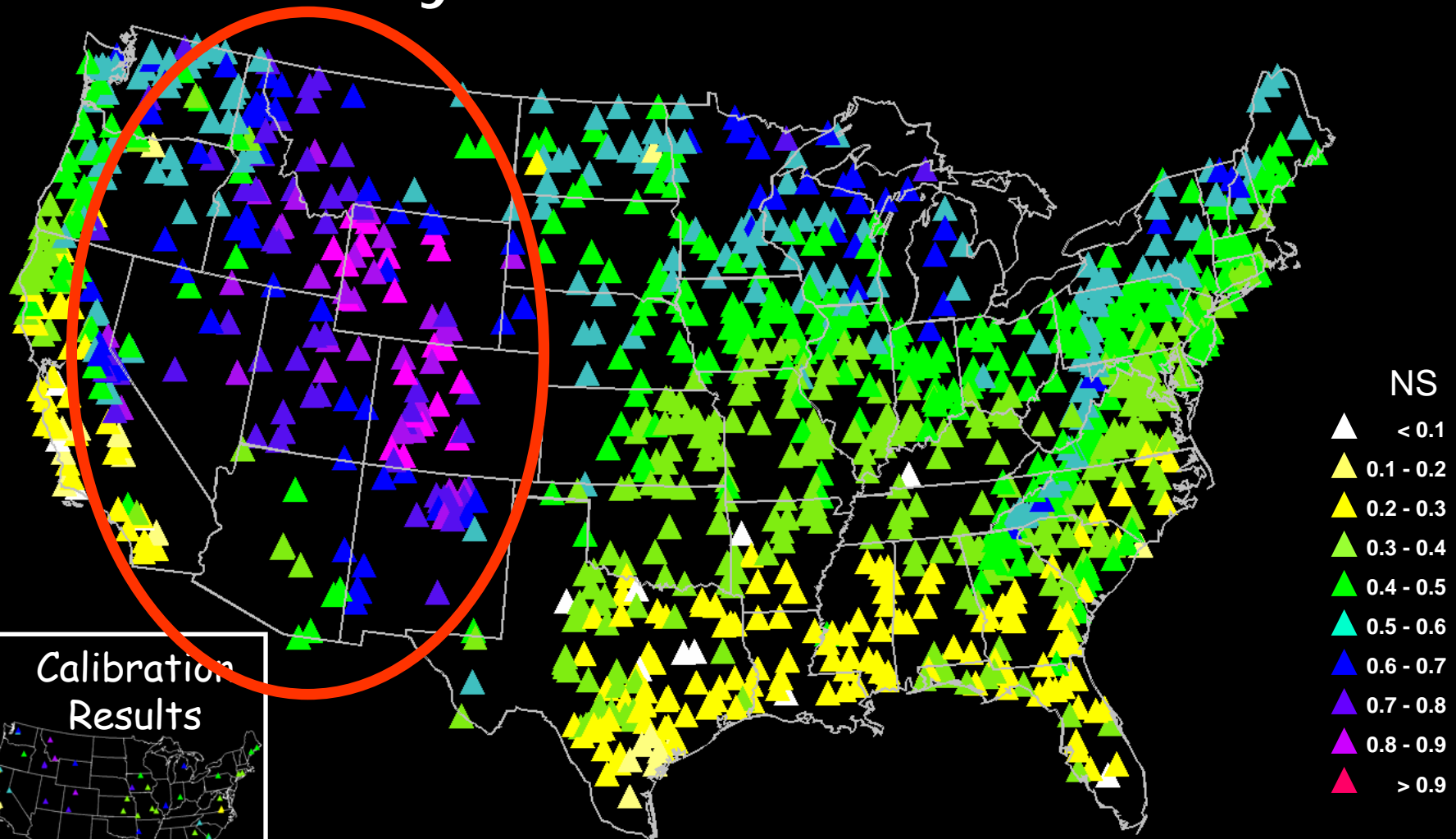
Hierarchal Approach to Estimate Parameters

- 4-step model calibration procedure using Shuffled Complex Evolution (SCE developed by Qingyun Duan):
- For each step calculate objective function(s) using "observed" and simulated:
 1. Solar Radiation
 2. PET
 3. Water balance components
 4. Daily runoff components

Spatial Variability of Hydrologic Model Performance

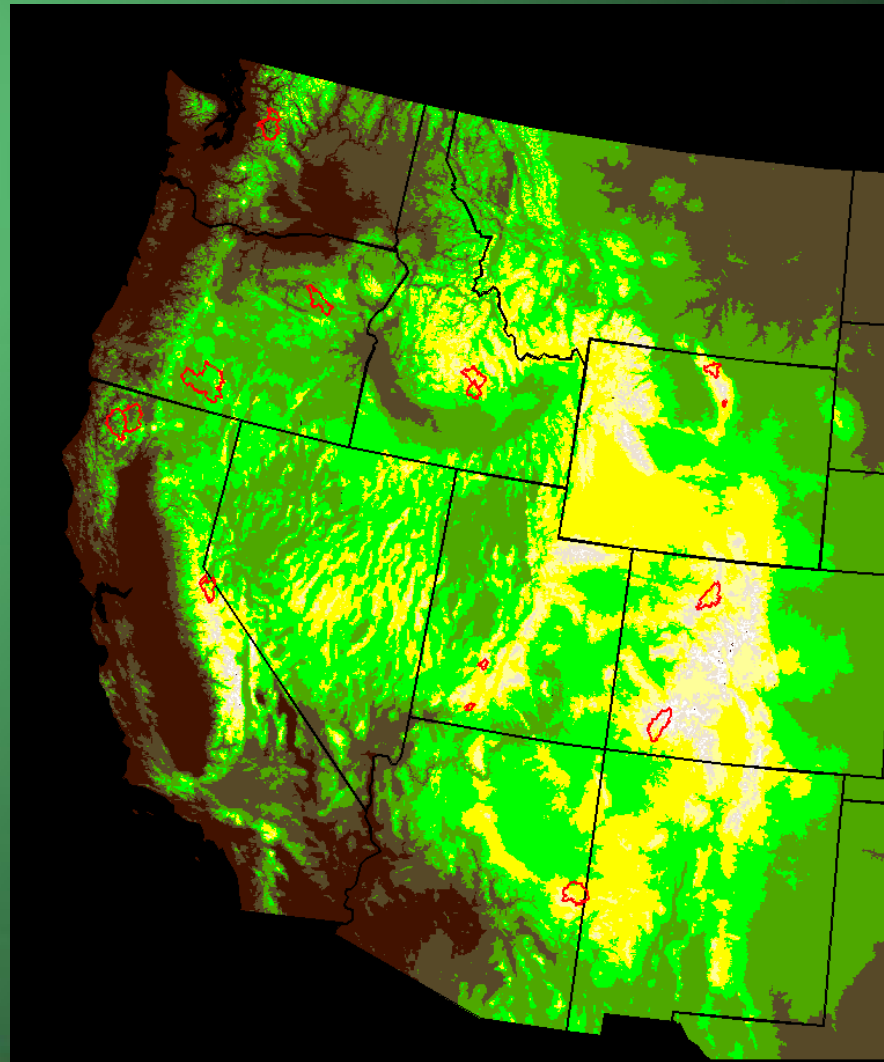
- Look at relation of model performance (Nash-Sutcliffe -- NS) versus basin characteristics
- Annual solar radiation, gage elevation, percent groundwater can be used to predict NS
- Use MLR equation to predict NS at 1300 HCDN (Hydro-Climatic Data Network) sites

Estimated Nash-Sutcliffe Coefficient of Efficiency statistic at HCDN sites



Current Study

Snow-melt
dominated
basins in the
western US



Hierarchical Approach to Estimate Parameters

4-step model calibration

1. Solar Radiation
2. PET
3. Water Balance
4. Daily runoff

GUI for Hierarchal Model Calibration

Allows users to modify the calibration procedure to their own models, data, objective functions, and calibration steps.

SCE

File Help

Instruction

1: Set the number of rounds & steps

2: Set MMS work directory & input files

3: Set calibration period

4: Set up each step

4-1: Select parameters

4-2: Set lower & upper bounds

4-3: Set SCE control parameters

4-4: Set # and type of objective functions

4-5: Set objective functions

4-6: Set simulated & observed variables

5: Run SCE

Parameter File:

Data File:

MMS Executable:

Detailed Instruction:

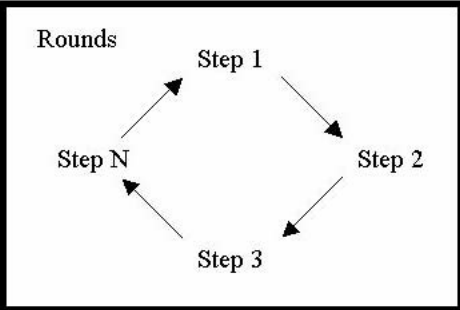
1. Select the number of rounds and steps.

2. Click the 'Next' button to go to the next instruction.

1. Set the number of rounds and steps per round.

The number of rounds:

The number of steps:



```

graph TD
    Step1[Step 1] --> Step2[Step 2]
    Step2 --> Step3[Step 3]
    Step3 --> StepN[Step N]
    StepN --> Step1
  
```

Each step is associated with a parameter set.
 A round consists of one or more steps.
 Calibration of parameter sets is repeated for specified number of rounds.
 Final parameter set in the given step is used as an initial parameter set for the next step.

<< Back Next >> Run SCE Stop SCE Exit

SCE File Help

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Parameter File:

Data File:

MMS Executable:

Detailed Instruction:

1. Select the MMS work directory. After it is selected, files in input/params/, input/data/, and models/ are displayed.
(Note: if an incorrect MMS work directory is selected, then no files are displayed.)
2. Select a parameter file, data file, and MMS executable from those directories.

2. Select the MMS work directory, input parameter file, data file, and executable.

MMS Work Directory:
 Browse

Parameter File

selected file:

Data File

selected file:

MMS Model Executable

selected file:

<< Back Next >> Run SCE Stop SCE Exit

SCE

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Parameter File:

Data File:

MMS Executable:

Detailed Instruction:

1. Select the start and end date for calibration period.

The calibration period must be longer than 1 year due to 1 year model initialization required for the MMS model.

3. Click the 'Next' button to go to the next instruction.

3. Set start and end date of calibration period.

NOTE:

- Include 1 year for model initialization
- The initial default value shown here is the beginning and end date in the data file

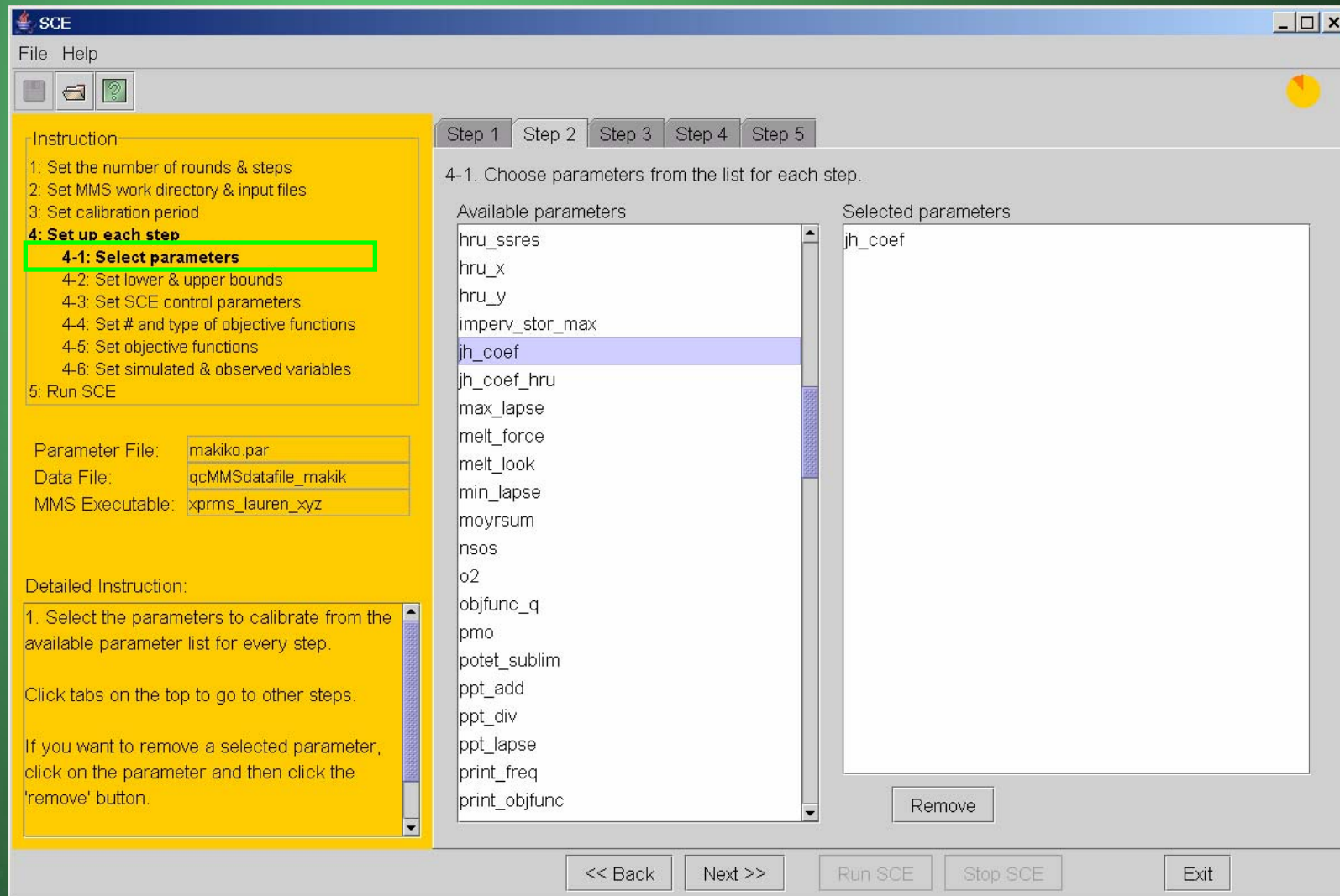
Start Date:

Year	Month	Day
<input type="text" value="1985"/>	<input type="text" value="10"/>	<input type="text" value="1"/>

End Date:

Year	Month	Day
<input type="text" value="2002"/>	<input type="text" value="12"/>	<input type="text" value="31"/>

<< Back Next >> Run SCE Stop SCE Exit



SCE File Help

Step 1 Step 2 Step 3 Step 4 Step 5

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Parameter File: makiko.par
Data File: qcMMSdatafile_makik
MMS Executable: xprms_lauren_xyz

Detailed Instruction:

1. Set the lower and upper bounds for each parameter.

Click on a parameter in the parameter list on the left to display its parameter values.

Check 'Use the mean value as parameter values' if you want to use the mean of the parameter values instead of individual values

4-2: Set lower and upper bounds for optimizing parameters for each step.

☒ Include initial point in population Restore Initial Values

jh_coef

Parameter Name: jh_coef

	Initial Parameter Value
1	0.045301
2	0.037617
3	0.020071
4	0.016708
5	0.012397
6	0.010766
7	0.010825
8	0.010989
9	0.0128
10	0.01608
11	0.036288
12	0.047907

☒ Use the mean value
☐ Use the individual values
☐ Parameters are binary (0, 1)

Lower Bound	Upper Bound	Mean
0.01	0.5	0.023146

Actual Range: 0.022379 to 0.474126

Do you want to save the changed parameter values in a new parameter file?

File: Browse Save

<< Back Next >> Run SCE Stop SCE Exit

SCE

File Help

Step 1 Step 2 Step 3 Step 4 Step 5

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Parameter File:

Data File:

MMS Executable:

Detailed Instruction:

1. Set values for SCE control parameters.

Click 'Restore Defaults' to restore default control parameter values if needed.

2. Set the output parameter file name.

Click tabs on the top to go to other steps.

4-3: Set values for SCE control parameters for each step.

SCE Control Parameter	Value
Number of complexes in the initial population	2
Number of points in each complex Default value = 2 * [Number of parameter values] + 1	3
Number of points in a sub-complex Default value = [Number of parameter values] + 1	2
Number of evolution steps before shuffling Default value = 2 * [Number of parameter values] + 1	3
Minimum number of complexes required	1
Maximum number of model execution	10000
Shuffling loops in which the criterion value must change by given % before optimization is terminated	5
Percentage for the criterion value (Range [0 - 1])	0.01

Restore Defaults

Output file

MMS File:

Parameter File:

<< Back Next >> Run SCE Stop SCE Exit

SCE File Help

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Parameter File: makiko.par
Data File: qcMMSdatafile_makik
MMS Executable: xprms_lauren_xyz

Detailed Instruction:

1. Set the number of objective functions to use.

Click tabs on the top to go to other steps.

3. Click the 'Next' button to go to Instruction 4-5.

4-4. Set the number and type of objective functions for steps.

The number of objective functions: 2

Objective Function Type

☐ NRMSE (Normalized root mean square error)
☐ NS (Nash-Sutcliffe)
☒ ABS (Absolute Difference)
☐ ABS log (Absolute Difference [log])

<< Back Next >> Run SCE Stop SCE Exit

SCE File Help

Step 1 Step 2 Step 3 Step 4 Step 5

4-5. Set the followings for each objective function (OF).

OF 1 OF 2

Weight of this OF: 0.5

☐ Use data_subdivide

data_subdivide value: 1

File: Browse

Time Step

☒ Daily Number of Days: 1

☐ Monthly Mean Period: Oct - Sep

☐ Mean Monthly Period: Oct - Sep

☐ Annual Mean

<< Back Next >> Run SCE Stop SCE Exit

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Parameter File: makiko.par
Data File: qcMMSdatafile_makik
MMS Executable: xprms_lauren_xyz

Detailed Instruction:

Set up the following for each objective function of every step:

1. Set the weight of this objective function
2. Check the check box if data_subdivide is used. Browse the data_subdivide file and select the data_subdivide value to use.

SCE File Help

Step 1 Step 2 Step 3 Step 4 Step 5

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Parameter File: makiko.par
Data File: qcMMSdatafile_makik
MMS Executable: xprms_lauren_xyz

Detailed Instruction:

1. Select where observed calibration data set come from.
2. Select simulated variable.
- 3a. If observed calibration data comes from statvar file, select observed variable from the combo box

4-6. Set simulated and observed variables for objective function for each step.

Simulated Variable: basin_cfs.strmflow Node Number: 1

Where does observed calibration data set come from?

☒ Statvar File
☐ External Source

Observed Variable from Statvar File

Observed Variable: runoff.obs Node Number: 1

Observed Data File from External Source

Specify File Format:

☒ Daily (year month day value)
☐ Monthly Mean (year month value)
☐ Mean Monthly (month value)
☐ Annual Mean (year value)

Example:
2002 10 1 10.5
2002 10 2 3.75

Browse

<< Back Next >> Run SCE Stop SCE Exit

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Parameter File: makiko.par

Data File: qcMMSdatafile_makik

MMS Executable: xprms_lauren_xyz

Detailed Instruction:

1. Option: You can save this setting by selecting 'Save' under 'File' on the menu bar.
2. Click the 'run SCE' button to calibrate parameters.

You can look at the current best values for each step of each round by clicking your desired step in the Rounds tree list.

5. Run SCE.

Program Current Status

Round:	0	
Step:	0	
Model Executions:	0	out of 10000
Objective Function Value:		

Best Values and Status of Each Step

Objective Function Value:

Model Executions: 0 out of 10000

Output Parameter File: round1_step1.par

adjmix_rain
0.364819
0.364819
0.486426
0.851245
1.216064
1.216064
1.216064
1.216064
1.216064
0.972851
0.486426
0.364819

----- Rounds -----

- Round 1
 - Step 1
 - Step 2
 - Step 3
 - Step 4
 - Step 5
- Round 2
 - Step 1
 - Step 2

It hasn't started yet

<< Back

Next >>

Run SCE

Stop SCE

Exit

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Hierarchical Approach to Estimate Parameters

4-step model calibration

1. Solar Radiation

2. PET

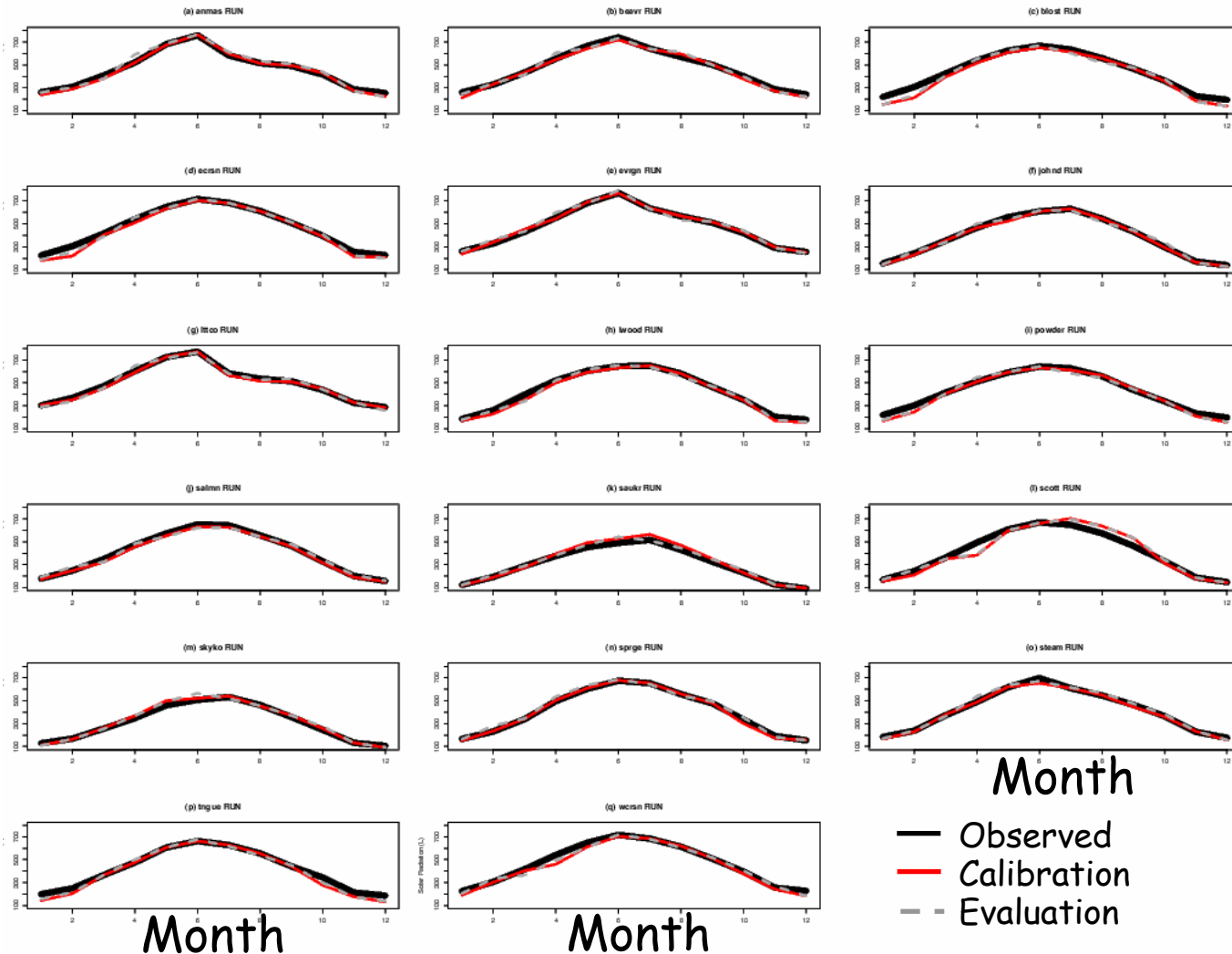
3. Water Balance

4. Daily runoff

Preliminary Results - 17 basins

Observed vs. Simulated Solar Radiation

Basin Mean Monthly Solar Radiation (L)



Hierarchical Approach to Estimate Parameters

4-step model calibration

1. Solar Radiation

2. PET

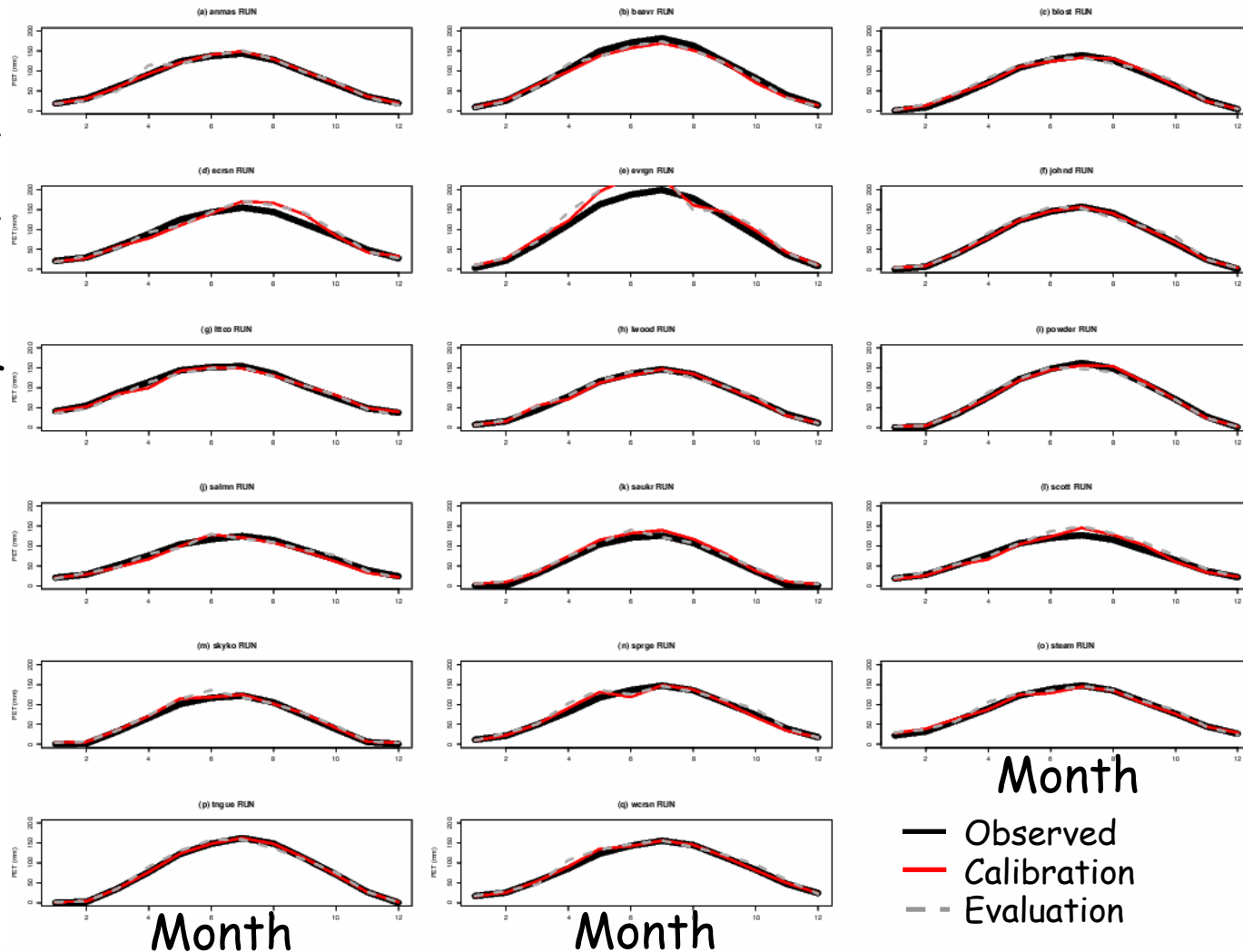
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Preliminary Results - 17 basins

Observed vs. Simulated PET

Basin Mean Monthly PET (mm)



Hierarchical Approach to Estimate Parameters

4-step model calibration

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HEPEX Workshop, July 2005



Hierarchical Approach to Estimate Parameters

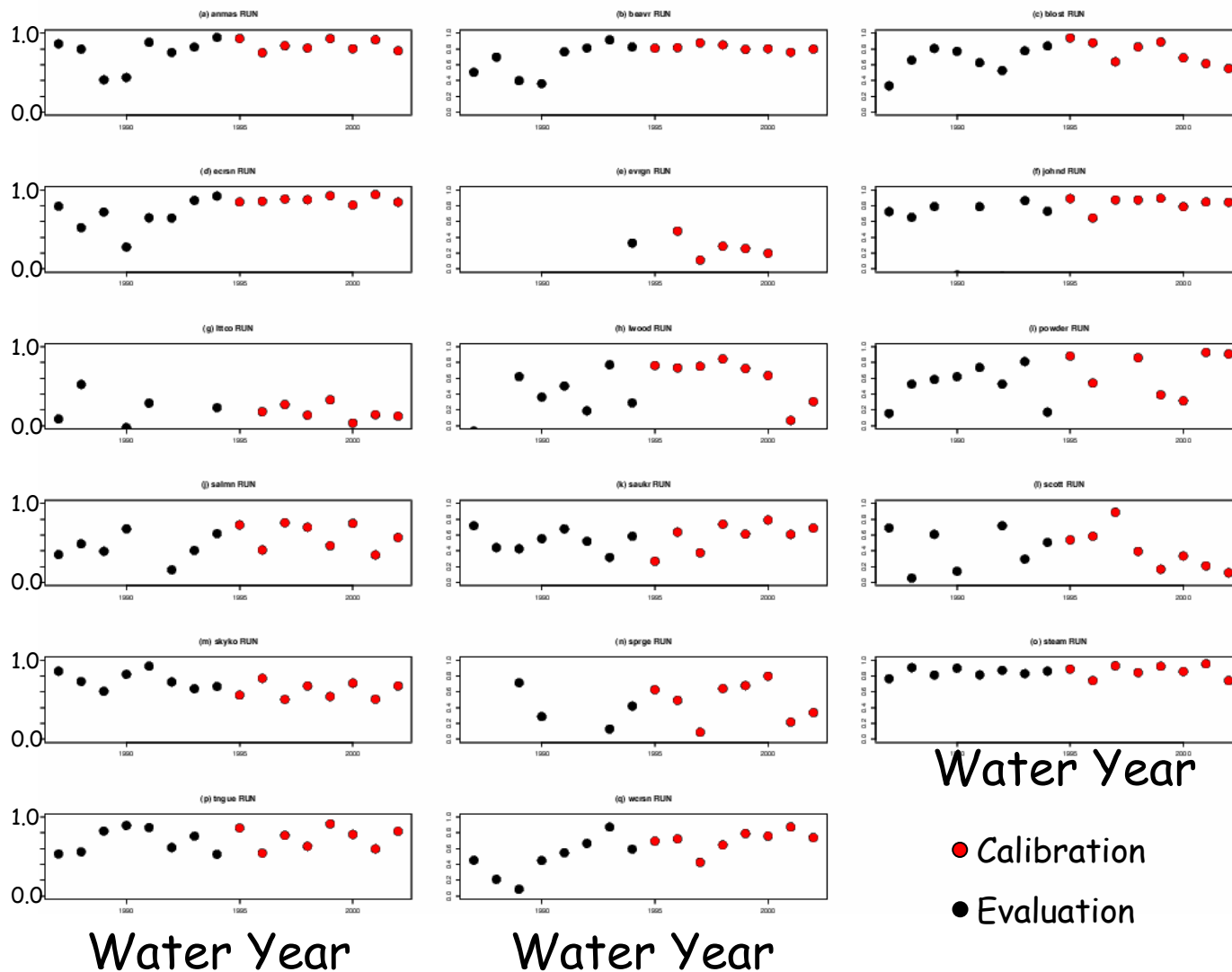
4-step model calibration

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Preliminary Results - 17 basins

Nash-Sutcliffe Goodness of Fit by WY

Nash-Sutcliffe Goodness of Fit

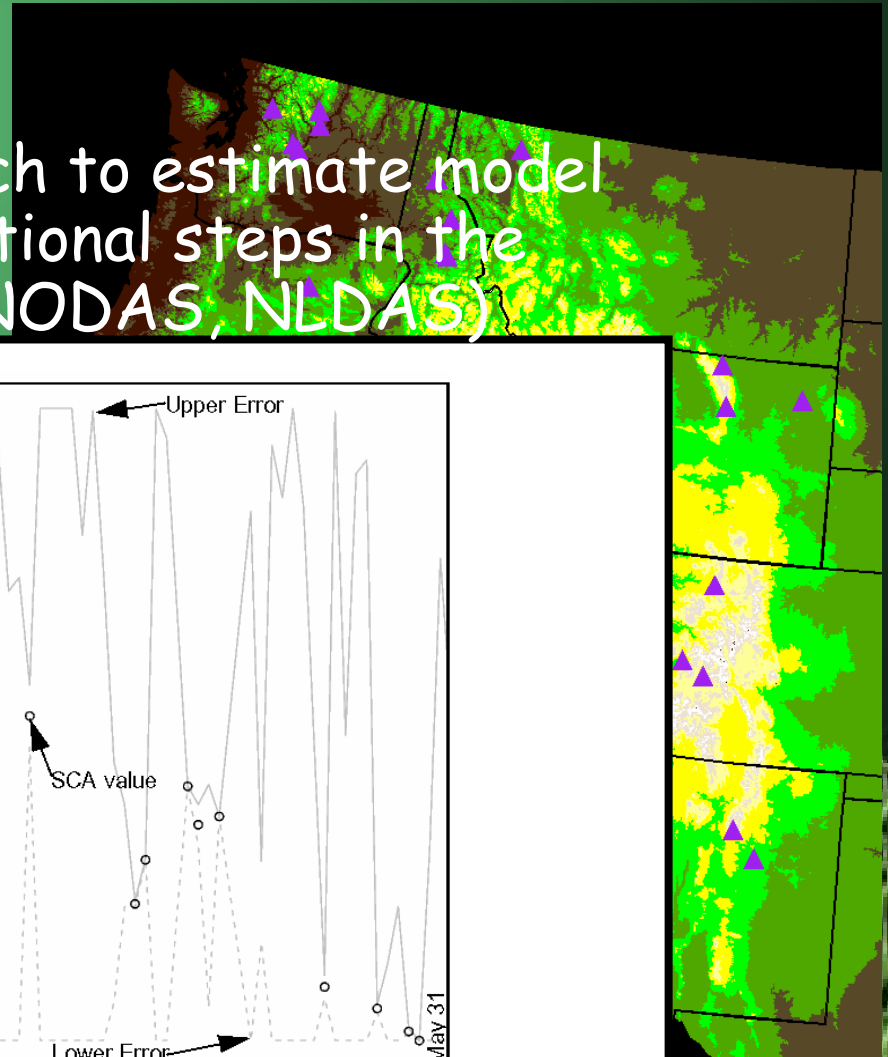
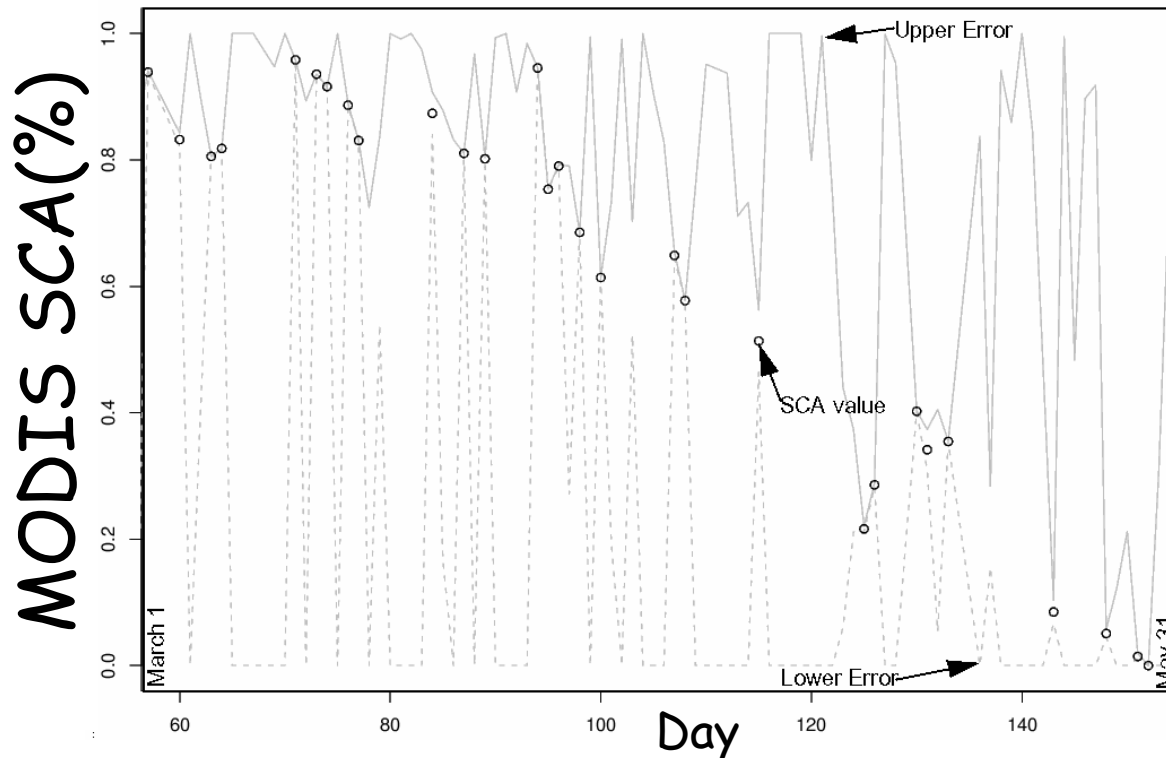


Current Study

- Additional snowmelt-dominated basins added (60 total).

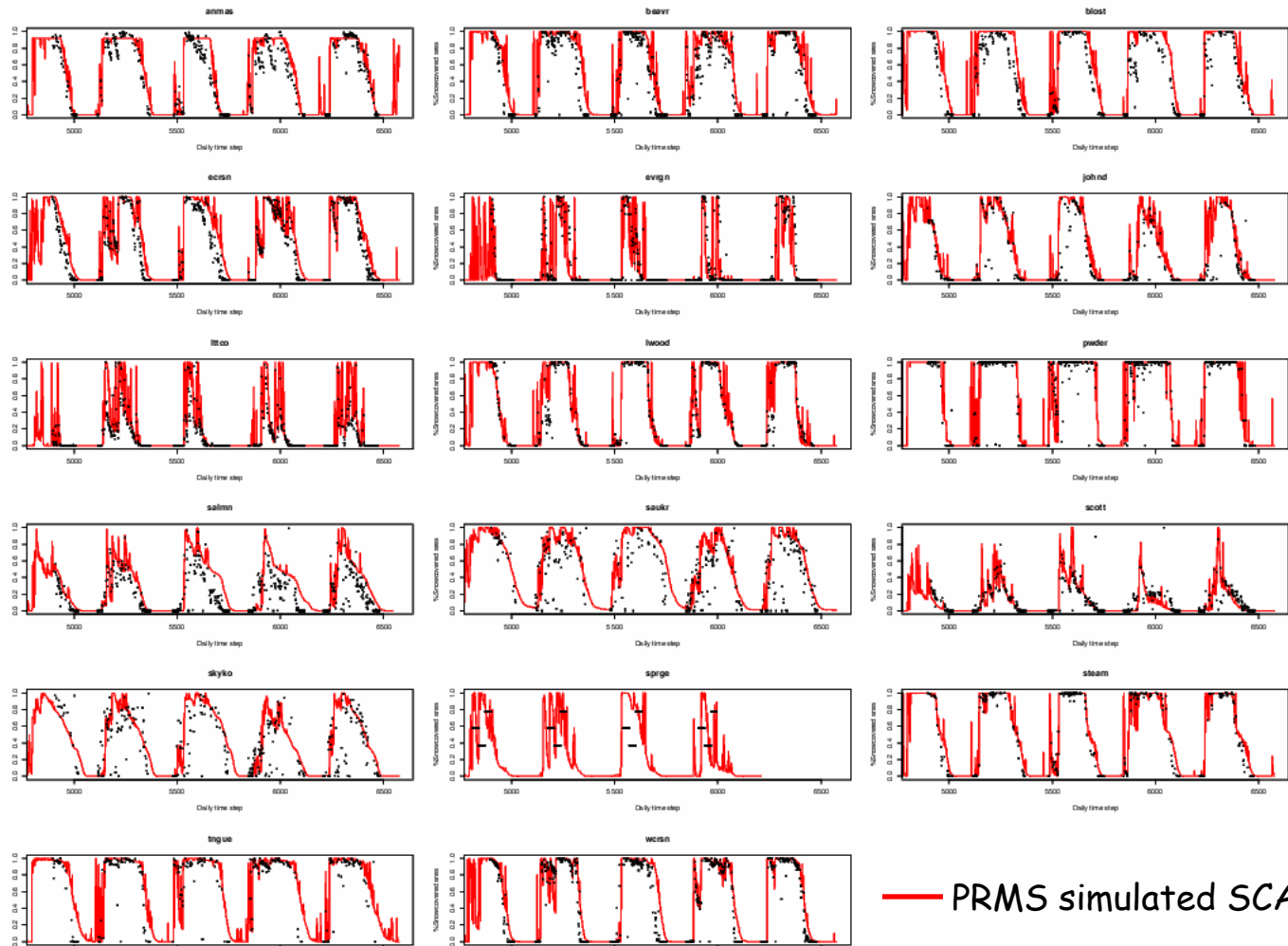
Methodology

- Apply hierarchical approach to estimate model parameters, adding additional steps in the calibration (MODIS, SNODAS, NLDAS)



Basin SCA: MODIS vs PRMS

Percent Snow Covered Area



Daily Time Step

Daily Time Step

- PRMS simulated SCA
- MODIS SCA

Current Study

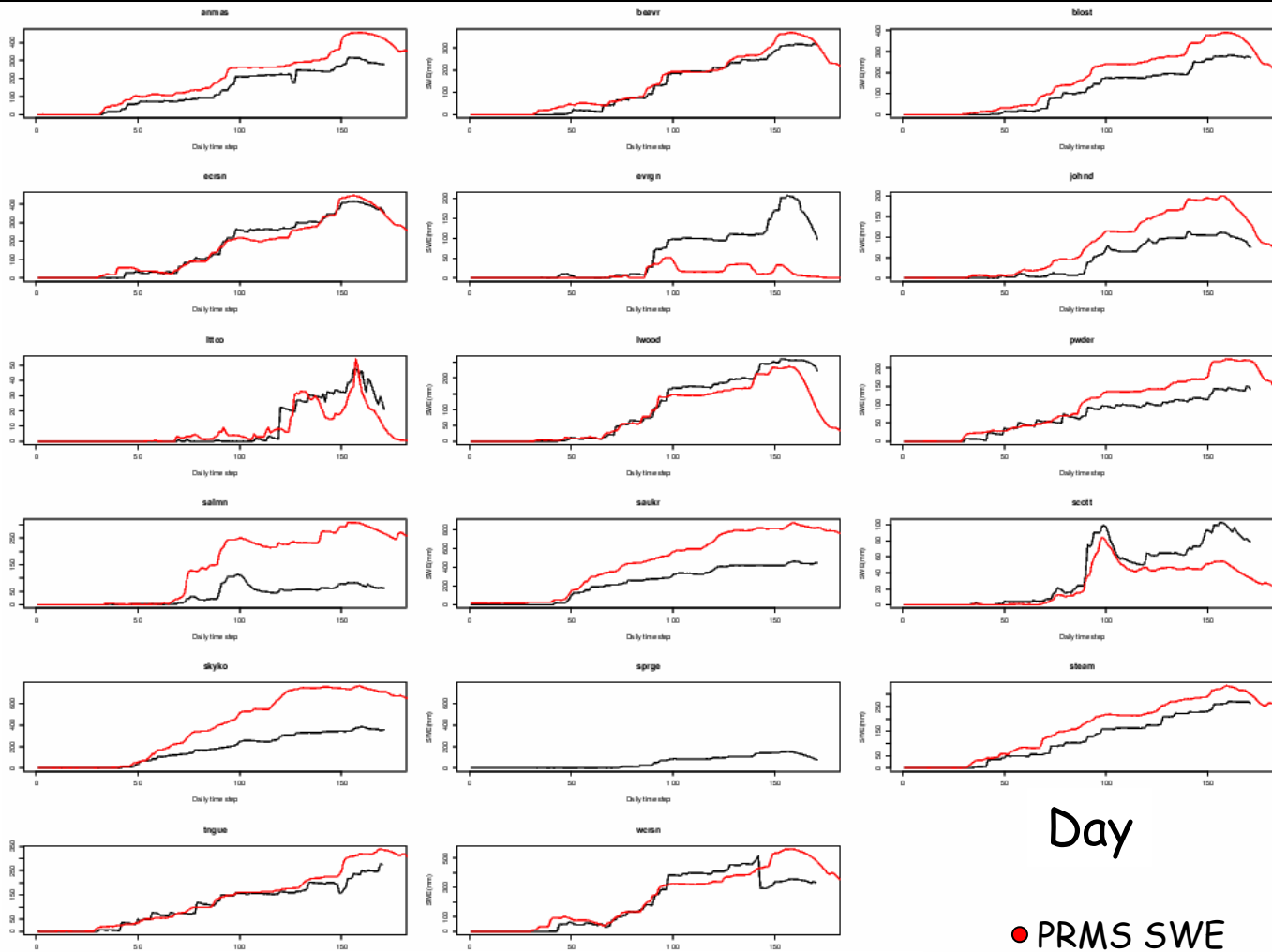
- Additional snowmelt-dominated basins added (60 total).

Methodology

- Apply hierarchical approach to estimate model parameters, adding additional steps in the calibration (MODIS, **SNODAS**, NLDAS)

Basin Snow Water Equivalent

Snow Water Equivalent (mm)



Day

Day

Day

- PRMS SWE
- SNODAS SWE

Current Study

- Additional snowmelt-dominated basins added (60 total).

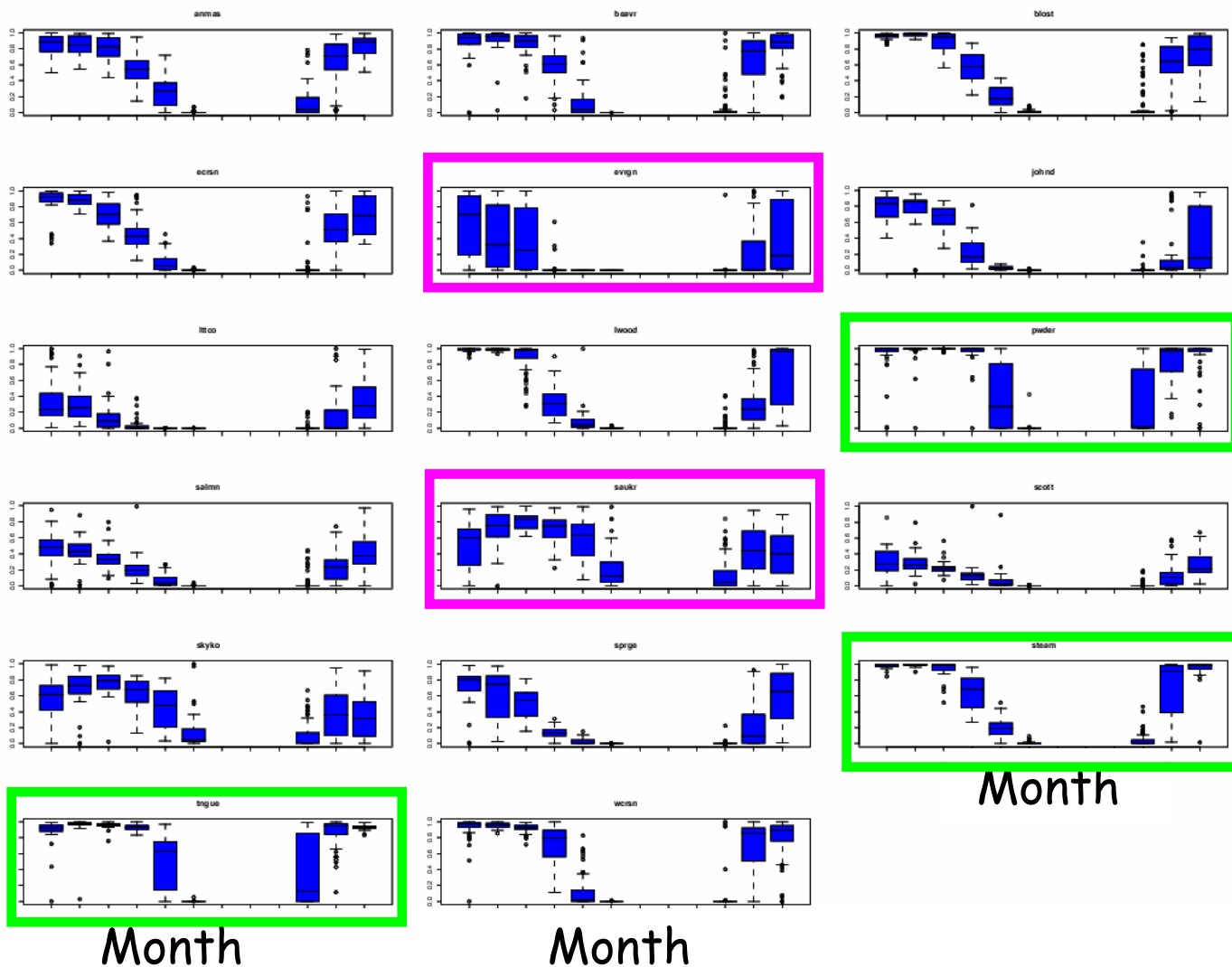
Methodology

- Apply hierarchical approach to estimate model parameters, adding additional steps in the calibration (MODIS, SNODAS, NLDAS)
- Evaluate accuracy to identify basins where streamflow simulations are poor. (Preliminary results show relation to streamflow characteristics, variation in SCA, climate)

Preliminary Results - 17 basins

Variation in MODIS Daily Snow Covered Area

Variation in daily MODIS SCA(%)



Methodology

- Apply hierarchical approach to estimate model parameters, adding additional steps in the calibration (MODIS, SNODAS, NLDAS)
- Evaluate accuracy to identify basins where streamflow simulations are poor. (Preliminary results show relation to streamflow characteristics, variation in SCA, climate)
- Implement additional modules , addressing issue of model complexity
- Produce improved streamflow forecasts for snowmelt-dominated basins using seamless suite of forecasting tools in an ensemble mode
- Incorporate into CHPS

