Hydrological Modeling in the Bull Run Watershed

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Project timeline

2011

Proposal writing

January 2013

Project start

April 17, 2013

Meeting 1: project kick off, 1st round model selection

November 14, 2013

Meeting 2: bias correction, model calibration, model inter-comparison, final selection

January 13-14, 2014

Meeting 3: model setup and training

A lot of communication also happened between in-person meetings with Portland Water Bureau and the University of Idaho team.

Evaluation criteria

Criteria in Scope of Work	Actual Evaluation Points
Non-proprietary	Freeware; open source
Able to process multiple runs through scripting	As stated in Scope of work
Appropriate spatial and temporal scale	Spatial discretization; spatial scale; time steps
General ease of setup and use	Interface (GUI); technical support; documentation; built-in pre- and post-processing tools; auto-calibration tools; number of parameters to calibrate
Model reputation	Past performance in climate change studies; used by other PUMA participants
Cost of setup and operation	Software cost; time required for setup and learn to operate
Additional	Processes important for climate change studies simulated; output parameters and spatial scale

Model Selection Process

Initial screening:

- Models listed in scope of work
- Models commonly used in climate change studies
- Models that could be used in-house

8 Models reviewed:

- Lumped: NWSRFS/SAC SMA
- Macroscale semi-distributed: VIC
- Semi-distributed: HEC-HMS, HSPF, PRMS, SWAT
- Fully-distributed: DHSVM, MIKE-SHE

Discussion also helped understand what was important for calibration and implementation

Discussion Points:

- What processes/output formats are important for the project?
- What computing capabilities exist?
- Absolute requirements?
- Additional thoughts or questions?
- Assign relative weights for each evaluation criteria (see table)

Preliminary Model Comparison Table

Weight	Model/Criterion	DHSVM	HEC-HMS	HSPF	MIKE-SHE

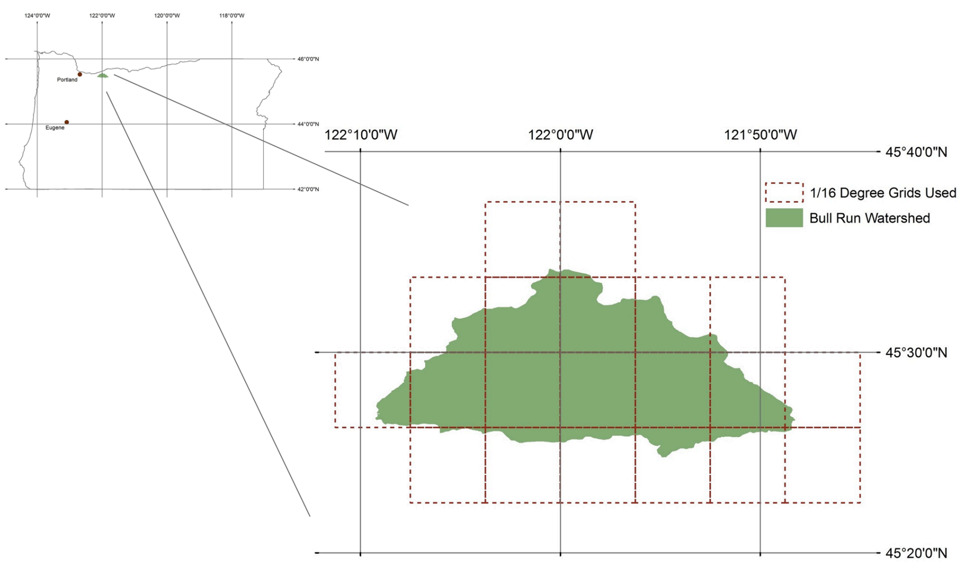
Weight	Model/Criterion	PRMS	NWSRFS/SAC-SMA	SWAT	VIC
	Logistics				
	Non-proprietary	Y	Y	Y	Y
	Open Source	Y	Y	Y	Y
	Related Agency	USGS	NWS	USDA	UW
	Technical Support	Contact USGS MoWS proect	Contact NWS personnel	Contact USDA, SWAT user group, USDA workshop (fee)	Only by UW staff
	Documentation	Good, free online videos	Good	Good, free online videos	Good
	Model Attributes				
	Interface	Windows and Unix GUI	Unix, Windows GUI not supported by NWS	Windows, ArcView, GRASS, and Unix interface	Unix/Command line
	Time to setup and operation	Long	Moderate	Long	Long
	Built-in Post-processing Tools	Y	Y	Y	N
	Auto-calibration	LUCA	Y	Internal and via SWAT-CUP	External (MOCOM)
	Able to process multiple runs through scripting	Y (via Unix) GUI capability not known	Y (via Unix) GUI capability not known	Y (internal? or via Unix)	Y
	Conceptual/Physical	Mixed	Mixed	Mixed	Physically-based
	Spatial Scale	Flexible	Flexible	Flexible	Medium-Large
	Spatial Discretization	Semi-distribu			
	Temporal Resolution	Daily			
	# of Parameters to Calibrate	High			
	Model Reputation				
	Past Climate Studies in PNW	Y			
	Used by Other PUMA Participants?	None			
	Processes Modeled				
	Snow Accumulation and Melt	Y (mixed)			
	Interception and Infiltration	Y			
	Vegetation	Y			
	Evapotranspiration	Y (mixed)			
	Regulated Resevoir	N (Y w/ GSFL			
	Output Format				
	Continuous Hydrograph	Y			
	Output spatial discretization	HRU			
	Additional				

Subtask 1: Model Selection Decision

- Selected DHSVM, PRMS, and VIC for further implementation
  1. Past usage in the PNW for climate change studies
     - DHSVM was implemented for Bull Run in the past
     - PRMS and VIC are widely cited in literature and reports
  2. Modeling physical processes suitable for PNW
  3. A range of spatial resolution

Historical forcing dataset (Livneh et al. 2013)

- Preliminary runs showed:
  - runoff and precipitation too low, a ratio of observed runoff to precipitation of 0.99
  - consistent low-bias in winter flows and high-bias in spring flows, suggesting low bias in winter temperature that results in a high bias in accumulated snow
- Bias was corrected for:
  - higher precipitation and lower winter minimum temperatures at high elevations
- Lessons
  - Could not just use an off-the-shelf dataset (1 weather station not representative of entire watershed)
  - Important step for confidence of results

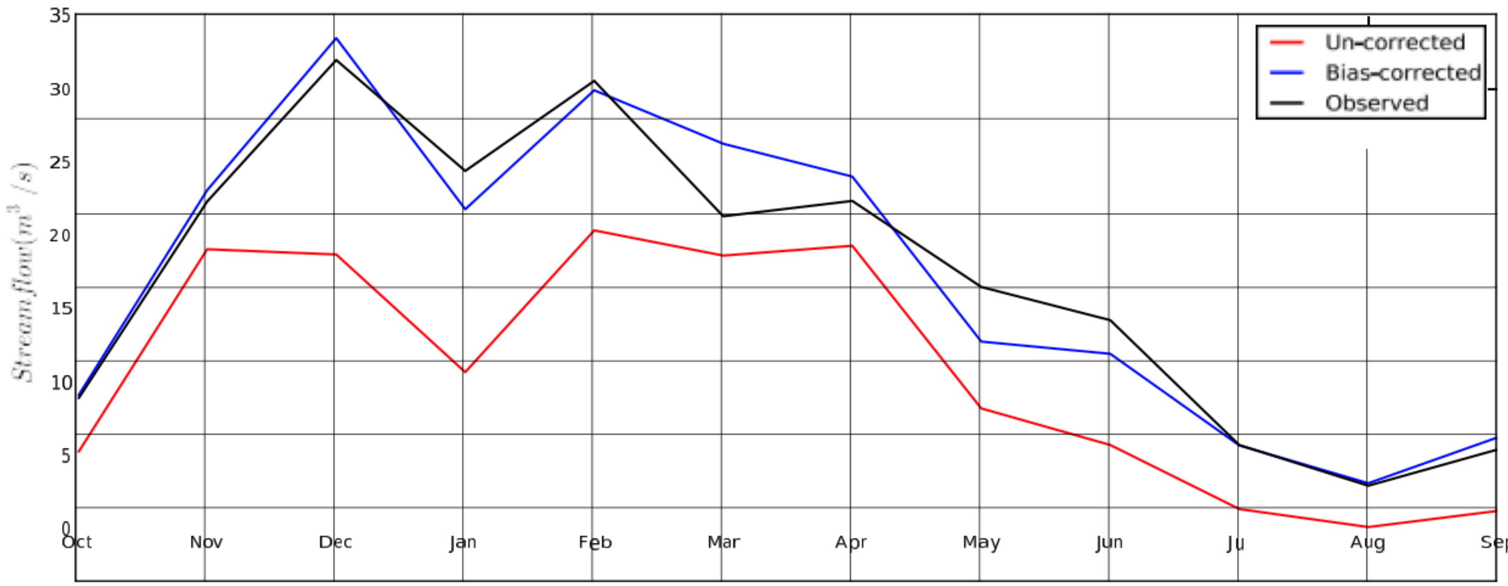


Note: 20 grids for entire watershed

Historical dataset bias-corrected with adjusted PRISM to achieve plausible water balance and seasonal trends

	Sim. Precip (mm/year)	Obs. Runoff/ Sim. Precip Ratio	Sim./Obs. Runoff Ratio
Un-corrected Livneh	2604	0.99	0.62
Bias-corrected Livneh	3241	0.77	1.00

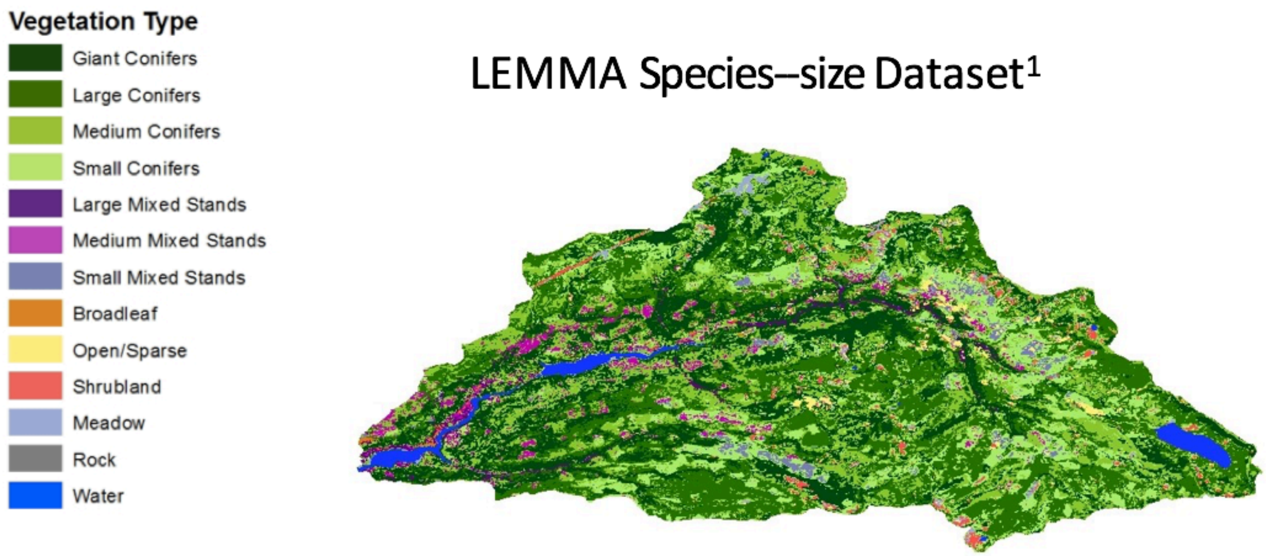
Mean Monthly DHSVM Simulated Streamflow



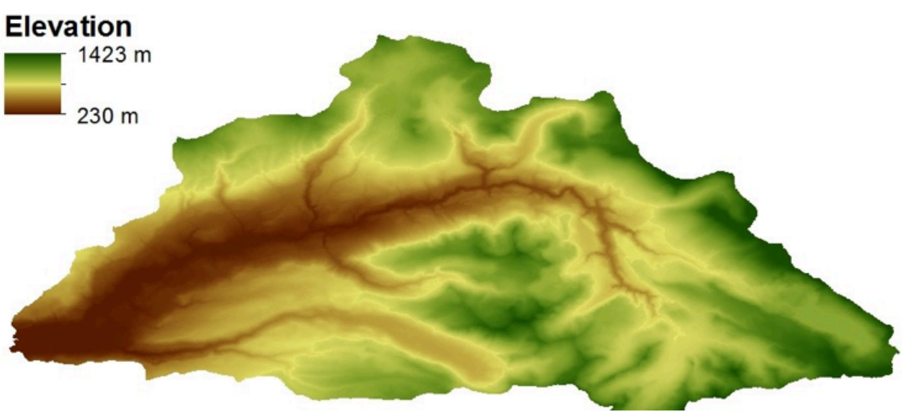
Model set up

GIS data = soil, vegetation, elevation maps

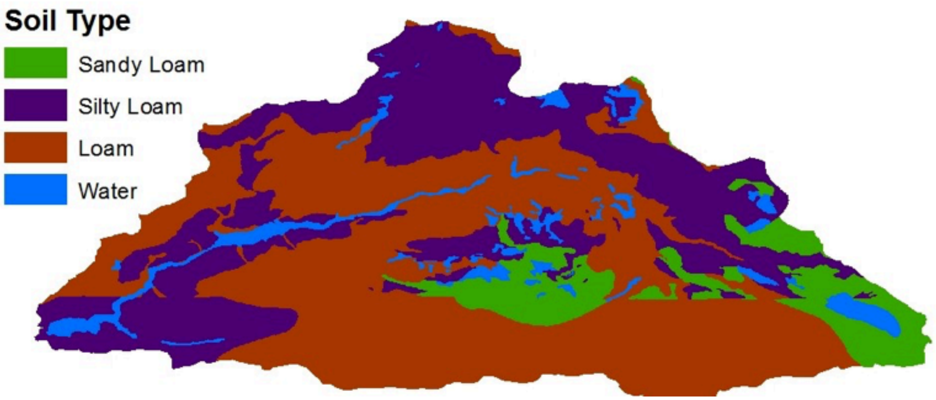
LEMMA Species–size Dataset[1]



Portland Water Bureau



NRCS STATSGO2 and SSURGO[2,3]



Model calibration strategy

Periods:

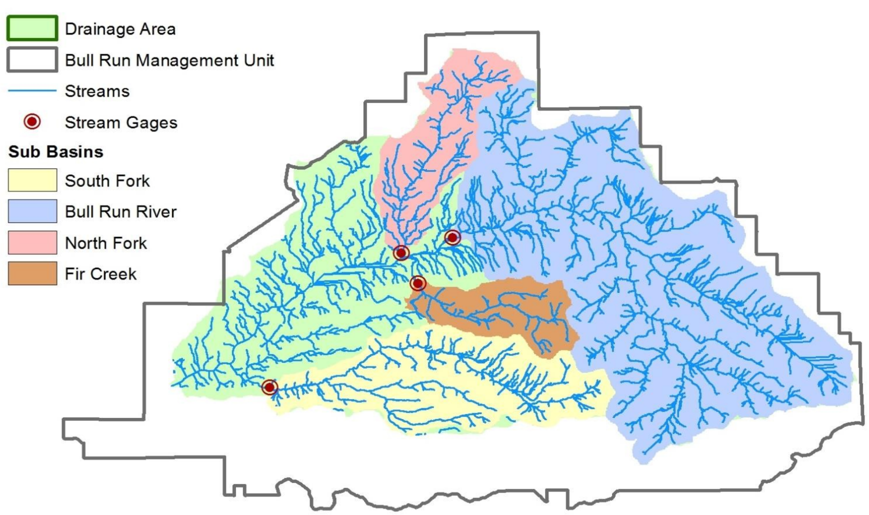
- Calibration: WY 1976-1988
- Validation: WY 1992-2005

Calibration performed to match:

- Multiyear water balance (annual flow at ET amount)
- Multiyear mean month flow (seasonal distribution of flow)
- Daily flow (peak flow and base flow)

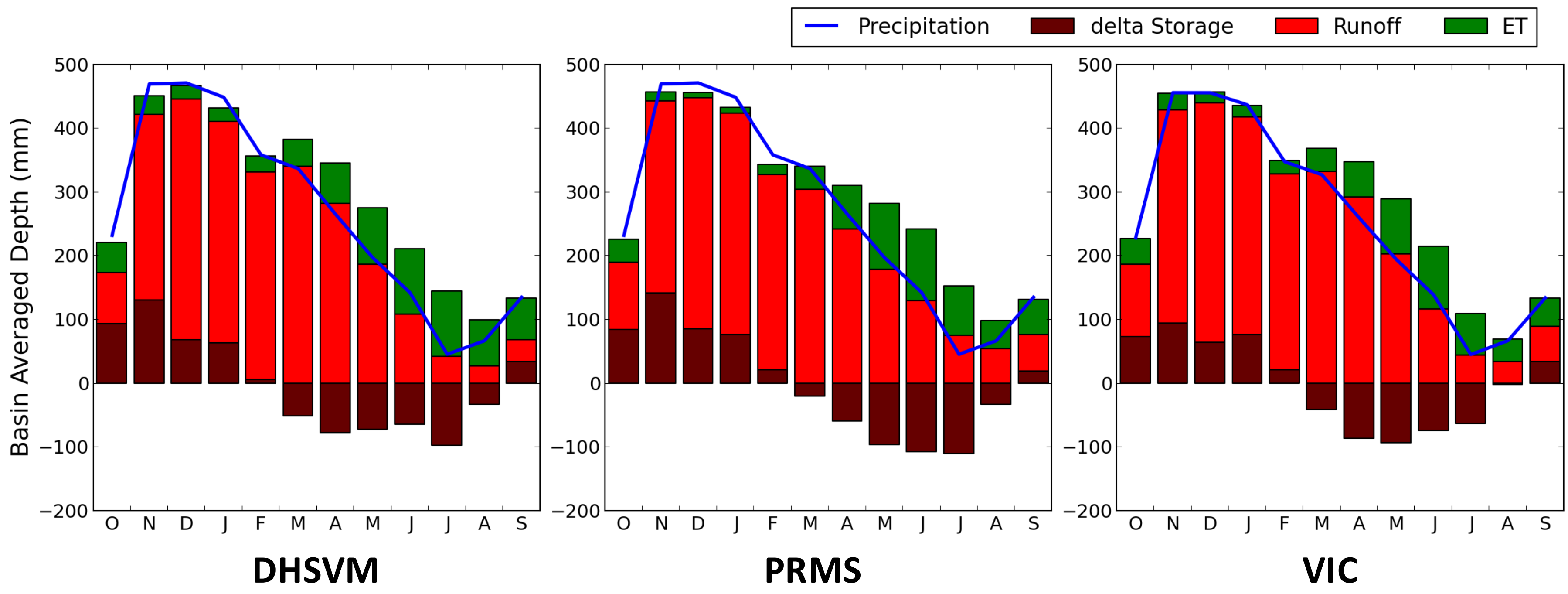
Parameters calibrated:

- Soil parameters related to infiltration rates and base flow
- DHSVM: vegetation parameters related to interception storage (ET)

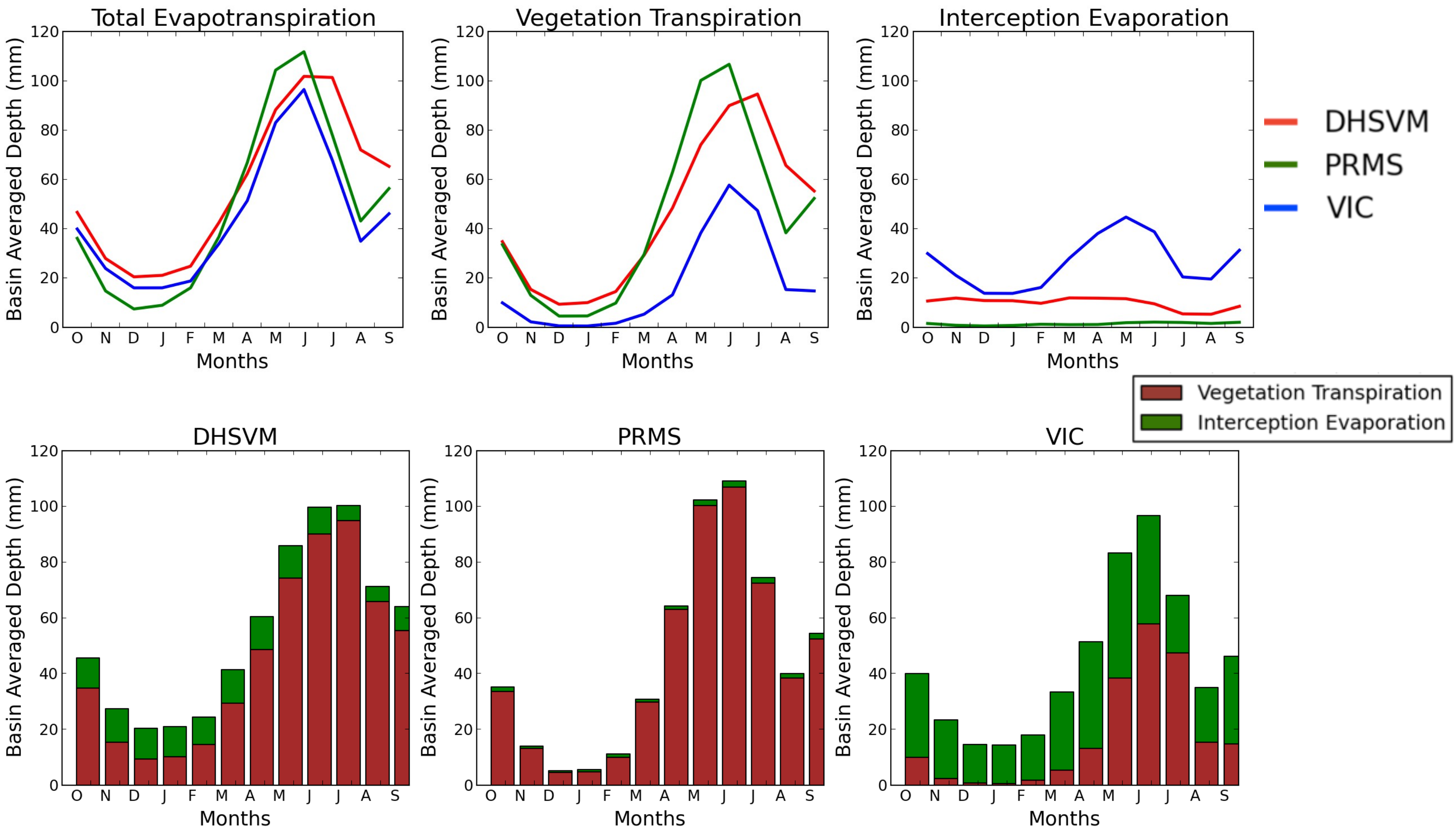


Model comparisons

Seasonal water balance shows (relatively slight) differences in ET and storage changes



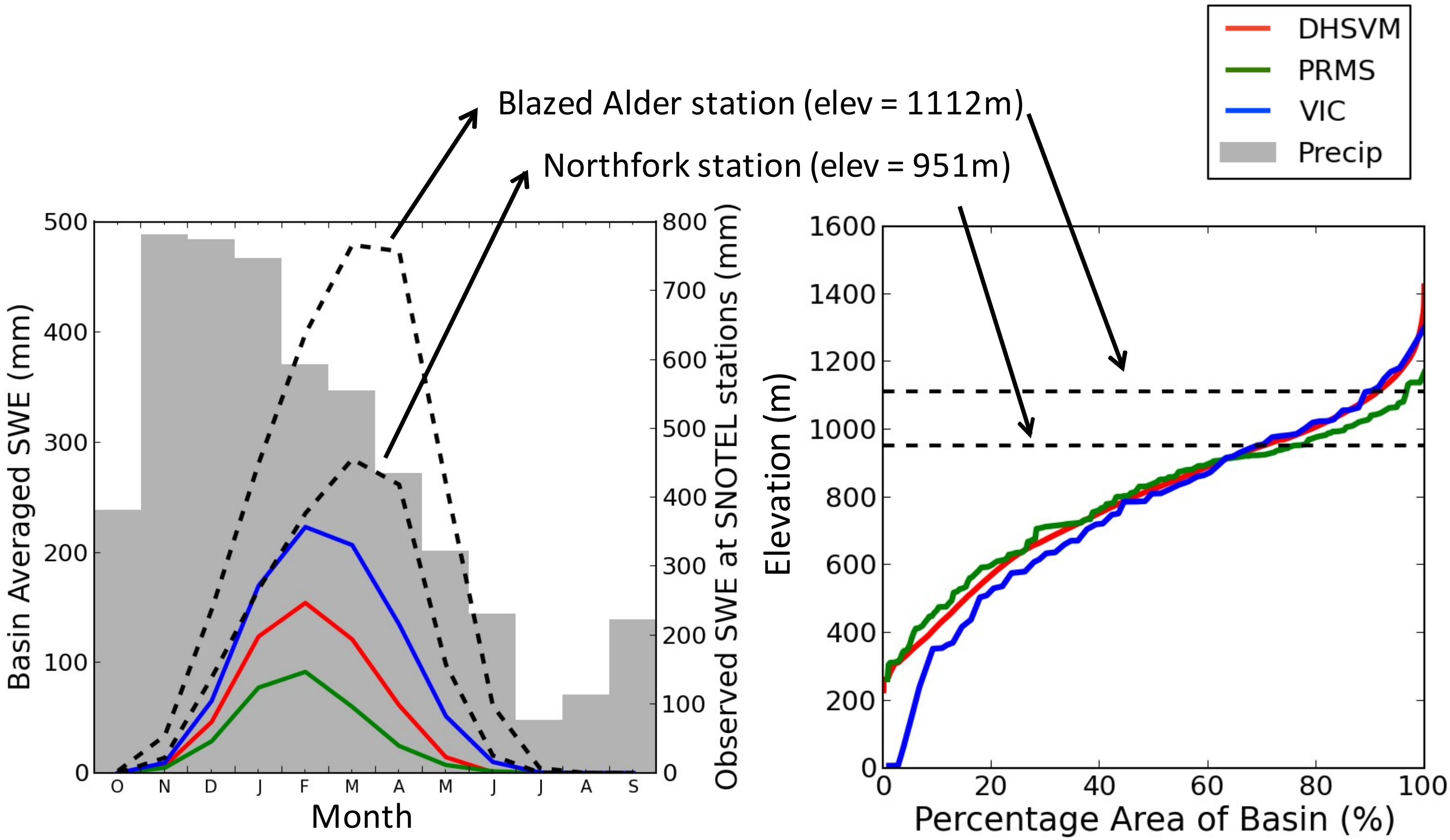
Model comparisons



(relatively large) differences exists in the partition of ET into vegetation transpiration and interception evaporation

Model comparisons

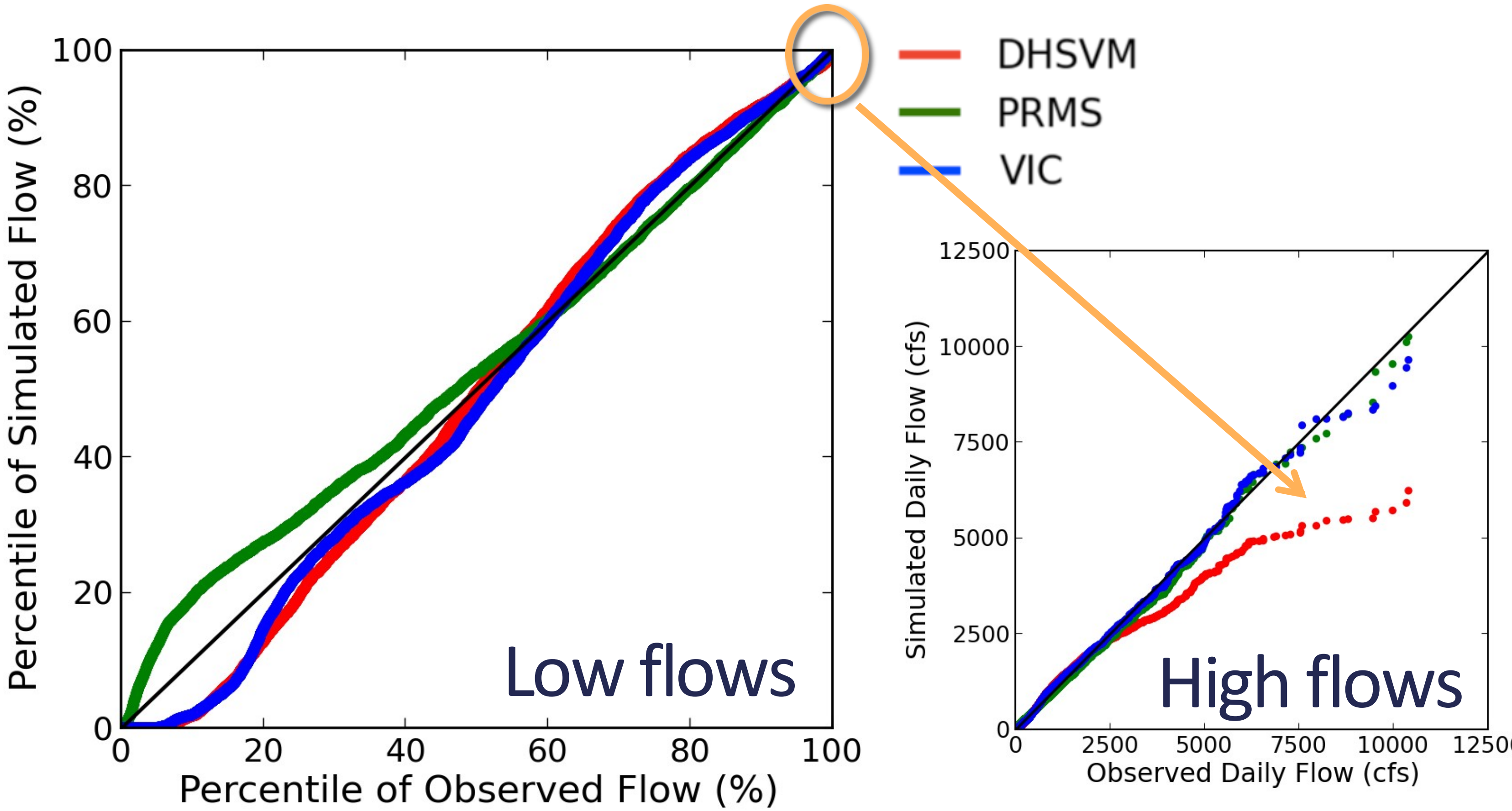
Differences in snow accumulation may contribute to differences in spring runoff, but the magnitude is smaller



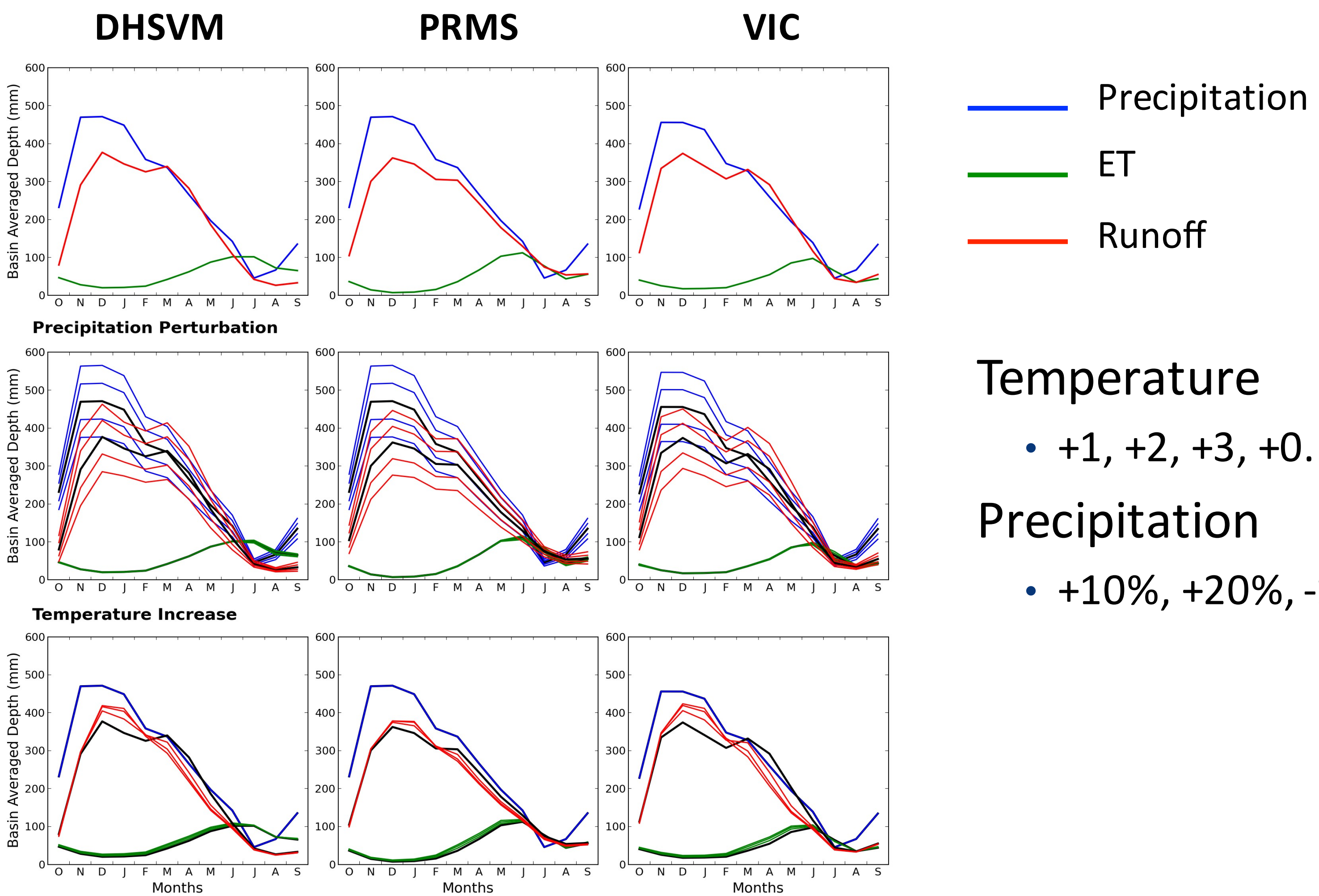
*Note that SWE is cumulative, while precipitation is not

Model comparisons

Percentile-Percentile plot



Sensitivity analyses



Temperature

- +1, +2, +3, +0.1 °C

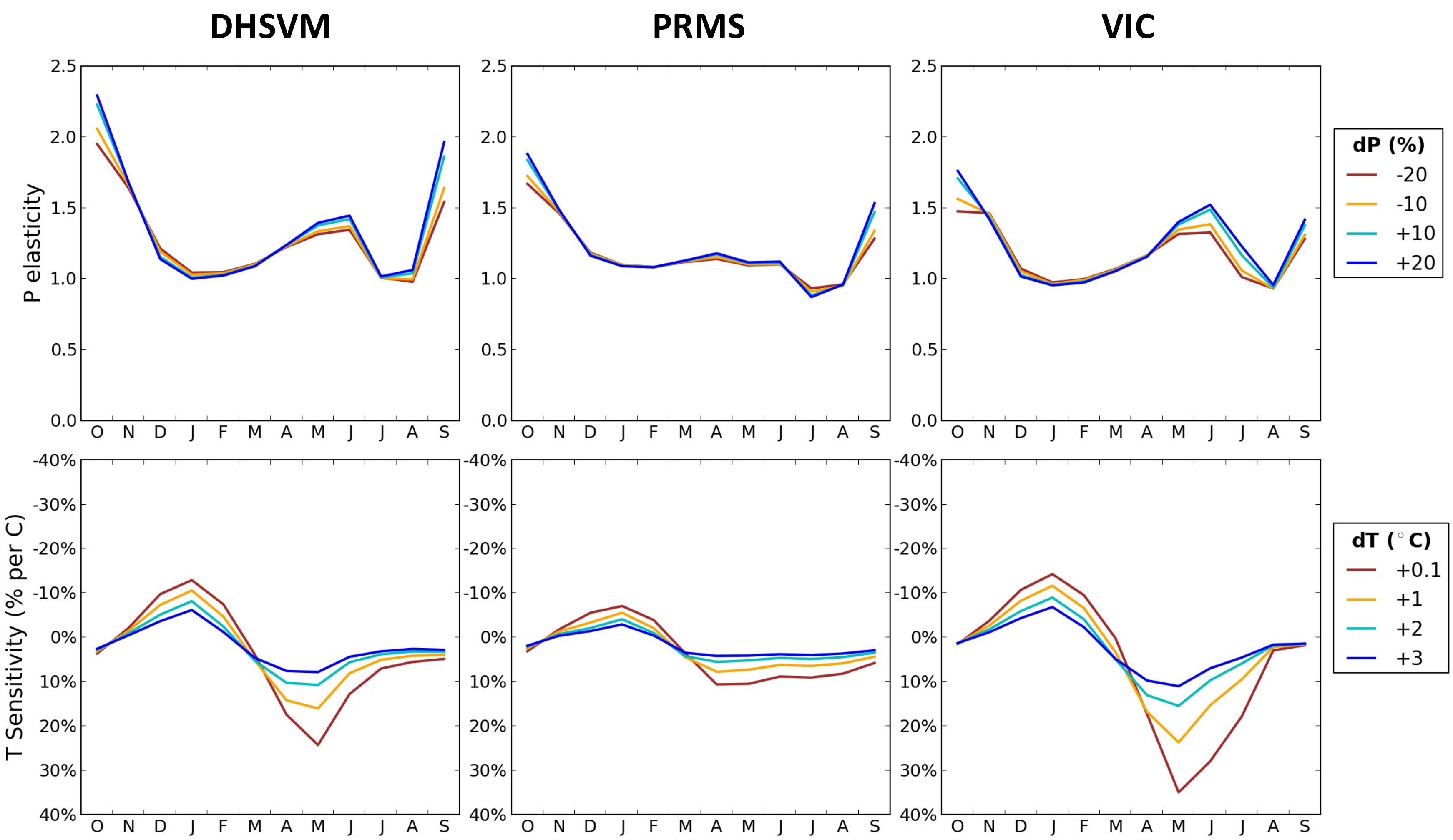
Precipitation

- +10%, +20%, -10%, -20%

*Basin-average, not of the calibration area

Sensitivity analyses

Seasonal responses to precip. and temp. perturbations is most dramatic in VIC and least in PRMS



Key advantage and drawbacks of each model

Model	Advantages	Drawbacks
DHSVM	1) High spatial resolution 2) Physical representation of land characteristics	1) Under Estimates high flows 2) Worse calibration performance 3) Long model run time 4) No graphic user interface (GUI)
PRMS	1) Good calibration performance 2) Shortest model run time 3) Integrated GUI	1) Over Estimation of summer low flows 2) Simplified vegetation representation 3) Highly parameterized 4) “batch run” ability not implement for GUI yet
VIC	1) Good calibration performance 2) Reasonable model run time 3) Flexible in input variables	1) Macroscale model 2) No graphic user interface (GUI)

Concluding thoughts…

Successful because:

- Evaluation criteria decided prior to any modeling, helped objectivity and increased understanding
- Bias correcting the forcing dataset helped build confidence in the rest of the process
- Multiple in-person meetings
- Attention was given to making knowledge transfer complete
- Evaluation team was fairly model-agnostic
- Mutual trust and respect was regularly demonstrated
- There was clear communication and expectations
- A willingness to find middle ground (e.g. publications/reports)
- Everyone generally enjoyed working together

Model selection, no clear winner, Portland Water Bureau had to assess tradeoffs.

Valuing the process

Importance of providing space for both research questions and management applications

“I think it was also successful because in the end both groups trusted each other and generally enjoyed working together. This means that both parties must be willing to park their egos at the door for the duration of the project. Meetings are not all that productive if they are continuously contentious or if one party feels that the other is not listening or not taking them seriously.” – Bart Nijssen