Comparison of Temperature-Index Snowmelt Models of Varying Complexity in $SWAT_{BF}$ for Predicting Water Yield in a Cold Region

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Introduction

- Snow significantly affects hydrology of watersheds in cold regions
- Hydrological models must account for snowmelt runoff
- Two types of snowmelt models
  - Temperature-index (TI)
  - Energy balance (EB)

Introduction

- Most operational hydrological models utilise TI models
- Yet to be demonstrated that EB models produce generally more accurate predictions than TI models (Beven, 2000)
- No need to use complex EB model in place of simpler TI model for operational hydrological model (Vehviläinen, 1991)

Introduction

- Important to realise both model types are valuable tools
- Bergström (1991) reminds us of the need to accept different modelling approaches

  > "There should not be a conflict between the use of physically based process-oriented models and the simpler, more empirical conceptual ones. We just have to realize that they are developed for different purposes and should be applied accordingly."

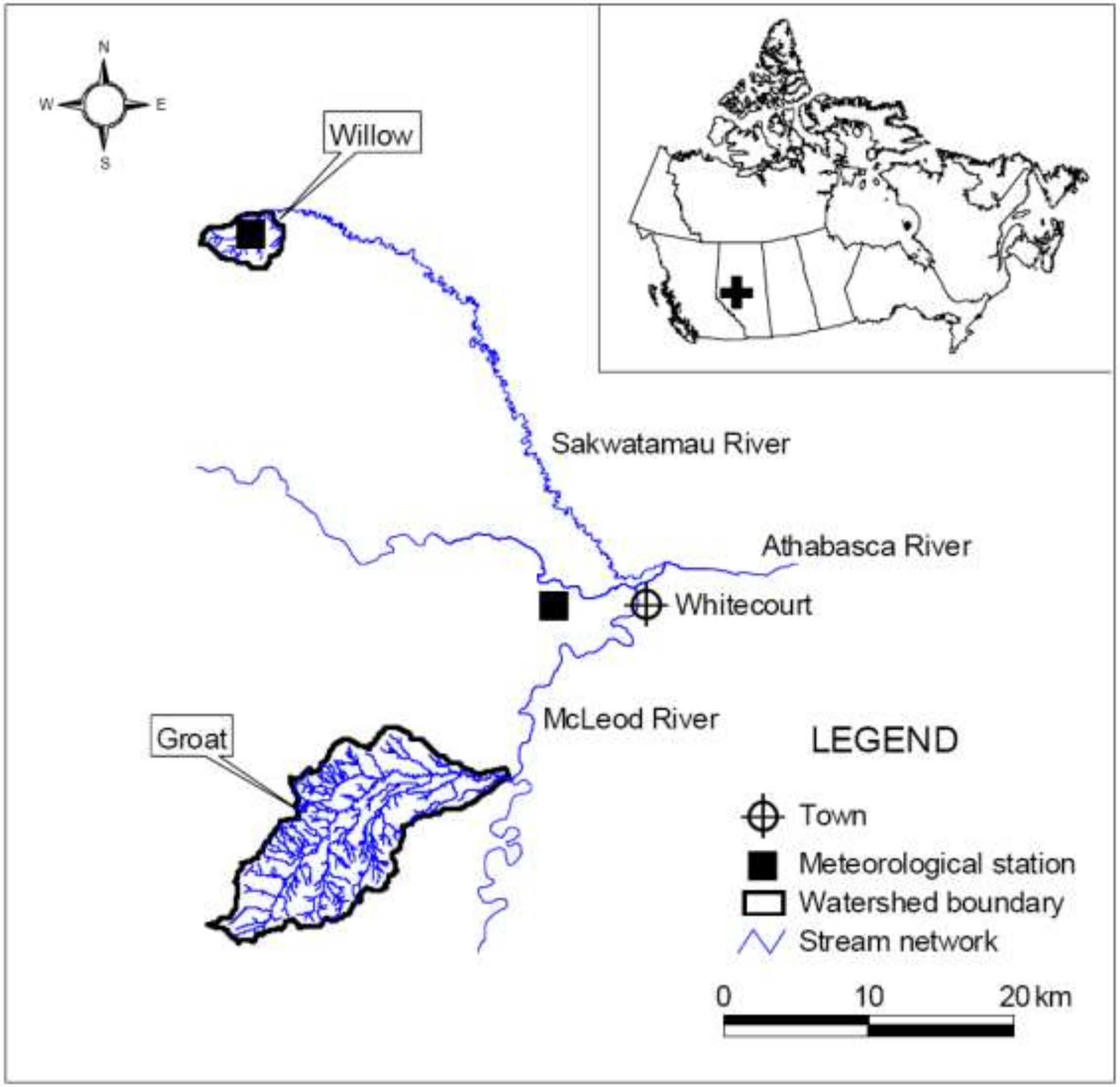
Introduction

- SWAT utilises a 7 parameter TI model
- Several studies have examined suitability of TI model in SWAT for different regions
- No study has investigated how complexity of TI models might influence accuracy of runoff predictions made by SWAT
- Comparison of TI models can provide useful insights into level of complexity needed to reproduce watershed response

Introduction

- The objective was to determine how TI models of varying complexity would affect the performance of $SWAT_{BF}$ for predicting runoff from watersheds in a cold region

Study Area


N
W
E
S
Willow
Sakwatamau River
Athabasca River
Whitecourt
McLeod River
Groat
LEGEND
Town
Meteorological station
Watershed boundary
Stream network
0
10
20 km

$SWAT_{BF}$

- SWAT does not account for important hydrological processes in boreal forests
- Applicability of model limited as a tool for forestry management purposes
- $SWAT_{BF}$ developed to ensure dominant hydrological processes represented

Snowmelt models

- TI models evaluated in this study
  - LIARDFLOW
  - SLURP
  - INCA
  - HBV light
  - SWAT2005
  - SWAT2005-EXT
- Published equations used to develop source code for each model in $SWAT_{BF}$

Snowmelt models

Process	LIARDFLOW	SLURP	INCA	HBV light	SWAT2005	SWAT2005-EXT
Form of precipitation						
Snow threshold temperature	✓	✓		✓	✓	
Rain and snow threshold temperatures			✓			✓
Snowpack temperature					✓	✓
Melt factor						
Constant	✓		✓	✓		
Variable		✓			✓	✓
Snow accumulation and depletion						
Single threshold temperature	✓	✓		✓		
Individual threshold temperatures			✓		✓	✓
Water retention in snowpack				✓		
Refreezing				✓		
Snow cover					✓	✓
Depression storage						✓

Snowmelt models

- Number of parameters required
  - LIARDFLOW → 2
  - SLURP → 3
  - INCA → 5
  - HBV light → 5
  - SWAT2005 → 7
  - SWAT2005-EXT → 11

Calibration procedure

- Calibration → 2002-2004
- Validation → 2005-2007
- Performance criteria
  - Deviation of runoff volumes (D_V)
  - Coefficient of efficiency (NSE)
  - Hydrographs
- All snowmelt parameters calibrated for each model as a first step

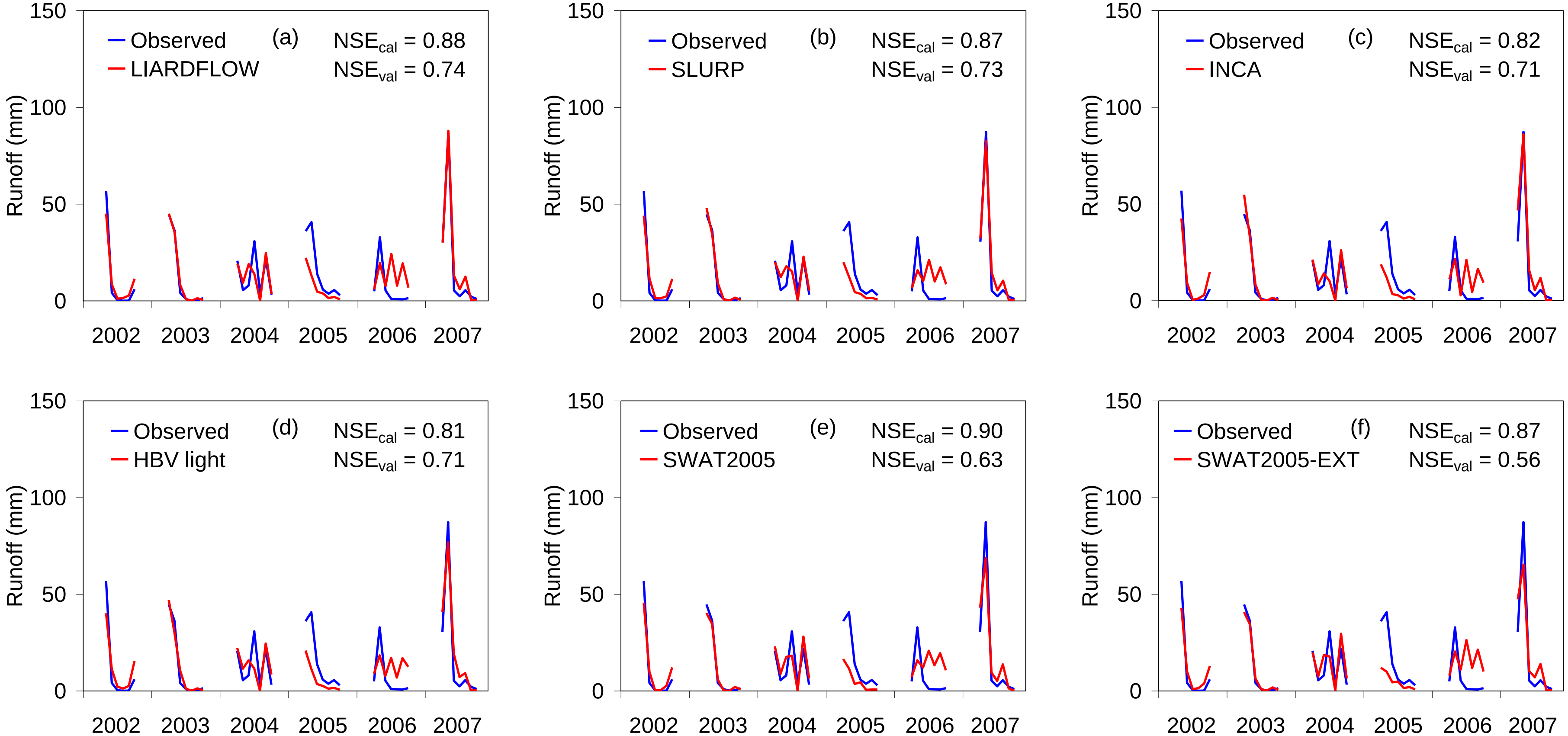
Results

- Deviation of runoff volumes

Model	Willow Creek		Groat Creek	
	Calibration	Validation	Calibration	Validation
LIARDFLOW	1.2	0.0	3.8	-7.8
SLURP	4.5	-3.3	1.9	-8.6
INCA	2.7	1.0	3.5	-9.8
HBV light	3.4	-2.0	8.0	-4.6
SWAT2005	3.2	-3.8	4.0	-8.4
SWAT2005-EXT	3.1	-0.3	-0.1	-9.3

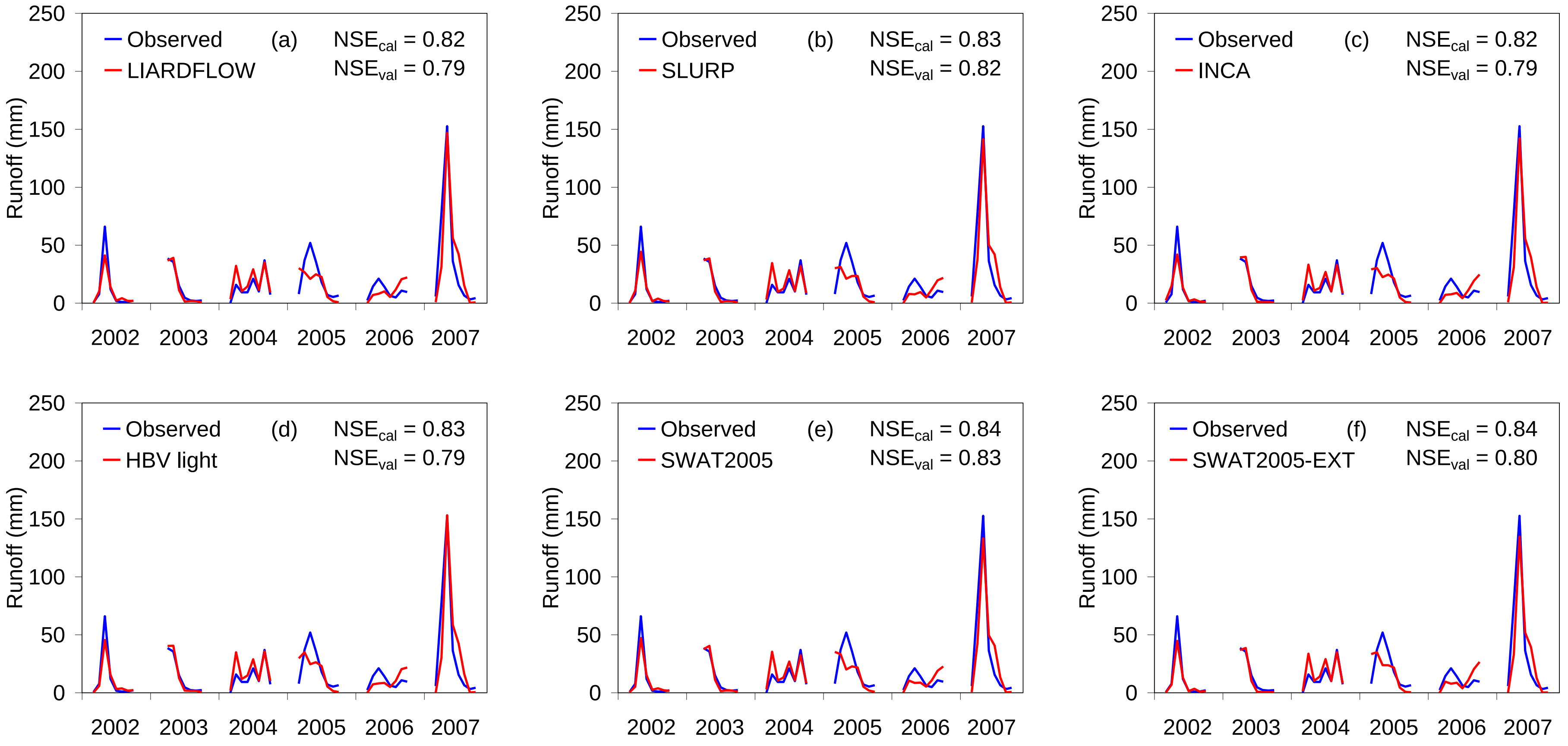
Results

- Monthly runoff – Willow Creek



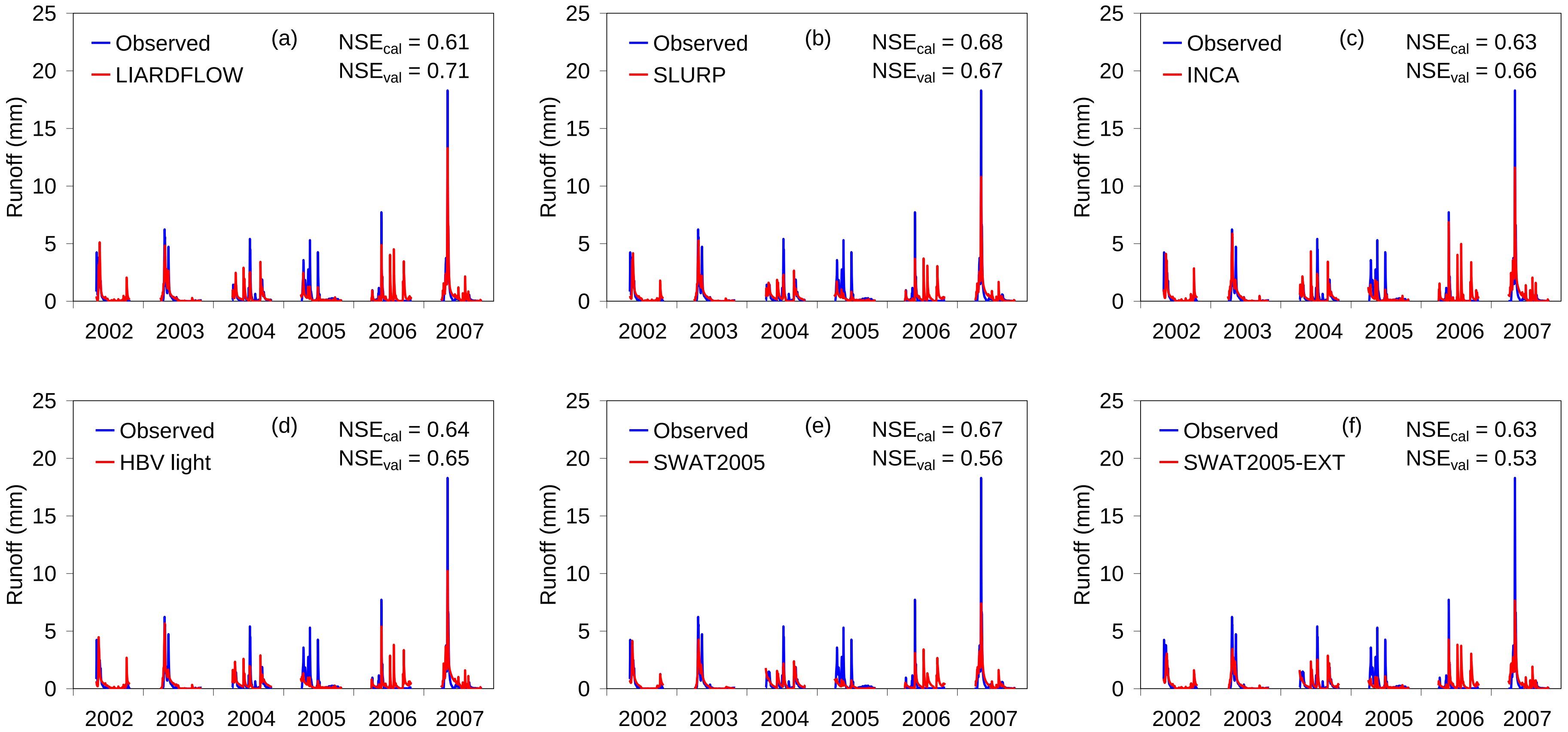
Results

- Monthly runoff – Groat Creek



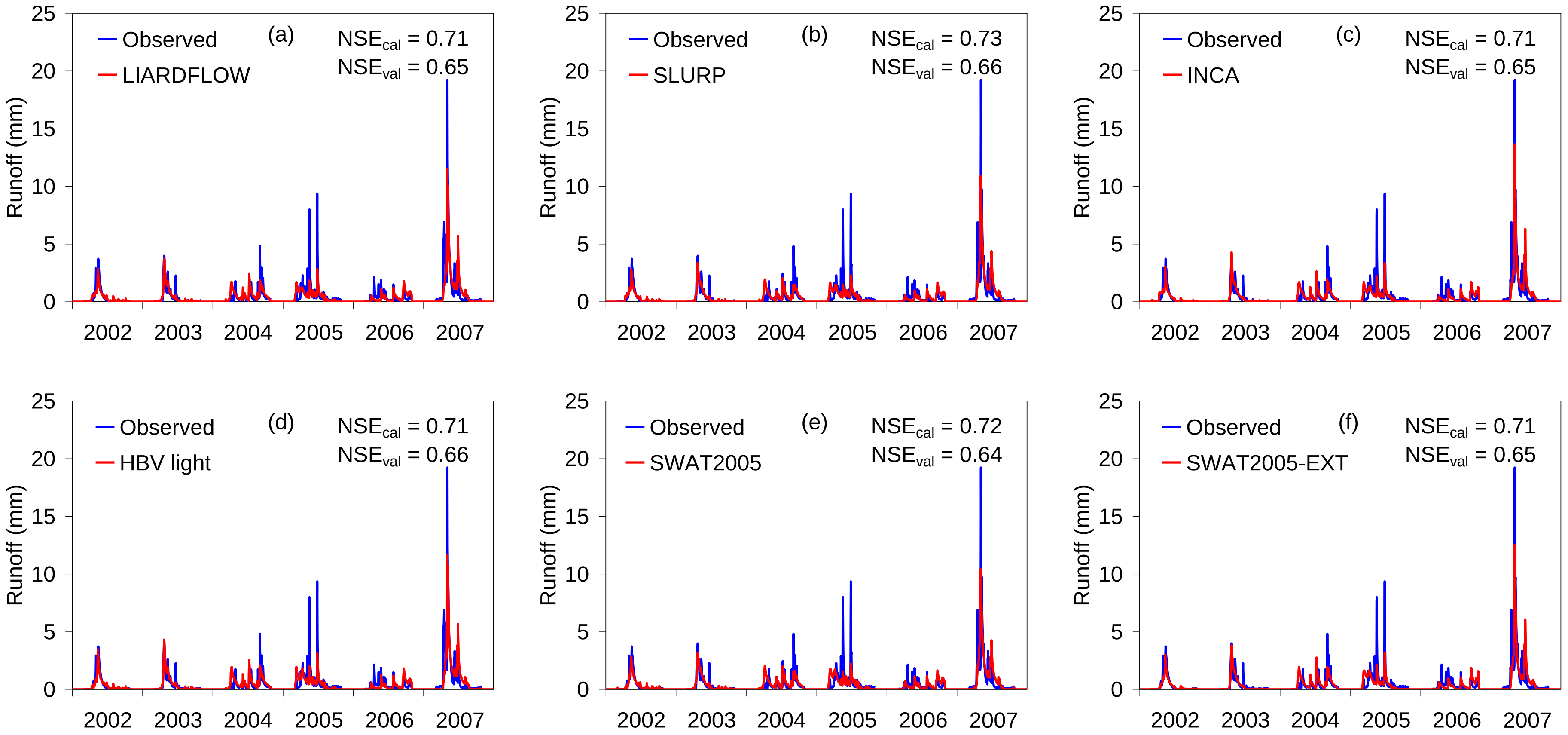
Results

- Daily runoff – Willow Creek



Results

- Daily runoff – Groat Creek



Discussion

- No major differences between overall performances of TI models
- Simpler TI models can perform just as well as more complex TI models
- Simulation of additional processes (snow cover, snowpack temperature, etc.) does not increase accuracy of runoff predictions

Discussion

- Sensitivity analysis performed for SWAT2005 and SWAT2005-EXT
- 4 most sensitive parameters calibrated

	Willow Creek				Groat Creek			
	Monthly		Daily		Monthly		Daily	
Model	Cal	Val	Cal	Val	Cal	Val	Cal	Val
SWAT2005	0.90	0.63	0.67	0.56	0.84	0.83	0.72	0.64
SWAT2005[4P]	0.81	0.62	0.60	0.56	0.80	0.81	0.67	0.61
SWAT2005-EXT	0.87	0.56	0.63	0.53	0.84	0.80	0.71	0.65
SWAT2005-EXT[4P]	0.85	0.63	0.60	0.56	0.80	0.75	0.68	0.54

Discussion

- Model performances relatively similar
- Sensitivity analysis worthwhile exercise
- Future work will determine least number of parameters that can be calibrated for each model and still produce satisfactory results
- Provide further insights into how complexity of TI models influence runoff predictions made by $SWAT_{BF}$
- This study is only the first step

Conclusion

- Overall performances of TI models similar
- Complex models did not outperform simpler models
- Utilisation of less complex TI models in $SWAT_{BF}$ not detrimental to prediction of runoff from two watersheds in a cold region
- Simpler model more parsimonious and will not be over parameterised

Thank you!

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