Hydrologic-Land Surface Modelling of a Complex System of the Saskatchewan River Basin under Precipitation Uncertainty

Fuad Yassin[1], Saman Razavi[1], Jefferson S. Wong[1], Alain Pietroniro[2], Howard Wheater[1]

[1]*Global Institute for Water Security, University of Saskatchewan. SK, Canada*

[2]*National Hydrology Research Center, Environment and Climate Change Canada, SK, Canada*

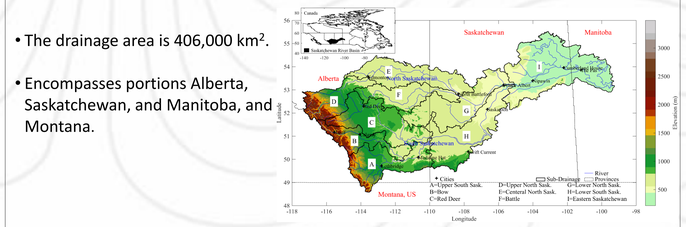
BACKGROUND AND MOTIVATION

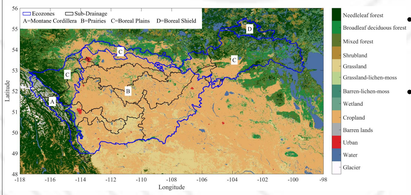
- To identify a suitable precipitation dataset for the H-LSM modeling based on: (1) precipitation error characteristics against ground-based observation, and (2) performance measure criteria based on streamflow simulation when used to drive default parametrized H-LSM.
- To conduct a multi-objective multi-station optimization approach, and evaluate the effectiveness of parameter transferability through validation in time and space, using independent multiple streamflow gauges.
- To test the model performance using multiple sources of observational information on model storage and output fluxes, to ensure that the optimal parameters obtained are as realistic as possible without error compensation across multiple outputs.

SASKATCHEWAN RIVER BASIN (SaskRB)

- The SaskRB presents a complex system characterized by hydrologically distinct regions that include the Rocky Mountains, Boreal Forest, and the Prairies, all of which affect the regional and global hydroclimate in unique ways.

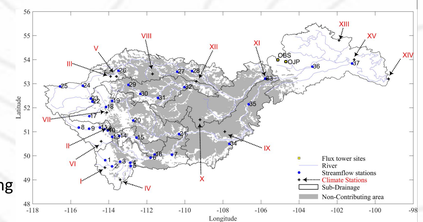
- The drainage area is 406,000 km^2.
- Encompasses portions Alberta, Saskatchewan, and Montana.

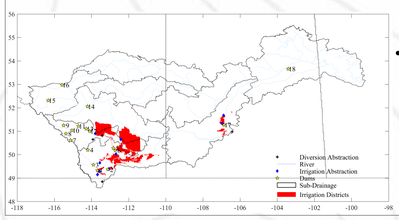




- SaskRB originates in the eastern slopes of the Canadian Rockies in Alberta and flow eastwards.
- The basin has four ecozones Montane Cordillera, Prairie, Boreal Plain, and Boreal Shield..

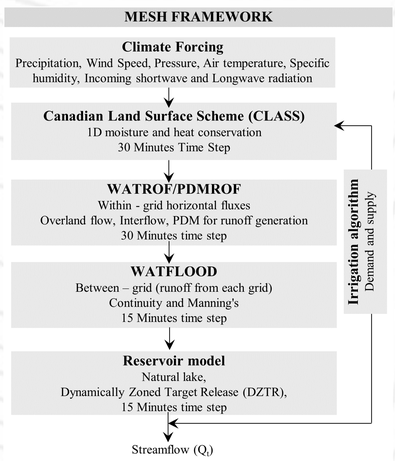
- 15 climate stations and 37 streamflow stations were used to evaluate climate dataset.
- The pothole topography prevents some areas from draining to the major river system the are commonly called “non-contributing areas”



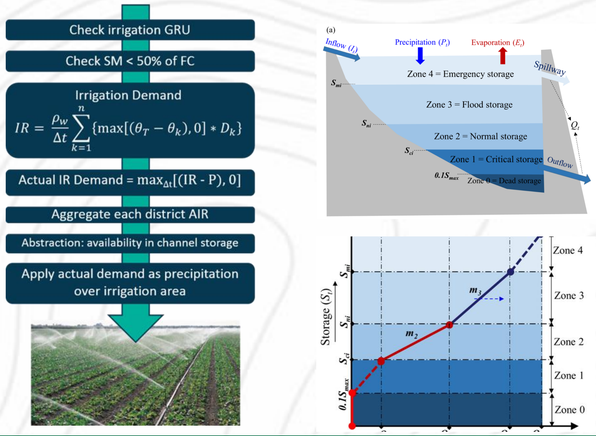


- SaskRB is regulated by many reservoirs, irrigation, and diversions, this study include 18 major reservoirs, and around 1.5 million acres irrigated area, and irrigation and non irrigation diversion.

MODELLING METHODOLOGY



Irrigation and Reservoir representation



MATERIALS AND METHODOLOGY

Precipitation dataset

Dataset	Full Name	Type	Spatial Resolution	Temporal Resolution	Duration	Coverage	Reference
CaPA	Canadian Precipitation Analysis	Station-based Model-derived	10 km (~0.0833˚)	6 hr	2002 – 2017	North America	Mahfouf et al. (2007)
Princeton	Global dataset at the Princeton University	Reanalysis-based multiple source	0.5˚ (~50 km)	3 hr	1901 – 2017	Global	Sheffield et al. (2006)
WFDEI [CRU]	Water and Global Change Forcing Data methodology applied to ERA-Interim [Climate Research Unit]	Reanalysis-based multiple source	0.5˚ (~50 km)	3 hr	1979 – 2017	Global	Weedon et al. (2014)
WFDEI [GPCC]	Water and Global Change Forcing Data methodology applied to ERA-Interim [Global Precipitation Climatology Centre]	Reanalysis-based multiple source	0.5˚ (~50 km)	3 hr	1979 – 2017	Global	Weedon et al. (2014)
NARR	North American Regional Reanalysis	Reanalysis-based multiple source	32 km (0.3˚)	3 hr	1979 – 2017	North America	Mesinger et al. (2006)

Multi-Criterion, Multi-Station calibration

$$\min_{x\in\theta} F(x) = \min_{x\in\theta}\left\{\left[\frac{\sum_i^m abs(F_{bias}(x)_i)}{m}\right] + \left[\frac{\sum_i^m -1*F_{nse}(x)_i}{m}\right] + \left[\frac{\sum_i^m -1*F_{lnse}(x)_i}{m}\right]\right\}$$

- Calibration (2003-2008), Validation (2009-2011),
- 60 % of the station model temporal calibration and validation, 40 % stations spatial validation

Parameter	Description	Range
	PDMROF parameters	
CMAX	Maximum storage parameter [m]	(0.01, 5)^{CJC,G}
B	Shape factor parameter []	(0.01, 10)^{CJC,G}
	WATROF parameters	
MANN	Manning's roughness coefficient 'n'	(0.05, 0.16)^{NF,BF,MF,SL} (0.05, 0.16)^{CGL,C,IC,B,BL}
KSAT	Saturated surface soil conductivity (m s^{-1})	(0.00001, 0.10)^{NF,BF,MF,SL} (0.00001, 0.10)^{CGL,C,IC,B,BL}
	River routing and baseflow parameters	
R2N	Channel Manning's rougness (N=9)	(0.03, 0.16)
R1N	Overbank Manning's rougness (N=9)	(0.03, 0.16)
LZF	Constant on lower zone function (N=9)	(1.0E-06, 1.0E-04)
PWR	Exponent on the lower zone storage (N=9)	(1.00, 3.00)
	CLASS parameters	
LAMAX	Annual maximum leaf area index	(3.00,10.00)^{BF} (3.00,5.00)^{CC,IC} (3.00,8.00)^{SL} (3.00,5.00)^{GG,GL} (0.50,3.00)^{NF}
LNZO	Natural logarithm of the roughness length	(0.00,1.10)^{BF} (-2.53,-1.05)^{CC,IC} (0.00,1.10)^{SL} (-3.91,-2.53)^{BF,GG,GL} (0.00,0.69)^{NF} (-4.60,-3.90)^{BB,BL}
ALVC	Average visible albedo when fully leafed	(0.02,0.10)^{BF} (0.02,0.10)^{CC,IC} (0.02,0.10)^{SL} (0.02,0.10)^{GG,GL} (0.02,0.10)^{NF} (0.02,0.10)^{BB,BL}
ALIC	Average near-infrared albedo when fully leafed	(0.20,0.40)^{BF} (0.20,0.40)^{CC,IC} (0.20,0.40)^{SL} (0.20,0.40)^{GG,GL} (0.20,0.40)^{NF} (0.20,0.40)^{BB,BL}
SDEP	Soil permeable depth (m)	(0.7, 4.1)^{NF,BF,MF,SL,GL,BB,BL}

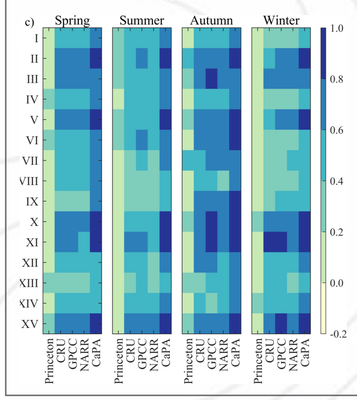
Ranges for different land-cover types: NF= Needleleaf Forest, BF=Broadleaf Forest, MF= Mixed Forest, SL=Shrubland, G=Grassland, GL=Grassland lichen moss, B=Barrenland, BL=Barren lichen moss, C=Cropland, IC, Irrigated Cropland, N number of classification over the basin

Precipitation Performance Measure	Equation
Percentage of Bias (P_{bias})	$\frac{\sum_t^N(G_i - R_i)}{\sum_t^N(R_i)} \cdot 100$
Root Mean Square Error (P_{rmse})	$\sqrt{\frac{\sum_t^N(G_i - R_i)^2}{N}}$
Correlation Coefficient (P_r)	$\frac{\sum_t^N(G_i - \bar{G})(R_i - \bar{R})}{\sqrt{\sum_t^N(G_i - \bar{G})^2}\sqrt{\sum_t^N(R_i - \bar{R})^2}}$
Standard Deviation Ratio (P_{σ_G/σ_R})	$\sqrt{\frac{\sum_t^N(G_i - \bar{G})^2}{N}}\Big/\sqrt{\frac{\sum_t^N(R_i - \bar{R})^2}{N}}$

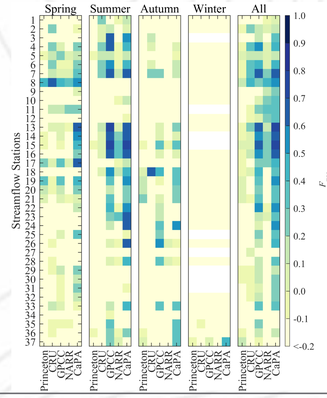
Streamflow Performance Measure	Equation
Percentage of Bias flow (F_{pbias})	$\frac{\sum(Q_{sim} - Q_{obs})}{\sum Q_{obs}} * 100$
Nash Sutcliffe Efficiency on flow (F_{nse})	$1 - \frac{\sum(Q_{obs} - Q_{sim})^2}{\sum(Q_{obs} - \bar{Q}_{obs})^2}$
Nash Sutcliffe Efficiency on log flow (F_{lnse})	$1 - \frac{\sum(ln(Q_{obs}) - ln(Q_{sim}))^2}{\sum(ln(Q_{obs}) - ln(\bar{Q}_{obs}))^2}$

RESULTS

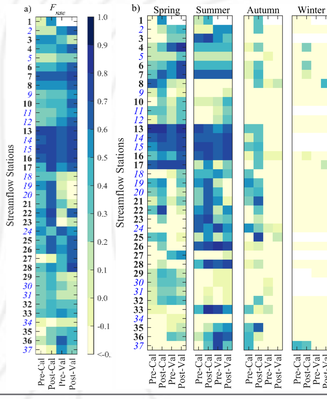
P_r Correlation b/n precipitation data & climate station



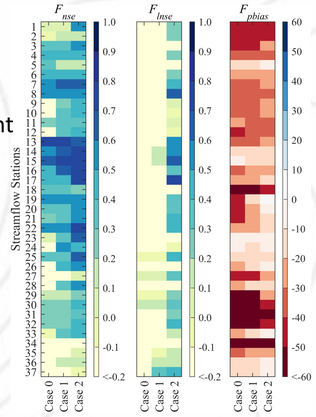
F_{NSE} (Streamflow simulation five precipitation data)



Model calibration & Validation F_{NSE} (CaPA Precipitation)



RESULTS

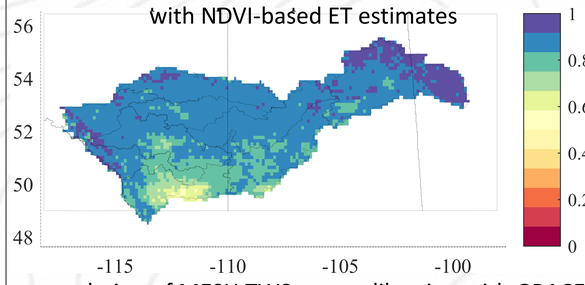


Case 0:
- no water management
- No calibration

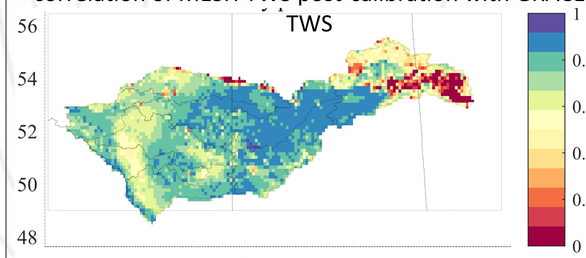
Case 1:
- water management
- no calibration

Case 2:
- water management
- calibration

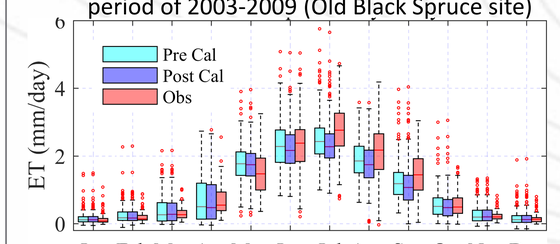
Correlation of MESH ET simulations post-calibration with NDVI-based ET estimates



correlation of MESH TWS post-calibration with GRACE TWS



Obs and sim pre and post-calibrated daily ET for the period of 2003-2009 (Old Black Spruce site)



References

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