Stochastic generation of precipitation and temperature: from single-site to multi-site

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Daily weather generators

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(1) Single-site weather generator: WeaGETS

(http://www.mathworks.com/matlabcentral/fileexchange/29136-stochastic-weather-generator--weagets)

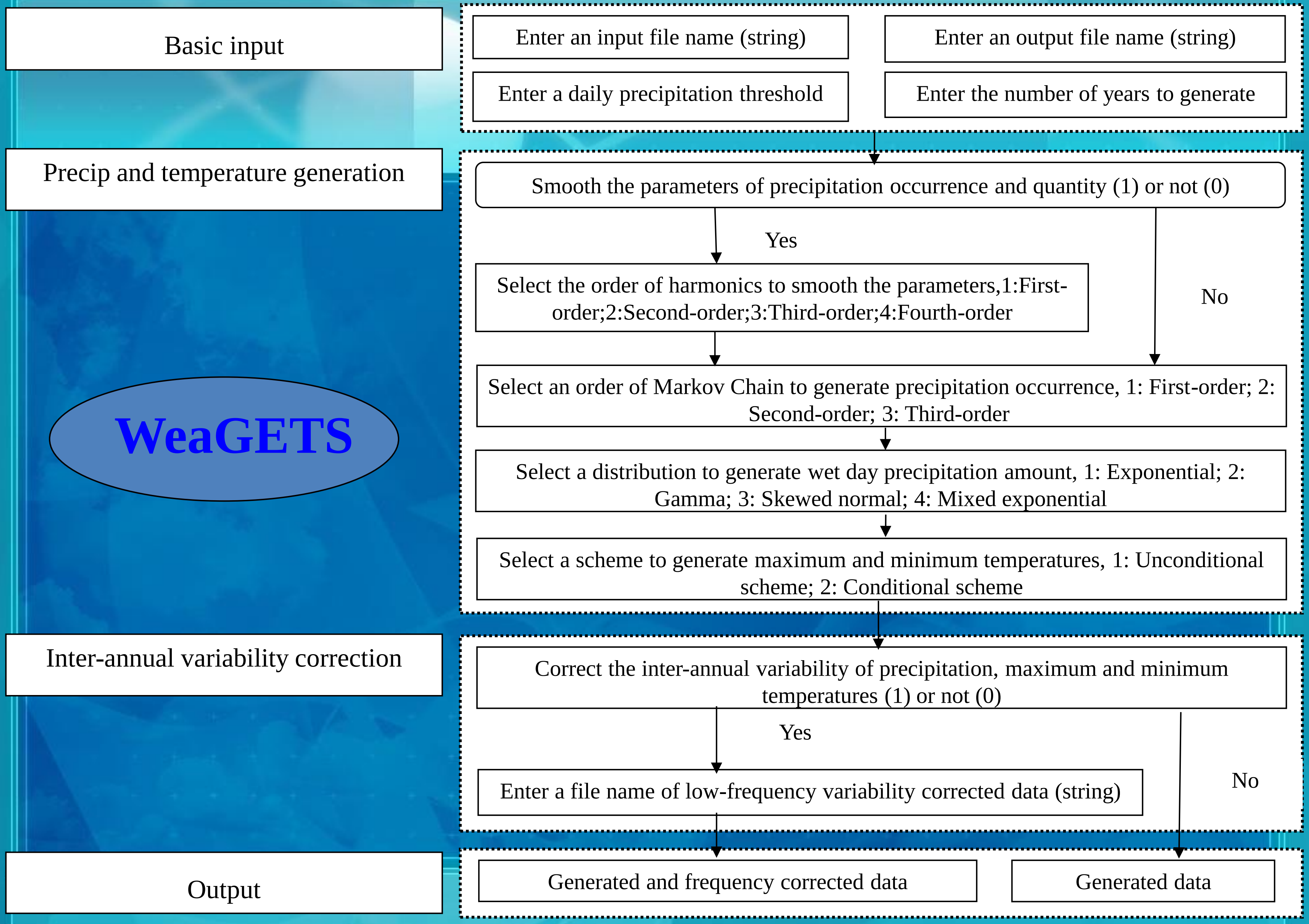
(2) Multi-site weather generator: MulGETS

(http://www.mathworks.com/matlabcentral/fileexchange/47537-multi-site-stochstic-weather-generator--mulgets)

Key problems (single-site)

Parametric distribution based weather generators

- Underestimation of heavy and extreme precipitation
  - Using compound distributions
- Underestimation of inter-annual variability
  - FFT based spectral correction method



Basic input
Enter an input file name (string)
Enter an output file name (string)
Enter a daily precipitation threshold
Enter the number of years to generate
Precip and temperature generation
Smooth the parameters of precipitation occurrence and quantity (1) or not (0)
Yes
No
Select the order of harmonics to smooth the parameters,1:First-order;2:Second-order;3:Third-order;4:Fourth-order
Select an order of Markov Chain to generate precipitation occurrence, 1: First-order; 2: Second-order; 3: Third-order
Select a distribution to generate wet day precipitation amount, 1: Exponential; 2: Gamma; 3: Skewed normal; 4: Mixed exponential
Select a scheme to generate maximum and minimum temperatures, 1: Unconditional scheme; 2: Conditional scheme
WeaGETS
Inter-annual variability correction
Correct the inter-annual variability of precipitation, maximum and minimum temperatures (1) or not (0)
Yes
No
Enter a file name of low-frequency variability corrected data (string)
Output
Generated and frequency corrected data
Generated data

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Precipitation occurrence

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Source		Ottawa (Wet station)				Churchill (Dry station)			
		OBS	M1	M2	M3	OBS	M1	M2	M3
Dry spell	Mean	3.0	3.0	3.0	3.0	3.2	3.2	3.2	3.2
	Stdev	2.6	2.4	2.5	2.5	3.0	2.8	2.8	2.9
	P25th	1	1	1	1	1	1	1	1
	P50th	2	2	2	2	2	2	2	2
	P75th	4	4	4	4	4	4	4	4
	P95th	8	8	8	8	9	9	9	9
	P99th	13	12	12	12	14	14	14	14
	Longest	25	29	30	28	43	32	31	39
	P value of K-S test	-	0.862	0.775	0.994	-	0.112	0.478	0.968
Wet spell	Mean	2.0	2.0	2.0	2.0	2.2	2.2	2.2	2.2
	Stdev	1.3	1.4	1.3	1.3	1.7	1.7	1.6	1.7
	P25th	1	1	1	1	1	1	1	1
	P50th	2	1	2	2	2	2	2	2
	P75th	2	2	2	2	3	3	3	3
	P95th	5	5	4	4	5	6	5	6
	P99th	7	7	7	7	9	8	8	9
	Longest	16	17	14	14	17	26	19	23
	P value of K-S test	-	0.000	1.000	1.000	-	0.119	0.328	1.000

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Precipitation amounts

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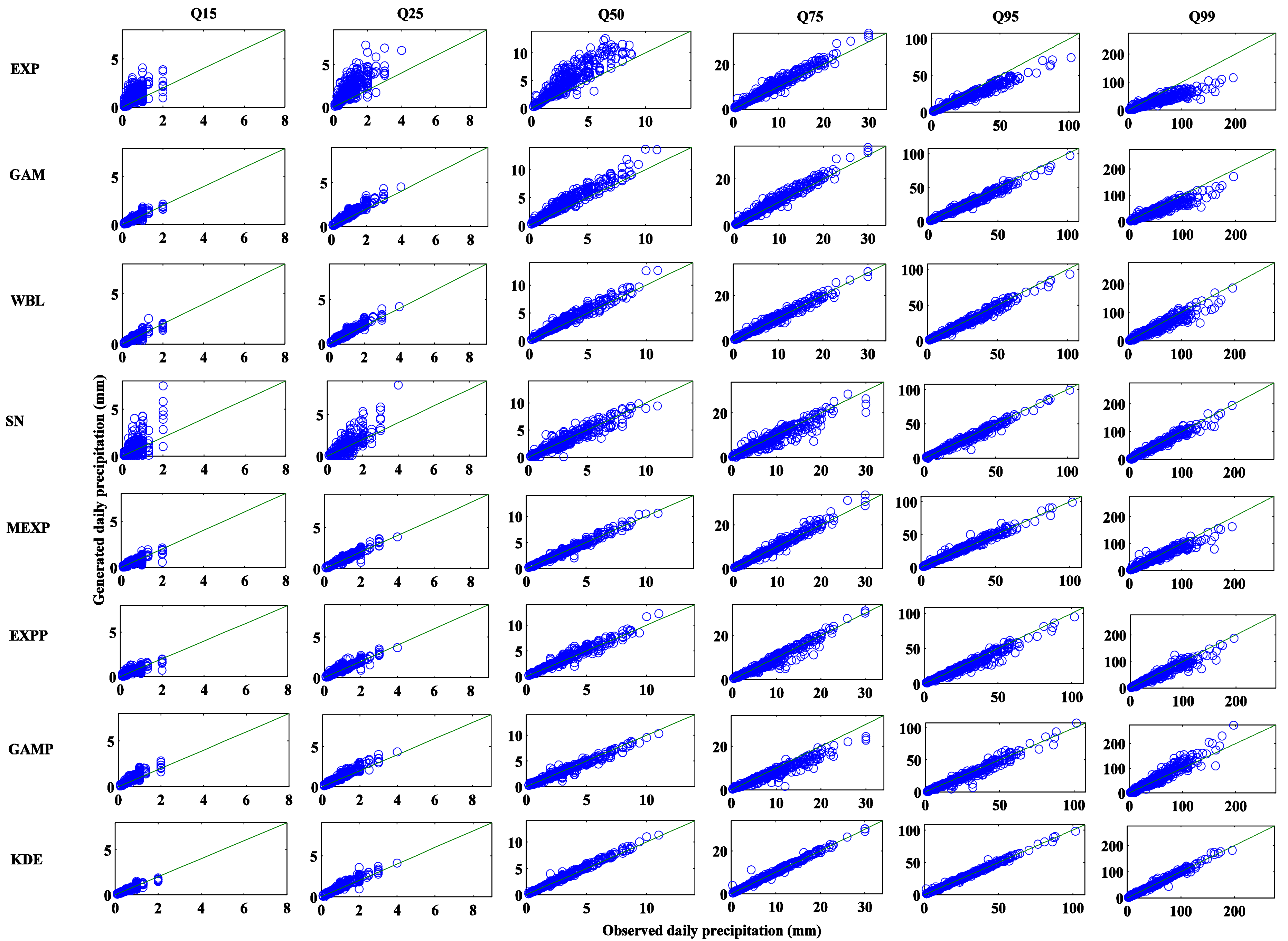
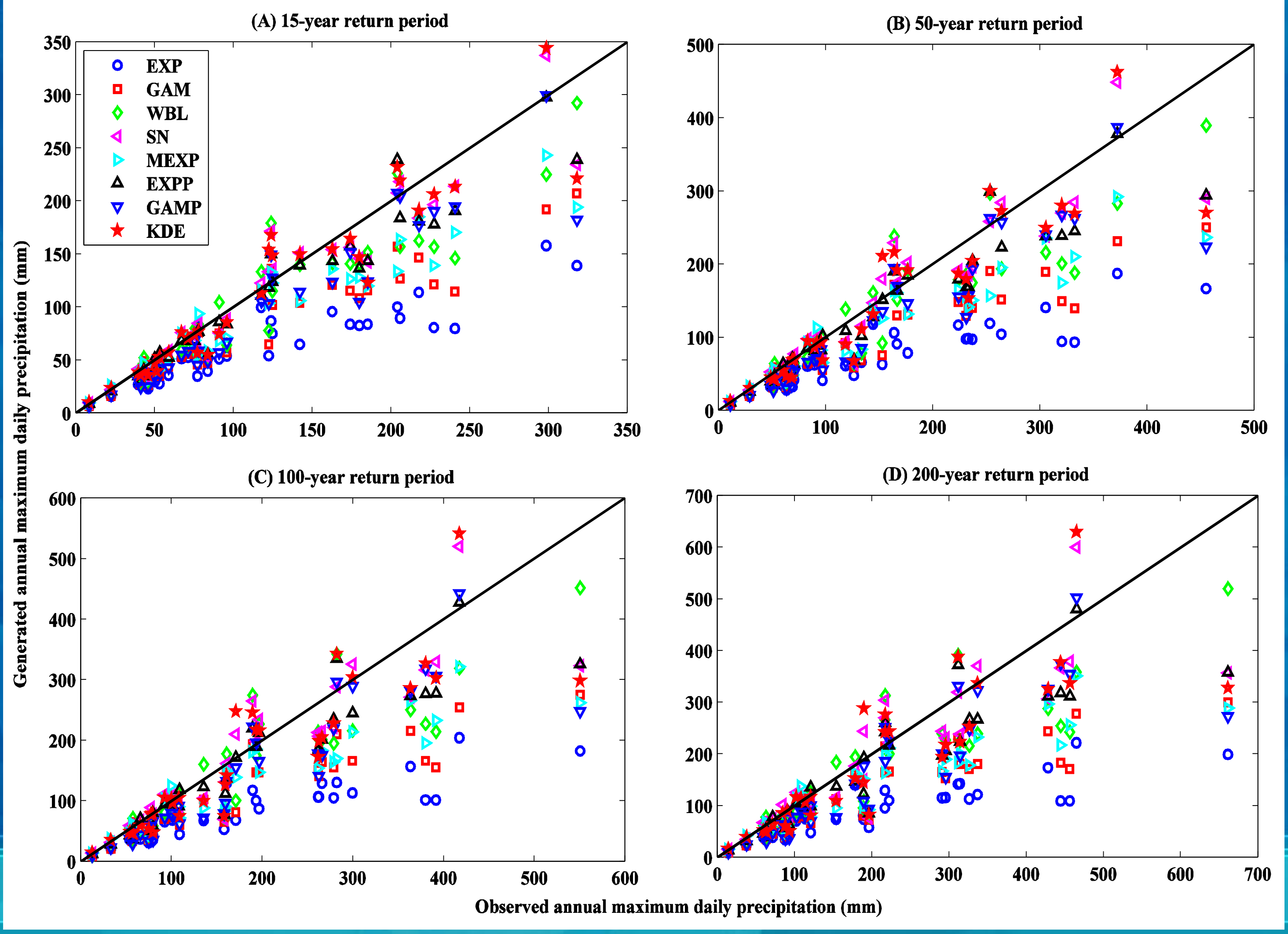
ID	Distribution	Abbreviation	Number of Parameters	Reference
1*	Exponential	EXP	1	Todorovic and woolhiser, 1975
2*	Gamma	GAM	2	Ison et al., 1971; Richardson and Wright, 1984
3	Weibull	WBL	2	Stöckle et al., 1999
4*	Skewed normal	SN	3	Nicks and Gander, 1994
5*	Mixed exponential	MEXP	3	Roldan and Woolhiser, 1982; Wilks, 1999b
6	Hybrid exponential and generalized Pareto	EXPP	3	Li et al., 2012a
7	Hybrid gamma and generalized Pareto	GAMP	4	Vrac and Naveau, 2008; Li et al., 2012a
8	Kernel density estimation	KDE	Nonparametric, Gaussian kernels	Sharma et al., 1997; Mehrotra and Sharma, 2007a, 2007b

Tested based on 35 stations around the world



Q15
Q25
Q50
Q75
Q95
Q99
EXP
GAM
WBL
SN
MEXP
EXPP
GAMP
KDE
Generated daily precipitation (mm)
Observed daily precipitation (mm)

Precipitation extreme (Frequency analysis)



EXP

GAM

WBL

MEXP

EXPP

GAMP

SN

KDE

Inter-annual variability correction

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Observed time series

FFT

$$C = X + i*Y \qquad (i = \sqrt{-1})$$

$$S = |C| = \sqrt{X^2 + Y^2}$$

$$\phi = \tan^{-1}(Y / X)$$

$$C = S * e^{(i*\phi)}$$

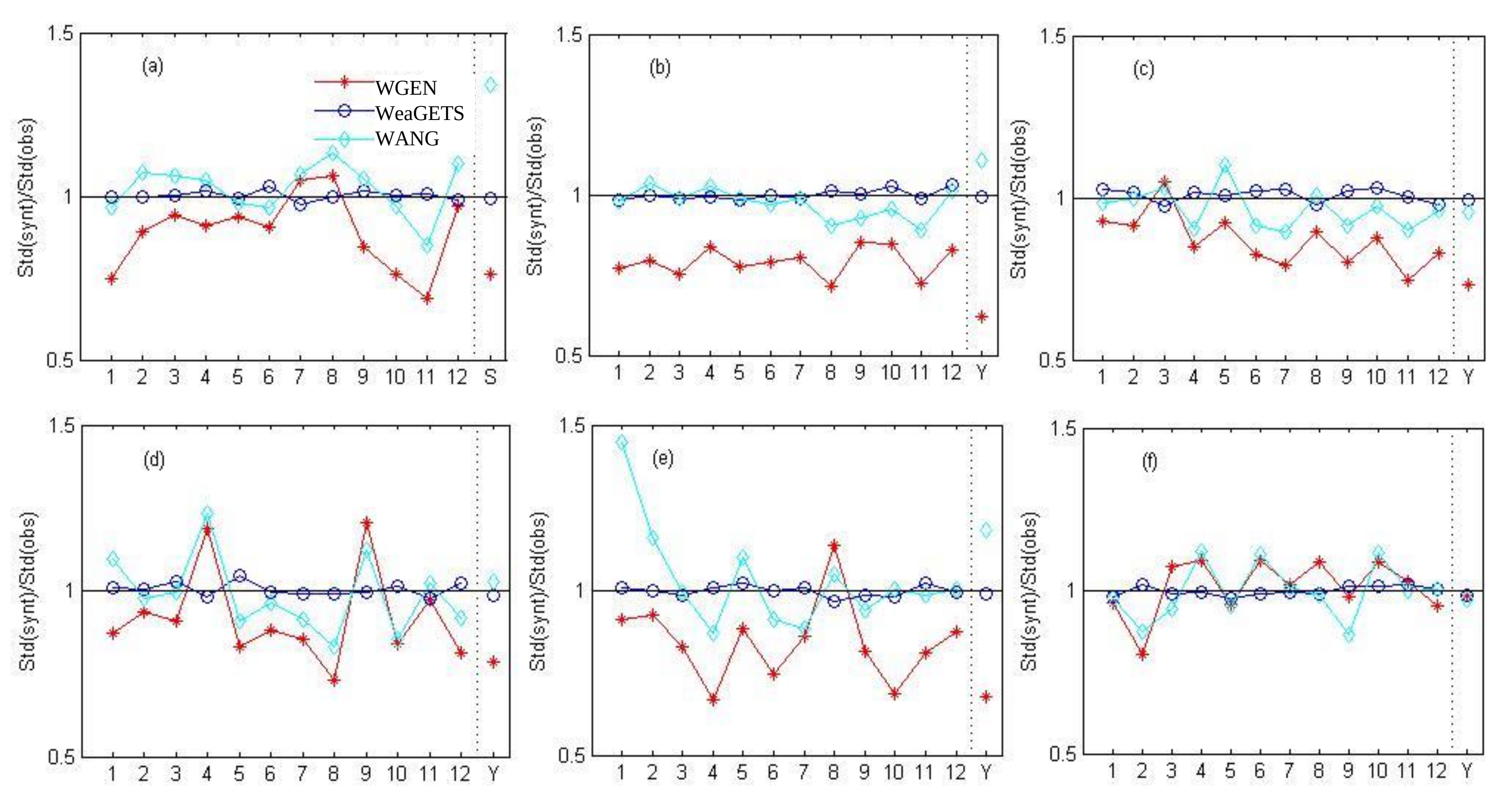
IFFT

Generated time series

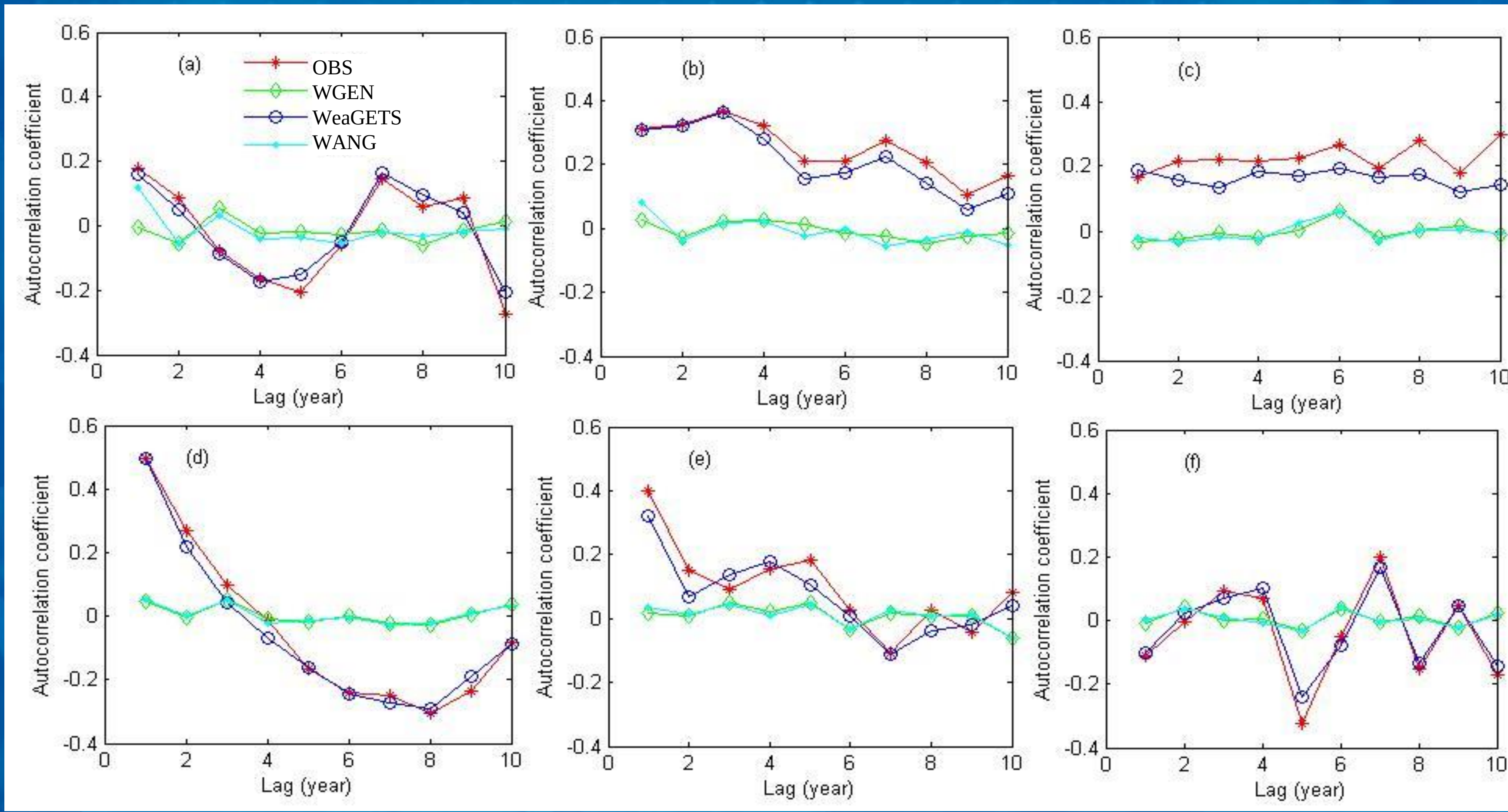
Correcting inter-annual variability for precipitation

Correcting inter-annual variability for temperature

Precipitation correction



Precipitation correction

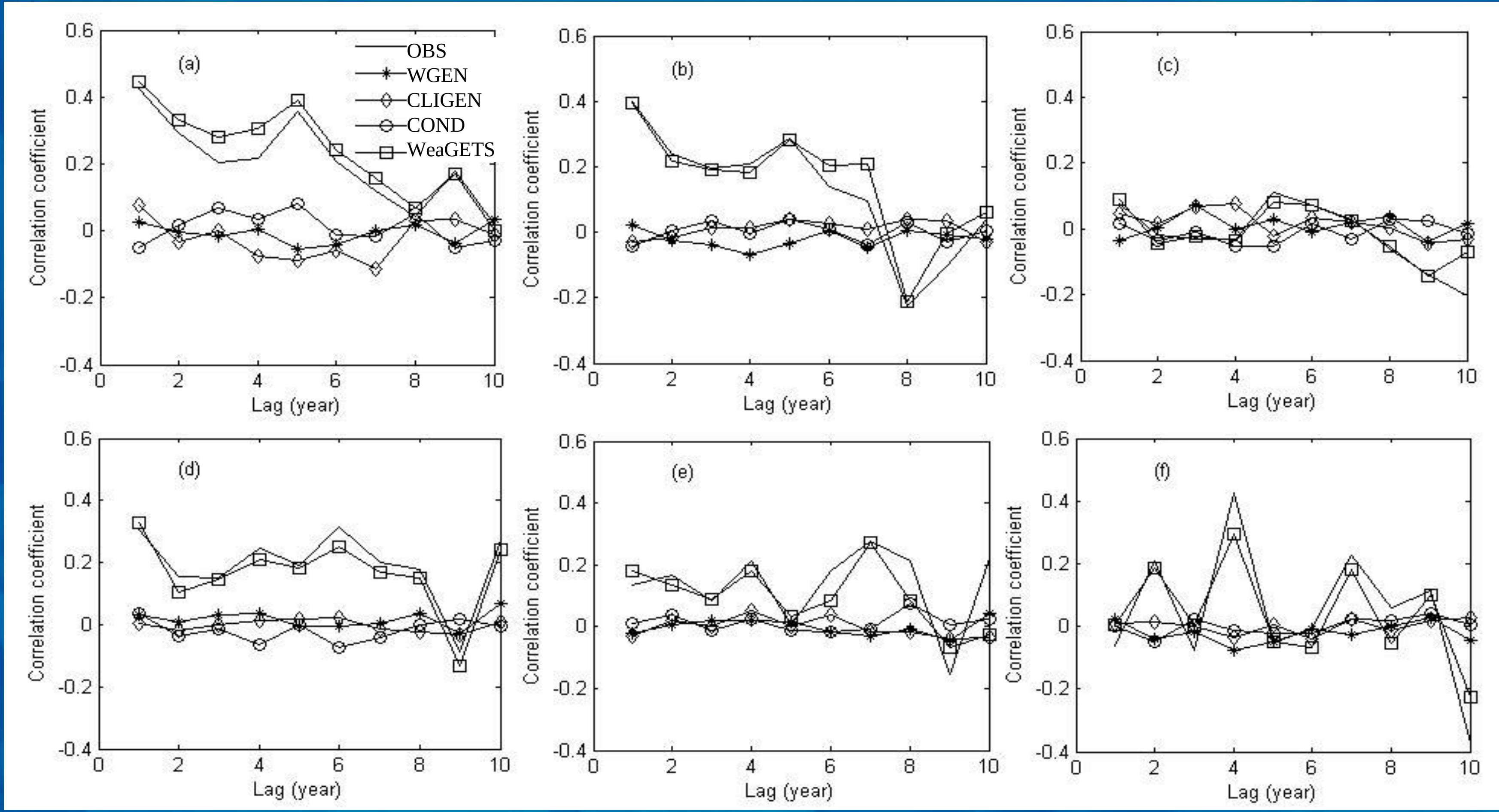


Temperature correction

Station	Tmax				Tmin			
	OBS	WGEN	CLIGEN	WeaGETS	OBS	WGEN	CLIGEN	WeaGETS
Victoria	0.67	0.22*	0.16*	0.67	0.59	0.27*	0.15*	0.59
Langara	0.66	0.19*	0.13*	0.65	0.72	0.26*	0.12*	0.71
VGR	0.88	0.29*	0.24*	0.88	0.95	0.55*	0.22*	0.94
Yellowknife	1.16	0.17*	0.35*	1.13	1.35	0.98*	0.35*	1.33
Churchill	1.25	0.23*	0.37*	1.21	1.18	0.70*	0.30*	1.12
Darval	0.66	0.18*	0.28*	0.64	0.82	0.65*	0.27*	0.79

* is different from observed time series at P = 0.05.

Temperature correction



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MulGETS

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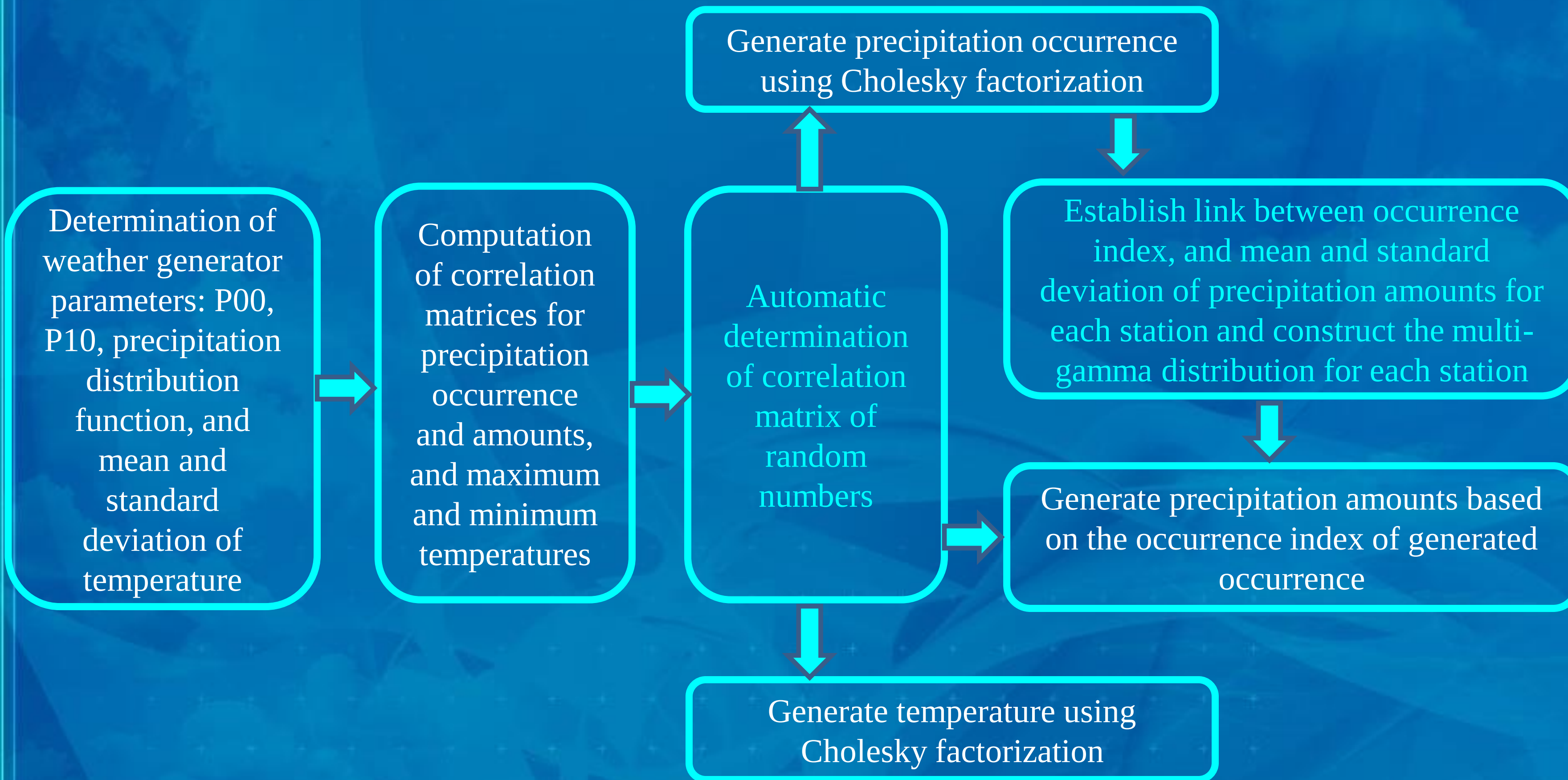
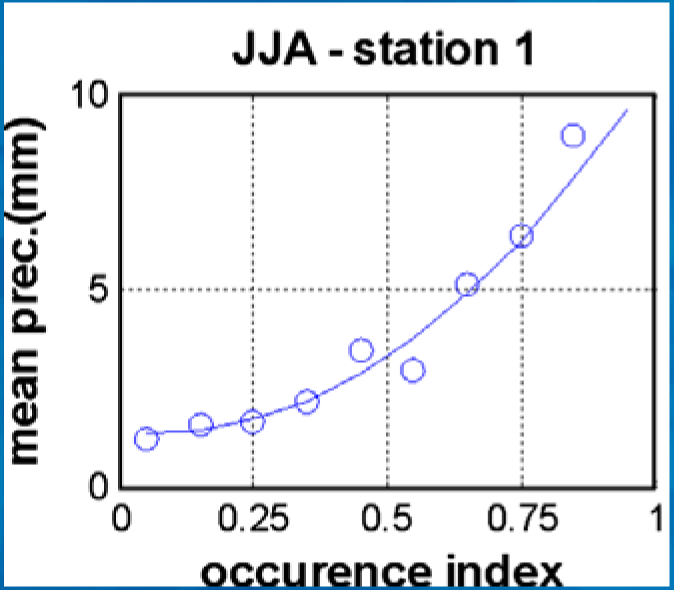


Key problems (multi-site)

- The generated precipitation occurrence and amounts are less correlated than the observed ones when using the observed correlation matrices to produce the spatially-correlated random number field.

$$C_{R_{i+1}} = C_{R_i} + \eta(C_{obs} - C_{syn})$$

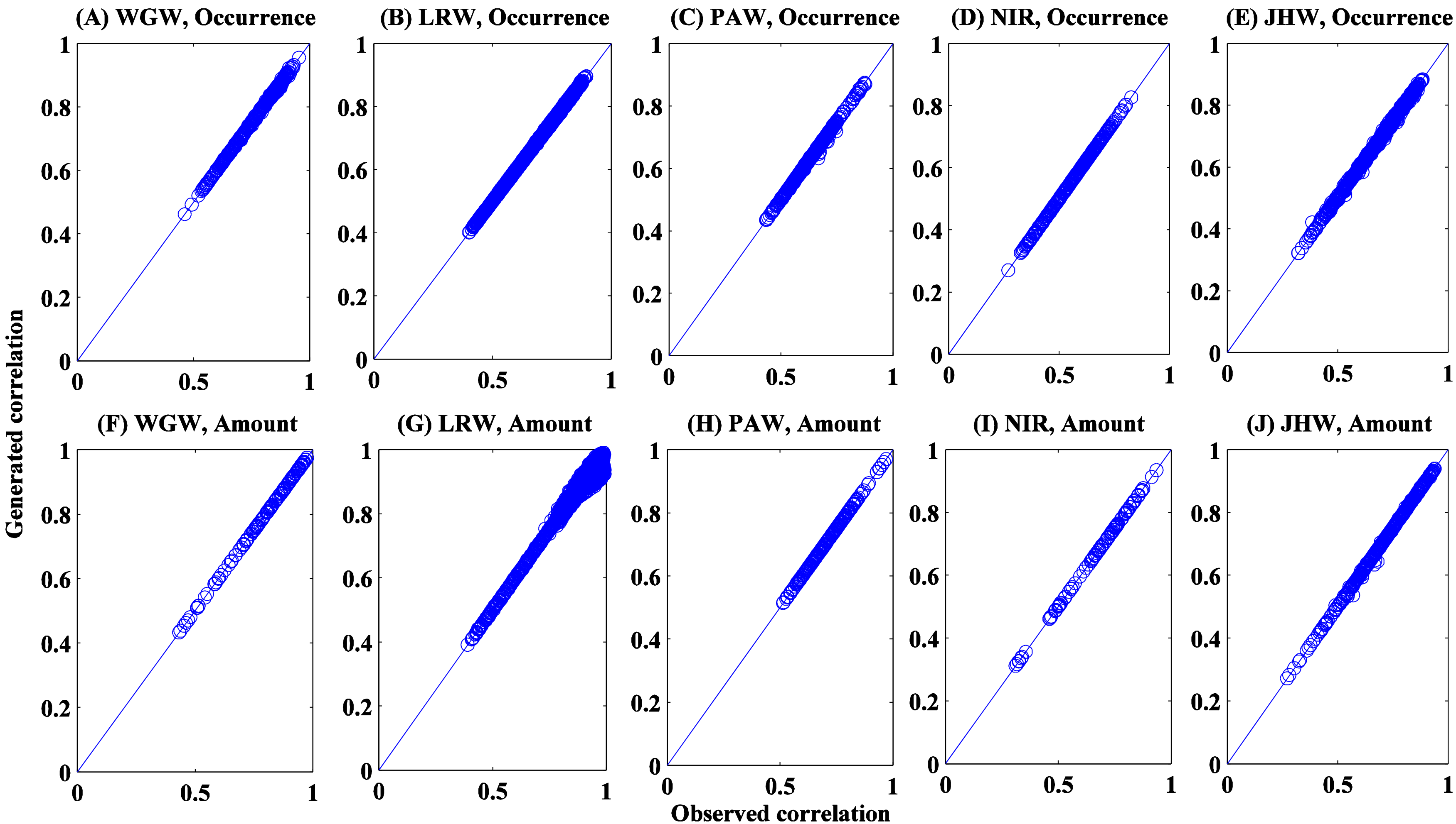
- The left equation may fail to converge when generating precipitation amounts when many of the elements of the correlation matrix of random numbers approach unity. (spatial intermittence)



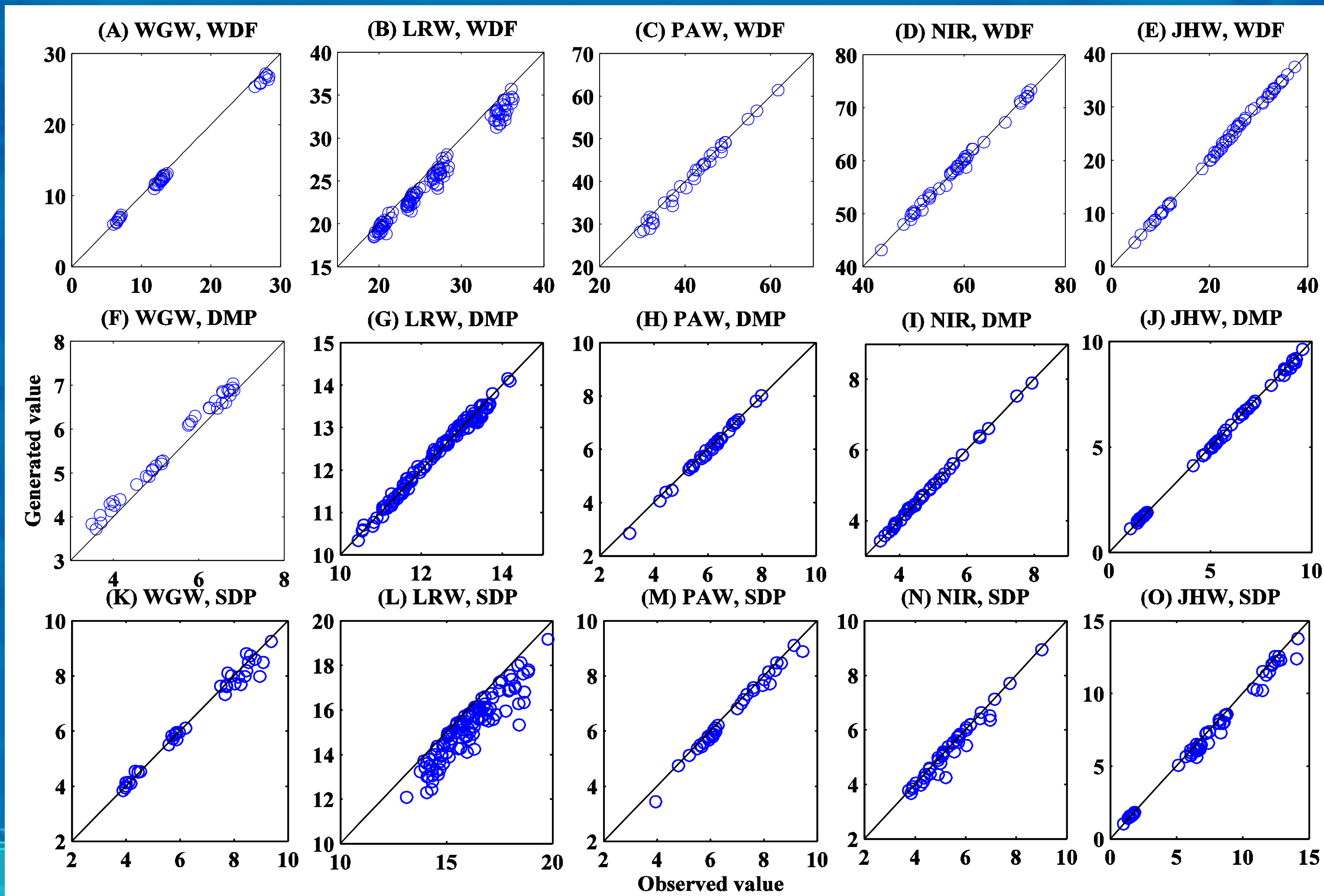
Evaluation of MulGETS

Country	Watershed name and abbreviation	Area (km^2)	Number of Stations	Common period for all stations	Mean annual precipitation (mm)
United States	Walnut Gulch Watershed (WGW)	149	9	1964-2012	312.0
United States	Little River Experimental Watershed (LRW)	334	28	1968-2009	1208.1
Canada	Peribonka Watershed (PAW)	9700	8	1964-1990	925.2
United Kingdom	Northern Ireland (NIR)	13843	11	1966-1985	1041.8
China	Jinghe Watershed (JHW)	45421	15	1961-2005	549.9

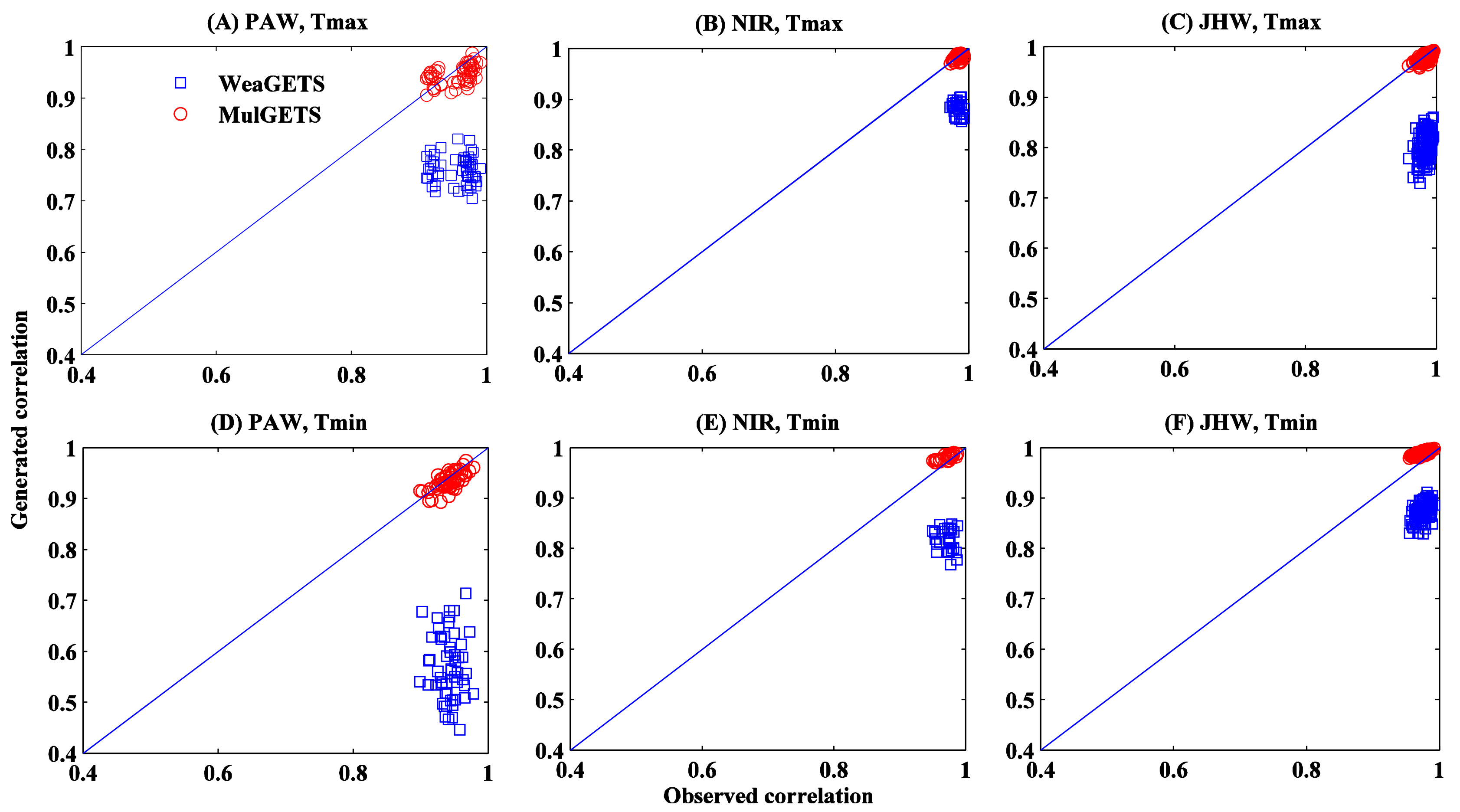
Precipitation correlation



Precipitation statistics



Temperature correlation



Hydrological modeling

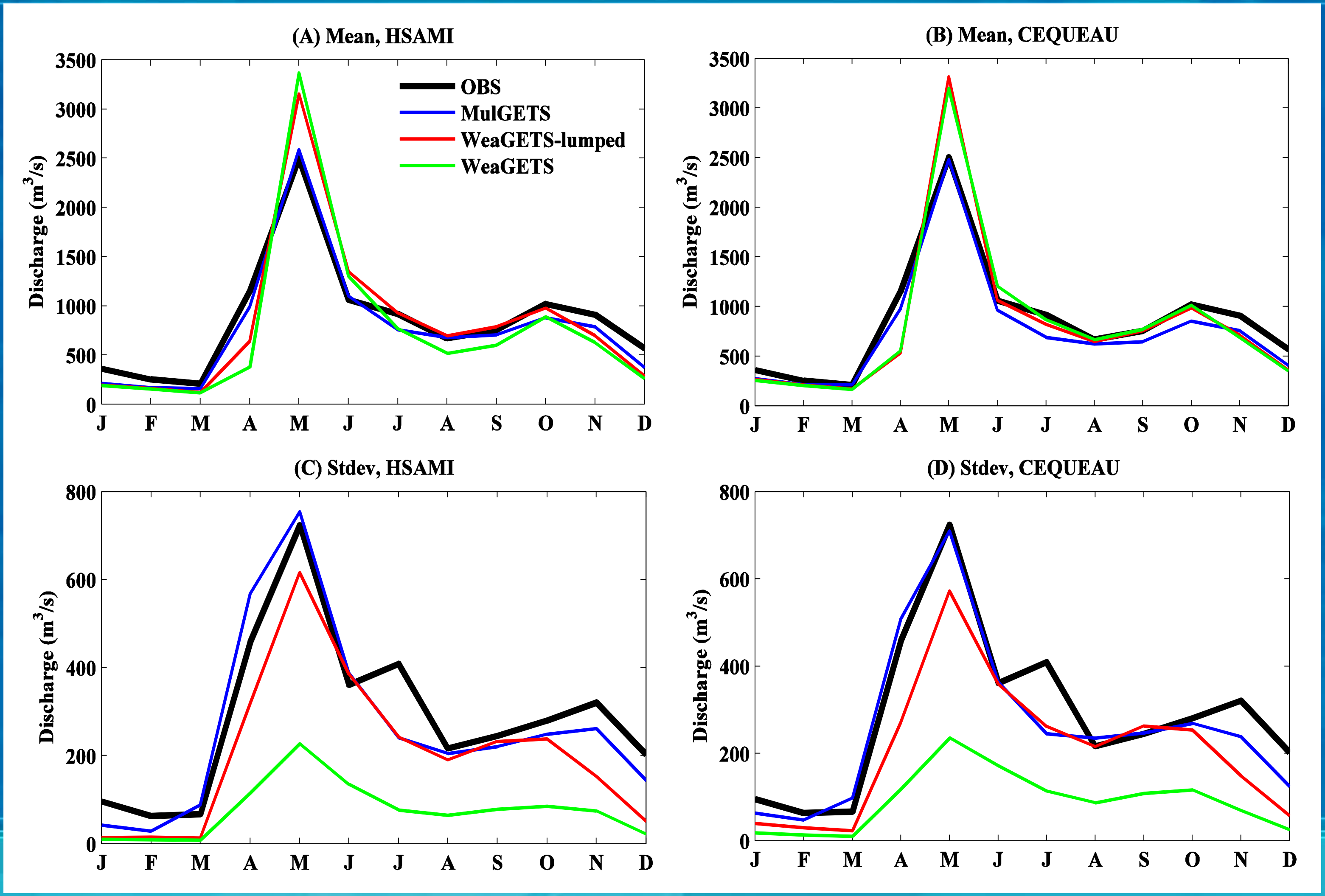
Watershed: Lac-Saint-Jean (45432 km^2)

Stations: 15 meteorological stations

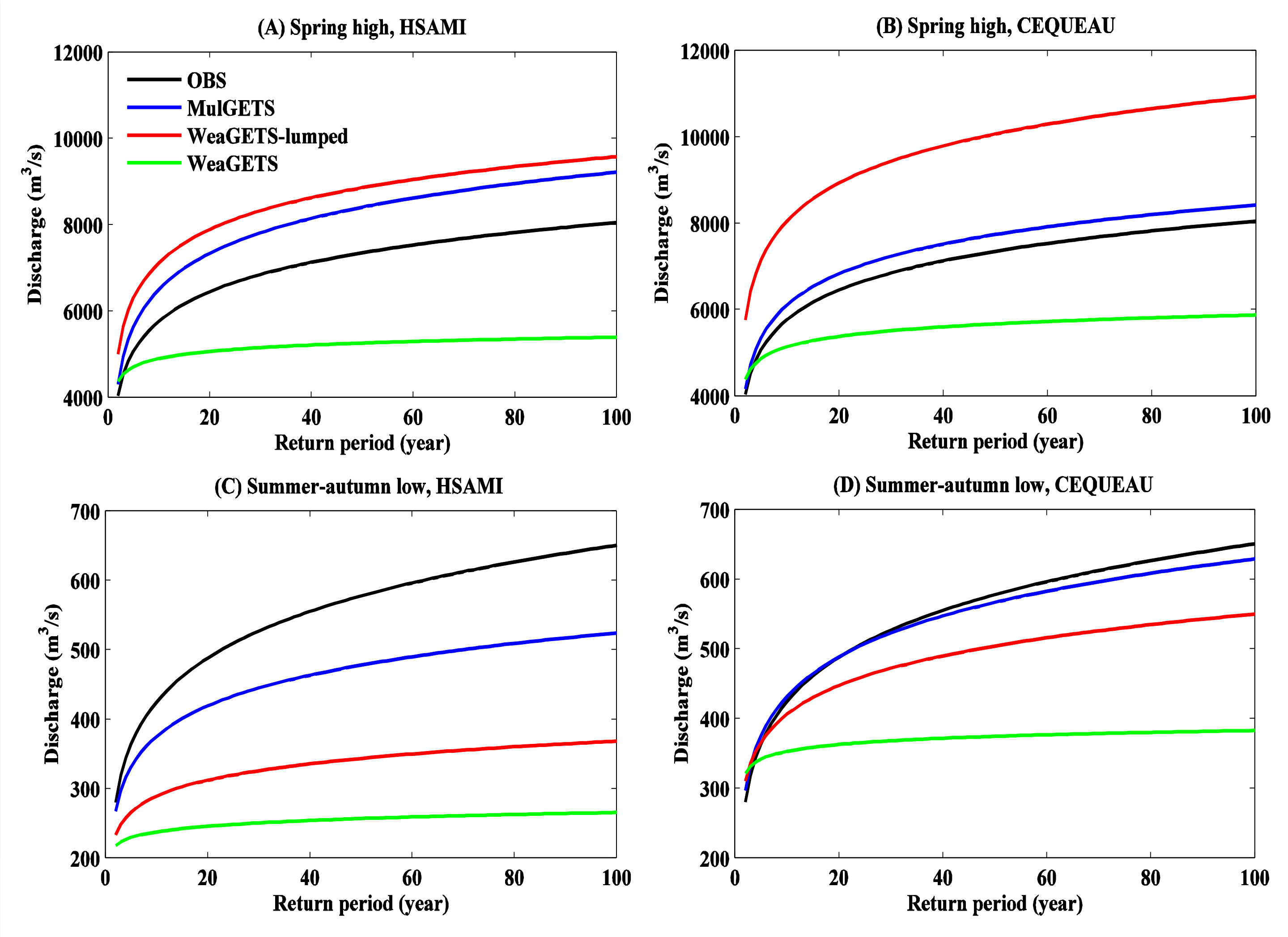
Time period: 1985-2010

Hydrological models: HSAMI (lumped model)
CEQUEAU (distributed model)

Mean and stdev of monthly flow



High and low flows (Frequency analysis)



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Thanks for your attention!