Accuracy of CFSR and WFDEI Precipitation Data for Brazil: Application in River Discharge Modelling of the Tocantins Catchment

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SWAT International Conference
Pula, Sardinia, Italy
24.06.2015

Hydrological Modelling - Input Data Challenges

Input data

- Landscape data
  - Topography (DEM)
  - Soil type
  - Soil cover (natural vegetation vs. land use)
  - (River network)
- Weather data
  - Temperature
  - Precipitation
  - (Solar radiation)
  - (Relative humidity)
  - (Wind speed)

Hydrological Modelling - Input Data Challenges

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- Weather data
  - Temperature
  - Precipitation
  - (Solar radiation)
  - (Relative humidity)
  - (Wind speed)
  - Impossible to reassess!

Alternatives to observed weather data

Name	Spatial res.	Temporal res.	Period	Reference
CRU	0.5°	Monthly	1901–2012	Jones et al. (1999)
MERRA	∼0.5°	Hourly	1979–present	Rienecker et al. (2011)
CFSR	∼0.312°	Daily	1979–2010	Saha et al. (2010)
ERA-Interim	0.75°	Daily	1979–present	Dee et al. (2011)
WFDEI	0.5°	3-hourly	1979–2012	Weedon et al. (2014)

CFSR

- First climate reanalysis that includes over the oceans
- More accurate representation of observed mean precipitation in tropical regions (Wang et al., 2012)

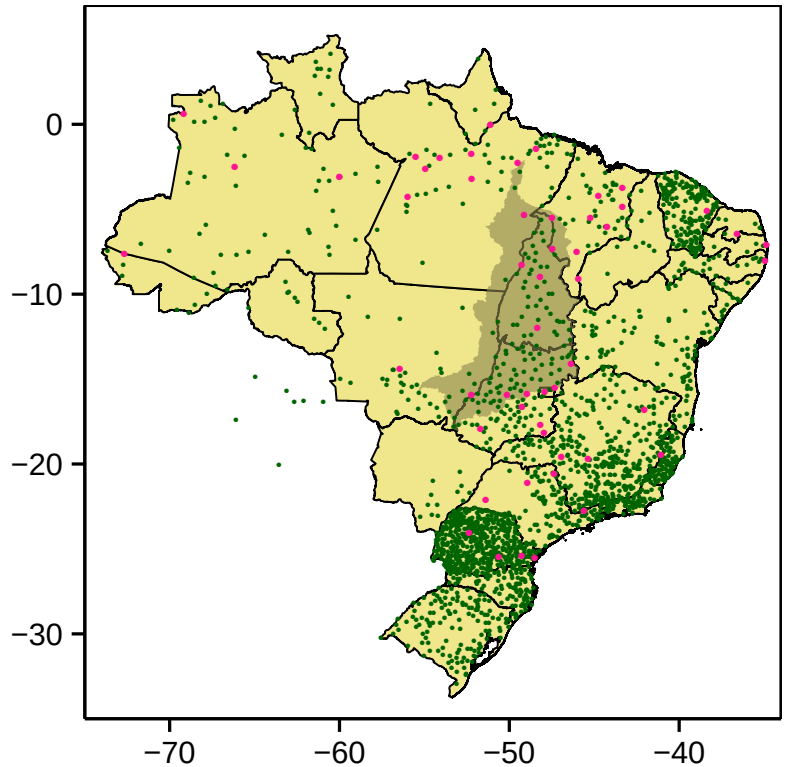
WFDEI

- WATCH Forcing Data (WFD) methodology applied to ERA-Interim (WFDEI)
- Highest temporal resolution

CFSR, WFDEI, INMET and ANA in Brazil

Availability and geographical distribution

- INMET observed data
  - 53* stations: 1980–2010
  - (15 in the Tocantins Catchment)
- ANA observed data (precipitation)
  - 1974* stations: 1980–2010
  - (105 in the Tocantins Catchment)
- CFSR
  - 7,223 grid cells
  - (651 in the Tocantins Catchment)
- WFDEI
  - 2,822 grid cells
  - (255 in the Tocantins Catchment)



* Series with <90% completeness

CFSR and WFDEI vs. Observations

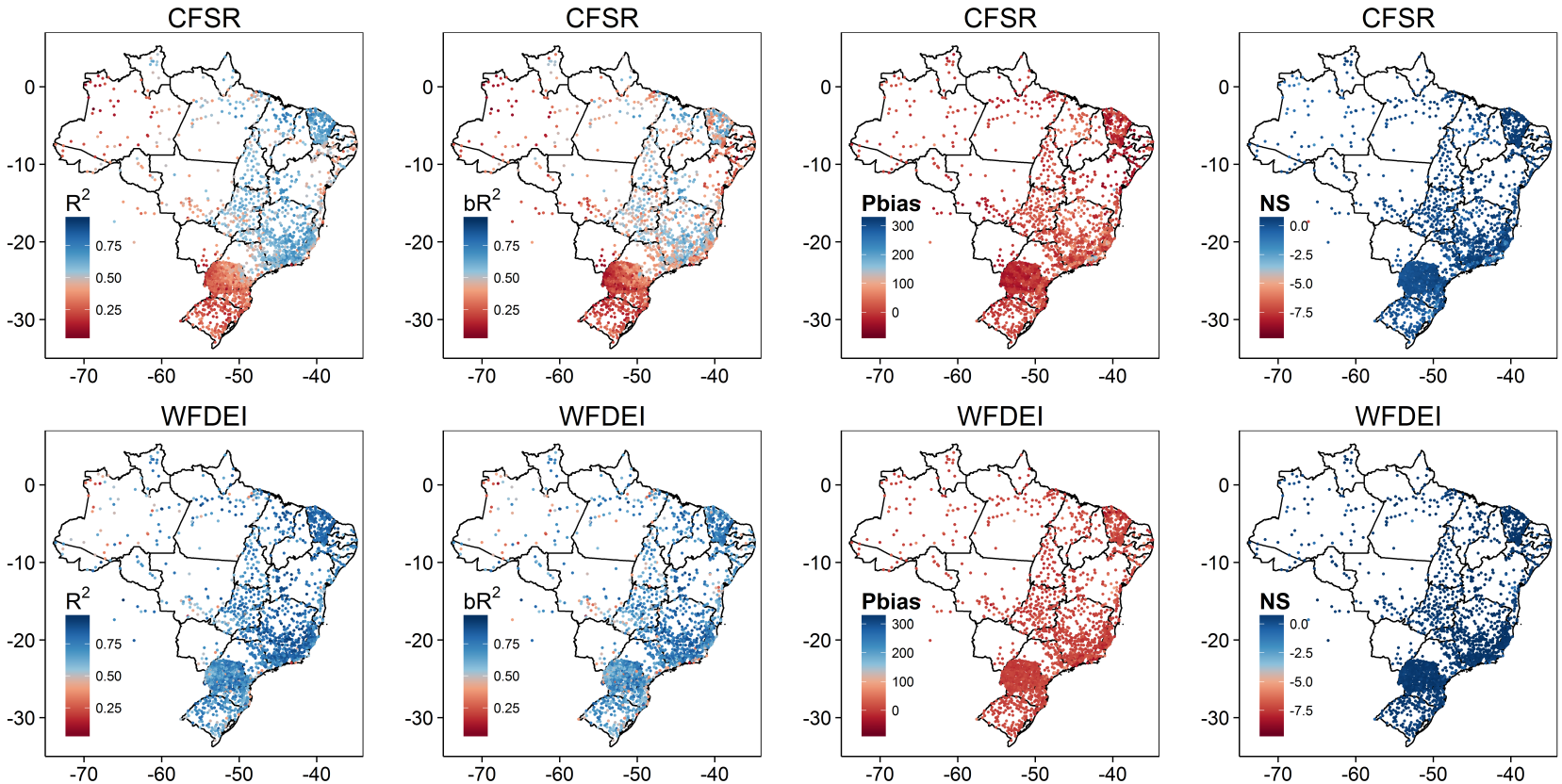
Methods

- Analysis restricted to precipitation
- Goodness of fit statistics
  - Each observation gauge was compared to the nearest CFSR and WFDEI grid cell
  - R^2: Coefficient of determination
  - bR^2: Slope $\times$ Coeff. of determination (Krause et al., 2005)
  - NS: Nash-Sutcliffe Efficiency (Nash and Sutcliffe, 1970)
  - Pbias: Percentage of bias
- Geographical trends
- Comparison of Goodness of fit statistics
  - Boxplot
  - Paired T-test

- Improve further best data set
  - $CF = \frac{Reanalysis}{Observation} \rightarrow \frac{Reanalysis}{CF} = Interpolation$
  - Observation = monthly cumulative precipitation
  - Observation = monthly averages

CFSR and WFDEI vs. Observations

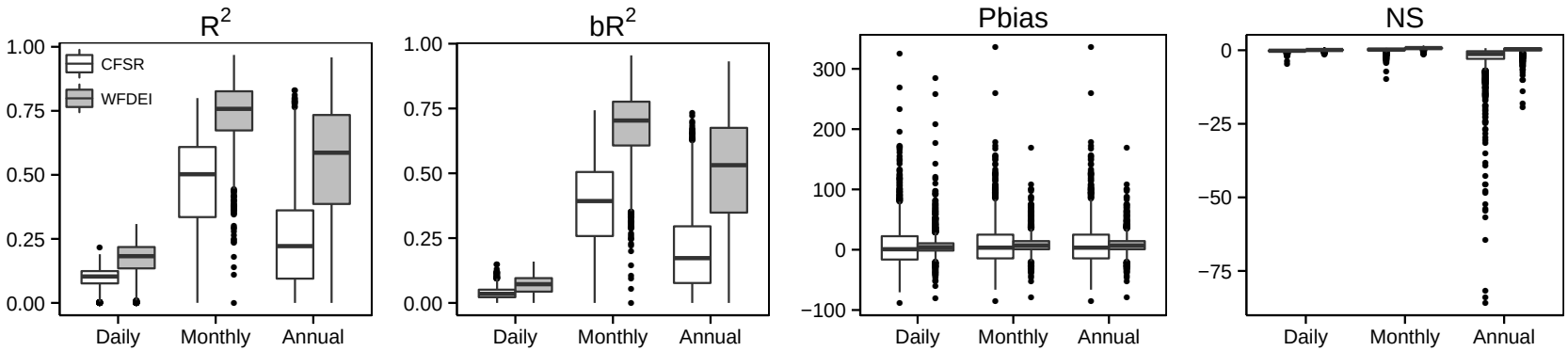
Results



- More general spatial variability in the performance of CFSR
- Worst CFSR performance along the coast and in the South (R^2 and bR^2)

CFSR and WFDEI vs. Observations

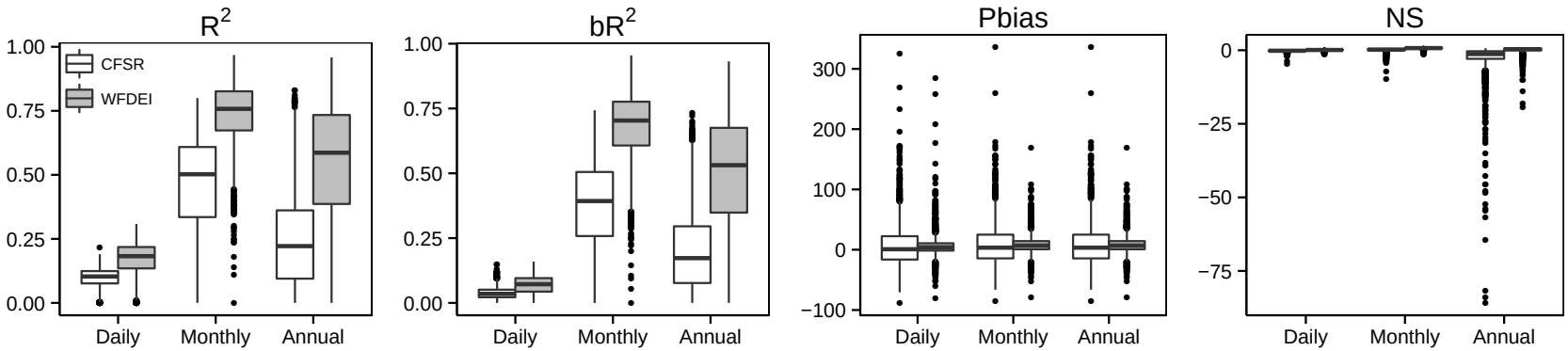
Results



- Monthly series had the best performance overall

CFSR and WFDEI vs. Observations

Results

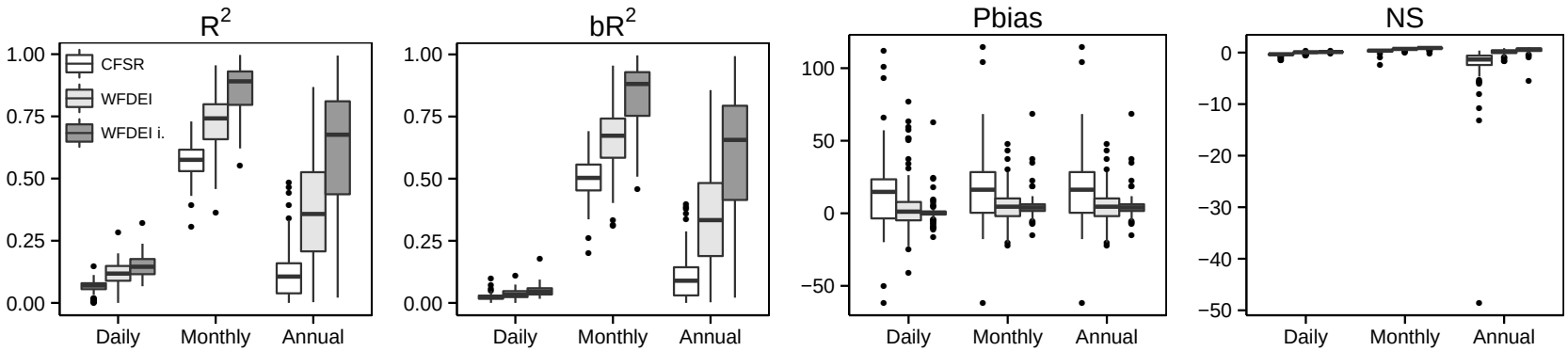


Statistics	$\tilde{x}$ CFSR	$\tilde{x}$ WFDEI	t	df	p
R^2	0.50	0.76	−96.8	2026	$\mathbf{p < 0.001}$
bR^2	0.39	0.68	−91.5	2026	$\mathbf{p < 0.001}$
Pbias	3.4	6.9	−0.031	2026	$p = 0.975$
NS	0.21	0.72	−46.8	2026	$\mathbf{p < 0.001}$

- Monthly series had the best performance overall
- Except for Pbias, all statistics indicated better performance by WFDEI

Interpolating WFDEI

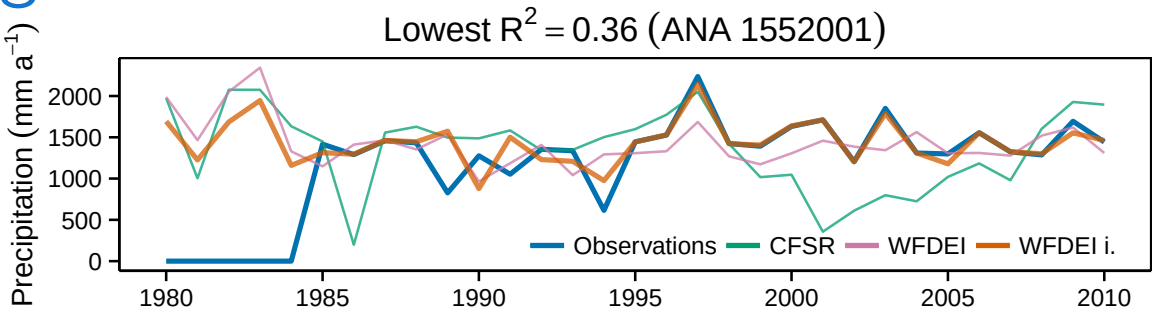
Results

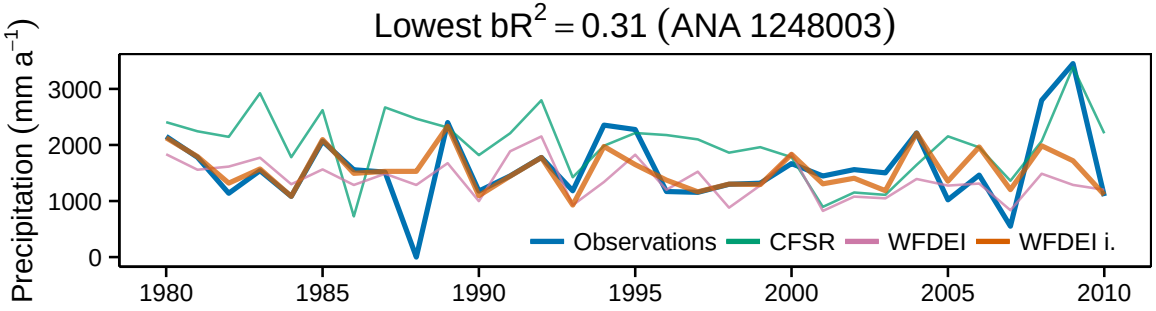


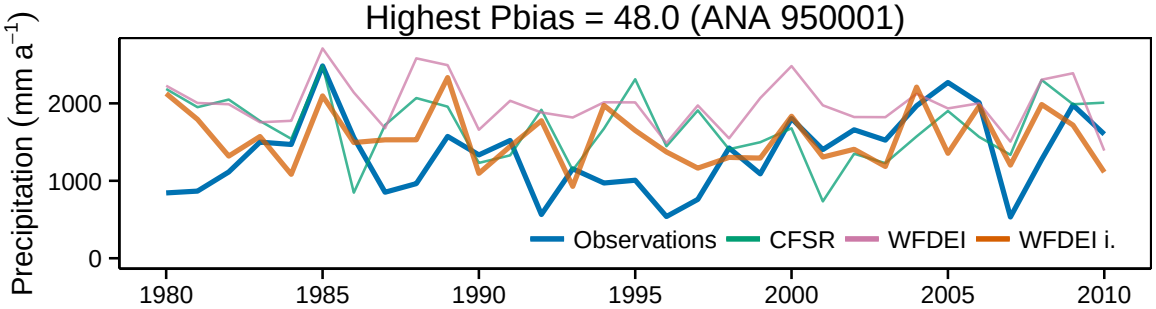
	Statistics	$\tilde{x}$ CFSR	$\tilde{x}$ WFDEI	t	df	p
CFSR vs. WFDEI (Tocantins)	R^2	0.58	0.74	−19.6	119	$\mathbf{p < 0.001}$
	bR^2	0.50	0.67	−14.6	119	$\mathbf{p < 0.001}$
	Pbias	16.3	4.6	5.7	119	$\mathbf{p < 0.001}$
	NS	0.37	0.71	−12.5	119	$\mathbf{p < 0.001}$
	Statistics	$\tilde{x}$ WFDEI	$\tilde{x}$ WFDEI i.	t	df	p
WFDEI vs. WFDEI i. (Tocantins)	R^2	0.74	0.89	−15.3	119	$\mathbf{p < 0.001}$
	bR^2	0.67	0.88	−15.0	119	$\mathbf{p < 0.001}$
	Pbias	4.6	4.0	−0.013	119	$p = 0.990$
	NS	0.71	0.89	−10.4	116	$\mathbf{p < 0.001}$

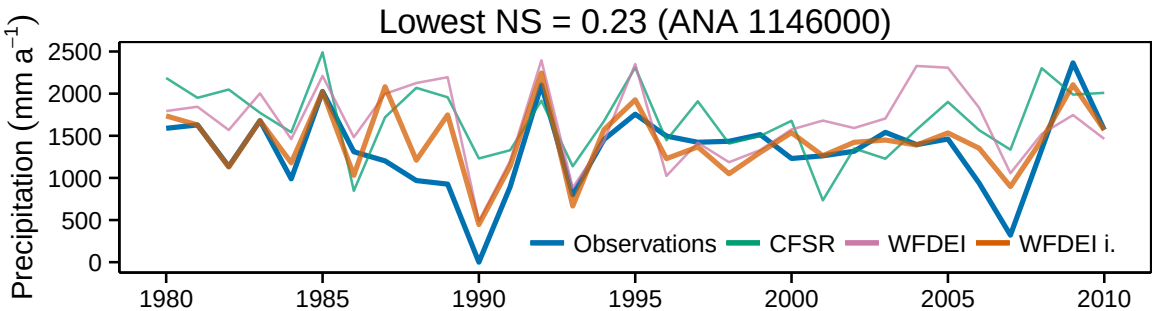
Interpolating WFDEI

Results







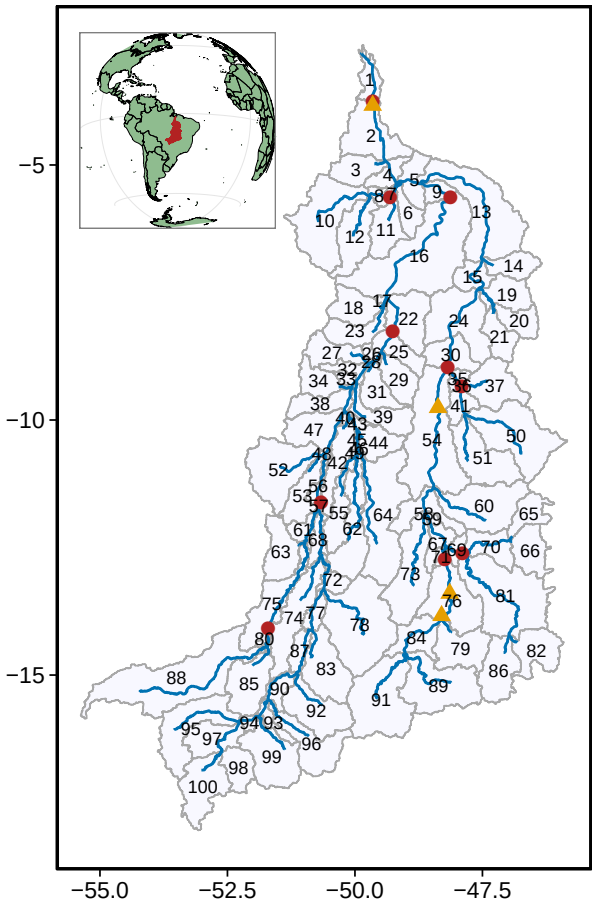


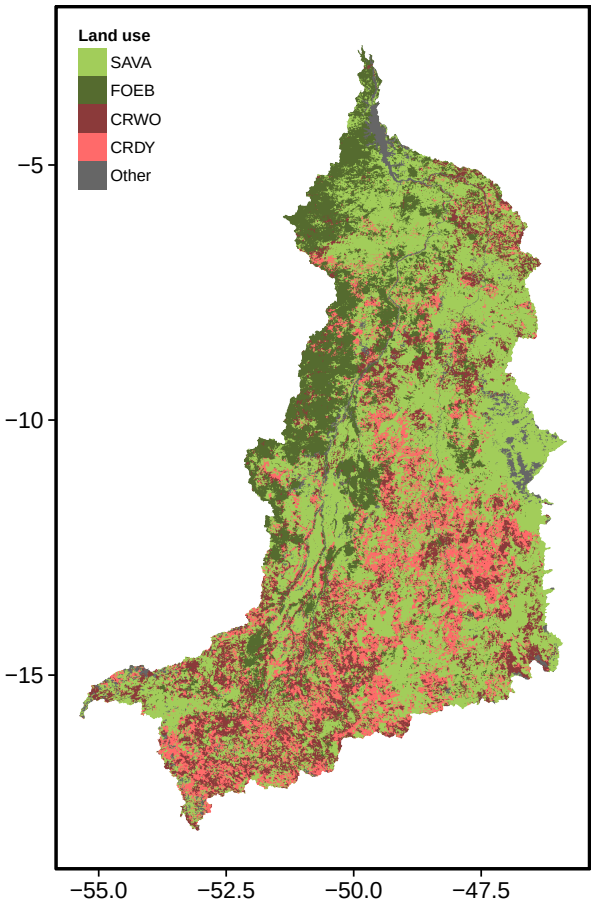
Tocantins Catchment SWAT Model

Model set up

Tocantins Catchment

- 803,250 km^2
- ∼51% Savannah, ∼16% Tropical forest
- Land conversion rate increasing from South towards North
- 10 river gauges
  3 dams
- SUFI2 with
  300 simulations





Tocantins Catchment SWAT Model

Uncalibrated Model Performance

		CFSR				WFDEI				WFDEI interpolated			
Gauge	Period	R^2	bR^2	NS	Pbias	R^2	bR^2	NS	Pbias	R^2	bR^2	NS	Pbias
Q_2 (16%)	Calib.	0.81	0.65	0.36	11.4	0.87	0.58	-0.01	44.4	0.88	0.45	-1.67	104.0
	Valid.	0.67	0.33	-3.48	110.8	0.83	0.54	-0.20	51.7	0.85	0.40	-2.75	122.1
Q_8 (4%)	Calib.	0.73	0.46	-0.78	49.5	0.92	0.78	0.78	11.1	0.90	0.62	0.37	49.2
	Valid.	0.71	0.36	-2.88	81.1	0.80	0.61	0.24	21.1	0.82	0.53	-0.14	54.5
Q_16 (7%)	Calib.	0.69	0.68	0.42	-13.3	0.70	0.52	-0.06	32.7	0.79	0.43	-1.39	97.2
	Valid.	0.62	0.50	-0.02	28.8	0.55	0.48	0.01	23.4	0.66	0.38	-1.33	95.6
Q_25 (17%)	Calib.	0.61	0.52	0.34	-23.4	0.59	0.48	-0.12	24.8	0.69	0.42	-0.95	74.5
	Valid.	0.61	0.48	-0.22	25.4	0.56	0.44	-0.48	29.5	0.66	0.35	-2.57	99.4
Q_41 (5%)	Calib.	0.74	0.74	-0.11	-19.8	0.89	0.75	0.16	-2.8	0.89	0.47	-3.02	67.9
	Valid.	0.81	0.60	-0.87	16.2	0.79	0.73	0.07	-6.7	0.89	0.45	-4.23	73.1
Q_54 (12%)	Calib.	0.88	0.73	0.73	22.8	0.87	0.49	-0.60	83.0	0.84	0.38	-2.78	135.1
	Valid.	0.47	0.15	-19.61	226.1	0.84	0.38	-4.20	107.5	0.76	0.26	-13.08	198.8
Q_57 (20%)	Calib.	0.60	0.49	0.02	-34.9	0.75	0.49	-0.89	40.5	0.73	0.34	-4.40	110.6
	Valid.	0.71	0.55	-0.31	17.9	0.75	0.43	-2.31	54.9	0.73	0.30	-8.23	130.4
Q_76 (8%)	Calib.	0.34	0.20	0.18	-30.9	0.52	0.41	-0.22	54.8	0.57	0.36	-1.06	89.5
	Valid.	0.71	0.45	-0.60	60.6	0.34	0.29	-0.74	44.4	0.43	0.33	-0.75	55.8
Q_80 (5%)	Calib.	0.39	0.17	-0.71	-65.4	0.84	0.60	-0.46	16.9	0.68	0.35	-4.08	84.7
	Valid.	0.85	0.66	0.22	-37.9	0.94	0.63	-1.23	22.9	0.70	0.33	-7.92	93.1
Q_81 (5%)	Calib.	0.80	0.50	-0.56	53.3	0.79	0.54	-0.07	42.0	0.65	0.33	-2.81	108.0
	Valid.	0.31	0.24	-2.13	39.3	0.30	0.29	-0.63	2.9	0.24	0.24	-0.93	13.5
Weigh. Aver.	Calib.	0.66	0.53	0.15	-9.4	0.75	0.53	-0.28	39.3	0.75	0.40	-2.31	96.6
	Valid.	0.64	0.42	-3.3	63.7	0.68	0.46	-1.22	44.2	0.69	0.34	-4.91	108.7

Tocantins Catchment SWAT Model

Uncalibrated Model Performance

		CFSR				WFDEI				WFDEI interpolated			
Gauge	Period	R^2	bR^2	NS	Pbias	R^2	bR^2	NS	Pbias	R^2	bR^2	NS	Pbias
Q_2 (16%)	Calib.	0.81	0.65	0.36	11.4	0.87	0.58	-0.01	44.4	0.88	0.45	-1.67	104.0
	Valid.	0.67	0.33	-3.48	110.8	0.83	0.54	-0.20	51.7	0.85	0.40	-2.75	122.1
Q_8 (4%)	Calib.	0.73	0.46	-0.78	49.5	0.92	0.78	0.78	11.1	0.90	0.62	0.37	49.2
	Valid.	0.71	0.36	-2.88	81.1	0.80	0.61	0.24	21.1	0.82	0.53	-0.14	54.5
Q_16 (7%)	Calib.	0.69	0.68	0.42	-13.3	0.70	0.52	-0.06	32.7	0.79	0.43	-1.39	97.2
	Valid.	0.62	0.50	-0.02	28.8	0.55	0.48	0.01	23.4	0.66	0.38	-1.33	95.6
Q_25 (17%)	Calib.	0.61	0.52	0.34	-23.4	0.59	0.48	-0.12	24.8	0.69	0.42	-0.95	74.5
	Valid.	0.61	0.48	-0.22	25.4	0.56	0.44	-0.48	29.5	0.66	0.35	-2.57	99.4
Q_41 (5%)	Calib.	0.74	0.74	-0.11	-19.8	0.89	0.75	0.16	-2.8	0.89	0.47	-3.02	67.9
	Valid.	0.81	0.60	-0.87	16.2	0.79	0.73	0.07	-6.7	0.89	0.45	-4.23	73.1
Q_54 (12%)	Calib.	0.88	0.73	0.73	22.8	0.87	0.49	-0.60	83.0	0.84	0.38	-2.78	135.1
	Valid.	0.47	0.15	-19.61	226.1	0.84	0.38	-4.20	107.5	0.76	0.26	-13.08	198.8
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	Valid.	0.71	0.55	-0.31	17.9	0.75	0.43	-2.31	54.9	0.73	0.30	-8.23	130.4
Q_76 (8%)	Calib.	0.34	0.20	0.18	-30.9	0.52	0.41	-0.22	54.8	0.57	0.36	-1.06	89.5
	Valid.	0.71	0.45	-0.60	60.6	0.34	0.29	-0.74	44.4	0.43	0.33	-0.75	55.8
Q_80 (5%)	Calib.	0.39	0.17	-0.71	-65.4	0.84	0.60	-0.46	16.9	0.68	0.35	-4.08	84.7
	Valid.	0.85	0.66	0.22	-37.9	0.94	0.63	-1.23	22.9	0.70	0.33	-7.92	93.1
Q_81 (5%)	Calib.	0.80	0.50	-0.56	53.3	0.79	0.54	-0.07	42.0	0.65	0.33	-2.81	108.0
	Valid.	0.31	0.24	-2.13	39.3	0.30	0.29	-0.63	2.9	0.24	0.24	-0.93	13.5
Weigh. Aver.	Calib.	0.66	0.53	0.15	-9.4	0.75	0.53	-0.28	39.3	0.75	0.40	-2.31	96.6
	Valid.	0.64	0.42	-3.3	63.7	0.68	0.46	-1.22	44.2	0.69	0.34	-4.91	108.7

Tocantins Catchment SWAT Model

Model Calibration and Validation

		SUFI2 Calibration					
Gauge	Period	p-factor	r-factor	R^2	NS	bR^2	Pbias
Q_2 (16%)	Calib.	0.35	0.35	0.94	0.94	0.91	-3.5
	Valid.	0.31	0.43	0.93	0.92	0.91	-0.9
Q_8 (4%)	Calib.	0.60	0.78	0.88	0.79	0.86	-9.7
	Valid.	0.72	0.90	0.76	0.61	0.68	-22.0
Q_16 (7%)	Calib.	0.36	0.29	0.92	0.92	0.91	-2.1
	Valid.	0.29	0.27	0.88	0.87	0.77	-9.6
Q_25 (17%)	Calib.	0.57	0.46	0.86	0.82	0.70	-16.9
	Valid.	0.53	0.59	0.83	0.81	0.79	-4.9
Q_41 (5%)	Calib.	0.71	2.03	0.85	0.33	0.69	10.4
	Valid.	0.67	2.18	0.87	0.31	0.73	7.3
Q_54 (12%)	Calib.	0.32	0.62	0.84	0.83	0.77	-1.4
	Valid.	0.29	1.23	0.74	0.43	0.63	16.0
Q_57 (12%)	Calib.	0.63	1.14	0.70	0.64	0.59	-15.2
	Valid.	0.58	1.33	0.64	0.32	0.64	-4.7
Q_76 (12%)	Calib.	0.80	1.18	0.60	0.24	0.52	38.4
	Valid.	0.58	1.12	0.41	0.19	0.38	11.5
Q_80 (12%)	Calib.	0.54	1.66	0.58	0.30	0.50	-16.5
	Valid.	0.47	1.94	0.51	-0.44	0.44	-25.2
Q_81 (5%)	Calib.	0.63	1.48	0.53	0.38	0.48	-1.6
	Valid.	0.52	1.13	0.21	-0.51	0.10	-49.4
Weighed Aver.	Calib.	0.52	0.84	0.78	0.70	0.68	-4.5
	Valid.	0.47	0.99	0.71	0.66	0.47	-4.0

Conclusions

- WFDEI and CFSR represent precipitation in Brazilian territory reasonably well
- WFDEI was significantly more accurate than CFSR
- Interpolation using observation data improved WFDEI further
- Weather reanalysis instead of scarce weather data is a valid option for SWAT and allowed for a successful calibration of the Tocantins Catchment

Acknowledgements

- Swiss National Science Foundation
- Jaclyn Tech, sending CFSR data
- ANA's personal, sending flow data

Thank you for your time!

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