Supporting Information for: Evaluating Streamflow Forecasts in Hydro-Dominated Power Systems–When and Why They Matter

Rachel Koh [1], Stefano Galelli [1,2]

[1]Pillar of Engineering Systems and Design, Singapore University of Technology and Design, Singapore

[2]School of Civil and Environemntal Engineering, Cornell University, Ithaca, NY

Contents of this file

1. Text S1
2. Figures S1 to S4
3. Table S1

Text S1. The rule curve of each reservoir is defined as a piece-wise linear function based on four parameters: the minimum and maximum water levels that a reservoir should reach within a year (H_1 and H_2) and the time at which the two levels should be reached (T_1 and T_2). As illustrated in Figure S1, there are three water levels that divide the storage into four zones. These levels are the dead water (or minimum elevation) level, the target water level, and the full (or maximum elevation) level. H_1 and H_2 cannot exceed the dead and critical water levels (H_{min} and H_{max}), respectively. The release dynamics when the reservoir water levels are in Zones 1, 2, and 3 are defined by Eq. 1.

$$R_d = \begin{cases} 0 & \text{if } S_d \le H_{min} \text{ (Zone 1)} \\ 0 & \text{if } \; H_{min} \le S_d \le S_{ts,d_{modT}} \\ & \;\text{and } \; S_{d-1} + Q_d \le S_{ts,d_{modT}} \\ & \;\text{(Zone 2, case 1)} \\ S_{ts,t_{modT}} - (S_{d-1} + Q_d) & \text{if } \; H_m in \le S_d \le S_{ts,d_{modT}} \\ & \;\text{and } \; S_{d-1} + Q_d > S_{ts,d_{modT}} \\ & \;\text{(Zone 2, case 2)} \\ (S_{d-1} + Q_d) - S_{ts,d_{modT}} & \text{if } \; S_{ts,d_{modT}} \le S_d \le S_{cap} \\ & \;\text{and } \; S_{d-1} + Q_d - R_{max} \le S_{ts,d_{modT}} \\ & \;\text{(Zone 3, case 1)} \\ R_{max} & \text{if } \; S_{ts,d_{modT}} \le S_d \le S_{cap} \\ & \;\text{and } \; S_{d-1} + Q_d - R_{max} > S_{ts,d_{modT}} \\ & \;\text{(Zone 3, case 2)} \end{cases} \quad (1)$$

where $S_{ts,d_{modT}}$ is the target storage at time t_{modT} (in our study, we use a period T of 365 days).

If the water level falls below the dead water level (Zone 1), the turbines are not operated. If the level is between the dead water and target level (Zone 2), the model first uses the information on the incoming daily inflow to solve a mass balance equation, in which the discharge from the dam is kept at zero. The aim is to understand whether the water level is expected to go beyond the target at the end of the day. If that is the case, the model discharges through the turbines the amount of water needed to keep the level close to the target. Otherwise, the turbines are not activated. In Zone 3 (between the target and full level), the turbines are used at their maximum capacity, until the water reaches the target level. In Zone 4 (i.e., level above the maximum elevation), both turbines and spillways are used.

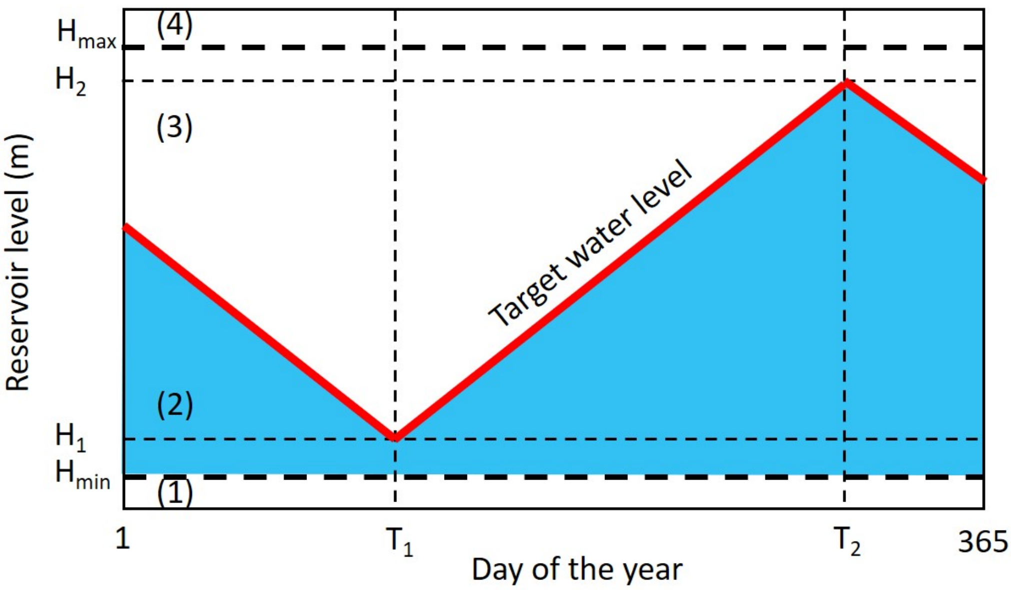

Figure S1. Rule curve.

.

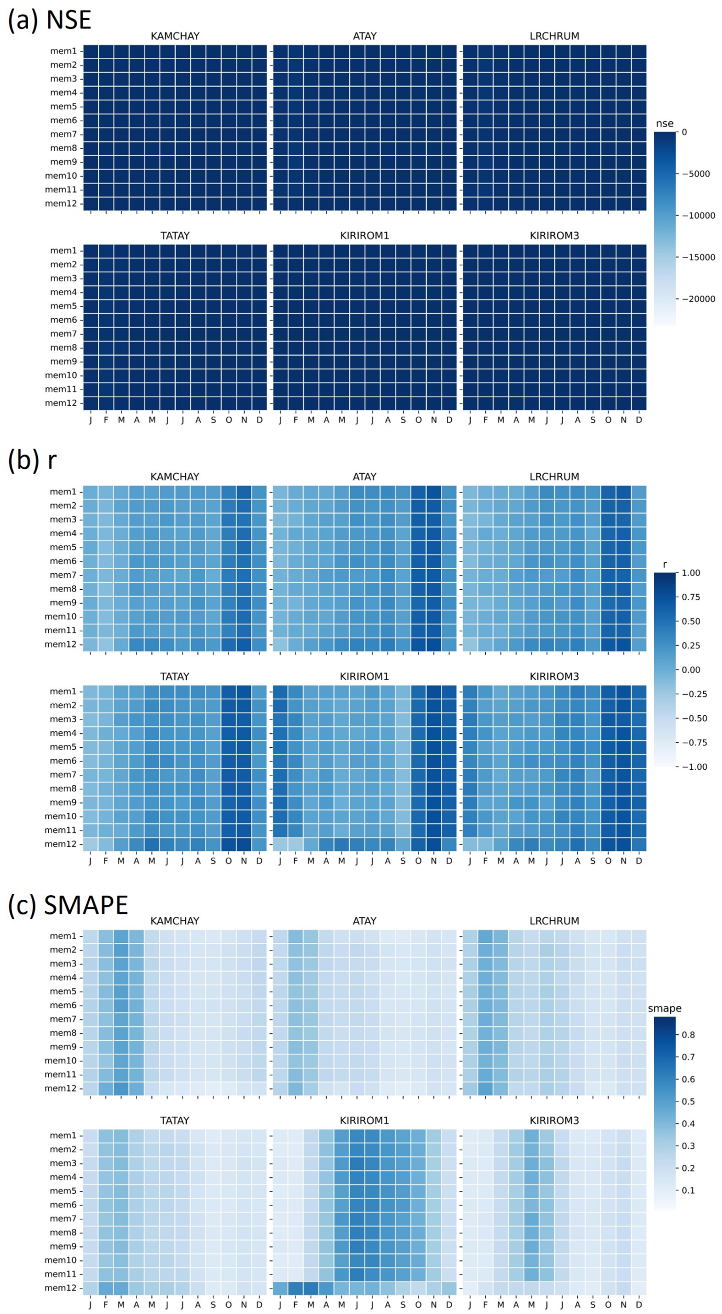

Figure S2. The average streamflow forecast skill of each ensemble member, measured in terms of (a) NSE, (b) r and (c) SMAPE. The six subgrids within each panel represent the six reservoirs in our case study. The range of the forecast metrics can be seen in the colorbar on the right of each panel. As seen in panel (a), NSE can go as low as -20000, amplifying the errors when we do a weighted aggregation. In panel (b), r is bounded by -1 and 1, subjecting them to the possibility of being cancelled out during aggregation. In panel (c), SMAPE ranges between 0 and 1, avoiding the two problems highlighted above.

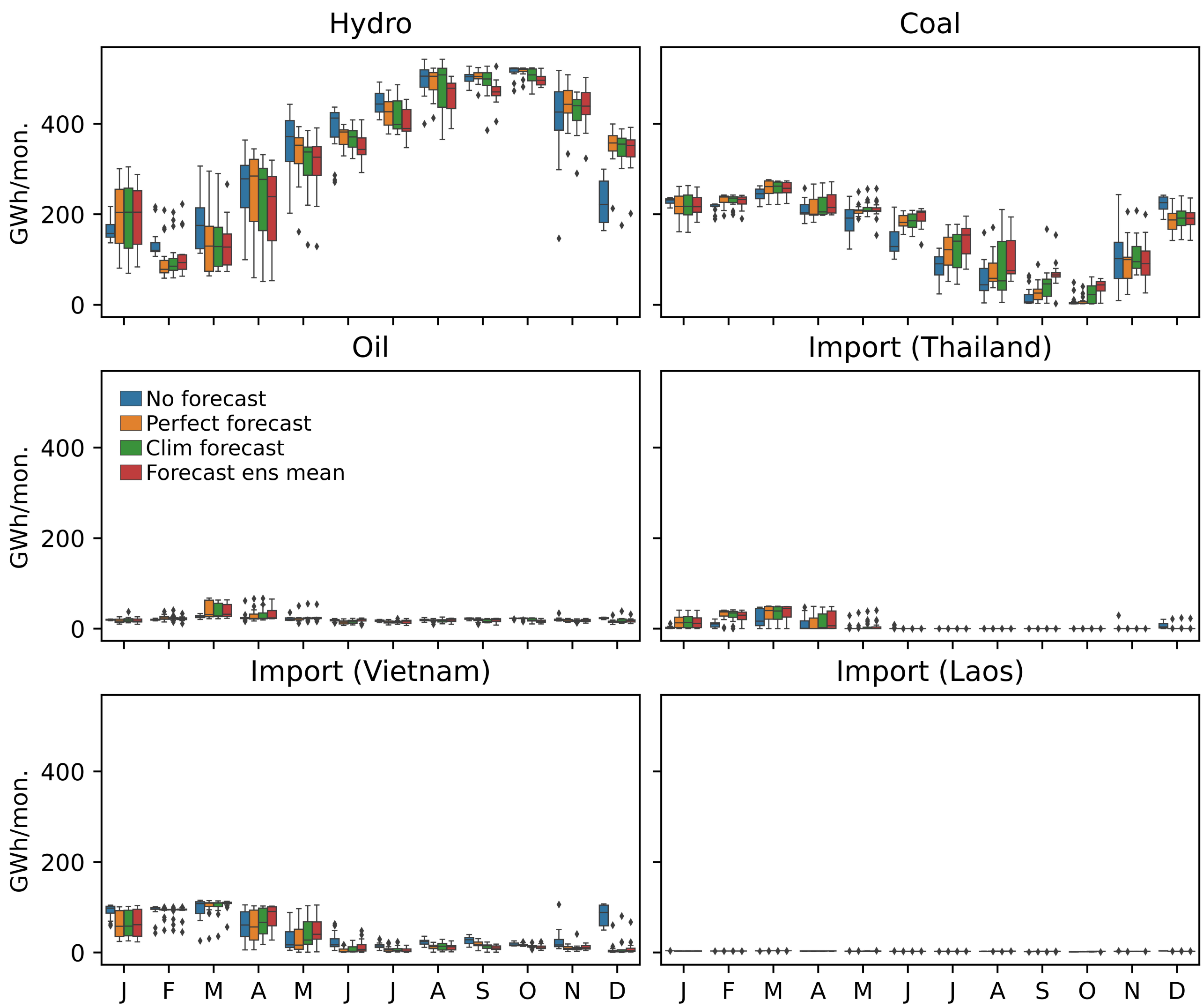

Figure S3. Monthly variability in Cambodia's generation mix under different forecast scenarios. All variables are spatially aggregated for the entire system. Within each panel, the results from three forecast scenarios (perfect, climatology forecast, and the forecast ensemble mean) are compared to the benchmark (no forecast).

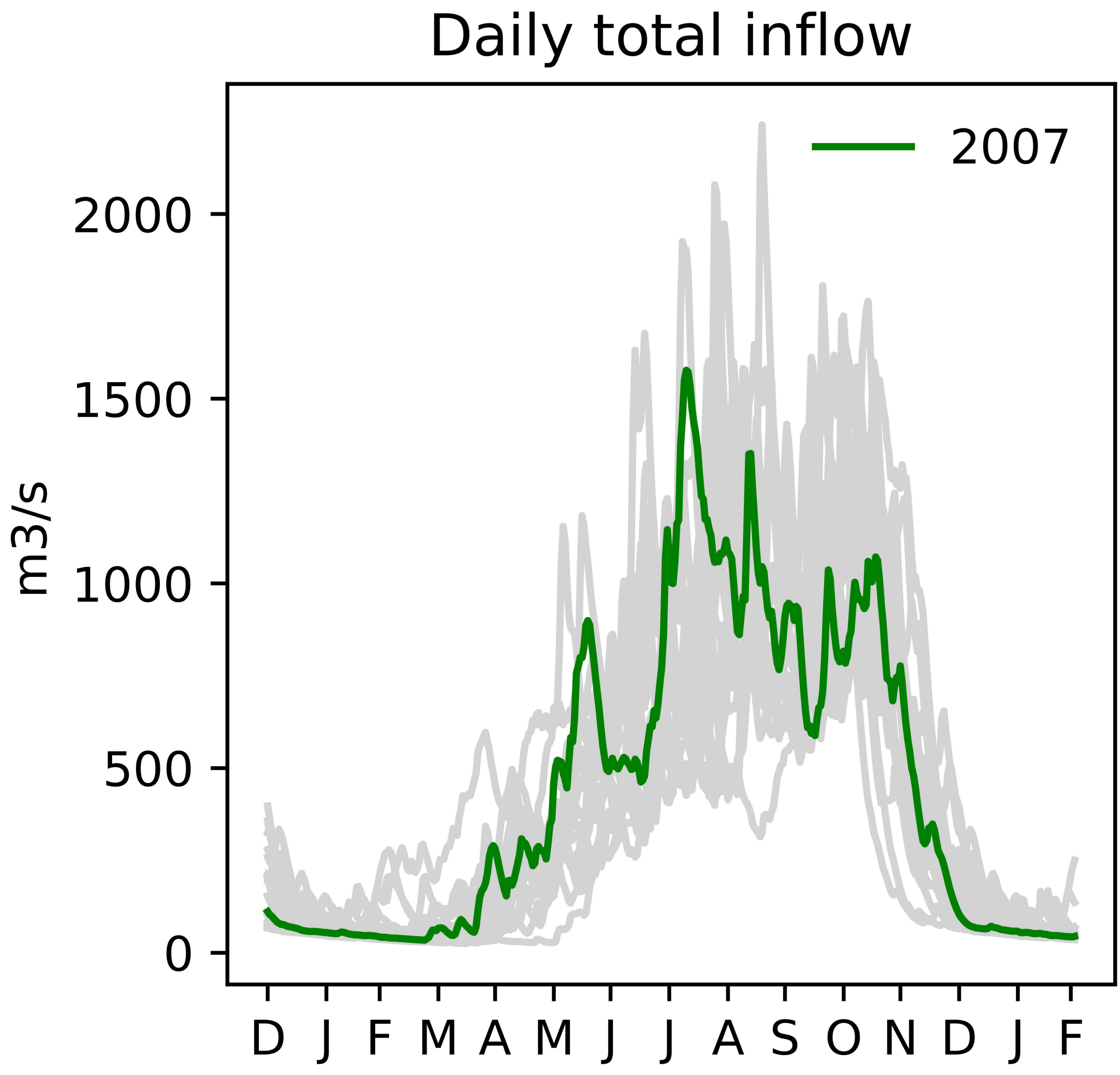

Figure S4. Daily reservoir inflow. Each gray line represents one year between 2000 and 2018. The profile for 2007 is highlighted in green.

Table S1. The generation mix obtained using streamflow forecasts under different scenarios (perfect, climatology and no forecast) under different forecast horizons, simulated over 19 years (2000-2018).

Forecast	Generation mix over 19 years (% of total generation)							Metrics		
horizon	hydro	coal	imp (Laos)	imp (Thai)	imp (Viet)	oil	slack	Cost	CO_2	% HP dispatched
Perfect forecast										
7	61.3	25.4	0.48	1.58	7.18	4.03	0.03	3078.5	37.48	82.0
14	62.1	25.0	0.48	1.54	6.82	4.00	0.04	3014.4	36.97	81.9
21	62.0	25.8	0.48	1.46	6.33	3.84	0.03	3016.3	37.90	83.3
30	61.6	27.0	0.49	1.40	6.24	3.76	0.03	3085.9	39.36	84.4
46	57.7	30.4	0.50	1.34	6.44	3.65	0.02	3345.8	43.74	86.9
Climatology forecast										
14	61.4	25.4	0.49	1.59	7.02	4.01	0.03	3068.1	37.53	82.4
30	59.7	28.0	0.49	1.47	6.53	3.75	0.04	3192.3	40.70	84.9
No forecast										
-	60.7	25.5	0.49	0.82	8.71	3.77	0.00	3129.8	37.39	81.7