



Supplement of

Land surface model underperformance tied to specific meteorological conditions

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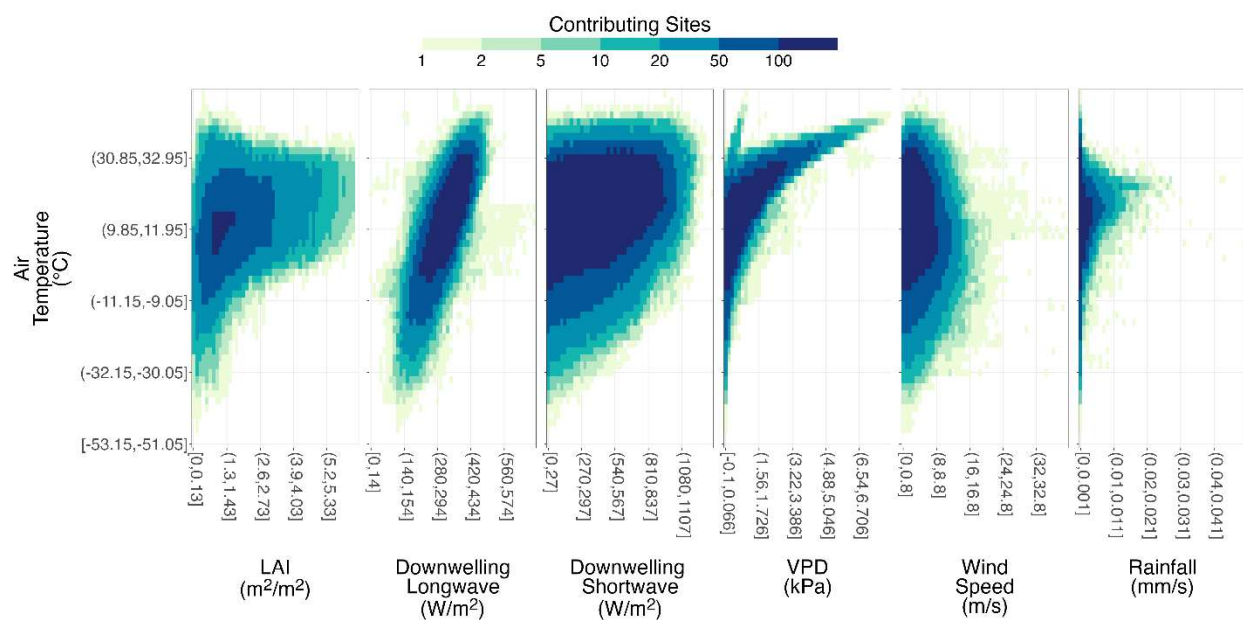


Figure S1: Number of sites contributing to each bin. The y-axis of each plot is air temperature and the x-axis the other variables, each split into 50 equal-sized bins with every 10th bin labelled. The colour indicates the number of sites for which at least one timestep fell within the corresponding 2-D variable cell.

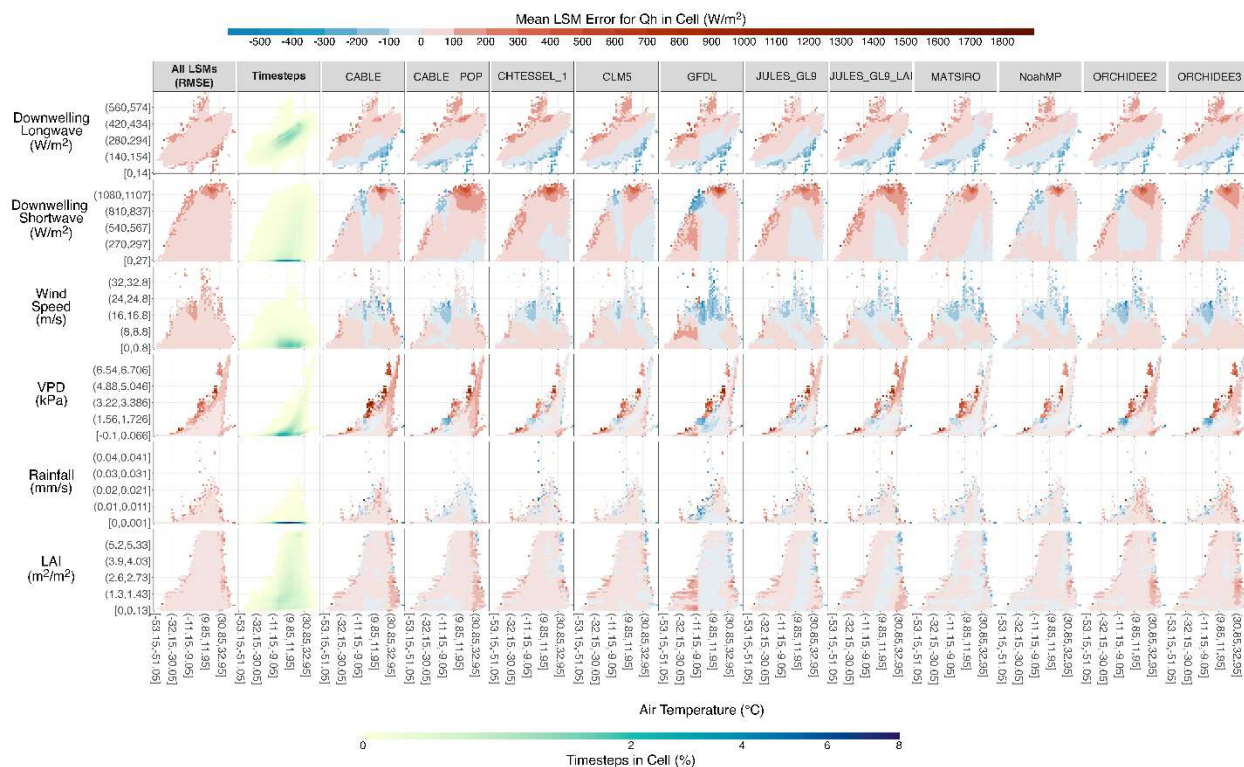


Figure S2: Mean LSM Error by Driving Variable and Model for Predicting Sensible Heat Flux. The x-axis of each plot is air temperature and the y-axis the other variables, each split into 50 equal-sized bins of which only every 10th bin is labeled. For the columns of individual models, each cell is coloured by the mean LSM error (modelled – observed) for all timesteps within the cell. For the timesteps column, the colour indicates the percentage of the total number of timesteps that fell within the 2-D variable cell. The 'All LSMs' column is coloured by the root mean square of the LSM error across all models. Note that since all models simulated the same site-timesteps, the cells and timesteps within each cell are approximately the same but not equal for every model (some LSMs did not submit simulations for every site, missing four sites at most).

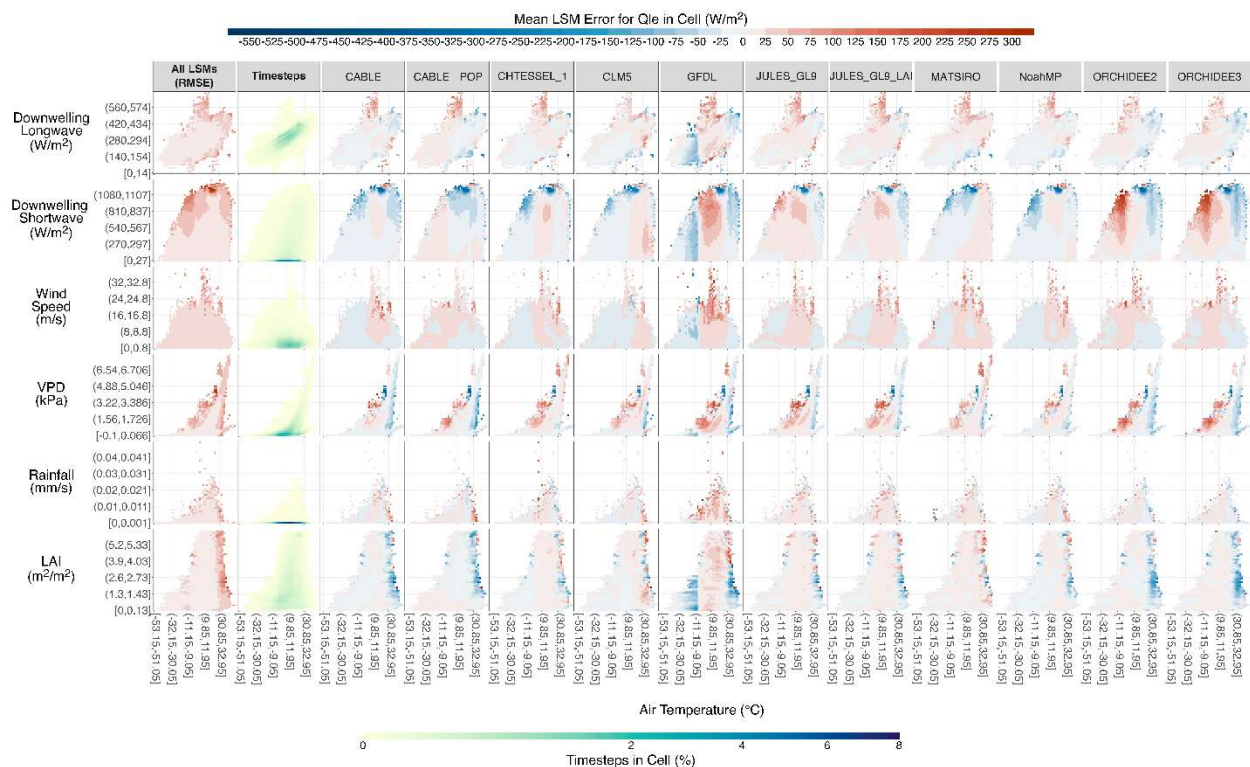


Figure S3: Mean LSM Error by Driving Variable and Model for Predicting Latent Heat Flux. The details are the same as Figure S2 but for predictions of the Qle flux.

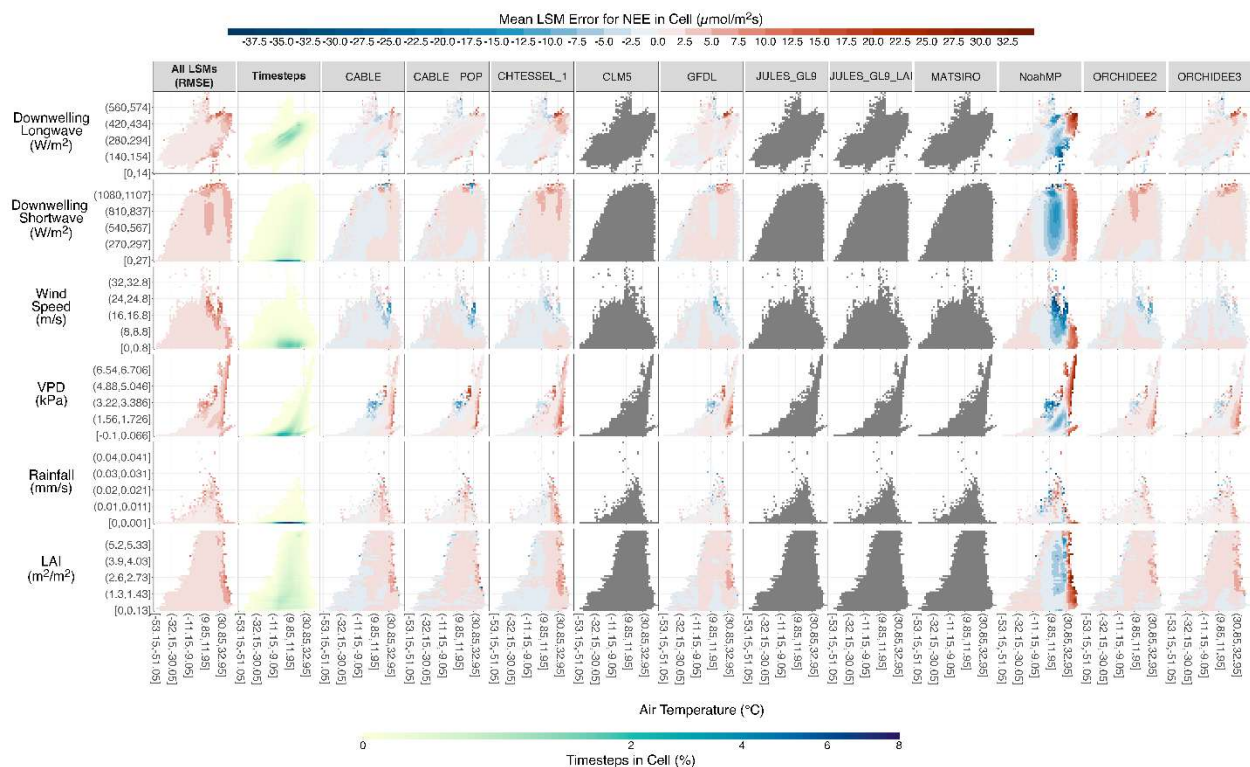


Figure S4: Mean LSM Error by Driving Variable and Model for Predicting Net Ecosystem Exchange. The details are the same as Figure S2 but for predictions of the NEE flux. Note that greyed out LSMs did not provide half-hourly NEE outputs to the PLUMBER2 experiment.

Table S1: *i*NMV Values for 95% LRF. 'Orig.' is the original *i*NMV for the model. 'Diff.' is the difference between $iNMV_{original}$ and $iNMV_{95\%}$. 'Rel. Diff.' is the relative difference $Diff / iNMV_{original}$.

Model	Qh				Qle				NEE			
	Orig.	95% LRF	Diff.	Rel. Diff.	Orig.	95% LRF	Diff.	Rel. Diff.	Orig.	95% LRF	Diff.	Rel. Diff.
CABLE	2.02	0.94	1.08	53%	0.59	0.13	0.46	78%	0.42	0.26	0.17	39%
CABLE-POP	2.20	0.69	1.52	69%	0.62	0.31	0.31	51%	0.88	0.60	0.28	32%
CHTESSEL_1	2.19	1.37	0.83	38%	0.67	0.09	0.59	87%	0.71	0.39	0.32	45%
CLM5	1.37	0.58	0.80	58%	0.54	0.10	0.44	82%	NA	NA	NA	NA
GFDL	3.79	2.93	0.85	23%	2.93	1.75	1.18	40%	0.86	0.57	0.29	34%
JULES_GL9	1.98	1.23	0.75	38%	0.67	0.04	0.63	94%	NA	NA	NA	NA
JULES_GL9_LAI	2.16	1.20	0.96	44%	0.79	0.17	0.62	78%	NA	NA	NA	NA
MATSIRO	1.43	0.46	0.97	68%	0.88	0.36	0.51	58%	NA	NA	NA	NA
NoahMP	1.03	0.45	0.59	57%	0.31	-0.04	0.35	114%	1.75	1.29	0.46	26%
ORCHIDEE2	1.90	1.10	0.80	42%	0.61	0.11	0.50	81%	0.69	0.42	0.27	39%
ORCHIDEE3	2.02	1.15	0.88	43%	0.69	0.09	0.61	88%	1.04	0.69	0.35	34%

Table S2: *i*NMV Values for 50% LRF. 'Orig.' is the original *i*NMV for the model. 'Diff.' is the difference between $iNMV_{original}$ and $iNMV_{50\%}$. 'Rel. Diff.' is the relative difference $Diff / iNMV_{original}$.

Model	Qh				Qle				NEE			
	Orig.	50% LRF	Diff.	Rel. Diff.	Orig.	50% LRF	Diff.	Rel. Diff.	Orig.	50% LRF	Diff.	Rel. Diff.
CABLE	2.02	-0.12	2.14	106%	0.59	-0.05	0.64	109%	0.42	0.15	0.27	65%
CABLE-POP	2.20	-0.12	2.33	106%	0.62	0.12	0.50	81%	0.88	0.43	0.45	51%
CHTESSEL_1	2.19	0.34	1.85	84%	0.67	-0.18	0.85	127%	0.71	0.39	0.32	45%
CLM5	1.37	-0.13	1.51	110%	0.54	-0.08	0.62	115%	NA	NA	NA	NA
GFDL	3.79	0.52	3.27	86%	2.93	0.05	2.88	98%	0.86	0.43	0.43	50%
JULES_GL9	1.98	0.22	1.77	89%	0.67	-0.20	0.87	130%	NA	NA	NA	NA
JULES_GL9_LAI	2.16	0.19	1.97	91%	0.79	-0.18	0.97	122%	NA	NA	NA	NA
MATSIRO	1.43	-0.20	1.63	114%	0.88	0.02	0.86	98%	NA	NA	NA	NA
NoahMP	1.03	-0.01	1.05	101%	0.31	-0.19	0.50	163%	1.75	0.37	1.38	79%
ORCHIDEE2	1.90	0.17	1.73	91%	0.61	-0.11	0.72	117%	0.69	0.34	0.35	51%
ORCHIDEE3	2.02	0.21	1.81	89%	0.69	-0.14	0.84	121%	1.04	0.50	0.53	51%

Table S3: iNMV Values for ‘Physical’ LRF. ‘Orig.’ is the original iNMV for the model. ‘Diff.’ is the difference between $iNMV_{original}$ and $iNMV_{Physical}$. ‘Rel. Diff.’ is the relative difference $Diff / iNMV_{original}$.

Model	Qh				Qle				NEE			
	Orig.	Physical LRF	Diff.	Rel. Diff.	Orig.	Physical LRF	Diff.	Rel. Diff.	Orig.	Physical LRF	Diff.	Rel. Diff.
CABLE	2.02	1.98	0.04	2%	0.59	0.60	-0.01	-1%	0.42	0.41	0.01	2%
CABLE-POP	2.20	2.17	0.03	2%	0.62	0.63	-0.01	-2%	0.88	0.89	-0.01	-1%
CHTESSEL_1	2.19	2.13	0.06	3%	0.67	0.63	0.04	6%	0.71	0.72	-0.01	-2%
CLM5	1.37	1.32	0.05	4%	0.54	0.53	0.01	2%	NA	NA	NA	NA
GFDL	3.79	3.76	0.02	1%	2.93	2.97	-0.04	-2%	0.86	0.85	0.01	1%
JULES_GL9	1.98	1.92	0.06	3%	0.67	0.67	0.00	0%	NA	NA	NA	NA
JULES_GL9_LAI	2.16	2.09	0.07	3%	0.79	0.79	0.00	0%	NA	NA	NA	NA
MATSIRO	1.43	1.38	0.06	4%	0.88	0.87	0.00	0%	NA	NA	NA	NA
NoahMP	1.03	0.99	0.04	4%	0.31	0.31	0.00	0%	1.75	1.68	0.06	3%
ORCHIDEE2	1.90	1.84	0.05	3%	0.61	0.61	0.00	1%	0.69	0.70	-0.01	-2%
ORCHIDEE3	2.02	1.97	0.05	3%	0.69	0.70	0.00	0%	1.04	1.04	-0.01	-1%

Table S4: iNMV Values for ‘Daytime’ LRF. ‘Orig.’ is the original iNMV for the model. ‘Diff.’ is the difference between $iNMV_{original}$ and $iNMV_{Daytime}$. ‘Rel. Diff.’ is the relative difference $Diff / iNMV_{original}$.

Model	Qh				Qle				NEE			
	Orig.	Daytime LRF	Diff.	Rel. Diff.	Orig.	Daytime LRF	Diff.	Rel. Diff.	Orig.	50% LRF	Diff.	Rel. Diff.
CABLE	2.02	2.50	-0.48	-24%	0.59	1.03	-0.44	-75%	0.42	0.56	-0.14	-32%
CABLE-POP	2.20	3.23	-1.03	-47%	0.62	1.04	-0.42	-68%	0.88	1.25	-0.37	-41%
CHTESSEL_1	2.19	2.37	-0.17	-8%	0.67	1.15	-0.48	-71%	0.71	1.47	-0.76	-108%
CLM5	1.37	1.61	-0.23	-17%	0.54	1.04	-0.50	-92%	NA	NA	NA	NA
GFDL	3.79	3.75	0.04	1%	2.93	3.25	-0.32	-11%	0.86	1.24	-0.38	-45%
JULES_GL9	1.98	1.85	0.14	7%	0.67	1.19	-0.52	-79%	NA	NA	NA	NA
JULES_GL9_LAI	2.16	2.37	-0.21	-10%	0.79	1.28	-0.49	-61%	NA	NA	NA	NA
MATSIRO	1.43	1.84	-0.40	-28%	0.88	1.30	-0.42	-48%	NA	NA	NA	NA
NoahMP	1.03	1.31	-0.28	-27%	0.31	0.67	-0.37	-120%	1.75	0.47	1.27	73%
ORCHIDEE2	1.90	1.94	-0.05	-2%	0.61	1.07	-0.45	-74%	0.69	1.22	-0.53	-76%
ORCHIDEE3	2.02	2.15	-0.13	-6%	0.69	1.21	-0.51	-74%	1.04	1.41	-0.37	-36%

Table S5: *i*NMV Values for ‘Windy’ LRF. ‘Orig.’ is the original *i*NMV for the model. ‘Diff.’ is the difference between *i*NMV_{original} and *i*NMV_{Windy}. ‘Rel. Diff.’ is the relative difference $\text{Diff} / \text{iNMV}_{\text{original}}$.

Model	Qh				Qle				NEE			
	Orig.	Windy LRF	Diff.	Rel. Diff.	Orig.	Windy LRF	Diff.	Rel. Diff.	Orig.	Windy LRF	Diff.	Rel. Diff.
CABLE	2.02	2.34	-0.32	-16%	0.59	0.83	-0.25	-42%	0.42	0.40	0.02	5%
CABLE-POP	2.20	2.35	-0.15	-7%	0.62	0.81	-0.19	-30%	0.88	0.91	-0.02	-3%
CHTESSEL_1	2.19	2.35	-0.15	-7%	0.67	0.96	-0.28	-42%	0.71	0.84	-0.13	-19%
CLM5	1.37	1.40	-0.03	-2%	0.54	0.74	-0.21	-38%	NA	NA	NA	NA
GFDL	3.79	3.98	-0.19	-5%	2.93	3.84	-0.91	-31%	0.86	0.89	-0.03	-4%
JULES_GL9	1.98	1.99	-0.01	0%	0.67	0.97	-0.3	-45%	NA	NA	NA	NA
JULES_GL9_LAI	2.16	2.22	-0.06	-3%	0.79	1.17	-0.37	-47%	NA	NA	NA	NA
MATSIRO	1.43	1.47	-0.04	-3%	0.88	1.09	-0.21	-24%	NA	NA	NA	NA
NoahMP	1.03	1.06	-0.03	-3%	0.31	0.49	-0.18	-59%	1.75	1.67	0.08	4%
ORCHIDEE2	1.90	1.84	0.06	3%	0.61	0.83	-0.22	-36%	0.69	0.80	-0.11	-16%
ORCHIDEE3	2.02	1.98	0.04	2%	0.69	0.95	-0.26	-37%	1.04	1.08	-0.04	-4%