Advancing summary process-diagnostics at the Canadian Meteorological Center

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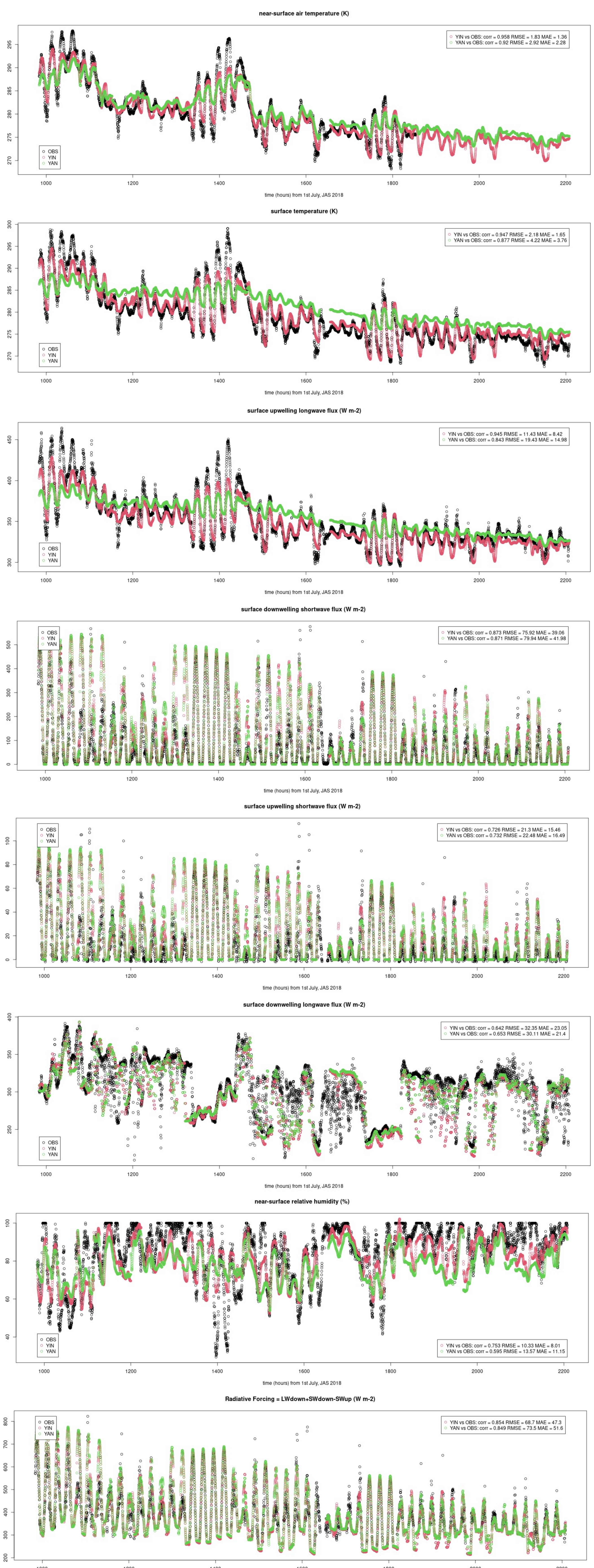
Aims: Verification of operational systems generally considers traditional meteorological variables (temperature, humidity, clouds, etc.), and compares the predicted versus observed values for each state variable separately. However, these variables are often interrelated through physical processes. Assessing whether numerical models can reproduce these relationships therefore provides insight into the accuracy of the representation of these processes. In this study, we propose some simple process-diagnostics for routine verification in operational environments.

Data: the diagnostics are developed by comparing the Canadian Arctic Prediction System (CAPS, ~3km, Casati et al, 2023) and Global Deterministic Prediction System (GDPS, ~25km, Mc-Taggart-Cowan et al, 2019) against multivariate observations from the Year of Polar Prediction supersites (Day et al, 2024; Uttal et al 2024). Here we illustrate the statistics comparing the 12-minute timeseries of the day2 forecast for two GDPS grid-points, from the YIN and YAN domains (Qaddouri and Lee, 2011), collocated with the Tiksi (71.60°N, 128.89°E) supersite. While the YIN grid-point is mainly land (71.83%), the YAN grid-point is mainly ocean (22.90%), which leads to different behaviours for the surface and near-surface physical variables. The relationships between surface long-wave and short-wave radiation, surface (skin) temperature and near-surface (2m) air temperature and relative humidity are investigated.



Univariate verification statistics

YIN vs OBS	corr	RMSE	MAE
tas	0.96	1.83	1.36
ts	0.95	2.18	1.65
hurs	0.75	10.33	8.01
rsds	0.87	75.92	39.06
rsus	0.73	21.30	15.46
rlds	0.64	32.35	23.05
rlus	0.95	11.43	8.42
radforcing	0.85	68.71	47.25

YAN vs OBS	corr	RMSE	MAE
tas	0.92	2.92	2.28
ts	0.88	4.22	3.76
hurs	0.60	13.57	11.15
rsds	0.87	79.94	41.98
rsus	0.73	22.48	16.49
rlds	0.65	30.11	21.40
rlus	0.84	19.43	14.98
radforcing	0.85	73.52	51.63

Bivariate process diagnostics

YIN vs OBS	VRMSE	Manhattan
tas.ts	2.37	3.14
tas.rlus	8.99	10.15
rlus.ts	8.79	10.00
tas.hurs	8.77	9.90
tas.radforcing	52.30	53.59
ts.radforcing	47.49	49.15
rlus.radforcing	50.45	56.92
rsds.rlds.day	101.46	120.67

YAN vs OBS	VRMSE	Manhattan
tas.ts	4.76	6.27
tas.rlus	18.59	20.68
rlus.ts	15.68	18.74
tas.hurs	11.23	13.08
tas.radforcing	58.05	59.86
ts.radforcing	52.05	55.09
rlus.radforcing	56.73	65.89
rsds.rlds.day	107.21	125.74

YIN vs OBS	2D-EMD Euclidean	2D-EMD Manhattan
tas.ts	1.39	1.80
tas.rlus	3.39	4.14
rlus.ts	5.25	5.76
tas.hurs	2.93	3.74
tas.radforcing	8.72	10.40
ts.radforcing	11.43	13.91
rlus.radforcing	22.31	30.03
rsds.rlds.day	47.38	65.18

YAN vs OBS	2D-EMD Euclidean	2D-EMD Manhattan
tas.ts	4.28	5.67
tas.rlus	9.79	12.56
rlus.ts	18.13	20.58
tas.hurs	5.89	8.07
tas.radforcing	16.47	20.01
ts.radforcing	32.78	36.48
rlus.radforcing	32.12	43.25
rsds.rlds.day	47.53	64.01

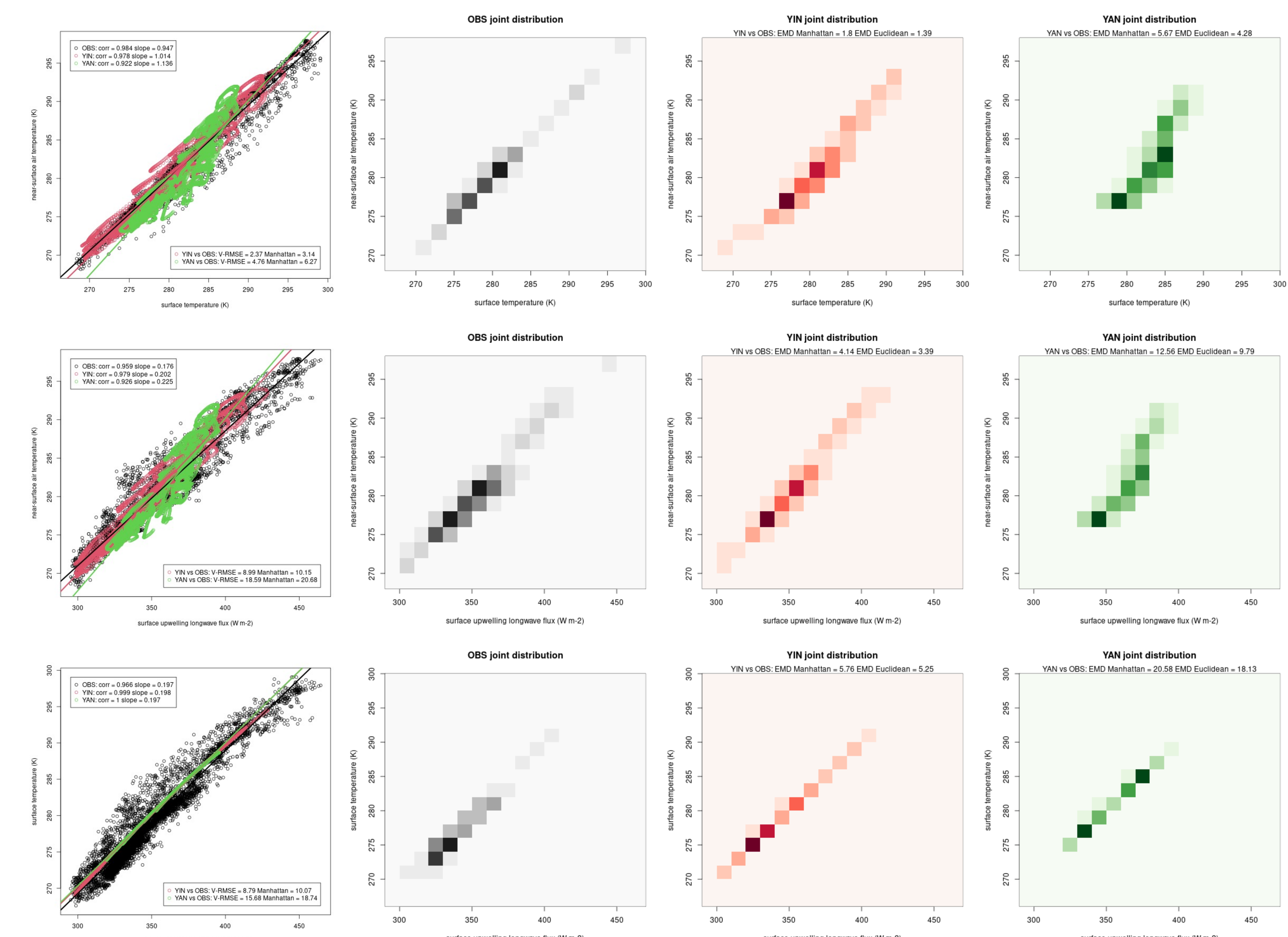
Summary statistics: verification of individual variables is performed by comparing the GDPS timeseries and observation measurements by calculating correlation, RMSE, MAE. Symmetrically, the relationship between the variables (x,y) is assessed by comparing the slope of the regression line, and evaluating the vector-RMSE and the Manhattan distance:

$$VRMSE = mean_{t=time}\sqrt{\left(x_{fcst(y)} - x_{obs(t)}\right)^2 + \left(y_{fcst(t)} - y_{obs(t)}\right)^2}$$

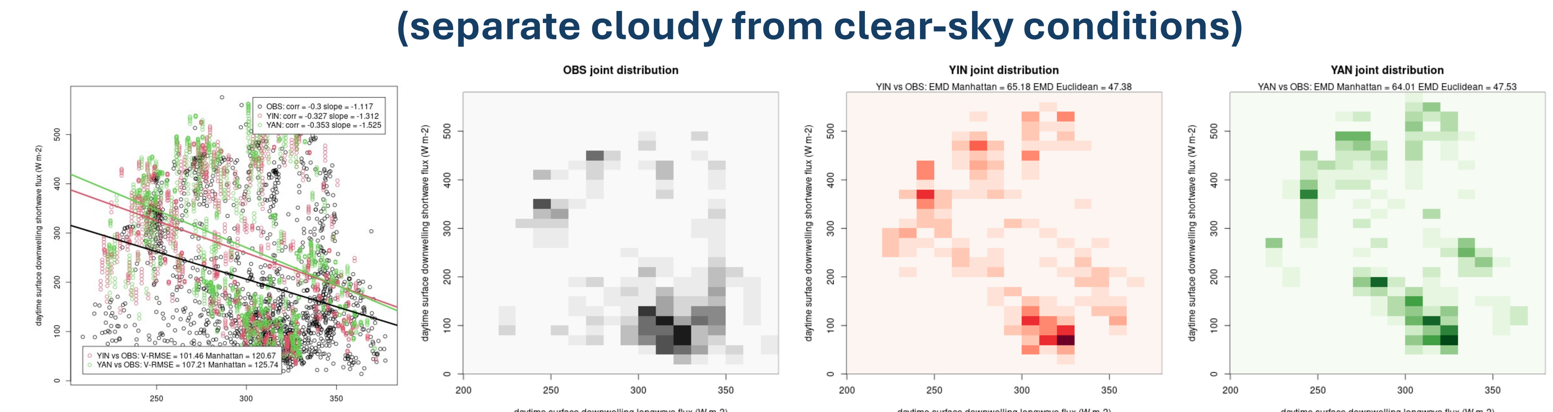
$$Manhattan = mean_{t=time}\left(\left|x_{fcst(t)} - x_{obs(t)}\right| + \left|y_{fcst(t)} - y_{obs(t)}\right|\right)$$

The 2D Earth Mover Distance (EMD, Rubner et al, 1998) is also calculated, to assess the similarity of the variable-relationship joint distributions (disregarding fcst-obs time matching). Euclidean and Manhattan distances are both tested for the calculation of the 2D-EMD.

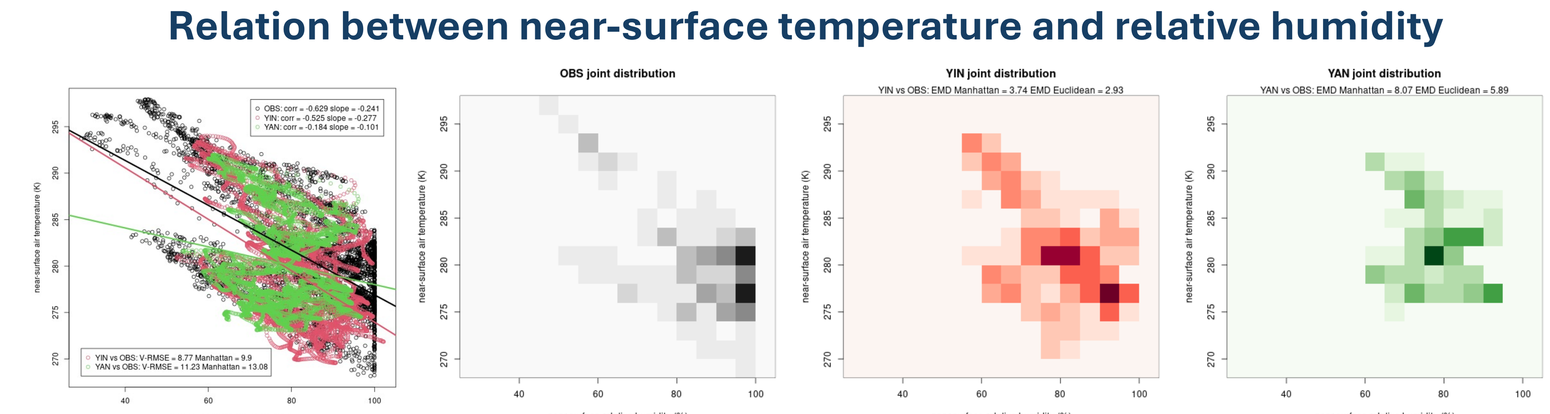
Relations between upwelling LW radiation and temperatures



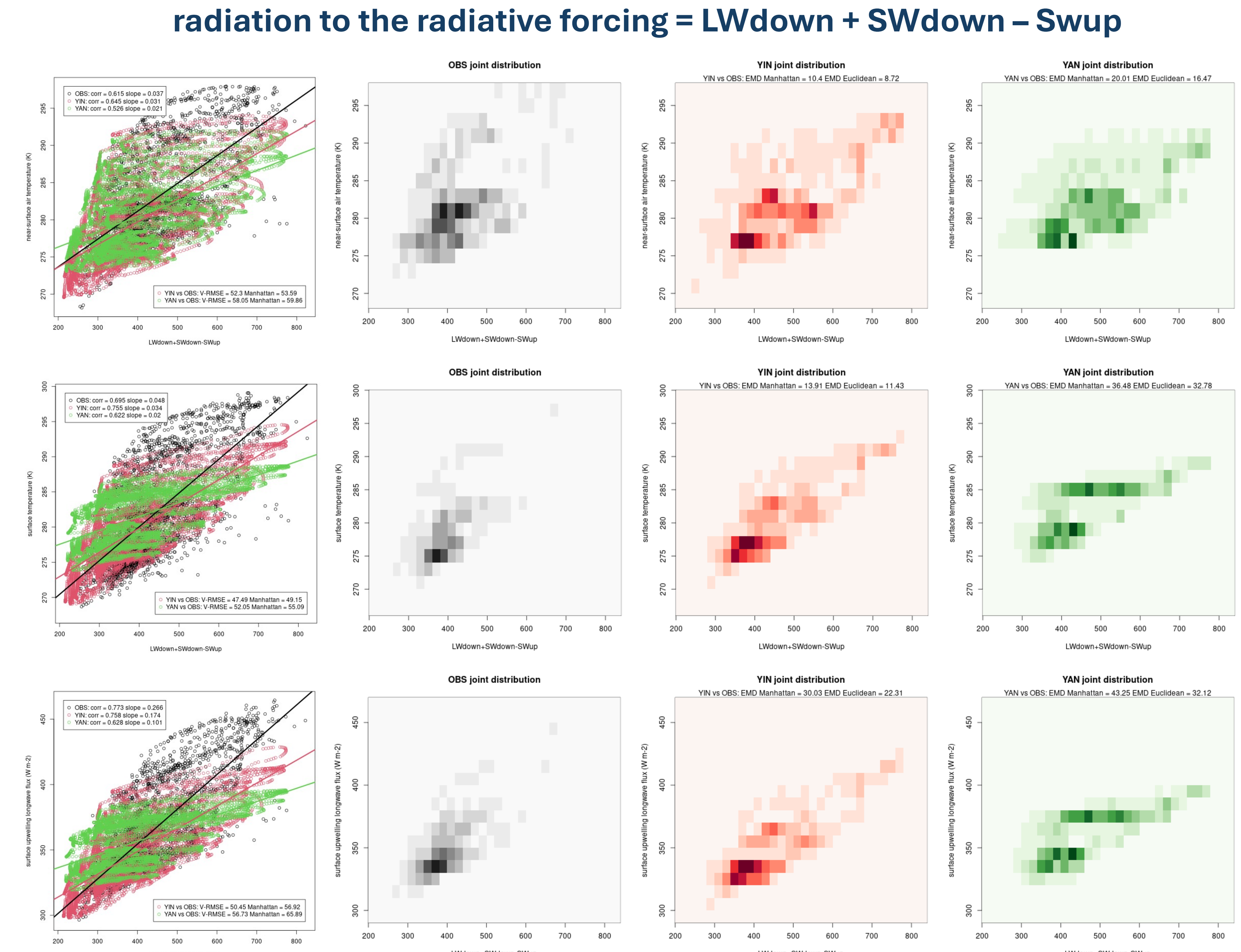
Relation between daytime downwelling SW and LW radiation (separate cloudy from clear-sky conditions)



Relation between near-surface temperature and relative humidity



Response of surface temperature, 2m temperature and upwelling LW radiation to the radiative forcing = LWdown + SWdown – Swup



Comparison of the least-square regression statistics

correlation	OBS	YIN	YAN
tas.ts	0.984	0.978	0.922
tas.rlus	0.959	0.979	0.926
rlus.ts	0.966	0.999	1.000
tas.hurs	-0.629	-0.525	-0.184
tas.radforcing	0.615	0.645	0.526
ts.radforcing	0.695	0.755	0.622
rlus.radforcing	0.773	0.758	0.628
rsds.rlds.day	-0.300	-0.327	-0.353

slope	OBS	YIN	YAN
tas.ts	0.947	1.014	1.136
tas.rlus	0.176	0.202	0.225
rlus.ts	0.197	0.198	0.197
tas.hurs	-0.241	-0.277	-0.101
tas.radforcing	0.037	0.031	0.021
ts.radforcing	0.048	0.034	0.020
rlus.radforcing	0.266	0.174	0.101
rsds.rlds.day	-1.117	-1.312	-1.525

Conclusions: While the correlation and regression-line slope are the least informative statistics (and unsuitable for assessing non-gaussian relationships), the vector-RMSE, Manhattan distance and 2D Earth Mover Distance demonstrate informative, and can separate poor from good performance.

Future work:

- Extend the analysis to more (YOPP) supersites, variables and relationships.
- Extend the analysis to the Canadian Arctic Prediction System timeseries.
- Evaluate the process-diagnostics by using satellite-based gridded products.