Response to Referee #2

Manuscript ID: egusphere-2026-2024

cSINGV v1.0: Development and evaluation of a 1.5 km coupled atmosphere-ocean-wave modelling system for the Western Maritime Continent

Dear Reviewer,

We sincerely thank you for the careful and constructive assessment of our manuscript, which has helped us improve it substantially. We appreciate your recognition of the technical contribution of cSINGV and of the breadth of the model evaluation. Our detailed responses are provided below.

Reviewer comment 1

The uncoupled run uses SST prescribed and updated daily from OSTIA, while the coupled run has hourly two-way SST feedback. Since much of the paper's argument rests on diurnal-scale processes (nocturnal offshore propagation, diurnal LHF), how much of the coupling benefit could simply reflect the difference between daily-updated and sub-daily-evolving SST, independent of two-way coupling per se? Authors can add an explicit paragraph in the Discussion or Limitations acknowledging this confound and, using only existing model output, show the actual sub-daily SST variability produced by cSINGV relative to the daily-fixed OSTIA field, so readers can judge the plausible magnitude of this effect?

Response

We thank the reviewer for highlighting this important limitation. To quantify the magnitude of the sub-daily SST variability, we calculated the daily SST range in cSINGV as the difference between the maximum and minimum of the 24 hourly SST values and then averaged these ranges over January–June 2019. The largest ranges occurred mainly in shallow and coastal waters, including parts of the Malacca Strait and waters surrounding Sumatra (Fig. R1). By contrast, the SST prescribed from daily OSTIA data in cSINGV_A remained fixed within each day and therefore had no sub-daily variability.

These results show that cSINGV generates appreciable and spatially heterogeneous sub-daily SST variability that is absent from cSINGV_A. This variability may modify the near-surface air–sea temperature and humidity gradients and thereby influence the timing and magnitude of turbulent heat fluxes and convection on diurnal timescales. Consequently, the comparison cannot distinguish two-way coupling effects from the influence of allowing SST to evolve at sub-daily timescales. We will revise the manuscript and explicitly acknowledge this limitation in the Discussion. Figure R1 will also be added to the Supplement.

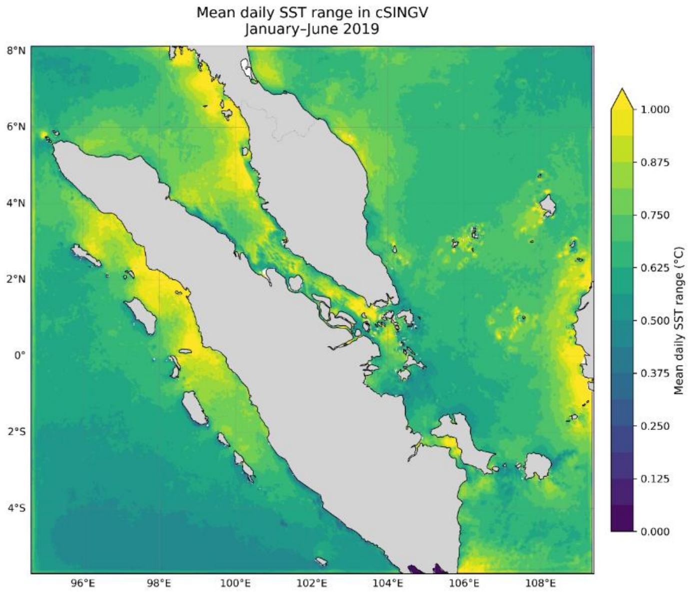

Figure R1. Mean daily sea-surface temperature (SST) range in cSINGV during January–June 2019. The daily SST range was calculated as the difference between the maximum and minimum of the 24 hourly SST values and then averaged over all available days.

Reviewer comment 2

cSINGV_A uses a fixed Charnock parameter of 0.011, while cSINGV derives surface roughness from the WW3 wave state. Authors can diagnose, from the existing coupled output, the effective or implied Charnock parameter or roughness length produced by the wave-dependent formulation over the domain and compare its range with the fixed value of 0.011? This would allow readers to assess whether the two configurations differ sufficiently in roughness to explain part of the flux and wind differences. This caveat should also be stated explicitly in Sect. 4.3 rather than left implicit.

Response

We thank the reviewer for this helpful suggestion. We agree that the different treatment of sea-surface roughness represents an additional distinction between cSINGV and cSINGV_A that should be made explicit. We have therefore analysed the wave-dependent Charnock parameter from the existing cSINGV output and compared it with the fixed value of 0.011 used in cSINGV_A.

To address one of the comments from the Reviewer 1, we have already prepared a figure (Fig. R2) to show the monthly mean differences in 10-m wind speed, SST and Charnock parameter between cSINGV and cSINGV_A. The bottom row shows that the wave-dependent Charnock parameter is spatially and seasonally heterogeneous. We will revise the Section 4.3 accordingly and include the Figure R2 in the Supplement.

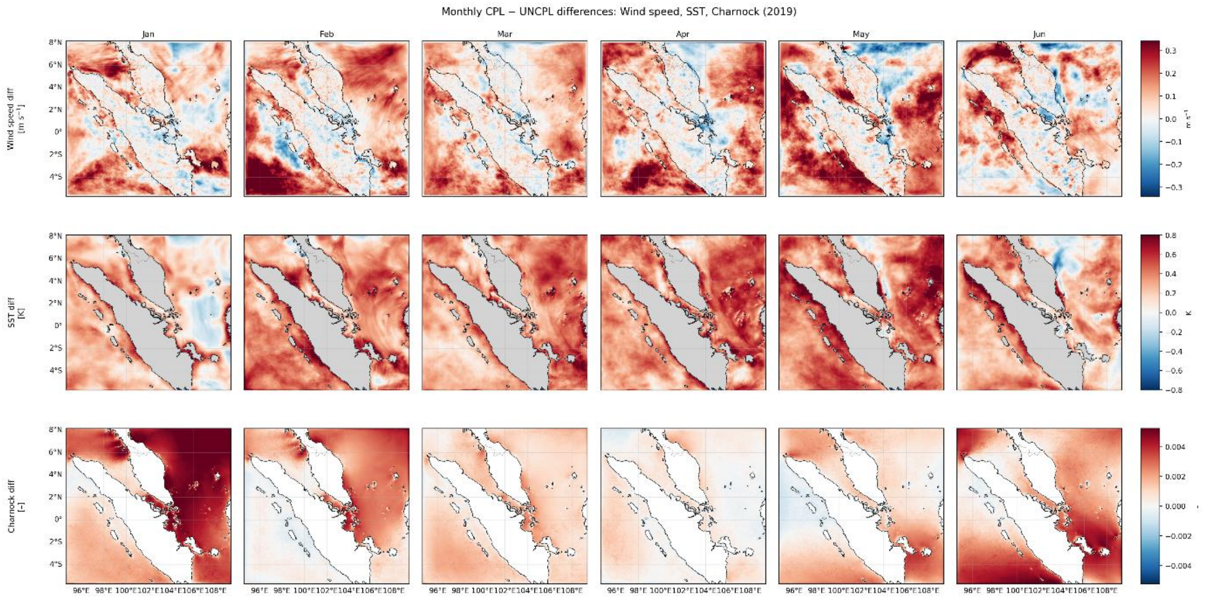

Figure R2. Monthly mean cSINGV − cSINGV_A differences during January–June 2019 in 10-m wind speed (top row; m s^{-1}), sea-surface temperature (middle row; K), and Charnock parameter (bottom row; dimensionless). For the Charnock parameter, differences are calculated relative to the fixed value of 0.011 used in cSINGV_A; positive values therefore indicate a larger wave-dependent Charnock parameter in cSINGV.

Reviewer comment 3

Figures 6, 9, and 10 report differences between cSINGV and cSINGV_A qualitatively. Using the existing daily time series already computed for these figures, could the authors apply a simple paired significance test, such as a sign test or day-by-day bootstrap of the RMSE or FSS differences, to determine whether the coupled advantage is statistically distinguishable from zero, particularly for the near-surface variables described as showing "limited sensitivity"?

Response

We thank the reviewer for this useful suggestion. We performed paired analyses using daily values from the two configurations. The analysed figures (Fig. R3–R5) will be added to the Supplement and will be discussed in Section 4.3.

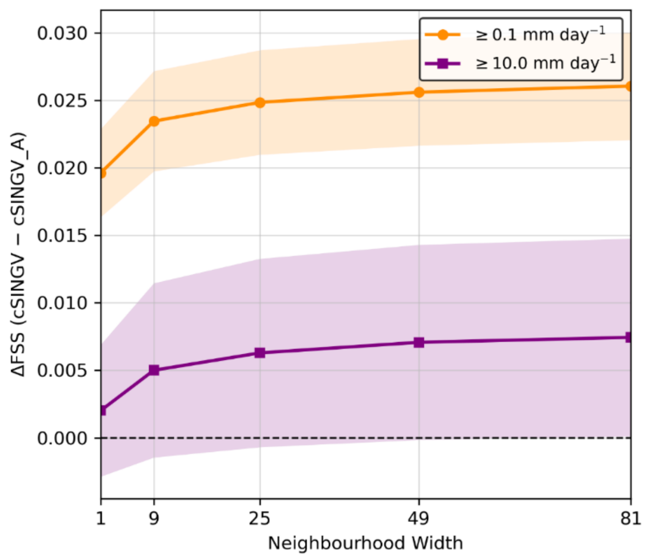

Figure R3. Mean paired difference in Fractions Skill Score (ΔFSS = cSINGV − cSINGV_A) as a function of neighbourhood width for daily precipitation thresholds of ≥0.1 and ≥10.0 mm day^{-1} during January–June 2019. Shading indicates the 95% confidence interval calculated from the paired daily differences, and the horizontal dashed line denotes no difference.

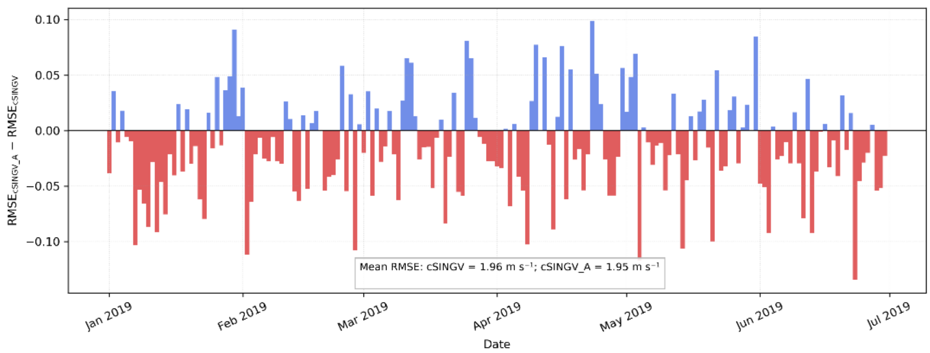

Figure R4. Daily paired differences in 10-m wind-speed RMSE (ΔRMSE = $RMSE_{cSINGV\_A}$ $-RMSE_{cSINGV}$) during January–June 2019. Positive (blue) values indicate lower RMSE in the coupled cSINGV simulation, whereas negative (red) values indicate lower RMSE in cSINGV_A.

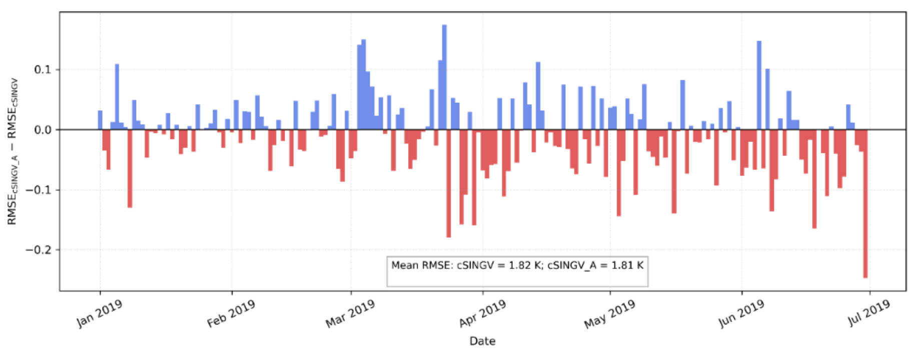

Figure R5. Same as Figure R4, but for 2 m air temperature.

Reviewer comment 4

All results derive from single deterministic six-month runs. Since generating an ensemble is not feasible given the computational cost of 1.5 km coupled simulations, the authors should add a clear limitations statement noting that the squall case-study differences (Sect. 4.4) and the regime-dependence conclusion are based on individual realizations of convection. Some of the apparent coupling impact could therefore reflect internal atmospheric variability rather than a systematic coupling effect. Tempering the causal language in this regard would strengthen the scientific credibility of the manuscript.

Response

We thank the reviewer for highlighting this important limitation. We agree that the single deterministic six-month simulations do not provide an estimate of the internal atmospheric variability. This limitation is particularly relevant to the individual squall cases examined in Section 4.4.

We will revise the Sections 4.4 as follows.

"cSINGV produced greater LHF over parts of the offshore region and a more sustained propagation of the squall than cSINGV_A. The enhanced LHF was primarily associated with changes in the air–sea humidity gradient, providing a physically plausible mechanism through which the coupled configuration may have contributed to the more sustained convection. However, because the comparison is based on single deterministic realizations, a larger event sample or ensemble analysis would be needed to establish this systematically."

We will also revise the regime-dependent conclusions to acknowledge this limitation. In Section 6, we will state that a broader analysis based on a larger sample of Sumatra squall events is ongoing.

Reviewer comment 5

Sect. 3.1 indicates that a wave-only configuration (cSINGV_W) was run for the full January–June 2019 period, yet Sect. 4.2 validates Hs only for January, chosen for Typhoon Pabuk. Since these data already exist, could the authors extend the Fig. 4-type statistics (RMSE, r, SI, KS) to the full six months to confirm that the tuned betamax = 1.75 configuration remains appropriate outside the strong-wind period?

Response

We thank the reviewer for this helpful suggestion. We agree that restricting the significant wave height evaluation to January 2019 does not demonstrate whether the selected $\beta_{\max} = 1.75$ configuration maintains its performance under the wider range of wave conditions occurring during the full simulation period.

We have therefore extended the evaluation of cSINGV_W from January to the complete January–June 2019 period and will include the figure (Fig. R6) in the Supplement. Across the six months, RMSE ranged from 0.179 to 0.287 m, correlation from 0.910 to 0.966, and SI from 0.150 to 0.270. The model exhibited a negative monthly bias ranging from −0.018 to −0.195 m. Performance was strongest in January–February and weaker in April–May, but correlations remained above 0.91 in every month. The monthly values of bias, RMSE, correlation coefficient, scatter index and Kolmogorov–Smirnov statistic (Table R1) will also be included in the Supplement. We will revise the Section 4.2 accordingly.

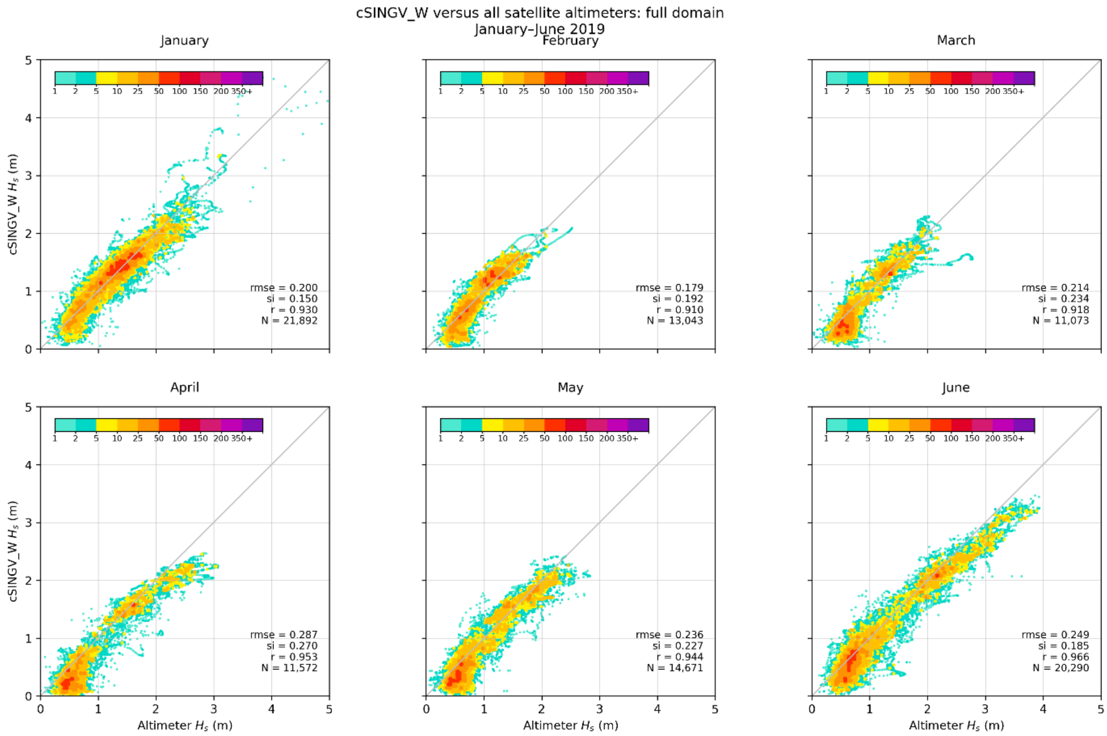

Figure R6. Monthly comparison of significant wave height (H_s) from the standalone wave simulation cSINGV_W against satellite-altimeter observations over the full model domain during January–June 2019.

Table R1. Monthly performance statistics for significant wave height (H_s) from the standalone cSINGV_W simulation against satellite-altimeter observations over the full model domain during January–June 2019. N denotes the number of observation–model pairs; SI denotes the scatter index; and KS denotes the Kolmogorov–Smirnov statistic.

Month	N	Bias (m)	RMSE (m)	SI	Correlation	KS_statistic
January	21892	-0.018	0.200	0.150	0.930	0.037
February	13043	-0.018	0.179	0.192	0.910	0.109
March	11073	-0.067	0.214	0.234	0.918	0.220
April	11572	-0.195	0.287	0.270	0.953	0.313
May	14671	-0.118	0.236	0.227	0.944	0.228
June	20290	-0.123	0.249	0.185	0.966	0.127

Reviewer comment 6

Sects. 4.1–4.2 evaluate cSINGV_O and cSINGV_W as standalone components. Since the fully coupled cSINGV run already exists and presumably outputs SST and Hs, could the authors add the equivalent RMSE and bias comparisons against OSTIA, CMEMS, and altimetry from the fully coupled run itself? This will clarify whether two-way coupling degrades or maintains ocean and wave fidelity relative to the standalone components.

Response

We thank the reviewer for this important suggestion. We agree that evaluating only the standalone ocean and wave components does not establish whether their fidelity is maintained after they are incorporated into the fully coupled system. We have therefore extended the SST and significant wave height evaluations to the fully coupled cSINGV simulation. SST from cSINGV was evaluated against OSTIA, while significant wave height from cSINGV was evaluated against satellite-altimeter observations.

We will add these results to Section 4.3 and revise the discussion accordingly. Figures R7 and R9 will be included in the revised manuscript, whereas Figure R8 and Table R2 will be added to the Supplement.

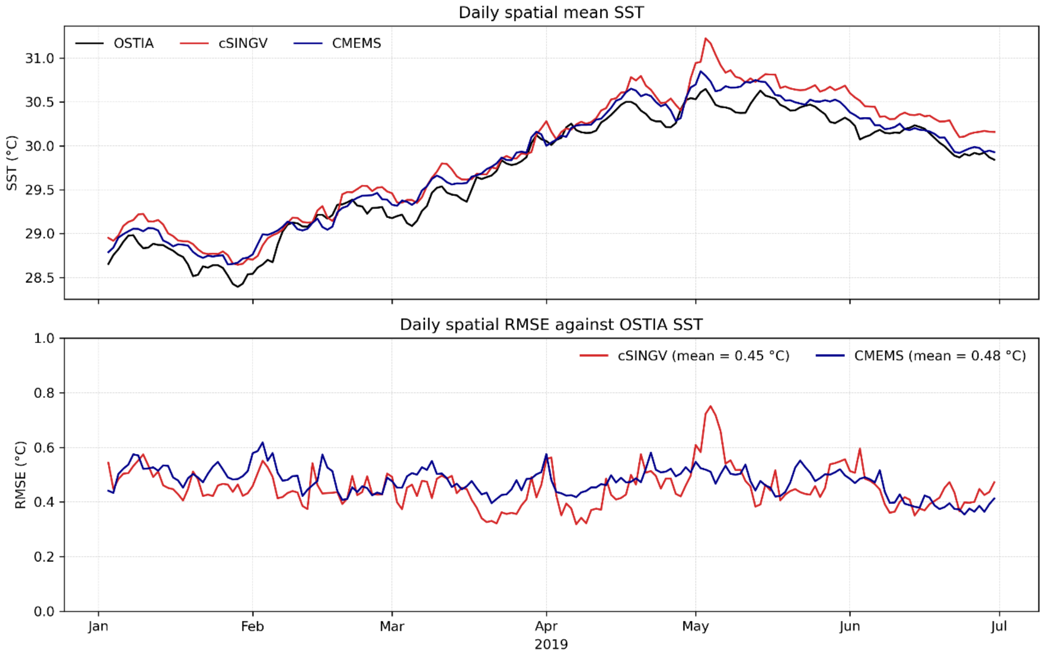

Figure R7. Daily spatially averaged sea-surface temperature (SST) from OSTIA, the fully coupled cSINGV simulation, and CMEMS (top), and the corresponding daily spatial RMSE of cSINGV and CMEMS relative to OSTIA (bottom) over the model domain during January–June 2019.

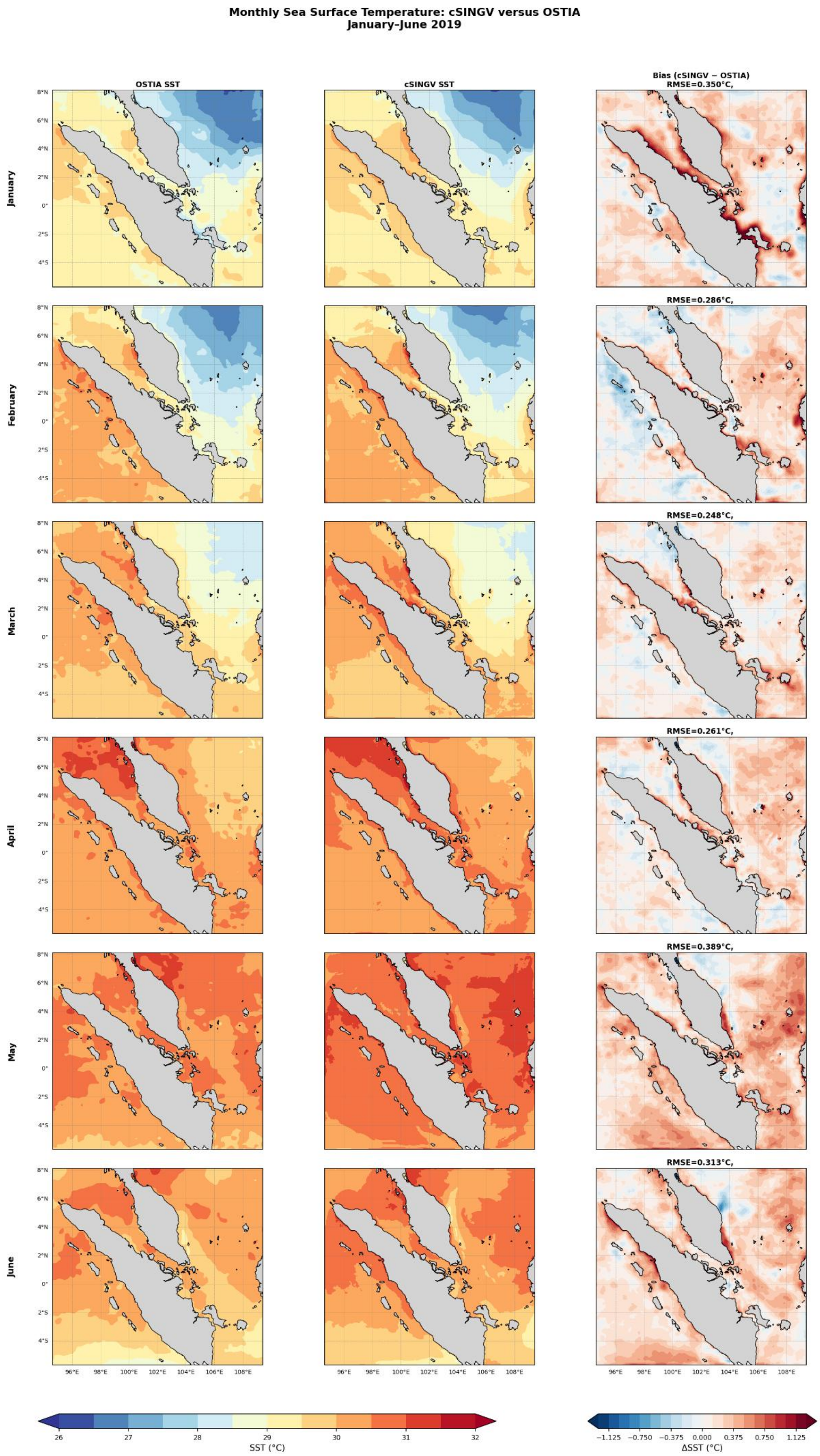

Figure R8. Monthly mean sea-surface temperature (SST) from OSTIA (left column) and the fully coupled cSINGV simulation (middle column), together with the corresponding cSINGV − OSTIA SST bias (right column), during January–June 2019.

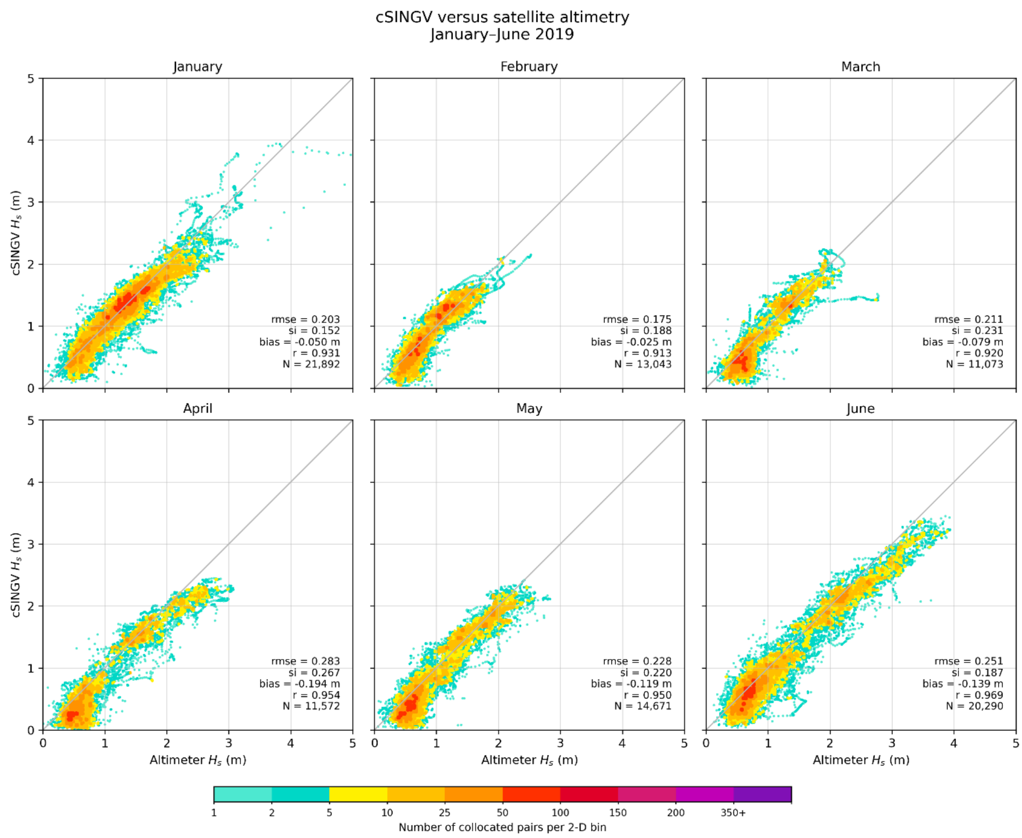

Figure R9. Same as Figure R6 but for the fully coupled cSINGV simulation.

Table R2. Same as Table R1, but for the fully coupled cSINGV simulation.

Period	Bias (m)	RMSE (m)	SI	Correlation (r)	KS score	N
January	-0.050	0.203	0.152	0.931	0.050	21892
February	-0.025	0.175	0.188	0.913	0.111	13043
March	−0.079	0.211	0.231	0.920	0.218	11073
April	−0.194	0.283	0.267	0.954	0.311	11572
May	−0.119	0.228	0.220	0.950	0.222	14671
June	−0.139	0.251	0.187	0.969	0.132	20290

Reviewer comment 7

Both configurations tend to produce more moderate and intense rainfall compared to the observations. Using the existing GPM comparison performed for Fig. 5, could the authors quantify, for example through a simple bias or intensity histogram, whether this wet bias differs systematically in magnitude between cSINGV and cSINGV_A? This would clarify whether coupling exacerbates or mitigates the rainfall bias.

Response

We thank the reviewer for this helpful suggestion. We have quantified the precipitation bias in both configurations using the existing daily GPM comparison (Fig. R10). Both simulations exhibit an overall wet bias, but its domain- and period-mean magnitude is larger in cSINGV (+0.96 mm day⁻¹) than in cSINGV_A (+0.55 mm day⁻¹). The corresponding cSINGV − cSINGV_A difference is +0.41 mm day⁻¹, indicating that coupling exacerbates the overall mean wet bias during the evaluation period, although the impact varies substantially with longitude and time and includes periods and locations with reduced bias. We will add the figure in the Supplement and revise the Section 4.3 accordingly.

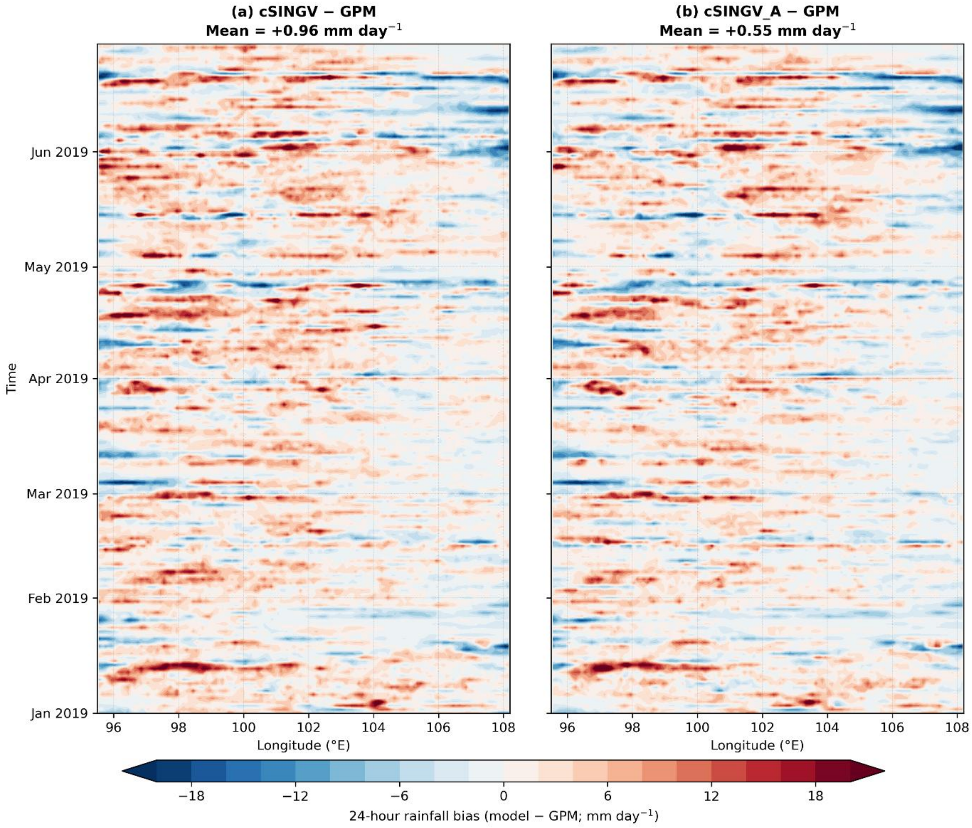

Figure R10. Longitude–time distribution of the daily precipitation bias relative to GPM averaged between 5°S and 8°N during January–June 2019 for (a) cSINGV and (b) cSINGV_A.

Reviewer comment 8

The squall case studies rely on four events selected from the existing MSS squall database using a threshold of >50 mm h⁻¹, of which only two show a clear coupling signal. Could the authors report, how many total qualifying events occurred in the study domain and period? This would clarify whether the four selected cases are representative of the broader population or constitute a favourable subsample.

Response

We thank the reviewer for raising this important point. Five observed squall events satisfying the >50 mm h⁻¹ criterion were identified within the study domain during January–June 2019: 4 April, 27 April, 8 May, 19 May, and 3 June. Of these, only the 4 and 27 April events were reproduced sufficiently well by at least one configuration to permit a process-based comparison. Neither simulation reproduced the remaining three events; therefore, they were not included in the detailed analysis. The other two cases discussed in the manuscript were examined using separate simulations outside the continuous January–June 2019 experiment. A broader evaluation using additional events is ongoing. We will explicitly describe this selection procedure in the revised manuscript and clarify that the selected cases are not necessarily representative of the broader population of observed squall events.

Reviewer comment 9

Since Sect. 6 frames cSINGV as a step toward an operational system, could the authors report the computational cost, such as core-hours and wall-clock time per forecast day, already logged for the completed coupled and atmosphere-only runs? This is a straightforward reporting that would substantially strengthen the paper's relevance to operational centres.

Response

We thank the reviewer for this helpful suggestion. We agree that reporting the computational requirements provides useful context for assessing the potential operational application of cSINGV. We have therefore added the computational cost of the coupled and atmosphere-only configurations to Sect. 6.

Based on the logged runtimes, the atmosphere-only cSINGV_A configuration uses 1,152 allocated cores and requires approximately 76 min of wall-clock time to complete one 24-h simulated forecast day. This corresponds to approximately 1,459 allocated core-hours per forecast day. The fully coupled cSINGV configuration uses 2,176 allocated cores and requires approximately 80 min per 24-h forecast day, corresponding to approximately 2,901 allocated core-hours.

Thus, the coupled configuration requires approximately twice the allocated core-hours of the atmosphere-only configuration. However, because the atmosphere, ocean, and wave components run concurrently in the coupled system, the elapsed wall-clock time increases by only approximately 5.3%, from 76 to 80 min per forecast day. These values will be reported in the revised manuscript and Table R3 will also be added to the Supplement. We will also clarify that these timings represent the present research configuration and may vary depending on the computing architecture, resource allocation, model configuration, and operational workflow.

Table R3. Computational requirements of the atmosphere-only cSINGV_A and fully coupled cSINGV configurations for one 24-h simulated forecast day. Allocated core-hours were calculated as the number of allocated CPU cores multiplied by the elapsed wall-clock time in hours.

Configuration	Allocated cores	Wall-clock time per 24-h forecast day	Allocated core-hours per forecast day
cSINGV_A	1,152	76 min	1,459
cSINGV	2,176	80 min	2,901

Minor points

Reviewer comment 1

Figure 3 caption enumerates panels (a), (b), and (c), but the panels are unlabelled in the figure. Please add the corresponding panel labels.

Response
We thank the reviewer for identifying this omission. The labels (a), (b), and (c) will be added to the corresponding panels of Figure 3 in the revised manuscript, consistent with the figure caption.

Reviewer comment 2

Please clarify whether the FSS in Figure 6 is computed within the red evaluation box shown in Figure 1 or over the full domain.

Response
We thank the reviewer for this helpful suggestion. The FSS presented in Figure 6 was calculated within the red evaluation box shown in Figure 1, rather than over the full model domain. This information will be stated explicitly in the methodology, Figure 1 caption, and Figure 6 caption.

Reviewer comment 3

A one-line in-text summary of Tables S2–S4, including the NEMO version changes and the betamax/shallow-water sensitivity results, would aid readability.

Response
We thank the reviewer for this helpful suggestion. We will add an in-text summary of Tables S2–S4, highlighting the principal NEMO version changes and the main outcomes of the WW3 betamax and shallow-water sensitivity experiments.

We appreciate the reviewer's comments, which have helped us improve the manuscript.

On behalf of the authors,

Rajesh Kumar (Corresponding author)