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Supplement of

Persistent SST anomaly vs. dynamical ocean model in winter weather forecasts: Global Ensemble Prediction System versions 5 and 6 over the North Pacific and North Atlantic

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This document contains hyperlinks to GEPS5 and GEPS6 technical reports, 1 section of text, 2 tables and 2 figures.

S1. HYPERLINKS TO TECHNICAL REPORT

- GEPS6 technical report (Lin et al. 2019): https://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/tech_notes/technote_geps-600_e.pdf

S2. TEXT

A. Handling 1-day Difference in start times

Since the start times in GEPS5 and GESP6 are off by 1-day, we use ERA5 as a reference dataset to compute bias. Since this approach is not traditionally used, here we provide our reasoning.

The ideal bias change computation is

$$\Delta\beta^{*}_{X}\left(t_s, t_l\right) = X_{\mathrm{GEPS6}}\left(t_s, t_l\right) - X_{\mathrm{GEPS5}}\left(t_s, t_l\right), \tag{S1}$$

where $\Delta\beta^{*}_{X}$ is the difference of variable X between GEPS5 and GEPS6 of start time t_s and lead time t_l in the ideal from, denoted by asterisk. However, due to operational reasons, start times of GEPS6 are always $\tau = 1$ day earlier than those of GESP5. Our bias workaround is

$$\Delta\beta_{X}\left(t_s, t_l\right) = \left[X_{\mathrm{GEPS6}}\left(t_s - \tau, t_l\right) - X_{\mathrm{ERA5}}\left(t_s - \tau + t_l\right)\right] - \left[X_{\mathrm{GEPS5}}\left(t_s, t_l\right) - X_{\mathrm{ERA5}}\left(t_s + t_l\right)\right]. \tag{S2}$$

Defining $\omega_{\tau,X}$ as the difference between (S1) and (S2), we derive

$$\begin{aligned}\omega_{\tau,X} &:= \Delta\beta_{X}\left(t_s, t_l\right) - \Delta\beta^{*}_{X}\left(t_s, t_l\right)\\ &= \left[X_{\mathrm{ERA5}}\left(t_s + t_l\right) - X_{\mathrm{ERA5}}\left(t_s + t_l - \tau\right)\right] - \left[X_{\mathrm{GEPS6}}\left(t_s, t_l\right) - X_{\mathrm{GEPS6}}\left(t_s - \tau, t_l\right)\right],\end{aligned} \tag{S3}$$

where $\omega_{\tau,X}$ would vanish if GESP6 is matches perfectly to ERA5.

To mitigate the impact of $\omega_{\tau,x}$, we apply a pentad window Δw on lead time t_l and average across the start times of the same start time group ϕ

$$\Omega_{\tau,X}\left(\phi, p\right) = \frac{1}{|\phi|}\left[\frac{1}{\Delta w}\sum_{t_s\in\phi}\int_{t_l=(p-1)\Delta w}^{p\Delta w}\omega_{\tau,X}\left(t_s, t_l\right)\,\mathrm{d}t_l\right] \tag{S4}$$

where $|\phi|$ is the size of the start time set, and p is a positive integer that numbers the lead pentad starting from 1. Because the synoptic scale dominates the medium-range weather, we choose $\Delta w = 5$ day. Moreover, assuming the distribution of $\omega_{\tau,x}\left(t_s, t_l\right)$ is a Gaussian with zero mean over start time $t_s \in \phi$. With these two reasons, $\Omega_{\tau,x}\left(\phi, p\right)$ should be sufficiently small. Therefore, with the usage of reference data ERA5 and averaging, (S2) can approximate (S1), i.e.,

$$\frac{1}{|\phi|}\left[\frac{1}{\Delta w}\sum_{t_s\in\phi}\int_{t_l=(p-1)\Delta w}^{p\Delta w}\Delta\beta^{*}_{X}\left(t_s, t_l\right)\,\mathrm{d}t_l\right] \approx \frac{1}{|\phi|}\left[\frac{1}{\Delta w}\sum_{t_s\in\phi}\int_{t_l=(p-1)\Delta w}^{p\Delta w}\Delta\beta_{X}\left(t_s, t_l\right)\,\mathrm{d}t_l\right] = \Delta B_X\left(\phi, p\right) \tag{S5}$$

where the mean bias change $\Delta B_X\left(\phi, p\right)$ is (4) in the main text. Although we cannot compute the expression (S4) because we have $X_{\mathrm{GEPS6}}\left(t_s, t_l\right)$ but not $X_{\mathrm{GEPS6}}\left(t_s + \tau, t_l\right)$, (S4) helps readers understand our approach. In principle, the smallness of (S4) depends on the quality of GEPS6 simulation, whose verification against ERA-Interim can be found in technical report provided above in Section 1.

S3. TABLES

Table S1. GEPS5 data count. Note that there are 20 years and 4 ensemble members.

Month	Count per year per member	Valid dates
Jan	5	3, 10, 17, 24, 31
Feb	4	7, 14, 21, 28
Mar	4	7, 14, 21, 28
Apr	4	4, 11, 18, 25
May	5	2, 9, 16, 23, 30
Jun	4	6, 13, 20, 27
Jul	0	N/A
Aug	0	N/A
Sep	1	27
Oct	4	4, 11, 18, 25
Nov	5	1, 8, 15, 22, 29
Dec	4	6, 13, 20, 27

S4. PLOTS

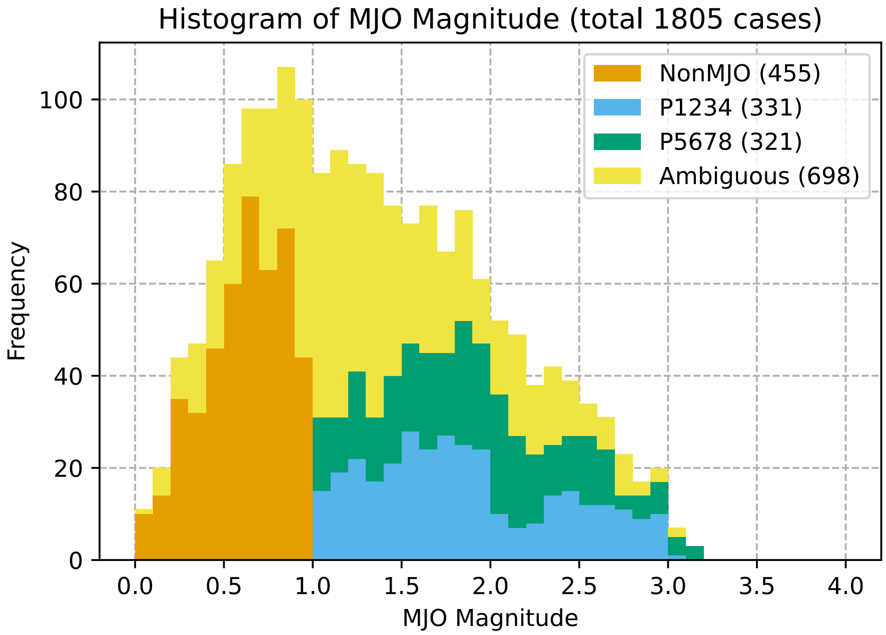

Fig. S1. Histogram of start times classified with MJO groups: NonMJO, P1234, P5678, and Ambiguous.

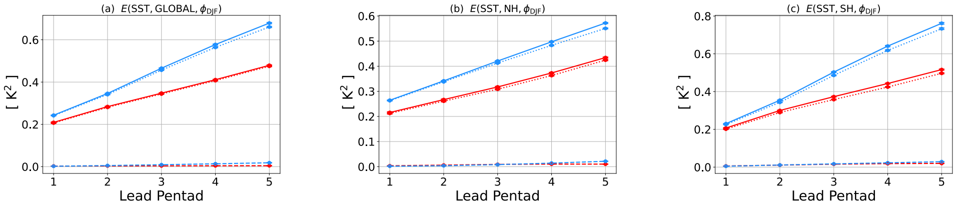

Fig. S2. Bias variance E analysis of global sea surface temperature (SST) as a function of pentads 1–6 computed from Global Ensemble Prediction System (GEPS) version 5 (GEPS5, red) to GEPS version 6 (GEPS6, blue) during December–January–February of lead pentads 1 to 5 in hindcast years 1998–2017. The regions presented are (a) global, (b) Northern hemisphere, and (c) Southern hemisphere oceans. The decomposition of E into mean ($\overline{E}$, dashed) and patterned ($\tilde{E}$, dotted) variances are added. The whiskers represent the standard error.

Table S2. GEPS6 data count and their start times. The count of subsampled GEPS6 is documented in parentheses, and the start times are underlined. Note that there are 20 years and 4 ensemble members.

Month	Count per year per member	Valid dates
Jan	9 (5)	2, 7, 9, 14, 16, 21, 23, 28, 30
Feb	8 (4)	4, 6, 11, 13, 18, 20, 25, 27
Mar	8 (4)	4, 5, 11, 12, 18, 19, 25, 26
Apr	10 (5)	1, 2, 8, 9, 15, 16, 22, 23, 29, 30
May	8 (4)	6, 7, 13, 14, 20, 21, 27, 28
Jun	8 (4)	3, 4, 10, 11, 17, 18, 24, 25
Jul	11 (0)	1, 2, 8, 9, 15, 16, 22, 23, 25, 29, 30
Aug	13 (0)	1, 5, 6, 8, 12, 13, 15, 19, 20, 22, 26, 27, 29
Sep	13 (1)	2, 3, 5, 9, 10, 12, 16, 17, 19, 23, 24, 26, 30
Oct	13 (5)	1, 3, 7, 10, 14, 15, 17, 21, 22, 24, 28, 29, 31
Nov	12 (4)	4, 5, 7, 11, 12, 14, 18, 19, 21, 25, 26, 28
Dec	9 (4)	3, 5, 10, 12, 17, 19, 24, 26, 31