Better Initial Conditions Significantly Improve Intraseasonal Prediction

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Introduction and Objectives

Intra-Seasonal Oscillation (ISO) is a dominant tropical variability with a quasi-oscillating period of 30-90 days, which offers an opportunity to bridge the forecasting gap between synoptic weather prediction and seasonal climate forecast. The northward-propagating ISO in boreal summer regulates the active and break periods of Asian summer monsoon. On its way eastward, the active phase of the ISO clusters the occurrences of tropical cyclones over Indian Ocean, North Western Pacific, North Eastern Pacific, and Atlantic Oceans. A capability of predicting the ISO beyond two weeks will have considerable social benefits to and is strongly desired by the communities impacted by the ISO and the associated extreme events (e. g., TC, flood and drought etc.).

Although most contemporary global models are still struggling to simulate a decent ISO, the IPRC/UH Hybrid-coupled GCM (so-called UH_HCM), which combined ECHAM-4 AGCM with UH intermediate ocean model, produces a robust Tropical Intra-Seasonal Oscillation (Figure 1). Using the UH_HCM, a suite of forecast experiments have been carried out. The objectives of this study are to:

(1) Document the biases of reanalyses in the representation of the ISO
(2) Assess the ISO prediction skills initialized with the original NCEP reanalyses and ERA Interim
(3) Explore a way to alleviate the ISO biases in these reanalyses
(4) Assess the impacts of modified reanalyses on ISO prediction skills

Simulation of Northward-Propagating ISO

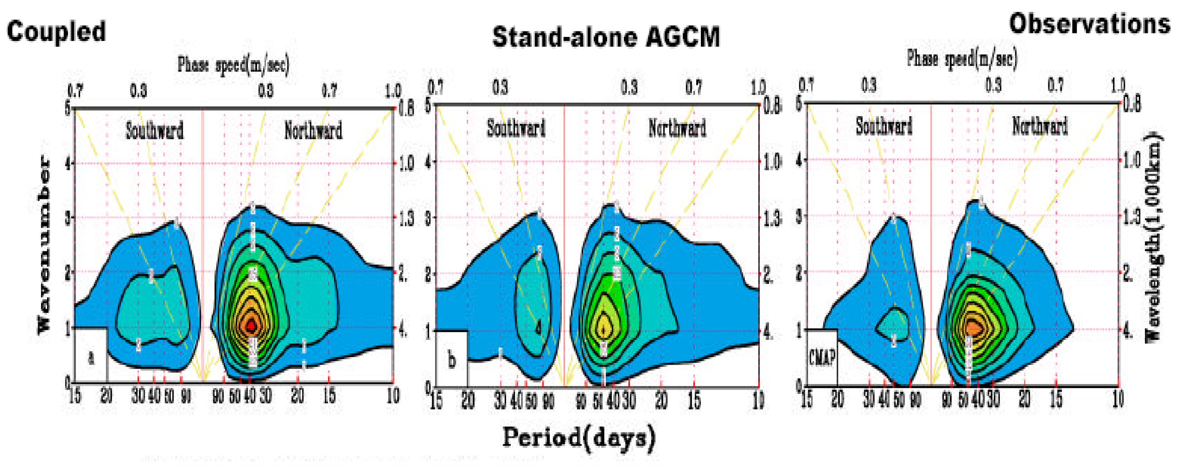

Figure 1. Wavenumber-frequency spectra (averaged between 65°E and 120°E) of northward/southward propagating ISO-related precipitation from the UH_HCM (left panel), the atmosphere-only run (middle panel) and the observations (right panel). The simulated northward-propagating ISO in the UH_HCM agrees well with the observed one.

Potential Predictability of the ISO

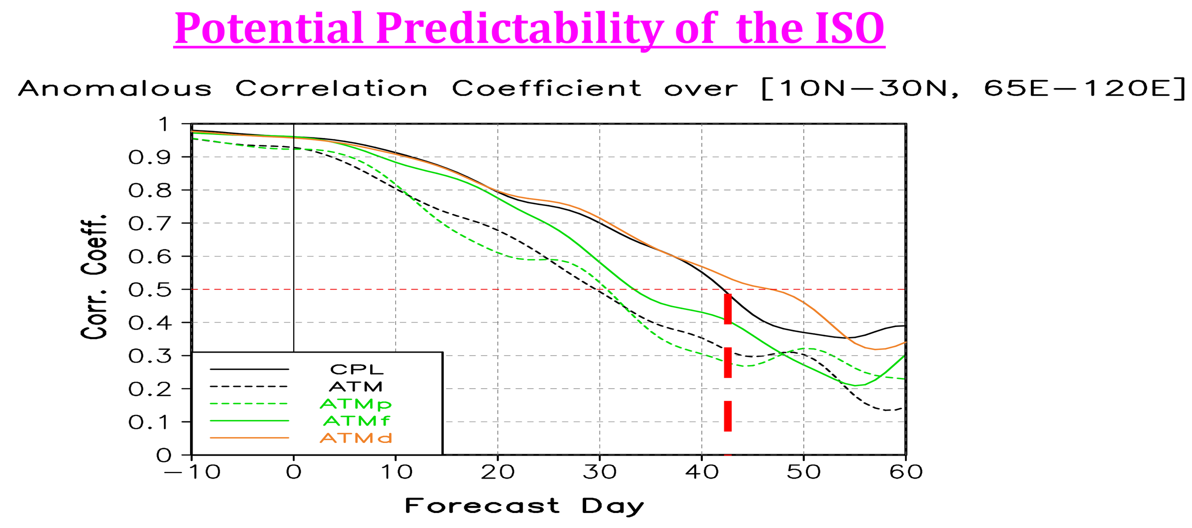

Figure 2. Potential predictability of ISO-related precipitation in days over Southeast Asia (10°N-30°N, 65°E-120°E) from the UH_HCM under different settings of lower boundary conditions. The potential predictability reaches 42 days if the lead time when ACC drops to 0.5 is used as the criterion.

Prediction Skill of the ISO

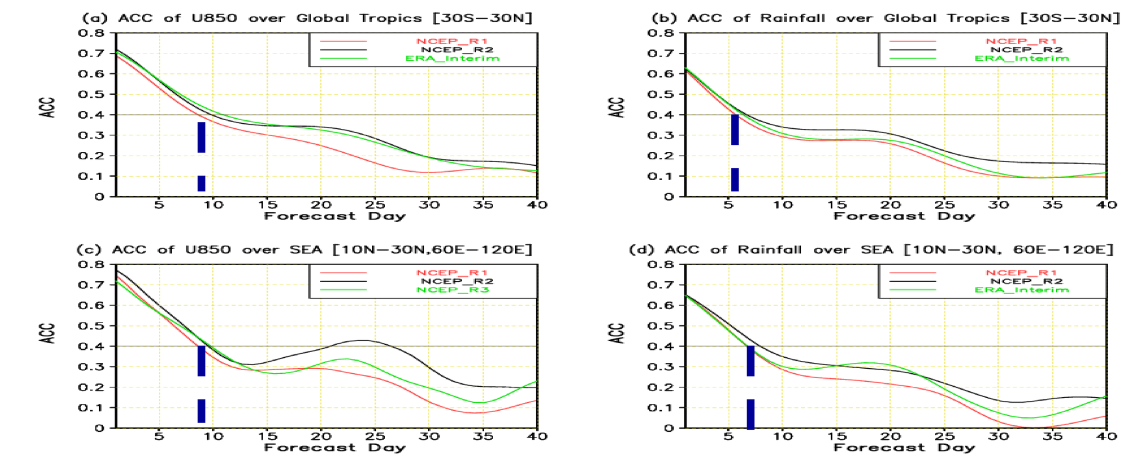

Figure 3. Practical prediction skills of ISO-related U850 and precipitation in 2004 summer over Southeast Asia and global tropics for the UH_HCM initialized with the original NCEP R1&R2 and ERA Interim. The prediction skills of U850 and precipitation are about 7-10 days over Southeast Asia and global tropics if the lead time when ACC drops to 0.4 is used as the criterion.

Many previous studies (e. g., Figure 1) using the UH_HCM indicate that this hybrid coupled model simulates a reasonable ISO in terms of its intensity and propagations, the potential predictability of ISO-related precipitation over Southeast Asia reaches 42 days (Figure 2). We expected a decent ISO prediction skill from this model when initialized with available reanalysis datasets (e. g., NCEP R1&R2, ERA Interim). Unfortunately, the resultant useful skills are only 7-10 days (Figure 3). This disappointing outcome left us pondering what went wrong during our execution: A nice model with interactive air-sea coupling initialized with state-of-the-art reanalyses? It turns out:

ISO intensity in reanalyses is significantly underestimated

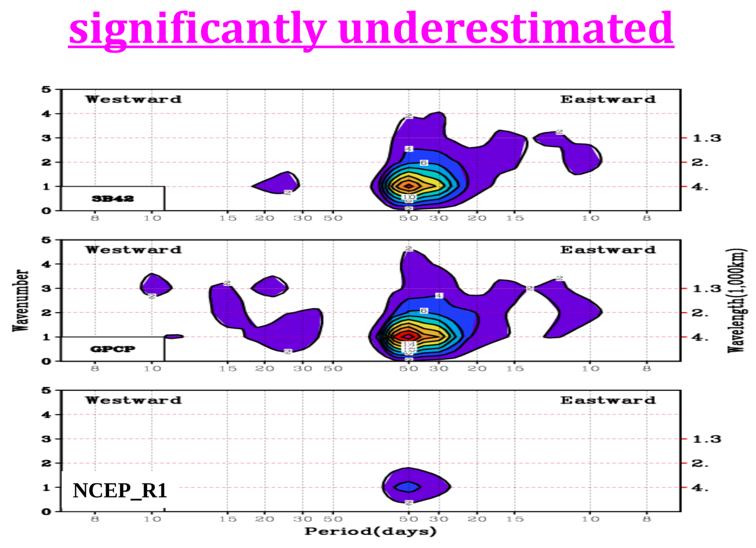

Figure 4. Wavenumber-frequency spectra (averaged over 10°S-10°N) of eastward/westward propagating precipitation from two observational datasets: (upper panel) TRMM 3B42; (middle panel) GPCP; and (lower panel) NCEP reanalysis. The intensity of eastward-propagating ISO in the reanalysis is 2-3 factors smaller than that in the observations.

Table 1, Forecast Experiment Design

Experiments	Initial Conditions
NCEP_R_f	AC[a] + low-frequency[b]
NCEP_R_unf	AC + low-frequency + high-frequency[c]
2*NCEP_R_f	AC + 2*low-frequency
3*NCEP_R_f	AC + 3*low-frequency
3*NCEP_R_unf	AC + 3*low-frequency + high-frequency

[a]AC (Annual Cycle) = annual mean + first three annual harmonics
[b]low-frequency = 30-90-day variability
[c]high-frequency = total – AC – low-frequency

Rainfall regimes in the observations and reanalyses

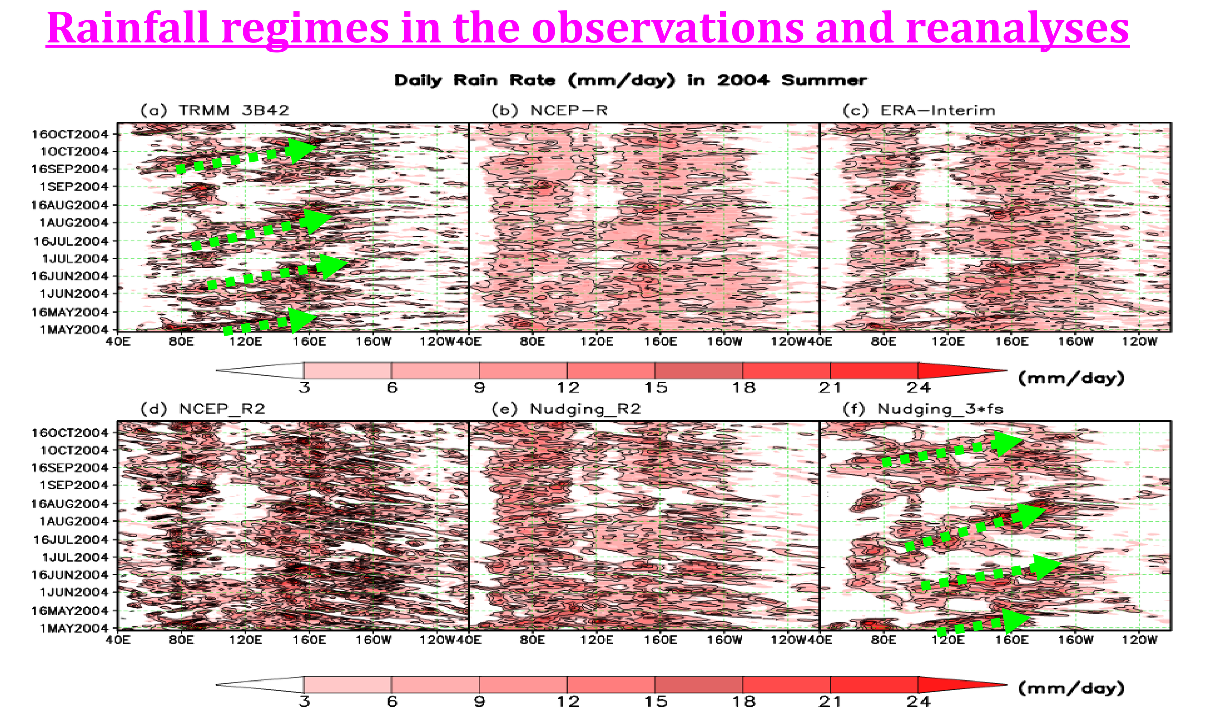

Figure 5. Time-longitude precipitation rate averaged over 10°S-10°N from (a) TRMM 3B42, (b) NCEP R1, (c) ERA Interim, (d) NCEP R2, (e) Nudging the original NCEP R2 into UH_HCM, and (f) Nudging the NCEP R2 with amplified ISO into UH_HCM. Four eastward-propagating ISO events are well discerned in the observations (a) but unclear in all three reanalyses (b, c, d, e). Nudging reanalysis with amplified ISO into the UH_HCM results in much better representation of the ISO (f).

ISO prediction skills for 2004 summer

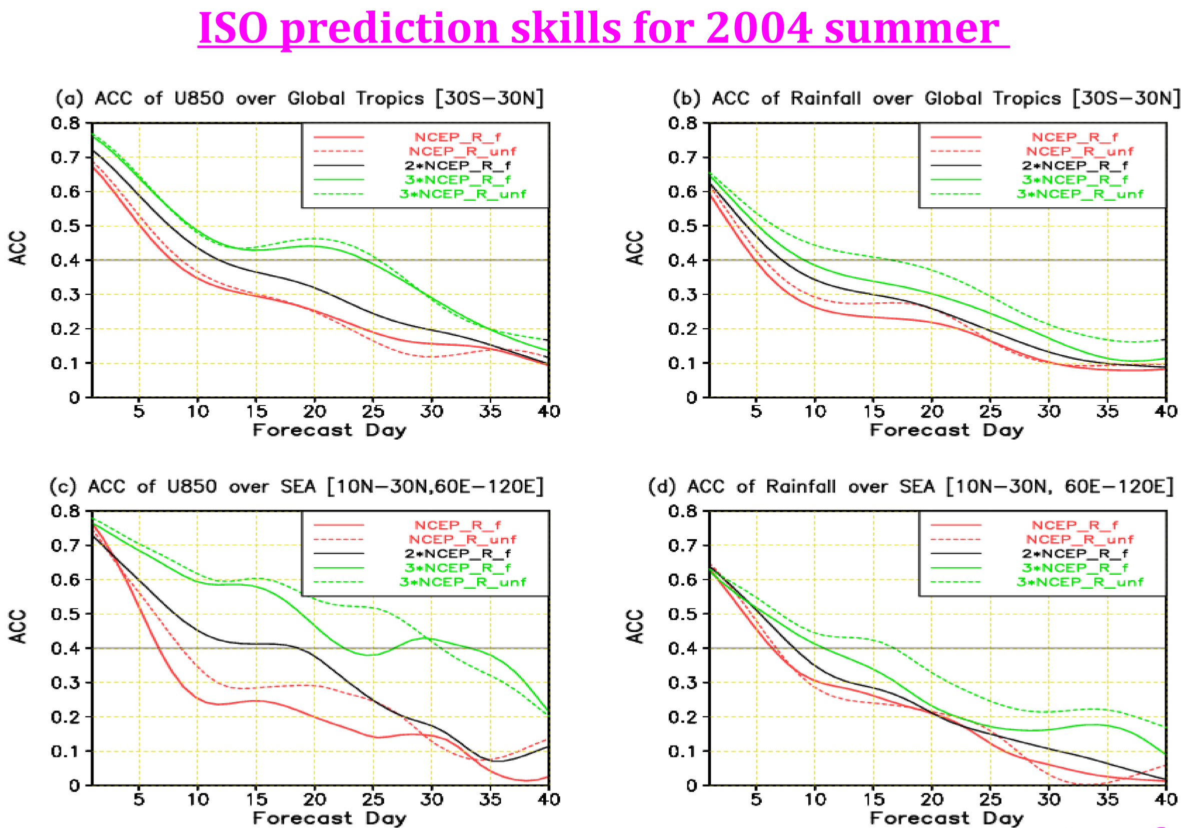

Figure 6 (upper). ISO prediction skills under different initial conditions. The settings of all experiments are given in Table 1. ISO prediction skills are measured as the Anonymous Correlation Coefficient (ACC) drops to 0.4. The main findings are: (i) when ISO signals in reanalysis are doubled or tripled, the corresponding prediction skills steadily increase; (2) including high-frequency disturbances in the initial conditions generally extends ISO prediction skills.

ISO prediction skills in recent five years (2004-2008)

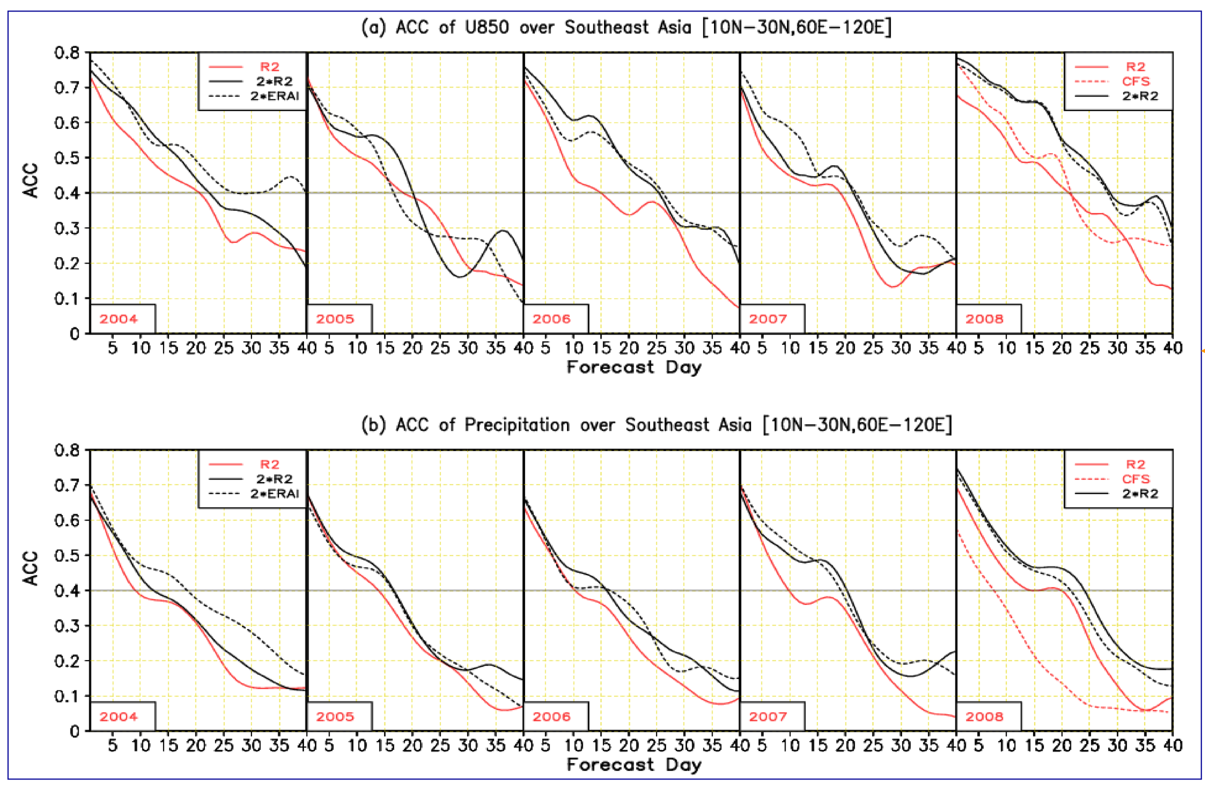

Figure 8 (left). Prediction skills of ISO-related U850 (a) and precipitation rate (b) over Southeast Asia (10°N-30°N, 60°E-120°E) initiated with the original NCEP reanalysis (red solid lines, R2); modified NCEP reanalysis with doubled ISO signals (black sold lines, 2*R2); modified ERA Interim with doubled ISO signals (black dashed lines, 2*ERAI). CFSv1 forecast skills in 2008 initiated with NCEP R2 are also given as an independent check (red dashed lines, CFSv1). No matter for NCEP R2 or ERA Interm, doubling ISO signals in the initial conditions result in consistent extension of ISO prediction skills.

One forecasted ISO event

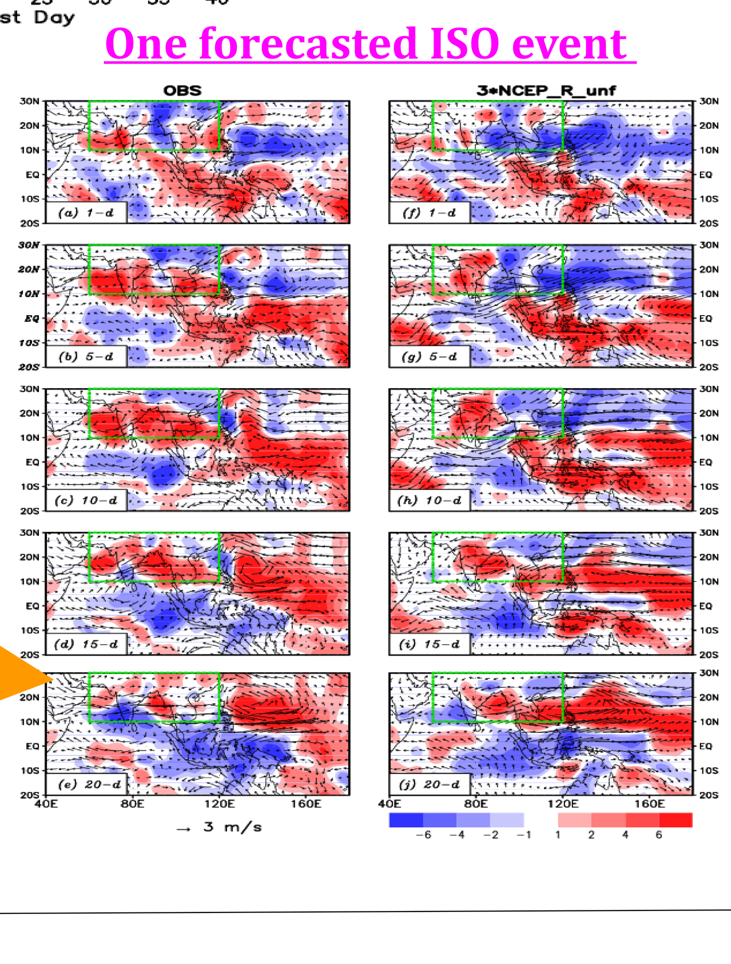

Figure 7 (right). Spatial-temporal evolutions of ISO-related precipitation rate and 850-hPa winds from (a) the observations and (b) model forecasts initialized on May 31, 2004. It is very encouraging to see that the active phase of this ISO event over the North Western Pacific can be predicted 20 days ahead.

Five-year mean ISO prediction skills

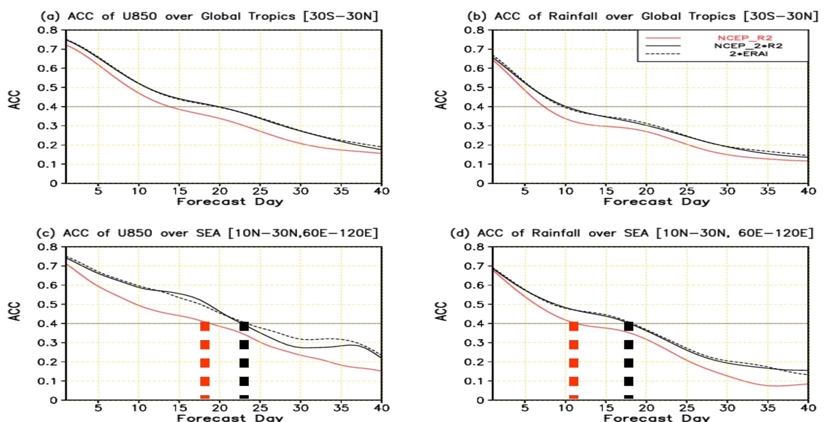

Figure 9 (upper). Five-year (2004-2008) averaged prediction skills of U850 and precipitation over global tropics and Southeast Asia initialized, respectively, with the original NCEP R2 (red solid lines), NCEP R2 with doubled ISO signals (black solid lines, 2*R2), ERA-Interim with doubled ISO signals (black dashed lines, 2*ERAI).

Summary

- Three reanalysis datasets (e. g., NCEP R1, R2, & ECMWF/ERA-Interim) underestimate ISO signals in the real world. This bias compromised ISO prediction skills when these reanalyses are directly used to initialize the forecasts.
- Enhanced ISO signals in initial conditions lead to consistent increase of ISO prediction skills. Initializing UH_HCM with doubled ISO in NCEP R2 and ERA-Interim results in a useful skill of 23 and 18 days for U850 and precipitation over Southeast Asia and 20 and 10 days over global tropics.
- Including high-frequency disturbances in initial conditions generally extends ISO prediction skills (Figure 6).

Fu et al. (2009) on GRL and Fu et al. (2010)

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