Impact of river freshwater on subseasonal to seasonal variability in a climate model

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Section 1 Background

The Bay of Bengal (BoB) receives a large amount of freshwater from rainfall and terrestrial rivers during the summer monsoon season. In-situ observations captured as a part of the Bay of Bengal Monsoon Experiment revealed that the arrival of freshwater plumes from terrestrial rivers can cause dramatic fluctuations in sea-surface salinity. As a result of the salinity stratification, the mixed layer depth decreases and thick barrier layers form. These thick barrier layers inhibit the cooling of shallow mixed layers due to entrainment. The thin mixed layer can hence be warmed more effectively by incoming solar radiation, aiding convection. BoB is considered to be the heart of the Indian Monsoon system. The sea-surface temperature (SST) in the BoB remain close to the convective threshold throughout the year. The north-western BoB is also the preferred location of genesis for monsoon low-pressure systems (LPS). The air-sea interactions in the BoB also aid in the northward propagation of the Intertropical Convergence Zone to Indian landmass at intra-seasonal time scales. Therefore, it is important to account for the river freshwater in this region in coupled ocean-atmosphere models.
Earth system models used for climate simulations include the representation of fresh-water fluxes from rivers, which are considered important for long simulations of the earth system. This aspect has received much less attention in coupled models used for sub-seasonal to seasonal (S2S) predictions. To address this, we couple a river-routing model to the Climate Forecast System version 2 (CFSv2). The impact of such coupling on sub-seasonal variability and seasonal prediction skill is assessed in seasonal hindcasts of the model.

Section 2 Model and experiment design

CFSv2 is used for operational S2S forecasts in India; hence, it was chosen to test the above-mentioned hypothesis. The RVIC streamflow routing model is coupled to the CFSv2 (referred to as RIV simulation). RVIC is typically used as a post-processor to the Variable Infiltration Capacity (VIC) hydrology model. Using a digital elevation map, river basins are delineated globally, and flow directions are generated as a pre-processing step. Hourly surface runoff generated by the land model is routed through this flow network, and the river discharge at land-ocean boundaries is obtained. The river discharge is passed to the ocean model once in twenty-four hours of model integration. The mixing at river mouths is enhanced in the ocean model to account for the ocean model's coarse vertical resolution. In the control run (CTL), climatological annual mean river-runoff is prescribed based on observations
Seasonal hindcasts were carried out from 1981 to 2017 using lagged initialization (ten ensemble members) with February initial conditions, and the model simulation is evaluated for the summer monsoon season (June-September; JJAS).

Section 3 Impact on S2S scale variabiltiy

Daily-varying river discharge impacts the synoptic and intra-seasonal variability in the model (Srivastava et. al. 2023a, b) and the seasonal prediction skill. On the synoptic time scales, due to enhanced SST gradients in the north-western BoB, frequent LPS genesis occurs, and these systems are more energetic. Thus, they bring more rainfall to the Indian landmass. Indian Summer Monsoon (ISM) has periods of enhanced (subdued) rainfall activity, which are referred to as the monsoon active (break) cycles. Enhanced rainfall activity over catchment areas will ultimately convert to surface runoff and reach the ocean after a time-lag. The lag composite of the standardized BoB river discharge index and the monsoon intraseasonal oscillation index (20-100 day filtered rainfall anomalies over central India standardized by its own standard deviation) is shown in Figure 1. It is evident that there is a time lag of 17 days between the rainfall over India and the discharge at river mouths. Therefore, the impact will be seen in the break spell and the subsequent active spell. To demonstrate this, we make the composites of rainfall and SST for the active spell, subsequent break spell, and the following active spell, and is shown in Figure 2. The cooling of SSTs in the Active and Active2 spells is larger in RIV compared to CTL, which is primarily attributed to the strong low-level monsoonal flow. From the rainfall composite, it is evident that the rainfall over northern BoB, central India, and Western Ghats is stronger in RIV