atmosphere

MDPI

Supplementary Materials

Text S1. Configuration of the CESM Simulations

The CAM5.1 uses the Rapid Radiation Method for GCMS (RRTMG) [1,2], double-moment cloud microphysics parameterization by Morrison and Gettleman [3], boundary layer parameterization by Bretherton and Park [4], and the shallow convection parameterization by Park and Bretherton [5].

Anthropogenic aerosol emissions used in the present study are from the Lamarque et al. data sets [6], including emissions for anthropogenic aerosols and precursor gases: sulfur dioxide, sulfate aerosols, primary organic aerosols, secondary organic aerosols, and black carbon aerosols (BC). The emissions of BC and organic carbon include the updates of Bond et al. [7] and Junker and Liousse [8]. Emissions of sulfur dioxide include an update of Smith et al. [9,10].

The addition of irrigation water to the land model follows the procedure in Wey et al. [11]. An estimation of 50% of irrigation water over the South Asia are from groundwater, assuming half of them come from unconfined aquifer. In the simulation, no water is removed from rivers, and evaporation from lakes is ignored (not significant in this region). Monthly data of irrigation amount are distributed evenly daily rates, and applied at every time step as previous studies [11–13]

Text S2. The Moisture Budget

The vertically integrated water budget equation can be written as [12,14,15]

$$\left\langle \frac{\partial q}{\partial t} \right\rangle = ET - P - \langle \nabla \cdot (Vq) \rangle \qquad \text{(Eqn. S1)}$$

where q is specific humidity, P is precipitation, ET is evapotranspiration, V is horizontal winds, and p is pressure; ⟨ ⟩ represent a mass integration throughout the troposphere. Since vertical velocity is relatively small at the surface and the top of troposphere, and for long-term averages, the time derivative term can be ignored, the change in precipitation can then be written as [14–16]

$$\Delta P = \Delta ET - \Delta\langle V \cdot \nabla q \rangle - \langle \Delta\omega \frac{\partial \overline{q}}{\partial p} \rangle - \langle \overline{\omega} \Delta \frac{\partial q}{\partial p} \rangle + residue \qquad \text{(Eqn. S2)}$$

where Δ represents the mean changes in a perturbed simulation relative to the Control simulation, ω is pressure velocity, ¯ represent the mean condition in the Control simulation. The second to the fourth terms on the right-hand side of Eqn. S2 represent the contribution to the total precipitation changes by the horizontal moisture convergence, by the vertical moisture convergence owing to the difference in vertical motion, and by the vertical moisture convergence owing to the difference in vertical moisture distribution, respectively. Figure S1 shows the spatial distribution of the change in each of these terms in OND owing to aerosol (ΔA), irrigation (ΔI) and their concurrent forcings (ΔAI).

Supplementary Figure

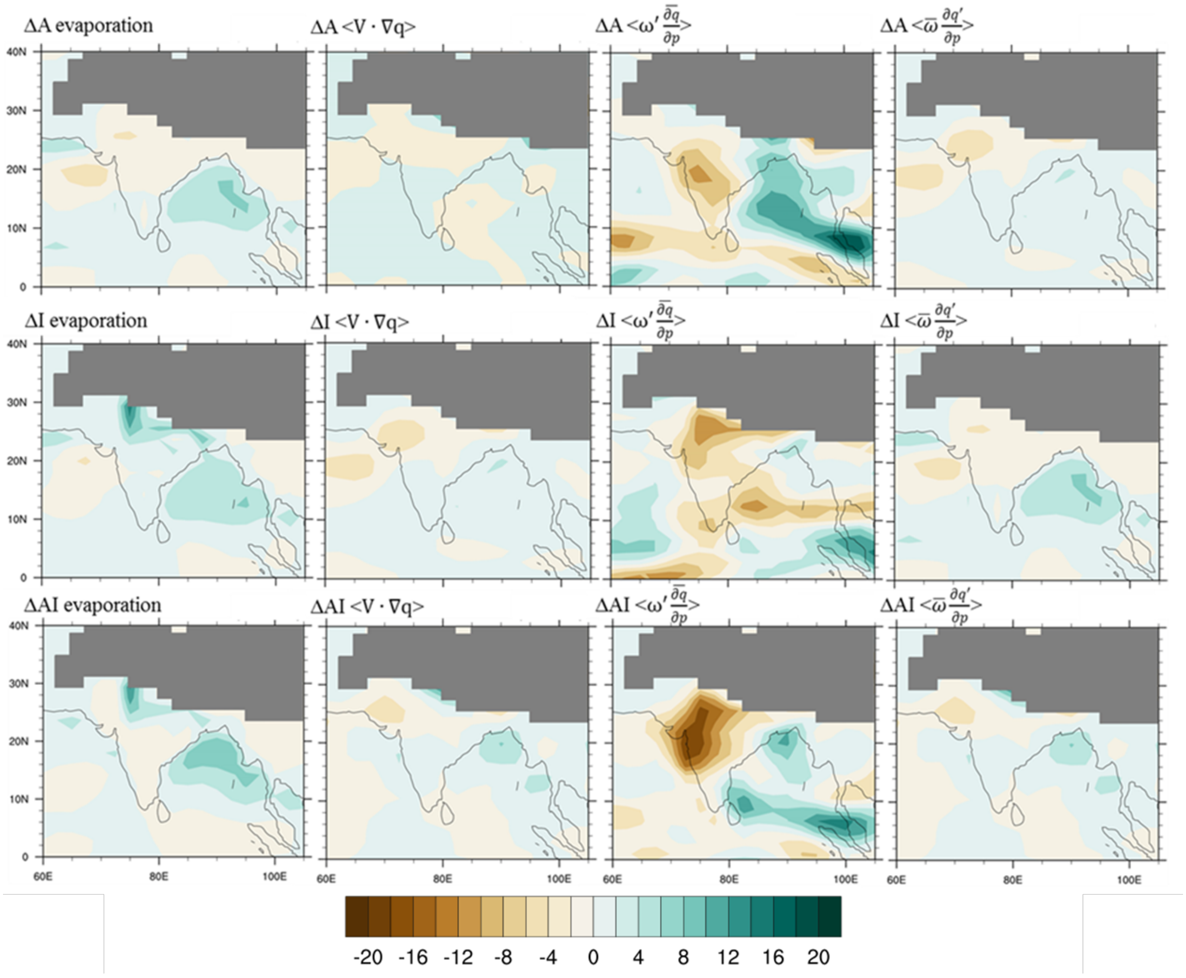

Figure S1. Differences in post-monsoon season (OND) moisture budget: (top) ΔA, (center) ΔI, and (bottom) ΔAI. Shown from left to right are (1) evapotranspiration, (2) horizontal moisture convergence ($-\Delta\langle V \cdot \nabla q \rangle$), (3) vertical moisture convergence by change in vertical motion ($-\langle \Delta\omega \frac{\overline{\partial q}}{\partial p} \rangle$), and (4) vertical convergence by change in moisture profile ($-\langle \overline{\omega} \Delta \frac{\partial q}{\partial p} \rangle$) in the right-hand side of Eqn. S2, respectively. All terms in unit of mm mon^{-1}., and positive (negative) values correspond to increasing (decreasing) precipitation.

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