

Table S1. Pluri-annual land averages (excluding Greenland and Antarctica) of the simulated variables over the different used periods for the evaluation (The chosen period does not markedly influence the observed mean, and thus the bias.)

| | Forced | | | Coupled | | |
|---------------------------------------|------------|------------|------------|------------|------------|------------|
| | 1987 -2009 | 1993 -1999 | 2003 -2009 | 1987 -2009 | 1993 -1999 | 2003 -2009 |
| Precipitation (mm/d) | 2.099 | 2.094 | 2.129 | 2.295 | 2.313 | 2.298 |
| SSM (m ³ /m ³) | 0.163 | 0.164 | 0.162 | 0.194 | 0.193 | 0.192 |
| ET (mm/d) | 1.074 | 1.072 | 1.077 | 1.182 | 1.180 | 1.189 |
| LAI (-) | 1.555 | 1.550 | 1.571 | 1.470 | 1.457 | 1.492 |
| Albedo (-) | 0.212 | 0.211 | 0.210 | 0.222 | 0.221 | 0.220 |

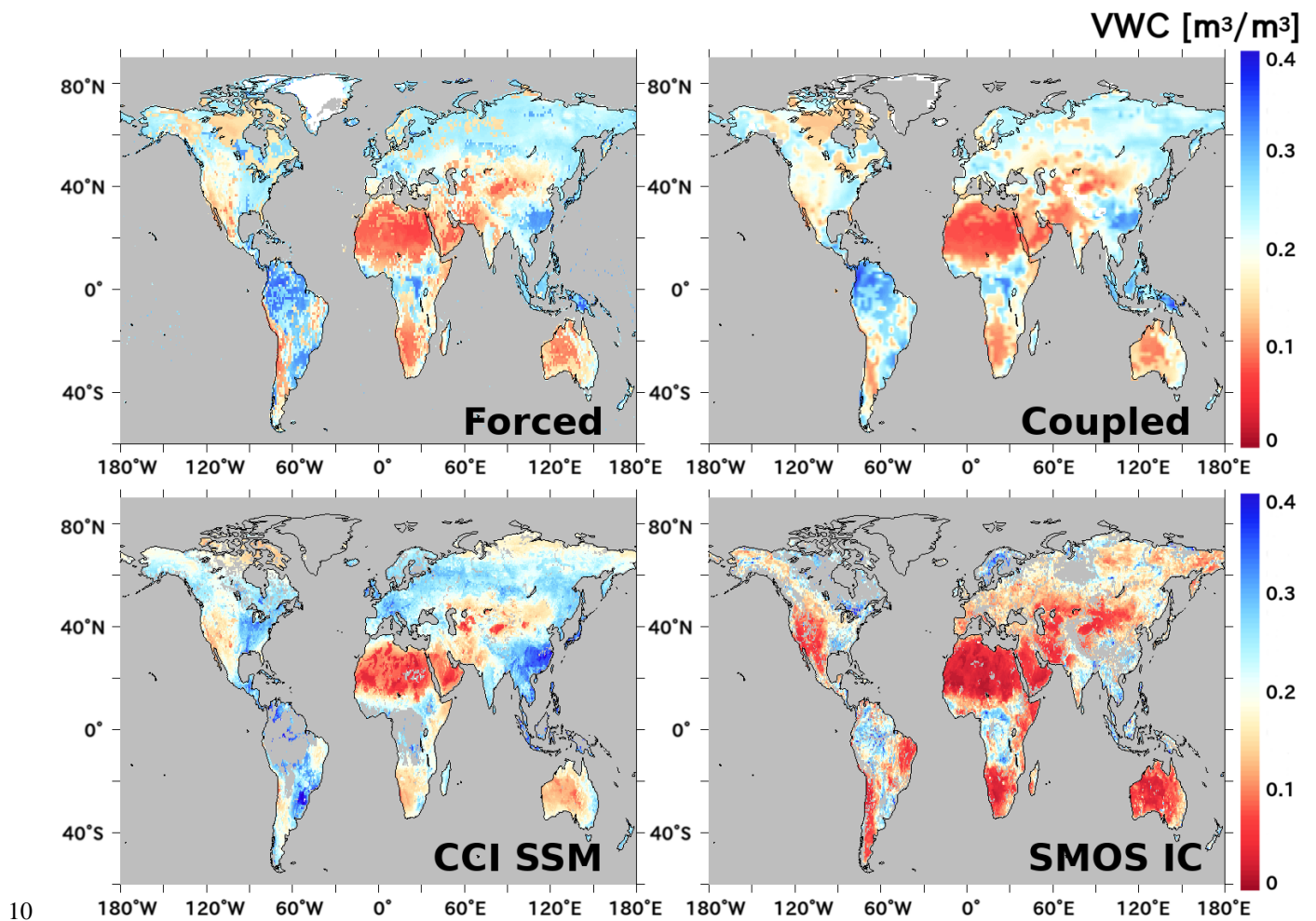
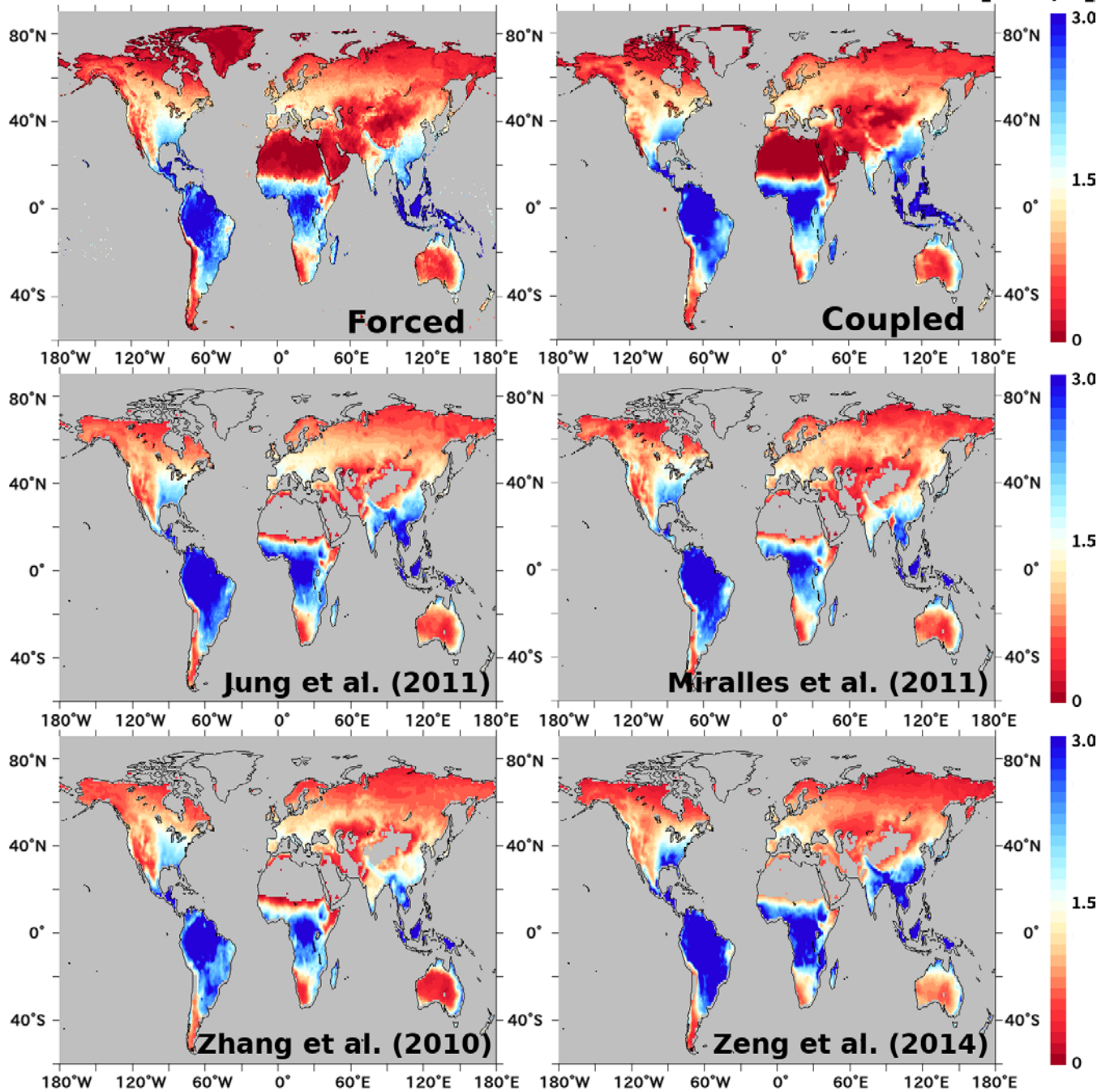


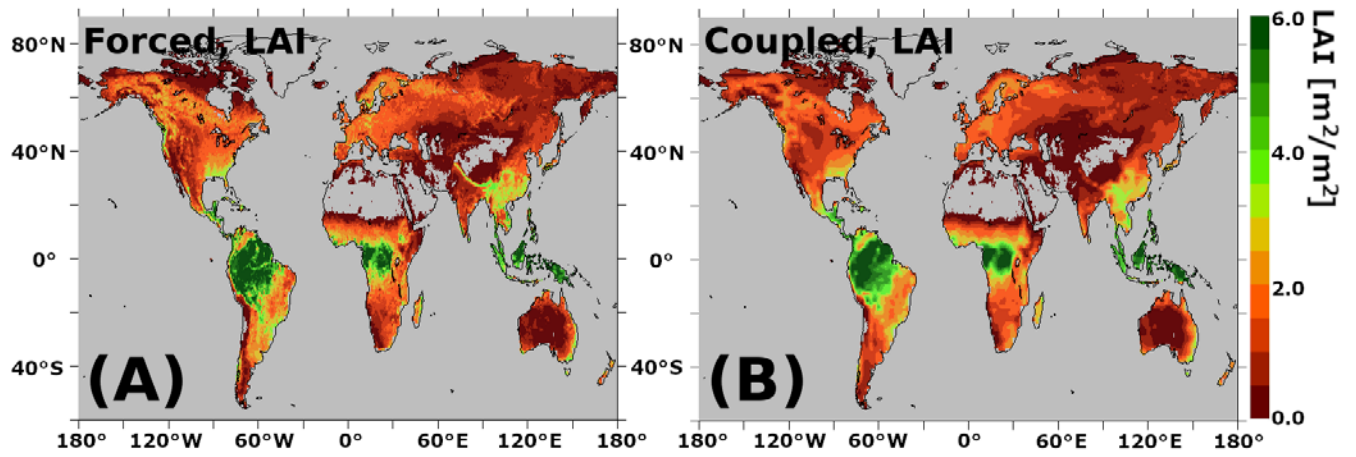
Figure S1: Comparison of the spatial patterns between the simulations (forced and coupled) and observations (In addition to the CCI-SSM, another observation data source (SMOS-IC [Fernandez-Moran et al., 2017] version 1.05, which is not shown in the main text, was used to just check the difference in reference data selection. All the available temporal data were averaged to create these maps (i.e., not separated into subperiods). The unit is SSM volumetric water content (VWC; m³/m³). Gray indicates the null values that were excluded in the quality control process.)

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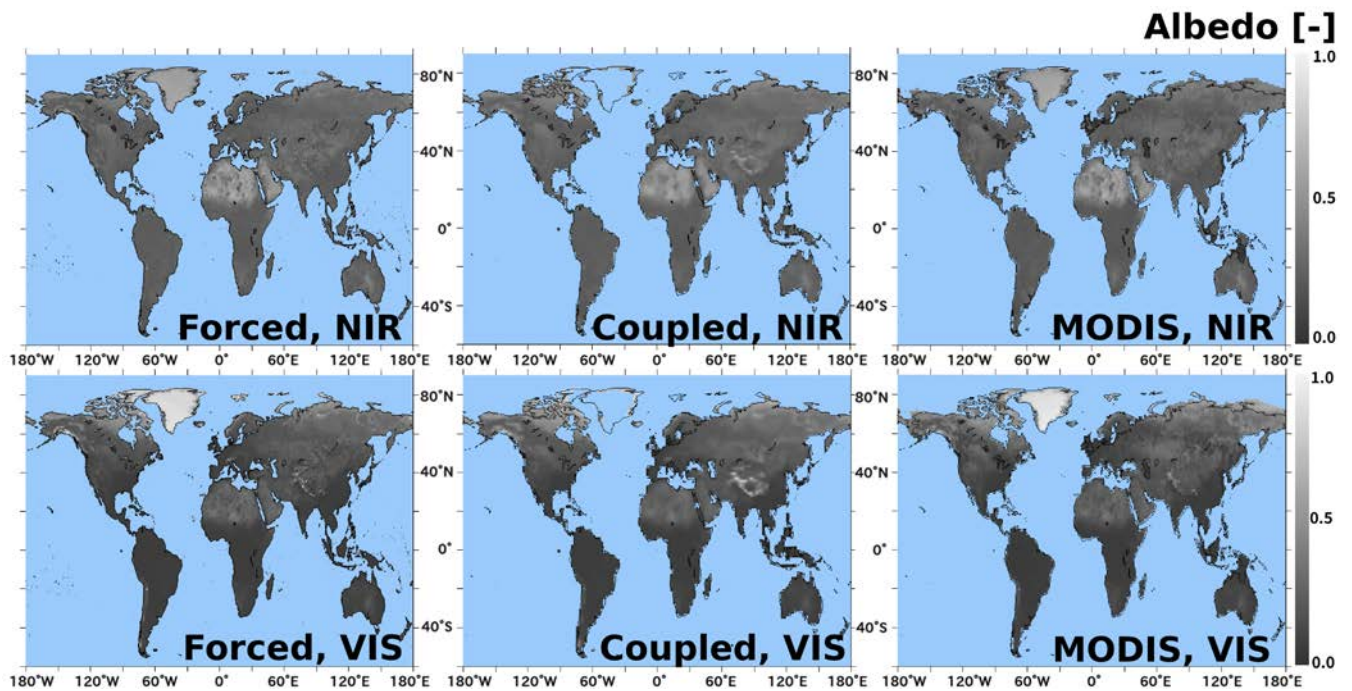
ET [mm/d]



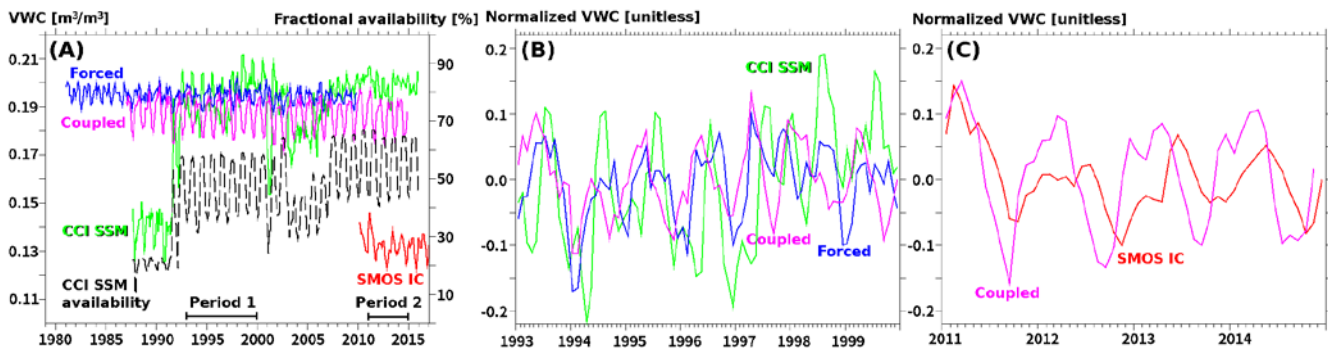
20 Figure S2: Temporally averaged evapotranspiration (ET) simulated in the forced and coupled mode and that of the reference data (In addition to the product by Jung et al. (2011), three other data sources (Miralles et al., 2011; Zhang et al., 2010; Zeng et al., 2014) were checked (not shown in the main text). They were temporally averaged during the common duration of all reference data (1987-2006).



25 Figure S3: Temporally averaged LAI simulated in (A) forced mode and (B) coupled mode. The reference LAI (Zhu et al., 2013) can be found in Fig. 1A.

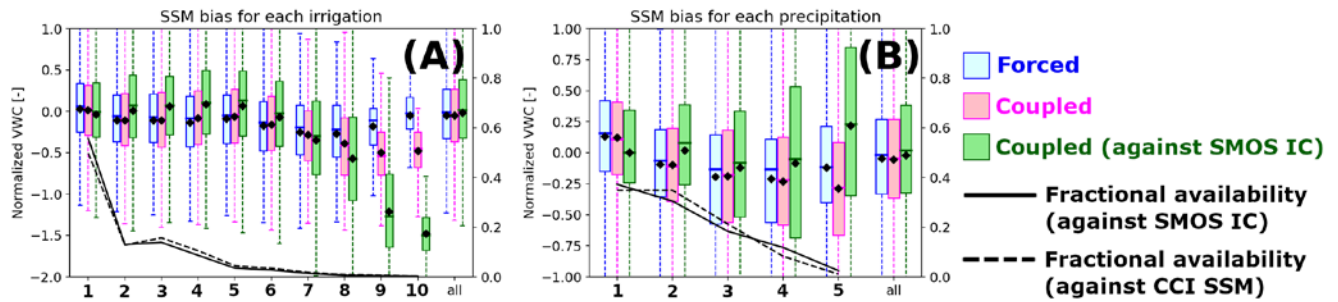


30 Figure S4: Temporally averaged albedo simulation in forced and coupled modes, and MODIS observation (Qu et al., 2014) for both near infrared (NIR) and visible (VIS) spectral domains.

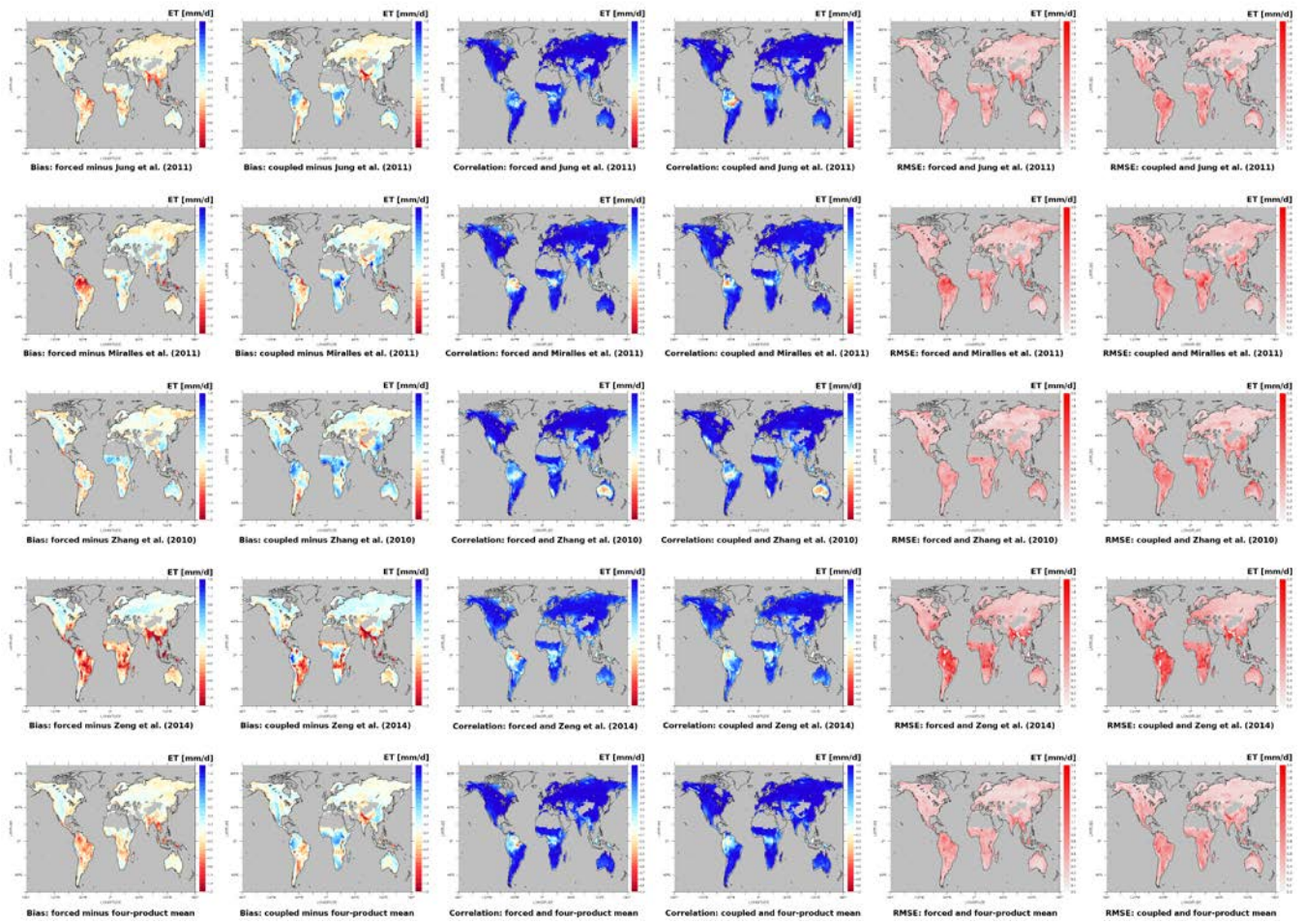


35 Figure S5: Time series of the globally averaged SSM of the forced and coupled simulations and observations (In addition to the CCI-SSM, another observation data source (SMOS-IC [Fernandez-Moran et al., 2017], which is not shown in the main text, was used to just check the difference in the reference data selection. (A) Time series of quality-controlled data before co-masking and normalization. Dashed black line shows ratio of available pixels to all land pixels (%), which strongly affected CCI-SSM values. (B) Time series after co-masking and normalization during subperiod 1 (1993–2009), including CCI-SSM and forced and coupled simulations. (C) That during subperiod 2 (2011–2014), including SMOS-IC and coupled simulation.)

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45 Figure S6: Different appearance in the factor analysis when using different reference data (CCI-SSM vs SMOS-IC) (The blue and pink boxes correspond to the mean bias of the forced and coupled modes against the CCI-SSM, respectively, and the green boxes correspond to the mean bias of the coupled mode against the SMOS-IC. The dashed and solid lines indicate the pixel availability (i.e., ratio of the sampled pixels to all the global land pixels) for each class in the CCI-SSM and SMOS-IC data, respectively. The irrigation class is defined based on the fractional coverage of the irrigated area: class1 (0%), class2 (0-0.1%), class3 (0.1-1%), class4 (1-5%), class5 (5-10%), class6 (10-20%), class7 (20-35%), class8 (35-50%), class9 (50-75%), and class10 (75-100%). The precipitation class definition is the same as in Table 2. Because of the different values and data coverages (particularly Amazon and Congo) between the CCI-SSM and SMOS-IC, the irrigation factor analysis (A) using the SMOS-IC emphasized the negative bias of the SSM in the coupled simulation in comparison with the CCI. The precipitation factor analysis (B) emphasized the difference between the reference data that were used (CCI or SMOS), especially in the areas with extremely high precipitation (classes 4 and 5).
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Figure S7: Mean bias, correlation coefficient, and RMSE maps derived from the different reference data (From the top row, Jung et al. (2011), Miralles et al. (2011), Zhang et al. (2010), Zeng et al. (2014), and the ensemble mean of those four data were used as references. From the left column, the mean bias of the forced simulation, those of the coupled simulation, the correlation coefficient of the forced simulation with each reference, that of the coupled simulation, the RMSE of the forced simulation, and that of the coupled simulation are shown. Jung et al. (2011) had a similar bias pattern to the four-product ensemble and had relatively less RMSE.)

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