Introduction

The supplementary text in this file provides further details on the reference reanalysis datasets used to assess the CMIP6 models in this study (Text S1); evaluation of reanalyses against independent evapotranspiration (E) and precipitation datasets (Text S2); and a detailed description of the Brubaker et al. (1993) model (Text S3) that was used to calculate precipitation recycling in addition to the Eltahir and Bras (1994) approach outlined in the main paper. In addition, we explain how integrated moisture fluxes were calculated (Text S4) and show how using monthly data instead of sub-daily data to compute moisture fluxes may have caused a slight negative bias in our recycling estimates (Text S5, Fig. S1).

Additional figures and tables contain information to support the methods and findings presented in the main manuscript. Figures include maps showing the relative difference in recycling between ERA5 and CMIP6 models (Fig. S2), seasonal results from the Brubaker analysis (Fig. S3), seasonal precipitation climatology for the Amazon and Congo (Fig. S4), seasonal cycles of wind and specific humidity in the lower troposphere (Figs. S5 & S6), and scatterplots comparing land-surface temperature biases with basin incoming wind speeds (Fig. S7). Tables include a summary of previous literature values (Table S1), details of the models, reanalyses and variables used in the study (Tables S2–S4), evaluation of reference datasets (Table S5), model-specific results on precipitation recycling representation over the Amazon and Congo (Tables S6 & S7), and correlations of Amazon and Congo recycling estimates with potential driving variables (Table S8).
Text S1: Reference data

CMIP6 models were evaluated against four independent reanalyses: 1) the European Centre for Medium-Range Weather Forecasts (ECMWF) fifth generation reanalysis (ERA5, Hersbach et al., 2019a, 2019b, 2020); 2) the Japanese Meteorological Agency’s Japanese 55-year Reanalysis (JRA-55, Japan Meteorological Agency/Japan, 2013, Kobayashi et al., 2015); the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR, Saha et al., 2010b, 2010a); and the Modern-Era Retrospective analysis for Research and Applications, version 2 (MERRA-2, Gelaro et al., 2017) from the Global Modeling and Assimilation Office (GMAO, 2015c, 2015b, 2015c; Table S4). Reanalyses assimilate a broad swathe of observations into a numerical model to provide a ‘best estimate’ of the global climate state. Assimilated observations include satellite and in-situ measurements of humidity, column water vapour, cloud liquid water, wind vectors and wind speed, helping these reanalyses to provide a realistic representation of atmospheric transport and moisture content. We retrieved the same variables as those obtained for CMIP6 models (Table S3) at monthly resolution for 1979 to 2014 or over the period of available data. For MERRA-2, we converted latent heat flux (LE, in units of W m\(^2\) = J s\(^{-1}\) m\(^{-2}\)) to E (in units of kg m\(^{-2}\) s\(^{-1}\)) as follows:

\[
E = \frac{LE}{\lambda}
\]  

(Eqn. S1)

where \(\lambda\) is the latent heat of vaporization at 20°C (2.453 \times 10^6 \text{ J kg}^{-1}).

In addition to the variables required for calculating precipitation recycling ratios, we analysed reanalysis precipitation and land surface temperature to explore reasons that the models might deviate from the reference datasets.
Text S2: Reanalysis evaluation

The reanalyses used to evaluate the models in this study may themselves struggle to represent key features of the tropical water budget (e.g. Builes-Jaramillo and Poveda, 2018, Baker et al., 2021). To assess the reliability of processes relating to precipitation recycling over each basin, we correlated seasonal variation in basin-mean E and precipitation with independent reference datasets. Due to the scarcity of in situ E data from the Amazon and Congo, and doubts over the reliability of remote-sensing E products over the Amazon as we have reported in a previous study (Baker et al., 2021), we selected catchment-balance E data as the best observationally-based estimates of E over each region. We obtained catchment-balance E for the Amazon and Congo from Baker et al. (2021), and Burnett et al. (2020), respectively. In these studies, E is derived as the difference between precipitation and runoff in each month, minus the change in groundwater storage. Accounting for variation in groundwater storage makes it possible to estimate seasonal variation in E, which wasn’t possible in earlier approaches that simply estimated E as precipitation minus runoff. Swann and Koven (2017) refer to catchment-balance E as a ‘direct’ estimate, unlike products based on algorithms such as the Penman-Monteith equation, or spatially interpolated flux tower measurements, which are likely to have few data inputs over the Amazon and Congo. The seasonal cycle in Amazon E from Baker et al. (2021) is consistent with previous estimates based on different datasets (Swann and Koven, 2017) and therefore expected to be robust. We provide a discussion of the strengths and weaknesses of catchment-balance E estimates in our earlier work (Baker et al., 2021).

Precipitation observations came from the 0.05° x 0.05° Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) version 2.0 dataset (Funk et al., 2015). CHIRPS2 has previously been validated against station precipitation measurements from northeast Brazil, including four Amazon stations (Paredes-Trejo et al., 2017). This study showed that CHIRPS2 has a mean bias of -3.6% and a standard error of 28 mm. Monthly correlations with precipitation from Amazon stations were all in excess of 0.94. Comparisons between CHIRPS2 and a gridded gauge dataset (NIC131) also shows that it performs relatively well in the Congo (Nicholson et al., 2019).

Our evaluation indicated that only two out of four reanalyses captured the seasonality of E over the Amazon (ERA5 and JRA-55), with the other two datasets showing opposite seasonal cycles to that of the reference data (Table S5). All reanalyses showed statistically significant correlations with CHIRPS2 precipitation and catchment E over the Congo. MERRA-2 and CFSR generally had larger relative biases compared to observations over both regions. The differences in reanalysis performance between the Amazon and Congo is likely due to differences in hydrological regime. E follows different seasonal cycles in each region, peaking during the drier part of the year in the Amazon, while in the Congo E broadly follows the same bimodal seasonal cycle as precipitation. Amazon E is strongly governed by surface radiation (r=0.93) and LAI (r=0.63) (Baker et al., 2021a). In the Congo, seasonal E is largely controlled by precipitation, though a lower E peak in the November rainy season compared to the March rainy season is largely caused by a combination of lower LAI associated with lower surface radiation, and lower vapour pressure deficit.
(though with some regional differences). These factors result in lower transpiration and thus E in November compared to March (Crowhurst et al., 2021). The fact that different mechanisms control seasonal E in each region could explain why reanalyses perform well over the Congo but less well over the Amazon.

Since ERA5 showed the strongest positive correlations for both variables in both basins, we used this as the primary reference dataset for evaluating CMIP6 models in this study. Deficiencies in ERA5, particularly the underestimation of Amazon E seasonality relative to catchment-balance E (Fig. 3b) are important to note. However, we do not expect the underestimation of E seasonality in ERA5 to affect the main conclusions that we draw in this study. The underestimation of recycling in the CMIP6 models in SON that we report relative to ERA5, is likely to be a conservative estimate. This is because if ERA5 E was closer to the catchment-balance E estimates, precipitation recycling calculated using ERA5 data would be correspondingly higher in SON, and the difference from the CMIP6 models would be even greater.
**Text S3: Brubaker model**

The Brubaker model (Brubaker et al., 1993) is an extension of the original precipitation recycling model from Budyko (1974) to a 2-dimensional area (Burde and Zangvil, 2001b). First, we calculated the Budyko recycling coefficient (β), which represents the ratio of locally evaporated to advected moisture within a given area:

$$\beta = 1 + \left( \frac{A \times E}{2F_{IN}} \right)$$  \hspace{1cm} (Eqn. 3)

where A is the reference area, E is the total evapotranspiration over A, and F_{IN} is the total atmospheric water vapour flux into A (in units of kg s^{-1}). To obtain F_{IN} for the North, East, South and West sides of the analysis domain, we calculated an area-weighted mean of the vertically-integrated water vapour flux vector (qu for W and E edges and qv for N and S edges, in units of kg m^{-1} s^{-1}, see Text S3 for a description of how these variables are derived) using all grid cells along the domain edge, multiplied by the length of a single grid cell in m, and multiplied by the number of grid cells along the relevant domain edge. Inward fluxes for the N and E boundaries are represented by negative vectors so for these edges we multiplied qv and qu by \(-1\). The proportion of precipitation within A that originated from E is the precipitation-recycling ratio (ρ), calculated as:

$$\rho = 1 - \left( \frac{1}{\beta} \right)$$  \hspace{1cm} (Eqn. 4)

In addition to the assumption of a well-mixed atmosphere (see main text) the Brubaker approach assumes parallel flow of moisture across the analysis region, which may not be valid in all months, particularly DJF in the Amazon (Burde et al., 2006). However, in terms of seasonality, the Brubaker model has previously shown good correspondence with seasonal variation in precipitation recycling estimates for the Amazon (Burde and Zangvil, 2001a, Burde et al., 2006) and Congo (Pokam et al., 2012) produced from models including incomplete vertical mixing and/or non-parallel flow effects.

Python scripts to estimate recycling following the Eltahir and Bras (1994) method and Brubaker et al. (1993) method have been uploaded to an online repository: https://doi.org/10.5281/zenodo.6511636.
**Text S4: Integrated vapour transport**

For CMIP6 models and reanalyses, we obtained monthly specific humidity \((q)\) and zonal \((u)\) and meridional \((v)\) winds on pressure levels. These were converted to column-integrated water vapour fluxes \((qu\) and \(qv, \text{ kg m}^{-1} \text{ s}^{-1})\), by calculating mass-weighted vertical integrals (Peixóto and Oort, 1984, Brubaker et al., 1994):

\[
qu = \frac{1}{g} \int_{p_t}^{p_s} q \cdot u \cdot dp \quad \text{ (Eqn. 1)}
\]

\[
vq = \frac{1}{g} \int_{p_t}^{p_s} q \cdot v \cdot dp \quad \text{ (Eqn. 2)}
\]

where \(g\) is the gravitational constant \((9.81 \text{ m s}^{-2})\) and \(p\) is the atmospheric pressure \((\text{Pa}=\text{kg m}^{-1} \text{ s}^{-2})\). Integrals were calculated from the top of the atmosphere \((p_t)\) to the surface \((p_s)\) for each model.

**Text S5: Effect of neglecting eddy fluxes**

Calculating \(qu\) and \(qv\) using monthly data (Text S3) meant that the eddy component of moisture fluxes was neglected in our approach. We used monthly data because not all models provide sub-daily simulations of \(q, u\) and \(v\) on pressure levels. To quantify the impact that neglecting the eddy fluxes might have had on our results, we obtained monthly-mean vertical integrals of northward and eastward water vapour flux (calculated using the 1-hour ERA5 data) and used these datasets to compute P recycling ratios using the Eltahir and Bras model (see figure below). We found that using monthly data to compute moisture fluxes results in slightly lower P recycling values than when sub-daily data is used (Fig. S1). However, we do not expect that neglecting the eddy component of the flux will have substantially altered the main findings of the paper, which are focussed on evaluating the CMIP6 models, since a consistent approach was applied to both models and reanalyses.
Figure S1. Impact of neglecting transient eddies in the computation of integrated water vapour (IWV) fluxes (i.e. qu and qv) on precipitation recycling ratios (Text S4). Recycling ratios for the Amazon (top panel) and Congo (lower panel) were computed using monthly q, u and v data to derive qu and qv (i.e. neglecting eddy component, blue lines) and using monthly means of 1-hourly data (i.e. accounting for eddy component, orange lines). All data come from ERA5.
Figure S2. – Spatial variation and relative differences in $\rho$ in ERA5 and CMIP6 models over the Amazon and Congo for DJF (a–f), MAM (g–l), JJA (m–r) and SON (s–x). Recycling was estimated for 1979–2014 using Eltahir and Bras (1994; EB94), with grid cell values weighted by normalized precipitation. Stippling indicates where at least 75% of the models agree on the direction of biases relative to ERA5.

Figure S3. Seasonal cycle in precipitation (P) recycling over the Amazon (a) and Congo (b) estimated following the method from Brubaker et al. (1993).
Figure S4. Seasonal precipitation (P) over the Amazon (a) and Congo (b) basins in CHIRPS2 (dark blue line), two reanalyses (black lines) and 45 CMIP6 climate models (narrow blue lines). The CMIP6 ensemble mean and standard deviation are shown by the thick light blue line and light blue shading, respectively.
**Figure S5.** Amazon incoming surface (1000–850 hPa) winds (a) and humidity (b) in two reanalyses (black lines) and 45 CMIP6 climate models (narrow blue lines). The CMIP6 ensemble mean and interannual standard deviation are shown by the thick light blue line and light blue shading, respectively.

**Figure S6.** Congo incoming surface (1000–850 hPa) winds (a) and humidity (b) in two reanalyses (black lines) and 45 CMIP6 climate models (narrow blue lines). The CMIP6 ensemble mean and interannual standard deviation are shown by the thick light blue line and light blue shading, respectively.
Figure S7 – The relationship between model SON-mean land-surface temperature (T) bias, relative to ERA5, and SON-mean basin incoming wind bias, relative to ERA5, over the Amazon (a), and the Congo (b), for 45 CMIP6 models. Pearson correlation coefficients are indicated.
| Basin     | $\rho$  | Reference                              |
|-----------|---------|----------------------------------------|
| Amazon    | 0.175*  | Bosilovich and Chern (2006)            |
| Amazon    | 0.24    | Brubaker et al. (1993)                 |
| Amazon    | 0.24    | Zemp et al. (2014)                     |
| Amazon    | 0.25    | Eltahir and Bras (1994)                |
| Amazon    | 0.26    | Burde et al. (2006)                    |
| Amazon    | 0.272*  | Bosilovich and Chern (2006)            |
| Amazon    | 0.28    | Van der Ent et al. (2010)              |
| Amazon    | 0.28    | Zemp et al. (2014)                     |
| Amazon    | 0.29    | Yang and Dominguez (2019)              |
| Amazon    | 0.3     | Costa and Foley (1999)                 |
| Amazon    | 0.31    | Burde et al. (2006)                    |
| Amazon    | 0.32    | Staal et al. (2018)                    |
| Amazon    | 0.34    | Trenberth (1999)                       |
| Amazon    | 0.36    | Tuinenburg et al. (2020)               |
| Amazon    | 0.41    | Burde et al. (2006)                    |
| Mean      | 0.298   |                                        |
| Standard deviation | 0.050 |                                        |
| Congo     | 0.284   | Dyer et al. (2017)                     |
| Congo     | 0.38    | Pokam et al. (2012)                    |
| Congo     | 0.47    | Tuinenburg et al. (2020)               |
| Congo     | 0.5     | Sori et al. (2017)                     |
| Mean      | 0.408   |                                        |
| Standard deviation | 0.097 |                                        |

**Table S1.** Annual mean precipitation recycling ($\rho$) values reported in the literature for the Amazon and Congo (survey conducted for this study). The two values marked with an asterisk (*) were for October–December only and were excluded from mean and standard deviation calculations.

**Table S2.** Details of CMIP6 models and simulations analyzed in this study (*file uploaded separately*).
Table S3. List of model variables required to replicate the analyses in this study. Note that variable names follow the CMIP6 naming conventions. 3D = three dimensional.

| Variable                                      | CMIP6 standard name                  | CMIP6 short name | Units       |
|-----------------------------------------------|--------------------------------------|------------------|-------------|
| 3D specific humidity                         | specific_humidity                    | hus              | kg kg⁻¹     |
| 3D zonal wind                                | eastward_wind                        | ua               | m s⁻¹       |
| 3D meridional wind                           | northward_wind                       | va               | m s⁻¹       |
| Evapotranspiration                           | water_evapotranspiration_flux        | evspsbl          | kg m⁻² s⁻¹  |
| Precipitation                                | precipitation_flux                   | pr               | kg m⁻² s⁻¹  |
| Surface temperature (skin temperature over ocean) | surface_temperature                 | ts               | K           |

Table S4. Details of reanalysis datasets used in study.

| Reanalysis  | Horizontal resolution (°) | # vertical levels for 3D fields | Date range used in study | References                                                                 | Digital object identifiers (DOIs) |
|-------------|--------------------------|---------------------------------|--------------------------|---------------------------------------------------------------------------|-----------------------------------|
| ERA5        | 0.25 x 0.25              | 37                              | 1979–2014                | Hersbach et al. (2020)                                                   | https://doi.org/10.24381/cds.6860a573 https://doi.org/10.24381/cds.f17050d7 |
| JRA-55      | 0.5625 x 0.5625          | 60                              | 1979–2014                | Kobayashi et al. (2015)                                                  | https://doi.org/10.5065/d6og3h5b  |
| MERRA-2     | 0.625 x 0.5              | 42                              | 1980–2014                | Gelaro et al. (2017)                                                     | https://doi.org/10.5067/5eskgqtzg7fo https://doi.org/10.5067/jrlvl8yv2y4 https://doi.org/10.5067/v92o8x30xb1 |
| CFSR        | 0.5 x 0.5                | 37                              | 1979–2010                | Saha et al. (2010b)                                                      | https://doi.org/10.1175/2010BAMS3001.1 |

Table S5. Evaluation of reanalysis evapotranspiration (E) and precipitation (P) over the Amazon and the Congo. Correlations (r) were calculated between the climatological seasonal cycle of reanalysis E and catchment-balance E, and between the seasonal cycles of reanalysis precipitation and CHIRPS2 precipitation. Annual mean biases in reanalysis E and P were calculated relative to annual-mean catchment-balance E and annual-mean CHIRPS2 P, respectively. Catchment-balance E estimates for the Amazon and the Congo came from Baker et al. (2021) and Burnett et al. (2020), respectively. Correlations that are positive and statistically significant at p<0.05 are shown in bold. Date ranges for the reference datasets are shown.
| Reanalyses   | Amazon                  | Congo                  |
|--------------|-------------------------|------------------------|
|              | Eltahir and Bras (1994) | Brubaker et al. (1993) |
| CFSR         | 36.2±1.2                | 21.6±1.5               |
| Mean ± standard deviation of reanalyses | 36.2±1.2                | 21.6±1.5               |
| CMIP6 models |                        |                        |
| ACCESS-CM2   | 40.3                    | 22.1                   |
| ACCESS-ESM1-S| 39.4                    | 19.1                   |
| AWI-CM-1-1-MK| 41.1                    | 20.9                   |
| AWI-ESM-1-1-LR| 41.3                   | 21.7                   |
| BCC-ESM1     | 32.4                    | 15.1                   |
| CAMS-ESM1-0  | 32.5                    | 14.3                   |
| CanESM5      | 32.6                    | 14.8                   |
| CanESM5-CanOE| 33.3                    | 15.1                   |
| CESM2        | 32.5                    | 16.4                   |
| CESM2-FV2    | 33.1                    | 16.5                   |
| CESM2-WACCM  | 32.7                    | 16.4                   |
| CNRM-CM6-1   | 46.1                    | 22.7                   |
| CNRM-CM6-1-HR| 43.0                    | 21.3                   |
| CNRM-ESM2-1  | 45.0                    | 21.5                   |
| E3SM-1-0     | 37.2                    | 18.8                   |
| E3SM-1-1-ECA | 37.8                    | 19.4                   |
| EC-Earth3-AerChem | 39.4                  | 19.1                   |
| EC-Earth3-CC | 38.7                    | 18.5                   |
| EC-Earth3-Veg-LR | 39.3                | 19.2                   |
| FGOALS-g3    | 26.4                    | 11.0                   |
| FIO-ESM-2-0  | 31.5                    | 16.7                   |
| GISS-E2-1-G  | 33.4                    | 18.6                   |
| GISS-E2-1-G-CC| 33.9                    | 18.8                   |
| GISS-E2-1-H  | 33.0                    | 19.1                   |
| HadGEM3-GC31-LL| 40.6                  | 23.4                   |
| HadGEM3-GC31-MM| 38.4                   | 22.2                   |
| IPSL-CM5A2-INCA| 30.1                   | 13.7                   |
| IPSL-CM6A-LR | 35.6                    | 18.9                   |
| IPSL-CM6A-LR-INCA| 36.0                | 19.2                   |
| MCM-UA-1-0   | 32.5                    | 14.4                   |
| MIROC6       | 39.2                    | 21.0                   |
| MIROC-ES2L   | 46.4                    | 27.1                   |
| MPI-ESM-1-2-HAM| 42.0                  | 22.4                   |
| MPI-ESM-1-2-HR| 40.1                    | 20.8                   |
| MPI-ESM1-2-LR| 40.1                    | 21.5                   |
| MRI-ESM2-0   | 39.1                    | 19.9                   |
| NESM3        | 41.6                    | 22.4                   |
| NorCPM1      | 26.0                    | 12.7                   |
| NorESM2-LM   | 31.8                    | 16.2                   |
| NorESM2-MM   | 31.4                    | 15.9                   |
| SAMO-UNICON  | 38.1                    | 20.6                   |
| TaesiM1      | 31.1                    | 16.5                   |
| UKESM1-0-LL  | 41.0                    | 23.0                   |
| Mean ± standard deviation of CMIP6 models | 36.5±4.9                | 18.7±3.3               |

Table S6. Annual mean $\rho$ values (%) for the Amazon and Congo basins.
| CMIP6 model       | Amazon Pearson’s $r$ | Absolute bias from ERA5 (%) | Relative bias from ERA5 (%) | Congo Pearson’s $r$ | Absolute bias from ERA5 (%) | Relative bias from ERA5 (%) |
|-------------------|----------------------|-----------------------------|-----------------------------|---------------------|-----------------------------|-----------------------------|
| ACCESS-CM2        | 0.40                 | 5.00                        | 14.00                       | 0.52                | 3.28                        | 7.67                        |
| ACCESS-ESM1-5     | 0.83                 | 3.75                        | 10.49                       | 0.48                | 4.26                        | 9.97                        |
| AWI-CM-1-1-MR     | 0.45                 | 5.33                        | 14.93                       | 0.77                | 4.67                        | 10.93                       |
| AWI-ESM-1-1-LR    | 0.36                 | 5.63                        | 15.75                       | 0.60                | 3.10                        | 7.24                        |
| BCC-CSM2-MR       | 0.44                 | -2.23                       | -6.23                       | -0.02               | -5.41                       | -12.64                      |
| BCC-ESM1          | 0.45                 | -3.27                       | -9.15                       | 0.70                | -5.36                       | -12.54                      |
| CAMS-CSM1-0       | -0.18                | -3.18                       | -8.91                       | 0.96                | -2.39                       | -5.59                       |
| CanESM5           | 0.16                 | -3.13                       | -8.75                       | 0.75                | -1.06                       | -2.47                       |
| CanESM5-CanOE     | 0.24                 | -2.45                       | -6.86                       | 0.73                | -0.69                       | -1.61                       |
| CESM2             | 0.92                 | -3.19                       | -8.94                       | 0.80                | -0.95                       | -2.22                       |
| CESM2-FV2         | 0.82                 | -2.49                       | -6.97                       | 0.73                | -3.38                       | -7.91                       |
| CESM2-WACC          | 0.93                | -2.99                       | -8.37                       | 0.80                | -0.17                       | -0.40                       |
| CESM2-WACC-FV2    | 0.64                 | -1.96                       | -5.49                       | 0.73                | -4.40                       | -10.28                      |
| CNRM-CM6-1        | 0.63                 | 10.25                       | 28.69                       | 0.35                | -3.20                       | -7.49                       |
| CNRM-CM6-1-HR     | 0.80                 | 7.10                        | 19.87                       | 0.43                | -3.73                       | -8.71                       |
| CNRM-ESM2-1       | 0.56                 | 9.23                        | 25.85                       | 0.38                | -6.55                       | -15.31                      |
| E3SM-1-0          | 0.36                 | 1.68                        | 4.69                        | 0.90                | -0.68                       | -1.58                       |
| E3SM-1-1-ECA      | 0.36                 | 2.36                        | 6.60                        | 0.94                | -1.57                       | -3.68                       |
| EC-Earth3-AerChem | 0.07                 | 3.71                        | 10.40                       | 0.74                | 1.53                        | 3.59                        |
| EC-Earth3-CC      | 0.19                 | 2.95                        | 8.25                        | 0.65                | 0.17                        | 0.39                        |
| EC-Earth3-Veg-LR  | 0.13                 | 3.59                        | 10.05                       | 0.65                | -0.35                       | -0.82                       |
| FGOALS-g3         | 0.93                 | -9.34                       | -26.14                      | 0.90                | -3.63                       | -8.50                       |
| FIO-ESM-2-0       | 0.94                 | -4.39                       | -12.29                      | 0.84                | -0.56                       | -1.30                       |
| GISS-E2-1-G       | 0.28                 | -2.22                       | -6.23                       | 0.52                | -8.71                       | -20.36                      |
| GISS-E2-1-G-CC    | 0.29                 | -1.64                       | -4.59                       | 0.51                | -9.13                       | -21.35                      |
| GISS-E2-1-H       | 0.22                 | -2.55                       | -7.14                       | 0.40                | -12.09                      | -28.27                      |
| HadGEM3-GC31-LL   | 0.44                 | 5.14                        | 14.39                       | 0.71                | 5.68                        | 13.28                       |
| HadGEM3-GC31-MM   | 0.81                 | 2.81                        | 7.86                        | 0.84                | 5.65                        | 13.22                       |
| IPSL-CM5A2-INCA   | 0.32                 | -5.29                       | -14.81                      | 0.67                | 0.48                        | 1.11                        |
| IPSL-CM6A-LR      | 0.79                 | -0.10                       | -0.27                       | 0.87                | -0.38                       | -0.89                       |
| IPSL-CM6A-LR-INCA | 0.80                 | 0.27                        | 0.74                        | 0.85                | 0.46                        | 1.07                        |
| MCM-UA-1-0        | -0.33                | -3.09                       | -8.66                       | 0.00                | -3.07                       | -7.17                       |
| MIROC6            | 0.51                 | 3.65                        | 10.23                       | 0.64                | 6.07                        | 14.19                       |
| MIROC-ES2L        | 0.73                 | 10.66                       | 29.83                       | 0.65                | 5.70                        | 13.34                       |
| MPI-ESM-1-2-HAM   | 0.35                 | 6.46                        | 18.07                       | 0.83                | 6.17                        | 14.43                       |
| MPI-ESM1-2-HR     | 0.64                 | 4.45                        | 12.47                       | 0.86                | 4.66                        | 10.88                       |
| MPI-ESM1-2-LR     | 0.40                 | 4.42                        | 12.38                       | 0.92                | 4.15                        | 9.70                        |
| MRI-ESM2-0        | 0.79                 | 3.58                        | 10.01                       | 0.88                | -3.30                       | -7.72                       |
| NEM3               | 0.38                 | 6.19                        | 17.32                       | 0.67                | 1.73                        | 4.04                        |
| NorCPM1           | 0.75                 | -9.63                       | -26.97                      | 0.16                | -12.92                      | -30.20                      |
| NorESM2-LM        | 0.77                 | -3.80                       | -10.64                      | 0.62                | -5.37                       | -12.55                      |
| NorESM2-MM        | 0.96                 | -4.39                       | -12.28                      | 0.55                | -3.26                       | -7.63                       |
| SAM0-UNICON       | 0.67                 | 2.35                        | 6.59                        | 0.91                | 4.86                        | 11.36                       |
| TaiESM1           | 0.81                 | -4.64                       | -13.00                      | 0.92                | 1.03                        | 2.40                        |
| UKESM1-0-LI       | 0.56                 | 5.46                        | 15.29                       | 0.70                | 4.92                        | 11.51                       |

Table S7. Comparing seasonal cycles in $\rho$ (calculated following EB94) from 45 CMIP6 models with ERA5 for the Amazon and Congo. Correlations were computed between climatological monthly mean values from each model and climatological monthly mean values from ERA5. Positive and statistically significant ($p \leq 0.05$) correlations are indicated in bold. Absolute and relative bias values for each model were calculated relative to ERA5 at the annual scale.
|                     | Amazon       |         | Congo       |         |
|---------------------|--------------|---------|-------------|---------|
|                     | ER5 $\rho$   | JRA-55 $\rho$ | CMIP6 mean $\rho$ | ER5 $\rho$   | JRA-55 $\rho$ | CMIP6 mean $\rho$ |
| Catchment-balance E | 0.97         | 0.90    | 0.13        | -0.59    | -0.39      | -0.41          |
| ERA5 moisture influx| -0.67        | -0.46   | 0.17        | -0.91    | -0.92      | -0.79          |
| JRA-55 moisture influx| -0.63       | -0.45   | 0.20        | -0.90    | -0.93      | -0.88          |

**Table S8.** Correlations between seasonal cycles of precipitation recycling ($\rho$), calculated following EB94, and its controlling variables (evapotranspiration, E, and imported moisture), over the Amazon and Congo in reanalyses (ERA5 and JRA-55) and the CMIP6 ensemble mean (45 models).

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