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Glacier surface mass balance and freshwater runoff modeling for the entire Andes Cordillera

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Glacier surface mass balance (SMB) observations for the Andes Cordillera are limited and, therefore, estimates of the SMB contribution from South America to sea-level rise are highly uncertain. Here, we simulate meteorological, snow, glacier surface, and hydrological runoff conditions and trends for the Andes Cordillera (1979/80–2013/14), covering the tropical latitudes in the north down to the sub-polar latitudes in the far south, including the Northern Patagonia Ice Field (NPI) and Southern Patagonia Ice Field (SPI). SnowModel – a fully integrated energy balance, blowing-snow distribution, multi-layer snowpack, and runoff routing model – was used to simulate glacier SMBs for the Andes Cordillera. The Randolph Glacier Inventory and NASA Modern-Era Retrospective Analysis for Research and Applications products, downscaled in SnowModel, allowed us to conduct relatively high-resolution simulations. The simulated glacier SMBs were verified against independent directly-observed and satellite gravimetry and altimetry-derived SMB, indicating a good statistical agreement. For glaciers in the Andes Cordillera, the 35-year mean annual SMB was found to be $^{-1}$.13 m water equivalent. For both NPI and SPI, the mean SMB was positive (where calving is the likely reason for explaining why geodetic estimates are negative). Further, the spatio-temporal freshwater river runoff patterns from individual basins, including their runoff magnitude and change, were simulated. For the Andes Cordillera rivers draining to the Pacific Ocean, 86% of the simulated runoff originated from rain, 12% from snowmelt, and 2% from ice melt, whereas, for example, for Chile, the water-source distribution was 69, 24, and 7%, respectively. Along the Andes Cordillera, the 35-year mean basin outlet-specific runoff (L s^{-1} km−2) showed a characteristic regional hourglass shape pattern with highest runoff in both Colombia and Ecuador and in Patagonia, and lowest runoff in the Atacama Desert area.