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Two drastically different climate states on an Earth-like terra-planet

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Using the general circulation model ICON, we show that, with a subsurface reservoir of water, an Earth-like terra-planet can exist in two drastically different climate states for the same set of boundary conditions and parameter values: A Cold and Wet state (present-day Earth-like climate) with dominant low-latitude precipitation and, a Hot and Dry state with only high-latitude precipitation. By varying the background albedo (α), we find that both climate states are stable below a threshold value of $\alpha \approx 0.15$ while for $\alpha > 0.15$, only the Cold and Wet state is stable. Also, we demonstrate that starting from the Hot and Dry state increasing α above the threshold causes an abrupt shift from the Hot and Dry state to the Cold and Wet state resulting in sudden cooling of about 35˚C globally which is of the order of the temperature difference between the present-day and the snowball Earth state. In contrast to the Snowball Earth scenario, we find that the sudden cooling in our study is driven by the cloud albedo feedback rather than the snow-albedo feedback. Overall our study reveals that, for a wide range of parameter values, liquid water can always be stable on an Earth-like terra-planet, provided a recycling mechanism exists which can transport water from melting of snow and ice in the higher latitudes back to the lower latitudes.