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Process-evaluation of tropospheric humidity simulated by general circulation models using water vapor isotopic observations and implications for climate sensitivity

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Evaluating the representation of processes controlling tropical and subtropical tropospheric relative humidity (RH) in atmospheric general circulation models (GCMs) is crucial to assess the credibility of predicted climate changes. Our goal is to design observable diagnostics to detect and understand biases in the representation of these processes. First, we use water vapor isotope measurements from space and ground to evaluate the 3D distribution of the tropospheric water vapor isotope composition simulated by several versions of the isotope-enabled GCM LMDZ. We show that the combined evaluation of water vapor atmospheric isotopic composition makes it possible to discriminate the most likely cause of RH biases. For instance, an overestimated vertical diffusion, excessive convective detrainment, or underestimated in-situ cloud condensation each produce a moist bias in the free troposphere. However, only an excessive vertical diffusion can lead to a reversed seasonality of the free tropospheric isotopic composition. Inter-comparing 6 other isotope-enabled GCMs, we suggest that the moist bias found in many GCMs in the mid and upper troposphere likely results from an excessive diffusion during vertical water vapor transport, possibly due to insufficient vertical resolution. Second, analyzing sensitivity tests in climate change experiments and inter-comparing climate models from the CMIP3 archive, we suggest that models exhibiting a moist bias due to excessive vertical diffusion are likely to overestimate the future upper troposphere drying. However, although this impacts slightly the water vapor feedback, consequences on climate sensitivity are blurred by the dominating spread in cloud feedbacks.