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Tracking the global flows of atmospheric moisture

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Many processes in hydrology and Earth system science relate to moisture recycling, the contribution of terrestrial evaporation to precipitation. For example, the effects of land-cover changes on regional rainfall regimes depend on this process. To study moisture recycling, a range of moisture tracking models are in use that are forced with output from atmospheric models, but differ in various ways. They can be Eulerian (grid-based) or Lagrangian (trajectory-based), have two or three spatial dimensions, and rely on a range of other assumptions. Which model is most suitable depends on the purpose of the study, but also on the quality and resolution of the data with which it is forced. Recently, the high-resolution ERA5 reanalysis dataset has become the state-of-the-art, paving the way for a new generation of moisture tracking models. However, it is unclear how the new data can best be used to obtain accurate estimates of atmospheric moisture flows. Here we develop a set of moisture tracking models forced with ERA5 data and systematically test their performance regarding continental evaporation recycling ratio, distances of moisture flows, and <q>footprints</q> of evaporation from seven point sources across the globe. We report simulation times to assess possible trade-offs between accuracy and speed. Three-dimensional Lagrangian models were most accurate and ran faster than Eulerian versions for tracking water from single grid cells. The rate of vertical mixing of moisture in the atmosphere was the greatest source of uncertainty in moisture tracking. We conclude that the recently improved resolution of atmospheric reanalysis data allows for more accurate moisture tracking results in a Lagrangian setting, but that considerable uncertainty regarding turbulent mixing remains. We present an efficient Lagrangian method to track atmospheric moisture flows from any location globally using ERA5 reanalysis data and make the code for this model publicly available.