Characterising extratropical near tropopause analysis humidity biases and their radiative effects on temperature forecasts

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A cold bias in the extratropical lowermost stratosphere in forecasts is one of the most prominent systematic temperature errors in numerical weather prediction models. Hypothesized causes of this bias include radiative effects from a collocated moist bias in model analyses. Such biases would be expected to affect extratropical dynamics and result in the misrepresentation of wave propagation at tropopause level. Here the extent to which these biases are connected is quantified. Observations from radiosondes are compared to operational analyses and forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS) and Met Office Unified Model (MetUM) to determine the magnitude and vertical structure of these biases. Both operational models over-estimate lowermost stratospheric specific humidity by around 70% of the observed values on average, around 1km above the tropopause. This moist bias is already present in the initial conditions and changes little in forecasts over the first five days. Though temperatures are represented well in the analyses, the IFS forecasts anomalously cool in the lower stratosphere, relative to verifying radiosonde observations, by 0.2K per day. The IFS single column model is used to show this temperature change can be attributed to increased long-wave radiative cooling due to the lowermost stratospheric moist bias in the initial conditions. However, the MetUM temperature biases cannot be entirely attributed to the moist bias, and another significant factor must be present. These results highlight the importance of improving the humidity analysis to reduce the extratropical lowermost stratospheric cold bias in forecast models and the need to understand and mitigate the causes of the moist bias in these models.