The Climatology of Tropospheric Specific Humidity Inversions in Three Reanalyses

Michael A. Brunke
Department of Atmospheric Sciences, The University of Arizona, Tucson, AZ USA

Steve T. Stegall
Department of Energy and Environmental Systems, North Carolina A&T State University, Greensboro, NC USA

Xubin Zeng
Department of Atmospheric Sciences, The University of Arizona, Tucson, AZ USA

Specific humidity is generally thought to decrease with height in the troposphere. However here, we document the existence of specific humidity inversions in three reanalyses: NASA's Modern Era Retrospective Analysis for Research Applications (MERRA), the ECMWF 40-year reanalysis (ERA-40), and the NOAA-NCEP second reanalysis (NCEP-2) for the period 1981-2000. In these reanalyses, specific humidity inversions are most frequent in the polar regions. They also occur less frequently in other regions, especially over a subtropical band at ~15° in both hemispheres including the subtropical stratus regions. Polar inversions are the most persistent in winter but are the strongest (as defined by the humidity difference across the inversion divided by the pressure difference across the inversion) in summer or autumn. Arctic inversions have low bases (at pressures > 900 hPa); Antarctic inversions are also close to the surface following the higher terrain from the ocean up to the South Pole. The subtropical stratus inversions are as thick but with higher bases generally at pressures < 900 hPa. However, there is a wider spread in the reanalysis inversion statistics in the Antarctic and the subtropical stratus regions, especially over the southeast Atlantic.

Focusing on the polar regions, these specific humidity inversions are confirmed by comparison with rawinsonde data in the Arctic from the Earth System Research Laboratory (ESRL) archive. MERRA's humidity profiles are generally lower here, while NCEP-2's profiles are usually higher. There are also discrepancies between the observed annual and diurnal cycle in inversion frequency and those portrayed in the reanalyses. For instance, the reanalyses at several locations have smaller annual and diurnal cycles than observed. However, all three reanalyses have true positives, i.e., when the reanalyses correctly have humidity inversions when compared to rawinsonde data, ~50% of the time in the Arctic. They also have true negatives, i.e., when the reanalyses correctly do not produce humidity inversions, ~25% of the time in the Arctic. However, NCEP-2 has slightly more false negatives (when it fails to produce a humidity inversion when it is observed) than positives (when it produces one when it is not observed), whereas MERRA and ERA-40 have about equal occurrences of false positives and negatives.

The specific humidity inversions in the polar regions are highly influenced by thermal inversions. For instance, the mean temperature difference across the thermal inversion is higher when there is a humidity inversion in every season. Also, the specific humidity difference across the humidity inversion increases as the temperature difference across the thermal inversion increases. Another potential influence on polar specific humidity inversions is humidity flux into the region. The total column-integrated specific humidity flux into both polar regions is highest in the summer coinciding with the occurrence of the strongest specific humidity inversions in these regions. On the other hand, these inversions show no correlation to interannual variability from the Arctic or Antarctic Oscillations or from the El Niño-Southern Oscillation.

The influence of changes in the assimilation of satellite data is also investigated here. For instance, the addition of High Resolution Infrared Radiation Sounder (HIRS) data has been shown to affect ERA-40 temperature profiles especially in the polar regions from 1997 onwards. Also, the inclusion of Advanced Microwave Sounding Unit (AMSU) radiances affect water vapor in MERRA beginning in 1999. ERA-40 inversion strength, bottom, and thickness show little change between 1997-2000 and 1981-1996 in the polar regions but may be higher in the subtropics. Similarly, MERRA inversion strength, bottom, and thickness are not changed very much by the addition of AMSU in 1999-2000, but its inclusion in other regions may have a larger impact.

Corresponding Author:

Name:	Michael Brunke
Organization:	The University of Arizona
Address:	Department of Atmospheric Sciences P.O. Box 210081 Tucson, AZ 85721-0081 USA