Humidity Inversions

Specific humidity, that is, the ratio of the mass of water vapor in the air to the total mass of air (water included), usually decreases with height (e.g., Peixoto and Oort 1992), but periodically layers develop in which humidity increases with height. These layers have been coined humidity inversions like layers in which temperature increases with height. Humidity inversions have not been widely recognized except to a certain extent in the Arctic (Serreze et al. 1995, Tjernström et al. 2004, Gerding et al. 2004, Tjernström 2005, Sedlar and Tjernström 2009, Sedlar et al. 2011, Vihma et al. 2011, Nygård et al. 2013a). Humidity inversions have also been documented in the Antarctic (Tomasi et al. 2006, Nygård et al. 2013b) and also less frequently outside of the polar regions (Liu et al. 2002, Roberts et al. 2010, Liu et al. 2010, Jiang et al. 2012).

The increase in specific humidity with height within inversions results in a downward flux of humidity, since humidity will flow from high to low quantities. When they are near the surface, they would be associated with instances of dew, frost, or fog. In fact, Liu et al. (2010) have documented a case of a humidity inversion associated with a fog event in Nanjing, China. Frost and fog along with "diamond dust," frozen precipitation falling from a clear sky, are also commonplace in the Arctic (Sverdrup 1933, Robinson and Ludwig 1966, Andreas et al. 2002) where humidity inversions are also quite frequent throughout the year. Humidity inversions have also been observed at or near the tops of Arctic stratus (Sedlar and Tjernström 2009, Sedlar et al. 2011, Solomon et al. 2011). The downward flux associated with these humidity inversions have been hypothesized to provide moisture to maintain the clouds from evaporation from the tops of the clouds (Sedlar et al. 2011, Solomon et al. 2011).

To understand these humidity inversions better, I recently undertook an analysis of the global climatology of humidity inversions based upon five reanalyses, model-generated global climatologies that have been constrained by assimilating surface and upper-level observations as well as satellite measurements. Humidity inversions are indeed quite frequent in the polar regions where inversions appear in 100% of the January and July monthly means in a large portion of the Arctic and Antarctic, respectively, in all five reanalyses. These two winter months are when humidity inversions are most prevalent in these respective regions as was found previously (Devasthale et al. 2012). Also consistent with previous findings (Devasthale et al. 2012), Arctic humidity inversions are found to be strongest and thickest in summer rather than winter. This coincides with when low level clouds are most prevalent, and the vertically-integrated humidity fluxes into the Arctic are highest. The annual cycle in Antarctic humidity inversions is small, and, similarly, the annual cycle in low level clouds is small.

Humidity inversions are also quite prevalent in the subtropics, particularly the subtropical stratus regions over the eastern ocean basins. Subtropical stratus inversions are as thick as polar inversions but are higher than their polar counterparts.

References

Andreas, E. L., P. S. Guess, P. O. G. Persson, C. W. Fairall, T. W. Horst, R. E. Moritz, and S. R. Semmer, 2002: Near-surface water vapor over polar sea ice is always near ice saturation. *J. Geophys. Res.*, **107**, 8033, doi:10.1029/2000JC000411.

Devasthale, A., J. Sedlar, and M. Tjernström, 2012: Characteristics of water-vapour inversions observed over the Arctic by Atmospheric Infrared Sounder (AIRS) and radiosondes. *Atmos. Chem. Phys.*, **11**, 9813-9823.

Gerding, M., C. Ritter, M. Müller, and R. Neuber, 2004: Tropospheric water vapour soundings by lidar at high Arctic latitudes. *Atmos. Res.*, **71**, 289-302.

Jiang, X., Y. Li, X. Zhao, and T. Koike, 2012: Characteristics of the summertime boundary layer and atmospheric vertical structure over the Sichuan Basin. *J. Meteorol. Soc. Japan*, **90C**, 33-54.

Liu, D., J. Yang, S. Niu, and Z. Li, 2010: On the evolution and structure of a radiation fog event in Nanjing. *Adv. Atmos. Sci.*, **28**, 223-237.

Liu, H., H. Zhang, L. Bian, J. Chen, M. Zhou, X. Xu, S. Li, and Y. Zhao, 2002: Characteristics of micrometeorology in the surface layer in the Tibetan Plateau. *Adv. Atmos. Sci.*, **19**, 74-87.

Nygård, T., T. Valkonen, and T. Vihma, 2013a: Characteristics of Arctic low-tropospheric humidity inversions based on radio soundings. *Atmos. Chem. Phys. Discuss.*, **13**, 22575-22605.

Nygård, T. T. Valkonen, and T. Vihma, 2013b: Antarctic low-tropospheric humidity inversions: 10-yr climatology. *J. Climate*, **26**, 5205-5219.

Peixoto, J. P., and A. H. Oort, 1992: *Physics of Climate*, Amer. Inst. of Phys., New York.

Roberts, J. B., C. A. Clayson, F. R. Robertson, and D. L. Jackson, 2010: Predicting near-surface atmospheric variables from Special Sensor Microwave/Imager using neural networks with a first-guess approach. *J. Geophys. Res.*, **115**, D19113, doi:10.1029/2009JD013099.

Robinson, E., and F. L. Ludwig, 1966: Atmospheric water vapour measurements on the Greenland Ice Cap, in Polar Meteorology, WMO Technical Note No. 87. WMO, Geneva, Switzerland, 15-28.

Sedlar, J., and M. Tjernström, 2009: Stratiform cloud-inversion characterization durig the Arctic melt season. *Bound.-Layer Meteorol.*, **132**, 455-474.

Sedlar, J., M. D. Schupe, and M. Tjernström, 2011: On the relationship between thermodynamic structure and cloud top, and its climate significance in the Arctic. *J. Climate*, **25**, 2374-2393.

Serreze, M. C., M. C. Rehder, R. G. Barry, J. D. Kahl, N. A. Zaitseva, 1995: The distribution and transport of atmospheric water vapour over the Arctic basin. *International J. Climatol.*, **15**, 709-727.

Solomon, A., M. D. Shupe, P. O. G. Persson, and H. Morrison, 2011: Moisture and dynamical interactions maintaining decoupled Arctic mixed-phase stratocumulus in the presence of a humidity inversion. *Atmos. Chem. Phys.*, **11**, 10127-10148.

Sverdrup, H. U., 1933: Meterology: Part I, Discussion, in *The Norwegian North Polar Expedition with the "Maud" 1918-1925, Scientific Results*. H. U. Sverdrup (Ed.), Geofysisk Institutt, Bergen, Norway, 331 pp.

Tjernström, M., 2005: The summer Arctic boundary layer during the Arctic Ocean Experiment 2001 (AOE-2001). *Bound.-Layer Meteorol.*, **117**, 5-36.

Tjernström, M., and R. G. Graversen, 2009: The vertical structure of the lower Arctic troposphere analysed from observations and the ERA-40 reanalysis. *Quart. J. Roy. Meteorol. Soc.*, **135**, 431-443.

Tomasi, C., and 10 co-authors, 2006: Characterization of the atmospheric temperature and moisture conditions above Dome C (Antarctica) during austral summer and fall months. *J. Geophys. Res.*, **111**, D20305, doi:10.1029/2005JD006976.

Vihma, T., T. Kilpelainen, M. Manninen, A. Sjoblom, E. Jakobson, T. Palo, J. Jaagus, and M. Maturilli, 2011: Characteristics of temperature and humidity inversions and low-level jets over Svalbard fjords in spring. *Advances in Meteorol.*, **2011**, doi:10.1155/2011/486807