Homogeneity of finnish radiosonde humidity records: effects of corrected RS80-A for trends

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The longest continuing water vapor profile information is in radiosounding archives, starting way before the time of satellite missions or ground based profiling instruments. However, the complication is that the radiosonde records are plagued by inhomogeneities caused by the instrument development. The aforementioned facts set challenges for the development of water vapor measurement technology and especially for the accurate homogenization of the historical records. This study aims to assess the homogeneity and trends of relative humidity measurements from Finnish radiosounding records. This long timeserie, beginning from 1965, generates a challenge as a result of the rapid sensor development. The most remarkable changes happened when hairhygrometers were replaced by Humicap technology in 1981, and RS80-A by RS90 in 1999. There is also a remarkable change inside hairhygrometer era when RS18 was taken in use in 1970s.

Finnish observation sites Sodankylä (67 N), Tikkakoski (62 N), and Jokioinen (61 N) have each long and continuous radiosonde measurement records with reported histories on changes of instruments and measuring practices, thus giving an opportunity for this kind of a study with an aim on shedding light to the radiosonde timeserie homogeneity issue, by recommendations for homogenization efforts, and a test of effectiveness of recent correction algorithms for Vaisala RS80-A radiosonde. Despite of the local nature of this study, the results are applicable to all radiosonde records consisting of Vaisala radiosondes.

The study is based partly on findings during a radiosonde comparison for assessing the RS80, RS90 and RS92 generation gaps; the international hygrometer intercomparison (LAUTLOS-WAVAP), which was held on February 2004 at Sodankylä. LAUTLOS-WAVAP radiosonde inter-comparison revealed large under estimations in RS80 humidity in saturated conditions with respect to modern RS92; the RS80-A had a maximum dry-bias ($>$ 30 RH%) in the upper troposphere (UT), while in the temperatures close to zero (in the lower troposphere (LT)) the dry-bias reduced approximately to 5 RH%. The RS80-A dry bias was observed to grow exponentially with the decreasing temperature. It was shown that the RS80-A dry-bias could removed (almost totally) with the correction algorithm by Leiterer et al. (2000). The comparison of RS92 and RS90 revealed a semi-linearly growing wet bias with decreasing temperature being approximately 10 RH% at -60 Celsius in the RS90. This would suggest that period

of RS90 measurements would introduce a small few % RH wet bias to the UT RH record, where as the RS80 measurements would cause a considerable dry bias.

According to this study it seems inevitable that the changes in instrument performance will affect the homogeneity of the radiosonde record, and eventually to the calculated RH-trends. The effects of developing measurement technology are demonstrated best in the comparison of radiosonde data and ERA-40 time-series. Basing om ERA-40 comparison, climatological trends and means for the whole record, and its sub-periods, i.e. technical eras, have been compared and the effects of changes in sonde generations estimated. In the beginning of the trend comparison study, it was shown that it is not possible to derive a robust climatological trend for RH -time series unless the effect of the developing measurement technology has been taken account. This finding inspires to seek for the opportunities for RH -record homogenization, which is the first task of this report.

As a second task, the differences between various Humicap applications, namely RS80-A, RS90, RS92 are assessed with the help of a representative set of parallel measurements during LAUTLOS-WAVAP -campaign. The performance of RS80-A in the upper troposphere have been debated for some years, and several correction algorithms have been presented for correction of these errors [J. Wang et al. 2002, U. Leiterer et al. 2000, L. Miloshevich et al. 2001]. The main problems with Humicap measurement technology are related to the temperature dependent dry bias and time lag, and in addition, the chemical contamination (in RS80). The third task of this study has been to evaluate these reported corrections and their impact on tropospheric RH. The final aim would be to deduce an estimate for climatological trends from the homogenized measurement set.

The homogeneity assessment of Finnish radiosonde records showed that the hairhygrometer and Humicap measurements should be separated for trend calculations. In addition, all hairhygrometer generations (RS13, RS15 and RS18) may be united for trend calculations in the lower troposphere (below approximately 3 km), but above that, RS18 should be separated from the others due to smaller thermal lag. Also RS80-A and RS90 with Humicap sensors are suggested to be separated for trend calculations at all heights. This generation gap can be narrowed with the help of the Leiterer's correction algorithm for RS80-A. With the corrected RS80-A humidity, all compared sonde generations may be united for the lower tropospheric trend calculations. The unifying of the hairhygrometer and Humicap data in the upper troposphere is not possible with correcting only RS80-A data. According to the LAUTLOS -comparisons, it seems that the introduction of a new Vaisala radiosonde (RS92) will result to the need for developing of a correction for RS90 also.

The humidity climatology derived from the Finnish radiosonde record (1965-2004) showed that by applying corrections for RS80-A, the RH trend diminished close to zero in the UT, and even changed its sign to positive in the mid troposphere (MT) if compared to the earlier reported, uncorrected trends. The correction seems to reduce the magnitudes of the RH trends below (or close) the level of the significance, for this period. For annual averages of radiosonde record, the level of significance (one sigma) is somewhat less than 1 %/decade depending on altitude (errors are bigger in the UT).

During the Humicap period, i.e. since the mid 1980s, it is seen that the inclusion of the correction of bias errors to the trend calculations has a major impact on the trend at the locations where modern Humicap types (in RS80-H, RS90 or RS92) are taken in use. Without the correction of RS80-A, the trend over past two decades would seem strongly positive (4 to 9 %/decade) at these sites. With the corrected RS80-A, the the magnitude of the trend in MT falls close to the level of insignificance and in the UT remains slightly positive. For a site with homogeneous set of RS80-A measurements, and for the same period, the trend is -1.5 %/decade in the MT and +1.5 %/decade in the UT (the level of significance is approximately 0.9 %/decade).

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