4.2 USE OF RADIOSONDES AND SATELLITES FOR MUTUAL INHOMOGENEITY DETECTION

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1. INTRODUCTION

A system of high quality radiosondes distributed over the Earth has been proposed (GCOS 2004, Folland et al. 2006). One function of such a system would be near-real time calibration of satellite retrievals for on-going operational weather forecast initialization. If the system is of high quality, the observations could also be employed to assess the stability of satellite sensors and even to aid in intercalibration of satellites. This latter function would serve to identify biases and/or drifts in satellite sensors, thus bolstering confidence in long-term variability and trends for climate applications.

In this report we will examine information in a recently published paper from which we may estimate the level of precision such a radiosonde system might provide.

2. BACKGROUND

Christy and Norris (2006, hereafter CN06) compared temperatures from radiosonde observations with those of two satellite datasets to discover potential shifts due to instrument or processing changes in all three datasets. The radiosonde dataset consisted of 31 U.S.-controlled VIZ stations for which the instrumentation was intended to remain fairly stable so that climate records could be constructed. From the individual radiosonde temperature profiles, CN06 simulated the microwave brightness temperature as would be observed from the Microwave Sounding Units MSUs) on several NOAA polar-orbiting satellites. Thus, the radiosonde and satellite data were directly comparable. From the two satellite datasets we calculated the temperatures for the same 31 locations. We shall examine the results from the layer known as MT (Mid-Troposphere or surface to about 75 hPa) which is derived from MSU channel 2 and from the Advanced MSU (AMSU) channel 5. The satellite datasets are produced by the University of Alabama in Huntsville (UAH, v5.1) and Remote Sensing Systems (RSS, v2.1).

Though the intent of the VIZ network was stability, changes inevitably occurred. The focus of CN06 was to identify and quantify changes in the VIZ stations with a secondary focus on discovery of possible satellite problems.

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3. RESULTS

To create a comparison study, we calculated the difference time series of monthly MT anomalies of VIZ minus UAH and VIZ minus RSS. These are shown as the lower two time series of Fig. 1. From this we performed a simple breakpoint test in which we differenced the 36-month averages of the difference time series on either side of each month. This difference was converted to a z-score (departure/standard deviation) and adjusted for degrees of freedom lost from autocorrelation. The top two time series represent the time series of absolute values of the z-scores as a way to determine the significance of the shifts found by this method.

There are 3 main shifts found between the satellite and radiosonde data labeled **A**, **B** and **C**. The numerical results are given in Table 1. For **A** we note the highly consistent values determined by comparison with the two satellite datasets, both showing a value of -0.180 K, or that the VIZ radiosondes experienced a downward shift in Jan 1990. The significance is exceedingly high. From metadata information we know that in Jan 1990 the ground station software and hardware were updated from MiniArt 2 to MicroArt, which included some

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changes such as a setting to limit the minimum reported temperature as 185.05 K. Because this was a system-wide change, and the satellite comparisons discover a breakpoint at exactly the same time and of exactly the same magnitude, we conclude that the radiosondes experienced a spurious cooling shift in Jan 1990.

Similarly, event **C** in Jun 1997 was discovered by both satellite datasets, was highly significant and of the same magnitude (+0.156 K, Table 1). This was the point in time when most of the stations switched from VIZ-B to VIZ-B2 instrumentation. The B2 instrument included a solid-state baroswitch which replaced the mechanical arm that rotated through 180 discrete electrical contacts. This change provided a more accurate pressure reading and allowed the pressure and temperature to be simultaneously (i.e. instantaneously) measured. There was generally a lag between the pressure reported from the baroswitch, being the last contact made, and the temperature. The net impact introduced warmer temperatures.

Event **B** is of more interest to the issue at hand. We were unable to locate any information that might implicate the radiosondes as having a shift to cooler temperatures during late 1991 to 1993 as depicted by the z-scores in Fig. 1. However, this is a period in the satellite record for which spurious discontinuities and shifts may have occurred. First, NOAA-12 became operational in Oct 1991, so its data were first merged into the time series at that point. Secondly, the adjustments necessary for NOAA-11 to account for drifting through the diurnal cycle and separately for its instrument calibration problem were of significant magnitude in this period. UAH and RSS apply different adjustments for these corrections. As seen in Fig. 1, the character of the z-score evolution is somewhat different between UAH and RSS, reflecting perhaps the different ways each group calculates and applies adjustments. Rather than being a distinct peak, representative of a sudden shift as in **A** and **C**, the z-scores show a broad, irregular period indicating that not only might there be a shift problem, but perhaps a trend problem as well.

Given the character of event **B** as depicted in the z-scores and no indication of radiosonde changes at this time, it is plausible to assume that the presence of differences in the late 1991 to 1993 time period are caused by problems in the satellite merging process. If so, then the VIZ network has detected errors in the satellite merging process for the layer temperatures known as MT (a spurious warming).

Assuming event **B** is a satellite problem, the 31 stations provide a sufficient sample size to determine that the shift is on the order of –0.08 ± 0.05 K (applying the 36-month breakpoint methodology). Thus, a radiosonde system with the stability implied by the VIZ network would be exceptionally valuable if distributed around the Earth.

Future instruments will no doubt carry better precision and (traceable) calibration than the vintage VIZ radiosondes and MSUs. We may generalize the results above to a typical problem that might affect future satellite missions. Suppose that a gap occurred for observations of microwave temperatures due to the failure of specific channels or the sudden loss of a spacecraft (e.g. communications failure, attitude control failure, etc.) before a replacement was launched. To determine the bias between successive instruments for which little or no overlap exists, a reference radiosonde network would be indispensable.

If such a network maintained about 30 stations distributed so that each sampled a spatial degree of freedom (for seasonal anomalies) we may estimate the precision with which the system may aid in patching satellite data across the gaps. Let us assume that the reference radiosonde network is characterized by a precision whose magnitude is 50% less than that of the VIZ network. Let us also assume the satellite sensors also are 50% more precise (i.e. less noise). If the each of the non-overlapping satellites had 36-months of overlap with the radiosonde network, we could estimate the instrument bias to within ±0.03 K.

5. SUMMARY AND CONCLUSIONS

A reference network of radiosondes with traceable calibration and sited with other profiling instrumentation, would be of great advantage in understanding the minute changes of temperature associated with some aspects of natural and human-induced climate change. The reference network would form a backbone for future Reanalyses projects and serve as a check on space-based climate records.

We close with Recommendation 7 from the Climate Change Science Program Synthesis and Assessment Product 1.1 (Folland et al. 2006).

> Following Key Action 12 of the GCOS Implementation plan (GCOS 2004), develop and implement a subset of about 5% of the operational radiosonde network sites for all kinds of climate data from the surface to the stratosphere.

6. REFERENCES

Christy, J.R. and W.B. Norris, 2006: Satellite and VIZ-radiosonde intercomparisons for diagnosis of non-climatic influences. J. Atmos. Oceanic Tech., 23, 1181-1194.

GCOS, 2004: Global Climate Observing System implementation Plan for the global observing System for Climate in support of UNFCCC, GCOS-92, WMO-TD 1219, WMO, Geneva, 136 pp.

Folland, C.K., D.E. Parker, R.W. Reynolds, S.C. Sherwood and P.W. Thorne, 2006: "What measures can be taken to improve our understanding of observed changes?" in *Temperature Trends of the lower Atmosphere, Steps for Understanding and Reconciling the Differences.* U.S. Climate Change Science Program, Synthesis and Assessment Product 1.1. Karl et al. eds. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington D.C.

Table 1 As shown in Fig. 1, the following are numerical values of the breakpoints identified in the figure. Generally speaking, z-score magnitudes greater than 2.5 are significant.

	Breakpoint	z-score	BP value (K)
UAH	A	-7.56	-0.180
RSS	A	-7.92	-0.180
UAH	B	-2.50	-0.064
RSS	B	-3.92	-0.093
UAH	C	+6.77	+0.156
RSS	C	+6.13	+0.156

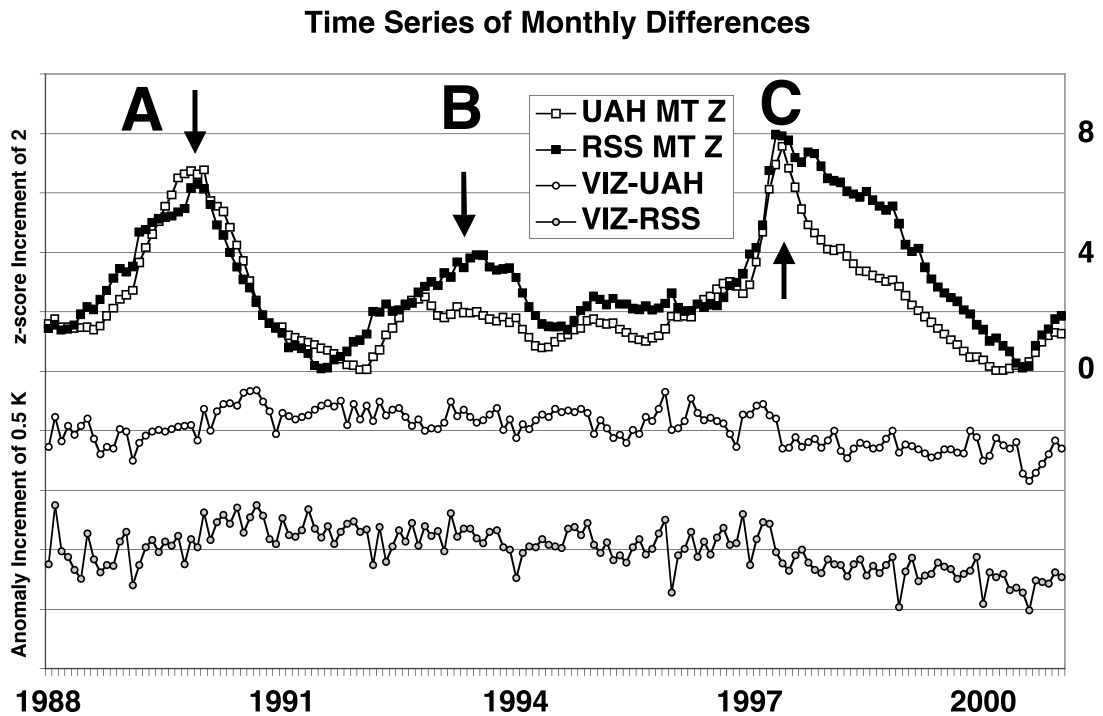

Fig. 1. Top: Time series of z-scores (see text) calculated from the difference time series of UAH minus VIZ (open squares) and RSS minus VIZ (solid squares). Lower: Time series of raw differences between monthly anomalies of MT for UAH minus VIZ (open circles) and RSS minus VIZ (darkened circles). Increments displayed by the horizontal grid lines are 2 for the z-scores and 0.5 K for the raw differences. VIZ represents the average MT temperatures of 31 radiosonde stations. The satellite temperatures represent the average at the same 31 geographic grids.