

## Satellite Upper Air Network and the Climate Retrieval Problem

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### 1. INTRODUCTION

During the past 25 years of NOAA operational polar satellites, it has become evident that a growing problem concerning their utilization in Climate and also Numerical Weather Prediction (NWP) applications are the systematic errors and uncertainties inherent in the satellite measurements. Similar arguments can be made for global radiosonde observations. These uncertainties are often larger than the sensitive signals and processes that satellite and radiosonde measurements are designed to reveal, particularly in the realm of climate. Possible strategies to quantify and compensate for these problems include the analysis of satellite overlap data and/or available collocations of satellite, radiosonde and numerical weather prediction (NWP) observations. However, overlap observations are typically not available except in extreme polar regions, and current strategies for analyzing collocated radiosonde and satellite (and NWP) observations are insufficient, further compounding the inherent uncertainties in these respective data platforms.

A Satellite Upper Air Network is proposed to provide reference radiosonde launches coincident with operational polar satellite(s) overpass. The SUAN consist of 42 global radiosonde stations sub-sampled from the Global Upper Air Network (GUAN) (Daan and DeBilt 2003) and Atmospheric Radiation Measurement (ARM) Programs and is designed to provide a robust and reliable sample of collocated global radiosonde and satellite observations conducive to the monitoring and validation of satellite and radiosonde observations. The routine operation of such a network in conjunction with operational polar satellites would provide a long-term record of performance for these critical observations, of particular importance for climate.

The integration and impact of SUAN with respect to global retrieval algorithms for deriving atmospheric products, particularly products for climate is also important. Such products require that systematic errors

and uncertainties in the measurements be compensated for prior to deriving products. The lack of a program such as SUAN has resulted in a poor historical record of such parameters and degraded product value for climate.

### 2. WHY SUAN ?

*Operational polar satellite measurements and derived products* utilize collocations of satellite data and radiosondes for validation and product tuning (Tilley et al., 2000). Troubling degrees of inconsistency among the global distributions of collocations per satellite and the need to broaden the time windows to achieve sufficient sample sizes and coverage raises questions concerning their suitability for these purposes. Typical global distributions of collocations for NOAA-15 (top) and NOAA-16 (middle) polar satellites are shown in the two panels of Figure 1. NOAA-16 and 15 have local ascending overpass times of 1330 and 1930, respectively, and when combined with the synoptic release times of radiosondes and time windows of less than 6- hours the observed sampling patterns emerge. The two panels of Figures 2 show corresponding mean and standard deviations differences for derived satellite and radiosonde temperature profiles for the 30N to 30S land regions. As can be seen the accuracy curves for bias are significantly different, however this difference is primarily sample driven.

*The problem of global radiosonde measurement errors* is an underlying issue since they are often a cornerstone of global scientific applications and/or validation. Such errors typically occur as either systematic, for example, due to a specific radiosonde type or correction procedure, or in a less predictable random manner due to the need for better measurement technologies. A component of this problem can also be traced to bookkeeping type errors, for example, uncertainties concerning the radiosonde types flown, launching protocols, corrections applied and other deficiencies concerning available meta-data records from long-term archive centers.

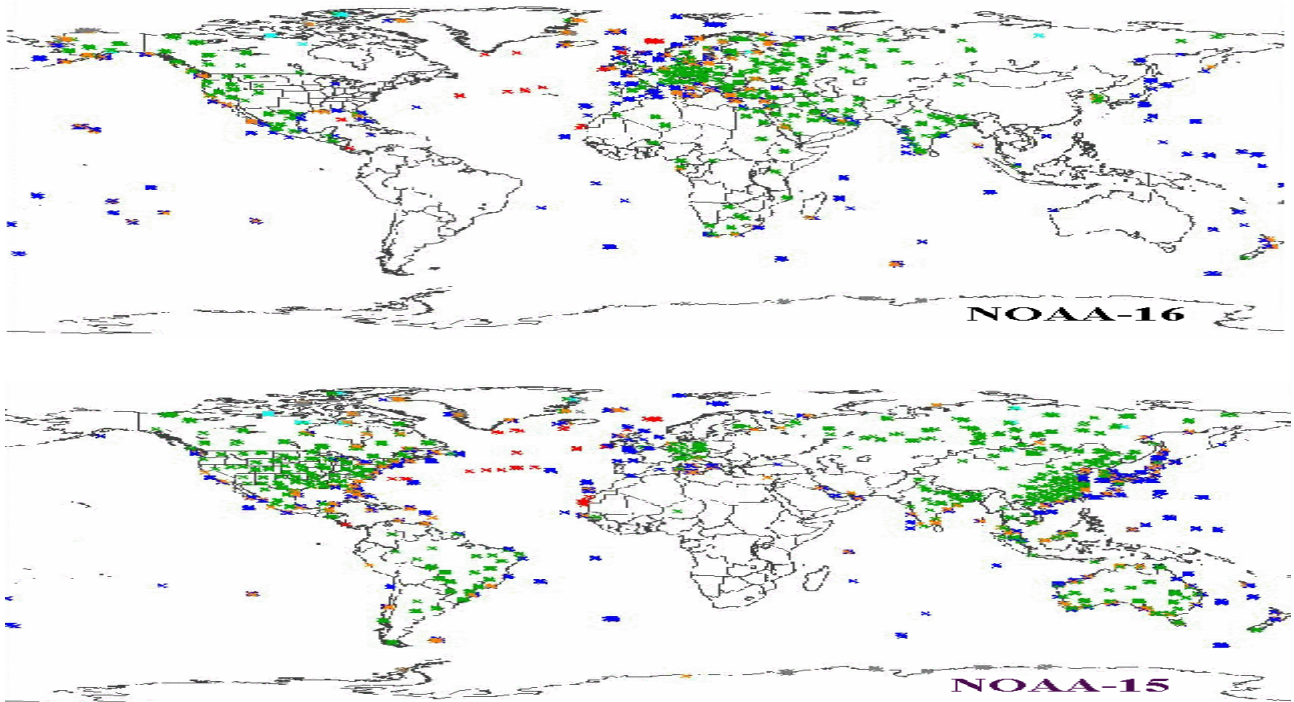


Figure 1: Collocated radiosonde and satellite observation samples compiled by NESDIS for NOAA-16 (upper) and NOAA-15 (lower) over a 3-day period using 3-hour (land) and 5-hour (sea) time windows; Blue are sea, Green are over land, Orange are coastal, Gray are sea-ice, Light blue are snow, and Red are ships.

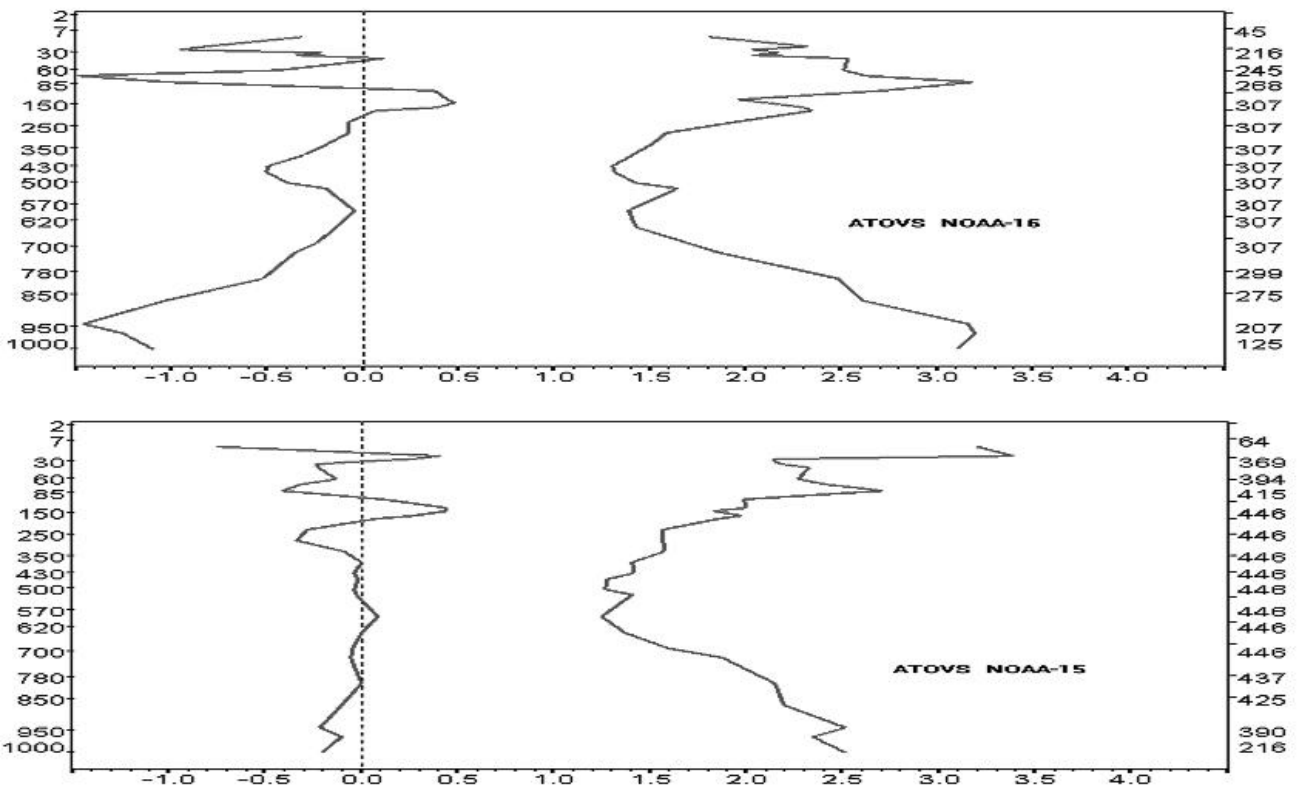


Figure 2: Vertical accuracy statistics of mean (left) and standard deviation (right) satellite minus radiosonde differences for NOAA-16 (top) and NOAA-15 (bottom) over a 7-day period for land data from 30N to 30S with sample distributions as illustrated in Figure 1.

*The deployment of SUAN would provide a “manageable” program for monitoring radiosondes,* not only SUAN radiosondes but potentially the greater radiosonde network as well, and provide a very good network in support of radiosonde instrument testing, new technology research and development. For example, SUAN sites located in the vicinity of existing synoptic sites would offer ample opportunities for a variety of studies ranging from straightforward inter-comparisons of the radiosonde measurements to the modeling of localized effects such as frontal passage, local weather features, terrain, and balloon drift. Appropriately planned multi-instrument launches at SUAN sites would provide attractive locations for long-term studies of instrument performance, data corrections, new technologies (i.e., drift-sondes) and integrated ground based spectral measurements. Finally, analysis of SUAN data could ultimately provide information for determining absolute radiosonde accuracy, for example, through the use of Radiative Transfer (RT) models and collocated satellite observations as a transfer standard for inter-sonde validation (McMillin *et.al.* 1988).

*RT models* represent a scientific area shared among the satellite, climate and NWP communities and a critical process for determining absolute accuracy. Unfortunately, unresolved errors in the satellite and radiosonde data used as the basis for developing and validating RT models make absolute validation difficult. However, a carefully designed SUAN data-set which minimizes collocation errors in the spectral and meteorological (radiosonde) data would provide the caliber of information needed to segregate real error components in the measurements. This is a critical element for developing and maintaining the highly accurate RT models needed to optimize the scientific impacts of the current suite of observations and hastening the deployment of planned next generation satellite and in-situ data platforms.

*The problem of detecting global climate change* from operational satellites and radiosonde observations has been addressed by a number of researchers with often conflicting results or a conclusion that the data available may not be suitable for detecting climate signals (Klein *et al.* 2004). Attempts to utilize the

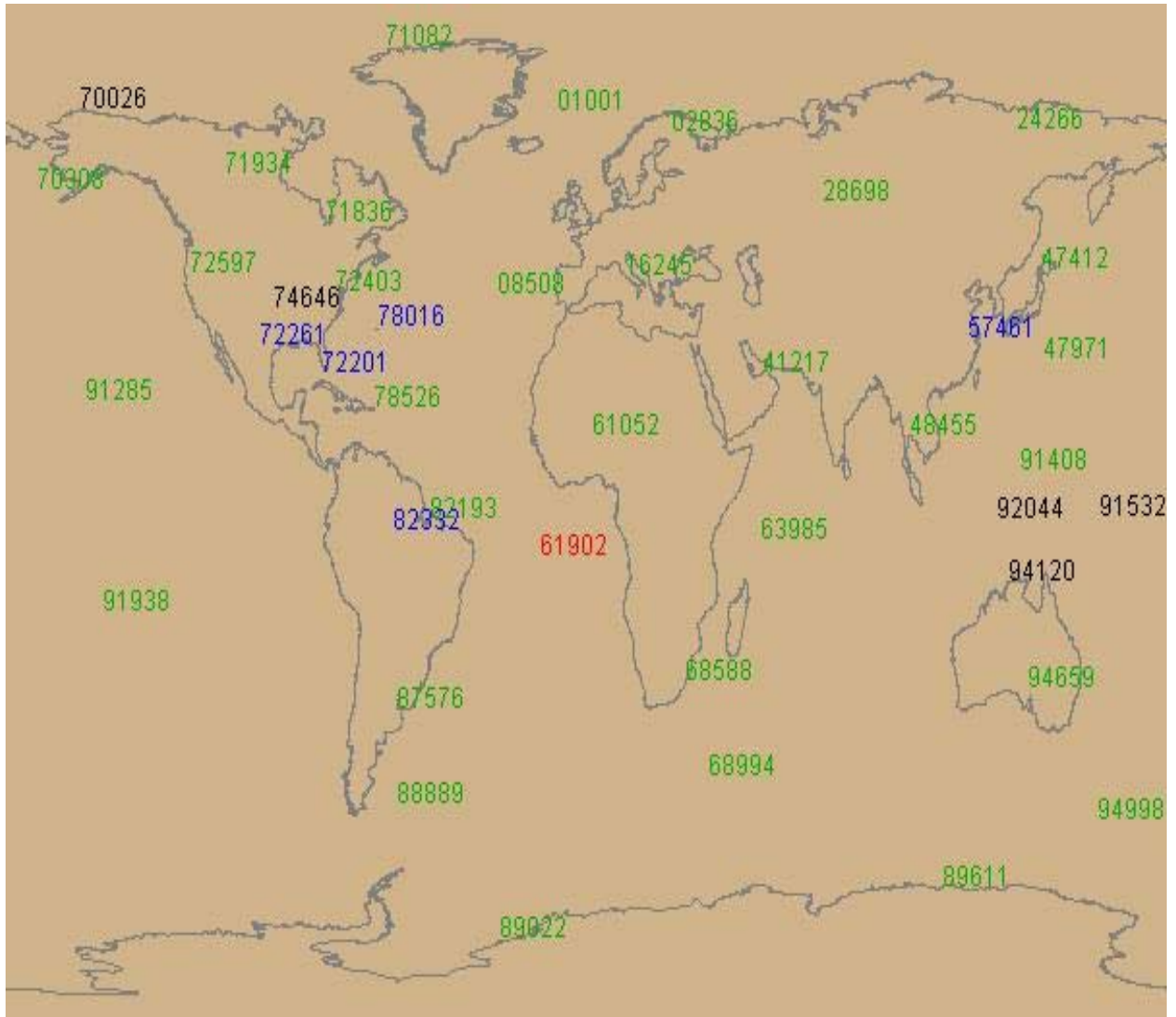
20+ years of historical TOVS-MSU data and radiosondes to detect climate changes in many cases have resulted in little overlap, with recent constructions of climate data-sets nominally serving to increase the uncertainty in the true multi-decadal trends (Seidel *et.al.* 2004). Without a reliable transfer standard, one cannot unambiguously conclude how to remove non-climatic effects in an absolute sense, even if they all can be identified; as a result large uncertainties remain. A potentially significant portion of such uncertainty could disappear in the presence of a sufficiently robust and consistent transfer standard, most critical for example for free-troposphere variables such as those observed by the radiosondes and satellites. The potential of using the SUAN in this context is quite high.

*The deployment of planned next generation data platforms (i.e., METOP and NPOESS)* would benefit from having a SUAN in place prior to their scheduled implementation, particularly users trying to integrate existing and new data in ongoing applications. SUAN sites would provide attractive locations in support of ongoing validation (CALVAL) activities currently underway in support of the next generation advanced instruments (Aumann *et.al.* 2003), accelerating their operational deployment and facilitating a smooth transition in the long-term record, for example from AMSU to AMTS and MHS, HIRS to IASI and CRIS, and AVHRR to MODIS to VIRS.

### **3. SUAN SITE SELECTION**

The recent WMO-Atmospheric Observations Panel for Climate (AOPC) held in Geneva, April, 2004, recommended that SUAN sites be selected as a subset of existing GUAN (Daan and Bilt 2003) sites, comprising a network of “super-stations” that would provide additional reports on a daily basis coincident with polar satellite overpass and serve as focal points for the deployment of standardized, advanced ground station measurements technologies and research.

Therefore, the strategy for selecting candidate SUAN sites was to choose a subset of GUAN stations with demonstrated good performance and robust global distribution.



**Figure 3: Global distribution of radiosonde sites (identification numbers) for proposed Satellite Upper Air Network (SUAN) Radiosonde stations.**

Figure 3 shows a global plot of the candidate SUAN sites, color coded based on performance analysis conducted by NESDIS and the UKMO, for which:

- **Green;** UKMO 5-year performance at least 70% successful with NESDIS observing at least 10 good reports in a 14-day test period,
- **Blue;** UKMO and NESDIS analysis disagreed on performance,
- **Red;** UKMO 5-year performance less than 70% successful with NESDIS observing less than 10 good reports over 14-day test.
- **Black;** ARM sites.

As can be seen in Figure 3, only six (6) of the forty-two (42) SUAN candidate sites showed less than successful performance. Overall, the global distribution is good, comprised of 19 predominantly inland, 19 maritime and 4 sea-ice locations. If each site was to provide one launch per day in support of two-polar satellites, the result would be over 7000 “standardized” collocations per year per satellite.

The candidate SUAN sites shown in Figure 3 do not include possible ship candidates, also considered an important part of the program. Other factors including the availability of additional ground measurement capabilities and available resources will ultimately determine the final network. However

#### 4. ENDORSEMENTS

Recommendations toward a SUAN are available::

- *NOAA Council on Long-Term Climate Monitoring*, January 2003 (Karl, 2003),
- Workshop to Improve Usefulness of Radiosondes, (Durre *et.al.* 2004),
- White Paper: Creating Climate Data Records from NOAA Operational Satellites (Goldberg *et.al* 2003),
- International ATOVS Study Conference (ITSC-13), November, 2003 (Saunders and Achtor 2004), and
- WMO Atmospheric Observations Panel for Climate (AOPC), April, 2004.

SUAN is scheduled for presentation at the scheduled NOAA Upper Air Observations Requirements Workshop in 2005.

#### 5. ACKNOWLEDGEMENTS

The contents are the opinions of the authors and not necessarily a statement of policy, decision, or position on behalf of the U.S. Government.

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