3.5 A Candidate GCOS Atmospheric Reference Observations Network (GARON) Consisting of ARM, BSRN and WMO Reporting Sites and Satellite / In-situ Data Collection Strategies

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1. INTRODUCTION

During the past 25 years of NOAA operational polar satellites, the lack of a dedicated (or reference) network of upper air observations to provide reliable and consistent monitoring and scientific validation of operational measurements and associated meteorological data in the context of numerical weather prediction has been a growing concern. With the emergence of climate as a critical component of the polar satellite mission, further need for a reference network to provide consistent and accurate long-term records of critical upper air observations in the context of climate has also been raised (Seidel 2004). The ongoing series of NOAA / GCOS workshops are attempting to integrate these concerns under a proposed GCOS Atmospheric Reference Observation Network (GARON) for climate.

The following report summarizes related weaknesses in the global sample of radiosonde, in-situ and collocated satellite observations currently used to monitor operational satellite measurement and derived product error characteristics. Examples of existing surface and upper-air measurement networks and observing sites leading to a candidate GARON are presented. Arguments for GARON observations that include synchronization with operational polar satellite overpass are proposed. The report concludes with some basic data sampling and management strategies that can be readily integrated into current operational polar satellite data processing systems.

2. WHY REFERENCE NETWORKS

Satellite data providers (Reale, 2002) and more recently the climate community (Seidel 2004) have experienced analytical ambiguities due to perceived anomalies in observational error characteristics. In both cases the problem has resulted in reduced sensitivity, for example, in satellite derived weather product depiction of real-time weather or climate model prediction of global change parameters with associated reduced capabilities to validate. This two edged sword has undermined data utility, particularly costly with respect to satellite observations which provide the bulk of available information for real-time weather and climate applications compared to other data platforms. It therefore would appear to make the most sense to optimize data collection strategies for reference networks with polar satellite observations.

Demonstration of sampling bias and overall inconsistency of the existing global network of routinely available “operational” meteorological data to monitor and validate global polar satellite data (Tilley 2000) is illustrated in the four panels of Figure 1. Each panel display global samples of collocated radiosonde and operational polar satellite data for specified time windows and satellites. The uppermost and bottom panels show samples for NOAA-18 (local overpass at 1430) and NOAA-15 (local overpass at 1930) respectively using a time window of up to 3 hours over land and 5 hours over sea. The two middle panels show associated collocations for each satellite using time windows up to -1 hour. The distance window for all collocations is up to 100km.

It is evident from Figure 1 that the sampling of collocations over land that are within 3-hours is largely mutually exclusive particularly over land where a

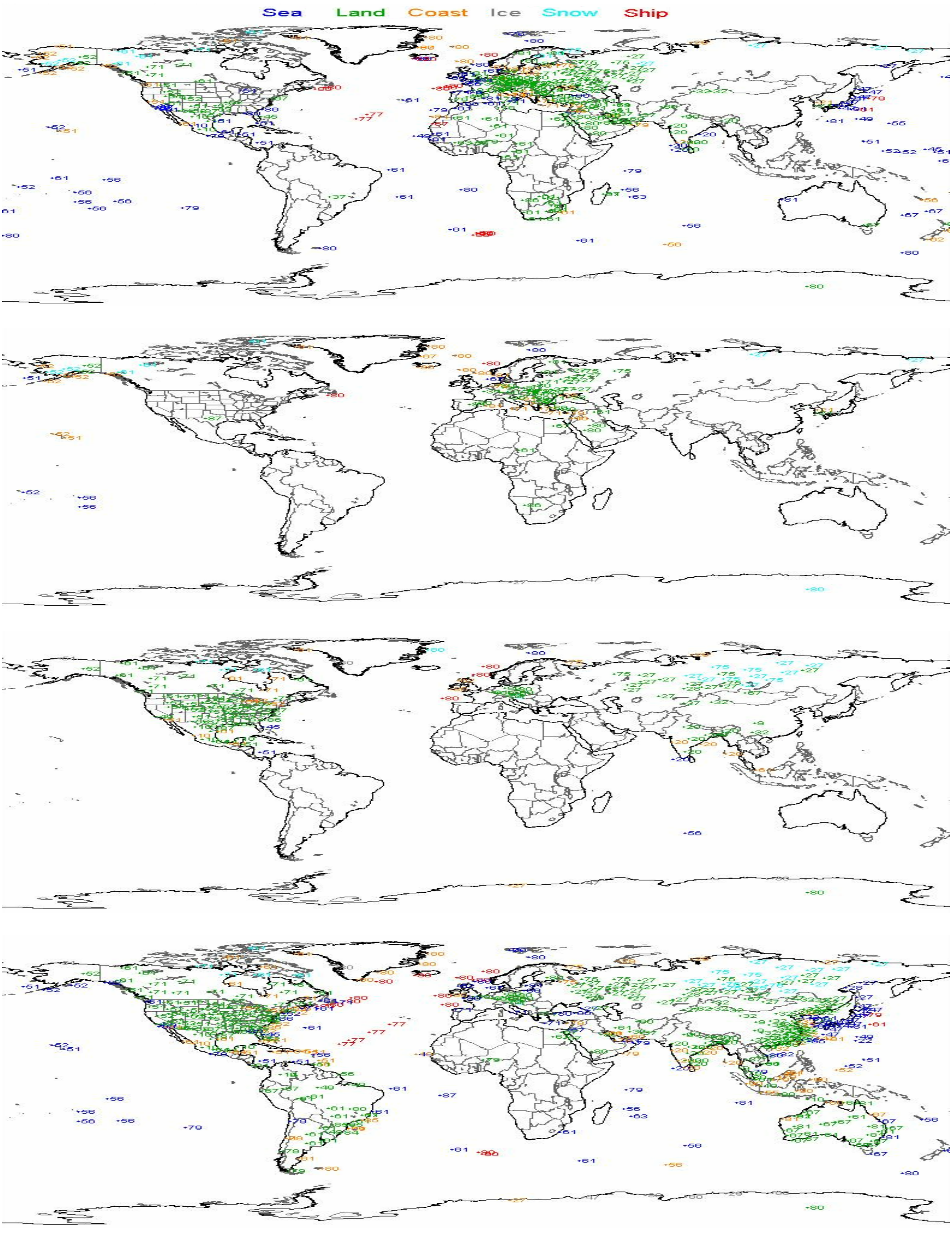

Figure 1: Global samples of collocated radiosonde and operational polar satellite data using a time window of up to 3 hours over land and 5 hours over sea for NOAA-18 (Top; local overpass at 1430) and NOAA-15 (Bottom; local overpass at 1930) respectively, and using a time window of up to -1 hour for NOAA-18 (second from top) and NOAA-15 (second from bottom).

majority of the collocations for NOAA-18 lie in the region of Europe whereas for NOAA-15 they are in the Eastern U.S. and China regions. Collocations for which the radiosondes are launched up to 1 hour prior to satellite overpass show very restricted global coverage per satellite. The few common collocations over Europe correspond to sites launching every six hours.

The contention is that the available sample of multi-data platform collocations containing sun-synchronized polar satellite observations as signified by existing collocations with the predominantly synoptic WMO is problematic. This essentially de-sensitizes subsequent applicators to validate and utilize these data, for example, in the numerical weather prediction and in particular the climate applications for which they are intended.

3. NETWORK CONSTRUCTION

A plan for constructing a GCOS Atmospheric Reference Observations Network (GARON) is now under for which a primary goal is to address the problem of characterizing the respective error characteristics of the multiple platform data-sets of observations used in climate prediction models. Thus, a goal is to construct a network of sites which provided multiple, same-same observations of critical data that provide an accurate and globally robust database in the most cost-efficient manner.

A first issue that arises is whether there are existing sites or networks which provide observations that meet (or begin to meet) these requirements. A preliminary listing of existing candidate networks is listed below:

- Baseline Surface Radiation Network (BSRN) (see http://bsrn.ethz.ch/)
- The Atmospheric Radiation Measurement (ARM) Program (see http://www.arm.gov/)
- A number of individual national observatories
- Global Climate Observing System (GCOS)
- World Meteorological Organization (WMO) radiosonde network
- Network for Detection of Atmospheric Composition Change (http://www.ndacc.org/)
- Aeronet (http://aeronet.gsfc.nasa.gov/)
- Global Atmospheric Watch ozone network
- International GNSS (Global Navigation Satellite Systems) Service (IGS) (see http://igscb.jpl.nasa.gov/)
- The network of surface GPS total column water vapour instruments

Assuming a basic requirement for each site is to provide surface and atmospheric weather parameters, construction of a preliminary network can be limited to the first five networks listed.

Current BSRN sites with in-situ and upper-air observations include (with WMO identifier):

- Tamanrasset, Algeria 60680
- Tateno, Japan 47646
- Bermuda 78016
- Cocos Is, Aus. 96996
- A. Samoa (Pago) 91765
- Lerwick, UK 03005
- Von N., Antarc. (Ger) 89002
- Syowa, Antarc. (Jap) 89532
- Amun-Scott, Ant. (US) 89009
- Alice Springs, Aus 94326
- De Aar, S. Africa 68538
- Ny Alesund, Norway 01004
- Desert Rock, Nevada 72387

Observations taken at each BSRN are being documented.

ARM sites with upper-air observations:

- ARM sites (http://www.arm.gov)
  - Tropical Western Pacific (92044, 91532)
  - Southern Great Plains (74646)
  - North Slope Alaska (70026; *also BSRN*)
  - Darwin (94120; *also BSRN*)

Supplementary ground observations available at ARM sites are well documented. A preliminary requirement for reference networks might begin with supplementary ground-based (upward looking) radiometers that match the space based radiometers on board polar satellites. Such a list could include:

- Microwave Radiometer Profiler (T, H20 and CLW profiles @ 20-30 and 50-60 GHz)
- GVR (183 +/- 1, 3, 7 and 14 gHz)
- Raman Lidar (H20 Vapor, Cloud, Aerosol)
- Radiosonde (Vaisala RS-92, dual humicap)
- AERI (RT, Clouds , T, H20 and Trace Gas)

Identified national observatories with upper-air observations include:

- Lindenberg, Germany (10393; *also BSRN*) (www.dwd.de/en/FundE/Observator/MOL)
- Camborne, U.K. (03808, *also BSRN*)
- Payerne, Switzerland (06610; *also BSRN*),

- Cabauw, Netherlands (*also BSRN*) (http://www.cesar-observatory.nl/)
- Sodankylä, Finland (http://www.sgo.fi/) (02836)
- Heredia, Costa Rica
- Lauder, New Zealand (National Institute of Water and Atmospheres (NIWA); *also BSRN*)
- Boulder / Denver, U.S. (*also BSRN*)
- Beltsville, U.S. (http://meiyu.atmphys.oward.edu/beltsville/inde3.html)

The three panels of Figure 2 illustrate global distributions of BSRN and an earlier proposed Satellite Upper Air Network (SUAN) for monitoring operational polar satellites (Reale and Thorne 2004) consisting of GCOS and WMO upper-air reporting sites.

Figure 3 presents a candidate GARON network consisting of selected BSRN (brown), ARM (red), national observatory (green) and SUAN (blue) sites with the sites color-coded as indicated. Obviously, the degree of resources needed to establish and maintain such a network is significant. Staged deployments, beginning with more established programs at the national observatories followed by the ARM and BSRN facilities will be necessary. The feasibility of establishing reference caliber programs at the remaining WMO and GCOS sites comprising SUAN will likely be considerably more expensive. Studies quantifying the importance of improved global representation on climate model impact and the overall cost-benefit of adding sites are needed.

4. COLLECTION AND MANAGEMENT

Supposing that some component of the network presented in Figure 3 is realized, the problem of data collection and management becomes an immediate concern. Concepts concerning the critical information required from reference networks are widely varied and a current focus of the ongoing NOAA / GCOS workshops.

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The notion that operational polar satellite data comprise the main (bulk) component of information that drives the climate model leads to a requirements that the data collected at reference network be synchronized with satellite overpass. Therefore, on the first order, if there isn't a satellite overpass there is no requirement to collect multiple platform data at reference sites.

Strictly from the perspective of satellite data processing, the collocated observations from reference networks will be invaluable with respect to “tuning” (Reale 2002) and validating operational satellite sensor data and derived products. Ultimately, one or both of these combinations provide the bulk information for assimilation into the climate model. Over the long-term record, such a database could be precisely what the climate community needs to unravel the mysteries of data error characteristics, bias and compensation that are undermining their impact to monitor climate change.

Another concept concerning reference networks is that they provide a fingerprint of the data as available at a given time. As new and improved technologies become available, the data collected at reference networks will change and likely expand. An important component of the information from reference networks is to provide an historical record of such changes and subsequent impacts on data integrity. .

Therefore, to assume (as some do) that reference networks must provide a standard, best and unchanging component of information is unrealistic. Changes in reference instrumentation will occur. Transitions from old to new instruments must be done consistent with existing GCOS protocols.

Some basic strategies for operating reference networks should include:

- Synchronization of data collection (or portions thereof) operational satellite overpass
- The establishing of data collection and management protocols at each site and identified critical observations
- Data collection and management protocols that are easily expanded as new (improved) data are introduced
- Adherence to GCOS monitoring principles
- Complete meta-data records
- Routine data transfer to a central processing facility for database integration and access.

Preliminary data supporting the need for certain synchronized satellite and reference site observations are given in Figure 4 which compares dropsonde (dark), NWP (red) and derived satellite moisture (green) profiles for cases in which the time difference between the

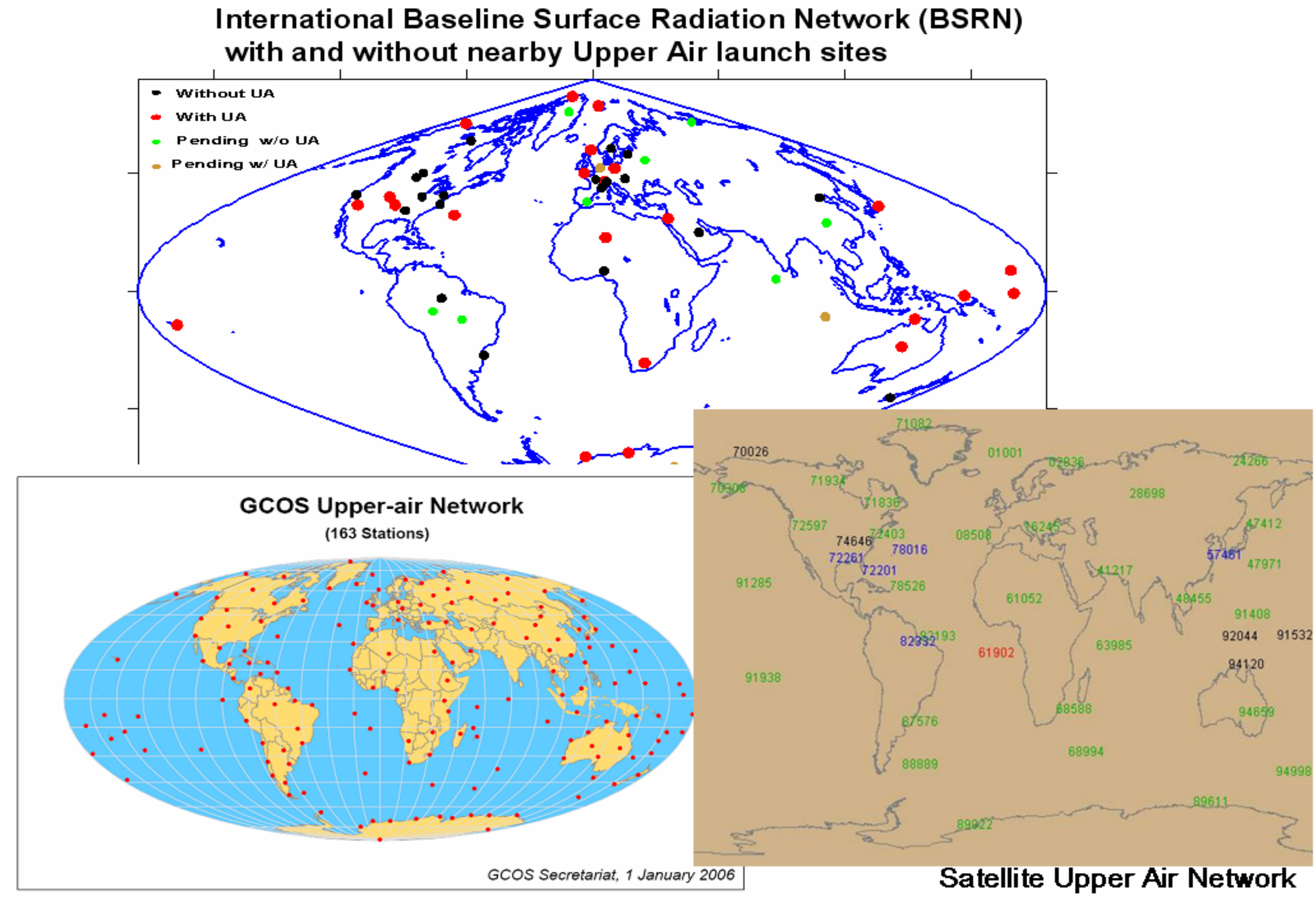

Figure 2: Global distributions of BSRN (top) and an earlier proposed Satellite Upper Air Network (SUAN) for monitoring operational polar satellites comprised of GCOS and WMO upper-air reporting sites.

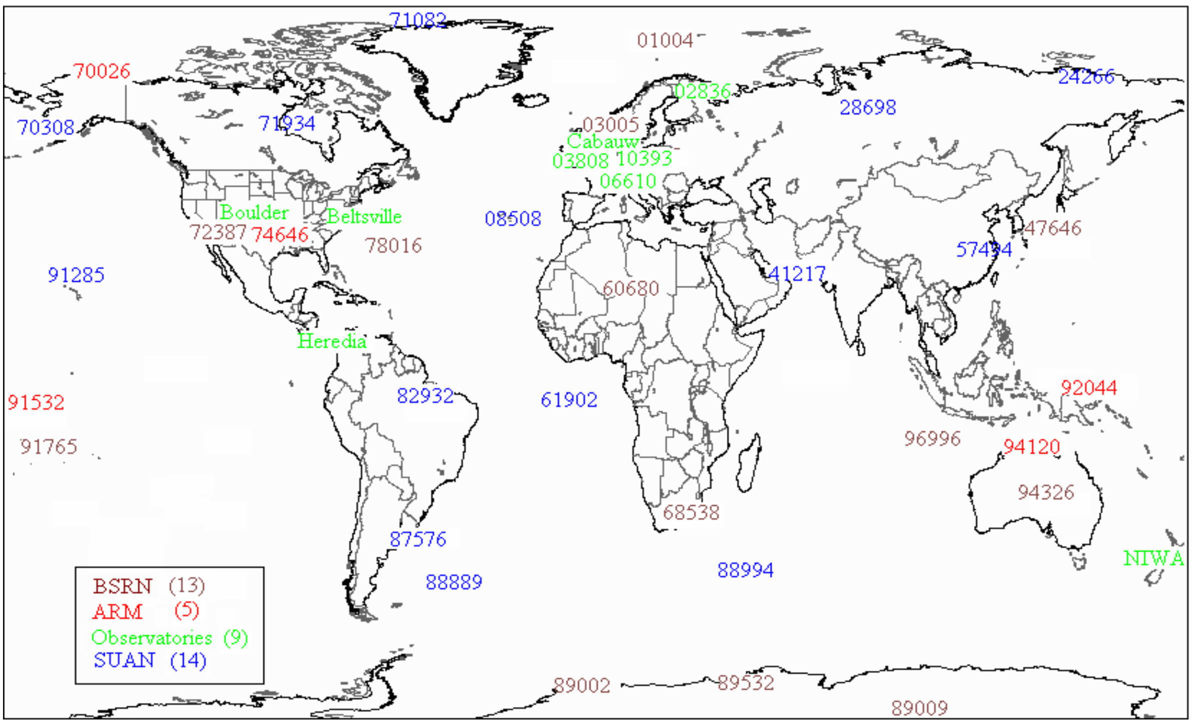

Figure 3: Candidate GARON network consisting of selected BSRN (brown), ARM (red), national observatory (green) and SUAN (blue) sites with the sites color-coded as indicated

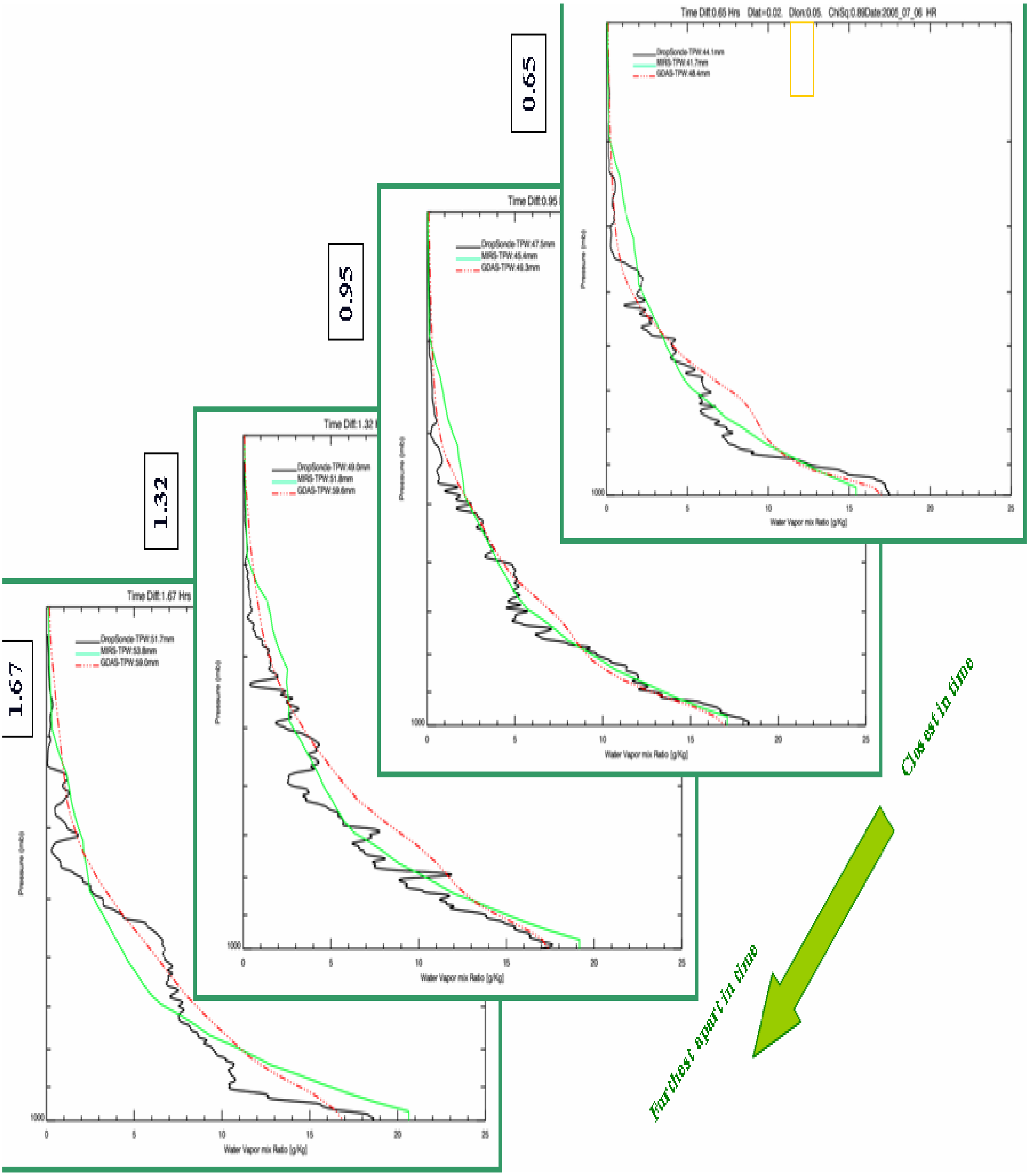

Figure 4: Comparison of dropsonde (black) versus NOAA operational NWP (red) and satellite derived moisture profiles from AQUA-AIRS onboard NASA-EOS research satellites (Aumann *et al* 2003)as the time differences from the dropsonde vary from .65 to 1.65 hours; with pressure in 100mb increments (vertical axis) and water vapor mixing ratio in 5 g/kg increments (horizontal axis).

(courtesy of Antonia Gambacorta, Chris Barnet , Dave Tobin, Leslie Moy, Scott Hannon, Larrabee Strow, and Dave Whiteman ; AIRS Science Meeting, 09-27-2006)

satellite and NWP data versus the dropsondes varies from .65 hours (upper right) to 1.67 hours (low left).

Results such as those shown in Figure 4 will be investigated further through the NOAA / GCOS workshops. The goal is to quantify the sensitivity of the observations collected at reference networks to temporal spatial differences of the observations in order to justify requirement for synchronization of the polar satellite and in-situ observations, in particular the launching of radiosondes and other crucial episodic observations.

The effort to compile and maintain the complete data base of surface and atmospheric observations collected at reference sites will be significant. However, collocated ground and polar satellite observations are already compiled in conjunction with operational processing systems and significant expansions are pending. The operational polar satellite processing environment is a good central location for compiling and maintaining the databases in conjunction with reference networks, particularly those synchronized with the polar satellites.

The up-side for satellite data providers is to be able to take advantage of a global reference network of observations that are synchronized (or otherwise resolved) to the time of satellite overpass. Similarly, the reference network program can take advantage of existing operational capabilities to coordinate and manage the extensive databases from reference networks. It's a mutually beneficial arrangement. Hopefully, such planning will be the focus of future NOAA / GCOS working groups.

5. SUMMARY

This report summarizes current activities underway to define requirement for a GCOS Atmospheric Reference Observation Network (GARON) to identify long-term trends in observational data error characteristics used in climate. Existing networks providing surface and atmospheric observations, including Baseline Surface Radiation Network (BSRN), Atmospheric Radiation Measurement (ARM), selected national observatories and WMO reporting stations are identified and a candidate network of sites proposed. Preliminary results showing the importance of synchronizing reference network observation with polar satellite overpass are presented. The report concludes with discussion of the data management problem and potential mutual benefits of coordinating the processing of reference network observations within routine polar satellite operational systems.

* The contents of this manuscript are solely the opinions of the author and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government.

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