

3B.4 THE U.S. GLOBAL CLIMATE OBSERVING SYSTEM (GCOS) PROGRAM: AN UPDATE ON CONTINUING EFFORTS TO IMPLEMENT REFERENCE CLIMATE OBSERVATION SITES

Howard J. Diamond *
NOAA National Climatic Data Center (NCDC), Silver Spring, Maryland

1. Introduction

Long-term, high-quality observations of the global environmental system are essential for defining the current state of the Earth's system, its history, and its variability. This task requires both space- and surface-based observation systems. As a clarification, in many instances observing systems are identified as being either satellite-based, or *in-situ* to indicate a ground-based system. However, many people believe that the use of the term "*in-situ*" is seriously misused as it appears to include all non-satellite measurements which it does not. In the past, remote sensing from the ground, balloons, or aircraft have been included in this *in-situ* designation, and this is clearly wrong and misleading. For example, atmospheric observations necessary for climate studies include both real *in-situ* measurements (where we directly sample the air mass surrounding the instrument) as well as non-satellite remote sensing measurements. Therefore, this paper will simply distinguish observing systems as being either non-satellite or satellite in nature.

2. Background

The term *climate observations* can encompass a broad range of environmental observations, including (1) routine weather observations, which, when collected consistently over a long period of time, can be used to help describe a region's climatology; (2) observations collected as part of research investigations to elucidate chemical, dynamic, biological, or radiative processes that contribute to maintaining climate patterns or to their variability; (3) highly precise, continuous observations of climate system variables collected for the express purpose of documenting long-term (decadal-to-centennial) change; and (4) observations of climate proxies, collected to extend the instrumental climate record to remote regions and back in time to provide information on climate change for millennial and longer time scales. A full documentation of all U.S. systematic climate observational activities can be found in "*The United States National Report on Systematic Observations for Climate for 2008: National Activities with Respect to the Global Climate Observing System (GCOS) Implementation*". The following input will summarize, and where appropriate, update that information.

* *Corresponding author address:* Howard J. Diamond, NOAA's National Climatic Data Center, 1100 Wayne Avenue, Suite 1202, Silver Spring, MD 20910; e-mail: Howard.Diamond@noaa.gov.

Satellite observations provide a unique perspective of the global integrated Earth system and are necessary for good global climate coverage. Non-satellite observations are required for the measurement of parameters that cannot be estimated from space platforms (e.g., biodiversity, groundwater, carbon sequestration at the root zone, and subsurface ocean parameters). Non-satellite observations also provide long time series of observations required for the detection and diagnosis of global change, such as surface temperature, precipitation and water resources, weather and other natural hazards, the emission or discharge of pollutants, and the impacts of multiple stresses on the environment due to human and natural causes.

One critical challenge to the Earth observation field is to maintain existing observation capabilities in a variety of areas. For example, maintaining the observational record of stratospheric ozone is essential in discerning the effects of climate change on the nature and timing of ozone recovery. Other key areas include radiative energy fluxes of the Sun and Earth, atmospheric carbon dioxide, and global surface temperature.

3. Documentation of U.S. Climate Observations

The United States supports a broad network of in-situ global atmospheric, ocean, and terrestrial observation systems, as well as a large number of remote sensing satellite platforms that are essential to climate monitoring. The U.S. contributes to the development and operation of several global observing systems, both research and operational, which collectively provide a comprehensive measure of climate system variability and climate change processes. These systems are a baseline Earth-observing system and include NASA, NOAA, and USGS Earth-observing satellites and extensive non-satellite observational capabilities.

The U.S. also supports several ground-based measurement activities that provide the data used in studies of the various climate processes necessary for better understanding of climate change. U.S. observational and monitoring activities contribute significantly to several international observing systems, including the Global Climate Observing System (GCOS) principally sponsored by the World Meteorological Organization (WMO); the Global Ocean Observing System sponsored by the United Nations Educational, Scientific, and Cultural Organization's Intergovernmental Oceanographic Commission (IOC); and the Global Terrestrial Observing System sponsored by the United

Nations Food and Agriculture Organization. The latter two have climate-related elements being developed jointly with GCOS.

Meteorological surface-based networks, utilized for climate purposes, make observations of important climate factors, atmospheric profiles, and pollutant emissions, aerosols, and ozone. These surface-based networks are intended to provide the basic observational set needed to define the status and trends in climate of the world, and also to calibrate and validate satellite-based observations.

U.S. priorities for advancement of the atmospheric, oceanic, and terrestrial observing components of GCOS include: (1) reducing the uncertainty in the global carbon inventory (in the atmospheric, oceanic, and terrestrial domains), sea-level change, and sea surface temperature; (2) continuing support for existing non-satellite atmospheric networks in developing nations; and (3) planning for surface and upper air GCOS reference observations consistent with USGCRP Synthesis and Analysis Report 1.1ⁱⁱ.

The global ocean observing system will make incremental advances, building out to 60% completion in 2010, in which 50 surface drifters will be equipped with salinity sensors for satellite validation and salinity budget calculations, particularly in the polar regions; a new reference array will be added across the Atlantic basin, to measure changes in the ocean's overturning circulation—an indicator of possible abrupt climate change; a pilot U.S. coastal carbon observing network will enter sustained service, to help quantify North American carbon sources and sinks and to measure ocean acidification caused by carbon dioxide (CO₂) sequestration in the ocean; and dedicated ships will target deployments of ARGO and surface drifters in undersampled regions of the world oceans.

The North American Carbon Program (NACP), under the auspices of the U.S. USGCRP, aims heavily at terrestrial uncertainties and these are supported by a growing set of atmospheric measurements to place constraints on flux estimates. These observations are on-going and involve participation from numerous agencies and institutions.

4. Reference Climate Observations

From a global workshop held in October 2007, "Learning from the IPCC Fourth Assessment Report - Workshop and Survey Report"ⁱⁱⁱ it was stated the following, and as such provides solid scientific justification. On a global basis, for funding improvements in global non-satellite climate observations:

"Contingency plans for gaps in the climate record must be developed to cover, for example, instrument failure. For some ECVs, such as solar irradiance, a gap cannot be filled, but for other ECVs, it may be possible to bridge gaps with other measurements. Such measurements

must be of sufficient quality, accuracy and sampling to act as a transfer standard. In situ reference observing networks leveraging on existing or partially completed networks of reference sites taking multiple measurements of many different variables will be an important element of any future observing network. Implementation of these reference networks is of high priority to ensure the value of future observations. For example, the GCOS Reference Upper Air Network (GRUAN), aiming at reference atmospheric profile measurements of several ECVs, is now in the process of being established."

In the very near-term, full U.S. support for the GRUAN set of reference upper air network observations in support of higher quality upper tropospheric and lower stratospheric water vapor would go a long way towards getting the kind of reference climate observations in place that the climate community and society would benefit from. In the U.S., GRUAN has the advantage of including activities from NOAA, the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Program's Climate Facility (ACRF), the National Center for Atmospheric Research (NCAR), as well as university research community partners such as Howard University (HU) in working together (on an international basis) towards addressing one critical aspect of climate observing^{iv}. Of the eventual global total of 30-40 GRUAN sites, 7 of these candidate sites are from the U.S. (ACRF – 5; NCAR/NOAA – 1; and HU – 1). Beginning in 2010, NOAA and ACRF will collaborate in the prototype operation of one U.S. GRUAN station at the ACRF Southern Great Plains site in Oklahoma. The U.S. GCOS Program has also committed to some global activities including the support of the international GRUAN Working Group, production of an operating manual, and facilitation of support for a GRUAN data management via a joint ACRF/NOAA data center working agreement, and in collaboration with the GRUAN Lead Center in Lindenberg, Germany.

The importance of reference climate observations in establishing on a global basis is of critical importance to the climate community. The vision of the U.S. GCOS Program is to extend reference surface and upper air climate observations both domestically as well as internationally. The goal is to extend that vision by building a network with our partners, on a global basis, that 50 years from now can with the highest degree of confidence answer the question: *How has Earth's climate changed over the past 50 years?*

5. Conclusion

The emphasis of the U.S. GCOS program is on high-quality, sustained, and robust reference observations (both satellite and non-satellite) to ensure that over the next 50 years, we can document with certainty the regional and national climate signatures and trends in surface air temperature and precipitation over the U.S. including maximums, minimums, and

frequency of extreme events to characterize and document changes in climate. From a non-satellite point-of-view, the four most important efforts we see are: (1) the installation of soil moisture/soil temperature and relative humidity sensors at all 114 USCRN stations; (2) the expansion of the USCRN to Alaska, the Pacific, and other high latitude (e.g., polar), high elevation (e.g., Andes), and tropical locations; (3) the initiation of the GRUAN (including 7 U.S. sites) in order to better document the key climate forcing variables of upper tropospheric and lower stratospheric water vapor; and (4) the initiation of the Surface Radiation Budget Network which provides benchmark observing stations for measuring surface solar and infrared radiation, as well as energy budgets.

A sustained global observing system is the foundation for all climate services. The climate community needs, in particular, an integrated set of global, atmospheric reference observing systems to fulfill both its climate monitoring and services missions. Atmospheric observations are a key input to climate forecast models, and are essential in assessing the changing state of the climate. It is absolutely critical that we now establish a global atmospheric climate reference observing system and commit to sustaining it, so that future generations will have the tools necessary to resolve questions about long-term trends in climate observations.

A new generation of space-based instruments is planned on NOAA's suite of polar orbiting satellites. These instruments will be the raw data needed by all countries to adequately monitor global climate change. Specifically, observations from these instruments will provide the first step in a process to discriminate among one of the many possible trajectories of climate change now projected for the 21st Century. It is critical that ongoing efforts to sustain continuity in many records continue, and this must remain a major priority.

However, contingency plans for the inevitable gaps in the satellite climate record must be developed as well. It is actually likely that a gap will occur even if the efforts to get the instruments into space are realized (such as from a vital instrument failure). For some measurements, such as solar irradiance, such a gap is disastrous for the climate record. But for other measurements it may be possible to bridge such gaps with other measurements. Such measurements must be of sufficient quality, accuracy and sampling that they can act as a transfer standard. A non-satellite Reference Observing Network leveraging on existing or partially completed networks with reference sites taking multiple measurements (such as temperature, ozone, radiation, and water vapor) will minimize costs and increase efficiencies. Implementing these reference networks must take on a high priority to ensure the value of past and future space based observations. Several assessments by worldwide climate experts (e.g., GCOS, CCSP 1.1 Synthesis and Assessment

Product) have argued for the importance of such atmospheric reference networks.

The critical nature of the need for sustained climate observations was underscored in a speech to the 3rd World Climate Conference held in Geneva, Switzerland, in September 2009 by Dr. R.K. Pachauri, *Chairman of the Intergovernmental Panel on Climate Change*, when he said: *"I think there is still time to see that these are addressed before Copenhagen. I want to also highlight the fact that we are very grateful to the WMO and its partners for the observations that they have collected over the years. Indeed as far as the work of the IPCC is concerned it has been supported immensely by the data and by all the observations in its assessment. One of the major findings that we had in the Fourth Assessment Report is the fact that "Warming of the climate system is unequivocal as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global sea level". And I think this is essentially highlighting the importance of observations. Since the conference that we are attending today is primarily focused on the value of information and science, may I say that as far as observations on issues related to climate change are concerned they have enormous value. But we need to make these efforts wider, deeper, more detailed and comprehensive. We know, for instance, that extreme events are on the increase but we need to collect information from across the globe so that science can address this issue on the basis of authentic and continuous information on the subject. We know that floods, droughts, heatwaves, extreme precipitation events are increasing and will continue to increase in intensity, frequency and duration."*

As such, the continuing goal of the U.S. GCOS program will be in advocating the implementation, maintenance, and continuing need for high-quality and specific networks (satellite and non-satellite) that are designed expressly for maintaining a continuous and homogeneous climate record well into the future. As always the challenge will be resources devoted to this, but again, these are a necessary and vital infrastructure component to furthering the goals of understanding climate.

Reference Web Links

ⁱ See < <http://www.climatescience.gov/Library/UNFCCC-report.htm> >

ⁱⁱ See <<http://www.climatescience.gov/Library/sap/sap1-1/finalreport/default.htm>>

ⁱⁱⁱSee <<http://www.wmo.int/pages/prog/gcos/Publications/gcos-117.pdf>>

^{iv} See <<http://gruan.org>>