J4.9 THE U.S. GLOBAL CLIMATE OBSERVING SYSTEM (GCOS) PROGRAM: PLANS FOR HIGH ELEVATION AND HIGH LATITUDE GCOS SURFACE NETWORK SITES BASED ON THE BENCHMARK U.S. CLIMATE REFERENCE NETWORK (CRN) SYSTEM

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1. INTRODUCTION

The U.S. GCOS program (see website at [http://www.ncdc.noaa.gov/oa/usgcos/index.htm] based at NOAA's National Climatic Data Center supports the international GCOS effort. This support fits in with a proactive process approach for GCOS implementation planning with the goal of obtaining a sustainable and robust GCOS observing network for international atmospheric, oceanographic, and terrestrial climate observing. Actions have been taken and plans are in place regarding international, regional, bi-lateral, and U.S. national level GCOS activities. Performance measures are being used to determine where and how best to fill gaps in GCOS surface and upper air network global coverage.

2. BACKGROUND

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. Although hundreds of millions of dollars are spent each year on developing and operating space-based observation systems, surface-based meteorological networks are "under reporting" their observations in many parts of the developing world. This is because of declining economies and the lack of understanding of how these observations contribute to the global effort to monitor climate. Consequently, these networks are operating substantially below their design standards and important observations are either not being made, or are not being communicated to users.

The support for GCOS in developing nations fits in with plans for possibly extending the capability of the U.S. Climate Reference Network (CRN) [see http://www.ncdc.noaa.gov/crn] into a larger effort for establishing an international surface reference monitoring effort aligned with GCOS. The first Synthesis and Assessment product produced by the U.S. Climate Change Science Program, Product 1.1, *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences,* which was released in April 2006 and has specific recommendations related to GCOS with particular emphasis on the need for reference climate observing sites. That report is posted at http://www.climatescience.gov/Library/sap/sap1-1/finalreport/default.htm. The CRN began deploying 114 climate monitoring stations across the USA in 2000. 77 stations are now operational. Network completion will be late 2008. CRN will give national decision-makers high-confidence information on national climate variances, as well as providing benchmark-quality data for climatologists.

As such, the U.S. GCOS Program at NCDC is interested in developing partnerships for installing a network of CRN sites which could be used as part of a global long-term climate reference network to be used in data sparse high elevation and high latitude locations (e.g., the American Cordillera, Arctic, and Antarctic regions). The scope of this extension will depend on the availability of resources. In concert with the International Polar Year (IPY), there is interest (based on available funding) in installing such reference GCOS surface stations, by building on what has been done to date in Alaska and Canada, by installing stations in the Russian Arctic, and Greenland. Preliminary planning for the installation of a CRN site in Tiksi, Russia, has begun in concert with the IPY's International Arctic Systems for Observing the Atmosphere project. Data from the Southern Hemisphere are also critically important, so locations in the Antarctic, and isolated island locations in the Southern Ocean are sought as additional possible sites. The goal is to partner with other national meteorological services in these areas that can assist with on-going maintenance and operations expenses.

A U.S. regional-level network is being prototyped. Like CRN, the regional network is autonomous and provides climate-quality temperature and precipitation data at 5-minute intervals. Derivative CRN stations are proposed for use as the Global Climate Observing System (GCOS) for high-elevation surface observations, for possible International Polar Year observing locations in the Russian Arctic and other high-latitude sites, in a World Bank initiative for tropical glacier monitoring in South America as well as for observing in remote and unique Pacific island locations. Finally, this technology is being considered for a mountain backbone network of research and operational stations known as the

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Mountain Research Institute, which includes several meteorological and other research institutions along the Andean portion of the Great American Cordillera. The Canadian Reference Climate System, also using CRN technologies and monitoring principles, is locating stations in the Canadian Rockies.

3. CLIMATE MONITORING IN THE CORDILLERA

A long-term climate monitoring network is proposed for the Greater Andean/Sierras Region of the American Cordillera from Tierra del Fuego, Argentina to Barrow, Alaska. State-of-the-art climate stations can instrument the Andes and Sierra Mountains of South and Central America. A Cordillera Climate (CORDCLIM) network would be laddered vertically at three cordilleran elevations. The highest stations would be spaced at selected intervals along a chain at or near the upper treeline. Medium-level stations would be near the lower treeline. A third chain could tie into at least 13 national meteorological networks at low elevations. The eventual goal would be to have a network populated by between 197-235 automatic stations, using existing, proven technology. Observations would be reported via satellite to national and international archives.

However, this effort cannot be realistically or practically accomplished with the most high-end sustainable GCOS quality stations. As such, this is our opportunity to build on the work discussed at the CONCORD workshop in Mendoza, Argentina in April 2006 in order to matrix more research-level, but existing observations, along with more sustainable long-term GCOS observations (e.g., NOAA Climate Reference Network sites as discussed at the CONCORD workshop) in order to begin providing systematic climate observations without having to build a more long-term and cost prohibitive system. This approach takes advantage of existing activities to help lay the foundation for providing better climate observations in a more flexible fashion in order to address a number of applications (e.g., glacier monitoring, climate change, biodiversity, etc.) along the Cordillera.

The Great Andean Cordillera of Latin America stretches for over 8000 km, or 86 latitudinal degrees, from Tierra del Fuego (55º S) to Northern Mexico (31º N). The integrated Great Cordillera of the Americas includes the Andes of South America, the Sierras of Central America, and the Rockies of North America. The combined, tri-continental mountainous chain runs from the Antarctic Peninsula (76º S) northwards along the long Andean spine of South America, through Central America and Mexico (34N), and continuing though the Greater Rocky Mountain chain of the U.S. and Canada, ending in Northern Alaska (71º N at the shores of the Arctic Ocean. Including the Antarctic Peninsula (76º S), this vast feature runs a nearly unbroken straight-line distance of over 14,000 km, south-to-north.

This vast south-north, intercontinental mountainous platform of the Americas, despite its subset of names, is essentially one unit – and more markedly, it is the largest contiguous land feature on the Planet Earth.

Due to its interactions with the global atmosphere from near-pole to near-pole, the Great Cordillera of the Americas offers an unmatched global opportunity to gather very high-value, long-term, stable climate observations using three pole-to-pole chains of permanent locations distributed vertically through the lower troposphere. The advantages of using this inter-hemispheric mountain system as a monitoring resource are many: it is a stationary platform; it offers multi-altitudinal observing points for repeated, periodic observations; access and maintenance are easier and operational costs are lower than the more expendable balloon-borne radiosonde, ship, buoy, or aircraft platforms; and it is a unusually rich repository of well-preserved and meaningful climate proxy data (e.g., dendrochronological, glaciological, pedological, lacustrine and limnological, and palynological evidences) related to primary atmospheric processes ranging from long/medium/short-term climate events such as major Pleistocene and Holocene Events to El Nińo-Southern Oscillations as well as Pacific Decadal Oscillations. The value of these climate proxy data has increased markedly during the past decade with the increased science productivity of glaciological, dendrochronological and other climate proxy evidence centers in Canada, the U.S., Mexico, Chile, Argentina, Bolivia, and Peru.

Additionally, the American Cordillera provides a permanent platform for the collection of a deep vertical slice of the lower troposphere through automatic, continuous, precision instrumental observations which may be collected without harm accruing to human observers in even the most extreme conditions. Also important for long-term climate monitoring is that the vast majority of these regions are removed or largely removed from major human disturbances and influences. This provides an environment which reduces questions concerning climate influences of human constructs, heat sources, or direct human modification. As with any climate network, station sites must be carefully chosen using expert local knowledge, and in accordance with defined WMO standards for the siting of climate monitoring stations.

A reasonable next stage for the pan-American climate community is to coordinate, certify, and integrate common climate surface observations networks over large regions. This is a new and great opportunity for the Americas. A principal focal point could be coordinated deployment of standardized climate observations using automatic reference stations along the eastern and western slopes of the Great Cordillera. Canada and the United States are now beginning such a coordinated deployment of their respective national climate surface observations networks in the combined Rocky Mountains. The two nations have now exchanged equipment at sites within each nation, are already exchanging data, have developed common data processing and quality control procedures, and are developing common scientific analysis techniques and product generation formats this year. Mexico has also joined in the drought monitoring and analysis efforts of Canada and the U.S., and individual national and joint international drought products are now being operationally generated for decision-makers at the national and regional levels in all economic sectors within and among all three nations. This Mexico-U.S.-Canada drought monitoring partnership is one model of international science success which has developed without impinging upon sovereignty issues.

For observing climate in mountainous areas in a systematic and common way, the United States joined with Canada beginning in 2004 in instrumenting individual mountain sites within each nation as well as developing a coordinated line of Climate Reference Stations along the spine of the "Andes of the North", the integrated Rocky Mountains. To date, 18 stations have been installed or are slated for installation from Arizona and New Mexico north to Montana and Idaho. About 40 Canadian stations have been upgraded or are slated for upgrades from southern Canada in British Columbia and Alberta northwards to Alaska. In Alaska, two stations have extended this chain northwards to the Arctic Ocean, and have been operating since 2002. Another eleven Alaskan mountain stations are planned for deployment in the next several years. The CORDCLIM would tie into the comparable Canadian and U.S. climate networks now extending to Point Barrow in northernmost Alaska. The result of this proposal would be a permanent, land-based, latitudinal and altitudinal climate monitoring network that would almost extend from pole-to-pole across the Americas.

For maximum resource efficiencies, it is wise to standardize technology and deployment of long-term climate monitoring stations along the entire Cordillera. Up to three vertical station chains may suffice with latitudinal spacing of about 1.5-2.5° to allow inclusion of existing stations for this near pole-to-pole network. The science extensions and benefits of such an integrated multi-hemispheric, permanent, and in-situ atmospheric monitoring network are enormous - not just in scale - but in disciplinary and international breadth, enrichment, and leveraging.

Finally, it should be noted that a geographical gap in an integrated, international Arctic-to-Antarctic montane monitoring program is the lack of a standardized U.S. montane network. Individual high-quality U.S. stations exist. Although the CRN has a few western mountain stations, these may be insufficient in geographic and ecotonal representation and may not be fully appropriate in configuration for an integrated montane climate monitoring program. A systematic census of existing monitoring stations is necessary for this region prior to proceeding further.

4. A POSSIBLE WAY FORWARD

In order to move forward on establishing the CORDCLIM as a viable effort, the following issues and activities (there are probably others, but this is just a start) need to be addressed:

- Establishment of a steering group of interested individuals to shepherd this program along (most business can be done via teleconference and e-mail; with occasional meetings as opportunities arise.
- The compilation of candidate sites and stations that are willing to be considered as part of the CORDCLIM effort. The steering group would then look at which sites were the best candidates from a physical, as well as from an institutional basis.
- The development of a policy governing the collection and sharing of climate data from CORDCLIM sites; in order for this effort to succeed it is key for the data from CORDCLIM sites to be freely available.
- The determination of what climatic variables should be part of the system, and that could also include the incorporation of paleoclimatic data elements.
- The establishment of a data center that is able to manage, steward, and provide easy access to the data from CORDCLIM sites. This includes all the required metadata regarding who has collected the data, the equipment configuration, site information, etc. NOAA/NCDC may be a candidate for being that data center, but we do not want to preclude other institutions that may want to take on that role.
- Investigate possible cost-sharing partnerships such as the Earth Observation Partnership of the Americas (EOPA) initiative. The EOPA initiative is a regional effort under the Global Earth Observation System of Systems detailed at http://earthobservations.org. Through EOPA, the U.S. is exploring partnerships with countries and scientific organizations in the Americas and the Caribbean to share Earth observations develop and strengthen data networks and enhance delivery of benefits to society.

5. PARTNERSHIPS

The first EOPA meeting took place in Argentina in June 2005, with representatives from Argentina, Belize, Bolivia, Brazil, Chile, Costa Rica, El Salvador, Guatemala, Guyana, Honduras, Mexico, Netherlands Antilles and Aruba, Panama, Paraguay, Peru, Uruguay and the United States agreed that "the formation and growth of Earth observation partnerships in the Western Hemisphere will promote the successful development of the Global Earth Observation System of Systems (GEOSS). Regional partners committed to continue their work to enhance availability of and access to data and information from their respective Earth observing systems, both satellite and *in situ*."

One of the key partnerships which has evolved as a result of the EOPA process has been the possibility of a joint NOAA/World Bank project involving the monitoring of 10 high elevation tropical glacier sites in South America. EOPA has provided a framework and focus for building partnerships such as the one with the World Bank. To date, resources have still not been secured, but planning is well underway should resources become available. First, we envision this taking up to three seasons to implement given the fairly short, high-elevation field seasons with which to have sufficient time for such installations. We are estimating that each field season has 8-10 weeks in it where one can get about, do field work, do the labor, and do all of that without getting into weather trouble. Other considerations involve the following elements: as follows:

- Working with the local meteorological services or interested research institutes to assist in finding the most appropriate and practical sites. Train national personnel for handling incoming data (e.g., communications, QA/QC, algorithms applied, data flows, health-of-the-network training, data archival and distribution, data-to-products, GIS, data-to-decision makers, etc.).
- Work with local meteorological services on a variety of technical issues (e.g., maintenance capable, calibration capable, engineering/logistics) so that they can replicate these systems within three years
- Ensure that the data remains in the public domain.
- Ensure station integrity and security.
- Conduct a regional workshop in order to establish a common framework for the operation of all sites.
- Translation of technical manuals and supporting materials.
- Logistics and Customs - identify the appropriate organizations that we must interface/coordinate with and get those relationships going smoothly and positively rather than creating roadblocks.

The genesis of the cooperation and partnerships established with respect to this CORDCLIM effort was initiated at the Climate Change: Organizing the Science for the American Cordillera Conference (CONCORD) that took place in Mendoza, Argentina, in April 2006. CONCORD was organized by the Mountain Research Institute [http://mri.scnatweb.ch/], and they have become a key partner in helping to facilitate progress on the CORDCLIM proposal process in the region. Dr. Raymond Bradley of the University of Massachusetts set a very positive tone at CONCORD by proposing an integrated approach calling for a mix of long-term CRN-like stations along with a set of more shorter time scale research level stations, and this has become the underlying operational philosophy for the CORDCLIM project.

Finally, with respect to high-latitude observing, the U.S. GCOS Program Office has also been working with International Arctic Systems for Observing the Atmosphere (IASOA) [http://iasoa.org/]. IASOA was established in context of the IPY to establish a coordinated network of Arctic atmospheric observatory sites that are year-round, intensive, permanent, and with sufficient infrastructure and personnel to operate sophisticated atmospheric instruments that can provide information for detailed process studies, provide educational and outreach infrastructure, and support IPY intensive campaigns. As a result of this, the U.S. GCOS Program Office will be working with the Russian Federal Service for Hydrometeorology and Environmental Monitoring in order to establish a CRN surface reference site in Tiksi in the Russian Arctic beginning in late 2007 in support of the IPY super site being implemented at Tiksi.

6. CONCLUSION

The U.S. has been very supportive of the overall international GCOS program effort and has provided considerable support on both a global, regional, as well as bi-lateral basis. It is believed that support for GCOS should be global in nature and the U.S. is working to be a leader in helping to make GCOS a sustainable and robust system both regionally and globally, and that can serve the needs of an improved global climate monitoring system that is part of GEOSS) being planned internationally by more than 60 nations and over 40 international organizations; see the following URL for more details: http://earthobservations.org.

The U.S. GCOS Program Office at NCDC has identified high elevation and high latitude surface observing sites as being a high priority for filling critical gaps in global surface observing. The partnerships and associated activities identified here have been keys in beginning to address these gaps on a long-term and sustainable basis.