1.2 CLIMATE CHANGE SCIENCE MID-LIFE CRISIS – CHALLENGES AND OPPORTUNITIES

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1. INTRODUCTION

Detecting climate change, understanding and attributing change to specific climate processes, and projecting climate impacts on the Earth system requires, among other capabilities, a long-term (many decades), consistent, and comprehensive observing system. Many climate trends are small and can only be distinguished from short-term variability through careful analysis of long time series. Short data records or long gaps in the records can make such detection and analysis much more uncertain and costly.

Projecting climate trends and impacts requires a comprehensive suite of measurements ranging from physical variables such as sea surface temperature, wind stress, and water vapor, to biogeochemical variables such as oceanic chlorophyll and land cover. Confidently detecting small climate shifts, requires instrument accuracy and stability better than generally required for weather research for both in situ and satellite observations. Currently, the U.S. is struggling over how to transition research satellite observing systems to sustainable long-term operations. While research-driven satellite missions have revealed many of the important science issues, helped define observing requirements, and tested new technology, sustaining these observing systems without gaps is an essential component of understanding, monitoring, and predicting climate variability and change. How to accomplish this, within the context of a global observing network including various in situ observations, is a Grand Challenge.

2. BRIEF HISTORY OF CLIMATE OBSERVATIONS IN THE UNITED STATES

The history of the study of average weather conditions and the annual cycle has a very long history going back to earlier civilization and religious, agricultural, and military applications. The collection and analysis of weather record data was a subject of Renaissance scholars. Early American statesmen recognized the importance of the collection and analysis of weather records, and early records from Benjamin Franklin can still be found in the archives of NOAA's National Climatic Data Center.

Earliest official U.S. government legislation related to climate observation dates back to the late 1800s. Although an Act of Congress directed the Secretary of War to take meteorological observations and give warning of the approach of storms, the collection of climatological observations, in support of agricultural warnings, was organized by State Weather Services in 1883. In October 1895, control of these services passed from the states to the United States Weather Bureau and a set of 'voluntary observers' of the Smithsonian network were then merged into the Climate and Crop (now Climatological) Service of the Weather Bureau. Publication of these weather and climate records was initiated by the Smithsonian and subsequently the National Climatic Data Center.

As applications of weather record data have evolved, so has the relative importance of different observations and the importance of high quality observations. With the advent of commercial aviation, a growing focus became the collection of weather observations at terminal airport sites. With the discovery of the jet stream in World War II, the collection and analysis of upper air observations gained increased importance.

The modern era of U.S. climate records and observations begins in 1950 with the Federal Records Act which authorized the General Services Administration to delegate authority for storage, processing and servicing of weather and climate records to a center operated by the head of any Federal Agency. Thus, in 1951, the Weather Bureau Records Center was established per agreement with the General Services Administrator. This agreement established a joint Weather Bureau-Air Force-Navy weather records center in Asheville, North Carolina. The civilian component is now known as the National Climatic Data Center (NCDC). NCDC joined the National Oceanic and Atmospheric Administration (NOAA) when several different components related to atmospheres and oceans were merged in 1970. At that time, the mandate of the Data Center was expanded to include environmental satellite data.

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3. TRANSFORMING OPERATIONAL WEATHER OBSERVATIONS INTO CLIMATE CHANGE OBSERVATIONS

Dating back to 1906, one of the requirements of the NCDC was to ‘secure accuracy in the data published’. Over the years, various subjective and objective tests have been established to identify erroneous reports, particularly for extreme records. As interest and concern in Climate and Global Change increased in the 1980s, it was recognized that a greater effort was needed to improve the accuracy and reliability of the long-term observational data set. In response, NCDC organized the Global Climate Laboratory in 1988 to provide a greater emphasis on the science and quality control required to make the long-term in situ observational data sets useful for climate change science studies. Under this group, now the Scientific Services Division, NCDC has established itself as an international leader in climate change observational studies using in situ data sets and helping to establish the record of global temperature trends over the last 100 years using in situ data.

Based on the experience of trying to deal with the inhomogeneties and other problems found during this work, the NOAA has begun installation of a U.S. Climate Reference Network. The U.S. Climate Reference Network (USCRN) is a network of climate stations now being developed as part of a National Oceanic and Atmospheric Administration (NOAA) initiative. Its primary goal is to provide future long-term homogeneous observations of temperature and precipitation that can be coupled to long-term historical observations for the detection and attribution of present and future climate change. Data from the USCRN will be used in operational climate monitoring activities and for placing current climate anomalies into an historical perspective. The USCRN will also provide the United States with a reference network that meets the requirements of the Global Climate Observing System (GCOS)

A similar set of GCOS recommendations for an upper air network have recently been formulated to make the observational networks “fit for purpose” and hence to provide long-term data sets that can be used reliably to monitor and detect emerging signals of global and regional climate change. Specifically, the network is required to: provide long-term high quality climate records; constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites); and characterize the full properties of the atmospheric column.

4. SATELLITE REMOTE SENSING OBSERVATIONS FOR CLIMATE CHANGE STUDIES

Satellite observations of the atmosphere, ocean, and land surface offer the possibility of truly global coverage and repeated observations from a single instrument over time. Operating in the space environment, however, is a high cost and high risk business. The record of continuous observations from space is led by the NOAA operational polar orbiting and geostationary satellites which have been providing coverage for over 27 years. Transforming those observations into quality sufficient for climate changes studies, however, had been challenging. The operational satellite observations were not designed for use in long term climate studies and thus, similar to the in situ observations, ad hoc adjustments have to be made to correct for orbital drift and systematic differences between similar channels on different instruments. Despite these difficulties, the operational satellites have been primary contributors to studies of climate change, particularly the use of the microwave sounding unit data for tropospheric temperature trends and the high-resolution infrared sounder data for studies of upper tropospheric humidity. In addition, operational data from the geostationary satellites, combined with information from research satellites, plays a critical role in earth radiation budget and global precipitation climatologies.

NASA Earth Observing System (EOS) is a multi-billion dollar effort to understand global climate, but not to provide for long term observations. Thus far, the success of the EOS program for helping to understand climate has been mixed. Are we in the middle of trying to understand and apply these observations and so it is simply too early to assess its impact or has EOS failed to include a strategy for coordinating their system of satellites with operational agencies in order to support a system for long-term coverage? Only time will tell.

In an attempt to address the issue of long-term coverage, NASA became involved in trying to transition some of the EOS observing capabilities to the next generation of operational satellites, the National Polar-Orbiting Environmental Satellite System (NPOESS). Originally designated to be solely a weather satellite, NPOESS, in the late 1990s, added climate elements as well. This was a controversial move and there was concern expressed at the time about how and whether this transition could take place. These concerns turn out to have been well founded. As the costs of the

NPOESS system grew, a mandatory government review resulted recently in a major revision of the system and most of the climate sensors have been dropped.

5. MOVING FORWARD: IDEAS FOR A SUSTAINABLE CLIMATE OBSERVING SYSTEM

Analogous to the different stages in life, the stages of any major scientific endeavor evolve. The U.S. Climate Change Science Program (CCSP) is currently in a major life cycle transition, particularly the observational part. As this Program struggles to mature into a long-term sustainable observational program, the analog to how individuals cope with their own transition through what is often called 'mid-life crisis' may be apt. The symptoms of mid-life crisis include: discontentment with the current situation, wanting to do something different, questioning decisions made years earlier, and confusion about where things are going. These symptoms sound eerily similar to those that are currently being addressed by an ongoing National Research Council decadal study. A white paper prepared at the start of that study concluded that the CCSP's diffuse objectives and lack of priorities have left the program marginalized and politically expendable.

So, where does this leave the prospect for long-term climate change observations, particularly space-based observations? How does the United States, and the world, move towards sustaining a long-term, space-based climate observing system? Here are some thoughts on getting through the climate change mid-life crisis:

- Adopt a maturity model to assess the science and technology, assure information preservation, and ensure societal benefit. We must find a way to logically evaluate what observations and the technologies that provide them are sufficiently well-developed to transition to operations and how to ensure resources for this purpose. Information preservation in the digital age is non-trivial and often more difficult to preserve than hard-copy records. Finally, a long-term commitment of public resources requires a clear return on that investment back to the public good. Scientists must work with social scientists and applied fields to demonstrate a practical use of these observations.
- Greater international cooperation and integration are required. The list of nations with plans to fly satellites is rapidly increasing. It is becoming increasingly difficult, however, to coordinate the collection and to share these observations and ensure optimum use. There is actually a more than sufficient global resource for observing the planet. The ineffective and uncoordinated approaches now used, however, are resulting in waste and duplication. This problem is very difficult to address, but more effort must be given to addressing it or we all stand to lose.
- A long-term observing system must be simple and sustainable, but simple and sustainable is not easy to market. Marketing a space-base observing system that is relatively inexpensive and long-lived often runs contrary to the business rules that require ever increasing profits. Serving the public good is not always aligned with business priorities in this traditional sense and scientists may have to sell a new business model to attract public and commercial interest.

6. CONCLUSION

These are just a few of the many possible approaches to moving beyond what is shaping up to be a difficult mid-life transition for the U.S. climate change observing system. The stakes are high. New and innovative approaches will be required to ensure that the long-term record is available for our children's, children's children.