Environmental Data Through Time

Extending The Climate Record

Stephen Del Greco
Chief Climate Services and Monitoring Division, National Climatic Data Center (NCDC), National Oceanic and Atmospheric Administration (NOAA), Stephen.A.Delgreco@noaa.gov

Abstract
The National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) is responsible for acquisition, archive, and dissemination services for climate and environmental data and information that fulfill much of the Nation’s climate data requirements. Those include stewardship for in situ, satellite and radar data and information. Over 5 petabytes of data reside in the archives, and growth trends over the next several years are expected to increase tenfold. The Center is also assigned the analytic role of describing the climate and providing scientific assessments, such as the Climate Change Science Program (CCSP), “State of the Climate” reports and National and Global Assessments. Towards that end, NCDC has several programs that involve extending the climate record, and the NCDC led the Climate Database Modernization Program (CDMP). CDMP provided substantial funding between 1999 and 2012 to rescue and preserve historic climate and environmental data. CDMP has currently placed online over 57 million images and some 14 terabytes of weather and environmental data. In addition, hourly weather records keyed through CDMP continue to be integrated into NCDC’s digital database, extending the period of record for many stations back into the 1800s [1]. Millions of data images available online also have associated environmental data that need to be digitized. NCDC is using its remaining CDMP resources and Crowdsourcing [4] to digitize and analyze those climate data. In partnership with the Cooperative Institute for Climate and Satellites (CICS), it is deriving Climate Data Records (CDRs) for atmosphere and terrestrial features using satellite data (Global Essential Climate Variables) that date back to the 1970s. The Center also performs research in Paleoclimatology. Paleoclimate data come from natural sources such as tree rings, ice cores, corals, and ocean and lake sediments and extend the archive of weather and climate information back hundreds to millions of years. The Center maintains the world’s largest archive of climate and paleoclimatic data. While it is important to highlight the development of proxy datasets using paleo data and the development of satellite-based CDRs, this paper focuses on extending the climate record by rescuing past observational data.

Author
Stephen Del Greco is the acting Chief of NOAA’s National Climatic Data Center (NCDC) Climate Services and Monitoring Division (CSMD). He provides oversight, leadership and management for CSMD activities that include User Engagement and Services, Climate Monitoring and Assessments, Data Access and Applications, and Regional Climate Services. The division develops and maintains systems to meet NOAA planning and execution for data discovery, data dissemination, data display and data interoperability. The division also delivers climate products to operations in support of assessment of the State of the Climate Regionally, Nationally and Internationally. Stephen’s primary focus is providing climate services and robust access capabilities for weather and climate information using data federated systems and tiered services. He holds a degree in Atmospheric Sciences from the University of North Carolina and attended Harvard University, John F. Kennedy School of Government, Public Service Executive Education program.
1. NOAA partnerships for data rescue - U.S. data

In partnership with the private industry, the NOAA's NCDC imaged and keyed over 56 million images and over fourteen terabytes of data from paper and microfilm records. Those data are available free of charge via the Image and Publication System for images (IPS) [2] and the Climate Data Online (CDO) System for digital records [3]. While NCDC continues to image and digitize retrospective weather and climate data using remaining CDMP resources, the center is partnering with other institutions and also transitioning to using public volunteers to digitize records through crowdsourcing [4] and Citizen Science Alliance [5] programs. Several completed and/or ongoing projects and partners are listed and briefly described below:

1.1 Surface Airways Observations (SAO) Project

NOAA contributed to extending the U.S. climate record by rescuing National Weather Bureau and National Weather Service (NWS) Surface Airways Observations (SAO) data for NWS sites dating back to 1893. The project imaged over 2 million forms and keyed over 400 million hourly surface observations records and added over 50 years of hourly/synoptic data for over 700 U.S. locations [Figure 1]. The SWO library is the largest in IPS.

1.2 U.S. Founding Fathers Weather Journals

Weather and climate data recorded by George Washington, Thomas Jefferson and Benjamin Franklin and other colonists are archived in original manuscripts, microfilmed and stored at the National Archive and Records Administration (NARA). The records were also imaged and are available on IPS. These colonial diaries and data are a treasure trove for the climatologist seeking data on climate of the 18th and 19th century [figure 2].

1.3 U.S. Forts Project

NOAA partnered with the Midwest Regional Climate Center [6] to image and digitize historical climate data from U.S. Army forts. The “Forts Project”, focused on imaging and keying data from 1820-1892 for Army forts; however, other sources of climate data, such as Smithsonian Institution's 19th century network of voluntary observers, United States Signal Service observations and private citizen observation journals, were included in the program. The digitized data went through extensive quality control processes prior to becoming available to the public; the forms [figure 3], some almost 200 years old, are available on IPS, and the digitized data on CDO.

1.4 Shoreline Vectorization - National Ocean Service/Coastal Services Center

A digital national shoreline database used for spatial analysis of coastal areas. Rescue work converts topographic sheet images to a geo-referenced vector format. These shoreline data are used to help protect coastal resources, sustain the environmental quality of the coastal environment, and mitigate impacts from coastal processes [7].
1.5 Defense Meteorological Satellite Program (DMSP) Film Imaging - National Geophysical Data Center

Scanning of DMSP film from the early 1970s to the mid-1980's. The DMSP film contains observations relevant to global cloud climatology, hurricane and typhoon climatology, the extent and conditions of polar ice, continental and mountain snowpack, and the record of expansion in human settlements [8].

1.6 Imaging of NOAA Central Library Holdings - NOAA Central Library

Imaging of foreign climate data books; U.S. daily weather maps from 1871 to the late 1960s; and, in coordination with the American Meteorological Society, imaging of the Monthly Weather Reviews. These images are made available online at the NOAA Central Library [9].

1.7 Imaging of Historical U.S. Coast Pilot Editions - National Ocean Service/Office of Coast Survey

The Coast Pilot collection consists of approximately 800 volumes from the 1800s to today. The volumes are available online at the Office of Coast Survey and the NOAA Central Library. The collection includes significant navigation information, and descriptions and locations of localized atmospheric features and conditions [10].

1.8 Digitization of Ionospheric Data - National Geophysical Data Center

Digitization of ionosphere bottom side vertical incidence sounding data values from the 1930s through 1957. The paper media contain both half hourly and hourly data [11].

1.9 Digitization of U.S. Upper Air Pilot Balloon (Pibal) Data - National Weather Service

Imaged (from film) and keyed U.S. pibal observations prior to 1948.

2. NOAA partnerships for data rescue - International Projects

NOAA partnered with 27 countries across several continents to rescue surface, marine and upper air data. For example NOAA partnered with the World Meteorological Organization [12] to rescue weather balloon upper air data in seven African nations: Kenya, Malawi, Mozambique, Niger, Senegal, Tanzania and Zambia [figure 5]. The African countries imaged their data locally, and sent the images to NOAA’s NCDC for keying and uploading to IPS and NOAA’s Integrated Global Radiosonde Archive Database (IGRA) [13]. IGRA consists of radiosonde and pilot balloon observations at over 1500 globally distributed stations [figure 6]. Observations are available for standard surface, tropopause and significant levels. Variables include pressure, temperature, geopotential height, dewpoint depression, wind direction and wind speed. Over 150,000 images of pibal (upper air wind) records from the 1940s to 2003 from the 7 African countries are digitized. The digital data files were also provided to the host countries that imaged the data while the keyed data files are hyperlinked to the actual images, providing an easy access to the original records. Another data rescue example is the partnership with the United Kingdom to image and digitize the marine logbooks in the British Archives. It included the English East India Company (EIC) Instrumental Observations 1789-1834. The Met Office Hadley Center imaged over 1100 of the
original 2000 logbooks of the English East India Company (EIC) held at the British Library. The selection of logs was based on their holdings of weather observations, visual and instrumental, as well as the significant spatial coverage of voyages from England to India and China through the Atlantic, Indian and Southern Oceans during those years. The EIC collected commenced well before the landmark 1853 Brussels Maritime Conference [14] devoted to coordinating an international effort for global systematic collections of marine instrumental and visual observations, and is probably the largest and earliest collection of such systematic instrumental observations. The project captured all noon observations containing location, instrumental observations of pressure and air temperature (and occasionally sea surface temperature), and visual estimates of winds, state of weather and state of sea. From the digitized logbooks, over 285K observations were digitized, significantly increasing early instrumental coverage both spatially and temporally [15].

2.1 Crowdsourcing

Rescue of United Kingdom marine data continues. Weather observations made by Royal Navy ships around the time of World War I were recently digitized as part of a Zooniverse (crowdsourcing) [16] project called oldWeather [17]. Volunteers digitized over 1 million, six hundred thousand Royal Navy-derived weather observations. That was the first phase for the project; OldWeather is currently in phase two, to digitize weather observations by ships in the Arctic. The citizen volunteers have completed 46% of the ship logs for recovering Arctic and worldwide weather observations made by United States ships since the mid-19th century.

3. Paleoclimatology – Extending the climate record using “proxies”

Paleoclimatology is the study of past climate prior to instrumental weather measurements. Paleoclimatologists use information from natural climate "proxies," such as tree rings, ice cores, corals, and ocean and lake sediments, that record variations in past climate [figures 7, 8]. Records of past climate from such proxy records are important for several reasons. Instrumental records of climate are limited in many parts of the world to the past 100 years or less, and are too short to assess whether climate variability, events, and trends of the 20th and 21st centuries are representative of the long-term natural variability of past centuries and millennia. For example, was the 1930s Dust Bowl drought, a widespread and severe event in the United States, a rare occurrence or have similar events occurred in past centuries? Knowledge of the long-term natural variability of the Earth Climate system, and its causes, will also allow an understanding of the roles of natural climate variability and human-induced climate change in the current and future climate. In particular, reconstructed temperatures from proxy data for the past 1000 years have allowed an assessment of the warming over recent decades [18].

4. Climate Data Records – Extending the climate record using satellite data

NOAA's NCDC recently initiated a satellite Climate Data Record (CDR) program to provide continuously objective climate information derived from weather satellite data that NOAA has collected for more than 30 years. Those data comprise the longest record of global satellite mapping measurements in the world, and are complemented by data from other sources including NASA and Department of Defense satellites and foreign satellites. The mission of NOAA's Climate Data Record Program is to develop and implement a robust, sustainable, and scientifically defensible approach to producing and
preserving climate records from satellite data [figure 9]. For the first time, NOAA is applying modern data analysis methods, which have advanced significantly in the last decade, to these historical global satellite data. The program will unravel the underlying climate trend and variability information and return new economic and scientific value from the records. In parallel, NCDC will maintain and extend these Climate Data Records by applying the same methods to present-day and future satellite measurements. The results will provide trustworthy information on how, where and to what extent the land, oceans, atmosphere and ice sheets are changing. In turn, this information will be used by energy, water resources, agriculture, human health, national security, coastal community and other interest groups. The CDR data will improve the Nation's resilience to climate change and variability, maintain our economic vitality, and improve the security and well-being of the public [19].

5. Conclusion

OldWeather project’s mission statement, “Old Weather: Our Weather’s Past, the Climate’s Future” is one that resonates with climatologists. To gain better understanding of the earth’s physical processes and the future state of the climate it is essential to be able to reconstruct past climates. NOAA continues to work with partners in both the public and private sectors to look for innovative ways to rescue retrospective weather and climate data from deteriorating media, and to make the data available in digital formats and accessible online for the public. Once converted into electronic formats, the data are more portable, can quickly and easily be shared, and contribute further to global climate studies.

References

2. National Climatic Data Center Image and Publication System web page  
   http://www7.ncdc.noaa.gov/IPS/  
3. NOAA National Climatic Data Center Climate Data Online web page  
   http://www.ncdc.noaa.gov/cdo-web/webservices  
4. Crowdsourcing web page  
   http://www.crowdsourcing.org/  
5. Citizen Science Alliance web page  
   http://www.citizensciencealliance.org/  
6. Midwest Regional Climate Center  
   http://mec.sws.uiuc.edu/  
7. Shoreline Mapping
http://shoreline.noaa.gov/

8. Defense Meteorological Satellite Program (DMSP) Film Imaging  
http://www.ngdc.noaa.gov/dmsp/index.html

9. NOAA Central Library  
http://docs.lib.noaa.gov/rescue/data_rescue_home.html

10. Imaging of Historical U.S. Coast Pilot Editions  
http://www.nauticalcharts.noaa.gov/nsd/hcp.htm

11. Digitization of Ionospheric Data - National Geophysical Data Center  
http://www.ngdc.noaa.gov/stp/IONO/ionohome.html

12. World Meteorological Organization  
http://www.wmo.int/pages/index_en.html

13. Integrated Global Radiosonde Archive Database (IGRA)  


16. Zooniverse web page  
https://www.zooniverse.org/

17. oldWeather web page  
http://www.oldweather.org/

18. NOAA National Climatic Data Center Paleoclimatology web page  
http://www.ncdc.noaa.gov/paleo/paleo.html

19. Climate Data Records  
http://www.ncdc.noaa.gov/cdr/index.html
Figures

Figure 1. SAO Surface Weather Observation image.
Figure 2. Colonial Log Book image.

Figure 3. Forts Weather Observations image.
Figure 4. International data rescue projects

Figure 5. Upper Air data rescued in Africa
Figure 6. Locations of all stations in IGRA

Figure 7. Types of proxy datasets used in describing past climates.
The interval of time spanned by different paleoclimate proxies, displayed on a logarithmic scale.

Figure 8. Paleoclimate proxies time scales

Figure 9. Climate Data Records Essential Climate Variables