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Climate Services - A USDA Perspective

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1. INTRODUCTION

The climate and weather services requirements of individual U.S. Department of Agriculture (USDA) agencies reflect the varied and diverse missions and programs that currently exist throughout the Department. Internet access to both real-time and historical climate data, along with software tools to support critical economic and natural resource decisions are essential to the Department's mission. This paper provides a historical perspective of the role of climate in agriculture. It outlines these critical mission areas and their dependence on climate information to support climate-based decisions dealing with production agriculture, water supply availability, drought assessment, and other natural resource conservation activities.

2. A BRIEF HISTORY OF CLIMATE AND AGRICULTURE: 1890 - 1940

"The National Weather Service, was created as a branch of the Signal Service, later the Signal Corps of the Army, by a Joint Congressional Resolution approved February 9, 1870. It provided "for taking meteorological observations at the military stations in the interior of the continent and at other points in the States and Territories of the United States, and for giving notice on the northern lakes and at the seacoast, by magnetic telegraph and marine signals, of the approach and force of storms." (NOAA, 2003)

"While the Weather Service was originally designed for the benefit of navigation on the seacoast and the Great Lakes, it was soon extended to include the interior districts and the great rivers of the central valley. The benefits of a National Weather service were soon recognized and business industries, the general public, and farmers demanded special forecasts and warnings applicable to their needs. These demands soon became so voluminous that the urgent need of a new organization, devoid of militarism, and with a more scientific status, became apparent. Accordingly, when this need was brought to the attention of Congress, an Act, approved October 1, 1890, transferred the weather service of the Signal Corps to the Department of Agriculture effective July 1, 1891." (NOAA, 2003)

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"The Act of October 1, 1890, charged the Chief of the newly created civilian agency with the following duties:

The Chief of the Weather Bureau, under the direction of the Secretary of Agriculture (Commerce), shall have charge of the forecasting of weather, the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce, and navigation, the gauging and reporting of rivers, the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation, the reporting of temperature and rainfall conditions for the cotton interests, the display of frost and cold-wave signals, the distribution of meteorological information in the interests of agriculture and commerce, and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties. (15 U.S.C. 313)

The Weather Bureau was transferred from the Department of Agriculture, where it had been a constituent bureau since July 1, 1891 (Act of October 1, 1890, 26 Stat. 653) to the Department of Commerce (DOC) on June 30, 1940, under authority of Reorganization Plan No. IV of the President which was submitted to the Congress on April 11, 1940.

In his message submitting Reorganization Plan No. IV, with reference to the Weather Bureau, the President said:

The importance of the Weather Bureau's functions to the Nation's commerce has also led to the decision to transfer this Bureau to the Department of Commerce. The development of the aviation industry has imposed upon the Weather Bureau a major responsibility in the field of air transportation. The transfer to the Department of Commerce, as provided in this plan, will permit better coordination of Government activities relating to aviation and to commerce generally, without in any way lessening the Bureau's contribution to agriculture." (NOAA, 2003)

3. USDA CLIMATIC RESEARCH

During the USDA's 49-year stewardship of climate and weather services, a significant number of research activities were focused on the relationship

between climate and agriculture with the establishment of the Climatic and Physiographic Division in 1935. Scientific research was aimed at discovering the interaction of climate and erosion, the stages of natural and culturally induced erosion, and the characteristics of erosional landforms. Climatic studies, employing existing Weather Bureau records as well as original field observations, were concerned with drought and wind erosion, the long-term aspects of rainfall, and the short-term problems of rainfall intensity and storm patterns (NARA, 2003).

The 1938 seminal publication by C. W. Thornthwaite, USDA Soil Conservation Service, summarized the role of climate factors in water and wind erosion, intensity and duration of rainfall for reservoir design, frequency of rainless periods for determining drought and consequent erosion hazard, rainstorm morphology, spacing of raingages, determination of the maximum storm, field moisture deficiency as a climate factor, and studies of evaporation (Thornthwaite, 1938).

This research culminated in the publication of "Atlas of Climatic Types in the United States 1900-1939" (Thornthwaite, 1941). The atlas categorized climate by moisture regimes (i.e. super-humid, humid, sub-humid, semiarid, and arid), provided definitions of effective precipitation, the use of vegetation as a climatic indicator, and discussed climatic variation. The atlas also contained annual crop season climate type maps for the period 1900-1939. Normal crop season maps were also published. Climate mapping has seen a renaissance with USDA co-sponsored efforts performed in partnership with Oregon State University (Daly, 2002).

4. DOC AND USDA CLIMATE AND AGRICULTURE ACTIVITIES: 1941 - 1979

With the outbreak of WWII, The Weather Bureau had very little statistical data describing foreign climates in a useable for at the outbreak of war. Significant efforts were placed in summarizing climate for armed forces aviation, gathering upper air information, standardizing climate summary punch card formats, determining degree-day climatologies, and the standardization of procedures to process and publish climate summaries.

As a result of security plans formulated previously by the Defense Meteorological Committee, the Weather Bureau, in December 1941, was enabled to continue forecast and warning service to the public and comply with security requirements. Most of the weather service provided to public individuals was in the form of operational advisories. For example, orchardists desiring to spray fruit trees were informed as follows: "Spraying conditions satisfactory next three days" (NOAA, 2003)

Detailed agricultural forecasts were provided after WW II and in 1971 the Department of Commerce published a "Federal Plan for a National Agricultural Weather Service" (NOAA, 1971). This plan summarized user requirements and potential service value, the present NOAA Agricultural Weather Service Program, and NOAA's Plan for an Improved Agricultural Weather Program.

Three user categories were defined; Category I - Producers, Category II - Supporting Services, and Category III - Shippers, Processors, and Marketers.

Each category defined needs by geographic areas, important weather parameters required, necessary agricultural operations, and planning information required. Implementing an Agricultural Weather Service relied on cooperation between the National Weather Service, Environmental Data Service, State Universities, State Climatologists, and the Department of Agriculture. The plan was never implemented for a variety of reasons.

In August of 1979, the General Accounting Office published a report titled "Agricultural Weather Information is Not Effectively Communicated to Users" (GAO, 1979).

The purpose of the report was to survey the agricultural community in order to clarify the Department of Commerce (DOC) and USDA respective roles, responsibilities, and goals, in order to establish an effectively coordinated Agricultural Weather Service Program.

The report concluded, "agricultural weather information is not being communicated to users and potential users. The need for certain improvements in the program has been noted by Departments of Agriculture and Commerce. As a result, the Departments have reached some agreements to improve cooperation; however, much more remains to be done."

A previous GAO report (1978) stated that "Congress has never specifically mandated the extent to which NWS should provide specialized weather services for users, such as agricultural weather information, and recommended that Congress clearly define NWS's role and responsibilities for providing such services."

The 1979 report recommended that the "DOC, in cooperation with the Secretary of Agriculture, clarify and strengthen the roles of your Departments in Agricultural Weather Service Program. This should include: 1) improving the methods for publicizing and communicating weather information to users and potential users and 2) providing program coordination by updating the "Federal Plan for a National Agricultural Weather Service."

In 1978, an Interagency Agreement between the DOC and USDA established the Joint Agricultural Weather Facility (JAWF) which exists to date. The JAWF was created as a world agricultural weather information center located in USDA and is jointly staffed and operated by DOC/NOAA/NWS/Climate Prediction Center (CPC) and USDA/OCE/World Agricultural Outlook Board (WAOB). The JAWF serves as USDA's overall focal point for weather/climate information and agricultural impact assessments.

5. DOC AND USDA AGRICULTURE CLIMATE AND WEATHER ACTIVITIES IN THE 1990S

Agricultural weather activities and user needs took on greater importance and urgency with the termination of the NWS Agricultural Weather Program on April 1, 1996. An NWS letter to NWS Agricultural Weather Services Customers (NOAA, 1996) stated that "the NWS will make every effort to maintain agricultural weather observation networks in the months ahead. The inventory of NWS weather observing equipment will be examined closely to determine what data sources will remain available for use by private meteorologists. The NWS will continue observations and records pertaining to recording and predicting the nation's climate and for other programs such as public forecasts and warnings. The basic data critical to making agricultural forecasts is still available to all users such as freeze and frost warnings."

A paper presented to the American Meteorological Society 10th Conference on Applied Climatology (Motha, 1997) provided a comprehensive definition of climate services for agriculture. The paper addressed the role of data collection and product generation in USDA climate monitoring and impacts. It also highlighted the important roles of national, regional and state climate offices in providing climate services.

In 1998, the DOC requested the USDA to prepare a report of requirements for weather and climate data, services, and information. An interagency USDA committee produced a report titled "Operational Meteorological Data Requirements (USDA, 1999).

Nine USDA agencies contributed to the report; the World Agricultural Outlook Board and Joint Agricultural Weather Facility, Farm and Foreign Agricultural Services, Farm Service Agency, Risk Management Agency, Forest Service, Natural Resources Conservation Service, Agricultural Research Service, Cooperative State Research, Education, and Extension Service, and National Agricultural Statistics Service.

While the requirements of USDA are numerous, they can be categorized into four basic areas that are covered by weather service operations as follows:

- *Current Measurement and Observational Data and Services* - These services consist of the operation of acquisition programs, observing systems, data collection and quality control, and networks to provide the data essential to defining the state of the atmosphere and its impacts on man and his activities. They are largely concerned with assembling weather observations into useable databases and providing them for use in analyses and applications.

- *Climate Services* - These services provide for the acquisition, storage, management, and summarization of historical weather data. They also include the analyses of climatological data to characterize climate conditions or regimes for different geographical areas or time periods. Climate services also include the development of normals, freeze probabilities, and drought indices.

- *Forecasting Services* - Prediction of future weather events or climatic conditions and their associated probabilities.

- *Other Services* - Consultation, analyses of particular weather events, interpretation of forecast materials, monitoring and summarizing recent weather events, weather briefings and summaries, special studies and analyses, and user education.

Converting voluminous weather data into crop-specific agronomic information that can be easily understood by its non-meteorological community is one of the largest challenges faced by USDA. The worldwide scope of production agriculture and exchange of agriculture products has driven the need for a wide variety of weather and climate data. Fifteen general data requirements are described in the Table 1. The table describes the type of data required, desired reporting frequency and the significance to agriculture.

Weather plays a vital role in all phases of agricultural production. In addition to general weather requirements for agricultural production, each type of agricultural activity has a unique set of weather variables that affect it. Twenty-two specific weather data elements are given in Table 2. Individual agricultural activities are described for each weather element.

For decision making, USDA needs current weather information for research and to assist growers with their management operations. This includes strategic decisions (what to plant), or tactical decisions (when to irrigate). As a result, USDA agencies that assist farmers in their decision-making require a more detailed set of weather requirements. The weather data requirements for 14 specific agricultural activities, ranging from soil preparation to freeze

protection, are published in the USDA report. Near real-time access to these weather data through the Internet is highly desirable and preferred.

Finally, weather and climate information are essential factors in natural resource assessment and conservation planning across the nation. The Natural Resources Conservation Service (NRCS) has identified 11 legislative programs that require basic climate and weather data from the NWS. Of primary concern to western interests is the Snow Survey and Water Supply Forecasting (SS/WSF) program. The SS/WSF Program, in partnership with the NWS, provides water supply forecasts for 711 western basins. Tens of thousands of users access water supply forecasts via the Internet every year. Recent extreme drought and wildfires have heightened the need for real-time data collection, drought-specific products, and ready access to products via the Internet.

Historical and current weather data are also used by Insurance Services and compliance programs as an additional information resource in determining if losses are reasonable and if producers and reinsured companies are in compliance with the insurance contracts. USDA is also leading the National Drought Policy Commission and is working on drought policy issues, which require monitoring of drought conditions and forecasting.

National and International Agricultural Production General Data Requirements

Data Type	Time Period	Agricultural Significance
National and International Surface Observations	Hourly and/ or 3-hourly	Required to monitor current conditions affecting agriculture and in planning agricultural activities
Local and Regional Automated Weather Data Networks	15-minute intervals, hourly	Required for accurate assessments of rainfall rates that affect erosion and runoff processes. Precision agriculture needs high resolution spatial and temporal data for irrigation, research and regulatory issues, livestock operations, and crop management
Cooperative Network Surface Observations (station level)	Daily	Required for daily monitoring of agrometeorological conditions that affect agricultural operations and production. Many of these sites are located in agriculturally important areas
Global Daily Summary Data (station level)	Daily	Required for daily monitoring of global weather conditions that affect agriculture
Global Weekly Summary Data	Weekly	Required for determining the cumulative effects of weather on agriculture during the growing season
Global Monthly Summary Data	Monthly	Required for determining the cumulative effects of weather on agriculture on a monthly scale
CLIMAT Data for the World	Monthly	Required for quality control of Global Monthly Summary Data
Global Normals	Daily, Weekly, Monthly	Required to determine anomalous weather conditions that may affect agriculture
Freeze Dates	Spring and Fall	Required for Weather Risk Assessment and Crop Vulnerability
Historical Data	Daily, Weekly, Monthly	Required for analog growing season comparisons
Global Satellite Data (cloud imagery)	Variable Hourly to Daily	Required to document significant weather features and likely coverage within a crop area and in quality control of surface data
Sea Surface Temperature Data	Weekly and Monthly	Required for monitoring El Niño-La Niña conditions
Radar Data	Variable	Required to augment precipitation data in areas of limited data coverage
Upper Air Data (all mandatory pressure levels)	Variable	Required to monitor weather patterns on a synoptic scale that are affecting agriculture
Forecasts and Outlooks (local, regional, national, and international)	Hourly, 1-3 days 3-5 days, 6-10 days, Monthly, Seasonal, El-Niño, La-Niña	Required for plant disease forecasting, agricultural research and extension service models, resource allocation, policy-level briefings and decision making, drought and flood monitoring, daily weather write-ups, and weekly briefings to the Secretary and top staff

Table 1. National and International Agricultural Production General Data Requirements

Specific Weather Data Requirements for Agricultural Activities		
Data Type	**Time Period**	**Agricultural Activities**
Temperature (global)	Hourly and accumulated means and extremes	Planting, harvesting, crop-weather monitoring, freeze detection/protection, defoliation, crop modeling, disease risk, lambing and calving shelter, pest control, sheep shearing, PET computations, vapor pressure deficit computations, chill hours for stone fruit, growing degree day computations
Maximum Temperature (global)	Daily and Weekly Extremes	Required to determine optimum or unfavorable conditions for crops and livestock, crop modeling, extreme events monitoring, snow cover estimations, growing degree day computations
Minimum Temperature (global)	Daily and Weekly Extremes	Required to determine optimum or unfavorable conditions for crops or livestock, freeze detection, defoliation, crop modeling, overwintering conditions, and extreme events monitoring, snow cover estimations, growing degree day computations
Precipitation (global)	Daily	Planting, harvesting, fertilizer applications, cultivation, spraying, irrigation, crop-weather monitoring, crop modeling, disease risk, livestock and poultry protection and watering, extreme events (drought or flood) monitoring, snow cover estimations
Rainfall Intensity	15-minute, Hourly	Flood potential, erosion, runoff, water quality
Dew Point and Humidity (global)	Hourly	Harvesting, determine freeze potential, pollination, spraying, drying conditions, vapor pressure deficit computations, crop stress potential, PET computations
Hail	Hourly	Crop damage, risk assessment, productivity impact
Temperature Inversions	Hourly	Areal spraying for agriculture, frost protection measures
Atmospheric Pressure (global)	Hourly	General crop-weather monitoring, type of freeze (radiation, advection etc)
Sky Cover (global)	Hourly	Fertilizer application, spraying or dusting, PET computations
Cloud Height (global)	Hourly	Fertilizer application, spraying or dusting,
Present Weather (global)	Hourly	Snow Cover estimations, fieldwork, crop stress potential
Wind Speed (global)	Hourly	Planting, defoliation, harvesting, freeze potential/protection, lambing and calving shelter, pest control, pruning, PET computations, spraying or dusting, pollination, blizzard conditions
Wind Direction (global)	Hourly	Freeze potential/ protection, cold or warm air advection over crop areas
Vapor Pressure Deficit (global)	Hourly	Derived from temperature and dew point
Solar Radiation, Duration of Sunshine, **or** Amount of Cloud Cover (global)	Daily	PET computations, crop modeling, planting, harvesting
Snow Depth (global)	Daily	Monitor overwintering conditions for winter wheat, prepare water supply forecasts for water users in the western U.S., estimate soil moisture reserves for the next growing season
Soil Moisture (global)	Daily	Planting, harvesting, fertilizing, crop modeling, transplants, spraying, irrigation, monitoring of growing conditions, stress indices
Blizzards, Hurricanes, Tropical Storms	Daily	Crop monitoring, risk and productivity damage assessments, resource conservation
Storm Tracks/Storm Strengths	Daily	Agricultural impacts, risk management, flood potential, drought monitoring
Soil Temperature (global)	Daily	Planting, overwintering conditions, crop modeling, transplants, fertilizing
Pan Evaporation (global)	Daily	Irrigation scheduling, water budget computations, PET comparisons, crop-water usage

Table 2. Specific Weather Data Requirements for Agricultural Activities

6. THE ESSENCE OF CLIMATE SERVICES FOR THE 21ST CENTURY

Although many essential elements of a climate services system exist, some portions are poorly funded and others suffer from a lack of coordination. Climate tools, such as Geographic Information Systems, powerful desktop computers, and the Internet, give us an opportunity to succeed if we can focus our efforts on four goals.

1. A temporally and spatially diverse climate database that supports a wide variety of user-oriented analysis tools.

2. A national, interactive climate information system that delivers a family of user-selectable products to meet customer needs via the Internet.

3. A climate applications research program that provides national leadership to address climate-relevant natural resource and economic needs.

4. An education program that provides training, educational materials, and workshops to improve the use of climatic information in all sectors of the user community.

Achieving these goals requires leadership and coordination among national, regional, state and cooperating climate services providers. Climate extremes, such as drought, can act as a catalyst to accomplish these goals.

The time for action is now. The pervasive and persistent western drought has placed a premium on a fractured climate services infrastructure to meet water and agricultural resource management. A measured and coordinated implementation of these four goals will be a triumph for all involved, and a public success for our customers.

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