AGRICULTURAL CLIMATOLOGY

Kenneth G. Hubbard

High Plains Regional Climate Center
The University of Nebraska

2007

Journal of Service Climatology

Volume 1, Number 2, Pages 1-9

A Refereed Journal of the American Association of State Climatologists

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Kenneth G. Hubbard

High Plains Regional Climate Center
School of Natural Resources
University of Nebraska

Kenneth G. Hubbard, High Plains Regional Climate Center, School of Natural Resources, 711 Hardin Hall, University of Nebraska, Lincoln, NE 68583-0997, USA. Tel. 1-402-472-8294, khubbard1@unl.edu

Editor's note: This is an invited review paper on the state of service climatology.

1. Background and Definitions

With the diversification of the U.S. economy over the past century, agriculture has changed. We can say the farm sizes have increased over time, the number of farmers and those employed in farming have decreased over time, and as the economy has grown the relative contribution of agriculture to the total economy has decreased due to growth in other sectors. The farm prices have not changed significantly over many years while costs for energy, machinery, and land have generally increased. The combination of these factors has generally narrowed the profit margin and the highest productivity will no longer ensure the highest profit. This has made the decision making trees more important and has raised the importance of weather and climate related information as producers take advantage of every piece of information they can access.

In 2004, agriculture and related industries had a 4.8% value added share of nominal gross domestic product. This seemingly small percent is more important than first glance might suggest because the magnitude of the value is tied to the very large magnitude of the gross domestic product and because society in general values food along with shelter, and safety.

a. Climate

A review of the terms to be used is provided here to give the reader insight to how weather, climate, and agricultural climatology are related. The term *weather* refers to the state of the atmosphere at a given time and place (Lutgens and Tarbuck, 2001) where the state of the atmosphere is usually described using measured values of variables such as temperature, moisture, wind velocity, and barometric pressure. Certain combinations of the state variables will result in unique phenomena that we can identify and observe. According to http://encyclopedia.thefreedictionary.com/weather regular weather phenomenon include wind, cloud, rain, fog, and snow while less frequent phenomenon include natural hazards like tornadoes, hurricanes, and ice storms. For agriculture such phenomena as rain, cloud, frost, windstorm, and hailstorm are of significance albeit dependant on geographical location.

The climate is traditionally considered to be the weather averaged or integrated over a long time period (http://encyclopedia.thefreedictionary.com/Climate). Statistics are used to help describe the average weather. Variations, extremes, and probabilities must be included to fully portray the character of the climate of a region (Lutgens and Tarbuck, 2001). One can easily see that climate analyses are constrained by the variables addressed in weather monitoring systems. For example, for agricultural climatology applications it may be useful to know the average number of hours of leaf wetness (dew on the leaves) during different times of the growing season. However, since none of the weather monitoring systems observe this variable the climate of leaf wetness cannot be assessed. We could list other variables that we might desire in decision making but in the field of climatology we must realize that if we can't or don't measure a particularly critical variable then we won't be able to make informed decisions in light of the statistical probability or risk associated with that variable.

More and more, real-time decision makers in agriculture are looking toward the scientific and service community to furnish information specific to their decision. The thing that most decisions hold in common is the need for information on four time-scales: 1) the *weather* of this season prior to the current time (technically *climate*), 2) the current *weather*, 3) the forecast *weather*, and 4) how the combination of these first 3 items fit into the historical context (*climate*).

Sometimes there is confusion about the terms weather and climate. It may help to keep in mind how the two areas form an alliance. A climate data base is essentially a storage of measured weather variables usually taken on some fixed frequency. So the storage of daily rainfall measurements for one or more locations for the period 1948-2006 would be considered a *climate* data base and it consists of past *weather* measurements. It is correct to call the values from the most recent days either weather or climate. Technically the values are from the past so they belong to climate however; if one is considering the current weather and perhaps how the current weather pattern developed it is appropriate to speak of data from this period as weather.

b. Agricultural Climatology and Service

Agricultural climatology is the study of climate as it relates to the agricultural sector. Building on the explanation of climate given in a) above, the agricultural climate is the characterization or description of the climate in a manner that portrays the climate resources and risks with respect to producing crops and livestock in a specific location. For closely related topics one might consider reading the Handbook of Agricultural Meteorology (Griffiths, 1994) and the Farm Weather Handbook (Schwanz, 1997).

Those who perform public service in areas where agriculture is an important component of the economic sector must be ready to give the best climate information available. A typical phone request might go something like this:

Client: I need temperature data, do you have a station near Westbend.

Expert: What is the question you are trying to answer?

Client: I want to know the length of the freeze free season so I can decide whether to buy the new corn hybrid offered by my seed dealer.

Expert: We can provide the average length of the growing season but, we also can provide information on the variability so we can provide answers to the question ‘how many years out of 10 would the growing season exceed 175 days. Would you be interested in this analysis?

Client: Yes, I knew that each growing season was different but, I didn’t know how to include that in addressing my problem.

Expert: We can also show that years with the same number of growing season days often have a difference in heat available, or GDDs (note GDD is discussed later), to move the crop to maturity. We can assess the GDDs by year and give you information to answer how many years out of 10 does the accumulated GDD exceed a threshold, e.g. 2800.

Client: That would be great.

This type of conversation is repeated many times throughout the day at different offices performing climate services. Notice how the expert doesn’t answer the client’s initial question but, turns the focus to what question or decision needs to be addressed. This is because the expert knows well the many types of data/information that are available and desires to provide the best and most relevant information in light of the client’s situation.

c. Crops and Livestock

The production of crops and livestock is the heart of agriculture. There are many related businesses including transportation, processing, packaging, restaurants, agrichemicals, agricultural machinery, and seed production. In areas that are predominantly agricultural the volume of revenue in related businesses is proportional to the revenues of agriculture. Beyond those businesses mentioned above, locally there may be impacts on banking, health services, and new car sales. Thus agricultural production links to many other sectors.

Today’s agriculture is usually thought of as a highly managed ecosystem where inputs to the system are determined based on the production goals and a knowledge of the system. In temperate latitudes we generally understand that we need to plant crops after the last hard freeze in spring. We further want the crop to reach maturity prior to a hard freeze in fall. We also need to understand how the rainfall variability may affect the yield over time. Finally, if the crop is sensitive to high temperature stress we need to plan to reduce the risk of high temperature stress.

Livestock producers also have many climate sensitive decisions to make. In the cattle industry, ranchers with mother herds must plan calving season to avoid weather that would be undesirable for newborns. The grazing potential of pastures fluctuates with the rainfall and drought so the number of days for cattle to graze a particular pasture will vary and the number of days associated with various rainfall probabilities may be useful for setting-up schedules to move the cattle to new pastures.

For feedlot operators, who acquire the calves from the mother herd at about one year of age and feed them out to slaughter weight, other climate factors come into play. High temperature stress can cause decreased weight gain and even mortality in the feedlot.

The feedlot operators must deal with the risk of heat stress by providing sufficient modifications to the microclimate (e.g. spray or shade).

Table 1. A frost summary for De Kalb, IL.

Station: DE KALB **State:** IL **ID:** 112223
Latitude: 41.93 degrees **Longitude:** -88.78 degrees **Elevation:** 873 feet
Station period of record: 03/01/1966 - 03/20/2007

CLIMOD Product: Frost Summary **Creation Time**: 03/20/2007 08:59 CDT
Requested years: 1966 - 2007 **Distribution**: Pearson Type III

Probability of Later Date in Spring Than Indicated

Temperature	Earliest	.90	.80	.70	.60	.50	.40	.30	.20	.10	Latest
36	04/19	04/26	05/01	05/05	05/08	05/11	05/14	05/17	05/21	05/27	06/10
32	03/28	04/12	04/18	04/22	04/26	04/29	05/02	05/06	05/10	05/15	05/27
28	03/24	04/02	04/06	04/09	04/12	04/15	04/18	04/22	04/26	05/01	05/11
24	03/13	03/22	03/26	03/30	04/02	04/04	04/07	04/10	04/14	04/20	05/07
20	02/27	03/10	03/14	03/18	03/21	03/23	03/26	03/29	04/02	04/06	04/13
16	02/17	03/01	03/07	03/11	03/14	03/17	03/20	03/23	03/26	03/31	04/08

Probability of Earlier Date in Fall Than Indicated

Temperature	Earliest	.10	.20	.30	.40	.50	.60	.70	.80	.90	Latest
36	09/06	09/19	09/24	09/28	10/01	10/03	10/06	10/08	10/11	10/15	10/23
32	09/20	09/27	10/01	10/04	10/07	10/09	10/12	10/14	10/17	10/22	11/01
28	09/27	10/04	10/10	10/14	10/17	10/21	10/24	10/28	11/02	11/09	11/20
24	10/08	10/19	10/24	10/28	11/01	11/04	11/07	11/11	11/15	11/21	12/09
20	10/19	10/28	11/03	11/06	11/10	11/13	11/16	11/19	11/22	11/27	12/09
16	10/30	11/07	11/12	11/16	11/19	11/22	11/26	11/30	12/04	12/11	12/24

Probability of Longer Than Indicated Freeze Free Period (days)

Temperature	Longest	.10	.20	.30	.40	.50	.60	.70	.80	.90	Shortest
36	170	163	159	155	151	147	142	137	131	120	87
32	203	186	178	173	168	164	159	154	149	141	124
28	224	210	202	196	192	187	183	179	174	167	160
24	255	237	229	223	218	213	209	204	198	191	173
20	264	255	248	243	239	234	230	225	219	211	193
16	283	276	268	262	256	252	247	242	236	228	221

Notes:

- These tables present probabilities of observing a temperature as cold, or colder, later in the spring or earlier in the fall than the indicated date (month/day).
- Temperature thresholds are in degrees Fahrenheit.

d. Freeze Free Season

The freeze free season is usually measured in days and is the time between the last freeze in spring and the first freeze in fall. Generally, in temperate latitudes this can also be taken as a measure of the growing season however, for specific crops the growing season doesn't start until the crop is planted and ends when the crop reaches maturity or its development is interrupted due to a freeze. A summary of the freeze statistics for De Kalb IL is presented in Table 1. This summary is a product of the ACIS system (rcc-acis.org) described in Hubbard et al. (2004).

As can be seen in the table, a freeze with respect to agriculture is not always based on the freezing point of water. The damage to plants depends both on how cold it gets and how long the temperature is below a given threshold. For a particular crop, the user may elect to work with the terms mild freeze (32F), hard freeze (28F), and killing freeze (24F). There is only a 10 % probability that a killing freeze will occur at De Kalb after April 20. In the fall there is a 10 % probability that a hard freeze will occur before October 19. These numbers may represent a safe risk to the producer in terms of avoiding serious freeze damage. If so, the producer is looking for a corn hybrid he can plant on about April 20 which will reach maturity before the 19th of October.

The choice of hybrids is important because generally the hybrids that take longer to reach maturity are higher yielding. However, choosing from the later maturing hybrids may not be wise, if the growing season is not sufficiently long to allow maturity before a freeze occurs.

e. Growing Degree Days

The date associated with a certain plant developmental stage, for example flowering, can be estimated by prescribed summation of temperature readings. Shelford (1930) discussed the early work on the concept of relating temperature summations with both plant development and the appearance of migrating birds. The naturalist Réaumur (1735) may have been the first to advocate the use of the sums of mean daily temperatures in comparing different climates and estimating the time of maturing of plants.

Today such sums are used widely for estimating crop and insect developmental stages. In today's approach the required inputs are the maximum daily temperature (T_{max}), minimum daily temperature (T_{min}), base temperature (T_{base}), and the sill temperature (T_{sill}), where T_{max} and T_{min} are the high and low temperature for the day, T_{base} is the temperature below which development comes to a stop, and T_{sill} is the temperature beyond which temperature increases do not further accelerate development.

We call the excess of temperature above the base temperature the growing degree days (GDD) for that day and when these are summed for all days from planting to the current date we obtain the accumulated GDD. For a given day the GDD can be calculated as follows:

$Tu=T_{max}$

$Tl=T_{min}$

If $Tu>T_{sil}l$ then $Tu=T_{sill}$

If $Tu<T_{base}$ then $Tu=T_{base}$

If $Tl>T_{sill}$ then $Tl=T_{sill}$

If $Tl<T_{base}$ then $Tl=T_{base}$

$GDD= 0.5*(Tu + Tl) - T_{base}$

For corn, the base temperature is 50 F and the sill temperature is 86 F. The GDD are then accumulated for the site. For a corn hybrid that is rated 2900 GDDs from planting to maturity the estimated maturity date depends then on the planting date and the date at which accumulated GDD reaches 2900. It should be noted that because of variability, the maturity date will vary from year to year (even if the planting date was held constant).

Table 2. The number of growing degree days between April 20 and October 19 for the years 1997-2006 at De Kalb, IL. The base is 50 and the sill is 86 F.

Year	Accumulated GDD
1997	2775
1998	3200
1999	3022
2000	2897
2001	2998
2002	3134
2003	2874
2004	2765
2005	3307
2006	2978

Returning to the example from the previous section, we examine the accumulated GDD for De Kalb, IL over a 10 year period. There are 8 cases when the corn planted on April 20 would receive at least 280 GDD. The other two cases have GDD accumulations of 2775 and 2765 respectively. The producer may decide that a hybrid that requires 2800 GDD from planting to maturity represents an acceptable risk of slight damage to corn yield in some years. Note that this approach reduces the risk of freeze damage while at the same time exposing the crop to the maximum available GDD during the crop season.

f. Evapotranspiration

Green plants are able to create living matter from inorganic raw materials. Land plants do this by combining atmospheric CO2 with soil-derived water while converting solar radiation into chemical energy in the process of photosynthesis (Stewart and Nielsen, 1990). Only a small amount of water used by the plant is involved directly in photosynthesis. The bulk of the water escapes as the stomates in the leaves open to let in CO2. The water that escapes the plants this way is called transpiration. Plants suffering water deficits often show a reduction or cessation of growth (Bannister, 1976) concurrent with a reduction in transpiration. Evaporation from the soil or from water on the leaves is another component of the water balance and doesn't provide direct benefit to plants as does transpiration. Evaporation and transpiration taken together are called *evapotranspiration* or ET and an estimate of ET can provide some insights as to whether a crop's water needs will be met at a particular location. In this way ET becomes important to the choice of a crop.

We illustrate this by taking an example at Imperial, NE. Suppose the producer is interested in finding a crop for which the local precipitation can fill at least 60% of the crops water requirements. If only 60% of the water requirement is filled the result will be a yield reduction but, not crop failure. In this example we are comparing wheat and corn crops. The data have been summarized in Table 3. We can see that 60% of the wheat's water requirement is met in all 10 years while for corn the requirement is met in only 4 of the 10 years. Producers near Imperial grow rain-fed wheat which is in keeping with this analysis. Some producers also grow corn but only under irrigation.

Table 3. The precipitation from harvest to harvest compared to seasonal ET for well-watered wheat and corn at Imperial, NE.

Maximum ET(in.)			Precipitation (in.)		Precipitation > 0.6 ET	
1-Apr		15-May	Same Period			
4-Jul		10-Oct				
Year	Wheat	Corn	Wheat	Corn	Wheat	Corn
1997	20.22	28.59	22.24	15.99	yes	no
1998	21.32	26.44	16.65	16.97	yes	yes
1999	19.61	26.77	17.75	23.23	yes	yes
2000	22.67	30.26	18.15	14.15	yes	no
2001	18.84	29.08	20.49	22.25	yes	yes
2002	24.14	31.85	14.62	15.47	yes	no
2003	17.96	31.65	17.1	16.7	yes	no
2004	21.44	29.63	18.32	16.72	yes	no
2005	18.41	29.29	14.83	15.71	yes	no
2006	23.01	26.31	16.02	18.36	yes	yes

g. Crop Models

According to Rasmussen (1991) most agronomic models are mechanistic simulations of specific processes developed by highly specialized researchers. Here mechanistic simulation is taken to mean that the model quantitatively describes the relationship between some phenomenon and underlying first principles of cause. Models may also be constructed based on the observed relationship of experimental data. Such models are called empirical models. Some models are a combination of empirical and mechanistic simulation.

Crop models require input information on climate, soils, and plant characteristics. Depending on the model it may also require input information on management options like fertilizer treatment and seeding density. The model then simulates the growth and development of the crop.

The Hybrid-Maize Model (Yang, et al., 2006) simulates the growth and development of a corn crop. By appropriate use of the model, users can 1) assess the yield potential of a site and its variability based on historical weather data, 2) evaluate changes in attainable yield associated with different combinations of planting date, hybrid maturity, and seeding density, 3) analyze corn yield in relation to the timing of silking and maturity in specific years, 4) assess soil moisture status and strategies for irrigation management, and 5) from within the growing season predict probable yields assuming the remainder of the season could take on any of the specific weather represented in the years of the historical record.

Suppose a user wanted information on the interaction between planting date, hybrid maturity, and yield in preparation for selecting corn seed and scheduling planting. A number of combinations of hybrid and planting date could be run to examine the interations. Table 4 shows 4 combinations of hybrid and planting date. As can be seen from Table 4 the average yield for the period increases with longer maturing hybrid and with later planting date. Both factors lead to a longer grain filling period for the corn and thus a higher yield. Other combinations (not shown) lead to even higher yields however, experts say (Yang et al., 2006) that the increased yields must be weighed against the higher risk of frost prior to maturity, the likely higher moisture content of the grain at harvest, and the possibility of on-set of winter before or during the harvest period.

Table 4. Crop model simulations for Lincoln, NE for the years 1986-2004 using the Hybrid-Maize Model.

Hybrid (GDD, base 50F)	2700	2700	2862	2862
Planting Date	May 1	May 10	May 1	May 10
Lowest Yield (Mg ha^{-1})	11.8	11.9	12.7	13.7
Average Yield(Mg ha^{-1})	13.8	14.2	15.5	15.9
Highest Yield	16.2	17.3	18.2	17.8
Probability of Frost	0	0	0	5

h. Heat Stress in Cattle

Cattle in both dairy and feedlot operations face the risk of heat stress. Heat stress is one of the leading causes of decreased production and fertility in dairy cattle during summer months (Keown et al., 2005) and domestic cattle have difficulty coping with temperatures above 90 F when fed high energy feedlot diets (Mader, et al., 2000). These two references discuss the mitigation efforts that can be undertaken by cattle managers. A well managed cattle operation should have a plan in place. The plan should address an ample supply of water, minimal or no handling of livestock during heat stress, changes in feeding patterns and diet, improved airflow in pens, adequate shade, use of water misters, and insect control.

According to Mader et al. (2000) the cattle will have difficulty when the temperature reaches 90 F or above. The number of days where the maximum temperature reaches 90F or above during the summer months varies considerably from site to site. In Table 5 the number of days that reach 90 F or above are shown for the 20, 10, and 2.5% probability levels. This example shows that a feedlot manager would have a 10% chance of dealing with 59 or more "difficult" days for the cattle at Greeley, CO. At the 10% probability level, the number of difficult days would increase to 66 at Wichita, Ks, to 77 at Lubbock and to 87 days at San Antonio, TX. Other things being equal one would choose Greeley over the other sites shown.

Other non-weather factors like the proximity to sources of young livestock and feed producers are important. Additionally on the climate side one should consider the occurrence of cold temperatures, the frequency of blizzards in winter, and the frequency and amount of rainfall

Table 5. The number of days that reach 90F or above for select probabilities along an approximate north-south transect.

	Probability (%) of days>90F		
Location	***20***	***10***	***2.5***
Greeley, CO	47	59	71
Wichita, KS	60	66	75
Lubbock, TX	74	77	80
San Antonio	85	87	89

as excessive rain can create a poor pen environment,. On the societal side it is important to do a wind analysis to determine where odors from the feedlot will be transported and to ensure that there are no nearby dwellings that will be adversely affected by odor due to proximity to the feedlot. The affect of humidity and temperature is often applied in the form of the temperature humidity index. In this example, the impact of humidity was not considered.

2. Agricultural Climatology Data Outlets

The public can obtain data from many different sources. Many services are available commercially from members of the Certified Consulting Meteorologists or the Certified Agricultural Consultants. The consultants are for hire and can focus on the individual needs of the producer and advise on exactly how the data should be applied or better yet assist in applying the data to the client's situation. Many times the weather and climate data used by consultants comes from public sources but, the recommendations provided and the tailoring of the information to the particular situation is a value-added service.

State Climatologists are also quite active in providing services to the public. They are quite knowledgeable about the networks in their state and the characteristics of the available weather stations. State Climatologists are often located at Universities or within state agencies.

The Regional Climate Centers also provide data and information to the public and in addition engage in applied research that will increase the understanding of how data can be applied in various sectors, including agriculture. The Regional Climate Centers (RCCs) have developed the Applied Climate Information System (ACIS) for use in providing climate and weather data through internet based interfaces (see the interface shown in Figure 1. The data served from ACIS by the RCCs is synchronized across the six RCC servers and offers the redundancy necessary to handle need for increased band width during times of high demand as well as a fall over feature should a site go down. A suite of standard products (many of them used in the examples in the above sections of this paper) has been developed by the RCCs. Within the ACIS frame work any application developed at one RCC becomes immediately available to all other RCCs.

The web sites of the RCCs offer up maps and other products from ACIS and receive well over 100M hits per year. More serious users of climate information can subscribe to use the interface to ACIS and drill into the stations and products that are most useful to them. The partnership between the RCCs, NCDC, and the NWS Climate Services Division has led to an interface called NOWdata on the web sites of all NWS offices. NOWdata is an active interface to ACIS that allows NWS customers to look at recent observations in standard summaries.

The National Climatic Data Center (NCDC) is the official archive for climate data in the United States. NCDC is the world's largest active weather data archive and it produces a number of reports that users can obtain by subscription, including:

Local Climatological Data (airport locations)

Climatological Data by state (Coop location)

Climate Atlas Maps

Other publications include Storm Data (tornados, thunderstorms, wind, hail, flood by date), Hourly Precipitation Data (~2800 sites), Normals, Precipitation Probabilities, Climate Atlas of the U.S., Radiosonde data, and NEXRAD (radar data). For a more complete listing of available resources visit the NCDC web page (http://www.ncdc.noaa.gov/oa/ncdc.html). NCDC also participates in the creation of the Drought Monitor.

The US Department of Agriculture and the National Oceanic and Atmospheric Administration sponsor the Joint Agricultural Weather Facility (JAWF). JAWF monitors the weather and assesses its impact on crops around the world. JAWF prepares and releases publications to assist the public in understanding the impacts of recent weather on crops. Examples of these publications are (http://www.usda.gov /oce/weather/pubs/index.htm):

The Weekly Weather and Crop Bulletin

U.S. Agricultural Weather Highlights (daily)

Major World Crop Areas and Climatic Profiles

In addition to timely publications, JAWF also participates in the National Drought Monitor which identifies areas experiencing drought with various impacts, e.g. agriculture, water, etc. JAWF also participates in the process of forecasting commodities and the so called crop forecast can be found on the JAWF web pages.

The National Weather Service has formed the Climate Services Division (CSD) to oversee the NWS climate services program. First among their objectives is to deal with climate prediction products from a week out to one year in the future. This includes then oversight on the application of seasonal forecasts and threats assessment. The CSD provides leadership for training of personnel at NWS offices who will engage, inform, and advise local customers.

The National Drought Mitigation Center helps parties to adapt measures that will reduce societal vulnerability to drought. The NDMC

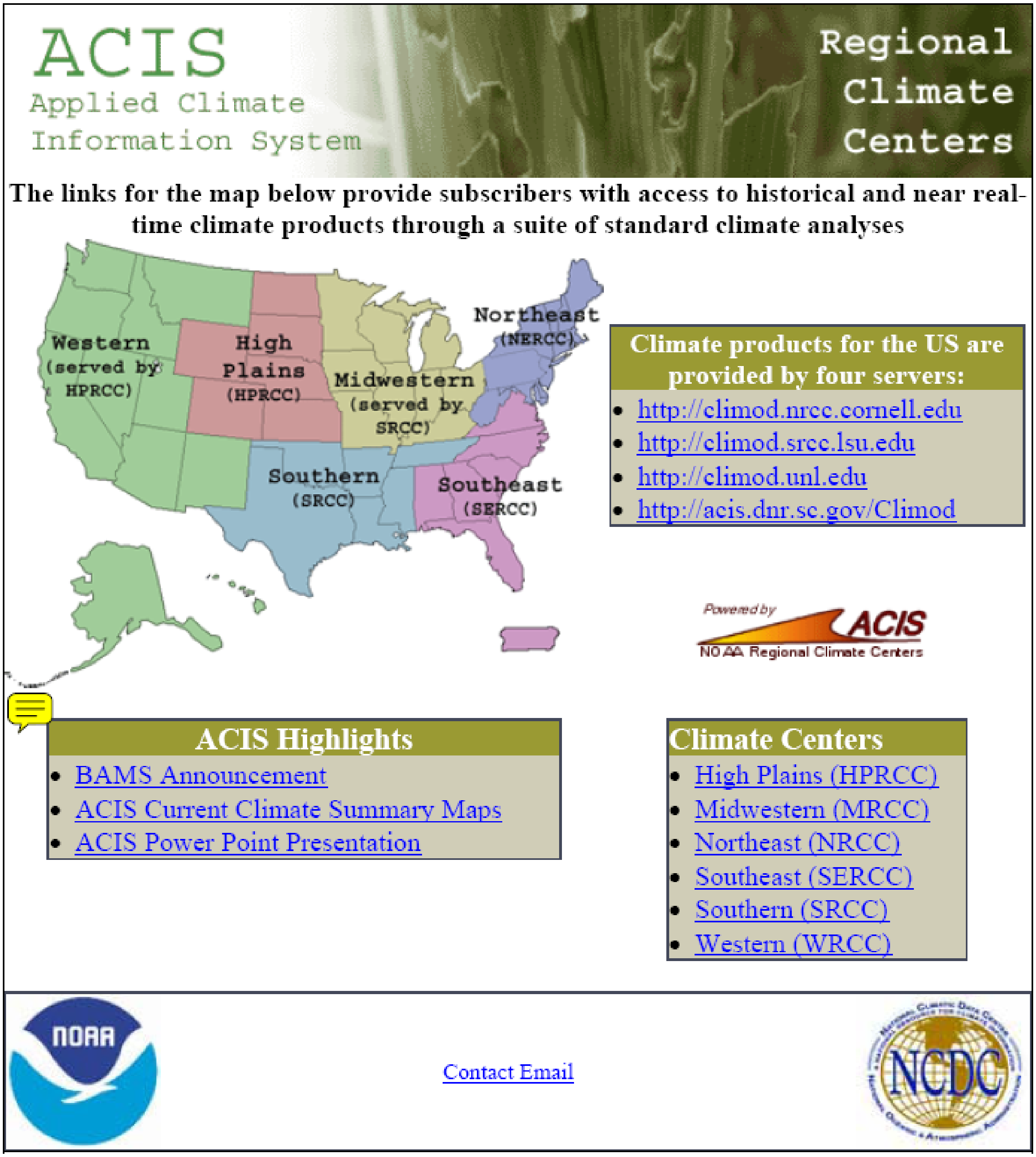

Figure 1. Entry point into ACIS for the six Regional Climate Centers (http://rcc-acis.org/).

publishes a newsletter (DroughtScape) and participates in the production of the drought monitor. In addition to the drought monitor, NDMC also provides up-to-date indices of drought including for example the Palmer Drought Index and the Standarized Precipitation Index. Many other links and information useful to agriculture can be found at the NDMC web page (http://drought.unl.edu/index.htm), e.g. Crop Moisture Index and Fire Danger Index.

The National Water and Climate Center (NWCC) is part of the USDA's Natural Resources Conservation Service. One mission of the NWCC is to serve the USDA's Service Centers (http://offices.sc.egov.usda.gov/locator/app) located across the U.S. These Service Centers offer customers access to services provided by the Farm Services Administration (FSA), the NRCS, and the Rural Development agencies. In addition to providing weather and climate information the NWCC is also a source of conservation planning information. Some of the unique datasets archived by NWCC are the snow survey data, SNOTEL and SCAN network data. NWCC also provides updates on the snowpack, water supply in reservoirs, and streamflow forecasts.

3. Final Remarks on Agricultural Climatology

As discussed above, Agricultural Climatology can play a role in decisions related to "What Crop Should I Plant?", "When Should I Plant?", "What Hybrid Should I Plant?", "What is Happening with Crops in other Parts of the World?", and "Where Should the Feedlot be Located?".

There are a host of other questions that Agricultural Climatology can help to answer including: "What Seeding Density Should I Choose?", "What is the Optimal Fertilizer Treatment?", "How do I Choose Effective Pest Treatment?", "When should I conduct aerial spraying?", "Is Irrigation an Effective Option?", "Can I Grow a Second Crop?", "Will an On-the-Farm Wind Energy Plant be Cost Effective?", "Where is the Optimal Location of a new Ethanol Plant?", "Is the Duration of the Growing Season Changing?", and "Is the Likelihood of Heat Stress Changing?".

For Agricultural Climatology to reach its potential with respect to these and other decisions federal investments and commitments are needed. First and foremost the federal government must commit to supporting data gathering networks. Secondly, the federal institutions must support the infrastructure necessary to archive and disseminate the basic data. Quality Control/Assurance must be standardized between agencies and institutions and any changes to existing data sets should be synchronized so that all parties have the "best" available data. A suite of standardized products should be supported so that the data can be provided to potential users in the agricultural sector in formats that are readily used

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