SAES-422 Multistate Research Activity Accomplishments Report

Project No. and Title:	NC1179 Food, Feed, Fuel, and Fiber: Security Under a Changing Climate
Period Covered:	05-2012 to 05-2013
Date of Report:	10-Aug-2013
Annual Meeting Dates:	Aug 07, 2013 (08:00 AM) to Aug 8, 2013 (12:00 PM) at NWS Training Facility in Kansas City

NC1179 Meeting
August 7-8, 2013
National Weather Service Training Center, Kansas City, MO

Participants

Mickey Ransom (Kansas State University), Robert Seem (Cornell University), Dennis Todey (South Dakota State University), Gerrit Hoogenboom (Washington State University), Jeff Andresen (Michigan State University), Adnan Akyuz (NDSU), Pat Guinan (University of Missouri), Joanne Logan (University of Tennessee), Qingwu Xue (Texas A&M), John Holman (Kansas State University), Ken Hubbard (University of Nebraska), Steve Hu (University of Nebraska), Karen Garrett (Kansas State University), Clyde Fraisse (University of Florida), F. Abel Ponce de Leon (Administrative Advisor).

Brief Summary of Minutes of Annual Meeting

1. Meeting started Aug 7 at 8:00 a.m.

2. Introductions

3. Review of meeting objectives/agenda:
    a. Review of current project timeline and objectives
    b. Quick overview of participants' activities in previous year
    c. Planning for preparation of final report
    d. Discussion of our potential role in USDA climate hubs
    e. Planning for preparation of new proposal
    f. Officer selections
    g. Location and time of next meeting

4. Project ends Sep 30, 2014

5. Draft Report needs to be submitted within 60 days of meeting, need to focus on integration that has not been clear in the past. If we want Hatch funding, we need to justify the regional approach and connections between the partners.

6. New proposal needs to be written. Ken said we should each write a part and then someone puts it together, whatever makes it more efficient.

7. Ken – discussion about funding and how to sell the project at their university, regional project without funds is difficult at best; some of us got travel money, others did not. Some places use it purely as a pass through and none of the money gets to the researcher. People on the project and we don't even know who they are. In theory, this makes sense. How money gets distributed varies greatly by state.

8. How the formula works for the formula funding? Not really clear but most places have a large amount of it going into salaries. Two types of Hatch dollars – same pot, but regional is about 25% of the total pot. Experimental Station must allocate this money to regional projects. Hence the increase of unknown people on the regional projects. Basically up to the directors to determine how the funds are used.

9. Dennis Todey led a review of current project objectives:
    a. Enhance the understanding of crop-climate-soil interaction at a regional scale;
    b. Application of risk assessment tools, including the existing NC-1018 database, for the crop-climate-soils interface on a regional scale;
    c. Enhance the understanding of potential bioenergy production systems;
    d. Disseminate the research outcomes on the potential effects of climate variability and climate change effects on crop production resource use and adaptation options to users and stakeholders.

- NC-1179 is the only agro climate regional project. So with increasing importance of climate change, this project should remain intact. We need to rewrite with this in mind.
- This project has been in existence for more or less 60 years. Original database of soil, clop climate for each county in the NC region. Software ended up in Illinois. If we update this we should publish in the Journal of Service Climatology. It can still be updated. Right now, about 3 yrs out of date. Only covers a limited area. Clyde says he has a database system for the Southeast. Three soil descriptions per county (main agricultural soils in FL, AL, and GA) developed for running crop model simulations)
- Ken has climate database of continental US, estimates of missing data, station by station, 1700 stations, min, of 40 yrs of record, up to 80 or 90 years. Temp and precipitation. NCDC no longer supporting tape formats. Now it's their GHCN data. May impact the updates on the NC database.
- We should report any progress on gridded data that we have been using.
- We've been criticized in the past because of focus on data and not on applications.

- Objective 1c. Pull in some pieces from water use efficiency. Clyde – three states – DSSAT model. GDD tool.
- Karen – regional effects and bioenergy crops. Bioenergy camp based out of Iowa. We can justify using individual state research to justify that they might be possible to be region-wide. Ken – can all these ethanol plants survive – too much overlap? Publications should be included in the report. This is relevant to Objective 3 (Bioenergy production systems).
- Adnan mentioned the regional webinars in ND. The 2010 corn growing degree-days study in North Dakota. 36% is climate change related in the decision on which hybrid to use, etc. More and more farmers are switching from small grains to corn due to increased GDD accumulation during the season. Fear that they might lose the wheat production to Canada. Technology and planting dates have gone earlier. Plus can plant many more acres in a day. Season length increasing, but no huge increase in GDD. Most of the warming in the winter and spring.
- Bob Seem on Horticultural crops – apples, etc. Chilling hours, GDD increase cause crops to break dormancy early, but freeze dates about the same, increasing risk of damage.
- Xue: Starting April 10, for 3-4 weeks, had a hard freeze (Texas). This had never happened before.
- Mickey – We need to have a meeting report within 60 days of this meeting as well as any recommendations. Next year – final report with a lot more substance. There are page limitations so it has to be very concise. Deadline for new project completed proposal due by Dec 1, 2013. We need to focus on tools, risk assessment, climate projections, climate projections using existing forecasts. Check e-mail Clyde Fraisse sent to the group on May 27 for deadlines.
- Gerrit says we were ahead of the USDA regional climate hubs. Maybe new project should be more at the national in scale. Need objectives, outcomes, and good outline ready before this meeting end.
- AFRI – maybe we can apply as a group?
- Advantage we have – disseminate research results very important. Hubs trying to use existing climate info with their ag audience. This plays well into what our project has been trying to do.
- Mickey – Administration Advisor selection process has changed. Maybe Bob is interested? What level do you have to be at to be an AA? Some sort of dean who will your advocate when the directors consider the projects. Can be department heads or former department heads. Trying to broaden the list because having a hard time finding enough people to serve. Has to be somebody in the NC region. Everyone needs to be thinking about this. Ponce de Leon?
- Share names within the next week. Short list of advisors. We need to have a project title. List of objectives. Issues and ramifications. Writing committee. This is the way the last proposal was tackled. Can now request to have the same number NC-1179. Visibility and familiarity, continuity.

Wed Morning 10 AM – noon, State Reports

- Adnan Akyuz, North Dakota State University: ND Ag Weather Network NDAWN, Saving sugar beet producers money for not having to spray as much, wind direction, air temp, really nice maps, based on their mesonet data, 22 out of 74 are real-time stations (reporting every 10 minutes). Others work with data ending the previous day, In process of switching all stations over to real-time (last 10 minutes). Will be using Verizon at $9/station/Month. Pay $5 additional to be in the shared plan. Cell phone friendly, but based on web site not app. $300,000 biannual money from state. To be used to update equipment. Will add 14 additional stations for counties that do not currently have a station. Some money used to maintain – 50% state match. $1250 per station per year for maintenance. First time installation $8-10 K. CM 10, 10 ft tripod, standard configuration. Sugar beet farmers are investing – Red River area of MN.

- Clyde Fraisse University of Florida: Southeast Climate Consortium AgroClimate site. Southeast Climate Extension project – 4 states. Outreach ideas. Climate Adaptation Exchange Fair: We bring farmers, extension agents and researchers together – climate resilience theme. How to develop ideas for AgroClimate Site. Station based, working on a grid based system. Uses mesonet and coop data – works on a daily basis, not hourly. Working on mobile apps. Disease alert systems use two leaf wetness sensors at each station, compared each day. Studied – using model of leaf wetness as input for disease model. Dew point depression model overestimates lead wetness duration but is safer to use. Penman-Monteith-based model that simulates latent heat flux is more accurate. Net radiation estimated by empirical equations was compared to observed values using a net radiometer, seems to be working ok. Studies methane emissions from cattle – can it be reduced by changing stocking rate? (No significant difference noticed in initial results).

- Dennis Todey South Dakota: Want some midsummer heat in the northern corn belt. Climatology for ET. Source of planting data information? Proxy from USDA data. Ken – do we have GDD info on the new hybrids; are the relevant dates changing based on the new GDDs? Lack of good observed phenology, hard to get plot data. GDD increasing, esp during vegetation. Companies are going back to reporting days, not GDD. Company quote “Needs the heat, but will adapt somewhat if it later in the season.” Dennis’s GDD/phenology website uses gridded database over the NC region. He will provide email with the link – still in testing mode. Relative to flood, need better snow measurement and soil moisture monitoring across the state. Flood issue 2011 on the Missouri River. Better soil moisture data from the Plains and better snow data. What would it cost to do soil moisture and snow pack monitoring in the Plains? Dropped into a federal bill, sitting in the House right now. Help augment the ND and SD, add networks in MT and WY. NOAA and USDA updated a MOU. How to do widespread soil moisture monitoring. Various rumbling in DC about trying to do widespread soil moisture monitoring. More to come. Can’t measure soil moisture the same everywhere. Soil moisture under a standard surface such as grass.

- Jeff Andresen Michigan State University: Mesonet Enviro-weather Michigan. Also responsible for a few in Wisconsin. Located in ag regions of the state. All financed by local groups and individual growers. 10K includes three years of maintenance, $1200/yr maintenance. Analytics. 60% of queries are for actual data. There are 40 applications, but raw data is more popular. Most apps have to do with fruit production. Cherry and apple growers, 50% of acreage people use the system. 2,000,000 value per year, efficiency of spray application. Can't get data about fruit quality, but hard data to get. Did a survey with NASS to determine economic payback. U2U project crop modeling. Regional Crop Simulation Results – doesn't work so well. Soil moisture – MI has 10-15% more annual rainfall than 50 years ago. 2012 was an anomaly.

Wed 1:30 – 2 PM

- Mickey Ransom, Kansas State University: Announcements about new jobs related to Agroclimate. Crop modeler - Arandhi Swamy, plus new assistant professor from Brazil, trained in Guelph, Eduardo Santos. Trying to update website for KS mesonet. Beta version of the new website. Hardware upgrades. Standardized datalogger code for the entire state. Power consumption/efficiency. They officially have 62 stations.

- Q. Xue, Texas A&M: Amarillo. Improve crop yields and WUE in the US Southern Great Plains. Ogallala Aquifer. Texas High Plains. Very high corn yields. High Plains produces 50% of total state production of corn. Daily ET demand is huge. 37-38" irrigation water to get the high yields. Can't do this with the current pumping capacity. 2012 is a drought year. Half cotton, half corn. Cotton only needs half the irrigation of corn. Wheat irrigation not very profitable. Wheat benefit – good soil moisture management. If you want to maximize wheat production, you have to use a lot of water. Not very good returns on doing this. 176,000,000 cubic meters of water used to supply corn production in the High Plains. Can't continue to pump at this rate. Since 1958, number of wells decreased, amount pumped per well decreased. Once level drops, will likely never return to previous levels. Number of wells stable since 1990's. Now more difficult to get a new well. Management strategies to save water include soil (no-till, strip tillage, straw mulch), crop (rotation), and water (ET calculation and prediction, irrigation technologies, irrigation scheduling, deficit irrigation). Corn only meets partial demand of livestock industry. They have to import from MidWest. Cattle gain better under drier conditions. Feed – corn, cottonseed, alfalfa. Soybeans don't fit their environment very well. Used to have some, but no more. Overall goal – improve the WUE and heat tolerance of wheat.

- Pat Market, Missouri: 30 weather stations 20 of them real-time and 11 with CR1000. CR1000 has a built in ET estimate. They charge $3,000 per station to keep them up an running – private sponsors provide the funds. Data does get uploaded to NWS. Many are located on ag stations, but they don't sponsor them for the most part. They get some money from USDA ARS $9,000/yr for those

stations. Pat maintains the station, has to send sensors off to be calibrated. Some offer $12,000 to set up a station, but they don't accept unless they offer to cover maintenance expenses as well. Co-sponsors – makes it more difficult to invoice. You have to make sure someone is using the data so if you shut it off, no repercussions. Crop water use calculator – only the stations with CR1000 dataloggers. Can choose corn, soybeans, cotton or rice to generate crop water use reports. Hope to add more crops and weather stations. Resource dollars are out there, but it takes time to go out and find them. QC is a huge issue for MO. Right now – Pat is pretty much it. He's trying to get the IT folks to help automate the QC program. Wayne Decker had started it, but the program never was launched.

- Robert Seem - New York Cornell- Geneva: Perennial crops (Grapes) and pests associated with it related to center of origin. Pests co-evolved at the same time, Evolutionary interplay between host and pathogen and man usually screws this up. Powdery and downy mildews are a good example. Overwintering structure of powdery mildew (PM). Phenology of wild grape – comes out of dormancy much earlier, Different crop with different phenology, mildew completely misses and no infection. Phenological heterogeneity in grapes. Seeing the phenology change. Cold stressed disease resistance – short periods of cold will turn on resistance. When grapes are grown in warm areas, the bloom period is extended and difficult to control for powdery mildew. In colder areas, bloom period is short so disease control is easier. These factors will change as climate warms up. Strawberries is an alpine crop. Strawberry PM has co-evolved. Anywhere where strawberries are produced with slightly warmer cropping temp, much less of a problem with PM. One cold stress event will result in 24 hr protection. 2-10 C at night. Ken – this is a really interesting area. Not just diseases but also insects are affected by microclimate. Out of whackness!!!!

Wed 2 PM – 5 PM

- Abel Ponce De Leon AA for our project: Conference call to discuss potential links with USAD Climate hubs. Cooperative extension service, land grants, USDA - knowledge to farmers, ranchers, and foresters. Utilize the data we already have about climate change, adaptation, and mitigation and use it at the regional level. See attachment that was sent by email about the USDA Climate Hubs. $100 million per year for this effort. Comes from Sec of Ag. Start delivering products!
- The question is if there is a role for this NC project? Abel says he sees room for both – regional projects and individual state efforts too. No specific financial support to engage and investigate areas of innovation. Most effort on delivery of products and knowledge to the constituents. Realignment of funding.
- Our NC has reps from 5 different regions. Dennis thinks we should continue a regional project, but what to do when we go over 5 regions.
- Abel has two proposals – Northern Plains (Colorado wrote it) and MidWest. Each region has one ARS person and one Forest Service person. Their website has all this info.

- How does Hub related to other efforts in climate and climate change? Bring all the disparate efforts into one hub.

New proposal discussion:

- Timeline is short. Best approach is to define concretely the objectives for the next three years. Then once you have a consensus on that, appt one chair per objective to lead the writing and collection of info for that objective and develop it fully. One month, followed by a conference call with everyone to give their opinions, or do by email. Chair will address all the comments and concerns and produce a final product. Final document needs to be submitted by Dec 1. Chairs should donate 100% time to this, but realistically this will be difficult. Ask members for references, info, etc, so chair stays focused on the narrative. Which land grants are going to do what.
- Review process – assigned to the MRC Experiment Station Directors who will decide if a project moves forward or not. Might invite ad-hoc reviewers for their opinions. Big Q – is this multistate project needed by each state. What is the focus of the work for the next three years – can they be accomplished? What is the level of impact that this particular project has or might have in the future? Usually 3-4 reviewers/proj. MRC meets by conference call and passes judgment on 30-40 projects.
- We need to stress the fact that we are an active group that can deliver products to benefit the USDA Hubs.
- Be innovative, water is a major component of this effort, which is why hubs are divided by watersheds. One of the objectives should focus on water.
- Mickey suggests that we rework Objectives 1,2 and 4 and drop 3, the one about bioenergy crops. Important to address mitigation and adaptation.
- Abel is willing to review and edit the project. Abel is stepping down from his current position, but he has been granted permission to continue as AA.
- Adaptation and mitigation needs to be listed as a specific objective
- Ken – we should focus on soil water. Looking at historical ET for a well-watered crop, minus precip. Would be cool on a regional basis to see how it plays out. Water use/efficiency.
- Measurements – soil moisture, greenhouse gasses, snow depth.
- Tools and decision support system – irrigation, pest management
- Three general broad objectives; don't need to wordsmith yet.
- We have multi state collaboration, but insufficient publications. Ken's suggestions about publishing about the database.
- U2U shows collaboration.
- Fed Govt does not know who their stakeholders are.
- Can we use the climate forecasts to help farmers with some of their decisions like cutting their cover crops earlier so they don't continue to suck up water.
- Develop climate smart crop systems. SMART Agriculture. Climate Smart Agriculture or Systems. Would include life cycle modeling.
- Lexicon of key words that will be incorporated by all writing teams.

- Cornell NE proposal will be submitted by ARS, Forest Service. Please remember that the proposals are internal to USDA. Land grants interested in partnering with USDA can submit letters of interest. Looking for exp sta and extension resources that help right now? No additional money. USDA is doing more of the coordinating, but not contributing as much money, Gerrit – next year, more NIFA money available for these projects?
- Ken #3 Using risk assessment tools developed and assessed in 2, provide climate smart advice to farmers and farm advisers
- Reviewers may not realize that soil climate involves water
- Clyde wrote 4 possible titles, and we seemed to like #2 and #3 the most:
    - Risk Management Adaptation and Mitigation to Climate Change and Variability
    - Managing Agricultural production systems for a changing climate: Interactions of weather, water, crops, and pests
    - Climate Smart Agricultural Production Systems: Managing risks under climate variability and change
    - Climate Smart Agricultural Production Systems: Interactions of weather, water, crops, and pests

Thu 8 AM – 10 AM

State Reports continue:

- Ken Hubbard, University of Nebraska, Lincoln: Apps Climate App. Sample map – crop water use for corn. Qi Hu: UNL Climate change – predicted decrease of 8-12% corn over this century – due to drier conditions. Climate classification RCCP8.5 2070-2100. 8.5 stands for the increase in watts/m2. Semi tropic moves north of 38 lat in U.S. More dry areas in the West. Polar regions change from E to D, D climates change to C, etc. Change of vegetation distribution. Potential impacts to crops grown in each region of U.S.
- Karen Garrett, Kansas State Uiversity/Plant Pathology: Simulations. Decision support system for integrated pest management. How to make useful to farmers? Data needed – hourly temp, rainfall, humidity, etc. One – three weeks forecasts have improved but there are still limitations.

New Proposal discussion:

- Karen shared new alternative for a title: Climate Smart Agricultural Production Systems: Managing weather, water, crop, and pest interactions.
- Ken – multistate cooperation, as we write we should keep this in mind.
- U2U corn belt – common tools and approaches.
- Clyde – transfer and test ideas throughout our region.
- Ken NC 94 – regional studies ET. Using GDD to select a hybrid best suited for that location. Database is regional in scope. People worry that we don't have a specific regional project.

- Pat – will offer station ET data to Ken so that he can include in ET map. Have to be willing to give up some of our independence to whomever is leading the project at the time.
- Qi has a concern that we are not justifying the purpose of doing this work as a regional project.
- Clyde says the basic weather info such as leaf wetness, GDD, etc are basic data required for lots of different models. Building foundation of understanding. Can write a proposal for a project later. Data are everywhere now. Need a better understanding of how to best use it.
- Mickey – objective 1 not much different than the current project – just the database.
- Clyde – we need to scale back and promise what we can do.
- 9:35 group voted to accept current 4 objectives. Should we try to start breaking people off to these, or just assign writing committee?
- Single coordinator – Dennis Todey
- Objectives 2 and 3 are very connected and almost need to be combined, at least in the initial outline

People listed below are not interested in the objective:
- Objective 1 – Clyde, Pat, Dennis
- Objective 2 and 3 John, Qi, Mickey,
- Objective 4 – Karen, Bob, Qingwu Xue, Xiaomao Lin

- We need title, objectives, statement of issues and justification; not expected to be the final product at all. Possible to just use the old one and update it and make sure we add arts about climate variability and USDA climate hubs.
- Dennis, Clyde, Jeff and Bob said they would work on draft of first draft – issues and justification
- Ken – format of each objective – have a template to use for each one, why to do, continuing on until we have told the story. How did we do the layout on current projects – objectives and sub-objectives? Bob says the reviewers did NOT like the sub-objectives specifically states, and rather should be incorporated into the narrative.
- Dennis – one leader for each objective, he would bring it all together, just one page per objective so has to be written very concisely
- Focus should remain in NC, but fine to include other states. Activities concentrated in the NC, but outside folks bringing value and different disciplines to the project.
- Everyone interested needs to apply through their own experiment station – what objectives you're going to work on. Due Nov 15. All done online. Dean approves it.
- Final objective assignments – Jeff Andresen - #1, Gerrit Hoogenbom - #2, Clyde Fraisse - #3, Pat Guinan – 4. General ideas of what would fit under this, objectives, etc. Should folks submit ideas or should we leave them alone? Gerrit thinks they should solicit input.

- We will use a listserv for communication (Gerrit) and dropbox (Karen) to share files
- A week to 10 days to formulate ideas and rough drafts. Better to get as much done quickly before classes start up
- Please step up and offer to help where you can.
- Main bulk is due Oct 15 – objectives; Dec 1 final copy; National request for participation will be sent out. Clyde thinks we should try to get it done early, everything by Sep 15.
- Officers:
- Secretary – Joane Logan
- Chair-elect – Pat Guinan
- Chair – Karen Garrett, 2 year term
- Karen – do we just have everyone send a summary and she compiles into one report?
- Bob - Reviewers will look at out reports and maybe wonder if we truly integrated our work and that the new proposal is clearly geared toward collaborative work. Need to highlight areas that were successful. Legitimate in doing pilot projects before we move to the entire region. Karen wants us to submit our reports to dropbox – include any publications.
- Bob – established network of collaborations. This is a project that we as a group should be submitting proposals. Be able to tie in what we are doing to what is proposed for the hubs will strengthen our proposal.
- Karen – should we set up intermediate goals and deadlines?
- Give folks until the 23rd for input.
- Meeting for next year – same time and place? U2U has not set up a meeting for next summer yet. Clyde suggested we meet alone and not joint with another meeting.
- Highlight anything of a multi-state effort that you are doing.
- Jeff – temporal scale important too.
- Bob – can't delay, we need to be able to cope with the change right now, not down the road
- Dennis – don't have long period of record of other variables such as solar radiation and soil temperature. Identify changes on these as well. Identifying and tracking disease over the region.
- Karen – National Climate Assessment, agricultural indicators part, she's working on this part. Long list, will pick a few that will be the test indicators and probably incorporated into the climate hub,. Select a few from each committee, like ag, in Spring 2014. National.
- 10:50 moved to adjourn, all in favor yes.
- Conference call early Sep, maybe once a month after that, or more often as needed.

Accomplishments

In addition to the accomplishments described in the meeting minutes above:

Akyuz: A website was developed to display annual accumulated growing degree days for corn for the continental U.S. (http://www.ndsu.edu/pubweb/GDD/). It is now on the North Dakota State University (NDSU) public web site which is more secure and sustainable and maintained by the NDSU Information Technology Services. The site allows the end users to drill down to state and local levels with individual time series of annual accumulated corn growing degree days and trend lines. Users are also able to access the statistical information as well as raw data used. We presented the use of the page at several workshops and meetings. North Dakota Agricultural Weather Network continued to observe weather variables at 73 prime agricultural locations. We added a near-real-time page (http://ndawn.ndsu.nodak.edu/ten-minute-data-summary.html) that displays 10-minute data updated every 10 minutes. It is a summary page for 13 weather stations to aid local farmers with real time decisions such as pesticide and herbicide application from the wind information. We also developed the page so the layout is mobile phone friendly. We interacted with K-12 students with presentations related to climate change, severe storms and education related to taking meteorological measurements. Also taking basic meteorological measurements (dry-bulb temperature, and wet-bulb temperature) were implemented in the Soil 217 curriculum. Soil 217, Introduction to Meteorology and Climatology is a general education course offered every spring semester at NDSU.

Garrett:
We have completed several projects contributing to system optimization for management of plant pathogens under global change. For example, Garrett et al. (2013) evaluated the effects of climate variability and the color of weather time series on agricultural diseases and pests, and also evaluated the effects of these patterns on the efficacy of decision making for disease management. They also developed a computer program for evaluating the effects of these patterns. Garrett et al. (2012) evaluated the prospects for managing plant health under climate change and proposed new experimental options for designing research spillover from plant genomics to understand the role of microbial communities. Skelsey et al. (in review) have developed a new approach for evaluating climate change impacts in maps of plant disease risk.

We have presented in a number of symposia and meetings on these topics. Recently Garrett co-organized a meeting for the CGIAR Climate Change, Agriculture and Food Security (CCAFS) program in Lima, Peru, to bring together an international team of scientists to address this topic. We have also engaged four statistics graduate students in projects related to this topic.

Guinan:
Regional Collaboration of Local Mesonets
Four state climate offices representing IL, KY, MI and MO met in Champaign, IL in March 2013 for 1 .5 day regional meeting to discuss technical aspects and feasibility of assimilating weather data from their state mesonets into the Midwestern Regional Climate Center's Applied Climate System (MACS). Initially, each state presented an overview on the operation of their mesonet to the Midwestern Regional Climate Center Director (MRCC), Dr. Beth Hall, and MACS technical staff. A discussion followed on

developing a uniform platform for development of a regional mesonet database, including metadata and quality control.

The MRCC identified formatting and other technical requirements for ingesting data, including development of applications using mesonet data. Discussion also extended to developing options for uniform instrumentation and development of one or more test beds for comparing the performance of different sensors used by various mesonets.

The 1.5 day meeting was sponsored by the MRCC and representatives from each state participated in the meeting. Attendees represented IT and operational staff expertise.

The following excerpts are from a report co-authored by participants at the meeting, including the primary author of the report, Dr. Beth Hall.

"The decision was made at the March workshop to begin with one variable from all the mesonets. Daily summary information of that parameter would be provided operationally, and the MRCC would ingest and synthesize the data into a regional map. No raw data from these mesonets would be distributed to users by the MRCC, but the MRCC would provide web information on how users could contact the mesonet managers directly. Table 1 summarizes the variety of information from each of the mesonets present at the workshop.

Table 1 - A list of mesonet networks that attended the March 2013 workshop. The list also provides information about the four networks.

State	Network	Start Year	Sites	Air T	R H	Wind	Ppt	Solar	Leaf	Soil T	Soil M	Td	PET
IL	ICN	1989	19	X	X	X	X	X		X	X	X	X
KY	KY Meso	2007	63	X	X	X	X	X		X	X	X	
MI	ENWX	1997	80	X	X	X	X	X		X	X	X	(X)
MO	ECAAWSN	**1992**	30	X	X	X	X	X	(X)	X	**(X)**	**(X)**	**(X)**

() not all stations report this parameter

Real-time data are necessary for weather forecasters and climatologists to monitor conditions, but many of the important parameters are difficult to find in real-time. One of these parameters was soil temperature. Each mesonet that attended the workshop collects soil temperature data – some sensors under bare soil, others under sod – so it was decided to start with this parameter."

Soil temperature maps, on a daily and weekly basis, are now being provided through MACS and can be accessed at the following links:

Daily Soil Temperature map
http://mrcc.isws.illinois.edu/MESONET/Regional/stmp_04in_1day.png

Weekly Soil Temperature map
http://mrcc.isws.illinois.edu/MESONET/Regional/stmp_04in_7day.png

Vegetation Impact Program

The Vegetation Impact Program (VIP) is a monitoring, assessment, and networking program hosted by the Midwestern Regional Climate Center (MRCC). Major impacts on vegetation are often influenced by various weather and climate scenarios. For example, frost events, drought, and flooding can significantly impact vegetation in areas of agriculture, horticulture, nurseries, or home gardening. Anybody can contribute to the VIP and include NWS staff, University Extension personnel, local gardening enthusiasts, horticultural and agricultural retailers and specialists, and regional and state climatologists.

Some links with more detailed information on the VIP can be found at:

Main VIP web site
http://mrcc.isws.illinois.edu/VIP/index.html

PDF brochure of the VIP
http://mrcc.isws.illinois.edu/VIP/images/VIPBrochure_June2013.pdf

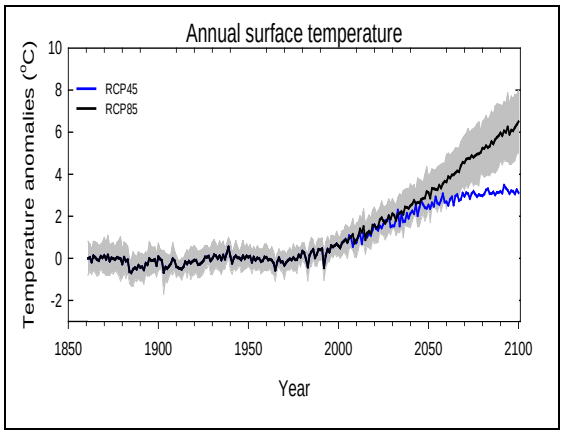
Frost/Freeze Guidance Products:
http://mrcc.isws.illinois.edu/VIP/indexFFG.html

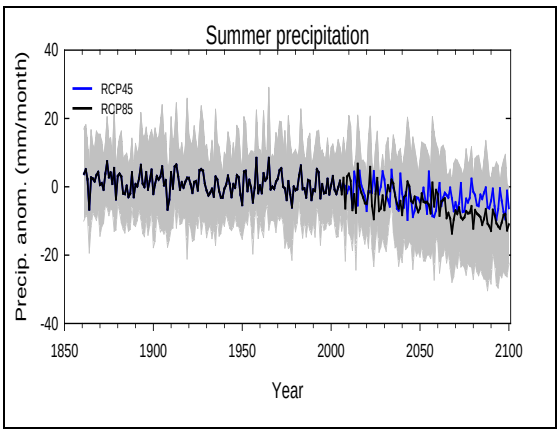
Hoogenboom:
Increased crop production and expansion of irrigated acreage in the USA have increased agricultural water use during the past two decades. To optimize irrigation water use, it is important to know when to irrigate and how much water should be applied. We evaluated the Cropping System Model (CSM)-CERES-Maize model with measured data for the amount of water required for supplemental irrigation. Then both monthly and annual water demand for maize was determined for each county. The results from the evaluation showed that the model was able to simulate the amount of water required for maize irrigation in good agreement with the observed data. This demonstrated the potential application of the CSM-CERES-Maize model as a tool for estimating water demand for irrigation. The estimated water requirements for supplemental irrigation can be used by both policy makers and local farmers for planning the amount of water required for supplemental irrigation as well as for improvements in irrigation management for water conservation.

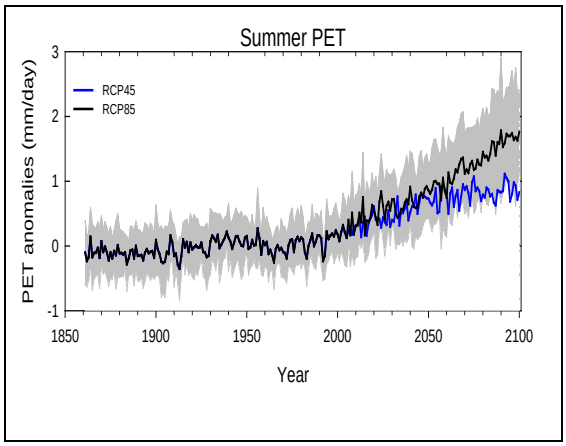
Frost damage is responsible for more economic losses than any other weather related phenomenon in the United States (USA) and many other regions across the globe. With sufficient warning, producers can minimize the potential damages caused by frost and freeze events. However, the severity of these events is dependent upon several factors including air temperature, dew point temperature, and wind speed. Methods for assessing this risk are not easily quantifiable and require the insight of experts familiar with the process. Georgia's Extreme-weather Neural-network Informed Expert (GENIE) incorporates the knowledge of expert agrometeorologists and additional information on air temperature, dew point temperature, and wind speed into a fuzzy expert system to provide warning levels of frost and freeze for blueberries and peaches. Artificial neural network (ANN) predictions of air temperature and dew point temperature across the state

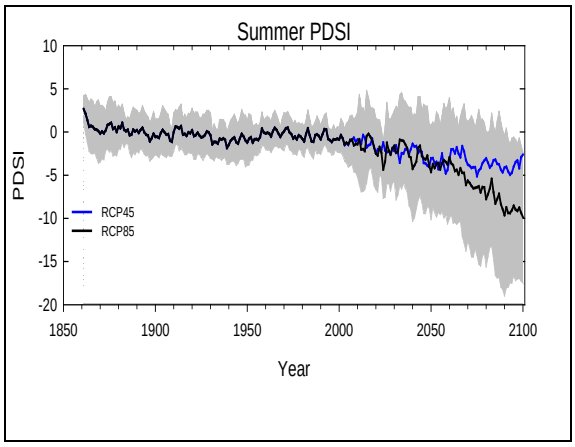
of Georgia for one to twelve hours ahead and observed wind speed are used as input variables for this fuzzy expert system. Meteorological conditions were classified into five levels of frost and freeze by the expert agrometeorologists. These expertly classified scenarios were then used to develop fuzzy logic rules and membership functions for GENIE. Additional scenarios were presented to GENIE for evaluation and it classified all scenarios correctly.

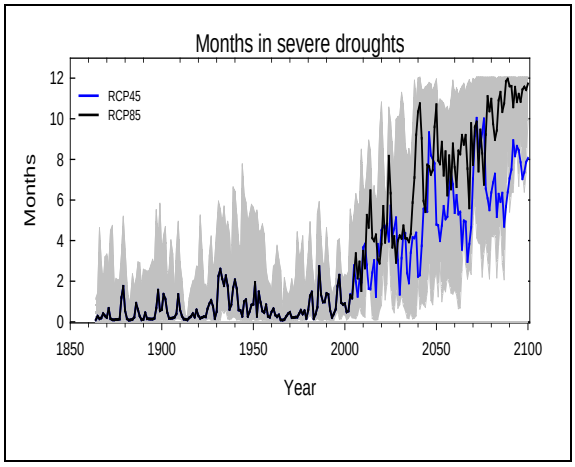
Hu:
We examined the past and future climate in Nebraska simulated by 20 general circulation models in the Fifth Coupled Model Inter-comparison Project (CMIP5), which is the project providing model data and analysis results for the IPCC AR5 document. Most of these models simulated the past climate reasonably well, thus offering some confidence for their simulated future climate. In our analysis, we focused on the multi-model ensemble means of the surface temperature, summertime precipitation, surface evaporation, and PDSI for the state of Nebraska. Model simulations made with two climate change/emission scenarios were used, the RCP4.5 and RCP8.5 which closely resemble the B1 and A2 scenarios, respectively, in the IPCC AR4.
The annual surface temperature averaged in the state is projected to continue rising in the twentieth century. By the mid-century it would become 3.6C and 3.2C warmer than the 1971-2000 mean in RCP8.5 and RCP4.5 scenarios, respectively. Along the trend, the surface temperature would become 6.2C and 3.6C warmer than the 1971-2000 mean values, respectively in the RCP8.5 and RCP4.5 scenarios. Accordingly, the potential evapotranspiration (PET) is predicted to rise substantially. Summertime precipitation is showing decrease since the late 1990s and continuing to decrease through the twentieth century, although the magnitude of the decrease is smaller for the RCP4.5 scenario. The combined effect of higher temperature, larger ET, and less precipitation is the increasing drought potential in the area, as indicated by the model simulated PDSI and the number of months of severe drought defined by the PDSI<3.
These results suggest more frequent summer droughts in the area in the future. This information was presented to the Nebraska Department of Natural Resources and other venues.











In addition, we also examined climate variations in the central U.S. using the Köppen-Trewartha (K-T) climate classification by analyzing observations during 1900-2010, and simulations during 1900-2100 from the twenty global climate models in CMIP5. Based on the projected changes in temperature and precipitation, the K-T climate types would shift toward warmer and dryer climate types from the current climate distribution in the central U.S. The magnitudes of the projected changes are stronger in the RCP8.5 scenario than the RCP4.5. On average, the climate types in 31.4% and 46.3% of the areas are projected to change by the end of the twenty-first century under RCP4.5 and RCP8.5 scenario, respectively. Further analysis suggested that changes in precipitation played a slightly more important role in causing the shift of the climate types during the twentieth century. However, the changes in temperature play an increasingly important role and dominate the shift of the climate types when the warming becomes more pronounced in a warmer climate of the twenty-first century.

Hubbard:

1) We evaluated future corn yields in Nebraska based on the relationship of the yield and climate conditions and general circulation model (GCM) projected climate for the future decades in the twenty-first century. The yield data used in this study were the rain-fed corn yield from 52 counties in Nebraska from 1966-2010, the climate data were from the same region for 1950-2010, and predicted future climate conditions of the region from 2010-2100 were from 16 GCM simulations used for IPCC AR4 with varying CO_2 emission scenarios. Regression models were built using the historical data to describe the corn yield as functions of the climate conditions, e.g., drought which is measured by the Standardized Precipitation and Evaporation Index (SPEI) and the Palmer Drought Severity Index (PDSI) in this study. The regression models were validated using the yield and climate in 2002 and 2003 when severe droughts occurred in the central and western U.S. After the validation the models were applied to estimate yields in the future climates simulated from the IPCC's climate change scenarios.

2) We also re-calculated the drought variations using PDSI and SPEI using the output of 20 climate models participating in the phase 5 of the Coupled Model Inter-comparison Project (CMIP5) during 1900-2100. Those model results became available this spring. The CMIP5 models have higher spatial resolution and improved model physics compared to previous models used for IPCC AR4. The future scenarios were also revised and termed as Representative Concentration Pathways (RCP). The observed and projected future drought occurrences in the Great Plains as well as the global land areas were also analyzed using those new model results.

3) We collaborated with scientists in the Nebraska Department of Natural Resources (DNR) to understand the impacts of possible climate variability on crop water management. The possible scenarios of future irrigation requirement were mapped to understand the challenges that arise from climate variability. The mapped "best" and "worst" scenarios can provide water resource planners with perspectives of the range of climate variations to develop corresponding strategies to cope with these challenges.

4) We continue to evaluate the possible impact of climate change on water quantity and quality in the 4 watersheds in Nebraska using the SWAT model In addition an empirical relationship was developed to describe water content in different layers as a function of precipitation and temperature, see publication 4 below.

5) We evaluated the historical and current corn yield gaps in Northeast China using the APSIM crop model. Northeast China produces about 30% of China's maize (3). Increases in maize production in China are required in order to keep pace with the increases in population. Increasingly, producers in Nebraska need to be aware of the impact of changes in production in other important maize production areas of the world.

Ransom and colleagues:

This project used crop simulation models to examine the impacts of cropping systems within the 10 states of the North Central Region. The project accomplished activities related to modeling and weather data collection and dissemination. Biotic system models have been used to investigate soil carbon dynamics, the performance of cellulosic biofuel crops, and the impact of biomass removal on soil quality and soil erosion. Crop models were used to evaluate the potential impact of climate change on crops in Western Kansas.

Soil and environmental benefits of cover crops in the semiarid central Great Plains were investigated. We also completed a risk analysis of tillage and crop rotation alternatives with winter wheat. In regards to weather data collection and dissemination, the mesonet was expanded in Kansas, which included the deployment of soil moisture sensors. The results were distributed to peers, crop producers, and policy makers through peer-reviewed research articles, presentations at scientific society meetings, extension publications, and web-based publications.

Seem:
In New York (NY-G), we continue to study the impact of environmental conditions (especially weather) on plant disease development within a variety of cropping systems. Recent work has focused on the influence of temperature and light on powdery mildew development in strawberry and rose. Strawberry is an alpine crop that has been adapted to grow in a broad range of climates. Strawberry's co-evolved powdery mildew pathogen (*Podosphaera aphanis*) has not fully adapted to the broad range of climates of current strawberry production. The fungus requires cool temperatures (<13 C) to initiate its sexual stage for survival during the intercrop period (usually winter). Consequently, the sexual spore stage is not often observed in production regions like Florida. Lack of the sexual stage can influence management strategies in many production areas, and strategies will need to be altered further under a changing climate.

Light quality also affects powdery mildew development in a variety of crops (rose, cucumber, strawberry and grape). We, along with colleagues in Norway, have shown that that the UV-B portion of the light spectrum can significantly suppress powdery mildew development when exposed to a little as 1.2 W per square meter for as short as 2 minutes during a dark period. Further work has shown that blue light exposure at the time of UV-B exposure will counteract the damaging effects of UV-B. Preliminary studies indicate that blue light initiates a DNA repair mechanism in the fungus that overcome the damage cause by UV-B, thus allowing the fungus to survive under daylight UV-B bombardment. However, short UV-B exposure to crops (typically greenhouse crops) at night can effectively manage powdery mildew without associated damage to the crop.

Xue:
Wheat: Field experiments have been conducted at 2 locations under 5 soil water regimes (from irrigated to dryland) among 20 genotypes with a wide range of genetic background and yield potential. Quantified seasonal water use by monitoring soil water content, precipitation and the amount of irrigation; measured canopy temperature depression to differentiate drought and high temperature tolerance among wheat genotypes, using wireless infrared thermometers (IRTs), hand-held IRTs and thermal camera; measured CO2 assimilation rate, stomatal conductance, transpiration and water use efficiency at leaf level in dryland plots; analyzed biomass accumulation, yield components, harvest index, and carbon remobilization among wheat genotypes. Corn: Field experiments have been conducted to 1) determine the yield responses of corn with only 300 mm irrigation water in 3 hybrids at 4 planting densities; We limited the amount of irrigation less than 300 mm; 2) determine the response of commercially available first generation drought tolerant corn hybrids to seeding rate and different irrigation levels (100%, 75% and 50%

ET). Quantified seasonal evapotranspiration (ET); measured aboveground biomass at silking and maturity; quantified yield components, harvest index, and water use efficiency. Sorghum and cotton: Field experiment has been conducted in 3 irrigation regimes (dryland, limited irrigation and full irrigation) and 3 N fertilization treatments under sorghum-cotton ration. Data collections included soil N and P levels before planting and after harvest, biomass, yield, and yield components.

Impacts

In addition to the impacts described in the meeting minutes above:

Akyuz: With the annual accumulated corn growing degree day study, we were able to identify the portion of the corn production increase due to climate change in the Northern Plains where the production is limited to the accumulated heat unit that allows corn to mature. It was important in terms of separating the impact of genetic engineering enabling corn to mature in colder climates with lesser heat requirement. The NDAWN system's near-real time component adds security and saves money. TCP-IP telecommunication with wireless technology allows us to download data from multiple stations simultaneously at no extra cost. It also allows us to select station locations that are independent from its proximity to nearest land line service. Through our K-12 outreach we were able to educate students with hands on activities related to environmental observation, severe weather and Earth's climate system. Integrating meteorological observation in an introductory meteorology and climatology course at NDSU made daily weather measurements understood by the students. Students not only learned to calculate dew point temperature and relative humidity, but also learned the concept of atmospheric humidity with a hands-on experience. Every student was given a sling psychrometer to take weather measurements. Some select students interacted with K-12 students to explain the process. It allowed students to become teachers.

Guinan: Impacts from the regional mesonet meeting and Vegetation Impact Program include:

- Increased multi-state collaboration
- New tools and products developed to aid in management decisions for the agricultural and horticultural sectors.

Garrett:
The outputs described above are published or in the process of being published. The new insights and models we have been developing have been adapted by CCAFS as part of their program for addressing climate change and plant disease, and we have been awarded research funds from CCAFS for new work in the area.

Hubbard:

1) Impact of future drought on corn yield in Nebraska

a) Our results showed that the climate in the future decades in the twenty-first century will be drier in North America by varying intensities than the current climate under all climate change scenarios. In the middle-range SRES A1B scenario, the mean PDSI during 2030s will be -1.18, suggesting mild drought conditions. The drought will intensify and the PDSI will be -3.63 and -4.29 during 2050s and 2080s, respectively.
b) The following example shows corn yield reductions at the SRES A1b Scenario based on the PSDI-yield regression model results and their comparisons with yield losses in 2002-03 droughts. As the dryness intensifies with time, the yield loss becomes severer. In the 2050s the mean PDSI index of -3.63 suggests severe drought as the average climate condition. In such climate the corn yield would decrease in the range from -1 to about 50 bushels per acre. Severer losses were indicated in the regression results for the even drier decade of the 2080s.
c) These reductions of corn yield on the basis of 150 bushels/acre in the current rain-fed standard would translate up to 1/3 loss of the yield in the 2050s and nearly 1/2 loss in the 2080s.

	Year	Mean PDSI (varying range for the decade)	Yield anomalies (varying range) (bushel/acre)
Observation	2002-03	-2.517	-17.78
SRES A1b	2030s	-1.18 (-3.10, 0.74)	-8.35 (-21.92, 5.23)
	2050s	-3.63 (-7.10, -0.16)	-25.66 (-50.18, -1.13)
	2080s	-4.29 (-8.90, 0.33)	-30.28 (-62.87, 2.31)

2) Future drought variability using the new CMIP5 models under the RCP scenarios

a) Under low emission scenario (RCP4.5), the annual temperature in Nebraska is projected to increase by 5.5-6.3^{o}F by the end of this century. An 8-9^{o}F increase is projected under high emission scenario (RCP8.5).
b) The annual precipitation is projected to decrease by 5-15% in the southern Great Plains, and to increase by 5-10% in the northern Great Plains. There are no noticeable changes in annual precipitation in Nebraska, but the summer precipitation is projected to decrease in Nebraska.
c) Persistent drying is projected over most of the contiguous U.S. In Nebraska, our results showed that 45-65% of the future months will in severe drought conditions (like this summer) under low emission scenario. The number increases to 55-75% under high emission scenarios.
d) We were invited to present our results to the general public and the scientists on hydrology and public health four times this year.

3) Impact of the climate variability on irrigation requirement in Nebraska

a) Overall, most climate models indicated an increasing trend of irrigation requirement.

b) Assuming current land use and irrigation efficiency unchanged, Nebraska needs more water.
c) Better water management is needed.

4) Impact of climate variability on water quantities and quality in Nebraska
We are writing papers to summarize the continuation of this work. We have one paper published and one paper is in review.

5) Yield gaps in Northeast China
It was found that current maize gaps are fairly high and that additional fertilizer management and the use of water to irrigate maize will help to close the yield gap. One paper is published and one paper is in review. This work demonstrates how to determine the attribution of yield changes to shifting planting date and introduction of new hybrids.

Ransom and colleagues:
Our work shows that crop models are useful tools in studying cropping system performance within a region. The results from the simulations will allow producers and policy makers to develop programs aimed at maintaining rural economic viability under a changing climate coupled with a decline in the availability of ground water. The coupling of a crop model, a soil drainage model, and an economic model resulted in initial evaluations of crop selection and irrigation practices on recharge in the Ogallala Aquifer. The addition of soil moisture sensors to the mesonet has expanded soil moisture monitoring efforts.

Seem:
A changing climate alters conditions that regulate the pattern and intensity of disease development on agriculturally important crops. Improved understanding of how disease development occurs will lead to better management through altered strategies and tactic that can take into account the climate changes. Regardless if these changes result in warmer summers, colder winters or a more variable climate, plant disease management must be able to address these changes before significant crop loss or misdirected management efforts reduce grower profits.

Xue:
The 2012 was another dry and hot year for crop production in the Texas High Plains even though there was more rainfall than 2011. Drought and heat remained the predominant abiotic stresses for reducing crops yields and WUE. Under drought conditions, adoption of drought tolerant wheat cultivars and corn hybrids is an important strategy for improving crop yield and WUE. The results of wheat studies indicated that maintaining higher biomass at anthesis is important for high yield under drought stress. The higher biomass may be related to vigorous early growth and effective use of soil water. The results also demonstrated that good soil water profile at planting is the key to root development and drought survivability. The drought tolerant corn studies indicated that the newly developed drought tolerant hybrids showed significant yield gains under reduced irrigation conditions. These results are not only important to producers in the

Texas High Plains but also important to Mid-west producers because of the historic drought in the corn-belt in 2012.

Publications

Ahmad, S.,A. Ahmad, C.M.T. Soler, H. Ali, M. Zia-ul-Haq, J. Anothai, A. Hussain, G. Hoogenboom, and M. Hasanuzzaman. 2012. Application of the CSM-CERES-Rice model for evaluation of plant density and nitrogen management of fine transplanted rice for an irrigated semiarid environment. Precision Agriculture 13(2):200-218.

Ajayi, S., S. Krishna Reddy, S. Liu, P. Gowda, Q. Xue, T. Marek, J. Rudd, C. M. Biradar, and K. E. Jessup. 2012. Reflectance based characterization of wheat cultivars for identifying drought tolerance. ASA-CSSA-SSSA, 2012 International Annual Meetings. Cincinnati, OH.

Akyuz, F. A. 2011: Weekly Crop and Pest Report, May through August 2011. NDSU Extension Service. http://www.ag.ndsu.nodak.edu/aginfo/entomology/ndsucpr/

Akyuz, F. A. 2012: North Dakota State Climate Office. The State Climatologist. 2011-2012 Annual Summary. http://stateclimate.org/publications/files/2011AASCAnnualReport.pdf. American Association of State Climatologists. V. 30, No. 1. Pp. 118-120.

Akyuz, F. A. and B. Mullins. 2012: 2012 Growing Season Weather Summary: http://www.ndsu.edu/ndsco/publication/gss/2012.pdf

Akyuz, F. A. and B. Mullins. 2012: Quarterly North Dakota Climate Bulletin (Summer 2011): http://www.ndsu.edu/ndsco/publication/ndsco/bulletin/summer12.pdf

Akyuz, F. A. and B. Mullins. 2012: Quarterly North Dakota Climate Bulletin (Spring 2012): http://www.ndsu.edu/ndsco/publication/ndsco/bulletin/spring12.pdf

Akyuz, F. A. and B. Mullins. 2012: Quarterly North Dakota Climate Bulletin (Winter 2012): http://www.ndsu.edu/ndsco/publication/ndsco/bulletin/winter12.pdf

Akyuz, F. A. and B. Mullins. 2012: Quarterly North Dakota Climate Bulletin (Fall 2011): http://www.ndsu.edu/ndsco/publication/ndsco/bulletin/fall11.pdf

Amjed, A., S. Sanjani, G. Hoogenboom, A. Ahmad, T. Khaliq, S.A. Wajid, I.R. Noorka, and S. Ahmad. 2012. Application of crop growth models in agriculture of developing countries: A review. New Horizons in Science & Technology 1(4):95-99.

Armstrong, J., B. Arnall, M. Boyles, J. Bushong, J. Damicone, E. DeVuyst, F. Epplin, K. Giles, C. Godsey, W. Heer, G. Hergert, J. Holman, D. Jardine, J. Jennings, C. Jones, B. Kard, D. Mengel, T. Peeper, D. Peterson, K. Roozeboom, T. Royer, H. Sanders, M. Stamm, C. Thompson, and H. Zhang. 2012. Great Plains canola production handbook. Kansas State University Extension Bulletin MF-2734.

Aslaf, B., Gadoury, D.M., Tronsmo, A.M., Seem, R.C., CadleDavidson, L., Brewer, M.T., and Stensvand, A. 2013. Temperature regulates the initiation of cleistothecia in powdery mildew of strawberry. Phytopathology. 103:717-724.

Assefa, Y., K.L. Roozeboom, S.A. Staggenborg, and J. Du. 2012. Dryland and irrigated corn yield with climate, management, and hybrid changes from 1939 through 2009. Agron. J. 104:473-482.

Becker, J. B., B. W. Bean, Q. Xue, and T. H. Marek. 2012. 2011 Pioneer Optimum AquaMax first generation drought tolerant corn trial progress reports. Texas AgriLife Research. http://amarillo.tamu.edu/files/2010/11/2011-AQUAmax-trial.pdf.

Becker, J. B., B. W. Bean, Q. Xue, and T. H. Marek. 2012. 2011 Syngenta Agrisure Artesian First Generation drought tolerant corn trial. Texas AgriLife Research. http://amarillo.tamu.edu/files/2010/11/2011-Syngenta-Agrisure-trial.pdf.

Becker, J. B., B. W. Bean, Q. Xue, and T. H. Marek. 2012. 2011 Syngenta Quilt Xcel Application on corn grown under different irrigation stress levels. . Texas AgriLife Research. http://amarillo.tamu.edu/files/2010/11/2011-Syngenta-Quilt.pdf.

Becker, J. D., B. Bean, Q. Xue, and T. Marek. 2012. Drought tolerant corn under varying irrigation and seeding rates. ASA-CSSA-SSSA, 2012 International Annual Meetings. Cincinnati, OH.

Blanco, H. and J. Holman. 2012. Soil and environmental benefits of cover crops in the semiarid central Great Plains. *In* Annual meetings abstract [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Chevalier, R.F., G. Hoogenboom, R.W. McClendon, and J.O. Paz. 2012. A web-based fuzzy expert system for frost warnings in horticultural crops. Environmental Modeling & Software 35(1):84-91.

Collins, Mary, Dawn Ferris, Robert Michitsch, David Lindbo, Patrick Drohan, Michel D. Ransom, Brian Slater, Mark McClain, Ann Rossi, and Jerrell Lemunyon. 2012. National Soil Science Field Camp: An Update. *In* Annual Meetings Abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Courtier, J.R., R.J. Johnson, W.C. Bridges, and K.G. Hubbard. 2013. Assessing migration of Ruby-Throated Hummingbirds (*Archilochus Colubris*) at broad spatial and temporal scales. Auk. 130(1): 107-117.

Cox, C. M., W. W. Bockus, R. D. Holt, L. Fang, and K. A. Garrett. 2013. The spatial connectedness of plant species: Potential links for apparent competition via plant diseases. Plant Pathology, online early.

Dawson, N.W., A.R. Lupo, and P.E. Guinan, 2012. A Long-Term Study of Tropical Systems Impacting Missouri. *Transactions of the Missouri Academy of Science, 20-28.* (33%)

Garrett, K. A. 2013. Big data insights into pest spread. Nature Climate Change 3:955-957.

Garrett, K. A. 2012. Information networks for plant disease: Commonalities in human management networks and within-host signaling networks. [Invited] European Journal of Plant Pathology 133:75-88.

Garrett, K. A., A. Dobson, J. Kroschel, B. Natarajan, S. Orlandini, H. E. Z. Tonnang, and C. Valdivia. 2013. The effects of climate variability and the color of weather time series on agricultural diseases and pests, and decision making for their management. Agricultural and Forest Meteorology 170:216-227.

Garrett, K. A., A. Jumpponen, C. Toomajian, and L. Gomez-Montano. 2012. Climate change and plant health: Designing research spillover from plant genomics for understanding the role of microbial communities. [Invited] Canadian Journal of Plant Pathology 34:349-361.

Garrett, K. A., G. A. Forbes, L. Gomez, M. A. Gonzales, M. Gray, P. Skelsey, and A. H. Sparks. 2013. Cambio climático, enfermedades de las plantas e insectos plaga. In Cambio climático en los Andes. E. Jimenez, ed. In press.

Garrett, K. A., P. D. Esker, and A. H. Sparks. 2013. An introduction to key distributions and models for epidemiology using R. Exercises in Plant Disease Epidemiology, 2nd Edition. K. Stevenson and M. Jeger, eds. APS Press, Minneapolis, MN. In press.

Garrett, K. A., S. Thomas, G. A. Forbes, and J. Hernandez Nopsa. 2013. Climate change and plant pathogen invasions. In Invasive Species and Climate Change. L. Ziska and J. Dukes, eds. CABI Publishing. In press.

Gomez-Montano, L., A. Jumpponen, M. A. Gonzales, J. Cusicanqui, C. Valdivia, P. Motavalli, M. Herman, and K. A. Garrett. 2013. Do bacterial and fungal communities in soils of the Bolivian Altiplano change under shorter fallow periods? Soil Biology & Biochemistry 65:50-59.

Haag, L., J. Falk, A. Schlegel, and J. Holman. 2012. Grain and forage yield, yield components, water use, and rotational effects of field pea grown in the Central High Plains. *In* Annual meetings abstract [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

He, Y., H. Wang, B. Qian, B. McConkey, H. Cutforth, R. Lemke, R. DePauw, K. Brandt, T. McCaig, K. Hu, and G. Hoogenboom. 2012. Effects of climate change on killing frost on the Canadian prairies. Climate Research 54(3):221-231. (DOI 10.3354/cr01114).

Holman, J. 2012. Extension and Education community poster. *In* Annual meetings abstract [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Holman, J., L. Haag, M. Zarnstorff, J. Ransom, S. Maxwell, and T. Roberts. 2012. Impact of hail damage (stand thinning) on irrigated corn. *In* Annual meetings abstract [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Holman, J., T. Roberts, and S. Maxwell. 2012. Making a profit replacing fallow but not with cover crops. *In* Annual meetings abstract [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Hou, X., K.E. Jessup, Q. Xue, and B.A. Stewart. 2012. Grain Sorghum Response to Soil Water Deficit and Nitrogen Rate. 2012 Annual Student Research Conference, West Texas A&M University, April 13, 2012, Canyon TX. 10.Reddy, Y.S., B. A. Stewart, B. C. Blaser, and Q. Xue. 2012. Influence of plant geometries on transpiration efficiency and harvest index in corn, sorghum and millet. 2012 Annual Student Research Conference, West Texas A&M University, April 13, 2012, Canyon TX.

Jennings, Joshua, Kraig Roozeboom and Michael Stamm. 2012. Effects of Preceding Crop On No-till Winter Wheat Yield and Quality. Agronomy Abstracts. ASA Madison, WI.

Jennings, Joshua, Kraig Roozeboom and Randall Nelson. 2012. Improving the Performance of Winter Wheat Planted without Tillage After Grain Sorghum. Great Plains Sorghum Conference. Manhattan, KS.

Jongrungklang, N., B. Toomsan, N. Vorasoot, S. Jogloy, K.J. Boote, G. Hoogenboom, and A. Patanothai. 2012. Classification of root distribution patterns and their contributions to yield in peanut genotypes under mid-season drought stress. Field Crops Research 127(1):181-190.

Kamble B., A. Irmak, and K. Hubbard. 2013. Estimating crop coefficients using remote sensing based vegetation index. Remote Sensing. 5: 1588-1602.

Krishna Reddy, S., S. Liu, J. C. Rudd, R. N. Devkota, Q. Xue, P. Payton, and J. Mahan. 2012. Gene expression profiling of water deficit stress responses in widely adapted wheat cultivars TAM 111 and TAM 112. Plant Biology 2012, Austin, TX.

Krishna Reddy, S., S. Liu, Q. Xue, J. C. Rudd, M. Fuentealba, K.E. Jessup, P. Payton, and J. Mahan. 2012. Mechanisms of adaptation to water-stress conditions in widely planted TAM wheat cultivars. ASA-CSSA-SSSA, 2012 International Annual Meetings. Cincinnati, OH.

Lamsal, A., A. Anandhi, and K. Roozeboom. 2012. Sensitivity of CERES-Sorghum Simulated Yields to changes in climate and genetic coefficients. UNIDATA Users Workshop, 9-13 July 2012, Boulder, Colorado.

Leelaruban, N., F. A. Akyuz, G. Padmanabhan, P. Oduor, S. Shaik. 2012: A Study of Drought Impact and Severity Based on Developed County Wide Drought Severity and Coverage Index in North Dakota, USA. H073. Advancing Drought Monitoring and Prediction with Applications to Decision Making. AGU Fall 2012. Session December 3-7, San Francisco, CA.

Leelaruban, N., P. Oduor, A. Akyuz, S. Shaik, G. Padmanabhan. 2012: Leveraging a Spatio-Temporal Drought Severity and Coverage Index with Crop Yield Modeled As a Stochastic Process. International Journal of Hydrology Science and Technology (IJHST) Vol. 2 No. 3, 219-236.

Liesch, A.M., D.A. Ruiz Diaz, D.B. Mengel, and K.L. Roozeboom. 2012. Interpreting relationships between soil variables and soybean iron deficiency using factor analysis. Soil Sci. Soc. Am. J. 76:1311-1318.

Liu Z., S. Yang, K.G. Hubbard, and X. Lin. 2012. Maize potential yields and yield gaps in the changing climate of Northeast China. Global Change Biology. **18:** 3441-3454.

Liu Z., S. Yang, K.G. Hubbard, and X. Lin. 2012. Negative effects of climate warming on maize yield are mitigated by the changing of sowing date and hybrids in Northeast China. Global Change Biology.

Liu, S., Q. Xue, A. M. Ibrahim, S. Krishna Reddy, and J. C. Rudd. 2012. Genetic and physiological evaluation of yield and other important traits of hard red winter wheat in the Texas High Plains. ASA-CSSA-SSSA, 2012 International Annual Meetings. Cincinnati, OH.

Lupo, A.R., N.B. Smith, P.E. Guinan, and M.D. Chesser, 2012. The long-term climatology of the Missouri Region dew points and the implications for regional climate and human comfort. Accepted *National Weather Digest*. (25%)

Mahmood, R,R. Pielke, Sr., K.G. Hubbard, and 17 others, 2013. Land cover changes and their biogeophysical effects on climate. International J. Climatology. Accepted. DOI: 10.1002/joc.3736

Mahmood, R., A. Ashley, K.G. Hubbard, J. You. 2012. Observed data-based assessment of relationships among soil moisture at various depths, precipitation, and temperature. Applied Geography. 34:255-264.

Mahmood, R., Keeling, T., Foster, S. A., and Hubbard, K. G.. 2013. Did irrigation impacts 20th century air temperature in the Ogallala aquifer region. Applied Geography. 38: 11-21.

Marek, T., Q. Xue, W. Xu, B. Bean, G.J. Michels, S. H. Amosson, J. M Sweeten, T. A. Howell, P. D. Colaizzi, and P. Gowda. 2012. 2011 North Plains Research Field 12-200 Limited Irrigation Corn Production Study. Publication AREC 2012-19, Texas AgriLife Research-Amarillo.

Mullins, B. 2012: 2011-2012 North Dakota Monthly Climate Summary and Impact. http://www.ndsu.edu/ndsco/publication/index.html

Nyren, P. E., G. Wang, R. Patton, Q. Xue, G. Bradbury, M. Halvorson, and E. Aberle. 2012. Evaluation of Perennial Forages for Use as Biofuel Crops in Central and Western North Dakota. North Dakota State University, Central Grassland Research Extension center, 2011 reports. http://www.ag.ndsu.edu/CentralGrasslandsREC/biofuels-research-1/2011-report/Biomass_for_ethanol.pdf.

Olatinwo, R.O., T. Prabha, J.O. Paz, and G. Hoogenboom. 2012. Predicting favorable conditions for early leaf spot of peanut using output from the Weather Research and Forecasting(WRF) model. International Journal of Biometeorology 56(2):259-268.

Pathak, T.B., J.W. Jones, C.W. Fraisse, D. Wright, and G. Hoogenboom. 2012. Uncertainty analysis and parameter estimation for the CSM-CROPGRO-Cotton Model. Agronomy Journal 104(5):1363-1373.

Paz, J.O., P. Woli, A. Garcia y Garcia, and G. Hoogenboom. 2012. Cotton yields as influenced by ENSO at different planting dates and spatial aggregation levels. Agricultural Systems 111(1):45-52.

Rijal, I., X. Jia, X. Zhang, D. D. Steele, T. F. Scherer, and A. Akyuz. 2012. Effects of Subsurface Drainage on Evapotranspiration for Corn and Soybean in Southeast North Dakota. J. of Irrigation and Drainage. DOI: 10.1061/(ASCE)IR.1943-4774.0000508.

Romero, C.C., G. Hoogenboom, G.A. Baigorria, J. Koo, A.J. Gijsman, and S. Wood. 2012. Reanalysis of a global soil database for crop and environmental modeling. Environmental Modeling & Software 35(1):163-170.

Roncoli, C., N. Breuer, D. Zierden, C. Fraise, K. Broad, and G. Hoogenboom. 2012. The art of the science: climate forecasts for wildfire management in the southeastern United States. Climatic Change 113(2):1113-1121. (DOI 10.1007/s10584-012-0526-1).

Roozeboom, K., D. Mengel, D. Blasi, and J. Holman. 2012. Prussic acid poisoning. Kansas State University Extension Bulletin MF-3040.

Roozeboom, K., J. Holman, and J. Jennings. 2012. Cropping systems and cover crops. p. 18-23. *In* Presley, D., D. Shoup, J. Holman, and A. Schlegel (ed.). Efficient crop water use in Kansas. Kansas State University Extension Bulletin MF-3066.

Roozeboom, Kraig, Dorivar Ruiz Diaz, Doug Jardine, Curtis Thompson, and R. Jeff Whitworth. 2012. Kansas Sorghum Management 2012. Cooperative Extension Service, Kansas State University, Manhattan, KS. MF3046.

Saberali, S.F., S.A.M. Modarres-Sanavy, M. Bannayan, M.A. Baghestani, H. Rahimian-Mashadi, and G. Hoogenboom. 2012. Dry bean competitiveness with redroot pigweed as affected

Salazar, M.R., J.E. Hook, A. Garcia y Garcia, J.O. Paz, B. Chaves, and G. Hoogenboom. 2012. Estimating irrigation water use for maize in the Southeastern USA: A modeling approach. Agricultural Water Management 107(1):104-111.

Schmer, M. R., Q. Xue, J. R. Hendrickson. 2012. Salinity effects on perennial, warm-season (C4) grass germination adapted to the northern Great Plains. Canadian J. Plant Sci. 92: 873-881.

Shein, K. A., D. P. Todey, F. A. Akyuz, J. R. Angel, T. M. Kearns, and J. L. Zdrojewski, 2012: Evaluating Statewide Climate Extremes for the United States. Journal of Applied Meteorology and Climatology. November 2012. Vol. 51, No. 11. 2047-2059.

Shoup, D. and J. Holman. 2012. Controlling weeds to conserve water. p. 33-35. *In* Presley, D., D. Shoup, J. Holman, and A. Schlegel (ed.). Efficient crop water use in Kansas. Kansas State University Extension Bulletin MF-3066.

Skelsey, P., K. A. With, and K. A. Garrett. 2013. Why dispersal should be maximized at intermediate scales of heterogeneity. Theoretical Ecology 6:203-211.

Sparks, A. H., G. A. Forbes, R. J. Hijmans, and K. A. Garrett. In review. Climate change effects on the global risk of potato late blight.

Stooksbury, D, J. N. Gammon, A. Akyuz, K. G. Hubbard, L. Dupigny-Giroux, M. Timofeyeva, 2011: AASC Recommendations for the Education of an Applied Climatologist. AGU Fall Meeting. 5-9 December 2011, at the Moscone Convention Center, San Francisco, California.

Stougaard, R. N., and Q. Xue. 2012. Spring wheat seed size and cultivar effects on yield and wild oat interference. 2012 Weed Science Society of America Annual Meeting, February 6-9, Waikoloa, HI.

Suthaparan, A., Stensvand, A., Solhaug, K.A., Torre, S., Mortensen, L.M., Gadoury, D.M., Seem, R.C., Giselrod, H.R., 2013. Suppression of powdery mildew (*Podosphaera pannosa*) in greenhouse roses by brief exposure to supplemental UV-B lighting. Plant Dis. 96:1653-1660.

Sutrave, S., C. Scoglio, S. A. Isard, J. M. S. Hutchinson, and K. A. Garrett. 2012. Identifying highly connected counties compensates for resource limitations when evaluating national spread of an invasive pathogen. PLoS ONE 7:e37793.

Thorp, K.R., J.W. White, C.H. Porter, G. Hoogenboom, G.S. Nearing, and A.N. French. 2012. Methodology to evaluate the performance of simulation models for alternative compiler and operating system configurations. Computers and Electronics in Agriculture 81(1):62-71.

Van Liew, M.W., S. Feng and T. B. Pathak (2012). Assessing climate change impact on runoff and water quality at the field scale for four locations in the Heartland. Transaction of ASAE (revised and in review).

Van Liew, M.W., S. Feng and T.B. Pathak (2012). Climate change impacts on stream flow, water quality and best management practices for the Shell and Logan Creek Watersheds in Nebraska. International Agricultural Engineering Journal, 5, 13-34.

Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, M. Aillery, E.A. Ainsworth, C. Ammann, C.J. Anderson, I. Bartomeus, L.H. Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M. Dabney, J.A. Delgado, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D. Goodrich, S. Hu, R.C. Izaurralde, R.A.C. Jones, S-H. Kim, A.D.B. Leaky, K. Lewers, T.L. Mader, A. McClung, J. Morgan, D.J. Muth, M. Nearing, D.M. Oosterhuis, D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, C. Rice, M. Rivington, E. Rosskopf, W.A. Salas, L.E. Sollenberger, R. Srygley, C. Stöckle, E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright-Morton, L.H. Ziska. 2013. Climate Change

and Agriculture in the United States: Effects and Adaptation. USDA Technical Bulletin 1935. Washington, DC. 186 pages. This report is available at: http://www.usda.gov/oce/climate_change/effects.htm

Wang, H., Y. He, B. Qian, B. McConkey, H. Cutforth, T. McCaig, G. McLeod, R. Zentner, R. DePauw, R. Lemke, K. Brandt, T. Liu, X. Qin, J.W. White, T. Hunt. 2012, and G. Hoogenboom. Climate change and biofuel wheat: a case study of southern Saskatchewan. Canadian Journal of Plant Science 92(3):421-425.

Williams, J.R., M.J. Pachta, K.L. Roozeboom, R.V. Llewelyn, M. M. Claassen, and J. S. Bergtold. 2012. Risk Analysis of Tillage and Crop Rotation Alternatives with Winter Wheat. Journal of Agricultural and Applied Economics. 44. No. 4:561-576.

Xue, Q., B. A. Stewart, M. D. Lazar, G. Piccinni, and C. D. Salisbury. 2012. Genotypic variation in osmotic adjustment and transpiration efficiency among closely-related wheat lines. J. Crop Improvement 26:258-281.

Xue, Q., W. Liu and B. A. Stewart. Improving wheat yield and water use efficiency under semi-arid environment. The US Southern Great Plains and China's Loess Plateau.In: R. Lal and B. A. Stewart (eds.), Advances in Soil Science: Soil Water and Agronomic Productivity. CRC Press, Taylor & Francis Group, 2012, New York.

Zhang, Y. H., Q. Xue, B. A. Stewart, K. E. Jessup, and Z. M. Wang. 2012. Genotypic variation of drought tolerance and water use efficiency in wheat seedlings in the US Southern High Plains. ASA-CSSA-SSSA, 2012 International Annual Meetings. Cincinnati, OH.

Zhang, Y. H., S. L. Zhou, Q. Huang, G. H. Leng, Q. Xue, B. A. Stewart, and Z. M. Wang. 2012. Effects of sucrose and ammonium nitrate on phosphoenolpyruvate carboxylase and ribulose-1, 5-bisphosphate carboxylase activities in wheat ears. Australian J. Crop Sci. 6: 822-827.

Zhang, Y. H., Y. P. Zhang, N. Niu, D. Su, Q. Xue, B. A. Stewart, and Z. M. Wang. 2012. Effect of source/sink manipulation on accumulation of micronutrients and protein in wheat grains. J. Plant Nutr. Soil Sci. 175:622-629.