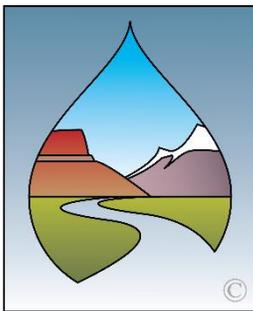


IRRIGATION
MANAGEMENT
INFORMATION SYSTEMS
IN THE WEST:
CAPABILITIES AND
CHALLENGES

October 2016

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WESTERN STATES
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WORKSHOP ON WEATHER STATION NETWORKS AND IRRIGATION MANAGEMENT INFORMATION SYSTEMS

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Introduction

The Western States Water Council (WSWC) has emphasized the importance of accurate and timely data on precipitation, temperature, soil moisture and other weather-related phenomena for effective water management in the West. The Council has also long supported updating and improving our observation systems for climate trend analysis, assessing drought impacts, and allowing for improved irrigation management (i.e., when and how much to water crops and urban landscaping) ¹. The ability to strategically apply water as needed, and to manage irrigation for a drier climate is especially relevant, and can be used to effect greater resiliency during extended periods of drought. To this end, the States, local water agencies, growers, landscape managers, private industry, climatologists, meteorologists, researchers and others may use an array of agricultural weather station networks positioned and operated throughout the West that report key parameters. These agricultural weather station networks are essential for the collection, quality control, and dissemination of data, which are the basis of so many derivative data products. WSWC has identified a wide variety of users and applications, ranging from consultants in irrigation scheduling, fertilizer application, and pest management; water agencies and public agencies for estimating water consumption; home owners for lawn irrigation; to researchers who are exploring weather patterns or water consumption, or modeling irrigation strategies. The data can also be used for firefighting, air quality monitoring, weather forecasting, and water infrastructure engineering designs.



FIGURE 1 WATER CONSERVATION STRATEGIES CAN INCLUDE IRRIGATION MANAGEMENT

As the weather stations age, their extremely limited budgets impact their ability to continue to operate effectively, and threaten their data continuity. Many suffer from spatial data gaps where greater coverage is needed, and the networks become less useful and comprehensive when stations become inactive or need to be decommissioned. Many systems need greater resources, including staff, equipment and sensor maintenance, and quality control processes in order to operate effectively. Additional resources are also needed to improve data dissemination efforts, such as creating and publishing reports, as well as reaching and communicating with their users.

Background

More recently, the WSWC member states have been working together to identify programs to augment and conserve water in their interstate water basins. Water used for irrigation of agriculture is the lion's share of water diverted and consumptively used in the West. One significant application

¹ Positions #356, #366, #385, #392, - See Appendix B.

of the data collected by weather station networks enables and allows for greater irrigation efficiencies and water management based on the day-to-day, real-time, and forecasted weather. In other words, if the weather station network indicates that the air over a particular region is more humid, a nearby farmer can apply less water to his crops. Conversely, if the current weather outlook is drier, and crops have a greater need for water, the farmer can apply more for the duration of the dry period. The agricultural weather stations that provide data for estimation of water requirement based on current weather conditions can also be referred to as an Irrigation Management Information System (IMIS). **For the purposes of this report, the term IMIS is used to describe the subset of weather stations that have irrigation management as one of their core purposes.** All IMIS are based on data provided by weather stations, but not all weather stations (and their networks) function as, or provide data related to irrigation management. Both are described and discussed in greater detail below.

Use of IMIS data can improve agricultural water use efficiency and thereby improve drought resiliency. A great example of a system that operates as described is the California Irrigation Management Information System (CIMIS). The California Department of Water Resources (CDWR) has operated CIMIS, a large state-wide network with over 150 urban and agricultural-based weather station for providing weather information and scheduling applications to farmers and municipal landscape managers since the 1980s. CIMIS gathers key parameters and then estimates the water requirement based on those data, and on the crop-types being grown. The estimate for water requirement is primarily based on equations that use weather station parameters (wind speed, solar radiation, etc.) to calculate Reference Evapotranspiration (ET_r or ET_o , referred to generally as ET for the remainder of this report), and the Crop Evapotranspiration (ET_c), using the selection of the correct Crop Coefficient (K_c)². Accurate estimates of ET_r/ET_o , ET_c , and K_c help growers and landscape managers to apply water optimally. Aside from leaving water instream or underground that would otherwise be diverted, such operations also allow for decreased runoff and application of pesticides and fertilizer, which results in water quality benefits downstream.

Another benefit derived from IMIS data are their use as a ground-truth for estimates of ET generated from satellite imagery and remote sensing. The WSWC supports the use of remote sensing in water management, advocating for related programs and the inclusion of a Thermal Infrared Sensor (TIRS) on Landsat 9³. The TIRS can be used to estimate evapotranspiration and related crop water requirements at a field-level scale and provides greater coverage across the West. Local weather station data is needed in order to calibrate and validate those estimates.

California has seen great benefits from utilizing CIMIS, including: (1) mitigating impacts of drought/climate change; (2) improving the environment and the landscape; (3) producing higher quality crop yield; and (4) irrigation scheduling and management, one of their top strategies for

² Walter, I., Allen, R., Elliott, R., Jensen, M., Itenfisu, D., Mecham, B., Howell, T., Snyder, R., Brown, P., Echings, S., Spofford, T., Hattendorf, M., Cuenca, R., Wright, J., and Martin, D., ASCE's Standardized Reference Evapotranspiration Equation, 2001, <http://ascelibrary.org/doi/pdf/10.1061/40499%282000%29126>.

³ Position # 356 – See Western States Water Council Policies Webpage. Access at: <http://www.westernstateswater.org/policies-2/>.

conserving water and meeting water conservation goals⁴. Due to the CIMIS program's success in California, there is an interest in investigating the potential to expand the CIMIS technologies, standards, and data dissemination techniques into neighboring and interstate basins with potentially interested agricultural weather network partners. In particular, California asked the WSWC to identify networks in interstate river basins that could take advantage of CIMIS' sophisticated database, software, and data publication capabilities, which allows users to generate customized reports of crop water requirement for their area and region, and to receive that information daily in convenient formats, including on their mobile devices. Potentially, other networks could more fully expand irrigation scheduling information and facilitate the adoption of data use by more municipal irrigators and farmers.

To investigate the potential for greater collaboration, the WSWC agreed to co-host a survey and workshop, and to publish a summary report. This report evaluates the capabilities of selected, large-scale agricultural weather station networks and IMIS in the West, determines their data collection capabilities, quality control techniques, and data dissemination; and assesses their potential compatibility with CIMIS. The workshop participants also discussed challenges and data gaps, and assisted in determining what resources may be needed and available to the networks for regional collaboration.



FIGURE 2 A WEATHER STATION IN SNAKE VALLEY, NV

Weather Stations and Networks

Most automated agricultural weather stations gather primary variables that form the basis of reference ET calculations: solar radiation, wind, temperature, and relative humidity. These parameters and others are measured using a variety of sensors and instruments, which are mounted to a fixed weather station stand.

Ideally, a weather station should be installed within or at the edge and downwind of a large expanse of irrigated vegetation that receives enough water to support ET at or near maximum levels. The crop area around the weather station

represents a boundary condition and the energy balance overlying the ground surface. The properties of this area can impact whether or not the weather measurements taken by the station are a reflection of the wider environment and suitable for ET estimation. Weather stations should be removed from obstacles that could impede wind or provide shade to the site. If fencing is necessary, it should be porous and should not extend too high. Unfortunately, there are times and locations where an optimal site, especially in urban areas, is simply not available. This doesn't necessarily

⁴ Temesgen, B. "California Irrigation Management Information System (CIMIS)." Irrigation Management Information Systems Workshop. San Diego, CA. 25 August 2016. PowerPoint presentation.

mean that the weather station can't be used, but that the data from the station should be examined and adjusted for these site conditions.

A weather station is composed of various hardware, including a sturdy base structure capable of supporting the sensor array through inclement weather conditions, solar panels for power, data-logger instrumentation, and a lightning rod. The sensors themselves most commonly include the following:

- a thermometer for measuring temperature of the surrounding air;
- a thermistor for high-precision measurement of temperature via changes in resistance (i.e., resistance that decreases as the temperature rises);
- a pyranometer use to measure solar radiation flux density over wavelengths in the shortwave range;
- wind sensors, including anemometers that measure changes in wind velocity and changes in atmospheric pressure, and potentiometers that measure changes in direction of a wind vane; and
- a hygrometer, which measures moisture levels in the atmosphere via changes in temperature, pressure, or electrical change in a substance as moisture is absorbed.

Other instruments/sensors that are typical among agricultural weather stations include tipping bucket rain gauges or other instrumentation for collecting and measuring precipitation, barometers for measuring air pressure, and reflectometers or other equipment for measuring soil volumetric water content.

While wind and solar radiation are important factors contributing to evapotranspiration rates, these phenomena can interfere with other measurements, especially humidity and temperature readings. Instruments should have adequate shields or protection for the sensors because of this sensitivity, and weather stations should be properly installed far from vertical reflecting surfaces, exhaust fans, etc. in order to avoid interference.

The data-logger of the weather station operates by polling the sensors on a frequent basis, usually every 1 to 15 minutes. These readings are averaged or totaled over intervals (generally between 15-60 minutes), and transmitted to the data server on an ongoing (usually hourly) basis. The data are then used to calculate daily maximum, minimum, average, and total values. Some of the data may be stored in the data-loggers, while other data may be discarded. Network operators then conduct quality control, sometimes with the assistance of automated systems, flagging and reviewing anomalies, and adjusting the data to reflect true environmental factors as needed.

Once the data have been vetted, the ET values are calculated using standardized equations, such as the ASCE Penmen-Monteith, or other equations that may be useful for the network operator or users. Hourly ET estimates can then be aggregated to produce a daily ET estimate. These estimates can be used directly by irrigators and farmers by applying a crop coefficient to calculate a specific crop's ET requirement. Sometimes individual site estimates for the variables that comprise the ET calculation can be interpolated and then aggregated to provide a more spatially expansive coverage of ET estimation. In other words, ET can be derived for an entire grid coverage when data are available at a spatial resolution that enables interpolation. This interpolation is accomplished by coupling parameters measured at weather stations and remotely sensed solar radiation data, which produces

spatially distributed ET estimates. These interpolated estimates are especially important in areas of diverse land cover, topography, climate, and where there is a lack of available weather station data.

Weather station networks in the western states are managed by a variety of public agencies, private companies, and educational institutions. Some networks collect and provide their own data directly to users, while other networks serve as data aggregators, providing weather and IMIS data collected by other smaller networks (e.g., MesoWest or the Meteorological Assimilation Data Ingest System (MADIS)). Contributors to both types of networks may be public and private entities who share provisional, non-proprietary, and publicly available data. Some networks manage and share data collected by their own stations as well as data collected by other networks (e.g., AgriMet and the Utah Climate Center (UCC)). Networks can be large or small, with hundreds or just a few contributing stations. Network operation usually involves staff located at a central data repository to oversee the network's operation, to check and process data as it is received, and to maintain and calibrate weather station equipment. As networks are independent of each other, often they have different methods for data quality control, sensor purchasing and maintenance, as well as data dissemination, which can present challenges to regional integration.

IMIS Workshop

The following sections contain information presented at the WSWC/CDWR workshop from selected, larger-scale weather station networks that also function as Irrigation Management Information Systems (IMIS). It summarizes each network's capabilities, equipment operation and maintenance, data gathered, quality control procedures, adoption and usage, and funding. The information provided is a synthesis of the information presented by the network's representative at the workshop, as well as preliminary background research on the network, in no particular order. There are other weather station networks located in the West that were unable to attend the workshop. Due to report size limitations they are omitted here. As part of the workshop preparations, a comprehensive survey was distributed to several larger weather station network operators and aggregators. The survey results are provided in Appendix C.

Tony Willardson, Executive Director of the Western States Water Council welcomed the participants to the workshop and discussed the Council's role facilitating discussions on the science and technology needed to effectively manage water resources in the West. The Council has worked on a variety of related topics, including maintenance of hydrologic monitoring networks, including streamgages, SNOTEL sites, weather stations, and a larger effort to maintain the Thermal Infrared Sensor capabilities on the LandSat satellite missions. The Council also coordinates with a large number of federal agencies with water responsibilities in the West through a collaborative body called the Western Federal Agency Support Team (WestFAST). Tony noted that the purpose of the workshop was to determine the current status of the various larger weather and irrigation management information system networks around the West, and that he and the other attendees were excited to learn more about how they are being operated, maintained, funded, and used.

Jeanine Jones, Interstate Resources Manager, CDWR, expanded on the motivation behind the workshop. She explained the benefits that California had been able to gain from using the CIMIS weather station network. The workshop is a means of exploring any synergies or opportunities that exist to expand this beneficial experience to other neighboring state basins. It will also explore if there are any other ways to assist the networks being discussed (and others), either through information exchange, or support and advocacy by the WSWC.

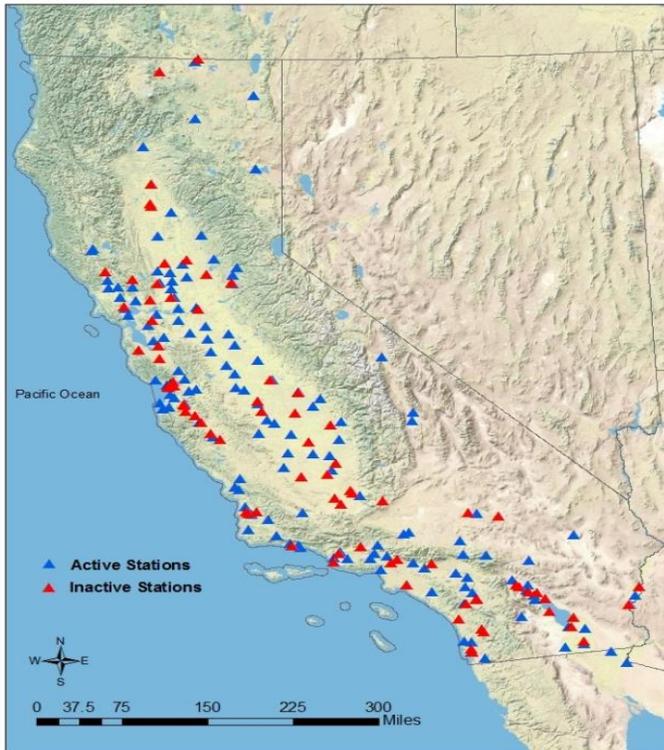


FIGURE 3 CIMIS NETWORK WEATHER STATIONS

CIMIS

Bekele Temegson, a Senior Land and Water Use Scientist for CDWR, presented on the California Irrigation Management Information System (CIMIS). CIMIS was a joint effort between CDWR and the UCD begun in 1982, with CDWR taking over the program entirely in 1985. CIMIS is comprised of over 150 automated weather stations (with an additional 96 inactive stations with archived data) (See Figure 3).

A typical CIMIS weather station apparatus sports the standard array of sensors, but is required to be sited over a ground cover of fully-transpiring grass or vegetation extending 200 meters in all directions. Some stations are owned by CDWR, while others are owned by cooperators on the network, including local water agencies, universities, cities, the U.S. Department of Agriculture, the

U.S. Bureau of Reclamation, water conservation districts and private entities. Data are logged every minute, and then averaged and totaled every hour. These are then used to calculate the daily maximum, minimum, average and total values for each variable. CIMIS servers retrieve the data every hour and they undergo a quality control procedure. Reference ET values are generated for every hour and then aggregated to a daily time step. The Penman-Monteith and a modified Penman-Monteith (CIMIS Penman) equations are used to calculate reference ET, with the intent to move toward Penman-Monteith only in the future.

Over the past 15 years, users have grown to approximately 55,000, with annual hits on their website generally around 2 million, while in 2015 (during drought) there were 12.5 million hits⁵. Applications of the data include: irrigation scheduling, air quality monitoring, firefighting, energy generation, engineering designs, weather forecasting, and pest management. The myriad benefits reported from using CIMIS data include water and energy savings, mitigating drought impacts, improving the environment, higher crop yields, and improved landscapes.

One of the most useful products provided by CIMIS is Spatial CIMIS data, a product that began publication in 2009, which addresses spatial gaps in the network by using spatial interpolation of the variables that are used for ET calculations. Spatial CIMIS couples remotely sensed data from a Geostationary Operational Environmental Satellite (GOES) system with CIMIS weather station data to

⁵ California Irrigation Management Information Systems (CIMIS) Webpage. Accessed 9/13/2016 at: <http://www.cimis.water.ca.gov/>.

provide daily two-kilometer resolution grid maps of reference ET (See Figure 4). These data are also made available to users using the CIMIS website in spatial reports that are address-searchable.

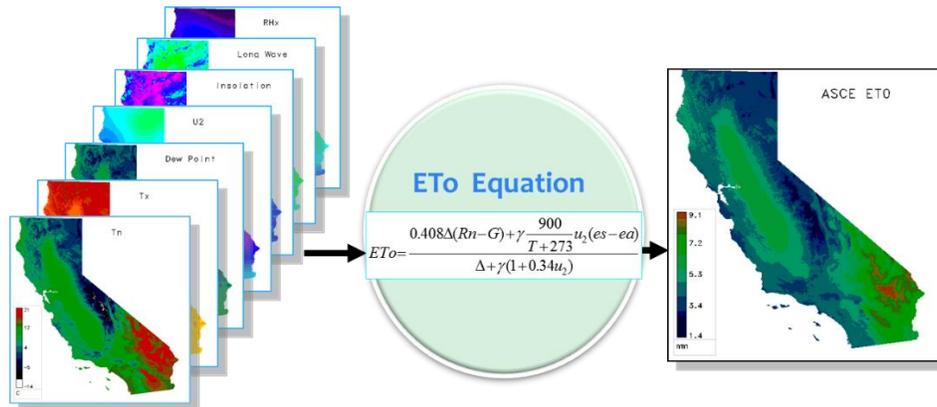


FIGURE 4 SPATIAL INTERPOLATIONS OF WEATHER DATA COMPRISING SPATIAL CIMIS ET ESTIMATES

Funding continues to be a challenge for the CIMIS network, as its budget has not increased, despite massive growth in stations and in the number of users and applications. Future plans for CIMIS include extending the network and continuing to develop other derivative products, tools (developing an app with UCD), estimates (including crop coefficients and estimates of ET), and forecasts based on CIMIS network data.

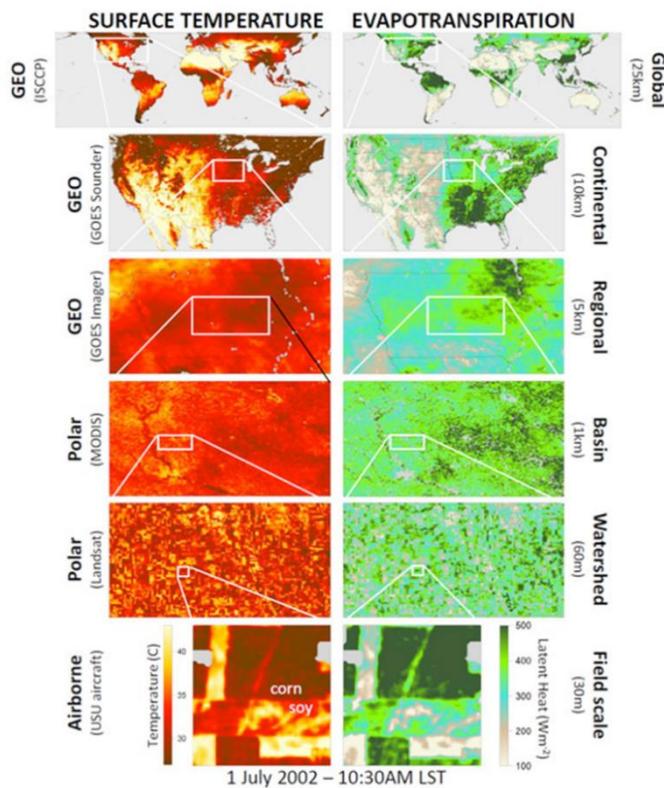


FIGURE 5 A VARIETY OF SCALES FOR NASA-AMES PRODUCTS

Forrest Melton, a Senior Research Scientist with the National Air and Space Administration (NASA)-Ames Research Center, discussed the emerging importance of weather station networks and related ET estimation due to recent droughts and water quality issues. Forrest highlighted a significant list of applications that are dependent on quality weather station and ET data. He also highlighted the need for data development to implement California's new Sustainable Groundwater Management Act (SGMA). To address this need, a variety of agricultural water use-related products are currently in development. These products are geared toward a number of different scales (field-scale, watersheds, basins, regions, continents and global coverage) (See Figure 5).

As ET data providers, NASA-Ames has found that it is not enough to provide the raw ET data to growers and other users; instead, they need the data to be translated to more directly aid management decisions, using pre-configured tools that assist with

determining irrigation run times. Their approach to operationalize ET mapping includes combining the strengths of different methods to ensure data continuity and provide the best available data. This includes automating the Mapping EvapoTRanspiration with Internalized Calibration (METRIC)⁶ energy balance approach, where ET is calculated as the residual of the balance between incoming and outgoing radiation at the earth's surface. Additionally, the Satellite Irrigation Management System (SIMS) uses a reflectance-based approach, which relies on satellite-measured reflectance and indices of vegetative cover and health to map crop cover, crop coefficients, and crop evapotranspiration. These, combined with CIMIS and spatial CIMIS, bring many tools to the hands of water managers and irrigators alike to make good decisions with their water. NASA-Ames would like to simplify the process even more with the development of the IrriQuest tool, which aims to bring CIMIS data together with input from a grower, for crop evaporation estimates and resulting irrigation schedules.

The METRIC automation task allowed for a greater number of model runs using a Monte-Carlo simulation, but computation times were high. To resolve this NASA has brought high-performance computing to run METRIC for entire states over a period of years (i.e., using approximately 100 scenario runs per satellite "scene" for 100 different annual totals for ET). The Monte Carlo simulations provides estimates of uncertainty for ET datasets, and NASA is currently quantifying the accuracy of such runs using eddy covariance and soil balance estimates of ET for multiple crop types.

Forrest highlighted many other projects under development at NASA to assist with water management, but emphasized one major development – the creation of a Western Water Applications Office⁷ at the Jet Propulsion Lab (JPL). This new local western office will help to inform water decisions with NASA data. This new office is under development, with a focus on stakeholder engagement, project transitioning (from research to applications), and funding project awards.

AgriMet

A presentation on the AgriMet network was given by Jama Hamel, the AgriMet Program Coordinator. She is based at the U.S. Bureau of Reclamation (USBR) Pacific Northwest Region office in Boise, ID⁸.



AgriMet was developed by the USBR, the Bonneville Power Administration (BPA), and others as a subset of the USBR's Hydromet network. Under the umbrella of Hydromet's broader goal, which is to provide data that is useful for near-real-time management of the USBR's water operations, AgriMet provides data for agricultural applications such as crop water use modeling and irrigation management in order to promote conservation of water and energy.

Since the program began in 1983, the network has expanded geographically from the Pacific Northwest to Montana and Idaho, with more than 170 weather stations (See Figure 6). The AgriMet

⁶ Allen, Richard G., Masahiro Tasumi, and Ricardo Trezza. "Satellite-based energy balance for mapping evapotranspiration with internalized calibration (METRIC)—Model." *Journal of irrigation and drainage engineering* 133.4 (2007): 380-394

⁷ NASA Applied Sciences Program – Water Resources website. Accessed 9/13/2015 at: <http://appliedsciences.nasa.gov/programs/water-resources-program>.

⁸ U.S. Bureau of Reclamation Pacific Northwest Region Office – AgriMet Program website. Accessed 9/13/2016 at: <http://www.usbr.gov/pn/agrimet/>.

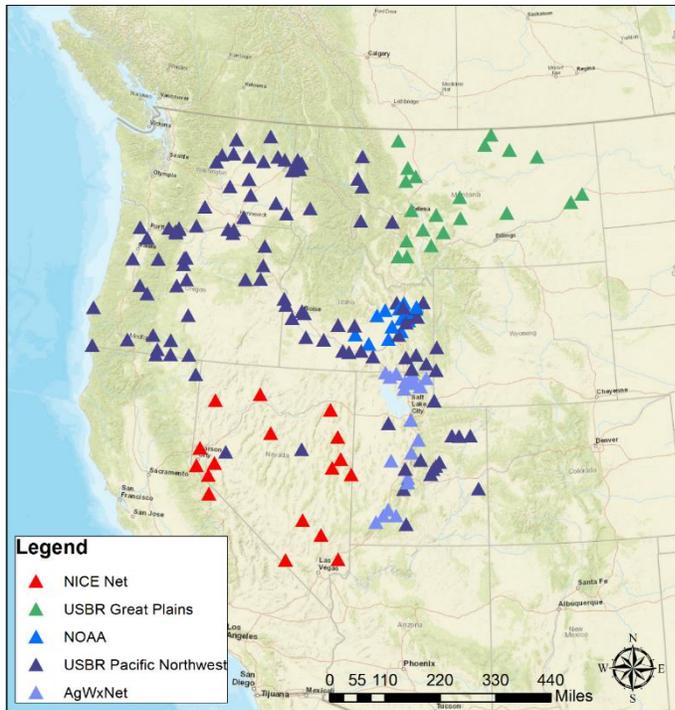


FIGURE 6 AGRIMET NETWORK WEATHER STATIONS

data portal also provides data collected by other networks, including AgWxNet (managed by the UCC), NICE Net (managed by the Desert Research Institute), the National Oceanic and Atmospheric Administration (NOAA), and the Department of Energy's Idaho National Laboratory weather stations.

Jama discussed the advantages of working as a cooperative network. The size, funding, and legislative authority at the USBR ensure the longevity of the program. The network is sponsored primarily by the USBR and the BPA, and is also supported financially by the USDA Agricultural Resource Service, the USDA Natural Resources Conservation Service, and a number of other state, federal, and private interests (such as Anheuser-Busch).

Costs of the network are shared across these partnerships between the USBR and other agencies and institutions. The costs of initial purchase and installation of new weather stations (estimated at \$8,000 each) are shared with different sponsors, while the ongoing operation and maintenance costs (estimated at \$1,600 annually) are supported by individual sponsors.

Each of the sensors on AgriMet stations provide data every second, which are then compiled to more manageable frequencies. The data are collected via cellphone modem, and then processed at the USBR Pacific Northwest Region office. For quality control purposes, the data are reviewed on a daily basis by using both automatic and manual reviews. As data are uploaded into the database, automatic procedures and validation tests flag possible errors from transmission, calculation, or in measurements themselves.

These flagged data are excluded from summary calculations, such as average daily temperature or daily evapotranspiration estimates, until adjustments can be made. Daily manual reviews include checking satellite transmission quality parameters and comparing graphs of sensor data from sites with similar climate characteristics. Poor data (determined by manual reviewer discretion) is either estimated (linearly interpolated) or deleted and subsequent calculations are recomputed. AgriMet stations undergo annual maintenance and inspection each spring, which includes calibration and maintenance for the instruments and sensors installed on the station. This is more frequent maintenance than what is called for by the ASCE standard, which is every two years.

Quality-controlled hourly data and related ET estimates are then made available for download over the AgriMet website. Additionally, daily data for individual (or multiple) parameters may be downloaded for user-defined periods for individual stations from a historical archive. Currently, AgriMet is moving towards standardizing data retrieval, calibration, and maintenance across state

boundaries (though there are still improvements to be made in standardization across networks). Many of the locations for AgriMet stations are not located directly over well-irrigated crops (but are generally located in or near pivots, or their corners). The station's siting is often determined by availability and convenient access. Jama estimated that only a small percentage of the AgriMet weather stations would meet an extremely rigorous standard of siting over a ground surface of fully-irrigated vegetation/turf, such as is required by the CIMIS network.

Crop water use and ET information provided by AgriMet is used by individual irrigators as well as local agricultural consultants, the Cooperative Extension Service, and the USDA Natural Resources Conservation (NRCS). One study found that AgriMet (and other online services) are the most commonly used source for obtaining ET information⁹.

In addition to the use of AgriMet data for ET and crop water needs, other agricultural applications rely on weather information such as wind speed and direction to schedule and plan different activities such as field burning and aerial pesticide application. Other non-agricultural users include State Divisions of Environmental Quality for investigating pollution from pesticide application and groundwater contamination, the National Weather Service for forecast verification, local utilities for forecasts of daily energy requirements and peak power use, academic researchers for modeling regional consumptive water use, and many others.

User and public outreach efforts have included signage to explain the purpose of the station and the network, working with the network sponsors to encourage growers to use the data products consistently, and introducing weather data in schools to encourage interdisciplinary involvement. According to AgriMet program estimates, the AgriMet website receives roughly 150,000 visits per month.

Challenges for the ongoing maintenance and operation of AgriMet include significant understaffing. This includes staffing for the data processing phase, as well as data-sharing and publication, and website maintenance. AgriMet has a very limited budget for these concerns and for the expansion of the network itself. The geographic distances involved in the maintenance of such a large network are a challenge. AgriMet operators have come up with many creative solutions to try to save funds on replacing and calibrating equipment at remote locations, such as finding reliable local contractors, shipping parts, and training them to perform the needed work. Another challenge for AgriMet is the difficulty of determining who their users are and what they are doing with the data. Currently, website metrics such as web page access and number of downloads are the only automated, non-anecdotal means AgriMet has of knowing how usage of the data is increasing or decreasing.

Jim Prairie, a hydraulic engineer for the USBR, also presented on some initiatives that the USBR is interested in pursuing that are specific to the Upper Colorado River Basin (UCRB) region in the future. During the initial stages of the initiative, the USBR and UCRB worked with the States' climate network administrators to assess the suitability of existing weather stations for inclusion in a UCRB climate station network pilot. Existing stations that met the UCRB-prescribed standards cover a total of 1.02 million acres of land. The USBR and UCRB would like even greater coverage, and have plans

⁹ Kema-Xenergy, Inc. 2003. "A Study of Irrigation Scheduling Practices in the Northwest". Prepared for Bonneville Power Administration, Portland, Oregon, September 5, 2003.

to install an additional 30 stations for a total coverage of 1.3 million acres in 2017. The proposed climate stations will be purchased and “owned” by the USBR, but the State Climate Network operators will work with land owners to install the stations and perform annual equipment/sensor maintenance. They will also perform the necessary quality control on the data provided.

With the additional coverage, UCRB plans to conduct a basin-scale remote sensing study that will evaluate different methods for estimating ET and consumptive use, including a comparison of Blaney-Criddle and Penman-Monteith methodologies. The Blaney-Criddle method is relatively simplistic, requiring inputs of only air temperature and precipitation. It results in estimates of ET that are generally less accurate than the Penman-Monteith method, and is used mainly for coarse (monthly or greater) estimates of ET. In order to ensure that there is clarity between the accuracy of the methods analyzed by the study, the UCRB also plans to install three to four eddy covariance towers that will provide a mechanism for “ground-truthing” the study results. These will be managed by the UCC staff.

The hope is that, once a methodology is standardized for the UCRB, it can be used to generate consumptive use estimates for irrigation every six months, instead of every two years. Having that refinement of information regarding irrigation water requirements will provide significant benefit for not only USBR, but for many stakeholders that need water use information for the UCRB region.

CoAgMet

Zach Schwalbe, the Network Manager for CoAgMet (short for Colorado Agricultural Meteorological Network), provided an overview of the network for the workshop attendees. It consists of 96 weather stations distributed throughout Colorado, which are classified by different siting locations, either partially irrigated, fully-irrigated, or dry-land siting. There are 27 stations in a dry-land environment,

36 in fully-irrigated, and 28 in partially-irrigated environments (one is unspecified). These stations are shown in Figure 7. The network has grown from eight stations in eastern Colorado to the current 96 stations as interest from potential users led to increased funds and support.

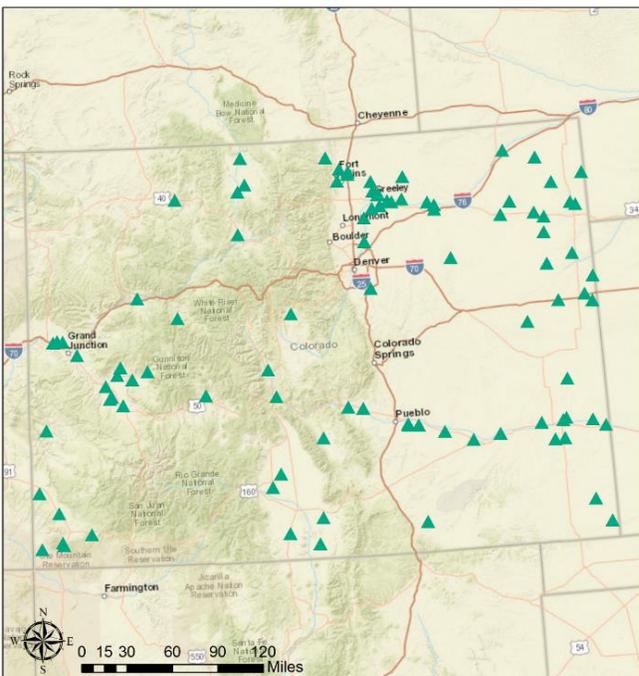


FIGURE 7 CoAgMET NETWORK WEATHER STATIONS

Established in the early 1990’s, the network was the result of the combined efforts of Colorado State University plant pathology researchers and the United States Department of Agriculture - Agricultural Research Service, who shared a motivation for obtaining weather data for their respective interests, prediction of disease outbreaks in high value crops, and to provide recommendations for irrigation scheduling. Incidentally, the current network configuration and management structure was partly motivated by a Supreme Court

lawsuit which required an improved monitoring of crop consumptive use. As more applications for the network's data evolved, more partners and more opportunities for expansion of the network emerged. The twenty years that the network has been operated, it has used a model of "shared benefits and shared responsibilities" among the partners, including the extensions, the National Resource Conservation Service, conservation districts, commodities groups, and gradually water professionals. These include sharing field technicians and maintenance of the stations, pooling year-end funding and donations. CoAgMet will also benefit from the expansion described by Jim Prairie.

The stations in the CoAgMet network measure temperature, humidity, solar radiation, wind speed and direction, precipitation, and soil temperature, and report on both an hourly and daily basis. Since 2014, the data have been transmitted via cell modem. Quality control of the data is done manually, using a software package designed to facilitate the task. The weather station database is updated immediately with any adjustments to the data and shared online. Data for multiple parameters are available to users in numerous formats and summaries, and users can access archives from 1992 to the present. ET data are calculated using the Penman-Monteith (ASCE Standardized) and using the Penman-Kimberly method. These data are also disseminated over CoAgMet's website as a regional report.

Evapotranspiration and other weather data reported by the CoAgMet program are widely used by growers or producers throughout the state. This information is used for irrigation scheduling (timing and amount of water applications), and to plan pesticide applications. Other non-agricultural uses include drought monitoring, environmental monitoring, and renewable energy applications. According to Nolan Doesken (Colorado State Climatologist) and Thomas Trout (research leader for USDA-ARS Water Management Unit), the number of water consultants, engineers, and attorneys involved in water law currently outnumber the number of agricultural producers or consultants who use the CoAgMet data. For example, the Colorado Division of Water Resources (DWR) uses CoAgMet data to estimate crop water use in key water basins, and the State Engineer uses CoAgMet data in the management of the Arkansas River Compact (1948) between Colorado and Kansas.

One of the key challenges for the CoAgMet network is siting weather stations. Most of the current stations are located near agricultural lands, but some were simply sited where open space was available, in sometimes non-optimal settings. Funding is a challenge as well. There are no full-time employees dedicated to the maintenance of the stations, so the network relies on its partners to maintain them in most cases. Sensors are replaced every other year, with the exception of the bearing in the cup anemometer, which are replaced annually. There is funding from the State of Colorado now, as the Colorado Basin Roundtables learn about consumptive water use and how the information yield water conservation benefits. Funding is primarily used for maintaining the network's data quality, but has also been used to develop an online mapping and metadata system. The mapping tool can show up-to-date and historical data, and provides photos of the weather station site, as well as metadata concerning the site's configuration and maintenance¹⁰.

NICENet

Daniel McEvoy, from the Desert Research Institute, provided information on the Nevada Integrated Climate and Evapotranspiration Network (NICENet). NICENet was developed



¹⁰ CoAgMet Homepage. Accessed on 9/13/2016 at: <http://ccc.atmos.colostate.edu/~coagmet/>.

during the 2010-2012 period through a collaboration between the Desert Research Institute (DRI), the Western Regional Climate Center, the State of Nevada Division of Water Resources/Nevada State Engineer's Office, and the USBR. The USDA and Southern Nevada Water Authority are also part of this collaborative effort, operating one station each. Currently, there are a total of 18 weather stations (shown in Figure 8). Most weather stations in Nevada are located in non-irrigated environments, and have been found to produce errors as large as 30% when used for estimating crop water demand due to extreme aridity. However, as the focus of NICENet is on irrigation and agricultural water requirements, the stations included in the network are located specifically in irrigated environments. Estimates for operating and maintaining costs for the system are \$1,500 per station annually. Previously, this funding was through a USBR grant.

NICENet has relaxed standards for siting weather stations although they are primarily in an agricultural setting and also tend to be located in valleys. The stations are designed with an emphasis on precipitation measurements (include both tipping buckets and weighing gages for frozen precipitation) because of the intended use in irrigation water requirement estimation.

The NICENet stations measure solar radiation air temperature, relative humidity, wind speed, precipitation, barometric pressure, soil temperature, and soil moisture. Computed variables are also available, including reference ET, heating, cooling, and growing degree days, wind chill, heat index, and dew point temperature. These data are transmitted on an hourly basis from the individual stations through Geostationary Operational Environmental Satellite (GOES) satellites.

NICENet is markedly different from other weather station networks in that only raw data are published. These and other data products, such as time series graphs and hourly frequency distributions, are provided through the NICENet data portal¹¹. The NICENet operators do use a software package that assists with checking historic data for anomalies, but it is for in-house review and analysis. NICENet uses the Penman-Monteith equation to estimate reference ET and resulting water requirements by crop type.

The NICENet team has supported several other applications and studies related to ET data, including the Google Earth Climate Engine for disseminating ET data products more widely, and the use of ET

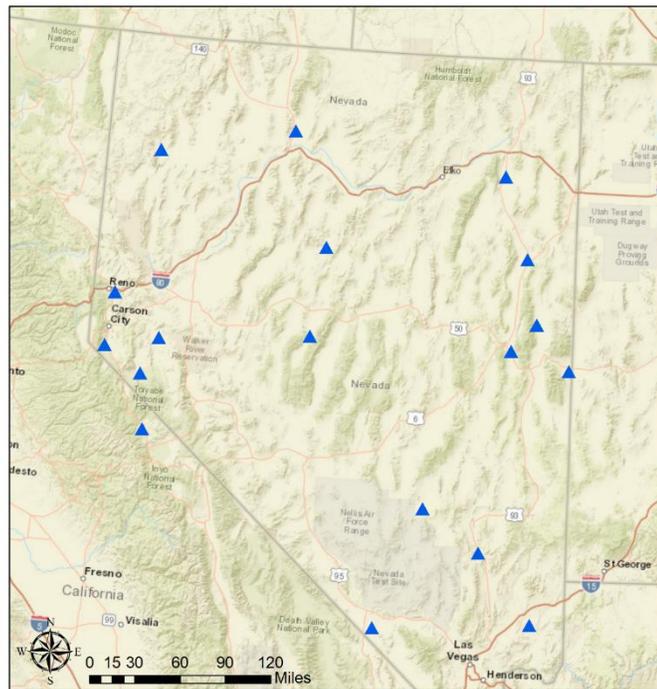


FIGURE 8 NICENET WEATHER STATIONS

¹¹ NICENet – Nevada Integrated Climate and Evapotranspiration Network website. Accessed 9/13/2016 at: <http://nicenet.dri.edu/>.

as a metric for drought detection via an Evaporative Demand Drought Index.

Other users of the data include a variety of local irrigators, as well as conservation districts. For example, the Carson Water Sub-Conservancy District has used NICENet ET data to determine how much water to use in municipal parks throughout several counties. Some farms, such as Winnemucca Farms, rely on a combination of their own weather stations and NICENet station data to manage irrigation scheduling. In addition to irrigation/agricultural applications, weather data from NICENet stations have also been used by the USBR to estimate water evaporation losses from Lake Mead. Future plans include integrating NICENet data into an Irrigation Scheduler App and further emphasizing the use of the data for drought monitoring and forecasting.

AZMET

Bruce Russell and Paul Brown (presenting remotely) expanded on the Arizona Meteorological Network (AZMET) for the workshop attendees. The AZMET program, which began in 1987 through the University of Arizona, consists of both urban and rural agricultural/production-focused weather stations. Currently, there are 28 active weather stations (with several deactivated and temporary stations) located throughout Arizona (Figure 9). The original purpose of the AZMET network was to provide near real time information about weather and crop water needs to agricultural and horticultural producers, though it has expanded to users outside of the agricultural industry. AZMET is currently the only program which continuously monitors and provides information regarding ET, water use, and other weather/climate parameters in Arizona. Over the life of the program, the network has also expanded to provide useful monitoring of the hydrologic cycle along the Colorado River.

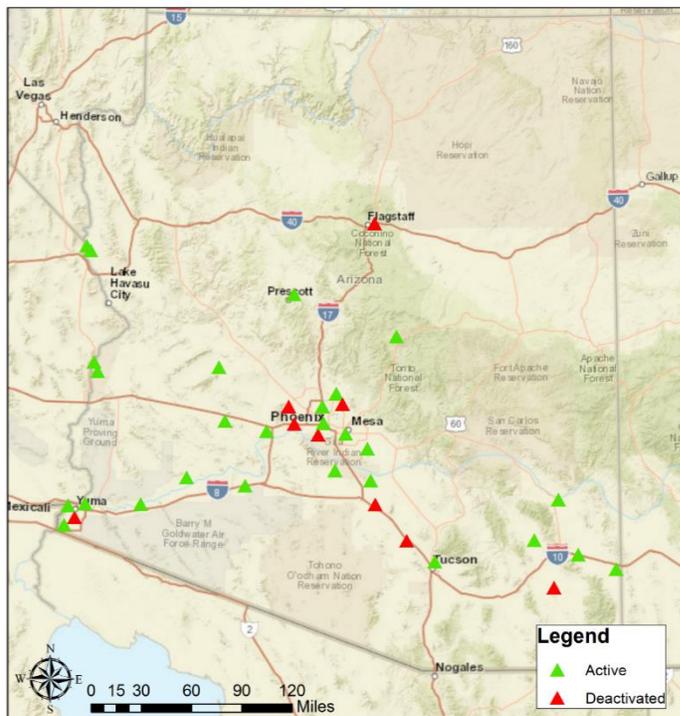


FIGURE 9 AZMET NETWORK WEATHER STATIONS

Data collection by AZMET includes temperature (air and soil), humidity, solar radiation, wind (speed and direction), and precipitation. AZMET also provides a variety of computed variables: heat units (degree-days), chill hours, and reference and crop evapotranspiration estimates using modified and a standard Penman-Monteith equation. A central data-logger reads the sensor measurements continuously, and stores the measurements on an hourly basis. The data is automatically transmitted via cellphone modem to the University of Arizona on a daily basis. The data are processed by an automated and manual review, and made available to the public soon after. These data are provided in both tabular summaries and ASCII text files. Additional data products include special reports such as the Phoenix Area

Turf Water Use Report and the Weekly Cotton Advisories.

Maintenance of the sites occurs on both seasonal and annual bases. Each station is visited by an AZMET technician at least once every three months, where laboratory-standard sensors are used to test the performance of the sensors and calibrate. Some sensors, such as the wind speed and solar sensors, are removed and recalibrated on an annual basis, while others (temperature and humidity sensors) are recalibrated every other year.

The AZMET program, its data products, and reports provide a number of benefits in addition to general irrigation management. For example, the reported heat units have been credited with increasing efficiency of melon and vegetable harvesting (by planning the timing of planting and harvesting), and are useful in predicting both crop and insect development (which aids in planning for insect/pesticide applications).

A 2001 survey by the University of Arizona Cotton Monitoring Program indicated that 80% of participating growers alter management of cotton based on information provided by the advisory reports (produced by AZMET and the Arizona Cotton Advisory Program), and 96% of growers indicated that they would like the advisory program (and the reports it produces) to continue.

These reports generated by AZMET include water-use (current and projected) recommendations for corn and alfalfa, heat-stress reports which are used by a number of growers/vineyards, and development tracking for specific small grains. AZMET data have also been used in livestock management to reduce heat stress on cattle, resulting in increased milk production. Other non-agricultural industries which have used AZMET data include aquaculture, environmental cooling system design, construction planning, and automotive engineering. AZMET data and reports have also been used in environmental impact assessments concerning air quality, insurance claims, and water rights adjudication¹².

Another major group of users are golf courses and those in the turf industry. Three Phoenix-area stations are located directly on golf courses, and are used to determine water requirements for many of the area's golf courses. The information gathered from these stations are used to create Turf Water Use Reports in both the Tucson and Phoenix areas. As of 2000, the turf web management page (maintained by AZMET) was accessed more than 1600 times/year. In addition to the web page, the information is also distributed to 16 "large turf facilities" (locations with more than 10 acres of turf, namely golf courses and parks) via email on a daily basis.

Some of the main challenges for the AZMET program include performing regular maintenance due to the large distance to many stations. Again, stations are typically visited on a quarterly basis. Funding and uncertainty in program continuity are also of concern. Currently, there are three people coordinating and managing the system, and there is a great deal of uncertainty about future coordinators. Four stations are being decommissioned due to lack of funding.

New Mexico's AgMet

David DuBois, the New Mexico State Climatologist, presented an overview of the status of New Mexico's AgMet Network. It was begun in the late 1980's by New Mexico's first state climatologist

¹² AZMET - the Arizona Meteorological Network website. Accessed on 9/13/2016 at: <http://ag.arizona.edu/azmet/>.

Ken Kunkel. The weather stations are sited at New Mexico State University (NMSU) Agricultural Science Centers and co-located with National Weather Service stations. There are currently ten active stations statewide, with another three that have been decommissioned (See Figure 10). The program intends to bring four stations back online after being relocated.

The New Mexico AgMet program has evolved over time, and now is able to collect data in a more automated fashion into a database management system. The data are accessible from the NMSU website. Annual operating funds are provided by external grants, contracts, and additional funding from a national Mesonet contract. Some of the weather station sites are in ideal locations downwind of agricultural fields, and over active vegetation, but several are not. Many of the stations face siting challenges because of the temporary fetch conditions that reflect changes in research projects. The sites gather the standard suite of weather parameters described for other networks. However, maintenance records have only been collected since 2010. About this same timeframe is when some of the equipment was re-serviced and re-calibrated. Some local operators have also agreed to assist with site maintenance and operation. The current maintenance schedule for the sites includes an annual visit, with sensor replacements every three to four years, with wind-sets being repaired and reused.

The data are given a quality control step using an automated routine that looks for out-of-range values and missing data. These are flagged for manual review and relayed to technicians for adjustment. The New Mexico State Engineer's Office also performs a quality control check on the data by conducting a physical evaluation of the sites and review of their data. Efforts to provide ET estimates for the state of New Mexico have led to their incorporation into the National Weather



FIGURE 10 NEW MEXICO'S AGMET NETWORK WEATHER STATIONS

Services' Experimental Forecast Reference Evapotranspiration (FRET) product disseminated over the NWS website. The New Mexico AgMet has conducted several comparisons between the FRET products and various other methods of estimating reference ET. NMSU does provide Penman-Monteith and Hargreaves ET estimates through an online web portal¹³.

Current challenges include upgrading the quality control procedures and maintenance of weather stations, and addressing the disconnect between the AgMet and other networks (UCC and AgriMet) to standardize maintenance and quality control procedures. There is also a plan to include further metadata about the sites and maintenance in later data publishing. Funding for the program remains a significant challenge, with the budget being used for salary for the State

¹³ New Mexico State University – New Mexico Climate Center – Weather Station Data website. Accessed 9/13/2016 at: <https://weather.nmsu.edu/wx-stn-data/>.

Climatologist position, equipment operations and maintenance, and data processing and publication. The New Mexico AgMet is hoping to develop new partnerships with regional users of the data – possibly new crop growers or other state agencies.

Utah Climate Center Network

Pawel Szafruga, a research technician from the UCC, presented on their various network capabilities and products. Their data network includes data from UCC weather stations, but also data from over 160,000 other stations provided by the Fruit Growers Network (FGNet), AgWeather, AgriMet, U.S. Climate Reference Network (UCRN), and other research-based stations (See Figure 11). There are many different applications for the data, including inversion forecasting, pest management, and other resources.

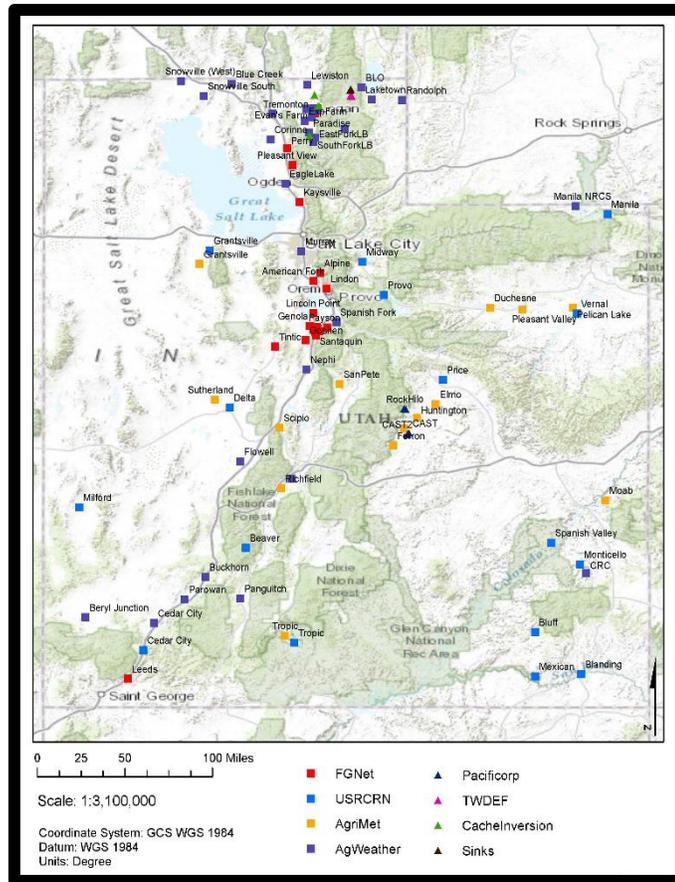


FIGURE 11 UTAH CLIMATE CENTER NETWORK WEATHER STATIONS

The data collected from the stations undergo an automated and manual quality control and processing scheme before being provided to the public in the form of graphs and charts of the various weather station variables available and ET estimates. These are also provided in an Irrigation Scheduler mobile application (in part due to the UCC’s partnership with the AgriMet network)¹⁴.

Instrumentation inspections are conducted annually, with most problems predicted from data coming from the various sensors. The network program will replace and recalibrate temperature and relative humidity sensors every two years, tipping buckets annually, and wind speed sensors every two years. The instrumentation maintained by UCC also includes five eddy covariance systems for research-based projects. The UCC also uses their weather station data to produce water supply-related research, lake elevation forecasts for the Great Salt Lake, and 30-day forecasts for inversion/bad air quality days in the Salt Lake and Cache valleys.

The UCC conducts a significant amount of outreach and education, with multiple interviews, lectures, newsletters and other visualizations/use cases for their data. They also participate in collaborative

¹⁴ Utah State University – Utah Climate Center website. Accessed on 9/13/2016 at: <https://climate.usurf.usu.edu/>.

international research addressing paleoclimate, drought, climate extremes, trends, predictions, severe weather, including tropical cyclones.

Future work for the UCC includes a revamp of their current web tools, including a mobile application for irrigation scheduling. They would also like to continue to develop their automated quality control systems and back-fill bad data. Investments could be made to “bullet proof” weather stations on the network, and to increase the reliability of data telemetry. The annual budget for the UCC is about \$400,000 and supplemental income from research grants and contracted services. These cover the salaries of UCC professional staff and technicians, pay for contracted IT services, and the operations and maintenance of the stations on the network.

Final Discussion: Challenges for Operators

During the final discussion of the materials presented at the workshop, several key challenges were identified by participants as themes to focus on during follow-up activities:

Station Siting and Maintenance – Many networks are unable to install stations in areas with ideal pitch/crop conditions. Some of the obstacles include finding willing partners with suitable crop types, changing crop types/irrigation practices to accommodate research needs, and ease of access for maintenance and calibration technicians. Local conditions may have a significant impact on the accuracy of parameters used to calculate ET, and differences in siting standards may impact the ability to share data across networks. Regular station maintenance and calibration of sensors is required to ensure the quality of the data. Stations may need maintenance because of aging infrastructure/sensors, fouling from the elements, or from vandalism. Networks often differ in standards and available resources for maintenance and calibration, which creates potential problems in sharing data with other networks.

Opportunities for Collaboration - Managers and coordinators of the various weather station networks do not meet often, which can lead to disconnects (such as differences in quality control methods for UCC and AgriMet, even though they share data with each other) or missed opportunities for partnerships. Different policies and standards for data, sensors, maintenance, and calibration create problems when sharing what could be compatible data alongside other networks’ data.

Funding - Funding challenges are common among the workshop participants. Securing funding sources is extremely important, especially for smaller networks where tens of thousands of dollars could make or break the system. Many networks are understaffed due to funding shortages, which limits the amount of maintenance, quality assurance, and analysis that can be done by those who manage the network. In some cases, the networks are managed by one or two people, or a handful of personnel who are only available to work on the network part-time.

Many of the networks have not had increases in their operating budgets for many years (and in some cases, no budget increase since program inception), or have lost their funding sources. In order to continue to provide high-quality data that underpins so many other important tools, more resources should be directed to the network operators to fill in data gaps, maintain equipment, and further develop their data gathering and quality management techniques.

A summary of rough annual program budgets for each of the networks that participated in the workshop is provided in Table 1.

TABLE 1 SUMMARY OF IMIS NETWORK PROGRAM BUDGETS AND FUNDING SOURCES

Network Name	Approximate Annual Program Budget	Funding Source
CIMIS	\$1,000,000	CA General Fund
AgriMet	\$300,000	Federal, State, Local and private partnerships
CoAgMet	\$185,000	State, Colorado Water Conservation Board
NICENet	\$40,000	Previously: Federal funds; Currently: Unfunded
AZMET	\$160,000	University and Private partnerships
AgMet	\$30,000	National Mesonet contract
UCC	\$400,000	State Allocations

Sensor Failure – Failure of individual sensors results in poor data/loss of data. Regular calibration and maintenance helps prevent catastrophic sensor failure, however individual networks differ in maintenance and calibration policies. Additionally, inconsistent QA/QC policies result in a variety of approaches to dealing with the loss of accurate data. The unscheduled replacement of sensors may require additional resources for maintenance technicians, or in some cases, network operators have established partnerships with local entities who are able to replace failed sensors/perform needed maintenance.

Importance of Outreach - Outreach is another challenge faced by most of the workshop participants. Oftentimes, potential users do not know that their local network exists, and that usable data is available for free, or that there are tools and data products that can aid in their day-to-day decision-making. Conservation districts have been key in promoting the networks (by mentioning them in newsletters or talking about the networks and available data in regular meetings) and establishing them as a go-to source for valid and useful information for irrigators. They have been extremely influential in spreading awareness of IMIS networks and available tools for data implementation.

In areas where water is severely over-appropriated, there is generally more interest in newer precision agriculture techniques such as irrigation scheduling based on crop demand. For example, the Diamond Valley, Nevada community became interested in use of weather station information because of their continued water shortage and challenges with water appropriation.

Data Dissemination and Evaluating User Needs – Network operators often struggle to identify who uses their data and how to better meet their needs, since farmers and other users have been reluctant to provide registration information in exchange for access to the data. Discovering how data are being used and to what extent that is impacting production and water conservation remains a significant challenge. One possible solution that is being explored by a number of networks is a user registration requirement, which could help system operators better connect with their users and begin to create user communities.

Closely related to challenge of understanding diverse and unclear user needs is the ability of an IMIS network to publish data in a format and at a frequency that meets these needs. Some networks utilize automated programs to produce regular summaries and reports which are used to provide near real-time general guidance for growing/irrigation scheduling. Other networks have been able to utilize web and mobile applications (such as Washington State University's Irrigation Scheduler App) which works with the existing data formats to produce more user-friendly data products and data summaries within a convenient user-interface. As more networks are able to leverage these types of tools, it is expected that use and implementation of their network data will increase.

Looking Ahead: The Future of Weather Station and IMIS Networks

Increased collaboration between managers and coordinators of weather station networks and IMIS may help overcome some of the difficulties caused by differences in quality control methods and/or maintenance/calibration. This is especially important for strengthening the partnerships between networks and ensuring the integrity of data for users who may find differing data products (derived from the same original data) depending on quality control practices on the part of those who publish the data.

Related to this issue, is an effort to establish a consistent method of reporting ET. Currently, networks use a variety of methods (such as the Penman-Monteith equation, modifications of the Penman-Monteith equation, or the Blaney-Criddle equation) to calculate reference ET and may report one or more of these values to users. This creates confusion for end-users, and may be problematic when sharing data across networks or attempting to use derived data to make policy or management decisions. A number of networks plan to move towards reporting only the standardized ASCE Penman-Monteith method. A study by the USBR is planned for 2017 to use remote sensing data to compare several ET estimation techniques, in order to establish an agreed upon method for the Upper Colorado River Basin (UCRB) region and to address concerns from those who may be reluctant to settle on and use a particular standardized method for basin-wide analyses. Opportunities for collaborative efforts such as the Western Extension Research Activity (WERA) workshops, where network managers and operators discuss challenges and work together to share information and establish uniform standards, should be encouraged and expanded.

Network operators are interested in continuing to develop relationships with entities and individuals who rely upon the data, building partnerships, including financial partnerships. These have served some networks well and provided an alternate reliable funding source. Establishing consistent funding sources will remain a top priority for many network operators.

Additionally, future plans for a number of western states' weather and IMIS networks include physical expansion of the networks by installing additional stations, which will require additional funding/support. Expansion is also planned for data products and derivative tools. Some examples of this are the CIMIS network, which is partnering with the University of California-Davis (UCD) to develop more applications, some of which will be made available to mobile devices, or the NICENet network, which is seeking to integrate their data on an Irrigation Scheduler application. Additional derivative data products planned for networks include crop-specific ET estimates and forecasts.

Lastly, along with physical expansion, network operators plan to increase public engagement and outreach with established users to continue to advocate network capabilities and data products.

Contact users to determine the success of the application of data on irrigation operations. New methods for data dissemination will include metrics on data access, downloads, and other means of assessing the value derived from the data provided to users.

The challenges discussed in this report detail the hurdles that remain before regional integration could be attempted. However, with greater collaboration between network operators – working together, addressing the challenges listed, and implementing the strategies described – integration may become possible in the future.

APPENDIX A – Agenda and Attendees

Irrigation Management Information Systems' Workshop

August 25-26, 2016 • San Diego, CA

THU AUG 25 DAY 1 ACTIVITIES AND OBJECTIVES

- 12:30 Registration
- 1:30 Welcome and Opening Remarks, Workshop Background & Desired Outcomes
Tony Willardson, Western States Water Council (WSWC)
Jeanine Jones, California Department of Water Resources (CDWR)
- 2:00 The California Irrigation Management Information System (CIMIS) – Bekele Temesgen, CDWR
- 2:30 Applications of CIMIS Reference ET and Satellite Data to Support Irrigation Scheduling and Management – Forrest Melton, NASA
- 3:00 BREAK
- 3:15 Pacific Northwest/ Great Plains Agrimet Systems – Jama Hamel, U.S. Bureau of Reclamation (USBR)
- 3:45 Upper Colorado River Basin Agrimet Systems – Jim Prairie, USBR
- 4:15 Colorado's Agricultural Meteorological Network (CoAgMet) – Zach Schwalbe, Network Manager
- 4:30 NICENet & Reference ET in Nevada – Daniel McEvoy, Desert Research Institute
- 5:00 Wrap up

FRI AUG 26 DAY 2 ACTIVITIES AND OBJECTIVES

- 8:00 Continental Breakfast
- 8:30 AZMET: Looking Back and Looking Forward – Bruce Russell, University of Arizona
- 9:00 Irrigation Management and Scheduling in New Mexico – David DuBois, New Mexico State Climatologist
- 9:30 Utah Climate Center AgWeather Network – Pawel Szafruga, Utah State University
- 10:00 Break
- 10:15 Next Steps Discussion
- 12:00 Adjourn

Workshop Attendees

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APPENDIX B – Related WSWC Position Statements

**POSITION #356-
POSITION
of the
WESTERN STATES WATER COUNCIL
Regarding
NASA’S APPLIED SCIENCE RESEARCH PROGRAM
Deadwood, South Dakota
October 3, 2013**

WHEREAS, the Western States Water Council is a policy advisory body representing eighteen states, and has long been involved in western water conservation, development, protection, and management issues, and the member states and political subdivisions have long been partners in cooperative federal water and climate data collection and analysis programs; and

WHEREAS, in the West, water is a critical, vital resource (much of which originates from mountain snows) and sound decision making demands accurate and timely mapping of, and data on, altimetry, topography, precipitation, temperature, snow water content, groundwater, land use and land cover, water use, water quality parameters, and similar information; and

WHEREAS, the demands for water and related climate data continue to increase along with the West’s population, and this information is used by federal, state, tribal, and local government agencies, as well as private entities and individuals to: (1) forecast flood and drought occurrence; (2) project future water supplies for agricultural, municipal, and industrial uses; (3) estimate streamflows for hydropower production, recreation, and environmental purposes; (4) facilitate water management and administration of water rights, decrees, interstate compacts, and international water treaties; (5) assist in disaster response; (6) assess impacts of climate variability and change; and

WHEREAS, thermal infrared imaging data available from Landsat 7 and Landsat 8 is used to measure and monitor agricultural and other outdoor water uses and needs, and is increasingly important for present and future management of our scarce water resources, and is an example of the application of basic science pioneered by the National Aeronautics and Space Administration (NASA); and

WHEREAS, spaceborne interferometric synthetic aperture radar (InSAR) has a demonstrated ability to measure land subsidence due to groundwater extraction and is now being evaluated in a research mode for its potential ability to measure changes in groundwater elevations; and

WHEREAS, airborne light detection and ranging (LiDAR) using light waves instead of radio waves to measure the distance to objects and imaging spectroscopy are now being flown in California and Colorado to estimate basin-wide snow water equivalent; and

WHEREAS, additional airborne and spaceborne remote sensing research and observations have a potential to provide other information on varied temporal and spatial scales that could with sustained engagement ultimately be useful for water resources planning, management and decision-making; and

WHEREAS, NASA has identified the “water and energy cycle” and “water resources” as topics to support in the agency’s research and applications programs respectively; and.

WHEREAS, NASA’s ARRA demonstration project on California applications for use of remote sensing information has illustrated that the potential exists for repurposing data collected from certain

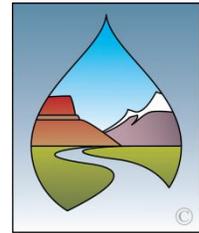
present NASA missions for water management applications, and that additional potential exists for research applications with sensors planned in future Decadal Survey missions such as the Deformation, Ecosystem Structure and Dynamics of Ice mission (DESDynI), which would combine radar and LiDAR technologies to get three-dimensional views; and WHEREAS, the successful transfer of technology from the research domain to the applications domain is dependent, in part, on on-going communication between researchers and those responsible for resource management and policy decisions and a long term commitment to maintain such communication;

NOW THEREFORE BE IT RESOLVED, that the Western States Water Council urges the Administration and NASA to enhance the agency's focus areas on research for water resources applications, and to promote long term engagement with the Council and the state and regional agencies in the western United States responsible for water management and water policy to maximize benefits to the public from NASA's existing and future investments in Earth observations, Earth system models and systems engineering; and

BE IT FURTHER RESOLVED, that the Council urges the Administration and NASA to plan and provide for long-term continuity of observations from key sensors such as the thermal infrared sensor and InSAR; and

BE IT FURTHER RESOLVED, that the Council strongly supports an expedited NASA review of options for a continuing National Land Imaging Program, including existing thermal imaging capabilities, and expresses its strong preference for an immediate short-term effort to replicate and launch a satellite similar in design and instrumentation to Landsat 8 to minimize any loss of data – while exploring the potential for medium and longer-term advances in technology, design and future capabilities to meet existing and future uses

**POSITION #366 -
RESOLUTION
of the
WESTERN STATES WATER COUNCIL**



**supporting
FEDERAL RESEARCH AND DEVELOPMENT OF UPDATED HYDROCLIMATE GUIDANCE
FOR FLOODS & DROUGHTS
Helena, Montana
July 18, 2014**

WHEREAS, Western states continue to experience extreme flooding, droughts, or wildfires that threaten public safety, tax aging water infrastructure, and/or have significant economic consequences; and

WHEREAS, according to the National Oceanic and Atmospheric Administration (NOAA), the nation's top ten multi-billion dollar disasters have occurred since 1980, with six of those in the last decade; and

WHEREAS, we must be prepared to effectively manage for frequent, extensive, and severe storms, floods, coastal inundation, and droughts; and

WHEREAS Western states experienced extreme drought in 2011-2014, as well as recent floods of record in areas such as parts of the Missouri River Basin in 2011 and Colorado in 2013, and further Winter Storm Atlas in 2013; and

WHEREAS, key long-term observation networks needed for monitoring extreme events, such as USGS streamgages and the NWS Cooperative Observer network, face continued funding and programmatic challenges that threaten the continuity of crucial long-term data records; and

WHEREAS, snow water content and soil moisture monitoring are also critical for drought and flood forecasting and management, but the NRCS snow survey and water supply forecasting program, related SNOTEL sites, and its Soil Climate Analysis Network remain underfunded; and

WHEREAS, some of NOAA's probable maximum precipitation estimates used by water agencies for dam safety and other analyses have not been updated since the 1960s and the federal Guidelines for Determining Flood Flow Frequency Analysis (published as Bulletin 17B) have not been revised since 1981; and

WHEREAS, flood frequency analyses are used by public agencies at all levels of government to design and manage floodplains, and for construction of flood control and stormwater infrastructure, with Bulletin 17B still representing a default standard of engineering practice; and

WHEREAS, federal funding for hydrology research has waned since the 1970s-1980s, and alternative statistical methodologies for flood frequency analyses or deterministic analytical procedures are not being supported and transitioned to common engineering practice; and

WHEREAS, the Federal Emergency Management Agency has adopted a process for local communities to explicitly incorporate "future conditions hydrology" in the national flood insurance program's flood hazards mapping; and

WHEREAS, the present scientific capability for forecasting beyond the weather time domain – beyond the ten-day time horizon – and at the sub-seasonal to interannual timescales important for water management is not skillful enough to support water management decision-making; and

WHEREAS, the Council has co-sponsored a number of workshops on hydroclimate data and extreme events, to identify actions that can be taken at planning to operational time scales to improve readiness for extreme events; and

WHEREAS, multiple approaches have been identified at these workshops that could be employed at the planning time scale, including ensembles of global circulation models, paleoclimate analyses, and improved statistical modeling, that could be used to improve flood frequency analysis or seasonal forecasting; and

WHEREAS, advances in weather forecasting research, such as that of NOAA’s Hydrometeorological Testbed program on West Coast atmospheric rivers, demonstrate the potential for improving extreme event forecasting at the operational time scale; and

WHEREAS, WGA and NOAA signed a Memorandum of Agreement in June 2014 on improving resilience to droughts and floods;

NOW, THEREFORE, BE IT RESOLVED, that the federal government should update and revise its guidance documents for hydrologic data and methodologies – among them precipitation-frequency estimates, flood frequency analyses, and probable maximum precipitation – to include subsequently observed data and new analytical approaches.

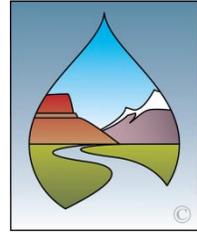
BE IT FURTHER RESOLVED, that the federal government should place a priority on improving sub-seasonal and seasonal precipitation forecasting capability that would support water management decisions.

BE IT FURTHER RESOLVED, that the Western States Water Council supports development of an improved observing system for Western extreme precipitation events such as atmospheric river storms, as well as baseline and enhanced stream, snow and soil moisture monitoring capabilities.

BE IT FURTHER RESOLVED, that the federal government should sustain and expand its Hydrometeorology Testbed – West program, in partnership with states and regional centers, to build upon the initial progress made in that program for developing and installing new technologies for precipitation observations.

BE IT FURTHER RESOLVED, that the Western States Water Council urges the federal government to support and place a priority on research related to extreme events, including research on better understanding of hydroclimate processes, paleo-flood analysis, design of monitoring networks, and probabilistic outlooks of climate extremes.

BE IT FURTHER RESOLVED, that the Western States Water Council will work with NOAA and WGA in supporting efforts on climate extremes, variability, and future trends.



**POSITION #385-
POSITION
of the
WESTERN STATES WATER COUNCIL
Regarding
FEDERAL WATER AND CLIMATE DATA COLLECTION AND ANALYSIS PROGRAMS
Manhattan, Kansas
October 9, 2015**

WHEREAS, the Western States Water Council is a policy advisory body representing eighteen states, and has long been involved in western water conservation, development, protection, and management issues, and the member states and political subdivisions have long been partners in cooperative federal water and climate data collection and analysis programs; and

WHEREAS, in the West, water is a critical, vital resource and sound decision-making demands accurate and timely data on precipitation, temperature, evapotranspiration, soil moisture, snow depth, snow water content, streamflow, groundwater, water quality and similar information; and

WHEREAS, the demands for water and related climate data continue to increase, and this information is used by federal, state, tribal, and local government agencies, as well as private entities and individuals to: (1) forecast flooding, drought and other climate-related events; (2) project future water supplies for agricultural, municipal, and industrial uses; (3) estimate streamflows for hydropower production, recreation, and environmental purposes, such as for fish and wildlife management, including endangered species needs; and (4) facilitate water management and administration of water rights, decrees, and interstate compacts; and

WHEREAS, without timely and accurate information, human life, health, welfare, property, and environmental and natural resources are at considerably greater risk of loss; and

WHEREAS, critical and vital information is gathered and disseminated through a number of important federal programs including, but not limited to: (1) the Snow Survey and Water Supply Forecasting Program, administered by the National Water and Climate Center (NWCC) in Portland, Oregon, and funded through USDA's Natural Resources Conservation Service (NRCS); (2) NWCC's Soil and Climate Analysis Network (SCAN); (3) the U.S. Geological Survey's (USGS) Cooperative Streamgaging Program and National Streamflow Information Program (NSIP), which are funded through the Department of Interior; (4) Landsat thermal data, archived and distributed by the USGS, and other remotely-sensed data acquired through the National Atmospheric and Space Administration (NASA) and its water-related missions; (5) USGS ground water measurement and monitoring; (6) the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service and Climate Programs Office; and (7) the Environmental Protection Agency's National Environmental Information Exchange Network (NEIEN); and

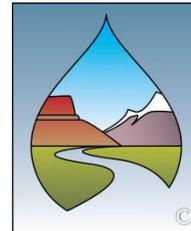
WHEREAS, state-of-the-art technology has been developed to provide real or near real-time data in formats that can be shared and used by different computer programs with the potential to vastly improve the water-related information available to decisionmakers in natural resources and emergency management, and thus better protect the public safety, welfare and the environment; and

WHEREAS, over a number of years, the lack of capital investments in water data programs has led to the discontinuance, disrepair, or obsolescence of vital equipment needed to maintain existing water resources related data gathering activities; and

WHEREAS, there is a serious need for adequate and consistent federal funding to maintain, restore, modernize, and upgrade federal water, weather and climate observation programs, not only to avoid the loss or further erosion of critical information and data, but also to address new emerging needs, with a primary focus on coordinated data collection and dissemination.

NOW THEREFORE BE IT RESOLVED, that the Western States Water Council urge the Administration and the Congress to give a high priority to the allocation and appropriation of sufficient funds for these critical, vital programs, which benefit so many, yet have been or are being allowed to erode to the point that it threatens the quantity and quality of basic data provided to a myriad, growing and diffuse number of decisionmakers and stakeholders, with significantly adverse consequences.

**POSITION #392-
POSITION STATEMENT
of the
WESTERN STATES WATER COUNCIL**



**in support of
STRENGTHENING THE RESILIENCY OF OUR NATION TO THE IMPACTS OF EXTREME
WEATHER EVENTS
Bismarck, North Dakota
July 15, 2016**

WHEREAS, the West and the Nation continue to suffer the effects of increasingly extreme weather events, including tornadoes, hurricanes, extreme precipitation, flooding and drought, including loss of life and economic, social, and environmental damages; and

WHEREAS, Western States have recently experienced extreme seasonal and year-to-year weather volatility that has brought record or near-record events with floods, followed by drought and wildfires, as well as devastating tornadoes, all threatening public safety and property, and often taxing the capacity of our aging water infrastructure; and

WHEREAS, prolonged drought increasingly afflicts the West and the Nation, and affects the performance of interstate compacts and international treaties; and

WHEREAS, droughts have been magnified in regions of the country due to the failure of Mexico to deliver the water required to the United States under the treaties executed by the two countries, and

WHEREAS, present water resources planning and sound decision-making depends on our ability to understand, monitor, predict, and adapt to droughts, floods, extreme storms, and other weather events; and

WHEREAS, investments in observations, research, forecasting, and monitoring the development of extreme weather events provide an opportunity to significantly improve planning and project design and operation to maximize storage, avoid or minimize the loss of life and property, as well as mitigate economic and environmental damages; and

WHEREAS, advances in weather forecasting and research, such as that of NOAA's Hydrometeorological Testbed program on West Coast atmospheric rivers, demonstrate the potential for improving extreme event forecasting at the operational time scale; and

WHEREAS, in the West, sound decisionmaking demands accurate and timely data on precipitation, temperature, soil moisture, snow depth, snow water content, streamflow, and similar information; and

WHEREAS, western states' precipitation originates as storms moving over the Pacific Ocean and Gulf of Mexico, and the absence of key ocean observations constrains the ability to improve skill of subseasonal to seasonal (S2S) precipitation forecasting; and

WHEREAS, there is a need for maintaining and improving existing monitoring networks that help provide early warning as well as tracking impacts of extreme events; and

WHEREAS, the Council has supported development of an improved observing system for Western extreme precipitation events, to aid in monitoring, prediction, and climate trend analysis associated with extreme storms; and

WHEREAS, there is a need for developing new monitoring technologies such as remote sensing that provide more timely data availability and better spatial coverage for assessing drought impacts; and

WHEREAS, the Council is actively working with the National Oceanic and Atmospheric Administration (NOAA) on improving S2S precipitation forecasting capabilities; and

WHEREAS, the Council continues to support NOAA's National Integrated Drought Information System, and emergency drought response authorities for the Bureau of Reclamation and other federal agencies; and

WHEREAS, there is a continuing need for greater collaboration between and among federal agencies, state agencies, local governments, non-governmental organizations and public/private organizations and businesses; and

WHEREAS, a National Academy of Sciences' report suggests a pathway and 10-year research agenda for advancing our capabilities with a vision of a decade from now of using S2S forecasts as widely as we now use 5-10 day weather forecasts.

NOW THEREFORE BE IT RESOLVED that the Western States Water Council supports as a high priority appropriate federal actions to plan, prepare for and avoid, minimize or mitigate the impacts of extreme weather events, including developing an expanded and enhanced research program and westwide extreme precipitation monitoring system, including expanded ocean observations.

BE IT FURTHER RESOLVED that the Western States Water Council also supports legislation advancing the goals of: (1) minimizing the loss of life and property and economic, environmental and social cost from extreme weather events; (2) improving collaboration and coordination among agencies and organizations at all levels; (3) increasing consultation with state, local and tribal governments; (4) maintaining and enhancing data gathering and monitoring, as well as communication capabilities, identifying and addressing gaps and overlap; (5) identifying and addressing federal agency responsibilities, as well as regulatory and other preparedness and response barriers, (6) recognizing and addressing regional differences; and (7) advancing research within the physical sciences, and dynamical and statistical modeling to improve our S2S forecasting capabilities.

BE IT FURTHER RESOLVED that the Western States Water Council pledges to work with the Congress to appropriately address current and future needs to improve S2S forecasting and extreme events response and resiliency.

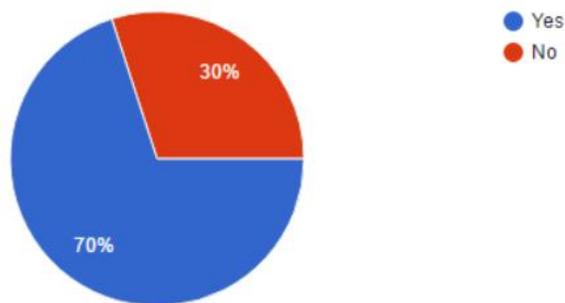
APPENDIX C – Survey and Summary of Responses

The purpose of this survey is to collect information about existing Irrigation Management Information Systems (IMIS) in the Western United States. This will provide valuable information in preparation for our upcoming workshop. We invite you to respond to the survey, even if you are not able to attend the workshop.

Your Name and Title (10 responses)

What is the name of the network/system that you manage or use? (10 responses)

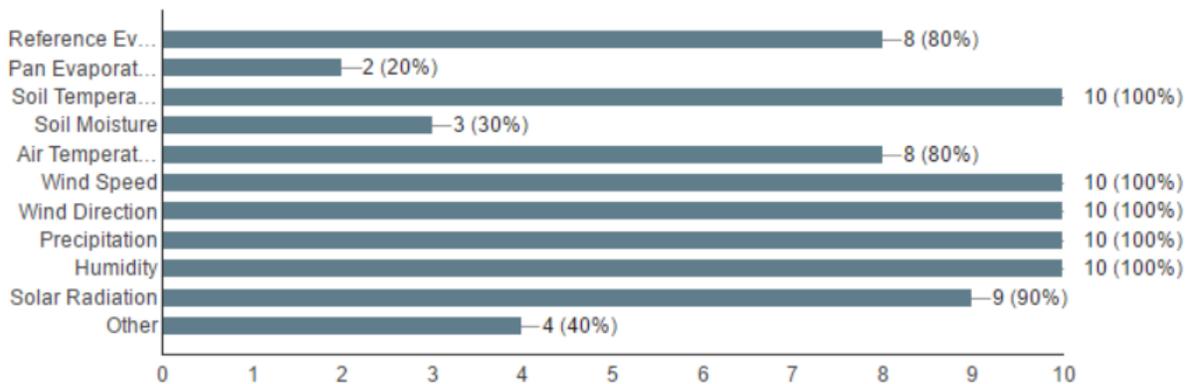
Does it cover more than one basin or state? (10 responses)



How many stations are in your system? (9 responses)

- 128
- 50
- 75
- 150
- 200+
- 18
- 9 currently with 4 more in progress
- 28 permanent + 3-7 supplemental station
- 20-30

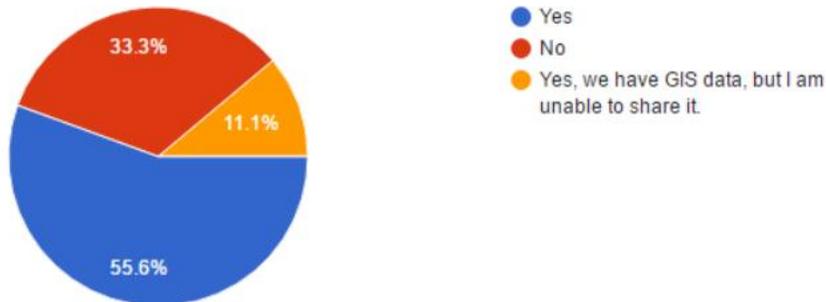
What parameters are measured or reported by your network? (10 responses)



What, if any, parameters not now measured would you like to add/wish you measured? (5 responses)

- Barometric pressure
- Open Water Evaporation
- 4 component net radiation, ground heat flux, sensible heat flux, latent heat flux (i.e. eddy station..dreaming :))
- none
- soil temperature at other depths, soil moisture

Do you currently have GIS data for your network? (And would you be able to share it with the WSWC?) (9 responses)



How accurate are your estimates of reference ET? (10 responses)

We use the Campbell Scientific "ETsz" command in our logger programs to calculate reference ET which uses the ASCE Standardized Reference ET equation.

N/A

It depends on how well the crop coefficients you are using compare to the crops in the area you are estimating ref ET.

We believe it is fairly accurate

Fair, depending on station variables

Given that our stations are in irrigated areas, I think fairly accurate, but the web available ETo estimates have issues sometimes. We post processes the data available on the web, and QAQC before we compute reference ET, and this is done off line.

I would estimate within 3%; no more than 5%.

we haven't done an accuracy study yet

+/-10-15%

Our stations are monitored by AgriMet, so fairly good.

What standards and procedures do you adhere to for calibration and/or quality assurance of your data? (10 responses)

We exclude data that is out of range. We also visually monitor check plots that help us identify sensor issues or if data is out of range. All stations are visited annually for an inspection/calibration that helps us verify our sensors are working correctly.

ASCE-EWRI 2005

Annual visits, at the least, of stations and bi-annual replacement and calibration of temp/rh sensors and pyranometers.

We calibrate most of our sensors regularly and have an automated quality control procedure that flags data.

ASCE, standards developed over 30 years

We follow FAO-56 and ASCE guidelines, so solar radiation corrections to clear sky, visualize RH, Temp, and wind and throw out bad data. We replace bad data using various stats based on the historical data and empirical approaches for estimating Rs if needed.

Temperature/RH sensors are calibrated every 2 years; anemometers, solar sensors are calibrated every year. The raw data is collected and checked for gross errors prior to processing automatically each night. I graph and review the data each morning. Too many procedural details to relate here.

Prior to 2010 there were no standard or procedures for the network. We've been implementing our own procedures for QA and sensor replacement but primarily dependent on funds.

Quarterly on-site calibration vs travel standards, preventive maintenance which involves sensor rotation prior to sensor degradation, daily computer checks against extremes/unrealistic data/event, regular graphical comparisons with nearest neighbor stations and outside data sources

USU does this under supervision of AgriMet

How do you identify who is using your system? (e.g., irrigators, municipalities, students, avid weather watchers, federal agencies, state agencies, local governments, irrigation districts, etc.) (9 responses)

We don't have a comprehensive system to monitor this.

federal and state agencies

Other than known partnerships, we don't keep track of this info, except those that log into outside sites that utilize CoAgMet data.

We keep record of who is using our data for statistical purposes. Growers and consultants are the largest users. Other users include water agencies, home owners, researchers, firefighters, students, weather forecasters, lawyers, etc.

Public Relations, WSU tracker info (App), email/phone calls when site has issues

Currently we don't keep track. This is something that I want to add... a dreaded login page.. BUT I do know that farmers, state agencies, and federal agencies use our page.

Dr Paul Brown stays in close contact with agri-business and horticultural professionals across the state of Arizona.

Mainly irrigators, researchers, and students use our ET data. We have some municipalities and private users depending on location.

We operate an open system and thus don't know exactly how the data are used. However, we have 20+ funding lines that support the network, many of which are concerned with irrigation management (irrigation districts, urban water providers, etc.). Our network operates within Cooperative Extension and we are responsible for educational programs and thus work with a number of stakeholder on issues related to use of the data, including irrigation management.

How do you measure use of your system? (e.g., number of website hits per day, mobile access to data, specific data accessed, anecdotal information, etc.) (10 responses)

We don't measure this.

just getting started

Basic website tracking. When a station isn't working properly, we usually hear from folks.

We keep record of hits per time. We are in the process of developing smartphone apps.

web statistics

All of the above.

Apache files from our college server are evaluated for usage page-views, etc.

We have website statistics on hits over time.

We now track website user sessions.

We have some metrics for lawn guide use. Contact Eric Klotz for details.

What metrics (if any) do you use to determine whether collecting data and making it available is having a positive impact on water conservation? If you do not evaluate water conservation benefits of your system, is there someone else who does? (9 responses)

We don't have any such metrics.
just getting started

We are currently working with UC Berkley to quantify the benefits of using CIMIS data. We have also been receiving feedbacks from users and researchers at different times.

Howard Neibling, U of I; Troy Peters, WSU, Anheuser-Busch

We currently are not keeping track of water conservation impacts, rather we are keeping track on water use reporting impacts. Without our stations, accurate water use reporting would not be possible.

Again, Dr. Paul Brown stays in close contact with agri-business and horticultural professionals across the state of Arizona. Also, the City of Phoenix Water Conservation Dept. monitors the effectiveness of our data.

I have not quantified any water conservation benefits yet. There might be others that have quantified it.

Lack of funding limits formal evaluation. That said, most of our funding comes from outside sources involved in water management/delivery and they continue to support our network.

Municipal water use is collected annually. We determine what part is from conservation vs. the weather.

What barriers exist to grower use of irrigation scheduling data? (8 responses)

Social behavior and technology. Due to limits in allocation and timing, there is a prevalent mindset to use whatever you can. As well, there are technological limitations making access to the scheduling data hard for some users to access.

N/A

The most important barrier, in my opinion, is growers not knowing the existence and benefits of using CIMIS data. Despite our efforts, many growers either do not know it existed or prefer traditional methods of irrigation.

Learning new technology, taking the time to input data

Making the data known and readily available to them.

Our ET values must be copied off our website and manually input into an irrigation system.

The availability of the data, ease of use in scheduling tools, justification of the use of scheduling rather than what they're used to doing

Most ET based irrigation scheduling programs that require a soil water balance are too complex for most growers and thus are used only by large growers that have trained staff that can operate these systems. Growers using pressurized systems are more likely to monitor ET and adjust schedules, but pressurized systems are rare in Arizona. Another major challenge are the lags associated delivery of irrigation district water. Often water has to be called several days in advance, or simply shows up on a given date.

To what extent (if any) is your system used for "ground-truthing" remote sensing satellite data? (8 responses)

Several of our new stations in the Upper Colorado region will be used for the METRIC system. This is just starting up.

We are adding 3 EC Towers in addition to weather stations for ground-truthing RS

In my opinion, CIMIS data is the bases against which remote sensing (or other models) are compared for verification. This is not only an opinion but a fact as we see comparisons being made all the time.

Heavily through U of I with Rick Allen, Metric; Upper Colorado Basin

We use our system with remote sensing data to provide anchor/calibration points for well-watered ET estimates (i.e. ETo estimates). Eddy covariance or Bowen ratio stations would be needed for ground-truthing.

No known use at present. Back in the late 1980s, our data was used to ground-truth several satellite overflights.

We have collaborated some with researchers but nothing substantial. I haven't heard back from them.

Don't know

What are the biggest challenges to growing or maintaining your system? (10 responses)

At every part of the process we are a bit understaffed. This leaves us in a state where we can usually maintain the necessities, but lack the time to refine and improve. As well, our IT side moves very slowly.

Implementing changes or improvements to make data easier to access takes a long time/

Securing and maintaining funding

Funding and staff.

Lack of resources (funds, land on which stations are installed, local cooperators to assist maintaining stations).

Staff

Funding

Maintenance of the stations is very labor (and travel) intensive. Also, the daily grind of collecting/processing/disseminating the data. Keeping the solar sensors clean.

When I started 6 years ago in this position, it was starting from scratch. In the past it has been funding but there has been some help in that area for sensor replacements and salaries. Now it's a matter of growing the network slowly and incorporating more QA and procedures over time.

Funding which limits personnel; travel distances which translates into personnel costs; high time costs associated with stakeholder activities; crop rotation which regularly degrades weather station sites; and the chronic challenges of fundraising.

Money

How much does it cost to maintain your system? (9 responses)

The Utah Climate Center has an annual budget of about \$400,000. Obviously not all of that goes to the system, but we have two technicians who spend the majority of the time servicing our networks.

\$2.25k per weather station, \$26.3k per EC tower

~\$185,000

It is not easy to quantify as it varies for each station.

\$300k per year (1 full time employee, 1 student, help from other FTEs)

We estimate ~2 - 3K per year, per station... so ~40K for the entire NICE Net.

We charge ~\$2500-\$2700 per station per year. (Dr. Paul Brown has the details.)

Approx. \$30K/year which includes salary, travel, sensor replacements. Figure also includes maintenance of USRCRN network of 15 stations across NM

~\$160,000/year

How much would it cost to add a single station? (10 responses)

Around \$8k, depending on the sensor suite.

\$9k weather station \$55k EC tower

~\$8,200

About \$7,000.

\$9K for station, \$1600k/year maint.

~5-10 K.

Cost of a station ~\$4000(?) plus annual fee of \$2500+. (Dr. Paul Brown has more details.) At this point, with 28 stations, we are already stretched to our labor-limit.

About \$7K for basic ET station

Cost of station must be borne by outside entity plus they must pay all non-labor + 25% of labor costs which approaches \$3000/year. The remaining labor costs are generated through grants

\$10,000

How is your system funded? Has this changed over time? (10 responses)

We are funded through state allocations, along with some supplements. Our state allocation has increased overtime, but I don't know much more besides that.

combined Federal and state funding

Sponsored stations, CO's Ag Experiment station, Colorado Water Conservation Board (new funding that we need to apply for)

Support for the CIMIS program is budgeted annually in the state General Fund (roughly \$1 million annually). Most of the stations are purchased by cooperators.

Federal, State, Local, Private

Originally funded from federal funds to the State of Nevada. Currently unfunded, but the State of Nevada is looking to fund it this year... maybe..

A mix of hard (university) and soft money (agri-business). Back in the 1980s we were 100% funded by hard money. Over time that has dropped to probably 50-60%. (My estimate; Paul knows the exact amount.)

Currently through National Mesonet contract. In the past it was funded from state and federal grants. Some years more some years very little.

Yes, state support began to decline after 9/11 then almost completely disappear during Great Recession USBR, USU, Pacific Corps

If you had more money, how would you spend it? (10 responses)

Although there are a few pieces of equipment that would help our efficiency, at this point we would hire more personnel. We could really benefit from another technician who could split their time between field work and data management/quality control and website design.

upgrade to weighing precip. instruments, add soil moisture probes, additional EC towers

Development of products, a dedicated service vehicle, equipment upgrades.

Expand the network and refine the spatial model that produces daily maps of ETo. We also need more staffing in the regional offices.

Staff

Maintenance, adding new stations, developing enhanced web tools

Sensor and equipment upgrades.

First salary and then maintenance on existing stations. Thirdly we would consider adding new stations.

Personnel for database management, upgrading data processing and product development (weather-based products of interest to stakeholders)

Something else, other than IMIS

Are you aware of any studies of the economic benefits of the system or information the system provides? (8 responses)

No.

no

One was conducted in the 1990s and another one is currently underway.

Anheuser-Busch study

I do not.

Paul did an agri-business evaluation several years ago. Sorry, I do not have that report. It was a significant amount.

There are very few studies on the economic benefits. I heard one state was working on this but I don't remember the details.

I don't believe there is anything formal. Cooperative Extension in Arizona has hired an evaluation specialist and we hope to have this individual assist with an evaluation, perhaps in cooperation with our Economic Impact Analysis program.

What benefits, if any, might accrue from an interstate watersheds and/or westwide system? (9 responses)

Standardize maintenance/calibration and data QA/QC procedures

Collaboration of network, standardization of protocols, more product development.

I assume the benefits will be shared resources and expertise. It may also improve the accuracy of spatially distributed ETo values.

Data consistency, streamline data retrieval,

We would benefit a lot. We have a station in CA (Bridgeport, CA), and also share many water ways with AZ, UT, and CA, so it makes good sense to get a western state funded network support structure going.

Sorry, I am not qualified to provide an accurate answer to this question.

I would be very supportive of more cooperation. Currently there is an effort but it is slow getting started and not much funds available.

The issue is not generation of ET or weather information; it is who will do the legwork required to sell/educate the stakeholders on how to effectively use ET and/or other weather information. While generation of good reference ET information is not as easy as it sounds, the far more challenging issue is stakeholder engagement/use; a regional network would need to support these efforts.

Water savings

What obstacles exist to such a system? (8 responses)

not sure

Standardizing already established networks.

Logistics. How can the different networks coordinate their efforts (data format, quality, maintenance activities, maintenance records, etc.).

Ensuring compliance with maintenance standards, Data QA/QC consistency

Getting federal and state buy-in to commit to pitching in every year to maintain the "super network."

Sorry, I am not qualified to provide an accurate answer to this question.

Lack of a project champion to keep the momentum going would be difficult. Funding is always an obstacle.

Different supporting entities (federal, state and university/Extension), outside ownership of equipment, providing a quantifiable benefit to the existing networks to join such a system

Are there any other questions that you feel should be addressed at the workshop? (5 responses)

No.

How would you enforce compliance, how will struggling networks afford it?

How can we work together to make a united effort to get funding to support our networks for the long term? How do we deal with raw vs. QA/QCed data in our database, and should we post both the raw and QA/QCed data on our websites. What do other networks do with raw vs. QA/QCed data on their websites? Do they host both?

As the 'nuts-and-bolts' guy, I am most interested in sensor maintenance and data processing, error checking, etc. Beyond that, I would like to close the 'data-loop' within our system. That is to say, the direct delivery of our ET values to an irrigation system. Of course, there would be a liability risk with this idea.

I'd like to know how other networks operate their QA and maintenance and how funding works to keep the operations going. I've had a difficult time in getting acceptance on using climate based irrigation scheduling with pecan growers even with the help of extension staff. I'd like to discuss how we can encourage these types of growers and if others had similar experiences.