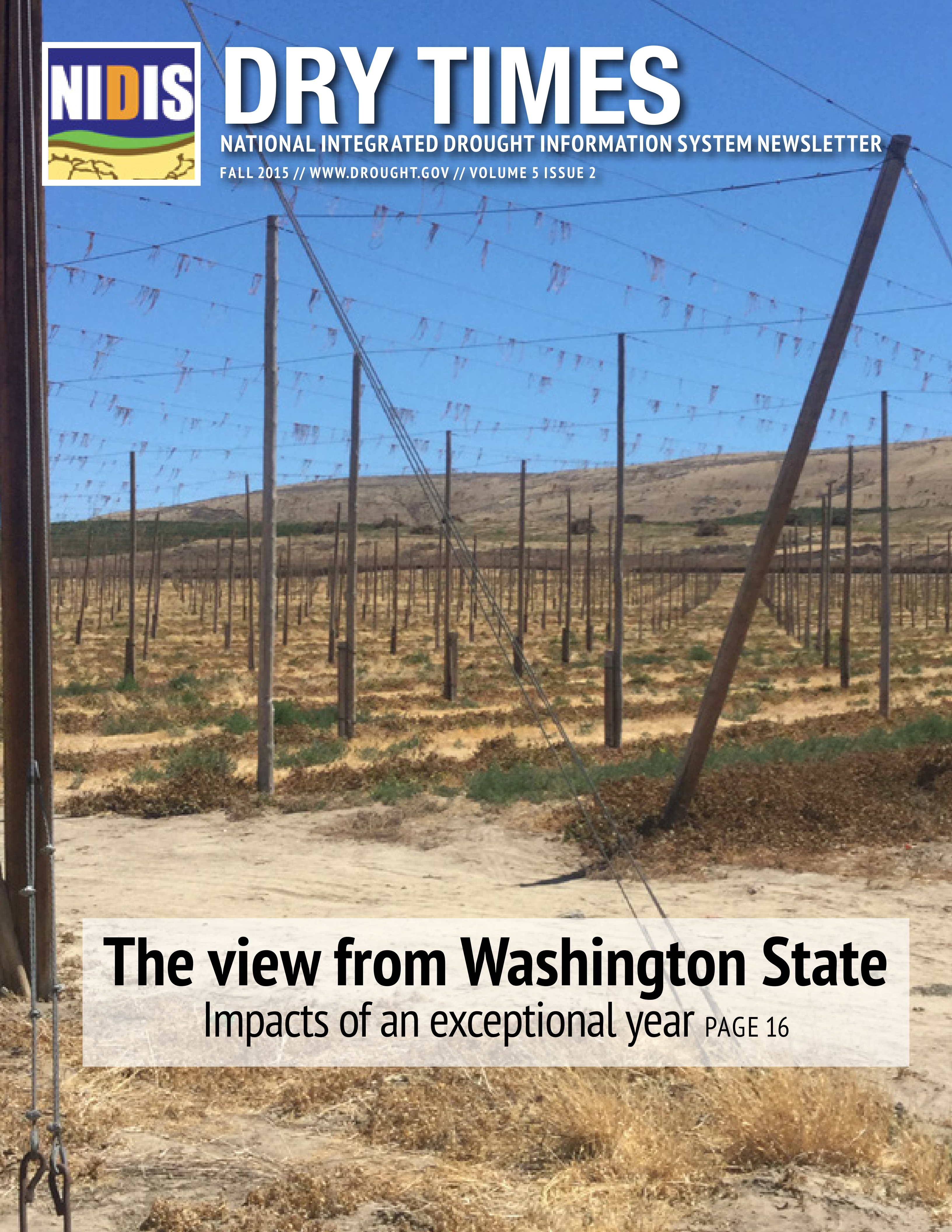


DRY TIMES

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM NEWSLETTER
FALL 2015 // WWW.DROUGHT.GOV // VOLUME 5 ISSUE 2

The view from Washington State

Impacts of an exceptional year PAGE 16

National Integrated Drought Information System
325 Broadway, Boulder CO 80305
NIDIS.program@noaa.gov

Roger Pulwarty, Director
(Roger.Pulwarty@noaa.gov)

Veva Deheza, Deputy Director
(Veva.Deheza@noaa.gov)

Courtney Black
(Courtney.Black@noaa.gov)

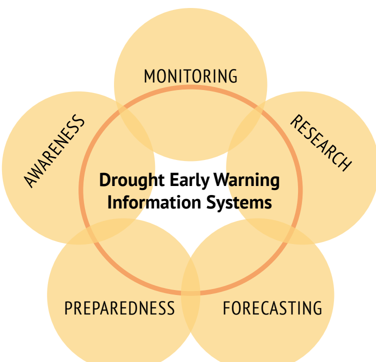
Kathleen Bogan (Kathleen.Bogan@noaa.gov)

Michael J. Brewer (Michael.J.Brewer@noaa.gov)

Alicia Marrs (Alicia.Marrs@noaa.gov)

Chad McNutt (Chad.McNutt@noaa.gov)

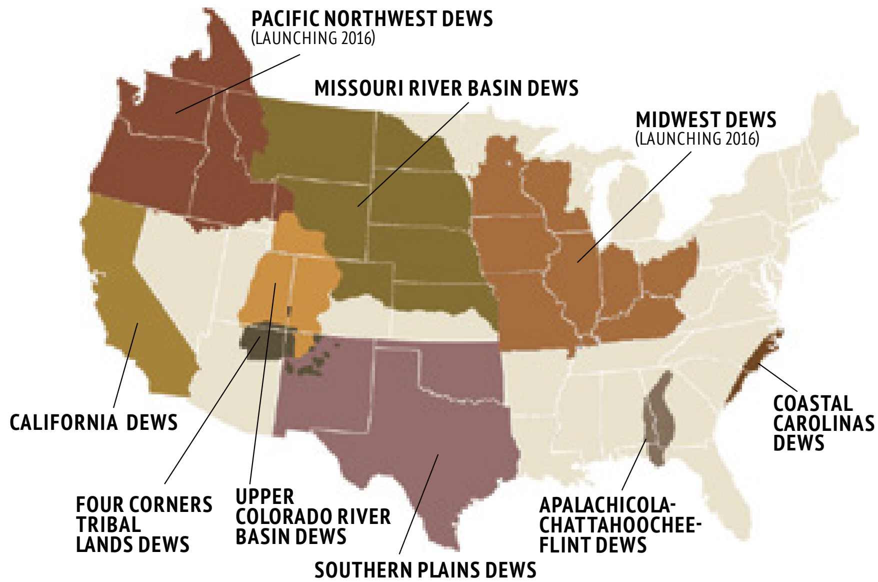
Claudia Nierenberg
(Claudia.Nierenberg@noaa.gov)



Inside this edition

NIDIS NEWS

NIDIS Drought Early Warning Systems



Regional coordinators join NIDIS

NIDIS welcomed Courtney Black and Alicia Marrs this year in roles as regional drought information coordinators for the NIDIS Drought Early Warning Systems (DEWS.) Alicia works with DEWS west of the Rockies; Courtney with those to the east and the Southern Plains. Their fellow regional coordinator Chad McNutt helps work with the Upper Missouri River Basin DEWS.


BLACK


MARRS

About our new team members:

Courtney Black, P.E., has provided consulting services to a variety of clients on municipal and watershed resources planning, stakeholder outreach, water rights litigation, environmental impact statements and wetland restoration projects in Colorado and other areas of the U.S. She has developed drought planning guidance documents, contributed to state drought planning efforts and designed one of the first "drought tournaments" in the U.S. Courtney earned a B.S. in civil and environmental engineering from Lehigh University and a M.S. in environmental engineering from the University of Florida.

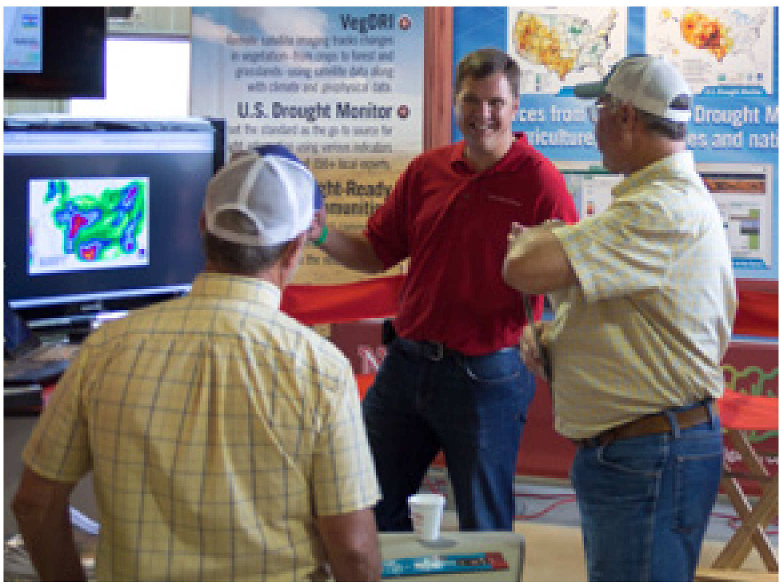
Alicia Marrs worked at the U.S. Environmental Protection Agency (EPA); promoting water-efficient products and practices for the WaterSense® Program, and coordinated collaborations between untraditional partners, be they home builders and water utilities, or local governments and plumbing manufacturers, with the ultimate goal of promoting water efficiency in their communities. She also served as national coordinator of EPA's Clean Water Indian Set-Aside grant program and addressed capacity building issues for EPA's Office of Environmental Justice and with EPA Region 8's Drinking Water Program.

Alicia holds a B.A. in Environmental Planning and Policy from Western Washington University's Huxley College of the Environment, and an M.A. in Global Environmental Policy from American University in Washington, D.C.

On the cover A Yakima Valley farmer has allowed this hops field to go fallow in order to allocate water to other crops. Junior water rights holders in the Yakima Basin received 47% of their water allocation this year. See page 12-13 for more photos of drought impacts in Washington State. Photo: Washington Department of Ecology

University of Nebraska's National Drought Mitigation Center to foster cross-communication among states, support future resilience

'Vital role' for new center: Offer the best in drought info



Brian Fuchs, in red shirt, a National Drought Mitigation Center climatologist, discusses the prospects for rain at an agriculture trade show in Nebraska. Fuchs and many of his colleagues at NDMC will be working through the new Drought Risk Management Research Center to increase states' resilience to drought.

BY NIDIS/ NDMC STAFF

NIDIS in June 2015 funded the Drought Risk Management Research Center (DRMRC), at the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln.

The new center will help state and local governments be better prepared to respond to drought, said retired Coast Guard Vice Admiral Manson Brown, assistant secretary of commerce for environmental observation and prediction and the deputy administrator of NOAA. Brown made the announcement at the annual meeting of the Western Governors' Association in Lake Tahoe, Nevada, where coping with the ongoing multi-year drought in western states topped the agenda.

"The Drought Risk Management Research Center will fill a vital role in providing states, communities and businesses with the best available drought research, data and information," Brown said. "This critical environmental intelligence will strengthen their ability to stay resilient to drought and leverage the collaborative work of NOAA and other federal and state partners."

The center will focus on research to improve drought monitoring, impacts assessment and risk management in close partnership with NIDIS and its partners, domestically and internationally. These efforts will advance preparedness for drought events and contribute to mitigation of its impacts.

"The formation of the Drought Risk Management Research Center strengthens NOAA and the federal-state partnerships that help to make the nation more resilient to drought," said Roger Pulwarty, director of NIDIS. "It will fill a vital role in linking the best available research, data and information to states and communities as they plan for and cope with the impacts of this pervasive hazard."

"This will solidify a long-standing relationship between NOAA, NIDIS, and the NDMC" said Michael J. Hayes, director of the NDMC. "The emphasis on research will help us address critical needs related to drought monitoring, impact assessment and planning strategies. One of our goals will be to help states and other entities learn from each other based upon what they have experienced, such as what is happening across the West right now, and become more resilient to droughts in the future."

The DRMRC will conduct research and applied studies to:

(1) help to develop improvements to the U.S. Drought Monitor and supporting products and tools,

(2) engage and integrate socio-economic information across all scales of drought preparedness and impacts,

(3) advance the societal and economic benefits of regional drought early warning systems,

(4) advance innovations in planning for drought, including incorporating drought information into multi-hazard mitigation planning, and

(5) help to communicate and coordinate drought-related activities across the NIDIS partner network.

FOR MORE INFORMATION about the DRMRC, contact NIDIS at nidis.program@noaa.gov or NDMC at ndmc@unl.edu.

Study results can guide the issuance of drought severity-based water restrictions

Decadal, inter-decadal climate variability modulate droughts

BY SARMISTHA SINGH, PUNEET SRIVASTAVA, ASH ABEBE, AND SUBHASIS MITRA
Auburn University

Droughts have been a major factor leading to the Tri-State Water Wars in the southeastern U.S. One of the primary issues related to the conflict is the reduction in baseflow levels in the Flint River during droughts. This affects the availability of freshwater resources to support the endangered mussel species in the Flint and Apalachicola Rivers and threatens the shellfish industry in the Apalachicola Bay.

Study of large-scale climate phenomena as well as the interactions of interannual with decadal and multidecadal oceanic-atmospheric phenomena can provide valuable information regarding regional climatic conditions such as droughts and their impact on water resources. This study was conducted to quantify the impacts of climate variability cycles on baseflow levels in the Flint River. The impacts of the El Niño–Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), and North Atlantic Oscillation (NAO) on baseflow were studied.

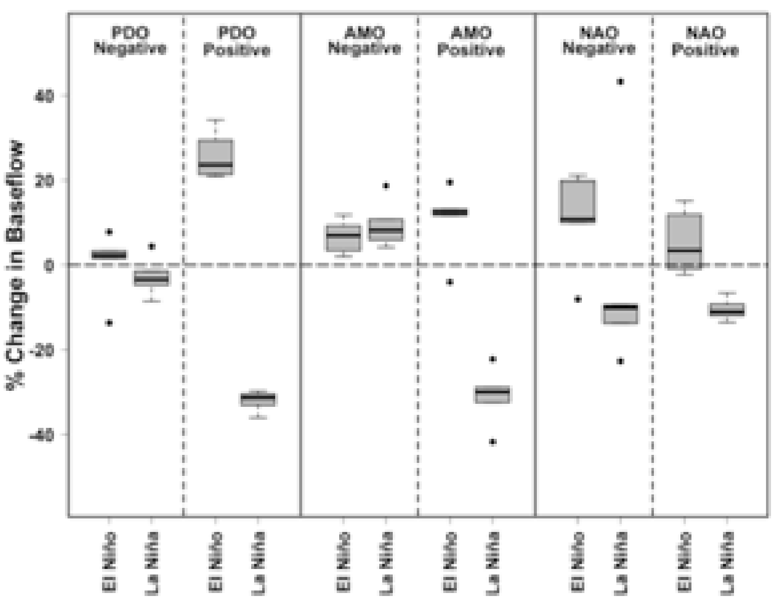


FIGURE 1.

Box and whisker plots of the percent increase/decrease in baseflows for Flint River. The boundaries of the box represent the first (Q1) and third (Q3) quartiles and the whiskers extend from the boundaries of the box to the extreme data points which are no more than 1.5 times the interquartile range (Q3 - Q1).

A novel non-parametric Joint Rank Fit (JRFit) procedure was used to identify and quantify the individual and coupled effects of climate variability phenomena on historic baseflow levels of the Flint River. Study of the individual effects of ENSO, PDO, AMO and NAO showed that the phases of ENSO, AMO and NAO had significant impact on baseflow; however, the effect of the phases of PDO was not statistically significant.

Coupled analysis of the effect of ENSO-PDO, ENSO-AMO and ENSO-NAO on baseflow provided interesting relationships. The interactive effect of the phases of ENSO-PDO and ENSO-AMO on baseflow was found to be highly significant. However, the interactive effect of the phases of NAO and ENSO on baseflow was not found to be statistically significant. In particular, during the PDO positive phase, occurrence of La Niña results in greater decrease in baseflow (approximately 28%) and this can cause severe drought in the ACF River Basin (Figure 1). Similarly, the occurrence of a La Niña event during an AMO positive phase leads to greater decrease in baseflow (approximately 33%).

Therefore, the study indicates that the effect of La Niña in the ACF River Basin is intensified by the positive phases of PDO and AMO. However, although La Niña periods are generally associated with below-normal baseflow, this was found to not be the case when La Niña occurred during the negative phase of AMO.

The negative effect of La Niña on baseflow appeared to have been mitigated by the effects of the negative phase of AMO resulting in above normal baseflows. During the AMO negative phase, baseflow exhibited similar patterns regardless of the fact that the period was El Niño or La Niña, suggesting that negative phase of AMO suppresses the effect of ENSO (Figure 1).

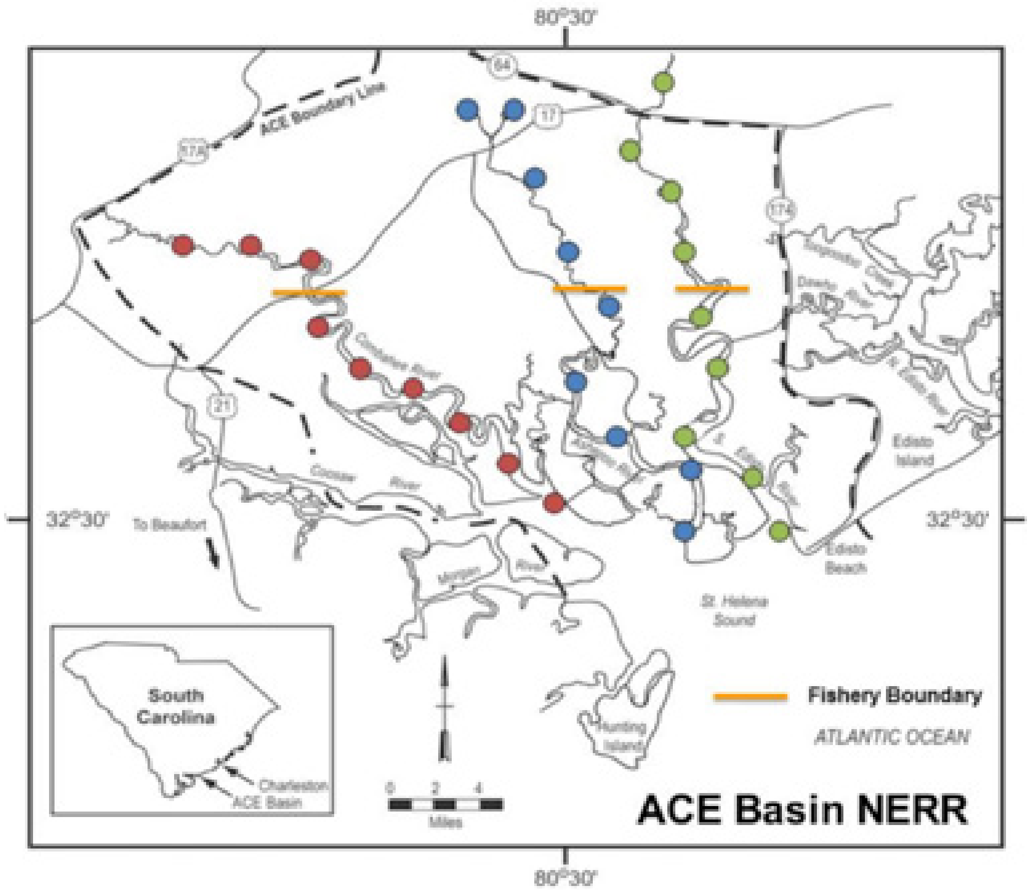
The results illustrate the importance of coupled analyses of climate variability by providing a better understanding of the severity of droughts and their impact on baseflows. The results obtained from this study can be used by water managers in the region as a guide for the issuance of drought severity-based water restrictions.

Study examines the future of river discharge and its impact on South Carolina's valuable blue crab catch

Figure 1

Map shows the locations for the field study of salinity impact on blue crab population structure in the ACE Basin National Estuarine Research Reserve, South Carolina. Twenty-one stations (nine per river) were sampled quarterly for four years from June 2008 until May 2012. Salinity profiles along each river were related to measures of blue crab life history including disease prevalence, relative predation, post-larval settlement, and size-frequency distribution.

During this drought period, blue crab abundance decreased in the low-flow Combahee River (red dots) due to increased infection by Hematodinium sp. parasites, but increased in the high-flow Edisto River (green dots) due to decreased predation by alligators. The seasonal, spatial and interannual differences in river discharge, salinity profile, growth, predation, disease, post-larval settlement, movement and fishing effort were then incorporated into a spatially-explicit individual-based population of blue crabs to estimate the non-linear effects of salinity variation on blue crab commercial landings.



Forecasting a crab fishery using real-time freshwater flow data

BY MICHAEL CHILDRESS
Clemson University

Blue crabs (*Callinectes sapidus*) are one of the most important commercial fisheries in the state of South Carolina with annual landings averaging 5.5 million pounds. Inter-annual variation in S.C. crab landings is significantly correlated with annual levels of freshwater discharge, explaining more than 40% of its variation.

During droughts, freshwater input to marshes decreases and salinity increases. As salinity increases, crab abundance decreases due to increasing infection by a lethal parasite, *Hematodinium sp*. However, the degree to which the population decline is linked to decreasing freshwater depends on the level of freshwater flow into the marsh.

A four-year study of the blue crabs in the ACE Basin National Estuarine Research Reserve (named for the Ashepoo, Combahee, and Edisto Rivers), South Carolina (Figure 1, above) during the 2008-11 drought found that crabs decreased in the low flow Combahee River due to increased parasites (*Hematodinium sp.*) but increased in the high flow Edisto River due to decreased predation by freshwater predators (alligators).

Since drought can have both positive and negative effects on blue crabs, there is considerable interest in understanding how future variation in river discharge will impact commercial blue crab landings.

This project for the Coastal Carolinas Drought Early Warning System (DEWS) used historical and

continued on next page

forecasted Edisto river discharge levels as input for a spatially explicit, individual-based blue crab population model parameterized for conditions in the ACE Basin National Estuarine Research Reserve (SCBCRABS IBM).

The model crab landings for the first 25 years of historical river discharge were then standardized to the observed S.C. commercial landings for the same period. Future projections of crab landings showed that when Edisto river annual average discharge remained at or above a critical minimum level (1250 cfs annual average) for three consecutive years, statewide crab landings increased.

However, when river discharge dropped below this critical minimum, crab landings decreased.

Both statistical models of river discharge trends (seasonal ARIMA) and climate forecast surface runoff models (OpenNSPECT) suggest that the annual river discharge will continue to decrease while the interannual variation in river discharge will remain high. Given these forecasted conditions, future blue crab landings may experience periods, three to five years in duration, of increase and of decline, but ultimately, if river discharge continues to decrease, crab landings will fall to 50% of the historical commercial landings within the next 15-20 years (Figure 2).

The good news is that blue crabs occupy a large latitudinal gradient, and thus, when blue crabs are declining due to drought in the southern portion of their range, blue crabs in the northern portion of their range may be increasing due to elevated river discharge levels.

Future work will attempt to expand the blue crab forecast to examine the ability of blue crabs to persist given the likely scenarios of climate change and river discharge across their entire geographic range. We can accomplish this by incorporating both better predictions of future surface flow (ongoing collaboration with Dan Tufford and Greg Carbone of the University of South Carolina) and incorporating a real-time coastal drought index as a metric for estimating critical minimum flow conditions for blue crabs across their entire geographic range (ongoing collaboration with Paul Conrads, USGS).

FOR MORE INFORMATION regarding the SCBCRABS blue crab forecast model visit the SC Blue Crab Forecast web blog at: http://scbcrabs.blogspot.com.

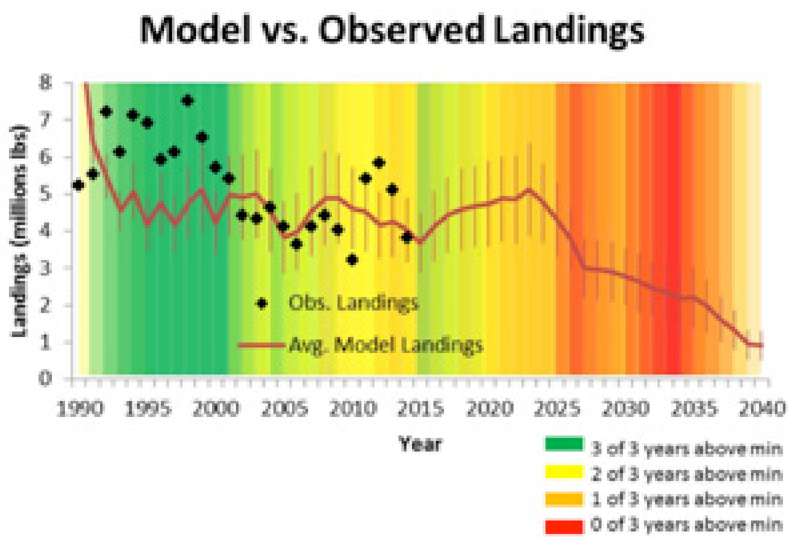


Figure 2.

A comparison of observed commercial blue crab landings for SC with the SCBCRABS IBM predicted landings. Observed landings (in millions of pounds landed annually in SC) are black diamonds and predicted landings (from SCBCRABS IBM) are the red line with mean and SD for 3 replicate runs of the model.

Edisto river discharge is indicated by the color heat map based on a critical minimum discharge level of 1250 cfs average annual flow. Historical river discharge data (1990-2014) is from the USGS gaging station at Givhans Ferry, SC. Projected river discharge (2015-2040) is from a seasonal ARIMA statistical model of future river discharge levels.

When river discharge is above this critical minimum for the 3 previous years, the river condition is green for the next five years. When river discharge is below this critical minimum for the 3 previous years, the river condition is red for the next five years.

Crab landings increase during wet periods (green) and decrease during dry periods (red) and since the year 2000, observed landings typically fall within a standard deviation of the predicted landings.

Comparing environmental indices in Eastern North Carolina

Assessment of indicators for coastal zone fire risk

BY COREY DAVIS, REBECCA CUMBIE, RYAN BOYLES
State Climate Office of North Carolina

Monitoring burning conditions in eastern North Carolina's organic soils can be challenging. Existing measures of near-surface dryness, such as drought indices and National Fire Danger Rating System (NFDRS) parameters, have often been considered poor indicators of fire risk in organic soils, which have complex compositions, can burn and smolder several feet underground, and are often found in regions with subtle but meaningful terrain differences. This project sought to further compare these commonly used environmental indices, including several new gridded products, with an experimental Estimated Smoldering Potential dataset in search for better indicators of organic fire risk.

A Gridded KBDI Dataset

One commonly used fire risk parameter is the Keetch-Byram Drought Index (KBDI), which estimates dryness in the uppermost eight inches of the soil. KBDI has historically been available only at Remote Automatic Weather Stations (RAWS), so much of eastern North Carolina did not have direct coverage. Using daily radar-derived precipitation estimates from the National Weather Service and daily maximum temperature and annual average precipitation data from the PRISM dataset, a gridded KBDI dataset was created at 4 km resolution for the period beginning in March 2007.

A comparison with the RAWS KBDI observations showed that the gridded data generally underestimates values, with annual maximum values 136.65 points lower in the gridded dataset, on average. This difference is likely due to the underestimation of maximum temperatures in the PRISM dataset and/or a warm bias in RAWS temperature observations.

ESP Comparisons

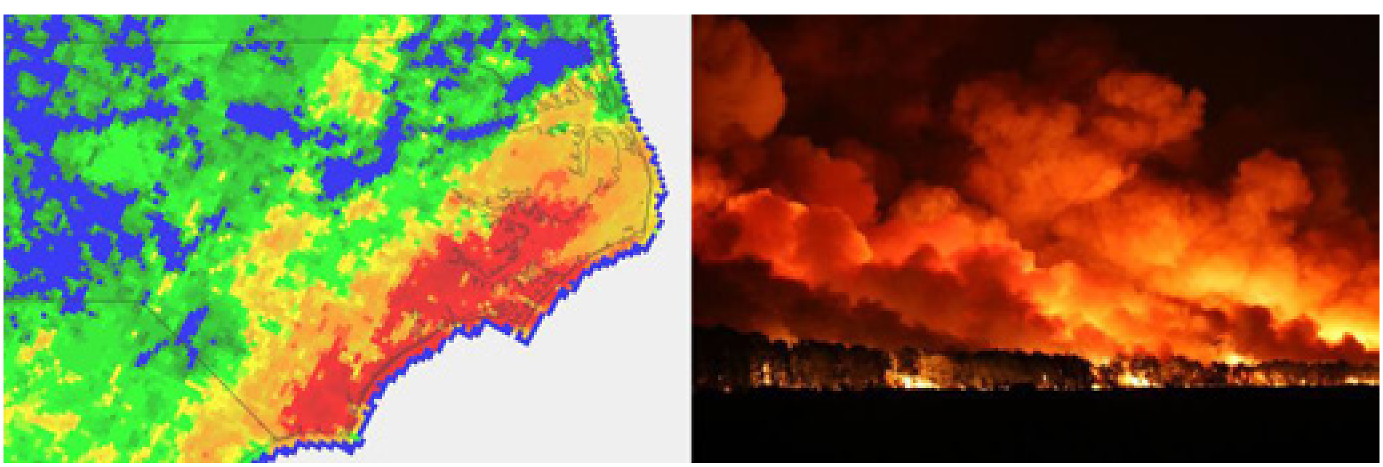
Several gridded indices including KBDI, daily precipitation, and the Standardized Precipitation Index (SPI) over one- to four-month periods, were then compared with soil moisture data from an experimental Estimated Smoldering Potential (ESP) dataset.

This ESP data was collected intermittently from 2012 to 2014 at three coastal stations: in the Pocosin Lakes National Wildlife Refuge in Hyde County, in the Alligator River National Wildlife Refuge in Dare County, and near Green Swamp in Brunswick County.

The results showed that all three gridded indices were only weakly correlated with the ESP data. Separate comparisons with Energy Release Component (ERC) data from nearby RAWS stations using both fuel models G and O also showed only weak relationships with the soil moisture observations from the ERC dataset.

The weak correlations are likely because these

continued on next page



Gridded KBDI values in eastern North Carolina (right) exceeded 500 in mid-June 2011, when the Pains Bay fire (right, by Lloyd Brown) and several others burned.

indices cannot capture the terrain, drainage, and composition of organic soils. To that extent, few to no existing indices can model this combination of environmental and non-meteorological characteristics.

Because of this, no single index based on current widely available data is likely to be a consistent indicator of organic fire risk. A combination of monitoring recent NFDRS parameters to assess surface fuel burning, local soil sampling, and groundwater levels is recommended until further improvements are made.

	Alligator River (n = 349 days)	Allen Road (n = 278 days)	Green Swamp (n = 51 days)
Soil moisture vs. 1-month SPI	0.253	-0.075	0.833
Soil moisture vs. 2-month SPI	0.483	-0.235	0.725
Soil moisture vs. 3-month SPI	0.479	-0.316	0.648
Soil moisture vs. 4-month SPI	0.391	-0.352	0.711
Soil moisture vs. gridded daily precipitation	0.017	0.125	0.091
Soil moisture vs. gridded KBDI	0.372	-0.331	-0.563
Soil moisture vs. ERC (fuel model O)	-0.116	-0.057	-0.254
Soil moisture vs. ERC (fuel model G)	0.147	0.011	-0.217

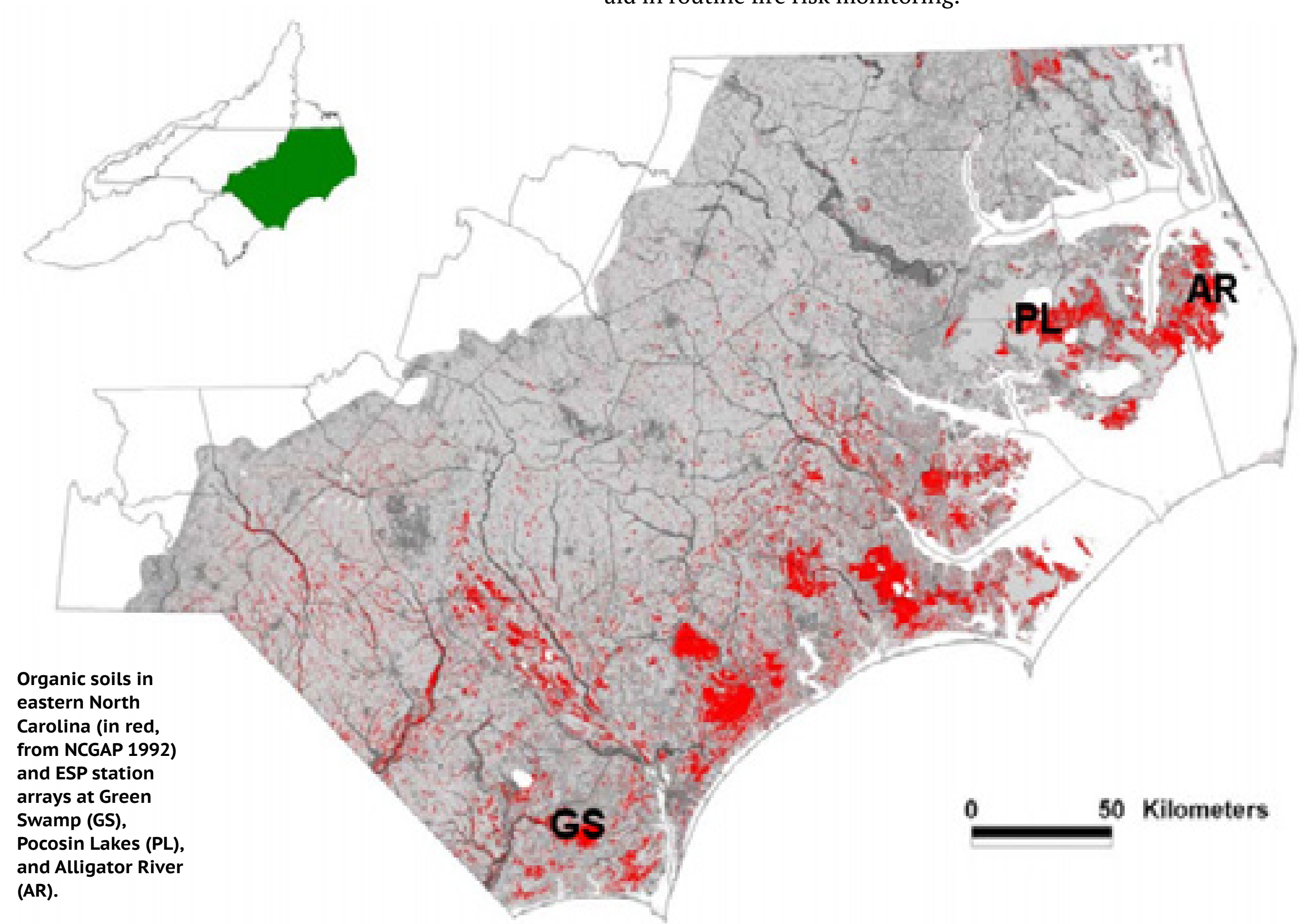
Correlation coefficients (r) between soil moisture data from ESP arrays and other gridded and point-based datasets.

Future Work

Additional research may suggest better options for monitoring organic fire and smoldering conditions. Separate studies are currently examining remotely sensed soil moisture data as an indicator of smoldering in organic soils. The deployment of soil moisture probes across eastern North Carolina could also establish a reliable sensor network and provide a longer period of record than the ESP stations. Along with providing a finer-scale monitoring network in this part of the state, this would allow for a more robust comparison with existing datasets to search for good indicators of organic fire risk.

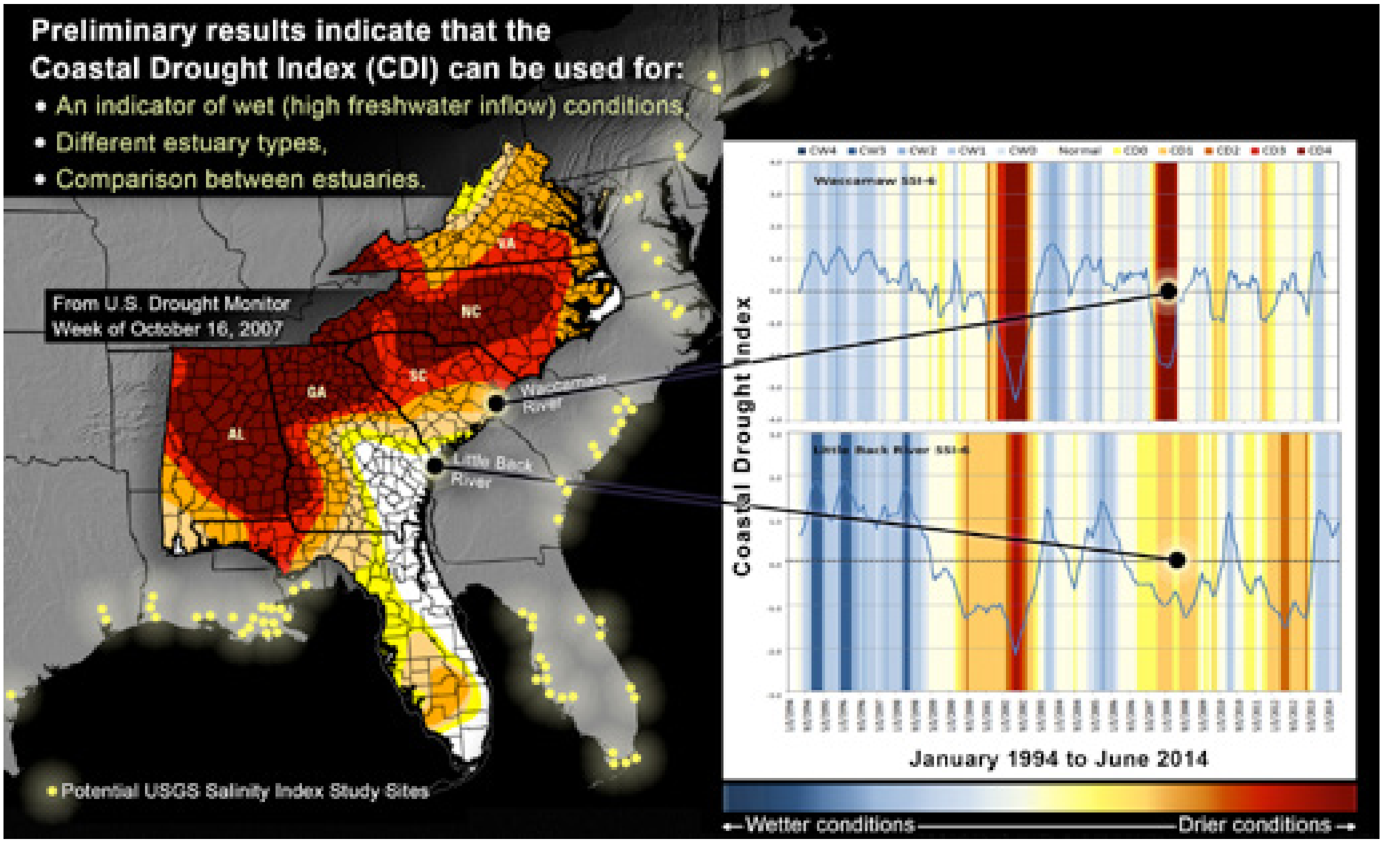
Although it does not provide meaningful guidance for organic regions, the gridded KBDI dataset should become a valuable monitoring tool, especially for assessing response and mop-up with lightning-caused fires, in non-organic regions since it provides local estimates between weather stations.

Additional evaluation of temperature datasets may suggest a more accurate option than the daily PRISM data. If a daily relative humidity dataset was also found, gridded 100-hour and 1000-hour fuel moisture and ERC datasets could also be created to aid in routine fire risk monitoring.



Organic soils in eastern North Carolina (in red, from NCGAP 1992) and ESP station arrays at Green Swamp (GS), Pocosin Lakes (PL), and Alligator River (AR).

Finding ways to tell the story of drought on the coast



This graphic shows the computed coastal drought index for the Waccamaw River (upper plots) and the Little Black River (lower plot). The background colors are the drought declarations (CD0 – CD4) and wet declarations (CW0 – CW4) from pre-determined threshold values for each drought or wetness level. The plots show there are times when there are different drought conditions in the Waccamaw River basin than the Savannah River basin. For a period in October 2007, the CDI was compared to the US Drought Monitor map for the week of October 16th. The map shows that the Yadkin-Pee Dee Basin was in greater drought than the Savannah River Basin. The CDI also indicated a similar change in drought along the coast. The background map shows potential USGS real-time gaging locations where the CDI could be applied. Sites were selected based on length of record and concurrence of upland drought.

Tracking salinity and ecological response data on the coast

BY PAUL CONRADS
USGS

Coastal droughts have a different dynamic from upland droughts that are typically characterized by agricultural, hydrologic, meteorological, and/or socio-economic impacts.

The location of the freshwater-saltwater interface in surface water bodies is an important factor in the ecological and socio-economic dynamics of coastal communities. Because of the uniqueness of drought impacts on coastal ecosystems, a coastal drought index (CDI) that uses existing real-time and historical salinity datasets for sites in South Carolina, Georgia, and Florida was developed by using an approach similar to the Standardized Precipitation Index (SPI).

Salinity is a critical coastal response variable that integrates hydrological and coastal dynamics

continued on next page

including streamflow, precipitation, sea level, tidal cycles, winds, and tropical storms. CDIs characterizing the 1- to 24-month salinity conditions were developed and the evaluation of the CDI indicates that the index can be used for different estuary types (for example, brackish, olioghaline, or mesohaline estuaries), for regional comparison between estuaries, and as an index for wet conditions (high freshwater inflow) in addition to drought conditions.

Unlike the SPI where long-term precipitation datasets of 50 to 100 years are available for computing the index, there are a limited number of salinity data sets of more than 10 or 15 years for computing the CDI. To evaluate the length of salinity record necessary to compute the CDI, a 29-year dataset was resampled in 5-, 10-, 15-, and 20-year interval datasets.

Comparison of the CDI for the different periods of record show that the range of salinity conditions in the 10-, 15-, and 20-year datasets were similar and results were a close approximation to the CDI computed using the full period of record.

The CDI computed with the 5-year dataset, with a smaller range of salinity conditions, had the largest differences from the CDI computed with the 29-year dataset, but did provide useful information on coastal drought and freshwater conditions.

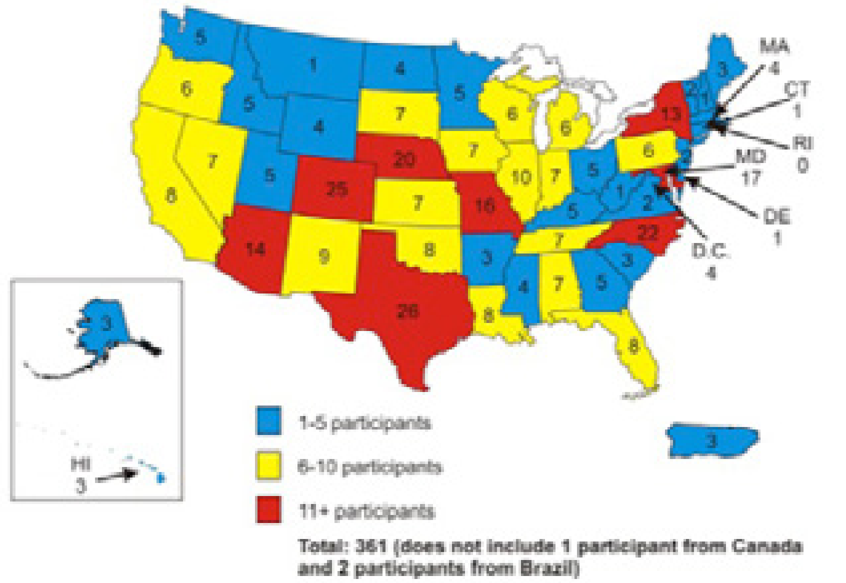
As a next step, the CDI will be correlated to coastal drought response parameters to show the importance of a unique coastal drought index.

However, identifying potential coastal drought response datasets is challenging. Coastal drought is a relatively new concept and existing datasets may not have been collected or understood as "drought response" datasets.

Some potential drought response datasets include tree growth and liter fall in tidal marshes, harmful algal blooms occurrence, Vibrio infection occurrence, shellfish harvesting data, and shark attacks.

An ongoing project supported by NOAA's Sectoral Applications Research Program (SARP) is working to develop ecological linkages to the CDI and evaluate the effectiveness of the CDI as a prediction tool for adaptation planning for future drought.

Drought Monitor contributor update



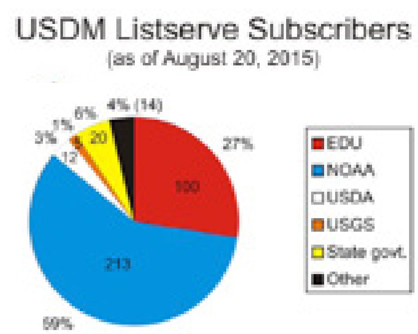
The USDM roster: Where input comes from

BY BRIAN FUCHS, NDMC

Every week more than 350 experts offer their input to the U.S. Drought Monitor (USDM) author, to help determine the range and status of drought throughout the U.S. The conversation takes place via e-mail, which the author combines with monitoring data and impact information to determine the shape of the map each week.

U.S. Drought Monitor author Brian Fuchs, climatologist at the National Drought Mitigation Center, recently updated information about participants in the USDM process.

Over the past year, about 20 individuals joined the conversation and 10 opted out. The top three states contributing to the impact information are Texas (26 participants), Colorado (25) and North Carolina (22). However, in some states one person synthesizes feedback from a group of several contributors, and relays it to the author, so the numbers shown on the map above don't add up to 350. In Montana for example, that single point of contact is actually providing feedback from more than 20 people. So, the numbers can be deceiving if you try to read too much into them.



More than half of the contributors with NOAA; about a quarter are affiliated with an academic institution, as displayed on the pie chart above.

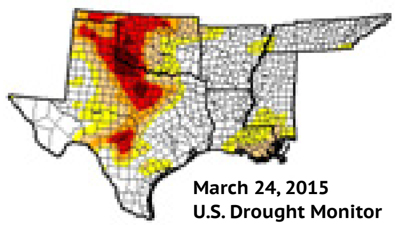
The authors welcome more input, especially from USDA, USGS and other agencies. For more information, contact Brian at bfuchs2@unl.edu.

Study: One out of four droughts in the Southern Plains ends abruptly

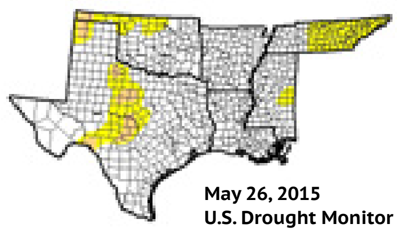
Where droughtbusters happen

BY KATARINA AND JORDAN CHRISTIAN
University of Oklahoma

Just as Bilbo Baggins in *The Hobbit* made a long journey and returned safely to the Shire, the Southern Great Plain's long journey into drought came to an abrupt end last spring. Although the region had experienced extreme to exceptional drought continuously from Nov. 30, 2010, through May 12, 2015, the drought disappeared in a matter of weeks. Reservoirs that were at or near record lows filled to record crests.



March 24, 2015
U.S. Drought Monitor



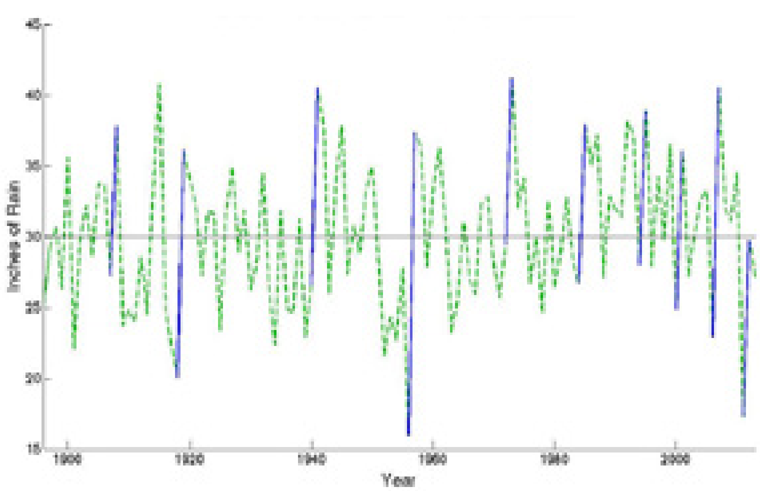
May 26, 2015
U.S. Drought Monitor

Nobody could have anticipated such a rapid recovery.

However, abrupt transitions in much of the Great Plains are not altogether unusual. New research has shown that numerous "dipole events" -- rapid transitions from drought to flood (pluvial) -- occur within the Great Plains. The concept is based on the dipoles of a magnet, which have completely different characteristics but occur closely together. These dipole events have been able to erase multi-year drought in a matter of months.

To study this phenomenon, significant dry and wet years were identified throughout the climatological record. Those years with normal annual precipitation totals of 90% of normal or less were termed drought years and those with 110% or greater of normal annual precipitation were termed pluvial, or wet, years. These were then examined for a drought year being immediately followed by a pluvial year.

Figure 1, below: Figure shows the large inter-annual dipoles within the Southern Great Plains regardless of drought or pluvial phase.



More information

Additional details of the project are described in Christian et al. (2015): "Drought and Pluvial Dipole Events within the Great Plains of the United States", Journal of Applied Meteorology and Climatology (in press); http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-15-0002.1

The analysis was done for several spatial scales, including the Oklahoma climate divisions, the Southern Great Plains, the High Plains, and the Northern Great Plains. In addition to these fixed definitions, the climatological record was also examined for large inter-annual increases regardless of drought or pluvial phase (i.e., from an extremely dry year to a less dry year or a normal year to a very wet year).

Based on the period 1896-2013, the overall probability of a significant drought year being followed by a significant pluvial year was approximately 25% of the time for the Southern and Northern Great Plains and 16% of the time for the High Plains.

Thus, approximately one out of every four droughts in the Southern Great Plains ends abruptly, as was experienced in 2015. Other notable historical occurrences included 2006-2007, 1995-1996 and 1956-1957. Similar to the most recent drought, the event that ended in 1957 was multi-year (beginning in 1952) and considered a record drought for both Texas and Oklahoma.

The drought of 2010-2015 ended with an exceptionally wet spring, particularly the month of May. This was not unprecedented, although the research found that October was most frequently the month most likely to be abnormally wet. In the High Plains, September was the most frequent pluvial month while in the Northern Great Plains, May was the most frequent pluvial month.

The study also showed that dipole events may be more frequent within the recent decades as compared to earlier in the records. Using the criteria of large inter-annual changes, regardless of the existence or end of drought, such events were considerably more frequent in the latter half of the dataset (1955-2013) compared to the first half (1896-1954) for the Southern Great Plains.

For the High Plains and Northern Great Plains, no such trend in dipole events was evident.

The possible implications of elevated sea surface temperatures in the Pacific

El Niño: unknown territory

BY JULIE KALANSKY

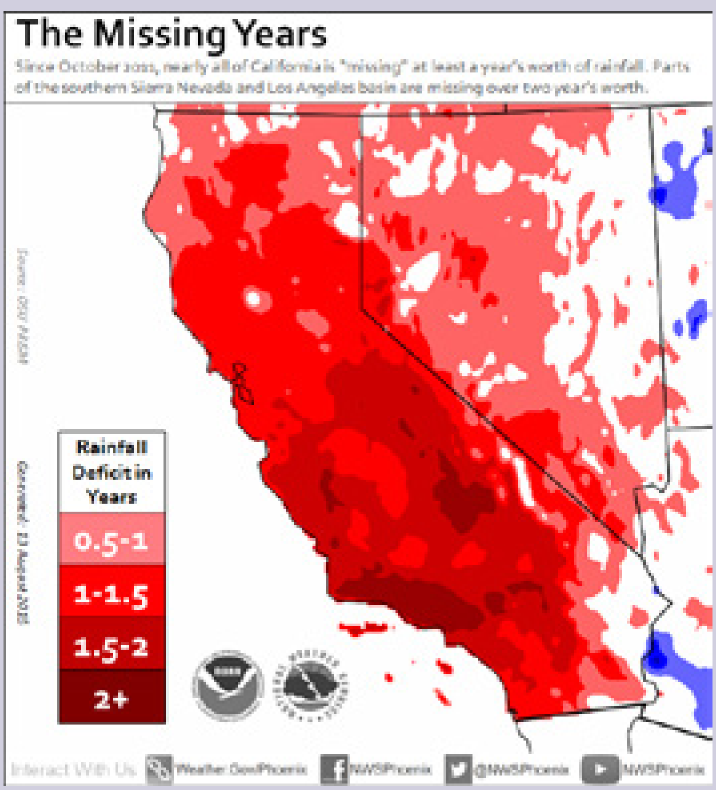
DAN CAYAN

MIKE DETTINGER

Scripps Institution of Oceanography

Much attention is being paid to the El Niño conditions that have developed since this spring in the tropical Pacific. Numerous media outlets have reported about what El Niño might mean for climate conditions this winter, and in particular how El Niño might impact the current drought in California. El Niño conditions, defined as warmer than normal eastern tropical Pacific sea surface temperatures (SSTs), are gaged SST departures from average in the "Niño 3.4 region" (5˚N-5˚S, 170-120˚W). Currently the Niño 3.4 SST is 2.2˚C warmer than average. This is a large anomaly, which has raises the potential for a large El Niño this winter. NOAA predictions give a 90% chance of El Niño conditions continuing through the winter and an 85% chance they will persist through the spring of 2016.

El Niño has important implications because warmed waters in the tropical Pacific can impact atmospheric circulation and weather patterns throughout the world. In California, historical events have shown us that El Niño has often yielded an increase in cool season (October-April) precipitation totals in Southern California. Even in Southern California though, precipitation amounts have varied between El Niño cases, and elsewhere in the state, seasonal precipitation has been erratic--some events have been quite wet, and some quite dry. Statewide, El Niño has produce both the wettest years and the driest years on record. Thus, just knowing that an El Niño is coming does not guarantee that California will have a wet winter. However, because the current development in the tropical Pacific is large and shows signs of being a very strong El Niño this winter, the odds of a wet winter in California are increased. Since 1950, only two events, the 1982-83 and 1997-98, El Niños had sustained SST anomalies of 2˚C or greater for several months and in both of these cases, California was extremely wet, statewide.



Paul Iniguez of the National Weather Service used PRISM data to contextualize the severity of the California-Nevada drought, putting precipitation deficits in terms of years rather than inches or percentages).

Currently, there are some important unknowns that obscure our ability to assess how this El Niño will affect the ongoing California drought. The first is how El Niño will develop this fall and if tropical Nino 3.4 SST anomalies will exceed the 2˚C threshold throughout the winter. If not, historical cases do not present a reliable indication that this upcoming winter will be especially wet statewide. Another unknown is the impact of the extraordinarily warm SSTs in the North Pacific off the coast of North America that has been coined "the blob". Most research has indicated that warm SSTs in the extratropics do not have much effect on West Coast precipitation, but the current anomalies are exceptionally strong and there is little understanding of how the blob might influence California precipitation. There is also little certainty as to how the blob might influence temperatures or the effects of a strong El Niño in California. Despite the many unknowns, the predicted strong El Niño conditions will likely produce more vigorous atmospheric circulation patterns than the past winters.

Concerning the drought, large parts of California have accumulated a precipitation deficit of two average-year's worth of precipitation or more over the past four years and almost everywhere the deficit is at least a full-year's worth. Thus unless a remarkable 200 to 300% of normal precipitation falls this winter, many drought symptoms will remain. A normal or very wet winter will be very welcome; though it is unlikely the drought will not be completely "washed away" everywhere.

Preparing for launch in the Pacific Northwest

Developing a DEWS

BY ALICIA MARRS, NIDIS
KATHIE DELLO, Oregon State University

When you think about the Pacific Northwest, what comes to mind? Salmon? Craft beer? A blossoming wine industry? Snowcapped mountaintops? Evergreens? Relentless rains?

Probably not historically low streamflows, catastrophic wildfires, and water restrictions, but all those became the norm this past summer in much of the region.

While attention had been focused on drought in California and Nevada, the drought conditions that had simultaneously existed in southern Oregon and Idaho intensified and crept north into Washington and traditionally wet coastal areas. Abnormally warm winter temperatures meant precipitation fell as rain rather than snow, and snowpack traditionally relied upon to supply rivers and reservoirs throughout the spring and summer didn't materialize. There was little hope for relief in the form of spring rains when the precipitation tap turned off at the end of winter. The warning signs were there.

One goal of the National Integrated Drought Information System (NIDIS) is to observe and communicate warning signs like these, and to develop a system of information helping communities prepare for and cope with drought. Ultimately NIDIS' goal is to build a nationwide Drought Early Warning System (DEWS.)

The path to achieving that goal is through building regional DEWS, responsive to particular geographic and hydrologic circumstances and the information needs specific to stakeholders in the respective regions and sub-regions. Regional DEWS are underway in the coastal Carolinas; Apalachicola-Chattahoochee-Flint River system in Alabama, Georgia and Florida; the Southern Plains states of Texas, Oklahoma and New Mexico; California; the Upper Colorado River Basin; Four Corners Tribal Lands and Missouri River Basin.

A Pacific Northwest DEWS, consisting of the states encompassing the Columbia River Basin (Idaho, Montana, Oregon and Washington), is a logical next step, especially given the current conditions in the region. The process for establishing the DEWS relies on feedback from stakeholders within the region to guide its development.

A Washington State Department of Ecology (DoE) employee stands on rock normally under several feet of water during June on the Snoqualmie River. this past summer. The photo is part of a collection of drought impact photos from the state's DoE. See more photos on page 12-13 following, or view the entire collection here: http://waecy.maps.arcgis.com/apps/MapTour/index.

NIDIS and a core group of partners (see box below) have come together to hold a series of drought outlooks. Participants heard from experts on current and expected drought, climate, fire and hydrologic forecasts, and then discussed what information, services and products they hope the PNW DEWS will offer.

In May 2015, 45 water managers representing the agriculture, energy, recreation, forestry, and fish and

continued on next page

Partners working toward the PNW DEWS

National Weather Service's (NWS) Western Region

NIDIS

NOAA West Regional Climate Services Director

Pacific Northwest Climate Impacts Research Consortium, which includes:

- Climate Impacts Research Consortium (CIRC)
- Oregon Climate Change Research Institute (OCCRI)
- Northwest Climate Science Center (NWCSC)
- Oregon Climate Service (OCS)

University of Washington's Climate Impacts Group

Western Regional Climate Center

Office of the Washington State Climatologist wildlife sectors from across the Pacific Northwest gathered at the National Interagency Fire Center (NIFC) campus in Boise, Idaho, for an Inland Pacific Northwest Drought Outlook to initiate the discussion of how to shape a potential DEWS for the Pacific Northwest.

The meeting began with a winter recap and drought outlook from Climatologist Kelly Redmond of the Desert Research Institute. Snow drought plagued most of the Pacific Northwest in winter 2014-15. The National Weather Service in Boise and the National Interagency Fire Council both discussed hydrologic and fire outlooks for the upcoming summer.

A panel of key representatives from each of the aforementioned sectors reflected on water management challenges and successes over the past year. Each panelist offered some thoughts about what they would like to see included as part of a DEWS for the Pacific Northwest. Breakout discussion followed, where the groups considered ideas beyond requesting a better seasonal forecast. They expressed a desire for better communication about what is and is not known about climate outlooks. Participants appreciated the opportunity for face-to-face networking with colleagues from throughout the region.

In September 2015, NIDIS and its partners held a similar meeting in Vancouver, Washington, to explore coastal drought impacts and conditions affecting communities, ecosystems and industries west of the Cascade Range.

There will be a lunchtime listening session to elicit more input on directions for the DEWS at the 6th Annual Pacific Northwest Climate Conference in Coeur D'Alene, Idaho, in November.

NIDIS is targeting a formal launch of the Northwest DEWS in the first quarter of 2016.

Workshops bring together researchers, information providers, and stakeholders

Snowpack monitoring = drought monitoring

BY JEFF LUKAS
CIRES Western Water Assessment / University of Colorado

Chad Pickett and Kevin Pantle of the Wyoming State Engineer's Office conduct snowpack reading at the Haskins Creek Snow Course in Wyoming's Sierra Madre Mountains. Photo by Matt Hoobler, Wyoming SEO

Workshop objectives

-- **Help improve the usability and use** of snowpack monitoring information for runoff forecasting, drought early warning and planning, and other applications.

-- **Provide background information** on snow hydrology and snow measurement

-- **Describe operational snow-monitoring products** and how they are used in runoff forecasts

-- **Provide guidance** for accessing and interpreting operational data

-- **Introduce and demonstrate new snow-monitoring products** using satellite and airborne sensors being developed by WWA researchers and others

-- **Facilitate interaction and further conversation** among stakeholders, researchers, and operational data providers in NRCS

For water providers and others in the Rocky Mountain West who depend on the pulse of runoff from the melting snowpack from April through July, snowpack monitoring is drought monitoring. A well-below-average snowpack, as measured by snow-water equivalent (SWE), is a harbinger of not only low water supply but also other drought impacts, such as increased fire risk and below-normal summer soil moisture.

However, the snowpack is complex, varying tremendously over short distances and from year to year, and changing rapidly during the season, especially in the spring. The in-situ snow monitoring network—from snow courses and SNOTEL sites—provides a robust snapshot of conditions in most years and most basins, but may not capture large deviations from more typical patterns of snow accumulation and melt.

The CIRES Western Water Assessment (WWA) at the University of Colorado Boulder, recently organized and delivered three all-day workshops intended to improve the usability of snowpack monitoring information in the Rocky Mountain West, with a view to enhancing that monitoring with new technologies. WWA is one of 11 RISA (Regional Integrated Sciences and Assessments) programs sponsored by the NOAA Climate Program Office.

The workshops took place in West Jordan, Utah; Lander, Wyoming; and Broomfield, Colorado, supported by NIDIS' "Coping with Drought" funding. The events brought together a total of 180 participants, mainly representing the core user community of local, state, and federal water managers, along with other stakeholders, researchers, and operational information providers.

Key partners for all three workshops

continued on next page

Links

The presentations and particpant lists from the workshops are available by accessing the respective workshop homepage from http://wwa.colorado.edu/events/workshops/index.html, or specific workshop home pages:

Utah: http://wwa.colorado.edu/events/workshops/UTsnow2015.html

Wyoming: http://wwa.colorado.edu/events/workshops/WYsnow2015.html

Colorado: http://wwa.colorado.edu/events/workshops/COsnow2015.html

were NIDIS, the Natural Resources Conservation Service (NRCS) Snow Survey offices, and the NOAA NWS Colorado Basin River Forecast Center (CBRFC). Presenters from those entities described the current state of drought monitoring and early warning in the region, operational in-situ snowpack monitoring, and the operational seasonal runoff forecasts from both NRCS and NOAA. Local and state water entities provided a view of how operational snowpack and runoff information is currently being used. And a pre-workshop survey of participants rounded out the picture of current use of this information.

A repeated theme was how critical the SNOTEL-based monitoring capacity is to managers, forecasters, and researchers.

NOAA CBRFC hydrologist Stacie Bender described how CBRFC is piloting the use of satellite information to supplement their picture of the snowpack from SNOTEL sites. This served as a bridge to the afternoon portion of the workshops, which focused on emerging applications of remote-sensing technologies for snowpack monitoring.

Snow hydrologists on WWA's research team (Jeff Deems and Noah Molotch) are involved with two such efforts: NASA's Airborne Snow Observatory (ASO) that measures snow depth at extremely high resolution (~ 1m) using LIDAR (laser) altimetry; and a wide-area SWE reconstruction product based on 1-km satellite imagery from the NASA MODIS sensor.

In both cases, the new products depend on and complement the in-situ snow monitoring network, but are not intended to replace it. Workshop participants expressed high interest in expansion of current pilot efforts in the western U.S., mainly California, to additional basins in Utah, Wyoming, and Colorado.

Post-workshop evaluations indicate that participants consistently reported gains in knowledge of snow hydrology and monitoring, and improved awareness of existing and emerging products. They also expressed a need for follow-up training workshops to better access and use operational snow monitoring information, especially in Wyoming.

WWA recognizes that there will need to be more, and smaller, conversations, to work out the implementation of new capabilities in a cost-effective manner.

WWA will be summarizing the findings from the workshops in a report by November 2015; please contact Jeff Lukas at WWA (lukas@colorado.edu) for any questions about the workshops or the report.

NASA's Airborne Snow Observatory (ASO) measures snow depth at extremely high resolution (~ 1m) using LIDAR (laser) altimetry.

Workshop sponsors

NIDIS

NOAA Colorado Basin River Forecast Center

NRCS Snow Survey

Wyoming State Engineer's Office

Colorado Water Conservation Board

Additional presenters

Central Utah Water Conservancy District

Bureau of Reclamation

Colorado Climate Center

Denver Water

NCAR

Participants

180 total

Utah workshop: 55

Wyoming workshop: 50

Colorado workshop: 75

Included state and local water managers, also federal resource managers and researchers, consultants

June 5, 2014

Snowpack on Bogachiel Peak, Olympic Mountain range

June 6, 2015

Bare slopes of Bogachiel Peak, Olympic Mountain range

December 10, 2014

Dungeness River at Old Olympic Highway Bridge. Flow about 5000 cfs.

August 25, 2015

Dungeness River at Old Olympic Highway Bridge. Flow about 60 cfs.

PORTRAIT OF DROUGHT

PHOTOS FROM THE DEPARTMENT OF ECOLOGY, WASHINGTON STATE

The Washington State Department of Ecology is painting a drought portrait through mapped set of photographs depicting the impacts of the exceptional drought in 2015. Their goal is to identify and understand emerging patterns of water availability in smaller tributaries and at-risk aquifers in the event that this year's weather patterns become the norm.

See the entire collection of photographs here: http://waecy.maps.arcgis.com/apps/MapTour/index.html?appid=c7872e8483784d47b24b9cfbe9a25e90

You can submit your photographs of drought in Washington State here: http://waecy.maps.arcgis.com/apps/GeoForm/index.html?appid=20a9968f9aca42eda95e34d313feb166

Sept. 7, 2015

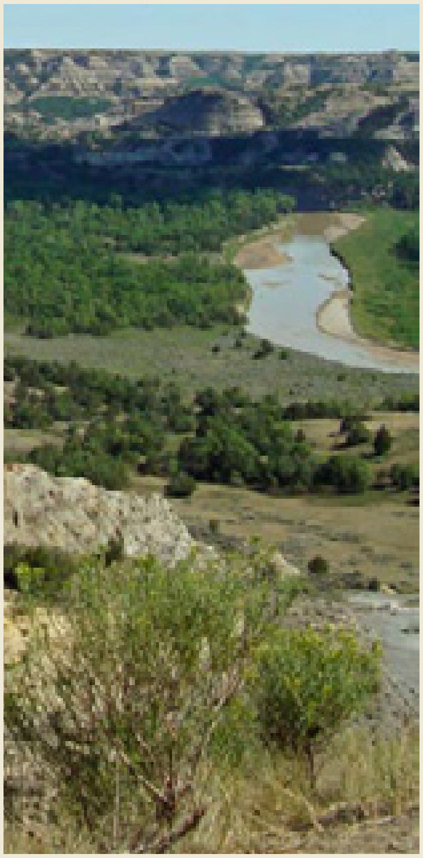
A water-efficient center pivot irrigation device stands idle in Kittitas County becasue the irrigation ditch is dry.

August 2015

Apple trees near Prosser in the Yakima Valley.

May 2015

Siebert creek does not quite reach the Strait of Juan De Fuca, background, because of low flow. Declining water levels on surface streams make passage for salmon smolt and other fish difficult or impossible.



The Little Missouri River flows through Theodore Roosevelt National Park in North Dakota. US Park Service photo.

Partnering for change in the Missouri River Basin

Using recent Missouri River Basin examples, an article published in Water Resources Impact describes decision support and drought and resiliency planning efforts conducted with tribal communities using the National Integrated Drought Information System. The authors also describe a collaborative process and provide information on how to build productive relationships.

Citation: Stiles, C.J., N. Umphlett, J. Rattling Leaf Sr., M.D. Shulski, D. Kluck, M. Hayes, and C. McNutt, 2015: Improving Climate Resiliency in Tribal Communities: Partnering for Change in the Missouri River Basin. Water Resources Impact, 17(4), 15-17.

Eastern Shoshone, Northern Arapaho team up with scientist coalition

Collaboration on the Wind River

BY KELLY HELM SMITH
National Drought Mitigation Center
SHANNON MCNEELEY
Colorado State University

The Eastern Shoshone and Northern Arapaho Tribes on the Wind River Indian Reservation in Wyoming are preparing for drought and other climate fluctuations with help from a broad coalition of scientists.

"I appreciate all the collaborative effort that has gone into it so far," said Mitchel Cottenoir, the Eastern Shoshone and Northern Arapaho Tribes' Tribal Water Engineer. "I'm excited to see how things will progress."

The Tribes have worked with climate and social scientists in the past year to prepare regular climate and drought summaries for use in making water and resource decisions on the reservation and in surrounding areas. A new phase of work began this summer, under a two-year grant from the Department of the Interior North Central Climate Science Center (NCCSC) and led by Cody Knutson of the National Drought Mitigation Center (NDMC), based at the University of Nebraska-Lincoln, and Shannon McNeeley, Colorado State University (CSU)and NCCSC.

This stage will help the Tribes conduct a vulnerability assessment, to see how they can reduce the likelihood of experiencing future drought-related impacts. Both the current and future generations of tribal decision-makers will be involved, finding ways to integrate scientific and traditional knowledge. The ultimate goal is for this information to be used to inform the development of a reservation-wide drought plan.

Cottenoir said the new project will put valuable tools in the hands of the Wind River Water Resources Control Board, which is charged with administering the water rights on the Wind River Reservation and balancing water resources for the 15 equally important beneficial uses of water that are identified in the Wind River Water Code.

"We're going to have trigger points, and be able to gauge where we are, so we can be prepared

continued on next page

Co-investigators on the vulnerability assessment

Mitchel Cottenoir, Shoshone and Arapaho Tribes Office of the Tribal Water Engineer

Jennifer Wellman, Wyoming Experimental Program to Stimulate Competitive Research (ESPCoR, on the Wind River Reservation)

Mark Svoboda, NDMC

Gary Collins, former tribal water engineer, and Al C'Bearing (Office of the Tribal Water Engineer) as well as NDMC staff serve on the project management team.

Collaborating organizations

High Plains Regional Climate Center

NIDIS

Great Northern Landscape Conservation Cooperative

USDA's Natural Resources Conservation Service and its Northern Plains Regional Climate Hub

University of Wyoming

U.S. Geological Survey's University of Wyoming Cooperative Unit

Wyoming State Climate Office

Wind River Community 4-H,

Western Water Assessment (one of NOAA's Regional Integrated Sciences and Assessment teams) and have water for all of the reservation," Cottenoir said. "Agriculture is just one of 15 beneficial uses in our water code. Water is also used in cultural and religious ceremonies."

He added that water for domestic use also becomes an issue at times. Scant surface water supplies have resulted in community members having to boil water before using it.

Top drought-related concerns that tribal members cited in interviews with McNeeley included having enough water for ranching and grazing livestock, for irrigation, for fish and fisheries, and for wildlife. Drought also affects subsistence activities, such as harvesting berries and hunting and fishing, and ceremonies and rituals. People were also concerned about decisions made by the Bureau of Indian Affairs and by various state and federal agencies.

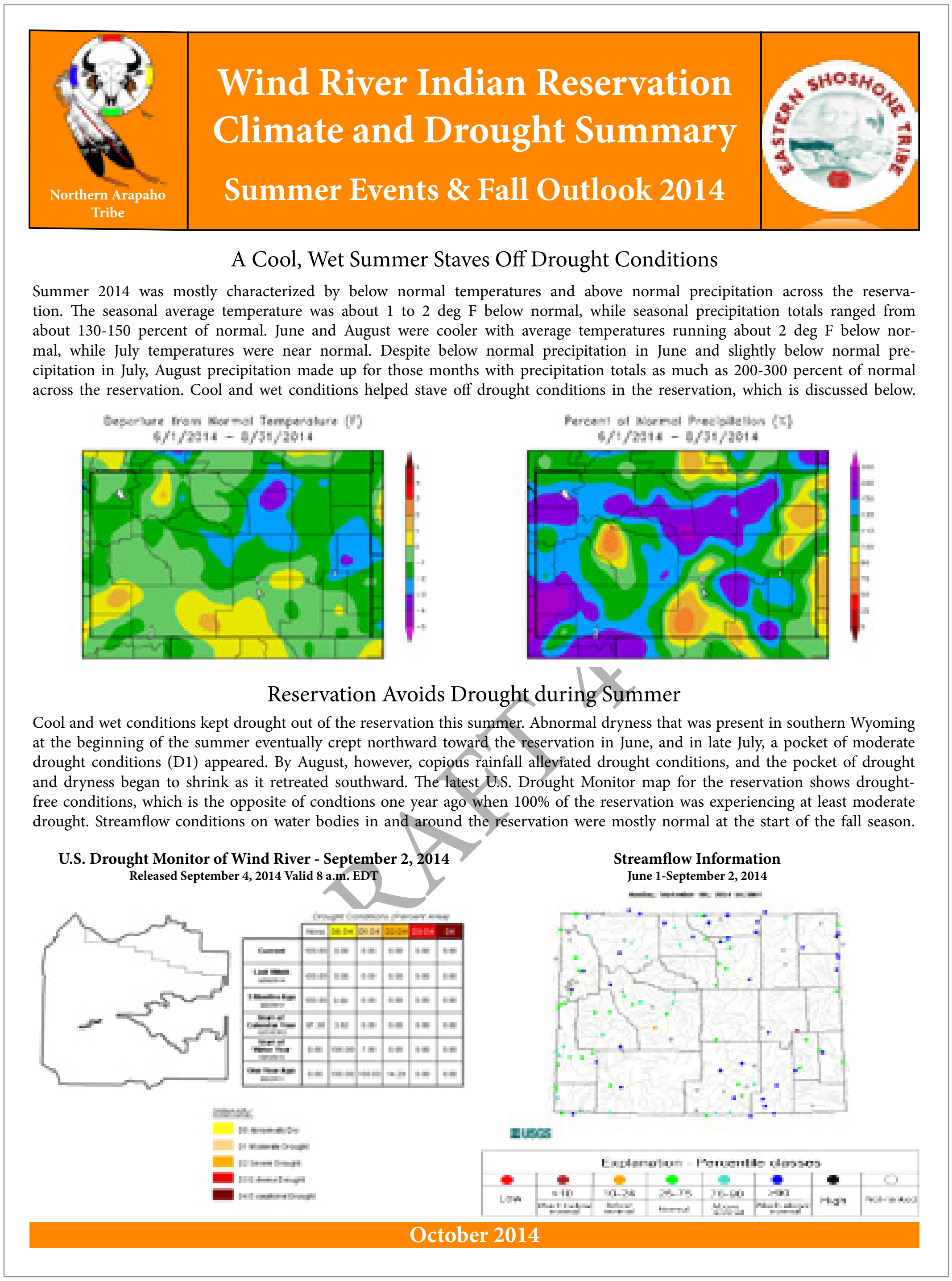
"A primary goal of this project is to be a model for real co-production of science with the Tribes from end-to-end, starting with working with them on the proposal development phase, integrating local knowledge and observations with the science, developing decision support tools like the drought summary, and ultimately informing their development of a drought plan," McNeeley said.

An integral part of the new project is involving youth and young professionals, who will be working with water supply issues in the future. "They'll be dealing with water supply issues when the rest of us have moved on," Cottenoir said. "We're bringing young people along, and getting them involved."

This project builds on a preceding year of effort that included many meetings, workshops, and

continued on next page

For more information about collaborators and the project's Advisory Committee, please refer to the project summary: http://revampclimate.colostate.edu/revamp/project/wind-river-drought-preparedness



Northern Arapaho Tribe

Wind River Indian Reservation Climate and Drought Summary

Summer Events & Fall Outlook 2014

EASTERN SHOSHONE TRIBE

A Cool, Wet Summer Staves Off Drought Conditions

Summer 2014 was mostly characterized by below normal temperatures and above normal precipitation across the reservation. The seasonal average temperature was about 1 to 2 deg F below normal, while seasonal precipitation totals ranged from about 130-150 percent of normal. June and August were cooler with average temperatures running about 2 deg F below normal, while July temperatures were near normal. Despite below normal precipitation in June and slightly below normal precipitation in July, August precipitation made up for those months with precipitation totals as much as 200-300 percent of normal across the reservation. Cool and wet conditions helped stave off drought conditions in the reservation, which is discussed below.

Reservation Avoids Drought during Summer

Cool and wet conditions kept drought out of the reservation this summer. Abnormal dryness that was present in southern Wyoming at the beginning of the summer eventually crept northward toward the reservation in June, and in late July, a pocket of moderate drought conditions (D1) appeared. By August, however, copious rainfall alleviated drought conditions, and the pocket of drought and dryness began to shrink as it retreated southward. The latest U.S. Drought Monitor map for the reservation shows drought-free conditions, which is the opposite of condtions one year ago when 100% of the reservation was experiencing at least moderate drought. Streamflow conditions on water bodies in and around the reservation were mostly normal at the start of the fall season.

U.S. Drought Monitor of Wind River - September 2, 2014
Released September 4, 2014 Valid 8 a.m. EDT

Streamflow Information
June 1-September 2, 2014

October 2014

webinars at Wind River Reservation, which resulted in the quarterly Wind River Climate and Drought Summary, with regular production shifting into the hands of the Eastern Shoshone and Northern Arapaho tribes that share the reservation.

"We want the climate summary to be a valuable tool to the agricultural community," Cottenoir said. In drought years, "crops burn up in the field, especially if there's no water, as in some cases, past the Fourth of July. We're just trying to provide them the best possible information so they can prepare and decide which crops they're going to plant, and know if they're going to have to get into a conservation mode, and what time frame that's going to be, rather than waiting until there's no water in the ditch."

The climate and drought summary can be of use across and beyond the reservation. Cottenoir said his office is developing a website, sharing it via email with surrounding irrigation districts, and is exploring distribution options such as inserting it into local newspapers.

NIDIS supported development of the climate and drought summary. The High Plains Regional Climate Center and the NDMC, together with NCCSC, worked with tribal water decision-makers and technicians as the summary was being created.

"The climate summary is an invaluable tool for decision-makers because it condenses a vast amount of climate information into a simple format with non-technical language that is intended for a general audience," said Crystal Stiles, an applied climatologist at the HPRCC who helped create the summary.

"It provides a snapshot of climate, water, and drought conditions from the previous season, as well as what can be expected during the next season. The greatest challenge in creating the climate summary is being mindful of the language and jargon used that a general audience may not have been exposed to, so feedback from decision-makers has been extremely valuable."

WEBINARS: Keep up with current conditions in your area

Several of NIDIS' partner organizations offer regular live reports through webinars on drought conditions in their regions. Upcoming and past webinar listings are at http://www.drought.gov/drought/content/regional-programs/regional-drought-webinars. How to sign up for future events, or view past sessions:

Managing Drought in the Southern Plains

The Southern Climate Impacts Planning Program (SCIPP) holds bi-weekly discussions of drought and its impacts on the second and fourth Thursdays of each month at 11:00 a.m. Central Time. States covered include Oklahoma, Texas, and New Mexico. To join in, please register at http://www.southernclimate.org/ . You can view past webinars on YouTube at https://www.youtube.com/user/SCIPP01 .

Upper Colorado River Basin Webinar

The Colorado Climate Center conducts Climate, Water and Drought Assessment briefings detail events in the basin states of Colorado, Utah and Wyoming. To register, please visit: http://ccc.atmos.colostate.edu/drought_webinar_registration.php

Midwest and Great Plains Drought Update

The National Oceanic and Atmospheric Administration (NOAA), the American Association for State Climatologists (AASC) and the High Plains Regional Climate Center (HPRCC) have responded to drought across the Midwest and Great Plains by organizing, creating and presenting webinars since July 2012. These presentations are held monthly but can be more frequent when conditions warrant.

The webinars consist of a regional climate summary, impacts due to drought and climate outlooks.

The webinars are held on the third Thursday of every month at 1pm Central Time. A link to the webinar registration page, along with recordings and powerpoints from previous webinars, can be found here: http://www.drought.gov/drought/news/midwest-and-great-plains-drought-webinar-jan-15-2015 .

Apalachicola-Chattahoochee-Flint (ACF) River Basin Drought Assessment Webinar

The Southeast Climate Consortium (SECC) organizes a drought assessment webinar that includes current conditions and outlooks for the ACF basin.

Currently the webinars occur monthly, and will increase in frequency if drought conditions warrant. Webinar partners include the U.S. Army Corps of Engineers, National Weather Service and USGS. To receive webinar announcements, send a request to reuteem@auburn.edu to get on the email list. To view previous webinar summaries, visit http://www.drought.gov/drought/regional-programs/acfrb/acfrb-home and choose from the list on the right side of the page.

The National Integrated Drought Information System (NIDIS) is a nexus of drought information, policy and research. We promote collaboration among government agencies, communities and individuals at all levels to share information about drought, and provide resources for planning, forecasting, management and recovery. Together with our federal, state and local partners we pursue these goals:

- **Leadership and networking among all sectors to plan for and cope with the impacts of drought**
- **Supporting research on the science of drought, including indicators, risk assessment and resilience**
- **Creating regional early warning systems for drought management**
- **Developing resources, systems and tools to promote drought awareness and response**