The 2018 MOISST Workshop: From Soil Moisture Observations to Actionable Decisions

Trenton Franz

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Daugherty Water for Food Global Institute Faculty Fellow

Planning Committee: Mike Cosh (USDA-ARS Hydrology and Remote Laboratory), Trenton Franz (Univ. of Nebraska-Lincoln), Tyson Ochsner (Oklahoma State University), Andres Patrignani (Kansas State University), and Steven Quiring (Ohio State University).

Welcome to Lincoln Nebraska!

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Mark Mesarch- SNR, Website and logistics
Jacki Loomis- SNR, Meeting organization, food, coffee, logistics
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Justin Gibson- SNR, Logistics
William Avery- SNR, Logistics

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Keith Bellingham through Stevens Water Monitoring Systems

This will be the eighth consecutive year for the workshop, which is an initiative of the community of researchers that has developed from the Marena, Oklahoma, In Situ Sensor Testbed (MOISST). This year's workshop will be hosted by the University of Nebraska-Lincoln and will include a special session on the National Drought Mitigation Center (NDMC) and the National Soil Moisture Network (NSMN), an ongoing initiative to develop a national system that integrates diverse sources of soil moisture observations including federal and state in-situ monitoring networks, satellite remote sensing missions, and numerical models.

Why Nebraska?

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FEATURED

No. 50 of 50; director digging in to solve Nebraska tourism image problem

JoANNE YOUNG Lincoln Journal Star Oct 30, 2017 (11)

Why Nebraska?

- #1 US state with irrigation (~9 million acres, ~78,000 center-pivot irrigation systems)

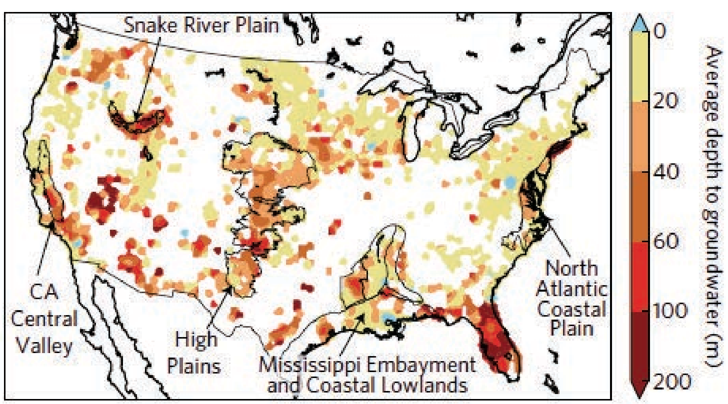

Figure 1 | Average groundwater level depth below ground surface for deep wells. White indicates no water level data; the scale is nonlinear. Five regional aquifer systems are outlined. CA, California.

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Depletion and response of deep groundwater to climate-induced pumping variability

Tess A. Russo[1,2]* and Upmanu Lall[2,3]

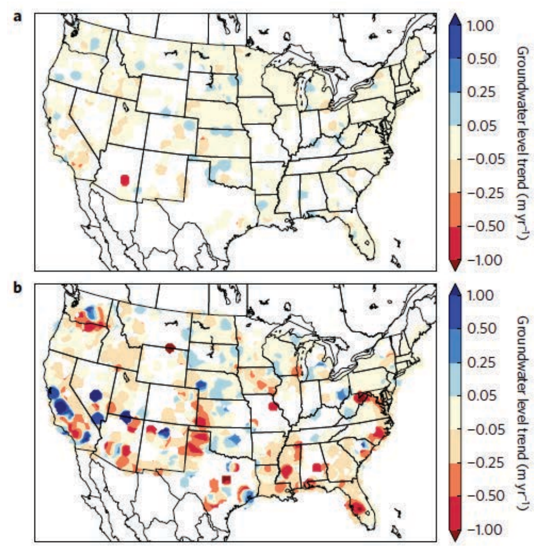

Figure 2 | Average groundwater level rate of change from wells with statistically significant trends ($p < 0.1$) observed between 1940 and 2015. **a**, Average groundwater level rate of change from shallow wells (depth <30 m). **b**, Average groundwater level rate of change from deep wells (depth >30 m). Negative trends (orange/red) indicate an average decline in groundwater level, and positive trends (blue) indicate a rise in groundwater level.

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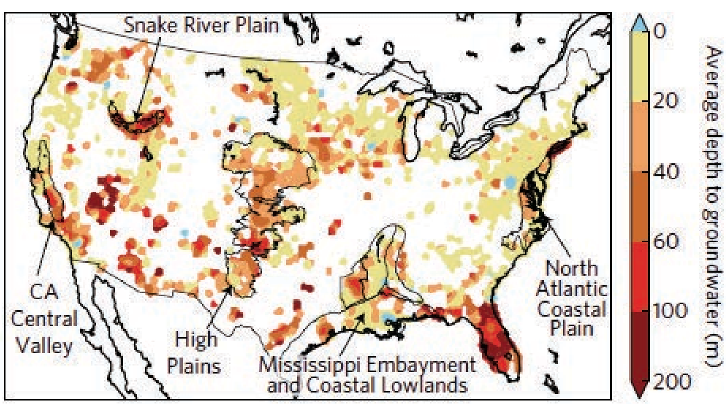

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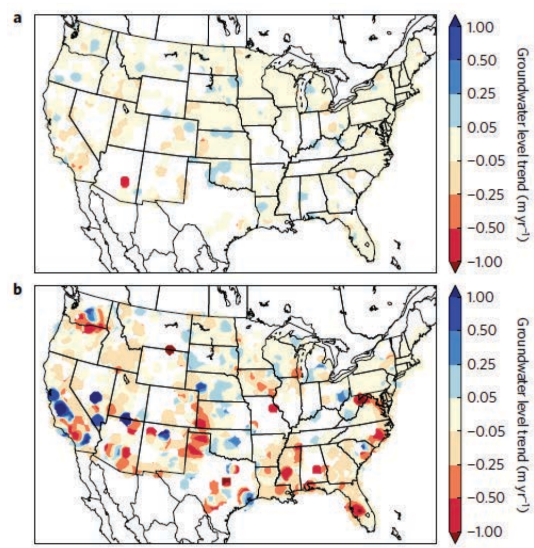

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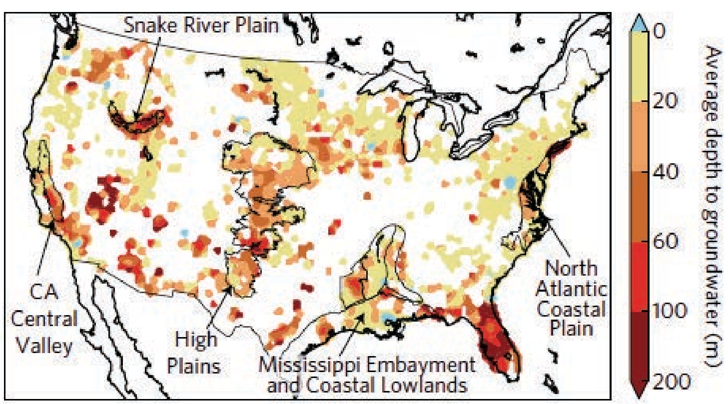
- >90% of state consumptive water use goes to agriculture
- 40% of global food production from irrigation which occupies 20% of arable land



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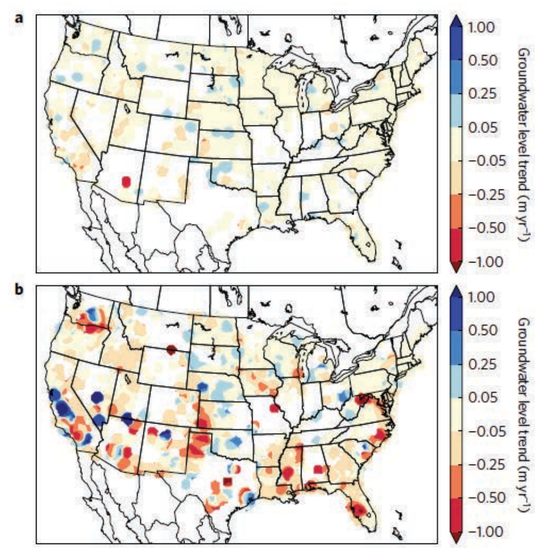

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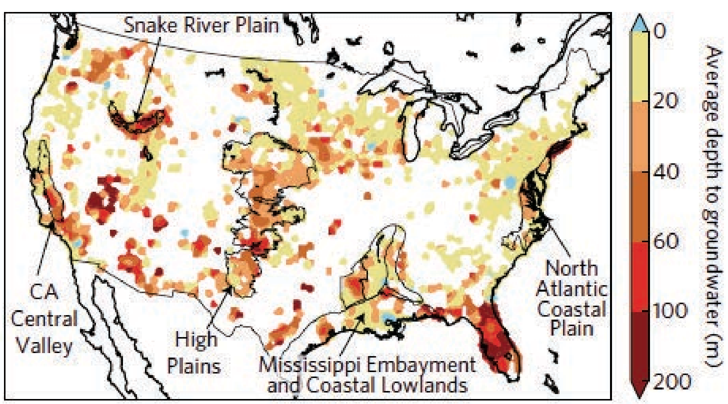

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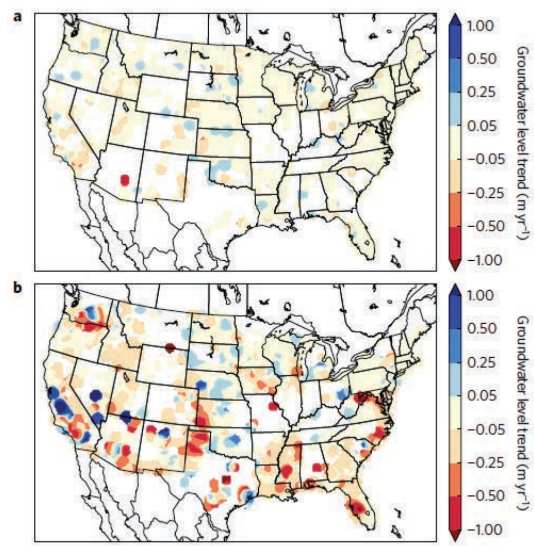

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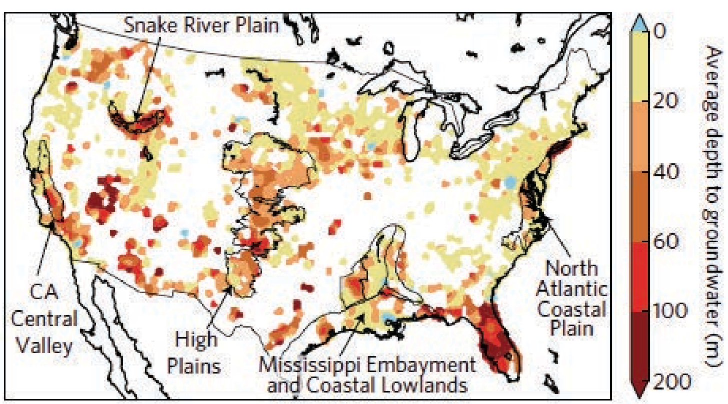

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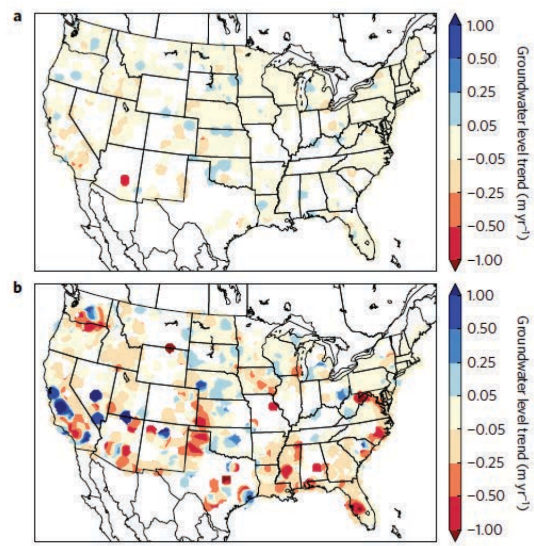

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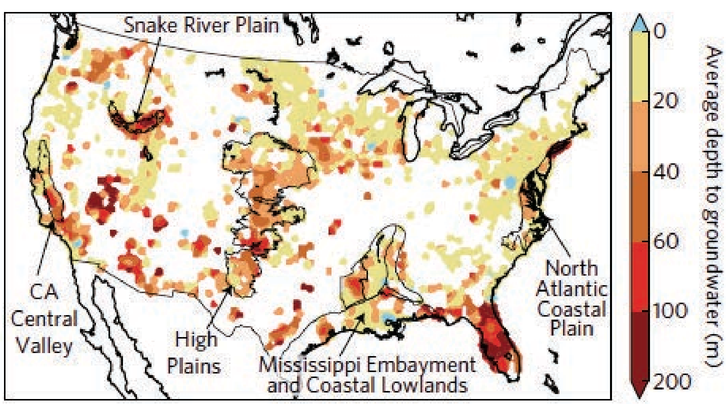
- Long history of world class observational networks (Flux tower/Licor, NE ADWN/Mesonet)
- Home of the National Drought Mitigation Center



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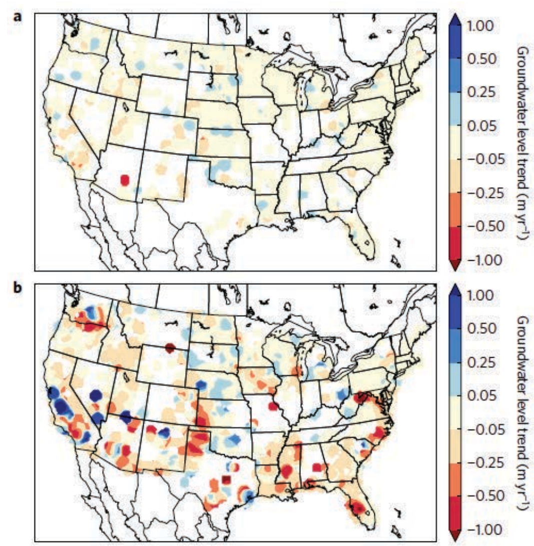

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2. Assimilation of soil moisture into models can further increase skill of weather forecasts

3. Society really cares about fluxes of water (runoff, evapotranspiration, irrigation requirement, recharge) but soil moisture/tension is key state variable to understand flux

If soil moisture is so great why don’t all farmers use it schedule irrigation?

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Table 22. **Methods Used in Deciding When to Irrigate: 2013**

[Excludes institutional, research, and experimental farms. For meaning of abbreviations and symbols see introductory text]

Geographic area	All farms	Farms reporting method used [1]										
		Any method	Condition of crop	Feel of soil	Soil moisture sensing device	Plant moisture sensing device	Commercial or government scheduling service	Reports on daily crop-water evapo-transpiration (ET)	Scheduled by water delivery organization	Personal calendar schedule	Computer simulation models	When neighbors begin to irrigate
United States	229,237	229,237	179,490	90,361	22,656	3,669	17,982	17,815	37,301	49,048	1,915	13,717
Alabama	1,022	1,022	919	426	70	1	34	41	6	168	2	6
Alaska	181	181	150	94	15	7	-	-	-	16	-	-
Arizona	4,380	4,380	3,171	1,964	174	21	356	288	694	1,029	5	68
Arkansas	4,212	4,212	3,978	1,452	222	53	186	140	31	707	35	234
California	44,347	44,347	33,163	18,097	7,429	2,127	3,132	5,206	5,344	14,922	715	3,673
Colorado	12,501	12,501	8,270	4,229	673	78	1,058	487	5,493	1,946	29	1,469
Connecticut	715	715	641	340	33	11	3	22	3	71	3	20
Delaware	396	396	354	192	60	10	39	44	2	73	16	30
Florida	8,120	8,120	6,865	2,971	803	181	468	351	127	1,165	171	138
Georgia	3,545	3,545	3,128	1,401	309	22	237	233	7	432	27	75
Hawaii	1,919	1,919	1,628	650	53	11	21	29	35	489	15	33
Idaho	14,092	14,092	10,025	5,867	521	61	1,208	814	5,168	4,124	5	728
Illinois	1,807	1,807	1,692	801	104	14	62	134	9	196	18	111
Indiana	1,893	1,893	1,770	845	151	29	53	192	7	197	13	161
Iowa	1,090	1,090	1,007	502	128	6	18	90	5	142	6	56
Kansas	5,243	5,243	4,340	1,646	596	50	1,525	900	130	542	55	66
Kentucky	1,212	1,212	1,046	465	80	9	8	12	8	179	-	30
Louisiana	2,130	2,130	1,936	695	62	17	80	65	13	321	18	31
Maine	946	946	818	352	19	11	43	1	-	126	1	-
Maryland	890	890	817	524	86	11	9	38	5	135	7	17
Massachusetts	1,398	1,398	1,233	739	122	-	31	82	7	140	13	19
Michigan	3,662	3,662	3,172	2,111	318	28	146	438	13	626	65	82
Minnesota	2,162	2,162	1,924	1,135	246	34	208	299	20	273	34	123
Mississippi	1,843	1,843	1,684	842	203	6	98	92	6	274	10	104
Missouri	2,569	2,569	2,436	1,159	162	22	152	179	12	383	33	142
Montana	7,384	7,384	5,674	2,393	446	26	376	187	1,959	1,789	11	693
Nebraska	15,747	15,747	13,491	6,957	3,599	45	2,549	3,792	1,449	1,496	113	619
Nevada	2,149	2,149	1,170	578	53	12	230	80	923	488	8	246
New Hampshire	528	528	483	262	32	1	-	2	-	88	1	-
New Jersey	1,255	1,255	1,118	569	175	36	7	22	5	149	1	11
New Mexico	8,733	8,733	4,988	2,659	203	20	1,239	255	2,934	1,569	2	1,586
New York	1,936	1,936	1,836	952	146	2	12	73	10	247	6	16
North Carolina	2,710	2,710	2,403	1,286	106	10	6	149	22	410	15	15
North Dakota	533	533	435	298	56	11	65	70	20	97	10	23
Ohio	1,453	1,453	1,322	688	92	17	11	27	5	164	-	4
Oklahoma	1,672	1,672	1,467	648	181	4	131	136	24	334	1	42
Oregon	12,299	12,299	8,923	4,355	999	156	776	649	2,899	3,065	26	417
Pennsylvania	3,126	3,126	2,865	1,278	128	3	14	63	2	333	8	62
Rhode Island	294	294	272	168	4	12	-	14	-	40	-	-
South Carolina	1,046	1,046	940	418	67	7	38	29	7	182	7	2
South Dakota	1,274	1,274	1,091	550	121	14	45	103	88	218	-	66
Tennessee	1,108	1,108	988	349	95	9	23	35	10	185	12	18
Texas	13,259	13,259	11,494	5,695	1,289	217	559	869	549	2,795	37	426
Utah	10,357	10,357	6,137	2,215	370	159	2,060	272	5,223	2,532	135	706
Vermont	567	567	494	326	14	2	-	17	3	74	-	-
Virginia	1,342	1,342	1,214	614	114	7	11	26	12	298	18	10
Washington	10,575	10,575	8,247	4,444	1,236	55	295	359	2,161	2,001	181	586
West Virginia	297	297	261	148	24	3	3	9	3	31	3	3
Wisconsin	2,427	2,427	2,226	1,288	387	21	98	333	10	388	21	81
Wyoming	4,891	4,891	3,784	1,724	80	-	259	67	1,838	1,399	3	669

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- Only about 10% of people use SM probes!
- Condition of crop and feel of soil overwhelmingly used
- Over Twice as many people use personal calendar
- About half as many people rely on their neighbor

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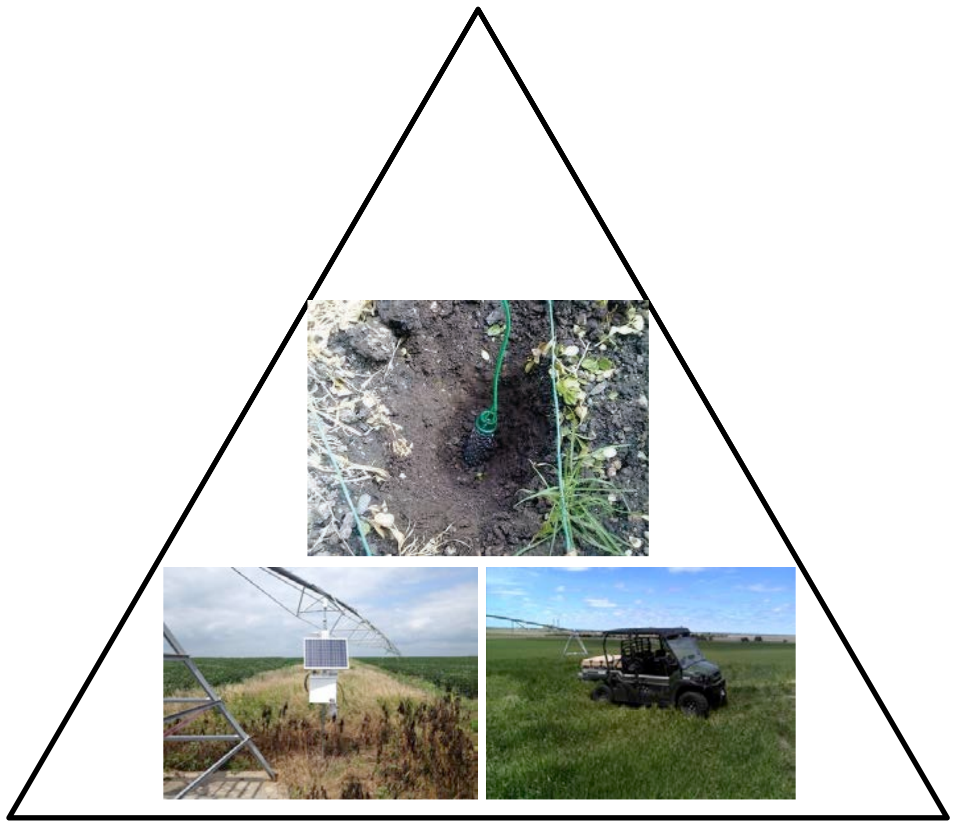
Utah	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	159	2,060	272	5,223	2,532	135	706
Vermont	567	567	494	326	14	2	-	17	3	74	-	-
Virginia	1,342	1,342	1,214	614	114	7	11	26	12	298	18	10
Washington	10,575	10,575	8,247	4,444	1,236	55	295	359	2,161	2,001	181	586
West Virginia	297	297	261	148	24	3	3	9	3	31	3	3
Wisconsin	2,427	2,427	2,226	1,288	387	21	98	333	10	388	21	81
Wyoming	4,891	4,891	3,784	1,724	80	-	259	67	1,838	1,399	3	669

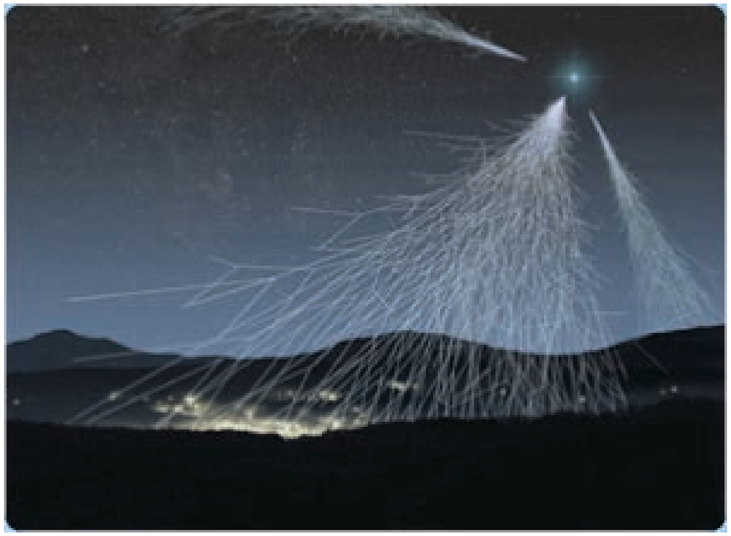
Percentages (5-20%) not that much different even in regions with depleting GW resources

The Paradox of Soil Moisture Sensors, pick 2



“Many ag. companies give away free soil moisture probes but they often never leave the barn”

Cosmic-ray Neutron Probe Guy



IAEA-TECDOC-1809

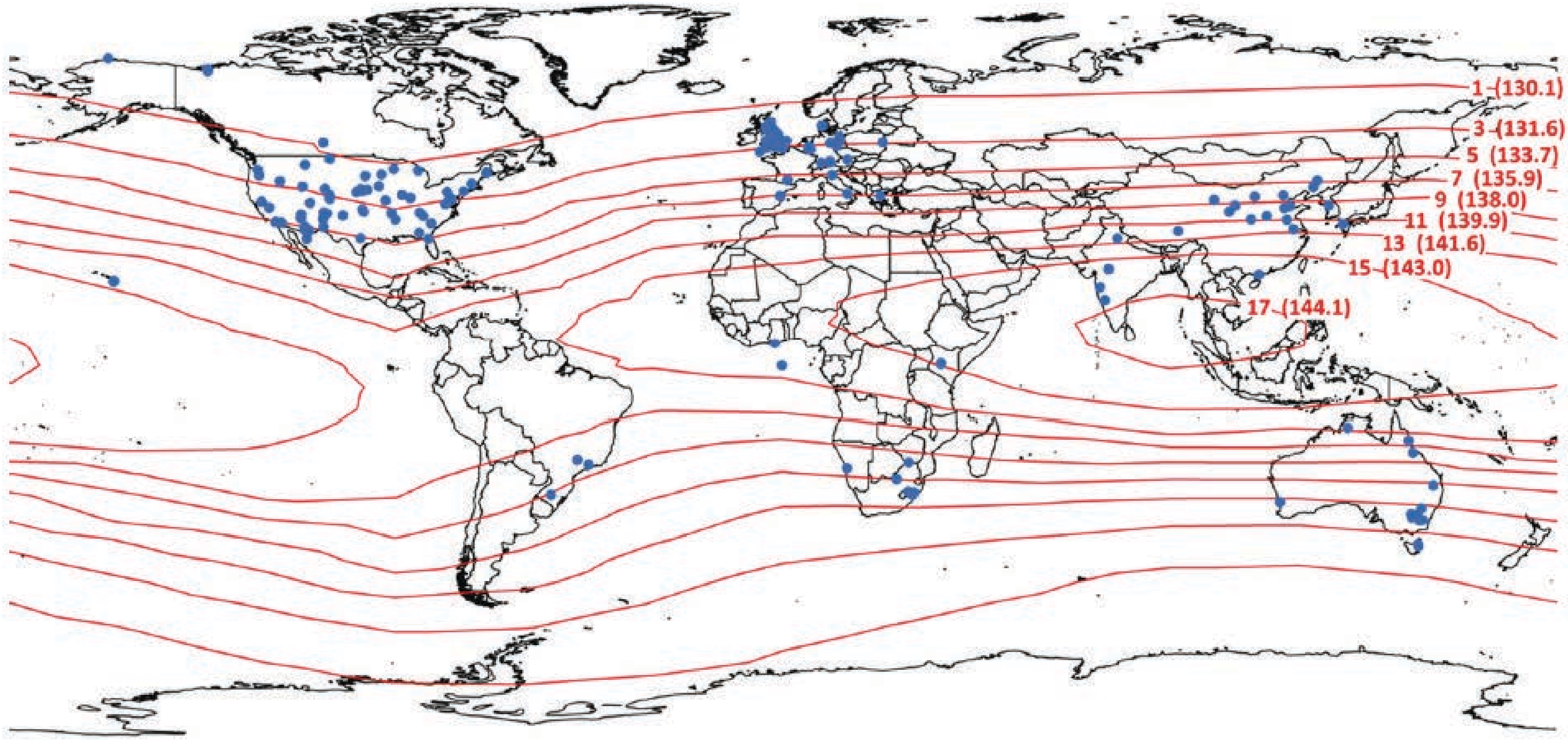
Cosmic Ray Neutron Sensing:
Use, Calibration and Validation
for Soil Moisture Estimation

IAEA-TECDOC-1845

Soil Moisture Mapping
with a Portable
Cosmic Ray Neutron Sensor

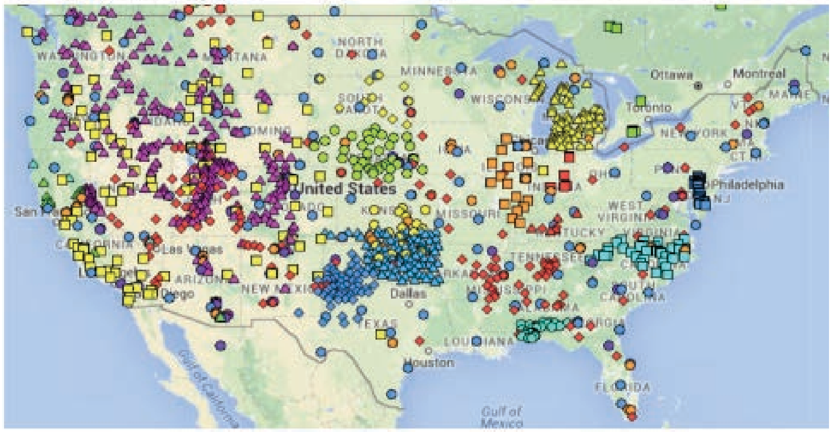
COSMOS Project

- COSMOS data freely available at (http://cosmos.hwr.arizona.edu/) with some quality control, usually co-located with eddy covariance towers, over 90% reliability
- Probes: 70 COSMOS (10 UNL), 200 Independent networks around globe (CosmOz, TERENO, UK, South Africa), with more to come online (Saudi Arabia, Brazil, China?)



Andreasen, 2017 VZJ

So Many Networks



This map shows soil moisture monitoring networks in the contiguous U.S., built from the database of networks maintained by Texas A&M University. http://soilmoisture.tamu.edu/

SELECTED IN SITU SOIL MOISTURE NETWORKS IN THE U.S.

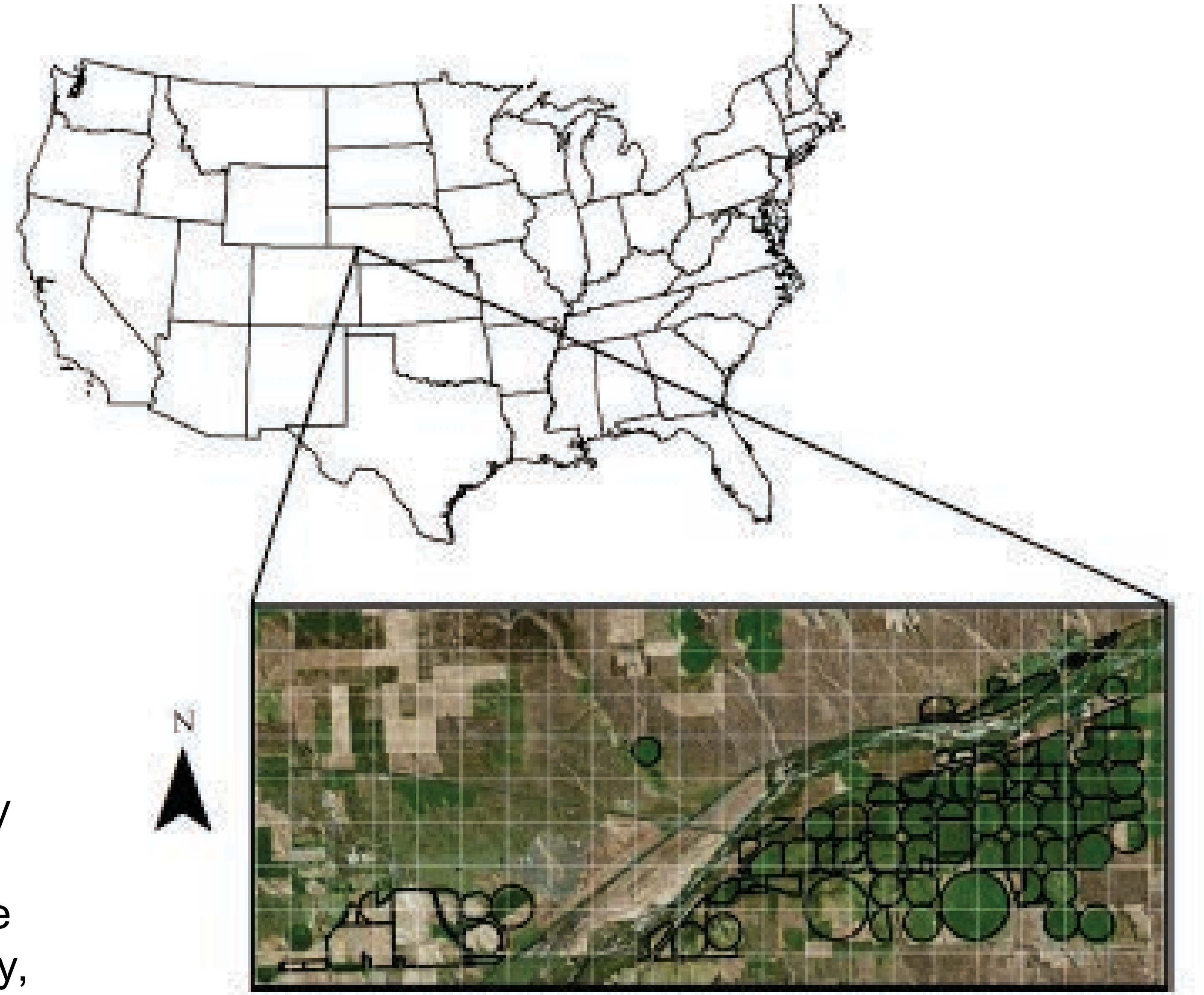
Network Name	Geographic Region	# of Stations	Period of Record	Observing Depths (cm)
Agricultural Research Service (ARS)	Oklahoma	44	2005-present	5, 25, 45
AmeriFlux	United States	39	1997-present	Variable
Atmospheric Radiation Measurement (ARM)	Kansas, Oklahoma	17	1996-present	5, 15, 25, 35, 60, 85, 125, 175
Automated Weather Data Network (AWDN)	Nebraska	52	2006-present	10, 25, 50, 100
Climate Reference Network (CRN)	United States	114	2009-present	5, 10, 20, 50, 100
Cosmic Ray Soil moisture Observing Station (COSMOS)	United States	54	2008-present	Variable
Delaware Environmental Observing System (DEOS)	Delaware	29	2004-present	5
**Georgia Automated Environmental Monitoring Network (GAEMN)	Georgia	79	1992-present	Variable
Illinois Climate Network (ICN)	Illinois	19	1988-present	5, 10, 20, 50, 100, 150
Kansas Mesonet	Kansas	15	2008-present	5, 10, 20, 50, 100
Michigan Enviro-weather (Automated Weather Network, MAWN)	Michigan, Wisconsin	80	2000-present	5, 10
Missouri Agriculture Weather Network (MAW)	Missouri	8	2002-present	5, 10
**New Jersey Mesonet	New Jersey	10	2003-present	5
NOAA Hydrometeorological Testbed	Western U.S.	25	2004-present	Variable
North Carolina EcoNet	North Carolina	36	1999-present	20
Oklahoma Mesonet	Oklahoma	113	1998-present	5, 25, 60, 75
**Remote Automated Weather Stations (RAWS)	Western U.S.	50	1983-present	Variable
Snowpack Telemetry (SNOTEL)	Western U.S.	414	2000-present	Variable
Soil Climate Analysis Network (SCAN)	United States	203	1996-present	5, 10, 20, 50, 100
South Dakota Automated Weather Network (SDAWN)	South Dakota	11	2000-present	5, 10, 20, 50, 100
UA Fairbanks Water and Environmental Research Center (WERC)	Alaska	24	2000-present	Variable
West Texas Mesonet	Texas, New Mexico	64	2000-present	5, 20, 60, 75

Data from Mike Strobel presentation, https://www.drought.gov/drought/sites/drought.gov.drought/files/media/calendar/pre_SoilMoisture2016_Strobel1.pdf

Applications of Soil Moisture/Hydrology in Western Nebraska Irrigation Project (2014-2017)

See J. Gibson poster as well

What are we finding from the Western Nebraska Irrigation Project (2014-2017)?



Funding provided by Coca-Cola in partnership with The Nature Conservancy, NEWBA, SPNRD, UNL

Producers tend to hit irrigation plus precipitation target of 700 mm/yr (28 inches)

Better local realtime rainfall data + pivot telemetry can lead to actionable decisions and reduced pumping

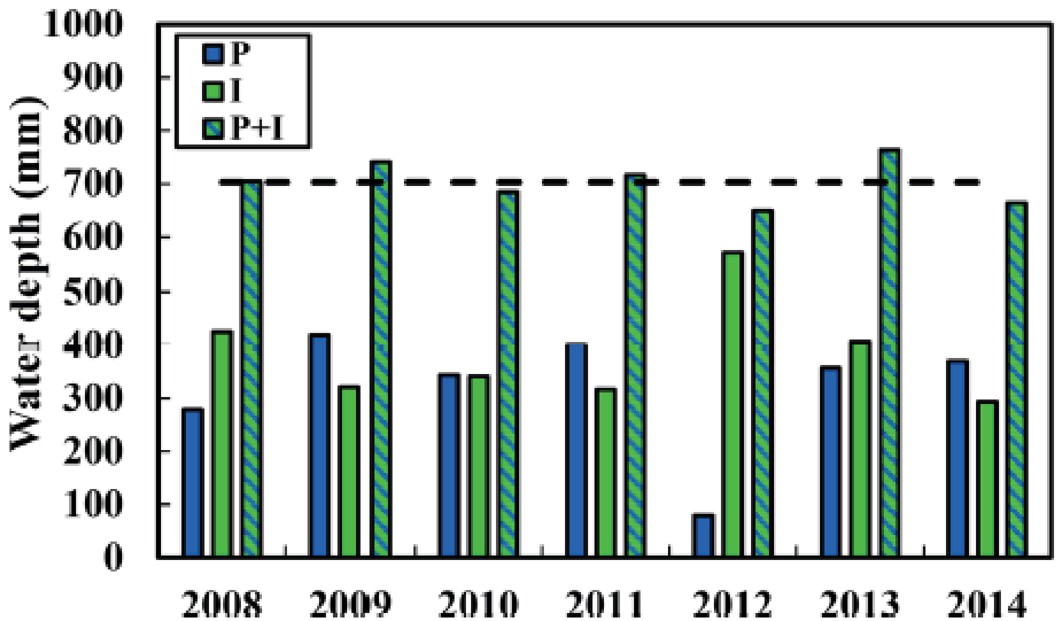


Figure 5. Observed growing season totals for precipitation (P), irrigation (I), and $P+I$. The dashed line represents the historical average for $P+I$.

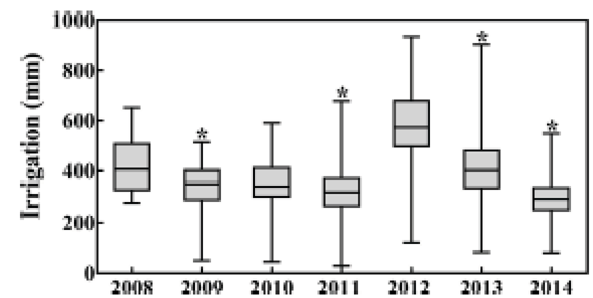


Figure 4. Box and whisker plots of historical irrigation depths for all sites. The upper and lower boundaries of the boxes indicate the 75th and 25th percentile, respectively. The horizontal line within the boxes is the median value. Whiskers are the maximum and minimum values. Asterisks indicate that irrigation distribution deviates from a normal distribution (D'Agostino–Pearson test, $p < 0.01$).

From Gibson et al. 2017 HESS

Crop model with 4 different irrigation triggers indicates pumping savings with no impacts on yield

up to 100 mm/yr of reduced pumping with <3% yield losses

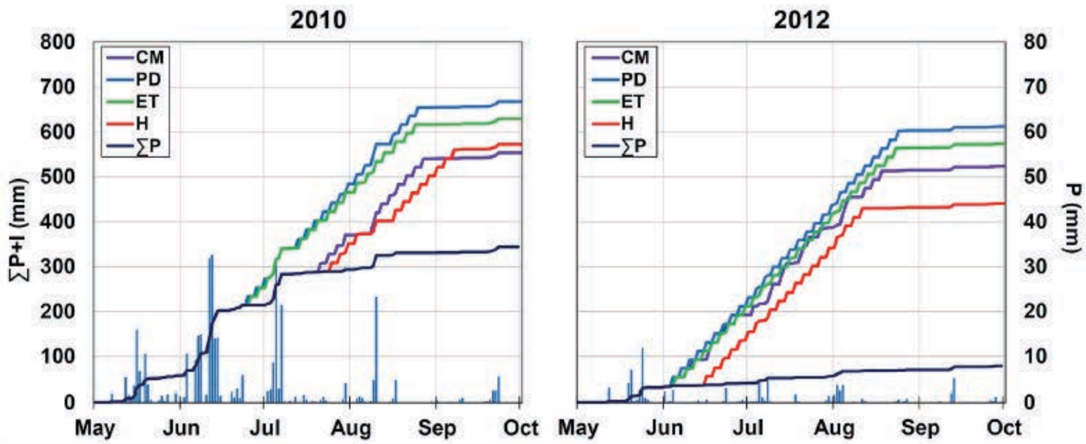


Figure 8. Example of simulated growing season cumulative P and $P+I$ with daily P values plotted on the secondary y axis for the four irrigation routines in a wet (2010) and dry year (2012). Irrigation starts later for routines that track soil moisture, thus leading to reduced pumping.

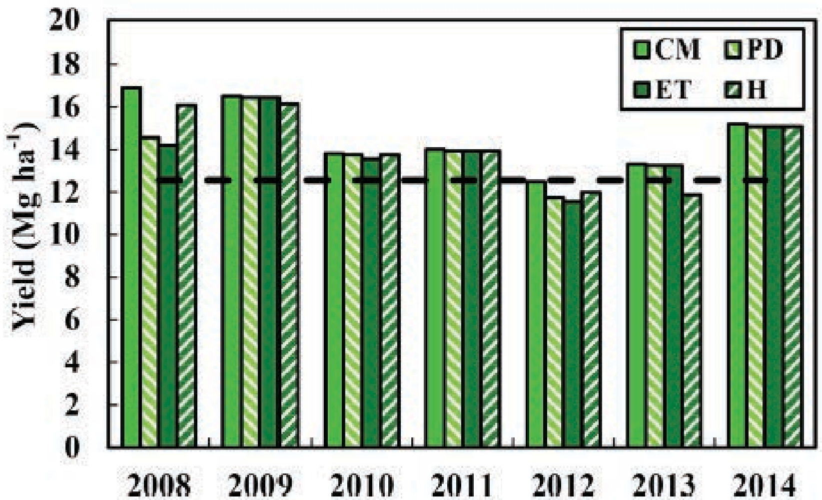
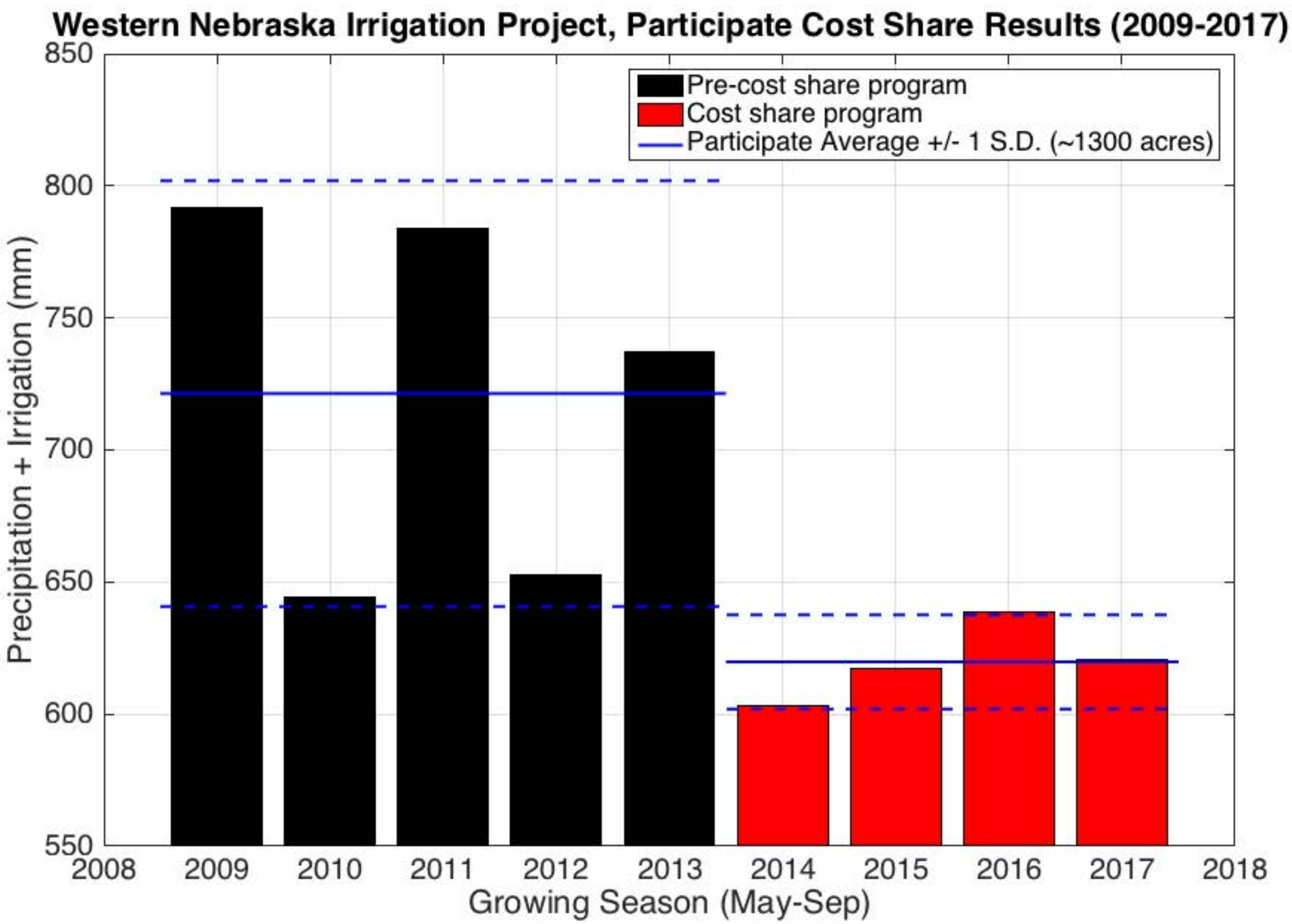


Figure 7. Potential yield simulated by Hybrid-Maize using the four irrigation routines: crop model (CM), precipitation delayed (PD), evapotranspiration replacement (ET), and Hydrus-1D (H).

From Gibson et al. 2017 HESS

Preliminary results of WNIP cost share indicate realized reductions in pumping ~100 mm/yr (2014-2017) vs. (2009-2013) for 1300 acres of corn in western corner according to NRD flow meters

Anticipate similar savings across other NRDs over several years and continued support of extension/liason services (J. Fritton TNC)



Preliminary results from TNC WNIP, based on South Platte NRD database and Brule AWDN gage

Workshop Goals:

1. Provide a highly focused venue for presenting cutting-edge research and new concepts related to soil moisture monitoring.

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3. Stimulate progress towards realizing the vision of the National Soil Moisture Network.