Stable isotopes in precipitation and meteoric waters: Investigating the North American monsoon across the Four Corners region

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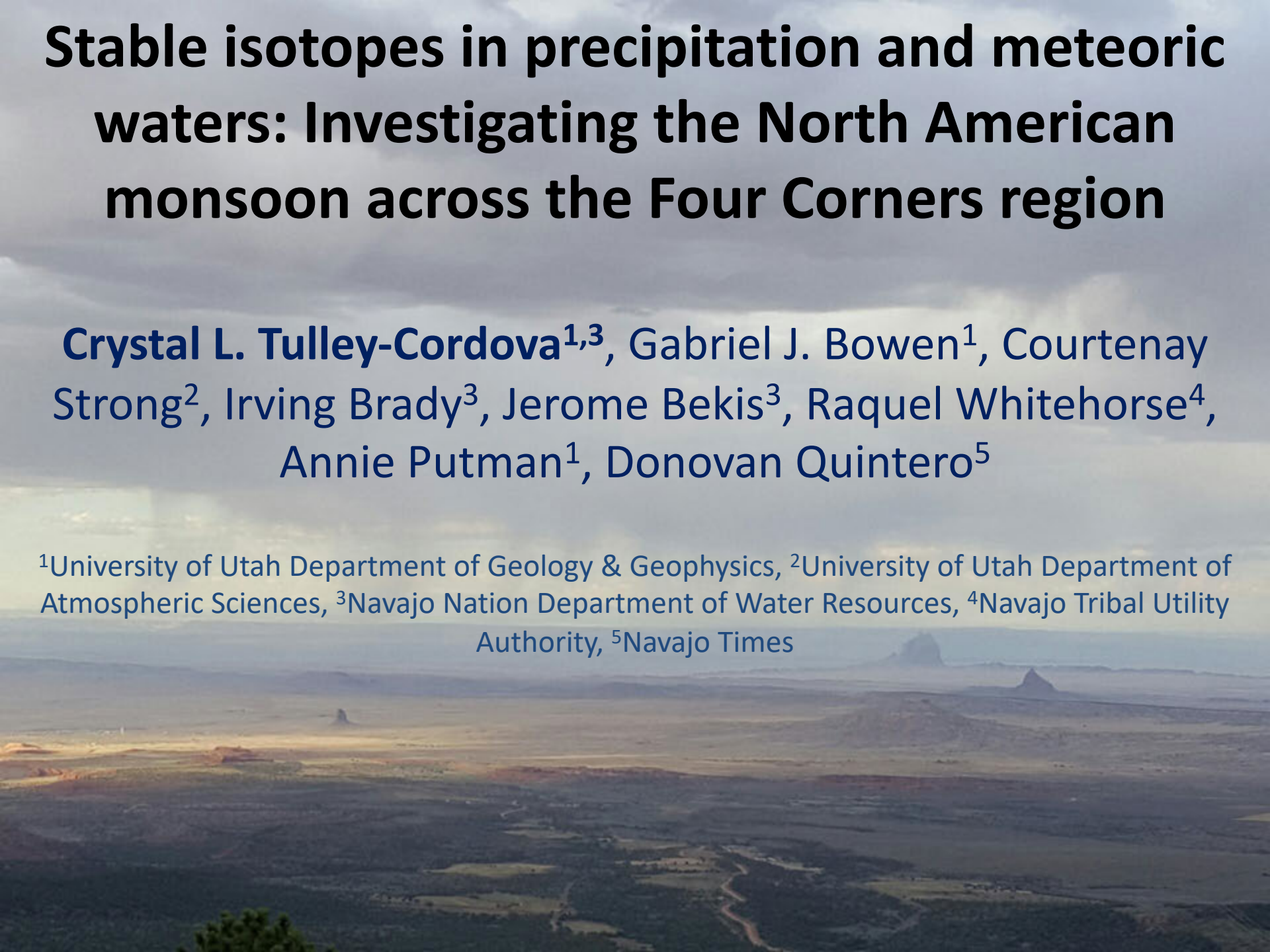


Shí éí Crystal Tulley-Cordova yinishyé.

Tódích'íi'nii nishłí
Ta'neeszahnii báshishchiin
Hashk'ą́ą́n Hadzohí dashicheii
Tó'aheedlíinii dashinalí

Tó éí *iiná áté*





NEWS

Navajo Division of Transportation fights flooding on Navajo Nation

Originally Published: October 8, 2013

Monsoonal rains damage 21 Arizona chapters along with 26 chapters in New Mexico and six chapters in Utah

An ongoing emergency

Feb. 27, 2014

As drought persists, Navajo Nation must secure its water future

January 3, 2015

Snow is pretty; won't redeem lousy water year

July 13, 2015

On Parched Navajo Reservation, 'Water Lady' Brings Liquid Gold

Jun 18, 2018

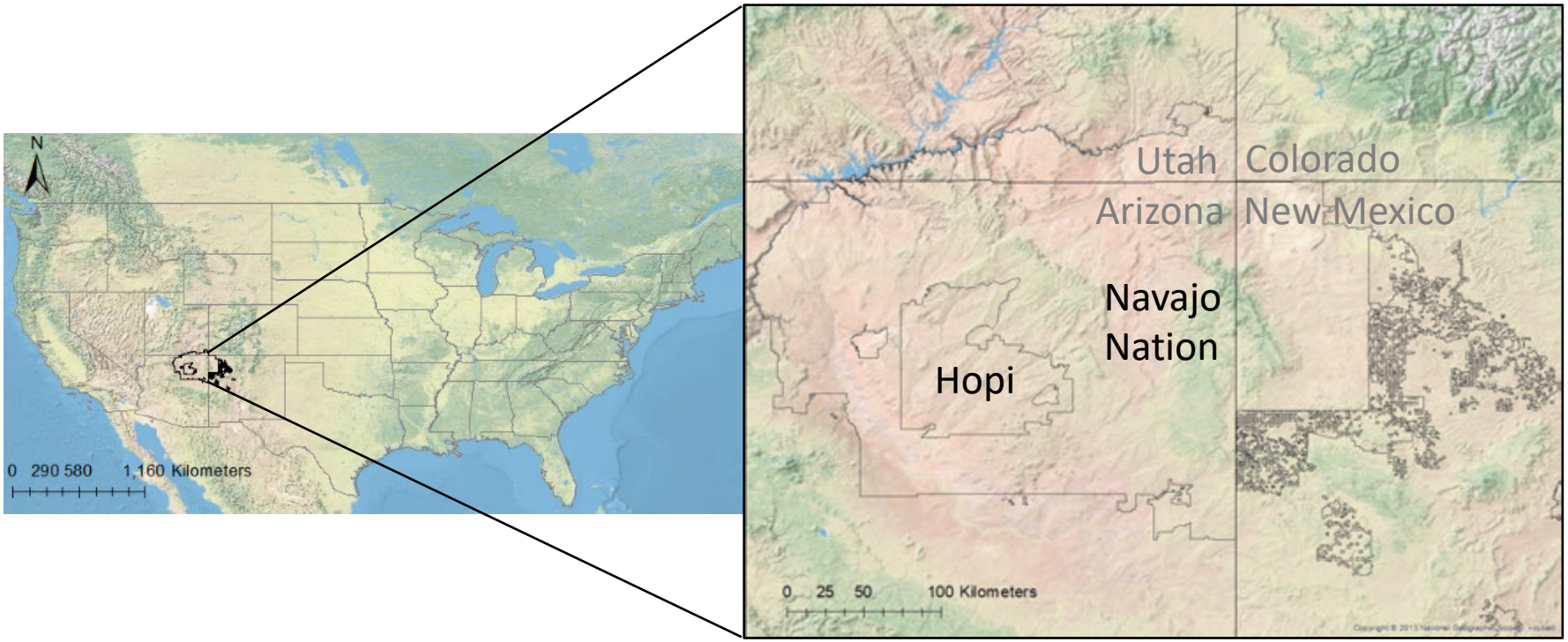
Feds, state rights clash in Navajo water dispute

How off-the-grid Navajo residents are getting running water

Jun 20, 2018

Navajo Nation

- Navajo reservation was established in 1868
- Over 71,000 km^2
- Largest land-based tribe in the U.S.
- Primary water source is ground water



Entities involved with Navajo Water

Navajo Nation Division of Natural Resources

"Land, Water, Power and Quality of Life"

NAVAJO TRIBAL UTILITY AUTHORITY

NTUA

UTILITIES FOR THE NAVAJO NATION

GREAT SEAL OF THE NAVAJO NATION

USDI

BUREAU OF INDIAN AFFAIRS

FORESTRY & WILDLAND FIRE MANAGEMENT

NAVAJO

FISH & WILDLIFE

USDA

Natural Resources Conservation Service

Arizona

United States Department of Agriculture

Changes in precipitation

Church Rock, NM

July 15, 2018

Leupp, AZ

Photo credit: Donovan Quintero

Lake, stream, spring, and ground water recharge

Frequency of dust migration and strength of winds

Flow in ephemeral and perennial streams

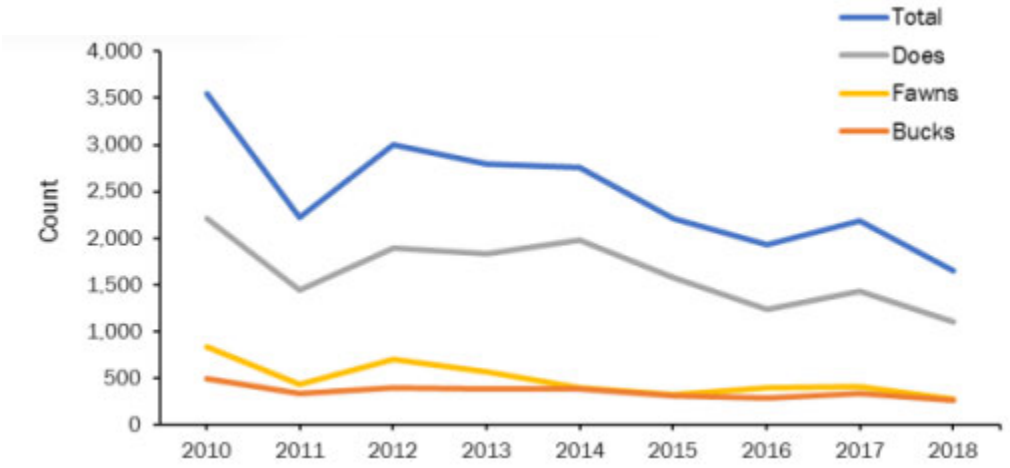
June 2017

July 2017

Red Valley Wash near Navajo, NM

Aquatic species populations

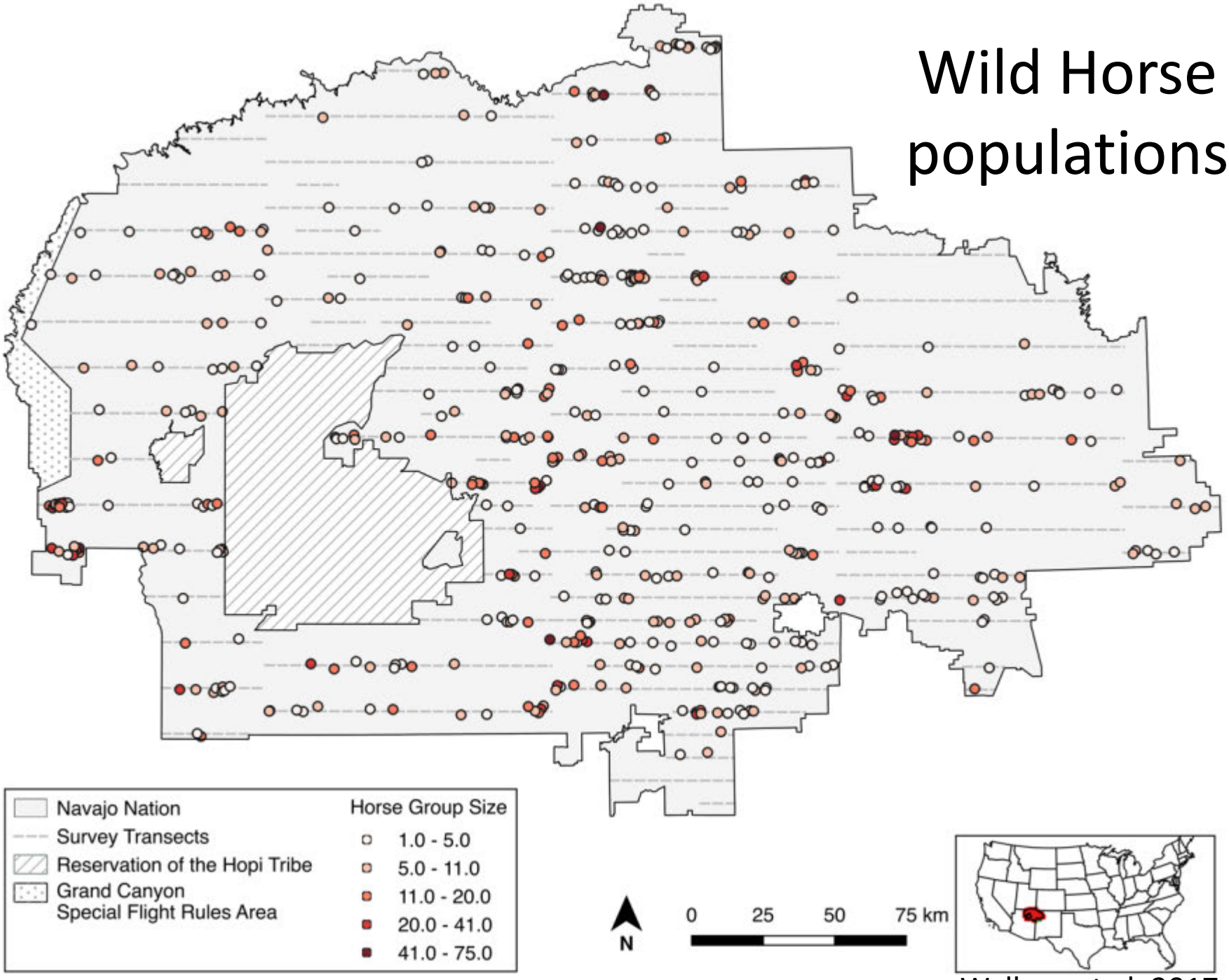
Deer populations



Navajo Fish & Wildlife 2018

Photo credit: Sam Diswood

Wild Horse populations



Wallace et al. 2017

Narbona Pass

Wildfires

Mushroom Peak fire

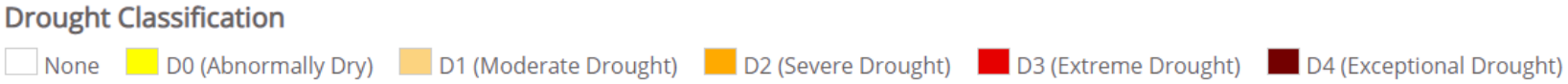
September 2018

Photo credit: Neil Damon

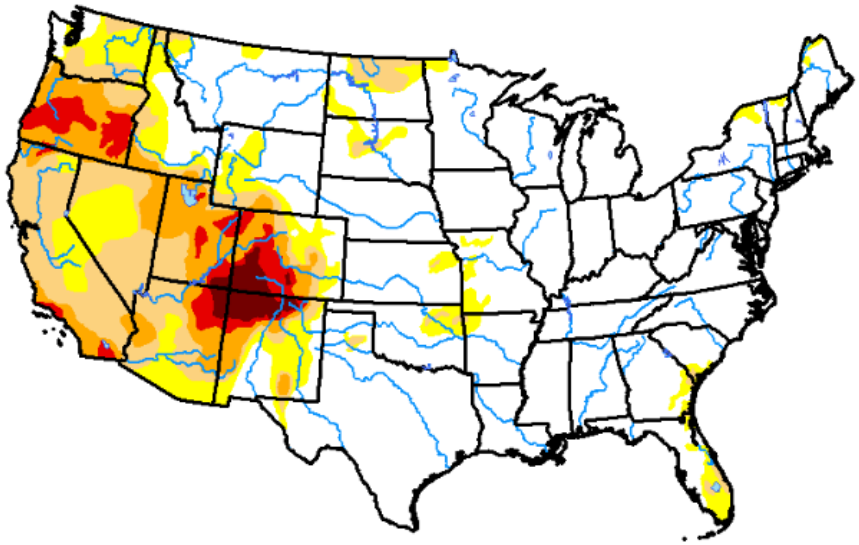
change in vegetative cover and possible alterations in species composition

Dennehotso, AZ

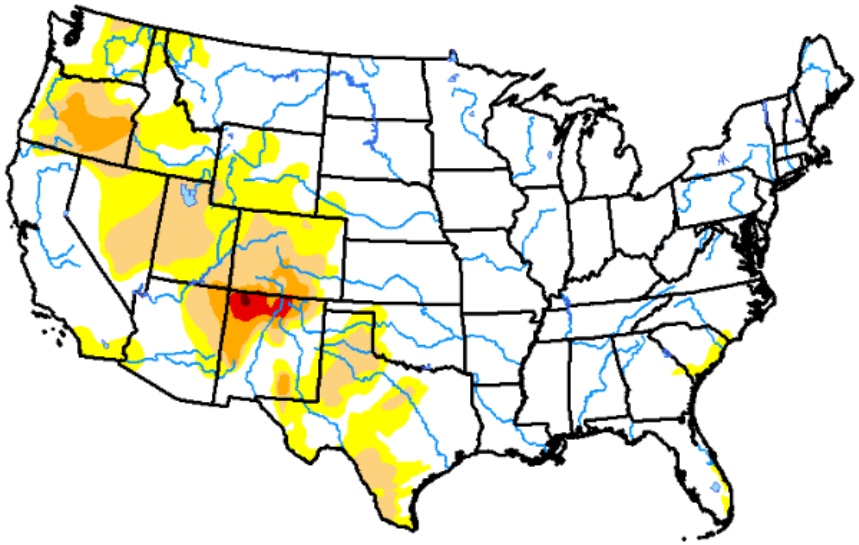
U.S. Drought Monitor



November 27, 2018

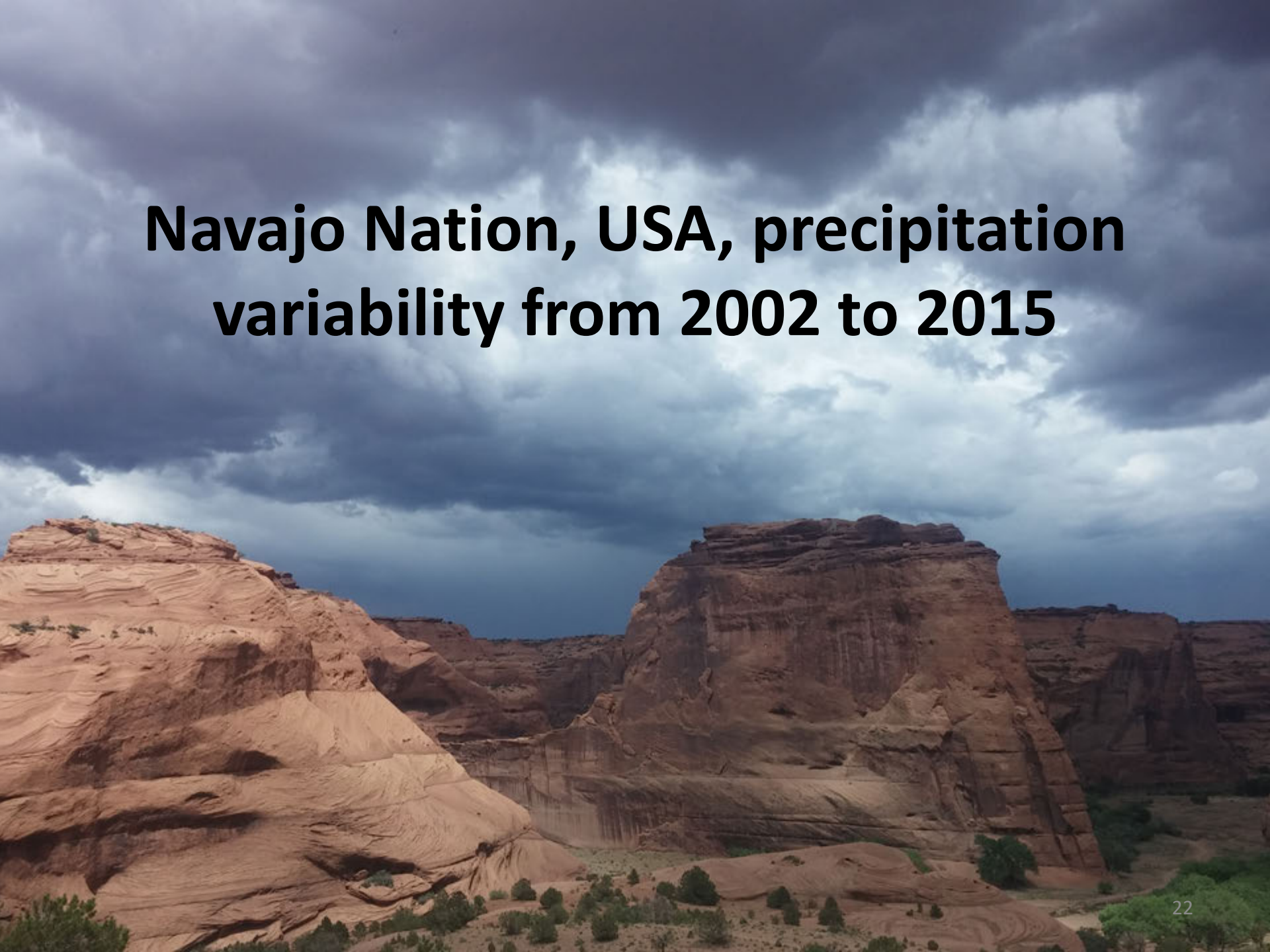


March 5, 2019



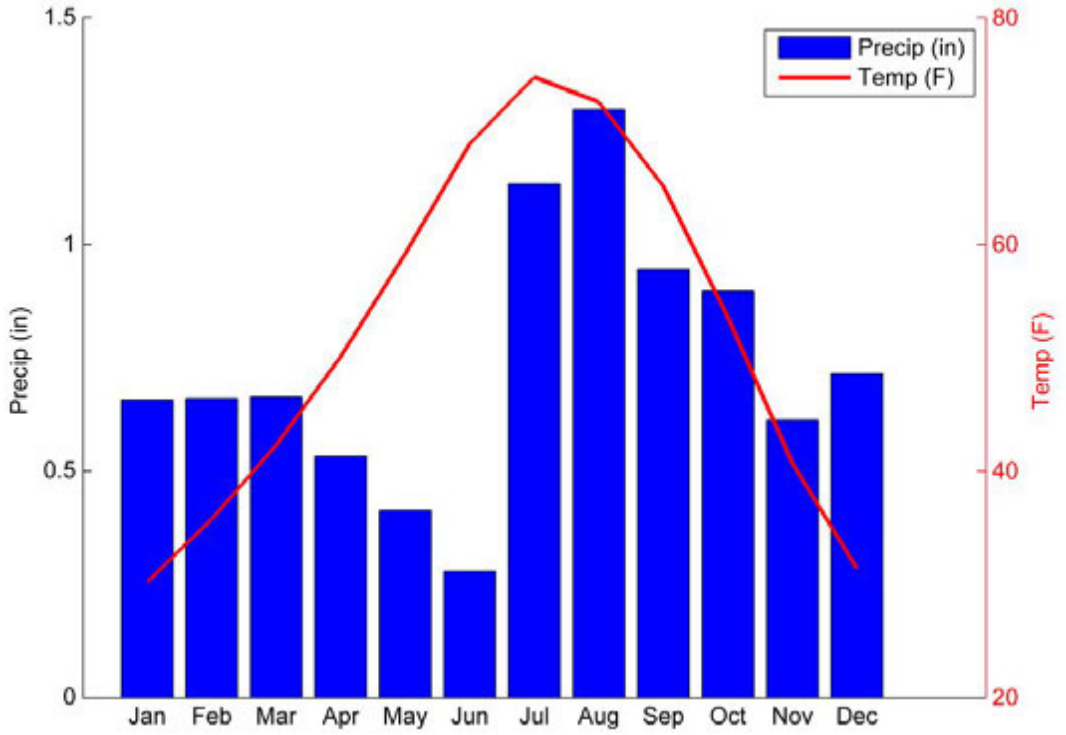
droughtmonitor.unl.edu

Navajo Nation, USA, precipitation variability from 2002 to 2015



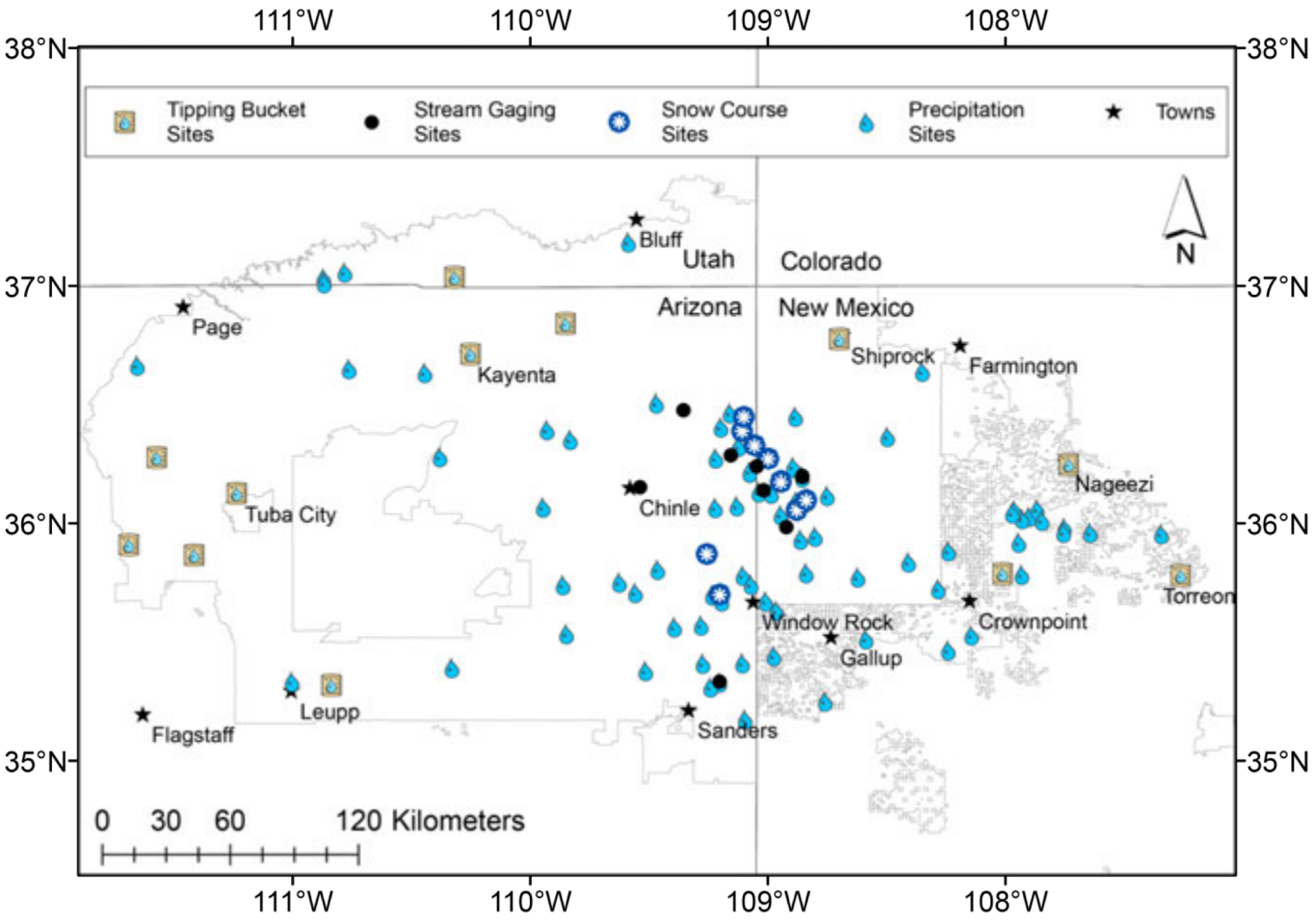
Previous studies

- individual location sites and data collection dates vary
- few sites have remained operational, but others have not due to funding



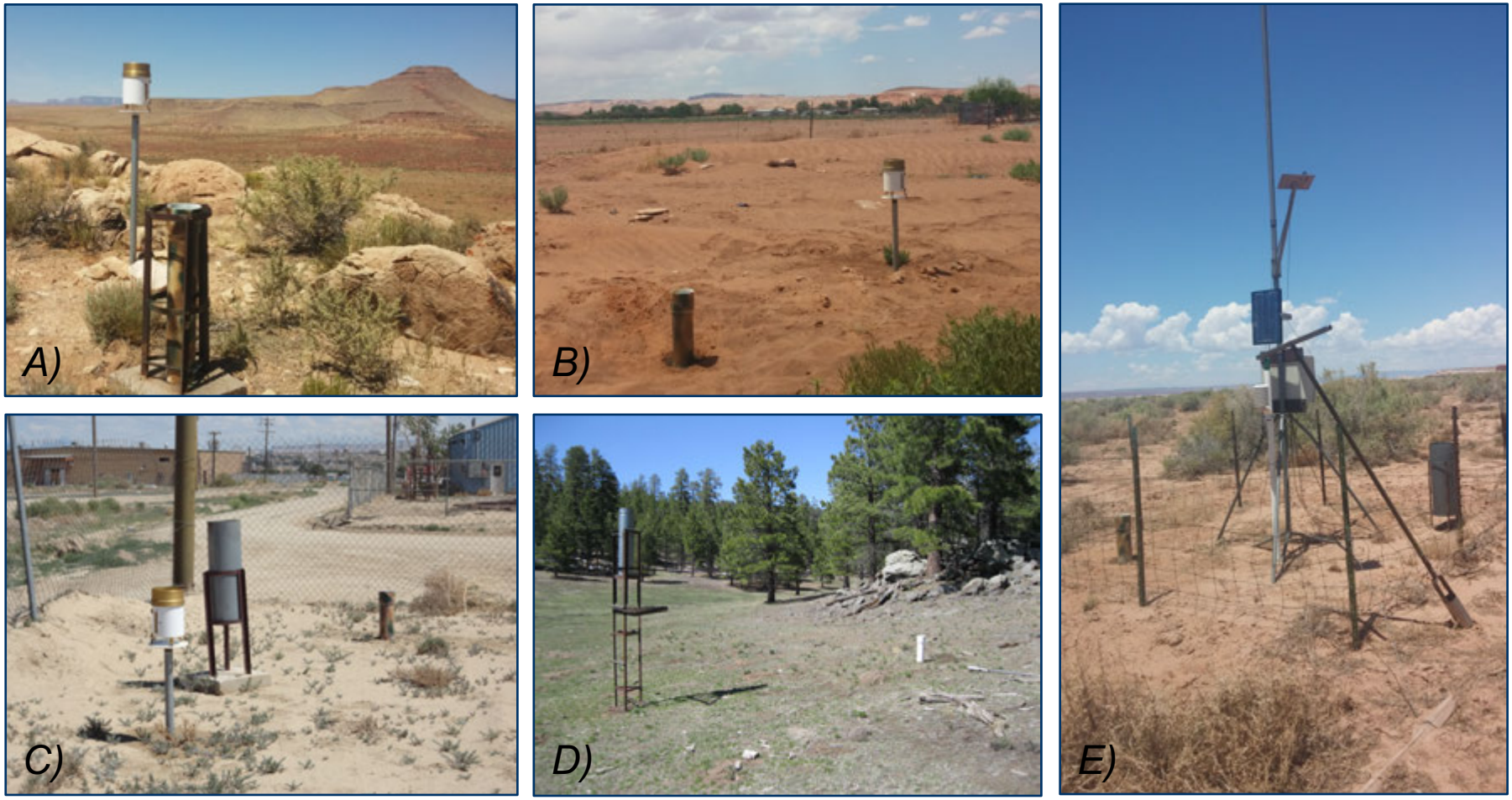
Crimmins et al., 2013

Hydrometeorological network



Tulley-Cordova et al. 2018, JCWRE

Precipitation Collectors



A) Bodaway, AZ, B) Dennehotso, AZ, C) Shiprock, NM, D) Todacheene Lake, NM, E) Bluff, UT

NN data collection

Navajo Nation Precipitation Report
Department of Water Resources * Water Management Branch
PO Box 678 * Fort Defiance, Arizona 86504 * Phone: (928) 729-4004 * Fax: (928) 729-4126

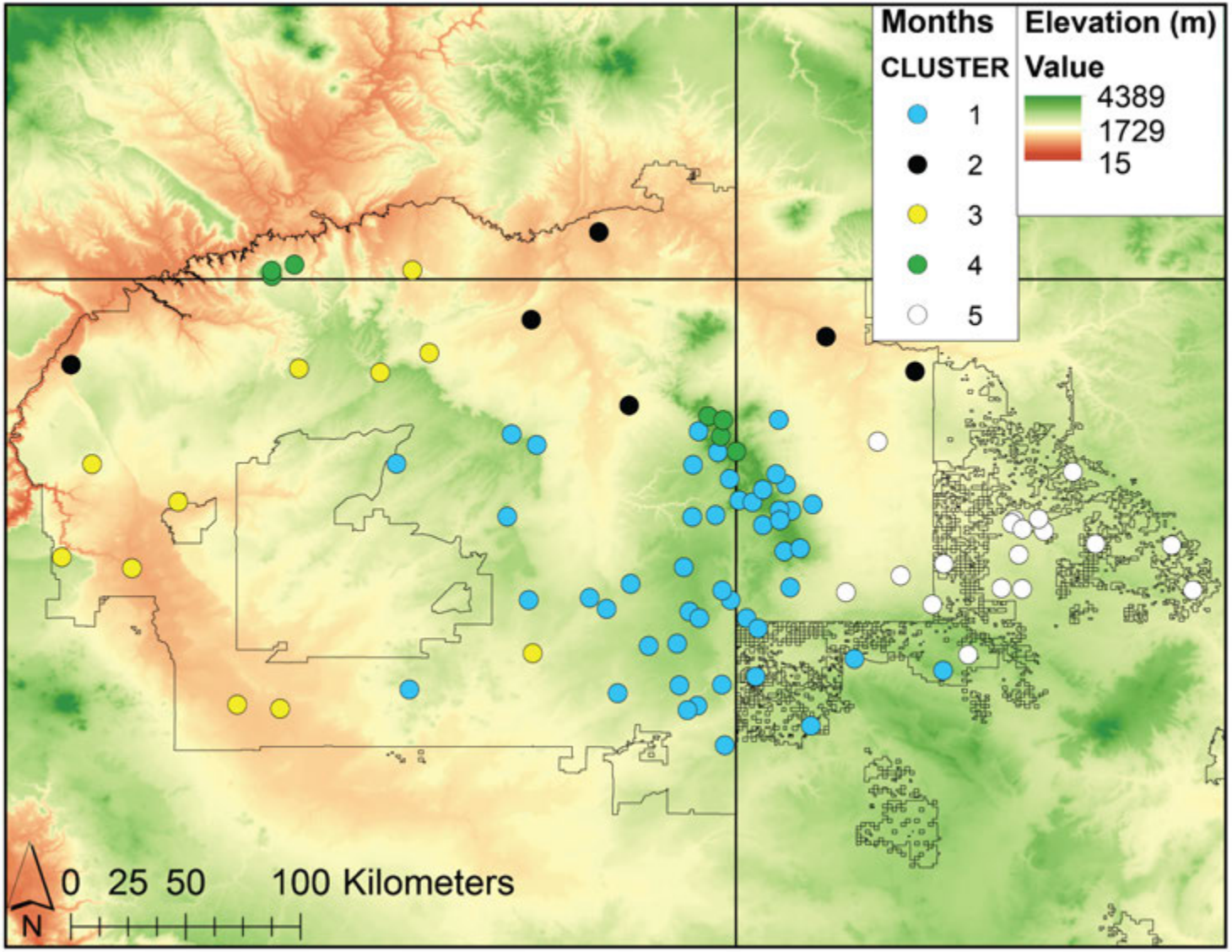
MONTHLY AVERAGES (INCHES) FOR ALL RAINCANS IN CHINLE AGENCY

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	WY Monthly AVG
2000	0.05	0.12	0.41	1.60	0.67	2.19	0.62	0.22	0.39	0.84	1.77	0.74	0.80
2001	3.24	0.68	0.83	1.76	1.38	1.35	1.42	1.54	0.79	1.61	2.62	0.37	1.47
2002	0.32	0.66	1.07	0.37	0.30	0.49	0.47	0.11	0.03	1.27	0.79	3.03	0.74
2003	1.02	0.96	1.08	0.33	1.85	2.25	0.58	0.30	0.21	1.11	2.36	1.55	1.13
2004	1.15	1.12	0.93	0.95	1.35	0.73	1.87	0.12	0.20	1.49	1.15	2.96	1.17
2005	1.40	1.71	1.17	2.76	3.49	1.44	1.79	0.36	0.39	0.96	3.03	0.92	1.62
2006	1.29	0.07	0.21	0.71	0.07	1.47	0.59	0.16	0.39	1.52	2.45	1.71	0.89
2007	2.64	0.31	0.96	0.65	1.41	1.39	1.49	1.19	0.22	2.04	2.18	1.72	1.35
2008	0.16	0.03	2.76	2.36	1.75	0.03	0.28	0.74	0.43	1.58	1.95	0.75	1.07
2009	0.58	0.87	2.67	0.53	1.16	0.42	1.20	1.07	0.35	0.79	0.44	0.96	0.92
2010	0.43	0.59	1.55	2.80	1.68	1.19	1.06	0.13	0.15	2.53	2.07	1.34	1.29
2011	1.15	0.83	1.20	0.39	0.77	0.69	1.04	0.93	0.01	2.05	1.60	1.72	1.03
2012	1.59	1.67	0.74	0.58	1.13	0.56	0.41	0.09	0.04	2.15	2.05	0.86	0.99
2013	0.21	0.48	1.51	2.29	1.19	0.52	0.58	0.37	0.08	1.93	3.22	3.12	1.29
2014	0.63	1.67	0.87	0.15	1.28	0.99	1.05	0.70	0.05	1.77	1.48	1.98	1.05
2015	0.80	0.64	1.55	1.65	2.82	0.92	0.87	2.87	1.97	2.59			1.67
	Summary for CHINLE AGENCY (16 detail records)												
Average	*1.04*	*0.77*	*1.22*	*1.24*	*1.40*	*1.04*	*0.96*	*0.68*	*0.36*	*1.64*	*1.94*	*1.58*	
Minimum	*0.05*	*0.03*	*0.21*	*0.15*	*0.07*	*0.03*	*0.28*	*0.09*	*0.01*	*0.79*	*0.44*	*0.37*	
Maximum	*3.24*	*1.71*	*2.76*	*2.80*	*3.49*	*2.25*	*1.87*	*2.87*	*1.97*	*2.59*	*3.22*	*3.12*	

Research questions

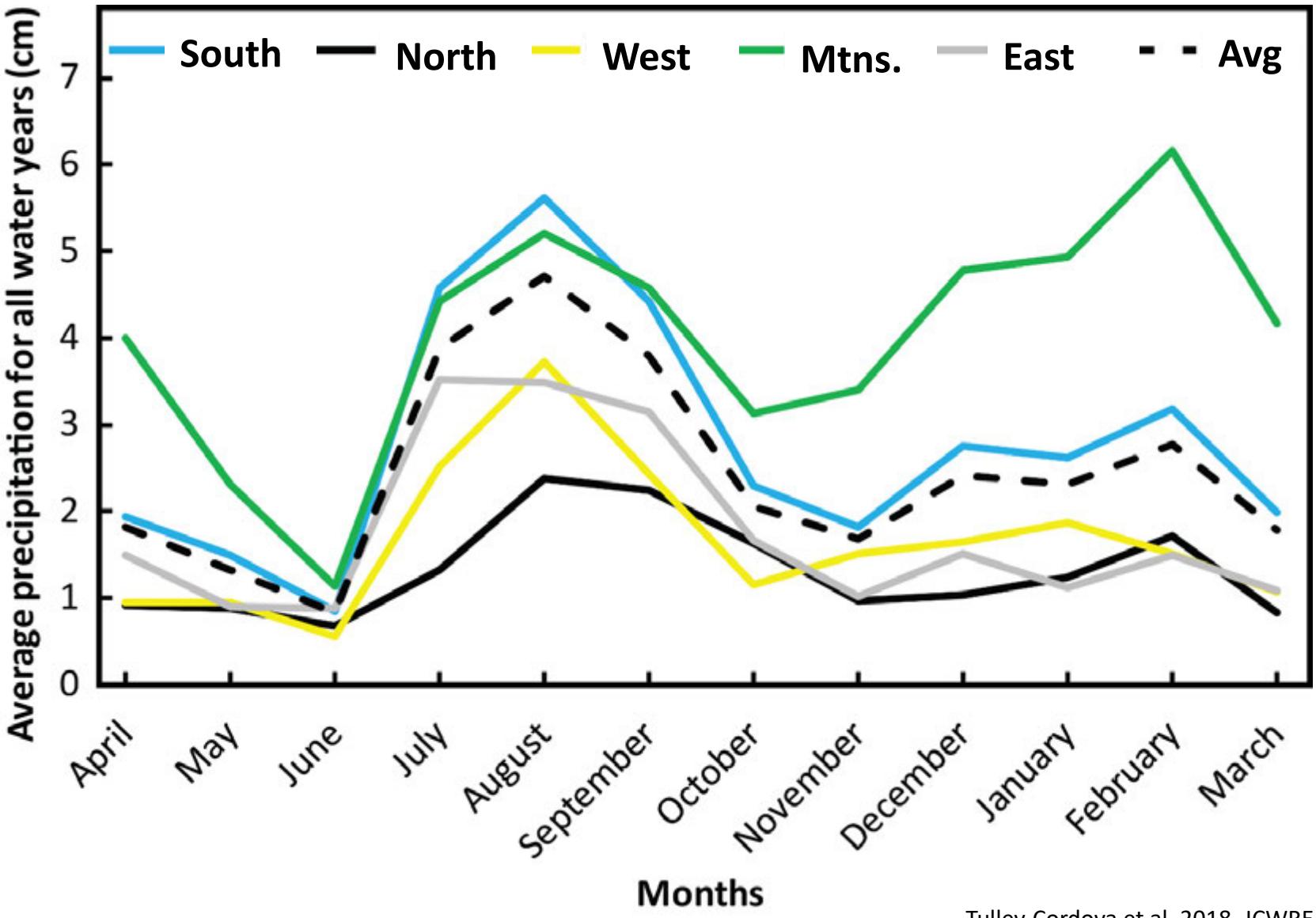
- Are there different hydroclimatic regions on the Navajo Nation?
- Is there a bimodal precipitation regime?
- What are the seasonal precipitation patterns?
- Are the length and onset of monsoon different for each region?
- What is the major contributor to total annual precipitation?

Hydroclimate regions of the Navajo Nation

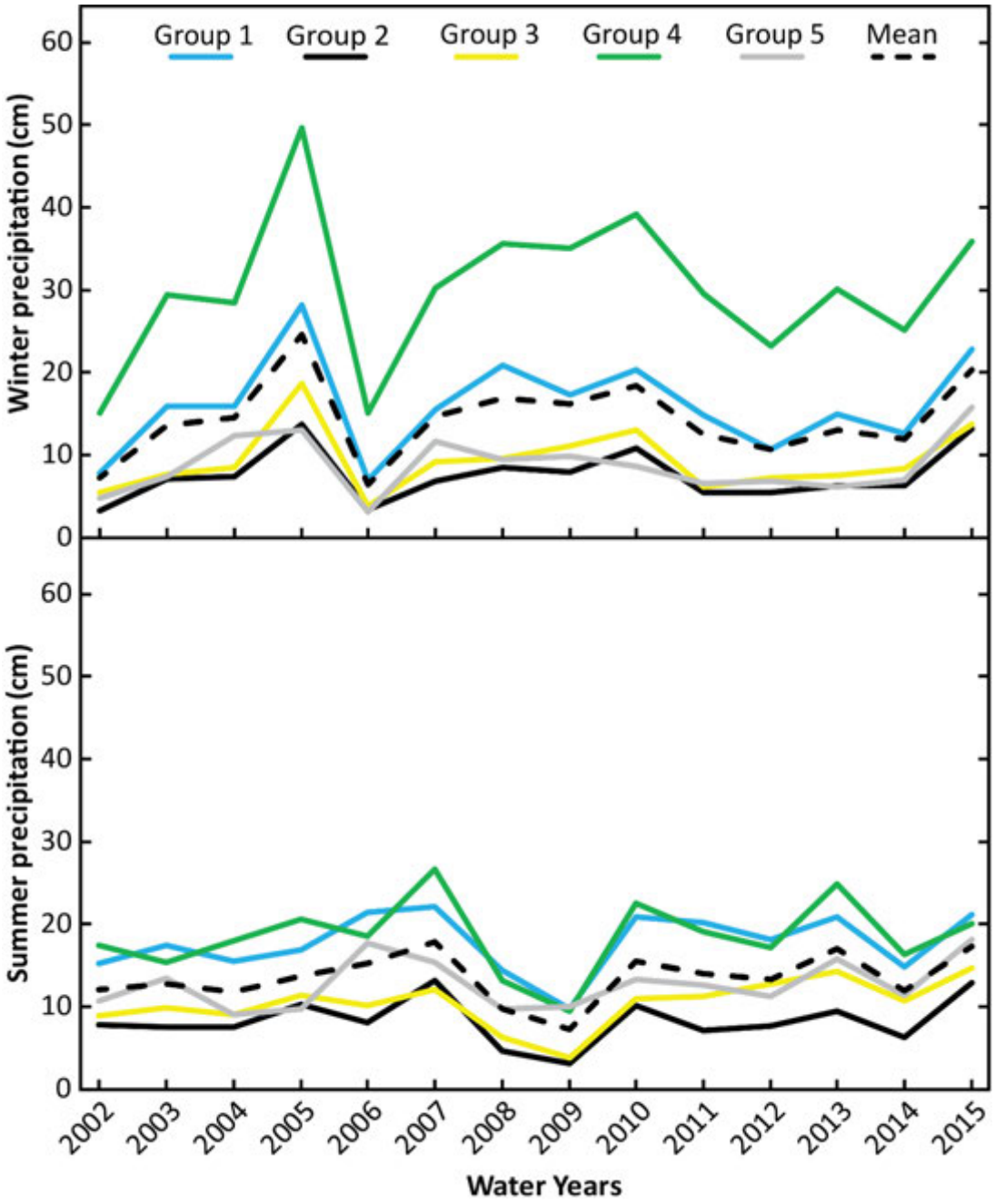


Tulley-Cordova et al. 2018, JCWRE

Precipitation climatology



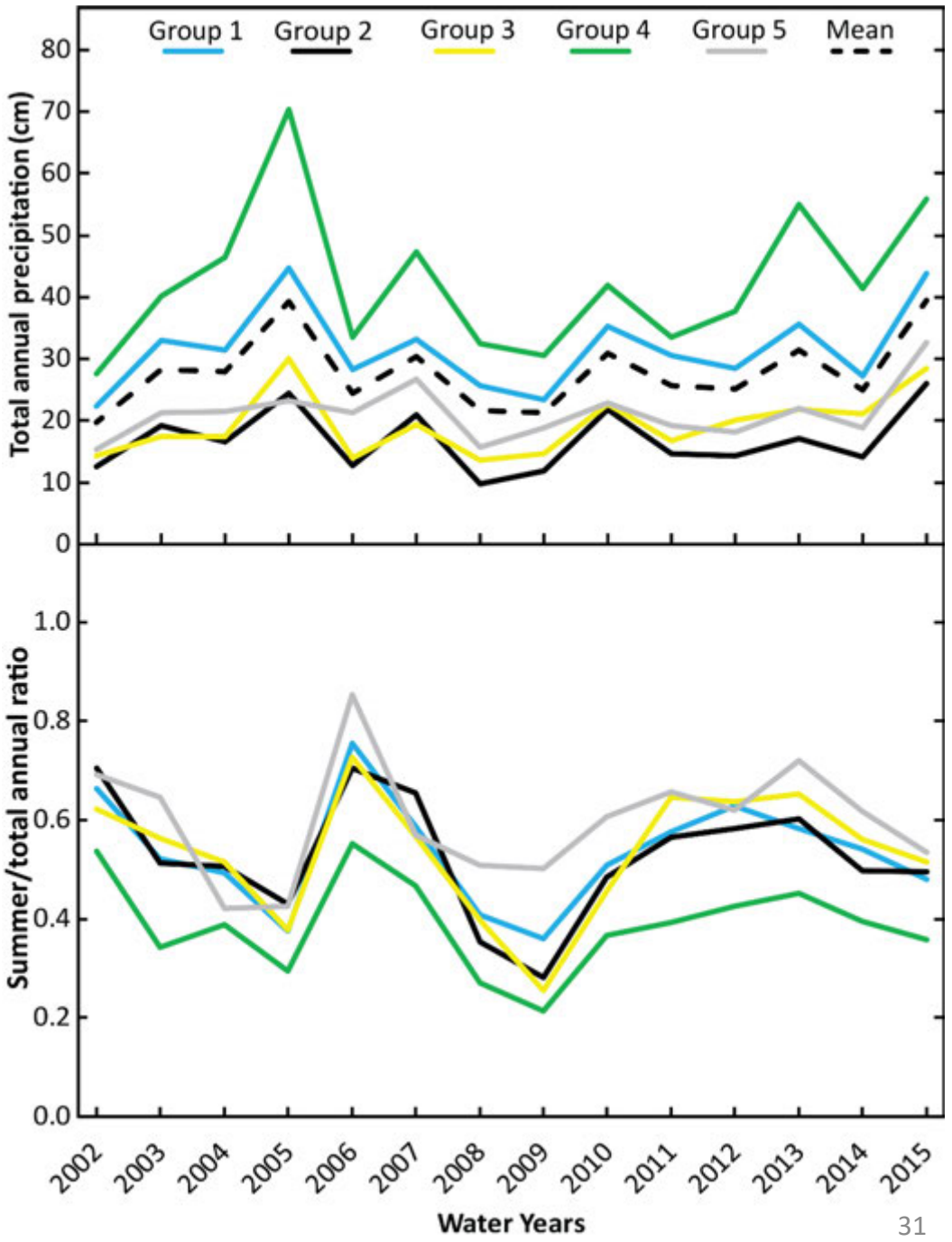
Tulley-Cordova et al. 2018, JCWRE



Tulley-Cordova et al. 2018, JCWRE

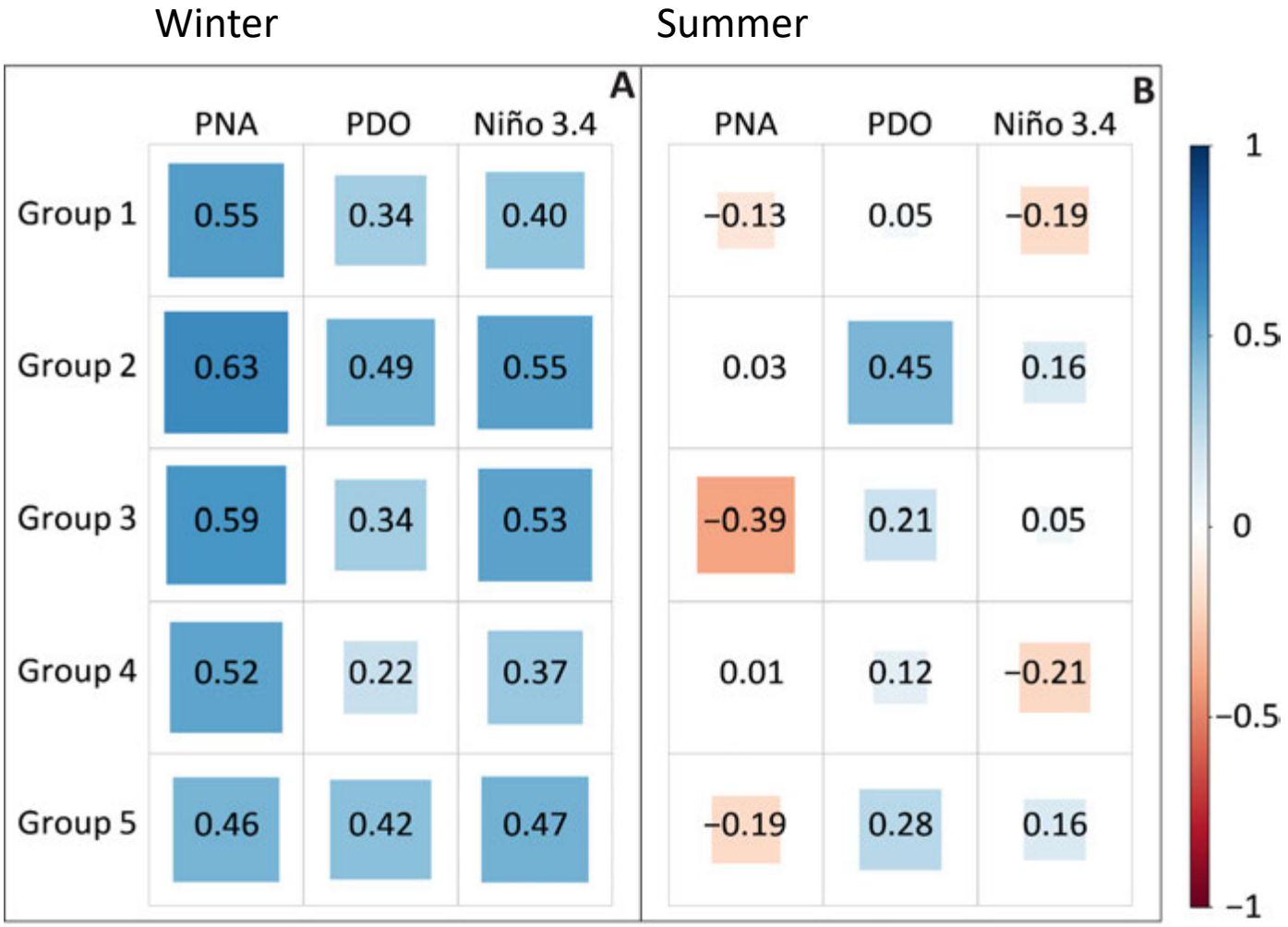
Seasonal precipitation

Year-to-year comparison



Tulley-Cordova et al. 2018, JCWRE

Seasonal patterns compared with climate indices



Tulley-Cordova et al. 2018, JCWRE

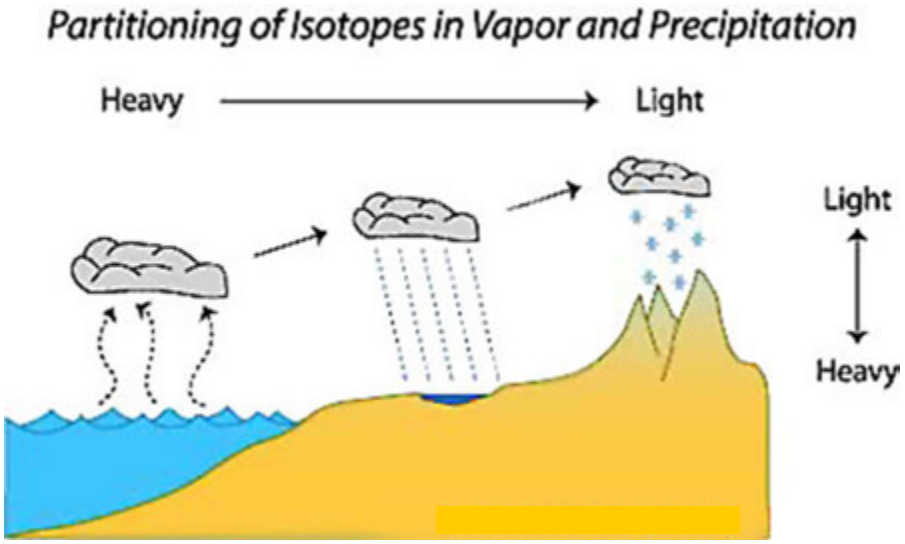
Inter- & intra- annual precipitation conclusions

- Climatology on NN varies depending on region
- Length and onset of monsoon different for each region
- Summer and winter precipitation contributions to annual precipitation variable
- Extremes in winter and summer independent of each other
- Winter precipitation sensitive to PNA
- Summer precipitation responds weakly to major climate modes

Stable isotopes in precipitation and meteoric water: Recording the North American monsoon in Arizona, New Mexico, and Utah

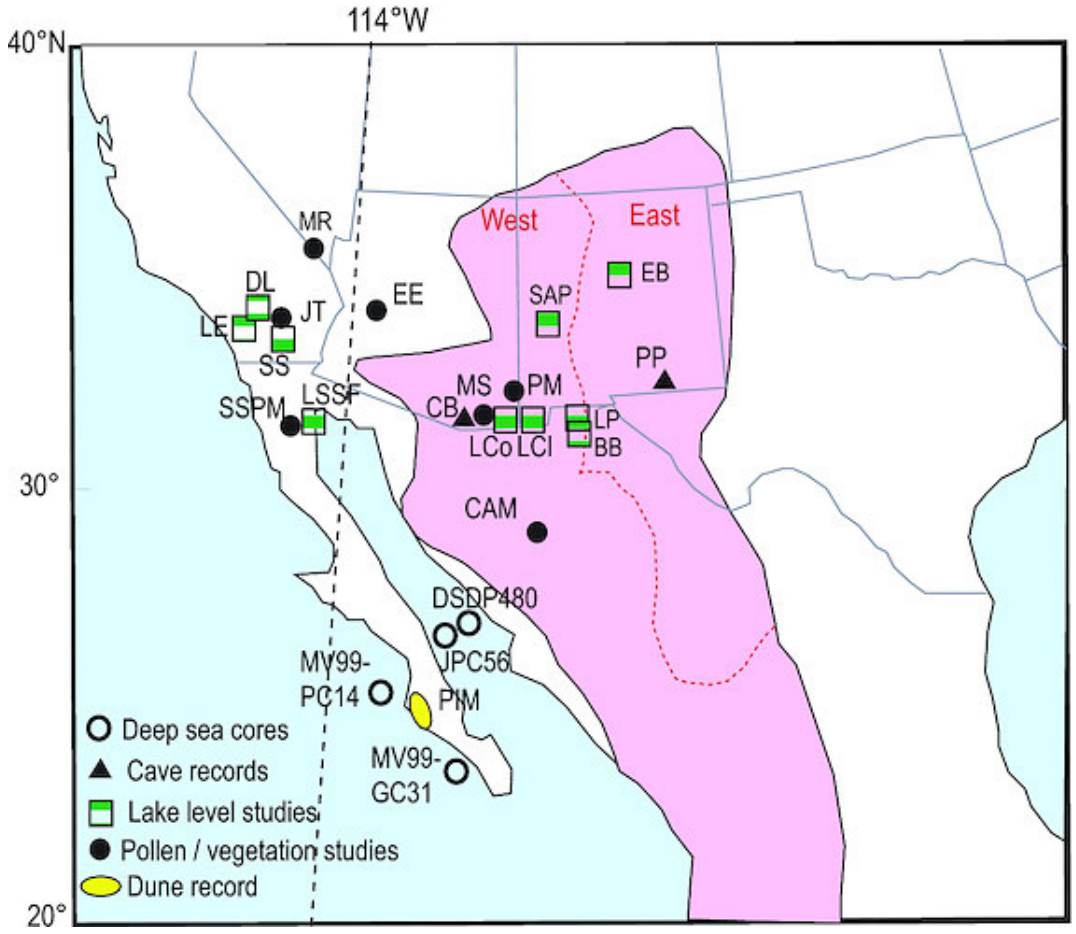
Why study stable isotopes?

Stable isotope ratios of hydrogen and oxygen can be used to distinguish the origin of water in precipitation, surface and ground waters



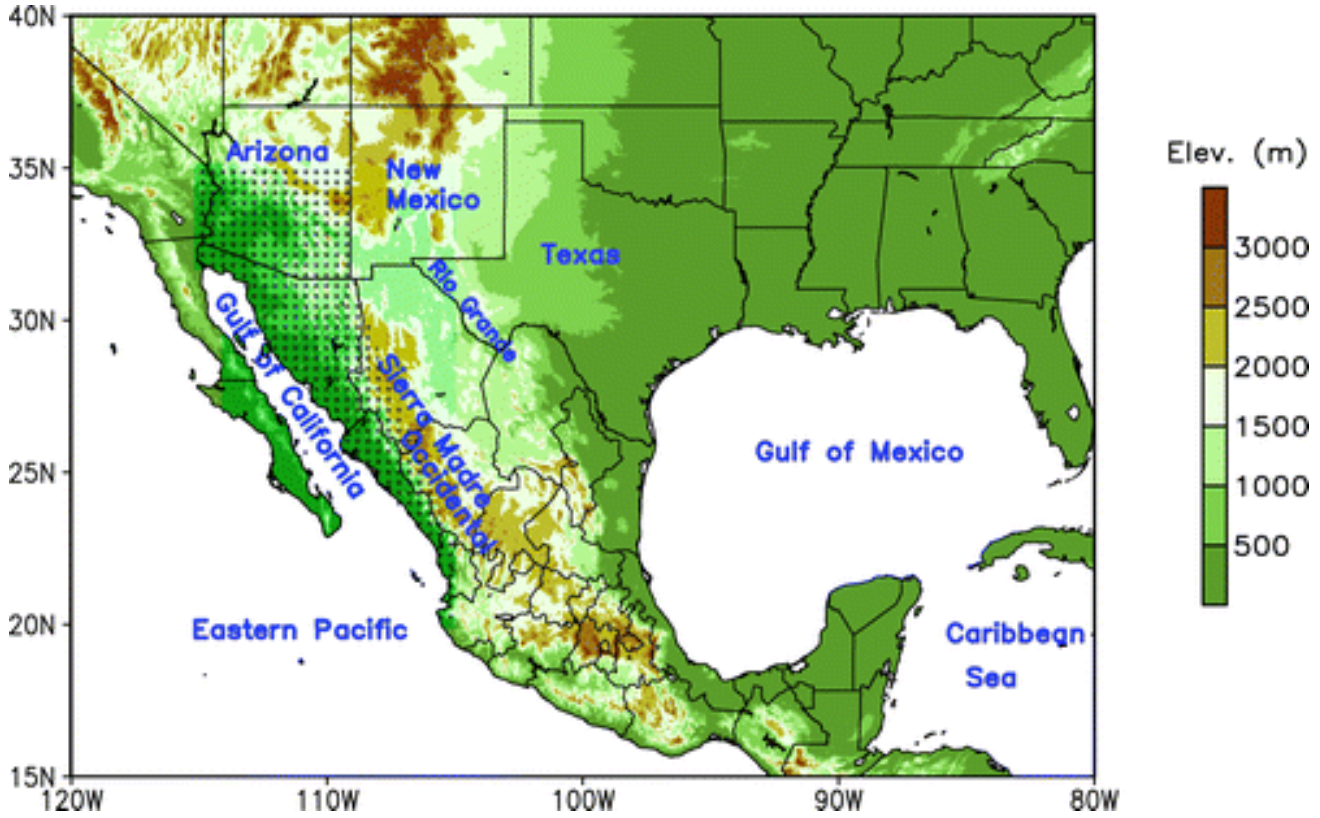
waterisotopes.org

North American monsoon



Barron et al. 2012

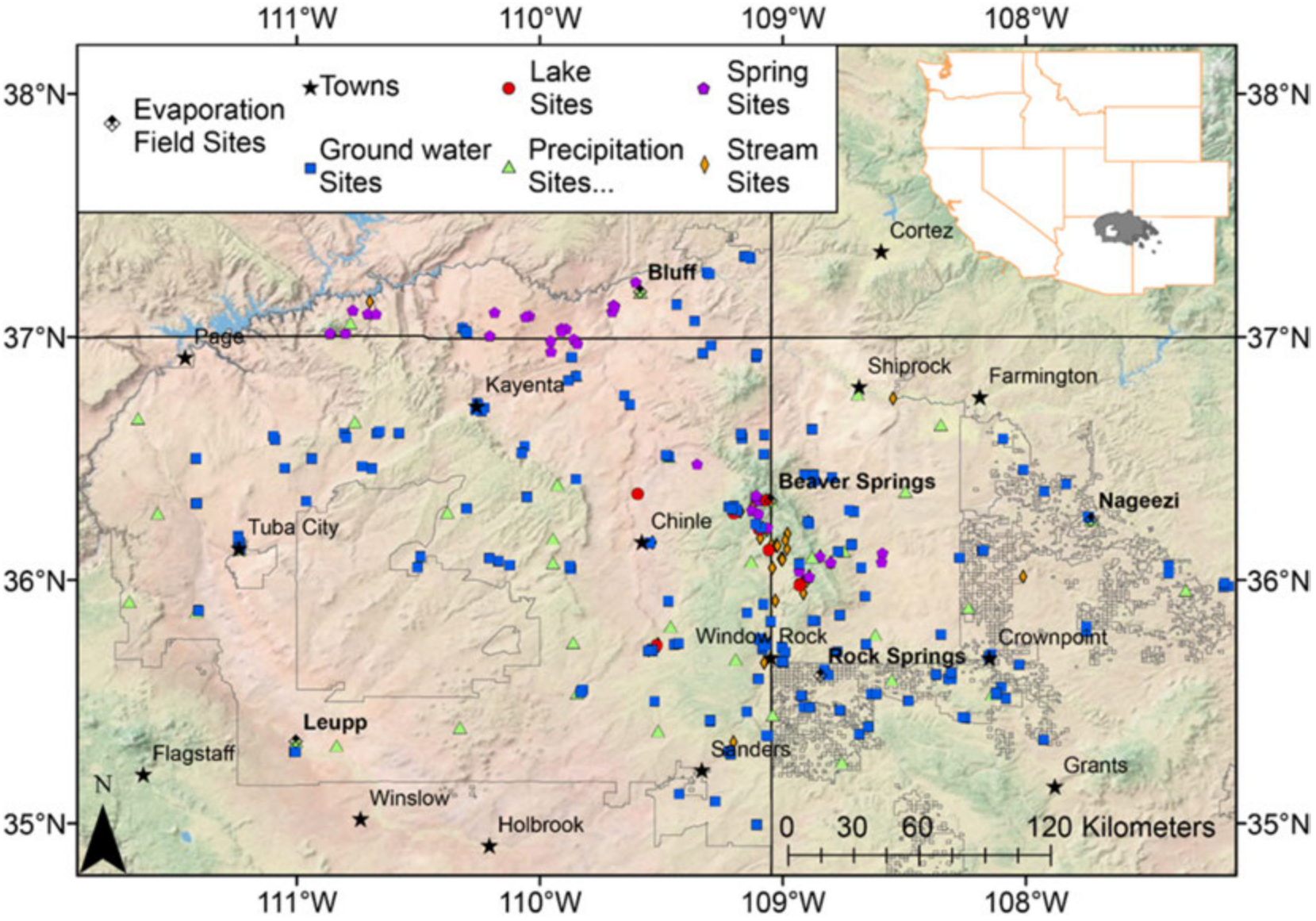
North American monsoon region



Hu & Dominguez 2015

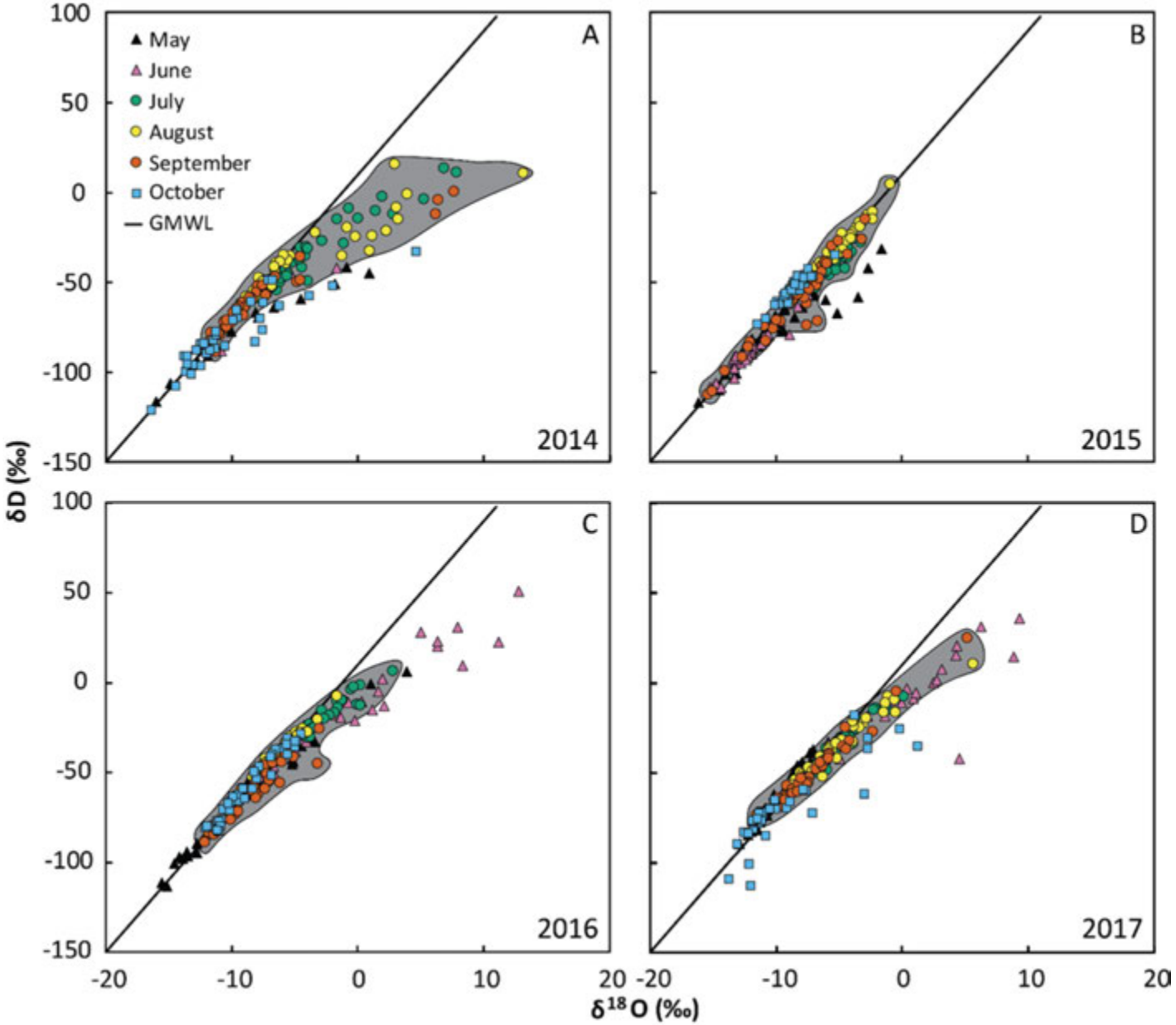
Research questions

- What are the spatio-temporal distributions of water isotopes in precipitation and associated waters across the Navajo Nation?
- Are ground waters derived from monsoonal precipitation?
- Will ground water and associated waters be sensitive to future changes in the monsoon?



Tulley-Cordova, Putman & Bowen 2018, in prep

North American monsoon temporal patterns



Tulley-Cordova, Putman & Bowen 2018, in prep

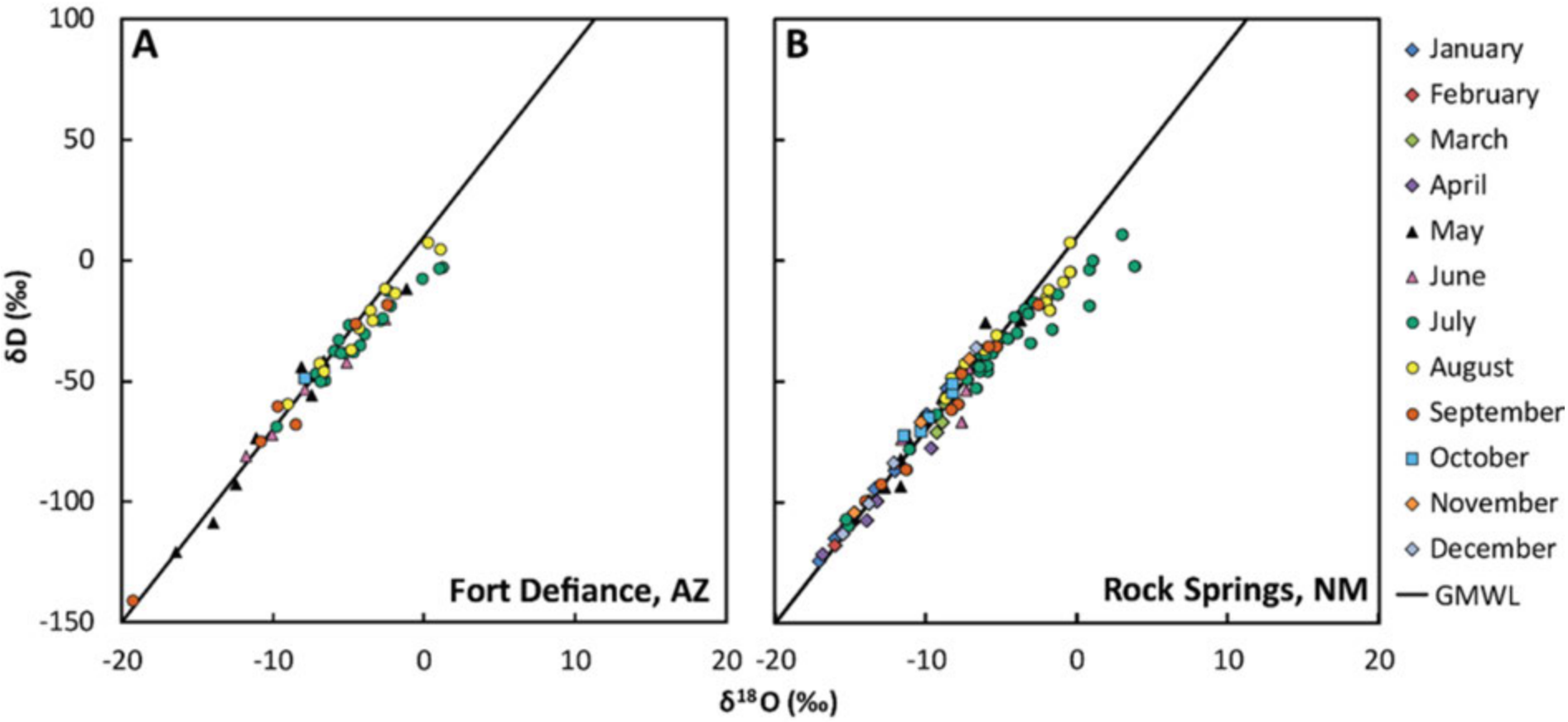
Oxygen-18

Season		2014			2015			2016			2017			All years		
		$\delta^{18}O$	δD	d	$\delta^{18}O$	δD	d	$\delta^{18}O$	δD	d	$\delta^{18}O$	δD	d	$\delta^{18}O$	δD	d
Pre-monsoon	Average	-8.4	-75.3	-8.2	-10.9	-80.9	6.1	-4.4	-39.0	-3.7	-5.6	-40.4	4.3	-7.4	-57.0	2.0
	SD	5.5	27.2	19.1	2.9	18.4	8.6	7.0	38.0	21.2	5.7	30.2	19.5	5.8	34.7	16.6
	Minimum	-18.8	-138.2	-52.0	-16.1	-117.1	-30.7	-15.5	-113.2	-92.4	-12.9	-89.7	-78.7	-16.1	-117.1	-78.7
	Maximum	0.9	-41.6	13.2	-1.7	-31.1	15.3	14.2	50.8	16.7	9.3	35.8	20.6	12.8	50.8	20.6
Monsoon	Average	-5.4	-45.2	-2.3	-6.1	-42.2	6.4	-5.8	-40.2	6.5	-5.8	-40.8	5.4	-5.9	-42.7	4.1
	SD	5.0	23.2	19.8	2.5	19.7	5.0	2.8	19.6	6.3	2.9	17.5	6.9	3.5	20.6	11.7
	Minimum	-12.0	-88.9	-94.5	-15.3	-112.6	-18.5	-12.1	-89.0	-20.2	-11.5	-74.0	-35.3	-15.3	-112.6	-94.5
	Maximum	13.1	15.7	15.0	-0.9	4.2	14.8	2.8	6.3	16.3	5.7	24.7	17.9	13.1	24.7	18.9
Post-Monsoon	Average	-10.1	-79.0	2.0	-8.5	-52.5	15.5	-8.6	-57.4	11.5	-9.2	-70.0	4.0	-9.1	-63.9	8.8
	SD	4.0	18.6	17.6	1.1	7.1	2.7	2.3	17.3	3.9	3.9	21.3	16.6	3.0	19.3	12.8
	Minimum	-16.4	-121.3	-69.7	-11.5	-73.3	7.9	-12.1	-82.6	3.4	-13.8	-112.8	-45.2	-16.4	-121.3	-69.7
	Maximum	4.6	-32.8	19.4	-5.3	-34.7	20.3	-4.5	-28.6	16.7	1.2	-18.2	18.9	4.6	-18.2	20.3

Tulley-Cordova, Putman & Bowen 2018, in prep

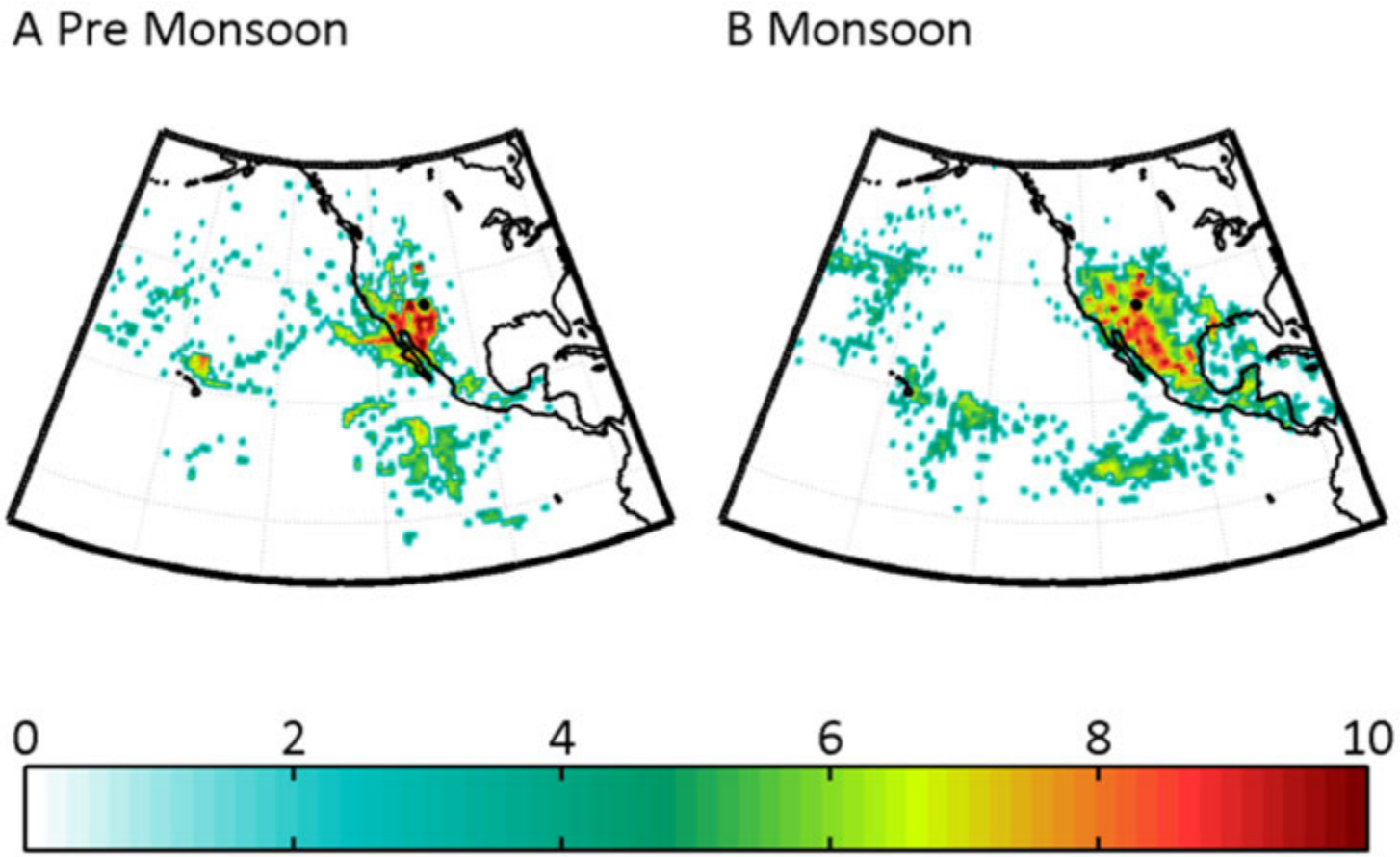
Precipitation event sampling 2015 to 2017

LMWL $\delta^2H = 6.8 * \delta^{18}O - 2.2‰$



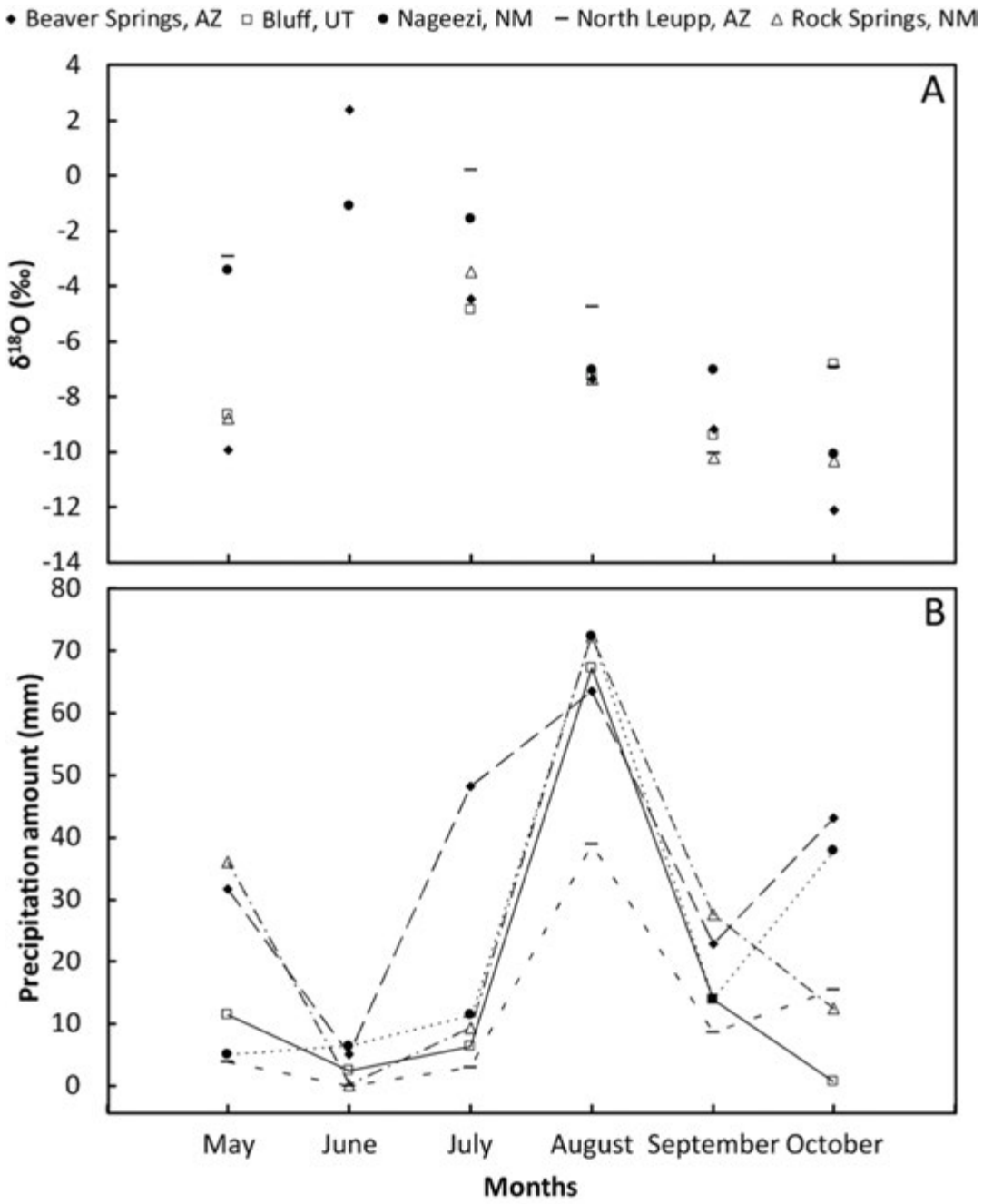
Tulley-Cordova, Putman & Bowen 2018, in prep

Vapor source for North American monsoon precipitation



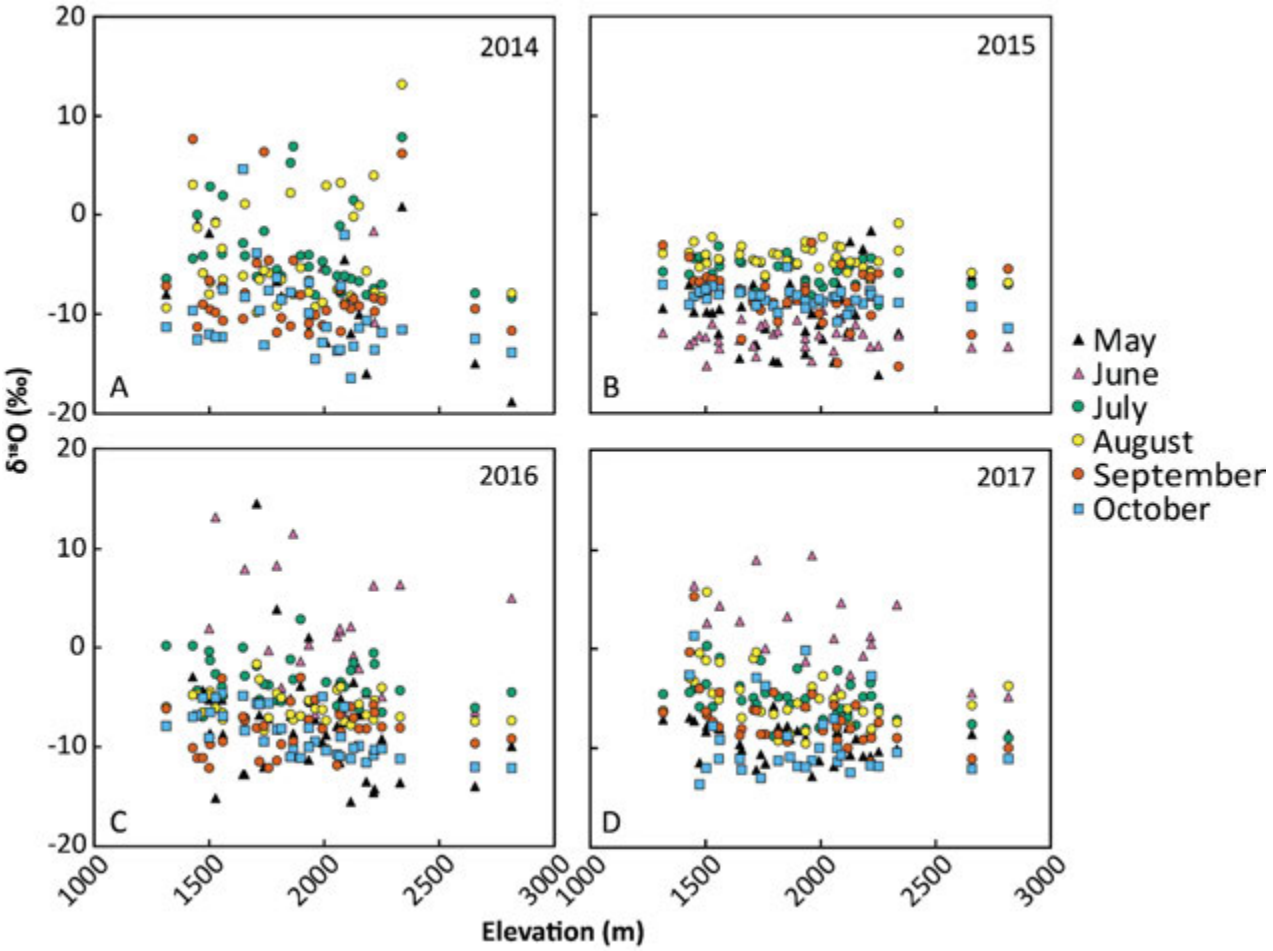
Tulley-Cordova, Putman & Bowen 2018, in prep

Seasonal effect on monthly precipitation



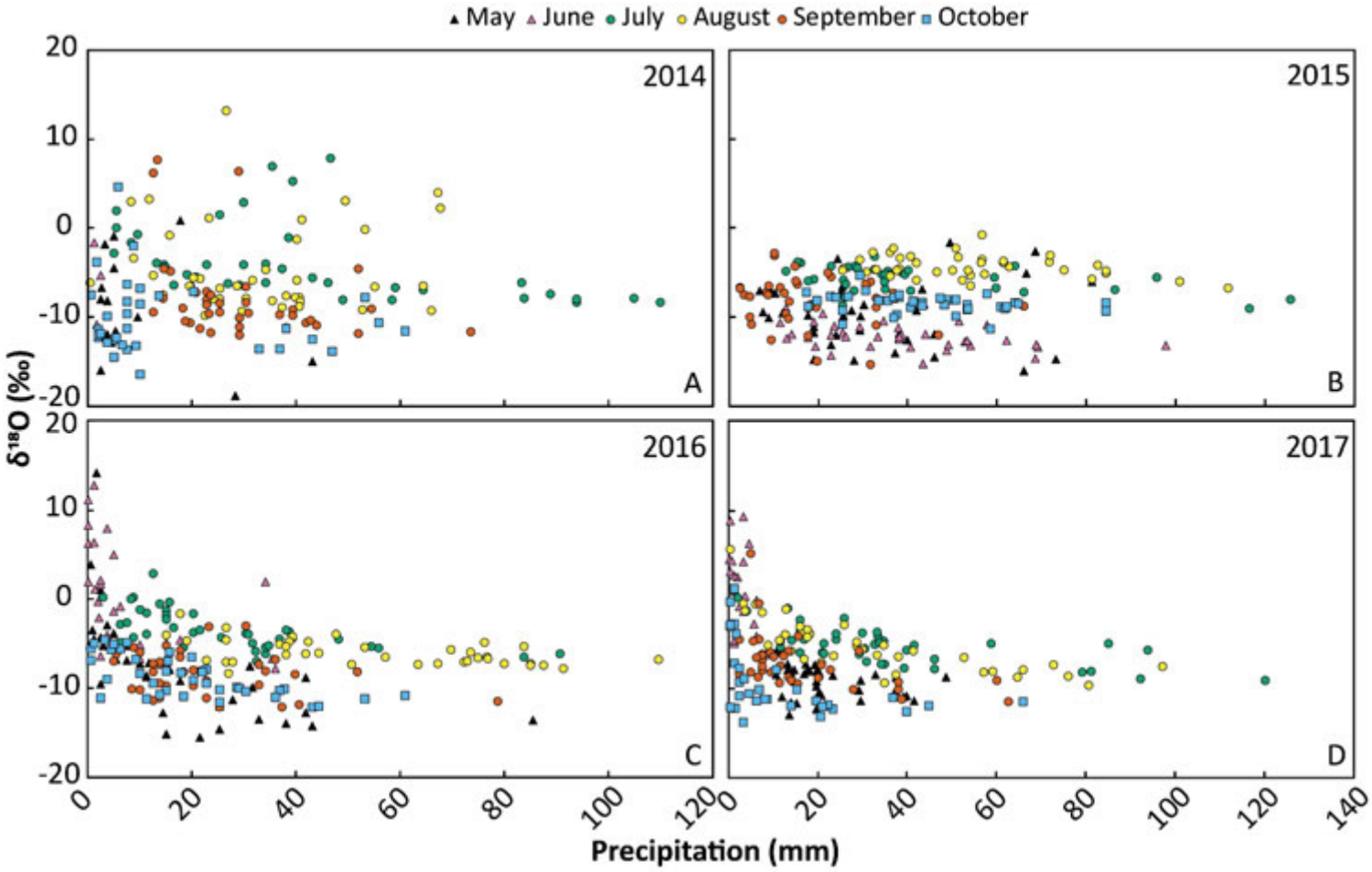
Tulley-Cordova, Putman & Bowen 2018, in prep

Altitude effect



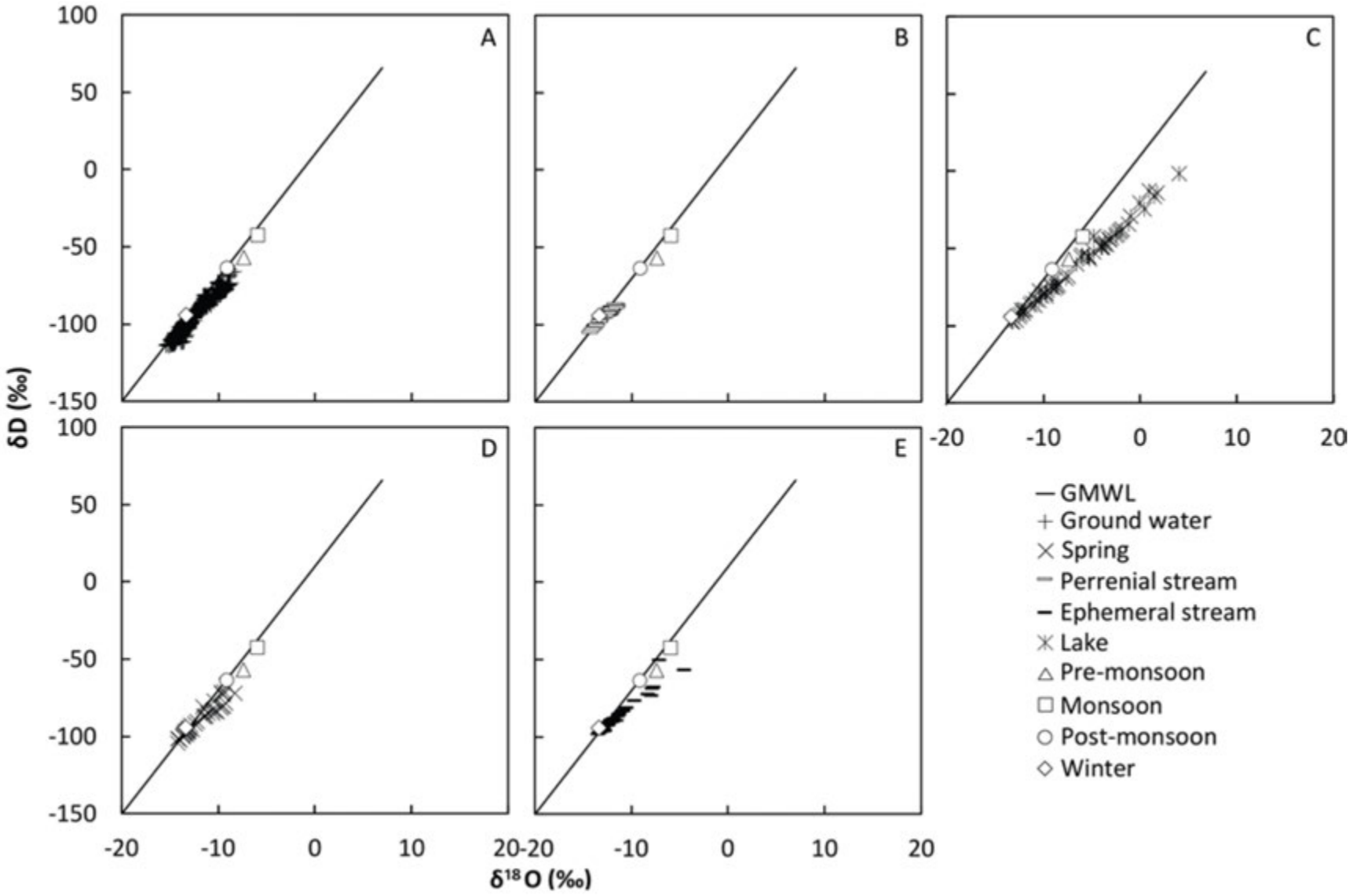
Tulley-Cordova, Putman & Bowen 2018, in prep

Amount effect



Tulley-Cordova, Putman & Bowen 2018, in prep

Relationship of Navajo waters to precipitation



Tulley-Cordova, Putman & Bowen 2018, in prep

Stable isotopic conclusions

- Evident monthly and inter-annual temporal patterns for precipitation.
- Weak spatial patterns across the Navajo Nation for precipitation.
- Stable isotopic signature of ground water, springs, streams, and lakes are more similar to winter than summer precipitation
- Navajo ground waters are less likely to be sensitive to future monsoonal changes.

Ahéhee’

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Kip Solomon
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Brenda Bowen
Annie Putman
Sagarika Banerjee
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Wil Mace

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Winona Shirley
Jonathan Shirley

<u>Navajo Environmental Protection Agency</u>
Yolanda Barney

<u>Citizen scientists</u>
Tulley and Cordova families

Ahéhee’ nitsaago

References

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- Crimmins, M.A., Selover, N., Cozzetto, K., and Chief, K. 2013. Technical Review of the Navajo Nation Drought Contingency Plan – Drought Monitoring.
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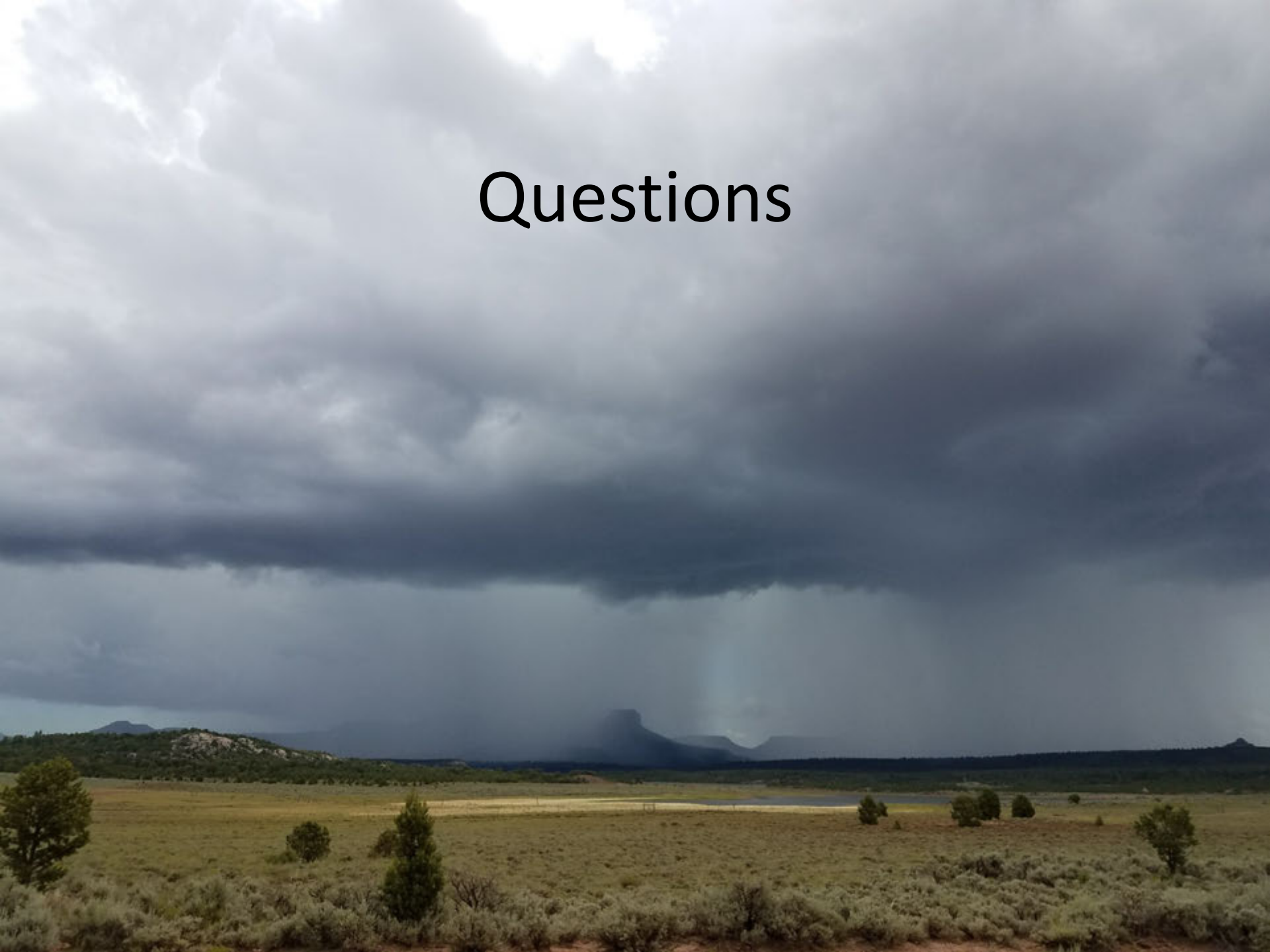
- Tulley-Cordova, C.L. and Bowen, G.J. 2018. Stable isotopes in precipitation and associated waters: Recording the North American Monsoon in Arizona, New Mexico, and Utah. Manuscript in prep.


Questions