Rain Days to Dry Spells: Exploring New Ways to Track Drought Across the Southwest U.S.

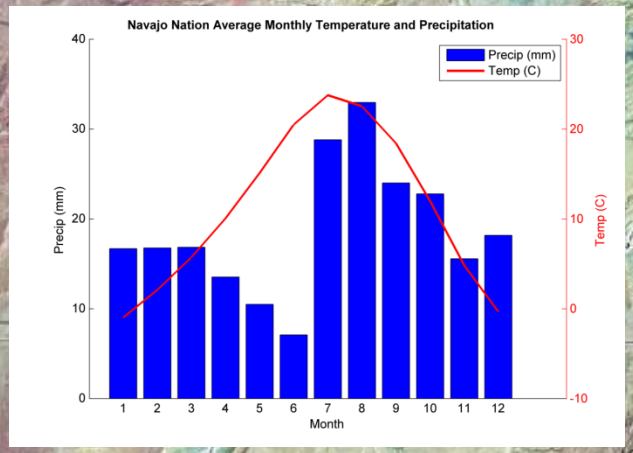
Mike Crimmins
Dept. of Soil, Water and Environmental Science

Project Team: Dan Ferguson, Alison Meadow, Jeremy Weiss, Holly Faulstich, and Alena Kimbrough

Climate Assessment for the Southwest

Background

- NOAA/NIDIS funding (2010) to support drought monitoring and planning efforts for Hopi Tribe and Navajo Nation
- 2010-2014: Interviews, focus groups, field visits, working meetings, and presentations
- Need for synthesis of existing climate/drought information in data sparse region
- What datasets, metrics, and monitoring strategies are available and appropriate for region



COLORADO

NEW MEXICO

Kayenta

Shiprock

Tuba City

Navajo Nation

Kykotsmovi

Window Rock

Hopi Reservation

Gallup

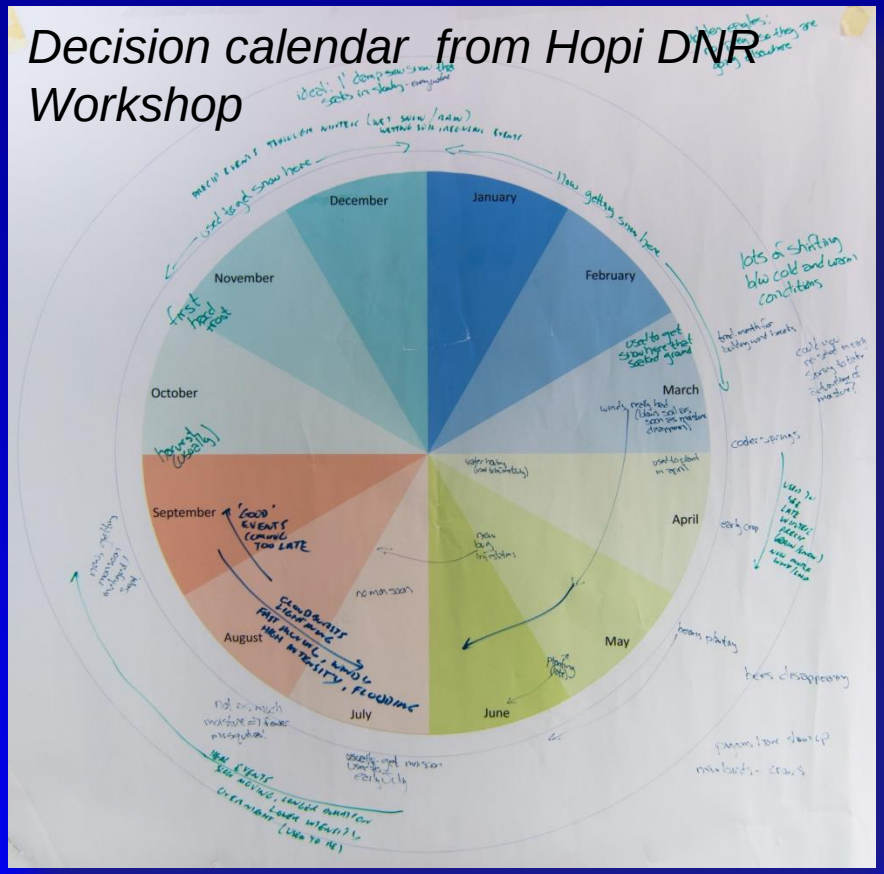
Flagstaff

Winslow

Holbrook

Climate/drought concerns

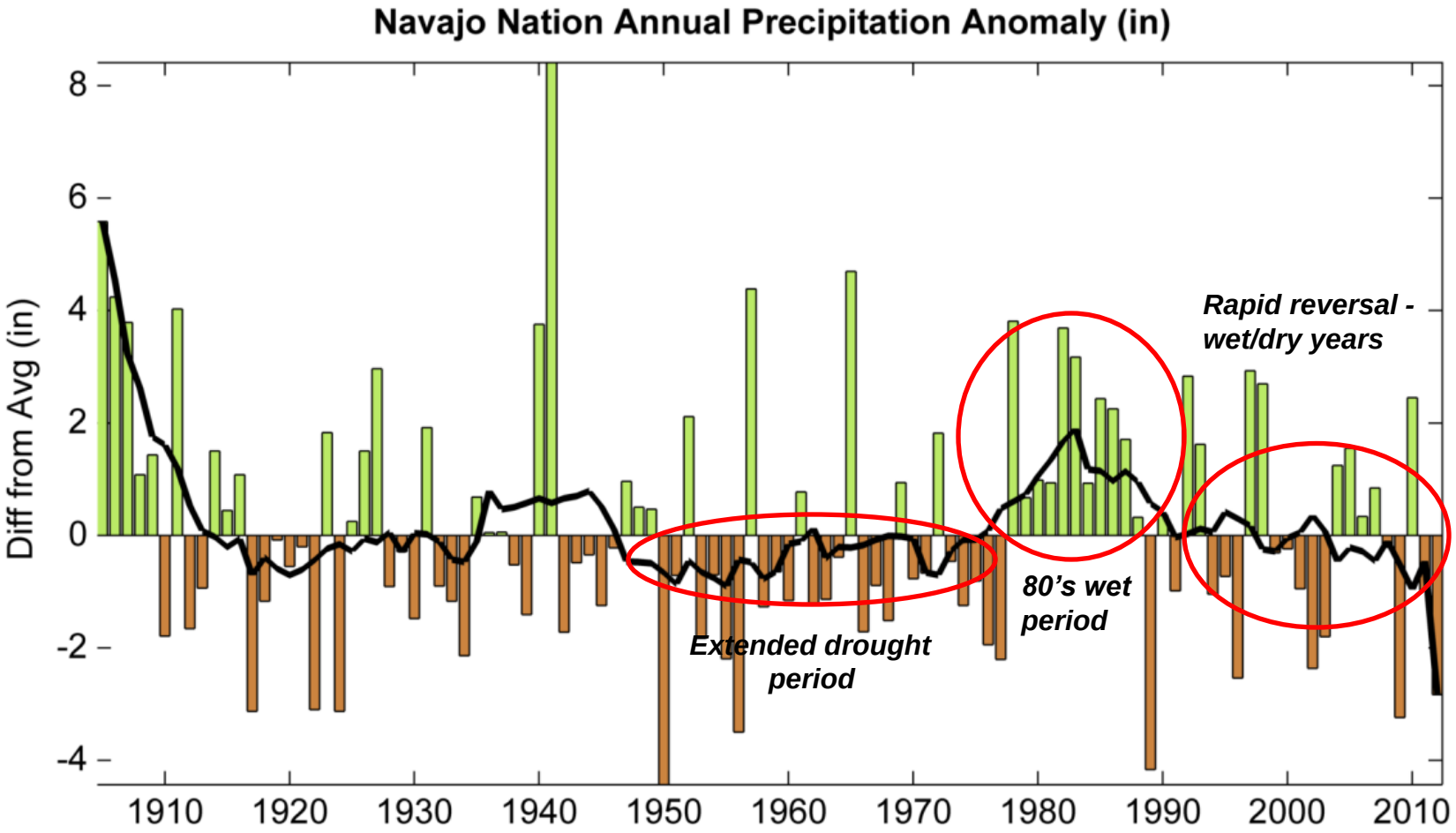
- Impact of recent droughts on unique cultural and natural resources → range conditions, water resources, dryland agriculture, ecosystems
- Shifts in seasonality; snow vs. rain and impact on soil moisture status
- Shifts in *timing* and *intensity* of precipitation events within seasons; dry spells
- Warming temperatures



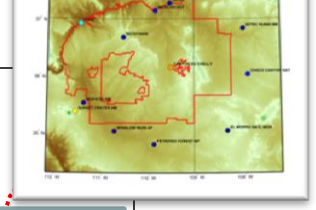
Decision calendar from Hopi DNR Workshop

Often subtle changes in discrete *weather* extremes within *climate* context

Annual Average Precipitation



Regional Composite Daily Cumulative Precip



min/max
1 stdev
mean

Snow/water res

wildifres

soil moisture recharge

dryland agriculture (growing seas)

rangeland forage

Snow/water res

cumulative precip (mm)

350
300
250
200
150
100
50
0

01/01
04/01
07/01
10/01
01/01

Day of Year

Winter storm season
Spring dry season
Summer monsoon season
Fall transition season

Good start, but what are we missing in an ‘event-driven climate’?

- Frequency, intensity and distribution of precipitation events → ‘effective’ precipitation
- Are droughts sometimes hidden by hydroclimatic extremes in annual and seasonal totals?
- Other indices to track ‘flavors’ of drought?

TABLE 1 | The Extreme Temperature and Precipitation Indices Recommended by the ETCCDI (Some User Defined Indices are Not Shown)

ID	Indicator Name	Indicator Definitions	Units
TXx	Max Tmax	Monthly maximum value of daily max temperature	°C
TNx	Max Tmin	Monthly maximum value of daily min temperature	°C
TXn	Min Tmax	Monthly minimum value of daily max temperature	°C
TNn	Min Tmin	Monthly minimum value of daily min temperature	°C
TN10p	Cool nights	Percentage of time when daily min temperature < 10th percentile	%
TX10p	Cool days	Percentage of time when daily max temperature < 10th percentile	%
TN90p	Warm nights	Percentage of time when daily min temperature > 90th percentile	%
TX90p	Warm days	Percentage of time when daily max temperature > 90th percentile	%
DTR	Diurnal temperature range	Monthly mean difference between daily max and min temperature	°C
GSL	Growing s	June in SH) TG>5 °C days with	days
FD0	Frost days	< 0 °C	days
SU25	Summer d	C	days
TR20	Tropical nights	Annual count when daily min temperature > 20 °C	days
WSDI	Warm spell duration indicator	Annual count when at least six consecutive days of max temperature > 90th percentile	days
CSDI	Cold spell duration indicator	Annual count when at least six consecutive days of min temperature < 10th percentile	days
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
RX5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	The ratio of annual total precipitation to the number of wet days (≥ 1 mm)	mm/day
R10	Number of heavy precipitation days	Annual count when precipitation ≥ 10 mm	days
R20	Number of very heavy precipitation days	Annual count when precipitation ≥ 20 mm	days
CDD	Consecutive dry days	Maximum number of consecutive days when precipitation < 1 mm	days
CWD	Consecutive wet days	Maximum number of consecutive days when precipitation ≥ 1 mm	days
R95p	Very wet days	Annual total precipitation from days > 95th percentile	mm
R99p	Extremely wet days	Annual total precipitation from days > 99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total precipitation from days ≥ 1 mm	mm

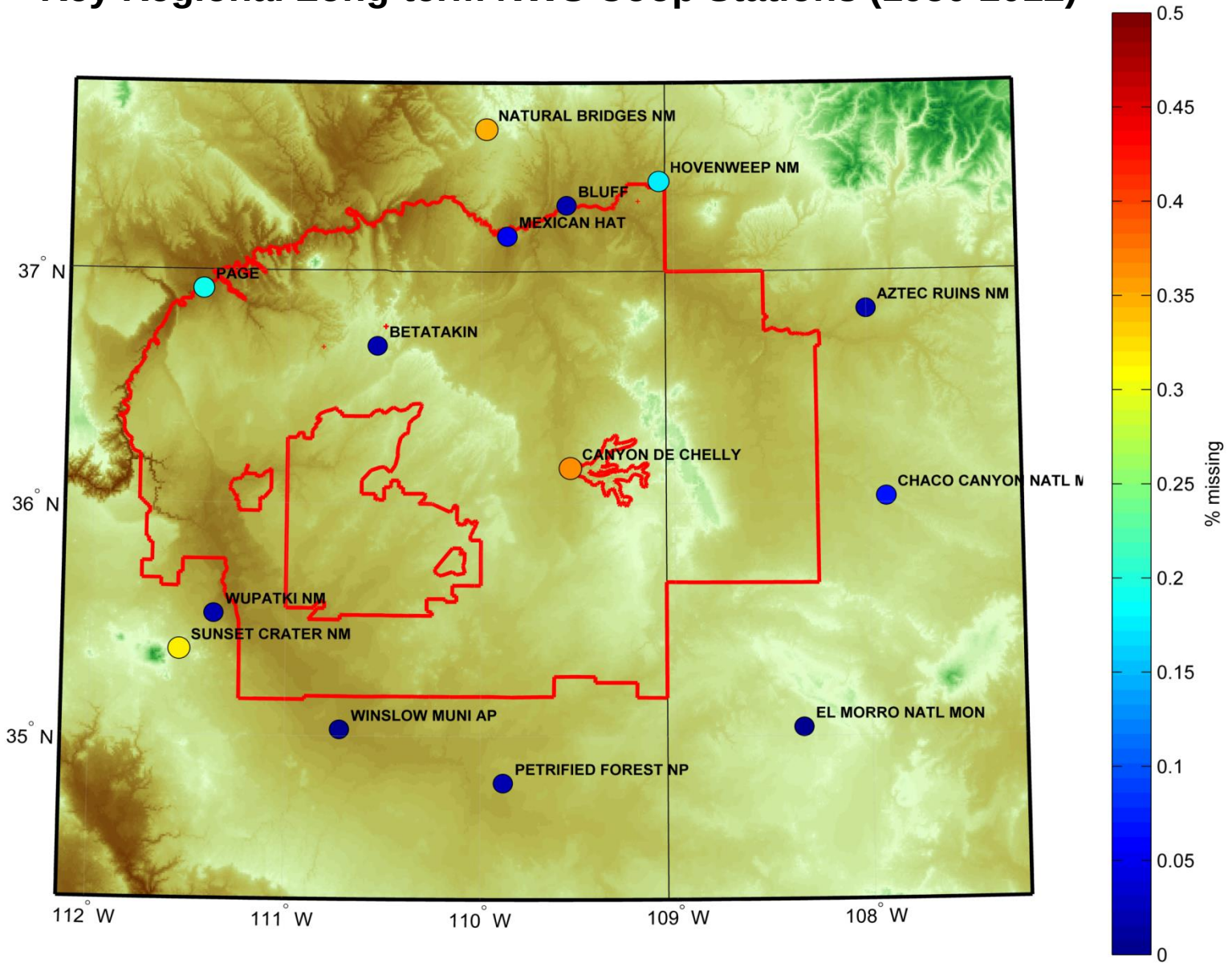
Precise definitions are given at http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.html.

Can we use these research metrics for the application of drought monitoring?

Regional Hydroclimatic Extremes Indices

- Identify National Weather Service Cooperative Observer sites with high-quality long-term records
- Calculate standard WMO extremes metrics from daily temperature and precipitation records → annual values
- Combine into regional indices using Standardized Anomaly Index method
- Principal components based data reduction to objectively identify key metrics
- Captures coherent regional signal (*regional-scale events*, *not local variability*)

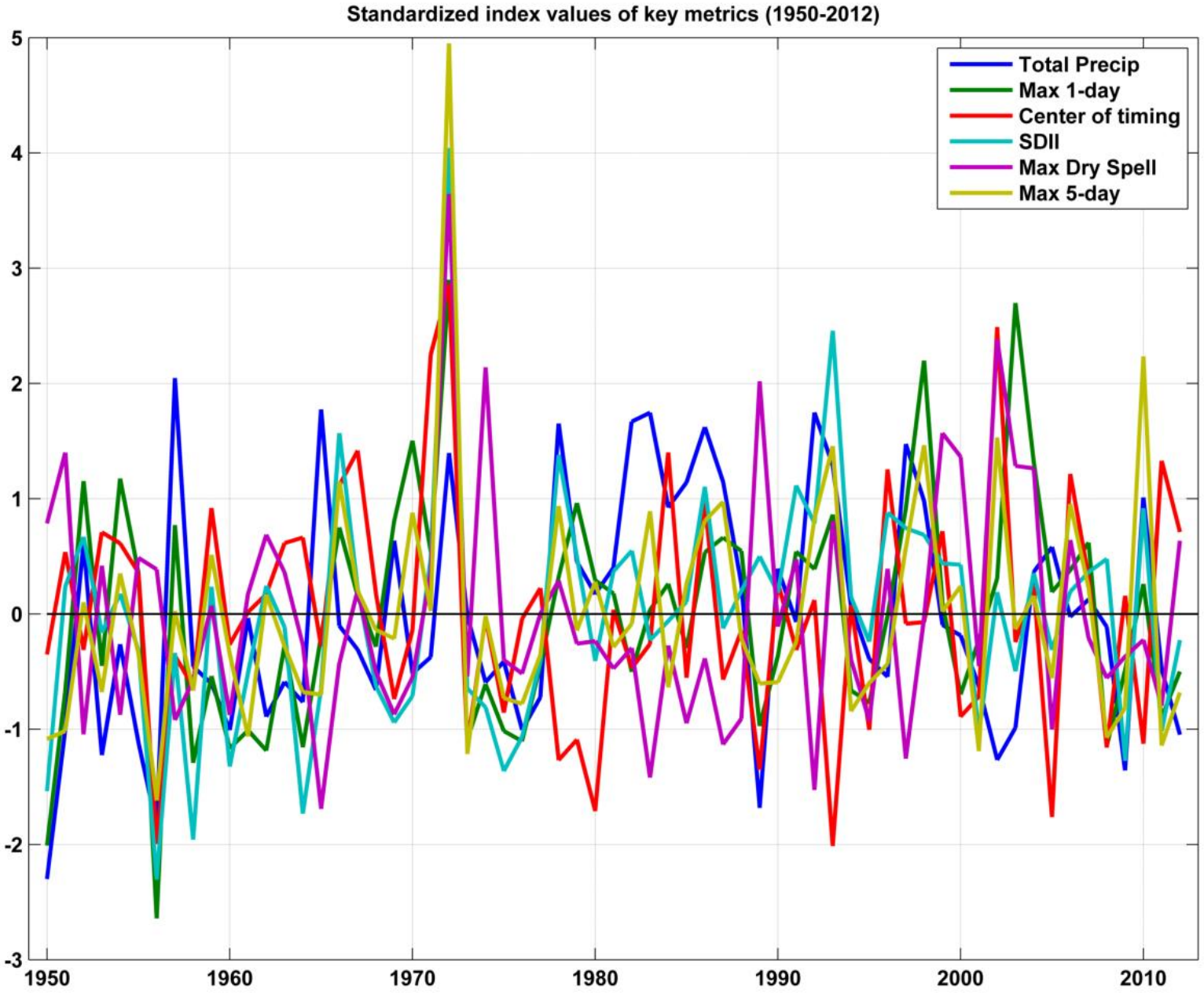
Key Regional Long-term NWS Coop Stations (1950-2012)



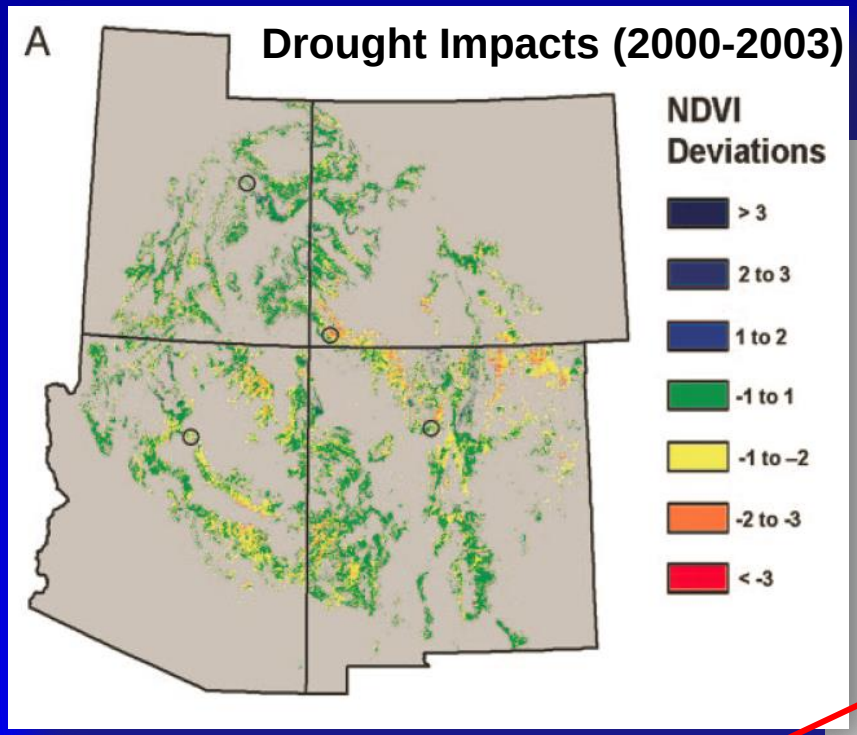
Key Metrics*

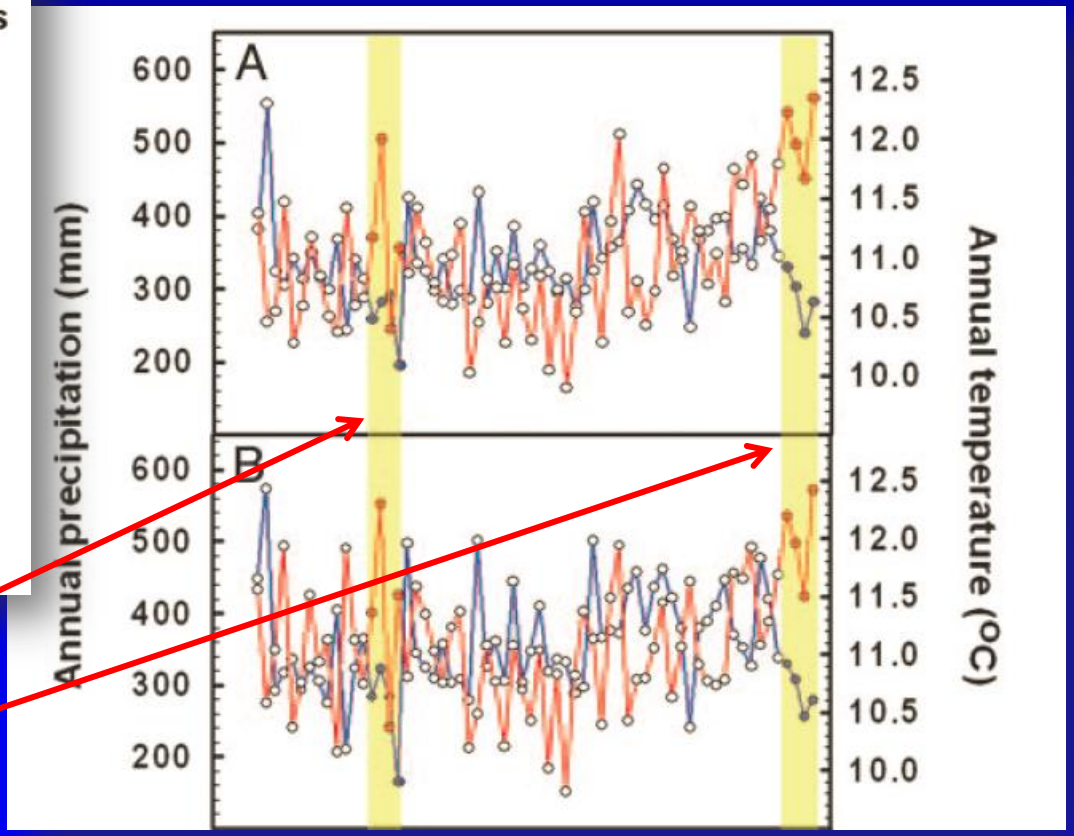
Metric	Calculation
Total Precipitation	*Simple annual total of daily observations (mm)*
Max 1-day total	*Highest 1-day total in year from daily observations (mm)*
Center of timing	*Day of year half of annual total is accumulated (day of year)*
Simple Daily Intensity Index	*Ratio of total annual precipitation to days with precipitation (mm/day)*
Max Cumulative Dry Days	*Maximum stretch with no recorded precipitation (days)*
Max 5-day total	*Highest total precipitation recorded in moving 5-day window through entire year*

*highest correlating variables (of 13) on first 6 rotated principal components


Standardized index values of key metrics (1950-2012)
Total Precip
Max 1-day
Center of timing
SDII
Max Dry Spell
Max 5-day
5
4
3
2
1
0
-1
-2
-3
1950
1960
1970
1980
1990
2000
2010

‘Flavors of drought’

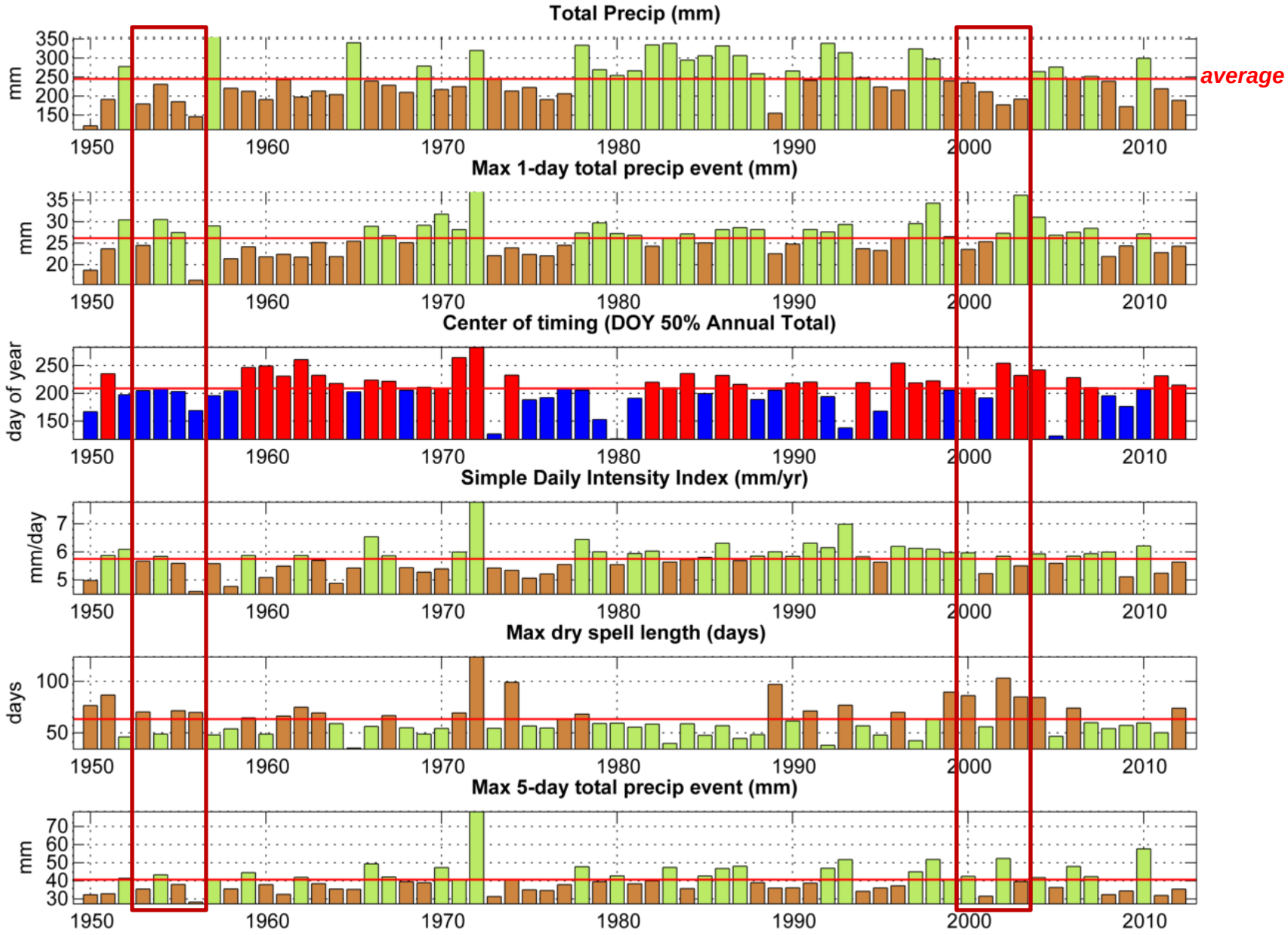




Cool droughts (1953-1956) vs.
Warm droughts (2000-2003)

Breshears et al. 2005

Regional index values of key metrics – 1950-2012



1953-1956 vs. 2000-2003 drought periods

Regional Index Z-Scores

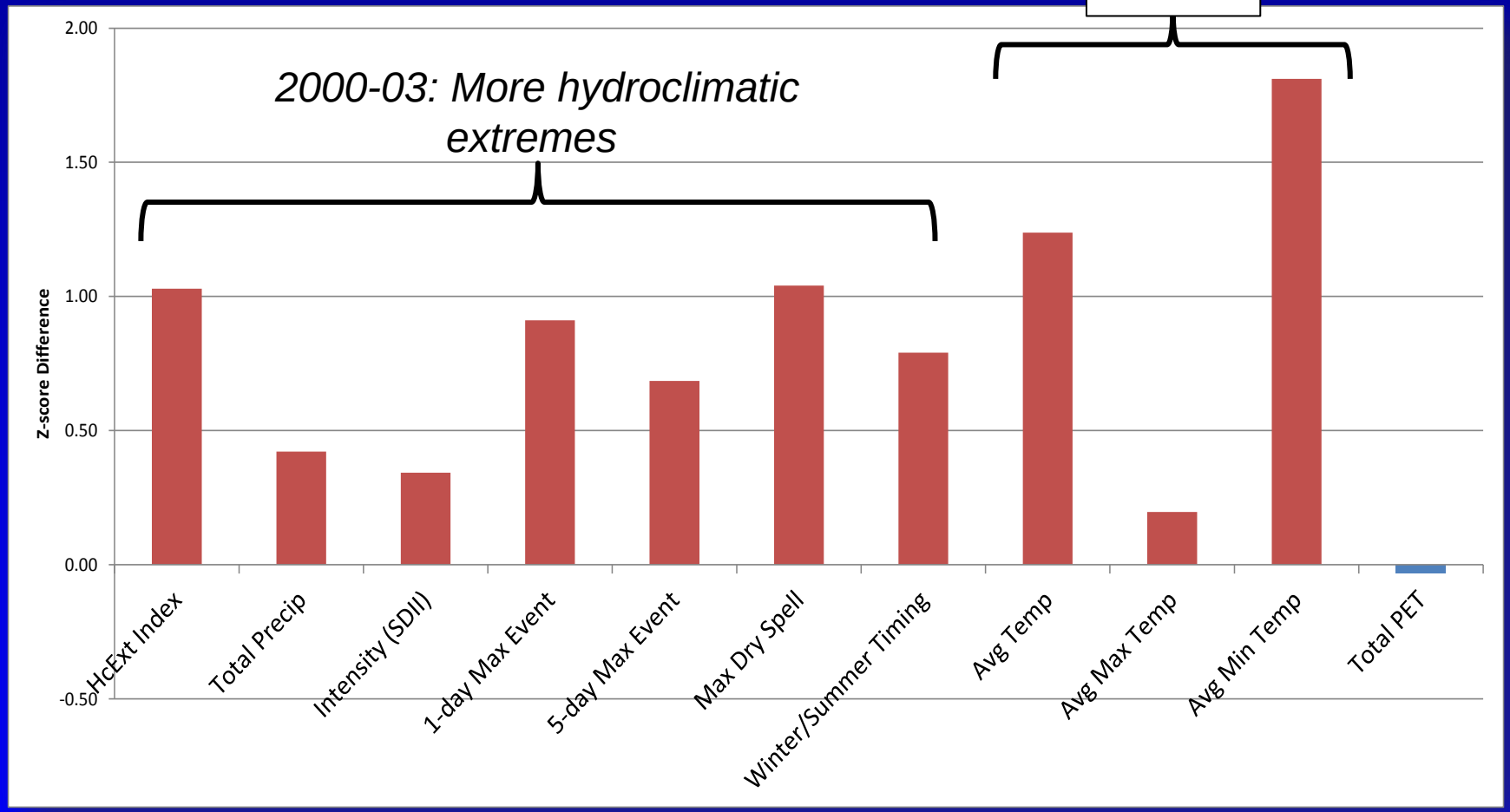
years	HcExt Index	Total Precip	Intensity (SDII)	1-day Max Event	5-day Max Event	Max Dry Spell	Winter/Summer Timing	Avg Temp	Avg Max Temp	Avg Min Temp	Total PET
1953	-0.56	-1.22	-0.16	-0.45	-0.68	0.42	-0.12	0.01	0.58	-0.59	0.59
1954	-0.20	-0.26	0.17	1.17	0.35	-0.87	-0.01	1.86	2.22	1.02	1.36
1955	-0.23	-1.11	-0.31	0.36	-0.34	0.49	-0.17	-0.67	-0.18	-1.09	-0.38
1956	-1.35	-1.84	-2.30	-2.64	-1.62	0.39	-1.23	0.00	1.18	-1.10	1.63
2000	-0.03	-0.19	0.43	-0.70	0.24	1.36	0.01	1.97	1.54	1.74	1.09
2001	-0.87	-0.63	-1.04	-0.22	-1.19	-0.45	-0.52	1.44	0.96	1.72	0.41
2002	1.65	-1.27	0.19	0.31	1.53	2.38	1.41	0.72	0.79	0.36	0.74
2003	1.03	-0.99	-0.50	2.70	-0.13	1.29	0.73	2.01	1.31	1.87	0.85

Less Extreme — More Extreme

Cooler — Warmer

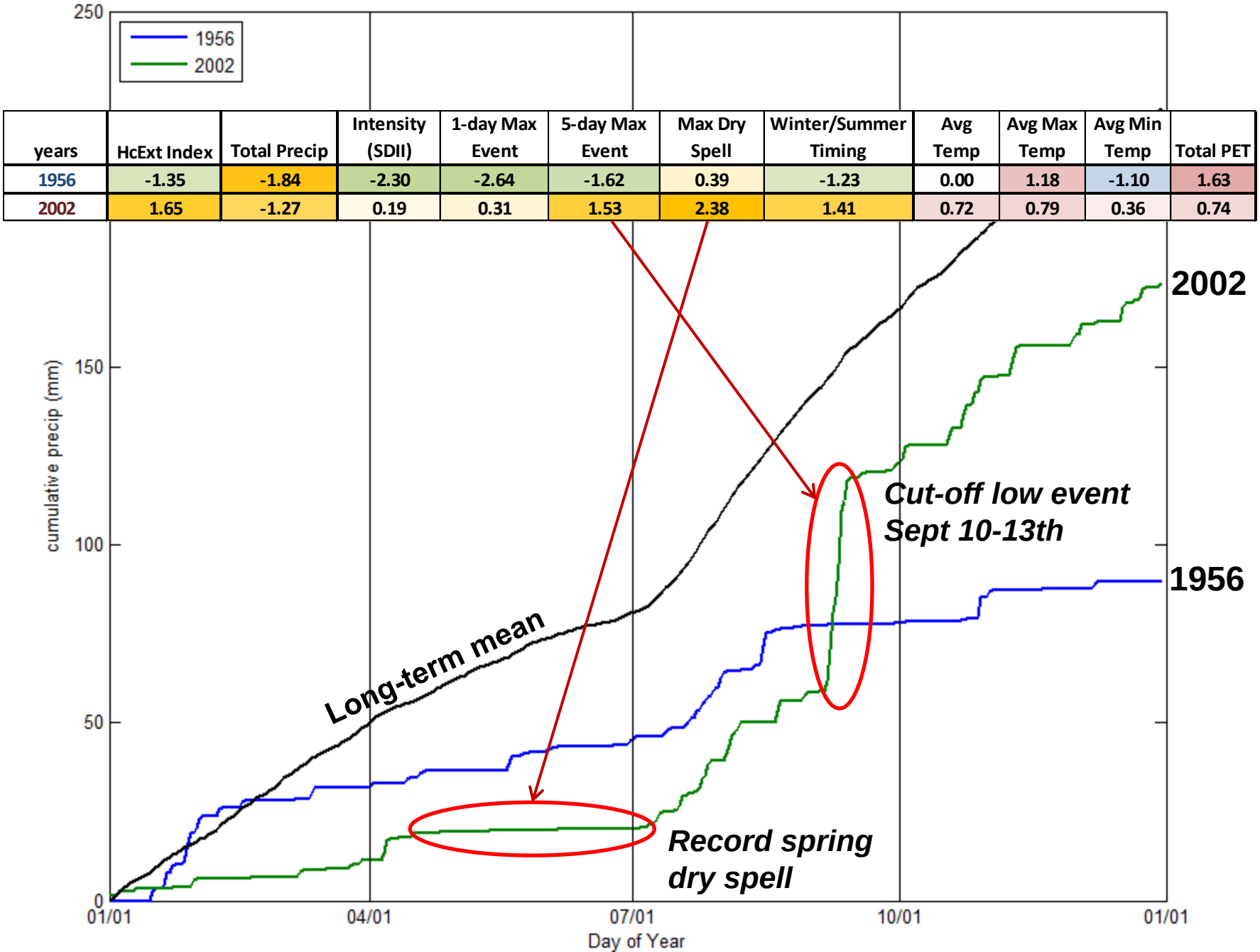
2000-03: Warmer, not as dry, but more hydroclimatic extremes (less effective precipitation?)

Drought period differences: 2000s-1950s

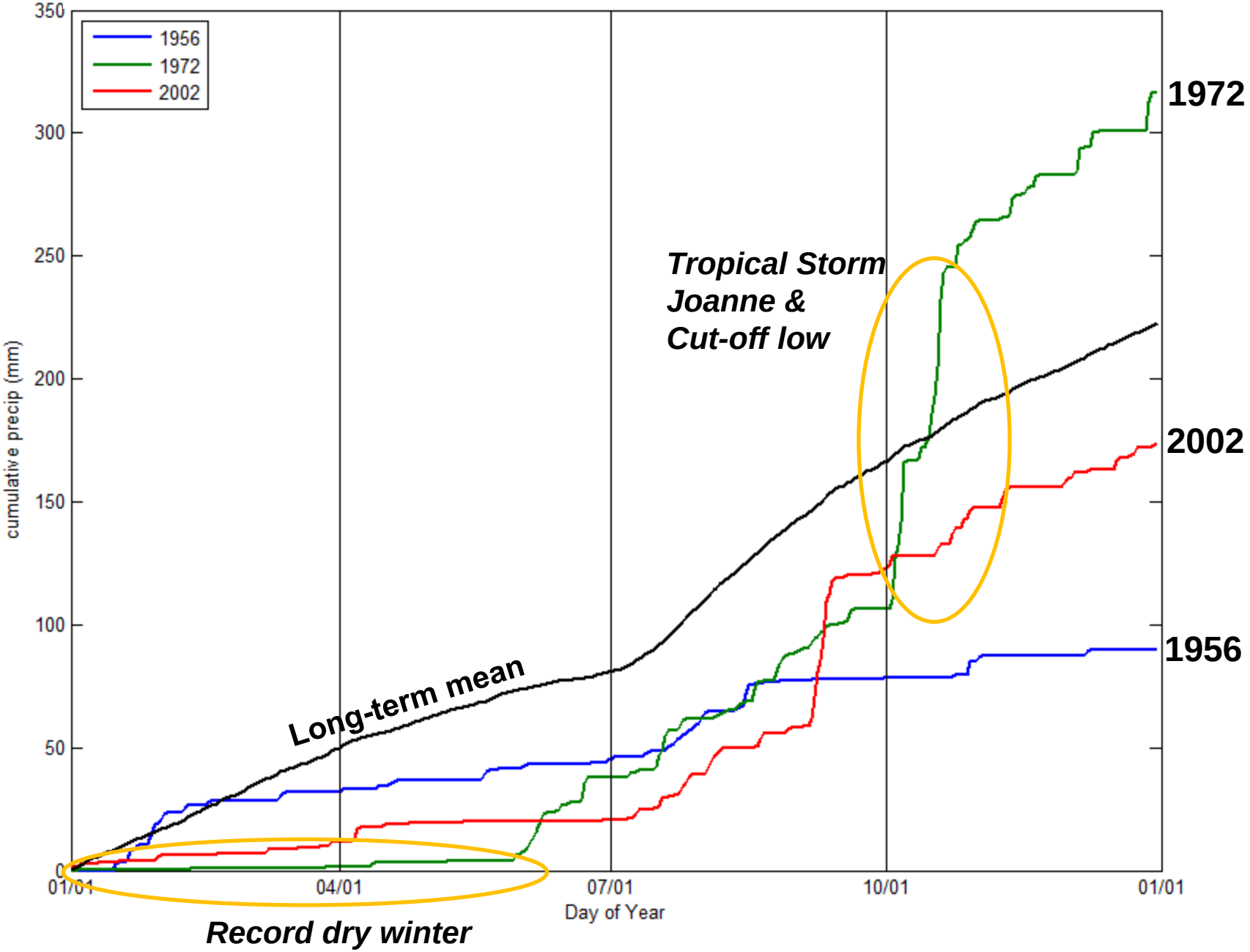


Regional Composite Daily Cumulative Precip – 1956 vs. 2002

years	HcExt Index	Total Precip	Intensity (SDII)	1-day Max Event	5-day Max Event	Max Dry Spell	Winter/Summer Timing	Avg Temp	Avg Max Temp	Avg Min Temp	Total PET
1956	-1.35	-1.84	-2.30	-2.64	-1.62	0.39	-1.23	0.00	1.18	-1.10	1.63
2002	1.65	-1.27	0.19	0.31	1.53	2.38	1.41	0.72	0.79	0.36	0.74



Regional Composite Daily Cumulative Precip – 1956, 2002 and 1972



Implications for resource management and drought monitoring on regional Tribal lands

- *Event-driven regional climate* – traditional drought metrics may not match regional drought impacts
- Importance of timing/distribution/intensity of precipitation relative to regional agroecosystems and water resources
- Case study provided in 1950's vs. 2000 drought periods → insight into temperature *and* effective precipitation?
- Harder to do, though…requires at least daily measurements – very few long-term monitoring sites
- Desperately need soil moisture monitoring strategies

Thanks!

crimmins@email.arizona.edu

http://cals.arizona.edu/climate