Diagnosis of Changing Cool Season Precipitation Statistics in the Western U.S. from 1916-2003

Joe Hamman[1], Alan F. Hamlet[1,2], Jeremy Littell[2]

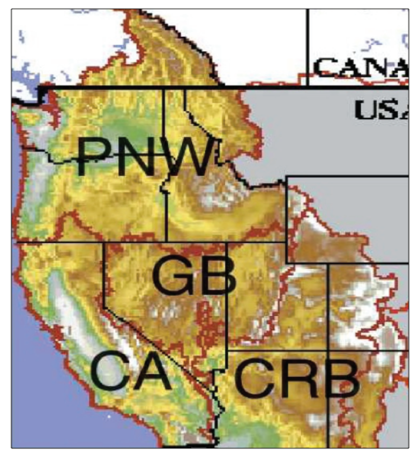
(1) Department of Civil and Environmental Engineering, University of Washington, (2) Climate Impacts Group, University of Washington

ABSTRACT:

Since about 1977, cool season (Oct-March) precipitation in the Western U.S. has increased in variance, autocorrelation, and regional covariance. These changes have manifested themselves in increasing flood risk, increasing covariance of regional hydropower resources, and increasing drought and fire impacts in the west. We explore these changes in precipitation variability using two approaches: statistical analysis of regionally averaged cool season precipitation (mean, variance, autocorrelation, and regional covariance) and an EOF analysis of 1/8th degree gridded cool season precipitation anomalies over the western U.S. The changes in cool season precipitation are characterized by statistically significant changes in the variance (p=0.05). Increases in autocorrelation and regional covariance, although substantial on an absolute scale, are not statistically significant (p=0.05). The EOF analysis shows increased amplitude of the PC associated regional covariance (EOF1) starting around 1977, and the PC associated with the NW/SE dipole (ENSO/PDO) (EOF2) also shows evidence of expanding variance at about the same time. Although the paleological record supports the argument that natural variability is sufficient to explain the late 20th century patterns in the CORB and SSJ, it remains unclear whether global climate change is contributing to the effects or not. GCMs do not reliably simulate the changes in precipitation variability seen in the observed record (thus conventional detection and attribution studies typically fail in the initial step); however this could also be related to other factors such as GCM deficiencies in simulating cool season precipitation variability at the regional scale. That said, there is currently little evidence to support the hypothesis that recent changes in cool season precipitation variability are an expression of global greenhouse forcing.

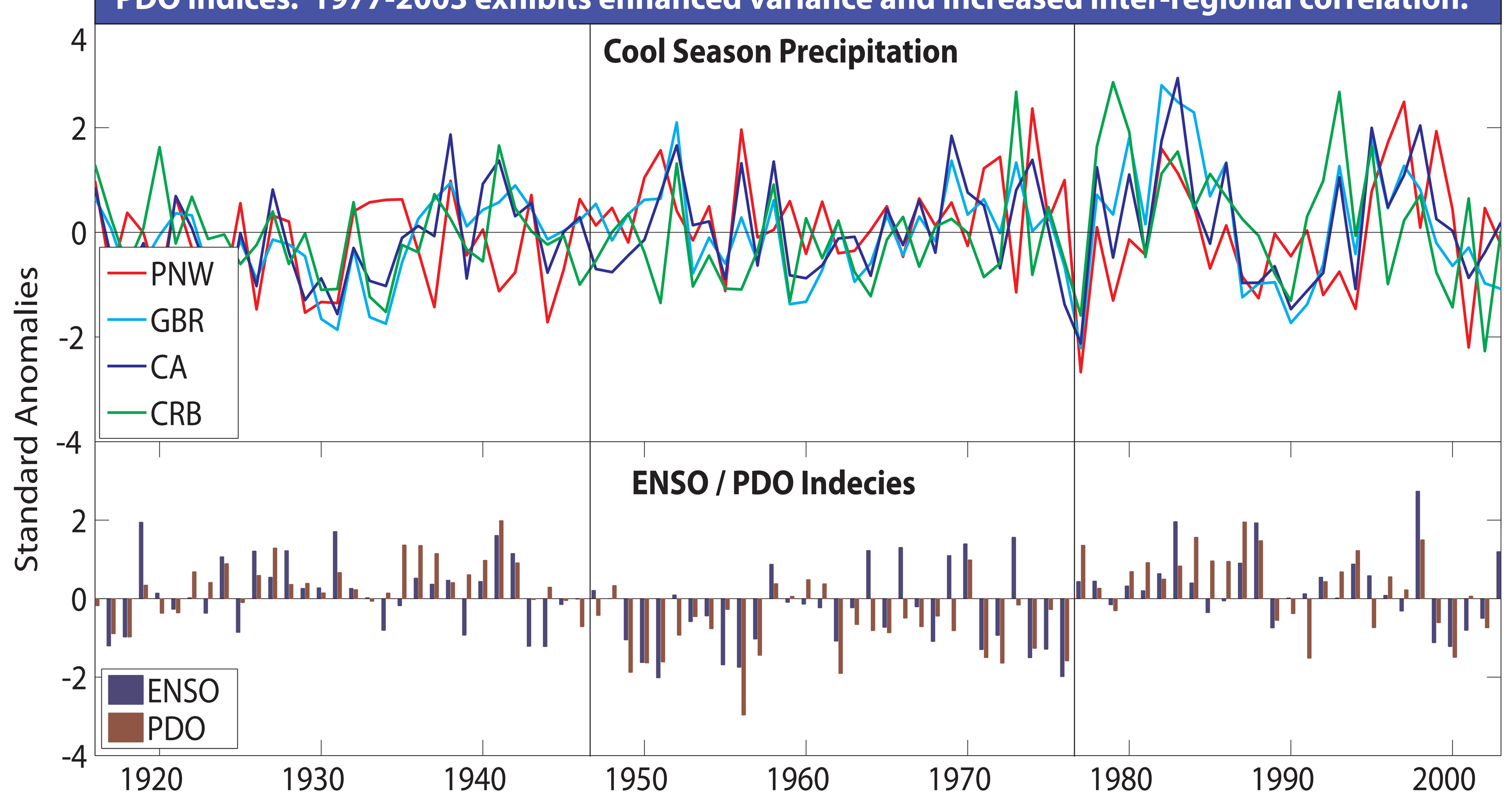
DATA:

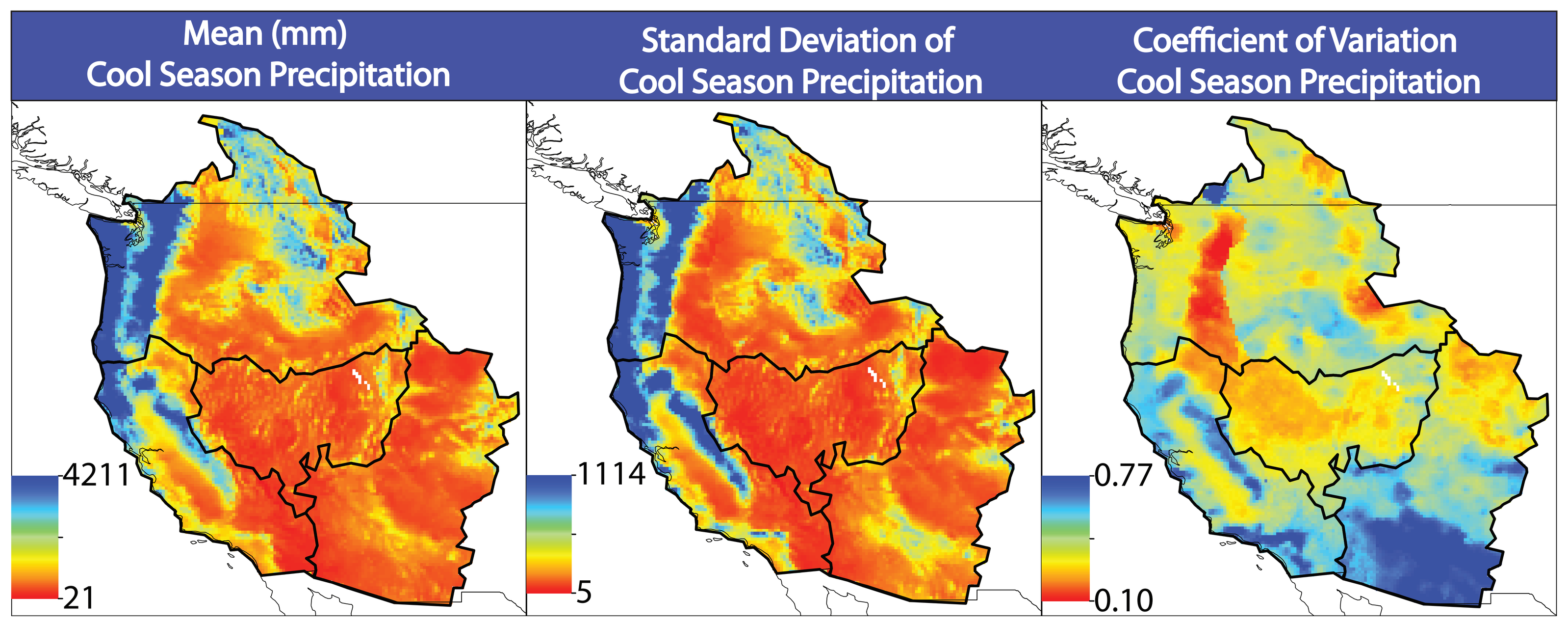
1/8th degree gridded precipitation data developed by Hamlet and Lettenmaier (2005) using linear interpolation techniques on distributed CO-OP and HCN gauged station data. Monthly precipitation was adjusted for temporal inconsistencies and topographic effects.



Cool season (Oct-Mar) precipitation for each grid cell was calculated as the sum of the first 6 months of each water year. Regional averages were calculated as the simple average.

Time series of standardized regionally averaged cool season precipitation and the Nino3.4 and PDO indices. 1977-2003 exhibits enhanced variance and increased inter-regional correlation.





EOF ANALYSIS

METHODS:

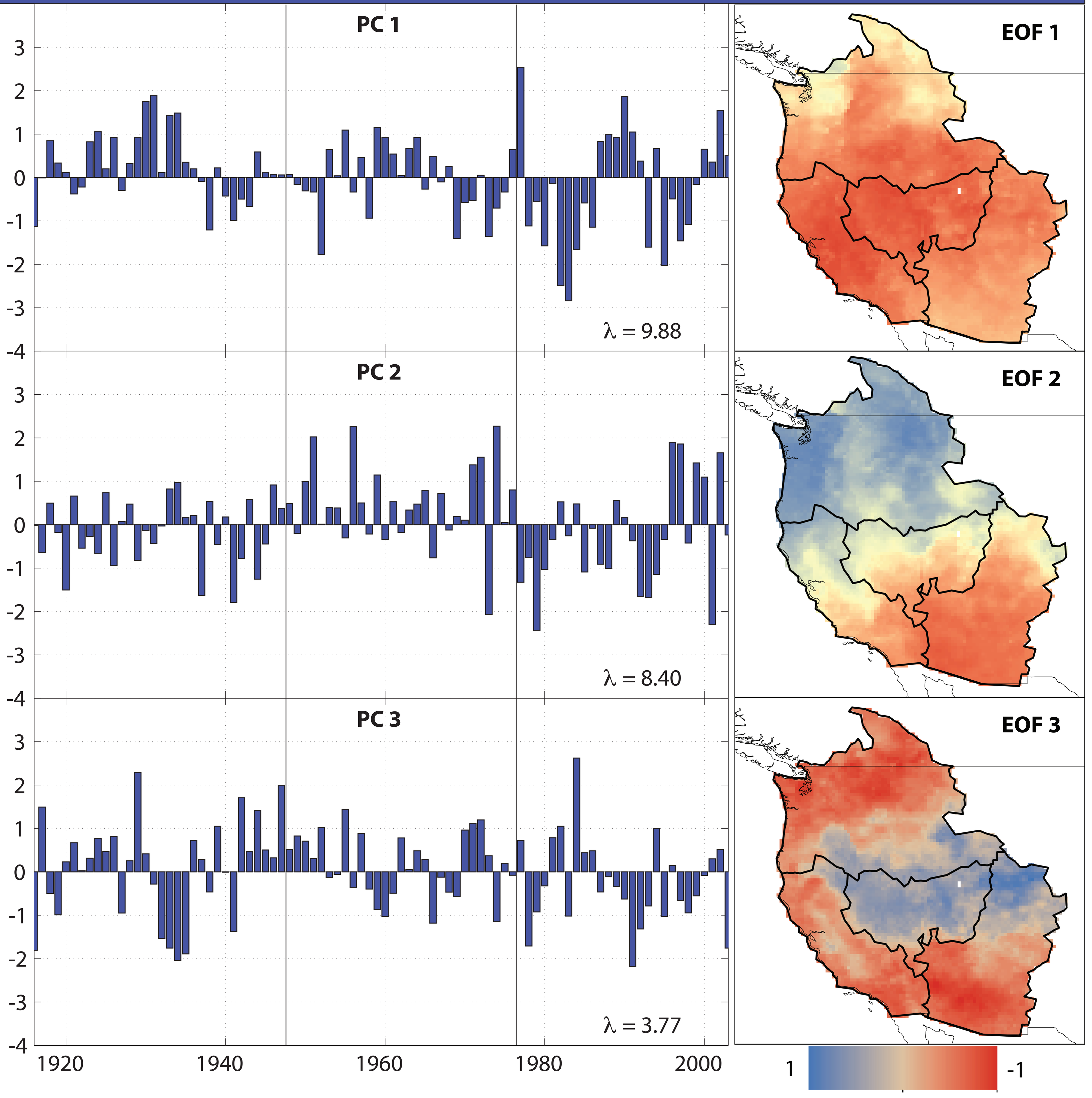
This study performed EOF analysis on gridded standardized cool season precipitation anomalies derived from Hamlet and Lettenmaier's 2005 data set for the western United States. The EOF analysis produces the discrete modal representations of the spatial patterns (EOFs) and the corresponding temporal signals (PCs) describing the observed variance in time and space. These structures are often useful in identifying mechanisms that produce variability in the observed climate.

RESULTS:

The EOF analysis shows increased amplitude of the PC associated regional covariance (EOF1) around 1977. The PC associated with the NW/SE dipole (EOF2), which is well correlated (~0.5) with ENSO/PDO also shows evidence of expanding variance at about the same time. Although the mean of the PCs do not significantly change after 1977, the change variance is strongly statistically significant (p=0.05).

	PC Statistics	Mode 1	Mode 2	Mode 3
1916-1946	Mean	0.25	-0.19	0.02
	Standard Deviation	0.78	0.75	1.10
	Lag 1auto Correlation	0.43	-0.26	0.20
	Correlation with ENSO	0.35	-0.27	-0.20
	Correlation with PDO	-0.14	-0.39	-0.13
1947-1976	Mean	-0.06	0.44	0.22
	Standard Deviation	0.73	0.90	0.80
	Lag 1auto Correlation	0.06	-0.46	0.22
	Correlation with ENSO	-0.26	-0.68	-0.09
	Correlation with PDO	0.16	-0.50	-0.19
1977-2003	Mean	-0.21	-0.25	-0.24
	Standard Deviation	1.33	1.16	1.00
	Lag 1auto Correlation	0.38	0.15	0.04
	Correlation with ENSO	-0.24	-0.37	-0.32
	Correlation with PDO	-0.17	-0.34	0.27
1916-2003	Mean	0.00	0.00	0.00
	Standard Deviation	0.99	0.99	0.99
	Lag 1auto Correlation	0.37	-0.02	0.18
	Correlation with ENSO	-0.10	-0.45	-0.24
	Correlation with PDO	-0.04	-0.49	-0.07

Principal components and spatial EOFs for the leading modes of the EOF analysis. The first 3 modes are shown below and represent approximately 20% of the system's variance.



STATISTICAL ANALYSIS

METHODS:

The mean, variance, autocorrelation, and covariance were calculated for each basin and for four periods: 1916-1946, 1947-1976, 1977-2003 and 1916-2003. Inference testing was performed on the periods before and after 1977 to determine whether the observed in the mean and variance changes were statistically significant. For this study, statistical significance was defined as p=0.05.

	Regional Statistics:	PNW	GB	CA	CRB
1916-1946	Mean (mm)	574.68	172.36	443.88	174.71
	Standard Deviation	88.79	23.59	100.12	30.56
	Lag 1auto Correlation	-0.17	0.58	0.07	0.08
	Trend (% per decade)	-1.07	3.68	6.87	-3.45
1947-1976	Mean (mm)	640.27	180.90	477.13	168.57
	Standard Deviation	84.44	23.90	99.32	33.99
	Lag 1auto Correlation	-0.41	0.08	-0.01	-0.33
	Trend (% per decade)	1.53	-0.11	2.79	3.83
1977-2003	Mean (mm)	594.33	185.53	488.06	190.79
	Standard Deviation	126.18	41.42	141.91	50.83
	Lag 1auto Correlation	0.20	0.43	0.11	0.14
	Trend (% per decade)	6.28	-6.91	-0.34	-12.34
1916-2003	Mean (mm)	603.07	179.31	468.77	177.55
	Standard Deviation	103.16	30.41	114.56	39.55
	Lag 1auto Correlation	0.0002	0.44	0.14	0.08
	Trend (% per decade)	0.79	1.06	1.83	0.89

RESULTS:

The changes in cool season precipitation are characterized by statistically significant changes in the mean in the PNW region and variance throughout the entire west. Autocorrelation is found to increase in most basins but the changes are not statistically significant.

Increases in the regional coherence have also been observed. Each basin shows substantial increases in correlation with all other basins between 1916-2003. These increases point to an increased congruity throughout the west.

Correlation:	CA-CRB	CA-GB	CA-PNW	CRB-GBAS	CRB-PNW	GBAS-PNW
1916-1946	0.37	0.75	0.51	0.63	-0.17	0.17
1947-1976	0.30	0.72	0.29	0.54	-0.46	0.14
1977-2003	0.64	0.91	0.80	0.63	-0.06	0.52

DISCUSSION:

- The expansion of variance in PC1 explains both increased variance and increased regional coherence in the regional average time series.
- PC1 shows more red noise characteristics post 1975 indicating increasing persistence and amplitude of cohesion throughout the west.
- PC2 seems to be functioning more on interannual time scales and exhibits less long-term persistence. (I.E. the ENSO/PDO pattern associated with EOF seems to be getting stronger in the extremes, but expresses itself only in isolated years and therefore does not greatly interfere with the large coherent swings associated with the expansion of variance in PC1).
- Strong spatial and temporal correlations between and the ENSO/PDO patterns further confirm these the role of these patterns in Western U.S precipitation.
- Marked changes in statistics coincides with statistically significant changes in the variance associated ENSO and PDO.
- Paleological records support the argument that natural variability is sufficient to explain the late 20th century patterns in the CORB and SSJ.
- It remains unclear whether global climate change is contributing to the effects. GCMs do not reliably simulate the changes in precipitation variability seen in the observed record, thus conventional detection and attribution studies typically fail in the initial step. However this could also be related to other factors such as GCM deficiencies in simulating cool season precipitation variability at the regional scale.
- There is currently little evidence to support the hypothesis that recent changes in cool season precipitation variability are an expression of global greenhouse forcing.

REFERENCES:

1. Hamlet, A. F., & Lettenmaier, D. P. (2005). Production of Temporally Consistent Gridded Precipitation and Temperature Fields for the Continental United States. Journal of Hydrometeorology, 330-336.

CORRESPONDING AUTHOR: Alan Hamlet: hamleaf@u.washington.edu