Future extreme precipitation events in the Southwestern US: climate change and natural modes of variability

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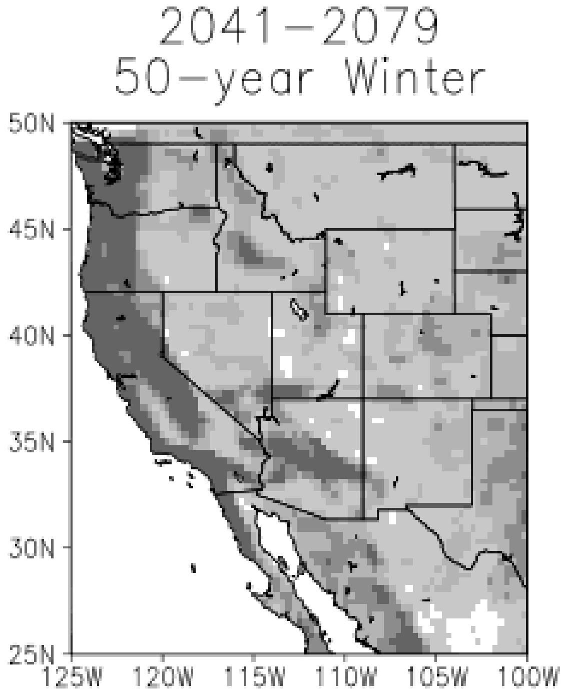
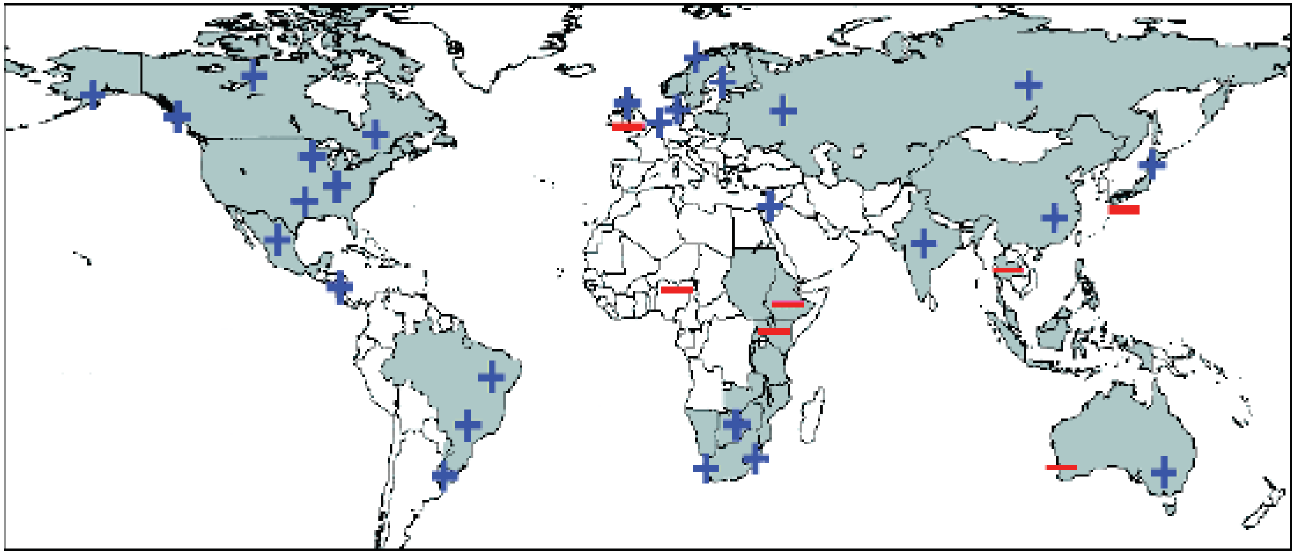


U.S. DEPARTMENT OF ENERGY

The goal of this work is to investigate how climate change will affect the intensity of precipitation in the western US.

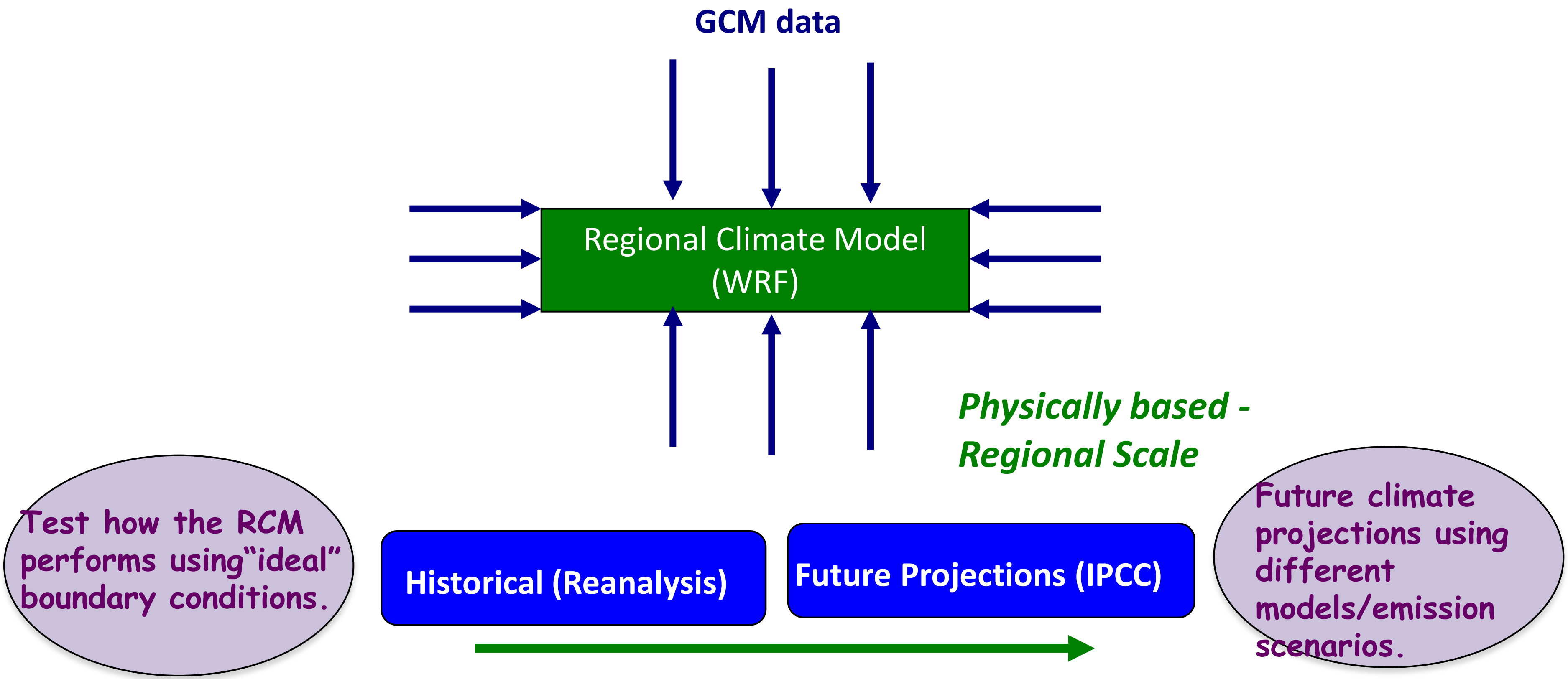


Regions where disproportionate changes in heavy and very heavy precipitation during the past decades were documented as either an increase (+) or decrese (-) compared to the change in the annual and/or seasonal precipitation (updated from Groisman et al, 2005), taken from Trenberth et al. (2007)

Recent work has shown that the intensity of extreme precipitation events in the NH has increased.

→ ***This has many important implications for many areas including urban infrastructure.***

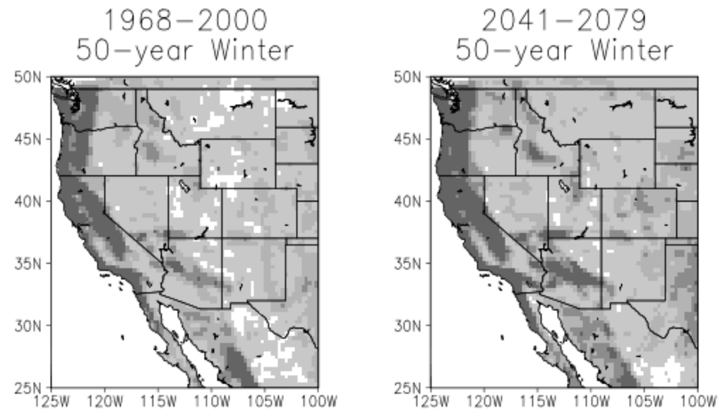
We use a regional climate modeling framework to address issues of non-stationarity and capture the physical mechanisms of extreme rainfall events.



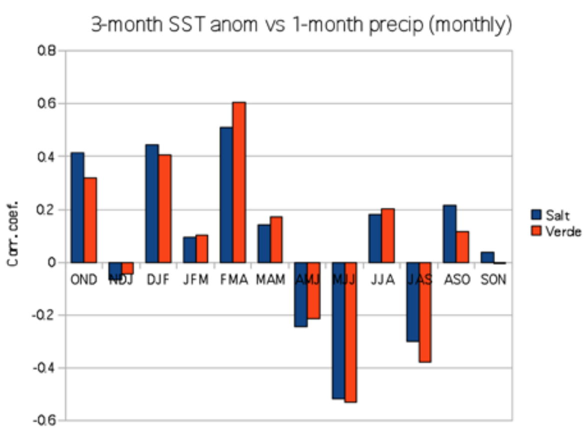
We use a 112-year continuous simulation using WRF forced at it's lateral boundaries with HadCM3 A2 data.

From this WRF-HadCM3 112-year simulation we will present two analyses:

1. Analysis of extreme precipitation events



2. ENSO relationship to precipitation in the SW



We use a "Poisson–GP model" to characterize the statistical distribution of extreme events. (Katz et al. 1999, 2002, 2010).

We don't use GEV theory because it is limited to block maxima, and we would loose information.

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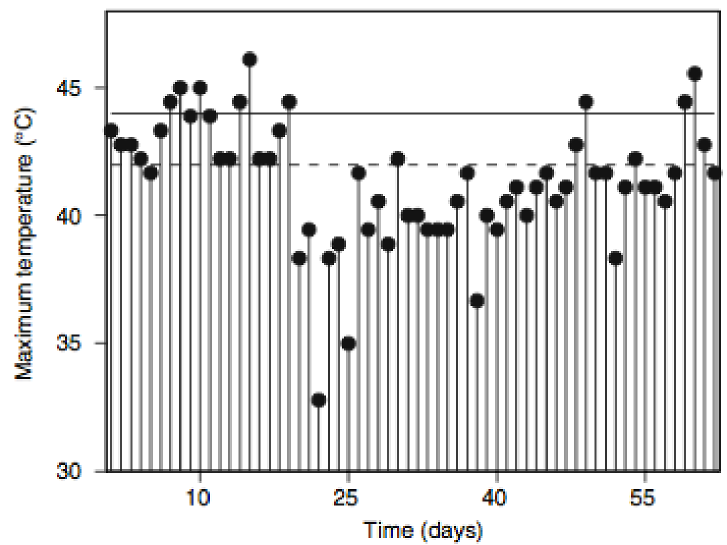
Fig. 1 Time series of daily maximum temperature during July–August 1948 at Phoenix, AZ, with two thresholds, one at 42°C (*dashed line*) and another at 44°C (*solid line*), to motivate point process approach to extreme value analysis

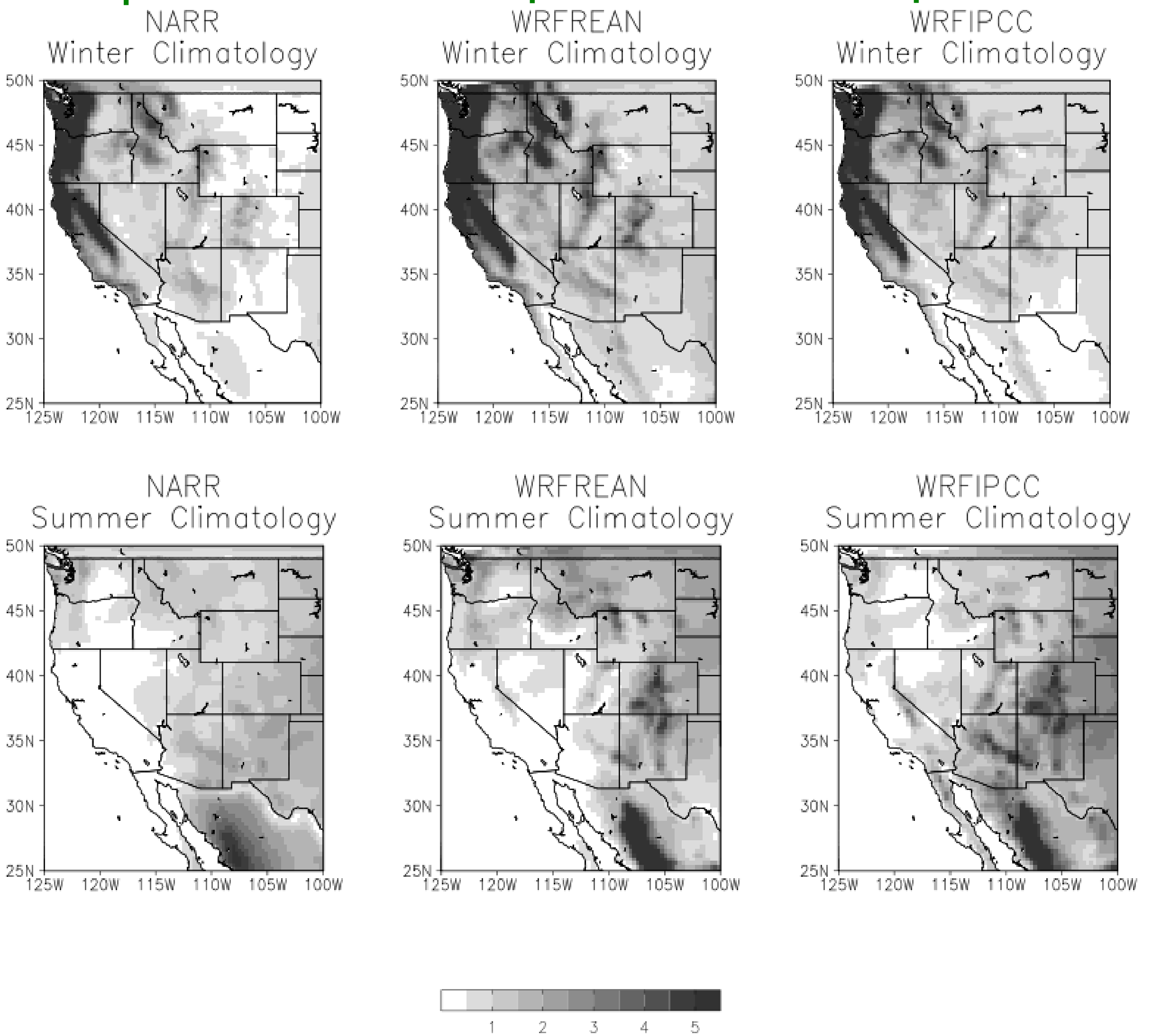


Katz,
Climatic Change 2010

Consists of a Poisson process to model the occurrence of an exceedance of a high threshold and a generalized Pareto (GP) distribution to model the excess over the threshold.

WRF-downscaling shows a realistic characterization of the climatology of precipitation and of the intense events.

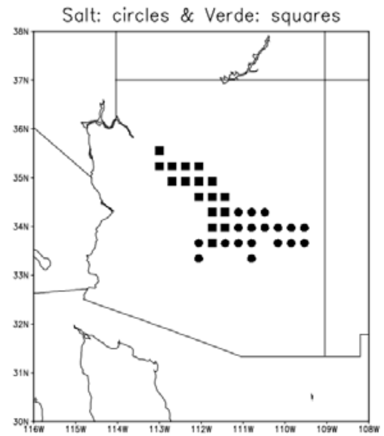
"Observed" Precipitation | **WRF-Reanalysis II Precipitation** | **WRF-UKMO HadCM3 Precipitation**

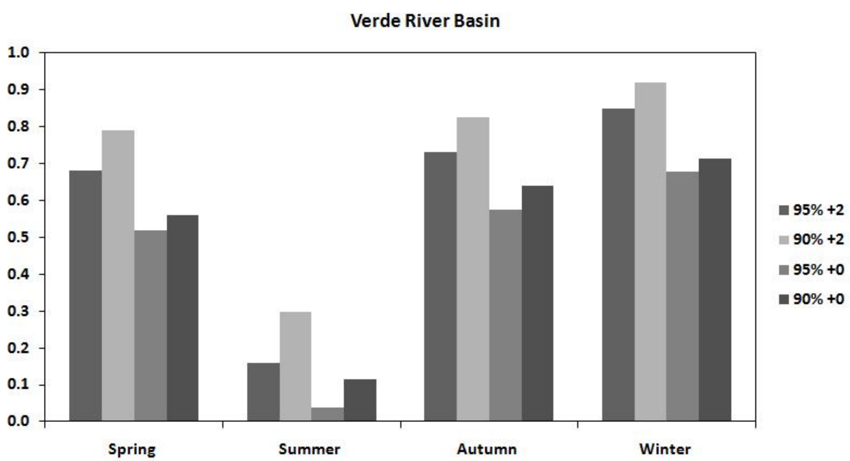


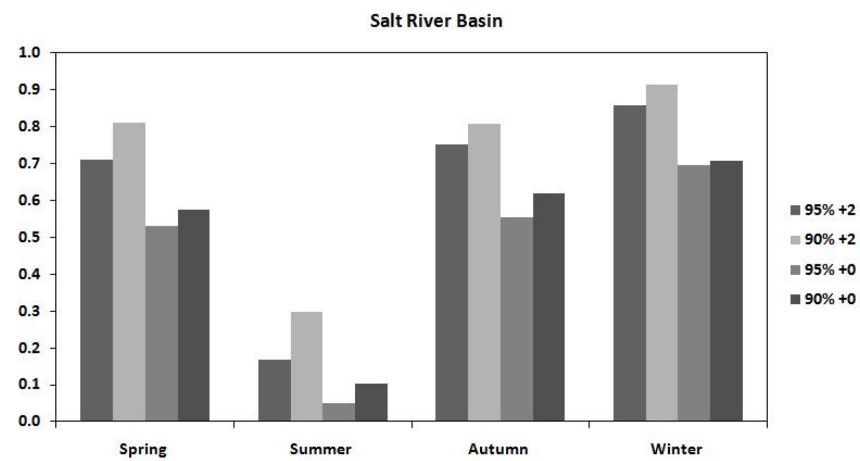
The spatial pattern of precipitation and the magnitude is realistically captured for both winter and summer.

WRF-downscaled rainfall seems to be biased high in both Reanalysis and UKMO-HadCM3

WRF-Reanalysis II shows an impressive ability to capture individual cool-season events.

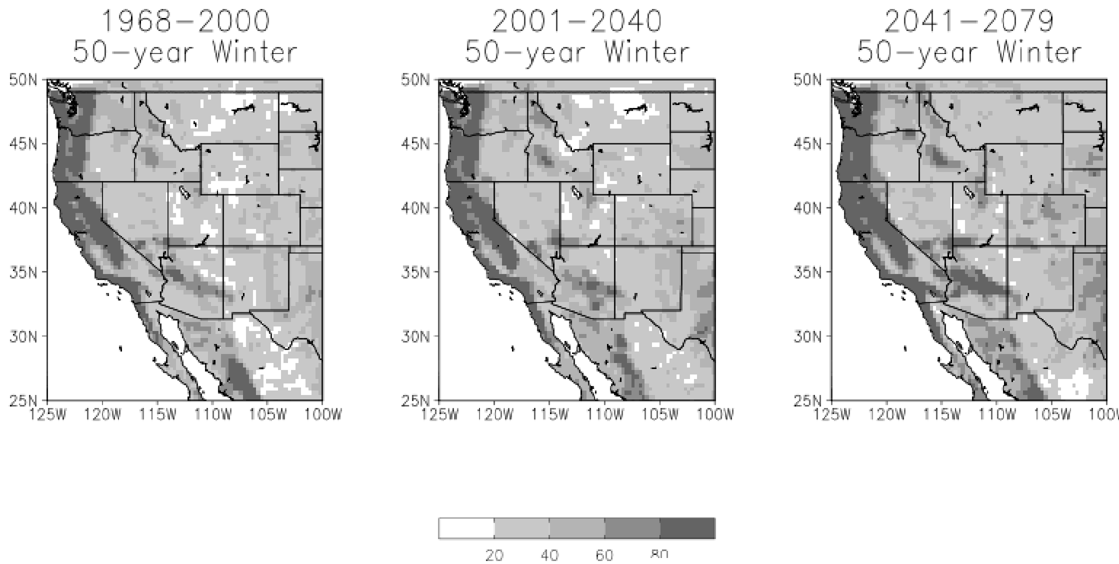




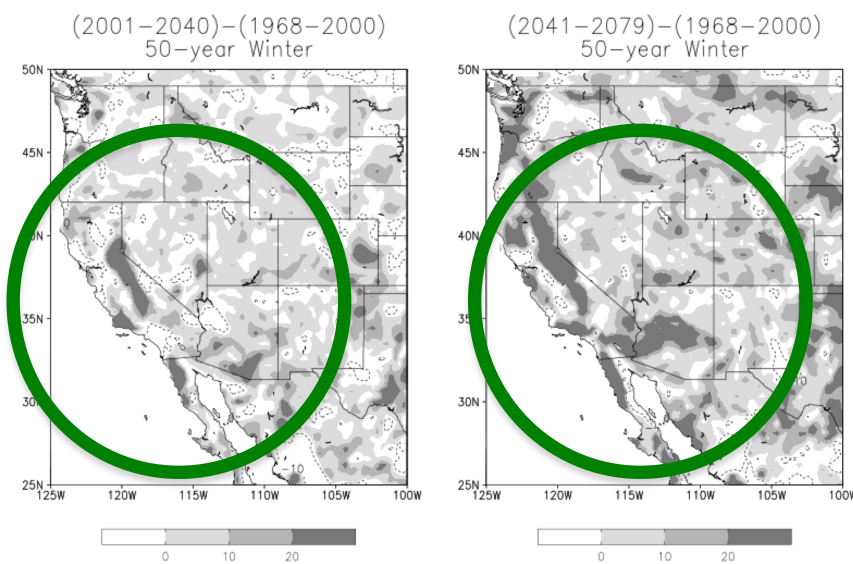


Summer season convective storms are much more difficult to capture, and show decreased skill.

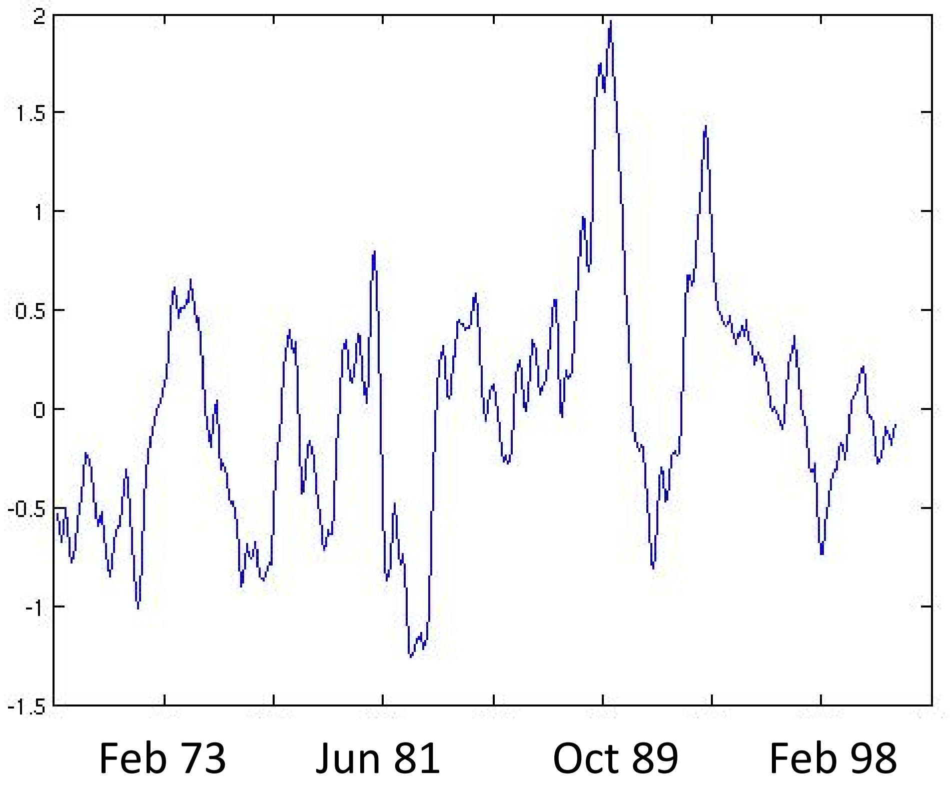
In the future, we see a generalized increase in the intensity of extreme events in the winter season.



Pattern is very heterogeneous, with distinct regions of significant increases.



WRF-HadCM3 SST 3-month anomalies are used to calculate the model ENSO-index (shown for 1969-2000)



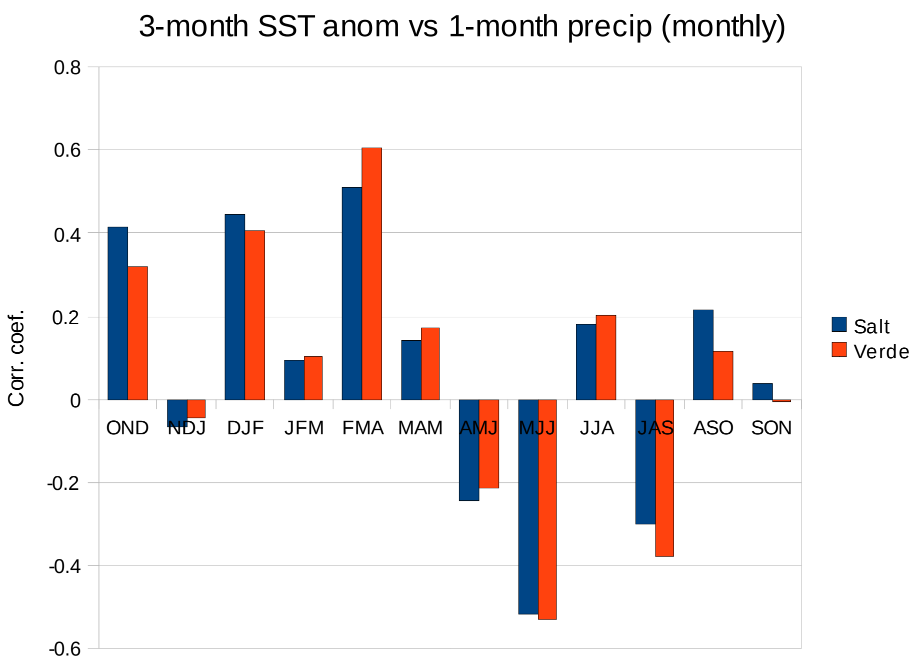
- Monthly SST temperature (HADcm3)
- Regional average
- Monthly climatology (currently 1968-2000)
- Calculate 3-month SST anomaly (DJF, JFM, etc).
- Identify the SST anomalies into El Nino (>0.5° C), La Nina (<0.5° C) and Neutral.

Following Trenberth 1997 and CPC website.

HADcm3 SST 3 month anom (1969-2000), calculation following Trenberth 1997, and CPC website (blue: La Nina; red: El Nino; black: Neutral)

	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND
1969	-0.53255028	-0.60446088	-0.67266359	-0.60467378	-0.50112296	-0.58157471	-0.71391671	-0.78066296	-0.74376823	-0.68736674	-0.56366363	-0.44108978
1970	-0.33766539	-0.22157071	-0.23192214	-0.25247265	-0.31512546	-0.43332988	-0.52485185	-0.59632281	-0.55155804	-0.52699568	-0.64784357	-0.80125241
1971	-0.85344518	-0.77852849	-0.68080538	-0.61583197	-0.59230517	-0.59095903	-0.48481624	-0.39659146	-0.3039269	-0.3836033	-0.5235361	-0.81117489
1972	-0.94258312	-1.01784761	-0.93789953	-0.74441589	-0.4787622	-0.33029516	-0.23935946	-0.16883819	-0.10065038	-0.05865188	-0.00690262	0.03512732
1973	0.0782362	0.14232916	0.15340376	0.31717754	0.48355306	0.58595809	0.61186237	0.55138061	0.45762388	0.50610322	0.5095761	0.54842788
1974	0.54367282	0.65471373	0.57156135	0.52603349	0.436749	0.46077788	0.3407338	0.20822076	0.00304993	-0.06875604	-0.19216671	-0.05924762
1975	0.01200963	0.04492462	-0.18544357	-0.31076061	-0.27983906	-0.30112751	-0.34419207	-0.4557955	-0.48059277	-0.47133519	-0.57912277	-0.73770414
1976	-0.8980234	-0.86528056	-0.77020658	-0.69081304	-0.74684287	-0.76145759	-0.7448627	-0.67122889	-0.75230808	-0.85257951	-0.8736844	-0.8383329
1977	-0.79485816	-0.78230029	-0.79003262	-0.49446768	-0.3280171	-0.18293338	-0.15891882	0.0129584	0.20472924	0.3430798	0.39371216	0.31436688
1978	0.28424222	0.33447441	0.10297631	-0.15217337	-0.4259413	-0.42133399	-0.30756552	-0.18446134	-0.16018061	-0.25691318	-0.39036387	-0.47809154
1979	-0.52510243	-0.65188751	-0.71998287	-0.67269765	-0.61836637	-0.6330102	-0.63498449	-0.4987098	-0.21545545	0.03810131	0.2758457	0.32258095
1980	0.34407965	0.2577427	0.13840348	0.13362429	0.18253807	0.28409701	0.37641631	0.37194564	0.17273814	0.03470804	0.19085259	0.53240115
1981	0.76812722	0.79448379	0.60904268	0.38960573	-0.02435104	-0.44551489	-0.78389278	-0.86803425	-0.78481771	-0.5680675	-0.4810939	-0.5828549
1982	-0.72979813	-0.78654412	-0.74259332	-0.82394085	-0.98083851	-1.22247657	-1.25968459	-1.24671774	-1.16638931	-1.1668962	-1.13820656	-1.2236034
1983	-1.17365657	-1.16916003	-0.98874375	-0.70014962	-0.3366053	-0.10581111	0.08876957	0.23655492	0.31839588	0.2236883	0.07425473	0.05068856
1984	0.08636312	0.26386319	0.26928474	0.44141713	0.45361841	0.43378339	0.42439718	0.39584328	0.40936762	0.43582742	0.5528397	0.58741078
1985	0.49244985	0.33986583	0.1065324	0.00775993	-0.06345298	0.00544786	0.09015577	0.12141996	0.05368231	-0.01335039	-0.11073691	-0.21258389
1986	-0.26171905	-0.23884903	-0.28073632	-0.26819164	-0.19802859	-0.0231413	0.17040611	0.24443936	0.17492844	0.01847314	-0.01583549	0.08648244
1987	0.19852253	0.34676224	0.32927166	0.29366638	0.15189012	0.07598487	0.09729049	0.15649566	0.24038025	0.35577237	0.48317381	0.55314764
1988	0.55528702	0.31594378	-0.01298286	-0.03945284	0.12499789	0.18906439	0.1524597	0.18716078	0.376979	0.50849407	0.69463285	0.84652811
1989	0.97594623	0.96354983	0.74480539	0.69256752	0.77896059	1.11978884	1.51900962	1.7391903	1.74975455	1.63921357	1.60742786	1.75775638
1990	1.89880622	1.96544168	1.75740859	1.60599066	1.512452	1.2776178	0.96370804	0.65060061	0.50051224	0.35678579	0.11363139	-0.08495534
1991	-0.15822424	-0.17736159	-0.21826686	-0.1876964	-0.19725657	-0.34699687	-0.58151175	-0.76609769	-0.81156566	-0.73240612	-0.55757297	-0.37191382
1992	-0.29786358	-0.3301184	-0.4682891	-0.45940663	-0.35972625	-0.23588187	-0.21501946	-0.235976	-0.23093521	-0.05299014	0.23350377	0.50497254
1993	0.67504581	0.67923391	0.62573807	0.65456791	0.77225566	0.92584984	1.15762099	1.37592842	1.43510103	1.32568144	1.10655154	0.880812
1994	0.7087316	0.58470565	0.5068172	0.49165929	0.46473537	0.41886815	0.43089426	0.4710638	0.40237607	0.37896244	0.33035914	0.38261277
1995	0.36577938	0.42141231	0.36685942	0.44648191	0.34586563	0.31184967	0.22248737	0.27007498	0.28135372	0.2532663	0.25802292	0.21463671
1996	0.16413458	0.11638614	0.01799709	-0.00679512	0.01276482	-0.03022304	-0.06787792	-0.1004335	-0.05130739	0.10547171	0.19922869	0.27992173
1997	0.28496469	0.37276172	0.24829171	0.18035986	0.01319246	-0.05180386	-0.11752285	-0.28388233	-0.31537668	-0.31542568	-0.27917463	-0.45784299
1998	-0.63000787	-0.73550456	-0.74259019	-0.59262064	-0.45690424	-0.36759612	-0.34185559	-0.31134729	-0.30603296	-0.20970848	-0.17147042	-0.18409845
1999	-0.25730908	-0.18186878	-0.07705749	0.03101619	0.08239998	0.09541393	0.16476234	0.2066656	0.21682546	0.14375755	0.00111454	-0.04391651
2000	-0.04359227	-0.05731213	-0.20912687	-0.2796418	-0.2342372	-0.17486551	-0.09554802	-0.11588517	-0.13077037	-0.18320135	-0.10988985	-0.07892838

Correlations between WRF-HadCM3 SST anomalies vs. monthly precipitation anomalies in the Salt-Verde show positive winter – negative summer relations (1969-2000)



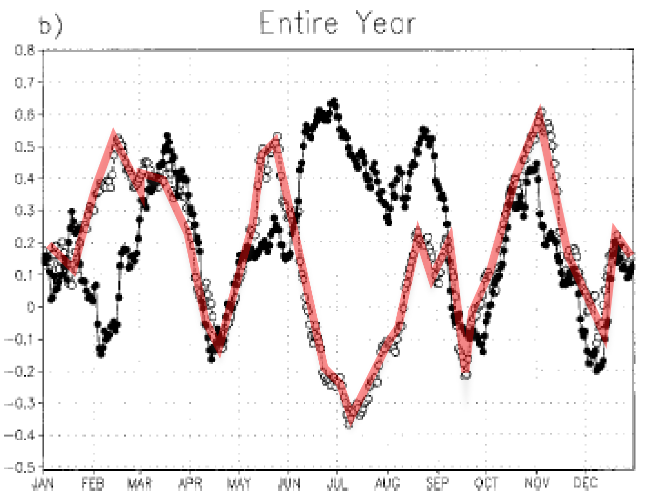
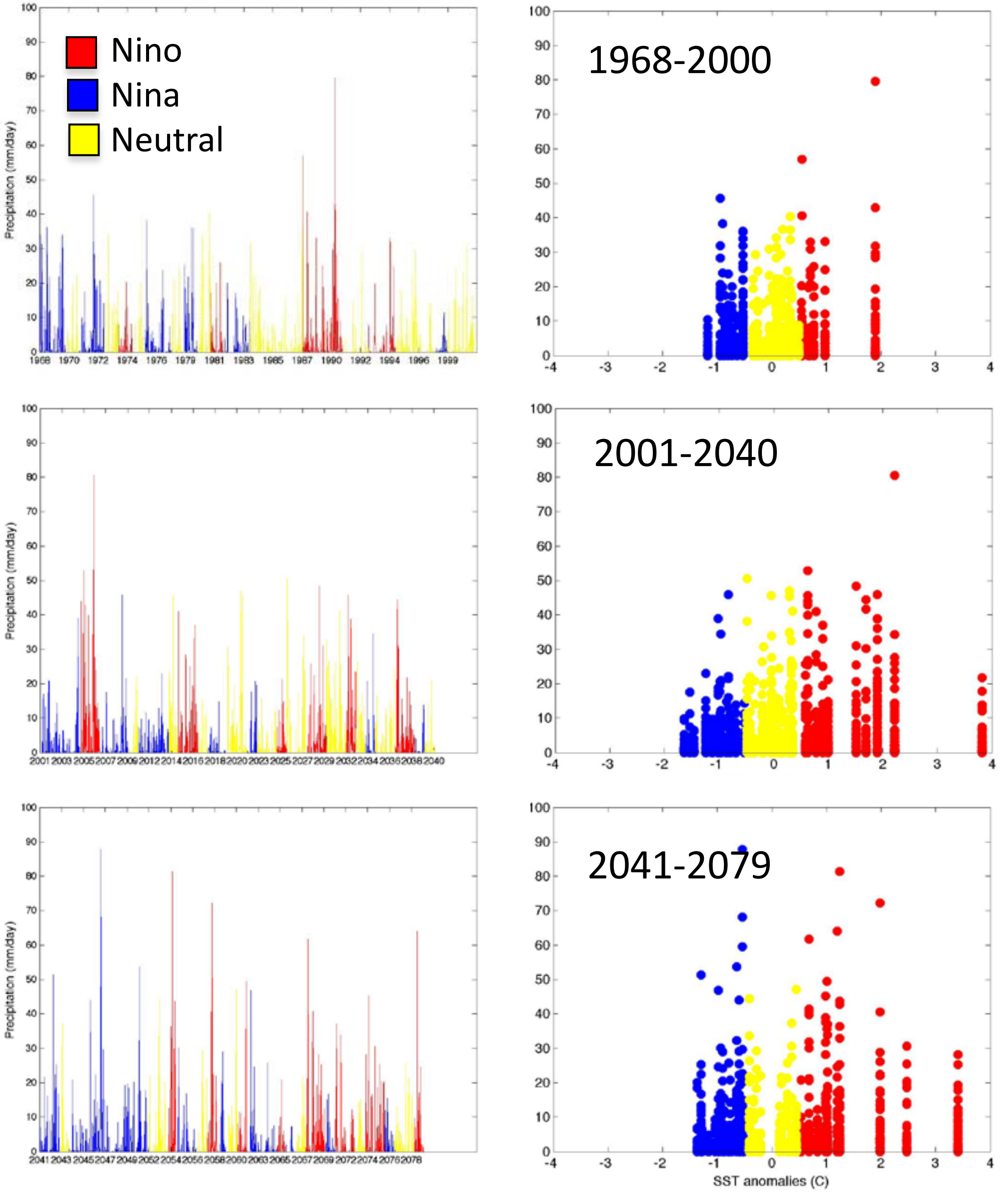


FIG. 10. Correlation of time-coincident P index with regional precipitation indices for the Great Plains (solid line, dark circles) and Southwest (dashed line, open circles) for (a) monsoon season (May through Sep) and (b) the entire year.

This has been shown in the literature using observed data (Castro et al. 2001).

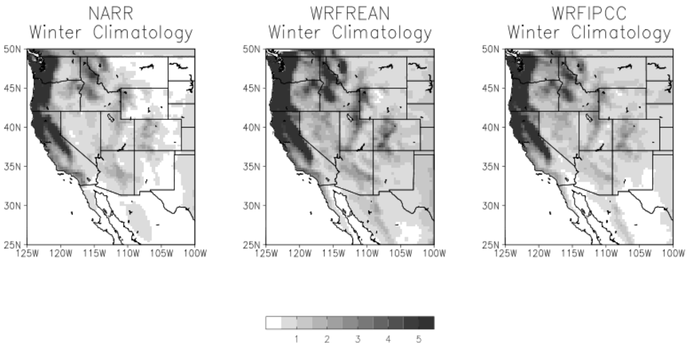
Daily precipitation Salt River Basin shows a future increase in very intense events associated to climate change.



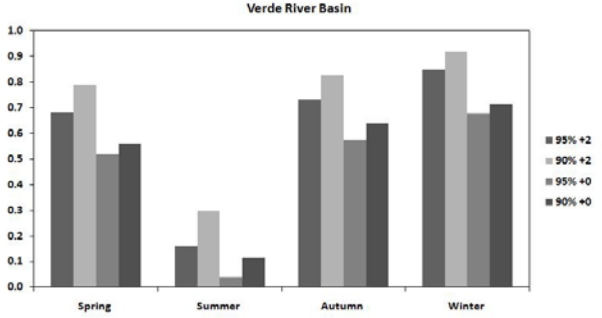
Non-parametric significance test shows that the in the 2001-2079 period, El Nino events are associated with the higher values of rain (99% significant) and La Nina with lower (99%).

In Conclusion - Model Validation

1 – WRF Downscaled HadCM3 data show a realistic climatology when compared to observations. The model is biased high.

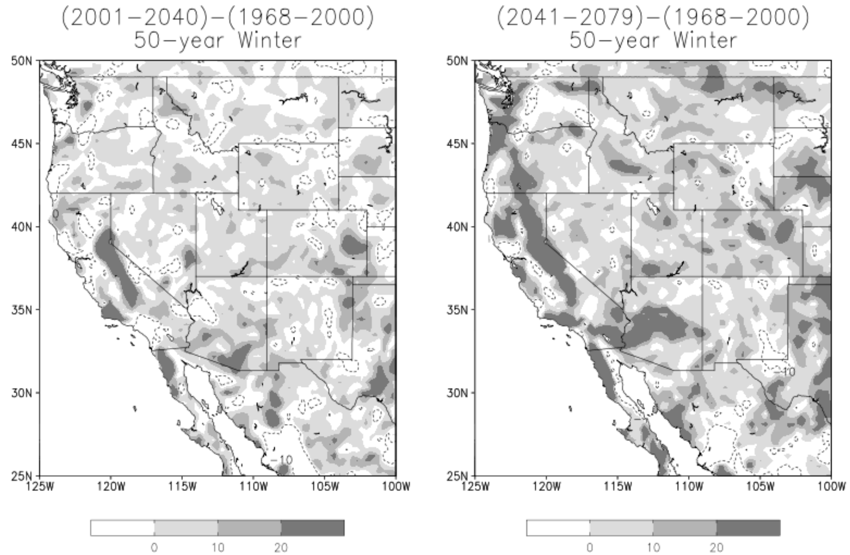


2 – Extreme events for the Salt-Verde basins are captured by the WRF-Reanalysis II simulations for all but the summer season



In Conclusion – Future Projections

3 – We see a generalized increase in extreme events throughout the region, and the patterns are closely tied to topography.



4 – The model shows that extreme events in the future will have a higher probability of occurrence during ENSO years.