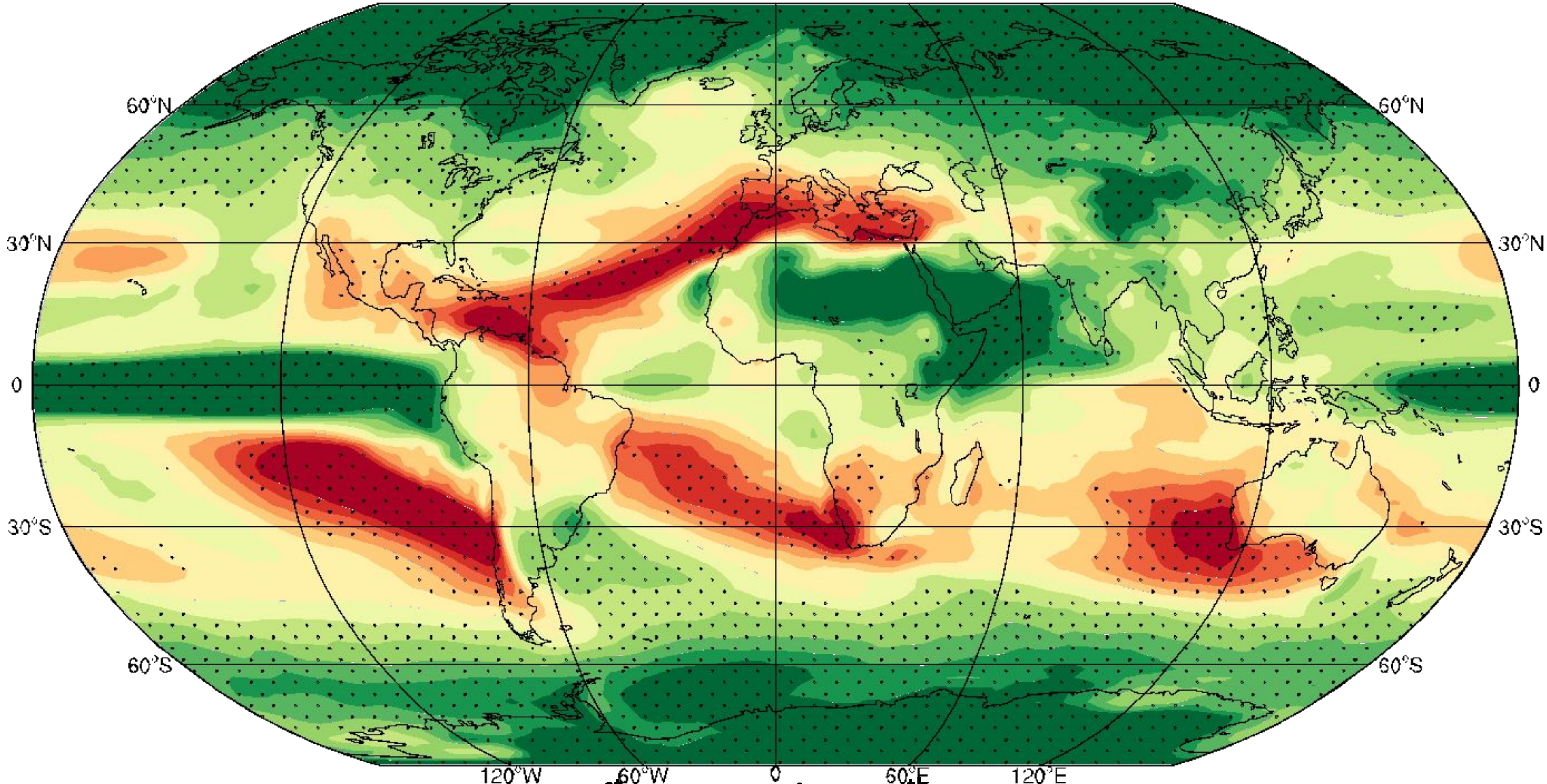
Role of Atmospheric Rivers in Projected West Coast Precipitation Regime Change

Alexander (Sasha) Gershunov, Tamara Shulgina, Rachel Clemesha, Kristen Guirguis, Julie Kalansky, and Marty Ralph

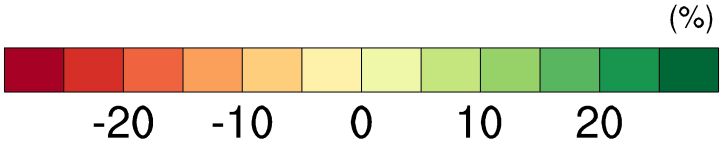
Center for Western Weather and Water Extremes

Precipitation Regime Change



Late 21st century – late 20th century

Annual precipitation change

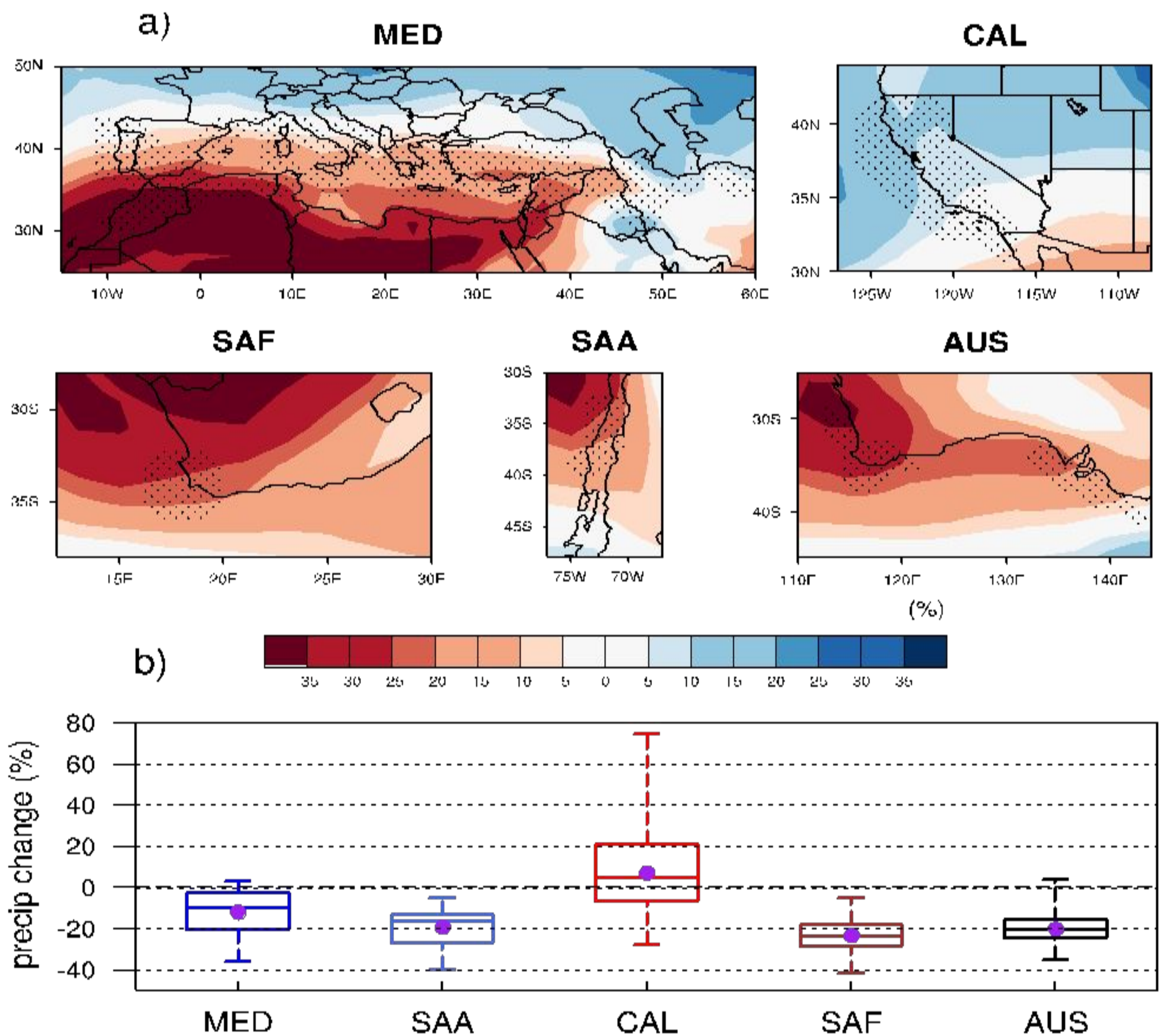


Polade, S.D., D.W. Pierce, D.R. Cayan, A. Gershunov and M.D. Dettinger, 2014: The key role of dry days in changing regional climate and precipitation regimes. *Nature Scientific Reports* 4, 4364; DOI:10.1038/srep04364.

Precipitation Regime Change

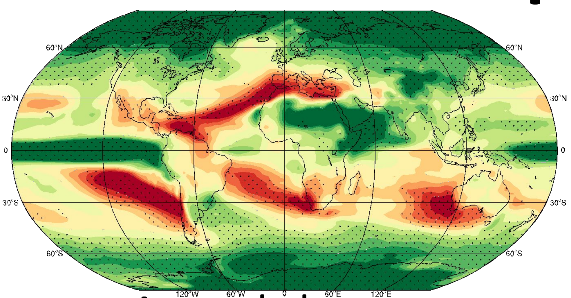
In Mediterranean Climate Regions

WINTER
DJF



Polade, S.D., A. Gershunov, D. Cayan, M.D. Dettinger and D.W. Pierce, 2017: Precipitation in a warming world: Assessing projected hydro-climate of California and other Mediterranean climate regions. *Nature Scientific Reports*, 7: *10783*, DOI:10.1038/s41598-017-11285-y

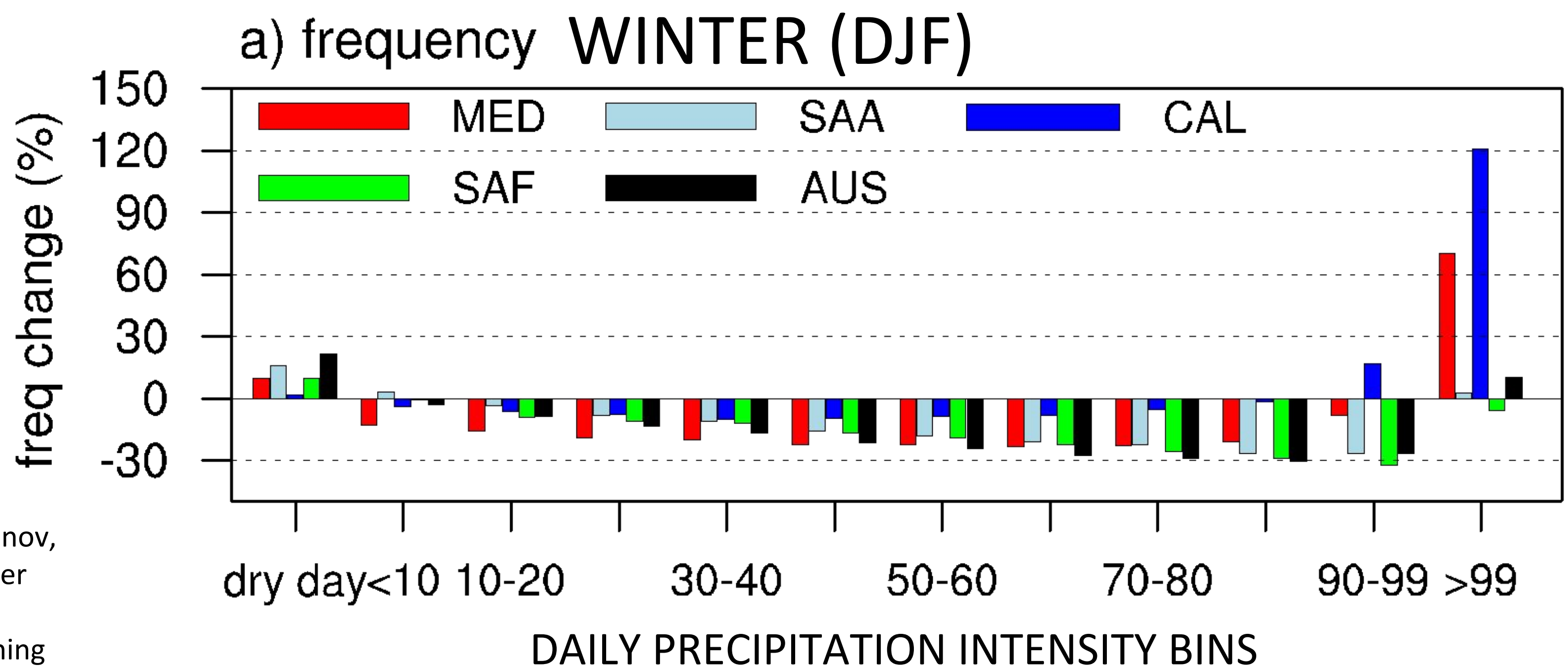
Precipitation Regime Change



Annual changes

In Mediterranean Climate Regions

Late 21st century – late 20th century by Mediterranean climate region

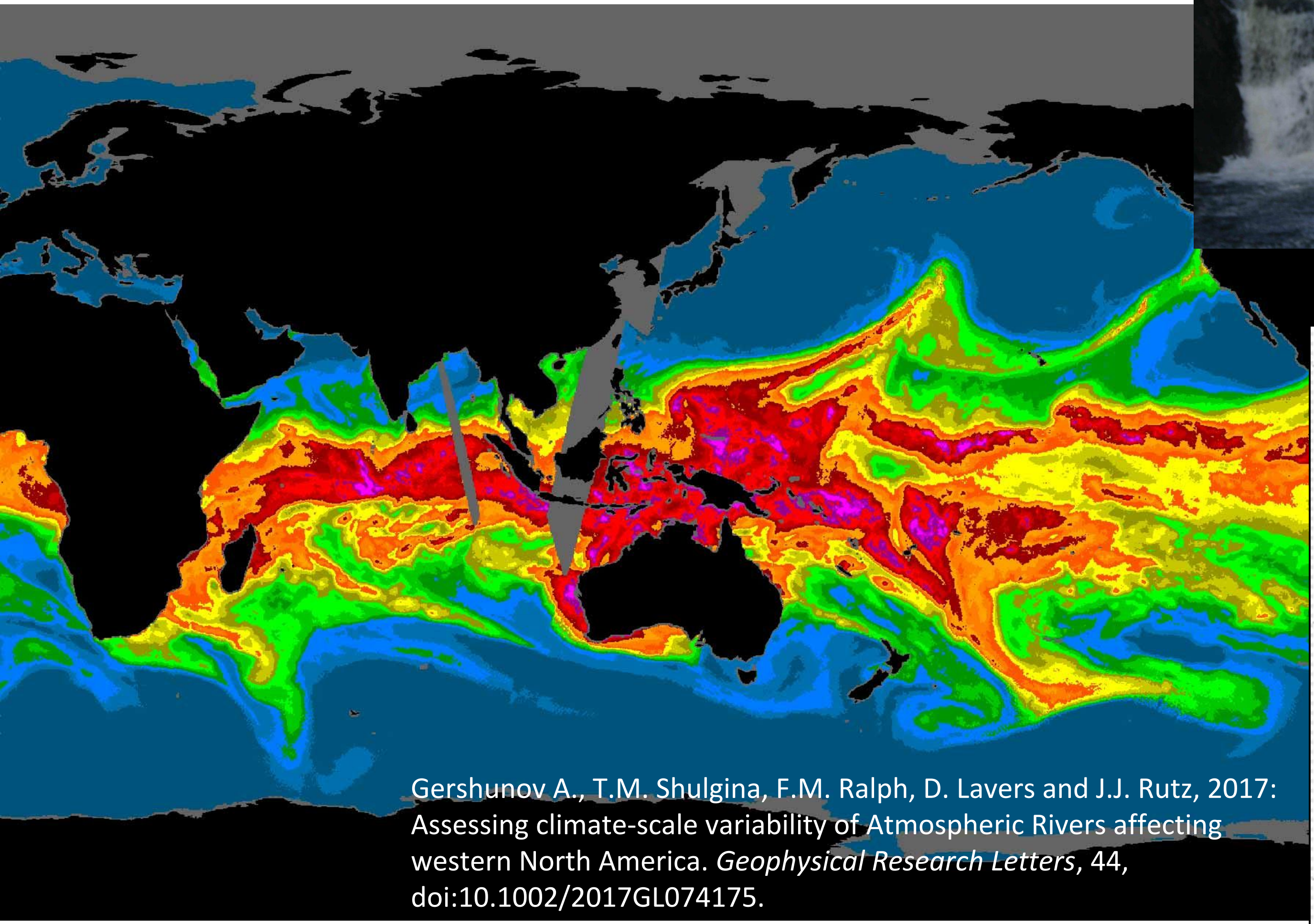


Precipitation distribution shifting towards more intense events

Polade, S.D., A. Gershunov, D. Cayan, M.D. Dettinger and D.W. Pierce, 2017: Precipitation in a warming world: Assessing projected hydro-climate of California and other Mediterranean climate regions. *Nature Scientific Reports*, 7: *10783*, DOI:10.1038/s41598-017-1 1285-y

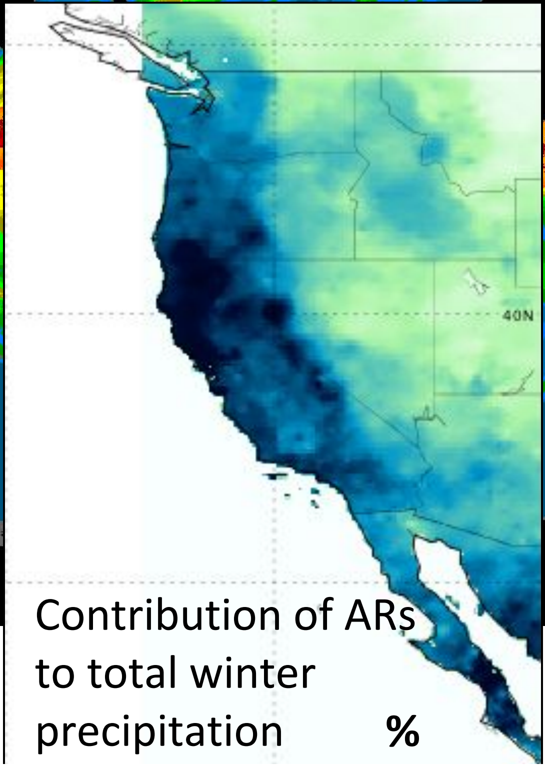
Atmospheric Rivers

With Tamara Shulgina

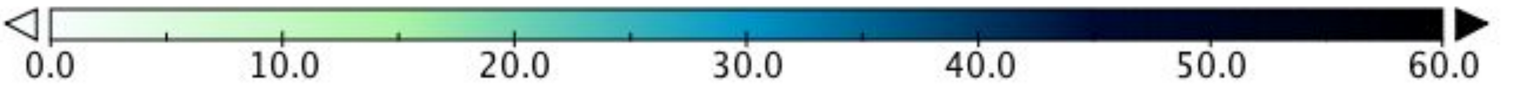


Gershunov A., T.M. Shulgina, F.M. Ralph, D. Lavers and J.J. Rutz, 2017: Assessing climate-scale variability of Atmospheric Rivers affecting western North America. *Geophysical Research Letters*, 44, doi:10.1002/2017GL074175.

ATMOSPHERIC WATER VAPOR



Contribution of ARs to total winter precipitation %



CMIP5 GCM AR statistics

ARDT: [Gershunov et al. 2017] adjusted for daily data
Time period: July 1950- June 2000 (historical), July 2050 - June 2100 (RCP8.5)
Spatial domain: North American West coast [20-60^o N]

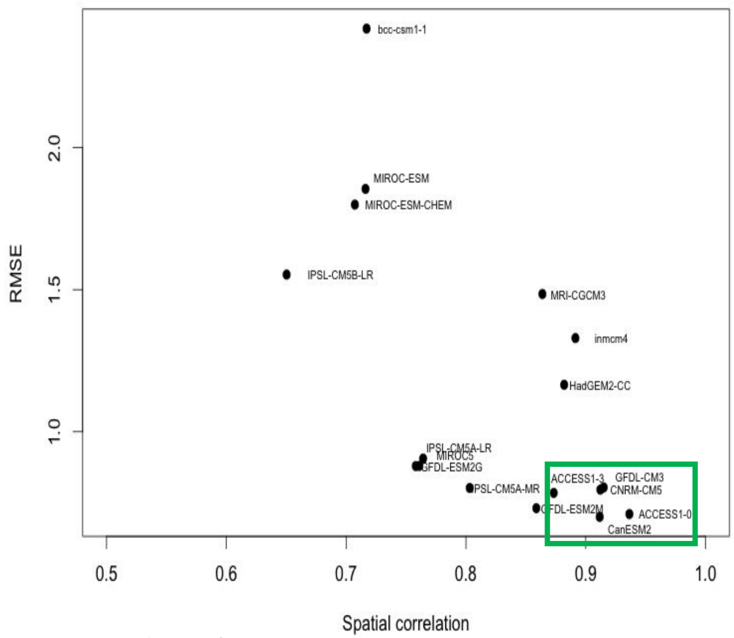
Center for Western Weather and Water Extremes

	Model	Latitude size	Longitude size	Frequency of AR events per year		Change (%) in AR event frequency	Frequency of AR days per year		Change (%) in AR day frequency	Duration of AR events (hours)		Change (%) in AR event duration	Average IVT per AR event		Change (%) in average IVT per AR event	Average maximum IVT per AR event		Change (I) in average maximum IVT per AR event
				1951-2000	2051-2100		1951-2000	2051-2100		1951-2000	2051-2100		1951-2000	2051-2100		1951-2000	2051-2100	
1	**ACCESS1.0*** (CalWat)	1.25	1.875	39	50	26 %	78	118	51 %	48	57	19 %	337	354	5 %	365	400	10 %
2	**ACCESS1.3***	1.25	1.875	41	51	20 %	82	126	53 %	48	60	23 %	339	362	7 %	370	411	11 %
3	**BCC-CSM1.1**	2.7905	2.8125	63	68	8 %	164	206	26 %	62	73	17 %	382	402	5 %	444	485	9 %
4	**CanESM2** (CalWat)	2.7905	2.8125	44	54	23 %	84	131	55 %	46	58	25 %	366	387	6 %	402	450	12 %
5	**CNRM-CM5** (CalWat)	1.4007	1.406	52	62	20 %	111	159	43 %	51	62	20 %	374	392	5 %	418	461	10 %
6	**GFDL-CM3*** (CalWat)	2	2.5	57	67	19 %	123	182	48 %	52	65	24 %	362	387	7 %	404	459	14 %
7	**GFDL-ESM2G***	2.0224	2.5	47	62	30 %	97	148	53 %	51	57	13 %	357	372	4 %	394	425	8 %
8	**GFDL-ESM2M*** (till 1995)	2.0224	2.5	50	63	31 %	103	146	42 %	49	56	14 %	358	376	5 %	395	428	8 %
9	**HadGEM2-CC** (CalWat)	1.25	1.875	35	50	35 %	68	125	84 %	47	63	33 %	351	374	7 %	383	430	12 %
10	**Inmcm4**	1.5	2	54	57	4 %	140	168	20 %	63	72	14 %	371	378	2 %	424	445	5 %
11	**IPSL-CM5A-LR ***	1.8947	3.75	37	45	22 %	84	132	58 %	55	71	29 %	365	389	7 %	408	464	14 %
12	**IPSL-CM5A-MR***	1.2676	2.5	43	56	31 %	95	150	59 %	54	65	22 %	368	385	5 %	415	457	10 %
13	**MIROC5*** (CalWat)	1.4007	1.40625	44	58	33 %	93	137	47 %	51	57	12 %	356	366	3 %	398	419	5 %
14	**MIROC-ESM***	2.7905	2.8125	53	65	21 %	123	182	48 %	56	68	21 %	355	375	6 %	395	431	9 %
15	**MIROC-ESM-CHEM***	2.7905	2.8125	52	62	15 %	122	185	51 %	56	72	30 %	357	370	4 %	394	429	9 %
16	**MRI-CGCM3***	1.12149	1.125	67	74	11 %	166	210	27 %	60	68	15 %	378	389	3 %	435	463	6 %
17	**NCEP 4 levels**	2.5	2.5	50	-	-	95	-	-	45	-	-	343	-	-	372	-	-

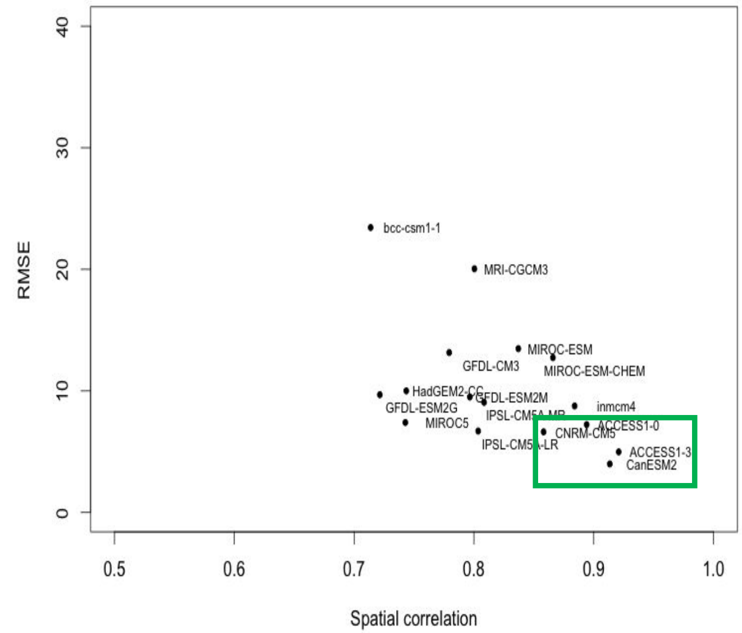
***** - The VT data at 1000 Mb were replaced by near-surface VT data
CalWat – GCM selected for California Water Resources Planning

Assessment of GCM realism in simulating AR landfalls and their contribution to total precipitation (LOCA downscaled)

Number of AR days by month and landfall latitude

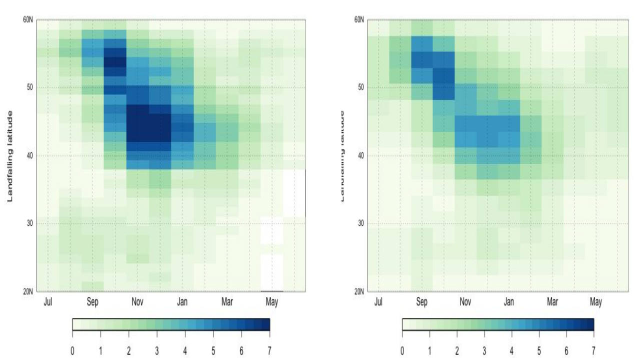


Contribution of AR precip to annual total precip



Number of AR days, 1950-2000

CNRM-CM5 NCEP/NCAR



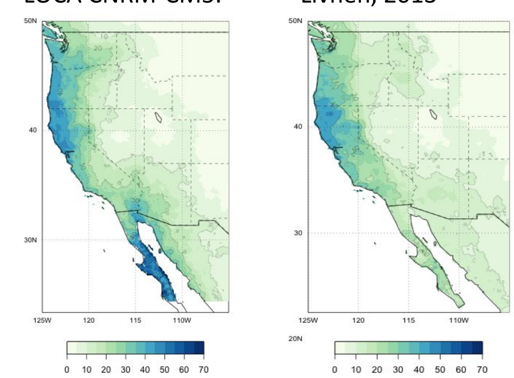
"Green box" GCMs:

1. ACCESS1-0* (CalWat)
2. ACCESS1-3*
3. CNRM-CM5 (CalWat)
4. CanESM2 (CalWat)
5. GFDL-CM3* (CalWat)

*- the data at 1000Mb are replaced by the data near the surface (red dots)
CalWat – GCM selected for California Water Resources Planning

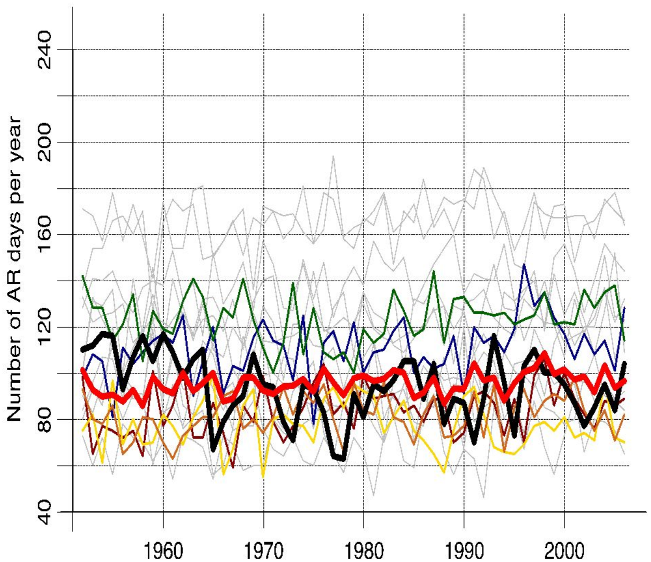
AR PR contribution (%), 1950-2000

LOCA CNRM-CM5. Livneh, 2013

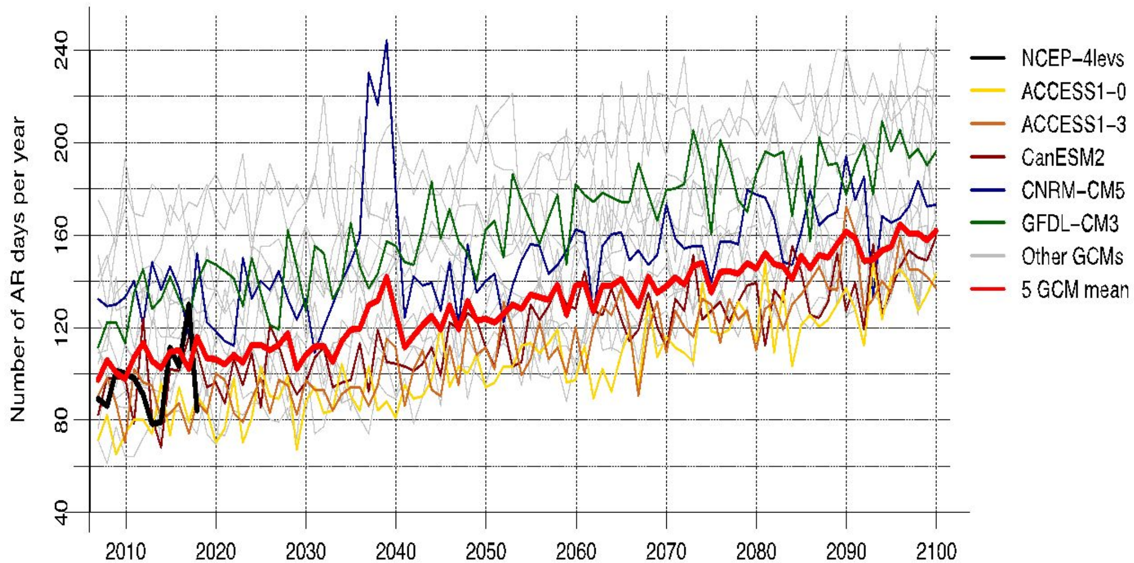


ARs land-falling at the North American West Coast (20-60°N)

Historical: 1950 - 2005

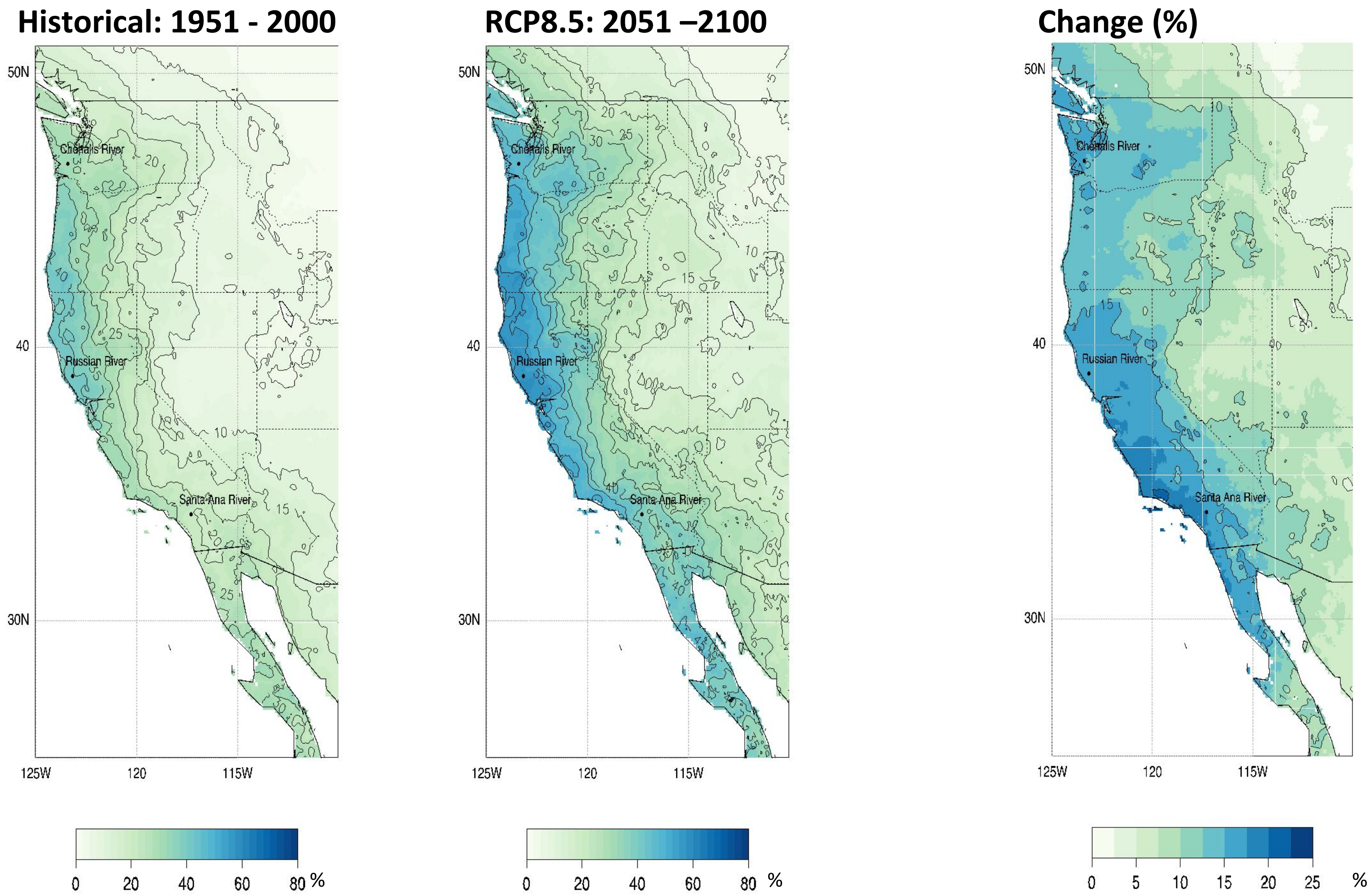


RCP8.5: 2006 –2100



The annual number of days associated with ARs at the North American West Coast [20-60N] during (left panel) historical (1951-2005) and (right panel) projected (2007-2100) time periods. Year is July – June. Top 5 ranked GCMs are presented in color, other GCMs are in gray. Thick red curve represents the mean of the top 5 models. Thick black curve shows annual AR days based on NCEP/NCAR Reanalysis data.

AR precipitation contribution to total precipitation (5 GCM ensemble average)

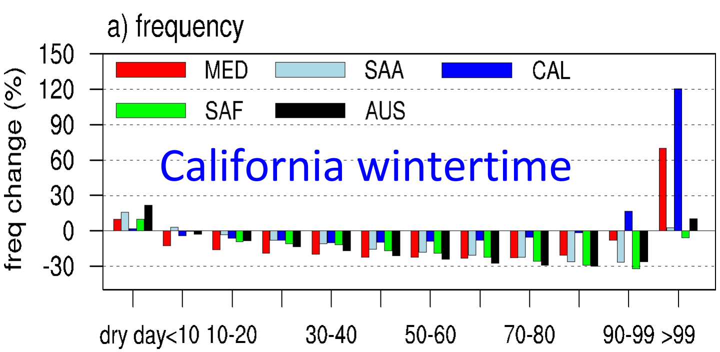


LOCA-downscaled precipitation (Pierce et al. 2015)

Change (%) in precipitation frequency by intensity bins (LOCA, 5 GCM average):

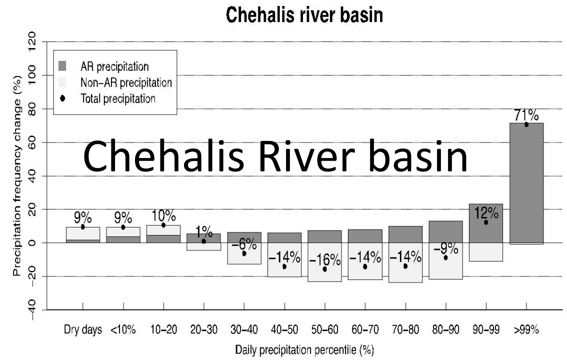
EXTREME PRECIP INCREASING DUE TO ARs

(PRECIP PDF SHIFTING TO MORE EXTREME VALUES DUE TO ARs)

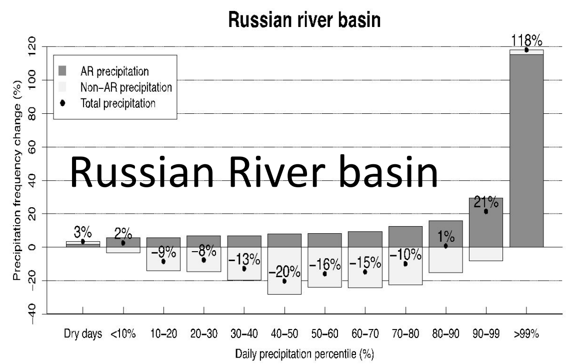


Polade et al. (2017)

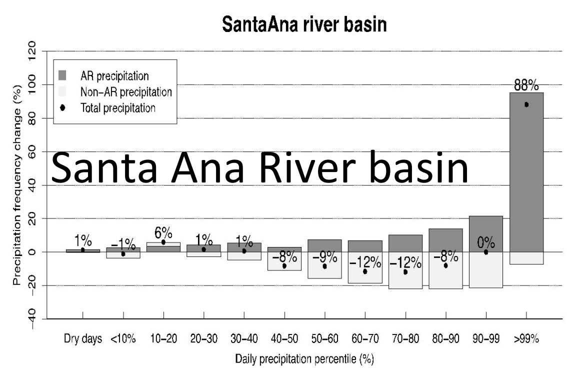
% change in precipitation frequency by intensity bin



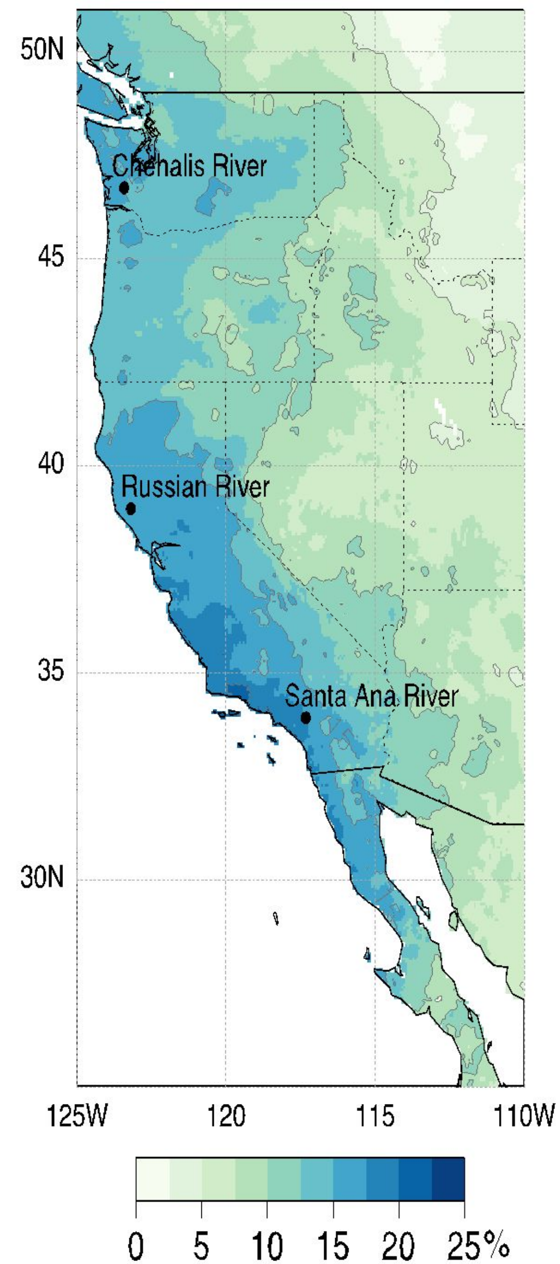
HISTORICAL INTENSITY BINS



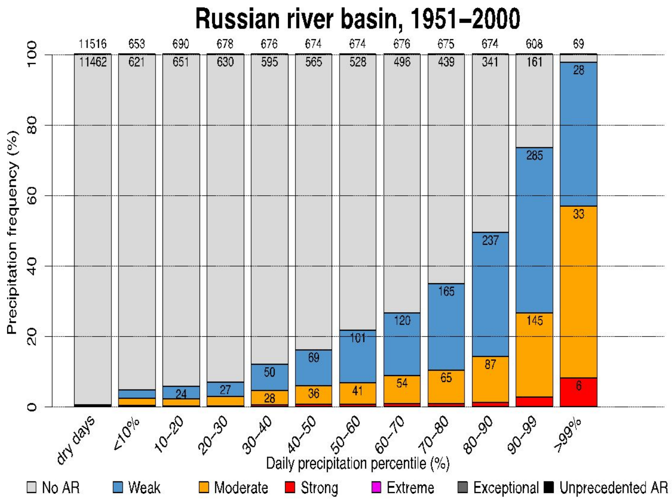
HISTORICAL INTENSITY BINS

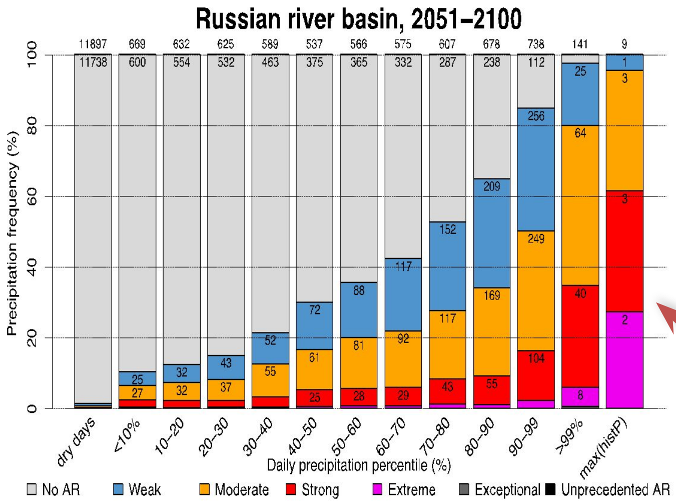


% change in the contribution of ARs to total precipitation

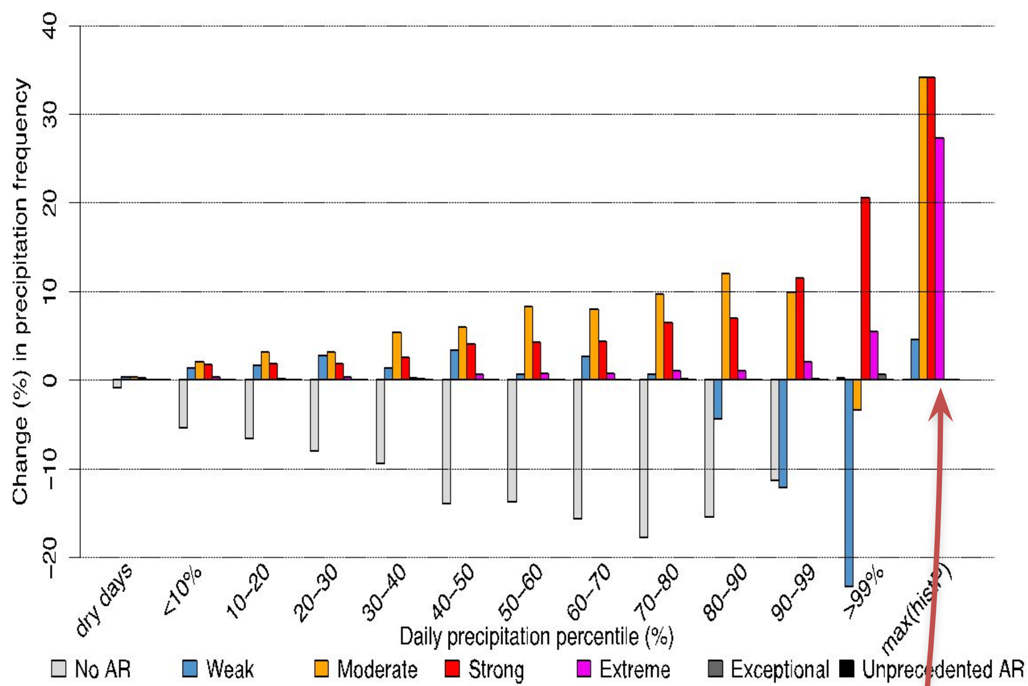


AR contributions to precipitation intensity bins by AR category in the Russian River Basin
(5 GCM average)



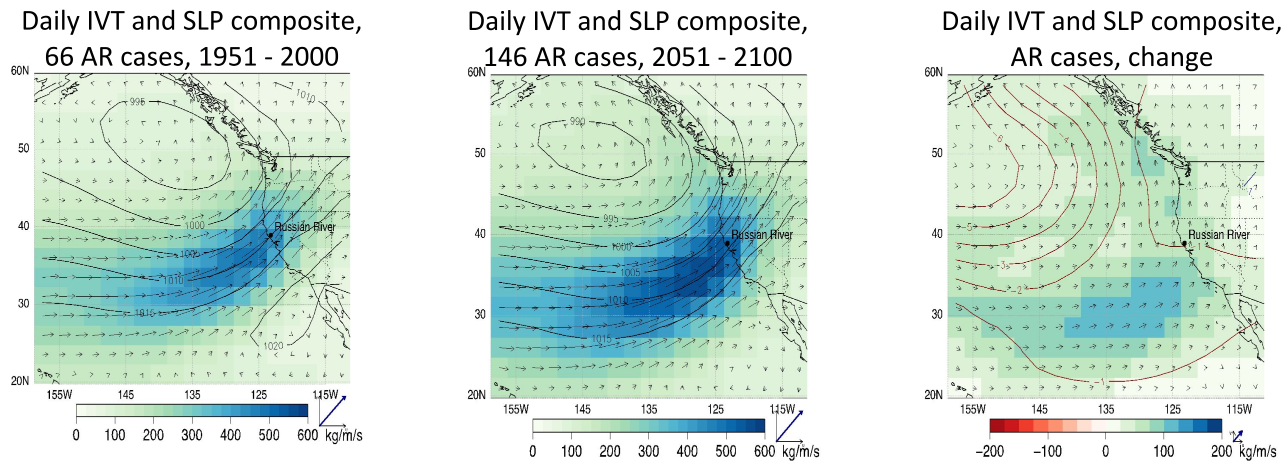


Russian river basin, change in precipitation frequency

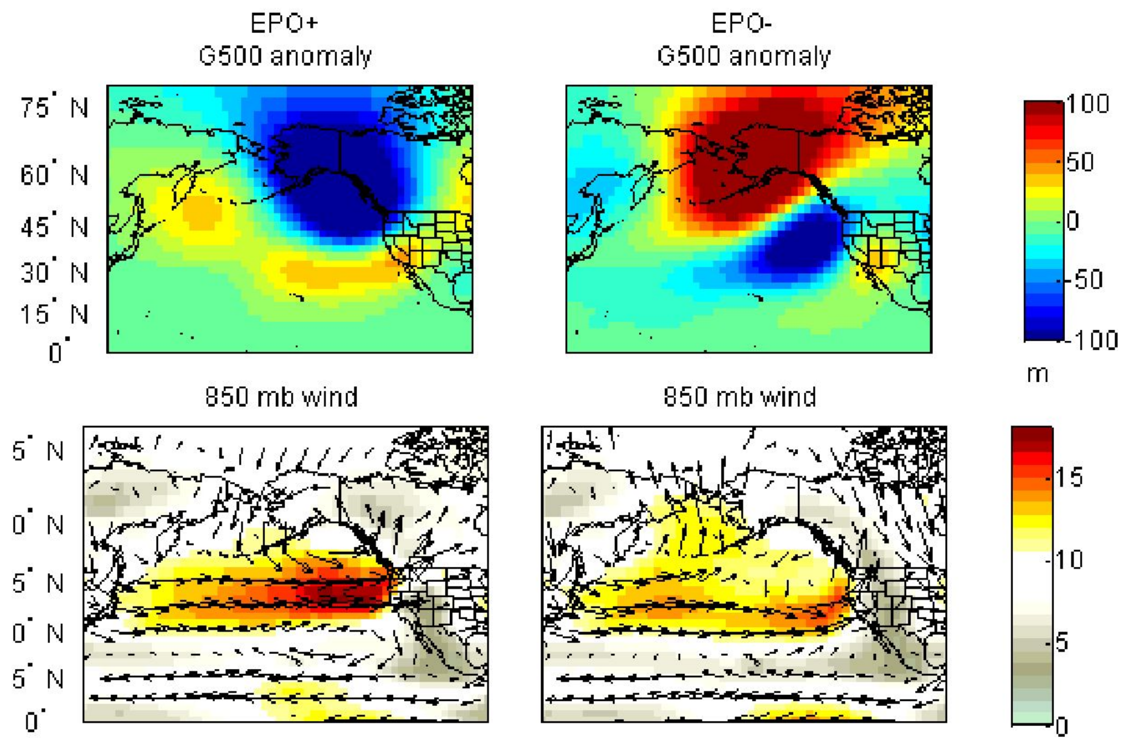


Unprecedented precipitation events

Some of the change is of dynamical origin → precipitation pattern changes



Russian River Basin-centered analysis

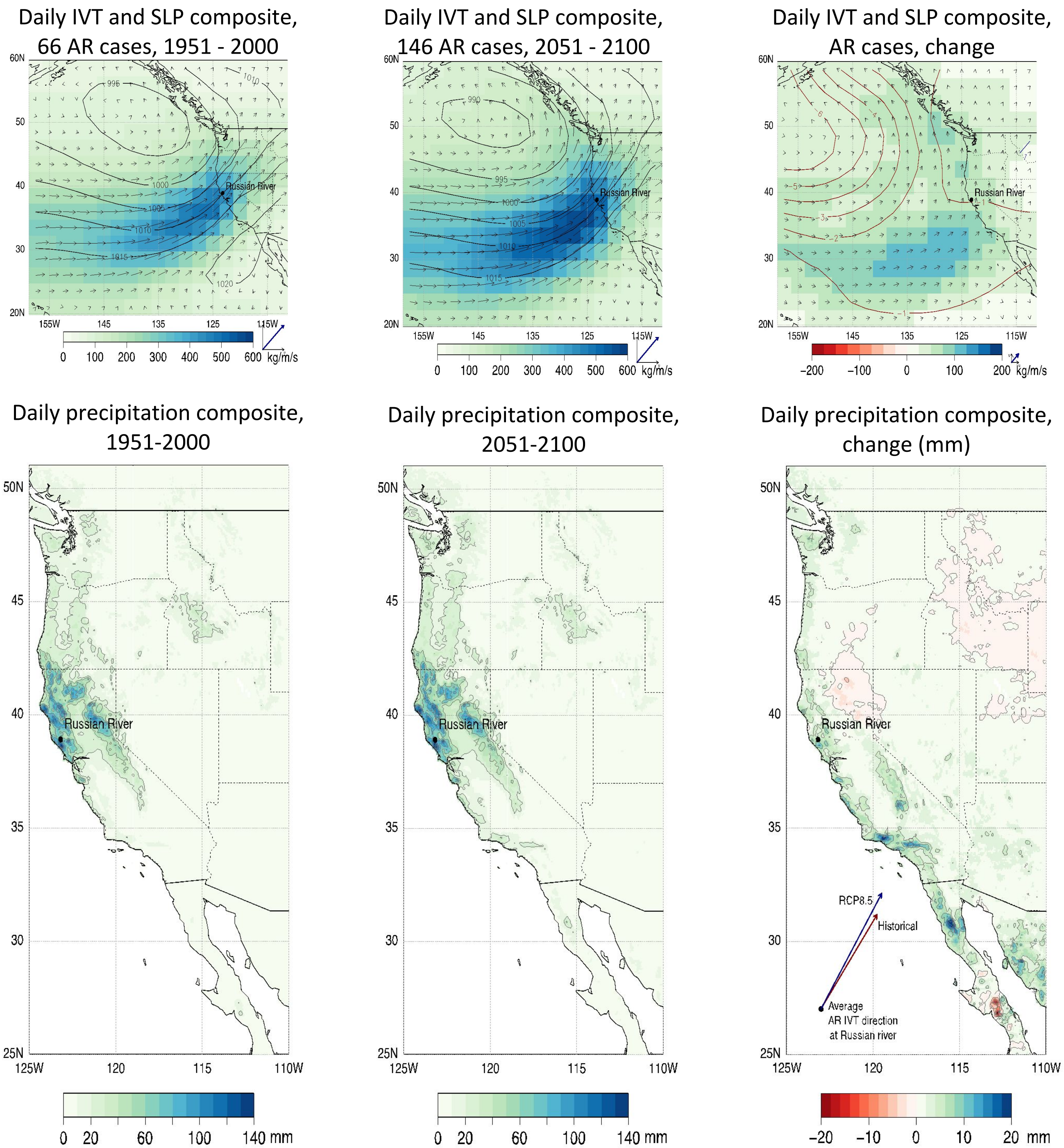


Guirguis et al., in press

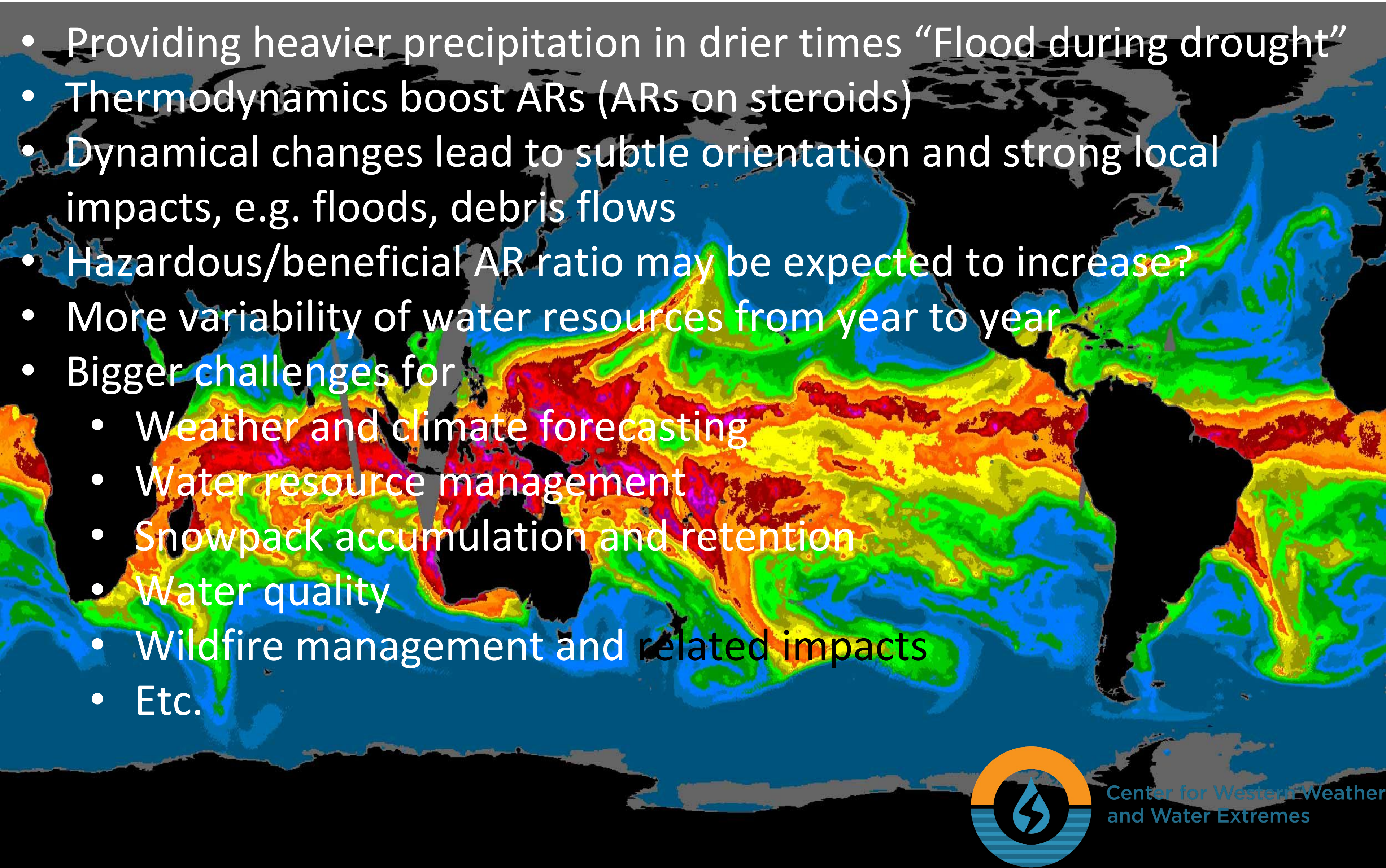
Some of the change is of dynamical origin → precipitation pattern changes

Russian River Basin-centered analysis

(LOCA)



Atmospheric Rivers are poised to play a more important role in a warmer future



- Providing heavier precipitation in drier times “Flood during drought”
- Thermodynamics boost ARs (ARs on steroids)
- Dynamical changes lead to subtle orientation and strong local impacts, e.g. floods, debris flows
- Hazardous/beneficial AR ratio may be expected to increase?
- More variability of water resources from year to year
- Bigger challenges for
  - Weather and climate forecasting
  - Water resource management
  - Snowpack accumulation and retention
  - Water quality
  - Wildfire management and related impacts
  - Etc.

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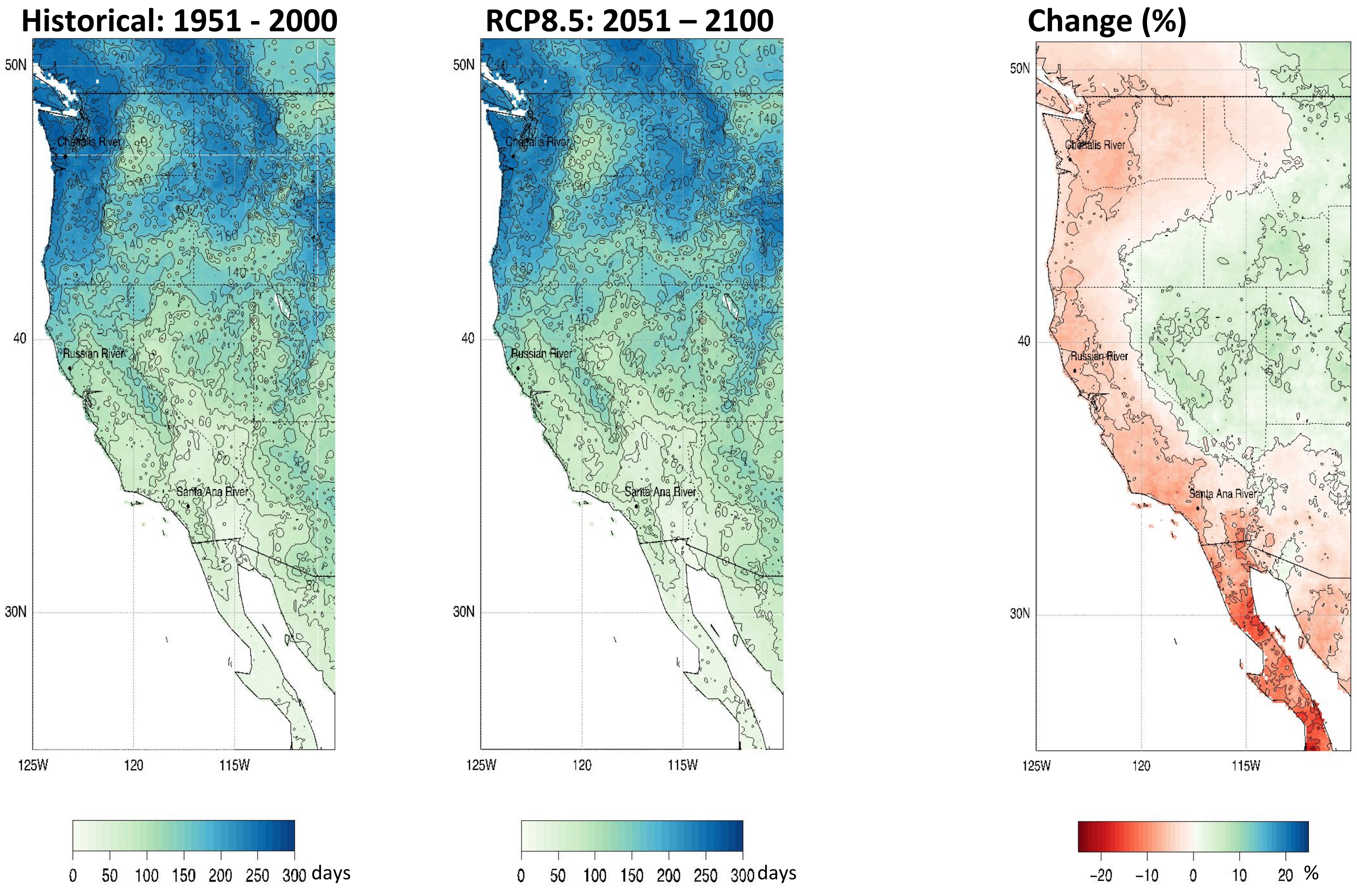
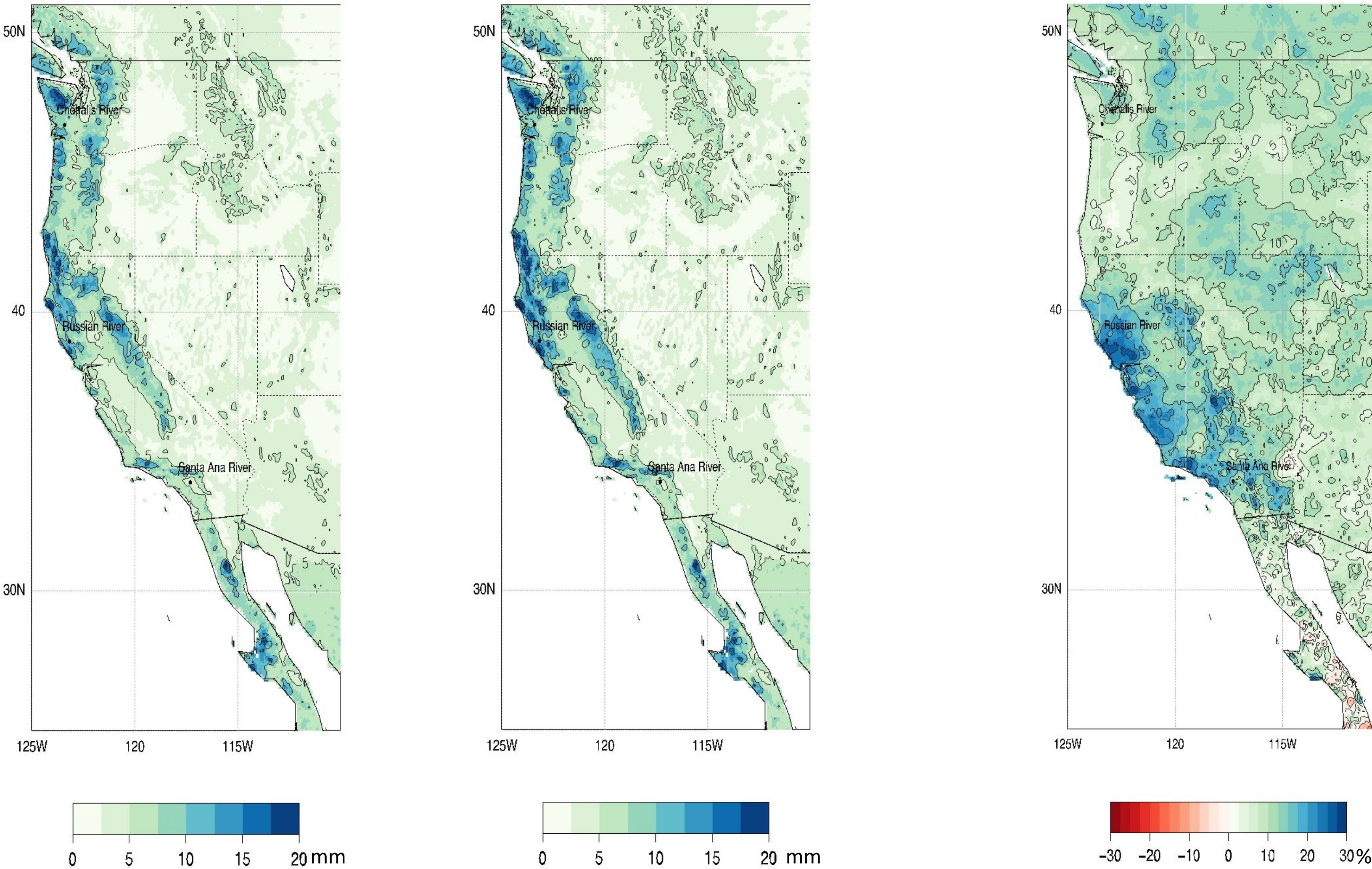
5 GCM average: Annual mean precipitation frequency



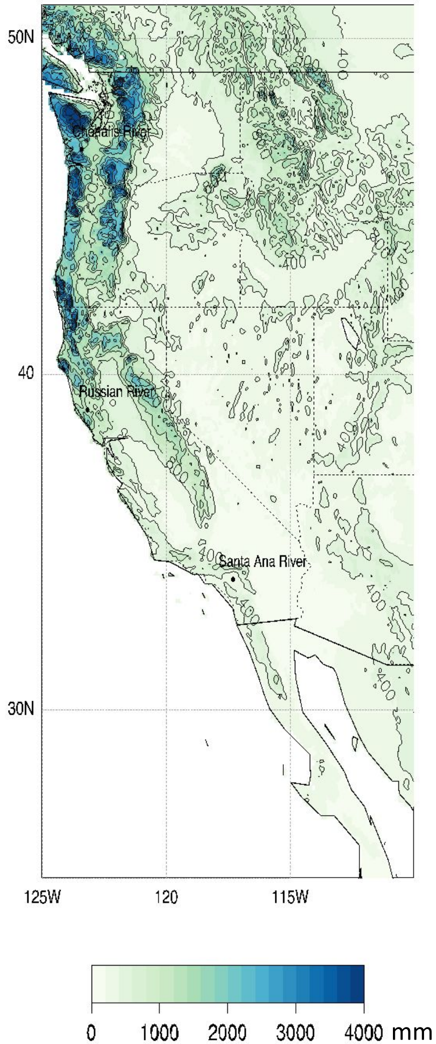
5 GCM average: Daily average precipitation intensity

Historical: 1951 - 2050　**RCP8.5: 2051 –2100**　**Change (%)**

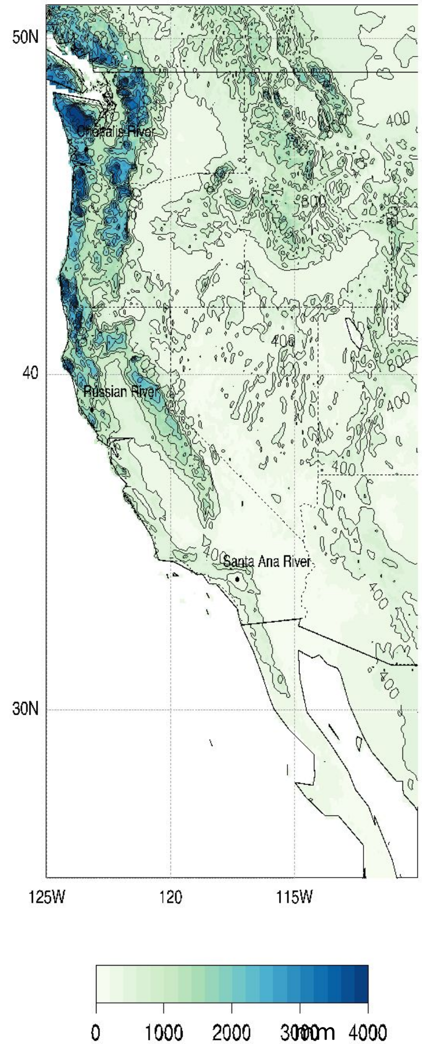


5 GCM average: Annual total precipitation

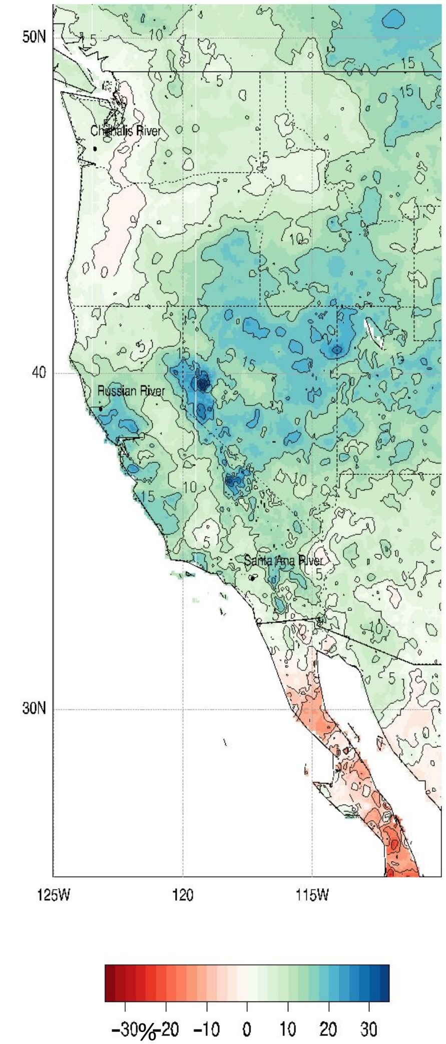
Historical: 1951 - 2000



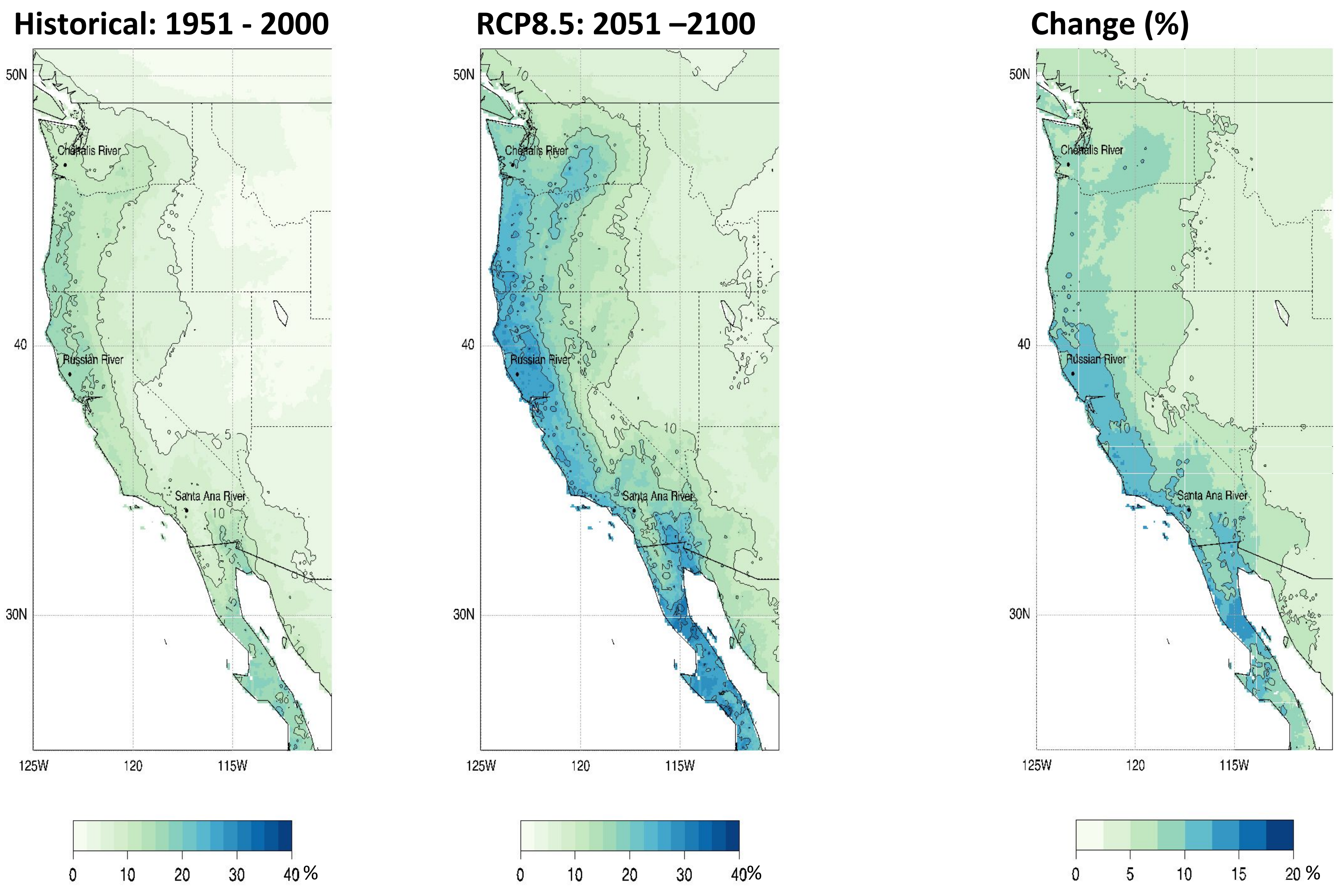
RCP8.5: 2051 –2100



Change (%)



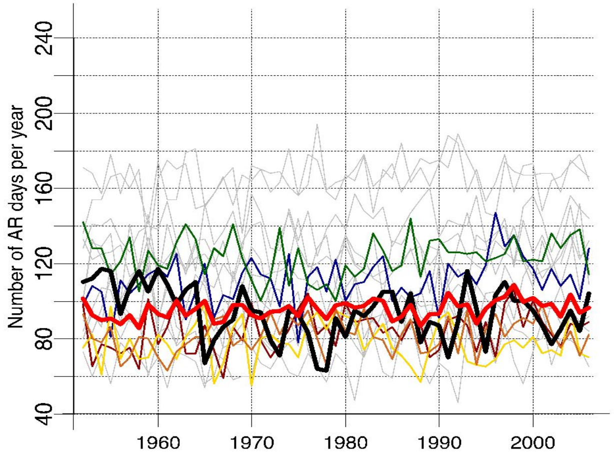
5 GCM average: AR Precip frequency contribution to all Precip frequency



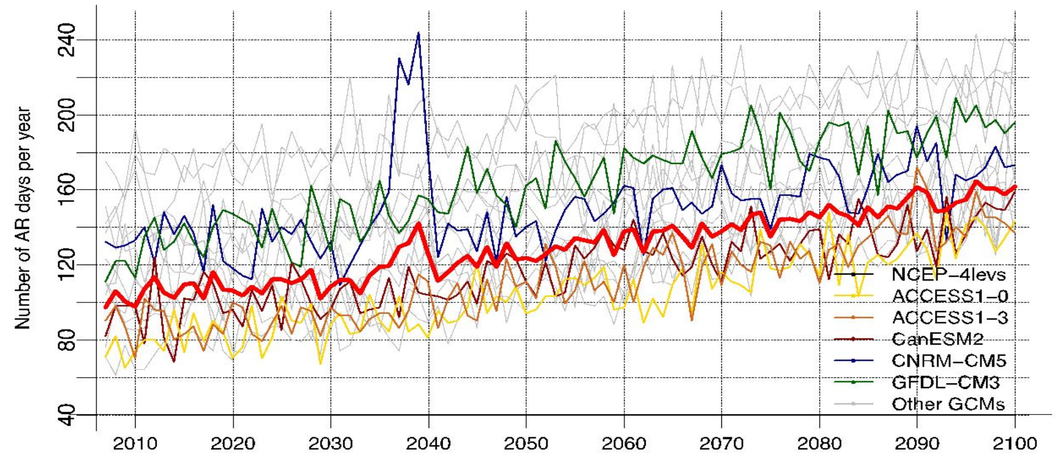
ARs land-falling at the North American West Coast (20-60°N)

Historical: 1950 - 2005 | **RCP8.5: 2006 –2100**

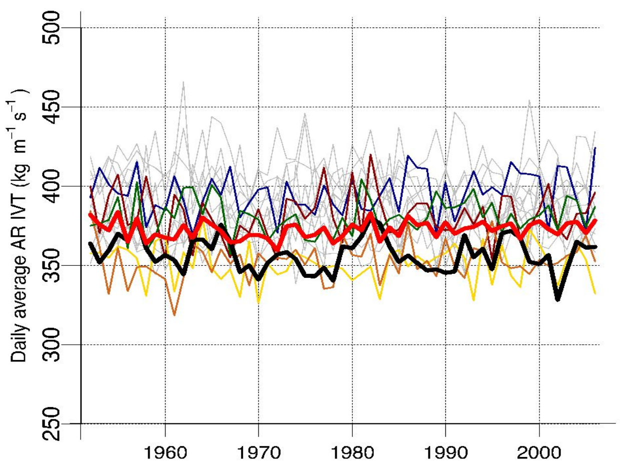
(a) Annual number of AR days



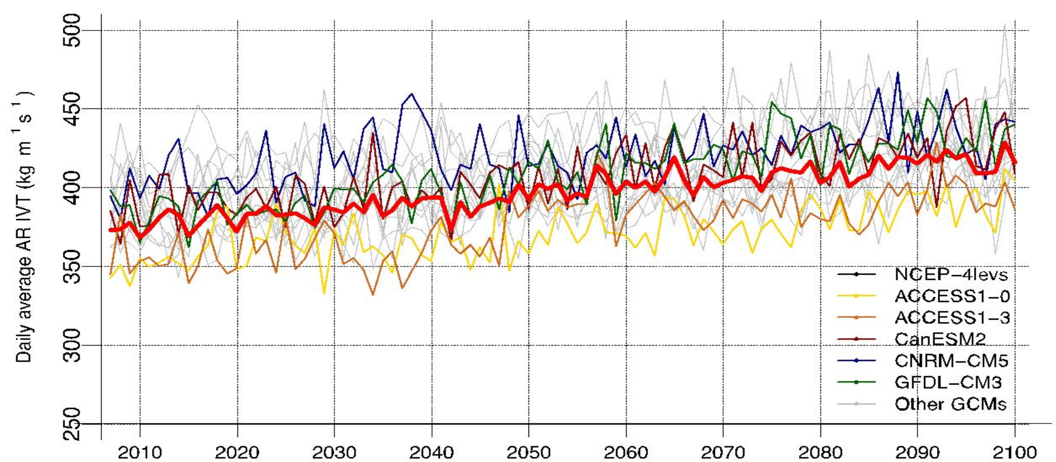
(b) Annual number of AR days



(c) AR day IVT intensity



(d) AR day IVT intensity

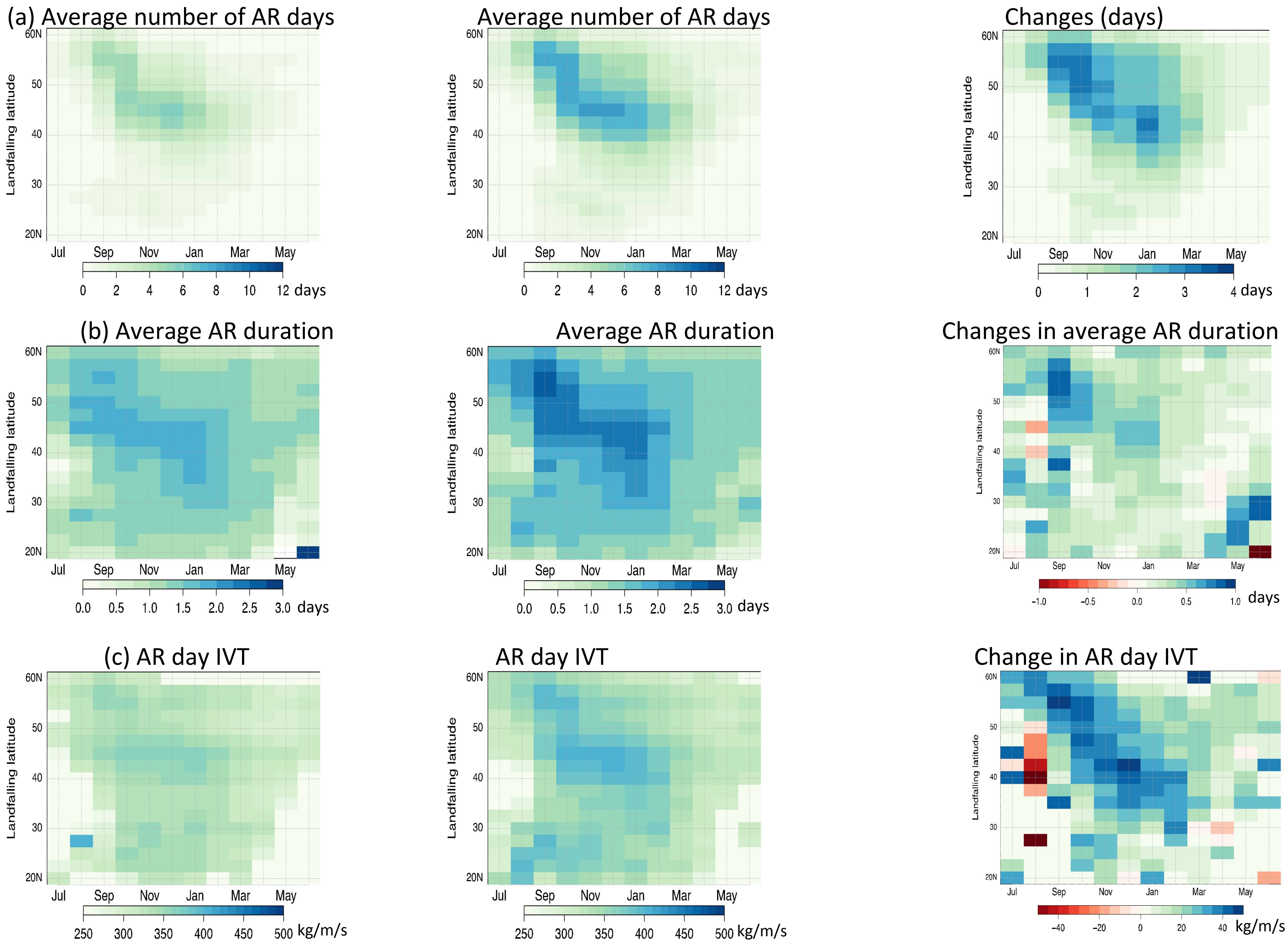


The annual number of days associated with ARs (a-b) and the average IVT during those days (c-d) at the North American West Coast [20-60N] during (left panel) historical (1951-2005) and (right panel) projected (2007-2100) time periods. Year is July – June. Top 5 ranked GCMs are presented in color, other GCMs are in gray. Thick red curve represents the mean of the top 5 models. Thick black curve shows annual AR counts (a) and daily AR IVT (c) based on NCEP/NCAR Reanalysis data.

Landfall climatology, 5 GCM average

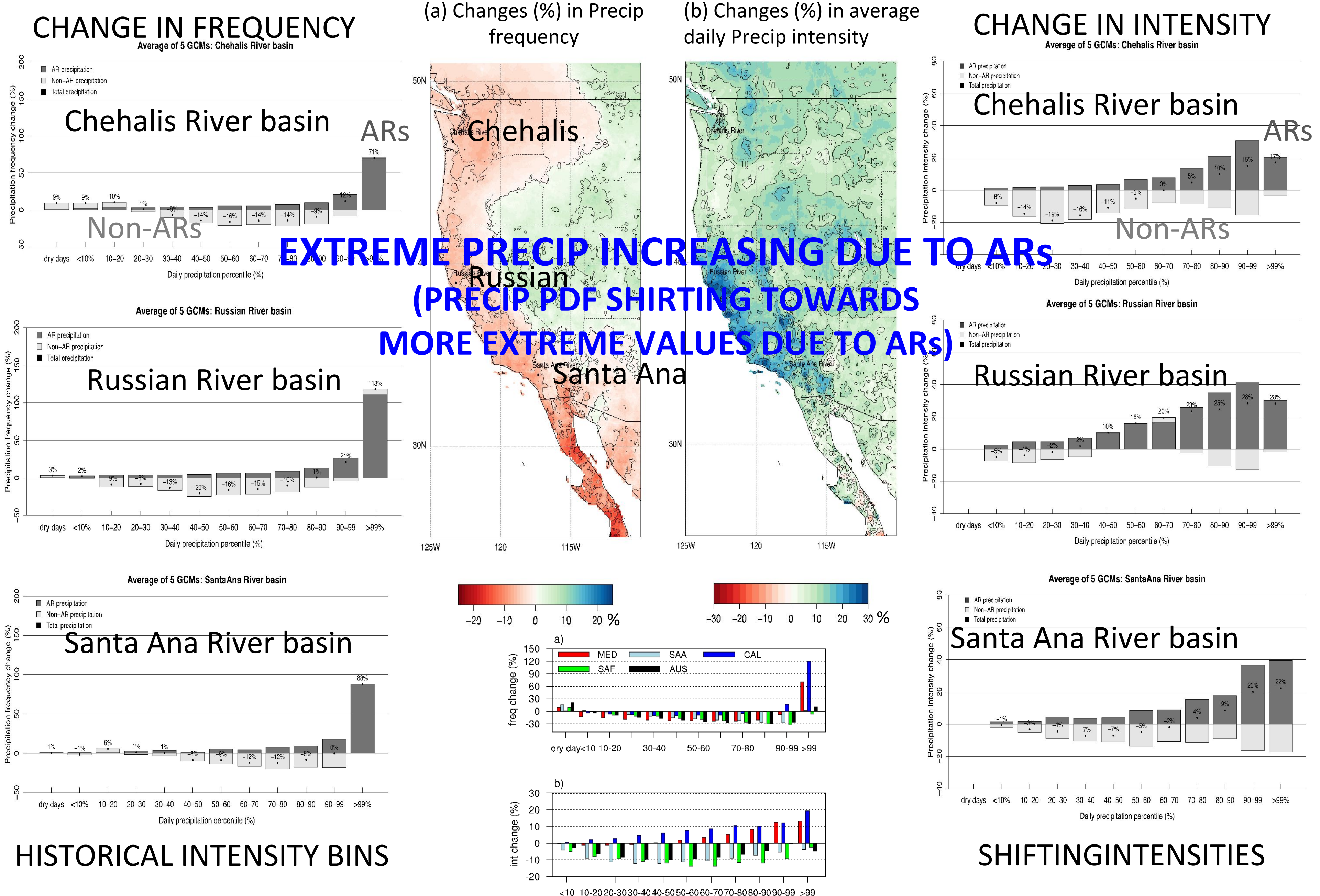
Historical: 1950 - 2005

RCP8.5 future: 2006 –2100



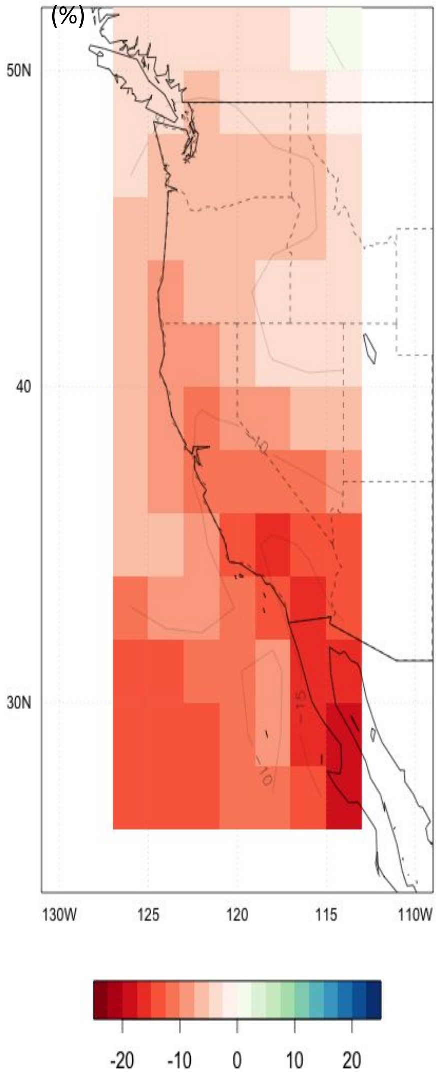
Monthly climatology of (a, horizontally) land-falling AR day counts, (b, horizontally) average local land-falling duration and (c, horizontally) daily average IVT (kg/m/s) associated with ARs at the North America west coast during projected 1951-2000 (left panel, vertically) and 2051-2100 (middle panel, vertically) time periods. Right panel shows the change. Average climatology was estimated based on ACCESS1-0, ACCESS1-3, CanESM2, CNRM-CM5, GFDL-CM3 GCM data.

5 GCM average: changes (%) in precipitation frequency and intensity



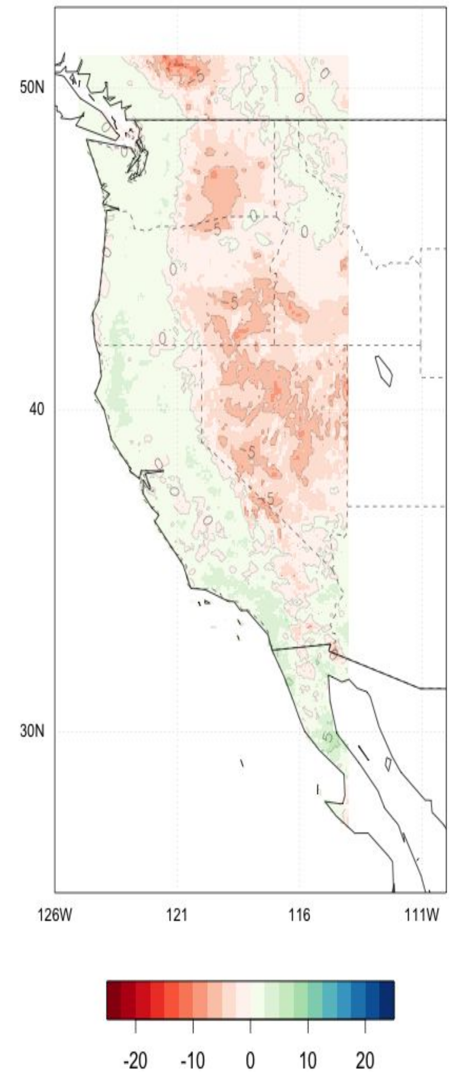
25-model ensemble Precip frequency: LOCA vs. GCM (%)

Changes in GCM PR frequency (%) (%)



Changes in LOCA PR frequency (%)

GCM – LOCA change difference

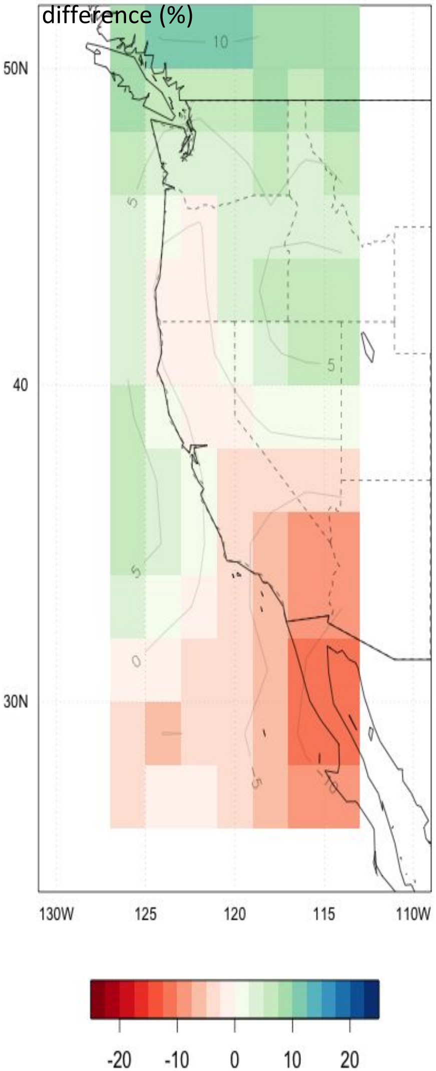


25-model ensemble total annual Precip: LOCA vs. GCM (%)

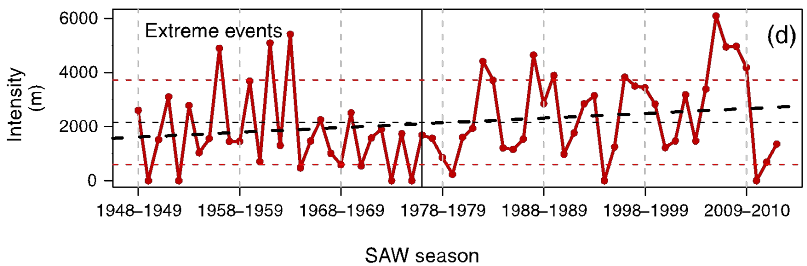
Changes in GCM annual PR sum (%) difference (%)

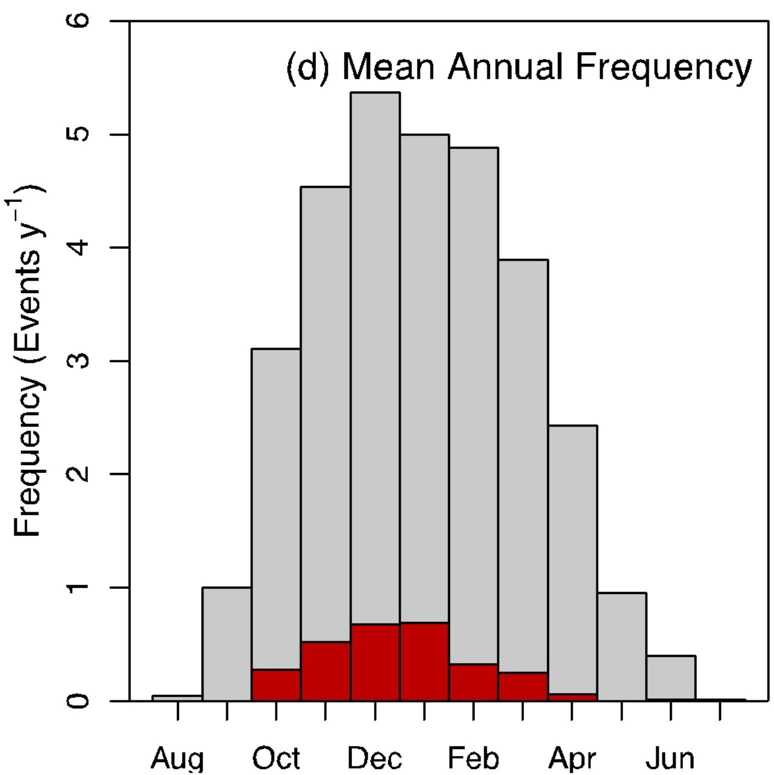
Changes in LOCA annual PR sum (%)

GCM – LOCA change



Santa Ana Winds





Guzman Morales, J., A. Gershunov, J. Theiss, H. Li and D. Cayan, 2016: Santa Ana Winds of southern California: their climatology, extremes and behavior since 1948. *Geophysical Research Letters*, 43, doi:10.1002/2016GL067887.