Climate GCM Evaluation
for California water issues

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based upon CCTAG Scenarios sub-group 11/14/13 and subsequent

GCM Evaluation, for California DWR, multiple planning purposes

- Global Scale Metrics

  P. Gleckler (PCMDI, LLNL) evaluation of GCMs at global scales

  Gleckler is member of international team conducting GCM evaluation

- Regional Scale Metrics western U.S.

  David Rupp, Phil Mote, OSU Southwest U.S. evaluation

metrics are scalar measures comparing GCM historical to observed historical climatology.

"it remains largely unknown what aspects of observed climate must be correctly simulated .. to make reliable predictions of climate change." Gleckler et al 2008

- California/Nevada Scale diagnostics to Evaluate GCMs

  based upon CCTAG and other discussions.

Identifying GCMs for California Water Managers

- For many purposes, an ensemble of global models is required
- Using all 40+ available Global Climate Models (GCMs) isn't practical
- Remove (cull) GCMls that don't adequately represent historical conditions i

40+ GCMs

Global Climatology Assessment

Gleckler et al IPCC 5th Assessment Report evaluated modeled historical

- Radiation
- Temperature
- Pressure, wind

~20 GCMs

Regional Assessment

Rupp, Mote et al Southwestern U.S.

- Temperature & Precipitation
- Pressure patterns, El Niño structure

~15 GCMs

CA/NV Extremes Assessment

Cayan et al CNAP, SW CSC Group

- Dry and Wet Precipitation extremes
- Heat waves and cold snaps
- El Niño spatial & temporal patterns

~12 GCMs

Numbers of GCMs to be retained after Global, Regional Mean and Regional Extremes Assessments are a preliminary estimate

A subset of GCMs for California Water Resources Assessment

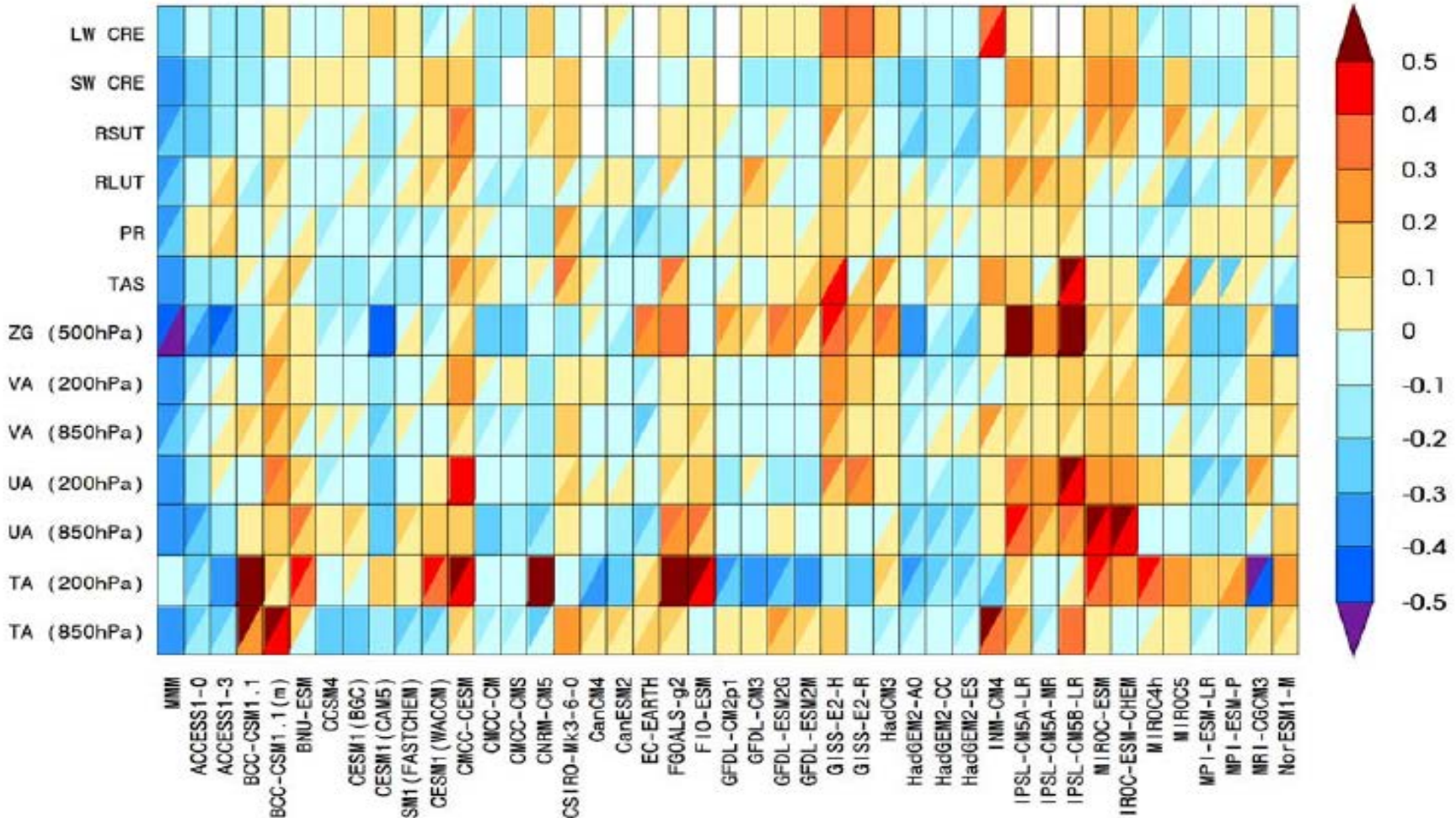
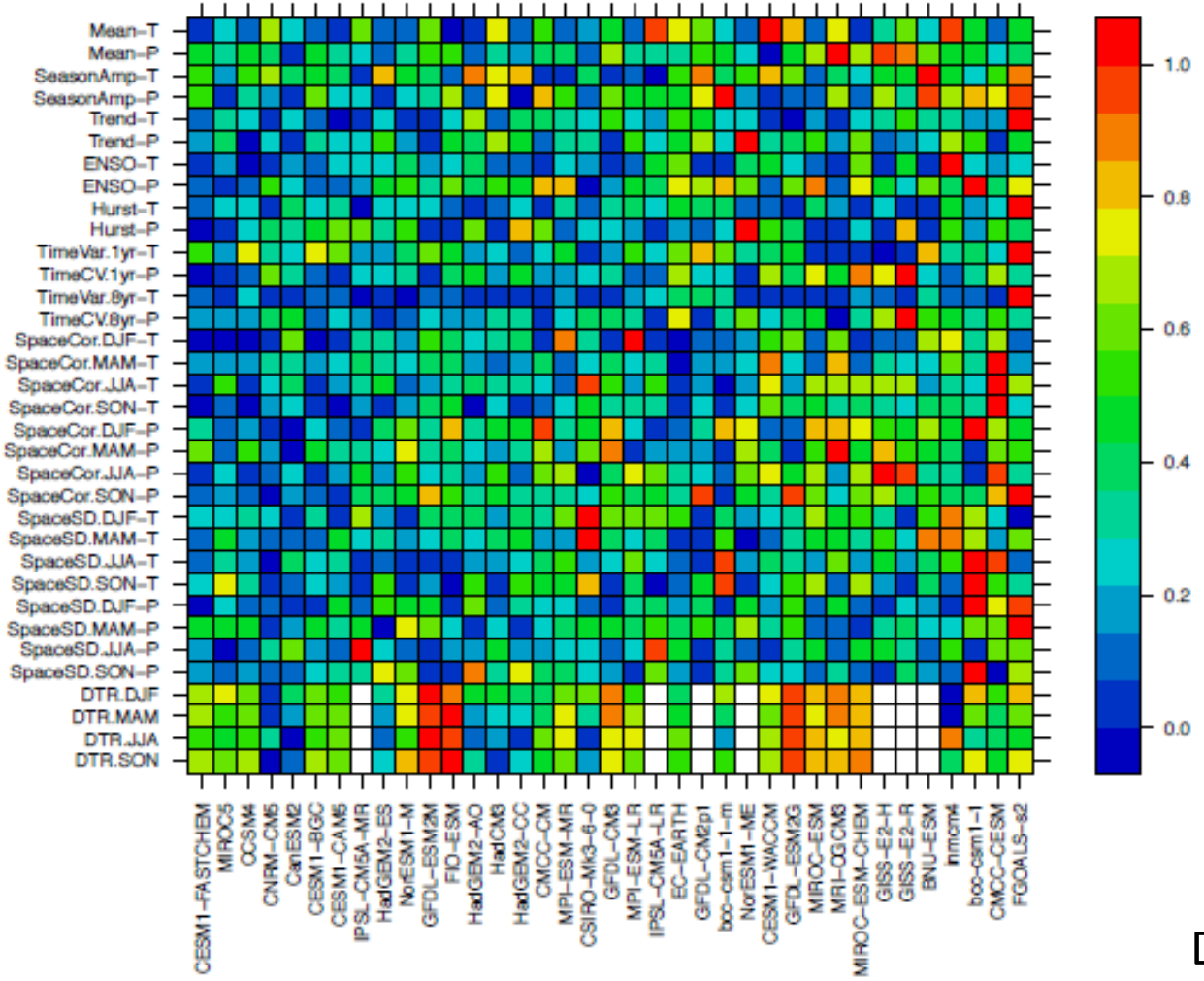


Figure 9.7: Relative error measures of CMIP5 model performance, based on the global seasonal-cycle climatology (1980–2005) computed from the historical experiments. Rows and columns represent individual variables and models, respectively. The error measure is a space–time root-mean-square error (RMSE), which, treating each variable separately, is portrayed as a relative error by normalizing the result by the median error of all model results (P. Gleckler, Taylor, & Doutriaux, 2008). For example, a value of 0.20 indicates that a model's RMSE is 20% larger than the median CMIP5 error for that variable, whereas a value of –0.20 means the error is 20% smaller than the median error. No color (white) indicates that model results are currently unavailable. A diagonal split of a grid square shows the relative error with respect to both the default reference data set (upper left triangle) and the alternate (lower right triangle). The relative errors are calculated independently for the default and alternate data sets. All reference data used in the diagram are summarized in Table 9.3.

Peter Gleckler: from IPCC AR5 Working Group I, ~~draft, not for distribution~~

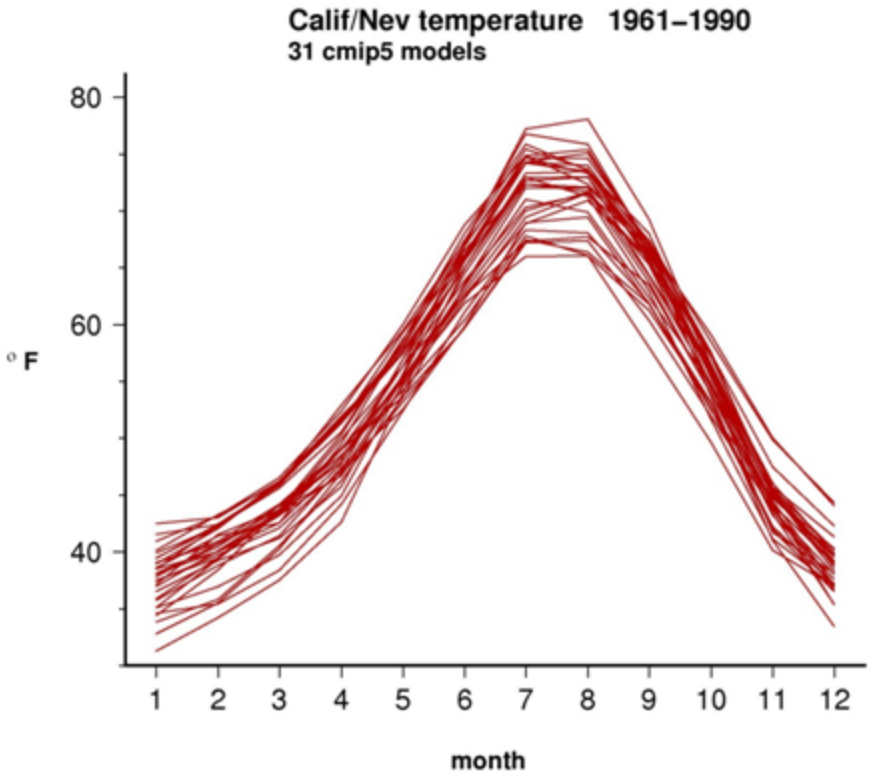


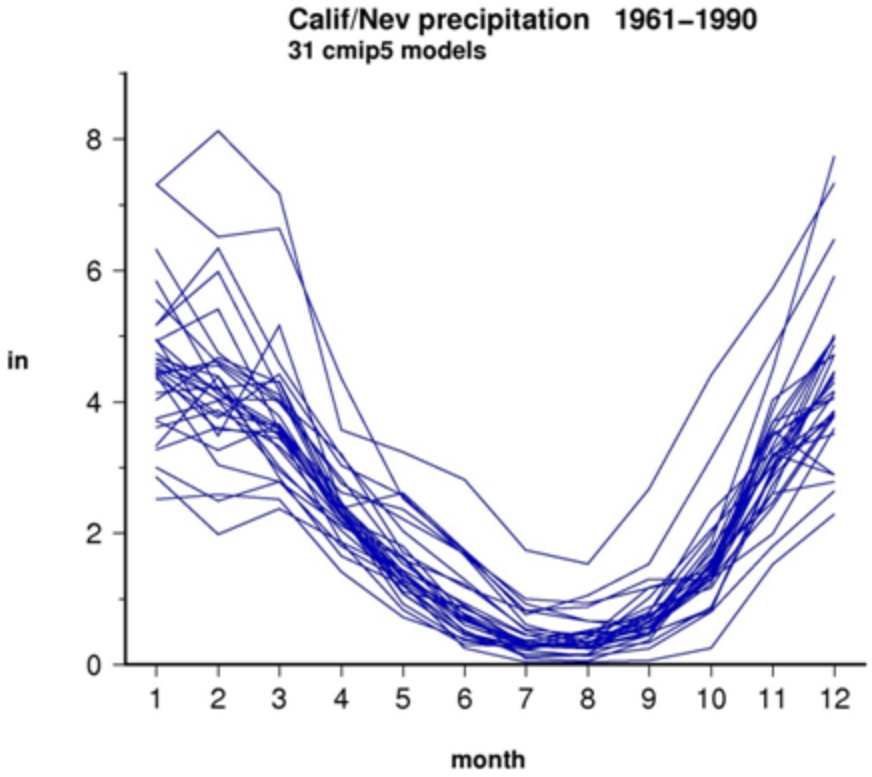
Rupp/Mote
Southwest U.S.
GCM metrics

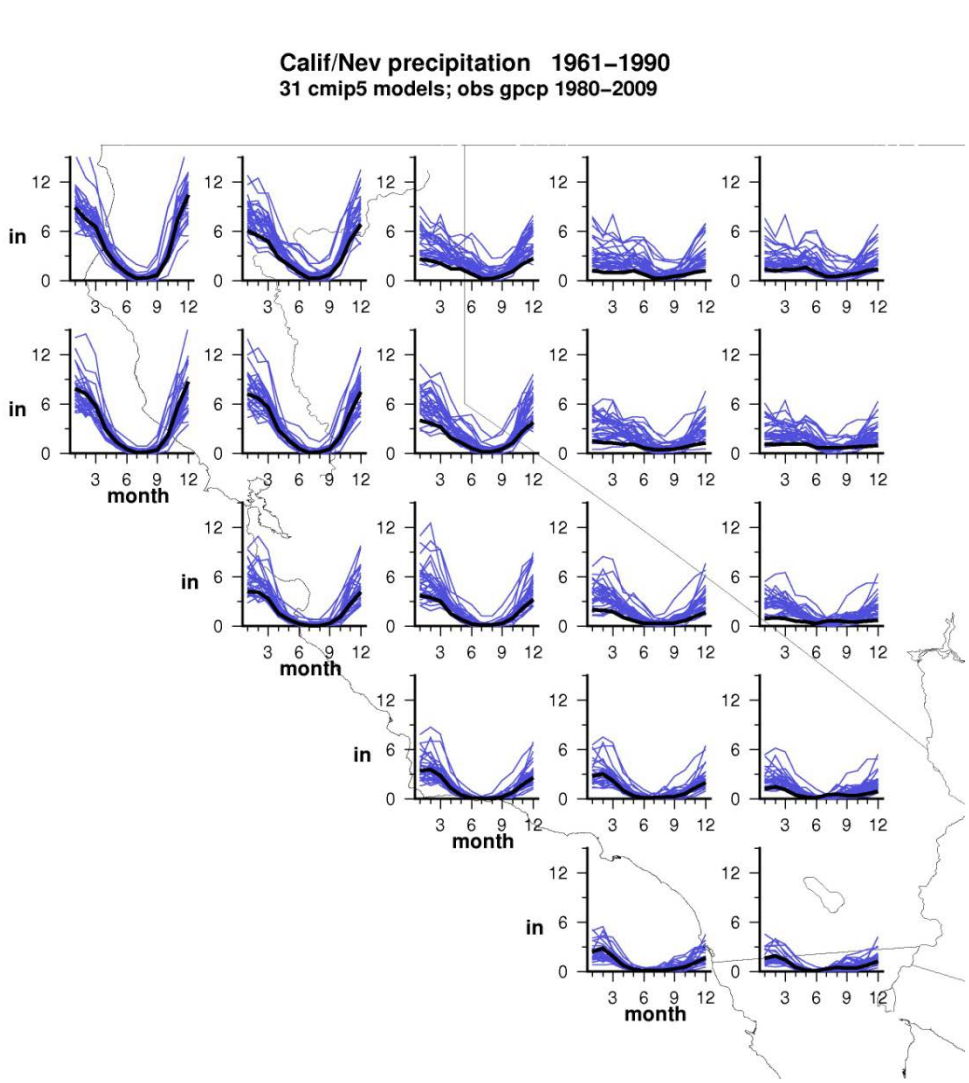
David Rupp, Phil Mote
Southwest U.S. evaluation

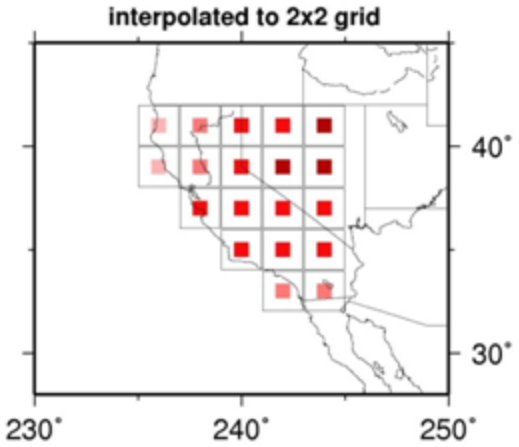
Figure 19. Relative error of the ensemble mean of each metric for each CMIP5 GCM. Models are ordered from least (left) to most (right) total relative error, where total relative error is the sum of relative errors from all metrics, excluding the diurnal temperature range (DTR) metrics. For 7 GCMs, the diurnal temperature range (DTR) metrics were not calculated (white squares).

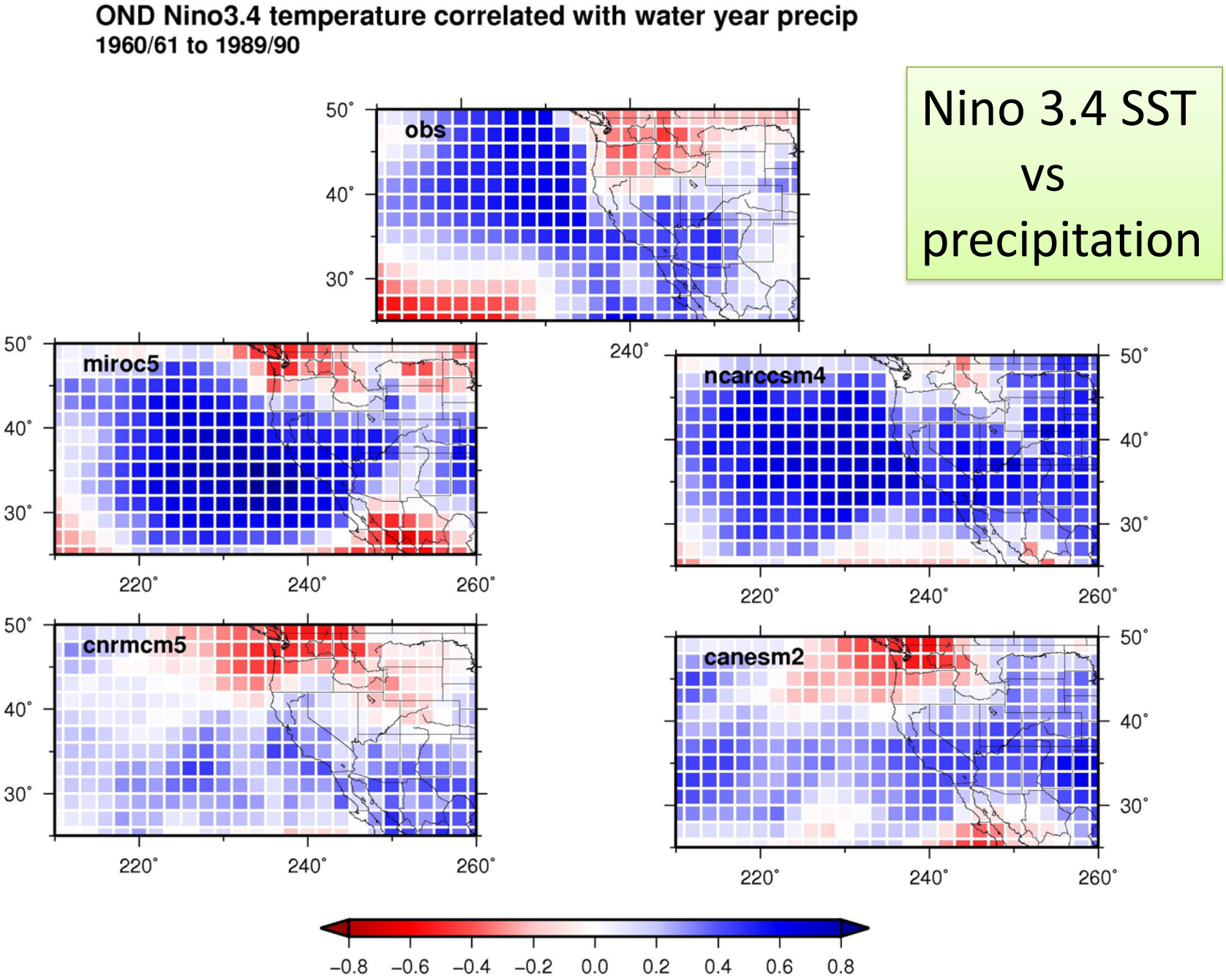
seasonal cycles are realistic






Calif/Nev precipitation 1961–1990
31 cmip5 models; obs gpcp 1980–2009
in
month
0
3
6
9
12


interpolated to 2x2 grid
40˚
30˚
230˚
240˚
250˚

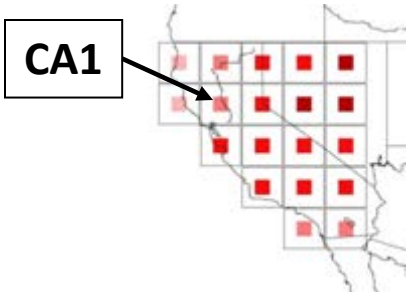


Nino 3.4 SST vs precipitation

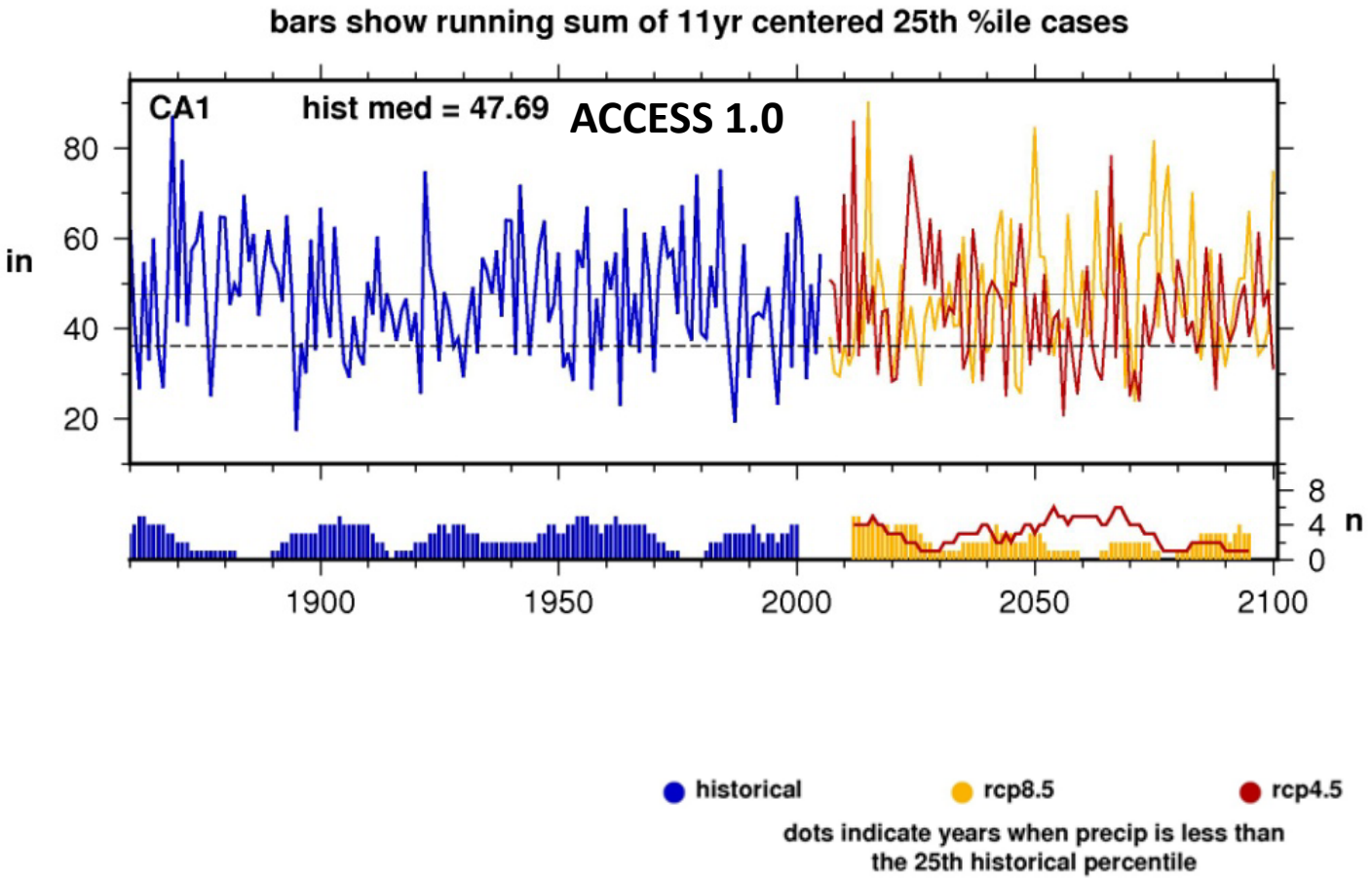
pattern correlation
Nino 3.4 SST vs precipitation

Pattern correlation between NCEP/NCAR Reanalysis 1 obs and CMIP5 models
OND Nino 3.4 SST anom and water year precipitation
Historical period 1961-1990

rm#	model name	pattern correlation
	ACCESS-1.0	0.52
26	bcc-csm1-1	0.20
2	CCSM4	0.51
5	CESM1-BGC	0.38
6	CESM1-CAM5	-0.47
12	CMCC-CM	0.46
	CMCC-CM5	0.58
3	CNRM-CM5	0.30
4	CanESM2	0.28
15	GFDL-CM3	0.31
10	GFDL-ESM2M	0.18
11	HadGEM2-CC	0.43
8	HadGEM2-ES	0.52
1	MIROC5	0.44
16	MPI-ESM-LR	0.10
7	IPSL-CM5A-MR	0.24
9	NorESM1-M	0.39
13	MPI-ESM-MR	0.20
14	CSIRO-Mk3-6-0	0.29
17	IPSL-CM5A-LR	0.54
18	EC-EARTH	-0.36
19	bcc-csm1-1-m	0.51
20	GFDL-ESM2G	0.08
21	MIROC-ESM	0.44
22	MRI-CGCM3	-0.21
23	MIROC-ESM-CHEM	0.31
24	BNU-ESM	0.33
25	inmcm4	0.20
	ACCESS-1.3	0.38
	FGOALS-g2	-0.11
	IPSL-CM5B-LR	0.03



Model Dry Year Spells



multi-year Dry Spell statistics

Decadal dryness; water year precipitation (cm)
1850/51 through 2004/05 (146 decades)
Sacramento region

rm#	model name	#dry yr σ	#dry yr avg	median wypr	avg wypr	25th %ile wypr
OBS	20th century reanalysis	1.25	2.09	60.35	62.02	43.96
	ACCESS-1.0	1.11	2.03	112.30	117.23	88.16
26	bcc-csm1-1	1.59	2.90	76.42	76.20	67.63
2	CCSM4	1.24	2.68	113.62	113.35	83.41
5	CESM1-BGC	1.16	2.60	103.06	107.37	80.54
6	CESM1-CAM5	1.60	2.16	102.00	102.81	81.80
12	CMCC-CM	0.95	2.58	112.53	117.61	89.55
	CMCC-CMS	1.04	2.14	121.16	124.34	94.34
3	CNRM-CM5	1.32	2.45	102.86	103.77	86.18
4	CanESM2	1.69	3.73	67.46	70.60	57.78
15	GFDL-CM3	1.14	1.73	127.23	130.56	104.95
10	GFDL-ESM2M	1.90	3.32	119.92	118.36	101.68
11	HadGEM2-CC	1.45	2.72	86.24	92.14	75.65
8	HadGEM2-ES	1.08	1.94	83.20	85.42	66.14
1	MIROC5	1.54	2.74	89.64	97.89	75.58
16	MPI-ESM-LR	1.02	1.99	107.19	108.11	83.84
7	IPSL-CM5A-MR	1.52	2.90	131.80	138.23	102.42
9	NorESM1-M	1.28	1.81	71.74	73.69	51.84
13	MPI-ESM-MR	1.34	2.50	115.80	114.06	93.65
14	CSIRO-Mk3-6-0	1.09	2.93	69.95	73.37	58.56
17	IPSL-CM5A-LR	1.00	2.29	92.89	98.68	70.96
18	EC-EARTH	1.31	2.99	119.81	120.04	104.41
19	bcc-csm1-1-m	1.53	2.60	117.36	116.65	101.74
20	GFDL-ESM2G	1.25	2.34	100.19	104.02	89.05
21	MIROC-ESM	1.59	2.25	83.50	83.82	71.50
22	MRI-CGCM3	1.16	2.83	185.31	191.66	164.88
23	MIROC-ESM-CHEM	1.27	2.71	85.41	88.02	77.40
24	BNU-ESM	1.19	2.33	79.23	80.47	66.85
25	inmcm4	1.26	1.80	90.81	94.34	72.67
	ACCESS-1.3	1.32	1.73	109.46	115.18	79.65
	FGOALS-g2	1.02	2.35	120.17	120.29	106.13
	IPSL-CM5B-LR	1.54	3.81	196.48	200.37	174.27

Maximum 3-day precipitation/annual total

Sacramento region
3-day maximum precipitation; ratio to water year precipitation
Max, median and sigma of ratio over 1961-1990 period

rm#	model name	max	median	sigma
OBS	20th century reanalysis	0.20	0.14	0.03
	ACCESS-1.0	0.24	0.12	0.03
26	bcc-csm1-1	0.12	0.08	0.02
2	CCSM4	0.19	0.10	0.03
5	CESM1-BGC	0.20	0.11	0.03
6	CESM1-CAM5	0.26	0.13	0.05
12	CMCC-CM	0.22	0.13	0.03
	CMCC-CMS	0.19	0.12	0.03
3	CNRM-CM5	0.15	0.11	0.02
4	CanESM2	0.19	0.11	0.03
15	GFDL-CM3	0.17	0.09	0.03
10	GFDL-ESM2M	0.16	0.08	0.02
11	HadGEM2-CC	0.27	0.14	0.04
8	HadGEM2-ES	0.25	0.13	0.04
1	MIROC5	0.17	0.11	0.03
16	MPI-ESM-LR	0.18	0.11	0.03
7	IPSL-CM5A-MR	0.20	0.13	0.03
9	NorESM1-M	0.20	0.11	0.03
13	MPI-ESM-MR	0.21	0.12	0.03
14	CSIRO-Mk3-6-0	0.23	0.15	0.03
17	IPSL-CM5A-LR	0.20	0.11	0.04
18	EC-EARTH	0.12	0.09	0.01
19	bcc-csm1-1-m	0.20	0.09	0.03
20	GFDL-ESM2G	0.20	0.09	0.03
21	MIROC-ESM	0.13	0.07	0.02
22	MRI-CGCM3	0.12	0.08	0.02
23	MIROC-ESM-CHEM	0.11	0.08	0.01
24	BNU-ESM	0.13	0.08	0.02
25	inmcm4	0.13	0.08	0.02
	ACCESS-1.3	0.21	0.11	0.03
	FGOALS-g2	0.08	0.06	0.01
	IPSL-CM5B-LR	0.13	0.08	0.02

Cull the 15 CMIP5 GCMs to 11 GCMs

rm#	model name	#dry yr σ	3dy max pr	pat corr n34	JJA tdel	n34 ts
	ACCESS-1.0	1.11	0.24	0.52	9.39	
26	bcc-csm1-1	1.59	0.12	0.20	9.46	
2	CCSM4	1.24	0.19	0.51	7.62	
5	CESM1-BGC	1.16	0.20	0.38	7.68	
6	CESM1-CAM5	1.60	0.26	-0.47	10.59	
12	CMCC-CM	0.95	0.22	0.46	10.51	
	CMCC-CMS	1.04	0.19	0.58	9.95	
3	CNRM-CM5	1.32	0.15	0.30	8.51	
4	CanESM2	1.69	0.19	0.28	12.07	
15	GFDL-CM3	1.14	0.17	0.31	10.33	
10	GFDL-ESM2M	1.90	0.16	0.18	7.95	
11	HadGEM2-CC	1.45	0.27	0.43	9.69	
8	HadGEM2-ES	1.08	0.25	0.52	10.39	
1	MIROC5	1.54	0.17	0.44	7.46	
16	MPI-ESM-LR	1.02	0.18	0.10	9.08	

Regional and California Screening (PRELIMINARY) : yields 11 GCMs

Institution and horizontal resolution

The table lists the abbreviated model name, the Institution that developed and/or oversaw the simulations and the size of the model's atmospheric grid (number of longitudes by number of latitudes.

model name	model institution	nlon x nlat
ACCESS-1.3	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)	192x145
CCSM4	National Center for Atmospheric Research	288x192
CESM1-BGC	National Science Foundation, Department of Energy, National Center for Atmospheric Research	288x192
CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici	192x96
CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	256x128
CanESM2	Canadian Centre for Climate Modelling and Analysis	128x64
GFDL-CM3	Geophysical Fluid Dynamics Laboratory	144x90
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory	144x90
HadGEM2-CC	Met Office Hadley Centre	192x145
HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	192x145
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	256x128

11 GCMs
change in JJA temp 2070-99 vs 1961-1990

Change in summer temperature (°F)
Sacramento region

rm#	model name	JJA 2070-2099 minus 1961-1990	
		rcp 4.5	rcp 8.5
	ACCESS-1.0	6.13	9.39
2	CCSM4	4.38	7.62
5	CESM1-BGC	4.12	7.68
	CMCC-CMS	5.39	9.95
3	CNRM-CM5	5.24	8.51
4	CanESM2	6.96	12.07
15	GFDL-CM3	7.47	10.33
10	GFDL-ESM2M	4.72	7.95
11	HadGEM2-CC	5.61	9.69
8	HadGEM2-ES	6.57	10.39
1	MIROC5	5.67	7.46

11 models
change in WY precip 2070-99 vs 1961-1990

Change in water year precipitation (inches)
Sacramento region

rm#	model name	WY 2070-2099 minus 1961-1990	
		rcp 4.5	rcp 8.5
	ACCESS-1.0	0.79	-5.08
2	CCSM4	0.19	0.62
5	CESM1-BGC	3.91	12.12
	CMCC-CMS	3.04	-0.99
3	CNRM-CM5	9.98	10.37
4	CanESM2	3.87	7.31
15	GFDL-CM3	-0.60	-3.55
10	GFDL-ESM2M	-3.12	-4.85
11	HadGEM2-CC	0.03	-1.59
8	HadGEM2-ES	0.31	3.35
1	MIROC5	-4.57	-1.36

11 models
change in JJA temp and WY precip 2070-99 vs 1961-1990

Change in summer temperature (°F)
Sacramento region

rm#	model name	JJA 2070-2099 minus 1961-1990	
		rcp 4.5	rcp 8.5
	ACCESS-1.0	6.13	9.39
2	CCSM4	4.38	7.62
5	CESM1-BGC	4.12	7.68
	CMCC-CMS	5.39	9.95
3	CNRM-CM5	5.24	8.51
4	CanESM2	6.96	12.07
15	GFDL-CM3	7.47	10.33
10	GFDL-ESM2M	4.72	7.95
11	HadGEM2-CC	5.61	9.69
8	HadGEM2-ES	6.57	10.39
1	MIROC5	5.67	7.46

ater year precipitation (inches)
Sacramento region

WY 2070-2099 minus 1961-1990	
rcp 4.5	rcp 8.5
0.79	-5.08
0.19	0.62
3.91	12.12
3.04	-0.99
9.98	10.37
3.87	7.31
-0.60	-3.55
-3.12	-4.85
0.03	-1.59
0.31	3.35
-4.57	-1.36

Project Status
frequency-dependent bias correction, LOCA downscaling

Testing and diagnostics
- daily precip western 6km and CONUS 12km
  - observed and GCM projection datasets
- daily temp in process

Method and results described in Pierce, Cayan, Thrasher report
- *reviews* via California Energy Commission anonymous
  - colleague reviews received
- *vetting* with US BurRecl, US ACE, other colleagues

Production runs for CMIP5 GCM simulations—
- discussion w California CEC, USBurRecl and USACE in process