Fidelity of CMIP5 simulations in representing the dynamics of the large scale meteorology associated with California hot spells

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1. Background and Motivation

- Grotjahn and Faure (2008); Grotjahn (2011, 2013, 2014) found that regional scale extreme heat in California Central Valley (**CCV**) is linked to Large Scale Meteorological Patterns (**LSMP**s). LSMPs are an equivalent barotropic, nearly-stationary wave train (ridge-trough-ridge) across the N. Pacific and western N. America.
- **Motivation:** LSMPs are easily resolved by climate models. LSMPs are upper air patterns, with key features located over the Pacific, are less sensitive to a model's capture of complex California topography and processes. Grotjahn (2011) developed a 'Circulation Index' (**CI**) to measure how similar any day is to the ensemble mean of observed hot spells. Grotjahn (2013, 2014) used the CI to assess hot spells in a climate model for AMIP and two RCP scenarios. **We assess how well 14 climate models approximate the LSMP patterns for CCV hot spells.**

2. Data and Methods

- **15 NCDC station daily surface Tmax**
- **NCEP –NCAR Reanalyses: 6hourly**
- **14 CMIP5 Historical simulations**
- **Data period:** 34 summers (JJAS), 1977-2010 for NCEP-NCAR, 1972-2005 for CMIP5
- **Event finding:** identify the hottest 5% of the days for each station (reanalysis) or CCV grid points (model data). Then require a minimum number of stations (CCV grid points) to exceed their own 95% threshold for at least 3 consecutive days
- **Composite analysis & CI calculation**

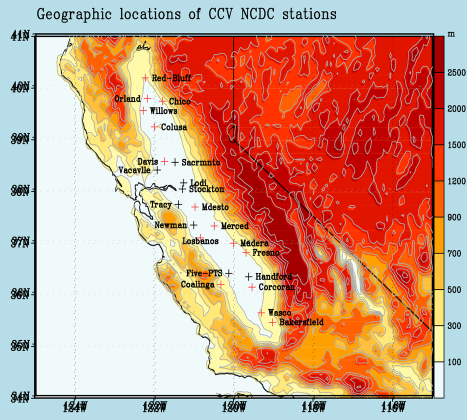

Fig. 1. Geographic location of California Central Valley (**CCV**) with NCDC stations (+) used.

3. Hot Spells Identification

Table 1. The 14 Models (1 reanalysis) considered; grid size of data provided; number of grid points (NCDC stations) associated with the CCV; minimum number of grid points (stations) that need to exceed the threshold to be an event day; average length of the hot spells; total number of hot spells during the 34 summers.

Model	Resolution	CV Grid #	Min. Grid #	Mean Duration (Days)	Event #
NCEP-NCAR	**NCDC Station!**	**15**	**6**	**4.07**	**28**
CCSM4	288x192	4	2	3.75	33
MRI-ESM1	320x160	5	3	3.64	33
bcc-csm1-1-m	320x160	5	3	4.16	31
CNRM-CM5	256x128	3	2	3.87	31
HadGEM2-CC	192x144	4	2	4.38	34
inmcm4	180x120	2	1	4.64	46
NorESM1-M	144x96	2	1	4.04	50
GFDL-CM3	144x90	3	2	3.48	29
GFDL-ESM2G	144x90	3	2	4.14	30
GFDL-ESM2M	144x90	3	2	4.38	30
bcc-csm1-1	128x64	1	1	4.24	34
MIROC-ESM	128x64	1	1	3.97	30
MIROC-ESM-CHEM	128x64	1	1	4.32	25
FGOALS-g2	128x60	1	1	4.16	38
				4.08	33.86

Average CCV heat wave duration in most models is similar to that observed. Number of events is also similar, though 2 models had more frequent hot spells. Lowest 5 values shaded.

4. LSMP time sequences observed and in models; CI calculation

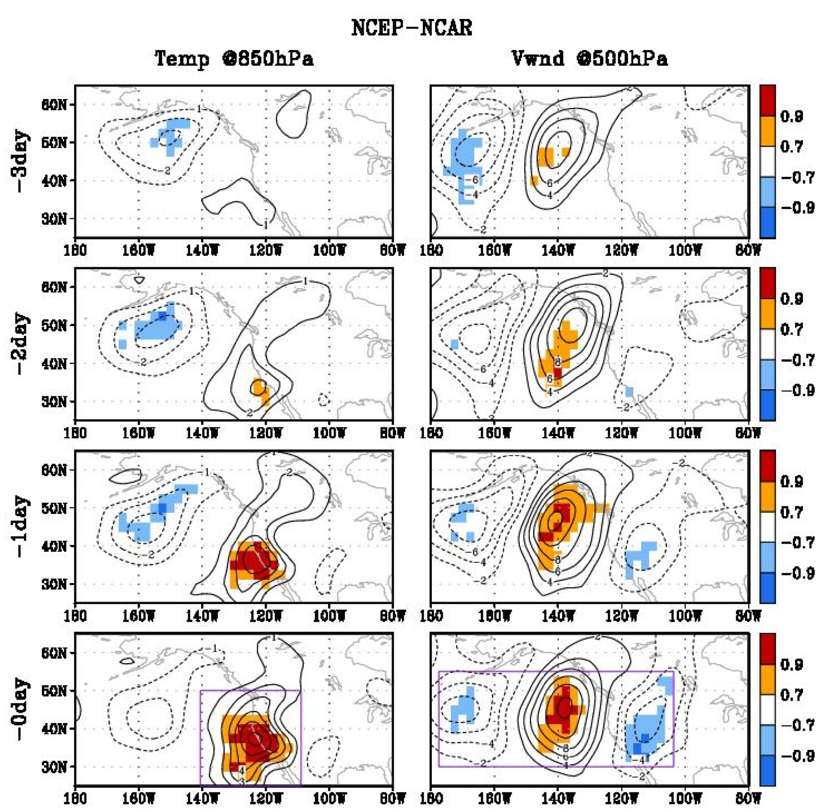

Fig. 2. Temperature anomaly, **Ta** (850 hPa) and meridional wind anomaly **Va** (500hPa) ensemble mean of 28 events. Shading at grid points where >70% of ensemble members (darker for >90%) have the same sign. Sequence starts 3 days before onset

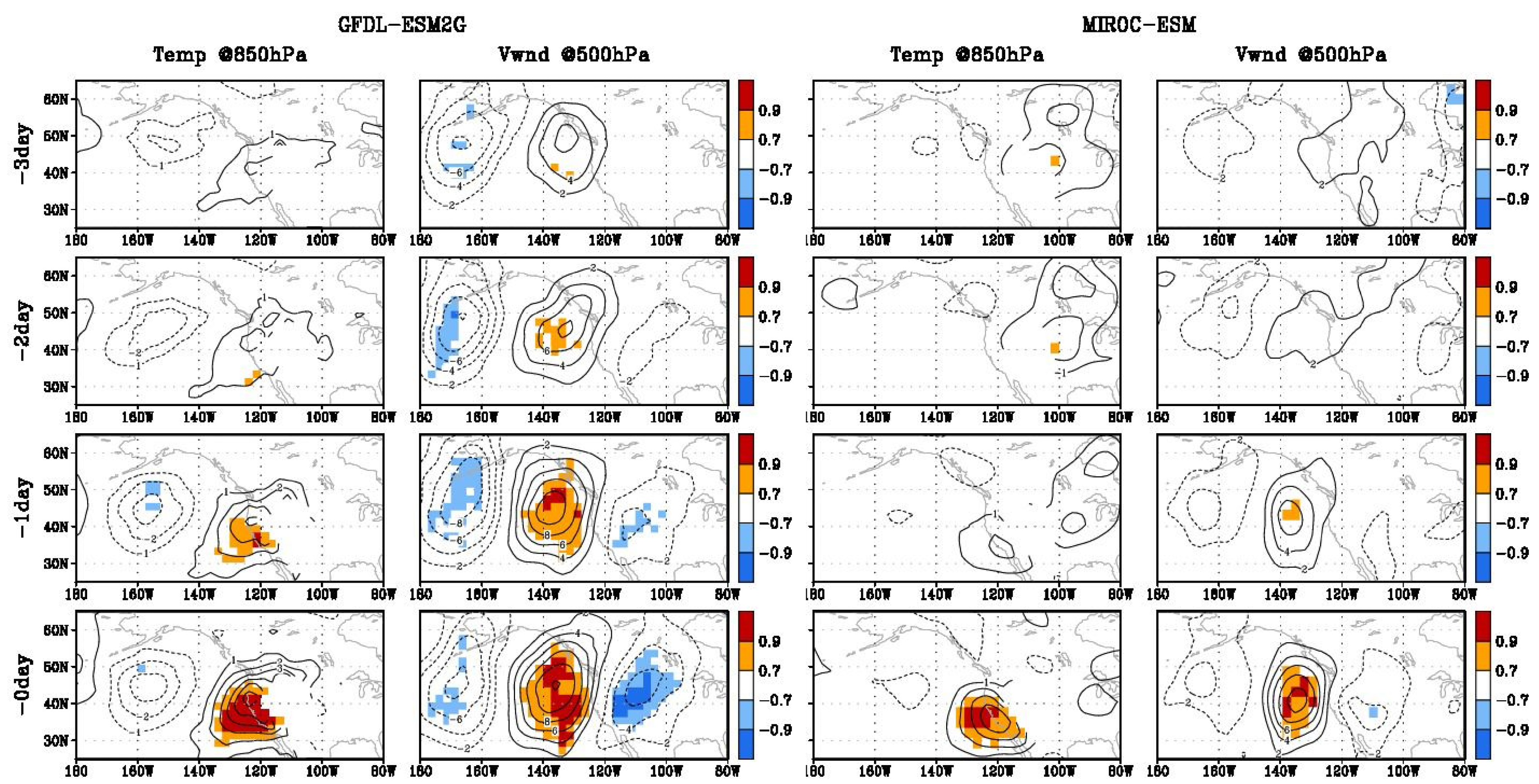

Fig. 3. Same as fig. 2 except for the model (left pair) with the best match to reanalysis and the model (right pair) with the least match to reanalysis. The matching was checked in the regions outlined in fig 2. Models center the temperature anomaly over the land (reanalysis centers Ta offshore). The model ensemble means are comparable or weaker than the reanalysis means, especially prior to onset. Most models have less variance among ensemble members (not shown) but some have more than reanalysis.

Reanalysis LSMPs visible for several days prior to event onset (fig. 2). Versus reanalysis, most models have weaker mean LSMPs but variance prior to onset varies greatly with model. Models have Ta centered over land; observed hot days Ta max is offshore to block sea breeze cooling, a process models may miss. All models have LSMP-like patterns, confirms using a measure (CI) of the LSMPs for model assessment.

CI calculation: 1) interpolate reanalysis onset composite (bottom row, fig. 2) to model's grid. 2) project each model field each day onto the shaded parts of the reanalysis onset composite. 3) combine the projection coefficients for Ta850 and Va500, with weights 0.6 and 0.4, to obtain the CI.

5. CI in reanalysis and models

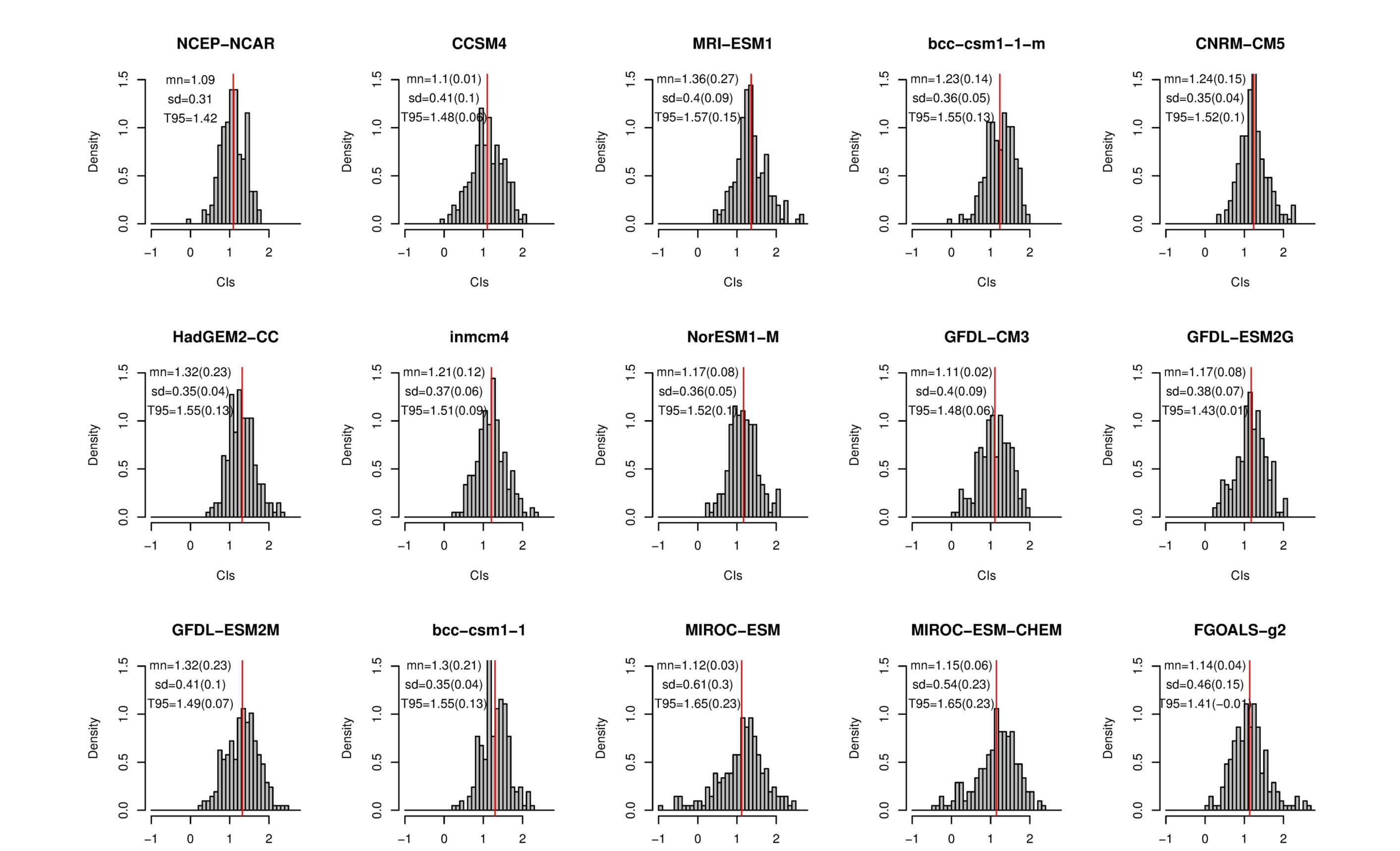

Fig. 4. CI values distribution for events in each model (and reanalysis). Number of events varies (Table 1) so ordinate is fraction of the total number of events in each 0.1 interval of CI. Some models have events with negative CI implying those models have some events with anomaly pattern of opposite sign to that observed. Normalized T max threshold shown for each model.

CI varies with events. Standard deviation: smaller in reanalysis, good and some poor simulations, larger in other poor simulations. Model hot spells have higher average CI than reanalysis

6. CI capture rate of surface events

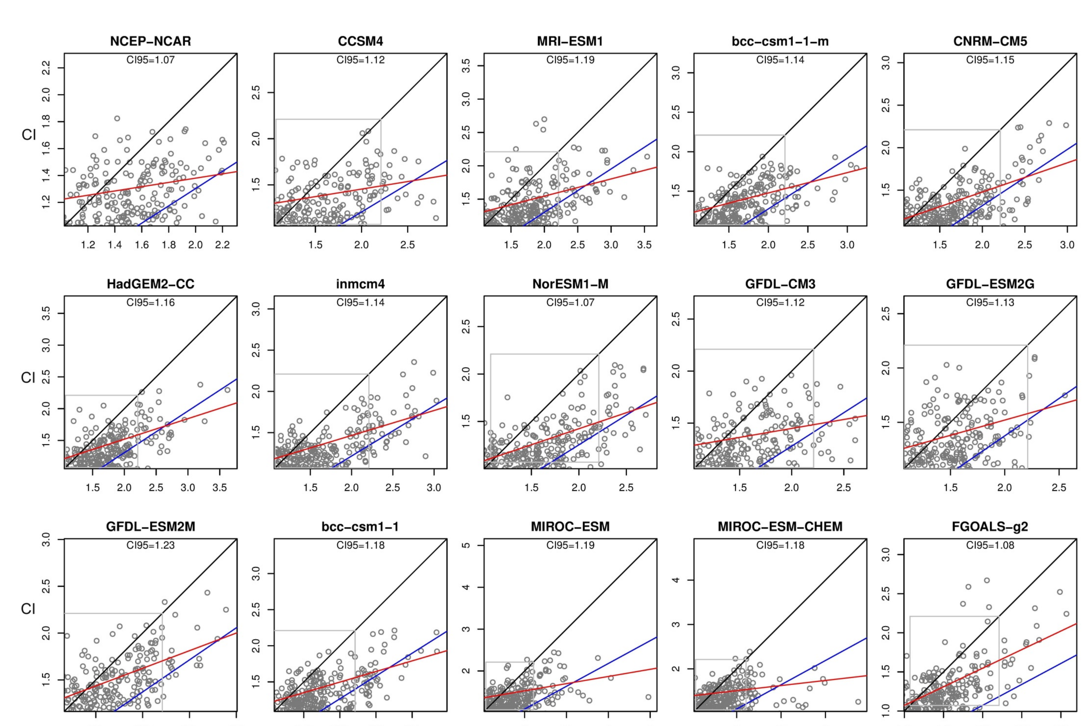

Fig. 5. Comparison of CI values on dates of the highest 5% of normalized anomaly max surface temperature (**Tamx**) values. Note: these dates include hot days of less than 3 days duration. Grey square indicates range in reanalysis data (upper left panel). Tamx values reach higher values in models than observed, much higher for some models. CI values also reach higher values. Red – regression of highest 5%; blue – regression of all data. Most models have stronger relation between CI and Tamx than observed.

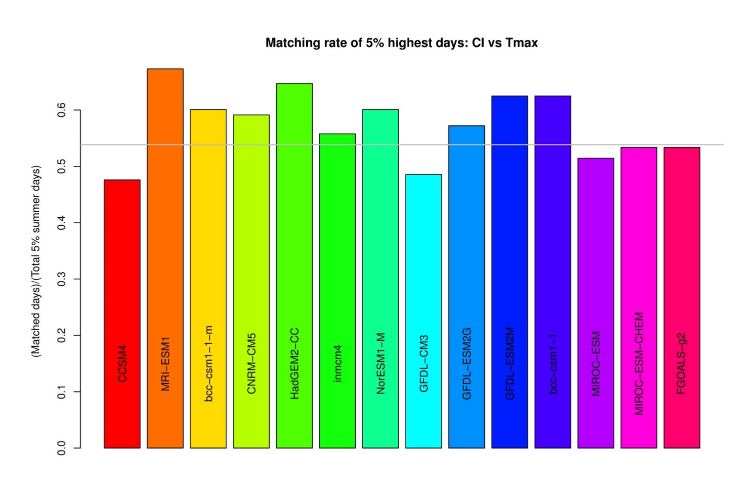

Fig. 6. fraction of dates in which there was a normalized anomaly max surface T above the 95% threshold that are also a date when the CI has a value above its 95% threshold. Grey line is fraction in reanalysis/NCDC data. Models with data at the highest resolution are on the left while models with progressively fewer grid points are towards the right. CI matching is not sensitive to model resolution. Note: these dates include hot spells of less than 3 days duration that were excluded when forming the CI projection fields (fig. 2).

CCV normalized anomaly max surface temperature and CI are both larger in models than in observations/reanalysis. Generally, higher CI with higher Tamx; most models have a stronger relation between the CI and Tamx than observed.

7. Conclusions

- ✓ **Hot spells ≥3 days duration have highly consistent large scale meteorological patterns (LSMPs) at onset and several days prior. (fig. 2)**
- ✓ **Models have LSMPs similar to reanalysis, but form the 850 hPa anomaly temperature (Ta) onshore instead of offshore, possibly missing important processes (e.g. sea breeze cooling that must be blocked). (fig. 3)**
- ✓ **CI measures strength of the hot spell LSMPs each day. CI is projection of daily anomaly data onto ensemble mean anomalies on the hot spells onset days, at grid points where ensemble members strongly agree on anomaly sign. Models CI distributions similar to reanalysis but higher (fig. 4)**
- ✓ **Models have similar or weaker ensemble mean anomalies (fig 3) but higher surface temperature anomalies (Tamx) than observed (fig. 5) since models' Ta misplaced over CCV.**
- ✓ **Most models have stronger relation between CI and Tamx than observed; CI captures more of the extremes (figs. 5 & 6)**
- ✓ **How observed LSMPs form fall into 2 clusters (see poster GC51A-0382 Friday). Test of one climate model shows it simulates one, but not the other cluster.**

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