Trends in CCSM4 simulated California heat waves from large scale patterns

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1. Introduction

What do the CCSM4 weather patterns associated with extreme hottest days for the California Central Valley (CV) predict for the future?

Grotjahn and Faure (2008) show Large Scale Meteorological Patterns (LSMPs) during extreme CV heat. Grotjahn (2011) used parts of selected LSMPs to predict extreme CV heat. Grotjahn (2013) compared observation-based data to LSMPs in a 20year historical simulation by CCSM4.

A longer historical period and two future climate scenarios simulations by CESM1 for the latter half of this century are now considered.

2. JJAS Data

"NNRA1"= NCEP/NCAR reanalysis 12 GMT daily data at 2.5x2.5 resolution. "NDRA2" NCEP/DOE AMIP-II 1979-88 target anomaly ensemble means. As in Grotjahn (2011, 2013) 1951-2005.

Corresponding historical (1951-2005) and RCP4 and RCP8 simulations by CESM1 (2046-2100) daily data regridded to 2.5x2.5 for (LSMP-based) CI calculation

3. Synoptics

Hottest days when subsidence inversion strong & low & sea breeze blocked by SLP gradient due to hot T anomaly being centered near coast

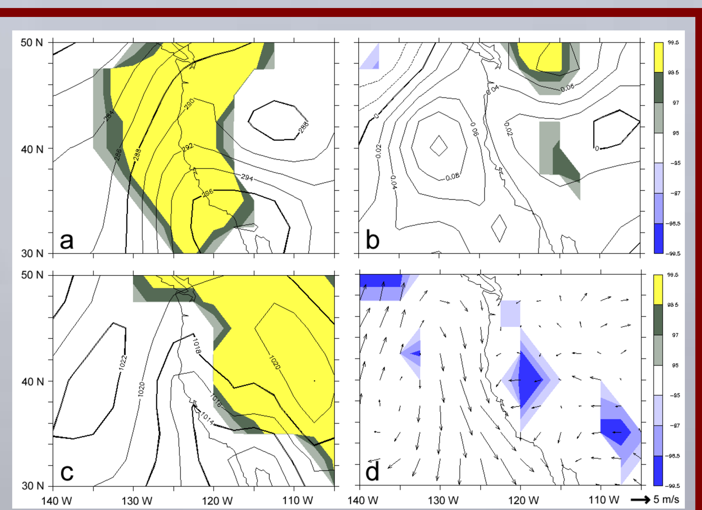

Figure 1. 4-panel chart: 850mbT, 700mb ω, SLP, sfc wind (u shaded). Shading top 1.5%.

4. A proxy for CV max surface T_a

1. **CCSM4 does not resolve CV; has broad topographic slope instead. (fig. 2)**
2. **Use CI as proxy for CV surface max T anomaly; CI measures LSMP strength.**
3. **The LSMP is forcing for a RCM or input for statistical downscaling.**
4. **Other factors: mitigating (e.g. irrigation) or enhancing (e.g. drought, urbanization) are not directly included.**
5. **Correlation: CI & observed max T_a =0.84**

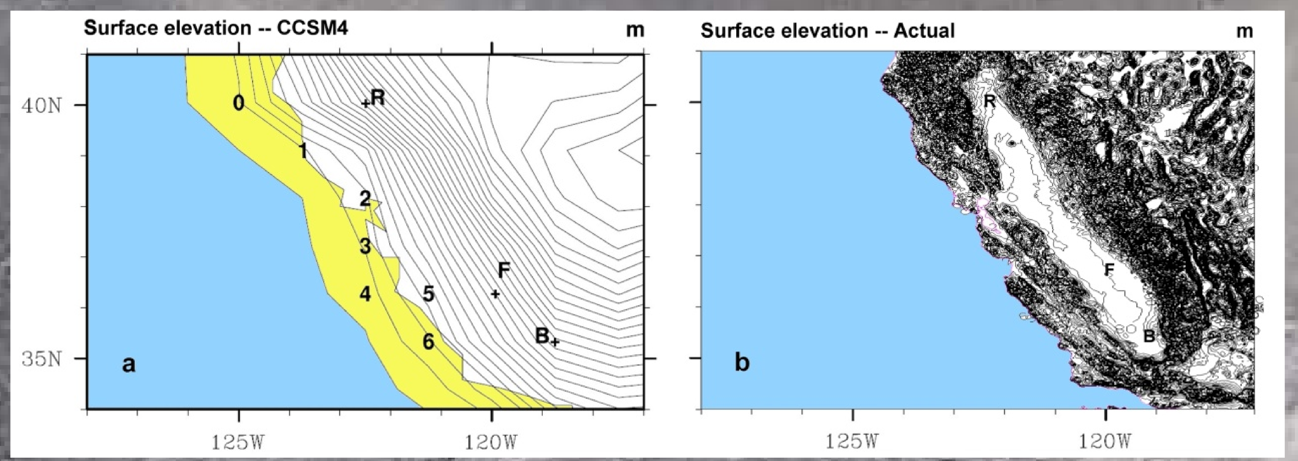

Figure 2. Comparison of topography in a.)CCSM4 (1.1deg) and actual. Locations of CV stations (R=KRBL, F=KFAT, B=KBFL) Same scale and contour interval (60m).

5. LSMPs index (CI) calculation

1. Project 850 hPa daily T anomalies and 700 hPa v anomalies on parts of respective target ensemble mean patterns (fig. 3a,b) to obtain daily circulation index (CI) as in Grotjahn (2011). Ensemble dates are hottest 1% of surface max T values (1979-88 period)
2. High CI implies hot surface max T_a values
3. CI calculated for NNRA1 & model data

6. LSMPs comparison

1. Ensemble means for NDRA2 shown in fig. 3a, b.
2. Ensemble means for CCSM4 (fig 3c,d) similar to observed but: i) weaker and ii) peak T anomaly is onshore, not off shore.

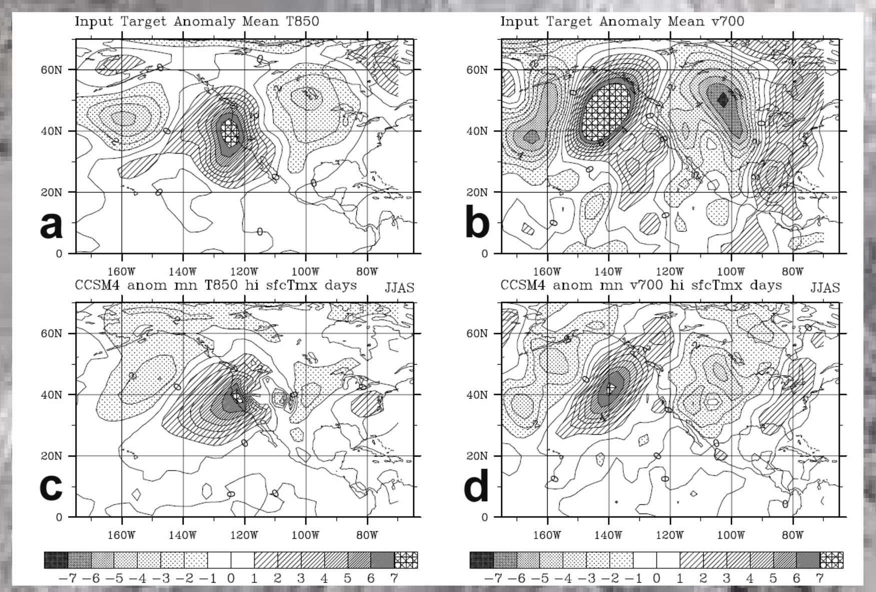

Figure 3. Ensemble mean fields. 850mb T anomaly: a) in NDRA2:, c) in CCSM4. 700mb v: b) in NDRA2, d) in CCSM4. CCSM4 based on extreme surface max T values at grid pts 1, 2, 5

7. Results

1. Historical CCSM4: range, standard deviation (0.75 Std. Dev. vs 0.91) & skew all smaller than NNRA1. (fig. 4)
2. Historical CCSM4: too few of highest CI
3. RCP 8 shifts median by 1 std. dev. (NNRA1 basis). RCP4 shift half that.
4. RCP cases: range increases as max values increase more than mins.
5. Model PDFs: RCP cases skew increases doubles historical period values. Historical CCSM skew 33% < NNRA1 skew, but CESM RCP 4 is 25% > NNRA1.
6. Large increases in durations above 1 std. dev. (1979-88 basis) due to shifts of medians. (fig.5)
7. 20-yr return values increase ~25% (2.2 → 2.8 (RCP4); → 3.1 std. dev. ~40% (RCP8)
8. Inter-decade variation (fig 6). Standard deviation varies +/- 2-7%
9. Surface station trend unclear, but weak trend in NNRA1 and CCSM4. RCP4 trend mixed. Trend exceeds inter-decade variation in RCP8

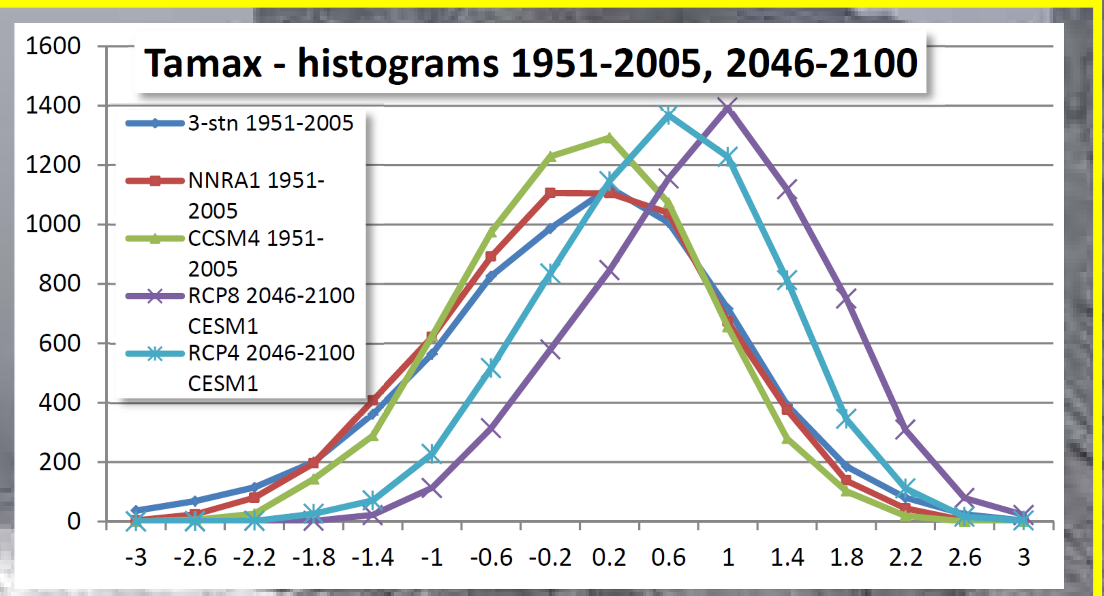

Figure 4. Full range histograms; CCSM too little: variation & skew. In future climate simulations skew doubles

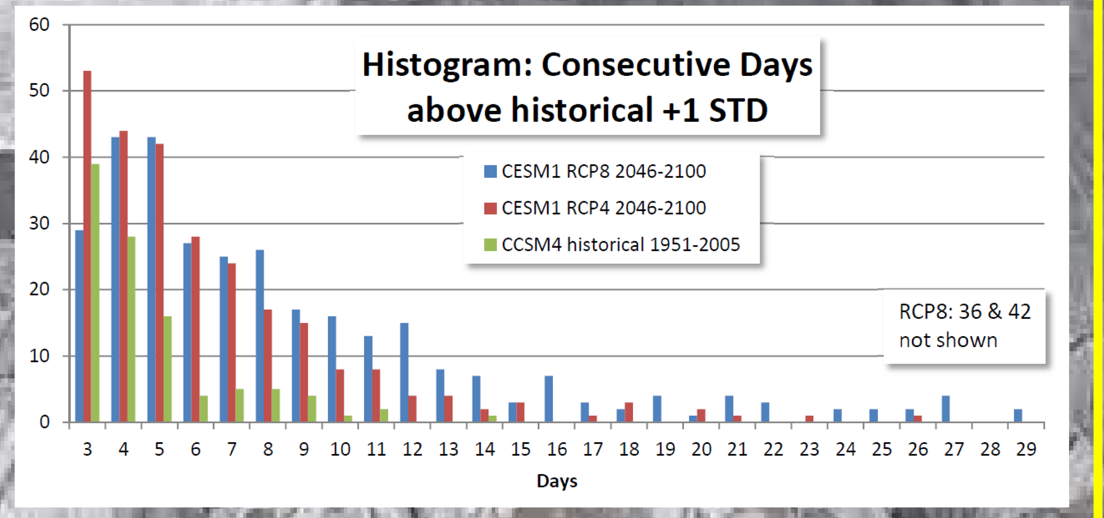

Figure 5. Durations above threshold of 1 standard dev. (of historical data).

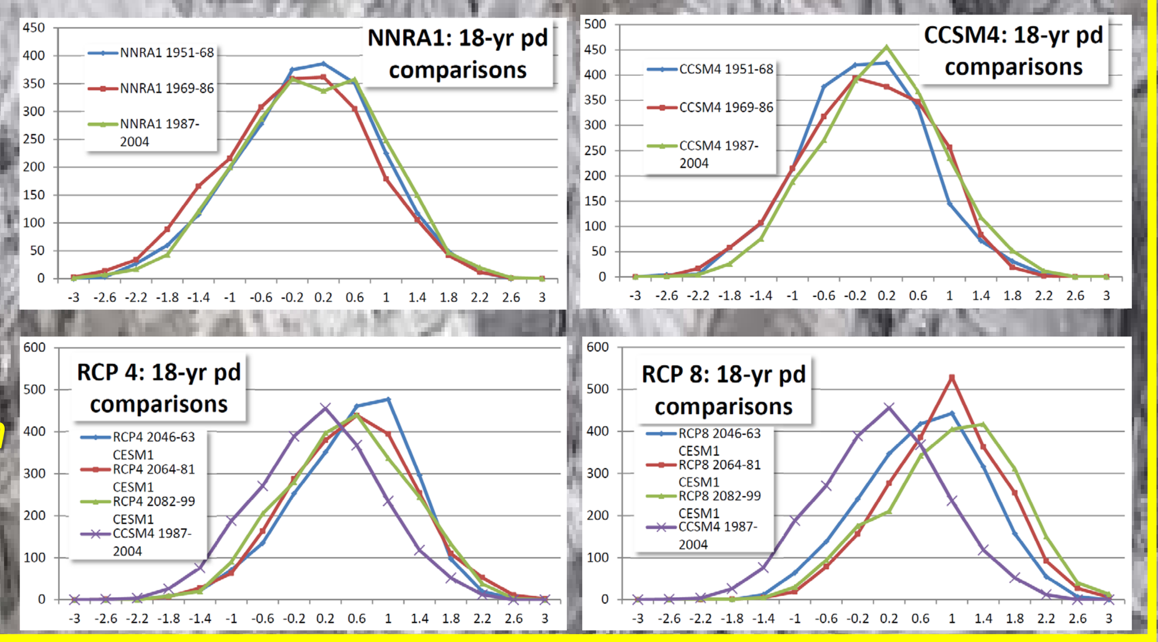

Figure 6. Trend between 18-year periods exceeds inter-period variability in RCP8 but maybe not RCP4

8. Conclusions

1. CV unresolved so use LSMPs-based index as proxy for surface max temperatures.
2. Model LSMPs similar to reanalysis-based LSMPs but too weak in CCSM. CCSM would not generate the hottest days adequately or often enough in historical runs.
3. In RCP scenarios, median shifts (0.5 – 1. std. dev.); skew doubles as min shifts less. Durations above 1 std. dev. increase greatly.
4. Return values (RV) increase greatly. In both RCP cases 20year RVs exceed historical asymptote, i.e. unprecedented values.
5. RCP cases have PDF trend. For RCP8 trend exceeds inter-decadal variability.

9. Acknowledgment & References

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