# On CCSM4 Versus Reanalysis Dynamics of Western North America hot spells

*Richard Grotjahn, Yun-Young Lee, Rui Zhang*
*Atmospheric Science Program, Department of L.A.W.R., University of California, Davis, 95616*

## 1. Prior work & Motivation

Previous work (Grotjahn and Faure,2008; Grotjahn 2011, 2013, 2014) find: Large Scale Meteorological Patterns (LSMPs) that amplify extreme heat in California Central Valley (CCV) on a regional scale. The LSMPs are an equivalent barotropic, nearly-stationary wave train (ridge-trough-ridge) across N. Pacific and western N. America. Model LSMPs are weaker and occur less frequently in CCSM4. LSMPs in the model do not incorporate unresolved topography and missing local circulations.

A motivation is to uncover the dynamics of the hot spells LSMPs in reanalysis and model data. Emphasis here is on Wave Activity Flux (WAF, Takaya & Nakamura, 2001, form), backwards trajectories, & diabatic heating.

## 2. JJAS Data

"NNRA1"= NCEP/NCAR reanalysis 12 GMT daily data at 2.5x2.5 LatxLon, 17 P levels, 6 hr resolution. 1981-2010.

CCSM4 interpolated to corresponding resolution (1970-1999)

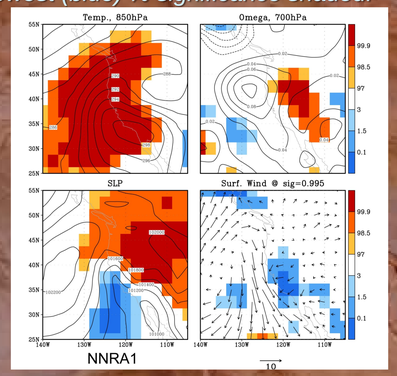
## 3. Hot spells identification

1. Remove long term daily means (LTDM)
2. Normalize by LTDM standard deviation (SD)
3. Apply to 15 CCV surface stations (5 grid points in model data)
4. Event onset if at least 6 stations (3 model grid points) exceed their hottest 5%
5. These dates define target ensemble for WAF, trajectories, other calculations.
6. 22 NNRA1 events; 24 CCSM4 events over 30 years

## 4. Synoptics

Thermal anomaly max near coast, SLP low at coast, strong offshore (downslope) flow; enhanced sinking.
Patterns in $T_a$, vertical motion, SLP gradient, and northerlies extend further north in CCSM than NNRA1.

*Figure 1 Ensemble averages at onset of hot spells in NNRA1 & CCSM4. Highest (red) lowest (blue) % significance shaded.*




## 5. Backwards trajectories

Most NNRA1 tracks from west, CCSM tracks from south; further north CCSM has west tracks; all sink over region

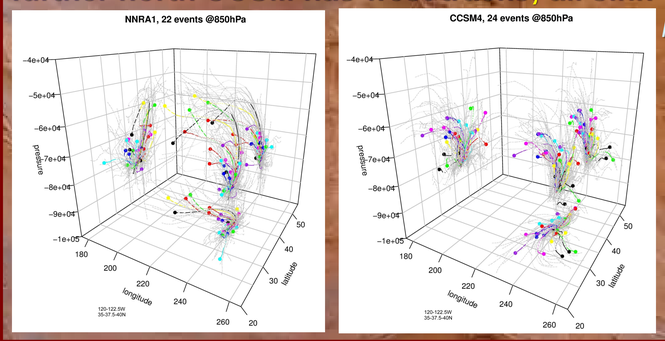
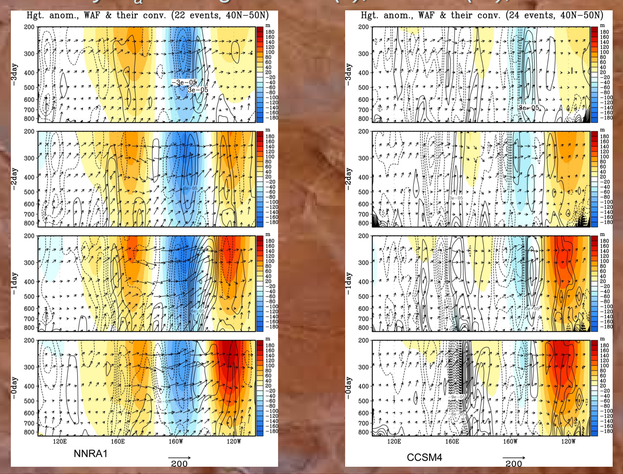



*Figure 2. Backwards trajectories: 3-D & 2-D projections over 4 days prior to onset for NNRA1 and CCSM4. Note different origins.*

## 6. WAF and diabatic heating evolution NNRA1 & CCSM4

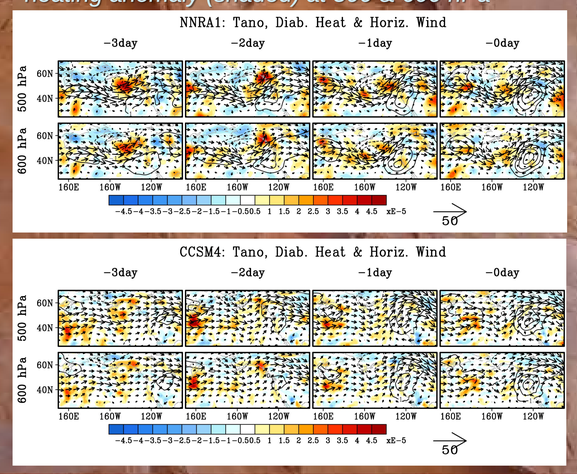
### $Z_a$, *W, & W* convergence weaker in CCSM upstream, only ridge similar to NNRA1

*Figure 3. W vectors, $-\nabla\bullet W$ contours, geopotential height anomaly: $Z_a$ shading. NNRA1 (L), CCSM4 (R ), at 40-50N.*




### NNRA1 paths cross strong diabatic heating to build ridge (not in CCSM)

*Figure 4. wind vectors; T anomaly (contours), diabatic heating anomaly (shaded) at 500 & 600 hPa*




## 7. Hot Spells Conclusions

1. NNRA1: LSMP evolution consistent with WAF convergence building: mid-Pacific trough & W coast ridge (KE increase) and W coast ridge (temperature increase)
2. NNRA1: Some trajectories from subtropics while *many* are zonal & pass through diabatic heating region ahead of trough. Then high potential temperature air aloft sinks over western US coastal region enhancing surface hot spell: adiabatic warming, lowered & intensified subsidence inversion, blocked sea breeze. Do 2 paths mean two ways to generate hot spell conditions?
3. CCSM4 has weaker: LSMP and WAF. $Z_a$ & WAF convergence patterns similar only where hot spell located.
4. CCSM4 trajectories from subtropics, not from west, before arriving at location where max sinking occurs. Model paths cross weak diabatic heating ahead of trough, sink over western US inland. CCSM LSMP extends much further north.
5. So: WAF weaker & origin of hot air more meridional in CCSM4 than in NNRA1 data. CCSM LSMP extends further north, but missing diabatic enhancement.

## 8. Acknowledgment & References

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