Downscaling Using Significant Features In Circulations Present On The Hottest Days In The California Central Valley

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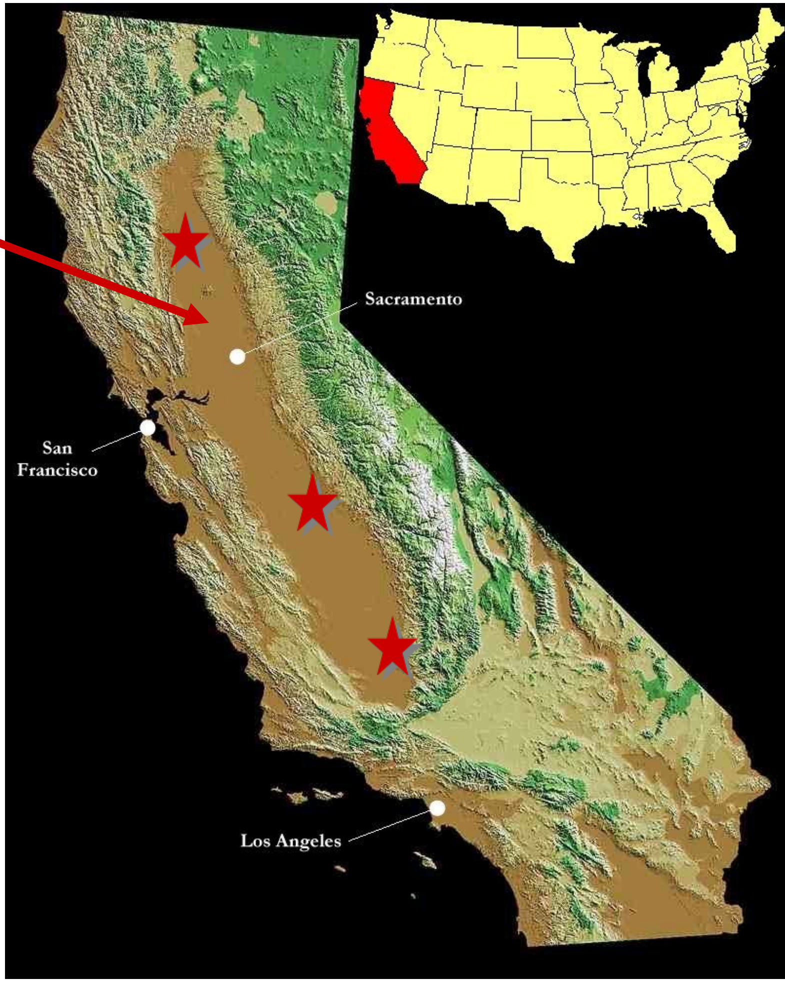
Outline of Talk:

1. California Central Valley (CV) Geography
2. Some statistical notes
   – Misleading monthly means, bootstrap, etc.
3. Observed patterns during CV hottest days
   – Synoptic situation
   – Hottest days target composites
4. Prototype downscale analysis/hindcast ‘pilot scheme’
   – Upper air downscale link to surface observations
   – Design & Performance
5. Climate model application (preliminary)
   – CESM ability to generate the large scale pattern
6. Conclusions & Future work

1. California Geography

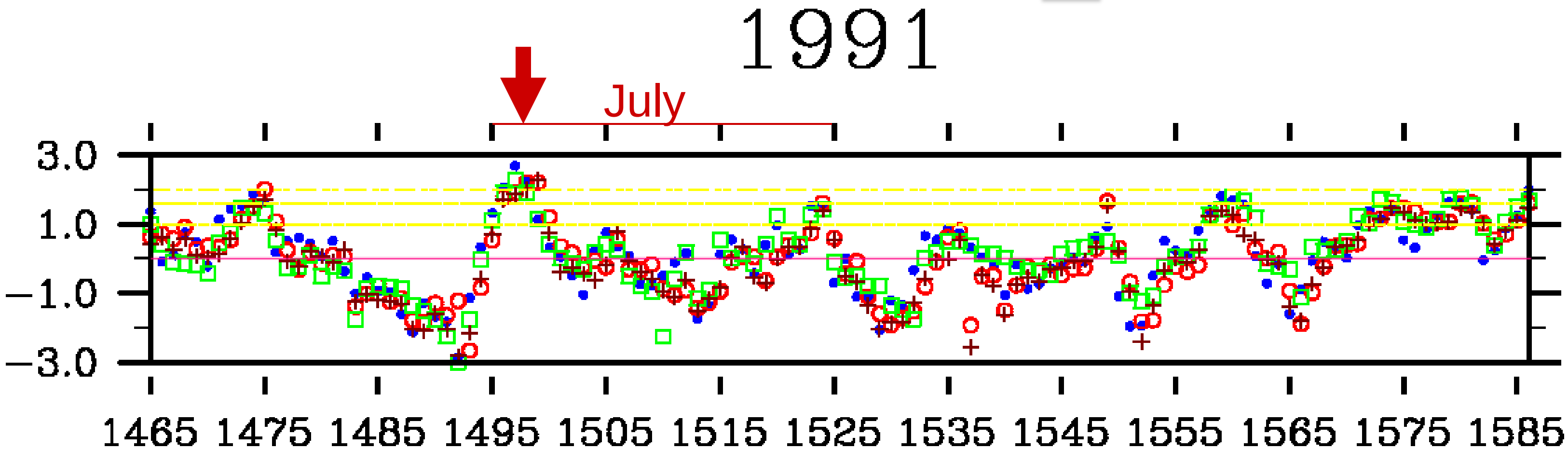
- Will make application to California Central Valley (CV)
  - 3 stations averaged ★
- CV extreme events.
  - Most only last a few days
  - Have big impact upon crops, infrastructure, people.
  - Might not show up on monthly means.
- Though ephemeral, they can be important for climate.



2. Some statistical notes

1. Monthly means miss extremes
2. Target dates from surface max temperature
3. Target ensembles of upper air data.
4. Bootstrap resampling
5. Other statistical considerations
6. (later) standard and extreme statistics tests to the data and pilot scheme

Monthly means miss extremes: Jul. 1991 CV Ta_max



Daily anomaly temperatures at 4 CV stations June-Sept. 1991
Normalized by each station's STD. Pink line is LTDM.

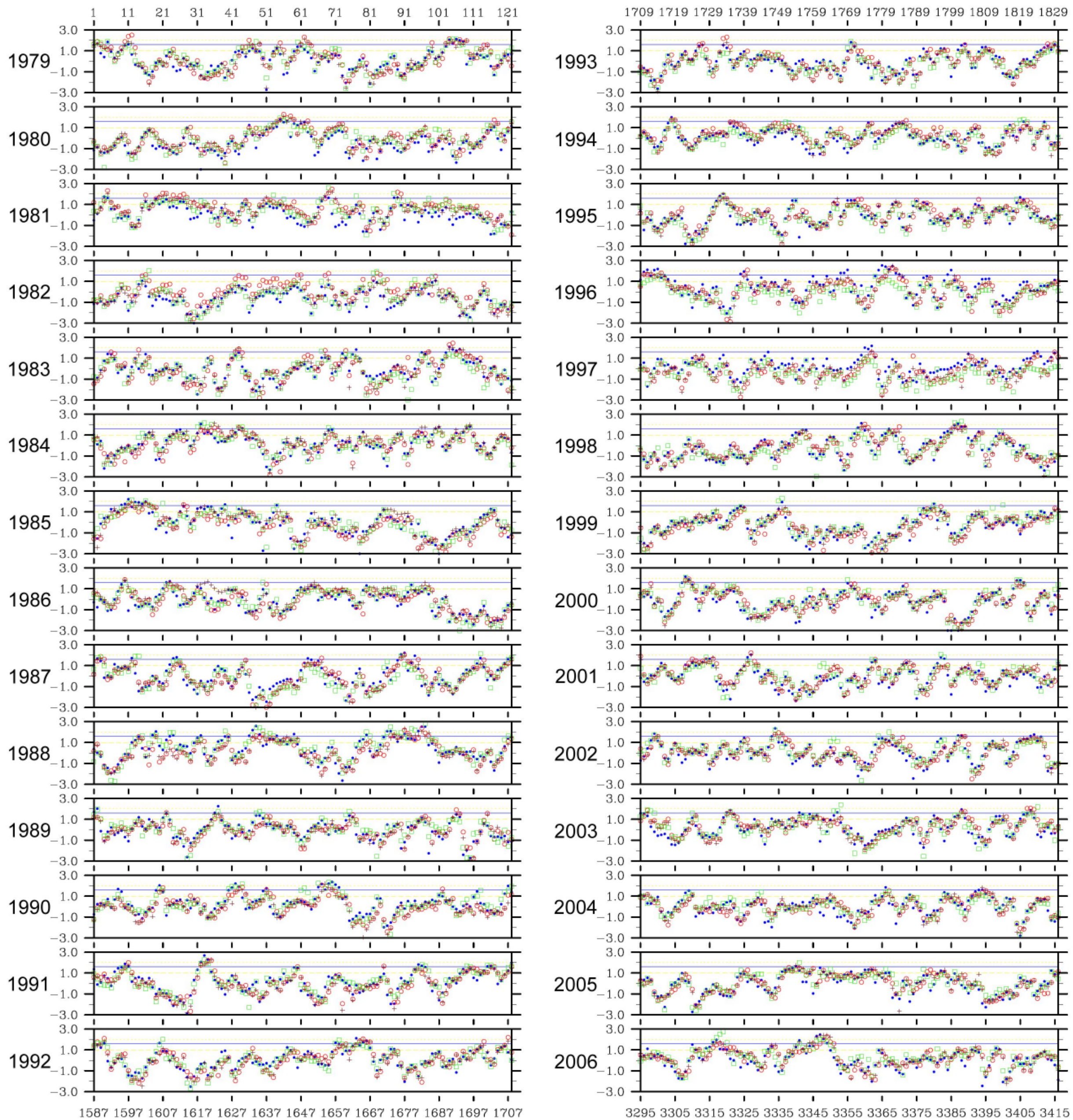
- The hottest days in at least 30 years.
- Daily anomaly temperatures show 4 days of extreme heat
- Rest of month was generally below average.
- The mean for the month? -0.2 STD (Standard deviations). Below normal!

- **A cooler than normal July had one of state's hottest heat waves**
- Conclusion: **The monthly mean misses this important event!**

June-September normalized max T anomalies @ 4 stations

Target dates

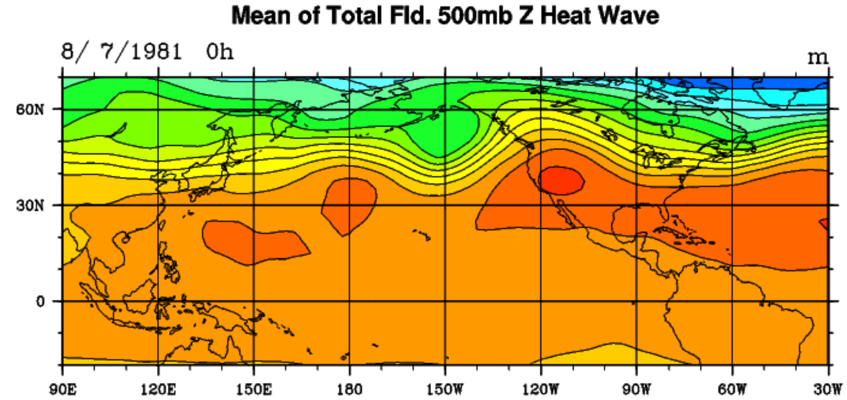
- **Time series:**
  - **Daily max temperatures at 3 CV stations (KSAC not used)**
  - **Daily anomalies normalized by each station's long term daily standard deviation**
  - **28 years (3416 dates)**
- **Define target ensemble dates**
  - **Each station's value must exceed 1.6**
  - **33 dates selected (1%)**



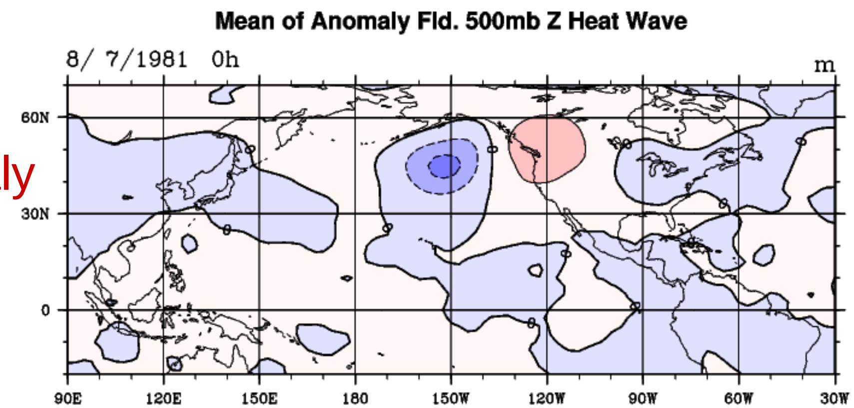
Target composites

- Define target ensemble from first 16 key dates (same as using 1979-88 as ‘training period’)
- Example: Z @ 500 mb:
  - Ensemble mean
  - Mean of daily anomalies (used by pilot scheme)
  - Significant areas identified via comparison to random ensembles
- Multiple fields tested

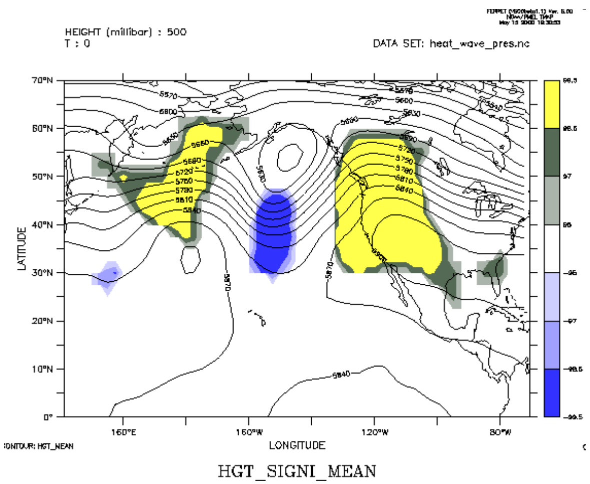
Total Field Z_{500}



Anomaly Field Z_{500}



Shading: highly significant

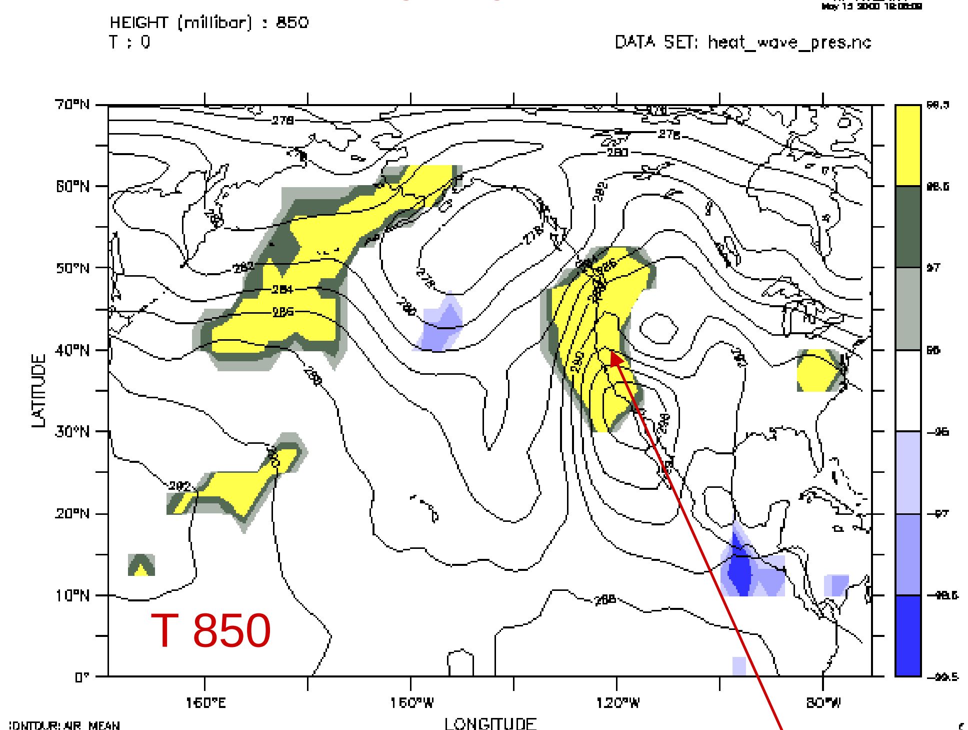


http://atm.ucdavis.edu/~grotjahn/EWEs/

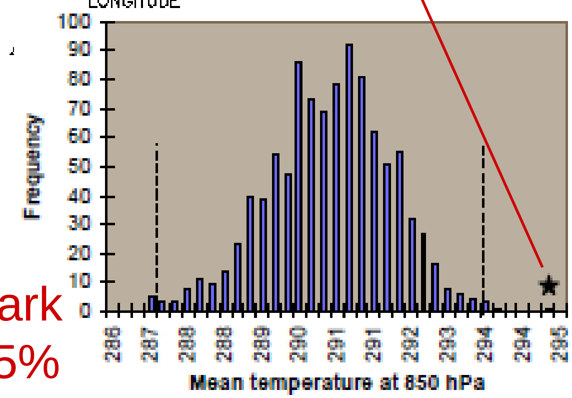
Bootstrap significance

- T @ 850mb shown
- Bootstrap resampling (with replacement) Compare target ensemble to 1000 random ensembles of the same size
  - Draw ‘random’ dates, form 1000 composites of such ‘random’ ensembles
  - Random ensembles define a distribution for each grid pt.
  - Yellow means: grid pt value highest 15 of the 1000 ‘random’ composite values
  - Blue means: grid pt value of target ensemble composite is in lowest 15
  - Highest 10 is highest 1% of values, etc.

Yellow shading: highest 1.5%



T850 distrib. @ grid pt near Sacramento. Dashed lines mark top & bottom 0.5%



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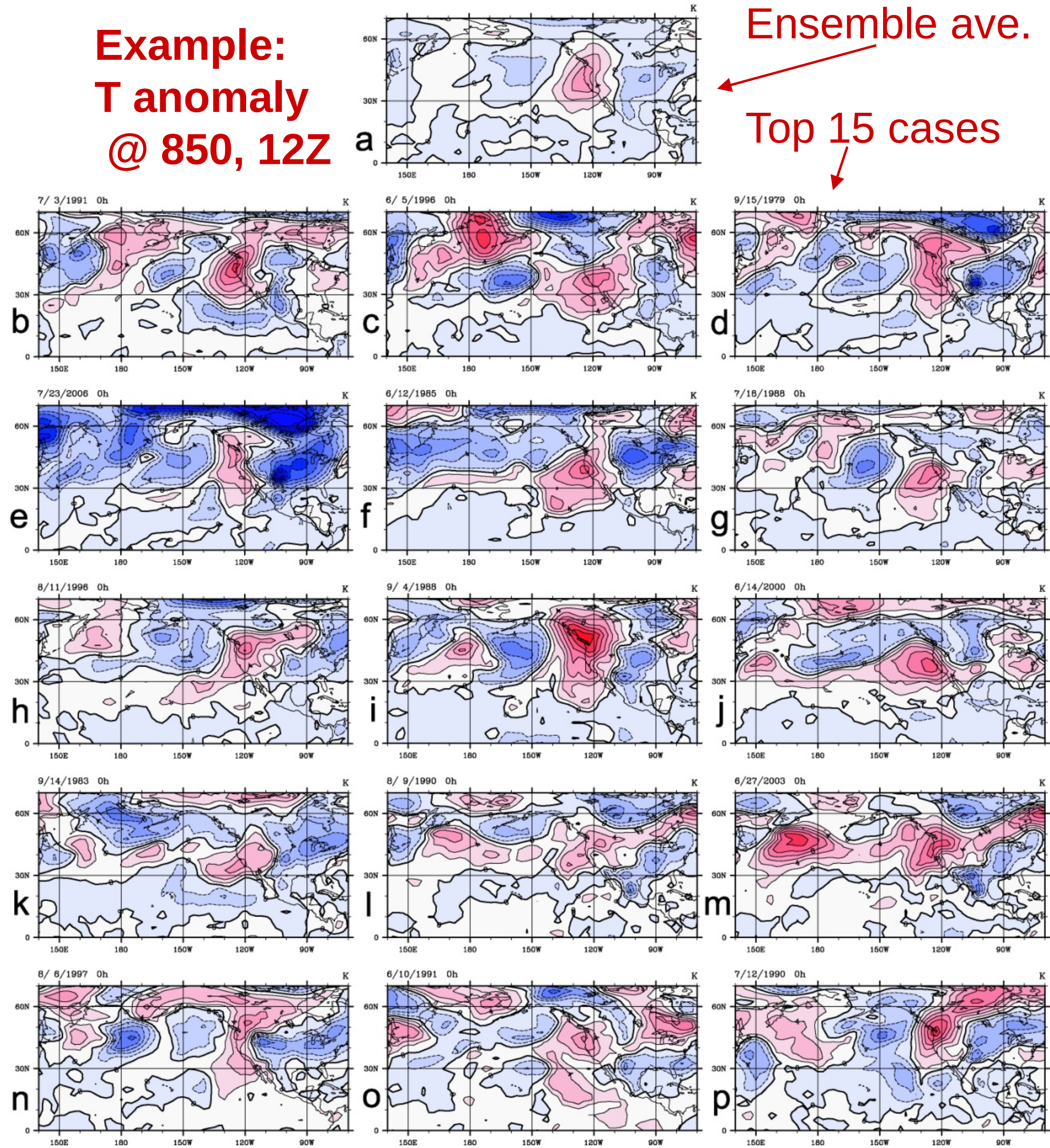
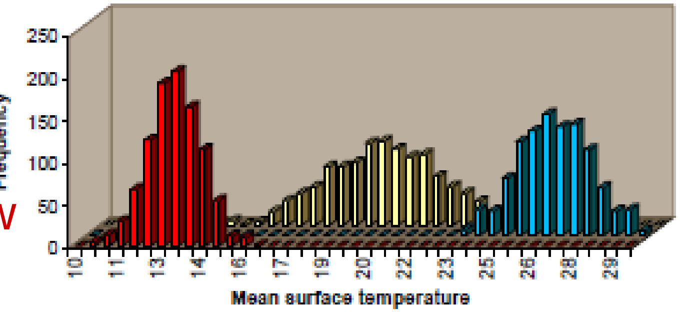
Significance vs consistency

- Significance does not guarantee consistency.
- But parts consistent for all dates of extreme heat events
  – In every case the strongest anomaly T is centered at or near west coast.
  – T850 shown for the top 15 events (b-p). 1979-2006 average of the 15 events (a).

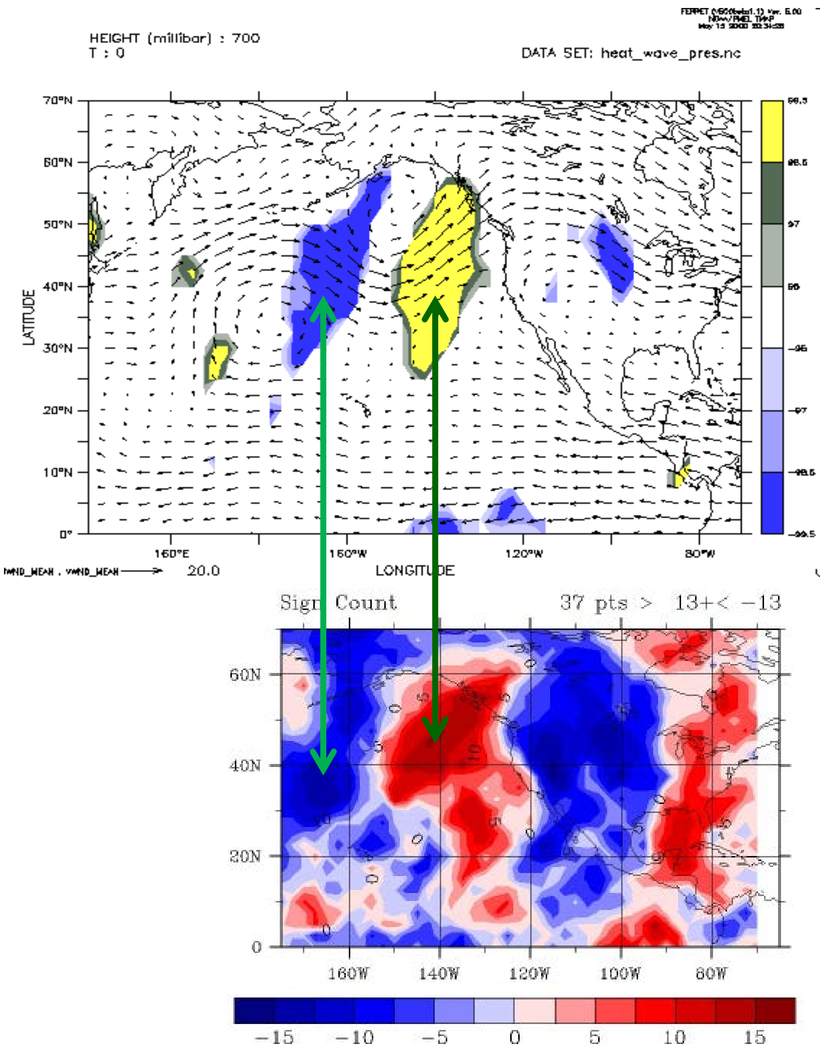


Some misc. Statistics:

12GMT - red
0GMT - blue
Mixed - yellow



- Compare same time of day (some variables have strong diurnal cycle)
- Aggregate adjacent grid points (regional significance – for similar features phase-shifted)
- Global statistical assessment of the map (how many pts are signif. Vs the number expected by chance)
- Test consistency
  - std deviation of target ensemble members vs same for random ensembles;
  - subjective comparison of the members;
  - ‘sign counts’

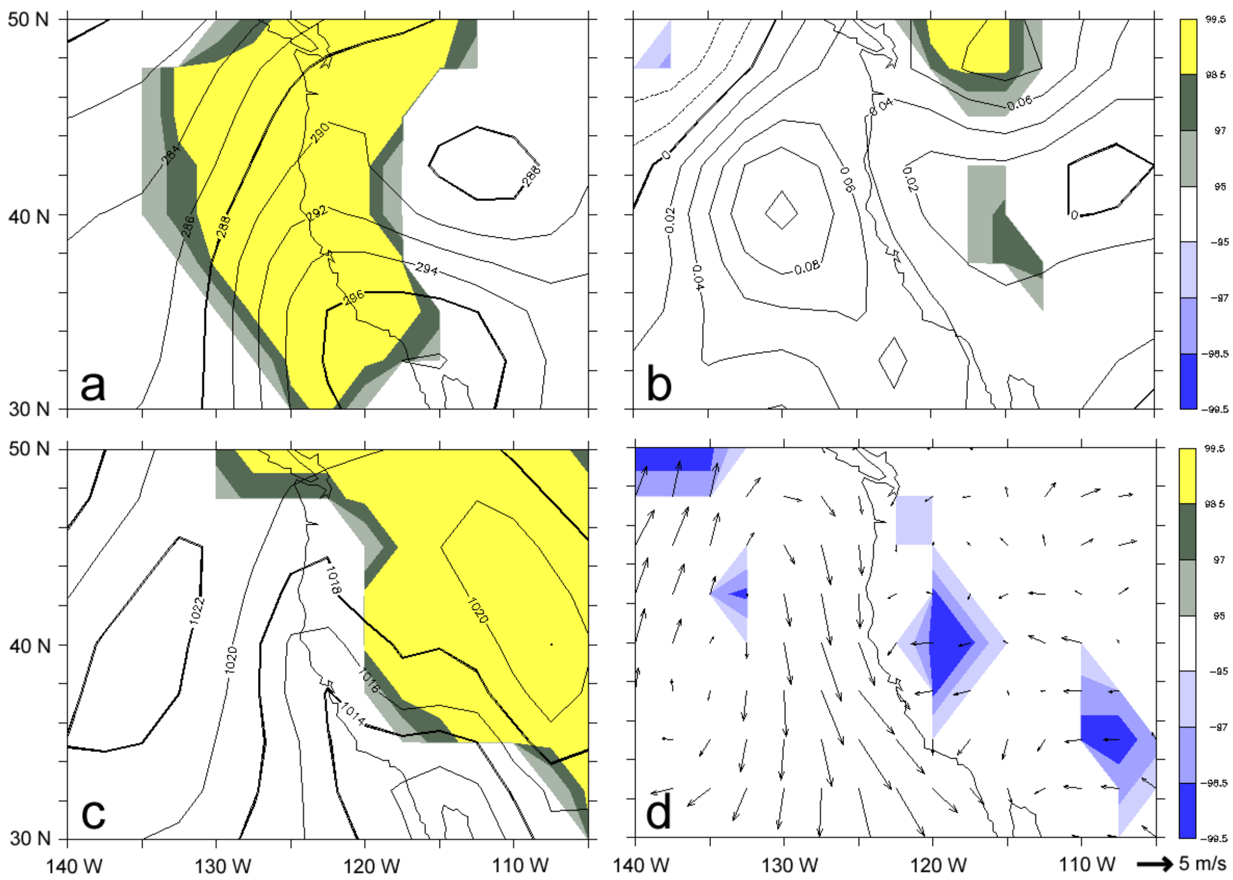


3. Extreme Weather Patterns

- **CV Hottest Days Upper Air Obs.**

Hottest Days: local pattern

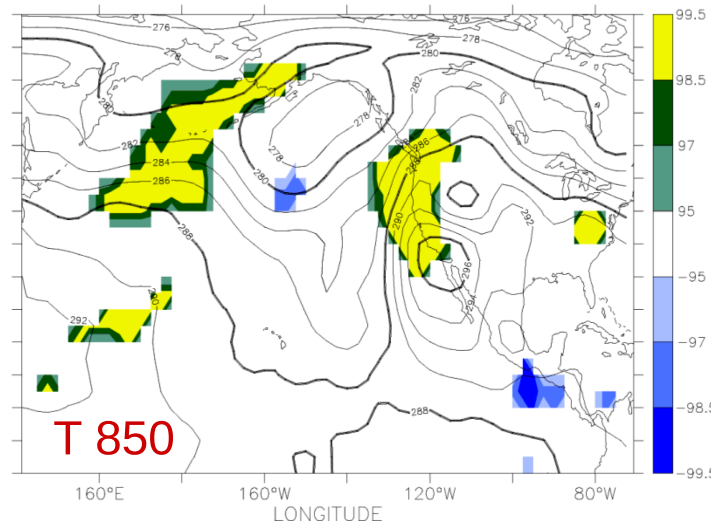
- "Local" pattern
  - Lower tropospheric T maximum (anomaly) just offshore
    - 'Themal low' offshore: offshore and downslope (weak) winds (P<800mb)
    - Lowers subsidence inversion & amplifies
    - Sinking elevates T in lower atmosphere
    - Solar heating of shallow bndy layer



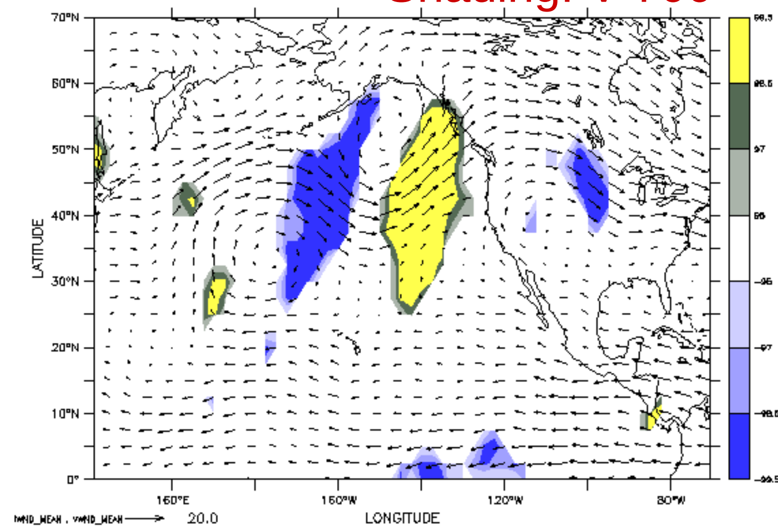
a. T @ 850hPa,
b. b. dp/dt @ 700hPa
c. SLP
d. Wind @ 850 (shading applies to u component)

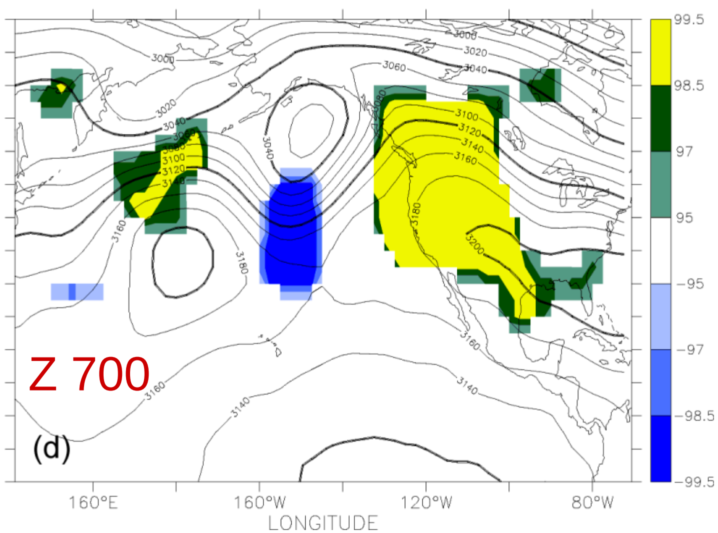
CV Hottest days upper structure

- Example target composites from severe heat waves (onsets) affecting Ca CV.
  - T at 850 hPa
  - V at 700 hPa
  - Z at 700 hPa
- Conclusion: very large scale pattern.
  - Highly significant >99% level (shaded)
  - Grotjahn & Faure, WAF, 2008
  - More posted on web, including lead-up
- Synoptic situation.
  - Large airmass displacements, including upstream, with corresponding height anomalies.



Shading: V 700

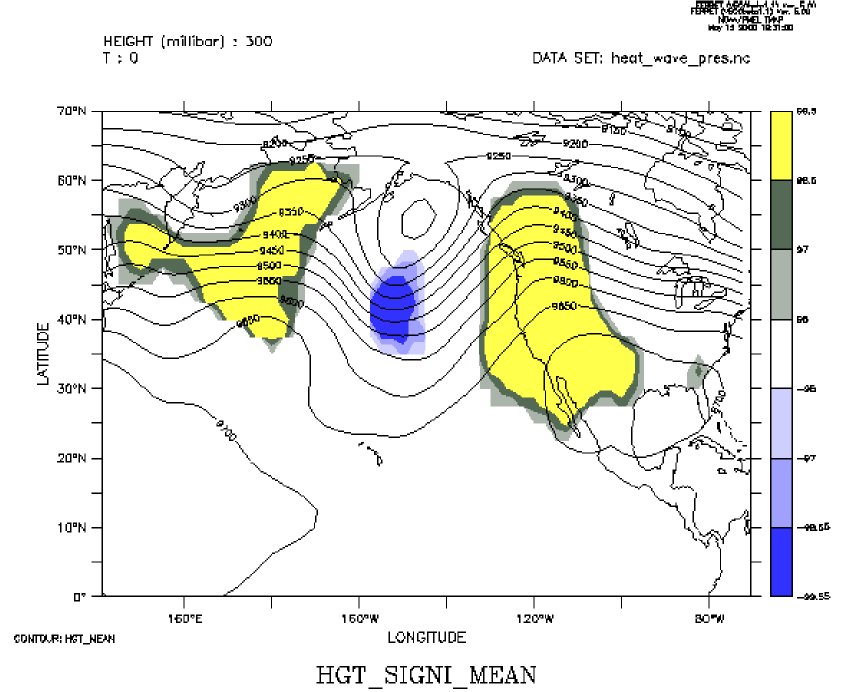




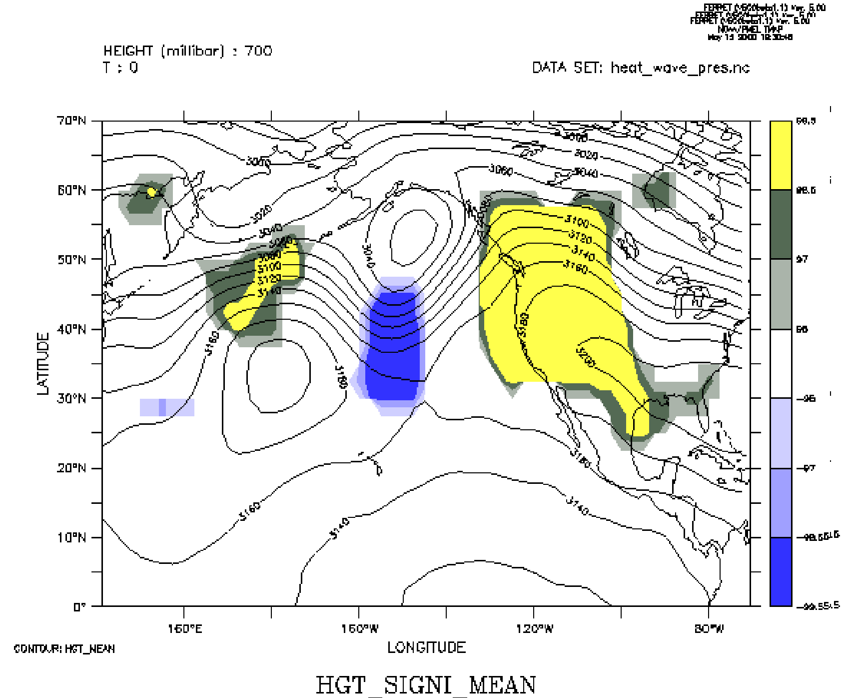
http://atm.ucdavis.edu/~grotjahn/EWEs/heat_wave/heat_wave.htm

Hottest days:

- Z 300 hPa
  - 36hr-0hr

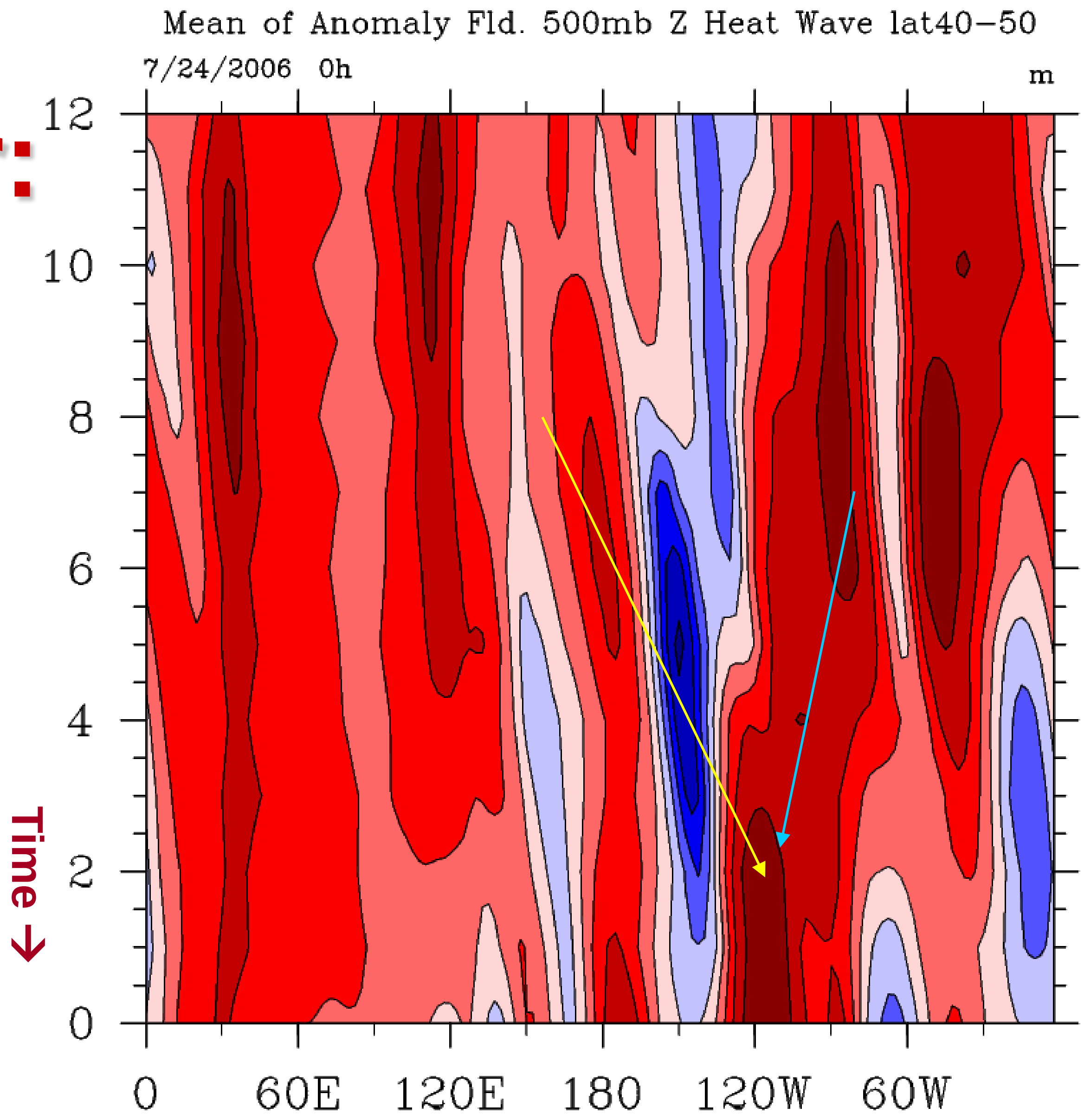


- Z 700 hPa
  - 36hr-0hr



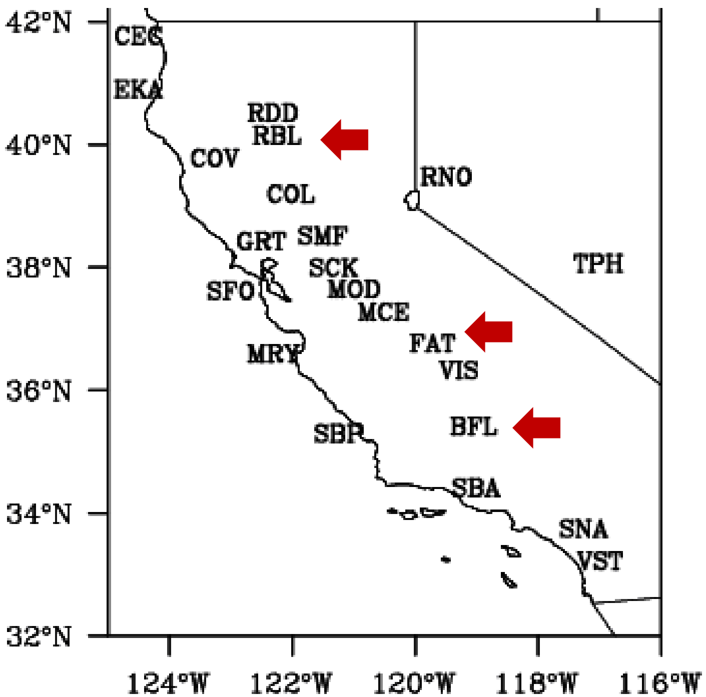
Unfiltered Hovmeuller: (time vs longitude)

- Z 500 hPa
  - 6 days -0hr



4. Pilot Scheme

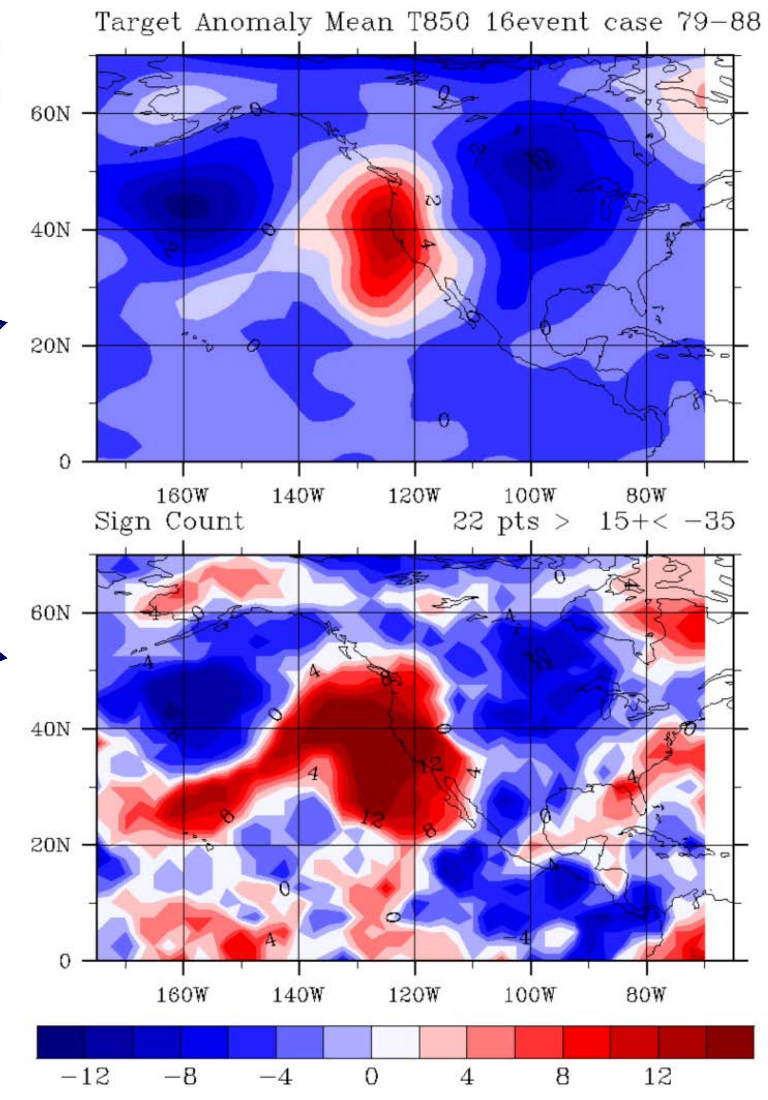
Pilot Project, part 1



- Pilot scheme described in Grotjahn, 2011, *Climate Dynamics.*
- Can one find extreme surface events from large scale upper air data?
- First find dates of obs. extreme events
  - daily anomalies of max-T = **max-Ta** for 28 summers (3416 days) 1979-2006
  - Average 3 stations spaced along the CV, (RBL, FAT, BFL)
  - Choose threshold to find hottest ~1% of max-Ta
  - 33 **'target dates'** of extreme heat were found when (max-Ta) / (std dev.) >1.6 at all 3 stations.
- Make daily anomaly fields from NCEP/DOE AMIP data: 2.5x2.5 grid.
- Make **'target composites'** of many variables on the target dates using anomaly gridded data from the **first 10 years** of data (= 16 of the target dates)

Pilot Project, part 2

- Use bootstrap to identify significant areas of target ensemble for each field
- Identify areas of consistent sign in anomaly field using 'sign counts'.
- Sign count is sum of +1 for >0, -1 for <0 at a grid point for all 16 target ensemble members. So, +16 means all 16 members had positive sign at that grid point.

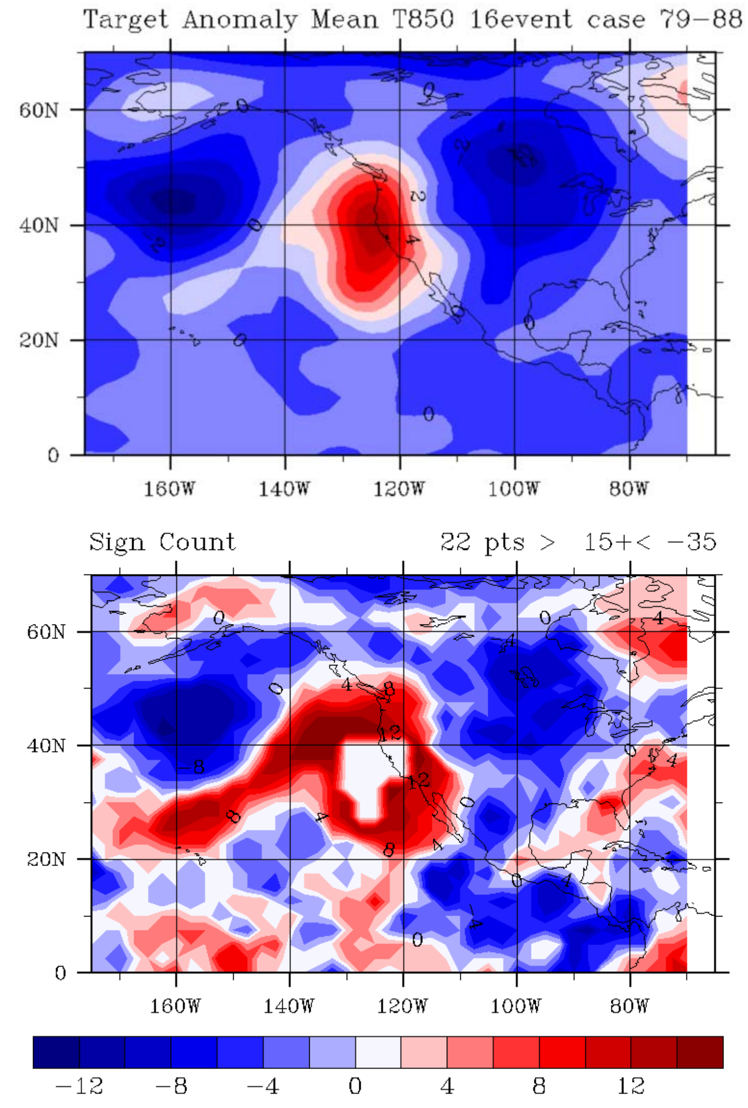


- Index based on an average of the 16 worst days at select points…

Example: Target composite and sign counts for 16 events. T850 hot consistently at & 10º ***west*** of CV

Pilot Project, part 3

- Find 'daily circulation index'
  - Project daily data onto selected highly consistent area(s) of the target composite (e.g. 'hole' in lower diagram)
  - Combine projections from variables to get an overall 'daily circulation index' for the date.
  - Index shown next combines T850 and V700 anomaly data. Goal is to hit most number of target dates
- Index based on 16 hottest (anomaly) days in CV during 1979-88…
- but applied to 1979-2006



Example: Target composite and sign counts for 16 events. T850 hot consistently at & 10º ***west*** of CV

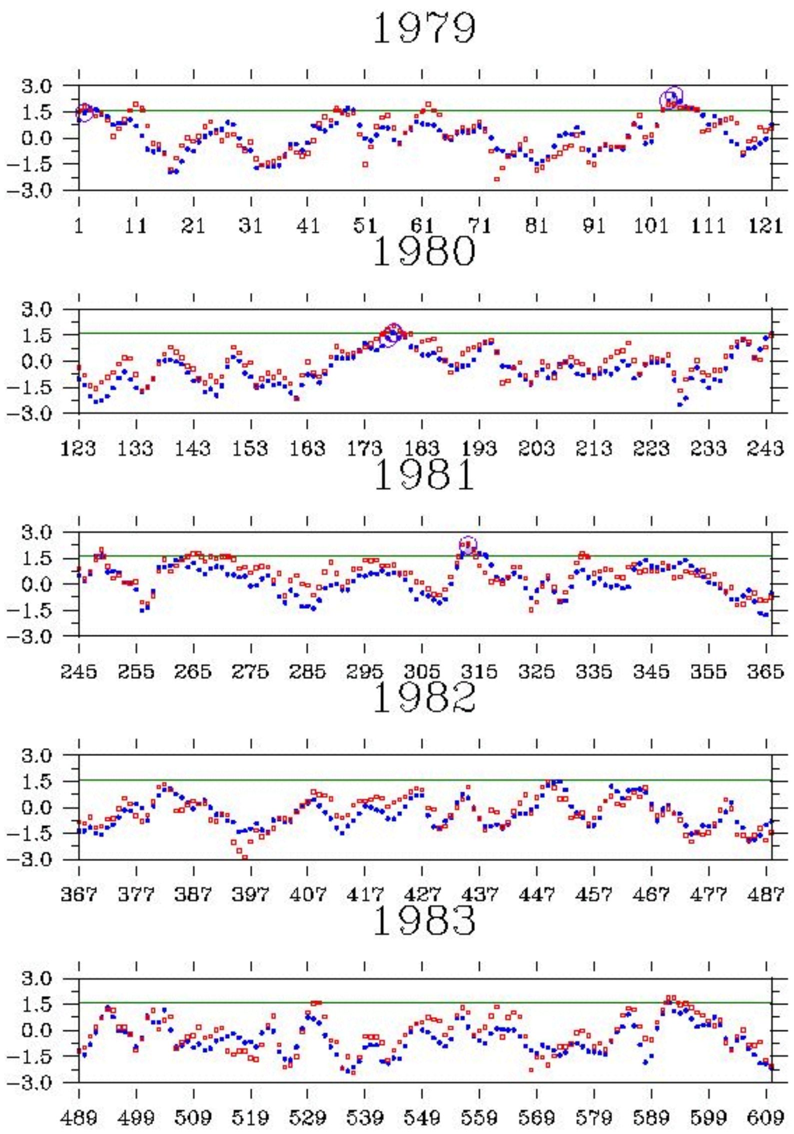
Pilot Scheme Results

- Plots compare index & obs. max T for all 3416 days of the 28 year period.
- Animation of time series
  - Observed anomaly (red)
  - Circulation index (blue)
  - Extreme event dates (blue circles)

- Performance (capturing extremes)
  - Highest 33 values of index match 15 of the 33 (46%) highest 1% events.
  - 15 of remaining 18 values of index are top 2% of obs. events
  - Skill similar outside training period

- Index picks up cold and near normal events very well, too.
  - Correlation between index and surface obs: 0.84
  - Bias: 0.04 F (index ave.)
  - Mean error: ~3C (comparable to WRF)

- Picks up many extreme surface events. Even outside period.



EVS scores

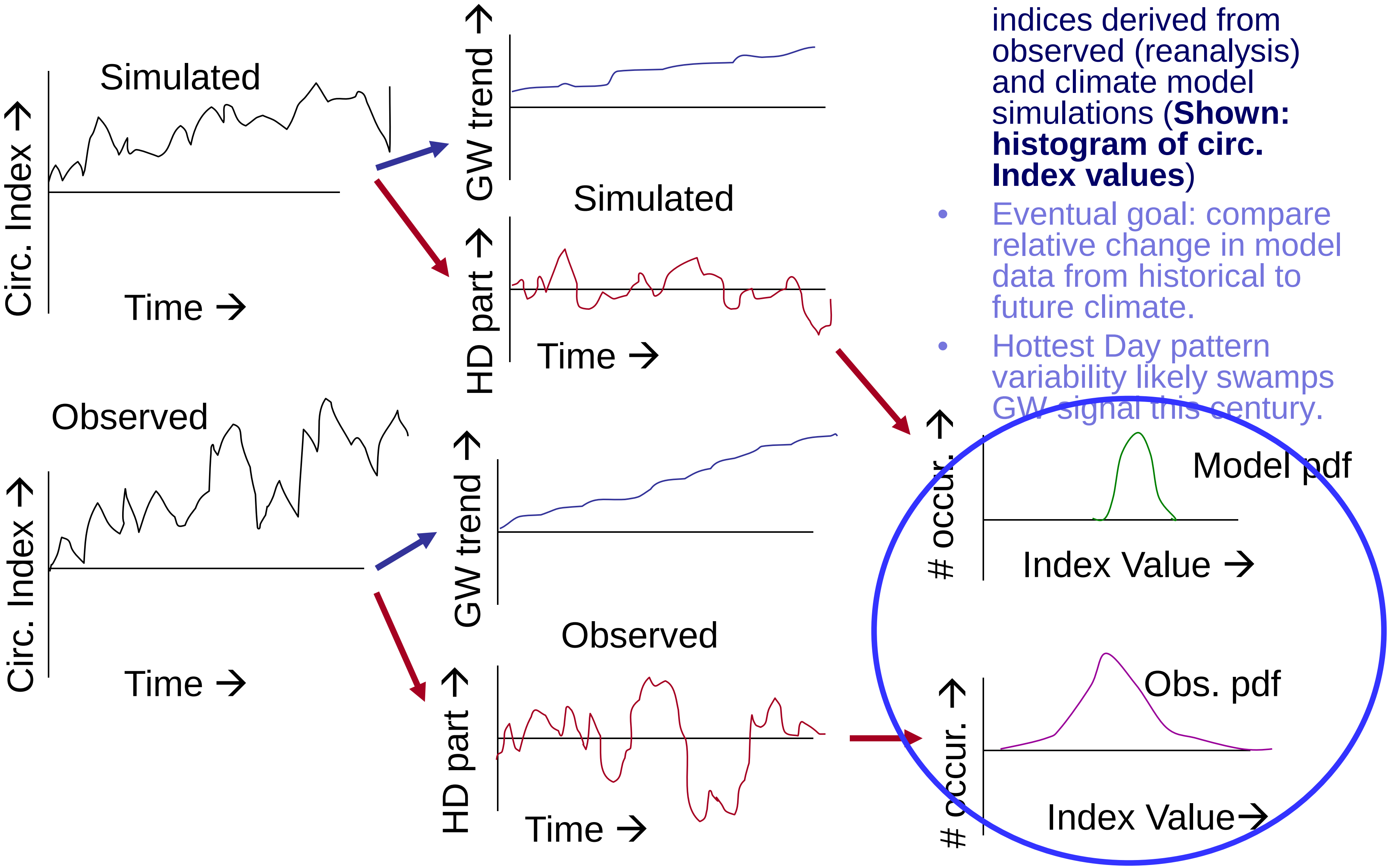
- Pilot scheme has skill in measures of rare events.
- Scheme better than ‘obvious’ alternative choices.
- 2 predictors superior 1

Table 3. Comparisons of skill and fit of extreme values in pilot scheme and alternative predictors
* estimated skill measure if random guesses are used

	Observed 3-station average	Pilot scheme (T850 & V700)	Pilot Scheme (Only T850)	3 CV grid pts: 12 GMT	3 CV grid pts: 0 GMT
Skill in capturing dates of high extreme temperatures					
Dates matching original 33 (1.6 threshold)	33	15	11	10	7
Dates of largest 30 in 3-station average	30	11	10	10	7
POD (Probability Of Detection) *0.0097 if random	–	0.4545	0.3333	0.3030	0.2121
FAR (False Alarm Rate) *0.9903 if random		0.5454	0.6667	0.6969	0.7878
CSI (Critical Success Index) *0.0049 if random		0.2941	0.2000	0.1786	0.1186
EDS (extreme dependency score)	1.0	0.71	0.62	0.59	0.50
Generalized Pareto Distribution fit using top 33 values					
Scale parameter (σ)	0.147	0.205	0.294	0.246	0.251
Shape parameter (ξ)	0.010	0.009	—-0.249	—-0.304	—-0.184
Location (specified)	1.858	2.04	2.35	2.07	2.00

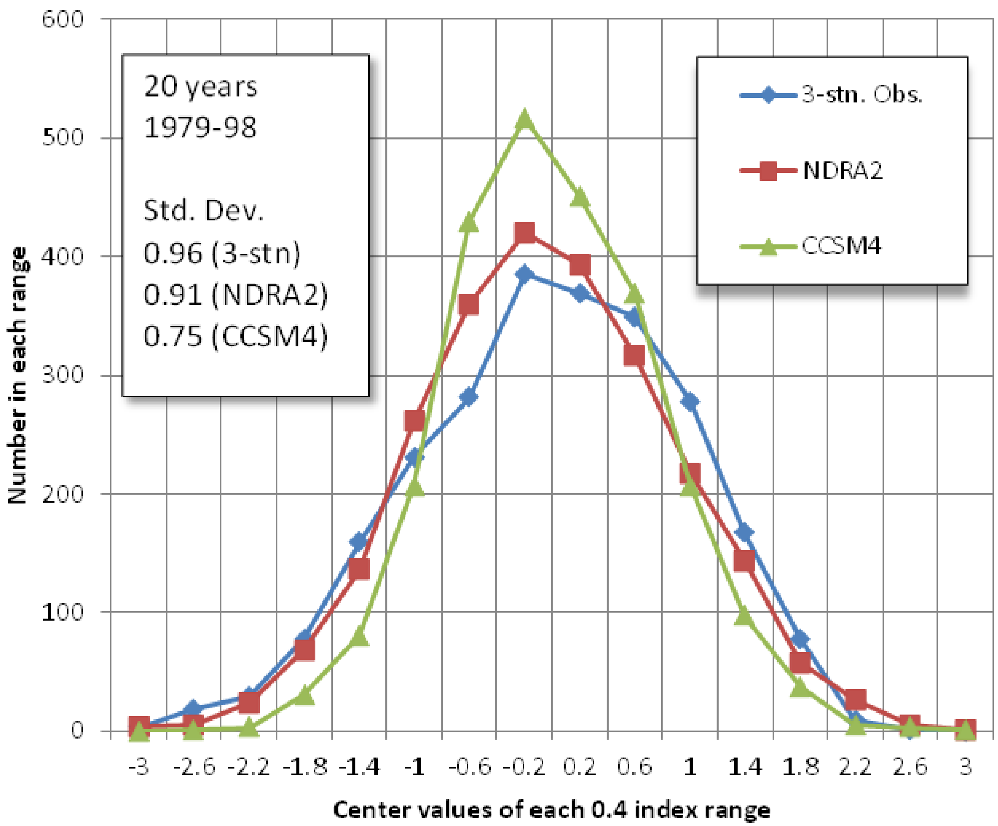
5. Climate Model Application (CCSM4, Preliminary)

Rescale GCM Simulations



- Compare time series statistics of circulation indices derived from observed (reanalysis) and climate model simulations (**Shown: histogram of circ. Index values**)
- Eventual goal: compare relative change in model data from historical to future climate.
- Hottest Day pattern variability likely swamps GW signal this century.

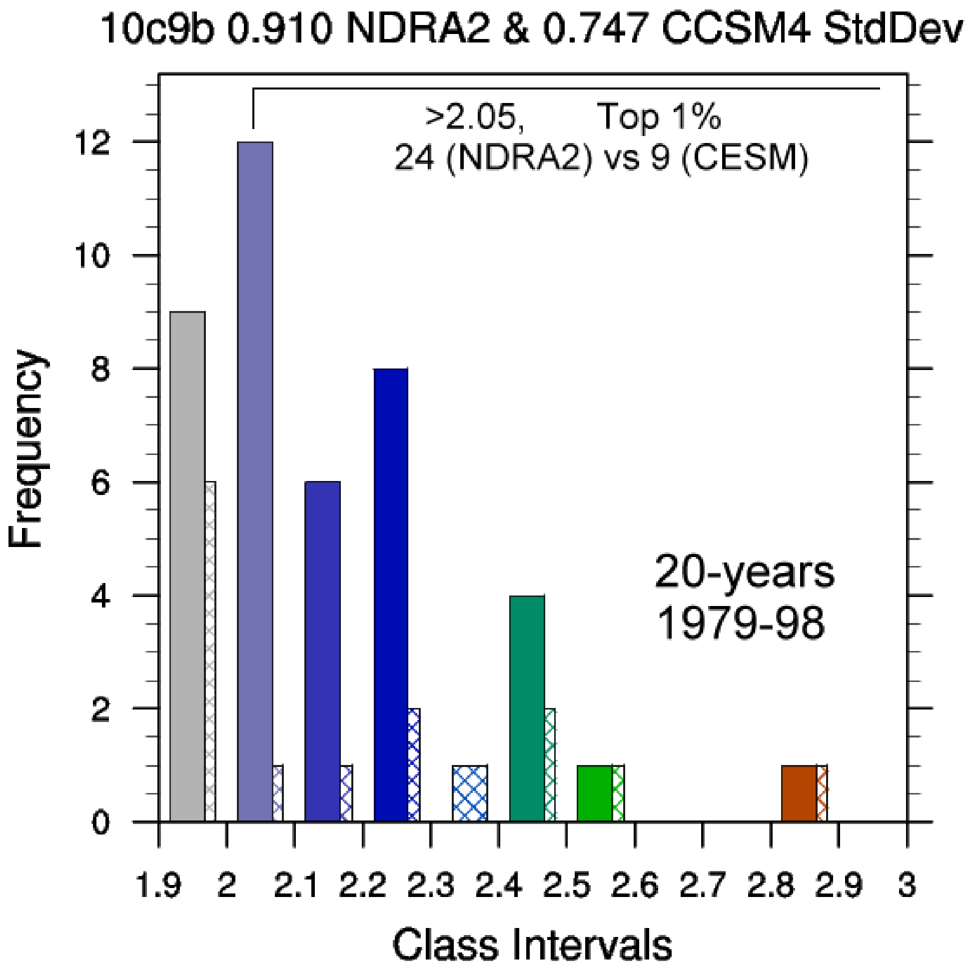
Comparison Histograms



- 3-stn vs ndra2 vs CCSM4 pilot scheme circulation index.
- CCSM4 std dev too small:
  - 3-stn, NDRA2, CCSM4
  - 1.00, 0.91, 0.67
- CCSM4 skew reversed:
  - 3-stn, NDRA2, CCSM4
  - -0.31, -0.05, +0.28

- **Hottest days in model will be too weak, too infrequent**
  - **Top 1% 9 vs 24 in 20 years**
- Coldest days will be missed
- Large scale errors cannot be overcome by an RCM

Comparison Histograms



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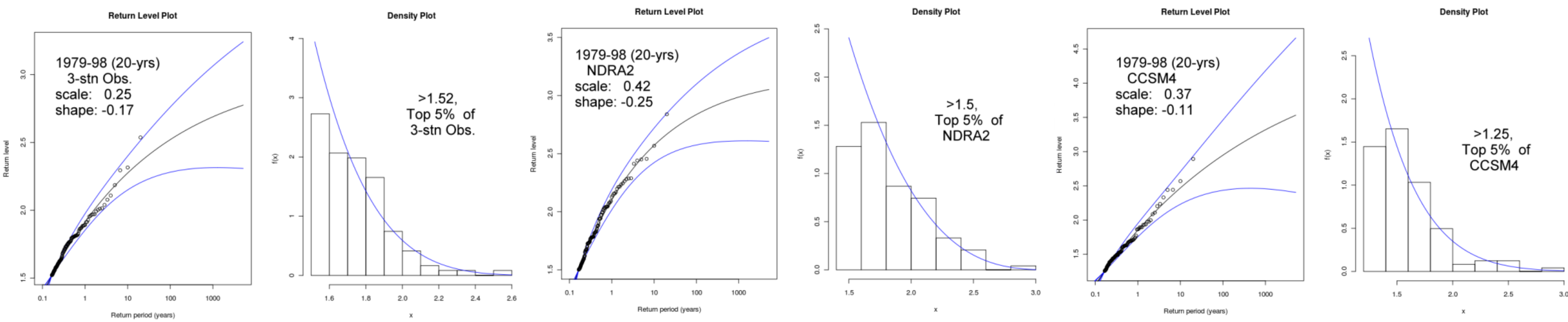
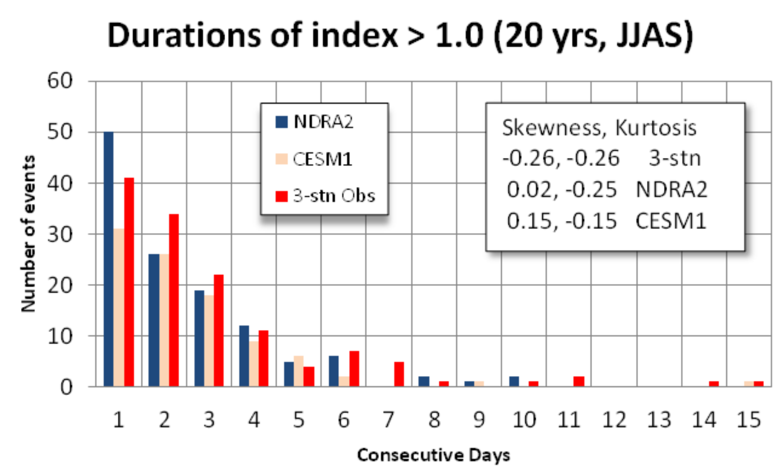
GPD & Duration Parameters

1. GPD fits for top 5 % of:
   …….. Obs v NDRA2 v CCSM4
   Scale: 0.25, 0.42, 0.37
   Shape: -0.17, -0.25, -0.11

Shape: CCSM4 has longer upper tail hence weaker upper bounds on hottest days pattern.



2. Durations of periods above thresholds. CCSM4 tail is heavier. Similar to NDRA2 and surface obs but only if <u>CCSM4 data rescaled by the smaller standard deviation</u>



6. Summary & future work

- **CV hottest day events**
  - **Short term events can have big impact,**
  - **Might *<u>not</u>* appear in monthly means**
  - **Have large scale patterns, parts very consistent & significant**
- **Propagation dynamics**
  - **Pattern develops over several days, from far distant locales**
- **Pilot project of California Central Valley heat waves**
  - **'circulation index' from daily pattern match to target composites**
  - **Index is skillful in finding extreme, very rare hottest events**
  - **Index picks up variability (warm, near normal, even cold days)**
- **Climate model application (CCSM4)**
  - **Calculated circulation index from 20-years of CCSM4 data**
  - **CCSM4 does not make hottest days pattern with enough amplitude**
  - **The large-scale pattern error cannot be overcome by RCM**
- **Future work**
  - **Improving circulation index procedure to capture extreme events**
  - **Evaluate a longer period of CESM data**
  - **Investigate the pattern dynamics (useful to improve model)**
  - **Evaluate relative change in IPCC scenarios;**
  - **Do same process for other extreme events**

The End

Thank you for your attention

Questions?

4. Pilot Project (background)

- T at CV stations fairly similar
- Correlations with Sacramento range, N to S:
  - 0.83 (RDD), 0.87 (RBL) to 0.83 (FAT), 0.86 (BFL)
  - N half of CV sfc T changes often lead S half by up to a day
- July 1991 event (worst in SMF July 2-4)
  - A very weak sea breeze can interrupts event (Stockton)
- CV max T coherent if avoid stations near the delta