Large Scale Weather Patterns Associated with California Heat Waves and their use in a Hindcast and Future Climate

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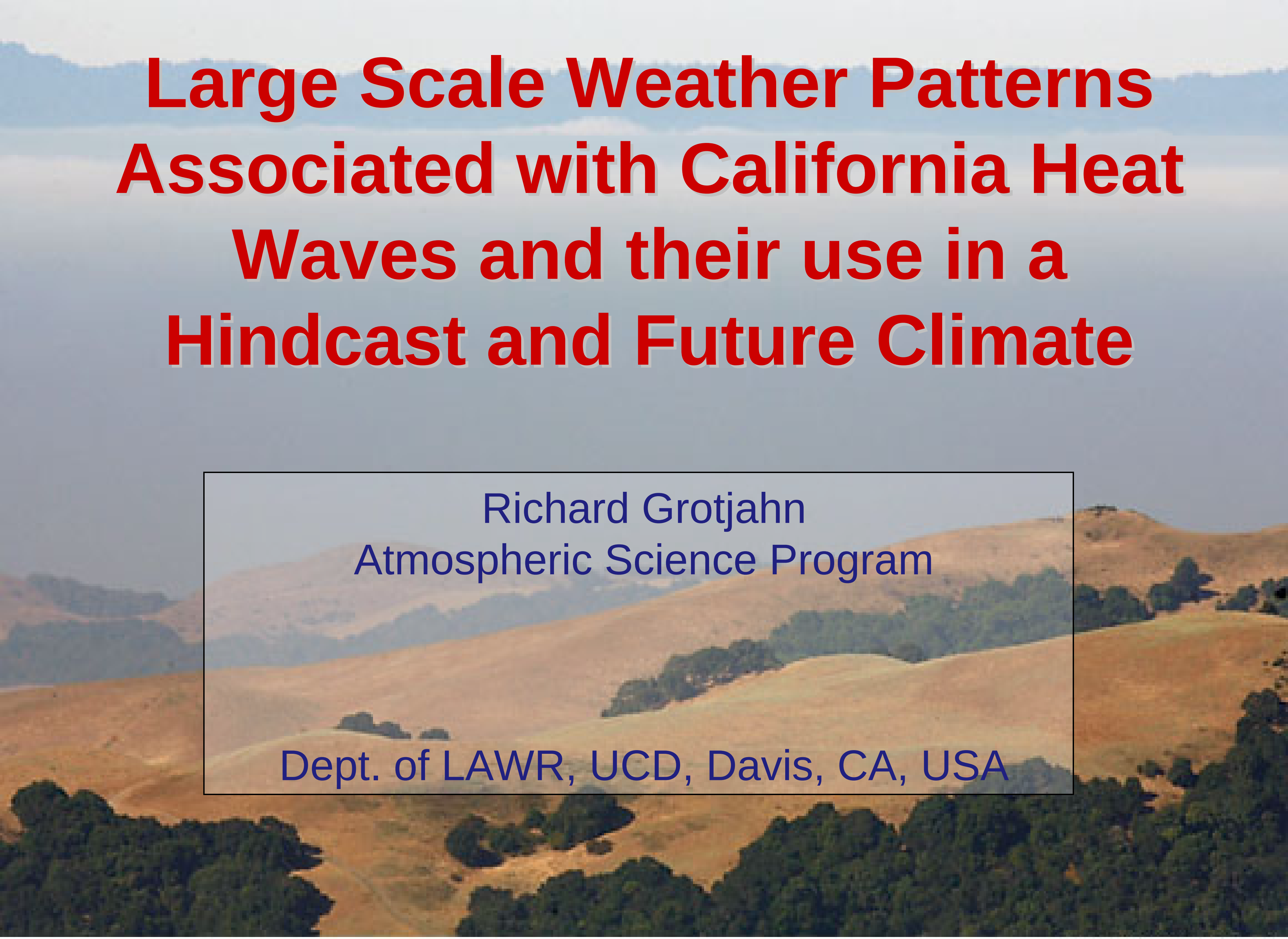

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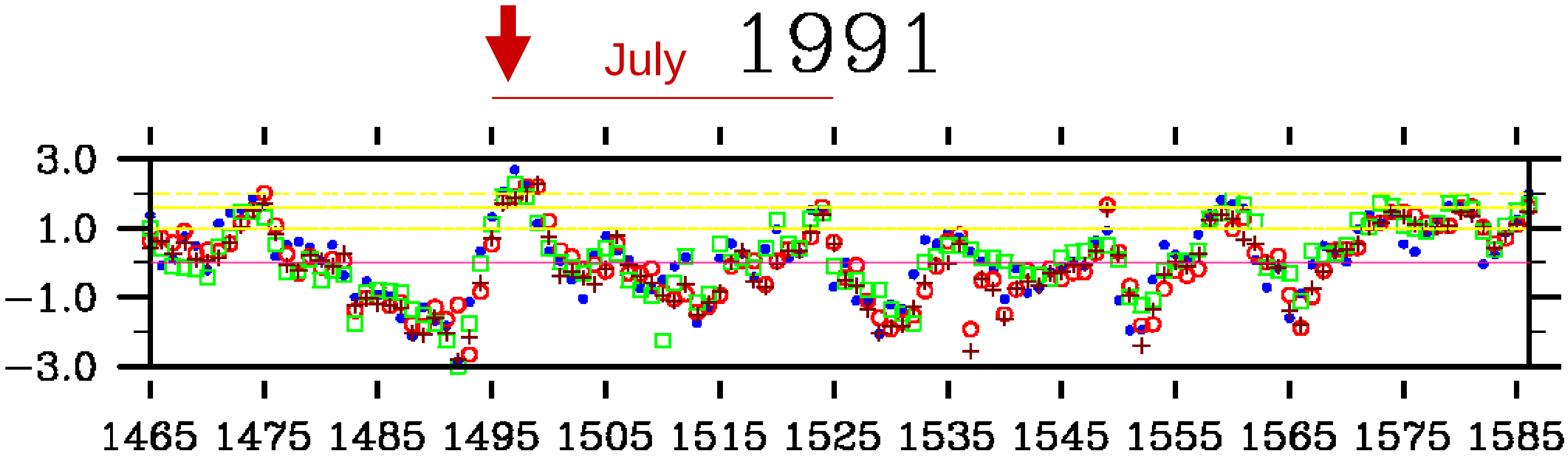
Outline of Talk:

- **CV Heat Wave Surface Obs.**
  - Short term events
  - Misleading monthly means
    - California, July 1991
- **CV Heat Wave Upper Air Obs.**
  - CV Forecast composites
    - Heat waves
  - Large scale air mass displacements
  - Large scale pattern as one might expect
- **Upper Air Downscale Link to Surface Obs.**
  - A prototype downscale analysis/hindcast scheme
    - How it works
    - How well it does
- **Conclusions & Climate Model Applications**

Consider:

- Will make application to California Central Valley (CV)
- CV extreme heat waves.
  - Only last a few days
  - Can have big impact upon crops infrastructure.
  - Might not show up on monthly means
- Though ephemeral, they can be important for climate.

Example: Jul. 1991 CVHW



Daily anomaly temperatures at 4 CV stations June-Sept. 1991

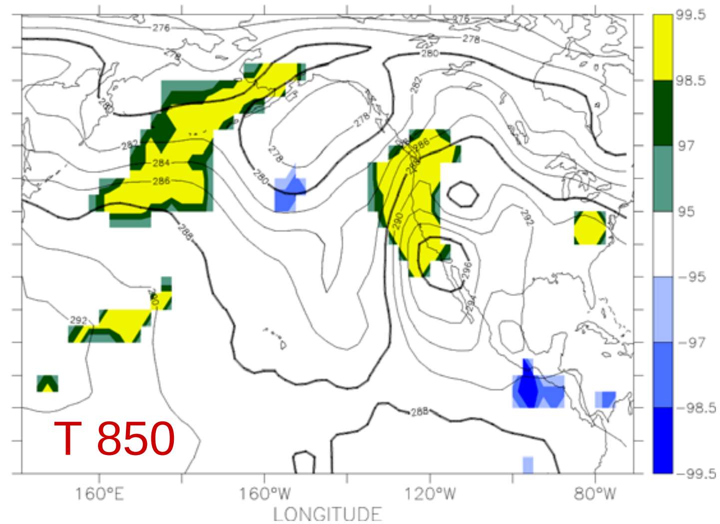
Normalized by each stations STD. Pink line is LTDM.

- **CVHW: California Central Valley Heat Wave**
- The hottest outbreak 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!

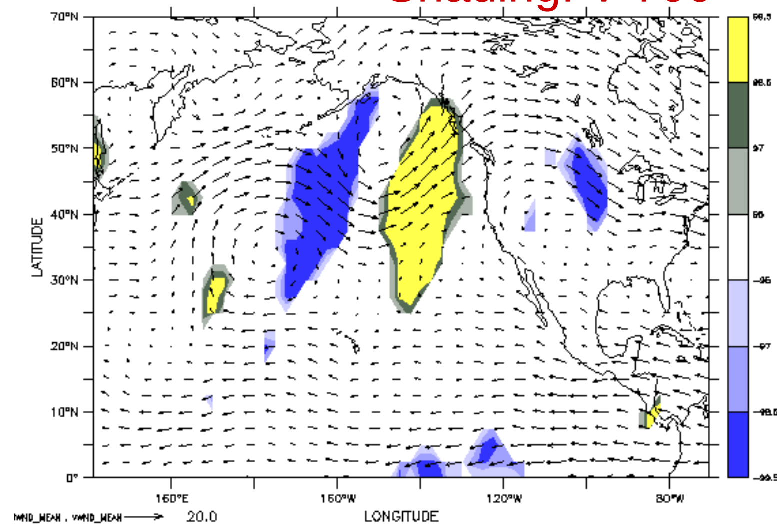
- **A cooler than normal July had the state's hottest heat wave.**
- Conclusion: The monthly mean misses this important event!

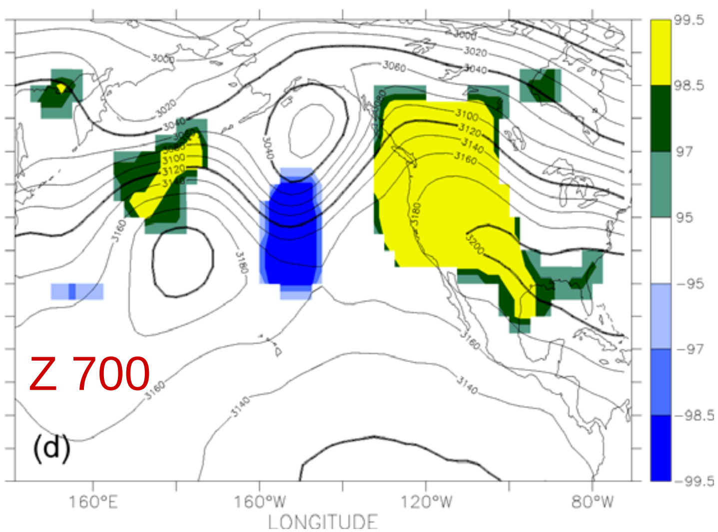
CV Heat waves upper structure

- 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
  - Grotjahn & Faure, WAF, 2008
  - More posted on web, including lead-up
- Is not surprising, only 1 circulation.
  - Large airmass displacements
  - Due to thermals, hypsometric and geostrophic eqns



Shading: V 700



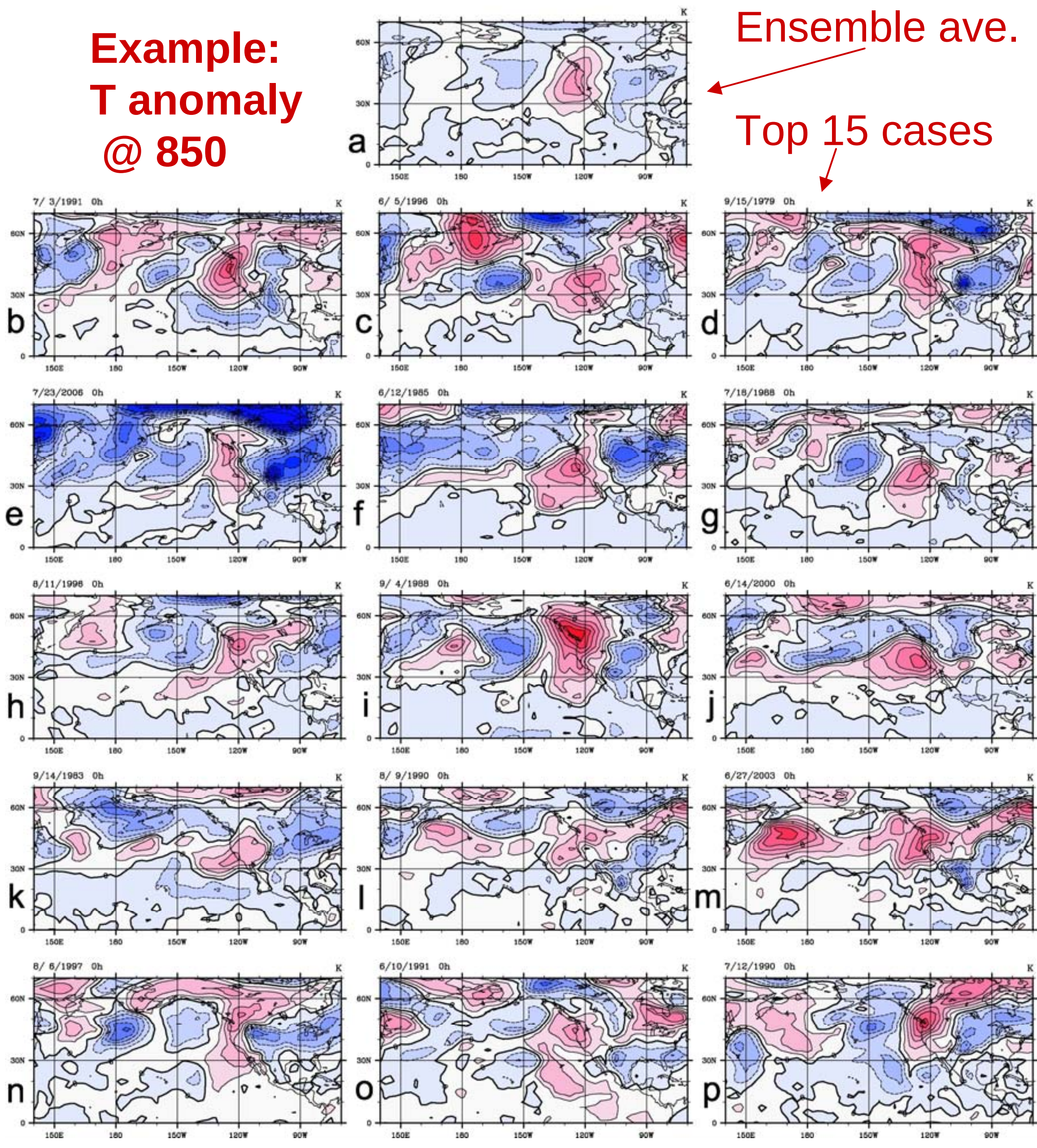


http://atm.ucdavis.edu/~grotjahn/EWEs/heat_wave/heat_wave.htm

Very Significant Pattern is very Consistent

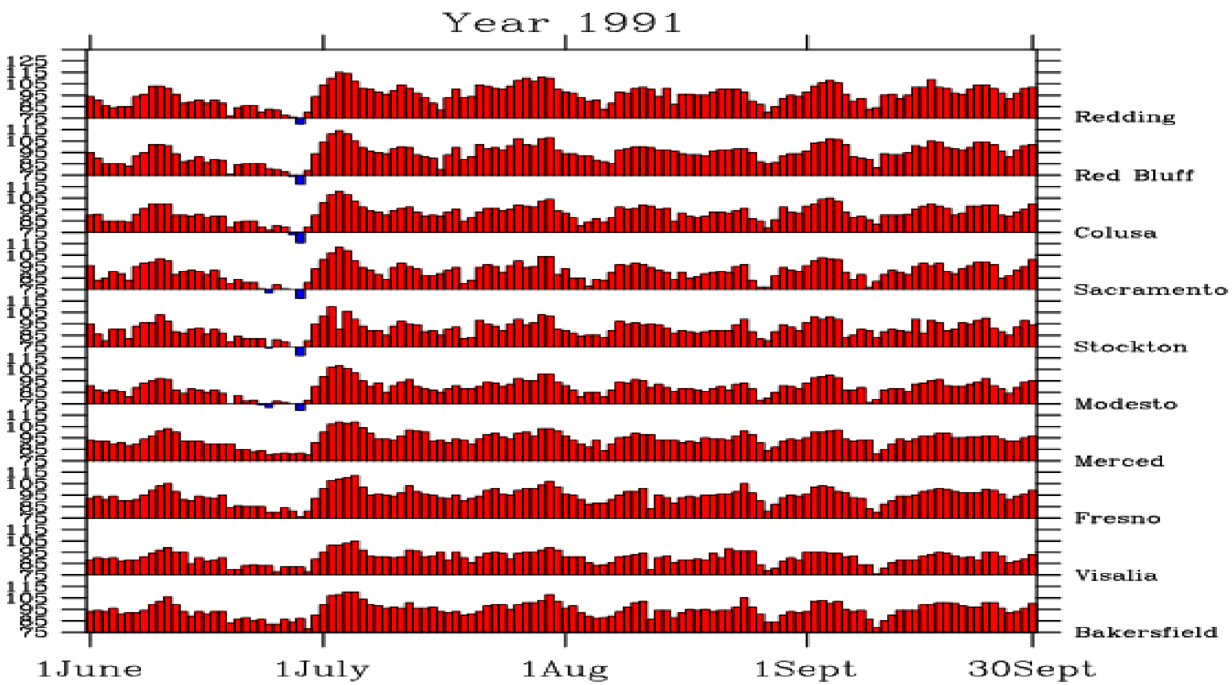
- Parts consistent for all occurrences of extreme events
  - In every case the strongest anomaly T is centered at or near west coast.
  - T850 shown for the top 15 events (b-p). 1979-2006 average of the 15 events (a).
- Hence Z ridge near coast. So…
  - So upper level sinking over CV and to the East
  - Downslope easterlies too
  - Adiabatic warming traps low level heating
- **Only 1 circulation can do this**.

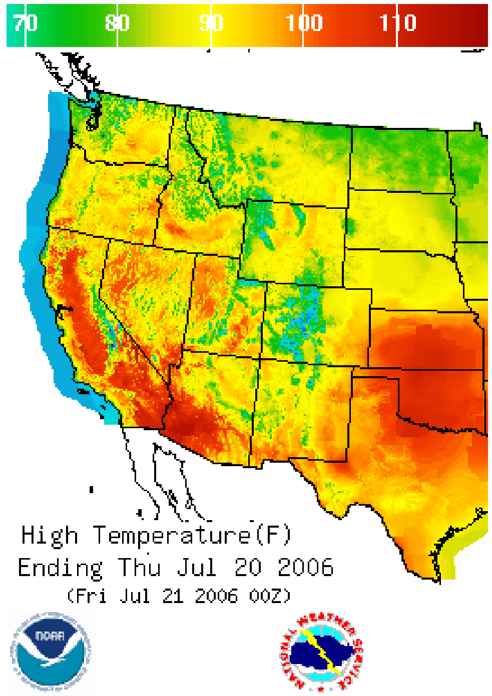
- BTW: Worst **freezes** also have highly significant & consistent areas. Again an optimized circulation occurs in the quasi-random atmospheric states.



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





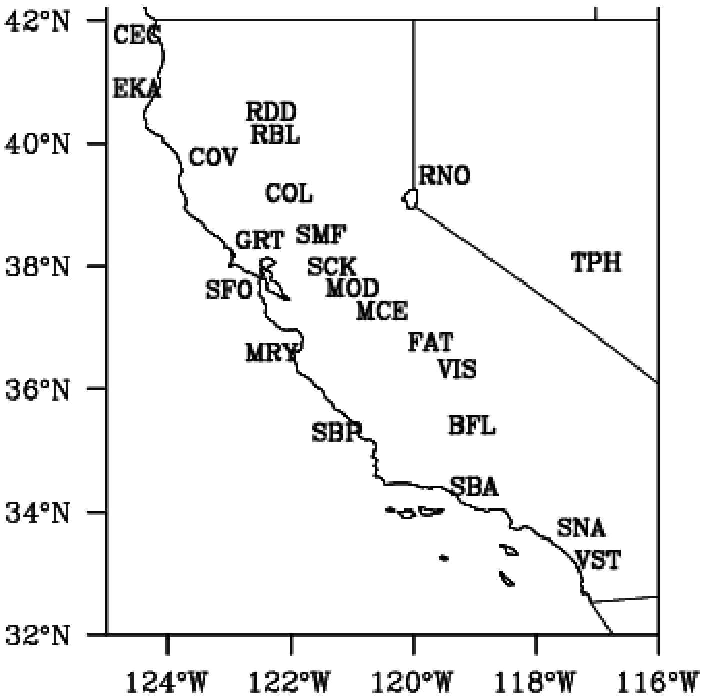
CV extreme heat waves (obs.)

- Conclusions (from observed heat waves)
  - Short events (with long-term consequences) may not show up in time means
  - Pattern understandable from basic dynamics
  - Temperature and wind related extremes have large scale
    - Heat waves, severe freezes, and diablos result from large displacements of air masses

- How to use this information? Data mining of climate models output.
  - Need events with large scale.
  - The large scale patterns can be resolved by medium resolution (e.g. T42) climate models.

- Test link between circulation & event with pilot project

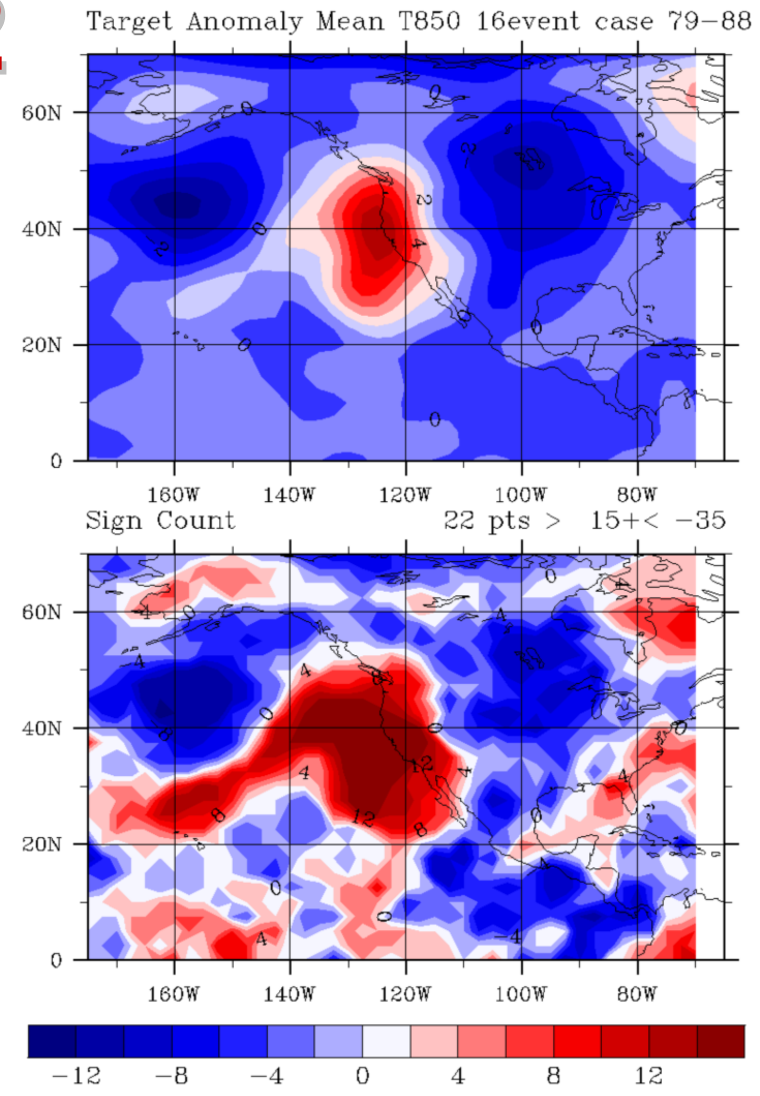
Pilot Project, part 1



- Purpose: Test if one can find extreme surface events from large scale upper air data.
- First find obs. 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 **first 10 years** of data (= 16 of the target dates)
- Then…..

Pilot Project, part 2

- Compare target composite with 1000 random composites, (each from 16 randomly-chosen dates). Bootstrap resampling identifies highly significant features
- Identify areas of consistent sign in anomaly field using ‘sign counts’. +16 means all 16 members had positive sign at that grid point.

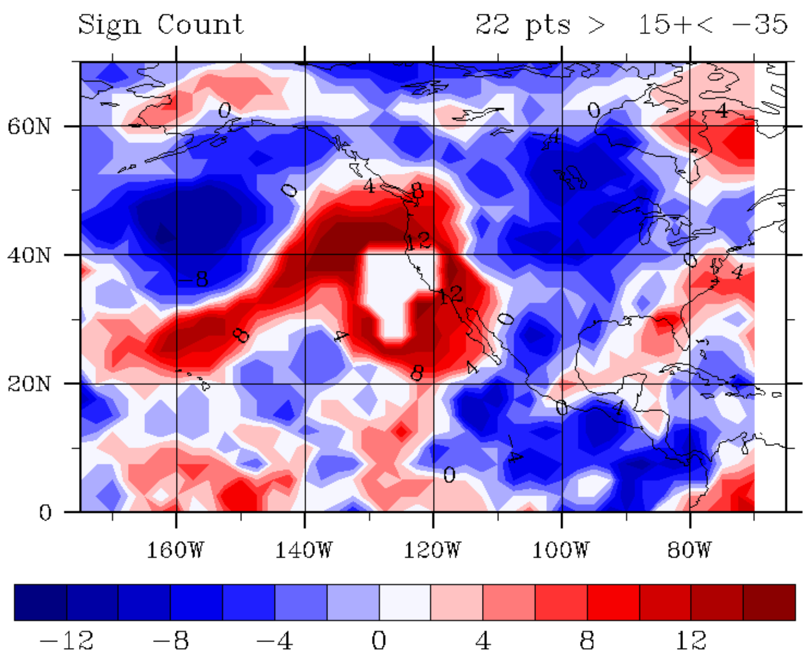


- Index based on an average of the 16 worst days at select points…

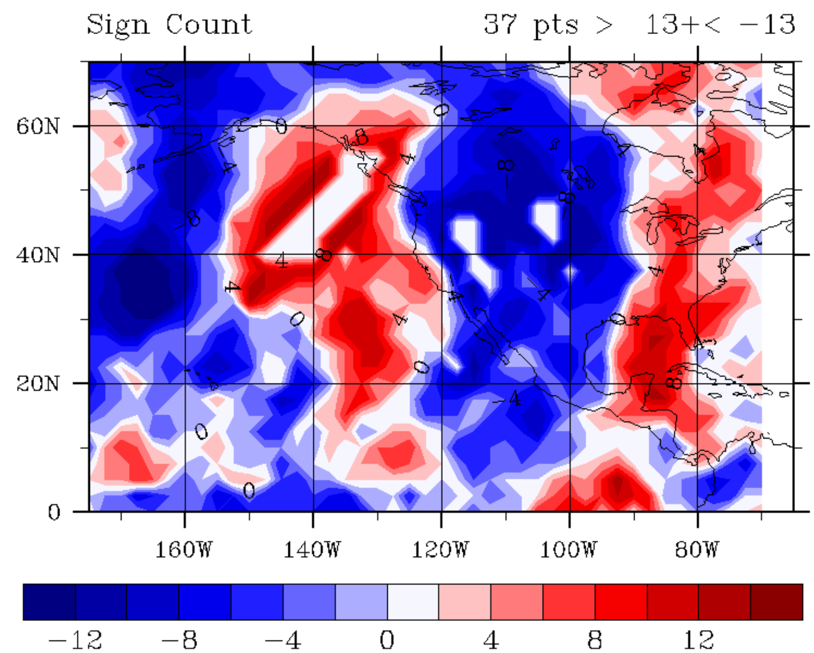
Example: Target composite and sign counts for 16 events. T850 hot consistently at & 10º ***west*** of CV

Pilot Project, part 3

- Use grid pts in select regions
  - Near CV (to reduce sensitivity to large scale wavelength)
  - Only those highly consistent between extreme events
  - Indicated by ‘holes’ on this slide



Example: sign counts for 16 events. T850 hot consistently over and 10º ***west*** of CV

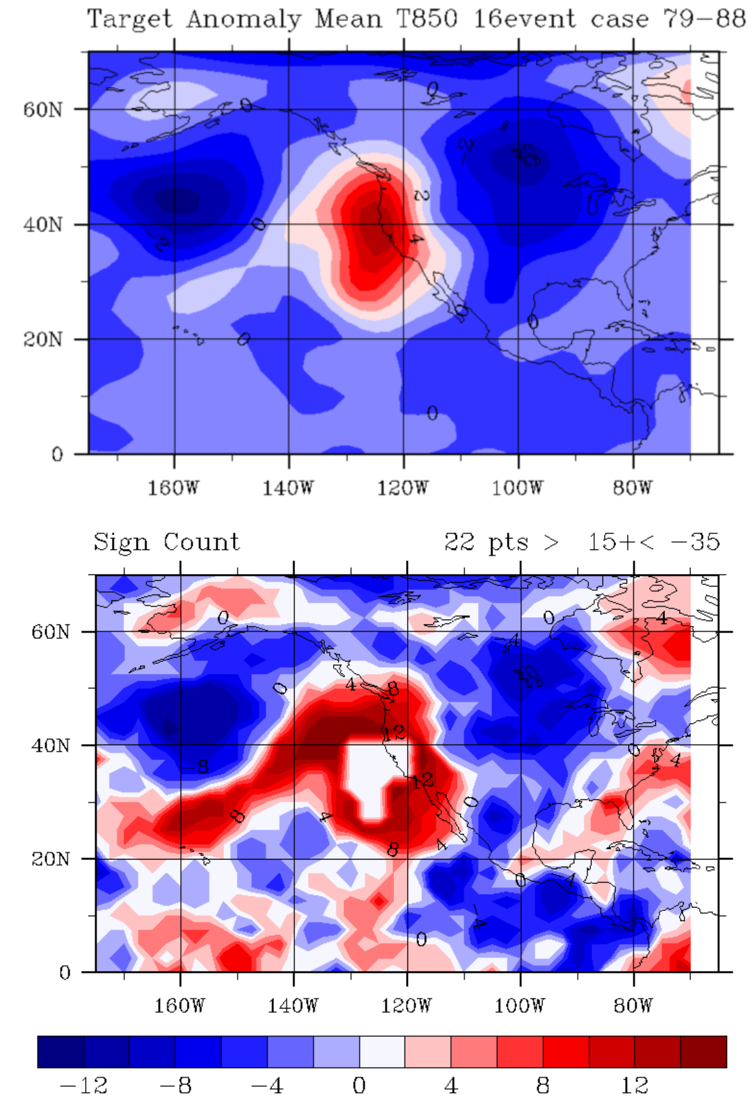


Example: sign counts for 16 events. V700 anomaly consistently 10º ***west*** of normal location

Pilot Project, part 4

- **‘daily circulation index’**
  - Correlate highly consistent areas of select target composites (or leading extreme EOF) with same areas in daily data.
  - Correlations from more than one variable are combined to get an overall ‘daily circulation index’ for the date.
  - Index shown combines T850 and V700 anomaly data to hit most number of target dates

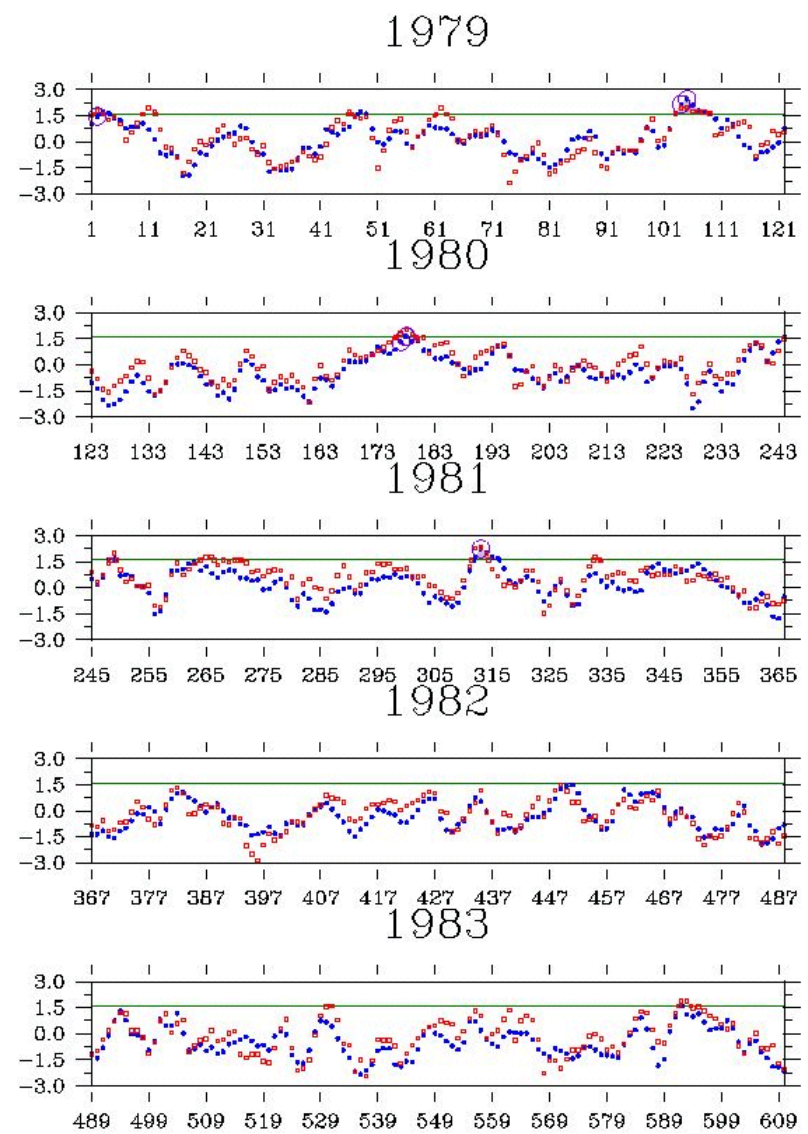
- Index based on an average of the 16 worst days at select points from the 1979-88 pd…



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

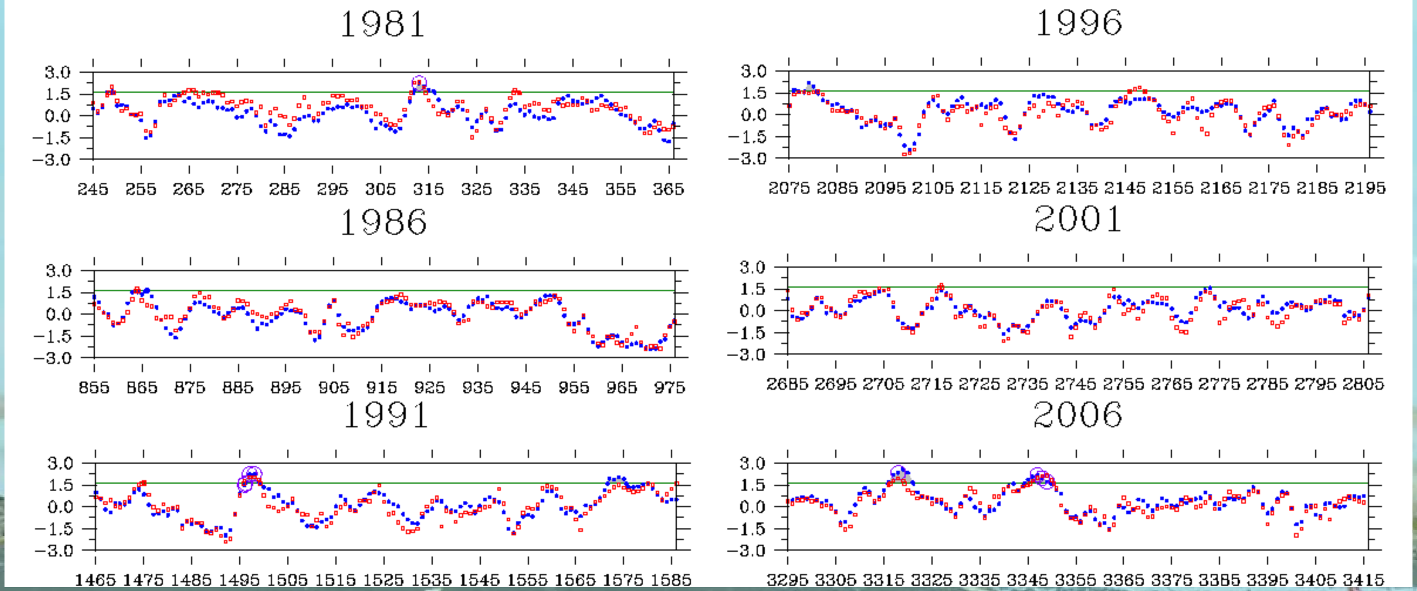
Pilot Project Results

- Index based on similarity of daily pattern to pattern from 16 extremely hot days from first 10 years (1979-88):
  - 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 (circles)**
- Performance (capturing extremes)
  - Highest 33 values of **index match 16 of the 33 (48%) highest 1%** extreme events.
  - 14 of remaining 17 values of index are top 2% of obs. events
- Surprise! 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.**



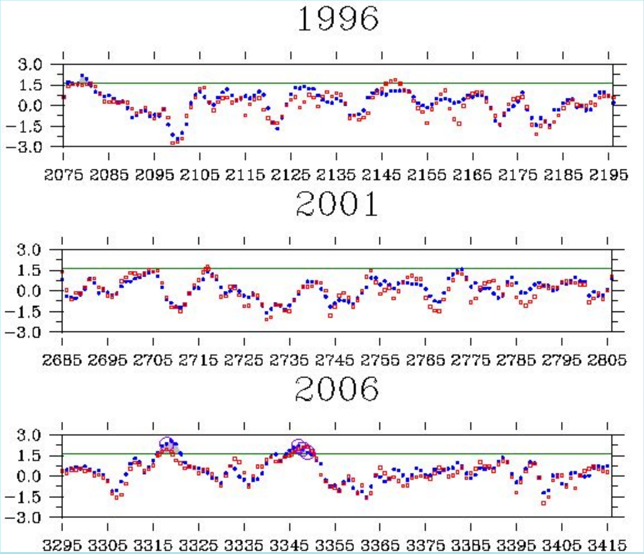
Climate Model Application, part 1

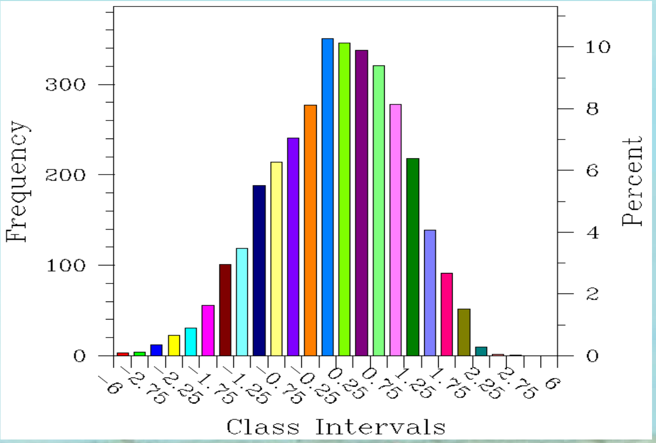
- Apply ‘daily circulation index’ idea to AMIP climate model output
  - Correlate highly significant areas of observed target composites with corresponding areas in daily simulation data (historical, AMIP runs).
  - Combine correlations from more than one variable to get an overall ‘daily circulation index’ for the simulated date.
- Study & adjust the daily indices found for historical simulations
  - Compare the distribution with the observed distribution
    - Gives **model variability bias** information, including extreme heat waves
    - Apply extreme statistical analysis to the peak values.
  - Could rescale index based on the model variability to bring it in line with the observed variability and study relative change: historical to future climate.
  - Assess impact of non-optimal data levels (for study of limited archived output)



Climate Model Application part 2

- Calculate 'daily circulation index' from climate model output for future scenarios.
- Compare circulation index **statistics** from historical simulations to those from future climate simulations.
  - Apply **extreme statistical analysis** to the peak values. (GPD, PP, GEV, etc.)
  - Presumably **'global warming' increases max-T**. T850 anomaly is primary predictor, so use historical definition of mean T850 & historical threshold to study heat waves due to the general warming.
  - How might future **variability** change? (also: duration, frequency, intensity compared with the historical threshold)
  - **Can separate general warming from change in future variability.**





Summary & future work

- CV extreme heat waves
  - Short term events can have bit impact,
  - Might not be captured by monthly means

- California CV heat waves are extreme events with large scale patterns

- Pilot project of California Central Valley heat waves
  - Example composites shown (many more on web)
  - Developed index based on similarity between daily pattern & composites
  - Index picks up most extreme, rare hot events
  - Index picks up variability (hot, cold, near normal pattern)

- Future application to climate model output
  - Various issues described (resol'n, extreme stats., etc.)
  - Assess IPCC scenarios
  - Consider occurrence of future heat waves from both long term warming trend and from variability change.

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

Questions?

- Thank you for your attention!

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