The Why, How, and What of Large Scale Meteorological Patterns

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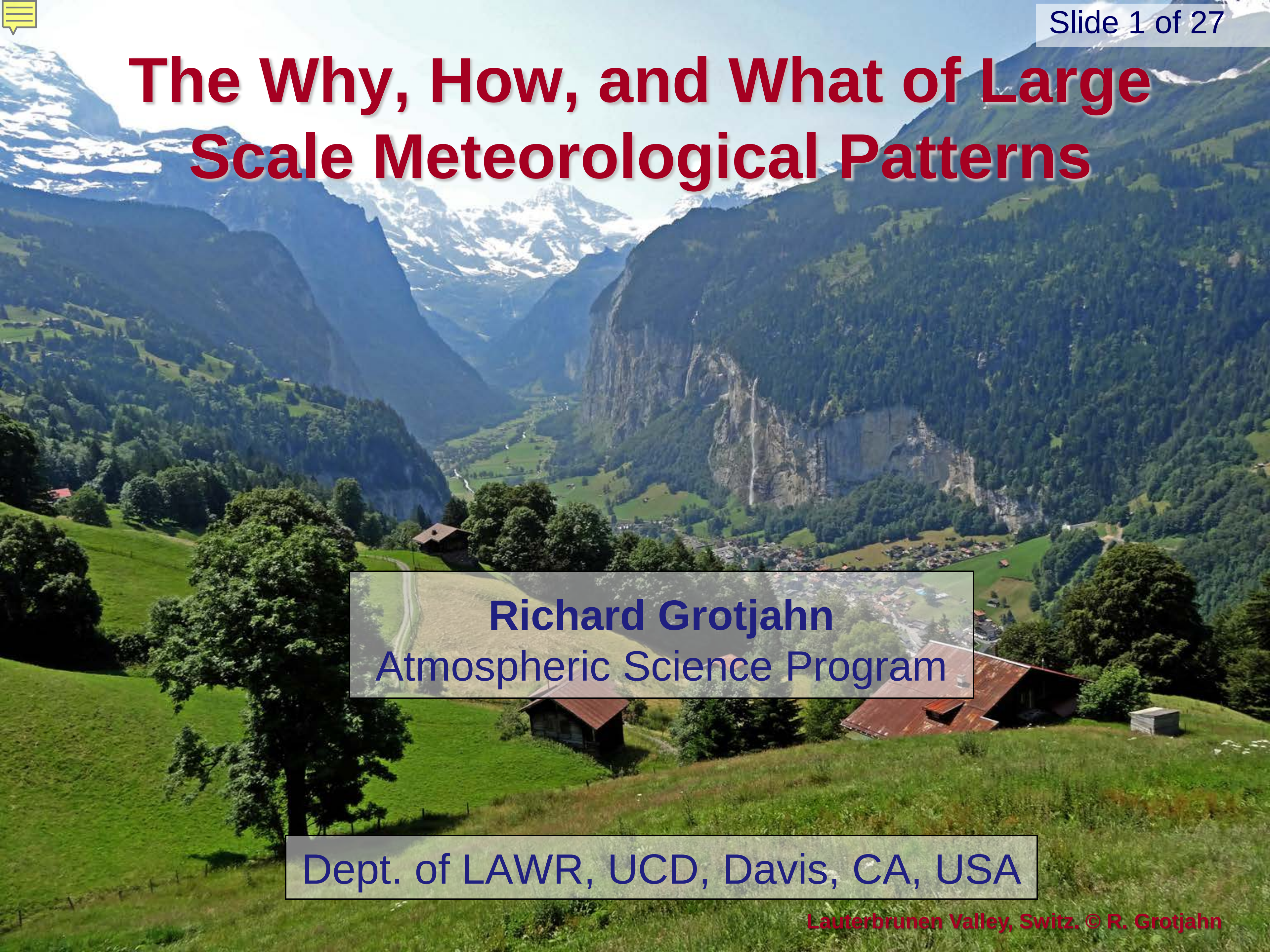

Lauterbrunen Valley, Switz. © R. Grotjahn

Outline of Talk:

- **Why? (Why examine the large scale meteorological patterns, LSMPs during extreme weather?)**
- **How? (How do statistical procedures identify LSMPs and how might one examine that information?)**
- **What? (What do the LSMPs look like, what do they indicate about the meteorology operating, what do they say about a model simulation?)**
- **Summary**

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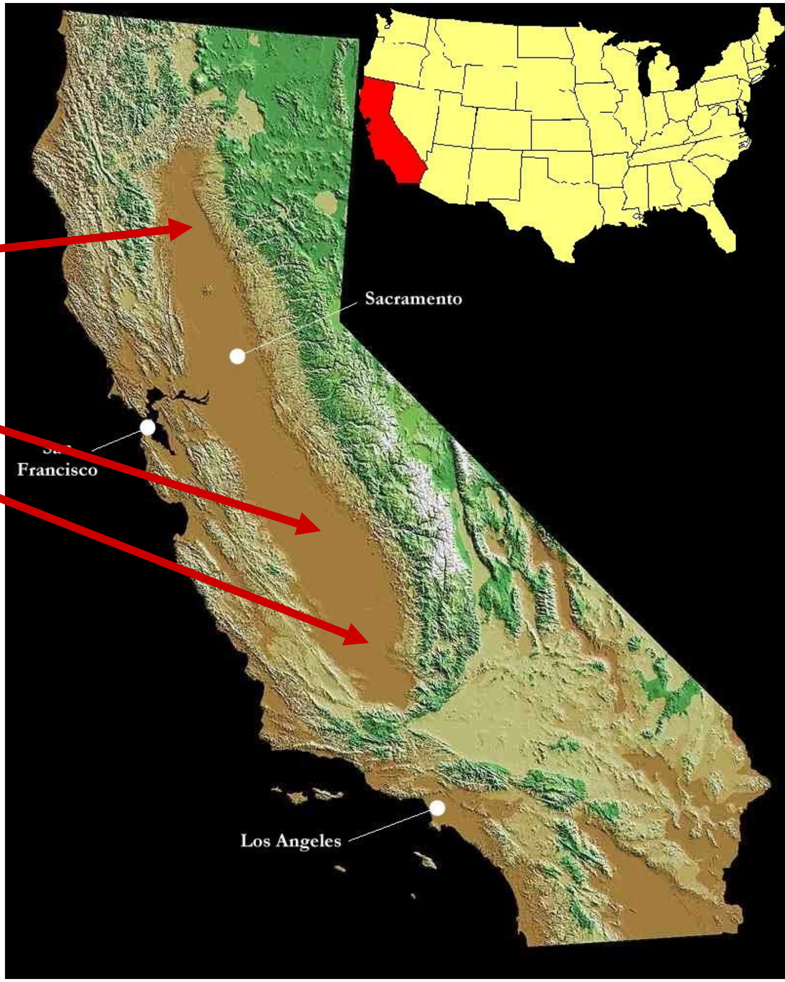
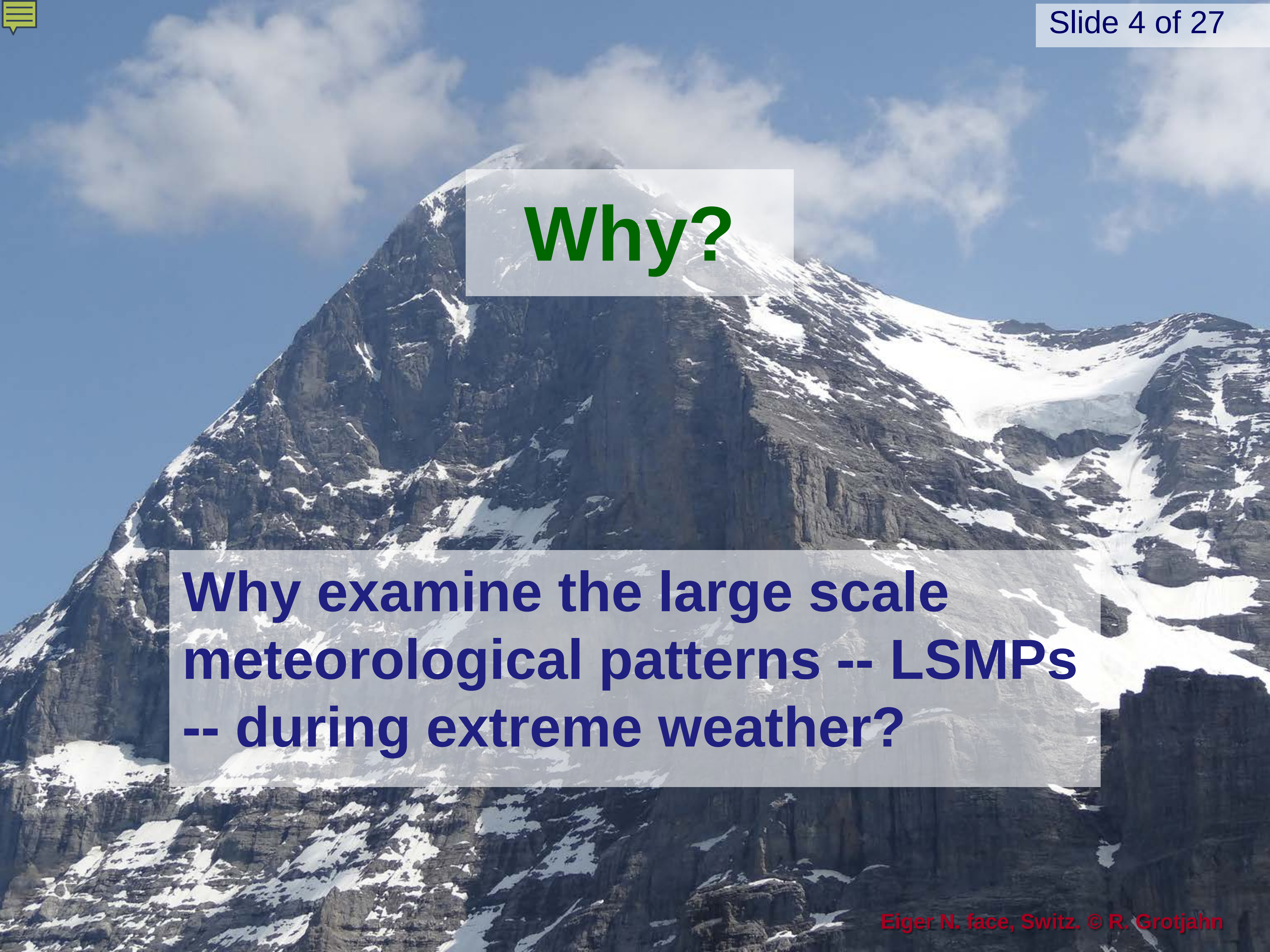
California ‘CV’ Geography

- Application to the workshop provided dataset max/min T
  - California Central Valley (CV) station data, BFL, FAT, RBL
  - Hot spells, CAOs
- CV extreme events.
  - Most only last a few days
  - Can have big impact
  - Might not show up on monthly means.
- Short events, but important for climate.



Why?

Why examine the large scale meteorological patterns -- LSMPs -- during extreme weather?



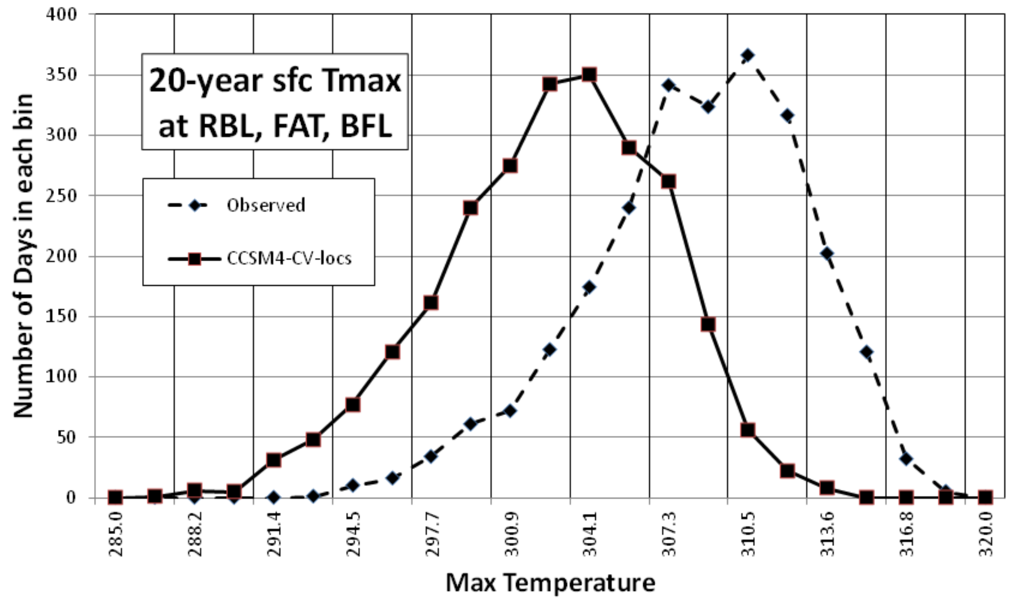
Eiger N. face, Switz. © R. Grotjahn

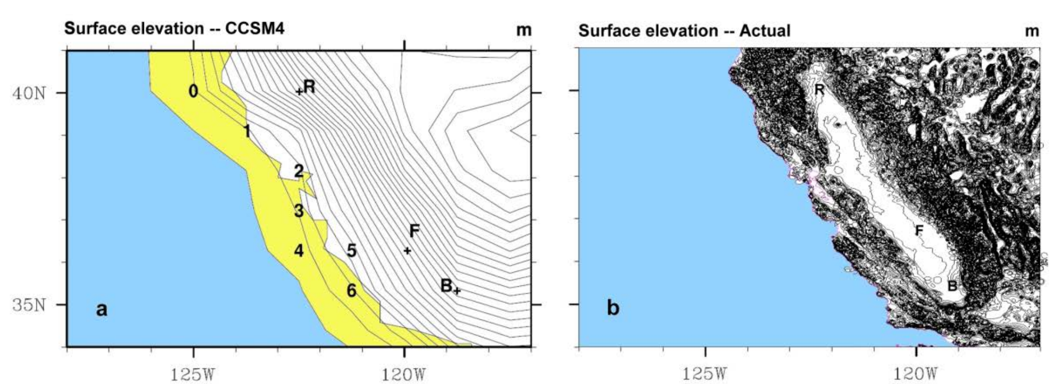
Why examine LSMPs associated with extremes?

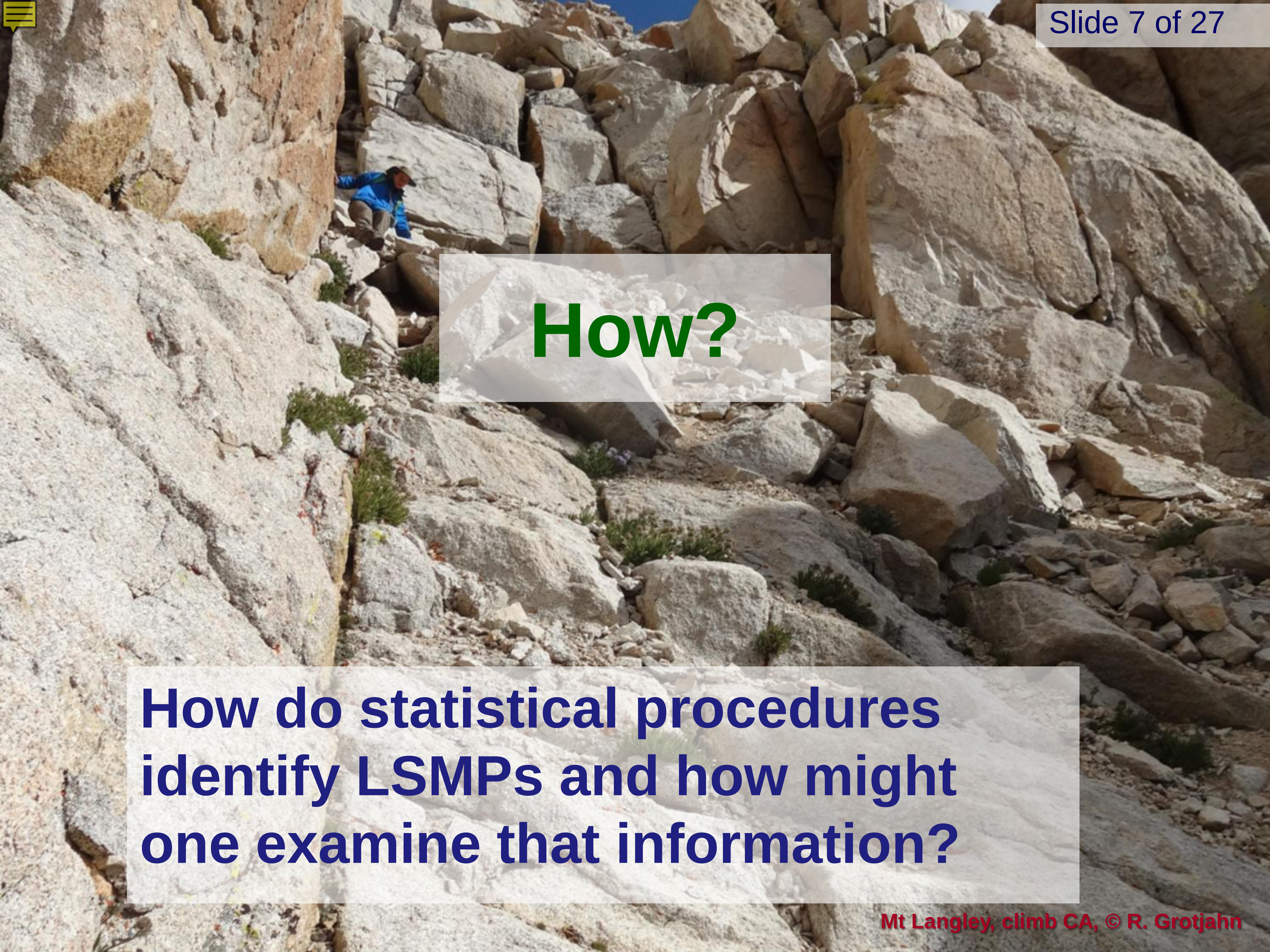
- Model surface values can be bogus for variety of reasons
  - – Poor surface simulation,
  - – Poor topographic resolution,
  - – etc.
- Such problems can be alleviated by a regional model or by statistical downscaling – but both need the correct large scale flow, i.e. correct LSMP

CV Sfc T simulation versus obs.

- Distribution of daily max T values global model CCSM4 (fv 1.1) versus observations at 3 CV stations
- Large negative bias, though std & skew ‘ok’
- Model topography has no CV (same contours in both topo maps). And, more than bias correction needed.







How?

How do statistical procedures identify LSMPs and how might one examine that information?

Mt Langley, climb CA, © R. Grotjahn

Statistical technique of event identification (part 1)

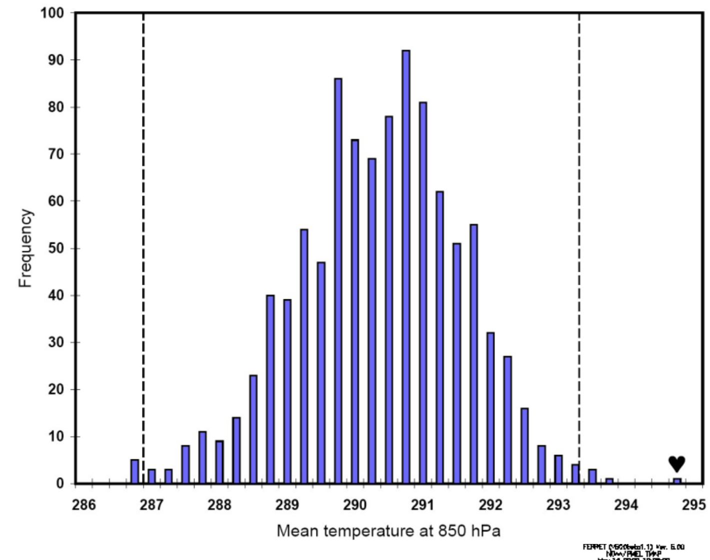
- Remove seasonal cycle of rise and fall (even winter and summer)
- Find long term daily mean (LTDM) annual cycle
- Subtract LTDM value from raw data to create anomaly fields.
- Anomaly fields make every date in the season intercomparable for that station.
- Anomaly fields replace absolute thresholds with relative thresholds. (Absolute thresholds important in some applications)

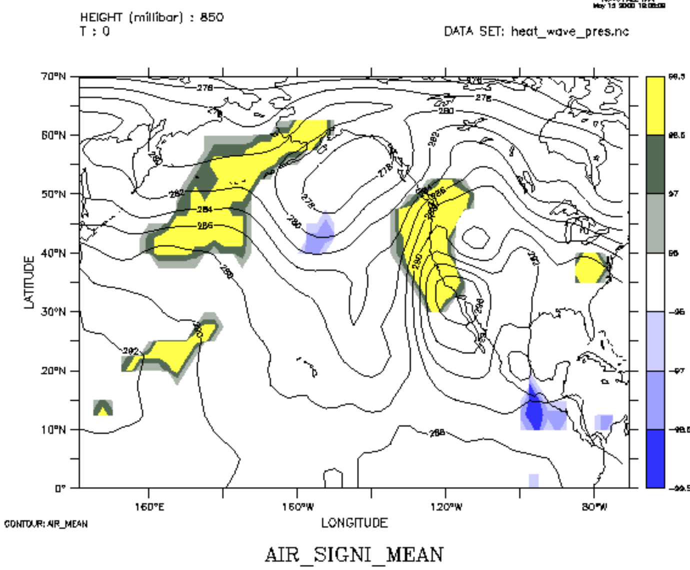
Statistical technique of event identification (part 2)

- Anomaly values are not intercomparable for different stations since variability differs
- Normalize anomaly values by the long term daily standard deviation for each station.
- Different stations can then be averaged.
- While variance information is lost, the purpose is to identify ‘target dates’ during which extreme values were widespread in relative sense (relative to the LTDMs)

Statistical technique: bootstrap

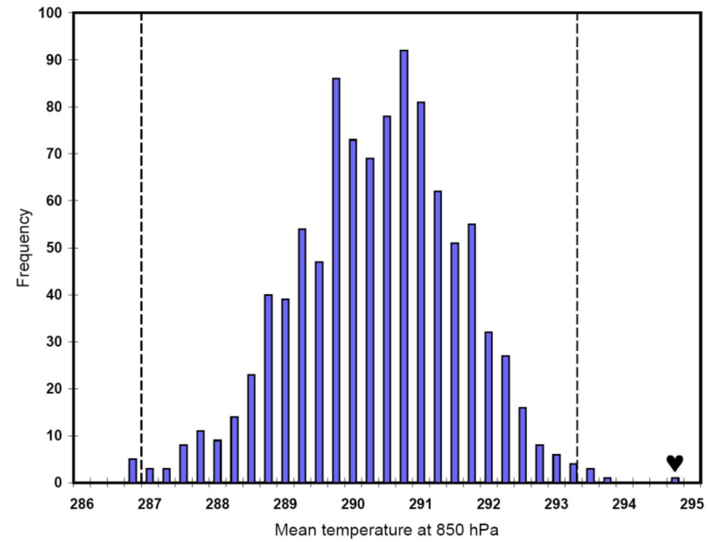
- Use CV-wide values above or below thresholds to identify target dates of extreme events.
- Define target ensembles from the target dates
  - Composite various upper air variables
  - T at 850 hPa composite shown at onset.
- What is significant in the LSMP? How consistent are the ensemble members?
- Use bootstrap for significance

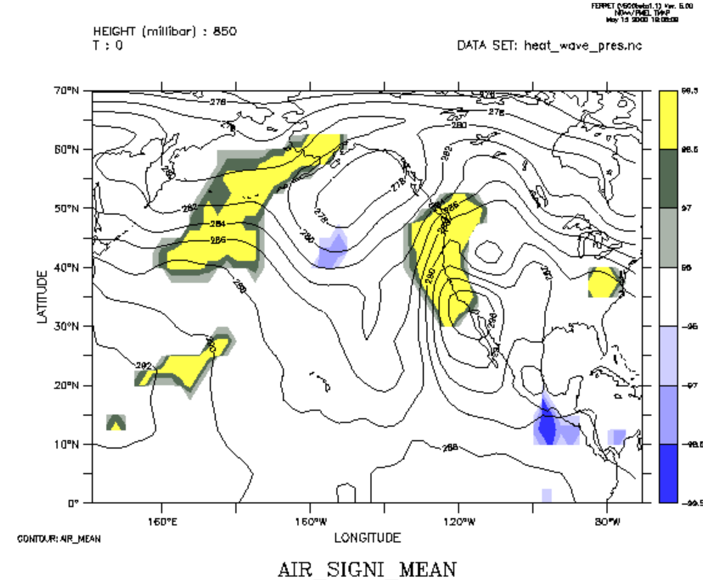




Statistical technique: bootstrap

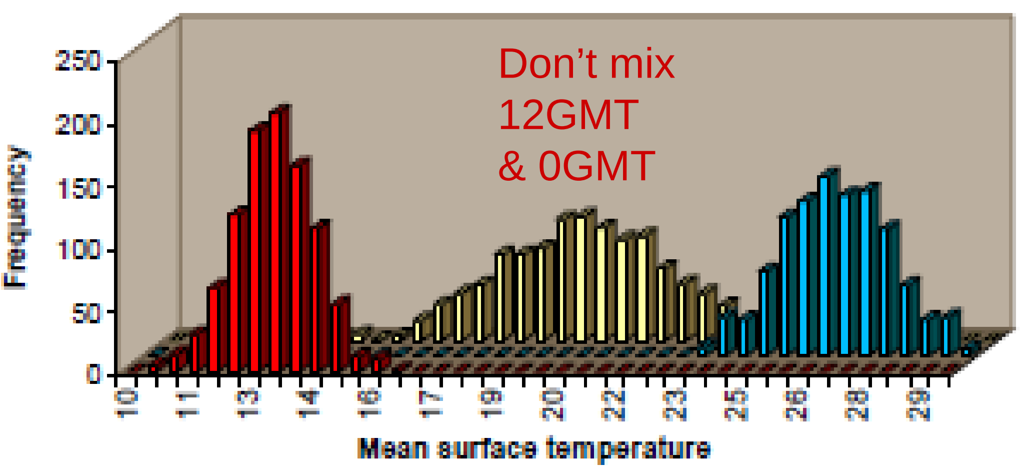
- Bootstrap resampling (with replacement) compares target ensemble to distribution from random ensembles of the same size
  - Draw ‘random’ dates. Form many (1000) composites of such ‘random’ ensembles at each grid pt.
  - Obtain distribution at each grid point
  - See where target ensemble value lies relative to the distribution of random ensembles at each grid point.
  - Highest 10 is highest 1% of values (Yellow shading) Lowest 10 are lowest 1% (Blue)
- Variations:
  - Times before onset as well.
  - Create time sequences leading to onset
  - Anomaly data = raw data minus long term daily mean (LTDM) for each grid pt.



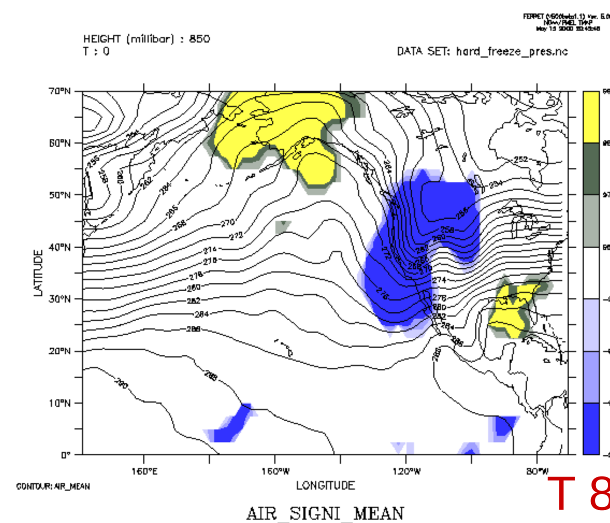


Some ensemble statistics notes:

- **Other considerations**
  - **Compare same time of day (diurnal cycle)**
  - **Global statistical assessment of the map (how many pts are signif. vs the number expected by chance)**
  - **Regional significance: may diminish with distance for similar structures of varying wavelength.**
  - **Test consistency as well (standard deviation of target ensemble members vs same for random ensembles; subjective comparison of the members; and ‘sign counts’.)**



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

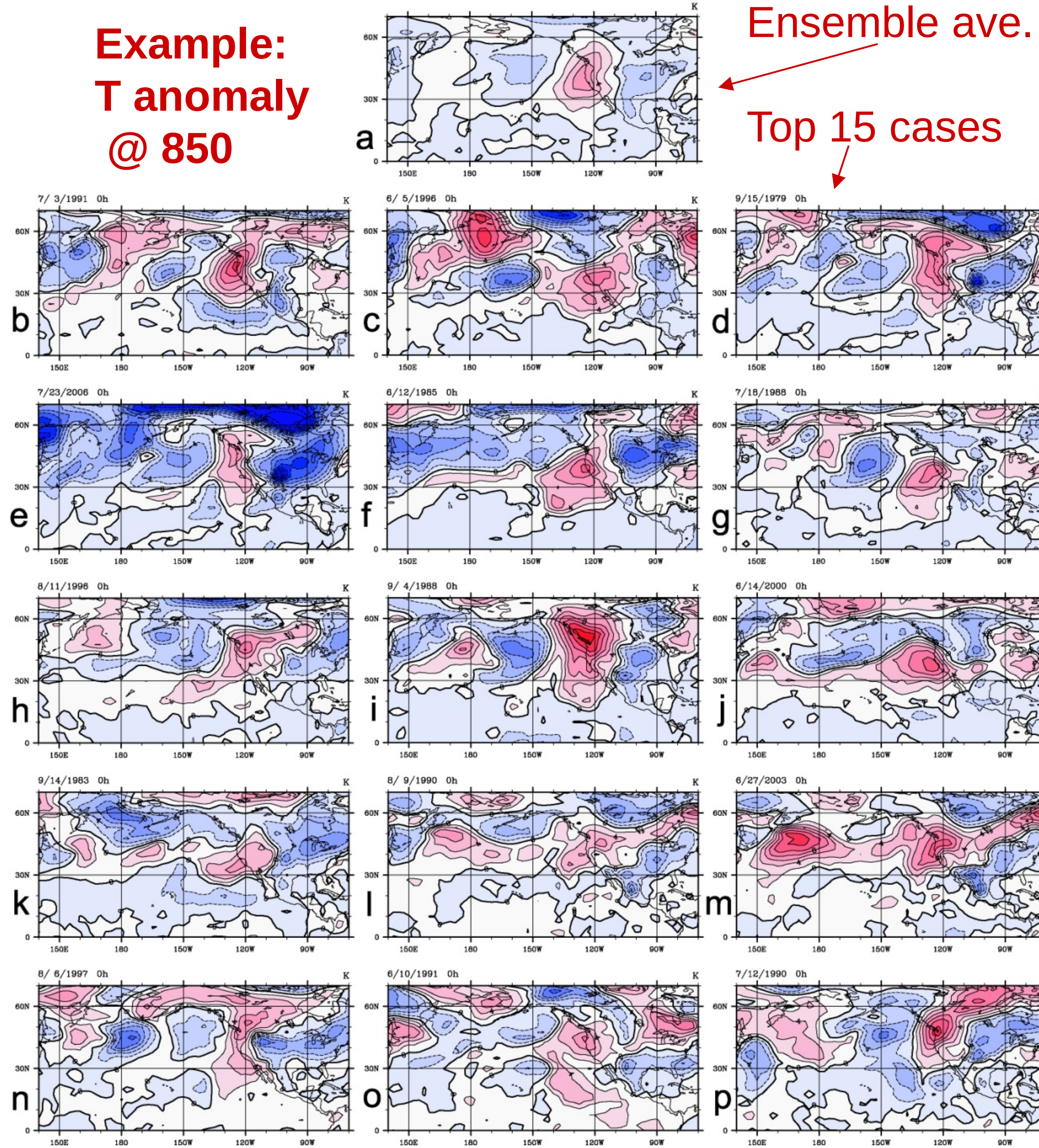


T 850

Shading: some pts by chance

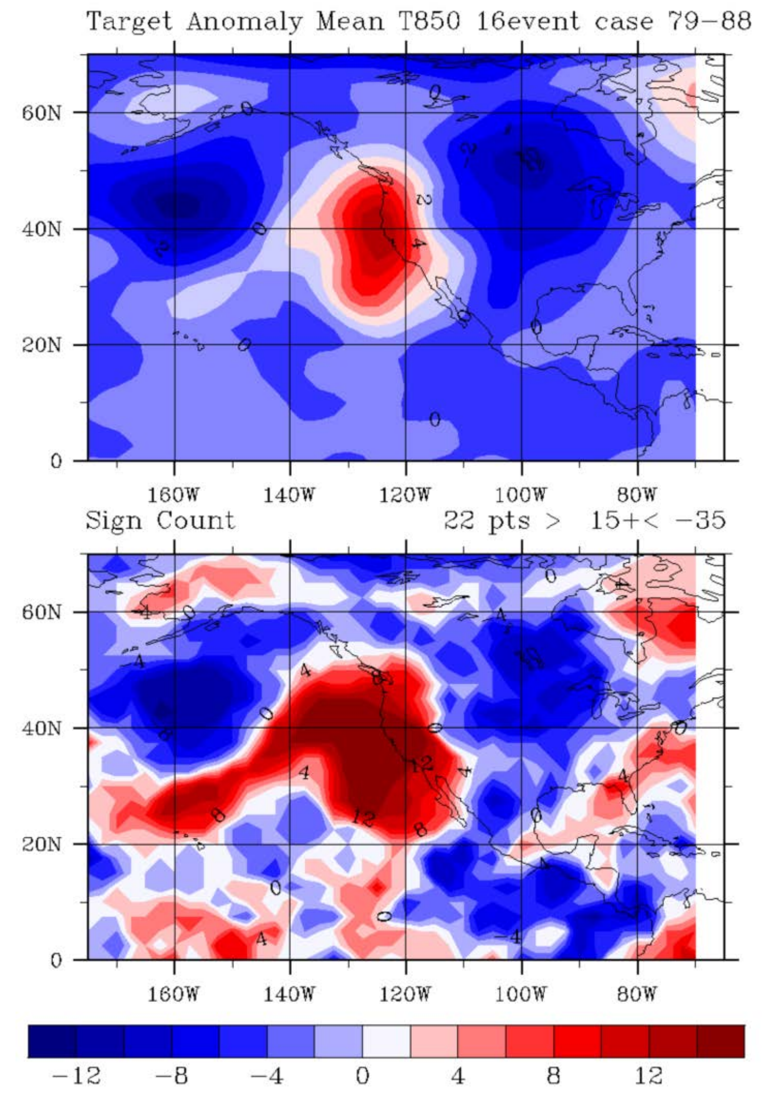
Ensemble members & target mean

- Pattern (anomaly shown) varies between the individual members
- Parts of the pattern are highly consistent and worthy of identification & study
- ‘Sign counts’ is one simple way to identify key parts of the target ensemble



Sign Counts

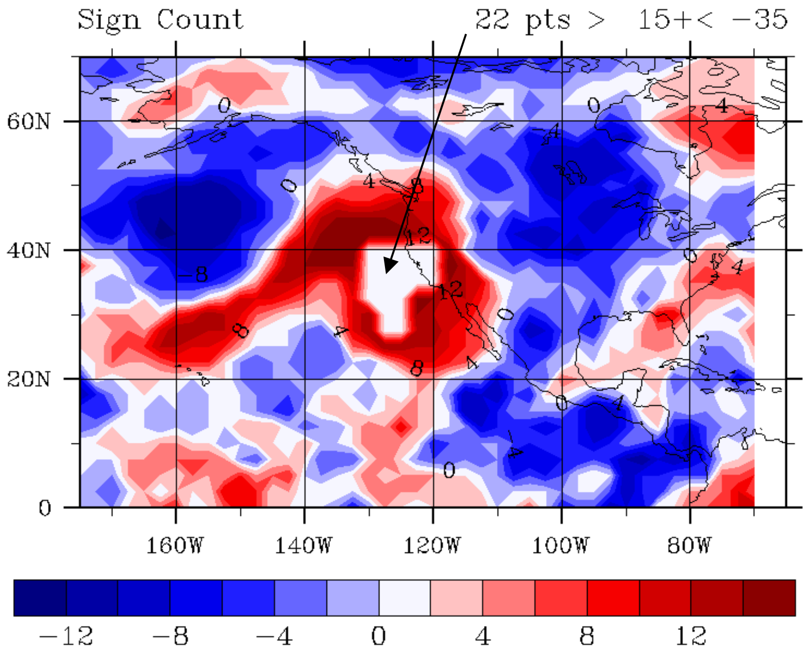
- Identify areas of consistent sign between the members of the target ensemble at each grid point.
- Net tally of the sign from the ensemble members is the 'sign count' at each grid pt.
- Example: ensemble of the 16 hottest days in CV during a 'training period' (1979-88)
- Sign count is sum of +1 for >0, -1 for <0 at a grid point of all 16 target ensemble members. So, +16 means all 16 members had positive sign at that grid point.



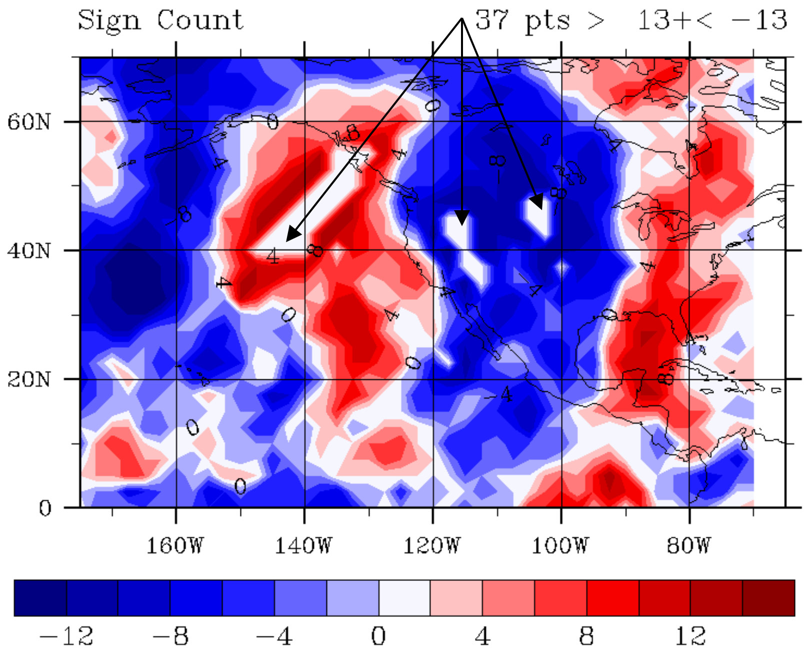
Example: Target composite and sign counts for 16 events. T850 hot consistently at & 10º ***west*** of CV

LSMP 'index'

- Make un-normalized projection of daily field onto target ensemble
  - Could use model, observational, or reanalysis data
- Project only at grid pts in select (ad hoc) regions
  - Near CV (to reduce sensitivity to large scale wavelength variation)
  - Only where highly consistent between extreme events (high sign counts)



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

Extreme value analysis of ‘index’

- ‘Index’ measures strength of LSMP,
- highly correlated with extreme values of governing parameter (e.g. high index values and high surface T for hot spells)
- Index reduces complex daily pattern to single number each day. Over time index has a distribution whose relevant tail is approximating the extreme studied.
- Various extreme statistical analyses can be applied to the tail of the index distribution as one might do with the surface data. (see next talk)
- The difference is the index measures the larger scale environment during the local extreme.

What?

What do LSMPs look like?

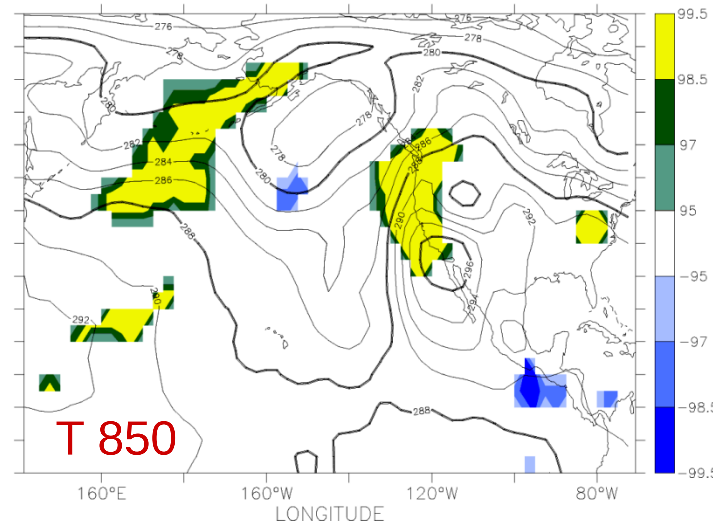
What meteorology do they indicate?

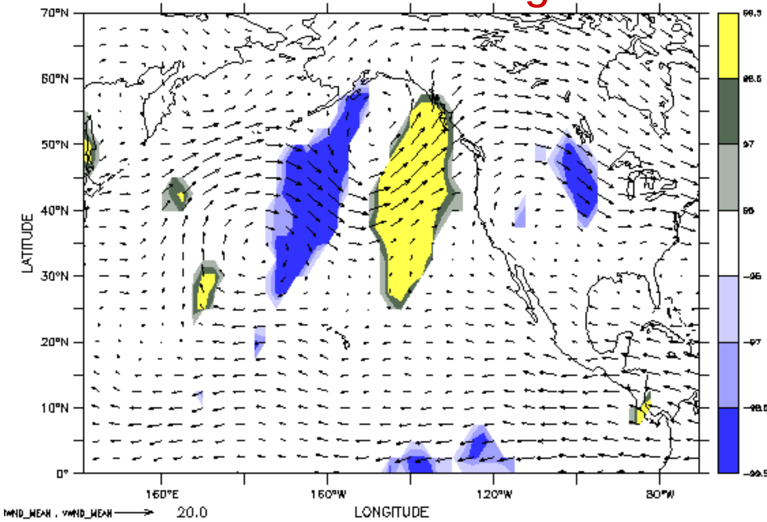
What do they say about a model simulation?

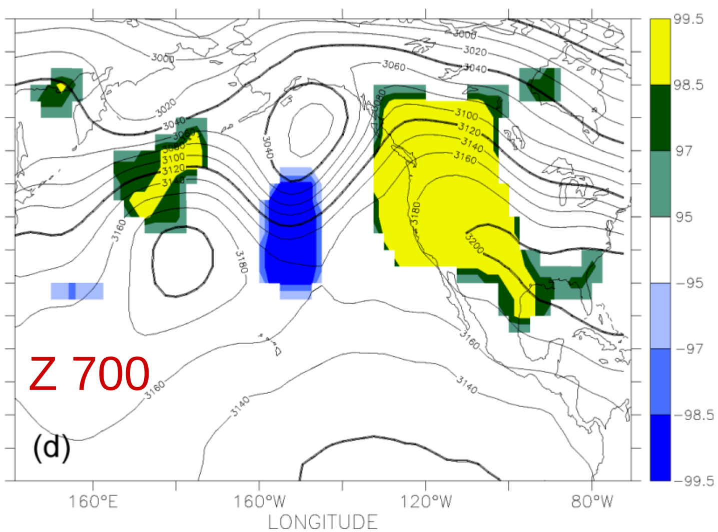
Mt Whitney from Mt Muir, CA, © R. Grotjahn

Example: CV hot spells LSMPs

- 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



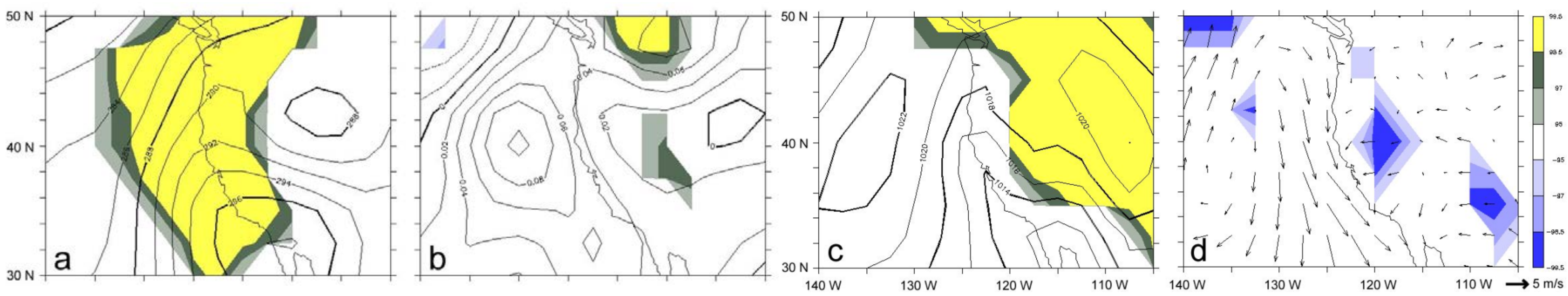




http://atm.ucdavis.edu/~grotjahn/EWEs/heat_wave/heat_wave.htm

Local impact of LSMP

- Large scale pattern
  - Ridge-trough-ridge across Pacific, Ridge in SE
- T 850: (fig a)
  - T maximum (anomaly) at and off shore
- SLP: (fig c)
  - ‘Themal low’ at shore or offshore
  - Unusually high SLP inland (upper ridge shifted west)
  - Low level P gradient opposes cooling sea breeze
- Surface winds (fig d; shading for zonal component)
  - Offshore flow (also downslope; though more complex than this reanalysis data)
- ω at 700 hPa (fig b;) has large scale sinking
  - Creates strong low level subsidence inversion
  - Elevated T in lower atmosphere
  - Solar heating of shallow bndy layer



CV hot spells:

- Variations:
  - Times before onset as well.
  - Create time sequences leading to onset
- Equivalent barotropic with upstream and downstream components:
  - Z 300 hPa
  - 36hr-0hr
  - Z 700 hPa
  - 36hr-0hr

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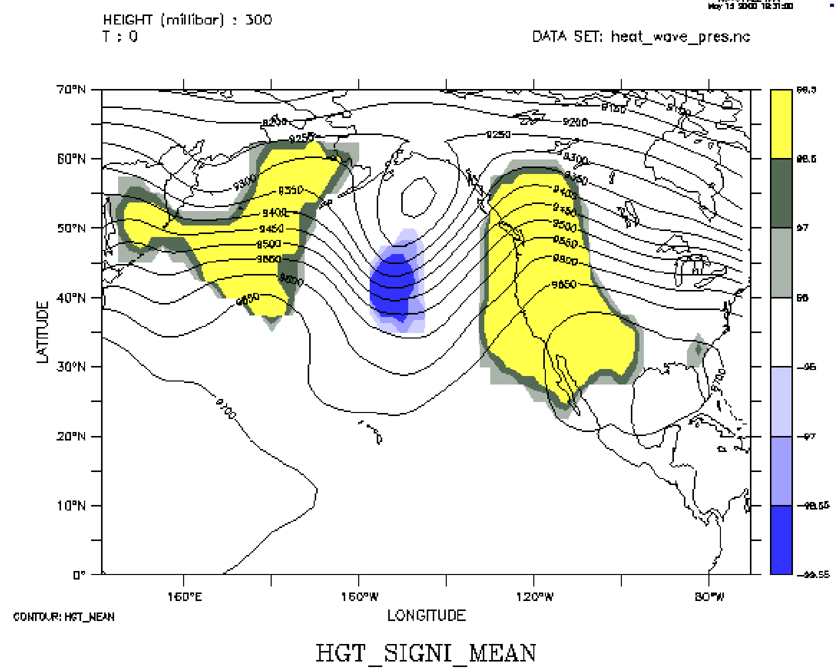
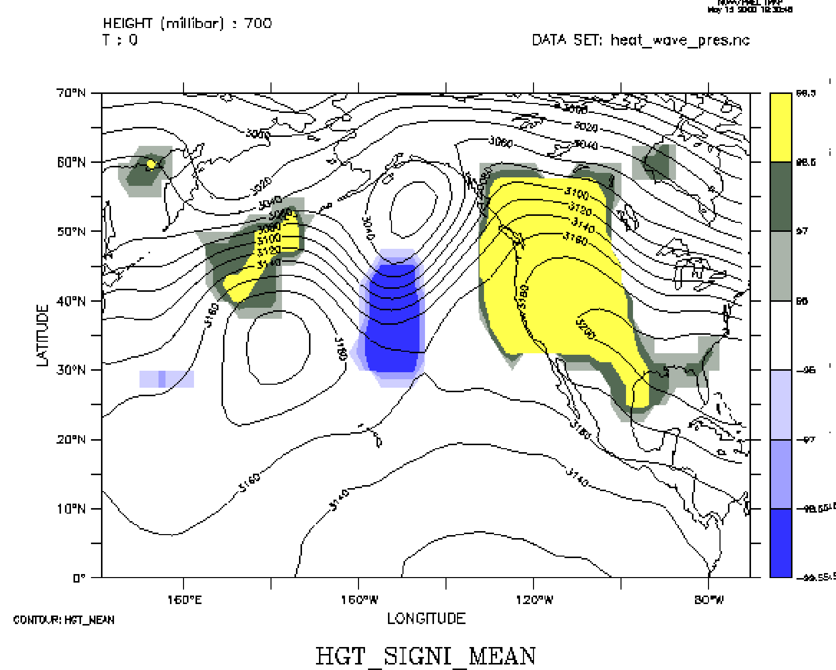
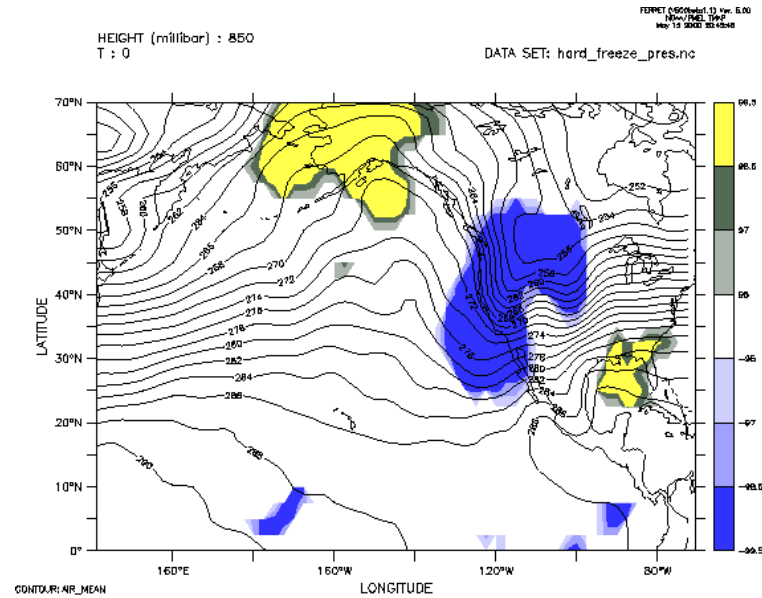




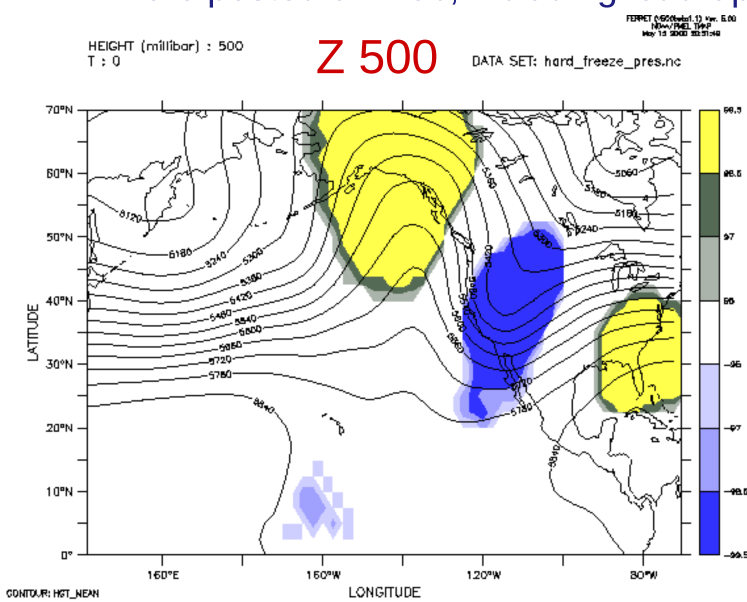
Example: CV CAOs LSMPs

- Example target composites from cold air outbreaks (onsets) affecting Ca CV.
  - T at 850 hPa
  - Z at 500 hPa
  - Wind at 700 hPa (shading for v)
- Composites: very large scale pattern.
  - Highly significant <1%; >99% levels over large areas.
  - Yellow means: grid pt value highest 1%
  - Blue means: grid pt value lowest 1%
  - Grotjahn & Faure, WAF, 2008
  - More posted on web, including lead-up

T 850



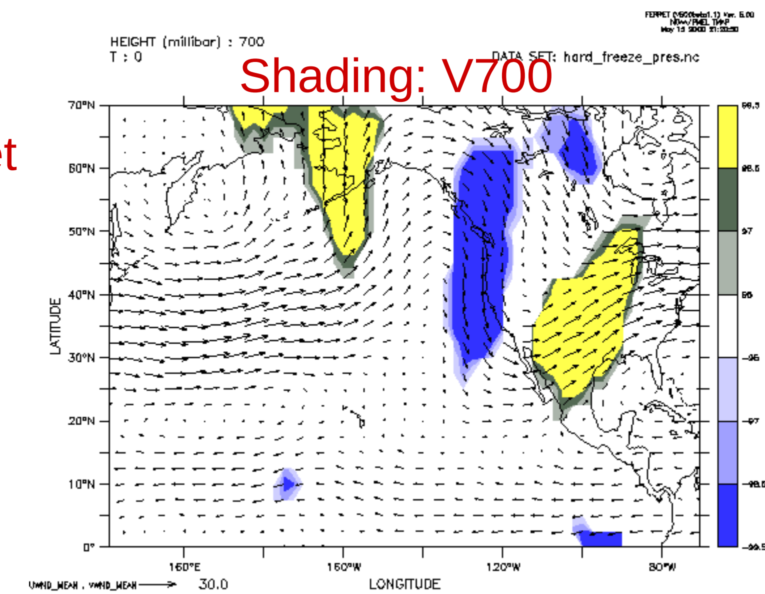
Z 500



HGT_SIGNI_MEAN

T=0 onset

Shading: V700



VWND_SIGNI_MEAN

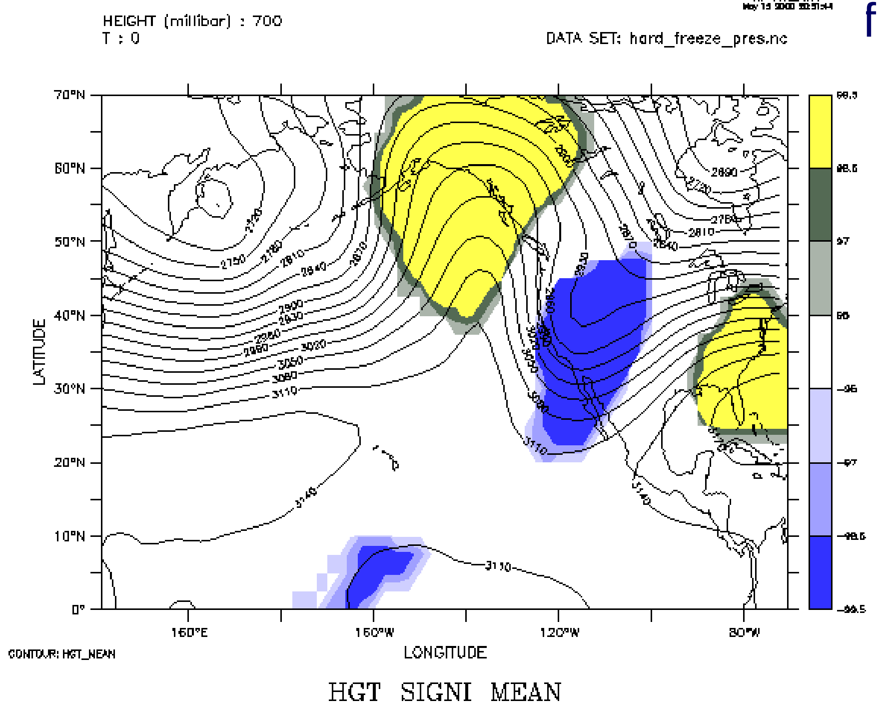
http://atm.ucdavis.edu/~grotjahn/EWEs/hard_freeze/hard_freeze.htm

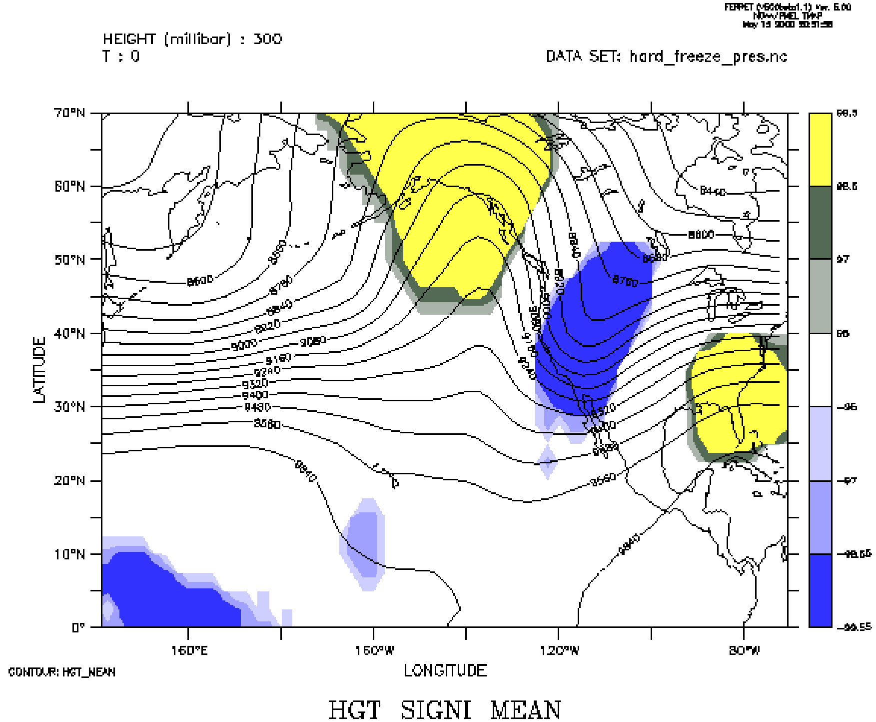
CV CAOs

- Variations:
  - Times before onset as well.
  - Create time sequences leading to onset
- Equivalent barotropic with upstream and downstream components:
  - Z 300 hPa
  - 60hr-0hr
  - Z 700 hPa
  - 60hr-0hr

CV CAOs

- Variations:
  - Times before onset as well.
  - Create time sequences leading to onset
- Equivalent barotropic with upstream and downstream components:
  - Z 300 hPa
  - 60hr-0hr
  - Z 700 hPa
  - 60hr-0hr

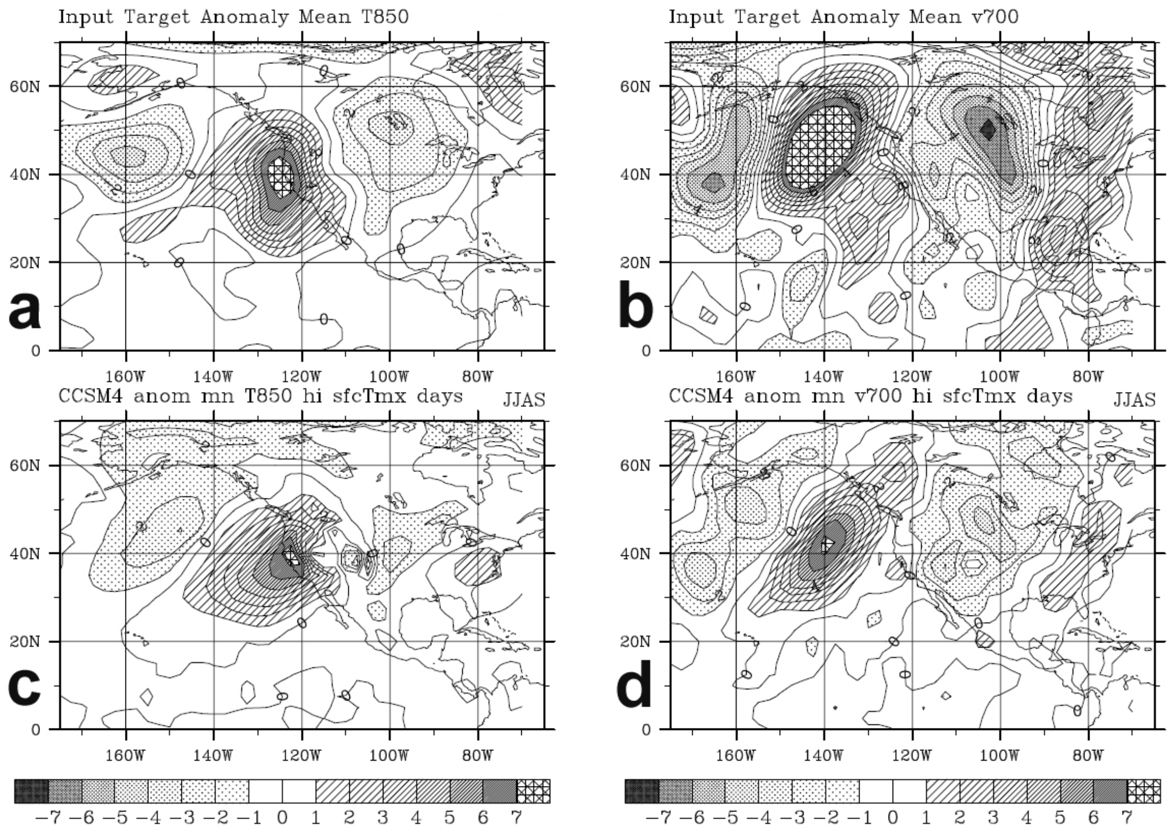




LSMPs in CCSM4 vs reanalysis

- Target ensembles from hot spells in both data systems
- Model LSMP pattern similar (basic dynamics)
- Biases: Model LSMP too weak in general; T anomaly centered onshore so some local processes missed.

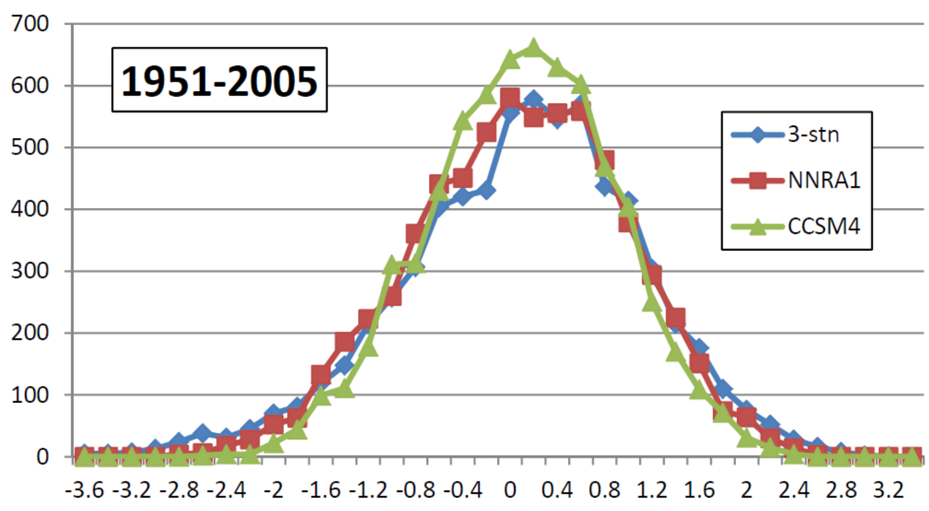
Ensemble mean fields. 850mb T anomaly: a) in NDRA2 (NCEP/DOE AMIP II), c) in CCSM4. 700mb v: b) in NDRA2, d) in CCSM4. CCSM4 based on extreme surface max T values at grid pts near coast.

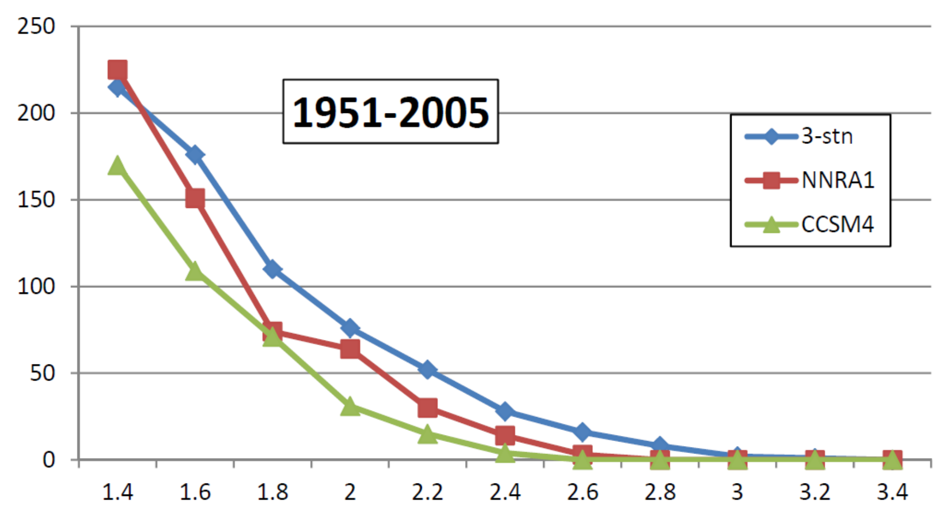


Histograms of ‘index’ that measures LSMP strength

- **Hottest days in model will be too weak, too infrequent**
  - **Top 1% 33 vs 71 over 55 yrs. (9 vs 24 1979-98)**
- Coldest days will be missed in model, too
- Large scale errors cannot be overcome by an RCM
- Extreme statistics can be applied to the tails

- 3-stn vs ndra2 vs CCSM4 pilot scheme circulation index.
- CCSM4 std dev too small:
  - 3-stn, NNRA1, CCSM4
  - 1.01, 0.90, 0.79
- Skew:
  - 3-stn, NNRA1, CCSM4
  - -0.36, -0.16, -0.11





Summary

- Why?
  - LSMP patterns may be present during extreme events.
  - LSMPs are large, well resolved by GCMs
  - LSMPs are key to RCM and statistical downscaling
- How?
  - Select target days
  - Composite upper air fields on target days to get LSMPs
  - Identify significant areas using bootstrap method
  - Identify consistent areas (e.g. sign counts)
  - Note other statistical issues
  - Project LSMP pattern onto corresponding field for each map time to obtain an index upon which other analyses can be done
- What?
  - Composites are LSMP patterns, but focus on significant, consistent areas
  - LSMPs illuminate synoptics of the extreme event type
  - Use LSMP as analysis tool (dynamics, climate trends, model biases)