Two Types of California Central Valley Heat Waves

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Virgin River junction with Orderville Canyon UT © R. Grotjahn

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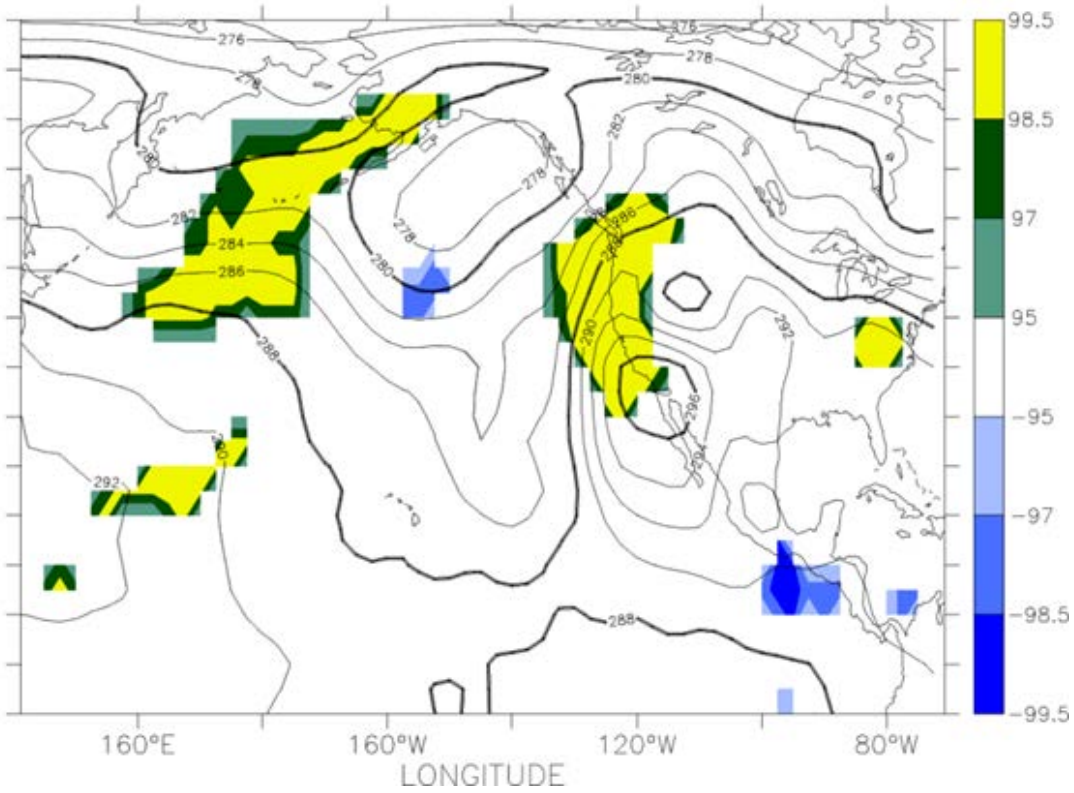
Anna Grotjahn on 5.10 pitch in UT © R. Grotjahn

1. Introduction

- California Central Valley (CCV) example events
- CCV HW extreme events:
  - 3 day minimum
  - majority of valley >95th %
- Though ephemeral, they can be important for climate.
  - Can have big impact upon crops, infrastructure, people.
  - Might not show up on monthly means.

California Heat Waves LSMPs

- Extreme heat has large scale meteorological pattern (**LSMP**) in many variables.
- Wave train spans Pacific and beyond
- Temperature LSMP affects the whole US West Coast.
- Shown: 850hPa T @ heat wave onset



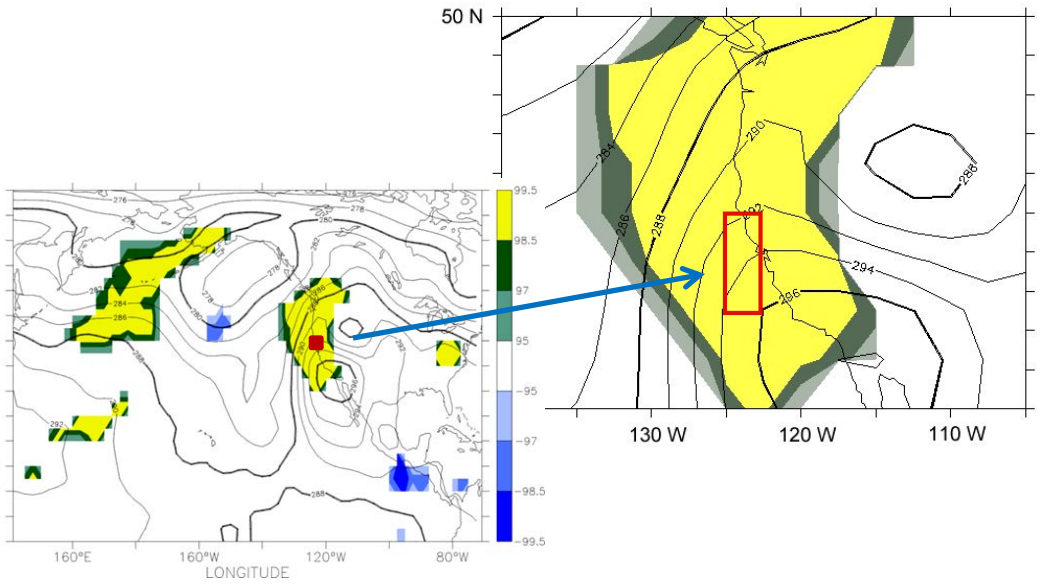
Shading is bootstrap significance
Yellow >98.5%, Blue < 1.5%

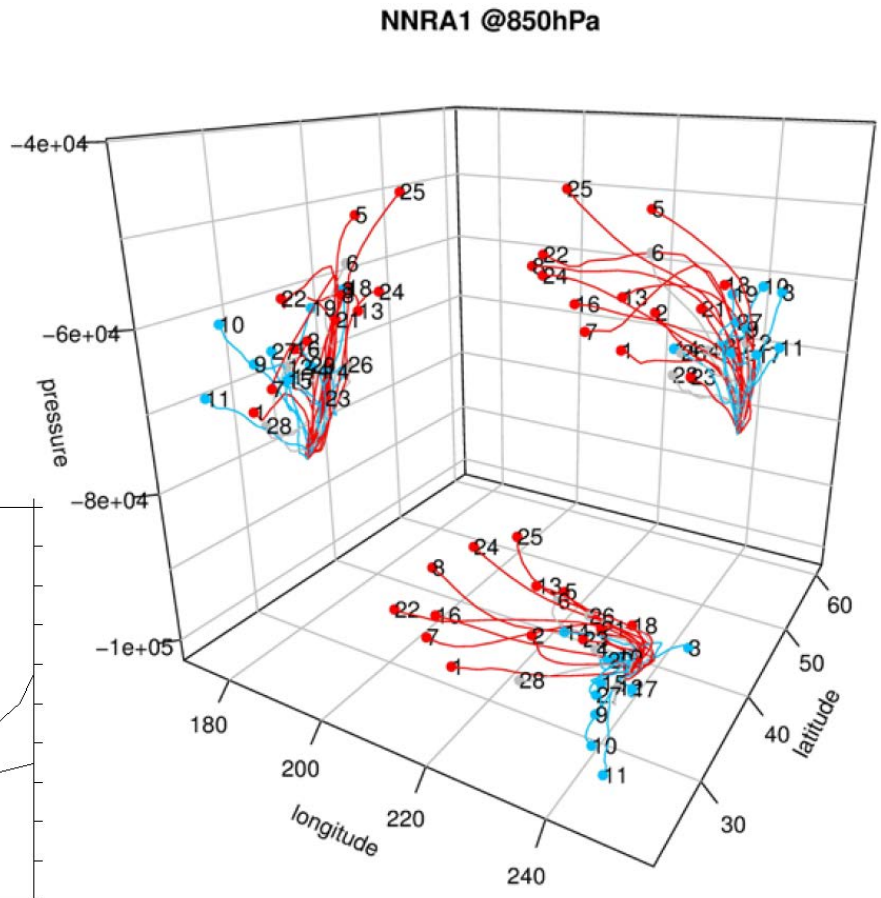
LSMPs for N. America in Grotjahn et al. (2015; Climate Dyn.)

Grotjahn and Faure (2008, Wea Anal Fcst)

Calculating Backwards Trajectories

- Air parcels that arrive in center of thermal low (red rectangle) are traced backwards in time
- Trajectories sort into two (or more) groups





Average paths over 4 days for 28 events

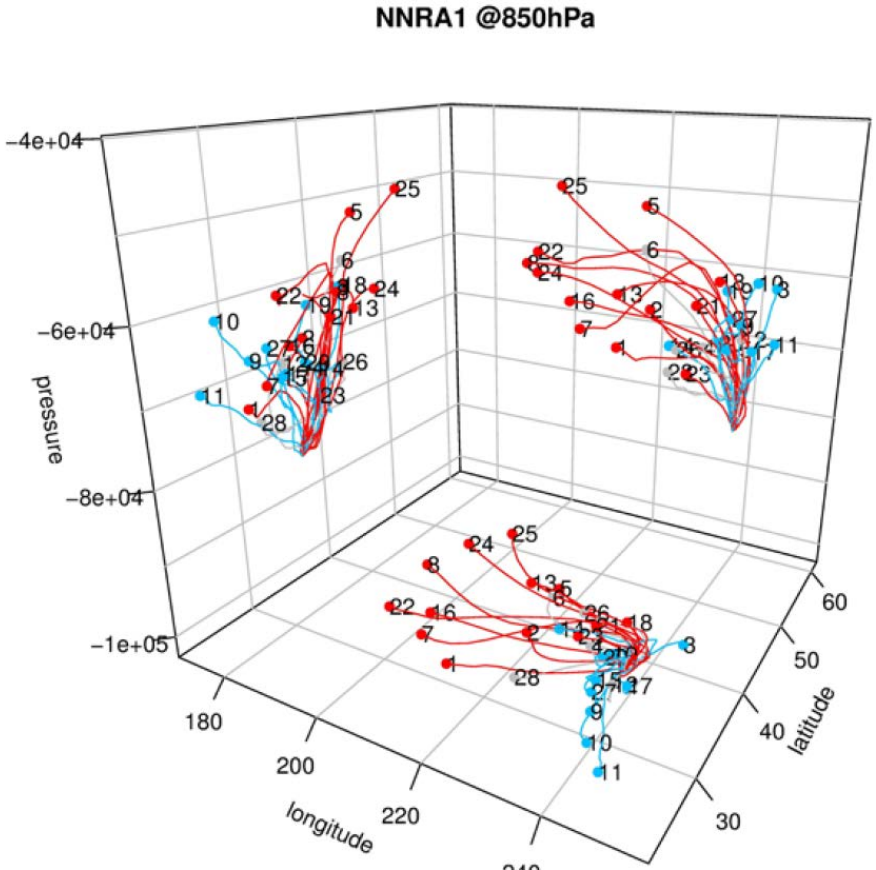
2. Clusters:
Two Paths to the Same End

Junction of 2 washes in Bryce Canyon UT © R. Grotjahn

Trajectories => Clusters

- Cluster analysis refined membership of which group
- The two groups are color coded.
- Red: cluster 1: crosses Pacific, strong westerly component
- Blue: cluster 2: more local, often with easterly component

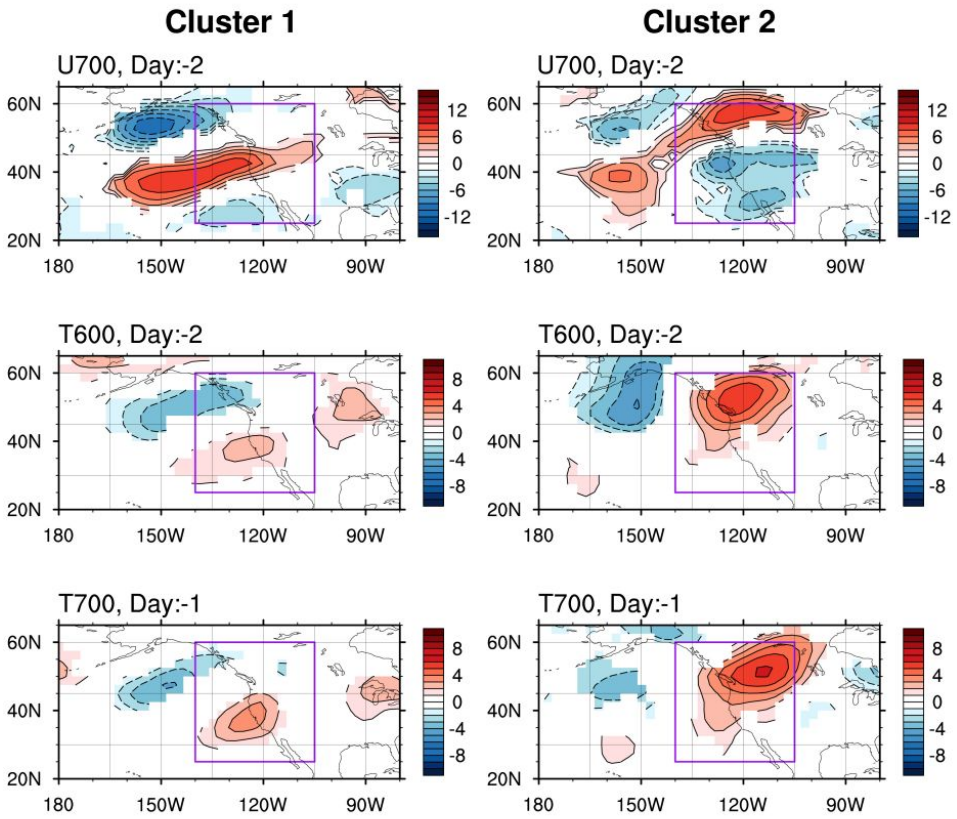
5% hottest days from normalized Tmax anomalies → dates with at least 6 extreme stations → 3 consecutive days and minimum 6 interval → 28 events (onset date) total during 1977-2010			
1	"06-05-1977"	15	"08-16-1992"
2	"09-06-1977"	16	"06-02-1996"
3	"06-05-1978"	17	"08-10-1996"
4	"08-05-1978"	18	"08-03-1998"
5	"09-12-1979"	19	"08-30-1998"
6	"07-24-1980"	20	"09-18-2000"
7	"06-11-1985"	21	"07-10-2002"
8	"07-17-1988"	22	"06-22-2006"
9	"08-25-1988"	23	"07-20-2006"
10	"09-03-1988"	24	"07-07-2008"
11	"07-12-1990"	25	"08-27-2008"
12	"08-05-1990"	26	"09-05-2008"
13	"07-02-1991"	27	"09-25-2009"
14	"06-02-1992"	28	"09-27-2010"



Average paths for 28 events

K-means Cluster Analysis

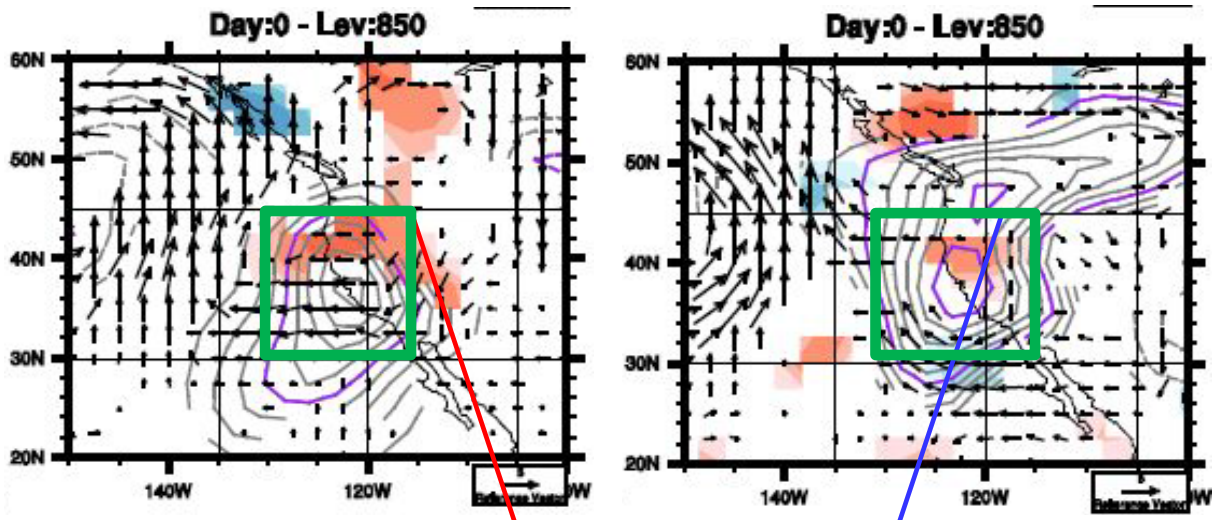
- Tested K=2, 3, 4.
- Few members in more than 2 clusters, hence k=2 for this
- Procedure:
  - divide events into two initial groups based on trajectories
  - nearly all trajectories (all average paths) remain between 500 and 850 hPa. So, examine lower tropospheric composites; identify areas where the two composites have very different properties.
  - select a few area, level, variable, & time to onset combinations where initial groups strongly differ
  - 700 hPa zonal wind at 2 days lead, 600 hPa temperature at 2 days lead, 700 hPa temperature at 1 day lead over 150W-100W, 20N-60N domain.



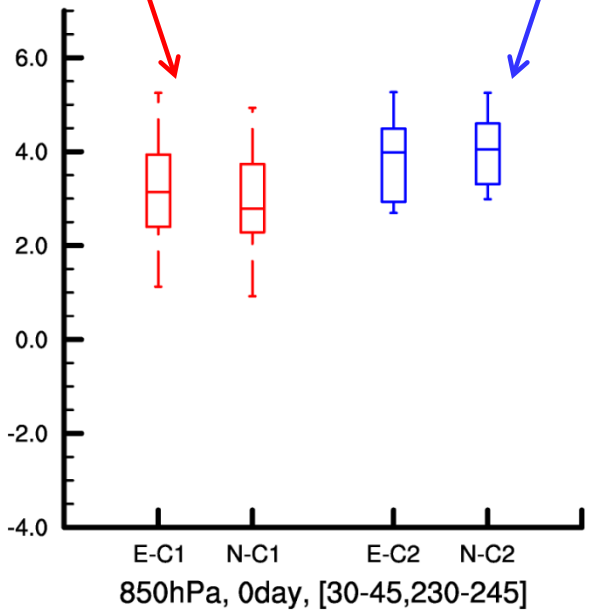
Cluster means: Temperature anomalies; zonal wind anomalies at indicated day before onset.

Cluster test – Ta control region

- Are clusters similar at heat wave onset?



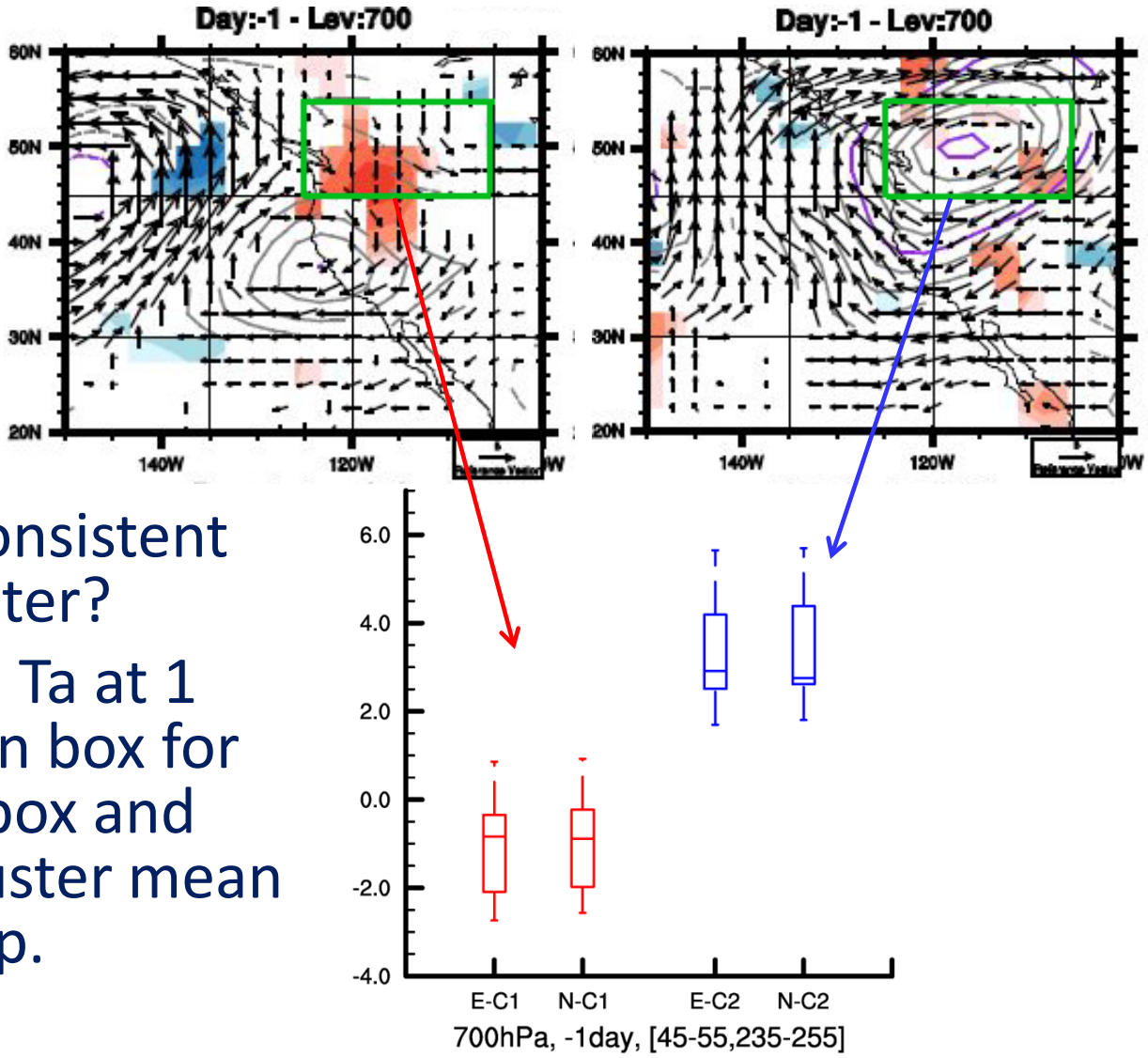
- Are members consistent within each cluster?
- Average 850hPa Ta at onset in green box for each member (box and whisker) and cluster mean (bar). “TA region” agree



Lee and Grotjahn (2015)

Cluster test – Ta difference region

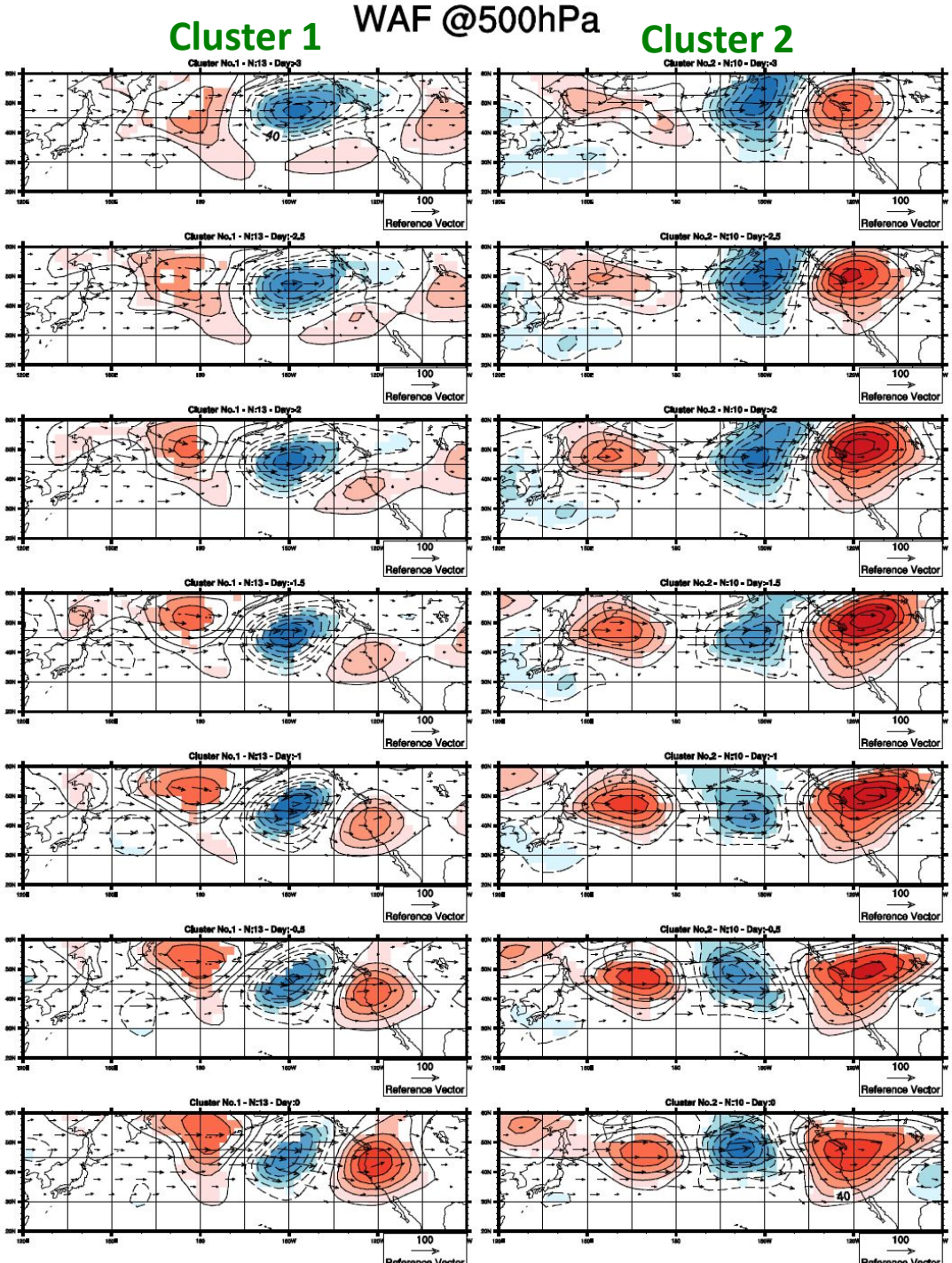
- Do members of one cluster separate from the other cluster?
- Are members consistent within each cluster?
- Average 700hPa Ta at 1 day lead in green box for each member (box and whisker) and cluster mean (bar). No overlap.



WAF

- Z_{500} and WAF_{500}
- WAF from higher latitude in cluster 1, subtropical in other.
- (WAF = wave activity flux. Similar to a flux of multiple forms of energy. 'Instantaneous' formulation used: Takaya and Nakamura, 2001)

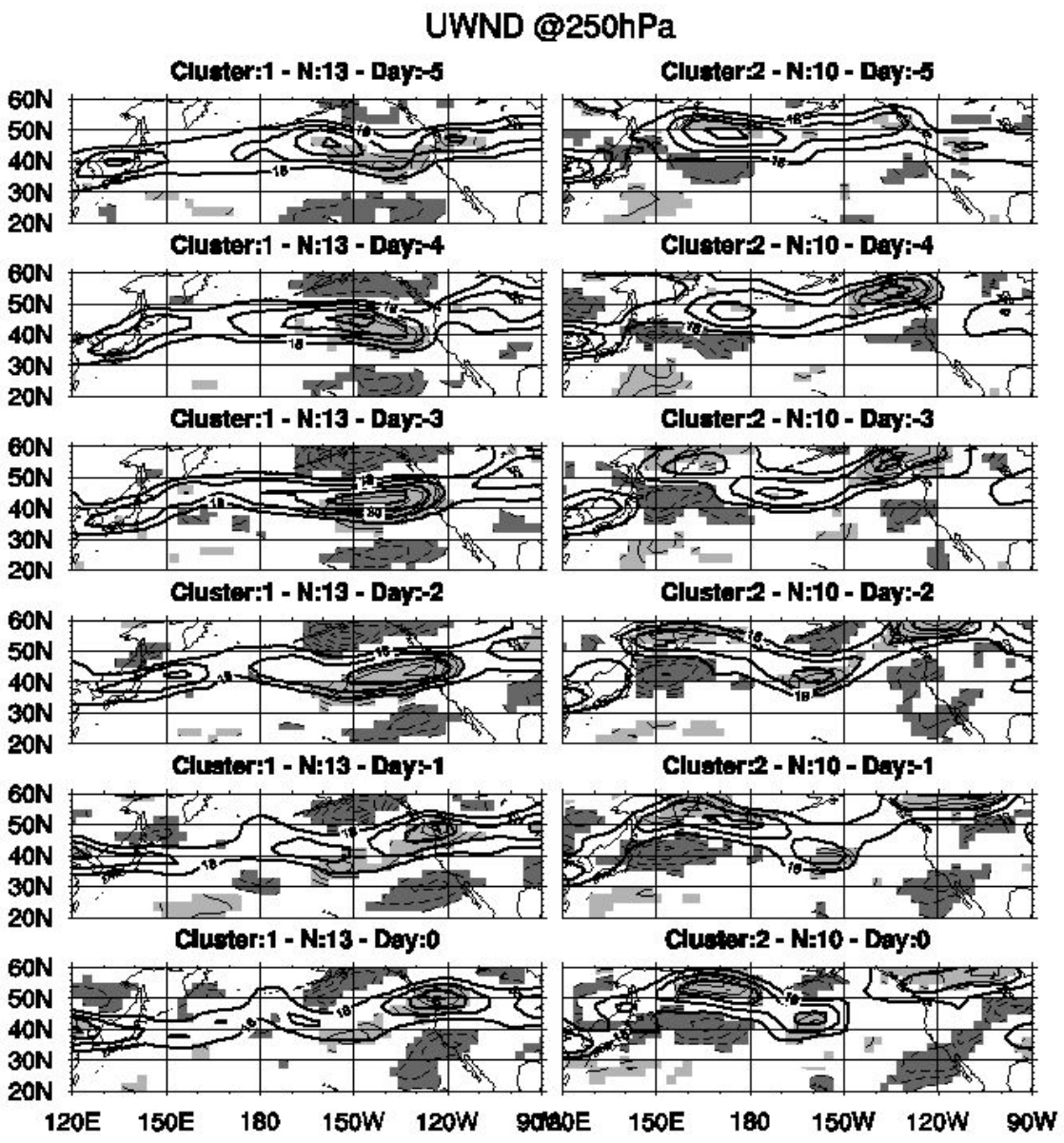
Lee and Grotjahn (2015)



Differences of the jet stream

- Subtropical jet extension: longer cluster 1 trajectories.
- Local flow weaker in cluster 2
- Jet streak accelerations imply upper level ageostrophic winds convergence (thus sinking below)

- thick contour: total wind; wind anomalies use shading and thin contours.



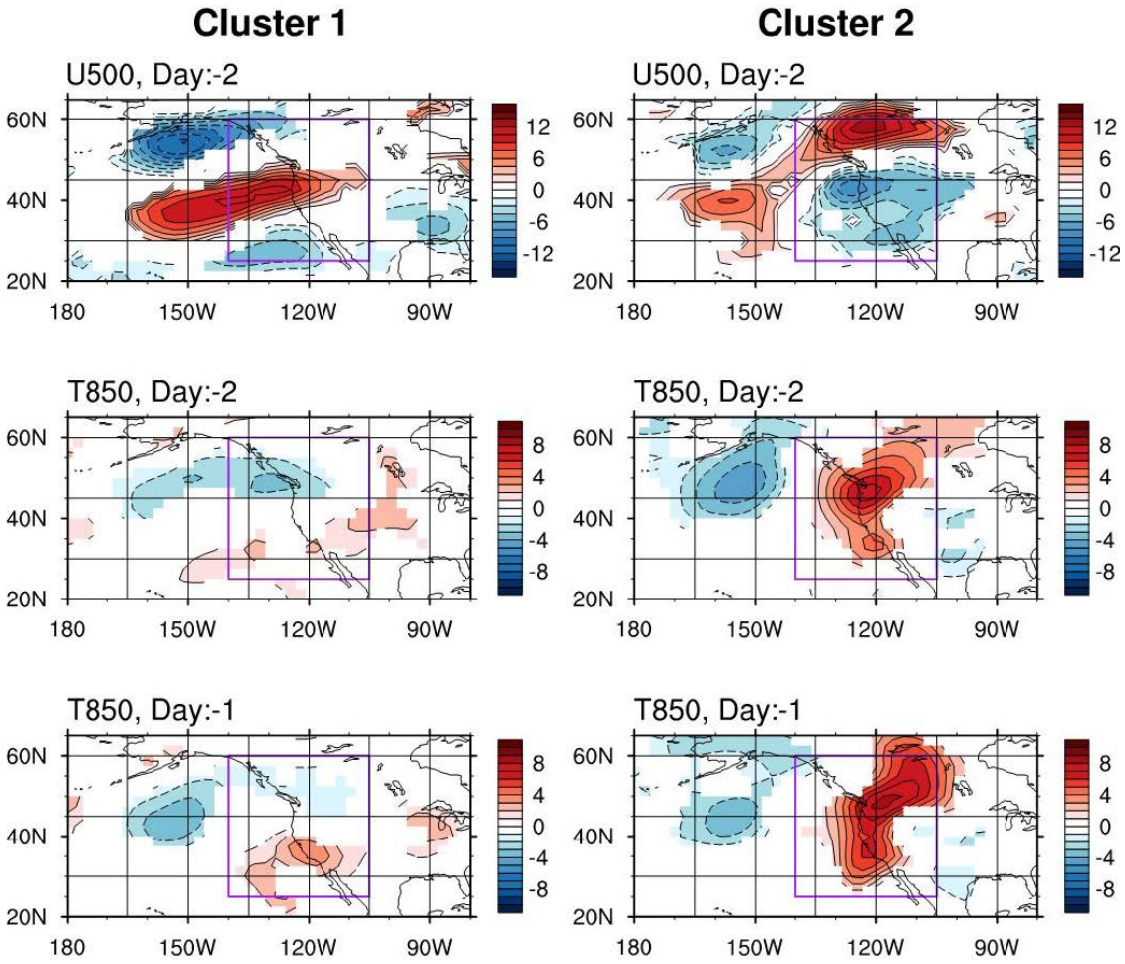
Lee and Grotjahn (2015)

3. Cluster Projections

Zion Narrows UT © R. Grotjahn

Cluster projections (CP)

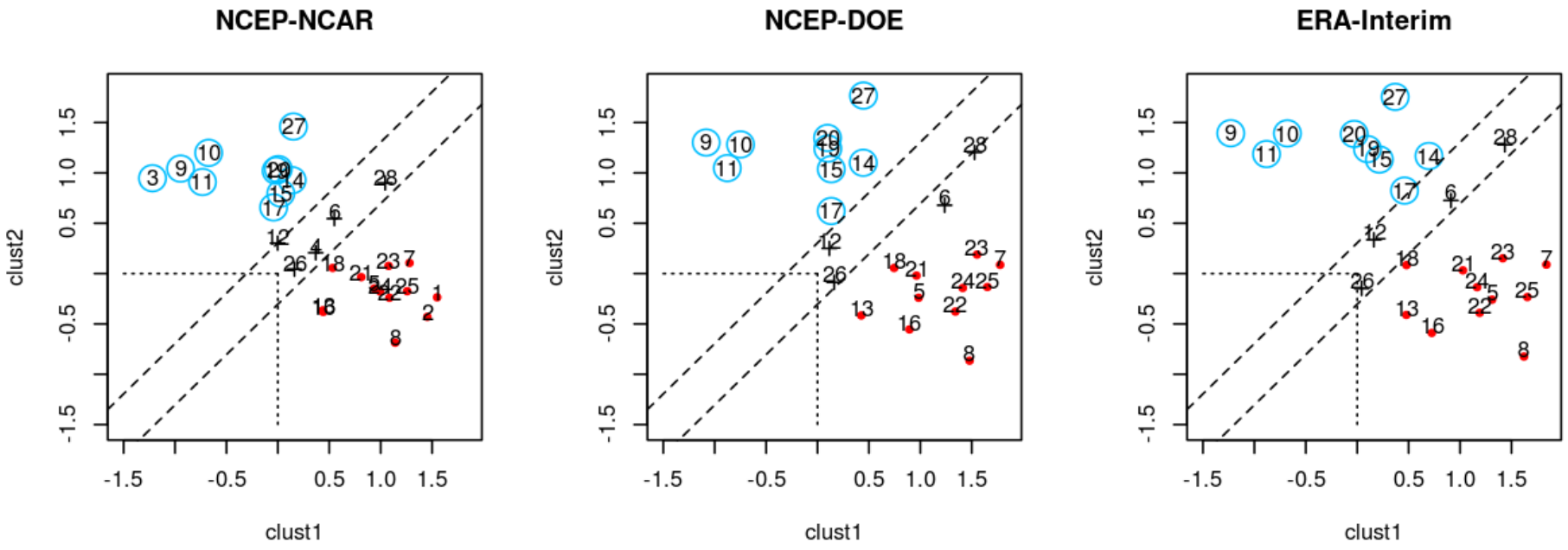
- Different levels than cluster analysis
  - to match model data
  - same cluster members
- Procedure:
  - 500 hPa zonal wind at 2 days lead, 850 hPa temperature at 2 days and 1 day lead over 150W-100W, 20N-60N domain. (purple)
  - Calculate projections between each event for the 3 field/level/time combinations
  - Average those 3 numbers to get the CP for that cluster



Cluster means: Temperature anomaly (°C); horizontal wind anomaly (m/s)

Reanalyses CP scatter plots

- Red dot for cluster 1 vs blue circle for cluster 2
- Mixed (dashed lines) when cluster 1 and cluster 2 differ by < 0.3



Lee and Grotjahn (2015)

4. Models Simulations

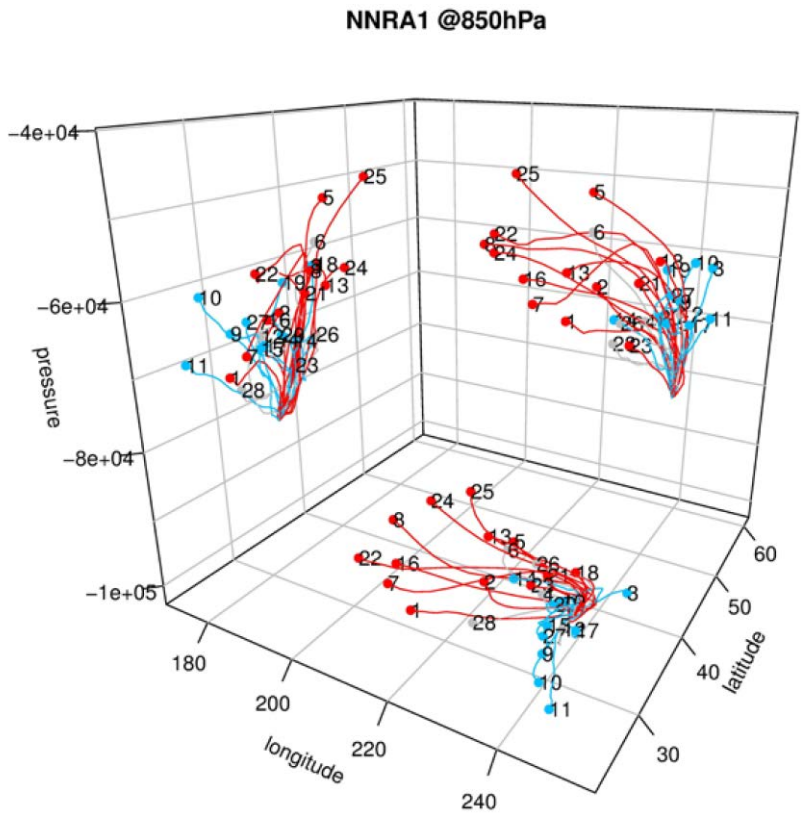
Barrier Canyon UT © R. Grotjahn

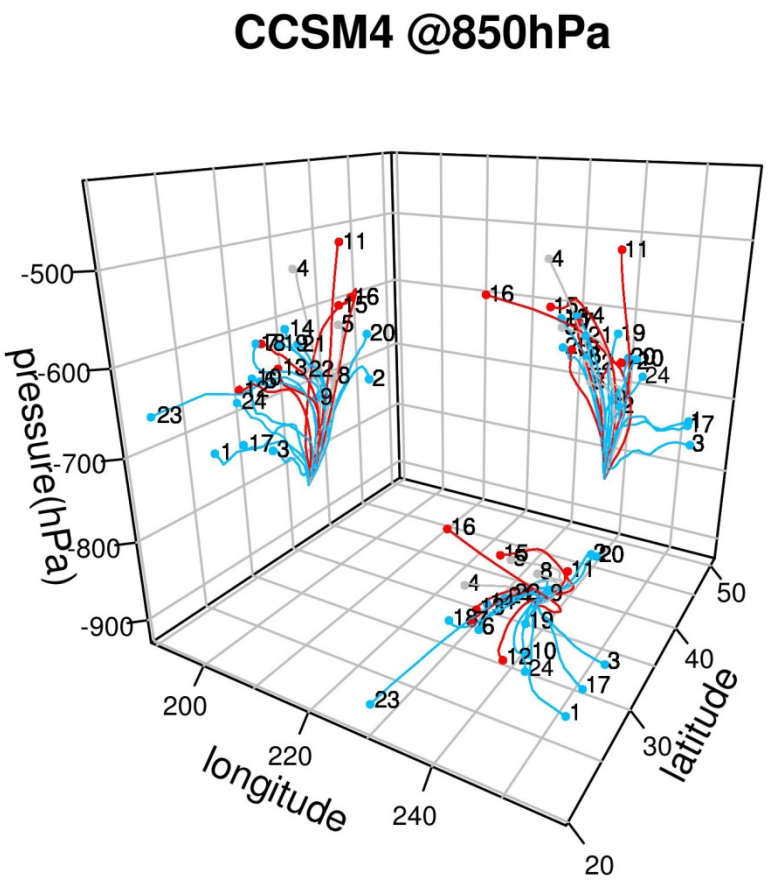
CMIP5 Models studied

Model	Horizontal resolution	HT vs LT	CV Grid #	Min. Grid #	Mean Duration	Event #
NCEP-NCAR	-	-	15	6	4.07	28
CCSM4	1:288x192	L	4	2	3.75	33
MRI-ESM1	2:320x160	H	5	3	3.64	33
bcc-csm1-1-m	2:320x160	L	5	3	4.16	31
CNRM-CM5	3:256x128	L	3	2	3.87	31
HadGEM2-CC	4:192x144	H	4	2	4.38	34
inmcm4	5:180x120	L	2	1	4.64	46
NorESM1-M	6:144x96	L	2	1	4.04	50
GFDL-CM3	7:144x90	H	3	2	3.48	29
GFDL-ESM2G	7:144x90	L	3	2	4.14	30
GFDL-ESM2M	7:144x90	L	3	2	4.38	30
bcc-csm1-1	8:128x64	L	1	1	4.24	34
MIROC-ESM	8:128x64	H	1	1	3.97	30
MIROC-ESM-CHEM	8:128x64	H	1	1	4.32	25
FGOALS-g2	9:128x60	L	1	1	4.16	38
					4.08	34

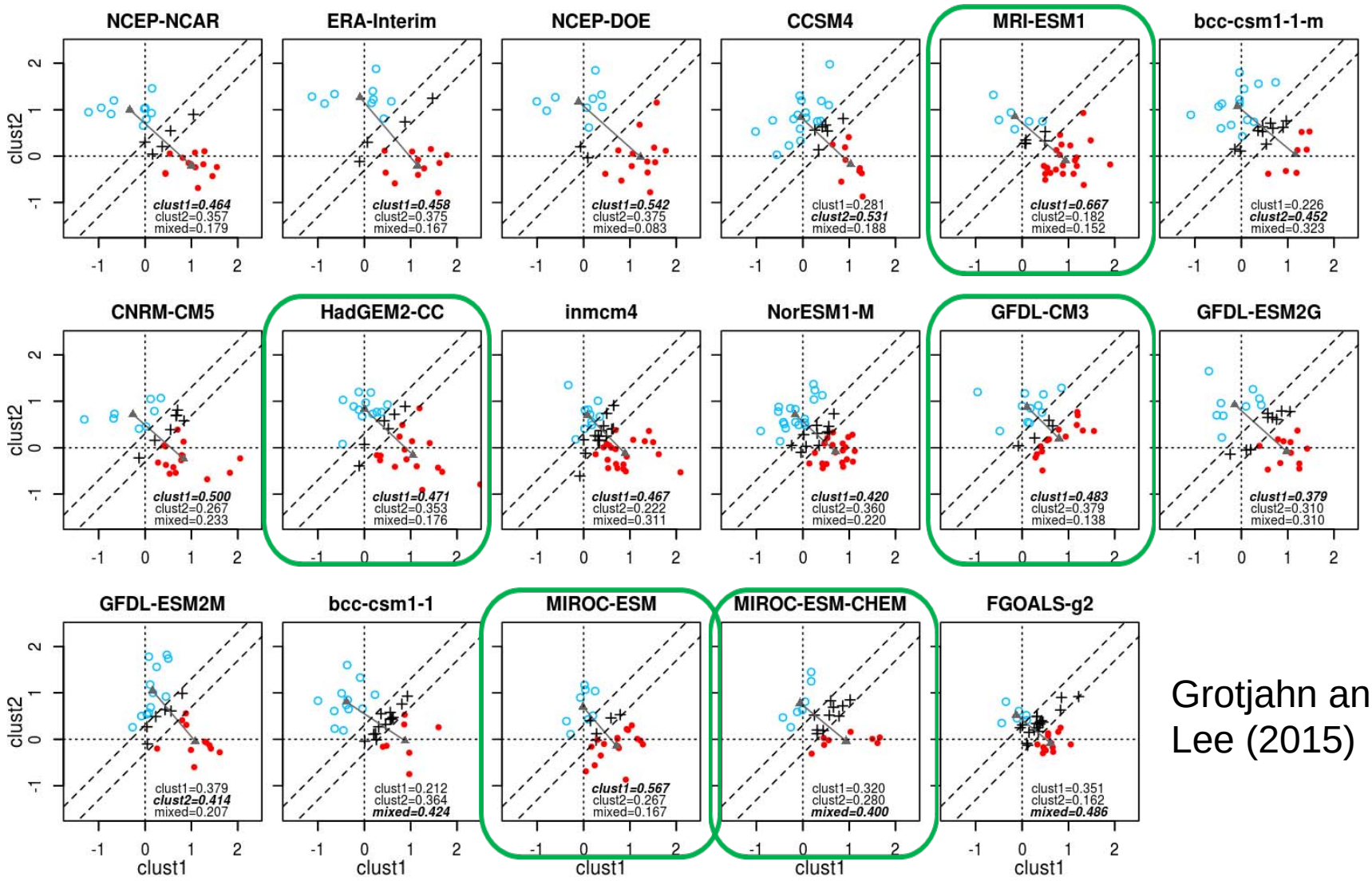
CCSM4 Backwards Trajectories

- NCEP/NCAR vs NCAR CCSM4
- (longitude and latitude ranges differ)
- Colors assigned from scatter plots





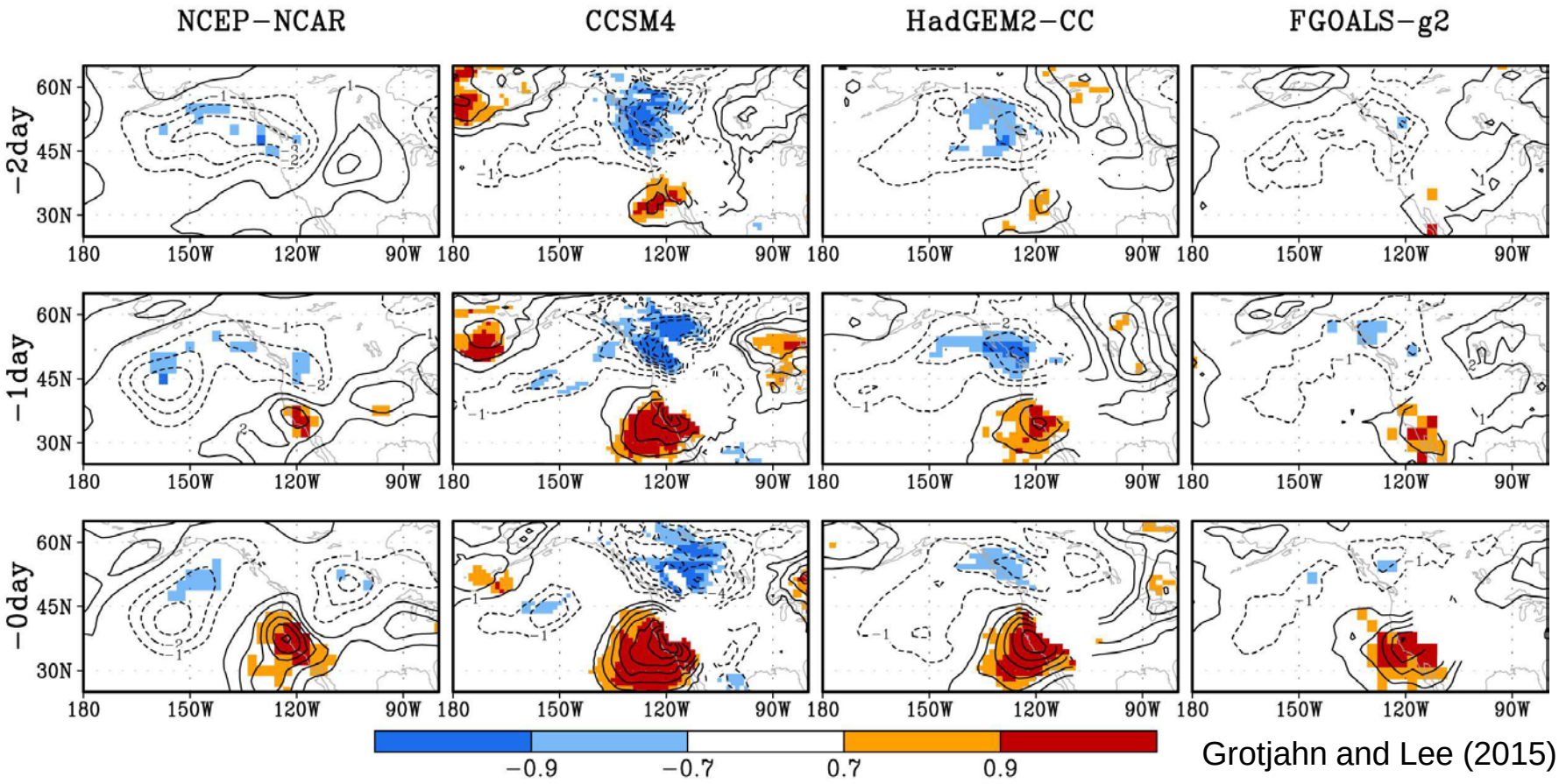
Models PC scatter plots



Grotjahn and Lee (2015)

Model LSMPs – Cluster 1

- NCEP/NCAR vs 2 popular & lowest resolution models
- models have weak mid-ocean trough, Ta anomaly onshore

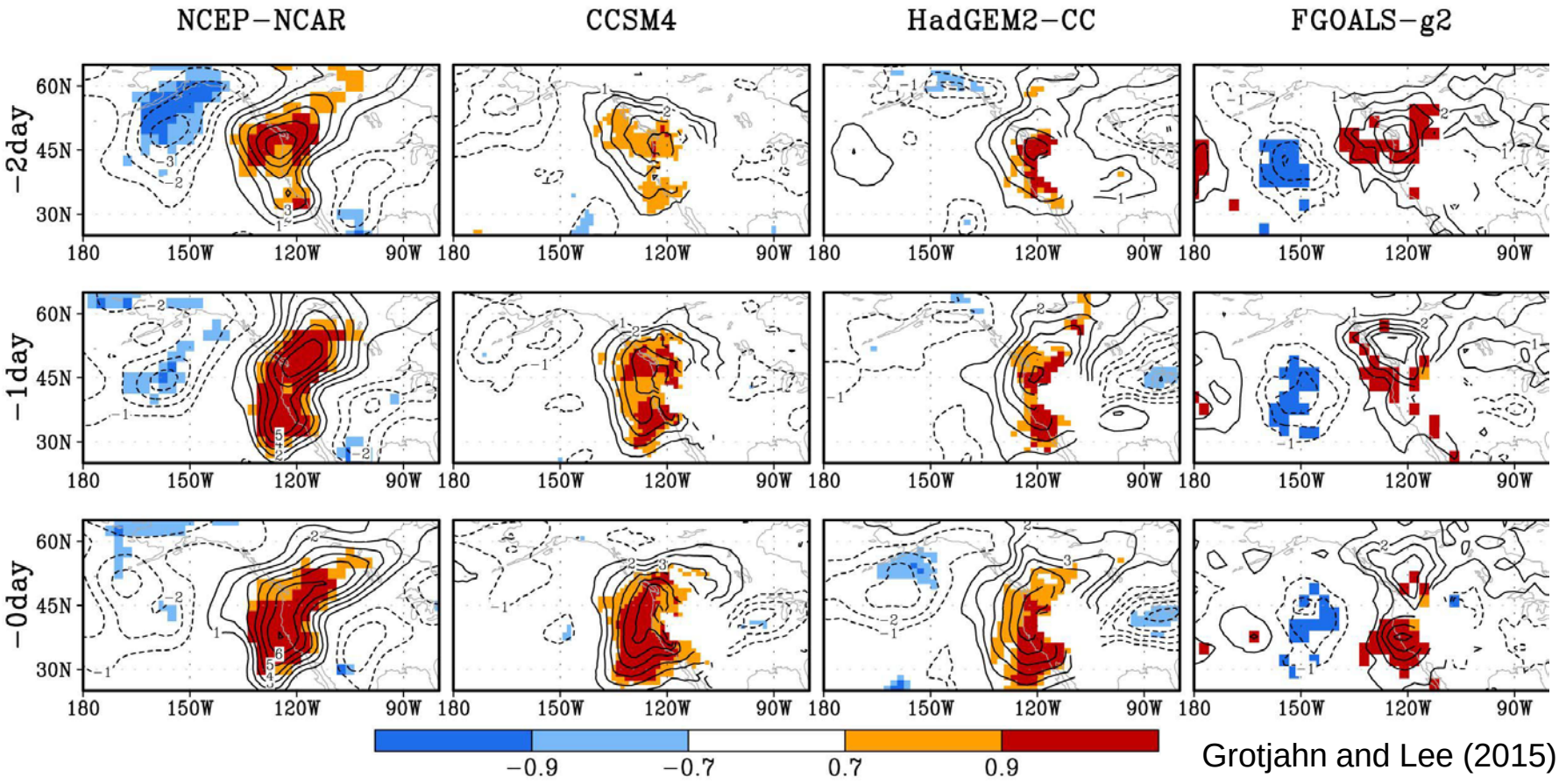


Grotjahn and Lee (2015)

Shading: sign counts; 0.7 means 84% of member have same sign

Model LSMPs – Cluster 2

- NCEP/NCAR vs 2 popular & lowest resolution models
- Mid-ocean trough varies; Ta onshore – except CCSM



Grotjahn and Lee (2015)

Shading: sign counts; 0.7 means 84% of member have same sign

5. Summary

- **Extreme California heat waves tend to form two ways**
- **Composites, trajectories, cluster analyses, all find these two types (plus events that are a mixture)**
  - Cluster 1: locally-formed T max; strong westerly flow, extension east of Asian jet; mid/high latitude WAF
  - Cluster 2: expansion southwest of pre-existing max T in SW Canada; weak flow; subtropical WAF
- **Type found is not sensitive to reanalysis nor projection level or area**
- **Climate models capture both types, but properties & mix of types varies. Tends to be better for higher resolution**


Thanks for your attention
Questions?