What We Know About Northern California Extreme Rainfall Events: An HPC Perspective

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BIOGRAPHICAL SKETCH

Mr. Junker has been operationally involved with quantitative precipitation forecast (QPF) since 1983. Mr. Junker is an active participant of the National Weather association (NWA) and American Meteorological Society (AMS). He has received several past awards from both the NWA and AMS for his individual efforts in research and forecasting. Mr. Junker has been a member of the U.S. Weather Research Working Group on QPF and has served as the Chair of AMS Committee of Weather and Forecasting. He also has served as program chairperson for the 13th and 16th Conferences on Weather Analysis and Forecasting and for the 12th Conference on Numerical Weather Prediction. He is both past Vice-President and President of the NWA and is a fellow of the American Meteorological Society.

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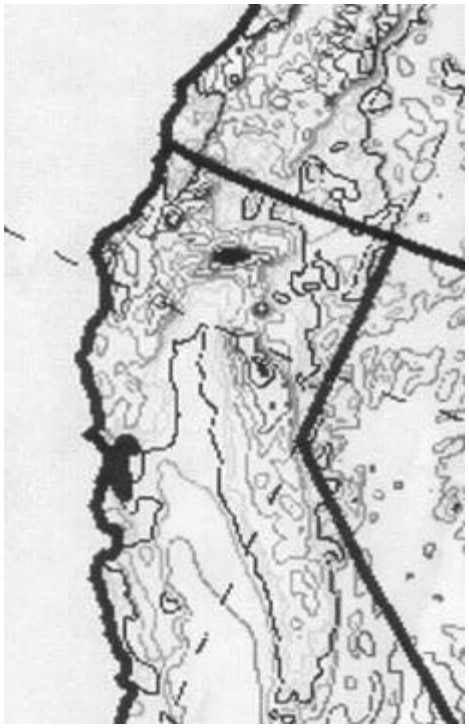
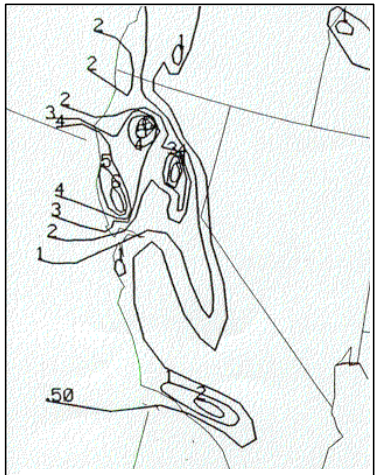
Precipitation is strongly modulated by orography



10 km PRISM climatology map

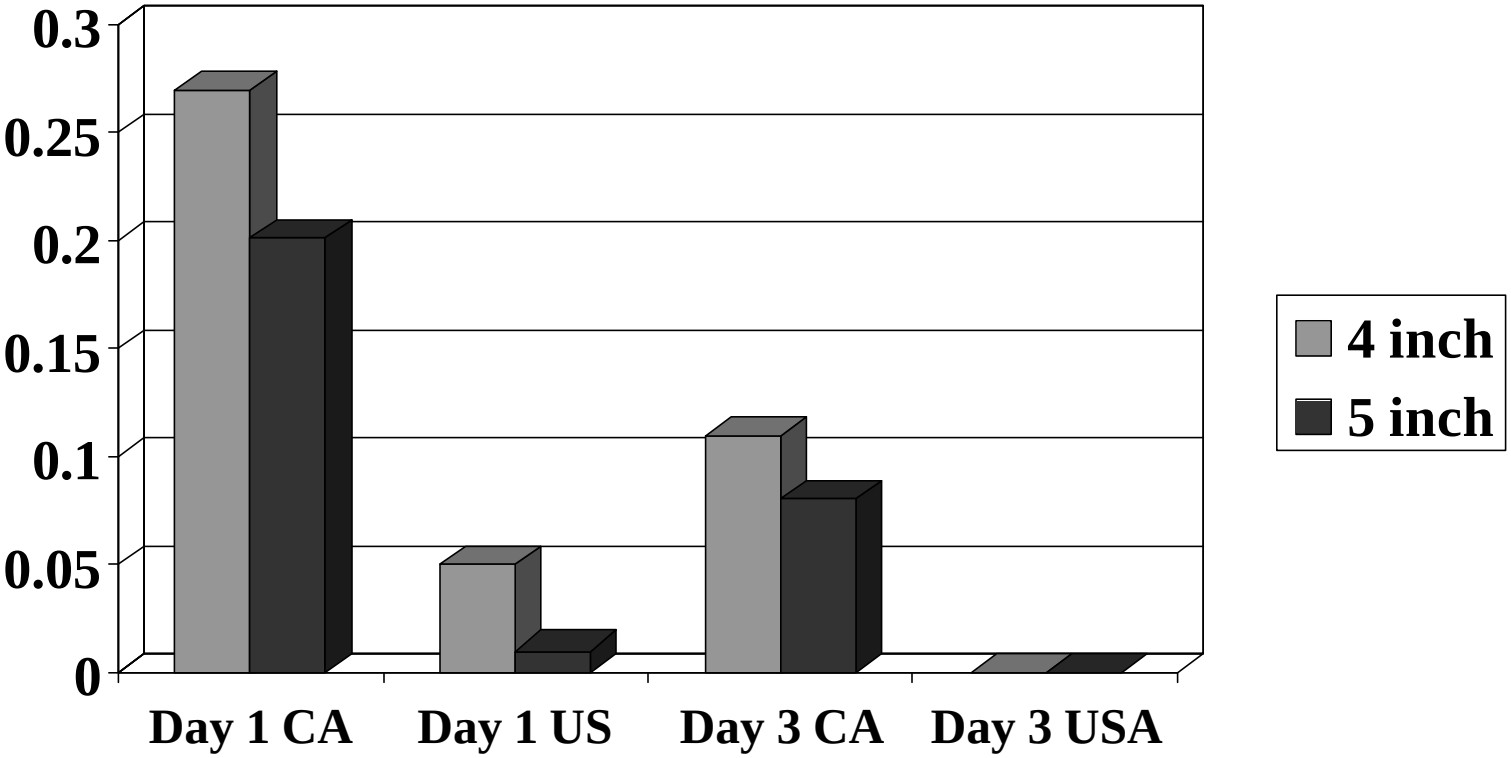


V.T. 1200 UTC 09 Jan 1995

V.T. 1200 UTC 10 Mar 1995

Similar maxes occurred near Shasta and in the northern Sierra range but elsewhere max locations were different.

Comparison of West coast heavy rainfall event HPC Threat Scores during 7 extreme rainfall events in northern CA with Threat scores for total CONUS in 2001

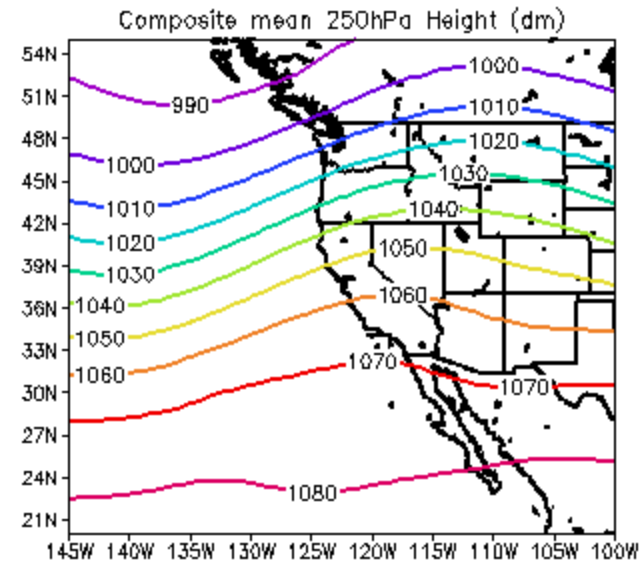


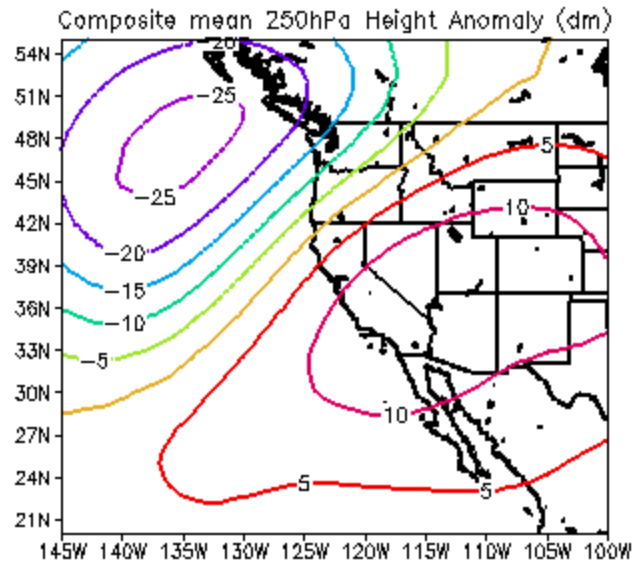
Scores are much higher for extreme northern CA rainfall events than elsewhere in the country. Why?

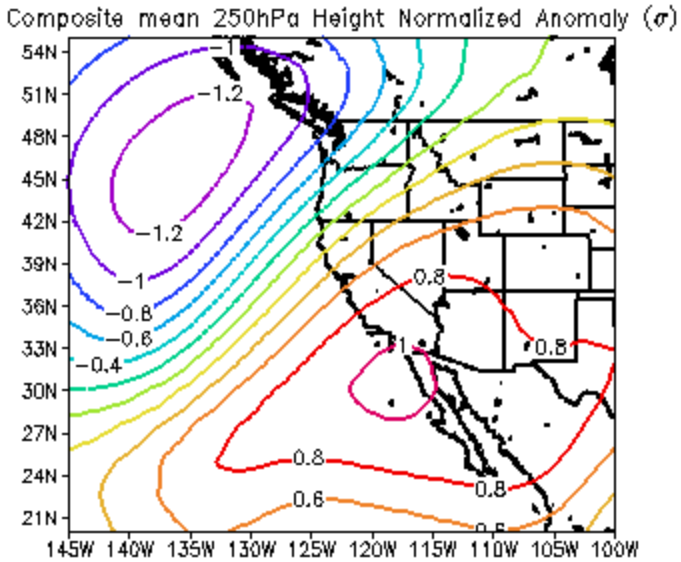
Climatological Study

- **Looked each 4 inch or greater event during 10-year period using HPC official 24 hour rainfall analyses**
- **Looked at various parameters and tried to determine which were most important**
  - **used NCEP reanalysis data 1961-1990 for Climatology**
- **developed composites for various parameters and used 30-year NCEP data to develop anomaly charts**
- **looked at <u>3 major flood cases</u> and compared their anomalies to the composites developed for 18 (4 inch or more) events.**

Mean 250 height composite for 18 heavy rainfall (4 inches or more) events in northern CA







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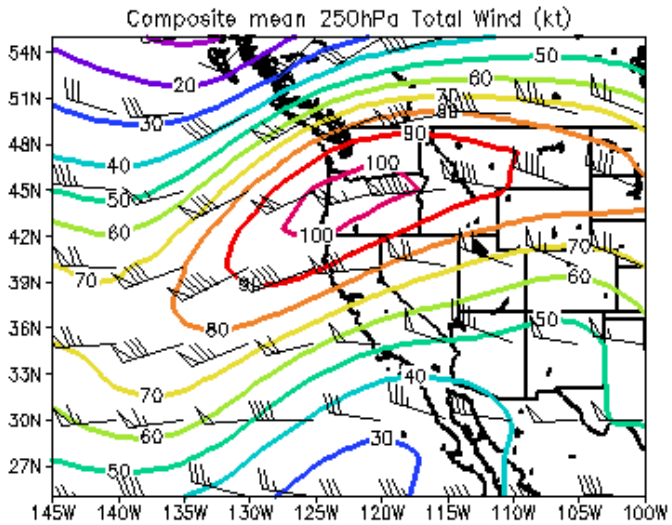
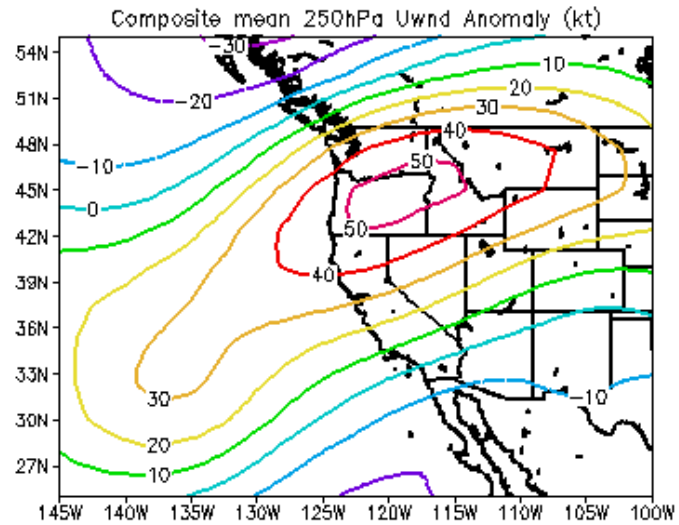
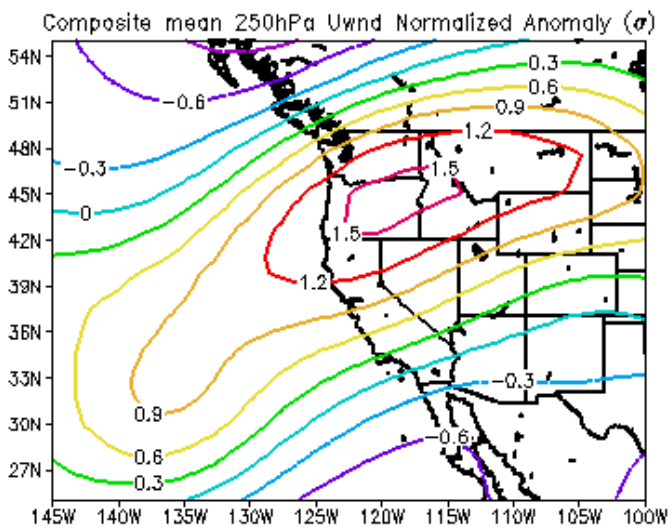
13) 00Z07FEB1999
14) 00Z14JAN2000
15) 12Z22FEB2000
16) 00Z30OCT1992
17) 12Z01JAN1997
18) 12Z25JAN1997

Dates used in composite

Composite 250 mb winds (top left), 250 mb anomalies of the u (top right) and v wind component







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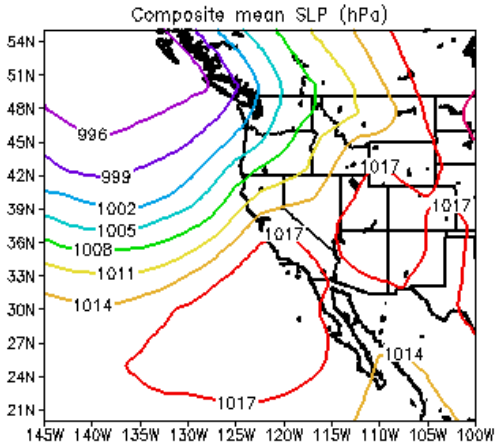
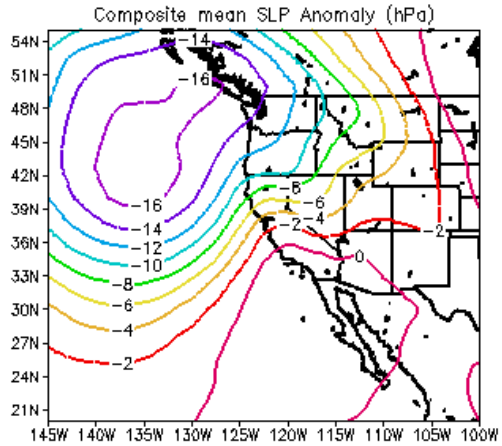
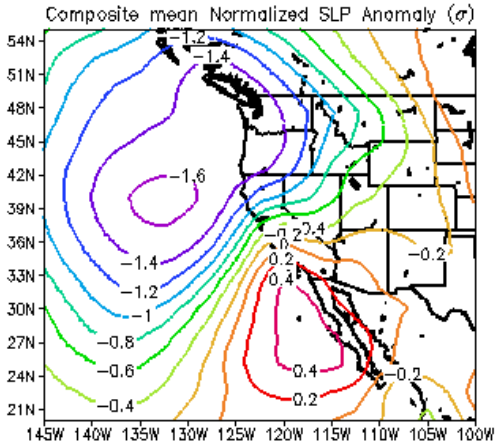
14) 00Z14JAN2000
15) 12Z22FEB2000
16) 00Z30OCT1992
17) 12Z01JAN1997
18) 12Z25JAN1997

Appear to occur near right entrance region of upper-level wind maximum

Mean sea level pressure composite and anomalies.







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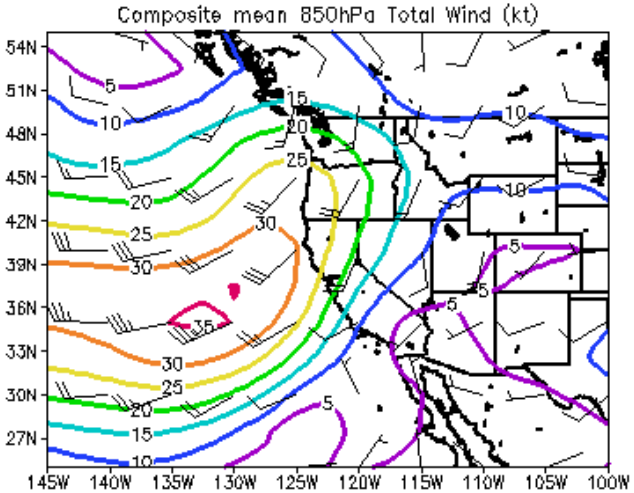
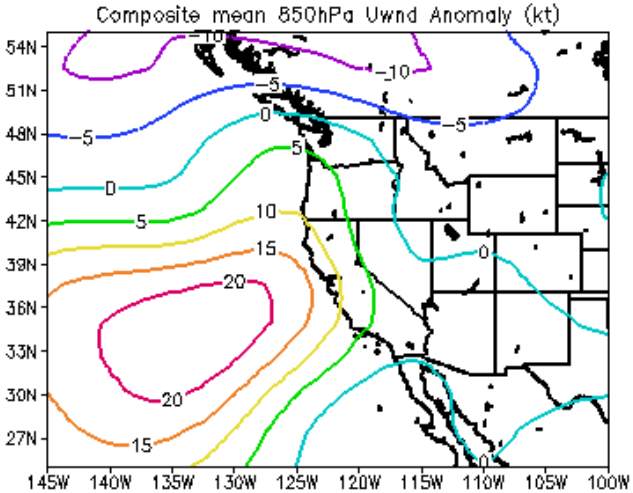
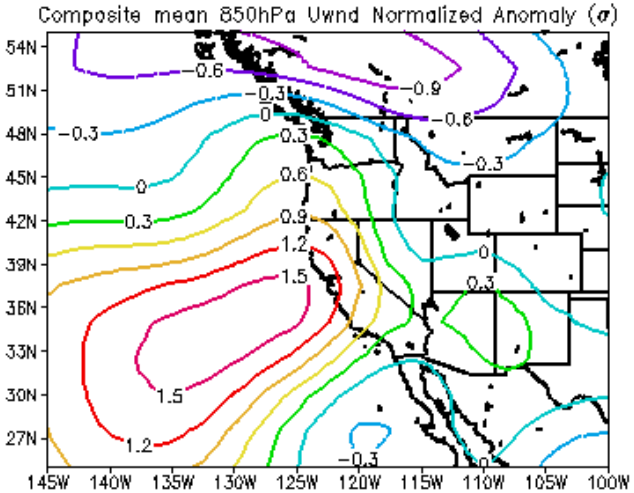
16) 00Z30OCT1992
17) 12Z01JAN1997
18) 12Z25JAN1997

Stronger than normal pressure gradient over northern California

Composite mean 850 wind and u and vwind component anomaly







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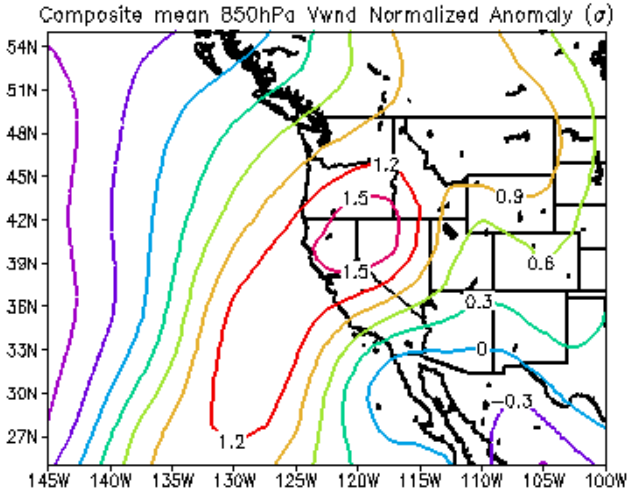
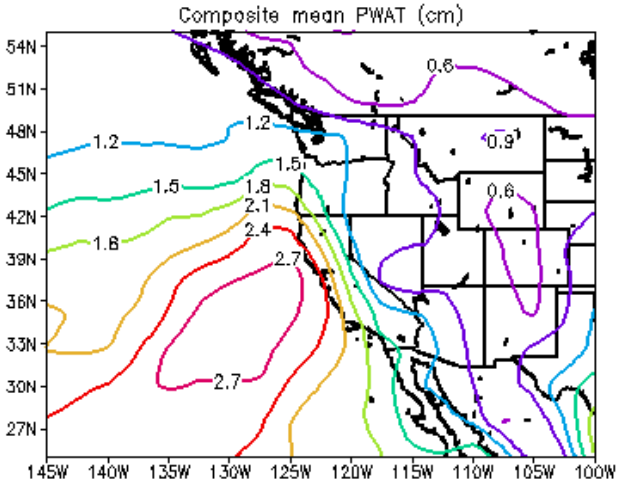
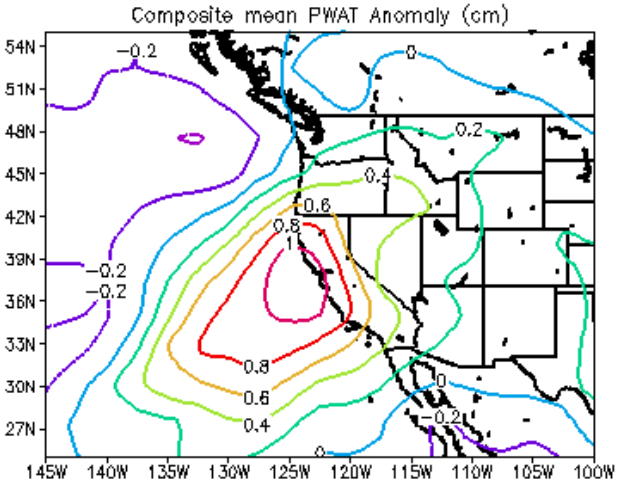


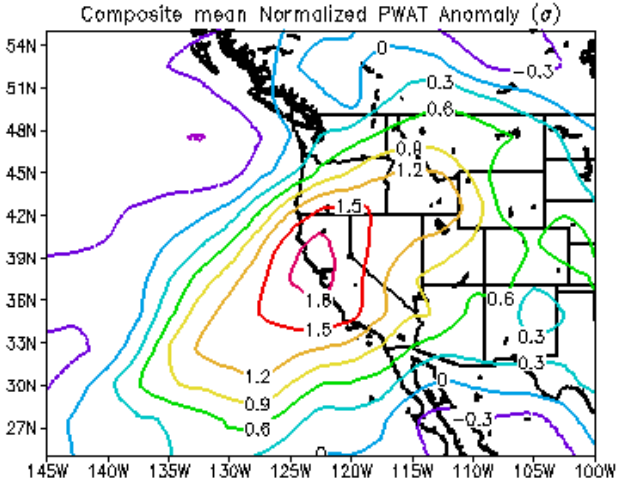
Normalized u component anomaly

Normalized v component anomaly

Composite mean precipitable water (PW) (top left), PW anomaly (top right), normalized PW anomaly (bottom panel)







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13) 00Z07FEB1999
14) 00Z14JAN2000
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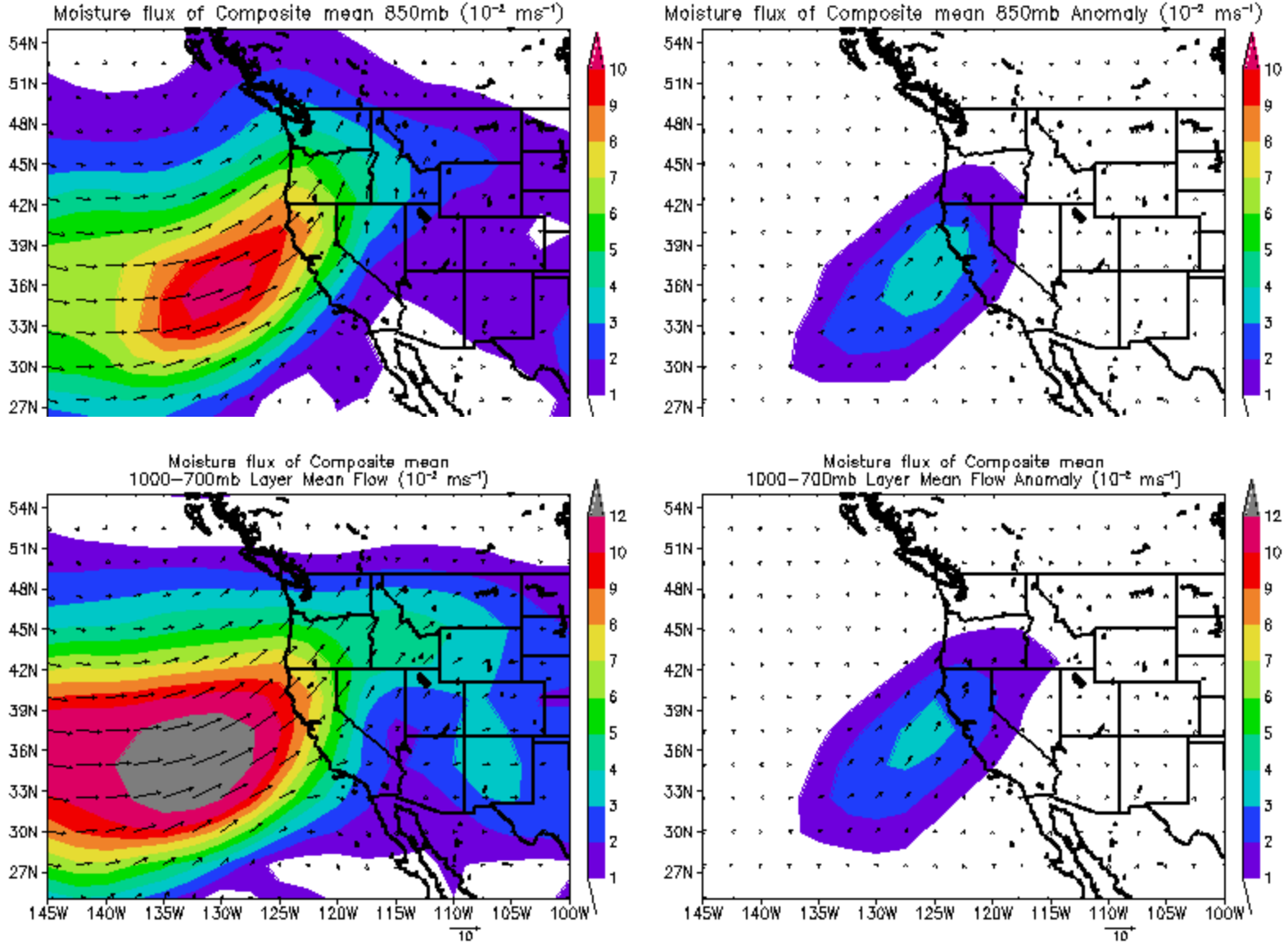
17) 12Z01JAN1997
18) 12Z25JAN1997

Precipitable water values averaged greater than an inch just off the coast.

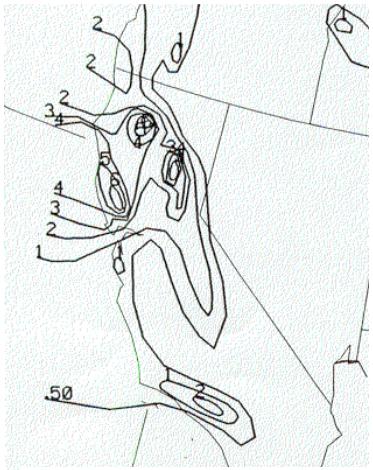
Moisture flux and moisture flux anomalies, 850 mb (top), 1000-700 mb bottom



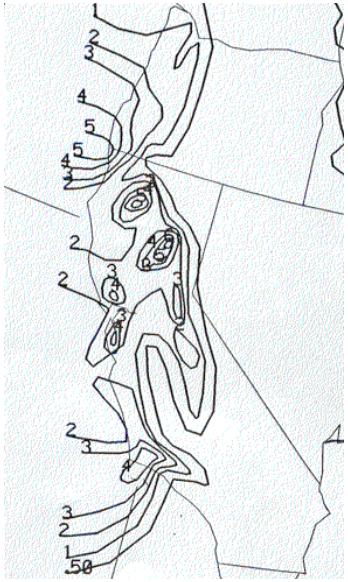
How are the major flood cases different

Examples of 3 Major Sierra Nevada precipitation events than caused flooding

- **9-10 Jan 1995, 9-10 March 1995, 31 Dec 1996-2 Jan 1997.**
  - **Slow moving mid level troughs.**
  - **strong onshore flow**
  - **Precipitable water and 850 and 1000-700 mb moisture flux anomalies much greater than normal.**
    - **Anomalies considerably higher than composite for 4 inch or greater events.**



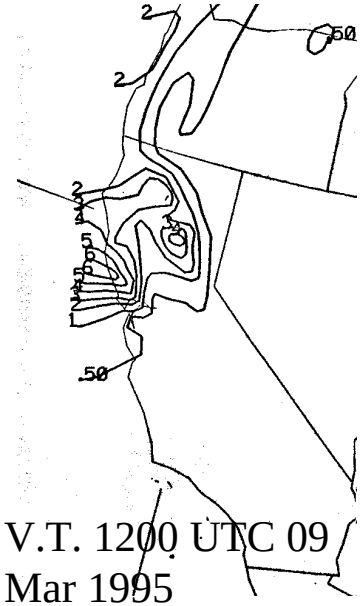
V.T. 1200 UTC 09 Jan 1995



V.T. 1200 UTC 10 Jan 1995

Major rainfall days that produced flash flooding across much of central CA.

The rainfall distribution is tied strong to terrain. Note how similar the patterns are during the various days.



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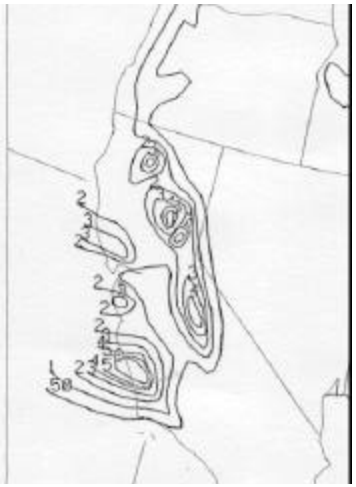

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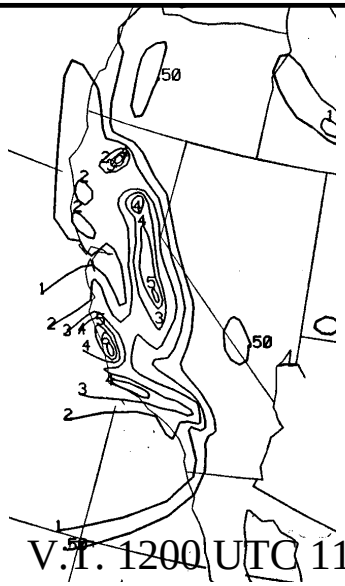
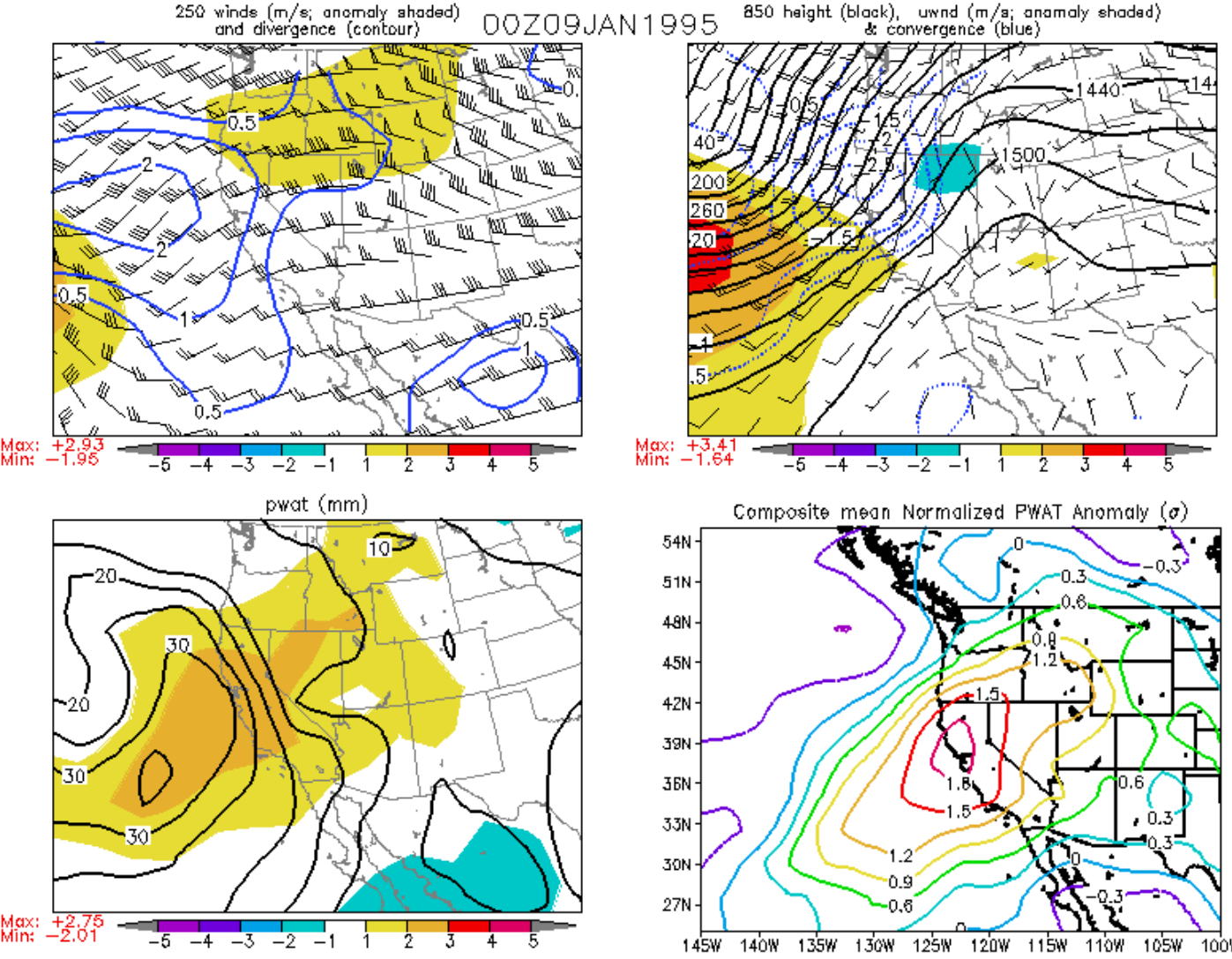


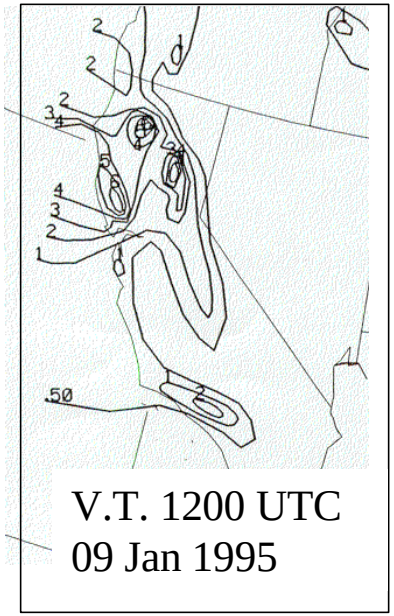
V.T. 1200 UTC 11 Mar 1995

V.T. 1200 UTC 01 Jan 1997

V.T. 1200 UTC 02 Jan 1997

PW anomaly (bottom left) is stronger than found in the 18 case composite mean (bottom right)

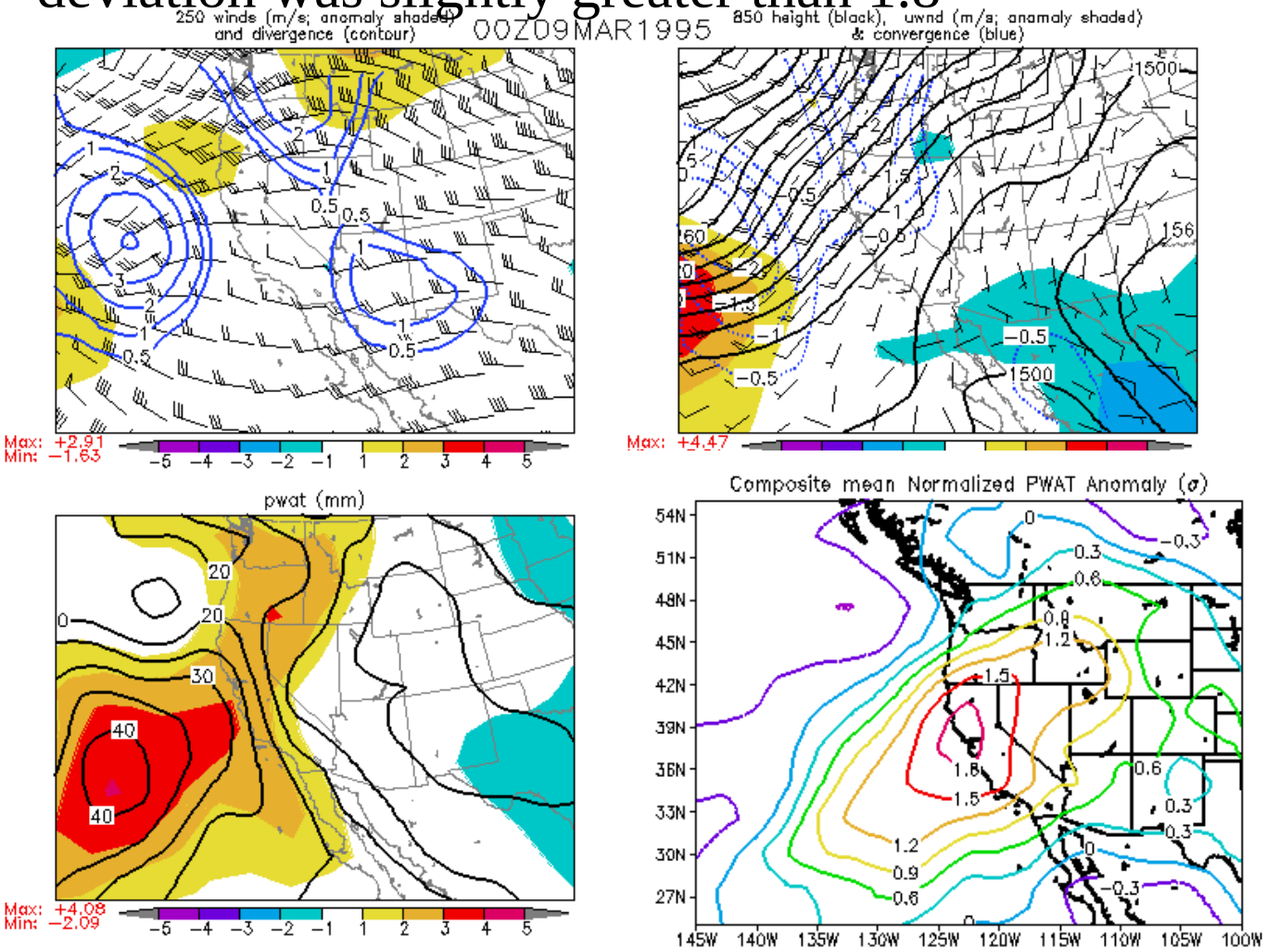


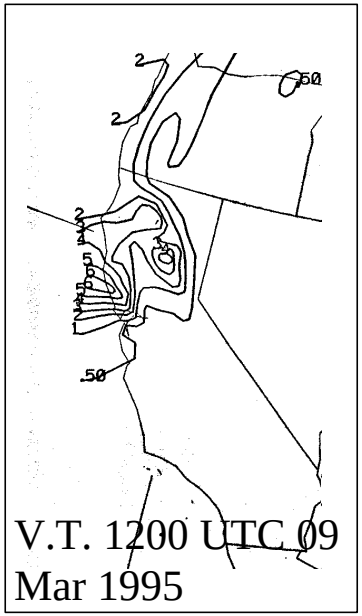


Note winds on these charts are in m/s not in knots. In the composites, we used knots

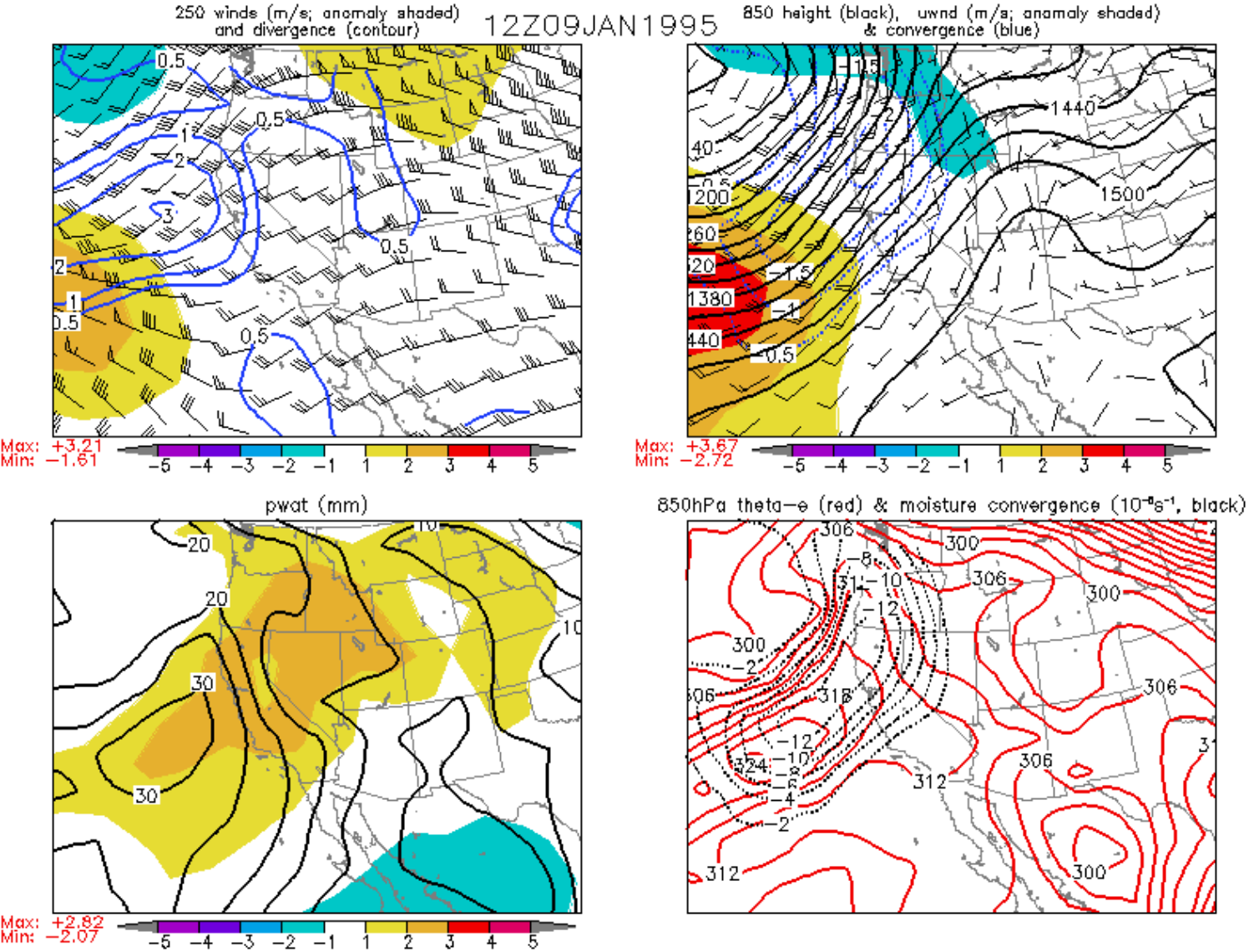
Strong precipitable water and 850 wind anomaly

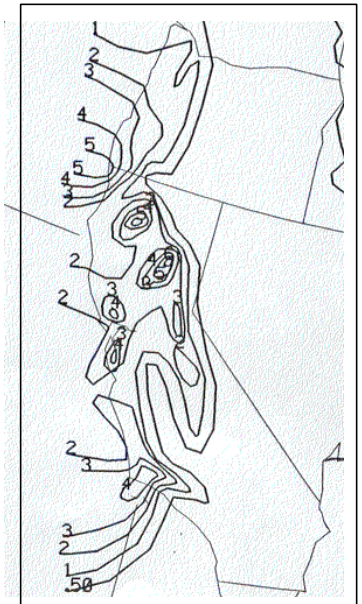
PW anomaly has greater than 3 standard deviation on Mar 09, composite mean value standard deviation was slightly greater than 1.8





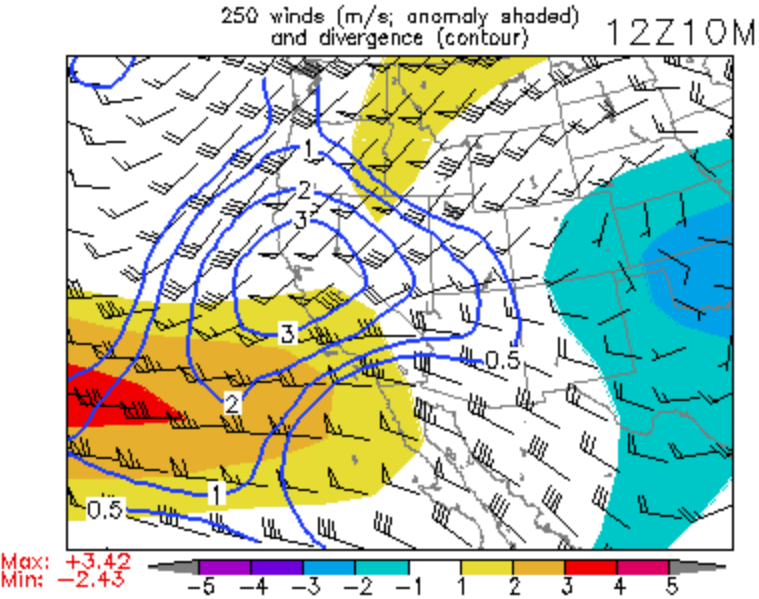
Note similarities between pattern between the two events

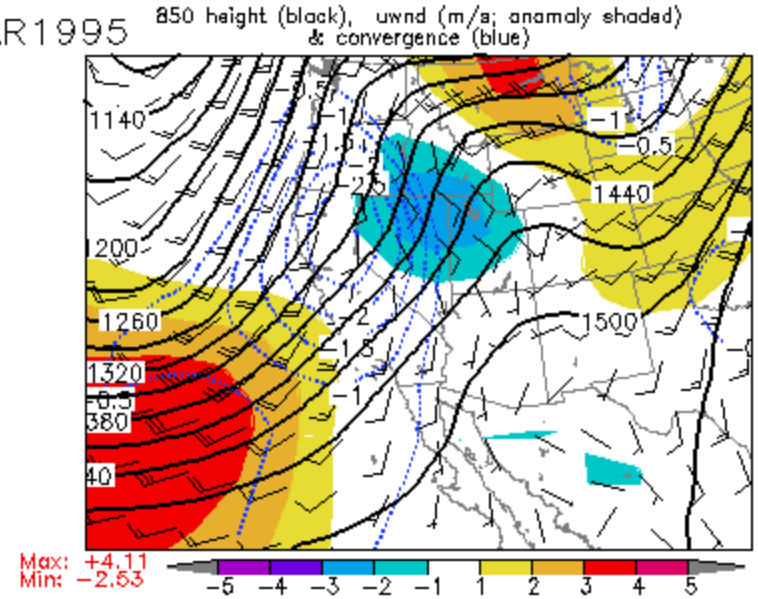


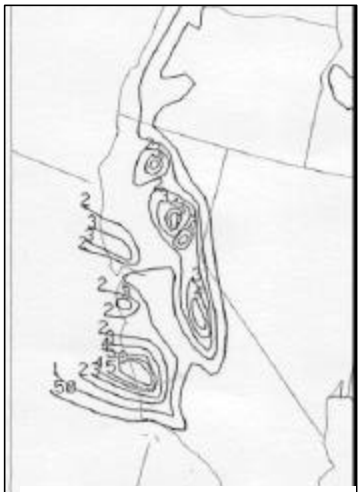


V.T. 1200 UTC
10 Jan 1995

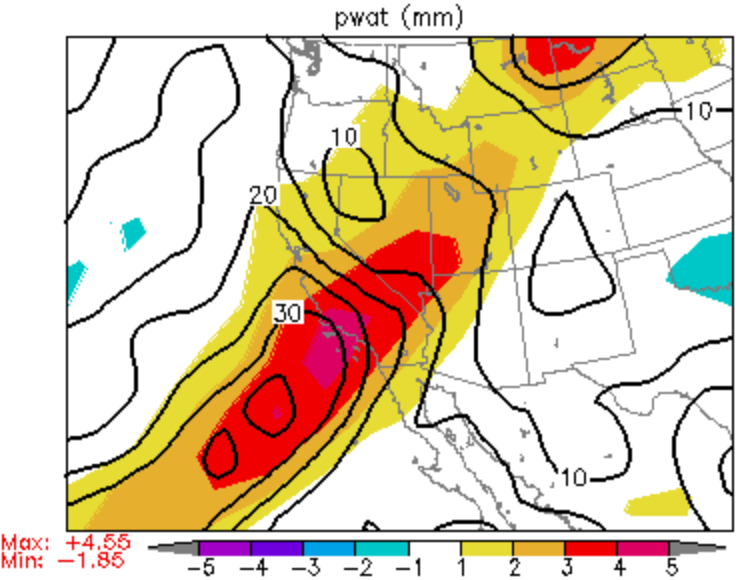
Note the anomalies in the PW and 850 mb winds off the coast, the moisture flux or transport (qV) anomaly must be large. Note approach of exit region of jet streak.

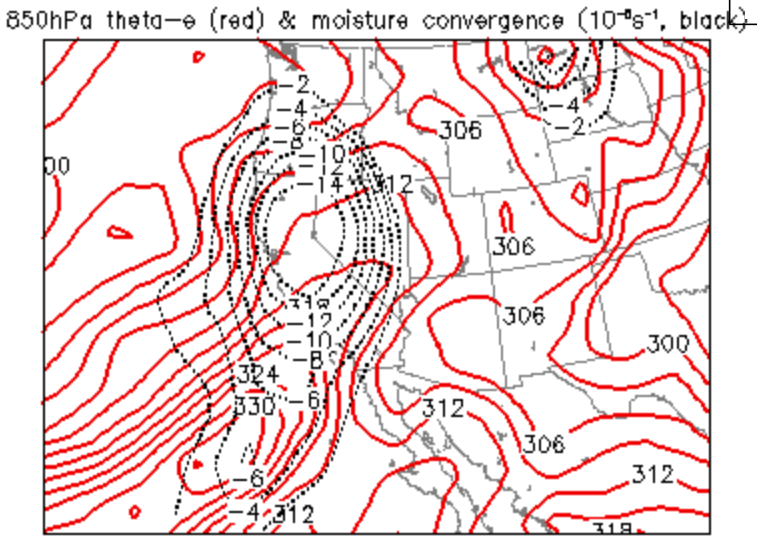






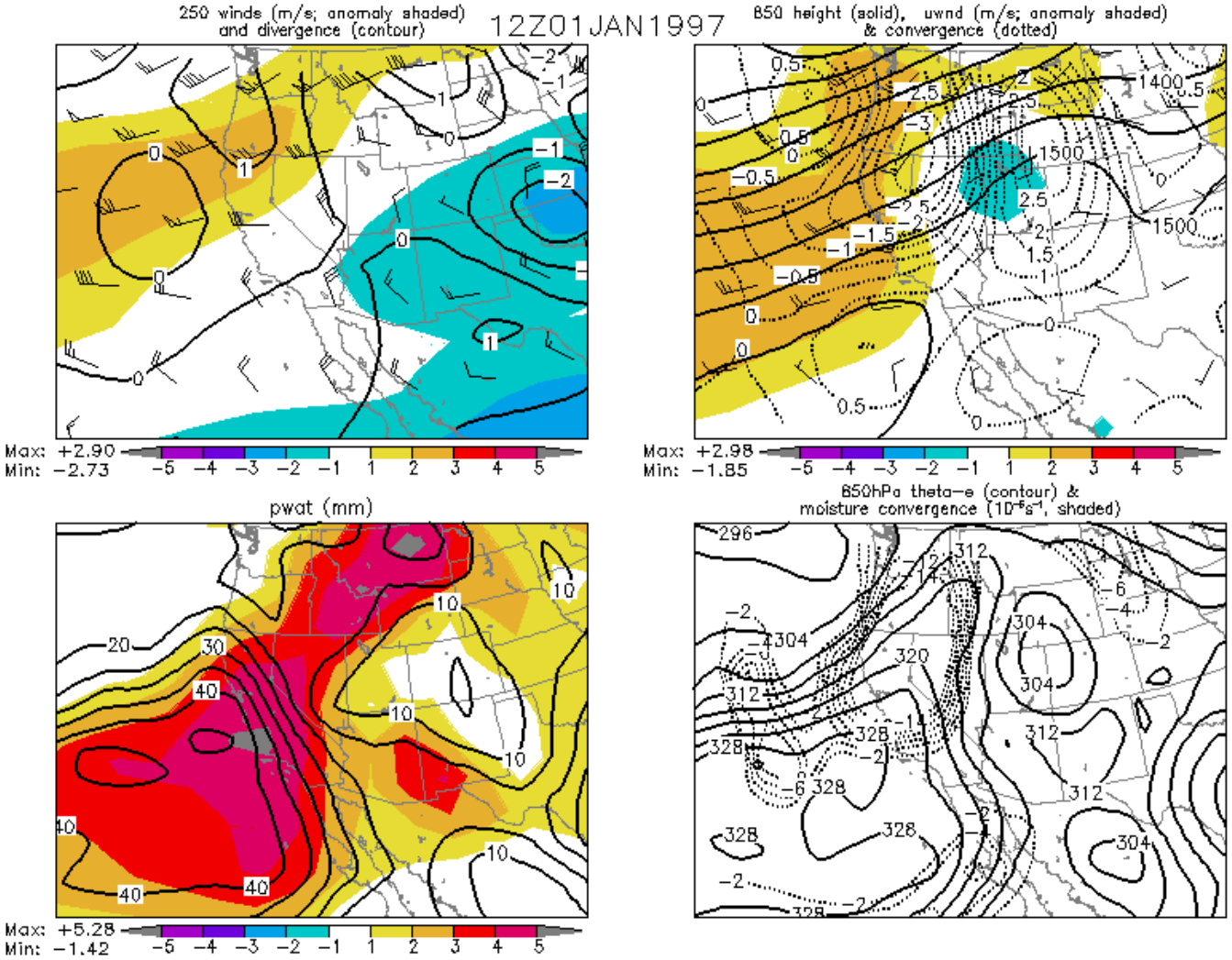
V.T. 1200 UTC
10 Mar 1995



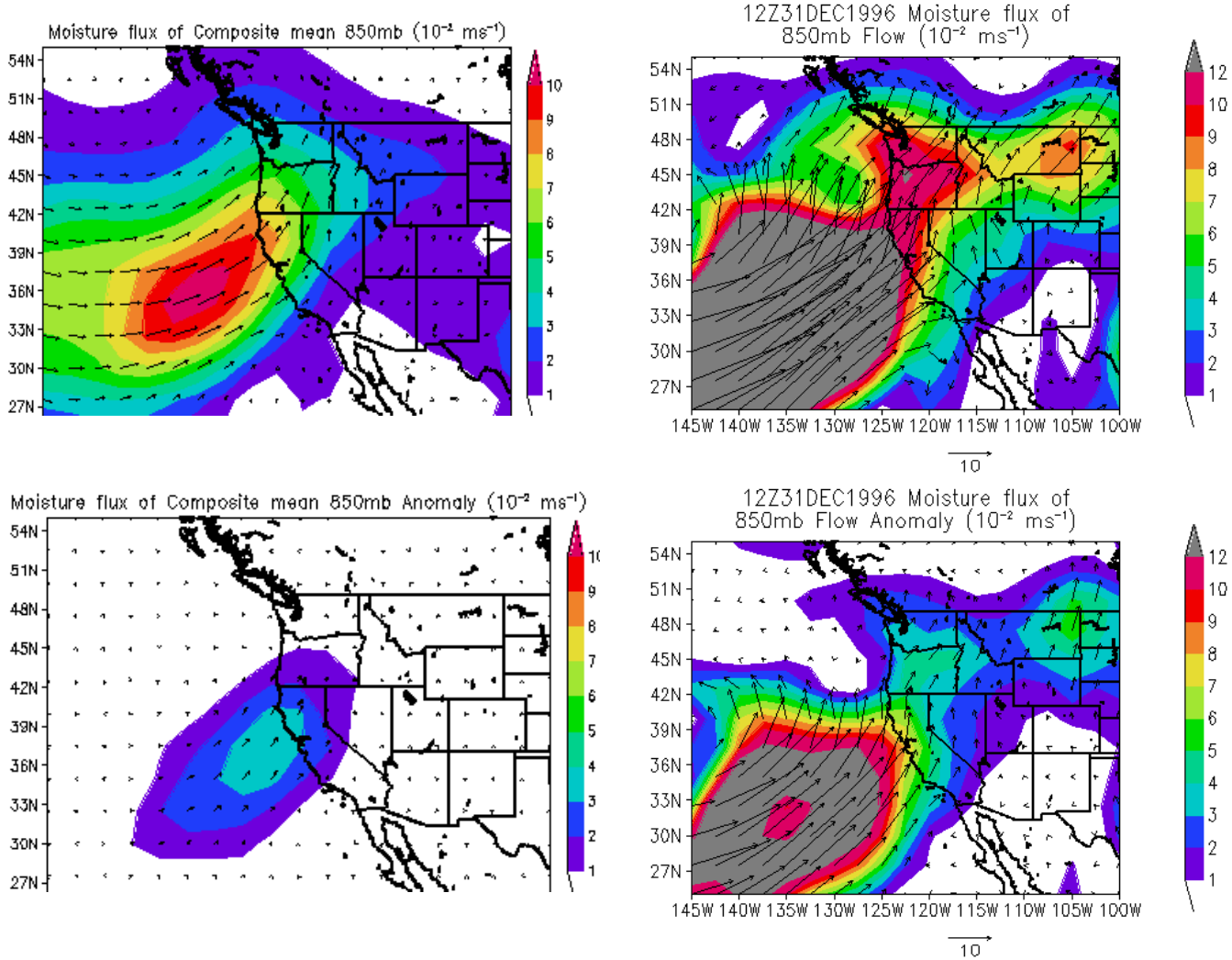


Again note strong anomalies and in this case a double upper-level jet streak structure

The PW anomaly at 12Z 01 Jan 1997 was greater than 5 standard deviations greater than normal, and was 2 to 3 standard deviations higher than for the 18 case heavy rain composite



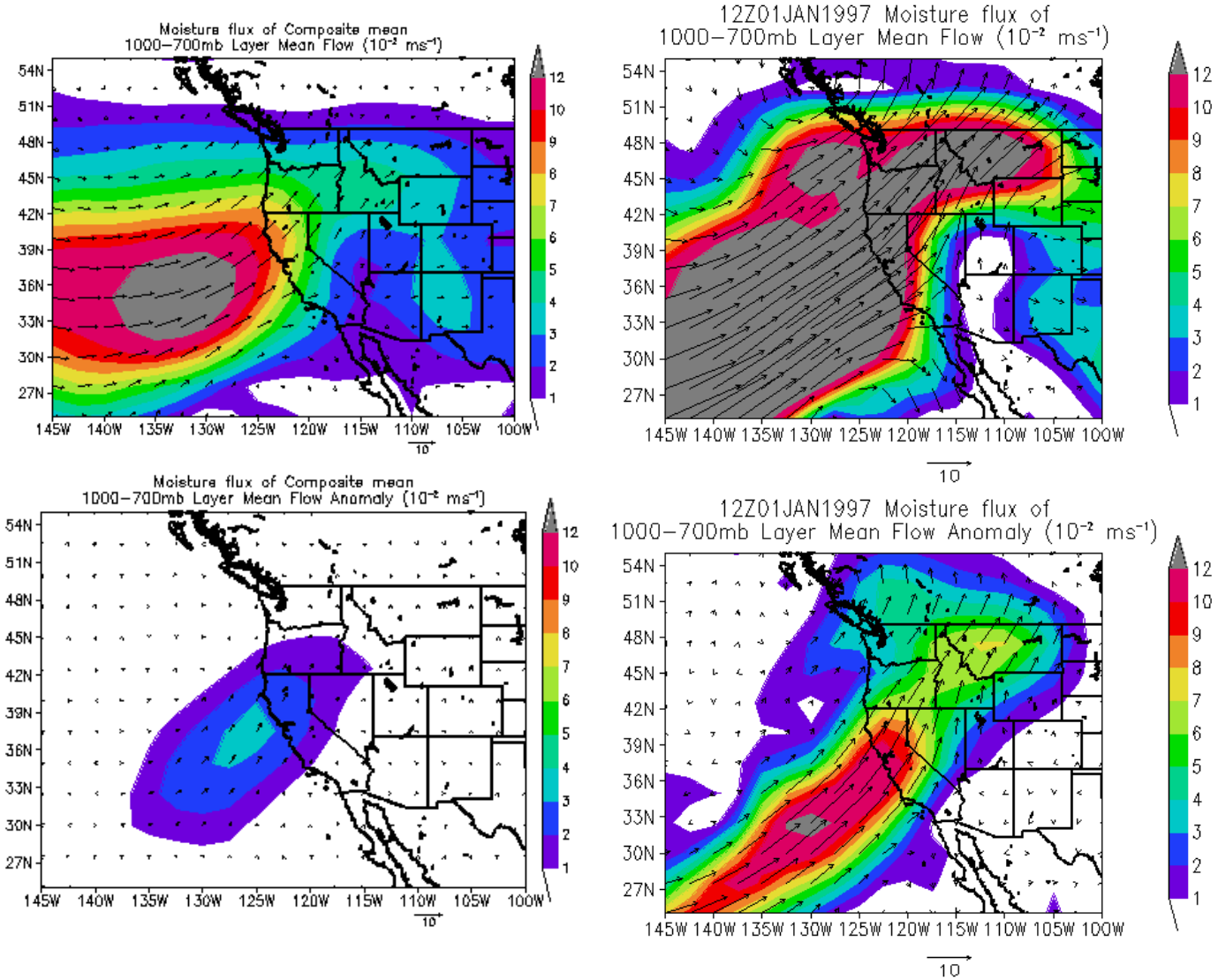
850 mb Moisture flux, composite mean for 18 cases (top left), flux values for major multi-day rainfall event 31 Dec 96-02 Jan 97 (top right)



850 mb Moisture flux anomaly, composite mean for 18 cases (bottom left), flux anomaly values for major multi-day rainfall event 31 Dec 96-02 Jan 97 (bottom right)

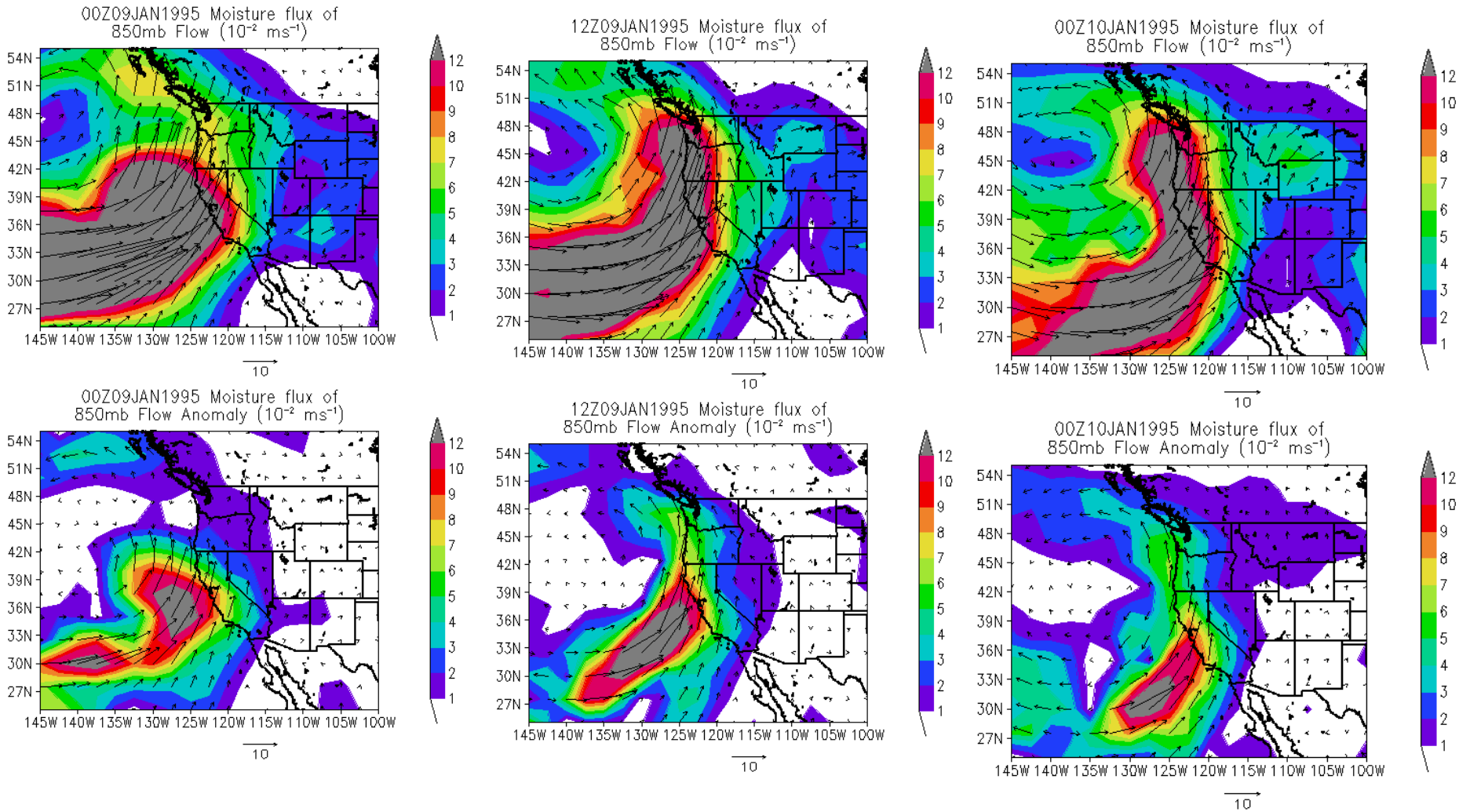
1000-700 mb moisture flux (top) and moisture flux anomalies (bottom)

composites

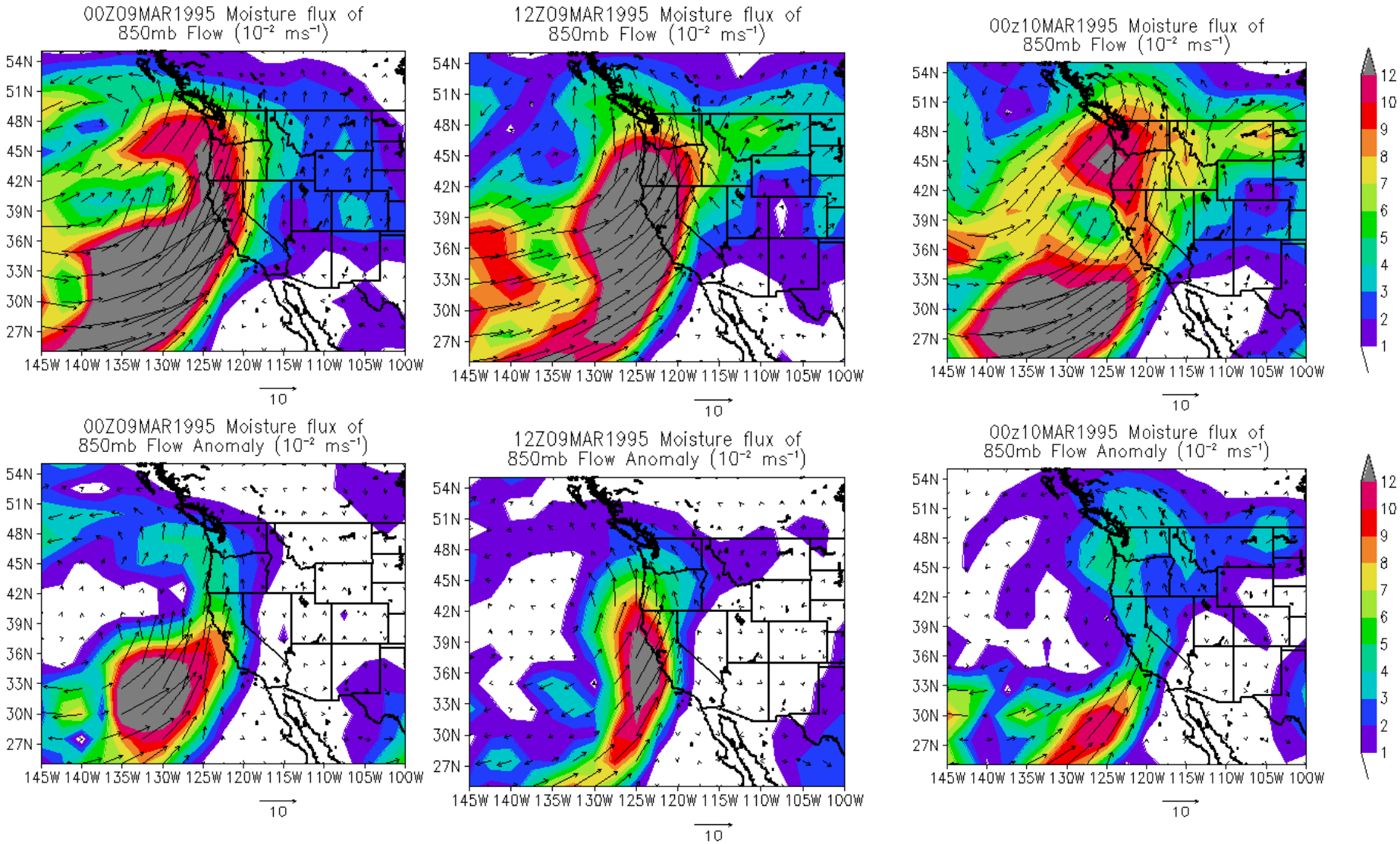


Big rain case
12Z 01 Jan 1997

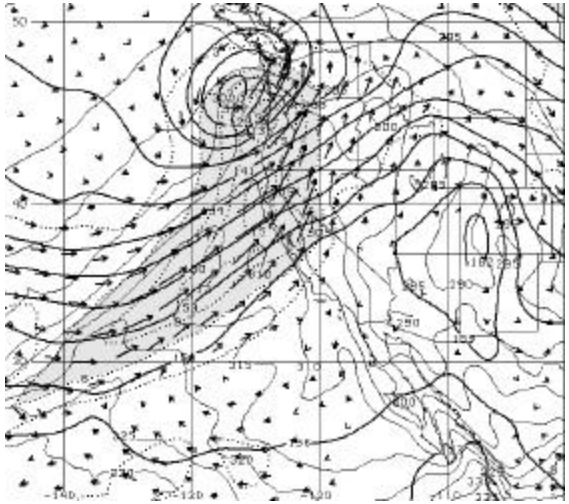
850 mb moisture flux anomaly values (top) and anomaly values (bottom) for major rainfall and flood event at 00Z 09 Jan 95, 12Z 09 Jan and 00Z 10 Jan 1995. Note anomalies are 3 times the values for the 18 case composite mean



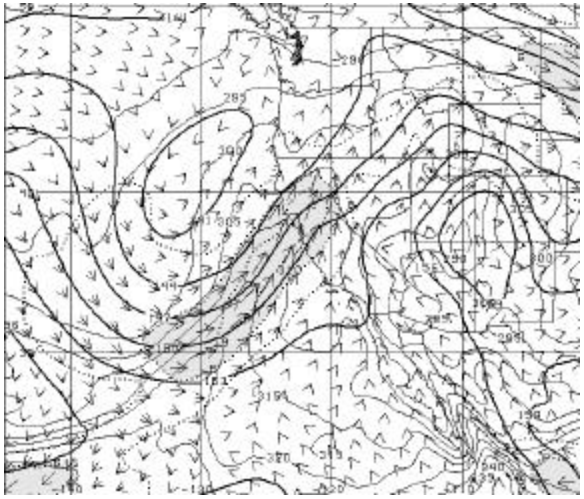
3 months later, Another major rainfall event and flood, note again that the 850 moisture flux anomaly values (bottom panels) for this multi-day event were 2 to 3 times the values for the typical 4 inch or greater events



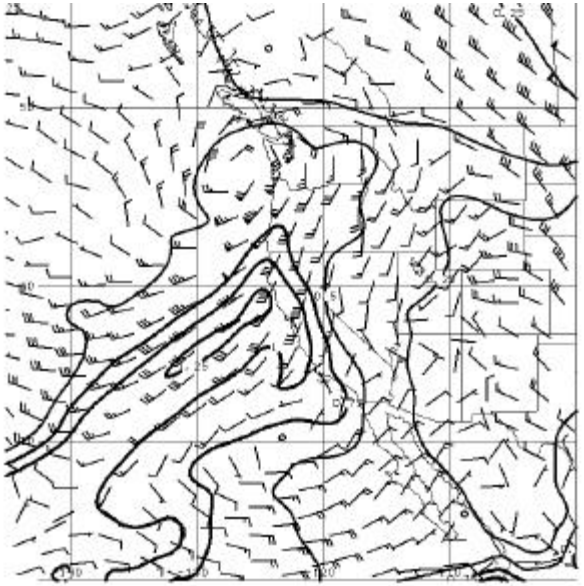
850 height (thick solid) and moisture flux vectors (arrows) and magnitude (thin dotted with greater than 6 shaded), boundary layer thetae (thin solid)

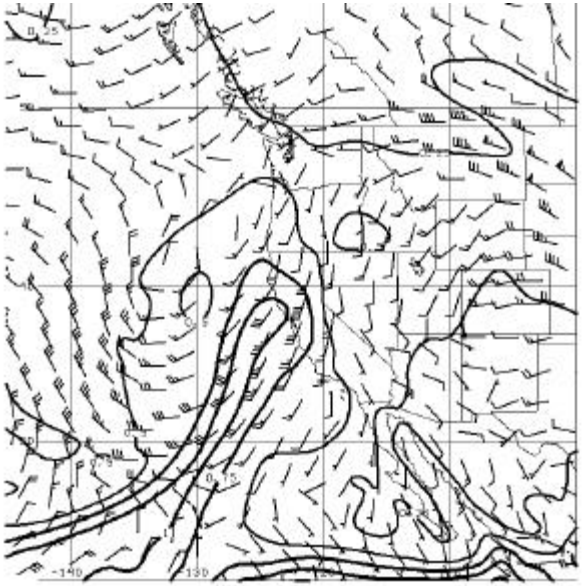


12 hr eta v.t. 12Z 27 Dec 2002



36 hr eta v.t. 12Z 28 Dec 2002

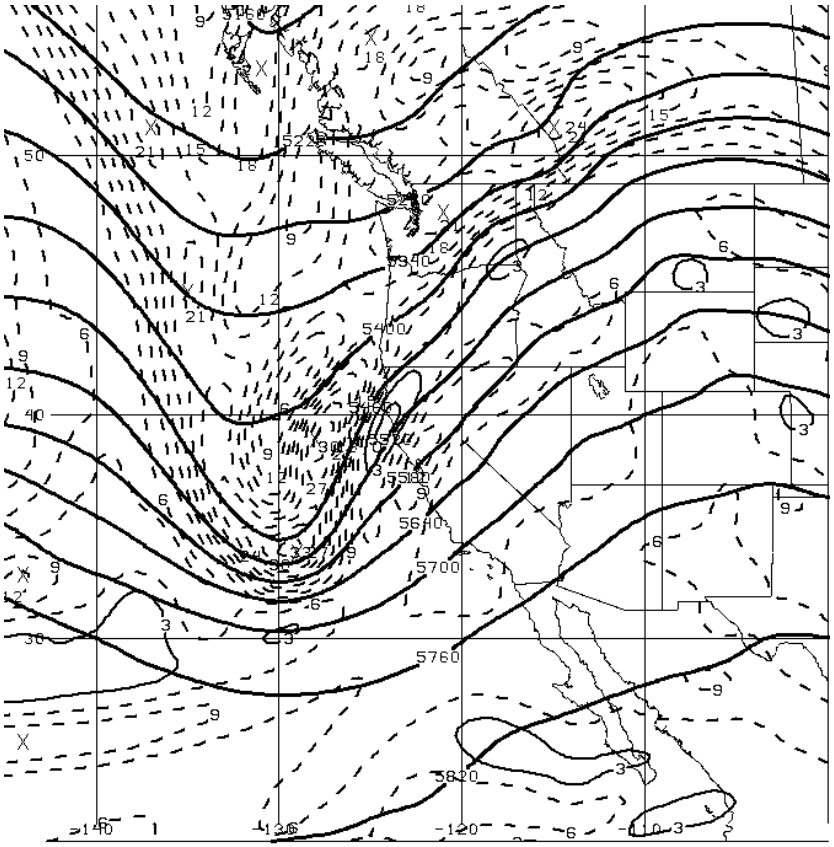


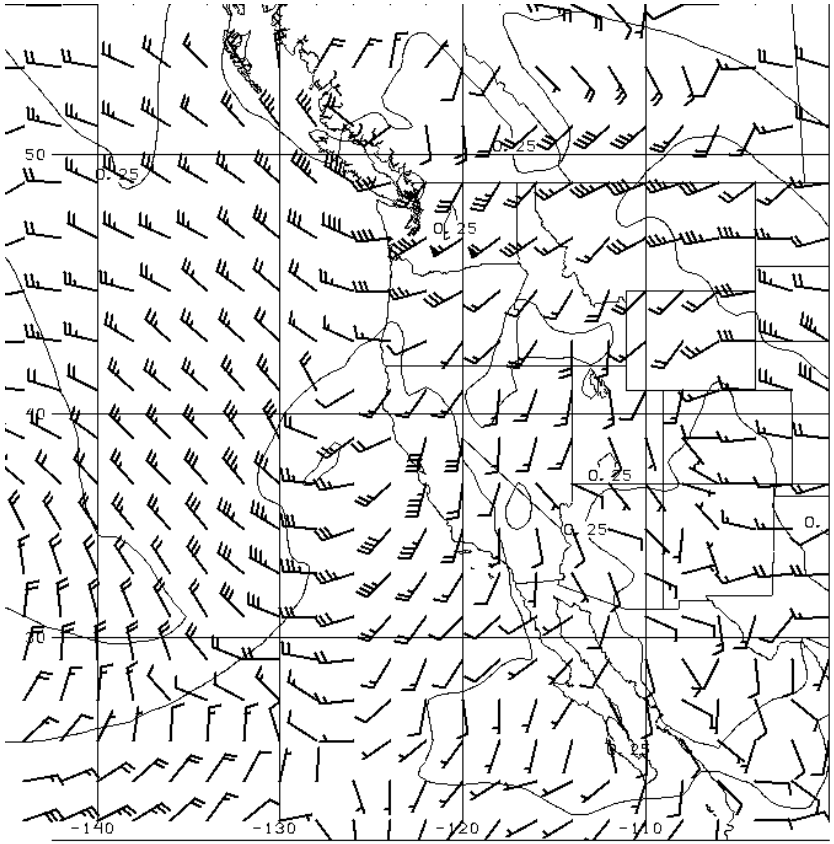


Can the models forecast the pattern?

At beginning of period eta was forecasting PWs greater than 31.75 mm. Values similar to those found in the 18 case composite.

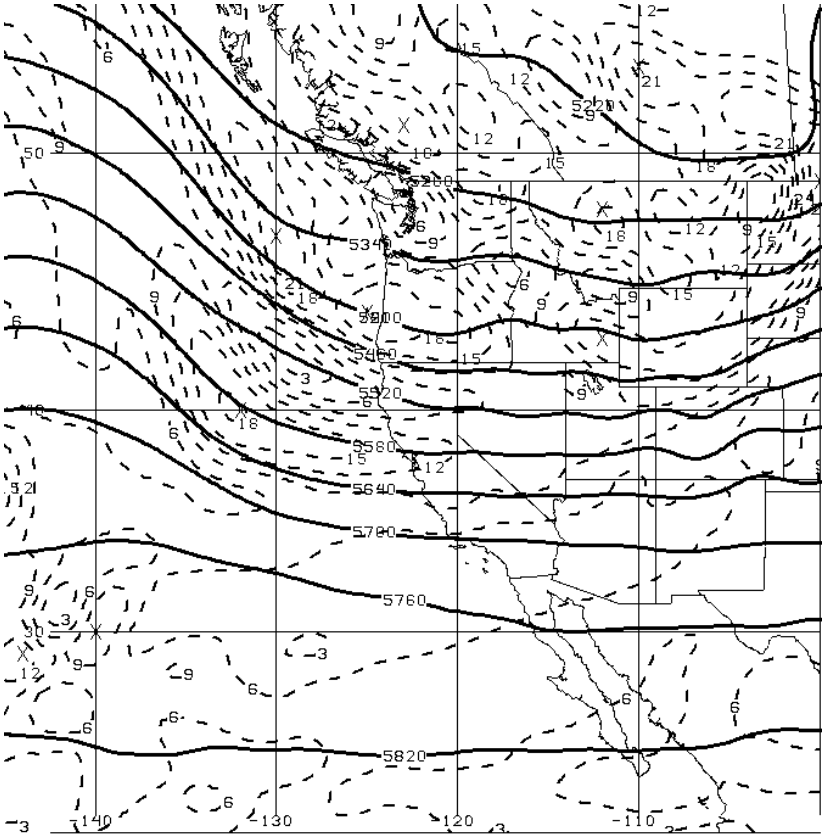
84 hr GFS valid 12Z 28 Dec 2002



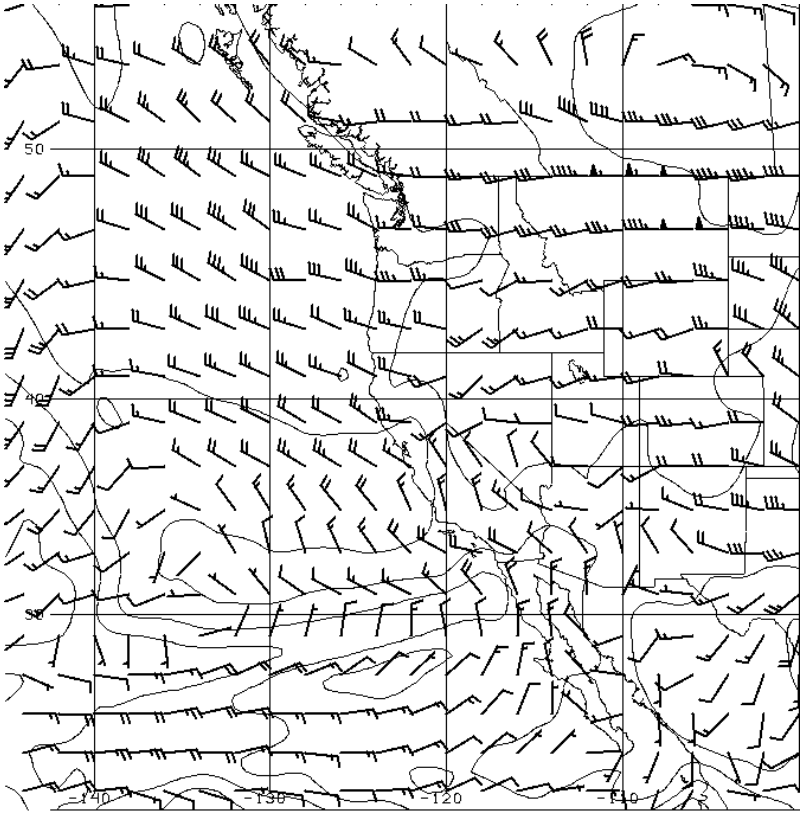


In the day 3 range implied significant rainfall event was possible but not well enough to specify exactly where. This is about par for the course

In the 5 day time range, the model did a poor job resolving the mid level trough.



SAT 021228/1200V132 500 hPa Heights/Vorticity



SAT 021228/1200V132 850 hPa WIND (KTS) AND PRECIP WATER

Would not have helped much. An ensemble approach might have helped.

What we know

- In the 1 to 2 day range, we can forecast that an event is coming fairly well. A good deal of the precipitation is tied to the terrain
  - The big flood producers are associated with
    - upper level troughs and jet streaks (sometimes the entrance region of one max and the exit region of another)
    - strong 850 u and v wind and 850 mb moisture flux anomalies
    - strong 1000-700 mb moisture flux and moisture flux anomalies
    - PWs that are significantly higher than normal for the three big dog events, in each the PWs were 2 to 5 standard deviations greater than normal.
- In 3 to 5 day range things depend on how well medium range models forecast pattern, ensemble runs may help but the ensemble mean may weaken pattern.
  - Could neural networks run using perfect prog data from the NCEP reanalysis improve forecasts?
- Higher resolution, non-hydrostatic models should help providing the model gets the basic pattern right.

What we think we know about model forecasts

- Higher resolution provides better scoring forecasts up to around 10 or 12 km
  - Work by Mass suggests 4 km grid spacing may not provide higher scores than 12 km grid spacing
- for 12 km eta and mm5 the bias is too high just upstream of highest terrain and too low on the leeward side of the same mountains
- For 12 km version which convective scheme you use impacts forecasts. For low thresholds BMJ may score better by having a high bias, but for higher ones the KF scores better.
- The microphysical processes within the cloud are important. May impact where along the mountain the max is forecast.