A DRAMATIC SHIFT FROM A WARM MONSOONAL PATTERN TO A COLD NORTHWEST EXPRESS PATTERN

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INTRODUCTION

Two distinct reservoirs of moisture for storms in southern California are monsoonal moisture (interior) and maritime (Pacific) moisture. Usually monsoonal moisture moves in from the southeast and eastern interior at about 650 - 700 mb and above. Pacific moisture is from the west and is often surface-based. In this case an upper level low went through both moisture phases, as well as generated a hot, dry Santa Ana wind in southern California during the pattern shift. This WES TA-Lite will explore the sequence of events surrounding this pattern shift that resulted in record rainfall and heavy snow.

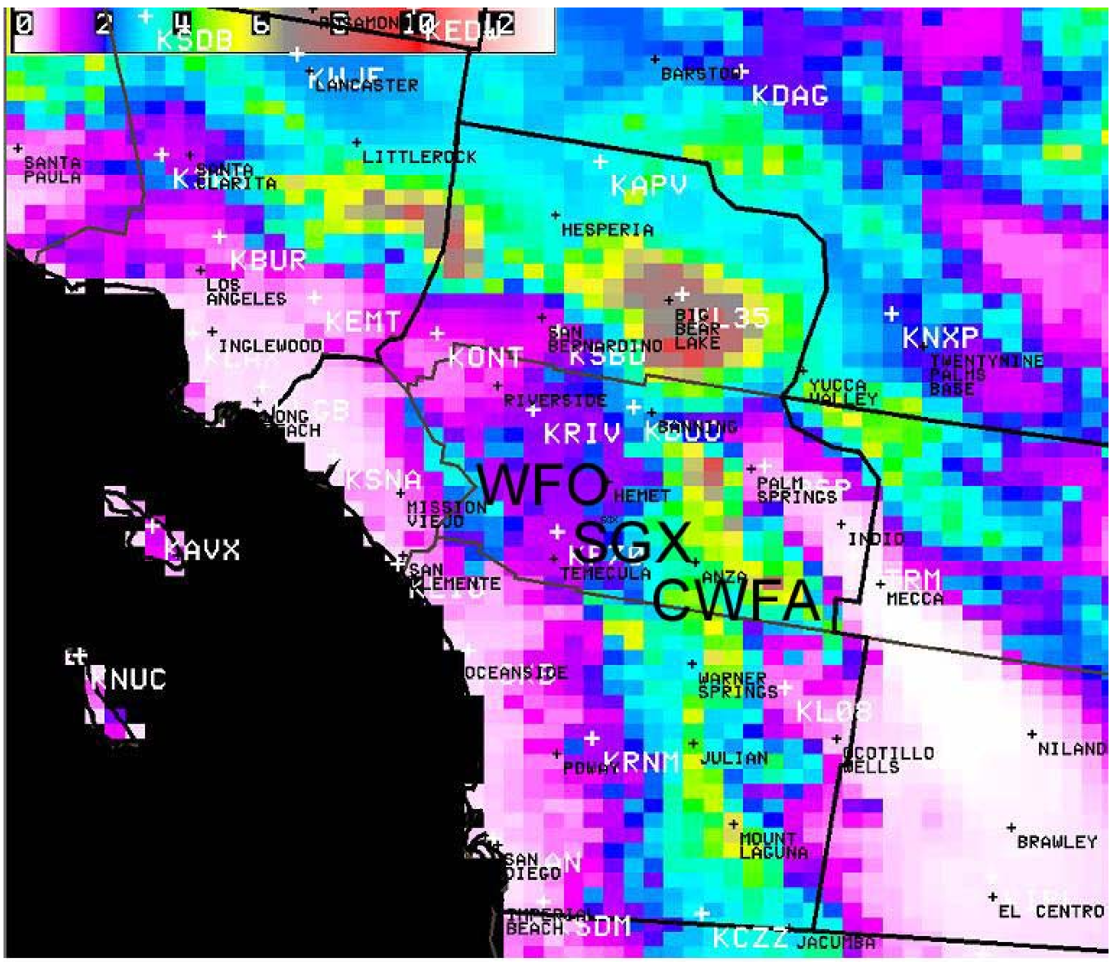

Fig. 1. Map of Southern California locations and terrain. Legend is in thousands of feet MSL.

THE SHIFTING STORM TRACK

On 9 October 2004 an initial trough set the stage for this event by moving inland over northern California and developing a temporary cut-off low over southern Nevada (not shown). This initial low was a "dry inside slider" (a trough or low where the dynamics move inland to our north with little or no rainfall in southern California). The only result was to deepen the marine layer to about 3000 feet deep, which is a common scenario for transition season systems. However, when the initial low finally moved east, it left a “weakness” over Nevada, and left the door open for a second cutoff low to drop south to take it place. This second, stronger low, which eventually experiences both types of moisture, dropped south through central Nevada into the “weakness” left behind by the initial low. (Figure 2). A problem that has to be watched is frequently the stronger lows that move almost due south near the coast may retrograde further west than the model solutions forecast. This seems to be especially true during strong “Northwest Express” patterns. (These patterns are characterized by a strong, more “meridional” jet from the Gulf of Alaska or Canada. They feed cold air into storms as they move south from the Pacific northwest or adjacent waters into southern California). These patterns should be carefully watched since storms can pick up more moisture than is otherwise expected). In this case the low does indeed retrograde. The models actually do a fine job with its location, moving it southwest as the upper high nosed into the Pacific Northwest on 15 October 2004 (Figure 3).

Eventually, the “kicker” in the form of a rapidly approaching Gulf of Alaska storm in the Northwest Express moved down the coast, and lifted the low through southern California

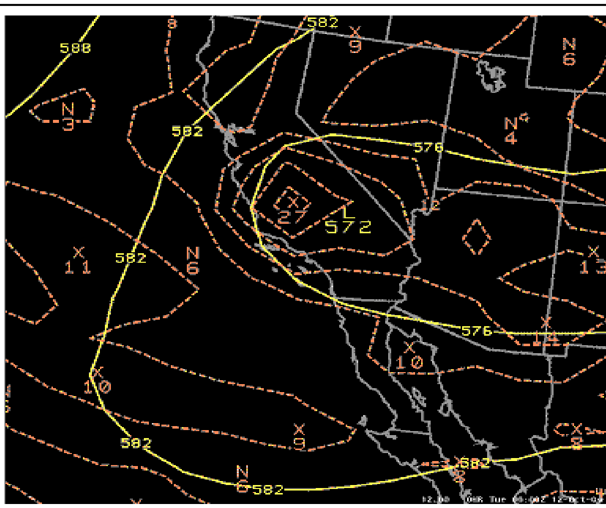

Fig. 2. 0000 UTC 12 October 2004 GFS 500 mb heights in dekameters (beige, solid) and vorticity (brown, dashed) in s^{-1}.

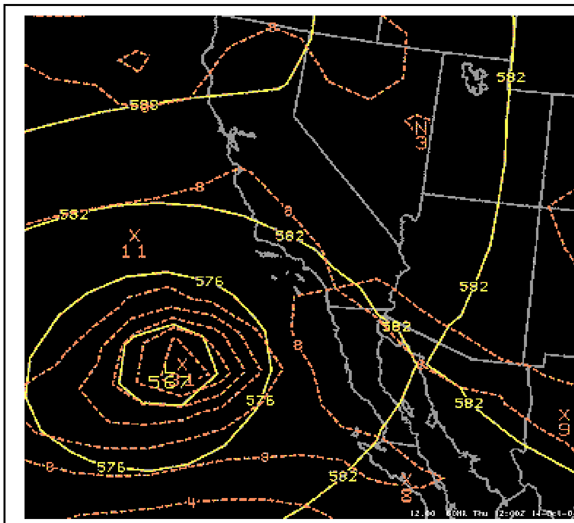

Fig. 3. GFS 60 hour forecast valid at 0000 UTC 15 October 2004. 500 mb heights in dekameters (beige, solid) and vorticity (brown, dashed) in s^{-1}.

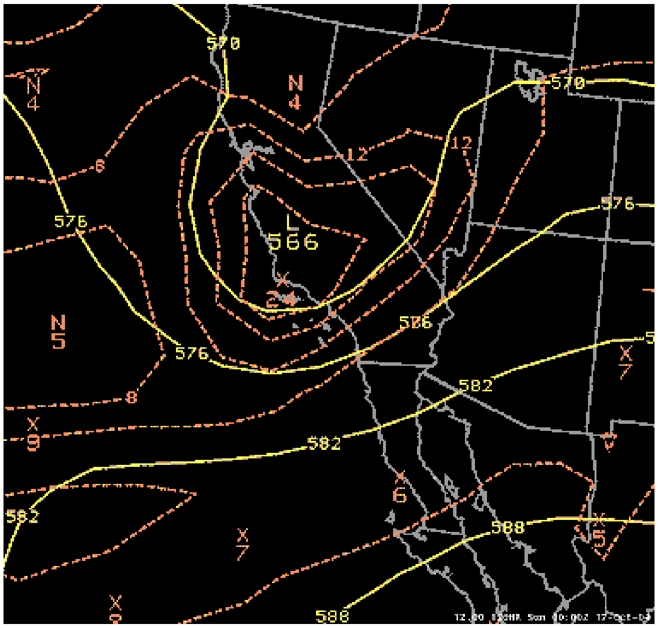

Fig. 4. 0000 UTC 17 October 2004 GFS 500 mb heights in dekameters (beige, solid) and vorticity (brown, dashed) in s^{-1}.

on 17 October 2004 (Figure 4) to complete the pattern shift. This storm, following the new storm track proceeded to drop over a foot of rain in the mountains of southern California.

THE CHANGING VERTICAL MOISTURE PROFILE OF THE SECOND LOW

The Nevada low that created the initial weakness over southern Nevada was a dry inside slider, since the trough did not develop until it moved inland over northern California. It accumulated little moisture from the Pacific. It rapidly deepened over southern Nevada then ejected off to the east with little time to generate or entrain moisture. However, the second low, which drops in behind it became a "wet inside slider". This second storm cut off over Nevada, allowing time for convection to be generated around the low center. It also entrained moisture from Mexico, Arizona, and Nevada as it slipped southwest (Figure 5.) Unlike the warmer, less frequent cut-off lows during the warm season, transition season cut-offs can not only entrain monsoonal moisture, they can supply significantly colder air aloft for a very unstable, convective scenarios. Figure 5 shows moisture wrapping into the low, which is common for lows that can move far enough south to generate south to southeast flow from locations such as the mountains of Mexico. This moisture from the interior is more moist and unstable than that over the coastal waters of southern California, mainly because the moisture is from the warmer waters west of Mexico and the Gulf of Mexico. In this case the airmass has also been lifted and moistened by convection. Destabilization via heating also occurs during the trip to the low. Even if the 700-500 mb relative humidity is less than 50 %, such upper lows still tend to somehow find the moisture and dynamics to produce elevated convection such as ACCAS (altocumulus castellanus) with sprinkles, or even thunderstorms.

Instead of moving rapidly east like the first Nevada low, a very strong jet behind the second low, (along with a strong vorticity center) caused the low to continue digging to the west, producing showers and thunderstorms over southern California as it moved through. Generally with this type of retrograding, a wet inside slider moves into Canada from the Gulf of Alaska or initially develops over Canada, and low elevation snowfall becomes a problem when it reaches Southern California.

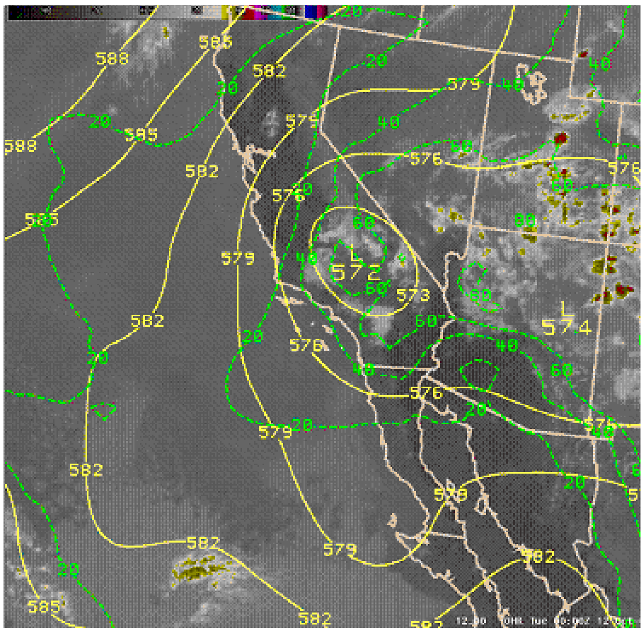

Figure 5. 0000 UTC 12 October 2004 mean MesoEta 500 mb heights in dekameters (beige, solid) and 700-500 mb mean relative humidity (green, dashed) in percent overlaid with the 0000 UTC 12 October 2004 infrared satellite imagery. Graphic shows the low continuing to dig southwest. There is mainly elevated moisture developing around the low center in addition to elevated moisture wrapping in from the southwestern states and Mexico. The moisture is mainly inside a region of 40-50 percent relative humidity or higher.

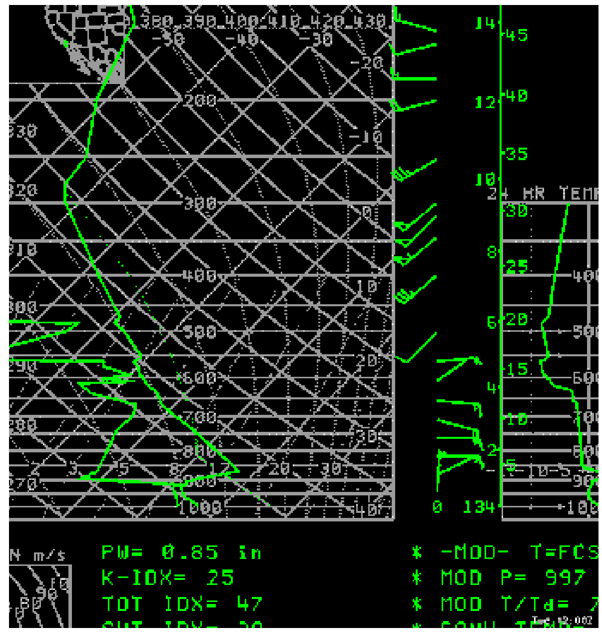

Figure 6. 1200 UTC 12 October 2004 KNKX Sounding. Sounding shows mainly elevated monsoonal moisture and a mid level unstable layer. Note the easterly winds supplying moisture to the low.

These storms can bring with it cold Canadian air, and possibly strong cold offshore flow. Also "wet bulb zero" effects can lower the snow level to unusually low levels (cold, wet type inside slider). In this case, since it moved inland further south along the California/Oregon/Idaho border, the air mass was somewhat warmer.

The dry phase of this event over southern California began as the low drifted to a position offshore (rather than remain over the coastline with continued precipitation) and a Santa Ana wind condition developed (Figure 7). Wind gusts in excess of 10 mph in and below canyons and passes are usually all that is needed to substantially warm the coastal areas in and below canyons and passes. In this case, gusts peaked at 30-40 mph and brought 90 degree high temperatures to those vulnerable areas of the coastal plain since 950 mb temperatures (basically, boundary layer temperature) reached the lower 20s C. The heating pattern was a typical one, with valley areas warmer than the coastal plain, since it was not a cool season event. (During the cool season “reverse heating” occurs, with valley areas actually cooler than the coastal plain).

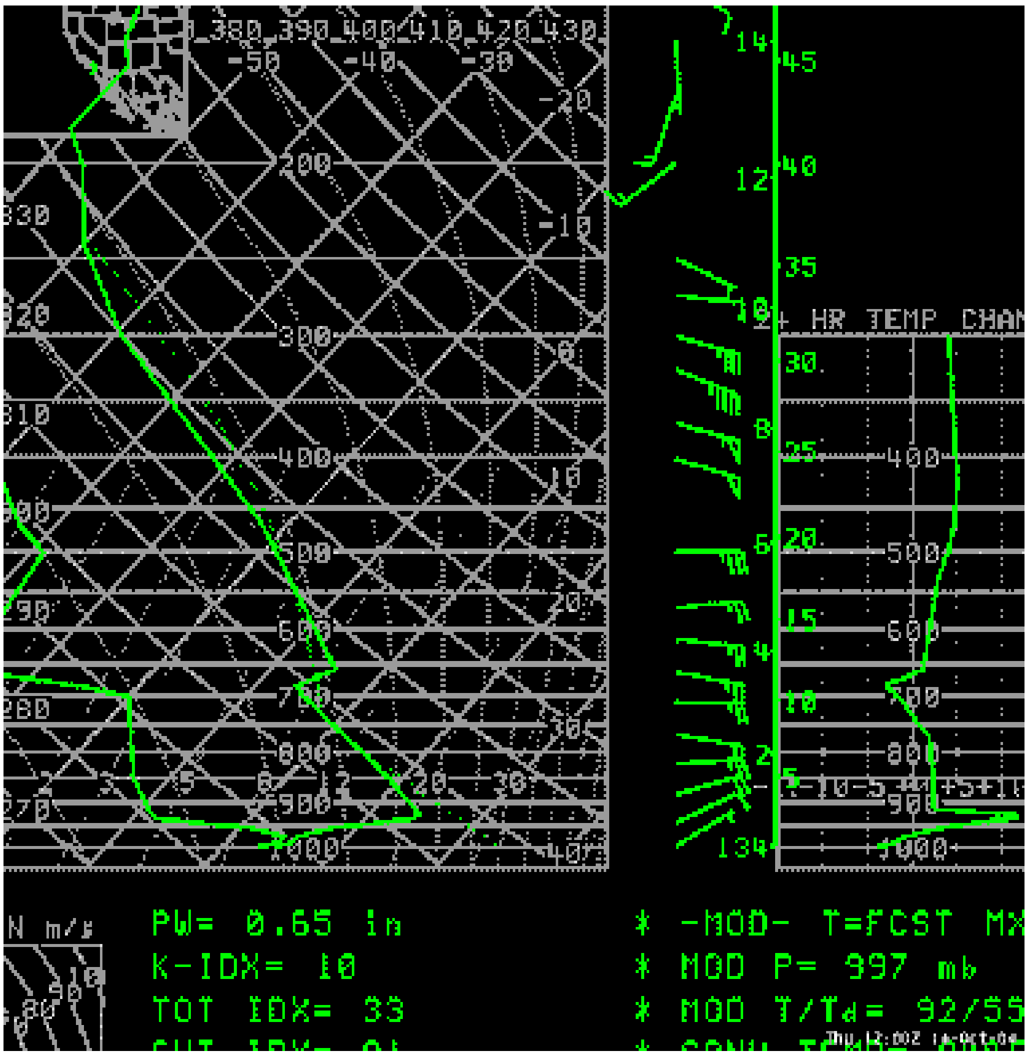

Figure 7. 1200 UTC 14 October 2004 KNKX Sounding. Sounding shows a lowered, strengthened marine inversion under strong offshore flow aloft.

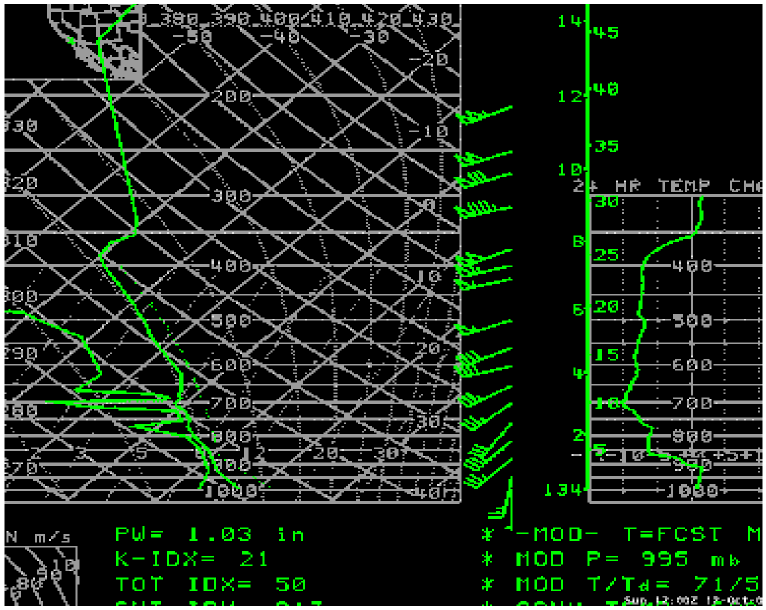

Figure 8. 1200 UTC 17 October 2004 KNKX Sounding. The moisture is rooted in the boundary layer, and mainly at or below 700 mb.

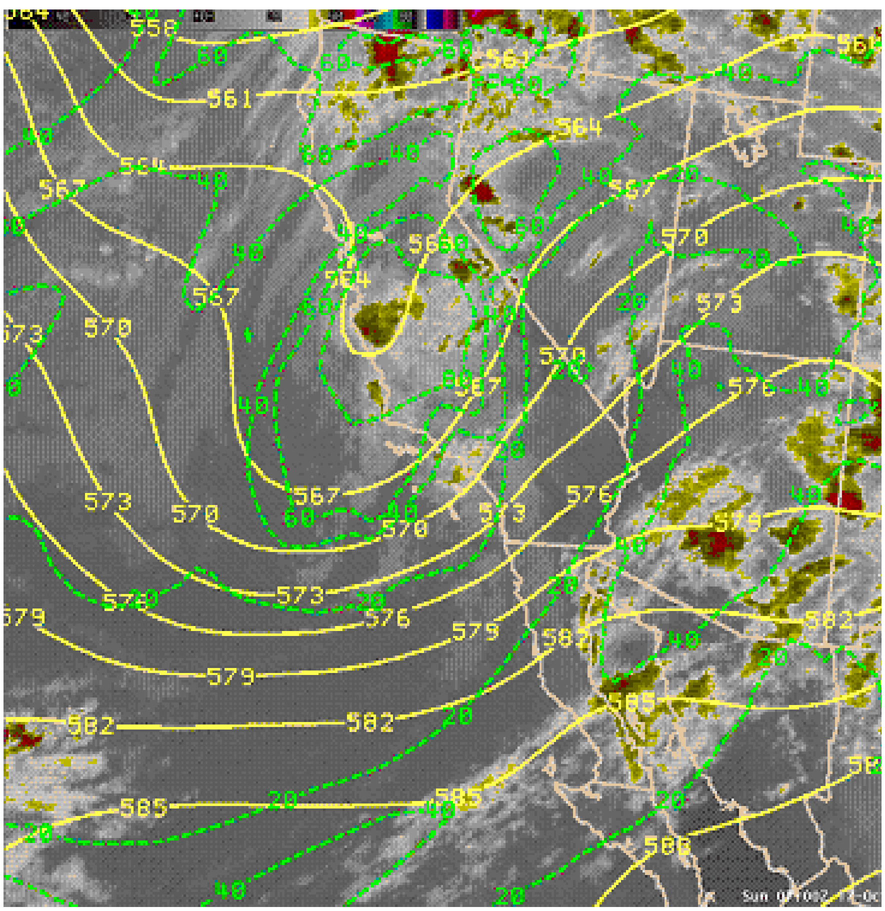

Figure 9. 0600 UTC 17 October 2004 MesoEta 500 mb heights (beige, solid) in dekameters, and 700-500 mb mean relative humidity (green, dashed) in percent, overlaid with the 0700 UTC infrared imagery. Frontal development has occurred.

As the second low moved offshore, it picked up low level moisture from the Pacific (figure 8). The low then moved back through, but this time, the moisture profile was reversed. Since the moisture from the Pacific was mainly below 700 mb essentially, a cold front had developed, and moved through southern California (figure 9). Another round of showers and thunderstorms moved through. Since the dynamics of the low basically moved through southern California, 500 mb temperatures warmer than -20 C still produced thunderstorms since the dynamics can seem to make up for the only "marginally cold air aloft". Had the low center and rising motion been further north of the area, it is more likely that the more common type of frontal passage (no thunderstorms) would have occurred. At this point the pattern shift was complete as the first huge low moved south in the new storm track into southern California. The series of storms following the pattern shift produced widespread flooding and heavy mountain snow.

FINAL DISCUSSION AND CONCLUSION

A series of inside sliders is shown to accompany a distinct weather pattern shift over extreme southwest California. A first, weak upper low produced no rain as it moved east. A second upper low made the transition from a “dry inside slider” to a “wet inside slider” and brought spotty, elevated convection to extreme southwest California. Next it moved offshore, producing Santa Ana wind. Finally, it moved back through as a frontal system with 1-2 inches of rain from moisture rooted in the boundary layer.

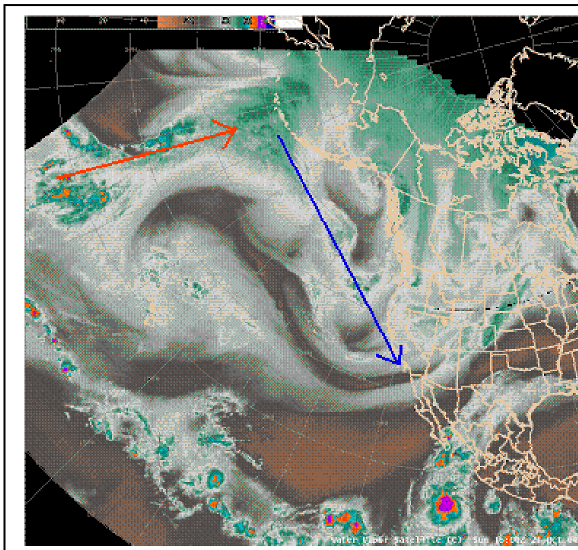

Figure 10. 1600 UTC 24 October 2004 water vapor imagery showing a strong flux of subtropical moisture from near Hawaii to the top of the ridge (red), then over the ridge to the northwest express (blue), and fueling a series of strong storms.

This second low was not a low elevation snow producer since it initially moved inland from the west near the California/Oregon border, rather than from the Gulf of Alaska or Canada. Early in the life of the second low, the low consisted mainly of elevated moisture, which is rather typical of an upper low that picks up monsoonal moisture from the interior rather than moisture from the Pacific. After it retrograded southwest to a position offshore, it then generated boundary layer moisture under the low before pushing inland. The storm left a weakness, allowing storms fueled by a very strong flow of subtropical moisture near the top of the ridge west of the International Dateline to drop down into that weakness to continue the pattern shift. For approximately 1 1/2 weeks, copious amounts of subtropical moisture moved north over the ridge to fuel a strong northwest express (or Aleutian express) pattern. This northwest express pushed a series of very strong storms south along the coast and through southern California (figure 10). This pattern, (the strong subtropical flow moving over the ridge into the Gulf of Alaska to feed the northwest express) resulted in some single storm totals of over 10 inches of rain, with over 20 inches of rainfall as low as the 2500-3000 foot level in the foothills for the series of storms. Many records for the month of October were broken, with some all time 24 hour records threatened. During the final storm in the series, 2 feet of snow fell in the mountains. (This was very different from the typical “pineapple express” pattern, when moisture flows from southwest to northeast from near Hawaii to the western states). Storms dropping south out of the Gulf of Alaska are thought of as being colder with less moisture than the low latitude storms associated with the pineapple express. However, this case shows that the fueling of a single Gulf of Alaska storm via subtropical moisture prior to the storm dropping south in the northwest express can still produce a foot of rain (and 2 feet of snow in the mountains) in southern California.