Probable Cause of a Significant Precipitation Episode in the Western United States

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ABSTRACT

This synoptic study for the period 22 September to 3 October 1974 involves a case analysis of an unforeseen major precipitation episode. This apparently resulted from the merging of an inactive propagating short-wave trough that moved east-northeastward out of the subtropics and an inactive extratropical low moving southeastward. Prior to the amalgamation of the two systems, weak upward vertical motion fields allowed only specks of high clouds to be associated with each. Almost immediately with the merging of the two systems, a rapid increase in upward vertical motion around the upper-level extratropical system took place, as evidenced on VHRR satellite imagery by the sudden development of rather organized middle and high cloudiness. Within 24 hours, a distinct vortex comprising all cloud levels was evident on satellite photographs. During the next 24 hours, a major rain-producing storm developed. The major impact of this storm was an abrupt end to the California dry season.

1. Introduction

Each year, towards the end of the warm season, a significant rain episode usually occurs in California, frequently ending the dry season. These episodes are at times not forecast in advance due to very rapid development and are frequently accompanied by organized thunderstorm activity. With increased coverage and accuracy of airline upper-wind reports (AIREPS) and satellite data, it appears that these "surprise" storms can sometimes be related to short-wave troughs originating in the persistent tropical upper tropospheric trough (TUTT) that has been investigated in-depth by Sadler (1967).

Sadler prepared upper-wind climatology maps for the central and eastern Pacific with the help of numerous AIREPS (Sadler, 1972). His mean September 300 mb flow pattern is given in Fig. 1. Note the positions of the TUTT, subtropical ridge, and subequatorial ridge. The TUTT can be present from May until November, but is best developed and most persistent from July to September (Atkinson, 1971). At times, this trough exists only as a shear line with imbedded short-wave troughs, but no apparent low centers. At other times, the trough is dominated by closed circulations. Clouds not associated with these cyclonic circulations are associated with the westerly flow between the near equatorial upper ridge and the TUTT (Sadler, 1967). However, the more intense convective cloud systems are generally associated with migratory closed lows (Anderson *et al.*, 1974).

Intensification of a closed vortex and possibly a short-wave trough originating in the tropical trough is thought to occur when phasing of this migratory subtropical feature occurs with a trough or vortex associated with the extratropical westerlies. Translational motion of the subtropical system then slows and convection becomes enhanced.

Sadler (1967) contends that the persistent upper tropospheric tropical trough during the warm season has been identified with the development of major surface circulation features in the subtropical north Pacific. A key point on which the present paper is based is that an upper vortex or imbedded short-wave trough can and frequently does move east-northeastward from the region of the tropical trough into the eastern Pacific during the transition season from summer to winter. If associated flow patterns are favorable, this system can phase with an upper trough or low of extratropical origin. A suggestion in this direction is given in Fig. 1, as the split in the flow near 40°N, 165°W lends itself to the possibility of extratropical and subtropical systems phasing in the vicinity of the converging streamlines between 30°–35°N, 120°–135°W. In addition, the existence of the mean ridge shown off the Washington-Oregon coast suggests the possibility of extratropical systems moving over the ridge and southward along or just off the West Coast, as is the case in this study.

The subsequent discussion follows the evolution of one such phasing for the period 22 September to 3 October 1974. It shows how a migratory short-wave trough in the subtropical westerlies combines with an inactive upper tropospheric trough of extratropical

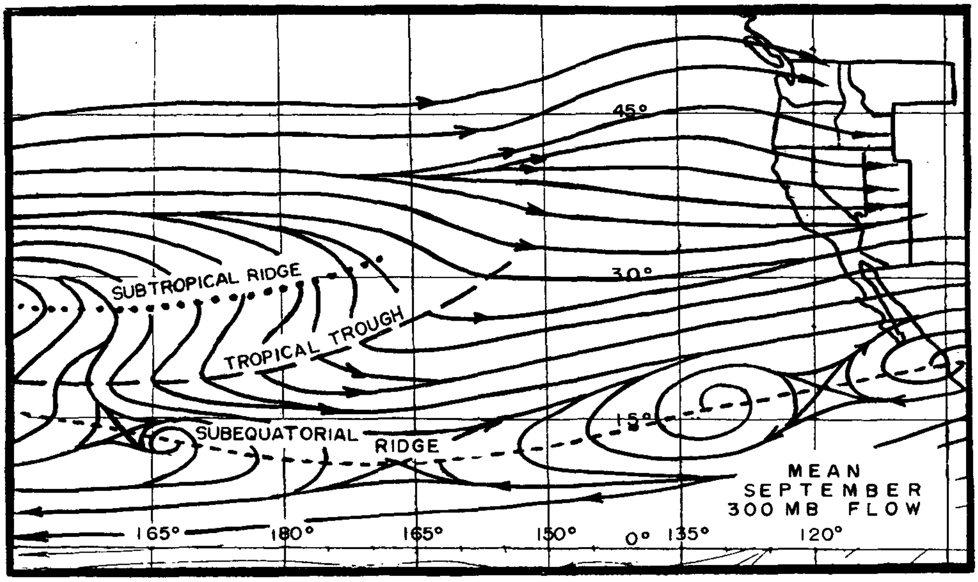


Fig. 1. Mean September 300 mb winds over the central and eastern Pacific with positions of tropical upper tropospheric trough, subtropical ridge, and subequatorial ridge (From Sadler, 1972).

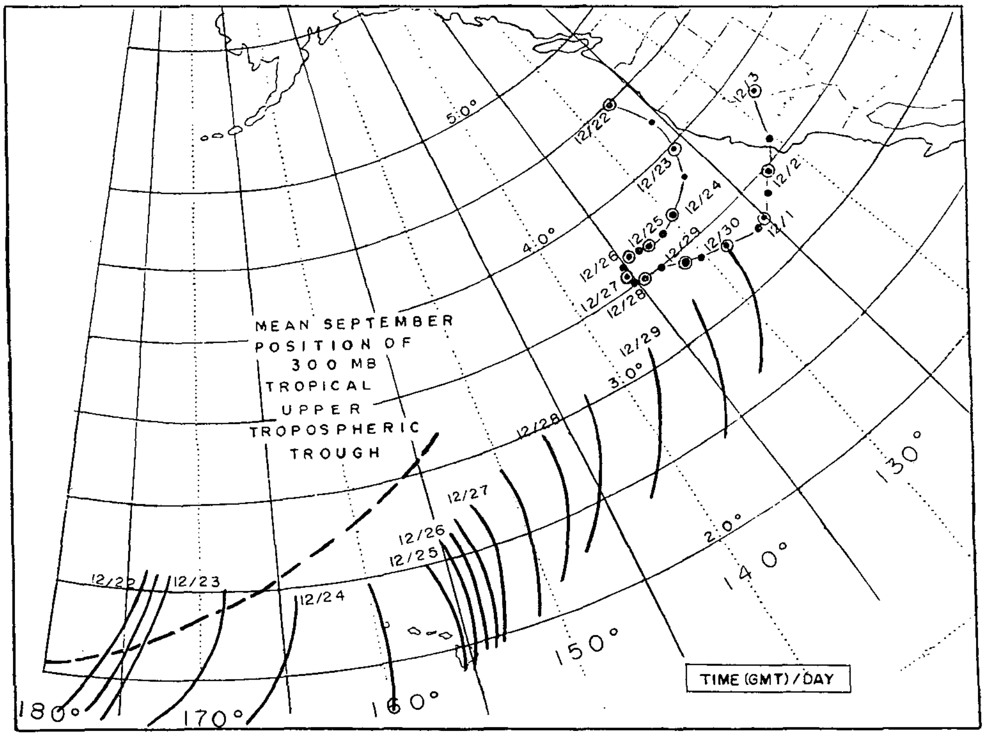


Fig. 2. Twelve-hour positions of the subtropical (solid line) and extratropical systems (dots) along with the mean location of September 300 mb tropical trough.

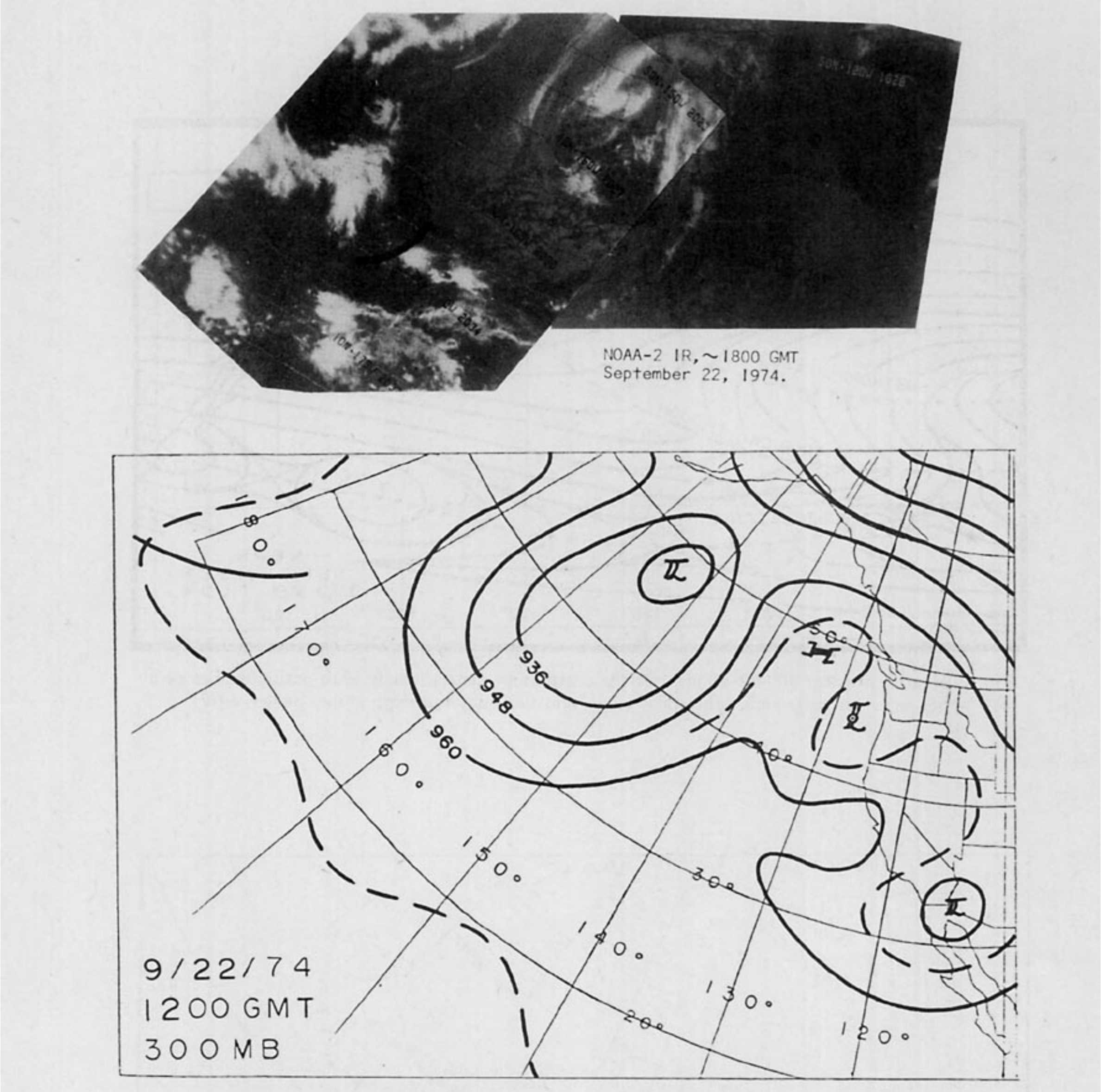


FIG. 3. 300 mb chart for 1200 GMT 22 September 1974 and corresponding NOAA-2 infrared satellite pictures.

origin to produce a major rain episode for portions of California and eventually northwest Arizona, and most of Nevada and Utah. The intent here is to bring out the important fact that the persistent upper tropospheric trough investigated by Sadler is not only a source of major weather systems during the warm season for the central and western Pacific, but also for the eastern Pacific and western United States as well.

2. Analyses used

Three-hundred-millibar analyses from the National Meteorological Center (NMC) were used in this study. However, the charts received were not the analyses normally transmitted over facsimile circuits, but rather hand-drawn analyses by NMC that involved the use of bogused, vertical temperature profile radiometer (VTPR), aircraft in-flight reports (AIREPS), and radiosonde observation (RAOB) data, as well as information obtained from satellite cloud imagery. Generally, the majority of available VTPR and RAOB data, along with limited AIREP data, are utilized in preparing the regular NMC-transmitted 300 mb analysis. However, the hand-drawn analyses received from NMC for this study involved a somewhat expanded use of AIREP and satellite information. Although many of the AIREPS were asynoptic and off-level data to standard analysis times and levels, they were assimilated in such a way as to be very useful, especially in no-data areas of the Pacific. The orientation, character and apparent advection of cirrus clouds were utilized to help provide good estimates of upper tropospheric wind directions and useful semiquantitative estimates of upper-level speeds (Johnson, 1966). It should be kept in mind, however, that not all upper-level cyclonic circulations or troughs over the tropics or subtropics produce clouds.

Each analysis underwent close examination by the author, and small refinements were made where necessary in order to insure the best possible analysis. Utilizing consistency between these analyses and the NOAA-2 and NOAA-3 satellite pictures, the locations, tracks, and characteristics of the subtropical and extratropical systems investigated in this study were determined.

3. Synoptic review

In this study, a migratory trough that was generated in the region of the tropical upper tropospheric trough and eventually combined with an inactive extratropical trough, is followed. Figure 2 displays the locations at 12 h intervals of the subtropical and extratropical systems for the period 22 September to 3 October. The positions were determined through the combined use of the NMC 300 mb analyses and satellite data.

The 300 mb analysis for 1200 GMT 22 September (Fig. 3) gives an idea of the flow pattern at a time when the subtropical system was rather active and the extratropical system was settling off the coast. The closest corresponding NOAA-2 satellite photograph is also shown. Note that the subtropical system was near 175°W and a concentrated area of convection was associated with it. In contrast, the lack of significant upward motion associated with the extratropical system off the Oregon coast is evident by the lack of IR clouds in the photograph. By 1200 GMT 25 September, the northern system had moved southward and then southwestward to 36.5°N, 132.5°W and in the process developed a good low-level circulation, as evidenced by the configuration of the stratus/stratocumulus in the satellite photographs (not shown). The southern system had accelerated eastward to near 155°W during this same period and lost much of its active weather. The trough was coarsely defined by cirrus configurations, but much better outlined by the 300 mb flow.

A definite slowing of both systems occurred by 0000 GMT 26 September. Although the southern system still existed as a well-defined trough in the 300 mb analysis, the dissipation of the associated cloud field made it barely discernible in the satellite imagery. The northern system drifted due west to near 36.5°N, 133.5°W (cf. Fig. 2). By 1200 GMT 26 September, a few wisps of cirrus associated with the northern system began to take on more of a curved band configuration. The southern system progressed slowly northeastward. Although still hard to find on the satellite pictures, it continued to be well defined in the 300 mb wind field.

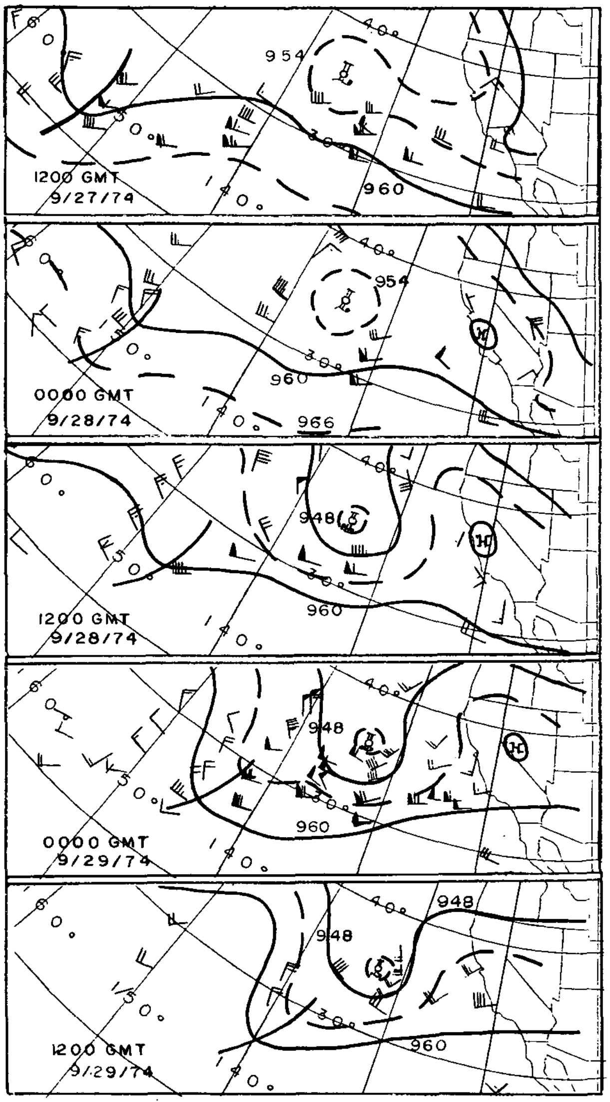
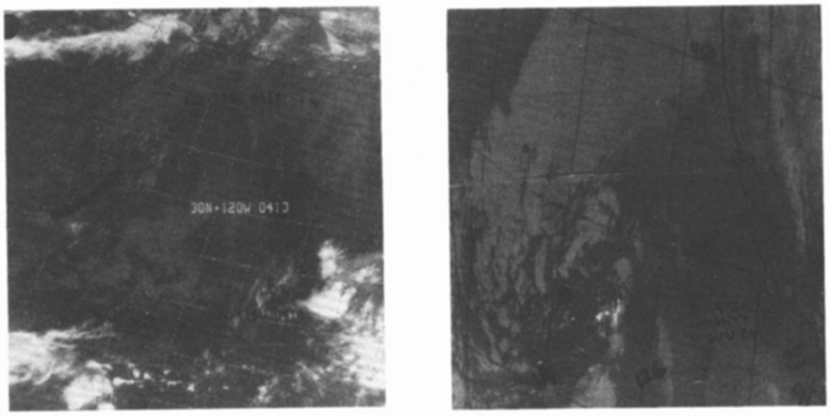


Fig. 4. 300 mb charts with corresponding airline upper wind reports for 1200 GMT 27 September 1974 through 1200 GMT 29 September 1974.

From 1200 GMT 27 September through 1200 GMT 29 September, the two systems appeared to converge as they moved basically eastward (Fig. 4). Associated cloud structures changed very little during this period (not shown). By 0000 GMT 30 September, the systems were very close to phasing (Fig. 5).

The systems became in-phase near 128°W about 1200 GMT 30 September (Fig. 6). The associated NOAA-2 daytime pass as well as the NOAA-3 day IR VHRR photograph for approximately the same time



NOAA-2 IR, ~0600 GMT September 30, 1974.

NOAA-3 VHRR IR, ~0600 GMT September 30, 1974.

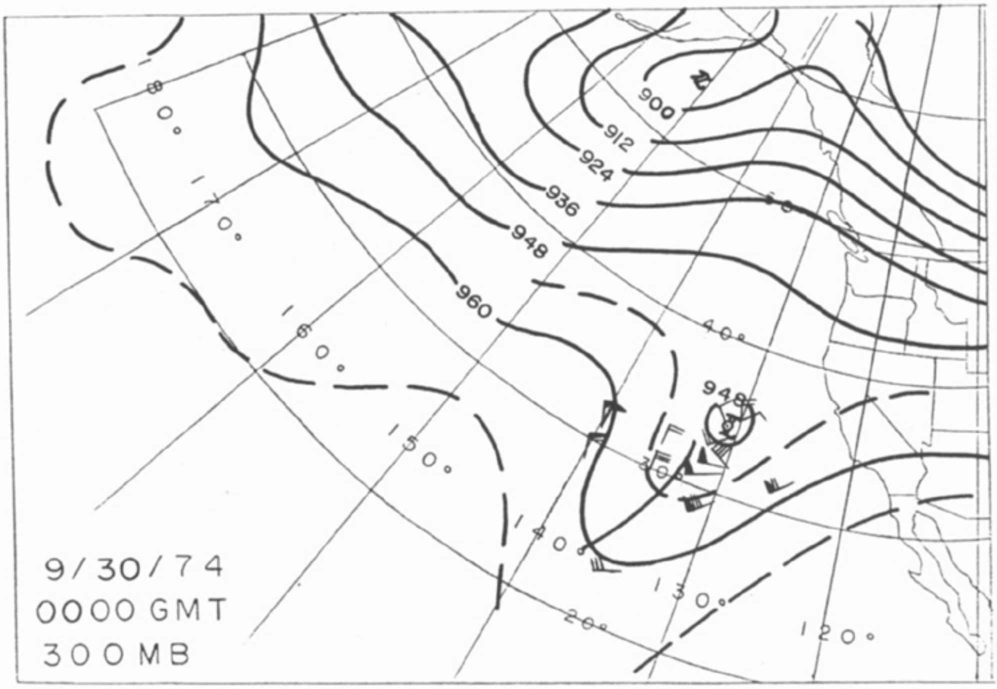


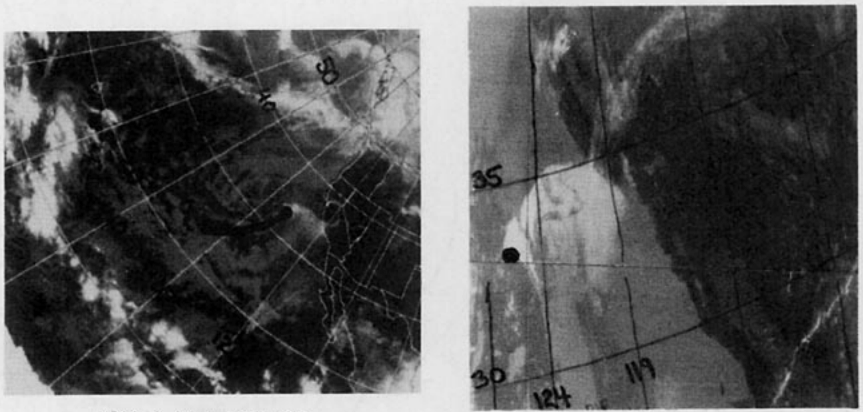
FIG. 5. 300 mb chart for 0000 GMT 30 September 1974 and corresponding NOAA-2 and NOAA-3 infrared satellite pictures.

shows that a remarkable increase of middle and high clouds took place. The sudden increase in upward motion implied by this accelerated cloud development at a time coincident with the phasing leads to the hypothesis: *When extratropical and subtropical systems become in-phase, the combined upward vertical motion field could suddenly become significantly stronger than that of the original individual fields.*

Shortly after 1800 GMT 1 October, satellite and RAREP data indicated a line of convective activity developing along the coast roughly between 34°N and 38°N (Fig. 7). An overall eastward spread of this activity can be seen in radar charts from 2135 GMT 1 October through 1935 GMT 2 October (Fig. 8). By 0000 GMT 3 October (Fig. 9), this cloud field continued to expand while moving rapidly eastward and being entrained into an approaching trough to the north.

4. Conclusions

A definite conclusion as to whether the increase in the upward vertical motion field associated with the quasistationary upper low resulted from the low latitude short wave merging with it or whether the increase was due to the downstream effect of the deepening trough from the Gulf of Alaska is not easily attainable. The 12 h continuity of polar satellites is not frequent enough to properly diagnose and describe rapidly developing synoptic scale systems. The increase in upward motion did occur, however, when the Gulf of Alaska trough was nearly 2000 n mi upstream, supporting a significant contribution from the low latitude system. Undoubtedly, the Gulf of Alaska trough had considerable influence in the final movement inland of the merged system. However, whether this merged system would have moved inland with as much vigor had the upstream trough not been approaching is inconclusive. The overall significance of the type of occurrence described above is emphasized when the total precipitation for the whole month of September is compared with the precipitation totals for each of the first three days of October. The comparisons (not shown) in this case were made for the central coast, south coast, San Joaquin, and southeast desert drainage divisions of California. The vast majority of stations reported no precipitation during September. However, storm totals for the same regions for the first 3 days of October averaged between 0.25 and 0.75 ince with several stations reporting totals in excess of one inch. The type of rapid development described in this paper has the potential for bringing the California



NOAA-2 IR, ~1800 GMT September 30, 1974.

NOAA-3 VHRR IR, ~1800 GMT September 30, 1974.

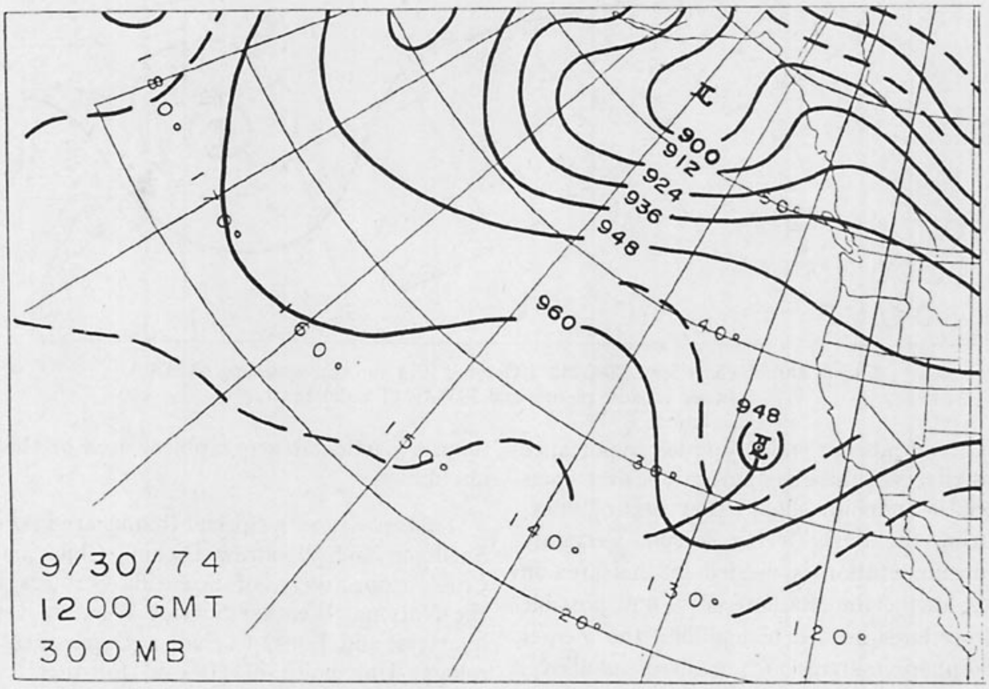
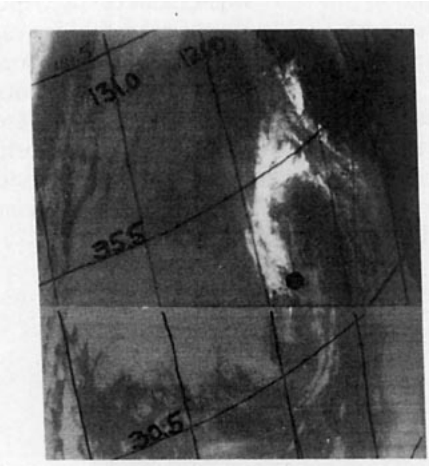
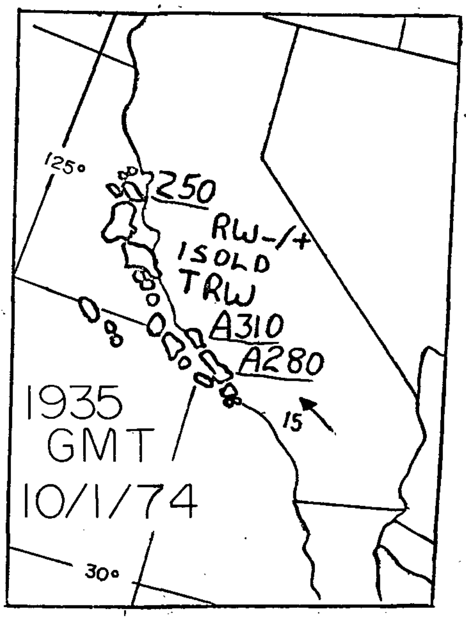


FIG. 6. 300 mb chart for 1200 GMT 30 September 1974 and corresponding NOAA-2 and NOAA-3 infrared satellite pictures.



NOAA-3 VHRR IR,~1800 GMT October 1, 1974.



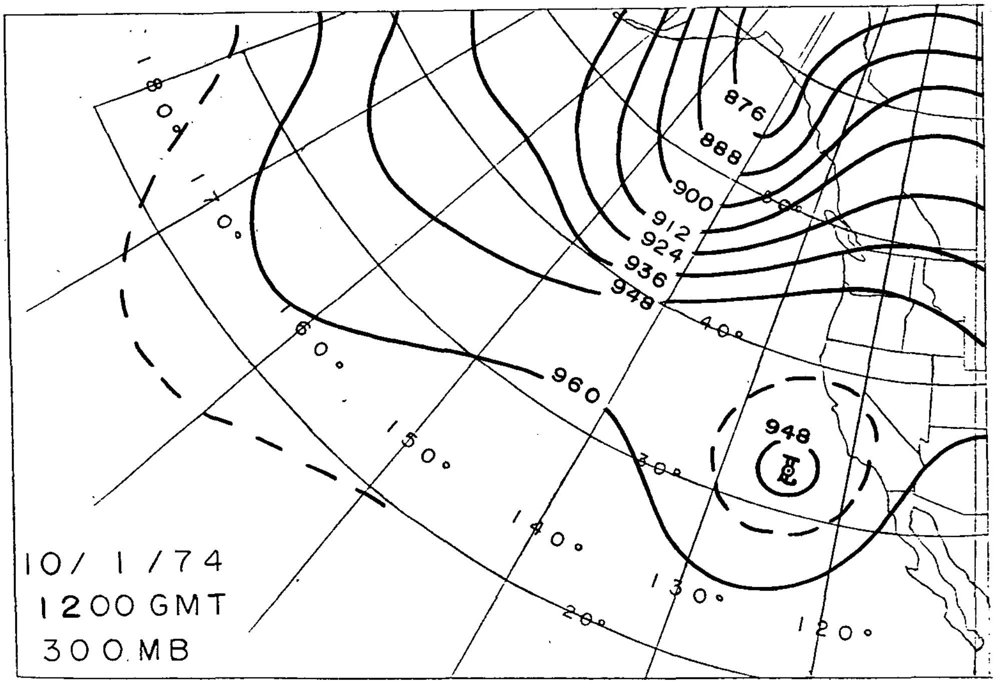


FIG. 7. 300 mb chart for 1200 GMT 1 October 1974 and corresponding NOAA-3 infrared satellite picture and 1935 GMT radar chart.

dry season to a very abrupt end. Of added importance is the fact that effects of these systems can be disastrous from a financial standpoint should they occur "unexpectedly" during the raisin-drying season. Certainly much more documentation is needed in this area in order to better define the characteristics and possible forecasting procedures needed in handling the merger of upper-tropospheric systems such as discussed above. Of particular interest would be whether the development with and following the phasing is dependent upon a particular geographical area or the large-scale circulation.

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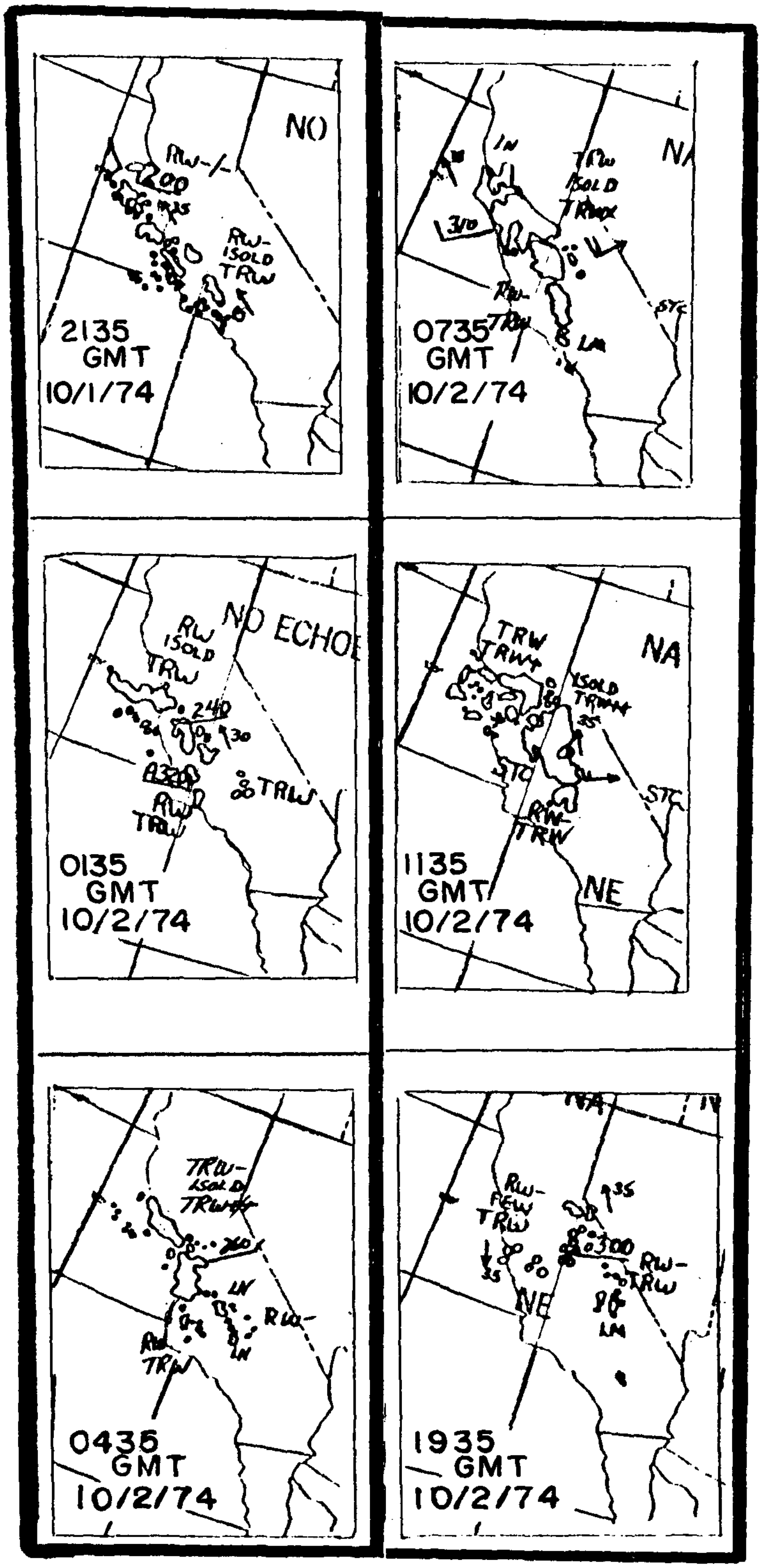
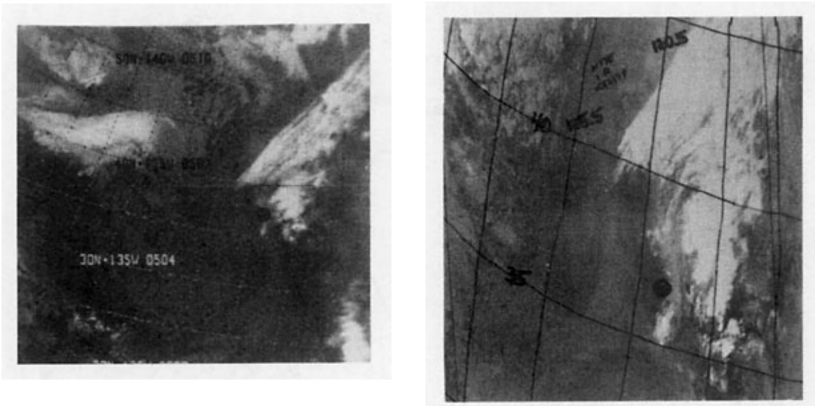


FIG. 8. Radar charts from 2135 GMT 1 October through 1935 GMT 2 October.



NOAA-2 IR,~0600 GMT October 3, 1974.

NOAA-3 VHRR IR,~0600 GMT October 3, 1974.

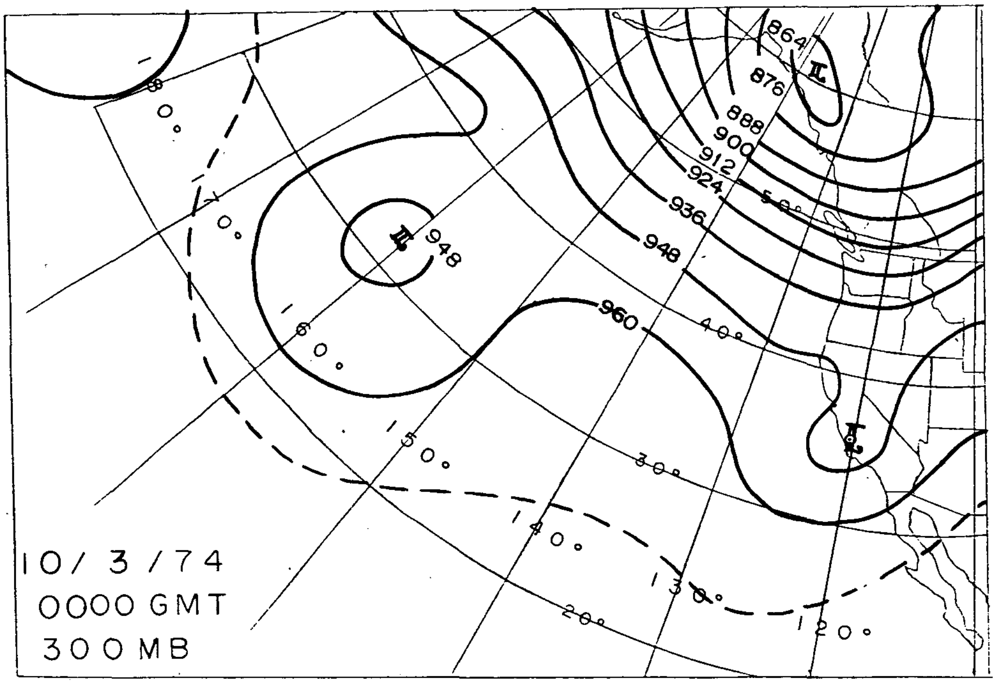


FIG. 9. 300 mb chart for 0000 GMT 3 October 1974 and corresponding NOAA infrared satellite pictures.

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