PICTURE OF THE MONTH

Development of Mesoscale Vortices along a Subtropical Frontal Remnant

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A fascinating example of mesoscale vortex development occurred along the shear line associated with a frontal remnant over the subtropical northeast Pacific on 10 and 11 February 1987 (Fig. 1). During a 24-h period, seven vortices developed and dissipated within a 2500 km long low-level frontal cloud remnant oriented southwest to northeast along 15°N, 145°W through 25°N, 115°W.

The event began after a weakening frontal band which had moved south during the previous 24 hours became quasi-stationary along 15°N, 145°W through 25°N, 115°W. At 200 hPa flow was northwesterly at 35–40 m s^{-1} while 500 hPa flow displayed a weak trough centered near 20°N, 135°W during the 24-hour period (not shown).

At 1301 UTC, 10 February, five innocuous cloud areas were vaguely evident along the frontal remnant (marked as A through E in Fig. 2). The vortices' life cycles from development to decay occurred during the subsequent 22-hour period through 1100 UTC 11 February (a time-slice satellite imagery composite for this period is shown in Fig. 3). The five vortices appear to have reached maximum intensity between 2031 UTC and 0031 UTC, during which time clearly defined circulation centers were evident and elongated rope-like clouds had developed along the south-southwest sectors of most of the vortices (see Fig. 1). The average distance between vortices was approximately 350 kilometers.

Vortices A and B remained nearly stationary through their lifetimes while C drifted northeastward at about 3 m s^{-1} and D and E drifted northeastward at about 7 m s^{-1} during the 22-hour period. Interestingly, between 2031 UTC and 0400 UTC two additional vortices (labelled F and G) formed near 20°N, 127°W along the same frontal remnant but northeast of the other five. Movement during their short life span was unclear.

A Navy interactive satellite display system (developed by the Naval Environmental Prediction Research Facility, NEPRF) was used to extract satellite measured infrared cloud top temperatures. A statistical technique developed by Lyons (1985), which relates cloud top temperature to cloud altitude via regression equations characterizing surface to cloud base lapse rates, is also interactive on the satellite display system. Cloud altitudes in the vortices were estimated using this technique which is normally accurate to within about 130 meters for clouds below 3300 meters. Average cloud top temperatures above the vortices were near 7°C which translate to cloud altitude near 2080 meters. Cloud tops in vortices D and E measured about 350 meters higher than cloud tops over A, B and C. All of these vortices were clearly low-level circulations.

Since estimated cloud tops were below 2200 meters, only light to at most moderate scattered precipitation was likely in each vortex, especially when the vortices first developed and clouds were even less vertically developed. Hence a CISK mechanism is unlikely to have been the primary contributor to vortex development. It is possible the vortices developed in response to barotropic instability along the shear line/frontal remnant. Nitta and Yanai (1969) discussed the necessary conditions for barotropic instability. Yanai (personal communication) suggested that this situation of vortex development did appear to qualitatively resemble a barotropic instability. To test whether the environment was favorable for barotropic instability, numerous Fleet Numerical Oceanography Center (FNOC) analysis fields were examined. For brevity we show only the FNOC surface zonal wind (u) at 1200 UTC, 10 February in the vicinity of vortex development (Fig. 4). The five initial cloud areas as they appeared on the 1301 UTC satellite image are schematized on Fig. 4. A strong meridional gradient in u is observed near 15°–20°N, 145°–135°W in the vortex development area. Following Nitta and Yanai (1969), the distribution of absolute vorticity ($f - \partial u/\partial y$) as computed from u are shown at the right in Fig. 4 for the latitude cross section along 139°W. A necessary condition for barotropic instability is that the gradient of absolute vorticity must

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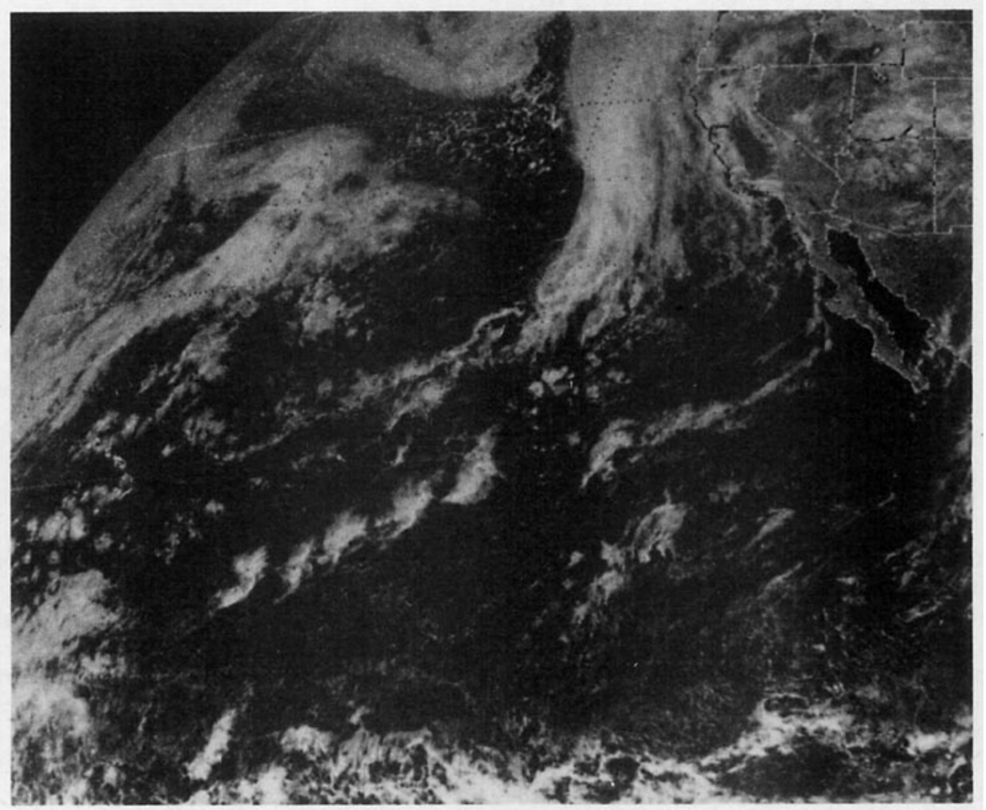


FIG. 1. GOES visible satellite image of the eastern north Pacific at 2031 UTC 10 February 1987. Five vortices extend from 19°N, 132°W to 15°N, 145°W.

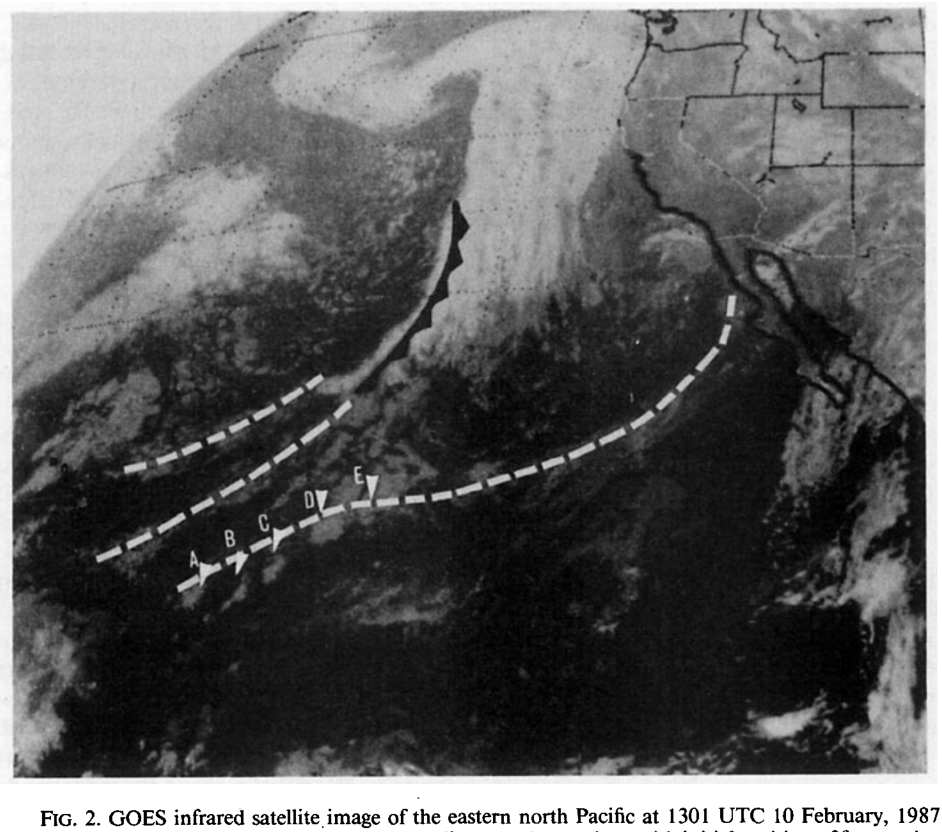
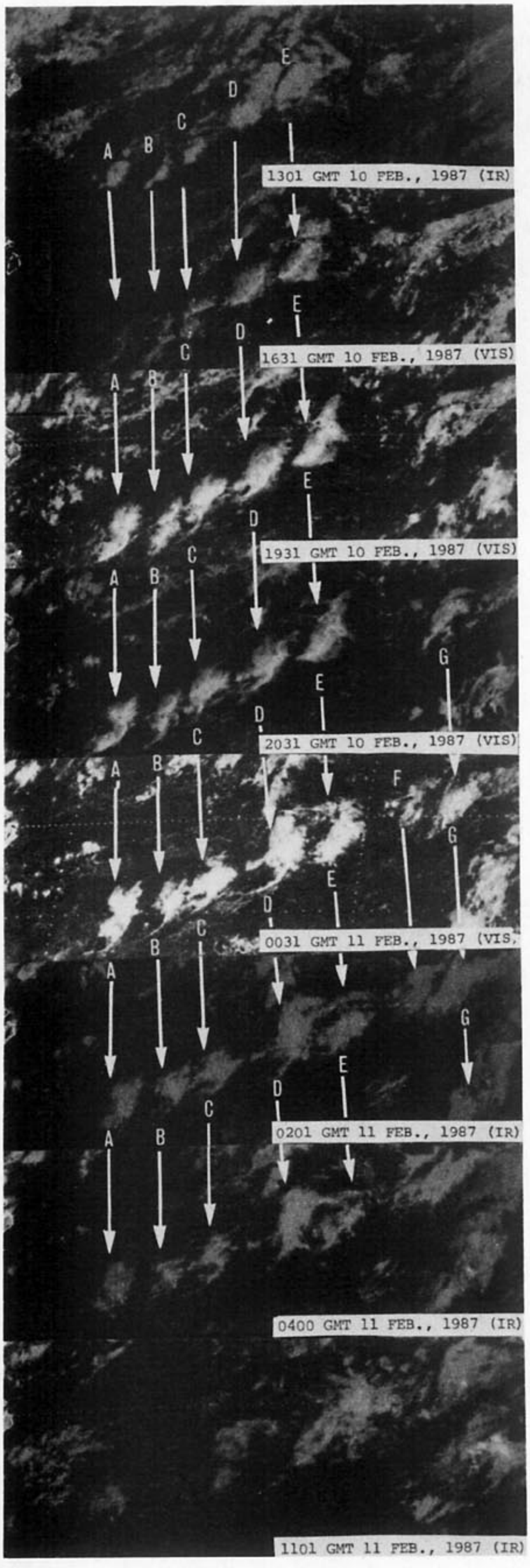


FIG. 2. GOES infrared satellite image of the eastern north Pacific at 1301 UTC 10 February, 1987. Author's subjective schematic frontal and shear lines are shown along with initial position of five vortices (marked A through E).



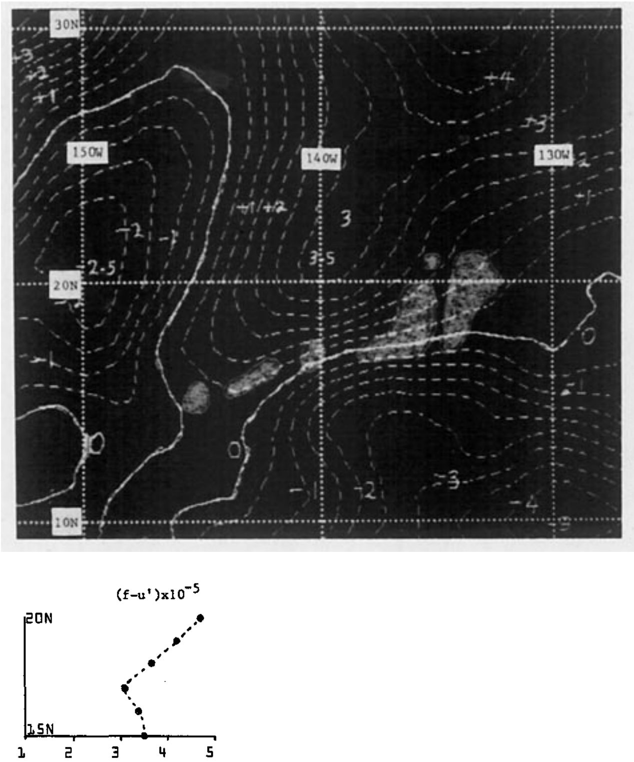


FIG. 4. FNOC surface zonal wind analysis for 1200 UTC, 10 February 1987. Units are meters per second, contour interval is 0.5 m s^{-1}. Zero line is solid. Satellite derived vortex positions are superimposed on u wind field. Right; latitude section from 15°N to 20°N along 139°W of $f - \partial u/\partial y$ (s^{-1}) computed from zonal wind field shown.

become zero somewhere. From Fig. 4 we see the gradient of absolute vorticity changes sign near 17°N, 139°W, and also along a line from 16°N, 142°W through 18°N, 135°W (not shown).

However, this is a region of strong anticyclonic shear, and development of cyclonic vortices here seems unlikely. Due to data sparcity the frontal remnant was not resolved. We can expect that a meridional compression of the shear line and a horizontal stretching has made it very narrow (as satellite cloud elements indicate). The absolute vorticity gradient along such a narrow cyclonic zone would become zero. Hence barotropic instability remains a possible development mechanism, however lack of data precludes satisfactory computational verification.

After 1101 UTC 11 February vortex decay was rapid and cloudiness associated with each circulation became diffuse and eventually dissipated. Deformation induced by a new front moving southeastward toward the line

FIG. 3. GOES visible and infrared satellite image time-slice for the period 1301 UTC 10 February through 1101 UTC 11 February 1987. Vortices are marked A through G.

of vortices probably helped contribute to vortex dissipation. Due to data sparsity in this region, detailed diagnostic analysis of the dynamics associated with this phenomenon is impractical; however it is exciting to see such clear interaction between synoptic scale frontal boundaries and mesoscale circulations.

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