Western Region Technical Attachment
No. 92-20
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EL NINO ENHANCED CONVECTION DEVELOPS ANOMALOUS HADLEY CELL RESPONSIBLE FOR AN UNUSUALLY STRONG WINTER 1991/92 SUBTROPICAL JET STREAM

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Most El Nino Southern Oscillation (ENSO) publications, advisories, and updates deal with ENSO from a purely statistical point of view. As one 1991 ENSO publication remarked, "Results have been obtained from statistical analysis of anomalous climatic conditions that occurred at the time of previous El Nino events." (Western Region Technical Attachment 91-46). There is, however, a simple physical explanation for one of the aberrations in atmospheric circulation, a strong subtropical jet stream, caused by El Nino. A strong subtropical jet is created by the balance of forces between, 1) strong meridional winter season upper tropospheric pressure gradients and, 2) latitudinal transfer of angular momentum imparted on the poleward mass transport of convective outflow from enhanced convection and Hadley cell circulation in warm El Nino waters.

In 1735, George Hadley, a British lawyer, first postulated the idea of an atmospheric meridional circulation cell, known as a Hadley cell, emanating poleward from the equatorial regions. After World War II, increased atmospheric pressure and wind observations provided data used to construct the modern day concept of the earth's general atmospheric circulation pattern, Figs. 1 and 2.

In Fig. 2, a quasi-permanent upper tropospheric frontal zone exists between both tropical Hadley and mid-latitude Ferrel cells. This upper tropospheric baroclinic zone forms a subtropical jet stream, strongest near the 200 mb level and located just north of the Hadley cell. [See Palmen and Newton (1969) for a more mathematical representation of the formation and maintenance of the subtropical jet.]

Northern hemispherical Hadley cell circulation, prominent during summer months, results from the poleward mass transport of outflow from Inter-Tropical Convergence Zone (ITCZ) convective bands. Meridional upper tropospheric pressure gradients at this time are relatively weak and so is the resulting subtropical jet. Figure 3 is a comparison of winter and summer northern hemispheric 300 mb height patterns, a reflection of upper-level pressure gradients. As the summer season comes to a close, well-established Hadley cell circulations begin to retreat south of the equator. If however, a strong Hadley cell were to continue over the northern hemispherical tropical Pacific during winter months, or even develop during ENSO events, conditions could exist for the formation of a subtropical jet of anomalous proportions. A balance between strong, winter-time meridional upper tropospheric pressure gradients, and the upper level poleward mass transport of low latitude angular momentum from convective outflow, would be key to the development of a strong subtropical jet. Such a jet stream could easily be maintained and reinforced as it encountered increasing meridional pressure gradients and/or merged with the polar westerlies during its long, fluctuating journey across the eastern Pacific.

Therefore, a very important and necessary feature for any full-fledged ENSO event is the development of persistent and enhanced central Pacific tropical convection. The establishment of this convective feature, which results in a Hadley cell, is necessary for the development of some anomalous global-scale circulation and precipitation patterns. The formation of an unusually strong and persistent subtropical jet aids in transport of subtropical moisture essential for anomalous precipitation patterns (Fig. 4), and contributes significantly to frontal wave development where it merges with the polar westerlies.

The Evolution of 1991/92 ENSO Convection

Warmer than normal sea surface temperatures (SSTs) were observed in the equatorial Pacific during the months of December 1989 and January 1991 suggesting the possibility of an ENSO trend. The following are short chronological excerpts from NMC/Climatic Analysis Center advisories regarding the formation of ENSO convection:

1. ENSO Diagnostic Advisory 91/2 (Feb. 19, 1991) - A Pacific warm episode has been in progress during the last year. However, persistent enhanced convection has failed to develop in the central equatorial Pacific, and atmospheric circulation features typical of warm episodes have not been observed.

2. ENSO Diagnostic Advisory 91/3 (July 2, 1991) - The evolution of anomaly patterns in the tropical Pacific will continue to be closely monitored with regards to the development of strongly enhanced convection.

3. ENSO Diagnostic Advisory 91/4 (July 23, 1991) - Two features which generally accompany warm episodes are lacking. 1) Convection in the central equatorial Pacific and, 2) SSTs along the west coast of South America have been near normal.

4. ENSO Diagnostic Advisory 91/5 (Aug. 20, 1991) - Enhanced persistent tropical convection has not yet become established in the central equatorial Pacific.

5. ENSO Diagnostic Advisory 92/6 (Oct. 15. 1991) - As yet only weakly enhanced convection has been observed in the central equatorial Pacific. <u>If convection increases and becomes persistent during the next two months, we can probably expect the development of a full-fledged warm ENSO episode during the upcoming northern hemispherical winter.</u>

6. ENSO Diagnostic Advisory 91/8 (Jan. 28, 1992) - Enhanced convection developed in the central equatorial Pacific during late October. It persisted and intensified in November. As an example, during the November 1986 ENSO episode, enhanced convection developed in the central equatorial Pacific accompanied by anomalous subtropical and extratropical upper tropospheric circulation features generally found during warm ENSO episodes.

Satellite pictures in Figs. 5 and 6 show just the eastern edge of ENSO equatorial convection. A subtropical jet can be clearly seen flowing northeastward from the convective region southwest of the Hawaiian Islands. The 1991/92 ENSO subtropical jet was truly astonishing in the way it stimulated rapid development and spin-up of even the weakest closed and cutoff upper lows west of the southern California and northern Baja California coasts. When eastern Pacific short-wave troughs periodically dipped south into the subtropical jet stream region, strong winds provided immediate upper support and divergence patterns necessary for explosive and sustained development. Continuous advection of subtropical moisture also fueled storms that eventually led to flooding in eastern Texas, Southern California, and over parts of Arizona this winter.

References

Byers, R. H., 1959: *General Meteorology*. 3rd ed., Mcgraw-Hill Book Company, Inc. pp. 260-284.

Palmen, E., and C.W. Newton, 1969: *Atmospheric Circulation Systems*. Academic Press, pp. 16-20, 102-109.

Trewartha, G.T., and L.H. Horn, 1980: *An Introduction to Climate*. 5th ed., Mcgraw-Hill Book Company. pp. 100-121.

Western Region Technical Attachment No. 91-08, ENSO Diagnostic Advisory 91/02, February 19, 1991.

Western Region Technical Attachment No. 91-26, ENSO Diagnostic Advisory 91/03, July 2, 1991.

Western Region Technical Attachment No. 91-28, ENSO Diagnostic Advisory 91/04, July 23, 1991.

Western Region Technical Attachment No. 91-34, ENSO Diagnostic Advisory 91/05, August 20, 1991.

Western Region Technical Attachment No. 91-43, ENSO Diagnostic Advisory 91-06, October 15, 1991.

Western Region Technical Attachment No. 91-46, El Nino in Tropical Pacific May Affect Climatic Conditions Worldwide, October 29, 1991.

Western Region Technical Attachment No. 91-47, ENSO Diagnostic Advisory 91/07, November 19, 1991.

Western Region Technical Attachment No. 92-05, ENSO Diagnostic Advisory 91/08, January 28, 1992.

Western Region Technical Attachment No. 92-06, ENSO Diagnostic Advisory 92/01, January 28, 1992.

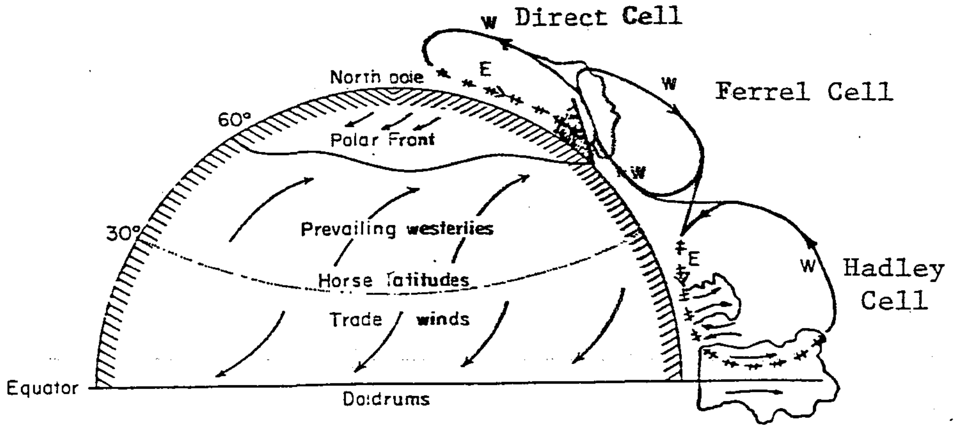


Figure 1. (Palmen and Newton, 1969)

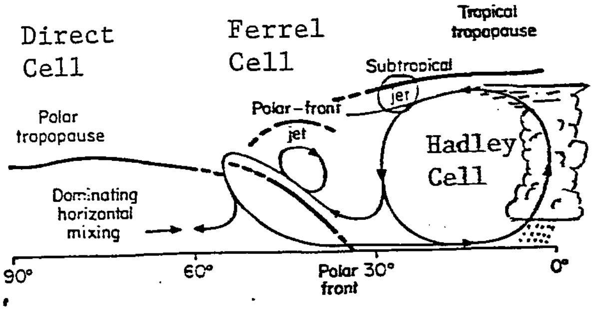


Figure 2. (Palmen and Newton, 1969)

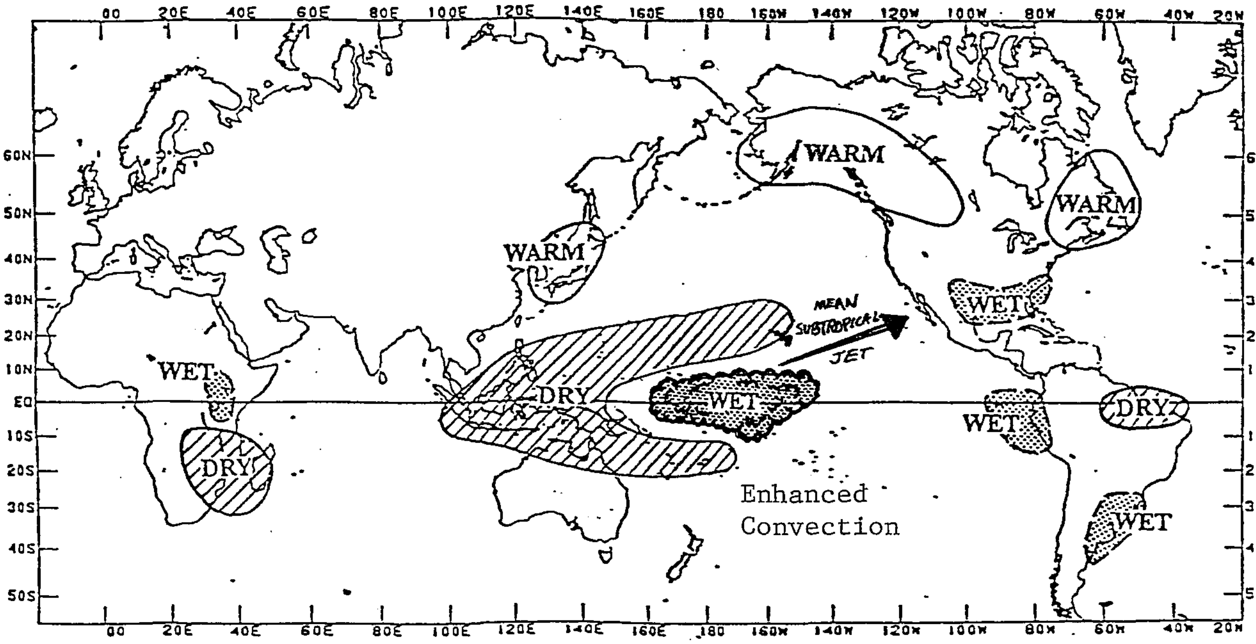
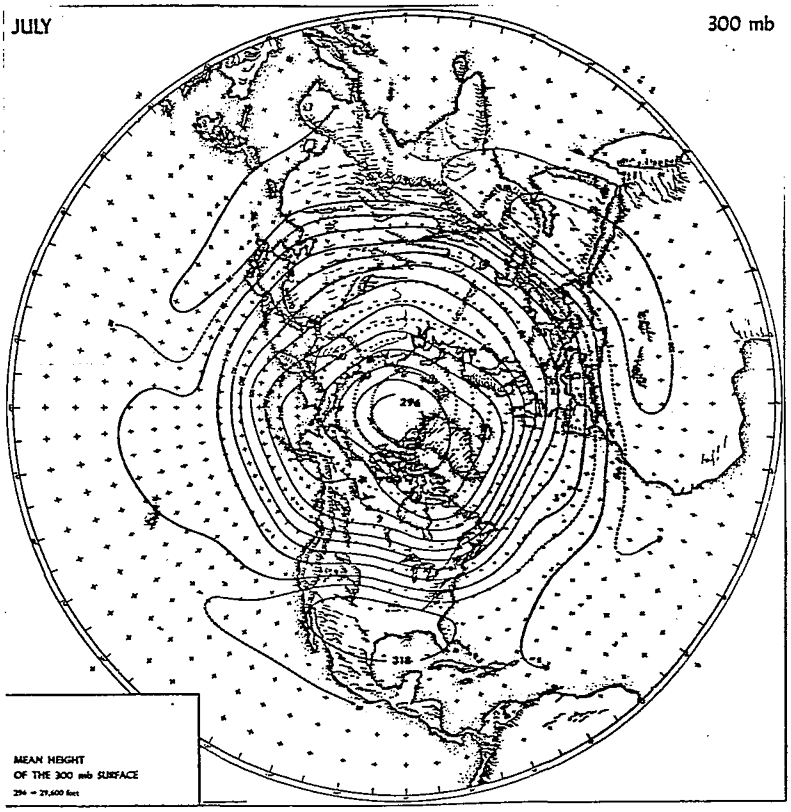
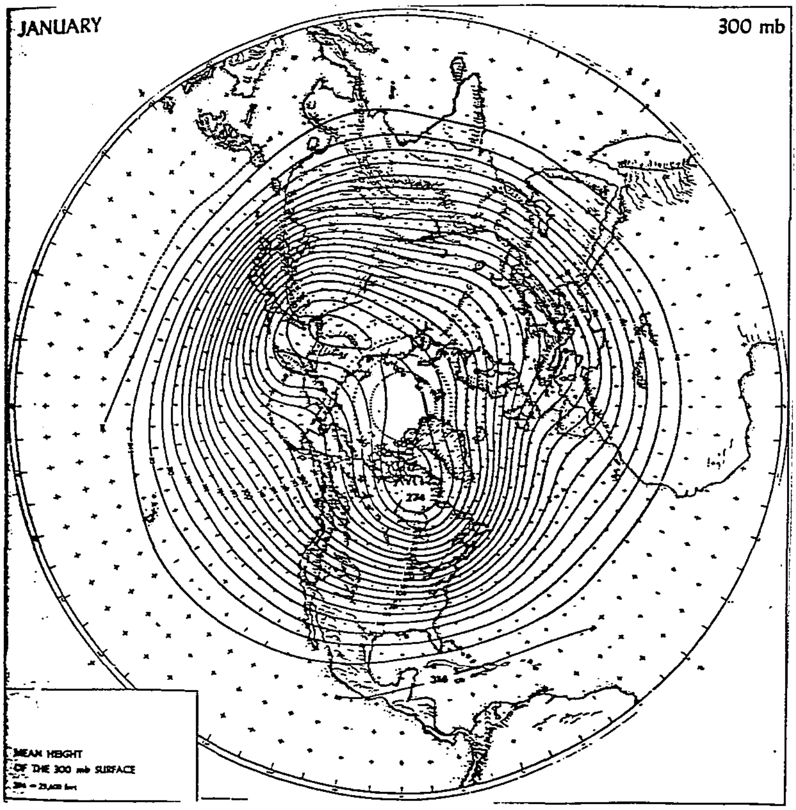


Figure 4. Temperature and precipitation anomaly patterns found during Nov. - Mar. warm ENSO episodes



July mean 300 mb height surface



January mean 300 mb height surface

Figure 3. (Trewartha and Horn,1980)

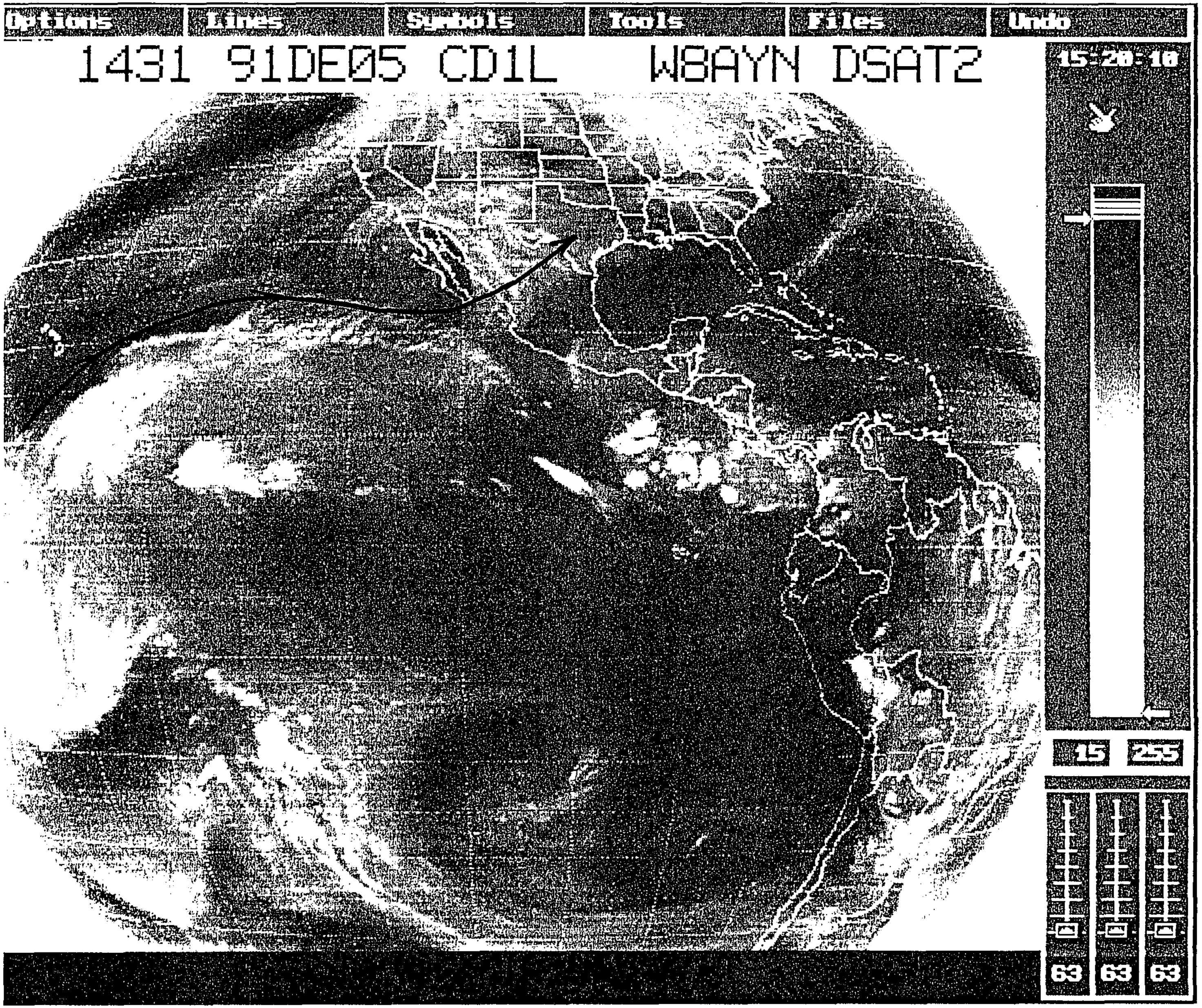

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Figure 5.

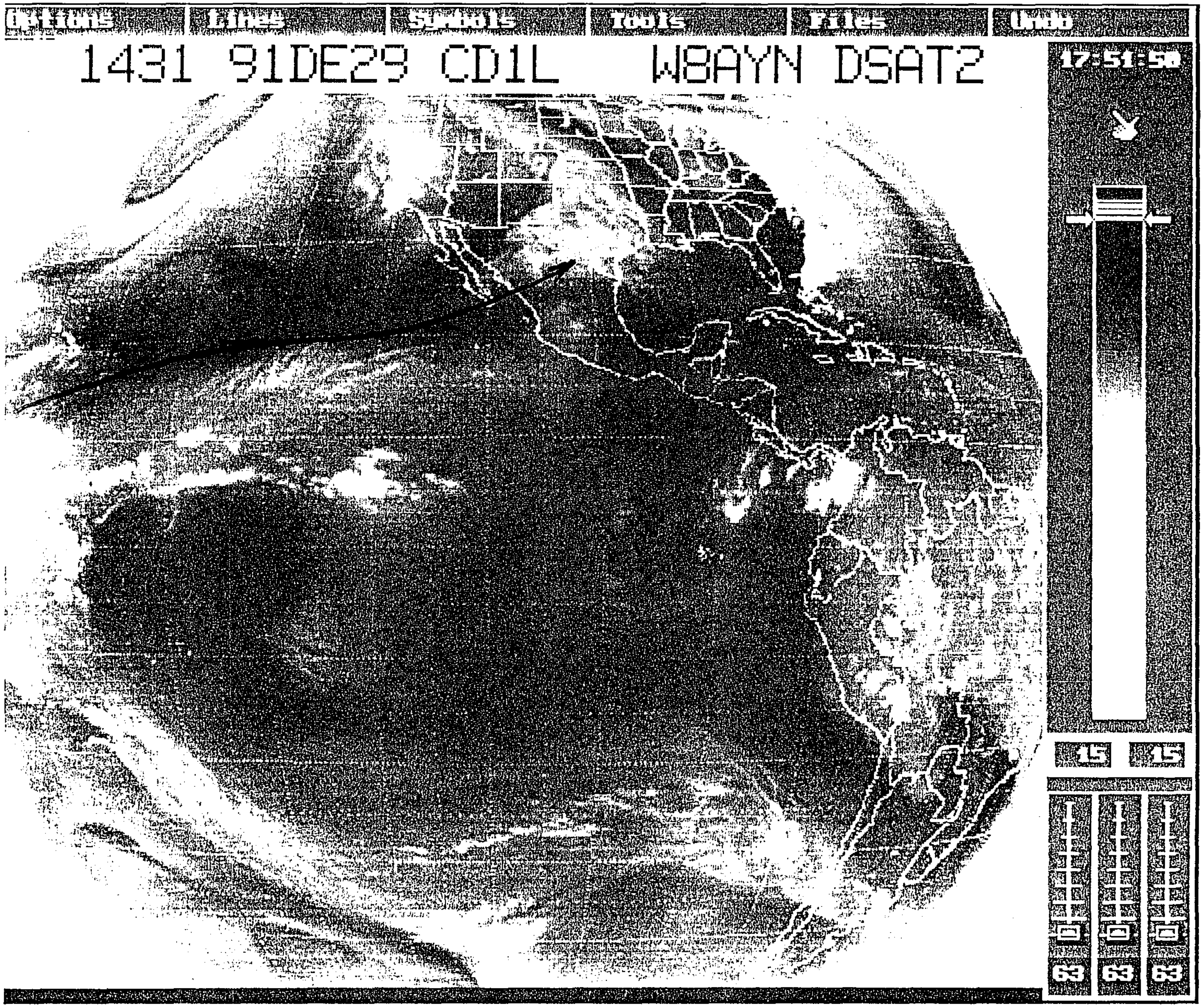
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Figure 6.