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PRECIPITATION, FRONTOGENESIS AND THE DEFORMATION ZONE

Frontogenesis is essentially the initial formation of a front or frontal zone through an increase in the horizontal gradient of density (or more commonly, temperature). According to the Glossary of Meteorology, one of the primary factors in the process of frontogenesis is horizontal deformation of the flow field.

This technical attachment will examine the kinematics (or the geometry of the flow field) as related to frontogenesis through deformation. A recent case will be used as a real-time example which shows the relationship between a deformation zone and the potential for precipitation.

Figure 1 is an example of a pure horizontal deformation field (i.e., irrotational and non-divergent). This field will tend to concentrate the isotherms along the axis of dilatation (line DZ in Figure 1), provided that the initial temperature field has a gradient from the northwest to the southeast. Warm advection over the southeastern half of Figure 1 and cold advection over the northwestern half will intensify the thermal gradient along DZ. If this occurs in the lower portions of the atmosphere, winds aloft will increase as a result of the intensified low level thermal gradient.

Figure 2 shows a flow field where a horizontal deformation field, with an east/west axis of dilatation, was added to a field of mean zonal flow. The result was a region of frontogenetic confluence. The implications of this region of frontogenetic confluence are described using Figure 3. In the center of this figure lies the intensifying horizontal thermal gradient (dashed lines). This requires an acceleration of the zonal flow in order to maintain geostrophic balance. As the jet accelerates, cyclonic vorticity must be generated north of the jet axis and anticyclonic vorticity to the south. Considering the vorticity equation, these changes in vorticity require that the flow at jet level be convergent north of the jet and divergent to the south. Mass continuity requires additional ageostrophic secondary circulations at low levels and in the vertical to balance the flow as indicated in Figure 3. The low level ageostrophic wind resembles the horizontal deformation zone with positive ageostrophic vertical motion south of the strengthening temperature gradient.

Figure 4 shows the initial conditions at 500 mb on 12Z Friday, 28 March 1986. The large scale pattern was dominated by wave number 2, with the main belt of westerlies pushed far north across the east Pacific and North America, and strong blocking in the low latitudes of the east Pacific. A series of short waves moved rapidly eastward in the zonal flow during the next 2 days. The 48-hour NGM forecast (Figure 5) shows a moderate short wave trough north of Montana with a weak vorticity lobe extending southwestward off the Oregon coast. Cold advection behind this trough as it would move eastward on Sunday and warm advection ahead of the cutoff low over the southern portion of the region prompted the following write-up in the Western Region Prognostic Map Discussion (PMD) on Friday the 28th:

> ..SUNDAY CONCRNS ME OVR THE CNTRL PORTN OF RGN WTH POTENTL
> FOR DEFORMATN ZN FRONTGNSIS AND SURPRISE CLDS AND PCPN.

The relatively benign dynamics across the west-central states implied little or no weather activity for Sunday. This was reflected in the forecasts and thus the reference to "surprise clouds and precipitation".

The 700 mb data from 00Z 31 March 1986 is shown in Figure 6a. A region of marked confluence is shown across northern Nevada and Utah. Subtracting the mean flow (of 18 kts at 270 degrees) from the area yields a well-defined deformation zone with an axis of dilatation extending from northwestern Wyoming southwestward across northern Nevada (Figure 6b). The 700 mb temperature difference had increased between SLC and BOI from 2°C at 12Z the 30th to 6°C at 00Z the 31st. Recalling that the positive vertical motion of the ageostrophic secondary circulation is located to the right of the intensifying temperature gradient, one would expect any enhanced cloudiness to exist across central Nevada and Utah.

The following excerpt is taken from the SFO SIM message at 00Z on the 31st:

> CNVTN HAS DVLPD ALG ILL-DFND DEFORMATN ZONE RUFLY CNTRL NV-THRU CNTRL UT.

The satellite pictures (Figures 7a and 7b) show the development of this convection between 18Z and 00Z south of the deformation axis of dilatation. Clouds and showers were widespread across a good portion of central Nevada and Utah, undoubtedly related to the dynamics of the deformation zone.

It should be noted that forecasting the location and intensity of clouds and precipitation associated with a deformation zone is, at present, a very difficult task. This is especially true as we head into the warmer season when flow patterns are weaker. Deformation zones also become a more important dynamical feature as the dynamics weaken during the warm season. Though not easy to forecast, recognition of the deformation patterns shown in this discussion and an understanding of the related dynamics may help the forecaster realize the potential for such events during otherwise relatively benign synoptic scale flow patterns.

References:

[1] Holton, J.R., 1979: An Introduction to Dynamic Meteorology, Academic Press, Inc., 391 pp.

[2] Huschke, R.E., Ed., 1959: Glossary of Meteorology, AMS, 638 pp.

[3] Sawyer, J.S., 1956: The Vertical Circulation at Meteorological Fronts and its Relation to Frontogenesis. Proc. Roy. Soc., 234, 346-362.

[4] Weldon, R., 1983: Synoptic scale cloud systems. Unpublished Report, Satellite Applications Lab, NESDIS/NOAA, Washington D.C., 35 pp.

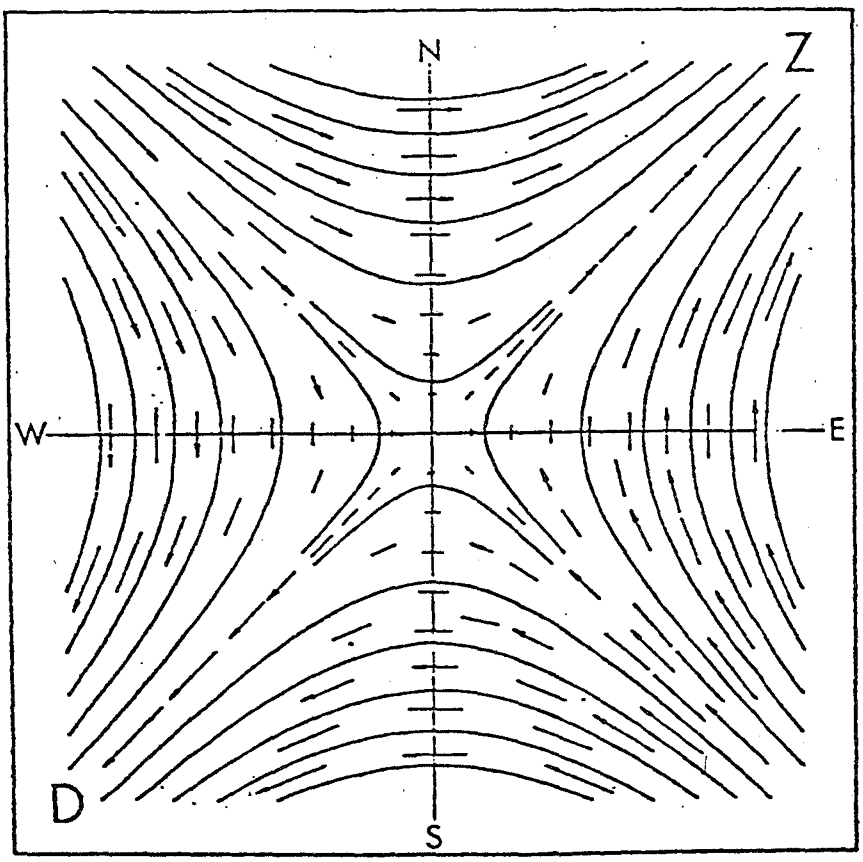

Figure 1. Example of pure deformation, with axis of dilatation along $\overline{DZ}$.

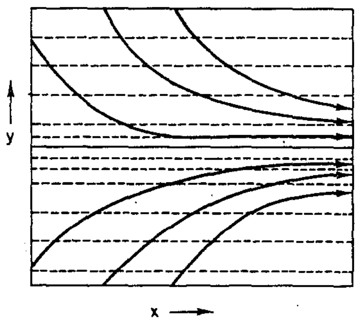

Figure 2. Horizontal streamlines and isotherms in a frontogenetic confluence (after Sawyer, 1956).

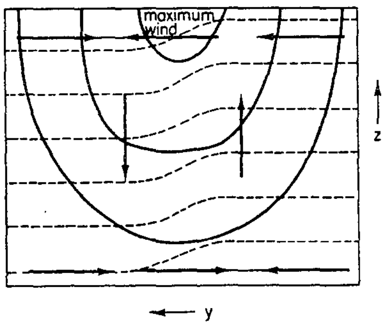

Figure 3. Vertical section across the confluence showing isotachs (solid), isotherms (dashed) and secondary circulation (arrows). After Sawyer (1956).

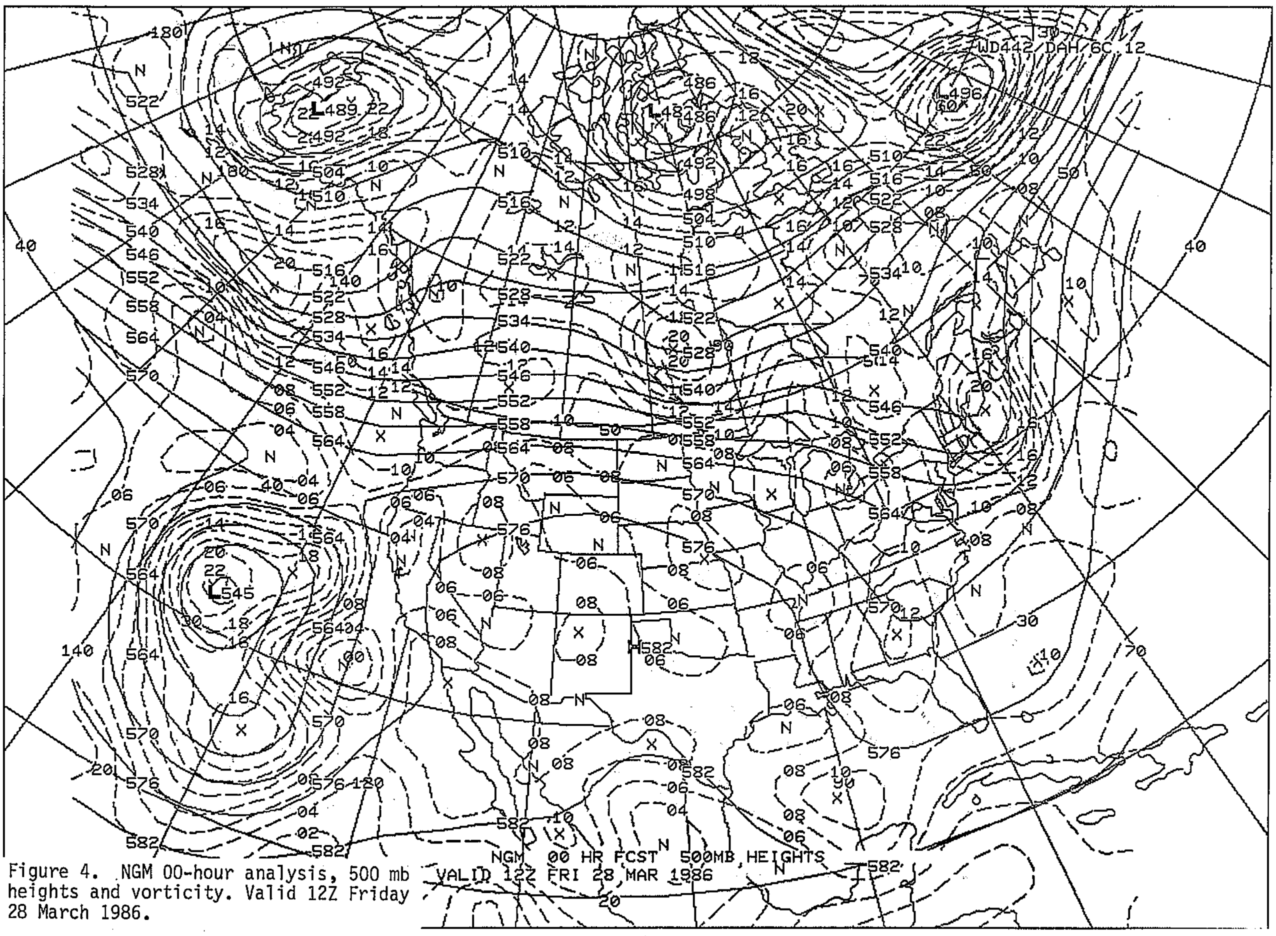

Figure 4. NGM 00-hour analysis, 500 mb heights and vorticity. Valid 12Z Friday 28 March 1986.

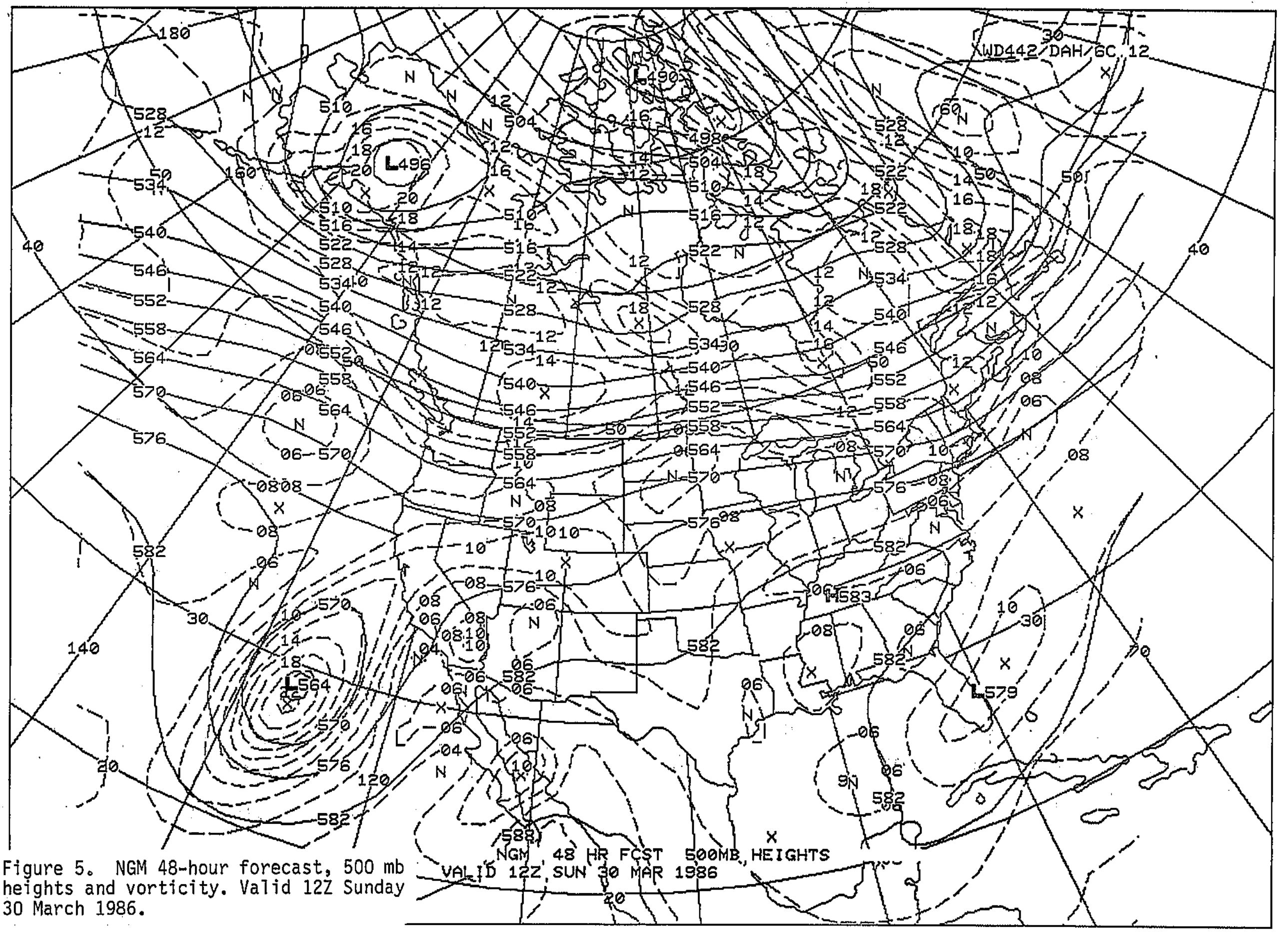

Figure 5. NGM 48-hour forecast, 500 mb heights and vorticity. Valid 12Z Sunday 30 March 1986.

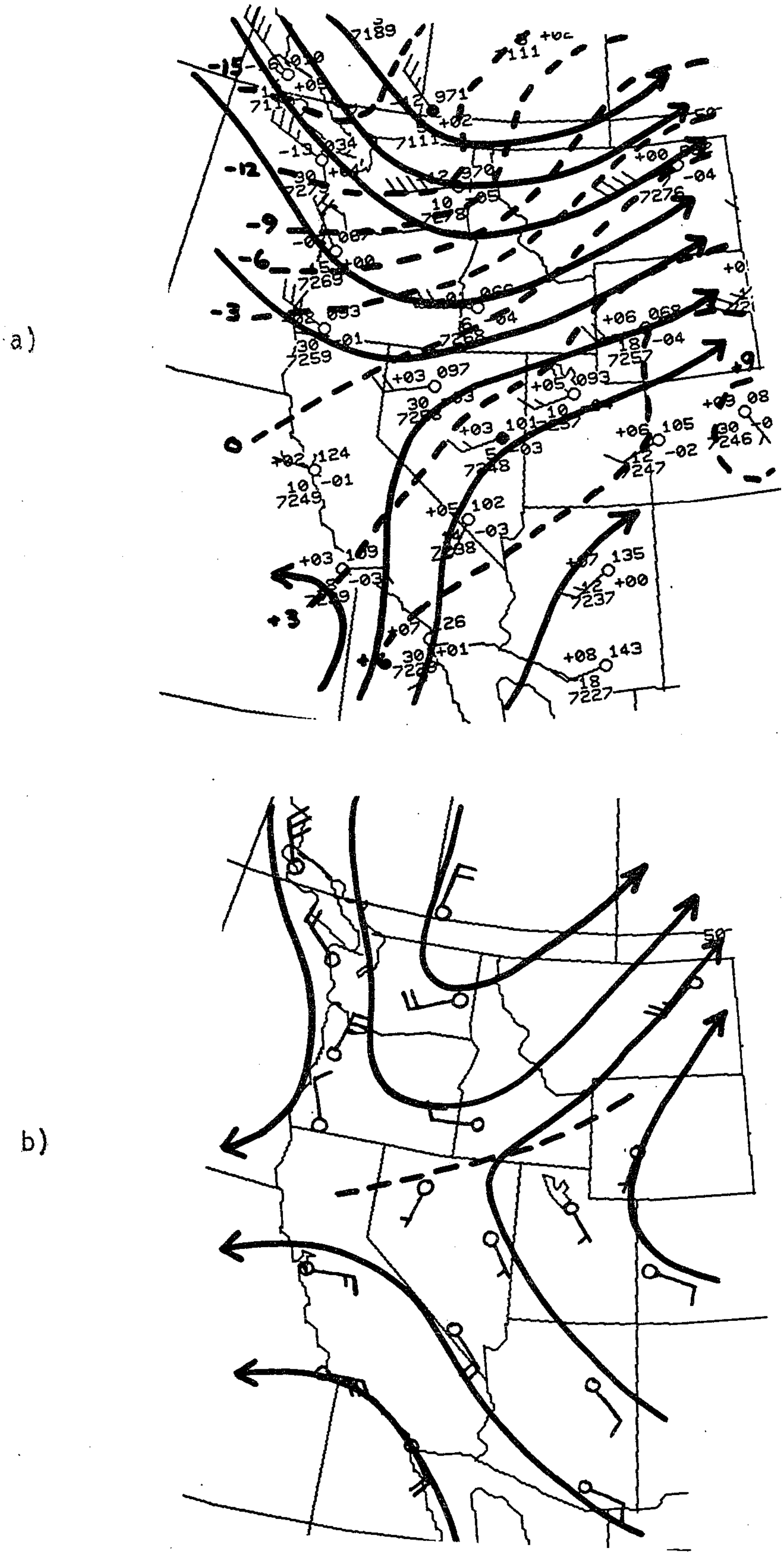

Figure 6. a) 700 mb plot from 00Z 31 March 1986 showing isotherms (dashed) and streamlines (arrows). b) streamline analysis of 700 mb field in a) minus the mean flow (18 knots at 270 degrees).

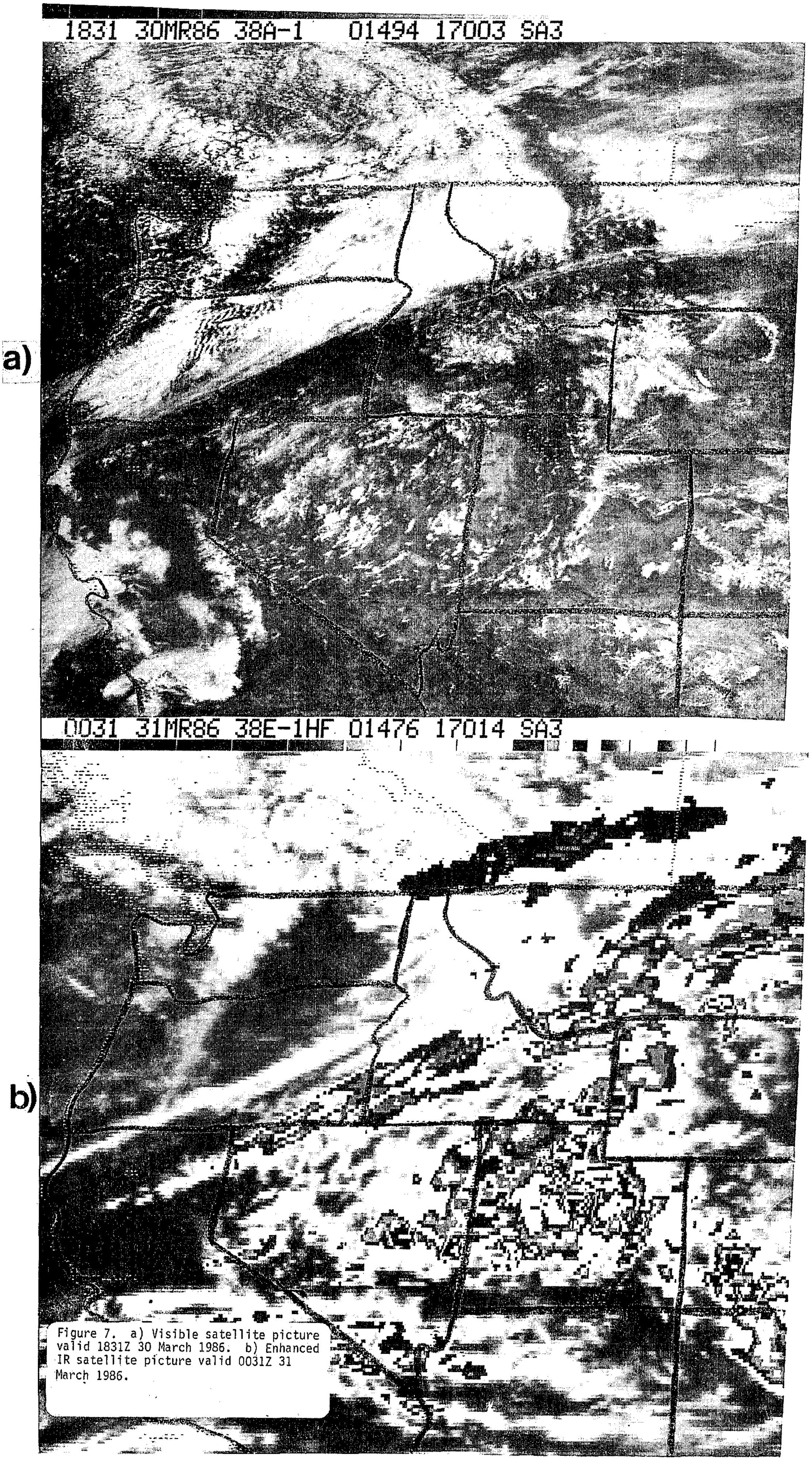

Figure 7. a) Visible satellite picture valid 1831Z 30 March 1986. b) Enhanced IR satellite picture valid 0031Z 31 March 1986.