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TECHNICAL MEMORANDUM No. 1

Local Uses of Vorticity Prognoses in Weather Prediction

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EASTERN REGION TECHNICAL MEMORANDUM

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UNITED STATES DEPARTMENT OF COMMERCE

Environmental Science Services Administration

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I. Introduction

This Memorandum illustrates some of the helpful uses of 500-mb contour and vorticity prognoses in the preparation of forecasts at field stations. A 500-mb numerical prognosis may be interpreted in terms of a surface pattern and areas of weather. Given a series of numerical prognoses, the movement of surface Highs, Lows and fronts, as well as areas of precipitation and cloudiness may be estimated.

This Memorandum is not intended to cover the complete procedure for using NMC guidance in field station forecasting. Any complete procedure should make judicious use of not only the numerical prognoses but also the surface, moisture and stability charts, maps indicating density advection and predictions of precipitation and temperature. Other charts may be used to a lesser degree. Proper use of this other guidance material will be the subject of subsequent Technical Memorandums.

One barotropic prognostic series (fig. 1) is used for illustrative purposes, and the interpretation and discussion of the series will be mainly confined to Northeastern United States - Eastern Region.

In addition to the usual contours and absolute vorticity isolines, the main area of positive vorticity advection (PVA) has been enclosed with scalloped lines in Figure 1. On the initial chart for 1200Z April 1, 1965, the concomitant observed surface Highs, Lows and fronts have been superimposed. The instantaneous precipitation for only the eastern half of the United States from the 1300Z weather depiction has been added as a stippled area. On the 12-, 24-, and 36-hour prognostic charts, reasonable interpretations of the circulation forecasts have been made using relationships and reasoning which will be described in the next section.

II. Relationships between 500-mb Vorticity Charts and the Surface Patterns and Weather

A. Highs and Lows

Surface Highs and Lows are related to the 500-mb vorticity centers. This is because the perturbations extend through a considerable depth of the atmosphere, and at the 500-mb level they are highlighted by the vorticity pattern. On the average, surface Lows are located approximately 5° of latitude downstream from the maximum vorticity centers. Typical variations for the average figure are as follows:

1. Young waves are found to the right of the flow (looking downstream) being displaced from the average positions towards lower vorticity values. As the storm develops, it migrates across the jet stream and the vorticity isolines towards higher vorticity values to the average, more common position.

2. Cold, completely developed Lows are almost vertical with the surface Low found directly underneath the upper-level vorticity center.

In the example (fig. 1) the young wave is located in Northern Illinois some distance south of the average position which would be near Sault Sainte Marie, Michigan. Also note that the surface Low is located close to the strongest PVA. (The strength of the PVA is inversely proportional to the area of the quadrilateral formed by the contours and vorticity isolines.) In the prognosis of the surface Low, some of the initial relationship is retained with a gradual change in time toward the average condition. Also, since it does not violate other rules, the surface Low is placed on the prognoses under the area of strongest PVA. This latter association frequently occurs and is particularly helpful in cases where the vorticity center is weak or non-existent.

If for good reasons a weak Low is forecast not to deepen, then very little migration of the surface Low across the vorticity isolines should be predicted. In our example, moderated deepening is forecast, so that the Low is moved in the 36-hour period from 10×10^{-5} to 14×10^{-5} units of vorticity.

Migratory cold Highs, because of their shallow nature, are less well related to the upper-level vorticity charts than Lows. Even so, Highs tend to be associated with minimum vorticity centers. In Figure 1, the weak High in Eastern Virginia is located under a minimum. Both the minimum vorticity center and surface High are forecast to move rapidly eastward. The cold High near James Bay appears to be associated with a vorticity minimum centered over Northern Quebec which is predicted to move southeastward. The surface High is predicted to move in the same direction gradually drifting in 36 hours to a position under the strongest, negative vorticity advection (NVA) over New England. This High could be forecast to weaken becoming only a pressure rise center as it moves into the major trough. The main high pressure would then be forecast to redevelop farther west, east of the major ridge under the weak NVA over the Mississippi Valley.

Another rough guide that can be used to advantage, especially in quasi-barotropic regions, is the fact that the surface flow often resembles the 500-mb vorticity pattern. Of course, there is the usual slope of the systems in the vertical due to any horizontal temperature gradients.

B. Surface Fronts

Positioning the Lows and Highs helps to locate in a crude way the surface fronts. Further aid in positioning the fronts comes from the vorticity pattern and its gradients. Because a strong vorticity gradient tends to be associated with a mid-tropospheric front, it indirectly indicates a preferred position for the surface front where a good estimate of the slope of the front is possible. This means that fronts, especially cold fronts, are usually associated with strong gradients of vorticity. The fronts are oriented parallel to the vorticity isolines and are located underneath the side of the strong gradient with the low values of vorticity. It is convenient to consider the vorticity isolines analogous to isotherms which are normally closely spaced on the cold side of the fronts. Warm fronts and cold fronts which are far removed from the Low, both of which have small and variable slopes may be found some distance from the strong, vorticity gradients. Significant fronts from the temperature standpoint should not cross many vorticity isolines, except when occluded. Also, the stronger fronts tend to remain near the same vorticity isoline.

It should be noted well that the vorticity prognoses are merely one aid, and it is paramount that the series of surface prognoses follow a logical evolution with good meteorological continuity. This is usually automatically attained with a proper interpretation of the numerical prognoses.

In our case, the nascent system with shallow fronts, initially over Central United States, is not well related to the vorticity pattern (fig. 1). However, in the prognostic series the front is predicted to become better related to the vorticity pattern, so that in 36 hours the strongest part of the cold front is oriented parallel to the strong packing of vorticity isolines over the Atlantic and Eastern United States with only the occlusion crossing the strong packing of vorticity isolines.

C. Precipitation

Locating the Highs, Lows and fronts will give some hints about the expected weather, but more direct indications are available in the vorticity advection fields. The equivalent-barotropic vertical motion is related to the vorticity advection - PVA produces ascent and NVA decent. This ignores the effects of temperature advection and orography which may operate to counteract the effects of vorticity advection. For example, the tendency for PVA to produce ascent can be effectively offset by cold advection in the lower troposphere.

Precipitation forecasting is further complicated by the fact that even though the mid-tropospheric vertical motion is correctly indicated by the vorticity advection, the moisture supply, low-level instability, lake effects, etc., may produce weather not indicated by the mid-tropospheric vertical motion. For this reason, it is important to make the initial association between the vorticity advection and the weather and to determine the physical processes which are going on that are producing or suppressing precipitation.

Again, in our example (fig. 1) most of the weather in Eastern United States is associated with PVA, but there are three small areas of precipitation that are not. Some shower activity is reported along the cold front in Northern Missouri where the vorticity advection is near zero. The precipitation occurring west of the trough in Wisconsin and Minnesota is probably low-level instability activity which frequently occurs in the cyclonic surface flow behind the Low under NVA. In South Carolina a small area of rain is reported which is associated with cyclonic easterly flow at the surface and near zero vorticity advection aloft. In the predictions, precipitation is retained for twelve hours in South Carolina, and then it is dropped as the Northwest flow aloft is forecast to increase and as the value of vorticity is predicted to decrease. The main area of precipitation, initially in the Great Lakes region, is carried along with the area of PVA with which it is originally associated maintaining essentially the same relationship throughout the 36-hour period. The low-level instability precipitation behind the trough is eliminated on the last chart because of the desiccating effects of the Appalachians along the East Coast with northwesterly winds. It should be emphasized that precipitation is not forecast over the entire area of PVA, but that the initial relationship is maintained with only small modifications forecast based on local factors. Studies have shown that calling for precipitation in all areas of PVA would grossly overforecast the occurrence of precipitation.

There is one significant area of NVA, which moves into Northeastern United States late in the period and favors rapid clearing over the Northeast

III. General Comments and Suggestions

A rapid analysis and interpretation of the vorticity prognoses by the field forecaster serves several purposes. It prepares him for the receipt of the NMC surface prognoses and provides, at least, a partial physical explanation for the existing weather and the weather shown on the NMC forecasts. It will also help him in the short-range prediction of the subsynoptic scale weather which is affected by the larger scale phenomena reflected in the vorticity pattern.

Therefore, it is urged that the vorticity prognoses be routinely analyzed including only the systems that will affect the forecaster's area of responsibility during the forecast period. Proficiency may be quickly attained by the forecasters - the entire process taking only a few minutes. The areas of PVA should be outlined and shaded in color with attention focused on the areas of significant strength ignoring regions of near zero PVA. Continuity of the PVA areas in the prognostic series should be clearly established and indicated by assigning a color to each perturbation. Areas of NVA should also be noted because of their association with clearing and radiational cooling at night. Significant surface features and areas of weather should be superimposed on the initial vorticity chart to facilitate determination of the initial relationships and physical processes involved. The initial conditions can then be projected into the future as illustrated in this Memorandum. This procedure will provide a good first approximation to the future weather and will automatically incorporate the continued improvements in numerical prediction.

Figure 1-A
Initial 500-mb Chart
1200Z April 1, 1965

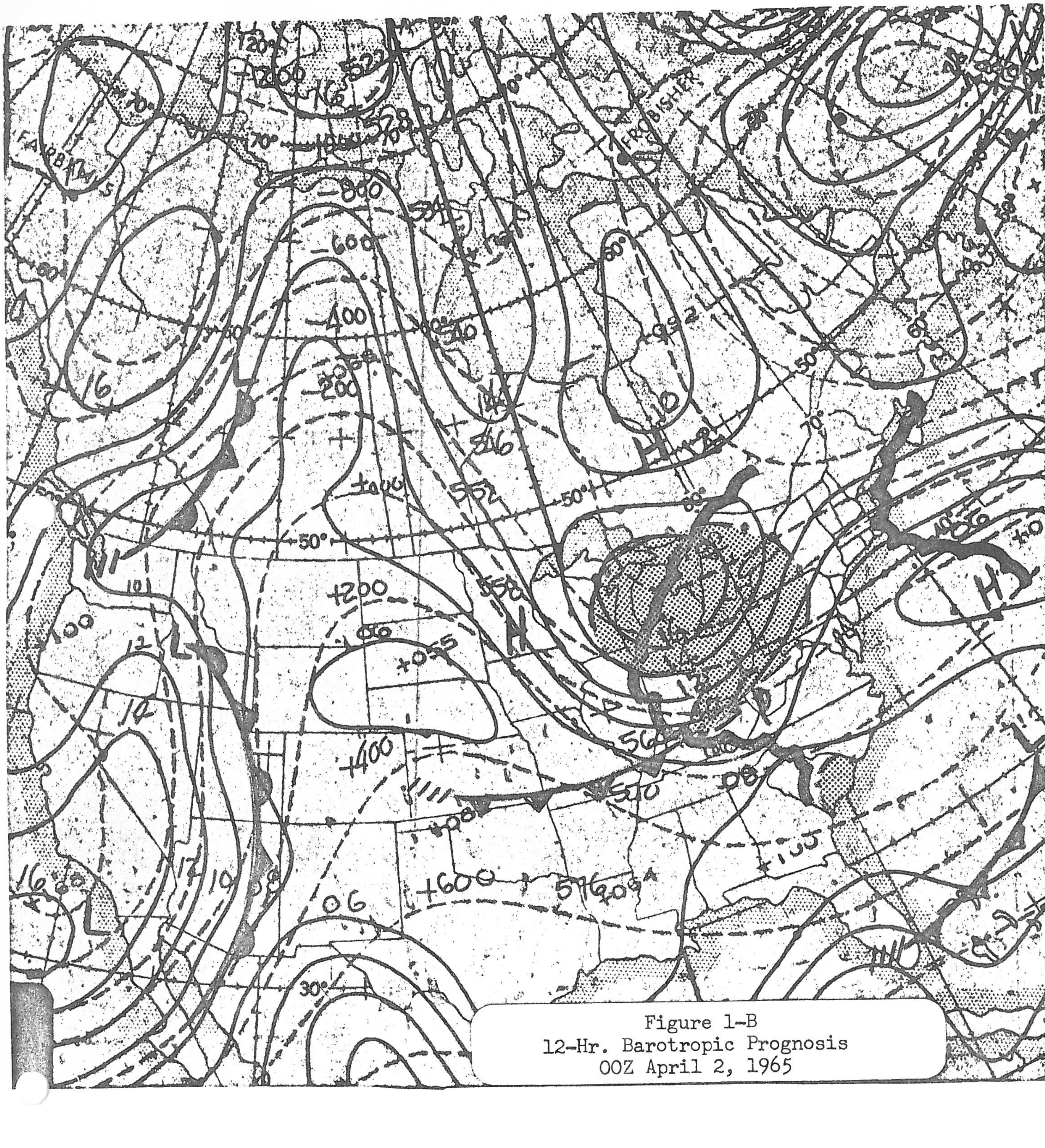

Figure 1-B
12-Hr. Barotropic Prognosis
00Z April 2, 1965

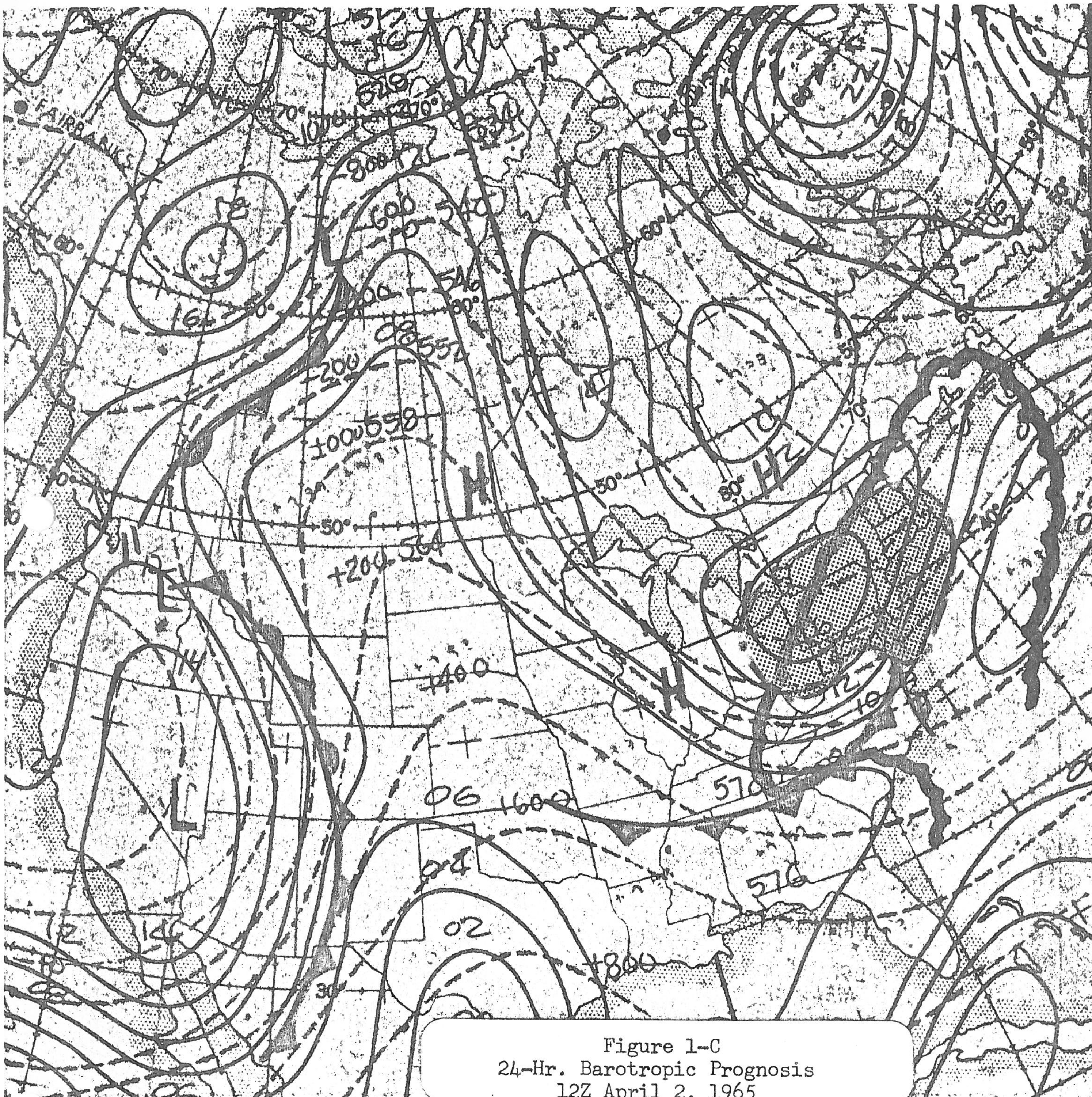

Figure 1-C
24-Hr. Barotropic Prognosis
12Z April 2, 1965

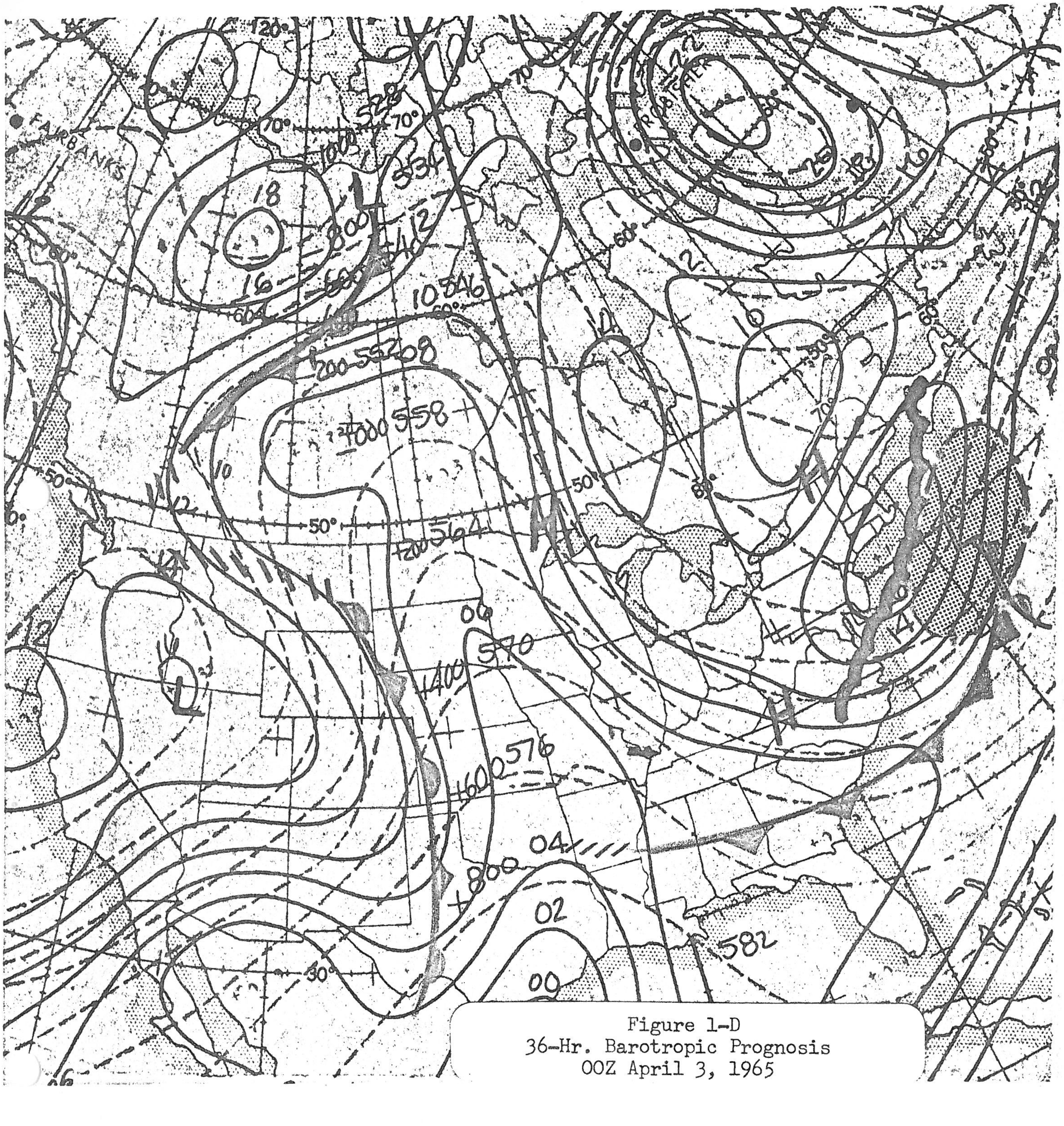

Figure 1-D
36-Hr. Barotropic Prognosis
00Z April 3, 1965