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Weight change charts for the atmosphere divided into three layers.

By

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Preliminary Report on Project II

Weight Change Charts for the Atmosphere Divided into Three Layers

Since the pressure at any one level is the integrated result of processes at higher and lower levels and cannot be understood without considering conditions at other levels, an attempt was made to study the synoptic distribution of 12 and 24-hour pressure and temperature changes in a series of three successive levels and to relate the synoptic developments at each level to the phenomena at other levels and to the surface weather.

For the purpose of this study as well as any forecast usage it is a logical desirability and a practical necessity to divide the atmosphere into as few a number of layers as possible. Our first choice was to divide the atmosphere into three layers: the lowest, from the surface to 3 kilometers includes the majority of surface effects such as, pressure and temperature changes which result from the migrations of cold domes of polar continental air; the middle layer, from 3 to 10 kilomters, includes the region where density changes are a minimum, where surface effects are not pronounced, and which is below the region where changes are taking place due to conditions or actions in the stratosphere; the third or top layer is made up of all the remaining atmosphere above 10 kilometers which will in general include the high troposphere as well as the stratosphere. The 3 and 10 kilometer levels divide the atmosphere into three layers roughly equal in weight: the lowest layer from about 1012 mb. to about 700 mb., or 312 mb.; the middle layer from about 700 mb. to about 260 mb., or 440 mb.; the top layer everything above 10 km., about 260 mb.

Charts were constructed to portray the 12-hour change in weight in each layer, the weight change being the 12-hour change in the difference of the pressure at the bottom and top of the layer. For the top layer, of course, the weight change is simply the pressure change at the 10 km. level. A series of 60 of these charts was constructed with isopleths of 12 hour weight change entered in a different color for each layer, together with the surface isallobars. For the isopleths of weight change within the 0 to 3 km. layer, 3 to 10 km. layer, and the layer above 10 km., we have used blue, red, and green respectively, and we shall refer to the various weight change regions simply as blue, red, or green areas with the appropriate sign and magnitude.

A preliminary study of the charts seemed to show the weight change areas moving along with the wind. If these areas result from the movement of cold or warm masses of air they should be expected to move with the wind. If, however, they result from the transmission of large scale pressure waves, it is not at all necessary that their movement should be either in the direction, or with the velocity, of the wind.

Trajectories of the air particles within a weight-change area were constructed and then compared with the observed movement of the areas. The agreement was very good for the blue areas, fairly good for the red areas, and only fair for the green areas.

The discrepancies between observed movement and that computed by using trajectories may be explained by one or both of the following statements: The trajectories as computed from the maps may be incorrect; The areas may not be masses of air of differing temperature, but may be due partially or wholly to individual divergence phenomena. In an attempt to answer the question of whether the regions were due to simple advection of air of different temperature or to divergence in the vicinity of the troughs or ridges, scatter diagrams were drawn to indicate relations between the mean virtual temperature of the column and the weight change of the column. For pure individual convergence positive weight changes should be associated with increase in temperature, while for pure advection or what is the same thing, pure local convergence, the reverse should be true.

For the layer 0 -- 3 km. the mean virtual temperature versus the weight gives such a scattering that a clear cut answer does not follow. There is some indication, however, that a tendency exists for the positive blue areas to be regions of cold air, and negative blue areas to be regions of warm air. For the 3 -- 10 km. layer the scattering is not so great and a distinct tendency is shown for the red areas to be warm for negative weight changes, and cold for positive. For the top layer, the height of the tropopause has been used as an indication of the average temperature in the "effective" portion of the layer. The height of the tropopause varied so that positive green areas were associated with high tropopause, that is, the positive green areas were regions of lower temperature.

The question of the relation of the weight change areas to the position of the troughs and ridges was then studied. In almost all cases for the lowest and middle layers, the troughs were regions of positive weight change while the ridges were regions of negative weight change. This condition was reversed for the top layer. This gives support to the idea of individual convergence as the cause of the weight change areas. It was thought in the beginning that with the areas due to masses of different density and advected with the wind, it would be a simple matter to construct trajectories for each area in the three layers and then sum algebraically in the vertical to get the subsequent surface pressure change. But with individual convergence playing a substantial part in the formation of the areas as indicated by the scatter diagrams, as well as by the location of the areas relative to trough and ridge positions, the difficulty of forecasting them is greatly increased. An attempt was made to relate the location of the weight change areas with respect to the troughs or ridges and their subsequent movement. It was thought that negative areas to the east of the trough would indicate more rapid eastward movement than if the negative area was to the west of the trough, but no consistent relation of this nature was found.

The question was raised as to which layer contributed most to the surface pressure changes. This question was quickly answered by observing the charts. It was seen that while at any one time any one of the layers may be responsible for the greater part of the surface pressure change, on the average each layer contributes almost an equal amount since each layer is roughly one-third of the total atmosphere.

The variation of weight in each layer is about one percent of the total weight of that layer. Again observing the charts, one sees that the areas of plus or minus 5 mb. move across the map in no set pattern, so that the conclusion is quickly drawn that the average weight change for each layer at any one station would be about 2.5 mb. In the upper layer plus or minus 10 mb. changes are occasionally observed so that the average weight changes in this layer should be somewhat higher. To check this conclusion data from all stations for alternate days in Dec. 1941 were averaged to give the weight changes for each layer. This tabulation gave 2.5 mb. for the 0 -- 3 layer, 2.5 mb. for the 3 -- 10 layer, and 3.1 mb. for the layer above 10 km. Comparing these averages with the average weight of each layer we get the percent variation in weight for each layer as:

$$\frac{2.5}{312} = .008 \quad \text{for the 0--3 km. layer}$$

$$\frac{2.5}{440} = .006 \quad \text{for the 3--10 km. layer}$$

and $$\frac{3.1}{260} = .012 \quad \text{for the layer above 10 km.}$$

Haurwitz, B. & Noble, J. R., "Maps of the Pressure Distribution in the Middle Troposphere Applied to Polar Anticyclones" Bul. A.M.S. March 1938, Vol. 19 No. 3, p. 107

Haurwitz, B. & Turnbull, W. E., "Relations between Pressure and Temperature Variations in Troposphere and Stratosphere over North America" Can. Met. Memoirs, Vol. 1, No. 3

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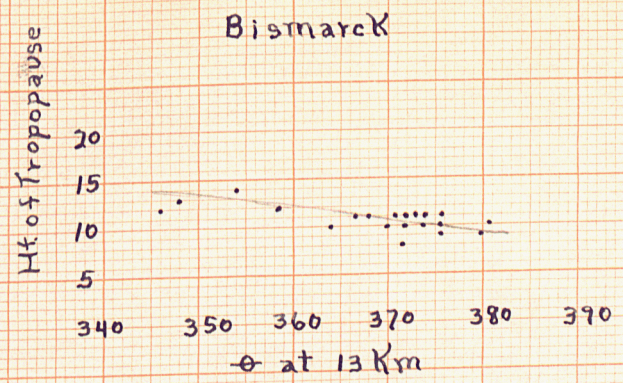

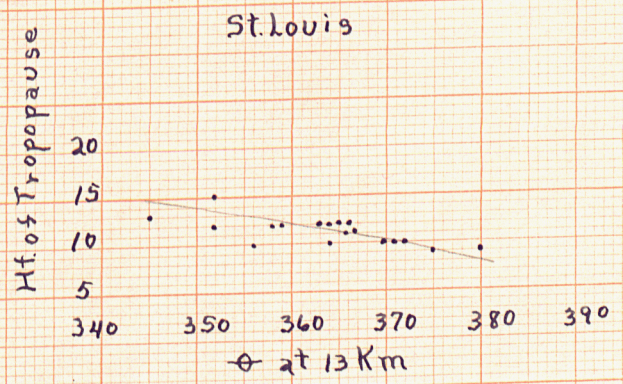

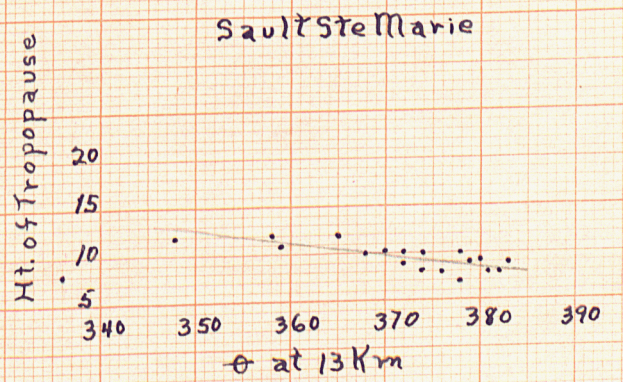

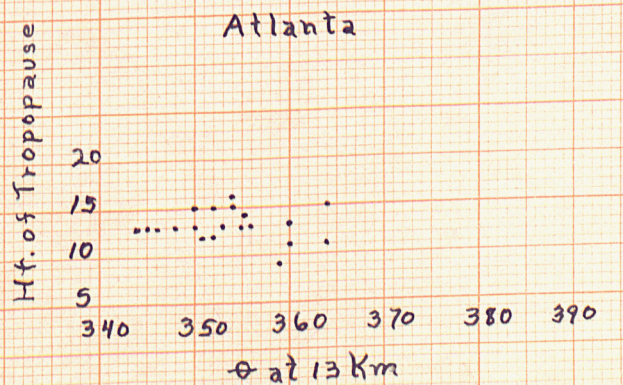

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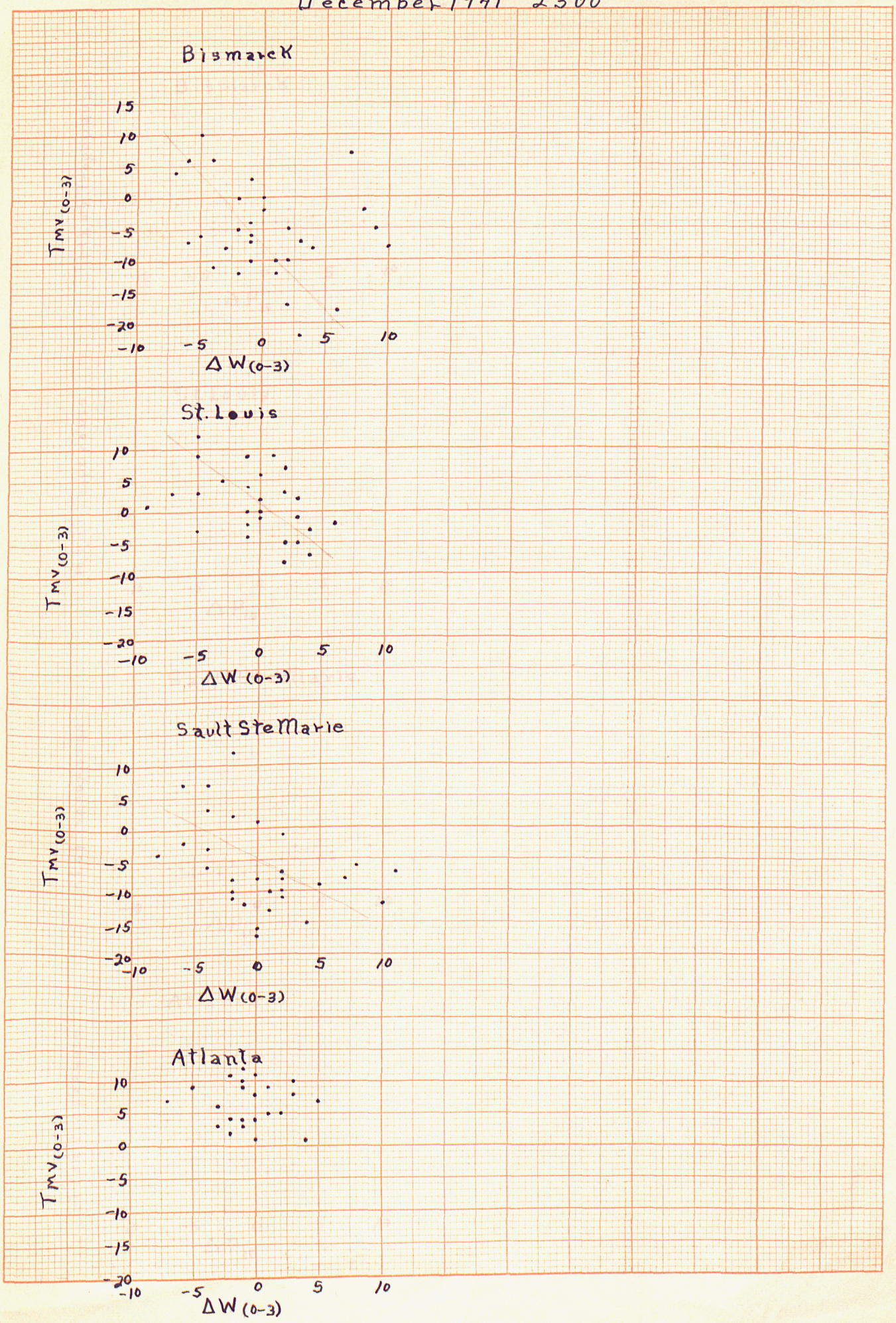

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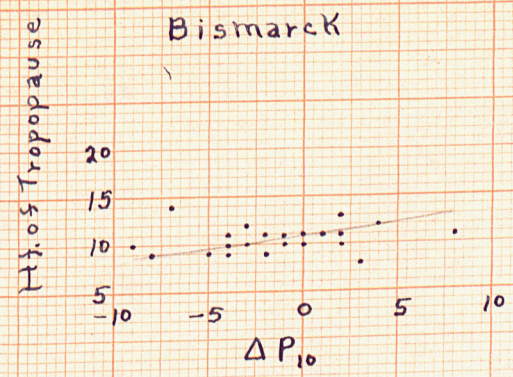

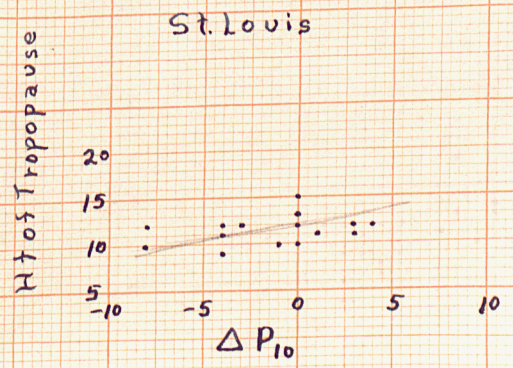

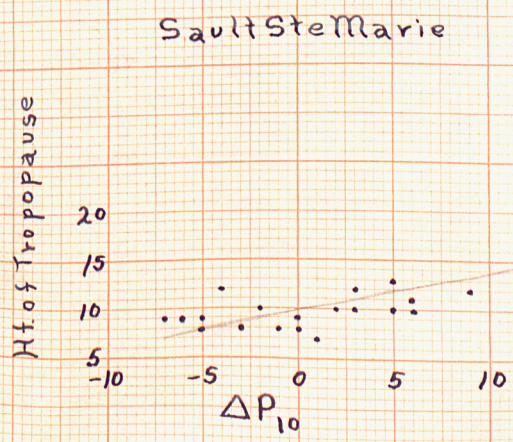

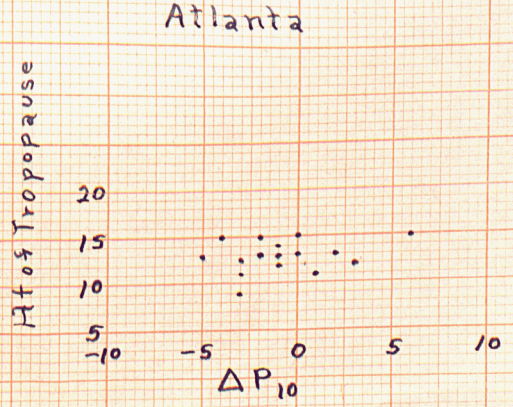

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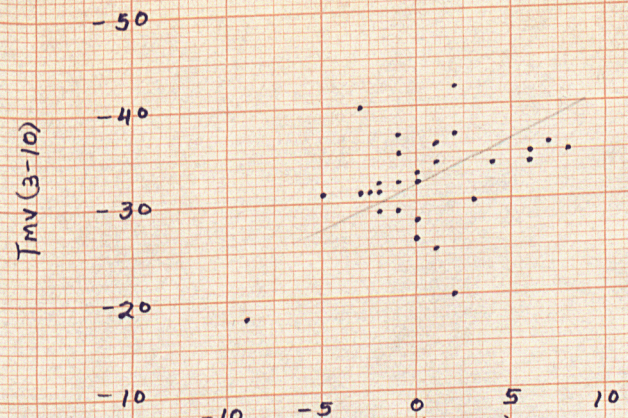

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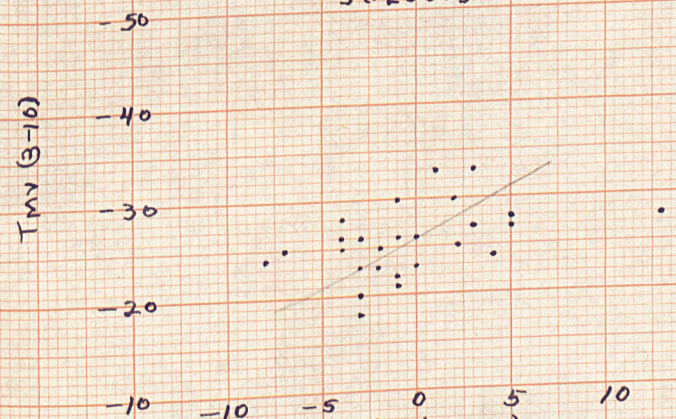

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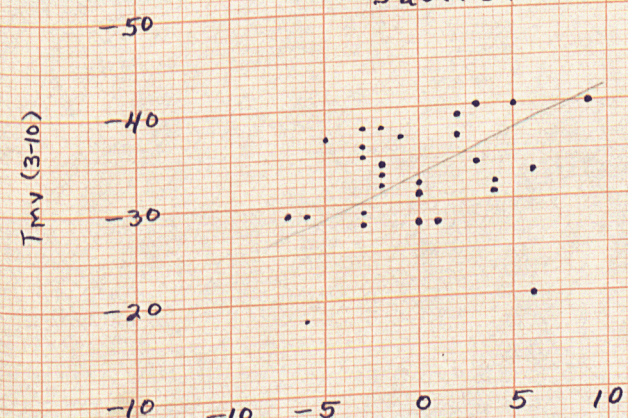
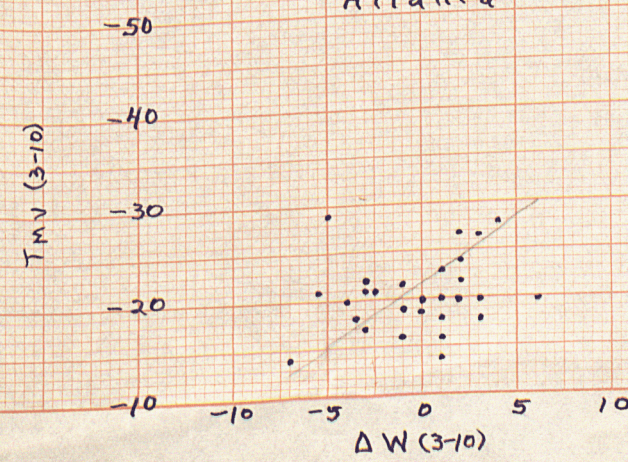
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