VERTICAL MOTIONS INFERRED FROM SATELLITE RADIOMETRY

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Medium resolution radiometer measurements on Nimbus 2 and 3 and relatively high resolution measurements on Nimbus 4 have been made in 6.4- to 6.9- and 20- to 23-μm water vapor absorption regions where the weighted means in the observed radiation occur in the troposphere near the 40- and 60-kN-m^{-2} (400- and 600-mbar) levels, respectively. An illustrative example of the imagery obtained from the Nimbus 4 temperature-humidity infrared radiometer (THIR) is shown in Figure 1. This example demonstrates clearly that there is a distinct pattern difference between the 6.7-μm observations coming from the midtroposphere and the more common 11.5-μm "atmospheric window" observations showing the emitted radiation associated with opaque surfaces such as the ground or optically thick clouds. The water vapor observations show considerable detail that is not well understood along areas where jetstreams and pressure troughs are occurring. We know that the darker areas in the 6.7-μm imagery are associated with relatively dry air and the lighter areas are associated with relatively moist or cloudy regions. Some qualitative explanations have been given in the past to explain how these observed features occur but very little definitive and quantitative work has been published that describes in detail the dynamic conditions such as vertical velocity and mass divergence that are associated with water vapor patterns such as those shown in the figure.

Over the past year this task of deriving dynamic parameters from conventional meteorological data and explaining the satellite observations has been undertaken using a 10-level diagnostic numerical model that provides relatively reliable, but otherwise difficult to obtain computations of vertical motion. A typical meteorological situation involving a well-defined pressure trough occurring over the United States October 17, 1969, was selected for study. At this time Nimbus 3 observations were available in both the 6.4- to 6.9- and 20- to 23-μm spectral regions at approximately 0600 Greenwich meridian time (GMT). The synoptic situation as represented by the flow at 50 kN m^{-2} (500 mbar) (5 km) for this time is shown in Figure 2. The trough in the pressure field extending from Hudson's Bay southward to the Great Lakes can be seen along the movement of this trough over the 12-hr period between 0000 and 1200 GMT on October 17. Vertical motions and other dynamic parameters were computed for both the standard 0000 and 1200 observation times. The 50-kN-m^{-2} (500-mbar) vertical-motion results, as interpolated to the satellite observation times of 0600 GMT, are shown in Figure 3.

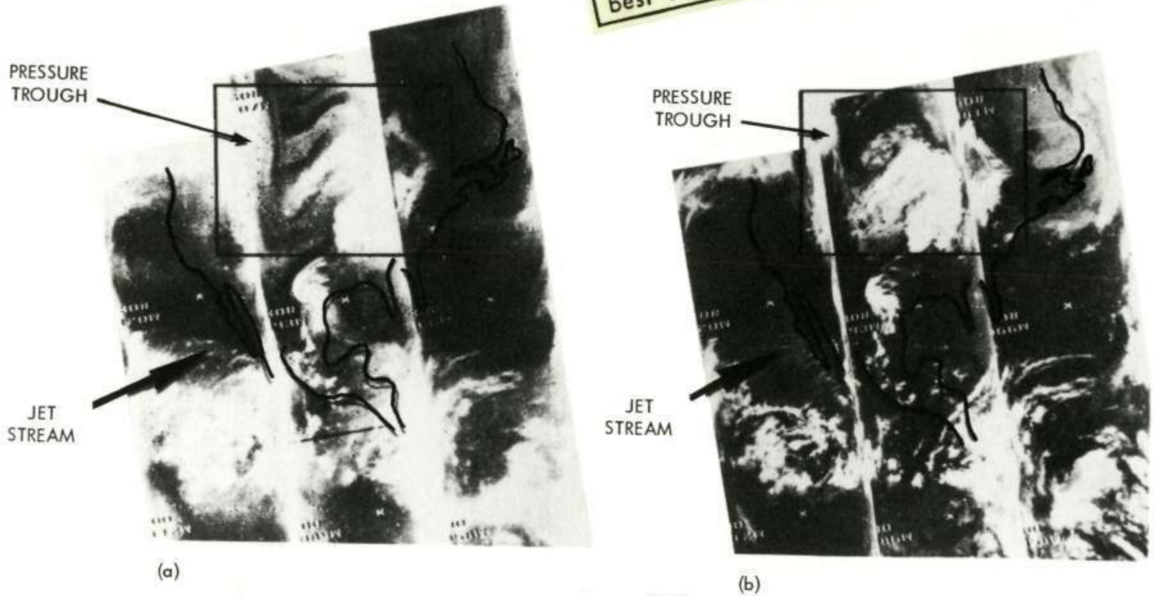

Figure 1–Imagery obtained from the Nimbus 4 THIR, May 14, 1970. (*a*) 6.7-μm wavelength observations. (*b*) 11.5-μm wavelength observations.

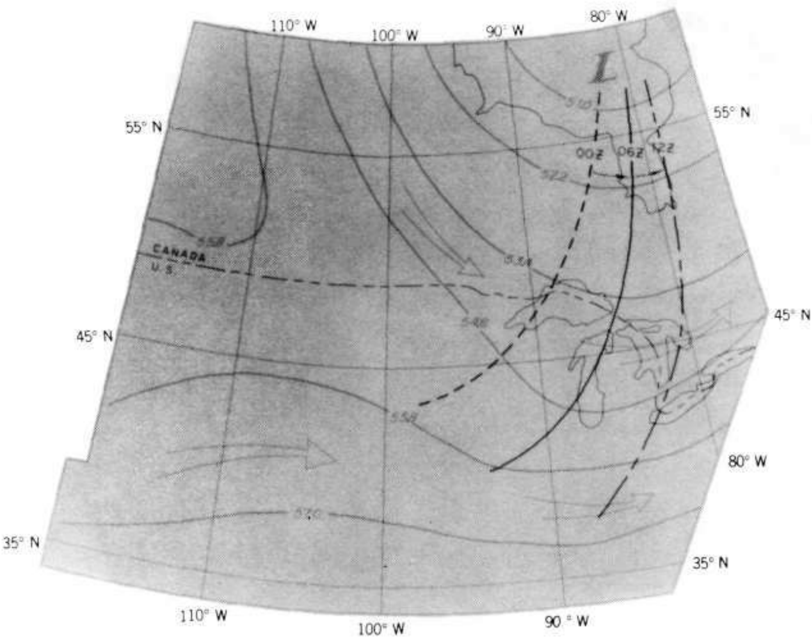

Figure 2–Motion of 50-kN-m^{-2} (500-mbar) flow at 0600 GMT, October 17, 1969.

All areas of sinking motion are within the area outlined with heavy black; are outside this area. The areas with more pronounced sinking or rising motions are in darker tones. Superimposed on the vertical motion field are the observed 20- to 23-μm brightness temperature patterns as represented by the 245, 251, and 258 K isotherms. One can easily note the general correspondence between the areas of sinking motion and the brightness temperatures greater than 251 K. In particular, note the correspondence between the area of maximum sinking motion and the 258 K isotherm. In the case of rising motions versus brightness temperature patterns, some ambiguity is introduced by clouds, and as a result the agreement is not quite so good. The same overall agreements shown in Figure 3 is also found in the 6.4- to 6.9-μm results when the fact that these observations occur at a higher level is taken into consideration. In conducting this research it has also been found that the radiometric observations of water vapor are very useful in providing more representative spatial detail in the analysis of point measurements of water vapor made by standard meteorological radiosonde networks.

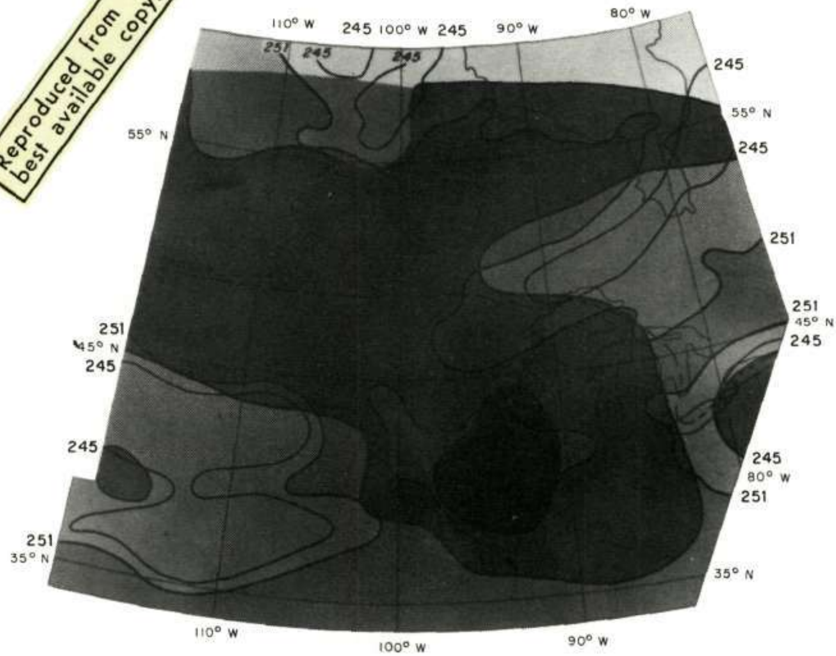

Figure 3–Vertical-motion results as interpolated to the satellite observation times of 0600 GMT.

In this study it is felt that quantitative verification has been provided that shows that Nimbus radiometric water vapor observations are reflecting important dynamic processes in the middle and upper troposphere and that these observations can be reliably used to delineate areas of vertical motion, particularly areas of strong subsidence or downward vertical motion. Certainly one can now proceed with a higher degree of confidence in applying these satellite observations to the study of weather systems in the tropics and large oceanic regions such as those in the Southern Hemisphere, where conventional meteorological data are sparse or nonexistent.

CHAIRMAN:

Are there any questions?

MEMBER OF THE AUDIENCE:

Why is it that one should expect warmer brightness temperatures with downward motion?

DR. SALOMONSON:

Observations made in the 6.4- to 6.9-μm and 20- to 23-μm spectral regions are sensitive to water vapor. When downward motion occurs, moisture at a given height is normally replaced by drier air and moved downward to a region of warmer atmospheric temperature. This causes the weighted mean associated with the observed brightness temperature of the two spectral regions to occur at a lower altitude and, as a result, to appear warmer.