Typhoon June Winds Estimated From Scanning Microwave Spectrometer Measurements at 55.45 GHz

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Microwave radiometric measurements in the 60-GHz oxygen band are considered, to infer atmospheric wind fields associated with tropical storms. On the basis of the thermal wind equation the radial derivative of brightness temperature is related to the vertically weighted tangential wind through a wind weighting function. The theory is tested in an analysis of Nimbus 6 scanning microwave spectrometer (Scams) 55.45-GHz data through typhoon June in November 1975. Scams-derived winds are obtained for 3 days throughout the storm area and are compared with 700-mbar aircraft reconnaissance winds. Major differences with the reconnaissance winds occur primarily near the storm center presumably owing to Scams' insufficient horizontal resolution. Also discussed are the errors due to upper level wind contributions and instrumental noise.

INTRODUCTION

Rosenkranz et al. [1978] used Nimbus 6 scanning microwave spectrometer (Scams) measurements to determine atmospheric temperature, water content, and sea surface winds through typhoon June. Combination of the data from the 22.23-GHz water vapor channel and the 31.65-GHz window channel enabled the determination of liquid water, water vapor, or sea surface winds under most conditions. However, two of the three Scams oxygen channels (52.85 and 53.85 GHz) that are generally used for sensing tropospheric temperatures could not readily be used in the typhoon because of liquid water attenuation in the lower channels. Only the highest-frequency channel (55.45 GHz) was unperturbed by precipitation and displayed the warm core temperature structure of the typhoon near 200 mbar (where the temperature weighting function peaks).

A technique was developed by *Kidder et al.* [1978] to estimate the central pressure and surface wind speeds outside the radius of maximum wind from the 55.45-GHz channel measurements for typhoon June as well as for less intense tropical storms during 1975. Surface pressure was estimated from the brightness temperature anomaly, using an empirical relationship. Surface wind speed was determined using the estimated surface pressure in conjunction with the gradient balance equation.

In the present study, measurements at 55.45 GHz over typhoon June are again considered but this time with respect to the atmospheric wind field. It is shown from the thermal wind equation that the radial derivative of brightness temperature can be related to the tangential wind through a 'wind weighting function' analogous to the more familiar temperature weighting function, which defines the contribution of temperature at different altitudes to brightness temperature measurements. For vertical profiles of tangential wind typical of tropical storms, the 55.45-GHz wind weighting function indicates a maximum contribution from the middle troposphere. On the basis of a theoretical wind relationship the radial derivatives of Scams 55.45-GHz brightness temperature are used to derive tangential winds for typhoon June on November 19, 21, and 23, 1975. Comparisons made with 700-mbar reconnaissance winds show reasonable agreement, with a major exception near the storm center. Here Scams has insufficient horizontal resolution to properly estimate the winds. Outside the central storm area the larger uncertainty due to upper level wind contributions and effects due to instrumental noise cause additional errors in the wind determination.

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Paper number 9C0465.
0148-0227/79/009C-0465$01.00

RELATIONSHIP BETWEEN BRIGHTNESS TEMPERATURE GRADIENT AND ATMOSPHERIC WIND

For steady state conditions and regions where frictional forces are negligible balance relationships exist between the motion and mass fields, which enable direct determination of wind components from temperature analysis, given proper boundary conditions. In the case of tropical storms, for certain regions the tangential winds can be computed from temperature data by using the equation

$$\frac{\partial}{\partial p}\left(\frac{v_\theta^2}{r} + f v_\theta\right) = -\frac{R}{p}\frac{\partial T}{\partial r} \qquad (1)$$

This expression is obtained from the radial momentum equation, where v_θ is the tangential velocity at pressure p and radial distance r from the storm center, T is atmospheric temperature, f is the Coriolis parameter, and R is the universal gas constant. The equation assumes steady state frictionless flow and neglects the contributions due to momentum advection and vertical flow, which are generally small in the middle troposphere. In a study of hurricane Hilda, *Hawkins and Rubsam* [1968] compared the tangential winds measured from aircraft with those computed from temperature analysis, using (1). The relationship was very accurate in the inflow layer but began to weaken as one goes from 900 to 500 mbar (i.e., half of the calculated values at 500 mbar differed between 10 and 20% from the observations). No comparisons were made above 500 mbar. In this study, the balance relationship is applied without modification and as such may produce doubtful results for regions where upper level wind contributions become appreciable. However, as shown later, there are more definitive sources of ambiguity restricting the following technique under this condition.

The brightness temperature T_B, measured by a remote sensor at frequencies at which the surface emission contribution