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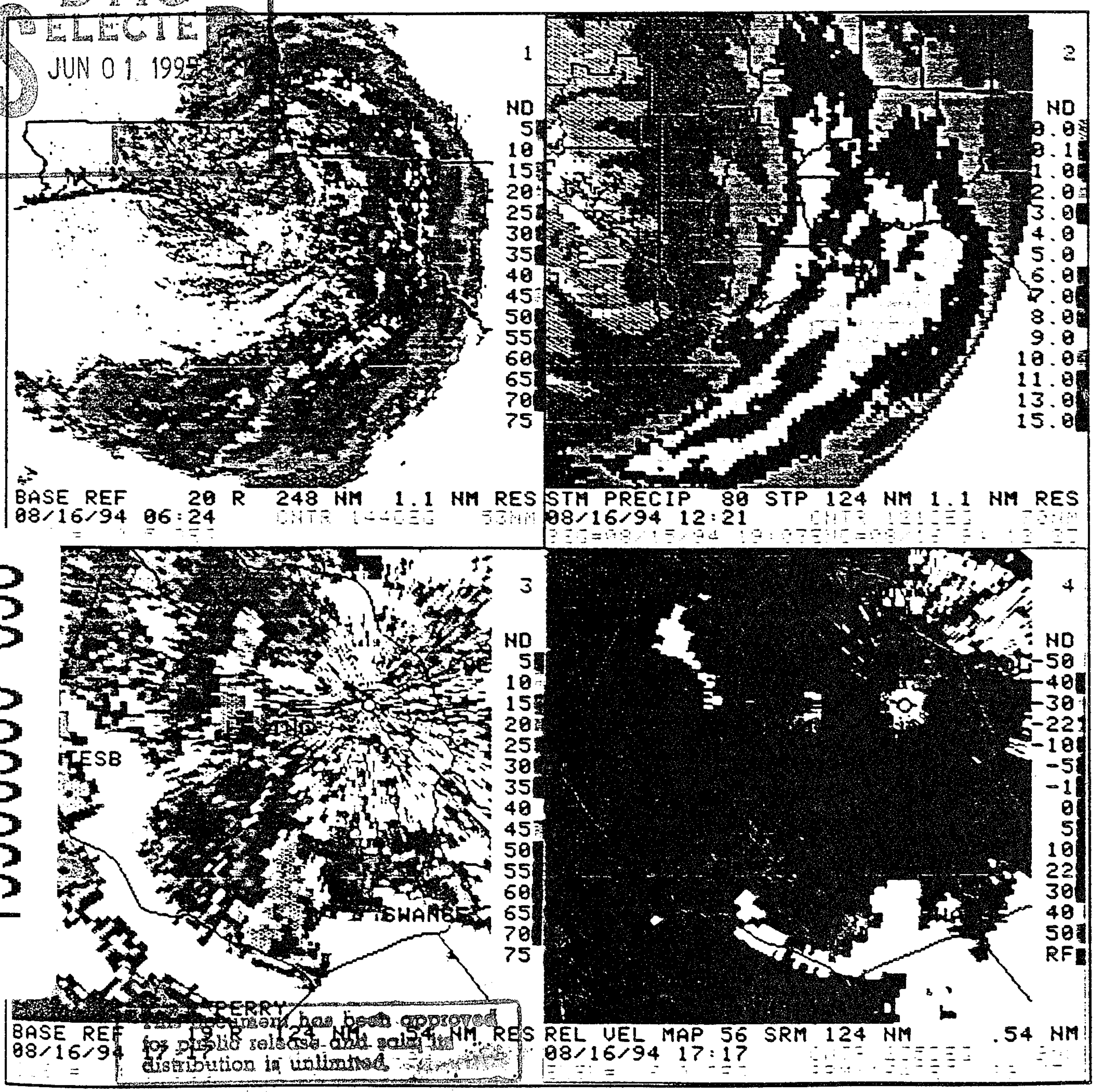

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TROPICAL CYCLONE INTENSITY AND STRUCTURE ESTIMATES VIA SATELLITE MULTI-SENSOR TECHNIQUES

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1. INTRODUCTION

A satellite multi-sensor approach is being evaluated to extract improved estimates of tropical cyclone intensity and storm structure. Forecast centers have operationally relied on intensity estimates derived from the Dvorak method (Dvorak, 1984) applied to visible and infrared imagery. This methodology has several shortcomings inherent with this type of imagery, such as when multiple cloud decks obscure the features required for accurate classification. Problems also arise when dealing with storms that rapidly change intensity, storms spun off of monsoon depressions, and midget typhoons. Thus, some type of "additional" data sources are needed to upgrade current capabilities, especially in the Pacific and Indian Ocean where aircraft reconnaissance is not available except in rare cases (e.g., when near Hawaii).

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2. REMOTE SENSING DATA SETS

Other data sets can be exploited in order to take the next step forward in improving satellite derived estimates of tropical cyclone structure and intensity. Sensors from both polar orbiters and geostationary platforms that have not been fully utilized due to a variety of reasons. The effort outlined here will include passive microwave data from the Special Sensor Microwave/Imager (SSM/I) on the Defense Meteorological Satellite Program (DMSP) polar orbiters, the Microwave Sounding

Unit (MSU) on the National Oceanic and Atmospheric Administration (NOAA) satellites, the microwave sounders on the DMSP spacecraft (SSM/T1 & T2), the scatterometer on the European Remote Sensing (ERS-1) polar orbiter and the water vapor channel from geostationary satellites.

Passive microwave data from the SSM/I has the potential to assist in depicting the storm's moisture and surface wind structure due to the multiple channels between 19 and 85 GHz. Many of these frequencies are largely unaffected by non-precipitating clouds and thus compliment the visible and infrared data that has been the mainstay of tropical cyclone monitoring. This data can be utilized by incorporating the brightness temperature (Tbs) images (e.g., 85 GHz due to its superior resolution of 12.5 km) or the derived geophysical parameters that include wind speed, rainrate, cloud liquid water and total precipitable water.

SSM/I surface winds can be used to detect the environmental winds that surround the main rain bands and storm center and thus assist in specifying the radius of gale force winds. Care must be taken to note the rain flags inherent in this data set and only use data whose quality has been determined to be of reasonable value. This data can be extremely valuable for warning messages, especially in detailing the asymmetries that often accompany tropical cyclones due to the synoptic conditions around the storm.

SSM/I derived total precipitable water, cloud liquid water and rainrate can also be used to provide the analyst with additional information about the storm structure and intensity. The amount and distribution of moisture can assist in locating the storm center when upper level clouds make use of visible and infrared imagery difficult for extracting storm locations.

Several investigators have also shown some correlation between SSM/I Tbs and rainrates over specific areas with storm intensities (Glass and Felde, 1989; Rao and MacArthur, 1994). Care must be taken when dealing with these quantities within the extremes encountered within the inner core of the storm. The relatively high correlations are likely due to the areal averages and not the SSM/I's ability to measure huge rainrates within the center regions (note: validation is sorely needed in many cases). Thus, our ongoing effort is geared to determine the limits for this data set.

The surface wind field can be augmented with scatterometer data from the ERS-1 satellite. The wind vectors from this microwave instrument will be demonstrated to provide significant detail concerning both the asymmetries in the wind field as well as the radius of gale force winds. The 500 km swath is the main limitation, but when available, this data set provides a wealth of information that can be used operationally to upgrade existing information on storm structure and intensity.

Sounding information can provide three-dimensional information on the structure of the temperature and moisture surrounding the storm. Velden, et. al., (1991) demonstrated that the warm, upper-level temperature anomaly depicted with MSU data is highly correlated with storm intensities as measured by aircraft validation. MSU derived errors are now near that of the Dvorak method. Similar techniques can be incorporated with SSM/T1 temperature data that would then effectively increase the number of measurements or "hits", from 1-2/day to 2-4/day. This method has the advantage of being totally automated.

Little work has been done using the SSM/T2 humidity profiler in a large scale systematic study. This effort will include this data set now that digital data sets are becoming available that cover a wide range of storms and environmental conditions. This type of water vapor information may provide a key ingredient to the overall task.

3. SUMMARY

Thus, no individual sensor method currently handles the range of conditions tropical cyclone analysts encounter operationally. This project is therefore geared to incorporate a multi-sensor approach that will endeavor to extract the inherent benefits of each sensor to provide a new estimate that is superior to the "singular" approaches used to date.

This project has acquired coincident infrared, and passive microwave imagery from the DMSP satellites for over 75 cases during the summer 1993 storm season and over 200 cases for 1994. Tropical systems ranging in strength from tropical depressions to super typhoons are included. The data set covers storms from the within the entire Pacific, Caribbean Sea, Gulf of Mexico and the Atlantic. Examples for each of the above data sets will be reviewed while highlighting the potential advantages and limitations with respect to the overall goal of upgrading remote sensing capabilities.

Acknowledgements

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