JP4.10 Normalized radar cross-section (NRCS) patterns from QuikSCAT-A new analysis tool over the tropical oceans

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1. INTRODUCTION

This paper examines meteorological features and surface wind patterns over the tropical oceans as depicted in high resolution Normalized Radar Cross-Section (NRCS) imagery. The NRCS are derived from the high resolution slice data obtained from the SeaWinds scatterometer onboard the QuikSCAT satellite. As is the case for all scatterometry data, the NRCS images are a reflection of the backscattered microwave energy from small centimeter length capillary waves on the ocean surface. In a process known as Bragg Scattering, this energy is highly correlated to the roughness of the ocean surface as determined by the instantaneous wind field. And similar to the wind data from scatterometer retrieval (Atlas, et al. 2000), the NRCS are also sensitive to large areas of rain and have little variation in the lower skill areas where the winds are either very light or very high. However unlike the more common 25 km resolution wind vector product, this imagery offers a view of the ocean surface at an estimated resolution of 6 km and has no dependency on either the ambiguity selection process or the initialization of any numerical weather prediction (NWP) model. This paper shows that although noisier than the processed wind vector data, meteorological patterns are readily visible in the imagery. In particular, the wind fields as seen in the NRCS images in the vicinity of tropical cyclones (TCs) are evaluated for their ease in depicting TC position and structure, as well as for their view of the surrounding tropical ocean environment. Used in conjunction with other meteorological data including the scatterometer-derived wind data, the NRCS can vastly improve the overall analysis over the tropical oceans.

2. THE NRCS IMAGE

The new, high resolution Normalized Radar Cross-Section (NRCS) product is a depiction of the normalized backscatter data signal (sigma-0) from the ocean surface taken from the forward looking (incident angle, i=52^{o}) vertically polarized Sea Winds sensor. This product was developed by the combined efforts of NOAA/NESDIS, the SeaWinds Science team at the Jet Propulsion Laboratory (JPL) and the BYU Microwave Earth Remote Sensing (MERS) Laboratory (Long 2000).

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The process takes advantage of the 'slice' data which are retrieved by the commandable variable range processor onboard QuikSCAT and which subdivides the original 25-km by 37-km microwave footprint into 2- to 10-km 'slices' (Perry 2000). The data are normally stored as part of the Level 2A SeaWinds data base at the JPL, Physical Oceanography Distribution Active Archive Center (PO.DAAC). The method used in this display, takes the near real time slice data and processes it through a smoothing routine which takes up to eight overlapping slices over a 3 km grid to create an image in dB of varying gray shades and with an effective resolution of 6 km. The NOAA/NESDIS TC Storm web page then remaps the data for display for each swath overpass of a TC. These images are generally available within 3 to 4 hours of the nodal time.

3. METEOROLOGICAL ANALYSIS WITH NRCS

The gray shades represent increasing degrees of surface roughness due to both wind and rain on the ocean surface as a function of the wave orientation and the sensor view. In particular, the higher (brighter) sigma-0 signals are easily distinguished from neighboring lower(darker) sigma-0 signals which generally correspond to a rougher surface caused by higher winds (and/or heavy rain). However, the variations in gray due to the directionally-dependent nature of the signal must also be taken in account. A schematic of the sinusoidal variation of the backscatter function is shown in Fig. 1.

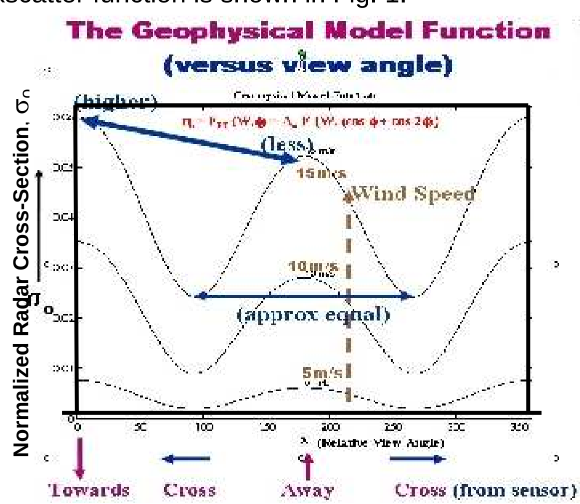


Fig. 1. Normalized radar cross-section versus relative view angle. Highest return is when the wave/wind orientation is towards (highest) or away (next highest) from the sensor (from Long, 2000).

Knowledge of this directional variation and the path of the spacecraft/sensor sub-track/scan geometry along the earth's surface allow the analyst to deduce the orientation of the wind field. This process is less difficult if the wind speed variation and the rain field orientation are known. Then changes in the gray field can be attributed to the wind field orientation. A comparison satellite image can also aid the analyst. Figure 2 provides an example of a NRCS image analysis over the northeast Pacific over Tropical Storm Alma (01E). In this case, the basic flow is understood, and so a more accurate TC position (especially in the east-west direction) is determined from the intersection of the two bright nodes and the dark band trough axis. The NRCS also allows for subtle refinement in the surrounding wind field by using cross-track (darker) and along-track (brighter) variation to correct adjoining flow in the ambiguities where the wind speeds and rain are almost equal.

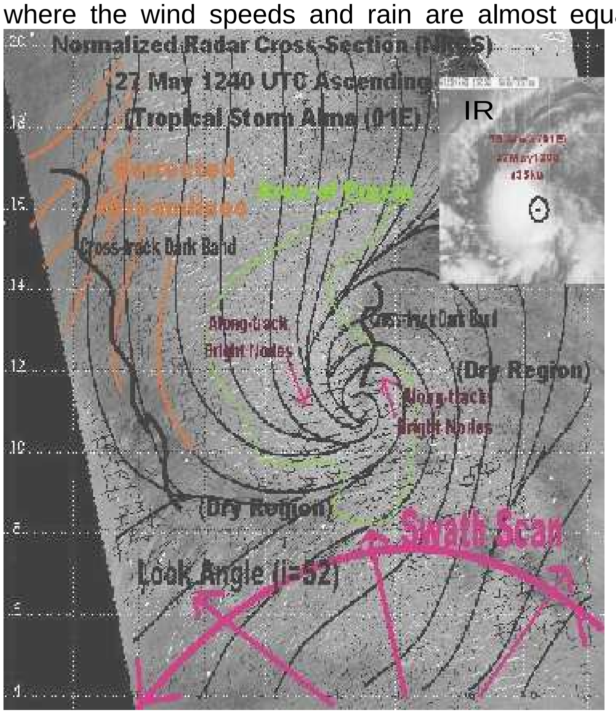


Fig 2. NRCS analysis for 27 May 2002, 1240 UTC. Note orientation of along-track bright nodes near the TC Alma's center, and cross-track dark bands. In upper left portion of the analysis, directions originally drawn with first guess from the ambiguities were corrected to fit the NRCS image.

3. EXAMPLES

a) Intense Tropical Cyclones

In this case there is rarely any confusion between the tropical cyclone's circulation and the environment because the heavy rain and winds coincide. The small 'dark' (low rain and low wind region) eye provides for very precise positioning of the TC . Here, the heavy rain pattern around the TC center looks similar to a microwave but often with a smaller central feature. In some cases other characteristics of the TC structure are seen such as concentric eyes or an asymmetric wind field (Figs. 3 and 4).

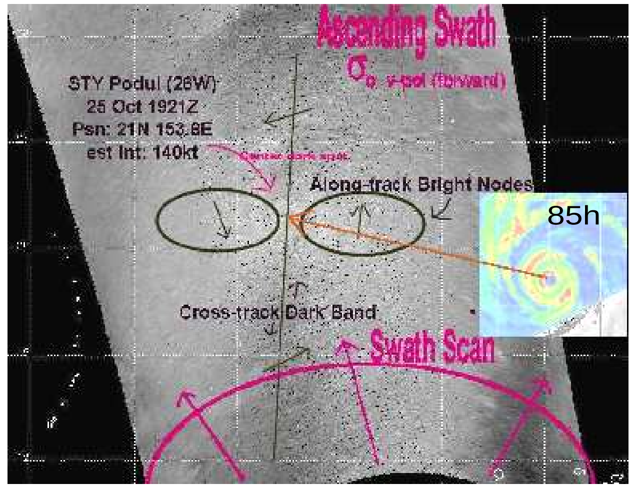
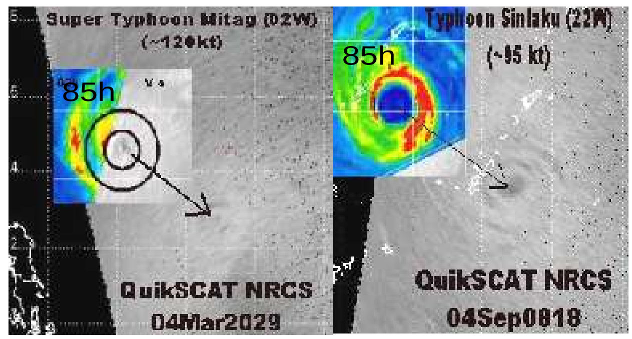


Fig. 3. Super Typhoon Podul (140kt).



a) b)

Fig. 4. NRCS views of (a) Super Typhoon Mitag and (b) Typhoon Sinlaku. In each case concentric eyes are evident. Center positions are precisely indicated due to the small calm and rain-free area.

b) Early Stages of TC Development

The clarity of the NRCS in these cases varies with the structure of both the developing TC and the synoptic environment that it is forming in. In most cases, the analyst needs to know the approximate location of where to look; however, it is possible to see the developing tropical depression at the earliest point of its existence. Even if a circulation center is not clearly evident in the scatterometer data, the axis of the light wind (and rain-free) trough often is visible in the NRCS. In addition, an enhanced wind (and rain) flow pattern is often apparent that develops asymmetrically along a portion of the trough. See Fig. 5 for an example of a complete analysis, including the use of the scatterometer ambiguities and a resulting overlay of the analyzed streamlines on to the visual imagery. One indicator of a developing system is the change in character of the trough (dark) region with each successive pass. As the TC develops, the dark trough region is seen to shrink and consolidate about its center. These images may also eventually provide guidance to show the features that are best indicative of future development in different types of environments (e.g. monsoon trough, TUTT related systems, waves in the easterlies…).

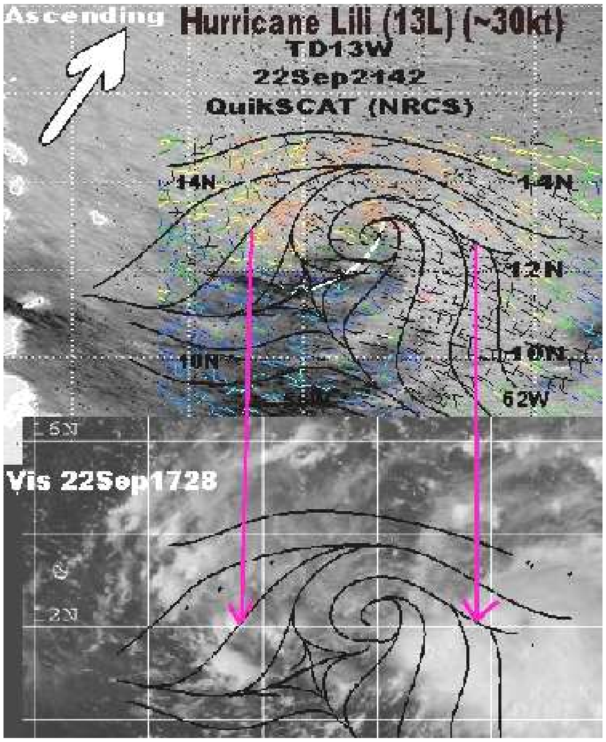


Fig. 5. NRCS analysis over the developing Hurricane Lili. Streamlines are performed with the help of the QuikSCAT winds and ambiguities and then overlayed onto a visual image.

b) Other Meteorological Features

1) Extratropical/Subtropical Systems

Although often evident from other types of remote sensing imagery, the NRCS offers a unique view of the wind field over a large area of the ocean where a need may exist for more precise positioning and character of a particular frontal system, trough, or ridge axis. A view of a vigorous subtropical low pressure area might, for instance, give an indication of a shrinking central light wind region as it transitions into a tropical cyclone.

2) Small scale features

The character of the 6km images offers a unique view of some small scale meteorological features that would most likely be missed, or not understood, in more conventional data. Such things as lee side lows and down slope and island features are readily observable in the NRCS imagery (Fig. 6). Although these features might also be available in high resolution visual imagery, NRCS images are available at times when the use of visual imagery is not possible.

4. DISCUSSION

The NRCS image offers a new and unique tool to analyze the winds on the ocean surface. The ability

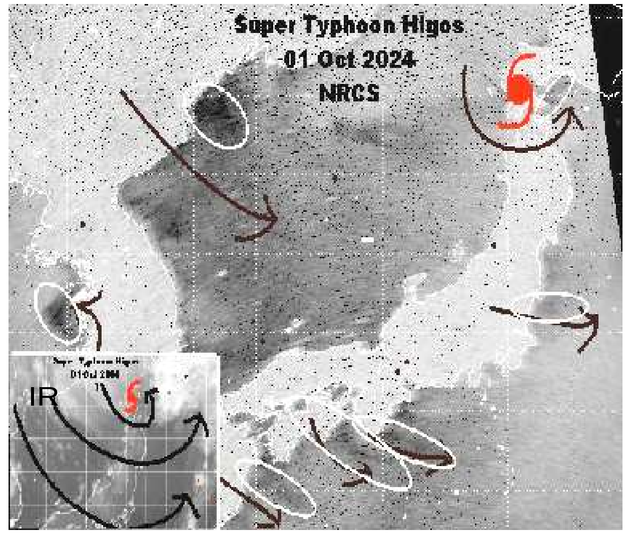


Fig. 6. NRCS view of Typhoon Higos over Japan. Local lee side calm regions are indicated in white. IR inset shows little cloud cover over area.

to see through obscuring wind and light rain conditions at high resolution makes it a desirable supplement to the meteorological forecaster's repertoire. Although the NRCS image can be more difficult to interpret than a standard microwave image, with practice, both small- and large-scale wind and rain patterns are readily discernable. In many cases it is necessary to use these data in conjunction with other conventional data to either aid or focus the analysis. However, as these data are looked at and understood, the authors believe that there are many more uses to be developed. For example, an automated pattern recognition process could help in the ambiguity selection of scatterometer winds; thus, improve the use of scatterometer data in both the daily NWP analysis and in TC positioning techniques.

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