MULTI-SATELLITE OBSERVATION OF MEGH CYCLONE

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ABSTRACT:

Cyclone Megh, a category-3 (Saffir-Simpson scale) cyclonic storm is regarded as the worst tropical cyclone to ever strike Yemen's island of Socotra. In this paper, we aim to investigate the wind structure of cyclone Megh using Synthetic Aperture Radar (RISAT-1 SAR) observations. An algorithm for the cyclone wind retrieval has been applied for SAR data of Nov 8, 2015 at 0238:09 UTC in the Arabian Sea. The intensity of cyclone is 30 m/s with the 16.65 km radius of maximum wind speed from the centre of the cyclone. The high resolution SAR data analysis bring to focus the possible presence of eyewall mesovortex in case of Megh. Recent work has shown that vorticity mixing in the tropical cyclone (TC) inner core can promote mesovortex (MV) formation and impact storm intensity. This has further been corroborated using INSAT-3D and MODIS optical band observations of clouds. Analysis of these satellite derived cloud microphysical properties shows the presence of larger hydrometeors surrounding the eye due to possible embedding of stratus and stratocumulus cloud decks. Thus, this kind of study helps in understanding the microphysical processes within a TC as well estimating their impacts on cyclone intensity and lifetime.

1. INTRODUCTION

Satellite remote sensing of wind speed via multi-sensors, such as scatterometers, radiometers, and synthetic aperture radar (SAR), has contributed accuracy to weather forecasts. The superior high spatial resolution of SAR is unique for mesoscale wind speed monitoring in coastal areas. Recently, C-band cross-polarized ocean backscatter has been documented as being insensitive to the wind direction or the radar incidence angle, and quite linear with respect to the wind speed, and thus can be used to directly retrieve wind speeds (Zhang et. al, 2011). An empirical C-band Cross Polarization (C-2P) backscatter model was developed to retrieve high resolution ocean surface wind speed from RISAT-1 SAR data, which eliminates the need for radar incidence angle inputs and provides a linear response at high wind speeds for tropical cyclones (Jagdish et. al, 2018a).

It is also interesting to examine the cloud microphysical structure within a TC. Different types of cloud systems are present within different regions of a cyclone and consequently different microphysical processes occur spatially throughout the TC extent. The eye is the region of low level clouds whereas eyewall and rainbands consist mostly of deep convective clouds (Houze, 2014). Studies have revealed that slight precipitation is associated with the eye and its diameter is related to the TC intensity (Franklin, 1988 and Lander,1999). In contrast, the eyewall and rainbands are regions of heavier precipitation (Cecil et. al, 2002). Moreover, the phase and spatial distribution of cloud and precipitation particles above the 0^0 C isotherms in three Atlantic hurricanes has been analysed through aircraft observations and it was found that ice particles were present largely in convective and stratiform areas of the storm (Black et al, 1986). In addition to observational analyses, model simulations have shown differences in size distributions in different regions of TC (Farquhar et. al, 2004). A proper understanding of different microphysical processes during cyclone events is still required. Thus, to a large extent this could be achieved by examining satellite derived cloud microphysical parameters (CMPs). Since satellite observations offer the advantage of global coverage of events, it is possible to analyse and understand the cloud microphysical characteristics of different synoptic scale events. Thus, in this regard, two main CMPs such as cloud optical thickness (COT) and cloud effective radius (CER) of TC Megh using observations from two satellite sensors are examined in this study.

TC Megh was an extremely severe cyclone that formed in the Arabian Sea on 5 November, 2015 and weakened on 10 November, 2015 after making landfall at Somalia and Socotra. It was a category-3 cyclone on Saphir Simpson scale. The 1-minute maximum sustained wind speed was 205 km/hr and 3-minute wind speed was 175 km/hr.

2. DATA AND METHODOLOGY

RISAT-1 has come up with a potential to monitor vegetation, coastal and Cryosphere. It is designed to image the Earth's surface in different modes i.e., HRS (High Resolution SPOTLIGHT), FRS-1(Fine Resolution STRIPMAP), FRS-2 (Fine Resolution Alternate Polarization STRIPMAP), MRS (Medium Resolution SCANSAR) and CRS (Coarse Resolution SCANSAR) of swath widths ranging from 30 to

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240 km (Jagdish et. al, 2018b).The Key datum for this study are RISAT-1SAR data. SAR image used in this study, is processed at Space Applications Centre, ISRO. The image is georeferenced CRS ScanSAR products with a pixel spacing of 36 m (range) × 36 m (azimuth). RISAT-1 provides vertical-transmit and vertical-receive (VV polarization) data. The

Table 1. Basic Megh cyclone information derived from RISAT-1 SAR.

Date	Time (UTC)	TC Location	Centre Lat	Centre Lon	Category	V_{max}	Pressure	Shape Of eye	Area Of eye	SAR
08-11- 2015	0238	Arabian Sea	12.42	55.38	3	30 m/s	964 hPa	Elliptic	871 sq.km	RISAT-1

spatial resolution and swath of a CRS image are 25 m and 223 km, respectively. The image is acquired during November 8, 2015 at 0238:09 UTC in the Arabian Sea near Socotra Island. The detailed methodology of retrieving tropical cyclone wind can be found in (Jagdish et. al, 2018a). The detailed information about cyclone Megh can be review in Table 1.

INSAT-3D derived CER and COT have been used in the present work. They are estimated from shortwave infrared (SWIR) and visible channels of INSAT-3D imager at 4 km spatial resolution. The retrieval is based on a look-up-table (LUT) approach (John et. al, 2016). The physical basis of their retrieval is that the reflectance in the visible region is mainly a function of cloud optical thicknesses and the reflectance in the SWIR region is primarily a function of cloud effective radius. Moreover, Moderate Resolution Imaging Spectro-radiometer (MODIS) data has been also used. MODIS is a 36 band spectroradiometer on board Aqua/Terra platforms. It provides data products at 250m, 500 m and 1000m spatial resolutions. For the present work, CER derived at 1 km spatial resolution has been used. Using both datasets, the spatial distribution of CMPs has been investigated. This has been done by extracting COT and CER acquired during November 8, 2015 at 0600 UTC of INSAT-3D. Further, using MODIS granule acquired at 0735 UTC of November 8, 2015, a transect passing through the centre of TC has been extracted. The variation of CER along this transect has been examined.

3. RESULTS AND DISCUSSION

Fig 1a shows the NRCS retrieved from RISAT-1 SAR. Fig. 1b shows the wind speed retrieved from the RISAT-1. NRCS values are converted to wind speed using developed GMF, C2P at Space Applications Centre (SAC). The intensity and radius of maximum wind speed from centre of the cyclone were found 30 m/s and 16.65 km, respectively. Fig. 2a and 2b show the transect plot of wind speed passing through the centre of cyclone along longitude and latitude. It can be clearly seen in Fig 2, there are two minima followed by a maxima in the eyewall. The observed maxima in eyewall is designated as the mesovortex.

Interestingly, however, the dynamics behind mesovortex generation remains an open research problem. Note that the relationship between mesovortices, damaging winds, and tornadoes has been reviewed. With one exception [Wakimoto et. al, 2006], studies of mesovortex-genesis have been based upon numerically simulated convective systems. Several distinct conceptual models have emerged for mesovortex formation [Schenkman and Xue, 2016].

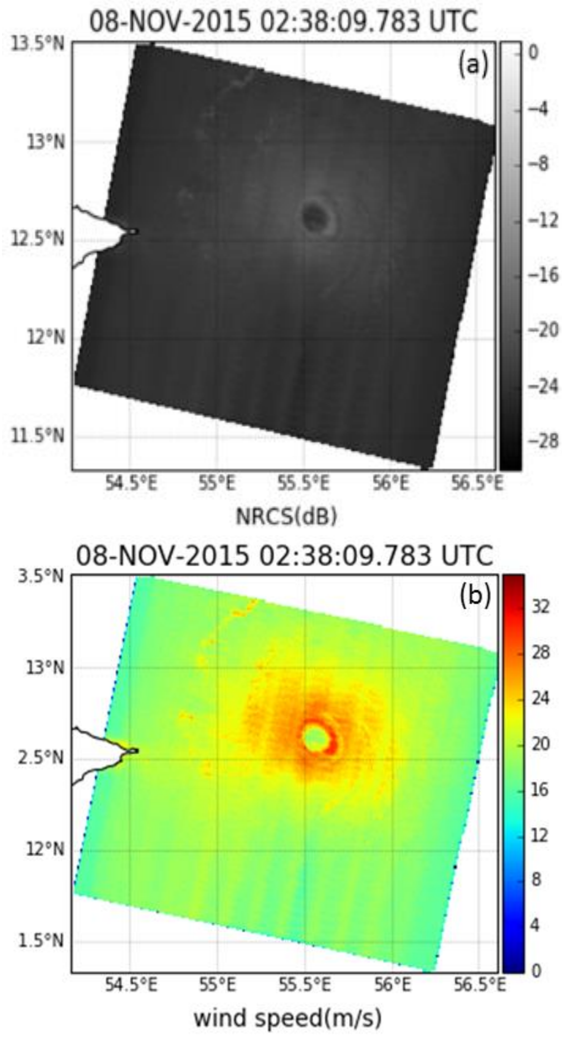

Figure 1. RISAT-1 retrieved NRCS (a) and wind speed (b).

Fig 3(a-b) displays the CER and COT derived from INSAT-3D. It is observed that the microphysical variability is significant along the different regions of TC. COT in the eye is low as compared to its surrounding area i.e. the eyewall, which indicates the presence of relatively optically thin clouds. The eye is not devoid of any clouds which are further confirmed by noticing the existence of hydrometeors of appreciable size within it. The droplet sizes lie around the range of 30 microns (Fig. 3a) and COT lie around 40 (Fig. 3b).

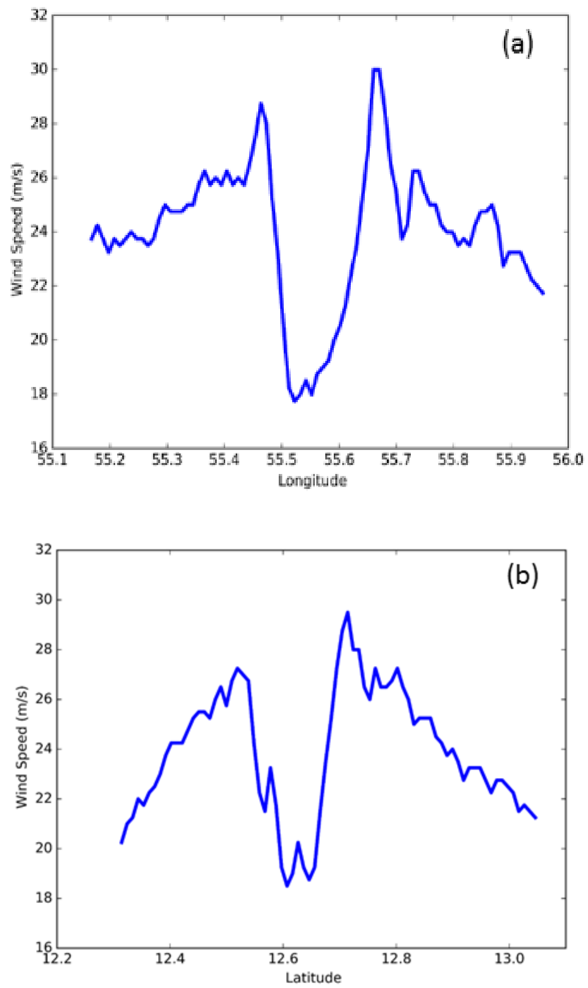

Figure 2. Variation of wind speed along a transect passing through the centre of the cyclone eye. (a) Along longitude and (b) Along latitude.

It is further noticed that larger hydrometeors as well as optically thick clouds are present in the region surrounding the eye. This indicates the area of deep convection where continuous and strong updrafts dominate resulting in bigger and heavier cloud droplets. Fig. 4 shows the CER distribution along the transect passing through the centre of the cyclone for 08 November, 2015 0735 UTC. It is observed that CER in the centre especially near the eye is in the range of 25-30 microns indicating the presence of low level stratocumulus clouds in the eye. The uniqueness of this study is observation of similar variation of cloud effective radius and wind speed in the cyclone transect.

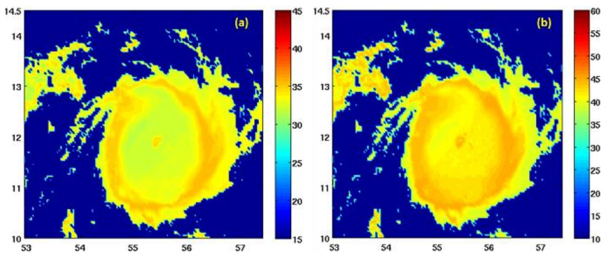

Figure 3. Spatial distribution of CMPs within the TC for 08 November 2015 0600 UTC derived from INSAT-3D. (a) CER and (b) COT.

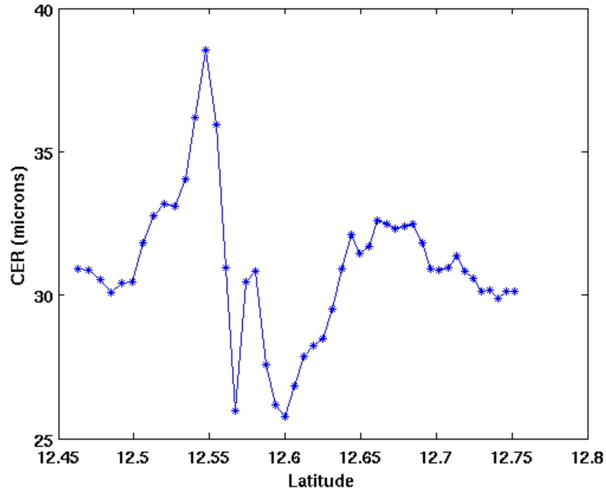

Figure 4. Distribution of MODIS derived CER along transect through the centre of the cyclone for 08 November 2015, 0735 UTC.

4. CONCLUSIONS

Multi-satellite optical and microwave observations of cyclone help us in understanding the complex processes taking place inside a cyclone.In this manuscript, Cyclone Megh has been analysed using synergistic observations from RISAT-1 SAR, MODIS and INSAT-3D data. The intensity of cyclone is 30 m/s with the 16.65 km radius of maximum wind speed from the centre of the cyclone. It is observed that CER in the centre especially near the eye is in the range of 25-30 microns indicating the presence of low level stratocumulus clouds in the eye region. The spatial examination also brings out the existence of low-level clouds surrounding the eye. This confirms the observations made by SAR focusing the possible presence of eyewall mesovortex in case of Megh. This kind of study will be very helpful in order to understand the microphysical processes within a TC as well as serve as inputs in numerical models for cloud radiative parameterization.

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