Snow Density retrieval using Hybrid Polarimetric Spaceborne SAR data

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ABSTRACT: Snow cover is important for global climate system. In regulating the global temperature snow cover plays a significant role. After the snow melts, snow converts in water and is a source for river and reservoirs. Hence proper monitoring of the snow covered areas is required. Snow parameters like snow density, snow depth and snow water equivalent are able to provide proper information about snow pack. This study is focused on retrieval of snow density parameter using hybrid Polarimetric technique. Previous studies for snow density retrieval have utilized the linearly polarized dual and quad pol datasets (Shi & Dozier, 2000; Thakur et al., 2013). Here, utilizing the hybrid polarimetric RISAT-1 dataset, the snow density parameter is retrieved. The datasets were acquired for the date 24-Feb-2014 in FRS-1 mode. The snow density was retrieved utilizing the theoretical and the modeled parameters. The Integral equation model (IEM) is implemented in this study. IEM model uses the Fresnel reflection coefficients which is the function of local incidence angle and the dielectric constant of the of the snow pack. The output snow density variation was ranged from the 0.05g/cc to 0.50g/cc.

1. INTRODUCTION

Snow is an important parameter which effects the global climate and is the source of fresh water for rivers originating from mountains. Hence for the hydrological modeling, proper management of the water runoff in the rivers and climate change assessment the role of snow cover is quite significant. Snow density is an essential parameter which gives the measure about amount of snow per unit volume. Snow density along with snow depth is successful in giving the information of total snow water equivalent. Hence continues retrieval of these snow parameters is important. The manual monitoring of these snow parameters throughout the year is very difficult and exorbitant because of the obscure and harsh conditions occurs in the snow covered areas situated in the higher altitude regions most of the time of year. Hence, Satellite remote sensing can used be for the uninterrupted monitoring can be used as a tool for the retrieval of various snow parameters. Researchers have used different optical and microwave remote sensing techniques for better estimation of the snow parameters(Carsey, 1992; Hall, Frei, & Déry, 2014; Lafaysse et al., 2017; Perovich, Polashenski, Arntsen, & Stwertka, 2017; Rees, 2006; Warren, 1982; Warren & Brandt, 2008). SAR remote sensing using the active sensor gives the privilege of operating day/night even in haze and cloud covered region. Other advantage of using microwave SAR sensor is that microwave penetrates inside the snow and is effected by the dielectric properties of the snow. This property of the microwave is immensely utilized for the snow parameter extraction as most of the snow parameters are correlated with the dielectric properties of the snow (Dozier, Shi, & Dozier, 2000; Leinss, Parrella, & Hajnsek, 2014; Thakur et al., 2013).

In this paper the new technique for snow density estimation has been introduced. Here, the hybrid polarimetric circularly polarized datasets has been utilized for the snow density retrieval. These datasets has the privilege of roll invariant property hence for better accuracy of the snow parameter specially snow density these datasets are used. This approach has used the compact decomposition technique and the IEM model for the snow density retrieval.

2. STUDY AREA AND DATASETS USED

2.1 Study Area

The study area is situated in the North-Western Himalayas covered with the snow and glacier covered areas in of Dhundi region of Manali district in Himachal Pradesh. The areas come under the bias river basin. The total area of 350.21 Km2 has been selected covering Manali area in the bias basin. The Automatic Weather station at ground Stations of SASE (Snow and Avalanche Study Establishment), DRDO and IIRS, ISRO are installed at Dhundi region of Manali District. Dhundi region is endowed with great natural beauty and have rich assemblage of fauna and flora. The area is characterized by subtropical pine forest, subalpine and alpine forest.

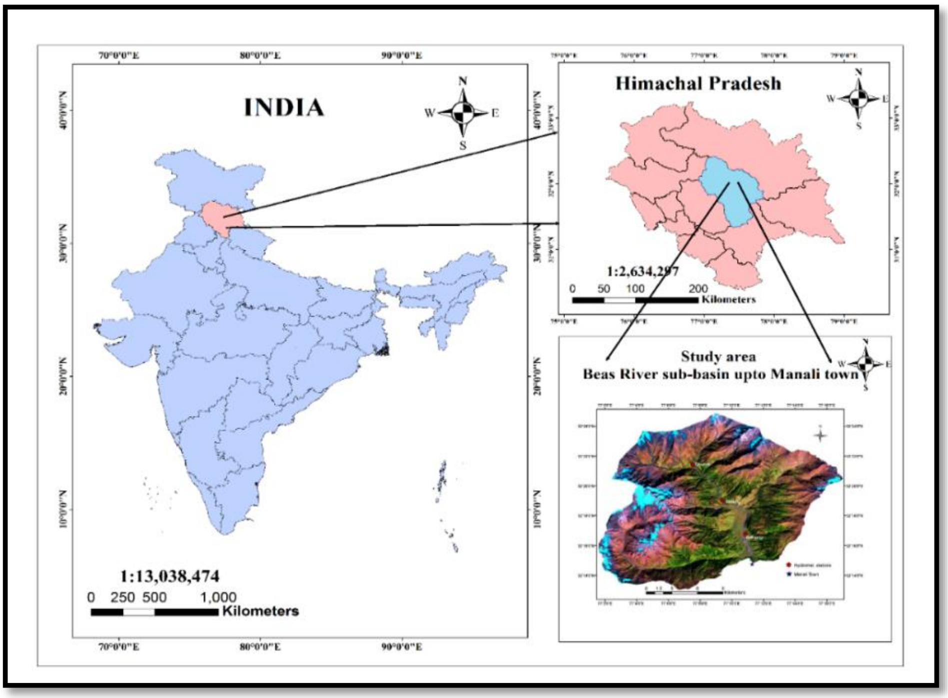

Figure 1-Study Area

1.1 Datasets Used

The RISAT-1 hybrid dataset the date 24-Feb-2015 was used in this study. The dataset specifications has been mentioned in the table-1 below.

Sensor Specifications	Data-1
Satellite-Sensor	RISAT-1
Date of Acquisition	24-Feb-2014
Wavelength	5.3 cm
Frequency Band	C - Band
Mode of Acquisition	Strip-map mode
Polarization	Hybrid-pol
Spatial Resolution (Rg x Az)	3.3m x 2.3m
Orbit Direction	Ascending
Slant range Distance	636918.8848 m
Mean Incidence Angle	37.685 degrees
Centre Latitude	32.251 degrees
Centre Longitude	77. 255 degrees

Table 1-Data Specifications

2. METHODOLOGY

The detailed methodology for the snow density retrieval is shown in this section. The fig.-2 shows the methodology flow diagram for the snow density retrieval. The modeled and theoretical polarimetric scattering angle alpha parameter. These parameters are independent of the surface roughness. The theoretical polarimetric scattering angle parameter alpha is calculated using the hybrid decomposition technique (Raney, 2007). The Integral equation modeling (IEM) approach is applied for the estimation of modelled scattering angle parameters. The Fresnel transmission coefficient is calculated during the model implementation which is the function of local refractance angle and dielectric constant of the snow pack. The comparative analysis is made to retrieve the snow pack dielectric constant. The looyenga's semi-empirical modeling approach (Looyenga, 1965) is applied for the retrieval of snow density of snow pack.

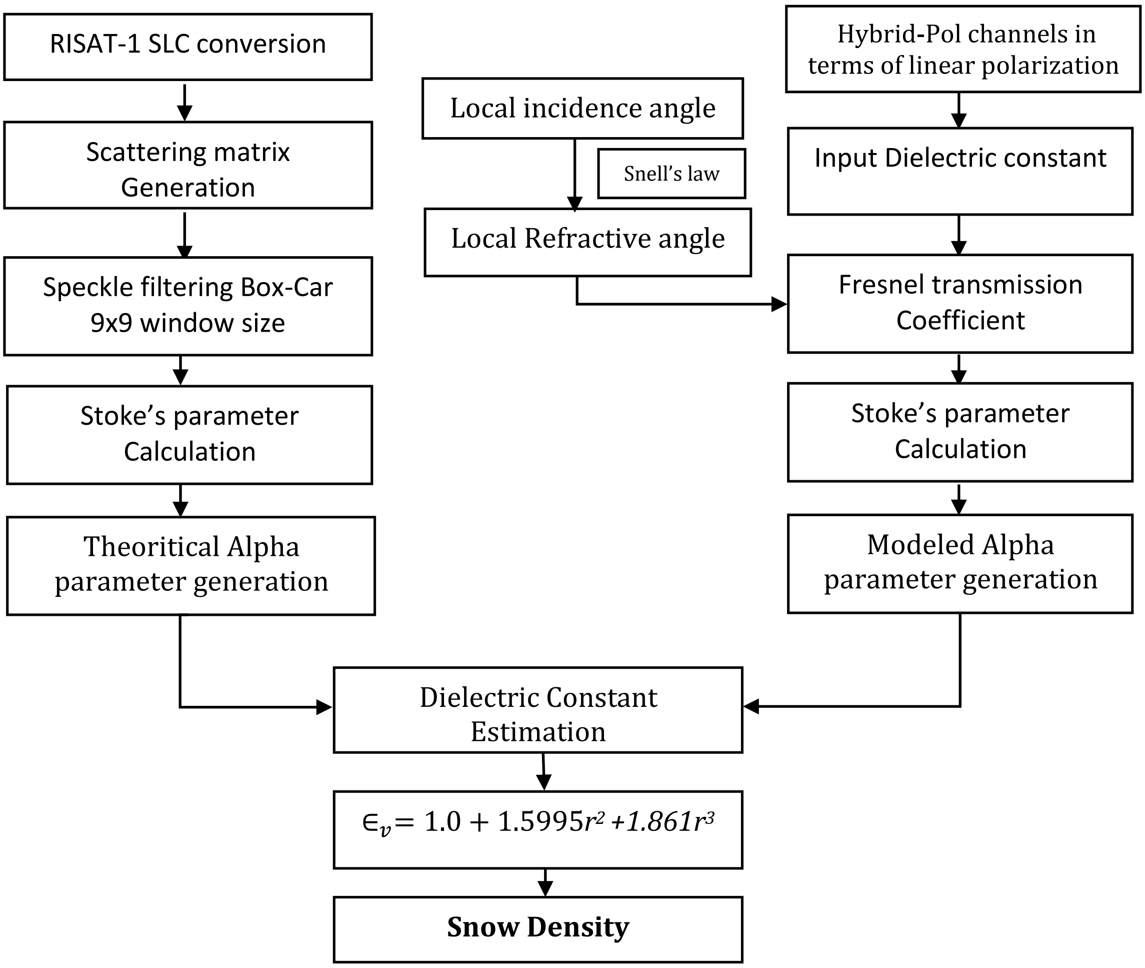

Figure 2-Methodology flowchart

3. RESULTS

3.1 Snow Density Retrieval

The snow density is retrieved using the Dielectric constant of the snow pack, the snow density was derived with the semi-empirical relation given by looyanga's (Looyenga, 1965). Fig-3 shows the snow density map was generated for the areas. The snow density of the snow pack is estimated and the range of the snow density was 0.01g/cm^3 to 0.5g/cm^3. The fresh snow density falls in the range 0.04g/cm^3 to 0.2 g/cm^3 (Parrella, 2015; Thakur et al., 2012). The mean was coming 0.289g/cm^3. For the fresh snow the value of the snow density is less. The snow density upsurges with the compactness of the snow. The snow particles settle and become compact and densified. As the snow density increases the corresponding dielectric constant also increases. This property is utilized using microwave remote sensing for the snow density retrieval.

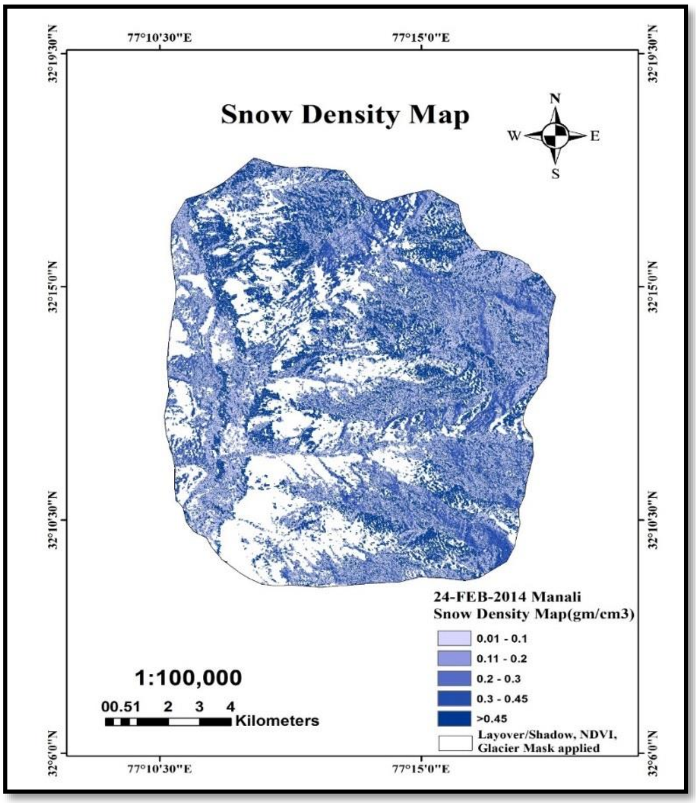

Figure 3-Snow Density Map for study area

3.2 Snow Density Accuracy assessment

The improved IEM based Snow Density retrieval approach using hybrid polarimetric RISAT-1 SAR gives a good correlation between the retrieved and the ground datasets. The ground validation of this technique was done using the data from the previous work of co-author (Thakur et al., 2016). Figure 4 shows the value of R^2 was 0.816 and a trend line of y=0.94x was observed during the statistical analysis. The hybrid polarized datasets has the advantage of least orientation angle shift leading to a greater accuracy compaired to the linearly polarized datasets especially applying in the hilly terrain area. Hence attaining a high accuracy during the accusation

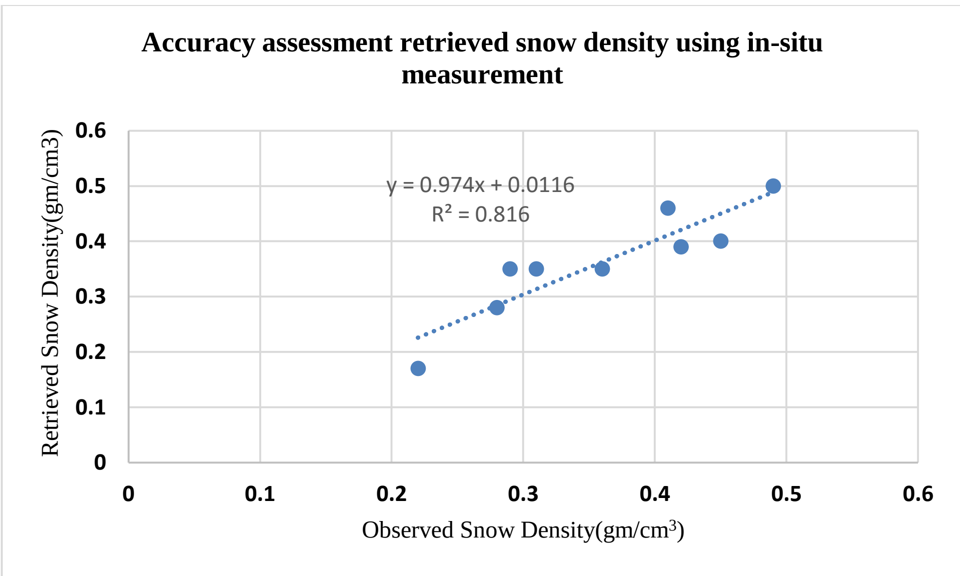

Figure 4-Accuracy assessment retrieved snow density

4 CONCLUSION

Hence this modeling approach was able to retrieve the snow density parameter with a high accuracy. The roll invariant property of the hybrid circularly polarized datasets were utilized for attaining high accuracy. This creates the scope for the retrieval of other snow parameters like snow wetness utilizing the advantages and benefits of this particular datasets.

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