Month-to-Month Variability of the Melting Layer Boundaries

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Abstract - The Bright-band is the typical enhancement in radar reflectivity during the melting process, which is still not completely determined. The seasonal variation over the year can give the characteristics that are valuable for designing and planning of a satellite link. The Malaysian Meteorological radar data, from Kluang Radar Station (Johor), is used to trace the signature of the melting layer during stratiform precipitations events. The trends of the boundaries of the melting layer were studied by considering data extended to cover a six-month period (January –June 1998). It was observed that the boundaries and the thickness of the melting layer are found to be seasonally dependent.

Keywords: Seasonal Variation; Meteorological Radar Data; Melting Layer; Bright-Band Heights.

1. Introduction

Knowledge of the extent and occurrence of periods when high and low attenuation is most likely to occur along slant path links during a typical day is important when planning the design, and use of, future slant path communication systems for satellite links. This is particularly true for those operating at frequencies above 10GHz, as they are often degraded by the hydrometers such as rain, hail, cloud and melting layer [1],[2], which can cause several problems, such as signal fading, depolarization and co-channel interference due to scattering. In particular, tropical regions have posed extra difficulties in predicting attenuation due to the lack of understanding of tropical precipitation and climate such as rainfall intensity and rainfall heights, and the variation of climate and its effect. Italian satellite ITALSAT F1 [3], which has a receiving ground station in the South of England, has been monitoring and measuring signals from beacons at frequencies near to 20, 40 and 50 GHz. Statistical analysis of one year measured slant path propagation characteristics at 20 and 40 GHz in Southern England; has shown the emphasis on the seasonal and diurnal variations of the attenuation statistics. The results presented will be of use to system planners who are seeking to make optimal use of low link margin satellite communication systems that incorporate EHF transmissions [3].

As mentioned before, tropical regions posed extra difficulties in predicting attenuation due to the lack of understanding of tropical precipitation and climate such as rainfall intensity and rainfall heights [4]. To explore this precipitation, direct measurement approach had been used, but due to the cost and time to collect statistically meaningful data and the difficulty to extrapolate the results to other sites, indirect measurement approaches are proposed. The radar, which is one of the instruments that is used to evaluate precipitation and climate, is well suited because of its inherent spatial resolution. The enhancement in radar reflectivity, which is the ability of radar target to return energy, caused by melting snowflakes below the 0°C isotherm is known as the "bright-band". This is due to changes in size, fall speed and phase during the melting process. If this region is not recognized, the variation over the year can lead to significant overestimation of precipitation reaching the ground, sometimes by as much as a factor of 5 [5].

2. Radar Specification and Data Description

The meteorological radar data was taken from Kluang Radar Station, which belongs to the Meteorological Department of Malaysia. This system utilizes the 3D RAPIC system that was developed by the Australian Meteorological Bureau. The specification of the Kluang Radar Station is shown in Table 1[6]. The duration of the meteorological data is 116 days covers the period from 2nd January to 18th July 1998, using two modes of scans, plan position indicator (PPI) and range height indicator (RHI). For PPI scan there are 15 volumetric elevation angles, 0.5°, 1.2°, 1.9°, 2.7°, 3.5°, 4.6°, 6.0°, 7.5°, 9.2°, 11.0°, 13.0°, 16.0°, 20.0°, 25.0°, and 32.0°, are used to build the vertical reflectivity profile (VRP). However, the radar image of each of these angles is recorded through the full RHI's scan range (360°). These scans have been made every thirty minutes during the first eight days (2nd –9th January 1998) and every ten minutes for the rest intervals, with a resolution range 500m. These data contains 285,231 encoded radar images (1.26 GB on disk) in the encoded text format.

Table 1: Radar Specifications

Meteorological Radar MR 781 S Kajicuaca, Kluang With RAPIC Transmitter EH663 v.8.00	
Station ID	3
Station Position	Latitude: 2.02°, Longitude: 103.320°, Height: 88.1m above MSL
Reflector	12 Feet parabolic (3.66m)
Frequency	2800 MHz
Polarization	Vertical
Gain	38 dB
Coverage	Elevation: -2° to +90°, Azimuth: 360°
Beam width	2.0°
Pulse duration	2.2μs
PRF	278 pps
Peak power	389 kW
STC range	230 km

3. Methodology

To trace the signature of the melting layer, many procedures have been developed. These scenarios include sorting out, filtering, decoding the meteorological data and building the vertical profile of radar reflectivity. From the plotted curve the melting layer is traced during the occurrences of the stratiform events. The classification of the rain event is evaluated according to the minimum amount of the rain rate that the radar can be sensed and confirmed by using the widely accepted empirical relationship of the radar reflectivity factor Z, and rainfall rate **R** that is given by $\mathbf{Z = a\ R^b}$ mm^6/m^3, (**R** in mmn/hr) where the most common values for ***a*** and ***b*** are 200 and 1.6, respectively. These are also the values used by the radar operator of the Malaysian Meteorological Department of Malaysia [6]. Then the average threshold of the reflectivity for the expected rain event is setup to 17 dBZ, which coincides with the threshold that is using for event classification for the TRMM radar data by applying the routine algorithm 2A23 [7].

However, to extract the heights of the melting layer from the detected signature, an algorithm that is based on the obtained vertical profile of reflectivity have been developed. This algorithm is based on that the height of the melting layer (BB_H) can be determined by the height of the maximum reflectivity in the vertical profile curve, which is a unique value. Also the height of the zero degree Celsius isotherm (h_0) and the rain height are evaluated by determining the height of the transition points from the ice region to the area of melting process and from this area to the rain region, respectively. By taking the advantage of the noticeable enhancement in radar reflectivity during the transition between the ice-melting and rain-melting regions, a minimum slope technique is used to trace the transition points and then to determine its corresponding height. The thickness of the melting layer (BB_{th}) is evaluated by calculating the difference between the 0°C isotherm height (h_0) and the rain height (h_R) as in [8]. However, following these study we has found the variation in the height and melting layer height has been affected to seasonal variation, which is revealed in the next section.

4. Results and Discussion

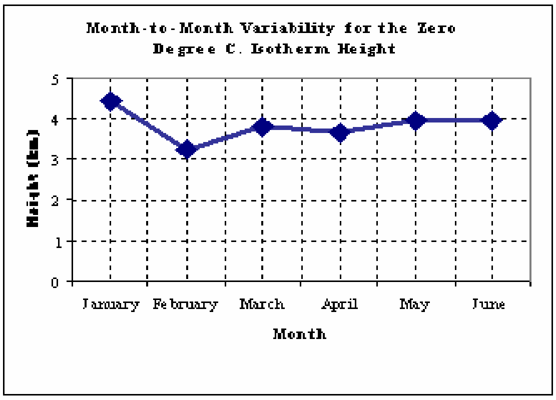
4.1 Month-to-Month Variability

The data utilized are distributed over 6 months, from 2nd January to 18th June 1998. By using the methodology described in the previous section, the trends of the boundaries of the melting layer are studied. As revealed by Table 4 and Figure 8, the boundaries and the thickness of the melting layer give a seasonal dependency.

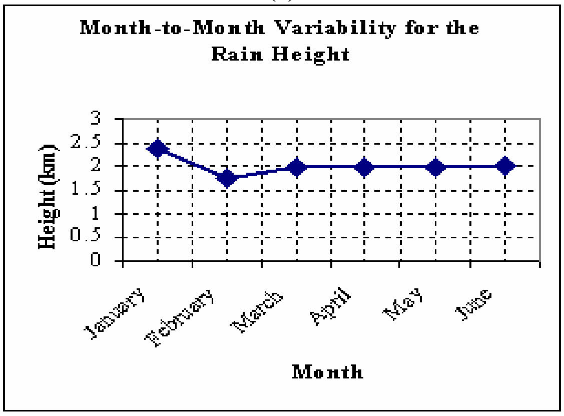
This dependency can be clarified by knowing that the highest values of the heights occurred during the Northeast monsoon (January), which is prevailing, from November or early December until March [9]. Furthermore, the lowest values are recorded during February, which is relatively dry month for Malaysia as a whole [9]. In April there is a noticeable decrease in the heights values. This decrease is due to the transition between monsoons, which occurred in April [9].

Table 2: Monthly variation of the statistical properties for the heights and thickness of the melting layer (from 2nd January to 18th June 1998.).

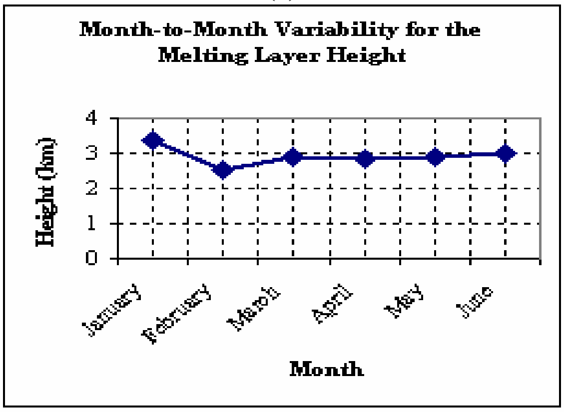
Months	January	February	March	April	May	June
Bright Band Height (BB_H km)						
Min	1.368	1.026	0.7949	0.513	1.026	1.026
Max	13	5.494	11.66	11.2	15.64	14.37
Mean	3.349	2.511	2.896	2.836	2.912	2.98
Std.	1.607	0.5617	0.9882	0.9717	1.146	1.097
Range	11.63	4.468	10.86	10.69	14.61	13.34
Zero Degree Celsius Isotherm Height (h_0 km)						
Min	1.69	1.268	2.362	0.6339	1.268	1.268
Max	19.08	7.419	11.13	15.1	21.2	19.08
Mean	4.424	3.23	3.805	3.67	3.966	3.964
Std.	2.2	0.8688	1.264	1.36	1.654	1.48
Range	17.39	6.151	8.766	14.47	19.93	17.81
Rain Height (h_R km)						
Min	0.1047	0.08727	0.04363	0.04363	0.02618	0.0618
Max	10.2	4.446	6.498	8.893	11.97	11.29
Mean	2.385	1.748	1.959	1.986	1.966	2.007
Std.	1.397	0.6919	0.8652	0.8707	1.104	1.072
Range	10.09	4.359	6.455	8.849	11.94	11.26
Melting layer Thickness (BB_{th} km)						
Min	0.5879	0.4409	0.4309	0.2205	0.4409	0.4409
Max	16.07	5.333	16.87	8.745	17.09	15.41
Mean	2.039	1.482	1.8	1.684	2.0	1.958
Std.	1.384	0.7826	0.953	0.9978	1.253	1.123
Range	15.48	4.892	15.05	8.525	16.65	14.97



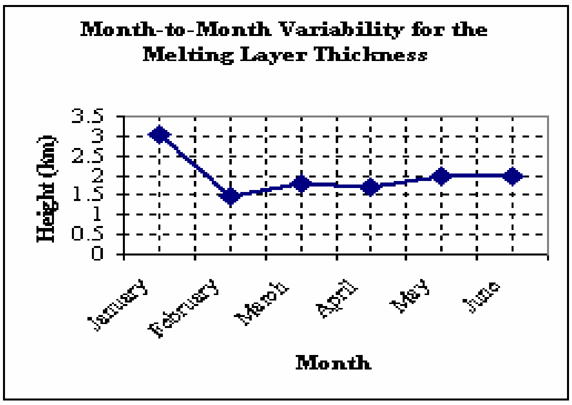
(a)



(b)



(c)



(d)

Figure 1: Month-to-Month variability for (a) h_0, (b) h_R, (c) BB_H, and (d) BB_{th}

5. Conclusion

One hundred and sixteen days of observations from the Kluang radar station, which belongs to the Meteorological Department of Malaysia and utilizes the 3D RAPIC system, have been analyzed to obtain the melting layer heights and thickness after tracing its signature during the stratiform precipitations events using a resolution range 500m. The bright band heights and thickness were compared with ITU-R Recommendations P.839, the results show that the seasonal variation of the melting layer height shows the expected trend during the Northeast monsoon, dry month, and transition between monsoons periods. This is achieved by tracing the signature of the melting layer and its heights through six months (January – June 1998).

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