Journal of Geomatics

Vol 8 No. 2 October 2014

AltiKa backscatter coefficient variation over land

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(Received: Jul 25, 2014; in final form: Oct 02, 2014)

Abstract: This paper presents the measurements over land taken by first Ka band Altimeter SARAL AltiKa. Altimeter backscatter coefficient (σ_0) varies intricately over the land surface due to change in composition (dielectric constant), texture and surface moisture. Soil and vegetation characteristics vary between different regions. The backscatter signal is the joint contribution of the surface and volume scattering which comprise the contribution from the ground, top of vegetation, water body, surface of terrestrial snow and the snowpack. Dynamic range of backscatter coefficient variation is -15 dB to +45 dB over various features of land. A significant seasonal variation defines a new way to define target characteristics over land.

Keywords: Altimeter, Soil moisture, Backscatter coefficient, Agriculture, Forest, Lake

1. Introduction

Altimeters are mainly designed for oceanographic applications and being used to map sea surface height, geostropic velocity, significant wave height etc. over global ocean to understand the role of ocean in climate and weather. Starting with SeaSAT (1978) until Jason2 (2007) altimeters operated in dual frequency Ku/SandKu/C- bands (Ulaby et al., 1986; Papa et al., 2001; Zieger et al., 1991; Remy et al., 1996; Guo et al., 2009). SeaSAT and GeoSATcatered measurements over ocean only. Starting with ERS-1 until Jason-2 altimeter data also used for monitoring ice dynamics, snow pack and ice sheet mass balance over Antarctica in addition to oceanographic applications. Attempts were made to address inland water monitoring during same time. AltiKa is first single frequency altimeter mission onboard SARAL operating in Ka band (Vincent et al., 2006).With the advancement in technology recent onboard tracker are capable to provide measurement over land which enables the altimeter to support other land applications e.g. forestry, Agriculture, flood/drought investigation etc (Papa et al., 2003). In this paper, seasonal variation of altimeter backscatter coefficient over forest, agriculture land, mountain and lake is reported over Indian land regions.

2. Study area and data used

Indian land mass is full of geographical diversity. It has Himalayan mountain ranges, northern plain, southern plateau full of various forest, lakes and rivers along with variety of vegetation from north to south. Around 80 SARAL track covers India as shown in Figure 1. SARAL was launched on 25 Feb. 2013 from Sriharikota (India) under ISRO-CNES collaboration. SARAL Interim Geophysical Data Record (IGDR) products are taken for a year (14 March 2013 to 8 May 2014) in this study. SARAL observation has repitivity of 35 days. Duration of different cycles of data is given in Table 1. SARAL product has backscatter coefficient value at the resolution of 1 Hz (~7 km spatial resolution) and 40 Hz (~175 m spatial resolution). There were many events of data saturation over land for 1 Hz backscatter observation therefore backscatter coefficient of finer resolution is taken for doing this work. ETM data of year 2000 is taken for feature identification over land.

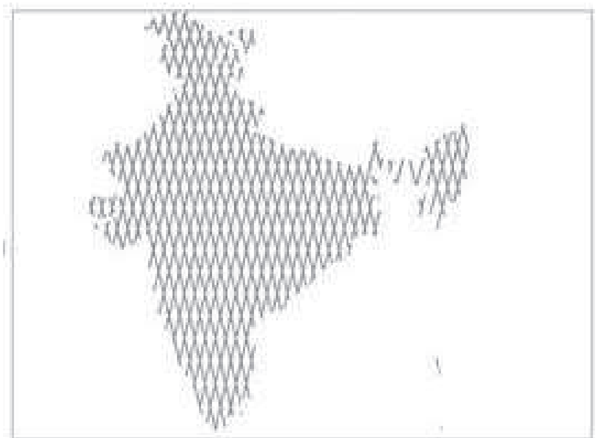

Figure 1: SARAL tracks over India in one cycle

Table 1: SARAL data cycle duration

Cycle no.	Duration of data
1	14 March 2013 – 18 April 2013
2	18 April 2013 – 23 May 2013
3	23 May 2013 – 27 June 2013
4	27 June 2013 – 1 August 2013
5	1 August 2013 – 5 September 2013
6	5 September 2013 – 10 October 2013
7	10 October 2013 – 14 November 2013
8	14 November 2013 – 19 December 2013
9	19 December 2013 – 23 January 2014
10	23 January 2014 – 27 February 2014
11	27 February 2014 – 3 April 2014
12	3 April 2014 – 8 May 2014

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3. Methodology and results

Backscatter coefficient for all 80 passes have been taken and interpolated using Kriging and generated backscatter image over India. Data availability is searched for different cycles over parts of deciduous forest, evergreen forest, vegetated land, mountain, river and lake for studying the seasonal variation of altimeter backscatter coefficient.

Signature of soil moisture

Soil surface moisture is a key scientific parameter. Radar backscatter from bare soil and vegetation covered surfaces is influenced by the dielectric properties and roughness of illuminated area like soil moisture, surface roughness, local topography and by the instrument characteristics. Figure 2(a) and 2(b) shows pre and post monsoon backscatter images over India respectively.

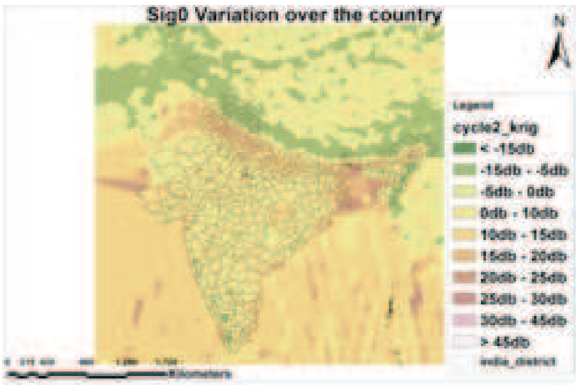

Figure 2(a): Pre monsoon (18 April – 23 May 2013)

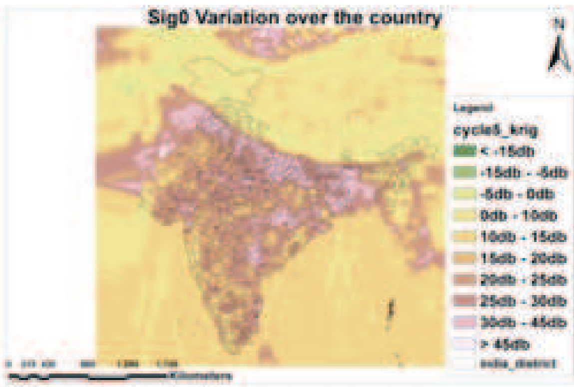

Figure 2(b): Post monsoon (1 August-5 September 2013)

Dry land has lower value of σ_0. Wet land has higher value of σ_0. The altimeters are designed to give more signal strength over presence of water or wet surface. Variation of backscatter coefficient in Figure 2(b) compared to Figure 2(a) confirms the presence of soil moisture.

σ_0 variation over forest

Ka band has negligible penetration over forest canopy. Table 2 lists the seasonal variation of σ_0 over a forest located in Alwar district. It is deciduous forest.

Table 2: σ_0 variation over forest

Forest	Cycle 5 (Aug – Sept 2013)	Cycle 8 (Nov. – Dec 2013)	Cycle 11 (Feb –Mar 2014)	Cycle 12 (Mar – April 2014)
Longitude (deg)	76.40 9486	76.41 1082	76.41 5464	76.41 69
Latitude (deg)	27.33 3293	27.38 3628	27.34 6289	27.33 995
σ_0	**9.96**	**13.2**	**2.2**	**1.78**
Description	Forest			
District (State)	Alwar (Rajasthan)			

Post monsoon fresh leaves are grown on the trees in the forest so from Aug to Dec 2013 σ_0 increased from 9 dB to 13 dB. During Feb to April the trees started to shed the leaves. Therefore microwave signal got scattered from branchedof the trees therefore backscatter in desired direction decreased to 2dB.

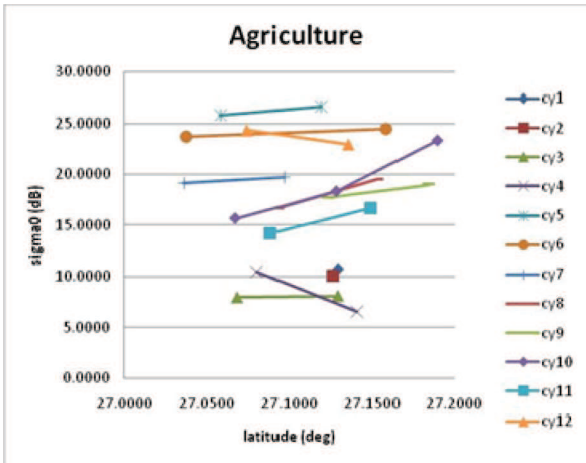

Figure 3(a): Latitudinal variation of σ_0

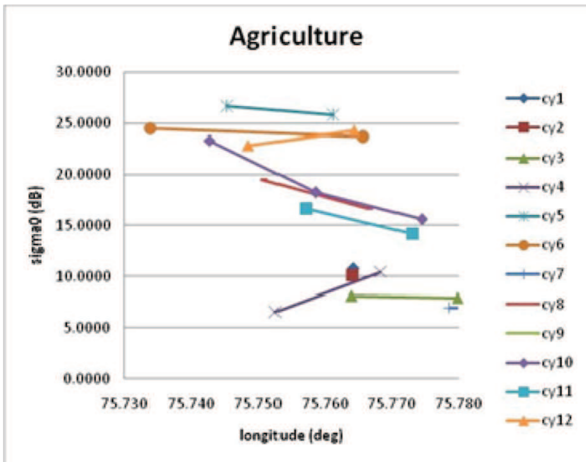

Figure 3(b): Longitudinal Variation of σ_0

σ_0 variation over agriculture land

Figure 3 shows the foot print of measurement. The longitudinal and latitudinal variation of σ_0 is evident over an agriculture field (20km x 5km) near Jaipur district in Rajasthan state for different seasons. Seasonal variation over agriculture field is quite evident in Figure 4 where interpolated value is taken on a fixed foot print. There is increase in σ_0 from 5 to 25 dB with increase in soil moisture due to rain as well as due to irrigated fields when seeds are sown in agriculture land (cycle 4 to 5 implies June to September period). As the vegetation started to grow in agriculture fields, electromagnetic energy has interacted with growing plants and got scattered in multiple directions which resulted a decreased $\sigma 0$ (cycle 6-8). There is not much variation in $\sigma 0$ which shows the field condition after harvesting the crop (Cycle 8-10).

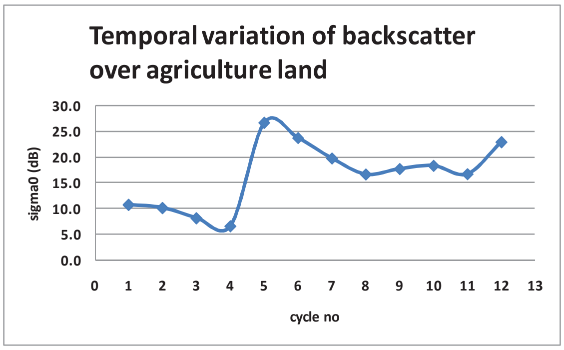

Figure 4: Seasonal variation of σ_0 (Refer Table 1 for date)

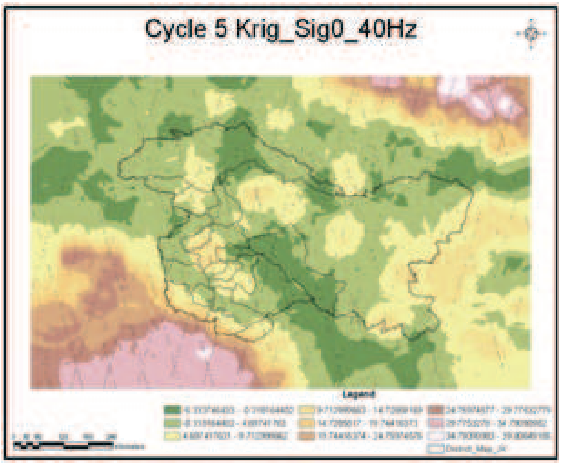

Figure 5(a): Aug-Sep13 -5.33 to 39.80 dB

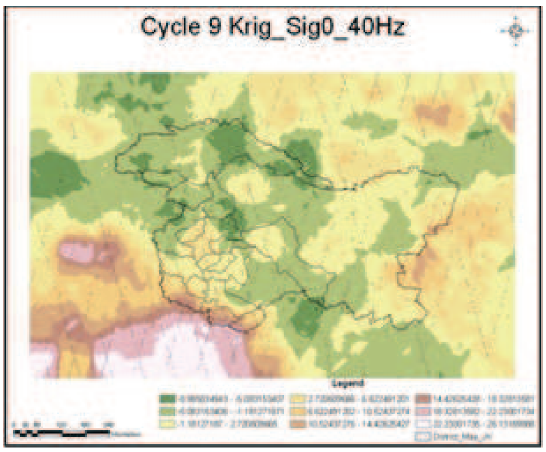

Figure 5(b): Dec13-Jan14 -8.93to 26.13 dB

σ_0 variation over Himalayan region

Earlier altimetry mission did not have better echo returns over mountains. Data products of RA2 and Jason2 have lesser footprints as compared to AltiKa over mountains. Transmitted microwave pulse was lost in the hilly terrain. AltiKa mission has ensured data over Himalayan region with increased pulse repetitions frequency (PRF). Figure 5 shows a large σ_0 variation over Himalayan region. During August to September 2013 it is -5.3 dB to 39.8 dB and During December 2013 to January 2014 σ_0 varies from -8.9 dB to 26.13 dB. Such observations are the precursor to take up altimetry measurements seriously over Himalaya.

There are no-snow fall and snow fall period over Himalaya mountain range. With increase in water content in ice the σ_0 increases until cycle 6 as depicted in Figure 6. Fresh snow starts falling over mountain range in winter season. With the increase in snow thickness over mountain electromagnetic energy is lost in subsurface layer scattering and σ_0 starts to decrease until cycle 9. In summer season there is increase in σ_0 and during winter σ_0 decreases with the fresh snow fall events (Remi and Parouty, 2009).

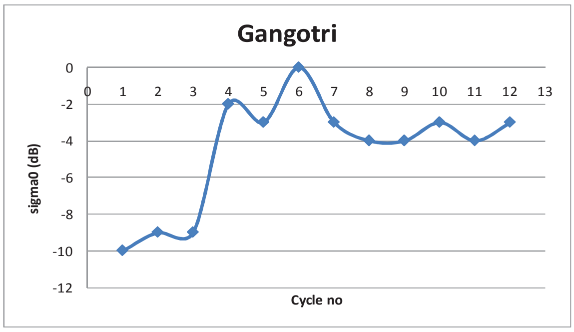

Figure 6: Seasonal variation of σ_0 over glacier

σ_0 variation over desert

Figure 7 shows one year foot print over desert area near Jaisalmer. Black line is the boundary between India and Pakistan. Desert region is free from vegetation. σ_0 variation is due to the soil moisture presence and due to movement of sand dunes. Figure 8 shows the seasonal variation.

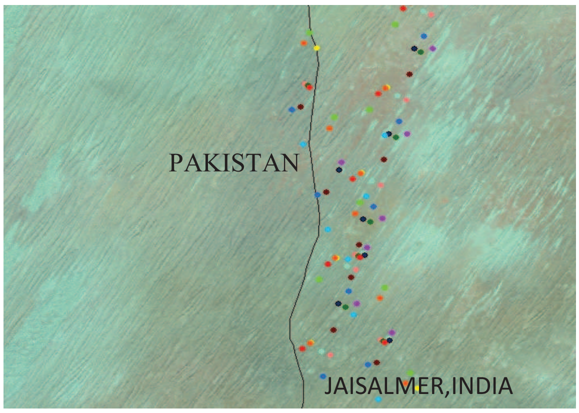

Figure 7: SARAL foot prints over desert

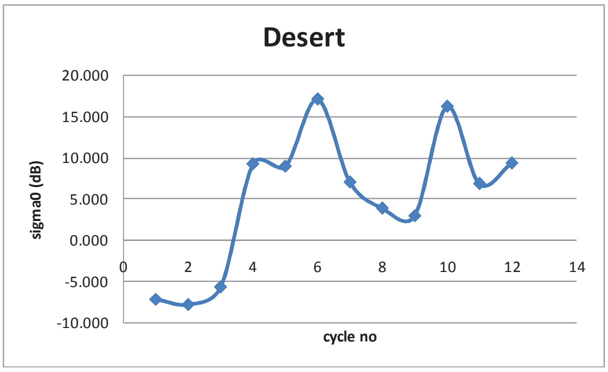

Figure 8: Seasonal variation of σ_0 over desert

σ_0 variation over lake

AltiKa foot prints for different cycles are shown in Figure 9 over a lake in Mandsaur, Madhya Pradesh. Figure 10 shows the seasonal variation over lake. One has to explore it with ground truth support. Since dielectric property of water does not change, possibly seasonal variation in wind can be one factor to change σ0 over lake.

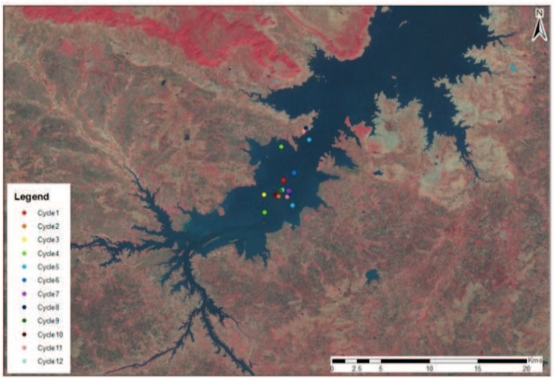

Figure 9: SARAL foot prints over lake

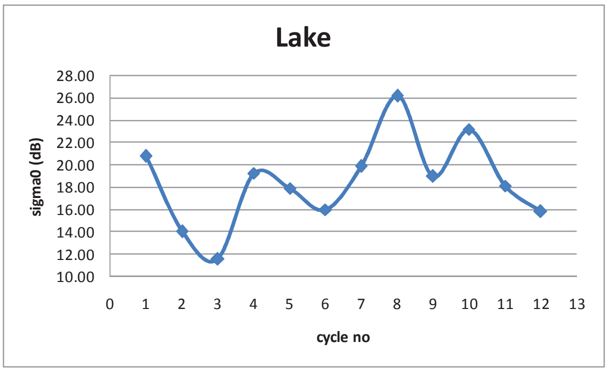

Figure 10: Seasonal variation of σ_0 over lake

Conclusions

Seasonal variation has wide dynamic range over different land surfaces and shows interaction of microwave energy with land features with different aspect, as altimeter is a nadir looking instrument. It provides an opportunity to consider electromagnetic interaction with various targets differently as compared to Synthetic Aperture RADAR (SAR) which takes land images at certain look angle.

Backscatter coefficient derived from altimeter waveform is rich in information and shows a significant temporal and seasonal variation over different features over land. Physics of measurements is very different at Ku and Ka band therefore results cannot be directly compared with previous altimeter missions. SARAL has smaller foot print, better temporal and spatial resolution, more absorption and scattering of microwave energy as compared to earlier altimeters flown in past. σ_0 of AltiKa is dominated by near subsurface echoes and sensitive to anisotropy of the target surface. Seasonal variation of σ_0 is different for different land features. Such study will contribute towards the requirement of SAR mode altimetry and wide swath altimeter missions in future.

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