Introducing: A Layman's Interpretation Guide to Synthetic Aperture Radar (SAR) data

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Abstract:

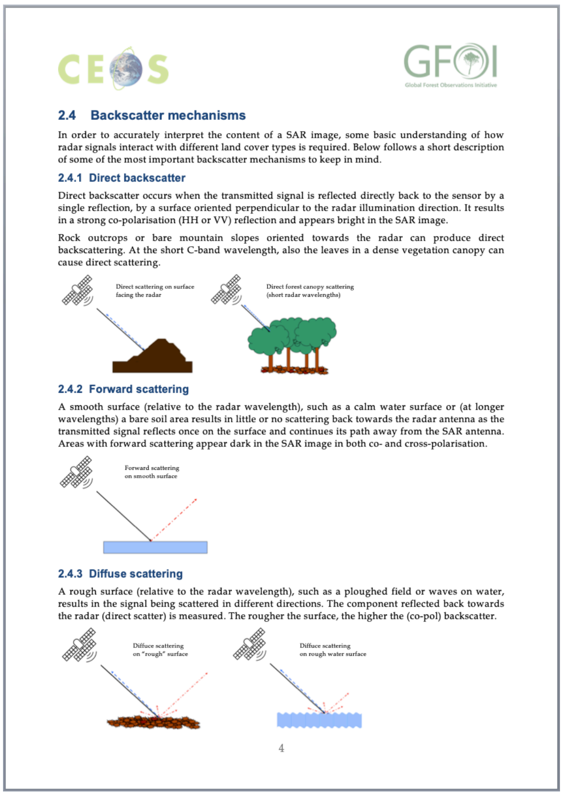
Interpretation of optical satellite data is intuitive to many users as optical instruments function similar to the human eye – they are passive sensors which record reflected visible and infra-red light from the sun. Radar sensors, on the other hand, are active system that operate in the microwave domain of the electromagnetic spectrum. Microwaves are not visible to the human eye and provide a very different view of the world from what we are used to. Different, but not necessarily difficult.

This "layman's" user guide was developed by soloEO, the Committee on Earth Observation Satellites (CEOS) and the GEO Global Forest Observations Initiative (GFOI) to provide users who have little or no experience of spaceborne Synthetic Aperture Radar (SAR) data with a simple reference document that outlines some basic concepts of radar remote sensing in a simple (non-electro engineering!) manner. Common radar terms such as radar wavelength, polarisation and sigma-0 are explained, as well as some of the basic backscatter mechanisms that explain how the radar signals interact with the ground. The guide also presents some commonly used SAR datasets, and provides some examples of how a few different land cover types may appear in Sentinel-1 and ALOS-2 PALSAR-2 SAR imagery.

The guide does however not go into the depths of microwave theory or radar processing (there is plenty of literature covering that) as expert knowledge today no longer should need to be a major concern for most users. Many space data providers are also now moving towards the provision of so called analysis-ready data (ARD) also for SAR, which can be used and integrated with other data sources with little or no need for users to undertake their own processing.

The guide is available free of charge for download at
http://ceos.org/ard/files/Laymans_SAR_Interpretation_Guide_2.0.pdf

Keywords: SAR, User Guide, ALOS-2, Sentinel-1



2.4 Backscatter mechanisms

In order to accurately interpret the content of a SAR image, some basic understanding of how radar signals interact with different land cover types is required. Below follows a short description of some of the most important backscatter mechanisms to keep in mind.

2.4.1 Direct backscatter

Direct backscatter occurs when the transmitted signal is reflected directly back to the sensor by a single reflection, by a surface oriented perpendicular to the radar illumination direction. It results in a strong co-polarisation (HH or VV) reflection and appears bright in the SAR image.

Rock outcrops or bare mountain slopes oriented towards the radar can produce direct backscattering. At the short C-band wavelength, also the leaves in a dense vegetation canopy can cause direct scattering.

2.4.2 Forward scattering

A smooth surface (relative to the radar wavelength), such as a calm water surface or (at longer wavelengths) a bare soil area results in little or no scattering back towards the radar antenna as the transmitted signal reflects once on the surface and continues its path away from the SAR antenna. Areas with forward scattering appear dark in the SAR image in both co- and cross-polarisation.

2.4.3 Diffuse scattering

A rough surface (relative to the radar wavelength), such as a ploughed field or waves on water, results in the signal being scattered in different directions. The component reflected back towards the radar (direct scatter) is measured. The rougher the surface, the higher the (co-pol) backscatter.

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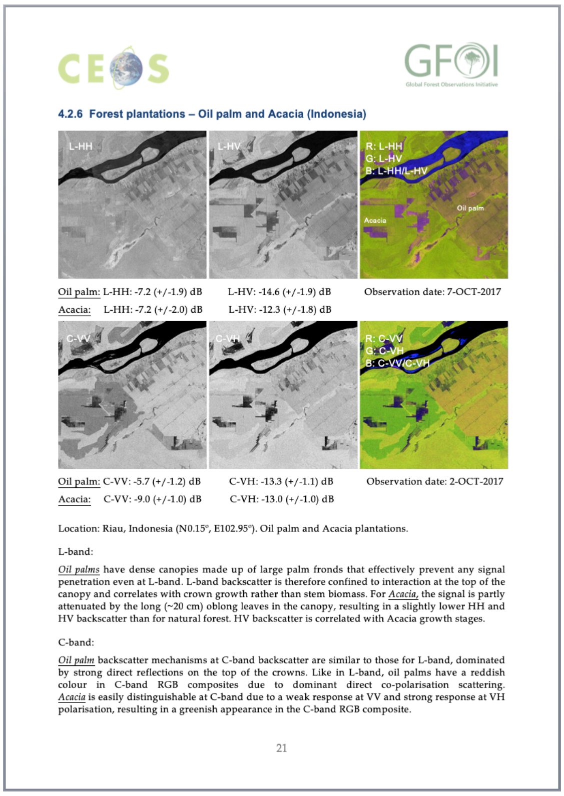

4.2.6 Forest plantations – Oil palm and Acacia (Indonesia)

Oil palm: L-HH: -7.2 (+/-1.9) dB L-HV: -14.6 (+/-1.9) dB Observation date: 7-OCT-2017
Acacia: L-HH: -7.2 (+/-2.0) dB L-HV: -12.3 (+/-1.8) dB

Oil palm: C-VV: -5.7 (+/-1.2) dB C-VH: -13.3 (+/-1.1) dB Observation date: 2-OCT-2017
Acacia: C-VV: -9.0 (+/-1.0) dB C-VH: -13.0 (+/-1.0) dB

Location: Riau, Indonesia (N0.15º, E102.95º). Oil palm and Acacia plantations.

L-band:

Oil palms have dense canopies made up of large palm fronds that effectively prevent any signal penetration even at L-band. L-band backscatter is therefore confined to interaction at the top of the canopy and correlates with crown growth rather than stem biomass. For *Acacia,* the signal is partly attenuated by the long (~20 cm) oblong leaves in the canopy, resulting in a slightly lower HH and HV backscatter than for natural forest. HV backscatter is correlated with Acacia growth stages.

C-band:

Oil palm backscatter mechanisms at C-band backscatter are similar to those for L-band, dominated by strong direct reflections on the top of the crowns. Like in L-band, oil palms have a reddish colour in C-band RGB composites due to dominant direct co-polarisation scattering. *Acacia* is easily distinguishable at C-band due to a weak response at VV and strong response at VH polarisation, resulting in a greenish appearance in the C-band RGB composite.

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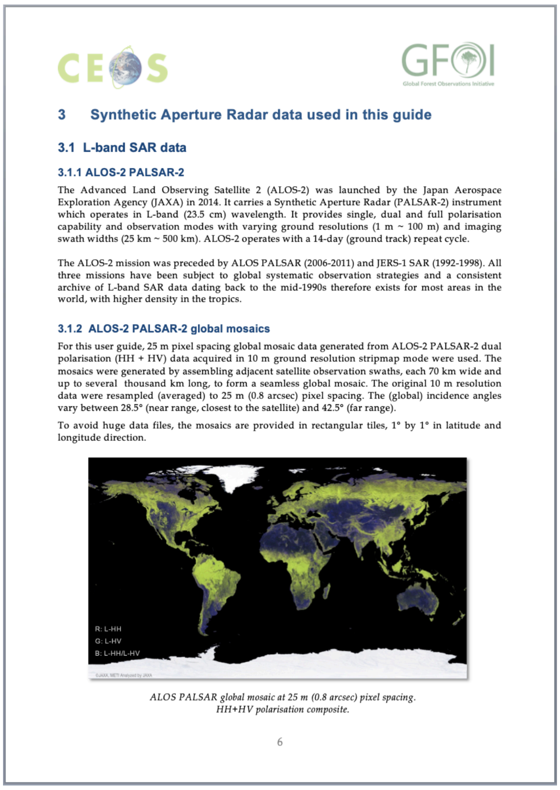

3 Synthetic Aperture Radar data used in this guide

3.1 L-band SAR data

3.1.1 ALOS-2 PALSAR-2

The Advanced Land Observing Satellite 2 (ALOS-2) was launched by the Japan Aerospace Exploration Agency (JAXA) in 2014. It carries a Synthetic Aperture Radar (PALSAR-2) instrument which operates in L-band (23.5 cm) wavelength. It provides single, dual and full polarisation capability and observation modes with varying ground resolutions (1 m ~ 100 m) and imaging swath widths (25 km ~ 500 km). ALOS-2 operates with a 14-day (ground track) repeat cycle.

The ALOS-2 mission was preceded by ALOS PALSAR (2006-2011) and JERS-1 SAR (1992-1998). All three missions have been subject to global systematic observation strategies and a consistent archive of L-band SAR data dating back to the mid-1990s therefore exists for most areas in the world, with higher density in the tropics.

3.1.2 ALOS-2 PALSAR-2 global mosaics

For this user guide, 25 m pixel spacing global mosaic data generated from ALOS-2 PALSAR-2 dual polarisation (HH + HV) data acquired in 10 m ground resolution stripmap mode were used. The mosaics were generated by assembling adjacent satellite observation swaths, each 70 km wide and up to several thousand km long, to form a seamless global mosaic. The original 10 m resolution data were resampled (averaged) to 25 m (0.8 arcsec) pixel spacing. The (global) incidence angles vary between 28.5° (near range, closest to the satellite) and 42.5° (far range).

To avoid huge data files, the mosaics are provided in rectangular tiles, 1° by 1° in latitude and longitude direction.

ALOS PALSAR global mosaic at 25 m (0.8 arcsec) pixel spacing. HH+HV polarisation composite.

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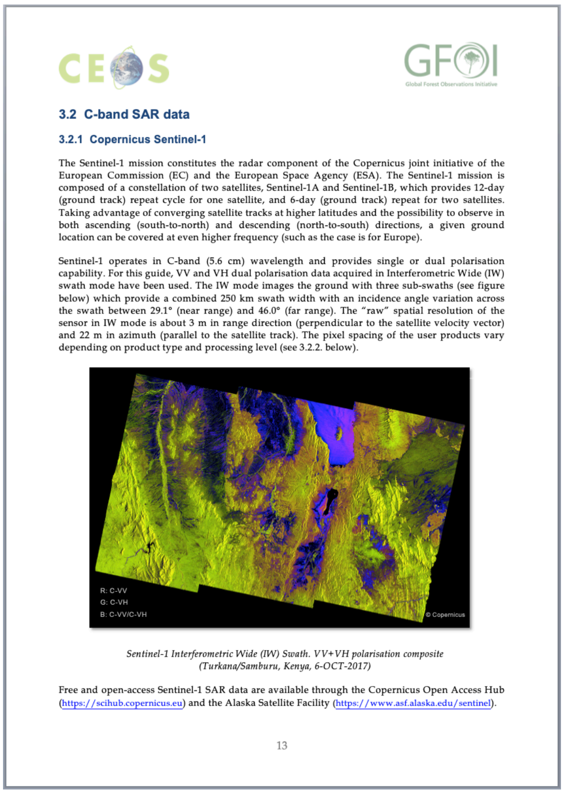

3.2 C-band SAR data

3.2.1 Copernicus Sentinel-1

The Sentinel-1 mission constitutes the radar component of the Copernicus joint initiative of the European Commission (EC) and the European Space Agency (ESA). The Sentinel-1 mission is composed of a constellation of two satellites, Sentinel-1A and Sentinel-1B, which provides 12-day (ground track) repeat cycle for one satellite, and 6-day (ground track) repeat for two satellites. Taking advantage of converging satellite tracks at higher latitudes and the possibility to observe in both ascending (south-to-north) and descending (north-to-south) directions, a given ground location can be covered at even higher frequency (such as the case is for Europe).

Sentinel-1 operates in C-band (5.6 cm) wavelength and provides single or dual polarisation capability. For this guide, VV and VH dual polarisation data acquired in Interferometric Wide (IW) swath mode have been used. The IW mode images the ground with three sub-swaths (see figure below) which provide a combined 250 km swath width with an incidence angle variation across the swath between 29.1° (near range) and 46.0° (far range). The "raw" spatial resolution of the sensor in IW mode is about 3 m in range direction (perpendicular to the satellite velocity vector) and 22 m in azimuth (parallel to the satellite track). The pixel spacing of the user products vary depending on product type and processing level (see 3.2.2. below).

Sentinel-1 Interferometric Wide (IW) Swath. VV+VH polarisation composite (Turkana/Samburu, Kenya, 6-OCT-2017)

Free and open-access Sentinel-1 SAR data are available through the Copernicus Open Access Hub (https://scihub.copernicus.eu) and the Alaska Satellite Facility (https://www.asf.alaska.edu/sentinel).

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Excerpts from the Layman's SAR Interpretation Guide