Korea Aerospace Research Institute (KARI)

CEOS Analysis Ready Data

Normalised Radar Backscatter (NRB)

SAR Algorithm Theoretical Basis Document

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1. Introduction

This Algorithm Theoretical Basis Document (ATBD) describes the algorithm used to generate Normalised Radar Backscatter (NRB) product, prepared as Committee on Earth Observation Satellites (CEOS) Analysis Ready Data (ARD) for Synthetic Aperture Radar (SAR). Following the CEOS-ARD Product Family Specification (PFS) for SAR, This document addresses the NRB product together with the generation of the per-pixel metadata layers provided with it. It presents the algorithm basis, the algorithm design and the application results.

2. Normalized Radar Backscatter (NRB)

2.1. Algorithm Basis

2.1.1. Flattening Gamma Algorithm

SAR imagery suffers distortion of the backscatter coefficient depending on terrain relief and the observation direction; therefore, terrain correction that accounts for the observation direction is essential for accurate estimation of the backscatter coefficient.

The NRB product is a backscatter image to which Radiometric Terrain Correction (RTC) has been applied in accordance with the CEOS-ARD standard; the measured gamma-naught mitigates distortions of the scattering values caused by various geometric factors such as the observation angle and terrain slope. The NRB product is provided in a standard scattering-coefficient form suitable for land-observation applications.

The Flattening Gamma algorithm (David Small, 2011) uses a high-resolution Digital Elevation Model (DEM) to compute the SAR observation geometry and terrain relief and thereby correct the backscatter coefficient. This removes the effect of terrain slope and provides a consistent backscatter coefficient for identical surface characteristics. Figure 1 illustrates the definitions of beta-naught (β^o), sigma-naught (σ^o) and gamma-naught (γ^o) used in the Flattening Gamma algorithm, together with their associated reference areas A_β, A_σ and A_γ; the ellipsoidal coefficients are related as $\gamma^o_E = \beta^o \cdot (A_\beta / A_\gamma) = \beta^o \cdot \tan\theta$ and $\sigma^o_E = \beta^o \cdot (A_\beta / A_\sigma) = \beta^o \cdot \sin\theta$.

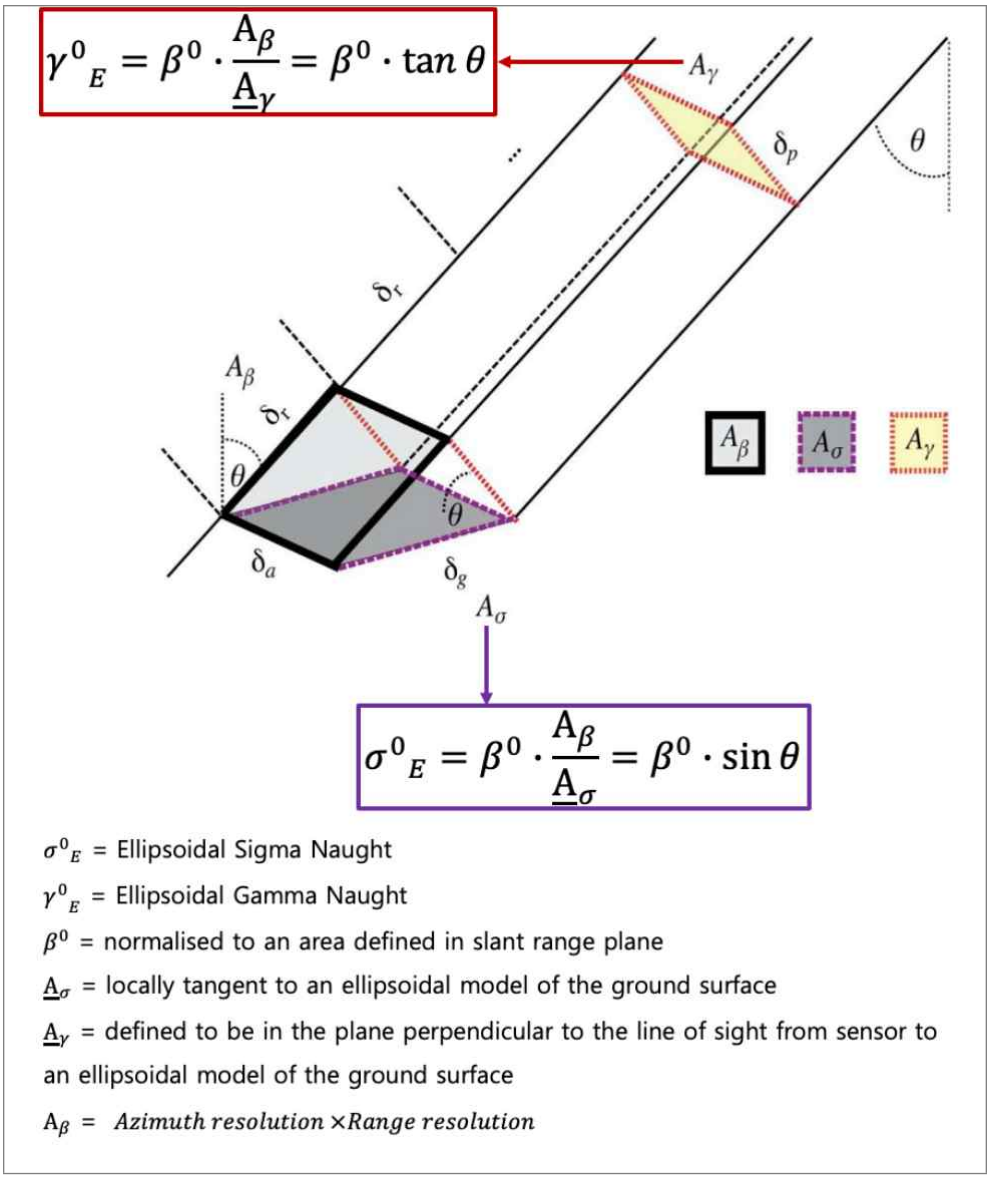


Figure . Definitions of β^o, σ^o and γ^o and their associated reference areas in the Flattening Gamma algorithm (Small, 2011).

The NRB product is generated through the processing chain shown in Figure 2.

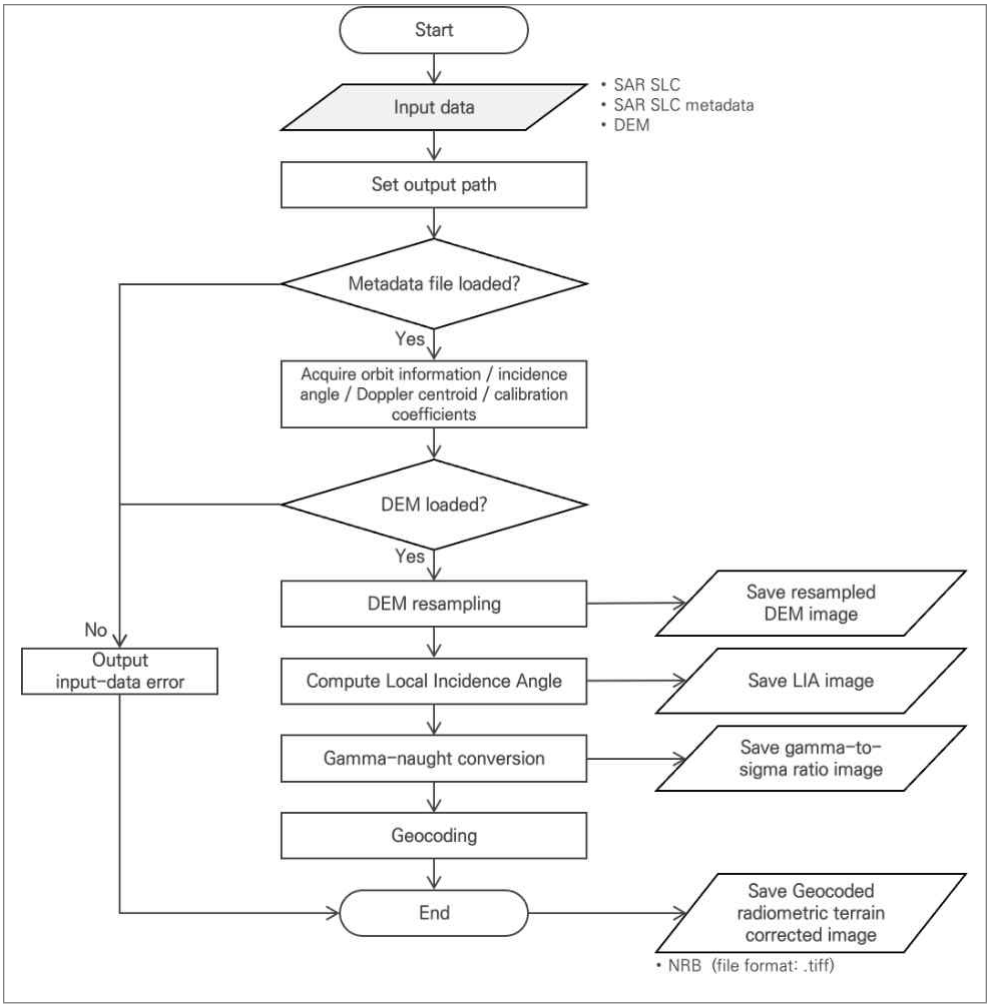


Figure 2. NRB products generation workflow.

The inputs and outputs of the NRB products are summarized in Table 1.

Table 1. Inputs and outputs of the NRB products.

Input	Output
- KOMPSAT-5 L1A image - KOMPSAT-5 metadata - DEM image	- Geocoded radiometric terrain-corrected image (.tiff) - NRB mask image (.tiff) - DEM image (.tiff) - Local Incidence Angle image (.tiff) - gamma-to-sigma ratio image (.tiff) - AcquisitionID image (.tiff) - Metadata (.xml)

2.2. Algorithm Design

2.2.1. Local Incidence Angle (LIA) Computation

The LIA computation algorithm reads the KOMPSAT-5 L1A image and its metadata. An orthorectified DEM image is then read; back-geocoding is performed to align the coordinate system with the KOMPSAT-5 L1A image, and the region corresponding to the L1A image is subset. The LIA is the angle between the surface normal vector of the terrain and the radar incidence vector, computed from the vector dot product between the terrain slope derived from the DEM and the incidence vector reaching the SAR sensor. The LIA computation workflow is shown in Figure 3.

$$\theta_{LIA} = \cos^{-1}(s \cdot n)$$

s : incidence vector
n : terrain normal vector
θ_{LIA} : local incidence angle

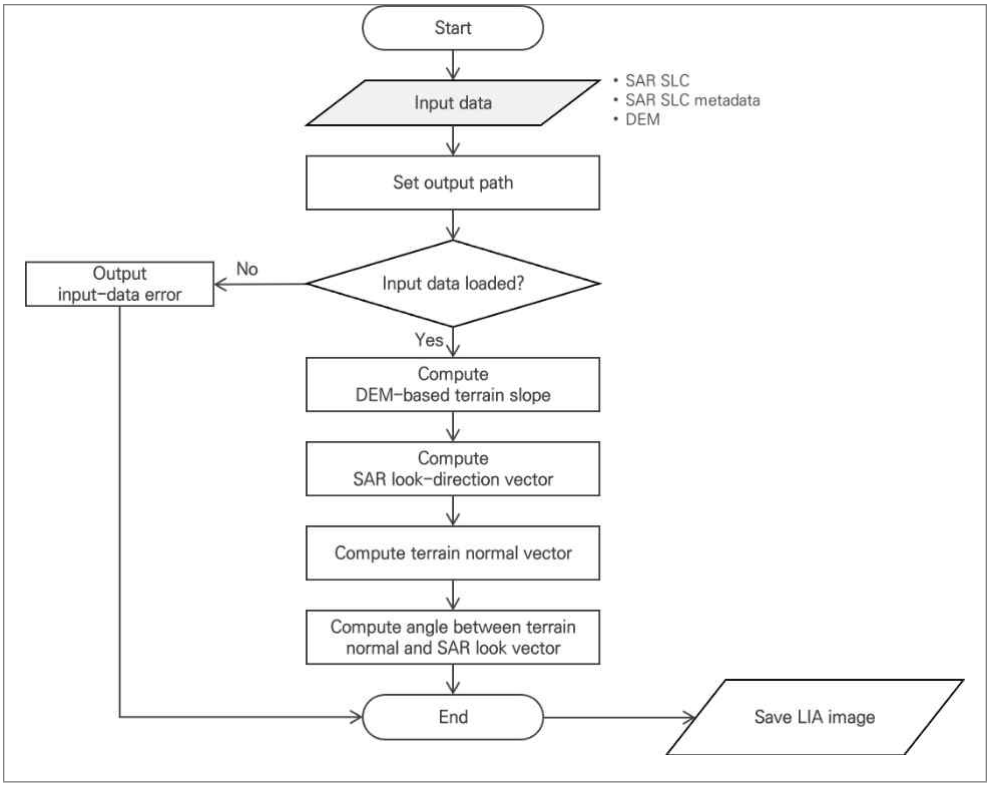


Figure 3. LIA computation workflow.

2.2.2. Backscatter Normalisation

After the DEM image is read and subset to the KOMPSAT-5 L1A image extent, the backscatter coefficient distorted by terrain is corrected to produce a physically consistent terrain-flattened gamma-naught.

a) Local area by Heron's formula

To perform terrain correction, triangular terrain facets are constructed using adjacent grid points on the DEM. Each facet is projected onto the plane normal to the SAR incidence direction and its area is computed using Heron's formula. The area A_γ is used as the normalisation factor for correcting terrain relief.

$$s = \frac{a + b + c}{2}, A_\gamma = \sqrt{s(s - a)(s - b)(s - c)}$$

a, b, c: lengths of the three sides of the projected triangle
s : semi-perimeter of the triangle

b) Area redistribution by bilinear weighting

The area obtained from Heron's formula is transformed into the corresponding radar coordinate system, distributing the area to the four neighbouring pixels with bilinear interpolation weights.

$$A_{I_r^0, I_a^0} += W_r \cdot W_a^c \cdot A_{E,N}$$

$$A_{I_r^1, I_a^0} += W_r \cdot W_a^c \cdot A_{E,N}$$

$$A_{I_r^0, I_a^1} += W_r^c \cdot W_a \cdot A_{E,N}$$

$$A_{I_r^1, I_a^1} += W_r \cdot W_a \cdot A_{E,N}$$

c) Terrain-flattened gamma-naught

The distributed areas are accumulated per pixel, and the terrain-flattened gamma-naught is finally computed through the normalisation relation.

$$\gamma_T^0(r,a) = K_\gamma \cdot \frac{\beta^0(r,a)}{\hat{A}_\gamma(r,a)}$$

$\gamma^0_T(r,a)$: terrain-flattened gamma-naught
$\beta^0(r,a)$: accumulated backscatter value per pixel
$\widehat{A}_\gamma(r,a)$: distributed area in the radar coordinate system
K_γ : calibration constant

2.2.3. Geocoding

The corrected SAR image is projected into a geographic coordinate system to produce a map-based backscatter image; each pixel's SAR coordinate is transformed into the map coordinate system and placed onto the pixel grid of the geographic image.

2.3. NRB Algorithm Results

The images in Figure 4 were acquired over the same area on different tracks. After Flattening-Gamma RTC, the normalised backscatter coefficients are expected to show consistent values for identical surface characteristics across ascending and descending acquisitions.

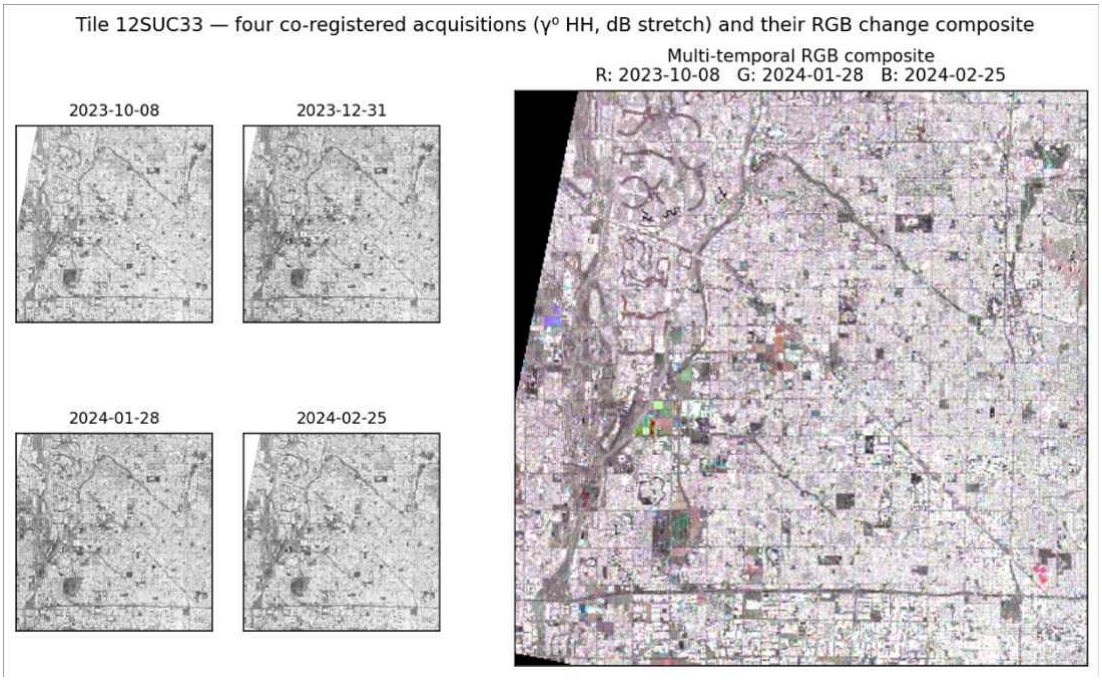


Figure . Multi-temporal use of NRB: four co-registered 12SUC33 acquisitions (γ^0 HH, dB) and an RGB change composite (R: 2023-10-08, G: 2024-01-28, B: 2024-02-25). Grey areas are stable between dates; coloured areas indicate temporal change.

2.4. Implications

(1) Suitability as a standardised SAR pre-processing technique. Because CEOS-ARD adopts Flattening-Gamma-based RTC as the default processing for the NRB product, it is likely to become established as a standard for SAR data pre-processing.

(2) Advantageous for multi-sensor fusion analysis. In spatio-temporal fusion SAR analysis using various orbits and sensors, the uniform removal of geometric distortion provides a basis for integrated analysis across images.

(3) Improved accuracy of downstream analysis. The normalised scattering coefficient can contribute to quality improvement as a fundamental input for downstream processing such as time-series change detection, machine-learning-based classification and relative-terrain-based statistical analysis.

3. Acronyms and Abbreviations

Acronym	Definition
ARD	Analysis Ready Data
ATBD	Algorithm Theoretical Basis Document
CEOS	Committee on Earth Observation Satellites
COSI	COrea SAR Instrument
CRS	Coordinate Reference System
DEM	Digital Elevation Model
DOI	Digital Object Identifier
EGM	Earth Gravitational Model
EIA	Ellipsoidal Incidence Angle
GeoTIFF	Geographic Tagged Image File Format
HH	Horizontal transmit / Horizontal receive polarisation
KARI	Korea Aerospace Research Institute
LIA	Local Incidence Angle
MGRS	Military Grid Reference System
NESZ	Noise-Equivalent Sigma-Zero
NRB	Normalised Radar Backscatter
PFS	Product Family Specification
PUM	Product User Manual

RTC	Radiometric Terrain Correction
SAR	Synthetic Aperture Radar
SCS	Single-look Complex Slant-range
UTM	Universal Transverse Mercator
γ^o / σ^o / β^o	Gamma- / Sigma- / Beta-nought backscatter

4. References

[1] D. Small, "Flattening Gamma: Radiometric Terrain Correction for SAR Imagery," IEEE Transactions on Geoscience and Remote Sensing, vol. 49, no. 8, pp. 3081–3093, Aug. 2011.

[2] CEOS, CEOS Analysis Ready Data Product Family Specification: Synthetic Aperture Radar (SAR), Version 1.3.1, Committee on Earth Observation Satellites, Jul. 2026.

[3] A. Rosenqvist et al., A Layman's Interpretation Guide to L-band and C-band SAR Data, Version 3.0, CEOS, May 2023.