ABSTRACT

This document serves as product guide for users of radiometrically terrain corrected ALOS PALSAR products processed by the Alaska Satellite Facility.
Document Preparation

The document was prepared with contributions from
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  Tom Logan
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Document Change Log

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<th>Revision</th>
<th>Date</th>
<th>Page</th>
<th>Change Description</th>
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<td>10/01/2014</td>
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<td>General revision</td>
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<td>06/01/2015</td>
<td>all</td>
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Acronyms and Abbreviations

ALOS  Advanced Land Observing Satellite
ASF  Alaska Satellite Facility
CONUS  Contiguous United States
DEM  Digital Elevation Model
GeoTIFF  Geo-referenced Tagged Image File Format
GIS  Geographic Information System
ISO  International Organization for Standardization
KMZ  Keyhole Markup Language Zip file
NASA  National Aeronautics and Space Administration
NED  National Elevation Dataset
PALSAR  Phase Array type L-band Synthetic Aperture Radar
RTC  Radiometric Terrain Correction
SAR  Synthetic Aperture Radar
SLC  Single Look Complex
SRTM  Shuttle Radar Topography Mission
XML  Extensible Markup Language
1 Document structure

The document is structured as follows:

Chapter 1 introduces the structure and scope of the document.

Chapter 2 describes the data processing in detail. First, it supplies information about the digital elevation models used in terrain and radiometric correction. The remainder of the chapter comprehensively covers the processing flow for terrain correction.

Chapter 3 provides terrain correction examples, showing how the terrain corrected products can be used.

Chapter 4 summarizes the product packaging.

Chapter 5 provides the necessary information to access the RTC products.
2 Data processing

2.1 Digital elevation models

The quality of the terrain correction results is directly related to the quality of the digital elevation models (DEMs) used in the process of geometrically and radiometrically correcting the SAR imagery. Table 1 summarizes the various DEM sources and the way they are used in the radiometric terrain correction (RTC).

Table 1: DEMs used and their priority in RTC processing

<table>
<thead>
<tr>
<th>DEM</th>
<th>Datum</th>
<th>Area</th>
<th>Posting</th>
<th>Sampling</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-res. DEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NED13</td>
<td>NAVD88</td>
<td>CONUS, Hawaii, parts of Alaska</td>
<td>10 m</td>
<td>Down sampling DEM to 30 m</td>
<td>12.5 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30 m</td>
<td></td>
<td>30 m</td>
</tr>
<tr>
<td>Medium-resolution DEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRTM GL1</td>
<td>EGM96</td>
<td>60 N to 57 S latitude</td>
<td>30 m</td>
<td>Up sampling 30 m product</td>
<td>12.5 m</td>
</tr>
<tr>
<td>SRTM US1</td>
<td>EGM96</td>
<td>CONUS, Hawaii, parts of Alaska</td>
<td>30 m</td>
<td>No</td>
<td>30 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Up sampling 30 m product</td>
<td>12.5 m</td>
</tr>
<tr>
<td>NED1</td>
<td>NAVD88</td>
<td>CONUS, Hawaii, parts of Alaska, Canada, Mexico</td>
<td>30 m</td>
<td>No</td>
<td>30 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Up sampling 30 m product</td>
<td>12.5 m</td>
</tr>
<tr>
<td>NED2</td>
<td>NAVD88</td>
<td>Alaska</td>
<td>60 m</td>
<td>No</td>
<td>30 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Up sampling 30 m product</td>
<td>12.5 m</td>
</tr>
</tbody>
</table>
Figure 1 shows the coverage of the various DEM sources used for terrain correction. The continental U.S., Hawaii, and parts of Alaska are covered with $\frac{1}{3}$ arc sec National Elevation Dataset (NED) at a 10 m resolution. The rest of Alaska above 60 degrees northern latitude is only available at 60 m resolution with 2 arc sec NED data. The best resolution for Canada and Mexico at 30 m is given by 1 arc sec NED. For the remaining globe, Shuttle Radar Topography Mission (SRTM) GL1 data at 30 m resolution is used. Greenland and Antarctica are mostly covered by ice and glaciers and not suitable for terrain correction. For areas in Eurasia above 60 degrees northern latitude, no suitable DEMs are available.

The DEMs were pre-processed by ASF to a consistent raster format (GeoTIFF) from the original source formats: height (*.hgt), ESRI ArcGrid (*.adf), etc. Many of the NASA-provided DEMs were provided as orthometric heights with EGM96 vertical datum. These were converted by ASF to ellipsoid heights using the ASF MapReady tool named geoid_adjust. The pixel reference varied from the center (pixel as point) to a corner (pixel as area). The GAMMA software, used to generate the terrain corrected products, uses pixel as area and adjusts DEM coordinates as needed. Where more than one DEM is available, the best-resolution DEM is used for processing. Complete DEM coverage from a single DEM source is required for processing to proceed.
2.2 Terrain correction processing flow

The processing flow for the terrain correction is summarized in Figure 2. A more detailed coverage about the processing flow can be found in the Algorithm Theoretical Basis Document.

Figure 2: Terrain correction processing flow
2.2.1 Pre-processing

The first step of pre-processing is the selection of the best DEM for the terrain correction. The DEM tiles are assembled to ensure sufficient coverage for the terrain correction of the ALOS PALSAR L1.1 single look complex (SLC) image. For the generation of low-resolution RTC products from high-resolution DEMs, the original DEM is down sampled from 12.5 m to 30 m. The application of the calibration parameters and multilooking are the only pre-processing steps to the SAR image.

2.2.2 Terrain correction

The terrain correction is performed in slant range geometry. The actual mapping of the initial image into projected space is only applied once to mitigate the propagation of any resampling errors. All intermediate steps only update the look up table used for the mapping.

The first step is the co-registration of the SAR image with a simulated SAR image derived from the DEM. An initial offset is first attempted as a single match, if failed with a larger number of image chips to determine an average offset in azimuth and range direction. This initial offset is then refined using strict matching criteria. The *dead reckoning* approach is taken when matching fails. No offsets are also applied when the magnitude of the residual offset errors is greater than 2 pixels or the maximum calculated offset is greater than 50 m. This approach solely relies on the geolocations calculated from state vectors.

Once the images are co-registered, a normalization area image is generated. The terrain correction results in a radiometrically calibrated multilooked image with $\gamma_0$ power scale values. The ratio between the pixel area of the uncorrected and the corrected images is determined and stored in an image. In order to create the RTC product, the SAR image is multiplied by the ratio image. In a final step the RTC product is geocoded into map-projected space.

2.2.3 Post-processing

After the terrain correction is completed, the RTC products are exported to GeoTIFF format. The high resolution RTC products from medium resolution DEMs are up sampled from the 30-m version to 12.5 m. In addition, a browse image and ISO XML metadata files are generated.
3 Terrain correction examples

The RTC products are generated in GeoTIFF, a user-friendly format that is GIS compatible. The main reason for the generation of these products is the correction of all the geometric distortions caused by the side-looking SAR geometry. Once corrected, the products can be used as "just another layer" within a GIS. The SAR data can be combined in a number of ways.

![Figure 3: Landsat 8 image of the Kilauea volcano, Hawaii.](image)

In many coastal areas, such as that of Hawaii’s Kilauea volcano, shown in Figure 3, cloud cover is a frequent occurrence. The inset shows that the SAR image can be used to replace optical-image information.
In another example, a false-color composite of a Landsat 8 image (Figure 4) shows Sumatra, Indonesia, which is mostly covered with tropical rainforest. As can be seen in the optical image, some areas have a similar spectral reflectance and are very homogeneous. The SAR image, overlaid with a 50 percent transparency in the inset, indicates that the backscatter offers complementary information for uses such as improving land-cover classification.

More advanced processing techniques include data fusion, either on a pixel level or on a feature level, using an object-oriented approach.
4 Product packaging

The naming convention for the RTC products follows as base name of this pattern:

\[
\text{AA\_BBBBB\_CCC\_FDDDD\_RTE} \quad (\text{e.g. } \text{AP\_26939\_FBS\_F3170\_RT1})
\]

<table>
<thead>
<tr>
<th>Component</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>mission</td>
<td>AP</td>
</tr>
<tr>
<td>BBBB</td>
<td>orbit number of image</td>
<td>26939</td>
</tr>
<tr>
<td>CCC</td>
<td>beam mode of image</td>
<td>PLR</td>
</tr>
<tr>
<td>DDDD</td>
<td>frame number of image</td>
<td>3170</td>
</tr>
<tr>
<td>E</td>
<td>terrain correction resolution (1=high, 2=low)</td>
<td>1</td>
</tr>
</tbody>
</table>

All files are stored in a folder with the base name. The file extensions used are:

<table>
<thead>
<tr>
<th>Extension</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>_HH.tif</td>
<td>terrain corrected product stored in separate files for each available polarization in GeoTIFF format</td>
<td>AP_26939_PLR_F3170_RT1_HH.tif</td>
</tr>
<tr>
<td>_HV.tif</td>
<td></td>
<td>AP_26939_PLR_F3170_RT1_HV.tif</td>
</tr>
<tr>
<td>_VH.tif</td>
<td></td>
<td>AP_26939_PLR_F3170_RT1_VH.tif</td>
</tr>
<tr>
<td>_VV.tif</td>
<td></td>
<td>AP_26939_PLR_F3170_RT1_VV.tif</td>
</tr>
<tr>
<td>.iso.xml</td>
<td>ISO compliant metadata in XML format</td>
<td>AP_26939_PLR_F3170_RT1.iso.xml</td>
</tr>
<tr>
<td>.dem.tif</td>
<td>digital elevation model used for terrain correction in GeoTIFF format</td>
<td>AP_26939_PLR_F3170_RT1.dem.tif</td>
</tr>
<tr>
<td>.inc_map.tif</td>
<td>layover/shadow mask in GeoTIFF format</td>
<td>AP_26939_PLR_F3170_RT1.inc_map.tif</td>
</tr>
<tr>
<td>.ls_map.tif</td>
<td>layover/shadow mask in GeoTIFF format</td>
<td>AP_26939_PLR_F3170_RT1.ls_map.tif</td>
</tr>
<tr>
<td>.geo.jpg</td>
<td>browse image of the amplitude (including world and auxiliary file) in JPEG format</td>
<td>AP_26939_PLR_F3170_RT1.geo.jpg</td>
</tr>
<tr>
<td>.kmz</td>
<td>browse image in Google Earth format</td>
<td>AP_26939_PLR_F3170_RT1.kmz</td>
</tr>
</tbody>
</table>

The format of the RTC product, particularly its ISO XML metadata, is described in further detail in the product format specification document.
5 Data access

Products are available to researchers who complete a two-page NASA proposal:
https://www.asf.alaska.edu/data-tools/submit-a-proposal/

To obtain information from ASF, or to view or download ALOS PALSAR RTC products, please see the links below:

ASF website: https://www.asf.alaska.edu/sar-data/palsar/
Vertex: https://vertex.daac.asf.alaska.edu/
API: https://www.asf.alaska.edu/get-data/api/

For details on accessing data, including other SAR datasets, see ASF’s Get Started guide:
https://www.asf.alaska.edu/get-data/get-started/