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NISAR NASA SDS Track-Frame Database Software Interface Specification (TFdb-SIS)

Rev A

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Document Change Log

Revision	Cover Date	Sections Changed	ECR #	Reason, ECR Title, LRS #*
Initial	2022/03/04	All	N/A	
WV R3.1	2022/08/05	Title and signature pages	N/A	Added D-number, Revision, and WORKING VERSION; updated URLs. Updated signatories.
WV R3.3	2023/04/28	All	N/A	Update for R3.3 release
Initial	2024/01/10	Cover Page, Sec. 1.3, Sec. 2, Sec. 4	N/A	Updated revision and data of the document; Updated the versions of applicable and reference documents; Updated Sec.2 and Fig. 2.1 to include all NISAR products; Added a description of the new columns introduced in the TFdb. Cleared for public release. URS CL# 24-0776.
Rev A	2025/04/28	Cover Page, Sec. 2, Sec. 3, Sec. 7	N/A	R4.0.2 - Update date and revision on cover page; Introduced the definition of Track #1 and improved paragraph readability; Removed Figure 3-1 in Sec. 3; Corrected satellite lat/lon coordinates origin in Sec.4; Updated link to RSO file in Sec. 7. URS CL# 24-3898. R4.0.7 – Add 3 new Track-Frame fields (insarProcess, offsetsProcessor, insarPSFCriteria)

* *Include the JPL Limited Release System (LRS) clearance number for each revision to be shared with foreign partners.*

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1 INTRODUCTION

1.1 Purpose of Specification

This document serves as the NASA-ISRO Synthetic Aperture Radar (NISAR) L-SAR Track-Frame database (TFdb), Software Interface Specification (SIS) document. The TFdb defined by this SIS will be used by the Program Control Manager (PCM) subsystem of the NISAR Science Data System (SDS) for managing the processing of Level-1 (L1) and Level-2 (L2) NISAR science data products.

1.2 Scope

This SIS defines the NISAR TFdb. This document includes an overview of the track-frame definition for NISAR, their geographic coverage in left and right looking modes, the spatial coverage of the frames, and the envisioned processing flow from L0B to L2 products.

1.3 Applicable and Reference Documents

Applicable documents levy requirements on areas addressed in this document. Reference documents are cited to provide additional information to readers. In case of conflict between the applicable documents and this document, the Project shall review the conflict to find the most effective resolution.

Applicable Documents

[AD1] NISAR NASA Science Algorithm Software Design Document, JPL D-102254, Rev A, Release 4.0, Jan. 10, 2024.

Reference Documents

[RD1] NISAR Mission Plan, JPL D-80830, Rev. A, Sept. 02, 2021.

[RD2] NISAR Mission Operations Concept Document, JPL D-80832, Rev. A, Sept. 09, 2019.

[RD3] NISAR Mission System Level 3 Requirements, JPL D-76366, Rev. D, Febr. 09, 2022.

[RD4] NISAR Science Data System (SDS) L4 Functional Design Document, JPL D-95657, Rev. A, Mar. 04, 2021.

[RD5] GPS Directorate (2019) “NAVSTAR GPS Space Segment/Navigation User Segment Interfaces, Rev. K” IS-GPS-200, p.36 https://www.gps.gov/technical/icwg/IS-GPS-200K.pdf

1.4 NISAR Track-Frame Database Background

The NISAR mission will orbit the Earth from a near polar orbit with a revisiting time of 12 days. The mission follows a dusk-down acquisition strategy, crossing the equator from ascending and descending passes at 6 AM and 6 PM local time respectively. The onboard L- and S-band radars are capable of covering a swath of ~250 km across the satellite track. With a mechanical maneuver of the platform, the radar observations can be collected from left or right look directions. Both radars can acquire science data in various operational acquisition modes. The latter are mainly defined by the range bandwidth, polarization, and Pulse Repetition Frequency (PRF). The NISAR observation plan is driven by NISAR science needs. The observations are generally contiguous acquisitions which could potentially reach hundreds of seconds. To make the NISAR L1 and L2 data products more user friendly and to manage the processing by the NASA SDS, the ground coverage of the NISAR acquisitions during a full cycle (12 days) is divided into fixed frames on the ground with approximate coverage of ~250 km at the equator.

2 NISAR TRACK-FRAME CHARACTERISTICS

The NISAR TFdb is composed of 173 tracks each representing a full orbit starting from the ascending node at the equator. Tracks are numbered from 1 to 173, with the first track (i.e., track 1) defined as the track whose orbit ascending node crossing at the equator is closest to the prime meridian. Each track contains 176 frames. The polygon defining each frame is fixed on the ground, i.e., the geographical coordinates defining the footprint of each frame on the ground are static in the track-frame database. The start and stop Universal Time Coordinated (UTC) time of each frame, relative to the reference ascending node UTC time (i.e., the time the satellite crosses the equator on the first orbit of a reference cycle), are recorded in the TFdb. Due to the controlled orbit of the NISAR platform, each frame's start and stop time differences from the ascending node time are expected to remain constant. This consistency allows for the assignment of track and frame numbers to the NISAR observations based on the start and stop times of the observation and the ascending node time of the first orbit in the corresponding 12-day cycle.

The TFdb is designed to have a 1-second overlap between subsequent frames. This overlap ensures enough common data between consecutive frames for interferometric or polarimetric science data products, allowing for possible calibration or adjustment at the product boundaries. For example, the overlap region between consecutive frames can be used to adjust unwrapped interferometric phases at the frame boundaries to mosaic the L1 RUNW or L2 GUNW products along a given track.

Most of the science data layers in the NISAR products have a spacing finer than 80 m. Therefore, any filters applied to the products, such as multilooking, have a spatial scale approximately equivalent to the product spacing. As a result, the 1-second overlap, which corresponds to approximately 7 km in the along-track direction, is anticipated to yield sufficient data overlapping at the junction of two consecutive products.

However, the ionospheric phase layer contained in the L1 RUNW and L2 GUNW products requires larger filter lengths, varying from 1-2 km to 20 km, depending on the NISAR acquisition mode and the quality of the InSAR products, which is influenced by the location and time of the observations. A preliminary analysis conducted by NISAR Algorithm Development Team advocates for a 3-seconds overlap between consecutive frames to ensure consistency between the ionospheric phase estimates in the overlapping portions of the products from neighboring frames. This requirement for a 3-seconds overlap should be formalized, and if confirmed, alternative solutions for its implementation in the NISAR SDS should be proposed in the future versions of this document. One possible solution is to increase by 3 seconds the overlap of the frames in the TFdb. Another option is to keep the overlap between the designed frames at 1 second, process the RSLCs with a larger overlap (i.e., 3 seconds), and propagate the same larger overlap to GCOV and GSLC products. The processing of interferometric products could start with input RSLCs with a 3 second overlap until ionospheric phase estimation step. At this stage, a mask of valid regions can be provided to indicate the areas with valid ionospheric phase estimate. The valid ionospheric phase mask corresponds to the region of valid interferometric data fully covered by the smoothing kernel. Figure 2-1 shows this concept where the consecutive frames in the TFdb have 1 second overlap and the RSLC, GSLC and GCOV products 3 seconds overlap, while the InSAR products shrink back to 1 second overlap.

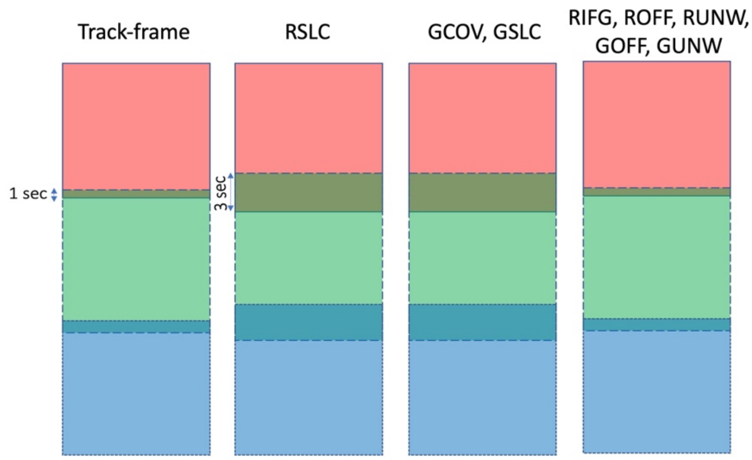

Figure 2-1. The overlap between designed frames and the need for larger overlap between RSLC products.

The NISAR products in the range-Doppler coordinates are aligned with the track-frame and they can essentially be mosaicked by simply concatenating the consequent frames along a given track. The different frames of the NISAR products in the geocoded coordinates can be mosaicked by mosaicking the geocoded grids of each product and accounting for invalid regions and overlaps.

Figure 2-2 shows RSLC products from two consecutive frames indicated as j and j+1 and the corresponding geocoded products for the same frames of j and j+1. The grid of the mosaic of the two geocoded products is also shown.

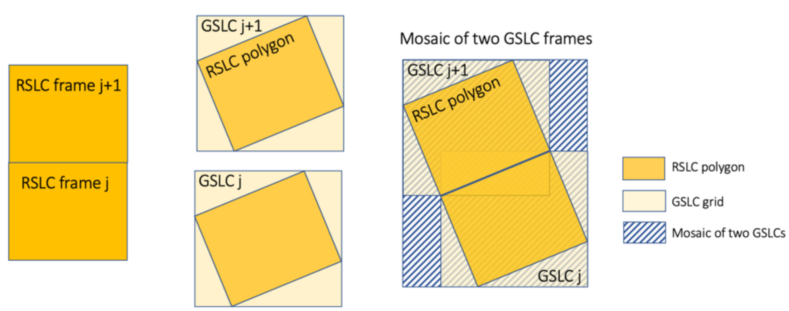

Figure 2-2. Two range-Doppler products from two consecutive frames of j and j+1 and the corresponding geocoded products of the same frames. The right panel shows the mosaic of the two geocoded products from frames j and j+1.

3 RADAR LOOK DIRECTION

The NISAR mission has the capability to acquire data from left or right looking directions. While NISAR science data will be acquired from the left looking direction, during the satellite's commissioning phase, acquisitions may occur from both left and right-looking directions. Due to complete different look directions, the ground coverage of the observations from the same orbit varies, leading to a different definition of tracks and frames. The NASA SDS shall check every L0B observation for its look direction and use the corresponding TFdb accordingly.

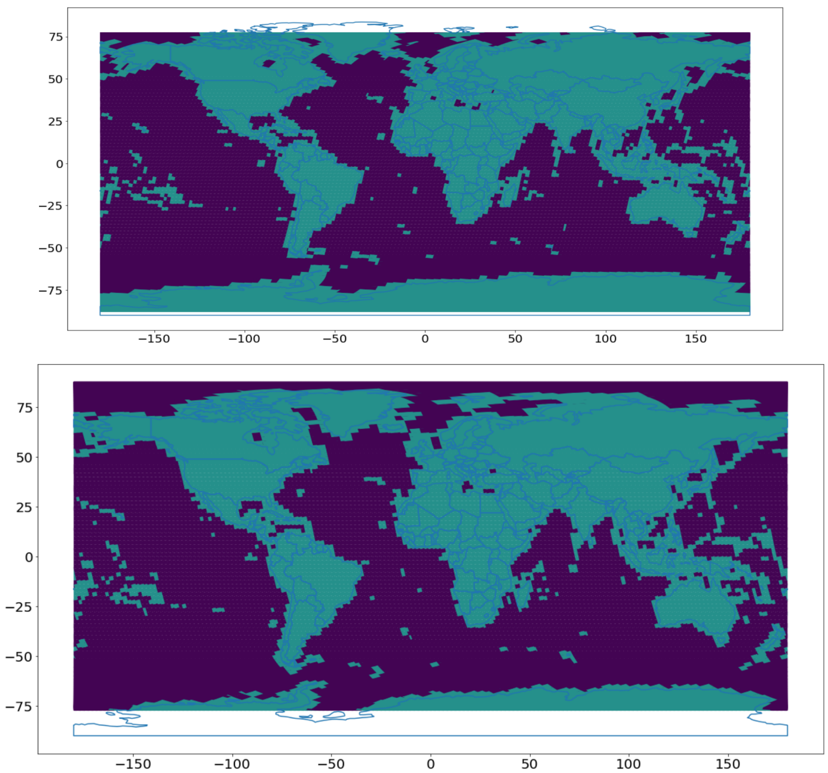

Figure 3-1: NISAR track-frames from the ascending paths for the left- (top) and right-looking (bottom) directions. Green color shows the frames with land coverage.

Figure 3-1 shows TFdb from the ascending paths for the left and right-looking cases. Note that with the NISAR orbit configuration the left-looking observations provide more coverage over Antarctica while the right looking provides more coverage over Arctic region.

4 NISAR TRACK-FRAME FIELDS

The NISAR TFdb must contain the following **required fields** for each frame:

- **track [int]**: Track number with values from 1 to 173
- **frame [int]**: Frame number with values from 1 to 176. Each track consists of 176 frames.
- **passDirection [str]**: the direction of the satellite passing along the orbit with "Ascending" or "Descending" values
- **crossDateline [bool]**: a Boolean flag informing if the given frame is crossing the dateline.
- **startCY [double]**: time difference between the start of the frame and the ascending node time of the first orbit of the reference cycle used to generate the TFdb. The ascending node time is the time that the satellite crosses the equator on the first orbit of the reference cycle used to generate the TFdb.
- **endCY [double]**: time difference between the end of the frame and the ascending node time of the first orbit of the reference cycle used to generate the TFdb.
- **hasLand [bool]**: a Boolean flag indicating if the frame covers any land mass.
- **hasSeaIce [bool]**: a Boolean flag indicating if the frame covers any sea ice.
- **epsg [int]**: the EPSG code indicating the projection system in which the L2 geocoded products will be generated.
- **isCalVal [bool]:** a Boolean flag indicating if the frame covers an instrument Calibration-Validation site.
- **isDNC [bool]:** a Boolean flag indicating if the frame covers sites for which the D&C products need to be generated.
- **produceGSLC [bool]:** a Boolean flag indicating if the GSLC product should be produced for this frame.
- **produceRIFG [bool]:** a Boolean flag indicating if the RIFG product should be produced for this frame.
- **produceRUNW [bool]:** a Boolean flag indicating if the RUNW product should be produced for this frame.
- **produceROFF [bool]:** a Boolean flag indicating if the ROFF product should be produced for this frame.
- **produceGOFF [bool]:** a Boolean flag indicating if the GOFF product should be produced for this frame.
- **produceSMST [bool]:** a Boolean flag indicating if the soil moisture product should be produced for this frame.
- **radioFrequencyInterference [string]:** a string containing the criteria to select which parameter set file needs to be used during the RSLC processing.

- **mapTopLeftX [float]:** the top-left X coordinate of the grid onto which geocode L2 products snapped by 720 m. The coordinate is provided in the projection system specified by “epsg”.
- **mapTopLeftY [float]:** the top-left Y coordinate of the grid onto which geocode L2 products snapped by 720 m. The coordinate is provided in the projection system specified by “epsg”.
- **mapBottomRightX [float]:** the bottom-right X coordinate of the grid onto which geocode L2 products snapped by 720 m. The coordinate is provided in the projection system specified by “epsg”.
- **mapBottomRightLeftY [float]:** the bottom-right Y coordinate of the grid onto which geocode L2 products snapped by 720 m. The coordinate is provided in the projection system specified by “epsg”.
- **insarPSFCriteria [string]:** specifies the criteria used to select the InSAR Parameter Set Files (PSF), which defines the InSAR processing parameters to use for generating InSAR products for the frame. Currently, possible values for the InSAR PSF criteria are “solid_earth”, “mountain_glaciers”, and “ice_sheets”
- **insarProcessor:** indicates the processing architecture used for generating the InSAR products (e.g., RIFG, RUNW, GUNW) for the frame. Valid values are “cpu” and “gpu”, corresponding to the execution on a CPU-based or GPU-based AWS instance
- **offsetsProcessor:** indicated the processing architecture used for generating the InSAR offsets product (e.g., ROFF and GOFF) for the frames. Valid values are “gpu” for execution on an AWS GPU-based machine or “None” when not generating ROFF and GOFF
- **Geometry [POLYGON]**: a polygon defining the boundary of the frame on ground in geographical coordinates.

Figure 3-2 and Figure 3-3 show the frames of the NISAR TFdb which are identified to have land or sea ice in the Arctic and Antarctic regions.

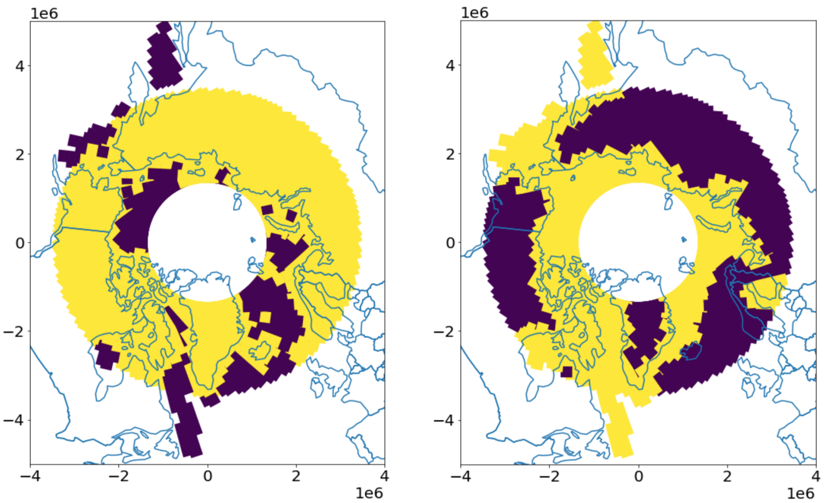

Figure 3-2 Frames of the ascending left-looking tracks that are labeled with left) hasLand and right) hasSeaIce in the Arctic region.

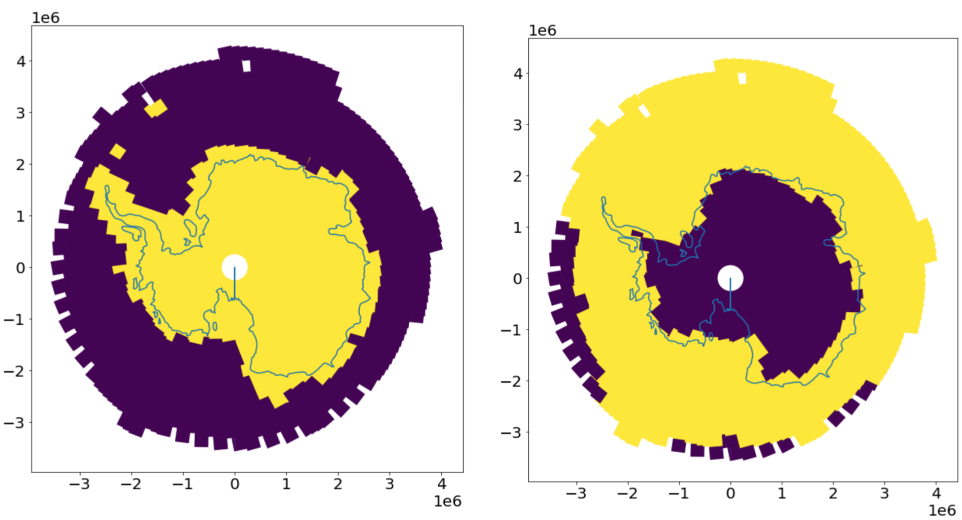

Figure 3-3 Frames of the ascending left-looking tracks that are labeled with left) hasLand and right) hasSeaIce in Antarctica.

The TFdb may also contain additional **optional fields** which are not currently used by the NISAR SDS and therefore not required to be populated.

- **satelliteLat [double]:** Latitude of the satellite at the corner of the frame
- **satelliteLon [double]:** Longitude of the frame at the corner of the frame
- **satelliteHeight [double]:** Height of the satellite above ellipsoid at the middle of the frame
- **velocityAlongTrack [double]:** Along-track component of the platform's velocity vector

- **velocityVertical [double]:** Vertical component of the platform's velocity vector
- **startET [double]:** Ephemerides time of the start of the frame
- **endET [double]:** Ephemerides time of the end of the frame
- **startAX [double]:** time difference between the start of the frame and the ascending node time of the orbit of the current track which the given frame belongs to
- **endAX [double]:** time difference between the end of the frame and the ascending node time of the orbit of the current track which the given frame belongs to
- **swathNearRange [double]:** slant range to the near edge of the frame (near to the satellite)
- **swathFarRange [double]:** slant range to the far edge of the frame (far from the satellite)
- **swathNearLookAngle [double]:** look angle corresponding to the near range
- **swathFarLookAngle [double]:** look angle corresponding to the far range
- **minTopo [double]:** minimum topographic height in the frame
- **maxTopo [double]:** maximum topographic height in the frame
- **medianTopo [double]:** median topographic height in the frame
- **meanTopo [double]:** average topographic height in the frame
- **fractionLand [double]:** percentage of the frame covered by land
- **isSNWG [double]:** flag indicating if the frame covered by the SNWG polygon

5 NASA SDS USAGE OF TRACK-FRAME DATABASE

The NASA SDS will use the TFdb for three main purposes:

1) **Determine which tracks and frames are covered by the L0B raw data observations:**

   The TFdb is primarily used to determine the track and frames covered by the L1 RSLC products which are then taken to higher-level products based on the "NASA SDS processing rules for the NISAR L-band data". For this purpose, the NISAR SDS will receive the ascending node time of the first orbit of every cycle, here after called "SDS cycle reference time", from the STUF file delivered by the Navigation team to the SDS. Given the "SDS cycle reference time", the TFdb can be queried to find the frames that are fully or partially covered by the L0B observations.

2) **Determine which products should be produced over a given frame:**

   Some NISAR standard products are defined only over certain regions on Earth. For example, the D&C products only cover certain areas. Given the track-frame number of the RSLC product, the NISAR SDS can check the TFdb for the given frame and determine the products that need to be generated based on the value of the different production flags such as *produceGSLC*, *produceROFF*, *produceGOFF*, etc.

3) **Determine certain processing parameters to run the SAS**

Some frame-dependent processing parameters are stored in the TFdb and can be used to populate the run configuration file required to run the SAS wrapped by the PGE. An example is the EPSG field which determines the projection system of the L2 geocoded products and is frame dependent. For InSAR processing, the TFdb stores the PSF criteria determining which specific InSAR processing parameters to use to process the frame. These sets of parameters may vary depending on the sensor acquisition mode or on the processing strategy

4) **Determine which processing architecture to use for generating InSAR products**

The *InSARProcessor* field specifies the type of AWS computing resource e.g., CPU or GPU to use for executing the InSAR processing workflow. This allows SDS to route InSAR jobs to the appropriate hardware environment, optimizing performance and ensuring compatibility with the selected InSAR processing configuration.

6 TRACK-FRAME FILE NAMING CONVENTION

The NISAR TFdb is a geospatial database stored in a geopackage format and readable by common spatial analysis software such as geopandas and QGIS. The filename of the TFdb follows the convention:

Mission_TrackFrame_LookDirection _CreationDate.gpkg

where

- NISAR – 5 characters to indicate the mission: NISAR
- TrackFrame – 10 characters for type of the database: TrackFrame
- LookDirection – 1 character representing the look direction: Left looking (L) or Right looking (R)
- CreationDate - 15 characters to indicate the UTC time tag of the product creation time in the YYYYMMDD format

Example:

A right looking NISAR TFdb generated on 20220202 has a filename:

NISAR_TrackFrame_R _20220202.gpkg

A left looking NISAR TFdb generated on 20220222 has a filename:

NISAR_TrackFrame_L_20220222.gpkg

7 ANCILLARY FILES FOR TRACK-FRAME DATABASE GENERATION

The generation of the NISAR TFdb requires multiple datasets.

1- Reference Science Orbit

One cycle of the reference science orbit is the primary input to generate the NISAR TFdb. This is a predicted orbit that is delivered by the Navigation team to Mission Planning. At the time of writing this document, phase D orbit was being used for generating the database. The relevant SPICE format files can be found at the following location:
https://alfresco.jpl.nasa.gov/share/page/site/erm-po/folder-details?nodeRef=workspace://SpacesStore/b56ecc40-4a61-4389-9da7-5120e0811157

2- Digital Elevation Model

We use GMTED 30arc sec for the TFdb as this covers also the Arctic and the Antarctic. This is available at:
https://edcintl.cr.usgs.gov/downloads/sciweb1/shared/topo/downloads/GMTED/Grid_ZipFiles/mn30_grd.zip

3- Sea ice mask

Four KML files with Sea Ice extent for each season is provided by the Mission Planning team. The four files were combined to one polygon in JSON format and used to identify frames with sea ice coverage.

4- Cal/val mask

A dummy shapefile was used as the mask for the cal/val sites to identify frames covering cal/val sites. This mask should be updated with actual cal/val sites and the track-frame should be regenerated.

5- D&C mask

A dummy kml file was used as the mask to identify frames which should be processed to generate the D&C products.

6- Shorelines

The full resolution shoreline shapefiles from NOAA for land masses and for Antarctica was used to populate the hasLand field in the right-looking track-frame database.

https://www.ngdc.noaa.gov/mgg/shorelines/

7- Cryosphere regions mask

A set of two shapefile identifying polar regions (e.g., Antarctica and Greenland) and world mountain glaciers. The shapefiles have been created based on ice velocity datasets provided by the NISAR Cryosphere ST.

- Antarctica ice velocity: https://nsidc.org/data/nsidc-0484/versions/2
- Greenland ice velocity: https://nsidc.org/data/nsidc-0478/versions/2
- Mountain glaciers ice velocity: https://doi:10.5067/6II6VW8LLWJ7

8 ACRONYMS

ADT	Algorithm Development Team
AT	Along Track
AWS	Amazon Web Service
BFPQ	Block adaptive Floating-Point Quantization
Cal/Val	Calibration and Validation (also sometimes cal/val)
CDR	Critical Design Review
CF	Climate and Forecast
CPU	Central Processing Unit
CRSD	Calibration Raw Signal Data
CSV	Comma-separated values
D&C	Dynamics and Control
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
DN	Digital Number
EAR	Export Administration Regulations
ECMWF	European Centre for Medium-Range Weather Forecasts
ECEF	Earth Centered Earth Fixed
EPSG	European Petroleum Survey Group
ESA	European Space Agency
FM	Frequency Modulation
FOE	Forecast Orbit Ephemeris
FOV	Field of View
GCOV	Geocoded Polarimetric Covariance (L2_GCOV)
GCP	Ground Control Point
GDS	Ground Data System
GMTED	Global Multi-resolution Terrain Elevation Data
GNSS	Global Navigation Satellite System
GOFF	Geocoded Pixel Offsets (L2_GOFF)
GPU	Graphics Processing Unit
GSLC	Geocoded Single Look Complex (L2_GSLC)
GUNW	Geocoded Unwrapped Interferogram (L2_GUNW)
HK, HKTM	Housekeeping Telemetry
InSAR	Interferometry Synthetic Aperture Radar
ISCE	InSAR Scientific Computing Environment
ISCE3	InSAR Scientific Computing Environment Enhanced Edition
ISO	International Organization for Standardization

ISRO	Indian Space Research Organisation (British spelling)
L-SAR	L-band Synthetic Aperture Radar
L0B	Level-0B (data)
L1	Level-1 (data)
L2	Level-2 (data)
LOS	Line-Of-Sight
LUT	Lookup Table
Mbps	Megabits per second
MHz	Megahertz
MOE	Medium-fidelity Orbit Ephemeris
NCSA	National Center for Supercomputing Applications
NetCDF4	Network Common Data Form version 4
NISAR	NASA-ISRO Synthetic Aperture Radar
NOAA	National Oceanic and Atmospheric Administration
NOE	Near-Realtime Orbit Ephemeris
PCM	Process Control and Data Management
PDR	Preliminary Design Review
PGE	Product Generation Executable
POD	Precision Orbit Determination
POE	Precision Orbit Ephemeris
PRF	Pulse Repetition Frequency
QA	Quality Assurance
REE	Radar Echo Emulator
RFI	Radio Frequency Interference
RIFG	Range-Doppler Interferogram (L1_RIFG)
ROFF	Range-Doppler Pixel Offsets (L1_ROFF)
RRSD	Radar Raw Signal Data
RRST	Radar Raw Science Telemetry
RSLC	Range-Doppler Single Look Complex (L1_RSLC)
RUNW	Range-Doppler UnWrapped Interferogram (L1_RUNW)
SAR	Synthetic Aperture Radar
SAS	Science Algorithm Software
SDS	Science Data System
SDT	Science Definition Team
SIS	Software Interface Specification
SLC	Single Look Complex
SNAPHU	Statistical-cost, Network-flow Algorithm for Phase Unwrapping

SNWG	Satellite Need Working Group
SPICE	Spacecraft Planet Instrument C-matrix Events
SRTM	Shuttler Radar Topography Mission
ST	Science Team
STUF	Spacecraft Trajectory Utility File
TAI	International Atomic Time (Temps Atomique International)
TCF	Terrain Correction Factor
TEC	Total Electron Content
TFdb	Trackframe Database
SWST	Sampling Window Start Time
UR	Urgent Response
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 84
XML	eXtensible Markup Language (xml in code)
YAML	YAML Ain't Markup Language
UTC	Universal Time Coordinated