



EALG-22011

Advanced Land Observing Satellite-2 (ALOS-2)

PALSAR-2 Level 2.2

Product Format Description

July 2022

Japan Aerospace Exploration Agency (JAXA)

PALSAR-2 Level 2.2

Cloud Optimized GeoTIFF (COG)

Product Format Description

Product Format Description

PALSAR-2 Level 2.2 (COG Format (Level 2.2)) Revision History (1/1)

Rev.	Date	Revision	Revision Contents
NC	2022/7/1		First Edition

Product format Description
(PALSAR Level 2.2, COG format)
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1. Overview

This document describes the format specifications for ALOS-2 PALSAR-2 Cloud Optimized GeoTIFF (COG) Level 2.2 products.

2. Product Specifications

2.1 Composition of Product

PALSAR-2 Level 2.2 COG product is generated according to the Normalised Radar Backscatter of the Analysis Ready Data for Land (CARD4L) product (<https://ceos.org/ard/>) of the Committee on Earth Observation Satellites (CEOS). Table 2-1 shows the overall product composition.

Terrain-flattened Gamma-Nought backscatter coefficient (γ^0), mask, and local incidence angle images are provided in COG format. The COG format is an extension of the GeoTIFF file format which enables more flexible access to Geospatial data. It allows users to perform HTTP range GET requests to extract specific portions of the file's data. COGs can provide the capability to view the file at a downsampled resolution with less data transfer and loading required, through internal file overviews. More information on the COG format can be found at cogeo.org/in-depth.html (Holmes, Cloud Optimized GeoTIFF in depth 2017). COG creation specifications are described in Section 2.2.

GeoTIFF image is an extension format, which allows geographical information to be added within Tagged Image File Format (TIFF) image.

Metadata that includes observation time, map projection, sensor information, external ancillary data information used, etc. is provided in XML (Extensible Markup Language) format.

Table 2-1 Overall composition of the product

Product	Filename	Data type	Format
Terrain-flattened Gamma-Nought backscatter coefficient (γ^0)	Scene ID_Product ID_Polarization_SLP.tif	unsigned int	COG
Mask	Scene ID_Product ID_MSK.tif	byte	COG
Local incidence angle	Scene ID_Product ID_LIN.tif	unsigned int	COG
Metadata	Scene ID_Product ID_summary.xml	-	XML

Scene ID = AAAAABBBBBCCCC-YYMMDD

AAAAA : Satellite/Sensor name (ALOS2)

BBBBB : Orbit accumulation number of a scene center

CCCC : Scene frame number of a scene center

- : Separator

YYMMDD : Observation date of scene center

(YY: lower 2 figures of a year, MM: month, DD: day)

Product ID = DDDEFFFGHI

DDD: Observation Mode

SBS: Spotlight mode

UBS: Ultra-fine mode Single polarization

UBD: Ultra-fine mode Dual polarization

HBS: High-sensitive mode Single polarization
 HBD: High-sensitive mode Dual polarization
 HBQ: High-sensitive mode Full (Quad.) polarimetry
 FBS: Fine mode Single polarization
 FBD: Fine mode Dual polarization
 FBQ: Fine mode Full (Quad.) polarimetry
 WBS: Scan SAR nominal [14MHz] mode Single polarization
 WBD: Scan SAR nominal [14MHz] mode Dual polarization
 WWS: Scan SAR nominal [28MHz] mode Single polarization
 WWD: Scan SAR nominal [28MHz] mode Dual polarization
 VBS: Scan SAR wide mode Single polarization
 VBD: Scan SAR wide mode Dual polarization
 E: Observation Direction
 L: Left looking, R: Right looking
 FFF: Processing Level
 2.2: Level 2.2
 G: Processing Option
 G: Geo-code
 H: Map Projection
 U: UTM
 I: Orbit Direction
 A: Ascending, D: Descending

Polarization (Transmission and Receiving) = XX

HH: Horizontally polarized wave transmission / Horizontally polarized wave receiving
 HV: Horizontally polarized wave transmission/ Vertically polarized wave receiving
 VH: Vertically polarized wave transmission/ Horizontally polarized wave receiving
 VV: Vertically polarized wave transmission/ Vertically polarized wave receiving

2.2 COG Creation Specification

The following configuration options were used to create the COG files.

- ✓ Internal tiling block size: 256x256 pixels
- ✓ Downsampling levels of internal overviews: 2, 4, 8, 16, 32, and 64
- ✓ Interpolation algorithm: "nearest-neighbors"
- ✓ Compression algorithm: "deflate"

3. Product Format

3.1 Terrain-flattened Gamma-Nought backscatter coefficient (γ^0)

Image file is a COG formatted one with each pixel value in integer, and location information and map projection information on its header. Image data is recorded in little endian.

3.1.1 TIFF tag

Some TIFF-tags used in GeoTIFF file are shown in Table 3-1.

Table 3-1 TIFF tags in the Terrain-flattened Gamma-Nought backscatter coefficient (γ^0) (1/3)

No.	Tag name	Tag type	Description	Remark
1	ImageLength	LONG	Number of lines	
2	ImageWidth	LONG	Number of pixels	
3	BitsPerSample	SHORT	Number of bits in one sample = 16 (fixed value)	
4	Compression	SHORT	Compression type = 8 (fixed value)	1 = No compression 2 = ITU-T Group3 1 dimension Huffman run length encoding 3 = ITU-T Group3 fax encoding 4 = ITU-T Group4 fax encoding 5 = LZW (fixed-length) compression 6 = JPEG compression (old style) 7 = JPEG compression (new style) 8 = Deflate compression 32773 = Packbits compression

Table 3-1 TIFF tags in the Terrain-flattened Gamma-Nought backscatter coefficient (γ^0) (2/3)

No.	Tag name	Tag type	Description	Remark
5	PhotometricInterpretation	SHORT	Color space type of bitmap image data = 1 (fixed value)	0 = WhiteIsZero (Pixel value: White=0, Black=(2 ^{BitsPerSample} -1)) 1 = BlackIsZero (Pixel value: Black=0, White=(2 ^{BitsPerSample} -1)) 2 = RGB direct color (Min = 0, max= (2 ^{BitsPerSample} -1)) 3 = Colormap (min= 0, max= (2 ^{BitsPerSample} -1)) 4 = Transparency Mask (definition of masked region)
6	Orientation	SHORT	Orientation of image = 1 (fixed value).	1 = row: Top to Bottom, column: Left to Right 2 = row: Top to Bottom, column: Right to Left 3 = row: Bottom to Top, column: Right to Left 4 = row: Bottom to Top, column: Left to Right 5 = row: Left to Right, column: Top to Bottom 6 = row: Right to Left, column: Top to Bottom 7 = row: Right to Left, column: Bottom to Top 8 = row: Left to Right, column: Bottom to Top
7	SamplesPerPixel	SHORT	Number of samples in one pixel = 1 (fixed value)	

Table 3-1 TIFF tags in the Terrain-flattened Gamma-Nought backscatter coefficient (γ^0) (3/3)

No.	Tag name	Tag type	Description	Remark
8	PlanarConfiguration	SHORT	Storing order of the data = 1 (fixed value)	1 = Chunky format: The component values for each pixel are stored contiguously (example: RGBRGBRGB...) 2 = Planar format: The components are stored in separate components. (example: RRR... GGG... BBB...)"
9	SampleFormat	SHORT	Data type information = 1	1 = unsigned integer 2 = signed integer 3 = float 4 = undefined 5 = complex integer 6 = complex float

3.1.2 GeoTIFF tag

GeoTIFF tags of Image file are shown in Table 3-2.

Table 3-2 Geo TIFF tags in the Terrain-flattened Gamma-Nought backscatter coefficient (γ^0) (1/3)

No	Tag name	Tag type	Description	Remark
1	ModelTiepointTag	DOUBLE	Tie point information	(I,J,K,X,Y,Z) (I, J, K) is the image coordinates and (X, Y, Z) is the corresponding ground coordinates.
2	ModelPixelScaleTag	DOUBLE	Pixel scale information	(ScaleX, ScaleY, ScaleZ) Pixel spacing in the X, Y, Z directions
3	GTModelTypeGeoKey	SHORT	Coordinate system type = 1 (fixed value)	1 = ModelTypeProjected (Projection Coordinate System) 2 = ModelTypeGeographic (Geographic Latitude-Longitude System) 3 = ModelTypeGeocentric (Geocentric (X, Y, Z) Coordinate)

Table 3-2 Geo TIFF tags in the Terrain-flattened Gamma-Nought backscatter coefficient (γ^0) (2/3)

No	Tag name	Tag type	Description	Remark
4	GTRasterTypeGeoKey	SHORT	Alignment of pixel value = 1 (fixed value)	1=PixellsArea The first pixel applies the domain surrounded by (0, 0), (0, 1), (1, 0), and (1, 1). The center of pixel is located in (0.5, 0.5). <pre> (0,0) (1,0) ↓ ↓ # ----- # ----- # ----- + + # ----- # ----- # ----- ↑ ↑ (0,1) (1,1) </pre> 2=PixelISPoint The first pixel applies the domain surrounded by (-0.5,-0.5), (0.5,-0.5), (-0.5, 0.5), (0.5, 0.5). The center of pixel is located in (0,0). <pre> (0,0) (1,0) ↓ ↓ + ----- + ----- + ----- + ----- + ----- + ----- ↑ ↑ (0,1) (1,1) </pre>
5	GTCitationGeoKey	ASCII	Zone number in UTM coordinate system	Example: "UTM Zone 54, Northern Hemisphere"

Table 3-2 Geo TIFF tags in the Terrain-flattened Gamma-Nought backscatter coefficient (γ^0) (3/3)

No	Tag name	Tag type	Description	Remark
6	GeogCitationGeoKey	ASCII	Geographic coordinate system: "WGS 84" (fixed value)	
7	GeogAngularUnitsGeoKey	SHORT	Coordinates unit (angle) = 9102 (fixed value)	9102=Angular_Degree[deg]
8	ProjectedCSTypeGeoKey	SHORT	Map projection code	When the map projection method is UTM: 32601~32660、32701~32760
9	ProjLinearUnitsGeoKey	SHORT	Projection coordinates unit (length) = 9001 (fixed value)	9001=Linear_Meter[m]

3.2 Local incidence angle, mask products

The local incident angle is the angle formed by the radar irradiation direction and the normal of the slope. The value multiplied by 100 is stored as an unsigned integer (16 bits).

The contents of the mask products are shown in Table 3-3. It is stored as an unsigned integer (8 bits).

Table 3-3 Content of the mask product

Value	Category
0	No data
1	Valid data
2	Layover
3	Shadowing
4	Ocean Water
5	Invalid data

3.2.1 TIFF tag

Some TIFF-tags used in the GeoTIFF file are shown in Table 3-4.

Table 3-4 TIFF tags in the local incidence angle/ mask (1/3)

No.	Tag name	Tag type	Description	Remark
1	ImageLength	LONG	Number of lines	
2	ImageWidth	LONG	Number of pixels	
3	BitsPerSample	SHORT	Number of bits in one sample	Local incidence angle: 16 Mask: 8
4	Compression	SHORT	Compression type = 8 (fixed value)	1 = No compression 2 = ITU-T Group3 1 dimension Huffman run length encoding 3 = ITU-T Group3 fax encoding 4 = ITU-T Group4 fax encoding 5 = LZW (fixed-length) compression 6 = JPEG compression (old style) 7 = JPEG compression (new style) 8 = Deflate compression 32773 = Packbits compression

Table 3-4 TIFF tags in the local incidence angle/ mask (2/3)

No.	Tag name	Tag type	Description	Remark
5	PhotometricInterpretation	SHORT	Color space type of bitmap image data = 1 (fixed value)	0 = WhiteIsZero (Pixel value: White=0, Black=(2 ^{BitsPerSample} -1)) 1 = BlackIsZero (Pixel value: Black=0, White=(2 ^{BitsPerSample} -1)) 2 = RGB direct color (Min = 0, max= (2 ^{BitsPerSample} -1)) 3 = Colormap (min= 0, max= (2 ^{BitsPerSample} -1)) 4 = Transparency Mask (definition of masked region)
6	Orientation	SHORT	Orientation of image = 1 (fixed value).	1 = row: Top to Bottom, column: Left to Right 2 = row: Top to Bottom, column: Right to Left 3 = row: Bottom to Top, column: Right to Left 4 = row: Bottom to Top, column: Left to Right 5 = row: Left to Right, column: Top to Bottom 6 = row: Right to Left, column: Top to Bottom 7 = row: Right to Left, column: Bottom to Top 8 = row: Left to Right, column: Bottom to Top
7	SamplesPerPixel	SHORT	Number of samples in one pixel = 1 (fixed value)	

Table 3-4 TIFF tags in the local incidence angle/ mask (3/3)

No.	Tag name	Tag type	Description	Remark
8	PlanarConfiguration	SHORT	Storing order of the data = 1 (fixed value)	1 = Chunky format: The component values for each pixel are stored contiguously (example: RGBRGBRGB...) 2 = Planar format: The components are stored in separate components. (example: RRR... GGG... BBB...)"
9	SampleFormat	SHORT	Data type information = 1	1 = unsigned integer 2 = signed integer 3 = float 4 = undefined 5 = complex integer 6 = complex float

3.2.2 GeoTIFF tag

GeoTIFF tags of Image file are shown in Table 3-5.

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Table 3-5 Geo TIFF tags in the local incidence angle/mask (1/3)

No	Tag name	Tag type	Description	Remark
1	ModelTiepointTag	DOUBLE	Tie point information	(I,J,K,X,Y,Z) (I, J, K) is the image coordinates and (X, Y, Z) is the corresponding ground coordinates.
2	ModelPixelScaleTag	DOUBLE	Pixel scale information	(ScaleX, ScaleY, ScaleZ) Pixel spacing in the X, Y, Z directions
3	GTModelTypeGeoKey	SHORT	Coordinate system type = 1 (fixed value)	1 = ModelTypeProjected (Projection Coordinate System) 2 = ModelTypeGeographic (Geographic Latitude-Longitude System) 3 = ModelTypeGeocentric (Geocentric (X, Y, Z) Coordinate

Table 3-5 Geo TIFF tags in the local incidence angle/mask (2/3)

No	Tag name	Tag type	Description	Remark
4	GTRasterTypeGeoKey	SHORT	Alignment of pixel value = 1 (fixed value)	1=PixellsArea The first pixel applies the domain surrounded by (0, 0), (0, 1), (1, 0), and (1, 1). The center of pixel is located in (0.5, 0.5). <pre> (0,0) (1,0) ↓ ↓ # ----- # ----- # ----- + + # ----- # ----- # ----- ↑ ↑ (0,1) (1,1) </pre> 2=PixelISPoint The first pixel applies the domain surrounded by (-0.5,-0.5), (0.5,-0.5), (-0.5, 0.5), (0.5, 0.5). The center of pixel is located in (0,0). <pre> (0,0) (1,0) ↓ ↓ + ----- + ----- + ----- + ----- + ----- + ----- ↑ ↑ (0,1) (1,1) </pre>
5	GTCitationGeoKey	ASCII	Zone number in UTM coordinate system	Example: "UTM Zone 54, Northern Hemisphere"

Table 3-5 Geo TIFF tags in the local incidence angle/mask (3/3)

No	Tag name	Tag type	Description	Remark
6	GeogCitationGeoKey	ASCII	Geographic coordinate system: "WGS 84" (fixed value)	
7	GeogAngularUnitsGeoKey	SHORT	Coordinates unit (angle) = 9102 (fixed value)	9102=Angular_Degree[deg]
8	ProjectedCSTypeGeoKey	SHORT	Map projection code	When the map projection method is UTM: 32601~32660、 32701~32760
9	ProjLinearUnitsGeoKey	SHORT	Projection coordinates unit (length) = 9001 (fixed value)	9001=Linear_Meter[m]

3.3 Metadata

The metadata is generated in xml format and corresponds to the Normalised Radar Backscatter of the CARD4L product. The contents of the metadata are shown in Table 3-6.

Table 3-6 Metadata item list (1/6)

Item	Description	Format/remarks
<Product>	Product type	Product Copyright="JAXA/EORC" type="Normalised Radar Backscatter"
<DocumentIdentifier>	Document Identifier	type="URL" https://ceos.org/ard/files/PFS/NRB/v5.5/CARD 4L-PFS_NRB_vx.x.pdf x.x: version numner
<DataCollectionTime> <NumberOfAcquisitions> <FirstAcquisitionDate> <LastAcquisitionDate>	Data collection time Number of data used Observation date of the first acquisition (UTC) Observation date of the last acquisition (UTC)	1(fixed value) YYYY-MM-DDThh:mm:ss.tttttZ YYYY : year MM : month (01~12) DD : day (01~31) hh : hour (00~23) mm : minute (00~59) ss : second (00~60) tttttt : micro second (000000~999999)
<SourceAttributes>	Attributes of source data used	Subsection header acqID="N" N: Number of data used
<SourceDataRepository>	Source Data Access	
<Satellite>	Satellite name	ALOS2(fixed value)
<Instrument >	Sensor name	PALSAR-2(fixed value)
<SatelliteReference>	Satellite information	
<SourceDataAcquisitionTime> <StartTime> <EndTime>	Source Data Acquisition time Start time End time	
<SourceDataAcquisitionParameters> <RadarBand> <RadarCenterFrequency> <ObservationMode> <Polarizations> <AntennaPointing> <BeamID> <RSP_Path_Number> <RSP_Frame_Number>	Source Data Acquisition Parameters Radar band Center frequency Observation mode Polarization Antenna pointing direction Beam ID Scene path number Scene frame number	L (fixed value) units = "GHz" Right or Left
<OrbitInformation > <PassDirection > <OrbitDataSource>	Source Data Orbit information Pass direction Orbit data source	Ascending or Descending [e.g., predicted/definite/precise/ downlinked etc.]

Table 3-6 Metadata item list (2/6)

Item		Description	Format/remarks
	<SourceProcParam> <ProcessingFacility> <ProcessingDate> <SoftwareVersion> <ProductID> <ProductLevel> <AzimuthNumberOfLooks> <RangeNumberOfLooks>	Source data processing parameters Processing facility Processing date Software version Product ID Product level Azimuth number of looks Range number of looks	YYYY-MM-DDThh:mm:ss.tttttZ SLC (fixed value) 1(fixed value) 1(fixed value)
	<SourceDataImageAttributes> <SourceDataGeometry> <AzimuthPixelSpacing> <RangePixelSpacing> <AzimuthResolution> <RangeResolution> <IncAngleNearRange> <IncAngleFarRange>	Source Data Image Attributes Image geometry Azimuth pixel spacing Range pixel spacing Azimuth resolution Range resolution Incident angle in near range Incident angle in far range	Well-known text (WKT) format
	<PerformanceIndicators> <NoiseEquivalentIntensity> <Estimates>	Image quality performance indicators Noise Equivalent Intensity (NESZ) Estimated value	Repeat number of polarizations Type of backscatter measurements type=["Beta0"or "Sigma0"or" Gamma0"] "N/A" is described for the observation mode and beam for which the estimated value is not published.
	<CARD4LProductAttributes>	CARD4L Product Attributes	Subsection header
	<DataAccess> <ProcessingFacility> <ProcessingTime> <SoftwareVersion> <Repository>	Processing parameter details Processing facility Processing time Software version Where to access the product	YYYY-MM-DDThh:mm:ss.tttttZ
	<ProductSampleSpacing> < ProductColumnSpacing > < ProductRowSpacing >	Product pixel spacing Column spacing Row spacing	

Table 3-6 Metadata item list (3/6)

Item		Description	Format/remarks
	<Filtering > <FilterApplied> <FilterType> <WindowSizeCol > <WindowSizeLine>	Filtering attributes Flags for filtering Filter type Window size in the column direction Window size in the line direction	TRUE/FALSE Not described if False Not described if False Not described if False
	<ProductBoundingBox> <Northing> <Easting>	Product Bounding Box	Describes geometric information in the coordinate system used at upper left and lower right diagonal corners
	<ProductGeographicalExtent>	Image geometry	Well-known text (WKT) format
	<SceneCenterLatitude>	Latitude at the scene center	
	<SceneCenterLongitude>	Longitude at the scene center	
	<SceneCornerLatitude> <SceneCornerLongitude>	Latitudes at the four corners of the scene Longitude at the four corners of the scene	Stored in the order of "UL, LL, UR, LR"
	<ProductImageSize> <NumberLines> <NumPixelsPerLine>	Product Image Size Number of lines Number of pixels	
	<PixelCoordinateConvention>	Definition of pixel coordinate	Values are [pixel centre, pixel ULC or pixel LLC]
	<CoordinateReferenceSystem>	Map projection related parameters used	EPSG code
	<CoordinateReferenceSystem>	Map projection related parameters used	Well-known text (WKT) format

Table 3-6 Metadata item list (4/6)

Item		Description	Format/remarks
	<PerPixelMetadata>	Per-Pixel Metadata	
	<DataMask>	Mask image information	
	<FileName>	Filename	
	<SampleType>	Metadata type	Mask (fixed value)
	<DataFormat>	Data format	Cloud Optimized GeoTIFF (fixed value)
	<DataType>	Data type	BYTE (fixed value)
	<BitsPerSample>	Bits per sample	8 (fixed value)
	<BitValues>	Value attributes	
	<NoData>	No data	0 (fixed value)
	<ValidData>	Valid data	1 (fixed value)
	<Layover>	Layover	2 (fixed value)
	<Shadow>	Shadow	3 (fixed value)
	<OceanWater>	Ocean	4 (fixed value)
	<InvalidData>	Invalid data	5 (fixed value)
	<LocalIncAngle>	Local incident angle image information	
	<FileName>	Filename	
	<SampleType>	Metadata type	Angle (fixed value)
	<DataFormat>	Data format	Cloud Optimized GeoTIFF (fixed value)
	<DataType>	Data type	UINT (fixed value)
	<BitsPerSample>	Bits per sample	16(fixed value)
	<ByteOrder>	Byte order	Little Endian (fixed value)
	<ConversionEq>	Conversion equation	LocalIncAngle=0.01*DN, units="degree"

Table 3-6 Metadata item list (5/6)

Item		Description	Format/remarks
	<BackscatterMeasurementData>	Backscatter measurement data	Repeat number of polarizations
	<BackscatterMeasurement>	Type of backscatter measurements	Gamma-0(fixed value)
	<BackscatterConvention>	Convention of backscatter measurements	Amplitude (fixed value)
	<BackscatterConversionEq>	Conversion to normalised radar cross section	10*log10(DN^2)-83, units="dB"
	<Polarization>	Polarization	
	<FileName>	File name	
	<DataFormat>	Data format	Cloud Optimized GeoTIFF (fixed value)
	<DataType>	Data type	UINT(fixed value)
	<BitsPerSample>	Bits per sample	16 (fixed value)
	<ByteOrder>	Byte order	Little Endian (fixed value)
	<BackscatterConversionEq>	Conversion to normalised radar cross section	$\gamma_0 = 10 \cdot \log_{10}(\text{DN}^2) - 83$, units="dB"
	<NoiseRemoval>	Noise removal	
	<NoiseRemovalApplied>	Flags for noise removal	TRUE/FALSE
	<NRAlgorithm>	Noise removal algorithm	Not described if False
	<RTCAAlgorithm>	Radiometric Terrain Corrections Algorithms	DOI of the reference
	<NoiseRemoval>	Noise removal	
	<NoiseRemovalApplied>	Flags for noise removal	TRUE/FALSE
	<NRAlgorithm>	Noise removal algorithm	Not described if FALSE
	<RadiometricTerrainCorrections>		
	<RTCAAlgorithm>	Radiometric Terrain Corrections Algorithms	DOI of the reference

Table 3-6 Metadata item list (6/6)

Item		Description	Format/remarks
	<GeometricCorrections>	Geometric Corrections	
	<DigitalElevationModel>	Type of DEM used	"Elevation" or "Surface"
	<DEMReference>	Reference for the DEM used	URL
	<EGMReference>	Reference for the Geoid model used	DOI of the reference
	<GeoCorrAccuracy>	Geometric Accuracy	Geometric accuracy of source data by point target evaluation
	<NorthernSTDev>	Standard deviation of northing error	"N / A" is described for the observation mode and beam whose geometric accuracy is not published.
	<EasternSTDev>	Standard deviation of easting error	
	<NorthernBias>	Bias of northing error	
	<EasternBias>	Bias of easting error	
	<GriddingConvention>	Gridding Convention	
	<IonosphericDelayCorrection>	Ionospheric delay correction	TRUE/FALSE "TEC model" or "Coregistration" Not described if FALSE For ScanSAR data, the correction for each scan is described from the first scan. Described when <IDCMethod> is "TEC model"
	<IonosphericDelayCorrectionApplied>	Flags for ionospheric delay correction	
	<IDCMethod>	Geometric correction method	
	<SlantRangeCorrection>	Slant range corrections (m)	
	<TECReference>	Reference of the TEC used	