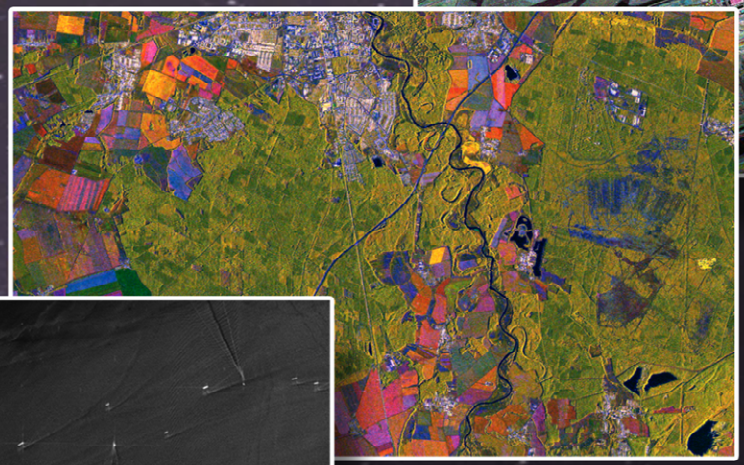
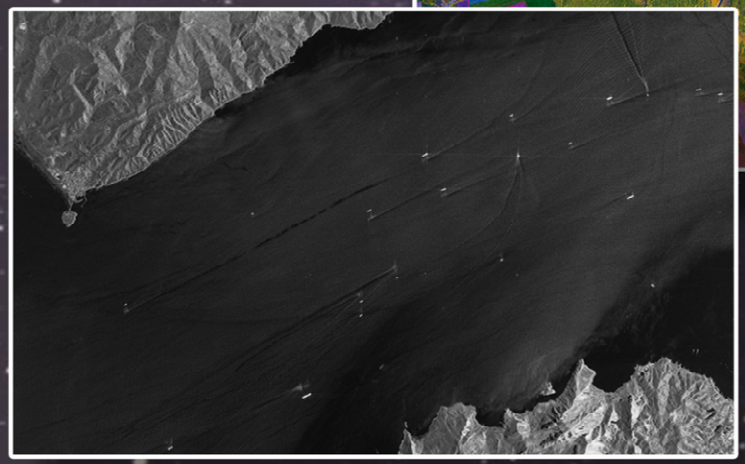
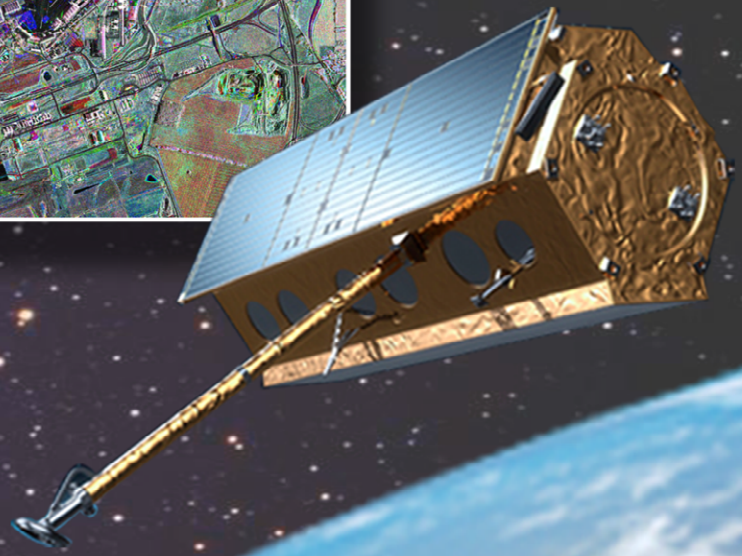
Airbus Radar Constellation Application Guide







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Radar Constellation (TerraSAR-X/PAZ) Satellite Image Applications, Acquisition Modes and Parameters

For reference use only, this document should be used as a guideline for understanding the Acquisition Modes of the Radar Constellation (German TerraSAR-X/TanDEM-X satellite formation (Airbus) and Spanish PAZ satellite (Hisdesat)). The indivdual Acquisition Modes differ in spatial coverage and resolution. Together with the available polarisations and incidence angles they are used for various different applications. To get further technical support and to ensure the selection of the optimum product for your specific application, please contact Airbus before submitting your order.

The **six key ordering parameters**:

1) **Area of Interest (place)**
2) **Acquisition Window (time)**
3) **Acquisition/Imaging Mode (6 modes available)**
4) **Orbit Direction**
5) **Polarisation**
6) **Incidence Angle (or Relative Orbit)**

The **imaging modes** from coarse resolution and large area coverage to fine resolution and coverage at the spot: WS Wide ScanSAR (40.0m), SC ScanSAR (18.0m), SM StripMap (3.0m), SL SpotLight (2.0m), HS High Resolution SpotLight (1.0m), ST Staring SpotLight (0.25m)

The choice of the **image product** (SSC, MGD, GEC, EEC) depends on the skills of the analyst and the available software implementation. In the table, recommendations are given, which are based on the experience with our clients. In MGD, GEC, EEC, resolution variants RE (radiometrically enhanced fo automated methods) or SE (spatially enhanced for visual exploitation) can be chosen.

Both **rapid and science orbit** calculation options can be used for interferometric applications.See abbreviations below.

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
1. Mapping and Charting - Imagery for Reconnaissance				
Recognition of infrastructure (e.g. road, rail, man-made structures) and **Topographic mapping** (e.g. types of terrain, forest, grassland, landcover, water)	StripMap (SM) SpotLight (SL) High Resolution SpotLight (HS) and Staring SpotLight (ST) depending on desired map scale and required minimum mapping unit (MMU)	Single polarisation data HH, to have maximum contrast between land cover classes, or VV, if texture of target class is important.	30°- 40° Small incidence angles if scattered / leafless vegetation shall be penetrated (close to 20°). Large incidence angle, if vegetation structure is important for recognition (close to 50°)	▪ Scale 1:25,000 to 1:50,000 for SM or SL ▪ Scale 1:5,000 or better for HS and ST. Small metal objects scatterers < 1 m sometimes detectable. ▪ Season of observation may be important (rainy season may show thunderstorm clouds in subtropical and tropical areas) ▪ Ascending and descending orbits may be required, depending on terrain of adverse orientation of objects towards the radar **Processing Parameters:** ▪ EEC ▪ Depending or radar expertise, the analysis can be done with SSC products. ▪ SE product variant is preferred for visual interpretation among classes, RE is required for any time series analysis ▪ Rapid or Science orbit
2. Structure Location and Identification				
Recognition of man-made objects (e.g. buildings, aircrafts, vehicles, vessels, pylons, lattice masts)	High Resolution SpotLight (HS) Staring SpotLight (ST)	Single polarisation HH preferred, since contrast vs. surrounding vegetation is best	Large incidence angles around 40°-50° Small incidence angles 20°-30° for roundish shapes (aircrafts), which will have a characteristic layover	▪ Important features which are needed for the interpretation are visible in both the shadow and the layover of objects (imagery acquired at large incidence angle close to 55° still shows enough layover and a large shadow for visual interpretation, e.g. of building façades,). Small incidence angles will be needed if forward scattering is stronger then backscattering. Layover is required for object interpretation. ▪ Awareness for the orientation of the object towards the radar will help select ascending or descending orbits. Make use of both ascending and descending orbits to obtain more holistic information from both possible observation directions in case of steep terrain or adverse orientation of

				object towards the radar.

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
Structure Location and Identification - Continued				
Recognition of man-made objects (e.g. buildings, aircrafts, vessels, pylons, lattice masts) - continued				▪ ST mode covers 4.0 x 3.7 km at 60 degr. inc. angle. ▪ HS mode covers 5.0 x 10 km **Processing Parameters:** ▪ SSC image for radar experts in case phase difference between image pairs needs to be exploited. ▪ MGD preferred, since data volume is small, if geocoding is unimportant (e.g. for working with a reference point) ▪ GEC preferred in order to avoid resampling artefacts of the EEC product in layover and shadow areas caused by the underlying DEM. Both, geolocation accuracy and superposition of two GEC products is still excellent in flat terrain. An image shift in range may need to be applied. ▪ SE product variant preferred over RE, due to best available spatial resolution. ▪ Rapid or Science Orbit
Ground Control Point Collection				
Ground Control Point Extraction (GCP) generation from Stereo Pairs (Radargrammetry)	StripMap (SM) and SpotLight (SL, HS, ST) can be used depending on desired degree of detail	Single polarisation, HH mostly preferred, since contrast among objects is best	At least one image at small incidence angle (close to 20°), one image at large incidence angle, better three images	▪ Applied method is radargrammetry ▪ GCPs are for example used for optical image rectification ▪ Depending on required accuracy, more than 2 acquisitions are needed, e.g. 2 ascending and 2 descending orbits acquired at large and small incidence angles, equired ▪ Stereo angle or disparitiy angle between images close to 21° preferable. **Processing Parameters:** ▪ MGD product is preferred since processing artefacts are minimal and moise level is low. Some radargrammetry software packages use SSC products. ▪ SE product variant preferred for maximum resolution ▪ Rapid or Science orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
4. Digital Elevation Models				
DEM derived from inteferometric image pairs	StripMap (SM) and SpotLight imaging modes (SL and HS) can be used	All polarisations, but need to be the same among image pairs	20°-55° Far range position close to 55° preferred, minimises layover effect	▪ DEM will be a digital surface model (DSM) top-of-canopy. ▪ Interferometric image pairs or stacks: the same incidence angle, orbit direction , polarisation required ▪ Applicability is restricted by dense vegetation cover and adverse atmospheric effects due to 2.5 day (near poles) to 11 day (near equator) offset between image pair acquisitions. Shorter temporal offset will be possible with PAZ (4 days and 7 days). ▪ HH polarisation preferred due to best contrast on land. **Processing Parameters:** ▪ SSC data format (single look slant range complex data format required, including amplitude and phase information) ▪ SSC is only available as RE procssing variant ▪ Rapid or Science Orbit
DEM derived from stereo image pairs (Radargrammetry)	StripMap (SM)	Single polarisation, HH mostly preferred due to best contrast	One image at small incidence angle (e.g. 25°), one image at large incidence angle (e.g. 45°)	▪ Data pairs acquired at different incidence angles are needed ▪ Disparity angle between images of 15° and 25° are recommended ▪ One pair of small and large incidence angle needs to be acquired at ascending orbit , the opposite image pair, also acquired at small and large incidence angles needs to be acquired at descending orbit (similar incidence angles if possible) ▪ Small temporal offset between acquisitions if possible. This depends on geographic latitude of the AOI. Processing Parameters: ▪ MGD product ▪ SE product variant required ▪ Rapid or Science Orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
5. Trail, Track and Path Detection				
Border control and border monitoring	StripMap (SM) and SpotLight modes (SL and HS)	Single polarisation with HH or VV, dual polarisation HH/VV as supplementary information	Any, but the same for image pairs or image stacks	▪ Amplitude Change Detection can be used in vegetated areas, Coherence Change Detection can be applied if the clutter coherence is high (e.g. non-vegetated areas, arid areas, deserts) ▪ MGD or GEC products need to be coregistered and geocoded, or EEC can be used for ACD ▪ SSC is product required for CCD ▪ Co-polarisation phase may be useful, Note: reduced spatial coverage and spatial resolution, if dual polarisation data are used ▪ In some cases, multitemporal data stack analysis - average amplitude image may reveal more detailed information due to better speckle suppression ▪ Ascending and descending image stacks may be required depending on terrain and visibility of objects. ▪ Awareness of time critical analysis needs to be raised: i.e. the satellite repeat cycle needs to be observed (2.5 days near poles, 11 days near equator) **Processing Parameters:** ▪ MGD, GEC, EEC or SSC depending on method and expertise ▪ Rapid or Science orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
6. Moving Target Indication				
Ship velocity estimation	ScanSAR (SC) and StripMap (SM)	Single polarisation HH	Intermediate incidence angle (30-35°)	▪ StripMap is a good compromise of covered area vs. spatial resolution ▪ Along track interferometry is not operational at the moment
Motorway monitoring/parking lot monitoring	StripMap (SM) and SpotLight (SL and HS)	All polarisations	Intermediate incidence angle (30-35°)	▪ Consider acquisitions times at 6 am and 6pm ▪ Amplitude data HH or VV show parked vehicles. Coherence can be exploited for change detection. ▪ Along track interferometry. ▪ SSC ▪ Science or Rapid Orbit
7. Disaster Extent and Damage Assessment				
Risk and vulnerability assessment (pre-disaster) and **Damage Assessment** (post-disaster)	All modes, depending on the required coverage and spatial accuracy, or even down to the highest spatial resolution at ST mode, if key objects/buildings are investigated	Single polarisation HH for best contrast between vegetation and man-made objects Single polarisation VV for texture Cross polarisation HV or VH for specific vegetation types	Small angles (close to 20°) for penetration of scattered vegetation; Large angles (close to 50°) for any information about vegetation and terrain	Note the comments on the recognition of man-made objects above. ▪ Monitoring of the area of interest pre- and post- disaster ▪ Generation of up-to-date reference maps ▪ Before / after comparison, amplitude change detection (ACD) ▪ Joint interpretation with optical imagery in order to achieve a longer observation period or to overcome acquisition gaps **Processing Parameters:** ▪ SE product for best differentiation of man-made structures, RE product required for vegetation assessment over time. ▪ Rapid or Science Orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
Disaster Extent and Damage Assessment - Continued				
Earthquakes	Mainly StripMap (SM) to cover larger areas	Single polarisation HH	30°- 40° depending on the damage assessment method used	▪ Deformation estimation based on interferogram stacking methods: o DInSAR (Differential Interferometry, 2-4 images over months or even years to study longterm effects); SSC products are required o SBAS (Short Baseline Subset Approach) for extended non-urban areas; more than 10 SSC products required o PSI (Persistant Scatterer Interferometry) for built-up areas: more than 15 SSC products required ▪ Shorter term monitoring (1-2 years) by interferogram stacking (PSI and SBAS): High observation frequency (11 day repeat), if possible ▪ The order of magnitude for the deformation estimation: centimeters (cm) to decimeters (dm) per day or event ▪ At near real-time conditions directly after the earthquake, visual assessment of the damages can be achieved using pre- and post-event imagery from SAR or optical satellites (possible input: MGD or GEC SE input depending on software); EEC data will include some artefacts, where DEM data were inavailble for product generation. ▪ Ascending and descending orbits can be required, if terrain is complex **Processing Parameters:** ▪ SSC for Interferometry or MGD, GEC for image to image comparison ▪ SE processing variant for image to image comparison; RE variant for interferometry ▪ Science or Rapid Orbit for SSC exploitation; Predicted or Rapid Orbit for visual interpretation
Flood Extent Mapping	Preferably SM,SC, or WS depending on area size	Single polarisation HH or VV for best contrast between water and land surfaces	> 30° preferred	▪ Choice of polarisation is based on backscattering analysis. On low to moderate wind conditions HH polarisation allow better discrimination between the flood (calm water) and the surrounding land. ▪ Rough surfaces of water next to rough vegetation surfaces may cause misinterpretations ▪ Built-up areas are excluded due to potential misinterpretation of building layovers ▪ Water under vegetation cover is not found (e.g. mangroves, other flooded vegetation)

				Processing Parameters: ▪ GEC or EEC or ORISAR (orthorectified image) depending on avaiable software (SSC may be used by some software packages) ▪ SE processing variant for best spatial resolution ▪ Science or Rapid Orbit
Volcanoes	StripMap (SM) and SpotLight (SL and HS) to cover the crater	Single polarisation HH	Small incidence angle (close to 20°)	▪ At near real-time conditions, visual assessment of the damages using a pre-event imagery also from optical sensors ▪ Long term observation at a moderate temporal sampling rate using DInSAR;PSI or SBAS methods using large number of images at a higher temporal sampling rate ▪ Result: time series of movement, Order of magnitude: millimeters (mm), centimeters (cm), decimeters (dm) per year depending on method and imaging mode. ▪ Processing Parameters: ▪ SSC product ▪ Rapid or Science orbit
Landslides and unstable slopes	StripMap (SM) and SpotLight (SL and HS)	Single polarisation HH	Full performance range depends on the AOI location (flat/hilly terrain or possible vegetation cover which can lead to incoherence	▪ Interferometric stacking methods: Persistant Scatterer Interferometry (PSI) or Small Baseline Interometry (SBAS) starting with 10-15 InSAR images. ▪ Longterm time series including a large number of images is necessary; especially for areas with moderate temporal coherent ▪ Chosen orbit direction depends on local terrain and possible invisibility of the slope from one side. Ascending or descending orbit required, depending on slope exposition ▪ Result: time series of movements per image pixel; the order of magnitude of the detected displacement: millimeters (mm) per year Processing Parameters: ▪ SSC product required including amplitude and phase ▪ Rapid or Science orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
Disaster Extent and Damage Assessment - Continued				
Vertical displacement or subsidence of infrastructure	StripMap (SM) and SpotLight (SL and HS)	Single polarisation HH	Small incidence angle (closer to 20°)	▪ Differential Interferometry can be used in areas with high phase coherence (arid areas). ▪ Interferogram stacking methods, such as SBAS or PSI can be used with or without artificial corner reflectors which are placed in the area and depending on the considered AOI. Long observation periods using a large number of images (e.g. 11 day repeat of the satellite orbit), especially in moderately coherent areas ▪ Result: time series of movement at each pixel; Order of magnitude: millimeters (mm), centimeters (cm) or decimeters (dm) per year **Processing Parameters:** ▪ SSC product ▪ Rapid or Science orbit
Planning and management of search and rescue operations	SpotLight (SL and HS)	Single polarisation; choice to be made depending on the considered application	Large incidence angle (> 35°)	▪ Mapping of the damaged urban and rural zones highlighting access roads or points ▪ Mapping of the safe zones, where refugee camps can be built ▪ Image interpretation, image to image comparison, Amplitude Change Detection (ACD) can be applied. ▪ Coherent Change Detection (CCD) in desert area can help to identify paths used by refugees, SSC product is necessary for this purpose which includes amplitude and phase. ▪ Ascending and descending orbits may be required depending on terrain slopes Processing Parameters: ▪ SSC for CCD methods ▪ EEC/SE or GEC/SE data, depending on the analysis method ▪ Science orbit for SSC exploitation with ACD or CCD methods. ▪ For quick EEC or GEC analysis, Predicted or or Rapid orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
8. Sea Ice Detection and Tracking				
Primary ice information o Ice edge location o Stage of development o Ice concentration	Wide ScanSAR (WS), ScanSAR (SC)	Single polarisation HH (dual-polarisation data would provide more information, but is not recommended note that swath size will be reduced)	> 30° preferred	▪ Large area coverage and frequent revisit are the driving requirements. In some cases, for tactical monitoring of a limited area StripMap (SM) or potentially even SpotLight (SL) may be useful. ▪ TerraSAR-X data possess an increased sensitivity to newly formed ice ▪ TerraSAR-Xhas limited area coverage due to 266 km and100 km swath width ▪ Methods: visual interpretation, thresholding, IC-CFAR, k-means clustering, edge detection, erosion/dilation filtering ▪ Frequent revisit times more important than a certain incidence angle (4 day repeat if TerraSAR-X, Tandem-X and PAZ are employed) **Processing Parameters:** ▪ GEC product (or EEC when covering landmass) ▪ Rapid or Science orbit
Secondary ice information o Leads o Ice thickness o Ice topography (ridges) o Ice decay (melt onset)	Wide ScanSAR (WS), ScanSAR (SC) StripMap (SM) - potentially used for the assessment of ice ridges			
Iceberg monitoring	ScanSAR (SC), Wide ScanSAR (WS)	Single polarisation HH (similar to ship detection)	Large incidence angle (> 35°) preferred to reduce clutter	▪ TerraSAR-X has limited area coverage due to 266 km and100 km swath width ▪ Methods: visual interpretation, thresholding, k-means clustering, edge detection, erosion/dilation filtering, region growing. ▪ Frequent revisit times more important than a certain incidence angle (4 day repeat if TerraSAR-X, TanDEM-X and PAZ are employed) ▪ Distinction of icebergs from ships: not only icebergs, but recurring ocean wave patterns are analysed (time series analysis) **Processing Parameters:** ▪ GEC product (or EEC when covering landmass) ▪ Rapid or Science orbit

Application	Imaging Mode	Polarisation	Incidence Angle	Comments / Described Results / Utility
9. Maritime Applications				
Wind velocity and direction	ScanSAR (SC) and StripMap (SM)	Single polarisation VV	Full performance range (20°- 55°)	▪ TerraSAR-X is sensitive to low wind velocity and is also sensitive to surface effects due to rain (rain cells)effects ▪ Rapid or Science orbit
Wave direction and height	ScanSAR (SC)	Single polarisation VV	~ 30°	▪ Current wind field: Observed -0.11 m/s to + 0.08 m/s. ▪ Current measuememt accuracy of 0.1 m/s at an effective spatial resolution better than 1 km can be met with TerraSAR-X Along-Track Interferometry (reduced spatial resolution due to the split antenna). ▪ Rapid or Science orbit
10. Oil Spill Detection				
Detection of Oil Spills	StripMap (SM) ScanSAR (SC) and Wide ScanSAR (WS)	Single polarisation VV or HH	30-40°	▪ Oil covered areas show less surface roughness than open water and can thus be distinguished from it ▪ VV is for optimal oil/water contrast often preferredDamping ratios are estimated from the TerraSAR-X data as a function of the Bragg wavenumber for various wind velocity. **Processing Parameters:** ▪ GEC product (depends on software implementation) ▪ SE processing variant ▪ Rapid or Science orbit
Recognition of Oil Spills	ScanSAR (SC) and Wide ScanSAR (WS)	Single polarisation VV	> 30°	▪ Interpretation of dispersion and direction of movement using a time series of images **Processing Parameters:** ▪ GEC product ▪ SE processing variant ▪ Rapid or Science orbit

11. Bathymetry and Obstacle Identification in the Littoral Domain				
Bathymetry, near shore sea bottom topography	StripMap (SM) or SpotLight (SL)	Single polarisation VV	tbd	▪ Research is ongoing on wind field estimation ▪ Fast Fourier Transform is applied. ▪ Demonstrations in scientific publications cover small areas only. ▪ Water extent can be extracted at various instants (tidal effect). Note acquisition times. ▪ Rapid or Science orbit
Delineation of coastline	all modes depending on desired scale	Single polarisation HV	n/a	▪ Best contrast in HV polarisation due to suppression of wave patterns. ▪ Combined amplitude and coherence evaluation to overcome ambiguous amplitudes near shore lines. ▪ Global coastline product based on TerraSAR-X and TanDEM-X bistatic StripMap imagery is available at Airbus. ▪ Rapid or Science orbit

Application	Imaging Modes	Polarisation	Incidence Angle	Comments / Described Results / Utility
12. Maritime Surveillance				
Detection of vessels in open waters	StripMap (SM) and ScanSAR (SC), Wide ScanSAR (WS)	Single polarisation HH	Large incidence angle (> 35°) preferred to reduce clutter	▪ Reduced interaction with water surface (e.g. waves) required, thus HH polarisation or VH polarisation. ▪ See ship velocity estimation **Processing Parameters:** ▪ GEC product, RE processing variant ▪ Rapid or Science orbit
Detection of vessels anchored in a wind protected area	High Resolution SpotLight (HS)	Single polarisation HH (VV)	Any; shallow angles > 45° preferred	▪ HH preferred, since less texture due to water surface roughness ▪ Large incidence angles are favourable for vessel recognition, and thus the visibility of the vessels' silhouette ▪ Size, material and orientation of object towards the radar is important. ▪ Both ascending and descending images may be useful depending on terrain around the harbour. **Processing Parameters:** ▪ GEC product ▪ RE processing variant ▪ Rapid or Science orbit
Recognition of docks, cranes, vessels, ships etc.	High Resolution SpotLight (HS), Staring SpotLight (ST)	Single polarisation HH (VV)	Large incidence angles > 45°	▪ For visual interpretation: HH provides maximum contrast between water and ships ▪ Large incidence angle will have small little layover and interpretable shadow ▪ Size and orientation of objects towards radar is important (e.g. gantry cranes can be smeared if inappropriate incidence angle is chosen) **Processing Parameters:** ▪ GEC product ▪ SE processing variant

Application	Imaging Modes	Polarisation	Incidence Angle	Comments / Described Results / Utility
13. Land Cover and Crop Types				
Mapping of broad land cover and land use classes	ScanSAR (SC) for large area mapping scales StripMap (SM) for medium scale maps or SpotLight (SL, HS) for hot-spot mapping	SC, single polarisation VV and HH SM/SL, single polarisation VV and HH and dual polarisation VV/VH	30° - 40°	▪ Visual interpretation can be performed on single polarisation SC, SM, SL or HS imagery. Information from texture (best at VV), contrast (best at HH) and landcover contex informationt (often EEC SE is preferred sinc interpretation happens in a GIS environment) ▪ More than one polarisation or multi-temporal acquisitions lead to better description of land cover class (e.g. semi-automated methods) (often EEC RE is used) ▪ Moderate incidence angles as a compromise for urban and rural areas ▪ EEC products in mountainous terrain may contain artefacts resulting from the applied DEM; use GEC or MGD instead and then transform result to map projection ▪ Polarimetry studies are ongoing, since TerraSAR-X is only partial polarimetric **Processing Parameters:** ▪ EEC, GEC or MGD depending on method ▪ SSC format for SAR experts ▪ SE for visual interpretation or RE for automated methods ▪ Rapid or Science Orbit
Detection of illicit crops Target: cocaine, poppy	ScanSAR (SC) for large area screening StripMap (SM) or SpotLight (SL) for hot-spots mapping	SC single polarisation VV for better texture exploitation SM/SL, single polarisation VV and dual polarisation (HH/HV)	Full performance range, for SM / SL better, more shallow angles >30°	▪ Crop discrimination can be improved by multi-temporal analysis within growing season, evaluation is needed for tropical crop types ▪ Note: cocaine is a bush vegetation 2-3 m tall that is sown / planted in clearings, poppy is grown on narrow fields with multiple harvests / year. Ongoing research. ▪ Multi-polarisation analysis enhances discrimination performance ▪ Local terrain and growth conditions need to be observed to evaluate feasibility. **Processing Parameters:** ▪ EEC, GEC or MGD depending on method ▪ SSC for SAR experts ▪ SE for visual interpretation or RE for automated methods ▪ Rapid or Science orbit

Application	Imaging Modes	Polarisation	Incidence Angle	Comments / Described Results / Utility
Land Cover and Crop Types - Continued				
Crop type recognition	ScanSAR (SC) for large area screening StripMap (SM) for detailed mapping	SC single polarisation SM / SL: HH for better contrast, VV for better texture exploitation Choice depends on crop types; cross polarisation HV opr VH only for a few types necessary	Full performance range (depending on terrain) >30° preferred	▪ Supervised classification multi-temporal acquisitions capture changes in crop growth stage and thus provide enhanced discrimination among crops. ▪ Classification accuracies can be improved by use of cross polarisation as helps discriminate among vegetation of specific structures. **Processing Parameters:** ▪ EEC, GEC or MGD depending on method ▪ SSC for SAR experts ▪ SE for visual interpretation or RE for automated methods ▪ Rapid or Science orbit
Mapping of urban areas	StripMap (SM) or SpotLight (SL) depending on mapping scale	Single polarisation HH	20°-30°	▪ Depending on required degree of detail either visual interpretation or semi-automated classification. ▪ Steeper incidence to avoid shadow areas, layover may be too strong. Incidence angle selection depends on type of buildings and surrounding. ▪ Interferometric coherence of image pairs can support the analysis. **Processing Parameters:** ▪ EEC, GEC, or MGD depending on method ▪ SSC for SAR experts ▪ SE for visual interpretation or RE for automated methods ▪ Rapid or Science Orbit
Forest type mapping	ScanSAR (SC) or StripMap (SM) depending on mapping scale	SC single polarisation VV SM dual polarisation VV/VH or HH/VV; partially polarised data	> 35°	▪ VV is first choice ▪ Forest types: Including peats and swamps. ▪ Separation coniferous, deciduous and mixed forest with single pol possible. VV preferred in order to exploit texture. **Processing Parameters:** ▪ EEC or GEC or SSC depending on method ▪ SSC for SAR experts ▪ RE product variant is preferred since it shows the best contrast between various vegetation types and contains less speckle than the SE variant. ▪ Rapid or Science orbit

Application	Imaging Modes	Polarisation	Incidence Angle	Comments / Described Results / Utility
Land Cover and Crop Types - Continued				
Tree Crown Coverage	StripMap (SM) or SpotLight (SL)	Single polarisation VV	> 35°	▪ Visual interpretation of open, medium, dense canopy ▪ Positional accuracy is very high. **Processing Parameters:** ▪ GEC, EEC or SSC fro SAR experts ▪ Rapid or Science orbit
Change detection	Selection depends on the Area of Interest size and application: ▪ StripMap (SM) or ScanSAR (SC) for urban growth ▪ SpotLight modes (SL and HS) for change detection in urban areas	Selection depends on the considered application: Forest other vegetation: VV for texture Landcover: HH for contrast to man-made objects	20-50° Note: length of layover at small incidence angles can disturb the analysis	▪ Amplitude change detection (ACD) between two scenes acquired before and after the changes occured, Either product can be employed; SSC for SAR experts, EEC is often preferred. ▪ Coherent Change Detection (CCD) based on the exploitation of the datasets interferometric phase coherence analysis, complex format products required (SSC product only) ▪ Further qualification by help of landcover classification is possible **Processing Parameters:** ▪ EEC, GEC or SSC depending on method; RE variant ▪ Rapid or Science orbit
Oils, Gas, Mineral Production	StripMap (SM)	Single polarisation HH for best detection of double/multiple bounce scatterers	Small angle, closer to 20°	▪ Longterm observation of a time seires at moderate acquisition sampling rate (for moderately coherent areas in arid areas) ▪ Methods: PSI, SBAS starting with 10-15 InSAR images. ▪ Result: time series of movement, mm to cm per year **Processing Parameters:** ▪ SSC ▪ Science orbit

Application	Imaging Modes	Polarisation	Incidence Angle	Comments / Described Results / Utility
Land Cover and Crop Types - Continued				
Ground Water Extraction Effects	StripMap (SM), SpotLight modes (SL and HS)	Single polarisation HH for best detection of double bounce scatterers	Steep angle, closer to 20°	▪ Longterm observation with high acquisition sampling rate (for moderately coherent areas) ▪ Method: PSI, SBAS ▪ Result: time series of movement in mm per year **Processing Parameters:** ▪ SSC ▪ Science orbit

Polarisation, Swath and Spatial Resolution:
Mean Spatial Resolution: Wide ScanSAR 40 m (WS), ScanSAR 18 m (SC), StripMap 3 m (SM), SpotLight 2 m (SL), High Resolution SpotLight 1 m (HS300), Staring SpotLight (0.25 m) depending on incidence angle.

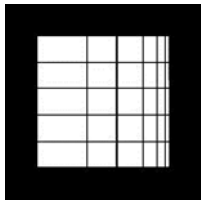
Note to match available polarisations and imaging modes. Single polarisation HH or VV or HV: 16 bit grey value image, in case of mono-temporal acquisition. Cross polarisation HV or VH. Co-polarisation: HH and VV and reduced swath and spatial resolution. Dual polarisation: HH and HV or VV and VH and reduced swath and spatial resolution.

Abbreviations:
ACD: Amplitude Change Detection; = Change detection methods; can be accomplished with detected products
CCD: Coherent Change Detection requires SSC product
DInSAR: Differential Interferometry; interferometry method
DLR: German Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt.
EEC: Enhanced Ellipsoid Corrected
GEC: Geocoded Ellipsoid Corrected
HS: High Resolution SpotLight Imaging Mode, 10 km, x 5 km, 1.0m, 20° - 55°, VV or HH polarisation PREDicted: 700.0 m along track.
MGD: Multi Look Ground Range Detected
PAZ: Spanish PAZ X-band satellite (owned and operated by Hisdesat Servicios Estratégicos S.A., Spain)
PSI: Persistant Scatterer Interferometry, usable for man-made objects;
Rapid Orbit: 0.2m up to 2.0 m positional accuracy, available after 5-15 hours after last satellite contact, delivery 24h at the latest after acquisition.1-2 days,
RE: Radiometrically Enhanced
SBAS: Short Baseline Subset Approach, usable for extended target
SC: ScanSAR Imaging Mode, 100 km x 150 km, 18.5m, 20°-45°, HH or VV
Science Orbit: Best available positional accuracy of 20.0 cm. Predicted Orbit – ~200.0 m and up to 700m worst case along track positional accuracy. Processing Near Real Time, Orbit estimation available before acquisition.
SE: Spatially Enhanced; one out of two product variants as MGD, GEC or EEC.
SL: SpotLight Imaging Mode, 10 km x 10 km, 2m, 20° - 55°, single VV or HH or dual polarisation HH and VV.
SM: StripMap Imaging Mode, 30 km x 50 km, 3m, 20° - 45°, single or dual polaristation (like and cross combinations)
SSC: Single Look Slant Range Complex (only as RE)
ST: Staring SpotLight Imaging Mode, 4 km x 3.7 km or larger depending on incidence angle, 0.24m in azimuth, 20°-45°, VV or HH polarisation.
Submission deadlines for data ordering: 8:30h and 21.30h UTC.
TDX: German TanDEM-X X-band satellite
TSX: German TerraSAR-X X-band satellite
UPS: Universal Polar Stereographic map projection.
UTM: Universal Transverse Mercator Projection
WGS84: World Geodetic System 1984, Earth ellipsoid model.
WS:Wide ScanSAR Imaging Mode; 270 km x 200 km, 40m in azimuth, 15.6° - 40°, VV or HH polarisation.

Radar Constellation (TerraSAR-X/PAZ) Processing Levels (Basic Image Products)

The Basic Image Products differ in content (amplitude and phase or amplitude only) and their similarity to a map geometry (UTM, WG84).

SSC - Single Look Slant Range Complex

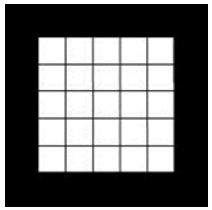


This product is **closest to the recorded raw data**. It possesses a slanted viewing geometry along the radar beam and down to the ground. This product best preserves the measured radiometry, but lets the image look compressed across the swath. It is preferred by those, who want to make use of the best achievable radiometry and do not want any image artefacts caused by reorganisation of the image pixels, e.g. through geocoding. Pixels are rectangular with higher spatial resolution in far range.

The 32 bit DLR CoSAR file format contains both amplitude (real part) and phase information (imaginary part) which is required for **interferometric processing (CCD, DInSAR, PSI, SBAS etc.)** which requires professional image processing software. The data is single look data.

Comparable product from other SAR satellites: ERS-1/2.SAR.SLC, ENVISAT/ASA.IMS.1P, Radarsat-1/SLC, Sentinel-1AB/SLC

MGD - Multilook Ground range Detected



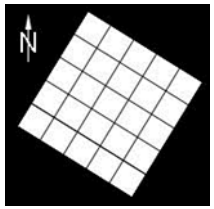
In the MGD product, is derived from the SSC product. It has been projected/detected to the ground (ground range geometry). **No geocoding** has been established yet. Only a rough Latitude and Longitude reference point at the centre of the image is given for better orientation.

Own precision geocoding or orthorectification with a DEM can be applied to the data and thus lets the user gain control over the image processing. The product is close to the originally detected radiometry and thus often used by **reconnaissance** interpreters. Multilooking has been applied to reduce speckle.

The 16 bit Geotiff format can in principle be displayed with any image processing software. Special care has to be taken upon histogram manipulation. Depending on the analysis purpose, different parts of the histogram may be used for enhancement.

Comparable product from other SAR satellites: ERS-1/2.SAR.PRI, ENVISAT/ASA_IMP_1P, Radarsat-1/SGF

GEC - Geocoded Ellipsoid Corrected



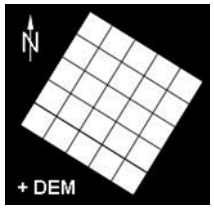
The product has been derived from the MGD product by introducing Earth ellipsoid correction. An average terrain height is used for **geocoding to Universal Transverse Mercator UTM** or Universal Polar Stereographic UPS map projections with WGS84 Earth ellipsoid. Flat terrain is very well represented by this image product. Hilly or mountainous terrain requires further correction steps and orthorectification (see EEC product).

The image product allows for a fast orientation and overview mapping **where no DEM is available or necessary**.

The 16 bit Geotiff format can in principle be displayed with any image processing software. Special care has to be taken upon histogram manipulation. Depending on the analysis purpose, different parts of the histogram may be used for enhancement.

Comparable product from other SAR satellites: ERS-1/2.SAR.GEC, ENVISAT/ASA_IMG_1P, Radarsat-1/SSG, Sentinel-1AB/GRDH

EEC - Enhanced Ellipsoid Corrected



This is the **highest level of processing**. Geometric reference points (included in the GEOREF.xml file) and a DEM from a DEM data base have been used for the geocoding. **Geocoding to Universal Transverse Mercator projection (UTM)** or Universal Polar Stereographic (UPS) map projections based on the WGS84 ellipsoid are available. -Optional, an additional geocoded raster file (Geocoded Incidence Angle Mask GIM) is included in the delivery which shows those pixels that are affected by layover and shadowing and which includes the local incidence angle.

The product allows a quick and **highly accurate overlay with other spatial data**. It is used for all kinds of mapping purposes that require a precise geocoding. Even Amplitude Change Detection can be performed, provided layover areas are excluded from the analysis.

The 16 bit Geotiff format can in principle be displayed with any image processing software. Special care has to be taken upon histogram manipulation. Depending on the analysis purpose, different parts of the histogram may be used for enhancement.

Comparable product from other SAR satellites: ERS-1/2.SAR.GTC, ENVISAT/DLR value added product, Radarsat-1/SPG

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