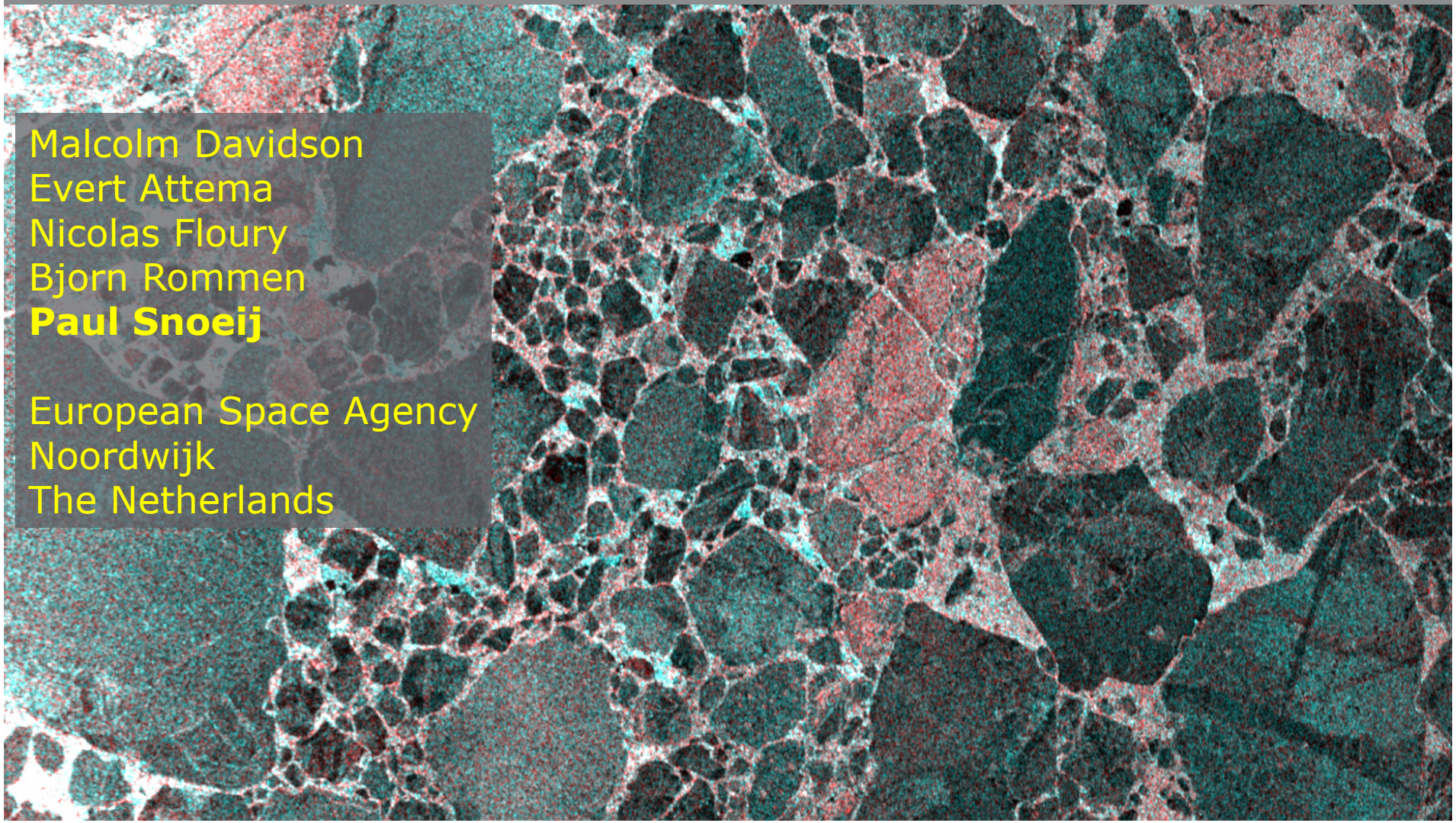
LINKING SENTINEL-1 LEVEL-1 DATA QUALITY WITH LEVEL-2 PERFORMANCE



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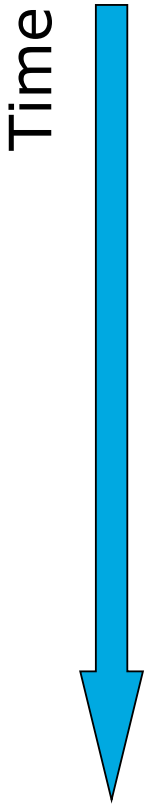
Outline

- Context
- Methodology
- Level-1 data quality
- Level-2 performance assessments for selected products
- Summary

Geophysical information product accuracy assessment context



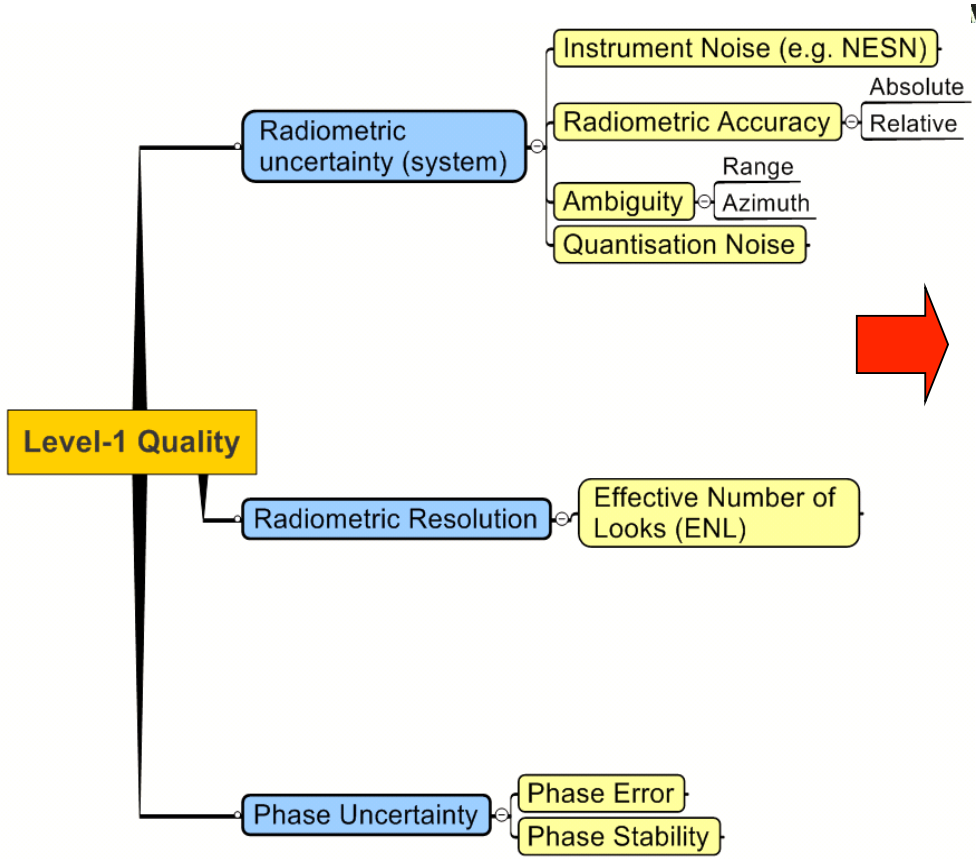
- Support design of mission and trade-off studies
- Verification of technical choices of the mission and system
- Basis for definition of calibration and validation activities
- Preparation user community for new data stream and its capabilities ahead of launch
- Framework to support joint exploitation of ESA GMES missions and national contributing missions (e.g. TerraSAR-X, COSMO/ Skymed)
- Feedback to Agency in design of future SAR missions and integration of evolving user requirements

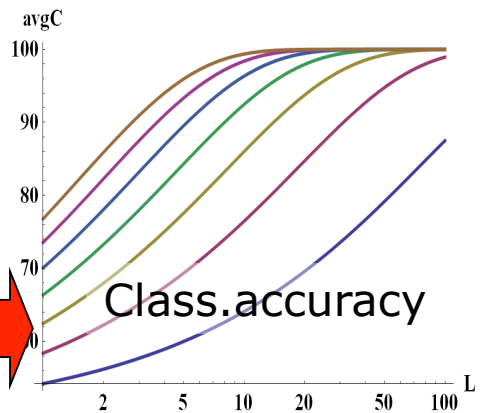
Assessment framework for Level-2 performance assessment

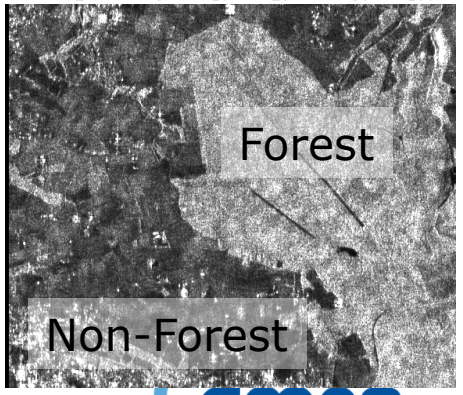
Mission and system performance

Level-1 product

Level-2 performance







Sentinel-1 Level-1 data quality specifications

Parameter	Strip-Map Mode (SM)	Interferometric Wide-Swath Mode (IW)	Extra Wide Swath Mode (EW)	Wave Mode (WV)
Polarisation	Dual (HH+HV, VV+VH)	Dual (HH+HV, VV+VH)	Dual (HH+HV, VV+VH)	Single (HH, VV)
Access (Incidence angles)	20° - 45°	25° (min. incidence angle)	20° (min. incidence angle)	23° + 36.5°(mid incidence angle)
Azimuth Resolution	**< 5 m**	**< 20 m**	**< 40 m**	**< 5 m**
Ground Range Resolution	**< 5 m**	**< 5 m**	**< 20 m**	**< 5 m**
Range Looks	Single	Single	Single	Single
Swath	**> 80 km**	**> 250 km**	**> 400 km**	**Vignette 20 x 20 km**
NESZ	**-22 dB**	**-22 dB**	**-22 dB**	**-22 dB**
Radiometric Stability	0.5 dB (3σ)	0.5 dB (3σ)	0.5 dB (3σ)	0.5 dB (3σ)
Radiometric Accuracy	**1 dB (3σ)**	**1 dB (3σ)**	**1 dB (3σ)**	**1 dB (3σ)**
Phase Error	**5°**	**5°**	**5°**	

Origin of geophysical products and sources of uncertainty

Information Product (Level-2)	Origin of Product (Level-1)	Random & Systematic Uncertainties to be Considered (List not exhaustive)
Soil Moisture Ocean Wind Speed	Absolute Value of Image Intensity	❑ Instrument Calibration, including Noise Bias and Non-linearity ❑ Radiometric Resolution, including Quantisation, Noise and Speckle (Effective Number of Looks) ❑ Phase Errors ❑ Instrument Stability ❑ Atmospheric Effects ❑ Geometrical Effects (orbit position, pointing) ❑ Temporal De-correlation of Interferometric Image Pairs ❑ Retrieval Uncertainties, including Retrieval Model Uncertainties and Validation Uncertainties
Ice Edge/Ice Map Oil Pollution at Sea Snow Cover Forest Map Land Cover Map	Image Intensity Contrast	
Interferometric Products, e.g. Subsidence	Complex Image (Amplitude & Phase)	

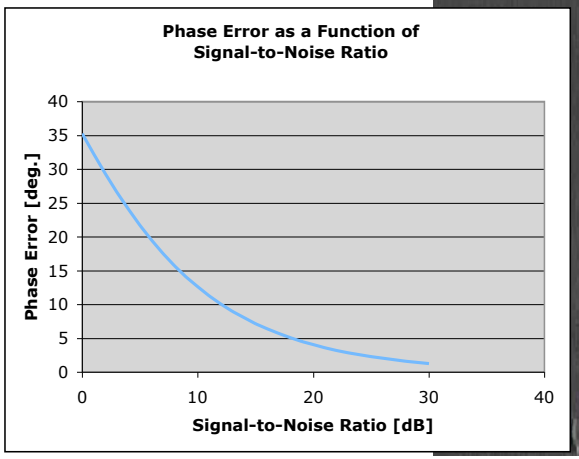
Interferometry (1)

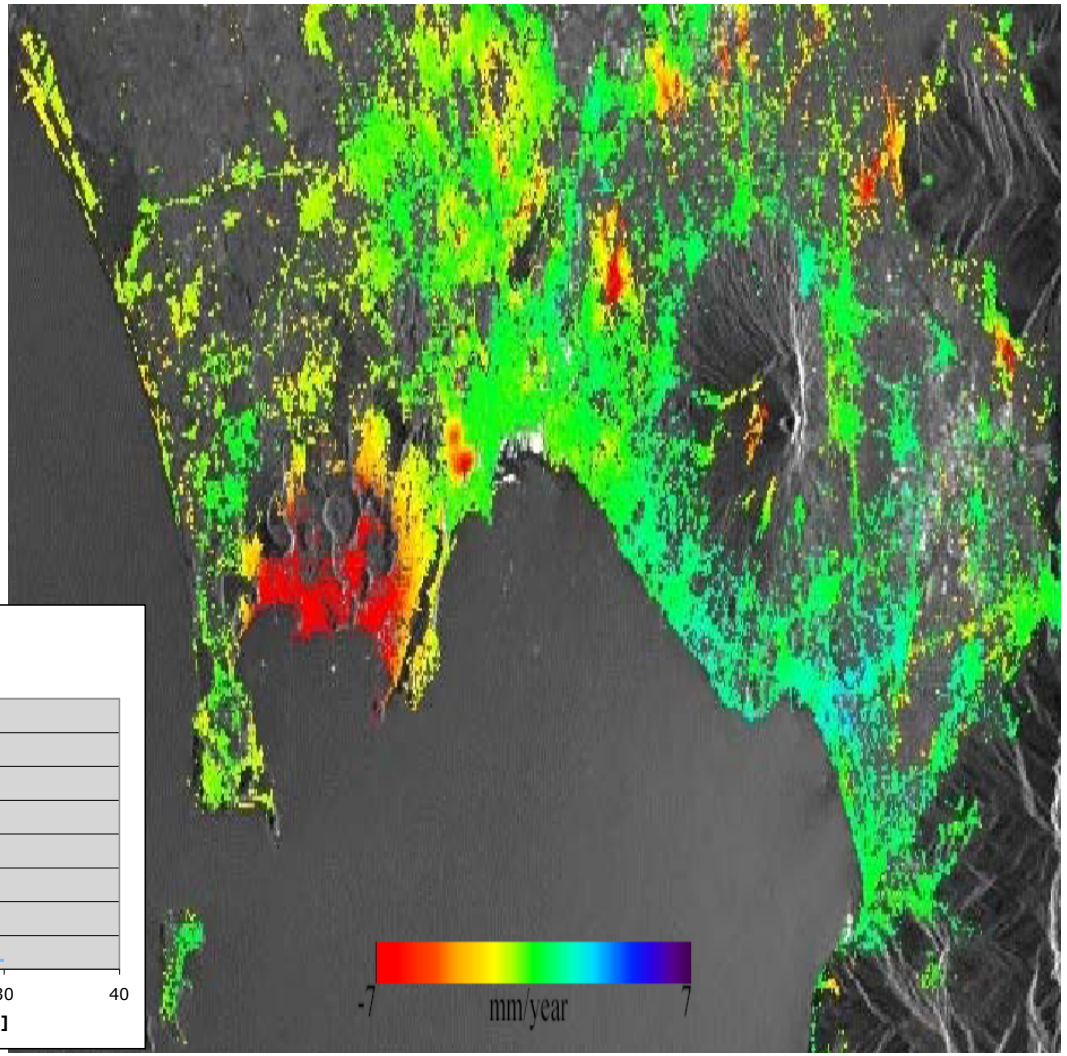
Application context

- Geo-Hazard Land Motion Services

Main mission parameters affecting performance

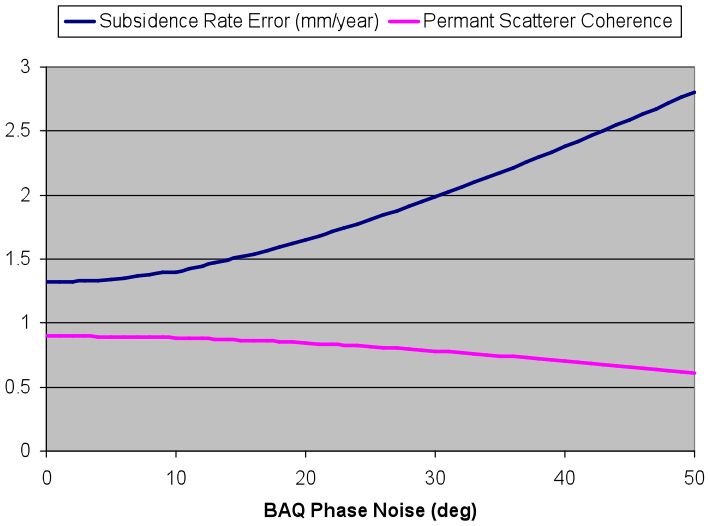
- Phase errors
- Quantisation noise
- Instrument noise

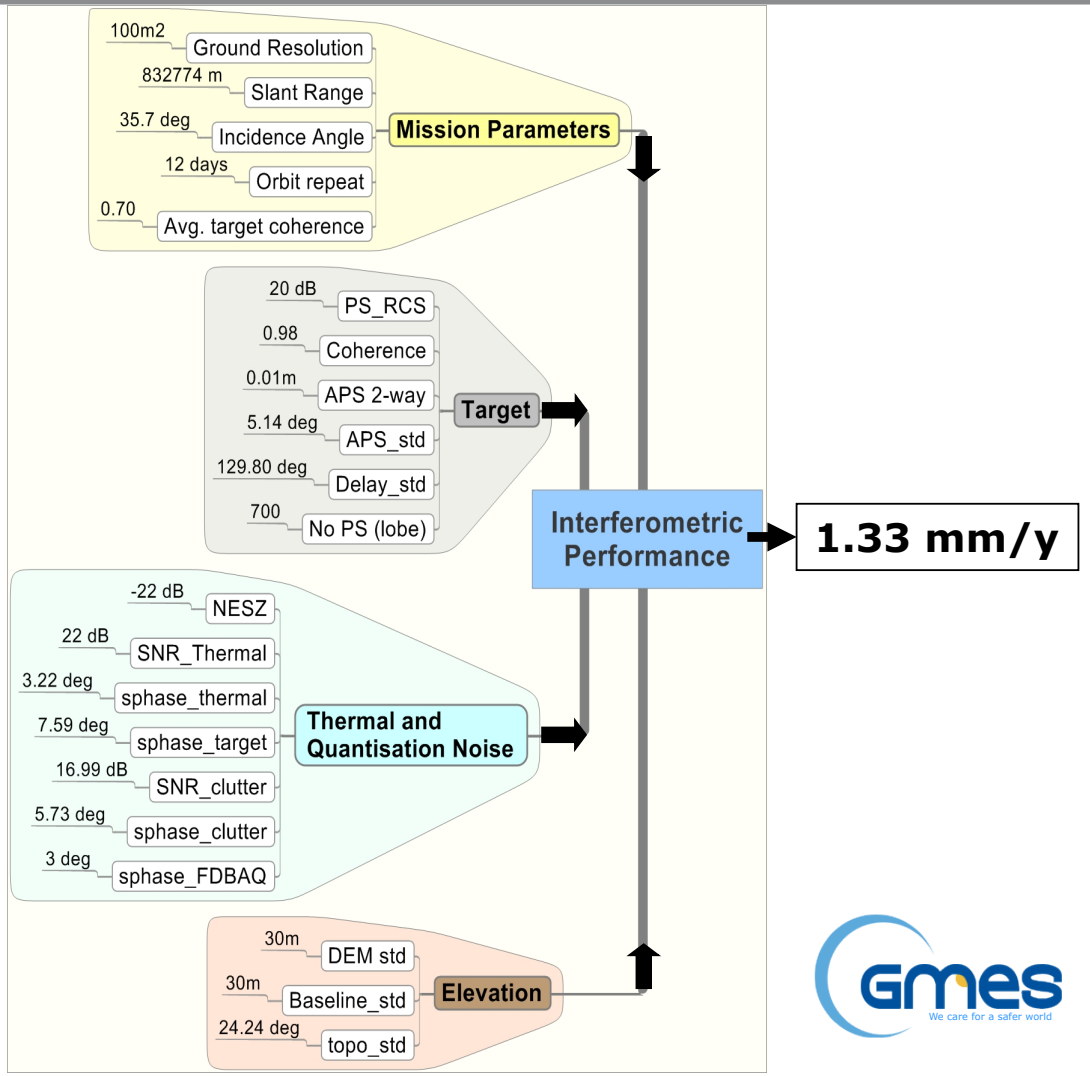




Interferometry (2)

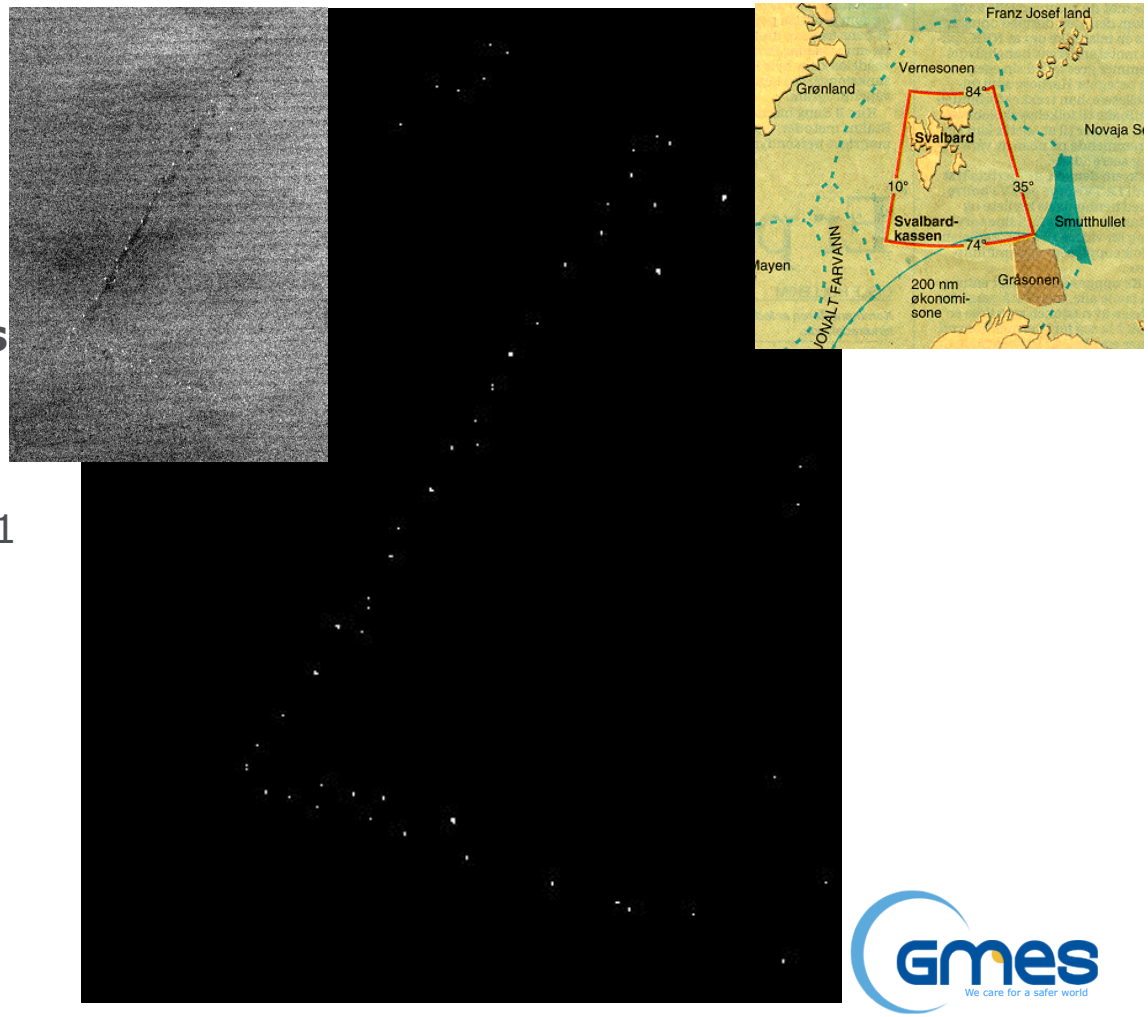
- Methods for evaluation of geophysical accuracy as a function of mission and system parameters well established
- Example reference scenario given on right





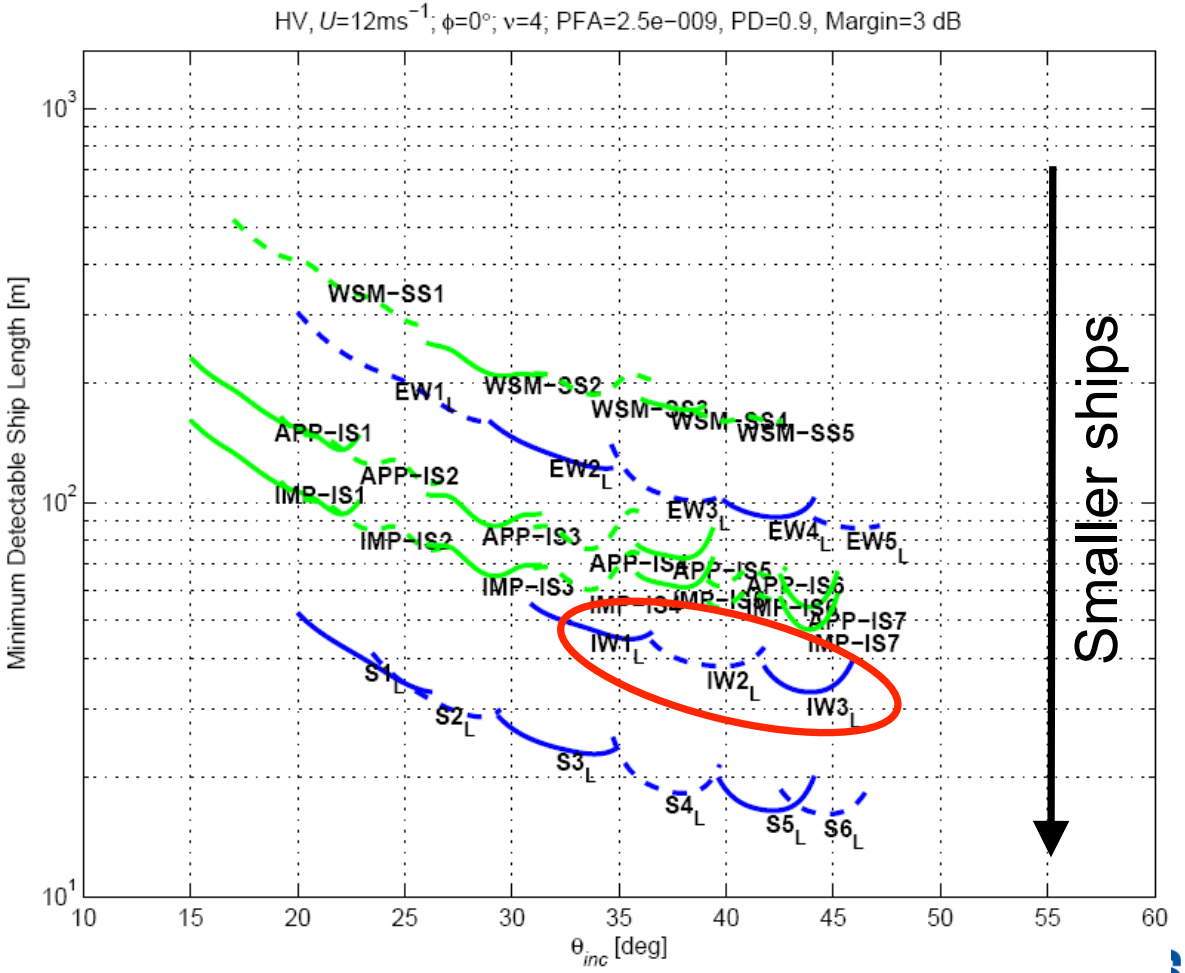
Ship detection (1)

- **Application context**
  - Security
  - Oil-spill monitoring
  - Fisheries/Transport
- **Main mission parameters impacting performance**
  - Swath Width
  - Timeliness of data (< 1 hour)
  - Resolution
  - Instrument Noise
- **Performance models exist linking Level-1 data quality with ship detection performance**



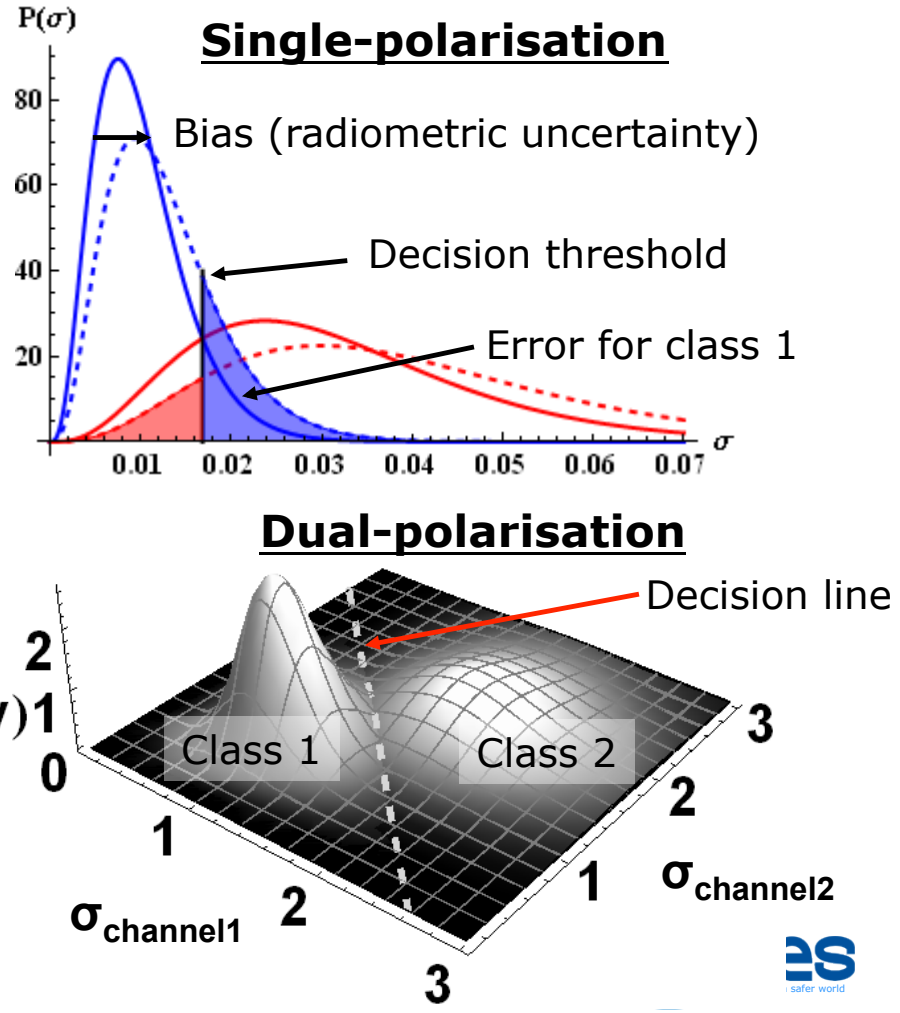
Ship Detection (2)

- Detection performance bette than existing C-band SAR satellites (ERS-2, Radarsat, ENVISAT)
- For the main IWS mode, ships with length > 40m can be detected with 90% accuracy
- For SM mode ships with length > 24m can be detected with 90% accuracy



Classification error as a function of contrast

- Methodology developed to explicitly calculate classification errors through integration of area/ volume of overlap
- Maximum likelihood criteria
- Classification error estimated as function of
  - radiometric contrast
  - level of bias (due to radiometric uncertainties)
- Applicable to wide variety of classification-based (thematic maps) applications



Ice monitoring (1)

Application context

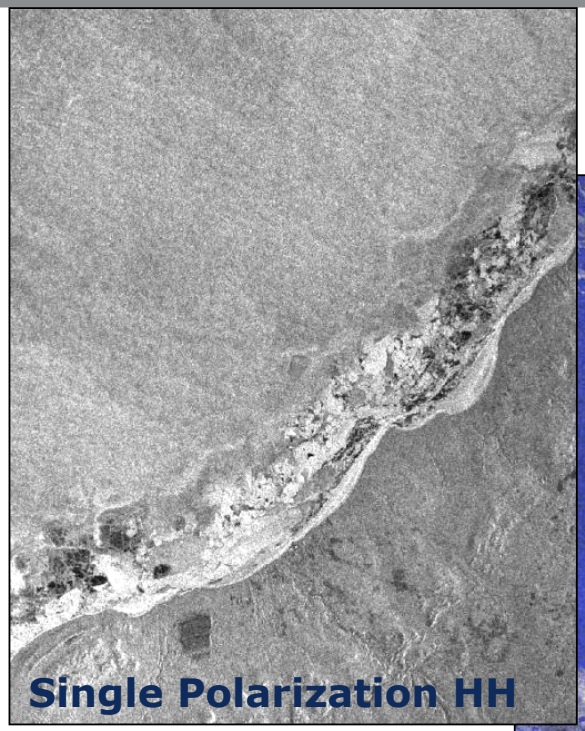
- ice services
- manual interpretation of SAR images

Main mission parameters impacting performance

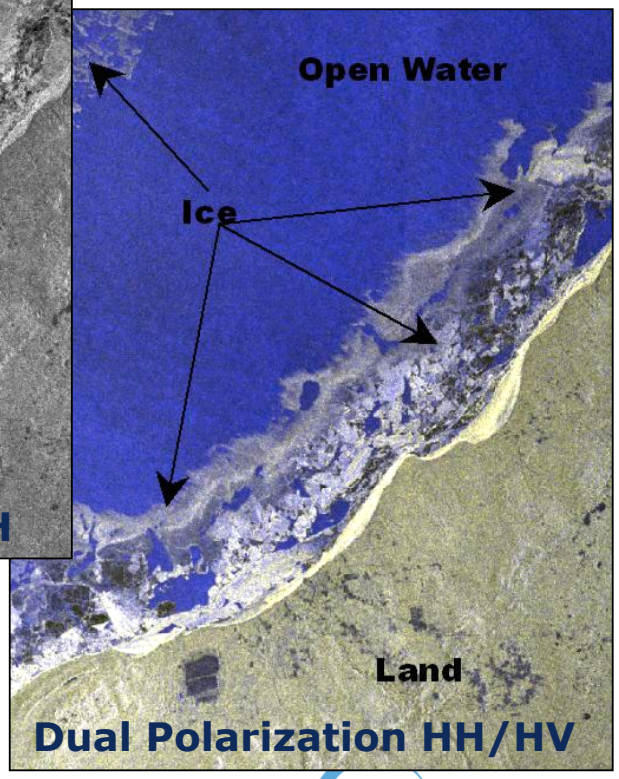
- Swath Width
- Timeliness of data
- Polarisation
- Instrument Noise

Geophysical accuracy

- combination of large swath and high resolution to provide needed coverage and input for interpretation
- dual-polarisation useful in detecting and mapping ice regimes

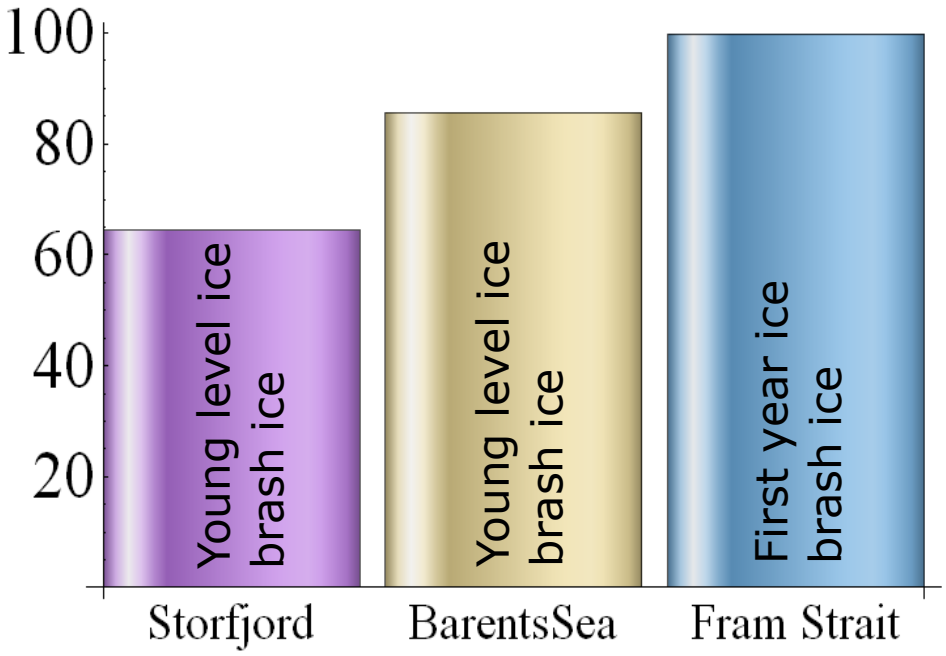


From Flett and De Abreu, Canadian Ice Service



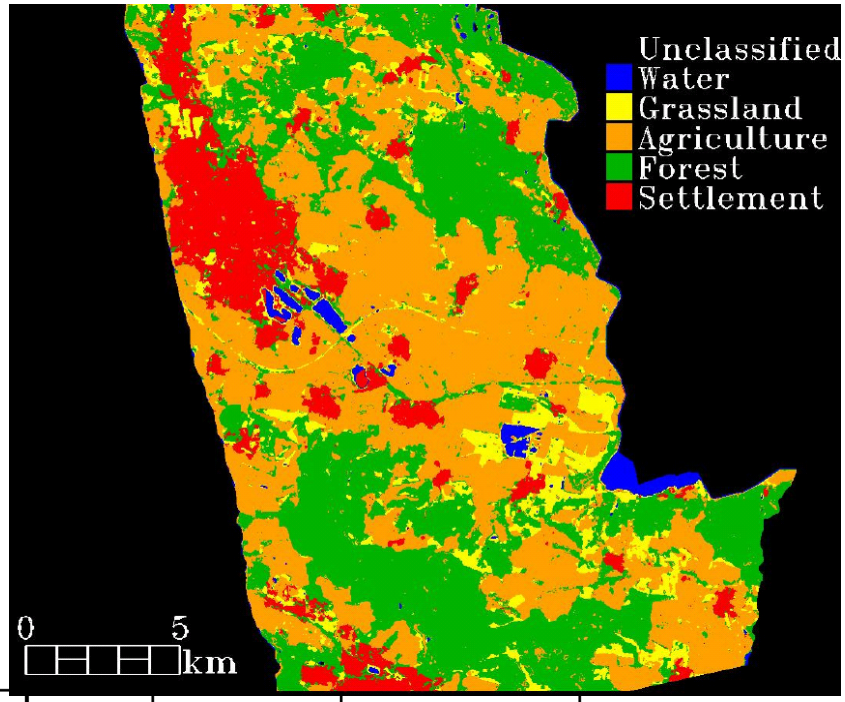
Ice monitoring (2)

- Errors in ice classification estimated using previous methodology
  - S1 IWS Mode
  - Level-2 product scale = 20 x 20m
  - 4 looks
  - 2 polarisations (VV+VH)
- Radiometric contrast between ice classes extracted from ESA IceSAR 2007 airborne campaign
- Main source of error: radiometric resolution



Land cover based on temporal signatures

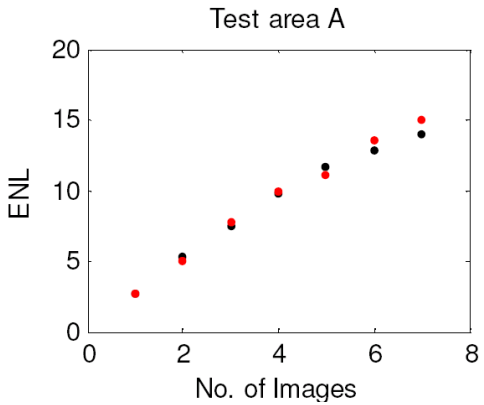
- Robust land cover classification enabled through frequent revisit and multi-temporal metrics
  - Mean annual variation (MVA)
  - Min/Max/Mean backscatter
  - Texture
- High classification accuracies for basic land classes for sufficient temporal coverage (example with 8 acquisitions during growing season)

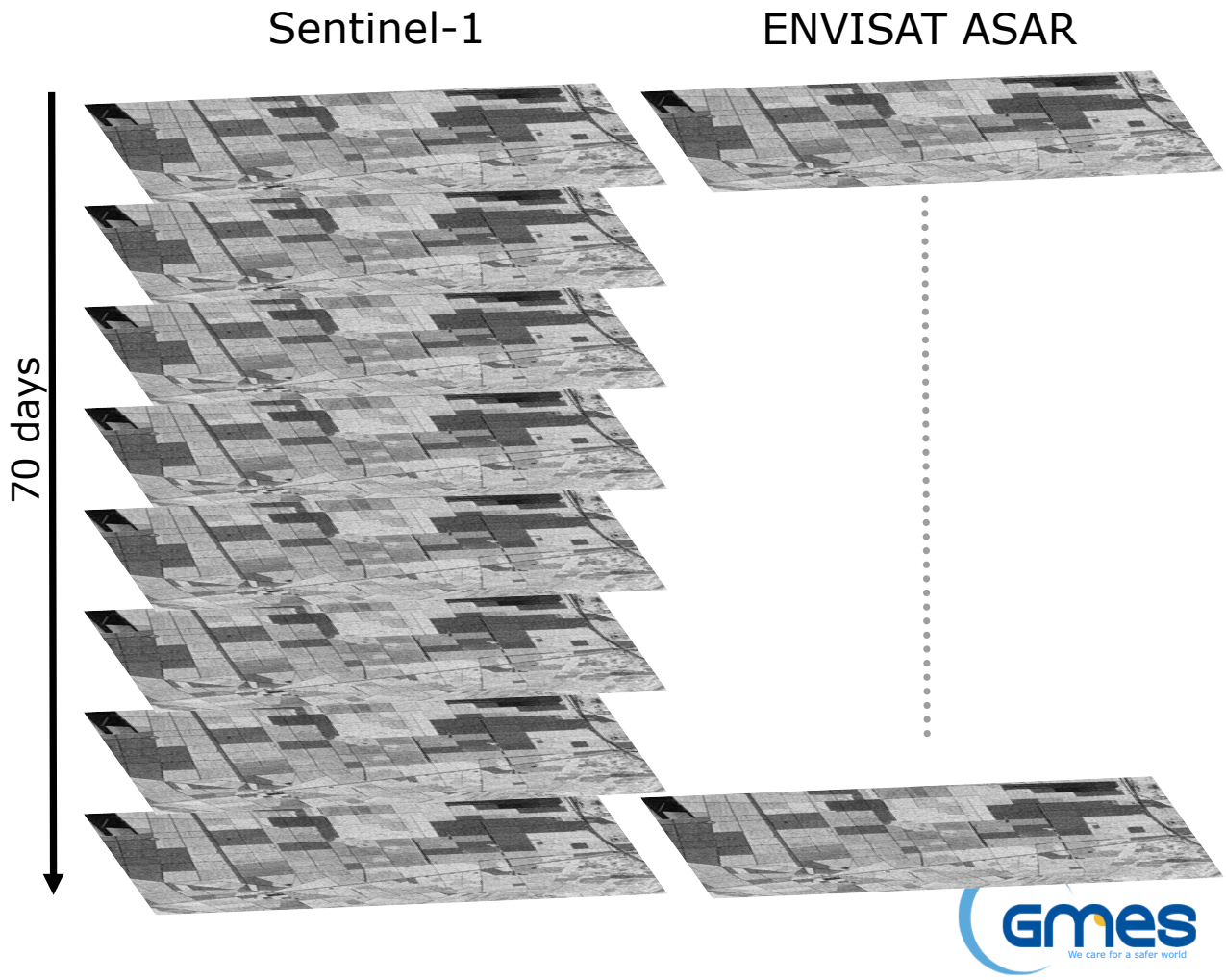


Maximum Likelihood VV & HV / 8 acq. dates	Water	Grassland	Cropland	Forest	Settlement	User accuracy
Water	97.88	1.217	0.27	0.22	0.85	89.35
Grassland	0.53	97.28	2.27	0.10	0.08	75.37
Cropland	1.24	1.503	95.99	0.64	16.82	97.73
Forest	0	0	1.15	98.92	0.085	99.21
Settlement	0.35	0	0.32	0.12	82.16	91.09
Prod. Accuracy	97.88	97.28	95.99	98.92	82.16	97.34

Radiometric Resolution

- Radiometric resolution is often a limiting factor on SAR-based classification performance
- Multi-temporal filtering exploiting image temporal stacks expected to significantly improve the radiometric resolution and classification performance





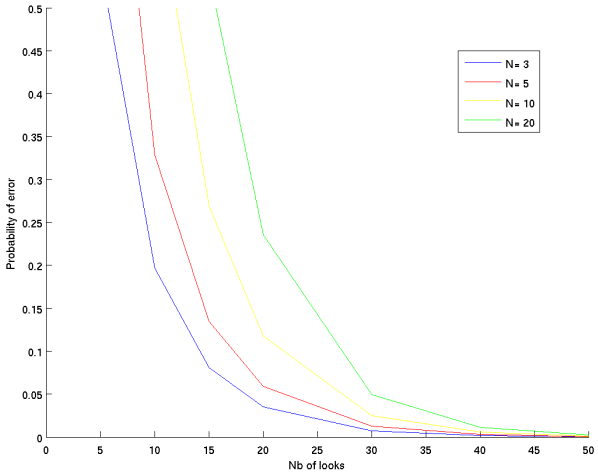
Forest/Non-Forest

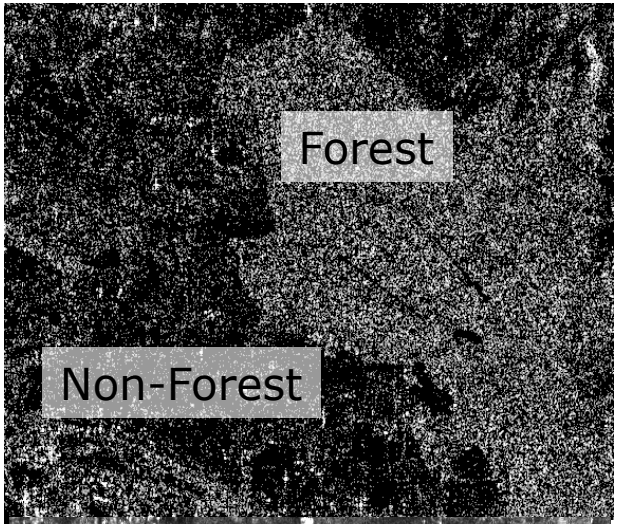
Context

– Forest/Non-forest mapping algorithms based on high temporal stability of forest with respect to other land cover classes

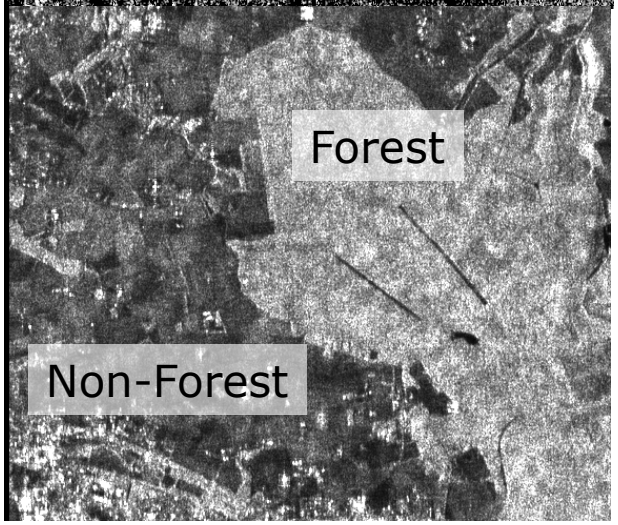
Main mission parameters impacting accuracy

– Radiometric resolution



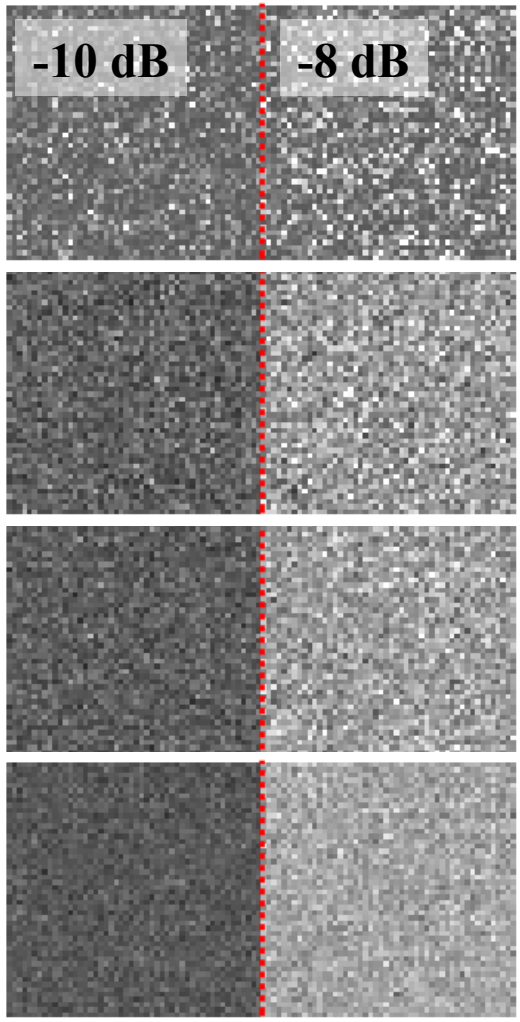


VV image
• Raw ASAR AP product



VV image
• Multitemporal filter
• 6 dates x 2 channels

Synthetic classification performance potential based on ideal multi-temporal filtering



Single look SAR image

58%

ERS-1/2 Multi-temporal 70 days

79%

ASAR - AP Multi-temporal 70 days

79%

Sentinel-1 IWS Multi-temporal 70 days

96%

Filter from Quegan and Yu (2001)

Performance prediction for geophysical products

S1 Level-2 Product	Resolution	Performance	Units
Subsidence Rate	5 x 20 m2	1.3	mm/year
Land Cover Classification (2 dB contrast)	100 x 100 m2	96	% correct classification
Forest Non-Forest Classification	30 x 30 m2	75	
Soil Moisture	100 x 100 m2	1.2	volume %
Flood Mapping	30 x 30 m2	79	% correct classification
Snow Cover Classification	30 x 30 m2	75	% correct classification
Ship Detection	5 x 20 m2	40	ship length (m) for 90% detection probability
Sea Surface Wind Speed	100 x 100 m2	0.8	m/s (1 sigma)
Sea Surface Currents	5 Hz	30	cm/s

Summary

- Sentinel-1 data products maintain the data quality of ESA's previous SAR missions (ERS-1/-2, ENVISAT ASAR)
    - Continuity in performance for geophysical products secured
- Evaluation of accuracy of geophysical products indicates improvements due to frequent revisit, coverage and dual-polarisation capabilities
    - System impact on Level-2 (and higher) evaluated based on Level-1 specifications
    - User requirements met or exceeded
    - Results documented in ESA Sentinel-1 Error Budget document
- Future work focus on development and standardisation of methodologies for accuracy assessment, product prototyping and (post-launch) verification of accuracy (e.g. through validation)