INTERNATIONAL SAR MISSION COORDINATION – THEMATIC AREAS

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OVERVIEW

- *Background to Int'l SAR Coordination and the "Thematic Areas"*
- *Summary of a first cut review of SAR observation requirements for some key science applications**
- *Summary/Discussion points for*

- *On-line Survey*

**** A Review of SAR Observation Requirements for Global and Targeted Science Applications**.*
Rosenqvist A., Jones C.E., Rignot E., Simons M., Siqueira P., Tadono T. (2021). IGARSS 2021.
DOI: 10.1109/IGARSS47720.2021.9553966

Int'l SAR Coordination: Thematic Areas

Thematic Areas support the Working Groups with cross-cutting issues concerning science & application requirements, and observation planning.

- Thematic Area 1: *Polarimetric and multi-frequency SAR applications*
- Thematic Area 2: *Interferometric SAR applications*
- Thematic Area 3: *Program and mission coordination*

Int'l SAR Mission Coordination	WG 1 Present & Near-Future Systems	WG 2 (Far) Future Imaging Systems	WG 3 Data Exploration
TA 1 Polarimetric & Multi-Frequency SAR Applications			
TA 2 Interferometric SAR Applications			
TA 3 Programme & Mission Coordination			

Present & Near-Future SAR systems (2020s)

- Task: Identify SAR coordination actions that could be taken in the near/mid-term that will improve science/applications overall

Future SAR Imaging Systems (2030+)

- Task: Identify and prioritize the long-term (2030+) goals and objectives for SAR coordination – the 'Game Changers' for the respective science disciplines.
- Consider novel trends, e.g. bistatic constellations – tandem or companion satellites; micro-SAR systems, etc.

Present & Near-Future SAR systems (2020s) – What have we got?

In orbit:

- *L-band: ALOS-2 (JAXA); SAOCOM-1 (CONAE)*
- *C-band: Sentinel-1 (ESA/EU), Radarsat-2, RCM (CSA), Risat (ISRO)*
- *S-band: NovaSAR (UK)*
- *X-band: TerraSAR-X, TanDEM-X (DLR), COSMO-SkyMed (ASI)*

  + Private Sector "New Space" SAR missions

Near-Future (2023/2024):

- *P-band: BIOMASS (ESA)*
- *L-band: ALOS-4 (JAXA), NISAR(L) (NASA)*
- *S-band: NISAR(S) (ISRO)*

Late 2020s/early 2030s:

- *ALOS-6, ROSE-L, Sentinel-1 Next-Gen, Harmony (S1 bi-static), TerraSAR-X 2G, COSMO-SkyMed 2G + Private Sector "New Space" SAR missions*

Polarimetric & Multi-Frequency SAR Applications (TA-1)

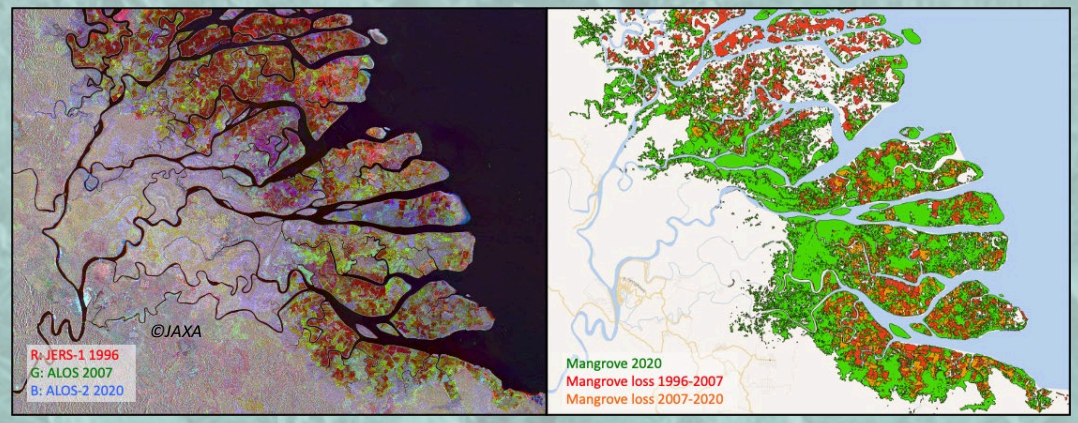
Main measurement(s):

- *Backscatter intensity (Single-, Dual, or Quad-pol) from one or more SAR frequencies (P/L/S/C/X)*
- *Polarimetric phase*
- *(InSAR often useful, but not main driver)*

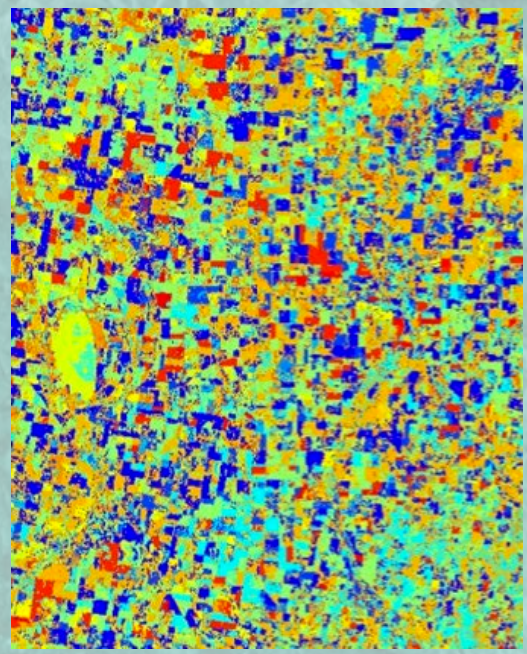
Application areas include e.g.:

- *Forest & Land Cover*
- *Vegetation structure & above-ground biomass*
- *Wetlands extent & inundation*
- *Agriculture*
- *Soil Moisture*
- *Ocean & Sea Ice*

Close connection with the IPCC AFOLU themes and the UNFCCC Paris Agreement. Strong interest from new, non-expert user groups.



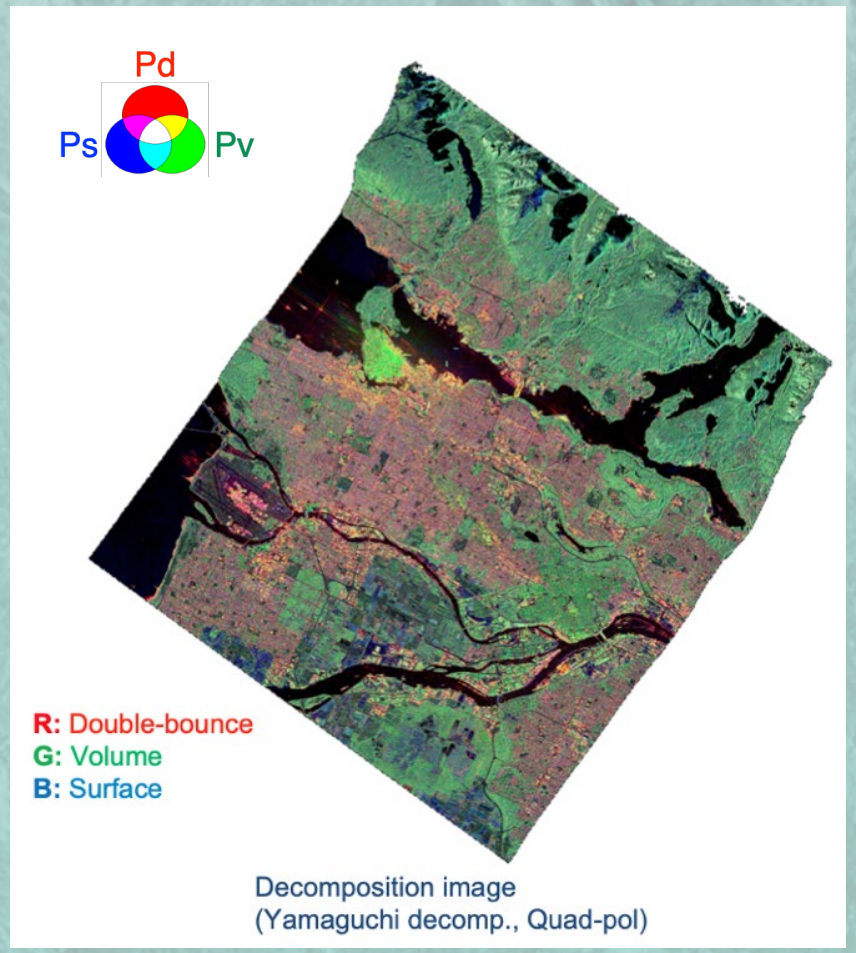
© Global Mangrove Watch (Bunting et al., 2022)



Ag crop map. C-band pol-decomposition (Zhou et al., 2018)

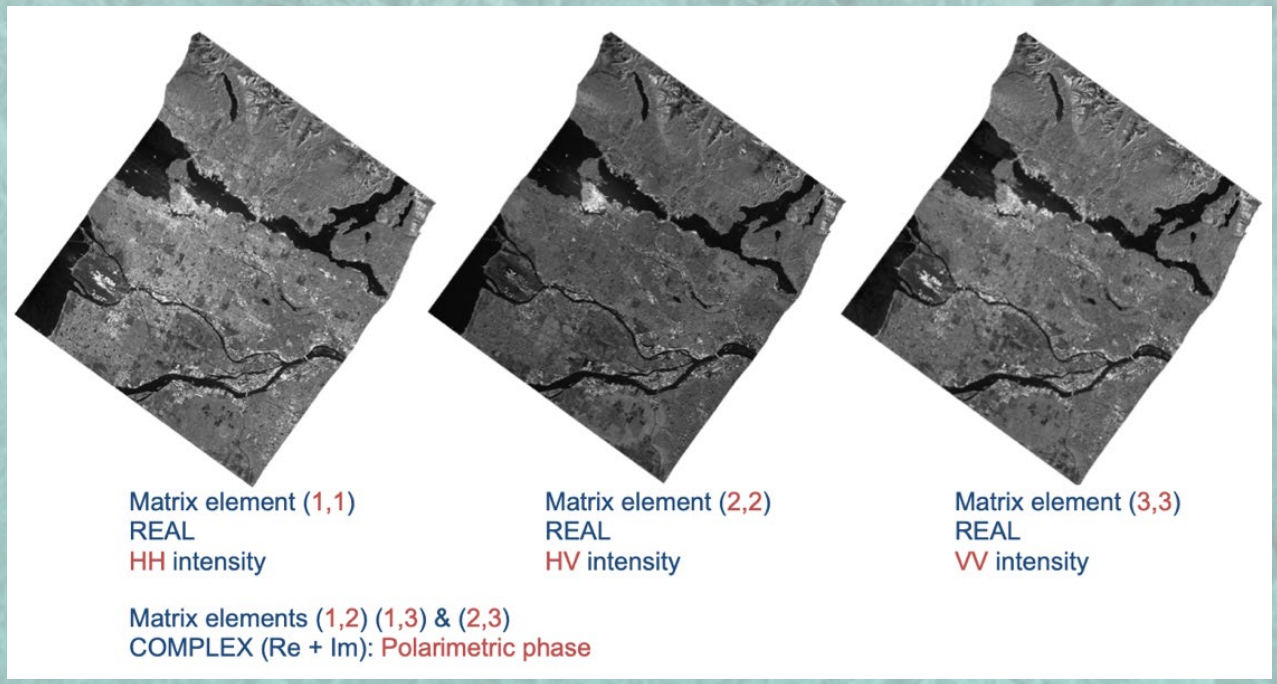
Tree crop identification. L-C band dual-freq. (Hoekman et al., 2016)

Polarimetric & Multi-Frequency SAR Applications (TA-1)



Decomposition image
(Yamaguchi decomp., Quad-pol)

What is "polarimetric phase"?



Matrix element (1,1)
REAL
HH intensity

Matrix element (2,2)
REAL
HV intensity

Matrix element (3,3)
REAL
VV intensity

Matrix elements (1,2) (1,3) & (2,3)
COMPLEX (Re + Im): Polarimetric phase

RADARSAT-2 (MDA) Yamaguchi decomposition (Charbonneau, 2020)

Polarimetric & Multi-Frequency SAR Applications (TA-1)

First assessment of challenges & gaps

- ***Ionosphere***
  - *Ionospheric conditions, esp. L- & P-band, cause path delay, Faraday rotation, irregular radiometric artefacts*
- ***Signal saturation***
  - *Saturation far below high-density tropical & temperate forests*
- ***Zero baseline control***
  - *Zero-baseline orbit control inhibits tomo-InSAR*
  - *Conflict with InSAR applications that require zero baseline*
- ***Soil moisture variations***
  - *Temporal revisit of current systems insufficient to capture sub-daily soil moisture variations*
- ***Vegetation type distinction***
  - *Polarimetric and multi-frequency time-series to improve class characterisation for agriculture, land cover and wetland inundation*

Interferometric SAR Applications (TA-2)

Main measurement:

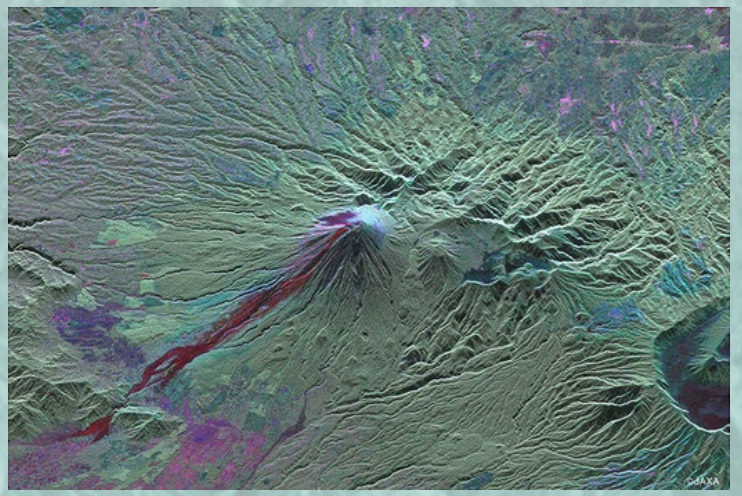
- *Interferometric phase*

(phase difference between two or more observations)

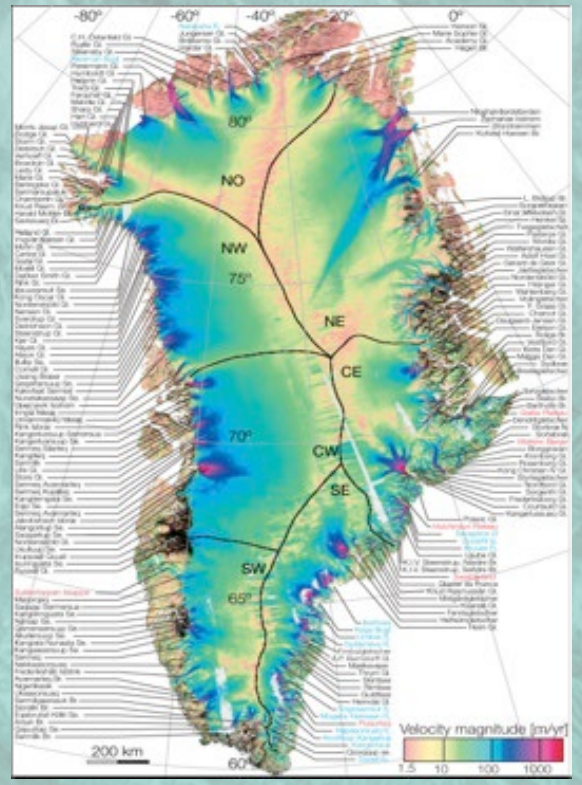
Application areas include e.g.:

- *Crustal deformation, subsurface magma migration, aquifers*
- *Earthquakes; volcano eruptions, land slides, subsidence*
- *Velocity of glaciers, ice caps, and ice sheets*
- *Glacier grounding line mapping*
- *Geo-hazards*

Applications of critical relevance to understanding the impacts of Climate Change, e.g., relative sea level rise, increased occurrence of natural disasters (frequency & location)



Pyroclastic flows (Mt. Semeru, Indonesia) ©JAXA 2021



Greenland, ice velocity (Rignot, Mouginot et al.)

Interferometric SAR Applications (TA-2)

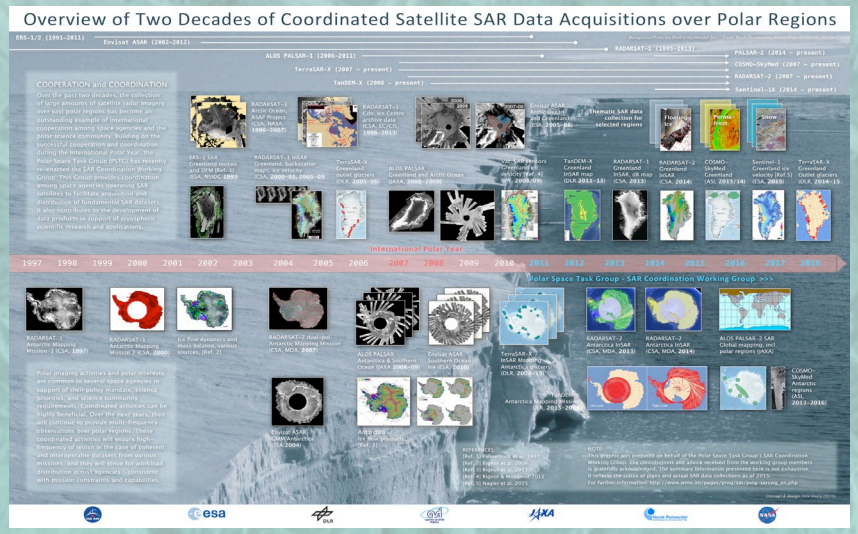
First assessment of challenges & gaps

- ***Temporal decorrelation***
  - *Current repeat cycles (weeks) do not maintain fringe visibility or coherence over fast-flowing ice, vegetated terrain, etc.*
  - *Temporal repeat is insufficient to understand rapid processes that operate at sub-weekly-to-daily time scales (e.g. iceberg calving, tidal seismic phenomena, some landslides, volcanoes).*
  - *Long wavelengths are more resilient to temporal decorrelation but we currently lack a spatially extensive, high resolution L-band time-series*
- ***Ionospheric and tropospheric delay***
  - *Significant sources of noise for InSAR measurements of small signals*
- ***Temporal revisit (Hazards)***
  - *Hazards characterised by abrupt initiation – rapid evolution - cascading events – global distribution*
    - ***Sub-daily repeat required** to measure transient and cascading processes*
- ***Line-of-Sight (LOS) diversity***
  - *Observations from 2 directions only (asc/desc) limits models to 2D only.*
  - *Mapping 3D phenomena in 2D - a serious compromise. Critical need for 3D mapping for all InSAR applications*
- ***Accessibility & latency in data delivery***
  - *Low latency critical for operational hazard response applications.*
  - *Open public access to data*

Programme and mission coordination (TA-3)

Task: Addressing programmatic challenges to inter-agency mission coordination

Challenge: *Current and near-future SAR missions do jointly have the potential to address several of the challenges identified. Success depends on the ability of space agencies to formally engage and consider potential modifications to mission plans already cut in stone.*



The Polar Space Task Group – SAR sub-group. (Final report, Oct. Oct 2018)

- ***The Polar Space Task Group (PSTG)*** *constitutes a successful example of how such a science-led coordination activity can be organised.*
- ***Data downlink capacity*** *is a major bottle-neck inhibiting optimal use of SAR payload capacity. Potential for greater inter-agency coordination also on ground segment.*
- ***Open data policies and free public access*** *is vital for data democracy and science development.*
- *SAR product and format standardisation across agencies and SAR missions. CEOS* ***Analysis Ready Data*** *(CARD) a promising initiative.*

Summary of key challenges (prel.)

- *Key requirement highlighted for several application areas is the* ***need to reduce observation revisit times to the order of days, or less****. For InSAR applications, temporal decorrelation constitutes a major limiting factor.*
- ***For the glacier and solid Earth applications, systematic observations from a variety of different (at least 3) viewing angles*** *is required.*
- ***For forestry applications, a variety of interferometric baselines*** *would enable tomographic retrieval of forest structural parameters. This can be achieved by relaxing the orbit control, which however affects other InSAR applications.*
- *For Forestry and Land Cover applications that rely on longer wavelength SAR:*
  Current ***lack of dense L-band time-series****.*
- ***Polarimetric and Pol-InSAR applications*** *are* ***under-developed*** *due to the lack of global polarimetric time-series data.*
- ***Multi-frequency applications*** *are also under-developed due to lack of coincident data for research. Simultaneous or near-simultaneous multi-frequency observation campaigns, in particular for land cover related applications, are therefore strongly encouraged.*

Recommendations (prel.)

- *No one single SAR system or agency has the capacity to address the full suite of requirements identified.*
- *In the near term, **close agency coordination** of current and already planned missions in the 2020s will be essential. **Current and near-future missions jointly have the potential** to address several of the requirements highlighted.*
- ***Good potential for synergy** between high capacity missions with global observation plans, and missions designed for more targeted focus – **including commercial systems**.*
- *In the 2030s perspective, potential for the joint development of an ambitious **multi-agency, multi-mission, mega "constellation of constellations",** that would comprehensively address the outstanding scientific requirements for temporal revisit, LOS- and baseline-diversity, polarimetry and multi-frequency observations.*
- *System supported by a constellation of Data-Relay Satellites visible from all orbits to optimise observation capacity, streamline downlink, and ensure short lead times.*

→ *For further discussion @*

Help influence how present and future SAR missions can best support *your* field of work

Participate in the On-line Survey

https://esa-survey.limequery.org/654789?lang=en .