TA2 Breakout Session topic

TA2: InSAR applications

- Hazards (Tomokazu Kobayashi and Cathleen Jones)
- Solid Earth Science (Yujie Zheng, Andy Hooper, Mark Simons)
- Permafrost (Line Rouyet & Annett Bartsch)
- Ice Sheets & Glaciers (Eric Rignot & Bernd Scheuchl)
- Ocean Applications (Paco Lopez Dekker, Johnny Johanessen, Bjorn Rommen)
- Non-zero Baseline InSAR (Bjorn Rommen)

Observation requirements for Hazards

*Tomokazu Kobayashi (Geospatial Information Authority of Japan)
Cathleen Jones (Jet Propulsion Laboratory, USA)

Suggestions for current and near future SAR missions

1. **Regular observations** in InSAR-compatible modes for pre-to-post **change detection** (including New Space SARs if possible)
2. Fund and maintain **processing systems** providing **low latency** InSAR products, free of charge, for global disaster response
3. **Major space agencies commit** to providing **low latency** products (<=1 hr, L0 or higher)
4. **Coordinated disaster response effort among space agencies**, independent of Disasters Charter, to provide data for forewarned or smaller events prior to charter activation
   - Smart Tasking, i.e., automatic tasking (acquisition & downlink (if necessary)) and expedited processing
   - Include New Space SARs

Suggestions for brave mission solutions in the next decade (2030s)

- Coordinated, multi-InSAR, multi-mission disaster response system that supports both continual monitoring and imaging within hours of an event
- Interagency coordination of orbits and observation plans for new missions
  - Coordinate SAR coverage to distribute overpasses (not near-simultaneous imaging) to reduce time to image an area post-disaster
  - Reduce latency to InSAR repeat passes
  - Possibly focus coverage to known areas with geohazards, for example

Observation requirements for Solid Earth Science

Yujie Zheng (UT Dallas, USA)
Andy Hooper (U. Leeds, UK)
Mark Simons (Caltech, USA)

Suggestions for current and near future SAR missions

- ALOS-2/ALOS-4, NISAR, SAOCOM-1a/B, Sentinel-1A/C, RADARSAT, EOS-04, TerraSAR-X, CSM,...
- Suggestions:
  1. **Increase temporal sampling:** Deploying companion satellites in the same orbit enhance temporal resolution of a single SAR mission
  2. **3D Deformation Reconstruction**: Use closely flying radar receivers to increase line-of-sight diversity (e.g., ESA's planned Harmony mission).
  3. **Achieve LOS diversity:** A combination of left- and right-looking observations from ascending and descending orbits, and potentially from highly squinted geometries.
  4. **Radar wavelengths diversity**: Utilize multiple radar bands (e.g., NISAR's L- and S-band) to improve data quality, especially in densely vegetated areas.
  5. **Continuous monitoring**: Plan missions with overlapping periods to maintain data continuity.

Suggestions for brave mission solutions in the next decade (2030s)

- **Daily repeat sampling**:
  - Consistent geometry, radar wavelength from multiple satellites
  - Geostationary SAR offers daily sampling, though it sacrifices global coverage and faces issues like rotational decorrelation
- **Path delay correction and 3D deformation reconstruction**:
  - Requires simultaneous interferometry from multiple LOS directions.

Observation requirements for Permafrost

Line Rouyet (NORCE, Norway)
Annett Bartsch (b.geos, Austria)

Summary and suggestions for current and near future SAR missions

- Permafrost monitoring from space requires:
  - the **combined use of a large set of parameters**.
  - the **integration of multiple proxies** and **advanced data fusion strategies** for assimilation into permafrost models.
- Utility of current missions for global assessment remains limited due to acquisition strategies which **disadvantage high-latitude permafrost regions**.
  - Need for **consistent acquisitions at pan-arctic coverage**.
- For several applications, C-band with a 12d repeat-pass is not enough.
  - Need for future missions with **shorter repeat-pass** and **lower SAR frequencies**.

Suggestions for brave mission solutions in the next decade (2030s)

- Due to the diversity of the parameters studied by the permafrost community, **no single SAR system can address all the needs**.
- Permafrost monitoring requires a **combination of frequencies, polarizations, acquisition strategies and modes**.
- Efforts to **coordinate simultaneous acquisitions of complementary SAR missions** is mandatory.

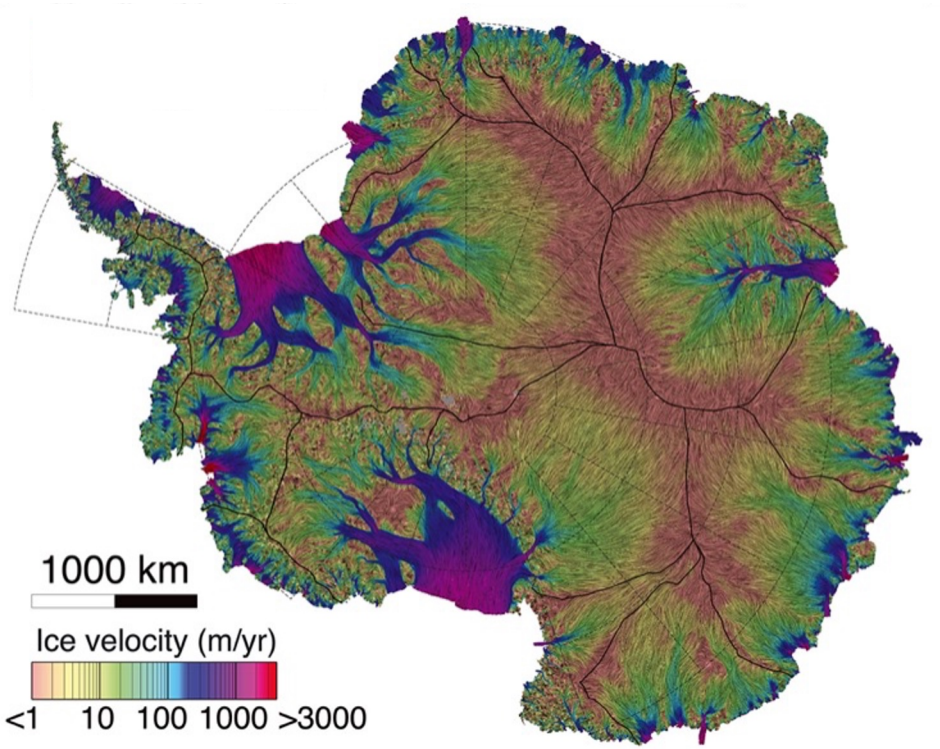
- **General need for SAR cal/val supersites and campaigns targeting permafrost applications**:
  Fill the knowledge gap for unambiguously interpretation of SAR signal in permafrost regions.
- **Priority for lowland permafrost applications:**
  Consistent acquisition and data delivery strategies over the whole circumpolar regions (incl. Siberia).
- **Priority for mountain permafrost applications:**
  Consistent low frequency missions and high spatio-temporal resolution.

Observation requirements for Ice Sheets and Glaciers

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Sea level rise worse than you think (1 to 2 m), "deep uncertainty" in rapid change, $T cost, new coastline w. pop. migration





Suggestions for current and near future SAR missions – C –Band

- **Sentinel-1 c-d (2024-2025) and NG (2032-)**
  - S1 long-term commitment (multi-generational) is a key aspect for long time series and stable data coverage.
  - Maintain (and improve) existing ongoing coverage for Antarctica and Greenland, esp. North Greenland.
  - Once the constellation is restored, revive 2-satellite coverage (6-day repeat).
  - Expand coverage to include ascending + descending tracks for 2D motion with phase.
  - With three satellites (a, c, d), reduce InSAR repeat to 4 days to cover key glaciers in West Antarctica (TBD).

- **Harmony and follow-on (2029-)**
  - Will enable 3D ice motion as S1 co-flyer but requires more S1 12-d acquisition in ascending and descending modes.

- **RADARSAT Constellation Mission (ongoing)**
  - Prioritize frames over the grounding line of fast-moving glaciers in Antarctica and provide sustained, consecutive 4-day repeat InSAR coverage for these regions.

Suggestions for current and near future SAR missions – L-band (+ S-band)

- **NISAR**
  - Gaps in Northern Greenland and South Pole must be filled using other missions.
  - NISAR will not enable phase mapping of fast-moving glaciers in Antarctica and Greenland (long repeat), grounding lines in Greenland (coverage) and key fast-moving glaciers in Antarctica (long repeat)
  - Make S-band data collected accessible to the community to improve grounding line mapping in Antarctica
- **ALOS-2/ALOS-4**
  - Modify the BOS to improve InSAR repeat pass collections in coastal Antarctica with the shortest repeat orbit (12 d). Wider swath of ALOS-4 provides more overlap near the Poles. Will provide geometry diversity to NISAR. Reserve several tracks for InSAR collection with minimum impact on other BOS goals.
  - Use combined ALOS-2/ALOS-4 to collect 7-day InSAR data over critical fast glaciers with asc/desc coverage.
  - Provide InSAR coverage (asc/desc) in northern Greenland to fill NISAR gap.
  - Cover South Pole (south of 84S) in left looking mode (NISAR gap). Temporal baseline may be relaxed to weeks.
- **SAOCOM-1a/b**
  - Provide 8-day repeat InSAR coverage (asc/desc) over (5-10) regions of coastal Antarctica. Will provide geometry diversity to NISAR and ALOS-4 PALSAR-3.

Suggestions for current and near future SAR missions – X –Band

Agency missions & public private partnerships

- **TerraSAR-X / TanDEM-X**
  - Continue DEM mission to collect DEM time series in coastal Antarctica (essential for ice-ocean interactions)
  - Provide a third global DEM.
  - Make DEM products more readily available (instead of SLC) online.
- **COSMO SKYMED Second Generation**
  - Utilize the 1-day InSAR capability to maintain data collection at the grounding line of (30+) fast glaciers in Antarctica.
  - Make data available to the science community in larger quantity.

Commercial missions

- **ICEYE**
  - Collect time series of 1-day asc/desc right/left looking InSAR over critical fast glaciers in Antarctica (10+) and Greenland (3). Critical capability not available from other SAR missions. Proven quality. Prospective of NASA contract.
- Other (Capella, Umbra, …)
  - Develop short-repeat InSAR capability.

Suggestions for future missions in preparation for IPY 2032.

Ice velocity, grounding lines, ice fracturing are best observed with InSAR. The results have an enormous influence on the science of projecting sea level rise, but this requires daily (Antarctica) to sub-daily (Greenland) repeat with phase only and a diversity of viewing angles.

Scientific progress for rapid sea level rise will be limited by the availability of these observations (+ in situ ocean observations). "We cannot model what we cannot observe":

Space agencies should work together to help polar science in preparation for IPY 2032. Advances and discoveries require a fast repeat, high resolution, multi-agency constellation striving to provide:

- Daily to sub-daily (2 hours (Greenland) to 6 hours (Antarctica)) along key coastal/fast sectors.
- Phase everywhere (multi-geometry w. diversity of short repeat cycles - Asc/Desc, Right/Left)
- Data openly available to the community, open software, advanced (L2-L3) products on the Cloud generated by experts, educational workshops, and growth of the user community.

Recommendations from the last workshop
TA2 - InSAR applications

Now/Near-term needs

- Open data policy for archives of all agencies (encourage New Space to participate)
- Standardized / unified interface for tasking and data discovery / download
- New Space data access: Commercial data buys by the funding agencies for PI projects
- Reestablish Polar Space Task Group for an International Polar Decade

2030+ Timeframe recommendations

- Harmonized coordination of satellites sensors to give interferometric capability between different agencies' SARs
- High resolution, daily-to-subdaily interferometric observations
- Harmony-like companions for more missions

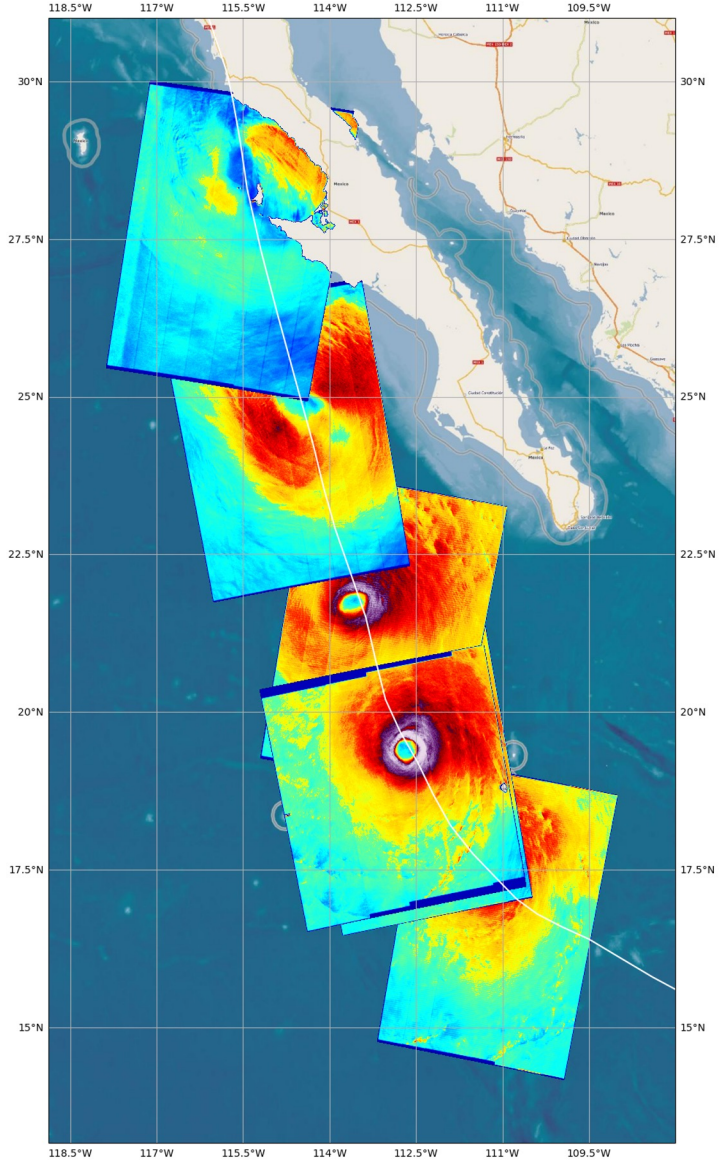
Evolution of PSTG: Timeline / Action Plan / Agreement

- Working to finalise Terms of Reference (ToR) – recent inputs have been provided; final review by early December;
- President of the WMO Infrastructure Commission has requested the chairs of the Advisory Group on the Global Cryosphere Watch (AG-GCW) and the Standing Committee on Earth Observing Systems and Monitoring Networks (SC-ON) to provide recommendations on the reporting structure for a new Team on Cryosphere and Polar Observations from Space (name tentative) by end 2024, between the two Commission Structures, and with a link to the WMO Executive Council Panel on Polar and High Mountain Observations, Research, and Services (PHORS). The proposal should address the engagement/interaction with the Expert Team on Space Systems and Utilization (ET-SSU);
- A call of representatives from those groups took take place on 6 November (yesterday);
- A decision of the President of INFCOM is expected by January 2025;
- Membership to be established in early 2025, to ensure that the team has the right composition to be effective;
- Expected to be able to communicate the outcome on structure and composition by April 2025 with a view of holding its first meeting mid 2025;
- The team composition would strive to avoid duplication and the links to observing requirements, gap analysis and WIGOS Vision, as well as GCOS, WCRP, etc. will be established through focal points in the team or invited experts, as agreed with each entity.

WMO

Observation requirements for Ocean Science

Paco Lopez Dekker (Delft University of Technology, NL)
Johnny Johannessen (NERSC, NO)
Björn Rommen (ESA/ESTEC)



Hilary, August 2023

Suggestions for current and near future SAR missions

- **HRWS-capable** SAR systems over the ocean to be operated in a narrow azimuth-beam mode, maximizing the antenna gain and exploit the available resources to either:
  - increase the range resolution
  - minimise the NESZ (in particular for cross-polarized channels)
  - to provide widely separated azimuth looks

- **ATI-capable** SAR systems by making use of:
  - Dedicated systems (Harmony, Seastar, …)
  - Exploitation of multiple ($\geqslant$2) phase centres in azimuth (e.g. Radarsat-2, TSX/TDX)

- Adding **directional diversity**, which is the key element in scatterometric wind retrieval
  - Including co- and cross-polarized channels

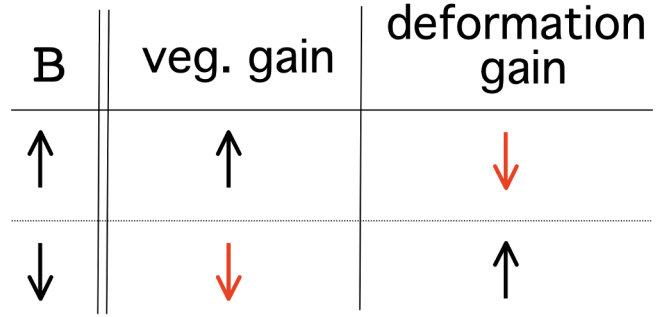
Suggestions for brave mission solutions in the next decade (2030s)

- Ocean sub-mesoscale (order 1 km) to mesoscale (>30 km) features have lifetimes, *O*(hours to 10´s of days). Regular cover of the sub-mesoscale by the repeat visit of any spaceborne mission not feasible
  - Need for continued algorithm developments to support provision of analyses of globally sparsely sampled ocean data (using e.g. generative AI)

- Develop high-resolution SAR ocean product validation approaches
  - Designation of coordinated super-sites?

- Combining near-collocated directional diversity, including the use of co- and cross-polarized intensity and exploitation of Doppler signals

Topography & Tomography



P. Siqueira, 2003

All “backbone” SAR missions at C- and L-band operate with ~ zero-baseline

- Largely benefiting surface deformation (reduction of volume/baseline decorrelation)
- Not optimised for height measurements (analogy: limited ‘parallax’) height of ambiguity
- Dedicated missions in favour of SAR tomography or for increasing InSAR/PolInSAR height sensitivity:

1) multi-pass acquisition stack collection for a single mission with controlled across-track baselines (e.g. Biomass)
2) Tandem satellite operation (e.g. TerraSAR-X+Tandem-X)
3) Single-pass acquisition stack collection for a companion mission with controlled across-track baselines (e.g. Harmony)
4) Single-pass acquisition stack collection for interferometric cartwheel like concepts (dedicated transmitter)

North-South sensitivity / 3D deformation

Options (non-exhaustive):

1) Exploiting ascending/descending + left-/right-looking geometries (e.g. ALOS-2/NISAR)
   - Disadvantage as toggling between left- and right-looking decreases the temporal resolution for each stack
     - ⍰ could still be fine when implemented systematically
2) Exploiting burst-overlap region in TOPS modes (e.g. Sentinel-1)
   - only applicable in the limited overlap region
3) Mid-inclination orbits (e.g. NIMBUS IRIDE), combined with SSO SAR (e.g. CSK)
4) Dedicated companions with large along-track separation (e.g. Harmony)

