Sentinel-1 Data Products and Dissemination

Ref#	Recommendation	From Session(s)
R-1	In the proposal *"A Proposal for Interferometric Time Series Product with Reduced Stochastic and Systematic Phase Errors"* Ansari et al. recommend[1] a new intermediate product level for InSAR, namely the reconstructed consistent interferometric phase series. The proposed product would: – Contain the consistent physical signals such as, but not limited to, atmospheric variations and surface displacements; – Significantly reduce the interferometric phase bias and variance; – Reduce the amount of interferometric data from the original pairwise interferograms within the data stack to a time series of higher quality and, optionally, subsampled interferograms; – Ease the data transfer and provide a unified input to the user community; – Enhance the reliability of InSAR for displacement analysis specifically for the retrieval of deformation velocity maps.	Advances in InSAR theory
R-2	It does not make sense for ESA to move from providing SAR SLC's and orbits to providing advanced InSAR products, such as interferograms. The reason is that there is not one single product that can be generated but a multitude of products - it depends on the application. The SLC's are the ingredients, but with the same ingredients we can make many recipes for meals.	Advances in InSAR theory
R-3	ESA should provide higher-lever interferometric ARD layers.	Data Products and Services
R-4	ESA should provide download access to single Sentinel-1 bursts in order to save bandwidth, disk space and processing resources at the user-end.	Data Products and Services; Earthquakes and Tectonics
R-5	Extended Time Annotation Dataset (ETAD) would help both geolocation and interferometry (for Sentinel-1) and should be provided.	Atmosphere and Ionosphere
R-6	Sentinel-1B vs Sentinel-1A geolocation offset requires investigation.	InSAR for the built environment

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[1] https://elib.dlr.de/130072/1/ARD_PhaseProduct_Ansari_etal.pdf

R-7	ESA should provide already coregistered images, or at least meta-data sufficient for coregistration, in order to save disk space and processing resources at the user end.	Atmosphere and Ionosphere; Earthquakes and Tectonics
R-8	ESA should provide atmospheric corrections (also ionosphere), solid-earth tides etc. in order to go towards absolute InSAR measurements.	Earthquakes and Tectonics
R-9	Sentinel-1 EW data for Arctic regions should also be provided as SLC (in addition to GRD and RAW).	InSAR for the built environment

Sentinel-1 Observation Scenario

Ref#	Recommendation	From Session(s)
R-10	Extend S1 systematic acquisitions for land cryosphere: • Continuous full coverage of Antarctic margins with 6 days repeat to support retrieval of ice sheet parameters including ice velocity (as basis for ice discharge), grounding line, cracking / calving events. On campaign basis (polar winter) crossing orbits should be acquired for InSAR velocity. • Full coverage of Greenland and Arctic Ice caps by crossing orbits during winter campaigns for InSAR velocity. • 6-days repeat-pass in for selected permafrost areas (e.g. Siberia).	Ice and Snow
R-11	For Sentinel-1A,1B systematic acquisitions with 6-day intervals (as much as possible and 12-day intervals elsewhere) are requested. Dual-pol. data is preferred over single co-pol. data. Changing modes (e.g. polarization) should be avoided as much as possible.	Land cover and vegetation
R-12	Sentinel-1A,1B acquisitions should continue to retain the shortest achievable repeat time over active volcanoes (e.g., in particular 6-day pairs would help for volcanoes in Southern Chile: descending track 83 and ascending track 91 where acquisitions have been intermittent since 2019).	Volcanoes
R-13	The community recommends to operate the Sentinel-1A,1B,1C constellation with 1-5-6 days repeat. The 1 day pair will have an significant improvement of coherence and will also allow to monitor fast changing processes not observable by 6 or 12 days repeat. This configuration is seen as a game changer and a big step forward in monitoring land cryosphere. The 4-4-4 constellation improves temporal sampling, but it will have no (or only minor) impact on coherence and retrieval of parameters and quality of the products.	Ice and Snow
R-14	For Sentinel-1A,1B,1C the operation with 1-5-6 day intervals and the operation with regular 4-4-4 day intervals are both attractive for the land cover and vegetation applications. The short 1 day interval can contribute additional (complementary) information, while the main multi-temporal rhythm remains at 6 days. The regular 4-day intervals would improve the temporal sampling to 4 days.	Land cover and vegetation
R-15	The advantages / disadvantages of different Sentinel-1A,1B,1C schedules (1-5-6 day versus 4-4-4 day repeat) should be investigated.	Land cover and vegetation

Future Studies and R&D

Ref#	Recommendation	From Sessions(s)
R-16	Study new SAR systems, like formations (MIMO and SIMO), dithered SAR, that trade additional noise, likely to be acceptable for interferometric applications, with extended swath, higher reliability, lower costs.	Advances in InSAR theory
R-17	Initiate R&D studies to enhance synergistic use of offset tracking and InSAR for large scale monitoring in the ice and snow studies.	Ice and Snow
R-18	Study the retrieval of Snow Water Equivalent (SWE) using InSAR, investigate temporal decorrelation due to snow conditions / accumulation at C- and L-Band. Initiate R&D studies for SWE retrieval with access to suitable time series of repeat pass L-Band data (e.g. SAOCOM A&B), take synergy with Sentinel-1 into account.	Ice and Snow
R-19	Initiate R&D studies to investigate the feasibility of C-band Single Pass - InSAR (close formation of Sentinel-1A & 1C).	Ice and Snow
R-20	Observations of 3D ice velocity with specific Sentinel-1 acquisition campaign should be performed for EE10 candidate Harmony. Bistatic backscattering from different surfaces needs to be further investigated in preparation of Earth Explorer 10 candidate Harmony.	Ice and Snow
R-21	Initiate R&D studies to develop concepts and algorithms for exploiting Sentinel-1 / ROSE-L synergy.	Ice and Snow
R-22	Initiate R&D studies on coherence and other InSAR applications for ice and snow in preparation of ROSE-L, NISAR.	Ice and Snow
R-23	Investigate the potential of the opposing imaging geometry Sentinel-1 (right looking) and NISAR (left looking), applying InSAR for various land cryosphere applications.	Ice and Snow
R-24	At present most algorithms depend on training data and can therefore not easily be scaled. Developing physical model (scattering model, coherence model) based algorithms would be useful. ESA should support this through „study contracts".	Land cover and vegetation

R-25	Recommendation to ESA to launch studies regarding the comparison of different algorithms of time series analysis over the same area, in order to assess the reliability of products.	Earthquakes and Tectonics
R-26	With Sentinel-1 we have gained a short-term coherence, but fading effects seem to be a limitation for multi-look processing. Approaches for areas where only short-term coherence is retained are also important - relying only on long-term interferograms is not always an option. Recommendation : A proper processing approach, including noise filtering, is needed to treat these effects. It is recommended to launch studies to advance the understanding of the physical scattering mechanisms and the proper processing approaches for short-term interferograms.	Subsidence and deformation
R-27	Stimulate deep learning initiatives, e.g. to better identify deformation patterns or handle large datasets.	Subsidence and deformation
R-28	Preparations for L-band coherence should be addressed in the future R&D studies.	Land cover and vegetation

Future Missions (Sentinel-1 NG, ROSE-L, NISAR etc.)

Ref#	Recommendation	From Session(s)
R-29	Study new SAR systems, like formations (MIMO and SIMO), dithered SAR, that trade additional noise, likely to be acceptable for interferometric applications, with extended swath, higher reliability, lower costs.	Advances in InSAR theory
R-30	Investigate solutions for L-band absolute geolocation (and phase) related to the ionosphere.	Atmosphere and Ionosphere
R-31	Don't adopt Quasi Quad Pol if you want to apply split-spectrum for ionosphere mitigation. If Quasi Qud Pol is adopted anyway, apply split spectrum to main bandwidth (NISAR).	Atmosphere and Ionosphere
R-32	It is also recommended to evaluate C-Band Single Pass - InSAR capabilities for several months during the commissioning phase of S1C, this will provide important knowledge for preparation of Sentinel-1 NG and other future SAR missions.	Ice and Snow
R-33	Constellation of Sentinel-1 and ROSE-L: Quasi simultaneous acquisition of Sentinel-1 and ROSE-L is the preferred constellation (S1 and ROSE-L in close formation). Dual frequency C/L-band data will improve the retrieval of ice and snow parameters and synergistic use will allow the development of significantly improved products and services.	Ice and Snow
R-34	There is a high interest in having „Sentinel-1 like data" also at other frequencies (e.g. L-band).	Land cover and vegetation
R-35	We consider the acquisition of up-to-date DEMs to be critical for InSAR in volcanology and for high quality automated processing, which should be done at higher spatial resolution for volcanoes where possible	Volcanoes
R-36	Re-assess the possibilities of a future spare Sentinel-1 in space. If at one point there are three working S1 in space, keep investigating the potential of using it within the Copernicus Mission objectives. E.g. using it for emergency response and other possibilities in an on-off way. Additional acquisitions are requested for example during volcanic crises.	Earthquakes and Tectonics; Volcanoes
R-37	Keep the North-South sensitivity operational and not pass it over to short-lived missions like Harmony. If Sentinel-1 NG is not acquiring in TOPS mode we need alternatives for sensing the third dimension in the 2030s and beyond.	Earthquakes and Tectonics

R-38	The requirement from many applications is the ongoing continuity for the Sentinel-1 constellation to have long time series of compatible data with consistent parameters including observation geometry. New features/flexibilities (e.g. larger baselines, longer burst overlap regions) have the risk to fragment the data. However, these new features should be considered for future complementary ESA missions.	Subsidence and deformation
R-39	"Enhanced continuity" provided by Sentinel-1 NG is of key importance.	InSAR for the built environment
R-40	There is a gap in systematic observation of high resolution surface elevation change for outlet glaciers of ice sheets and mountain glaciers. Currently this is done by TANDEM-X, but continuation of this mission is not planned.	Ice and Snow

3rd Party and Archived Missions Data Access

Ref#	Recommendation	From Session(s)
R-41	Coordination of systematic acquisitions of current L-band SAR sensors for ice sheets, glaciers, permafrost regions and mountain areas with seasonal snow, and access to archives, is required.	Ice and Snow
R-42	We aspire to international community-led coordination for SAR tasking over volcanoes in unrest and eruption	Volcanoes
R-43	Commercial SAR imagery could have a role providing rapidly acquired images during volcanic crisis response, but we need routes to obtain such imagery beyond the International Disaster Charter alone.	Volcanoes
R-44	SAOCOM A&B (8 days repeat) and ALOS-2 (14 days repeat pass) has similar repeat pass interval as ROSE-L with 6 / 12 days. Enable access to the SAOCOM and ALOS-2 archives for polar and mountainous areas.	Ice and Snow
R-45	We have seen few studies that combine "old" mission data from ERS and Envisat with Sentinel-1. We recommend to make the ERS and Envisat archive very easily accessible.	Earthquakes and Tectonics

International Collaboration

Ref#	Recommendation	From Session(s)
R-46	What can ESA do to stimulate the standardization of products from InSAR wide-area Ground Motion Services? Could ESA initiate a mechanism so that ground infrastructures with Corner Reflectors or Active Transponders would be acknowledged by satellite operators and their use and networking fostered?	Subsidence and deformation

Presentation of InSAR Results

Ref#	Recommendation	From Session(s)
R-47	Maturity level within the infrastructure life-cycle (e.g. planning, construction, monitoring). Recommendation: efforts needed to make sure that InSAR is embedded into the portfolio of infrastructure management workflows (e.g. civil engineering courses)	InSAR for the built environment
R-48	Regarding InSAR capability to provide information suitable for early-warning and alerting the community has two main requirements: 1. Geophysical/geological/ground data should <u>always</u> to be accounted for when looking for precursors/anomalies. 2. Early-warning triggering to be supported by robust statistics and according to engineering standards. Communicating results and their uncertainty – the key recommendations in this regard are: 1. Standardization of output products 2. Error-bars and easy-to-understand statistics should accompany results and derived products for more rigorous analysis.	InSAR for the built environment
R-49	Researchers shall use more care to fully explain the results and assumptions used regarding deformations, velocity maps, ground motion etc.	Advances in InSAR theory