W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

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POLAR SPACE TASK GROUP

(PSTG)

SEVENTH SESSION

INNSBRUCK, AUSTRIA

12-13 DECEMBER 2017

FINAL REPORT

WMO General Regulations

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation of behalf of the constituent body when the matter is, in his opinion, urgent and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

MEETING SUMMARY

1. WELCOME AND OPENING REMARKS

M. Drinkwater welcomed participants remotely. He gave his apologies for not being in Innsbruck due to adverse weather circumstances across Europe which had led to serious delays and cancellations. Rather than travel and become stranded, he had decided to cut CO2 emissions and participate remotely. It was noted that several people had sent apologies, though intend to participate remotely.

2. INTRODUCTIONS TO PARTICIPANTS

In a tour-de-table, participants introduced themselves (see attendance list in Appendix I). Apologies for not being able to participate were received from Bojan Bojkov (EUMETSAT), Raj Kumar (ISRO), Zhaojun Zheng (CMA), Manfred Gottwald (DLR), Marc Thibeault (CONAE), Ronald de Buss Souza (INPE), Masahiro Hori (JAXA).

3. APPROVAL OF AGENDA

M. Drinkwater thanked enveo for hosting the meeting, as one of the leading entities in Europe for delivering cryospheric products. M. Drinkwater introduced the agenda.

The session subsequently adopted the proposed draft agenda (Appendix II).

All meeting documents are available at http://www.wmo.int/pages/prog/sat/meetings/PSTG-7.php.

4. KEYNOTE PRESENTATION 1: ENVIRONMENTAL EO INFORMATION TECHNOLOGY CONTRIBUTION TO CRYOSPHERE PRODUCTS AND SERVICES

Helmut Rott raised science issues in monitoring the cryosphere, and contributions by enveo AG in terms of deriving snow cover extent, SAR-based glacier and ice sheet dynamics, and high-resolution snow water equivalent. Progress has been thanks to many partnerships. He covered operational products, experimental products and research activities. The latter includes investigations on using L-band SAR for deriving high-resolution snow mass (SWE), glacier tomography, and single-pass SAR interferometry for measuring glacier mass balance.

He showed examples for fractional snow area extent, snowmelt area, and ice velocity products, mainly derived from Sentinel-1. Ice velocity products for ice dynamic modelling showing changes of Larsen-B ice shelf. High-resolution snow water equivalent (SWE) mapping using SAR is still a challenge, as addressed in the NoSREx campaign, Sodankylä; retrieval from backscatter data requires a priori estimates of effective snow grain size. Glacier tomography is explored during the AlpTomoSAR campaign, through mapping glacier structure (firn body, ice, down to bedrock). Interferometric measurements of surface topography and elevation change show striking temporal stability of the surface elevation (using TanDEM-X and ICESat).

As main gaps, he identified:

- A consolidated method and satellite mission for high-resolution monitoring of SWE
- L-band InSAR satellite time series to assess the operational potential for high-resolution SWE monitoring at regional scale
- L-band SAR experiments for glacier tomography

- Continuity of Single-pass (SP)-InSAR for high-resolution monitoring of glacier volume change and mass balance (e.g., passive SAR formation as was proposed for SESAME)

Ben Holt asked about TanDEM-X latitude restrictions for single-pass data. Dana Floricioiu clarified that TanDEM-X was a global mission, with different baselines geared towards different latitudinal zones.

Mark Drinkwater noted that L-band gaps may be addressed within the Copernicus Expansion programme. Helmut Rott stressed that for tomography very precise repeat orbits were needed; Thomas Nagler said that the SAOCOM concept was to be tested in some areas in Antarctica; Craig Dobson noted that NISAR will provide 12-day repeat pass interferometry.

Mark Drinkwater asked whether it was more advantageous to de-couple L and C-band, or better to have collocation (spatial, temporal).

ACTION 7.1: SAR CWG to focus attention on obtaining collocated data from Sentinel-1, NISAR, RADARSAT-CM, PALSAR, over the different target areas identified by PSTG.

5. REVIEW OF ACTION ITEMS

The PSTG Action items list was discussed and updated (see Appendix III, including the Actions agreed at this session).

6. ADDRESSING STRATEGIC INITIATIVES

6.1 Global Cryosphere Watch

6.1.1 Overview and Recent Accomplishments

Jeff Key presented an overview of Global Cryosphere Watch (GCW) activities. There are various components of GCW, which is a WMO programme and reports to EC-PHORS: observations, products, research and services. GCW is in its pre-operational phase until 2019, and is planned to become an operational Programme in 2020 after WMO Congress 2019. “Operational” refers to the surface observing network CryoNet (120 stations approved, 50 candidate). GCW is a platform for broad engagement of a number of institutions and bodies, including PSTG.

Observing requirements are defined, contributing to the WMO OSCAR database, and how measurements should be made (standards and best practices). Minimum observing programmes at CryoNet stations are defined for each cryosphere component. A glossary of terms has been developed. The GCW data portal is hosted by met.no, and metadata for the various data sources have been standardized.

GCW climate monitoring products as well as NRT products are shown online (GCW website). SnowPEx results should be considered, and similar efforts should be undertaken for sea ice. He advocated multi-dataset products and blended data (mean snow depth, SWE). The intercomparisons help determine what products to put together, and how.

There still are major gaps in CryoNet, such as over the United States, Africa, Siberia.

There are a number of PSTG-GCW commonalities. For example, both groups are interested in product intercomparisons in order to better characterize errors and explore potential benefits of blending products. As CryoNet continues to develop and expand, some CryoNet sites may prove valuable for satellite product validation. Additionally, both groups are defining user requirements.

Data rescue efforts within GCW are still early stages.

6.1.2 CryoNet

Henning Löwe gave an overview of CryoNet Sites and Stations and their definition, and details on the Davos site. Locations such as Sodankylä, Zackenberg and others have greatly helped define the CryoNet concept. A site consists of several stations that are clustered in in an area such as the Davos valleys. One objective is to monitor snow stratigraphy evolution over time/season. A new station in Laret was set up as part of the Davos Site, focussing on MW-vegetation interactions. The ESA SnowLab project focusses on radar tomography, and relation between signals and evolution of microstructures in snowpacks.

Measuring snow cover in forested environments is complemented using UAVs and TIR techniques. He stressed that CryoNet Sites can be used for RT modelling activities, to understand snow microphysical structure impact on MW measurements. In the Dischma area, tree and snow attributes are monitored since the 1970s, for estimating biomass.

M. Drinkwater noted that reference measurements and basic research at CryoNet sites make a great contribution.

J. Key explained that there are several U.S.-based stations, many of which research-based. Gaps in CryoNet over the U.S. have in some cases been due to a lack of awareness by station operators. There has not yet been a GCW workshop in the U.S. or Canada to raise awareness by the community; such workshops have proven very popular in other regions.

6.1.3 Sea Ice Best Practices [DOC[1]]

Penelope Wagner presented jointly with Petra Heil (remote). The best practices are based on established procedures recommended in the literature and IICWG. The CryoNet approach fails for some sea-ice parameters (extent, concentration, velocity, floe size) due to the nature of sea ice (roughness, vastness, diversity). These may be obtained from Lagrangian observatories (drifting buoys, ice breakers) at low spatio-temporal coverage. Input from PSTG is sought on how to merge satellite and surface-based observations of sea ice. Autonomous measurements are needed.

A list of required variables has been developed (automatic/manual, measurement frequency, observation source). The CryoNet station criteria were analysed for spatial representativeness, and sustained operations.

Key questions are:

(1) What is the potential of PSTG and GCW to coordinate establishment of sea ice “supersites” in predefined areas, coinciding coastal CryoNet stations and infrastructure to provide routine monitoring

- Sites will contain areas that include fast and drifting ice
- CryoNet measurements could be used as calibration sites for different stations

(2) If a CryoNet site is working in conjunction with satellite acquisitions, establish how far from the observing station the data can be considered as representative of the area. In terms of spatio-temporal coverage:

- A CryoNet site should cover multiple footprints, or

[1] DOC indicates that a document is available to support this item at http://www.wmo.int/pages/prog/sat/meetings/PSTG-7.php

- Cover one footprint but has multiple observations through time to get statistics through temporal extent, or
- A combination of the two.

Four categories of sea ice-related sites / stations could be envisaged:

1. Stationary sites
2. Drifting stations
3. Potential Arctic Stations
4. Potential Antarctic Stations

The NISAR cal/val concept could be used to get guidance on siting CryoNet sites for sea ice. Antarctica is relatively well covered (13 stations) vs only 2 in the Arctic.

M. Drinkwater saw two thematic areas (i) snow intercomparisons, and (ii) sea ice studies:

(i) Snow intercomparisons

M. Drinkwater noted other sites performing this (Sodankylä). T. Nagler noted that to compare 15 Northern Hemisphere snow products, it took about a year to transform all data into a common projection (coastlines), to be able to perform a pixel-based comparison. Comparisons are easier done in radiance space (where intercomparisons are easier) rather than (classified) products. H. Löwe noted the gap in variables provided by the sites. What comes from stations is not standardized thus far, and are not necessarily the most appropriate parameters (for RT modelling, for example).

J. Key noted that there is a minimum set of variables at CryoNet sites but more are encouraged. The set of minimum variables is still open for comments. CryoNet manuals will provide guidance on how variables should be measured.

(ii) Sea ice studies

Stephen Howell noted that the Canadian Arctic Archipelago has a long history of fast-ice observation stations. These will be collocated with operational ice charting services (in-situ snow depth, ice thickness) and routine RADARSAT coverage.

M. Drinkwater noted that AWI are hosting mass balance buoys and Lagrangian drifters in the Arctic. G. Spreen mentioned AWI activities in the Fram strait, Laptev sea, Beaufort strait.

B. Holt mentioned a system of upward looking sonars.

P. Heil noted major differences between Arctic and Antarctic sites: not all Antarctic sites are suitable for monitoring fast ice. Some experience exists with drifters in the Weddell Sea; more experience is needed with Lagrangian or Eulerian sites, in both hemispheres.

M. Drinkwater noted satellite data gaps over Antarctica close to coastlines which are caused by mode switches of some SAR sensors. Use Lagrangian drift during MOSAiC and have satellite agencies contribute to see benefits. G. Spreen supported this idea given that there are a large amounts of measurements performed during MOSAiC and lessons on spatio-temporal representativity through comparing different satellite data types that can be learned.

P. Heil noted that lessons could be learned using buoy arrays even before MOSAiC. Deployment of buoys is within an area but exact locations are not known by definition. Sentinel-1 acquisition planning cannot be easily adapted; RADARSAT-CM should be easier.

ACTION 7.2: P. Heil, P. Wagner and PSTG Science Leads to define sea ice locations / drift sites for which to achieve collocated acquisition planning.

ACTION 7.3: T. Nagler, J. Key and H. Löwe to identify sites where snow intercomparisons could be performed.

Status of Planning: PSTG/GCW Workshop on Snow Radar Science and Concept Development

Yves Crevier informed about plans and preparations for the workshop, held at WMO Headquarters in Geneva on 30-31 January 2018, under the auspices of WMO PSTG and GCW. One of his roles is to identify user requirements within Environment and Climate Change Canada, and as a result, an important identified gap is knowledge about terrestrial snow mass. Terrestrial snow mass remains one of the observational gaps to be met by space agencies. Canada initiated a mission concept for a dedicated mission, following the momentum of the CoReH2O ESA Earth Explorer mission proposal. ESA also pursues a SAR concept study. Recommendations from these initiatives led to the idea of the workshop.

Members of the Organizing Committee are Mark Drinkwater, Michael Kern, Chris Derksen, Simon Yueh, and Alex Langlois.

One objective is to connect to key stakeholders, and to formulate recommendations related to a terrestrial snow mission, and to communicate these to Heads of Agencies and to WMO. Specifically, to:

- Address priority science, technical, operational challenges of new spaceborne radar snow missions
- Focus on mission-relevant recommendations
- Review gaps regarding observing system capabilities and key snow products (SWE/SE)

Secondary parameters could include SAR winds.

ACTION 7.4: Y. Crevier to circulate with PSTG the draft recommendations from the PSTG/GCW Snow Science workshop.

About 30 participants are expected. Organizations and programmes represented are ESA, EUMETSAT, Copernicus, ECMWF, GlobSnow, SnowPEx, WCRP-CliC, H2020 INTAROS, PolarView, NASA/JPL, USGS, CSA, Environment Canada, Airbus DS, WMO/PSTG, GCW, GEO-CRI.

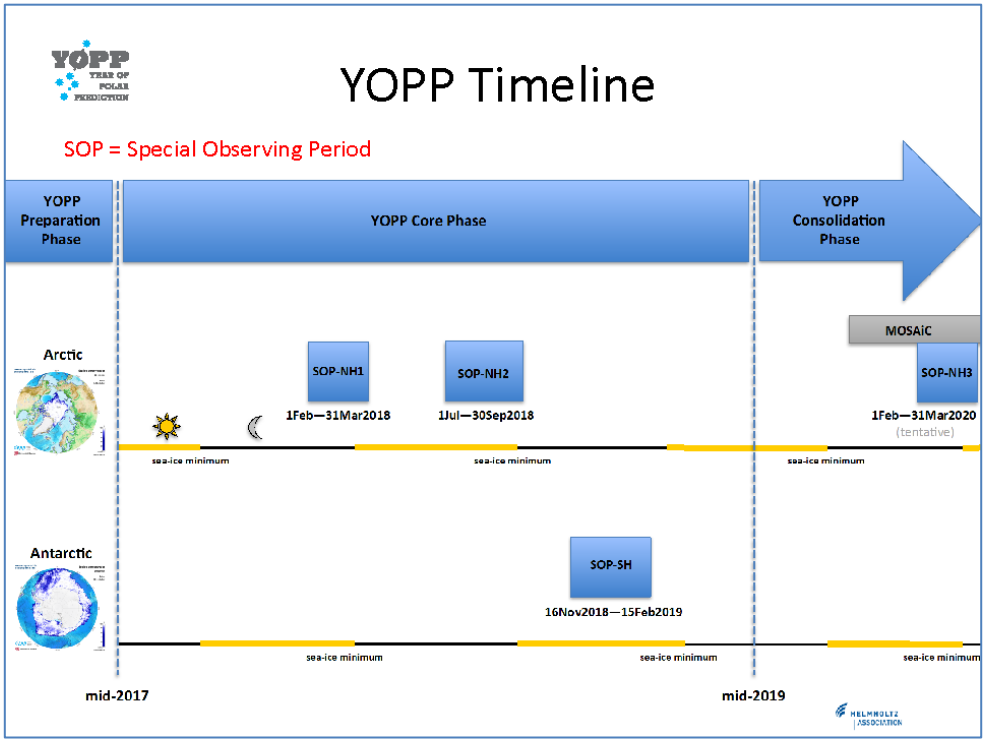
PSTG members and invitees are welcome to attend the workshop, which is otherwise by invitation only.

6.2 Year of Polar Prediction (YOPP)

Kirstin Werner gave an update on YOPP activities. She pointed out the polar observing gaps by showing ECMWF-assimilated data. The Polar Prediction Project (PPP) encompasses preparation

and consolidation phases, in addition to the YOPP core phase 2017-2019. The YOPP timeline includes two special observing periods in the Arctic, and one in the Antarctic. She provided some highlights of the YOPP preparatory phase: YOPP-endorsed projects, YOPP supersites, a GEarth-based visualization of YOPP activities, a metadata portal. H2020 and Canada Research calls were geared towards YOPP objectives. She mentioned the YOPP launch event during 2017 WMO Executive Council.

Timing of YOPP activities is as follows:



The YOPP core phase in Antarctica includes satellite snapshots (details remains to be clarified). Operational support during YOPP has been indicated by met services.

She pointed out the required parameters by YOPP – to which PSTG agencies should contribute. The YOPP community would like to see:

- Links to operational support, NRT data
- Links to available data
- NRT data
- Certain gaps – in datasets
- Improve uncertainty – satellite products to be characterized in terms of associated uncertainties
- Extra datasets

NRT in this context means data availability within a few hours after sensing. The spreadsheet of PSTG agency contributions yet needs to be fully filled in, including links to data portals and other sources (a WMO intern put together a preliminary list of data access points by PSTG member agencies).

ACTION 7.5: To finalize the collection of YOPP contributions by PSTG agencies, Kirstin Werner to send list to Secretariat, for consolidation and then validation by PSTG agencies.

C. Dobson wondered in what way PSTG agencies change observational strategies regarding YOPP opportunities. G. Spreen noted that snapshots can only refer to high-resolution SAR and high-resolution optical.

K. Werner mentioned the Oden cruise in August 2018 for 4-5 weeks, which could be an opportunity for collocating acquisitions.

S. Howell informed that CSA is engaged with YOPP organizers regarding special acquisitions. M. Drinkwater mentioned that Sentinel-1 acquisition may be tuneable regarding modes, with constraints to be discussed with. Sentinel-3 observes operationally during daytime. S. Howell said that lead time for acquisition requests is at least 3 months for RADARSAT-CM.

ACTION 7.6: K. Werner to discuss with YOPP steering group about special campaigns during YOPP that could be a target of PSTG agency acquisitions, and provide feedback to PSTG, noting that lead time for special acquisitions with agencies is at least 3 months.

6.3 MOSAiC: Multidisciplinary drifting Observatory for the Study of Arctic Climate International Drift Experiment (2019 – 2020)

G. Spreen reported on status of the expedition, after an implementation workshop held in St. Petersburg, Russia. The drift from northern Laptev Sea to Fram Strait via the transpolar stream will take from autumn 2019 until autumn 2020. The drift will be accompanied by networks of stations on the ice. Six legs for change of cruise personnel, with 2-4 weeks needed for scientists to get on and off. The science crew (~38) will change over for each leg. Multiple institutions collaborate. Satellite acquisitions over the Laptev Sea from March 2019 onwards would be desirable.

He showed schematics of the setup on sea ice, and remote stations.

He focussed on the remote sensing-specific aspects, and on scientific and operational planning. Challenges are around getting Polarstern into the ice and finding the right floe. Data management foresees that not all data from Polarstern are immediately disseminated (bandwidth will be limiting factor). All MOSAiC data will be openly available. High-resolution data from CNES and WorldView is under investigation.

ESA has endorsed a number of activities for surface-based experiments: MW radiometer, MW scatterometer (evaluating TanDEM-X, …, at multiple frequencies), optical measurements, GNSS-R. Airborne campaigns over the location of Polarstern are important for validation, potentially including NASA Operation IceBridge and ESA CryoVEx. On ice measurements will follow a defined setup: the remote sensing validation site design is subject to comments.

The EO dataset for scientific analysis is per-sensor, and for special acquisitions, focal points in agencies are being identified. From a remote sensing perspective, a drift close to the Pole is not optimal. The polar hole may be possibly filled with RADARSAT-CM. North of 82°, Sentinel-3 and SARAL/AltiKa, Calipso, CloudSat are probably not going to be used.

M. Drinkwater mentioned that Aeolus may make a contribution.

Data collected by DLR TanDEM-X during the experiment will be available to the community based on a short proposal.

A. Lifermann asked about the modelling needs for data, since MOSAiC data are only available in a relatively small area, and transports from other areas may need to be considered.

MOSAiC focussed mostly on process studies and rather small-scale modelling (as distinct from YOPP), mainly in a radius of 50km around the ship. It will shed light on processes in the “new Arctic” with mostly first and second-year ice.

ACTION 7.7: G. Spreen to liaise with CNES and USGS representatives on needs of MOSAiC for optical data (Pléiades, Landsat).

6.4 SOOS

Penny Wagner presented the A. Pope et al. (2017) paper published in Antarctic Science “Community review of Southern Ocean satellite data needs”. Polar tourism to the Antarctic Peninsula is expected to increase significantly. Many operational products are too coarse for the needs of navigation in this area. A strategic goal is to achieve 3-day repeat cycle acquisitions over the entire Southern Ocean.

Recommendations regarding satellite observations include to collect more multi-frequency wide swath SAR imagery especially L-band.

There is a lack of coordinated campaigns in the Antarctic; a consolidated view of stakeholders in SOOS is required.

CSIRO signed an agreement with ESA to engage in the Southern Ocean, potentially through the new Australian Space Agency. IICWG have the best opportunity to influence satellite data acquisitions for Southern Ocean sea ice regions.

B. Holt noted that the NISAR objective is to cover the ice edge of Antarctica every 4-5 days

K. Casey mentioned the NASA PACE hyperspectral mission which would provide polar coverage with 1-2 day repeat cycle.

P. Wagner should serve as the focal point for PSTG regarding SOOS community needs.

ACTION 7.8: P. Wagner to lead the development of a SOOS advocacy group, to address issues and gaps in PSTG satellite agency acquisition plans in a coordinated way.

RECOMMENDATION 7.1: SOOS community to make strong connection to the International Ice Charting Working Group (IICWG) to secure systematic operational data acquisition and sea ice product generation.

7. USER REQUIREMENTS

7.1 Status Update

Snow

David Small showed an update of the requirements; he gave the example for mapping Alpine snow melting observed with Sentinel-1 at 12-day resolution. 6-day composites are the maximum temporal resolution achievable over the Alps without losing coverage. Mapping of snowmelt onset is clearly visible, for example over the Aletsch glacier. Observation of Ellesmere sea ice flow in 2016 shows improvement. 3-daily coverage is possible combining Sentinel-1 and RADARSAT-2, daily coverage will be possible with RADARSAT-CM available, probably as of next year.

Geometric and radiometric calibration work addresses the reduction of low absolute location error, critical to ensure co-registration of multiple swaths and sensors. Some RFI effects are visible in Sentinel-1 Alpine composites.

M. Drinkwater noted the hydrological connection of snowmelt.

Presentation of this work at the WorldCover ESRIN conference was well received. Many communities showed an interest (Iceland Siberia, Canadian Rockies, Finland).
Y. Crevier asked about the relation of this work to the CEOS Analysis-Ready Data initiative, looking at preparing multi-mission datasets.

In complement to D. Small's presentation, T. Nagler showed recent advances in snow monitoring, covering pan-European multi-sensor snow product, a summary of SnowPEx, and future directions. The SEOM project combines SAR and optical datasets (from Sentinel-1, Sentinel-3). An algorithm intercomparison in the Swiss Alps used Sentinel-2 as reference, and SAR Sentinel-1 IWS.

In low lands-dense forest-cultivated areas, mapping of wet snow is possible using a change detection technique; but radar backscatter technique also detects other changes (forest, fields). Generate fractional snow cover map using Sentinel-3 SLSTR. Cloud masking of SLSTR under revision with ESA. A cloud-cleared assimilated snow cover product has an accuracy of 15-20% regarding cloud cover.

Sentinel-1 offers excellent capabilities for operational monitoring of snow melt area at high spatial resolution.

SnowPEx results give insight into multi-annual trends of monthly average snow product; NH snow mass; snow extent trends.

The ESA snow_cci project starting in early 2018 has as objective to generate a long-term multi-sensor daily global snow extent product starting in 1981; improved time series of SWE product. Detailed analysis of the passive MW dataset (SSMI, AMSR) is part of the ITT. There is data available from FY-3 MWRI that would be worth exploring (not in the ITT).

The final results of SnowPEx will be published as a journal paper, followed by full release of the project reports; the datasets and protocols are or will be made available.

ACTION 7.9: T. Nagler to inform PSTG members about the SnowPEx publication once released.

Floating Ice

S. Howell reported on progress against key requirements:

Requirement 1: 3-day Arctic-wide data coverage from SAR is now achievable using Sentinel-1A/B and RADARSAT-2, and covering the gap in coverage over the Eastern Arctic Ocean still apparent in 2016. S. Howell showed a RCM coverage map based on a simulation.

More L-band coverage helps to better separate new ice from old and thicker ice, due to increased penetration depth of L-band vs C-band; no signal received if ice is too thin (<15cm), here C-band is better for detection. Temporal resolution analyses show better correlation of ice motion vectors using L-band over C-band especially during melt season or onset of winter. RADARSAT-CM is C-band; ice conditions have changed in the Arctic. NISAR would provide additional insight.

Requirement 2: Freshwater Ice Accomplishments

RADARSAT-2 coverage has been extended southward one frame to provide coverage of lakes in the Western Canadian Arctic; this coverage has been used in the ABOVE campaign.

CSA provided historical RADARSAT-2 data for monitoring lake ice; RCM will continue monitoring inland lakes once a week as a requirement from the Canadian Ice Service

Requirement 3: Potential gap in Passive Microwave Constellation (item 10)

Requirement 4: Coordinate with field campaigns: strong coverage for MOSAiC

Remaining gaps:

- Polar hole (to be addressed)
- Antarctica (need to improve year-round coverage)
- Others…

High-resolution SAR can now replace PMW since providing similar resolution, especially useful in "difficult" areas such as Canadian Archipelago.

Melt pond fraction from SAR has been tested using Sentinel-1 backscatter, first using landfast ice, now expanding to pan-Arctic.

Some results improving ice thickness estimates were discussed: effects of snow salinity and snow density (effect of brine) on estimating CryoSat-2 ice freeboard. M. Drinkwater argued the need to better understand radiative transfer within snow, since reduced signal travel time in saline or humid snow would have the opposite effect as portrayed in the paper (Nandan et al., 2017, GRL). This would be a very good theme to be addressed by MOSAiC.

Glaciers

Frank Paul focussed on the status of glacier observations from space, and related user requirements. He stressed that he did not address snow on glaciers. He gave an overview of sensors, timelines and products. Some generate their own Digital Elevation Model, but generally freely available DEMs are used by the community. Methods for data production are based on outlines, velocity and elevation changes. Landsat TM is the basis for glacier mapping, improved resolution of Sentinel-2 (10m) allows much better detection and mapping of crevasses, and more accurate estimate of glacier size.

One key task which remains to what is to correctly define the extent of the glacier. To date there remain gaps in the outline of glaciers, due to the type of observation/measurement and the ability to classify/recognise the surface types. Although Sentinel-2 and high resolution satellites (Quikbird) enable greater resolving power, their images still require better and more careful interpretation. Glacier outline delineation depends on presence of debris, but higher resolution of imagery does not necessarily provide more accurate outlines.

He quoted the Randolph Glacier inventory which is currently in its 6th version. Mapping of flow velocity, dynamics, and variability over time, which much higher spatial resolution is now available from Sentinel-2; he showed the example of the Vavilov ice cap surge of 2011 on Severnaya Semlya (where no ground truth is available, and which probably would have remained unnoticed without satellites).

Glacier elevation changes in the Himalayas-Karakorum region and trends over time were derived using reprocessed ASTER and TanDEM-X data. He compared different DEMs to assess their uncertainty, and highlighted the value of TanDEM-X.

He mentioned glacier activities within the ESA CCI and the C3S (to which University of Zurich and WGMS have responded with a service proposal).

He summarized the user requirements described in the accompanying document; a key requirement are precise DEMs, and use of the same DEM by NASA/USGS and ESA/CNES. Free availability of this DEM, perhaps at lower resolution, is desirable. The use of different DEMs leads to shifts in glacier outlines derived from Landsat-8 and Sentinel-2.

M. Drinkwater noted that glacier mapping is a very challenging terrain for use with satellite imagery; when agencies orthorectify imagery using a DEM, they do not necessarily think of this application of the data.

Y. Crevier informed that there is an ESA-USGS working group addressing the issue of using different DEMs, as part of the CEOS Analysis-Ready Data initiative.

PSTG fully supports the objectives of the ESA-USGS working group, and looks forward to a progress report at its next session.

ACTION 7.10: ESA and USGS to provide a progress report from the ESA-USGS working group looking at the use of DEMs for orthorectification as part of the CEOS Analysis-Ready Data initiative.

RECOMMENDATION 7.2: DEM selection for orthorectification of imagery datasets (Landsat, Sentinel-2, Pleiades, etc) must acknowledge the time variability of the cryosphere (glaciers, ice sheets)

Satellite information is critical to detect non-linear tipping points in the cryosphere which have potentially high significance in a changing climate. For example, major surges in uncharted areas such as Severnaya Semlya can be detected, contributing Gt in mass balance (and subsequently sea level change), which represent non-linear tipping points. Arctic DEMs are very important to detect elevation changes.

Availability of a public low-resolution DEM would be another objective.

A longer-term goal is to repeat the TanDEM-X global DEM on a decadal basis; M. Drinkwater indicated that private companies may offer such a service.

C. Dobson pointed out the realization that topography is time-variable, and that the community needs to address this in particularly in the cryosphere which represents some of the most rapidly changing places on Earth.

ACTION 7.11: PSTG agencies to provide comments on the draft Glacier User Requirements Document (v2.0) in terms of structure and content.

Ice Sheets

B. Scheuchl presented acquisition requirements, which are to be reviewed, taking into account the GCOS requirements review which includes addressing ice sheets. Coverage of Antarctica every 3 years is possible with the current constellation – with annual coverage being an objective. He updated on coverage status for Sentinel-1, Landsat-8, and RADARSAT-2.

T. Nagler showed a Sentinel-1-based Antarctic ice velocity map, currently produced as an aggregate over several years, not annually. Highest interest is in dynamic changes at the margins, e.g., Thwaites Glacier 6d/12d time series. 6-daily coverage would enable more accurate velocity estimates and enable interferometry. The ground line location over Antarctica was mapped using Sentinel-1 and the DInSAR method. CSK provides daily coverage of some glaciers, for mapping the grounding line of the Totten Glacier and Pine Island Glacier. The MEaSUREs programme also has a grounding line product.

NSIDC also produces a Landsat-based ice velocity map. A glacier bed product for Greenland was produced based on principles of mass conservation.

Greenland: annual ice velocity maps were produced using Sentinel-1. All Arctic ice caps are also processed (Svalbard, Severnaya Semlya). With regular mapping using Sentinel-1, the seasonal variation of glacier velocity (Petermann) is clearly detectable. Some examples were shown of using CSK high-resolution imagery to detect detailed ice velocity changes over time.

A new effort in ESA CCI is using the routine monitoring to estimate freshwater flux from ice sheet into the ocean. The average velocity and ice flux have increased by 6% between 2014 and 2016. ESA CCI ice flow information was also used to track the position of a lost aircraft engine over Greenland. A cryosphere data portal has been set up.

In closing, there is significant improvement in continuous mapping of margins/grounding zones. He iterated on the high level acquisition requirements. Marginal zone should be covered more frequently, every repeat pass should cover them; annual full coverage sufficient. For missions with a 1-day interval, multiple 1-day repeats in the grounding zone of glaciers would be an asset.

P. Potin asked how the left looking capability of NISAR could provide complete coverage in Antarctic pole hole. Alternate left and right looking intervals are planned for NISAR. As far as Sentinel-1 is concerned, there is a long term commitment to deliver data for the Copernicus Marine Environment Monitoring Service. This may allow trades in terms of modified coverage in Antarctica.

At present attempts are to fill pole hole with combination of RADARSAT-2 and Landsat. Coverage of central part of Antarctica is at intervals of 3 years.

B. Scheuchl reiterated the glacier recommendation on DEM.

Permafrost

A. Bartsch reported that within the ESA GlobPermafrost project, a first set of products is available, including use of Sentinel-2 and TerraSAR-X, and CSK access has been requested and approved. The NASA ABOVE campaign included an extensive field survey. The new H2020 project NUNATARYUK focusses on coastal erosion and infrastructure. She described novel land cover products based on Sentinel-1 and Sentinel-2. Shrub height for permafrost modelling from Sentinel-2 is important for permafrost modelling (as from 40cm snow height, permafrost temperate regime disconnects from the atmosphere): there are gaps due to clouds and cloud masks being not precise enough. Sentinel-1 limitations are due to switches in EW-IW Sentinel-1 mode that change resolution and polarization.

P. Potin responded regarding the modes of Sentinel-1.

A WebGIS-based permafrost information system has been developed.

In the NUNATARYUK H2020 project (integration through b.geos), coastal erosion is looked at, specifically using X-band SAR. The project also performs an infrastructure inventory (Sentinel-1 and Sentinel-2) to assess the impact of climate change on local populations. Major publications include a review on space-borne studies of permafrost for climate science, and on community efforts monitoring ponds from satellites or aerial photography. Most investigators focus on core

permafrost, with little coverage of the transition zones. A Remote Sensing special issue on dynamic permafrost regions is in preparation.

7.2 New user requirements

M. Drinkwater posed the question whether to maintain a continuing link to the scientific needs related to the Southern Ocean.

Y. Crevier noted that climate change is global, and changes in the Southern Hemisphere affect Canada as well, therefore there is an interest. He recommended that ocean coverage requirements should be addressed through the IICWG, which have increasing interest in monitoring the Southern Ocean. P. Wagner informed that there is a Data Group within IICWG generating Southern Ocean products for use by Australia, South Africa, Russia. Y. Crevier asked whether the SAR datasets generated there could be released.

M. Drinkwater would like to have daily ice charts over the Southern Ocean. P. Wagner would put focus on high-traffic logistics and science routes, and related users.

P. Wagner noted the reporting of the IICWG through JCOMM regarding ocean and maritime services.

M. Drinkwater noted that SOOS requirements for cryosphere are largely addressed within the floating ice requirements document. He advocated a revisit of SOOS requirements over time. In the meantime, SOOS should develop advocacy through IICWG to have traction (see item 6.4 and Actions there).

8. STATUS OF AGENCY RESPONSES TO PSTG STRATEGIC PLAN

ASI

M. G. Daraio updated on the Cosmo-SkyMed (CSK) programme which now spans more than 10 years of activities. She gave an overview of CSK capabilities, utilization strategy, and open call initiatives. ASI provided an update of their contributions to PSTG objectives. They contributed covering 43 permafrost cold spots by 4-8-day repeat mapping, and ice sheets. 87% of the CSK polar acquisitions are of interest to PSTG. A number of open call projects over polar areas or mountain areas were activated in 2015-2017. One project addresses the dynamics of the Filchner-Ronne ice shelf. Regarding floating ice, there are continuing acquisitions.

Some data are available on the Copernicus Open Data Hub – others are made available through ASI and Announcements of Opportunity; CSK acts as a contributing mission to Copernicus; there is collaboration to make Sentinel-1 and CSK data generally available over Antarctica for common regions and specific periods of interest 2014-2015, e.g., Pine Islands, Thwaites Glaciers and some other areas. PSTG will be kept informed on progress. Data volumes are significant.

C. Dobson enquired whether such plans are also underway for data acquired over the Arctic. F. Battazza informed that there were some technical challenges related to data volumes, and that data availability over the Hub and through ASI was a first step.

F. Battazza informed that the PRISMA mission will be launched in late 2018, and CSK 2nd generation in 2019.

CMA

Z. Zheng provided presentational material which was presented to the session – he apologized for not being able to attend, nor to present remotely.

CNES

A. Lifermann presented on behalf of CNES and associated science teams. She covered the Pleiades glacier observatory, aimed to facilitate access to satellite stereo-imagery and DEMs for glaciologists; imagery is acquired at the right time of year, generally at the end of the melt season. Three campaigns were completed in 2016-2017 over the Northern and Southern Hemisphere. Sites were selected in coordination with WGMS, and a PI is needed for each site and responsible for validation. The data are in principle openly available.

The CNES AltiCryo altimetry concept dedicated to observing the cryosphere capitalizes on SARAL/AltiKa heritage (Ka band, one antenna). User requirements were identified by LEGOS and the European user community. Studies on information content of Ka/Ku band over Antarctica reveal differences in ice sheet elevation derived from Ka and Ku band, indicating that the influence of the frequency on penetration depth can result in differences between up to +/- 1m. In general penetration is much higher in Ku band, than Ka band.

She elaborated on studies to investigate wave-ice interaction, using wave buoys, to investigate the relation between raft ice thickness and wave forcing.

The new satellite for wind-waves CFOSAT is set for launch in late 2018, with a Ku-band wave scatterometer and a Chinese wind scatterometer as payload. While focussing on the oceans, it can be used for studying the cryosphere, together with other contributing missions.

Another mission in preparation is the Sea Surface Kinematics Multiscale monitoring (SKIM), with a Ka-band instrument based on CFOSAT heritage, and selected as a ESA EE9 candidate mission; it provides for good revisit time for studying drift and wave spectra in the marginal ice zone (“the Arctic becoming a giant marginal ice zone”).

She presented studies on CNES algorithm development: results for Arctic sea ice thickness over 2002-2017 were published, and compared with records from CryoSat, IceSat; there is ongoing development of an Arctic snow record.

M. Drinkwater encouraged linkage of CNES to the SOOS community, with respect to wave scatterometry and marginal ice zone mapping.

CSA

Y. Crevier reported on CSA activities, acknowledging the contributors and noting that details are provided in separate presentation (on the meeting website). He recalled the major contribution by RADARSAT-1 1995-2013, and noted the current RADARSAT-2 mission. All imagery is in principle available for science use either through the Polar Data Catalogue, or through AOs. RADARSAT-CM coverage is focussed on the Northern Hemisphere, providing three times the coverage frequency of RADARSAT-2. The ambition is to have a similar data policy as Sentinel-1.

He mentioned the one-year terrestrial snow mass concept study, co-led by ECCC and CSA, addressing: (i) environmental prediction (NWP, hydrological forecasting, seasonal prediction), (ii) climate services (freshwater availability, snow monitoring, process studies). A loose convoy (~3h) with the Microwave Imager (MWI) instrument on the European EPS-SG B satellite is foreseen.

He summarized the contribution to PSTG requirements: for snow, he stressed the importance of interoperability of D. Small’s method to produce “analysis-ready data” based on integrating

different sensors. He mentioned the YOPP field campaign activities. CSA would like to support MOSAiC, support to validation studies for ICESat-2.

K. Werner asked whether during the YOPP Special Observing Period Southern Hemisphere Nov 2018 – Feb 2019, the Antarctic pole hole could be covered; B. Scheuchl to connect with K. Werner about addressing this request, and perhaps in SAR CWG;.S. Howell noted that RADARSAT-CM may address the pole hole; D. Floricioiu remarked that a TerraSAR-X contribution may also be possible.

ACTION 7.12: B. Scheuchl and Kirstin Werner to liaise on whether the Antarctic pole hole could be covered during the YOPP Special Observing Period Southern Hemisphere Nov 2018 – Feb 2019.

P. Potin asked about access RADARSAT-2 systematic coverage in the Western Antarctica. S. Howell and Y. Crevier asserted that the data is in principle available, but with a delay of 3-6 months.

DLR

Terrestrial

D. Floricioiu briefed on the TerraSAR-X and TanDEM-X timeline (with ~10 years of TerraSAR-X, and ~7 years of TanDEM-X). Both missions are exceeding nominal lifetime. She explained data access from both missions; through requests for background mission data (no delivery), general science data proposals, or NRT services in polar areas. Archived data (older than 18 months) can be ordered from the archive for free (http://sss.terrasar-x.dlr.de). TerraSAR-X allowed mapping of Greenland outlet glaciers 2016-2017, providing more detail than Sentinel-1 due to higher resolution. She looked at trade-offs between spatial and temporal resolution for estimating ice velocity: due to uncertainty considerations, higher spatial resolution is more important than temporal resolution.

Over Antarctica in the context of the ESA IceSheets_cci, TerraSAR-X focusses on the pole hole. TerraSAR-X cold spot monitoring is based on high-resolution dual-pol-X-band SAR data.

She summarized the status of TanDEM-X including mission planning and data acquisitions. There are TerraSAR-X supersites.

Future plans of DLR include: Tandem-L mission, phase B1 is ongoing, intermediate design review occurred recently, with key decision points in 2018. It responds to requirements from the Helmholtz Earth Dynamics Alliance. Data will be acquired in monostatic and bistatic modes incl. left-looking. Data products from L1A to L3; 24 high-level products are proposed by the science community.

Atmosphere (Gottwald)

M. Gottwald provided slides for the meeting. Among other plans, first results from the recently-launched Sentinel-5 precursor on monitoring trace gases, and compared with GOME results.

M. Drinkwater noted the Paris December 2017 One Planet Summit, aiming at putting fresh impetus on implementing a carbon monitoring and observing system.

ESA

M. Drinkwater briefed on highlights in ESA contributions to monitoring the cryosphere. ESA are in their 7th year of CryoSat and 8th year of SMOS sea ice products. There were launches of Sentinel-2B and Sentinel-5p in 2017. Sentinel-3B, and Aeolus are readied for launch in 2018. The ESA CCI released a toolbox, a dashboard (akin to the ECV inventory), and addresses a number of ECVs.

He gave details on the ESA contributions to MOSAiC and YOPP.

Six new Copernicus High-Priority Candidate Missions are being prepared by ESA including a passive microwave imaging mission. He showed results of using CryoSat and combinations of sensors such as on Sentinel-3, allowing the derivation of Arctic Sea Ice Volume trends (accumulation and melting), monitoring Arctic gyro circular flow; operational support to the operations of the BAS Halley station in Antarctica.

He showed examples for permafrost monitoring using Sentinel-2, and new products on albedo over Greenland using Sentinel-3 OLCI and SLSTR. He further provided an overview of missions and launches planned by ESA. The Aeolus launch is delayed to June 2018 from Plesetsk, Russia.

ISRO

I. Bahuguna presented remotely two case studies for deriving surface elevation and changes over Antarctica using AltiKa altimeter data. Scatsat-1 scatterometer data quicklooks are displayed via the MOSDAC data portal. Over the Pine Island glacier, velocity changes and calving lines were derived using Sentinel-1 and Scatsat. Risat-1 C-band data were used for coverage of the Himalaya-Karakorum region, and analysis of glacier behaviour, such as velocity (Siachen glacier, Gangotri glacier, Bara Shighri glacier). Results show 87% of glaciers not changing, 12% retreating, 1% advancing. Over the same area, ISRO developed snow cover products and analysed trends since 2004. The main challenge in the Himalaya-Karakorum area will be to understand the response of glaciers to climate change.

He raised two science questions related to glaciers:
- To what extent are debris-covered glaciers protected from influences of the atmosphere, compared to debris-free glaciers?
- Does debris load on glaciers give rise to more pressure and thus faster melting of glaciers?

He commented to the effects of DEM on deriving glacier properties.

NASA

C. Dobson gave a summary of activities. He pointed out the hydrology and terrestrial ecosystems activities in NASA which also include some cryosphere-related aspects. ICESat-2 is on its way to launch in Sep-Oct 2018. The Oceans Melting Greenland campaign continues, as is Operation IceBridge where underflights of Envisat, CryoSat-2 and Sentinel-3A are carried out since 2009. He showed some results from Ron Kwok on deriving trends in Arctic sea ice volume.

NASA plans the ISSIUMAX experiment (Ice sheet and sea ice ultra-wideband MW airborne experiment) in Antarctica, in collaboration with the Italian Antarctic Research Programme.

To investigate snow thickness on sea ice, NASA and ESA are engaging within the NESOSI initiative, exploring the use of CryoSat and ICESat over the Arctic basin.

NOAA

Sean Helfrich presented on the NESDIS focus on floating ice and snow. In addressing PSTG priorities, NCEI distributes the 30+ year climate data record from AVHRR, updated daily. There is continued validation of VIIRS and AMSR-2 ice concentration with high-resolution data. AMSR-2 ice

products became operational in March 2017. VIIRS ice products became operational in July 2017, with NOAA VIIRS expected in mid-2018.

He gave an overview of contributions to operational monitoring of snow and permafrost (via SnowWatch and SnowPEx). He showed evaluations of SWE performance using ATMS and AMSR-2.

Polar winds are produced from MODIS, AVHRR and VIIRS that are used in 13 NWP centres in 9 countries, and new products are explored.

NOAA provided input to the PSTG-YOPP contributions spreadsheet. Coordination with IICWG should explore how IICWG can engage with YOPP. There are contributions to polar reanalyses. He updated on the recently-launched GOES-16 and NOAA-20 satellites, with some first results of VIIRS ice products. A NOAA Polar Watch site has been put up: https://polarwatch.noaa.gov . Some experimental products are under investigation, including on ice motion, integrated snow products, combined VIIRS polar winds.

USGS

K. Casey briefed on USGS responses to PSTG priorities. Re Action 6.9 (see Appendix III), since 2013, community requests have increased for Landsat data, and these are now considered nominal and are re-activated every year. Requests can be submitted at https://landsat.usgs.gov/landsat-data-acquisition-request; the USGS Landsat 7 and 8 acquisition plans are available at https://landsat.usgs.gov/LTAP8 and https://landsat.usgs.gov/LTAP7. Landsat-7 is no longer acquiring over the ice sheets since Landsat-8 is available.

For geolocation details and DEMs, a joint NASA/USGS/ESA group is addressing the improvement of geometric calibration and co-registration. USGS and NASA continue work toward DEM improvements and they await the ESA Global Reference Image database releases to further implement collocations.

USGS also responded to Action 4.13 which is now closed.

USGS established a cal/val centre of excellence at EROS in mid-2017 to focus on radiometric, geometric and spatial characterization and calibration of optical remote sensing system data, and to improve the accuracy and precision of all derived data products distributed. In general, at USGS, data provision technology and algorithm development continues towards analysis ready data, cloud compute processing and other options. The tool "AppEEARS" (https://lpdaac.usgs.gov/tools/data_access/appeears) was shown as an example of one such Earth observation data distribution tool, where MODIS, VIIRS, Landsat, SMAP, SRTM and GPS data can currently be accessed, processed and distributed based on user needs. Landsat analysis-ready data have been released for continental US. Global analysis-ready data for the Landsat time series are foreseen.

Specific to cryospheric data, USGS/NASA/NSIDC Landsat 8 Global Land Ice Velocity Extraction data is available now in near-real time from NSIDC https://nsidc.org/data/golive. GoLIVE ice velocity data is available for both ice sheets and all glaciers >5km^2. Some other Landsat ice velocity data sets are also available at NSIDC (e.g. Landsat Ice Speed for Antarctica, LISA, 750m mosaics; and MEaSUREs Greenland ice sheet velocity 200m and 500m mosaics from Landsat 8/ Sentinel-1A,-1B, TerraSAR-X/TanDEM-X).

As for Landsat-9, it has passed the key decision point moving the mission into Phase C (production), scheduled for launch in 2020. A follow-on Sustainable Land Imaging Mission is under discussion.

9. Keynote Presentation

This item was dropped due to time constraints.

10. Passive MW Constellation for mapping sea ice

M. Drinkwater recalled the request from CEOS SIT to PSTG to investigate the coverage of satellite missions for monitoring sea ice, focussing on polar-orbiting passive MW missions. He showed a timeline of missions. The risk has been that of a gap between the end of SSMI and the beginning of AMRS-2. This gap would be mitigated by successful commissioning of CMA FY-3D which was launched in November 2017. The continuous record of sea ice ECV would be possible, provided cross-calibration. MWRI does not have the C-band channel. MWI on Metop-SG for 2022 does not have the desired spatial resolution (5-10km) for operational sea ice applications, and has no C-band channel for SST.

The EU decided that a daily <10km sea ice concentration product was necessary support for EU Arctic Policy, via feeding into CMEMS and ice services.

FY-3 sea ice products are available through the CMA NSMC web portal.

He shared his thoughts on measuring sea ice parameters using various and combined passive MW frequencies. The EU intends to include a C-band channel instrument on the prospective Copernicus Expansion mission. Loose formation flying with Metop-SG MWI is planned.

In summary, there is no immediate threat of a gap in PMW sea ice products at >10 km resolution, and thus continuity of the ECV record is not under threat. Efforts are needed to intercalibrate and process the FY-3D MWRI data in conjunction with the other missions. The data are freely available upon registration. Engagement by CMA in the CEOS-CGMS Working Group Climate would be desirable, for coordinating such issues.

Beyond AMSR-2, there are high-priority user requirements for <10km PMW data, including a low-frequency band. Operational ice charting user needs for <10km daily bi-polar ice extent / ice concentration is a high priority requirement to be treated by PSTG. Consideration of low-frequency MW radiometer channels is necessary to fulfil requirement for all-weather SST (C-band) and seasonal ice thickness products (L-band). JAXA is studying accommodation of an AMSR-2 follow-on PMW instrument on GOSAT-2.

S. Howell reached out to the Canadian Ice Service and largely agrees with the priorities, although SAR is preferred over PMW. PMW is considered important for NWP by ECCC.

P. Wagner remarked that sea ice charting often requires higher resolution than 5-10km.

Further investigation on the combination of frequencies for the various applications is necessary. Reporting back to CEOS SIT is not explicitly requested – Mark and Secretariat should provide a short report on the discussion at PSTG-7.

ACTION 7.13: Chair and Secretariat to provide a short summary on the discussion on the passive microwave radiometer constellation for monitoring sea ice (present and future), to CEOS SIT chair.

11. Communications

11.1 ESA Polar Science Collocation meeting

A report on the ESA Polar Science Collocation meeting held in June 2017 is provided as part of the meeting documentation.

11.2 Communicating the value of PSTG

ACTION 7.14: B. Scheuchl to suggest a formulation for acknowledging PSTG accomplishments / contributions in scientific publications or other means of communication (websites, brochures etc.).

12. Reporting

12.1 EC-PHORS-7

The WMO Executive Council Panel on Polar and High-Mountain Observations, Research and Service (EC-PHORS), 7th meeting, 21-24 March 2017 presentation by M. Drinkwater is available on the meeting website.

12.2 CGMS-45

The PSTG report to the 45th session of the Coordination Group for Meteorological Satellites (CGMS) is available on the meeting website.

12.3 CEOS SIT

Y. Crevier noted that he is no longer engaged in CEOS since CSA are no longer serving as Chair. The European Commission is now CEOS chair, and ESA provides secretariat functions.

13. Summary of PSTG-7 Actions

To be finalized via correspondence (see Appendix III).

14. Plans for the next meeting

B. Scheuchl offered hosting at U Irvine, CA, USA.

D. Small offered hosting at U Zurich, Switzerland.

WMO and DLR OP are also back-up options.

S. Helfrich suggested hosting at NOAA in Washington D.C., back-to-back with AGU in 2018.

The session took the decision to hold the meeting at WMO HQ Geneva in the week of 15-19 Oct 2018, or 22-26 Oct 2018 as back-up (D. Small to confirm alternative hosting possibilities at University of Zurich).

15. Any other business

None raised.

16. ADJOURN MEETING

The meeting was adjourned at 18.00 on Wednesday 12 December 2017.

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APPENDIX II

AGENDA AND WORK SCHEDULE

ENVEO, Fürstenweg 176, AT - 6020 Innsbruck
Room: Berlin, 2nd floor

12 DECEMBER 2017

09:00-09:10 **1. Welcome and Opening Remarks**

09:10-09:25 **2. Tour de Table – Introduction to New Participants**

09:25-09:30 **3. Approval of Agenda** (M. Drinkwater)

09:30-09:50 **4. Keynote Presentation 1:** (Helmut Rott)
Environmental Earth Observation Information Technology's Contribution to Cryosphere Products and Services

09:50-10:30 **5. Review of Action Items** (Secretariat)

10:30-10:45 **Coffee Break**

10:45-12:45 **6. Addressing Strategic Initiatives**

6.1 Global Cryosphere Watch (GCW)

- Overview & Recent Accomplishments (J. Key/R. Nitu) (20')
- CryoNet (Henning Löwe) (20')
- Sea Ice Best Practices (Penelope Wagner) (20')
- Framework for Product Validation / Intercomparisons (All - discussion) (40')
    - Priorities? (Science Representatives)
    - Analysis-ready data/products? (e.g. mountain snow depth; sea ice thickness; sea ice snow cover; ice surface temperature; frost depth etc)
    - Mobilising resources for intercomparisons

- Status of Planning: PSTG/GCW Workshop on Snow radar science and concept development (Y. Crevier/M.Drinkwater) (20')

12:45-14:00 **Lunch Break**

6.2 Year of Polar Prediction (YOPP)

- Status of Activities (Kirstin Werner) (20')
- Response by Agencies 2017-2019 (verbal only, details under item 8) (15')

6.3 MOSAiC: International Arctic Drift Experiment

- Status of Planning: St. Petersburg Implementation workshop (Gunnar Spreen) (20')
- Agency MOSAIC Planning & Commitments (verbal only, details under item 8) (15')

6.4 SOOS (Penelope Wagner) (25')

15:30-15:45 **Coffee Break**

15:45-17:30 **7. User requirements: State of Play**

7.1 Status Update:
- Snow (D. Small/T. Nagler) (30')
- Floating Ice (S. Howell) (30')
- Permafrost (A. Bartsch) (30')

17:30 **End of Day 1**

19:00 **GROUP DINNER (NO-HOST) AT WEINHAUS HAPP**

13 DECEMBER 2017

09:00-10:30 **7. User requirements: State of Play (ctd)**

7.1 Status Update:
- Glaciers (F. Paul) (30')
- Ice sheets/ice caps (B. Scheuchl) (30')

7.2 Discussion of new user requirements: (All) (30')
- Southern Ocean Observing System (SOOS) requirements
- Third Pole/High Mountain regions

10:30-10:45 **Coffee Break**

10:45-12:45 **8. STATUS OF AGENCY RESPONSES TO PSTG STRATEGIC PLAN (MEMBER AGENCIES)**

Agency Status Updates, including:
- Focus on GCW, MOSAIC and/or Strategic Plan items

- Updates on In-situ/campaign activities, supporting:
  technology advancement, algorithm development or instrument concepts, or activities for preparation of future missions or Cal/Val

- Update to Agency Table of Commitments (All Members) 12:45-

14:10 **Lunch Break**

14:10-14:30 **9. Keynote Presentation 2**: (T. Nagler)
Operational Services for Cryosphere by enveo

14:30-15:00 **10. PASSIVE MW CONSTELLATION FOR MAPPING SEA ICE (ALL)**

10.1 Climate and operational needs for sea ice extent and concentration
10.2 Potential AMSR-2 follow-on gap
10.3 Consolidated Interagency plan for passive microwave imaging of sea ice

15:00-15:30 **11. Communications**

11.1 ESA Polar Science Collocation Meeting, Frascati June 2017 (M. Drinkwater) (15')
11.2 Communicating the value of PSTG: Forthcoming opportunities, meetings (All) (15') 15:30-15:45

Coffee Break

15:45-16:30 **12. Reporting**

12.1 EC-PHORS (M. Drinkwater) (15')
12.2 CGMS-45 (Secretariat) (15')
12.3 CEOS SIT (Y. Crevier) (15')

16:30-17:15 **13. Summary of PSTG-7 Actions (Secretariat)**

17:15-17:25 **14. Plans for Next Meeting**

17:25-17:30 **15. Any Other Business**

17:30 **Adjourn Meeting**

Reference documents

Meeting URL: http://www.wmo.int/pages/prog/sat/meetings/PSTG-7.php

APPENDIX III

ACTION ITEMS FOR PSTG

I. Actions from PSTG-7	
ACTION 7.1: SAR CWG to focus attention on obtaining collocated data from Sentinel-1, NISAR, RADARSAT-CM, PALSAR, over the different target areas identified by PSTG.	
ACTION 7.2: P. Heil, P. Wagner and PSTG Science Leads to define sea ice locations / drift sites for which to achieve collocated acquisition planning.	
ACTION 7.3: T. Nagler, J. Key and H. Löwe to identify sites where snow intercomparisons could be performed.	
ACTION 7.4: Y. Crevier to circulate with PSTG the draft recommendations from the PSTG/GCW Snow Science workshop.	
ACTION 7.5: To finalize the collection of YOPP contributions by PSTG agencies, Kirstin Werner to send list to Secretariat, for consolidation and then validation by PSTG agencies.	DONE.
ACTION 7.6: K. Werner to discuss with YOPP steering group about special campaigns during YOPP that could be a target of PSTG agency acquisitions, and provide feedback to PSTG, noting that lead time for special acquisitions with agencies is at least 3 months.	
ACTION 7.7: G. Spreen to liaise with CNES and USGS representatives on needs of MOSAiC for optical data (Pléiades, Landsat).	Ongoing.
ACTION 7.8: P. Wagner to lead the development of a SOOS advocacy group, to address issues and gaps in PSTG satellite agency acquisition plans in a coordinated way.	
ACTION 7.9: T. Nagler to inform PSTG members about the SnowPEx publication once released.	
ACTION 7.10: ESA and USGS to provide a progress report from the ESA-USGS working group looking at the use of DEMs for orthorectification as part of the CEOS Analysis-Ready Data initiative.	
ACTION 7.11: PSTG agencies to provide comments on the draft Glacier User Requirements Document (v2.0) in terms of structure and content.	
ACTION 7.12: B. Scheuchl and Kirstin Werner to liaise on whether the Antarctic pole hole could be covered during the YOPP Special Observing	Pierre Potin has taken an action to follow-up the recent PSTG and to discuss with ASI the possibility of covering the Arctic polar hole

Period Southern Hemisphere Nov 2018 – Feb 2019.	for first SOP.
ACTION 7.13: Chair and Secretariat to provide a short summary on the discussion on the passive microwave radiometer constellation for monitoring sea ice (present and future), to CEOS SIT chair.	
ACTION 7.14: B. Scheuchl to suggest a formulation for acknowledging PSTG accomplishments / contributions in scientific publications or other means of communication (websites, brochures etc).	
II. Actions from PSTG-6	
ACTION 6.1: P. Potin to investigate whether Sentinel-1B data acquired over the NH summer 2016 could be made available to the community.	DONE. Addressed at SAR CWG-5 on 14 Dec 2017.
ACTION 6.2: M. Drinkwater and J. Key to formulate a PSTG position on support to the intercomparison of sea-ice thickness products, for communication at the ESA Cryosphere science meeting in March 2017.	DONE. ESA-NASA bilateral discussion initiated about a potential Sea Ice Mass Balance Intercomparison Exercise (SIMBIE) - to complement the ice sheet effort. This would be a way of both confronting the models during YOPP, and a way to coordinate the satellite/airborne sea ice thickness product intercomparisons. IceSAT not launched until Sep 2018; ESA-NASA bilateral focussed on estimating snow on sea ice; Copernicus Expansion mission aims to have dual-frequency wide-beam altimeter (Ka and Ku band); NASA-ESA Snow on Sea Ice (NESOSI) effort Document intercomparison efforts subject of PSTG-7 discussions
ACTION 6.3: T. Jung on behalf of YOPP to initiate a list of parameters that should be provided for by operational satellite products in support of YOPP; PSTG to iterate with YOPP based on the initial list.	DONE. NASA, CMA and ESA have indicated their contributions; ASI is developing an agreement with WMO. WMO completed list with links to data and product catalogue maintained by agencies.
ACTION 6.4: Y. Crevier to introduce MOSAiC responsibles to the IICWG contact John Falkingham regarding tactical ice charting support to the campaign.	DONE.
ACTION 6.5: A. Lifermann and S. Hosford to investigate with MOSAiC responsibles the details of requirements of the experiment for high-resolution optical data from CNES.	DONE. Action ongoing, discussion about test acquisitions using Pléiades.
ACTION 6.6: Add MOSAiC status and PSTG support to the agenda of the	DONE.

PSTG-7 meeting.	
ACTION 6.7: M. Gottwald to find out the instrument and operational planning of the HALO in support of MOSAiC and to get in touch with Manfred Wendisch, DFG Coordinator of HALO.	DONE. During MOSAiC there will be no HALO flights; possibly HALO flights in 2019; aim to use HALO for validating Aeolus
ACTION 6.8: PSTG to endorse the Terms of Reference of the SAR-CWG.	DONE.
ACTION 6.9: USGS to provide a formal response to PSTG on their acquisition campaign over Greenland, Antarctica, and high-mountain glaciers, including details on geolocation details and the DEM used for this purpose.	DONE in presentation to PSTG-7. The USGS is committed as resources allow to acquiring cryospheric science data over Greenland, Antarctica and high-mountain glaciers. From late 2013 forward, community requests have resulted in Landsat 8 tasking of data collection over Antarctica and Greenland, some via "emergency off-nadir" acquisitions. Many of the ice sheet special tasking requests are now part of nominal operations that are suggested for approval & reactivation each year. Note, that the actual acquisition of the data depends on tasking priority, season, cloud forecasting and other constraints. Mountain glaciers are included in nominal “all landmass” data collection. Landsat science target data additional acquisition requests are open to any international person or organization. Such submissions are reviewed and adjudicated upon receipt based on resources, synergies and scientific merits. Landsat data acquisition requests can be submitted here: https://landsat.usgs.gov/landsat-data-acquisition-request Landsat 8 Long Term Acquisition Plan: https://landsat.usgs.gov/LTAP8 Landsat 7 Long Term Acquisition Plan: https://landsat.usgs.gov/LTAP7 (Note that since Nov 2013, Greenland and Antarctica data is no longer acquired with L7) Re geolocation details and DEM: Landsat 8 OLI on-orbit geometric calibration and performance is detailed in Storey et al., RS, 2014, doi:10.3390/rs61111127, and Landsat 8 OLI, Sentinel-2 MSI temporary misregistration in Storey et al., RSE, 2016, doi::10.1016/j.rse.2016.08.025, among other publications and presentations. An ongoing NASA/USGS/ESA collaboration is working toward improving Landsat & Sentinel-2

	geometric calibration and jointly co-registered data. The USGS/NASA team has completed the three-phase Landsat Global Land Survey (GLS) ground control point improvement (e.g. discussed in Storey et al., RSE, 2016). Work on the NASADEM new digital elevation model products continues, however, scope was reduced to +60/-60 latitude, and thus other available high latitude national and other DEMs (e.g. ArcticDEM, REMA, Scandinavian, Canadian) are being considered. The USGS awaits ESA Sentinel-2 team Global Reference Image (GRI) assembly in order to implement further L8/S2 co- registration accuracies. Previous estimates had all of these above mentioned efforts expecting completion and implementation in data processing by late 2018.
ACTION 6.10: Encourage all science leads to look at the current CONAE SAOCOM acquisition plan and provide feedback to Marc Thibeault, with the understanding that Argentina is the highest priority of the mission, by 31 Jan 2017.	OPEN. Follow-up with Marc Thibeault to interact; PSTG is mentioned in the SAOCOM acquisition plan .
ACTION 6.11: Agencies or Science Leads to propose achievements facilitated by PSTG, for communication through WMO channels, and through their own communication offices.	OPEN. Propose agreed wording to acknowledge PSTG when publishing accomplishments (item 11.2)
ACTION 6.12: PSTG members and Science Leads to review the Table of Contributions and Achievements. By 31 Jan 2017	OPEN. Update table by 28 Feb 2018.
ACTION 6.13: Secretariat to amend the PSTG interface diagram in the Strategic Plan, and remove the list of Space agencies (these are referred to in an Annex to the Plan).	OPEN. In EC-PHORS-7 presentation.
III. Other Actions, and Status	
ACTION 5.2: B. Scheuchl to prepare a draft update of the Requirements Document. Deadline: mid-2016.	OPEN To be updated by early 2018
ACTION 5.3: Frank Paul to provide User Requirement Document for Glaciers. The Secretariat to place User Requirement Document for Glaciers on PSTG webpage	OPEN New draft available for PSTG-7, for feedback by members within 3 months

ACTION 5.7: Annett Bartsch to provide CNES with locations of cold spots and coastal sites for complementary HR optical data.	OPEN Subset of cold spots identified; publication to be determined; by end of 2016 ; details need to be determined on what data types are needed; clarify with Annett
ACTION 5.8: PSTG members to provide an inventory of in-situ activities supporting technology advancement, algorithm development or airborne concepts, or in-situ activities for preparation of future missions addressing global snow and to stimulate work on in-situ activities and engagements of space agencies with in-situ partners.	OPEN; to be addressed under agenda item 6.1.4
ACTION 5.9: CSA to provide a concept study for next 18 months on active radar for complete northern hemisphere coverage every two to three days for SWE. Science advisory team, Chris Derksen, should preparation follow-up ideas. NASA should conduct activities to support an instrument proposal	DONE; Presentation on concept study by Chris Derksen made available to PSTG for information (8 Feb 2017); update on PSTG/GCW workshop 2018
ACTION 4.13: USGS to investigate how PSTG could interact with the Landsat Science Team in responding the user requirements presented at PSTG-4, in particular the permafrost-related needs. By 10 Jan 2014	DONE. USGS presentation to PSTG-7: Scientific requirements documents, such as those from PSTG, are welcomed and can be submitted to the Sustainable Land Imaging USGS requirements analysis team. In general, periodically, there are calls and requests for information that we encourage parties to respond. Recently, there have been three such calls: 1) the U.S. National Academy of Sciences, Space Studies Board Decadal Survey for Earth Science and Applications from Space request for information, which will provide input toward the next decade of US space missions (2017-2027), 2) the request for information and requirements for follow on Sustainable Land Imaging, and 3) the request for participation in the Landsat Science Team.
IV. Recommendations	
RECOMMENDATION 7.1: SOOS community to make strong connection to the International Ice Charting Working Group (IICWG) to secure systematic operational data acquisition and sea ice product generation.	
RECOMMENDATION 7.2: DEM selection for orthorectification of imagery datasets (Landsat, Sentinel-2, Pleiades, etc) must acknowledge the time variability of the cryosphere (glaciers, ice sheets).	