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)

FIFTH SESSION

DLR (GERMAN AEROSPACE CENTRE)
OBERPFAFFENHOFEN, GERMANY

5 – 7 OCTOBER 2015

FINAL REPORT

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

1.1 Mark Drinkwater, the Chair of the Polar Space Task Group (PSTG) welcomed attendees to the fifth meeting, and noted several apologies had been received from the Members of PSTG (INPE, NASA, CNES), for not being able to attend and mentioned reasons for these apologies. K. Holmlund (EUM) had sent apologies for due to the overlapping CGMS meeting, though Francois Montagner was in attendance on behalf of EUMETSAT.

1.2 In thanking the DLR hosts for organizing this meeting, the Chair recalled the predecessor IPY-STG meeting in DLR eight years ago that had provided fresh fuel to the group. He recalled the fantastic arrays of developments since that time, including new launches of a number of satellites that are critical for Earth observations of polar regions, but also noted the unfortunate loss of the radar on SMAP, and also the end of the Aquarius mission (on SAC-D). The Chair explained the challenging week ahead to capture the successes and progress since last year's meeting at NASA-GSFC, and also due to the 4th PSTG Synthetic Aperture Radar Coordination Working Group (PSTG-SAR CWG) meeting to take place on the two days following PSTG-5. The decision was made to hold back to back meetings to minimize travel of participants who will be attending both meetings.

1.3 Richard Bamler, the Director of Remote Sensing Technology Institute (IMF) in the Earth Observation Centre (EOC) officially welcomed participants to the PSTG-5 and to DLR in Oberpfaffenhofen on 6 October. He briefly described the IMF activities, with a focus on aspects of cryosphere monitoring. In his short introduction, he mentioned IMF work on Synthetic Aperture Radar (SAR) and the development of SAR processors for TerraSAR-X (TSX), TanDEM-X (TDM), Tandem-L, SAR Tomography, and optical processors for the EnMAP and DESIS/ISS hyperspectral missions as well as processors for the future Sentinel 5p/4/5 atmospheric Copernicus missions.

1.4 Manfred Gottwald (DLR), the local host, provided logistics and other important information for participants during the session (see Presentation 1).

2. Introductions to Participants

2.1 In a tour-de-table, participants introduced themselves, see attendance list in Annex I. M. Drinkwater recalled the role of PSTG, mentioned several apologies and reasons for these apologies and welcomed new participants.

3. Approval of Agenda

3.1 M. Drinkwater presented the Agenda, stressing the importance of the thematic focus sessions addressing their respective user requirements, and noted that member Agencies could respond most efficiently by establishing ambitious goals and then planning relevant activities to move towards achieving those goals over the next year. He proposed that the PSTG SAR discussions agenda would stay on a relatively high strategic level and that the plans and implementation details should be left for the PSTG-SAR CWG meeting discussions.

3.2 Frank Paul proposed to hold a discussion which would focus on free/open and easy access to satellite data products, and Yves Crevier suggested that the relation and coordination of PSTG and PSTG SAR CWG be addressed before the SAR CWG meeting takes place.

3.3 The session subsequently adopted the Agenda for the meeting, see Annex II.

3.4 All meeting documents, presentations and this report are made available at: http://www.wmo.int/pages/prog/sat/meetings/PSTG-5.php.

4. Review of Action Items

4.1 The Action items from the last PSTG meetings were discussed and updated, see Annex III (a).

5. DLR Radar Based Polar and Cryosphere Activities

5.1 Manfred Zink (DLR) introduced DLR's Current and future SAR Mission, focusing on TerraSAR-X, TanDEM-X and Tandem-L (See Presentation 5).

5.2 TerraSAR-X has been in operation for some 8 years. M. Zink explained TerraSAR-X imaging modes, namely StripMap mode, ScanSAR mode and SpotLight mode and provided various examples reinforcing the flexibility of left/right looking, particularly for filling the Antarctic pole-hole in other right-looking SAR data. Example images were highlighted documenting the power of all-weather interferometric imaging by this satellite, such as the mapping of Drygalski glacier and the velocity mosaic of Recovery Ice Stream in Antarctica. Newly introduced, and in operation since October 2013, are Wide-ScanSAR and Staring SpotLight imaging modes. With the reference to the SAR image evolution, comparison images of StripMap mode, Staring-Spotlight Mode and HiRes-Spotlight Mode were used to highlight the improvement brought by the continuous evolution in data processing methods.

5.3 **T**erraSAR-X-**a**dd-o**n** for **D**igital **E**levation **M**easurements (TanDEM-X) was launched in June 2010. M. Zink explained acquisition of a global DEM according to Level-3 standard, generation of local DEMs with Level-4 like quality, and demonstration of innovative bistatic imaging techniques and applications. He recalled standards for digital elevation models set by DTED-1, TDED-2, TanDEM-X and Level-4 and presented TanDEM-X Global DEM Acquisition Plan (2010-2014) and its data coverage. He presented classification of the Greenland Ice Sheet using TanDEM-X interferometric acquisitions over Winter 2010-2011 and penetration depth on Greenland Ice Sheet.

5.4 Tandem-L is a proposal for an innovative radar mission for systematic monitoring of Earth System Dynamics. M. Zink compared imaging capabilities of TanDEM-X (one global coverage per year) and Tandem-L (two global coverages per week). He brought to the attention of participants 3-D structure mode of polarimetric SAR interferometry (Pol-InSAR). Tandem-L monitoring of Cryosphere includes: glacier flow (weekly), soil moisture (weekly), Snow Water Equivalent, SWE (seasonal), and ice structure change (seasonal).

6. EC-PORS-6 Update

6.1 M. Drinkwater presented (see Presentation 6) an update from the WMO Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS). PSTG has been established under the auspices of EC-PHORS, and formally reports to the Panel. The 6th EC-PHORS meeting was held in Reykjavik, Iceland, 8-14

September 2015, where M. Drinkwater gave a presentation on behalf of PSTG. In his presentation he referred to the PSTG collaborative approach, PSTG-SAR CWG, progress made, key scientific results, PSTG strategic plan, SOOS user requirement survey and the Year of Polar Prediction (YOPP).

6.2 M. Drinkwater informed PSTG on action items from EC-PHORS-6, which include:

- Reviewing the mandate of the PSTG to inform, support and advocate for PSTG activities;
- Southern ocean satellite data requirements is one aspect that needs further focus in the future to maintain bipolar balance;
- Reviewing the PSTG Strategic Plan prior to the PSTG-5 meeting on October 5-7, 2015;
- Re-engaging with existing space agencies (Brazil/INPE), to extend the mandate, and to attract new members (e.g. Argentina/CONAE, India/ISRO, and Spain/CDTI/hisdeSAT) that may be interested in contributing;
- Extending the mandate of PSTG under new EC-PHORS terms of reference (see: https://www.wmo.int/pages/prog/www/polar/index_en.html) until 2018; and
- Supporting Cal/Val of Space-based observations before and during the YOPP intensive Observation Period (IOP).

6.3 PSTG discussed the issues of extending the mandate of PSTG and re-engaging with existing space agencies.

6.4 **ACTION 5.1**: Personalized letter be sent by the WMO Secretary-General to the individual space agencies focusing on benefits, achievements, individual contributions of each agency since 16th World Meteorological Congress, and including a proposal to extend their mandate for another 4-year period to support the new WMO priority of Polar and High Mountain Regions.

6.5 PSTG was briefed on the update at 17th World Meteorological Congress (Cg17), which included information on Polar and High Mountain Regions that became the new WMO Priority for 2016-2019. This includes improving operational meteorological and hydrological monitoring, prediction and services in polar, high mountain regions and beyond by: (a) operationalizing the Global Cryosphere Watch (GCW); (b) better understanding the implications of changes in these regions on the global weather and climate patters; and (c) advancing the polar prediction under the Global Integrated Polar Prediction System (GIPPS). Due to this development the EC-PHORS terms of reference had been updated to include “high mountains”. As regards GCW, detailed presentation follows in Item 7.

7. Global Cryosphere Watch (GCW)

7.1 CryoNet Status

7.1.1 M. Ondráš, on behalf of J. Key, provided information (Presentation 7a) on the development and implementation of the WMO Global Cryosphere Watch (GCW). An important decision was made at the Cg-17 (May-June 2015) that decided to mainstream and implement GCW in WMO Programmes as a cross-cutting activity and that implementation activities will be undertaken during the next financial period (2016-2019) as one of the major efforts of the Organization with the goal that GCW should become operational, It also requested the Secretary-General to establish a GCW Coordination/Project Office. The GCW Implementation Plan (GCW-IP) became the guiding document for the implementation of the GCW. Establishment of the core standardized surface-based network – the CryoNet – is the highest priority for GCW and 36 stations were approved for the pre-operational phase of CryoNet. The CryoNet Integrated Sites can be used for validation of satellite products and/or process models.

7.1.2 Michael Zemp (WGMS) proposed that CryoNet makes more effort to include additional (glacier) sites/stations that have long-term observations and are of higher quality that some of those currently listed under CryoNet. GCW CryoNet Team should seek view of WGMS in selecting those stations. M. Zemp proposed that through a joint initiative, via a letter or an email, the glacier sites/stations can be made aware of the GCW and CryoNet thus filling the existing gaps in CryoNet.

7.2 Snow Products Intercomparison

7.2.1 Thomas Nagler (ENVEO) in Presentation 7b provided information on the progress made in the Satellite Snow Product Intercomparison and Evaluation Experiment (SnowPEx). The primary objectives are to: (a) Intercompare and evaluate global / hemispheric (pre) operational snow products derived from different EO sensors and generated by means of different algorithms, assessing the product quality by objective means; (b) Evaluate and intercompare temporal trends of seasonal snow parameters from various EO based products in order to achieve well-founded uncertainty estimates for climate change monitoring; and (c) Elaborate recommendations and needs for further improvements in monitoring seasonal snow parameters from EO data. The project will support the setup of a consolidated operational satellite snow observation system for the WMO Global Cryosphere Watch and help to improve the snow cover data base for climate monitoring, as addressed by the WCRP-CliC programme.

7.2.2 The main task of SnowPEx are to: (a) Review of Algorithms and products focusing on Snow Extent (SE) and Snow Water Equivalent (SWE); (b) Define protocols and methods for validation and intercomparison of SE/SWE products; (c) Define and compile reference data sets for quality assessment of SE and SWE products; (d) Intercompare SE/SWE products from various institutions and the quality assessment against reference data base; (e) Analyse the Hemispheric/Global SE and Snow Mass Trends and its uncertainty; (f) Study the synergy of SE and SWE products; and (g) Make conclusion and recommendations for satellite snow monitoring and publication of project results. One of the major outcomes so far is a register of existing Snow Extent Products.

7.2.3 The outcome of the 2nd International Satellite Snow Product Intercomparison Workshop (14-16 September 2015) are: (a) Agreed protocols and procedures for validating and inter-comparing snow products; (b) Agreed data sets for validation and data sets; (c) Agreed approach for analysing and studying temporal trends of SE and SWE using SnowPEx data sets; and (d) Agreed framework for reporting results on SnowpEX website, in peer reviewed journal (joint publication) and conferences. There are 17 international partners in the SnowPEx Project Team.

7.2.4 T. Nagler presented the mean 3-monthly RMSE and Bias from products intercomparisons 2003/2004, snow difference maps from 8 different sources, intercomparison of seasonal trends for snow areas and validation with high resolution snow products Landsat Data Set. Validation results showed that unbiased RMSE varies within a range from 8.88 to 23.5 between four selected products (CRCLIM 5 km, JXAM5 5 km, JXM10 5 km, M10C05 500 m). He also presented first validation results using the Extended ECMWF in-situ data on Snow Depth for GLSSE, MOD10C05 and PATHF. Finally, he presented SnowPEx SWE datasets and validation protocol and concluded that spatial and temporal availability of in-situ data is sufficient for validation.

8. Finalizing the Strategic Implementation Plan 2015-2018

Note this discussion of this agenda item was postponed to day 3 (appearing under Section 19.)

9. DLR Atmospheric Missions with relevance to Cryosphere-Atmosphere Coupling

9.1 Future Atmospheric Missions

9.1.1 Thomas Trautmann (DLR-IMF) presented DLR atmospheric missions with a focus on cryosphere–atmosphere interaction, including past and current European atmospheric missions and future European atmospheric missions using both passive and active remote sensing techniques (see Presentation 9a).

9.1.2 Establishing satellite Doppler wind lidar profiling capability and Monitoring of atmospheric composition (ozone, methane, carbon dioxide and aerosols) belong to WMO strategic priorities for polar regions, as they are needed for a better understanding of the polar atmosphere and cryosphere - atmosphere coupling.

9.1.3 ENVISAT/Sciamachy and ERS-2/GOME are the past sensors/platforms with DLR involvement. The current are MetOp-A & B while MetOp-C is anticipated to start in 2017.

9.1.4 Past and current European sensors for ENVISAT/Sciamachy & ERS-2/GOME & for MetOp/GOME-2 – these missions are no longer active, with the exception of MetOps, MetOp-C as from 2017. Absorption spectroscopy is used as the information retrieval concept for atmospheric composition.

9.1.5 Future European sensors and platforms include Sentinel 5 Precursor (after 2016), Sentinel 4 & 5 (after 2021), ADM-Aeolus (after 2016) and MERLIN (after 2019).

9.1.6 Sentinel 5 Precursor mission will use DLR scientific L2 algorithm development and operational data processor and will focus on tropospheric trace gases, O_3, SO_2, HCHO and clouds.

9.1.7 Copernicus Sentinel 4 is the first European GOME-type spectrometer in geostationary orbit. Will be launched on Meteosat Third Generation sounder platform: MTG-S1 ~2021, MTG-S2 ~2029. Level 2 Products include: O_3, NO_2, SO_2, HCHO and AOD over Europe/North Africa (nadir pixel size 8x8 km^2). DLR is leading the ESA S4 level 2 development project. Copernicus Sentinel 4 will provide air quality measurements with fast repeat cycle every 60 minutes during daytime.

9.1.8 GMES/Copernicus Sentinel 5 will fly on EUMETSAT Polar System 2nd Generation platform (EPS-SG) with a Nadir pixel resolution 7x7 km^2 and swath width of 2700 km. It will provide high spatial resolution for quantitative determination of air pollution on city-scale with identification of emission sources and sinks. There will be daily coverage in the tropics.

9.1.9 ADM-Aeolus is the first European lidar mission from ESA and the first Doppler wind lidar mission worldwide. Its objective is to improve weather forecasting by providing global wind-profile observations. It is a polar orbiting satellite at 400 km with single payload instrument - the Doppler lidar ALADIN (Atmospheric LAser Doppler INstrument). It measures profiles of wind in line-of-sight direction from ground up to 20-30 km with a vertical resolution of 250-2000 m averaged over 90 km. It has a very demanding requirement for the systematic error (bias less than 0.4 m/s).

9.1.10 The mission objective of the French-German Climate Mission "MERLIN" is to measure column-integrated dry-air volume mixing ratio of CH_4 using the IPDA Lidar technique at all seasons and high latitudes in winter time. It should provide estimates on regional scale (200x200 km^2) of CH_4 surface emission on a monthly basis using inverse modeling and the secondary data products on canopy height, surface retro-reflectance, cloud-boundaries and strong aerosol layers. Duration of mission is three years.

9.2 Cryosphere-Atmosphere interaction: Ozone and Bromine Monoxide

9.2.1 Diego Loyola (DLR-IMF) presented GOME-2 products from MetOp-A & B for various atmospheric composition variables, including ozone (O_3) and bromine monoxide (BrO) and provided information on tropospheric O_3 depletion events and BrO explosions (See Presentation 9b). The main source of natural halogens in the polar regions is the sea salt, particularly in regions of newly forming sea ice where high concentrations are observed at the surface and in the snow.

9.2.2 D. Loyola presented trace gas retrieval algorithm with an improved O_3 retrieval. Collected data from GOME/ESA, SCIAMACHY/DLR-NSO and GOME-2/EUMETSAT provide a unique picture of the evolution of the ozone hole over the Antarctic since 1995. He presented differences in total ozone comparison between models and satellites since 1970 and a creation of the long-term climate data records.

9.2.3 D. Loyola recalled that the major bromine sources are salt lakes and volcanoes. In Polar Regions, sea salt comes from fresh sea ice, sea salt aerosols, sea salt enriched snow and frost flowers. "Bromine Explosions" lead to an exponential increase of BrO in the lower atmosphere. The initial release can be localized to small regions under special conditions: sea salt and low temperatures/sunlight. Transport processes can play an important role for distribution and release of BrO. BrO can be mainly observed above sea ice areas, therefore, Greenland, Antarctic continent and shelf ice do not show enhanced BrO. Enhanced BrO values can be observed every year in polar springtime. The same sea ice covered regions are affected, but variations are apparent. As special conditions are needed during the release process, changing temperatures and sea ice coverage due to climate change are highly important.

9.2.4 In a discussion, M. Drinkwater noted that it would be useful for polar prediction, including YOPP, and use of atmospheric trace gases to be able to foresee some of the data products being resampled on a polar grid. This would allow coupled modeling groups to use these data. Model domains may be specific and limited, and there are unique aspects of use of data in Polar Regions.

10. Progress Update: SAR CWG Activities

10.1 Yves Crevier, the Chair of SAR Coordination Working Group, provided information on SAR GCW activities, management, communication, coordination and data acquisition (see Presentation 10).

10.2 The SAR CWG is a subsidiary group to PSTG and coordinates its activities and membership with the PSTG. Based on the Terms of Reference, adopted in November 2014, it aims at fulfilling the need for inter-Agency SAR mission acquisition planning, carries out implementation actions at agency level, provides coordination across space agencies with SAR missions, facilitates acquisition and distribution of fundamental SAR satellite datasets, and contributes to or supports the development of specific derived products in support of cryospheric scientific research and applications. Members are all SAR Operating Agencies (thematic experts and mission managers), as well as other agencies (*i.e.* optical/ground segment, etc.) to ensure availability complementary datasets, plus members of the science community representing thematic sectors of priority.

10.3 Y. Crevier presented briefly the Data Compendium, a concept of capturing space agency contribution initiated during the IPY STG that should become a definitive information source regarding SAR data sets of the cryosphere acquired or processed under the auspices of the IPY STG and PSTG. It should also show what SAR community has achieved and could achieve through coordination. It will be helpful aid for the science community and an information tool for the Policy community.

10.4 Y. Crevier introduced the plan for the 2nd issues SAR CWG Brochure that should focus on achievements, should include update from the thematic science groups and be circulated in events, conferences, workshops, and be also used as an information tool for internal communication.

10.5 Timeline Poster should be another communication and outreach tool. A concept of Timeline Poster was presented to PSTG-5 and, when completed, it should provide an overview of two decades of coordinated satellite SAR data acquisitions over Polar Regions.

10.6 Finally, Y. Crevier informed on a progress in data acquisition for permafrost, wet snow, Ice sheets and floating ice. The plan was to discuss data access in the SAR CWG and to consolidate the tables capturing the responses to the strategic objectives related to SAR.

11. Focus Session: Progress in Addressing Floating Ice User Requirements

11.1 Progress in Addressing Science Goals

11.1.1 Stephen Howell (Environment Canada) presented progress in scientific requirements for studying floating ice, progress update on Sentinel-1, science highlights, gaps and future planning (See Presentation 11a).

11.1.2 The scientific requirements for floating ice include: (a) The establishment of a multi-agency plan for acquiring contiguous (seamless) six days repeat pan-Arctic SAR imaging at a consistent polarization combination; (b) The establishment of Arctic Tundra lakes and river monitoring sites, as extension of sea ice coverage; (c) Assuring continuity in all-weather ice concentration, extent, motion and thickness data in support of the sea ice climate data time to secure the sea ice Essential Climate Variable; and (d) Coordination with field campaigns, ice camps and drifting buoys to maximize synergies and product validation possibilities (and uncertainty estimates).

11.1.3 S. Howell presented the first Sentinel-1A sea-ice chart that was drawn by DMI and an example of iceberg detection (Disko Bay) from Sentinel-1A. DMI delivers maps of iceberg density on a 10x10 kilometer grid to Copernicus and also developed a daily iceberg map product, however, it should be noted that some of the potential icebergs may be ships, the detection algorithm presently cannot distinguish between them. Regarding the ice drift from Sentinel-1, ENVISAT ASAR data allowed development of methods and derivation of daily maps of ice drift in the Arctic. Routine Sentinel-1 Satellite SAR data now enables ice drift determination all year round, Other satellite ice drift products are only available during winter.

11.1.4 NASA's Operational IceBridge (OIB) conducts extensive airborne surveys of Earth's polar ice to bridge the gap between **I**ce, **C**loud, and land **E**levation **Sat**ellite (ICESat-1; 2003-2010) and ICESat-2 (2017). Of primary interest to the sea ice community are the ice thickness and snow depth on sea ice. OIB gets 1-3 day coverage over OIB sea ice domain from RADARSAT-2 and is used for field validation and preflight planning. The other science highlights included: (a) Invisible Polynyas; (b) Ice thickness in the Northwest Passage; (c) Satellite observations of ice drift vs. Copernicus model forecasts; (d) Ice drift vs Wind; and (e) Downstream Services available through:www.seaice.dk.

11.1.5 Regarding science gaps, S. Howell mentioned a very good daily coverage of the Atlantic/European sector of the Arctic Ocean and limited, but improving, coverage of the Pacific sector, and hardly any overlap from day to day over Antarctica, thus having ice drift derivation only from very limited areas. In the Southern Hemisphere there is a need of a combination of ascending and descending passes to get day to day overlap areas to be able to detect ice drift and deformation. More than two satellites are needed to give equivalent Southern Hemisphere coverage to that in the North.

11.2 Agency Tour-de-Table: Initiatives Addressing User Requirements

11.2.1 Susanne Lehner (DLR-EOC) presented activities of DLR Research Lab „Maritime Safety and Security" in Bremen that included ship detection, iceberg detection, oil spill detection, wind and waves, ice classification and campaign support (See Presentation 11b).

11.2.2 Pablo Clemente-Colón (NOAA) provided examples (See Presentation 11c) of comparisons of ice surface temperature (IST) between IceBridge KT19 and VIIRS IST, information on AMSR2 snow and ice products that are now running daily at CIMSS, VIIRS sea ice thickness example, information on one-dimensional thermodynamic ice model OTIM. JPSS and GOES R Next Generation NASA/NOAA satellites will further enhance the ability to detect ice and snow. Further improvements of sea ice edge forecasting are available through the U.S. National Ice Center (NIC) analysis assimilation. Here models provide forecast guidance and NIC analysts incorporate real time data to produce interpretive analysis. Ice experts from the University of Colorado Boulder, the U.S. Navy, the NIC and other institutions have developed a new technique for estimating sea ice concentration in the Arctic ocean, and the new method improves the U.S. Navy's short-term sea ice forecast of ice edge location by almost 40 percent.

11.2.3 P. Clemente-Colón provided information on NOAA access to European Sentinel missions, to Italian Space Agency (ASI) and JAXA ALOS-2 mission.

11.2.4 P. Clemente-Colón showed an interesting example of NOAA Operational SAR Surface Winds Products that can capture rapid freeze-up at shell drilling site and informed on the research into automated ice identification using SAR surface wind speed input. This product will be useful at the National Ice Center, in the NWS in Alaska and in the Great Lakes Environmental Research Laboratory for improving ice analyses and ice product production efficiency.

11.2.5 François Montagner (EUMETSAT) presented information on OSI SAF Suite, ice surface temperature, future microwave sensors on EPS-SG, and Sentinel-3 Sea ice freeboard (See Presentation 11d). As for the plans of the EUMETSAT Polar System, the mission will continue until at least 2023 (joint Metop-A-B operation until 2018, Metop-C launch in 2018), the new product of IASI Ice surface temperature will be available in 2017, and applications of ASCAT "high resolution" (6km sampling) products will contain, among others, ice concentration and ice drift.

11.2.6 F. Montagner informed on the EUMETSAT plans for EPS Second Generation, including MWI products, covering also snow and sea ice variables. ESA and EUMETSAT will jointly operate the Copernicus Sentinel-3 mission. ESA develops the S-3 satellites and Ground Segment with EUMETSAT support, will perform the initial operations of the Sentinel-

3 satellites and operate the Land Services. EUMETSAT will perform the routine operations of the Sentinel-3 satellites and operate the Marine Services. Launch of Sentinel-3A was in December 2015, operational services will start mid-2016 (level 1 products) to 2017 (level 2 products), and mission duration is more than 7.5 years. Launch of Sentinel-3B will be 18 months later. Sentinel-3C and D are being procured by ESA. Sentinel-3 orbit: sun-synchronous, 98.6º inclination, 814 km mean altitude, with 27-day repeat cycle. The products include: S-3 Marine Altimetry Products (Sea Ice Freeboard), S-3 Marine SLSTR Products (sea surface temperature and ice surface temperature), and S-3 Marine OLCI Products (provides a potential for biological processes and water quality observation in Polar Regions *e.g.* algal blooming near ice edge, river discharge during snow melt period).

11.2.7 As regards OSI Sea Ice Product Suite, Changes introduced on 15/09/2015 cover: (a) Global sea ice edge and sea ice type - a change of the algorithm to improve transition between seasons as well as robustness against sensor degradation; (b) Low resolution sea ice drift – ingesting AMSR-2 data in addition to SSMI/S and ASCAT as input to the algorithm; and (c) Global sea ice concentration – providing uncertainty estimates in the product.

12. World Glacier Monitoring by Satellites

12.1 The Global Terrestrial Network for Glaciers

12.1.1 Michael Zemp (WGMS) introduced the organizational structure of the Global terrestrial network for Glaciers (GTN-G) and its support to GFCS (Presentation 12a). Internationally coordinated glacier monitoring was initiated in 1894, GTN-G, the scientific collaboration network, was established in 1998 and its aims is to: (a) combine in-situ and remotely sensed data; (b) process understanding and global coverage; and (c) combine traditional observations and new technologies.

12.1.2 GTN-G has Advisory and Executive Boards. Global Land Ice Measurements from Space (GLIMS) is responsible for inventory, World Glacier Monitoring Service (WGMS) for fluctuation and US National Snow and Ice Data Center (NSIDC) for data hosting. All this is done with some 3.1 FTE staff. GTN-G is strong at long-term storage of existing databases and at active compilation of glacier change data from in-situ network, however, it lacks resources for tapping the great potential in remote sensing.

12.2 Glacier Monitoring from Satellite- Status & Needs

12.2.1 Frank Paul (Department of Geography**,** University of Zurich) presented satellite-derived glacier products (Presentation 12b), providing an overview of products and sensors by respective space agencies, including proposals, such improving access to ESA data, get free access to CNES archive and make DEMs available. He presented examples of glacier mapping by Landsat and Sentinel, examples of DEM differencing and flow velocities.

12.2.2 The major conclusions: all kinds of satellite data (optical, microwave, altimetry) and satellite derived products are utilized today for glacier monitoring. They are combined for complimentary products and extension of spatio-temporal coverage (global and FCDRs). Glaciers benefit from both a wide swath width (inventories) and high spatial resolution (change detection). Data volume restrictions (AO's) or access restrictions due to the commercial distribution of satellite data is currently preventing global monitoring. Opportunities to map important events are missed, creation of FCDRs is challenged, and redistribution of results hampered. Scientists find a way through the restrictions (AO's, GLIMS, colleagues) but this is neither efficient nor sustainable. Possibilities for improved data access should be checked if a contribution to overarching goals (GEOSS) is desired.

13. Focus Session: Progress in Addressing Glacier & Ice Sheet Requirements

13.1 Progress in Addressing Science Goals

13.1.1 Bernd Scheuchl (University of California, Irvine, UCI) made presentation on progress with respect to ice sheets (Presentation 13a) Ice sheets are acknowledged by WMO and UNFCCC as Essential Climate Variable (ECV) needed to make significant progress in the generation of global climate products and derived information. Spaceborne SAR is an important resource for ice sheet science and ice velocity, grounding line and calving front can be determined. The challenge is that none of the current SAR missions are science missions and science campaigns need to be carefully planned and compete for resources.

13.1.2 Goal of remote sensing is to better understand the earth's ice sheets, how they react to a changing climate, and how they contribute to global sea level rise and the role of remote sensing is to: (a) Collect and keep a data record of our planet; (b) Provide data for the nowcast, enough to enable modelers to run projections; and (c) Broadly distribute the data for maximum science impact.

13.1.3 B. Scheuchl identified data sources from satellites used up to now and from new missions, presented large scale ice sheet monitoring projects, such as NASA's MEaSUREs Program (Making Earth System Data Records for Use in Research Environments) and ESA Ice Sheet Climate Change Initiative (CCI), and recalled ice sheet products resulting from IPY data collection.

13.1.4 Based on literature review and ESA CCI User Survey for Greenland the new user requirements for ECV parameters were already presented to PSTG. Since then, a separate user survey was undertaken for Antarctica.

13.1.5 Based on previous experience and discussions, general recommendations were made, namely: (a) Polarization: HH ; (b) Stripmap is preferred but S-1 IWS shows promising results for acquisition mode/resolution ; (c) Incidence Angle range worked fine for 25 to 45 degrees (even 57 deg. over flat terrain to cover South Pole) but the same range of incidence angles should be used where possible; and (d) A need to acquire long tracks (coast to coast i.e. rock to rock).

13.1.6 The general observational requirements for Antarctica are as follows: (a) Annual coverage of all of Antarctica with at least three changed to four consecutive cycles in winter observations. More cycles are considered an asset ; (b) More frequent observations of critical areas with every possible acquisition of selected tracks (Pine Island / Thwaites Glacier region; Antarctic Peninsula; Totten Glacier). B. Scheuchl also presented reduced observation requirement (if sensor capacities require scale down).

13.1.7 The general observational requirements for Greenland are as follows: (a) Annual coverage of all of Greenland with at least four consecutive cycles for winter observations. More cycles are considered an asset. Time of Year: December to March; (b) A secondary full coverage each year would be an asset. Suggested timing for such a secondary campaign would be July-September. Less correlation can be expected due to summer conditions. More coverages in winter would also be an important science contribution (to reduce errors); (c) Higher frequent observations of critical areas with every possible acquisition of selected tracks. Need to acquire ascending and descending coverages. This would improve accuracy in the interior where the InSAR phase could be used in both directions. Again, B. Scheuchl also presented reduced observation requirement (if sensor capacities require scale-down).

13.1.8 Draft requirements were presented to PSTG-4 and the SAR CWG-3 in 2012 and SAR Science Requirements for Ice Sheets were published as V1.0 in May 2013. Since then communications with space agencies had continued regarding sensor specific recommendations. B. Scheuchl proposed to update the Requirements document, including a round of public comments, to reflect recent specific recommendations that were made to space agencies.

13.1.9 **ACTION 5.2**: B. Scheuchl to prepare a draft update of the Requirements Document. Deadline: mid-2016.

13.1.10 B. Scheuchl identified information needs for mountain glaciers and ice caps (glacier outlines, velocities, late summer snow line, elevation, and elevation changes) and areas of interest. Shape files of all glaciers in the world are available from the Randolph Glacier Inventory (RGI) at: http://www.glims.org/RGI/. Glacier requirements are mentioned in the appendix of the ice sheet Requirements Document (SAR focus only).

13.2 Progress in Ice Sheet monitoring using Sentinel satellites

13.2.1 Thomas Nagler (ENVEO) presented Greenland Ice sheet CCI project (Presentation 13b) for monitoring of ice velocity, surface elevation changes, grounding lines, calving front location and gravimetric mass balance and respective products. Daily updates on Greenland ice sheet surface condition, glacier movements and the contribution to global sea level, as well as satellite products is available from the Polar Portal on monitoring ice and climate in the Arctic (www.polarportal.dk). T. Nagler presented proposed revised Sentinel-1 and Sentinel-2 acquisition strategy for Greenland (e.g., one annual S-1 campaign with eight consecutive acquisitions, December - March, includes the tracks used for monitoring the margins; and and June – September synergetic Sentinel-2 monitoring of the margins to and regions of significant changes) and Antarctica (e.g., one campaign with four consecutive repeat acquisitions per year, IW HH mode, June – September, plus extension by monitoring margins and to regions with main ice export and significant changes).

13.3 TerraSAR-X and TanDEM-X Data Acquisition Status over Polar Areas

13.3.1 Dana Floricioiu (DLR) presented TerraSAR-X "cold spot" monitoring, of a large number of Greenland sites from 2012 to 2015 (still ongoing) using StripMap with HH, HH/VV, HH/HV polarization and Spotlight with HH/VV polarization (see Presentation 13c).

13.3.2 The objective of TerraSAR-X (TSX) Greenland outlet glaciers (2009 – 2015) monitoring is to measure ice velocity of Greenland outlet glaciers and to monitor rapidly changing outlet glaciers. Twenty-seven sites are monitored with TerraSAR-X Stripmap (30 km swath width) about 14 times /year. Number of acquisitions has increased in order to obtain a continuous series in summer. Additional twenty-six sites are monitored about 10 times/year, giving a total of ~640 TSX L1b products per year.

13.3.3 The objective of TerraSAR-X Antarctica background mission (peninsula and ice shelves) is to monitor glaciological processes, map detailed structures of the glaciers. Future TSX data acquisition could be ordered through general science data proposals, but detailed acquisition plans for future acquisitions are needed. TerraSAR-X data could be used in support for the Antarctic Ice Sheet CCI project. The aim is, similar to the Greenland Ice Sheet CCI project, the long-term and reliable production of a set of key parameters: (a) surface elevation change; (b) ice velocity; (c) grounding line location; and (d) gravimetric mass balance.

13.3.4 D. Floricioiu recalled TanDEM-X Mission status, science phase, super sites and operational data acquisition.

13.4 Agency Tour-de-Table: Initiatives Addressing User Requirements

13.4.1 B. Scheuchl presented NASA, CReSIS and NSF contribution on Greenland Ice Mapping Project: New Version of an all Greenland Mosaic is ready for release. It uses interferometric phase rather than speckle-tracking for much of the interior. Mosaic includes data from ERS-1/2, RADARSAT 1, ALOS PALSAR and TerraSAR-X.

13.4.2 B. Scheuchl presented NSIDC contribution on Landsat 8 and mapping of the cryosphere. A greatly improved ground system for Landsat 8 data reception and processing has enabled acquisition and processing of ~725 images per day. This greatly reduces the impact of cloud obscuration over ice sheets and glaciers. Unlike most previous optical imaging sensors, Landsat 8 is sensitive to surface texture of ice surfaces, which results in a continuous mapping coverage of ice velocity, similar to speckle tracking with SAR.

13.4.3 Y. Crevier presented CSA contribution on ice sheet science (See Presentation 13d). This included: InSAR coverage of ice sheets; RADARSAT-1 Greenland 2005-2008 and 2013; RADARSAT-2 Greenland 2014-2015; RADARSAT-2 Antarctica 2009, 2011, 2013 and 2014-2017; indicating objectives, approaches and metric estimates.

13.4.4 M. Drinkwater presented ESA contribution on routine operational mapping of ice sheets and glaciers (See Presentation 13e). This included: CryoSat ice surface deflation, CryoSat swath processing, DEMs and altimetry; S-1A and S-2A calving; S-2 Greenland glaciers; S-2 ice stream velocity; S-2 preliminary ice velocity map, with noting that glacier velocity fields from S-2 look very promising, as a result of good radiometric and geometric performance and 10 m resolution. Velocities can be retrieved even for comparably slow glaciers. This allows for measurement of summer velocities in addition to annual ones. Good results also in cloud and mountain shadow due to 12-bit resolution.

13.4.5 **ACTION 5.3**: Frank Paul to provide User Requirement Document for Glaciers. The Secretariat to place User Requirement Document for Glaciers on PSTG webpage.

14. Year of Polar Prediction Planning Status

14.1 Thomas Jung (AWI) presented motivations behind the Polar Prediction Project (PPP) and the Year of Polar Prediction (See Presentation 14).

14.2 PPP should promote cooperative international research enabling development of improved weather and environmental prediction services for the Polar Regions, on time scales from hourly to seasonal. The Year of Polar Prediction (YOPP) should enable a significant improvement in environmental prediction capabilities for the polar regions and beyond, by coordinating a period of intensive observing, modeling, prediction, verification, user-engagement and education activities. YOPP has three main phases: (a) Preparation phase (2013 to mid-2017); (b) YOPP mid-2017 to mid-2019; and (c) Consolidated phase (mid-2019 to 2022).

14.3 The core period is from mid-2017 to mid-2019 and includes e.g., intensive observing periods (IOPs), dedicated model experiments, coupled data assimilation and intensive verification. For IOPs more observations are needed in general and preferably at the same time.

14.4 The purpose of the YOPP-Satellite component is to enhance the use of satellite products for polar prediction purposes. Selected elements include: (a) Make use of existing satellite data; (b) Comprehensive satellite snapshot; (c) Satellite validation and ground truthing (snow on ice); (d) Improved atmospheric products in lower atmosphere; (e) Sea ice information (thickness, deformation etc.); (f) Icebergs; and (g) Improved model and data assimilation systems.

14.5 T. Jung presented some highlights of the YOPP Summit (Geneva,13-15 July 2015) and further progress. As a summary: (a) PPP and YOPP have gained a high level of visibility (large momentum); (b) Involvement of satellite agencies could be strengthened; (c) A lot of relevant satellite data are available (prediction community has to catch up); (d) There is scope for a comprehensive satellite snapshot (especially SAR data during YOPP IOPs); (d) PSTG might like to review and add to the YOPP Implementation Plan; and (e) All communication should go through the International Coordination Office for Polar Prediction (ICO), see http://polarprediction.net.

14.6 During discussion it was proposed that a proper focus should be given to existing long-term surface data in addition to the new data.

14.7 **Action 5.4**: PSTG to formulate a list of operational products that PSTG believe are suitable to YOPP and this should be complemented by research products. This requires that space agencies make their commitments and provide a table of proposed products for YOPP; this could be an appendix to the YOPP Implementation Plan.

14.8 **Action 5.5**: T. Jung to provide list of SAT products that are endorsed by national PIs.

14.9 François Montagner presented EUMETSAT proposal for YOPP, which included: (a) OSI SAF Sea Ice Product Suite, (b) EUMETSAT Polar System; (c) Sentinel-3 for marine altimetry, S-3 marine SLSTR and OLCI Products.

14.10 P. Clemente-Colón presented the US National Ice (NIC) Center YOPP plans, namely: (a) The NIC will be used as a part of NOAA YOPP Assets/Projects; (b) NIC will provide operational access to spaceborne radar surface wind observations; (c) Targeted deployment of Arctic buoy platforms during MOSAiC will be increased; (d) In collaboration with Naval Research Laboratory (NRL), will provide improved regional sea ice forecasting products for Arctic and Antarctic regions.

14.11 **Action 5.6:** To add soil moisture in the Strategic Priorities 2015-2018 for Polar Prediction.

15. Focus Session: Progress in Addressing Permafrost User Requirements

15.1 Progress in Addressing Science Goals

15.1.1 Annett Bartsch (ZAMG) presented a review of requirements, achievements and expected data for permafrost (See Presentation 15a). She recalled the development since the PSTG-4. The White paper was made available through PSTG, CliC and Pangaea epic. The full Pangaea record includes 49 cold spots and transects and metadata. Cold spots and a Permafrost white paper were presented at ESA-CliC (WCRP), EGU 2015, ESA Sentinel-3 conference and ESA Arctic instrumentation workshop. The InSAR – Permafrost focus group was initiated. Four cold spots where included in the SPOT5-Take5 campaign by ESA request. There were several ESA calls with a reference to White paper, e.g. ESA Polaris, ESA Future EO missions and ESA DUE GlobPermafrost.

15.1.2 Requirements are available for ECV parameters (permafrost extent, soil temp profiles, active layer thickness, ground ice condition). The interest for Earth observation is placed on: (a) Coastal erosion; (b) Thaw lakes (summer extent, winter ice; time stamp missing on land cover products) and wetlands (circumpolar account for flux studies required); and (c) Subsidence. There is a need for circumpolar accounts, baseline for future monitoring and temporally and spatially consistent acquisitions of optical, thermal and microwave.

15.1.3 Earth Observation usage challenges coming from ESA CliC workshop in January 2015: (a) Subsurface temp – via models (currently LST and SWE from satellites is used); (b) Soil properties to estimate response (carbon content, ice/water content); (c) Carbon exchange to atmosphere, to lakes, rivers and oceans; and (d) Trends in surface parameters (major challenge scale, varying fraction of water-non water challenge for all global products.

15.1.4 Several developments in research coming especially through HGF Alliance initiative and PAGE21, e.g. investigation of role of moisture changes for InSAR applications. Field work in 2015 devoted to intensification of activities related to TSX but also ALOS PALSAR and SPOT5-Take5 campaigns. Special issue Remote Sensing of Changing Northern High Latitude Ecosystems was completed. Circumpolar account of wetlands for flux studies was addressed in PAGE21.

15.1.5 There is a need to place the in-situ measurements into wider context: Circumpolar landscape units were derived from ESA DUE Permafrost products (LST, ASCAT freeze/thaw, DEM) and SAR and WMO Cold spots and monitoring transects.

15.1.6 Support modeling of sub-surface conditions: Permafrost extent modeled with the approach of Westermann et al. for Scandinavia and West Russia. Proper description of soil properties (indirectly from land surface characteristics) is needed. CCI land cover now includes a class lichens and mosses (represents a range of different surface types; class 'sparse vegetation' needs to be revised).

15.1.7 A. Bartsch informed on data availability from: (a) SPOT5-Take5 (none glaciated); (b) Sentinel-1 (so far no lowland InSAR possible for permafrost research outside of Europe); and (c) ALOS-2 PALSAR (since May 2015)

15.2 Agency Tour-de-Table: Initiatives Addressing User Requirements

15.2.1 Y. Crevier presented CSA contribution. CSA will start to develop time series for some areas, e.g. Alaska and Yukon. CSA did not start the monitoring process but will do it and need to understand what exactly is needed. RADARSAT-1 collected data over the northern Canada – these are historical interferometry data and are available from Polar Data Catalogue. There is a need to coordinate RADARSAT and Sentinel missions.

15.2.2 DLR D. Floricioiu and A. Roth presented DLR contribution (See Presentation 13c, and Presentation 15b). Information was provided on how Terra-SAR-X "Cold Spot" Monitoring will support Permafrost user requirements.

15.2.3 M. Drinkwater presented ESA contribution. "Requirements for Monitoring of Permafrost in Polar Regions", a community white paper, was developed in 2014 in response to PSTG, following the Permafrost workshop in February 2014. This white paper was based on the derived user needs, and following consolidation at the 4th European Conference On Permafrost (EUCOP-4) in Portugal and community input. ESA issued an ITT for a project to address these user requirements and will close on 30 September 2015. ESA ITT for DUE GlobPermafrost project is closed (focus on S-1,-2,-3 + other capabilities). Proposals currently in evaluation – in relation to addressing the Permafrost strategic priorities

GlobPermafrost. In Horizon 2010, ESA coordinates with EC DG R&I (Research and Innovation) a content of the Workplan for polar related Horizon 2020 calls and 2016-2017 Workplan is available. Activities requiring Arctic infrastructure will be coordinated under EU-PolarNet (AWI). There are also collaborative projects with ArcticNet+. Other activities include: SMOS+Frost2 to revise the SMOS freeze/thaw detection and exploit the impact of the satellite data sets in scientific and future applications and prepare for a multi-mission product.

15.2.4 **ACTION 5.7**: Annett Bartsch to provide CNES with locations of cold spots and coastal sides for complementary HR optical data.

16. Focus Session: Progress in Addressing Snow User Requirements

16.1 Progress in Addressing Science Goals & Remaining Gaps

16.1.1 David Small (Dept. of Geography, University of Zurich) presented a progress in science requirements for wide area snowmelt monitoring. While spatial resolution (100 m) is achieved by current SAR satellites, temporal resolution (target 1 day) is not. He recalled Key general recommendations of the WMO White paper on SAR Acquisition Planning for Terrestrial Snow Monitoring (see Presentation 16a).

16.1.2 D. Small informed on requirements for highly accurate geometric and radiometric calibration, on a lack of homomorphism (No one-to-one correspondence between slant range and map geometries on fore- and back-slopes) and on radiometric normalization conventions.

16.1.3 He presented Sentinel-1A C-band backscatter image specifications over Swiss Alps: (a) S-1 Interferometric Wide-swath mode; (b) VV/VH polarizations; (c) Ground Range Detected High resolution; (d) Radiometrically terrain corrected images calculated at 10m using *swissALTI3D;* (e) Time span: Jan. 1 – June 30, 2015; and presented both geometrically and radiometrically terrain corrected images.

16.1.4 Regarding the wet snow classification, examples of comparison of S-1-based vs independent operational model were provided. In the examples of composite backscatter image over Alps he pointed out long duration Radio frequency interference (RFI) observed in Sentinel-1A acquisitions over the Adriatic sea, Italy, and Austria on 16 August 2015. The cause was investigated and found to be simultaneous operation of Radarsat-2 on coincident orbits (12d S1A, 24d RS2 resonance) over the same European alpine region.

16.1.5 D. Small showed a comparative British Columbia Sentinel-1 SAR backscatter image time-series: (a) Sentinel-1 Interferometric Wide-swath mode; (b) VV/VH polarizations; (c) Ground Range Detected High resolution; (d) Radiometrically Terrain Corrected images calculated at 3sec using *SRTM3*; (e) Time span: 1 January to 30 September 2015.

16.1.6 D. Small showed progress in addressing snow user requirements and presented C-band SAR Backscatter image time-series taken by Sentinel-1 (European Alps, Swiss Alps, British Columbia Coastal Mountains, and Ellesmere Island). The examples showed that PSTG mountain wet snow products can also provide practical support to EC-PHORS, whose terms of reference now include high mountains in addition to Polar observation, research and services.

16.1.7 Conclusion for composite backscatter mosaics: (a) Wide area potentially seamless coverage is needed; (b) Analysis is possible based on composites with lower data volumes; and (c) "Tighter" time window would be possible with multi-sensor integration. This depends on high standard of geometric and radiometric calibration. Wet snow-state product validation is still on-going.

16.1.8 D. Small completed his presentation with a summary table of all snow relevant Satellite SAR instruments, modes and swaths, namely: ENVISAT ASAR, Sentinel-1, R-2, TerraSAR-X, Paz, and Cosmo-Skymed.

16.2 Progress in Addressing Science Goals for Snow - Monitoring by means of SAR

16.2.1 T. Nagler (ENVEO) recalled operational requirements for satellite-based snow extent products for for operational hydrology and climate research as they are reported in IGOS Cryosphere Theme Report, namely: (a) spatial resolution of 100 m; and (b) revisit time of 1 day (See Presentation 16b). Product type of the current satellite-based C-band SAR Systems "Extent of snow melt area" is based on backscatter sensitivity to wet snow. C-band SAR is not suitable for operational monitoring of dry snow areas due to the very limited sensitivity to dry snow.

16.2.2 SAR concept for retrieval of snowmelt area is based on: (a) Exploitation of the contrast of backscatter between wet snow and snow-free surfaces; (b) Application of the backscatter ratio to compensate for topographic effects (local incidence angle); and (c) Application of a segmentation procedure to separate the two surface types in ratio images. T. Nagler presented Sentinel-1 maps of snow melt area over the Alps (April and May 2015), comparison of MODIS Snow Extent with Sentinel-1 Snowmelt Area.

16.2.3 T. Nagler also presented prototype algorithm for Sentinel-3 Snow Mapping that was developed and tested with AATSR and MERIS of Envisat and presented a sample image of MERIS & AATSR 300 m.

16.2.4 As a conclusion: (a) The Sentinel-1 satellite formation offers excellent capabilities for operational monitoring of snow melt area at high spatial resolution; (b) The Interferometric Wide swath mode data provide four to six day revisit capability at mid-latitudes, improving to two to three days after deployment of the second satellite. Daily revisit will be feasible at high latitudes; (c) A prototype algorithm for retrieval of snowmelt area has been developed, applying the fusion of co- and cross-polarized channels to optimize the discrimination of snow vs. snow-free areas over a wide range of incidence angles; (d) SSC-mode data as input for the retrieval provide the full backscatter signal statistics and geometric resolution, enabling optimum exploitation of sensor capabilities for speckle filtering, channel fusion, segmentation, and rectification; (e) Further testing and validation of the snow product and algorithm is recommended, in order to assess the performance in different snow regions; and (g) Systematic S-1 acquisition of mountain regions especially during melting period is needed.

16.3 Timeline snow cover products and Global SnowPack

16.3.1 Andreas Dietz (DLR) introduced (See Presentation 16c) TIMELINE (Time Series Processing of Medium Resolution Earth Observation Data assessing Long-Term Dynamics in our Natural Environment). It provides 30–year time series with AVHRR land and atmosphere products, enables change detection analyses and the identification of geo-scientific phenomena and trends, is enhancing our ability to automatically process mass data, and provides simple user-access / download possibilities for the time series.

16.3.2 TIMELINE variables include snow and ice over land and sea ice. TIMELINE Snow cover processor include: ESA GlobSnow algorithm, MODIS snowmap, Canadian SPARC, and APOLLO Snow-detection algorithm, however the final processor is still under development.

16.3.3 Global SnowPack is based on MODIS daily snow cover products MOD10A1 and MYD10A1 (version 5), 500 m spatial resolution, daily snow cover information. The products include snow cover duration and late and early season snow cover duration. There is a consistency since 2000. Processing of AVHRR time series is under development (1km spatial resolution, daily data since ~ 1985 available for some regions only).

16.4 Agency Tour-de-Table: Initiatives Addressing User Requirements

16.4.1 M. Drinkwater presented ESA contribution covering Sentinel-3 snow cover extent, mountain snow, CryoSat Mountain Glacier and a potential new multi-instrumented snow in-situ cal/val site in the Swiss Alps.

16.4.2 For S-3 Snow products, several satellites and sensors will be used, such as: ERS-2 ATSR-2, Envisat AATSR, +Suomi VIIRS, +MetOp AVHRR and S-3 SLSTR. Daily and monthly composites will be available in NH coverage (25°- 84°N) in a grid of 0.01°× 0.01°. Data will be accessible at: http://www.globsnow.info/.

16.4.3 Polar View snow services were established as part of the ESA GMES Service Element (GSE) in 2005. Regional products have user defined specifications. Since 2010, a combined product of Pan-European snow map will be available online at: http://www.snowsense.de.

16.4.4 Copernicus CryoLand Service "the Pan-European Snow and Land Ice Service" is online since 1 December 2013. It is funded by EU to stimulate the cryosphere aspects of the Copernicus Land Service and it is based on satellite and in-situ data. Copernicus Sentinels are to fulfill data requirements.

16.4.5 ESA studies include Tibet ELBARA and SnowLab. Tibet ELBARA - L-band in-situ radiometer was installed in conjunction with GEWEX/CliC. This high mountain site for year round radiometer data acquisition will provide snow/soil moisture measurements. SnowLab (future missions related to Snow and Ice) will focus on exploring Seasonal snow cover accumulating on land surfaces and glaciers as an important part of the global water and energy cycles. The goal is to provide a comprehensive multi-frequency, multi-polarization, multi-temporal dataset of active and passive microwave measurements over snow-covered ground.

16.4.6 **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.

16.4.7 **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 lead preparation follow-up ideas. NASA encouraged to conduct activities to support an instrument proposal.

17. New User Requirements

17.1 Community Review of Southern Ocean Satellite Data Needs

17.1.1 M. Drinkwater presented Southern Ocean Observing System (SOOS) User Requirements' survey that was triggered by PSTG and coordinated by SCAR/SCOR and WCRP CliC with SOOS users. The work was presented as SOOS SG in June 2015 and the results are available online. Current draft is undergoing public review "Community review of of Southern Ocean Satellite Data Needs", see:

https://docs.google.com/document/d/1oCXwPU8ykGYv9h4W0i5lzlqWpcpF0m4JX6MRP6BjEJs/edit?pli=1.

17.1.2 PSTG welcome SOOS community to finalize user requirements and would also welcome greater interaction with the user community. There is a need for a dialogue and participation of SOOS in PSTG future meetings to explain the background and underlying details of the of SOOS user requirements.

17.2 Discussion on new requirements

17.2.1 It was concluded that there is a need to understand that the science communities have some responsibilities in terms of ensuring that what is presented is endorsed and representative of the community needs as a whole. It must support the priority science questions considered by the PSTG. New or additional requirements will need to be in line with the priorities established in the Strategic Plan to be invoked by PSTG. These need to be addressable by missions within the PSTG portfolio. New requirements will also need to reflect prioritization of a broad cross-section of scientists, should be endorsed and represent a cross-section of the community. Requirements can be also brought forwards by space agencies as a policy priority. They need to be independently endorsed and need to act as an independent authority.

18. Synthesis of Agency Contributions to Address User Requirements

The Chair presented a summary of agencies' contributions and commitments that came out from presentations and discussions at the session, see Annex IV. This draft document will be refined by all agencies after PSTG-5 and will be placed on the PSTG webpage.

18.1 **ACTION 5.10**: Members of PSTG to refine agencies' contributions and commitments, see Annex IV.

19. **Finalizing the** PSTG reviewed the **Strategic Plan 2015-2018**

19.1 Strategic Priorities 2015-2018 before each of the focus session. In this session, the PSTG Chair presented draft Strategic Plan (Presentation 8) as a whole, addressing suggestions and comments received from agencies and members of PSTG. This draft Plan was also presented to WMO Members at Cg-17 and to EC-PHORS-6. He focused on latest comments received during telecom on 15 January 2015. This will be basis for the next period during the renewed mandate.

19.2 CSA suggested considering a reference to SAR CWG in the Strategic Plan.

19.3 **ACTION 5.11**: CSA to provide text regarding a reference to SAR CWG on PSTG interfaces to be included in the Strategic Plan.

20. Status of Membership

20.1 M. Ondráš presented current list of members of PSTG that were officially nominated by space agencies. There are currently 15 members from the following agencies: ASI, CNES, CSA, CMA, DLR, ESA, EUM, INPE, JAXA, NASA, NOAA, Planeta and USGS. Meeting discussed whether there are any gaps that should be filled and concluded that possible new members could come from ISRO (RISAT), CONAE (SAOCOM), UKSA (NovaSAR) and CDTI (Paz).

20.2 **ACTION 5.12**: M. Drinkwater to seek membership from CONAE.

20.3 **ACTION 5.13**: B. Scheuchl to contact P. Rosen to seek ISRO point of contact via NASA-India NISAR connection.

21. Summary of PSTG-5 Actions

21.1 Meeting reviewed actions coming out of the discussion during the session, see Annex III (b).

22. Plans for Next Meeting

22.2 The Chair proposal to hold next PSTG meeting in The Netherlands with a backup in WMO. PSTG in The Netherlands (ESTEC) would be held from 6 to 8 September 2016 or from 13 to 15 September 2016. The same periods will be for a back-up plan in WMO.

23. Any Other Business

23.1 EUMETSAT Meteorological Satellite Conference will be held in Darmstadt, last week of September 2016 at a time to celebrate 30-year anniversary.

23.2 PSTG agreed to submit a paper to 3rd Arctic Observing Summit (AOS-2016), Fairbanks, Alaska, March 2016. Mark Drinkwater will draft the paper and will circulate among PSTG members for comments.

Meeting was adjourned on 7 October 2015, at 17:00 hours.

Annex I

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Annex II

Agenda

1. **Welcome and Opening Remarks**
2. **Introductions to Participants**
3. **Approval of Agenda**
4. **Review of Action Items**
5. **DLR Radar Based Polar and Cryosphere Activities**
6. **EC-PORS-6 Update**
7. **Global Cryosphere Watch (GCW)**
   - 7.1 CryoNet Status
   - 7.2 Snow Products Intercomparison
8. **Finalizing the Strategic Implementation Plan 2015-2018**
9. **DLR Atmospheric Missions with relevance to Cryosphere-Atmosphere Coupling**
   - 9.1 Future Atmospheric Missions
   - 9.2 Cryosphere-Atmosphere interaction: Ozone and Bromine Monoxide
10. **Progress Update: SAR CWG Activities**
11. **Focus Session: Progress in Addressing Floating Ice User Requirements**
    - 11.1 Progress in Addressing Science Goals
    - 11.2 Agency Tour-de-Table: Initiatives Addressing User Requirements
12. **World Glacier Monitoring by Satellites**
    - 12.1 The Global Terrestrial Network for Glaciers
    - 12.2 Glacier Monitoring from Satellite- Status & Needs
13. **Focus Session: Progress in Addressing Glacier & Ice Sheet Requirements**
    - 13.1 Progress in Addressing Science Goals
    - 13.2 Progress in Ice Sheet monitoring using Sentinel satellites
    - 13.3 TerraSAR-X and TanDEM-X Data Acquisition Status over Polar Areas
    - 13.4 Agency Tour-de-Table: Initiatives Addressing User Requirements
14. **Year of Polar Prediction Planning Status**
15. **Focus Session: Progress in Addressing Permafrost User Requirements**
    - 15.1 Progress in Addressing Science Goals
    - 15.2 Agency Tour-de-Table: Initiatives Addressing User Requirements
16. **Focus Session: Progress in Addressing Snow User Requirements**
    - 16.1 Progress in Addressing Science Goals & Remaining Gaps
    - 16.2 Progress in Addressing Science Goals for Snow - Monitoring by means of SAR
    - 16.3 Timeline snow cover products and Global SnowPack
    - 16.4 Agency Tour-de-Table: Initiatives Addressing User Requirements
17. **New User Requirements**
    - 17.1 Community Review of Southern Ocean Satellite Data
    - 17.2 Discussion on new requirements
18. **Synthesis of Agency Contributions to Address User Requirements**
19. **Finalizing the Strategic Plan 2015-2018**
20. **Status of Membership**
21. **Summary of PSTG-5 Actions**
22. **Plans for Next Meeting**
23. **Any Other Business**

Annex III (a)

Actions from previous meetings

ACTION	COMMENTS
ACTION 4.6: PSTG to nominate a focal point for the planning of YOPP and its planning summit in 2015, in order to refine the satellite-related data requirements. By 1 Dec 2014.	OPEN Nominate a rep: K. Holmlund, or other space agency representative, or scientist TBD with vested interest in interfacing to the PSTG; Ian Renfrew (BAS?/THORPEX)?); François Montagner (EUMETSAT)?
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.	OPEN Larry Hothem (USGS) investigating case studies showing Landsat-7/8 contributions to polar research, and plans for using Landsat-9
ACTION 4.14: USGS to nominate a new representative to PSTG, by sending a letter to WMO. By: 31 Dec 2014.	OPEN Larry Hothem (USGS) is point of contact; not yet formalized

Annex III (b)

Actions from PSTG-5

1. ACTION 5.1: Personalized letter be sent by the WMO Secretary-General to the individual space agencies focusing on benefits, achievements, individual contributions of each agency since 16th World Meteorological Congress, and including a proposal to extend their mandate for another 4-year period to support the new WMO Priority of Polar and High Mountain Regions.

2. ACTION 5.2: B. Scheuchl to prepare a draft update of the Requirements Document. Deadline: mid-2016.

3. ACTION 5.3: Frank Paul to provide User Requirement Document for Glaciers. The Secretariat to place User Requirement Document for Glaciers on PSTG webpage.

4. Action 5.4: PSTG to formulate a list of operational products that PSTG believe are suitable to YOPP and this should be complemented by research products. This requires that space agencies make their commitments and provide a table of proposed products for YOPP; this could be an appendix to the YOPP Implementation Plan.

5. Action 5.5: T. Jung to provide list of SAT products that are endorsed by national PIs.

6. Action 5.6: To add soil moisture in the Strategic Priorities 2015-2018 for Polar Prediction.

7. ACTION 5.7: Annett Bartsch to provide CNES with locations of cold spots and coastal sides for complementary HR optical data.

8. 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.

9. 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.

10. ACTION 5.10: Members of PSTG to refine agencies' contributions and commitments, see Annex IV.

11. ACTION 5.11: CSA to provide text regarding a reference to SAR CWG on PSTG interfaces to be included in the Strategic Plan.

12. ACTION 5.12: M. Drinkwater to seek membership from CONAE.

13. ACTION 5.13: B. Scheuchl to contact P. Rosen to seek ISRO point of contact via NASA-India NISAR connection.

POLAR SPACE TASK GROUP

AGENCIES' CONTRIBUTIONS AND COMMITMENTS
(Draft for comments)

Scientific Foci	Strategic Priority	CSA	DLR	NOAA	ESA	EUMETSAT	NASA/ USGS	Status/Gaps
Floating Ice	Establish multi-agency plan For multi-SAR datasets	S-1: ice charting Iceberg mapping (polarisation) DTU - PolarView: ice drift / velocity maps CSA: RADARSAT support to ice thickness and snow surveys during OIB (NASA). Since 2014 CSA providing 1-3d coverage of OIB domain For field validation and	Tactical Ice support with TSX in NRT for ships operating in ice. Using Neustrelitz station. Combination of sea ice parameters and meteo (conc/winds) from TS-X Unique HH/VV combination for floe-size distribution. Wind/wave interaction in marginal ice zone. (SWH	VIIRS Ice Surface temperature AMSR2 ice concentrations – tuned for NOAA VIIRS ice thickness in thin ice (AVHRR → VIIRS) NOAA operational processing of any available SAR dataset. For metocean and sea ice analyses. Goal: to use CSK to fill polar hole.	CryoSat Sentinel-1 SMOS River ice.	Noted low res. sea ice conc, ice edge. Type, motion, on common grid. EPS- until 2018 – with launch of MetOp C New IASI Ice surf. Temp. From 2021 - Microwave Imager MWI Sentinel-3: altimetry and optical mission Sea ice freeboard;		Sentinel-1 on Canadian and Alaskan Arctic . Plan to discuss filling this gap during SAR CWG. Southern Hemisphere SAR coverage needs some attention. Clearly not close to addressing the needs in terms of coverage and repeat.

		planning (particularly snow loading error on sea ice thickness) 531 scenes in March-April 2014; and 762 in 2015. Surface measurements in Eureka sound.	and peak wavelength). Iceberg tracking- for IIP but insufficient repeat to track icebergs.	Demonstration of capability to fill pole hole. Combination of CSK multi sat data to replace IIP flights. NOAA request for CSK support for resupply to McMurdo SMAP good during summer melt – delineates ice better. Shame that SMAP radar failed.		SST and IST.		Pole Hole in SAR coverage in Arctic. CSK data currently acquired over N. pole. Coverage of Antarctic punctually good, and regionally ok, but consistent coverage not available presently throughout the year.
	Establish tundra lakes and river monitoring sites	CSA monitoring of lakes in wintertime	TSX classification of river and lake ice – in tundra regions Water; frozen to ground; consolidated ice ; frazil ice.					

			Classification of Sentinel-1 data using Kennaugh elements.						
	Assure continuity in ice conc./extent, thickness, motion								
	Coordinate with field campaigns to maximise synergies								

Scientific Foci	Strategic Priority	CSA	DLR	NOAA	ESA	NASA	EUMETSAT	Status/Gaps
Ice sheets, Ice caps and Glaciers	Follow coordinated ice sheet observation plan	R-2 data from 2014 under special effort of PSTG to coordinate data. Also R1 data. See quad sheets submitted by CSA – indicating the data assembled to date – covering ice sheets	April 2015 – DLR joined Antarctic CCI TSX supports generation of the ECV parameters Grounding Line Location and Ice Velocity Science phase of TanDEM-X (TDM) started one year ago in Oct 2014. Regular TDM coverage of supersites, in Greenland and Antarctica (e.g. Helheim glacier) Operational coverage of Greenland 2 complete in		CCI Phase 2 user requirement survey. Reflects need to update reqts doc. Update to request 4 consecutive cycles for redundancy in G/L location. Annual campaign in winter (8 consecutive acquisitions) Continuous monitoring of Greenland margins. (6 tracks) Sentinel-2 can extend S-1 SAR tracking in summer due to	TSX mapping of ice sheet outlet glaciers (I. Joughin) - with repetition of 14x per year.. More detailed temporal resolution needed in summer for speedup of ice streams.		Update to User requirements needed to refresh the requirements document – based on user survey for Antarctic and based on currently implemented acquisition plans L-band SAR summer InSAR pairs/coherence needed for debris glacier mapping L-band SAR ice sheet coverage lver the margins of Greenland and Antarctica in BOS

			2011 and 12 (asc orbits) 2 complete coverages of Ant. in 2013 and 14 (r and l looking) TDM – 90m pixel spacing DEM planned to be available by 2016. A call for data will be established.		decorrelation in InSAR S-1 coverage in Antarctica good, but some gaps remaining - Already processed demonstration products . 1 year campaign ice sheet wide InSAR coverage, with subsequent extension of coverages in margins			Insufficient to meet user requirements Sentinel-2 acquisition strategy over greenland Sentinel-1A and –B combined for 6 day repeat strategy in summer – where significant added value of optical tracking. CSK 1d repeat pass data over Antarctic grounding line ~~Intertrack geolocation shift observed.~~ Need to plan Sentinel-1

								Acquisition strategy. Proposal made to SAR CWG. Currently no Sentinel-2 data planned over Antarctica. Global Standard reference DEM needed for ice mass balance, with refresh on regular 10 yr basis. Need assurance of long term commitment to ice sheet/glacier coverage from Landsat
	Extend Ice sheet mass balance intercomparison exercise		Elevation change using TDM DEM differencing to compute		Via ESA Ice Sheets CCI ENVEO – T. Nagler.	Via NASA Measures Programme U. Irvine		

			mass balance of glaciers in Antarctica		Originally Phase 1 just Greenland, and now incl. Antarctica Products Ice Velocity (IV) Surface Elevation Changes(SEC) Grounding line Loc (GLL) Calving Front Location (CFL) Gravimetric mass balance (GMB) Ice velocity map from S-1 Now outlet glaciers mapped every 12 days, and calving front locations. Constitutes a pre-	Results for Antarctic ice streams now using Landsat for velocity back to 1970s and now for all SAR data. New results for Totten Glacier and grounding line. Caltech results using Cosmo-Skymed to look at Rutford Gl, and tidal NSIDC – Landsat 8 Led by Ted Scambos (also USGS) Ice velocity results indicate summer monitoring and velocity mapping.		

					operational basis for regular product generation. Polar Portal	First look at uncertainties (e.g migration of surface features – falsifying features).		
	Provide complementary data on ice sheet accumulation and albedo				ESA CCI phase 2 Option (for Antarctica) considering melt area products from scatterometer Potential for S-3 albedo products.	Today airborne datasets primary contribution (e.g. OIB)		No direct measurement capability for snow accumulation on ice sheets
	Secure gravimetry data for mass change estimates		GRACE-FO and GRACE-2		Now included in Ice Sheet CCI	GRACE-FO and GRACE-2		
	Develop SAR altimeter swath mapping capability and products				ESA CryoTop follow on Study			

Scientific Foci	Strategic Priority	CSA	DLR	NOAA	ESA	NASA/USGS	EUM	Status/Gaps
Permafrost	Establish coordination and acquisition planning needed to achieve routine high-resolution circumpolar coverage for monitoring variability in carbon pools		Stripmap mode		and Sentinel-2			S-1 routine coverage not yet assured
	Establish multi-sensor monitoring around key research locations where GTN-P and in-situ measurements are made ("cold spots") (supplement existing T-		10 cold spot sites routinely monitored by TSX from 2012 – 15 In stripmap HH and HH/VV and spotlight HH/VV		GlobPermafrost planning to cover 10 colds spots and 5 mountain permafrost areas (with focus on rock glaciers)			

	SAR-X acquisition; Bi-weekly InSAR for permafrost modeling)							
	Obtain <1m summer (July-Aug) optical images around each Arctic Cold Spot for up-scaling/downscaling of local periglacial processes							Annett Bartsch to address CNES with Requirements for test sites over cold spots
	Quantify rates of pan Arctic coastal erosion (Annual circumpolar Arctic coastline mapping at < 10m optical resolution;		Demonstrations using TSX in limited areas					Not yet comprehensive coverage to observe changes over time

	InSAR estimates of erosion/degradation)							
	Establish SAR monitoring of Arctic permafrost transects on routine basis to supplement existing 30-300m pan-Arctic multispectral imaging (Antarctic Peninsula covered by sea ice requirements)							Routine monitoring transects requires commitments in SAR CWG
	Derive SAR DEM and land surface classification map suitable for permafrost community				CCi Land cover			Revision of CCI Land cover to incorporate more categories
	SWE, frost				GlobSnow		ASCAT soil	Frost depth

	depth, soil moisture and LST products assumed developed elsewhere				LST from Sentinel-3 (SLSTR)		moisture product adjusted for lake wind effect	products need to be distributed more broadly to engage permafrost community

Scientific Foci	Strategic Priority	CSA	DLR	NOAA	ESA	NASA	EUM	Status/Gaps
Snow								
	Assure continuity in routine continental scale monitoring of snow areal extent and SWE data in support of GCW Snow Watch and snow applications and service development		DLR producing AVHRR based snow retrieval – for 30 years of snow products.		Sentinel-3 OLCI/SLSTR ENVEO proposes to combine sensors to do snow mapping. Preparing algos for use of 300m data			
	Plan SAR data as complement to passive microwave and 300m optical data for continental scale snow extent/SWE – and in Alpine regions and	RADARSAT-2 coverage over Alps to test methods			Sentinel-1 routine coverage over European Alps British Columbia And Ellesmere Island (planned)			Comprehensive coverage of Mountain snow in unified dual pol strategy European coverage extended eastwards to Caucasus

	rugged topography where other methods fail							
	Establish less than three day repeat SAR monitoring (ascending/descending combinations) of European Alpine region and other selected mountain regions (Scandinavia, Canadian Pacific mountains) during seasonally-limited snow melt time window				S-1 alpine monitoring of European Alps With S-1B in 2016 the monitoring will be more complete. S1 acquisitions over British Columbia And Ellesmere Island, Canada HH/HV Offers subdaily coverage. Tighter time series will allow demonstration			DEM required to demonstrate capability in Scandinavia
	Establish common polarization/ mode	RADARSAT-2 unified VV/HV over Alps			Unified S-1 and R2 VV/VH acquisitions			More complete A/D coverage in

	observation strategy between SAR missions							B.C.
	Demonstrate routine snow melt data processing				Snow extent products, and snow melt ENVEO algo developed for snowmelt area using VV and VH			
	Pilot a snow melt service (seasonal snow melt/runoff/hydropower/water resource availability)				Timeseries will demonstration of potential products/services			
	Expand temporal/spatial revisit to operationalize services.				For future – with S-1A/B and RCM.			
	Develop new methods for snow depth retrievals on sea ice				SPICE project – add on to Sea Ice CCI			

	Develop snow product intercomparison exercise in connection with GCW CryoNet to assure product validation, and quality assurance (via member engagement in activities such as SnowPEx)				SnowPEX ISSP Workshops			

Scientific Foci	Strategic Priority	Agency #1 (CSA)	Agency #2 (NOAA)	Agency #2 (EUM)	Agency #2 (ESA)		Agency #2 NASA	Status/Gaps
Polar Prediction	During the period of this strategy (2015-2018), a basic pan-Arctic observing strategy shall be developed to secure routine, regular, and robust year-round all-weather active microwave acquisitions at resolutions greater than 50m, complemented by seasonal cloud-free coverage using Vis/IR optical systems. Routine, daily pan Arctic coverage is needed to characterise	Possibility of interleaved R2 coverage of Chukchi Sea and Beaufort Sea	S		Routine Sentinel-1 European Arctic coverage			Central Arctic pole hole not covered by SAR today

	the dynamic and thermodynamic processes governing sea-ice, snow and permafrost variability.							
	Plans shall be established to support the Year of Polar Prediction (YOPP) in the mid 2017-mid 2018 timeframe, in order to improve polar prediction capability. As part of this effort, plans are being developed for a comprehensive set of complementary multi-scale satellite and airborne		Std Operational Products during YOPP – list provided by NOAA Some regional products such as winds And high res. ice extent/conc. NOAA contributions Including drifting buoys **Catalogue operationally available products for YOPP community	Concentration /extnt Type/motion Passive microwave and scatt drift products at low res. **Catalogue operationally available products for YOPP community	CryoSat ADM-Aeolus Potentially EarthCARE in 2019		NASA Melt/Freeze and Ice Age Tschudi – Ice age OIB IceSat -2 Cal/Val	

	remote sensing measurements of the atmosphere and surface in support of the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC: www.mosaicobservatory.org).							
	Satellite observations performed during YOPP in conjunction with MOSAiC. Planning of in-situ observations together with aircraft campaigns (and satellite systems would provide critical		Routine obs	Routine obs	CryoVEx ADM Cal/Val campaigns possibility		OIB IceSat -2 Cal/Val	Need to engage YOPP for feedback on other special requirements

	information with which to facilitate improved modelling of the sea ice, weather and Arctic climate system.							