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)

FOURTH SESSION

NASA GODDARD SPACE FLIGHT CENTER
GREENBELT MD, USA

29 SEP – 1 OCT 2014

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

Piers Sellers (Deputy Director, Sciences and Exploration Directorate, NASA Goddard Space Flight Center (GSFC)) welcomed attendees to the Fourth Meeting of the Polar Space Task Group (PSTG) and to NASA GSFC. He briefly described Earth science and cryosphere activities at GSFC and encouraged participants to work hard in contributing to better understanding and prediction of the cryosphere - in his view the biggest environmental science challenge over the next 10-20 years.

M. Drinkwater as Chair welcomed attendees to the meeting. Apologies had been received from the following Members of PSTG for not being able to attend: F. Battazza (ASI), D. Floricioiu (DLR), K. Holmlund (EUMETSAT), R. Buss de Souza (INPE), M. Shimada (JAXA), P. Zhang (CMA). Meanwhile Larry Hothem (USGS) attended on behalf of Jerry Mullins (USGS, retired).

2. INTRODUCTIONS TO PARTICIPANTS

In a tour-de-table, participants introduced themselves (see attendance list in Appendix I). M. Drinkwater briefly explained the role of PSTG as successor of the IPY space task group in coordination and federating agency action, and this in response to globally coordinated and consolidated user requirements. This session offered the opportunity to initiate a space agency response to requirements which had been assembled for permafrost (through A. Bartsch), wet snow (D. Small), floating ice (J. Falkingham), and weather prediction in Polar Regions (T. Jung). B. Scheuchl and Y. Crevier would present achievements of PSTG action in response to user requirements assembled for observations of the ice sheets.

The Chair reflected on the major contribution that NASA through GSFC could make to PSTG and expressed his deep appreciation to NASA for hosting the meeting.

3. APPROVAL OF AGENDA (M. DRINKWATER)

M. Drinkwater explained the logic of the agenda (Appendix II), including presentation of user requirements, and agencies' responses. He noted that the main objective of presenting on progress with ice sheet requirements was that scientists understand how requirements should be framed and formulated such that space agencies on PSTG could respond effectively.

Item 10 was changed to "Strategic Plan 2015-2018". T. Wagner commented that NASA campaign activities such as IceBridge, Arctic Boreal Vulnerability Experiment (ABOVE) and networks in Antarctica and Greenland (PoleNet (A-NET, G-NET), GC-NET, PROMISE, etc.) should be reflected in a strategic plan for PSTG. Such a plan should also help ensure that PSTG activities are well-connected to other international activities in the cryosphere.

The session subsequently adopted the proposed draft agenda.

All meeting documents are available at http://www.wmo.int/pages/prog/sat/meetings/PSTG-4.php.

4. NASA RADAR AND CRYOSPHERE ACTIVITIES

4.1 NASA Cryosphere Program (T. Wagner)

T. Wagner described the NASA satellite and aircraft programmes relevant for polar science, both those currently in operations and those planned. A number of pertinent NASA missions are slated for launch in the coming five years (SMAP, IceSat-2, GRACE-FO etc.); airborne and field

campaigns are undertaken for complementary information and to provide process knowledge, in addition to satellite data (such as through IceBridge, CARVE). He stressed that international and inter-agency collaboration are an integral part of the NASA Cryosphere Program, as illustrated by the IceBridge/ESA CryoVEx CryoSat validation activities.

The US Interagency Arctic Research Policy Committee (IARPC) working under the White House Office of Science and Technology Policy (OSTP) developed an Arctic research plan. Since there is commonality with the US National Security Council's Arctic Strategy, a common Implementation Plan was developed which now serves as guidance for US action in the Arctic. Arctic issues have a strong profile in the US, from the general public to the highest policy level, and NASA and PSTG should seize every opportunity to contribute to answering key questions, such as the cryosphere contribution to projected sea level rise, or Arctic-induced changes in the patterns of jet streams and polar lows. With the US taking on the Arctic Council chairmanship in 2015, more opportunities are likely to arise for PSTG members to demonstrate the importance of remote sensing for solving the Arctic science challenges, and to take action.

T. Wagner raised the question whether the IARPC Implementation Plan poses an opportunity to address major Polar science questions, and whether requirements as stated in the IGOS Cryosphere report and presented to PSTG could be re-framed in this regard, and turned into actions.

Several activities at the US National Academy of Sciences address fundamental science questions in the cryosphere, such as recent workshops on permafrost, an update to the Decadal Survey, and a number of cryosphere community working groups (such as SumUp, Sea ice). Arctic stations to monitor biodiversity (e.g., the Distributed Biodiversity Observatory) are, however, particularly hard to maintain by any one nation, and T. Wagner raised the question whether satellite data could support such stations more effectively.

4.2 Radars and the NASA NISAR Mission (C. Dobson)

The NASA-ISRO SAR (NISAR) mission concept is based on the DESDynI (Deformation, Ecosystem Structure, and Dynamics of Ice) concept and planned for launch in late 2020 or early 2021. Collaboration is based on a 2008 NASA – ISRO framework agreement, and the NASA-ISRO agreement on NISAR was signed on 30 Sep 2014. The mission moved from the concept phase to Phase B of implementation in spring 2014. India is contributing the launch vehicle, the spacecraft, and the S-band radar, whereas NASA contributes the L-band radar. Both radars operate in polarimetric ScanSAR mode with a swath width of 320-340 km and precise repeat passes. Data will be downlinked to NASA (with free and open access) and India. The instruments' duty cycle is around 30 minutes. An observations plan is being developed, aiming at uniform products where possible. Level 1 baseline requirements include sea ice, motion of ice sheets, mountain glaciers, and permafrost.

USGS is hosting an applications workshop on 28-29 Oct 2014 in Reston VA, USA.

The session noted that the ISRO-operated RISAT instruments were functioning well but data access to users outside India was very limited due to a ground segment requirement focussed on national users. The Group stressed that ISRO should be part of PSTG (Kiran Kumar is the right contact person).

ACTION 4.1: Chair and Secretariat, in collaboration with NASA, to write a letter to ISRO inviting them to participate in PSTG and explaining how the planned NISAR mission could address global polar and cryosphere-specific requirements. By 1 Dec 2014

C. Dobson furthermore noted that NASA supports ground segment activities for the Argentinian (CONAE) SAOCOM L-band SAR programme and the generation of data records through the MEaSUREs program.

5. REVIEW OF ACTION ITEMS

The Action items list from the last meeting was discussed and updated:

ACTION 3.8: PSTG Members to provide examples on the use of remote sensing products in data assimilation for improved polar prediction. Deadline: PSTG-4

> **CLOSED; presentations from WWRP-THORPEX workshop hosted by ECMWF to be hosted permanently on PSTG website.**
>
> **NEW ACTION 4.2: Secretariat to post presentations from WWRP-THORPEX-ECMWF workshop on polar prediction on PSTG website. By 31 Oct 2014.**

ACTION 3.11: A. Bartsch, K. Luojus and P. Bauer to review the polar/cryosphere-related requirements specified in the WMO RRR database (http://www.wmo-sat.info/oscar/observingrequirements), and to provide feedback to the application area focal points and WMO. Deadline: 1 Dec 2013

> **OPEN for snow, atmosphere requirements; CLOSED for permafrost community;**

ACTION 1.4: WMO RRR Observation Requirements; participants are encouraged to review requirements stated in the RRR database by application area (http://www.wmo-sat.info/oscar/applicationareas).

> **CLOSED; see Action 3.11**

ACTION 3.12: All PSTG members are invited to provide feedback to the mission overview charts and recommended content in PSTG-3/Doc.11-1-1. Deadline: 1 Dec 2013

> **CLOSED; monitoring of the use of datasets and products important, but beyond the scope of the Group**

ACTION 3.13: Draft a strategic implementation plan, with Lead by PSTG Chair and Vice-Chair. Deadline: 1 Jan 2014

> **CLOSED; addressed under item 10.**

A summary of all Action items is given in Appendix III.

6. EC-PORS-5 UPDATE (M. DRINKWATER)

M. Drinkwater presented an update from the WMO Executive Council Panel of Experts on Polar Observations Research and Services (EC-PORS). PSTG has been established under the auspices of EC-PORS, and formally reports to the Panel. The 5th EC-PORS meeting was held in Wellington, New Zealand, in March 2014, and M. Drinkwater gave a presentation remotely, on behalf of PSTG. EC-PORS has the objective to engage with WMO constituent bodies, intergovernmental organizations (e.g., Intergovernmental Oceanographic Commission (IOC), Arctic Council), other coordinating bodies and space agencies (through PSTG). He noted that member agencies of PSTG have different mandates, ranging from pure research to supporting operational services, which determines their activities nationally and in the PSTG context. The ultimate need to support applications should be a driving principle for action within PSTG.

Measuring and monitoring snow parameters should definitely be pursued by PSTG since snow and related cryosphere parameters tend not to be a focus in water cycle programmes and in the water cycle community (at conferences etc.). This gap in awareness was a major driver for compiling the 2007 IGOS Cryosphere Theme report.

J. Key gave a short brief on the WMO Global Cryosphere Watch (GCW). Approval by WMO Members at the 17th World Meteorological Congress in 2015 is sought to establish a GCW Programme, to coordinate and strengthen observations, research and services in the cryosphere. The CryoNet is a network of ground-based stations, to be developed under the purview of GCW. PSTG members should express their needs regarding such stations, for example for validating satellite data (see item 9.1).

In relation to international coordination of observations, research and services in the Arctic, E. Key described the US National Science Foundation's Arctic Observing Network (AON) program, which encompasses environmental, socio-cultural, and economic observations of the changing Arctic, their archiving, and value-added product development to meet user needs. She also mentioned her role in the US interagency coordination of Arctic Observing Networks, and as the US representative to the Sustaining Arctic Observing Networks (SAON) board. To support the development of best practices and coordination of observing networks in the Arctic, she has funded an open international collaborative workspace, the ArcticHub (www.arctichub.net).

7. STATUS OF ACTIVITIES IN RESPONSE TO ICE SHEET REQUIREMENTS (Y. CREVIER)

Y. Crevier and B. Scheuchl described accomplishments in PSTG, through several agency contributions, responding to ice sheet community requirements. Two leaflets were produced to document these (*Continued and Coordinated Ice Sheet Observations from Space*), and an article was published in the WMO Bulletin 63(1) 2014.

A consolidated user requirements document and the response plan over the years 2013-2015 was presented to PSTG-3 (see PSTG-3 meeting report and website). An ESA CCI Ice Sheet user survey for Antarctica is ongoing, and its results will be considered in further evolving the PSTG response to ice sheet requirements.

The value of coordinating ice sheet monitoring from space through the PSTG SAR Coordination Working Group consists of:
- multi-frequency observations over polar regions;
- ensuring high-frequency of revisit in "coherent and inter-operable" datasets from various missions;
- ensuring workload distribution across agencies – justified by mission constraints and capabilities.

PSTG has produced tangible outcomes since 2013, and Y. Crevier presented quad sheets to concisely show each agency's specific contributions to the response plan (cf. Fig. 1 for an example). These contributions include or will include ASI, CSA, DLR, ESA, JAXA, NASA, and the Norwegian Space Centre, along with their commercial partners (MDA, ASF, E-GEOS, Airbus Defence and Space). The upcoming 3rd SAR CWG meeting in November 2014 should allow for the opportunity to reflect on successes and needed improvements in its activities.

The Group noted the JAXA ALOS-2 Basic Observation Scenario which could also support ice sheet observations, once the satellite has been declared operational.

The Sentinel-1 preliminary observation plan addresses areas in Europe, Greenland and coastal regions of Antarctica. Extensions to this plan, e.g., to include pan-Arctic coverage, would have to be addressed to the European Commission through the Copernicus User Forum. Member states of ESA and the EU could also potentially consolidate and address such needs via the Arctic Council.

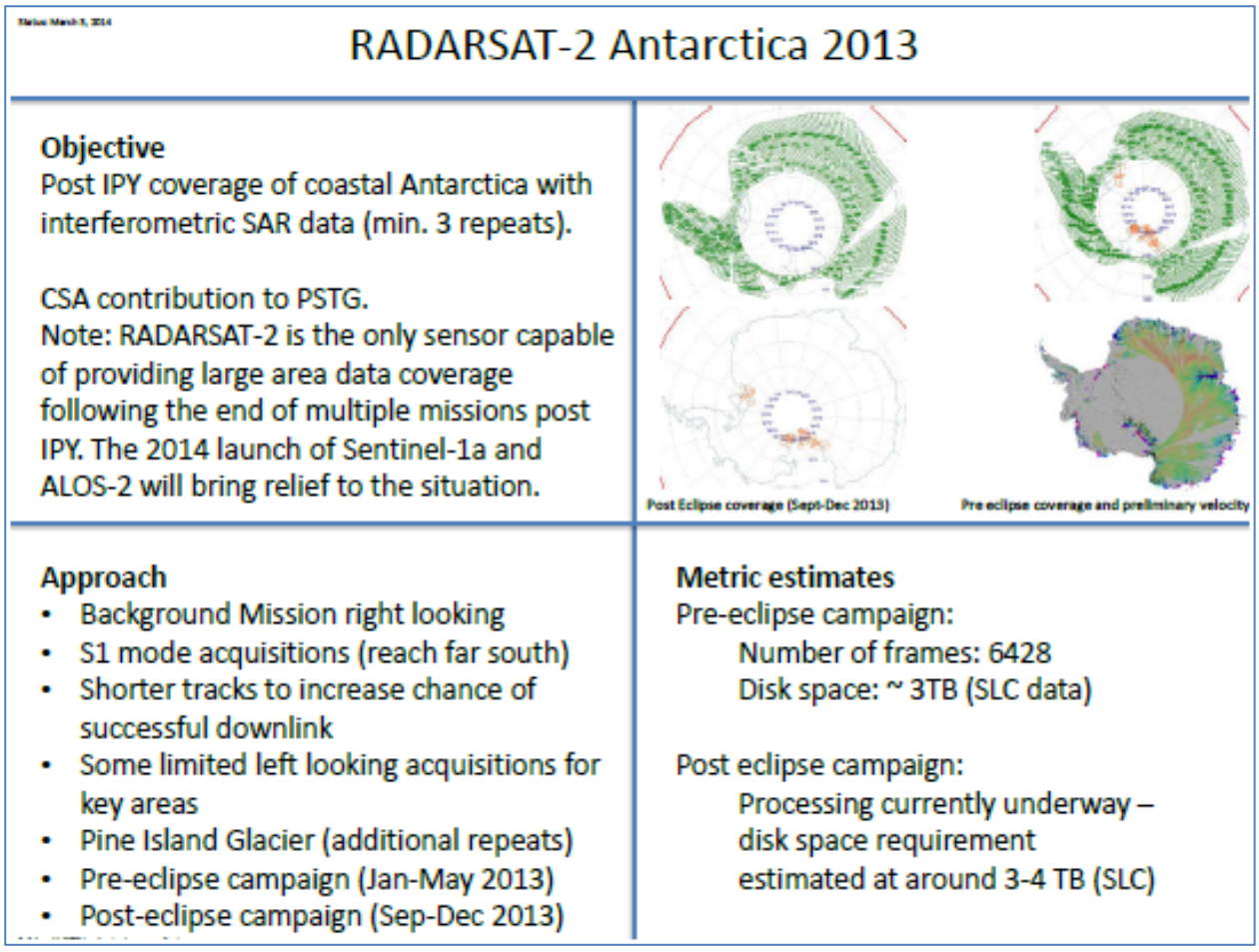

Fig. 1: Summary of RADARSAT-2 coverage of Antarctica in 2013 within the CSA contribution to PSTG.

B. Scheuchl briefed on the NASA MEaSUREs program and the ESA Climate Change Initiative (CCI) to generate climate data records and products to support science in Antarctica and Greenland. Numerous national efforts are funding the analysis of data for smaller regions.

C. Dobson highlighted the success of the MEaSUREs program and its impact on advancing cryospheric science and applications. He however remarked that restrictions in data access imposed by some agencies prevent scientific investigation and independent verification of scientific results. This is partly to do with commercial interests dictating the data policy of such agencies. He stressed that data from cryospheric missions of all agencies should be made more openly available to answer some of the key science questions (such as the WCRP Grand Challenges).

S. Hosford noted that many space agencies such as CNES and others running under a public-private partnership principle are moving towards a data access model where recognized, registered scientific users who have been confirmed and vetted by the agency will be have broader access to mission data.

E. Key mentioned the relevance of ice sheets to issues of national security for many Arctic Council nations. She suggested that ice mass loss, large calving events, and icebergs might be of interest to the Arctic Council's Emergency Prevention Preparedness and Response (EPPR) working group as it relates to Arctic marine shipping. Many national military representatives inform EPPR and might be able to provide user requirements for satellite products and/or make the recommendation that commercial satellite information be made available as it relates to national security.

8. NEW USER REQUIREMENTS

8.1 Snow (D. Small)

D. Small introduced space-borne SAR-related user requirements for mapping wet snow parameters at higher resolution than using passive microwave radiometry (PMR) or VIS/IR optical datasets. The reason for focussing on SAR here is that snow mapping from using space-borne PMR and optical sensors is adequately covered by routine operations in the near future from satellite instruments such as GCOM-W1 AMSR-2, SNPP VIIRS and Sentinel-3 OLCI/SLSTR. The white paper (PSTG-4/doc.08-01) with detailed requirements was developed with support from a range of users, and Table 1 contains a summary of recommendations.

The key science requirements for wide area monitoring of snow are *snowmelt area* and *snowmelt liquid water content*, at ~100m spatial resolution and with daily resolution. For moving from PMR (~25km spatial resolution) or optical products (~300m) to SAR-based products (<100m scale), radiometric terrain corrections are necessary to isolate the snow melt signal from terrain effects, particularly in areas with marked topographic features. The benefits of snowmelt data in mountainous and alpine regions to hydrological applications are apparent: to inform on water availability for hydropower (energy), agriculture and human consumption.

It is possible to overcome the limited revisit time of a single mission and achieve shorter revisit intervals by using multiple missions through *local resolution weighting* (Small et al., 2012[1]). This approach was applied to a long time series of ASAR data to demonstrate the capability for monitoring the retreat of the snow melt line with the onset of spring over the Swiss Alps. He described factors determining revisit interval, of which some can be influenced by the operators, such as active times of the instrument. Wide swaths are preferable (100km+), preferably with relatively low speckle noise.

To constrain observation planning and resulting data volumes, a seasonal observation window for SAR missions observing snow at northern temperate latitudes should include high temporal resolution acquisition between 15 Feb and 30 May. Outside this window, regular (e.g., bi-weekly) observations are also important to observe winter events such as avalanches or rain on snow events. A standardized polarization mode of VV/VH is preferable. The accuracy of the geolocation of Sentinel-1a is O(7cm) in range and O(40cm) in azimuth, as estimated in a recent calibration campaign in Switzerland. This confirmed the suitability of Interferometric Wide (IW) data for snow mapping in alpine topography.

Acquisition planning should start with the objective of first achieving contiguous, weekly ascending/descending SAR coverage in limited geographical regions, such as the European Alps, Scandinavia, and Canada. Subsequent plans could incorporate a ramp up in temporal revisit using a combination of SAR sensors in order to progress towards the ultimate goal of daily coverage.

Table 1: Summary of recommendations from the snow community requirements white paper.

R1	**Use wide-swath modes** to enable wide area monitoring with high temporal resolution (i.e. RSAT2 SCN or SCW, Sentinel-1 IW or EW, TSX "SC Wide" & CSK "Huge Region" ScanSAR modes).
R2	Build combined **ascending/descending** coverage by default into acquisition plans covering mountainous regions. Favour asc./desc. acquisition sets acquired within a **tight time window** (1-3 days) to allow a narrow time-attribution to composites generated from these sets.
R3	Concentrate snowmelt acquisitions on the **seasonal window** when the majority of snow melting occurs (Feb. 15 through May 30 at temperate northern latitudes). The *highest temporal resolution possible* is requested during this critical melting period. Although some further acquisitions are also requested *outside* of this seasonal window, lower temporal resolution at these less critical times is acceptable.

[1] Small D. *SAR backscatter multitemporal compositing via local resolution weighting*. Proc. IGARSS 2012, Munich, Germany, pp. 4521-4524. doi:10.1109/IGARSS.2012.6350465

R4	Standardise dual-pol. mode acquisitions on **VV/VH** combination: a cross-platform consistent polarization simplifies combination of datasets from multiple providers (e.g. S1/RSAT2/RCM or TSX/CSK).
R5	**Harmonise acquisition plans** of satellites with compatible calibrated backscatter values (e.g. S1/RSAT2/RCM or TSX/CSK). Utilise the available diversity of orbits to achieve the desired diversity of tracks – e.g. to achieve the fullest possible ascending/descending coverage.
R6	Assure **full coverage over land also in coastal regions** when other modes are by default programmed over ocean (e.g. favour Sentinel-1 IW or EW over WV).
R7	Maintain a **regular observation plan also during the winter** to assure frequent observations of other important snow parameters, and other phenomena related to the winter period such as avalanches and rain on snow events
R8	Concentrate snowmelt acquisitions on the **seasonal window** when the majority of snow melting occurs

S. Bojinski stressed that Central Asia is a key area of interest for inferring water availability from snowmelt. This region provides potential scope for ISRO and NASA commitments for the planning of acquisitions from RISAT C-band SAR and NISAR L-band SAR.

M. Drinkwater stressed that users need to be realistic about whether daily 100-m resolution datasets can immediately be used in product and service development (given that only 25-km resolution passive microwave (PMW) or 300m optical datasets have been available for a long time). He asked whether a set of pilot areas could be identified to allow demonstration of the capabilities for generating and exploiting wet snow products, as well as firmly establishing the maturity of SAR-based snowmelt applications. On this basis, the operational benefits would ultimately drive the user demand for more frequent time-space coverage, as well as help achieve the goal for daily coverage.

P. Clemente-Colón suggested that the specification for SMAP high-resolution L-band radar products (HR 1km) should be considered regarding whether they could meet some of the stated requirements. D. Small explained that high spatial resolution (<100m) is necessary to correct for complex terrain effects (layover, foreshortening, and shadowing). Dual-track views (ascending, descending) reduce massively the amount of shadow. The snow wetness maps would be used to inform the source term of hydrological models, complementing in-situ measurements, although the Group noted that the full value chain of wet snow maps for hydrological models may need maturing. The CoReH$_2$O report[2] for mission selection contained such elements.

C. Dobson noted the availability of a good digital elevation model (DEM) as a precondition for correcting for terrain effects. He noted that the US are releasing in November 2014 the 30m SRTM DEM successively and globally (with 65 m native resolution).

Y. Crevier noted that the initial areas requested were not very large and that the SAR coordination working group meeting could consider how to begin to respond to the user requirements in its November meeting.

Initial steps in a PSTG response to the presented snow requirements should include:

- To come up with a pilot activity for SAR-based wet snow monitoring, and steps for scaling up, noting that high spatial resolution is needed in complex terrain;
- Existing operational services such as those delivered by NOAA and the EUMETSAT H-SAF to provide snow water equivalent (SWE) and snow cover extent should be taken into account;
- When scaling up, Central Asia and the Third Pole should be considered as focus areas in an acquisition strategy (particularly involving space agencies from China, India, and Japan); users from these regions should be included in refining an acquisition campaign.

[2] ESA(2012), CoReH2O - Report for Mission Selection - An Earth Explorer to observe snow and ice. ESA Special Publication SP-1324/2

ACTION 4.3: PSTG recommends that agencies on the SAR CWG to consider requirements in doc PSTG-4/Doc 08-01 and come up with proposals on how to respond to these snow user community needs. By: SAR-CWG-3 (5 Nov 2014)

ACTION 4.4: Based on acquisitions foreseen in currently running proposals (with DLR on TerraSAR-X), D. Small should devise a plan with steps towards acquisition and utilization of relevant data in Switzerland and the European Alps. By: SAR-CWG-3 (5 Nov 2014)

8.2 Atmosphere: Polar Prediction, YOPP & Mosaic Ice Camp (T. Jung)

T. Jung introduced the WWRP Polar Prediction Project (PPP) and its 10-year Implementation Plan (PSTG-4/doc.08-02-01) through 2022. PPP is one of three follow-on projects of WWRP/THORPEX. The insurance company Lloyd's published the "Arctic opening" report with opportunities and risks regarding investments (an estimated >$100b over the next decade), impacts of change, and gaps in understanding of weather and climate in Polar Regions. He recalled the PPP mission statement, aiming at improved prediction services on hourly to seasonal timescales. Recently, an International Coordination Office for the Polar Prediction Project has been set up, and hosted by AWI (http://polarprediction.net).

Research areas of PPP include service-oriented research, forecasting system research, and underpinning research, all specific to high latitudes. For example, Ensemble Prediction Systems are optimized for lower latitudes assuming e.g., baroclinic and convective instability which both play a minor role in the high latitudes. Improvements in weather prediction skill in Polar Regions have impact on predictability over Eurasia and North America, and less so over the Atlantic and Pacific. Due to strong zonal flow around Antarctica, this effect is less pronounced in the Southern Hemisphere. High-resolution models start representing leads and cracks in sea ice, begging the questions how realistic these representations are in comparison with high resolution observations, and whether the new generation of models have predictive skill?

The Year of Polar Prediction (YOPP) in 2017-2019 (see draft YOPP Implementation Plan, PSTG-4/doc.08-02-02) should include a period of intensive observing and dedicated model experiments, with the purpose to provide a comprehensive "snapshot" of the area. The requirements may be quite different from those for monitoring the Polar Regions. *The satellite observation component during YOPP requires further definition*; it should aim at improving satellite-based products in the area, and helping to improve model and data assimilation systems.

A YOPP planning summit is scheduled for 8-10 July 2015 at ECMWF, and PSTG should be involved already in the planning stages.

T. Jung described the MOSAiC contribution to YOPP, to provide a ground-based observational basis for model improvement. One suggested activity is to have the research vessel Polarstern drift in the frozen sea ice pack, to make a suite of measurements in Lagrangian fashion across the Arctic. He suggested that PSTG may wish to study and comment on the MOSAiC science plan.

M. Drinkwater enquired on the format in which PSTG could make a contribution to the PPP and YOPP (in terms of data products, product latency, and data formats etc.). Data handling and format issues were raised (do datasets need to be delivered to the modelling centres in BUFR format to be useful in NRT data assimilation schemes, for example?). NRT availability of CryoSat-2 ice thickness data was identified to be a useful addition to the products available to data assimilation systems. Meanwhile, ADM-Aeolus should also be flying by the beginning of the PPP, producing line-of-sight vertical wind velocity profiles over the Arctic, as a valuable additional constraint on atmospheric dynamics.

T. Jung noted that the ultimate goal of the PPP would be to make seasonal predictions of Arctic sea ice extent, 3-4-day forecasts of sea ice structure, and improved weather forecasts in Polar Regions. He noted that data observed in the pan-Arctic ring is often sufficient to constrain

atmospheric conditions in the Arctic, such as on sea ice, clouds, and ocean parameters. He said that a detailed satellite-related requirements document on PPP and YOPP was in development.

PSTG noted the potential benefit of operational meteorological mission data for PPP and YOPP (such as from meteorological sounders on Metop and SNPP, from Sentinel-3 etc.).

ACTION 4.5: T. Jung to share with PSTG a detailed PPP-related observation requirements document. By 1 Dec 2014.

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.

ACTION 4.7: PSTG Members to consider a response to PPP-related observation requirements during the interval of YOPP and associated field campaigns. By 15 Sep 2015.

Funding agencies would require having detailed requests for YOPP support by mid-2015 in order to have resources in place by the beginning of YOPP in 2017.

8.3 Permafrost (A. Bartsch)

A. Bartsch described the permafrost requirements summarized in a community white paper (PSTG-4/doc.08-03) in relation to the key parameters *permafrost extent, soil temperature profiles, and active layer thickness*. Of interest is also thickness and spatial patchiness of permafrost.

Permafrost cannot be directly measured from space. However, satellite data can be used to:

- identify hot spots of surface change and thus advice on extension of *in-situ* monitoring networks;
- support modelling of sub-surface conditions (such as subsurface temperature and active layer depth);
- provide higher resolution (spatial and temporal) measurements in the proximity of long-term in-situ monitoring sites; and
- place the *in-situ* measurements into a wider spatial and temporal context.

Clarification is needed on the permafrost requirements in the WMO OSCAR RRR database in order to address Action 3.11.

A. Bartsch described the GTN-P and CALM networks of in-situ stations measuring active layer thickness and temperature. The GTN-P data are now accessible in standardized form through the Arctic Portal, along with satellite-related metadata (e.g., LST from MODIS). Projects on using satellite data for inferring permafrost conditions include ESA DUE Permafrost, ESA STSE ALANIS, EU FP7 PAGE21. Initial areas of interest were identified in the ESA DUE project. Other projects of interest are NASA ABOVE (Alaska, Canada), ADAPT (Canada), and DEFROST (Scandinavia).

In general, all regions underlain by permafrost are of interest for dedicated acquisition of satellite data. In a reduced scenario, particularly applicable to highest spatial resolution datasets, transects across permafrost zones as well as Arctic coasts should be considered (see Fig. 2). Priority should be in the Polar Regions and areas where no other data are available. Other permafrost areas could be added later, such as in the Andes and the European Alps. In addition, science mission requirements include acquisitions with higher resolution modes over long-term in situ monitoring sites (‘cold’ spots).

Surface parameters observable from satellite, which are of highest interest to the permafrost community include:

- land surface temperature
- land cover and disturbance (vegetation) (current land cover products are often limited in Polar Regions, e.g., mosses are mostly classified as “bare soil”)

- snow properties
- soil moisture
- terrain changes (coastal migration, polygons/patterned ground, active layer detachments)

For example, long records of SAR data are used to measure subsidence due to thawing permafrost. Requirements documents include IGOS 2007, ESA DUE 2009, NRC 2014 (specifically looking at the remote sensing role for inferring on permafrost).

A. Bartsch described the satellite-based observing requirements for the following permafrost-related phenomena (details provided in PSTG-4/doc.08.03):

- Thermokarst and subsidence (still a research area)
- Rock glacier and landslides
- Coastal erosion (occurring at rates of 1-10m per year in some areas; optical data at this resolution would be useful for tracking).
- Thaw lakes and wetlands (these are typically of <30m size and not visible in 300m optical imagery and land surface products)

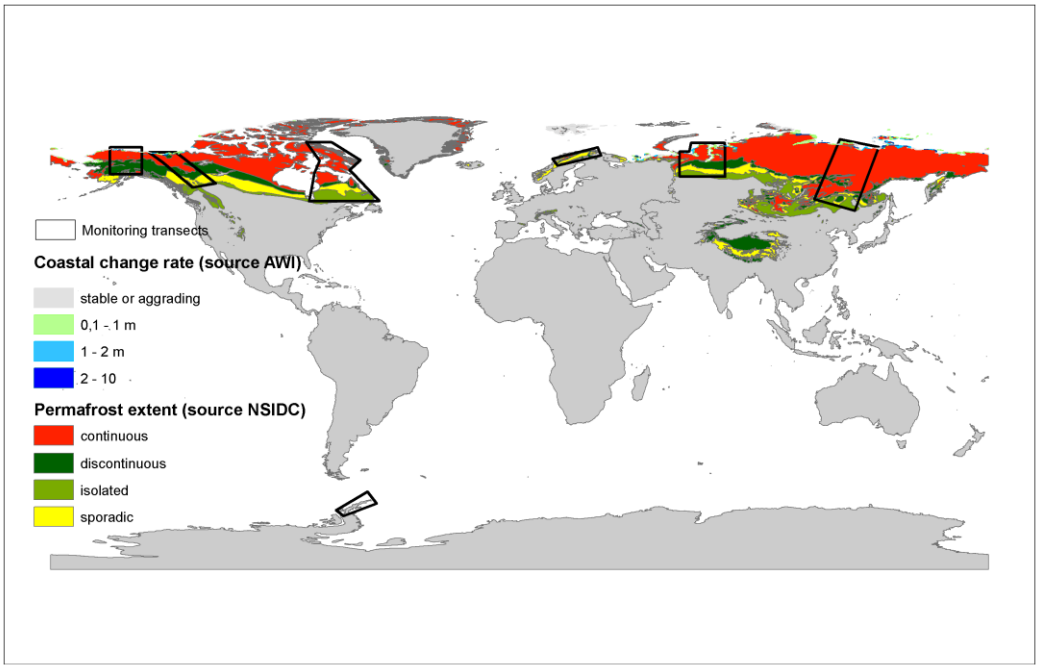

Fig. 2: Areas of interest for permafrost and related observations. In general, all regions with permafrost extent are of interest for dedicated acquisition of satellite data. In a reduced scenario, transects across selected permafrost zones should be considered. Areas with high rates of coastal erosion also require monitoring. (PSTG-4/doc.08-03)

In addition, she described requirements specific to:

- Land surface modelling
- Permafrost modelling

The summary of SAR-related recommendations includes bi-weekly acquisitions for all “cold spots” for InSAR applications.

Optical-related recommendations include annual high-resolution optical (<1m) acquisitions of all “cold spots” during the period July-August. Regarding coastal erosion, the question was raised whether the CNES Pléiades system could contribute to studying this phenomenon. S. Hosford informed that access to data for scientific study can be facilitated by CNES, whereby areas and times of priority need to be determined. Similar request for Landsat data would have to be presented to the USGS Landsat Science Team.

The Group raised the question of priorities. A. Bartsch responded that these would have to be further discussed in the permafrost community. Priorities could be, for example: collocated datasets over cold spots; a combination of different satellite datasets over the transects delineated in the white paper.

S. Bojinski recalled the PSTG mandate to address all of the cryosphere, not limited to the Polar Regions. It was noted that there are significantly greater challenges in achieving the desired revisit intervals at lower latitudes due to orbital decalage (difference of longitude between two successive equatorial crossings in the same phase (descending or ascending) and, in association with the instrument swath, determining the time needed for a full Earth surface observation (observing coverage)).

The importance of circumpolar data, especially for inferring variability in carbon pools, was highlighted. Achieving circumpolar coverage at high resolution should be a strategic goal of PSTG in support of the permafrost community.

C. Dobson noted that the circumpolar coverage requirement was challenging to meet as a requirement for all agencies, and they would need to be assured that the requirements were not only a "desire" which needed substantiation. He asked whether limited-area views, or airborne campaigns, such as over the "cold spots" could be used to help in turning "desires" into "requirements".

The agencies noted that a number of datasets such as MODIS, VIIRS, Landsat, and Sentinel-2 and Sentinel-3 in the future are being collected in a routine fashion to address the need for pan-Arctic multispectral datasets, at resolutions between 30 and 300m. These data would go some way to establishing a foundation for obtaining multi-sensor datasets around the cold spots, and in the required transect regions.

M. Gottwald pointed out that there is a current DLR commitment to fulfil the need for regular repeat coverage of some cold spots in Siberia and Canada, for the purpose of high-resolution study of thermokarst and subsidence.

ACTION 4.8: A. Bartsch to identify among the existing cold spots a number of reference sites (including sites with ongoing active coastal erosion) for remote sensing, with the strategic goal to focus the PSTG agency acquisitions on these sites and to achieve multi-sensor coverage. By 10 Jan 2015.

An inventory of existing datasets at NSIDC, USGS archives will be useful to satisfy the permafrost requirements for historical data for comparative purposes.

8.4 Sea Ice (J. Falkingham)

J. Falkingham introduced requirements for satellite observations of *floating ice*, i.e. sea ice, icebergs and freshwater ice on inland water bodies (lakes, rivers). He noted that routine availability of passive microwave, altimeter, scatterometer and optical data allowed this document to focus on using SAR data. The objective is to identify the required set of satellite measurements to address key science questions relevant to the assessment of the impacts of climate change in the Polar Regions. The comprehensive white paper (PSTG-4/doc.08-04) was reviewed by more than 150 scientists, with a focus on areas where PSTG could add value and particularly in relation to data which currently do not exist. In summary, the document identified the properties of sea ice, icebergs and freshwater ice that are of greatest scientific interest with respect to the impacts of climate change, and recommended strategies to monitor and measure these properties with SAR from space. Input was accepted also from operational communities for what would be needed scientifically in order to improve their services. Compiling the requirements was conducted between December 2013 and March 2014.

As most important sea ice parameters, the white paper identified, in order of priority:

1. Ice thickness and thickness distribution (for NWP initialization and validation; quantifying atmosphere-ocean transfer of energy; etc.)
2. Snow cover on sea ice (to infer on energy transfer)
3. Ice deformation (importance of leads and impact on turbulence)
4. Other characteristics

The following tables (Tables 4-3, 4-4 and 4-6 in PSTG-4/doc.08-04) summarize general SAR-related observation requirements for ice thickness, snow cover on sea ice, and ice deformation.

Table 4-3: General Observation Requirements for Sea Ice Thickness

Target Geographic Location	• Global polar and sub-polar sea ice areas • Arctic Ocean ice export gateways (Fram Strait, Kane Basin, Northwest Passage) • Antarctic regions around bases and experimental sites
Repeat Cycle	• At least daily • Every 6 hours in cases to capture diurnal and tidal effects
Resolution	• 10's of km for climate models • 10`s of m for NWP • <10m for tactical support and process research
Frequency	• C+L or X+L • Investigate S
Polarization	• Multi-polarization (HH, VV, HV, VH) • Research with full polarimetry
Incidence Angle	• 10-50°
Seasonality	• Year-round
Complementary Sensors	• Altimeters, Low frequency PMR, VIS/IR

Table 4-4: General Observation Requirements for Snow Cover on Sea Ice

Target Geographic Location	• Global polar and sub-polar sea ice areas • Priority to Antarctic (as the least understood area)
Repeat Cycle	• At least daily • Every 6 hours in cases to capture diurnal and tidal effects
Resolution	• <10m for process research to develop algorithms
Frequency	• Combinations of all bands (C, X, L, S, Ku) needed to develop algorithms
Polarization	• Multi-polarization (HH, VV, HV, VH) • Research with full polarimetry
Incidence Angle	• 10-50°
Seasonality	• Winter, spring months
Complementary Sensors	• Altimeters, Low frequency PMR, VIS/IR
Comments	• Interferometry potential

Table 4-6: General Observation Requirements for Sea Ice Deformation

Target Geographic Location	• Beaufort/Chukchi Seas, Baltic Sea, Sea of Okhotsk, Kara Sea, Caspian Sea • Other Arctic areas of economic activity for synergy with commercial operations • Antarctic
Repeat Cycle	• At least daily • Every 6 hours for weather coupling to ice convergence and to capture internal ice oscillations, diurnal and tidal effects • Hourly or better to capture ridge formation
Resolution	• 1-10m for process research to develop algorithms
Frequency	• L • Combination of all bands (C, X, L, S, Ku) needed to develop algorithms
Polarization	• Multi-polarization (HH, VV, HV, VH) • Research with full polarimetry
Incidence Angle	• 10-50°
Seasonality	• Year-round
Complementary Sensors	• Altimeters
Comments	• Interferometry potential

Regarding icebergs, the most important questions are whether iceberg distribution patterns are changing and what are the causes and future changes? On freshwater ice, the most important parameters are lake ice freeze-up and break-up timing, classification, concentration, ice and snow thickness. River ice is of high societal interest, e.g., for transport and disaster risk reduction (e.g., related to ice jam flooding).

In summary, SAR-related observation requirements are:

– Multi-frequency observations:
  - L-band with either C- or X-band.
  - Little demand for C- and X-band together except to increase temporal resolution.
  - All SAR frequencies available, ideally simultaneously.
– Keep differences in time and incidence angles as small as possible between different satellites providing multi-frequency observation
– Finer temporal resolution
  - Diurnal and tidal effects have an impact on both SAR observation and floating ice properties
  - Approximately 6-hourly intervals are needed to resolve these effects
- Spatial resolution needed for scientific investigation of processes is typically an order of magnitude finer than for operational use
  - 50-100 metres is common for operational ice charting and NWP
  - 5-10 metres is a more typical requirement for research

Regarding acquisition modes:

– The minimum polarization requirement is HH+HV and HH+VV
– Quad-polarization and full polarimetry needed to advance understanding and algorithm and model development
– Further research is required with compact polarimetry to validate its information content
– A broad range of incidence angles is required
– Increased interest in assessing steeper angles than have historically been used (<20°)

– Swath width should be as large as possible while meeting the requirements for resolution, polarization and interferometry
– Keep effective noise floor as low as possible (<-35dB) particularly at steep incidence angles and with cross-polarization

Geographic areas of interest are
- Arctic Ocean, from the Beaufort Sea to Fram Strait
- Canadian Arctic Archipelago
- Entire marine area around Antarctica and extending to the limit of
- Iceberg drift
- Comprehensive coverage of fast ice around the Antarctic ice sheet
- margins
- Marginal ice zones globally
- The Great Lakes–St Lawrence River system
- Lakes and large rivers of northern North America and Eurasia
- Barents Sea, Baffin Bay, Labrador Sea and around the Antarctic bases

Table 8-1 in the white paper (PSTG-4/doc.08-04) summarizes, per variable, these observation requirements.

J. Falkingham further noted the importance of:
- Seeking partnerships with commercial sector to overcome potential conflicts in data acquisition
- Recognizing the impact of SAR data highest for regional modelling
- Field data acquisitions
- Making data access easier especially for historical SAR data

Y. Crevier remarked that data collected for the purpose of commercial activities should be made accessible after a period of time for scientific investigation. A list of potential recipient institutions and other users should be included in the requirements document. The commercial partners in the SAR CWG should help in this.

D. Small pointed out the need for trade-off between high temporal and spatial resolution, and whether priorities can be identified. J. Comiso highlighted the importance of mass balance studies, for which thickness, concentration and dynamics (advection) are needed in concert.

M. Drinkwater said that the SAR CWG should first identify the possible temporal frequency that is feasible to acquire; then discuss frequencies that can be provided today, and then go into detail about the potential steps to achieve the ultimate goal of sub-daily revisit. SAR CWG should make an inventory of data that are available.

He suggested that the strategic goal should be daily pan-Arctic and pan-Antarctic coverage using C-band, with an intermediate goal of coverage every 3-6 days – available possibly with a time delay for scientific purposes. Two steps towards this should be:

1. To focus multi-satellite SAR resources special acquisitions on achieving a threshold of sub-weekly pan-Arctic and Antarctic sea ice coverage with offline product and data processing (for sea ice process studies and operational applications) with a view to achieving the goal of 3d coverage in NRT (by 2016), and 1d coverage by 2019.

2. To focus SAR resources on achieving multi-frequency satellite coverage and potentially airborne campaigns over MOSAiC ice camp (Polarstern) or other instrumented in-situ field sites

ACTION 4.9: PSTG members in the SAR CWG to devise a plan to achieve an initial 6-day repeat coverage of the Arctic Basin and Southern Ocean sea ice, respecting the other priorities identified in PSTG-4/doc.08-04. By: PSTG-5.

It is recognized that operational needs of monitoring sea ice will be addressed in large portions of the domain by the ice charting services coordinated in the International Ice Charting Working Group (IICWG) and services such as the Copernicus Marine Core Service.

9. GLOBAL CRYOSPHERE WATCH

9.1 CryoNet and Requirements for Satellite Cal/Val Sites (J. Key)

J. Key described the value chain from missions and measurements to societal benefits, for the Cryosphere. M. Drinkwater confirmed that PSTG had identified a number of scientific and societal issues that were discussed at its first session.

J. Key then described Global Cryosphere Watch (GCW) objectives and activities. CryoNet aims at a global network of surface sites measuring the same parameters, following the same practices. More than 150 sites have expressed interest in becoming part of CryoNet (some overlapping with existing global networks such as GAW, GTN-P). There are 14 initial sites (baseline sites, integrated site, reference sites). A hierarchy of baseline, reference, and integrated sites is followed. The data centre and website for CryoNet are hosted by the Norwegian meteorological service met.no.

The question was raised whether CryoNet sites can be useful for validating satellite products. A response from PSTG to CryoNet could include:
– adding an existing station to CryoNet that will adhere to accepted measurement practices,
– adding specific measurements at a site,
– adding new sites (a long shot).

Points to observe in this regard, using the SnowPEX experience (see 9.2), are:
– Standard operating practices across networks
– Standardization of reporting, characterisation, and documentation
– Easy and timely access to “standardized” datasets
– Temporal and geographical representativity
– Geographical coverage of measurements

These principles are all reflected in the GCW implementation plan.

Other questions raised by the Group were:
– Can CryoNet sites be funded within a grant model?
– Are the sites funded over the long term vs only for a campaign?
– What is the geographic representation?
– Should all sites have a core package of instruments?
– What is the common denominator for CryoNet sites?

ACTION 4.10: Agencies to provide feedback to J. Key on their specific needs or requirements for CryoNet sites for cal/val purposes. By 10 Jan 2015.

9.2 SnowPEx – Snow Product Validation and Intercomparison (B. Bojkov)

B. Bojkov introduced the ESA SnowPEx project and the Arctic Products Validation and Evaluation (APVE) workshops. He gave an overview of continental to hemispheric satellite snow extent products (e.g., NOAA IMS, ESA GlobSnow, NASA MOD10, AVHRR Pathfinder) and pointed out

the problem of unknown uncertainty which needs addressing to properly assess global and regional change. SnowPEx aims at developing best practices for snow product intercomparisons, to organize two intercomparison workshops, and to contribute to GCW. Aims are quantitative comparisons that enable traceability, and help determining uncertainty in products. Priorities highlighted at the first workshop held in July 2014 are: (i) establishment of EO validation protocols; such protocols are published on the CEOS WGCV website under SnowPEX workshop; (ii) define representative reference sites; (iii) "point to area" representativity issue. The challenge of monitoring snow in partly or fully forested areas was highlighted.

Other issues mentioned in the workshop are (i) the need for high-resolution optical datasets, (ii) consistent L1 (re)processing of high-resolution satellite data (e.g., orthorectification with common publicly available DEM using common auxiliary data and cloud clearing methods).

ACTION 4.11: B. Bojkov to send recommendations from the first SnowPEX workshop to the Secretariat (S. Bojinski) for distribution to PSTG members. By 31 Oct 2015.

B. Bojkov then described the APVE, a collaborative effort of ESA, LOOKNorth and CSA, which aim at more rigorous validation of products under the particular challenges in high latitudes (e.g., under large solar zenith angles or polar night conditions) while addressing the scientific and societal needs of the Arctic. Progress has been made in accounting for special scene conditions in product processing. The first workshop is planned 12-13 Nov 2014 in Ottawa, Canada, and a second planned in Sweden in 2015.

10. STRATEGIC PLAN 2015-2018 (M. DRINKWATER)

M. Drinkwater pointed out the need for a PSTG strategic plan 2015-2018, to communicate mandate, goals, key functional areas, and achievements of the Group. This is necessary given the very high profile of the cryosphere and its change globally, and to ensure the formal agreement by WMO Members to the continuation of PSTG after the 17th World Meteorological Congress 2015.

Strategic foci of the Group were discussed at PSTG-1 (see final report, Appendix II) were:
- Sea ice mass balance and mass variability
- Ice sheet mass balance contribution to sea level
- Atmospheric products to facilitate improved polar NWP
- Freshwater budget closure at high latitudes (snow and permafrost impact on polar hydrological cycle)
- Circumpolar changes in permafrost and terrestrial biosphere (consequences for carbon and hydrological cycles)
- Physical forcing of atmospheric chemistry in polar atmosphere (surface/troposphere, and troposphere/stratosphere coupling in the UTLS)
- Ecosystem response to variability and change

M. Drinkwater presented a draft Table of Contents of a strategic plan. Most participants supported the idea for such a Plan and encouraged it to be a short (5-10 pages), high-level document. T. Wagner pointed out key scientific questions (e.g., sea level rise and Arctic contribution) that should be addressed in the Plan. The Plan should reflect on accomplishments of PSTG and includes a section "Measures of Success". S. Bojinski noted that the document would have to be available by Jan 2015, to be considered at WMO Congress 2015.

ACTION 4.12: M. Drinkwater to produce a draft Strategic Plan and circulate with PSTG members for comments. By 31 Oct 2014.

11. AGENCY STEPS TOWARDS RESPONDING TO USER NEEDS

SCOPE OF ITEM

In advance of this session, and to define the scope of the presentations, the following guiding questions were provided to agencies in advance of the PSTG session:

1. Which of your current activities could address any of these user requirements [presented to the session]?
2. What plans do you have that could address any of these user requirements?
3. How do these requirements fit into your strategic, scientific and technical priorities?

11.1 CNES (S. HOSFORD)

At the outset S. Hosford commented that most user requirements presented to the session were oriented toward SAR technology and asked whether and where optical imaging mission data could fit in. The Chair noted that the requirements expressed by the permafrost community (presented in item 8.3) and by the glacier and ice cap community could significantly benefit from optical satellite imagery, and that these provided focused areas in which the user communities were mature and equipped to use optical image datasets.

S. Hosford then updated the Group on the SPIRIT Programme, aimed at facilitating access to DEM and orthorectified imagery. Based on SPOT5-HRS (stereo imagery), DEMs (30m horizontal resolution) were made available for most of southern Greenland and small parts of Antarctica, generating a significant publication record. The datasets are freely available to the international glaciology community. It is expected that the SPIRIT DEM database will be publicly open before the end of 2014; this will be announced on the cryolist list server.

The SPIRIT-2 campaign 2013-2014 includes repeat acquisitions in key glacier areas of Antarctica, Greenland, Northern Territories, Svalbard, and Iceland. The first DEMs are processed between now and the beginning of 2015.

Y. Crevier noted that there is goal within PSTG to generate a compendium of scenes available from SAR, and a similar tool would be useful for the SPOT optical data in the above examples.

The CNES high-resolution optical Pleiades system will be used to generate DEMs which will be very useful for glaciology. Vertical accuracy attains 1m with σ ~1m, validated by differential GPS. The Incentive for the Scientific use of Images from the Spot system (ISIS) Programme provides access to SPOT and Pleiades archives and new acquisitions for European science users. Images are subsidized by CNES (85% CNES, 15% lab), at approx. 1€/km2 for the lab for Pleiades data. All data acquired in ISIS over Polar Regions will be available to the ISIS user community. The latter is open for use by the international science community.

The SPOT World Heritage Programme encompasses the following:

- Access to full 30+million archive of SPOT scenes acquired since 1986 up to “today – 5 years”
- Processing of archive to L1 and L2 required
- CNES to finance processing over 5 years, first 100 000 scenes under production
- Users can identify scenes to be processed and cover costs
- Once images processed, they are available to all free of charge
- Partnerships to be developed with funding agencies / foundations to further open access
- Quicklooks available on www.geostore.com
- Use for polar science needs to be explored

S. Hosford said that processing of additional historical SPOT scenes is contingent on processing power and additional funding, for which science funding agencies would be a preferred partner. T. Wagner noted the potential value of having a map of the SPOT archive data density in particular geographic regions. E. Key indicated interest from the communities of land ecology and landscape management for high-resolution optical imagery. Their needs in the US are currently addressed by accessing Ikonos and other commercial data through a government agreement.

S. Hosford then briefed the Group on the ISRO/CNES SARAL/AltiKa Ka-band altimetry mission and showed some scientific results based on its data (sea ice freeboard estimates, ice-sheet surface and sub-surface features inferred from Ka-band microwave backscatter). There are also results demonstrating iceberg detection in the Southern Ocean, and ship tracks.

11.2 CSA

This item was withdrawn, in view of the presentation under item 7.

11.3 DLR

M. Gottwald gave an overview of satellite missions with DLR involvement (including TerraSAR-X and TanDEM-X), and other polar activities supported by DLR.

The German Antarctic Receiving Station (GARS) O'Higgins is a German-Chilean collaboration facility on the northern tip of the Antarctic Peninsula, essential for reception of DLR-supported satellites, and a research hub. A junior research group has been created for process studies on the Antarctic Peninsula, and to exploit the SAR data available at the Station. The facility for Maritime Safety has been established with a DLR-EOC group residing in Bremen/Germany. Its task is to develop methods and procedures for ship, iceberg, oil spill detection and ice classification from radar data. The resulting products shall be used in near real-time services, such as e.g., campaign support to vessels operating in Antarctica. He introduced the TopoSAR activity which encompasses improved land cover classification and water/ice classification using TerraSAR-X, and the generation of a vulnerability index and water masks in Canada using TanDEM-X. He also showed work related to deriving global snow pack parameters using MODIS and AVHRR that may be useful to address snow wetness.

M. Gottwald updated the Group on the mission status of TerraSAR-X and of current acquisition and monitoring, e.g., two complete coverages of the Antarctic Recovery glacier system were made. Only a few left-looking TerraSAR-X acquisitions were possible south of 80° in 2014 since they were too close or overlapping with an exclusion zone, or due to conflicting right- and left-looking constraints. He also showed some examples of scientific study results using the satellite (e.g., on the Jakobshavn Isbrae acceleration, flowing in 2012/2013 on average three times faster than 20 years ago). TerraSAR-X will operate at least until Dec 2015.

After two global coverage phases, TanDEM-X has completed the "Difficult Terrain & Antarctica & Gap Filling" phase in mid-2014 and now enters a "Science Phase" (Oct 2014-Dec 2015), with new interferometric operations modes foreseen for science users (AO closed on 30 Jun 2014). The satellites had undergone a change of imaging geometry due to a swap.

DLR offered to contribute in response to the user requirements presented to PSTG. A. Roth and D. Floricioiu will attend the SAR CWG-3 meeting in November 2014. M. Gottwald suggested to bring someone from the Junior Research and the Maritime Safety Group at DLR to the SAR CWG, perhaps already to the upcoming 3rd meeting.

11.4 ESA

M. Drinkwater outlined which of the ESA activities could address the user requirements presented to PSTG. Starting with the current and planned EO missions including the Sentinels; he focussed on CryoSat-2 and showed converging results for sea ice freeboard produced by different groups.

Validation campaigns (NASA IceBridge, ESA CryoVEx) are critical to establish uncertainties in this product. First estimates of Arctic sea ice volume show variability over 2011-2013 and will allow for establishing trends. CryoSat-2 allows for a full polar view through its inclination angle and drifting orbit; its operations have been extended until 2017 and the current instrument health and fuel reserve indicate operations would be possible until at least 2018. It was noted that although the Sentinel-3 SRAL altimeter can also help capturing Arctic sea ice variability, it will be unable to provide a full polar view since the orbital coverage misses a large area around the poles comprising latitudes north of 82°.

For SMOS, useful for monitoring thin sea ice thickness and frozen soil dynamics, extension of operations has also been approved by ESA Member states until 2017. There is also interest in inferring on polar ice sheet properties from spatial signal variability observed using SMOS, such as low temperature due to subglacial lakes. The Concordia station at Dome C currently hosts a tower-based L-band radiometer for autonomous, year-round validation.

Furthermore, M. Drinkwater showed results on glacial isostatic adjustment (GIA) and CryoSat elevation rate corrections in Antarctica, Swath-SARIn Processing, the combined use of GOCE and GRACE to infer on ice mass change in Antarctica (e.g., leading to 0.51mm/year sea level rise contribution from Amundsen Sea Sector alone). He also briefed on the PolarGAP2015/2016 campaign designed to acquire the first airborne gravity dataset as joint collaboration between ESA and NSF, to supplement the GOCE dataset and to fill the remaining Antarctic polar gap gravity data.

As for the Copernicus Sentinels, he briefed the Group on Sentinel-1, 2, and 3 all of which will have beneficial impact by addressing cryosphere requirements. Sentinel-1A has been launched successfully on 3 Apr 2014, and the commissioning review passed in mid-September (see Nature (2014) article on Sentinels). Data access of Initial Operations Phase opened on 3 Oct 2014.

As for user services and data exploitation, M. Drinkwater mentioned:

- Regional snow services for Scandinavia, the Baltic Area, and Central Europe & Alps are available (Snowsense)
- The Copernicus CryoLand Service (to stimulate the cryosphere aspects of the Copernicus Land Service)
- The ESA Climate Change Initiative

11.5 NOAA

J. Key showed missions and products under NOAA responsibility relevant to PSTG. He showed that comparing VIIRS-based ice thickness model products with other ice thickness products show some skill. A VIIRS-based binary snow cover map agrees well with in-situ station data. He also mentioned the development of products describing leads, and polar winds products that are widely used by NWP centres. Generation of climate data records is ongoing, using AVHRR.

P. Clemente-Colón showed activities of the NOAA National Ice Center (NIC) in the polar and cryosphere regions. Several currently operational products, e.g., on sea ice, oil spill mapping, coastal winds, are using SAR, such as within the NOAA/NIC Interactive Multi-sensor Snow and Ice Mapping System. The aim at NIC is to develop automated or semi-automated methods for mapping ice structure and thickness, and for detecting other signatures. The contribution of JAXA ALOS-2 data is currently under consideration. Meanwhile, the NASA SMAP mission data are recognized to have potential for mapping ice, and a NOAA-NASA agreement is under consideration. There is high interest in accessing Sentinel-1 data, and a project to develop a S-1 SAR winds product at NIC by 2016 is underway.

The Argentinian Space Agency (CONAE) are planning the SAR Observation & Communications Satellite (SAOCOM) mission, comprising two L-band SAR satellites. It is planned to be operated

jointly with the Italian CSK constellation. The combination of L- and X-band data offers strong potential for polar ice.

11.6 USGS

L. Hothem introduced the Landsat Program in the context of USGS, as part of the climate and land use change program. Landsat-8 was launched in 2011 and successfully continues the Landsat series, which runs under joint responsibility of USGS and NASA. The Landsat Science Team oversees operations and determines response to scientific and operational user requirements. Landsat data was made freely available in 2008, leading to a massive increase in their utilization. Quicklook images are available, and the archive provides a very good opportunity for the development of climate data records. Ted Scambos (University of Colorado, USA) has been active on the Science Team to undertake cryospheric research using Landsat imagery (e.g., investigating land-surface temperature over Antarctica, lake ice cover, glacier mapping).

Priorities for future acquisitions of Landsat have been formulated in a long-term acquisition plan, foreseeing more data taken in Arctic and Antarctic regions. The Landsat Science Team decides on Landsat acquisition priorities and product development, and an Action from PSTG could have influence on these decisions.

L. Hothem argued that continuity of the POLENET/ANET field stations in Antarctica was important to complement satellite measurements from a geodetic standpoint, and to allow for GNSS-based studies of ice mass balance. Several sites are not communicating or have operational problems.

The Chair noted that USGS currently had no formal member on PSTG, given the retirement of Jerry Mullins.

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.

ACTION 4.14: USGS to nominate a new representative to PSTG, by sending a letter to WMO. By: 31 Dec 2014.

11.7 NASA

T. Wagner gave an overview of NASA activities in the Cryosphere, including:

- Ocean chlorophyll measurements in the Arctic (Distributed Biological Observatory)
- Operation IceBridge (aircraft campaigns to monitor Greenland and Antarctica, and sea ice)
- IceSat-2 (under development at GSFC)
- ABoVE (Arctic-Boreal Vulnerability Experiment; a major field programme looking at change in Arctic and boreal region that is open to collaboration by other partners)
- The MEaSUREs program (developing Earth system data records)

T. Wagner highlighted the Arctic as the most rapidly changing region of the planet. Through PSTG, agencies provide key information to shed light on these changes and help understand and predict them, using satellite data. He pointed out the importance of NSIDC as a key data centre for hosting NASA datasets (passive microwave, VIS/IR, altimetry).

Climate models often have Arctic sea ice rotating in the wrong direction, hence ocean circulation and ocean-ice interaction are critical factors to investigate for better understanding the Arctic. Sea ice concentration from satellites is used by modellers for independent verification and correction (the model output is corrected towards the satellite products). Work by Ron Kwok (NASA JPL)

within the MEaSUREs program on small-scale dynamics of the Arctic and the Southern Oceans using Envisat is an important contribution.

The global snow cover product will not be continued, the Greenland/Antarctica ice sheet velocity activities of E. Rignot's and I. Joughin's groups will be.

Results from the Distributed Biological Observatory have had some success in using satellite datasets in modelling of ocean biological properties, and thus help better understand resources available for Arctic economies and livelihoods.

T. Wagner pointed out the importance of the PSTG Strategic Plan: it should ensure that satellite datasets are easier and simpler to use, and lead to best practices in agency collaboration in support of the cryosphere.

Recent papers as a result of PSTG include:

- Ice flow in Greenland for the International Polar Year 2008–2009[3]
- Ice Flow of the Antarctic Ice Sheet[4]
- Sustained increase in ice discharge from the Amundsen Sea Embayment, West Antarctica, from 1973 to 2013[5]

11.7.1 Outlook on satellite ice freeboard, thickness and volume products by altimetry (N. Kurtz)

N. Kurtz gave an invited talk on this subject. He addressed the challenge to retrieve sea ice thickness using altimetry, since 1cm error in freeboard corresponds to 10cm error in sea ice thickness. Deriving sea ice thickness helps improving model physics and predictive skill, such as in PIOMAS. He gave credit to results by S. Laxon using ERS and ICESat and CryoSat-2 confirming a significant reduction in ice thickness over time in the Arctic. He noted issues with data availability of ERS and Envisat, and ICESat, although the ESA sea ice CCI (SICCI) project will help making complementary ice extent, concentration and thickness data more broadly available.

Six years of IceBridge operations have helped validating CryoSat-2, using a three tiered approach: small-scale in-situ data, regional-scale aircraft measurements with overflights of in-situ surveys, and global-scale satellite altimeter data. Tracking methods are critical to select the correct waveform trackpoint in the radar altimeter signal (Wingham et al.). A key challenge for radar altimetry is backscatter from snow (penetration), and approaches have been addressing the estimation of errors, which are largely a function of the backscatter properties of snow and ice. Using laser altimetry, a challenge is lead discrimination, cloud contamination, snow depth on sea ice (using PMR, snow radar, laser-radar co-use, and data assimilation).

He showed some of the issues related to characterizing snow on sea ice, none of which are intractable, however mostly focussed on Arctic sea ice, and that cooperation is required to establish the right methodology. More emphasis should be placed on the physics involved rather than empirical methods which are currently used.

He advocated for easier access to satellite data, simpler use and transparency in their generation.

[3] Rignot, E., and J. Mouginot (2012): Ice flow in Greenland for the International Polar Year 2008–2009, Geophys. Res. Lett., 39, L11501, doi:10.1029/2012GL051634.
[4] Rignot, E., J. Mouginot, and B. Scheuchl. 2011: Ice Flow of the Antarctic Ice Sheet, Science, Vol. 333(6048): 1427-1430. doi 10.1126/science.1208336.
[5] Mouginot, J., E. Rignot, and B. Scheuchl (2014): Sustained increase in ice dis- charge from the Amundsen Sea Embayment, West Antarctica, from 1973 to 2013, Geophys. Res. Lett., 41, 1576–1584, doi:10.1002/2013GL059069.

11.7.2 Sea ice concentration product intercomparisons and establishing the climate data record (W. Meier, J. Comiso)

W. Meier discussed climate data records and what PMR sensors with their long heritage (>30 years) can contribute to generating CDRs. He introduced some of the NASA work in generating cryosphere-related CDRs and their validation and application, as well as sea ice products developed in the framework of the ESA CCI. He discussed approaches to estimating relative uncertainty and described AMSR-2-derived sea-ice datasets from JAXA, NASA and NOAA. Intercalibration of records to apply bias corrections is necessary, as well as better documentation of necessary adjustments. The climate modelling community through obs4MIPs is a user of sea ice CDRs, for independent model validation. Uncertainty estimates need improving, and a project is starting to generate multi-sensor products (e.g., combining PMR and VIS/IR). On the whole PMR-based algorithms are mature, and a discussion is needed on how to integrate the PMR timeseries with other sensor data.

W. Meier stressed that PSTG should articulate the importance of continuity of the PMR record as fundamental for the sea ice climate data record. The Sea Ice ECV as defined by GCOS encompasses sea ice extent, concentration and thickness.

J. Comiso described comparative studies of sea ice concentrations and ice extents. He noted use of the emissivity contrast between water, old ice and seasonal sea ice as basis for constructing the long term time series from PMR. Results in the AR5 show the retreat in perennial ice in the Arctic ocean. ESA CCI Sea Ice Concentration uncertainty estimates are 3-5%, with the goal of achieving 2-4% in the next phase. From PMR uncertainty is estimated at 5-10% currently. Comparisons of different sea ice concentration products were made at a September 2014 workshop in Hamburg, Germany (for Arctic, Antarctica). Uncertainties are governed by limited knowledge of ice emissivity. He showed historical time series of sea ice extent from SMMR and SSM/I. Some biases are caused by the differences in resolution of the respective PMR instruments. Other issues include melt pond effects on summer retrievals using PMR. The NASA ARISE airborne project is currently trying to capture meltpond coverage. Landsat data are also potentially useful in this regard.

Currently the highest Antarctic sea ice extent since 1979, mainly due to dynamics and katabatic winds.

Although the trends between algorithms in US and Europe are similar, it is currently difficult to meet the 2-3% GCOS accuracy target when the algorithms results under certain circumstances can differ by 10%.

11.7.3 US Land Surface Imaging Programme (G. Gutman)

G. Gutman presented the NASA Land Cover Land Use Change (LCLUC) program which focusses on the Arctic and has been running since 1998 (including NEESPI). He showed the book publication in Springer on *Eurasian Arctic Land Cover and Land Use in a Changing Climate* (2011). Research projects have been on sea ice cover and forest cover change, land management and human settlements, landscape stresses through development of roads and pipelines inhibiting migration of animals, pollution in combination with increasing temperatures and precipitation, aerosols in Northern latitudes, increasing runoff into the Arctic.

The LCLUC program makes a contribution to compilation of information on zonal patterned ground ecosystems in northern North America. Climate change studies using MODIS data show correlations between sea ice and temperature, and NDVI trends in Eurasia and North America. There is a correlation between sea ice and summer warming due to summer sea ice retreat.

Regarding land monitoring at medium resolution, international cooperation is needed to meet all needs at all resolution levels; this includes the use of Sentinel-2. Landsat 9 is not secured yet,

while Landsat 8 is functioning well (some issues with Thermal IR). A Landsat-Sentinel-2 fusion project looks into merging datasets from both sensors. An open call for projects (ROSES-2014) was issued by NASA on 1 Oct 2014 to investigate multi-source land imaging and products using multiple sources, possibly with international partners. Selection will be sometime in mid-2015. This is in the spirit of the CEOS Land Surface Imaging Constellation. There is coordination with the Sentinel-2 related calls for science (through O. Arino). This activity is very important to foster integration of different data streams.

12. SYNTHESIS OF AGENCY CONTRIBUTIONS TO ADDRESS USER REQUIREMENTS

The Group initiated a discussion on how to address the user requirements presented to the session.

Regarding wet snow monitoring, the Group felt that a staged plan for achieving the stated requirement is needed, and that D. Small should attend the upcoming SAR-CWG session. Routine daily and global coverage is the goal, daily and global, using combinations of SARs at C-band. A demonstration of the utility of routine SAR data for wet snow mapping for hydrological applications should be provided, by starting with a pilot activity.

Regarding permafrost, initial focus should be on a few sites (cold spots) or transect regions using both SAR and optical data. High-resolution optical data should be planned initially at these anchor sites, with a view to upscale the information with the more routine 300m HR circumpolar data. High priority is, ultimately, a continuous circumpolar land cover map beyond the tree line. More analysis is needed by the user community to identify the most beneficial sites for an initial response.

Y. Crevier stated as an aim of CSA to move from an à-la-carte approach in operating RADARSAT-2 to a more strategic approach of routine acquisitions. P. Clemente-Colon noted that CSK is providing pan-Arctic coverage in huge wide mode.

J. Falkingham saw as challenge that (i) missions are being coordinated and acquisition regions do not overlap, (ii) that users generally do not have access to data from multiple missions, for a particular location and data type. Currently, most institutions and activities are tied to particular missions and not multiple missions.

Data would be useful even weeks or months after acquisition. The advent of Sentinel-1 may change access conditions to historical data.

The Group identified the need for continued PMR operations after 2020. P. Clemente-Colon agreed to investigate with US DoD on the planning of PMR missions after 2020. Continuity of PMR functionality is essential, and JAXA should be encouraged to confirm their plans for GCOM-W AMSR. GOES-R will also be important for monitoring sea ice.

Y. Crevier raised the possibility to achieve CEOS endorsement for PSTG work. S. Hosford informed that progress with polar activities is recognized in the CEOS SIT 3-year work plan. PSTG should work with EUMETSAT to get PSTG on the agenda of upcoming CEOS meetings.

ACTION 4.15: S. Hosford to provide a short high-level report on PSTG-4 to CEOS Plenary, through communication to the CEOS CEO. By 20 Oct 2014.

The Group noted the potential conflicts in data acquisition of SAR data over Antarctica and other key regions due to competing interests, and these will need to be addressed. This emphasizes the importance of prioritized plans for acquisitions that would meet the user needs of multiple user communities.

The establishment of a new Copernicus Climate Service may help to raise the profile of some of the issues regarding need for seamless global cryospheric products, particularly in relation to the generation of climate data records.

Visit of IceSat-2 Integration Facility

The Group visited the IceSat-2 satellite in the GSFC Integration Facility, guided by Cathy Richardson and Thorsten Markus.

13. PLANS FOR FORTHCOMING SAR COORDINATION WORKING GROUP MEETING (Y. CREVIER)

The PSTG SAR Coordination Working Group (SAR CWG) will hold its next meeting on 5-6 November 2014 hosted by ASI in Rome, Italy. This third session will be concentrating on (i) resolving remaining issues with RADARSAT-1 2013 Greenland campaign data; (ii) revising future acquisition plans in light of Sentinel-1a and ALOS-2; (iii) evaluating data needs for floating ice, snow and permafrost, and (iv) identifying areas of conflict. Coordinating a pan-agency Announcement of Opportunity is under development by the SAR CWG.

Other meeting objectives are:
- Finalization of governance-related topics (ToR)
- Review of achievements
- Review of scientific requirements presented to PSTG and discuss
    - Key science questions
    - Coordinated responses
    - Data access
- Planning response for next phase – current and future requirements

A question was raised whether a similar agency coordination approach should be taken for coordinating agencies operating optical sensors:

L. Hothem agreed to enquire internally on whether USGS would be able to respond to user requirements in conjunction with other optical or SAR data. CNES are positive about responding in some way to prioritized requirements related to permafrost and possibly other areas. The approach in other application areas has been the existence of a baseline dataset from Landsat, and additional specific requirements and acquisitions based on priorities. Pressure from the scientific user community is needed to ensure such a response. A generic or thematic data coordination group including all agencies may be an approach, rather than maintaining sensor-specific groups.

A first step should be to deliver some optical datasets in response to prioritized permafrost requirements, and explore their utility.

14. STATUS OF INVITATIONS TO NEW MEMBERS (S. BOJINSKI)

S. Bojinski led the review of PSTG membership and invitation lists.

S. Hosford suggested reaching out to the China CRESDA agency, noting their role in C-BERS and HJ-1A/B/C satellites, with optical and SAR capability.

T. Wagner confirmed that it would be worthwhile to explore ways to inform the Arctic Council about PSTG activities, given the US chairmanship in 2015. It was noted that WMO has observer status on the Council.

Further attempts to contact and engage SCAR should be made for PSTG-5.

M. Drinkwater agreed, as suggested by DLR, to explore whether Spain was interested joining PSTG given the plans for the PAZ SAR mission.

ACTION 4.16: M. Drinkwater to contact JAXA (Shimada Masanobu) on whether he would be in a position to report on progress with ALOS-2 and the relevance of the background operations scenario to PSTG-5. By: 10 Jan 2015

15. SUMMARY OF PSTG ACTIONS

The actions were summarized in session, resulting in the Action items listed in Appendix III.

16. PLANS FOR NEXT MEETING

PSTG will organize an inter-sessional teleconference on 14 or 15 Jan 2015 at 13.00-14.30 UTC (GMT).

The fifth PSTG meeting is planned for the week 5-9 October 2015. DLR agreed to investigate the possibility to host the next session in Oberpfaffenhofen, possibly in conjunction with a meeting of the SAR CWG. USGS indicated the possibility to host a meeting in the future.

17. ANY OTHER BUSINESS

In his closing remarks, M. Drinkwater emphasized the value of the Group fostering international cooperation in supporting cryospheric science and applications through coordinated space agency action.

18. ADJOURN

The meeting was adjourned at 13.00 on 1 Oct 2014.

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APPENDIX II

AGENDA AND WORK SCHEDULE

Meeting Room: Building 34, Room W305

Day 1 - 29 Sep 2014

8:30 *Site Entry/Registration*

9:00 **1. Welcome and Opening Remarks**
NASA Welcome
Local host information / logistics (T. Markus)
Mark Drinkwater (Chair)

9:15 **2. Introductions to Participants** (All)

9:30 **3. Approval of Agenda** (M. Drinkwater)

9:40 **4. NASA Radar and Cryosphere Activities** – 30 mins
4.1 Radars and the NASA NISAR Mission (C. Dobson) [doc. 04-01]
4.2 NASA Cryosphere Program (T. Wagner) [doc. 04-02]

10:10 **5. Review of Action Items** (Secretariat)

10:30 *Coffee Break*

11:00 **6. EC-PORS-5 Update** (M. Drinkwater) [doc. 06-01; 06-02] – 30 mins

11:30 **7. Status of Activities in Response to Ice Sheet Requirements** (Y. Crevier – Chair SAR CWG) [doc. 07-01; 07-02] – 30 mins

12:00 **8. New User Requirements**
8.1 Snow (D. Small) [doc. 08-01] – 60 mins

13:00 *Lunch Break*

14:00 **9. Global Cryosphere Watch (GCW)** – 60 mins
9.1 CryoNet and Requirements for Satellite Cal/Val sites (J. Key) [doc. 09-01] – 30 mins
9.2 SnowPEx – Snow Product Validation and intercomparison (B.Bojkov) [doc. 09-02] – 30 mins

15:00 **8. New User Requirements** (*Cont'd*)
8.2 Atmosphere: Polar Prediction, YOPP & Mosaic ice camp (T. Jung) [doc. 08-02-01, doc. 08-02-02] – 60 mins

16:00 **10. Strategic Plan 2015 – 2018** (M. Drinkwater) [doc.10-01] -– 60 mins

17:00 *Adjourn Day 1*

Day 2 - 30 Sep 2014

09:00 **8. New User Requirements** (*Cont'd*)

8.3 Permafrost (A. Bartsch) [doc. 08-03] – 60 mins
8.4 Sea Ice (J. Falkingham) [doc. 08-04] – 60 mins

11:00 *Coffee Break*

11:30 11. Agency Steps Towards responding to User Needs (All)

11.0 Scope of Session – Guiding questions are:

1. Which of your current activities could address any of these user requirements?
2. What plans do you have that could address any of these user requirements?
3. How do these requirements fit into your strategic, scientific and technical priorities?

11.1 CNES (S. Hosford) [doc. 11-01] - 20 mins
11.2 CSA (Y. Crevier) [doc. 11-02] - 20 mins
11.3 DLR (M. Gottwald) [doc. 11-03] - 20 mins

12:30 Lunch

13:30 11. Agency Steps Towards responding to User Needs (*Cont'd***)**

11.4 ESA (M. Drinkwater) [doc. 11-04] - 20 mins
11.5 NOAA (P. Clemente-Colón, J. Key) [doc. 11-05] - 20 mins
11.6 USGS (L. Hothem) [doc. 11-06] - 20 mins
11.7 NASA (T. Wagner) [doc. 11-07] - 20 mins

14:50 11.7.1 Outlook on satellite ice freeboard, thickness and volume products by altimetry (N. Kurtz, J. Comiso) [doc. 11-07-01] - 30 mins

15:20 11.7.2 Sea ice concentration product intercomparisons and establishing the climate data record (W. Meier) [doc. 11-07-02] - 30 mins

15:50 11.7.3 US Land Surface Imaging Programme (G. Gutman) [doc. 11-07-03] – 30 mins

16:20 12. Synthesis of Agency Contributions to Address User Requirements – 30 mins

17:00 Viewing of IceSat-2 satellite in GSFC Integration Facility (T. Markus)

18:00 *Adjourn Day 2*

Day 3 – 1 Oct 2014

09:00 12. Synthesis of Agency Contributions to Address User Requirements (cont'd) – 30 mins

09:30 13. Plans for Forthcoming SAR Coordination Working Group Meeting (Y. Crevier) - 20 mins

09:50 14. Status of invitations to new Members (S. Bojinski) [doc 14-01] - 10 mins

10:00 15. Summary of PSTG-4 Actions - 60 mins

11:00 Coffee Break

11:30 16. Plans for Next Meeting - 30 mins

12:00 17. Any Other Business - 60 mins

13:00 *Adjourn Session*

Reference documents

Meeting URL: http://www.wmo.int/pages/prog/sat/meetings/PSTG-4.php

APPENDIX III

ACTION ITEMS FOR PSTG

I. Actions from PSTG-4	
ACTION 4.1: Chair and Secretariat, in collaboration with NASA, to write a letter to ISRO inviting them to participate in PSTG and explaining how the planned NISAR mission could address global polar and cryosphere-specific requirements. By 1 Dec 2014	**OPEN**
ACTION 4.2: Secretariat to post presentations from WWRP-THORPEX-ECMWF workshop on polar prediction on PSTG website. By 31 Oct 2014.	**CLOSED; available at http://www-newdev.wmo.int/pages/prog/sat/pstg_en.php**
ACTION 4.3: PSTG recommends that agencies on the SAR CWG to consider requirements in doc PSTG-4/Doc 08-01 and come up with proposals on how to respond to these snow user community needs. By: SAR-CWG-3 (5 Nov 2014)	**OPEN**
ACTION 4.4: Based on acquisitions foreseen in currently running proposals (with DLR on TerraSAR-X), D. Small should devise a plan with steps towards acquisition and utilization of relevant data in Switzerland and the European Alps. By: SAR-CWG-3 (5 Nov 2014)	**OPEN**
ACTION 4.5: T. Jung to share with PSTG a detailed PPP-related observation requirements document. By 1 Dec 2014.	**OPEN**
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**
ACTION 4.7: PSTG Members to consider a response to PPP-related observation requirements during the interval of YOPP and associated field campaigns. By 15 Sep 2015.	**OPEN**
ACTION 4.8: A. Bartsch to identify among the existing cold spots a number of reference sites (including sites with ongoing active coastal erosion) for remote sensing, with the strategic goal to focus the PSTG agency acquisitions on these sites and to achieve multi-sensor coverage. By 10 Jan 2015.	**OPEN**
ACTION 4.9: PSTG members in the SAR CWG to devise a plan to achieve an initial 6-day repeat coverage of the Arctic Basin and Southern Ocean sea ice, respecting the other priorities identified in PSTG-4/doc.08-04. By: PSTG-5.	**OPEN**
ACTION 4.10: Agencies to provide feedback to J. Key on their specific needs or requirements for CryoNet sites for cal/val purposes. By 10 Jan 2015.	**OPEN**

ACTION 4.11: B. Bojkov to send recommendations from the first SnowPEX workshop to the Secretariat (S. Bojinski) for distribution to PSTG members. By 31 Oct 2015.	**OPEN**
ACTION 4.12: M. Drinkwater to produce a draft Strategic Plan and circulate with PSTG members for comments. By 31 Oct 2014.	**OPEN**
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**
ACTION 4.14: USGS to nominate a new representative to PSTG, by sending a letter to WMO. By: 31 Dec 2014.	**OPEN**
ACTION 4.15: S. Hosford to provide a short high-level report on PSTG-4 to CEOS Plenary, through communication to the CEOS CEO. By 20 Oct 2014.	**OPEN**
ACTION 4.16: M. Drinkwater to contact JAXA (Shimada Masanobu) on whether he would be in a position to report on progress with ALOS-2 and the relevance of the background operations scenario to PSTG-5. By: 10 Jan 2015	**CLOSED;** correspondence by email on 27/28 Oct 2014: ALOS-2 in initial calibration stage; promising first analyses of PALSAR-2 data, indicating that ALOS-2 may contribute to polar research; S. Masanobu uncertain about his attendance in PSTG-5 due to a forest PI meeting at that time
II. Actions from PSTG-3, and Status	
ACTION 3.11: A. Bartsch, K. Luojus and P. Bauer to review the polar/cryosphere-related requirements specified in the WMO RRR database (http://www.wmo-sat.info/oscar/observingrequirements), and to provide feedback to the application area focal points and WMO. Deadline: 1 Dec 2013	**OPEN for** snow, atmosphere communities to review requirements; **CLOSED** for permafrost community