

# PSTG Strategic Plan: 2015-2018

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## Polar Space Task Group (PSTG)

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# Polar Space Task Group: Strategic Plan

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## Executive Summary

Polar regions and the cryosphere constitute a unique, valuable, yet extremely sensitive component of the Earth system. Obtaining robust, routine information products for better scientific understanding and development of applications in these last remaining frontiers of our planet requires collective action.

In the 50 years between the International Geophysical Year in 1957 and the 4<sup>th</sup> International Polar Year (IPY) in 2007-2009, the space era transformed our capability to study the cryosphere. As the emerging economic opportunities begin to dictate interests in these fragile regions it becomes imperative to assemble scientific knowledge with which to exercise responsible management and stewardship. Space Agencies who participated in IPY in a federated effort to collect an integrated set of unique snapshots of the polar regions have contributed to an important data legacy. The next step is to harness this experience to build an integrated observing system and monitoring capability for the cryosphere in general. The vision for this system contains a space-borne element that provides data product as essential input to informed decision making at national and international level.

The Polar Space Task Group (PSTG) was established in 2011 and operates under the auspices of the World Meteorological Organization (WMO) Executive Council Panel of Experts on Polar and High Mountain Observations, Research, and Services (EC-PHORS). It comprises nominated representatives of Space Agencies and seeks to coordinate the efforts of space-faring nations in the joint endeavour of providing scientific information about the polar regions and the cryosphere in support of science and applications. The Group has developed a coordinating space agency action plan for monitoring the ice sheets, and the first resulting datasets have been released in 2013; PSTG has also initiated a coordinated response to scientific user requirement in support of permafrost, wet snow, floating ice; and atmosphere in support of polar prediction.

This strategic plan serves as a basis for the activities of the Polar Space Task Group (PSTG) for the period 2015 – 2018.

# 1. Introduction

The 4<sup>th</sup> International Polar Year (IPY-4), from 2007–2009, was a major international programme initiated by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). Remarkable progress was achieved through a combination of internationally federated, interdisciplinary research which yielded new scientific discoveries, development of new methods and tools to better understand the cryosphere. IPY4 has delivered an array of data which led to new understanding of the role of the polar regions in the Earth system [Krupnik et al., 2011].

The relatively young “space age” provided a new dimension to IPY-4, by comparison to the previous International Geophysical Year in 1957-1958. Satellites played an essential and fundamental role in the achievements of the IPY-4. An impressive array of new satellite data were acquired, with the associated products processed and archived as an important IPY legacy [Drinkwater et al., 2011].

During the International Polar Year (IPY) the Joint Committee (JCOMM) of WMO and ICSU mandated the IPY-Space Task Group (IPY-STG) to plan and coordinate the satellite data acquisition to fulfil the satellite data needs of approved IPY projects, thereby enabling their scientific objectives to be achieved. The IPY-STG comprised invited representatives of each of the major space agencies (including both CEOS and CGMS member agencies), thereby representing the interests of both Research and Development and Operational agencies.

The Polar Space Task Group (PSTG) was established under a mandate of the WMO Executive Council Panel of Experts on Polar and High Mountain Observations, Research, and Services (EC-PHORS) and comprises Space Agency experts. Membership of the PSTG is established by invitation from the WMO Secretary General, with formal nomination of member representatives by the respective Space Agency.

Establishment of the PSTG coincided with the four year interval bridging the WMO Congresses in 2011 and 2015 (i.e. Cg-XVI and Cg-XVII). Thus, the initial terms of reference foresaw a 4 year working interval, with the goal to review progress and renew the working mandate by the World Meteorological Congress in 2015. This plan provides strategic guidance for continuation of PSTG activities for the period 2015-2018.

## 2. Framework

### Mandate of PSTG

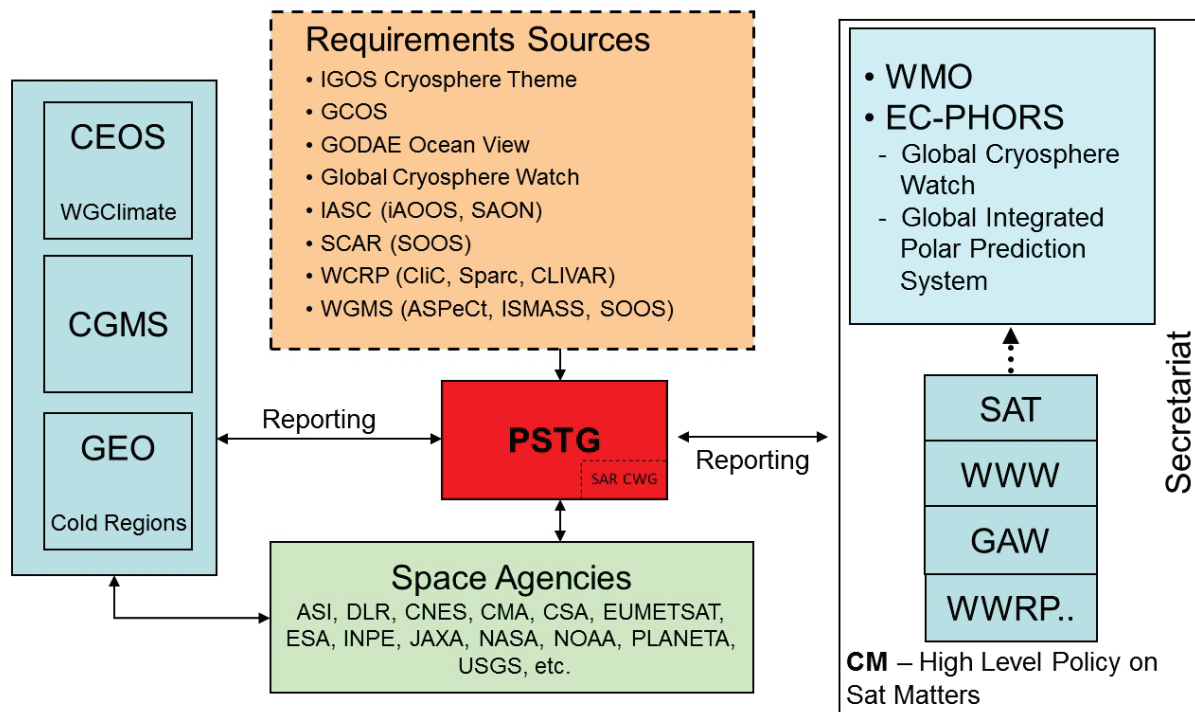
The Polar Space Task Group (PSTG) mandate is to provide coordination across space agencies to facilitate acquisition and distribution of fundamental cryosphere and polar satellite datasets, and to contribute to the development of specific derived products in support of cryospheric scientific research and applications. Benefits from the growing constellation of polar orbiting satellites will be realised by mobilising the unique and complementary capabilities of each of the respective participating Agencies, whether research and development or operationally oriented.

PSTG members shall facilitate acquisition and distribution of fundamental satellite datasets, and contribute to, or support development of, specific derived products in support of polar and cryospheric scientific research and applications. Participating space agencies are requested to allocate resources towards the achievement of tangible results.

The Terms of Reference for PSTG are at: [http://www.wmo.int/pages/prog/sat/pstg\\_en.php](http://www.wmo.int/pages/prog/sat/pstg_en.php).

## Interfaces

The chart in Figure 1 identifies the link across which the PSTG engages with key scientific stakeholder groups (intra-governmental, non-governmental, and institutional) representing the interests and needs/requirements of the broader science community (see Fig. 1 - orange box), and the Space Agencies. Meanwhile, the chart indicates the balance of reporting on the one side (Fig. 1 - left blue box) to the primary space agency coordinating bodies (Committee on Earth Observing Satellites (CEOS); and Coordinating Group on Meteorological Satellites (CGMS); and the Group on Earth Observations (GEO)). On the other side (Fig. 1 - right box) PSTG reports to WMO through its connection to EC-PHORS (in relation to its mandate).



**Figure 1.** Polar Space Task Group interfaces.

In respect to the activities of PSTG and implementation challenges, member representation also provides a direct interface to the Space Agencies engaged in CEOS and CGMS, thereby facilitating the necessary high-level coordination and interagency discussion on both research and development and operational topics.

The SAR Coordination Working Group (SAR CWG) has also been established as a subsidiary working group of the PSTG. It is tasked with implementing coordinated acquisition, dissemination, processing and analysis of satellite SAR data in response to user community needs, on behalf of PSTG.

## Functional Objectives

The high level functional objectives of PSTG are to:

- Assemble disciplinary science requirements for polar and cryospheric research uniquely addressable with spaceborne systems, through regular and broad interaction with the science community
- Through iteration and interaction between the mission planning and processing activities of the participating space agencies, develop a concise, prioritised list of observation plans based on:
  - satisfying science objectives best served by coordinated agency activities
  - efficient use of the international constellation of satellites
  - operating mandates of each space agency
- Address polar and cryospheric research priorities with the unique data provided by satellite remote sensing systems
- Regularly assess and revise observation acquisition scenarios and acquisition plans
- Review and update to the extent possible the observation priorities over time
- Develop plans to use shared resources for processing and distributing data and data products
- Establish subgroups addressing specific coordination issues
- Encourage broad participation by all interested space agencies.

## 3. Achievements 2011-2014

### Functional Achievements

- Established working activities amongst a group of 13 agencies, with establishment of a sub-group, the SAR Coordination Working Group (SAR CWG)
- Solicited and sourced comprehensive scientific community endorsed user requirements from the ice sheet, permafrost, floating ice and snow communities
- Established integrated multi-agency, multi-satellite monitoring strategy to meet ice sheet user needs, with data acquisition and shared processing in support of ice sheet topography, velocity, volume and mass variability assessments
- Established Interagency operational snow extent and mass monitoring in conjunction with Global Cryosphere Watch
- Initiated activities in response to permafrost, snow, polar numerical weather prediction, floating ice, and glacier user needs

- Space Agencies launched and began operating the following new polar-orbiting missions to complement the existing Global Earth Observing Infrastructure: HY-2A, Suomi NPP, GCOM-W1, GPM, Sentinel-1A, ALOS-2, SMAP, and developed, or began development of, new products relevant to monitoring the polar regions
- Space Agencies secured planning for new polar-orbiting missions with potential for polar science: ICESat-2; NISAR; Joint Polar Satellite System (JPSS); MetOp-Second Generation; Copernicus Sentinel-5.

## Scientific Achievements

- Multi-agency estimate of Antarctic and Greenland mass balance and respective sea level contributions as input to IPCC AR5, using altimetry, gravimetry and SAR interferometry data
- SPIRIT Spot-5 HRS stereo image-derived DEMs; and recent extension of SPIRIT activities
- [Randolph Glacier Inventory](#) global glacier outlines (for ~198,000 glaciers) derived from optical satellite images, as input to IPCC AR5 glacier mass balance sea level contribution evaluation
- Operational delivery of low-resolution Arctic sea-ice drift and pre-operational Antarctic products
- Distribution of 5 years continuous monthly sea ice thickness products from CryoSat and prototype thin ice thickness from SMOS L-band microwave radiometer as input to coupled ocean-ice-atmosphere modelling
- Distribution of circumpolar frost depth, snow extent, snow water equivalent, seasonal soil moisture, and surface temperature products
- Inter-agency airborne campaigns ([Operation IceBridge](#), [CryoVEx](#)) for ice sheet, glacier and sea ice; and satellite calibration/validation and product assessment (e.g. [SnowPEX](#)).

## 4. Scientific Foci

At its first meeting, the PSTG decided to focus its polar and cryosphere activities on a number of broad scientific topics. The list of priority topics provided below is based on key science requirements and grand challenges identified by authoritative polar science and application stakeholder groups (i.e. WCRP, EC-PHORS, GCW and related forums and activities):

- Sea ice mass balance and mass variability
- Ice sheet, ice caps and glacier mass balance contribution to sea level
- 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)
- Polar atmospheric products to facilitate improved NWP
- Cryospheric forcing of atmospheric chemistry in polar atmosphere (surface/troposphere, and troposphere/stratosphere coupling)
- Ecosystem response to cryospheric variability and change

- Identifying opportunities for new integrated applications of polar satellite data in response to emerging socio-economic issues .

This list provides strategic guidance to PSTG, though is anticipated to evolve and be refined by consultation and interactions with the respective scientific and application user communities. In developing coordinated action in these areas it is recognised that PSTG members need to match requirements in these areas against agency priorities and capabilities.

## 5. Strategy to Achieve Goals

### Sourcing and Responding to User Requirements

The group shall develop mechanisms to source user requirements, through Requirements documents, direct interactions with representatives of the scientific user community, and through participation in workshops, symposia and meetings of representative science coordination bodies.

The group shall review cryosphere and polar scientific requirements, including user needs and observational requirements stemming from, but not limited to the Integrated Global Observing Strategy Cryosphere Theme Report (IGOS, 2007), the Global Climate Observing System (GCOS), the World Climate Research Programme (WCRP) and relevant high-latitude Project aspects, the International Arctic Science Committee (IASC), the Scientific Committee on Antarctic Research (SCAR), the Global Ocean Data Assimilation Experiment (GODAE) Ocean View, the specific needs of the WMO Global Cryosphere Watch (GCW), and the Group on Earth Observations (GEO).

Representatives of GCOS, WCRP, IASC/SCAR, and GEO will receive a standing invitation to participate in the PSTG meetings to facilitate coordination. Other groups with specific polar interests (e.g. scientific coordination bodies such as US National Science Foundation, European Science Foundation, etc.) may also be invited to participate in PSTG meetings, as appropriate (on *ad-hoc* basis), in order to source, understand and consolidate user needs, or to understand topics prioritised for strategic scientific funding.

PSTG reviews the user requirements sourced from the scientific user communities and prioritises and consolidates these needs which can be best met within the scope of the PSTG members' technical capabilities and respective mandates. PSTG enables this by establishing close collaboration with designated focal points for each specific set of user requirements.

Agencies are asked to establish commitments on behalf of their Agency to support data acquisition, product development and/or establishment of relevant accompanying scientific studies, as appropriate for the respective Agency.

Observational requirements sourced by PSTG will be used as input to the Rolling Review of Requirements (RRR) process of the WMO Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE).



## Establishing Observation Plans

In respect to fulfilling these commitments, member agencies are requested to develop mission specific implementation steps incorporating satellite acquisition/observation planning, along with appropriate data processing and product distribution strategies.

Agency Members shall participate in the joint development and inter-agency coordination of mission specific plans with due consideration of:

- existing in-situ observing system infrastructure (e.g. [GCW CryoNet](#))
- time-space distribution of planned in-situ and air-/ship- borne campaign activities (e.g. [MOSAIC](#))
- individual agency mandates and resources, including space-segment and ground-segment assets.

## Products and Product Distribution strategies

Space Agencies are called on to archive acquired image data together with appropriate metadata to facilitate basic data discovery, and to ensure their sustained long-term accessibility. Meanwhile, space agencies are called upon to embrace free and open data access to specific image or derived product datasets within the scope of the respective mandates of the member agency, such as to facilitate their broad disciplinary usage.

Space agencies are encouraged to harmonise best practices for product quality control (e.g. [QA4EO](#)), to apply appropriate validation procedures, reprocessing, and to provide media updates of essential cryospheric data sets. In this respect, links to the core network of Global Cryosphere Watch *CryoNet* sites shall be strengthened, to facilitate the necessary reference measurements needed for validation, multi-satellite product intercomparisons and quality assessment.

## Evaluating Observation Gaps

In relation to the user needs, and capabilities of ongoing and planned missions Agencies are called on to periodically evaluate gaps in existing observing system capabilities. Gaps or weaknesses in existing capabilities can be brought to the attention of CEOS and CGMS through the respective PSTG interfaces, coupled with establishment of plans for development of new technical capabilities for cryosphere observations accordingly.

## Measures of Success

Positive indicators of success in the near-term include the initial development and realisation of consolidated inter-agency plans in response to well documented, and consolidated sets of user requirements, in the areas of the high level strategic science goals, as well as the development of the interfaces and interaction between PSTG and GCW.

It is proposed to review PSTG progress against the strategic scientific goals on a 4 year timescale in the year directly preceding each WMO Congress, and to identify the scientific products and scientific progress which would not have happened or been feasible without PSTG interagency coordination.

## 6. Strategic Priorities 2015-2018

The following strategic priorities are established, in alignment with the existing consolidated user requirements and broad scientific foci identified in Section 4.

PSTG place priority on achieving coordinated space-based observations of the elements of the polar regions and cryosphere identified in the following sub-sections, at the appropriate time and space scales, and where feasible collocated with airborne and/or ground-based measurements. These priority needs will be addressed by exploiting microwave imaging radar, microwave radiometer, altimeter, scatterometer, optical imagery, lidar, gravimeter and other relevant data sources, as relevant.

### Permafrost

For addressing the scientific requirements for studying permafrost and related parameters (Bartsch and others, 2014), to:

- Establish coordination and acquisition planning needed to achieve routine high-resolution circumpolar coverage for monitoring variability in carbon pools
- Establish multi-sensor monitoring around key research locations where GTN-P and in-situ measurements are made (“cold spots”) (supplement existing T-SAR-X acquisitions; 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
- Quantify rates of pan Arctic coastal erosion (Annual circumpolar Arctic coastline mapping at < 10m optical resolution; 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)
- Derive SAR DEM and custom land surface classification map suitable for permafrost community needs
- Use snow extent/snow-water equivalent (SWE), frost depth, soil moisture, and Land Surface Temperature (LST), products developed elsewhere.

### Floating Ice

For addressing the scientific requirements for studying floating ice and related parameters (Falkingham and others, 2014), to:

- Establish a multi-agency plan for acquiring contiguous (seamless) six days repeat pan-Arctic SAR imaging at consistent polarization combination (with view to expanding to an intermediate goal of less than three days repeat in future with right-looking Sentinel-1 (S-1), RADARSAT

Constellation Mission (RCM), etc.; and subsequently sub-daily data with C-, X-, S-, L-band SAR combined data sources)

- Establish Arctic Tundra lakes and river monitoring sites, as extension of sea ice coverage.
- Assure continuity in all-weather ice concentration and extent (DMSP SSMIS; AMSR-E; GCOM-W AMSR2), ice motion (RADARSAT-2; S-1; and RCM) and ice thickness data (AVHRR, MODIS, CryoSat-2; SMOS, VIIRS, Sentinel-3; and ICESat-2) in support of the sea-ice climate data time series, to secure the sea-ice Essential Climate Variable (GCOS, 2010)
- Coordinate with field campaigns, ice camps and drifting buoys (e.g. IABP, IPAB) to maximise synergies and product validation possibilities (and uncertainty estimates).

## Snow

For addressing the scientific requirements for studying terrestrial snow, snow melt and related parameters (Luoju and others, 2014, and Small and others, 2014), to:

- 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
- Plan SAR data as complement to passive microwave (AMSR-E; AMSR2) and >500m optical data (MODIS, Sentinel-3 OLCI, SLSTR) for continental scale snow extent/SWE – and in Alpine regions and 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
- Establish common polarization/mode observation strategy between SAR missions
- Demonstrate routine snow melt data processing
- Pilot a snow melt service (seasonal snow melt/runoff/hydropower/water resource availability)
- Expand temporal/spatial revisit to operationalize services.

For addressing the scientific requirements for freshwater budget and reducing uncertainties in solid precipitation and mass balance in the polar regions, to:

- Develop new methods for snow depth retrievals on sea ice (e.g. Operation Ice Bridge)
- 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](#))

## Ice Sheets, Ice Caps and Glaciers

For addressing the scientific requirements for ice sheets and ice caps (Schuechl and others, 2013), to:

- Follow through the coordinated acquisition plan of SAR/InSAR imagery over Antarctica and Greenland, initiated in 2013 ([SAR CWG, 2013](#)).
- To extend Ice Sheet Mass Balance Intercomparison Exercise (IMBIE) beyond 2009, to reduce uncertainties in ice sheet mass balance and to reconcile altimetry, SAR and gravimetric ice sheet mass balance estimates
- To provide complementary data on ice sheet surface accumulation and albedo
- To secure continuity in gravimetry data for mass change estimates

- To develop SAR altimeter swath mapping capability and products.

For addressing the scientific requirements for glaciers and ice caps, to:

- To extend optical imaging and stereo image data for generation of digital elevation models, glacier and ice cap outlines and hypsometry
- To secure routine SAR and optical imaging of high mountain regions
- To investigate capabilities of SAR altimetry over mountain glaciers and ice caps.

## Atmosphere

For addressing the scientific requirements for improved understanding of the polar atmosphere, and cryosphere–atmosphere coupling, to:

- Expand the reception of polar winds at direct broadcast sites in the Arctic and Antarctic, both in terms of number of sites and types of data used
- Establish and demonstrate satellite Doppler wind lidar profiling capability
- Coordinate availability of satellite-based products from all sources to initialise and validate NWP models in polar regions (e.g., on sea ice extent and thickness, snow mass, surface temperature, polar winds)
- Monitor polar atmospheric composition (aerosols and trace gases such as ozone, methane and carbon dioxide) to understand impact of permafrost degradation and critical feedbacks.

## 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 the dynamic, thermodynamic and other processes (e.g. precipitation, hydrology) governing sea-ice, snow and permafrost variability.

These 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 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](http://www.mosaicobservatory.org)). Satellite observations performed during YOPP in conjunction with MOSAiC will support an improved and integrated process understanding of the atmosphere-ice-ocean systems that impacts the sea-ice mass and energy budgets. Meanwhile, the planned in-situ observations together with aircraft campaigns (e.g. [Operation Ice Bridge](#) and [CryoVEx](#)) and satellite systems would provide critical information with which to facilitate improved modelling of the sea ice, weather and Arctic climate system.

PSTG shall furthermore review of the planned missions evaluate where critical gaps exist in the polar and cryosphere observing system, particularly in relation to observing network initiatives such as the Sustaining Arctic Observing Networks (SAON), and Southern Ocean Observing System (SOOS), as well as

assessing the impact of the satellite data sets in YOPP model data assimilation and in relation to improving predictive skill. The PSTG shall, and to bring the gaps in the observing system to the attention of space agencies in CEOS and CGMS, as appropriate.

## 7. Final Remarks

Based on its achievements and support base, and strong relations to users in science and application development, the PSTG is well-placed to respond to the strategic WMO objective to support cryospheric science and the development of polar climate services. Moreover, it is set to meet the rising demand for improved knowledge and information products on the polar regions. Continuing strong engagement by space agencies in PSTG, however, remains critical for its success.

Space Agencies not yet participating in PSTG are invited to express their interest to support these activities and to enlarge collective interagency contributions in support of meeting the needs of the polar and cryosphere user community.

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## Appendix: Membership of PSTG



Agenzia Spaziale Italiana (Italy)



Centre National D'Études Spatiales (France)



Canadian Space Agency (Canada)



Chinese Meteorological Administration (China)



Deutsches Zentrum für Luft- und Raumfahrt (Germany)



European Space Agency (International)



European Organisation for the Exploitation of Meteorological Satellites (International)



Instituto Nacional de Pesquisas Espaciais (Brazil)



Japan Aerospace Exploration Agency (Japan)



National Aeronautics and Space Administration (USA)



National Oceanic and Atmospheric Administration (USA)



SRC Planeta (Russian Federation)



United States Geological Survey (USA)