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| WORLD METEOROLOGICAL ORGANIZATION \_\_\_\_\_\_\_\_\_\_\_\_\_\_ COMMISSION FOR BASIC SYSTEMS OPEN PROGRAMMME AREA GROUP ON  INTEGRATED OBSERVING SYSTEMS  Inter Programme Expert Team on  Observing System Design and Evolution  (IPET-OSDE) *Second Session* GENEVA, SWITZERLAND, 11-14 April 2016 |  | CBS/OPAG-IOS/IPET-OSDE2/Doc.7.4.2(13),REV.1  (17.01.2017)  \_\_\_\_\_\_\_  ITEM: 7.4.2(13)  Original: ENGLISH |

**Adequacy of Existing SoGs in Responding to Global Cryosphere Watch (GCW) Observing Requirements**

*(Submitted by J. Key, M. Citterio, and Secretariat)*

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| **SUMMARY AND PURPOSE OF DOCUMENT**  The document provides a discussion on the adequacy of existing statements of guidance in responding to Global Cryosphere Watch (GCW) observing requirements |

**ACTION PROPOSED**

The Meeting is invited to note the information contained in this document when discussing how it organises its work and formulates its recommendations.

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**References:** Statements of Guidance at:

<http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG>,

with some updates on the web page for this meeting: [http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html - SOG](http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html#SOG)

IGOS, 2007. Integrated Global Observing Strategy Cryosphere Theme Report - For the Monitoring of our Environment from Space and from Earth. Geneva: World Meteorological Organization. WMO/TD-No. 1405. 100 pp. (Available at [http://globalcryospherewatch.org](http://globalcryospherewatch.org/))

**DISCUSSION**

1.1 The 16th World Meteorological Congress (Cg-16) approved the development of a Global Cryosphere Watch (GCW) in 2011. GCW implementation began in 2016 following the approval of the WMO Strategic Plan 2016-2019 (Resolution 69 (Cg-17)) that recognizes Polar and high mountain regions as one of the seven WMO priorities, including operationalizing of GCW. Cg-17 decided, through Resolution 43 (Cg-17), to mainstream and implement GCW in WMO Programmes as a cross-cutting activity. Recent progress includes the design, initial site selection and approval of the core surface network, called *CryoNet*, an inventory of existing measurement practices for snow, ice, and permafrost properties, the initiation of satellite intercomparisons for snow cover, the compilation of an extensive cryosphere glossary, and the compilation of observational requirements for the cryosphere. See Doc 6.3 for an update on GCW activities.

1.2 CryoNet is the GCW core network of surface measurement stations and sites, providing timely open access to quality controlled and well documented data for research, education and applications in the fields of glaciology, climate modelling, weather forecasting, hydrology, oceanography, remote sensing, energy and water resource planning, natural hazards, ecology, climate change adaptation and mitigation, and policy making. CryoNet makes available to the science community the expertise of WMO in defining observational requirements, guidelines for measurements, and data management.

1.3 CryoNet, by including all cryosphere components, encompasses a global range of environments, geographic regions, research fields and applications. The relevant scales in time and space range from instantaneous point measurements all the way to secular ice sheet fluctuations. CryoNet sites monitor glaciers, ice sheets, ice shelves, sea ice, iceberg tracking, snowpack, solid precipitation, permafrost, river and lake ice, and carry out a range of observations encompassing near surface weather, energy and mass fluxes, and related quantities.

1.4 GCW observational requirements have not yet been finalized. Progress since IPET-OSDE1 in 2014 has been limited. GCW’s requirements are drawing on various sets of existing user requirements, notably those compiled by the scientific community and reported in the Integrated Global Observing Strategy (IGOS) Cryosphere Theme Report published in 2007. It is available at on the GCW website at <http://globalcryospherewatch.org> (in the Reference section). The IGOS Cryosphere requirements are available in a searchable table on the GCW website (<http://www.globalcryospherewatch.org/reference/obs_requirements.php>).

1.5 Requirements for satellite observations of the cryosphere have been developed by, and in partnership with, the WMO Polar Space Task Group (PSTG). PSTG user requirements documents are available at http://www.wmo.int/pages/prog/sat/pstg\_en.php#UserRequirements.

1.6 GCW’s observational requirements are part of the WMO Rolling Review of Requirements (RRR) and will be accessible through the WMO’s Observing Systems Capability Analysis and Review Tool (OSCAR). A cryosphere theme has been created in the RRR. The RRR is specified in the Manual on WIGOS (WMO-No.1160), the Guide to the Global Observing System (WMO-No. 488), and described further at <http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html>.

**2. CRYOSPHERE VARIABLES IN THE STATEMENTS OF GUIDANCE**

2.1 The cryosphere variables listed in each Statement of Guidance (SoG) and/or in OSCAR are given below. Some variables are in OSCAR for a particular application area but not in the corresponding SoG; e.g., Hydrology has sea ice cover, sea ice elevation, and permafrost entries in OSCAR but no discussion of these in its SoG. **These are *italicized* in the list below**. Note also that the application areas in OSCAR are not consistent with the 14 formal application areas and some do not have statements of guidance. Missing are the various WCRP projects, which arguably are not application areas anyway, but rather users. This issue should be discussed at IPET-OSDE2.

* **Global NWP** - Sea ice cover, sea ice type, sea ice thickness, snow cover, snow depth, snow water equivalent, sea and lake ice surface temperature, surface albedo, precipitation

**High Resolution NWP** - Sea ice cover, sea ice thickness, *sea* ***ice surface temperature***, snow cover, snow water equivalent, precipitation

* **Nowcasting and Very Short Range Forecasting** – Sea ice cover, snow cover, snow cover over sea ice, snowfall, snow depth, snow water equivalent, lake-sea-ice surface temperature; all with the same requirements as High-Resolution NWP
* **Sub-seasonal to longer Predictions**  – Snow cover, snow depth, sea ice cover, sea ice concentration, sea ice thickness
* **Aeronautical Meteorology** - Precipitation/snowfall
* **Forecasting Atmospheric Composition** – (not available)
* **Monitoring Atmospheric Composition** - (not available)
* **Providing Atmospheric Composition information to support services in urban and populated areas** - (not available)
* **Ocean Applications** – Sea ice cover, sea ice thickness, sea ice motion, ***sea ice surface characteristics***, precipitation
* **Agricultural Meteorology** – Snow cover, snow depth, ***snow water equivalent***, precipitation

**Hydrology** – Snow cover, snow depth, ***snow status (wet/dry)***, snow water equivalent, ***sea ice cover, sea ice elevation, permafrost***

* **Climate Monitoring (GCOS)** – Essential Climate Variables (ECVs; in most cases these are variable categories rather than specific properties): snow cover, glaciers and ice caps, ice sheets, permafrost, sea ice, albedo
* **Climate Applications** – (Specific variables are not listed)
* **Space Weather** - No cryosphere variables mentioned

**3. CRYOSPHERE VARIABLES IN IGOS CRYOSPHERE AND OSCAR**

3.1 The cryosphere variables listed in the IGOS Cryosphere Theme Report and in OSCAR are given in Table 1. This list constitutes most, but not all, of the snow, ice, and permafrost properties that are of interest for various applications. Their importance to each application varies considerably. Table 1 also contains some additional variables that are being considered by GCW as minimum sets of measurements.

3.2 Requirements for some variables in IGOS Cryosphere and in OSCAR vary significantly. For example, the threshold for sea ice thickness varies from 1 cm (Climate-OOPC) to 200 cm (CliC). Snow cover uncertainties range from 10% to 50% with spatial resolutions from 0.5 km to 250 km. This emphasizes the importance of identifying the application.

Table 1. Cryosphere variables for which observational requirements exist in the IGOS Cryosphere Theme Report (2007) and/or in the Observing Systems Capability Analysis and Review Tool (OSCAR). Preliminary minimum observation requirements for GCW CryoNet stations are also indicated (from GCW working documents not yet finalized).

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| **Cryosphere Element** | **Variable** | **IGOS** | **OSCAR** | **GCW CryoNet minimum**  \* Recommended measurements for CryoNet stations.  § desired measurement’. CryoNet stations need to measure at least one of these) |
| Sea Ice: | Sea ice thickness | **\*** | **\*** | **\*** |
|  | Sea ice motion | **\*** | **\*** | **§** |
|  | Sea ice deformation (divergence/convergence) |  |  | **§** |
|  | Sea ice draft |  |  | **§** |
|  | Sea ice surface characteristics | **\*** | **\*** |  |
|  | Snow depth on ice | **\*** | **\*** |  |
|  | Sea ice cover | **\*** | **\*** |  |
|  | Sea ice surface temperature | **\*** | **\*** | **§** |
|  | Sea ice extent/edge | **\*** |  |  |
|  | Sea ice concentration | **\*** |  | **\*** |
|  | Leads/polynyas | **\*** |  | **§** |
|  | Ice age | **\*** |  |  |
|  | Ridge height | **\*** |  | **§** |
|  | Melt onset, duration of melt | **\*** |  | **(see next line)** |
|  | Sea ice salinity profile (vertical) |  |  | **§** |
|  | Sea ice stratigraphy |  |  | **§** |
|  | Sea ice temperature profile (vertical) |  |  | **§** |
|  | Sea ice phenomena (dates of freeze-up, fast-ice formation/breakout, melt onset, break-up) |  |  | **\*** |
|  | Volume/Mass flux | **\*** |  |  |
|  | Sea ice elevation |  | **\*** | **\* ‘freeboard’** |
|  | Sea ice type |  | **\*** | **\*** (level/rafted/ridged & floe descriptor) |
|  | Sea ice class (pack, fast ice) |  |  | **\*** |
|  | Form of ice (floe size, fast ice width) |  |  | **\*** |
|  | Stage of ice development |  |  | \* |
|  | Sea ice stage of melting |  |  | **\*** |
| Snow (see also solid precipitation listed separately below): | Snow cover | **\*** | **\*** | **\* Snow on the ground**  **(According to WMO code 0975: State of ground with snow or measurable ice cover.)** |
|  | Snow depth | **\*** | **\*** | **\*** |
|  | Snow water equivalent | **\*** | **\*** | **\*** |
|  | Snow status (wet/dry) |  | **\*** |  |
|  | Depth of snowfall |  |  | **§** |
|  | Water equivalent of snowfall |  |  | **§** |
|  | Snow profiles(density, grain shape & size, hardness, liquid water content, salinity, temperature) |  |  | **§** |
|  | Snow chemistry |  |  | **§** |
|  | Snow surface temperature |  |  | **§** |
|  | Snow temperature |  |  | **§** |
|  | Drifting snow |  |  | **§** |
|  | Specific surface area |  |  | **§** |
|  | Air temperature |  |  | **\*** |
|  | Air humidity |  |  | **\*** |
|  | Wind speed |  |  | **\*** |
|  | Wind direction |  |  | **\*** |
|  | Incoming shortwave rad. |  |  |  |
|  | Reflected shortwave rad. |  |  |  |
|  | Incoming longwave rad. |  |  |  |
|  | Outgoing longwave rad. |  |  |  |
|  | Solid precipitation (Requires both amount and type of precipitation to be measured) |  |  | **\*** |
| Freshwater Ice (GCW Lake Ice): | ice concentration | **\*** |  | **\*** |
|  | Ice class (pack, fast ice) |  |  | \* |
|  | Ice type (level/rafted/ridged & floe descriptor) |  |  | \* |
|  | Form of ice (floe size, coastal ice width) |  |  | \* |
|  | Ice phenomena (dates of freeze-up, fast-ice formation/breakout, melt onset, break-up) |  |  | \* |
|  | Freshwater ice areal extent | **\*** |  |  |
|  | Freeze-up and break-up date | **\*** |  | \* (plus: fast ice formation, melt onset) |
|  | ice thickness | **\*** |  | \* |
|  | Snow depth on freshwater ice | **\*** | **\*** |  |
|  | Areal extent of floating/grounded ice | **\*** |  | § |
|  | stage of ice development |  |  | \* |
|  | River ice jams and dams |  |  | \* |
|  | Flooding extent caused by jams and dams |  |  | \* |
|  | River icings (aufeis) |  |  | \* |
|  | Maximum level |  |  | \* |
|  | Ice openings (leads, polynyas, cracks) |  |  | § |
|  | Ice velocity |  |  | § |
|  | Ice deformation (rafting) |  |  | § |
|  | Ice ridge height |  |  | § |
|  | Ice ridge cover (concentration of ice ridges) |  |  | § |
|  | Ice stratigraphy |  |  | § |
|  | Surface temperature (surface-air interface) |  |  | § |
|  | Sea ice temperature profile (vertical) |  |  | § |
|  | River ice jams and dams | **\*** |  |  |
|  | Flooding extent caused by jams/dams | **\*** |  |  |
|  | River icings (aufeis) | **\*** |  |  |
|  | Stage of melting |  |  | **\*** |
| Freshwater Ice (GCW River Ice): | ice concentration | **\*** |  | **\*** |
|  | Ice class (pack, fast ice) |  |  | \* |
|  | Ice type (level/rafted/ridged & floe descriptor) |  |  | \* |
|  | Form of ice (floe size, coastal ice width) |  |  | \* |
|  | Ice phenomena (dates of freeze-up, fast-ice formation/breakout, melt onset, break-up) |  |  | \* |
|  | Freshwater ice areal extent | **\*** |  |  |
|  | Freeze-up and break-up date | **\*** |  | \* (plus: fast ice formation, melt onset) |
|  | ice thickness | **\*** |  | \* |
|  | Snow depth on freshwater ice | **\*** | **\*** | \* (under ‘snow’) |
|  | Areal extent of floating/grounded ice | **\*** |  | § |
|  | stage of ice development |  |  | \* |
|  | Ice openings (leads, polynyas, cracks) |  |  | § |
|  | Ice velocity |  |  | § |
|  | Ice deformation (divergence/convergence) |  |  | § |
|  | Ice ridge height |  |  | § |
|  | Ice ridge cover (concentration of ice ridges) |  |  | § |
|  | Ice stratigraphy |  |  | § |
|  | Surface temperature (surface-air interface) |  |  | § |
|  | Sea ice temperature profile (vertical) |  |  | § |
|  | River ice jams and dams | **\*** |  |  |
|  | Flooding extent caused by jams/dams | **\*** |  |  |
|  | River icings (aufeis) | **\*** |  |  |
|  | Stage of melting |  |  | **\*** |
| Ice Sheets: | Ice sheet margin | **\*** |  |  |
|  | Grounding line | **\*** |  |  |
|  | Surface accumulation | **\*** |  | **\*** |
|  | Surface ablation |  |  | **\*** |
|  | Surface net balance |  |  | **\*** |
|  | Basal melt magnitude | **\*** |  |  |
|  | Basal melt distribution | **\*** |  |  |
|  | Surface elevation | **\*** |  |  |
|  | Surface elevation change | **\*** |  |  |
|  | Snow/Firn density | **\*** |  |  |
|  | Snow grain size and shape | **\*** |  |  |
|  | Ice sheet surface temperature | **\*** |  |  |
|  | Internal temperature | **\*** |  | **§ Ice/firn temperature profile (point)** |
|  | Gravity field | **\*** |  |  |
|  | Surface velocity field | **\*** |  | **§ (point)** |
|  | Vertical velocity variation | **\*** |  |  |
|  | Ice sheet thickness | **\*** |  | **§** |
|  | Internal layer depth | **\*** |  |  |
|  | Iceberg calving rate | **\*** |  |  |
|  | Changes in ice sheet morphology | **\*** |  |  |
|  | Ice sheet topography | **\*** |  |  |
|  | Surface melt extent | **\*** |  |  |
|  | Surface melt duration | **\*** |  |  |
|  | Ice sheet mass change | **\*** |  |  |
|  | Geothermal heat flux | **\*** |  |  |
|  | Air temperature |  |  | **\*** |
|  | Air humidity |  |  | **\*** |
|  | Wind speed |  |  | **\*** |
|  | Wind direction |  |  | **\*** |
|  | Incoming shortwave rad. |  |  | **\*** |
|  | Reflected shortwave rad. |  |  | **\*** |
|  | Incoming longwave rad. |  |  | **\*** |
|  | Outgoing longwave rad. |  |  | **\*** |
| Glaciers: | Glacier area | **\*** |  | **\*** |
|  | Glacier topography | **\*** | **\*** |  |
|  | Glacier velocity | **\*** |  | **§** |
|  | Glacier dammed lakes | **\*** |  |  |
|  | Facies, snowline | **\*** |  |  |
|  | Accumulation | **\*** |  | **\* (point),**  **§ (glacier wide)** |
|  | Surface ablation |  |  | **\* (point),**  **§ (glacier-wide)** |
|  | Glacier mass balance | **\*** |  | **\*** |
|  | Basal Ablation (point) |  |  | **§** |
|  | Glacier ice thickness | **\*** |  | **§** |
|  | Glacier volume |  |  | **§** |
|  | Glacier cover |  | **\*** | **See next line** |
|  | Glacier area |  |  | **\*** |
|  | Surface temperature | **\*** |  | **\*** |
|  | Internal temperature | **\*** |  | **§ ‘Ice/firn temperature profile (point)’** |
|  | Air temperature |  |  | **\*** |
|  | Air humidity |  |  | **\*** |
|  | Wind speed |  |  | **\*** |
|  | Wind direction |  |  | **\*** |
|  | Incoming shortwave rad. |  |  | **\*** |
|  | Reflected shortwave rad. |  |  | **\*** |
|  | Incoming longwave rad. |  |  | **\*** |
|  | Outgoing longwave rad. |  |  | **\*** |
| Icebergs: | Limit of iceberg area | **\*** |  |  |
|  | Concentration of icebergs | **\*** |  | **\*** |
|  | Iceberg position | **\*** |  | \* |
|  | Iceberg size | **\*** |  | \* (plus ‘form’) |
|  | Iceberg draft | **\*** |  | **§** |
|  | Iceberg mass | **\*** |  |  |
|  | Iceberg velocity | **\*** |  | **§ (‘motion’)** |
|  | Iceberg height (above the sea) |  |  | **§** |
|  | Iceberg width, length (at waterline) |  |  | **§** |
|  | Underwater 3D form |  |  | **§** |
| Permafrost: | Permafrost (general) |  | **\*** |  |
|  | Permafrost thermal state | **\*** |  |  |
|  | Permafrost thickness | **\*** |  |  |
|  | Permafrost distribution | **\*** |  |  |
|  | Downslope creeping velocity | **\*** |  | **§** |
|  | Annual surface elevation change | **\*** |  | **§ (multi-year timescale)** |
|  | Ground ice volume | **\*** |  | **§** |
|  | Active layer depth | **\*** |  | **\*** |
|  | Soil temperature | **\*** |  | **\*** |
|  | Surface temperature | **\*** |  |  |
|  | Rock glacier mass balance |  |  |  |
|  | Rock glacier discharge |  |  | **§** |
|  | Rock glacier spring temperature |  |  | **§** |
|  | Soil moisture | **\*** |  | **§** |
|  | Duration of thaw | **\*** |  |  |
|  | Seasonal frost heave / thaw subsidence | **\*** |  | **§** |
|  | Onset of seasonal freezing | **\*** |  |  |
|  | Duration of freeze | **\*** |  |  |
|  | Distribution of seasonal freezing | **\*** |  |  |
|  | Coastal retreat | **\*** |  | **§** |
|  | Isostatic vertical motion | **\*** |  |  |
|  | Wind speed and direction | **\*** |  | **\*** |
|  | Air temperature |  |  | **\*** |
|  | Air humidity |  |  | **\*** |
|  | Incoming shortwave rad. |  |  | **\*** |
|  | Reflected shortwave rad. |  |  | **\*** |
|  | Incoming longwave rad. |  |  | **\*** |
|  | Storm surge | **\*** |  |  |
|  | Sediment transport | **\*** |  |  |
|  | Ice scouring depth | **\*** |  |  |
|  | Subsea permafrost distribution | **\*** |  |  |
|  | Subsea permafrost thickness | **\*** |  |  |
| Precipitation: | Snowfall amount | **\*** |  | **§ (‘depth of snowfall’ and ‘water equivalent of snowfall’)** |
|  | Precipitation / Snowfall rate | **\*** |  |  |
|  | Precipitation type | **\*** | **\*** |  |
|  | Snow particle size | **\*** |  |  |
|  | Precipitation intensity at surface |  | **\*** |  |
|  | Accumulated precipitation |  | **\*** |  |
| Ice shelves: | Basal ablation |  |  | **\*** |
|  | Ice velocity |  |  | **\*** |
| Other: | Snow/ice albedo | **\*** | **\*** |  |
|  | Snow/Ice surface temperature | **\*** |  |  |

**4. SUMMARY AND RECOMMENDATIONS**

4.1 There are considerable differences between the lists of cryosphere variables from the IGOS Cryosphere Theme Report, the entries currently in OSCAR’s cryosphere theme, and those that the various application areas above have identified in their SoGs. Specific requirements, such as uncertainty and spatial resolution, for some variables in the IGOS Cryosphere Theme Report and in OSCAR vary significantly.

4.2 Recommendations are:

1. GCW will identify application areas for each variable in the IGOS Cryosphere list (Table 1 above). New application area(s) for the RRR may be suggested, and corresponding Observational User Requirements independent from existing Application Areas entered in OSCAR. Note that GCW itself is not an application area as it is too broad.
2. GCW may engage the cryosphere community to update the IGOS Cryosphere requirements. This would be a major endeavor.
3. Points of Contact of application areas and the PSTG should work with GCW to clarify their needs and to resolve any ambiguities and inconsistencies in cryosphere requirements.

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