Suggested CryoNet Objectives: for discussion

GCW-CryoNET:

3 levels: Supersite - reference site – observation sites are suggested (the classification is indicative and the labels of each class need to be adjusted considering existing classifications of various cryospheric monitoring networks [WGMS, IACS, GTN_P, ...]). It is important not to downgrade the quality rating of existing networks.

1) **Tier 1 CryoNET sites (tentative name SUPER-SITE)**

| SUPER-SITE: | CryoNET station which monitors the physical and chemical properties of all components (GCW focal areas) of the local cryosphere in its full complexity and at the highest quality standards as well as the interaction of local/regional atmosphere. It has established linkages to satellite observations and to other disciplines such as hydrology, oceanography, ecology etc.). In many cases the stations are supported by more than one research agency, have strong scientific supporting programme and provide facilities for intensive campaigns. Super-sites are stations/observatories with on-site personal for maintaining the monitoring and scientific experiments. Super-site is a “high-level seal” of WMO-GCW for cryospheric observations similar as GAW global station. |

**Aims:**
a) Monitoring of changes of the physical and chemical properties of the cryosphere with respect to changes of the atmosphere (climate) and including interactions between different components of the cryosphere
b) Linkage of ground truth with satellite observations (ground truth, calibration, merge both information ...) in order to monitor the global cryosphere at high spatial and temporal scale
c) Estimation of the impact of changes of cryosphere on hydrology, water management, ecology, ...
c) Extensive datasets for cryospheric modelling approaches (validation, calibration)
c) Training of personal for cryospheric observations
d) Extensive information to the public

**Standards for measurements:**
Atmosphere: WMO, GAW, BSRN
Snow: IACS, WMO
Glaciers: IACS, WGMS/NSIDC, GTN-G
Permafrost: GTN-P
Lake/river ice: ???
Sea ice: ???

**Data availability:** real-time or near real-time

**Monitoring components:**
Atmosphere: SW-, LW-radiation, air pressure, air temperature, humidity, wind speed, wind direction, precipitation, aerosols, trace gases, ...
Snow: depth, SWE, snow temperature, snow density, stratigraphy, snow chemistry, share of solid
precipitation
Glacier/Icecap: winter-, annual mass balance, glacial discharge, surface velocity, ice thickness, stream flow water chemistry, stream flow water temperature, sediment
Permafrost: borehole temperature, active layer thickness, water chemistry, discharge
Lake/river ice: ice thickness,
Sea ice:

2) **Tier 2CryoNET sites (tentative name REFERENCE-SITE)**

| REFERENCE-SITE: | (=Cryonet station monitoring at least 1 component of the cryosphere at the level of reference site of relevant network organisation as e.g. WGMS for glaciers, GTN-P for permafrost etc.) |

**Aims:**
a) Monitoring of changes of the physical and chemical properties of the cryosphere
b) Extensive datasets for cryospheric modelling approaches
c) Training of personal for cryospheric observations
d) Information to the public

**Standards for measurements:**
According to the cryospheric parameter the relevant network determines the standard (e.g. IACS for glaciers and snow, GTN-P for permafrost etc.)

**Data availability:** dependent on cryospheric component, determined by relevant network-organisation

**Monitoring components:**
dependent on cryospheric component, determined by relevant network-organisation

3) **Tier 3CryoNET sites (tentative name OBSERVATION-SITE)**

| OBSERVATION-SITE: | (=Cryonet station monitoring at least 1 component of the cryosphere at the level of accepted GCW standards) |

**Aims:**
a) Monitoring of changes of the physical and chemical properties of the cryosphere
b) Datasets for cryospheric modelling approaches
d) Information to the public

**Standards for measurements:**
According to the cryospheric parameter the relevant network determines the standard (e.g. IACS for
glaciers and snow, GTN-P for permafrost etc.)

**Data availability:** dependent on cryospheric component, determined by relevant network-organisation

**Monitoring components:**
dependent on cryospheric component, determined by relevant network-organisation
ANNEX 8 from protocol of GCW Implementation meeting 1

IDEAS ON MONITORING STATIONS IN CRYONET (FINLAND)

A8.1 Finnish Meteorological Institute (14 Nov. 2011)

The focus here is on seasonally-snow covered, terrestrial (non-mountainous) cryosphere (boreal forest and sub-arctic zones). Regarding the monitoring of snow cover, the network should cover different snow regimes of the world. They are listed in Table 1 following the article: Sturm, M., Holmgren, J., and Liston, G. (1995), A seasonal snow classification system for local to global applications, *Journal of Climate*, 8:1261-1283.

Table 1: Snow classes to be included (and excluded) in target areas of the Phase 1 of the mission with a 3-day repeat cycle, classes and their description according to Sturm et al. (1995).

<table>
<thead>
<tr>
<th>Snow coverclass</th>
<th>Typical characteristics</th>
<th>Indicative range of max. SWE before melt (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tundra</td>
<td>A thin, cold and wind blown snow cover; high density</td>
<td>40 - 280</td>
</tr>
<tr>
<td>Taiga</td>
<td>Thin/moderate depth cold snow cover with low density, depth hoar typical</td>
<td>80 – 300</td>
</tr>
<tr>
<td>Alpine</td>
<td>A deep snowpack with intermediate to cold temperatures, some wind crust and some melt-refreeze effects</td>
<td>200 – 750</td>
</tr>
<tr>
<td>Maritime</td>
<td>A warm deep snow cover, melt features very common</td>
<td>250 – 1700</td>
</tr>
<tr>
<td>Ephimeral</td>
<td>A thin, very warm snow cover</td>
<td>0 – 150</td>
</tr>
<tr>
<td>Prairie</td>
<td>A thin (except in drifts) moderately cold snow cover. Wind effects.</td>
<td>0 – 180</td>
</tr>
<tr>
<td>Mountain (specialclass)</td>
<td>Highly variable snowcover</td>
<td>-</td>
</tr>
</tbody>
</table>

A8.1.1 Parameters to be monitored at supersites

Continuous automatic data (distributed observations covering, for example, different ecosystems/soil/land cover types)

- Soil moisture profiles (distributed)
- Soil temperature/soil frost profiles (distributed)
- Snow depth and/or SWE (distributed)
- Snow temperature profiles (distributed)
- Automatic synoptic weather station observations (including temperature 2 m, temperature ground, dew point temperature, air pressure, air relative humidity, wind
speed, wind direction, precipitation, cloud height, amount of clouds, visibility, snow depth, prevailing weather code)
  o Radiation observations (incoming and reflected)
  o Distrometer observations on precipitation
  o Atmospheric soundings (troposphere and stratosphere)
  o CO2 and/or methane fluxes between the atmosphere and soil-vegetation system (preferably for different ecosystems)
  o Watertable depth on wetlands

*Regular manual observations*

  o SWE and snow depth on snow pits (forest and bog sites)
  o Snowpack layering and snow grain size on snow pits (visible snow grain size observations/photography and/or SSA measurements)
  o Soilfrost depth
  o Snow surveys (snow courses with a preferable length of some kilometres)

*Optionally*

  o Specific reference measurements for Earth Observation (EO) instruments (e.g. reference systems of cryosphere monitoring satellite instruments)
  o Aerosol optical depth
  o Energy fluxes (sensible, latent and soil heat), evaporation/transpiration and soil respiration.

**A8.1.2 Parameters to be monitored at regular sites**

*Continuous automatic data*

  o Soil moisture profiles
  o Soil temperature/soil frost profiles
  o Snow depth and SWE
  o Snow temperature profiles
  o Automatic synoptic weather station observations
  o Radiation observations (incoming and reflected)

*Regular manual observations*

  o SWE and snow depth on snow pits (forest and bog sites)
  o Snowpack layering and snow grain size on snow pits (visible snow grain size observations)
  o Snow surveys (snow courses with a preferable length of some kilometres).

**A8.2 China (High Asian Cryosphere)**

The State Key Laboratory for Cryospheric Sciences has summarized their ECV measurements for the cryosphere and also identified gaps. Examples are below.
An Example of Observed ECVs and methods Used: Glacier

<table>
<thead>
<tr>
<th>Component</th>
<th>ECVs</th>
<th>Methods (manual/auto)</th>
<th>accuracy</th>
<th>Standard method recommended</th>
</tr>
</thead>
</table>
| Glacier           | Massbalance                                    | ● stake/snowpit (manual)  
                                 ● waterbalance (manual/auto)  
                                 ● Geodetic survey (alitmetry, in-situ survey, stereography, DEM) (manual/Auto) | ● 5 mm ~ 20 mm  
                                 ● 10 mm ~ 100 mm  
                                 ● -               | Stake/snowpit |
|                   | Surfaceicevelocity                             | ● In-situ survey (theodolite, all-station, RTK-GPS (manual)  
                                 ● InSAR (auto)  
                                 ● Sub-pixel methods (auto) | ● 1 mm ~ 1 m  
                                 ● -              
                                 ● variable       | In-situ survey |
|                   | Area                                           | ● in-situ geodetic (manual)  
                                 ● stereography (manual)  
                                 ● remote sensing (auto) | ● 1 mm ~ 1 m  
                                 ● Instrument depends  
                                 ● variable        | in-situ geodetic |
|                   | Thickness                                      | ● ice-penetrating radar (manual)  
                                 ● DEM (SAR, in-situ geodetic, stereography, remote sensing) (manual/auto) | ● ~ 5m               | Ice-penetratingradar |
|                   | Icetemperature                                 | 20m quartztemperature sensor (manual/auto) | 0.1°C                                           | 20m quartztemperaturesensor(auto) |
|                   | Meltwaterrunoff                                | Hydrological section survey (manual/auto) | Instrument depends                              | Hydrological section survey (manual/auto) |
|                   | Surfaceenergybalance                           | AWS (auto)            | Instrument depends                              | AWS                         |

An Example of Gaps in ECV Measurements: Freshwater Ice

<table>
<thead>
<tr>
<th>Applications</th>
<th>Essential Cryospheric Variables (ECV) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>River ice</td>
<td>Length of frozen river, thickness, frozen date, break-up date, snow cover on ice, concentration, types, roughness, ice volume, width, flow velocity</td>
</tr>
<tr>
<td>Lake ice</td>
<td>Frozen date, break-up date, thickness, snow cover on ice, concentration, temperature, salinity, surface energy balance</td>
</tr>
</tbody>
</table>

Bold: operated ECVs