A Global Cryosphere Watch Initiative
– for improving *in-situ* snow observations and their access
– for rescuing/collecting historical *in-situ* snow data

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Rationale:

- Snow cover is a major component of hydrological resources in North America, Northern Eurasia, Mediterranean countries, and Asian and South-American river basins including high mountain regions.
- Snow cover is a major source of positive climate feedbacks (e.g., ice-albedo feedback).
- Snow cover is a very sensitive indicator of climate change.
- Snow cover strongly impacts surface meteorological conditions.
- There remain large uncertainties in snow water equivalent (SWE) and snow depth (SD) satellites retrievals. These uncertainties are significantly reduced when ground-based snow depth observations are assimilated.
- SD observations from synoptic weather stations are critical for the analysis of snow cover in numerical weather prediction (NWP) and reanalysis systems.
- Synoptic stations make up only a portion of available SD observations which also are provided by many climate observing networks.
- SD and snow density are critical variables for the seasonal and long-term evolution of frozen ground and permafrost.

Consequently, present, past, and future ground-based SD and SWE observations (as well as snowfall, SF) are of utmost importance for operational water resources monitoring, for climate change detection, for satellite snow products evaluation, for snow model evaluation, for meteorological reanalysis evaluation, and for climate model evaluation.

1. Improvement of the operational ground-based SD and SWE observations

During the GCW SnowWatch Workshop held in Toronto, January 2013, several issues were identified:

- Issue 1: In snow covered regions, many SYNOP messages omit SD observations when snow is not present on the ground (see Figure 1 showing the seasonal variation in the number of SD observations extracted from the ECMWF MARS server). It is therefore very difficult to unambiguously identify the onset and vanishing dates of the snowpack, making it difficult to analyse the snow cover in NWP and reanalyses systems, with an asymmetry between snow and snow-free periods. In addition, scarcity of SYNOP reports of SD (even in snow covered conditions) in large areas such as the US (Figure 2), UK, China, and southern hemisphere is an issue for NWP and other near-real time applications.

- Issue 2: Occasional errors occur in SYNOP SD observations, which impact the analysis of SD in NWP systems (see Figures 3 and 4) and in some satellite-based snow products.

- Issue 3: SD observations from automatic stations often show an offset of a few centimetres which limits the possibility to detect the onset or the vanishing dates of the snowpack.

- Issue 4: Scarcity in SWE observations collocated with SD observations, which are critical for creation of many products (hydrology / NWP analysis and others) as well as for the evaluation of satellite-based products.

To analyse and possibly solve these issues, the GCW task team has formed a working group with the following objectives:

- Issue 1: An analysis of the current situation, in links with WMO Commission for Basics Systems (WMO/CBS) and some stakeholders (climate data centres, ECMWF, National Meteorological and

Hydrological Services (NMHS), …), should lead to a rapid identification of the reasons for this issue. WG1 should identify the solutions to be implemented, probably based on the practices already existing in some countries, such as the BUFR template described below. Large regions and countries show extremely sparse SYNOP stations reporting SD. For some of these areas, however, national networks provide NRT data that could be made available on the WMO Global Telecommunication System (GTS). In Europe, an initiative from ECMWF consisted of developing a BUFR template (see Annex 1) that ECMWF member states are encouraged to use to report their national network SD data at 06UTC. European national network observations have been available on the GTS since March 2011. To this date six countries put their national SD data on the GTS in addition to SYNOP data (Sweden, the Netherlands, Denmark, Romania, Hungary, and Norway) and the data are used in the operational ECMWF snow depth analysis. This BUFR template is available to be used by WMO Member states and SD data providers to report and put on the GTS network SD data for the NWP and NRT applications communities.

- Issue 2: In priority and starting from recent examples, an analysis of the real-time availability of SD data should lead to proposals for making data from synoptic and climate networks more widely available over the GTS; e.g., the US COOP Network and others globally. This should be addressed in close relationship with WMO/CBS. With a lower priority, WG1 should make proposals for the implementation of quality control (QC) algorithms. QC algorithms could be implemented either at the level of the observation producers or at the level of data centres or users. These algorithms could be derived from those to be developed for the action on SD data rescues (see Section 2 below).

- Issue 3: Building on the experience of some operators of automatic snow observations networks, WG1 should analyse the current practices and promote a wider use of QC and correction algorithms.

- Issue 4: WG1 should analyse the current situation, in links with CBS and the concerned NMHS, which should lead to the promotion of regular ground-based SWE observations, at least over a reference network.

Tentative membership of WG:

- Co-chairs: Eric Brun (France) and Jay Lawrimore (USA)
- Julie Friddell (Canada)
- Patrica de Rosnay (ECMWF)
- Ioannis Mallas (ECMWF)
- Rick Fleetwood (Canada)
- A representative of WMO/CBS (tbd)
- An expert in observation networks from Russia (tbd)
- An expert in observation networks from China (tbd)
- An expert in climate data processing (Germany) (tbd)
- .....

2. Rescue and/or collection of ground-based SD and SWE historical data

Some ground-based SD and SWE quality-controlled data sets exist and are extensively used by the scientific community (North-America, former Soviet Union / Russia, …) but there is an immense gap between user needs and current availability of snow data of all types, due primarily to the following reasons:

- It is very difficult to access historical SD data from many European and Asian countries.
- There are large gaps in historical records of SD and SF throughout large parts of the world.
- SD quality-control is relatively weak or absent.
- Relevant meta data are unavailable.

It is likely that a huge amount of past SD observations (such as those from SYNOP messages which may be accessible through the US National Oceanic and Atmospheric Administration/National Climatic Data Center (NOAA/NCDC) as well as SD observations from other climate networks) could be rescued from paper archives or collected from existing digital datasets held in NMHS's. These observations could be subsequently quality controlled and made accessible through the GCW portal.

This represents an important effort which could be led by GCW relevant teams in partnership with the concerned NMHS and data centers (including ECMWF). Different stages are necessary:

- Establishment of a formal WMO initiative towards its national members and world data centers.
- Development of a questionnaire and subsequent distribution to the concerned organisations for the identification of potential sources of data, a first estimate of the work to be done for their processing, and level of interest.
- Establishment of an expert team or working group for the rescue and collection of historical data and development of an integrated living *in situ* snow dataset (similar to and in cooperation with existing international efforts for temperature and pressure, likely to start from the end of the 19^{th} century).
    - This step may begin with identification and focus on a single target dataset and proceed to additional datasets following establishment of an accepted rescue and processing procedure.
    - It is possible that funding may be required for staffing. The activity co-chairs would help identify potential funding sources.
- Identification and development by an expert team of quality control algorithms to be applied, based either on existing algorithms (like NSIDC quality control algorithm for FSU data) or on specific algorithms to be developed for that purpose, taking advantage of satellite products, meteorological reanalyses, and snow models.
- Selection of one or several volunteer organisations for hosting, updating, and maintaining the data sets.

Such an activity could generate one or several scientific publications and would benefit from important visibility. This could be a source of motivation for gathering the required personnel to contribute to this effort. This activity is deemed to be consistent with the GCW Implementation plan, thus we seek review and approval by WMO for its formalization.

A side-product could be identification of a list of reference stations which have a long-term historical record. Those could be considered as the core network for long-term monitoring of ground-based snow cover.

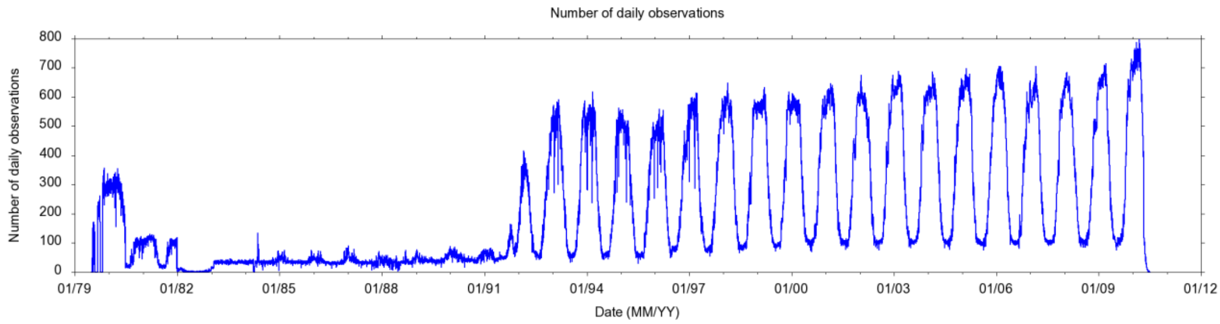

Figure 1: Number of available snow depth observations (once per day) from the ECMWF MARS (Meteorological Archive and Retrieval System) server, from 1979 to 2010.

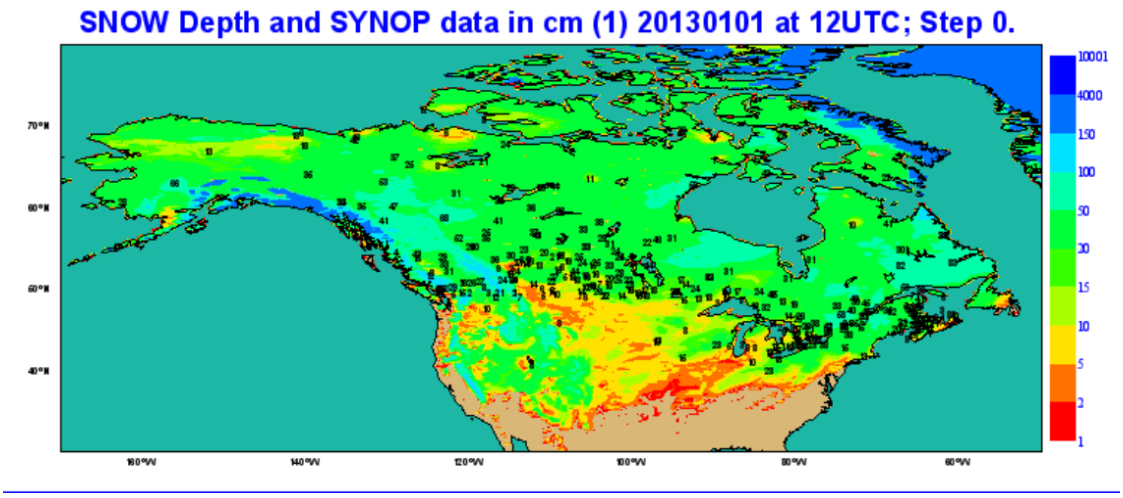

Figure 2: ECMWF snow depth analysis field and SYNOP reports on 01 January 2013 at 12UTC.

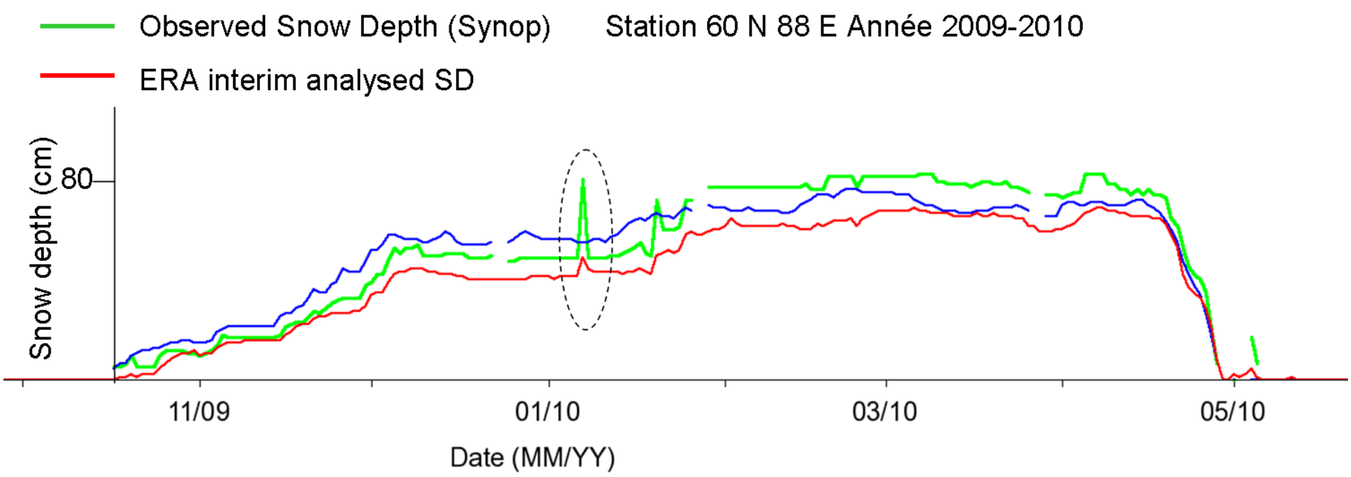

Figure 3: Evolution of snow depth during the winter season 2009-2010. An error in SD observation (green) around 7 January impacts the analysed ERA-interim snow depth (red).

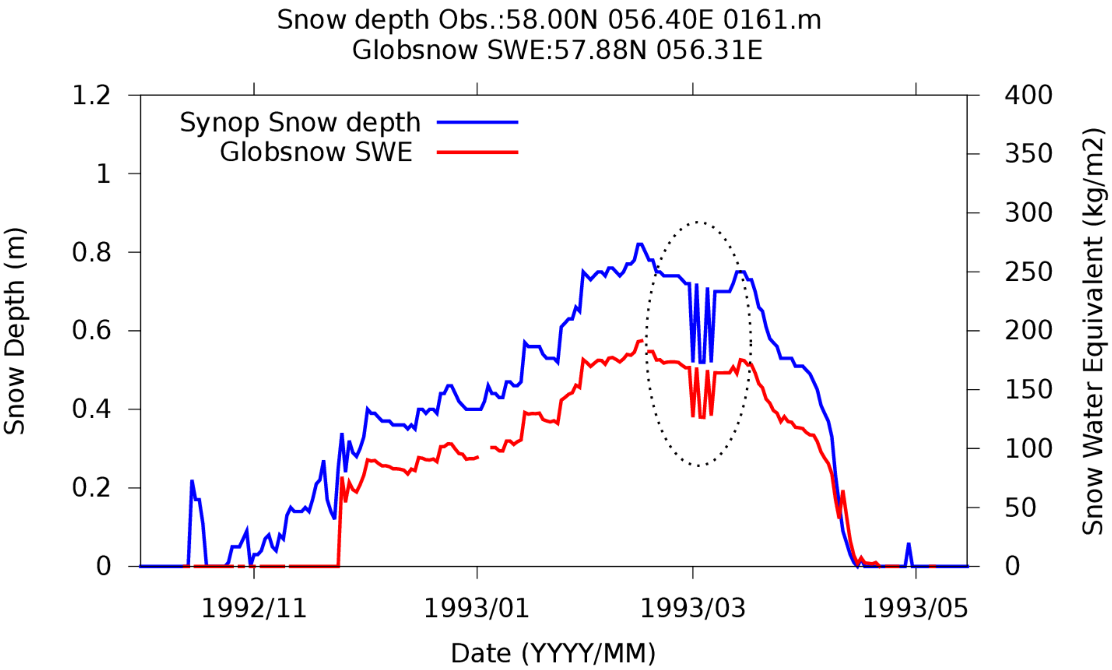

Figure 4: Evolution of snow depth during the winter season 1992-1993. An error in SD observation (blue) around 1st March impacts the Globsnow SWE (red).

Annex 1 : **Technical description of the BUFR Template**

A. GTS bulletin headers

Already used for the extra snow depth bulletin are:

COUNTRY	TTAAII	CCCC
SWEDEN	ISXD(62,63,64)	ESWI
DENMARK	ISDX97	EKMI
ROMANIA	ISMD62	YRBK
NETHERLANDS	ISND62	EHDB
NORWAY	ISXD(62,63,64)	ENMI

for Bulgaria has not determined yet, but should be
BULGARIA IS(AAii) LZSO

Those bulletins headers have to be requested from UKMO in order to be routed accordingly.

B. Template

The following template is been used from European countries they provide snow BUFR data at ECMWF. Here an example of expanded snow observation.

```
BUFR DECODING SOFTWARE VERSION -  7.2
          1 APRIL  2007.


 Your path for bufr tables is :
 /pp1/tables/bufr/000320/
BUFR TABLES TO BE LOADED  B0000000000000014000.TXT,D0000000000000014000.TXT
1
        BUFR SECTION 0

 LENGTH OF SECTION 0 (BYTES)                 8
 TOTAL LENGTH OF BUFR MESSAGE (BYTES)      4920
 BUFR EDITION NUMBER                         4
1
       BUFR SECTION 1

 LENGTH OF SECTION 1 (BYTES)         22
 BUFR MASTER TABLE                    0
 ORIGINATING CENTRE                  82
 ORIGINATING SUB-CENTRE               0
 UPDATE SEQUENCE NUMBER               0
 FLAG (PRESENCE OF SECTION 2)         0
 DATA CATEGORY                        0
 DATA SUB-CATEGORY                    0
 LOCAL DATA SUB-CATEGORU              0
 VERSION NUMBER OF MASTER TABLE      14
 VERSION NUMBER OF LOCAL TABLE        0
 YEAR                              2011
 MONTH                                5
 DAY                                  1
 HOUR                                 6
```

MINUTE 0
SECOND 0

BUUKEY : KEY DEFINITION NOT KNOWN

PRTKEY : RDB KEY NOT DEFINED IN SECTION 2.
1
BUFR SECTION 3

LENGTH OF SECTION 3 (BYTES) 44
RESERVED 0
NUMBER OF DATA SUBSETS 82
FLAG (DATA TYPE/DATA COMPRESSION) 128

DATA DESCRIPTORS (UNEXPANDED)

1 001101
2 001102
3 001019
4 002001
5 004001
6 004002
7 004003
8 004004
9 004005
10 005001
11 006001
12 007030
13 007032
14 012101
15 007032
16 002177
17 020062
18 013013

DATA DESCRIPTORS (EXPANDED)

1 001101 STATE IDENTIFIER
2 001102 NATIONAL STATION NUMBER
3 001019 LONG STATION OR SITE NAME
4 002001 TYPE OF STATION
5 004001 YEAR
6 004002 MONTH
7 004003 DAY
8 004004 HOUR
9 004005 MINUTE
10 005001 LATITUDE (HIGH ACCURACY)
11 006001 LONGITUDE (HIGH ACCURACY)
12 007030 HEIGHT OF STATION GROUND ABOVE MEAN SEA LEVEL (SEE NOTE 3)
13 007032 HEIGHT OF SENSOR ABOVE LOCAL GROUND (OR DECK OF MARINE PLATFORM)
14 012101 TEMPERATURE/DRY-BULB TEMPERATURE
15 007032 HEIGHT OF SENSOR ABOVE LOCAL GROUND (OR DECK OF MARINE PLATFORM)
16 002177 METHOD OF SNOW DEPTH MEASUREMENT
17 020062 STATE OF THE GROUND (WITH OR WITHOUT SNOW)
18 013013 TOTAL SNOW DEPTH

```
STARTING SUBSET TO BE PRINTED :  ENDING SUBSET TO BE PRINTED :
    1 STATE IDENTIFIE     0.6430000000E+03 CODE TABLE 1101
    2 NATIONAL STATIO     0.1101494000E+08 NUMERIC
    3 LONG STATION OR     0.1032000000E+04 CCITTIA5              KALVTRASK

    4 TYPE OF STATION     0.1000000000E+01 CODE TABLE 2001
    5 YEAR                0.2011000000E+04 YEAR
    6 MONTH               0.5000000000E+01 MONTH
    7 DAY                 0.1000000000E+01 DAY
    8 HOUR                0.6000000000E+01 HOUR
    9 MINUTE              0.0000000000E+00 MINUTE
   10 LATITUDE (HIGH      0.6466917000E+02 DEGREE
   11 LONGITUDE (HIGH     0.1980444000E+02 DEGREE
   12 HEIGHT OF STATI     0.2650000000E+03 M
   13 HEIGHT OF SENSO     0.2000000000E+01 M
   14 TEMPERATURE/DRY             MISSING K
   15 HEIGHT OF SENSO             MISSING M
   16 METHOD OF SNOW      0.0000000000E+00 CODE TABLE 2177
   17 STATE OF THE GR     0.0000000000E+00 CODE TABLE 20062
   18 TOTAL SNOW DEPT     0.0000000000E+00 M
```

C. Documentation

Use BUFR/CREX format checker

http://www.ecmwf.int/products/data/d/check/

to verify WMO BUFR/CREX templates used to create data for GTS exchange

For any question concerning encoding and distribution issues contact Ioannis Mallas (Ioannis.Mallas@ecmwf.int) or Patricia de Rosnay (Patricia.Rosnay@ecmwf.int)