EUROPEAN SNOW BOOKLET – AN INVENTORY OF SNOW MEASUREMENTS IN EUROPE

Anna Haberkorn1*, Charles Fierz1, and Christoph Marty1

1 WSL Institute for Snow- and Avalanche Research SLF, Davos, GR, Switzerland

ABSTRACT: The “European Snow Booklet” (ESB) is a book of reference for snow measurements that is produced in the framework of the European Cooperation in Science and Technology (COST) Action ES1404 HarmoSnow. The ESB is a unique collection of information about current operational snow observations in the European countries and what methods are used to perform basic measurements of snow on the ground: snow depth (HS), presence of snow on the ground (PSG), depth of snowfall (HN) and water equivalent of the snow cover (SWE). Numerous institutions of 38 European countries provided detailed information on their operational snow measurement networks. Similarities and differences between the countries, that is, the spatial and altitudinal station distribution, or the methods applied are pointed out, indirectly showing the relevance of snow for each country. The ESB will therefore improve the awareness of both the scientific community and operational services dealing with snow measurements, as well as of the general public with regards to different basic snow measurement methods applied in each European country. Thus the ESB aims at a better knowledge transfer between all these communities, also fostering a large network of researchers and practitioners from all parts of Europe.

KEYWORDS: COST Action, harmonisation of snow measurements, snow measurement methods, spatial distribution of snow measurements in Europe.

1. INTRODUCTION

Practitioners and researchers worldwide have developed different best practices for snow-related in-situ measurements. The bulk of these guidelines are alike throughout the world, but local particularities are often included. These regional practices lack harmonisation and thus hamper further developments, such as numerical weather prediction models, remote sensing applications and spatial analysis, used in hydrological and climatological applications. Besides the need to harmonise practices across borders, there is a strong interest in both the operational and the scientific communities in using data that can be interpreted the same way at the global level for easy data and knowledge exchange. Consistency is essential! The European Union COST Action ES1404 “A European Network for a Harmonised Monitoring of Snow for the Benefit of Climate Change Scenarios, Hydrology and Numerical Weather Prediction“, which is henceforth referred to as HarmoSnow (www.harmosnow.eu) therefore aims to harmonise practices and standards applied to snow measurements as well as to build a better connection between snow measurements and models and between observers and researchers.

The “European Snow Booklet” (ESB) is a reference book of the national operational snow measurements in many European countries that has been produced within the framework of the COST Action HarmoSnow. Along with the foundation of national weather services in the 19th century, operational snow monitoring networks were set up to perform snow observations on a regular basis. Despite the fact that some long-term snow records are available, little is known about the measurement principles which are used today at the inter-European level. Therefore, the aim of the ESB is to improve the current knowledge and awareness of both the scientific community and the operational services dealing with snow measurements, as well as the general public, with regards to different basic snow measurement methods applied in each European country. This is an important issue because the European snow science community currently lacks knowledge about which European countries operationally measure snow, not to mention which snow variables are measured with which methods.

A large network including both researchers and practitioners from all parts of Europe has been established within the COST Action HarmoSnow, thus closing the gap between research and applied sciences. The ESB is an essential contribution and a valuable dissemination product of the COST Action HarmoSnow beneficial for all actors involved in snow-related research and

* Corresponding author address:
Anna Haberkorn, WSL Institute for Snow- and Avalanche Research SLF, Davos, Flueelastrasse 11, CH-7260 Davos Dorf, Switzerland; tel: +41 81-4170-213; fax: +41 81-4170-110 email: haberkorn@slf.ch
operational services, not only from the western but also from the eastern parts of Europe, including: (1) snow scientists and (2) practitioners such as observers, national meteorological and hydrological services and engineers. Further, the ESB is relevant for stakeholders interested in snow observations, i.e. those in the fields of meteorology, hydrology, climatology, avalanche warning, data assimilation and satellite product development.

The intention of the ESB is to foster better knowledge transfer between the snow science and measurement communities, as well as the general public. In this manuscript we provide insights on the operational snow measurements and methods applied in each European country (Section 2) and a comprehensive analysis and evaluation of all country data together (Section 3). Besides the aforementioned points, the ESB additionally consists of several issues related to snow observations, which are the following: (i) a detailed description of the four basic snow variables measured on the ground (HS, PSG, HN, SWE) what relies on the currently developed WMO Global Cryosphere Watch best practices for measurements of snow. (ii) Recommendations from the COST Action HarmoSnow field campaigns, including details of three SWE inter-comparison campaigns, such as lessons learnt from SWE measurements performed with different instruments by several observers. (iii) Summaries and discussions of two questionnaires performed during the COST Action HarmoSnow lifetime. These issues, however, are not presented here.

2. EUROPEAN COUNTRY REPORTS

The ESB provides a unique inventory of operational snow observations in the European countries (Fig. 1) and the methods used to perform the following four basic measurements of snow on the ground:

- Snow depth (HS)
- Presence of snow on the ground (PSG)
- Depth of snowfall (HN)
- Water equivalent of snow cover (SWE)

Information and metadata for these basic snow variables were collected through a comprehensive survey, the so-called “ESB questionnaire” between August 2017 and March 2018. The ESB questionnaire was sent to one or several institutions of the following 40 European countries (Fig. 1): Albania, Andorra (AD), Austria (AT), Belarus, Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Iceland (IS), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Republic of Macedonia (MK), Republic of Moldova (MD), Montenegro (ME), the Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Serbia (RS), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH) with Liechtenstein, Turkey (TR), Ukraine (UA) and the United Kingdom (UK). Out of the 40 countries that received the questionnaire, answers were received from one or several institutions from 38 of the above-mentioned countries except Albania and Belarus (Fig. 1). In addition, information and metadata on the snow monitoring network of Russia was provided, but was not included in the analysis presented in Section 3. No information was requested from Kosovo, Malta, Monaco, San Marino or Vatican City because no contact could be established.

Based on the country-specific information provided, a “country report” was written for each European country, describing the current status of the operational snow observations and the methods used by one or several institutions. The core of the book is therefore 38 country reports. Similarities and differences among the countries, i.e. the spatial and altitudinal station distribution, the measurement interval, and the methods applied, are pointed out, indirectly showing the relevance of snow for each country. It is important to note that complete information does not exist for all countries, owing to missing metadata and the unresponsiveness of some institutions. In addition, the number of stations included in operational monitoring networks changes over time, owing to the opening and closure of stations, and consequently completeness cannot be guaranteed. Thus, rather than concentrating on the exact values presented in Figure 2, we recommend focusing on the order of magnitude of the various results. For detailed information of the European countries, we refer to the ESB, which can be downloaded upon completion from the HarmoSnow webpage (www.harmosnow.eu).
3. ANALYSIS OF COUNTRY DATA

Besides the individual country reports (Section 2), in the ESB the information collected from the different countries is additionally interlinked, bringing the data into a global context. Figure 2 shows comparisons of the number of manual snow depth, manual depth of snowfall and manual water equivalent of snow cover stations in the European countries. Only manual stations are shown because only manual measurements are performed for all three variables, because automatic depth of snowfall measurements are not considered reliable. For better readability the countries are separated into two subfigures depending on the number of stations (< 250 or > 250).

3.1 Snow depth

In all 38 European countries that contributed data, snow depth is measured operationally. The number of automatic snow depth stations (not shown) is much smaller than the number of manual stations in all the European countries except Turkey. In Figure 2 it is apparent that most stations are located below 500 m above sea level (a.s.l.), which corresponds to the relatively low mean altitude in many European countries. In addition, the fact that manual measurements are often performed in the vicinity of urban areas and less in sparsely populated mountainous regions is another contributing factor. In countries with large mountain ranges (e.g. Austria, France, Spain, Switzerland, Turkey), however, many snow depth measurement stations are located above 1000 m a.s.l. (Fig. 2). The number of automatic stations (not shown) operated in these countries is large because automatic stations need less man-power compared to manual ones, which is important in high-altitude and often remote station locations.

3.2 Depth of snowfall

Depth of snowfall is operationally measured in only 24 of the 38 European countries that contributed data, which results in a far smaller total number of depth of snowfall than snow depth stations. Depth of snowfall is only measured manually, as well as mainly at altitudes below 1000 m a.s.l.. Only few countries operate a depth of snowfall measurement network with a reasonable size compared to the area in the country that is above 1000 m a.s.l., i.e. Andorra, Austria, France, Italy, Spain, Switzerland and Turkey, and all of these countries feature large mountainous areas. Above 2000 m a.s.l. only 1.5% of all European depth of snowfall stations are located, which is a result of the increasing difficulty with measuring depth of snowfall at high altitudes, owing to e.g. stronger wind and more snow redistribution, or of the considerable expenditure of measuring depth of snowfall manually every day at high-altitude stations that are often difficult to reach.

3.3 Water equivalent of snow cover

Water equivalent of snow cover is measured mainly manually and rarely automatically (not shown) for operational purposes in 29 of the 38 European countries that contributed data. Although SWE measurements are important, the total number of SWE stations in all European countries is only half the total number of depth of snowfall stations and less than one-third of the total number of snow depth stations, because manual observations are time consuming and labour intensive. In most countries water equivalent of snow cover is mainly measured manually below 1000 m a.s.l., but Austria, France, Italy, Spain, Switzerland and Turkey also have a wealth of SWE stations located above 1000 m a.s.l. (Fig. 2). The number of SWE stations decreases strongly above 2000 m a.s.l., where only France and Spain have a
relatively large number of automatic SWE stations (not shown).

3.4 Linkage among the three variables

In many countries the number of manual snow depth stations is similar to the number of depth of snowfall stations (Fig. 2), most likely because these two measurements are often performed on a daily basis in the same measurement field. As with snow depth, France and Germany are the countries with the largest depth of snowfall monitoring networks. This is not the case for SWE measurements, for which the Czech Republic and Slovakia run the most SWE stations within their snow observation networks. The number of manual measurement stations of all three variables is similar only in the Czech Republic and Slovakia, which both have a wealth of stations below 1000 m a.s.l.

In several Eastern European and Scandinavian countries only snow depth and SWE are observed, while depth of snowfall is not measured operationally (e.g. Estonia, Norway, Romania, Sweden, Ukraine). In countries where snowfall is rare, often only snow depth (e.g. Denmark, Portugal) or snow depth and depth of snowfall (e.g. Cyprus, Ireland, United Kingdom) are measured and no SWE observations are performed. In two countries, the Netherlands and Luxembourg, no manual observations are indicated with bars in Figure 2, but automatic stations are in operational use.

4. SUMMARISING REMARKS

The ESB is a comprehensive overview of operational snow observations in Europe produced through collaboration with many European snow practitioners and snow scientists. Although complete information does not exist for all countries, this inventory should be considered a great success because in many countries it is incredibly difficult to find out which institutions are responsible for operational snow measurements, to contact the correct country representatives and finally to get useful metadata of the available stations and information of the methods used to measure snow.

Figure 2: Number of manual snow depth (H), depth of snowfall (N) and water equivalent of snow cover (S) stations in countries operating (top) more than 250 stations within their manual monitoring network and (bottom) 250 or fewer stations within their SWE monitoring network. The bars are stacked by altitudinal range. In cases where no bar is shown, no manual stations are located but automatic stations may exist, e.g. (top) the Netherlands (NL) has 321 automatic HS stations; (bottom) Luxembourg (LU) has 3 automatic HS stations. The country IDs on the x-axis are explained in Section 2.

ACKNOWLEDGEMENT

We acknowledge the Swiss National Foundation for Scientific Research on behalf of COST Switzerland for funding the project “European Snow Booklet: Best Practices for Snow Monitoring” (project number: C16.0077 / IZCNZ0-174839). Further, we are thankful to the COST Action ES1404 HarmoSnow Chair Ali N. Arslan as well as the HarmoSnow participants for their valuable contributions. We are additionally grateful to the many snow practitioners from European countries who contributed nation-wide data and information about their operational snow observation networks.

Proceedings, International Snow Science Workshop, Innsbruck, Austria, 2018