



Newsletter

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FINNISH METEOROLOGICAL INSTITUTE

GlobSnow Project Overview

The main objective of the European Space Agency (ESA) Data User Element (DUE) funded GlobSnow project was the development and implementation of methodologies for producing long-term records of snow cover information at the global scale intended for climate research purposes. The efforts were focused on developing and adapting algorithms for the derivation of snow extent (SE) and snow water equivalent (SWE) information based on satellite data.

The work involved acquisition of the long-term satellite data records, development and adaptation of suitable algorithms, and the implementation of software for producing snow cover information at a global scale spanning decades. A significant challenge was presented by the volume of the satellite datasets that were required for this task. The satellite data utilized for generation of the SE product set included ESA operated ERS-2 ATSR-2 and ENVISAT AATSR records starting from 1995 and extending to the present. The satellite data applied for the generation of the SWE product included measurements from two sets of sensors: SMMR and SSM/I (onboard the Nimbus-7 and DMSP F8, F11, F13 and F17 satellites) that form a continuous set of passive microwave observations starting from 1978 and continuing to the present.

The production of the long-term SE and SWE product sets included i, development and adaptation of suitable algorithms for production of multi-year datasets; ii, evaluation and validation of the algorithms by utilizing independent reference data from across the Northern Hemisphere;

iii, development of software capable of processing the vast amounts of satellite data within the project timeframe; iv, carrying out the production of the SE and SWE time series; and v, archiving and disseminating the final SE and SWE product sets for the user community.

The GlobSnow SE product is the first daily, moderate resolution record on fractional snow cover in the northern hemisphere that has been produced from ESA ATSR-2 and AATSR measurements. The GlobSnow SE dataset complements the previous records generated with greater temporal extent but a lower spatial resolution (AVHRR 1980-2011; Zhao and Fernandes, 2009) and records with similar resolution but a shorter temporal extent (MODIS 2001-2011; Hall et al., 2002) and is a unique dataset enhancing our understanding of historical snow conditions.

The GlobSnow SWE product is the first satellite-based daily SWE dataset for the northern hemisphere that extends over 30 years. The previous existing daily SWE records have spanned a shorter time period (2002-2011; Kelly, 2009) or described the snow conditions on a monthly basis for a similar period (1978-2011; Armstrong and Brodzik, 2002). The GlobSnow SWE record utilizes a novel data-assimilation based approach for SWE estimation which was shown to be superior to the previous approaches depending solely on satellite-based data (see GlobSnow Deliverable D-1.7 - Design Justification File).

Complementary to the long-term SE and SWE time series, an operational near-real time (NRT)

snow information service was implemented which produces daily northern hemisphere maps of SE and SWE based on the same methodologies developed within the project. The efforts of GlobSnow project are thoroughly documented in the project reports. The GlobSnow product set, all the documentation and the independent validation data are available at the GlobSnow web site :

<http://www.globsnow.info>

The GlobSnow project was initiated in November 2008, and was coordinated by the Finnish Meteorological Institute (FMI). The project partners were NR (Norwegian Computing Centre), ENVEO IT GmbH (ENVEO), Finnish Environment Institute (SYKE), GAMMA Remote Sensing AG (GAMMA), Environment Canada (EC) and Northern Research Institute (Norut).

The GlobSnow project has succeeded in enhancing the state of the art in the generation of long-term data records on snow cover, based on remote-sensing measurements.



Photo: Sini Merikallio

GlobSnow Snow Water Equivalent Product Version 1.2

Over the course of the past three years, the GlobSnow snow water equivalent (SWE) project team has developed a new long-term record of SWE information at the hemispheric scale for climate research purposes. The project activities included:

1. implementation of the SWE retrieval methodology of Pulliainen (2006) complemented with the time-series melt-detection algorithm of Takala et al. (2009) for the production of multi-year SWE datasets for the Northern Hemisphere;
2. evaluation and validation of SWE estimates with independent reference data from across the Northern Hemisphere;
3. development of software for carrying out the production of the historical SWE time series and a near real time product;

4. archiving and disseminating the products for the user community.

The end result is the Final Product Set Version 1.2 (FPS v1.2) GlobSnow SWE product - the first satellite-based daily SWE dataset for the northern hemisphere that extends over 30 years. The GlobSnow SWE record utilizes a novel data-assimilation approach for SWE estimation - a complete overview of the development and validation of the GlobSnow SWE product is provided in Takala et al (2011).

Input Data and SWE Products

The GlobSnow SWE processing system combines satellite passive microwave measurements, weather station observations of snow depth, and forward simulations with a semi-empirical

snow emission model in an assimilation scheme to produce maps of SWE (in the EASE-Grid projection) over the northern hemisphere, covering all land surface areas with the exception of mountainous regions, glaciers, Iceland and Greenland (Figure 1). Between 1979 and 1987, the passive microwave measurements were acquired by the Scanning Multichannel Microwave Radiometer (SMMR on the Nimbus-7 platform); between 1987 and 2010 data were taken from the Special Sensor Microwave/Imager (SSM/I onboard various DMSP platforms). The weather station observations of snow depth were acquired from the archive of daily measurements maintained at the European Centre for Mid-range Weather Forecasts (ECMWF). SWE products are available at daily, weekly, and monthly intervals.

SWE Product Validation

The primary reference dataset for the evaluation of GlobSnow SWE retrievals was snow survey data collected across the former Soviet Union and Russia, extending from 1979 to 2009. A comparison of the reference measurements with the GlobSnow SWE FPS v1.2 weekly product show extremely good agreement (Figure 2). The root mean square error (RMSE) for SWE values ranging between 0 - 150 mm, was 32.1 mm, with a bias of +8.5 mm. These error characteristics represent significant improvement over any alternative algorithms. In order to identify any possible performance differences between different time periods, the RMSE and biases

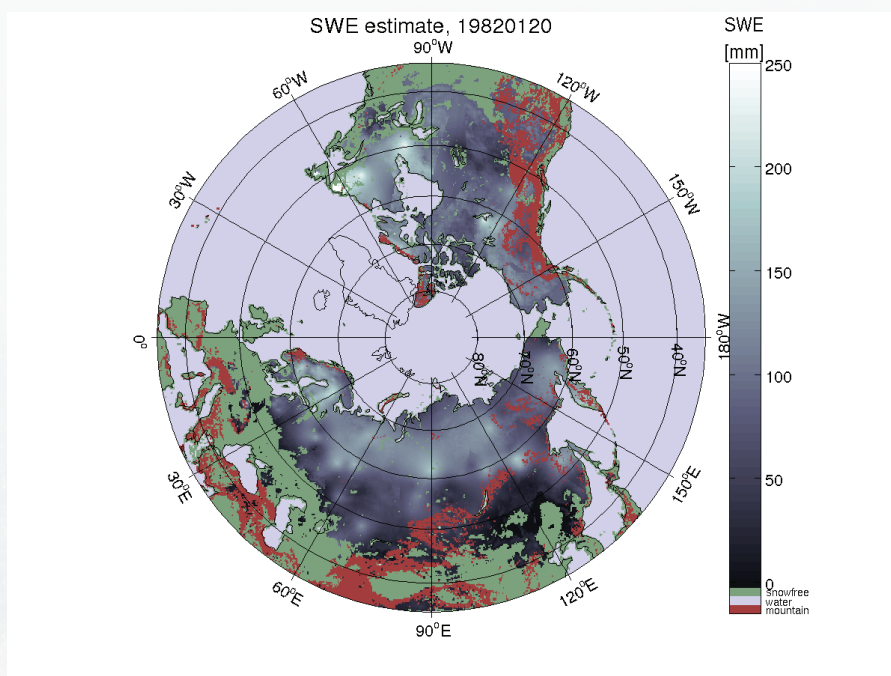


Figure 1. Example of the daily SWE product for 20 January 1982.

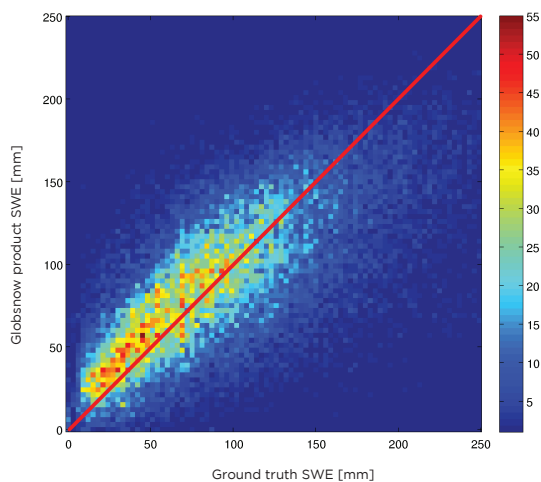


Figure 2. Density scatterplot of ground truth SWE vs. GlobSnow v1.2 SWE estimate. Color indicates number of observations within 3 mm x 3 mm bins.

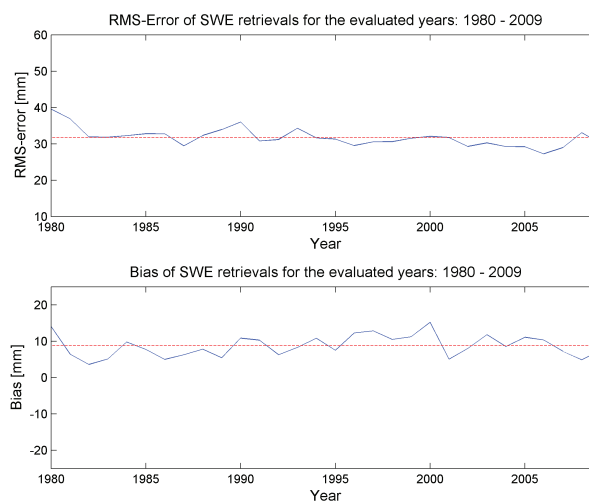


Figure 3. Time series of RMSE and bias statistics.

were calculated independently for each year. As seen in Figure 3, the error characteristics show consistent behaviour with no significantly outlying years. The GlobSnow FPS v1.2 SWE retrievals were also evaluated using Canadian reference datasets, which identified comparable statistical uncertainty compared to the evaluation over Eurasia.

Comparison with Other Gridded SWE Products

The GlobSnow SWE V1.2 product was compared with two other SWE products for the Northern Hemisphere: the Canadian Meteorological Center (CMC) daily gridded global snow depth analysis and SWE from the ERA-interim atmospheric reanalysis. Figure 3 shows the patterns of mean annual maximum SWE (1998/99 through 2009/10). The regional scale patterns are consistent between the three datasets, although the ERA estimates tend to be very high. Across the taiga and tundra zones (in both North America and Eurasia) the

GlobSnow retrievals are consistently higher than CMC. Given that the retrieval evaluation with Canadian and Eurasian reference data showed that the GlobSnow estimates tend to be biased low (particular under deep snow conditions), this suggests that the GlobSnow estimates are more realistic in these regions.

Future Work

Improvement and refinement of the GlobSnow SWE products will continue. The priority issues identified by the GlobSnow team include:

- assessment and incorporation of an improved forward model for snow emission;
- development of supplementary products including a merged SWE/snow extent dataset;
- evaluation of the potential for including SWE estimates for mountainous regions;
- continued evaluation of the SWE product with other gridded datasets.

References

- Pulliainen, J., 2006. *Mapping of snow water equivalent and snow depth in boreal and sub-arctic zones by assimilating space-borne microwave radiometer data and ground-based observations*. Remote Sensing of Environment, vol. 101, pp. 257-269.
- Takala, M., Pulliainen, J., Metsämäki, S. and Koskinen, J., 2009. *Detection of Snowmelt Using Spaceborne Microwave Radiometer Data in Eurasia from 1979 to 2007*. IEEE Transactions on Geoscience and Remote Sensing, vol. 47, no. 9, pp. 2996-3007.
- Takala, M., Luojus, K., Pulliainen, J., Derksen, C., Lemmetyinen, J., Kärnä, J.-P., Koskinen, J. and Bojkov, B., 2011. *Estimating northern hemisphere snow water equivalent for climate research through assimilation of space-borne radiometer data and ground-based measurements*. Remote Sensing of Environment, doi:10.1016/j.rse.2011.08.014.

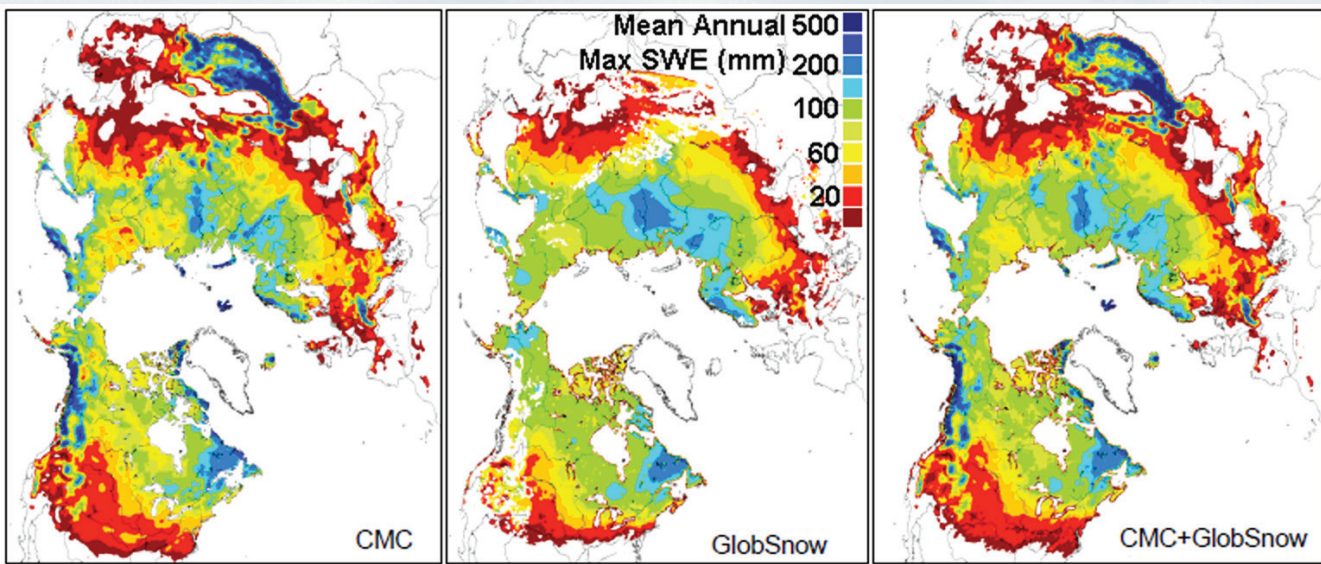


Figure 4. Mean annual maximum SWE patterns (derived from daily fields), 1998/99 - 2009/10.

GlobSnow Snow Extent Product Version 1.2

The GlobSnow SE product is the first northern hemisphere, daily, moderate resolution record on fractional snow cover that has been derived from ESA ESR-2 ATSR-2 (1995-2002) and Envisat AATSR (2002-2011) measurements. The GlobSnow SE dataset complements the previous records generated with greater temporal frequency but at lower spatial resolution (AVHRR 1980-2011) and records with similar resolution but a shorter temporal extent (MODIS 2001-2011) and is a unique dataset enhancing our understanding of historical snow conditions. Complementary to the long-term SE time series, an operational near-real time (NRT) snow information service was implemented which produces daily northern hemisphere maps of SE based on the same methodologies.

The development of the long-term SE product sets included i,

development and adaptation of suitable algorithms for production of multi-year datasets; ii, evaluation and validation of the algorithms by utilizing independent reference data from across the Northern Hemisphere; iii, development of software capable of processing the vast amounts of satellite data within the project timeframe; iv, carrying out the production of the SE time series; and v, archiving and disseminating the final product sets to the user community.

Four types of SE products

The SE products are available in a geographical (latitude/longitude) coordinate system based on the reference ellipsoid and datum WGS84, with a grid resolution of 0.01 degrees. The products cover

the Northern Hemisphere from 25°N to 84°N, which corresponds to the seasonally snow covered land areas of the Northern Hemisphere.

There are four types of SE products:

- Daily Fractional Snow Cover (DFSC), fractional snow cover (FSC in %) per grid cell for all satellite overpasses on a given day;
- Daily 4-class Snow Cover (D4SC), snow cover classified into four categories per grid cell for all satellite overpasses on a given day;
- Weekly Aggregated Fractional Snow Cover (WFSC) for all satellite overpasses within a 7-day period based on the aggregation of daily products. Available for each day based on a 7-day sliding time window giving the most recent observations highest weighting;

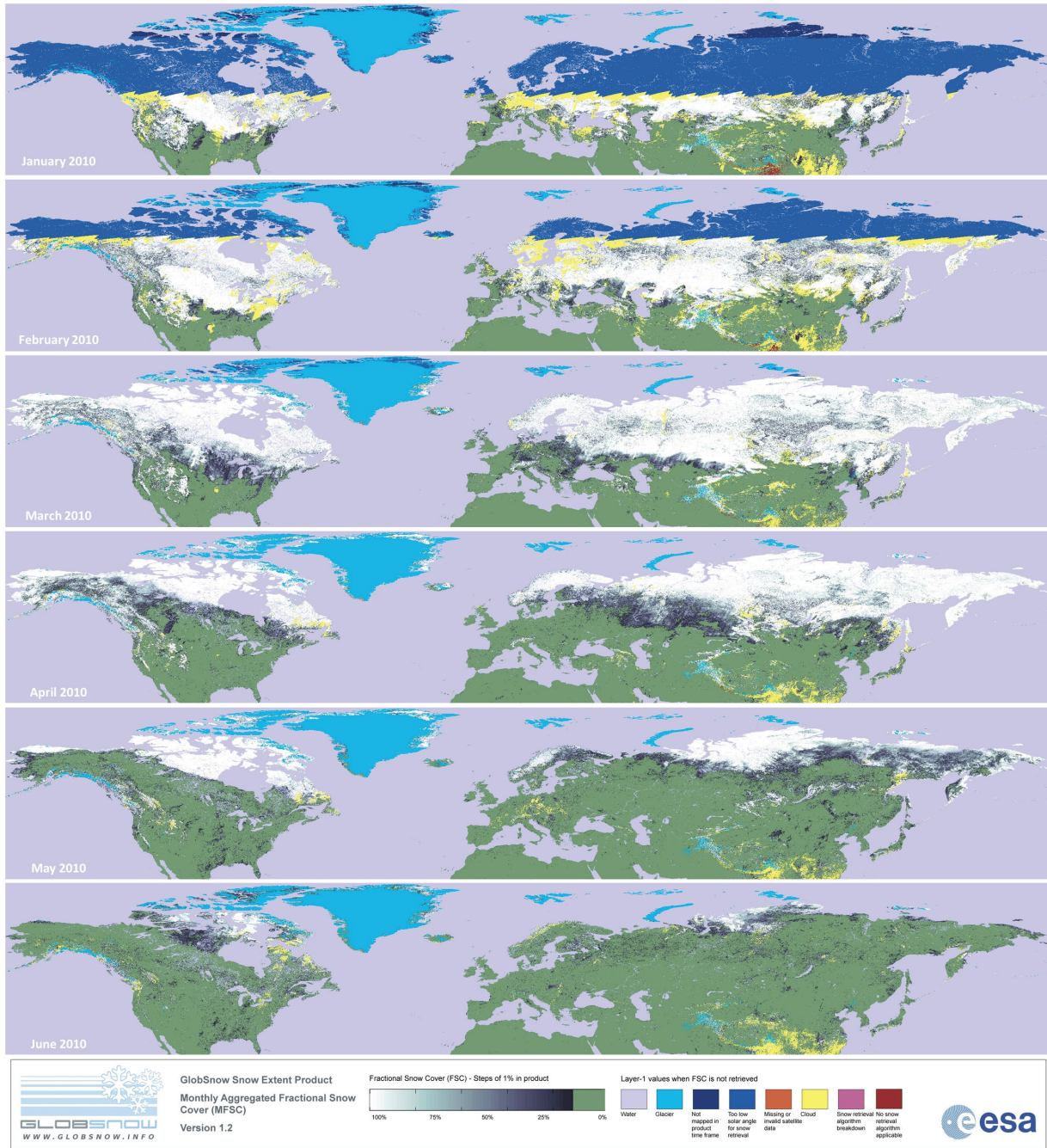


Figure 5: The Snow Extent (SE) monthly products for January until June 2010.



Photo by Sini Merikallio

- Monthly Aggregated Fractional Snow Cover (MFSC) for all satellite overpasses within a calendar month, providing the average, standard deviation, minimum and maximum FSC for the period.

Each product type includes a set of layers. For all SE products the first layer contains thematic information on the snow extent. For visualization, a common colour legend was defined. The next layers depend on the product type. The products are delivered in the netCDF CF format. Quick-look images are provided for quick and easy browsing in Portable Network Graphics (PNG) format. The products are stored at the Finnish Meteorological Institute and made freely available through both web and FTP interfaces.

Algorithms

The GlobSnow SE processing system applies optical measurements in the visual-to-thermal part of the electromagnetic spectrum. Clouds are detected by a cloud-cover retrieval algorithm (SCDA, developed for GlobSnow purposes) and masked out. Large water bodies (oceans, lakes and rivers) and glaciers are also masked out. The snow cover information is retrieved by two

algorithms, one for high-mountain areas of steep topography above the tree line (NLR) and another for forested and open areas (SCAmoD). The domains of the algorithms are determined by the thematic masks, and the retrieval results are merged. The resulting snow cover map is the basis of the generation of the four products described.

Development and validation

Project Phase 1 started by evaluating candidate algorithms for the SE product. Two algorithms were finally chosen, one for forested and open relatively flat terrain and one for mountainous terrain. The algorithms were then implemented in a laboratory system for snow mapping at the pan-European level and evaluated against other data for this larger geographical region. The laboratory system was in Phase 2 scaled up to cover the Northern Hemisphere. Some algorithm improvements were included in this version. Subsequent evaluation revealed that the cloud detection algorithm provides a reasonable cloud mask for most ground surfaces and cloud types. The snow information in the SE product was evaluated against NSIDC MODIS snow products

and Landsat data. The correspondence between GlobSnow products and MODIS snow maps as well as snow maps derived from Landsat is reasonable and in general within the uncertainty of the reference maps. Hence, SE mapping at the northern hemisphere was successful and demonstrated that maps of FSC can be retrieved at this scale. In Phase 3, further improvements were implemented resulting in better product quality and flagging of incomplete input data. The latest product release covering the full time series is Version 1.2.

The SE team

The algorithms, processing chains and products have been developed jointly by NR, SYKE, ENVEO, FMI and GAMMA. NR coordinated the SE development, developed the laboratory processing chain, and was responsible for the NLR algorithm. SYKE developed the SCDA and SCAmoD algorithms, while ENVEO evaluated the performance of the algorithms and collaborated in product improvement. GAMMA implemented the operational processing system. FMI carried out the processing of the historical time series and operates the near-real-time system for daily updates to the product time series.





FINNISH METEOROLOGICAL INSTITUTE

Project overview

The European Space Agency (ESA) funded GlobSnow project aims at creating a global database of snow parameters for climate research purposes. In addition to a historical data set comprising of 15 to 30 years of snow data an operational near-real time snow information service will be constructed. Information on two essential snow parameters: snow water equivalent (SWE) and areal snow extent (SE) will be provided. The archive and the demonstrated snow service will be based on data acquired from active and passive, optical and microwave-based spaceborne sensors combined with ground-based weather station observations.

GlobSnow consortium



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Finnish Meteorological Institute (FMI)

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ENVEO IT GmbH

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Environment
Canada

Environnement
Canada

Environment Canada (EC)

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S Y K E

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Co-operative partners



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