

# Supplementary Materials

## Review of Snow Data Assimilation Methods for Hydrological, Land Surface, Meteorological and Climate Models: Results from a COST HarmoSnow Survey

Jürgen Helmert <sup>1,\*</sup>, Aynur Şensoy Şorman <sup>2</sup>, Rodolfo Alvarado Montero <sup>3</sup>, Carlo De Michele <sup>4</sup>, Patricia de Rosnay <sup>5</sup>, Marie Dumont <sup>6</sup>, David Christian Finger <sup>7</sup>, Martin Lange <sup>1</sup>, Ghislain Picard <sup>8</sup>, Vera Potopová <sup>9</sup>, Samantha Pullen <sup>10</sup>, Dagrún Vikhamar-Schuler <sup>11</sup>, and Ali Nadir Arslan <sup>12</sup>

<sup>1</sup> Deutscher Wetterdienst (DWD), Offenbach 63067, Germany; Martin.Lange@dwd.de

<sup>2</sup> Anadolu University, Faculty of Engineering, Department of Civil Engineering, Eskisehir 26555, Turkey; asensoy@anadolu.edu.tr

<sup>3</sup> Deltares, Operational Water Management Department, Delft 2600 MH, The Netherlands, Rodolfo.AlvaradoMontero@deltares.nl

<sup>4</sup> Politecnico di Milano, Department of Civil and Environmental Engineering, P.zza L. da Vinci 32, Milano 20133, Italy; carlo.demichele@polimi.it

<sup>5</sup> European Centre for Medium-Range Weather Forecasts (ECMWF), Reading RG2 9AX, UK; patricia.rosnay@ecmwf.int

<sup>6</sup> Météo-France—CNRS, CNRM, UMR 3589, CEN, Saint Martin d’Hères F-38400, France; marie.dumont@meteo.fr

<sup>7</sup> School of Science and Engineering, Reykjavik University; Reykjavik 101, Iceland; fingerd@gmx.net

<sup>8</sup> UGA, CNRS, Institut des Géosciences de l’Environnement (IGE), UMR 5001, Grenoble 38041, France; ghislain.picard@univ-grenoble-alpes.fr

<sup>9</sup> Department of Agroecology and Biometeorology, Czech University of Life Sciences Prague, Kamycka 129, Prague 165 21, Czech Republic; potop@af.czu.cz

<sup>10</sup> Met Office, FitzRoy Road, Exeter, Devon EX1 3PB, UK; samantha.pullen@metoffice.gov.uk

<sup>11</sup> Norwegian Meteorological Institute, Oslo 0313, Norway; dagrun@met.no

<sup>12</sup> Finnish Meteorological Institute, Helsinki FI-00560, Finland; ali.nadir.arslan@fmi.fi

\* Correspondence: juergen.helmert@dwd.de; Tel.: +49-69-8062-2704

### 1. Questionnaire on using snow observation data in the modeling environment

The aim of this questionnaire is to identify and enhance the usage of snow data in numerical models. These models are used for assimilation, forcing, monitoring, validation, or verification with application in numerical weather prediction, hydrological services, in special models (e.g., road model) and reanalysis runs.

\* required information

Multiple choice

List of possible options. Allows you to select more than one option.

### 2. Personal information

Name and Surname\*

Position

Institute\*

Country\*

### 3. Modeling environment and snow observation data

Do you use snow observation data in your modeling environment?\*

Examples: NWP, Hydrology, Snow models

- Yes  
 No

### 4. Modeling environment and snow observation data

If possible, please give some reasons for not using snow observation data. \*

Examples: not enough information in real time, density of the network

### 5. Modeling environment

In which modeling environment are you using snow observation data? \*

- Numerical Weather Prediction with snow data assimilation  
 Numerical Weather Prediction without snow data assimilation  
 Hydrology (forcing using snow data)  
 Special application (e.g., road model with snow data)  
 Reanalysis using snow data  
 Other

### 6. Modeling environment

Please give a short description of your modeling environment. \*

Examples: Full NWP system with data assimilation, stream flow model.

### 7. Modeling domain

Please specify the modeling domain used in your application. \*

If you are running global and limited area/nested models with your own snow data assimilation, please fill out the form for each of the models.

- Global  
 Limited area

- One-way/two-way nesting of domains
- Other

**8. Model resolution**

Please specify the model horizontal resolution. \*

- Below 1 km
- Between 1 km and 5 km
- Between 5 km and 10 km
- Between 10 km and 20 km
- Between 20 km and 50 km
- Larger than 50 km
- Other

**9. Data assimilation questions**

I would like to answer the questions regarding data assimilation.\*

- Yes
- No

**10. Data assimilation method**

Which data assimilation method is used in your system for snow observations? \*

If "Other" is used, please give a short description or reference.

- Optimum interpolation
- Cressman analysis method
- Kalman Filter
- Ensemble Kalman filter
- Other

**11. Data assimilation update frequency**

Which update frequency is used for your snow data assimilation? \*

Example: data assimilation is running hourly or once a day

- 1 hour
- 6 hours
- 12 hours
- 1 day
- Other

**12. Data assimilation window**

During which time interval (window) are snow observations considered in your snow data assimilation? \*

Example: Observations are collected during a prescribed time interval for consideration in the assimilation cycle.

- 1 hour

- 3 hours
- 6 hours
- 12 hours
- Other

**13. SYNOP information**

Which information from SYNOP is used for your snow data assimilation? \*

Example: Snow height, SWE, Precipitation in combination with T2M-temperature

**14. Model variables**

What model state variable(s) is/are analyzed in your snow data assimilation system? \*

Example: Snow depth, snow water equivalent, snow density

**15. Processing**

How is the key parameter/ How are the analyzed variable(s) processed in your snow data assimilation system? \*

Please use "Other" to give a description if the processing differs between the horizontal and vertical directions.

- Update of absolute values
- Incremental update of first guess from model forecast
- Other

**16. Background field**

Which background field is used in your snow data assimilation? \*

- Model forecast
- Pre-Analysis
- External analysis
- Climatology
- Other

**17. Background error estimates**

Which estimates of the background error are used in your snow data assimilation?

Example: distance weighted (horizontal/vertical)

**18. Observation error estimates**

Which estimates of observation errors are used in your snow data assimilation?

**19. Observation data**

I would like to answer the questions on snow observations from WG1/WG2.\*

Please note: the WG1/WG2 questionnaire is focused on observations and the developing of instruments.

Yes

No

**20. Observation data**

Please access the questionnaire from WG1/WG2 in your own tab or window using the address: <http://costsnow.fmi.fi/index.php?page=Q1>.

The WG1/WG2 questionnaire is focused on observations and the developing of instruments.

**21. Further questions on snow observation data**

**22. Snow observations and products used in the modeling system**

Please describe the snow data sources used for the model application.

Snow observations and products\*

SYNOP

non-SYNOP ground-based

remote sensing ground-based (ultrasonic, laser)

remote sensing satellite (radiances)

remote sensing satellite (preprocessed product - SAF)

climatological datasets

Other

**23. Remote sensing ground-based**

Do you use ground-based remote sensing measurements or products\*?

Example: Snow height from ultrasonic or laser scanner.

Yes

No

**24. Remote sensing ground-based**

Please specify the system you use for ground-based remote sensing snow property measurements.\*

**25. Preprocessed product**

Do you use preprocessed snow products?\*

Example: H-SAF or Land-SAF snow products

Yes

No

**26. Preprocessed product**

Please specify the system you use for preprocessed product of snow properties.\*

Example: H-SAF or Land-SAF products

**27. Processing—Quality control**

Do you perform quality control of snow observations or products\*?

Yes

No

**28. Processing—Quality control**

What kind of data quality control is performed? \*

Please describe the quality checks applied on observation data: Handling of missing data, data management, preprocessing (which?)

**29. Data consistency**

Do you perform a consistency check of snow observations or products? \*

Example: In order to find inconsistent data that passed quality control.

Yes

No

**30. Data consistency**

Which data consistency checks are performed in your modeling environment? \*

Connecting data: example: snow height only when snow cover is larger than zero

**31. Observation data latency**

Which observation data latency is acceptable for your modeling environment? \*

Example: The acceptable time needed from measurement, data transmission, storage in a database until use in a data assimilation code

- Below 1 hour
- Below 3 hours
- Below 6 hours
- Below 12 hours
- Other

**32. Access requirements**

Is it possible to exchange the snow data used in your modeling environment with other groups? \*

- Yes
- No

**33. Access requirements**

Which access requirements exist for the snow observation datasets you are using? \*

Examples: FTP access, GTS only, special data format

**34. Additional observation sources**

Do you have concrete plans to use new or upcoming observation sources that could be interesting for your modeling environment? \*

- Yes
- No

**35. Additional observation sources**

Which of the new or upcoming observation sources could be interesting for your modeling environment? \*

Example: Satellite datasets currently in development, new ground-based observation from GPS sensors, wet snow from SAR, etc.



**36. Additional observation sources**

What are the particular barriers that prevent you from using new observation sources?



**37. Additional comments and suggestions**



Please use the following text box to write down important points that are missed in the questionnaire or are not explicitly asked about.



**38. Thank you very much, once again, for your support.**