NGI Technical note

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Weather stations in Norway suitable for SNOWPACK modelling in Norway in 2016

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Review and reference page

1 Introduction

A physical SNOWPACK model developed by Swiss Federal Institute for Snow and Avalanche Research, SLF, requires following meteorological observations as input data[1] for the model simulations:

- air temperature (TA)
- relative humidity (RH)
- wind speed (VW)
- incoming short wave radiation (ISWR) or reflected short wave radiation (RSWR)
- incoming long wave radiation (ILWR) or surface temperature (TSS)
- precipitation (PSUM) or snow height (HS)
- ground temperature (TSG, if available)
- snow temperatures at various depths (TS1, TS2, etc. if available and only for comparisons)

According to the data requirements specified for SNOWPACK model, above listed parameters must be available at least at an hourly time step.

2 Glossary of meteorological elements observed in Norway, which can be relevant for the SNOWPACK model simulations

The following tables are taken from eKlima.no. They contain codes and units of measured meteorological elements at Norwegian stations. Only the elements belonging to groups mentioned in Section 1 (e.g. "Air temperature") are listed here, providing an overview of what is theoretically observed in Norway among the necessary input parameters for SNOWPACK model.

It is important to note that there are quite a lot of inconsistence and imprecision in the code descriptions. After listing all the registered codes, we chose those that are most common to be observed in Norway among those that satisfy requirements to SNOWPACK model.

[1] Acronyms for the input data are taken from SNOWPACK model description. Observed meteorological elements in Norway may have different acronyms.

Table 1 Air temperature (TA)

Code	Name	Unit
TA	Air temperature, 2 m	ºC
TA10	Temperature, 10 m	ºC
TA25	Air temperature, 25 m	ºC
TAM	Mean temperature	ºC
TAN	Minimum temperature	ºC
TAN_12	Minimum temperature (12 hours)	ºC
TAN_24	Minimum temperature (24 hours)	ºC
TAX	Maximum temperature	ºC
TAX_12	Maximum temperature (12 hours)	ºC
TAX_24	Maximum temperature (24 hours)	ºC
TA_DELTA	Vertical difference in air temperature	ºC

The most commonly observed element is TA.

Table 2 Relative humidity (RH)

Code	Name	Unit
UH	Relative humidity, manual observation	percent
UM	Mean relative humidity	percent
UN	Minimum relative humidity	percent
UU	Relative air humidity, automatic registration	percent
UX	Maximum relative humidity	percent
X1UM	Relative humidity, 60 minutes mean	percent
X1UU	Relative humidity	percent

The most commonly observed element is UU.

Table 3 Wind parameters

Code	Name	Unit
DD	Wind direction (FF)	degrees
DD2	Wind direction (FF)	degrees
DDM	Average wind direction (cf FM)	degrees
DG	Wind direction (FG)	degrees
DG2_1	Wind direction (vectorised)	degrees
DG_010	Wind direction (vectorised)	degrees
DG_1	Wind direction (vectorised)	degrees
DX	Wind direction (FX)	degrees
DX2_1	Wind direction (FX_1)	degrees
DX_1	Wind direction (FX_1)	degrees
DX_3	Wind direction (FX_3)	degrees

FF	Wind speed (10 meters above ground)	m/s
FF2	Wind speed (2 meters above ground)	m/s
FFB	Wind force in Beaufort	Beaufort
FG	Maximum gust	m/s
FG2_1	Maximum gust (2 meters above ground)	m/s
FG_010	Maximum gust last 10 minutes)	m/s
FG_1	Maximum gust (last hour)	m/s
FM	Mean wind last hour	m/s
FX	Maximum mean wind speed	m/s
FX2_1	Maximum mean wind speed (2 meter above ground)	m/s
FXB	Maximum mean wind speed (beaufort)	Beaufort
FX_1	Maximum mean wind speed (last hour)	m/s
FX_3	Maximum mean wind speed (last 3 hours)	m/s
ITZ	Time period (FX)	code
KLFG	Time (FG)	time
KLFX	Time (FX)	time
STATFFDD	Status wind sensor	code
X1DD	Wind direction	degrees
X1FF	Wind speed (10 meters above ground)	m/s
X1FG	Maximum gust	m/s
X1FG_010	Gust wind speed	m/s
X1FG_1	Maximum gust (last hour)	m/s
X1FX	Max Wind Speed (10 min mean)	m/s
X1FX_1	Maximum mean wind speed (last hour)	m/s

The most commonly observed elements are FF and DD.

Table 4 Radiation and sunshine

Code	**Name**	**Unit**
QA	Albedo	minutes
QD	Radiation, diffuse, mean over last hour	W/m2
QF	Photosynthetic active radiation	W/m2
QLI	Longwave radiation from above, mean over last hour	W/m2
QLINETINST_01	Longwave radiation, diff. betw. incoming longwave from above and instrumental, last minute	W/m2
QLI_01	Longwave radiation from above, mean over last minute	W/m2
QLO	Longwave radiation from below, mean over last hour	W/m2
QLO_01	Long wave radiation from below, mean over last minute	W/m2
QLX	Longwave radiation, maximum last hour	W/m2
QOB	Radiation balance	W/m2
QOX	Shortwave radiation from above (global radiation, maximum minute value, last hour	W/m2

QSI	Shortwave radiation (global radiation) from above, mean over last hour	W/m2
QSI_01	Shortwave radiation (global radiation) from above, mean over last minute	W/m2
QSI_010	Shortwave radiation (global radiation) from above, mean over last ten minutes	W/m2
QSO	Shortwave radiation from below, mean over last hour	W/m2
QSO_01	Shortwave radiation from below, mean over last minute	W/m2
QLONETINST_01	Longwave radiation, diff. betw. incoming longwave from below and instrumental, last minute	W/m2
QNET	Net radiation, mean over last hour	W/m2
X1QSI	Short wave radiation from above, mean over last hour, sensor 1	W/m2
OT_01	Sunshine last minute	seconds
OT_010	Sunshine last 10 minutes	seconds
OT_1	Sunshine last hour	minutes
OT_24	Sunshine last 24 hours	hours

Table 5 Precipitation (PSUM)

Code	**Name**	**Unit**
IR	Precipitation measurements	code
ITR	Precipitation period	number of
RA	Total precipitation	mm
RRVIPP	Precipitation	mm
RR_01	Intensity of precipitation	mm
RR_010	Precipitation	mm
RR_1	Precipitation (1 hour)	mm
RR_12	Precipitation (12 hours)	mm
RR_24	Precipitation (24 hours)	mm
RR_3	Precipitation 3 hours	mm
RR_6	Precipitation (6 hours)	mm
RR_X	Precipitation	mm
RTS_1		number of
RT_010	Precipitation	mm
RT_1	Precipitation time	minutes

The most commonly observed element is RR_24.

Table 6 Snow height (HS)

Code	Name	Unit
SA	Snow depth	cm
SAM	Mean snow depth	cm
SAN	Minimum snow depth	cm
SAX	Maximum snow depth	cm
SD	Snow cover	code
SIGNSTR_SHM	Snow depth	code
SS_24	Snow depth	cm
STATSA	Status snow depth sensor	code

The most commonly observed element is SA.

Table 7 Ground temperature (TSG)

Code	Name	Unit
TJ	Soil temperature	ºC
TJ0	Soil temperature	ºC

Ground temperature is rarely observed in Norway.

Table 8 Snow temperatures at various depths (TS1, TS2, etc.)

Code	Name	Unit
TSA125	Snow temperature	ºC
TSA175	Snow temperature	ºC
TSA25	Snow temperature	ºC
TSA75	Snow temperature	ºC
TSN25	Snow temperature, minimum minute-value over last hour	ºC
TSN75	Snow temperature, minimum minute-value over last hour	ºC
TSN125	Snow temperature, minimum minute-value over last hour	ºC
TSN175	Snow temperature, minimum minute-value over last hour	ºC
TSS	Temperature	ºC
TSX25	Snow temperature, maximum minute-value over last hour	ºC
TSX75	Snow temperature, maximum minute-value over last hour	ºC
TSX125	Snow temperature, maximum minute-value over last hour	ºC
TSX175	Snow temperature, maximum minute-value over last hour	ºC

To uniform the acronyms in the following Sections, we will use the acronyms given in the SNOWPACK model description, namely:

- TA for air temperature,
- RH for relative humidity (equals to UU from eKlima.no),
- VW for wind speed (equals to FF from eKlima.no),

- ISWR for incoming short wave radiation (equals to QSI from eKlima.no),
- RSWR for reflected short wave radiation (equals to QSO from eKlima.no),
- ILWR for incoming long wave radiation (equals to QLI from eKlima.no),
- TSS for snow surface temperature,
- PSUM for precipitation (equals to RR_1 from eKlima.no),
- HS for snow height (equals to SA from eKlima.no),
- TSG for ground temperature (equals to TJ from eKlima.no),
- TS1, TS2, etc. for snow temperatures at various depths (equals to TSA25, TSA75, etc. from eKlima.no).

3 Meteorological stations in Norway

There are over 3500 stations registered at eKlima.no, an open Internet portal operated by the Norwegian Meteorological Institute (MET Norway). However, the observed elements (their amount and type) at each station vary considerably from station to station.

For instance, there are plenty of stations that measure either TA and VW or precipitation (PSUM) and HS. However, stations that measure simultaneously TA, VW, PSUM and HS are much fewer. In general, there are very few stations in Norway that observe radiation.

3.1 Radiation

There are 70 active stations observing at least one of the radiation parameters from Table 4. Sixty eight of those stations (except 90450 Tromsø and 39040 Kjevik) observe incoming short wave radiation (mean over last hour; ISWR). Only 8 of them are observing also RSWR.

Presently just 8 stations are observing incoming long wave radiation (mean over last hour; ILWR), 7 of them are observing outgoing long wave radiation as well.

These two mentioned above stations – 90450 Tromsø and 39040 Kjevik – observe only sunshine in minutes during last hour among all radiation parameters, which are listed in the Table 4. Seventeen additional stations (among the 70 that are presently observing radiation), also register the sunshine.

No station in Norway is observing albedo (QA), mean value of diffuse radiation over last hour (QD) and/or photosynthetic active radiation (QF). These parameters were observed only at 17850 Ås station in the period 01.01.1990 – 31.12.2008.

Similar situation is with net radiation (QNET) and radiation balance (QOB): no Norwegian station is presently observing these elements. There are historical

observation series of QNET at 15270 Juvvasshøe (11.02.2014-31.12.2014) and at 80610 Myken (13.02.2014-31.10.2014) as well as an observation series of QOB at 17850 Ås (31.12.1989-31.12.2008).

3.2 Humidity

Relative humidity (RH) is presently observed at 66 stations out of the 70 stations, which are observing at least one of the radiation parameters from Table 4. Station 91500 Nordnesfjellet (one of the four) is observing all over necessary parameters for SNOWPACK model simulations, whereas 89985 Sjufjellet, 87000 Ånstadblåheia and 68173 Trondheim-Gløshaugen lack also records of precipitation and HS (just the latter two). 68173 Trondheim-Gløshaugen does not observe TA either.

3.3 Precipitation and snow height

Unfortunately, not all of the 70 stations, which are presently observing radiation, observe precipitation as well. Seven of the stations do not observe precipitation, even though 5 of these 7 are still observing snow height (HS). However, all the rest 63 stations (61 if excluding Tromsø and Kjevik) have active time series of precipitation measured over every hour.

Just 19 stations among the 68 stations, which observe ISWR, measure snow height, including the 5 stations, which do not observe precipitation. In other words, just 17 stations observe ISWR, PSUM and HS simultaneously in Norway.

3.4 Wind

Twenty seven stations among the 68 stations, which observe ISWR in Norway, are presently recording wind speed. Excluding the stations, which observe neither precipitation nor snow height, nor relative humidity, there are 11 stations left, which then measure ISWR, PSUM, HS, RH and VW simultaneously (Table 9).

Table 9 Meteorological stations, which simultaneously observe ISWR, PSUM, HS, RH and VW at present time

Station number	Name	Elevation
16271	HØVRINGEN II	940
16400	DOVRE-LANNEM	560
18700	OSLO - BLINDERN	94
23550	BEITOSTØLEN II	965
31620	MØSSTRAND II	977
33950	HAUKELISETER TESTFELT	990
53530	MIDTSTOVA	1162
54710	FILEFJELL - KYRKJESTØLANE	956

80610	MYKEN	17
84210	LOSISTUA	740
97251	KARASJOK - MARKANNJARGA	131

Interesting to mention that the majority of the stations are situated rather high in the mountains.

3.5 Temperature

Air temperature TA is observed at almost all stations, which presently measure at least one of the radiation parameters from Table 4 in Norway. The exception is represented by 68173 Trondheim-Gløshaugen.

When it comes to snow temperature, there are just two stations in Norway which presently observe TSS (snow surface temperature), namely 7420 Rena-Ørnhaugen (872 m.a.s.l.) and 16400 Dovre-Lannem (560 m.a.s.l.). In addition, 53530 Midstova (1162 m.a.s.l.) is observing TSN25, TSN75, TSN125 and TSN175 as well as TSX25, TSX75, TSX125 and TSX175, which are minimum and maximum minute-values of snow temperature at 25, 75, 125 and 175 cm respectively observed over the last hour.

Ground temperature (TSG) is not observed at any of the 70 stations, which presently measure at least one of the radiation parameters from Table 4 in Norway.

3.6 Stations on Spitsbergen archipelago and on Jan Mayen

There are two Norwegian stations outside mainland Norway, which observe elements required as data input for SNOWPACK model. One of the stations – 99720 Hopen – is situated at 6 m elevation in Svalbard municipality of Norway on Spitsbergen. The other station – 99950 Jan Mayen – is situated at 6 m elevation on Jan Mayen island. Both stations observe both incoming short wave and incoming long wave radiation (ISWR and ILWR) at a good resolution of 1 minute. However, precipitation at these stations is observed only every 12 hours in contrast to the required 1 hour totals. Neither of the stations observe temperature of snow nor ground.

3.7 Meteorological research stations outside the network of the Norwegian Meteorological Institute

Two station of known relevance for the SNOWPACK model simulations are described below. First of them – NGI's Fonnbu research station – is situated at 943 m.a.s.l. and has been operative since October 1974. The other one – Finse – was set up by the University in Oslo in March 2016.

3.7.1 Fonnbu

Fonnbu research station own by NGI, is registered at the Norwegian Meteorological station net as 58710 Strynefjellet-Fonnbu. However, neither the metadata nor the observed time series are available at Eklima.no. Elements observed at the NGI research station are listed in Table 10.

Table 10 Elements observed at the NGI research station Fonnbu

Code	Description
RR_ABS	Accumulated Precipitation
RR_1	Precipitation last 1 hour
RR_6	Precipitation last 6 hours
RR_12	Precipitation last 12 hours
RR_24	Precipitation last 24 hours
RR_72	Precipitation last 72 hours
RR_120	Precipitation last 120 hours
FF	Wind speed, 10 min average
DD	Wind direction for FF
FG	Wind speed, maximum 3 seconds gust since last observation
DG	Wind direction for FG
FX	Wind speed, maximum of 10 min gliding mean
DX	Wind direction for FX
BA_PR	Air pressure reduced to sea level using TA
TA_M	Air temperature (mast)
TAN_M	Air temperature, minimum last hour (mast)
TAX_M	Air temperature, maximum last hour (mast)
UU_M	Relative humidity (mast)
TS1	Snow temperature 30 cm snow height
TS2	Snow temperature 60 cm snow height
TS3	Snow temperature 90 cm snow height
QS_I	Incoming short wave radiation
QS_O	Outgoing short wave radiation
QL_I	Incoming long wave radiation
QL_O	Outgoing long wave radiation
T_CNR	Temperature of the radiation instrument
QA	Albedo = QS_out / QS_in
QO_I	Total incoming radiation QS_in + QL_in
QO_O	Total outgoing radiation QS_out + QL_out
TO	Surface temperature (calculated from QL_out)
QE	Netto radiation balance QO_in - QO_out
TA_S	Air temperature (snow field)
UU_S	Relative humidity (snow field)

SA	Snow height total
SS_1	Snow height change last hour
SS_24	Snow height change last 24 hours

Some of the elements listed above are not actually measured but calculated based on other observed elements.

Table 10 shows that NGI research station Fonnbu observes all the necessary parameters which are required as input data for SNOWPACK model simulations.

3.7.2 Finse

Close to 25830 Finsevatn and 25840 Finse, there is an experimental field managed by University of Oslo (UiO).

From March 2012 there are three operational stations at this field, installed at an elevation range between 1290 and 1340 m.a.s.l. The automatic meteorological stations observe air temperature, air humidity as well as wind speed and direction, and record the observations for every hour. The station which is situated at 1340 m.a.s.l., observes also incoming and reflected shortwave radiation (ISWR, RSWR) with the same time step of 1 hour.

Additional sensors were installed at the experimental field 17th February. The sensors measure snow surface temperature (TSS), snow height (HS) and albedo.

All the observations are recorded on hard drives connected to the stations, and the stations must be physically visited to download the data.

Since this is an active research experimental field, new sensors may be installed at close but different locations. There is a plan to install four-component radiation sensor (ISWR, RSWR, ILWR and outgoing long-wave radiation), sensors for air temperature at different heights as well as some other sensors during summer 2016.

4 Conclusion

Among over 3500 meteorological stations in the Norwegian official meteorological network, there are 11 stations (Table 9), which observe all the elements required as necessary input parameters for SNOWPACK model simulations (see Section 1). Two of the stations – 16400 Dovre-Lannem (560 m.a.s.l.) and 53530 Midstova (1162 m.a.s.l.) – observe some snow temperature elements in addition: TSS at the first one and TSN25, TSN75, TSN125 and TSN175 as well as TSX25, TSX75, TSX125 and TSX175 at the latter one.

7420 Rena-Ørnhaugen (872 m.a.s.l.) observes almost all the required elements and registers TSS as well. It does not observe HS though.

NGI's research station Fonnbu and UiO's experimental field Finse provide necessary observations for SNOWPACK model simulations.

Two Norwegian stations outside the mainland Norway are also suitable for SNOWPACK model simulations, namely 99720 Hopen (6 m.a.s.l.) and 99950 Jan Mayen (10 m.a.s.l.).

All in all, there are 16 sites in Norway, which can provide necessary observations for trustworthy SNOWPACK model simulations.

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