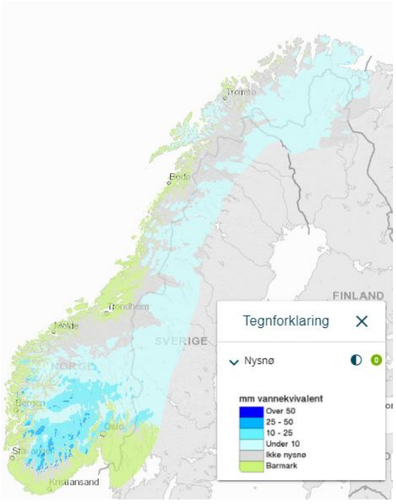
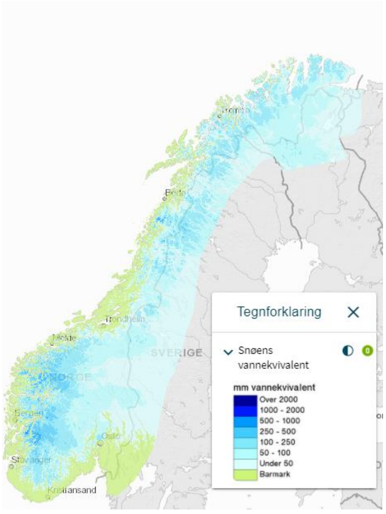
How are the snow maps in seNorge and Xgeo made?

In seNorge and Xgeo, there are several maps that give the user an overview of the snow conditions in Norway. To create the different snow maps, we use a snow model that calculates the snow conditions in each square kilometer in the country. This document explains how the snow maps in seNorge and Xgeo are made.



Map for new snow as it may look in seNorge.no



Map of *snow water equivalent* as it may look in seNorge.no.

Map of *skiing conditions* as it may look in seNorge.no.

The snow maps in seNorge and Xgeo consist of a collection of maps which shows the snow conditions in the country. These include maps of snow depth, fresh snow depth, snow water equivalent, skiing conditions, melting snow and snow load.

The snow maps are made with a snow model, which uses the precipitation- and temperature maps as input.

Most maps date back to 1957. Based on weather forecasts, we also make maps for 9 days ahead.

The snow model

In each square kilometer (one grid cell) in the country, the snow conditions are calculated based on the interpolated air temperature value and the precipitation value from the temperature- and precipitation maps. The snow model is a simple, but well-known model, based on the snow routine in the HBV model, a model that was developed in Sweden in the 1970s. The model run for three hours and one day (24 hours) time steps. In addition to the traditional HBV based snow modell, there are separate models that calculates the skiing conditions and the density of the snow and hence the snow depth.

The temperature determines whether it snows or rains

The interpolated temperature from the temperature map determines whether the snow model calculates the precipitation as rain or snow in the given grid cell. If the temperature is colder than 0.5 ° C, the model will assume that the precipitation comes as snow. If it is milder, the model interprets the precipitation as rain.

Example: If the precipitation map shows 10 mm of precipitation in a given grid cell and the temperature map shows that the same grid cell has an daily average temperature of -5 ° C, the snow map showing fresh snow (in mm) will indicate 10 mm of fresh snow that day.

On the other hand, if the temperature map shows that the daily average temperature in the grid cell is +5 ° C, the precipitation will be calculated as rain and it will be 0 mm of fresh snow in the fresh snow map. The 10 mm that apparently comes as rain will either go straight to runoff or moisturize the snow.

Fun fact for those who are particularly interested: In the latter case, the amount of snow (measured in mm water equivalent) will increase despite the rain. If there are snow on the ground prior to the rain event, the rain will only moisturize the snow until run off (the snow will act as a sponge to a certain extent).

The temperature determines if the snow melt

The temperature also determines whether the snow melts or not. If it is colder than 0 ° C, no snow will melt in the model. If it is warmer than 0 ° C, the snow will start to melt. The water content of the snow will increase and when then the water content reaches a certain threshold melt water will drain away.

If the snow is moist or even wet and the temperature is below the freezing point, the liquid water in the snow will refreeze to ice again.

Tip! Remember that snow does not get heavier when it melts. It just gets more wet and hence more compact. The number of kg / m2 is exactly the same. If the meter of fresh snow you have on your roof equals 100 kg / m2 prior to the mild weather, then the same snow pack equals 100 kg / m2 even after it has decompressed to 50 cm (given no additional precipitation). Nevertheless, when you are shoveling your roof, you will get more load on your shovel with heavy, wet snow than the fresh powder snow. Hence the wet snow feels heavier than then powder snow when you need to dig it away.

The model also calculates the liquid water content in the snow. In real life, you can illustrate this by thinking of the difference between dry snow from which it is impossible to make a snowball (almost no free liquid water) and a snowball of moist and wet snow where it is possible to squeeze water (a lot of free water in the snow). The map called *snow condition* gives you an estimate of the liquid water content in the snow.

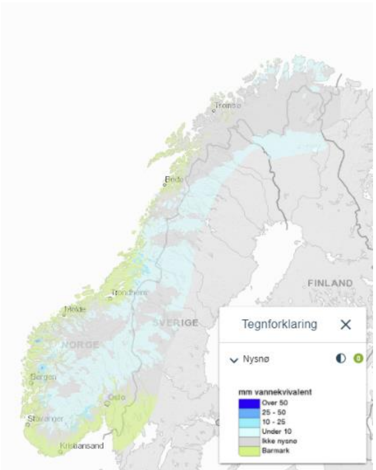
Modeling on several levels

Maps calculated in the "first round"

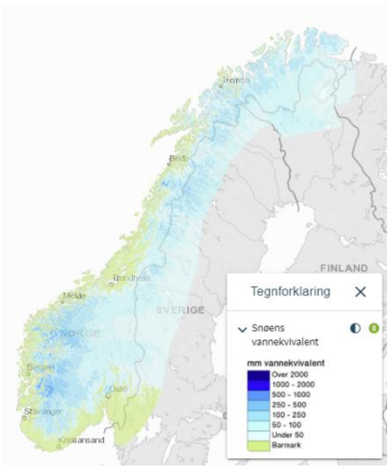
Since precipitation is measured and calculated in *amount of mm water*, it is the snow maps that illustrate snow in *mm of water* (fresh snow in mm, snow water equivalent, snow condition and snow melt) that the model calculates first. Afterwards, it is easy for the model to calculate what has happened to the snow during the last seven days (a sum of new snow and rundoff measured in mm of water last seven days) and the snow load map (one millimeter snow water equivalent equals 1 kg / m2 in the snow load map).

> Tip: Did you know that the term *snow water equivalent* means the total amount of water from the snow when it melts?

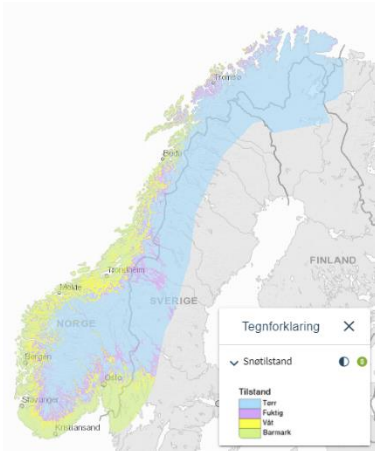
These maps are calculated in the «first round»:



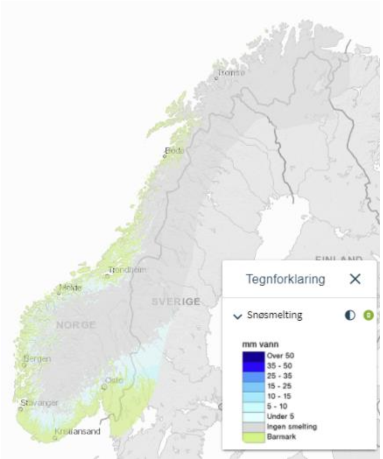
This is how the map showing *fresh snow* (in mm water equivalent) might look like in seNorge.



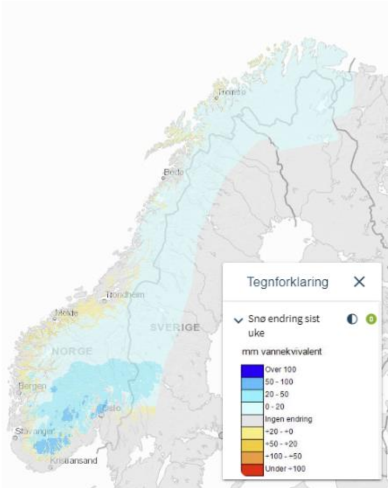
This is how the map showing the *amount of snow* (in mm water equivalent) might look like in seNorge



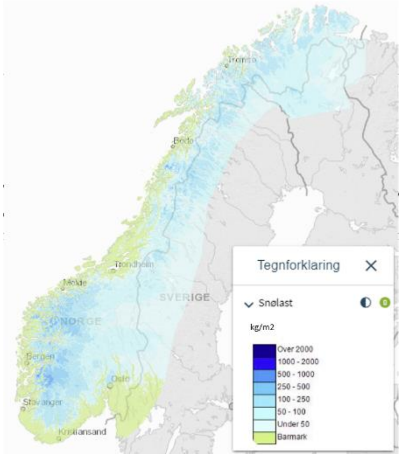
This is how the map that shows *snow humidity* might look like in seNorge.



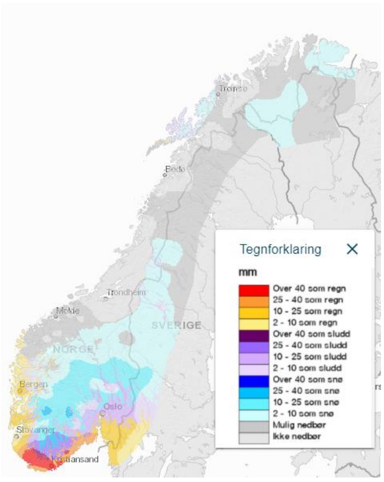
This is how the map showing *snow melt* measured in mm of water might look like.



This is how the map that shows *seven days changes* in the snow amount might look like.



This is how the map showing the *snow load* - in kg / m2 – might look like.



This is how the map that indicates where the *precipitation comes as snow, rain and sleet* might look like.

In the map that shows different forms of precipitation (snow, sleet, rain), we combine information from the precipitation map and information about the temperature from the temperature map. Precipitation at temperatures above 2.0 °C is calculated as rain, between 2.0 °C and -0.5 °C as sleet and below -0.5 °C as fresh snow.

«Second round»: From mm water to cm snow

Since precipitation is measured and calculated in the number of mm of water, it is, as mentioned before, the snow maps that show snow in mm water equivalent and in mm of melted snow / runoff that are calculated first. Second, then the model needs to calculate the snow depth in cm.

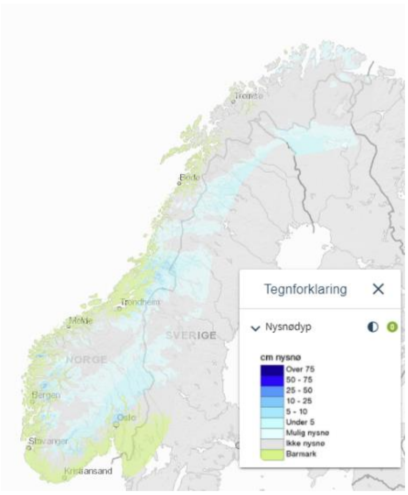
As in real life, snow depth depends on what temperature (and thus density) the fresh snow has when it arrives (think the difference between skiing in fresh, light "powder snow" and a skiing in the Easter holiday on fresh wet snow and sleet.

Tip! The rule of thumb that 10 cm of snow gives 10 mm of water only applies when it is quite cold. If it is around 0 ° C, or even milder, only a few centimeters of fresh snow can make up 10 mm of water when it melts.

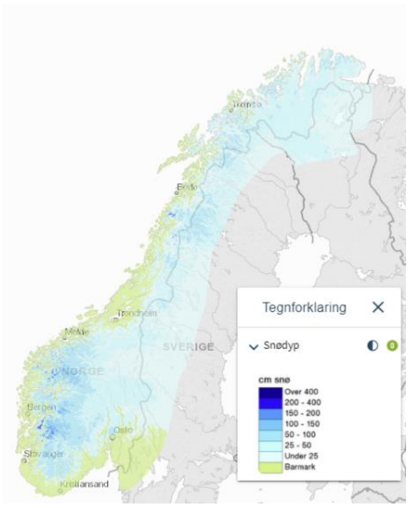
In addition, the model calculates how much the snow decompresses. Decompression can occur in three ways, either from the additional load of new snow that causes the old snow pack to decompress, decompression with time (snow might compress over time even with no additional load) or when it is mild and the snow decompresses or decreases by melting.

The skiing conditions map is calculated by combining information from the precipitation- and temperature maps, the snow condition map from the "first round" and the snow depth map.

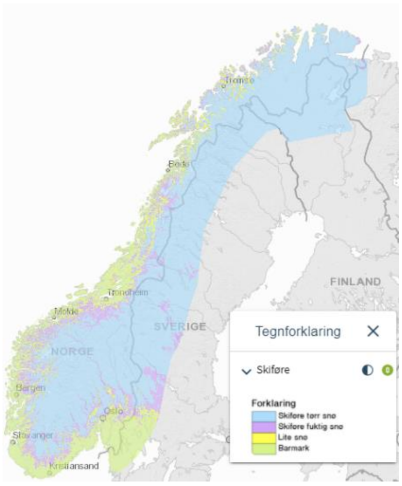
These maps are calculated in the «second round»:



Example of a map showing *new snow depth* (in cm).



Example of a map showing *snow depth* (in cm).



Example of a map showing *skiing conditions*.

Tip! The skiing condition map shows the conditions at the surface of the snow, in other words the map gives you tips on what wax to use then you are out on a cross country trip: Blue = dry snow = blue wax / dry wax, purple = moist snow = consider klister or warmer wax.

"Third round" - for experienced readers

In the "third round", we go further and calculate other types of maps based on the maps we have calculated so far. These are maps that are for the experts and / or map layers that are tested by the different warning services. Basically, this is maps that you only find in Xgeo.no

New snow 7 days: This map shows how much new snow (in *mm* of water) that has come in the last seven days.

New snow depth 3 days: This map shows how much new snow (*in cm)* that has come in the last three days.

The age of the snow: The map shows the number of days since the last snowfall.

Amount of snow - ranked: The map is based on the maps for snow water equivalent and rank the chosen date to the same date in the period 1958 - 2013. This map gives indications on how this winters snow amount are compared to earlier years.

Snow melt from the energy balance model: This map is based on the map for snow water equivalent, but to create this map we use a different type of model to calculate snow melt than in the regular snow melt map. In this map, we use the energy balance model to calculate melt. The energy balance model receives data for wind, cloud cover, solar radiation and relative humidity from a weather forecast model (MEPS-pp).

Danger maps: These maps are index maps that are intended to give the different warning services an indication of danger.

New snow, last 3 days: The map shows the sum of new snow (in mm water) over the last three days and compares it with a three day-threshold level of new snow.

New snow last day: The map is based on the new snow map (in mm) last day and compares it with a one day threshold levels of new snow.

Wind slab index: This map gives an indication of the amount of wind transported snow over the last 24 hours and is used primarily in the avalanche warning services. The map is based on the new snow depth map and combines it with daily mean values for wind speed (from a weather forecast model). In addition, the model considers the age and condition of the snow (dry snow is easier to move than wet).

Depth hoar index: This is an experimental map layer that aims to show the number of days where it is likely with formation of depth hoar in the snow map. The map is based on the assumed differences in the temperature in the snow. Depth hoar deeper in the snowpack are more likely to be estimated than depth hoar near the snow surface.

Sources of error

The maps are based on an interpolation of precipitation- and temperature data and a snow model that calculates the snow conditions based on precipitation and temperature data.

Errors in the snow maps can either be due to errors and uncertainty in the interpolation of precipitation and temperature or that the model interprets the conditions differently than the conditions are. It is especially when the air temperature is around 0 °C that errors and uncertainties in the interpolation and in the calculation might have major consequences. If it occasionally happens to snow while it is +2 °C, the model might interpret the precipitation as rain. If the temperature maps miss the conditions in real life, then the snow maps will be wrong. A local snowstorm that is not captured by a measuring station and therefore not captured in the precipitation map will not be included in the snow model either.

Basically, there are 24-hour maps that are shown in seNorge and Xgeo. This means that it is the average temperature over the day that forms the basis for whether the model interprets the precipitation as snow or rain, or whether the snow melts. If the temperature varies a lot during the day, the model will not be able to capture it. In Xgeo.no there is maps showing 3 hour of data. In these maps, variations during the day will appear more correct.

The maps are also made for 9 days ahead, and these are based on some of the same precipitation and temperature forecasts that you will find on Yr.no. Here, the uncertainty will be related to the uncertainty in the weather forecasts - a rule of thumb that the uncertainty increases the further ahead in the time the map applies.

Have you ever wondered? Why do we not use snow measurements in the model? The snow varies a lot from place to place and with altitude. In addition, there are more measuring stations for precipitation and temperature in the country than there are snow stations. This makes us think that we get a more accurate estimate of the snow conditions in the country if we calculate the amount of snow based on measurements of precipitation and temperature than by using measurements of snow depth or snow water equivalent. Even though snow depth is measured at many stations, we measure snow water equivalent and the density of the snow at less stations.

If you want to read more:

Bergström, S. 1995. The HBV model. In: Singh, V.P. (Ed.), Computer Models of Watershed Hydrology. Water Resources Publications, Highlands Ranch, 443-476.

Saloranta, T. M. 2014. New version (v.1.1.1) of the seNorge snow model and the snow maps for Norway. NVE Report 6-2014.

Saloranta, T. M. 2016. Operational snow mapping with simplified data assimilation using the seNorge snow model. J. Hydrol. 538, 314-325.