Keypoints

met.no report 6/2007

Climate change and natural disasters in Norway

An assessment of possible future changes

Full report: *http://met.no/english/r_and_d_activities/publications/2007/index.html*

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report

Title	Date
Climate change and natural disasters in Norway – An assessment of possible future changes	10.04.2007
Section Climate	**Report no.** 06/2007
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Client Statens landbruksforvaltning (SLF)	**Client's reference**

Abstract

The Norwegian Agricultural Authority (Statens landbruksforvaltning, SLF) is due to make new legislation on safeguarding and compensation for natural disasters and hazards, and has requested an updated assessment of whether the projected climate changes will make the Norwegian society more or less vulnerable to natural hazards in the next 30–50 years. The main results are described in a report (in Norwegian) to SLF («Utviklingen av naturulykker som følge av klimaendringer»). The present report provides the scientific background for the conclusions in the report to SLF, and addresses the extent to which changes are expected in Norway in frequency, extent and magnitude of damages associated with natural hazards under global warming.

The main types of natural hazard events discussed are changes in: precipitation, flooding and ice jams, strong winds, sea level and storm surges, avalanches and slides, permafrost, other hazards (e.g. earth quakes, tsunamis, sub sea slides) and the society's vulnerability to natural hazards and disasters.

This assessment is made in collaboration between several Norwegian institutions: met.no (Norwegian Meteorological Institute, main responsibility for the assessment); Cicero (Center for International Climate and Environmental Research); ICG/NGI (International Center of Geohazards/Norwegian Geotechnical Institute), NGU (Geological Survey of Norway), NVE (Norwegian Water and Energy Resources Administration).

Keywords

Climate change, natural hazards, society's vulnerability to natural hazards,

Disciplinary signature

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Contents of full report

Preface and summary

Excerpts of the mandate for natural disaster assessment

The Norwegian Agricultural Authority (Statens landbruksforvaltning, SLF) is due to make legislation on safeguarding and compensation for natural disasters and calamities[1], with a full reference of the background and objective of the national natural calamity management. In this context, it is important to have sufficient knowledge about weather and climatic conditions and the vulnerability of the Norwegian society.

The SLF has ordered an assessment of the up-to-date knowledge on weather and climate conditions and projections for the next 30–50 years. The assessment must address the question of how the future occurrence and magnitude of natural disasters may be affected be a climate change and provide a comparison with historical statistics. Moreover, the objective is to asses whether a climate change will make the society more or less vulnerable in terms of natural disasters/calamities in the next 30–50 years.

For the present situation, the natural calamity management focuses on flooding, storms, avalanches, and landslides. Therefore, the assessment addresses these types of events. Important questions are:

- Can we expect more extreme rainfall causing water catchments/rivers/brooks to flood?
- Do climate changes entail greater snow pack as well as more rapid melt-off, leading to severe ice runs and higher risk of flooding?
- Can we expect more frequent wind speeds exceeding 20.8 m/s?
- Does the frequency of combined spring tide and storm surge increase?
- Will the risk increase for greater snow accumulation and avalanches.
- Will the frequency of other forms of landslides increase?

The question whether damages linked to other natural disasters such as earth quakes, tsunamis, or sub-sea landslides will become more frequent is discussed only very briefly. Likewise permafrost and associated damages are only described concisely, and land heave and droughts are not regarded as relevant in terms of the national natural calamity management.

The assessment aims to address the extent to which changes are expected in frequency, extent, and magnitude of damages associated with natural disasters/calamities. As mentioned in the mandate attached to the letter from SLF dated December 20th, 2006, the following key points are elucidated:

- If a higher incidence of natural calamities/disasters can be expected as a result of changes in the weather statistics.
- If more extensive natural disasters can be expected.
- If the geographical distribution of natural accidents will be altered.
- If the link between natural calamities/disasters and causes will change.

1) *http://www.sdpi.org/help/research_and_news_bulletin/sept_oct_05/investing.htm*

Description of the strategy of the assessment

The latest IPCC (2007) results indicate that the global temperature is projected to increase by between 1.0 and 6.3 ºC up to year 2100, based on different global climate models and with different scenarios for emission of greenhouse gases and aerosols. The large spread is partly due to internal variability as well as the differences between the emissions scenarios for greenhouse gases. In the Norwegian RegClim project *(http://regclim.met.no*), data from global climate models are downscaled by dynamical and empirical methods to provide scenarios for regional and local climate changes in Norway for the next 50–100 years. Most dynamically downscaled scenarios for Norway represent the 2071–2100 period, but some projections describe the 2030–2050 period compared to 1980–2000. Empirical-statistical downscaling, on the other hand, tends to describe the total 2000–2100 interval.

It is essential to bring in facts about natural disasters for the legislation of a new Norwegian law on natural calamities, and hence questions whether climate change may influence the vulnerability of the society during the next 30–50 years need to be addressed. In Northern Europe, the climate conditions are influenced by large natural variability, both on inter-annual and decadal time scales. Random internal variations may dominate over regions like Scandinavia during the next 20–30 years, however, systematic changes caused by changes in radiative forcings will become more pronounced after that. Analyses of the climate development over Scandinavia must therefore include regional internal fluctuations in addition to the large-scale global warming.

The development and intensity of the extra-tropical cyclones may often result in extreme weather conditions and natural disasters in our region. These are formed and developed over the North-Atlantic and in the prevailing westerlies. Moreover, the cyclonic activity is crucial for extreme precipitation and wind events in Norway. During the latest 30–40 years there has been a substantial change in the cyclonic tracks, which may explain a large part of the «unusual» weather types over the Nordic region. Unfortunately it is not possible to state whether this is caused by global warming or whether it is a natural variation which would have occurred anyway. It is however a fact that the recent development in many aspects resembles features predicted by the climate models.

The assessment will consider the variability in occurrences of natural disasters and climatic extremes for the latest 50–100 years in order to relate the magnitude of the projected climate changes for the next 30–50 years with the actual historical climate variability. The main reference period used is the climatologically «standard normal period» 1961–1990. Observations from this period are the basis for a large number of dimensioning values for average and extreme climate elements.

All kinds of landslides are caused by weather or climate, but other factors may also play a role. Debris flow triggered by flash floods in river beds is one example where intense rainfall may be linked to such landslides when downpour exceeds critical thresholds within short intervals (~hour). Extensive avalanches are triggered by weather conditions during several days. An unstable layer in the snow may be formed over prolonged periods under right conditions, and high snowfalls on top may then cause a collapse. By studying the link between landslides and avalanches on the one hand and weather on the other, it is possible to elucidate how the frequency of such events may be affected by a climate change. This type of analysis is addressed in the ongoing project GeoExtreme (*www.geoextreme.no*).

Summary

This report aims to address the extent to which changes are expected in frequency, extent and magnitude of damages associated with natural disasters and hazards in Norway under global warming. The Norwegian Agricultural Authority (Statens landbruksforvaltning, SLF) is due to make new legislation on safeguarding and compensation for natural disasters and hazards, and has requested an updated assessment of whether the projected climate changes will make the Norwegian society more or less vulnerable to natural hazards in the next 30–50 years. The main results are described in a report to SLF in Norwegian («Utviklingen av naturulykker som følge av klimaendringer»), and the present report provides the scientific background for the conclusions in the report to SLF.

The main questions from SLF were:

- Whether a higher incidence of natural disasters and hazards can be expected as a result of projected climate changes in Norway
- Whether more extensive natural disasters can be expected
- Whether the geographical distribution of natural hazards will be altered
- Whether the link between natural calamities/ disasters and causes will change

The main types of natural hazard events SLF wanted elucidated were changes in: precipitation, flooding and ice jams, strong winds, sea level and storm surges, avalanches and slides, permafrost, other hazards (e.g. earth quakes, tsunamis, sub sea slides) and the society's vulnerability to natural damage.

Precipitation: The scenarios indicate a weak increase in extreme rainfall over large parts of Norway during the next 25 years, and a stronger increase up to year 2050. The projected increase is largest in parts of Western Norway and the counties of South Trøndelag and Nordland. For south-eastern Norway the scenarios indicate just small changes in extreme 1-day rainfall during the next 50 years.

Floods and ice jams: The scenarios indicate that the large snowmelt floods in major rivers, with high potential of flood damage to infrastructure on the flood plain, is likely to be reduced because of reduced snow volumes. The snowmelt floods will occur earlier in the spring than in the present climate. However, the inter-annual variability is large, and there may still be a few years with large snow volumes and potential for extreme snowmelt floods. Late autumn floods and small winter floods will become more common. The projected increase in extreme local high-intensity rainfalls may cause severe flash flood events in inland and urban areas. According to the climate projections, there will be more ice runs which may jam at new places. There will be an increased area along the coast with seldom ice, and longer stretches free of ice downstream in large lakes. Increased glacier melting will lead to a substantial increase in summer stream flow in the glacier rivers .

Strong winds: There are pronounced inter-annual and inter-decadal variations in the frequency of wind speed exceeding the threshold value for strong gales, but geostropical wind analysis of long sea level pressure records does not give any evidence of significant long-term trends since 1880. Scenarios for future wind conditions do not suggest any clear tendencies for the next 50–100 years, although several studies indicate that the most intense mid-latitude storms nevertheless may become more frequent in a warmer climate.

Sea level and storm surges: Along the Norwegian coast the global increase in sea level height will be ameliorated by the continental uplift in Scandinavia. Thus it is conceivable that there will be no net change in mean sea level height (SLH) at most locations along the Norwegian coast in the next 50 years. But if the SLH rise is larger than 0.5 m, significant increases in SLH will be evident at all locations along the coast. The evidence for changes in variability and frequency of extreme events is weak, and a future increase in extreme storm surge events is therefore dependent of increase in SLH.

Avalanches and slide events: The frequency of recorded slides (avalanches, debris slides and rock slides) has increased exponentially in Norway since 1960, but this was found to be mostly due to human factors. Snow avalanches are the slide type causing the highest number of casualties. The projections of future changes in slide frequencies are tentative, but it seems as if the southern coastal regions may expect a moderate to strong increase. In inland regions and the northern coastal regions a small increase in slide frequency is projected.

Permafrost: The mountain regions in Norway have an extensive amount of permafrost. At present the permafrost is warming considerably. It is evident that if the observed ground warming proceeds or even accelerates, major changes in mountain permafrost distribution in Norway will be anticipated through the 21st century.

Earth quakes, tsunamis, sub sea slides, etc.: Climate change will most probably not cause any changes in frequency of earth quakes or sub sea slides. Permafrost degradation in steep bedrock slopes can lead to increased instability. If this leads to more

rock slides in steep bedrock slopes, the risk of flood waves (tsunamis) will increase in some fjord and lake districts.

The society's vulnerability to natural damage: The analyses at the regional level give some indications of expected trends, but the information is not detailed enough to indicate where the vulnerability will be greatest and to which type of natural hazard. Generally the climate scenarios indicate that there will be an increase in all weather types that may trigger natural hazards. There is not necessarily a correlation between high assessed costs and the magnitude of the natural hazard; a major natural hazard (e.g. an avalanche) in an area with little infrastructure and few buildings can have an assessed damage cost close to zero, while a smaller natural hazard in a densely populated area can have high assessed damage costs. It is crucial to adapt the society such that the scope of damage is kept to a minimum. Investments in protection, good land-use planning and good building practices are all important elements to limit the damage from natural hazards.

Uncertainty: Several sources of uncertainty are linked to scenarios for future climate development. The most important are: a) Internal variations in the climate system leads to unpredictable natural variability, b) Uncertainty on future changes in climate forcings (Natural forcings as solar radiation and volcano eruptions and anthropogenic release of gases and particles), c) Imperfect climate models (Imperfect knowledge about forcing and processes; imperfect physical and numerical treatment of processes; poor resolution in the global models), d) Weaknesses in downscaling techniques. Simulations with different climate models and emissions scenarios may therefore give different projections. Particularly large uncertainty is linked to extreme events at specific localities; i.e. the weather events that may trigger the types of natural hazard described in this report.

2 Observed and projected changes in extreme precipitation

(Eirik J. Førland, Eli Alfnes, Rasmus Benestad, Torill Engen-Skaugen, Inger Hanssen-Bauer and Jan Erik Haugen, met.no)

Key points

- The annual precipitation in Norway has increased between 0.3 and 2.1 % per decade in different parts of Norway during the latest 100 years. The largest increase has occurred in Western-Norway and large parts of Central and Northern Norway.
- In Western Norway there has been a weak tendency of increasing 1-day rainfall extremes during the later decades. In the other parts of the country there has been very small changes.
- Up to year 2050 the downscaled scenarios project an increase in average annual precipitation of 0.3 to 2.7 % per decade in different parts of Norway. The largest increase is projected in north-western and western regions.
- The projections indicate a small increase in extreme rainfalls for the next 25 years, but with a stronger increase during 2025–2050. The projected increase is largest in parts of Western Norway, and in the Sør-Trøndelag and Nordland Counties.
- For all of Norway the scenarios indicate that daily rainfalls that are considered extreme today will be more common in the future.
- Also for monthly precipitation more extreme values can be expected, especially during winter, spring and autumn.

3 Expected change in the occurrence of floods as a consequence of climate change

(Lars Roald, NVE)

Key points

- Floods are caused by snowmelt and/or rainfall. Changes in the land use and impoundment of water in reservoirs will change the flood regime.
- The largest floods in Norway have occurred at the start or the end of a sequence of very cold years during the Little Ice Age. The generation of intensive rainfall during these events was nevertheless linked to high temperatures.
- Rainfall floods tend to occur in warm periods e.g. the 1930s and since 1987.
- Moderate winter floods will be more common in a warmer climate. The potential for large snowmelt floods will decrease in the later part of the scenario period.
- The snow storage can increase in the mountains, at least early in the period because of increasing winter precipitation. Large snowmelt floods can therefore still occur until the warming is high enough to cause melting episodes, even in high lying basins.
- Local flash floods can become more common in a warmer climate. These floods can cause local damage and loss of lives in inland valleys, especially where step tributaries join the main river on the valley floor.
- Late autumn floods will be more common, especially in basins in west Norway.
- Glacier melting can cause more floods resulting from drainage of glacier dammed lakes.
- The vulnerability to flood damage will increase more than the actual flood risk because of more intensive developments on the flood plain.

4 Expected changes in ice cover

(Randi Pytte Asvall and Ånund Sigurd Kvambekk, NVE)

Key points

- Only a few days shorter ice period in the most continental part of the country.
- The ice period decreases more towards the coast.
- Larger year to year differences.
- More ice runs which may jam at new places.
- Increased area along the coast with seldom ice.
- Longer reaches free of ice downstream large lakes.
- The lake ice will be thinner in the maritime regime, but less change in the area with continental regime.

5 Changes in frequencies of high wind speeds

(Rasmus Benestad, Eirik J. Førland and Knut Harstveit, met.no)

Key points

- There are pronounced inter-annual and inter-decadal variations in the observed frequencies of wind speeds exceeding the threshold value for strong gales.
- Analysis of observed wind series from coastal regions in Norway do not show any evident trend in the frequency of strong winds from 1961 to 2006.
- For a longer time-scale, analysis of estimated geostrophic wind does not indicate any significant changes in wind speeds in Norway and adjacent sea areas since 1880.
- Scenarios for future wind conditions do not indicate any clear tendencies for changes during the next 50–100 years, although several studies indicate that the most intense mid-latitude storms may become more frequent in a warmer climate.

6 Changes in sea level and frequencies of storm surges

(Joe LaCasce and Jens Debernard, met.no)

Key points

- Results from IPCC TAR suggested that the sea level height could rise between 0.025 and 0.25 m along the Norwegian coast over the next 50 years.
- More recent studies, which take into account increased melt water run-off from the Greenland and Antarctic Ice Shelves, suggest that the rise could be twice as large, or up to 0.5 m.
- The mean rise sea level rise will be ameliorated by continental uplift in Scandinavia, which will raise the Norwegian coasts by 0.05–0.25 m.
- Thus it is conceivable that there will be no net change in mean sea level height (SLH) at some locations along the Norwegian coast in the next 50 years. But if the mean SLH rise is large as 0.5 m, significant increases in SLH will be evident at all locations.
- The projections up to 2050 do not exhibit a significant change in the probability distributions of sea level height along the Norwegian coast. This implies that the standard deviations and the frequency of extreme events will not change significantly. The evidence for more frequent storm surges is therefore weak, in the absence of mean sea level rise.

7 Changes in the frequency of recorded slide events in the decades since 1960

(Kalle Kronholm and Christian Jaedicke, ICG/NGI, Knut Stalsberg and Kari Sletten, NGU)

Key points

- The national slide database comprise a total of ca. 3400 landslides and avalanches, – the oldest dating back to year 900 AD.
- After year 1600 the number of registered slide events per year shows a gentle increase towards a more constant level after 1850.
- The frequency of recorded slides (avalanches, debris slides and rock slides) has increased exponentially in Norway since 1960, but this was found to be due to human factors such as increased use of a database to record observations and an increase in the number of infrastructure units in potential slide terrain.
- Snow avalanches are the slide type causing the highest number of casualities.
- The strongest climate-related signal in the observed changes is that avalanches have moved from primarily dry snow over wet snow to slush flows over the past three decades, indicating more frequent high temperatures and high-intensity rain events when there is snow on the ground.
- Despite this climate-related effect, the most important causes of the observed changes are human and socioeconomic effects.
- To increase the usefulness of a slide database in the future, better coordination between the involved institutions and standardization of the recordings are needed.

8 Changes in damages caused by permafrost

(Ketil Isaksen, met.no)

Key points

- The mountain regions in Norway have an extensive amount of permafrost. In southern Norway the lower boundary of permafrost is about 1450 m a.s.l. in Jotunheimen, 1300 m a.s.l. in Dovrefjell, and 1100 m a.s.l. in Sølen close to Femunden. Preliminary results from Lyngen (Troms) and Romsdalen (Møre and Romsdal) show that the lower limit of mountain permafrost in these areas is lower than earlier estimated, approx. 600–700 m a.s.l. and 1500 m a.s.l., respectively.
- Analyses of permafrost temperature changes in Jotunheimen indicate a ground surface temperature increase of 0.5–1.0 degrees over the last 30–40 years. At present the permafrost is warming considerably. Since 1999 ground temperatures have increased by 0.3 degrees at 15 m depth. Present decadal warming rate at the permafrost table is in the order of 0.04–0.05 $^{\circ}C\ yr^{-1}$.
- The depth of active layer shows significant response to warm summers. The summers of 2002 and 2003 were among the warmest on record (warmest and fourth warmest respectively) in Norway. Active layer depths were 20 % greater in theses summers than previous years.
- In several mountain areas in Norway, ground temperatures are only a few degrees below zero. It is evident that if the observed ground warming proceeds or even accelerates, major changes in mountain permafrost distribution in Norway will be anticipated through the 21st century.
- The geotechnical consequences of permafrost warming in Norway are particularly related to slope stability and the integrity of engineering structures. Permafrost degradation in steep bedrock slopes can lead to increased instability. Studies from the Alps show that a large number of recent rock fall events most likely originated in permafrost areas. Studies of such relationships are in its infancy in Norway.

9 Considerations on changes in frequencies of other natural disasters in Norway, i.e. earth quakes, tsunamis or under-water rock slides

(Kari Sletten (NGU), Knut Stalsberg (NGU), Kalle Kronholm (NGI))

Key points

- Climate change will probably not lead to any changes in the frequencies of earth quakes in Norway.
- A changing climate will probably not cause any increase in the frequency of submarine slides.
- Increased precipitation and thawing of permafrost may cause more frequent rockslides, and thus tsunamis generated by rockslides into fjords or lakes.

10 Changes in vulnerability to natural damage

(Helene Amundsen and Grete K. Hovelsrud, Cicero)

Key points

- Landslides and floods are the most common natural hazards that cause damage in Norway today, and this is expected to be the case over the next 50 years as well.
- Floods are expected to occur at different times of the year compared to the trends that are common at present.
- With respect to landslides, it is uncertain where they will occur in the future, and there is no precise estimate for changes in the frequency of landslides – although an increase in frequency for some regions is expected.
- The climate scenarios provide a clear indication that Norway can expect an increased frequency in all types of weather events that trigger natural hazards. It is however presently not possible to say with certainty where the vulnerability will be greatest, and to which natural hazards.
- It is important to distinguish between increase and change in natural hazards as a result of changing climate conditions. Climate change will lead to changes in seasonal and geographical trends in flooding as well as an increased frequency during the winter season.
- To assess the vulnerability to natural damage, the correlating factors triggering natural hazards as well as a link to locality must be analysed in detail.
- The analyses at the regional level provide indications of expected trends, but we do not have enough detailed information to say with certainty where vulnerability will be the greatest, and to which natural hazards.