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Note

The Impact of Climate Change on Insurance Risk: A Study of the Effect of Climate Change Scenarios in Norway

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Abstract

As a result of climate change, the risk of weather-related damages to buildings is likely increase in many areas worldwide. This challenge is faced by society in general, but the insurance industry is particularly important in the management of the anticipated increase in risk. In addition to adjusting the premiums appropriately and gradually, they can also play an important role in prevention. In order to take action, it is crucial to know which areas are vulnerable, and to what extent. In this paper, a spatial regression model for linking weather-related insurance claims to meteorological and hydrological covariates is used to project the future number of claims. The model is trained on observed daily insurance claim and weather data at the municipality level in Norway. Three plausible scenarios for the future climate in the central and south of Norway are coupled with the model in order to project the future number of weather-related insurance claims. We show maps of the projected yearly number of claims for each municipality. Our results indicate a quite dramatic increase in the weather-related insurance risk in many parts of Norway, in some areas the numbers are more than doubled. These results clearly call for attention and action.

Keywords	Climate change impact, Risk projections, Insurance risk, Society risk, Risk management
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Project	Statistics for Innovation - $(\text{sfi})^2$ (ClimateInsure)
Project number	
Research field	Bank, Finance, Insurance and Power Market
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1 Introduction

It is important that the insurance sector is robust to the potential risk changes due to climate change. Because of relatively short contract periods, the insurance sector is to some extent able to cope with increasing risk by adjusting premiums. However, there is a danger of insufficient and/or delayed risk adjustment (Botzen et al., 2010). It is obviously advantageous for insurance companies to know of potential dramatic risk changes as early as possible, in order to prepare for the necessary adjustments such as a smoother rather than an abrupt premium increase, or seeing potential new business opportunities such as new types of insurance products. For the public and planning authorities, it is of great importance to know of areas in danger of becoming un-insurable, where it is not wise to plan new buildings or where protective measures should be put in place.

Mills (2005); Vellinga et al. (2001) early on highlighted the need for a better understanding of the consequences of climate change for the insurance sector, regarding both extreme and ordinary weather events, and helped put a focus on the role and challenges of the insurance industry imposed by climate change. The insurance sector around the world has become increasingly committed to dealing with the possible effects climate change. The risks and opportunities of climate change facing the insurance sector is a fast-growing field of commercial research and development (see e.g. Association of British Insurers, 2009; CEA, 2009; Dlugolecki et al., 2009; Mills, 2009). The emphasis is on face the increasing risks involved and to see new business opportunities, but also to contribute to adaptation and mitigation, e.g. by influencing and collaborating with governments, or by using premium incentives to encourage risk preventive actions or motivate green industry and building practices. Prior to the United Nations Climate Change Conference in Copenhagen in 2009, *ClimateWise*[1] called for the developed countries to commit to a reduction in greenhouse gas emissions of 40% by 2020[2].

The consequences of climate change for the insurance sector is a growing field of research also in academia (see e.g. Botzen and van den Bergh, 2008; Botzen et al., 2010; Hecht, 2008; Phelan et al., 2010). There is however a lack of academic case-studies on the effect of climate change scenarios on insurance risk. This can partly be attributed to a lack of available insurance data, mainly due to insurance companies being very protective of their data. Haug et al. (2009) model the daily number of weather-related insurance claims in each of the 19 counties of Norway separately, and use climate scenarios for 2071-2100 to project future insurance claims. They show a significant increase in the insurance risk. While the regional downscaled climate projections have since been improved upon, there are still considerable weaknesses in projecting the correct distribution of precipitation. In a new study, Orskaug et al. (2010) evaluate regional downscaled climate models by comparing the

1. ClimateWise is a global collaboration network of leading insurers, facilitated by the University of Cambridge, aiming at facing climate change (see `http://www.climatewise.org.uk`)
2. ClimateWise NEWS RELEASE (October 2009): ClimateWise calls for 40% emission cuts by 2020 to control the risks arising from climate change. See `http://www.climatewise.org.uk/news/2009/10/22/news-release-climatewise-calls-for-40-emission-cuts-by-2020.html`

projected precipitation distribution for 1961-2000 to the historical meteorological records. The results show among other things that higher levels of precipitation are underestimated. What is well-established, however, is that we are in fact facing climate change, and it is useful to consider different plausible scenarios of the future climate to investigate what the impacts might be. Given that the future regional downscaled climate projections are associated with such great uncertainty, it makes sense to do a simple study of the effect of plausible increases in precipitations compared to a present-climate reference year. Scheel et al. (2010a,b) propose a coherent spatial model for the daily number of weather-related insurance claims at the municipality level, fitted to the same historical insurance claims data as used by Haug et al. (2009). The present paper uses the resulting posterior predictive distribution for the number of claims to project the distribution of the yearly number of claims for each municipality for different scenarios corresponding to the low, medium and high climate projections for Norway in 2100 reported in Hanssen-Bauer et al. (2009). The projections are compared to the posterior predictive distribution of a reference year in the present climate. Because contracts for insuring privately owned buildings are generally for one year, the potential increase in the total yearly number is of particular interest. This illuminates how the weather-related insurance risks of different areas of Norway are likely to change due to plausible scenarios of climate change. As in Haug et al. (2009); Scheel et al. (2010a), the focus is on insurance for privately owned buildings, and exclude a small number of catastrophic weather-related events, which in Norway are covered by a separate national fund. The results show that the scenarios considered entail significant increases in the number of claims for the most populated areas of Norway, with quite dramatic risk changes for many municipalities. This calls for action, by both the insurance sector and the authorities. It also indicates the need for further research, e.g. similar studies for other areas, and in the future coupled with adequate regional downscaled climate projections.

This paper is organised as follows: In Section 2 the data and methodology are described, results are presented in Section 3, and Section 4 concludes with a brief discussion of the results.

2 Materials and methods

2.1 Data

The basis for the model we use for projecting insurance losses for the future scenario climates is the posterior predictive distribution found in Scheel et al. (2010a,b). This distribution (described in more detail in Section 2.2) results from fitting the proposed model to observed training data, hence obtaining the posterior distribution of the parameters given the training data, which in turn provides the posterior predictive distribution of new data conditioned on the training data. The dataset used in Scheel et al. (2010a,b) and the present paper consists of daily claim counts and number of insurance policies (exposure) for central and south Norway at the municipality level (319 municipalities) for the period 1997-2006, as well as meteorological and hydrological data (covariates) at the same temporal and spatial resolution. The insurance data was provided by the largest non-life insurance company in Norway[3], and contains claims from all insured private buildings due to damages caused by either precipitation, surface water, snow melting, undermined drainage, sewage back-flow or blocked pipes. See Haug et al. (2009) for a more detailed description of the data. The meteorological and hydrological data include daily mean precipitation, mean temperature, drainage run-off and snow water equivalent, which was collected and processed by the Norwegian Meteorological Institute[4] and the Norwegian Water Resources and Energy Directorate[5]. In addition to these basic variables, the covariates in the model include the derived variables precipitation on the previous day, the sum of precipitation in the previous three days and the change in snow water equivalent. See Scheel et al. (2010a) for more details on the meteorological and hydrological covariates. The training dataset consists of the 9 years of data which remain when the year 2001 is excluded. The data for the year 2001 was left out from the posterior analysis and preserved for evaluating the posterior predictive distribution in Scheel et al. (2010a). In this paper the data for the year 2001 serves as the reference (”baseline”) for the scenario data investigated.

The Norwegian government appointed NOU - Climate Change Adaptation committee report in Hanssen-Bauer et al. (2009) an increase in precipitation of 5% , 18% and 30% on a yearly basis for Norway as a whole (Hanssen-Bauer et al., 2009). The low (5%) increase corresponds to the 10-percentile, the medium (18%) to the median value and the high (30%) to the 90-percentile of a dynamic downscaling ensamble based on 22 climate projections. The high increase seems to agree with the observed increase the last 30 years (Hanssen-Bauer et al., 2009, Figure 5.2.11). The scenario meteorological and hydrological data used in this paper is derived from the 2001 data by increasing the precipitation by 5% (`Scenario1`), 18% (`Scenario2`) and 30% (`Scenario3`). The reasoning for restricting the focus to plausible increases in precipitation is that the variable selection results in Scheel et al. (2010a) show that precipitation is the most important factor for explaining the risk. The covariates derived from the daily percipitation are increased accordingly and the exposure (the number of insurance policies) are the same as in the original 2001 data.

2.2 The posterior predictive distribution for the number of insurance claims

The projections of the number of insurance losses are based on the model introduced in Scheel et al. (2010a,b) for the link between weather events and weather inflicted insurance losses. The losses in a municipality on a daily resolution are modelled by a Bayesian Poisson Hurdle (BPH) model with several meteorological and hydrological variables as covariates. The BPH model is a two-part model where the first part, the Hurdle, is a Bernoulli distribution for the binary event of presence or absence of insurance losses. The second part is a Positive Poisson distribution for the number of losses in the event of presence of claims. The rationale behind using this BPH model is that there is thought to be one process determining whether or not losses occur, and then if losses occur, another process controls

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3. Gjensidige, `http://www.gjensidige.no`
4. `http://www.met.no`
5. `http://www.nve.no`

the actual number. The covariates enter the model through two generalized linear models, one for the Hurdle part and one for the Positive Poisson part. Because the effect of the covariates are thought to vary depending on municipality specific characteristics such as for example building traditions and sewage system, the regression coefficients are municipality specific. Also, the Bayesian variable selection and model averaging is performed locally for each municipality, but are spatially linked by an Ising model controlling spatial dependence between neighbouring municipalities of the selection of which variables are important.

The posterior predictive distribution (PPD) used in this paper for projecting insurance losses for future scenarios is obtained as a by-product of the posterior simulation used for fitting the model to the training data in Scheel et al. (2010a,b). The resulting posterior distribution of the parameters in the model in turn provides the posterior PPD for an unobserved number of insurance losses at a given day for each municipality, conditioned on the covariates for that day and the training data. Details on the PPD can be found in Scheel et al. (2010a). From the daily PPD, the PPD for the aggregated yearly number of losses in each municipality is easily obtained. For obtaining the PPDs, the Markov Chain Monte Carlo (MCMC) simulation algorithms described in Scheel et al. (2010b) (implemented in a combination of `C` and `R`) were used.

In order to test a null hypothesis that two population distributions are identical against the alternative that one population is stochastically smaller than the other, the non-parametrical one-sided Kolmogorov-Smirnov two-sample test can be used (see e.g Gibbons and Chakraborti, 1992). In this paper, this test is used to test whether the posterior predictive distribution of the yearly number of claims for the reference year 2001 is identical to the posterior predictive distribution of the yearly number for the three scenarios. The alternative hypotheses are that the yearly number of claims for the reference year 2001 is stochastically smaller than the yearly number for the three scenarios. The tests were performed by using the `R` function `ks.test`.

3 Results

Figure 1 shows maps of the results of the Kolmogorov-Smirnov tests comparing the posterior predictive distribution of the yearly number of claims for the reference year 2001 to the posterior predictive distribution of the yearly number for (a) `Scenario1`, (b) `Scenario2` and (c) `Scenario3` for each municipality. For 16 municipalities, including the coastal cities Sarpsborg, Fredrikstad, Tønsberg, Larvik, Andebu, Lillesand, Farsund and Bergen (the second largest city in Norway, and the city with the highest exposure today), the yearly number of claims for the reference year 2001 is significantly stochastically smaller than the yearly number for all three scenarios. For the capital Oslo, the yearly number of claims for the reference year 2001 is significantly stochastically smaller than the yearly number for both `Scenario2` and `Scenario3`. The reference year 2001 is significantly stochastically smaller than the yearly number for `Scenario2` and `Scenario3` for 99 (31%) and 133 (42%) of the municipalities, respectively. Most of these municipalities are in the highly populated coastal areas. For data from discrete distributions, the Kolmogorov-Smirnov test have been shown to be conservative (Gibbons and Chakraborti, 1992; Goodman, 1954). This means that some of the null hypotheses may incorrectly not be rejected in Figure 1. But it also means that the ones that are rejected really indicate that the yearly number of claims for the reference year 2001 is stochastically smaller than the yearly number for the scenario under consideration at the given significance level (5%).

Figure 1. Maps of the central and south of Norway, divided into the municipalities, showing the results of the (one-sided) Kolmogorov-Smirnov test of the null hypothesis (H0) that the posterior predictive distribution of the yearly number of claims for the reference year 2001 is identical to the posterior predictive distribution of the yearly number of claims for (a) `Scenario1`, (b) `Scenario2` and (c) `Scenario3`, against the alternative that the yearly number of claims for the reference year 2001 is stochastically smaller than the yearly number for the three scenarios. The significance level is 5%.

(a) (b) (c)

It is also of interest to compare different properties of the distributions. Figure 2 shows maps of the percentage increase of the posterior predictive mean of the yearly number of claims for the three scenarios for each municipality. To consider this increase in the posterior predictive mean from the reference climate to the scenario is comparable to considering the change in Eq. (4.8) in Haug et al. (2009). The increases tend to be higher in the coastal areas for all three scenarios, of course with the highest increases for `Scenario3`. It is interesting to synthesise the results in Figure 2 with the ones from Figure 1, considering the increases in the means for the municipalities where the null hypotheses were rejected in the Kolmogorov-Smirnov tests (the KS significant municipalities). For `Scenario1`, the KS significant municipalities Nesodden, Tønsberg, Larvik, Andebu, Lillesand, Fjell, Askøy and Nesset show more than 10% increase in the means. For `Scenario2`, 21 of the KS significant municipalities show more than 50% increase in the means, among which are the cities Moss, Tønsberg, Lillesand and Grimstad. The last three are of the KS significant municipalities for `Scenario3` that experience increases in the means of between 100 and 200% `Scenario3`, while Moss together with Råde, Hurum, Re and Flekkefjord actually show increases of beween 200 and 300% for `Scenario3`.

It is also interesting to look at the change in the more extreme, less likely events such as the 95-percentile. Figure 3 shows maps of the percentage increase of the 95-percentile of the posterior predictive distribution of the yearly number of claims for the three scenarios for each municipality. Comparing Figures 2 and 3 we see that more municipalities do not experience an increase in the 95-percentile (Figure 3) than what was the case for the mean (Figure 2). Many of these municipalities experienced a moderate increase in the mean. However, some municipalities experience a much more dramatic increase in the 95-percentile than what is seen for the mean, some even for `Scenario1`. Comparing the results in Figure 3 to the ones from Figure 1, we see that for `Scenario1`, the KS significant municipalities Nesodden, Trysil, Tønsberg, Askøy and Nesset show more than 20% increase in the 95-percentiles. For `Scenario2`, 19 of the KS significant municipalities show more than 100% increase in the 95-percentiles, among which are the cities Moss and Tønsberg. Of the KS significant municipalities for `Scenario3`, 25 experience increases in the 95-percentiles of more than 200%, which include Moss and Tønsberg.

4 Discussion

Even though `Scenario3` entails quite a dramatic increase in precipitation (30%), actually practically all the daily scenario data was within the range seen in the training data used for estimating the posterior predictive distribution. Only 12 (`Scenario1`), 29 (`Scenario2`) and 66 (`Scenario3`) out of the 365×319 days had precipitation higher than what was seen in the training data, affecting at most 4 days per municipality, see Figure 4. Hence, there is very little extrapolation involved when using the posterior predictive distribution for the scenarios. Also, the municipalities affected by extrapolation are mostly located in areas of Norway where the results did not point to severe risk increases.

The results in this paper indicate quite dramatic changes in the risk of weather-related damages to buildings as a result of plausible climate change scenarios. Some areas and municipalities in Norway seem to be very vulnerable. Even for the very moderate `Scenario1`, highly populated municipalities can expect over 10% increase in the mean number of claims, that is twice the percentage increase in precipitation, and over 20% increase in the 95-percentile. For the other two scenarios the results are much more dramatic, with many municipalities showing over 50% increase in the mean and over 100% increase in the 95-percentile under `Scenario2`. Under `Scenario3`, this risk is more than doubled for many municipalities compared to the results for `Scenario2`. As mentioned in Section 2.1, `Scenario3` apparently coincide with the observed increase in precipitation the last 3 decades. The claim changes found in this study exceeds the ones found in Haug et al. (2009), where increases in the number of claims of up to 30% were reported.

These results show that preventive measures are needed for many areas of Norway. Both authorities and the insurance industry should be proactive in reducing these potential risk increases and/or to price them appropriately. The model proposed in Scheel et al. (2010a) and used in this paper can be applied also for case studies in other countries, our results clearly indicate the need for such studies elsewhere. Also, when regional downscaled climate projections are improved and found satisfactory, they should substitute the simpler scenarios considered in this paper, giving more certain insurance claim projections for the future.

Figure 2. Maps of the central and south of Norway, divided into the municipalities, showing the percentage increase of the posterior predictive mean of the yearly number of claims for (a) `Scenario1`, (b) `Scenario2` and (c) `Scenario3`, all compared to the reference year 2001, while (d) shows a map of the mean of the posterior predictive distribution of the yearly number of claims for the observed weather of the reference year 2001.

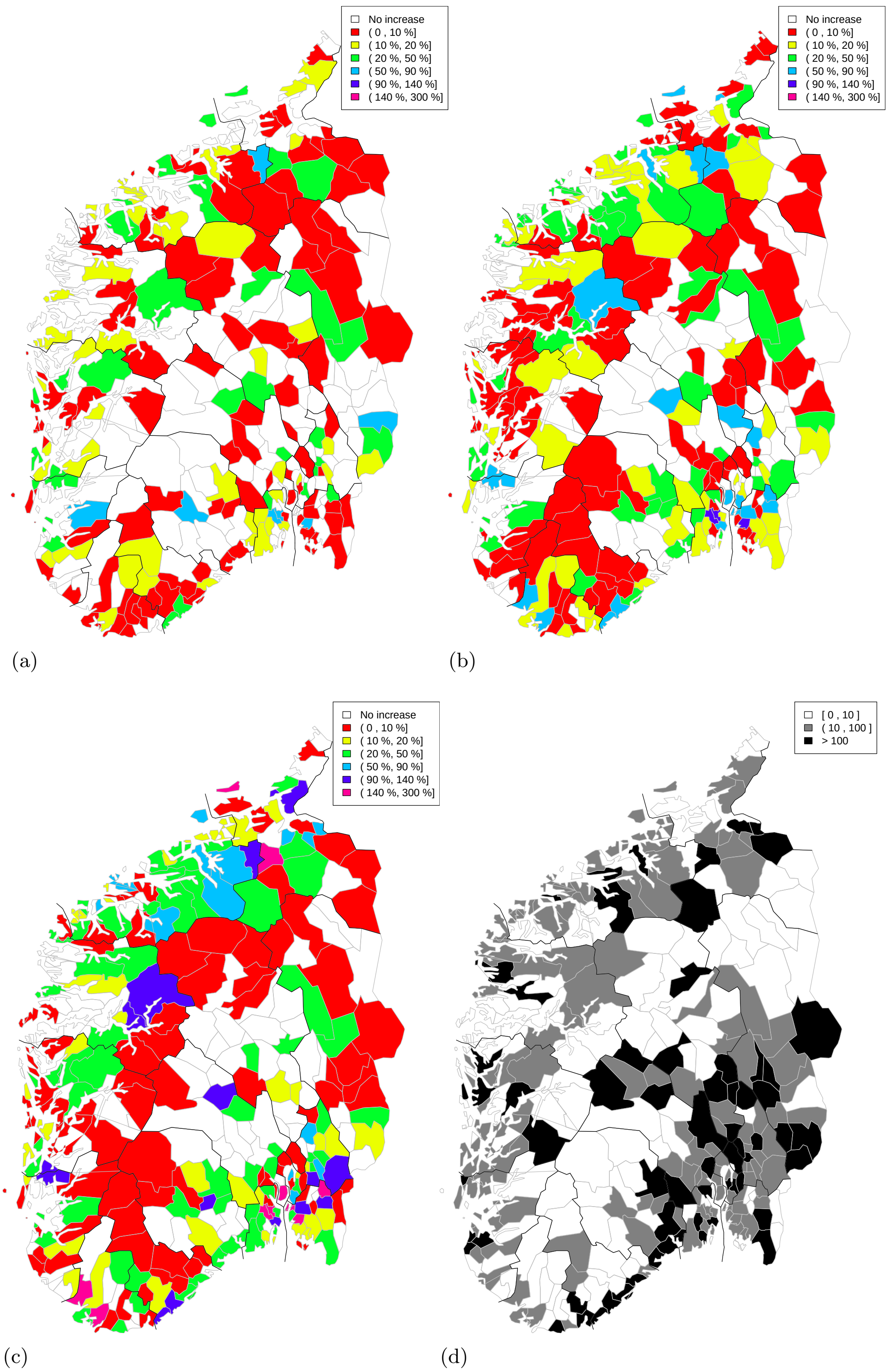

Figure 3. Maps of the central and south of Norway, divided into the municipalities, showing the percentage increase of the posterior predictive 95-percentile of the yearly number of claims for (a) `Scenario1`, (b) `Scenario2` and (c) `Scenario3`, all compared to the reference year 2001, while (d) shows a map of the 95-percentile of the posterior predictive distribution of the yearly number of claims from "original 2001 weather".

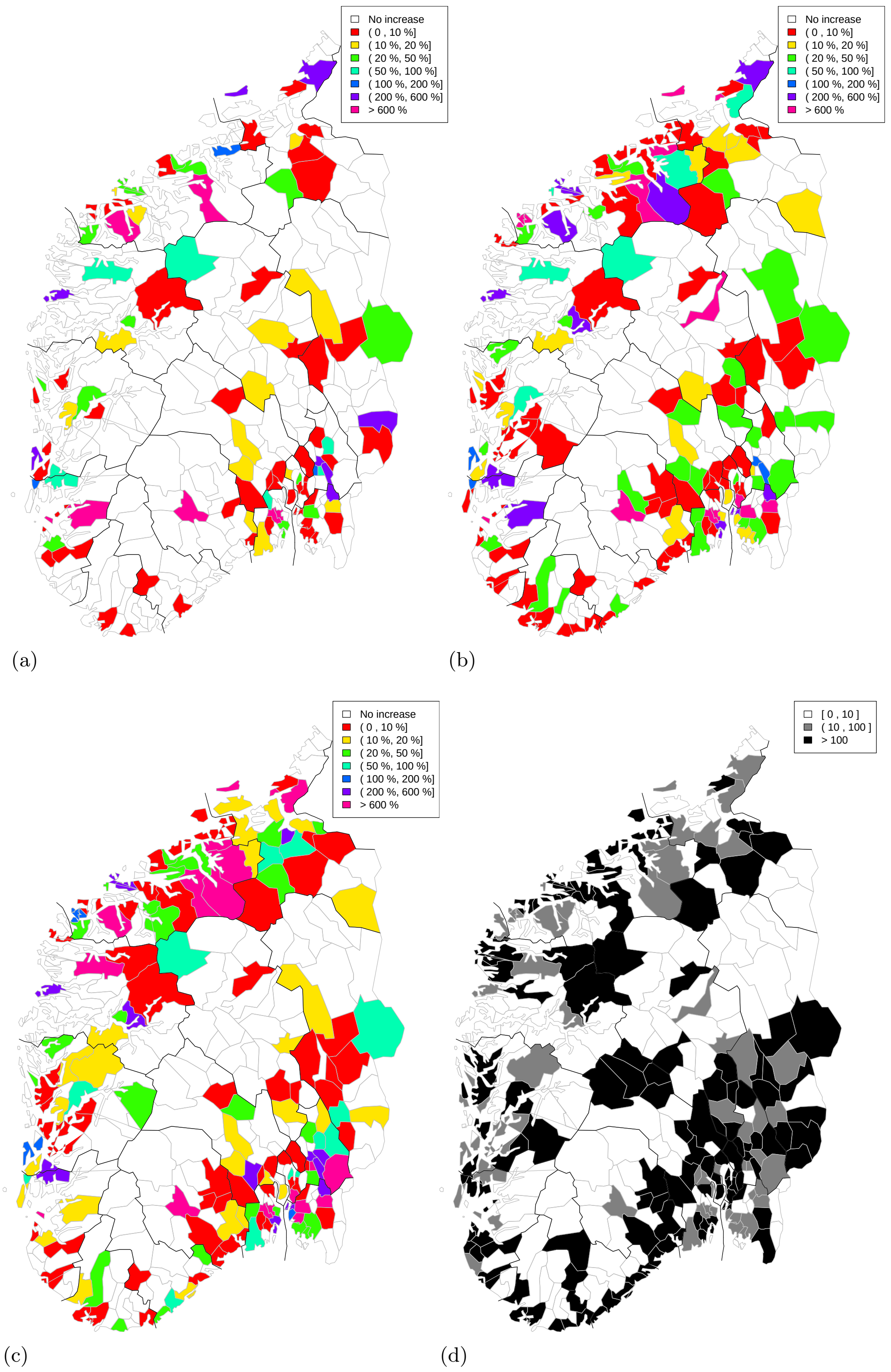

Figure 4. Maps of the central and south of Norway, divided into the municipalities, showing the number of days with scenario precipitation outside of the training range for (a) `Scenario1`, (b) `Scenario2` and (c) `Scenario3`. Of the days with extrapolation, the median of the ratio between the scenario precipitation and the the maximum precipitation seen in the training data was 1.1.

(a) (b) (c)

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