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Climate change

- and its impact on building water damage

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Background

- The insurance industry is vulnerable to climate change
  - Non-life insurance: Buildings, cars, …
  - Life insurance: Altered risks of death and diseases, …

Bergen, January 2005: Storm surge

Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

Background

- Back in 1999, Gjensidige Forsikring and Norwegian Computing Center started their fruitful collaboration
- Three major projects have been conducted to date
- Focus throughout: Externally inflicted water damage to buildings
- Overall aim:
  - Admitting that there will be certain climatic changes, what are the level and geographical pattern of losses to be expected in the future?

Background

- Prediction of future losses calls for:
  - A thorough understanding of the weather mechanisms that influence loss events and their severity
  - Information about future climate
  - Methods to merge the two types of knowledge

Background

- Relevant questions:
  - Can coherences between losses and weather be quantified?
  - Which weather elements are important?
  - Do coherences differ among different areas?
- In what ways can an insurance company make use of the results?
  - Limit the effects of climate change through preventive discussions with customers and local regulators
  - Update the company’s risk and premium calculations

Data: Insurance data

- Water losses from Gjensidige Forsikring's own portfolio of Private building policies
- 10 years of data (1997-2006)
- Spatial resolution at the level of municipalities
- Variables:
  - Number of claims and total payment (index-linked) (daily)
  - Population (number of policies) (monthly)

Data: Insurance data

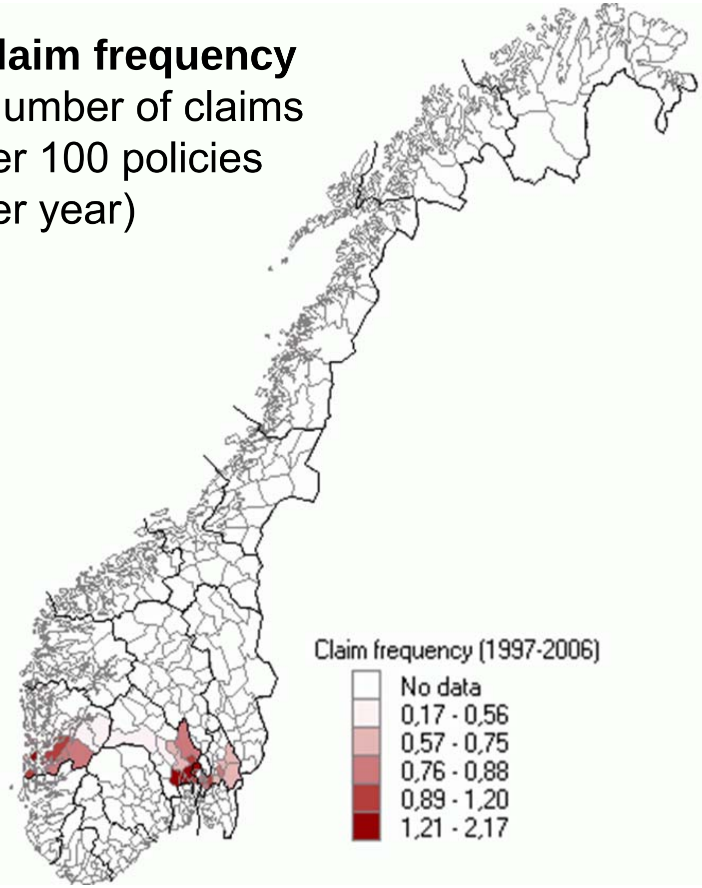
- Data are *frequency claims*, *i.e.* rather small losses that occur ”often” (as opposed to major catastrophes)
  - Main categories:
    - Water running into basements from above the ground
    - Blocked pipes
- Not included: Large-claim situations (losses due to flood, storm surge, slide, …)

Bergen, September 2005:
Extreme precipitation event

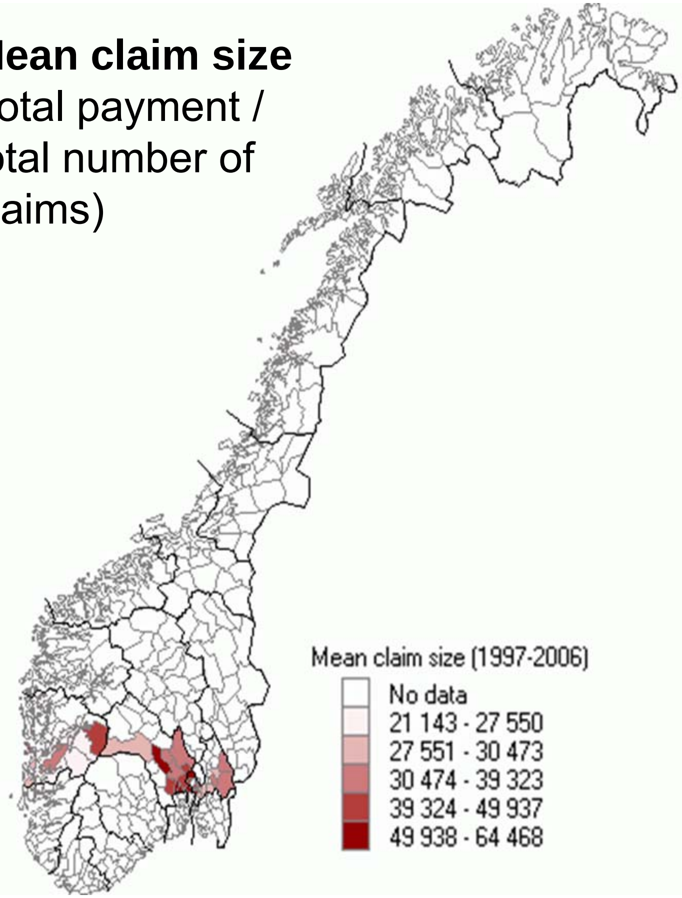
Data: Insurance data

Private buildings, claims from 1997 - 2006

Claim frequency (number of claims per 100 policies per year)



Mean claim size (total payment / total number of claims)

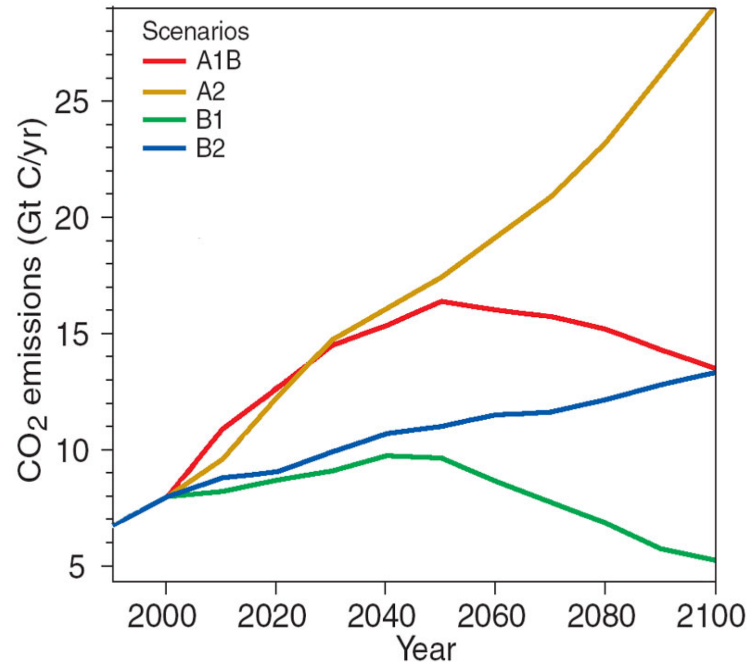


Data: Weather data

- The Norwegian Meteorological Institute (MI) and Norwegian Water Resources and Energy Directorate (NVE):
  - Daily values for each municipality (1961-2006) based on averages of interpolated (1x1 km^2) observations of
    - Precipitation and temperature
    - Runoff and snow water contents
- Spatial representativity of the values is improved by averaging over the most densely populated areas of a municipality only, *i.e.* the areas where losses will primarily occur
  - Essential since harmful weather often is very local

Data: Climate model data

- Regionally downscaled and locally adjusted global Hadley Institute HadAM3H model runs under the CO2 emissions scenarios A2 and B2
- The same variables available as for the weather data
- Climate model runs cover two separate periods:
  - 1961 – 1990 (control)
  - 2071 – 2100 (scenario)

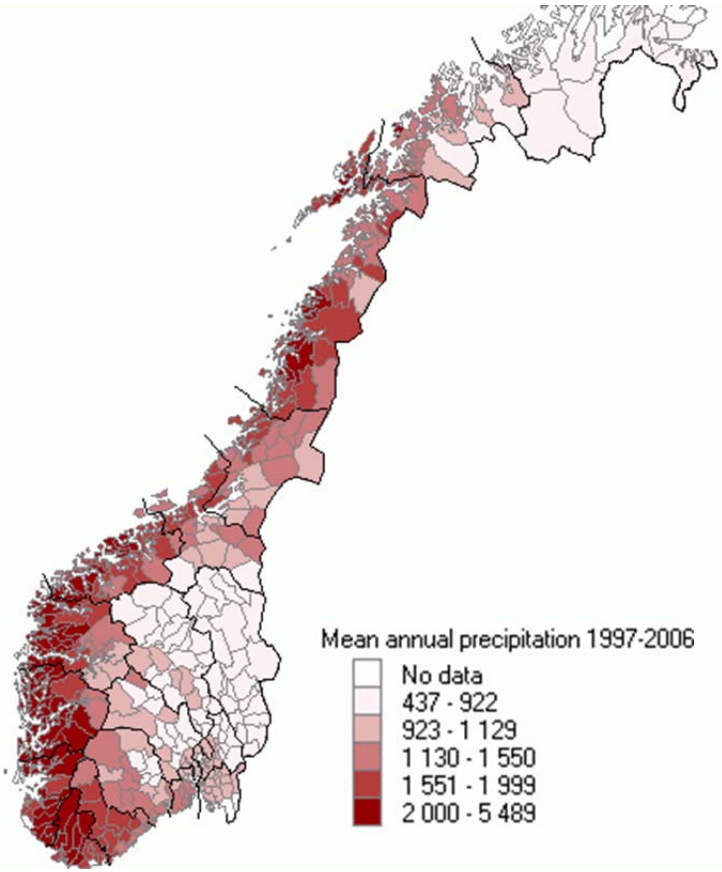


Data: Climate model data

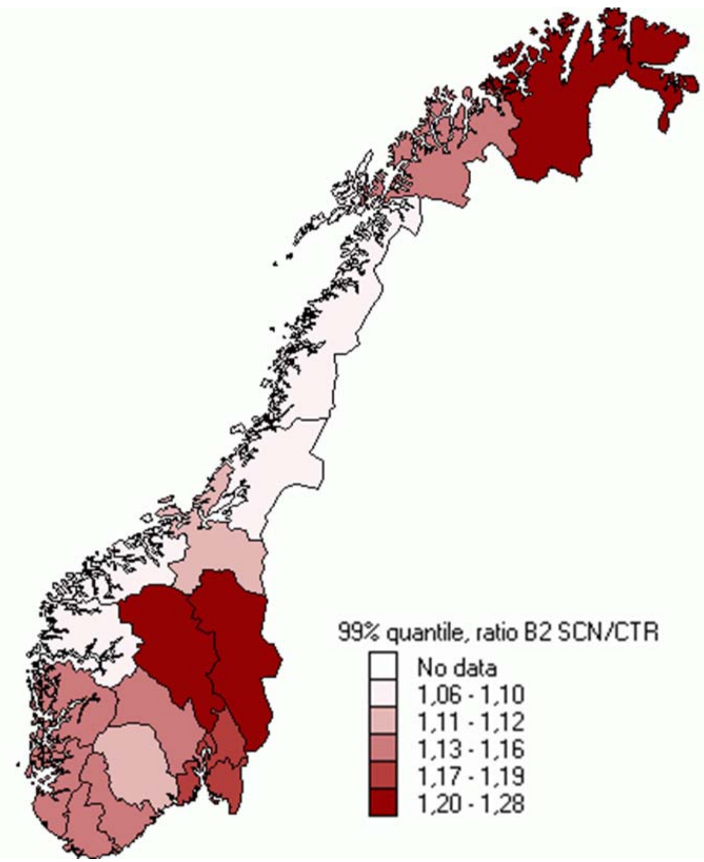
- Note:
  - Climate model data deviate from observed weather
- Therefore, climate model data are adjusted locally against weather observations over the control period 1961 – 1990
- After adjustment, the two data sets agree (locally) at an aggregate level (annual and monthly means and standard deviations)
- Still, however, variables from the two data sets are not supposed to agree *on a certain day*

Data: Weather and climate data

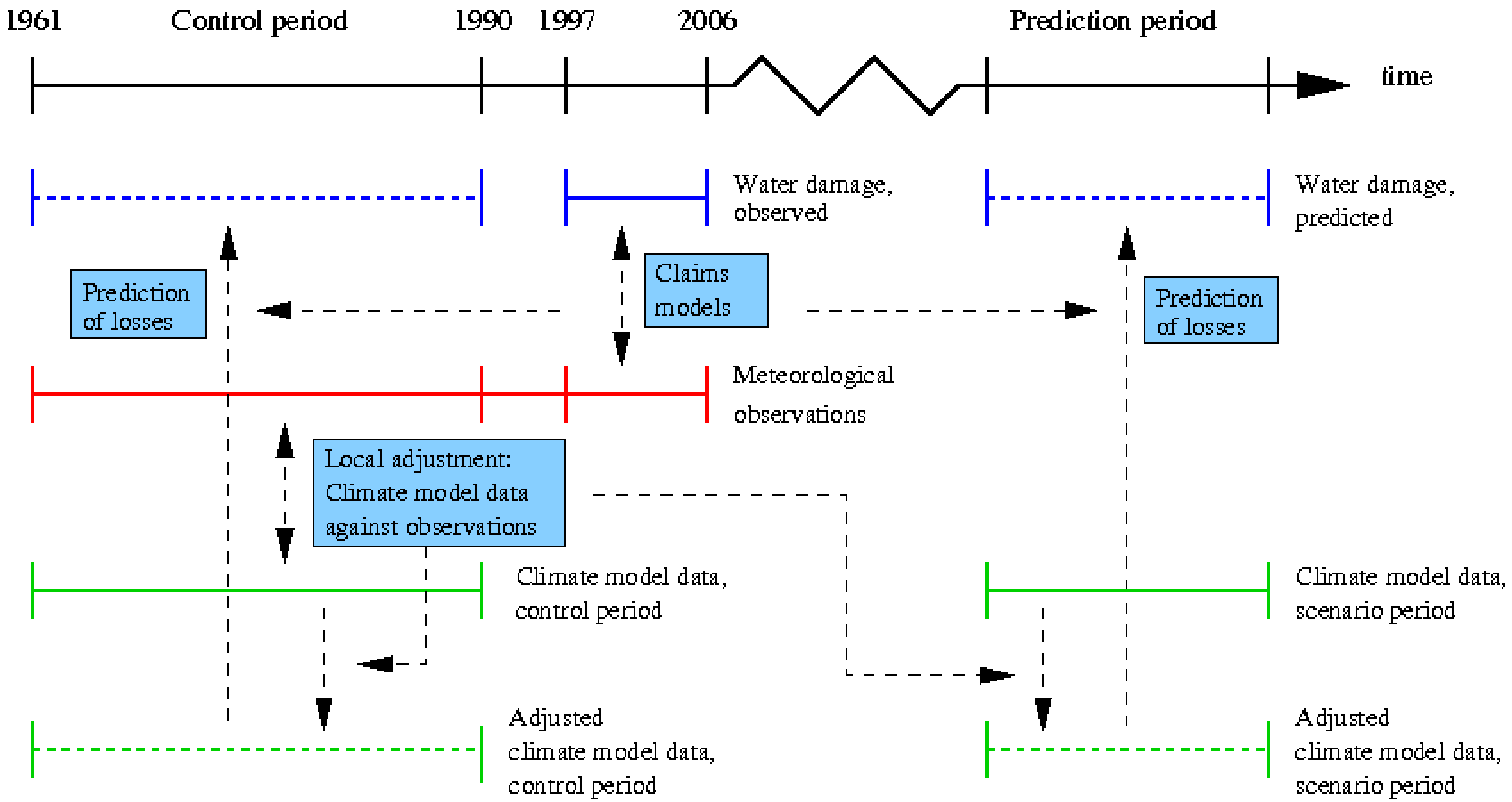
Mean annual precipitation 1997 - 2006



Change in precipitation: Ratio of 99% quantiles from B2 scenario and control period



How data are used…



Claims models

What determines the loss level in an area over time?

- The local climate in the area
- The sensitivity of the buildings in the area

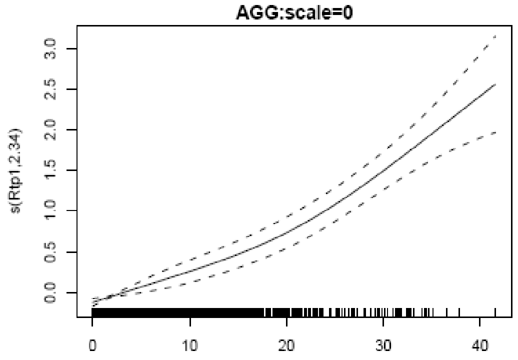
Claims models

- Statistical models for the coherence between water damage and daily weather variables established by means of GAM/GLM techniques
- *Number of claims* and *mean claim size* modelled separately
- Number of claims:
  - All days contribute information, also those with no claims
  - Lots of data, large variability:
    - Apparently identical weather conditions may give none or a few claims, *i.e.* not all underlying aspects of the claims are fully described through the weather
- Mean claim size:
  - Fewer data: Only days with claims contribute information on claim size

Claims models: Explanatory variables

- Tentatively, all claims day weather variables are included
  - Precipitation, temperature, runoff, snow water contents
- Additional variables:
  - Precipitation registered the day after the claims day (the precipitation day is from 06UTC – 06UTC…)
  - Aggregated precipitation over the five days before the claims day (saturation of ground and vegetation)
  - Trend: Accounts for potential systematic development of losses over time that is not related to weather (e.g. economic activity)
  - Seasonality: Periodic variation in claims level throughout the year

Claims models



- GAM plots are used to identify the most likely parametric forms of the explanatory variables to be used in the GLMs

- GLM model fitting
  - Applied to data from 1997 – 2006
  - Daily claims and weather data are matched at municipality level
  - Identical models throughout (most of) the country (*i.e.* the same explanatory variables are used)

Claims models: Number of claims

- Modelling the number of claims:
  - Separate model fits for each of 19 counties
  - Individual constant terms for each municipality
  - Other explanatory variables have coefficients that are common to all municipalities within a county

Example

Sogn og Fjordane county:
26 municipalities

Claims models: Number of claims

- Quasibinomial model, municipality *k*:

$$N_{kt} \sim \text{quasiBin}(A_{kt}, p_{kt})$$
$$\text{E}(N_{kt}) = A_{kt}\, p_{kt}$$
$$\text{Var}(N_{kt}) = \varphi_k\, A_{kt}\, p_{kt}(1 - p_{kt})$$

- GLM with a logit link applied to the claims probability,

$$\text{logit}(p_{kt}) = \beta_0 + \delta_k + \sum_{i=1}^{p} \beta_i x_{kti}, \qquad \sum_k \delta_k = 0$$

φ_k: Dispersion parameter
N_{kt}: Number of claims, day t
A_{kt}: Number of policies, day t
p_{kt}: Claims probability, day t
β_0: County component of constant term (common across munici-palities)

δ_k: Municipality adjustment of β_0
x_{kti}: The level of explanatory variable i, day t
β_i: Coefficients common across municipalities within a county

Claims models: Claim severity

- Modelling mean claim size:
  - Separate model fits for each of 5 regions (Gjensidige splits the country into regions with 2 – 5 counties)
  - Individual constant terms for each county
  - Other explanatory variables have common effects in all municipalities within a region

Example
Region "Innland",
2 counties:
- Hedmark
- Oppland

Claims models: Claim severity

- Gamma model for the mean claim size, municipality *k*:

$$\bar{S}_{kt} \mid N_{kt} \sim \mathrm{Gamma}(\xi_{kt}, \nu N_{kt})$$
$$\mathrm{E}(\bar{S}_{kt} \mid N_{kt}) = \xi_{kt}$$
$$\mathrm{Var}(\bar{S}_{kt} \mid N_{kt}) = \xi_{kt}^2 / (\nu N_{kt})$$

- GLM with a log link applied to the expected claim size

$$\log(\xi_{kt}) = \alpha_0 + \gamma_{F(k)} + \sum_{i=1}^{p} \alpha_i x_{kti}$$

F(k): County index

s_{ktj}: Individual claim size, day t

$\bar{S}_{kt}$: Mean claim size, day t:

$$\bar{S}_{kt} = \sum_{j=1}^{N_{kt}} s_{ktj} / N_{kt}$$

$\bar{S}_{kt} \mid N_{kt}$: Mean claim size given the number of claims

α_0: Region component of constant term (common across counties)

$\gamma_{F(k)}$: County adjustment of α_0

x_{ktj}: The level of explanatory variable i, day t

α_i: Coefficients common across counties within a region

Claims models: Total payment

- Total payment may be derived from the number of claims model and the mean claim size model
- Expected payment at day *t* in municipality *k* is

$$E\left(\sum_{j=1}^{N_{kt}} s_{ktj}\right) = E(N_{kt}\bar{S}_{kt})$$

$$= E(N_{kt})E(\bar{S}_{kt} \mid N_{kt})$$

$$= A_{kt}\, p_{kt}\, \xi_{kt}$$

Claims models: Final models

- Final GLM model selection by means of BIC
- Tested a subset of reasonable models (potential parametric forms from GAM plots)
- Final decision based on the sum of BIC-values over all counties or regions

Claims model	Weather-related explanatory variables
Number of claims	Precipitation Runoff Temperature Snow water contents
Claim severity	Precipitation Runoff (partly)

Prediction

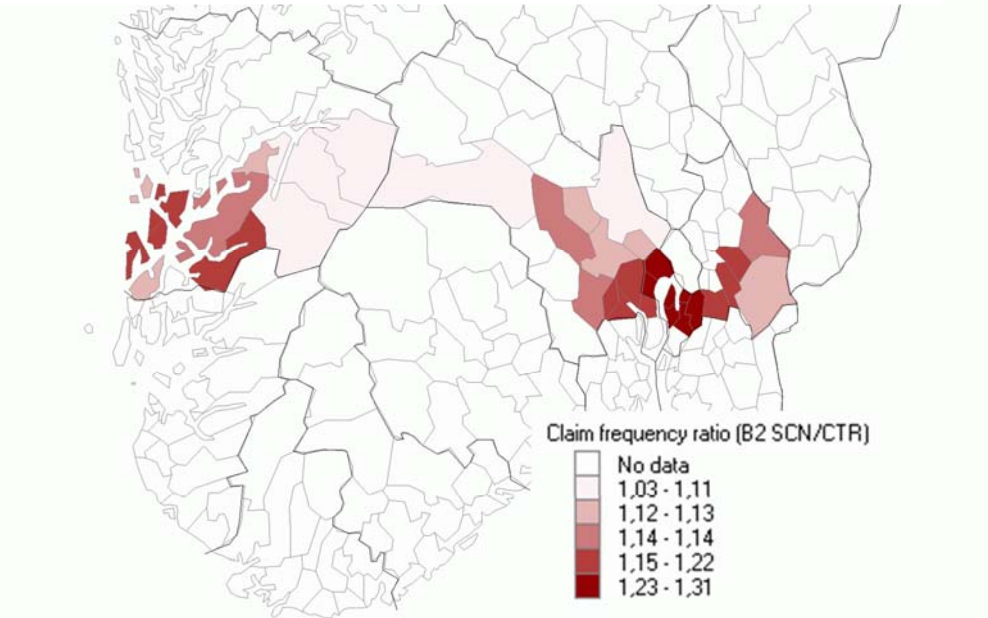
- Claim level predictions for the control and scenario periods are calculated from:
  - Fitted claims models (number and size)
  - Adjusted climate model data for both periods
- Predictions will be uncertain:
  - Uncertainty due to model fit (quantifiable)
    - Estimated from model simulation
  - Error due to true model discrepancy (not quantifiable)
  - Uncertainty in the climate model data (not quantifiable)

Prediction: Claims change

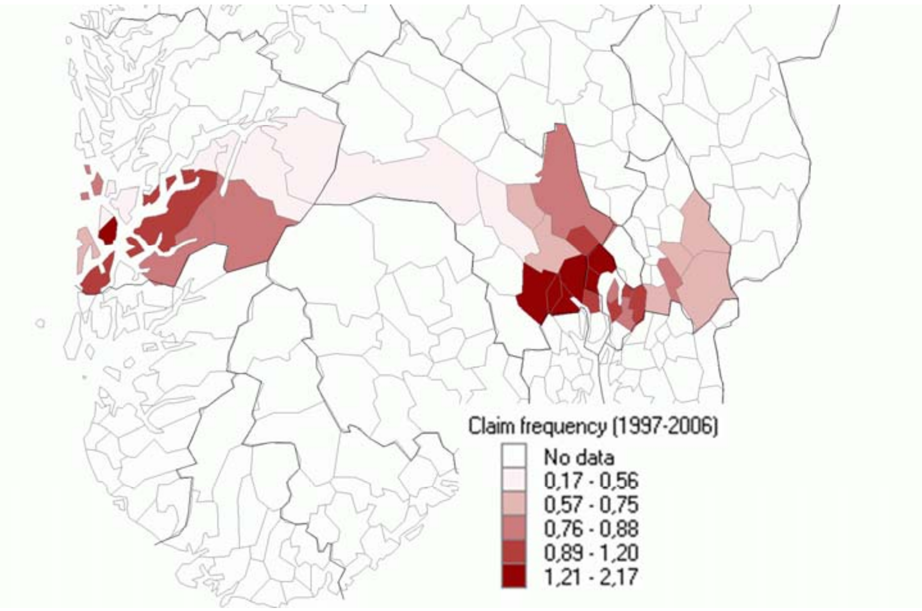
- Compare loss level predictions for the control and scenario periods by looking at ratios:
  - Number of claims: $r_k(scn, ctr) = \frac{\sum_{t \in scn} \hat{N}_{kt}^{scn} \mid A_{kt} = A_0}{\sum_{t \in ctr} \hat{N}_{kt}^{ctr} \mid A_{kt} = A_0}$
- The ratio for municipality *k* is a function of
  - The local vulnerability of the buildings (claims model)
  - The climatic change as told by climate models
- Ratios > 1 indicate an increased future loss level

Prediction: Change in number of claims

Ratio of number of claims (scenario period divided by control period)

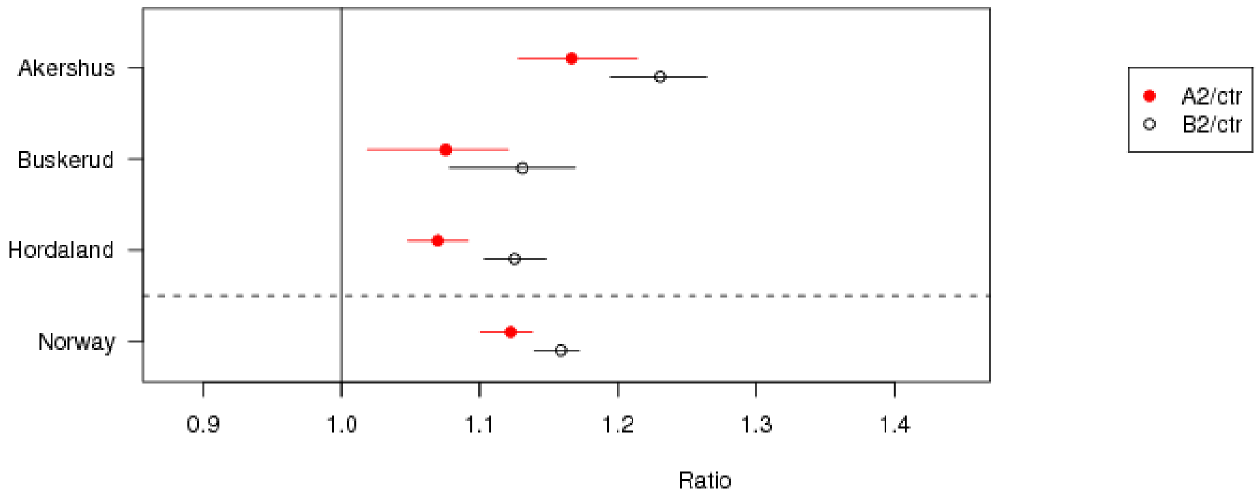


Number of claims, 1997 – 2006 (per 100 policies per year)



Prediction: Estimation uncertainty

- Fitted claims models: Assume a multinormal distribution for the model coefficients
- Compute a set of ratios from a simulation study (*n*=100)
- Use empirical quantiles as confidence limits



Summary

- Future loss level will increase, but predictions show considerable geographical variation
- Prediction uncertainty is probably substantial, due to:
  - Claims models specification and estimation
  - Climate model data
- Still, rough estimates indicate that the insurance industry may benefit from taking pre-cautionary measures to reduce undesirable effects of climate change
- Further research will be carried out
  - EU (Marie-Curie) granted project (2008-2011): *Climate Change and Insurance Industry* (*CCII*), together with London School of Economics, Lloyds and Gjensidige Forsikring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