



Climate change and design flood calculation for dams in Norway

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General background

- There are 335 large dams in Norway
- Most large dams in Norway are rockfill dams, and > 35 years old
- The main load is the design flood; calculated design floods change over time due to changes in methods and historical data records
- Since the 1980's; the design flood for large dams is set to the 1000-year flood (Q1000)
- Flood frequency analysis using historical data is the preferred method



General background

- Since the 1990's: dams are subject to regular safety reassessment, every 15 year. Thus, design floods must also be recalculated every 15 year
- Many dams need upgrading due to new flood calculations
- Heightening of a rockfill dam, a typical measure, is very costly



Future climate in Norway

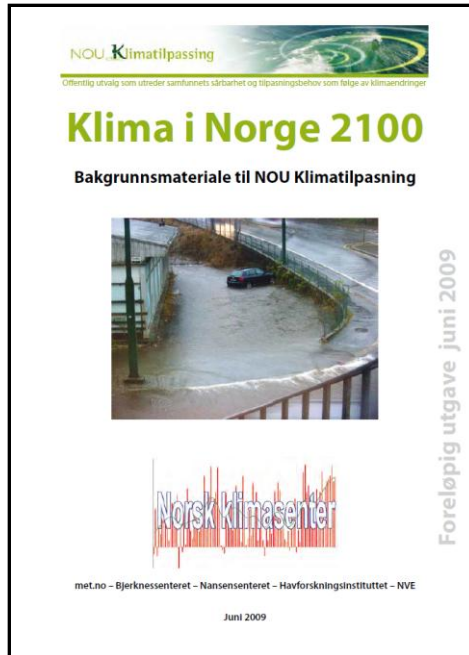
Projected changes for Norway:

Increased T (all seasons)

Increased P (esp. autumn/winter)

Increased extreme P

Changes in snow storage and runoff

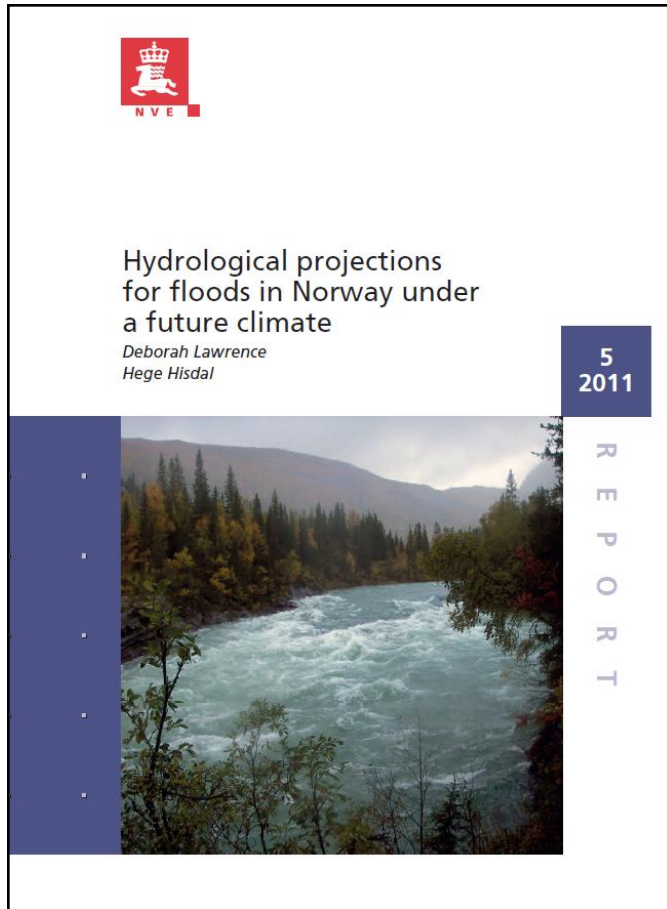


Hanssen-Bauer, I. *m.fl.* *Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilpassing. (Climate in Norway 2100. Background material for Norwegian Committee on Climate Change Adaptation.)* Norsk klimasenter, September 2009, Oslo.



How will these changes affect the design flood for a specific dam?

The effects on floods in Norway

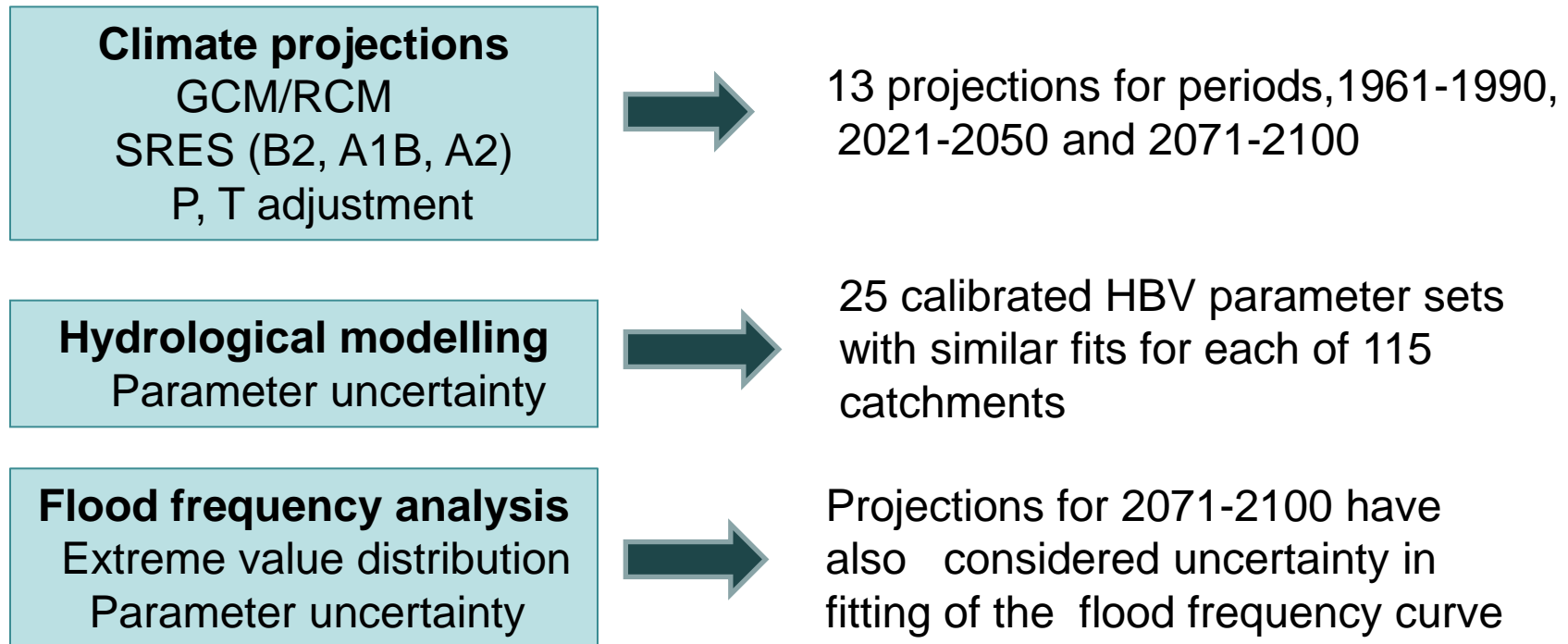


The project comprised:

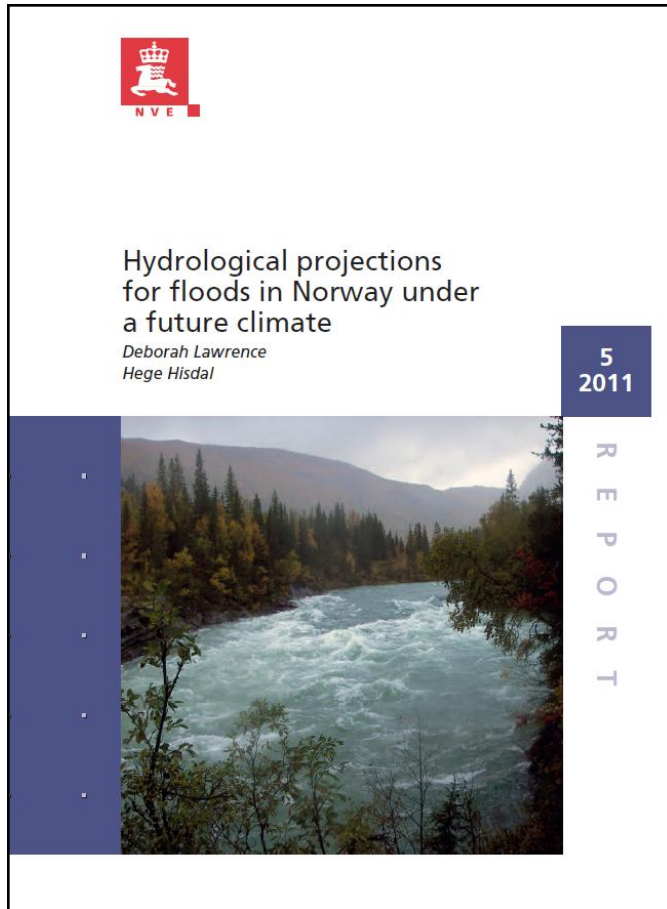
- Study of 115 catchments all over Norway using an ensemble method, enabling consideration of uncertainty in;
 - climate models
 - model parameters (HBV)
 - frequency analysis

Analysis of likely changes in flood frequency

=> 8000 model runs for each catchment



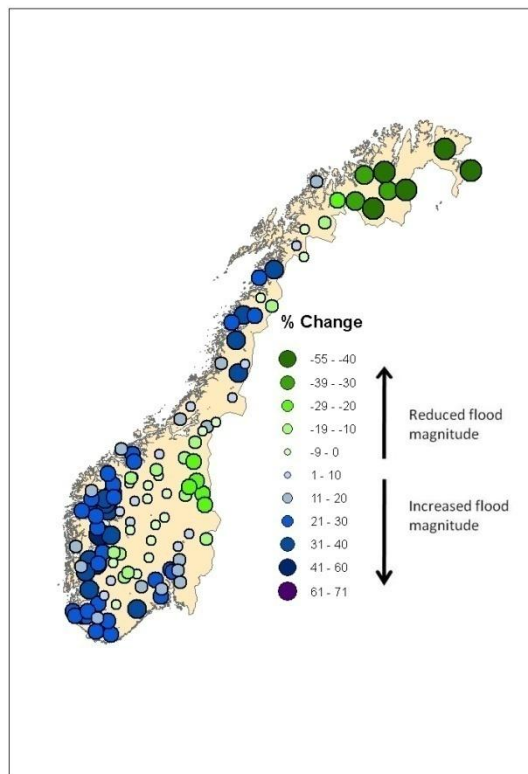
The effects on floods in Norway



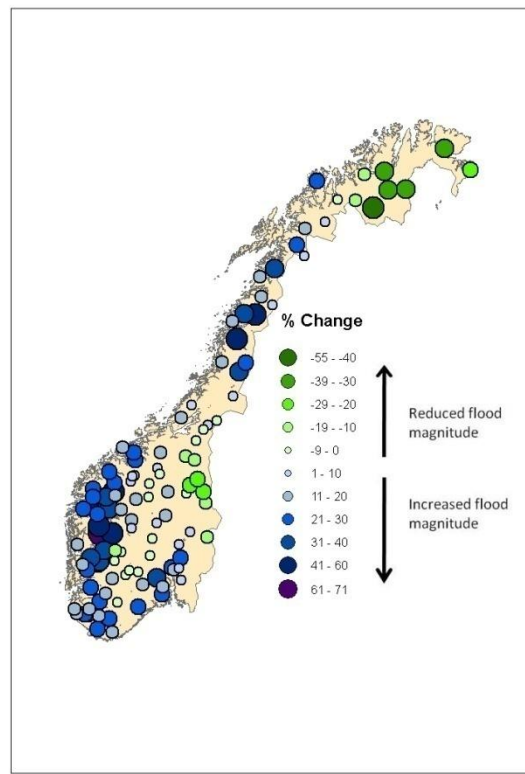
Results:

- Hydrological projections for the mean annual flood, the 200-year and 1000-year flood
- Regional recommendations for climate change adaptation

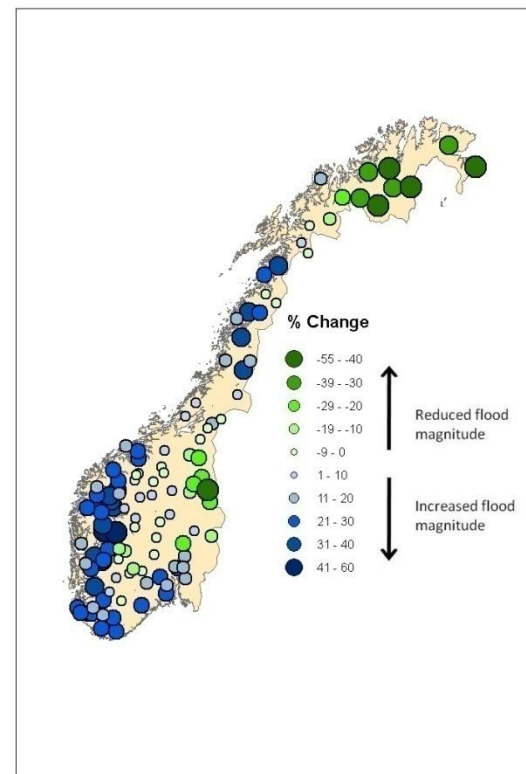
Projected changes in floods



Mean annual flood



200-yr flood

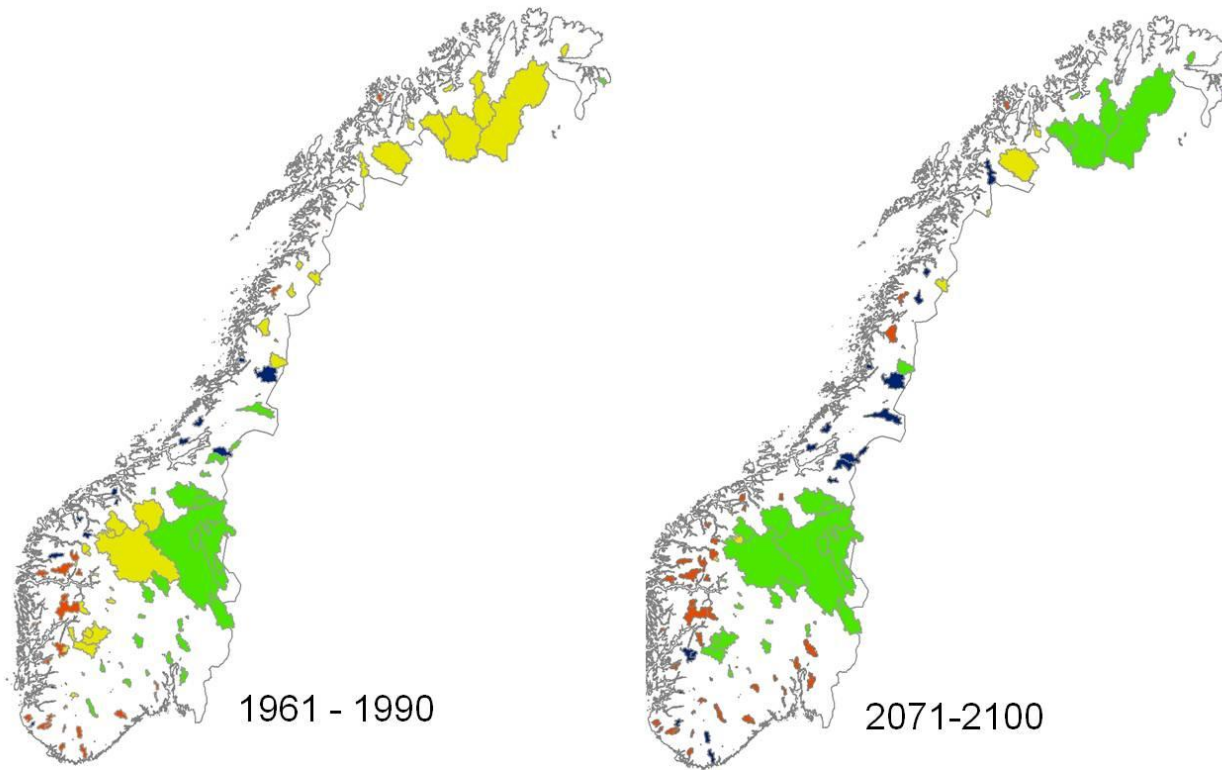


1000-yr flood



Percentage change is similar for all flood frequencies (median values).

Changes in seasonality is also expected in some areas

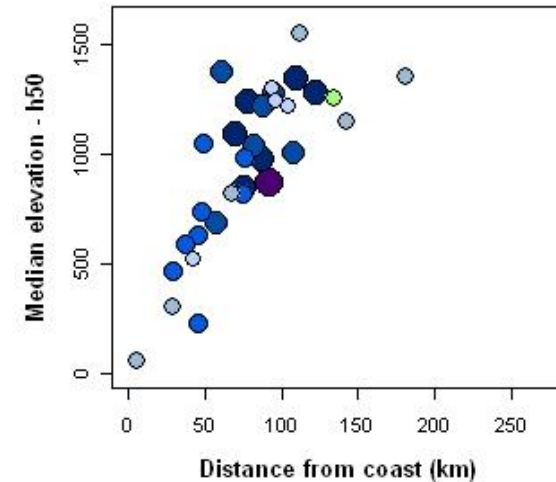
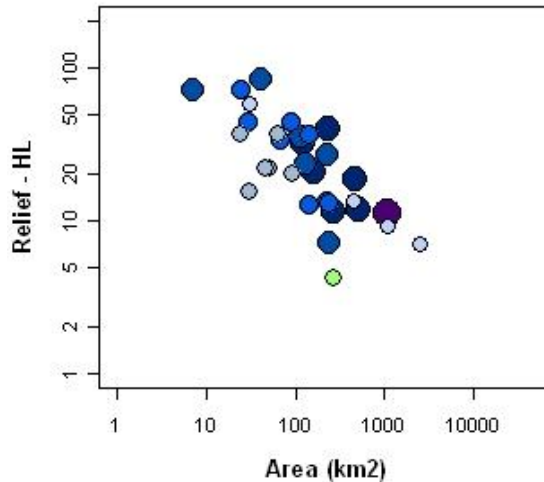
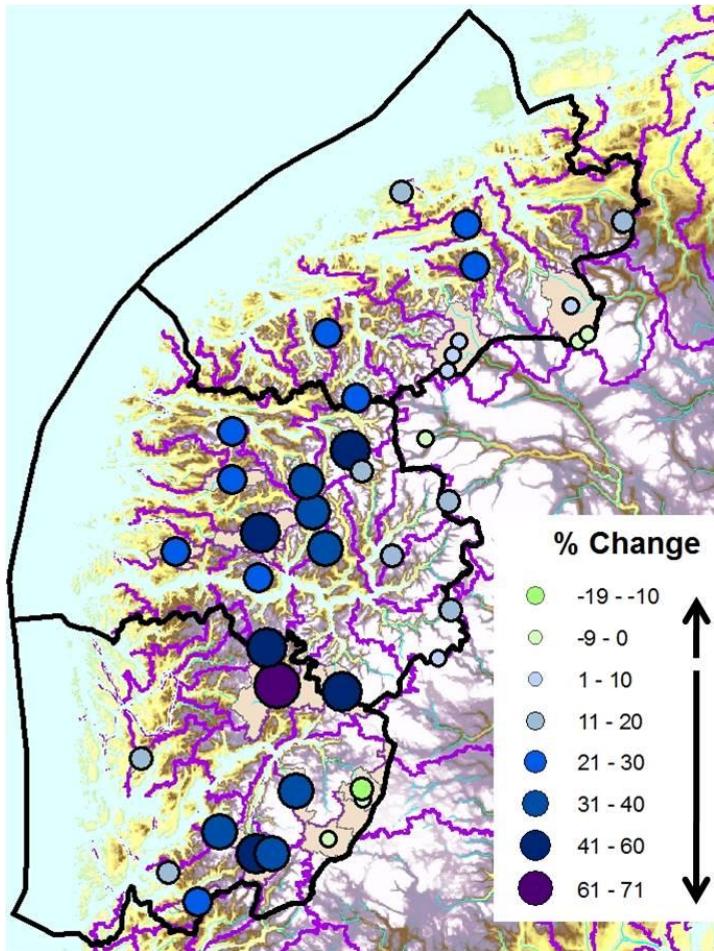


➔ MAM JJA SON DJF

➔ Earlier snowmelt floods; more autumn/winter rain-induced floods

Regional recommendations

– Western Norway



20 % increase – All catchments

40 % increase – All catchments in Hordaland and Sogn og Fjordane counties which are within or adjacent to catchments exhibiting large increases (i.e. > 40%)

Practical application of results (dam safety):

- It can be cost-effective to account for future increase in design flood when planning upgrading today, instead of postponing the problem to the next safety reassessment(s).
- However, the dam safety regulations do not require that the dam owners account for future climate change (that would be a major shift in safety policy)
- Thus, for dams in regions with expected increase in floods, it is **recommended** to do a sensitivity analysis of the relevant projected changes in floods (20%, 40%) with reference to NVE-report 5/2011, and if relevant; add an extra safety margin when planning necessary measures based on traditional dam safety reassessments.



Summary

- Hydrological projections for future changes in floods have been developed for Norway using GCM/RCM data, hydrological models and flood frequency analyses for 115 catchments
- Results indicate large regional variations in projected changes, with moderate to large increases in areas with rainfall-dominated flooding and possible decreases in areas with snowmelt-dominated flood regimes. Changes in seasonality in some areas are also expected.
- Results are used to give guidance to how dam owners can account for future climate change in different regions and different types of catchments.

