#### Flooding in Norway under a near future 2021-2050 climate: *Rainfall vs. snowmelt floods and their uncertainties*

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# Climate change impacts on flooding and their uncertainties

- Demand for information regarding climate change impacts on flood frequency for use in adaptation (dam safety, transport, areal planning)
- Differing climate scenarios, models and methods can produce dissimilar results: How can these be summarised and used in practical applications?
- ⇒ Ensemble methodology for analysing hydrological projections and their uncertainties



### Some factors contributing to flooding in Norway which are likely to be impacted by climate change:

Runoff from rainfall and/or snowmelt



Manndalen, May, 2010; Photo: NVE

### Excess rainfall in areas with limited infiltration



Hønefossen, May, 2008; Photo:NVE

### Intense precipitation in localised areas



Photo: NVE



#### Modelling chain for hydrological impact projections

**SRES Emission scenario Global climate model Regional climate model** Adjustment of P,T to local 1 x1 km grid Hydrological models Flood frequency estimation





# Ensemble approach for probabilistic hydrological projections

**3 GCM/RCMs (with SRES A1B emissions)** Echam5/HIRHAM5 BCM/RCA3 HadCM3Qref/HIRHAM

2 Methods for transferring RCM output to 1 x 1 km grid Delta change Empirical adjustment method (met.no)

**25 calibrated hydrological models** for 115 catchments

Flood frequency analysis for 200-year flood

⇒ Construct pdfs from 150 results for each catchment



from 3 to 15,000 km<sup>2</sup>

# Flood frequency estimation applied to annual maximum flood series





# Projected change in 200-yr. flood between 1961-1990 and 2021-2050





### **Range of uncertainty in projections**





#### Uncertainty – Relative magnitude of sampled sources



- Differences in GCM/RCM tend to be more significant in inland and northern areas
- Western Norway dominated by uncertainty from HBV and methods for adjusting P, T

Uncertainty source with largest magnitude:

- GCM/RCM
- EA/DC
- HBV parameter

N = 115 GCM/RCM = 50 EA/DC = 38 HBV = 27

#### Uncertainty from flood frequency analysis relative to model uncertainty

Viksvatn - 83.2 A1B HadCM3Qref/HIRHAM (25 x 25 km) 'Empirical Adjustment' til 1 x 1 km



# Seasonal analysis - Rainfall-induced peak flows in annual maximum series



 $\Rightarrow$  Change towards increasing occurrence of autumn/winter peak flows in annual series





# Projected increase in probable maximum precipitation (PMP)





#### **Further comments**

- •Ensemble approach is an effective method for summarising hydrological projections and the relative contributions of uncertainty sources
- •Only 'sampled' uncertainties are represented, and other factors should not be disregarded

### Implications for dam safety analyses in Norway:

Flood frequency analysis indicates regions of increase vs. reduction in low frequency events
Change of seasonality can have implications for the season considered in the flood calculations
PMP is projected to increase in all regions, so that PMF estimated with event-based modelling can be expected to increase