Norwegian Meteorological Institute
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Klimascenarier og effekter for snøforhold i Norge i framtiden

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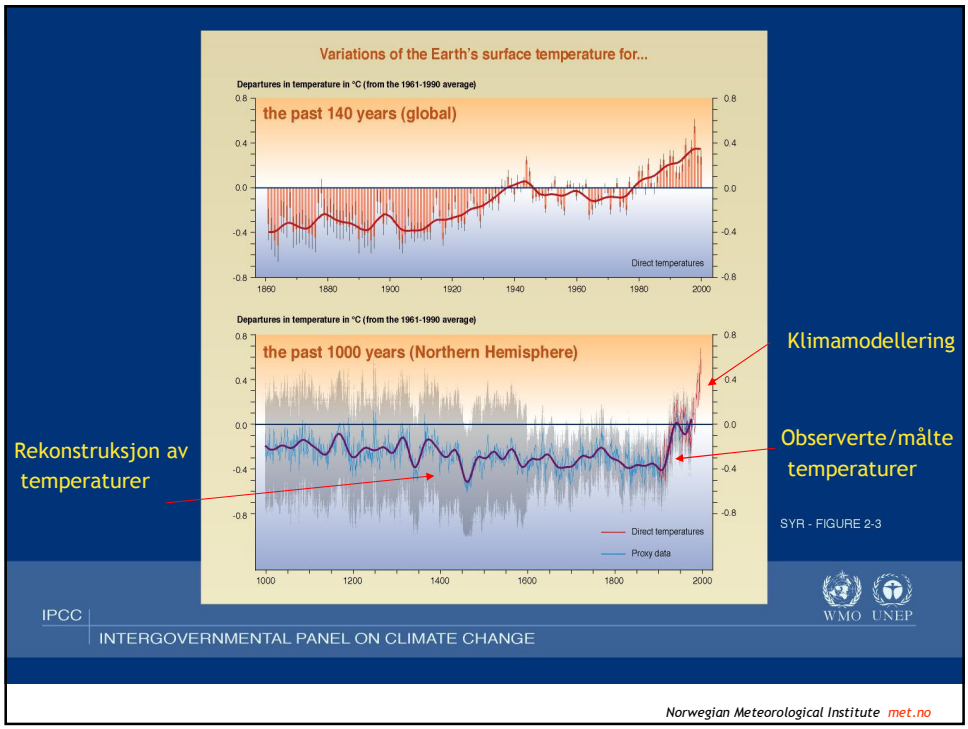
RegClim 3. mai 2006

Global oppvarming

- Siste 150 år
  - temperaturen på jordkloden økt ca. 0.6°C.
- Årsaker?
  - Naturlige svingninger?
  - Menneskelig påvirkning?
    - Forsterket drivhuseffekt grunnet økt menneskelig utslipp av drivhusgasser?

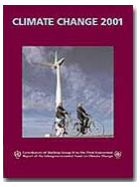


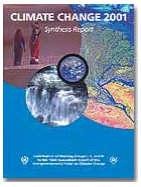
Organisasjoner

- IPCC: Intergovernmental Panel on Climate change (FN's klimapanel)
  - opprettet i 1988
  - flere hundre forskere som skriver og kontrollerer panelets hovedrapporter.
  - Rapportene oppsummerer "state-of-the art" av klimaforskning. Brukes som grunnlag for internasjonale klimaforhandlinger.

IPCC rapporter

- Third Assessment Report 2001
  - The Scientific Basis
  - Impacts, Adaptation and Vulnerability
  - Mitigation
  - Synthesis Report



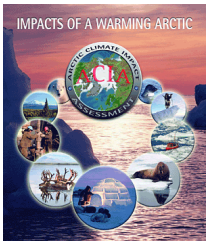


•http://www.ipcc.ch

•http://www.grida.no/climate/ipcc_tar/index.htm

Organisasjoner

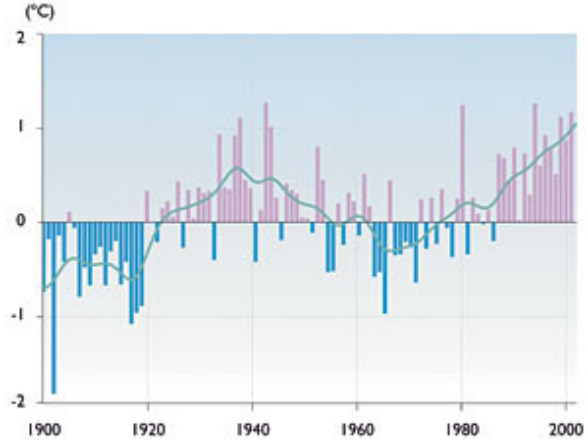
- ACIA: Arctic Climate Impact Assessment
  - over 250 forskere fra 8 arktiske land (Danmark, Canada, Norge, Sverige, Island, Finland, Russland, USA)
  - rapporter:
    - vurderinger og analyser av hvilke konsekvenser klimaendringer kan ha for miljø og samfunn i arktis.



•http://acia.cicero.uio.no/

Observert temperatur i Arktis 1900-2000.

- relativt til normalperioden 1961-1990



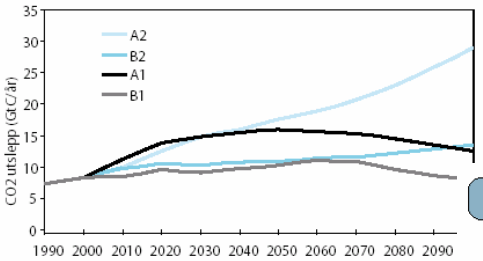
Større temperaturøkning i Arktis enn i resten av verden.

Klimascenarier

- Beregninger av hvordan klimaet på jorden vil være i framtiden. f.eks. fram til 2100.
  - FN's klimapanel utarbeider scenarier.
  - Faktorer bak valg av utslippsscenarier for drivhusgasser.
    - Befolkningsstørrelse, økonomisk utvikling, teknologisk utvikling

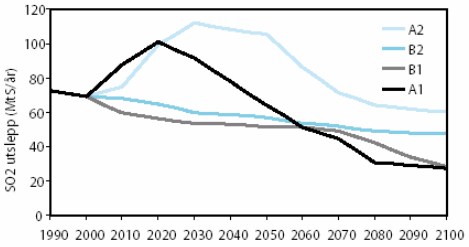
Fire utslippsscenarier fra FN's klimapanel (IPCC rapport 2001)

Figur 1. Globale CO_2-utslepp frå 1990 til 2100 målt i milliardar tonn karbon (GtC) per år.



CO2

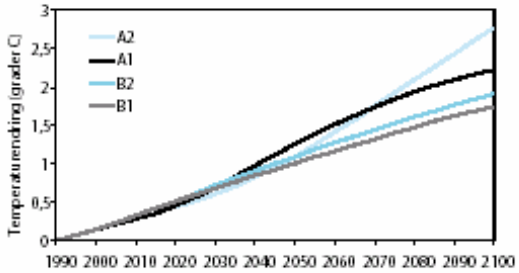
Figur 2. Globale SO_2-utslepp frå 1990 til 2100 målt i millionar tonn svovel (MtS) per år.



SO2
(svoveldioksyd)

Projisert endring i global middeltemperatur

Figur 3. Endring i global middeltemperatur målt i °C i forhold til nivået i 1990.



Globale klimamodeller
- Atmosphere-Ocean General Circulation Model (AOGCM)

- Koblede simuleringer mellom atmosfære og hav
  - over flere hundre år (hundreårskjøringer)
  - under ulike utslipp av drivhusgasser
- Skala: ca. 300 X 300 km romlig oppløsning
- Eksempler:
  - Max-Planck instituttet (MPI) i Tyskland
  - Hadleysenteret (HC) i England. Echam klimamodell

Globale klimamodeller
- Atmosphere-Ocean General Circulation Model (AOGCM)

- Beregner klimaet for hele jorden.
- Tar ikke hensyn til regionale og lokale effekter.

- Hva hvis man ønsker beregninger for bare Norge? Eller bare Arktis?

Regionale klimamodeller

- Nedskalering fra global klima til regional klima

- Metoder som forsøker å ta hensyn til:
  - lokale/regionale effekter på klimaet på skala 10-100 km.
  - fjell, kystlinjer, sjøer og overflatetyper.

Regionale klimamodeller

To metoder:

- Dynamisk nedskalering
  - regional numerisk atmosfæremodell med "høy" oppløsning: ca. 55 * 55 km (Hirham).
  - beskriver topografien sammen med data fra den globale modellen.
  - Eks. Hirham, Bergensmodellen

- Empirisk (statistisk) nedskalering
  - effekten av lokale påvirkninger representeres empirisk.
  - utvikler statistiske sammenhenger som forbinder variable på stor skala fra de globale modellene med lokale overflateparametre.

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Endringer i snøforhold

Dagrun Vikhamar-Schuler[1], Stein Beldring[2], Eirik J. Førland[1], Lars A. Roald[2] og Torill Engen-Skaugen[1]

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RegClim 3. mai 2006

Changes in snow conditions:
- from 1961-1990 to 2071-2100

- Part 1: Water balance model (HBV/GWB)

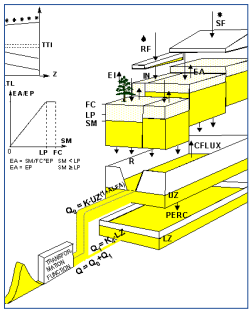
Vikhamar-Schuler, D., S., B., Førland, E. J., Roald, L. A., and Engen-Skaugen, T. (2006). Snow cover and snow water equivalent in norway: -current conditions (1961-1990) and scenarios for the future (2071-2100). met.no report no. 1.

- Part 2: Comparison of snow projections
  - Water balance model (HBV/GWB)
  - Meteorological model (HIRHAM)

Water Balance Model: HBV

HBV: Conceptual model ("Kar-modell").
- Snow routine,
- soil moisture zone,
- upper zone,
- lower zone.

Computes runoff from drainage area



Gridded Water Balance Model: GWB

= Spatially distributed HBV model (1 km × 1 km grid cells)

Per grid cell:

- Subgrid scale distribution of:
  - snow storage, soil moisture storage
- Groundwater storage and runoff response
- Max. four land cover elements:
  - E.g. forest, mountain, agriculture, lake and glacier area

Model is run with daily time step

- Input: Precipitation and temperature
- Output: Water balance elements
  - runoff, snow water equivalent, evaporation..

Snow model in HBV

- Snow accumulation:
  - Snow: T < TX
  - Rain: T > TX

T:	Observed temperature
TX:	Threshold temperature
M:	Melt (mm)
CX:	Melt factor
TS:	Melt threshold

- Snow melt:
  - Degree-day approach (temperature index)
  - M = CX (T-TS), for T>TS
  - M = 0, for T<TS

Temperature and Precipitation data from RegClim

Dataset	Observations met.no
A	1961-1990

Dataset	Climate model	Emission scenario	Control period	Scenario period
B	HadAm3	B2	1961-1990	2071-2100
C	ECHAM4/OPYC3	B2	1961-1990	2071-2100

Temperature and Precipitation data from RegClim

Processing:

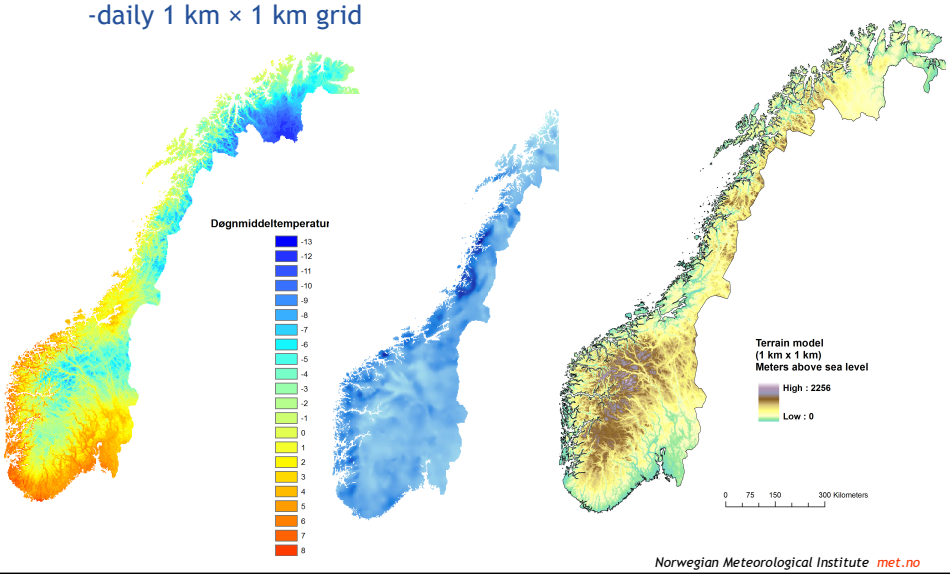
- HIRHAM: Dynamical downscaling of the global climate scenarios to ca. 55 km × 55 km grid (ref: Jan Erik Haugen).
- Adjustment of the climate scenarios to local stations (ref: Torill Engen-Skaugen).
- Interpolation to daily 1 km × 1 km grid.

Temperature

-daily 1 km × 1 km grid

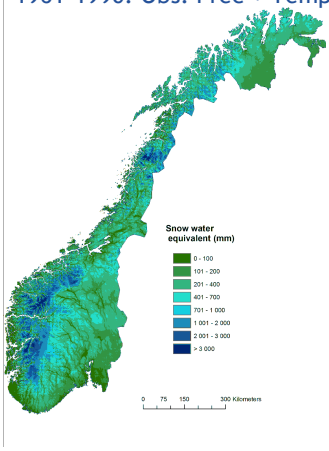
Precipitation

Topography

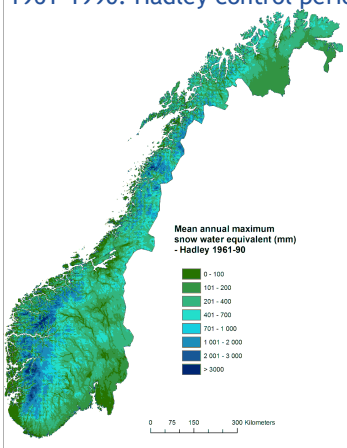


Mean annual snow water equivalent

1961-1990: Obs. Prec + Temp

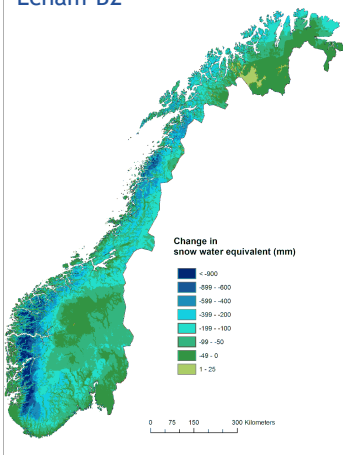


1961-1990: Hadley control period

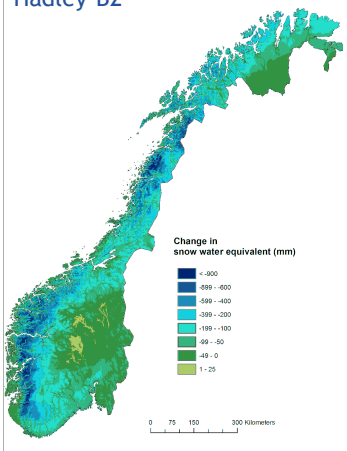


Change in mean annual snow water equivalent (mm): 1961-1990 to 2071-2100

Echam-B2

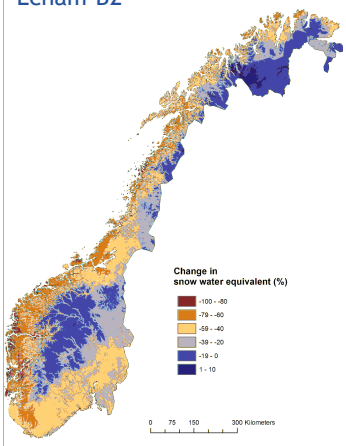


Hadley-B2

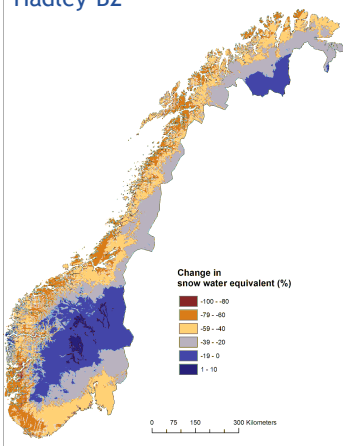


Change in mean annual snow water equivalent (%): 1961-1990 to 2071-2100

Echam-B2

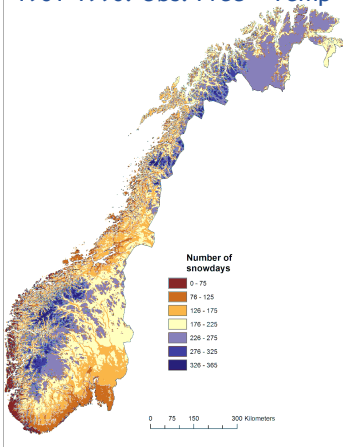


Hadley-B2

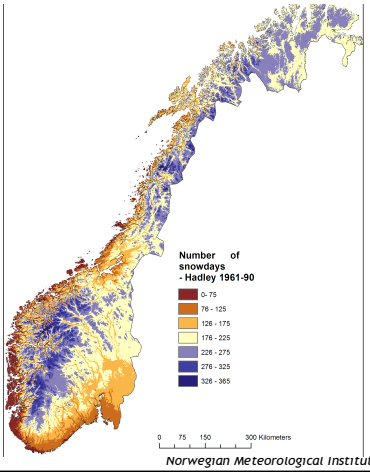


Mean number of days per year with snow cover > 50%

1961-1990: Obs. Prec + Temp

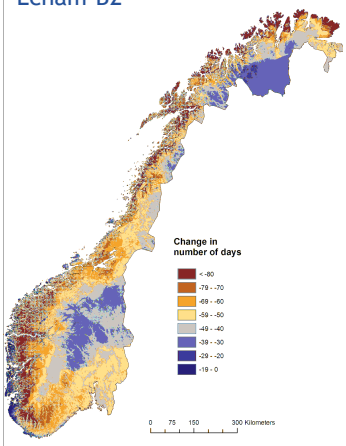


1961-1990: Hadley control period

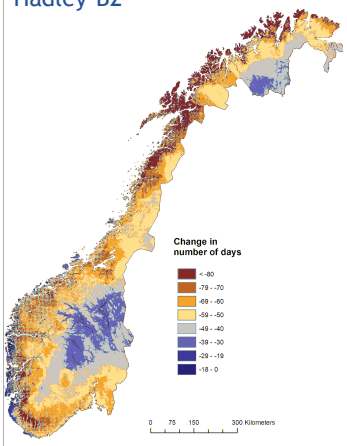


Change in mean number of days per year with snow cover > 50%: 1961-1990 to 2071-2100

Echam-B2



Hadley-B2

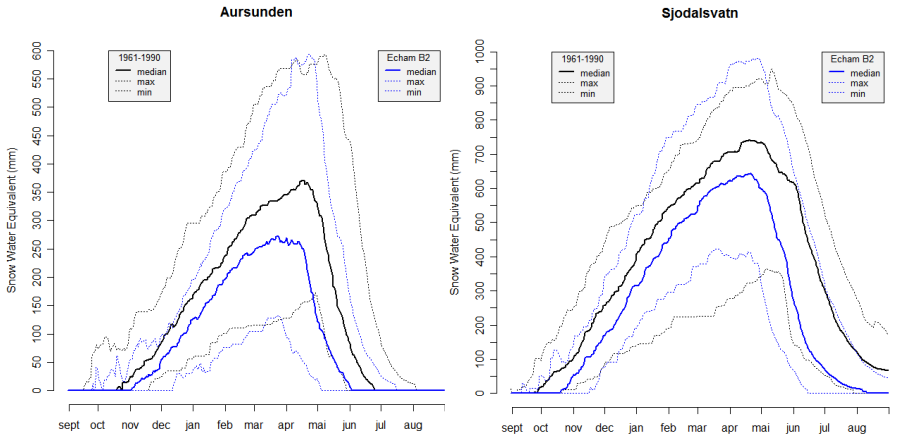


Andre analyser

- Statistikk beregnet for 12 utvalgte nedbørfelt:
  - Varighet av snøsesongen
  - Start og slutt
  - Endringer fra 1961-1990 til 2071-2100

→ Se egen met.no rapport nr.1-2006

Drainage areas



Summary: Snow conditions might change in the following way:

- Mean annual max. snow water equivalent is projected to decrease in Norway.
  - Largest relative changes (> 60%): coastal areas (inner and outer) in West-Norway and North-Norway.
  - Smallest relative changes (0-19% decrease):mountains, South Norway+ inner regions, North Norway (Finmarksvidda).
- Mean no. snow days: Snow season duration projected to be shorter in Norway.
  - Later start, earlier end.
  - Decrease gets smaller with increasing altitude and distance from the coast.
- Still large annual variability
  - Max. snow water equivalent might be higher than today in a few high altitude or northern drainage basins.

Summary: Sources of uncertainties in the scenarios

- Global and regional climate models.
- Local adjustment of prec. and temp. to climate stations.
- Hydrological model.

The uncertainty caused by the hydrological model are of less importance than the uncertainties caused by the representativity of the meteorological data driving the model.

Part 2:

Comparison of snow projections from:

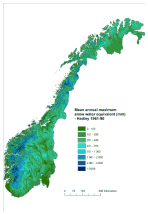
- Water balance model (HBV/GWB)
- Meteorological model (HIRHAM)

”Work-in-progress”

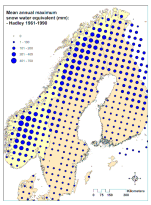
➡ met.no report no.??

Mean annual SWE (Hadley-B2, 1961-1990)

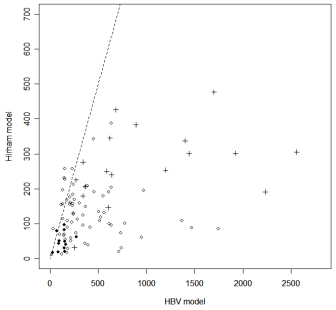
HBV

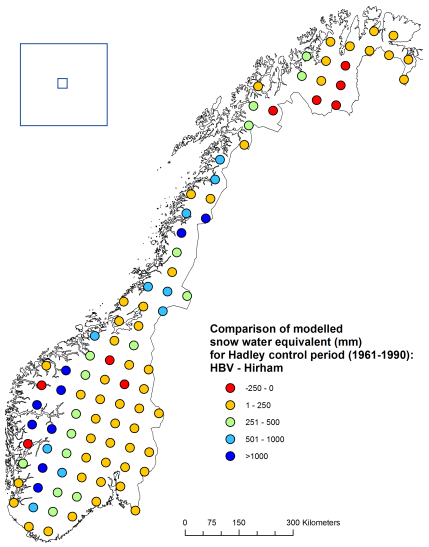


HIRHAM



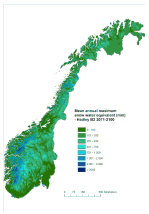
Snow water equivalent (mm), Hadley control period 1961-1990



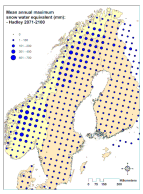


Mean annual SWE (Hadley-B2, 2071-2100)

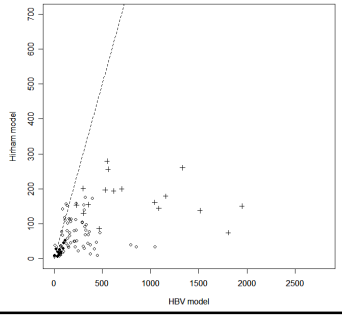
HBV

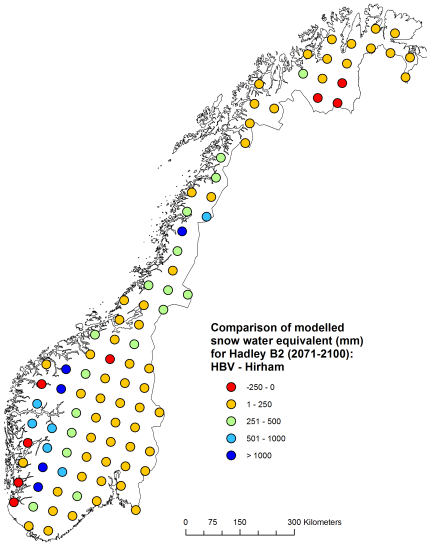


HIRHAM



Snow water equivalent (mm), Hadley B2 2071-2100





Reasons for the different results from the HIRHAM and HBV models

- Differences snow algorithms and parameter values.
- Differences in precipitation modelling.
- Different description of topography.

Snow model in HIRHAM

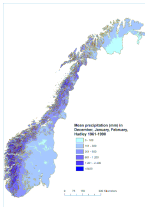
$$\frac{\delta}{\delta t} S_n = \frac{J_{Q_{S_n}} + P_{S_n} - M_{S_n}}{\rho_w}, \quad (1)$$

where: $J_{Q_{S_n}}$ is the evaporation rate per unit area over the snow pack, P_{S_n} is the snow fall rate per unit area, M_{S_n} is the snow melt rate per unit area and ρ_w is the density of water.

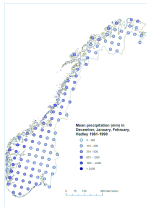
- Ps_n og Ms_n ?
- Parameter values applied during model run?

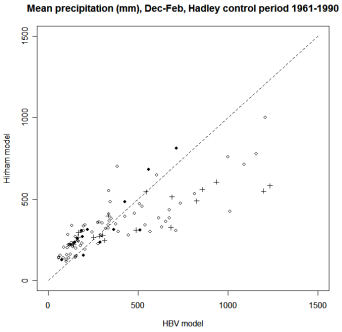
Mean precipitation (Hadley-B2, 1961-1990, Dec, Jan, Feb)

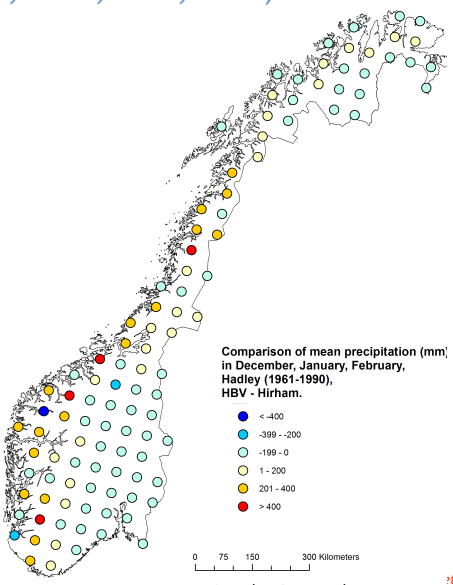
HBV



HIRHAM



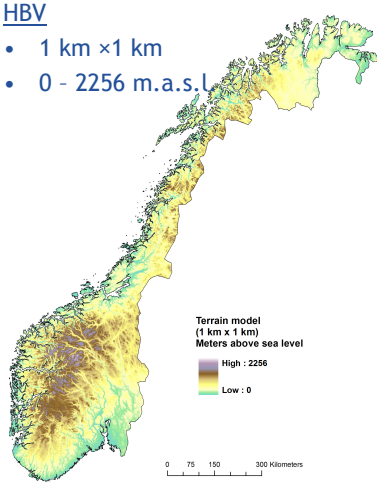




Different description of topography

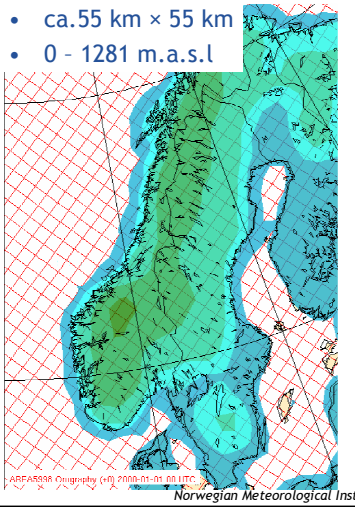
HBV

- 1 km ×1 km
- 0 – 2256 m.a.s.l



HIRHAM

- ca.55 km × 55 km
- 0 – 1281 m.a.s.l



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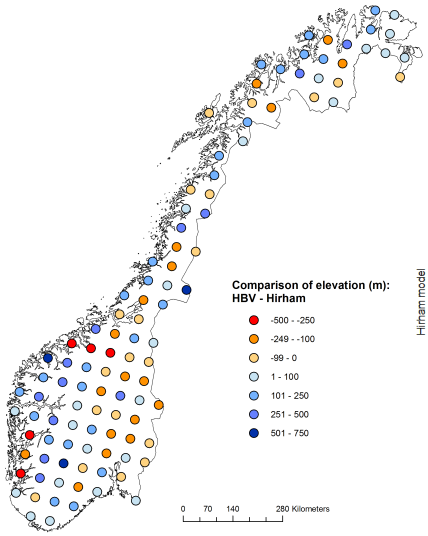
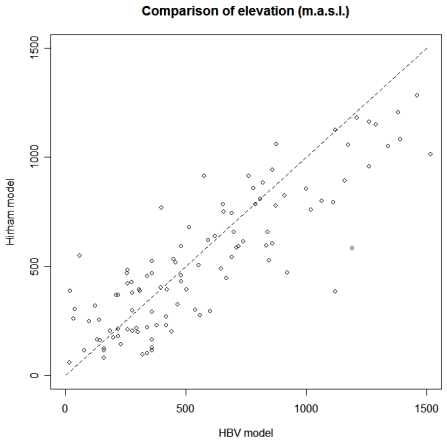
Different description of topography





Summary: Comparison of snow projections from HIRHAM and HBV

- Increasing altitude -> increasing differences in estimated SWE (both periods, both Hadley/Echam).
  - Below 200 m: both models provide ~similar SWE values.
  - Above 1000 m.: the HBV model estimates much higher SWE than the HIRHAM model. Largest SWE differences are found in these altitudes.
- Geography:
  - Min. differences: South-east Norway + Finnmarksvidda.
  - Max. differences: South-west Norway.
- Reasons:
  - Snow algorithm, precipitation modelling, topography, different spatial resolution, comparison method.