Hydropower in Arctic Regions – future potential and challenges.

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Objectives

- Background
- Hydropower potential
  - Global outlook
  - Local outlook
- Development challenges
  - Technical and operational
  - Social and environmental

Background

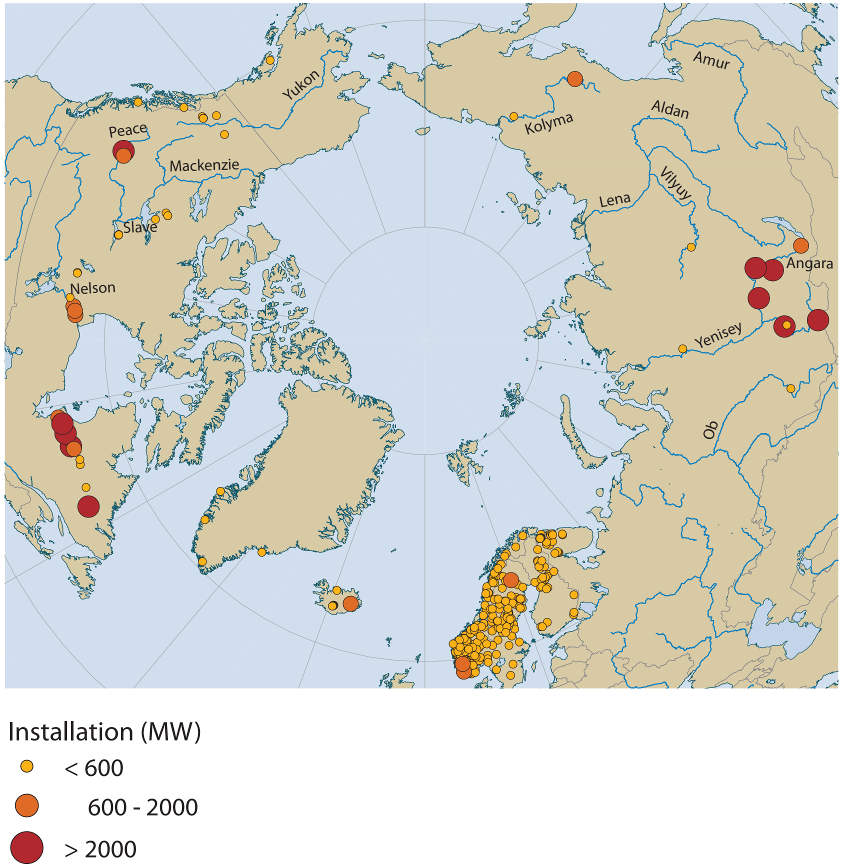
- Need for increased amount of renewable energy to meet emission targets.

- Hydropower is the only renewable with feasible storage, interesting:
  - As a renewable energy source in itself
  - For load balancing in a system with other renewables

- Proven technology, economically competitive (Kumar et al., 2011).

Current status

- Hydropower is developed in all arctic and arctic rim areas.
- Installed capacity > 90 000 MW (pr. 2006)
- Untapped potential exists today



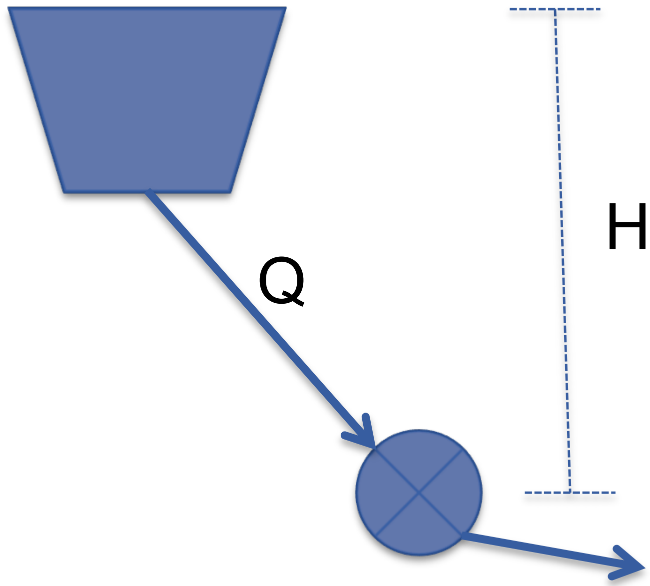
Prowse et al., in press.

Computation of potential

- Energy production

$$P = \eta \cdot Q \cdot H$$

  - H – head
  - P – production
  - Q – inflow to turbine
  - η - efficiency



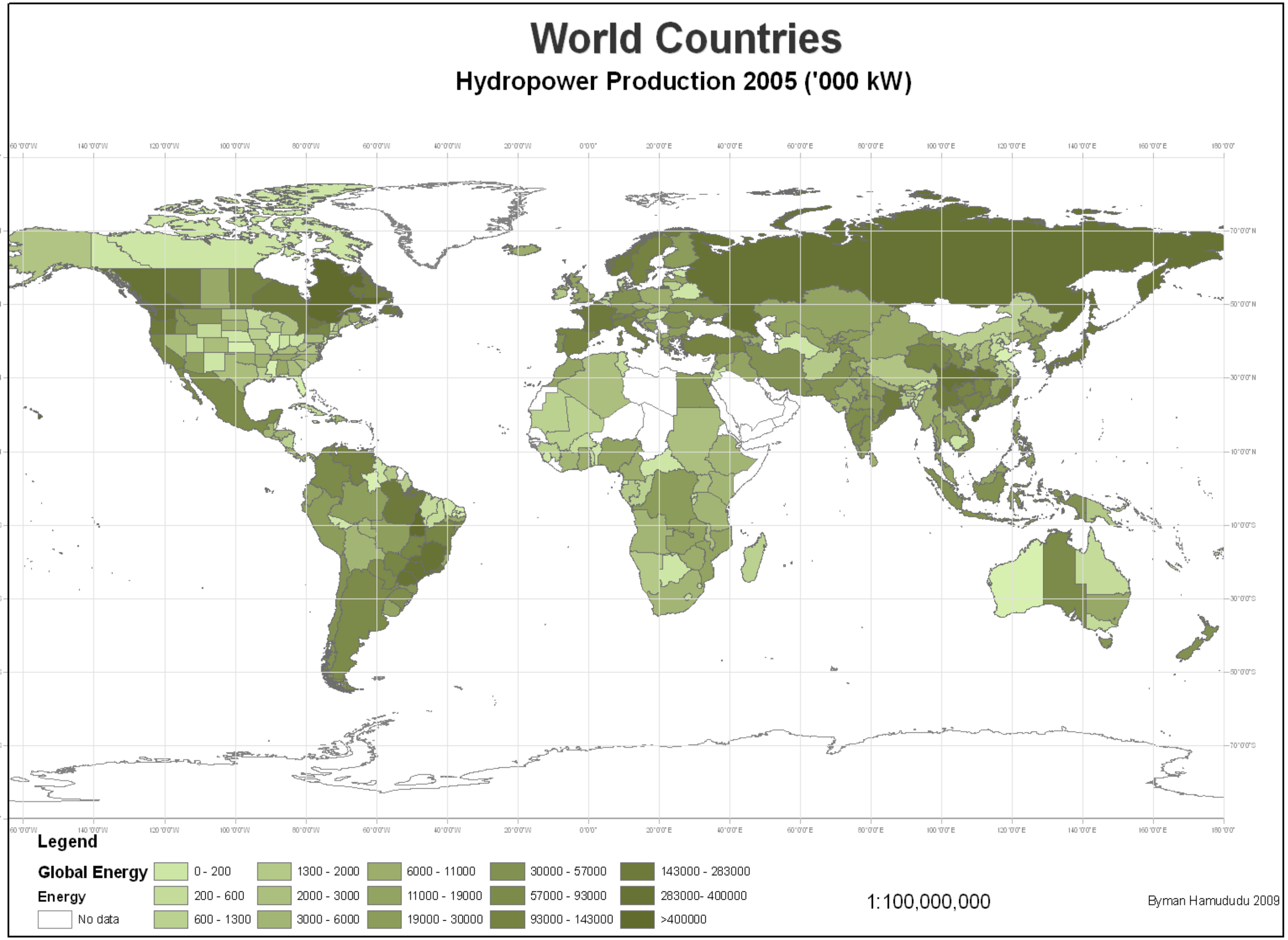
- To assess future changes we need to find Q

Resource assessment

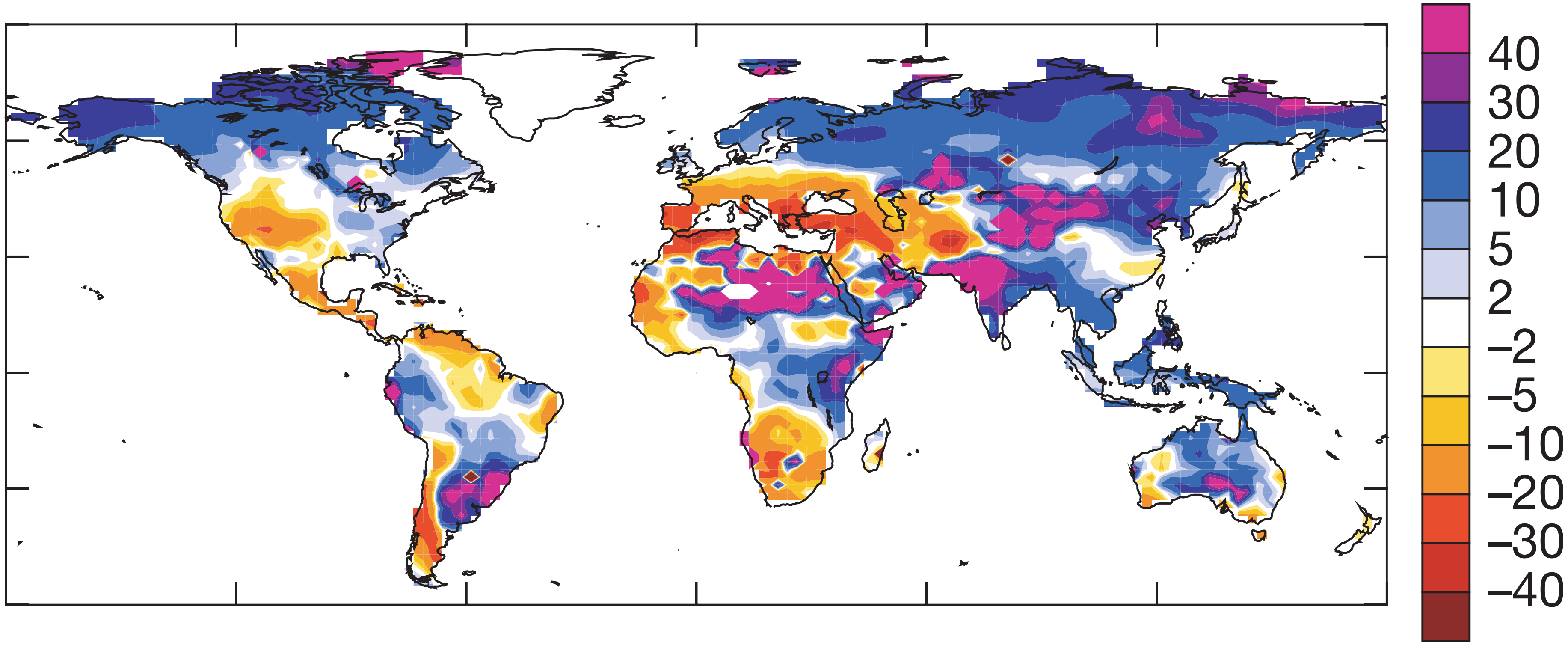
- Simulation of global hydropower potential
  - Q: based on GCM ensembles (Milly, et al. 2005)
  - H: average for regions from global DEM
  - Corrected for efficiency based on observed and simulated production for the situation today
  - Scenarios for:
    - Changes in current production given new runoff
    - Changes in production potential given new runoff

- Simulation of local system
  - Downscaled climate data as input to runoff modelling
  - Hydropower production model set up for today.

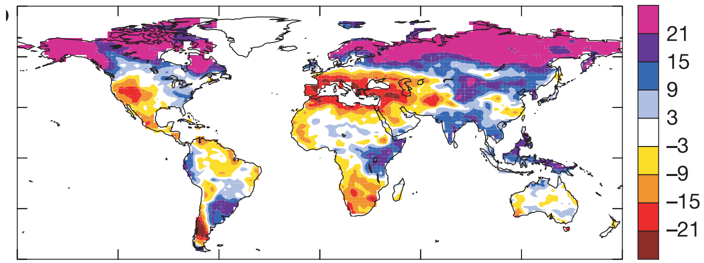
Current production



Runoff

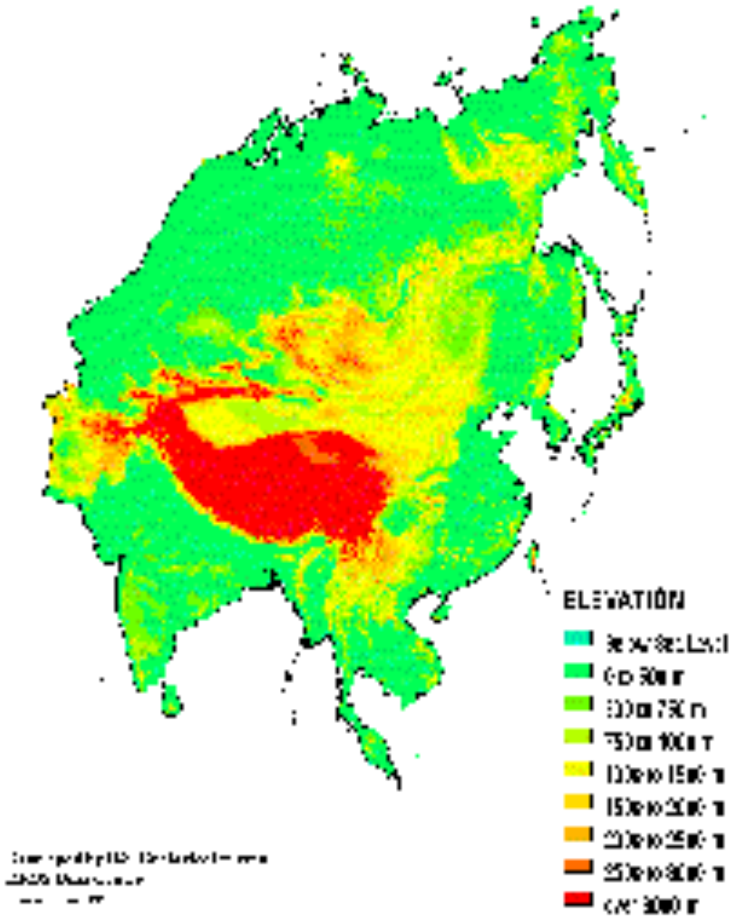


Relative changes in runoff for the 2041-60 period based on a 12 GCM ensemble



Milly et al 2005.

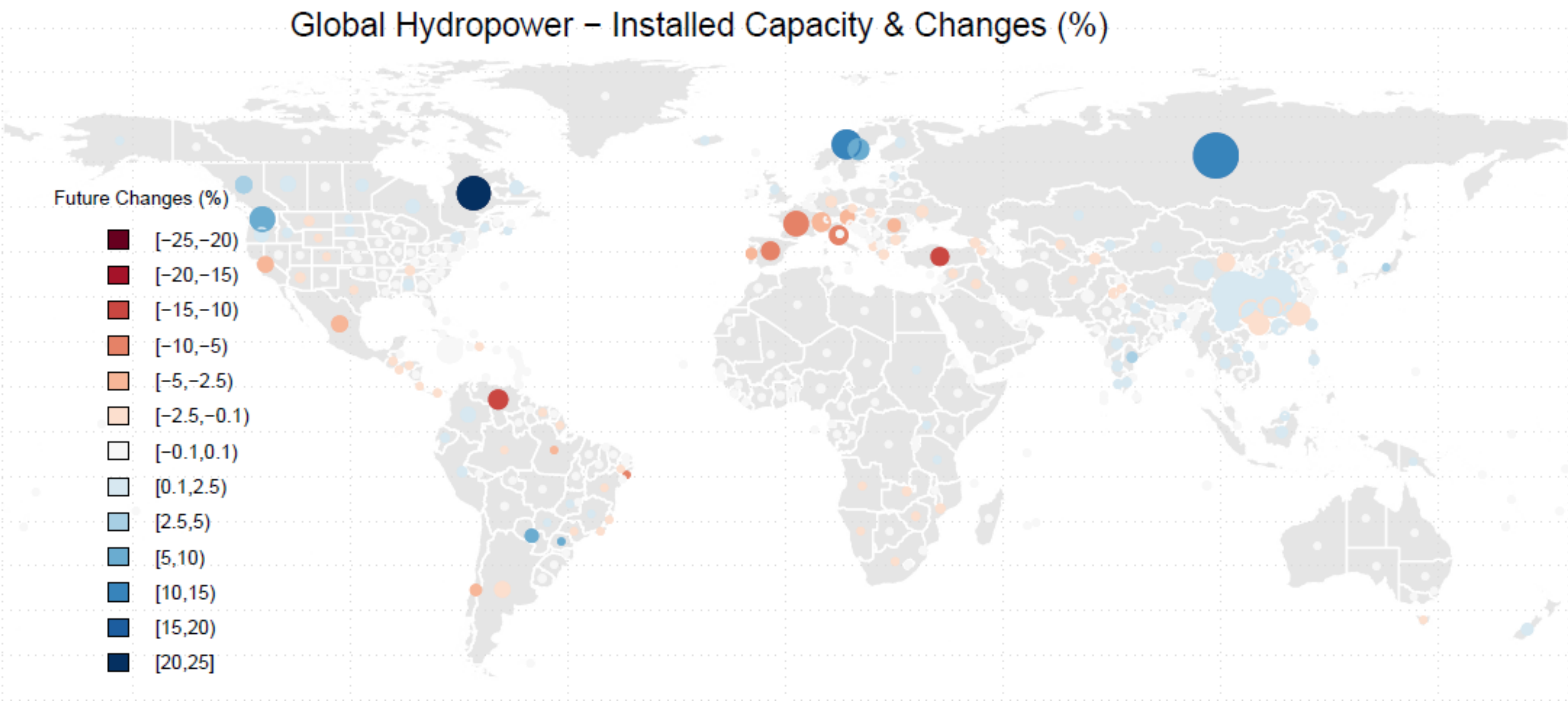
Head and efficiency



- Head
  - Head is estimated as the average regional elevation – elevation at region outlet.
- Estimation of efficiency
  - Production computed using the average head and estimates of todays runoff.
  - Compared to current production data – efficiency estimated from the difference
  - This efficiency is used for computing future scenarios

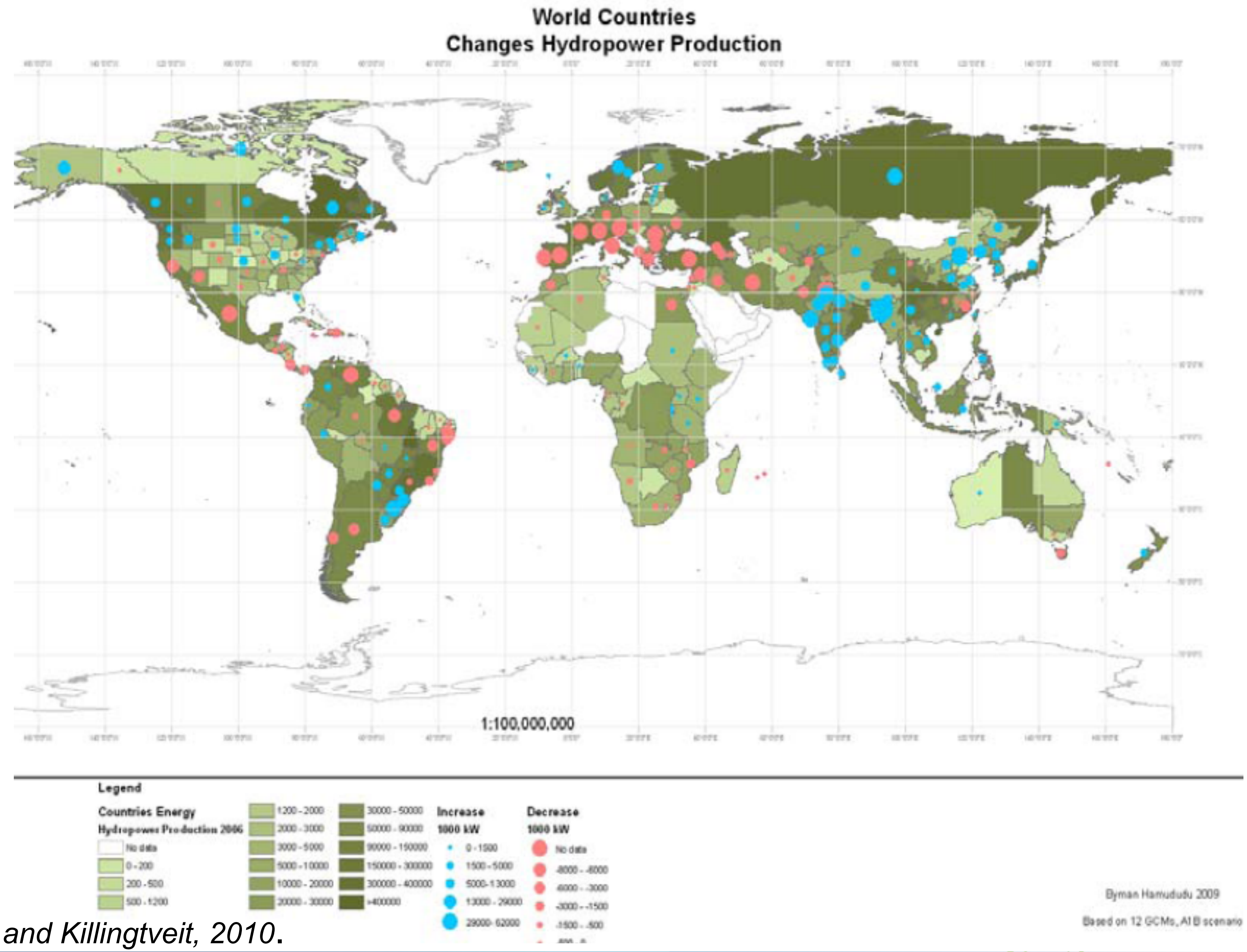
http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30/hydro

Future scenario with new inflow



Hamududu and Killingtveit, 2010.

Future potential



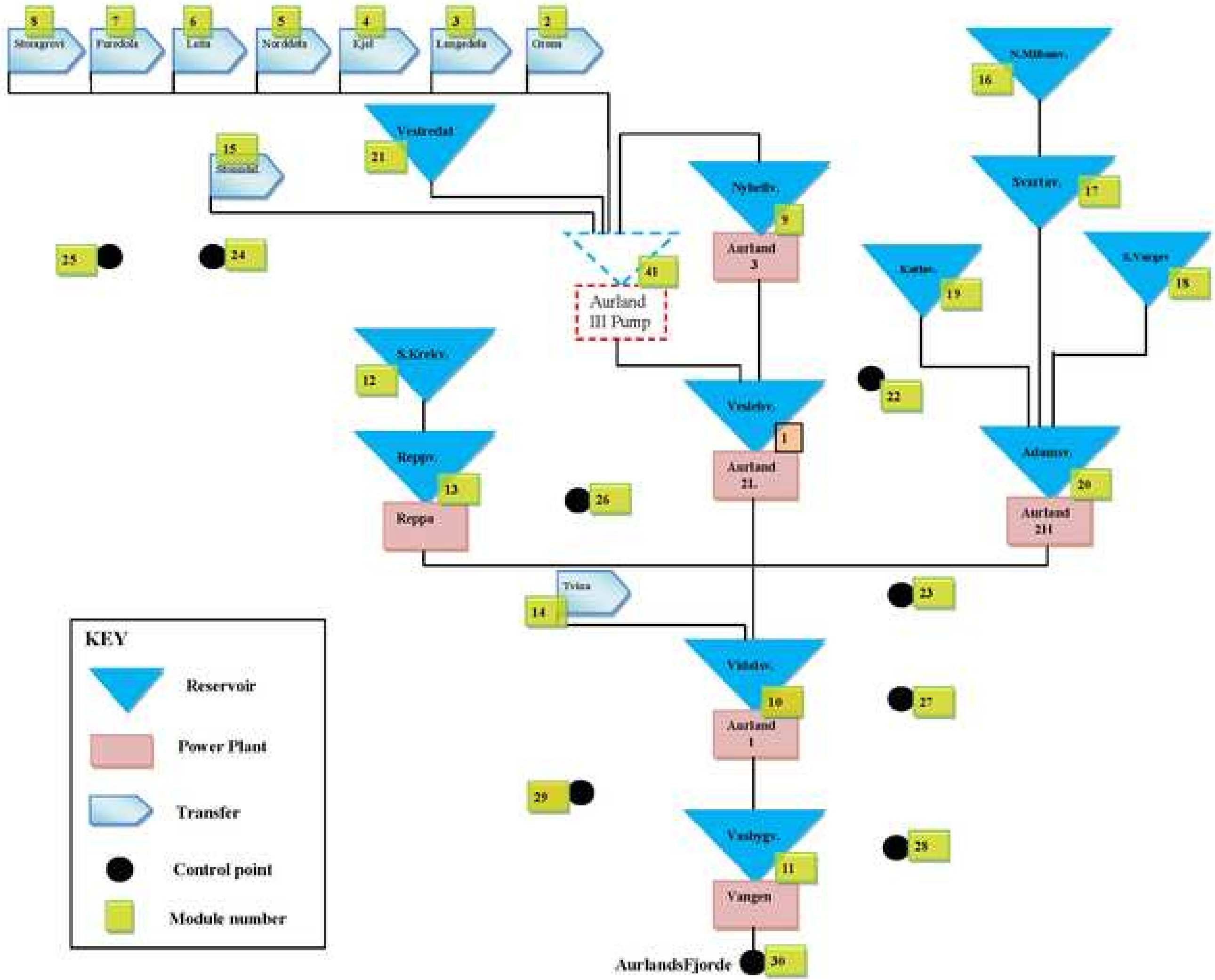
Hamududu and Killingtveit, 2010.

Local studies

- Regional studies shows increased winter runoff and increases in hydropower potential (e.g. Kumar et al. 2011, Lehner, 2005)

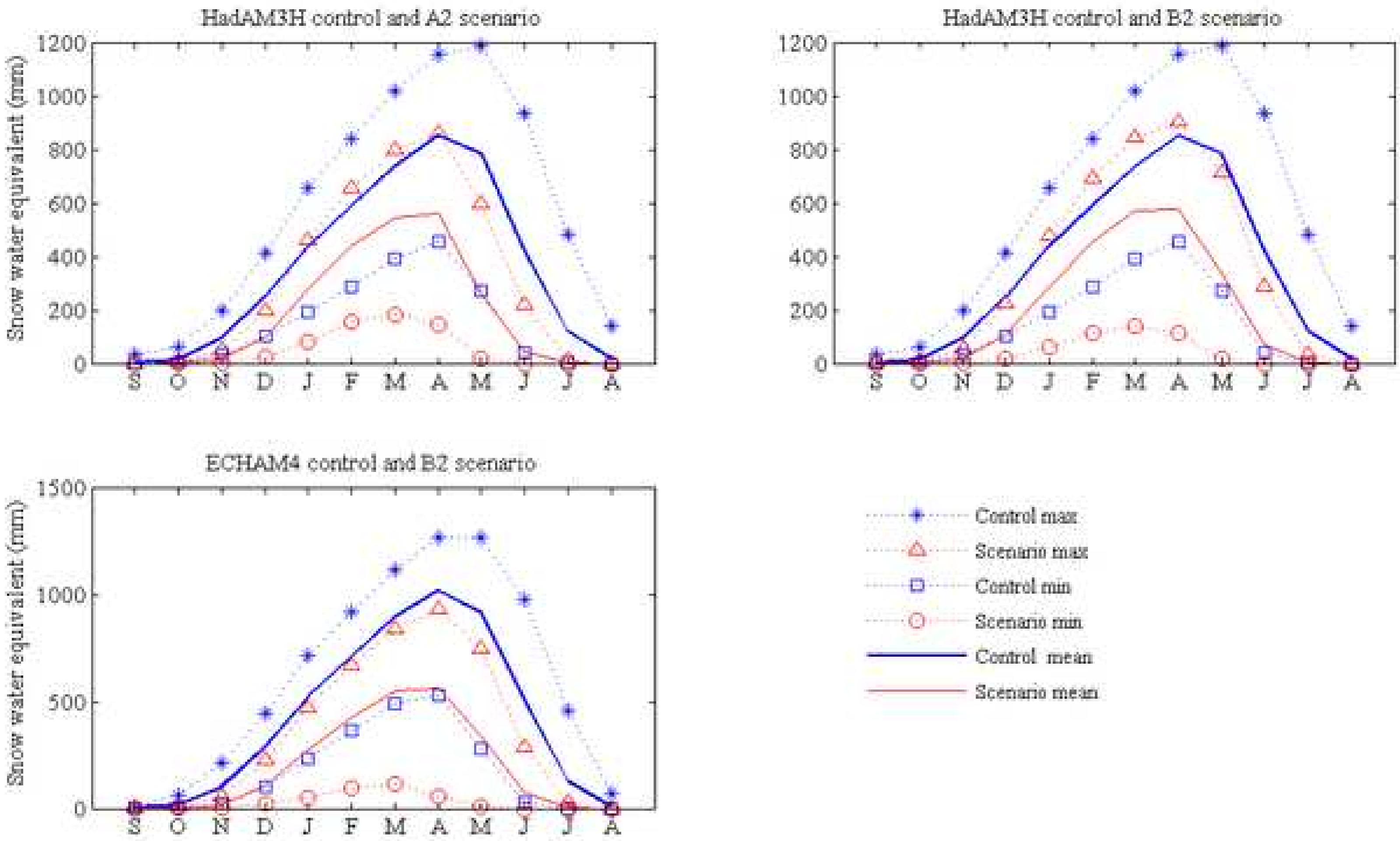
- To fully understand potential, production and also impacts from future developments – local scale studies needed. An example:
  - Downscaled data for temperature and precipitation from two different GCMs / emission scenarios used.
  - Inflow computed using a hydrological model calibrated using historical data – stationary assumption for mountainous catchment
  - Production model used to find production and reservoir development

System setup



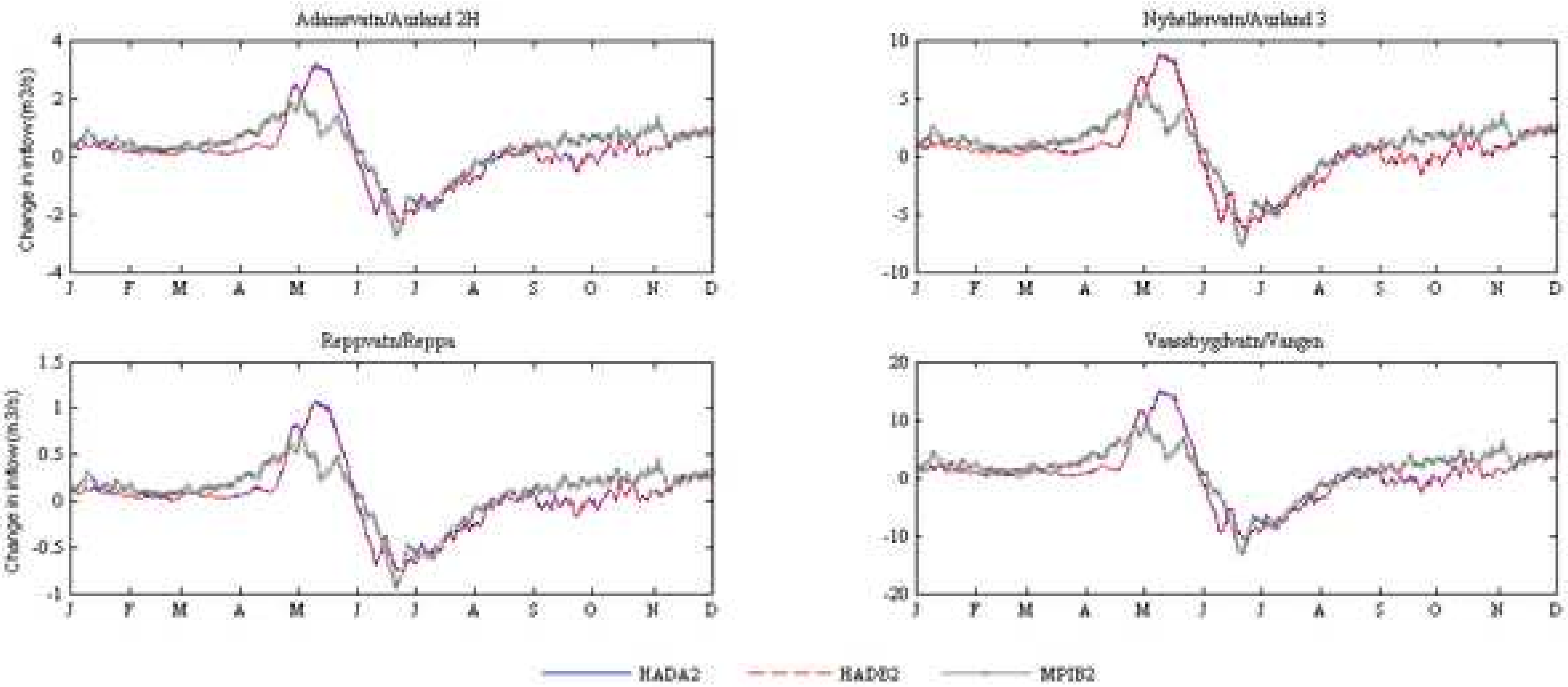
Chernet et al. (in review)

Scenarios for snow



Chernet et al. (in review)

Scenarios for future production



Power Plant	Capacity (MW)	Simulated annual production (GWh) HADCN	HADA2	HADB2	MPICN	MPIB2
Aurland 1	840	2095	2404	2360	2102	2615
Aurland 2H	72	205	234	229	206	254
Aurland 2L	68	173	200	197	175	218
Aurland 3	280	284	229	225	298	252
Reppa	9	29	33	32	29	36
Vangen	35	105	119	117	105	131
Total		2891	3219	3160	2915	3509
% increase			**12**	**9**		**20**

Chernet et al. (in review)

Technical challenges in the Arctic

- Building hydropower infrastructure in arctic areas.
- Operational constraints from ice in rivers and reservoirs
- Transmission infrastructure

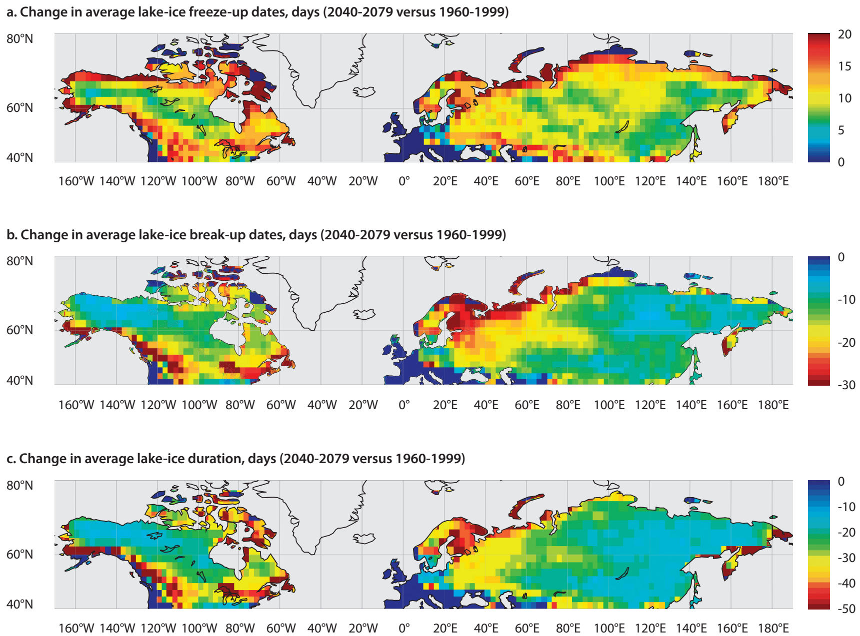
Winter and ice impacts

- Reservoirs
  - Ice loads
  - Dam safety
- Intakes
  - Clogging
  - Headloss
- Outlets
  - Break ups / increased ice formation
- Operational restrictions

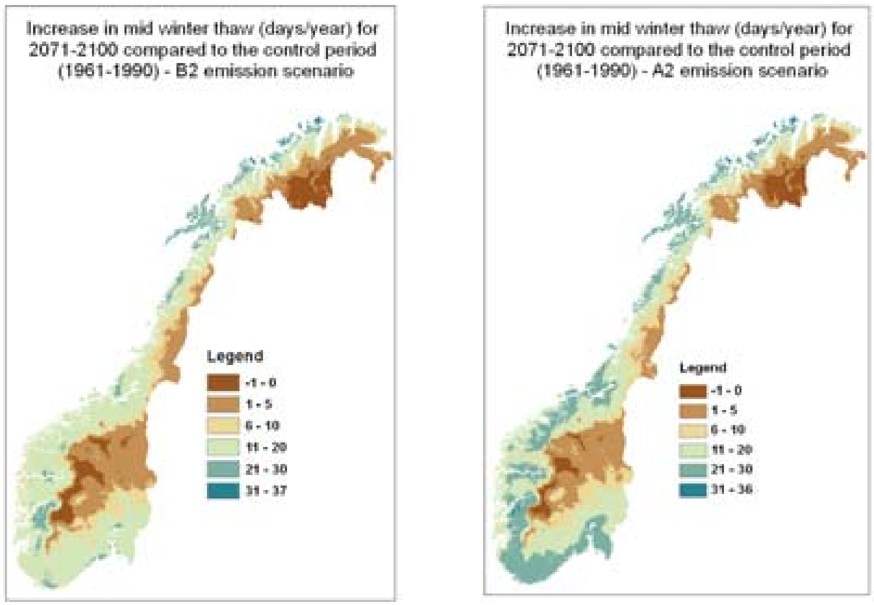
Prowse et al. (in press), Gebre et al. (in prep)

Scenarios for ice

- Future climate defines winter and ice formation
- For arctic areas, ice in can not be eliminated
  - Some problems will be reduced
  - More unstable winters can create new challenges
  - Shorter season of operational constraints



Dibike et al. 2011



Gebre & Alfredsen. 2011

Environmental and social impacts

- Impacts from impoundments and flow changes in river reaches on:
  - Hydrology and hydraulics
  - Terrestrial and aquatic ecosystems
  - Use of rivers and lakes
- Development of new transmission lines
- Public acceptance