CHALLENGES IN OPERATIONAL HYDROLOGY

Gaute Lappegard

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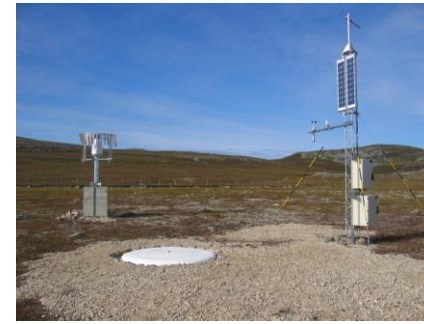
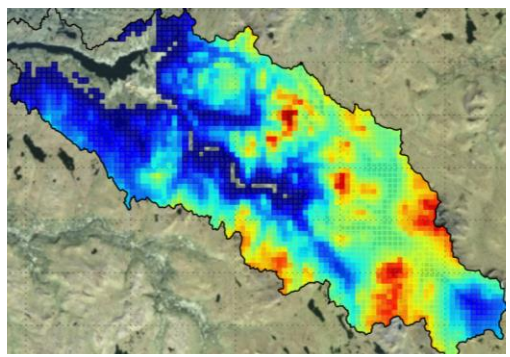
Outline

1. Introduction to
   - The power market
   - Energy management

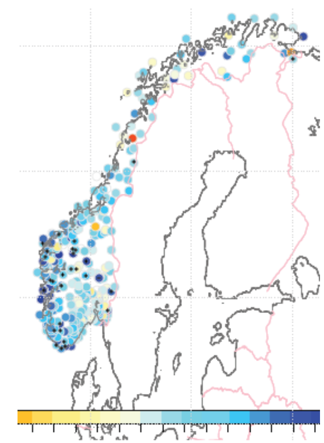
2. Data



3. Tools & models



4. Climate



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1. INTRODUCTION

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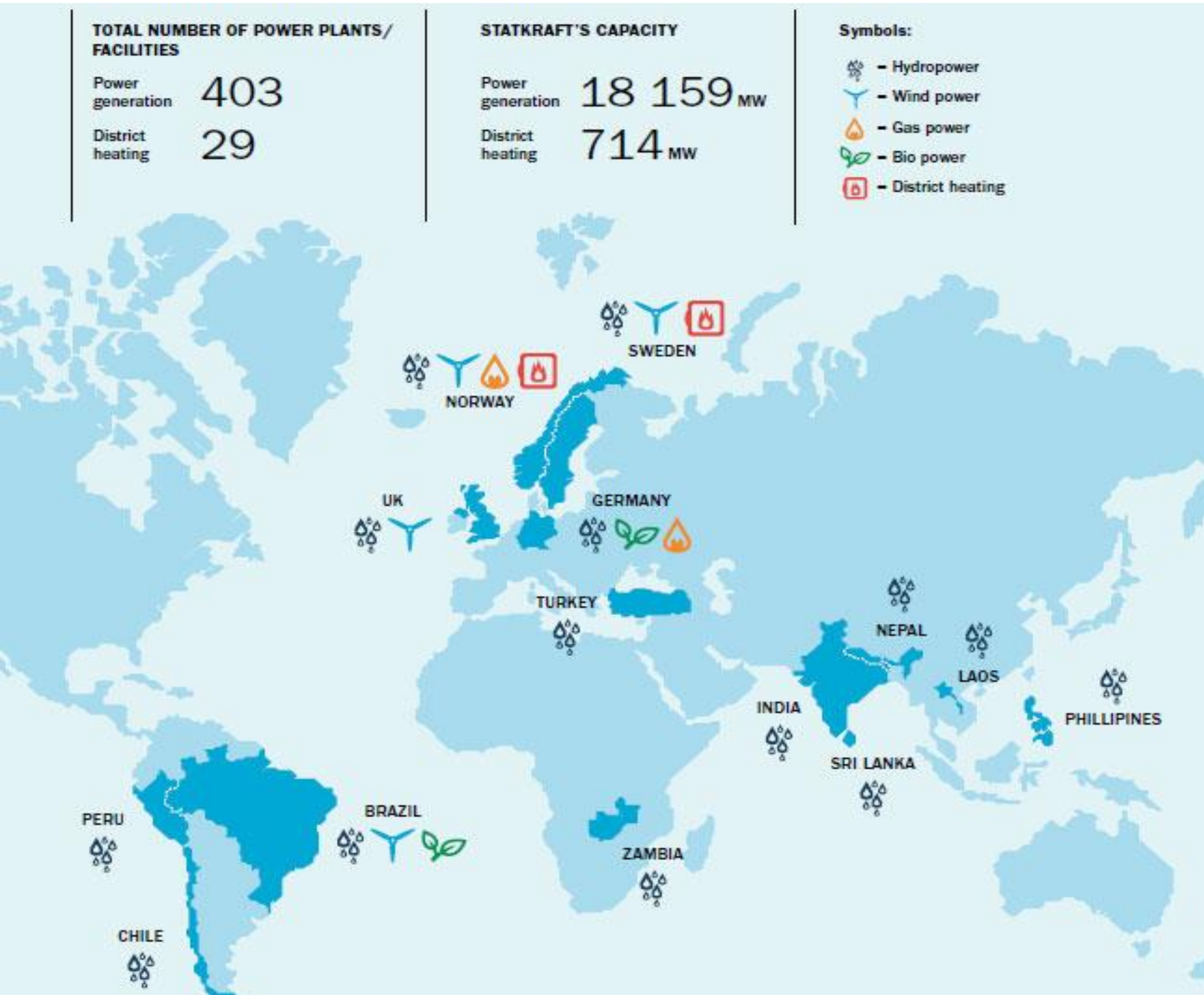
Facts about Statkraft



- Wholly owned by the Norwegian state
- European leader within renewable energy
- Core business areas within hydropower, wind power and district heating
- Total annual power production of 56 TWh, renewable percentage of 99%
- A significant player in the European energy exchanges with cutting-edge expertise in physical and financial energy trading and origination
- Develops hydropower in emerging markets outside Europe.
- The Group's gross sales amounted to NOK 52,2 billion in 2014
- 4200 employees and active in more than 20 countries

SPOT PRICES in the nordic MARKET

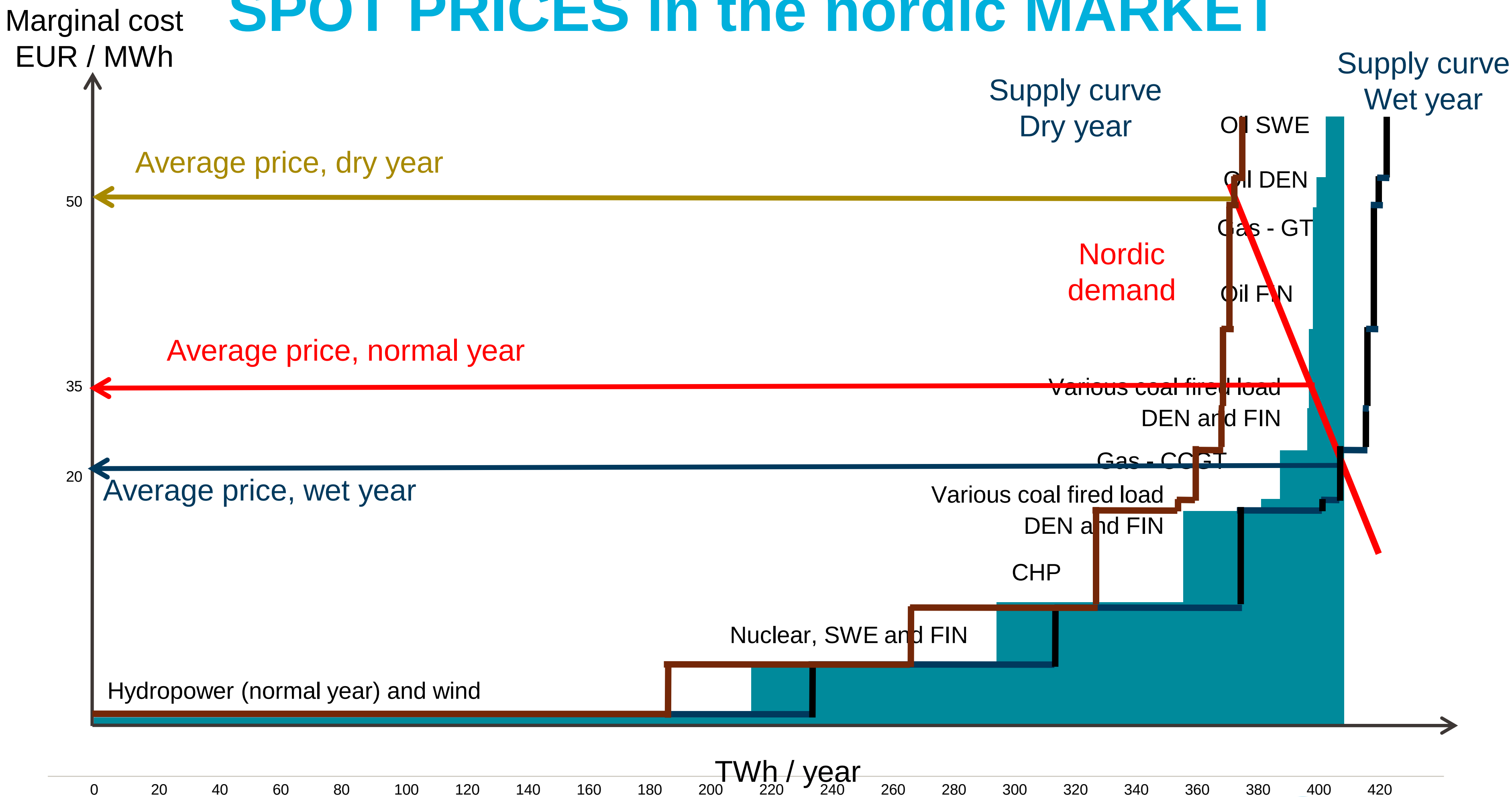
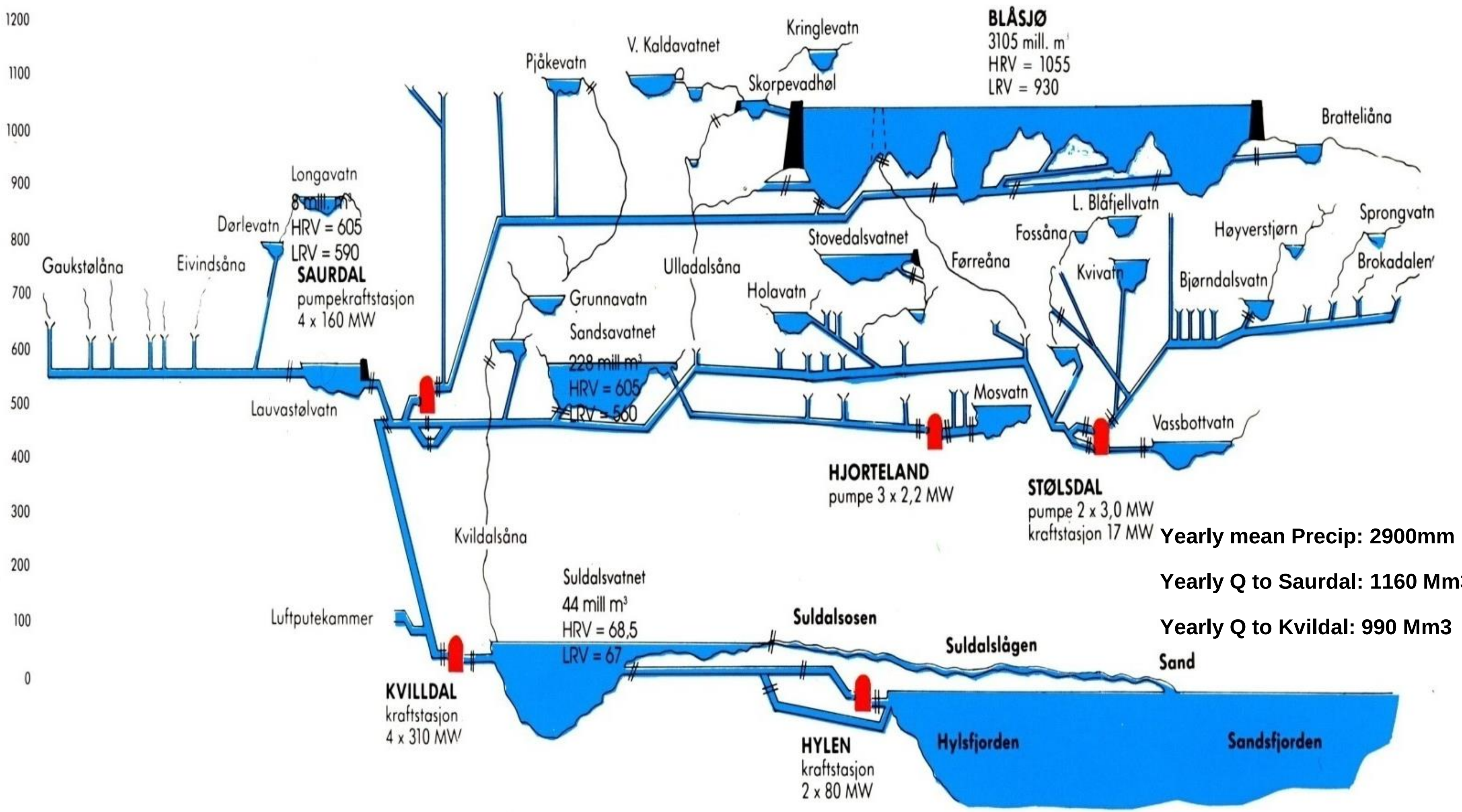


*Illustration. Marginal costs may vary

Blåsjø – Norway's largest energy reservoir: 7,8 TWh

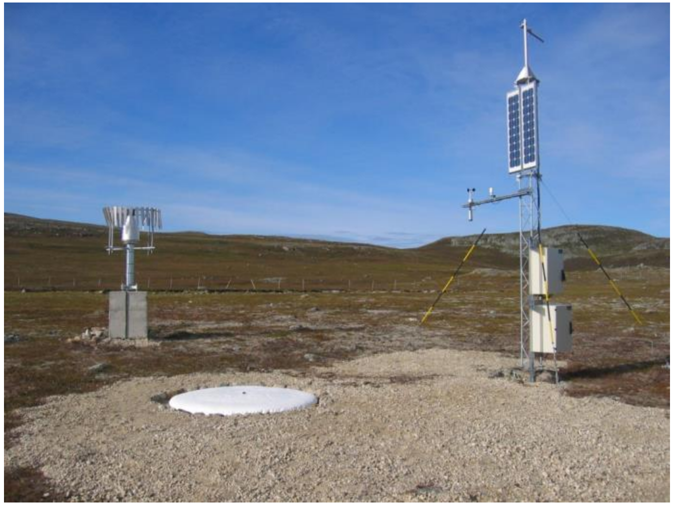


Yearly mean Precip: 2900mm

Yearly Q to Saurdal: 1160 Mm3

Yearly Q to Kvildal: 990 Mm3

2. DATA



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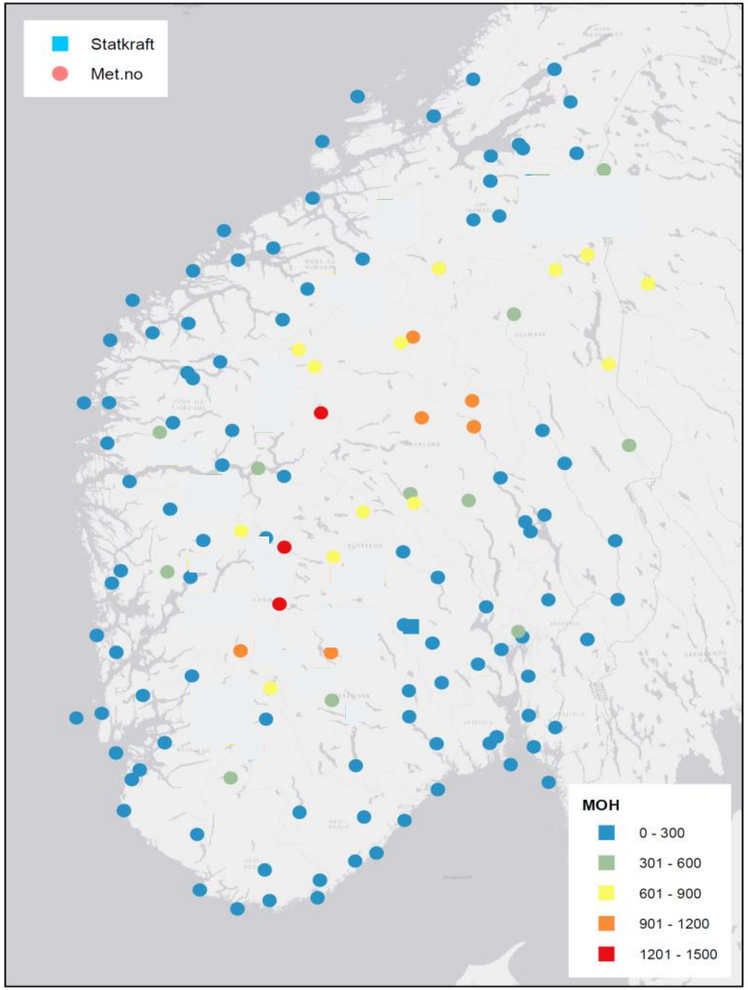
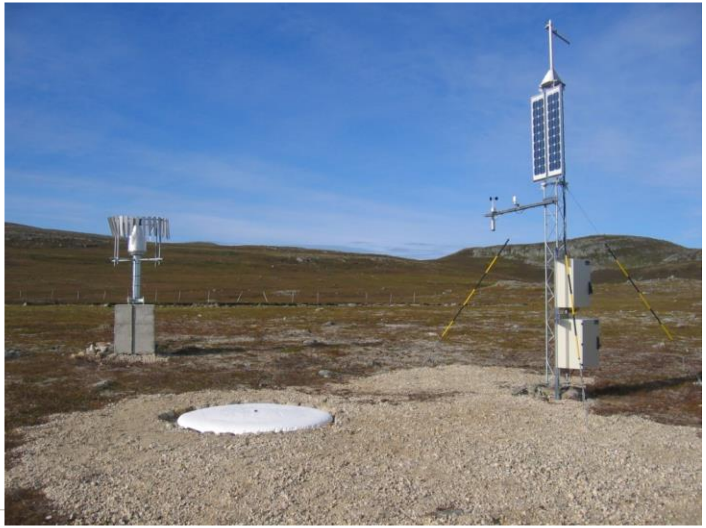
Statkraft's station network



MASL	MET	Statkraft
0-300	192	20
301-600	31	30
601-900	16	30
901-1200	6	28
1201 ->	3	6



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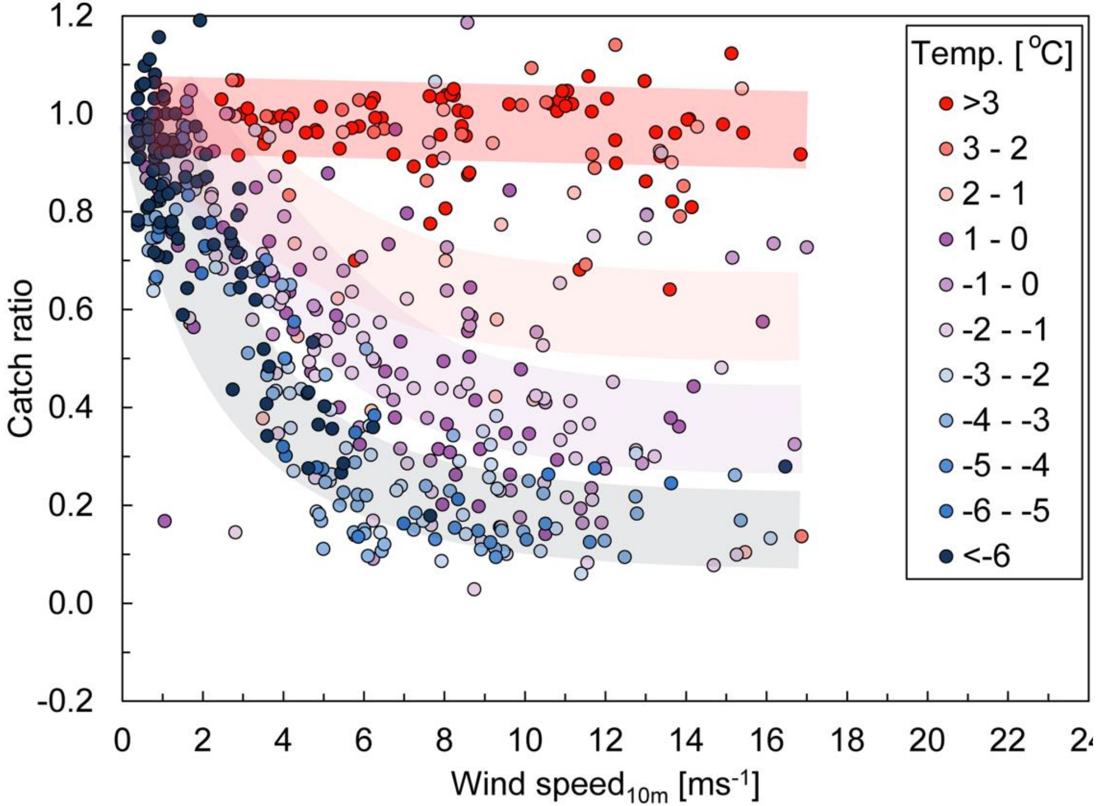
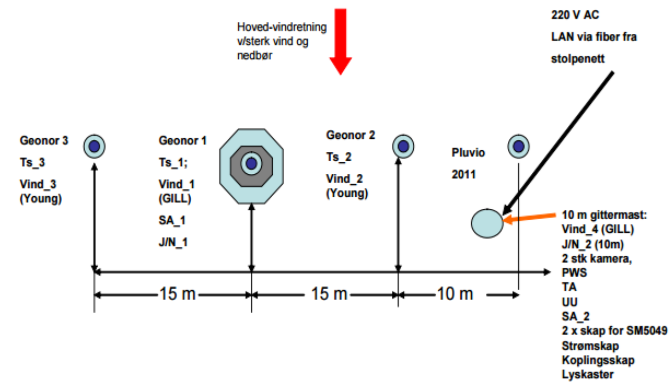
SPICE and DFIR at Haukeli: Undercatch





Wolf et.al, Hyd Earth sys, 2015

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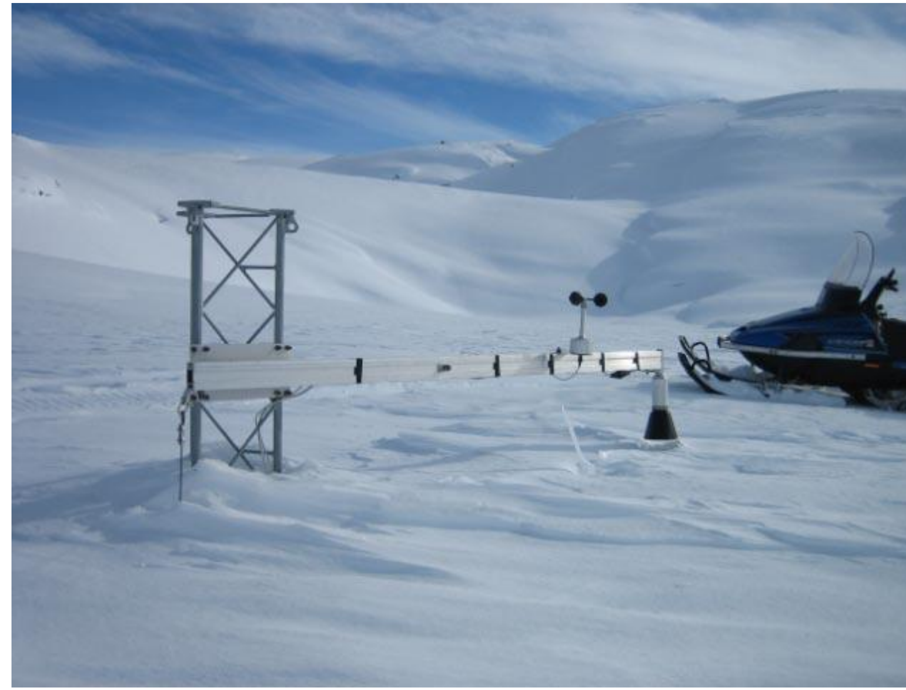
What do we measure?
How do we correct for undercatch?



Important for model calibration

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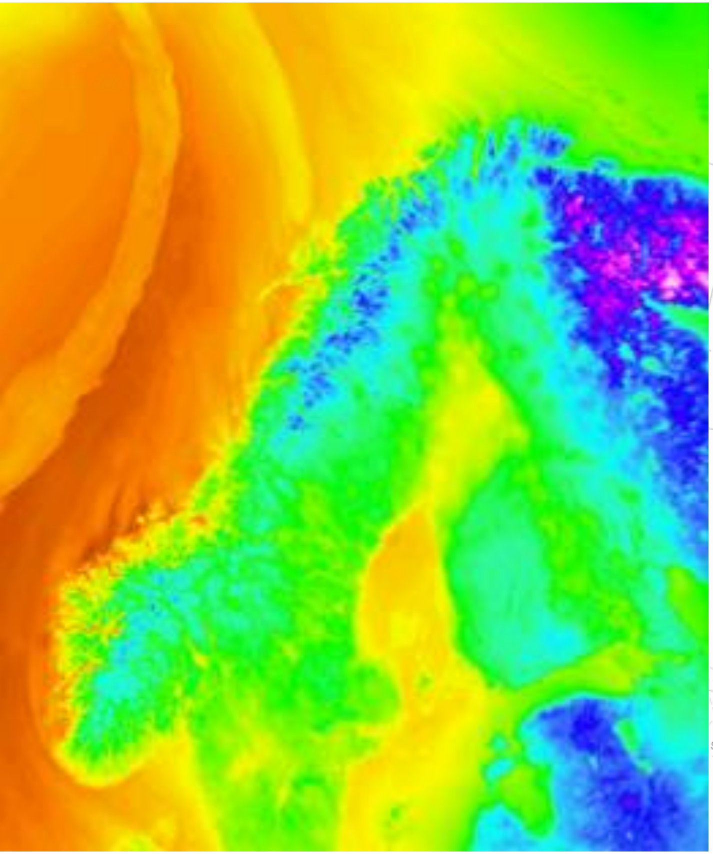
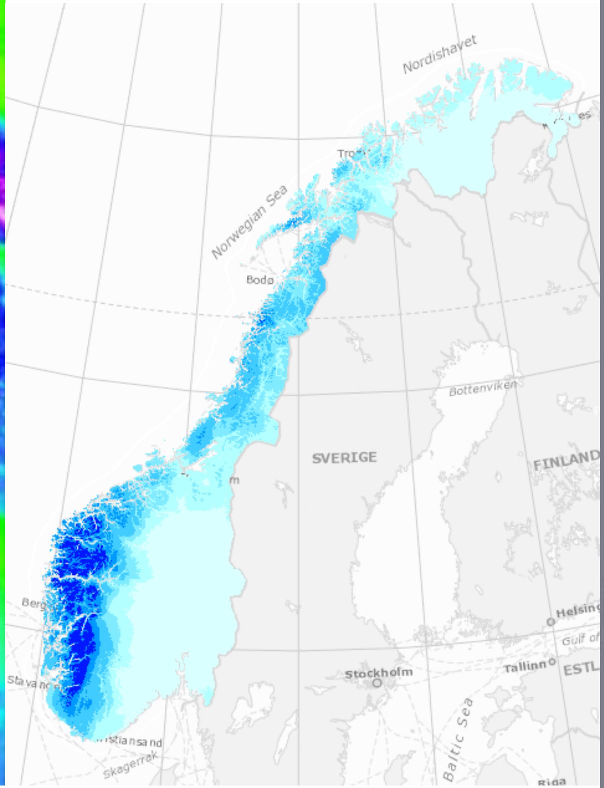
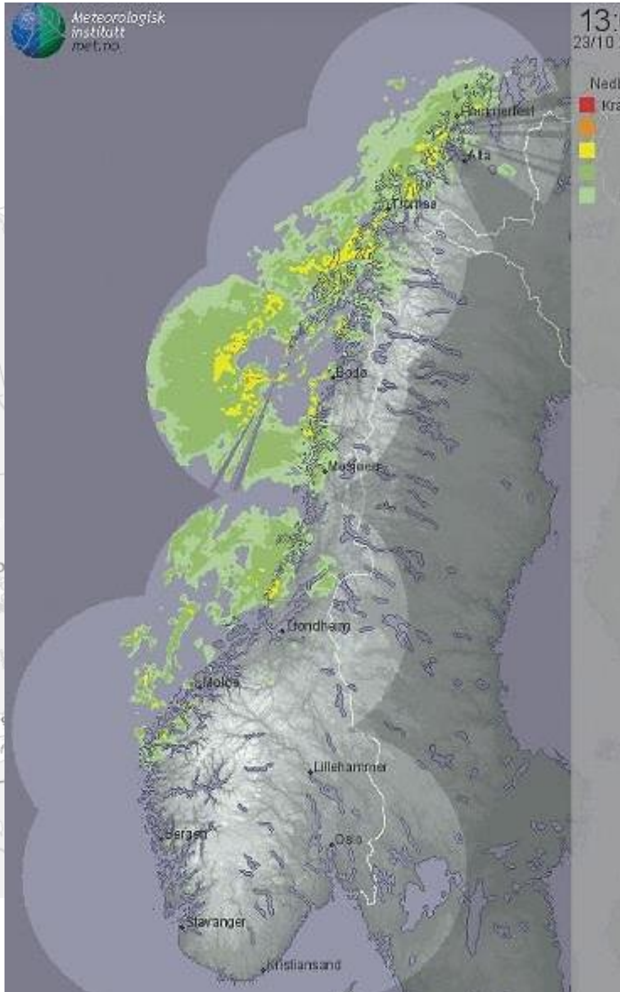
AROME, interpolation and weather radar







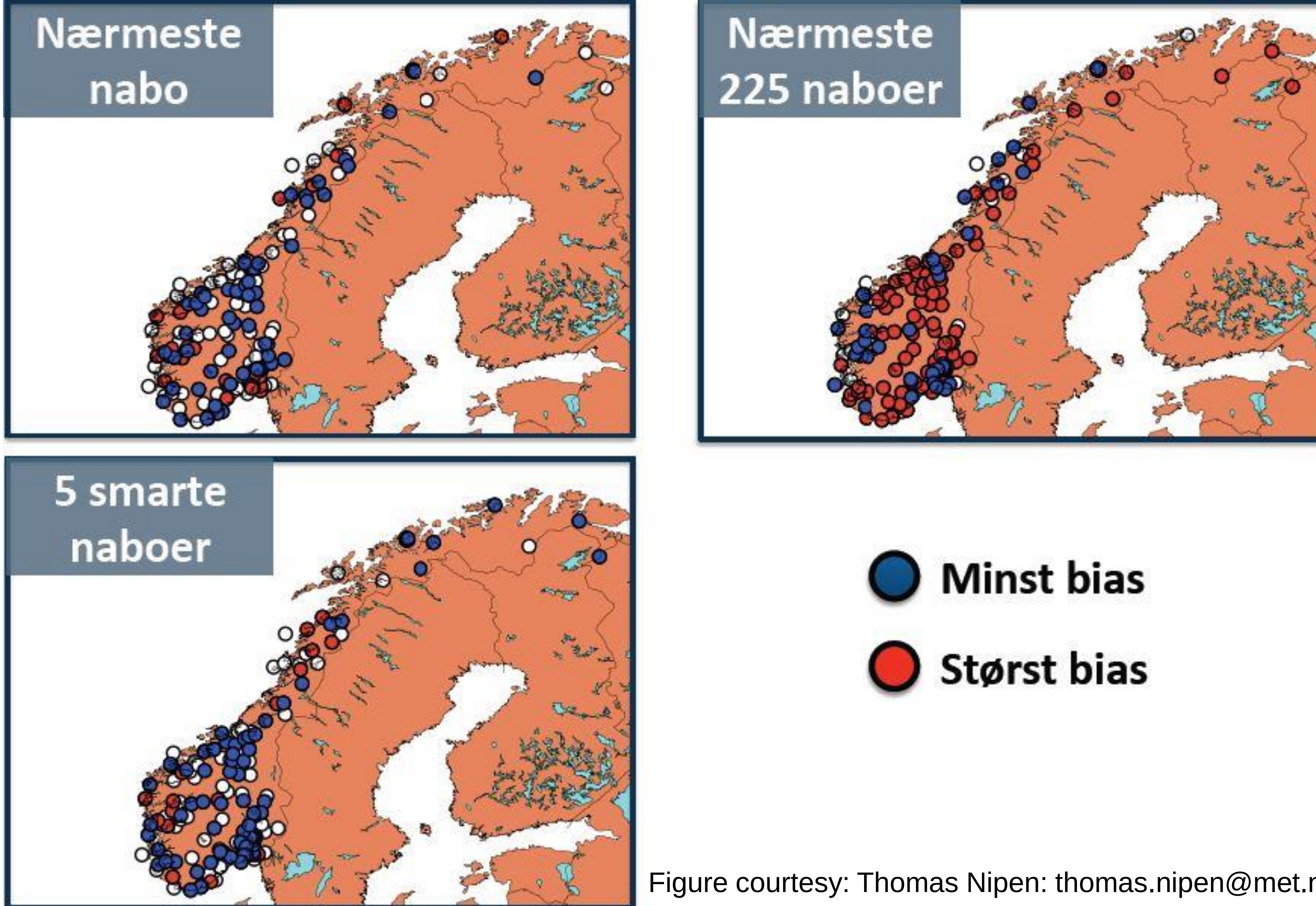
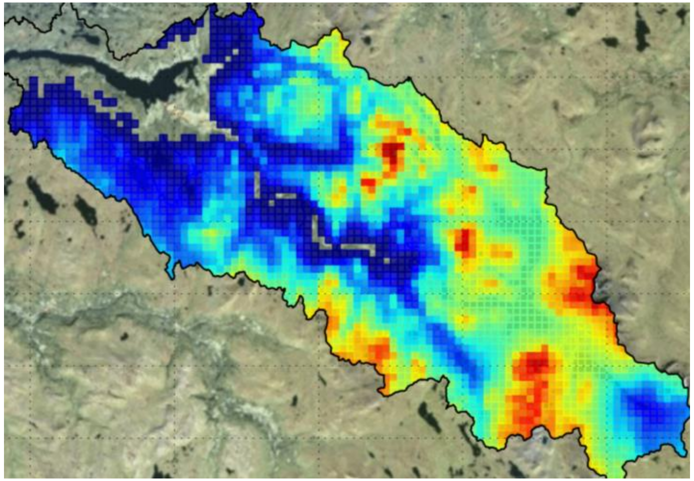


Figure courtesy: Thomas Nipen: thomas.nipen@met.no

3. TOOLS & MODELS



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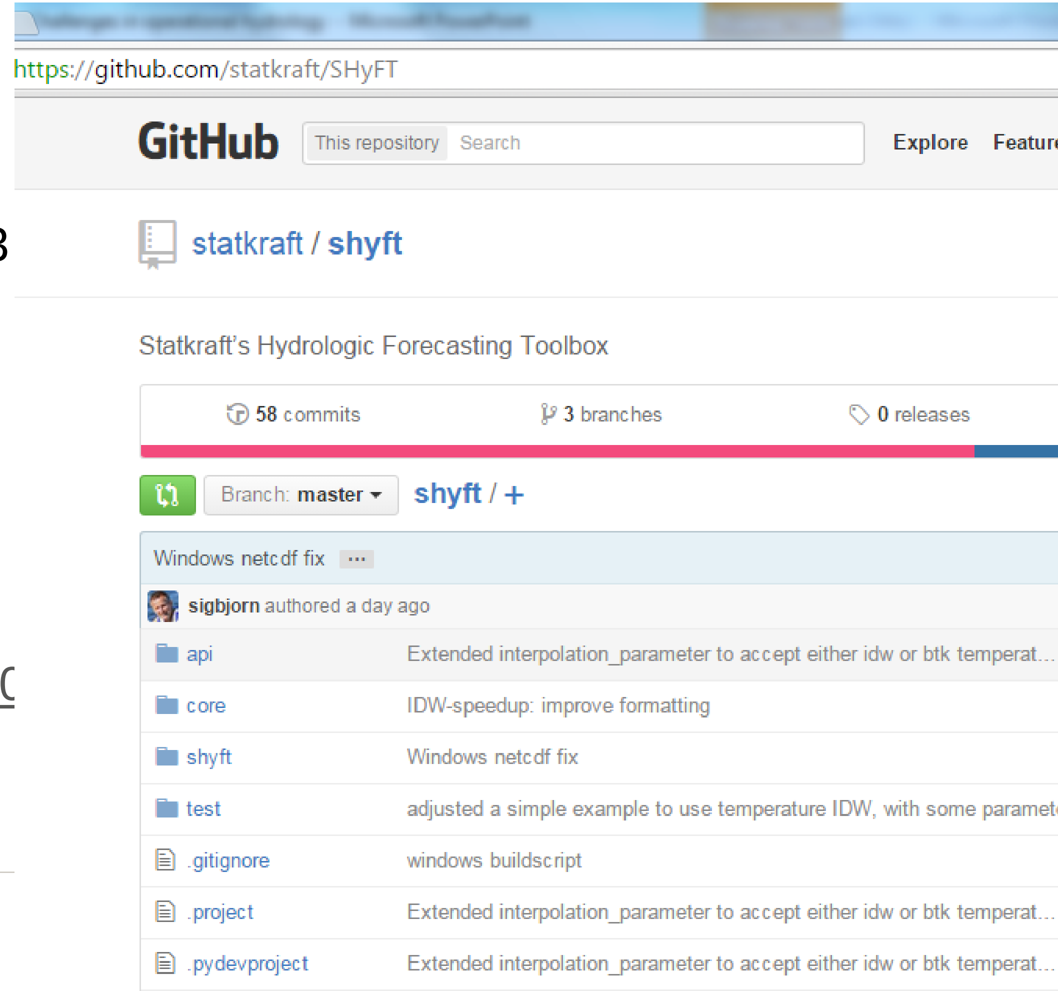
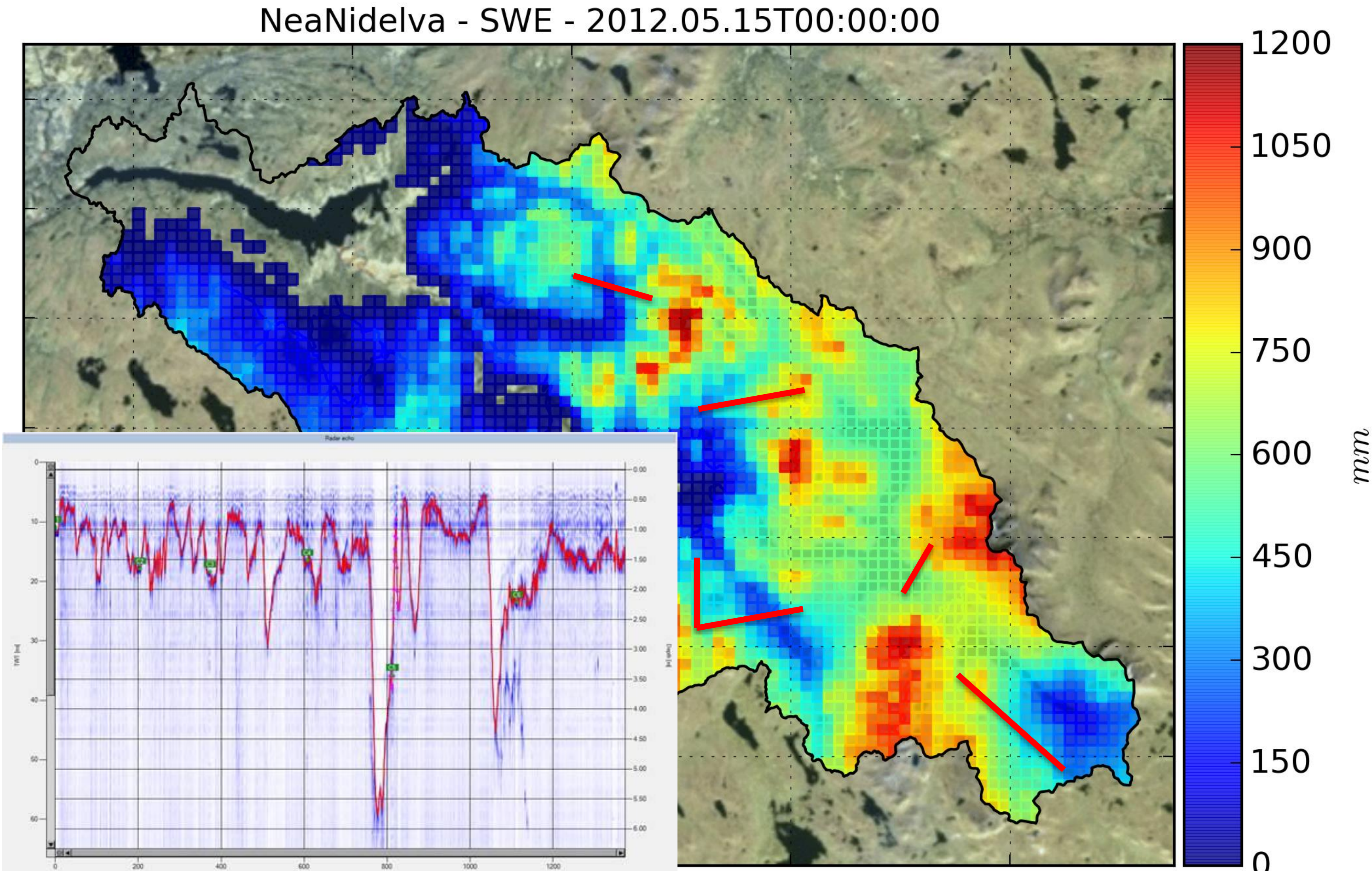
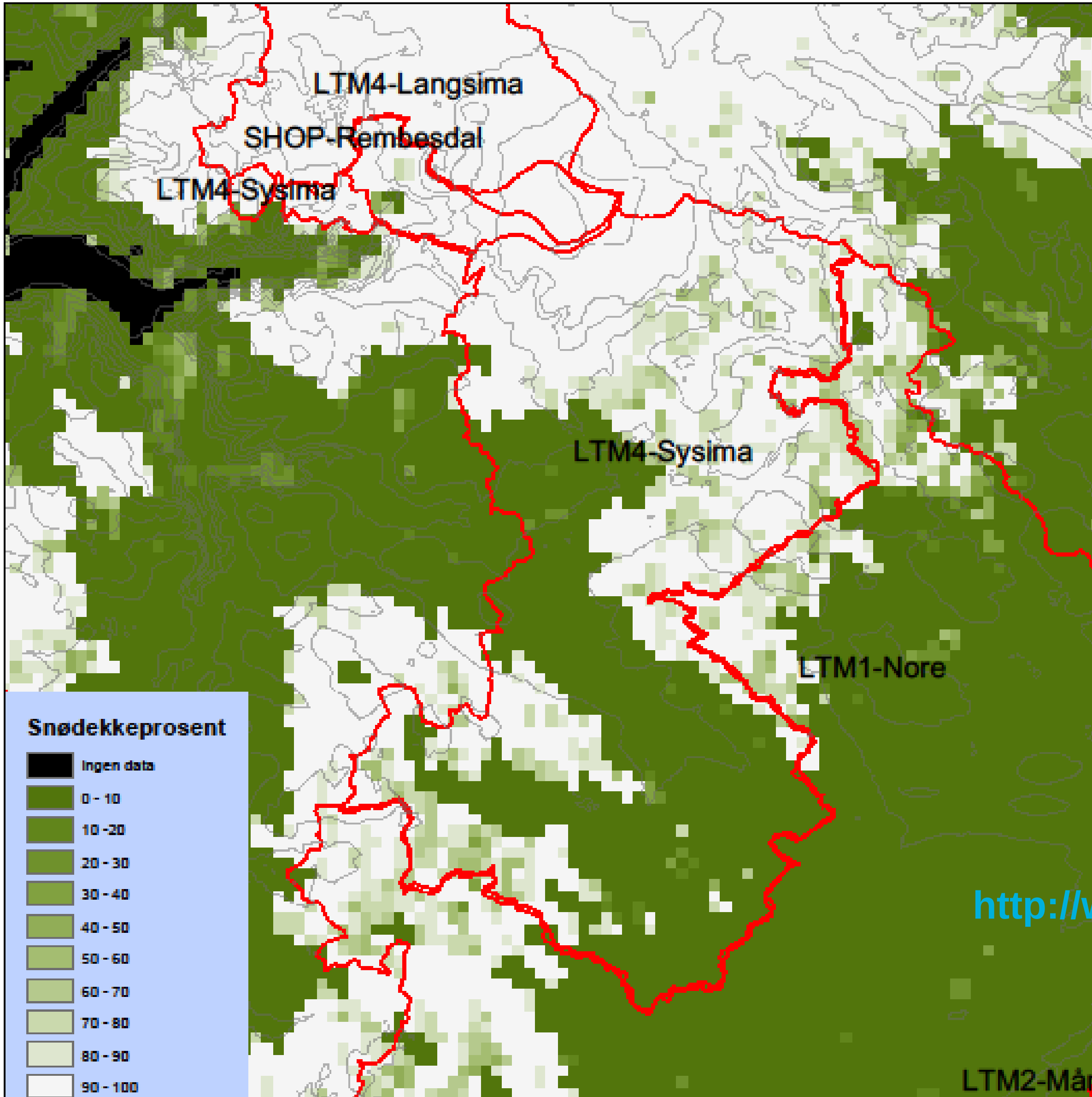
SHyFT: Statkraft's Hydrologic Forecasting Toolbox

- https://github.com/statkraft/SHyFT
- SHyFT is released under LGPL V.3
- Toolbox -> LEGO!
  - Modules to plug and play
  - Build stacks to test different modules
- NeaNidelva_SCA_20120501-2012(




NeaNidelva - SWE - 2012.05.15T00:00:00
1200
1050
900
750
600
450
300
150
0
mm



Satellite observed snow cover:

57%

Modelled snow cover:

75%

http://www.globesar.com/snow/

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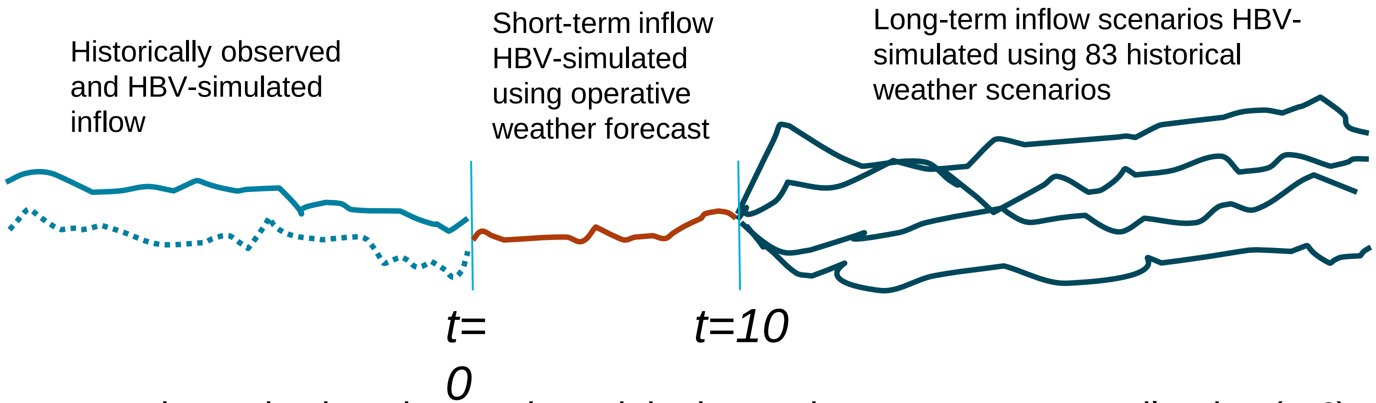
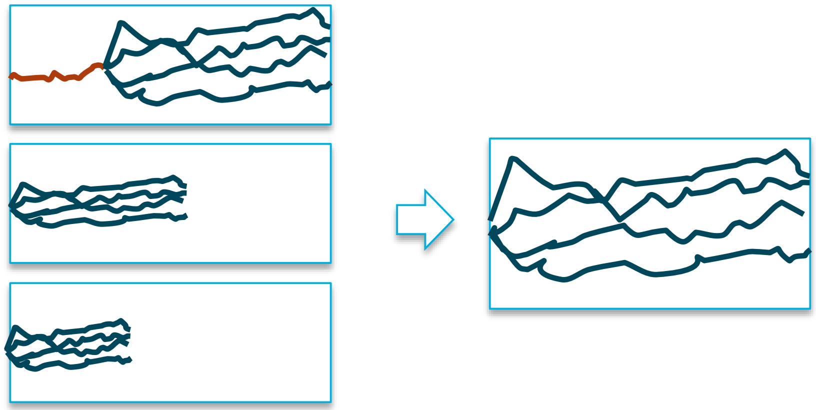
Simulation (operational) of inflow using HBV-models



- Start-state estimated using observed precipitation and temperature up until today (*t=0*)
  - Updated with snow measurements
  - Manual updating of temperatures if significant deviation between simulated and observed inflow
- Forecast horizon simulated using 10-day operational EC forecast
  - Manually corrected by meteorologist
- Scenarios for long-term horizon simulated from day 10 using end-state from forecast horizon as start state and 83 historical weather years (1931-2013)
  - Series back to 1931
  - Wind corrected precipitation
  - Climate corrected precipitation and temperature to 1980-2010 average

Quantile Mapping Goal

- Capture uncertainty in the forecast horizon
- Improve forecast by combining various weather forecast:
  - Arome short-term forecasts
  - EC-ENS: captures uncertainty
  - EC-Monthly
- Combine information from all forecast sources with historical scenarios into one dataset.
- Operational meteorologist determines interpolation period



<u>Question</u>: How do we generate 83 weather scenarios from day 0 that are consistent with short- and mid-term forecasted probability distributions and match historical scenarios in the long-term?

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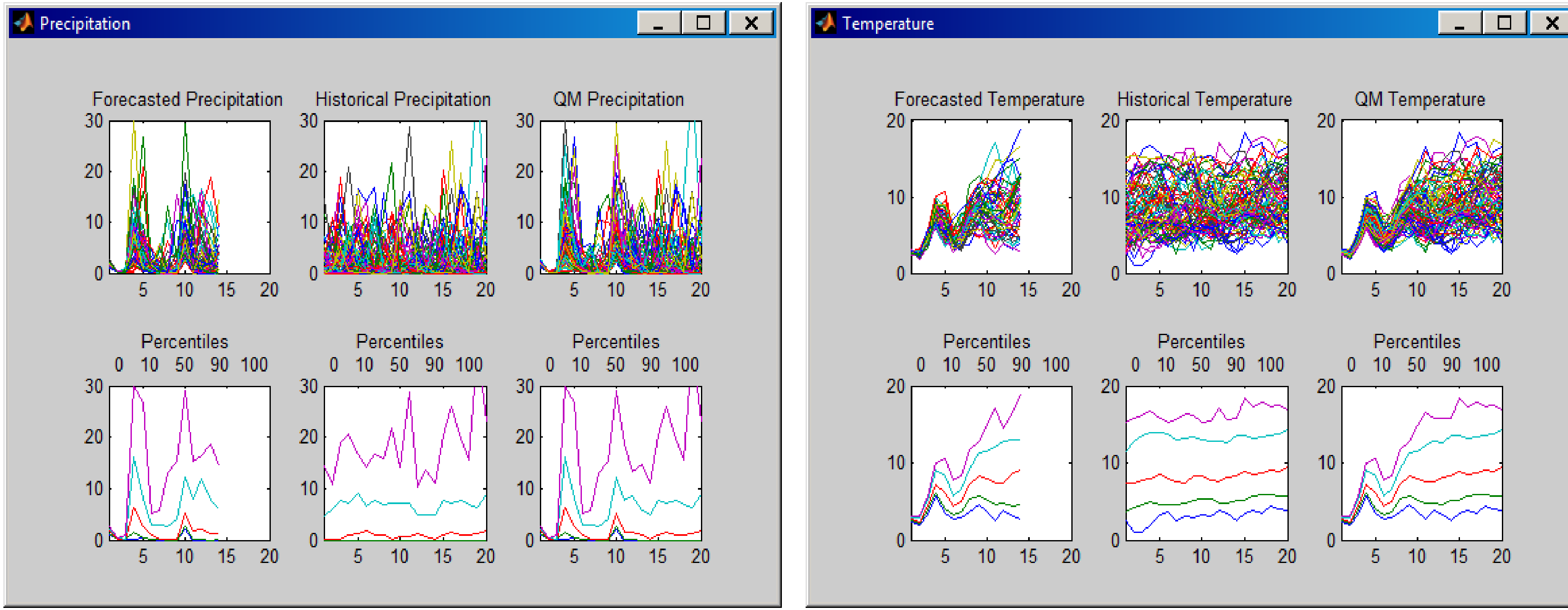
Example: Interpolation from day 10 to day 14



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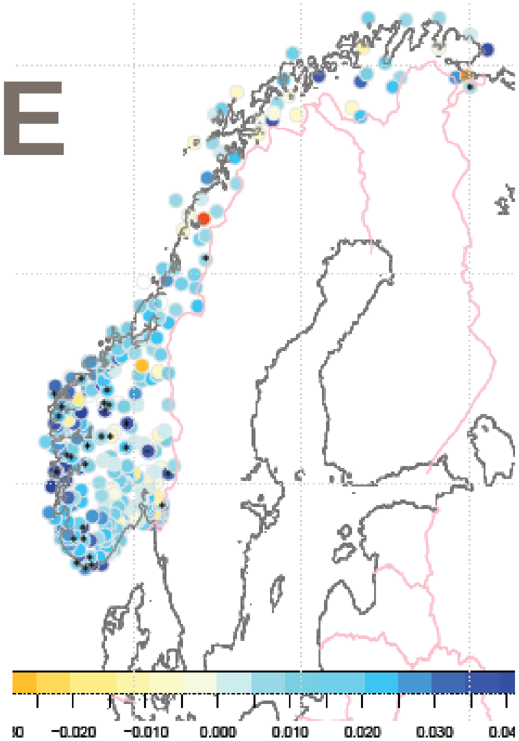
3. CLIMATE



Norway:

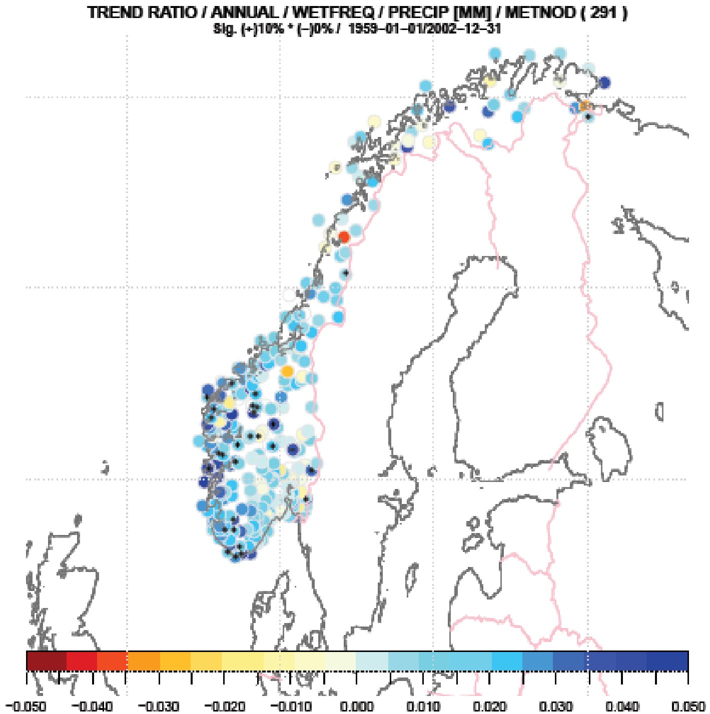
Stations

- 1300 -> 291
- 1959 – 2002

Sweden:

Stations

- 1600 -> 309
- 1961 – 2011



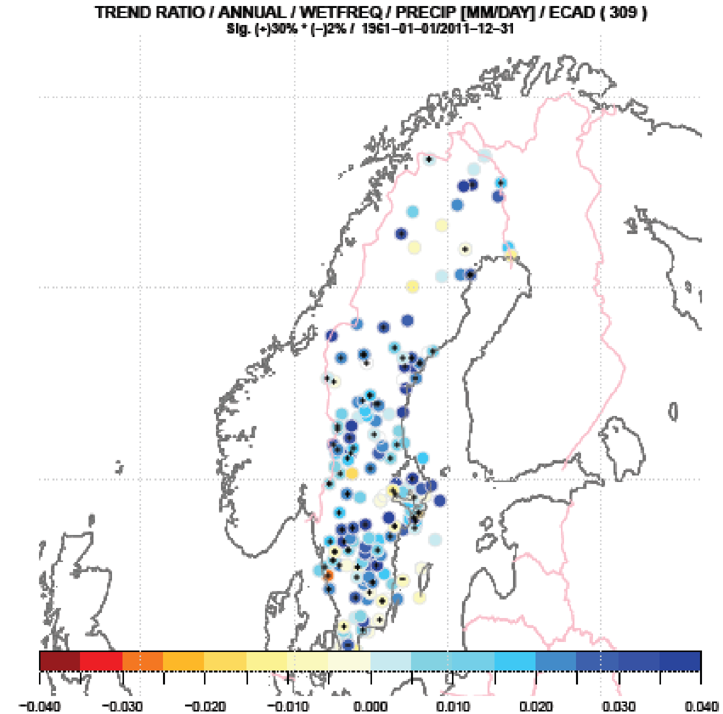
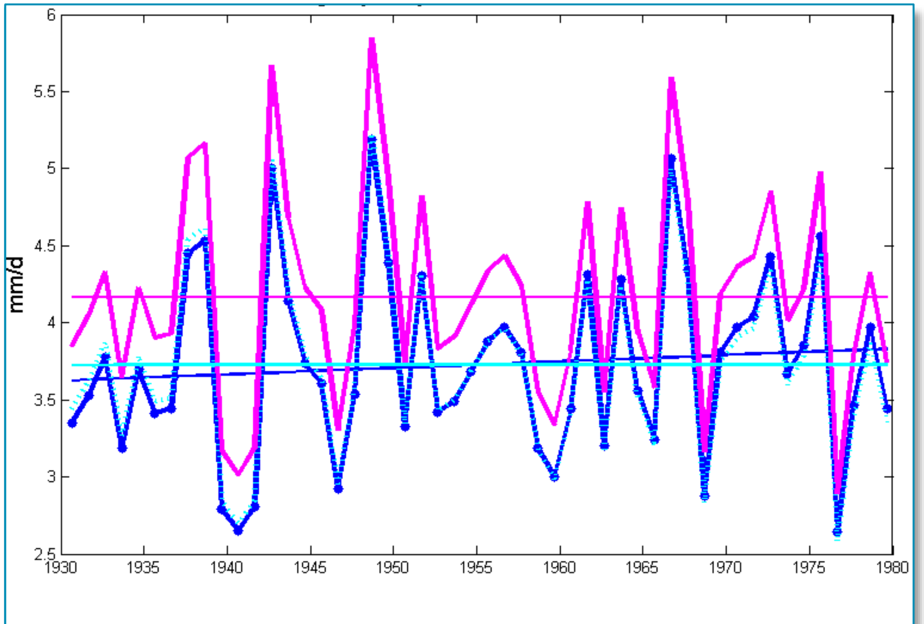


Figure courtesy: Abdelkader Mezghani, MET

- Overall positive trend ratio (5%/decade).
- More significant in Sweden rather than in Norway.

Correcting our historical data for the effects of climate change



1. Quality control of historical input time series (precipitation, temperature, discharge)
2. Detrending controlled historical input times series: 1931 – 1980
3. Homogenizing detrended input time series 1931–1980 relative to 1981-2010

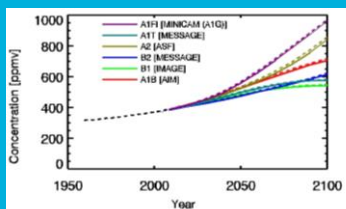
Volume consistency through our whole simulation period: 1931-2010

Turning climate research into business tools

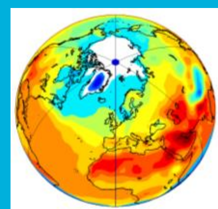
The research area is constantly maturing and we must continuously adapt

Assimilate climate change research

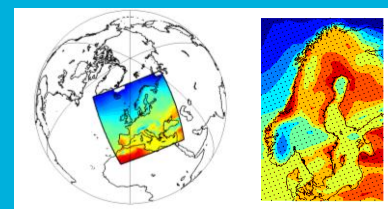
Adapt our models and data



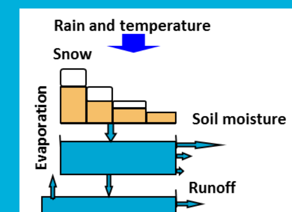
Emission scenarios



Global climate model



Regional climate models

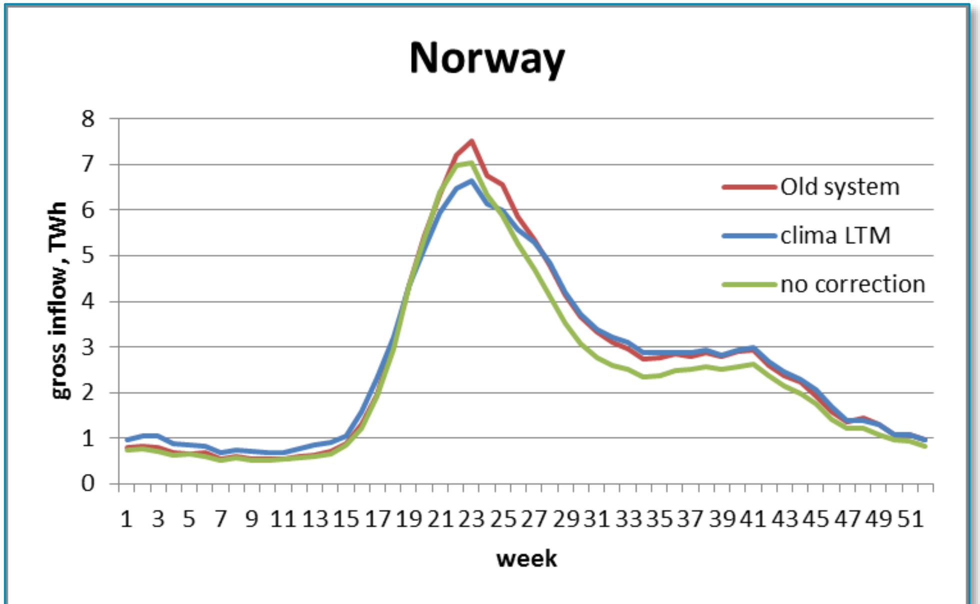


Hydrological model

Price, production and revenue forecasts

- Statkraft's hydrological models provide input for operational and long-term price forecasts as well as revenue forecasts for investment decisions
- Our climate is changing, and Statkraft takes the effects into account in our forecasts

Historical simulations 1931-2010 with de-trended dataset



- Same precipitation volume for the periods
  - 1931 – 1980 and 1981 – 2010
- Same average temperature for the periods
  - 1931 – 1980 and 1981 – 2010
- Change in seasonal discharge profile due to warmer winters and more glacier run off
- Hydrological model forced with CMIP 3 for Norway and Sweden

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THANK YOU

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PURE ENERGY

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