

Complex Cascade Dams Operation – The Glommen and Laagen Case



Hans-Christian Udnæs

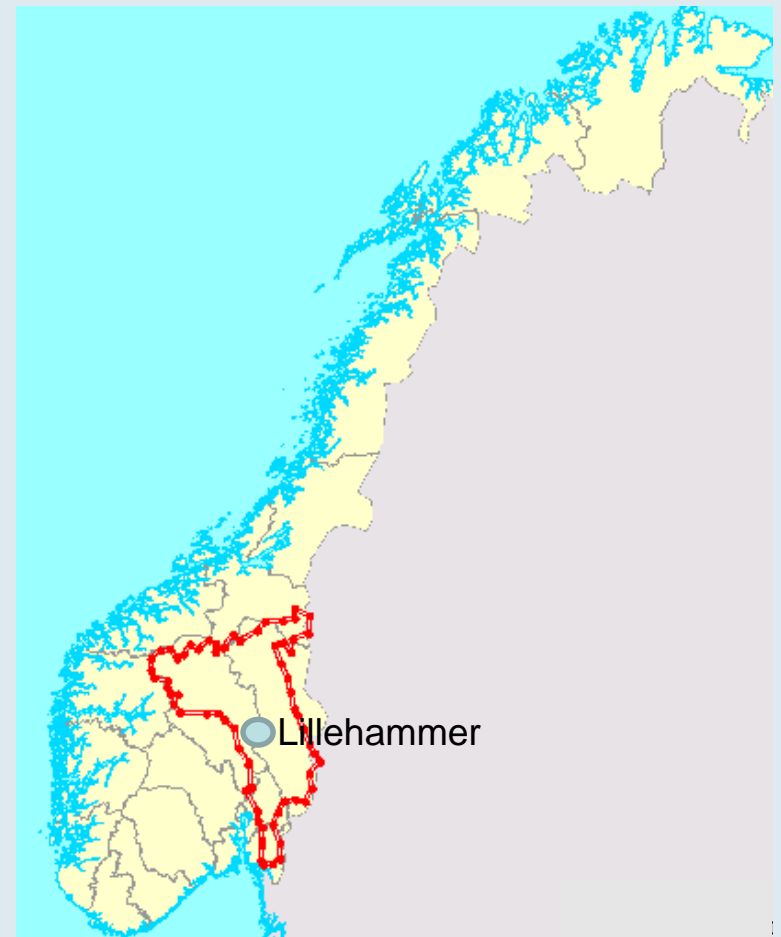
Head of Department – Hydrology, Eidsiva



About GLB

Glommens og Laagens
Brukseierforening (GLB)

is a Water Management
Association
for the largest river system
in Norway




Glomma & Laagen watercourse

- Catchment area: 42 000 km²
 - 13 % of Norway (0-2469 masl)
- 21 reservoirs and 5 diversions
 - Storage capacity: 3 500 mill.m³
- 50 hydroelectric powerstations
- Inst. capacity: 2 500 MW
- Production: 12 TWh/year
 - Appr. 9 % of Norway

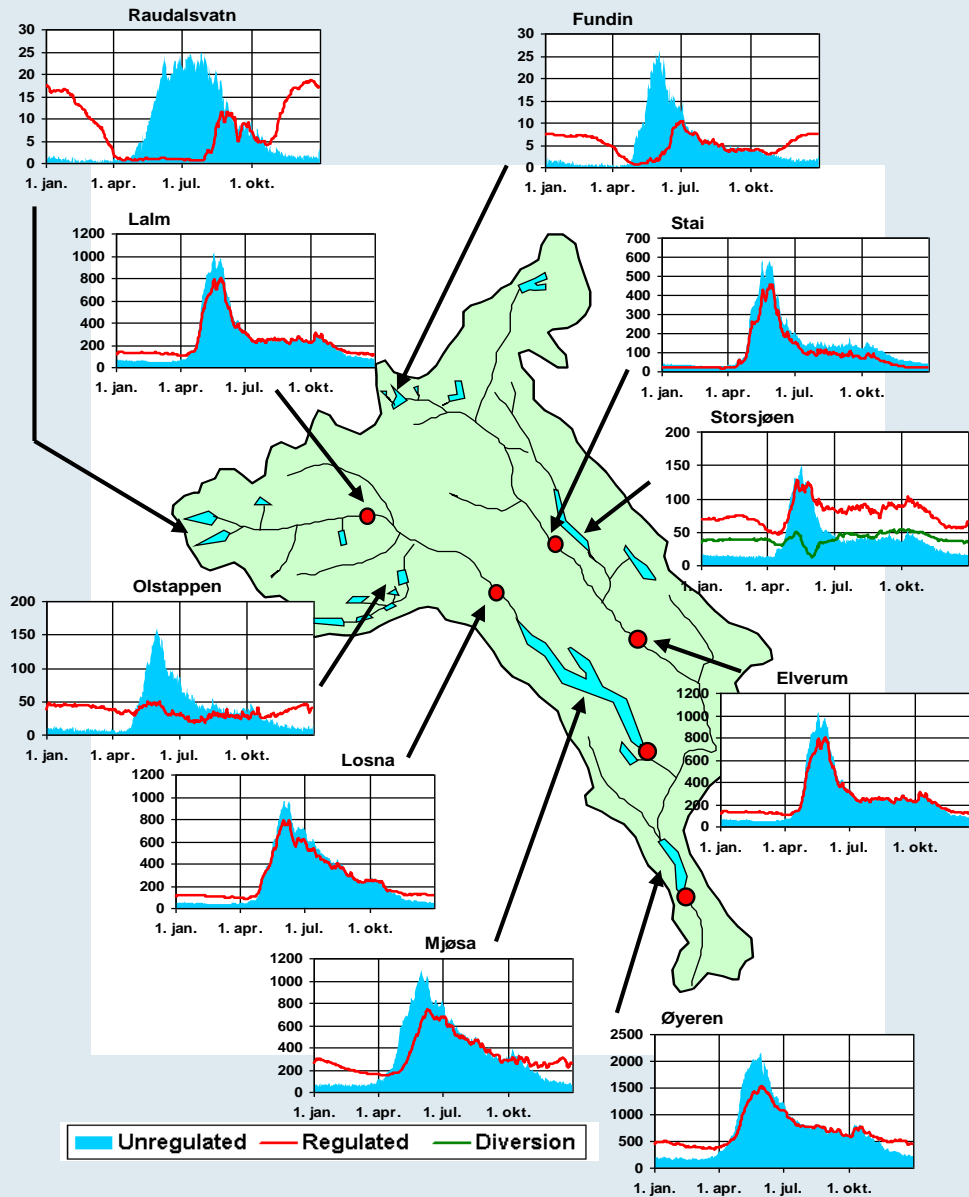


GLB – main task



“Regulate the water flow in the rivers Glomma and Laagen, within licensed conditions, in order to maximize energy production (economic outcome) in the hydropower stations. Commercial, but take into account all stakeholders”

Hydrological regimes - usefulness of regulations



Effect of regulations and diversions is about 2,5 TWh/yr (~20 % of total production).

Additional economic effect caused by variations in electricity price.

Requirements for operating the river system

Sufficient and reliable observations

Weather forecasts

Well calibrated hydrological models

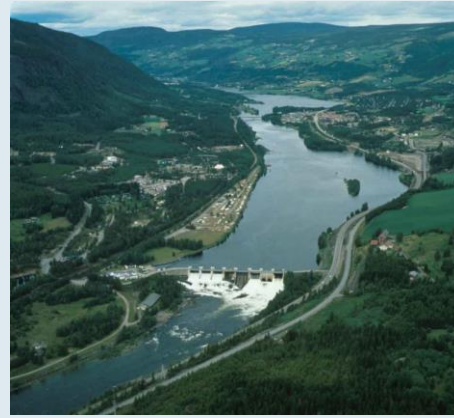
A river system model to link the sub catchments together and for planning how to operate

A model for optimizing the total profit within actual weather forecasts and known restrictions in the river system

Sufficient and reliable observations



Water level and outflow
(reservoirs)



Discharge
(power plants and hydrological stations)



Precipitation, temperature, snow
(meteorological stations)



Snow
(manual measurements)

GLB operates ~125 hyd./met. stations with hourly time resolution

Weather forecasts

Weather forecasts (precip.+temp.)
10 days ahead for specified areas
are imported every morning
into the hydrological models

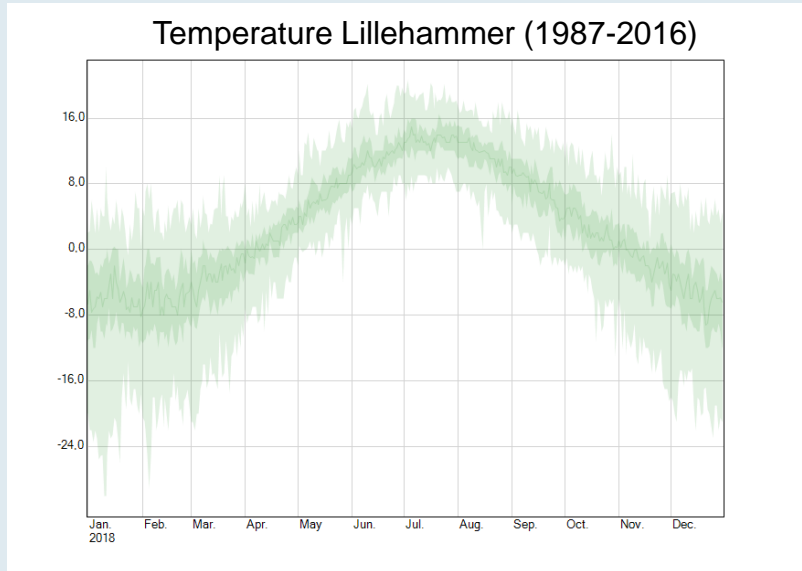
Overview
Hour by hour
Long term
Weather radar
Statistics
Maps

RELEVANT PLACES
Lillehammer
Vansjø
Fåvang
Hurdal Verk
Folkeheuskole
Glåmos
Åkrestrømmen
Doråseter
Einunndalen
Alvdal kommune
Grotli observation site

To the main menu at the page bottom

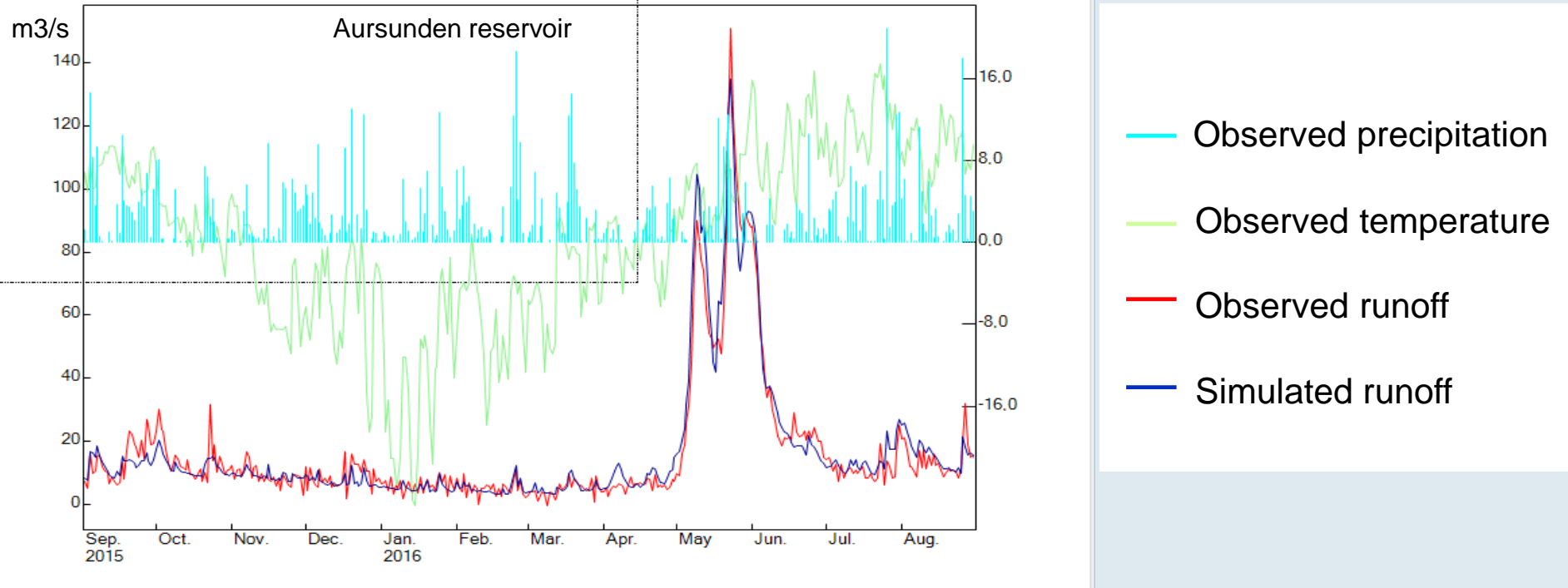
Detailed long term forecast

Date	Time	Forecast	Temp	Precipitation	Wind
Thursday 31/08/2017	00:00 -06:00		11°	0 mm	Light breeze, 2 m/s from northeast
	06:00 -12:00		10°	0 mm	Light air, 1 m/s from northeast
	12:00 -18:00		15°	0 mm	Light breeze, 2 m/s from west-northwest
	18:00 -00:00		14°	0 mm	Light air, 1 m/s from west-northwest
Friday 01/09/2017	00:00 -06:00		10°	0 mm	Light air, 1 m/s from north-northeast
	06:00 -12:00		9°	0 mm	Light air, 1 m/s from north
	12:00 -18:00		14°	0 mm	Light air, 1 m/s from west
	18:00 -00:00		14°	0 mm	Light breeze, 2 m/s from south-southeast
Saturday 02/09/2017	02:00 -08:00		10°	0 mm	Light air, 1 m/s from east
	08:00 -14:00		10°	0 mm	Light air, 1 m/s from northwest
	14:00 -20:00		17°	0 mm	Light breeze, 2 m/s from southwest
	20:00 -02:00		14°	0 mm	Light air, 1 m/s from south-southeast
Sunday 03/09/2017	02:00 -08:00		10°	0 mm	Light air, 1 m/s from northeast
	08:00 -14:00		11°	0 mm	Light air, 1 m/s from northeast
	14:00 -20:00		18°	0 mm	Light breeze, 3 m/s from south
	20:00 -02:00		14°	0 mm	Light breeze, 2 m/s from east-southeast
Monday 04/09/2017	02:00 -08:00		11°	0 mm	Light breeze, 2 m/s from east-southeast
	08:00 -14:00		12°	0 mm	Light air, 1 m/s from north
	14:00 -20:00		16°	0 mm	Light breeze, 3 m/s from south
	20:00 -02:00		14°	0 mm	Light breeze, 2 m/s from east-southeast
Tuesday 05/09/2017	02:00 -08:00		11°	0 mm	Light breeze, 2 m/s from south-southeast
	08:00 -14:00		12°	0 mm	Light air, 1 m/s from north
	14:00 -20:00		17°	0 mm	Light breeze, 3 m/s from southwest
	20:00 -02:00		14°	0 mm	Light breeze, 2 m/s from north-northeast
Wednesday	02:00		11°	0 mm	Light breeze, 2 m/s



Beyond 10 days historical observations are used

Well calibrated hydrological models



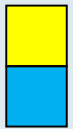
For each sub catchment a hydrological model is calibrated on historical data to establish the connection between the model input (precipitation and temperature) and output (runoff)

With this model runoff can be forecasted based on the meteorological forecast

Well calibrated hydrological models

GLB simulates runoff daily for 40 sub-catchments using the HBV model

Sub catchments

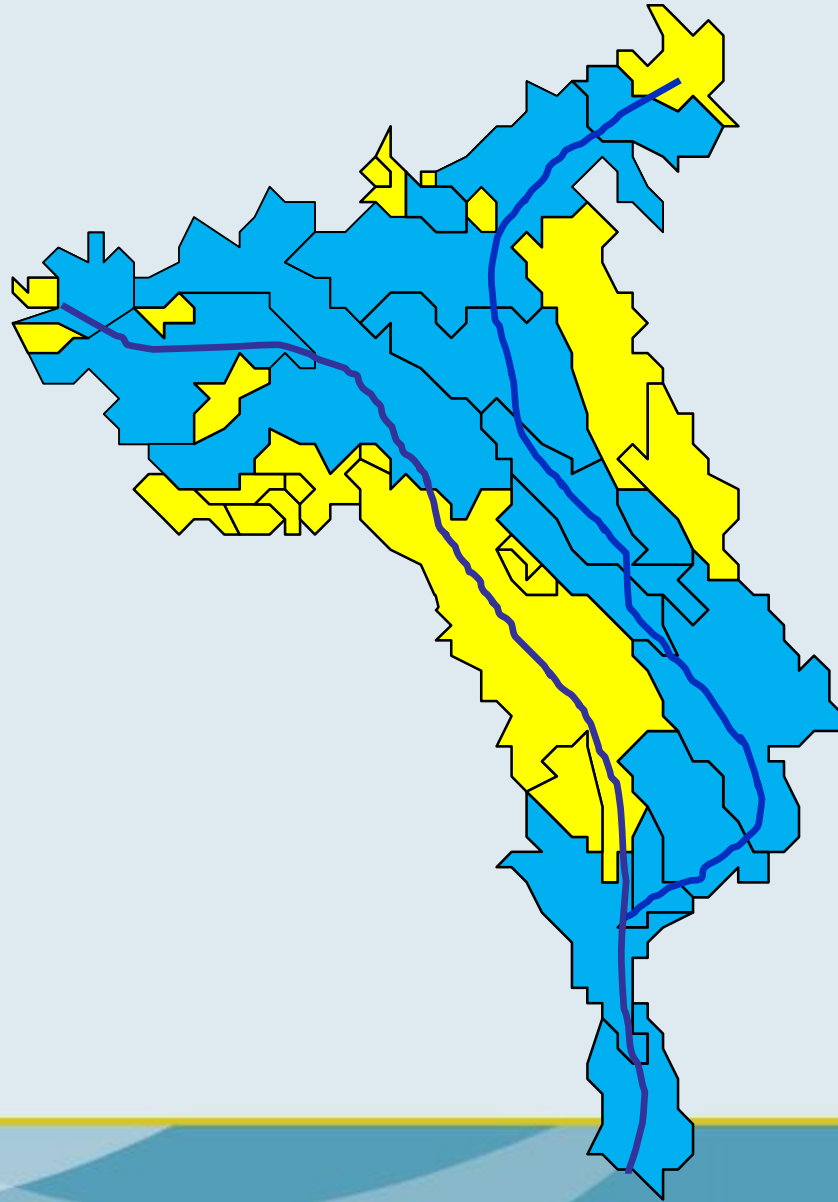


Regulated

Unregulated

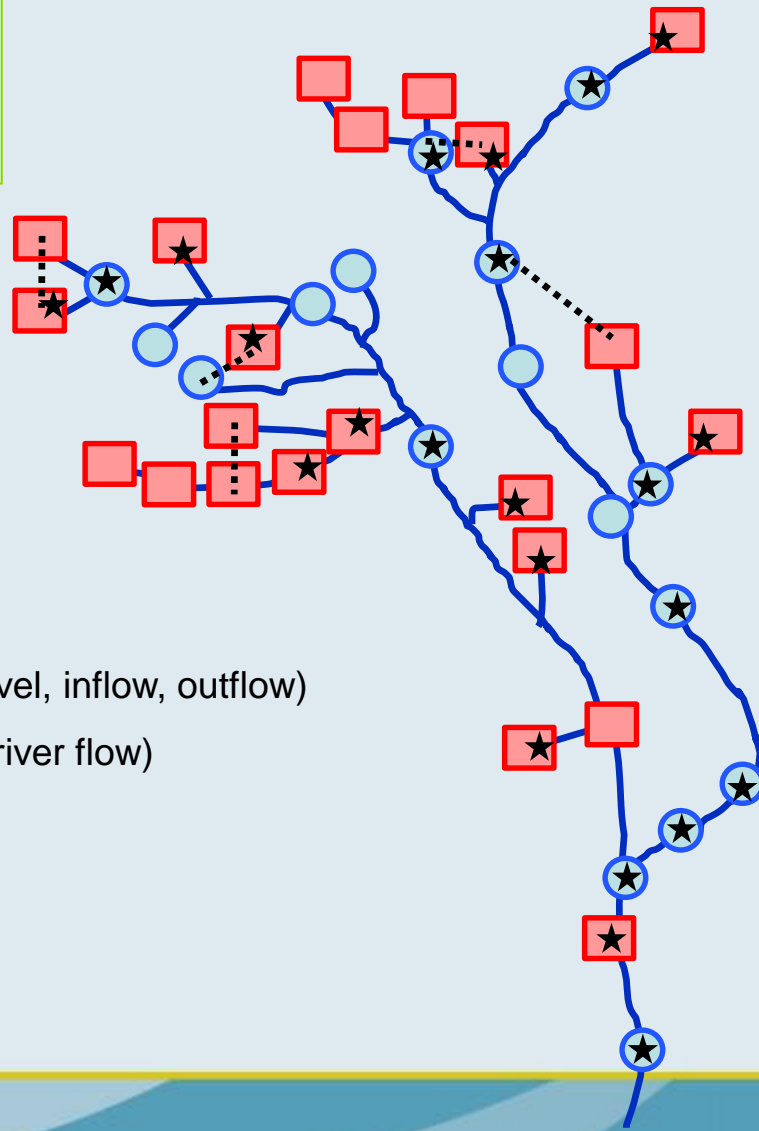


Main river



River system model

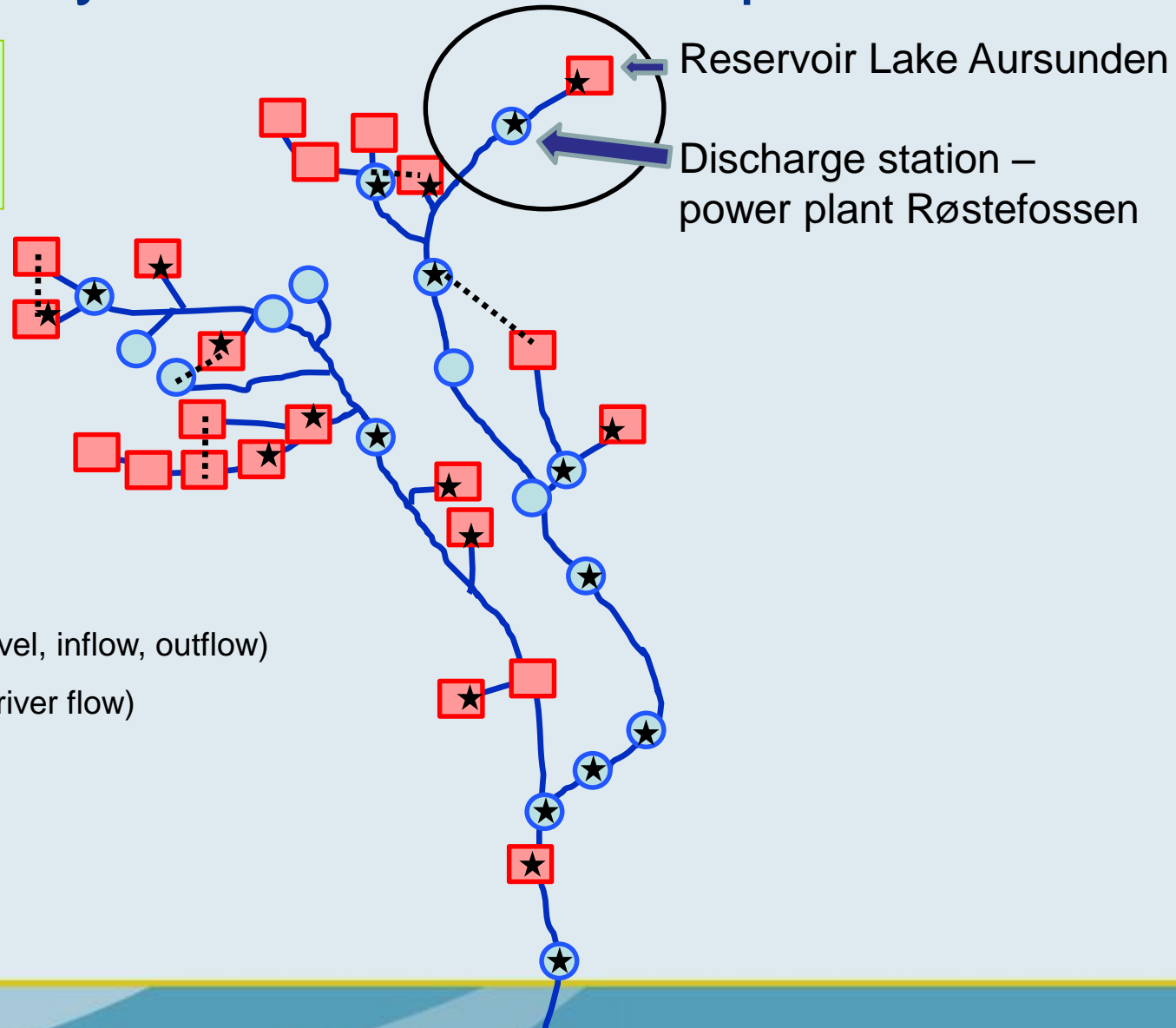
Schematic representation of the river system model



- Reservoir (water level, inflow, outflow)
- Discharge station (river flow)
- River
- Diversion
- ★ Power plant

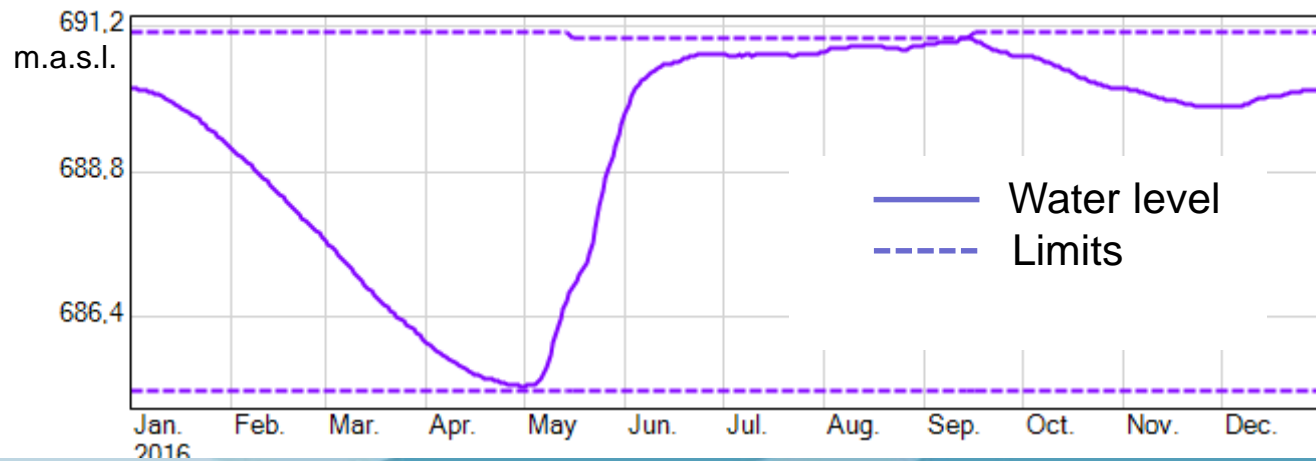
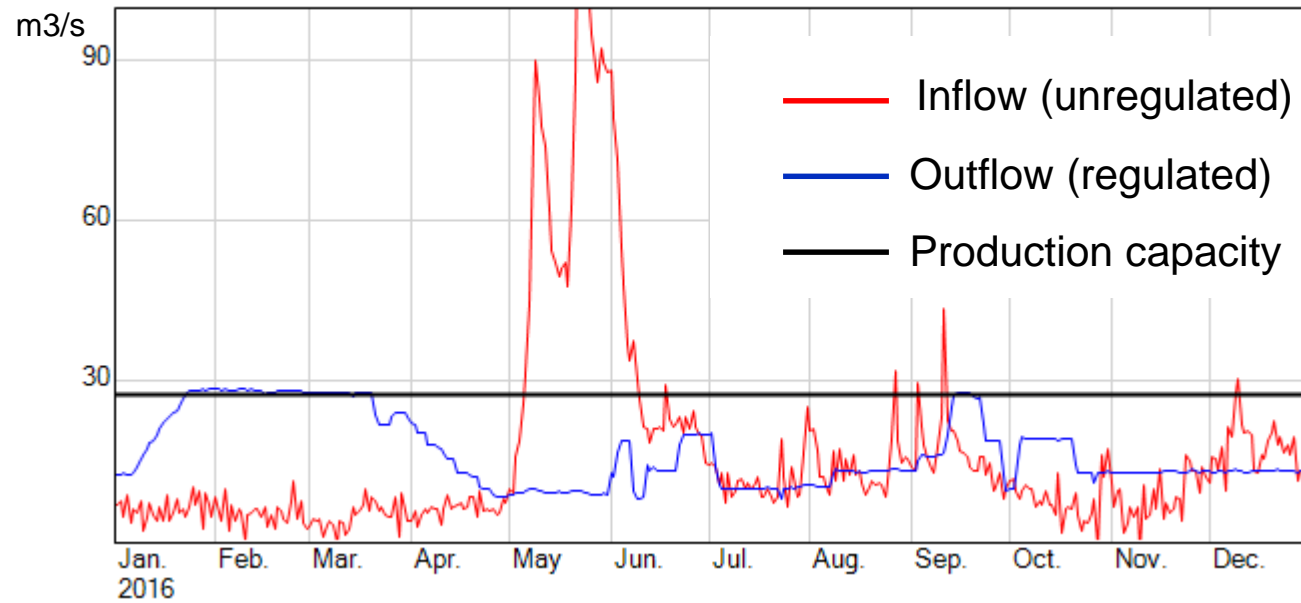
River system model - examples

Schematic representation of the river system model

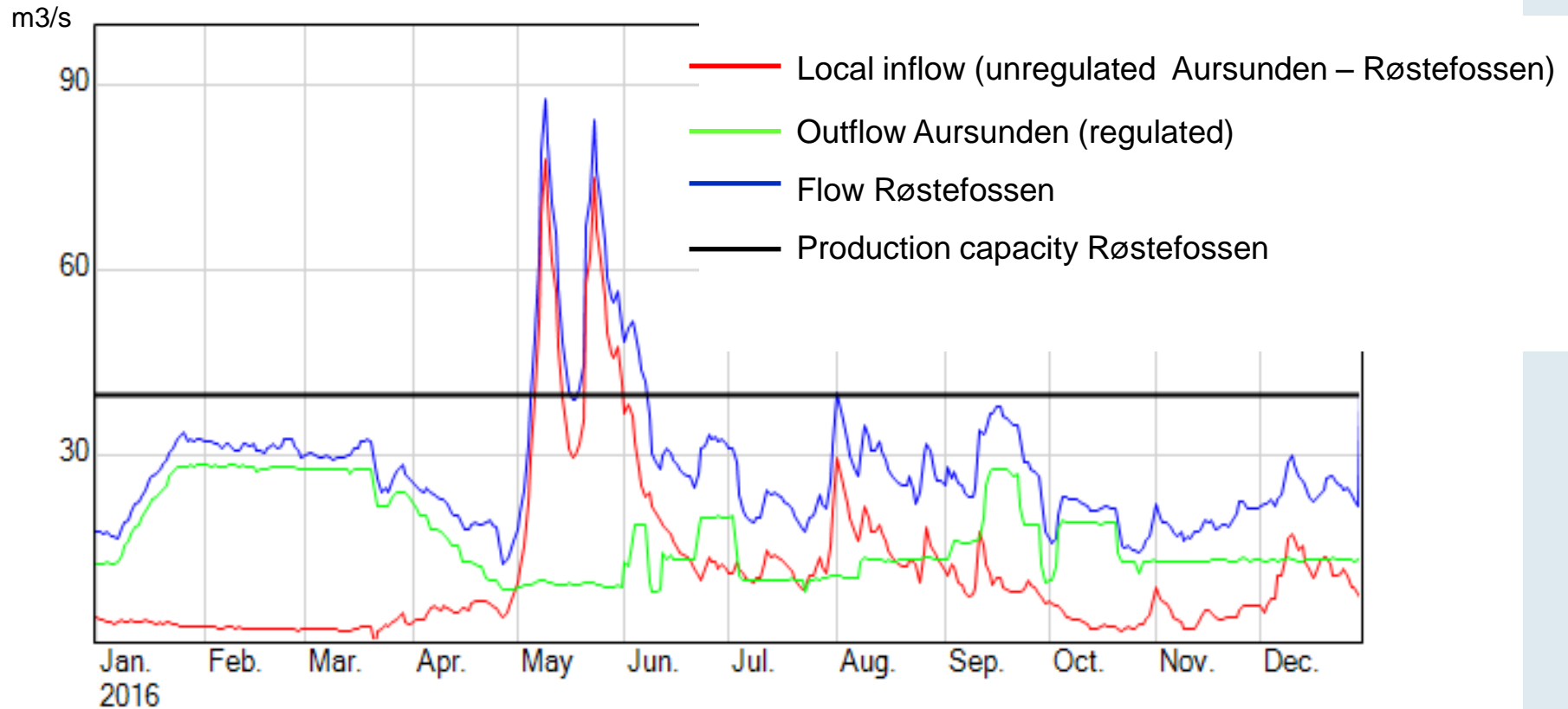


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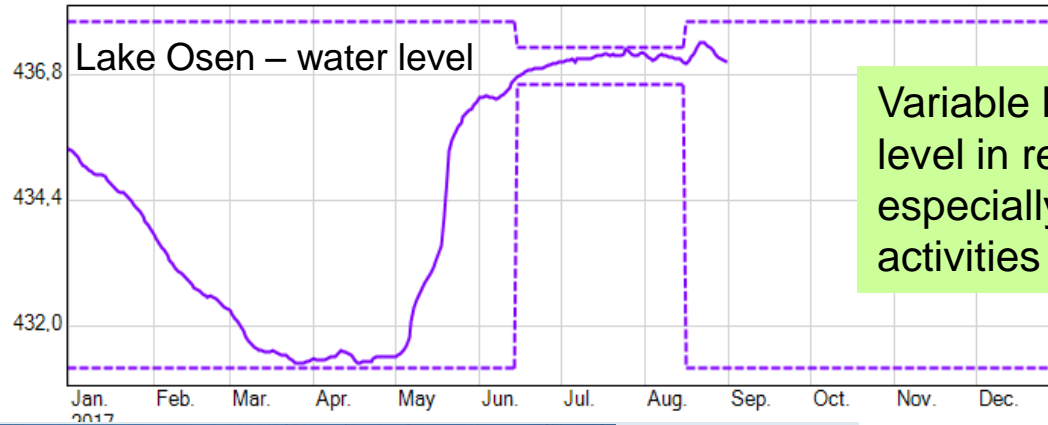
River system model – Reservoir; Lake Aursunden



River system model – Discharge station; Røstefossen



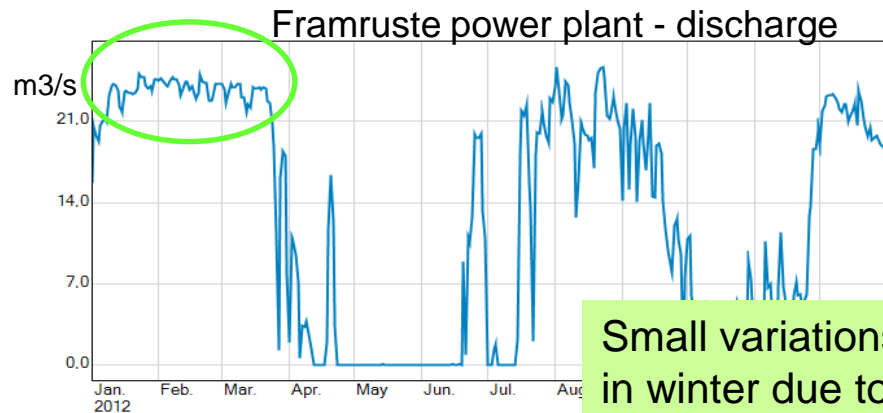
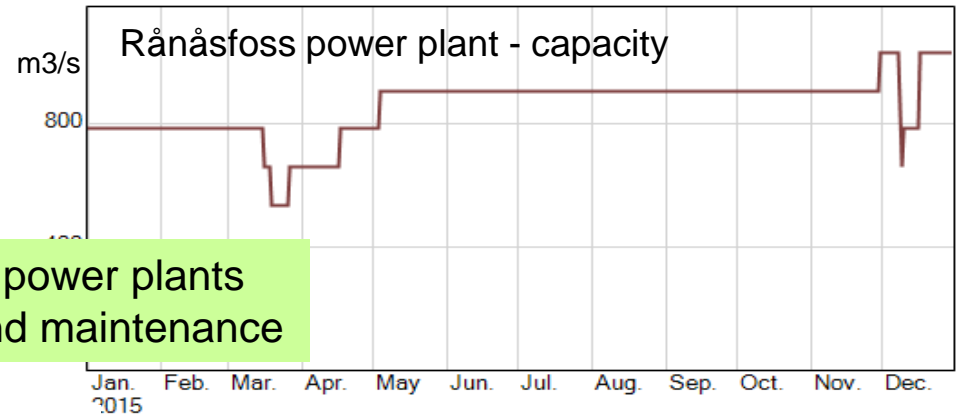
River system model – Restrictions



Variable limits for water level in reservoirs – especially due to leisure activities in summer



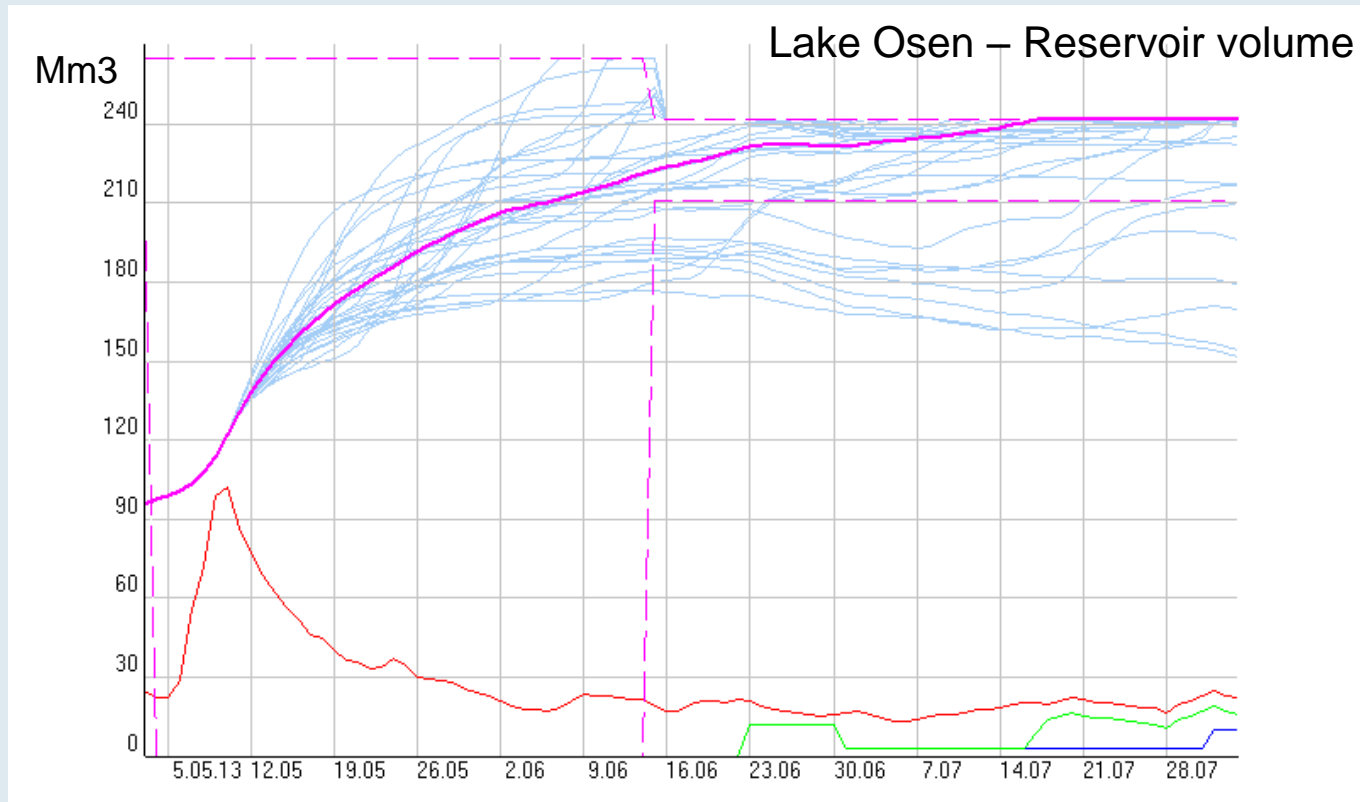
Variable capacity in power plants due to upgrading and maintenance



Small variations in outflow/production in winter due to ice conditions in the river



River system model – forecast single module



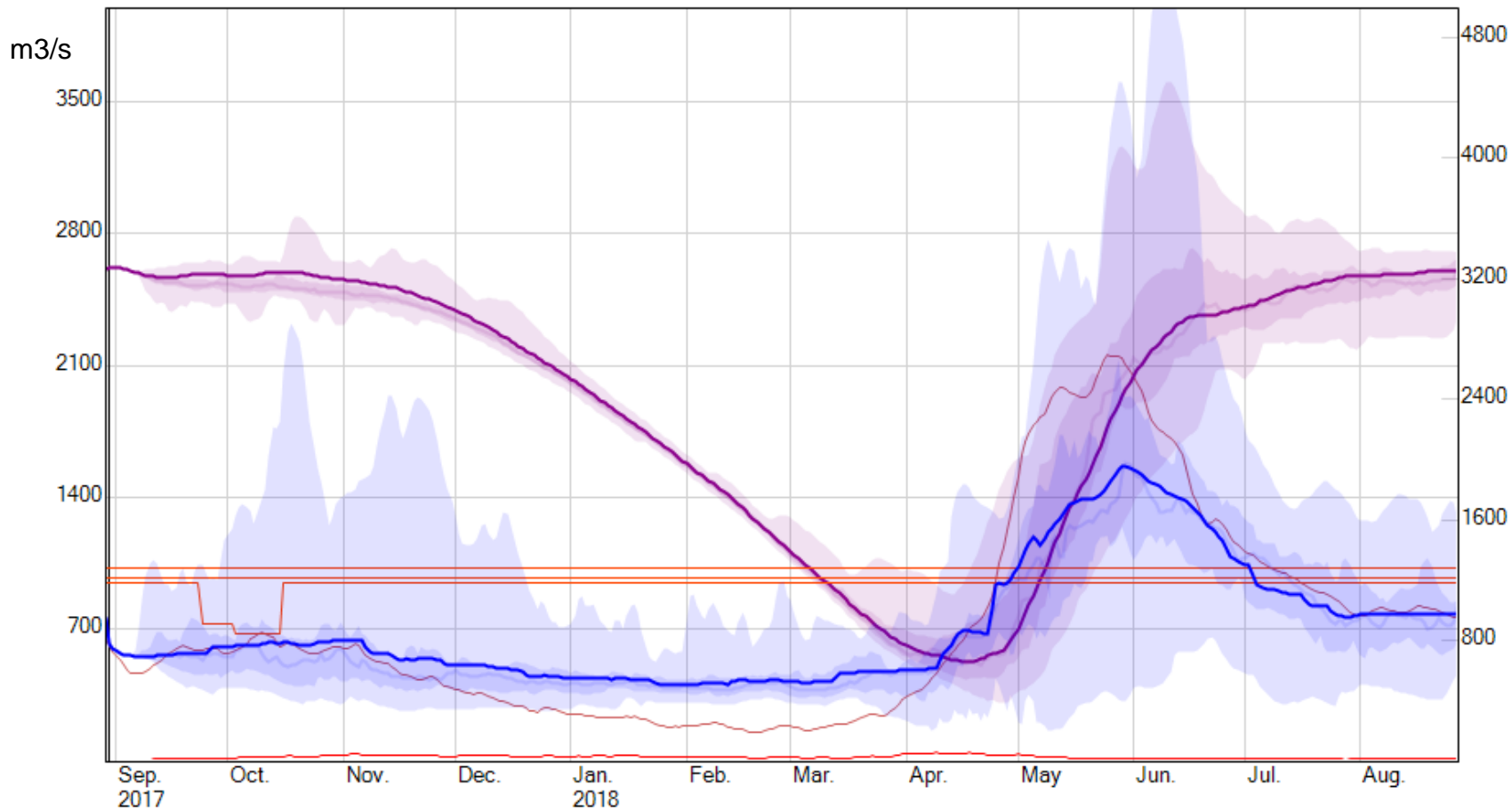
10 days forecast

Forecast/scenarios based on observed weather the last 30 yeras

Based on known restrictions, weather forecast for 10 days, and observed weather for the last 30 years, forecasts and plans are prepared daily.

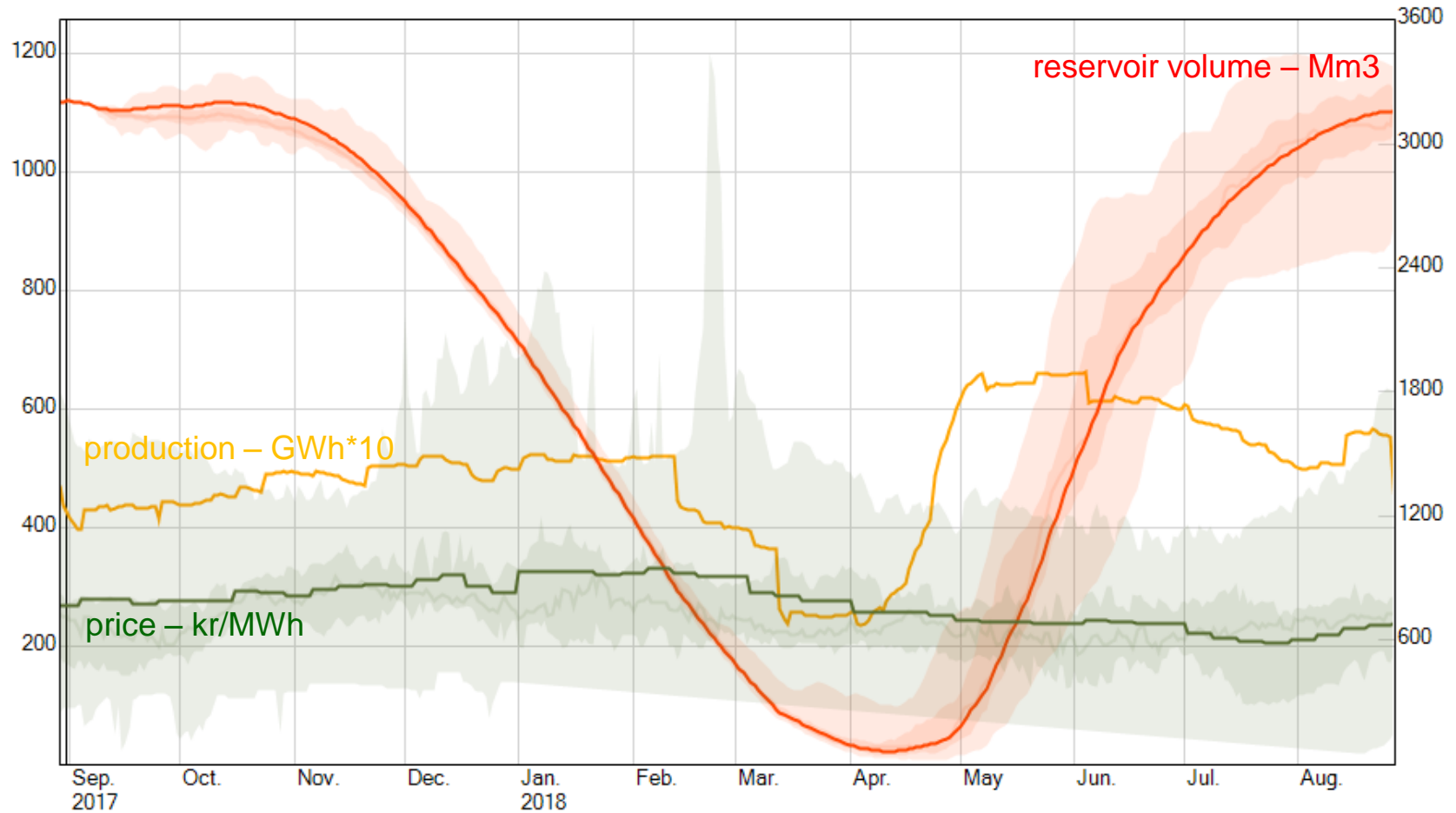
River system model – forecast for river Glomma downstream all reservoirs

Published: 30.08.2017 Starting from:29.08.2017 Sarpsfoss, plan: Flow, Runoff, total Reservoir -> Powerplant capacity: Fossumf./K., Vamma, Sarpsfoss.



River system model – forecast for river Glomma (totals)

31.08.2017 07 Glomma-Laag Power price prognosis Power Production plan ->



THE END



Lake Øyeren 1967, a flooding situation hopefully to be avoided in the future due to activities to reduce floods and optimal use of upstream reservoirs