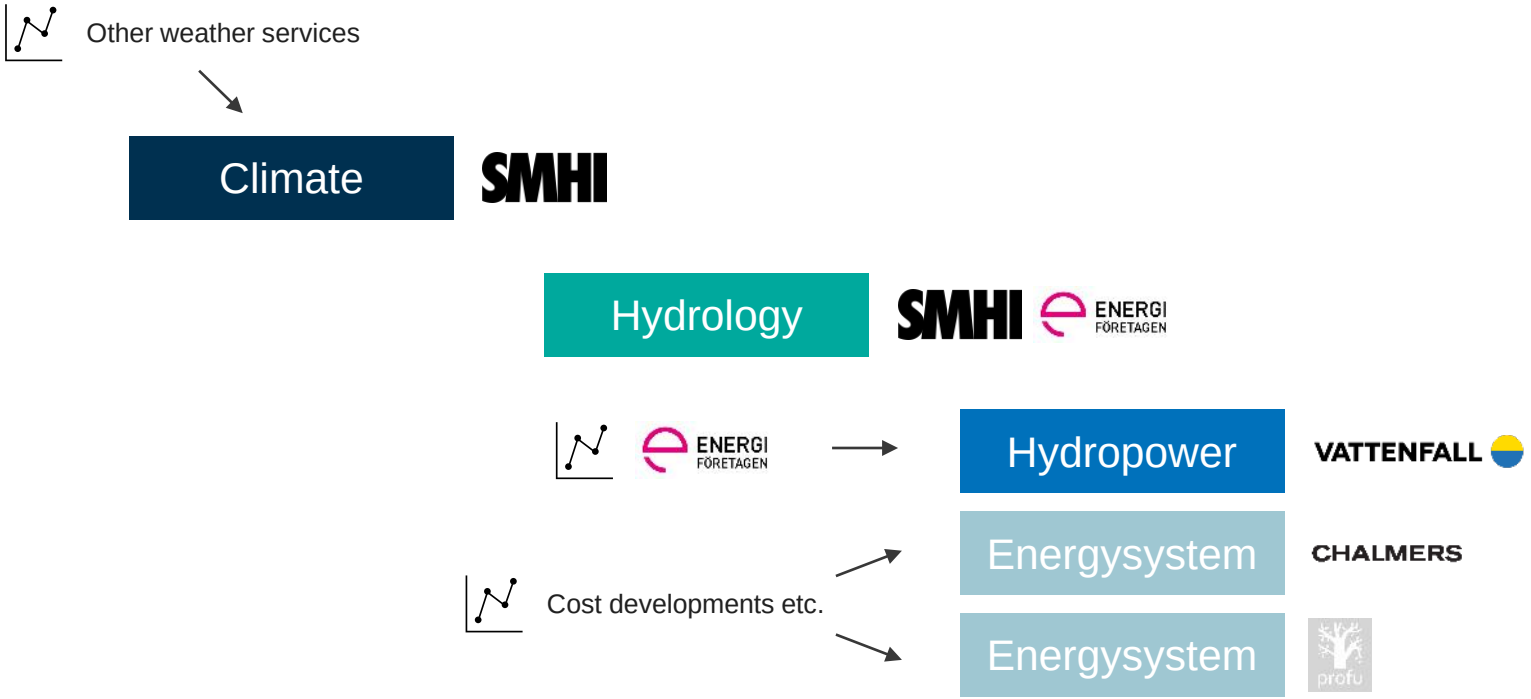
Connecting models

Interactions between climate, hydrological, hydropower, and energy system models – Lessons learned from the KLIVA project

Richard Scharff | Energitekniksystem | Chalmers & Vattenfall R&D
Yeshewatesfa Hundecha | SMHI Research

HUVA-dagen 2022 | 2022-11-30

Models used in KLIVA



Project group














What if **climate change** affects **hydropower**?

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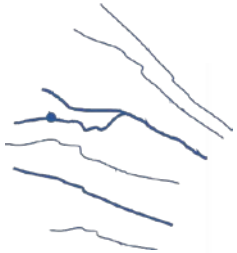
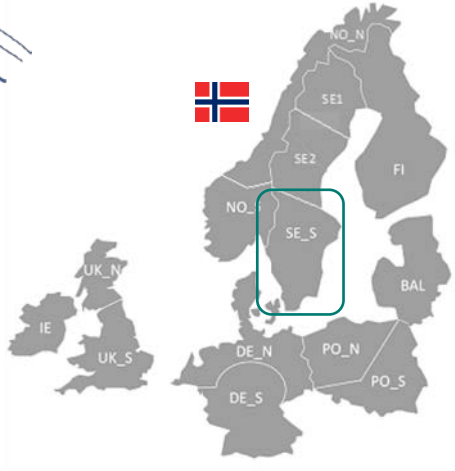
Questions we want to answer

Impact of **climate change** on:

- **Inflow** per reservoir
- Inflow **energy** per river system
- **Dispatch** per river system (production & flex)
- **Dispatch** in the electric power system
- Future electric power **system**





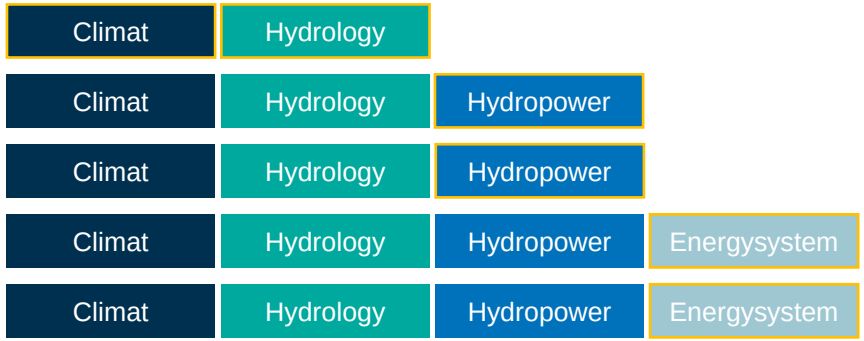
Hydropower plants	KLIVA	Sweden
Number	~200	~2000
Capacity (end 2020)	14 805 MW	16 335 MW
Energy (2020)	65 TWh	71 TWh

Map: OpenStreetMap.
Statistics: Energiföretagen (https://www.energiforetagen.se/globalassets/energiforetagen/statistik/energiaret/2020/energiaret-2020_tabeller.pdf).

Modelling ”cascade”

Impact of **climate change** on:

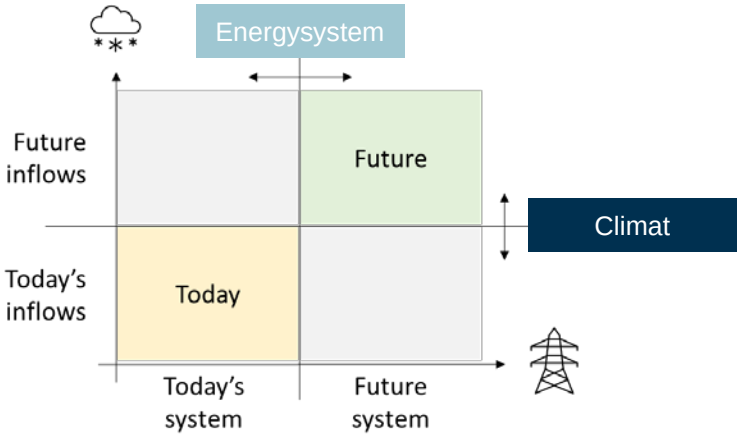
- **Inflow** per reservoir ……
- Inflow **energy** per river system .....
- **Dispatch** per river system (production & flex)…
- **Dispatch** in the electric power system ……..
- Future electric power **system** ……..



Horizon

Impact of **climate change** on:

- **Inflow** per reservoir
- Inflow **energy** per river system
- **Dispatch** per river system (production & flex)
- **Dispatch** in the electric power system
- Future electric power **system**

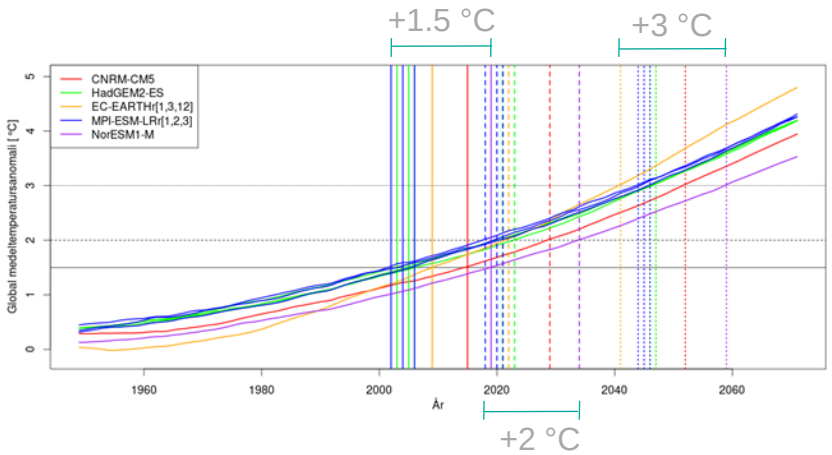


What about the **results**?

Climate change

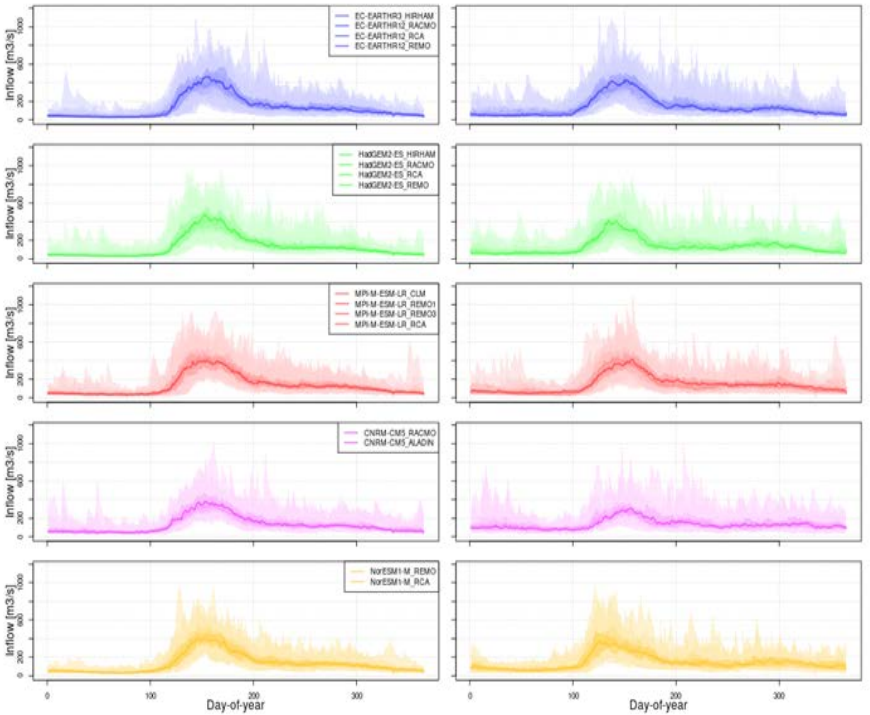
Climat | Hydrology

Projected increase in the global mean temperature above the pre-industrial period for RCP8.5



S-HYPE

Reference | GWL +2 °C

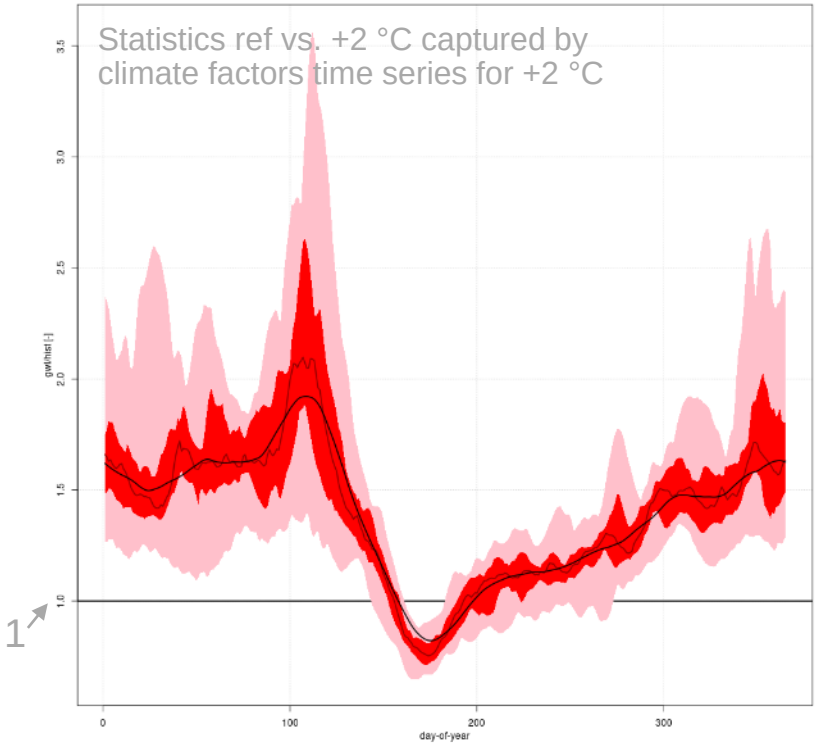


Climate factors

Climat | Hydrology

Example:

- Tjaktjajávrre (SUBID 35025)
- +2 °C

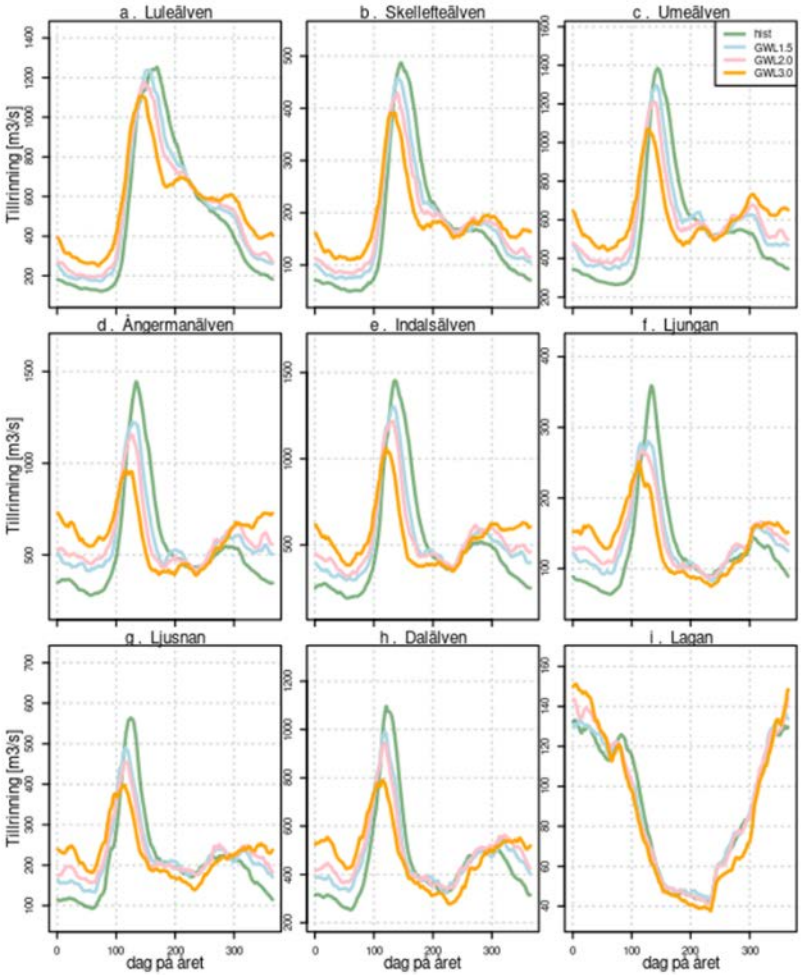


Local inflow

Climat | Hydrology

Annual cycle of aggregated local inflow to all reservoirs within each river system

(no propagation times)

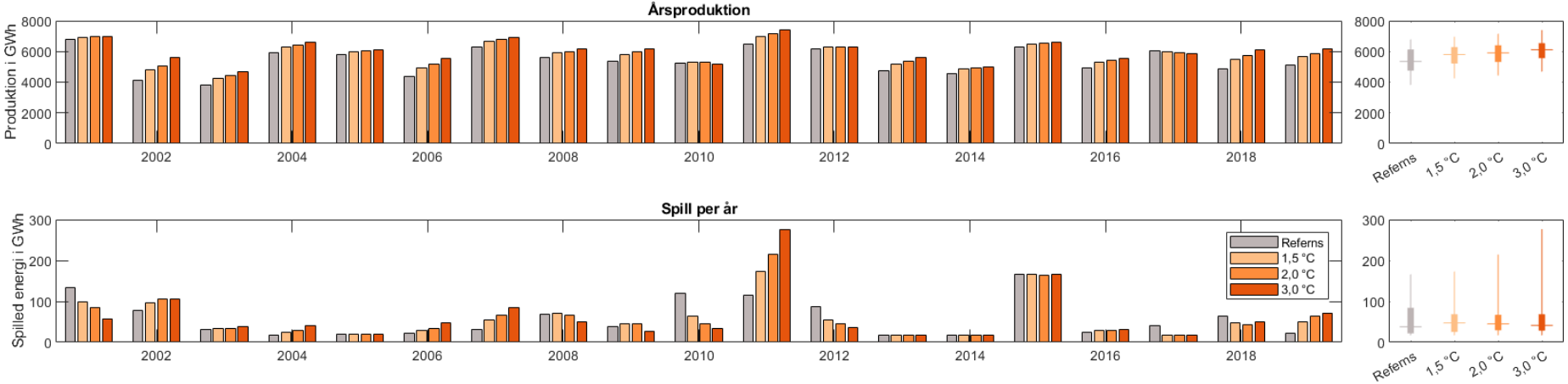


hist = HBV

Hydropower

Production & spillage

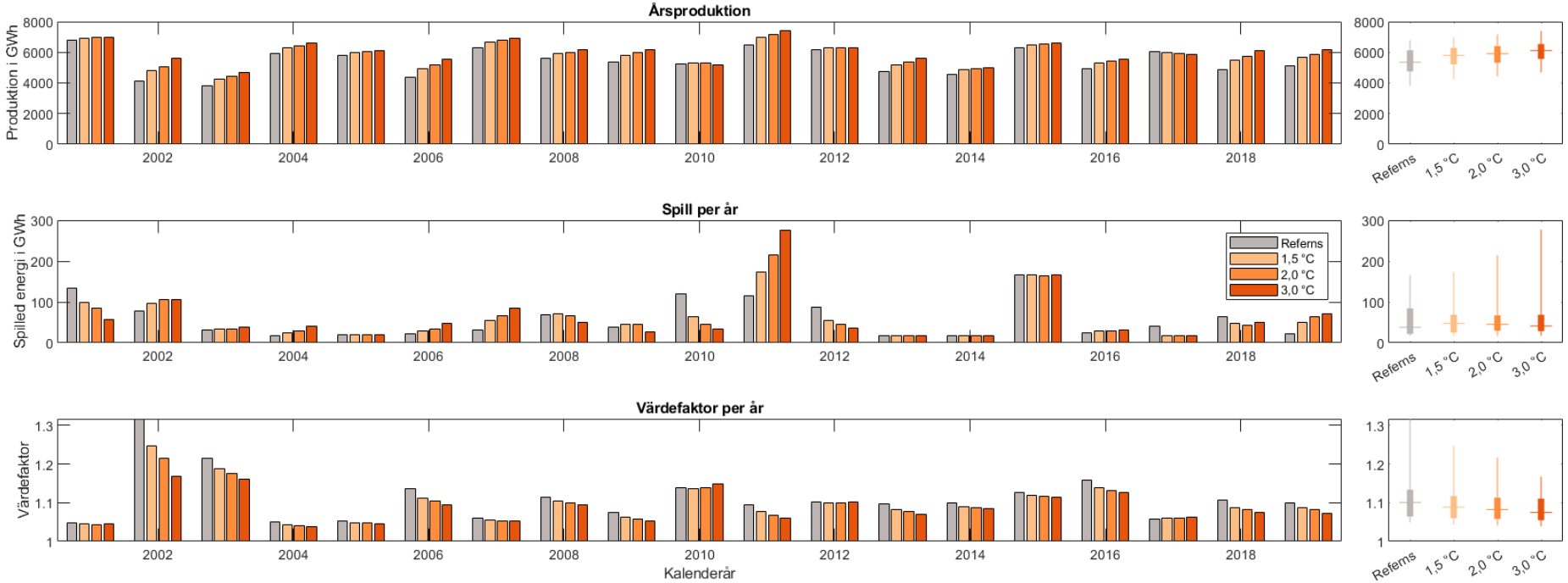
Example: Skellefteälven



Hydropower

Production & spillage

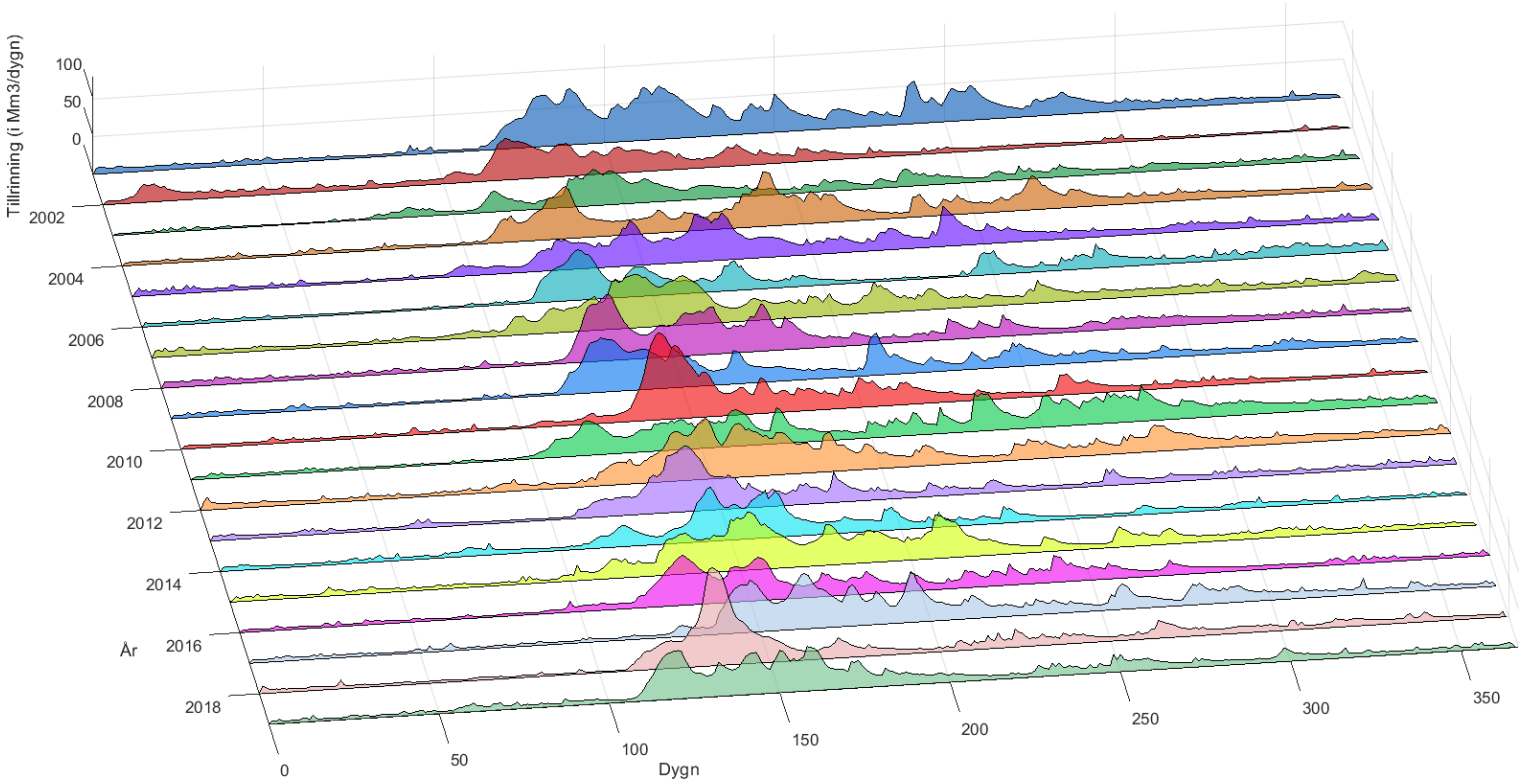
Example: Skellefteälven



Hydropower

Inflow patterns

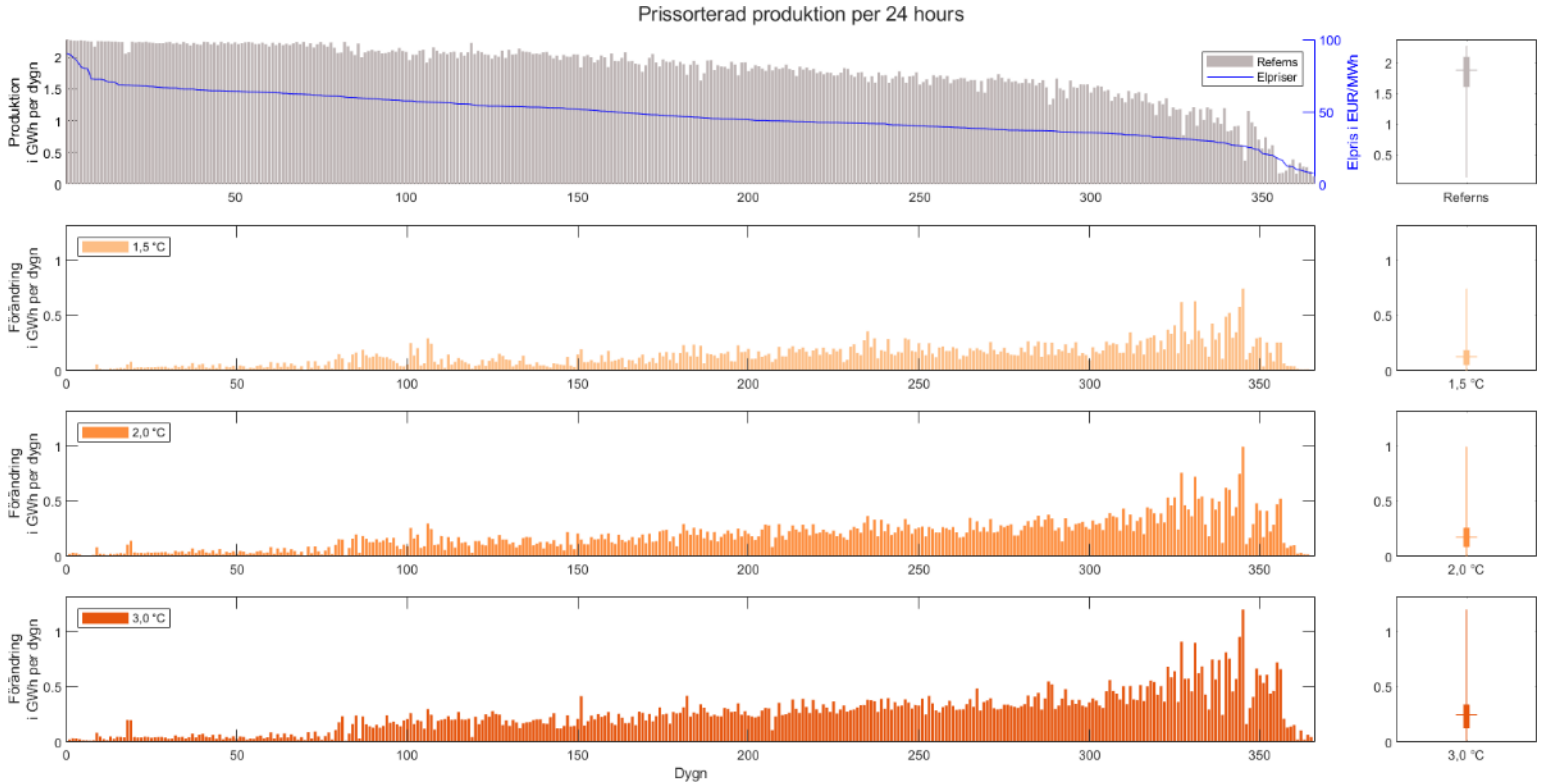
Example: Skellefteälven



Hydropower

Measure for flexibility

Example: Skellefteälven, 2011



Future electricity production 2050

Energysystem

- Fossil free, only
- Northern Europe
- Lifetime limited
- Cost efficient
- Electricity, heat, H_2, EV
- Electrification (+100 TWh)
- Transmission
- 1991 & 1992, inflow and demand temperature dependent

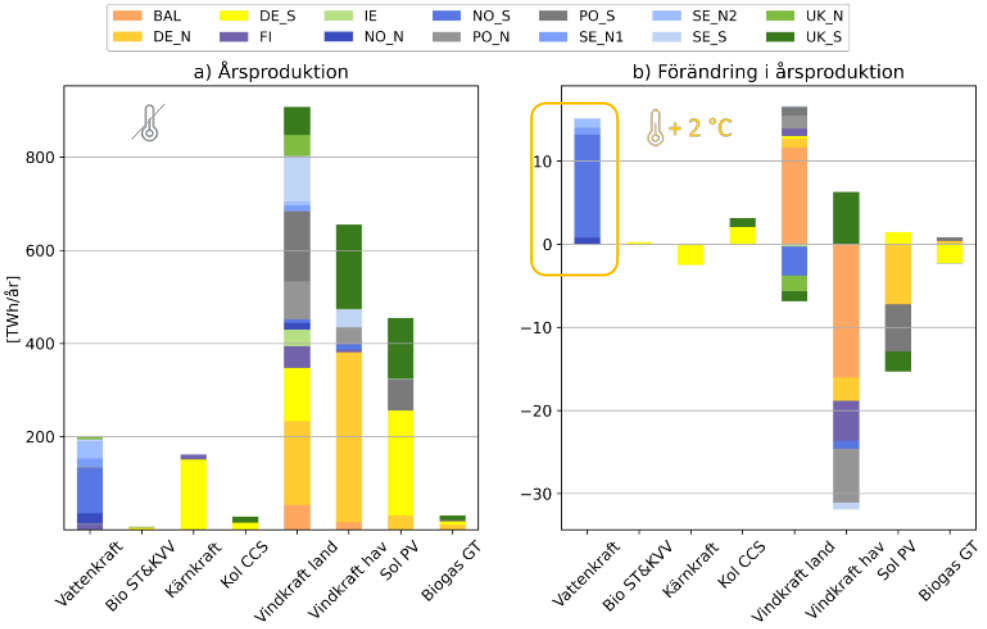


Figure describes the composition of electric power production in the cost optimal future energy system without(?) climate change (left) and how that changes if a climate change of 2 °C is assumed (right). File: Rapportutkast_v2 Lisa G.docx.

Have there been **challenges**?

Yes, but we got help!

Big **thanks** to Susanne, Anna, Linnéa and many more!!

Pictures: Vattenfall, Sveriges Radio.

Making data accessible

Accessible for research:

- **Shared** via Energiföretagen
- Energiföretagen's NDA

→ Enables similar **research also in the future**

ENERGI FÖRETAGEN

AVTAL

Datum
2021-03-18

Avtalsnummer
XXX

1 (2)

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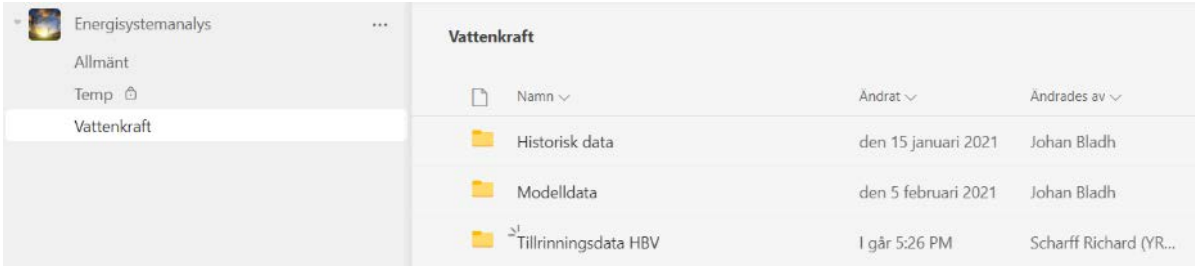
Sekretessförbindelse och medgivande om nyttjanderätt avseende data för energisystemstudier

Energiföretagen Sverige (föreningen) får återkommande förfrågningar från externa aktörer om data för exempelvis modellering och energisystemstudier.

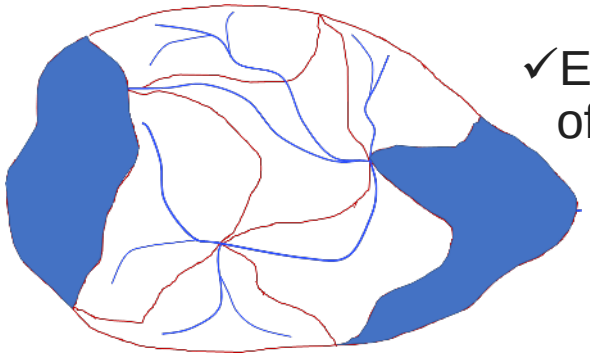


Difference S-HYPE versus HBV

- HBV: daily timeseries of local reservoir inflow closer to the reality
- S-HYPE: technical issue limits estimation of local inflow timeseries

  ➢ Estimation by deducting outflow from reservoirs located upstream from the total inflow

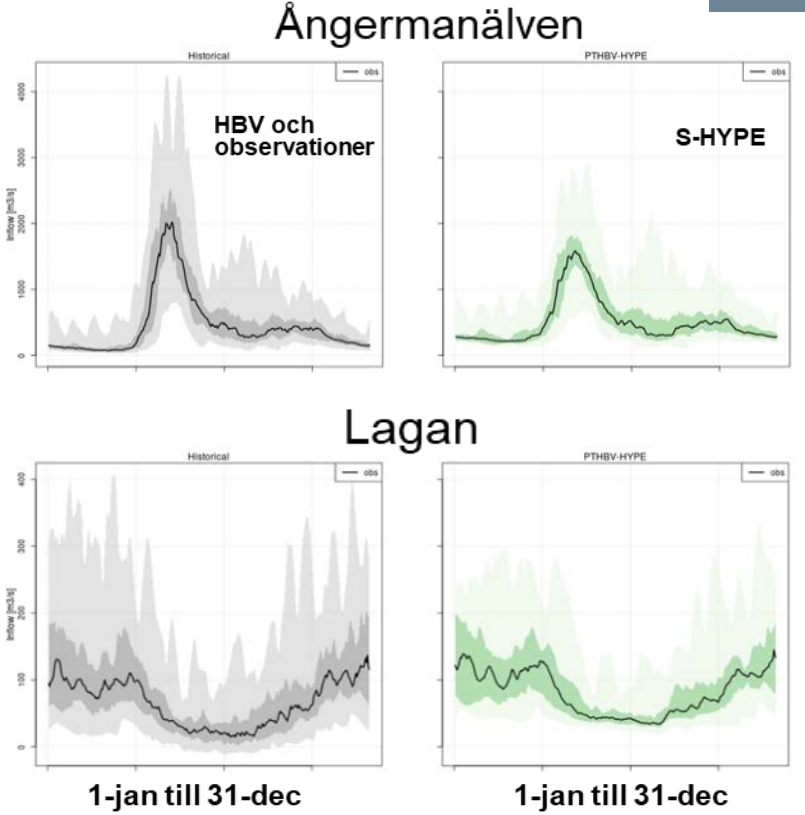
  ❖ Problem with delay of the outflow from upstream reservoirs



✓Estimate as the average value over a moving window of 10 days

Annual cycle of inflow to reservoirs within a river

- Total inflow to **all reservoirs** within a river system
  - Annual cycles well described
  - Inter-annual variability similar
- Local inflow to **individual reservoirs**
  - 22 out of 254 deviate from observations
  - Small deviations accepted
  - Large deviations but with little influence accepted



Internal ”regulation” in S-HYPE

Example: outlet Vänern (SUBID 4169)

- Simple **regulation routine** in S-HYPE
- Does not account for actual regulation
- Data on operation rule can improve prediction

Closest to ”reality”

Used to calculate climate factors

HBV ”modelled”

S-HYPE

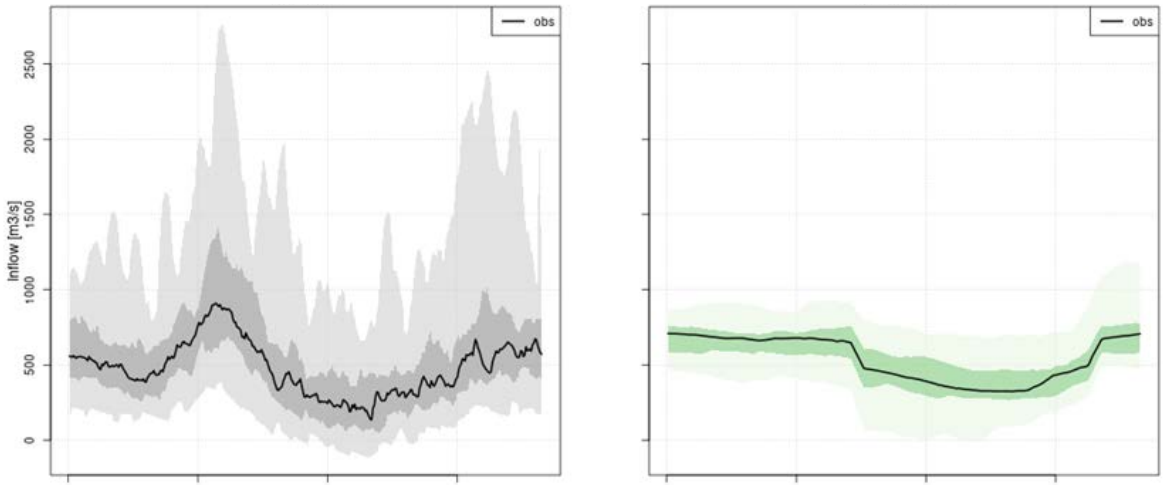
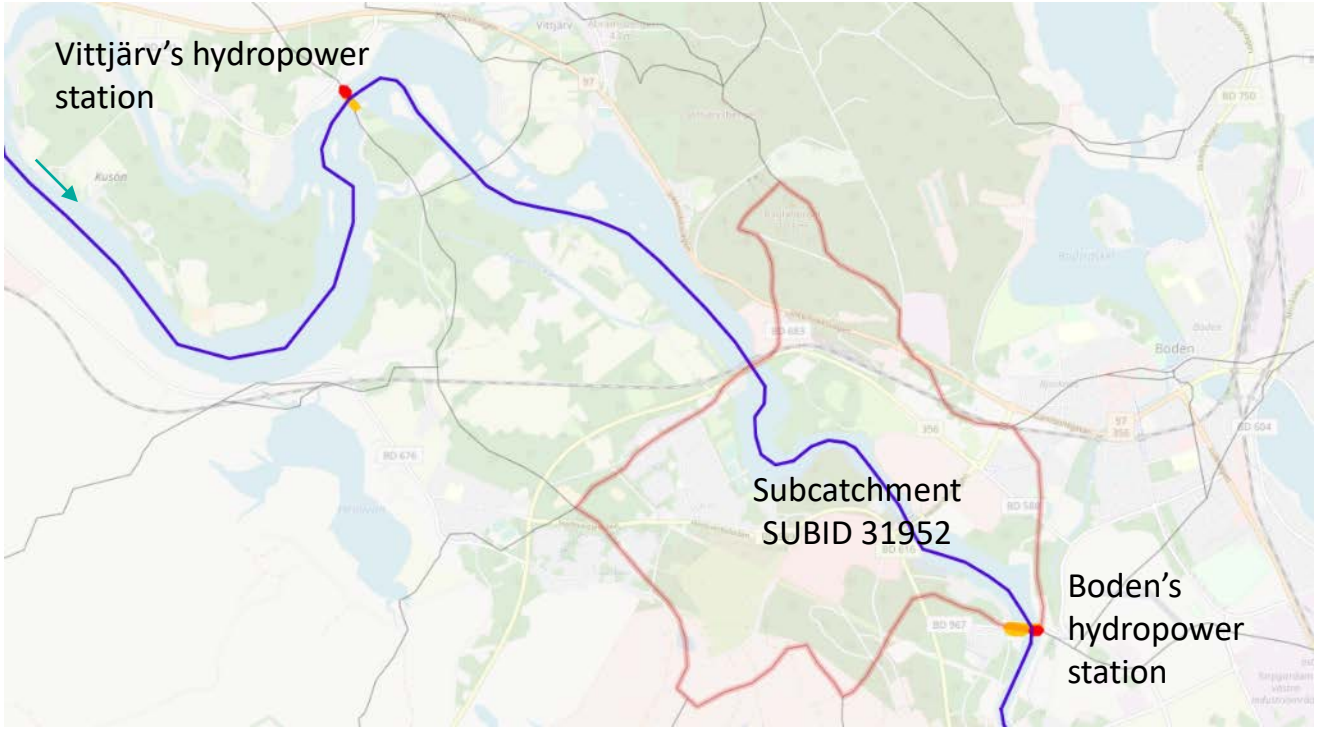


Figure shows local inflows for years 1970-2000. Median (solid line), 25 % and 75 % percentiles (dark grey/green), minimum and maximum (light grey/green).
File: scalingfactors_20220413\eval\Gotaalv\evalAlv_Gotaalv_4169.png.

Align models



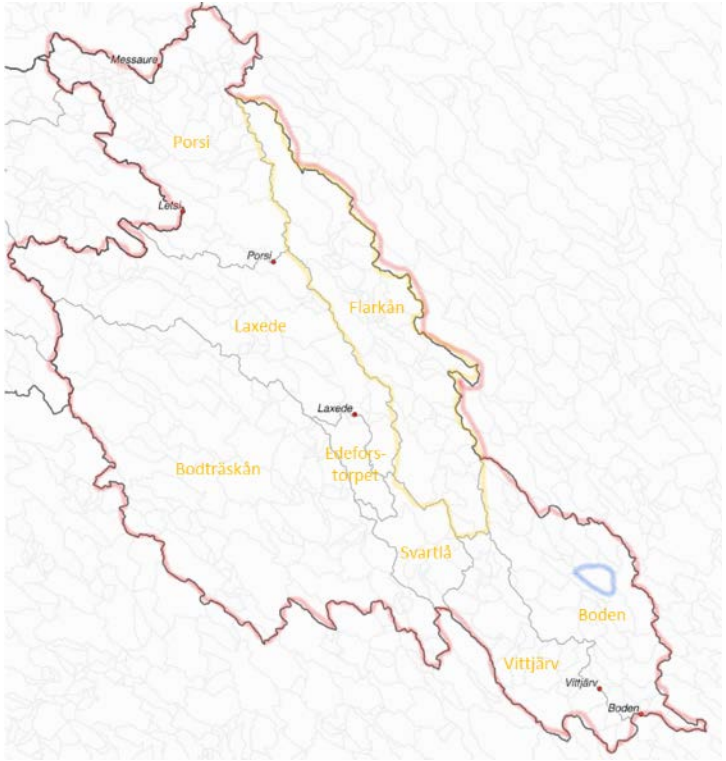
→ Guarantee a common description of the hydropower system in both

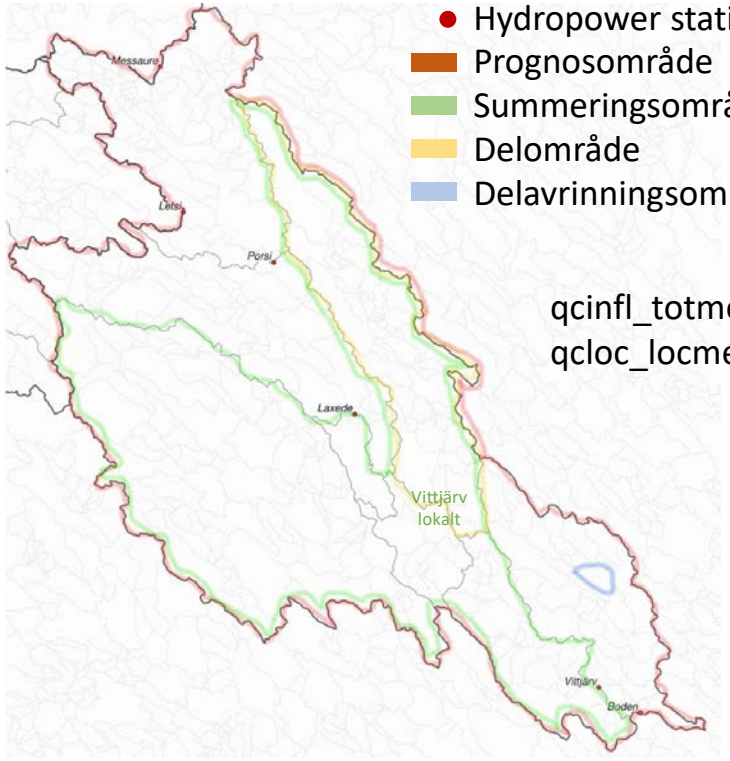
Hydrology | Hydropower

- Dam
- Power station
- Subcatchment
- Example for subcatchment

Map based on OpenStreetMap and SVAR/SMHI.

Some fun with ”details”





- Hydropower station
- Prognosområde
- Summeringsområde
- Delområde

} HBV

- Delavrinningsområde — S-HYPE

qcinfl_totmean (total inflow)
qcloc_locmean (local inflow)

Maps from https://hyfo.smhi.se/.

Legal rules on water regulation

Type	Luleälven	Skellefteälve	Umeälven	Ångermanäl	Indalsälven	Ljungan	Ljusnan	Dalälven	Göta älv	Lagan	Summa
WaterLevel	30	29	30	112	524	32	120	7	106	376	**1366**
MinSpill	0	27	15	28	48	30	28	13	0	0	**189**
MinFlow	4	14	5	7	40	2	4	9	0	5	**90**
MaxChangeWeek	2	0	0	16	10	0	0	0	0	0	**28**
MaxChangeDay	2	0	0	15	9	0	0	0	0	0	**26**
LevelAboveRamp	0	0	7	0	0	0	0	0	0	0	**7**
LevelBelowRamp	0	0	7	0	0	0	0	0	0	0	**7**
DailyLevelChangeLimit	0	0	0	0	0	5	0	0	0	0	**5**
SpillChangeTimeInterval	0	0	0	0	0	3	0	0	0	0	**3**
MinDailyFlow	0	0	0	0	0	1	0	0	1	0	**2**
WeeklyLevelChangeLimit	0	0	0	0	0	2	0	0	0	0	**2**
DailyLevelChangeLimitMean	0	0	0	0	0	0	0	1	0	0	**1**
HQ	0	0	0	0	0	1	0	0	0	0	**1**
MaxFlowTwoSegments	0	0	0	0	0	0	0	1	0	0	**1**
MaxSpill_ResLevel	0	0	0	0	0	1	0	0	0	0	**1**
MaxSpillChange_Day	0	1	0	0	0	0	0	0	0	0	**1**
MinWeeklyFlow	0	0	0	0	0	1	0	0	0	0	**1**
MovingMinWeeklyFlow	0	0	0	0	0	1	0	0	0	0	**1**
Spill_ResLevel	1	0	0	0	0	0	0	0	0	0	**1**
WeeklyLevelChangeLimitMean	0	0	0	0	0	0	0	1	0	0	**1**

Spine → VATTENFALL HydroProdPlan

Table shows overview on water regulation rules as found in the river system files as of October 2022.

What is a suitable historic year?

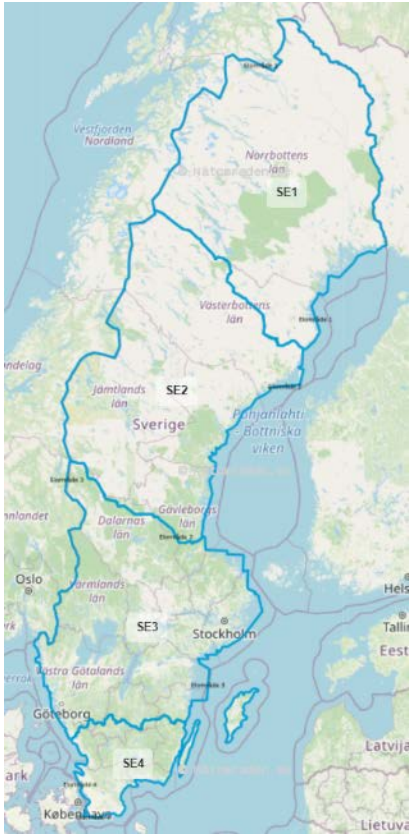
Limited calculation
capacity and brainpower ☺

Energysystem

Suitable for…
- …Sweden as a whole?
- …per bidding area?
- …for each river system?

Based on…
- …yearly values?
- …daily values?
- …visible patterns?

1991-1992



Map: Svk/OpenStreetMap.

What is a suitable historic year?

Limited calculation capacity and brainpower ☺

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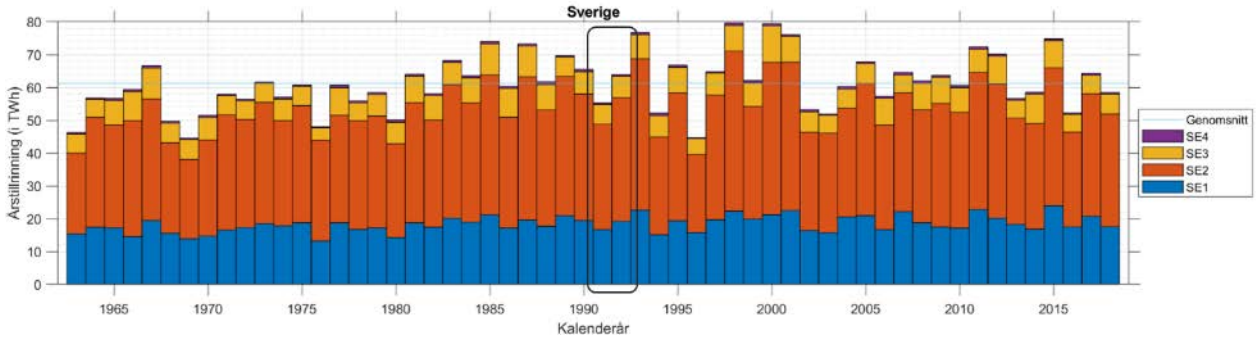

Figure shows local inflows per bidding area. The average yearly inflow (light blue line) is calculated for 1963-2018.
File: Årstillrinningar översikt.png.

What is a suitable historic year?

Limited calculation capacity and brainpower ☺

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- …per **bidding area**?
- …for each river system?

Based on…

- …**yearly** values?
- …daily values?
- …visible patterns?

1991-1992

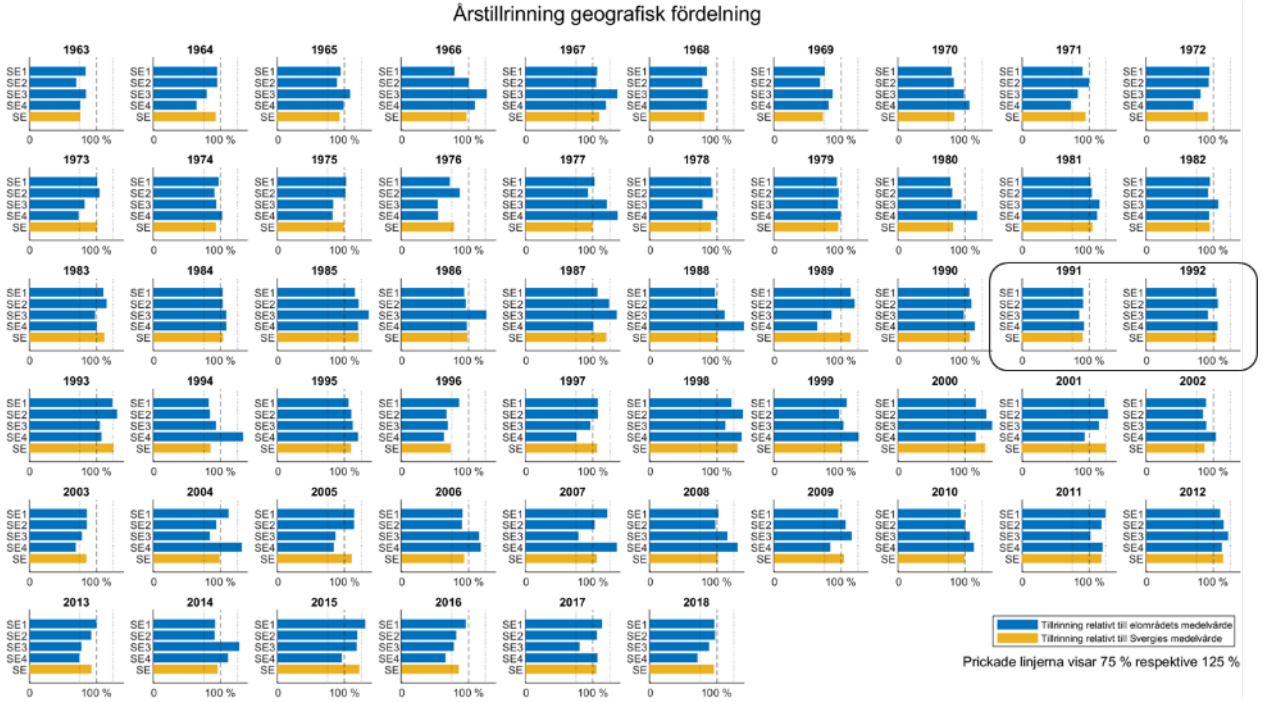

Figure shows local inflows per bidding area. The average yearly inflow (dashed line) is calculated for 1963-2018. 75 % and 125 % percentiles (dotted lines). File: Årstillrinning geografisk fördelning.png.

What is a suitable historic year?

Limited calculation capacity and brainpower ☺

Energysystem

Suitable for…
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- …per bidding area?
- …for each **river system**?

Based on…
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1991-1992

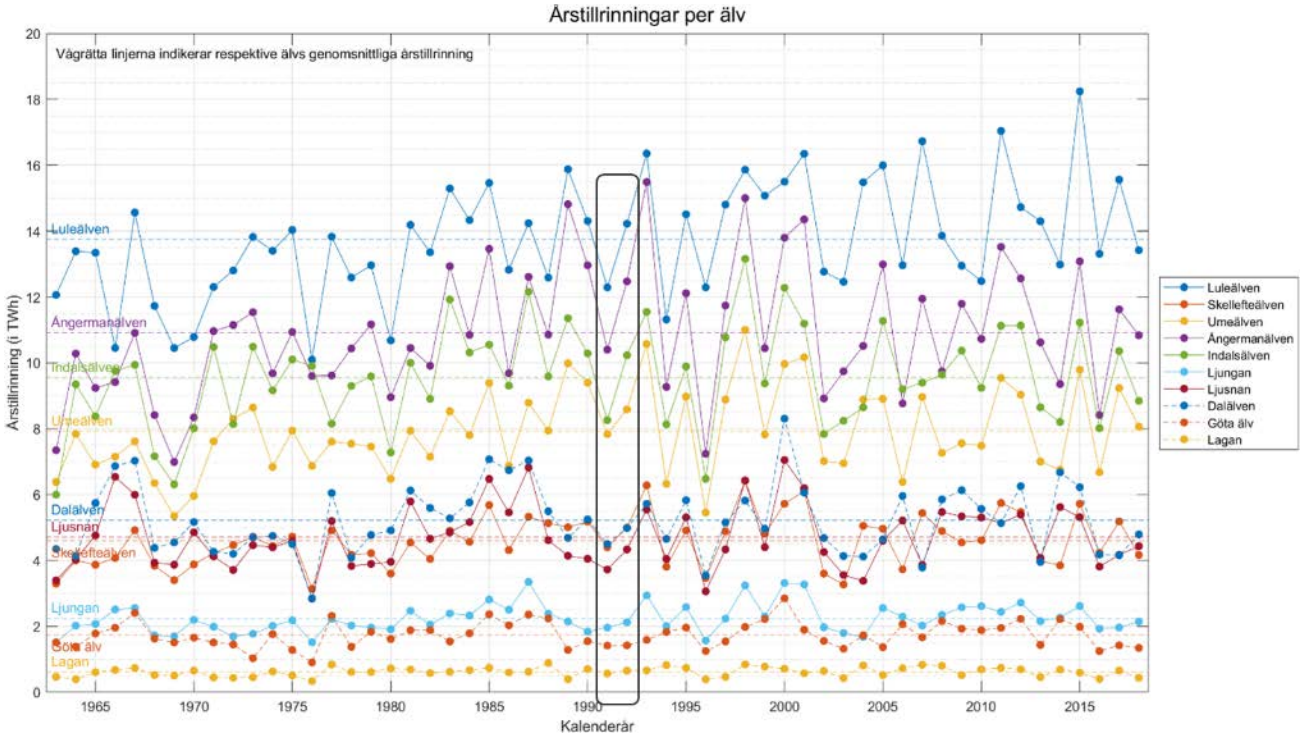

Figure shows local inflows per river system. The average yearly inflows (dashed line) are calculated for 1963-2018.
File: Årstillrinningar per älv.png.

What is a suitable historic year?

Limited calculation capacity and brainpower ☺

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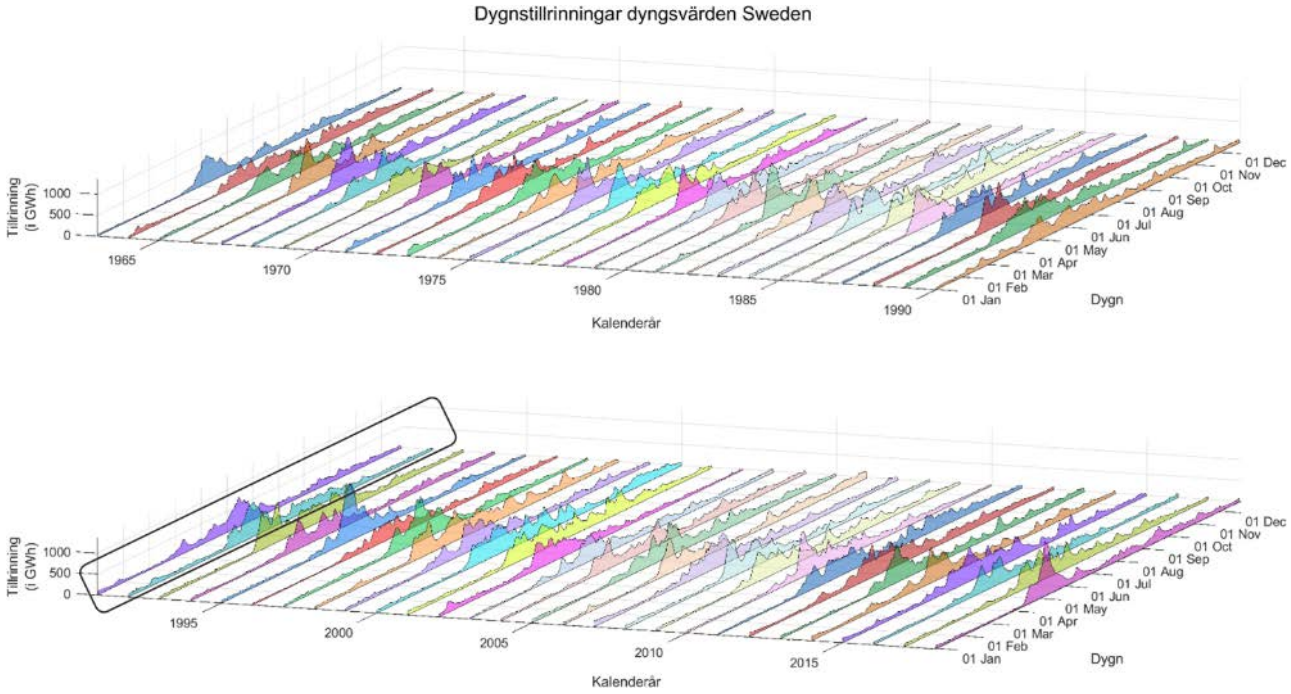


1991-1992

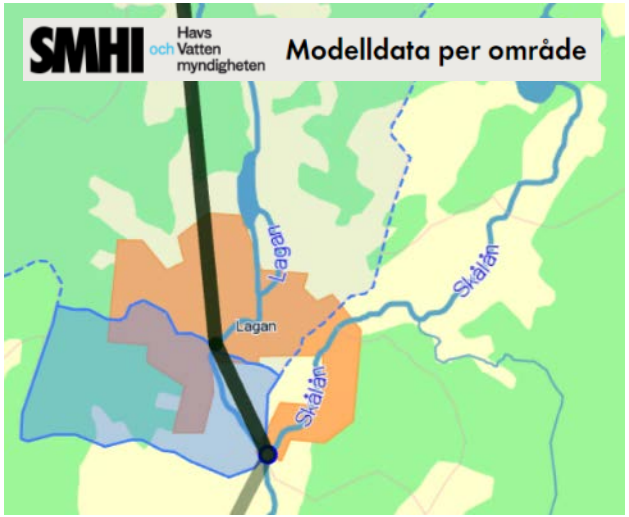
Figure shows the daily sum of all local inflows for the ten river systems we worked with in KLIVA. Propagation times assumed to be zero.
File: Dygnstillrinningar dyngsvärden Sweden.png.

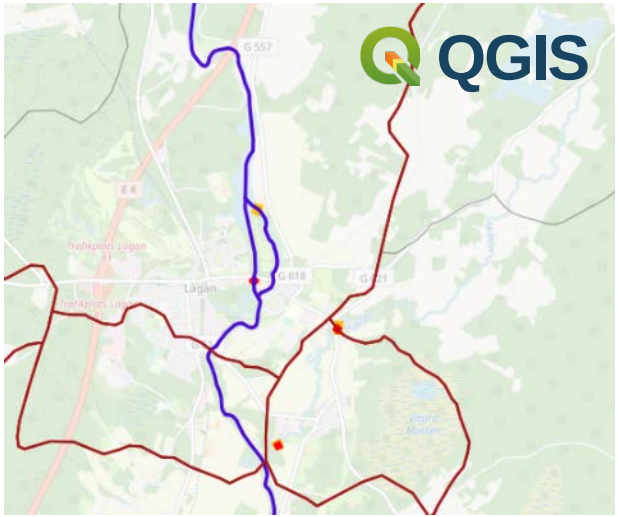
What about **suggestions for improvement**?

Vattenwebb I

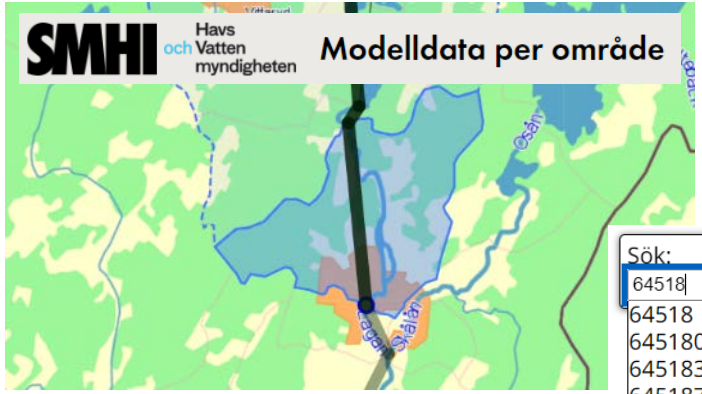
On http://vattenwebb.smhi.se/modelarea/:

- Improve backgound map, e.g. with OpenStreetMap



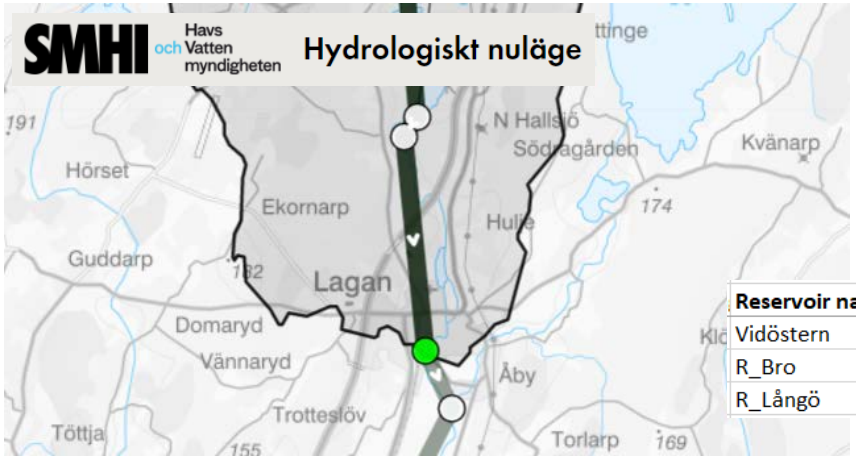


Vattenwebb II



On http://vattenwebb.smhi.se/modelarea/:

- Allow parameters in URL to show subcatchment, e.g. as in ”Hydrologiskt nuläge”



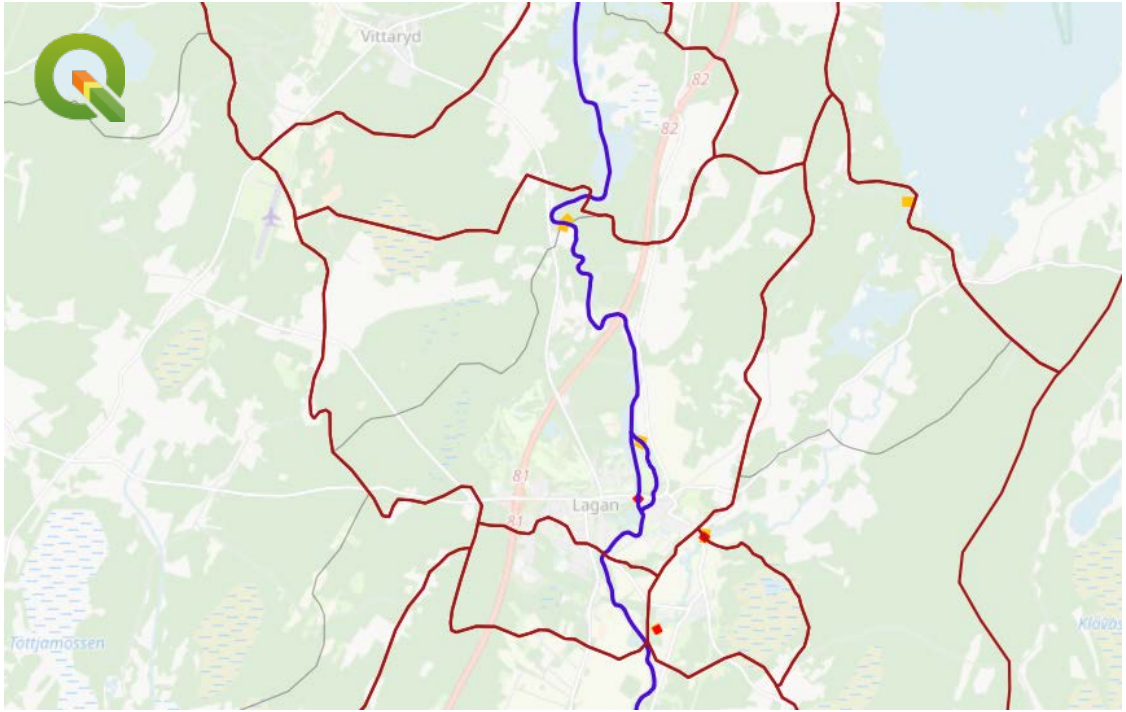
https://vattenwebb.smhi.se/hydronu/#%7B%22version%22:2,%22poi%22:64518,%22map%22:%7B%22center%22:%5B56.9245508,13.9988953%5D,%22zoom%22:6%7D,%22chartSubid%22:64518,%22showYear%22:false%7D

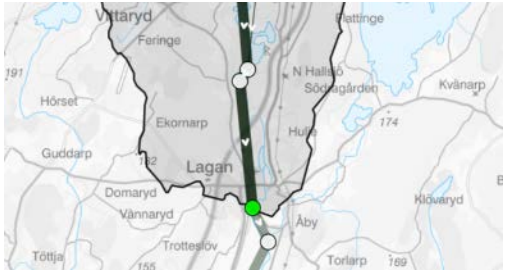
Reservoir name Energiföretagen	AROID	SUBID	KLIVA	Climate fa	Map catch
Vidöstern	631123-436360	64500	Yes	-	64500
R_Bro	631021-438711	64518	Yes	-	64518
R_Långö	635126-141576	2059	Yes	-	2059

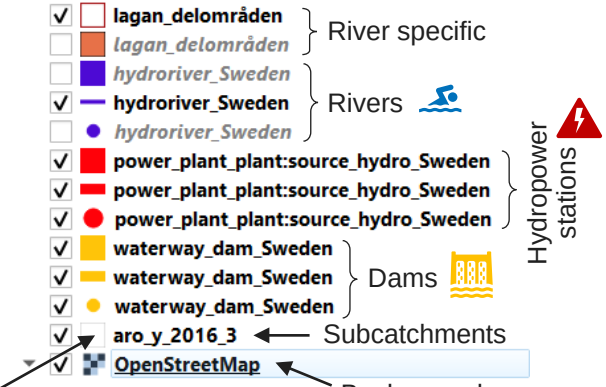
=HYPERLÄNK(SAMMANFOGA(…))

Just dreaming…

Reservoir name Energiföretagen	AROID	SUBID	KLIVA	Climate fa	Map catch
Vidöstern	631123-436360	64500	Yes	-	64500
R_Bro	631021-438711	64518	Yes	-	64518
R_Långö	635126-141576	2059	Yes	-	2059



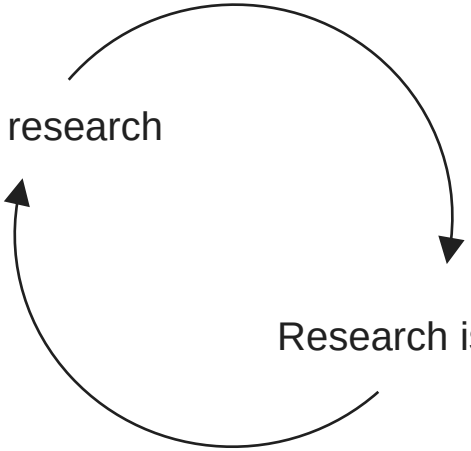




Wish: Include SUBID, not only AROID

Keep data accessible

Data is of high value for research



Research is of high value for **industry and society** ☺

”Extreme” weather events

”Extreme” weather events are *not* captured by our method!

Spahotell översvämmat – gästerna åker kanot till frukosten

1:26 min · 2022-08-23

eurelectric

7 Dec, 15-16:30
Online

Pictures: https://sverigesradio.se/artikel/hockeyprofilen-emma-i-gavle-ishallen-ar-mer-som-ett-badhus, https://sverigesradio.se/artikel/spahotell-oversvammat-gasterna-aker-kanot-till-frukosten and https://www.eurelectric.org/events/the-coming-storm-building-electricity-resilience-to-extreme-weather/

Thanks!

Want to discuss more? → Dissimination webinar **8 February**, 8-12, in Swedish
Coming soon https://energiforsk.se/konferenser/kommande/

KLIVA home page: https://energiforsk.se/program/klimatforandringarnas-inverkan-pa-vattenkraften/

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