Snabb beräkning av avbördningskurvor med RUHM-modellen och drönare

Ida Westerberg, Valentin Mansanarez, Reinert Huseby Karlsen, Norris Lam and Steve Lyon

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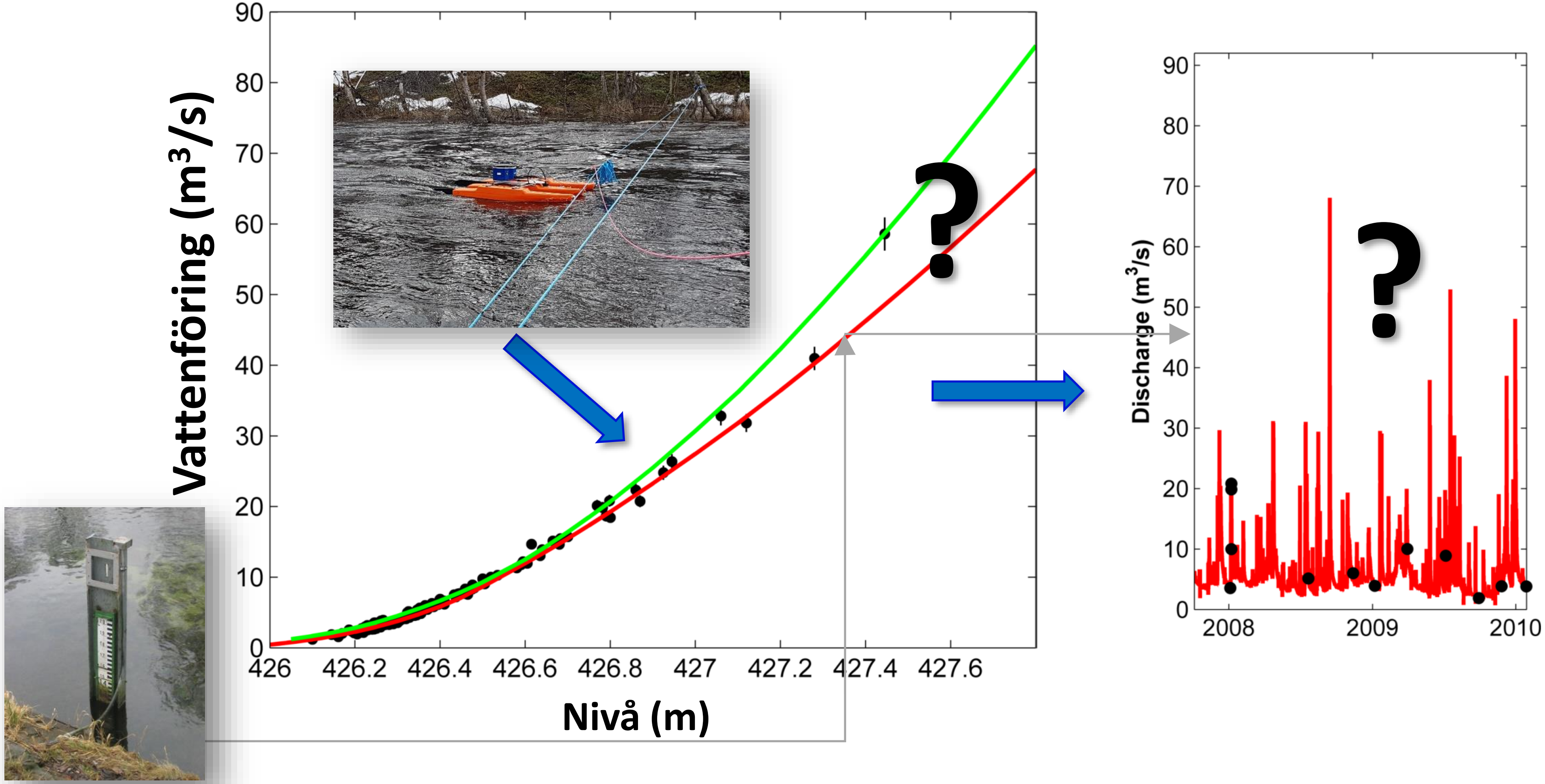
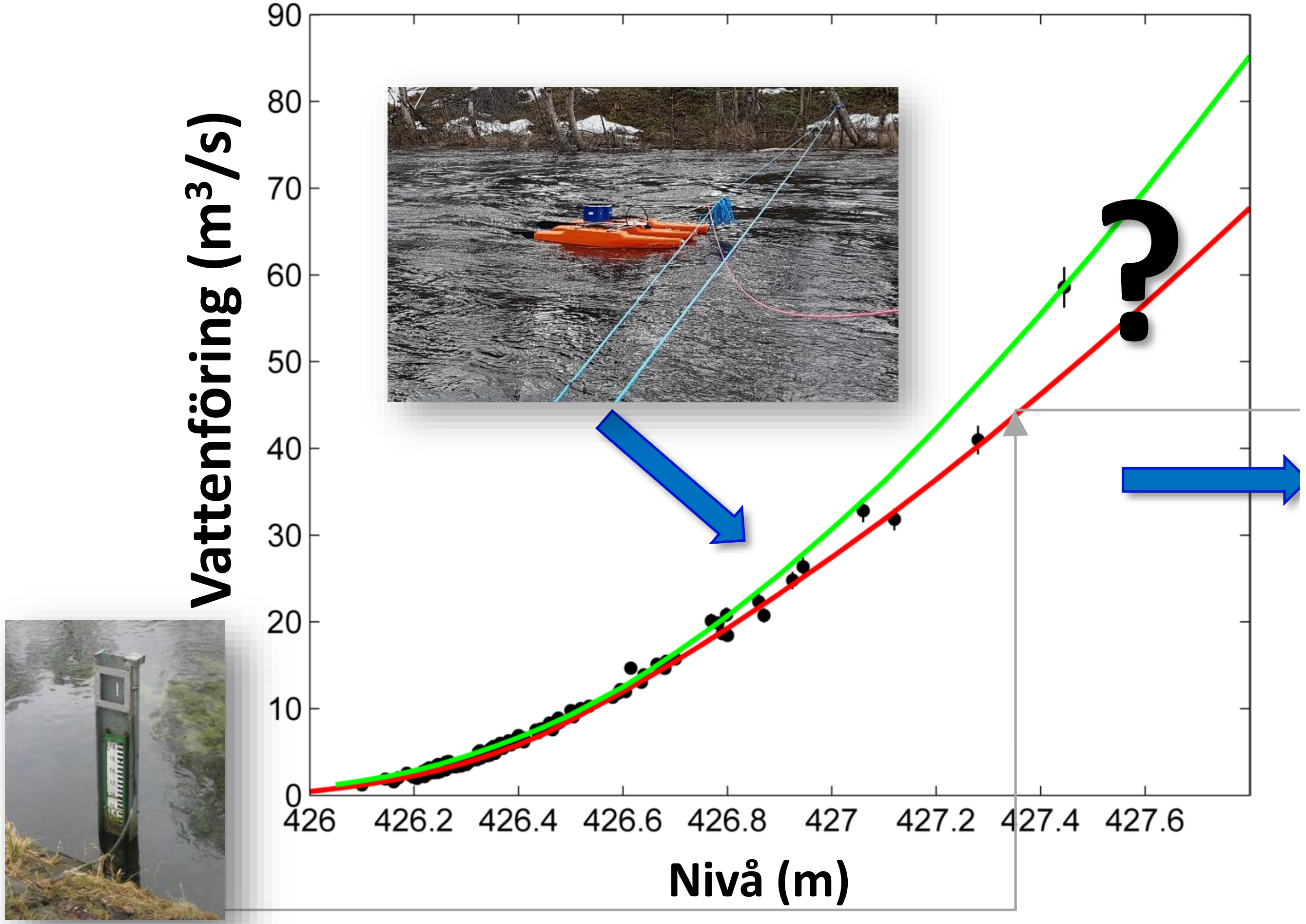
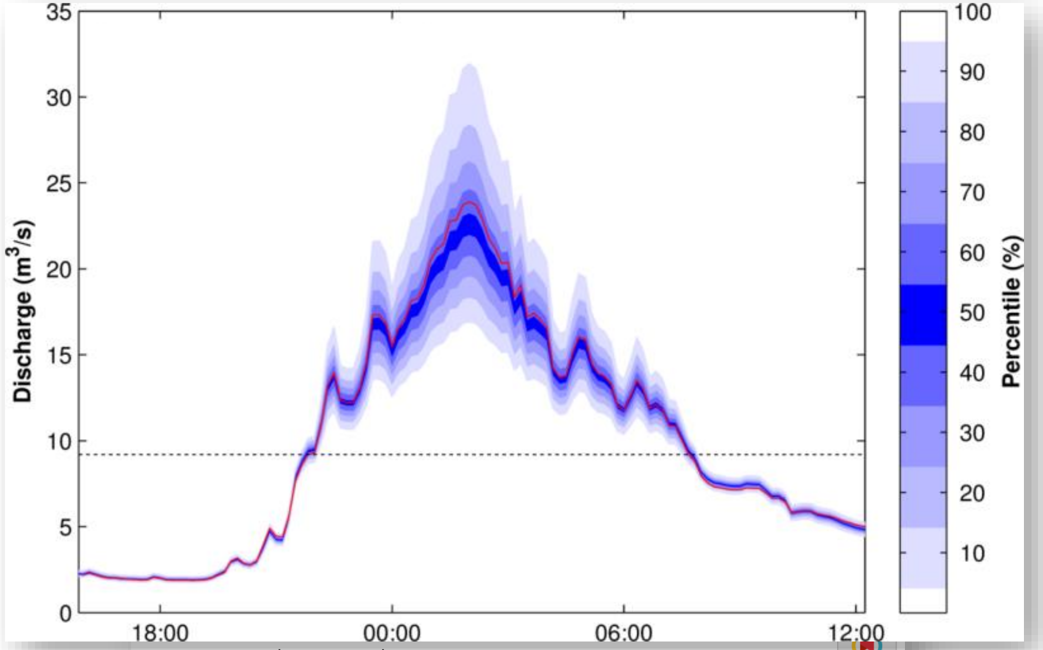
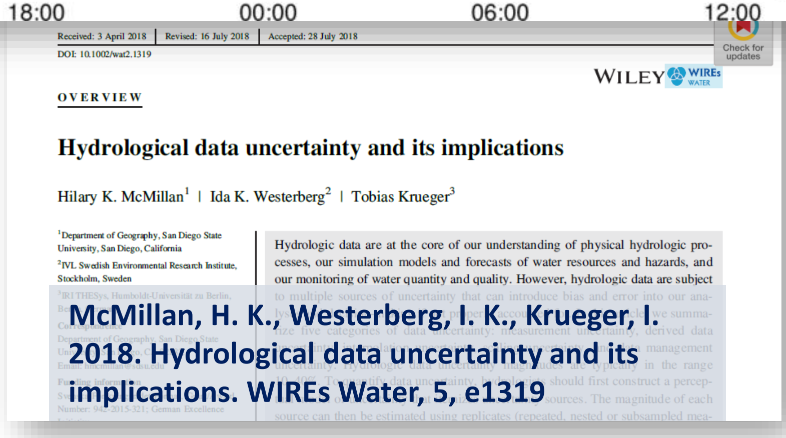
Vattenföringsmätning och avbördningskurvor



Vattenföringsmätning och avbördningskurvor







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WILEY WIREs WATER

OVERVIEW

Hydrological data uncertainty and its implications

Hilary K. McMillan[1] | Ida K. Westerberg[2] | Tobias Krueger[3]

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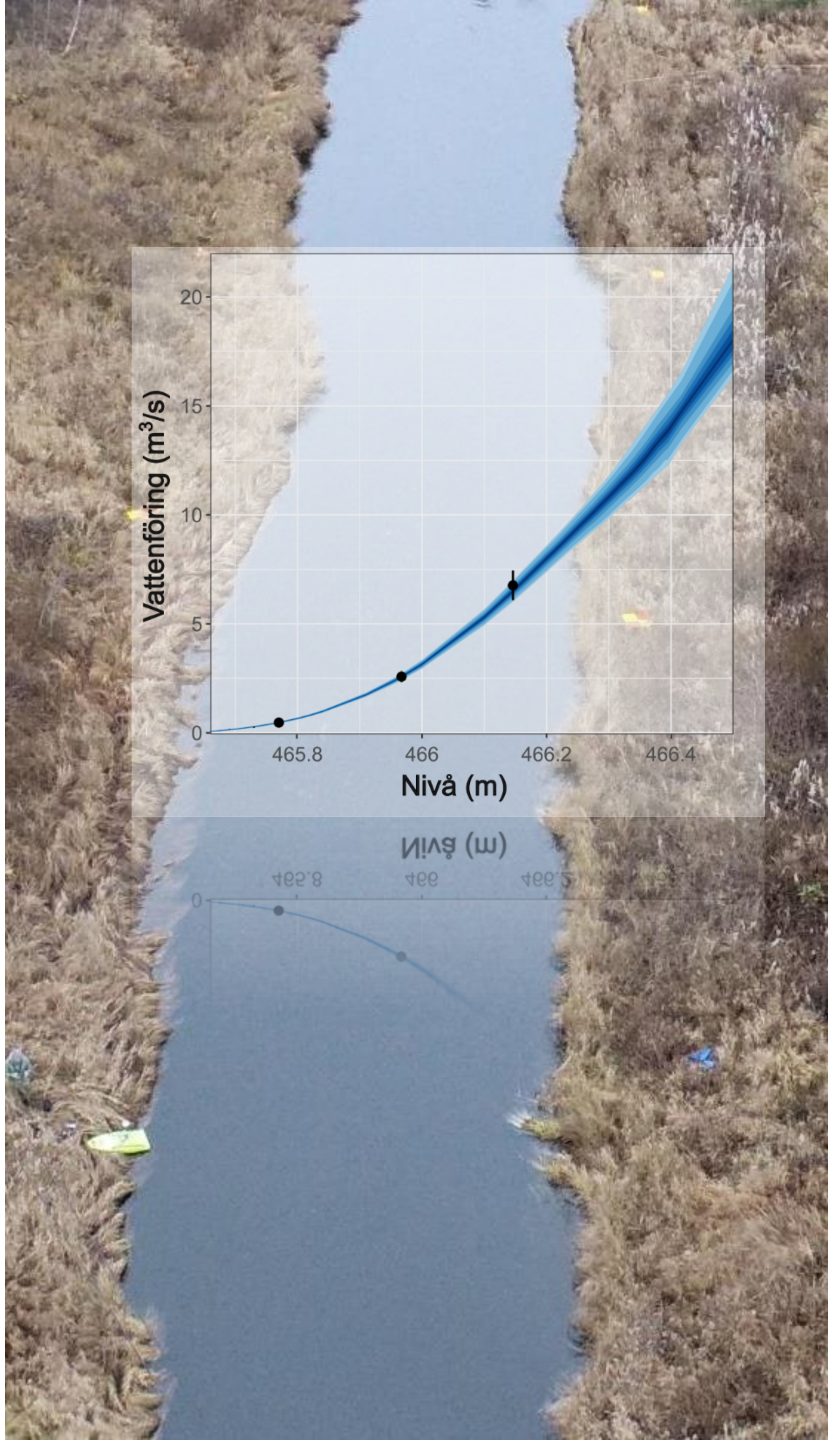
[2]IVL Swedish Environmental Research Institute, Stockholm, Sweden

Hydrologic data are at the core of our understanding of physical hydrologic processes, our simulation models and forecasts of water resources and hazards, and our monitoring of water quantity and quality. However, hydrologic data are subject

McMillan, H. K., Westerberg, I. K., Krueger, I. 2018. Hydrological data uncertainty and its implications. WIREs Water, 5, e1319

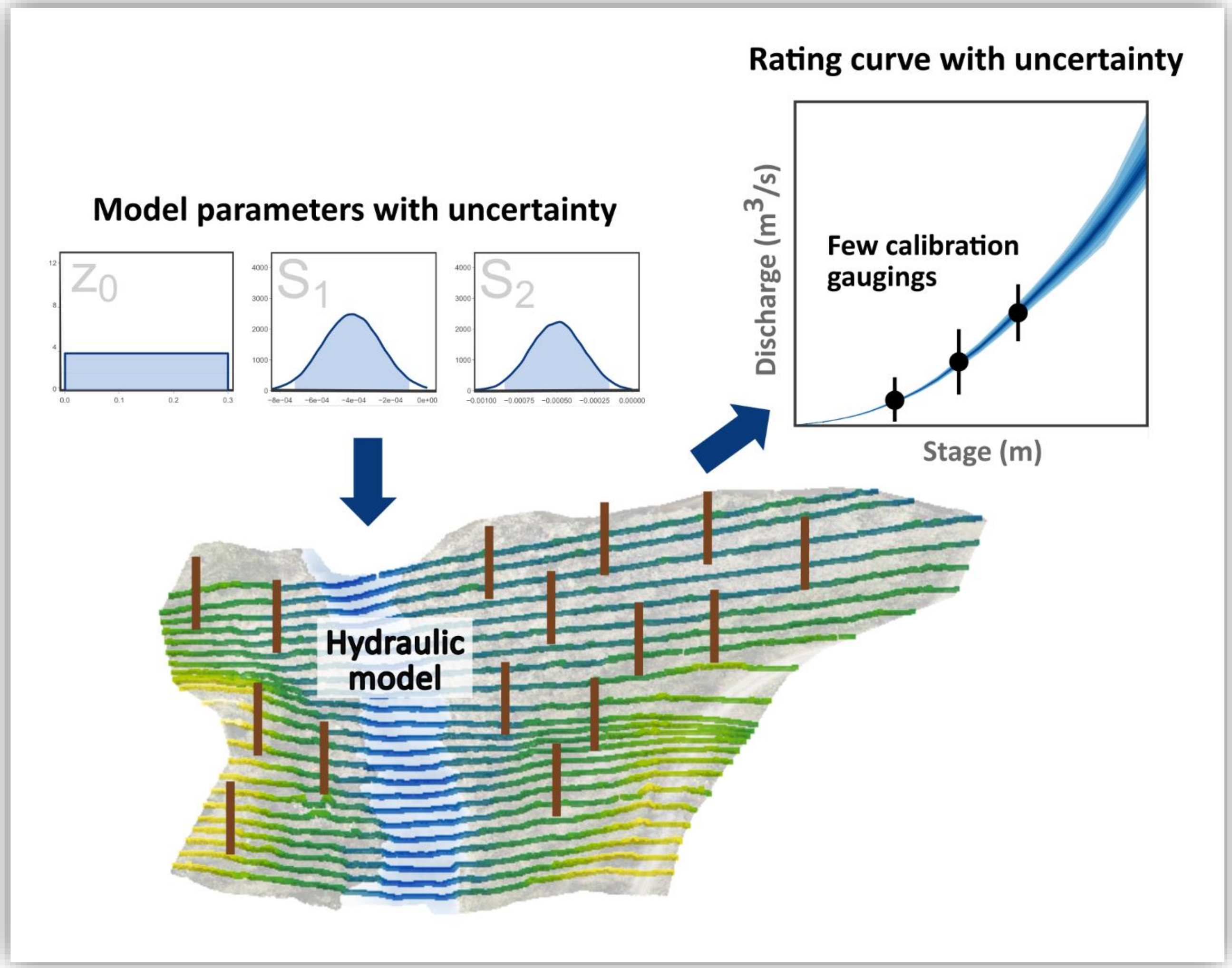
Vad är RUHM-modellen?

Verktyg för att snabbt beräkna avbördningskurvor och deras osäkerhet med få (3+) fältmätningar



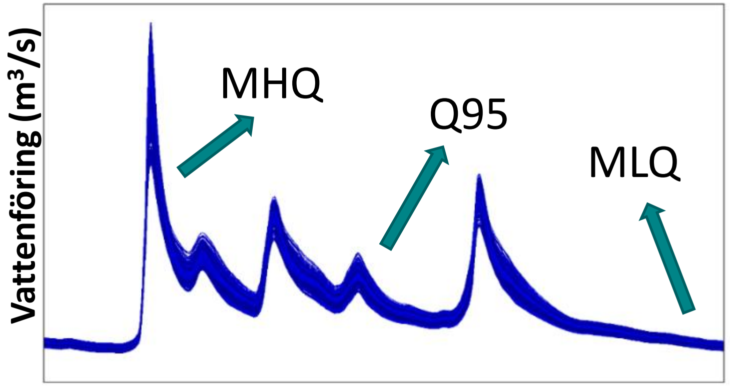
RUHM (Rating curve Uncertainty Estimation using Hydraulic Modeling)

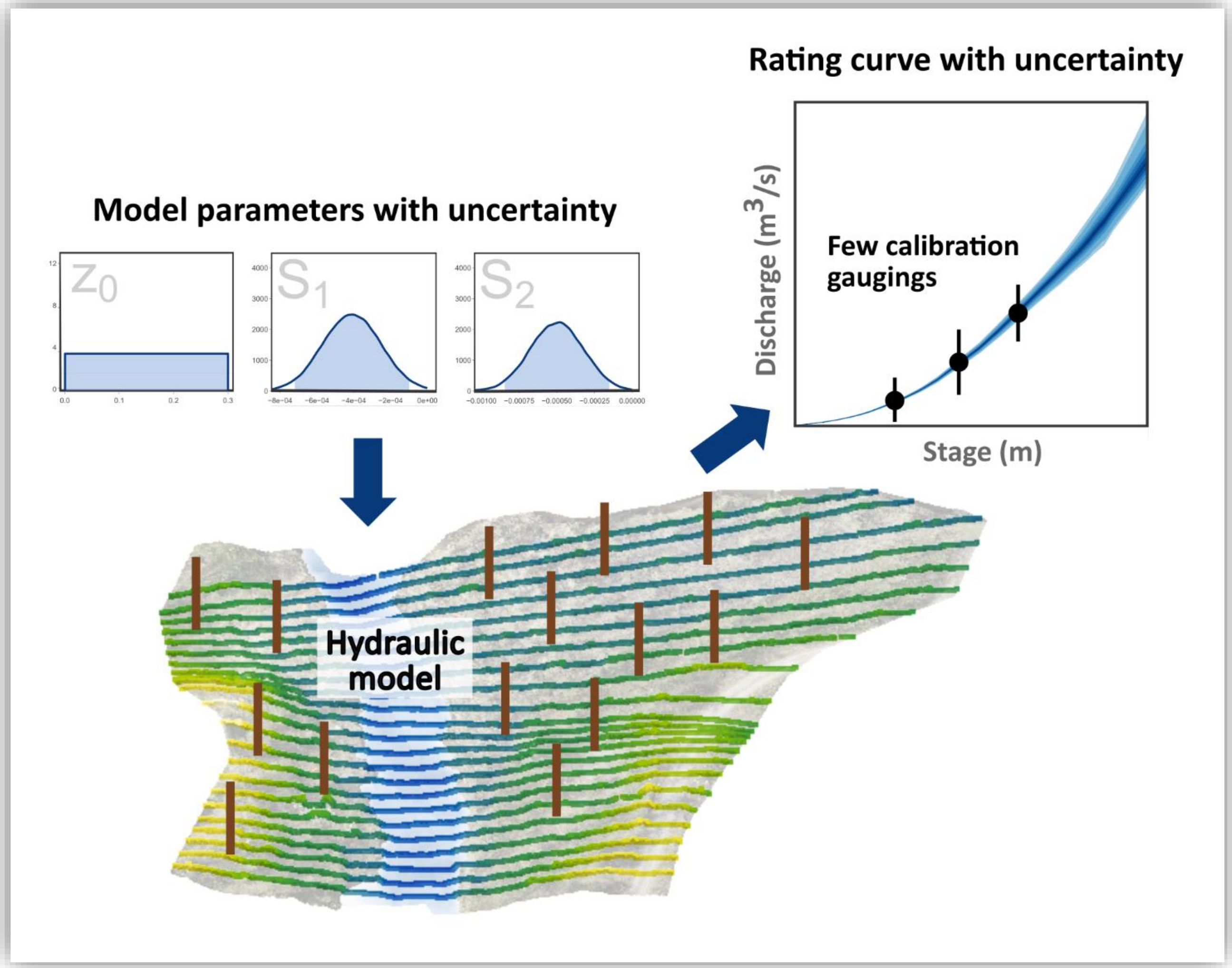
- 1D hydraulisk modell + Bayesiansk statistisk osäkerhetsanalys



RUHM (Rating curve Uncertainty Estimation using Hydraulic Modeling)

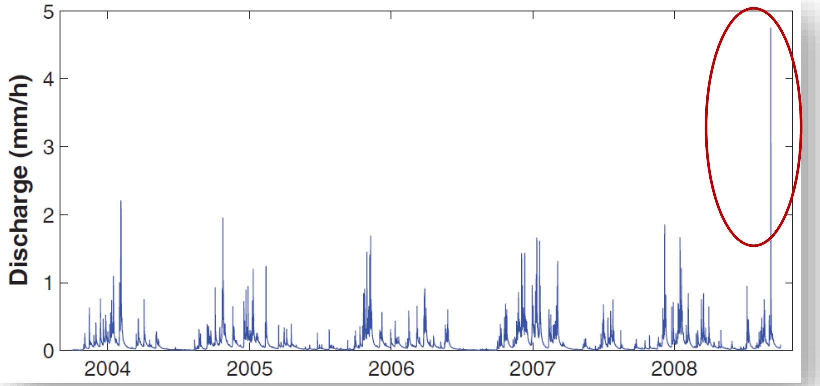
- Avbördningskurva med osäkerhetsskattning
- Osäkerheten kan fortplantas till vattenföringsdata och statistiska mått (MQ, HQ, Q95, etc.)

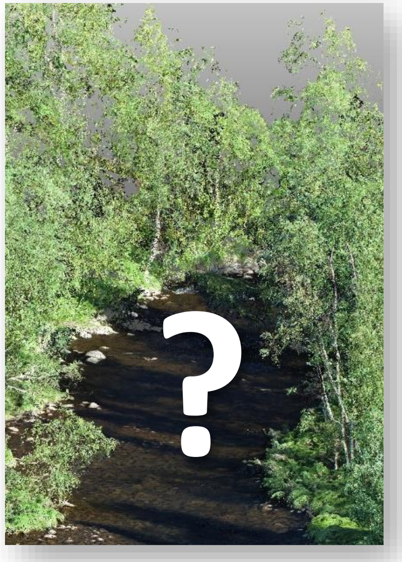


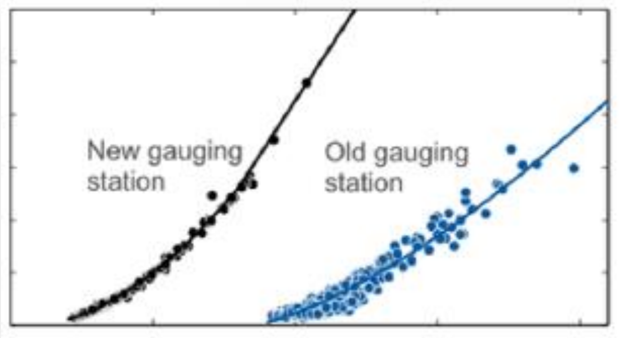


Varför RUHM?

- Snabbare få bra vattenföringsdata
  - ➢ För svårmätta och sällsynta extrema flöden
  - ➢ För nya mätstationer
  - ➢ För stationer med förändrade förhållanden
- Spara tid och resurser för fältmätningar

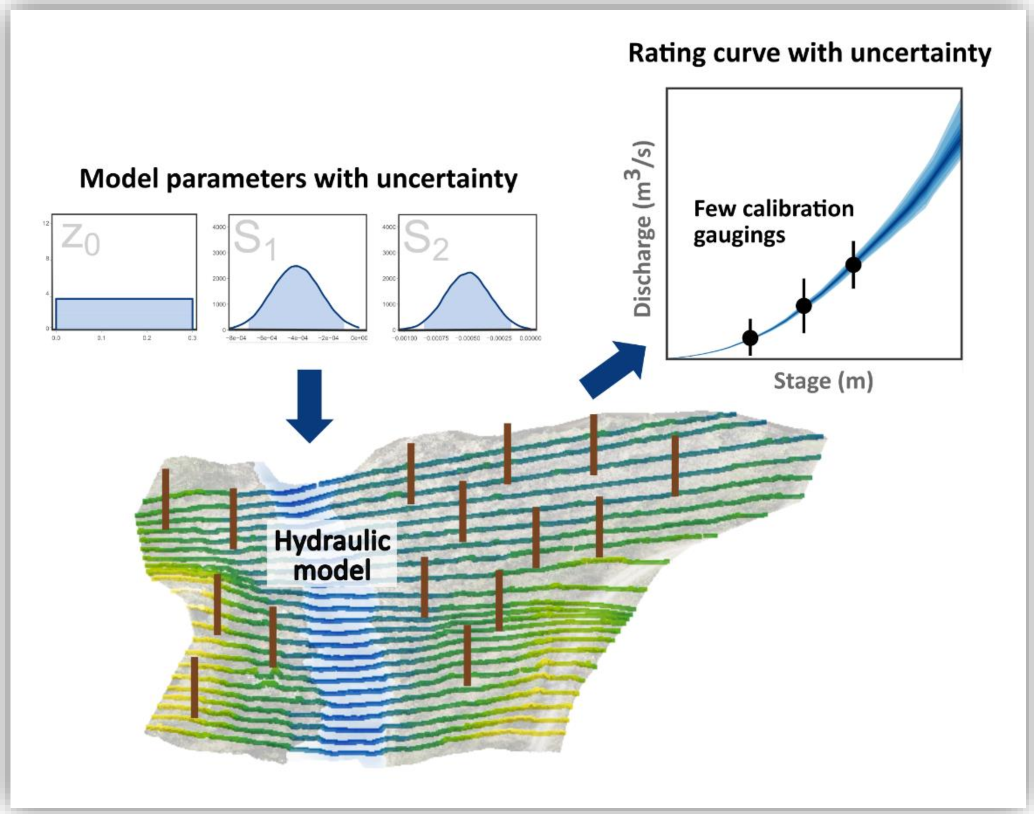






RUHM (Rating curve Uncertainty Estimation using Hydraulic Modeling)

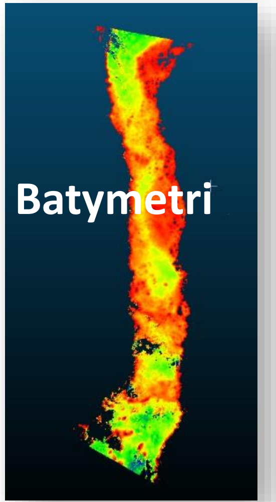
- Indata:
  1. **Höjdmodell: topografi + batymetri**
  2. **(X,Y) plats för avbördningskurvan + nivåintervall**
  3. **3+ inmätningar av vattenytans lutning** vid olika nivå
  4. **3+ nivå–vattenföring kalibreringsdata vid låg och medelflöden** – högflöden inte nödvändiga

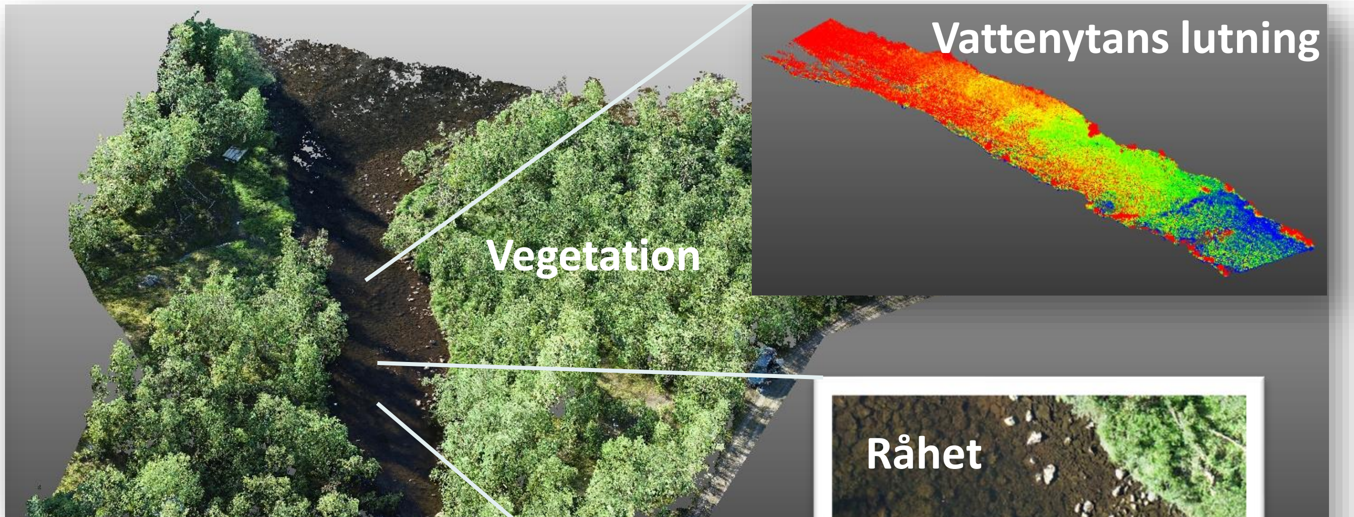


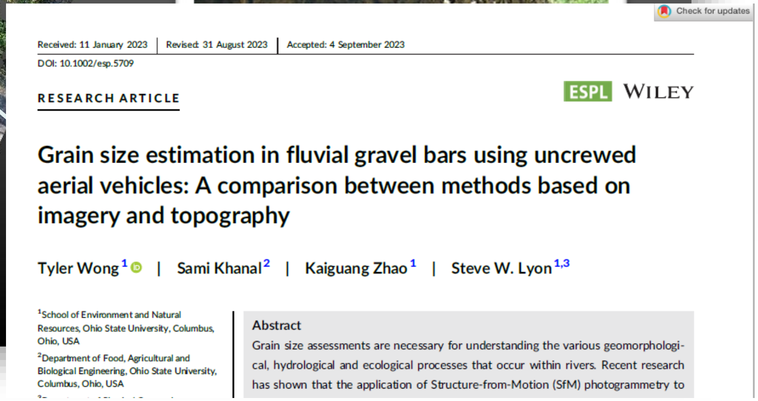
- Valfria indata:
  5. **Vegetationskartering**
  6. **Kornstorlekskartering**

All data kan samlas in med drönare

- Punktmoln från kamera eller lidardrönare (indata)
- Ytvattenhastighet från drönarvideo (kalibrering)







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DOI: 10.1002/esp.5709

RESEARCH ARTICLE

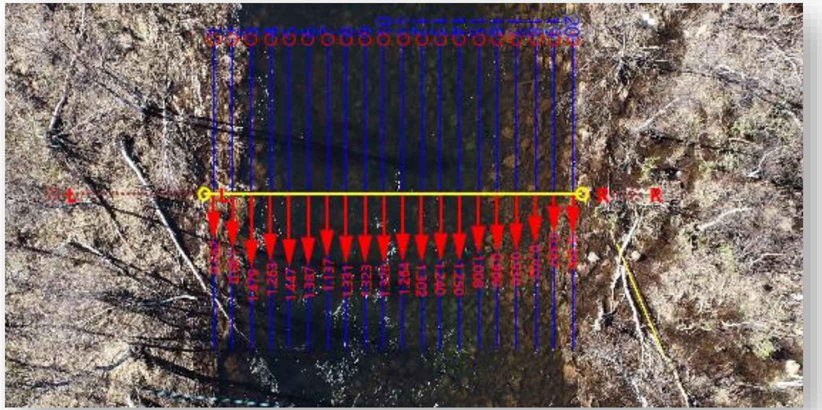
ESPL WILEY

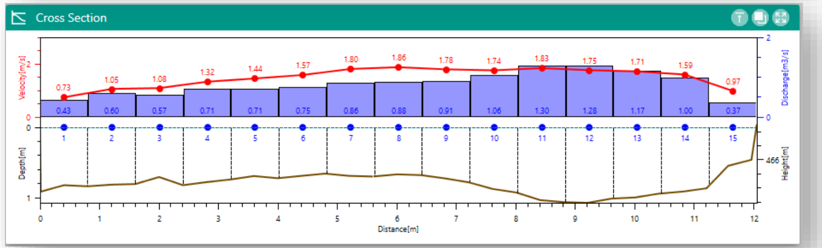
Grain size estimation in fluvial gravel bars using uncrewed aerial vehicles: A comparison between methods based on imagery and topography

Tyler Wong[1] | Sami Khanal[2] | Kaiguang Zhao[1] | Steve W. Lyon[1,3]

[1]School of Environment and Natural Resources, Ohio State University, Columbus, Ohio, USA
[2]Department of Food, Agricultural and Biological Engineering, Ohio State University, Columbus, Ohio, USA

Abstract
Grain size assessments are necessary for understanding the various geomorphological, hydrological and ecological processes that occur within rivers. Recent research has shown that the application of Structure-from-Motion (SfM) photogrammetry to

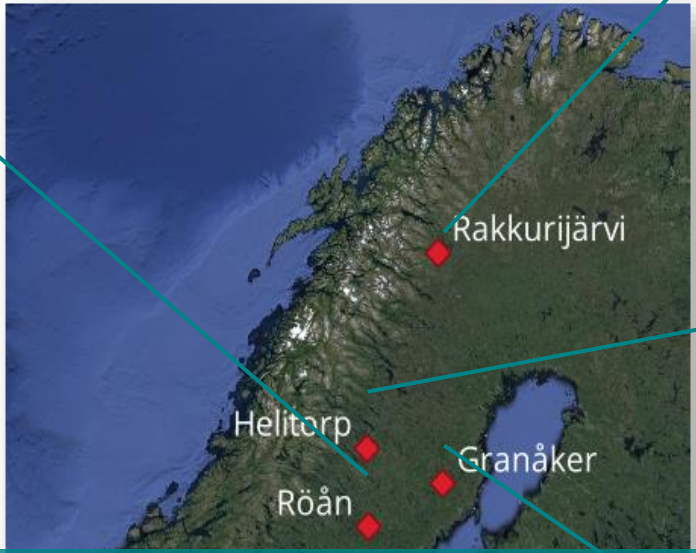




Tillämpningar med drönare

Röån 584 km², 0.6-26 m³/s

Ersbo 1103 km², 3-500 m³/s



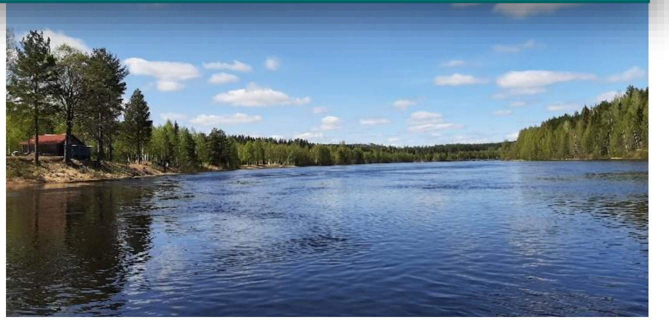
Insamlade data

- **Drönare:** Punktmoln med fotogrammetri/lidar, ytvattenhastighetsvideo
- **RTK-GNSS:** vattenytans lutning
- **ADCP med RTK-GNSS:** Vattenföring, batymetri
- **Kornstorlekskartering:** Råhet
- **Vegetationskartering:** Råhet

Rakkurijärvi 96 km², 0.1-17 m³/s

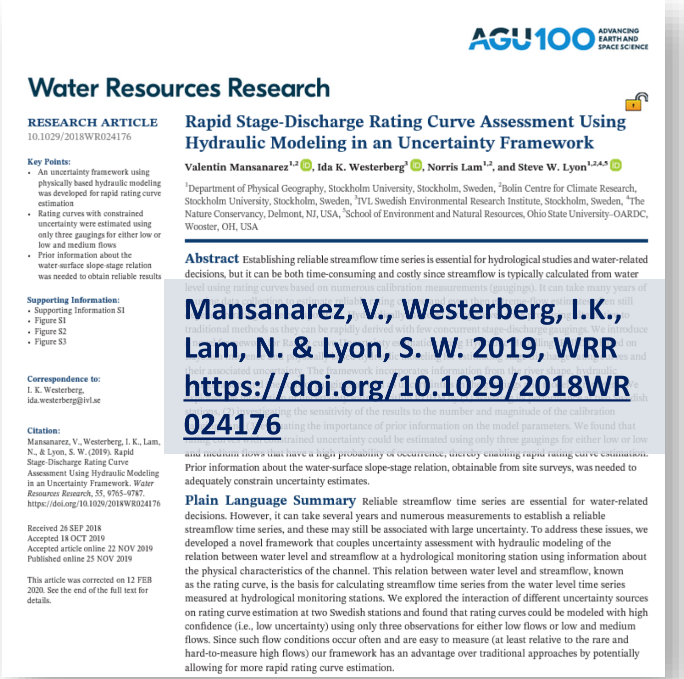
Helitorp, 2253 km², 0-350 m³/s

Granåker, 11846 km², 17-1800 m³/s



Bakgrund: Snabb beräkning av avbördningskurvor med RUHM-modellen och drönare

- **Utveckling av RUHM** (Formas- och Vinnovaprojekt)
- **Nyttiggörandeprojekt 2023–2026** (finansierat av Formas) **”Från satellit och drönare till vattenföringsdata för hållbar vattenhushållning”**
- **IVL, SMHI, VRF och VDM**
- **Två verktyg som publiceras *Open Access*:**
  - **RUHM** – snabbt beräkna avbördningskurvor och deras osäkerheter med drönardata och hydraulisk modellering
  - **Sat2Q** – samla in satellitdata för beräkning av avbördningskurvor och vattenföringsdata


Water Resources Research

RESEARCH ARTICLE
10.1029/2018WR024176

Rapid Stage-Discharge Rating Curve Assessment Using Hydraulic Modeling in an Uncertainty Framework

Valentin Mansanarez[1,2], Ida K. Westerberg[3], Norris Lam[1,2], and Steve W. Lyon[1,2,4,5]

[1]Department of Physical Geography, Stockholm University, Stockholm, Sweden, [2]Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden, [3]IVL Swedish Environmental Research Institute, Stockholm, Sweden, [4]The Nature Conservancy, Delmont, NJ, USA, [5]School of Environment and Natural Resources, Ohio State University–OARDC, Wooster, OH, USA

Key Points:
- An uncertainty framework using physically based hydraulic modeling was developed for rapid rating curve estimation
- Rating curves with constrained uncertainty were estimated using only three gaugings for either low or low and medium flows
- Prior information about the water-surface slope-stage relation was needed to obtain reliable results

Supporting Information:
- Supporting Information S1
- Figure S1
- Figure S2
- Figure S3

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Citation:
Mansanarez, V., Westerberg, I. K., Lam, N., & Lyon, S. W. (2019). Rapid Stage-Discharge Rating Curve Assessment Using Hydraulic Modeling in an Uncertainty Framework. *Water Resources Research*, 55, 9765–9787. https://doi.org/10.1029/2018WR024176

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This article was corrected on 12 FEB 2020. See the end of the full text for details.

Abstract Establishing reliable streamflow time series is essential for hydrological studies and water-related decisions, but it can be both time-consuming and costly since streamflow is typically calculated from water level using rating curves based on numerous calibration measurements (gaugings). It can take many years of [illegible] traditional methods as they can be rapidly derived with few concurrent stage-discharge gaugings. We introduce [illegible] their associated uncertainty. The framework incorporates information from the river shape, hydraulic [illegible] stations, (2) investigating the sensitivity of the results to the number and magnitude of the calibration [illegible] the importance of prior information on the model parameters. We found that [illegible] rained uncertainty could be estimated using only three gaugings for either low or low and medium flows that have a high probability of occurrence, thereby enabling rapid rating curve estimation. Prior information about the water-surface slope-stage relation, obtainable from site surveys, was needed to adequately constrain uncertainty estimates.

Plain Language Summary Reliable streamflow time series are essential for water-related decisions. However, it can take several years and numerous measurements to establish a reliable streamflow time series, and these may still be associated with large uncertainty. To address these issues, we developed a novel framework that couples uncertainty assessment with hydraulic modeling of the relation between water level and streamflow at a hydrological monitoring station using information about the physical characteristics of the channel. This relation between water level and streamflow, known as the rating curve, is the basis for calculating streamflow time series from the water level time series measured at hydrological monitoring stations. We explored the interaction of different uncertainty sources on rating curve estimation at two Swedish stations and found that rating curves could be modeled with high confidence (i.e., low uncertainty) using only three observations for either low flows or low and medium flows. Since such flow conditions occur often and are easy to measure (at least relative to the rare and hard-to-measure high flows) our framework has an advantage over traditional approaches by potentially allowing for more rapid rating curve estimation.

Mansanarez, V., Westerberg, I.K., Lam, N. & Lyon, S. W. 2019, WRR https://doi.org/10.1029/2018WR024176

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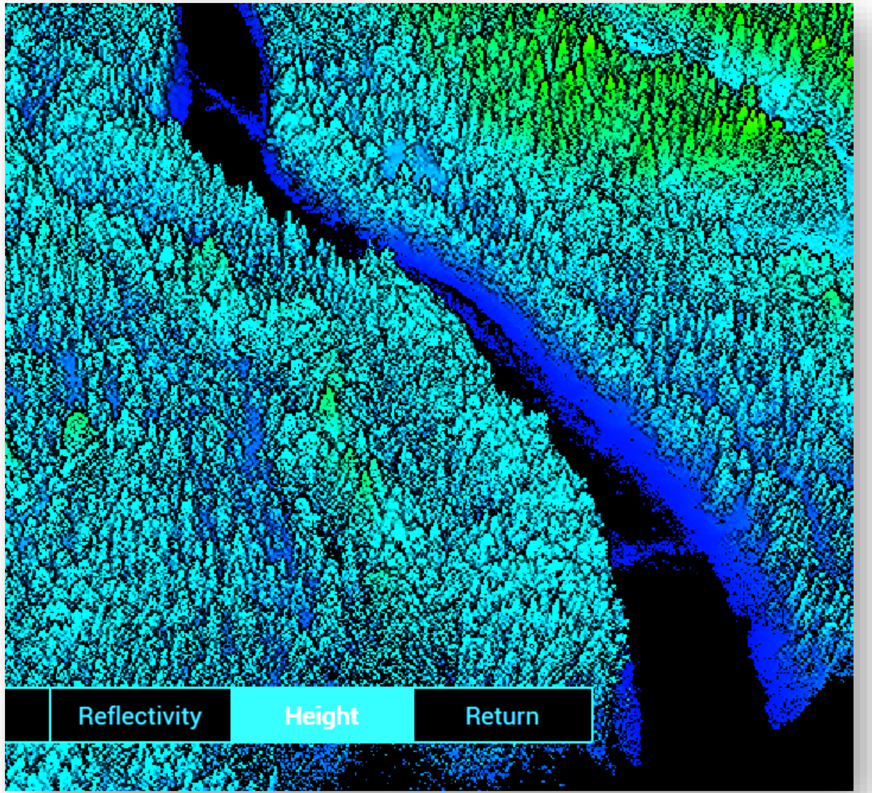
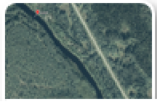
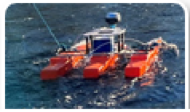
Open access version av RUHM, 2023-2026:

- Programmera om RUHM till mer användarvänlig mjukvara (Python)
- Arbetsflöden & verktyg för att processa drönarindata

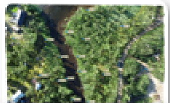




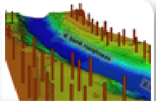
Preplanning
- Monitoring site choice
- RUHM: Field pre-planning



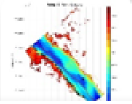
Data collection
- Satellites, drones and/or exisiting data
- RUHM: Field data collection



Data processing
- Drone and satellite data pre-processing
- Input data extraction



Hydraulic modelling (HM)
- Model set-up
- Sat2Q: baseline HM
- RUHM: detailed HM & uncertainty analysis



Results
- Rating curve results and uncertainties
- Streamflow time series generation

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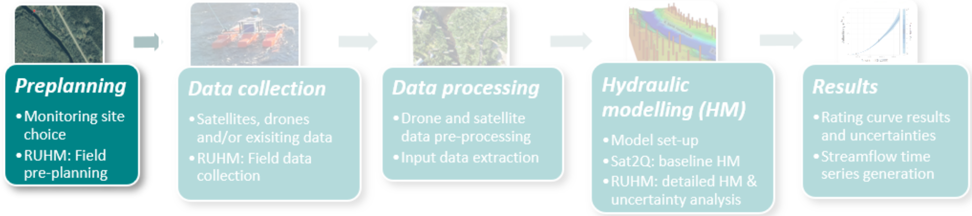
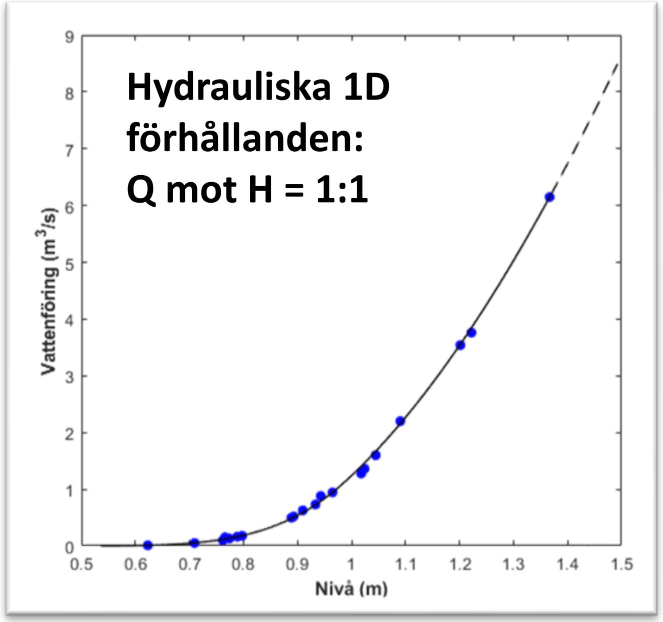
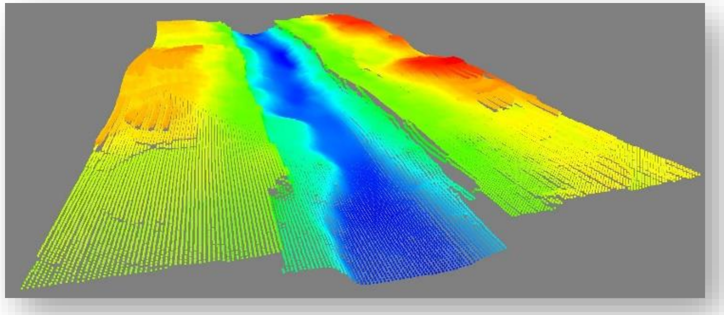


Val av mätplats & modellområde

- Rak strömfåra med längd > 5 gånger bredd
- Hydrauliska 1D förhållanden, Q mot H = 1:1.
- Liknande tvärsektionsgeometri och uniformt flöde längs modellområdet
- Inga ut- eller inflöden i modellområdet

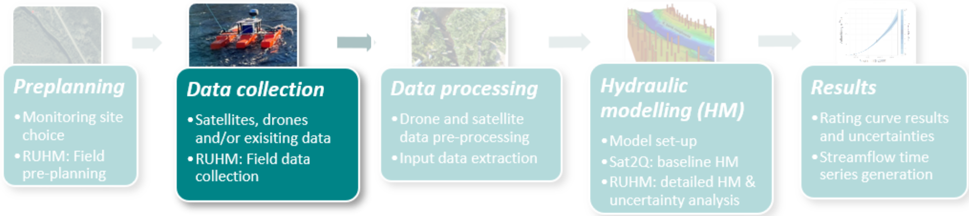


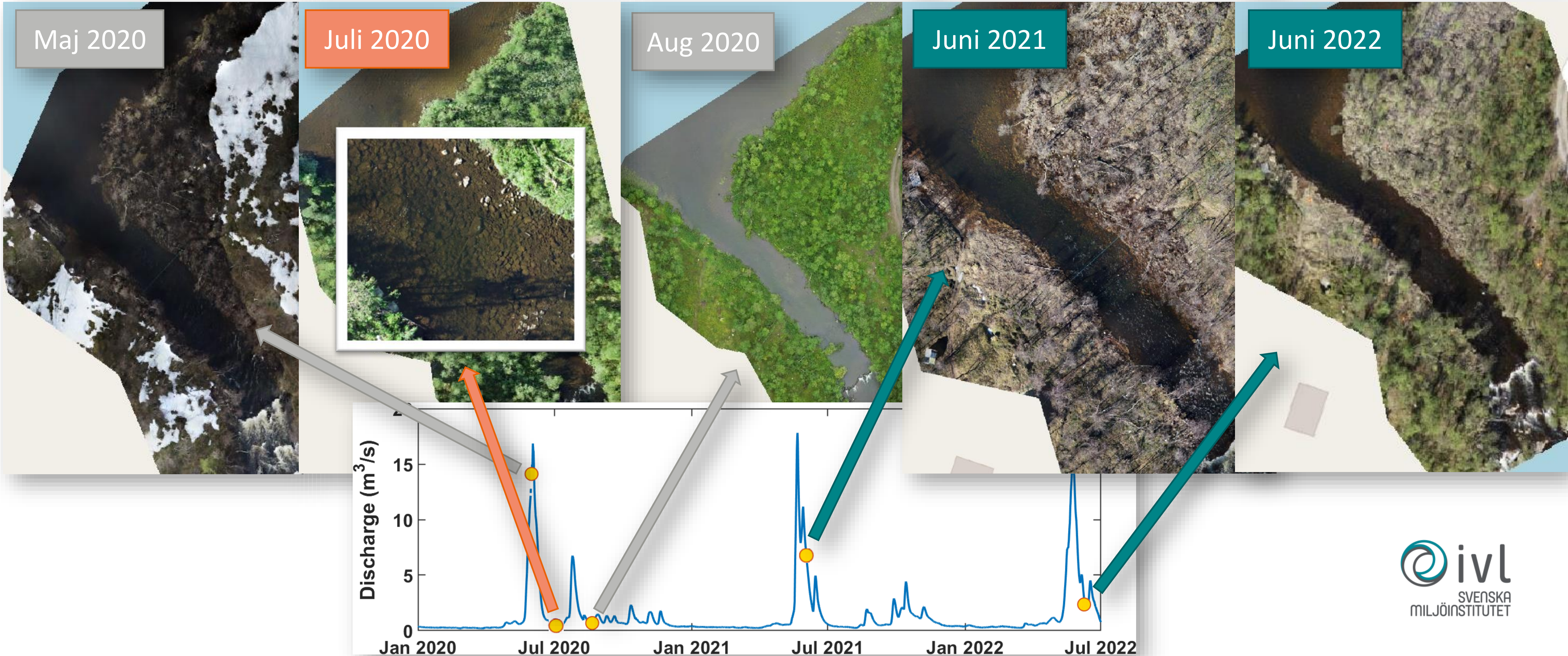
Batymetri – liknande tvärsektionsgeometri
(foton/fältbesök/flygbilder)



Datainsamling med drönare:
När?

➢ **Många variabler: ljus, vegetation, flöde, snö, vind….**





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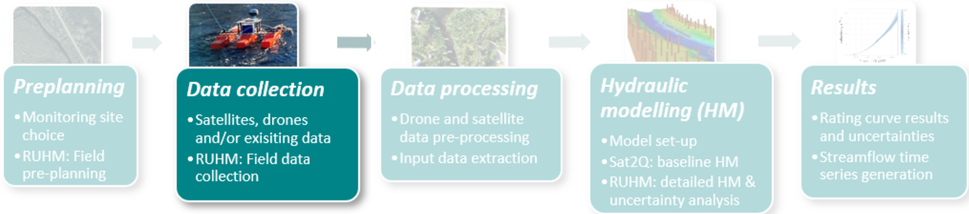
Vilken drönare?

DJI Matrice M300: Kamera & Zenmuse L1 Lidar



Vattenytan

Små löv, inga trädstammar

Kameradrönare: Structure-from-Motion (SfM)

Trädstammar, inga små löv

Batymetri (låg hastighet)

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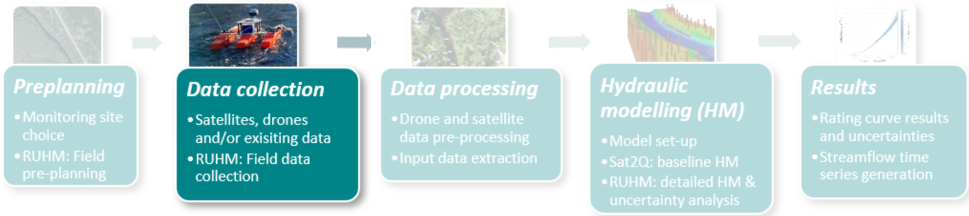
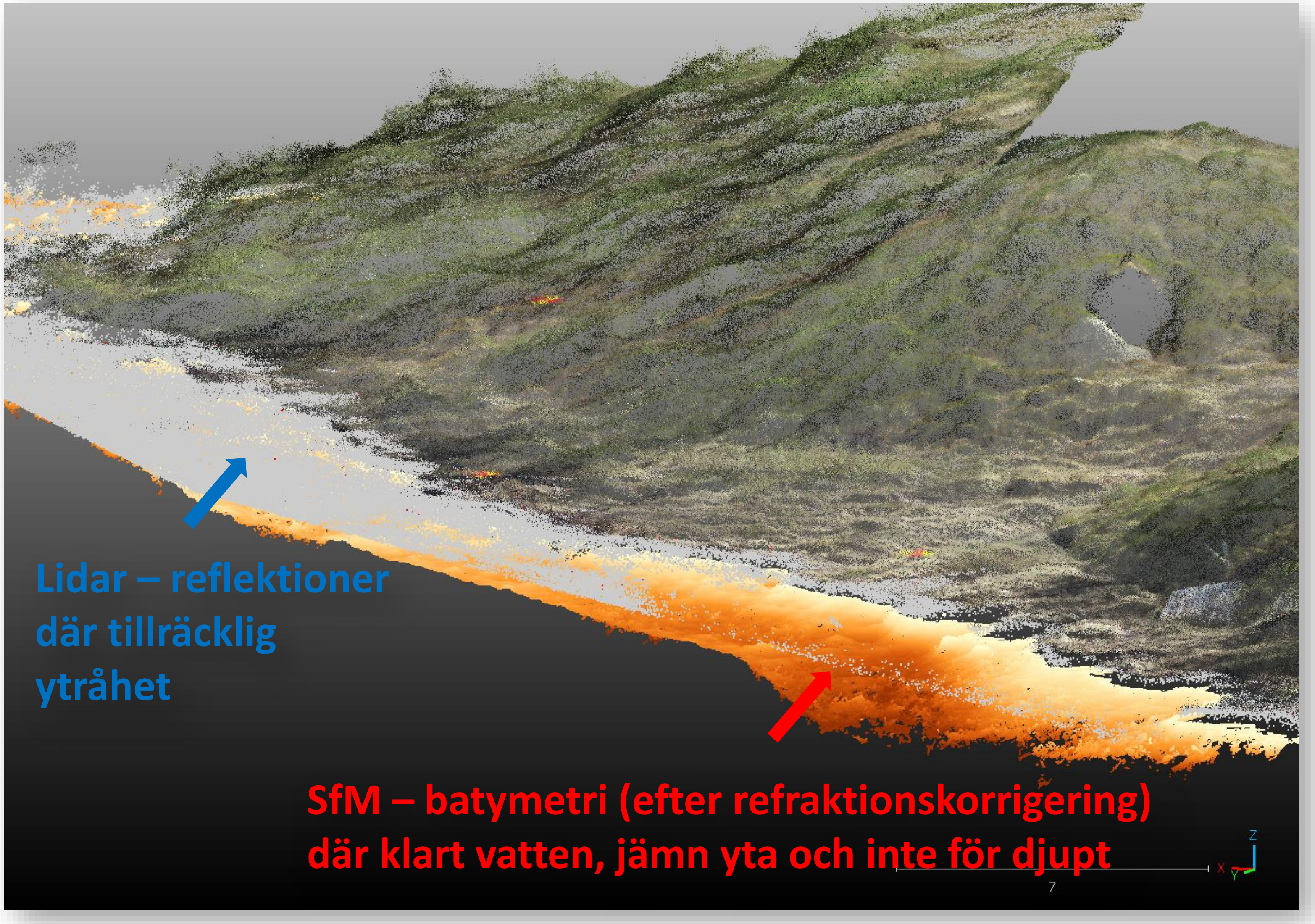
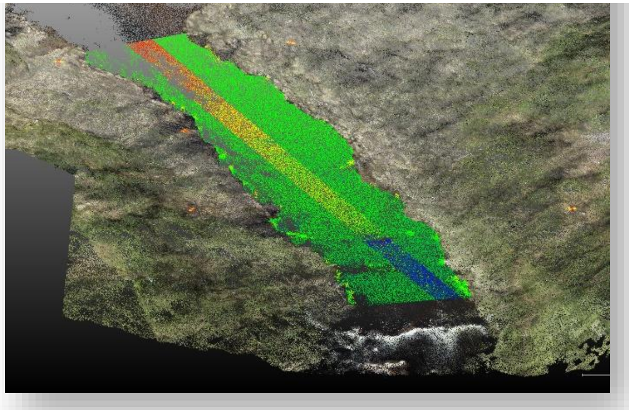
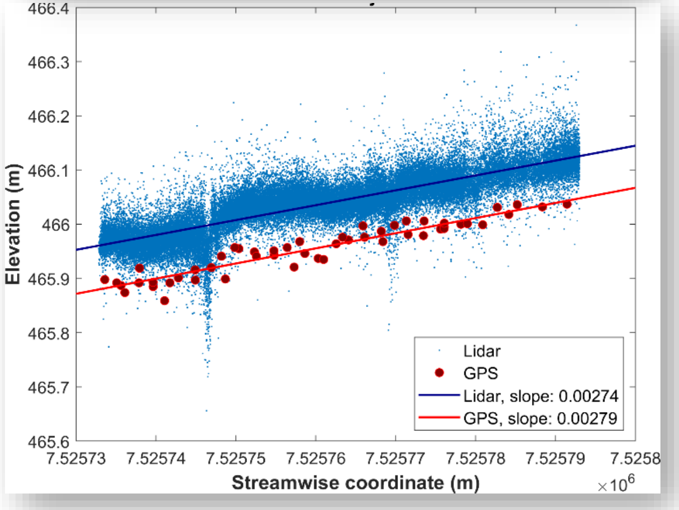
Vilken drönare?

Lidar & SfM: Skillnader i vattendraget









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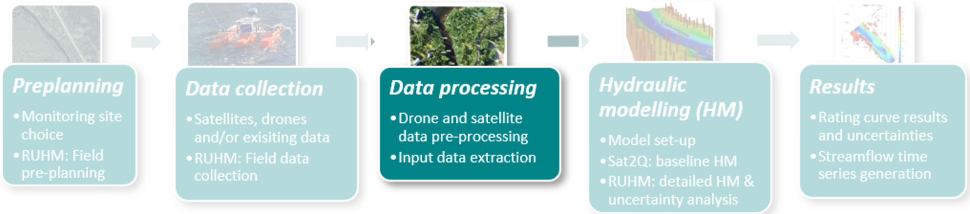
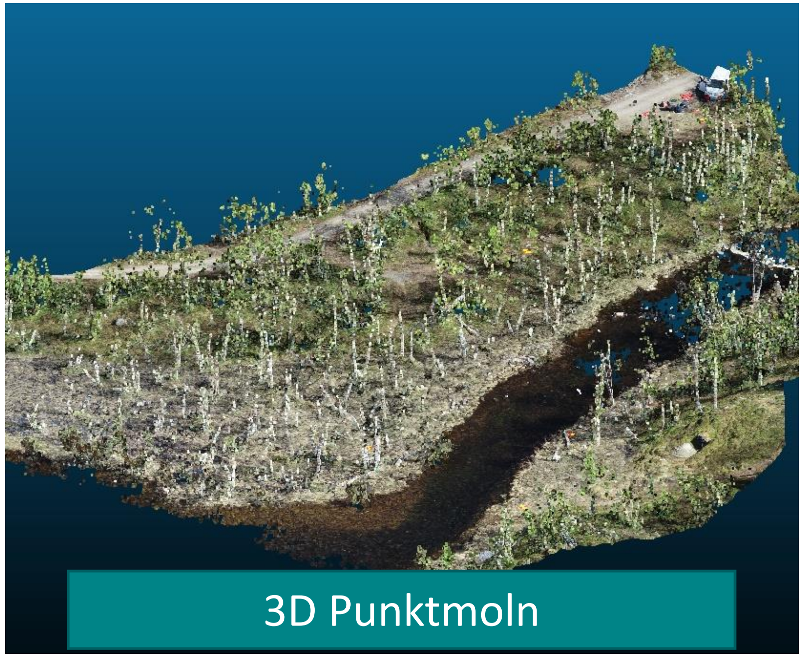
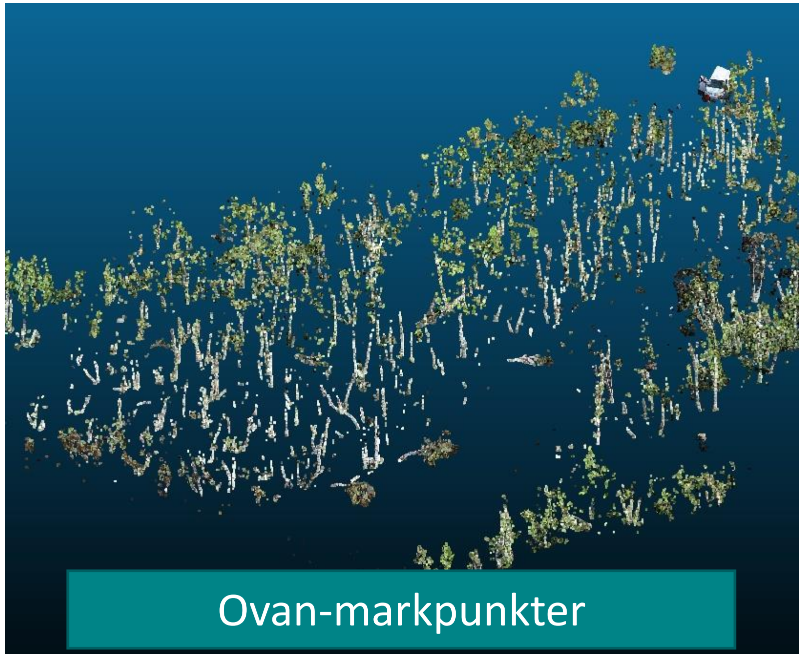


Bearbeta drönardata:
Tvärsektioner från höjdmodell med batymetri

- **Klassificering av markpunkter i punktmoln från drönare eller lidarscan**


3D Punktmoln


Ovan-markpunkter


Markpunkter

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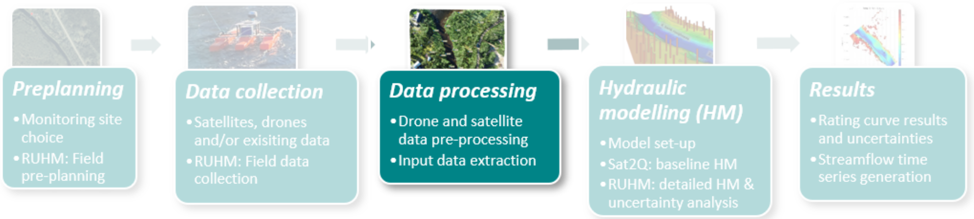
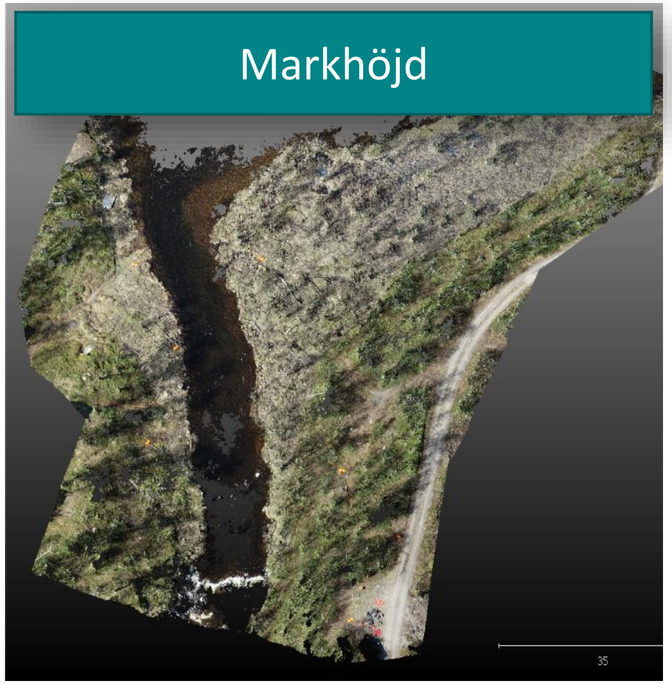
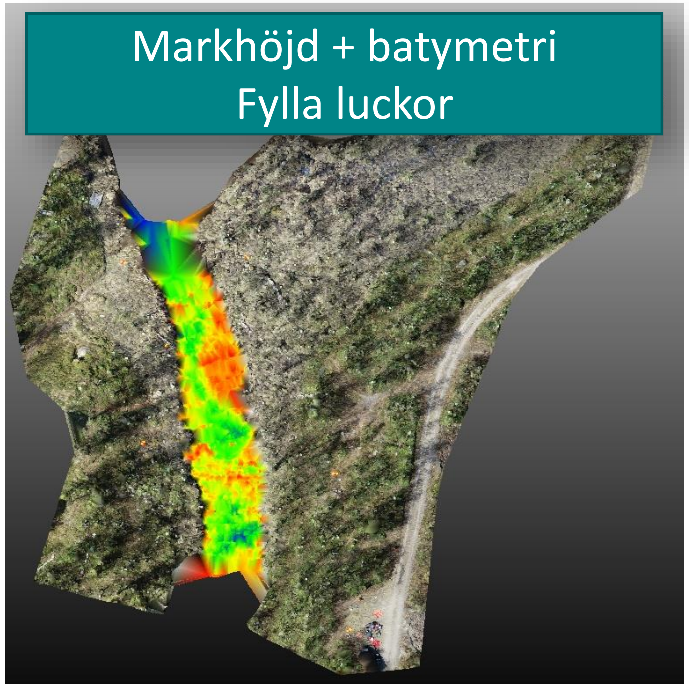
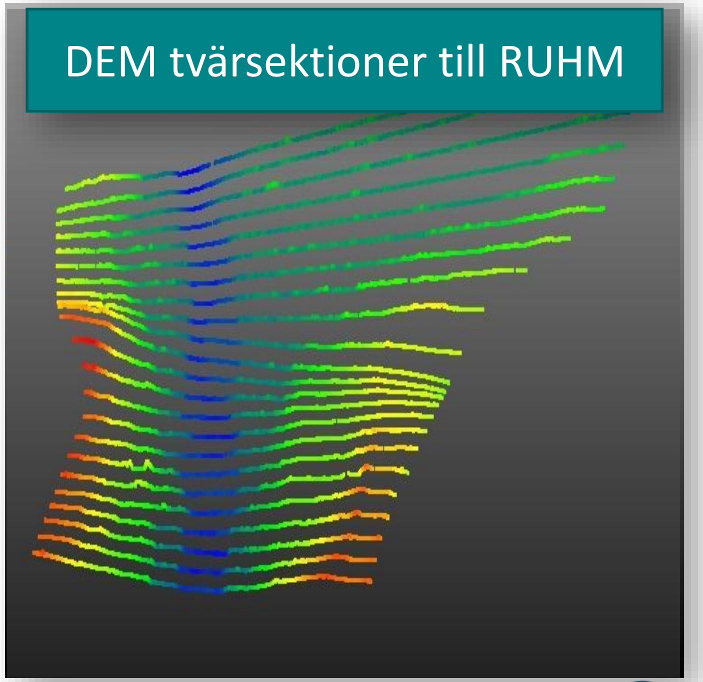


Bearbeta drönardata:

Tvärsektioner från höjdmodell med batymetri







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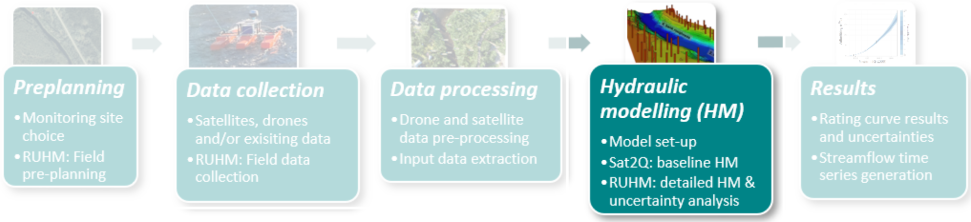
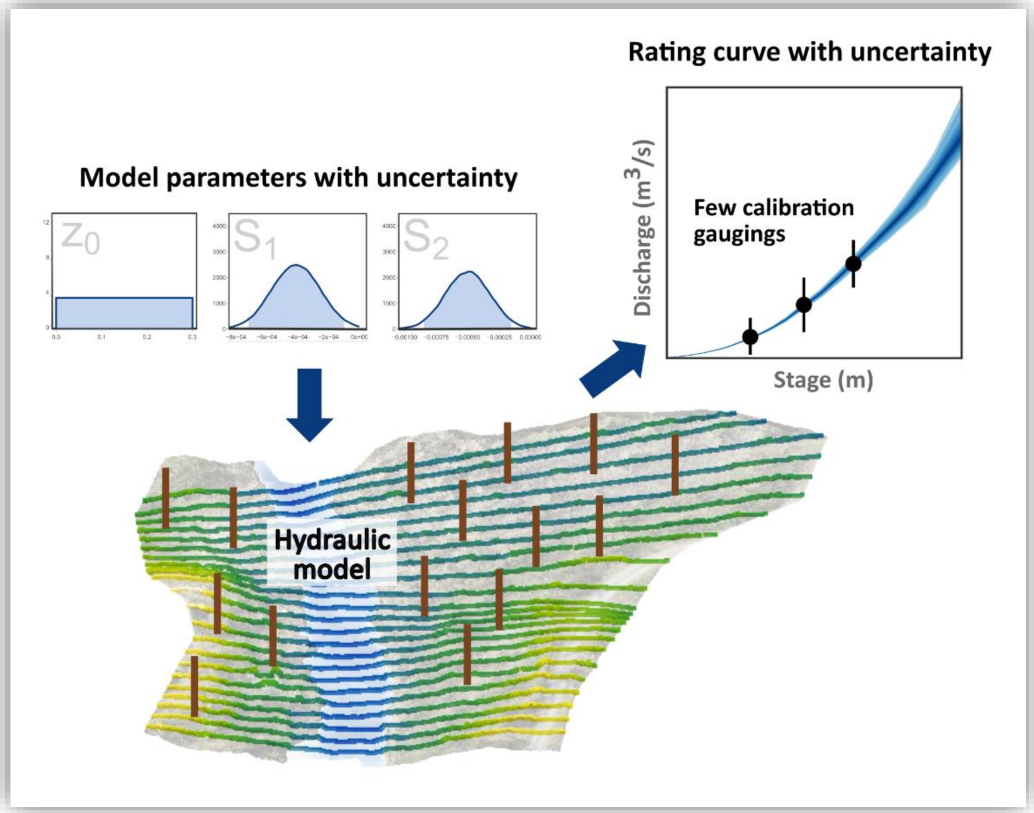
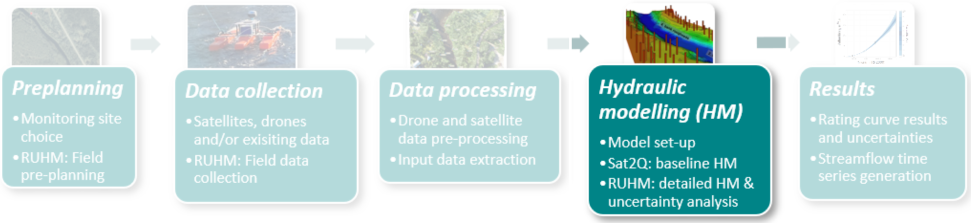


RUHM modellering

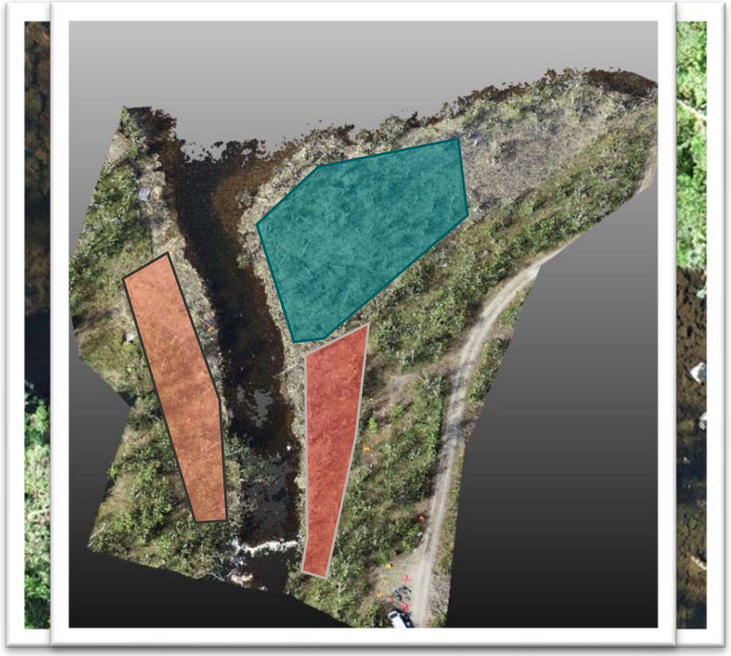
- Bayesiansk osäkerhetsanalys
  1. Antar osäkerhetsfördelningar för modell-parametrarna utifrån fältdata och litteraturvärden
  2. Uppdaterar osäkerhetsfördelningarna för modellparametrarna vid kalibrering (mot få data)
- Resultat: avbördningskurva med osäkerhetsskattning

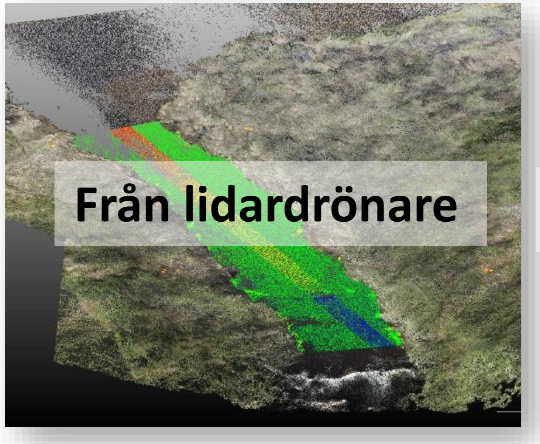


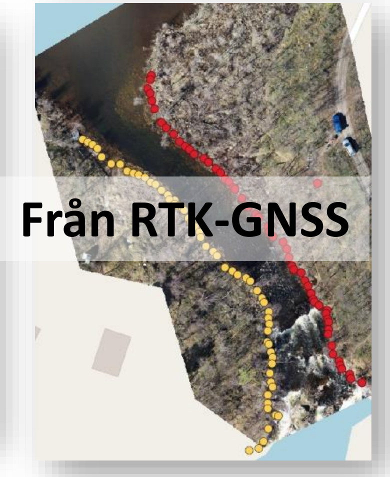


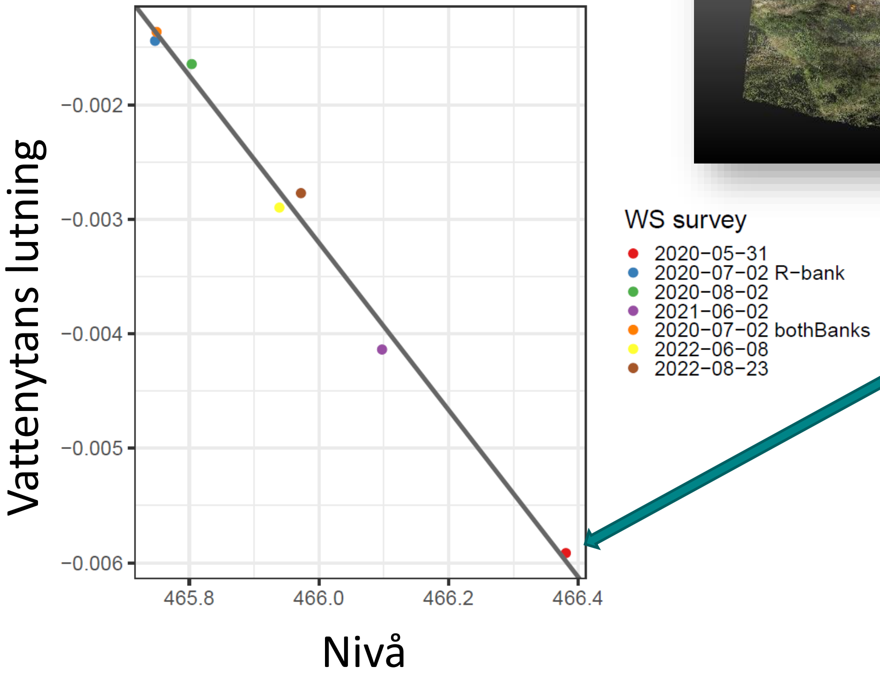
RUHM modellering

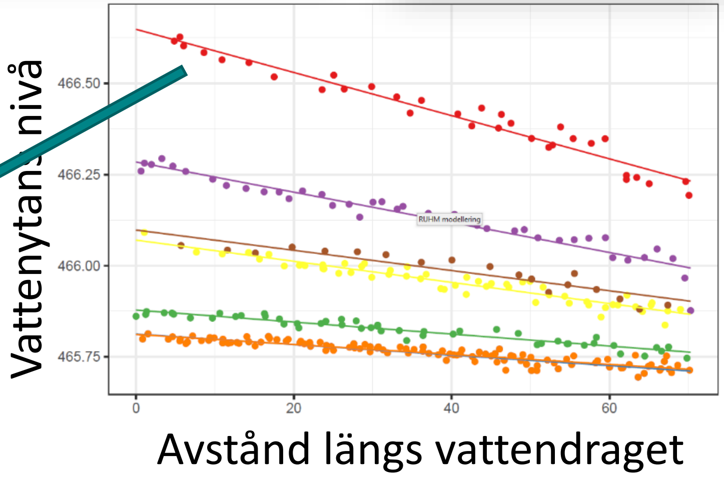
- **Tre modellparametrar med skattad osäkerhet**
  - Råhetskoefficient (*Roughness height*, **z0**)
  - Vattenytans lutning, linjärt samband med nivå (**S1** och **S2**)

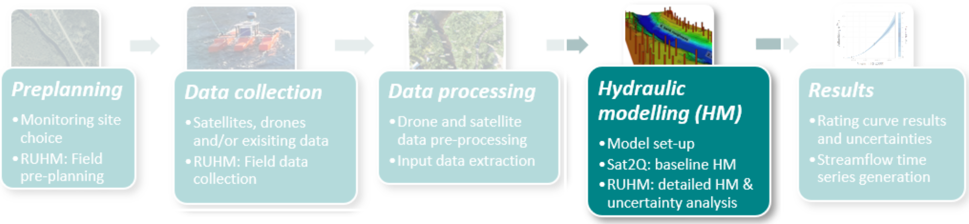






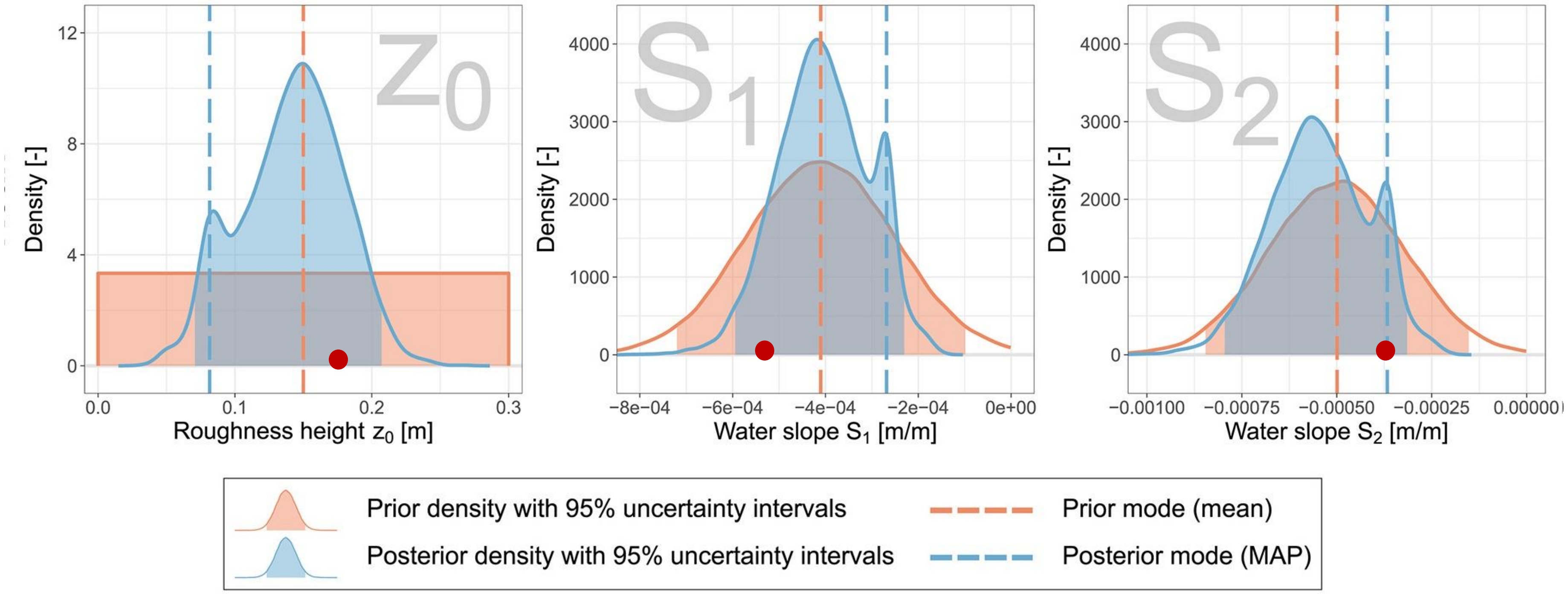


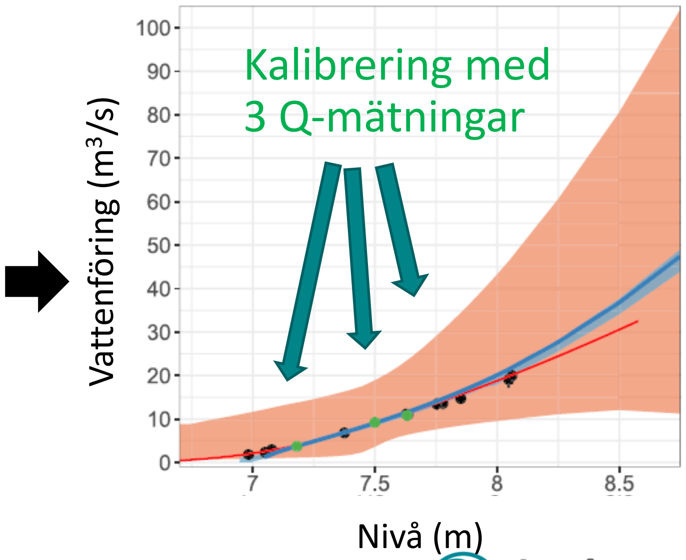


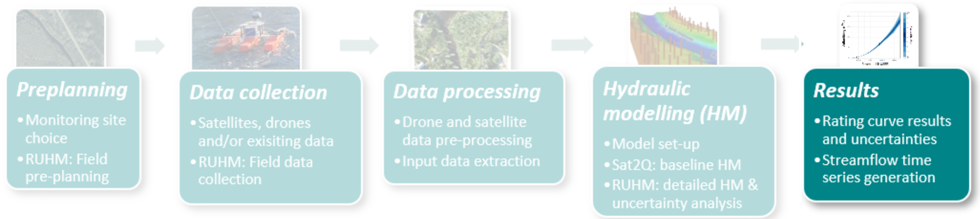


RUHM modellering

- **Osäkerhetanalys med Bayesiansk inferens**
  - Osäkerheten i modellparametrarna (***a priori-fördelning***) innan modellen kalibreras (från fältdata/litteratur)
  - Osäkerheten i modellparametrarna uppdateras genom kalibrering med likelihood-funktion (***a posteriori-fördelning***)

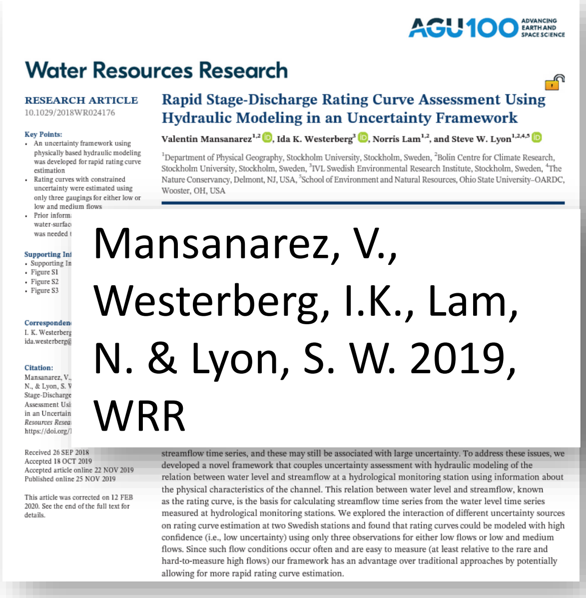




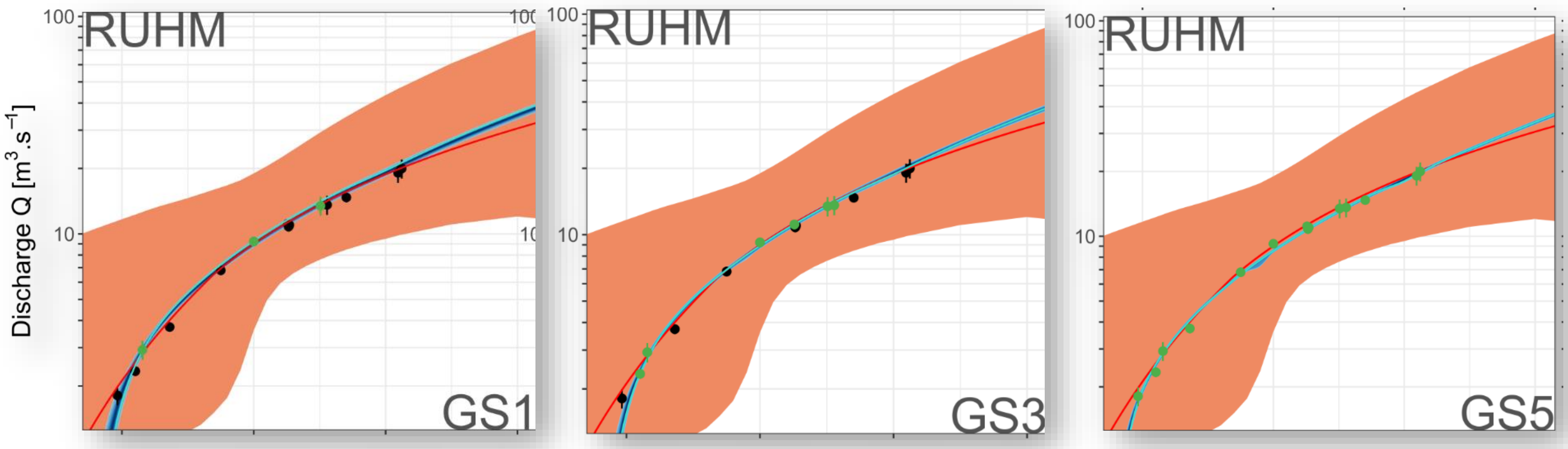


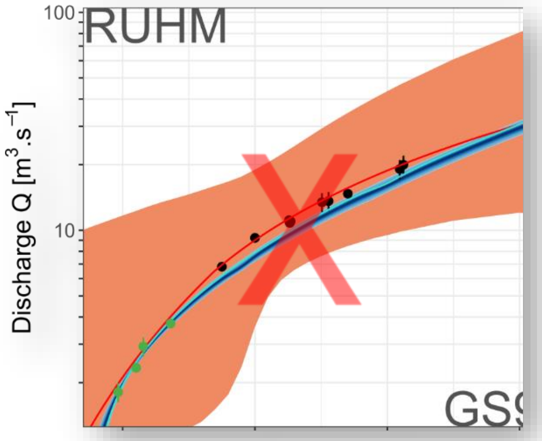
RUHM resultat

- Behövs bara låg och mellanflödes-mätningar för kalibrering

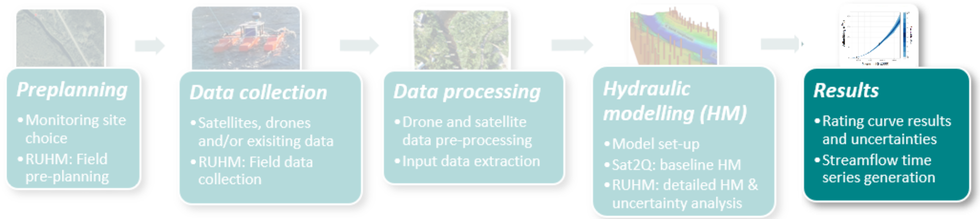


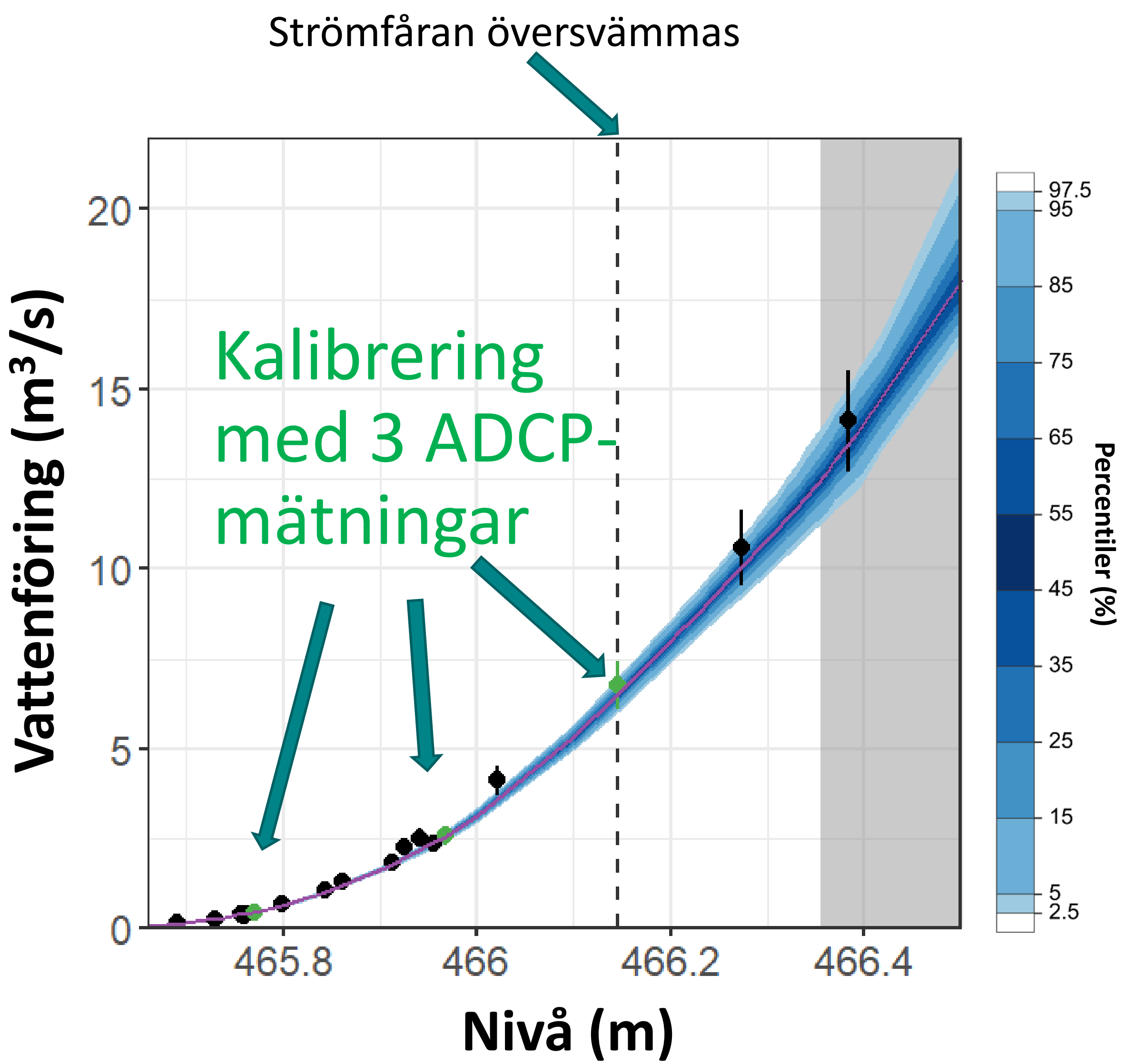
Mansanarez, V., Westerberg, I.K., Lam, N. & Lyon, S. W. 2019, WRR

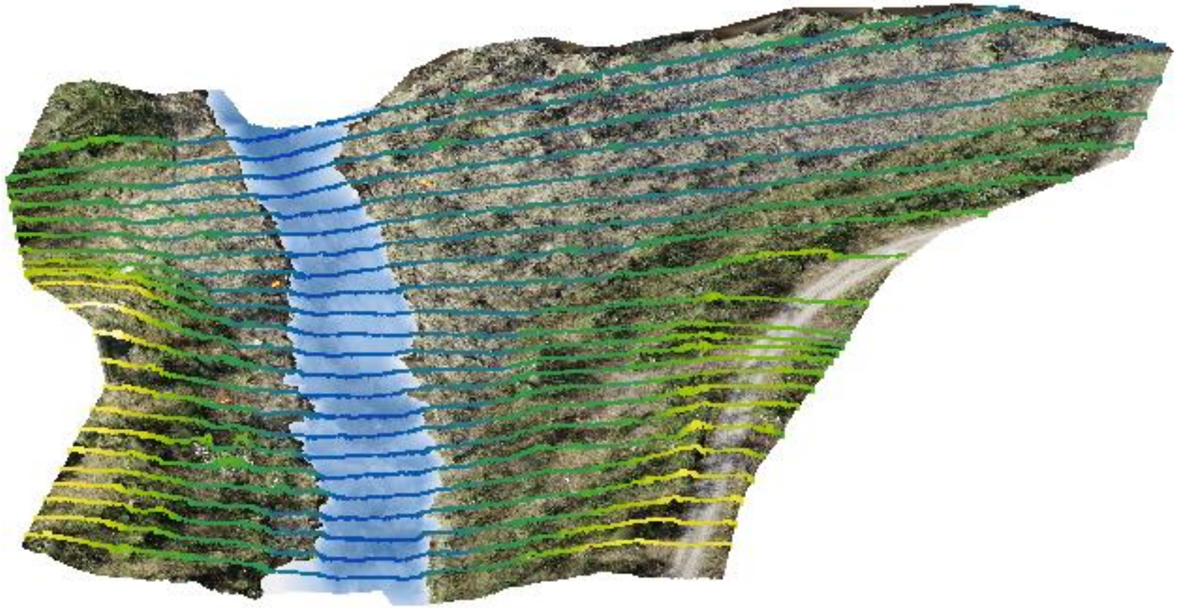




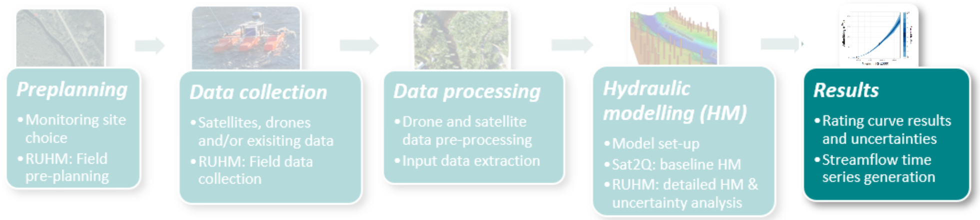
RUHM
Resultat med drönardata



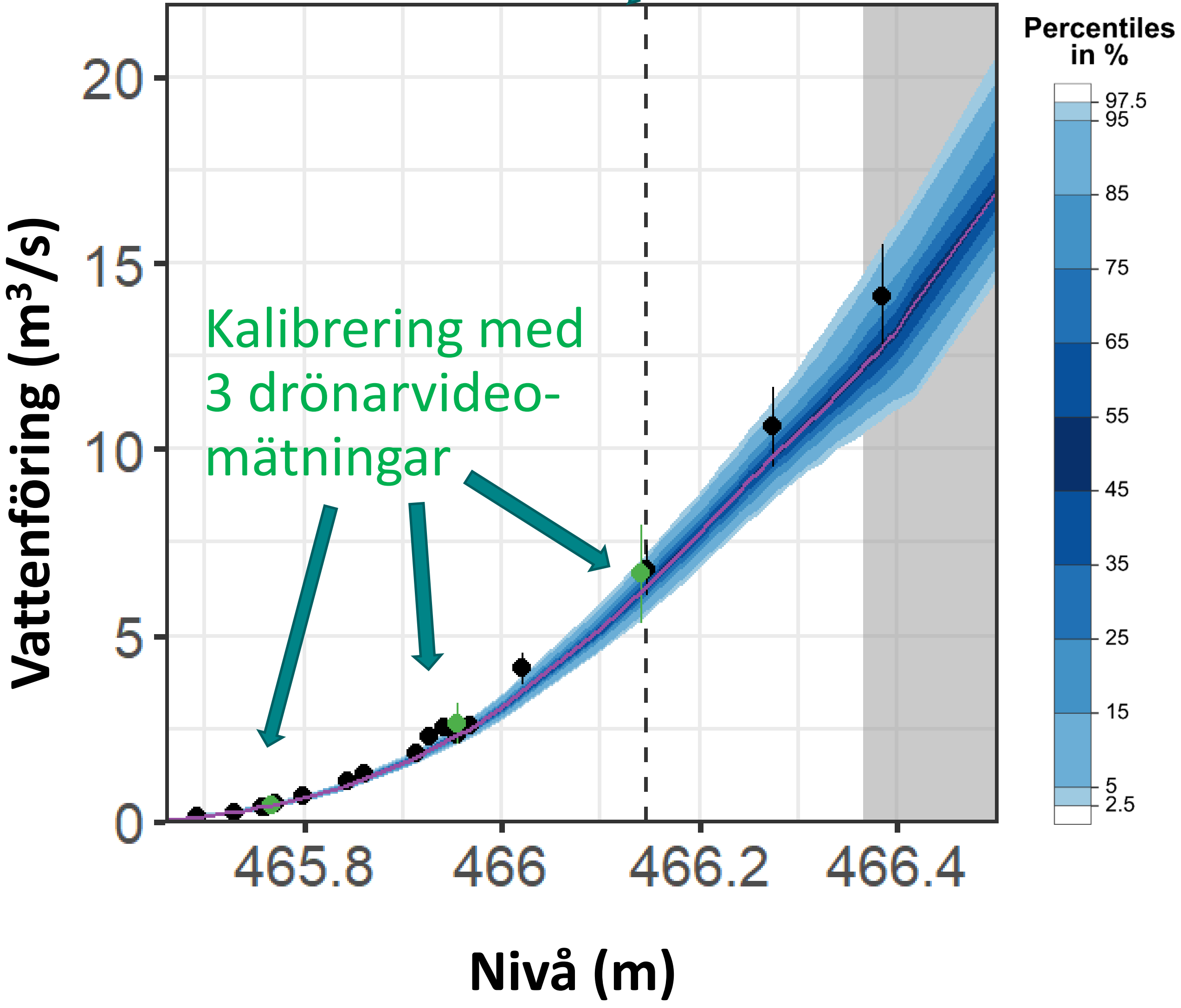


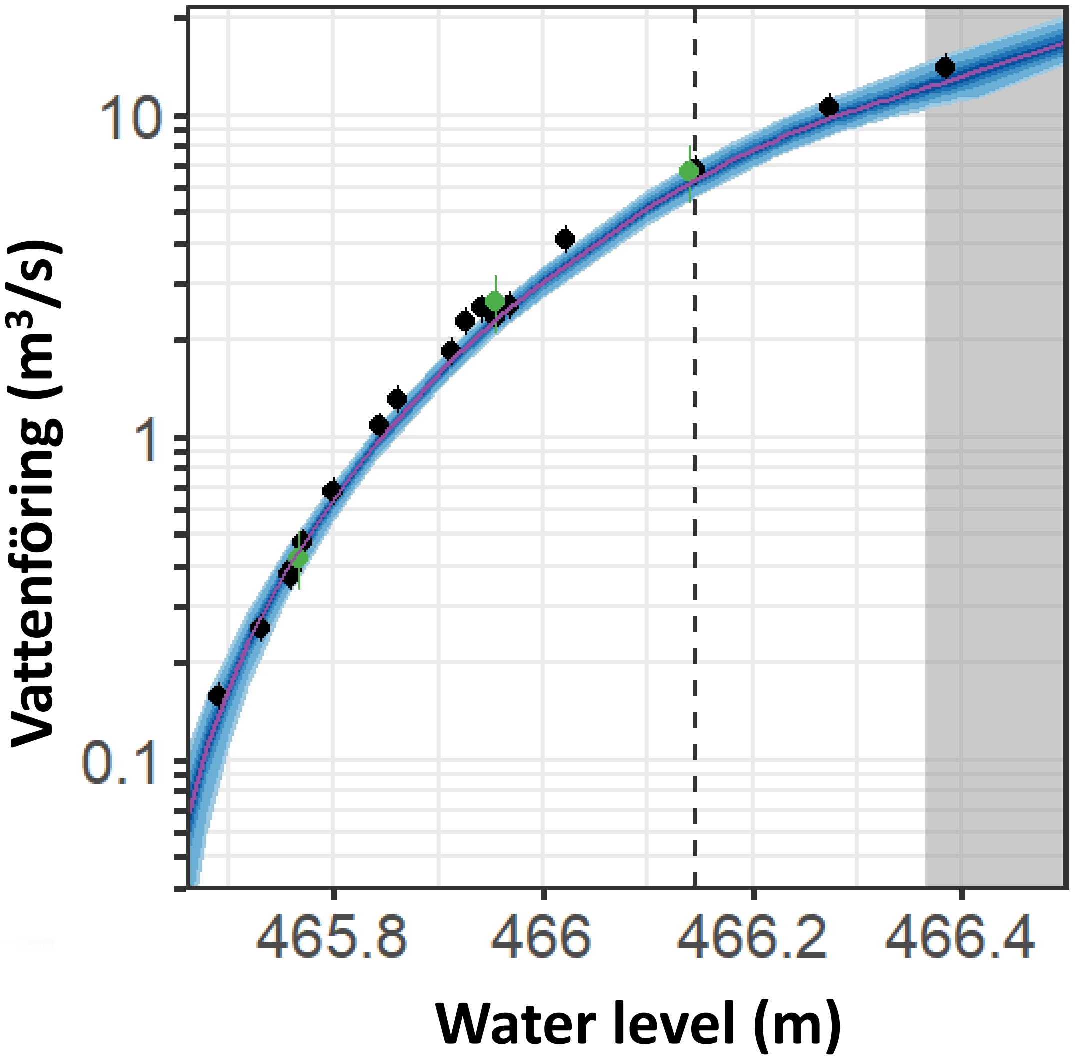


Kalibrering med drönarvideo

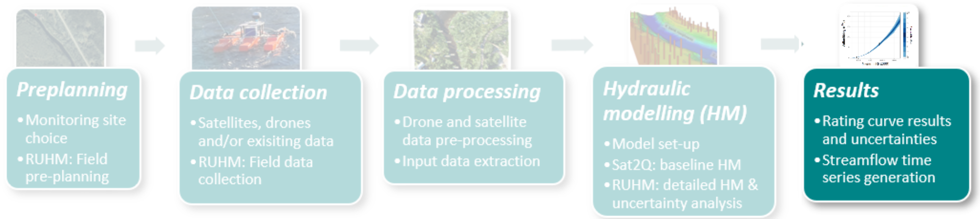


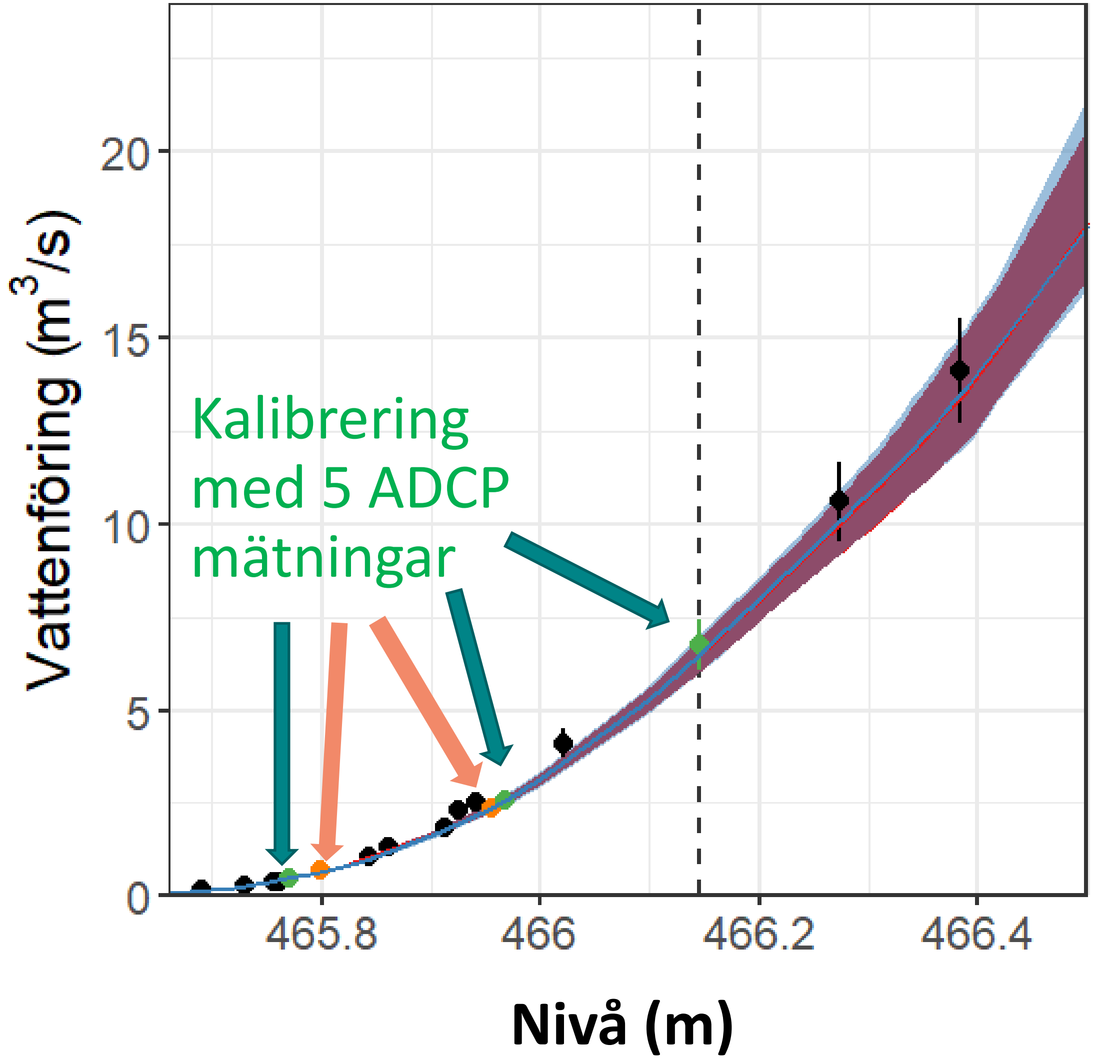
Strömfåran översvämmas

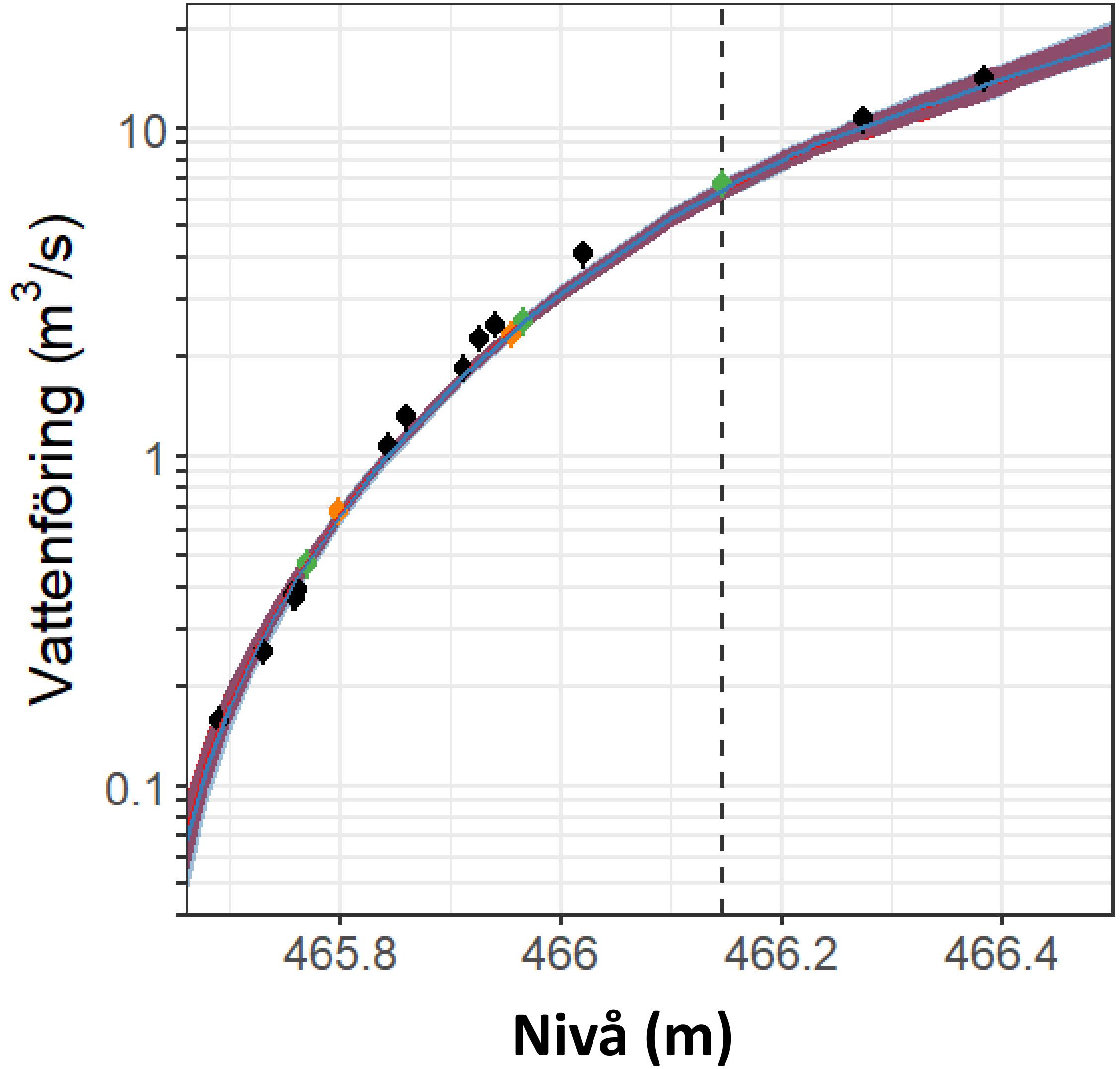




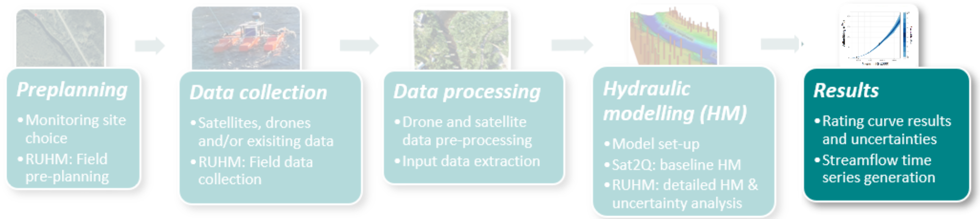
Med 5 ADCP mätningar

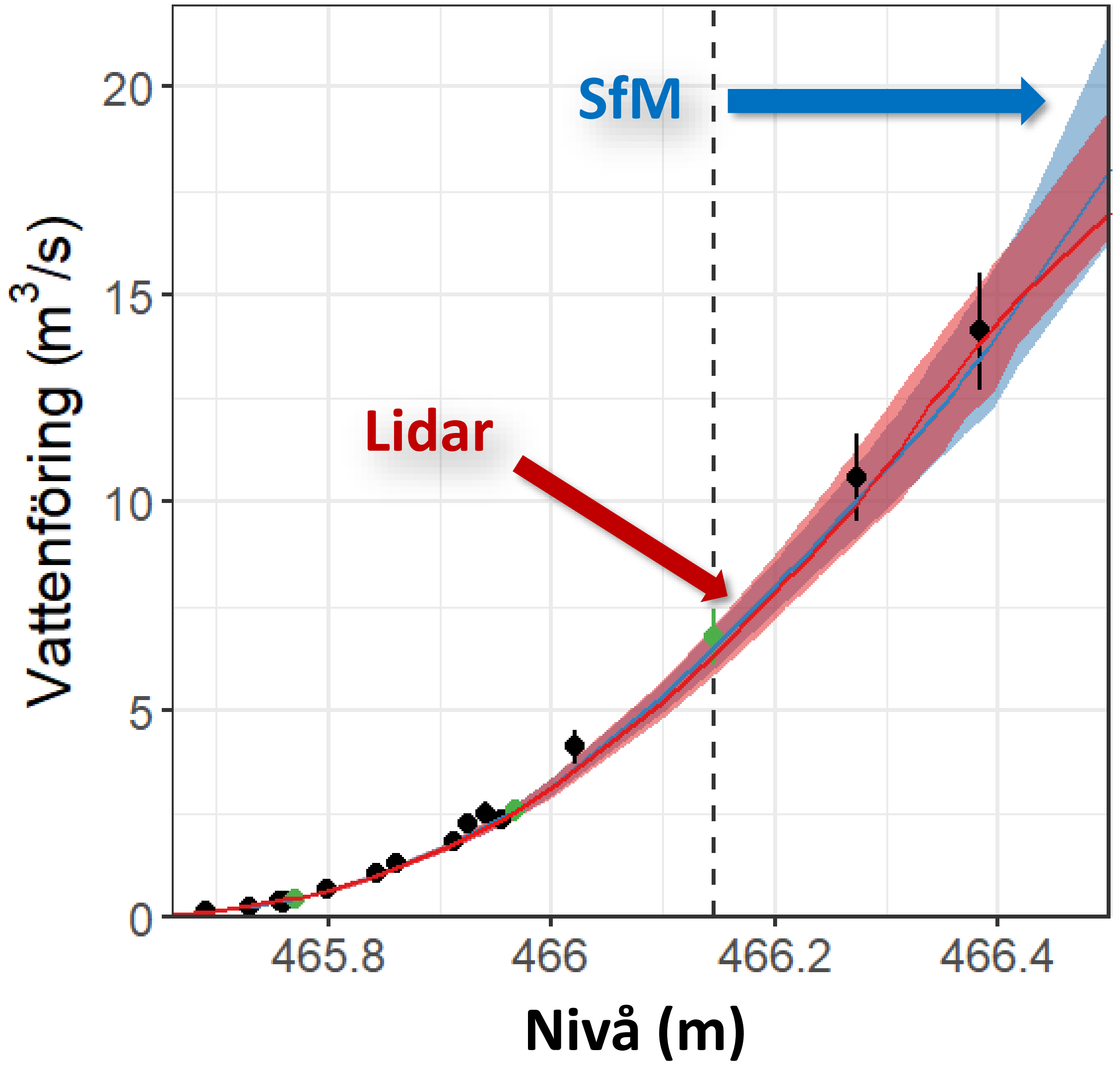


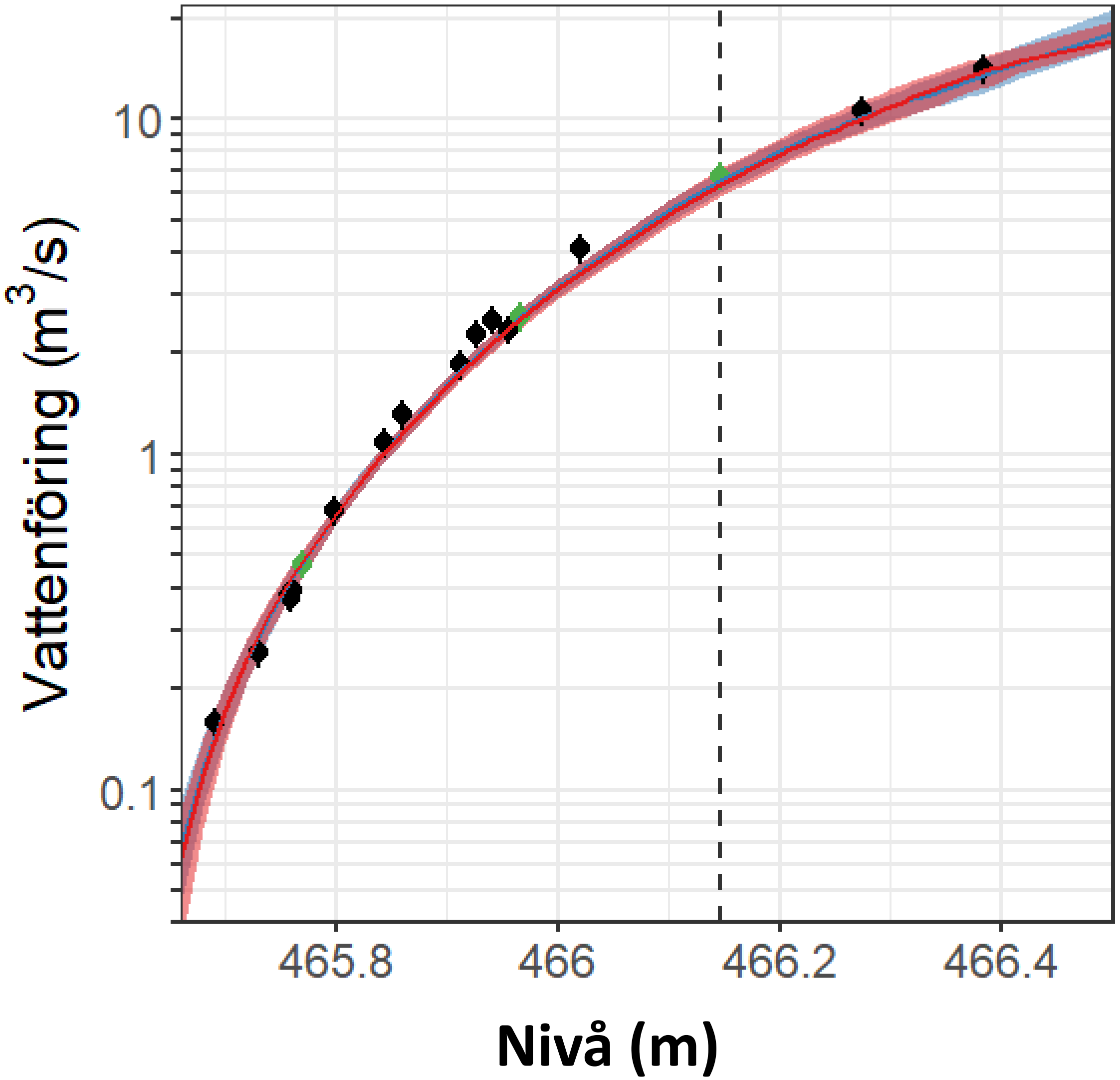




Lidar vs SfM topografi







Slutsatser

- Snabb beräkning av avbördningskurvor & osäkerhet
  - 3 låg-medelflödesmätningar = 1 fältsäsong
  - 1D-förhållanden krävs
- Effektiv datainsamling med drönare
  - Fältplanering viktigt, vegetation en utmaning
- Pågående: RUHM open access implementering, 2023-2026

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