Monitoring rivers and streams with drones

Main results of Grand Solutions project **Riverscapes**

2017-2021

http://www.riverscapes.env.dtu.dk/

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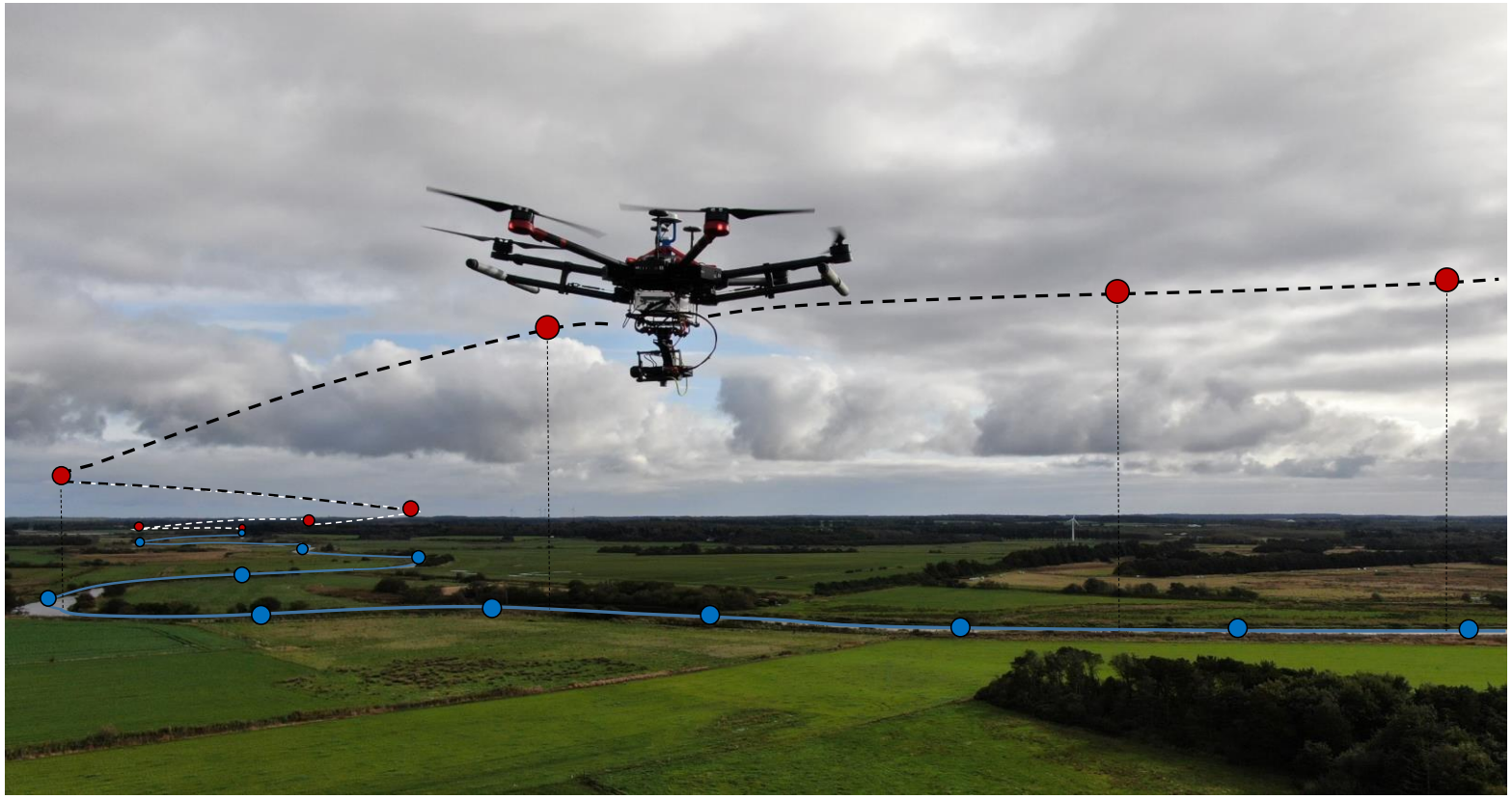
Riverscapes Vision

- Develop **new UAV payloads** for hydrometric and ecological monitoring of rivers and streams
- Demonstrate the **value of new datasets** collected with the UAV payloads
- Develop **new business areas** for UAV service providers and environmental consultants

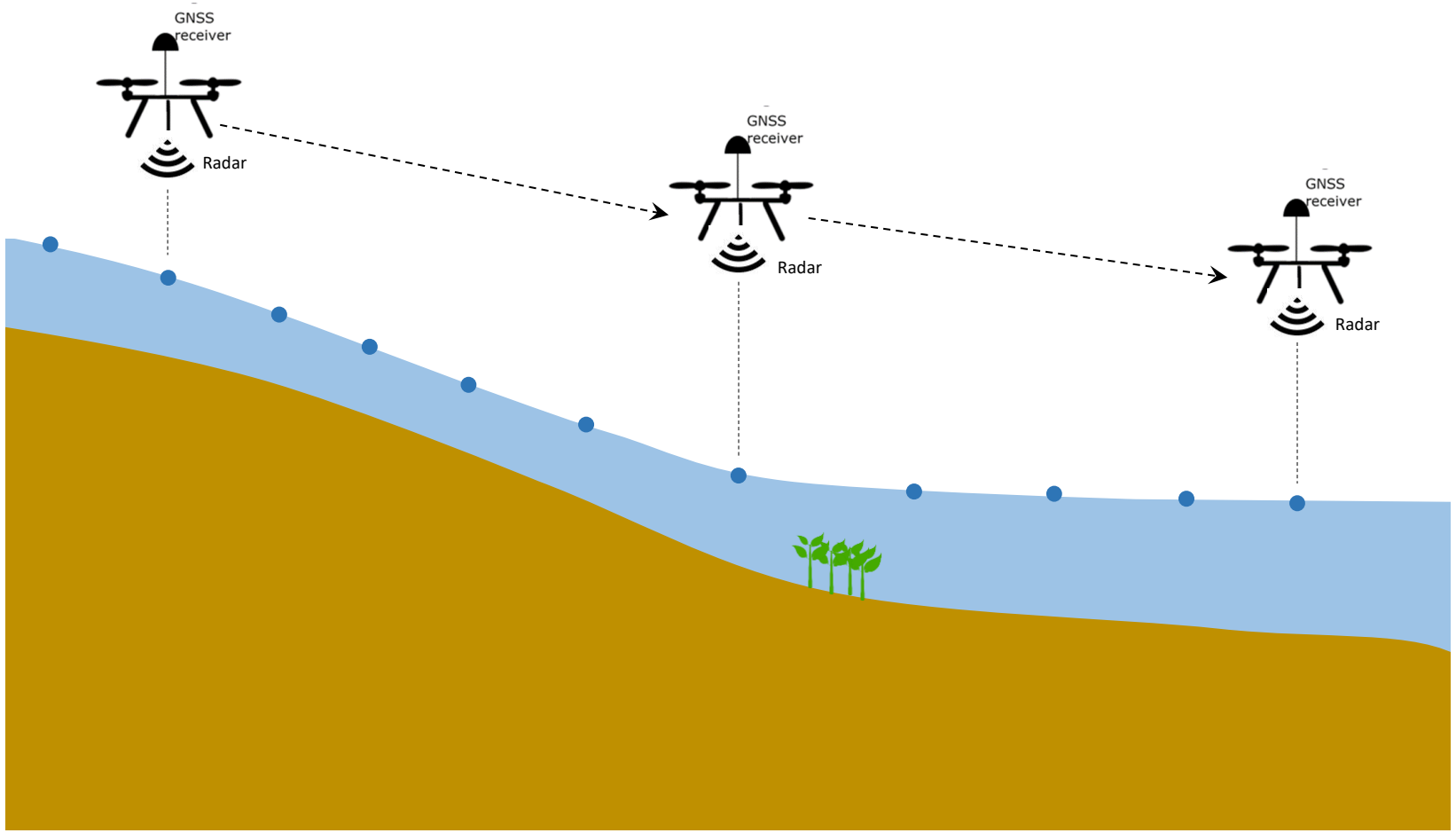


Project technical success criteria

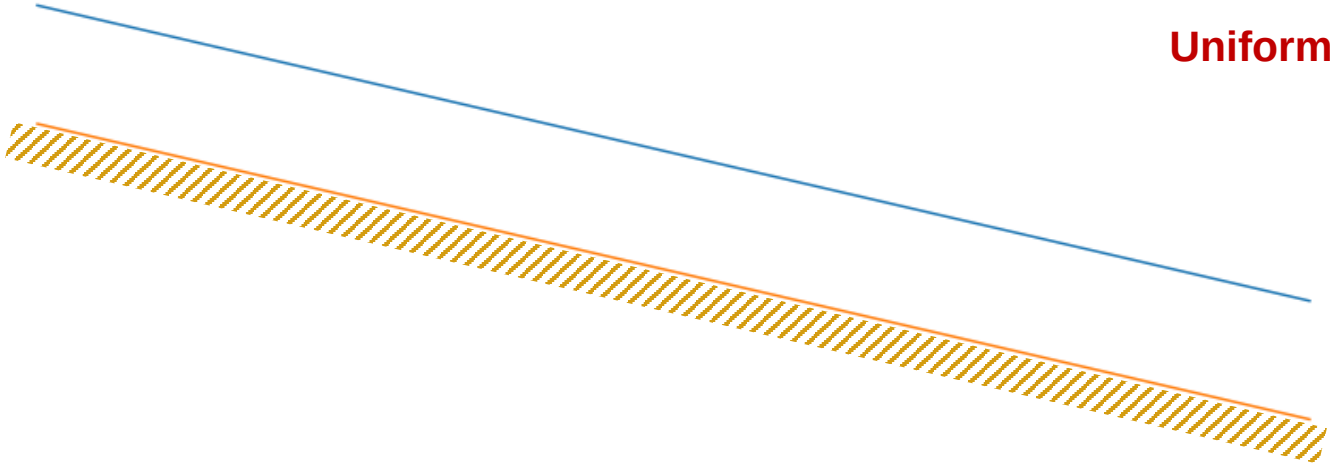
(copied from Investment Agreement)

- Accurate positioning of the platform during flights with 1-4 cm horizontal accuracy and <3-10 cm vertical accuracy.
  √ Fulfilled using kinematic post processing (PPK) of global navigation satellite systems (GNSS) data
- Water heights in rivers and lakes as height above mean sea level with 3-10 cm accuracy
  √ Fulfilled using a 77 GHz UAS radar altimetry solution
- Bathymetry of rivers and lakes with 10-20 cm accuracy
  √ Fulfilled using a 80 MHz ground penetrating radar solution / tethered sonar solution
- Water surface velocity and discharge from image cross correlation with 10%-15% accuracy
  (√) Partly Fulfilled using an image velocimetry workflow based on airborne videos (15%-20% accuracy)
- Thermal maps with 1-3 Kelvin temperature accuracy
  √ Fulfilled using airborne thermal mapping workflows with a FLIR Tau-2 camera
- Multi- and hyperspectral maps of riverscapes for habitat and water quality monitoring
  √ Fulfilled using airborne hyperspectral mapping workflows with a Cubert Firefly camera

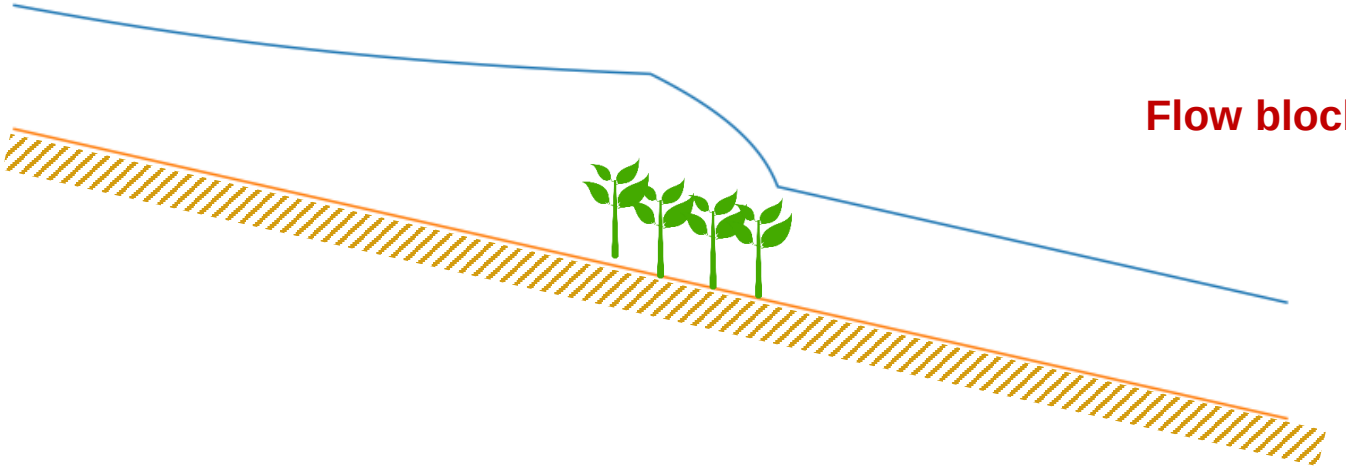
UAS radar altimetry - Concept



UAS radar altimetry - Purpose



Uniform Manning Roughness



Flow blocked by aquatic weeds

UAS radar altimetry – Results (https://doi.org/10.1016/j.rse.2019.111487)

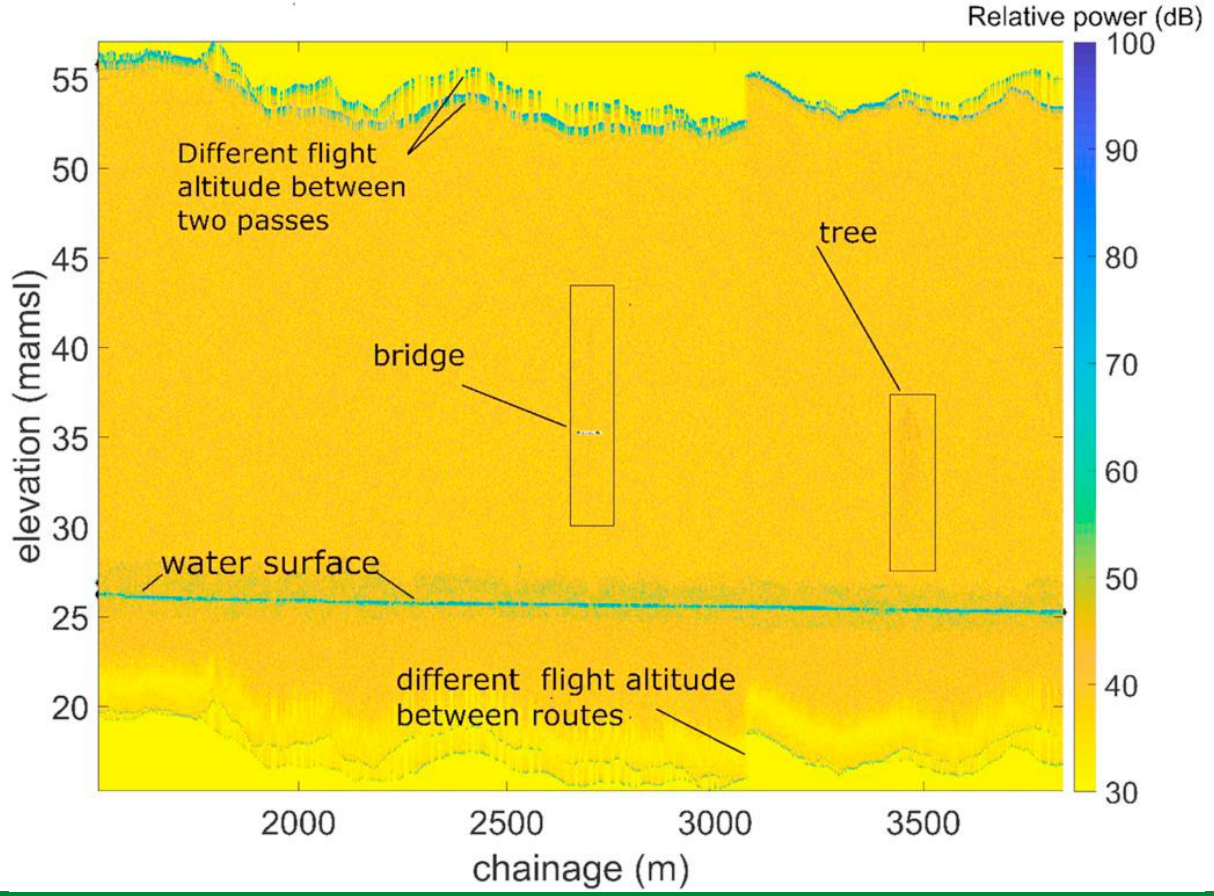
$$WSE = H_P - R - H_G$$

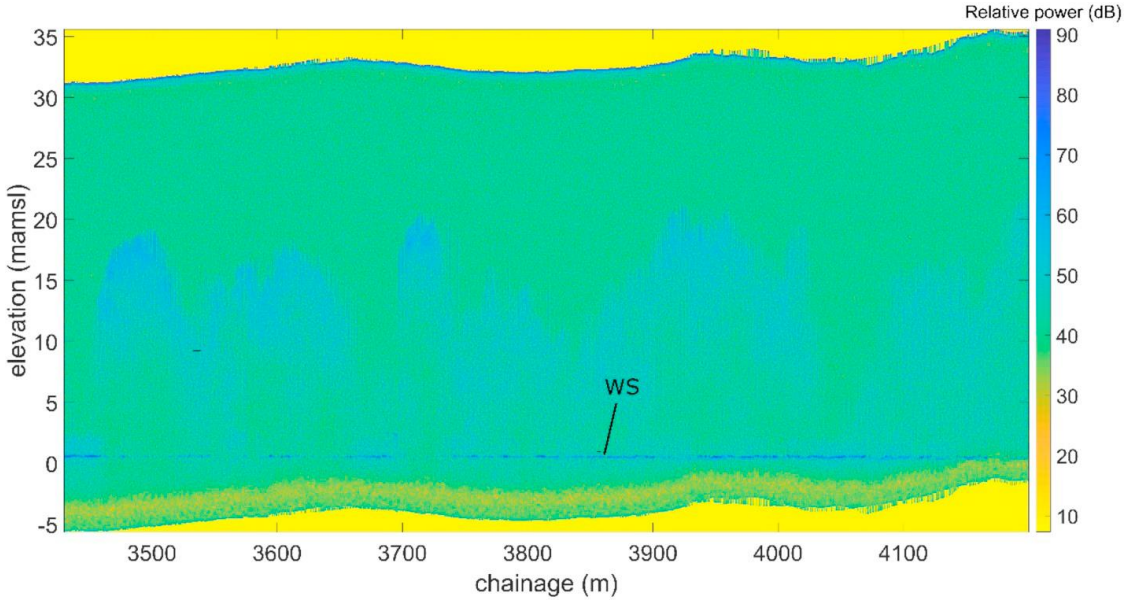
WSE: water surface elevation (mamsl)

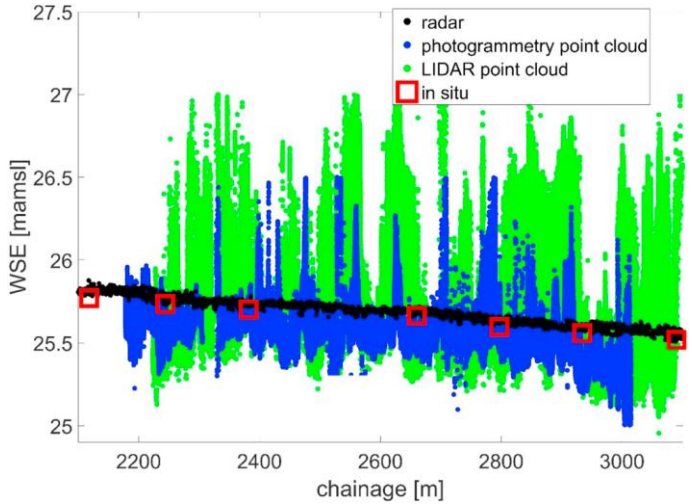
R: Range to water surface

H_P: Height of platform above ellipsoid (from GNSS)

H_G: Geoid undulation

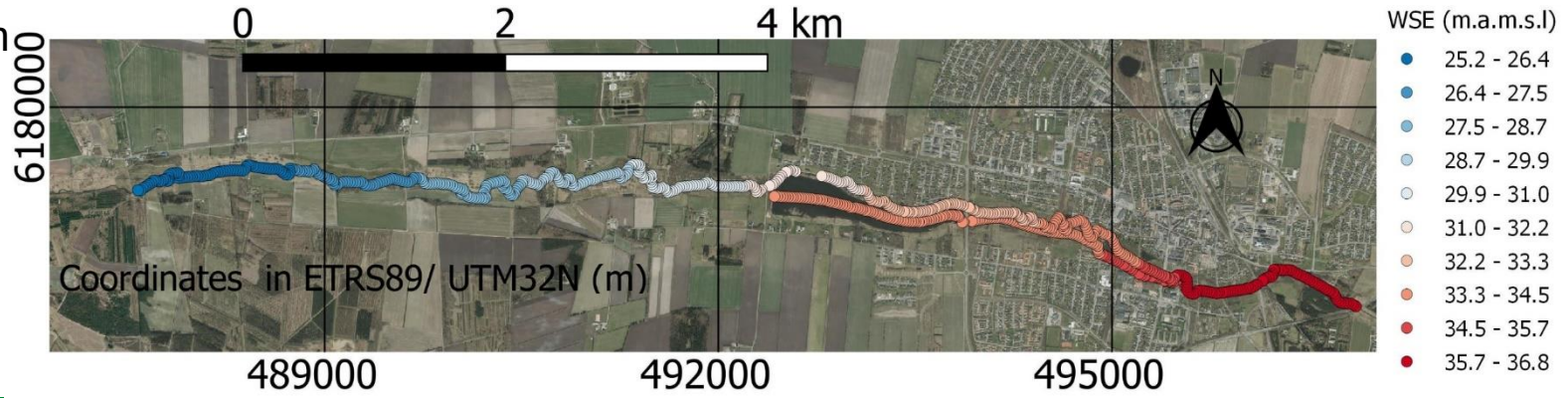




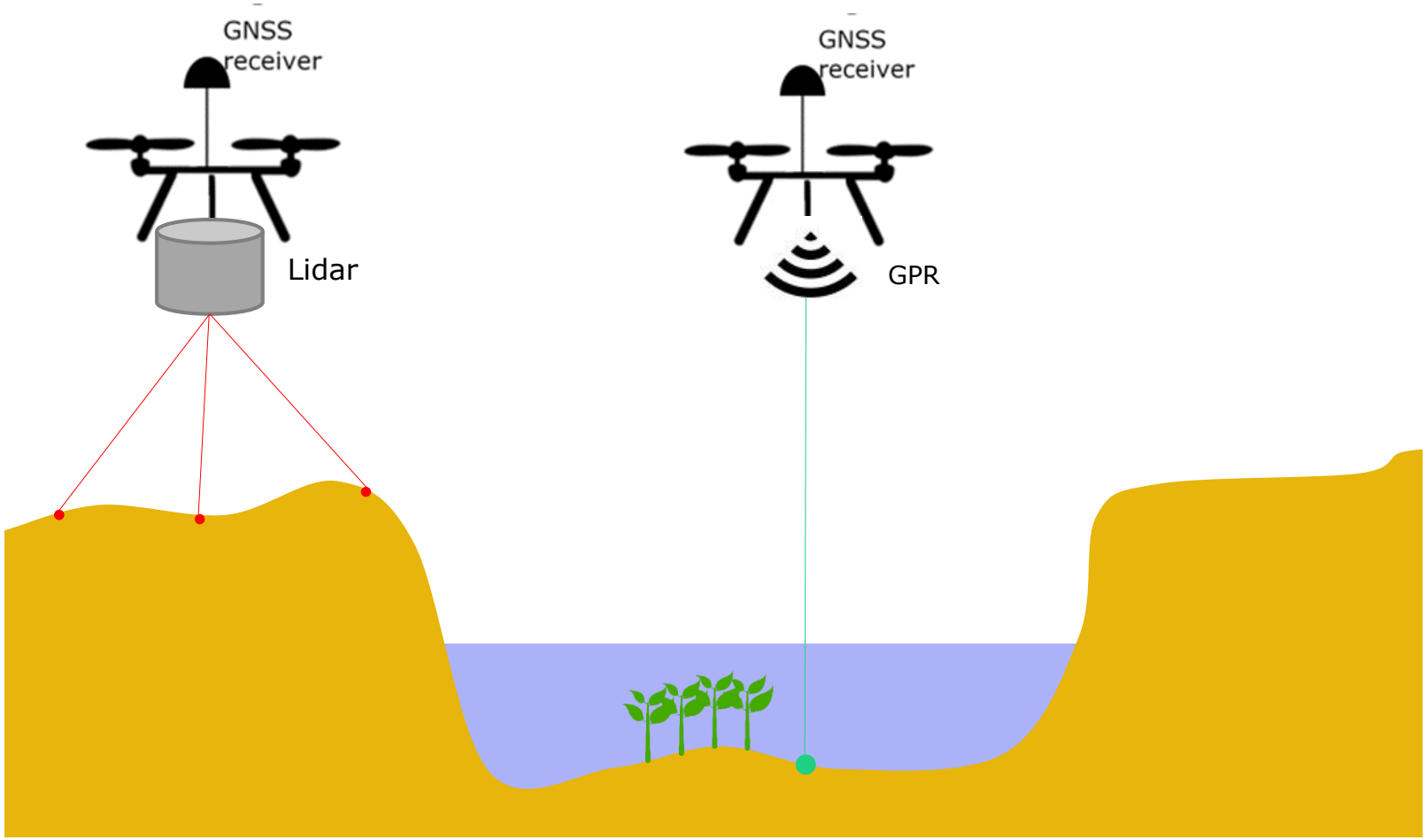


UAS radar altimetry - Impact

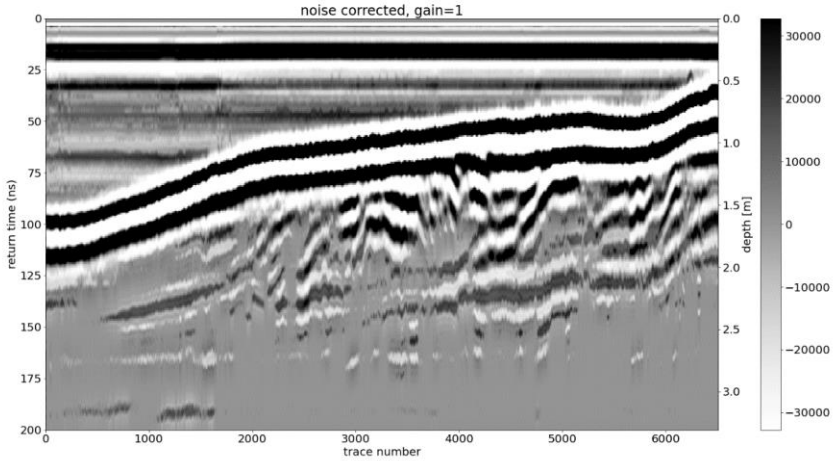
- Drone Systems has commercialized the workflow and has flown > 100 river-km over the last few months on a commercial basis (contact Henrik Grosen, henrik@dronesystems.dk)
- Suitable for all water surfaces wider than a few meters, accuracy at par with traditional in-situ
- Water surface can also be mapped when covered by vegetation
- The UAS radar alitmetry payload has been flown in China as part of the ChinaWaterSense project
- We have got inquiries about the commercial availability of the payload from Denmark, Sweden, New Zealand, Mexico, Chile, Germany
- Focus in Riverscapes: Monitoring of stream conveyance and stream maintenance
- Many other potential applications
  - Hydraulic model calibration
  - Flood prediction and flood risk analysis
  - Boundary conditions for groundwater models
  - Surface water – groundwater interaction
  - Surface-near groundwater
  - Monitoring of urban floods
  - …



UAS bathymetry - Concept

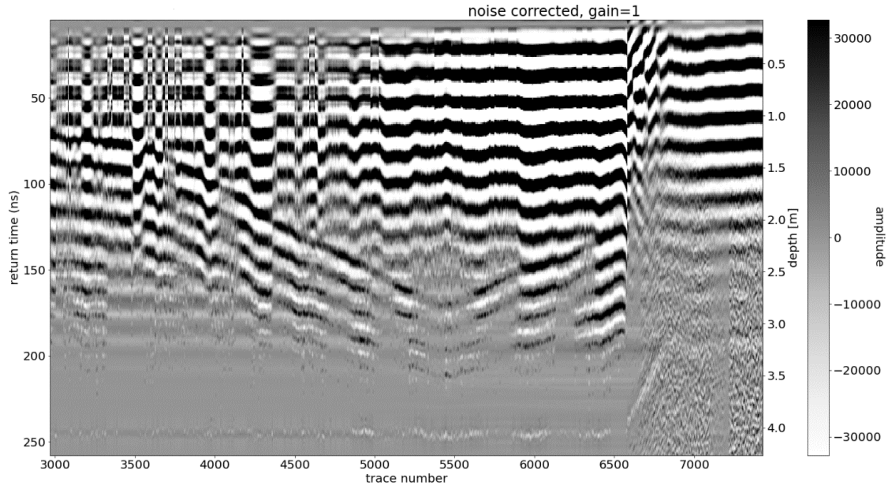


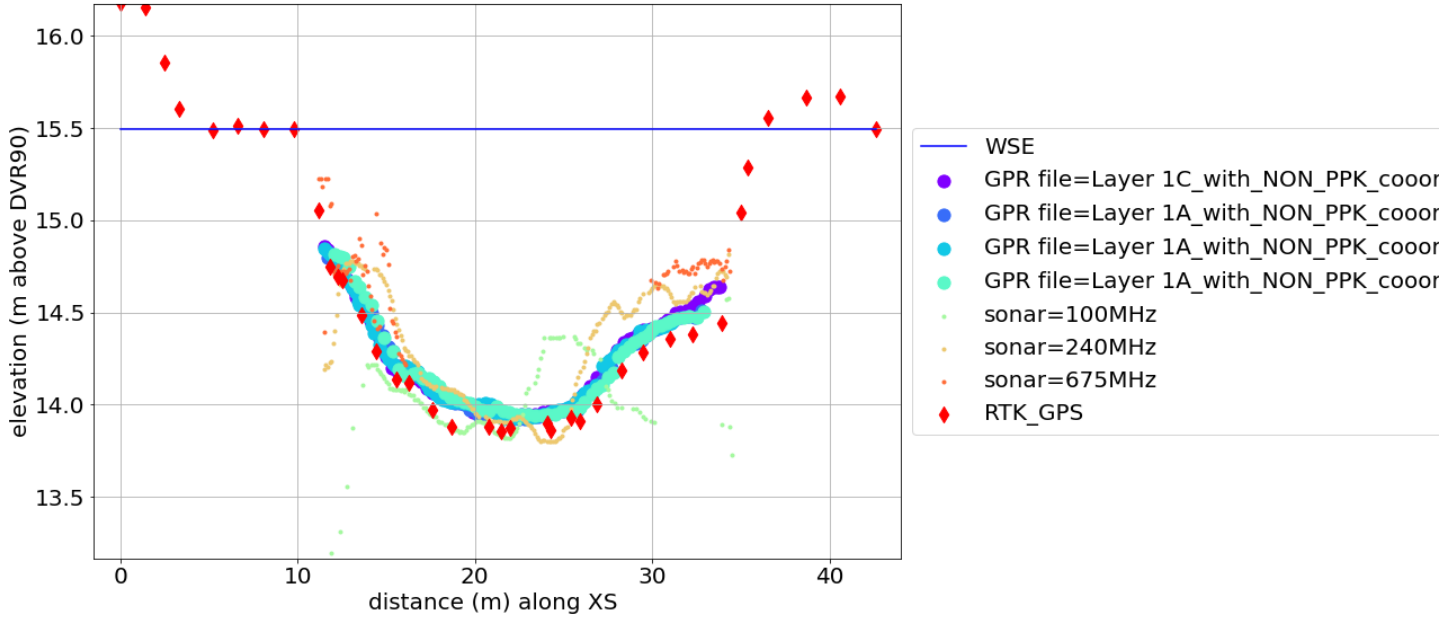
UAS bathymetry - Results



Water-borne Radargram

Airborne Radargram

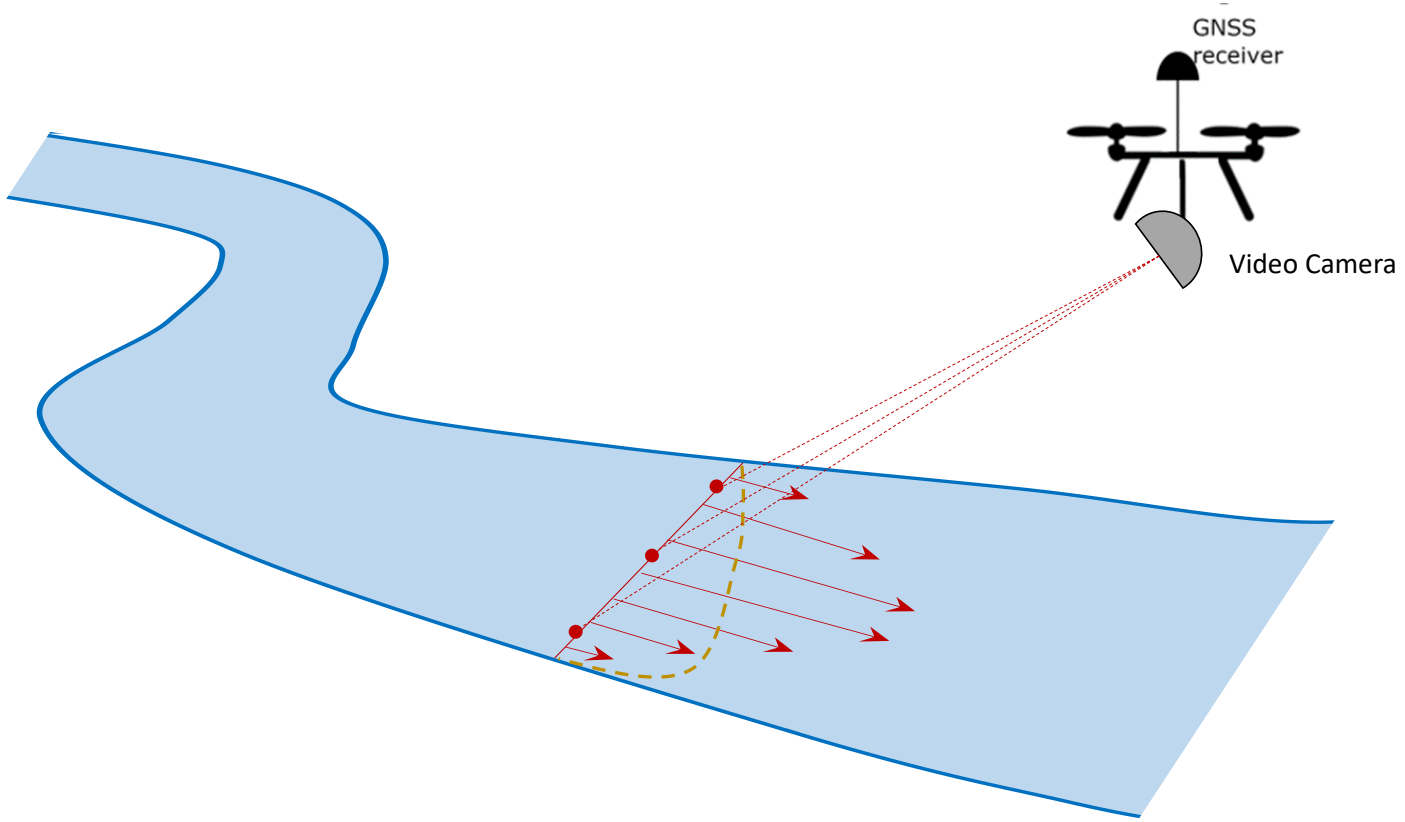




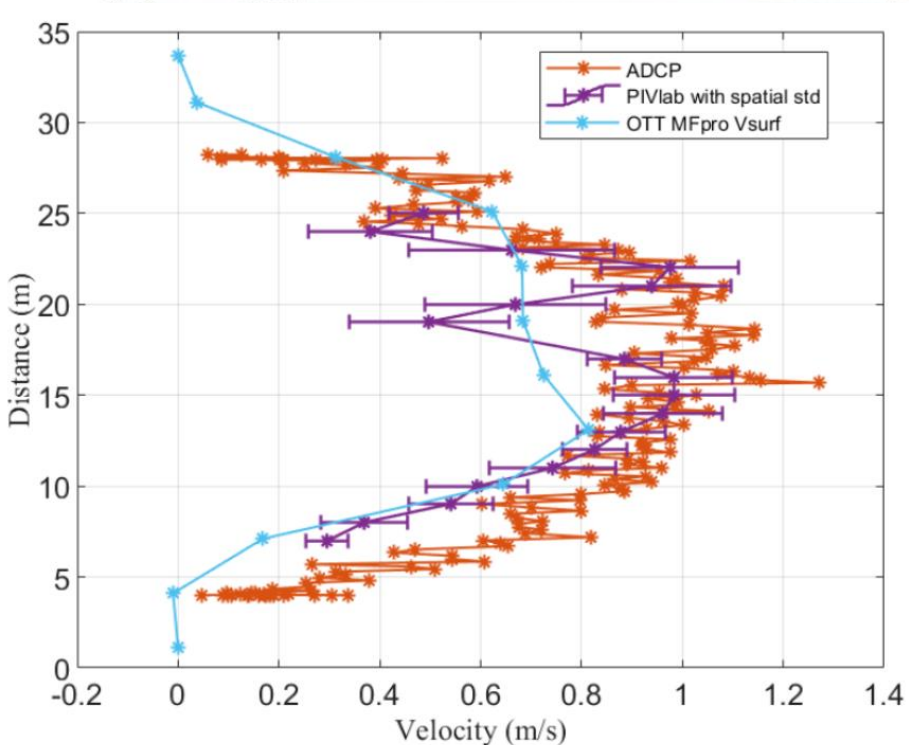
UAS bathymetry- Impact

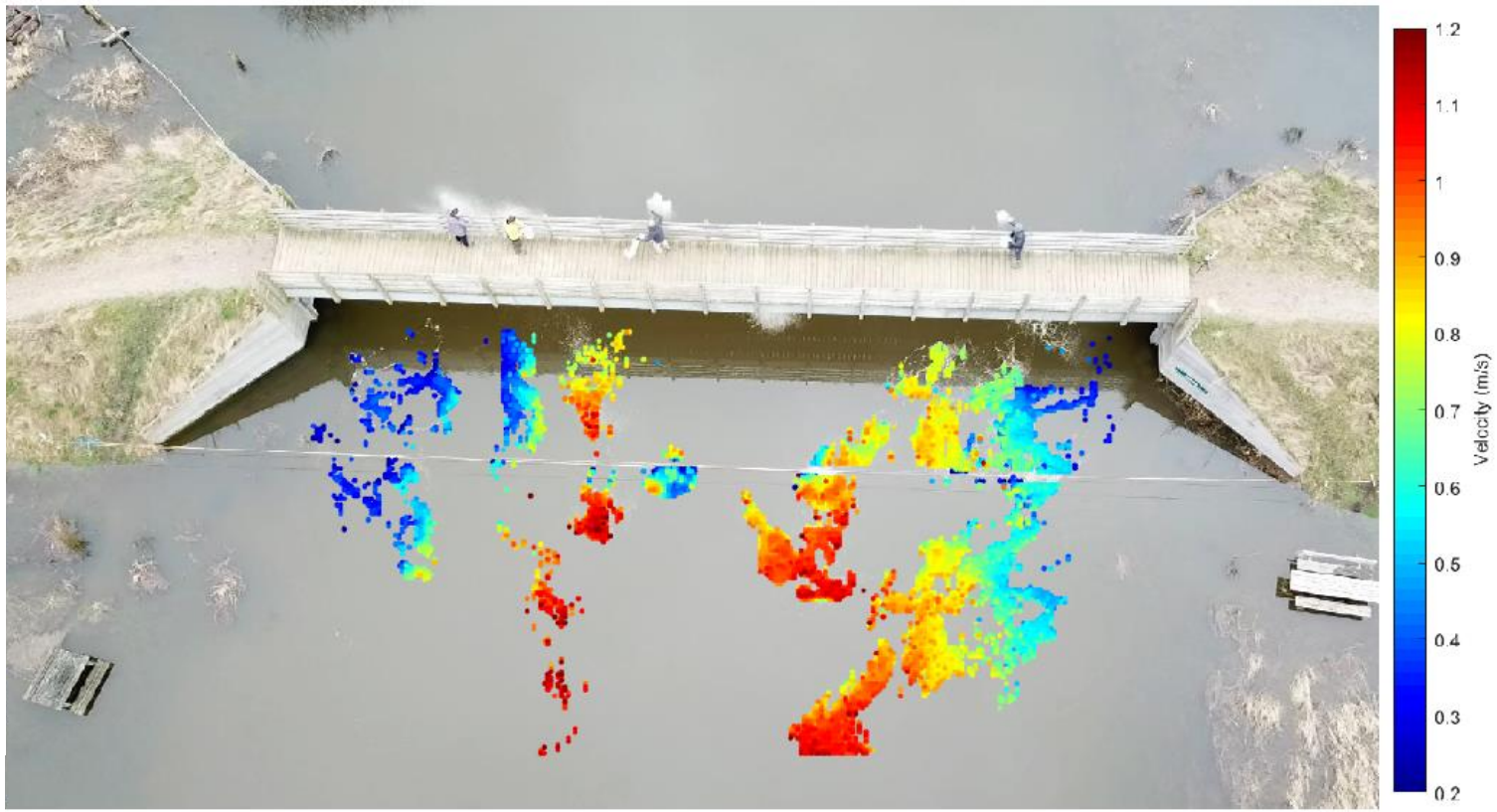
- WSP / Drone Systems are commercializing the workflow
- First cross section surveys carried out on a commercial basis in spring 2021
- Traditional surveying of one cross section in Gudenå-type rivers costs 5000 DKK – GPR can cut this cost by factors of 2-3
- GPR has unique capability to see through vegetation – sonar fails here and lidar will likely fail too
- Combination with lidar for the dry portions of the cross section
- Limitations
  - GPR only works in freshwater (EC less than 1000 micro-S/cm)
  - Airborne GPR is not effective for shallow waters (< 1m depth), because of surface clutter

UAS velocimetry and discharge - Concept

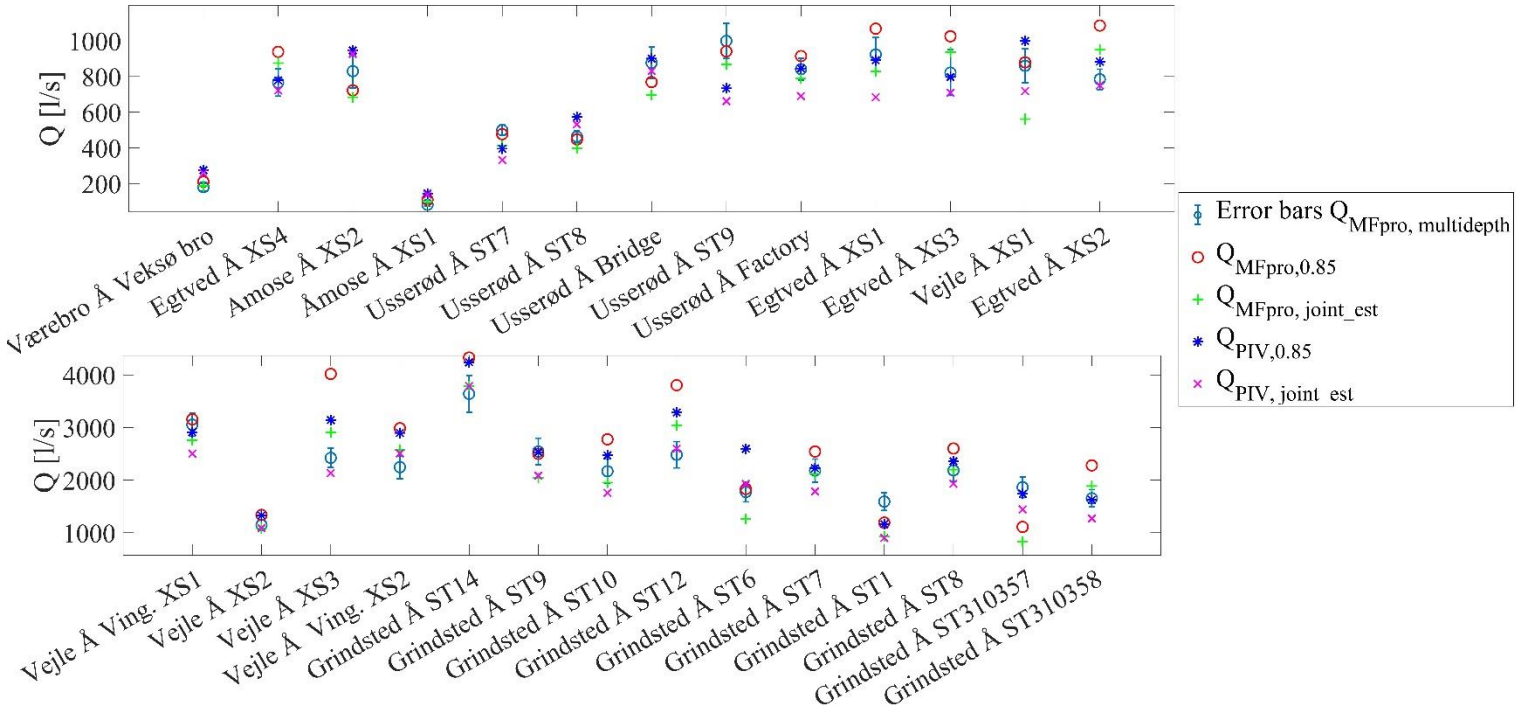


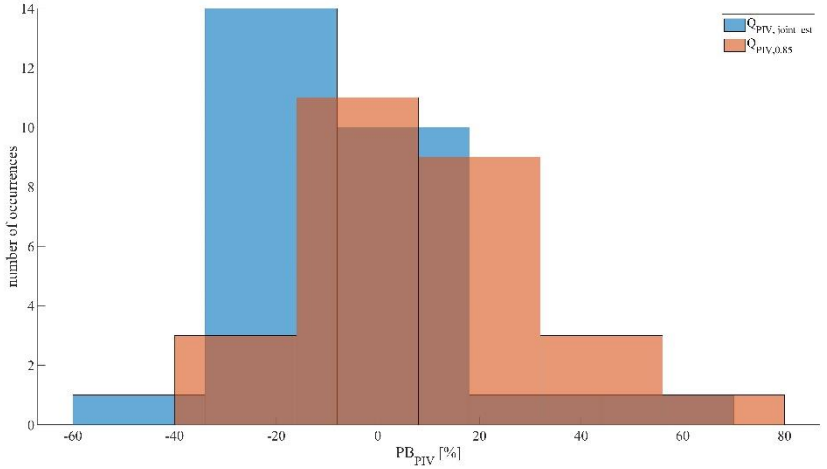
UAS velocimetry and discharge – Example Gudenåen - Gamle Skibelundsvej - Bjerringbro

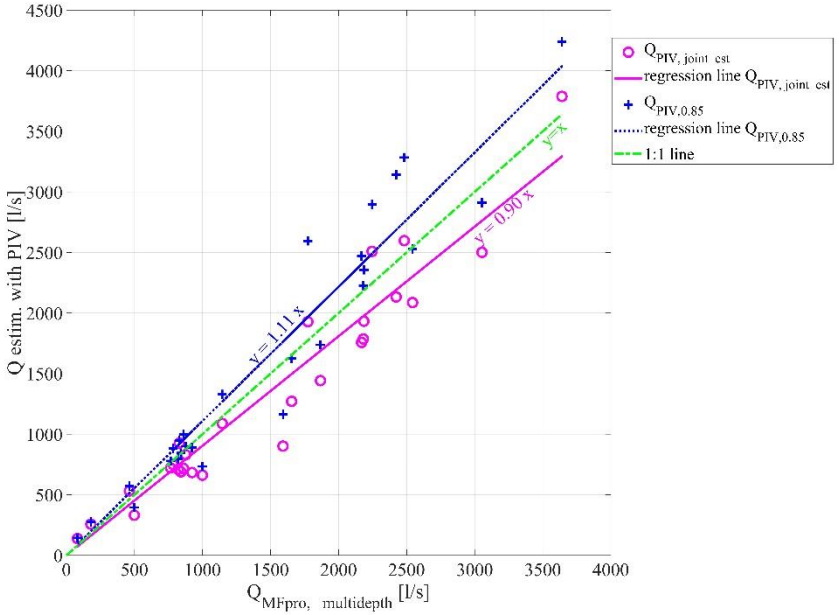




UAS velocimetry and discharge - Results





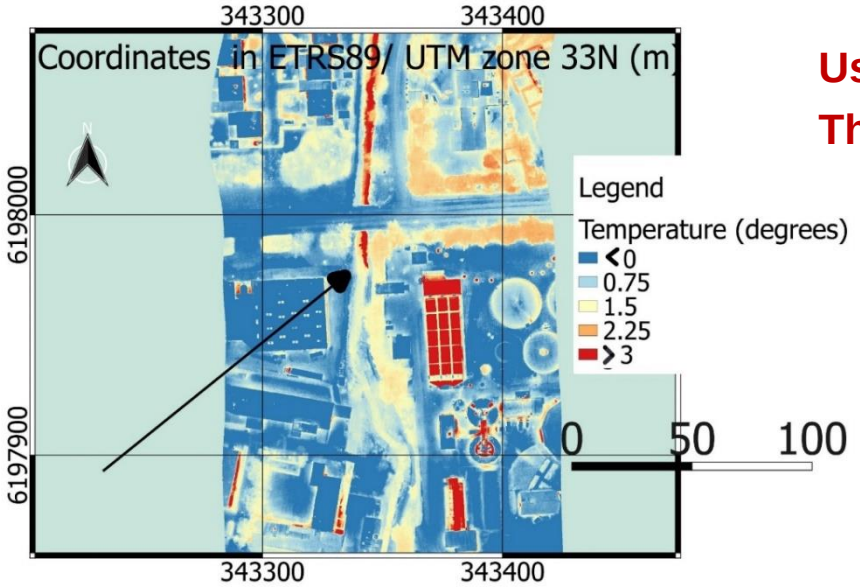


https://doi.org/10.1029/2020WR028266

UAS velocimetry and discharge - Impact

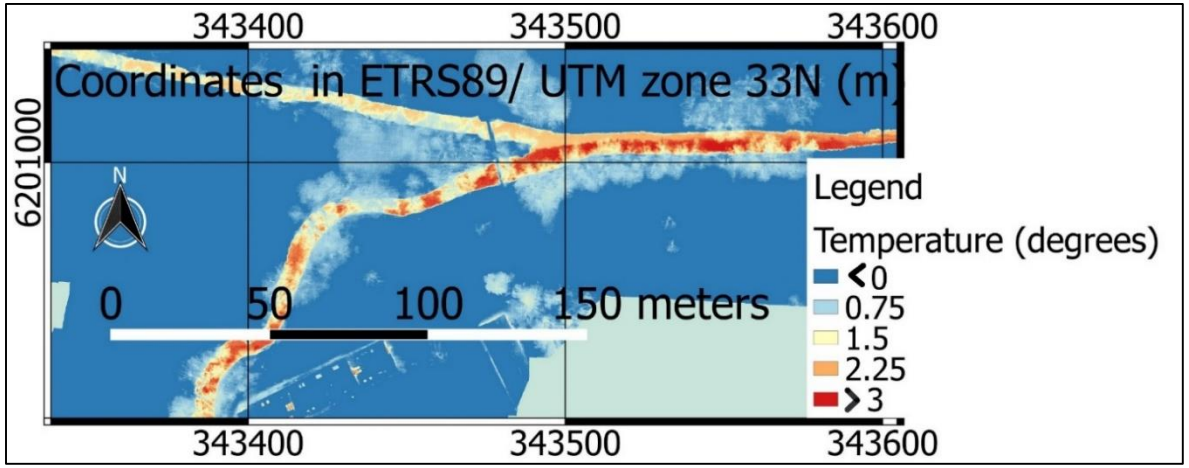
- We can get discharge with < 20% standard error from drones without any ground intervention except seeding
- Accuracy is not (yet) good enough for river gauging, but the technique has potential for
  - Hydrologic model calibration
  - Estimation of dilution of contaminant loads
  - Ecosystem status assessment
- The main bottleneck for improved accuracy is the complex relationship between surface velocity and bulk velocity in small and vegetated streams

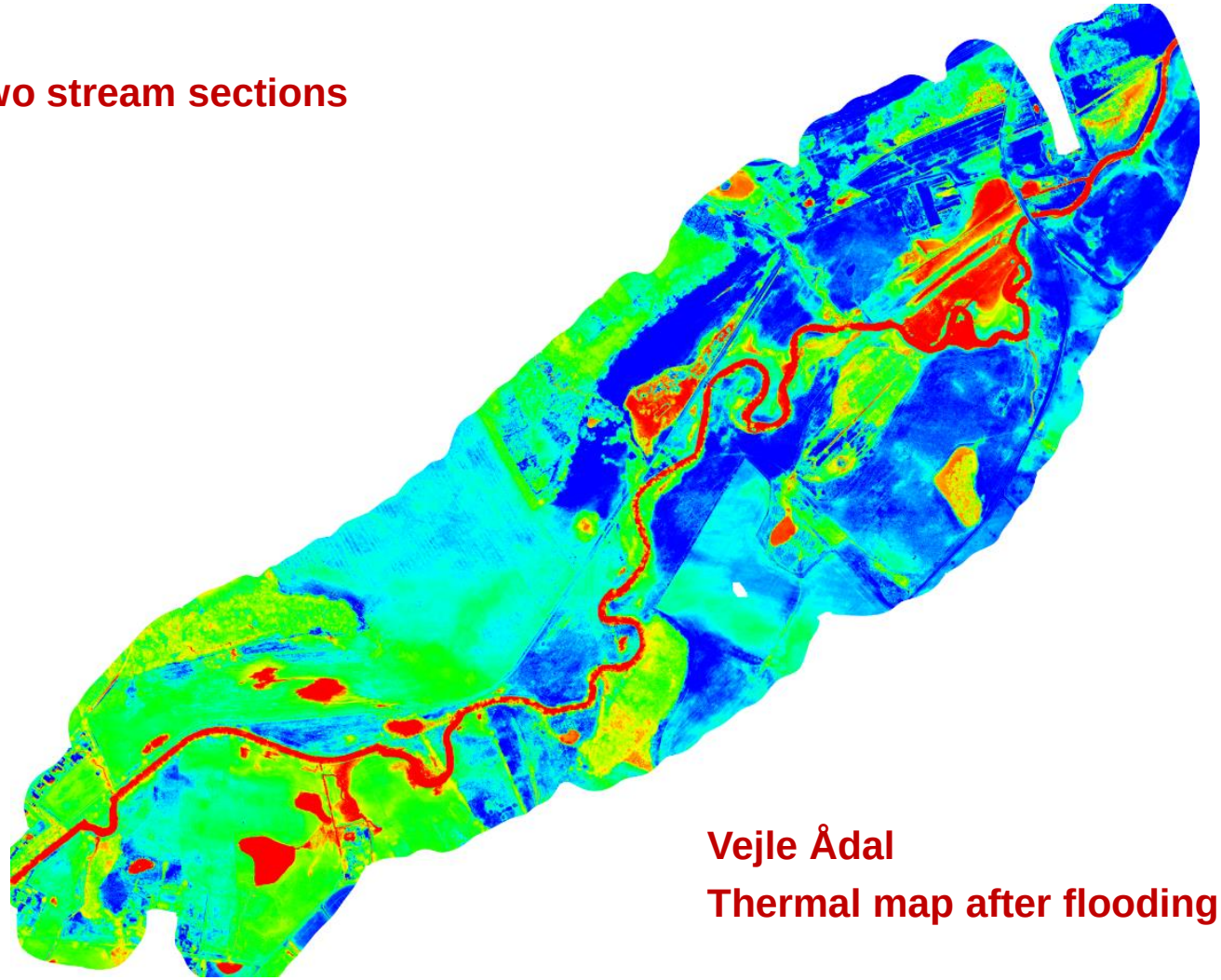
UAS Thermal mapping



Usserød Å

Thermal maps of two stream sections





Vejle Ådal

Thermal map after flooding

UAS thermal mapping - Impact

- Significant potential for highres surface water extent mapping / flood surveillance
- Effective tool to track unknown inlets – tile drains, pipes etc.
- Effective tool to map mixing processes in rivers and streams

- Thermal accuracy not good enough to directly map groundwater inflow to streams in most situations, as we are seeing water surface temperature, not sediment temperature

Conclusions

- Water surface elevation, bathymetry, discharge and water temperature can all be mapped at high spatial resolution using UAVs
- Riverscapes workflows have been commercialized and have spawned new applications and business opportunities
- Significant unexplored potential exists for the use of the new datasets in a wide range of applications – contact us if you have an idea – we are always interested!

UAS Hydrometry – Pro

- Efficient field procedures – low cost
- High spatial resolution and coverage
- Contactless remote sensing – no vulnerable in-situ installations

UAS Hydrometry – Con

- Accuracy for UAS discharge not (yet) at par with traditional in-situ
- Data processing workflows somewhat more complex compared to traditional in-situ

Outlook – the future of UAS hydrometry

- We are at the forefront in UAS hydrometry right now – also internationally
- In order to keep momentum, we need to make sure that the technology is used and creates value beyond the university
- Regulation and legal monitoring requirements need to be adapted and take into account the new technical possibilities from UAS hydrometry
- Payload hardware and low-level processing software need to be maintained by a commercial partner
- Main technical challenges in the future
  - Improved UAS velocimetry with (partial) penetration into the water column – laser Doppler technology holds significant promise
  - UAS bathymetry workflow for coastal areas based on lidar – will open up a new application area

Thank you for listening – Questions welcome!

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