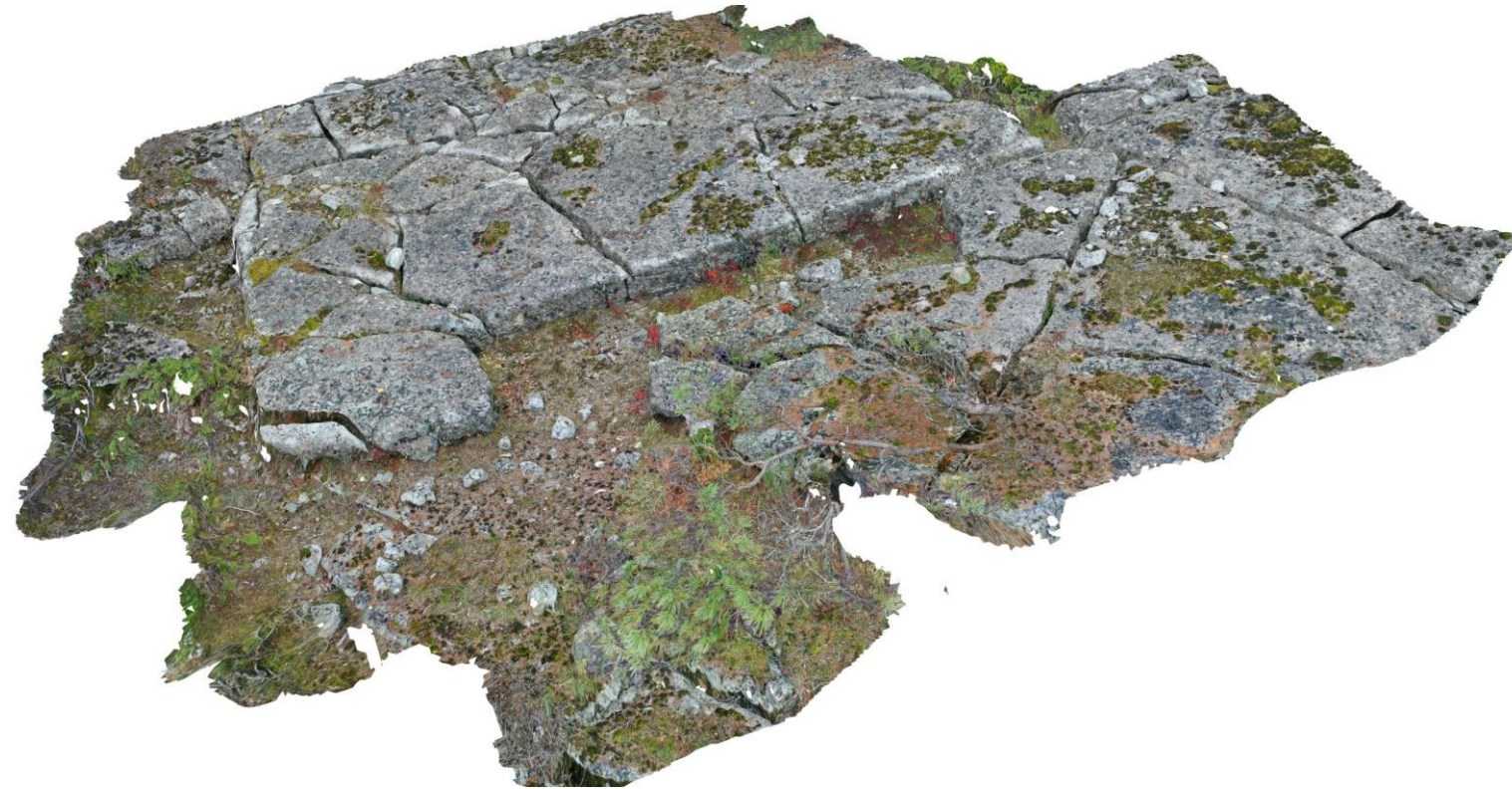


Distribution and characteristics of glaciokarst on the island of Gotland, Baltic Sea - its role on groundwater recharge and sensitive wetland ecosystems

Mikael Erlström et al.



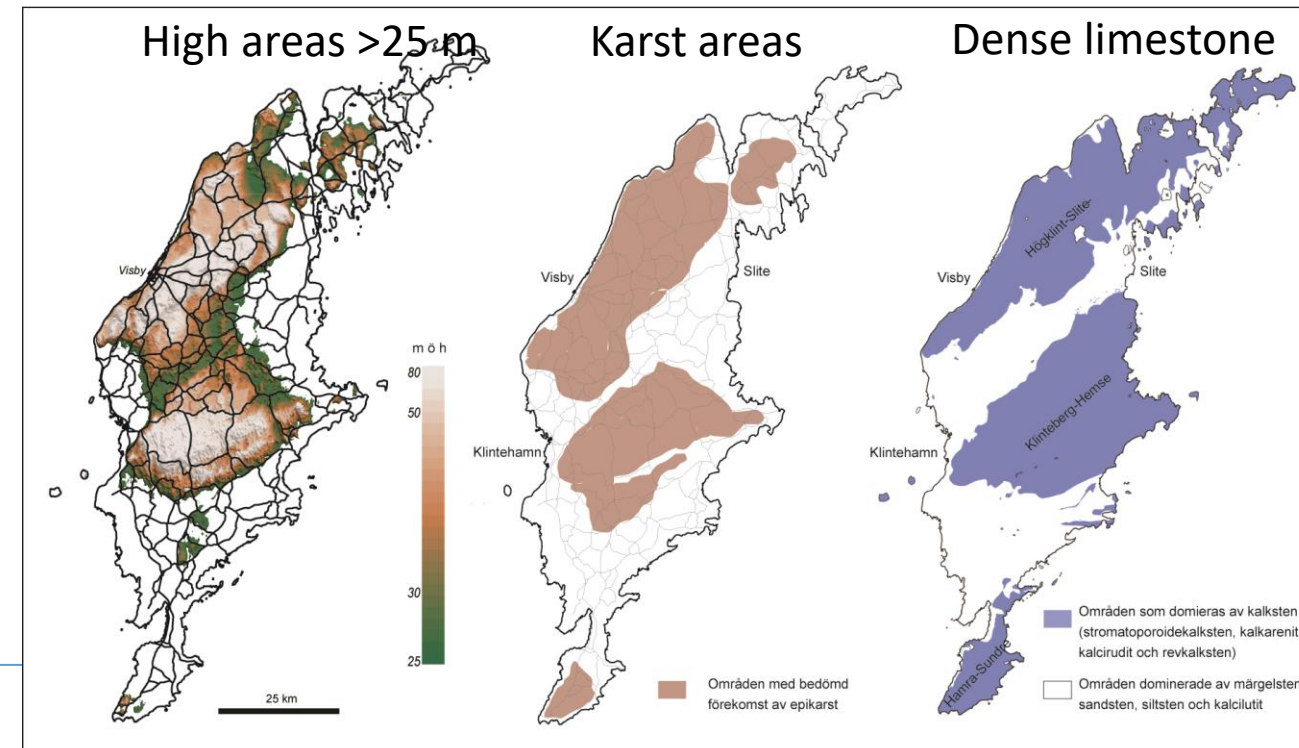
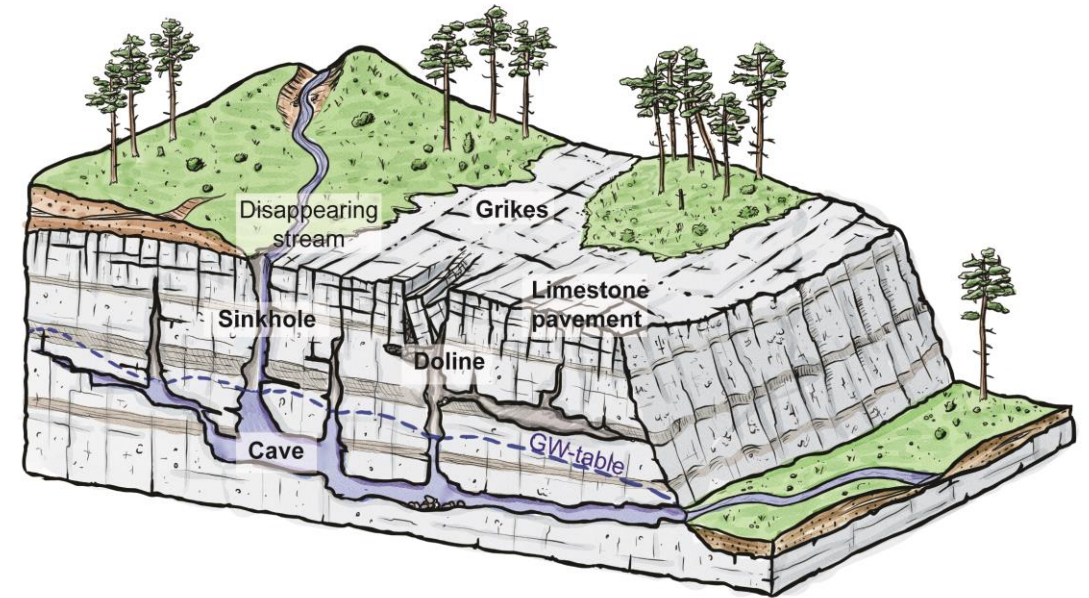
Background and Aim

- Sinkholes, dolines, grikes and limestone pavements are common karst features on the island of Gotland.
- The karst on Gotland is juvenile in comparison to mature karst areas in e.g., south Europe, but still plays an important role in groundwater recharge and subsurface drainage as well as providing unique habitats for fauna and flora.
- This study, including both biologists and earth scientists, highlights the importance of mapping and quantifying karst with aspects to groundwater recharge, surface runoff and the dynamics of karst-influenced sensitive wetlands.
- The study, was initiated from an increasing number of questions regarding karst and its importance for the sensitive wetlands as well as for the groundwater recharge protection of the groundwater.
- The final aim is to provide a comprehensive map, and database as well as achieving a mutual knowledge platform of the karst on Gotland.



Geological Setting

- The bedrock on Gotland consists entirely of Silurian sedimentary rocks dominated by different types of limestone and marlstone.
- Three main areas of dense and pure limestone coincide with topographic highs, up to c. 80 m above sea-level. The limestone consists mainly of planar beds of stromatoporoid limestone, biocalcarenite and scattered irregular bodies of stromatoporoid bioherms. Karstified limestone occurs primarily in the higher terrain (>c. 25 m a. sl.)
- Relatively softer marlstone subcrop the limestone. Thinner beds of marl and marlstone are also found scattered within the limestone-dominated sequences.
- Marls and marlstone dominate the bedrock in the lower lying areas on Gotland.



Karst structures on Gotland

- The karst on Gotland is classified as glaciokarst. Grikes and limestone pavements are the most common karst features. Although, less well documented, caves and subsurface channels also contribute to the complex hydrogeology in the bedrock.
- The karst is interpreted to have primarily been formed, before the Pleistocene when the landscape was humid and covered with acidic organic soils.
- Glacial erosion and postglacial karstification have also played significant roles in sculpturing the epikarst morphology we see today. Karst on Gotland



Characterization and Mapping

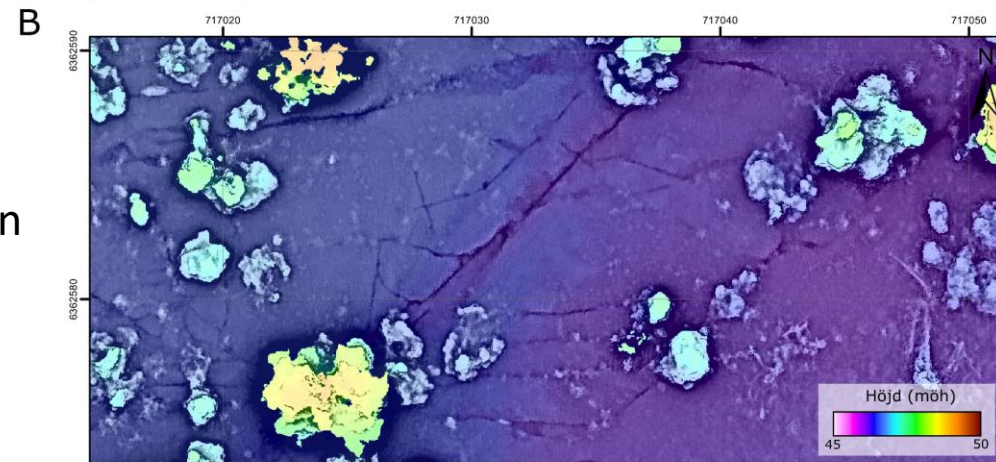
- Quantitative and qualitative characterization of karst was performed in four test areas on the island of Gotland, using high resolution aerial photographs acquired with a Mavic 2 Pro-drone from an altitude of 20-25 m.
- Over 3400 karst objects, mainly grikes, were mapped in the four test areas covering c. 18 hectare.



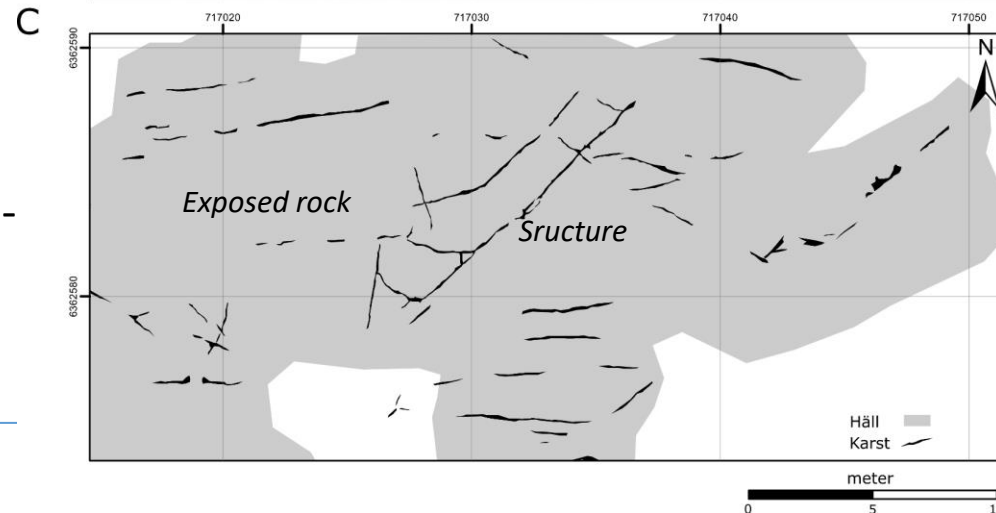
Drone photo



Elevation model

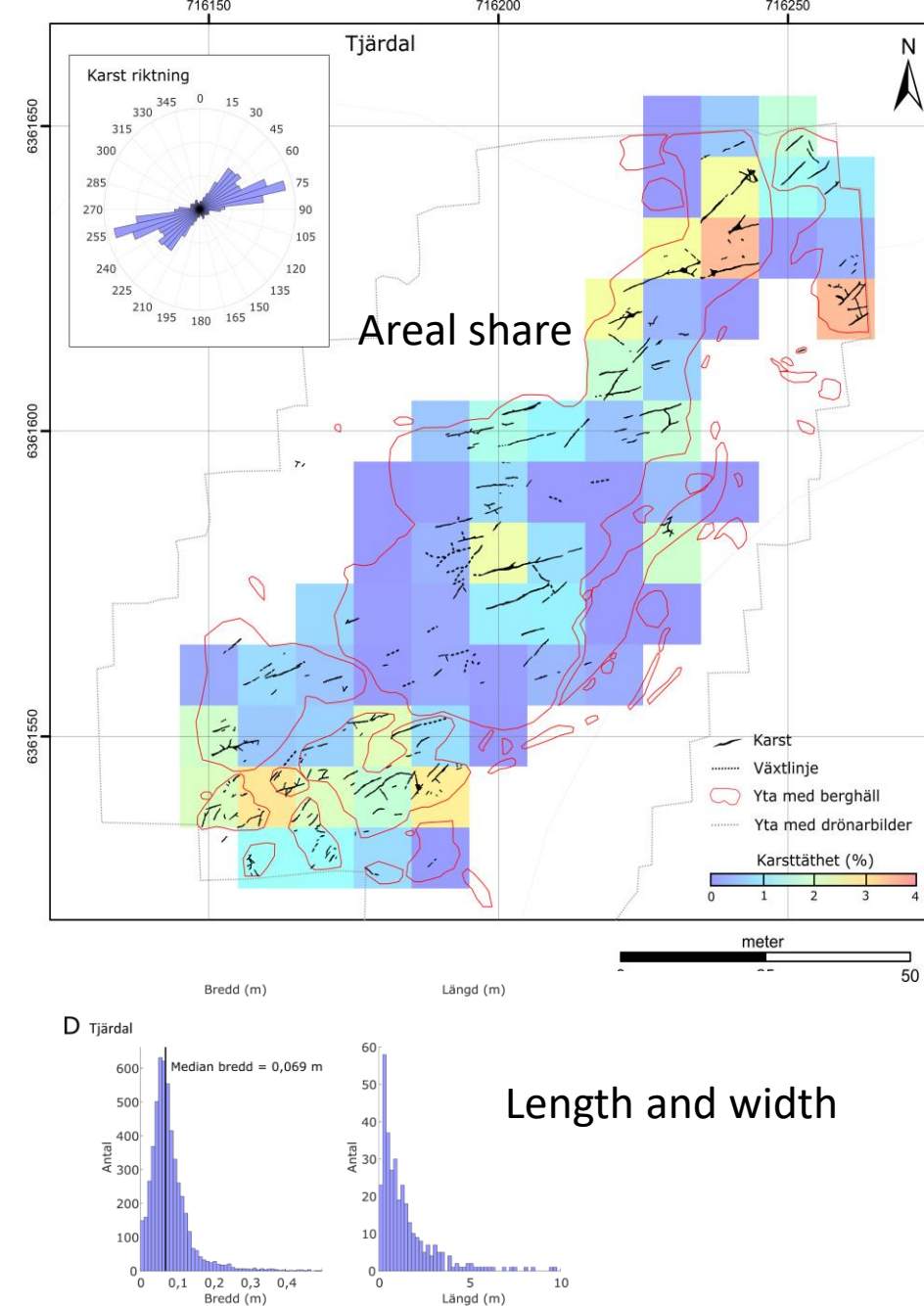


Interpretation



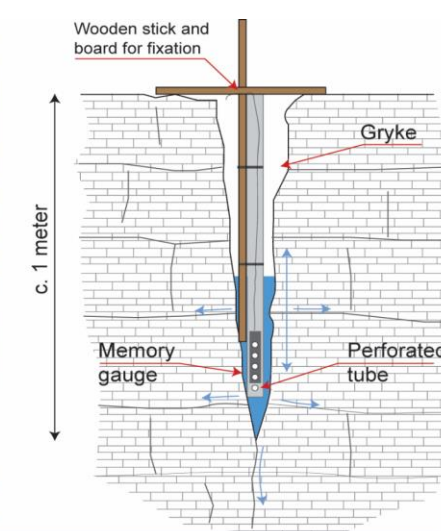
Distribution and areal share of karst

- The images were analysed in GIS-software to provide a statistical evaluation of length, width, and relative area with karst.
- The elevation model, using a Topcon GNSS-system, supported the quantification as well as visualization of the karst features in the terrain.
- The relative amount of open karst is up to c. 6% of the exposed bedrock area. The average open width is 0.15 m, and the length of the individual grikes rarely extend five meters. Most being between 0.2 and 0.8 m long. The orientation of the grikes varies between sites but NE-SW and NW-SE orientations dominate.

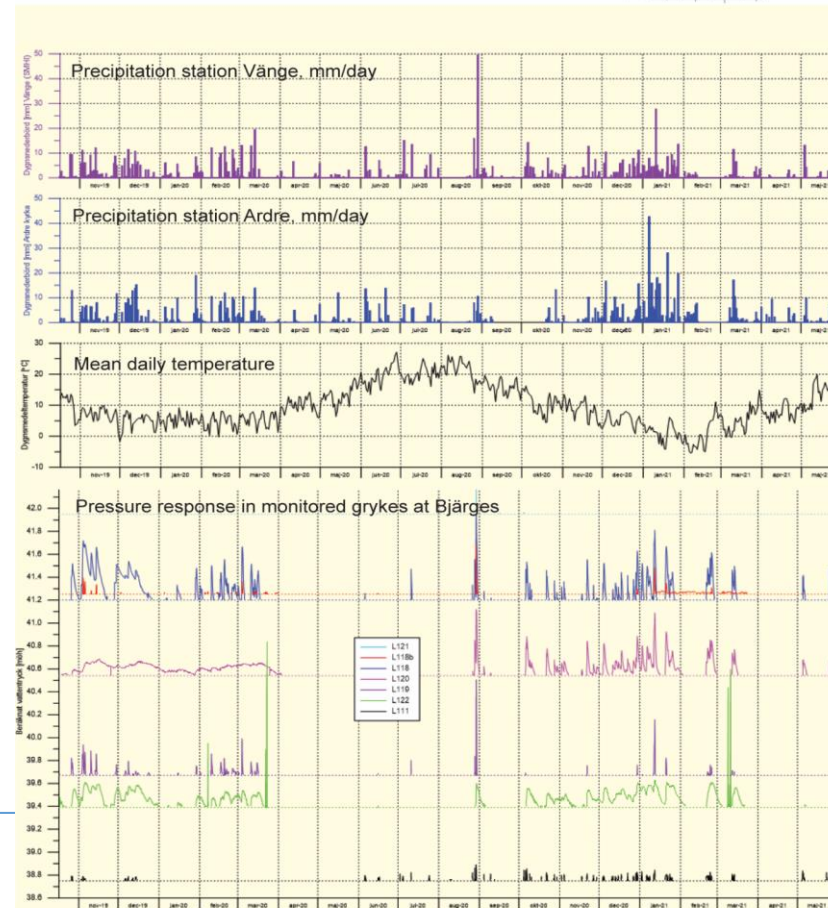


Hydrological monitoring

- One task and challenge in our study has been to monitor and interpret the interaction between precipitation and the detainment of meteoric water in the epikarts and its role as hanging aquifer.
- The water level in the grikes was monitored by using sensitive pressure gauges mounted inside perforated PVC-tubes (45mm ID) that were placed in eleven 1.0-1.5 m deep grikes in two of the test sites.
- The pressure response was compared with site specific real-time precipitation data from November 2019-May 2021.



Pressure gauges
in grikes

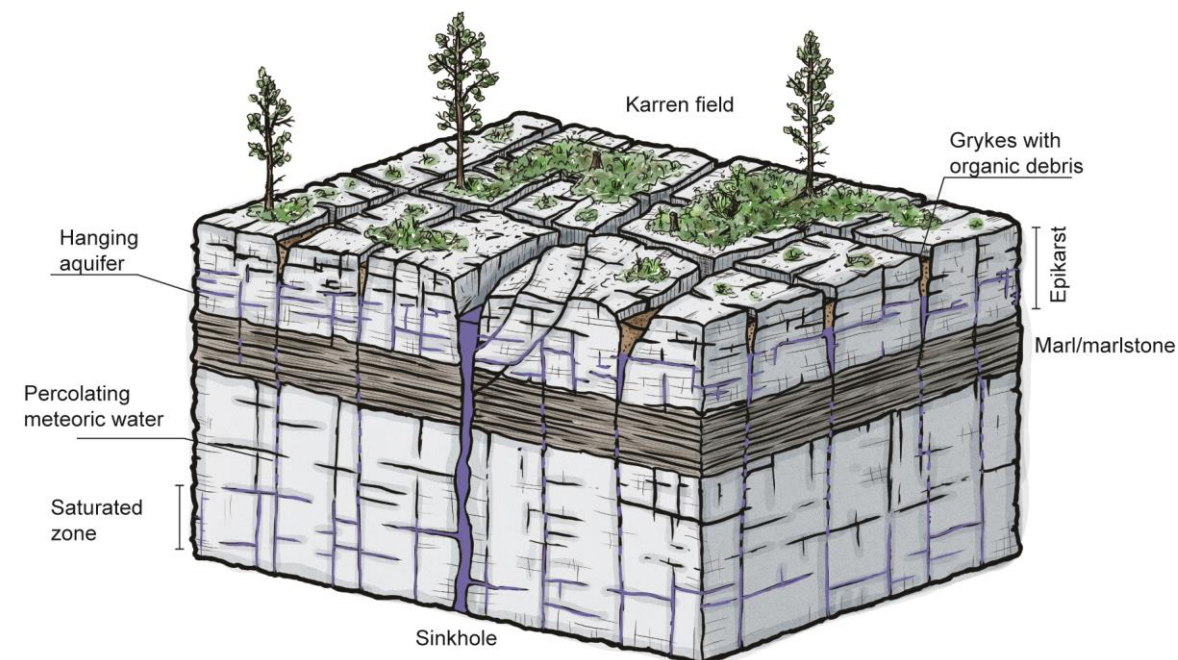


Precipitation
and temperature

Pressure response

Groundwater recharge and karst

- The results show a clear correlation with precipitation and pressure response in the monitored grykes.
- Some of the grykes show a rapid declining pressure indicating high drainage capacity, either laterally as surface run off or downwards via subsurface channels.
- In others the pressure declines slowly as the meteoric water stays in the grike for a longer time. Thus, contributing both to a percolating supply of meteoric water to the saturated zone as well as nourishing the specific habitats that thrive in these settings.
- Since most of the groundwater recharge is in the karstified higher terrain with limestone, mapping and quantification of karst is an important part of the groundwater modeling. Knowledge on karst also enables customized groundwater protection plans.
- The results so far have given valuable input to the groundwater models, especially the relative amount of karst. However, there are still much work to be done, such as quantifying the subsoil karst.



Karst influenced wetlands and ecosystems

- The limestone pavements with a network of "grikes" and "shattered pavements" offers a variety of microclimates allowing the establishment of complex vegetation consisting of a mosaic of different and unique habitates.
- The grikes provide a cold humid microclimate where shade-tolerant vascular plants thrive. In shady, moist hollows, drought-sensitive and shade-loving plants such as certain ferns thrive, while drought-tolerant species, such as sedges, grow on the exposed slopes.
- Many of the unique temporary wetlands on Gotland are also relying on the hydrodynamics of karst, such as upwelling groundwater from saturated karst systems.



Lush vegetation of ferns, herbs and mosses in a grike



Unique occurrences of *Rivularia haematitis*



Rare occurrence of hart's-tongue fern *Asplenium scolopendrium*



Temporary retention of meteoric water in a grike

Conclusions

- The developed drone methodology have provided time-efficient mapping and the statistical evaluation have given property values of relative share, width and length of the karst structures.
- The data on relative share and verified presence of hanging aquifers provide valuable input to the groundwater recharge models.
- The work between the involved authorities has also resulted in a mutual understanding of the karst on Gotland, which facilitates especially the evaluation of the sensitive wetlands and their relation to karst.

