

Borealis

Sensor network for vehicle speed profiling on E8

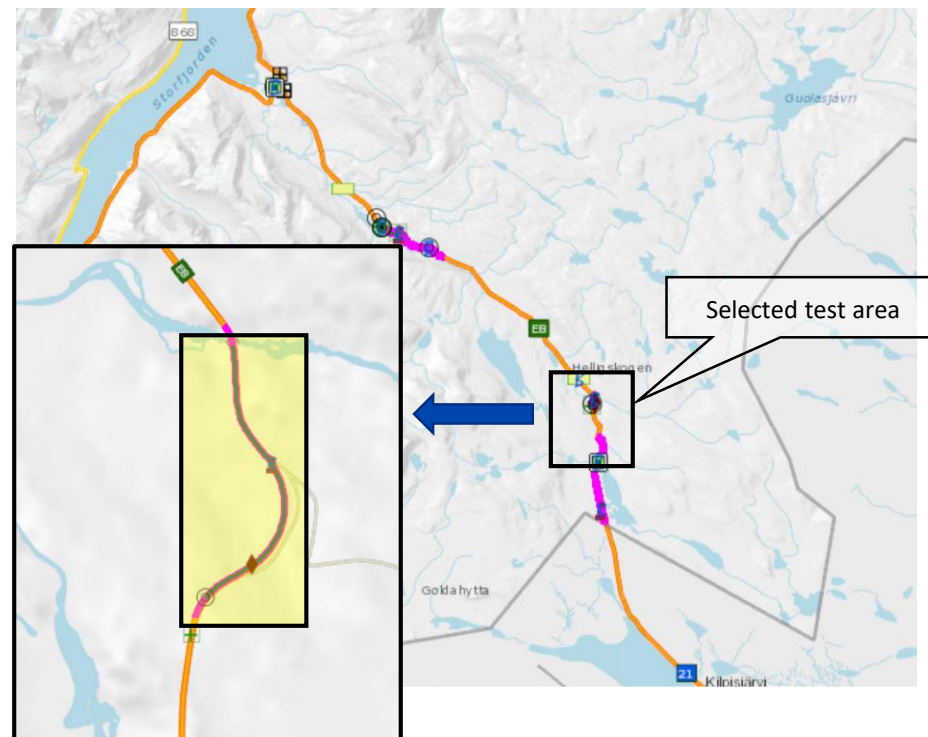
Ola Martin Lykkja, Q-Free Norge AS
2020-10-29



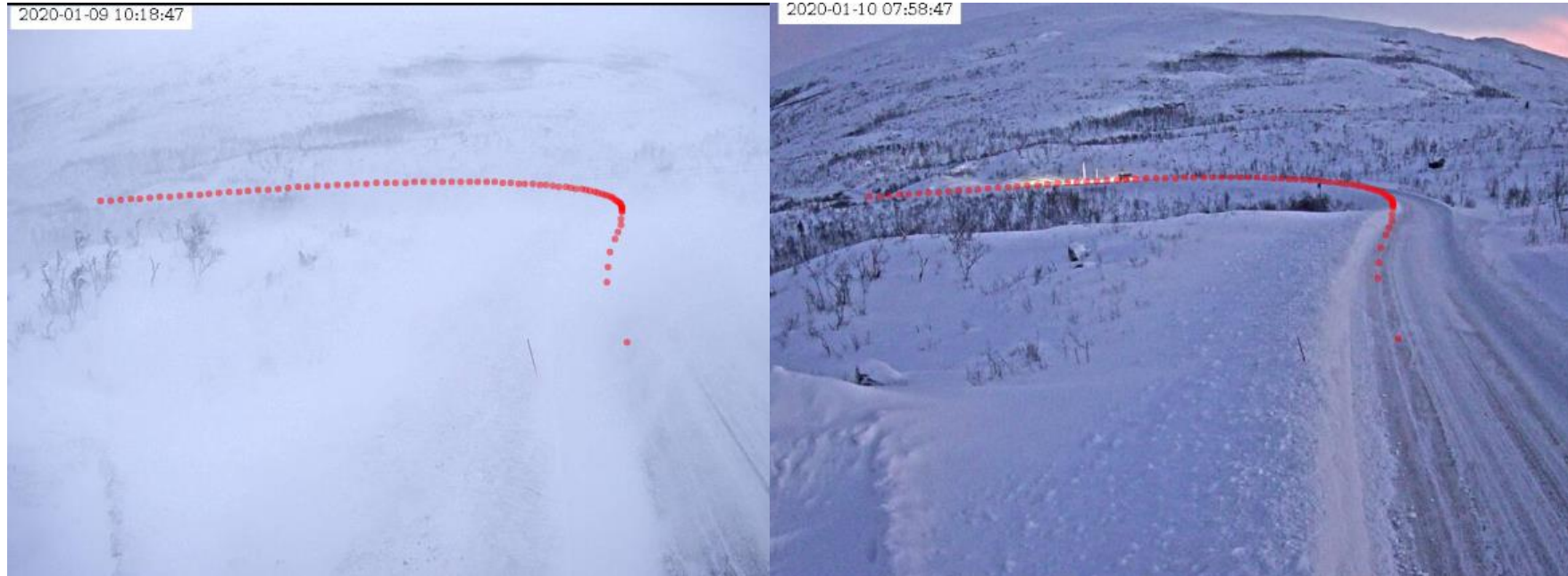
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Vehicle speed profiling

- Gardeborgbakken is a hill of 700 meters in the upper part of E8, right before the road enters the maintain plateau.
- Environmental conditions in the winter can make it difficult for vehicles to climb the hill because of gradient and curves.
- Q-Free was selected by Statens vegvesen in 2018 in an innovation competition to demonstrate the use of sensors embedded in the road surface to create speed profiles of vehicles and detect stopped vehicles.



Winter conditions



Sensors overlay on camera image



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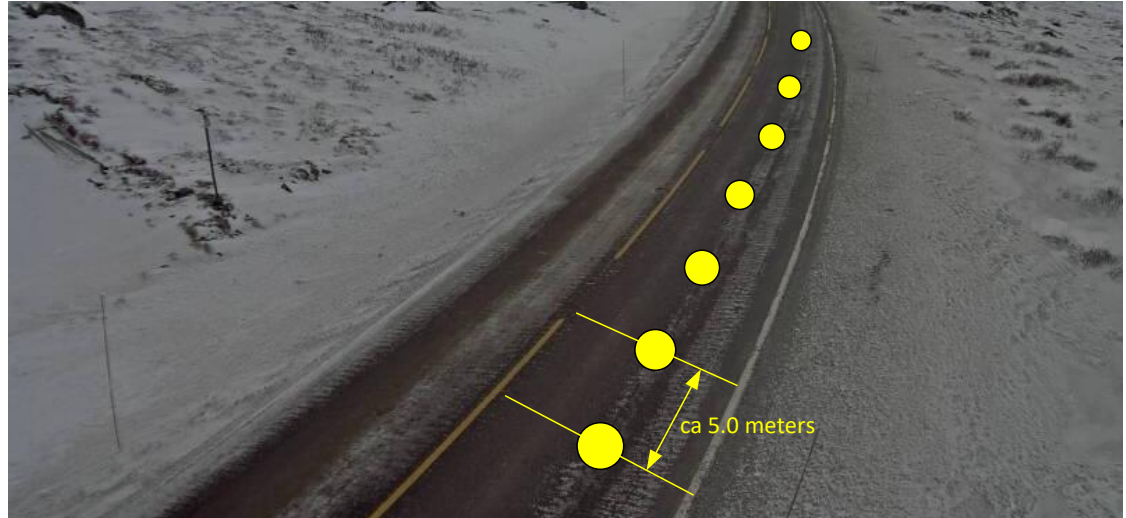
Sensors

- The sensor is a software retrofitted parking sensor from Q-Free
- Detects vehicles above sensor
- Magnetometer (all weather !)
- Radar
- Battery – 5-7 years
- Communicates with a base station in IMS band
- Security
- Privacy

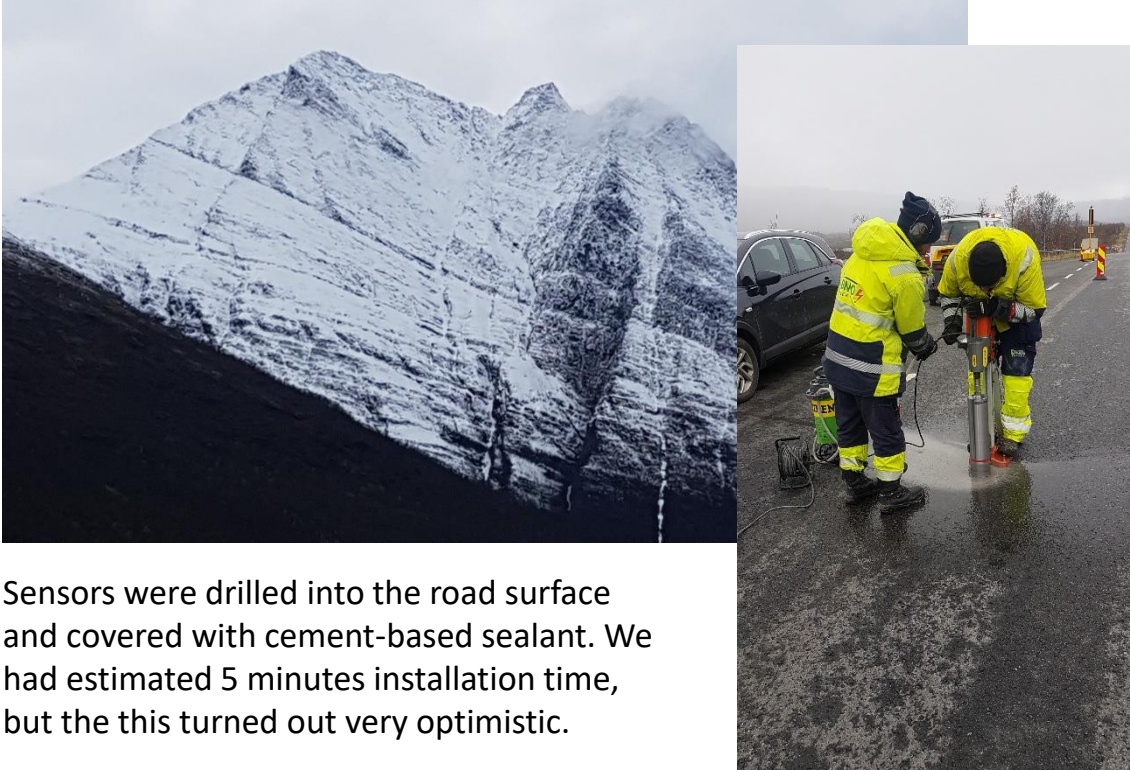


Sensor field layout

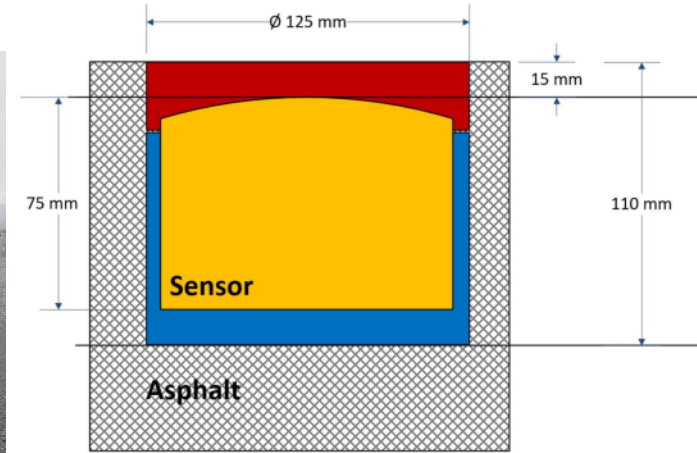
- 120 sensors
- 5 meters gap
- In middle of right, uphill lane
- 600 meters is covered
- Each sensor is undersampling
- Spatial redundancy
- The collective view if the sensors gives the required resolution in space and time



Sensor installation



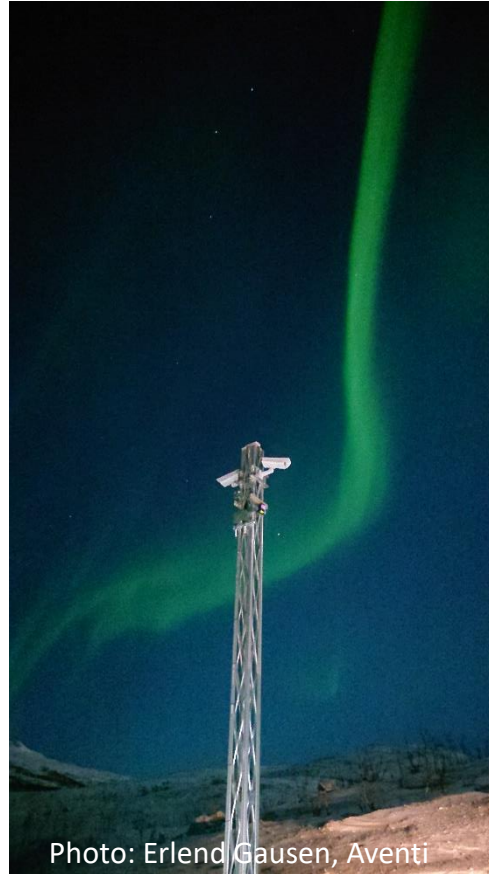
Sensors were drilled into the road surface and covered with cement-based sealant. We had estimated 5 minutes installation time, but this turned out very optimistic.



Sensors installed



Base station installation



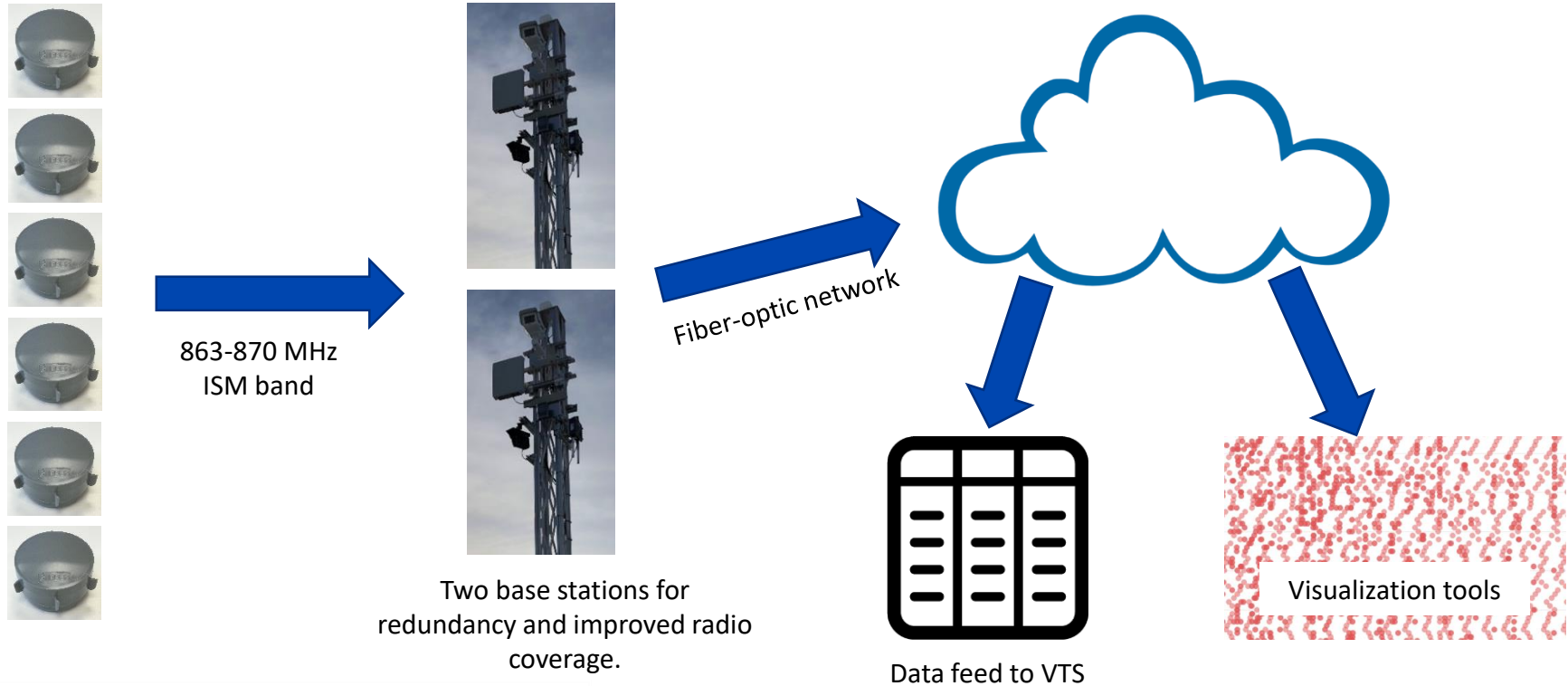
The real aurora borealis
also showed up!



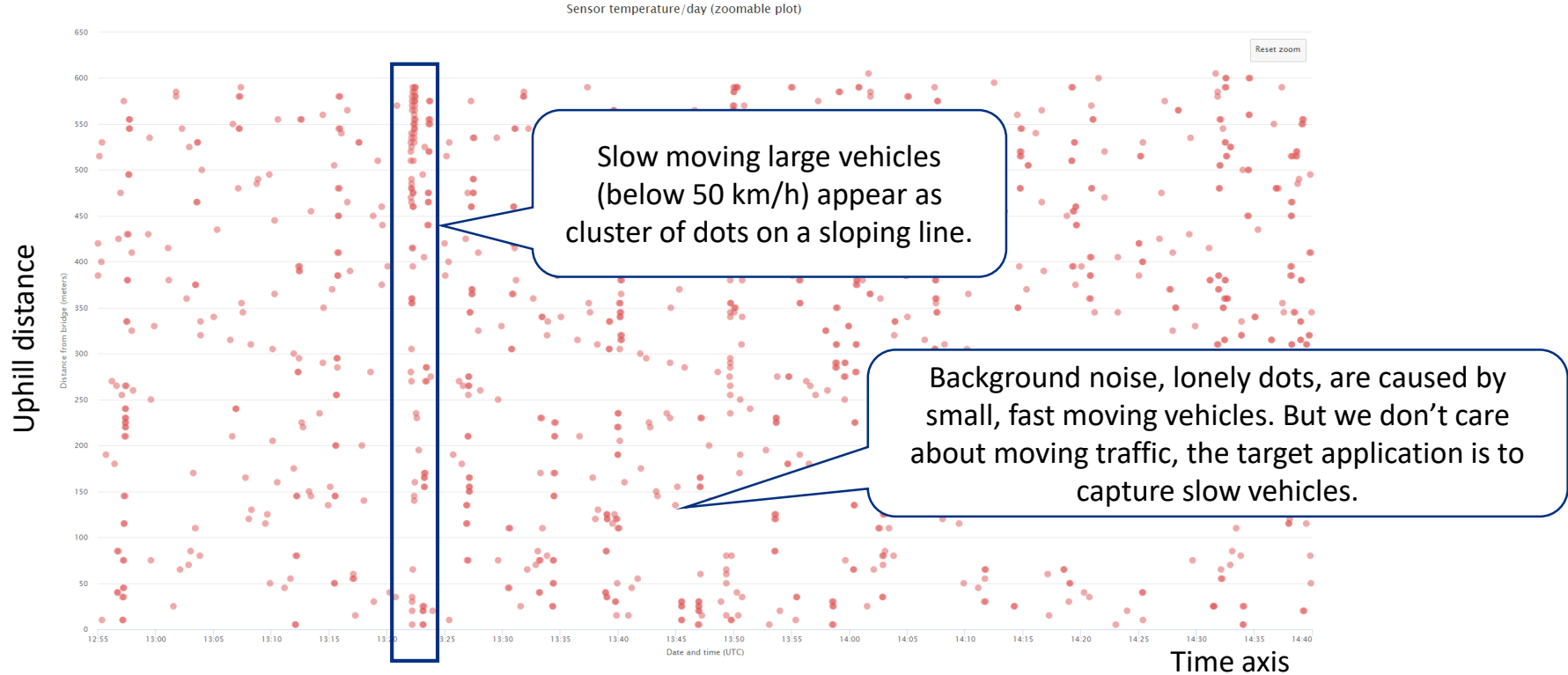
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Photo: Erlend Gausen, Aventi

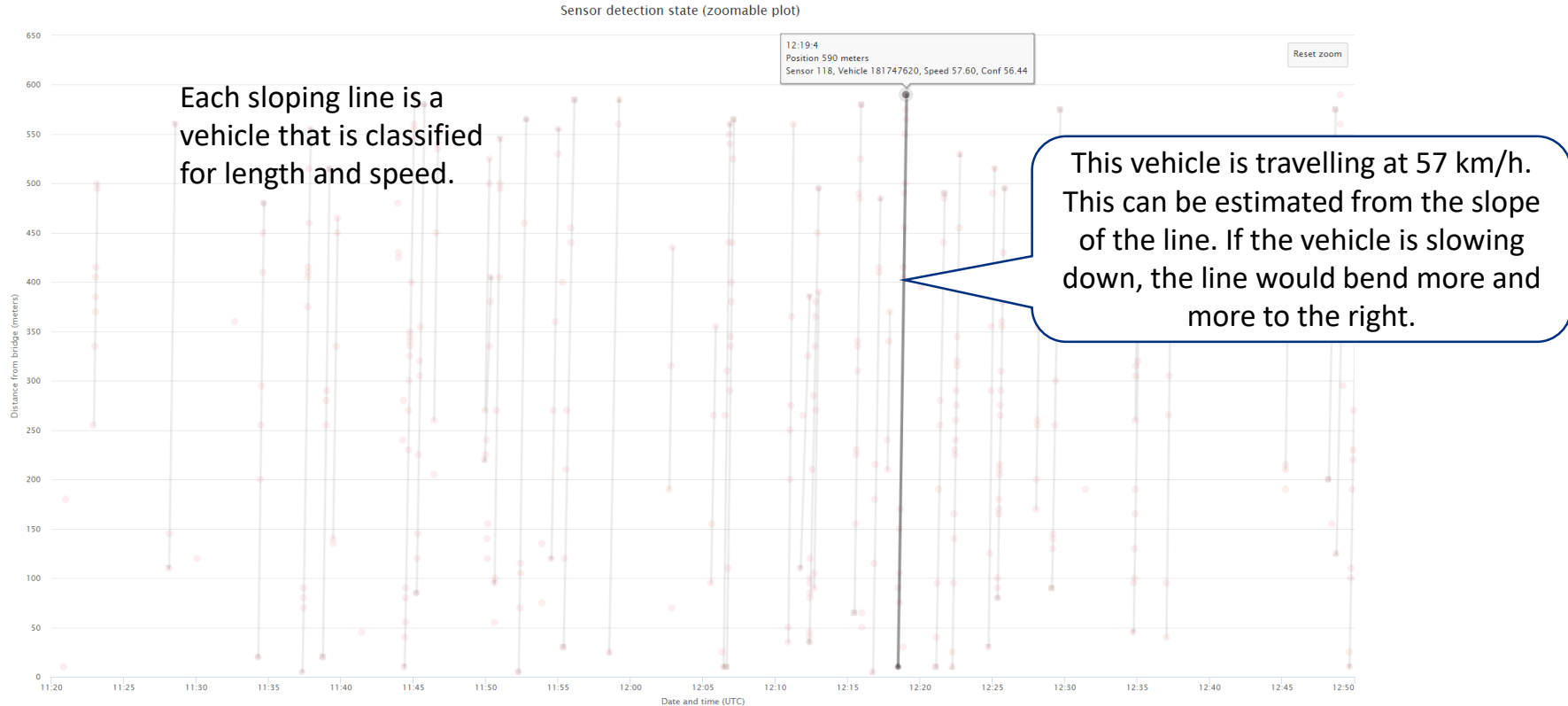
Sensor network topology



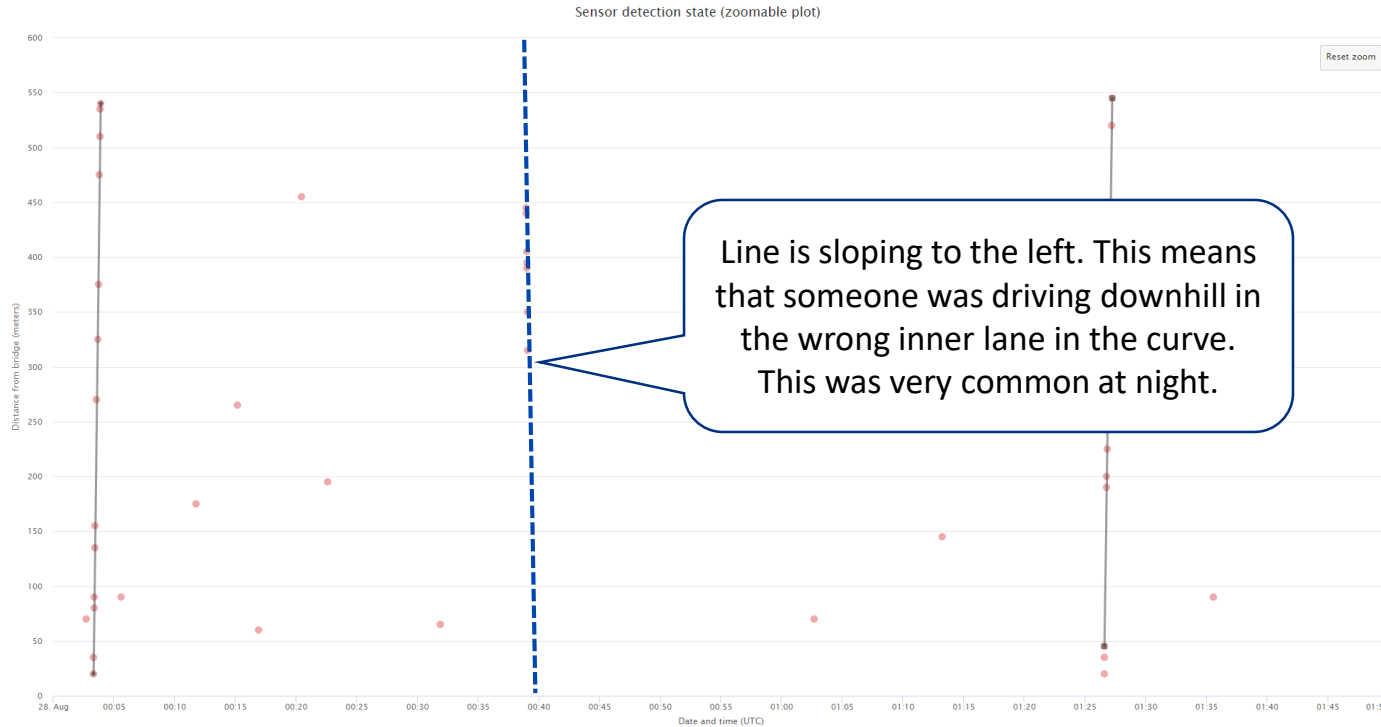
What does the raw sensor data look like?



Processed data

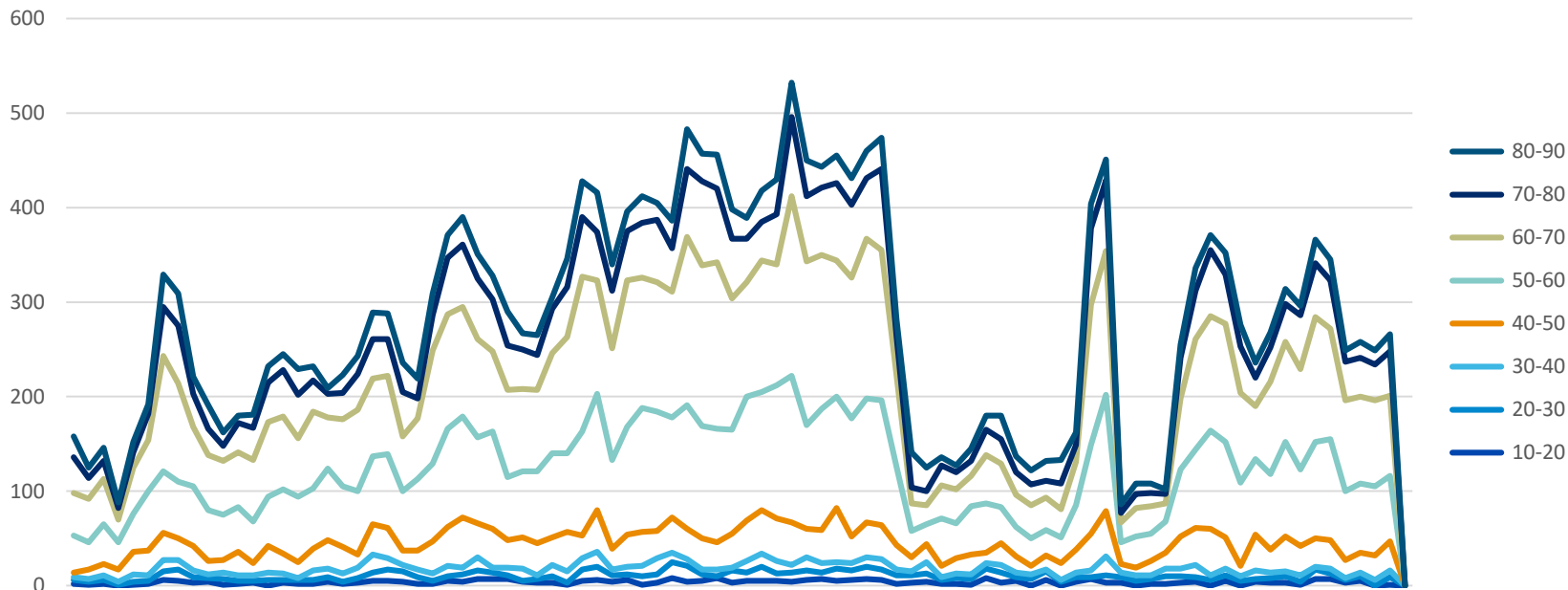


Data from night – crazy drivers



Vehicle speed statistics

Number of vehicles each day from 1 june to 28 aug by speed groups

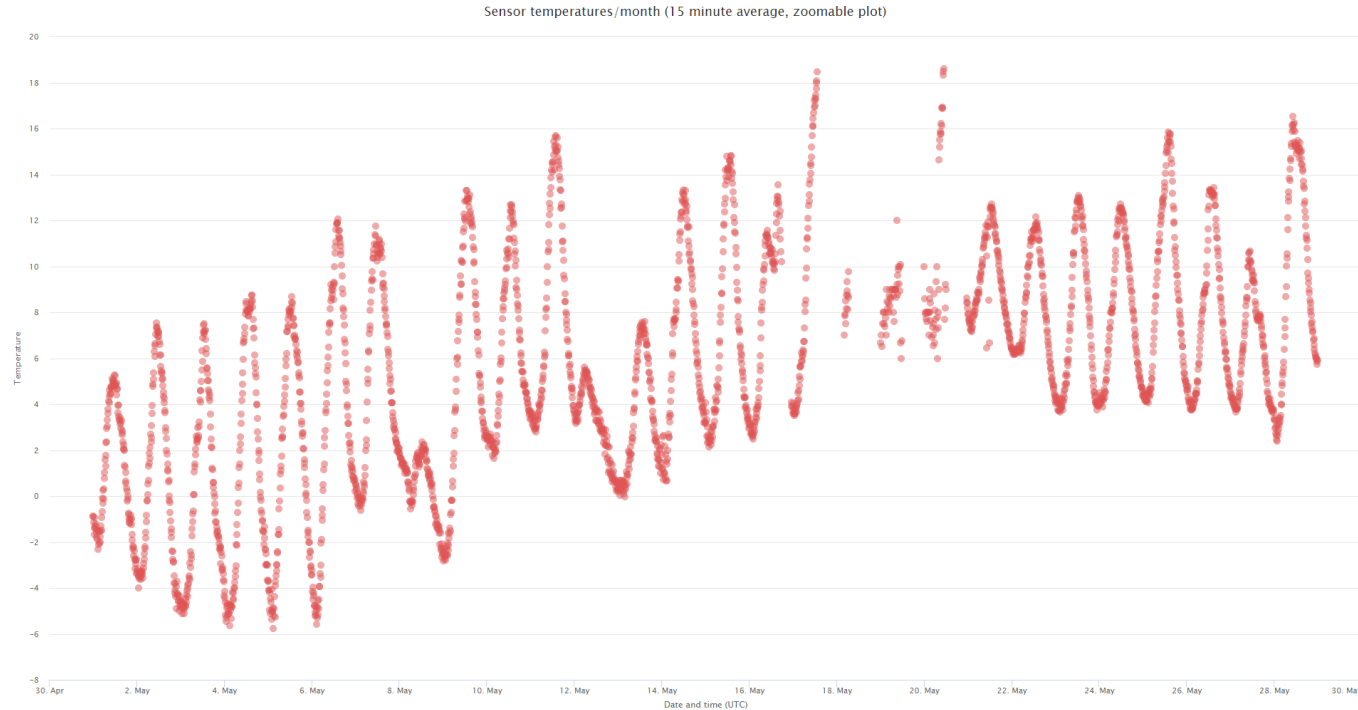


Analysis methodology

- The algorithmic challenge was to connect the dots to vehicles
- What dots belonged together?
- Particle swarm method
 - Each dot was assigned a number of probable vehicles with different speed profiles
 - For each particle, a score was calculated based on the number of matching dots
 - Particles with high score was kept and classified as vehicles
- Machine learning, artificial intelligence
 - We tried to promote a master thesis on the use of AI/ML on this problem at NTNU
 - No student took it – AI/ML was not explored
 - Scientific staff at NTNU questioned training data availability and quality
 - Just raise you hand and start now!



Auxiliary data – Ground temperature



Temperature every
15 minutes over 4
weeks.

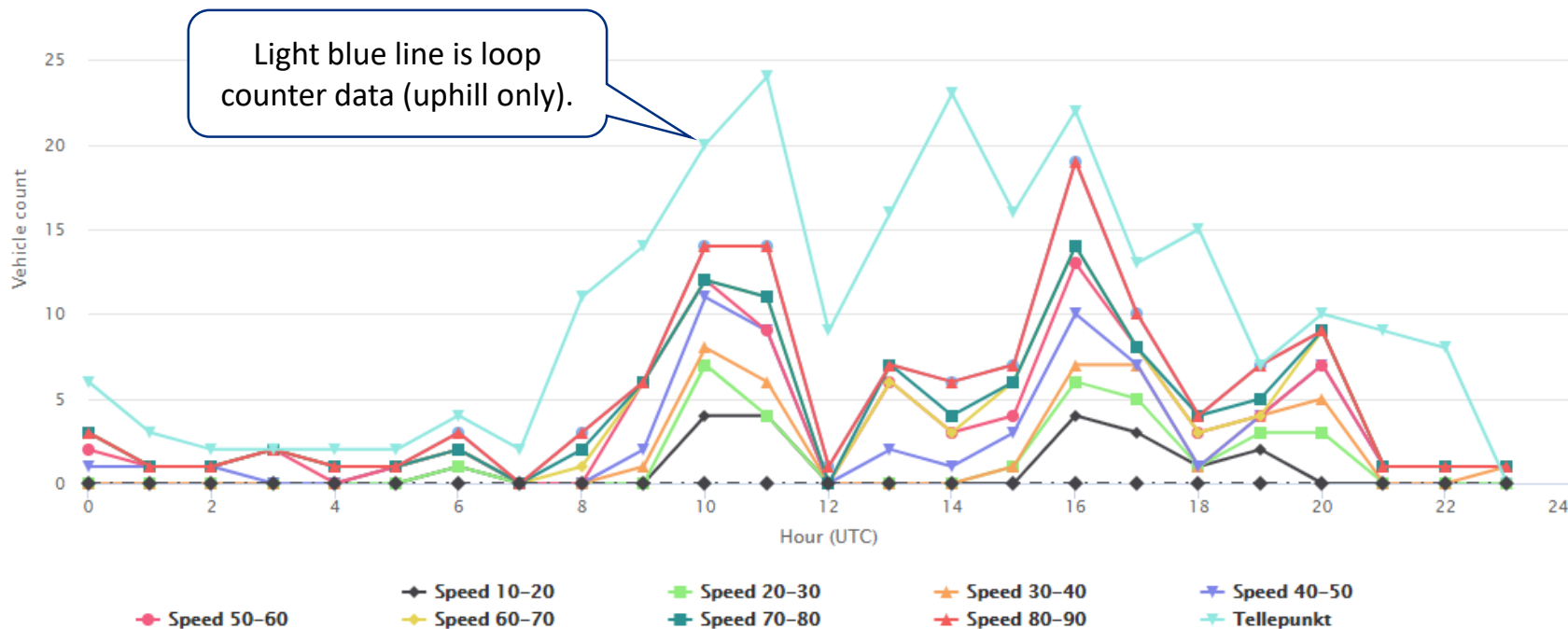


Validation – Loop data

- On the top of the hill there is magnetic loop detectors.
- For a limited time period in October 2019, we got access to detailed loop data. The data set had timestamp, speed, vehicle length and lane information.
- This allowed us to compare sensor data with loop data.
- The correlation proved to be very good, the sensor network systematically omitted a constant proportion of small passenger vehicles, but detected most large vehicles.



Validation – Loop data 24 hours (28 Jan)



Validation - Camera



Cameras was mounted on the upper pole, facing downhill. AI/ML technology was used to classify objects. It was not trained on reindeers and had a lot of false detections and a fair amount of missed detections.

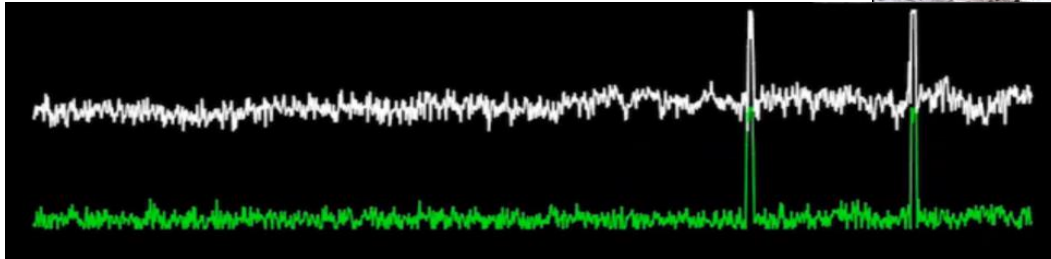
This helped us identify time where there was a vehicle on the road and we could manually look at sensor performance at that time.

However, the cameras often lagged, lost frames, and had relatively low resolution. This made it impossible to use the cameras as truth table for the sensor algorithms.



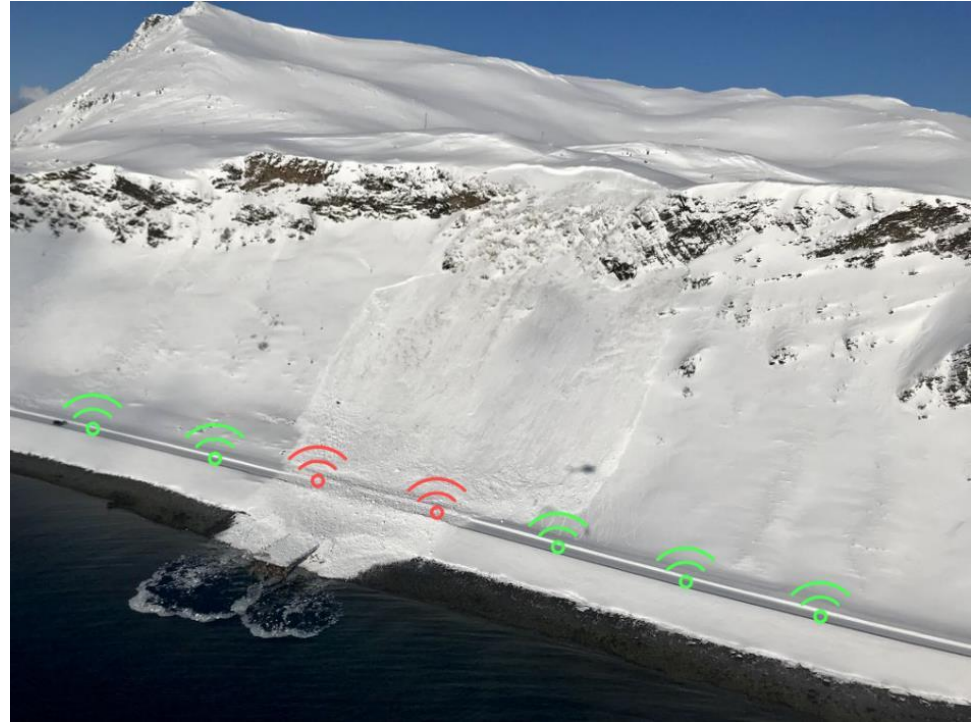
Related research in Q-Free

- Enabling the radar for contiguous use
- Parking sensor side-mounted on a tree
- Migrate to NB-IoT for communication
- Figure below shows radar peak from a passing vehicle.



Related sensor applications

- Sensors covered by deep snow in avalanche will be able to measure the snow cover (radar), but probably not be able to communicate out.
- Loss of communication for a local group of sensors may indicate avalanche.
- Other sensor could track vehicles on/out of the hazard area.



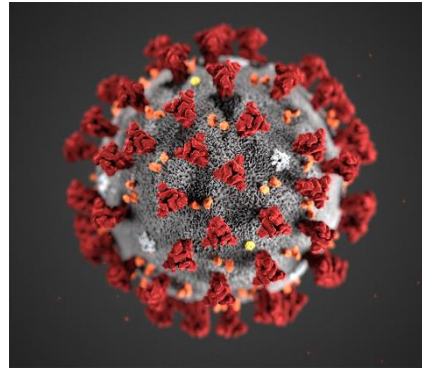
Access allocation to one-lane highways

- Sensor data can be used to estimate traffic and calculate allocation of meeting areas.



Activity in 2020 - Covid-19

- The “tail” work on the project did not work out as we had planned.
- Covid-19 travel restrictions made it almost impossible to visit the site.
- Covid-19 reduced traffic to very low volumes
- Network connectivity problems commenced 2020-03-16, first week of Norway lockdown, continuing for 2 months.



Summary

- Magnetic, in-ground sensors can be used to detect vehicles and estimate speed profiles.
- Battery life of several years, the sensors use virtually no power, communication of data takes most of the battery. Relaxing real-time requirements will drastically increase battery life. 10 years should be possible.
- Trade off between data latency and battery life
- Migration from ISM band to NB IoT or CAT M1 reduce infrastructure needs
- Suitable for low-volume roads in remote areas



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