QCam – UAS-mounted Doppler Radar for Measuring River Velocity

January, 2018

What is QCam?

A miniaturized coherent, continuous-wave (CCW) Doppler radar for measuring surface-water velocities and deployed on a 3DR™ Solo (*fig. 1*).

Why is QCam needed?

Traditionally hydrologic remote-sensing focused on high-altitude or satellite-based products. Because of their spatial scale, these platforms fill a significant void in global hydrologic studies and in regions that are gage-poor. However, sUAS platforms offer a solution for small-scale river systems: (1) 5 meters to 300 meters wide, (2) in remote basins such as Alaska, where access and infrastructure needed to support conventional streamgage operations, is limited, and (3) where extreme flow events pose a safety danger to hydrographers charged with collecting discharge data – *recent 2016 flooding in North Carolina is an example of the need for noncontact methods for capturing extreme events, where access to bridge sites and USGS streamgages was restricted because of rising waters).*

Figure 1 QCam Doppler Radar.

Qcam Specifications

QCam is a CCW Doppler radar (K-band) that operates at 24 GHz with the following specifications (*Courtesy Sommer Messtechnik*):

Velocity measurement	
Detectable measurement range	0.10…15 m/s (depending on the flow conditions)
Accuracy	± 0.01 m/s; ± 1 %
Resolution	1 mm/s
Direction recognition	+/-
Measurement duration	5…240 s
Measurement frequency	24 GHz (K-Band)
Radar opening angle	12 °
Distance to water surface	minimum 0.50 m
Necessary minimum ripple height	3 mm
Vertical inclination	measured internally

Table 1: Specifications of the velocity measurement

Automatic vertical angle compensation	
Accuracy	± 1 °
Resolution	± 0.1 °

Table 2: Specifications of the internal angle measurement

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Flight Envelope

- Avoid gusty and turbulent winds
- Fly with winds less than 10 knots
- Avoid ground speeds greater than 3 meters/second (m/s) in any direction
- Assign pitch, roll, and yaw response to medium
- Avoid flying at or above 2,770 meters (m) MSL density altitude
- Take-off from a pad rather than bare-ground
- Minimize flight times and extend cool down periods to restrict heat buildup
- Minimize prop wash by flying at altitudes greater than 5 m when surface-water velocity are less than 0.6 m/s.

Qcam Test and Trial Flights

QCam test flights (*fig. 2*) and trial flights (*fig. 3*) were conducted in the summer 2017 and fall 2017, respectively, near a USGS streamgage on the South Platte River; however, environmental conditions exceeded the flight envelope on 19 September 2017. Prior to our next deployment, we chose to optimize the flight stability of the 3DR™ Solo by upgrading the onboard GPS (ublox; https://www.u-blox.com/en/product/neo-m8-series), propellers (https://www.masterairscrew.com/collections/mr-series/products/3dr-solo-built-in-nut-upgrade-propellers-in-orange-mr-10x4-5-prop-set-x4-solo).

Upgrades were completed in early October, and six science flights (five to nine minutes each) were conducted on 24 October 2017. Instantaneous surface velocities were collected by spot dwelling at locations-of-interest ranging from the left edge of water (LEW) to the right edge of water (REW) for 20 to 30 seconds. Radar spectra were processed onboard and transmitted straight away to a laptop computer on the ground providing a measure of surface velocity and measurement quality. Conventional streamgaging methods (FlowTracker and StreamPro acoustic Doppler current profiler (ADCP) and a handheld radar (Stalker Pro II SVR) were used to validate the QCam-derived velocities. An ADCP measurement was made prior to the QCam flight. After data processing and peer review, a rated discharge equal to 3.45 m/s was computed using the ADCP. A radar-derived discharge equal to 3.36 m/s was computed using QCam and was within 2% of the measured discharge (*fig. 4*).

Figure 2 Initial test flights.

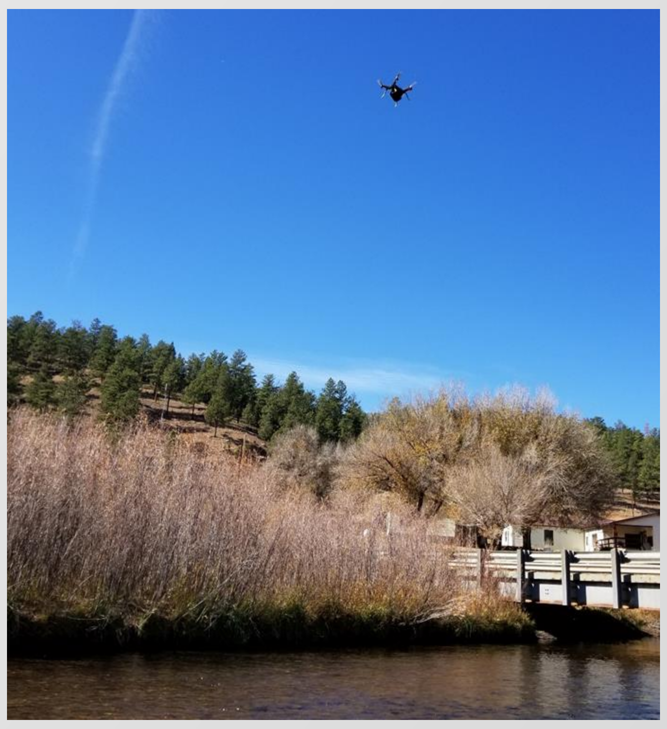

Figure 3 QCam field trials conducted on 24 October 2017 near the USGS streamgage 06701900 South Platte River below Brush Creek near Trumbull, Colorado, USA.

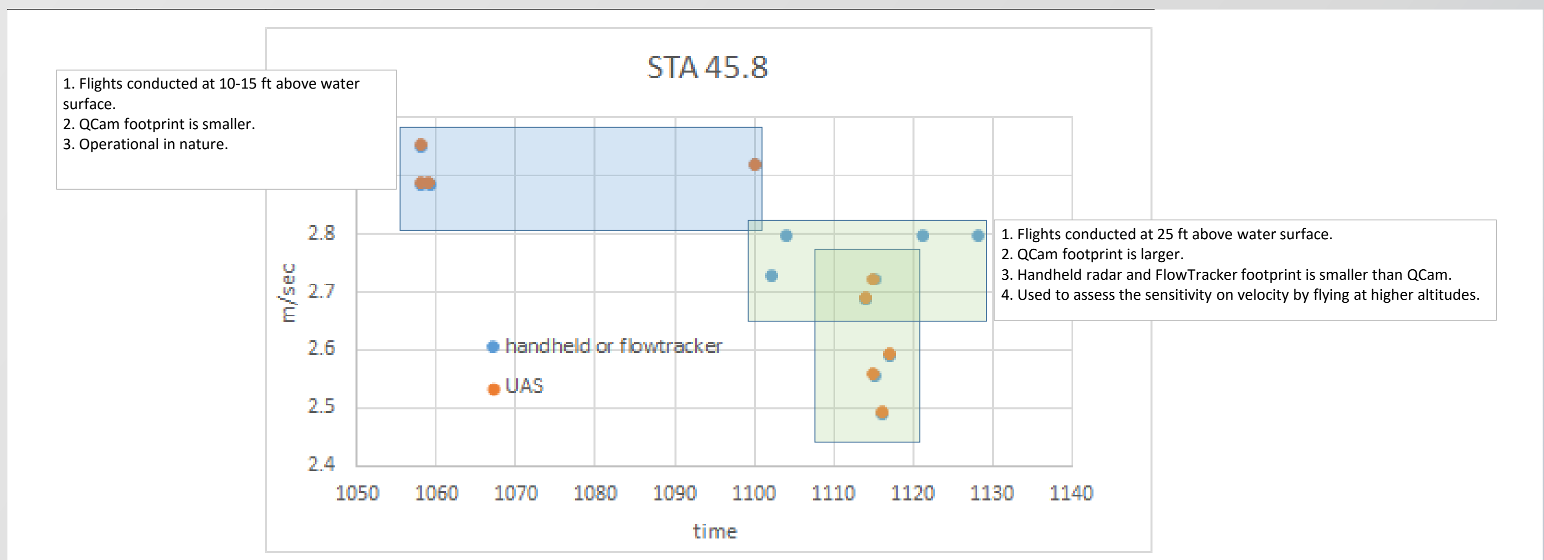

Figure 4 QCam velocity results.

Translating Surface-water Velocities to a Mean-Channel Velocity

The surface velocity was translated to a mean-channel velocity using an alternative velocity distribution equation called the Probability Concept, which was developed by Dr. C.-L. Chiu at the University of Pittsburgh

$$Q = u_{max} \times \phi \times Area$$