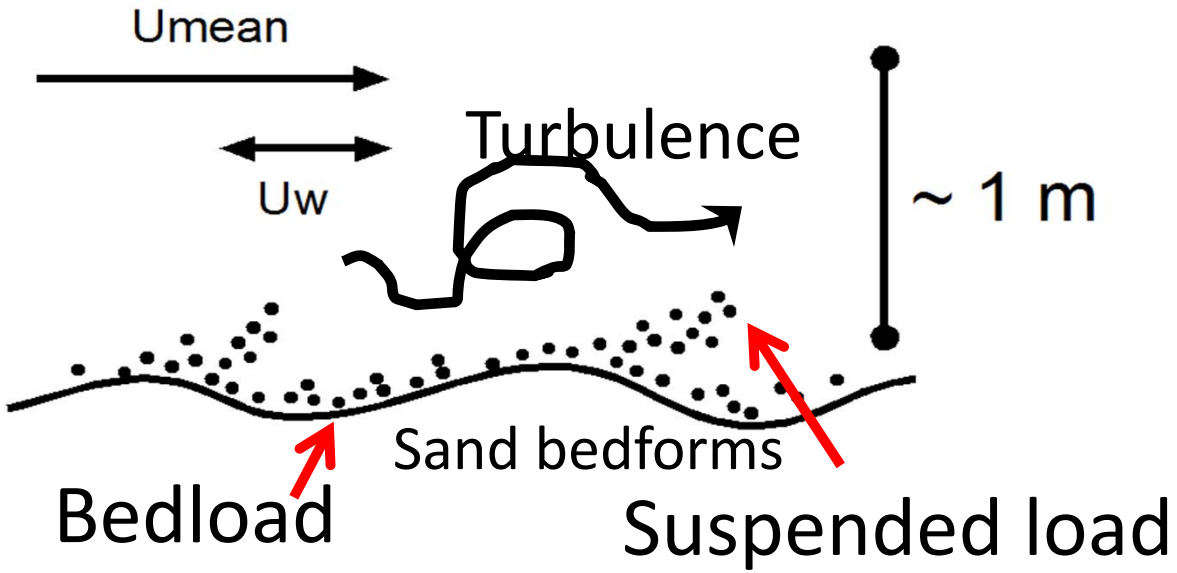
Swath Doppler: multi-beam Doppler sonar for scanning water velocity sections

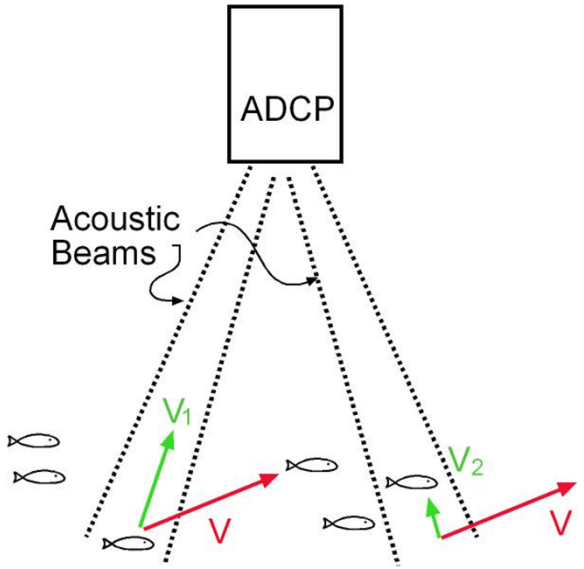
Mahdi Razaz[1], Len Zedel[2], Alex Hay[3]

1. Department of Marine Sciences, University of Georgia
2. Department of Physics and Physical Oceanography, Memorial University of Newfoundland
3. Oceanography Department, Dalhousie University

Near Bottom Sediment Transport



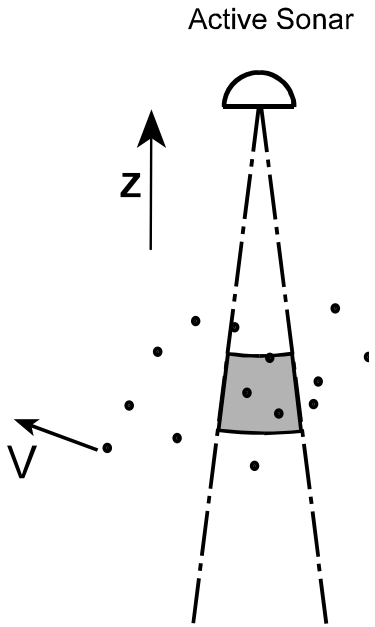
- Direct measurement in this environment disturbs the flow
- Conventional (diverging beam) Doppler sonar is not suitable



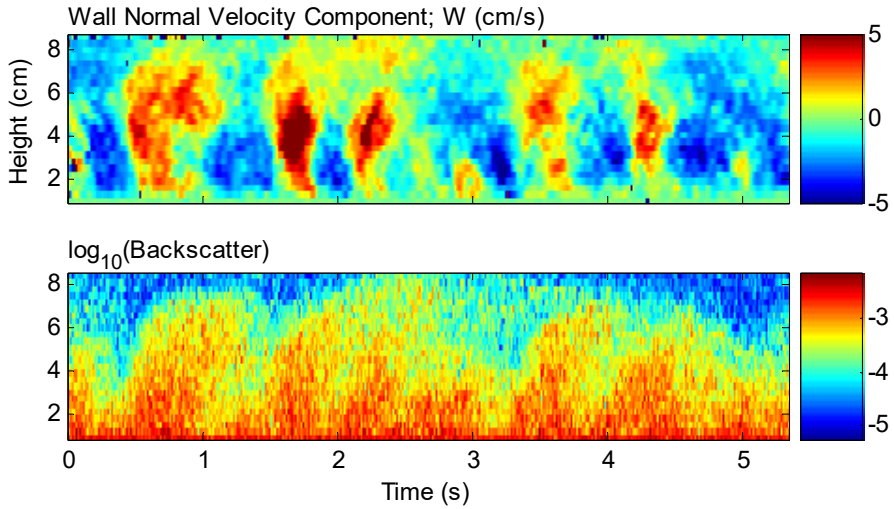
Doppler Sonar Geometry

1 Single Beam, Monostatic

One component of velocity along beam axis



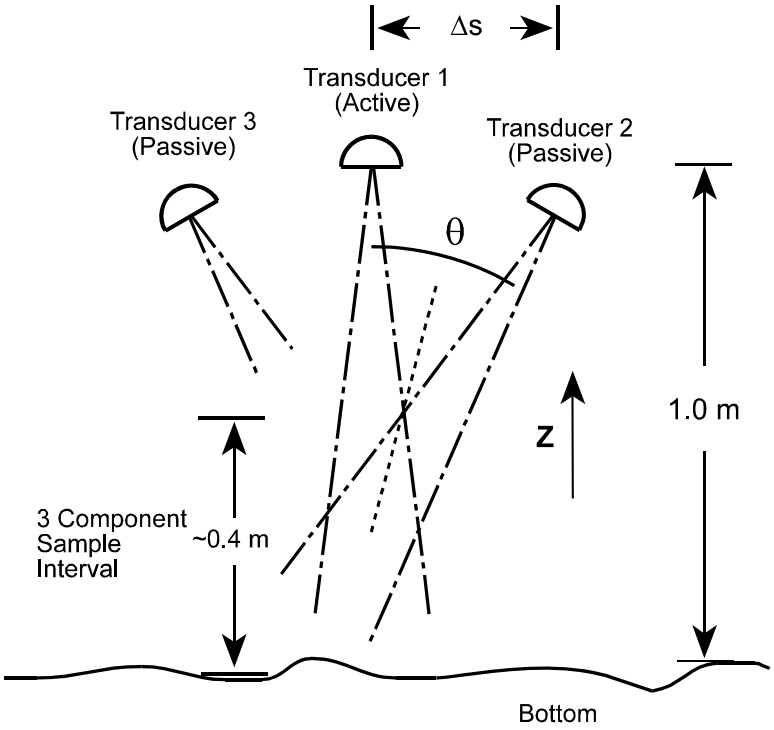
Zedel, Hay, Cabrera, Lohrmann, 1996, IEEE Journal of Oceanic Technology, 21, 290-297.



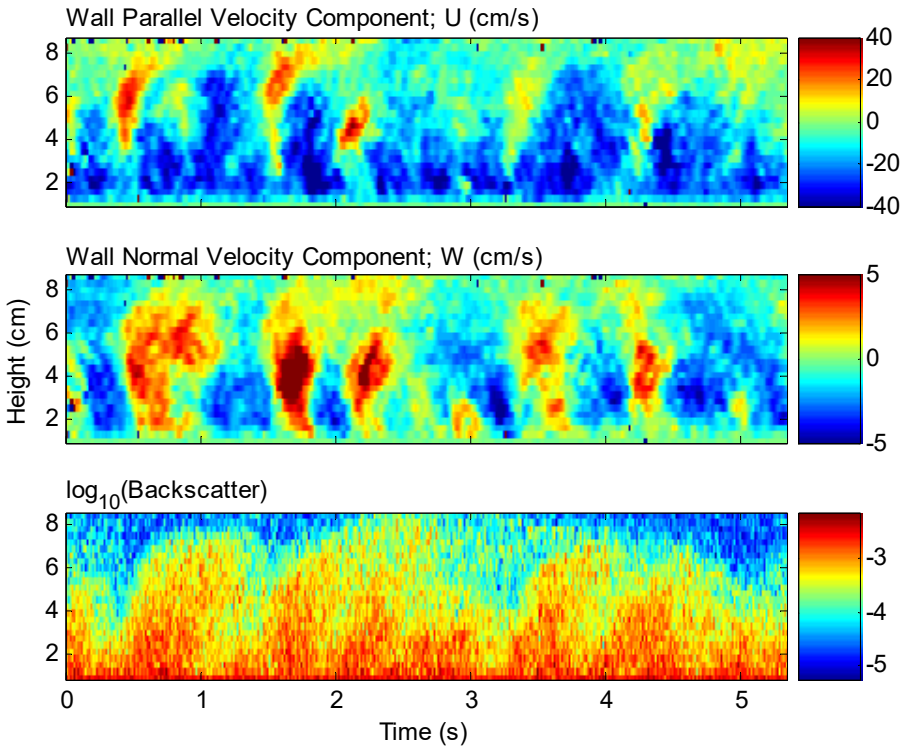
Doppler Sonar Geometry

2 Bistatic

Two components of velocity along beam intersection



Zedel, Hay, 2002: IEEE Journal of Oceanic Engineering, 27, 717-725.
Zedel, L., and A.E. Hay, 2010
IEEE Journal of Oceanic Engineering, 35, 847-851.



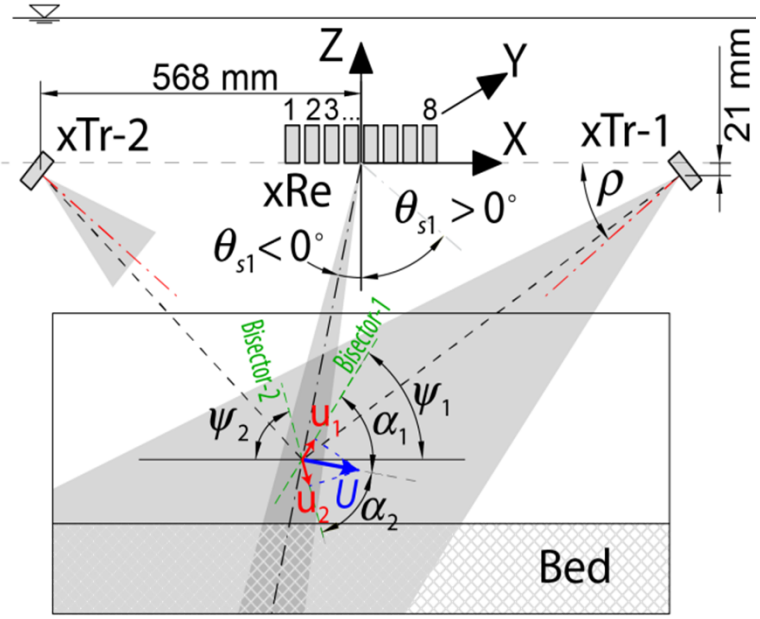
Doppler Sonar Geometry

3 Swath Doppler

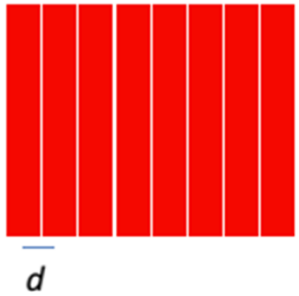
(Smith, 2002, JAOTech 19, 725-737)

Two component velocity over 2-D domain

If you use a transducer array, you can "steer" the beam in multiple directions SIMULTANEOUSLY (multibeam sonar)



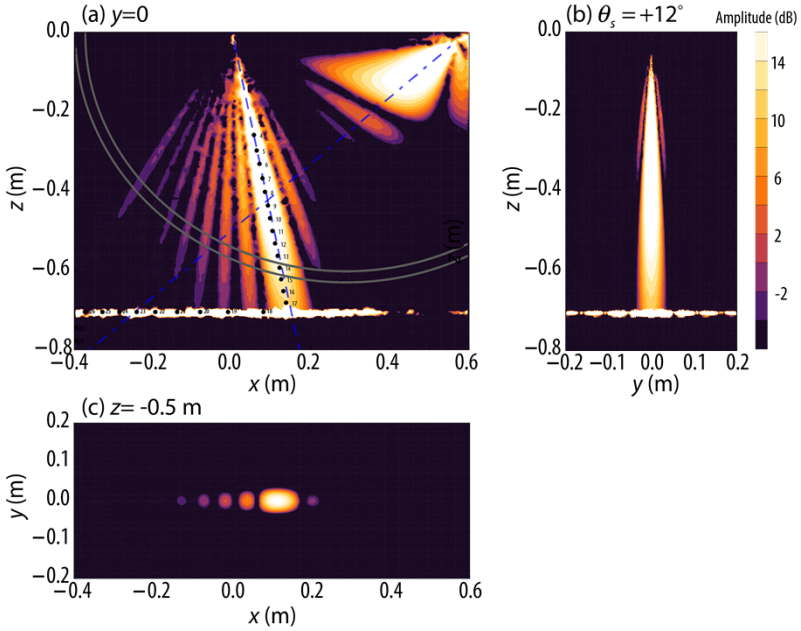
8 element array

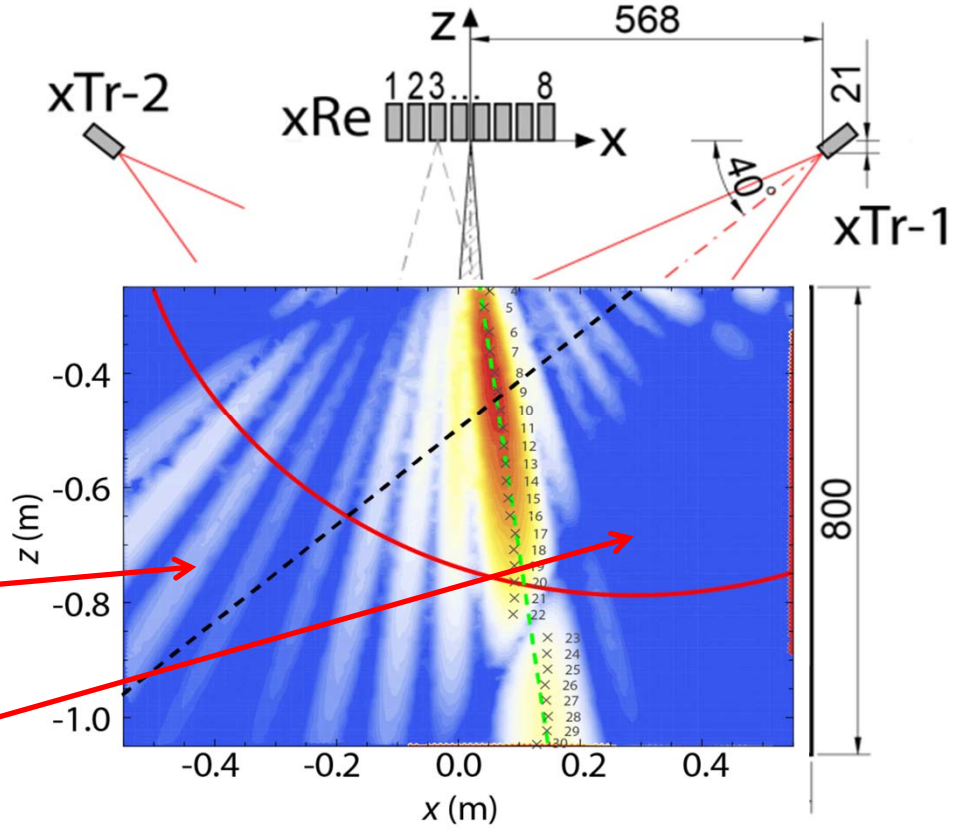


- 500 kHz
- 650 pings/second

- 8 linear elements, ca. 5 mm wide (i.e. a = 5 mm))
- Inter-element spacing as narrow as possible, so as to make the centre-to-center distance "d" equal to the element width "a"
- Overall dimensions: 4x4cm

Modelling Swath Doppler





Notice array sidelobes

+ve steer angles give shorter profile as you steer away from transmit beam!

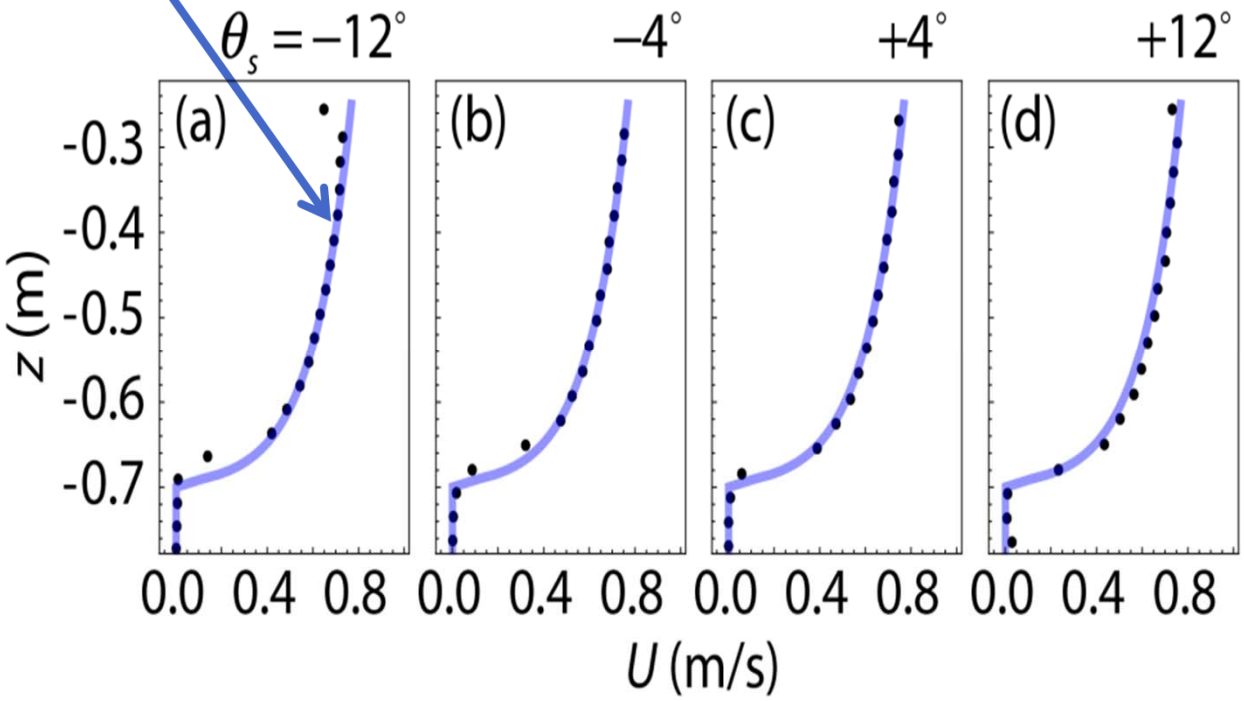
+ve steer also noisy due to less favourable component measurement

-ve steer angles

+ve steer angles

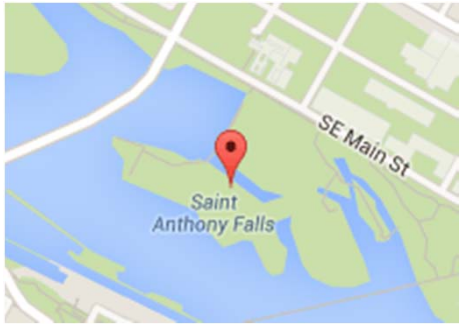
Profiles at Different Steer Angles (single transmitter)

Log law



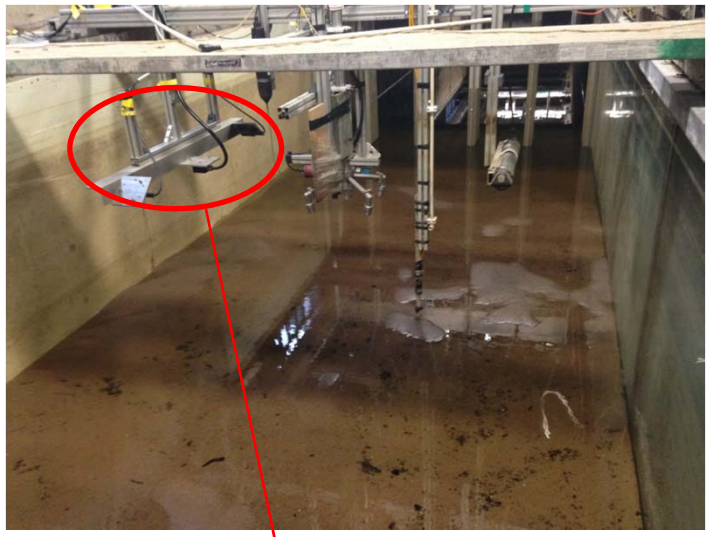
Average profiles reproduce input velocity

Models are great but … (SAFL)

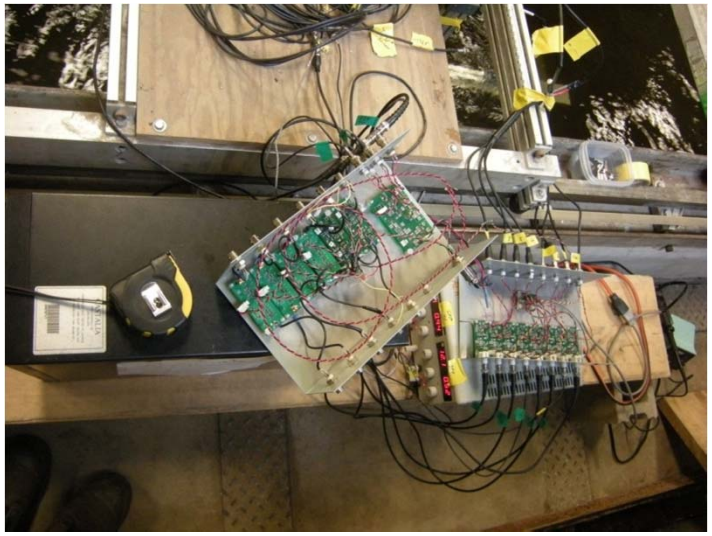


1.8 m deep
2.75 m wide
Up to 8.5 m^3/s

Challenges with noise



Swath System



Longish cable runs (3-4 m)

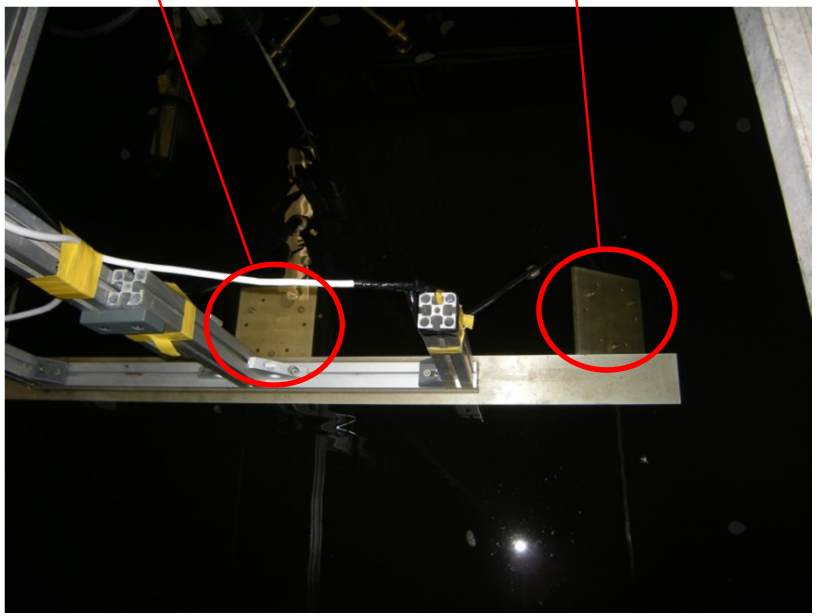
…RF pickup

Ground loops

But we were struggling for signal!

Receive Array

Transmitter

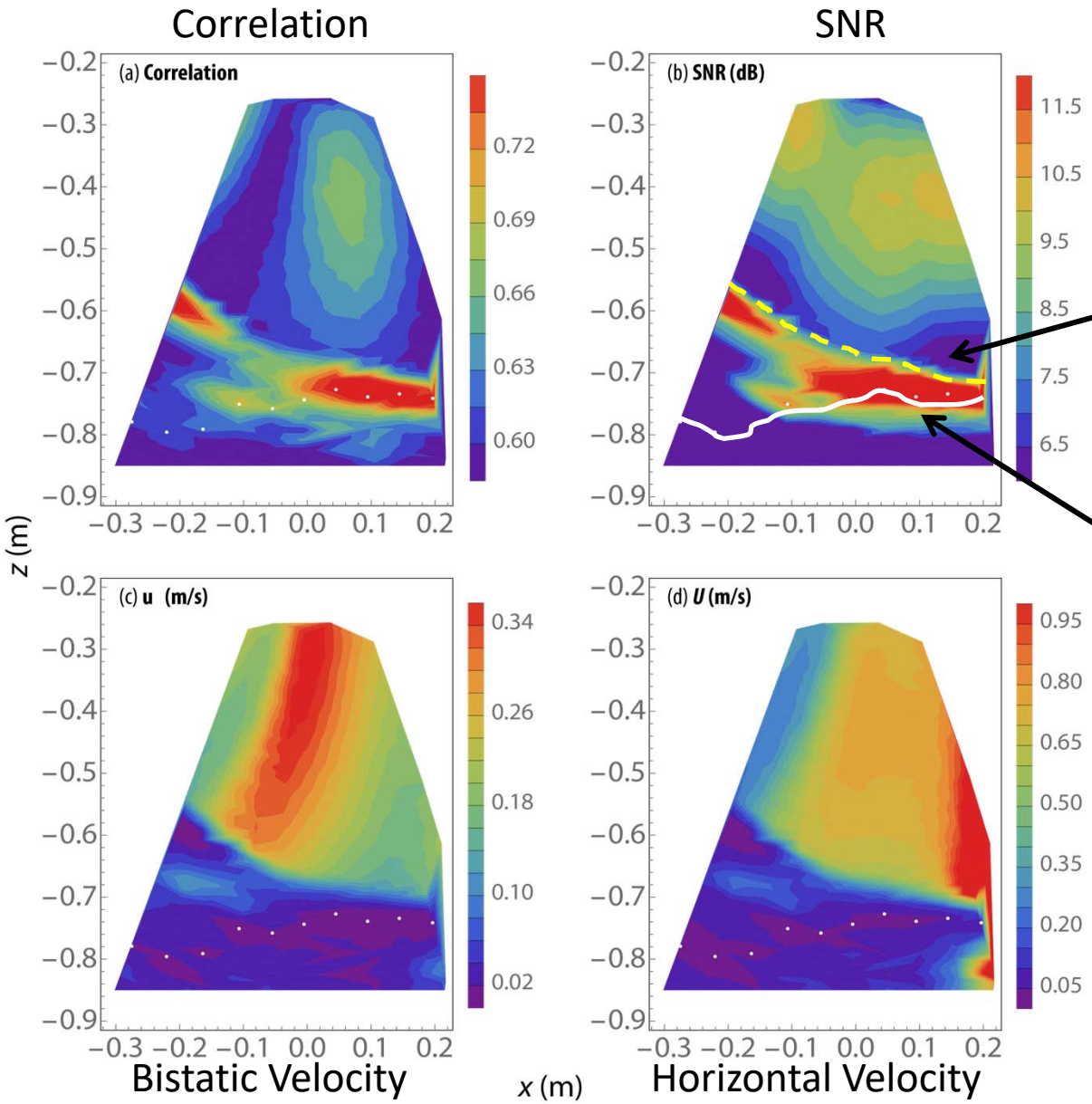


System Configuration

Center frequency	500 kHz
Bandwidth	50 kHz
Pulse repetition frequency	666 Hz
Range resolution	~3 cm
Angular resolution	4 degrees
Total number beams	11

(Only got good data (adequate S/N) from one of the transmit transducers)

Data Characteristics



Line of side-lobe contamination from bottom

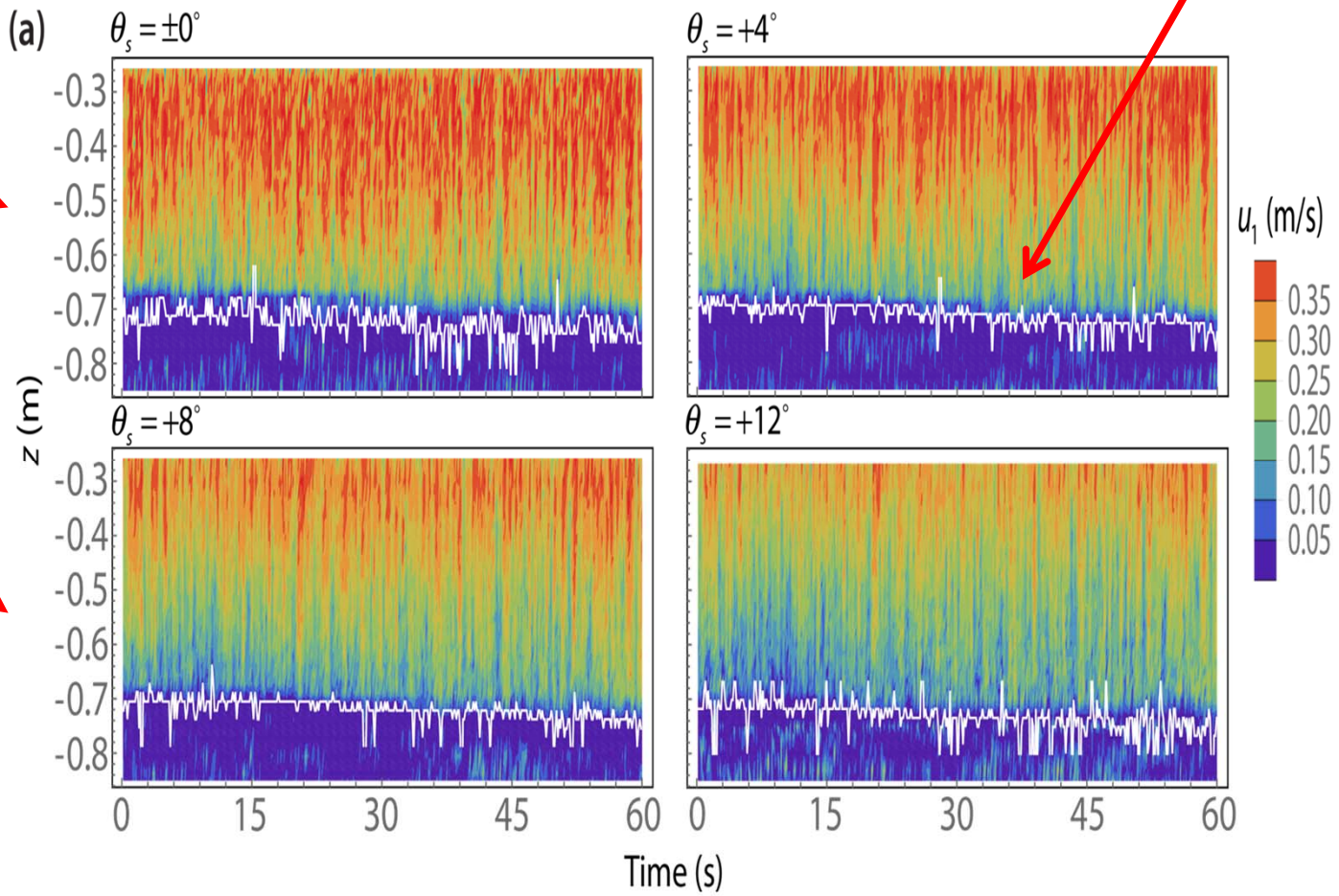
Bottom (as detected in swath data)

Things look okay so long as you don't go beyond 12° steer angles

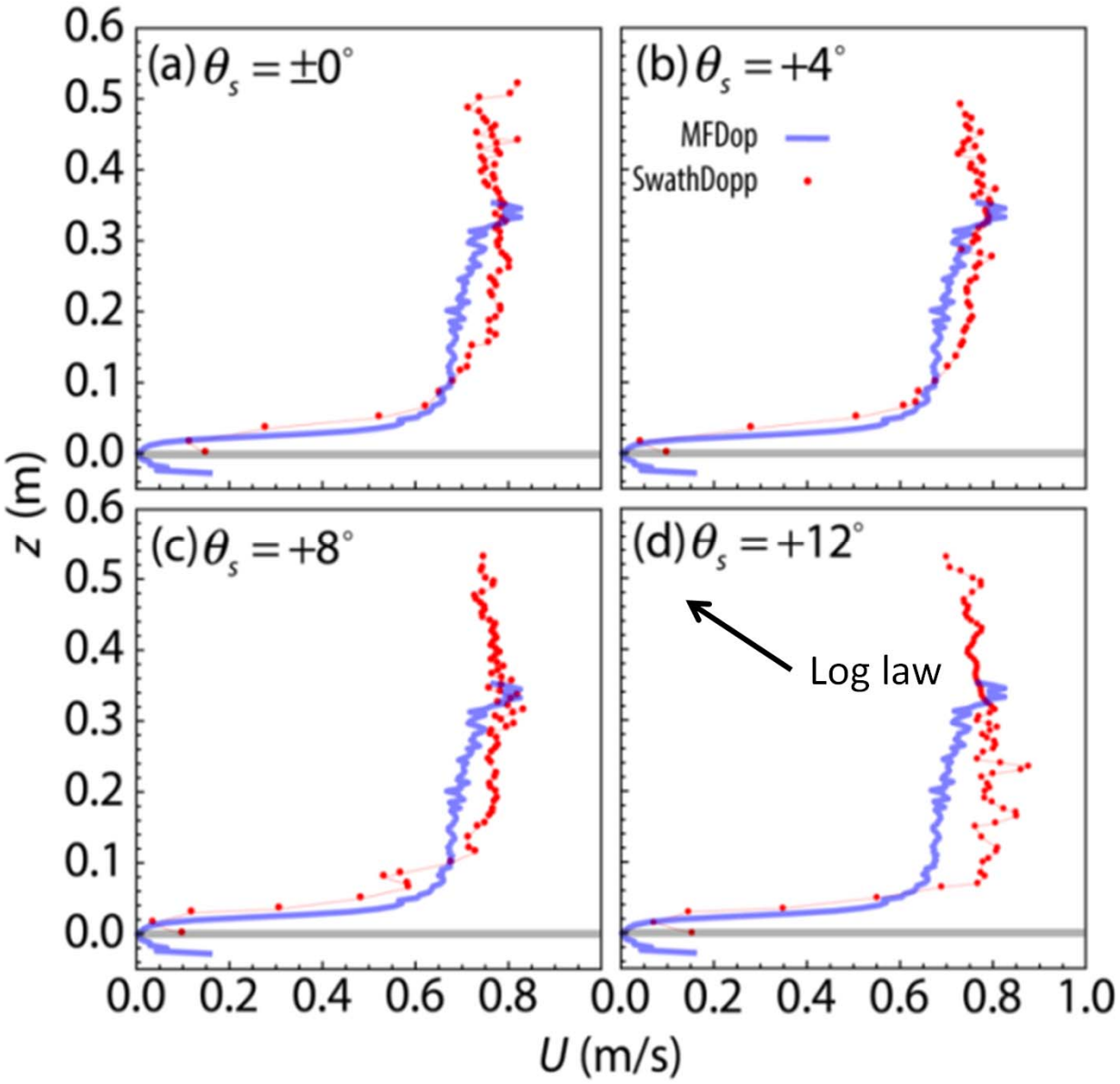
Raw Time Series

Measured component changes with steer angle

Range to bottom evolves with time due to bedforms



Are the Mean Velocities Accurate?



- Profiles at different steer angles agree
- Profile is flatter than log law but consistent with MFDop
- AND, profile is consistent with Nelson, Smith (1989), *JGR*, *94*(C6), 8146-8162.

MFDop
SwathDop

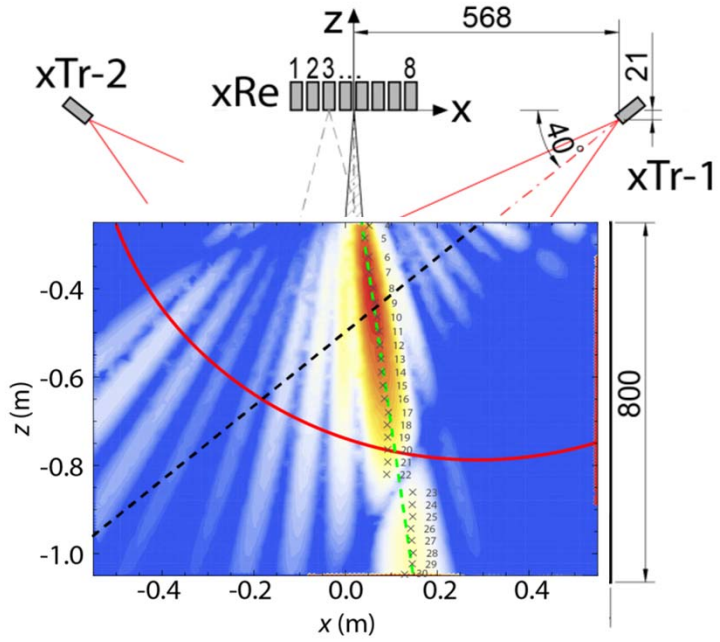
Summary/Conclusion

Demonstrated swath Doppler concept with modelling and lab trials

Struggling with data quality due to low S/N levels and (no surprise) sidelobes

Velocity profiles consistent with MFDop and Nelson & Smith (1989)

Haven't really looked at time-series … that will need to wait for improved signal quality.



Razaz, Zedel, Hay, *submitted* JTECH

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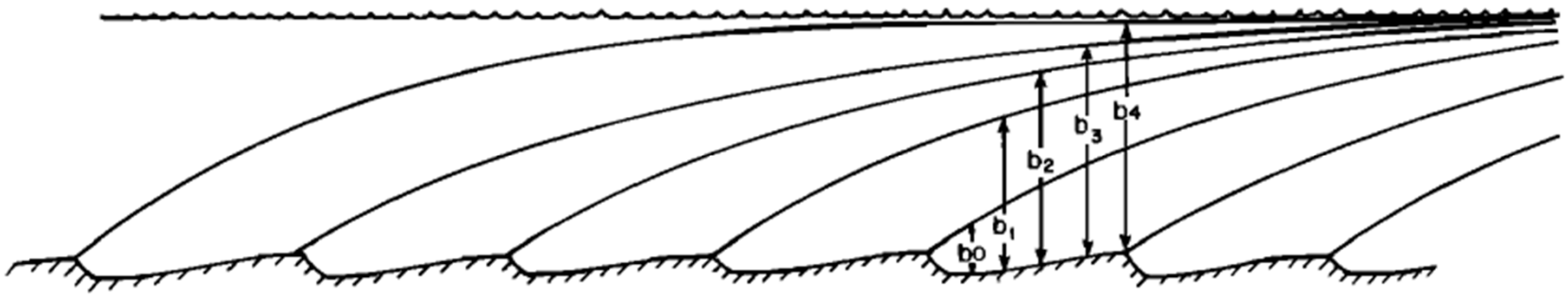


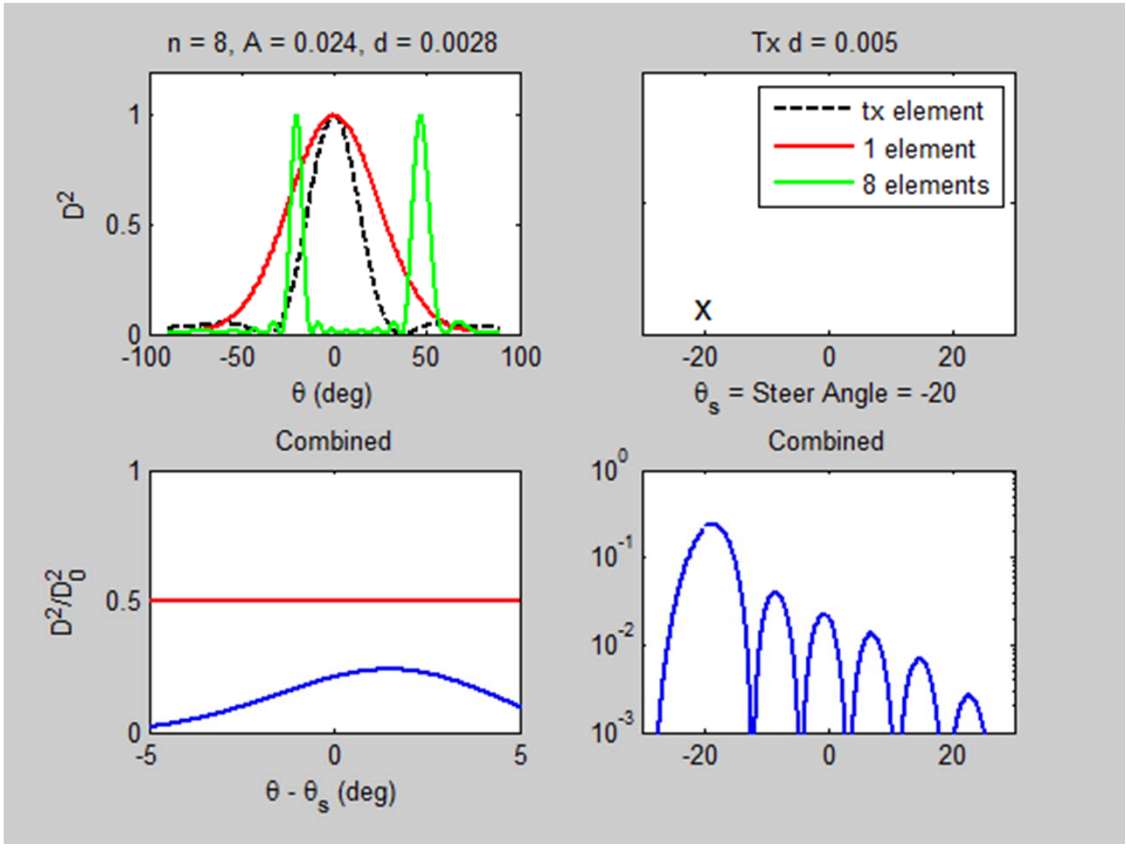
Fig. 2. Diagram of the wake heights over a train of bedforms, where b_i denotes the heights of wakes emanating from upstream dune crests. The vertical structure of the flow above the internal boundary layer is set by "stacking" wake solutions, as described in the text.

$$\bar{u}(z) = B_i \beta U_\delta \left[1 + \frac{2\pi}{\lambda} \eta \frac{\cosh\left(\frac{2\pi(z-H)}{\lambda} \right)}{\sinh\left(\frac{2\pi H}{\lambda} \right)} \right] \left[1 - g_i(x) f\left(\frac{z-\eta}{b_i} \right) \right] \qquad i = 0,1,\cdots,N$$

Nelson, J. M., and J. D. Smith (1989), Mechanics of flow over ripples and dunes, *Journal of Geophysical Research: Oceans*, *94*(C6), 8146-8162.

Steering the 8 element array

Record signal from each receive element (separately)
Adjust the phase of each element to select a desired steer angle



Sidelobes are problematical!