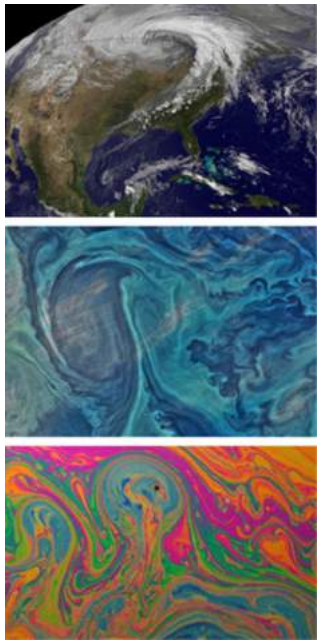
Capstone Presentation

Problem



Large-scale eddies in the atmosphere (top), ocean (middle) and soap film (bottom)

Ocean mixing results in dissipation of mechanical energy. Ocean turbulence occurs at the kilometer scale all the way to the millimeter scale. Current turbulence measurement tools are expensive (ADV costs ~thousands) and hard to maintain.

Goal: Develop a robust device that can observe small scale turbulence using a resonable budget

Applications

Fig. 4. Kármán vortex wake system behind a circular cylinder (Re = 110).

M. Gharib and P. Derango, “A liquid film tunnel to study two-dimensional flows,” Physica D 37, 406–416 (1989).

Small scale turbulence contributes to the energy dissipation in a fluid system. More data points would help refine oceanographic models contributing to things like land mapping and weather forecasting.

Velocimetry Methods

Knowing the velocity of ocean currents at the millimeter scale enables the calculations for kinetic energy dissipation.

Methods:

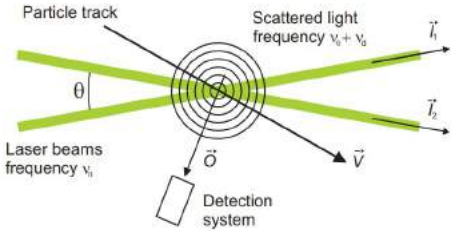
1. Laser Doppler Sensor
2. Piezoelectric Sensor Probe
3. Differential Pressure Sensor

Method 1: Laser Doppler Sensor

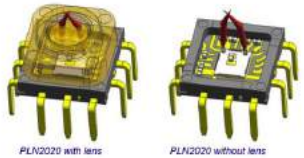
Idea: Reflected laser will cause fluctuations in the power of laser which can then be related back to the doppler frequency.

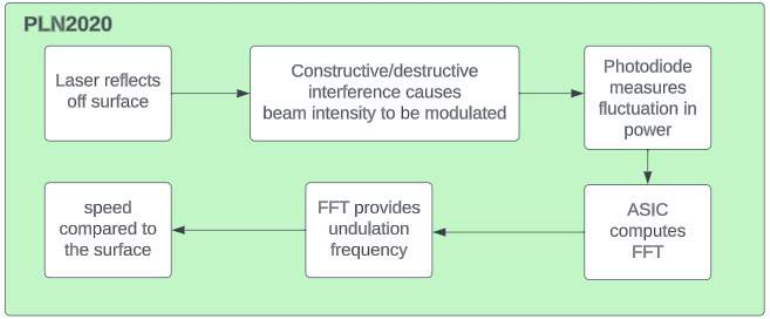
Inspired by Edward D. Zaron; Laser Doppler velocimetry using a modified computer mouse. Am. J. Phys. 1 October 2016; 84 (10): 810–813. https://doi.org/10.1119/1.4960466

Mad Catz R.A.T 5 Gaming mouse



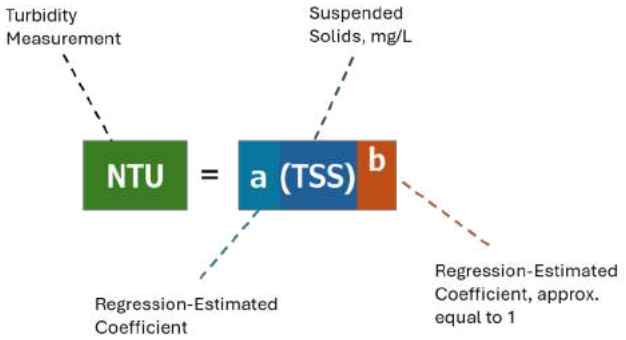
$$\nu_D = \nu_1 - \nu_2 = \frac{\nu_0}{c}(\vec{I}_2 - \vec{I}_1)\cdot\vec{V}$$

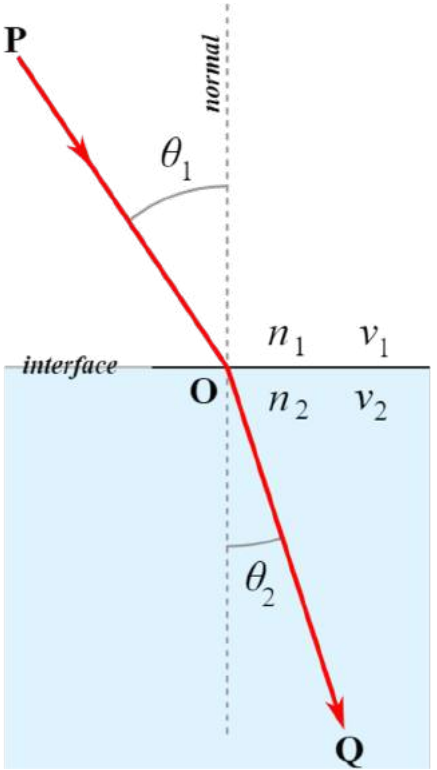




Potential Issues

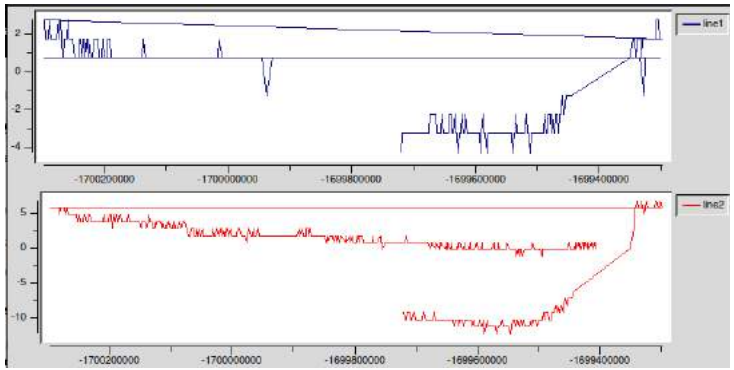
- Sensor focal point could move due to refraction in water
- Scattering in water instead of coherent reflections
- Turbidity (opaqueness) could affect light reflection
    - More particles - more reflection



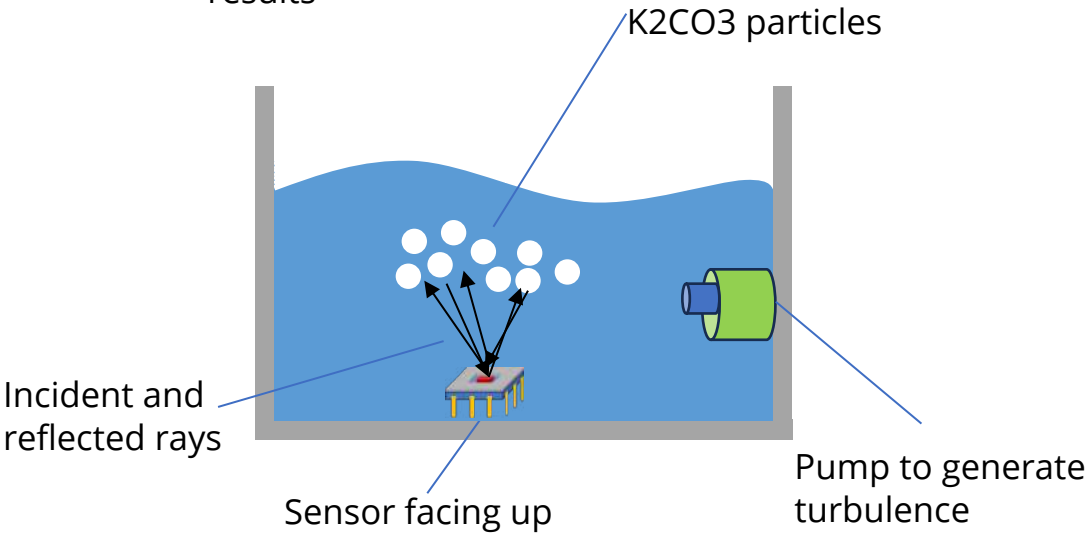


Testing: Dry & First Wet Run

Using the sensor with the included PCB over dry surface generated velocity vs time graphs in 2 directions.

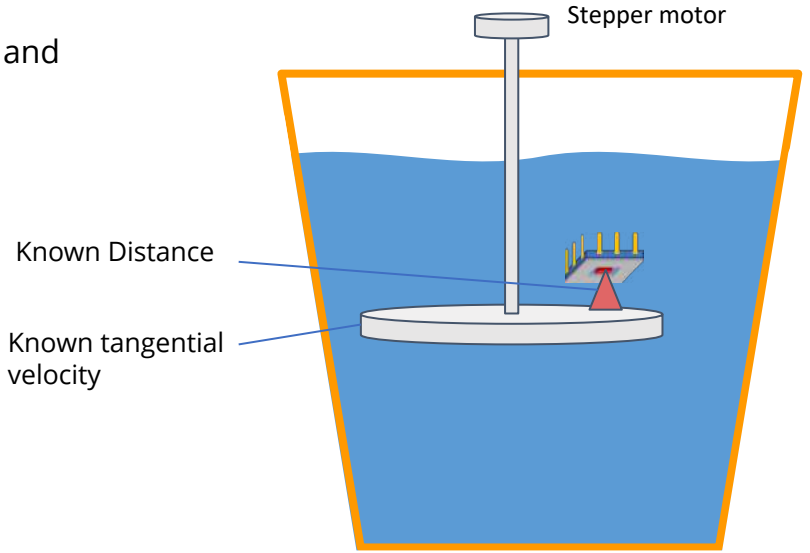


Mixing water with particles and mixing using a pump did not generate any substantial results



Testing: Range Calibration & Turbidity

- Range Calibration
  - Tests sensitivity of sensor in multiple ranges in air and in water
  - Sensor and disk suspended into bucket
  - Disk rotated by a stepper motor
- Turbidity
  - Test sensitivity in multiple levels of particle concentration



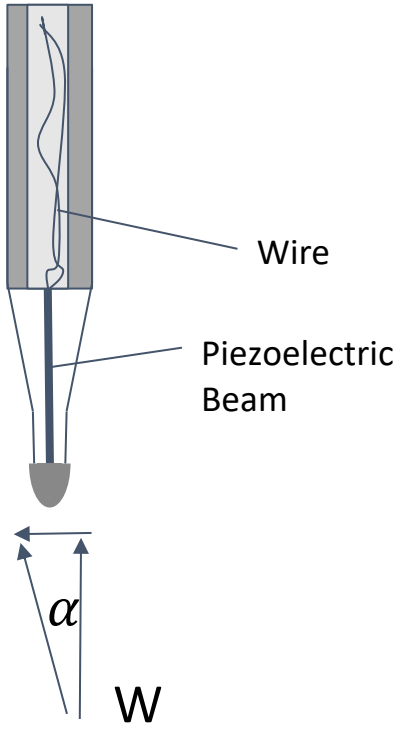
Method 2: Piezoelectric Sensor

Idea

- Piezo shear probes are being used to perform velocimetry measurements, but are expensive.
- Flex sensors are available and are functionally the same.
- Create lower cost version using ‘flex’ sensor

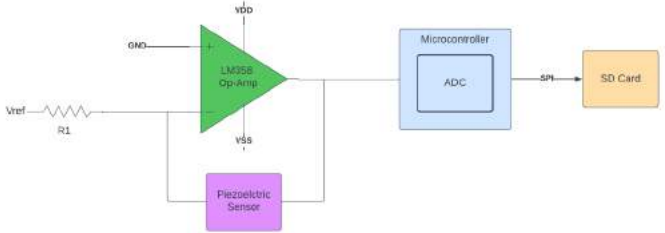
Operation

- Stress will cause electrical charge to shift which creates a voltage drop across the sensor

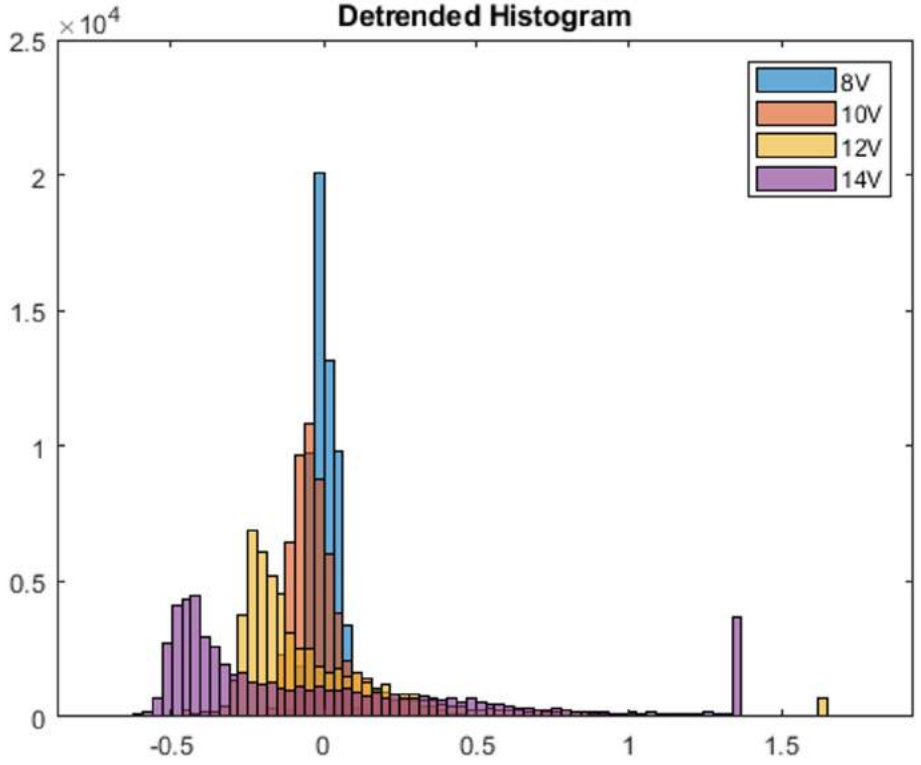


Experiment Setup

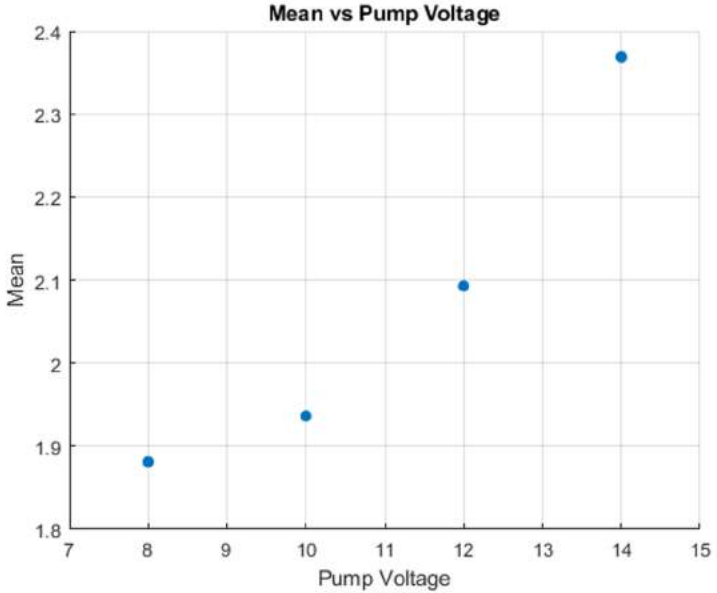
- Independent Variable: Pump voltage (allows for easy way to change water velocity)
- Dependent Variable: An output voltage signal as a function of the changing resistance of the flex sensor due to the water velocity.
- Water vortices caused by sensor
- Rectangular channel vs Racetrack
- Voltage Divider vs Op-Amp

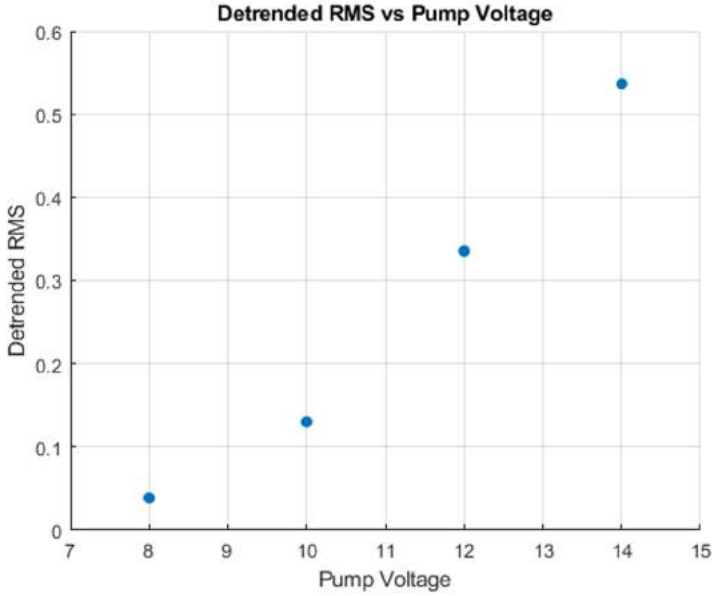


Results and Analysis



Results and Analysis



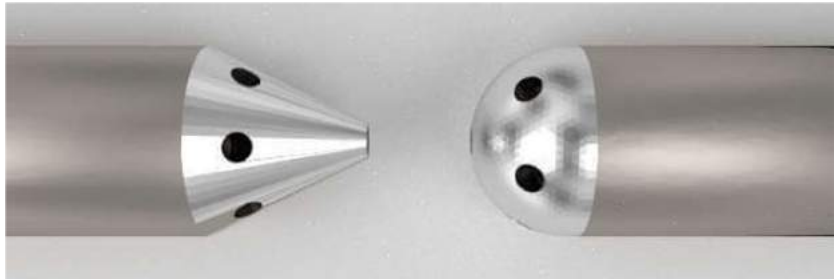


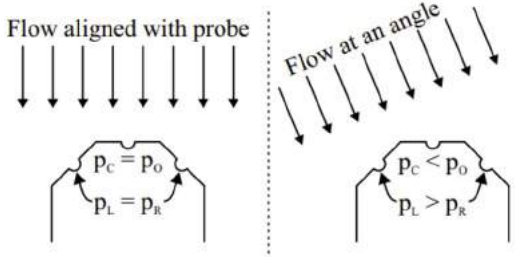
Sensor shows ability to detect different flow rates

Method 3: Differential Pressure Sensor

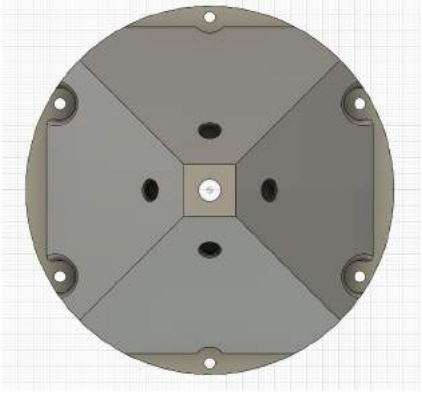
Operation

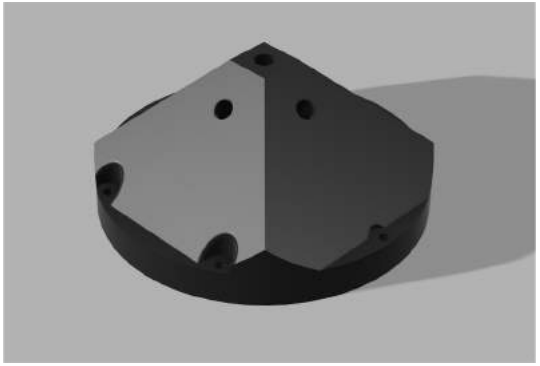
- Multiple pressure transducers on 4 slanted and 1 straight face
- Angled water flow will create pressure differential between sensors
    - Calculate water velocity and direction from data
- Can detect Velocity +/- 30 degrees from front face
    - Flow separation

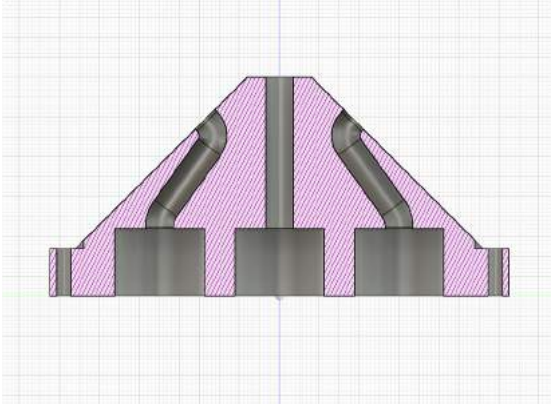


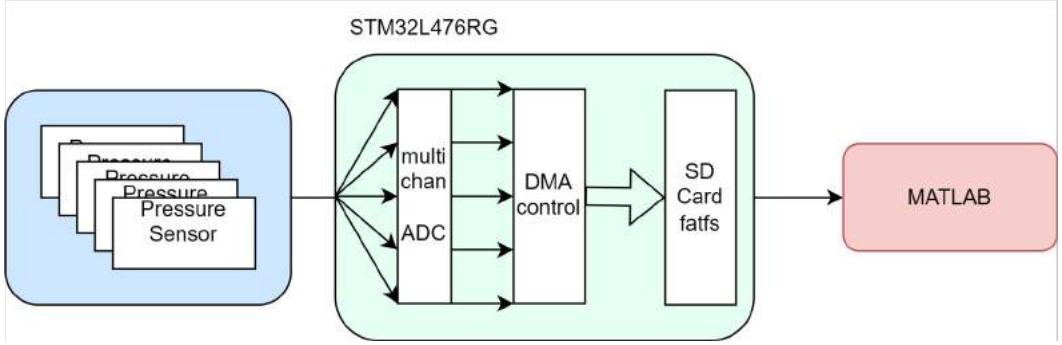


Method 3 Design

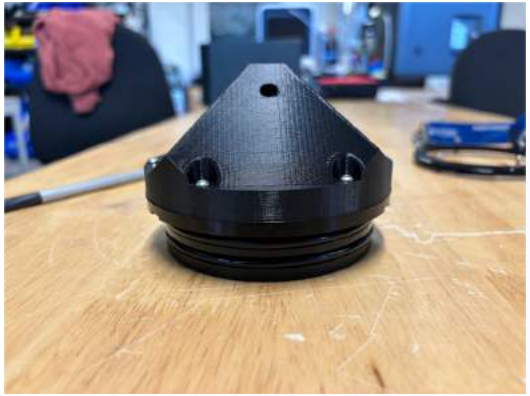


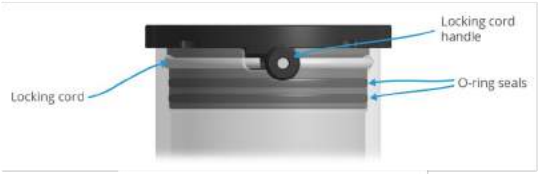


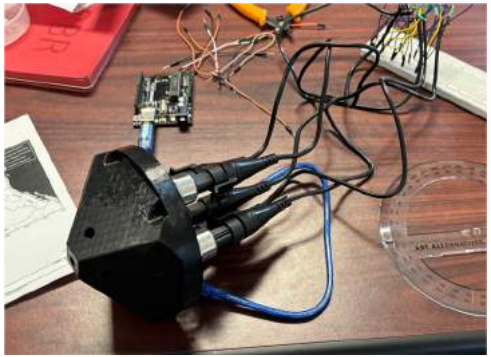




Method 3 Assembly



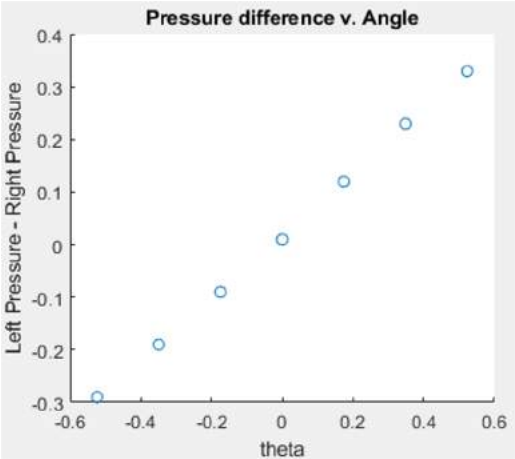




Method 3 Testing

Tests

- Tested calibration procedure
- Known flow speed and angle used to create a lookup table
    - During use lookup table inverted
- Reasonable results but only sensitive to flows above ~2 m/s



Thank you for listening