Current Retrieval from Remote Sensing Images of Ocean Waves

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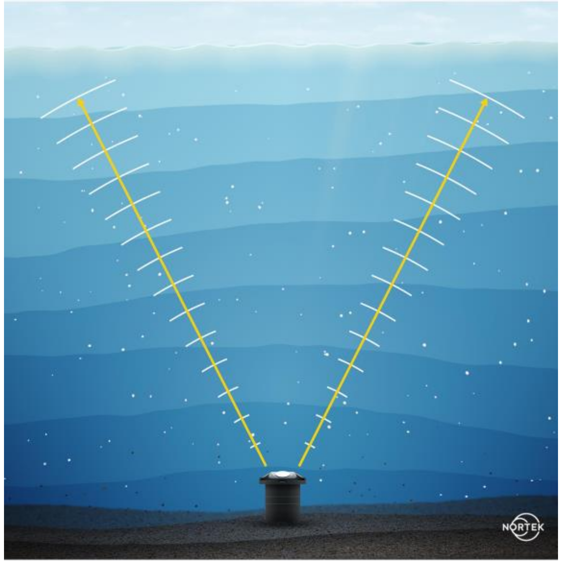
Problems with in-situ measurements

In-situ measurement methods:

- Drifting buoys
- Surface drogues
- Fixed current meters
- Underwater drogues
- Submerged moorings
- Acoustic Doppler Current Profilers (ADCPs)

There is no reliable method to find the current in the upper few meters of the water column.



Nortek ADCP

Why is the current in the upper layer important?

- Processes in the upper few meters of the ocean play a critical role in governing the exchange of energy, momentum and gases between the ocean and the atmosphere. This makes it an important factor for understanding air-sea interactions.
- The upper layer also impacts the direction of where oil spills and microplastics move.

Oil Spills

Microplastics Movements

The Use of Radar Images

- The use of radar images to find ocean current dates back to seminal work by Stewart and Joy (1974).

- Other work in the field has used the theoretical framework from Stewart and Joy to:
  - Generate current maps.
  - Reconstruct near surface currents in deep water and shallow water.
  - Invert current profiles.

None of these studies investigate the current just underneath the water surface.

Mathematical Theory

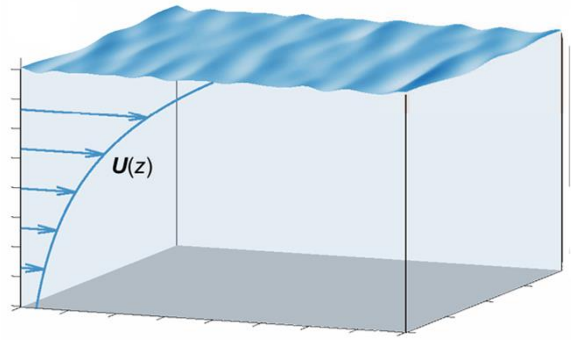
- The linear dispersion relation for water waves with a background current is:

$$\omega_{DR}(\vec{k}) = \sqrt{gk\tanh(kh)} + \vec{k}\cdot\overrightarrow{U_{eff}}$$

- ω_{DR} is found from the radar images. Meaning $\overrightarrow{U_{eff}}$ (Doppler shifts) can be calculated.
- The below integral was derived by Stewart and Joy from ocean wave theory:

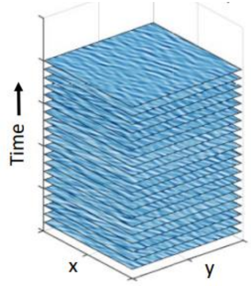
$$\overrightarrow{U_{eff}}(k) = 2k\int_{-\infty}^{0}\vec{U}(z)e^{2ks}\,dz$$

- An inversion method is required to solve this integral for $\vec{U}(z)$ which is the depth dependent current.



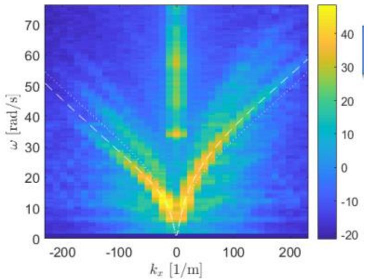
High Level Methodology

1) Radar Images of the ocean waves in space and time.



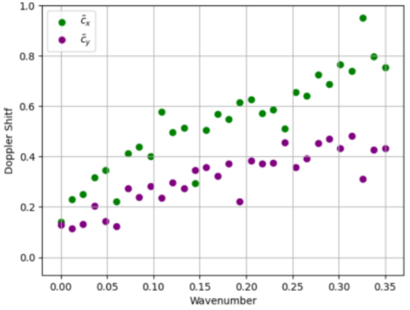
3D FFT

2) Perform 3D FFT to convert to wave spectrum.



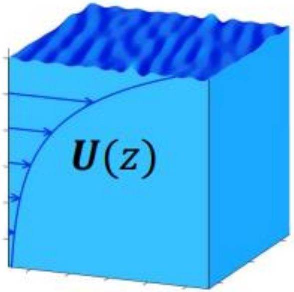
NSP Method

3) Find the Doppler shifts.



Inversion Method

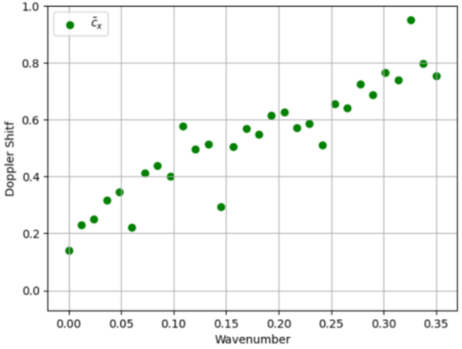
4) Reconstruct the depth dependent current.



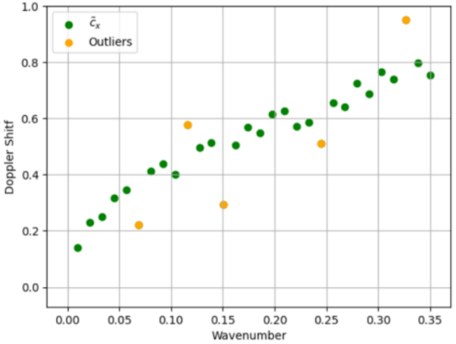
Our research focuses on this step

Additional Method for Upper Layer Current

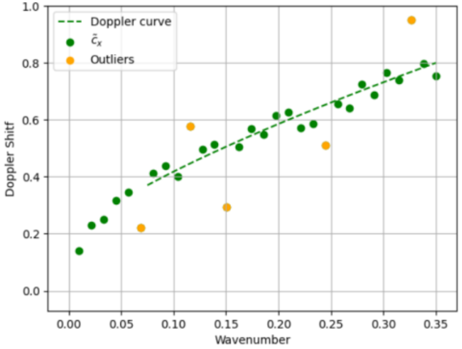
3) Doppler shifts



3.1) Remove outliers

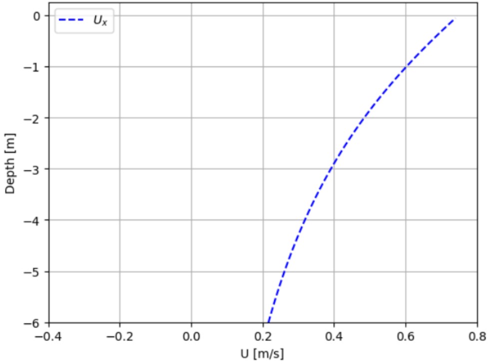


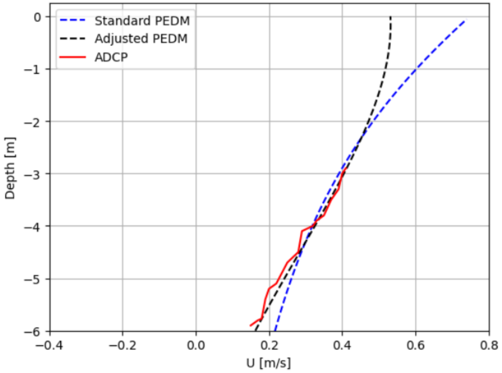
3.2) Minimisation Technique



4.1) Standard Inversion

- Performs the standard PEDM inversion





4.2) Adjusted Inversion

- Uses ADCP measurements to constrian the method

Data

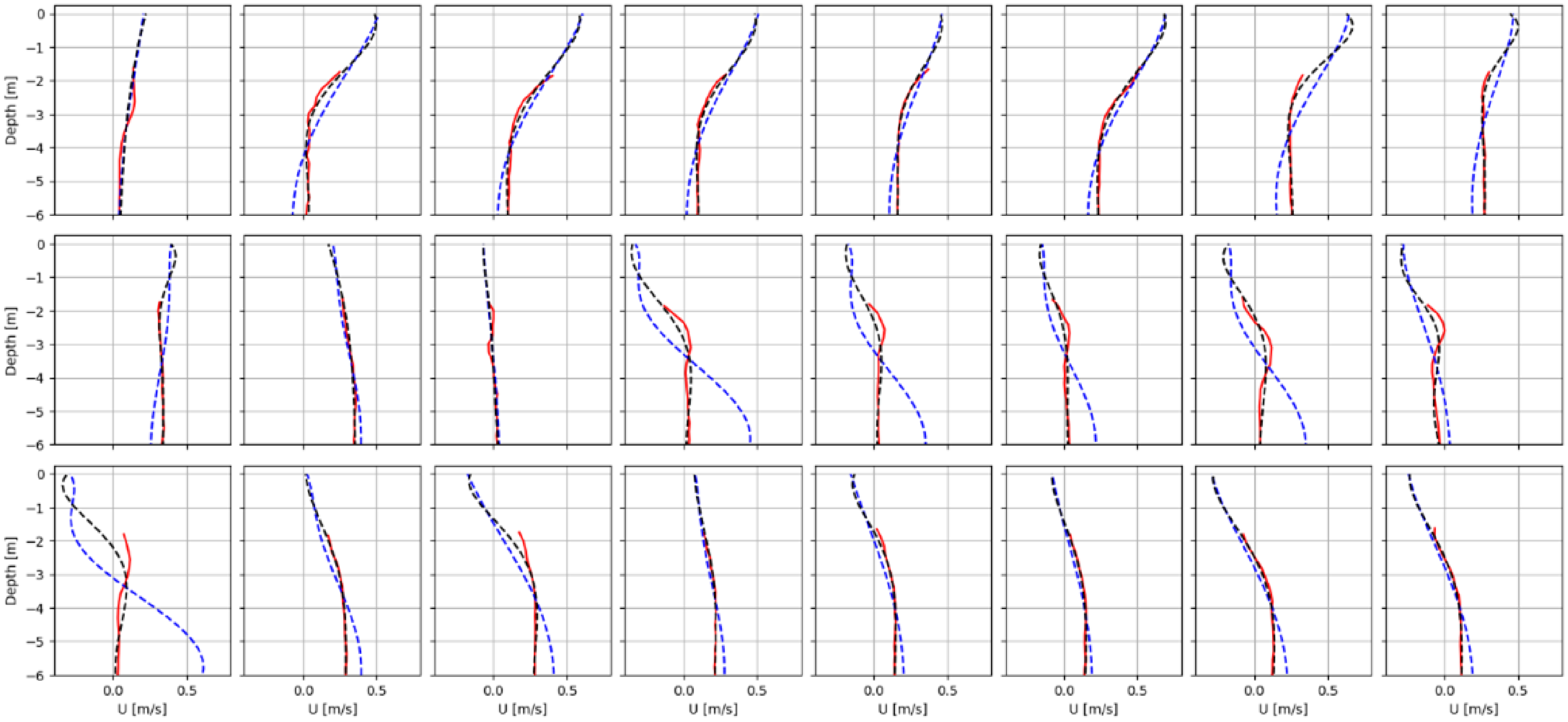
Radar Images

- X-band radar images are taken located in the Eastern Mediterranean Sea.
- Data was collected between 22:00, 18 January 2022 to 00:00, 20 January 2022.

ADCP

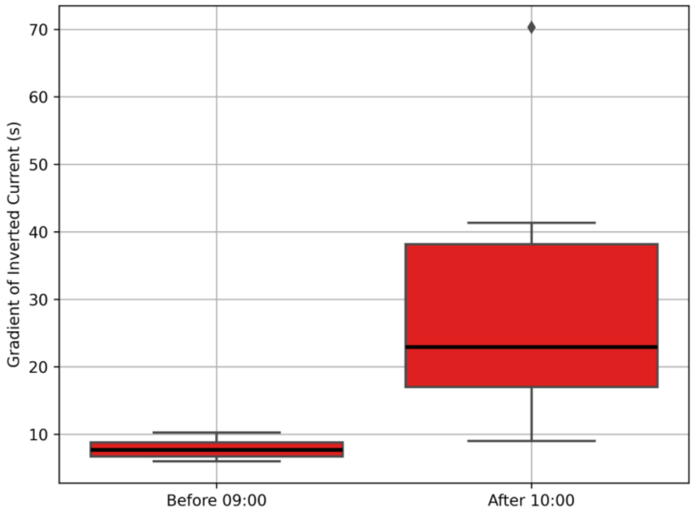
- A Nortek Signature ADCP was located on the ocean floor at a depth of ~16 m.
- This ADCP was located 1.5km off the coast.

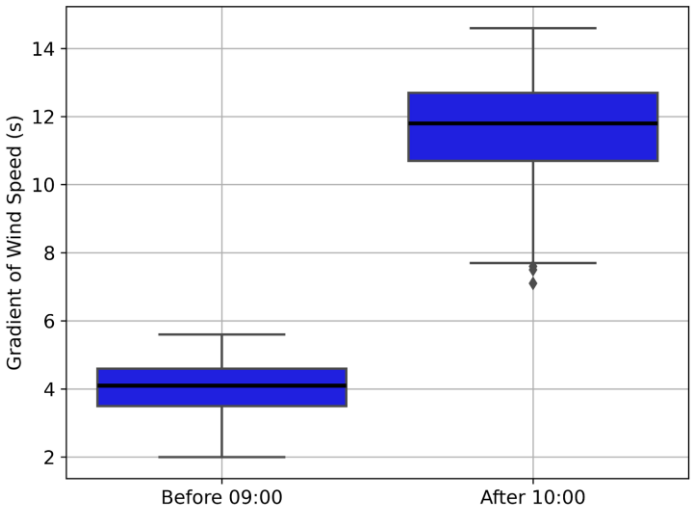
Main Results



Validation

- Validating our findings can be done by comparing to a reliable measurement like wind.
- We can see that there is an increase in inverted current gradient that was also seen in the wind data which tells us that we have captured this change in our upper currents.





Importance of our Results

1. We have shown that using a smoothing method means that radar images can be used to find current profiles to a reasonable accuracy.
2. We have found the uppermost current which is the layer that ADCPs struggle to measure.
3. We have displayed that including ADCP measurements into a radar image inversion method produces more accurate profiles.

Potential Future Work:
ADCP results could be replaced by a global model which could be used to constrain the method at lower depths.

Thanks for listening.

I hope you enjoyed.