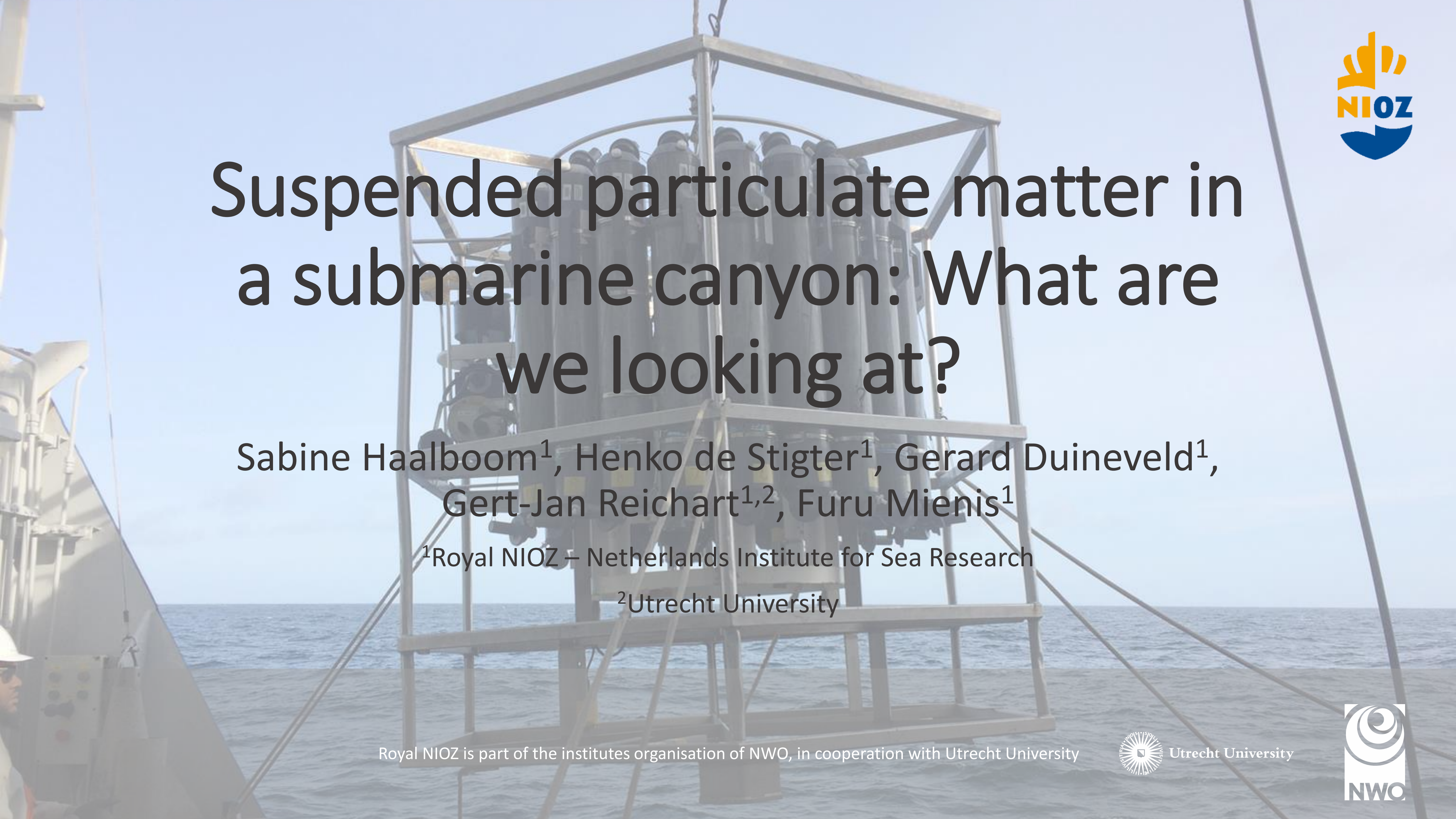

Suspended particulate matter in a submarine canyon: What are we looking at?

Sabine Haalboom[1], Henko de Stigter[1], Gerard Duineveld[1], Gert-Jan Reichart[1,2], Furu Mienis[1]

[1]Royal NIOZ – Netherlands Institute for Sea Research

[2]Utrecht University

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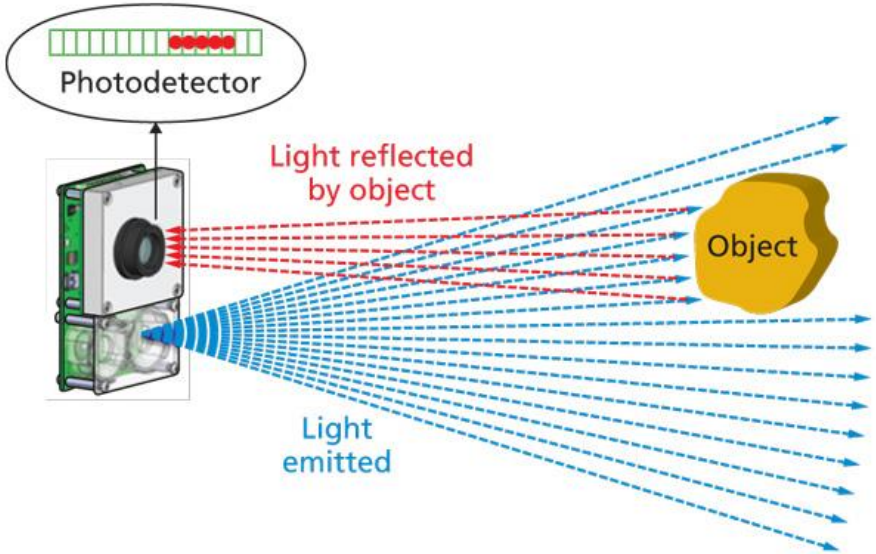
Introduction

- Optical and acoustic backscatter sensors find widespread application for studying suspended particulate matter (SPM)
  - → Contribute to our understanding of sediment transport processes
  - → Quantification of suspended sediment fluxes

- Interpretation of optical and acoustic backscatter data is not straightforward, since the detected signal is not only dependent on the concentration of particles, but also on the physical characteristics



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Introduction

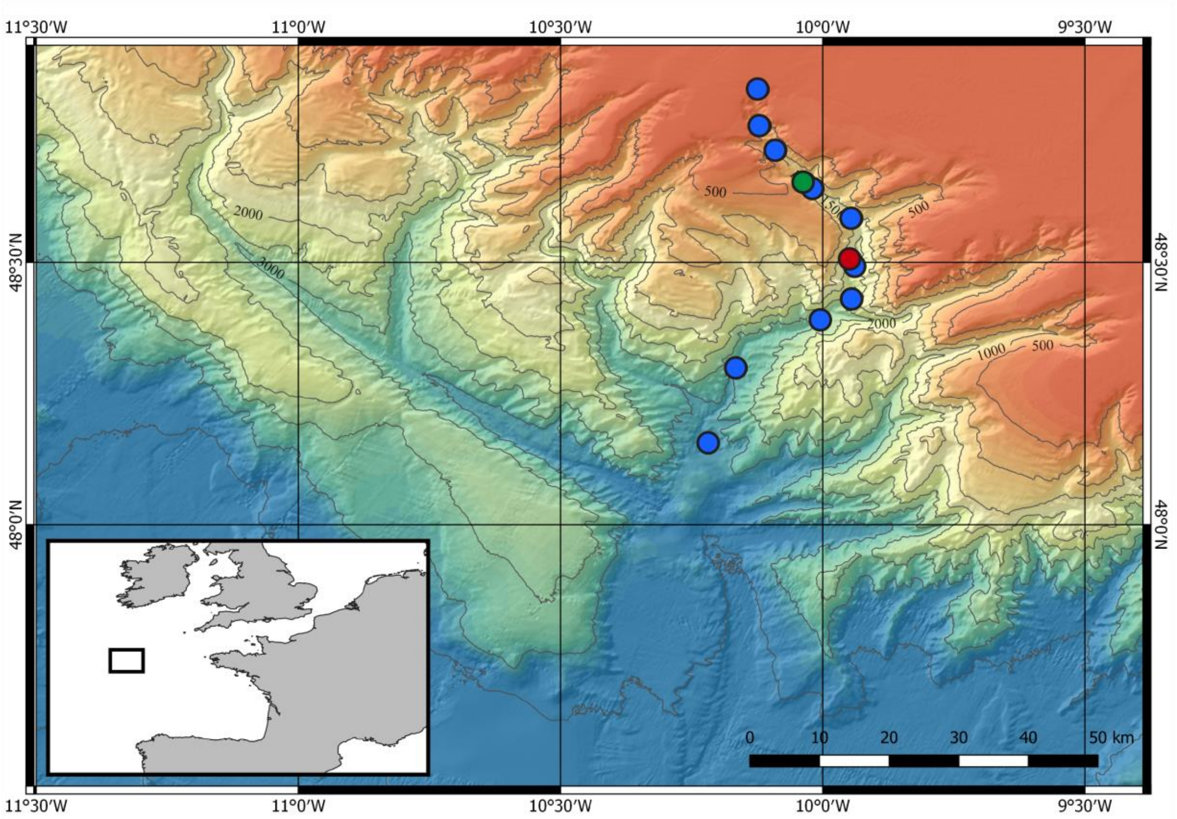
- Throughout the world's ocean, nepheloid layers, layers with increased SPM concentration, play an important role in the lateral transport of sediment, organic matter and pollutants
  - Submarine canyons
  - Hydrothermal vents
  - Anthropogenic disturbances, e.g. bottom trawling or deep-sea mining

- To evaluate their importance it is crucial to properly quantify the amount and type of material that is transported

Introduction

- Nepheloid layers are persistent features in submarine canyons, where they are formed under influence of energetic hydrodynamics

Aim: to understand relationship between turbidity measurements and physical properties of particles in order to properly quantify particle fluxes



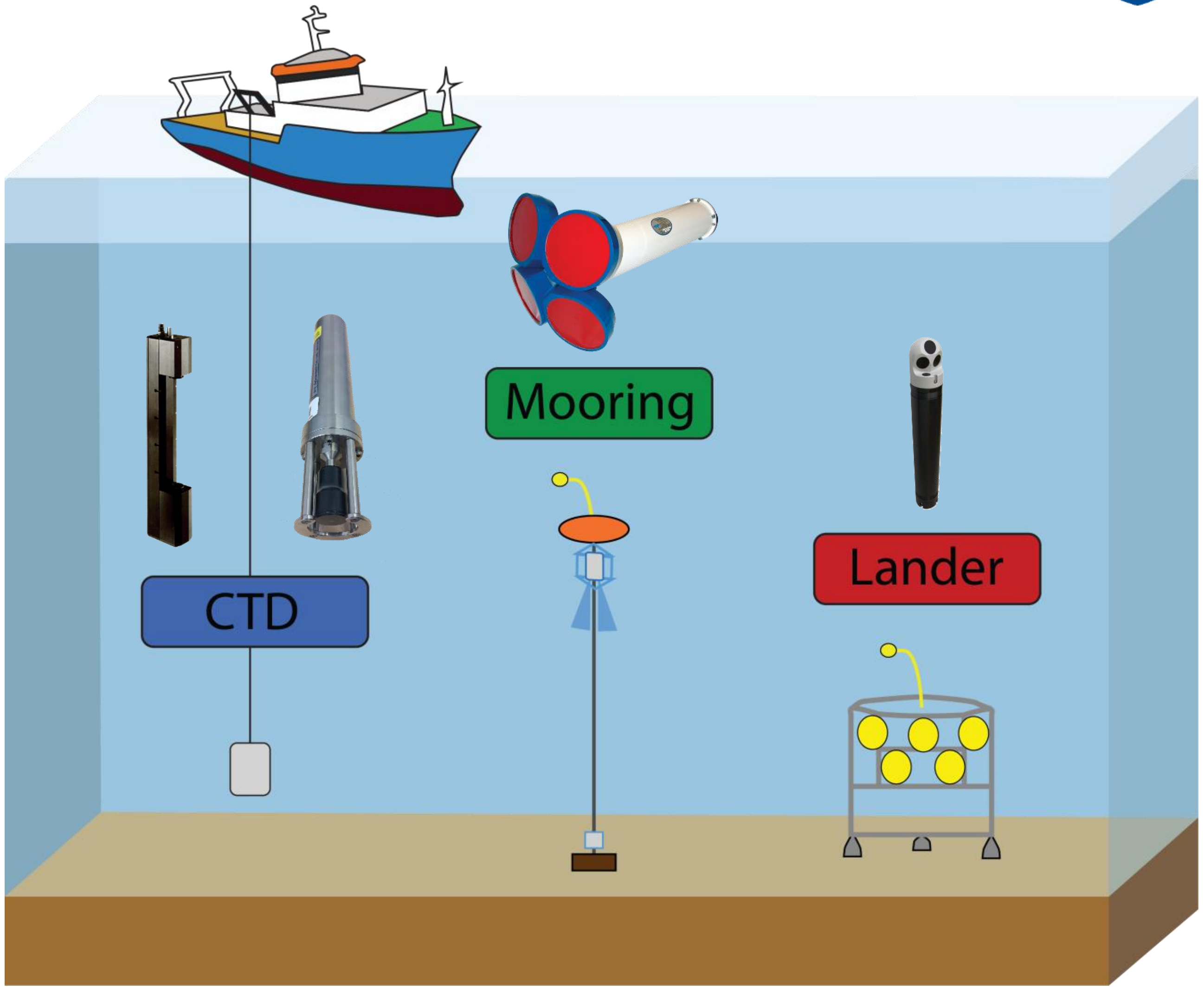
Map showing the Whittard Canyon. Blue) CTD stations. Green) Mooring. Red) Lander

Methods

- **CTD:**
  - WetLabs C-Star transmissometer (λ = 650 nm)
  - WetLabs FLNTU optical backscatter sensor (OBS) (λ = 700 nm)
  - JFE Advantech Infinity OBS (λ = 880 nm)

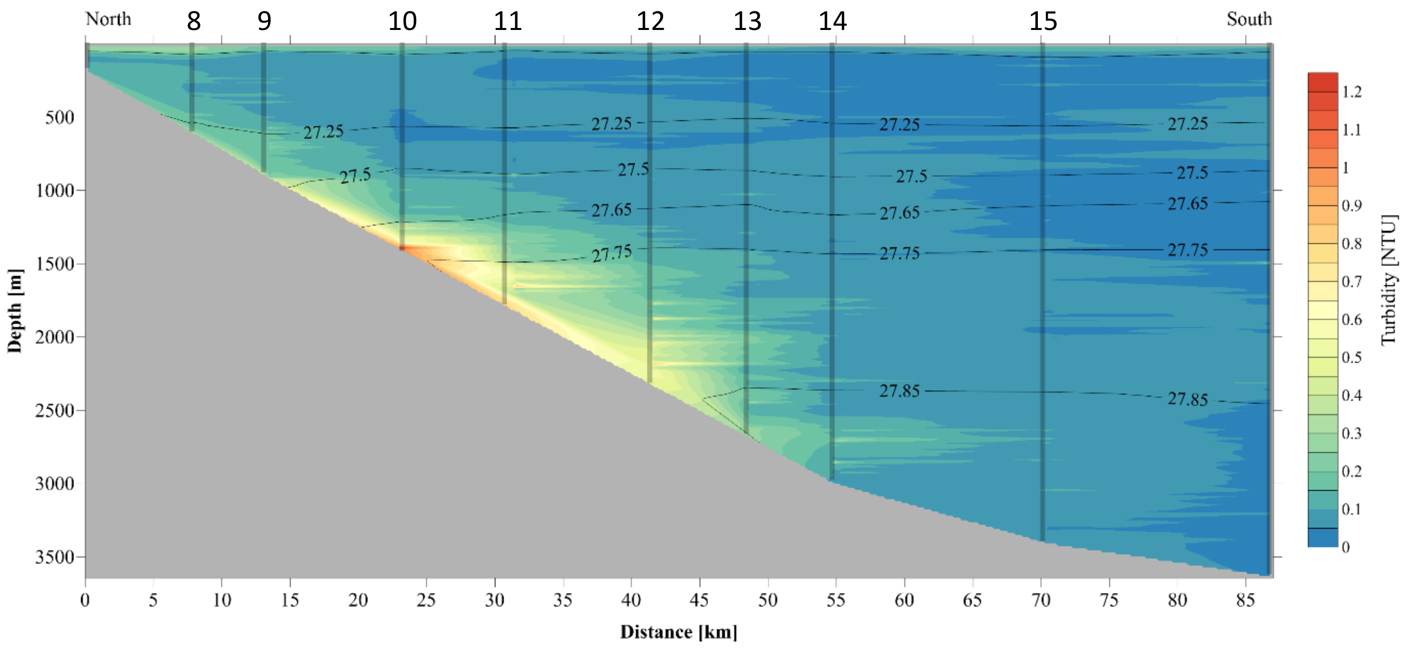
- **Mooring:**
  - 300 mab: Downward-looking 75 kHz RDI Workhorse ADCP
  - 5 mab: JFE Advantech Infinity OBS

- **Lander:**
  - 3 mab: 1 MHz Nortek Aquadopp current meter
  - 3 mab: JFE Advantech Infinity OBS

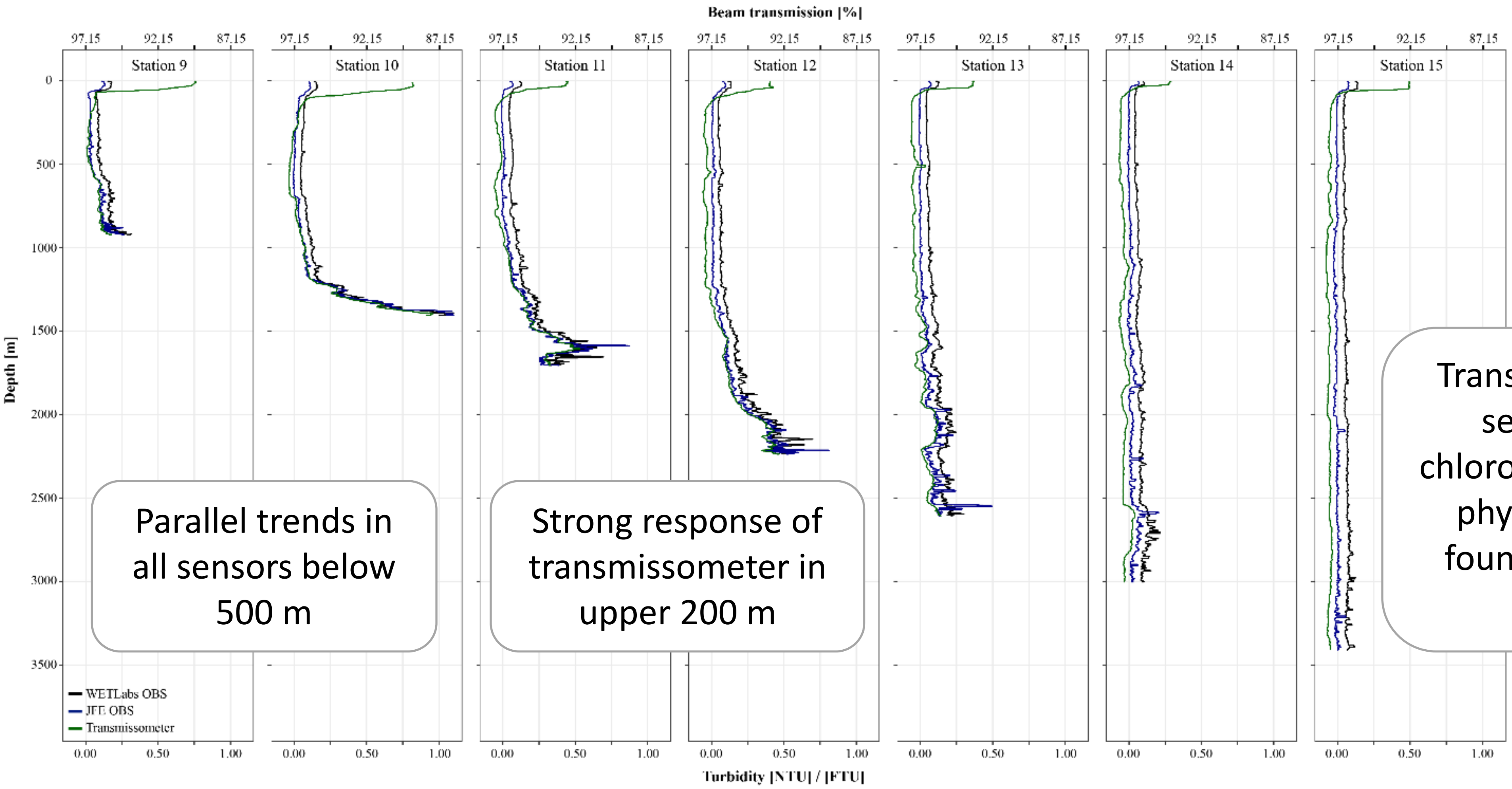


Results - CTD

- Intermediate and bottom nepheloid layers present at canyon depths between 1000 and 2500 m, with highest turbidity found between 1250 and 1750 m water depth



Results - CTD



Parallel trends in all sensors below 500 m

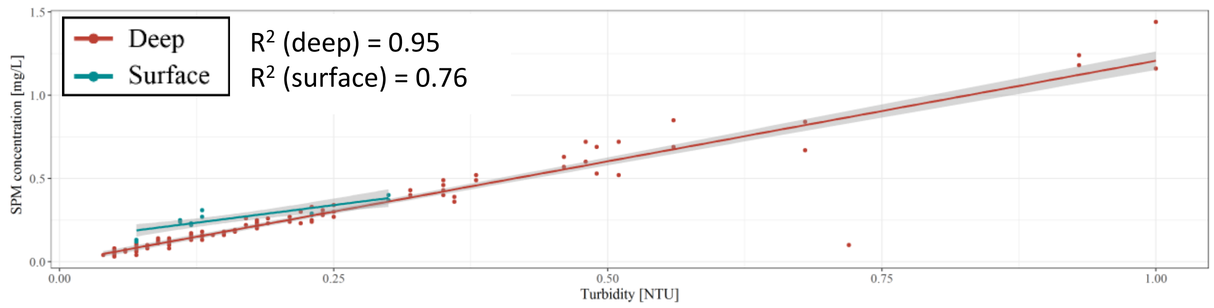
Strong response of transmissometer in upper 200 m

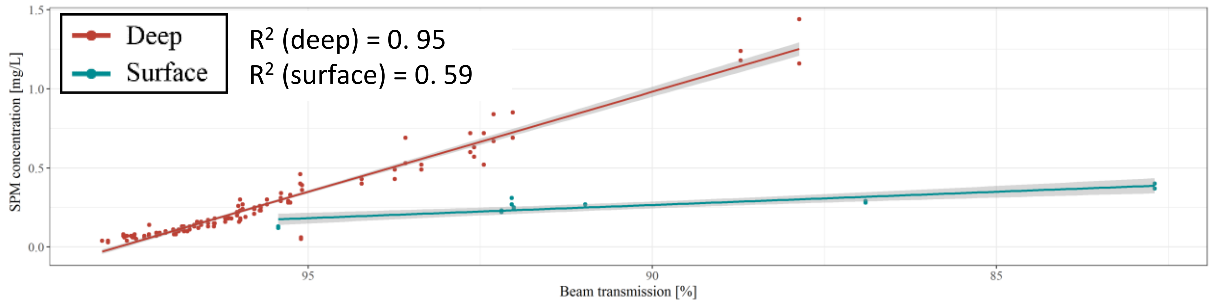
Transmissometer sensitive to chlorophyll-bearing phytoplankton found in surface layer?

Results - CTD

- Stronger response of the transmissometer in the surface layer may be attributed to a stronger absorption of light with a wavelength of 650 nm by chlorophyll-bearing phytoplankton, compared to the 700 and 880 nm light sources of the OBSs

- Similar response of OBS in surface layer compared to lower part of the water column

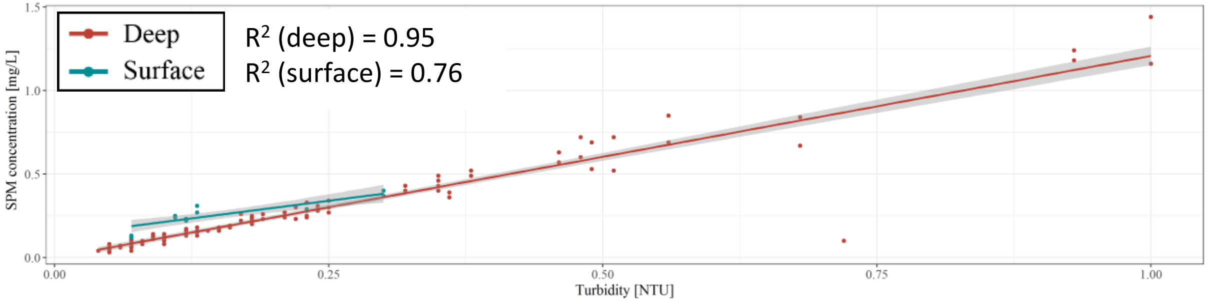


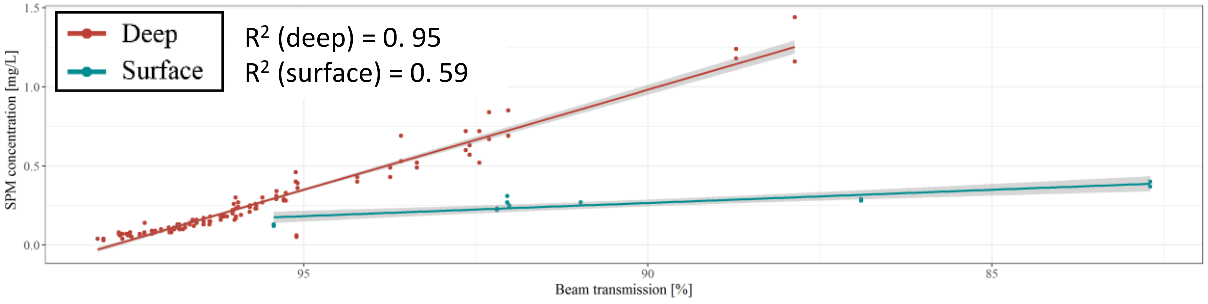


Results - CTD

- In order to properly quantify the responses of the optical turbidity sensors, these differences should be accounted for

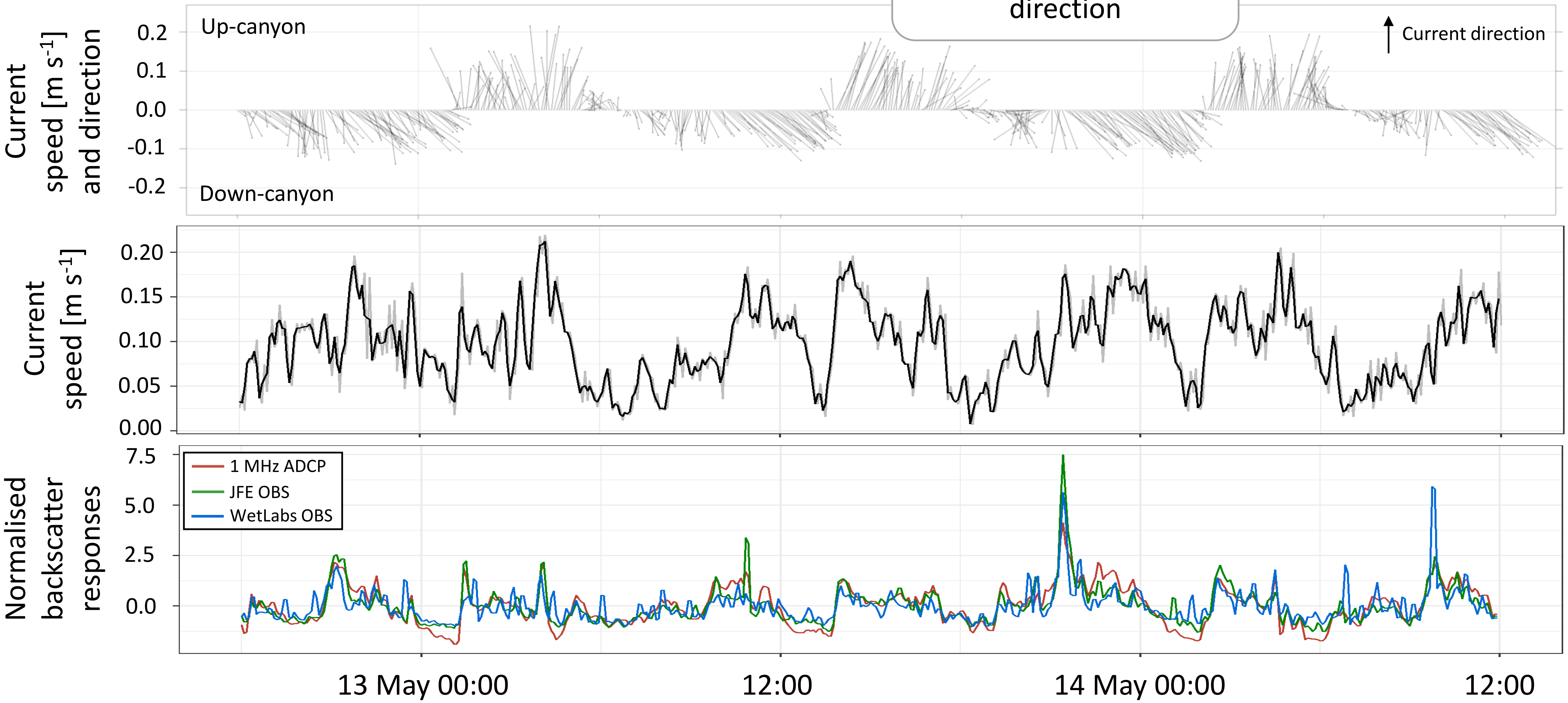
- If only one uniform regression line is calculated in the case of the transmissometer, the SPM concentration in the surface layer would be overestimated and the SPM concentration in the lower part of the water column would be underestimated





Results - Lander

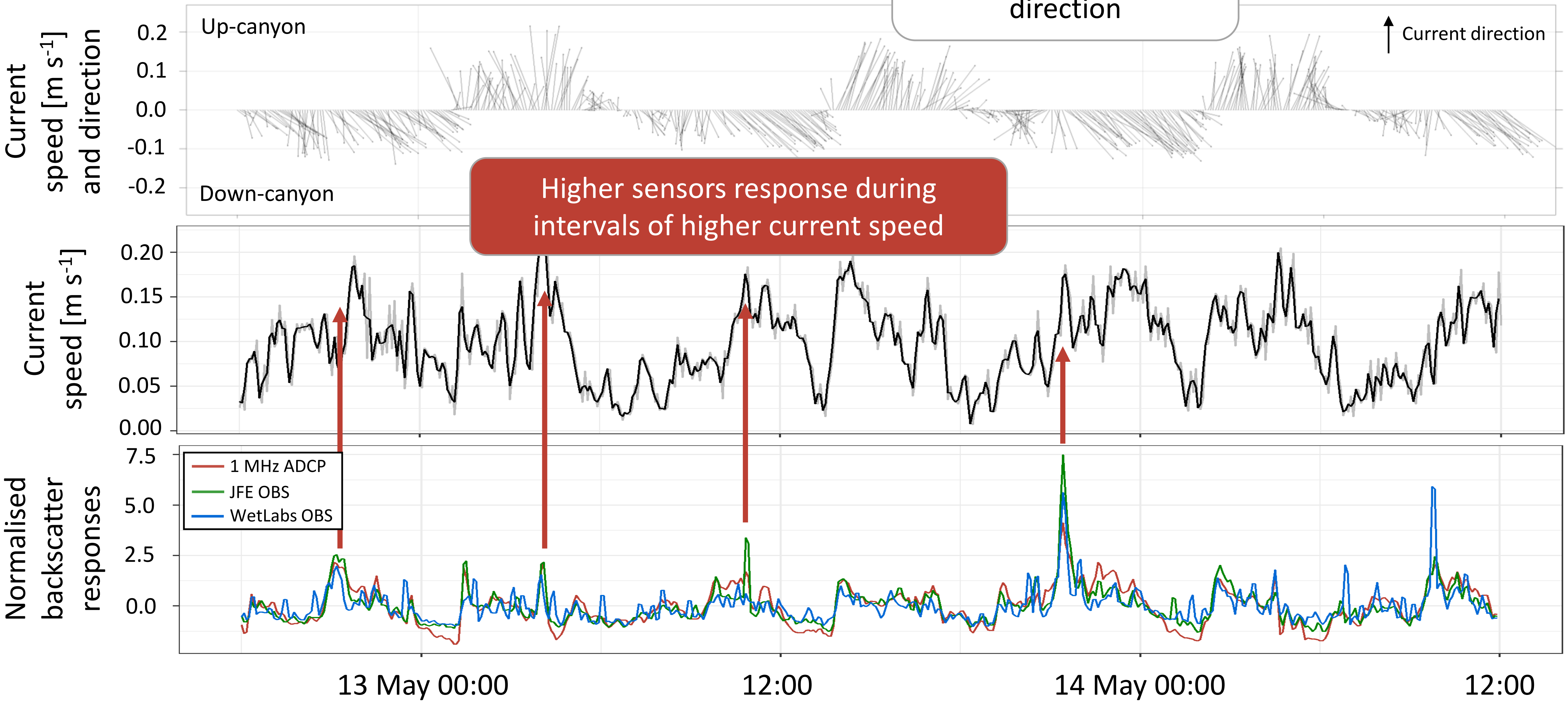
Semi-diurnal variation in current speed and direction



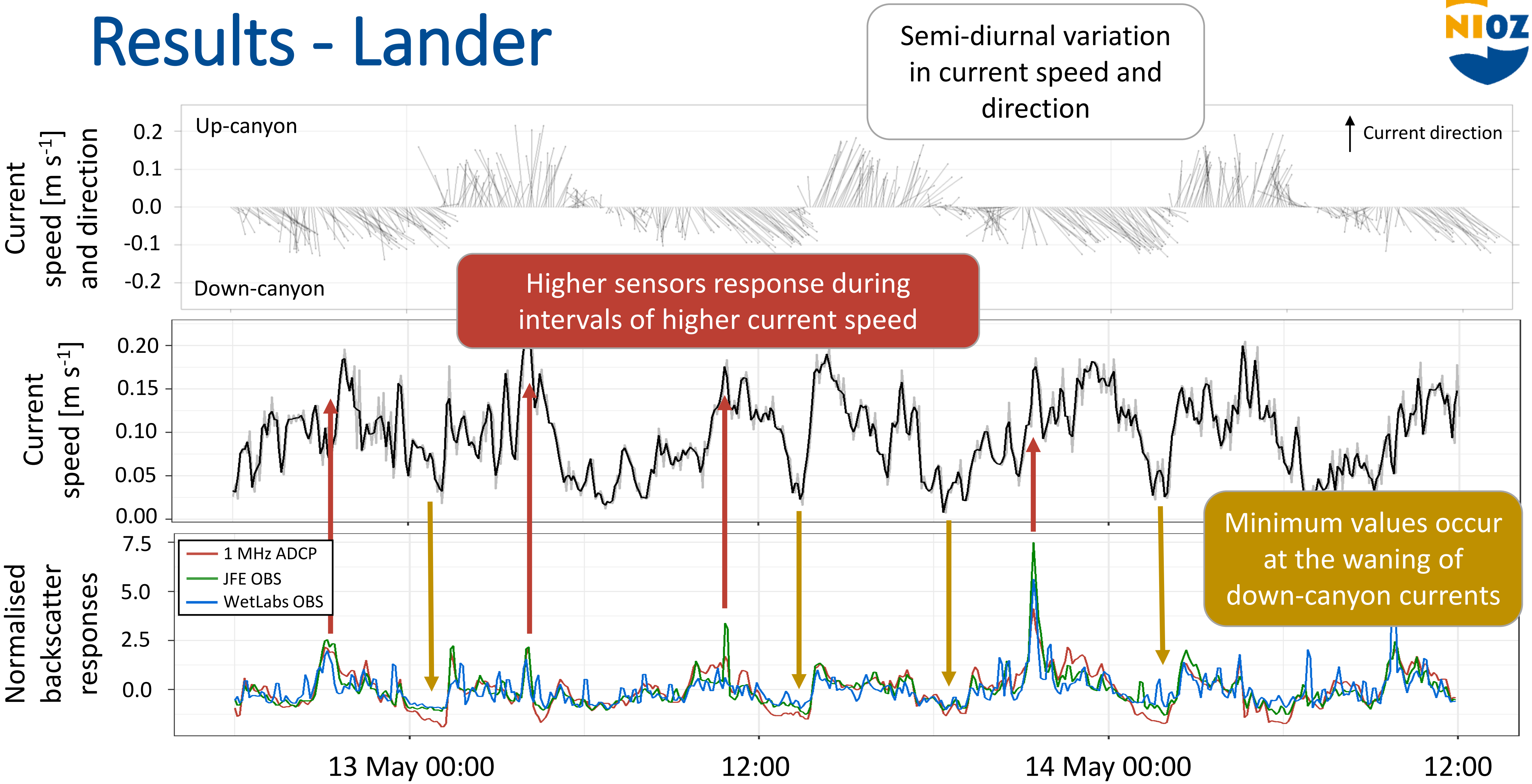
Results - Lander

Semi-diurnal variation in current speed and direction

Higher sensors response during intervals of higher current speed

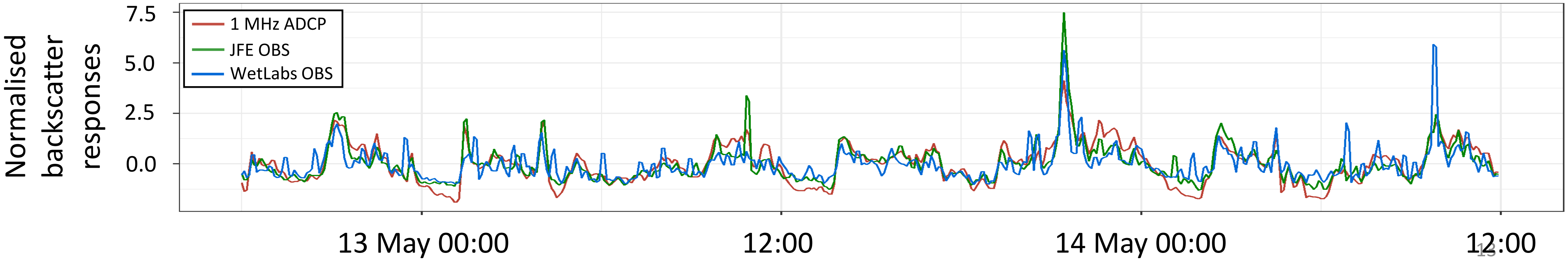


Results - Lander



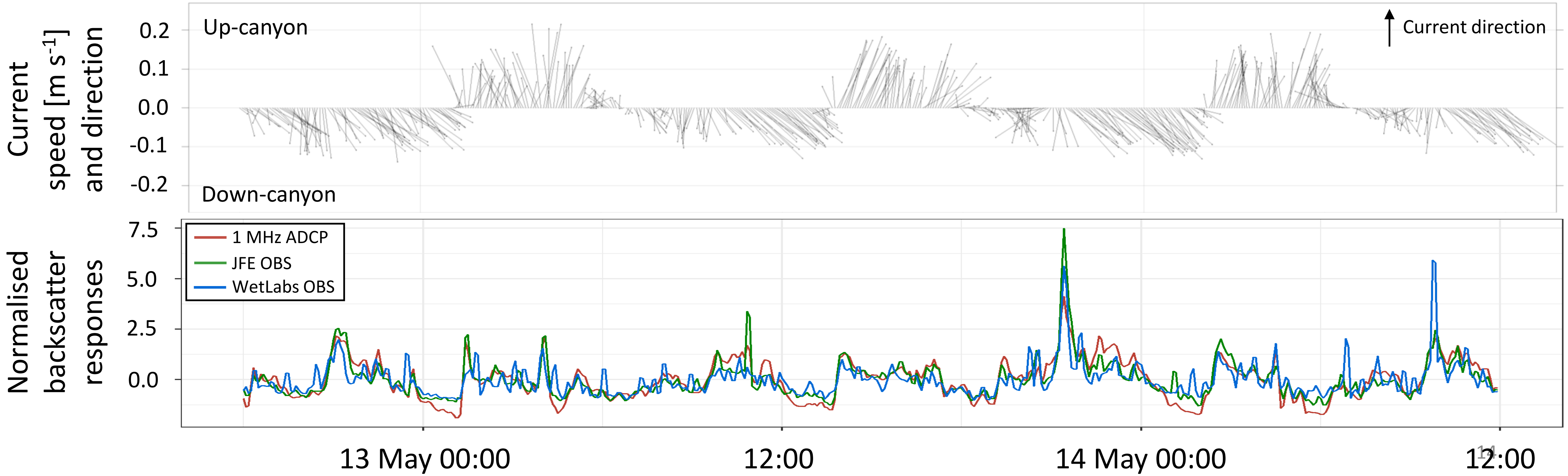
Results - Lander

- Sensor responses normalised to Z-scores, in order to better compare them
- Semi-diurnal variation in current speed and direction, with a main flow direction alternating between 15° (up-canyon) and 130° (down-canyon), and current speeds ranging from 2 to 20 cm s^{-1}
- OBSs and 1 MHz ADCP show remarkably similar turbidity patterns



Results - Lander

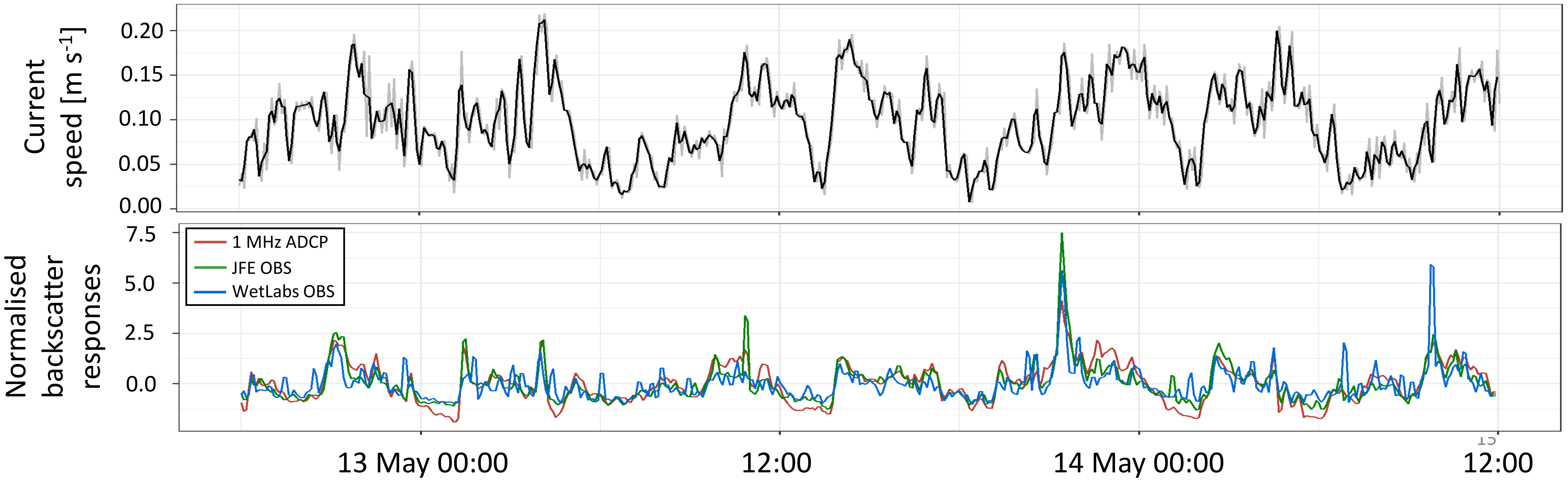
- Generally higher sensor response during intervals of higher current speed
- Minimum values occur with the waning of the down-canyon currents, and are followed by an abrupt increase in backscatter as the flow reverses



Results - Lander

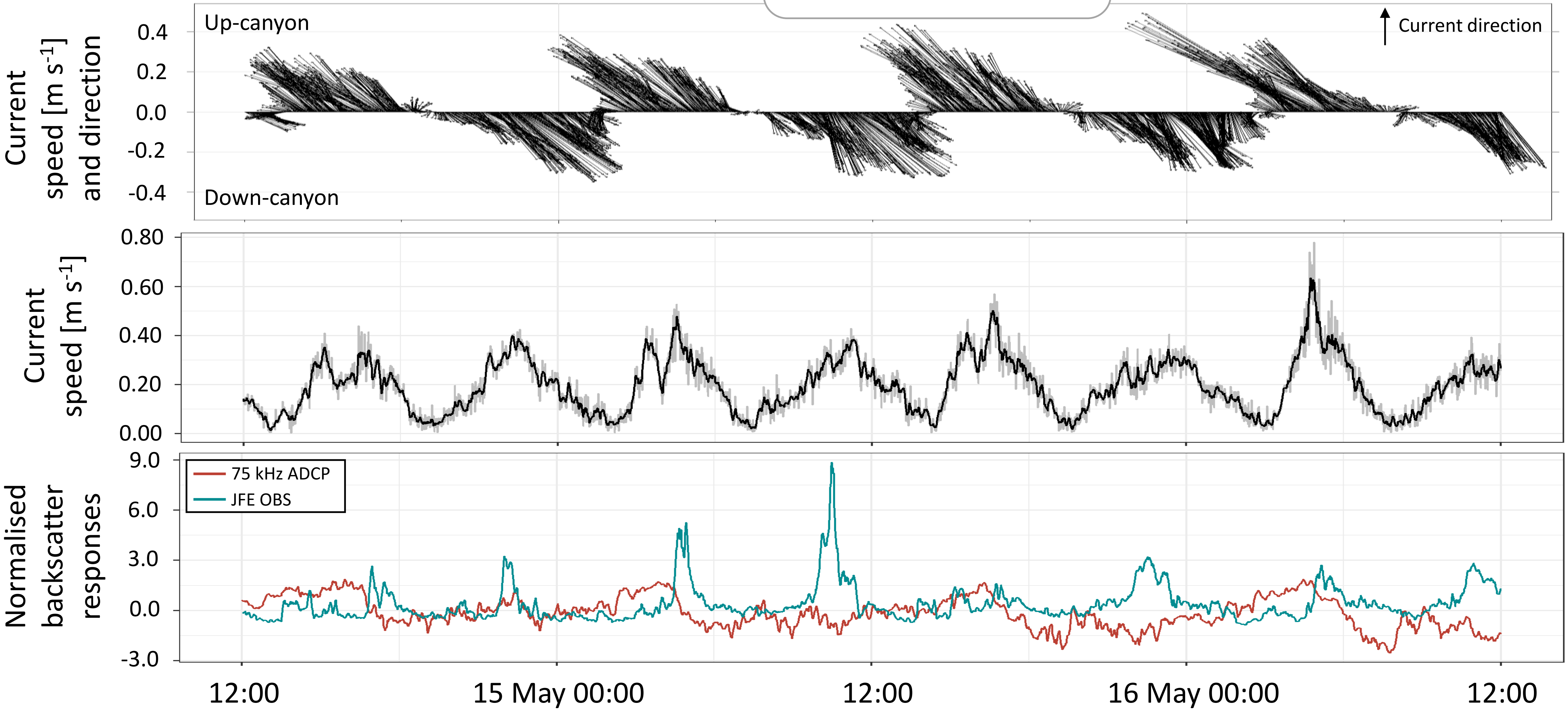
- Short-lived peaks in sensors response occur mostly during intervals of down-canyon flow when current speeds exceed 15 cm s^{-1}

  → may indicate local resuspension from the seabed or break-up of aggregates due to increased shear stresses



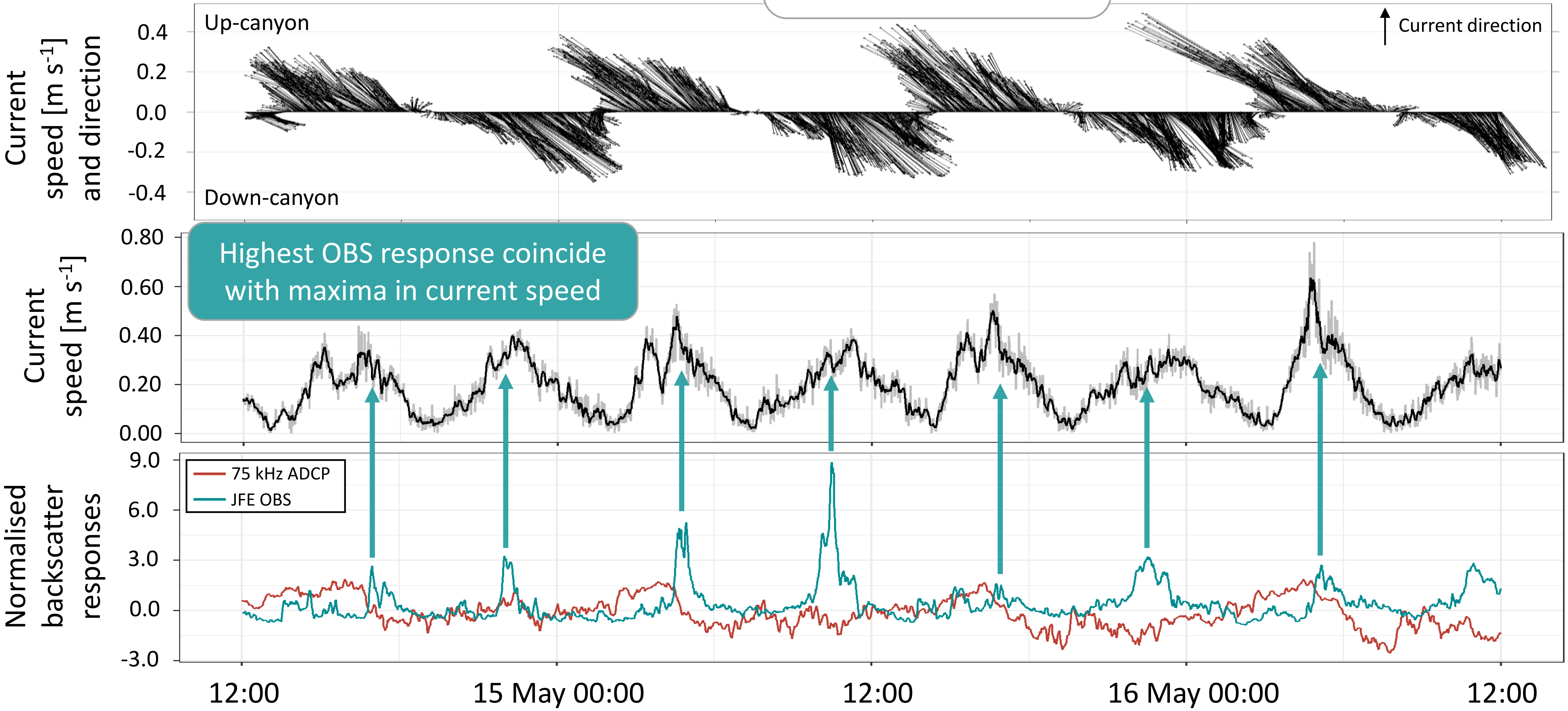
Results - Mooring

Semi-diurnal variation in current speed and direction

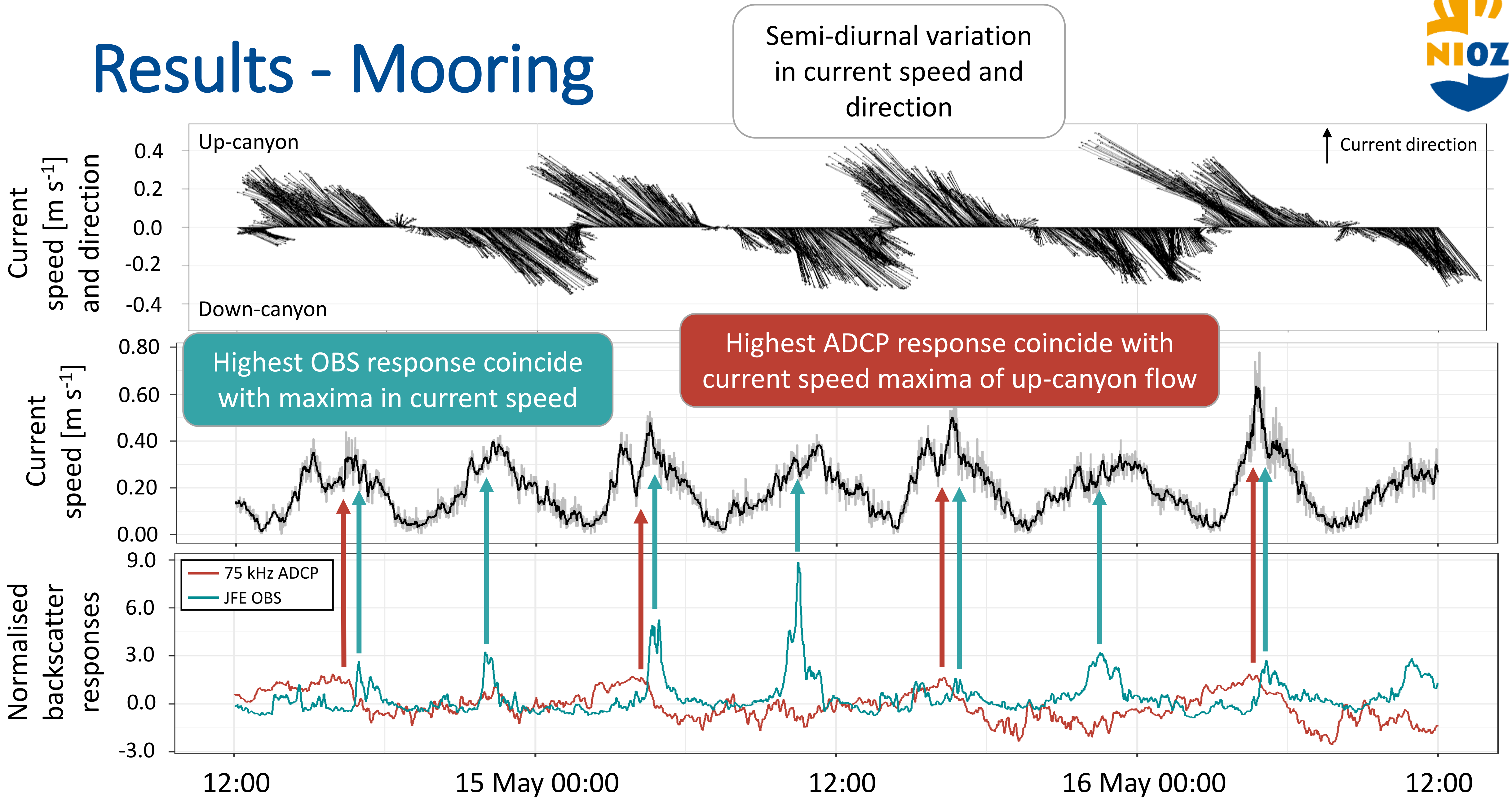


Results - Mooring

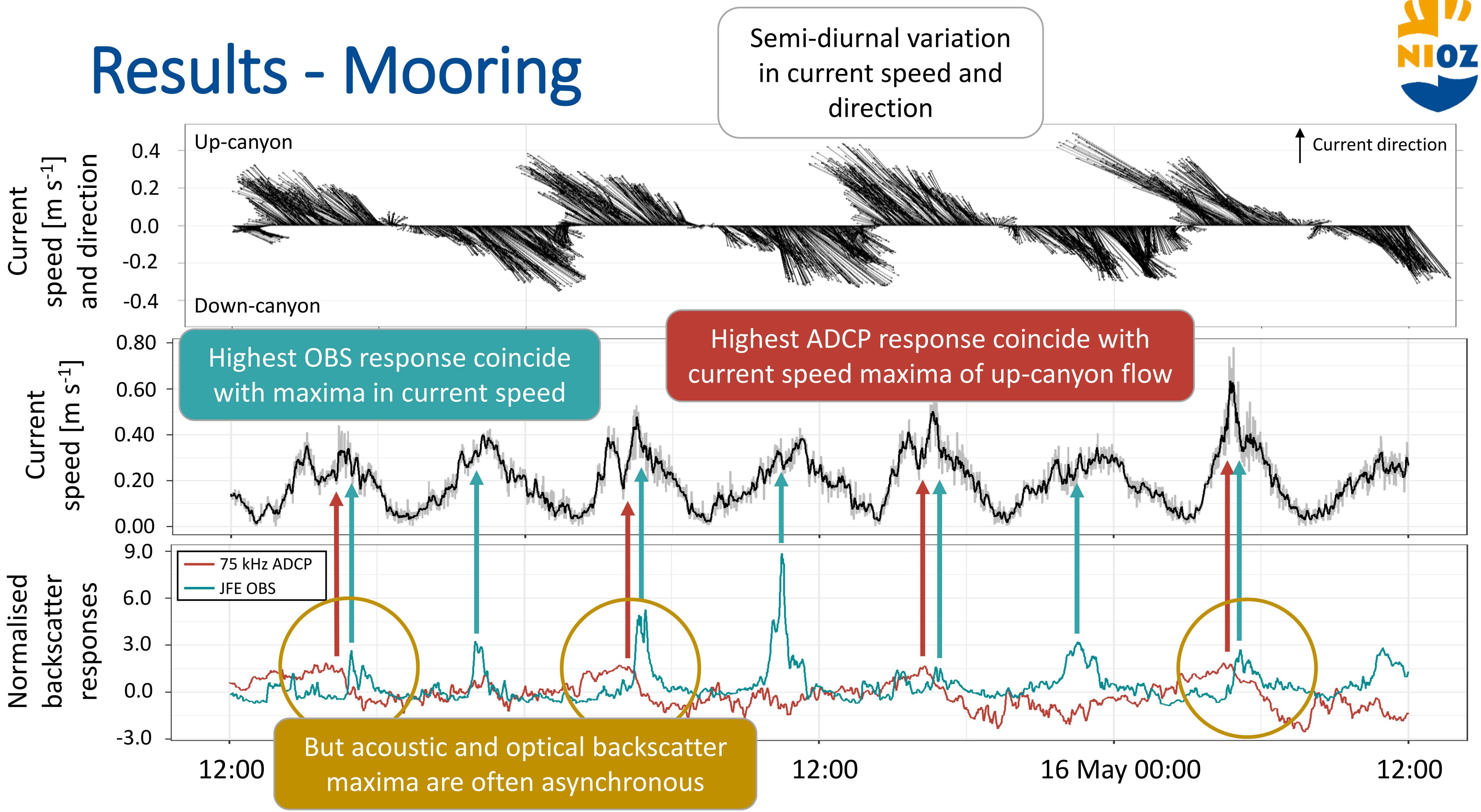
Semi-diurnal variation in current speed and direction



Results - Mooring

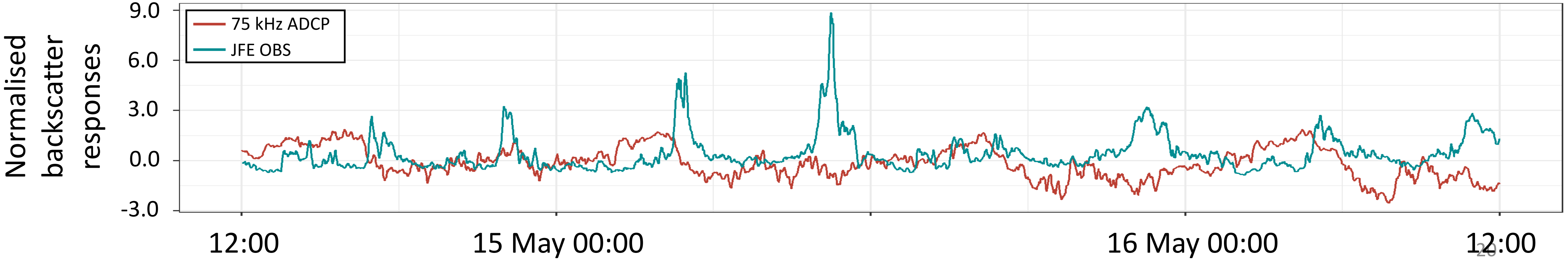


Results - Mooring



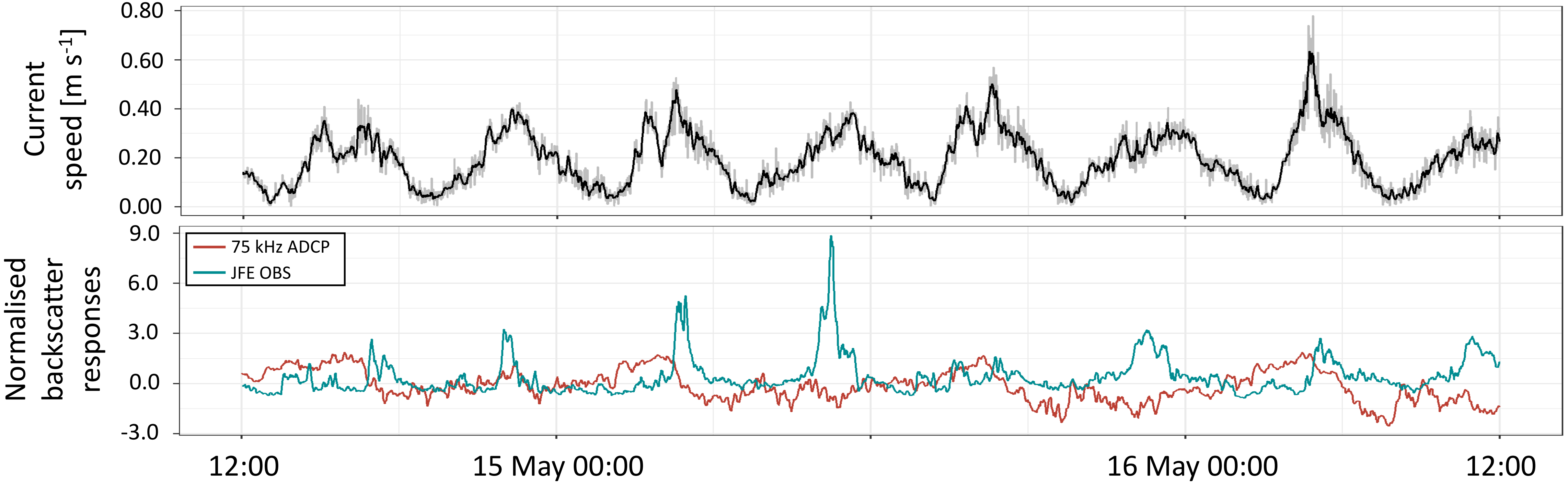
Results - Mooring

- Sensor responses normalised to Z-scores, in order to better compare them
- Semi-diurnal variation in current speed and direction, with a main flow direction alternating between 335° (up-canyon) and 155° (down-canyon), and current speeds ranging from 0 to 40 cm s^{-1}
- Records of OBS and 75 kHz ADCP do not match, but display different patterns



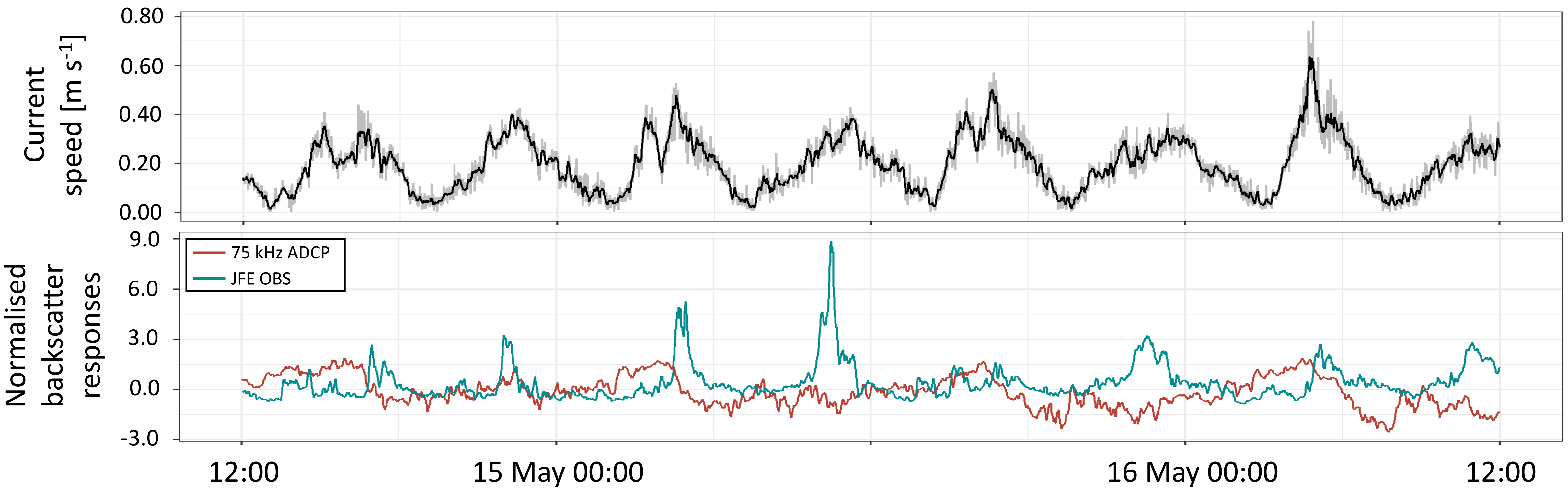
Results - Mooring

- Optical backscatter seems to respond closely to variation in up- and down-canyon current speed, with peaks in backscatter coinciding with maxima in current speed



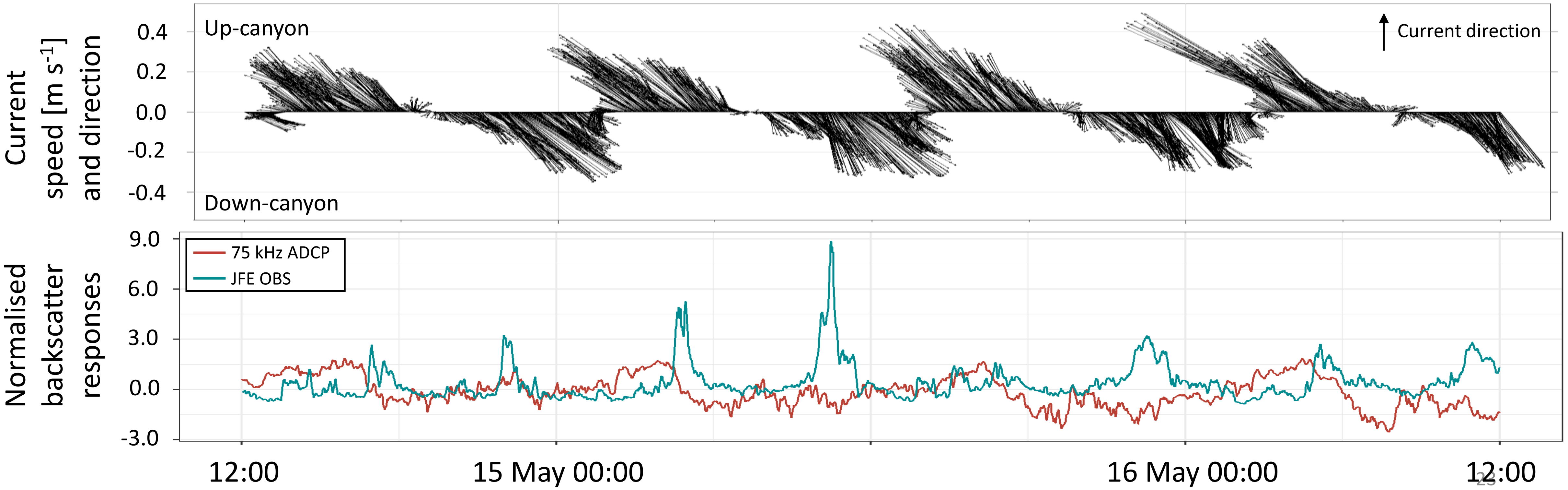
Results - Mooring

- Acoustic backscatter displays a broad, irregular sawtooth pattern, repeating itself every cycle of down-canyon to up-canyon



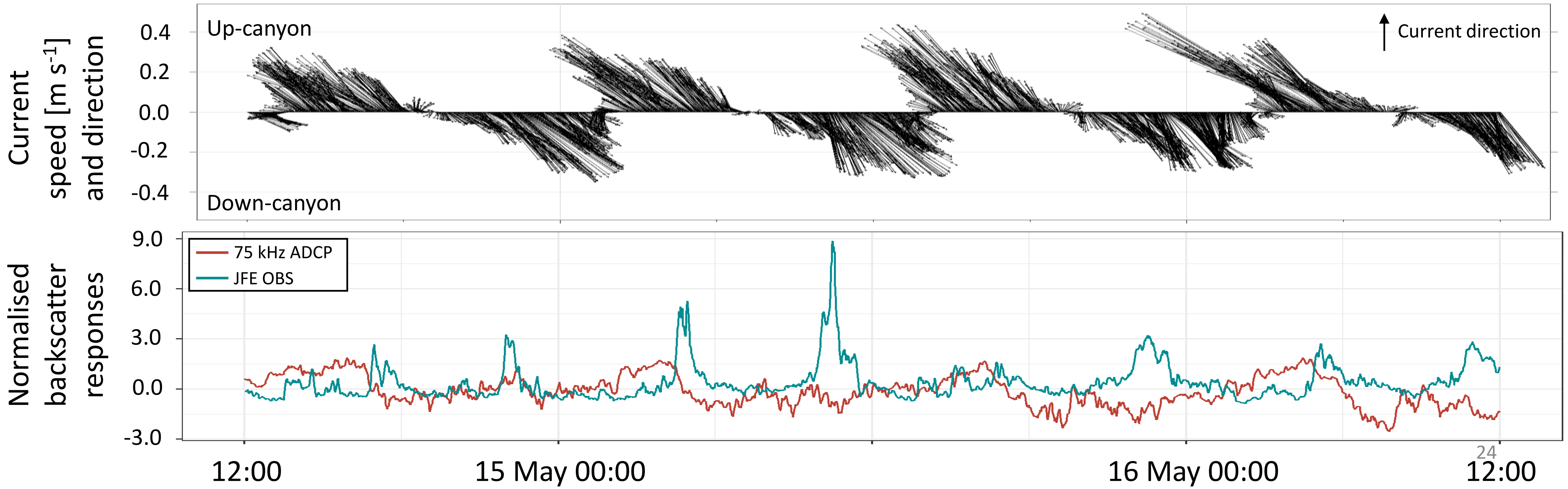
Results - Mooring

- Minimum optical and acoustic backscatter systematically occurs during intervals of low current speed, when the bottom water is turning from up-canyon to down-canyon



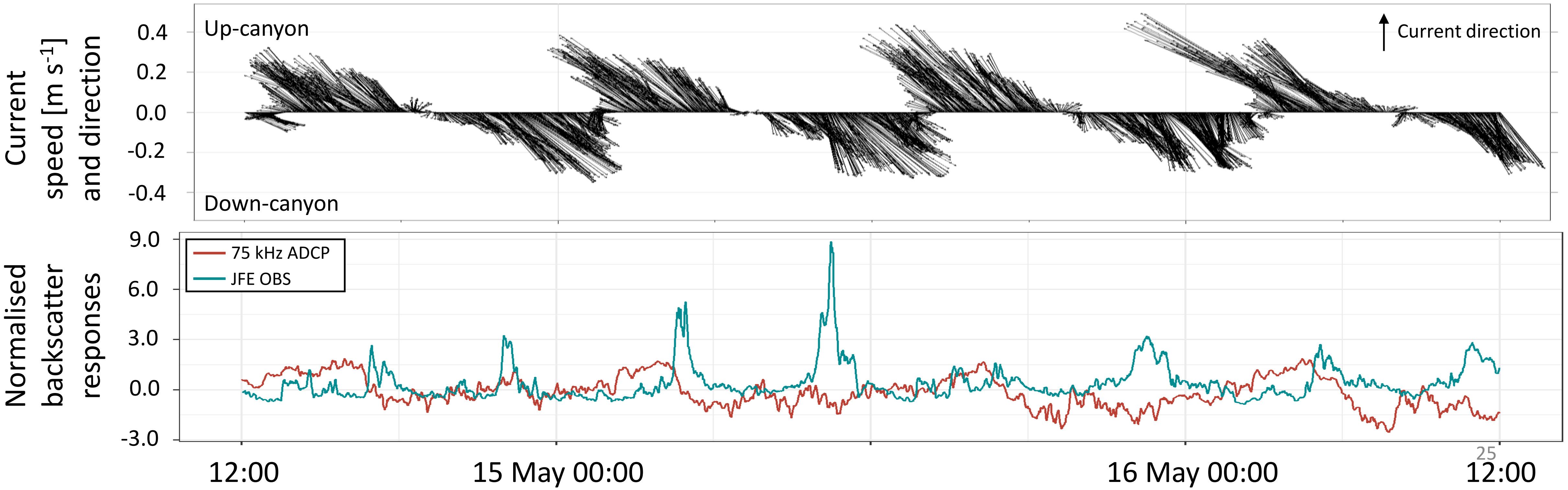
Results - Mooring

- Subsequently, acoustic backscatter gradually increases during the interval of down-canyon flow, and continues to increase during the following interval of up-canyon flow, to reach a maximum when the up-canyon current is at its maximum strength



Results - Mooring

- When up-canyon currents reach their maxima, acoustic backscatter steeply drops to minimum values. Peaks in optical backscatter generally do not coincide, but follow just after the peaks in acoustic backscatter



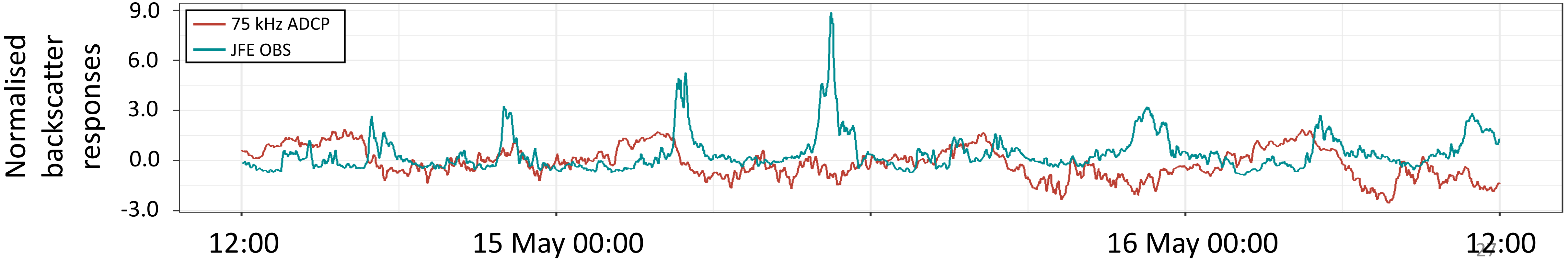
Results - Mooring

- Gradually increasing acoustic backscatter during a tidal cycle could reflect increasing amounts of aggregates picked up by the current from the canyon floor and entrained in the bottom water flow

- Recurrent peaks in optical backscatter at maximum up-canyon current could reflect the moment when the more cohesive sediment was also resuspended. However, the fact that optical backscatter tends to peak immediately after acoustic backscatter has peaked and already start to decline, suggest that a more direct, causal link may exist between the two signals

Results - Mooring

- The abrupt drop in acoustic backscatter at maximum up-canyon current speeds could reflect the break-up of larger aggregates into dispersed finer-grained particles, which is then reflected by a sharp increase in optical backscatter
- The subsequent steep decrease in optical backscatter and continuing decrease in acoustic backscatter could indicate re-aggregation and settling at the waning of the tidal current



Results - Mooring

- At the bottom of the canyon, optical and acoustic sensors responded differently during one tidal cycle, interpreted as cyclic resuspension, whereby different phases of disaggregation, reaggregation and settling of particulate matter were observed

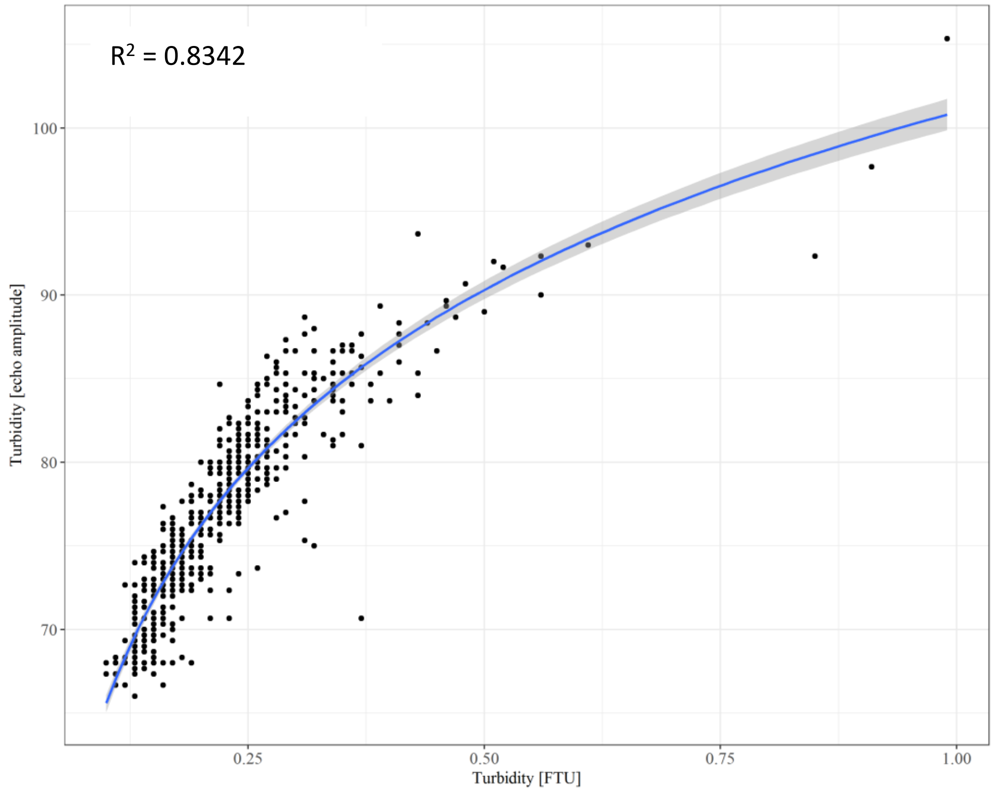
→ These differences in the records have implications on the estimation of mass fluxes of suspended particulate matter, which are vital for understanding for instance carbon transport processes in the bottom boundary layer

Results - Quantification

- Logarithmic relation between optical backscatter of OBS and acoustic backscatter of 1 MHz ADCP

→ Logarithmic relation between acoustic backscatter of 1 MHz ADCP and SPM concentration

→ Both sensors able to detect fine grained particles

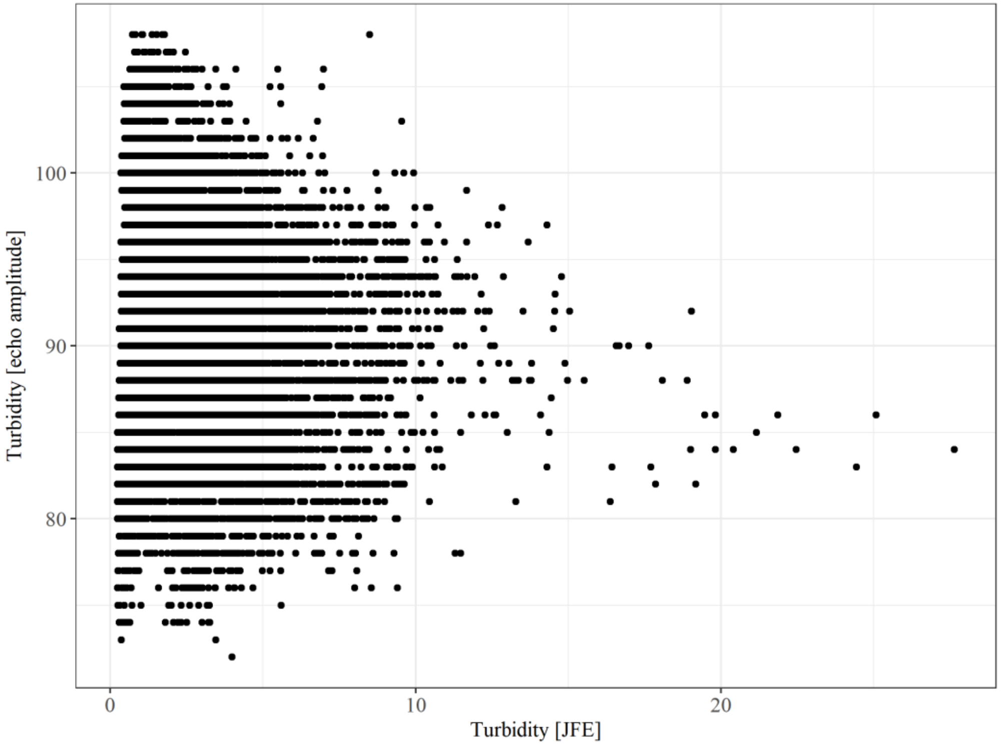


Results - Quantification

- No relationship between optical backscatter of OBS and acoustic backscatter of the 75 kHz ADCP

→ Sensors have different grain size sensitivities

→ Not able to properly quantify the response of the 75 kHz ADCP



Results - Quantification

- For a full quantification of the SPM transport in the bottom boundary layer, the responses of the OBS and the 75 kHz ADCP should be combined to account for both fine grained and coarse-grained particles

→ Created mixed model in which each sensors has a contribution based on the particle size distribution of the SPM
  - In-situ particle size measurements using a LISST (up to 500 µm)
  - In-situ particle size measurements using particle cameras (finest grain size hardly detectable)
  - Multi-frequency sensors (e.g. AQUAscat) (up to 500 µm)

Conclusions and recommendations

- In each study careful considerations should be made to determine which sensors, of which combination of sensors, should be used
  - Transmissometer:
    - Increased sensitivity for chlorophyll-bearing plankton
  - OBSs and high-frequency ADCPs:
    - Detection of fine-grained particles
    - OBS response linearly related to SPM concentration
    - ADCP response logarithmically related to SPM concentration
  - Low-frequency ADCPs:
    - Detection of large aggregates

Conclusions and recommendations

- Dynamic systems like Whittard Canyon:
  - Combination of OBS or high-frequency ADCP together with low-frequency ADCP to observe tidal-induced resuspension processes involving the break-up and formation of aggregates

- Monitoring dispersion of plumes created by anthropogenic disturbances (e.g. bottom trawling, dredging, deep-sea mining):
  - Close to the disturbance site mainly fine-grained material
  - Flocculation will be a major factor in the dispersion of these plumes (Gillard et al., 2019)
  - Combination of sensors to detect both fine- and coarse-grained material

End of presentation

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