

# Impact of Motion Correction on Momentum and Sensible Heat Fluxes Measured on a Moving Vessel in the Arctic

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## Background

Due to its stabilizing effect on the global climate system as well as its alarming warming rates, the Arctic has long been in the spotlight of atmospheric research. While the long-range transport of gases and aerosols into the Arctic is well-understood by now, additional research is needed to better comprehend the local particle-induced processes fueling the regional rise in temperature. (Mathes et al., 2025)

## Objectives

In an attempt to identify sources and sinks of aerosols, vertical near-surface particle, momentum and sensible heat fluxes were examined by collecting an eddy covariance data set over ice and water during the PS 131 expedition of the German research icebreaker *Polarstern*. The data set consists of three-dimensional wind speed and particle number concentration, recorded using an ultrasonic anemometer (Gill Solent HS-044, Lymington, UK) and an MCPC (Brechtel Model 1720, Hayward, USA) hung from the ship's bow crane outrigger (see Fig. 1).



Fig. 1 – Polarstern's bow crane outrigger

To minimize the inadvertent effect of the moving vessel on the recorded vertical wind data and thus the calculated fluxes, motion correction was carried out using the default as well as a novel approach specifically developed for the given situation.

## Standard: Reference Frame Realignment

For this method, first proposed by Fujitani (1981) and later expanded by Edson et al. (1998), the actual wind in a desired fixed coordinate system  $v_{act}$  is considered to be the sum of three components:

$v_{obs}$  Wind observed in the ship's frame of reference, aligned with desired fixed coordinate system using pitch, roll and yaw

$v_{rot}$  Apparent wind caused by ship's rotation around its axes, corrected using angular rates and anemometer offset

$v_{trans}$  Apparent wind caused by the vessel's translational motion in the fixed coordinate system

As the spatial offset between the motion sensor and the anemometer on the bow crane outrigger was unknown, it had to be approximated through testing. The optimal x offset appears to be 60 m (see Fig. 2). The effect of the y and z offsets proved to be negligible (not depicted).

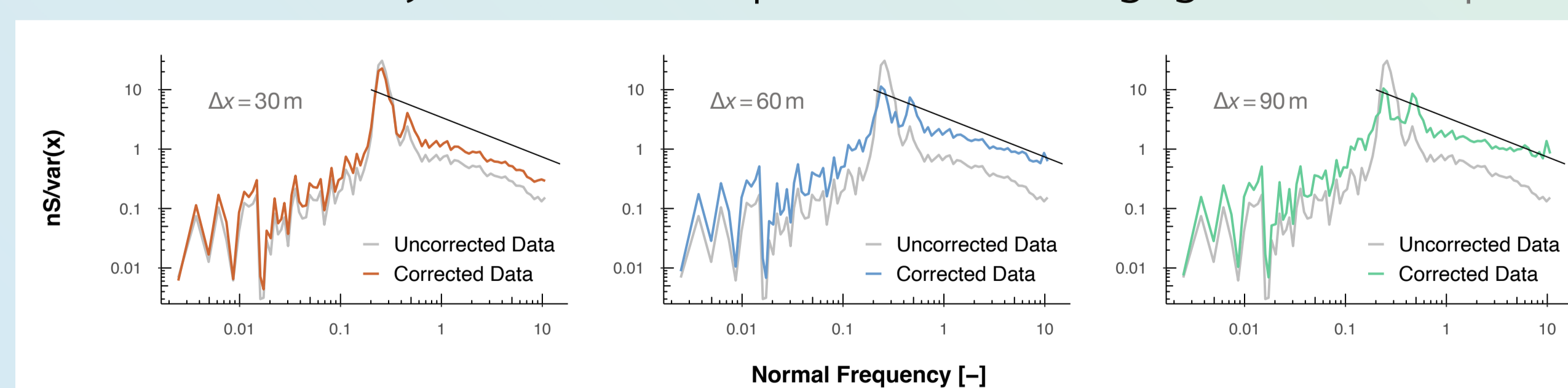


Fig. 2 – Effect of x offset on power spectrum of realigned vertical wind data

## Novelty: FFT Coefficient Manipulation

Assuming the contaminating components in the observed vertical wind are, at least for short periods of time, rather constant and only occur in narrow frequency ranges, it was attempted to filter out said frequencies using Fast Fourier Transformation (FFT) analysis (see Fig. 3).

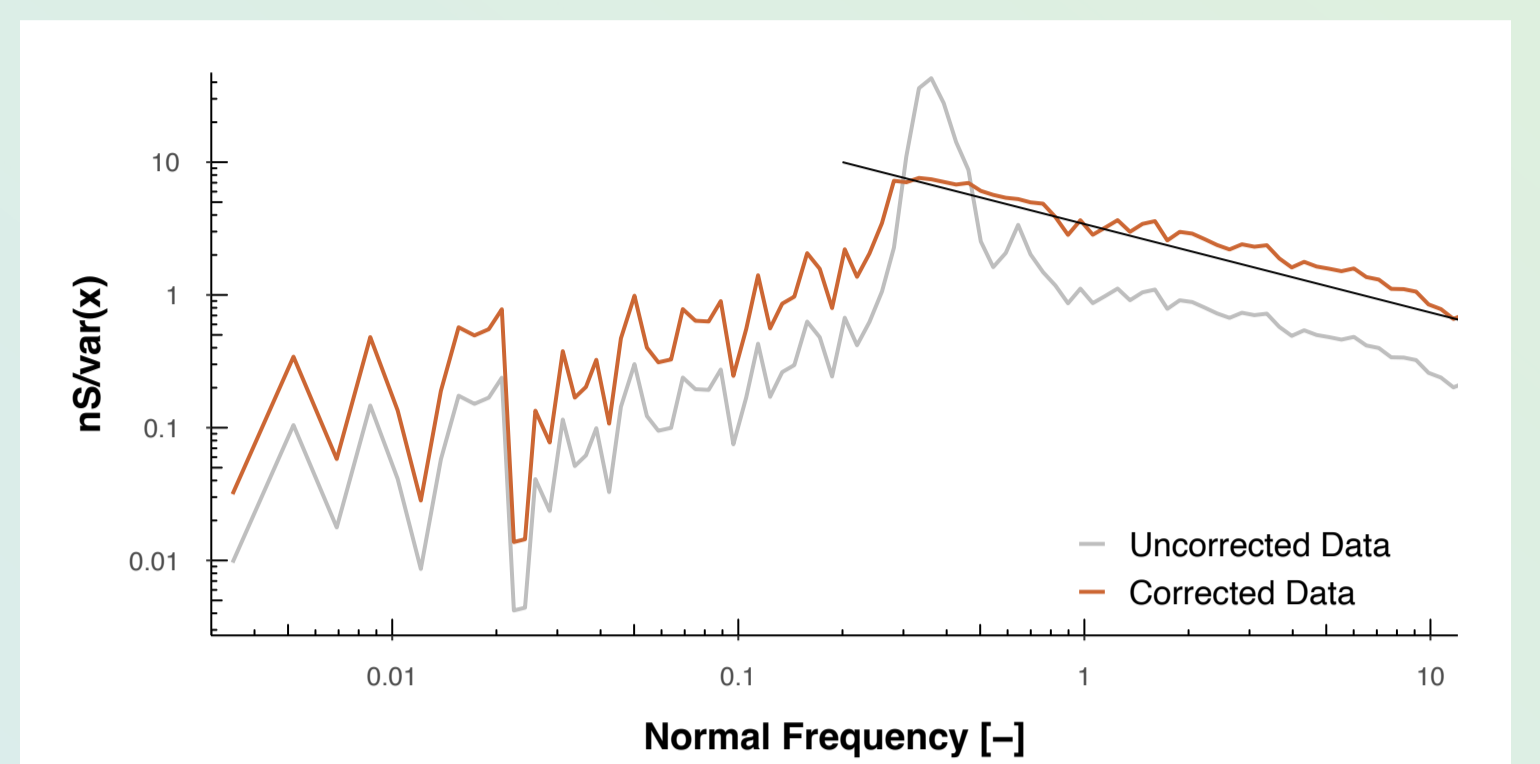


Fig. 3 – Effect of FFT correction on power spectrum

The correction process included the following steps:

- 1 Find affected frequency range in power spectrum
- 2 Manipulate corresponding FFT coefficients by applying a frequency-dependent dampening factor
- 3 Reconstruct time series from updated FFT coefficients (see Fig. 4)

For an exemplary 30 minute vertical wind data set, the frequencies most affected by the vessel's motion were between 0.28 and 0.70 Hz.

## Comparison and Conclusions

Figure 4 compares the results of both correction approaches applied to a vertical wind data set, while figure 5 depicts the momentum and sensible heat fluxes calculated from the raw and corrected data.

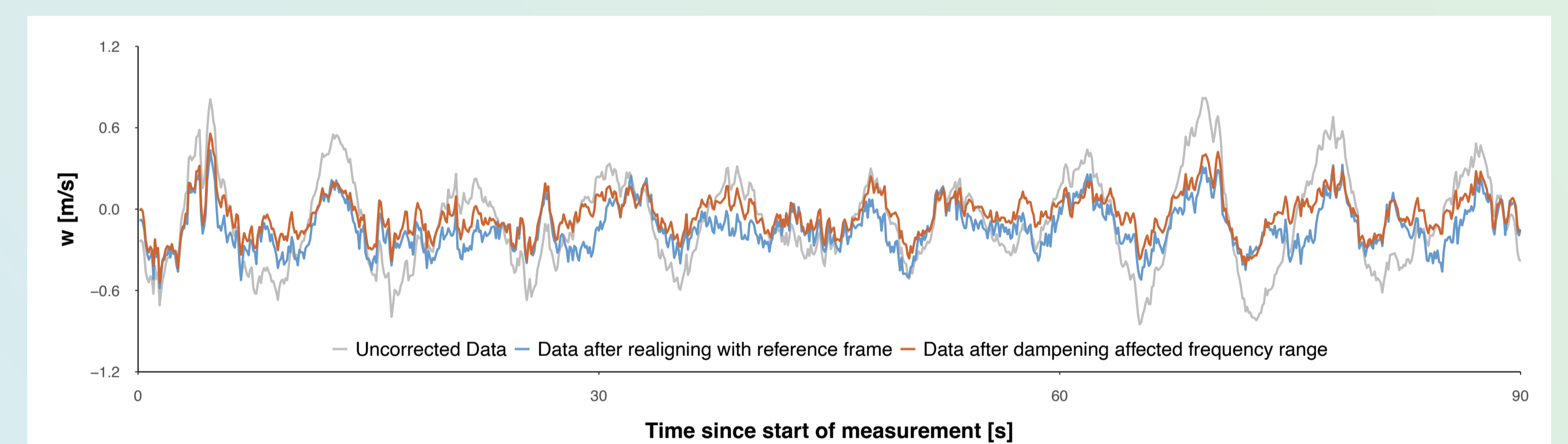


Fig. 4 – Time series of vertical wind after correction using both approaches (raw data in grey)

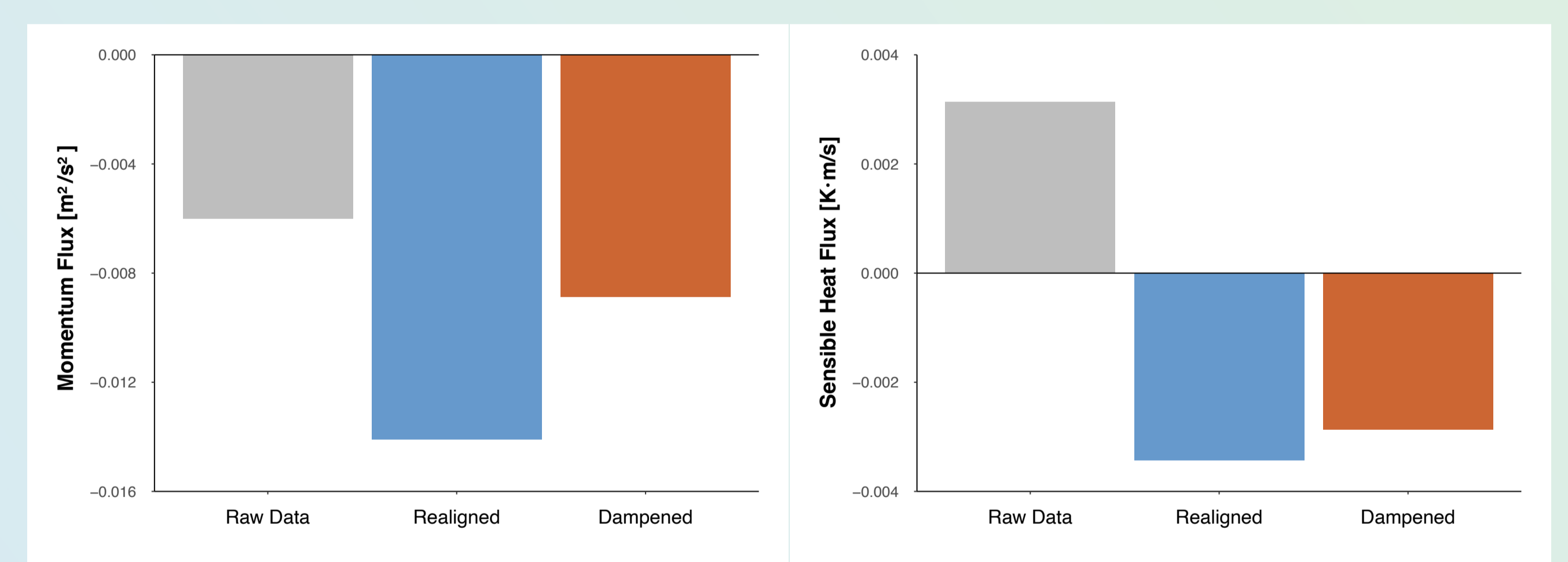


Fig. 5 – Effect of motion correction approach on momentum flux (left) and sensible heat flux (right)

Taking the results into account, it can be concluded:

- Reduction of vessel movement impact on data achievable with both methods, though relevant differences are visible (esp. in time series)
- Reference Frame Realignment appears to be a more reliable option with additional use cases (e.g. allows correction of horizontal wind), if necessary data regarding measurement setup is readily available
- Dampening of FFT coefficients easier to use and implement, while delivering similar results in the given case with limited complexity of data set (e.g. short intervals as frequencies introduced or amplified by vessel movement must be constant, negligible roll angles)