

How Does Source Water Depth Covary with Stratification and Upwelling in the Canary Upwelling System ?

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MOTIVATION AND AIM

Eastern Boundary Upwelling Systems (EBUS), such as the Canary Current Upwelling System (CCUS), are driven by wind-induced upwelling that supplies nutrient-rich waters to the surface. The depth of these source waters is controlled by the interplay between wind forcing and ocean stratification. Vazquez et al., (2024) shows that this interplay is not uniform: wind and stratification can reinforce or oppose each other depending on region and season, leading to both shoaling and deepening of upwelling source depths. However, the relative roles of wind and stratification and their seasonal interplay remain poorly constrained from observations. Here, we quantify the relative roles of wind forcing (UI) and stratification (N) in controlling density-derived source depth ($D_{upw,\rho}$), with a focus on seasonal contrasts (DJF vs JJA).

METHODS

Computations of :

$$UI = \frac{\tau_{alongshore}}{\rho_0 f}; \quad N = \sqrt{-\frac{g}{\rho_0} \frac{\partial \rho}{\partial z}}; \quad D_{upw,\rho} = z_{off}(\rho_{coast}(z_{MLD}))$$

 Multiple regression & partial correlations (direct effects)
 Generalized Additive Models (GAM; nonlinear response)

DATA

- CCMP v3.0 winds (10m);
- RAPID hydrography mooring array (26.5°N)

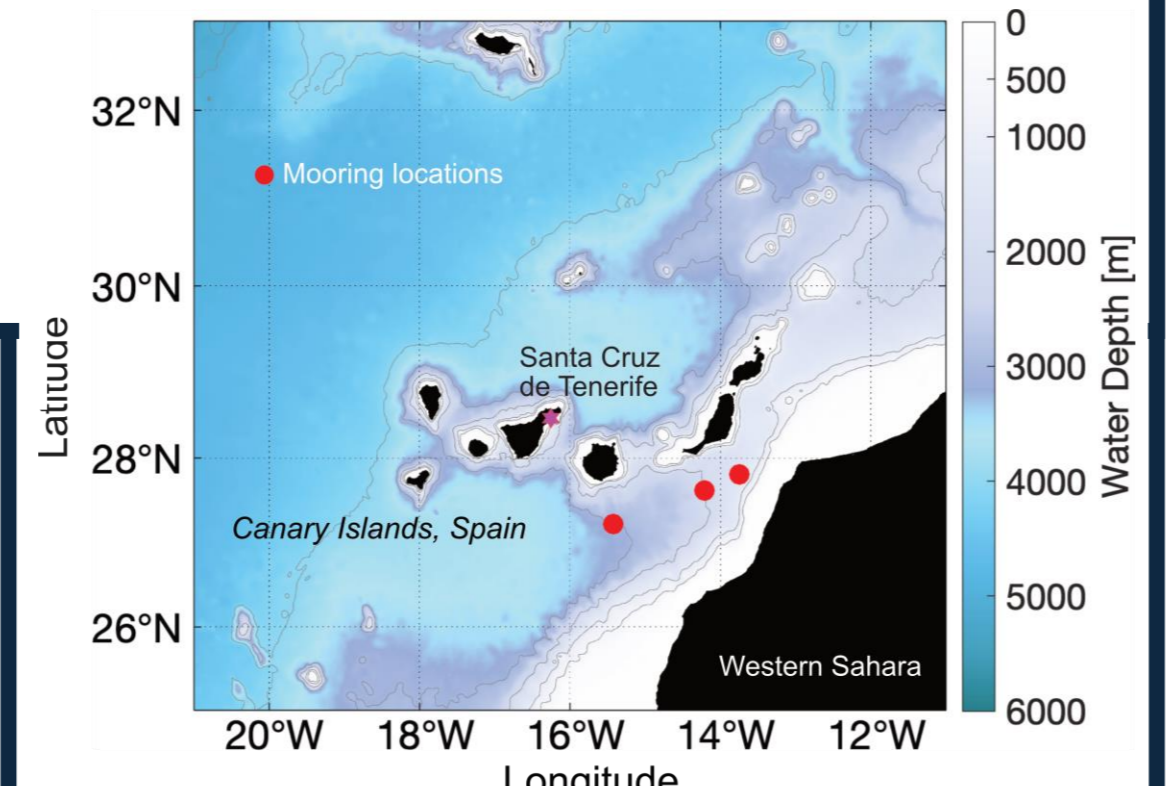


Figure 1: RAPID mooring array.

TIME SERIES : wind forcing, stratification, and source depth (2005–2023)

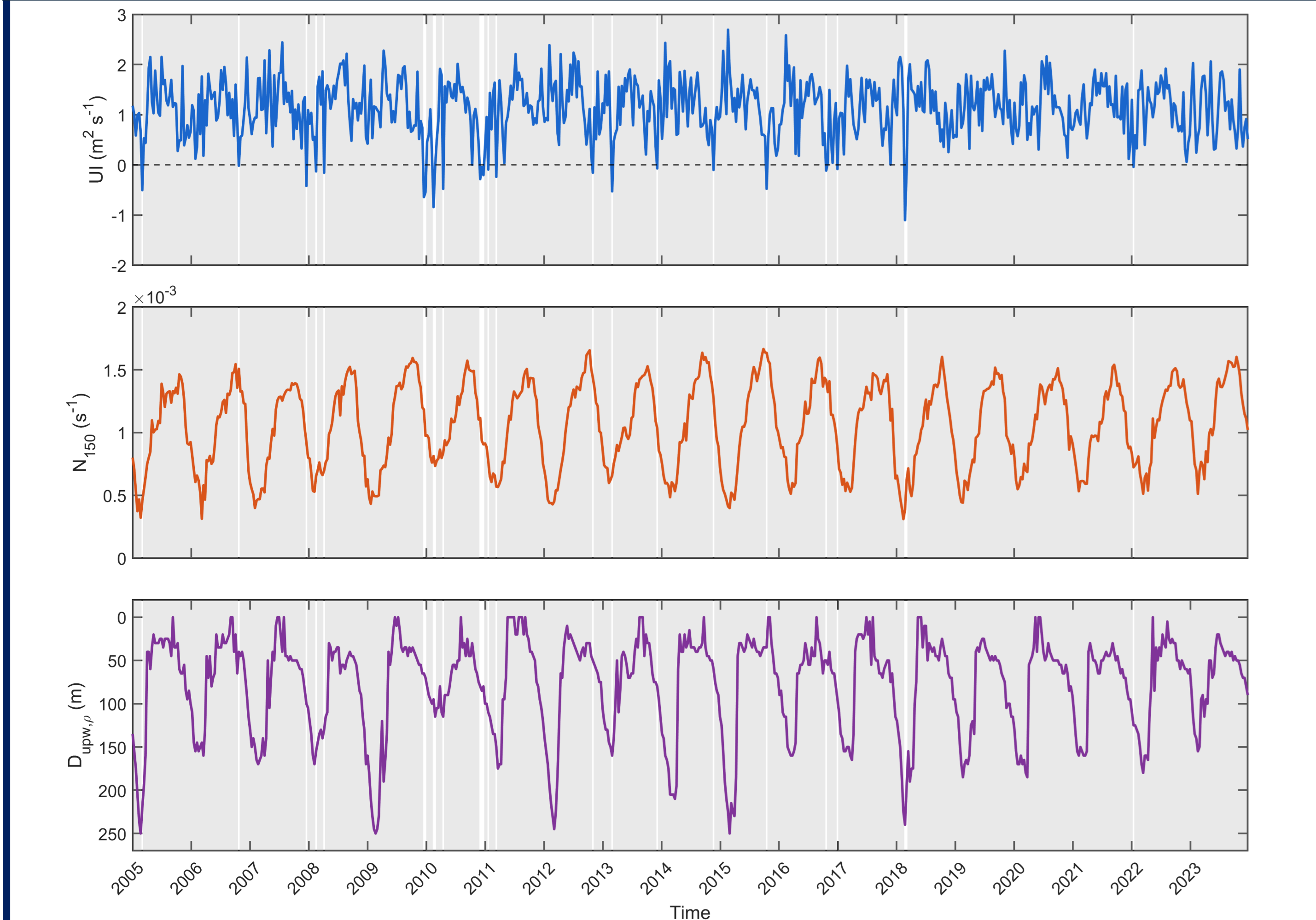


Figure 2. Time series of upwelling index (UI), Brunt-Väisälä frequency (N), and density-derived source depth ($D_{upw,\rho}$) at 10-day resolution (2005–2023). Variables are averaged over the 0–50 km coastal band. Shaded regions indicate upwelling conditions ($UI > 0$).

TRENDS

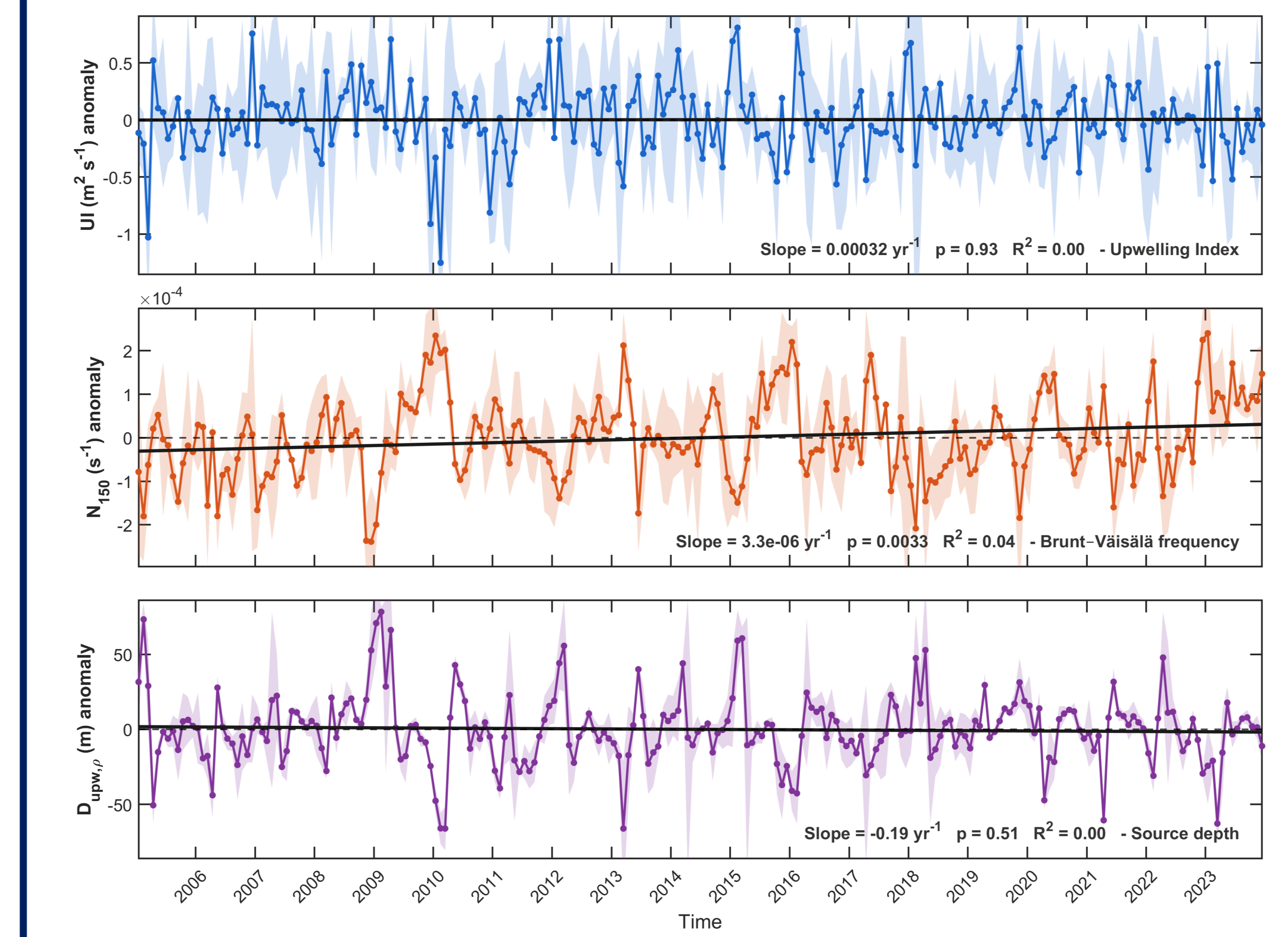


Figure 3: Solid lines show monthly mean anomalies, and shaded areas indicate intra-month variability (± 1 standard deviation). Black lines represent linear trends.

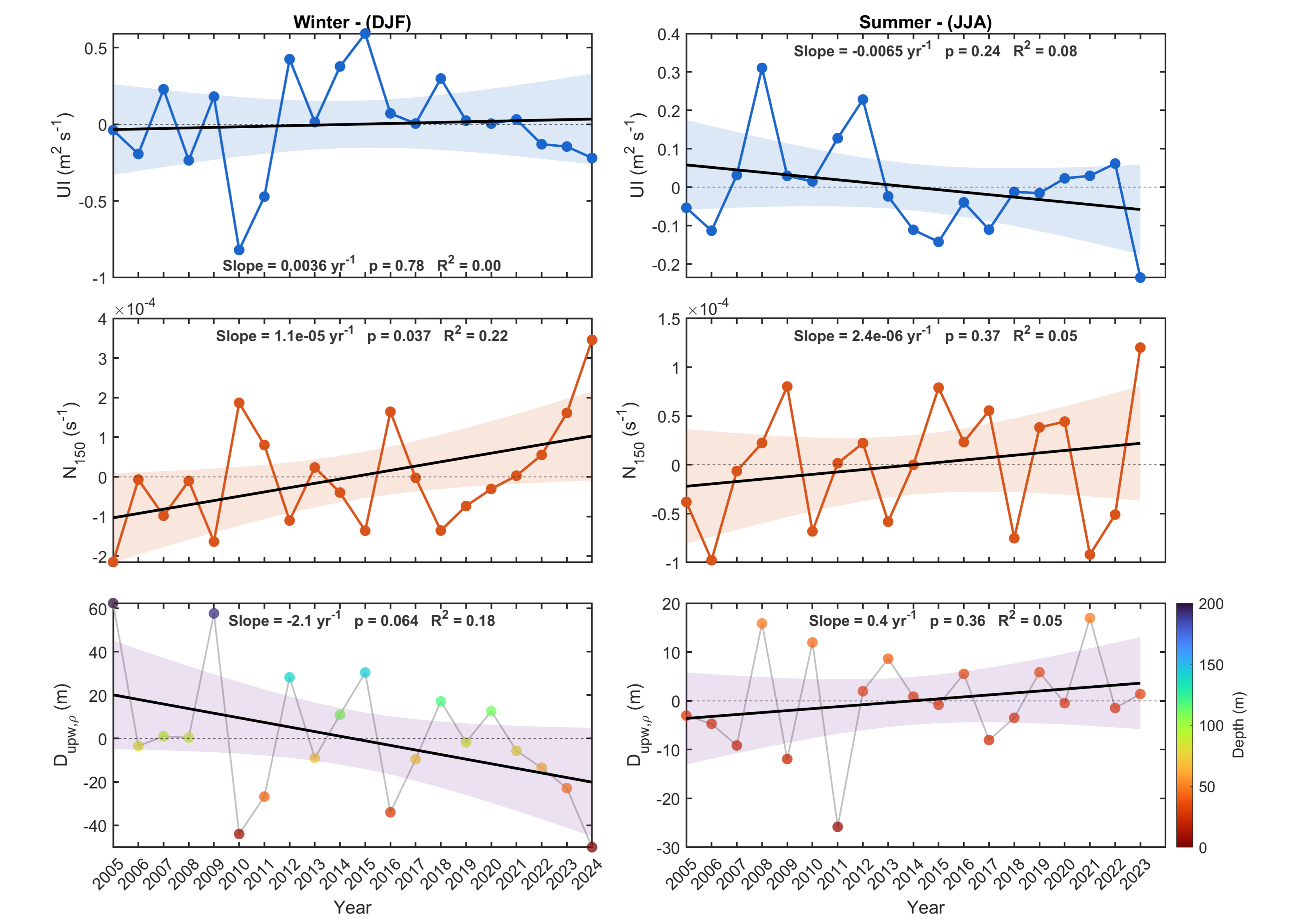


Figure 4: Seasonal trends of upwelling index (UI), Brunt-Väisälä frequency (N_{150}), and density-derived source depth ($D_{upw,\rho}$) for winter (DJF) and summer (JJA). Black lines denote linear trends, shaded areas indicating the 95% confidence interval. Colored markers in the bottom panels represent source depth.

RESULTS

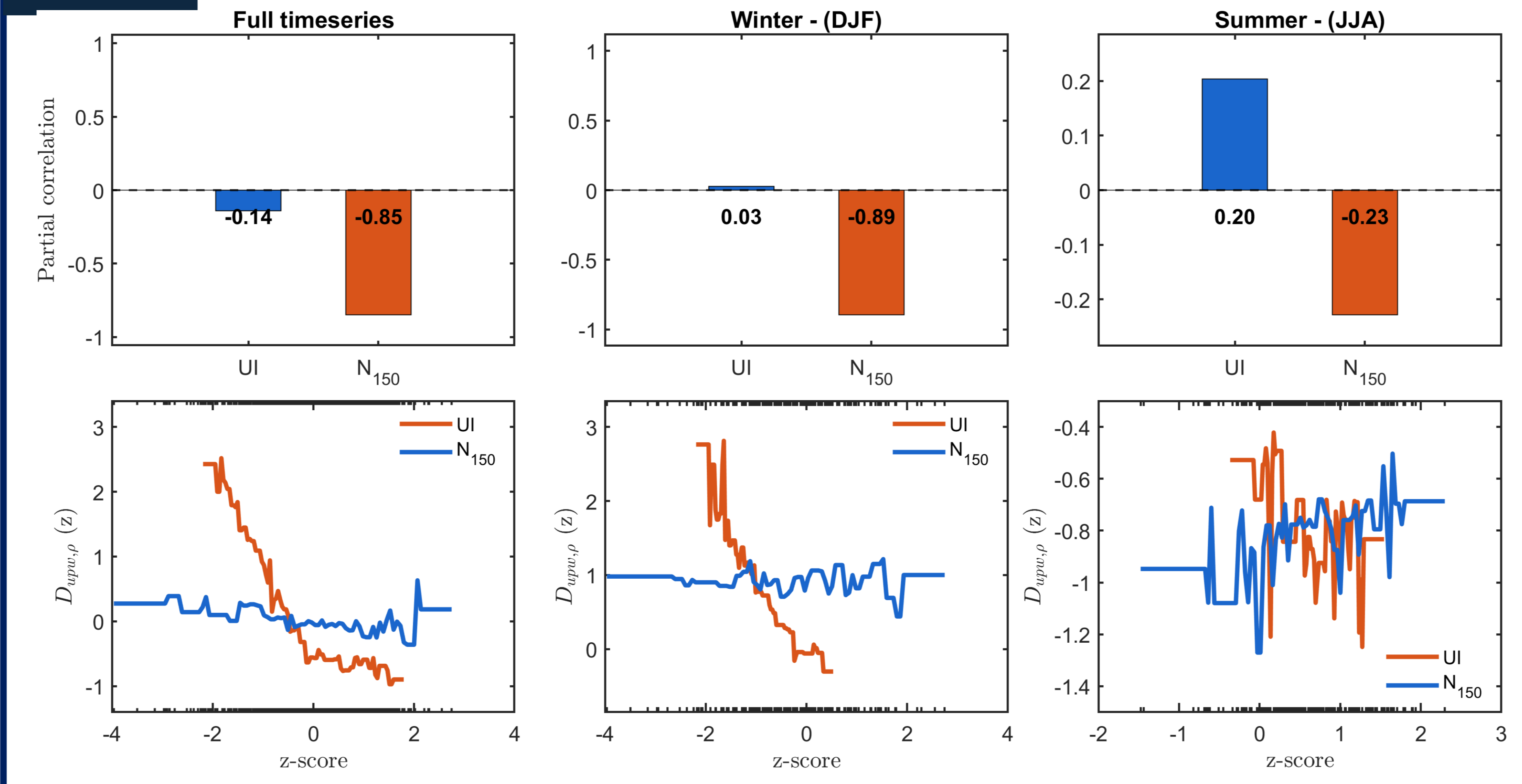


Figure 5: Seasonal controls on upwelling source depth variability. **Top row:** Partial correlations between density-derived source depth $D_{upw,\rho}$ and upwelling index (UI) and Brunt-Väisälä frequency (N_{150}), isolating the direct (linear) influence of each variable. **Bottom row:** Partial dependence (GAM) showing the nonlinear response of normalized source depth $D_{upw,\rho}$ to UI and (N_{150}). Results are shown for the full time series (left), winter (DJF, center), and summer (JJA, right).

MAIN CONCLUSIONS

- Stratification is the primary control on source depth variability annually ;
- Stronger stratification leads to shallower source waters (shoaling signal) ;
- Winter (DJF): system dominated by stratification ;
- Summer (JJA): wind influence increases and becomes comparable ;
- Long-term increase in stratification may weaken the connection between wind forcing and deeper waters