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E-SUDS – The next sedimentation super tool

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The ecosystem services provided by coastal wetlands, such as saltmarshes and mangroves, play a significant role in mitigating the effects of land use activities. For example, carbon sequestration by mangroves, per unit area, substantially exceeds that of terrestrial forests (Bimrah et al., 2022; Adame et al., 2021) and their ability to act as major sinks for contemporary and legacy fine sediments eroded from the land (Swales et al., 2020).

In addition, mangroves are increasingly recognised for their ability to enhance the resilience of low-lying areas to inundation and erosion by storm surges (Montgomery et al., 2019; Gijsman et al., 2021; Temmerman et al., 2023).

Coastal wetlands are, however, being threatened by rising sea levels and their future resilience will largely depend on their capacity to accrete sediments at a rate sufficient to keep up with sea level rise (SLR). The supply of fluvial sediment from catchments to maintain coastal wetlands will be a key factor (Swales et al., 2020). Research has highlighted the transitional region between the mangrove fringe forest and mudflat as a hotspot for change and complex hydro-sediment dynamics (Mullarney et al., 2017; Lovett, 2017; Haughey, 2017).

Managing coastal wetland adaption to SLR will depend on our ability to predict how these systems will respond under a range of relative SLR and sediment supply scenarios. Future decisions will need to be guided by robust models underpinned by quantitative measurements of sediment dynamics and geomorphic response in sedimentation hotspots.

NIWA research being conducted in the southern Firth of Thames is informing model development to predict the bio-geomorphic evolution of intertidal habitats over event- to decadal-scales. The study is a collaboration with researchers from the University of Twente, Netherlands, led by Dr Erik Horstman (Mangrove-RESCUE), and Waikato Regional Council (Dr Stephen Hunt).

A key component of this work has been the arrays of acoustic sensors and cameras continuously measuring sedimentation and erosion of the tidal flat and fringing mangrove forest. Sensors include the Estuary-Surface Ultrasonic Distance Sensor (E-SUDS), developed by NIWA and making continuous measurements since late 2019. A unique capability of E-SUDs are high frequency measurements of both water levels and tidal-flat elevations (when sites are exposed) (Figure 1).

This article updates a previous *Coastal News* item introducing the E-SUDS instrument system (Eager et al., 2021). E-SUDS utilises ultra-sonic technology to measure distances from a downward-facing transducer mounted above the water surface/seabed. High-frequency measurements (6 Hz) are made at 10-minute intervals, with data telemetered to a server. The high sampling rates and solar power supply allows for continuous measurement of dynamic intertidal processes across multiple time scales (seconds to years).

Distance from the sensor to the water surface or exposed intertidal flat is calculated from ultrasonic returns from a footprint that varies in size (i.e., decimetres) with sensor height. To determine this footprint, laboratory experiments were undertaken using various sized targets (e.g., wood dowels, plywood circles of varying diameter) and mimicking different substrate types (i.e., bare sand with and without ripples, different areal densities of pneumatophores). For a sensor height of 2.1 m above the bed (as deployed in the field) we found that the acoustic footprint was closer to 10 cm in diameter. Interestingly, E-SUDS was able to detect a single 1 cm diameter dowl, protruding 10 cm above a flat sand bed.

These experiments provided confidence in the accuracy of the field measurements and the ability of the instrument to integrate measurements to remove effects of small-scale bed variations (such as pneumatophores and ripples).

E-SUDS were deployed in the southern Firth of Thames at four sites along a cross-shore transect in the upper intertidal zone. Habitats range from mudflat and through the mangrove fringe forest (Figure 2). The mudflat (Site 1) is the most dynamic environment, being exposed to waves generated by northerly winds. E-SUDS was able to accurately measure water depth and significant wave heights (Figures 3A-B, D and E) and comparison of E-SUDS data with measurements of water depth from RBR pressure sensors demonstrate strikingly similar results (Figure 3A).

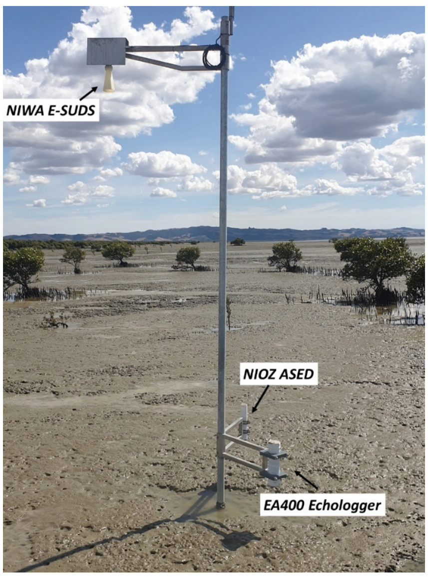

Figure 1: NIWA E-SUDS and Echologger and ASED acoustic sensors deployed on the intertidal mudflat, southern Firth of Thames.

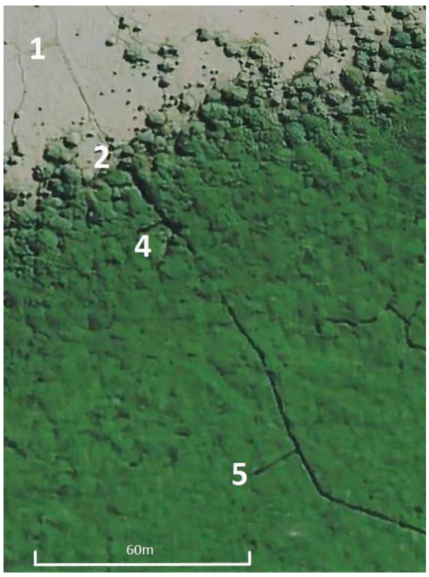

Figure 2: Location of E-SUDS in mangrove fringe forest and mudflat, Southern Firth of Thames.

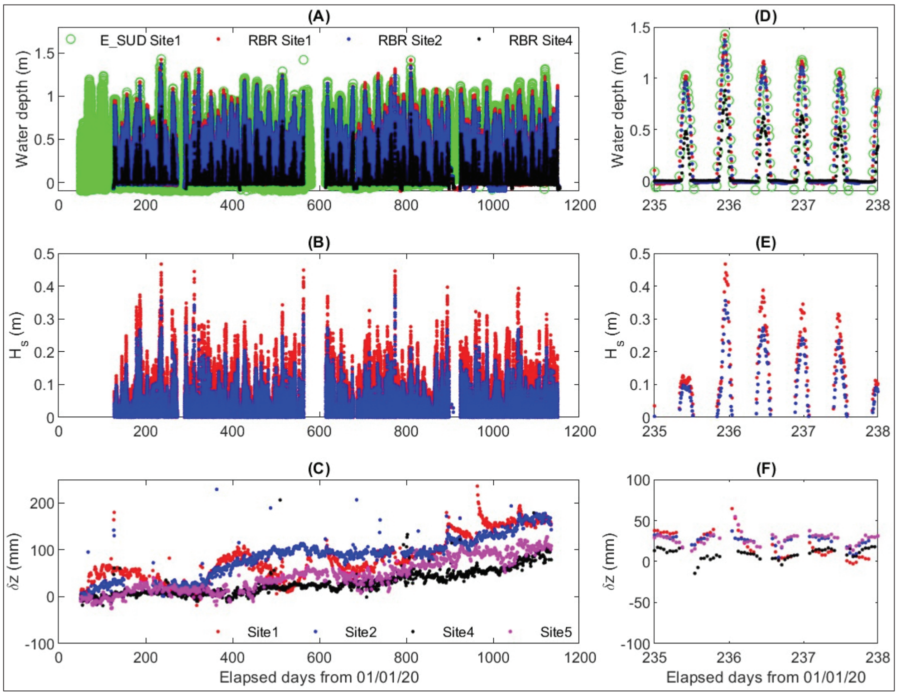

Figure 3: Three years of 12 hour averaged data showing (A) changes in water depth, (B) significant wave height, and (C) changes in vertical distance between the sensor and seabed surface. Figures 3D-F shows a zoomed in portion of the plots to demonstrate the E-SUDS ability to capture small scale events.

The E-SUDS captured seasonal and interannual cycles of mudflat accretion and erosion over the three years of continuous measurements. Net average rates of sediment accretion varied from ~6 cm/yr on the mudflat to ~3 cm/yr in the upper intertidal mangrove forest. Variability in bed level within the mangrove forest is less pronounced in comparison to the mudflat, which is consistent with a progressive reduction in sediment disturbance and sedimentation due to wave height attenuation and distance from the mudflat sediment source. The upper intertidal platform (Site 5) is only inundated by spring tides with resulting limited hydroperiod for sediment delivery and low wave exposure. This results in a less variable and lower rate of sediment accretion (Figure 3C).

Our three-year field experiment has also highlighted the capability of E-SUDS to capture small-scale morphological changes during episodic large wave events driven by strong onshore winds (Figures 3D - F). These formative events are not detected by more traditional methods of bed level monitoring, such as sediment accretion plates. As we complete these experiments, our impression is that E-SUDS can provide a cost-effective, reliable, and user-friendly tool, linking acoustic sensors and cameras, for real-time monitoring of New Zealand's estuaries.

References

Adame, MF et al. (2021). Future carbon emissions from global mangrove forest loss. *Global Change Biology*, 27: 2856-2866. https://doi.org/10.1111/gcb.15571

Bimrah, K et al. (2022). Ecosystem services of mangroves: A systematic review and synthesis of contemporary scientific literature. *Sustainability* 14(19), 12051. https://doi.org/10.3390/su141912051

Eager, CT et al. (2021). Sounding out the shallows. *Coastal News* 75, New Zealand Coastal Society, https://www.coastalsociety.org.nz/assets/Uploads/files/CN-75-2021-7.pdf

Gijsman, R et al. (2021). Nature-based engineering: A review on reducing coastal flood risk with mangroves. *Frontiers in Marine Science*, doi: 10.3389/fmars.2021.702412

Haughey, R (2017). *Modelling the hydrodynamics within the mangrove tidal flats in the Firth of Thames*. MSc thesis in Earth and Ocean Science, the University of Waikato, Hamilton, New Zealand.

Lovett, NJ (2017). *Sediment transport in the Firth of Thames mangrove forest, New Zealand*. MSc thesis in Earth and Ocean Science, the University of Waikato, Hamilton, New Zealand. https://hdl.handle.net/10289/11568

Montgomery, JM et al. (2019). Attenuation of storm surges by coastal mangroves. *Geophysical Research Letters* 46(5): 2680-2689.

Mullarney, JC et al. (2017). A question of scale: How turbulence around aerial roots shapes the seabed morphology in mangrove forests of the Mekong Delta. *Oceanography* 30 (3): 34-47.

Swales, A, Bell, R and Lohrer, D (2020). Estuaries and lowland brackish habitats. In: Hendtlass, C and Neale, D, *Coastal systems and sea level rise*. New Zealand Coastal Society Special Publication 4, pp 55–63.

Temmerman, S et al. (2023). Marshes and mangroves as nature-based coastal storm buffers. *Annual Review of Marine Science* 15: 1, 95-118.