PROPAGATION OF CARGO SHIP WAKE INTO SECONDARY CHANNELS

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INTRODUCTION

Cargo ship wake can be a strong and frequent source of energy along shorelines in the vicinity of commercial shipping channels. Large vessels in narrow channels produce low-frequency wake that consists of a positive *front wave* at the bow of the vessel, a depression (*drawdown)* spanning the length of the vessel, and an upwards surge produced by the *stern wave* at the stern. This low-frequency wake is followed by high-frequency wedge-shaped Kelvin wake, as well as continued low-frequency oscillations that may persist in the channel more than 30 minutes after a vessel passage.

Low-frequency cargo ship wake with wave heights up to 2.8 meters was identified as the dominant source of erosion at Bird/Long Islands in the Savannah River, Georgia, USA based on the analysis of one month of Aquadopp measurements that captured over 300 large vessel wake events. The islands divide the river into the Main Channel, which contains the shipping channel, and the South Channel, a shallow, sheltered secondary channel trafficked only by small craft. Cargo ship wake was the primary energy source in both channels.

The dominance of cargo ship wake energy in the sheltered South Channel demonstrated that the effects of wake extend beyond the shipping channel shorelines. This finding motivated three follow-up studies (**Figure 1**) to quantify the extent and significance of cargo ship wake in the far-field, secondary channels connected directly or indirectly to the shipping channel.

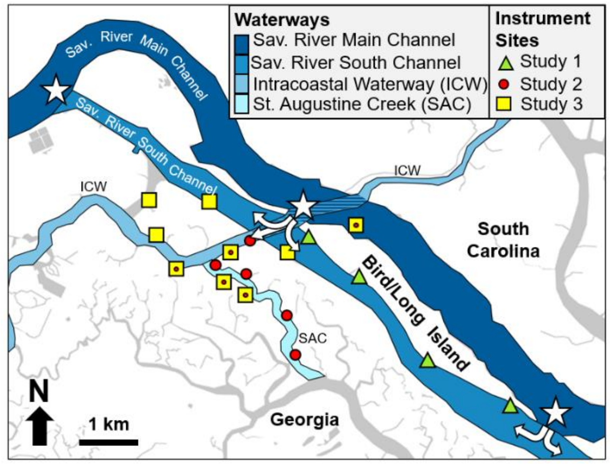

Figure 1 – Instrumentation near the Savannah River, Georgia, USA with potential wake sources (stars) and propagation directions (arrows) into secondary channels.

PROPAGATION EXTENT AND SIGNIFICANCE OF LOW-FREQUENCY WAKE IN THE FAR-FIELD

The first study uses measurements of wake in an array of four pressure sensors in the South Channel of the Savannah River behind Bird/Long Island. The timing of wake signals in the data are compared with Automatic Information System (AIS) vessel data, including vessel position, dimensions, and speed, to determine the time-lagged response of wake signals in the South Channel relative to vessel passages in the Main Channel. The wake readily propagates into the South Channel from both the north and south ends of Bird/Long Island where it continues to travel at least 6 km, the full length of the array.

A second study investigates the ability of wake to propagate out of the Savannah River and enter a far-field network of smaller waterways: the Intracoastal Waterway (ICW) and St. Augustine Creek (SAC). Data was collected from an array of four ADVs and five standalone pressure sensors deployed for 24 hours. During the deployment there were 12 cargo vessel passages, with lengths of 134 m to 366 m and speeds up to 7.7 m/s.

Three different junctions (I, II, and III) in the shipping channel are identified as possible sources of far-field wake and are associated with multiple propagation pathways (**Figure 2**). For each vessel passage during the measurements, linear long wave theory is used to predict the propagation of wake from each source down two possible pathways: A (lighter color) and B (darker color). Quantified uncertainty in bathymetry, tidal currents, and propagation distance are used to compute the uncertainty of the arrival time such that an arrival time window is obtained for each wave. The predicted arrival time windows for each site are compared to its band-pass filtered η time series; the band-pass filtering isolates low-frequency wake signals from tidal and Kelvin wake signals. The observation of low-frequency wake within the predicted arrival time windows shows that wake propagates along both pathways from each of the three sources. This means that a single vessel passage can produce six sets of wake at some the far-field sites, with overall wake effects exceeding an hour in duration.

An example of the normalized η time series at all instrument sites in Study 2 is shown in **Figure 3** for both an isolated cargo vessel passage and a time period when three cargo vessels are in the channel simtaneously. The propagation of the trough of the depression is predicted along both pathways from each junction, and the arrival time windows are indicated on the time series with boxes whose color indicates the pathway taken. These colors correspond with those in **Figure 2**. While the wake of the isolated vessel can be tracked through the instrument sites, the responses to the wakes of multiple vessels are highly complex. The waves of the three vessels are plotted on separate levels at each site; vertical overlap indicates different waves arriving at the same time.

The third study examines the propagation of wake from the three sources into the SAC. An array of four ADVs and 5 standalone pressure transducers were deployed for four days in February 2022. During this time, there were 36 cargo vessel passages, with lengths of 134 m to 366 m and vessel speeds up to 8.0 m/s. 16 of these events occured isolated from other vessel passages.

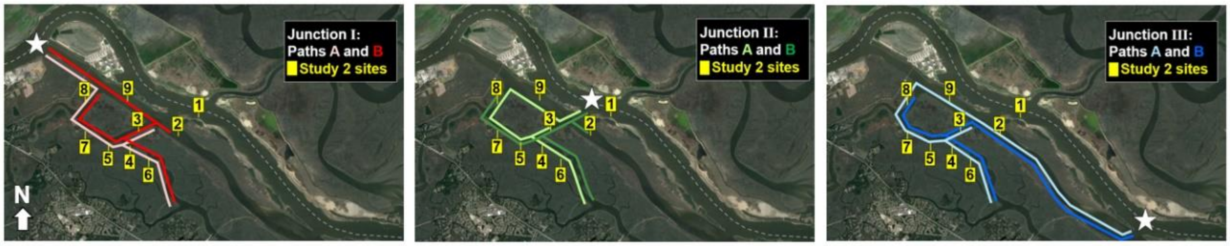

Figure 2 – Junctions I, II, and III and their associated pathways of propagation to the Study 2 sites.

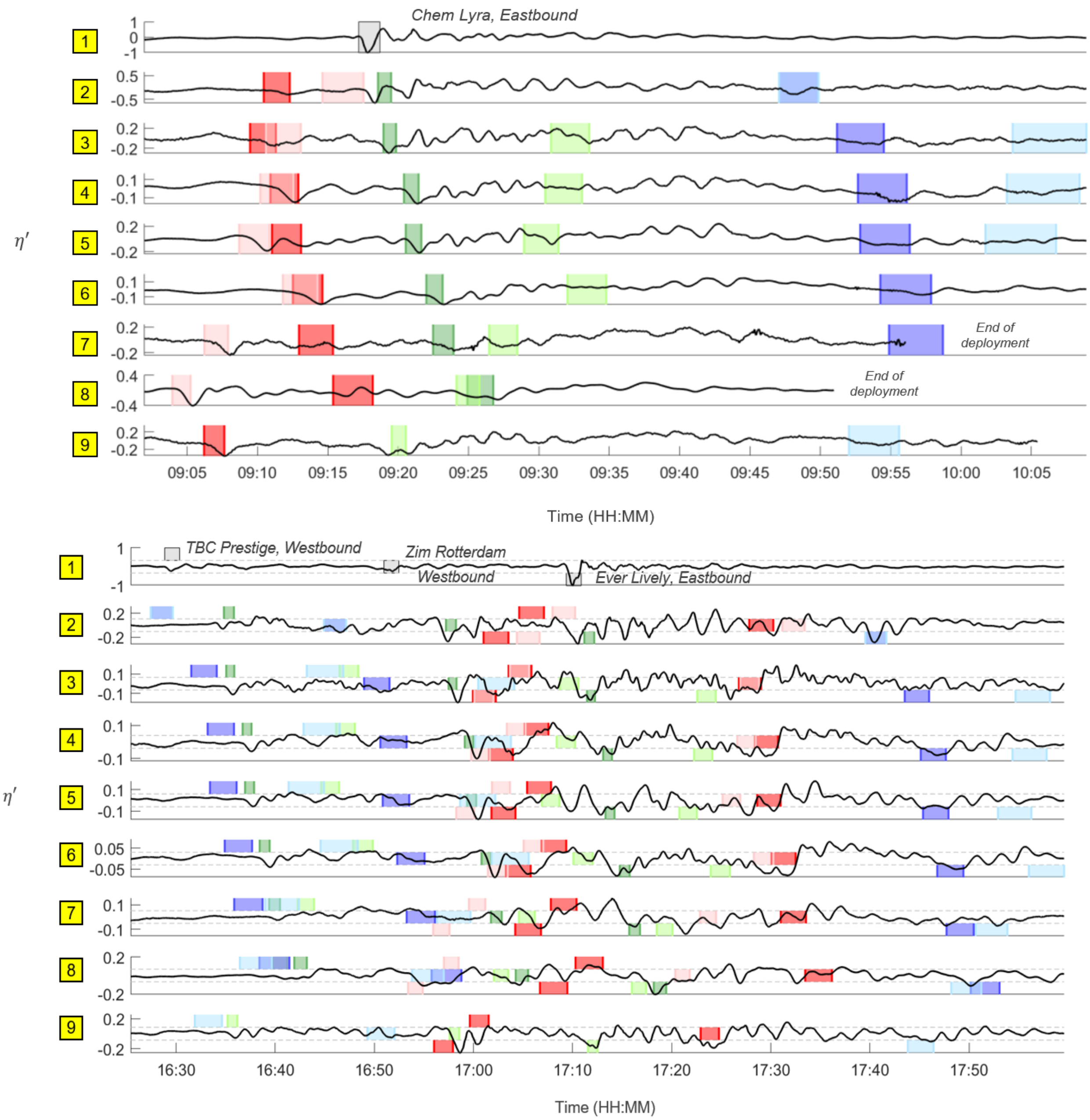

Figure 3 -Time of series $\eta/\max(\eta_1)$ showing the arrival time windows of wake propagating from various sources for (**upper**) one isolated vessel passage and (**lower**) the coinciding passages of three vessels.

Wake arrival time windows are predicted for propagation to the Study 3 sites along the six known pathways (**Figure 4.**) Individual waves from sufficiently isolated vessel passages are tracked propagating into and through the creek as demonstrated by the stacked times series of an isolated event in **Figure 5**. The longest confirmed propagation pathway to SAC is 16 km.

Using pressure and velocity data from ADVs at sites 3, 4, and 5, the portions of incoming wave energy flux entering the SAC is compared to that which continues west in the ICW. The ADV data is also used to evaluate the energy contributions of far-field wake and local tidal currents; it is found that the tidal and wake energy are of similar magnitude at the sites. Lastly, the pressure signals of sites in SAC are used to assess wave dissipation throughout the creek and the influence of changes in channel dimensions on wave heights.

In summary, the three field studies demonstrate the extent, behavior, and significance of low-frequency wake propagation into the far-field, providing key information for modelers seeking to capture wake behavior and for governmental agencies or coastal advocacy groups seeking to assess and/or mitigate environmental impacts of cargo ships.

REFERENCES

Haas & Muscalus (2019): Bird-Long Island Management Study Phase 1B: Hydrodynamic Characterizations for Bird/Long Island. No, FHWA-GA-19-1634. Georgia Department of Transportation.

Figure 4 - Junctions I, II, and III and their associated pathways of propagation to the Study 3 sites.

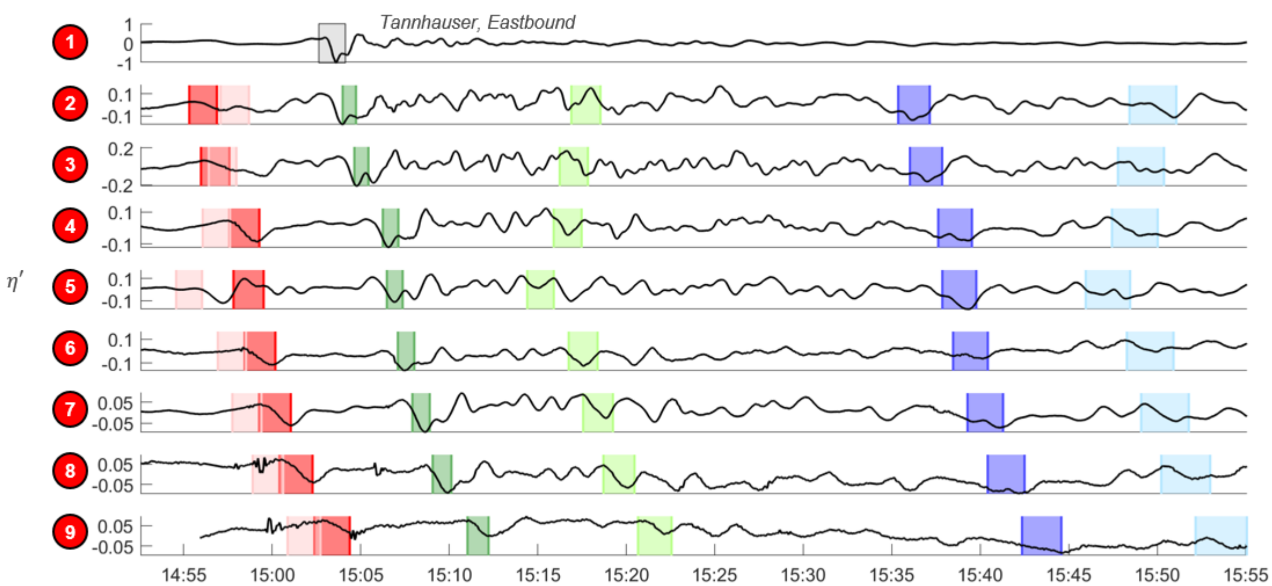

Figure 5 -Time of series $\eta/\max(\eta_1)$ showing the arrival time windows of wake propagating from various sources to the instrument array in SAC.