The variability of small mountainous river plumes revealed from 20-years of quasi-daily ocean color data

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more about this work: tedconroy.github.io/projects/hawkebay
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1. Motivation

- Sediment transported from small mountainous rivers accounts for a significant fraction of the input to the coastal ocean (Milliman and Syvitski 1992).
- Plume dynamics and sediment characteristics influence the initial sediment deposit, which is likely resuspended and transported further offshore (see diagram).
- Satellite remote sensing can now provide a long time series of surface plume variability, allowing for a greater range of spatial variability to be observed in comparison to traditional methods.
- *The aim of this work* is to detail the suspended sediment transport in river plumes variability, length scales of initial sediment deposition, and other causes of turbidity using satellite remote sensing.

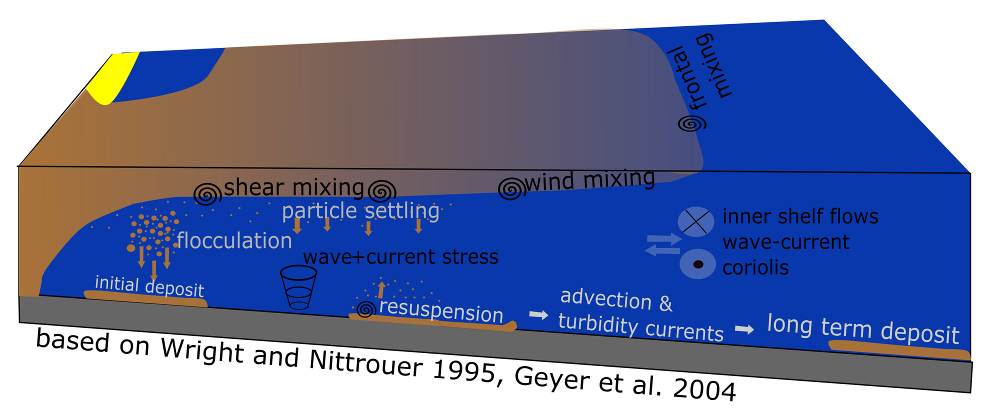
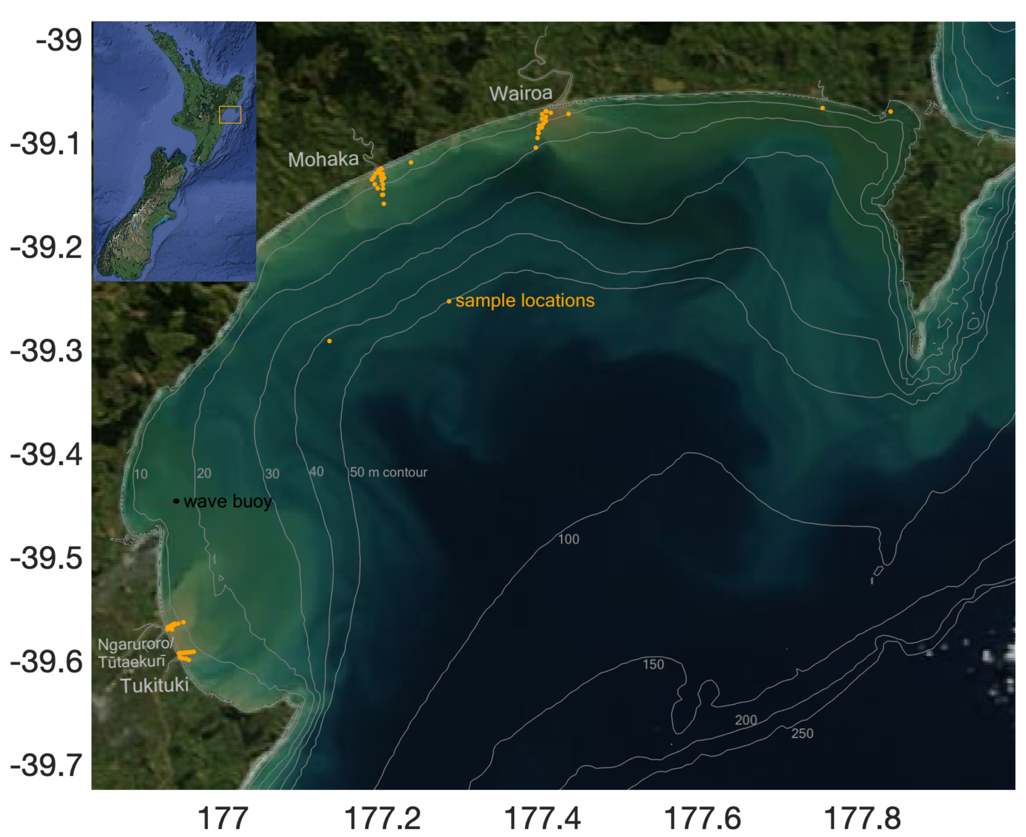


Diagram of processes that affect sediment transport from river plumes formed from small mountainous rivers. Particle settling and flocculation are thought to deposit most of the sediment close the river mouth and other processes can then transport the sediment further offshore to longer term deposits.

2. Study site

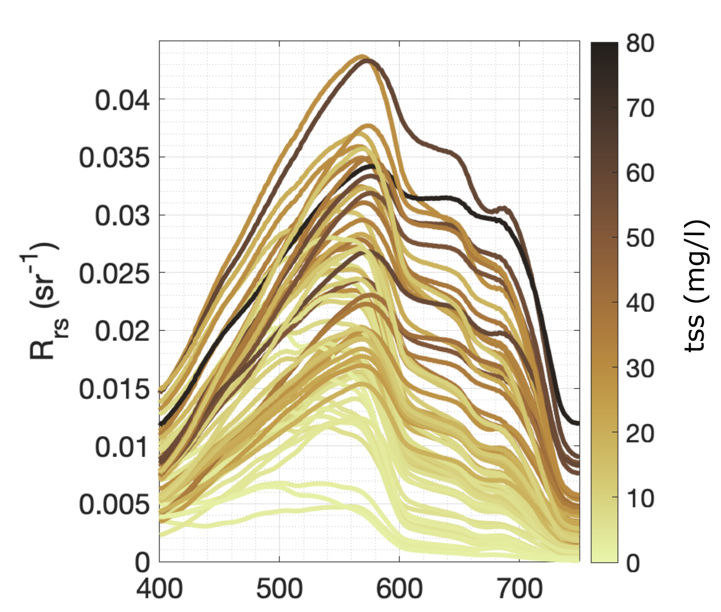
- Hawke Bay is a 40 by 80 km embayment located on an active margin in Aotearoa New Zealand.
- Discharge events are highly episodic from four major rivers. The mean and 99.9th percentile daily discharge (m^3/s) for the rivers are: Wairoa (110, 2183), Mohaka (71, 1015), Ngaruroro (47, 1241), Tukituki (41, 1329).
- 11 mt of suspended sediment/year is input to Bay on average (Hicks et al. 2011).
- Bay is subject to significant waves (mean sig. wave height 1.2 m) and strong offshore boundary currents.
- The rivers have short estuaries (0-2 km; Wairoa 0-12 km), variable inlet morphologies (width ranges from 0-200 m), and are tidally influenced (1.9 m range).
- The suspended sediment in rivers is mainly composed of fine silt; no measurements of aggregation have been made.
- Primarily muddy seafloor beyond 30 m.



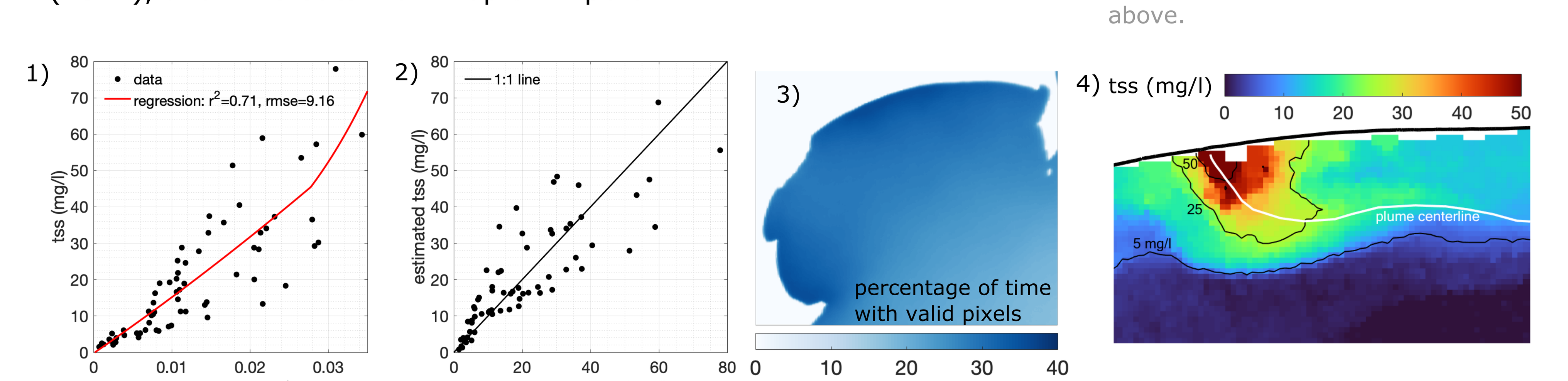
Map of Hawke Bay, Aotearoa New Zealand. Location of the Bay is shown in upper left corner. Sample locations are shown in orange and bathymetric contours (m) are in grey. Image is from NASA MODIS.

3. Methods

- Ocean color satellite remote sensing data from NASA MODIS (2000-present) is used.
- Atmospheric correction with L2GEN tailored for turbid waters, following Aurin et al. (2013), using the dark pixel approach with bands 748-859 nm, cloud masking using 2130 nm band with 0.018 threshold, and straylight and pixel saturation (hilt) flags off. Either an Aqua or Terra image was selected for each day dependent on maximum coverage.
- Red band (645 nm) MODIS data at 250 m resolution used with an empirical algorithm for total suspended solids (tss).
- 65 concurrent in-situ tss and hyperspectral remote sensing reflectance (R_{rs}) water surface measurements taken offshore rivers in Bay (see map). Piecewise quadratic and exponential fit.
- Data sources: river flow is from the HBRC, wave buoy data (15 m depth) is from Napier Port, tss rating curves from Hicks et al. (2011), and wind data from Napier Airport.



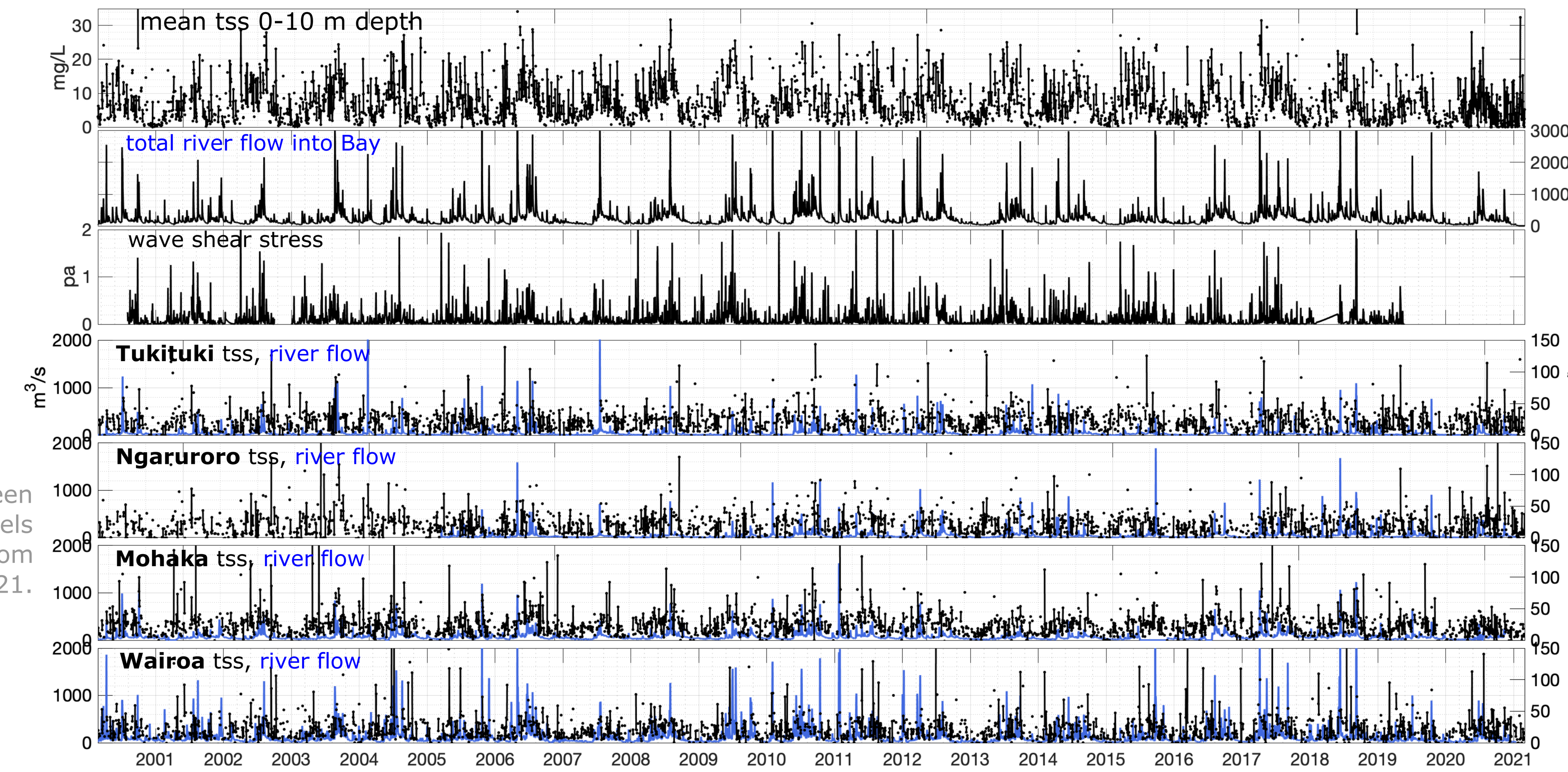
R_{rs} (sr^{-1}) spectrums colored by co-located tss (mg/l). Locations of samples are shown on the map above.



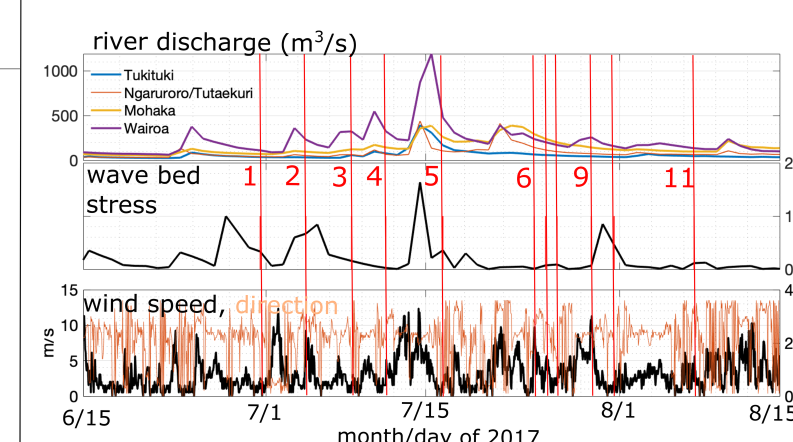
1) Piecewise quadratic/exponential regression between in-situ Rrs (using MODIS 645 nm spectral response function) and tss samples. 2) Results of estimated tss with measured tss. 3) Percent of total time in MODIS record with a valid data point. 4) Example of contouring and plume centerline for a river. Contours containing a river mouth are used to track the rivers spatial extent, and the centerline follows the main axis of the plume.

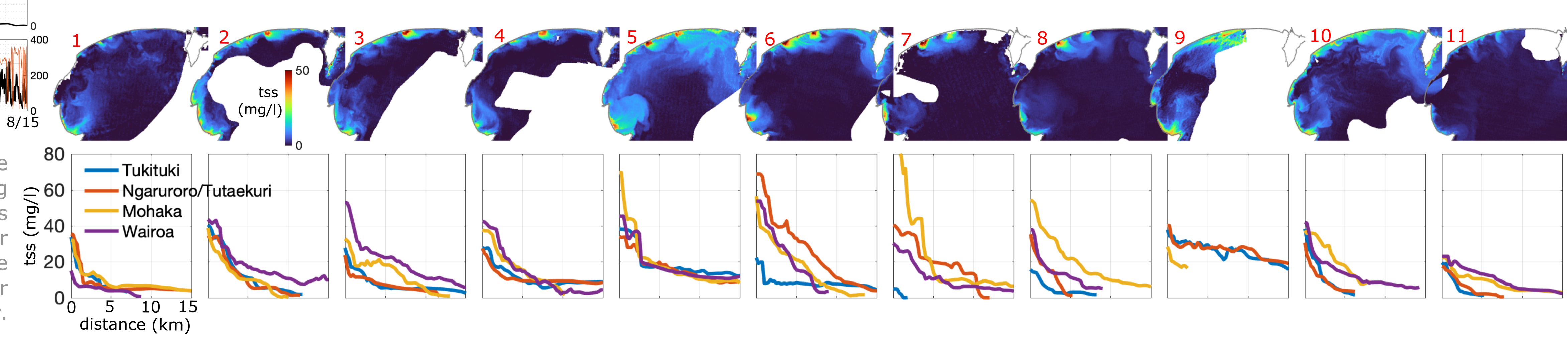
4. Temporal variability

- The tss offshore of the rivers and spatially averaged over the nearshore (0–10m depths), shows variability that mostly follows river discharge events and seasonal variations in discharge.
- Tss generally ranges from 0-20 mg/l for the nearshore and 0-150 mg/l offshore rivers.
- The remote sensing derived tss is generally 10-30% of the estimated river tss based on rating curves from Hicks et al. (2011).
- Example of events shown below.



Time series of remote sensing derived tss (mg/l) averaged between 0-10 m depth (top) and forcing variables. The bottom four panels show time series of tss (right axis) and river discharge (m^3/s) from indivual rivers from 2000-2021.

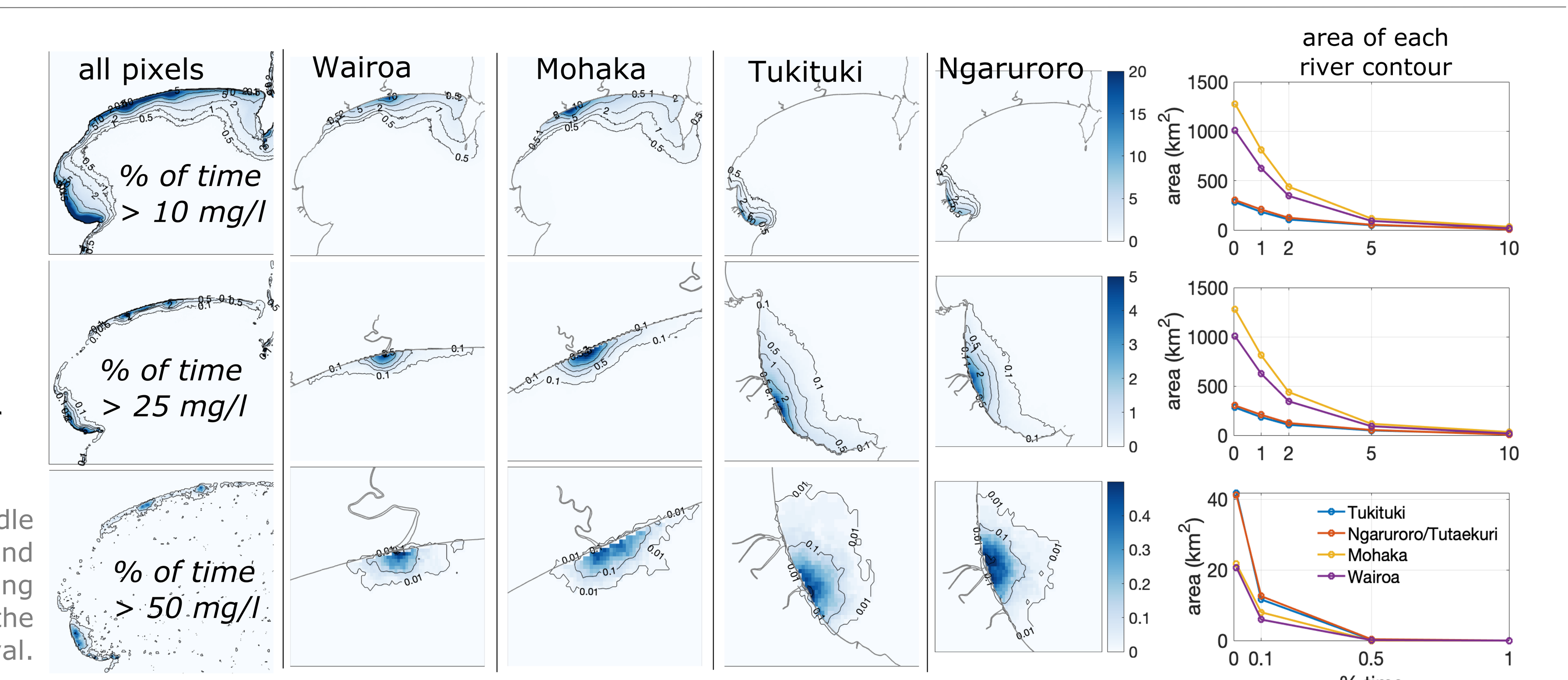




Example of a river discharge event in the winter of 2017. A time series of forcing variables are shown above, with red lines marking the times of tss panels in the upper right plots. Transects of tss along plume centerlines are shown in the lower right for each corresponding day for each river.

5. Spatial variability

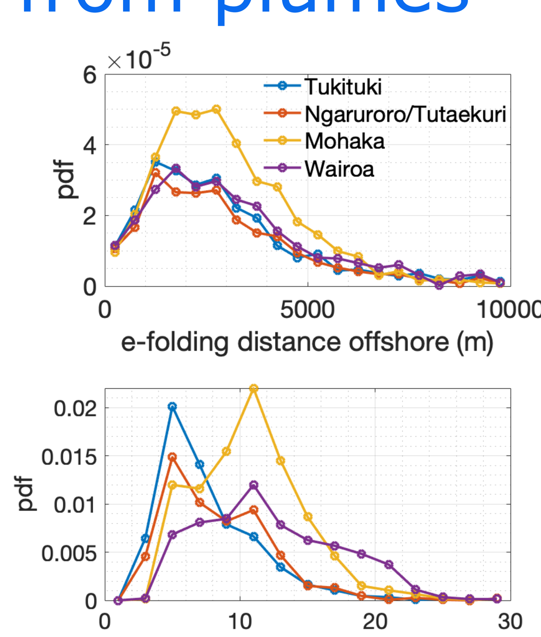
- Contours are mostly associated with river plumes (all pixels column) as well as resuspension areas.
- Areas with significant cliff erosion show persistant turbid water similar to river plume influenced regions.
- Plume contours show general dispersal pathways for sediment from each river. Contours from rivers join with nearby river plumes for 10 mg/l tss threshold.
- Mohaka and Wairoa have much larger spatial influence than other rivers.



The percentages of occurance of a tss value (10, 25, and 50 mg/l on the top, middle and bottom rows respectively) is shown for each pixel in the bay (first column), and subsequently for each river. The river plume boundaries are calculated from finding contours that contain each river mouth (see methods). The right column shows the area (km^2) for each river for each percentage interval.

6. Sediment settling from plumes

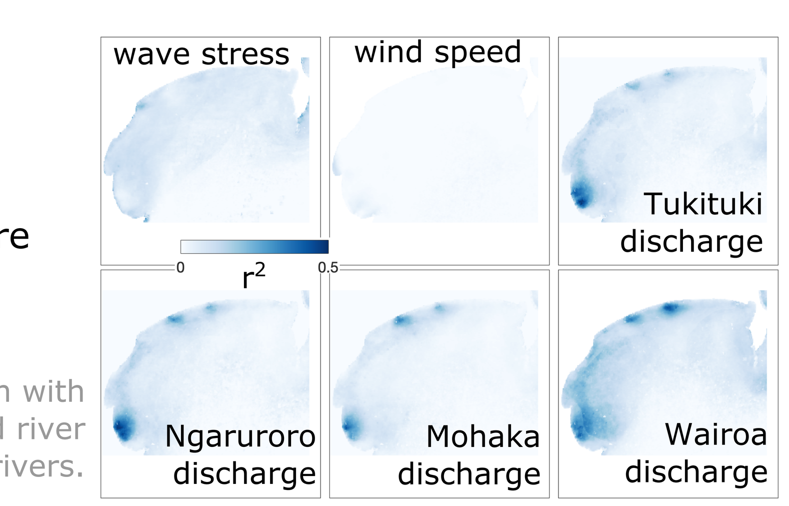
- E-folding distance of tss from plume centerline transects used as metric for length of inital sediment deposition from plume.
- E-folding distances are 0.5-4 km from river mouth, suggesting particle aggregation likely increases settling velocity.
- The locations of e-folding lengthscales generally are in depths of 4-20 m, suggesting that plumes do not transport fine sediments to long term depositional areas.
- Future work will use 1-d steady-state sediment balance with solution $c(x)=c_0 exp(-ck)$, where $k=w_e$ /uh. This approach may be useful for estimating w_e if u and h can be reliably estimated.



The e-folding distance (top) of tss for along plume centerline transects for each river, and the depth for each location (bottom).

7. Influence of forcing mechanisms

- A broad area of the Bay tss is correlated with wave stresses, while specific regions are further correlated with discharge from the nearest river.



The r^2 value from linear regression with wave stress, wind speed, and river discharge from specific rivers.

8. Summary

- River plumes tss magnitude and spatial extents were characterized by occurance percentages of varying tss values to show spatial extents.
- Initial sediment deposits are likely generally 0.5-4 km from river mouths to depths less than 20 m.
- Most of tss variance is sourced from river discharge, and smaller component is due to wave and wind driven events, which are likely important for offshore transport.

References

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