Characterizing Delta-Scale Process Connectivity Using Information Theory

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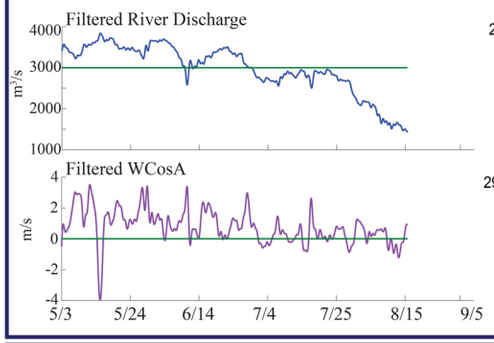
Wax Lake Delta, LA, USA

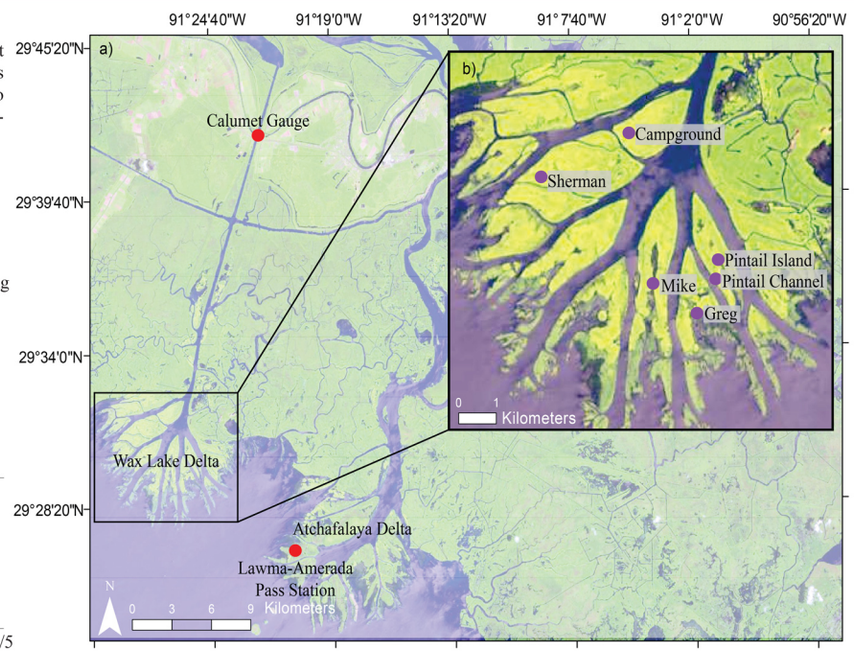
Objective: To create a process network of a river delta that characterizes the relationships between delta variables in terms of strength, direction, and scale. Here we present insights into the hydrologic connectivity of the system across multiple temporal scales based on field data.

Field Site Conditions:

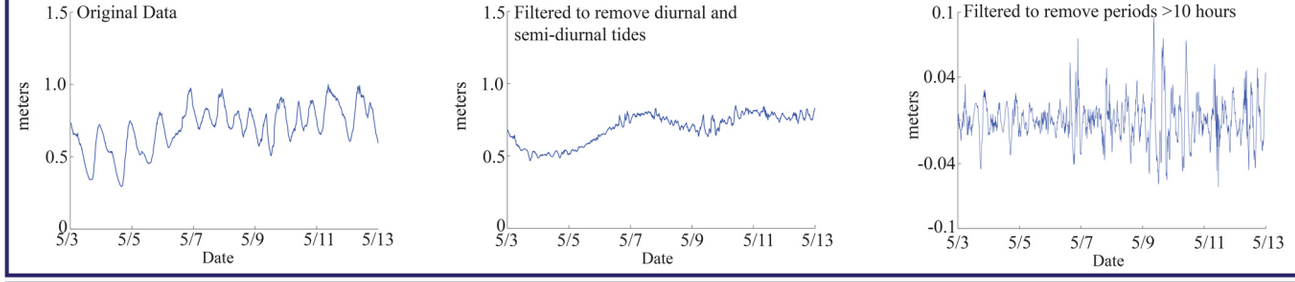
Naturally prograding river delta in coastal Louisiana
Actively prograding: 2 m/yr
Median discharge: 3000 m^3/s
Tidal range: 30 cm

Field Study: Six water level sensors on delta islands, collecting data from May 2014 to August 2014





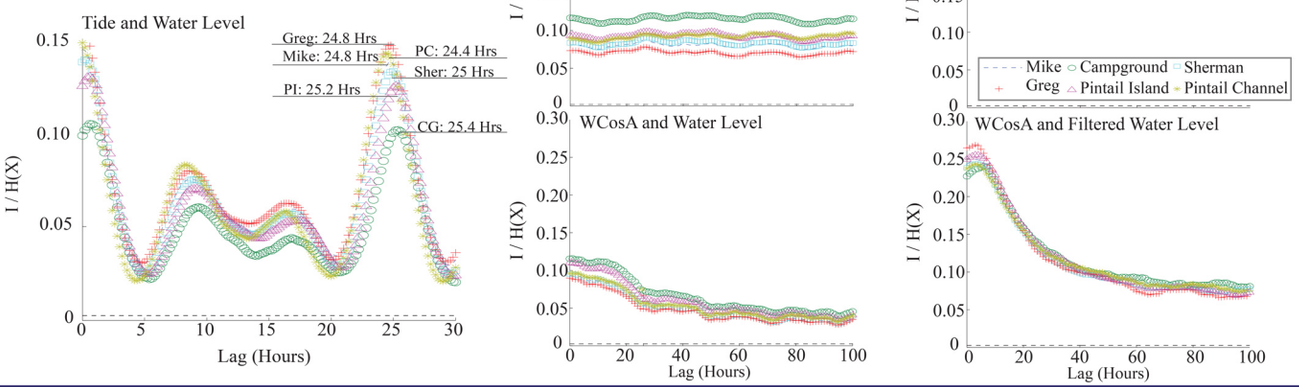
Filtering to isolate timescales



Synchronization with external forcings- Mutual Information Results

Mutual Information $$I(X_t, Y_t) = \sum_{x_t, y_t} p(x_t, y_t) log \frac{p(x_t, y_t)}{p(x_t)p(y_t)}$$

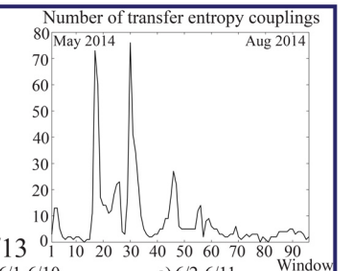
Shannon Entropy $$H(X) = -\sum_{i=1}^{N} \log[p(X_i)]\, p(X_i)$$

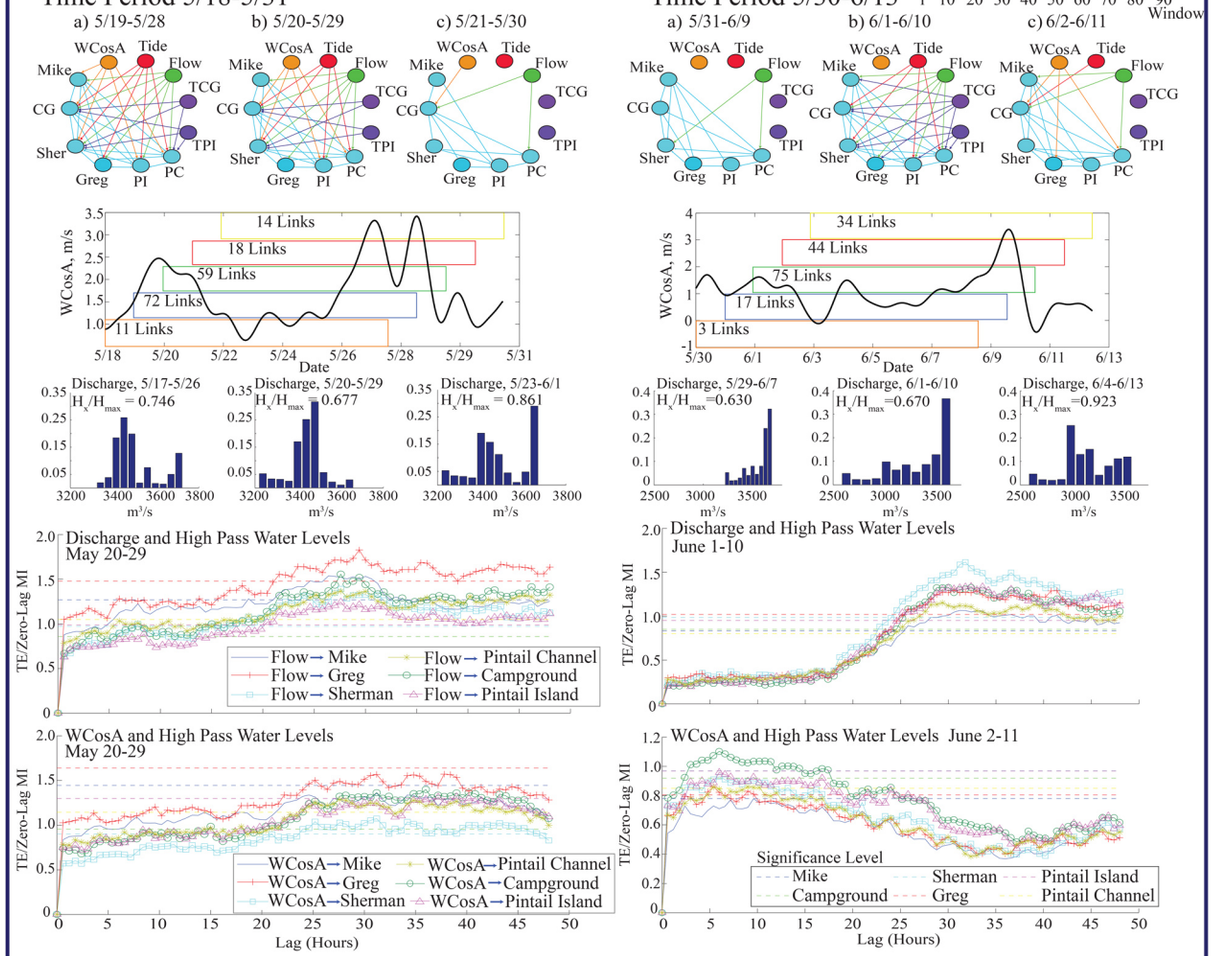


Network Changes Over Time- Transfer Entropy Results

Transfer Entropy $$T(X_t > Y_t, \tau) = \sum_{y_t, y_{t-\Delta t}, x_{t-\tau\Delta t}} p(y_t, y_{t-\Delta t}, x_{t-\tau\Delta t}) \log \frac{p(y_t | y_{t-\Delta t}, x_{t-\tau\Delta t})}{p(y_t | y_{t-\Delta t})}$$

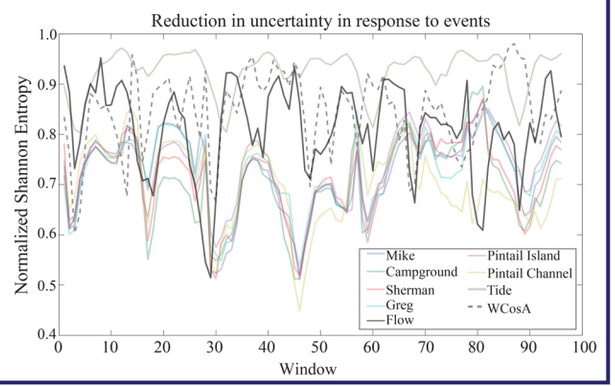
The water level data were filtered to retain the sub-daily fluctuations and the dataset of length 105 days was broken into 10 days windows each shifted by one day, resulting in 96 windows for the time period. Information theory statistics were then calculated for each window. Two time periods stand out in terms of connectivity of variables.





Conclusions

(1)Water levels synchronize with tides on the order of days, with wind on the order of hours, and discharge over longer timescales. Spatial differences between islands are captured at all of these scales. Filtering the data allows underlying relationships to be better quantified by information theory statistics.
(2)The change in the hydrologic connectivity over time due to environmental drivers is captured using discrete time windows. The different windows provide information on how the locations respond to events and at what timescale, giving us insights into redundant information sources and distributions of travel time.



Acknowledgements

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References: Ruddell, B.L., and P. Kumar (2009), Ecohydrologic Process Networks: 1. Identification,Water Resour. Res., 45, W03419, doi: 10.1029/2008WR007279
Ruddell, B.L. (2008), Process Network Software, version 11, accessed at http://www.dri.edu/stress4-workshop on December 5, 2013.