Drivers of Dispersion and Mixing in the Sacramento Deep Water Ship Channel

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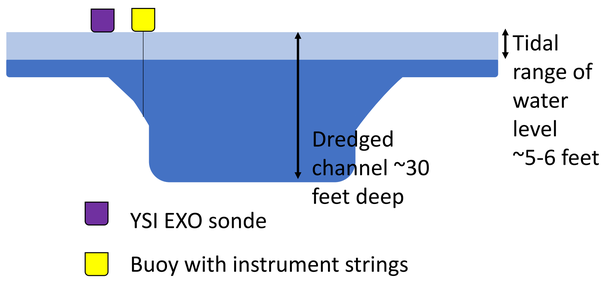
Nutrient Addition Experiment

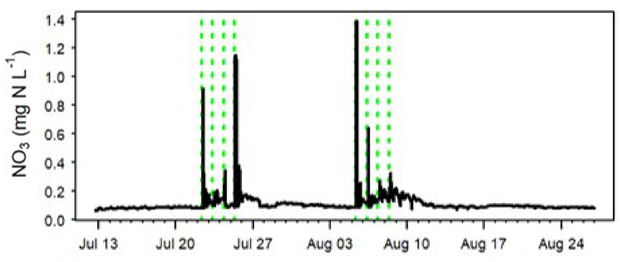
- DWSC is a dead-end channel—inoperable gates at Sacramento River, little to no freshwater inflow
- Tidally influenced at south end of channel at Cache Slough
- Deep center channel, shallow shoulders



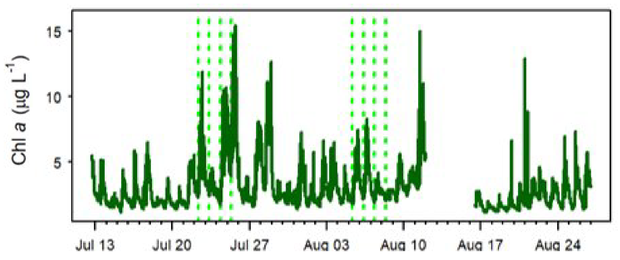
- Fertilized a 400 m section of the DWSC with calcium nitrate using a crop duster
  - Continuous water quality monitoring and daily sampling to monitor the fertilized plume as it dispersed and was consumed
- Deployed an EXO sonde near the surface and an instrument string with sensors at 0.5 m increments in the top 5 m of the water column to measure temperature, specific conductance, dissolved oxygen
- Conducted four 30-hour studies with hourly measurement of velocity profiles and CTD casts at the Navigation Light (NL) 74 cross-section

Nutrient Addition Results

- Nitrate levels returned to normal within 3-4 days



- Chlorophyll-a increased, but remained within normal range of variability observed before and after the additions
  - No major increase in phytoplankton densities

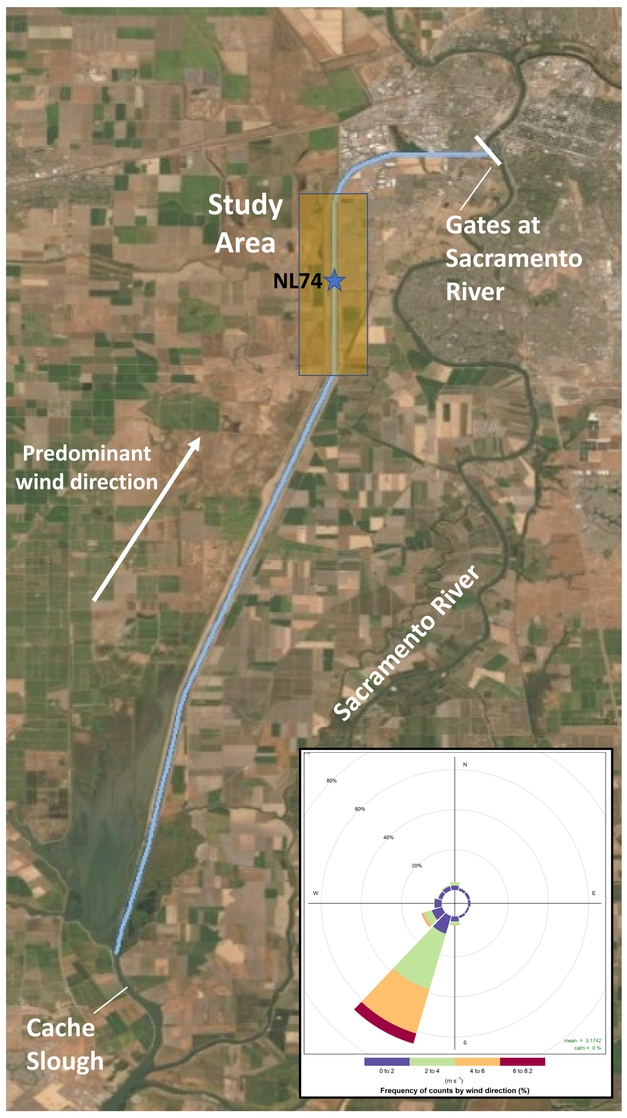


Where did the nutrients go?

- Dispersed throughout a larger area, concentrations fell below levels that would support greater primary production

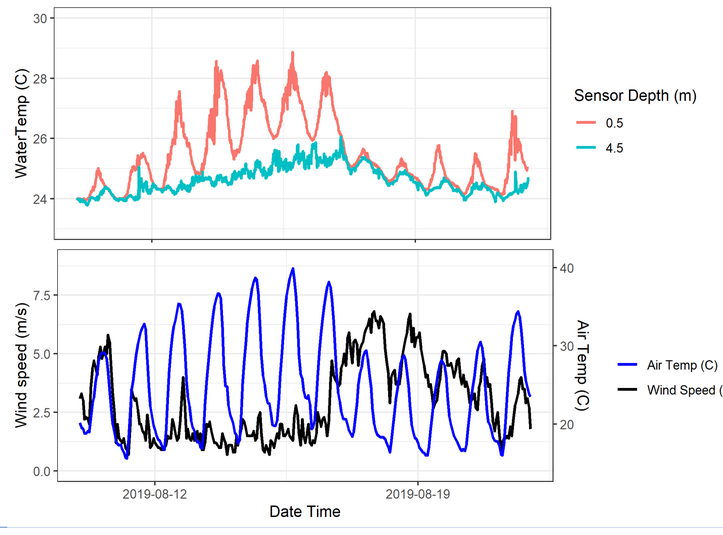
Mixing Timescale Estimates

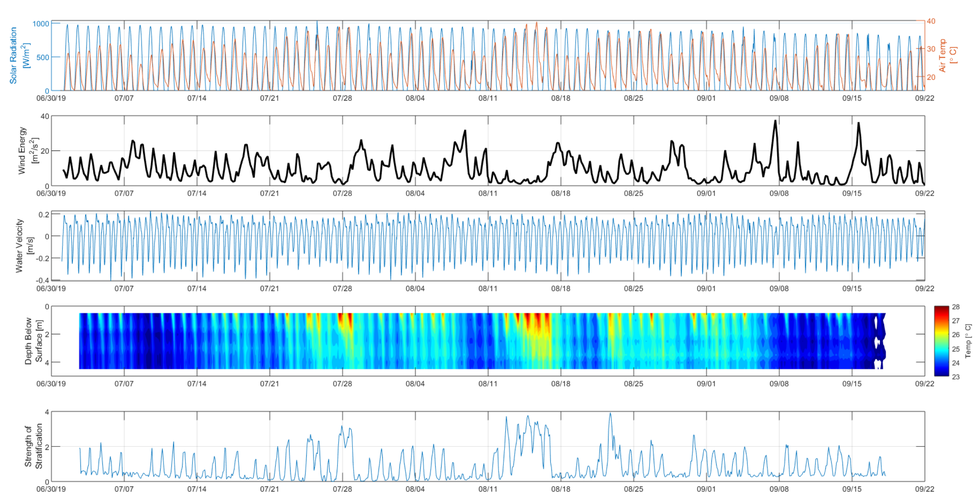
- Longitudinal – 9-15 hours
  - Driven primarily by tidal currents and secondarily by wind
  - No two-layer exchange flow (gravitational circulation)
  - No freshwater inflow
- Lateral – 30-37 hours
  - Driven by cross-channel tidal velocity shear
- Vertical – 1-6 hours
  - Dominated by wind creating shear at the surface
  - Tidal currents contribute
  - Mixing is slower under stratified conditions



Density Stratification

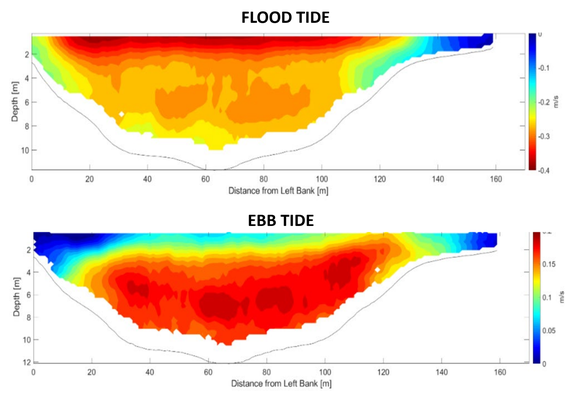
- Vertical density gradients are due to surface heating (not specific conductance differences)
- Density (temperature) stratification inhibits vertical mixing
- Water column stratified most days for a few hours, and stratification persisted overnight on 4 occasions
  - Stratification broken or prevented all together by wind
  - Stratification strongest during periods of very low wind
  - Spring/neap cycle differences in tidal current strength influenced development and persistence of thermal stratification, but stratification can still occur even during strong spring tide



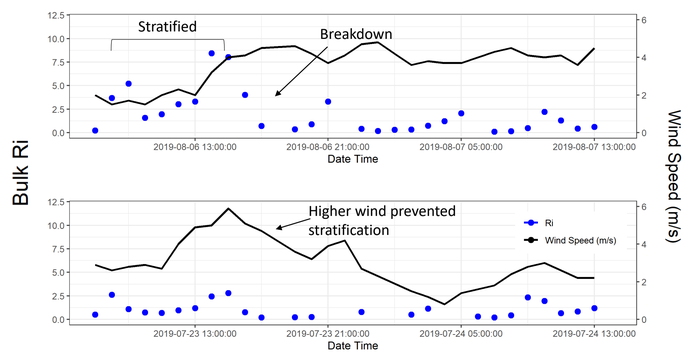


Vertical Mixing

- Vertical mixing is driven by wind shear
  - Wind was typically SSW and aligned with the channel major axis, causing:
    - Increased surface velocity on flood tide
    - Stalled surface velocities on ebb tide



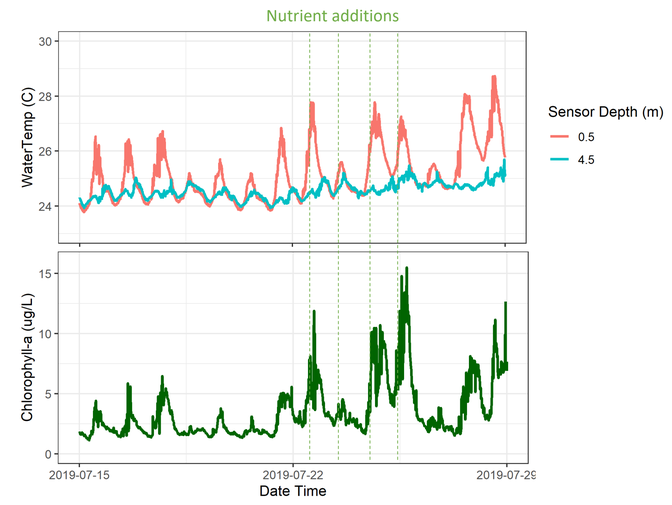
- Richardson number: $$\mathbf{Ri} = \frac{g * \frac{\Delta \rho}{\Delta z}}{\rho * \left(\frac{\Delta u}{\Delta z}\right)^2} = \frac{N^2}{S_h^2}$$
  - ratio of buoyancy frequency (N^2, from density stratification) to vertical shear (S_h^2, from vertical velocity gradient)



- Ri is elevated when there is vertical temperature stratification, stabilizing the water column
- Ri decreases with increase in wind speed: wind creates shear on water surface, acts to break stratification (8/06) or prevent stratification all together (7/23)

Stratification and Production

- While only minimal increases in biomass were measured, a closer look shows chlorophyll-a was elevated during periods of vertical thermal stratification



- Primary production is fundamentally linked to stratification
  - Isolation of upper water column = increase in light exposure for phytoplankton
- Productivity in the DWSC is at a tipping point between those forces that induce stratification:
  - density (thermal) stratification due to surface heating

  and those that vertically mix the water column:
  - tidal currents, wind energy

In cooperation with the Bureau of Reclamation

All data are provisional and subject to revision