Tidal frequencies and quasiperiodic subsurface water level variations dominate redox dynamics in a salt marsh system

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Abstract

Salt marshes are hotspots of nutrient processing en route to sensitive coastal environments. While our understanding of these systems has improved over the years, we still have limited knowledge of the spatiotemporal variability of critical biogeochemical processes within salt marshes. Sea-level rise will continue to force change on salt marsh functioning, highlighting the urgency of filling this knowledge gap. Our study was conducted in a central California estuary experiencing extensive marsh drowning and relative sea-level rise, making it a model system for such an investigation. Here we instrumented three marsh positions with different degrees of inundation (6.7%, 8.9%, and 11.2% of the time for the upper, middle, and lower marsh positions, respectively), providing locations with varied geochemical characteristics and hydrological interaction at the site. We continuously monitored redox potential (Eh) at depths of 0.1, 0.3, and 0.5 m, subsurface water levels (WL), and temperature at each marsh position to understand how drivers of subsurface biogeochemical processes fluctuate across tidal cycles, using wavelet analyses to explain the interactions between Eh and WL. We found that tidal forcing significantly affects biogeochemical processes by imparting controls on Eh variability, likely driving subsurface hydro-biogeochemistry of the salt marsh. Wavelet coherence showed that the Eh-WL relationship is non-linear, and their lead-lag relationship is variable. We found that precipitation events perturb Eh at depth over timescales of hours, even though WL show relatively minimal change during events. This work highlights the importance of high-frequency measurements, such as Eh, to help explain factors that govern subsurface geochemistry and hydrological processes in salt marshes.

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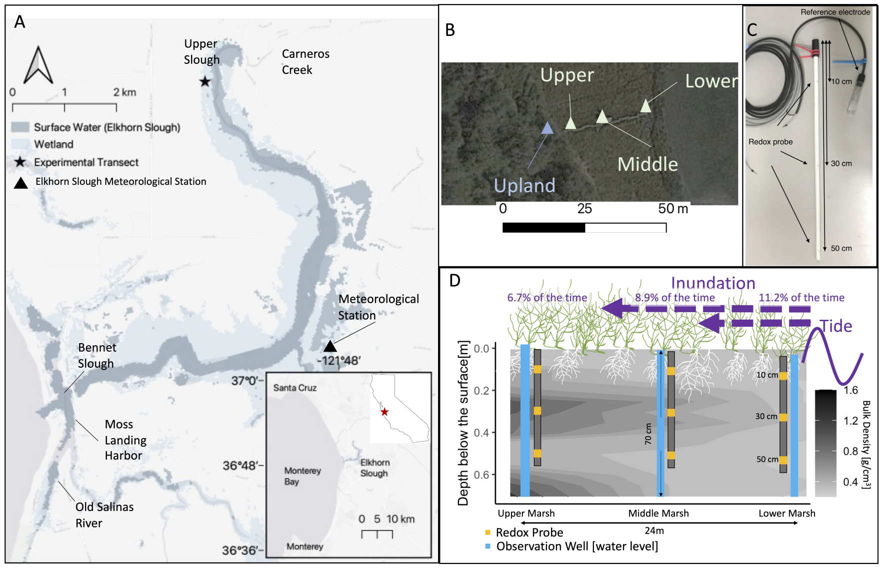
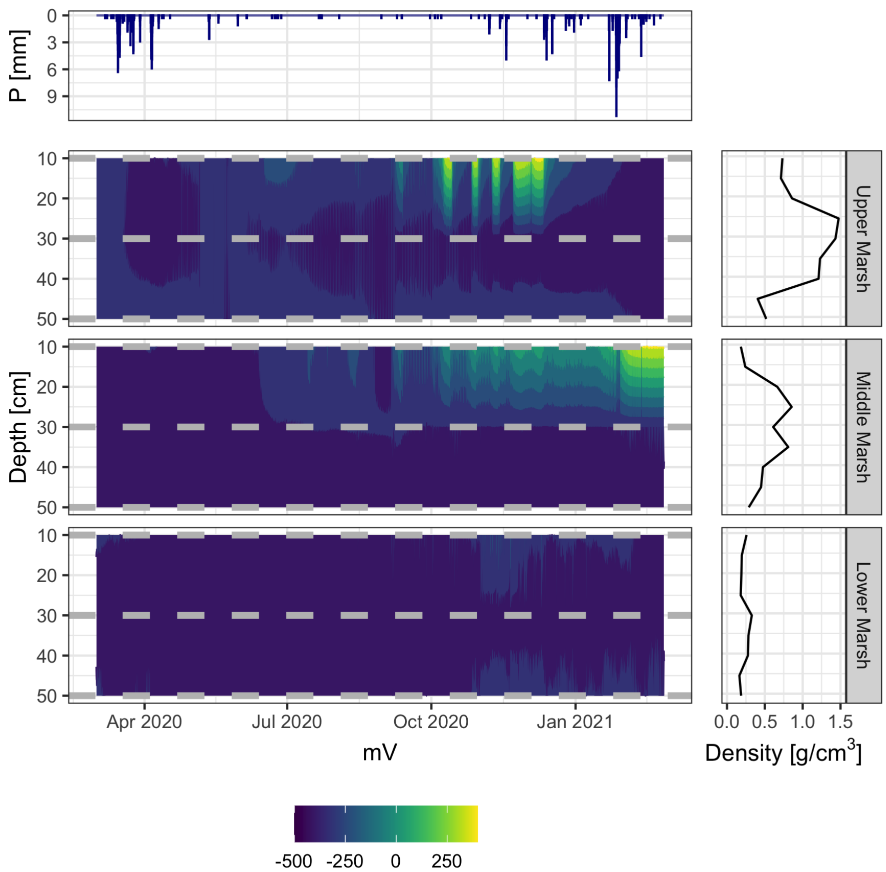
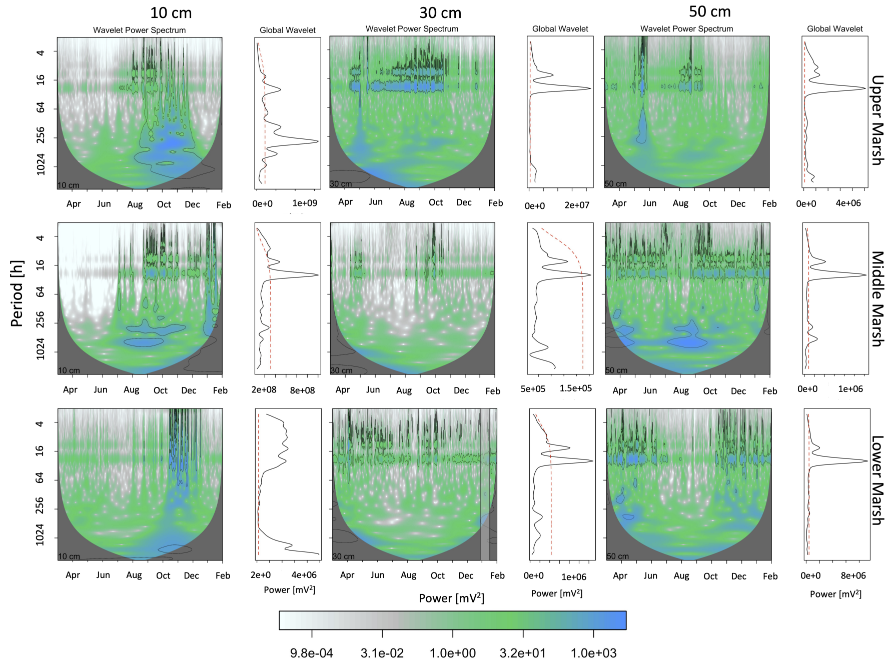
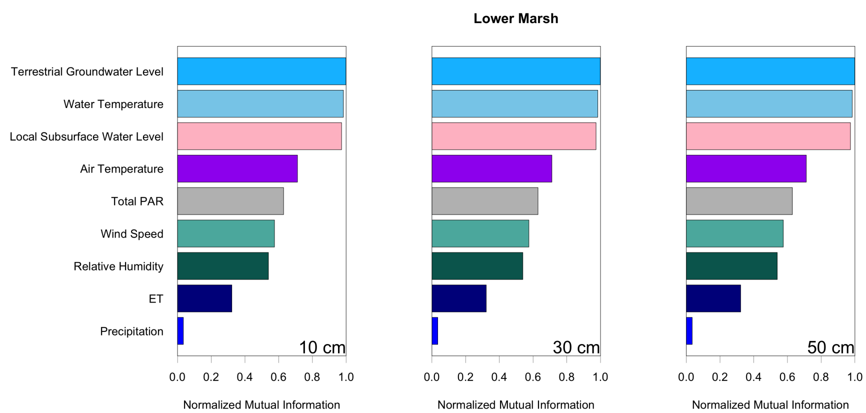
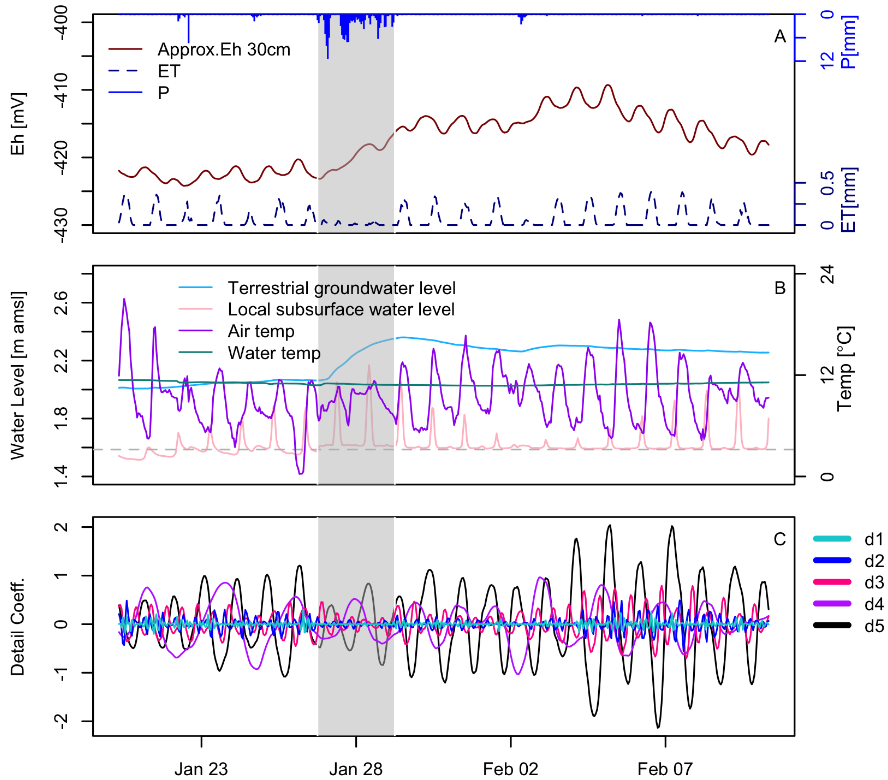
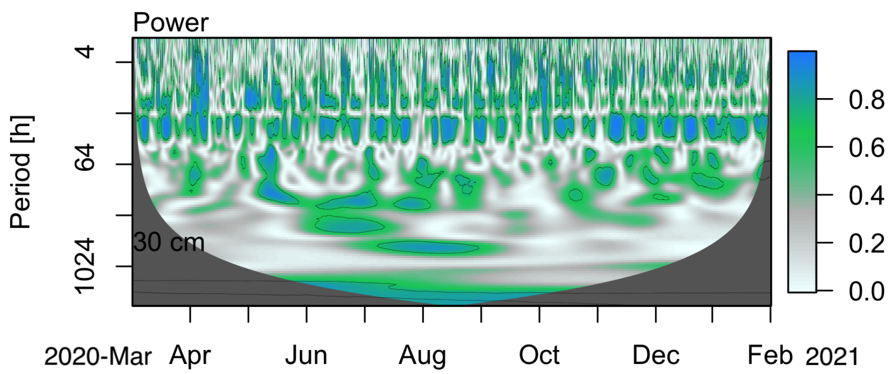

A
Upper Slough
Carneros Creek
0 1 2 km
Surface Water (Elkhorn Slough)
Wetland
Experimental Transect
Elkhorn Slough Meteorological Station
Meteorological Station
Bennet Slough
Moss Landing Harbor
Old Salinas River
-121°48′
37°0′
36°48′
36°36′
Santa Cruz
Monterey Bay
Elkhorn Slough
Monterey
0 5 10 km
B
Upper
Lower
Middle
Upland
0 25 50 m
C
Reference electrode
Redox probe
10 cm
30 cm
50 cm
D
Inundation
6.7% of the time
8.9% of the time
11.2% of the time
Tide
Depth below the surface[m]
70 cm
Bulk Density [g/cm³]
Upper Marsh
Middle Marsh
Lower Marsh
24m
Redox Probe
Observation Well [water level]

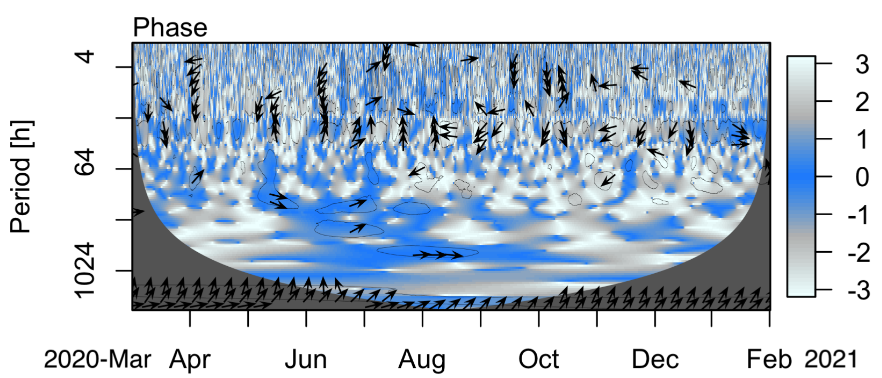

P [mm]
Depth [cm]
Upper Marsh
Middle Marsh
Lower Marsh
Apr 2020
Jul 2020
Oct 2020
Jan 2021
mV
Density [g/cm³]
-500 -250 0 250


10 cm
30 cm
50 cm
Wavelet Power Spectrum
Global Wavelet
Upper Marsh
Middle Marsh
Lower Marsh
Period [h]
4
16
64
256
1024
Apr
Jun
Aug
Oct
Dec
Feb
Power [mV²]
9.8e-04
3.1e-02
1.0e+00
3.2e+01
1.0e+03


Lower Marsh
Terrestrial Groundwater Level
Water Temperature
Local Subsurface Water Level
Air Temperature
Total PAR
Wind Speed
Relative Humidity
ET
Precipitation
10 cm
30 cm
50 cm
0.0
0.2
0.4
0.6
0.8
1.0
Normalized Mutual Information


A
Approx.Eh 30cm
ET
P
Eh [mV]
-400
-410
-420
-430
P[mm]
0
12
ET[mm]
0.5
0
B
Terrestrial groundwater level
Local subsurface water level
Air temp
Water temp
Water Level [m amsl]
2.6
2.2
1.8
1.4
Temp [°C]
24
12
0
C
d1
d2
d3
d4
d5
Detail Coeff.
2
1
0
-1
-2
Jan 23
Jan 28
Feb 02
Feb 07


Power
Period [h]
4
64
1024
30 cm
0.8
0.6
0.4
0.2
0.0
2020-Mar
Apr
Jun
Aug
Oct
Dec
Feb
2021


Phase
Period [h]
4
64
1024
3
2
1
0
-1
-2
-3
2020-Mar
Apr
Jun
Aug
Oct
Dec
Feb
2021