Nearshore Disposal of Fine-grained Sediment in a High-Energy Environment

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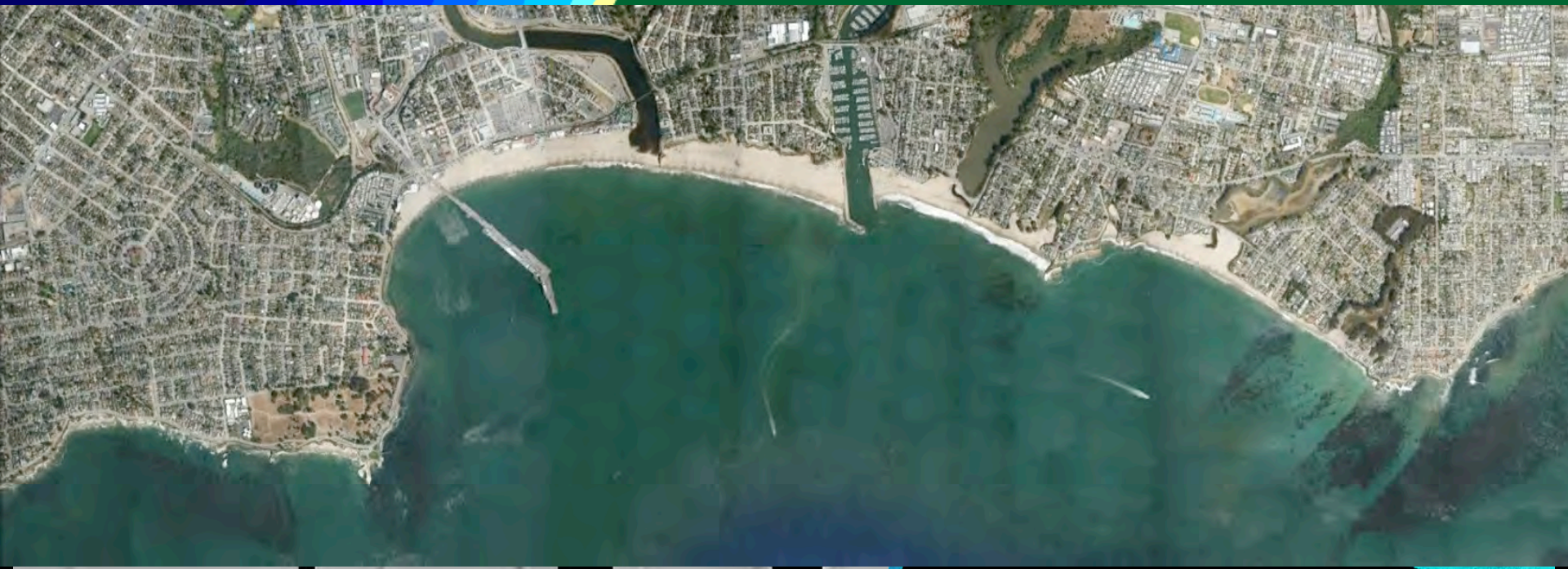
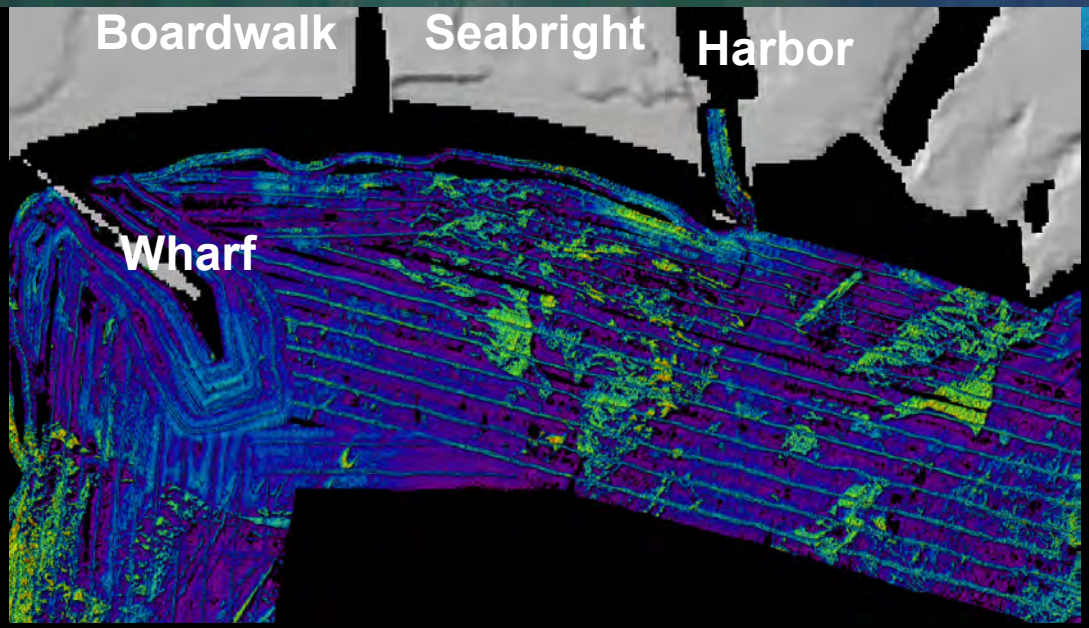
versus

***QUESTION:* Does fine-grained dredge material impact the coast, and if so, how does it compare to natural processes???**





Substrate

Rock

Sand

"The issue"

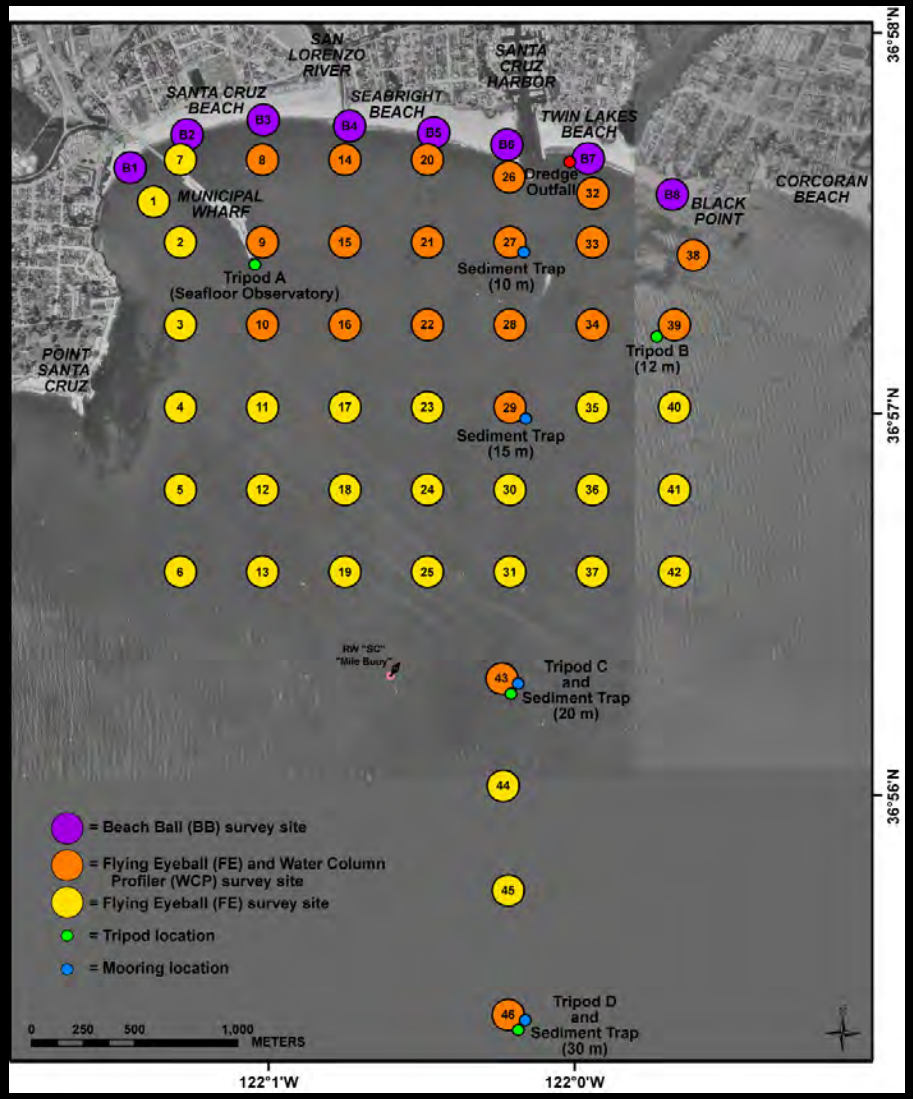
Erosion happens…

The "80:20" Rule

The Monterey Bay National Marine Sanctuary *REALLY* doesn't like dumping on its protected natural resources

UNITED STATES CODE OF FEDERAL REGULATIONS, TITLE 15, PART 922.40 "PROHIBITED ACTIVITIES"

The 2009 USGS experiment's goals



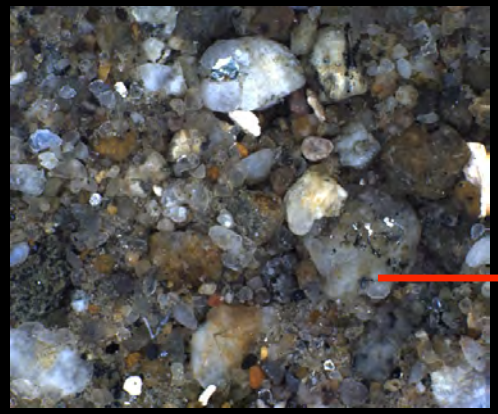
1) Determine if fine-grained dredge material is stable on the beach and inner shelf, and if not, why?

2) If the fine-grained dredge sediment is not stable, where does it go?

Determine if fine-grained dredge material is stable on the beach and inner shelf

Measure beach and seabed response (change in grain size) to determine if change, and thus impact, occurs

Measuring seabed grain size using the USGS "Flying Eyeball" from the *R/V Frontier*



?

If fine-grained dredge material is (or is not) stable on the beach and inner shelf, why?

Measure forcing (tides, waves, and currents) using instruments and determine if hydrodynamics are sufficient to allow or inhibit deposition of fine-grained material on the beach and inner shelf

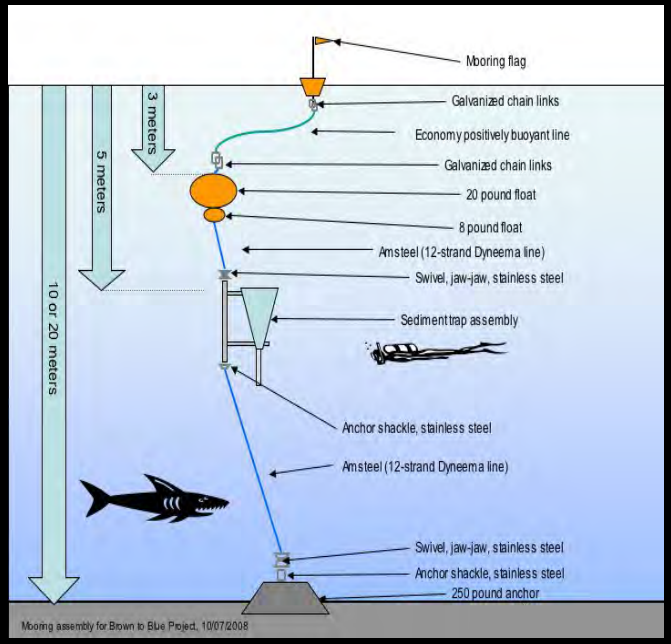
Deployment of hydrodynamic and sediment transport tripods from the *R/V Shana Rae*

Where does the fine-grained dredge material go if it is not stable on the beach and inner shelf?

1) Measure sediment flux

using tripods *(What are sediment concentrations, where are they going, and how fast?)* **and**

sediment traps *(Is sediment relict, fluvial, or dredge material?)*

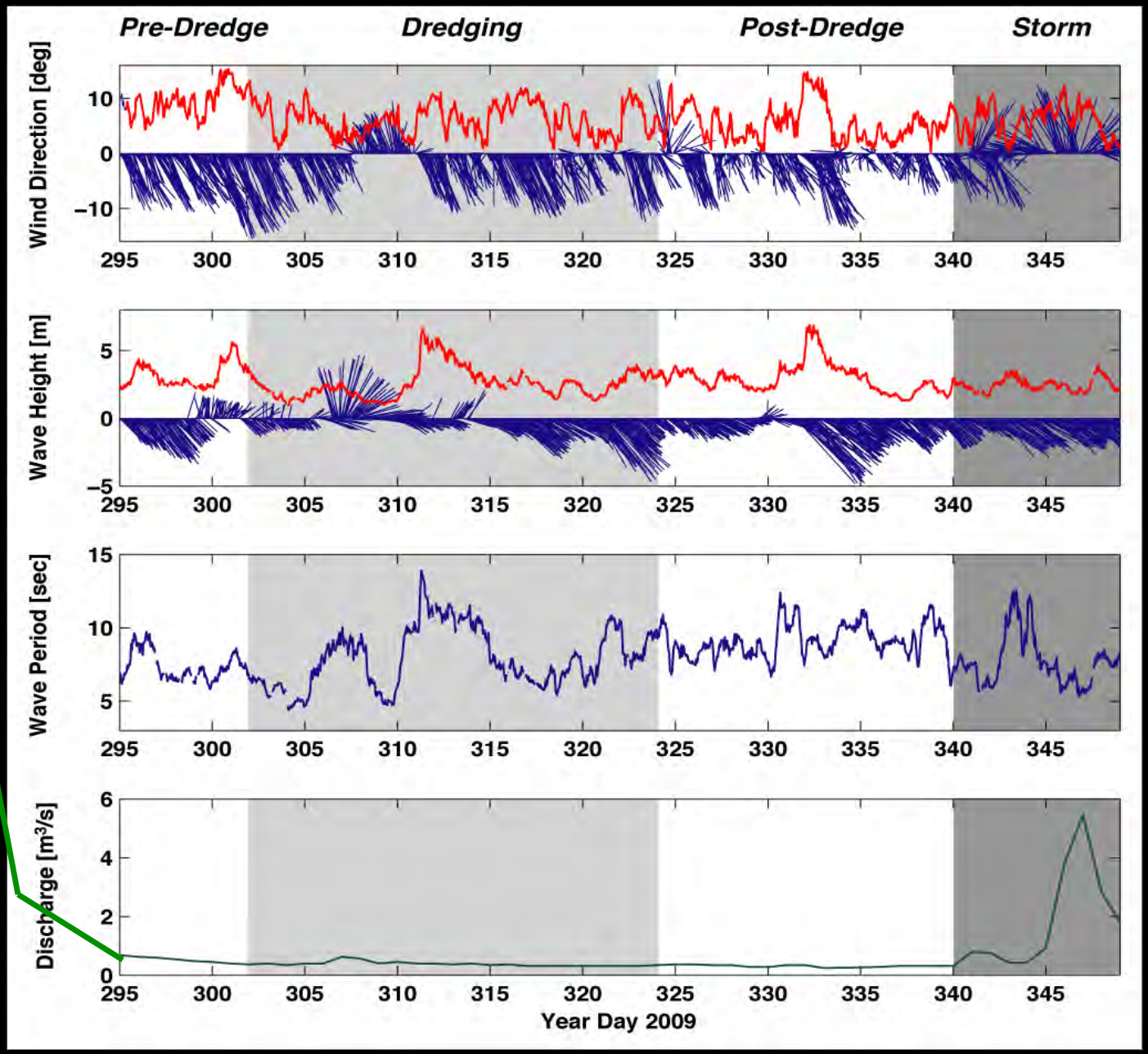


Schematic of sediment trap design

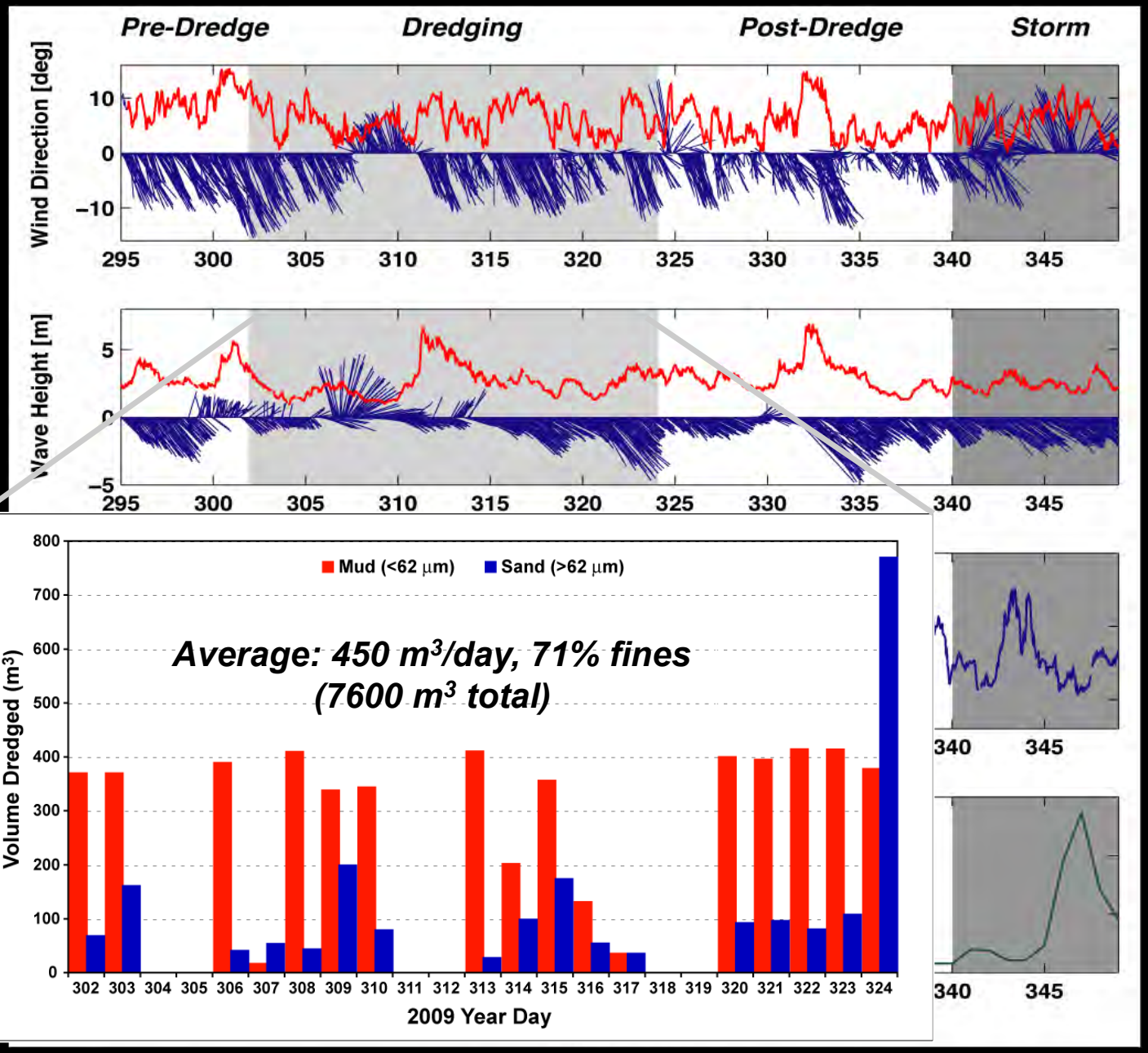
2) Model dredging using Delft3D

Using geochemistry to determine sediment origin

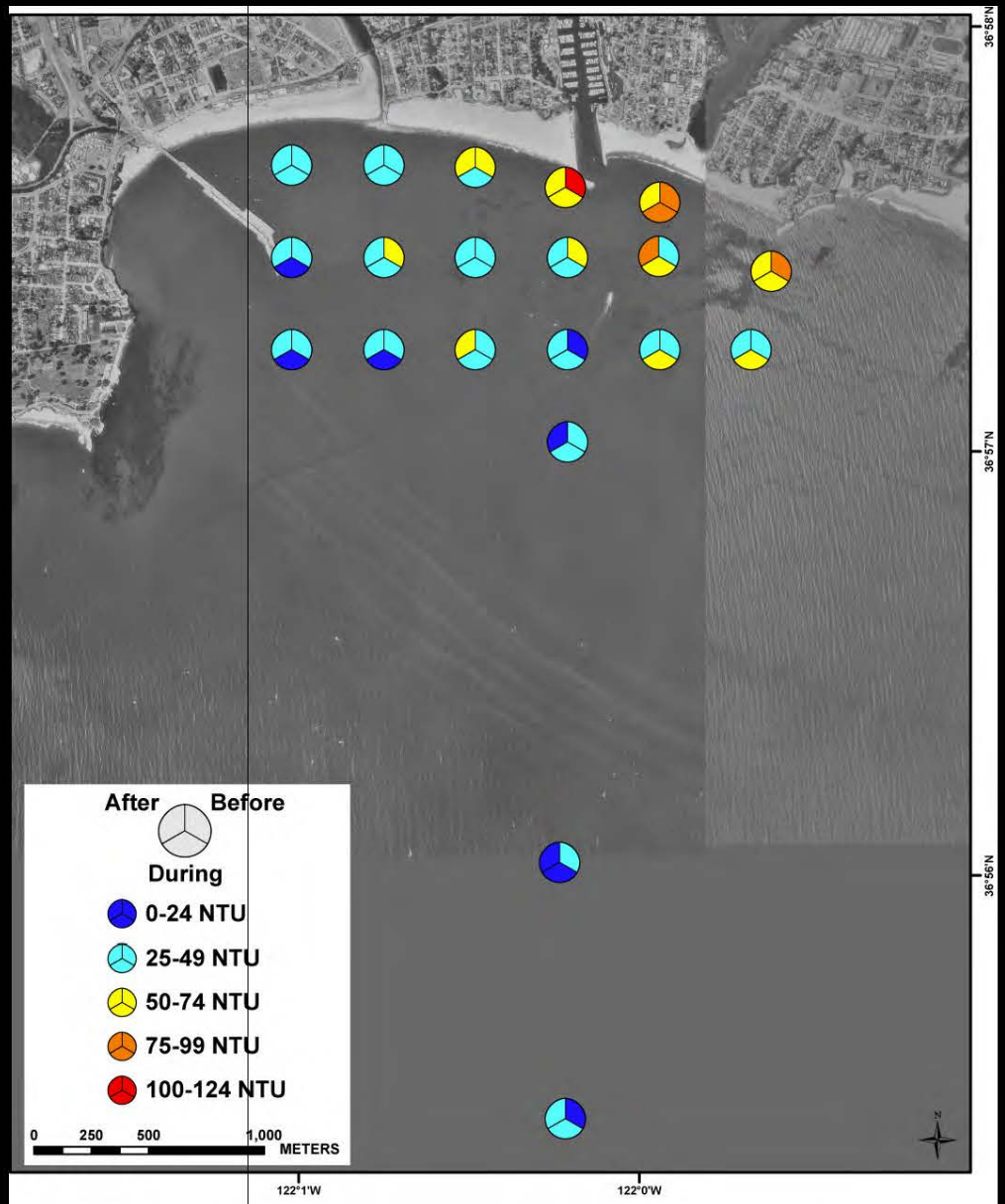
Dredge sediment:	High Cu, low ^{7}Be
Relict shelf sediment:	Low Cu, low $^{7}Be/^{210}Pb_{xs}$, low ^{7}Be
New fluvial sediment:	Low Cu, high $^{7}Be/^{210}Pb_{xs}$, high ^{7}Be



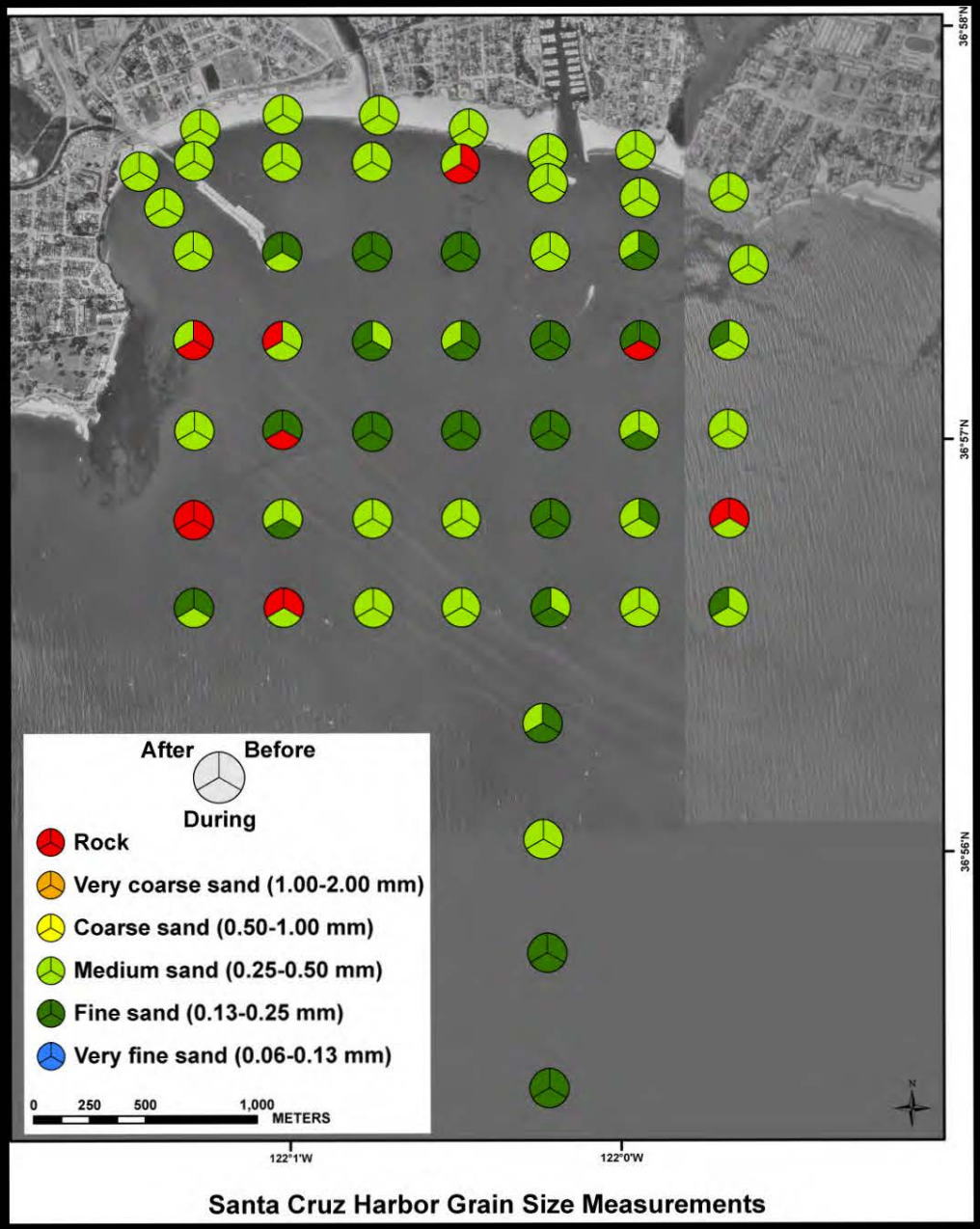
remnants of Super Typhoon Melor ~48 m^3/m

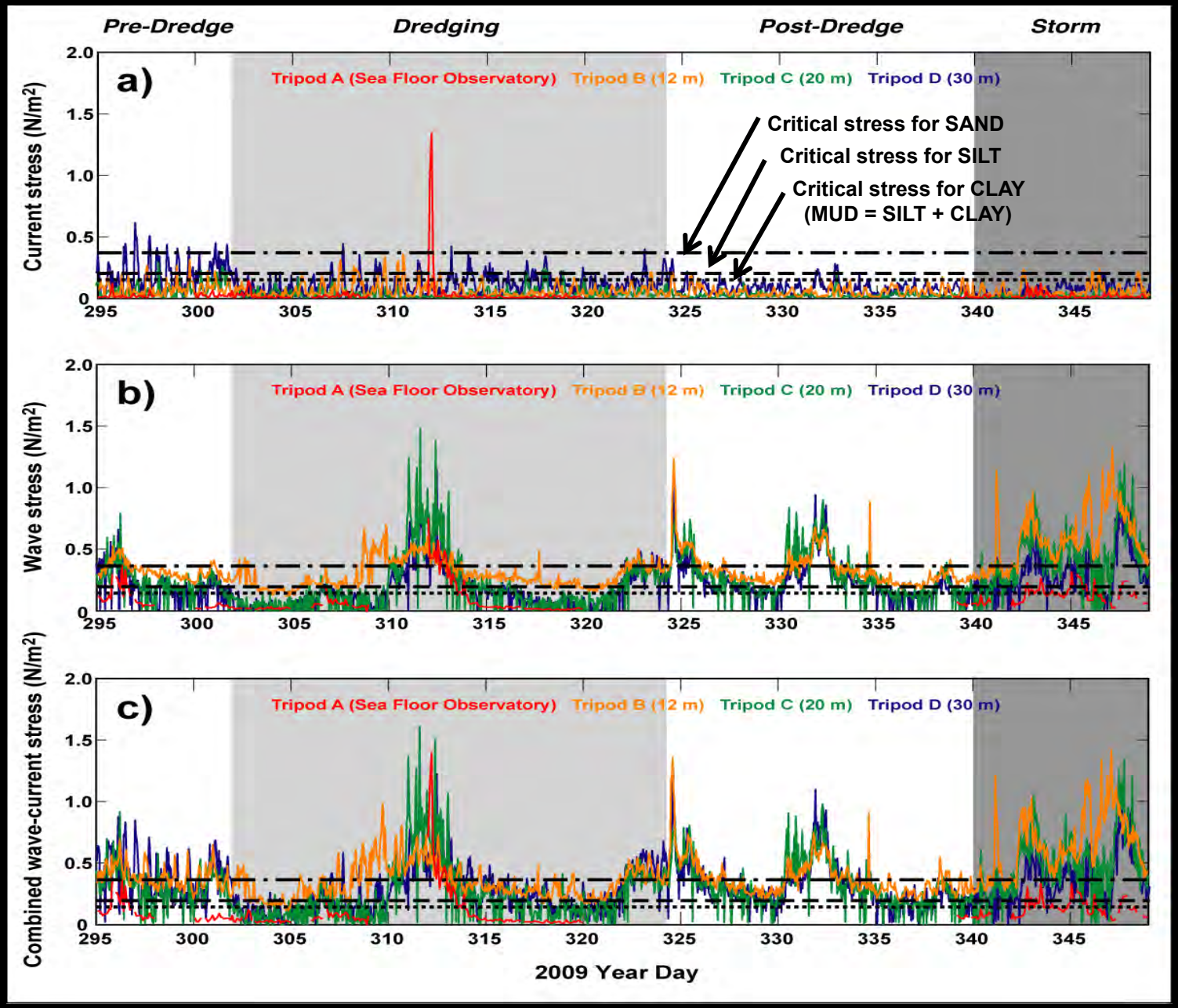


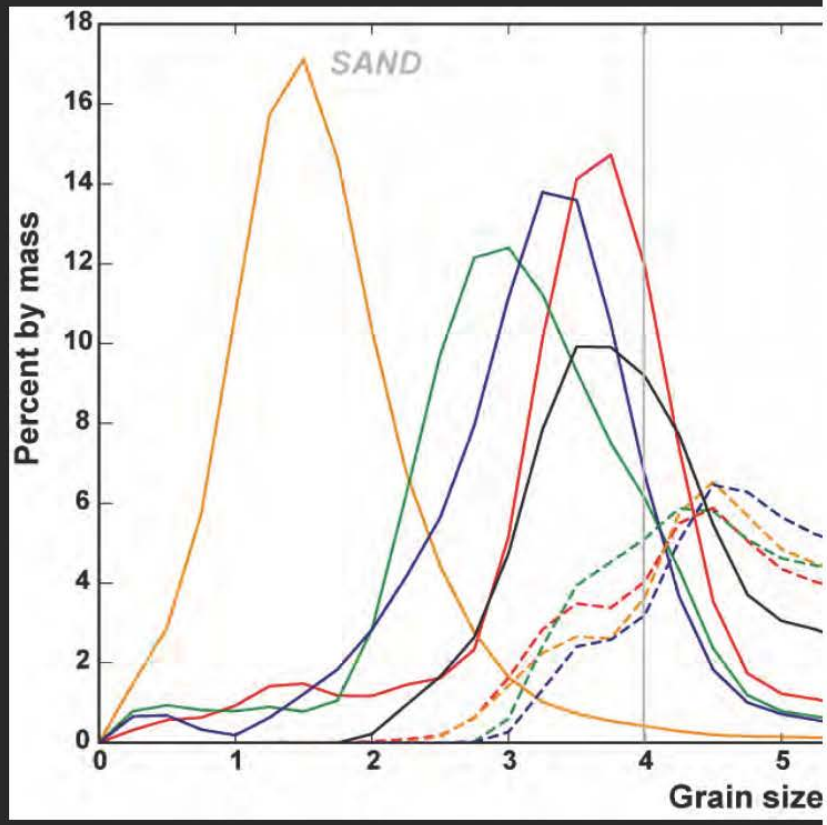
remnants of Super Typhoon Melor ~48 m^3/m

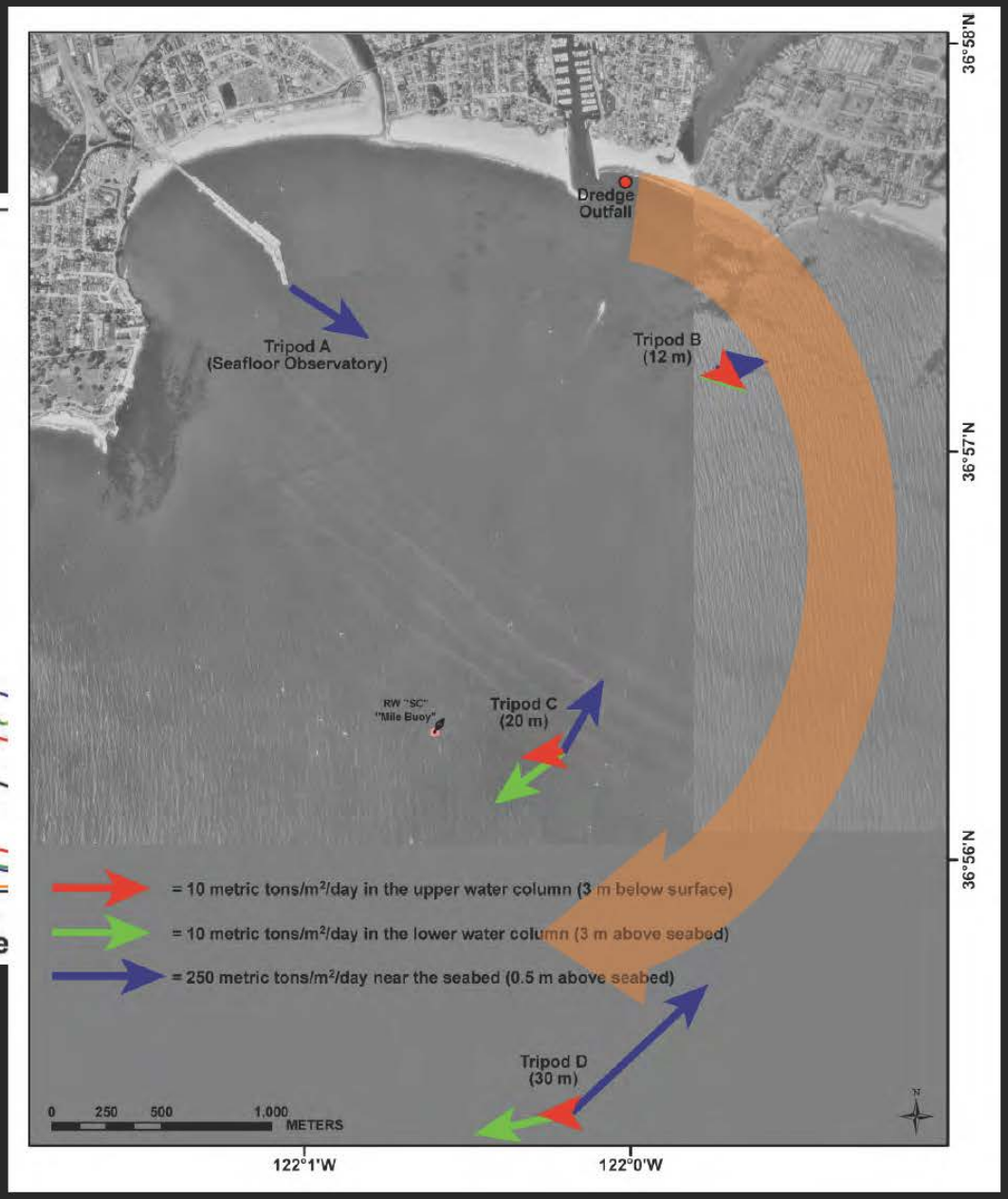


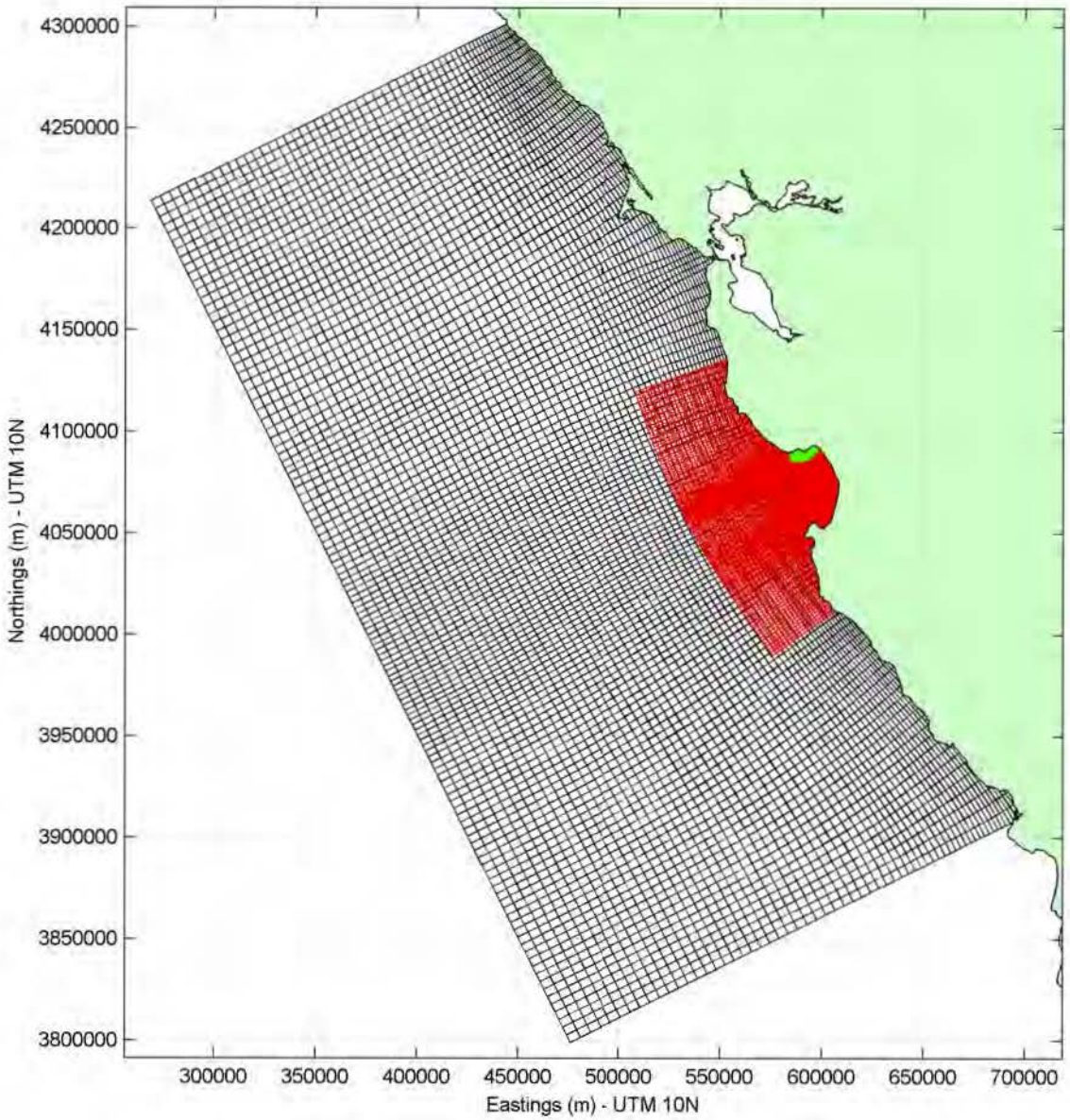
Santa Cruz Harbor Turbidity Measurements

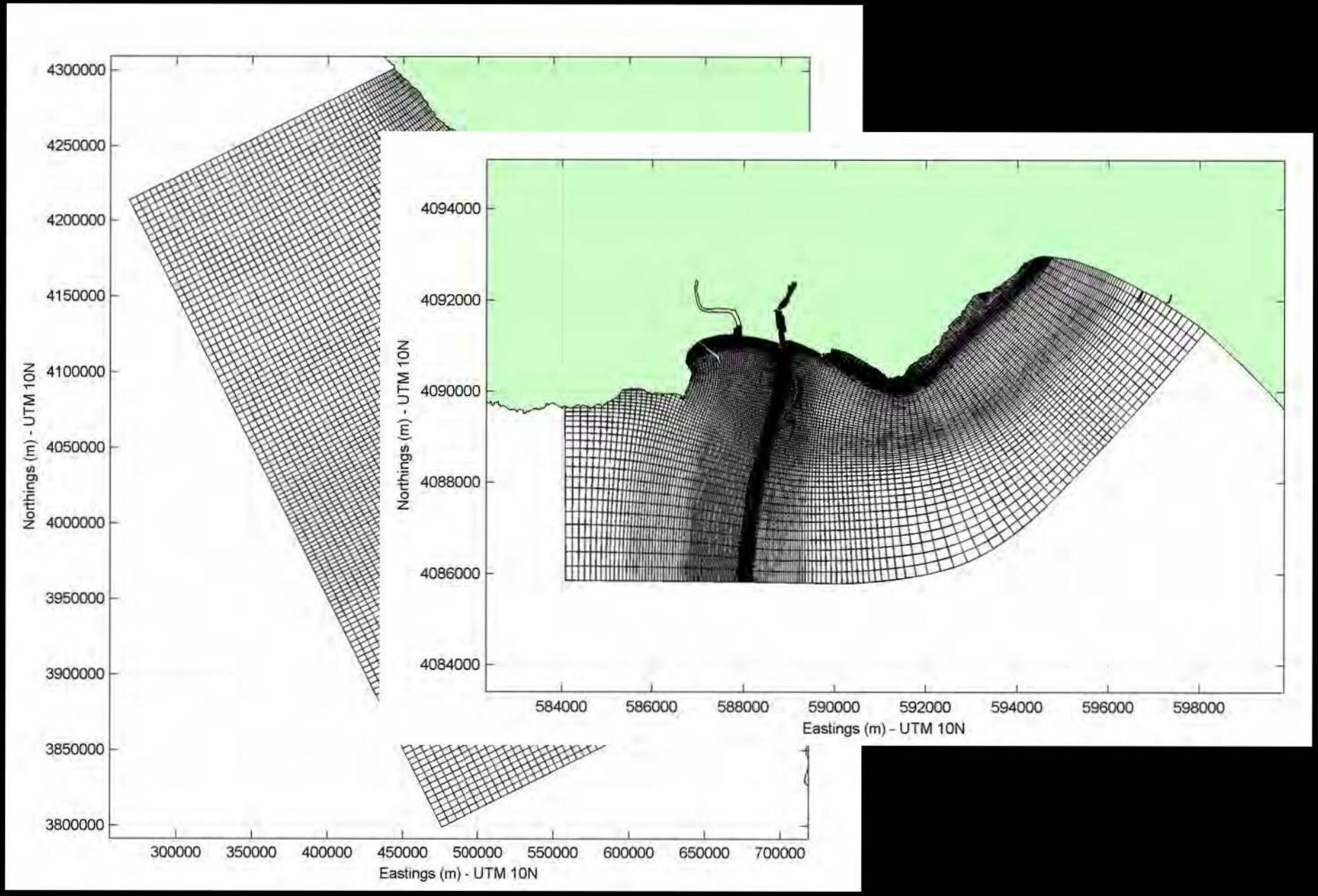

After
Before
During
Rock
Very coarse sand (1.00-2.00 mm)
Coarse sand (0.50-1.00 mm)
Medium sand (0.25-0.50 mm)
Fine sand (0.13-0.25 mm)
Very fine sand (0.06-0.13 mm)
0 250 500 1,000
METERS
36°58'N
36°57'N
36°56'N
122°1'W
122°0'W
N
Santa Cruz Harbor Grain Size Measurements

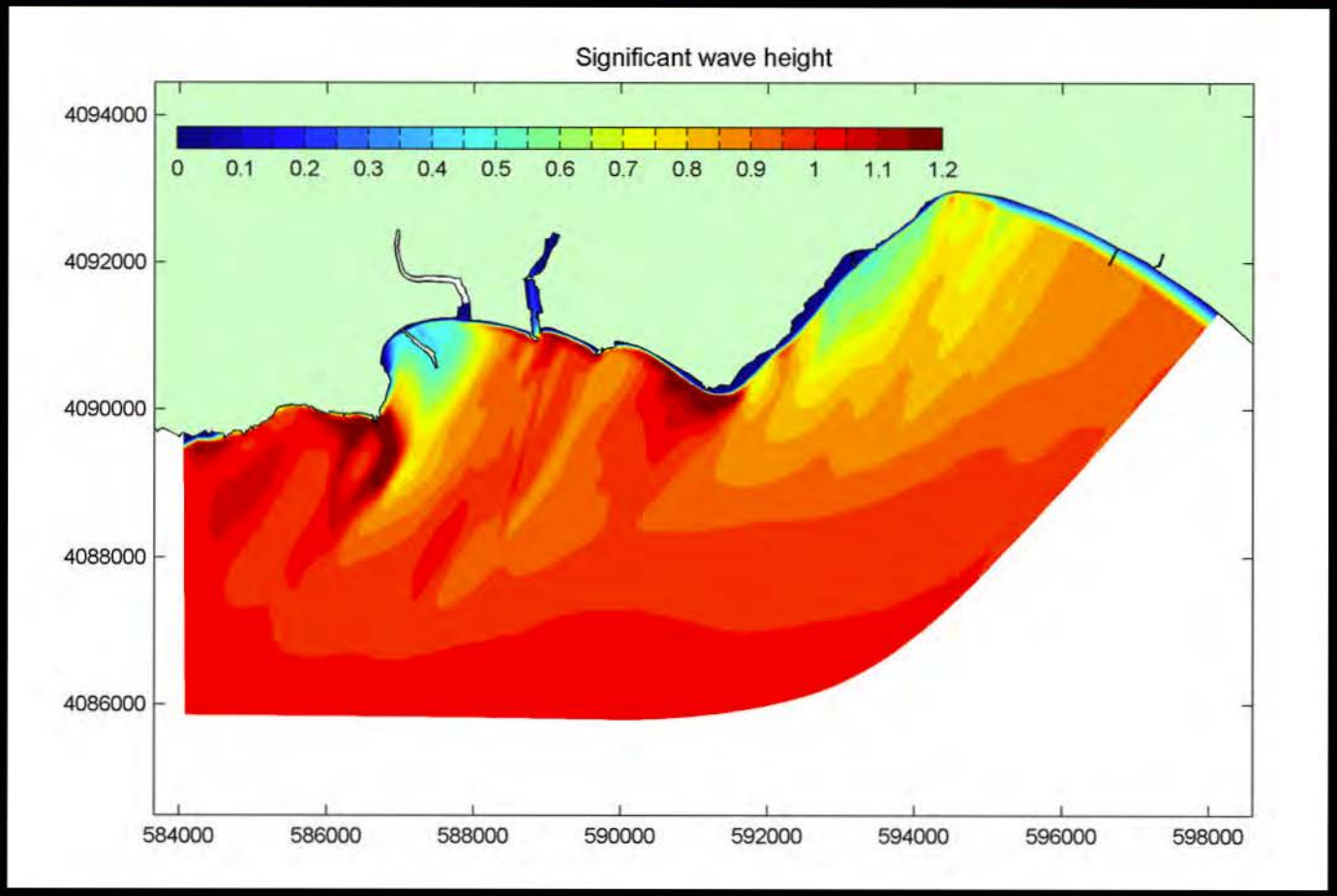

Pre-Dredge
Dredging
Post-Dredge
Storm
a)
b)
c)
Tripod A (Sea Floor Observatory)
Tripod B (12 m)
Tripod C (20 m)
Tripod D (30 m)
Critical stress for SAND
Critical stress for SILT
Critical stress for CLAY
(MUD = SILT + CLAY)
Current stress (N/m²)
Wave stress (N/m²)
Combined wave-current stress (N/m²)
2009 Year Day

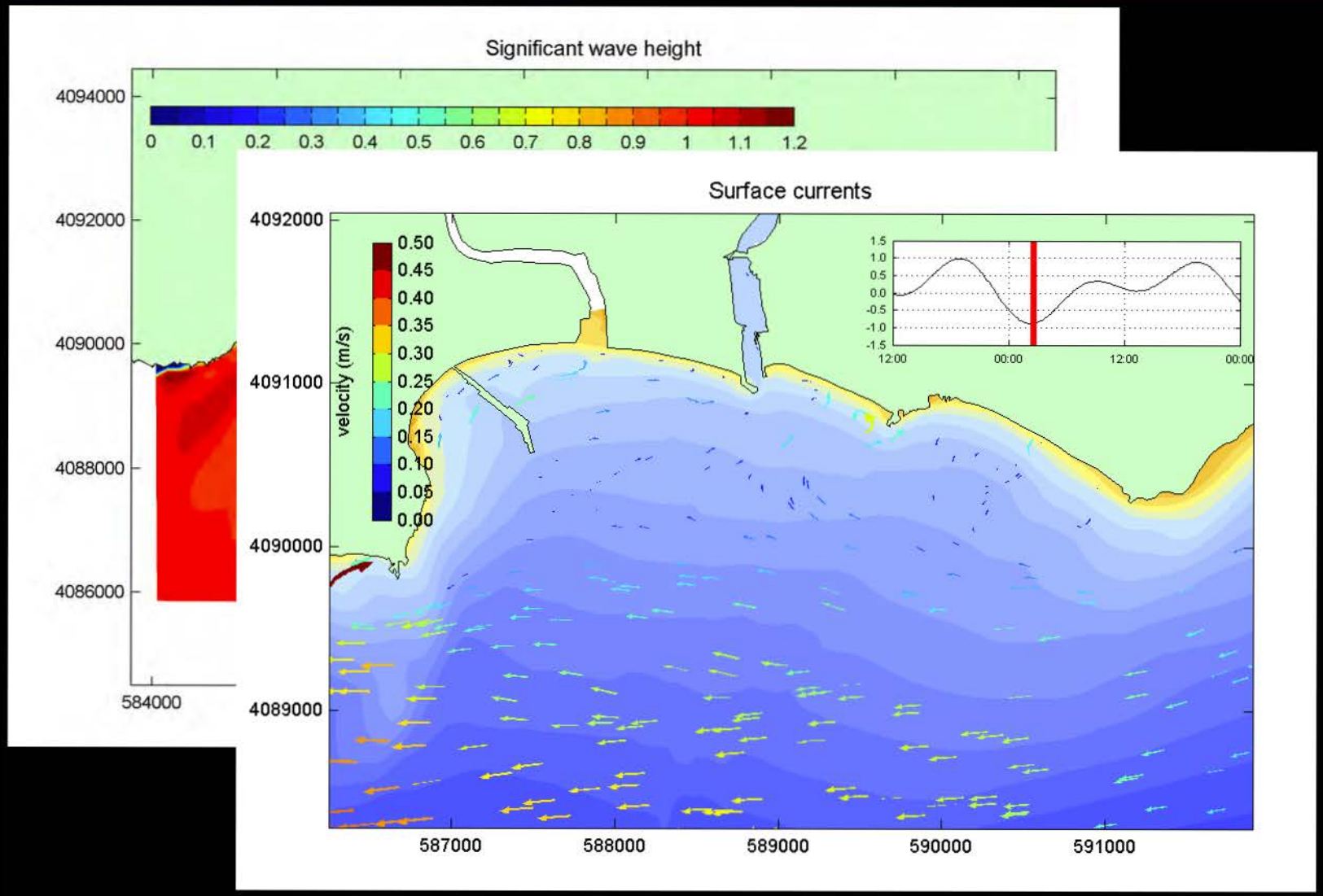

SAND
Percent by mass
Grain size
0
2
4
6
8
10
12
14
16
18
0
1
2
3
4
5

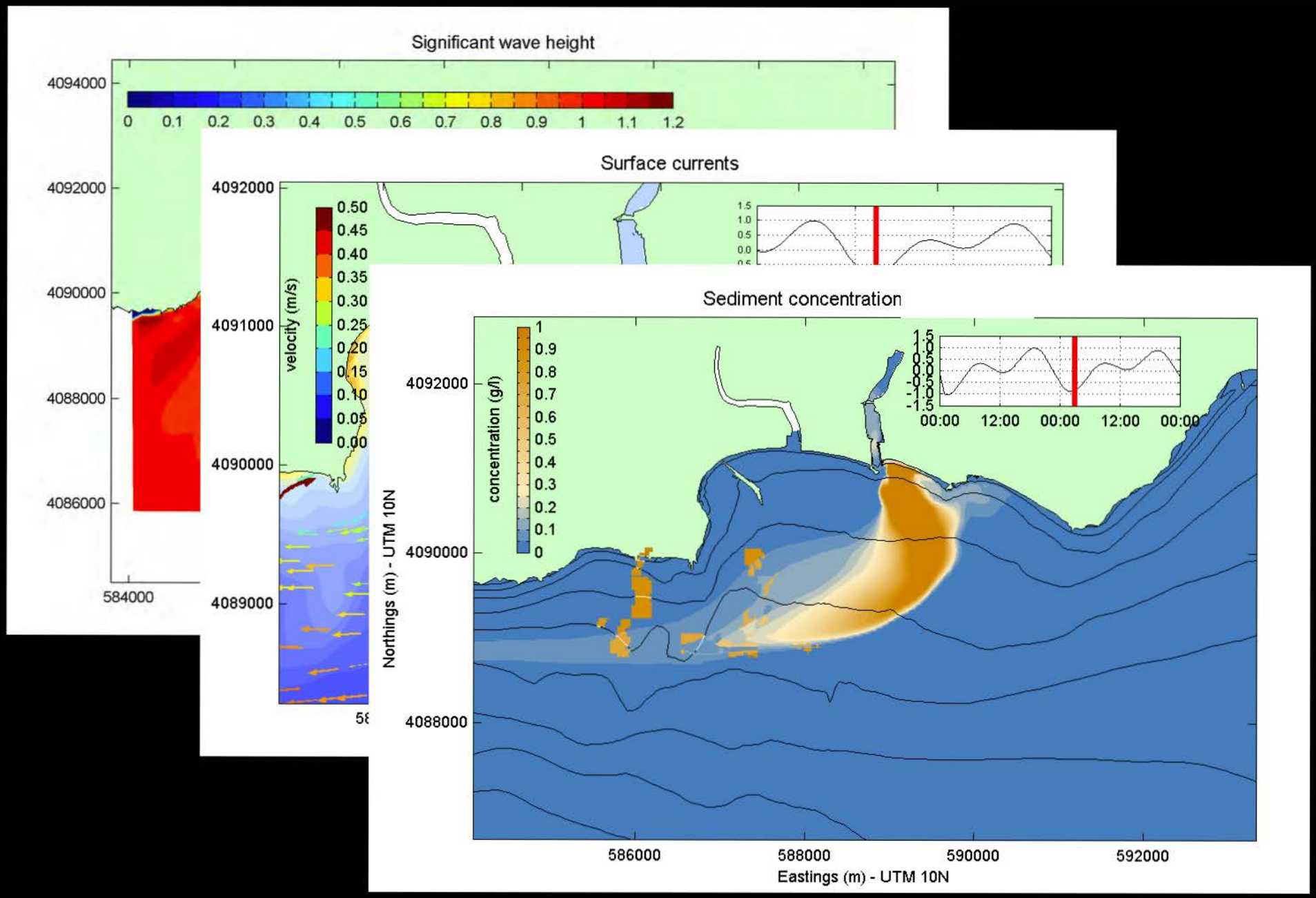

Dredge Outfall
Tripod A (Seafloor Observatory)
Tripod B (12 m)
Tripod C (20 m)
Tripod D (30 m)
RW "SC" "Mile Buoy"
= 10 metric tons/m²/day in the upper water column (3 m below surface)
= 10 metric tons/m²/day in the lower water column (3 m above seabed)
= 250 metric tons/m²/day near the seabed (0.5 m above seabed)
0 250 500 1,000 METERS
36°58'N
36°57'N
36°56'N
122°1'W
122°0'W

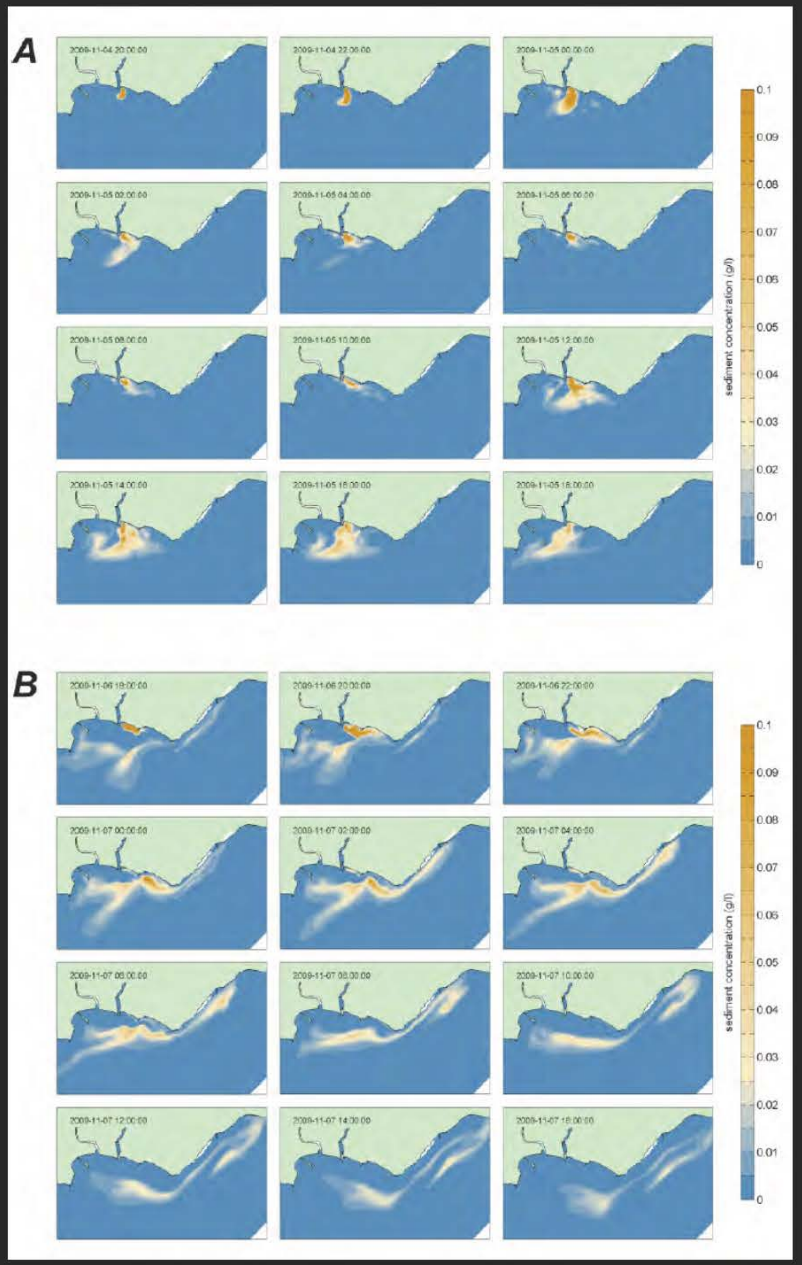

4300000
4250000
4200000
4150000
4100000
4050000
4000000
3950000
3900000
3850000
3800000
Northings (m) - UTM 10N
300000
350000
400000
450000
500000
550000
600000
650000
700000
Eastings (m) - UTM 10N

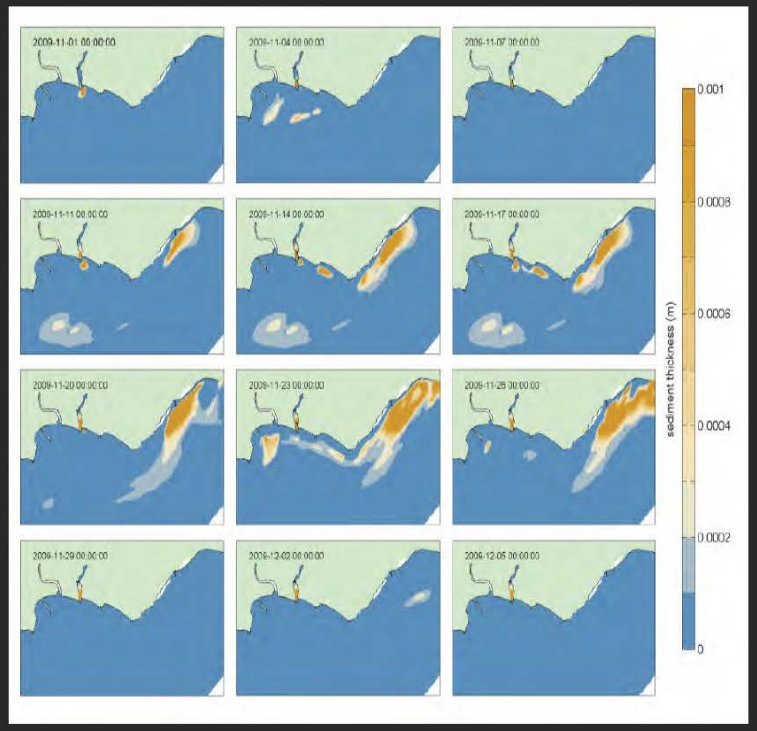

4300000
4250000
4200000
4150000
4100000
4050000
4000000
3950000
3900000
3850000
3800000
Northings (m) - UTM 10N
300000
350000
400000
450000
500000
550000
600000
650000
700000
Eastings (m) - UTM 10N
4094000
4092000
4090000
4088000
4086000
4084000
Northings (m) - UTM 10N
584000
586000
588000
590000
592000
594000
596000
598000
Eastings (m) - UTM 10N

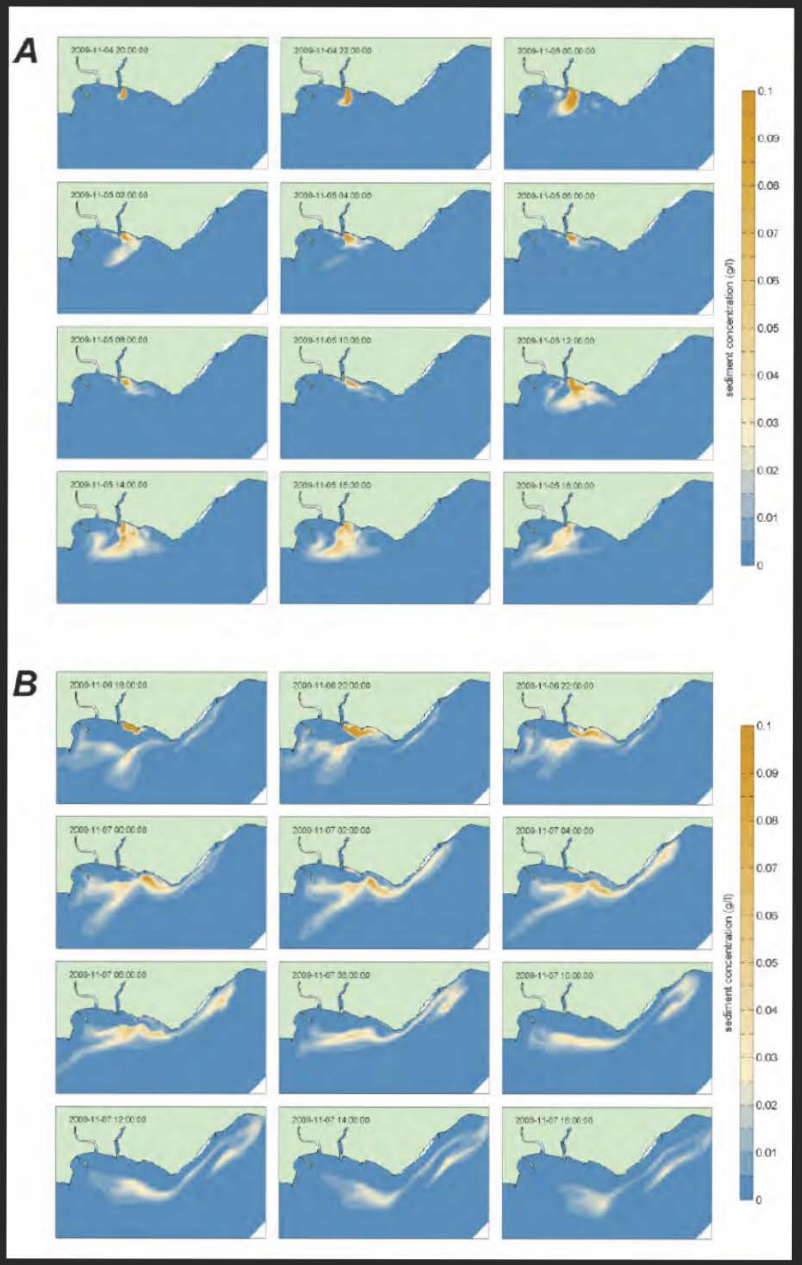

Significant wave height
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
4094000
4092000
4090000
4088000
4086000
584000
586000
588000
590000
592000
594000
596000
598000


Significant wave height
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2
4094000
4092000
4090000
4088000
4086000
584000
Surface currents
velocity (m/s)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
4092000
4091000
4090000
4089000
587000
588000
589000
590000
591000
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
12:00
00:00
12:00
00:00


Significant wave height
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2
4094000
4092000
4090000
4088000
4086000
584000
Surface currents
velocity (m/s)
0.50 0.45 0.40 0.35 0.30 0.25 0.20 0.15 0.10 0.05 0.00
4092000
4091000
4090000
4089000
Sediment concentration
concentration (g/l)
1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
00:00 12:00 00:00 12:00 00:00
Northings (m) - UTM 10N
4092000
4090000
4088000
586000 588000 590000 592000
Eastings (m) - UTM 10N


A
B
sediment concentration (g/l)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0


sediment thickness (m)
0.001
0.0008
0.0006
0.0004
0.0002
0


A
B
sediment concentration (g/l)
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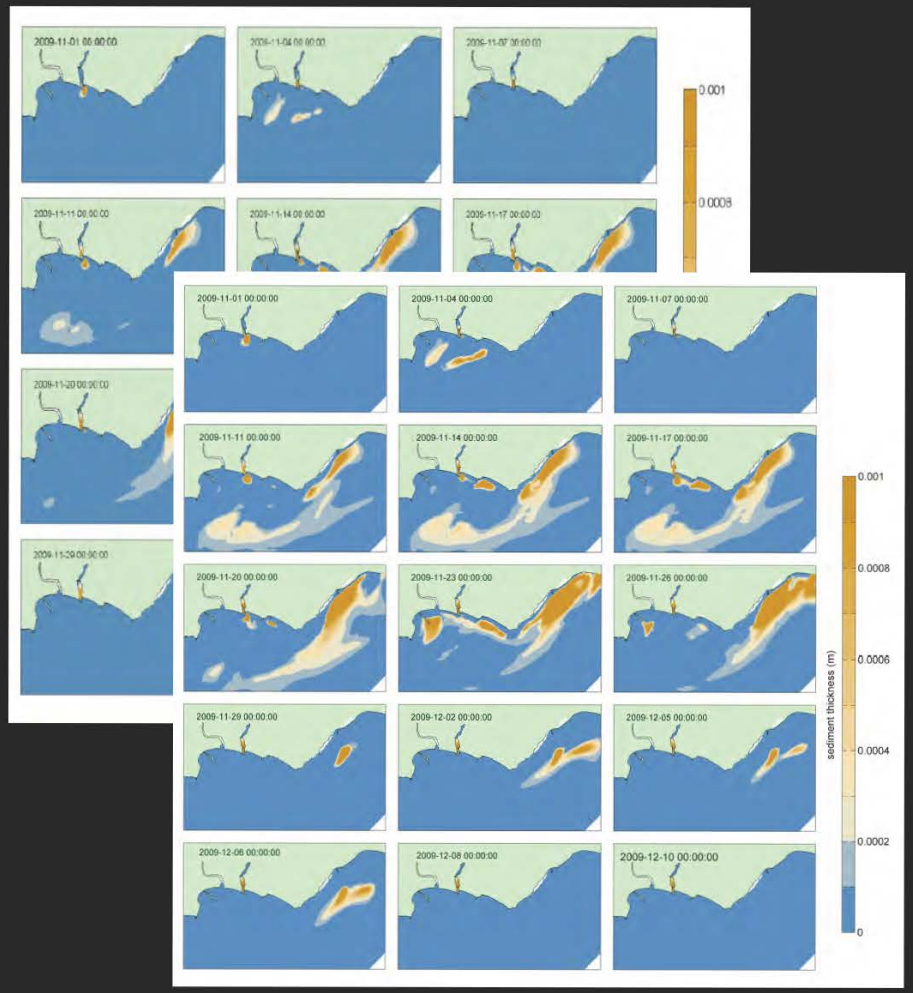
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0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2009-11-04 00:00:00
2009-11-07 00:00:00
2009-11-11 00:00:00
2009-11-14 00:00:00
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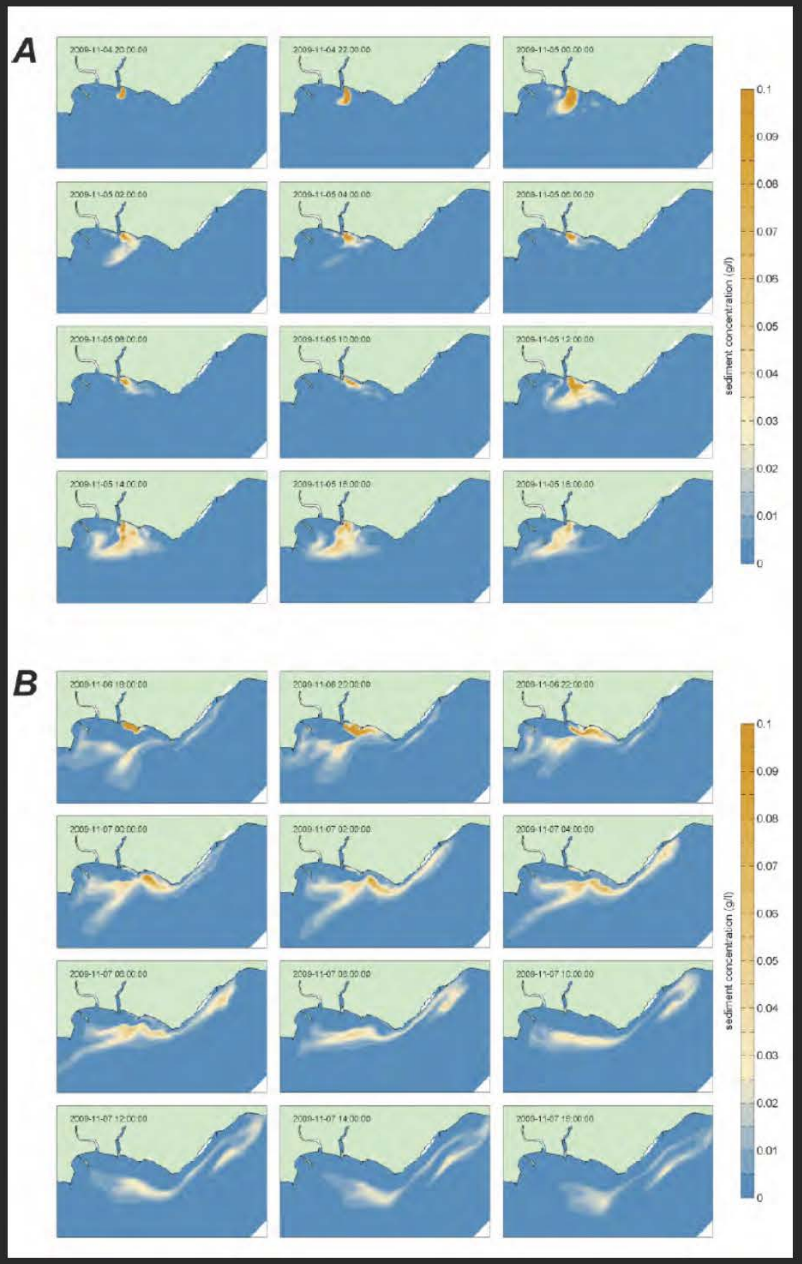
2009-11-20 00:00:00
2009-11-23 00:00:00
2009-11-26 00:00:00
2009-11-29 00:00:00
2009-12-02 00:00:00
2009-12-05 00:00:00
2009-12-06 00:00:00
2009-12-08 00:00:00
2009-12-10 00:00:00
sediment thickness (m)
0.001
0.0008
0.0006
0.0004
0.0002
0


A
B
sediment concentration (g/l)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
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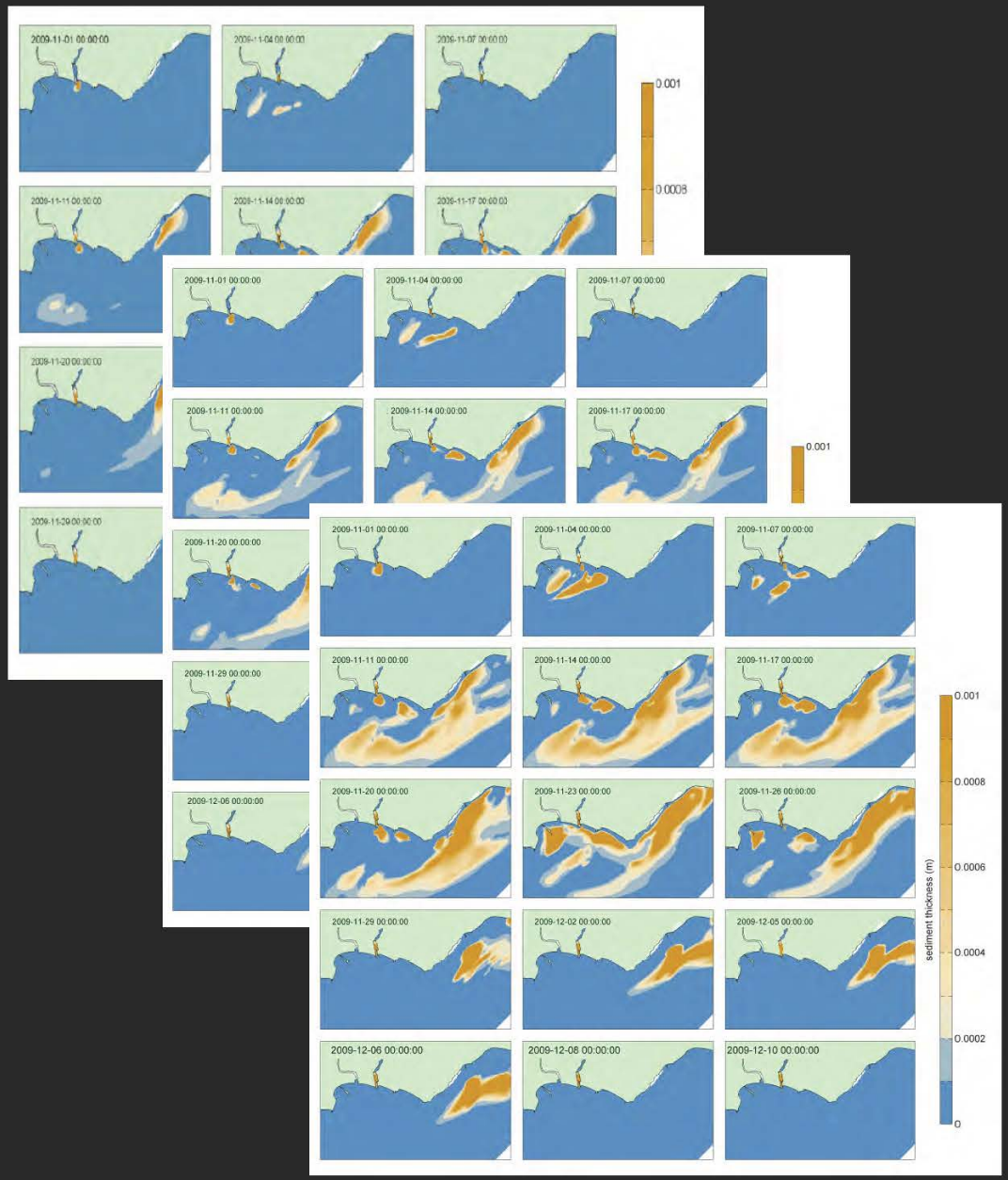
2009-11-01 00:00:00
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2009-11-14 00:00:00
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2009-11-26 00:00:00
2009-12-02 00:00:00
2009-12-05 00:00:00
2009-12-08 00:00:00
2009-12-10 00:00:00
0.001
0.0008
0.0006
0.0004
0.0002
0
sediment thickness (m)

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Spatial and Temporal Variations in Oceanographic and Meteorologic Forcing Along the Central California Coast, 1980–2002

Scientific Investigations Report 2005–5085

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Spatial and temporal variability in oceanographic and meteorologic forcing along Central California and its implications on nearshore processes

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Abstract

In the past two decades, the understanding of the important large-scale phenomena (El Niño, upwelling, California current, etc) that drive physical, chemical, and biological processes along the US West Coast has greatly improved. However, the ability to predict the influence of annual and inter-annual events on a regional scale still remains limited. High-resolution hourly data from 6 National Oceanographic and Atmospheric Administration (NOAA) buoys deployed since the early 1980's off Central California were analyzed to improve our understanding of spatial and temporal variability of oceanographic and meteorologic forcing along the coastline. Seasonal to inter-annual trends in wave height, wave period, sea level barometric pressure, sea-surface temperature, and wind direction were identified, as were significant departures in these trends during El Niño and La Niña periods. The results suggest there are increasing wave heights and wave periods, decreasing sea level barometric pressures and variability in sea-surface temperatures, and increasingly variable winds off Central California between 1980 and 2002. The impact of these climatic trends on coastal physical, geological and biologic processes will also be addressed.
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Keywords: Waves; Storms; Sea-surface temperatures; Winds; El Niño; La Niña

1. Introduction

The El Niño events between 1982–2002 (most notably in 1982–83 and 1997–98) have adversely affected the entire North American/Pacific coast (Komar, 1998). Studies by Seymour (1983) and Inman (1991) suggest that winter storm intensity and the resulting wave climate off Southern California have been increasing during the latter half of the 20th century. Allan and Komar (2000) and Bromirski et al. (2005) also note considerable inter-annual variability in storm-generated wave heights, as well as a general trend in increasing wave heights in the eastern North Pacific. Central California thought to be a "transition zone" between high energy in the Pacific Northwest and milder wave conditions off Southern California. This increased storminess, as well as storms propagating at lower latitudes across the northeastern Pacific (Brewer and Jackson, 2000) lead to greater coastal erosion, with

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The influence of El Niño-Southern Oscillation (ENSO) cycles on wave-driven sea-floor sediment mobility along the central California continental margin

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ABSTRACT

Ocean surface waves are the dominant temporally and spatially variable process influencing sea floor sediment resuspension along most continental shelves. Wave-induced sediment mobility on the continental shelf and upper continental slope off central California for different phases of El Niño-Southern Oscillation (ENSO) events was modeled using monthly statistics derived from more than 14 years of concurrent hourly oceanographic and meteorologic data as boundary input for the Delft SWAN wave model, gridded sea floor grain-size data from the nGSFRED database, and regional bathymetry. Differences as small as 0.5 m in wave height, 1 s in wave period, and 10° in wave direction, in conjunction with the spatially heterogeneous unconsolidated sea-floor sedimentary cover, result in significant changes in the predicted mobility of continental shelf surficial sediment in the study area. El Niño events result in more frequent mobilization on the inner shelf in the summer and winter than during La Niña events and on the outer shelf and upper slope in the winter months, while La Niña events result in more frequent mobilization on the mid-shelf during spring and summer months than during El Niño events. The timing and patterns of seabed mobility are addressed in context of geologic and biologic processes. By understanding the spatial and temporal variability in the disturbance of the sea floor, scientists can better interpret sedimentary patterns and ecosystem structure, while providing managers and planners an understanding of natural impacts when considering the permitting of offshore activities that disturb the sea floor such as trawling, dredging, and the emplacement of sea-floor engineering structures.

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1. Introduction

While discussions of marine biodiversity frequently focus on hard bottom ecosystems such as coral reefs, kelp forests, and the rocky intertidal (Thrush and Dayton, 2002), more than 70% of the earth's seafloor is composed of unconsolidated sediment (Snelgrove, 1999). Although this type of habitat may not appear to be as highly structured as some hard bottom marine habitats, unconsolidated sediments can support very high species diversity (Coleman et al., 1997; Snelgrove, 1999). Ecologists have long recognized that the structure and function of benthic marine ecosystems are closely linked to oceanographic processes (Mann, 1973; Graham et al., 1997); most studies, however, have relied either upon qualitative descriptions of oceanographic factors (e.g., "low", "medium", or "high" energy environments) or on quantitative values based on mean oceanographic conditions (e.g., tidal range or wave heights). Recently, the importance of intermittent disturbance on marine habitats has been addressed by Thrush and Dayton (2002), Roff et al. (2003), and Goodsell and Connell (2005) among others. These studies show that quantifying the natural spatial and temporal variability of disturbances affecting benthic marine ecosystems can be critical for managers and planners tasked with forecasting the effects of particular management practices such as marine protected areas. Understanding the natural variability of sea floor disturbance is also critical for local, State, and Federal agencies responsible for permitting offshore activities such as trawling, dredging, and the placement of sea-floor engineering structures (cables, pipelines, others) that disturb the sea floor.

The oceanographic processes that disturb the continental shelf and upper slope include the actions of surface waves, internal waves, and currents (tidal, density, wave-driven, wind-driven, and geostrophic). The North Pacific Ocean can generate extremely large surface waves, and the resulting near-bed wave orbital velocities on the continental shelf generally are much larger than velocities due to currents and internal waves (Sherwood et al., 1994; Storlazzi and Jaffe, 2002; Storlazzi et al., 2003). Although many studies have investigated the wave climate along central

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Spatial and temporal variability in oceanographic and meteorologic forcing along Central California and its implications

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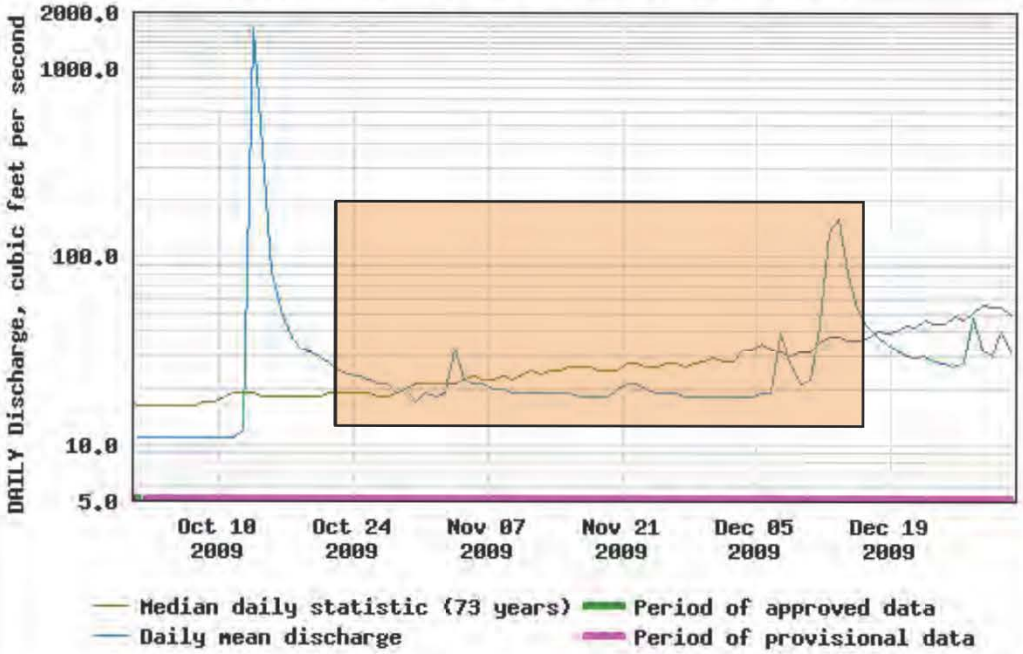

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The influence of El Niño-Southern Oscillation (ENSO) cycles on wave-driven sea-floor sediment mobility along the central California continental margin

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ABSTRACT

Ocean surface waves are the dominant temporally and spatially variable process influencing sea floor sediment resuspension along most continental shelves. Wave-induced sediment mobility on the continental shelf and upper continental slope off central California for different phases of El Niño-Southern Oscillation (ENSO) events was modeled using monthly statistics derived from more than 14 years of concurrent hourly oceanographic and meteorologic data as boundary input for the Delft SWAN wave model, gridded sea floor grain-size data from the usSEABED database, and regional bathymetry. Differences as small as 0.5 m in wave height, 1 s in wave period, and 10° in wave direction, in conjunction with the spatially heterogeneous unconsolidated sea-floor sedimentary cover, result in significant changes in the predicted mobility of continental shelf surficial sediment in the study area. El Niño events result in more frequent mobilization on the inner shelf in the summer and winter than during La Niña events and on the outer shelf and upper slope in the winter months, while La Niña events result in more frequent mobilization on the mid-shelf during spring and summer months than during El Niño events. The timing and patterns of seabed mobility are addressed in context of geologic and biologic processes. By understanding the spatial and temporal variability in the disturbance of the sea floor, scientists can better interpret sedimentary patterns and ecosystem structure, while providing managers and planners an understanding of natural impacts when considering the permitting of offshore activities that disturb the sea floor such as trawling, dredging, and the emplacement of sea-floor engineering structures.

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1. Introduction

While discussions of marine biodiversity frequently focus on hard bottom ecosystems such as coral reefs, kelp forests, and the rocky intertidal (Thrush and Dayton, 2002), more than 70% of the earth's seafloor is composed of unconsolidated sediment (Snelgrove, 1999). Although this type of habitat may not appear to be as highly structured as some hard bottom marine habitats, unconsolidated sediments can support very high species diversity (Coleman et al., 1997; Snelgrove, 1999). Ecologists have long recognized that the structure and function of benthic marine ecosystems are closely linked to oceanographic processes (Mann, 1973; Graham et al., 1997); most studies, however, have relied either upon qualitative descriptions of oceanographic factors (e.g., "low", "medium", or "high" energy environments) or on quantitative values based on mean oceanographic conditions (e.g., tidal range or wave heights). Recently, the importance of intermittent disturbance on marine habitats has been addressed by Thrush and Dayton (2002), Roff et al. (2003), and Goodsell and Connell (2005) among others. These studies show that quantifying the natural spatial and temporal variability of disturbances affecting benthic marine ecosystems can be critical for managers and planners tasked with forecasting the effects of particular management practices such as marine protected areas. Understanding the natural variability of sea floor disturbance is also critical for local, State, and Federal agencies responsible for permitting offshore activities such as trawling, dredging, and the placement of sea-floor engineering structures (cables, pipelines, others) that disturb the sea floor.

The oceanographic processes that disturb the continental shelf and upper slope include the actions of surface waves, internal waves, and currents (tidal, density, wave-driven, wind-driven, and geostrophic). The North Pacific Ocean can generate extremely large surface waves, and the resulting near-bed wave orbital velocities on the continental shelf generally are much larger than velocities due to currents and internal waves (Sherwood et al., 1994; Storlazzi and Jaffe, 2002; Storlazzi et al., 2003). Although many studies have investigated the wave climate along central

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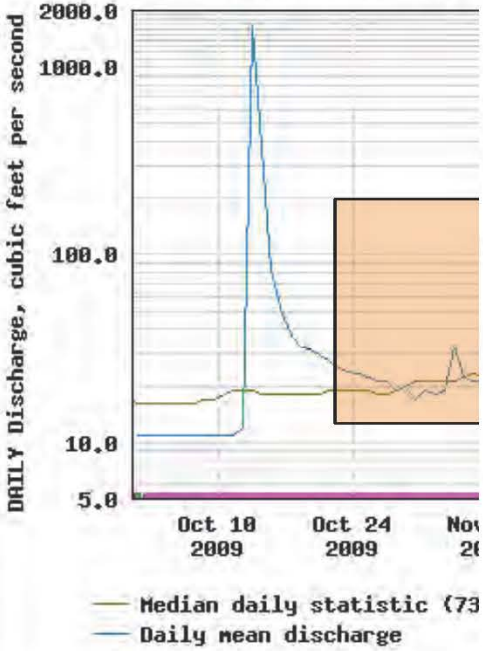

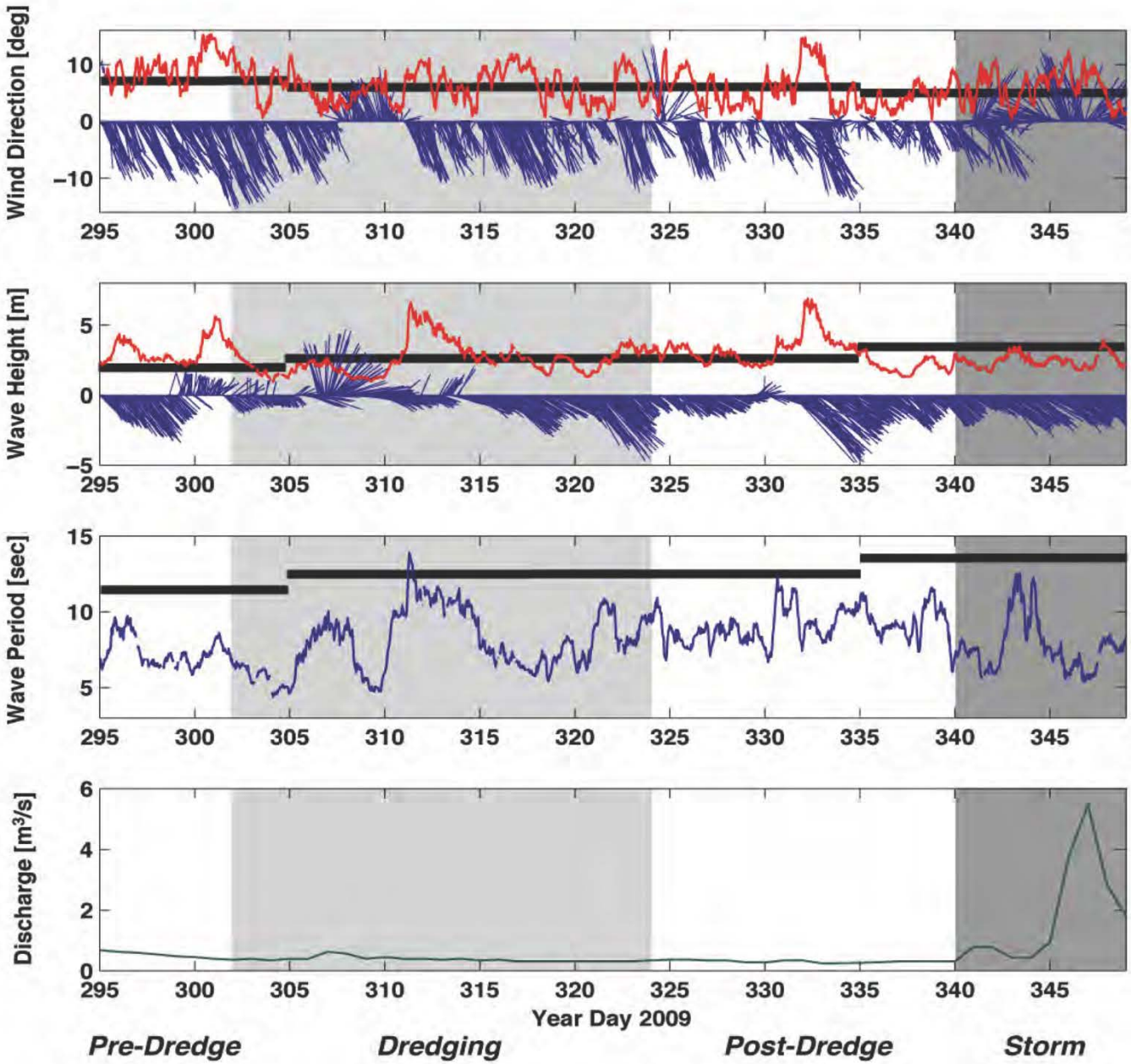

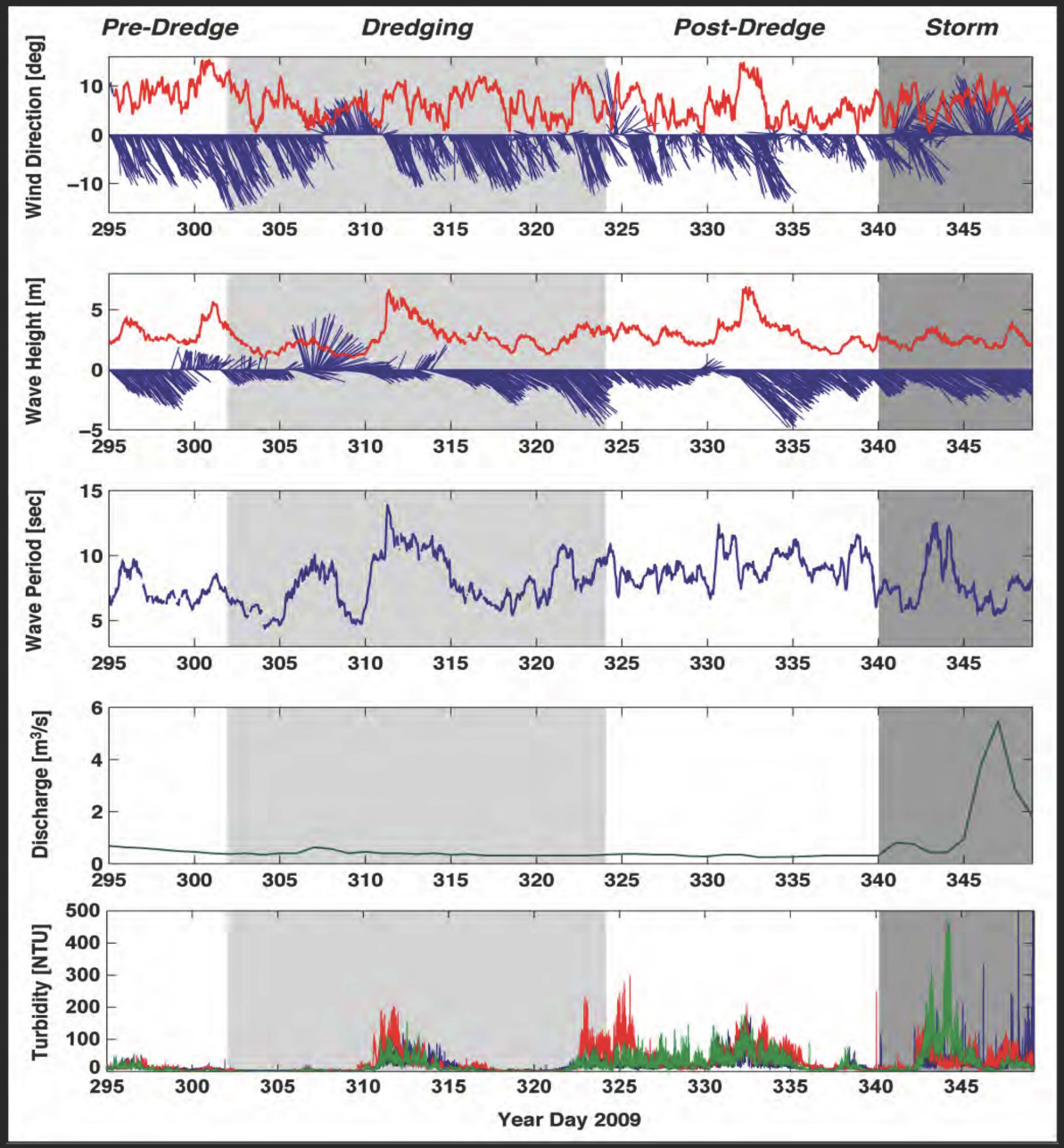
Pre-Dredge
Dredging
Post-Dredge
Storm
Wind Direction [deg]
Wave Height [m]
Wave Period [sec]
Discharge [m³/s]
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Year Day 2009

Implications of Findings to Dredge Disposal Projects

In situ **measurements to calibrate and validate numerical sediment transport models , in conjunction with meteorologic and oceanographic climatologies, can provide insight into the suitability of fine-grained dredge disposal for other locations.**

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