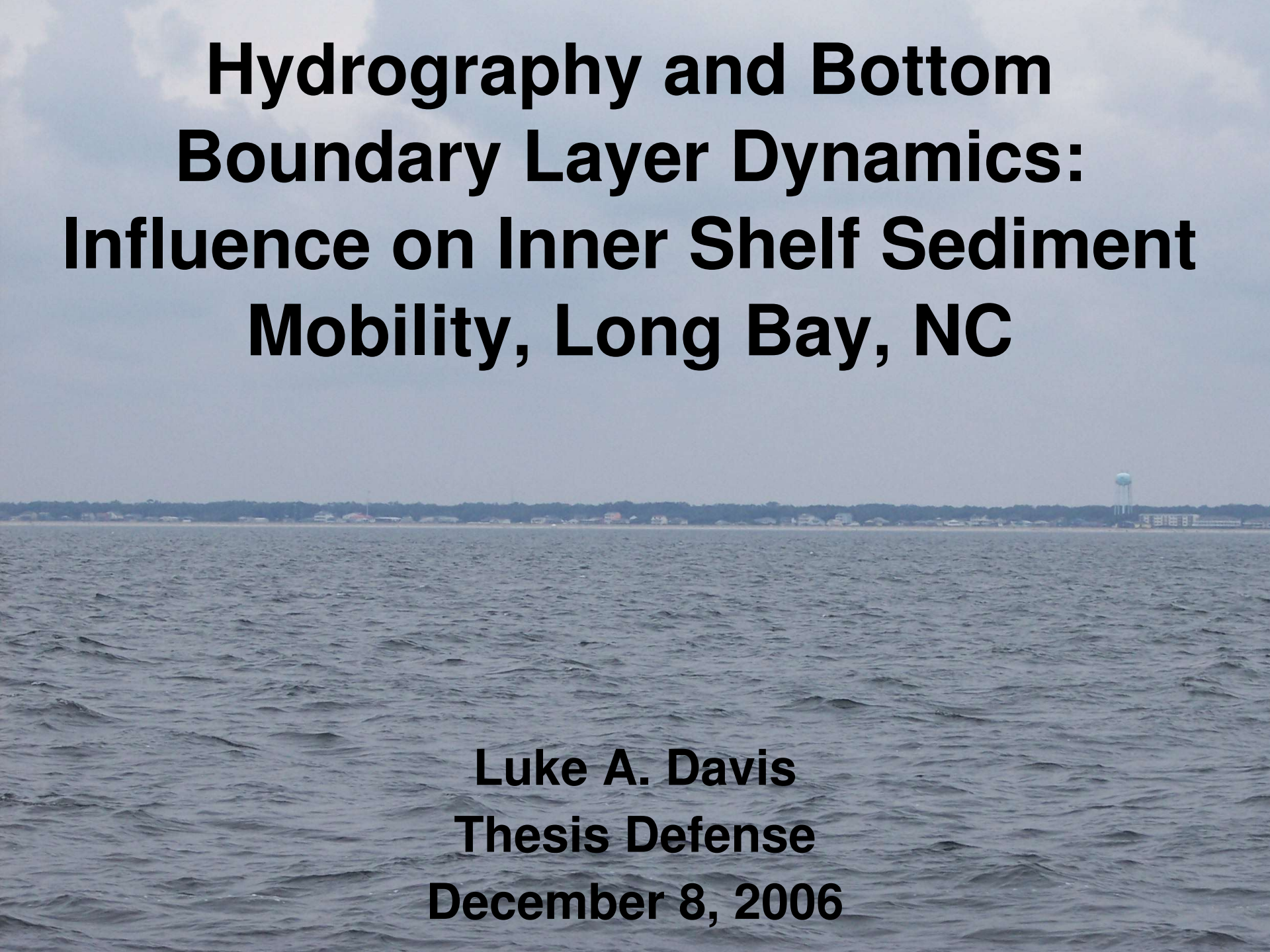
Hydrography and Bottom Boundary Layer Dynamics: Influence on Inner Shelf Sediment Mobility, Long Bay, NC



Luke A. Davis

Thesis Defense

December 8, 2006

Background

- The NC shelf is ‘sediment-starved’ from limited sediment inputs
- The region is frequently affected by storms
- Storms cause shoreline erosion, creating a demand for quality renourishment sand
- So, understanding physical processes that mobilize sediment during storms is critical

Study Rationale

- Several studies on storm processes for the NC shelf, but these occurred in Onslow Bay
- No study has linked physical process to sediment transport in northern Long Bay
- Data critical to developing:
  - improved models for predicting sediment transport
  - management strategies for offshore sand resources and commercial fisheries

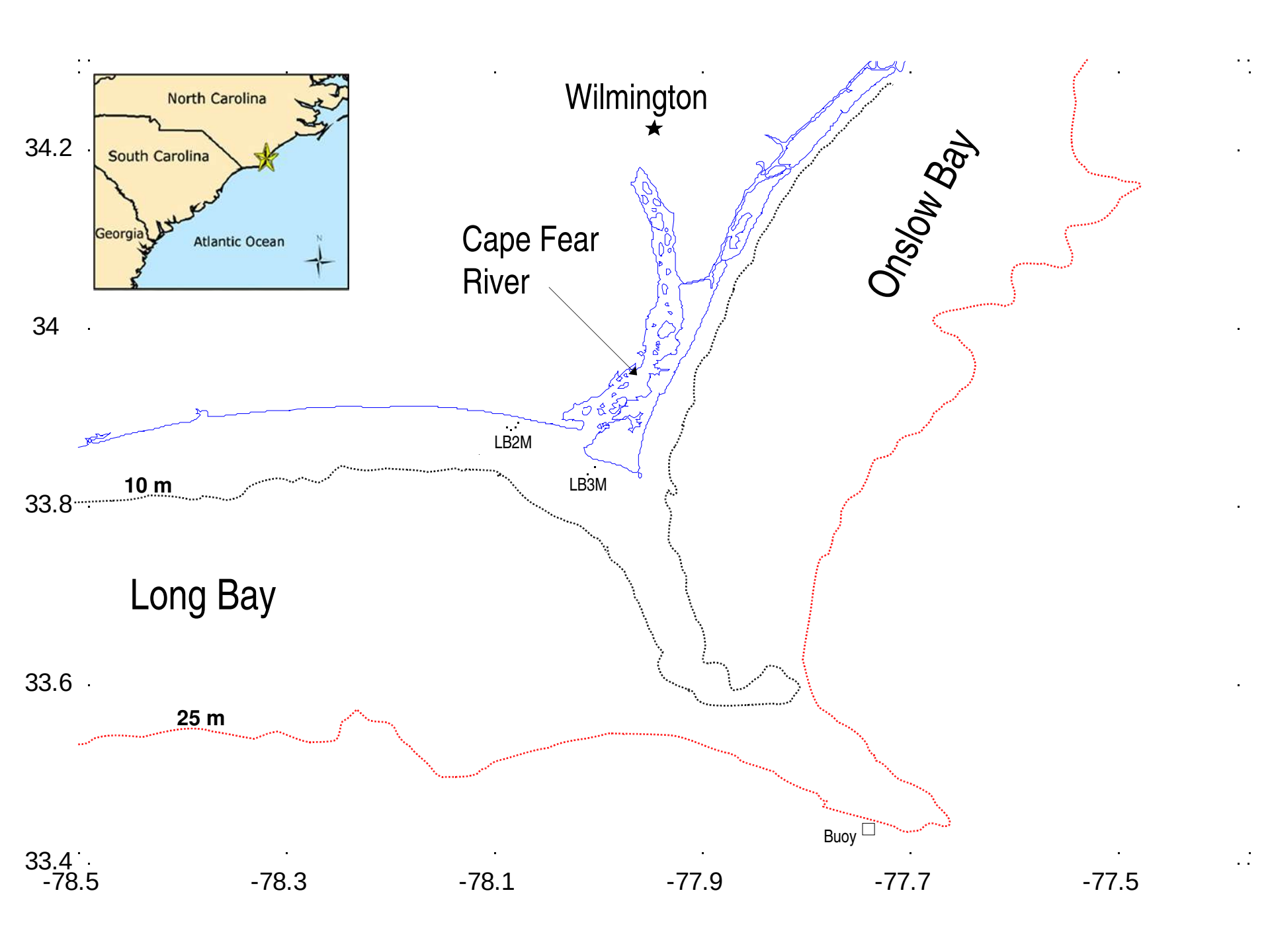
Goal

To identify and describe the physical mechanisms and bottom boundary layer dynamics during two coastal storms that mobilized sediment on the inner shelf of Long Bay, NC

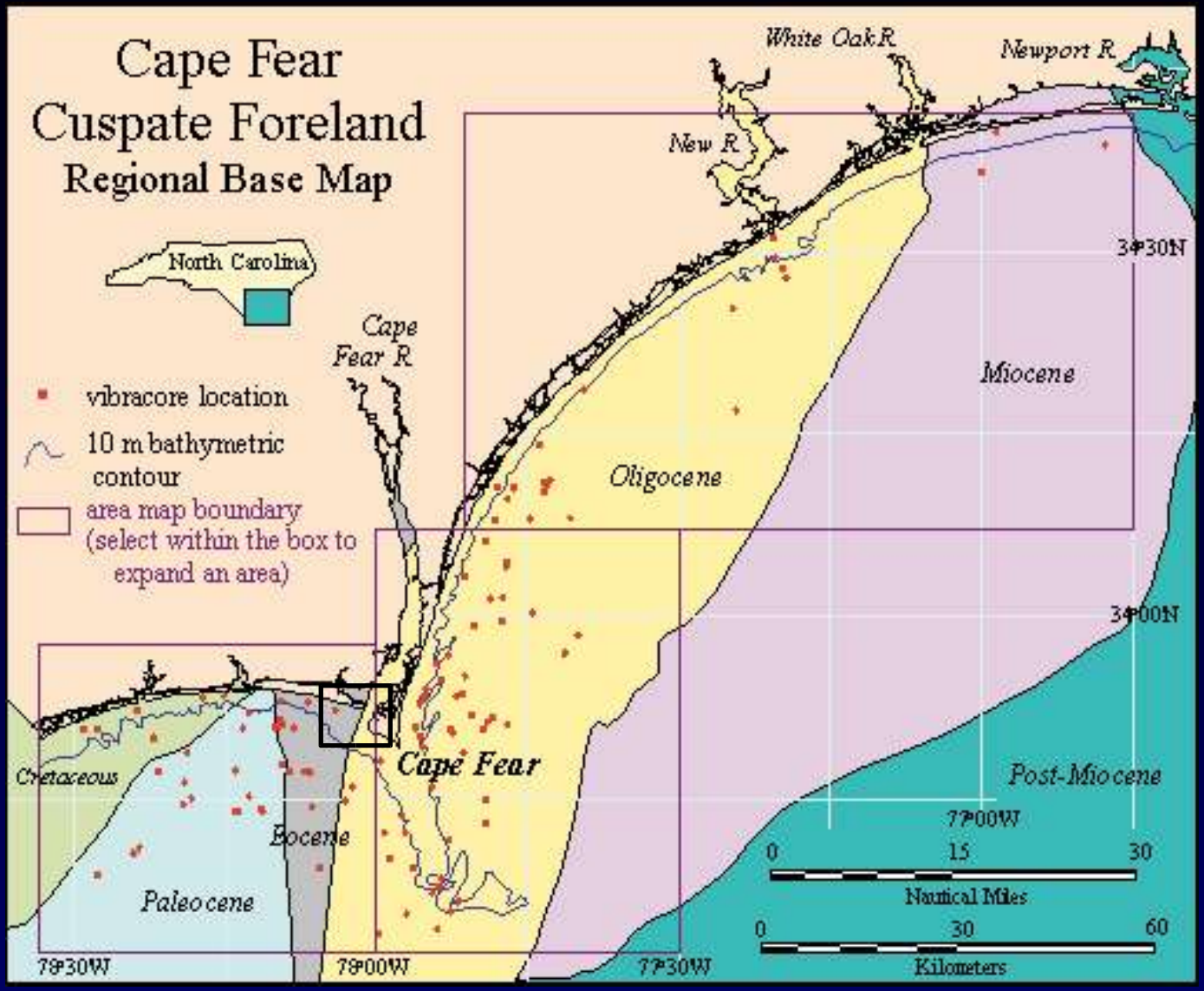
Objectives

- To compare the spatial and temporal variability of the hydrography and sediment response in Long Bay during the autumn of 2005

- To apply a bottom boundary layer model to quantify nearshore conditions and sediment mobility associated with the passage of 2 different storm types.

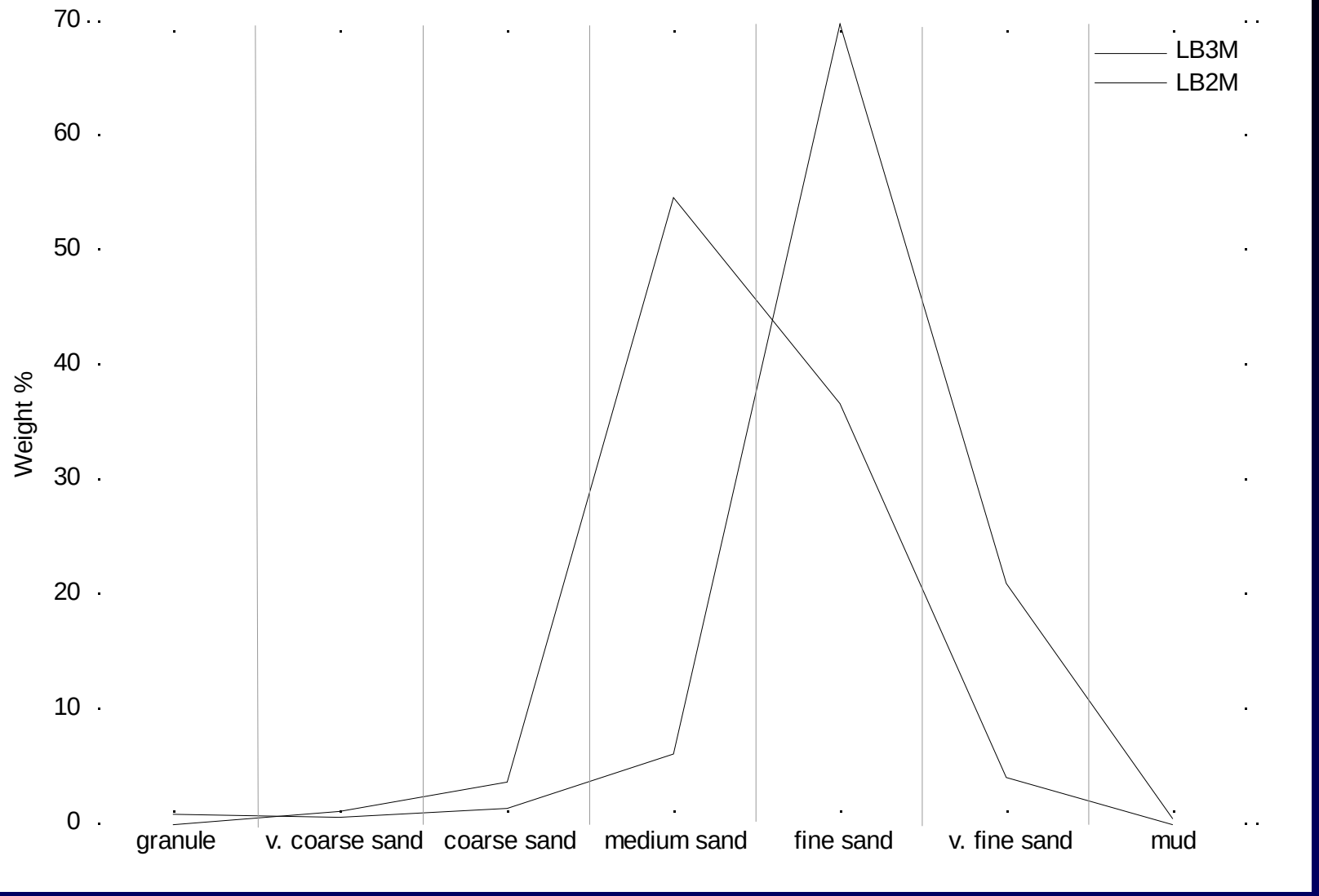

North Carolina
South Carolina
Georgia
Atlantic Ocean
Wilmington
Cape Fear
River
Onslow Bay
LB2M
LB3M
10 m
25 m
Long Bay
Buoy
34.2
34
33.8
33.6
33.4
-78.5
-78.3
-78.1
-77.9
-77.7
-77.5

Offshore Geology



Modified from Hoffman, et al., 1999

Sediments


70
60
50
40
30
20
10
0
Weight %
LB3M
LB2M
granule
v. coarse sand
coarse sand
medium sand
fine sand
v. fine sand
mud

Instrumentation

2 Acoustic Doppler Current Profilers

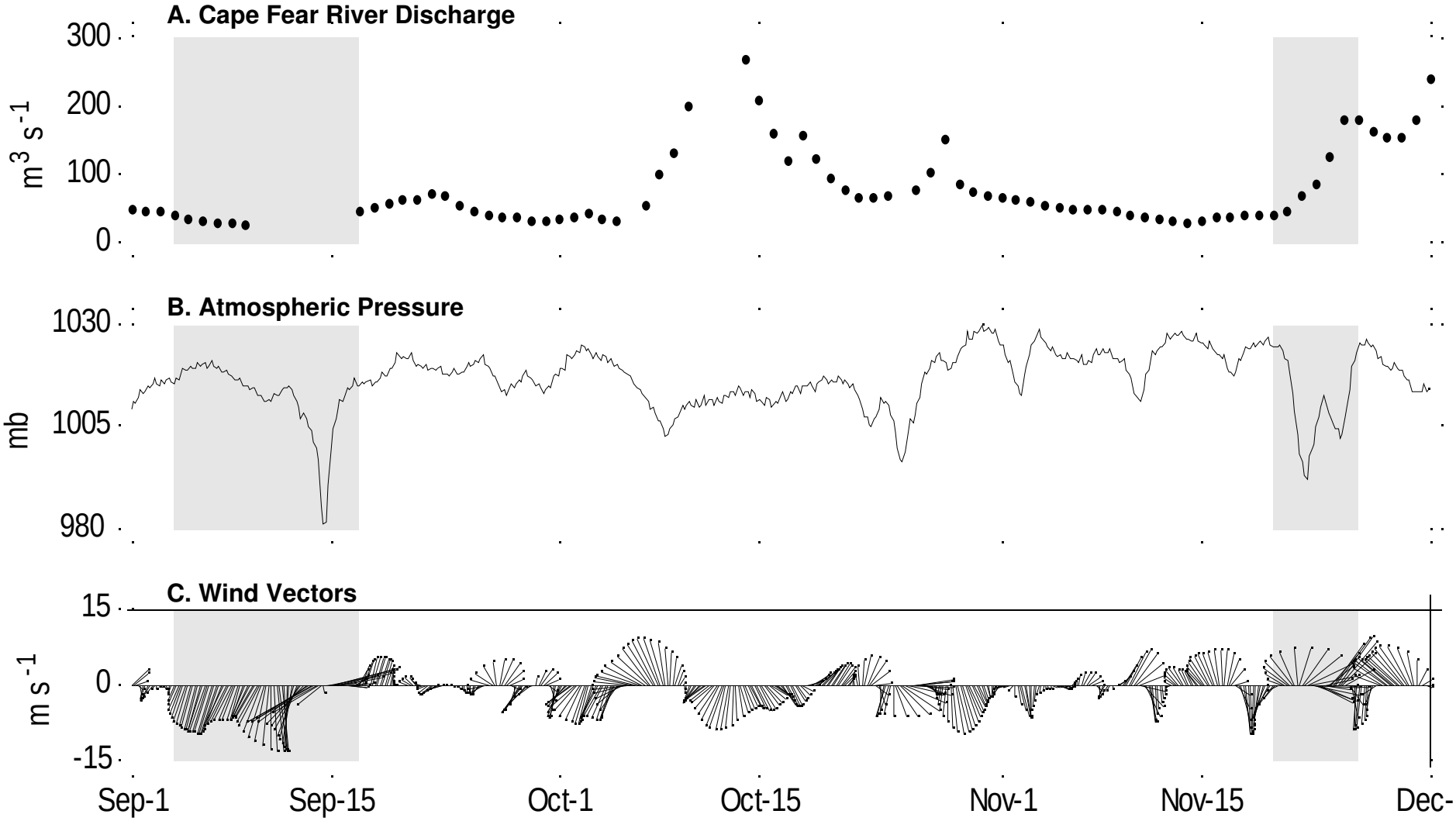
NDBC Buoy 41013

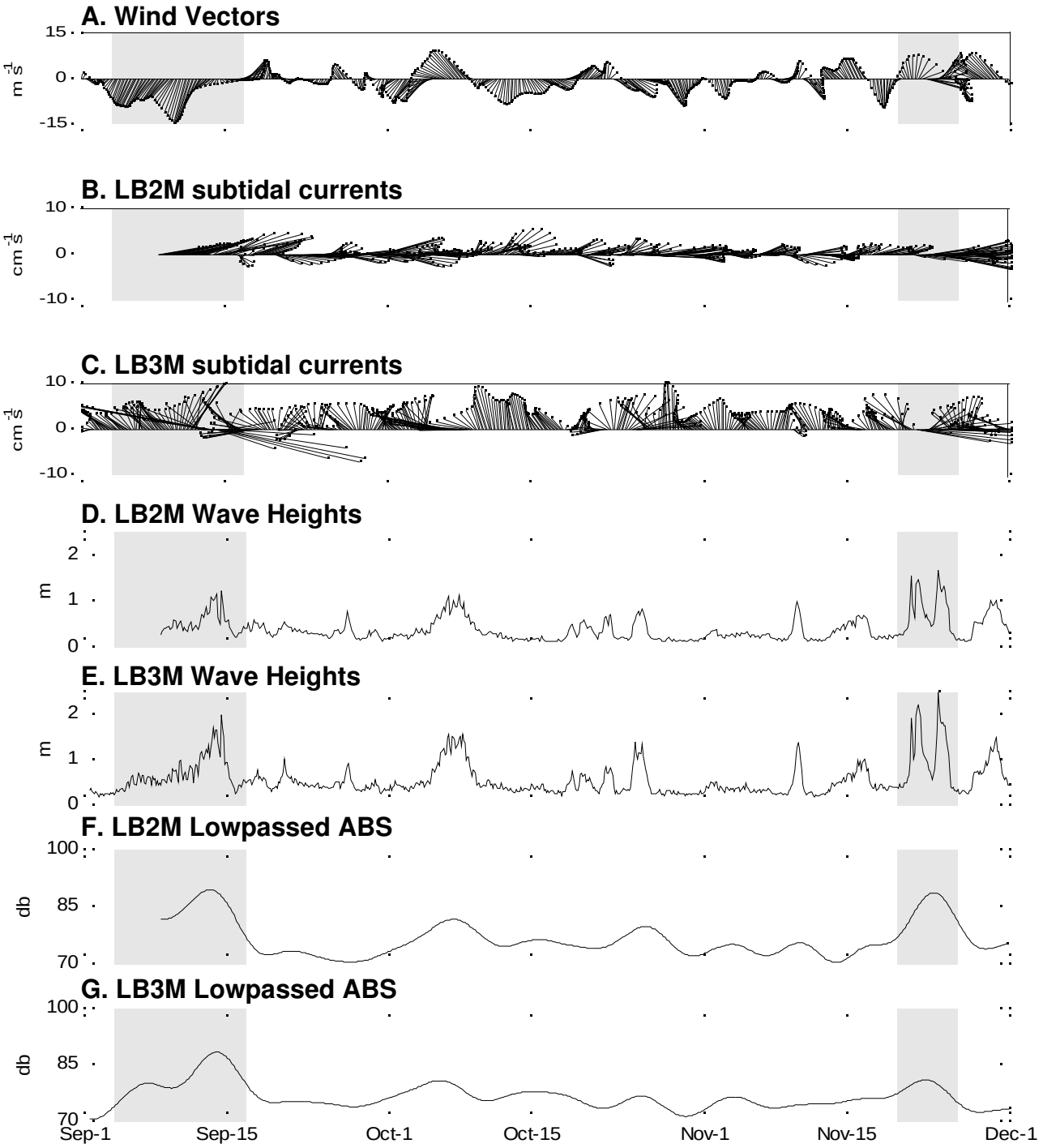
Data Analysis

- Data were used to create time series plots in MATLAB to describe autumn hydrography

- Generate time series of bottom boundary layer parameters and profiles using a bottom boundary layer model during 2 events

Part 1: Autumn Hydrography



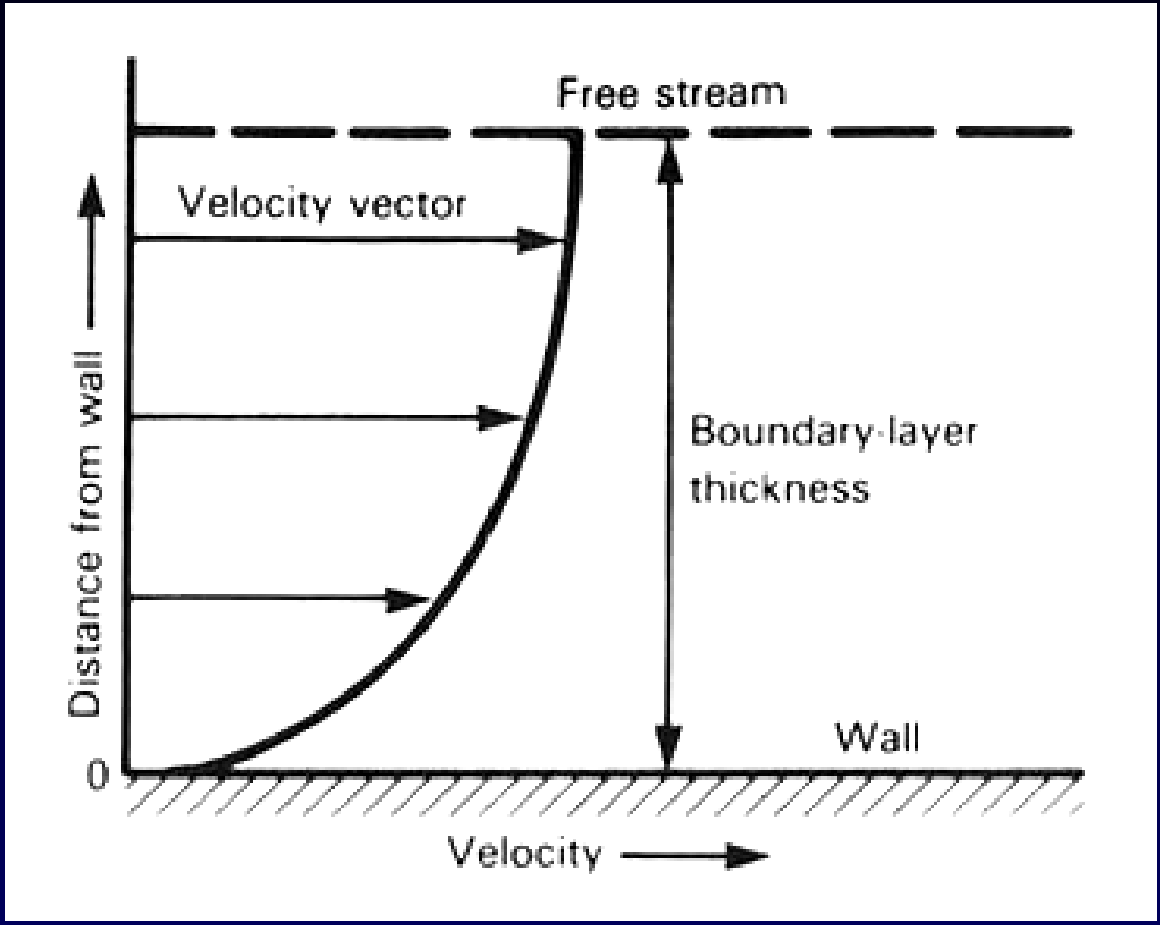

A. Wind Vectors
m s-1
15
0
-15
B. LB2M subtidal currents
cm s-1
10
0
-10
C. LB3M subtidal currents
cm s-1
10
0
-10
D. LB2M Wave Heights
m
2
1
0
E. LB3M Wave Heights
m
2
1
0
F. LB2M Lowpassed ABS
db
100
85
70
G. LB3M Lowpassed ABS
db
100
85
70
Sep-1
Sep-15
Oct-1
Oct-15
Nov-1
Nov-15
Dec-1

+ On / E
- Off / W

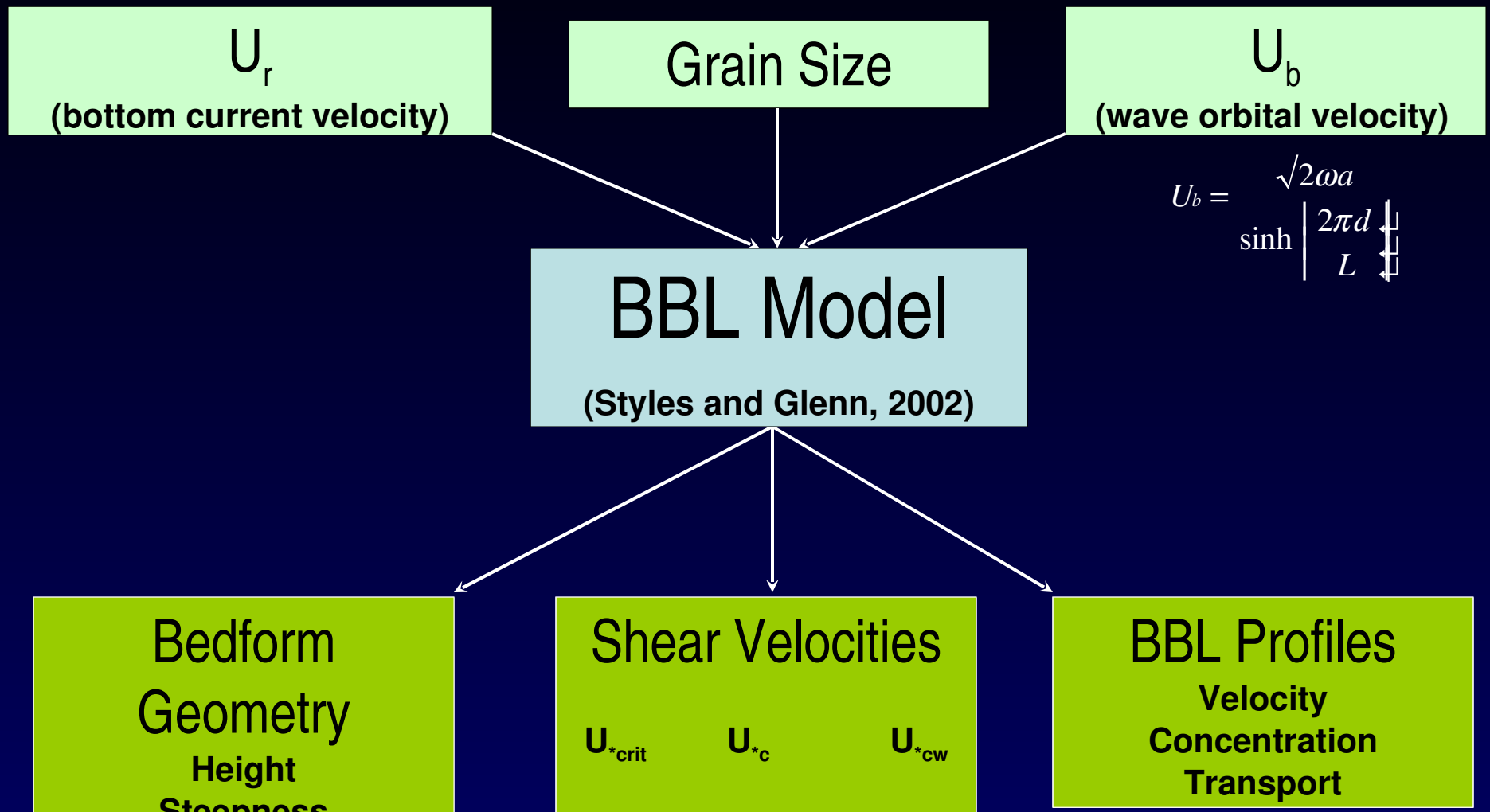
Summary

- Wind velocity, current magnitudes, wave heights, and ABS increased during events
- Current magnitude and wave height at LB3M exceeded those at LB2M
- During storms, current direction shifts to a more along-shelf direction

The Bottom Boundary Layer



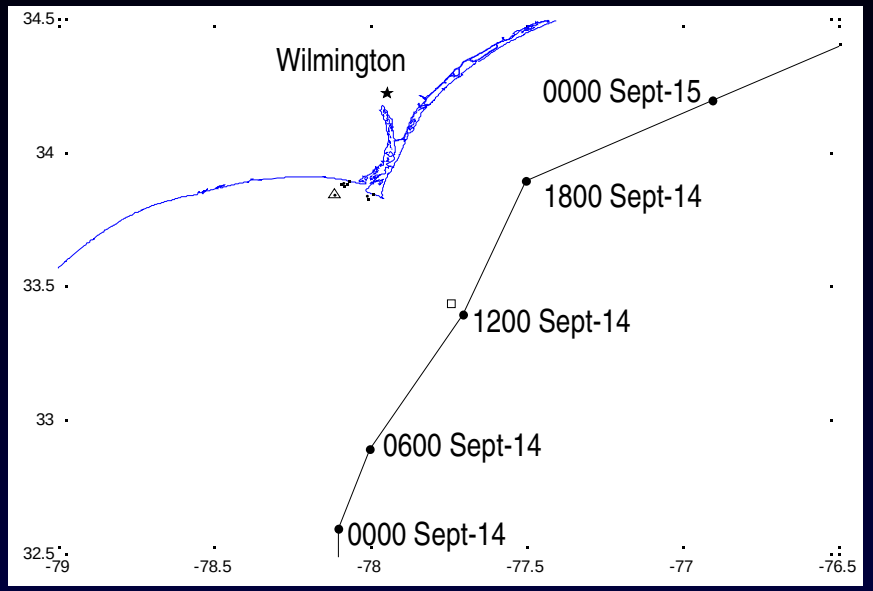
Bottom Boundary Layer Model

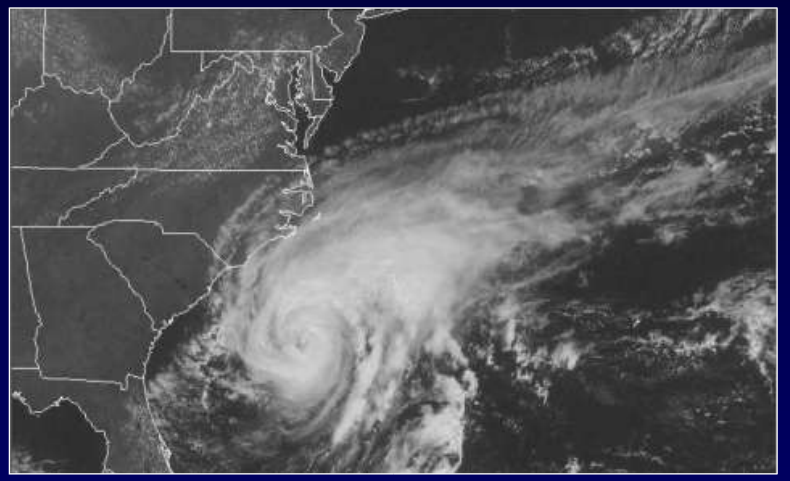


Transport= Velocity x Conc.

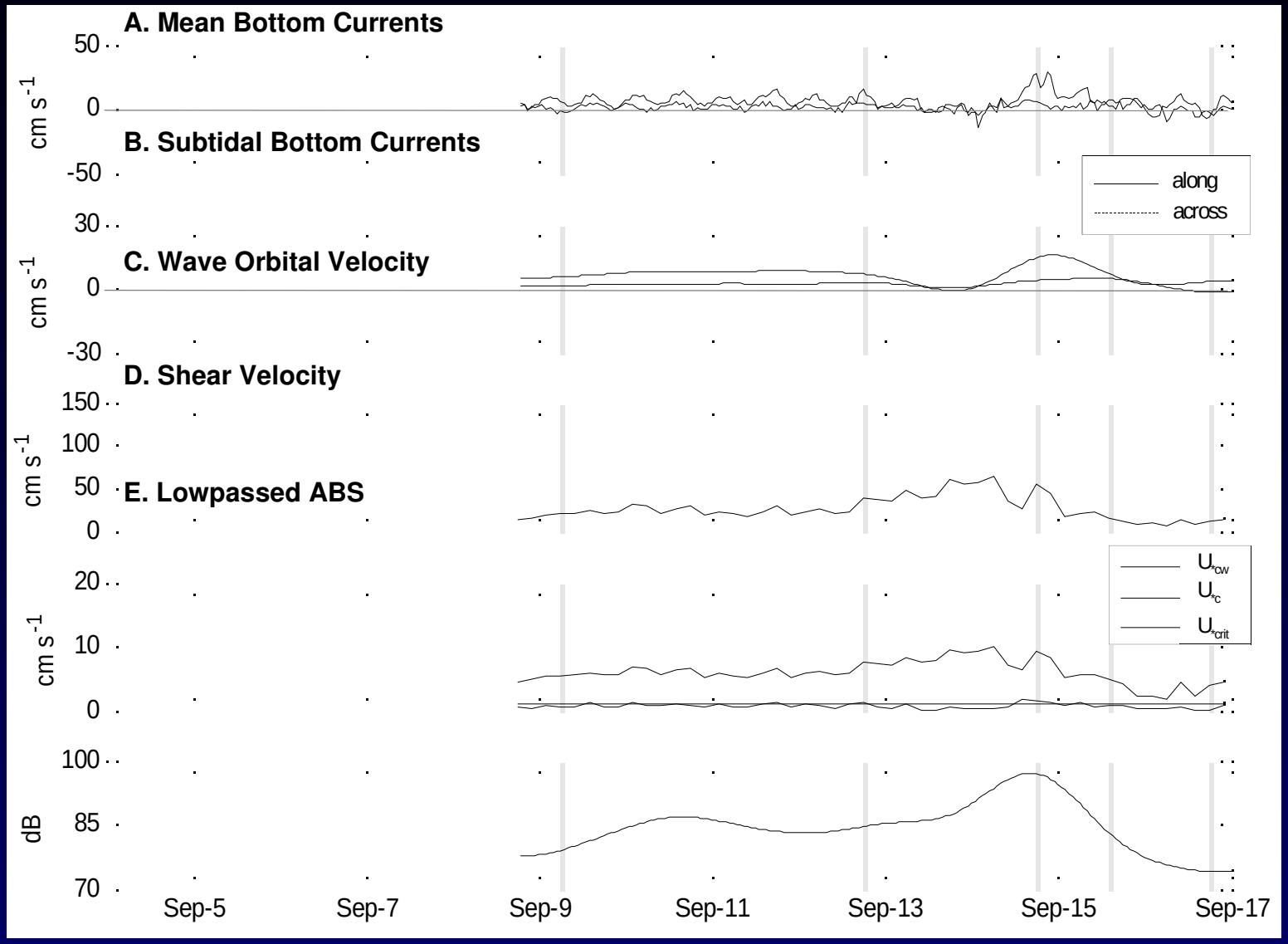
Event Descriptions

- Ophelia
  - Category 1 Hurricane
  - 8th Hurricane in 2005
- November Event
  - 2 autumn frontal systems
  - Class 1 Storm

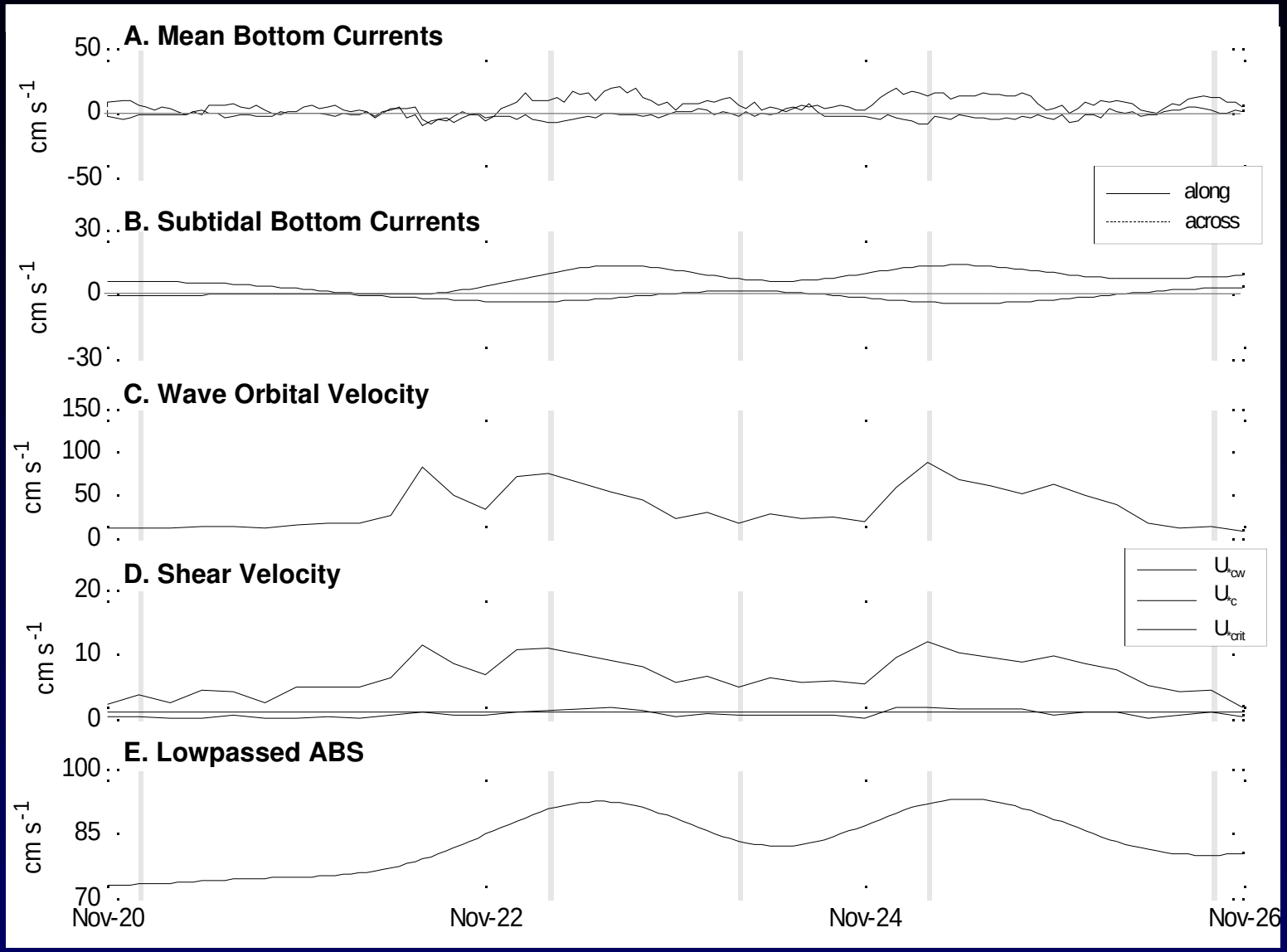


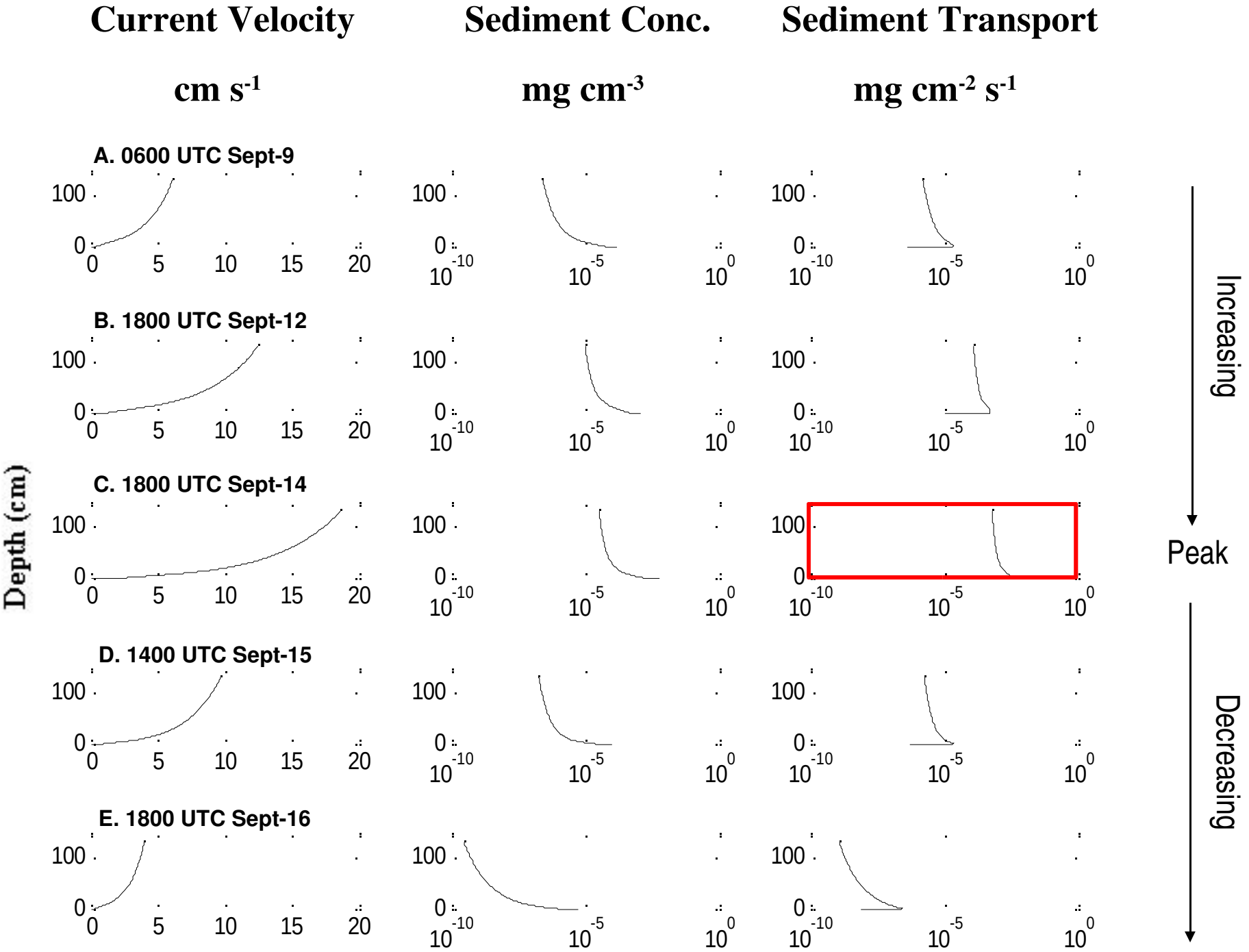


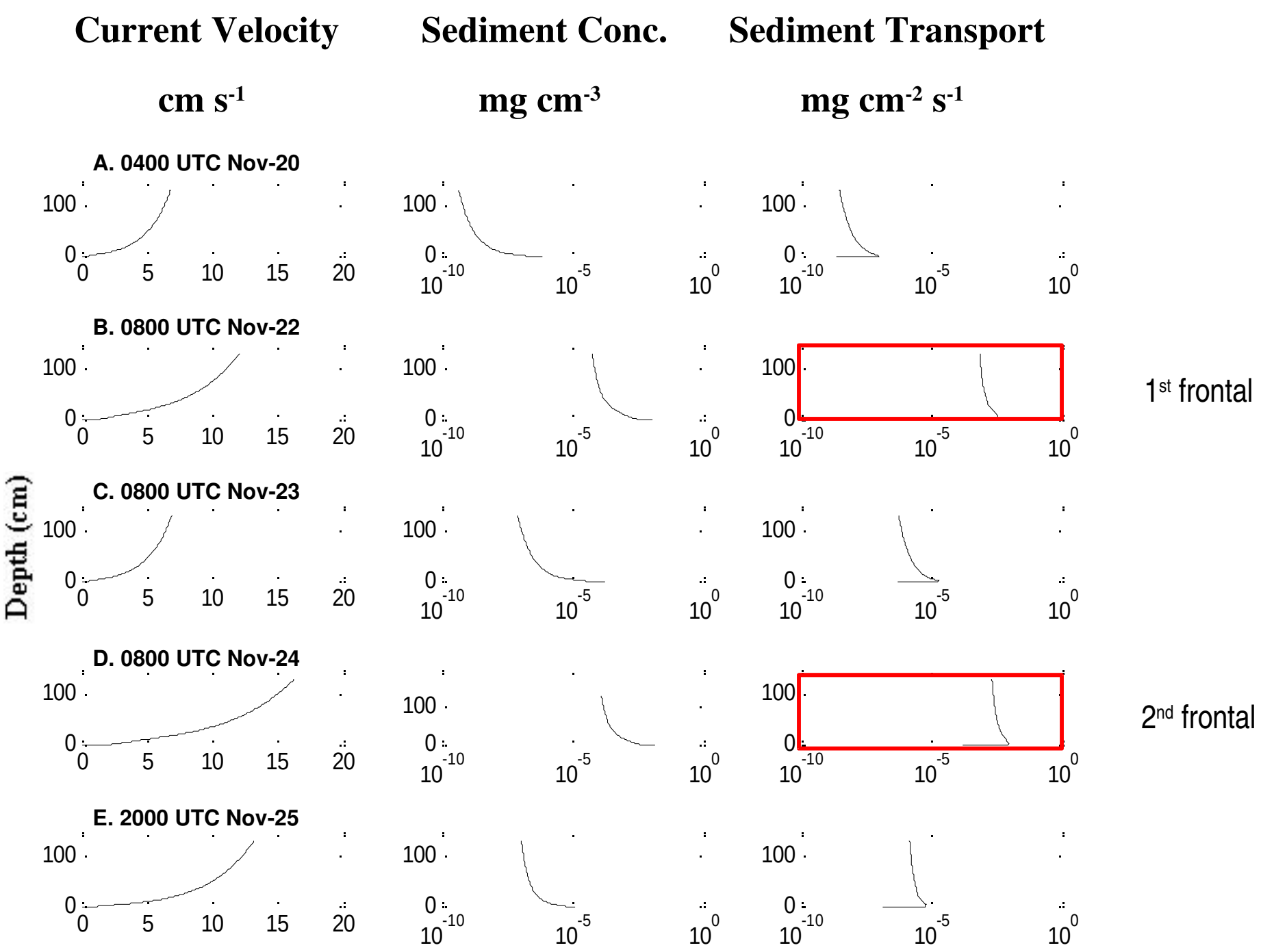
LB2M: Hurricane Ophelia



LB2M: November Event



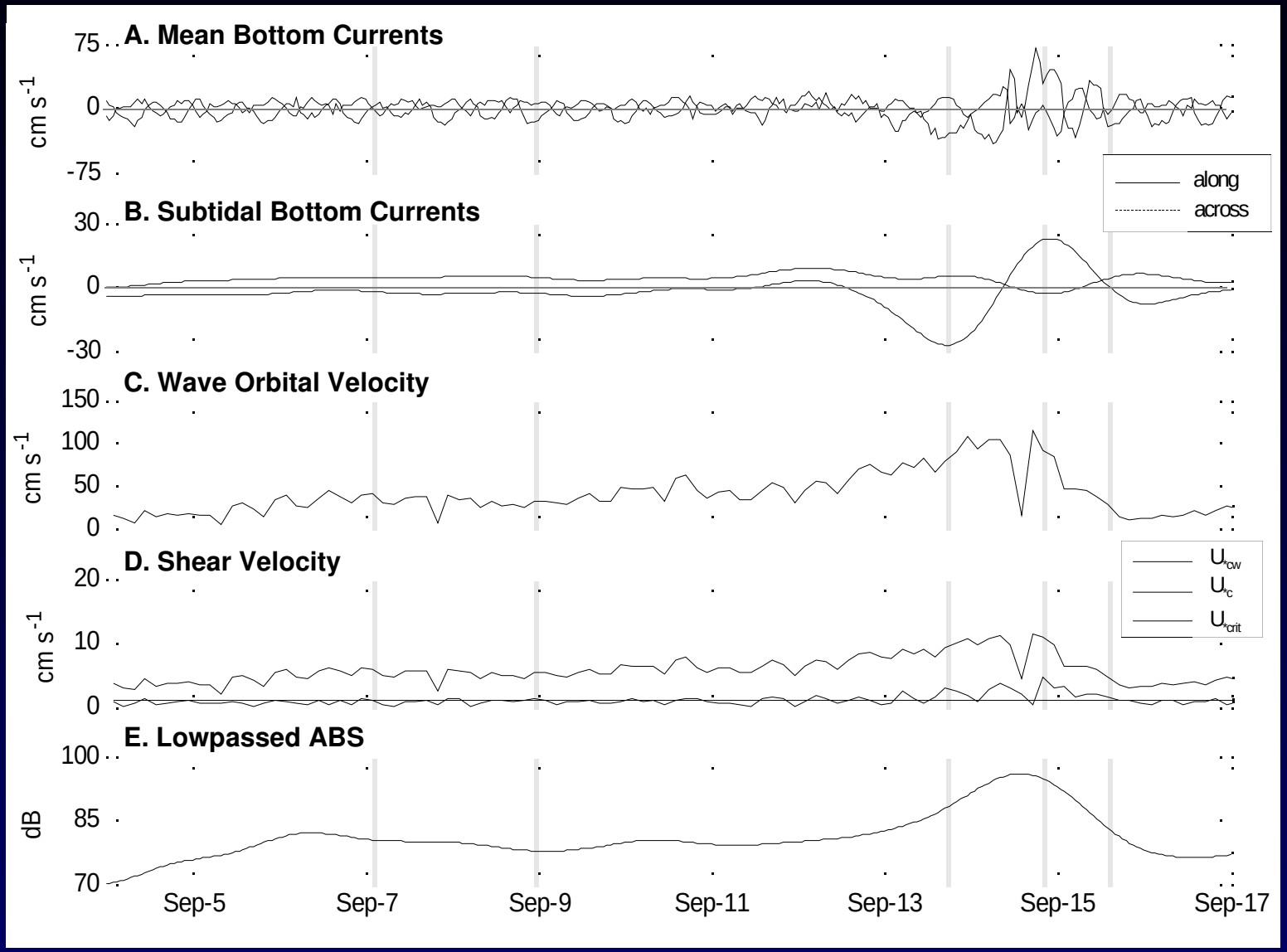

Current Velocity
cm s-1
Sediment Conc.
mg cm-3
Sediment Transport
mg cm-2 s-1
A. 0600 UTC Sept-9
B. 1800 UTC Sept-12
C. 1800 UTC Sept-14
D. 1400 UTC Sept-15
E. 1800 UTC Sept-16
Depth (cm)
100
0
0
5
10
15
20
10-10
10-5
100
Increasing
Peak
Decreasing


Current Velocity
cm s-1
Sediment Conc.
mg cm-3
Sediment Transport
mg cm-2 s-1
A. 0400 UTC Nov-20
B. 0800 UTC Nov-22
C. 0800 UTC Nov-23
D. 0800 UTC Nov-24
E. 2000 UTC Nov-25
Depth (cm)
1st frontal
2nd frontal

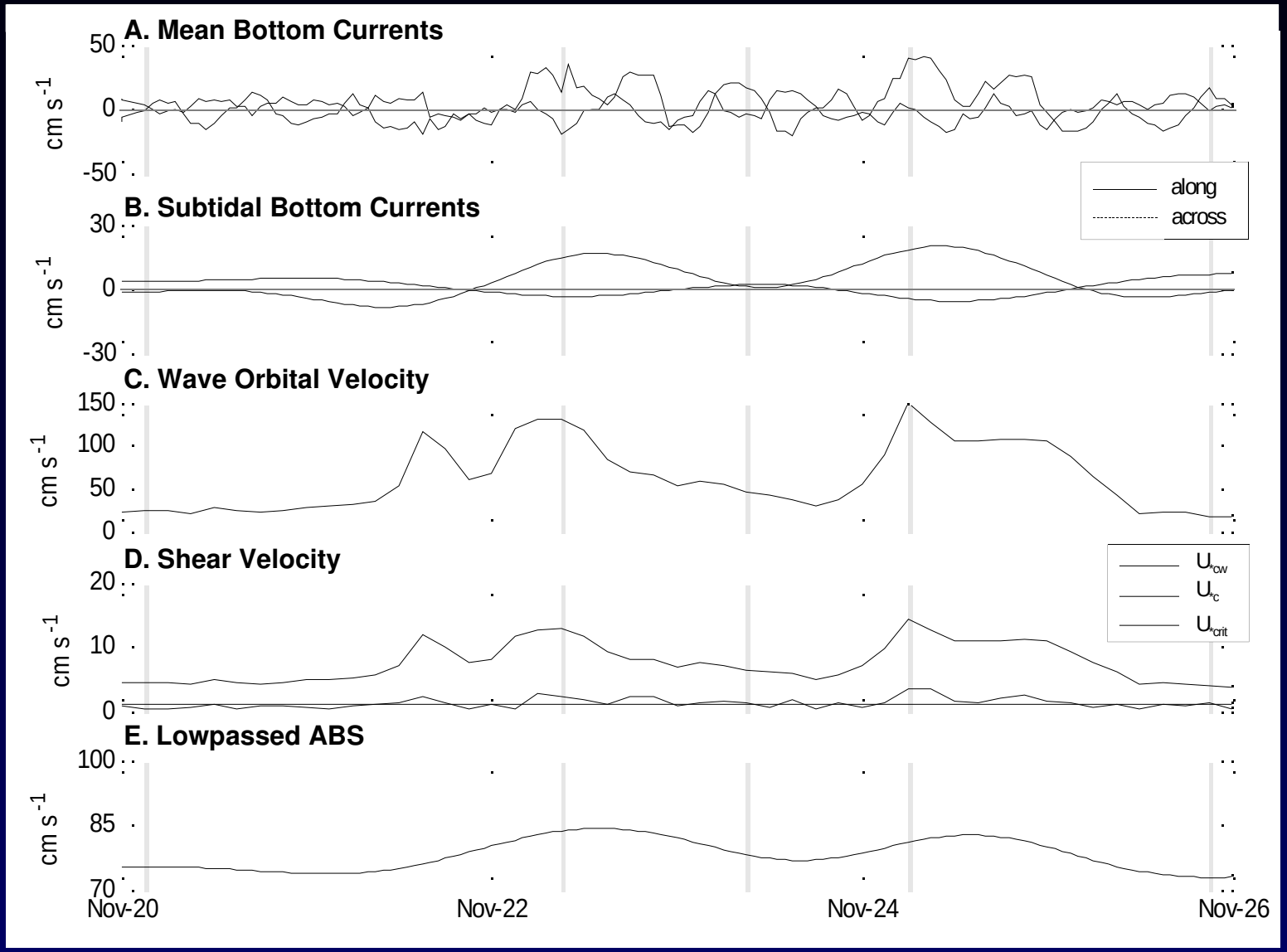
Effect of storm type at LB2M

- Along-shelf currents exceeded across-shelf currents for both events
- Along-shelf currents were directed eastward during both events
- ABS increased with U_b and U_{*cw}
- Transport in the bbl during the peak of theNovember event was 2-4 times greater than Hurricane Ophelia

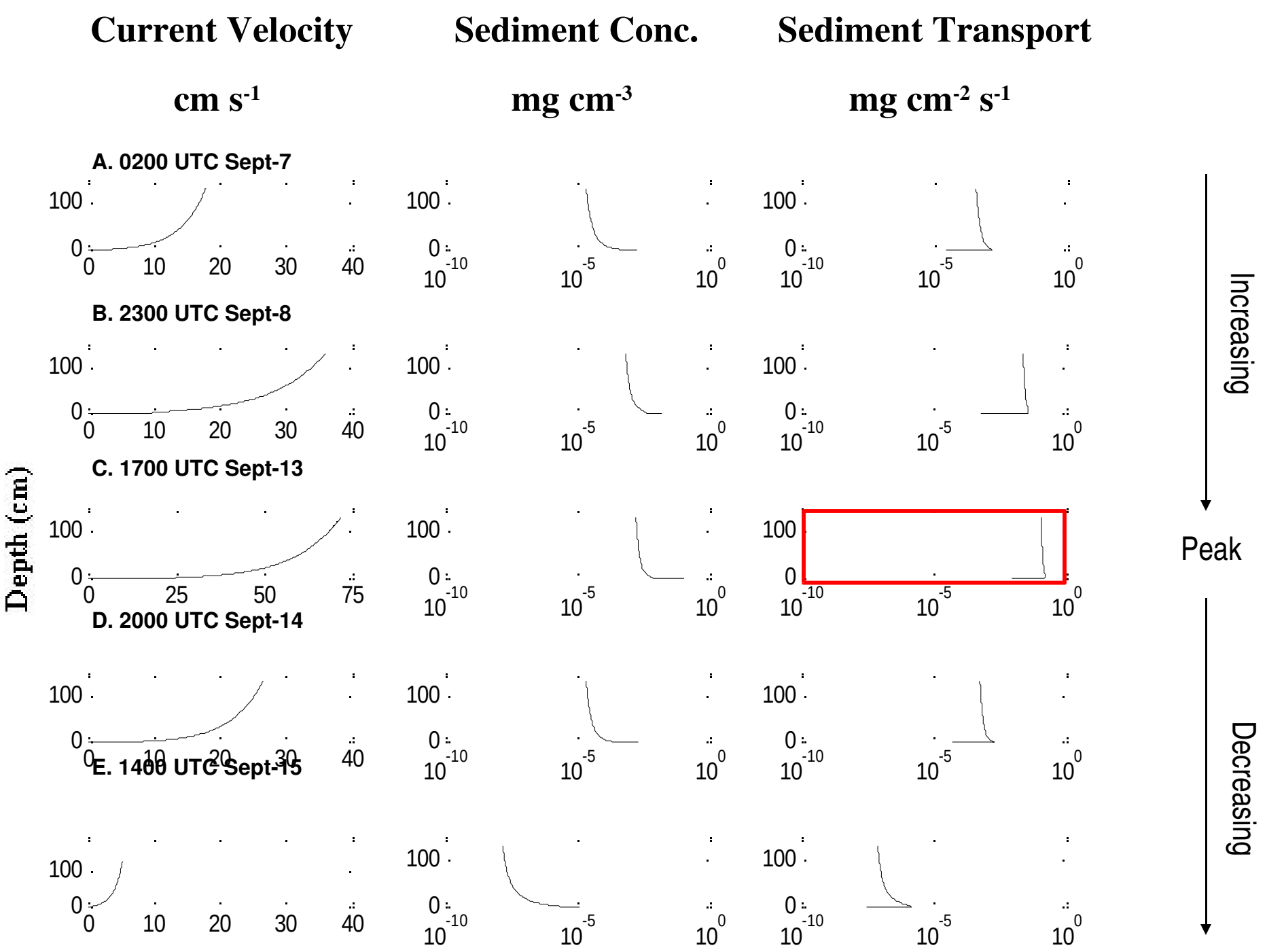
LB3M: Hurricane Ophelia

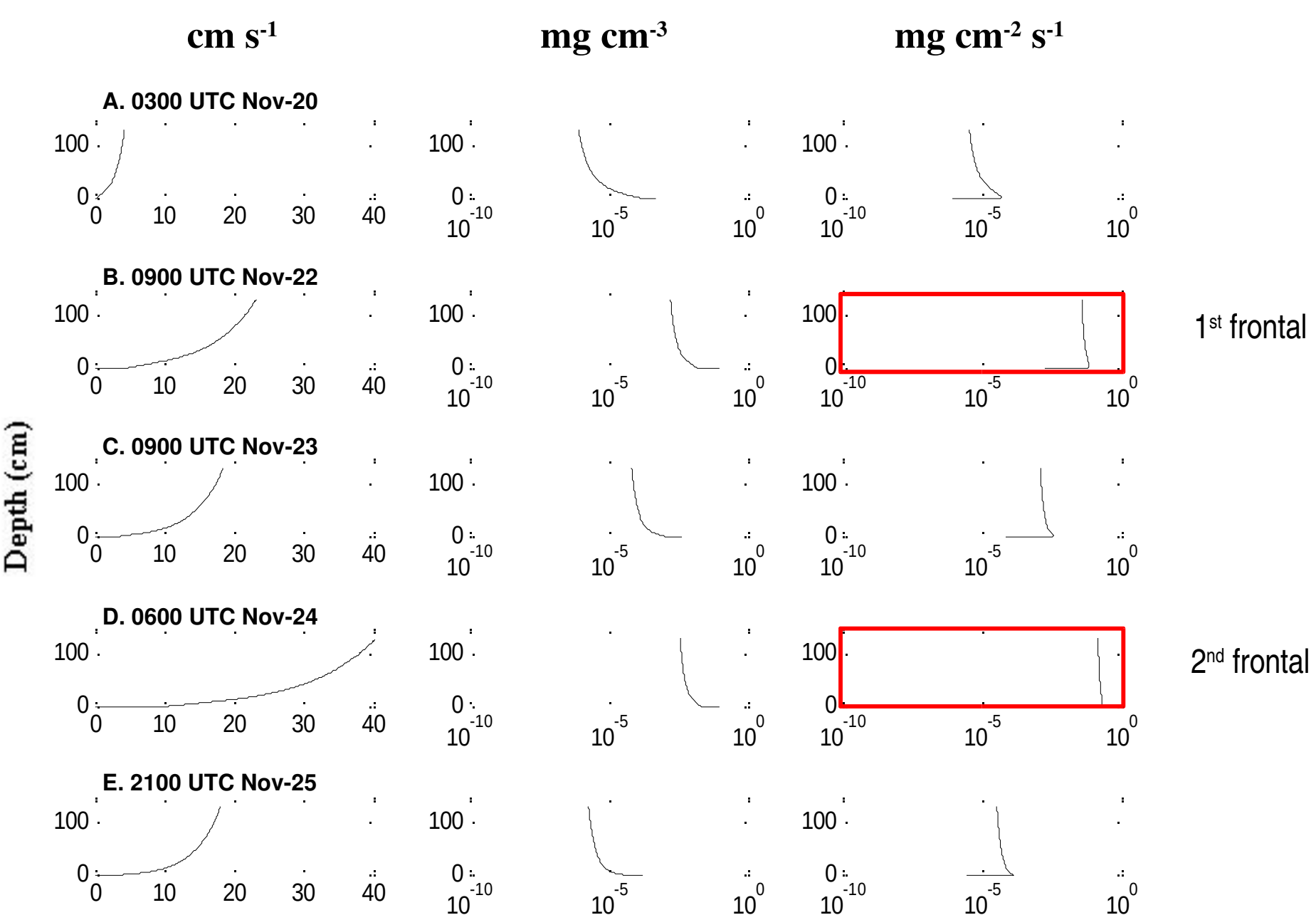


LB3M: November Event



+ On / E
- Off / W


Current Velocity
cm s-1
Sediment Conc.
mg cm-3
Sediment Transport
mg cm-2 s-1
A. 0200 UTC Sept-7
B. 2300 UTC Sept-8
C. 1700 UTC Sept-13
D. 2000 UTC Sept-14
E. 1400 UTC Sept-15
Depth (cm)
Increasing
Peak
Decreasing

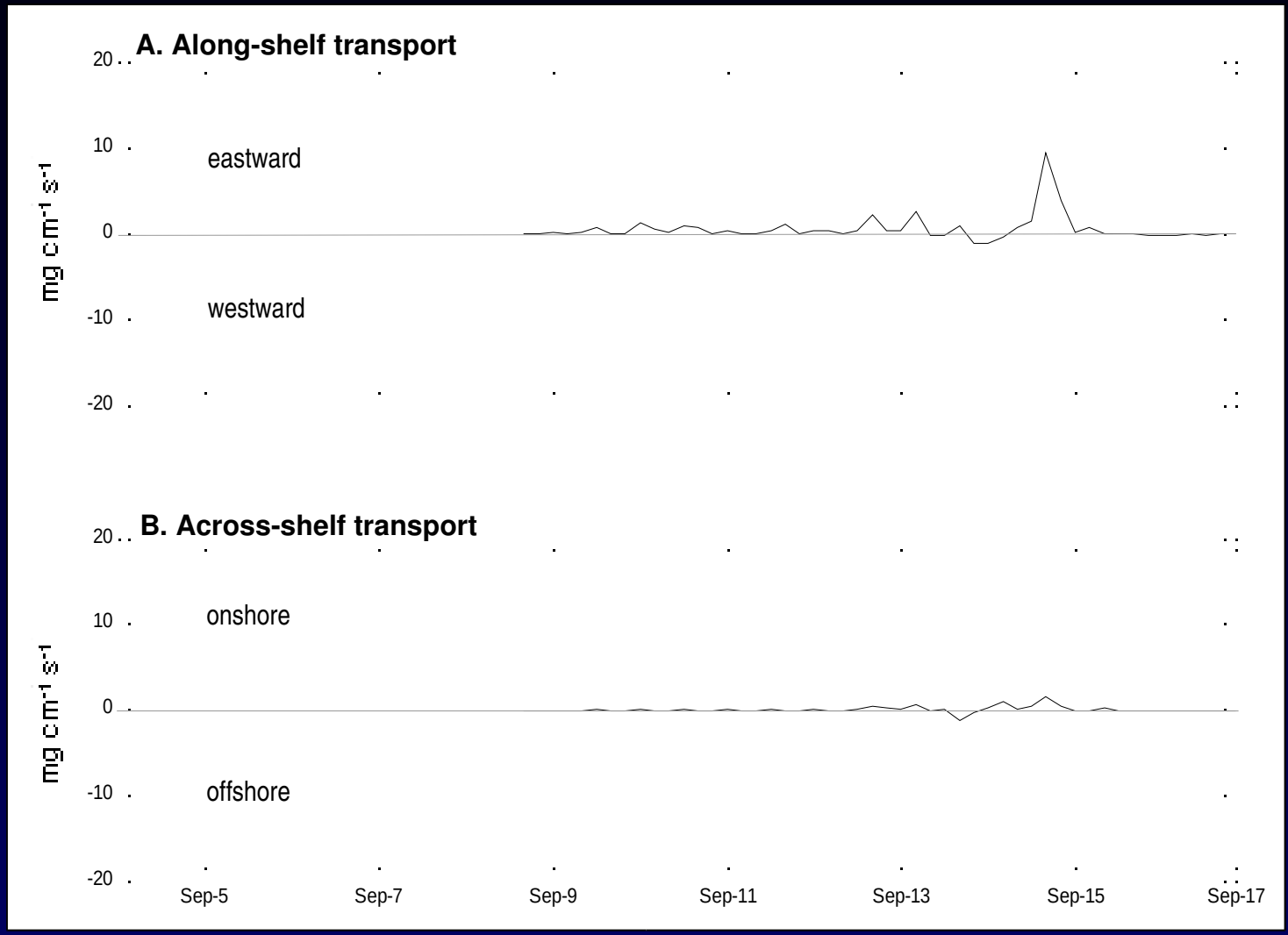

Current Velocity
cm s-1
Sediment Conc.
mg cm-3
Sediment Transport
mg cm-2 s-1
A. 0300 UTC Nov-20
B. 0900 UTC Nov-22
C. 0900 UTC Nov-23
D. 0600 UTC Nov-24
E. 2100 UTC Nov-25
Depth (cm)
1st frontal
2nd frontal

Effect of storm type at LB3M

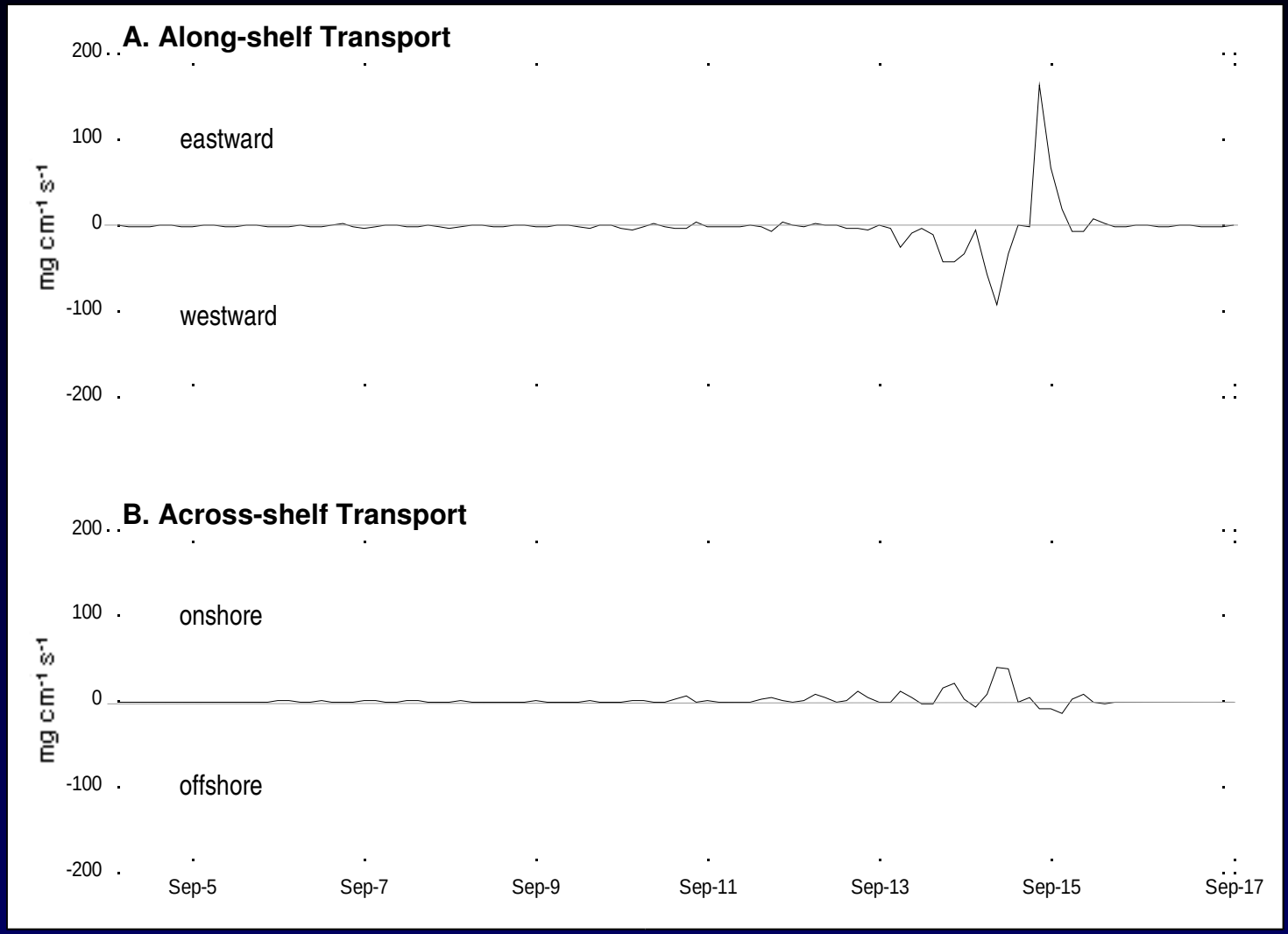
- Along-shelf currents exceeded across-shelf currents for both events
- Along-shelf currents were directed in opposite directions during each event
- ABS increased with U_b and U_{*cw}
- Transport in the bbl during the peak of the November event was 1.5 times greater than Hurricane Ophelia

How did sediment transport vary spatially in response to storms?

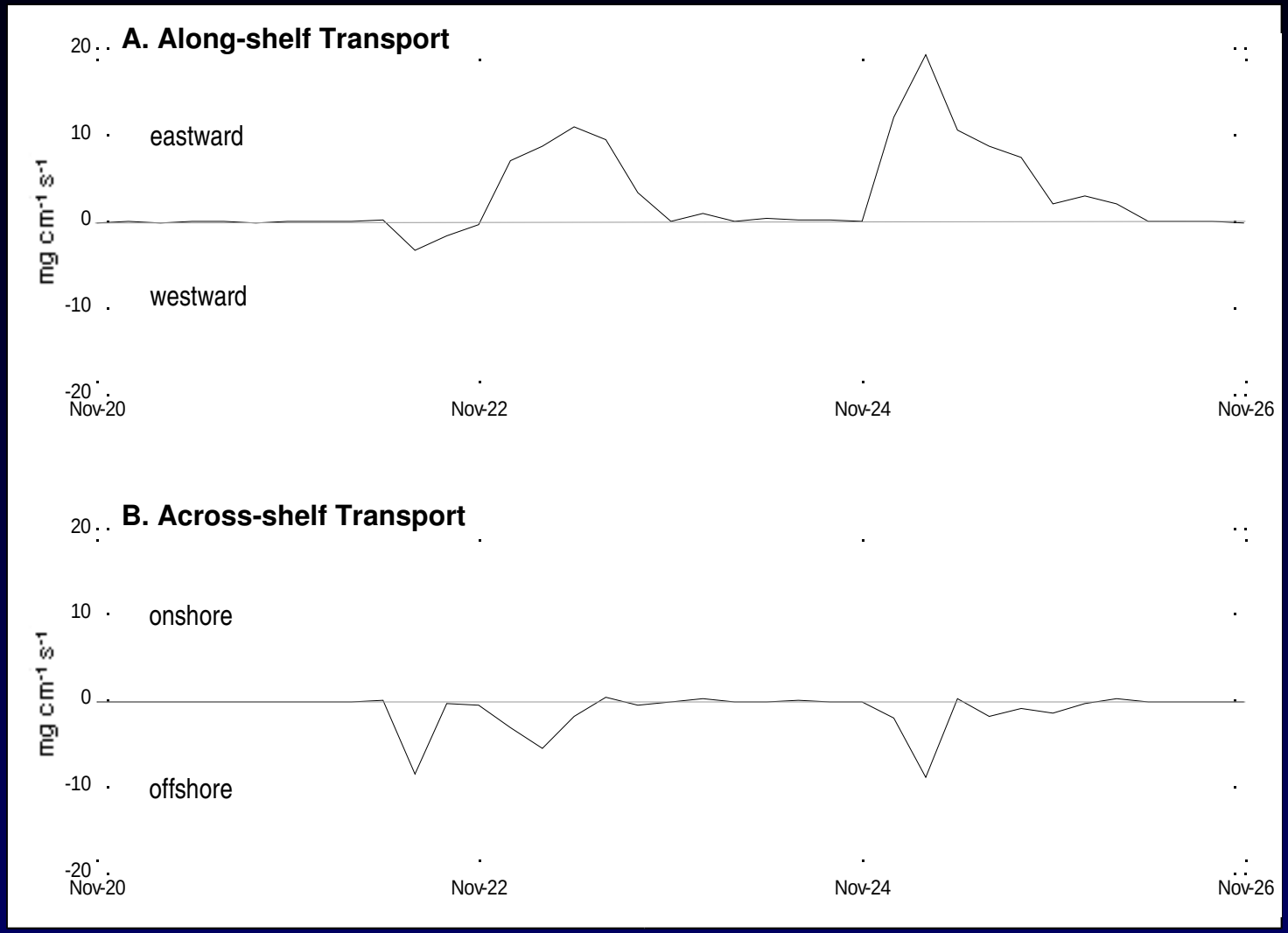
LB2M: Hurricane Ophelia



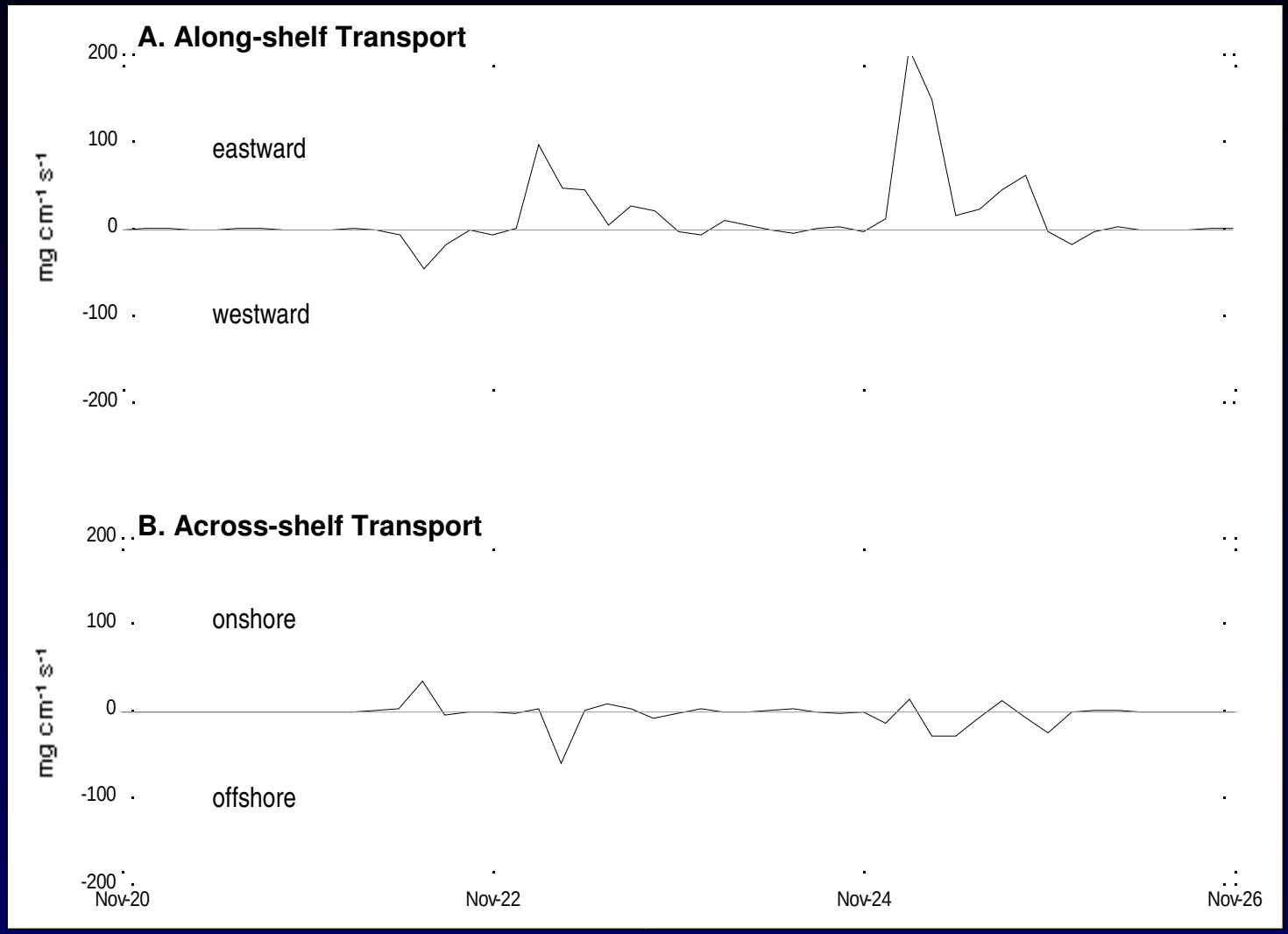
LB3M: Hurricane Ophelia



LB2M: November Event



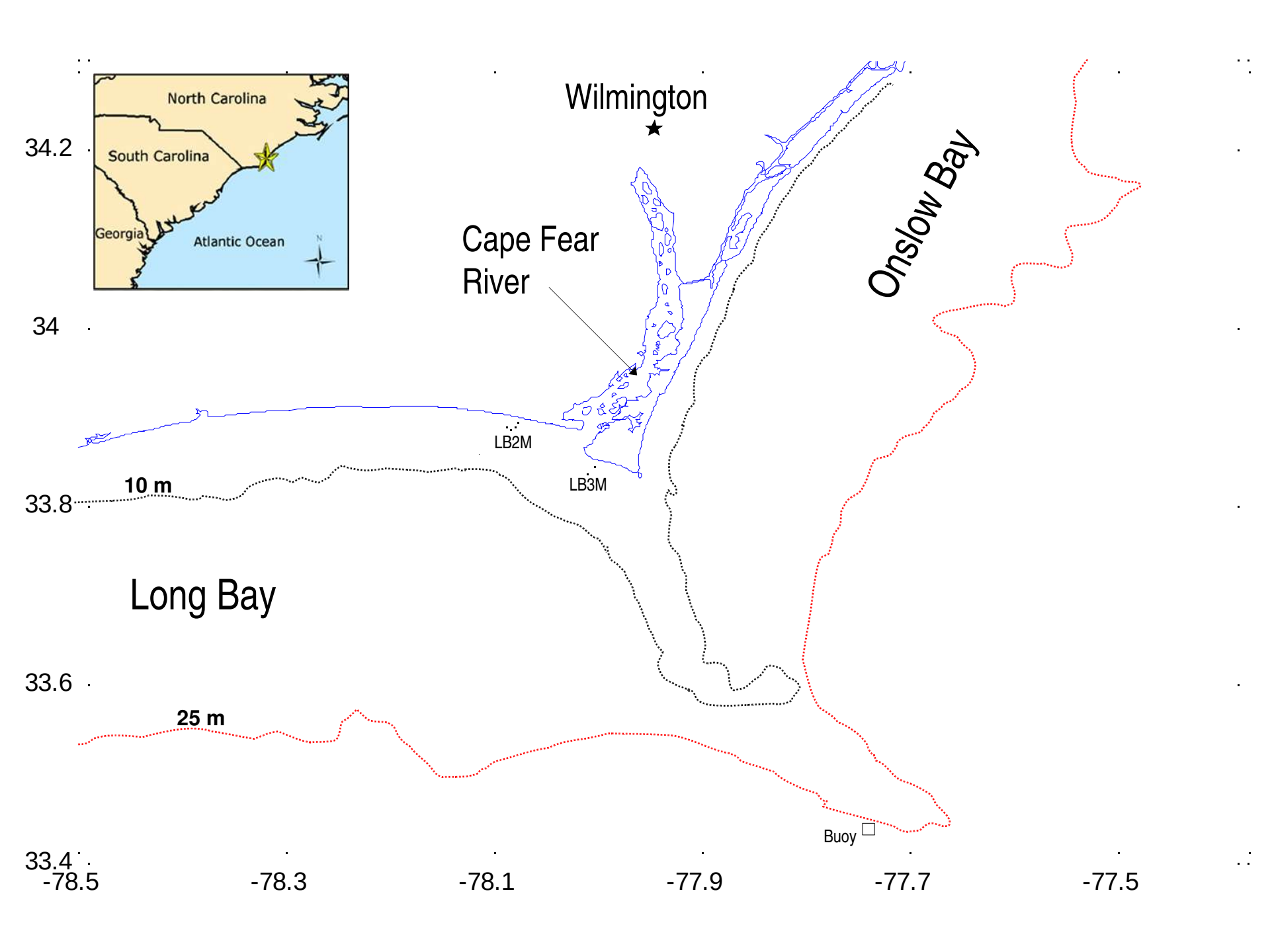
LB3M: November Event



Implications

- Key factors in influencing sediment response to storm passage:

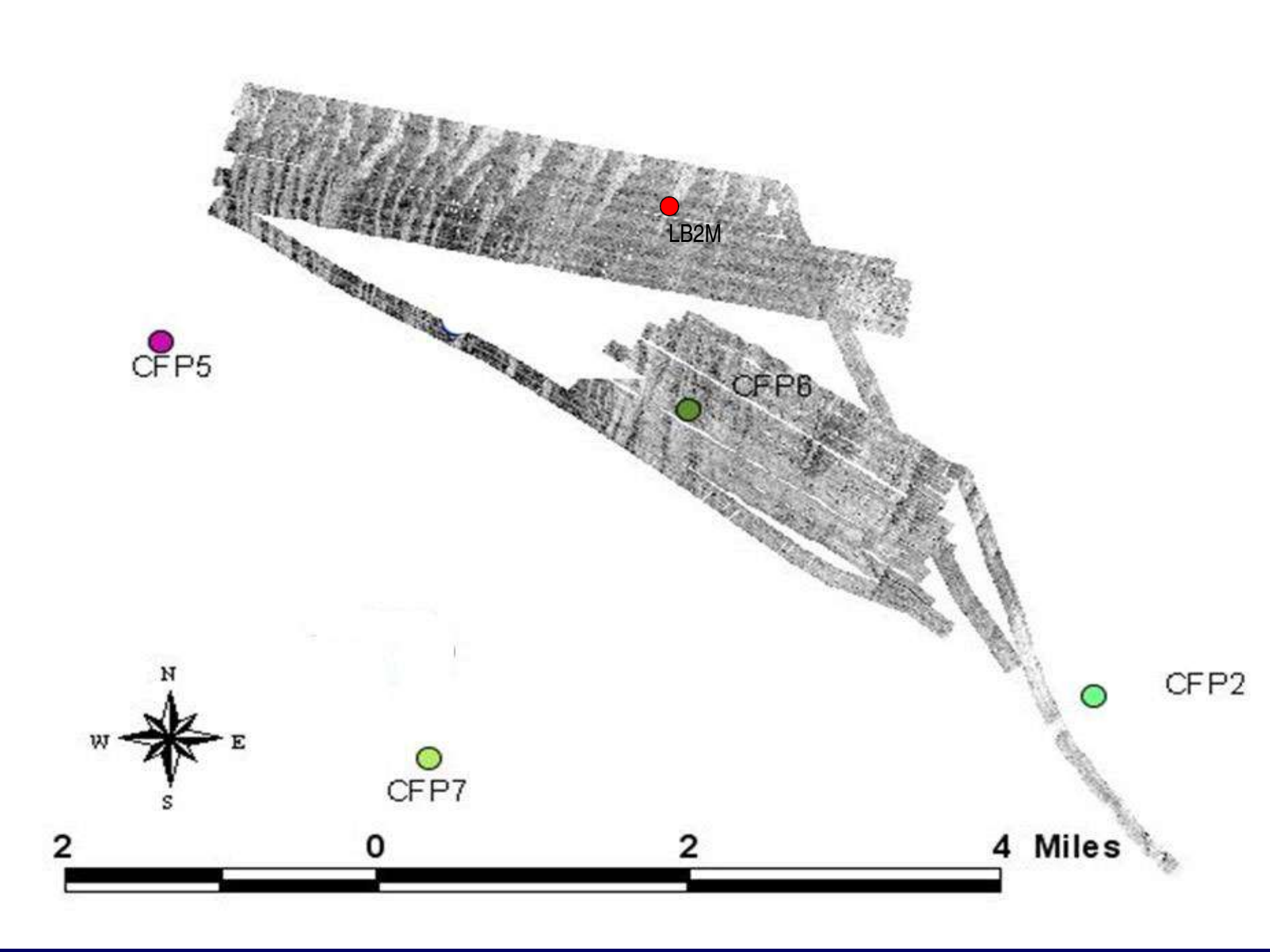
1. Storm track and shoreline orientation
    - Influences wind field, wind-driven currents, and waves


North Carolina
South Carolina
Georgia
Atlantic Ocean
Wilmington
Cape Fear
River
Onslow Bay
LB2M
LB3M
10 m
25 m
Long Bay
Buoy
34.2
34
33.8
33.6
33.4
-78.5
-78.3
-78.1
-77.9
-77.7
-77.5

Implications

- Key factors in influencing sediment response to storm passage:

2. Sediment heterogeneity


LB2M
CFP5
CFP6
CFP2
CFP7
N
W
E
S
2
0
2
4 Miles

Implications

- Key factors in influencing sediment response to storm passage:

3. Storm type and frequency
    - Extratropical storms are 30-40 times more frequent than tropical systems
    - Influence on transport is substantial
    - November event transported more sediments than Ophelia

Implications

- Influence on sediment distribution:

1. Net eastward along-shelf transport during storms
    - Storage of fine sands in shoals

2. Majority of offshore transport associated with the November event
    - Implications for offshore movement renourishment material

Conclusions

- Along-shelf transport was greater than across-shelf transport at both sites and was primarily eastward.
- Higher waves, elevated wind-driven currents, and smaller grain size resulted in an order of magnitude more transport at LB3M than LB2M during both events.
- Transport during the peak of the November event exceeded Ophelia by 20-50%.

Conclusions

- Extratropical storms may have a greater net influence on sediment transport than hurricanes because of higher frequency.

- Due to sediment distribution and water depths, these results are very site specific.

Acknowledgements

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Committee:

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LB2M Boxcore

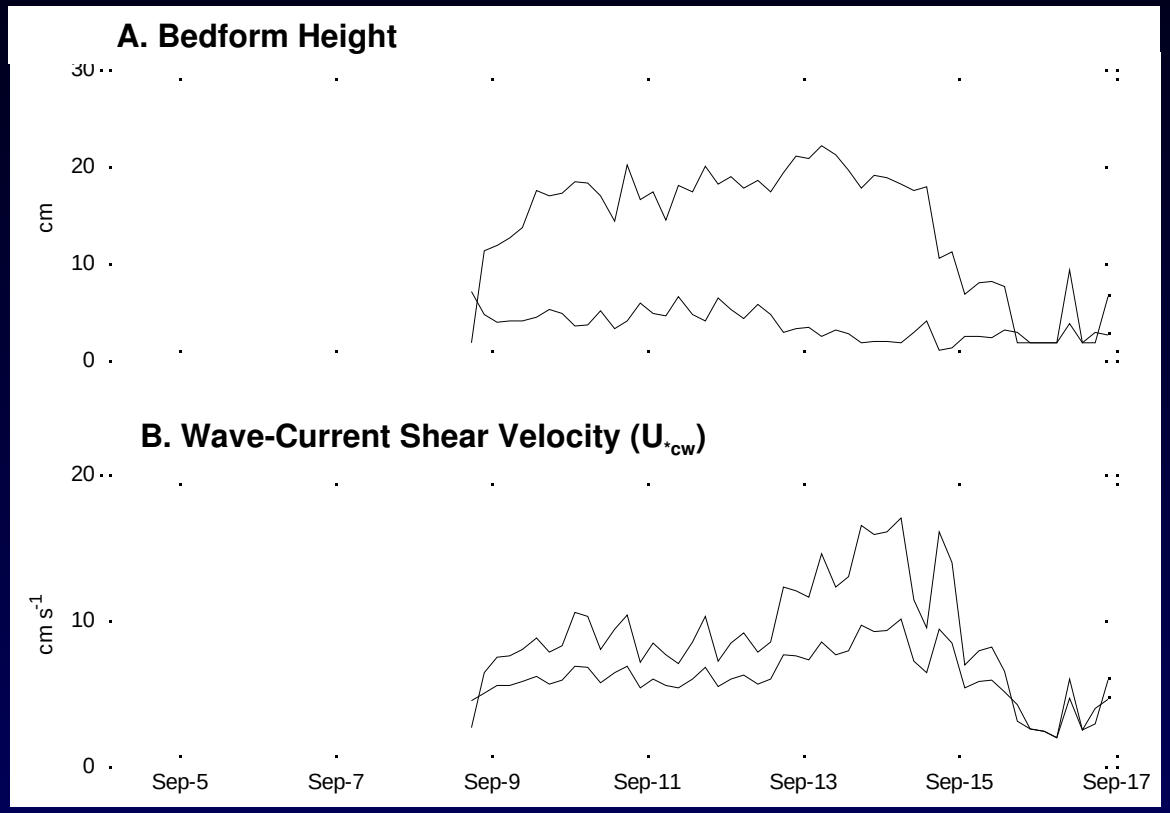
Coarse layer

5-10 cm

Fine layer

20-25 cm

Example


A. Bedform Height
30
20
10
0
cm
B. Wave-Current Shear Velocity (U_{*cw})
20
10
0
cm s^{-1}
Sep-5
Sep-7
Sep-9
Sep-11
Sep-13
Sep-15
Sep-17

- Summary for transport
- Mostly alongshore for all events, both sites mostly to east
- More transport during tropical storm at both sites
- More transport at LB3m (order of magnitude)

Study Limitations

- Site specific:
  - Spatial heterogeneity of sediments
    - Horizontal and vertical
  - Complex shoreline configuration
- Most applicable to shoreface (depths,Longshore)
- Small storm events (can’t extrapolate to larger events)

Background

- Sediment Mobility

- Coastal storms:
  - Influence
  - Type
  - Frequency