The Role of High-Concentration Suspensions in Dispersal of River Sediments

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Boston College

with lots of help along the way…

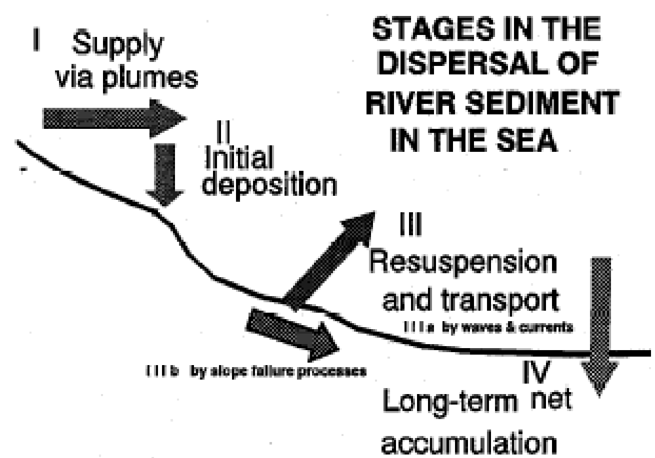


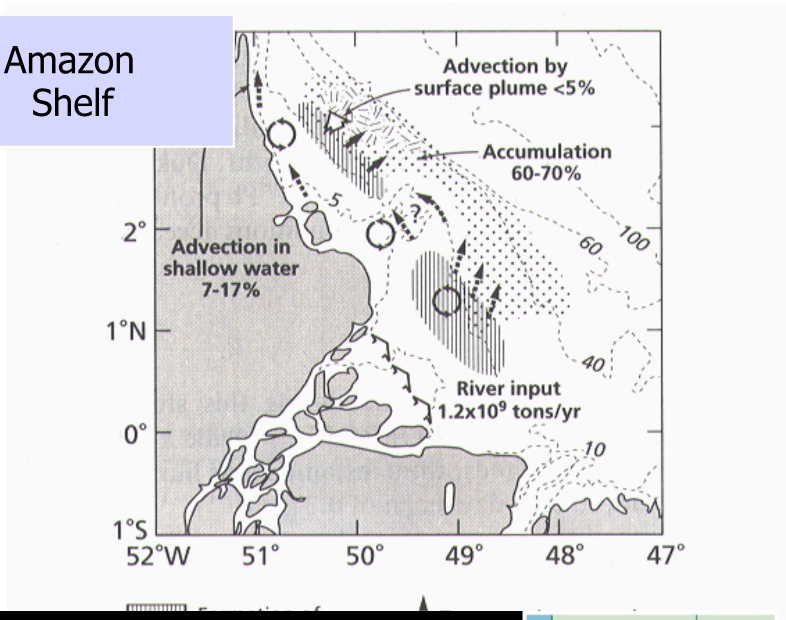
Fig. 2. Conceptual illustration of four major stages in the dispersal of river sediments in the coastal ocean.

Fine Sediment Dispersal in the Coastal Ocean,
Wright and Nittrouer 1995

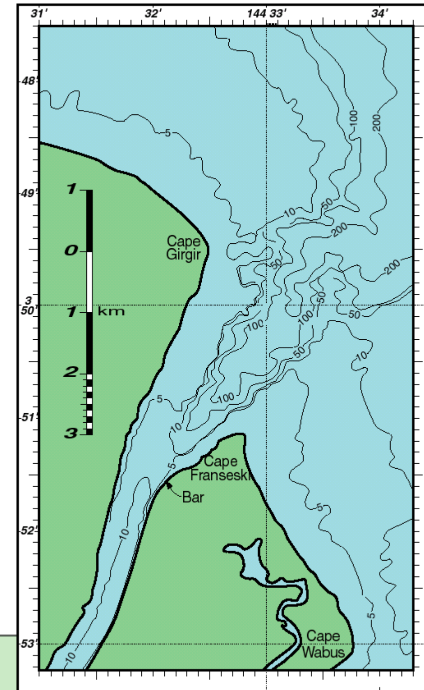
LINKAGES BETWEEN FLUVIAL DISCHARGE AND HIGH-CONCENTRATION FLOWS IN COASTAL ENVIRONMENTS.

1. Examples where there is a link between high-concentration flows in coastal environments.
2. *Conditions to form high concentration suspensions.*
3. A counter-intuitive example.

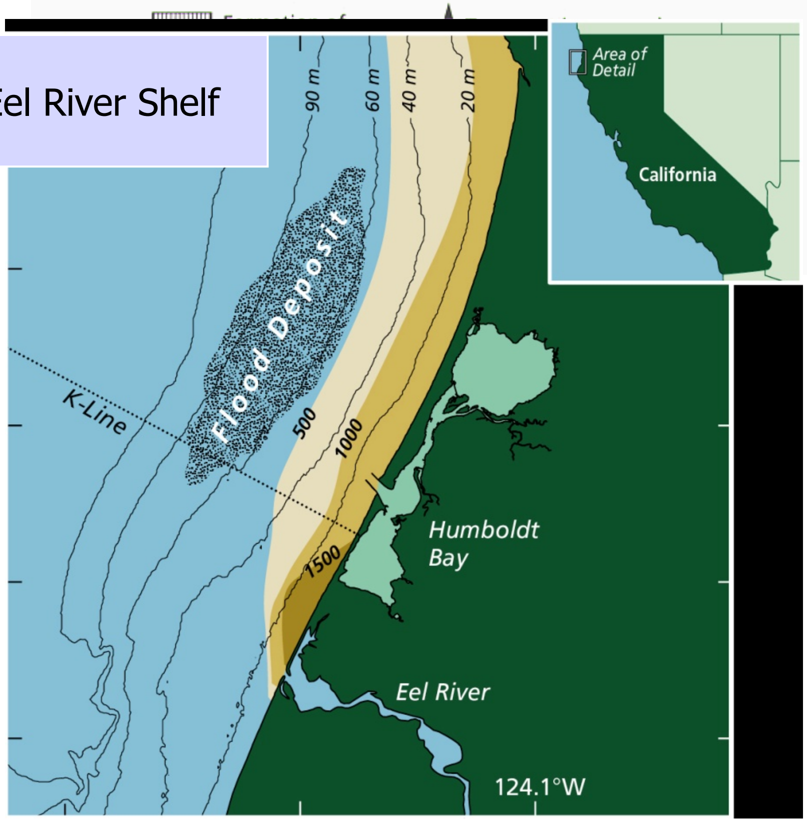
Amazon Shelf



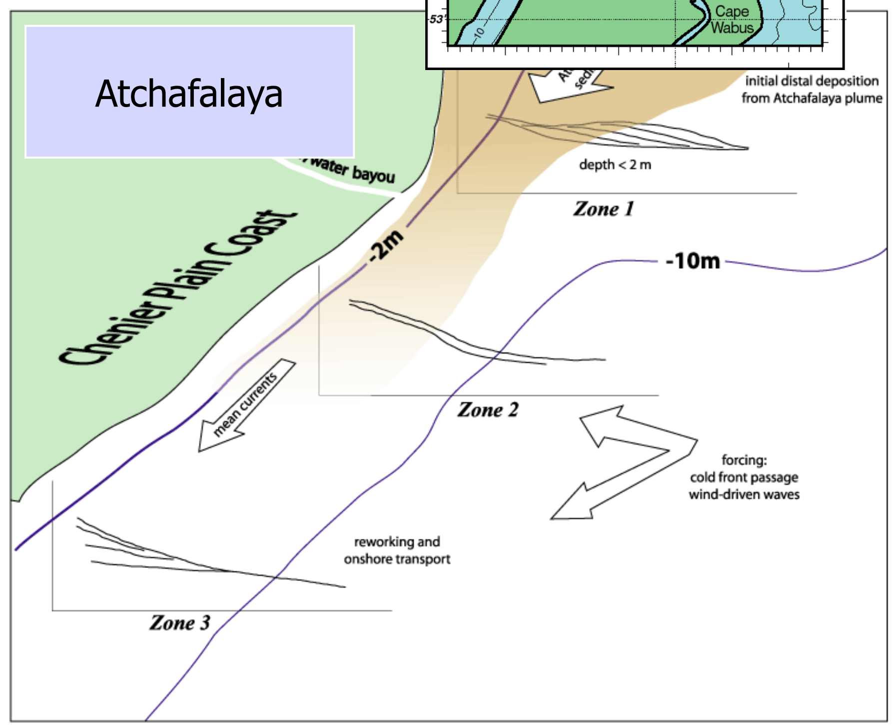
Sepik River

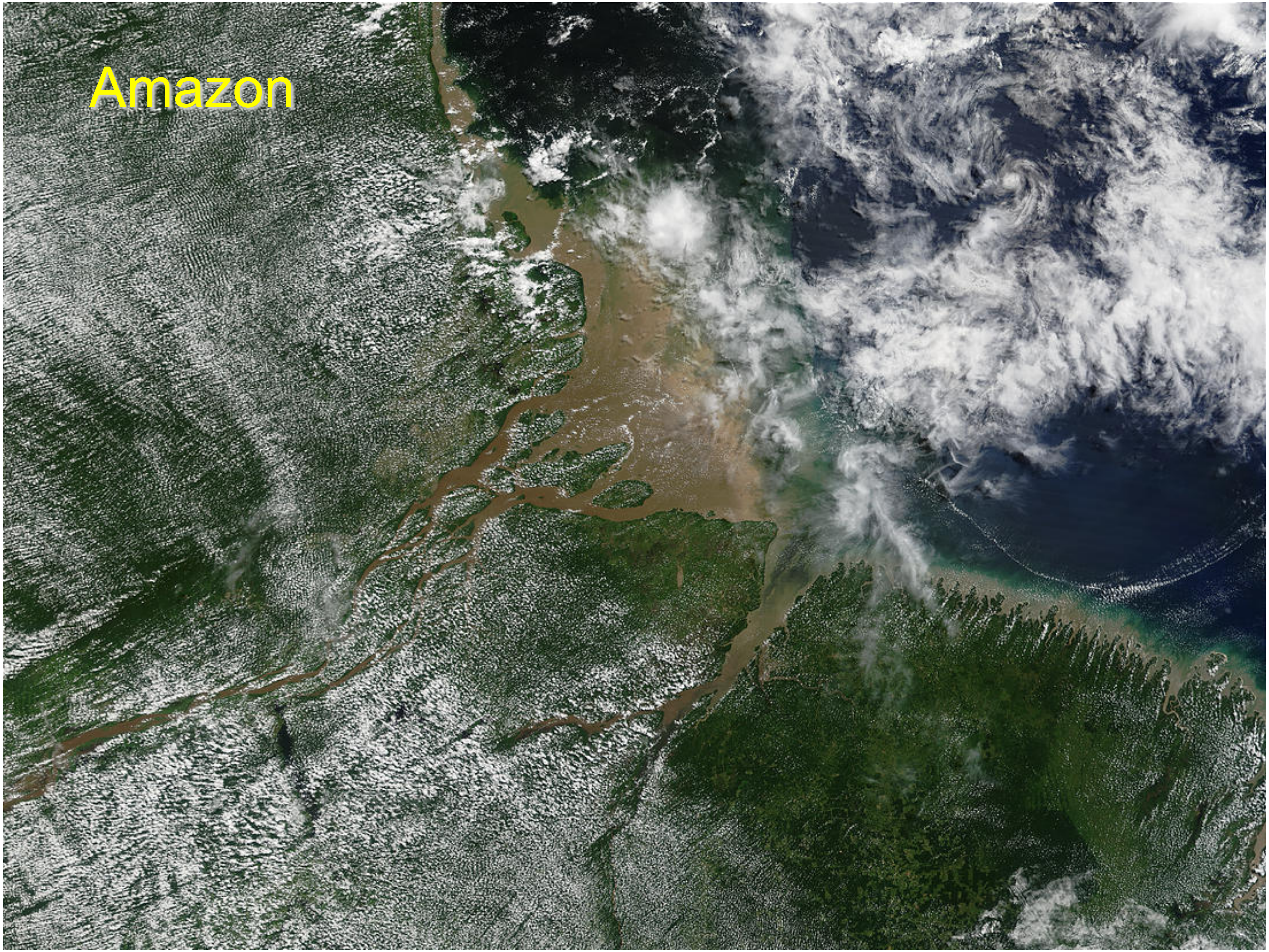


Eel River Shelf

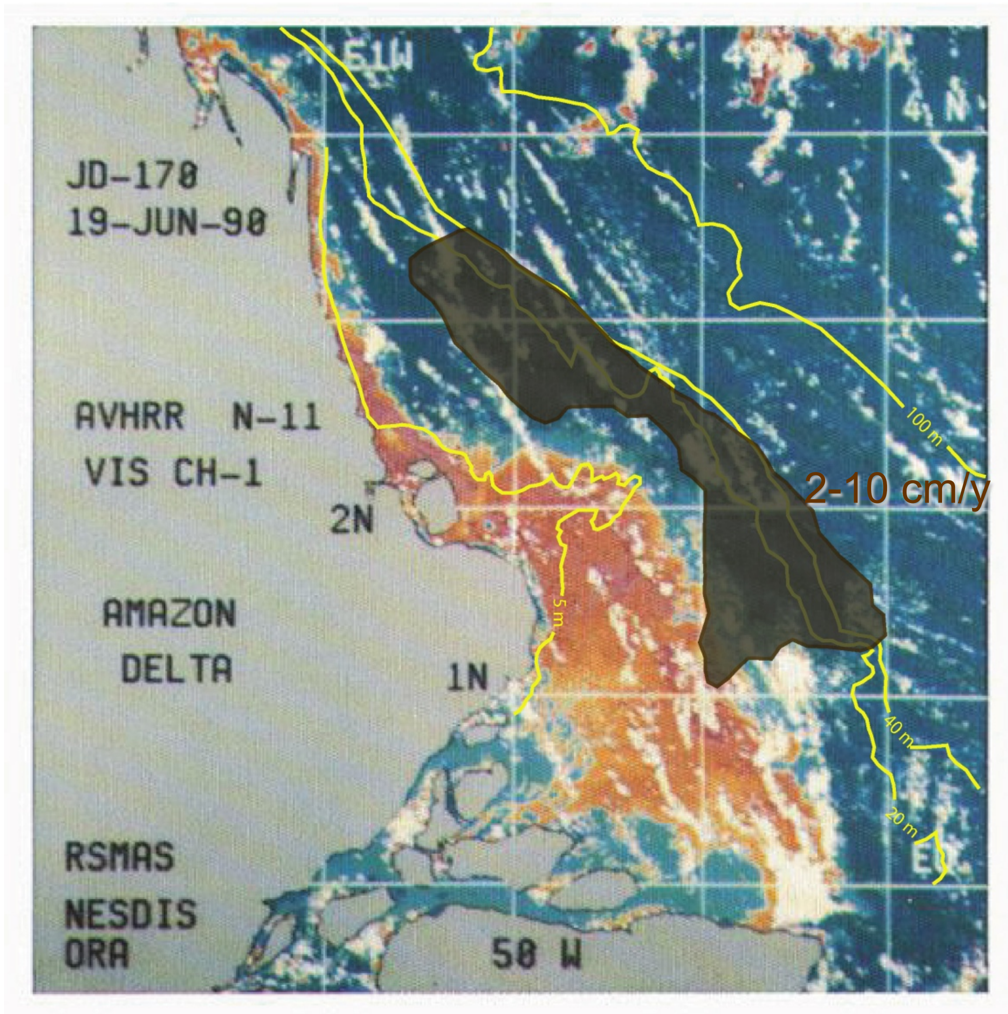


Atchafalaya

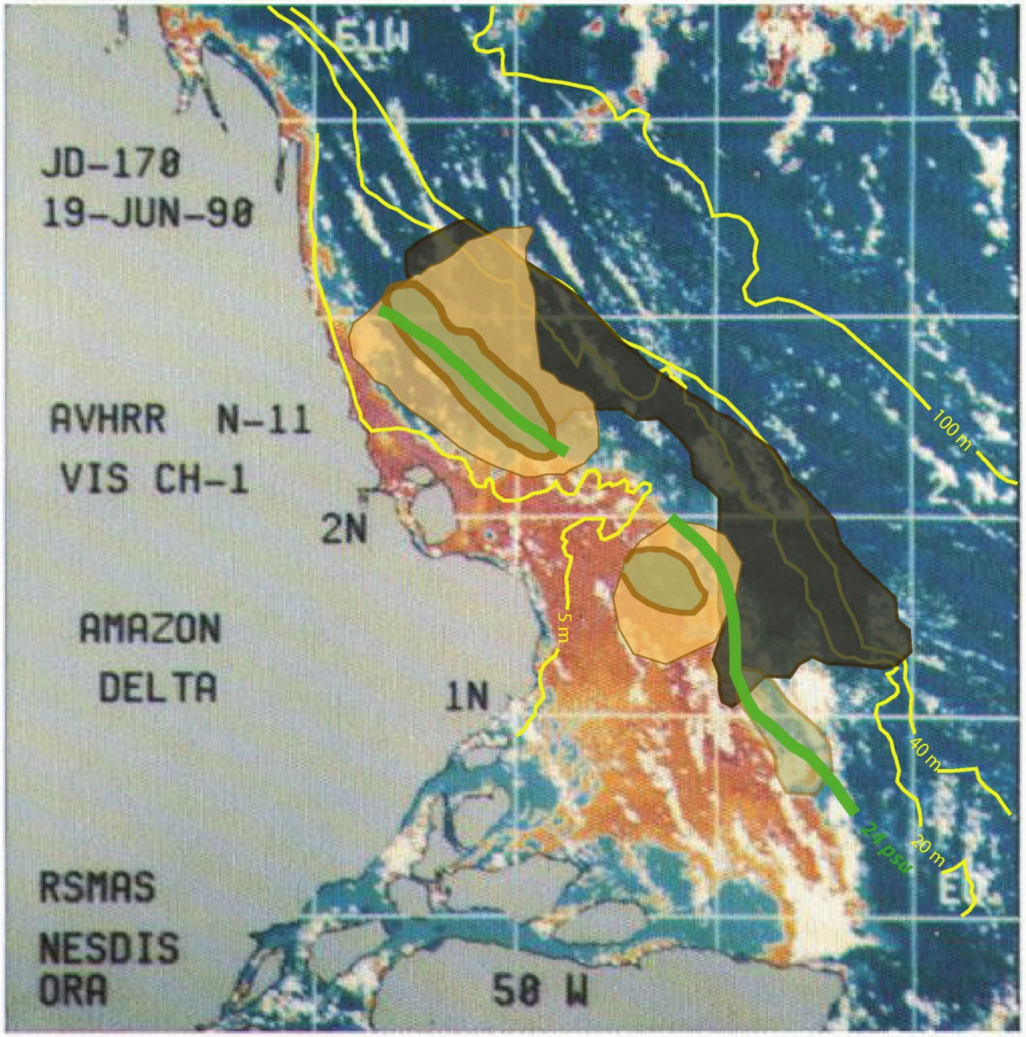



Amazon

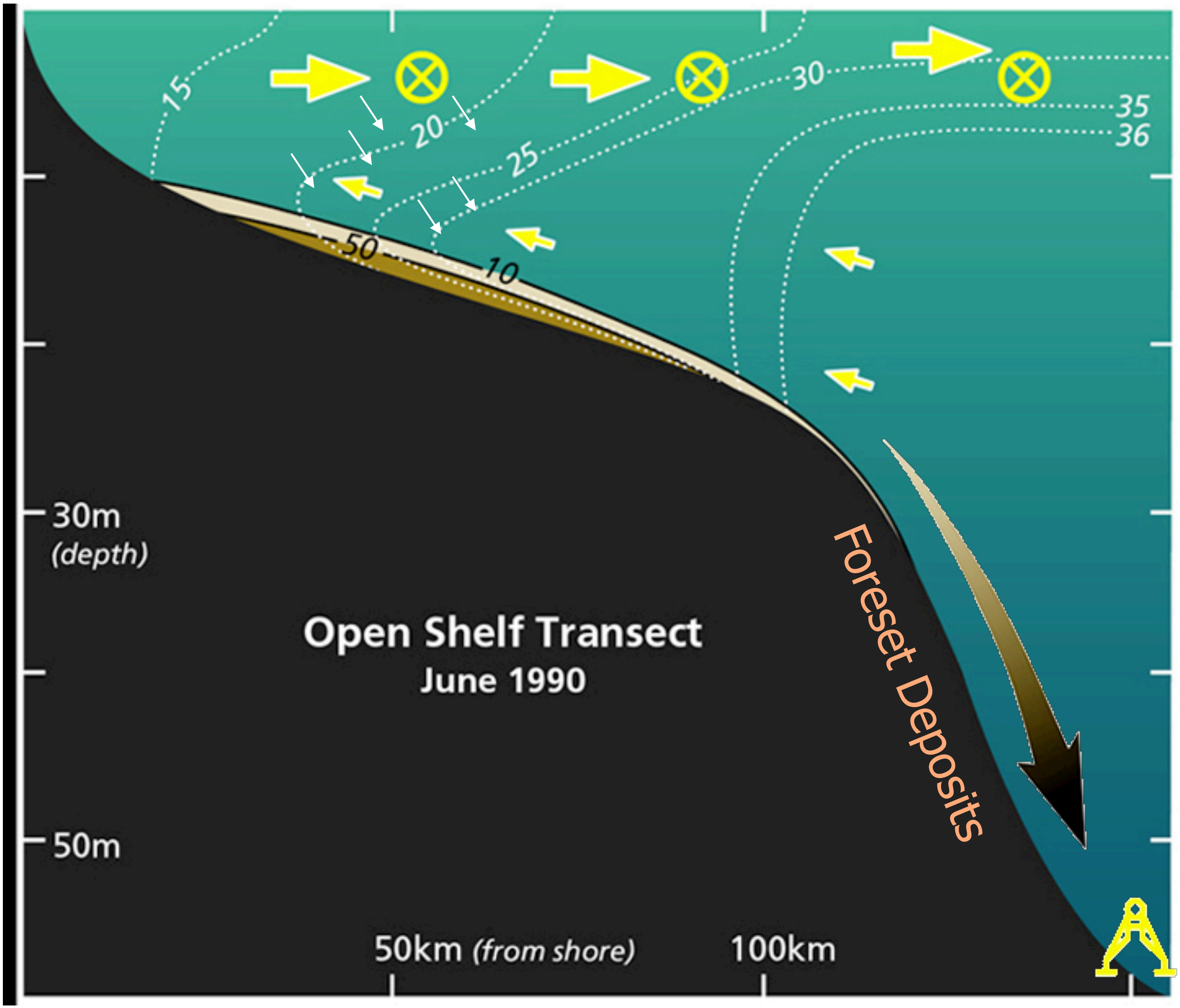
AmasSeds
A Multidisciplinary Amazon Shelf SEDiment Study



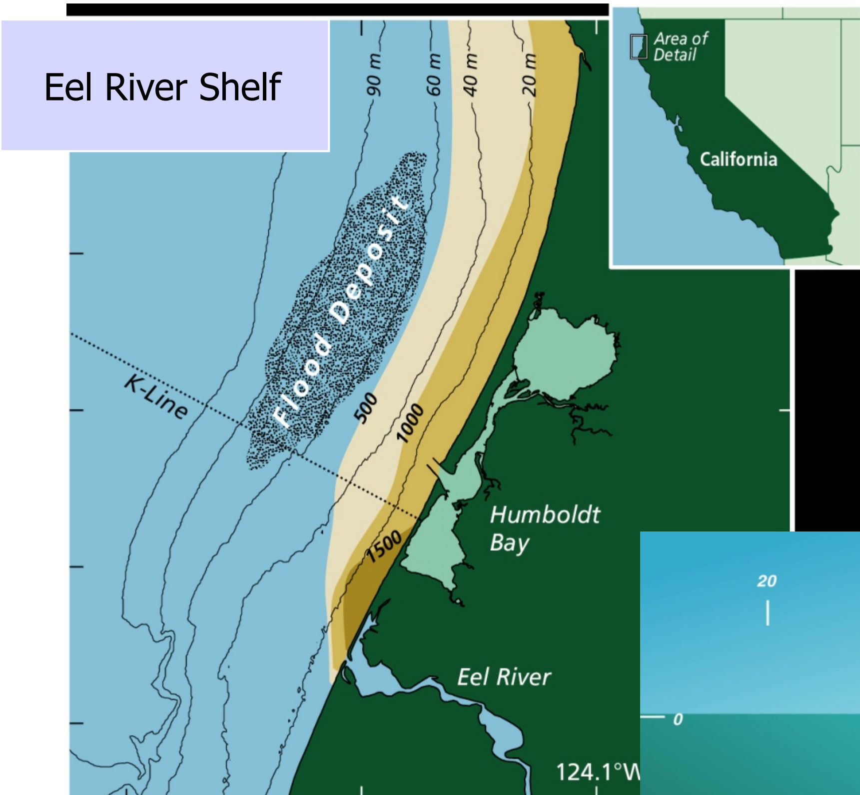
Kuehl & Nittrouer

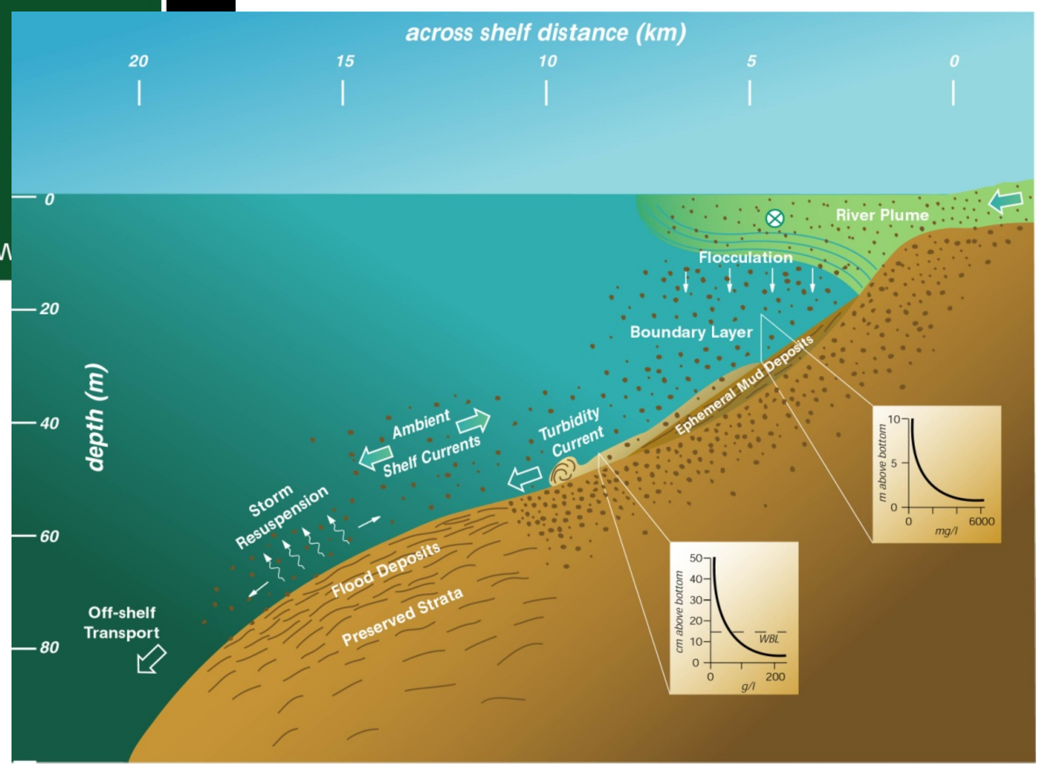


JD-170
19-JUN-90
AVHRR N-11
VIS CH-1
AMAZON
DELTA
RSMAS
NESDIS
ORA
51W
50 W
4 N
2 N
2N
1N
EQ
100 m
40 m
20 m
5 m
24 psu

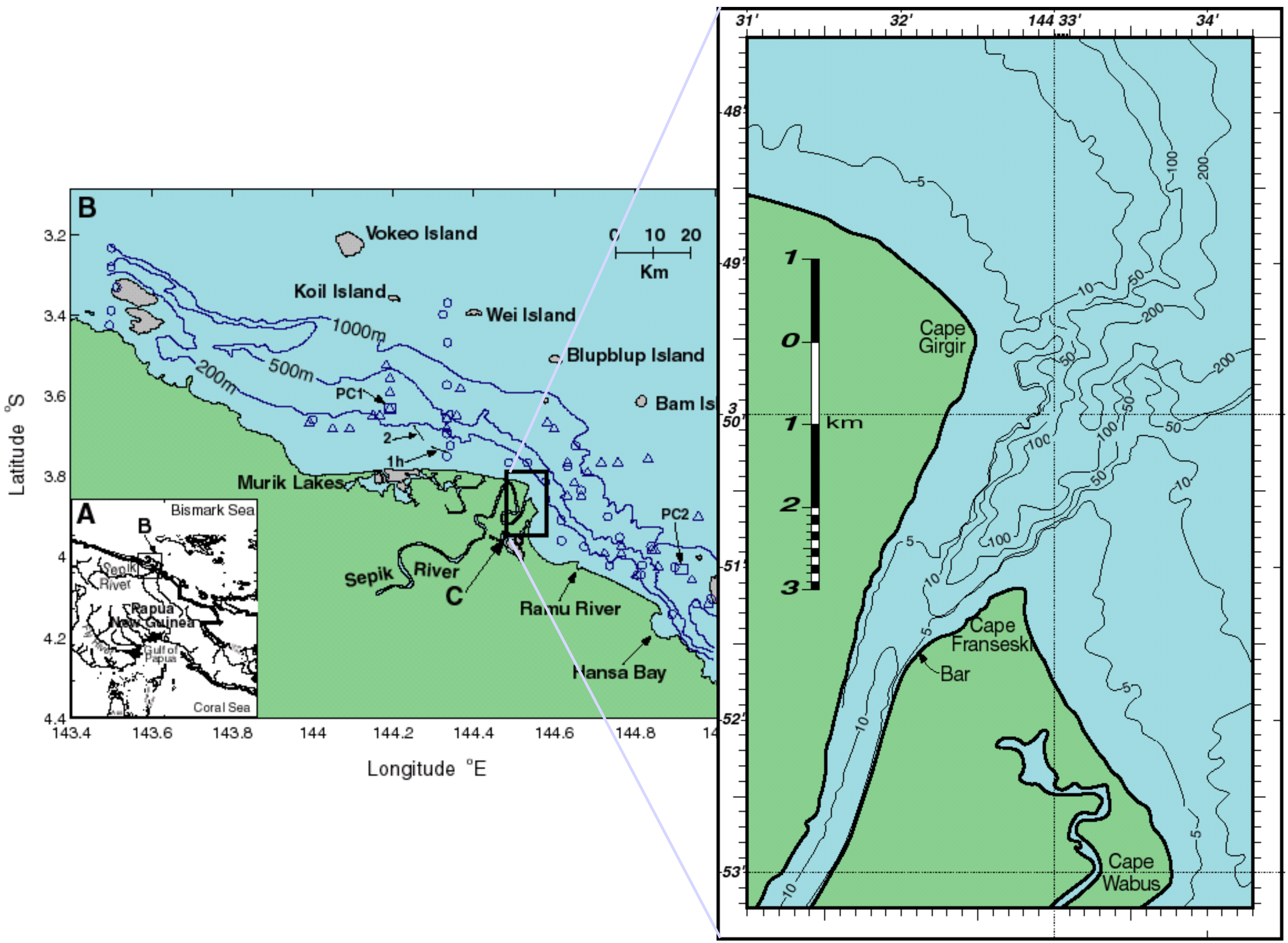

15
20
25
30
35
36
50
10
30m
(depth)
50m
Open Shelf Transect
June 1990
Foreset Deposits
50km (from shore)
100km

Wave Supported Gravity Flows

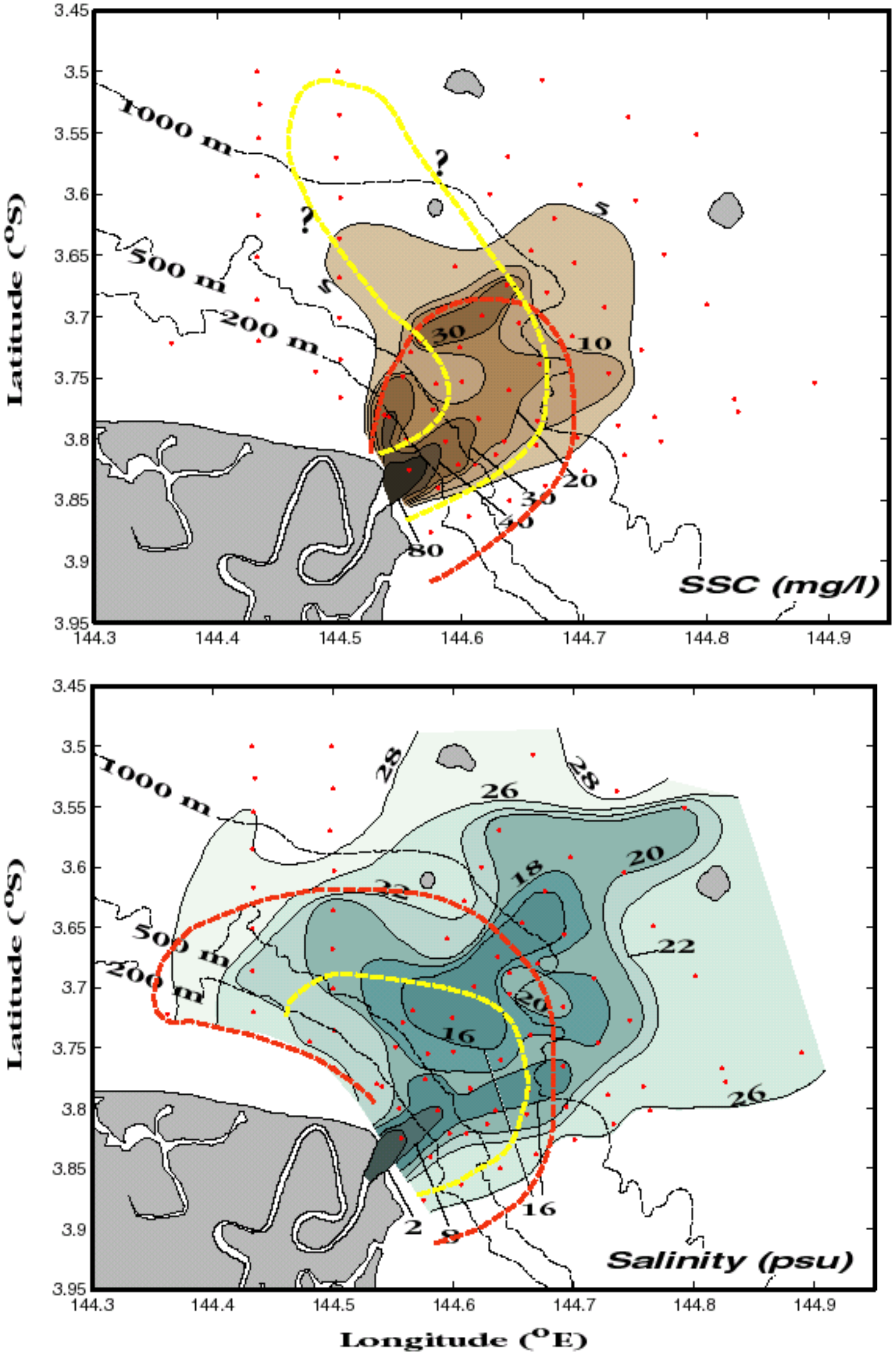




Traykovski, Geyer, Ogston

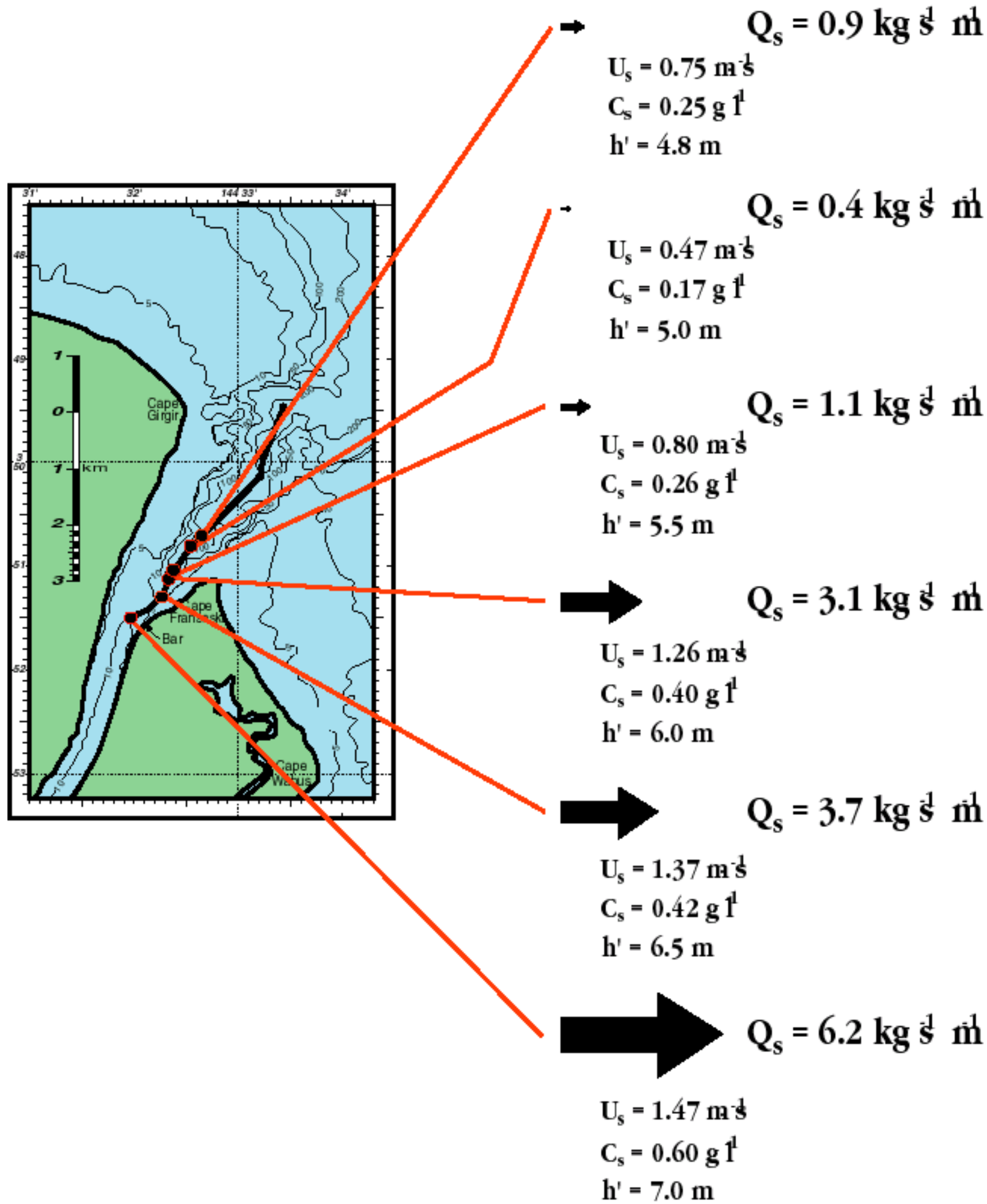

B
Vokeo Island
Koil Island
Wei Island
Blupblup Island
Bam Is
0 10 20
Km
1000m
500m
200m
PC1
PC2
2
1h
Murik Lakes
Sepik River
C
Ramu River
Hansa Bay
A
Bismark Sea
Sepik River
Papua New Guinea
Gulf of Papua
Coral Sea
Latitude °S
Longitude °E
3.2
3.4
3.6
3.8
4
4.2
4.4
143.4
143.6
143.8
144
144.2
144.4
144.6
144.8
31'
32'
144 33'
34'
48'
49'
3 50'
51'
52'
53'
km
Cape Girgir
Cape Franseski
Bar
Cape Wabus

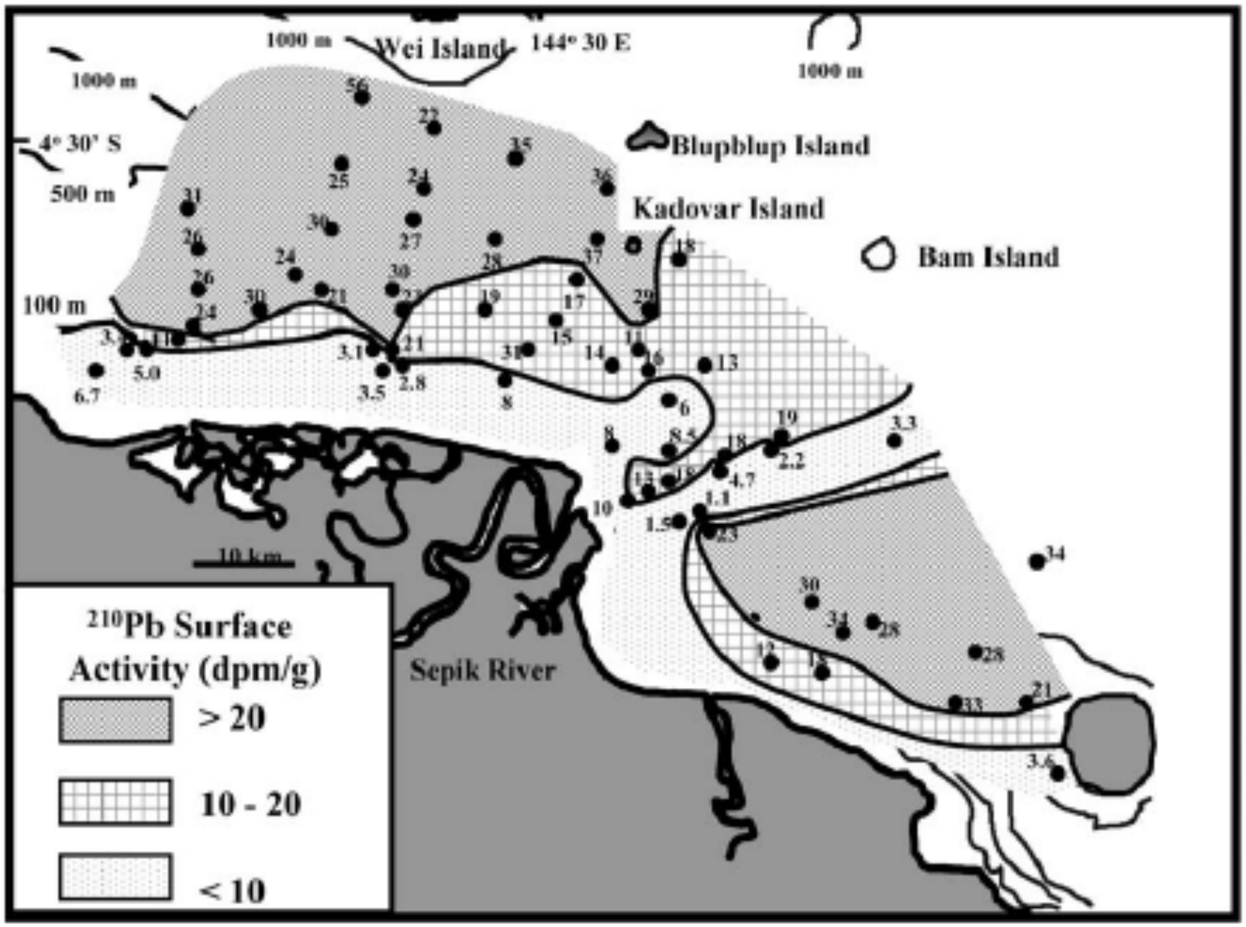
Surface Plume



Estimates of sediment flux in surface plume:

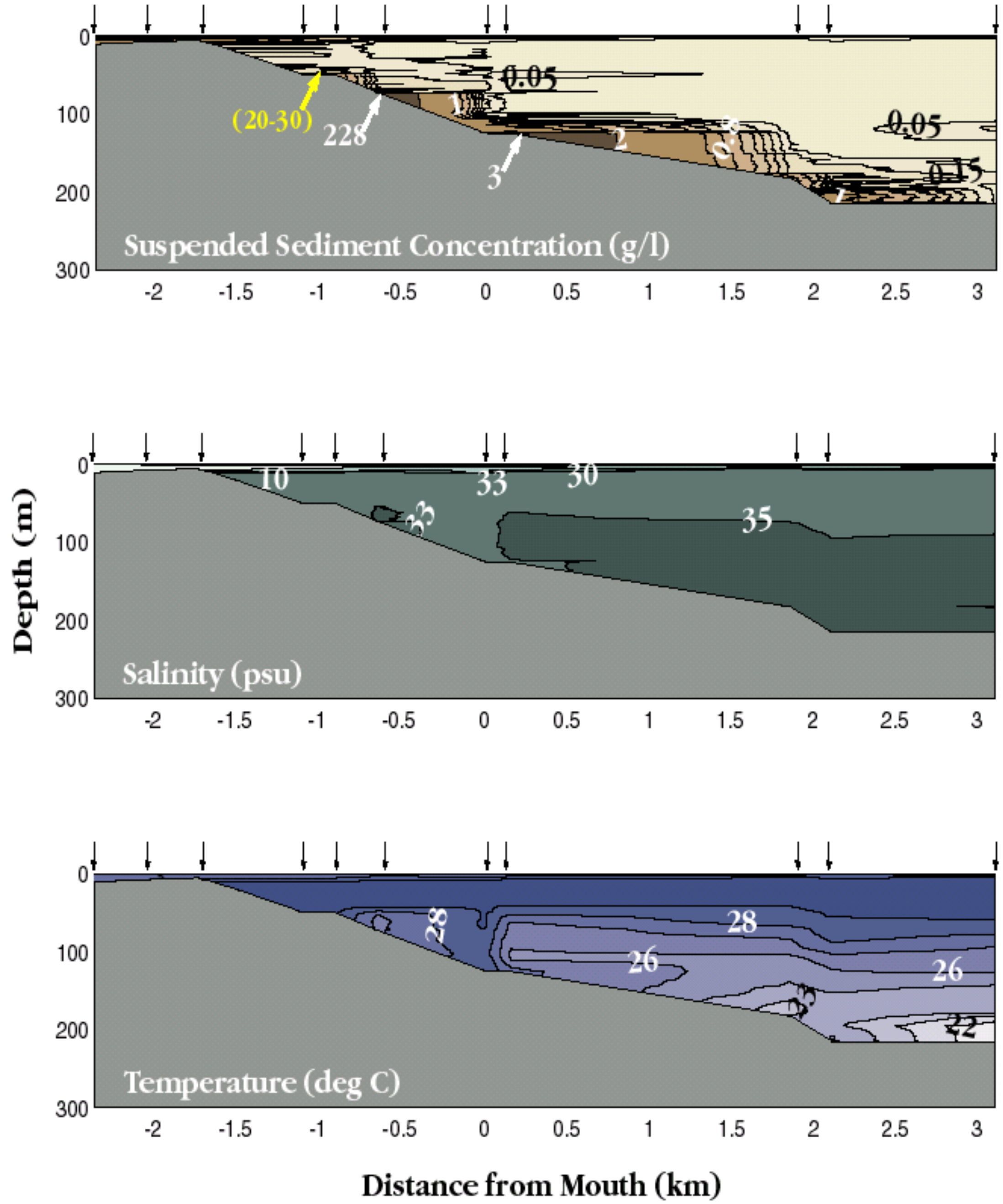
- Surface flux exiting river mouth is ~14% input at the bar (integrated over width)
- Implies w_s is O(1 cm s^{-1}) (0.3-2.2 cm s^{-1})



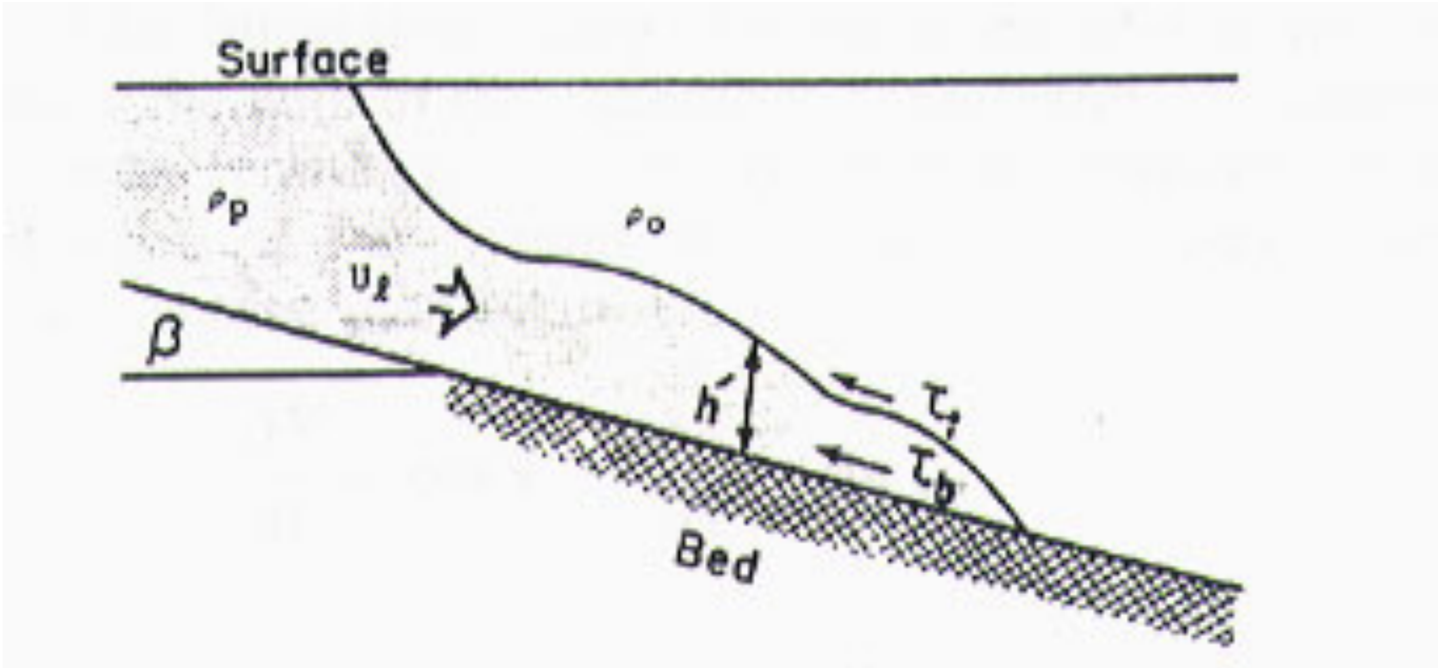


Kuehl et al. 2004

April 1999



0
100
200
300
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
0.05
0.05
0.15
1
2
(20-30)
228
3
Suspended Sediment Concentration (g/l)
10
33
30
33
35
Salinity (psu)
28
28
26
26
22
Temperature (deg C)
Depth (m)
Distance from Mouth (km)



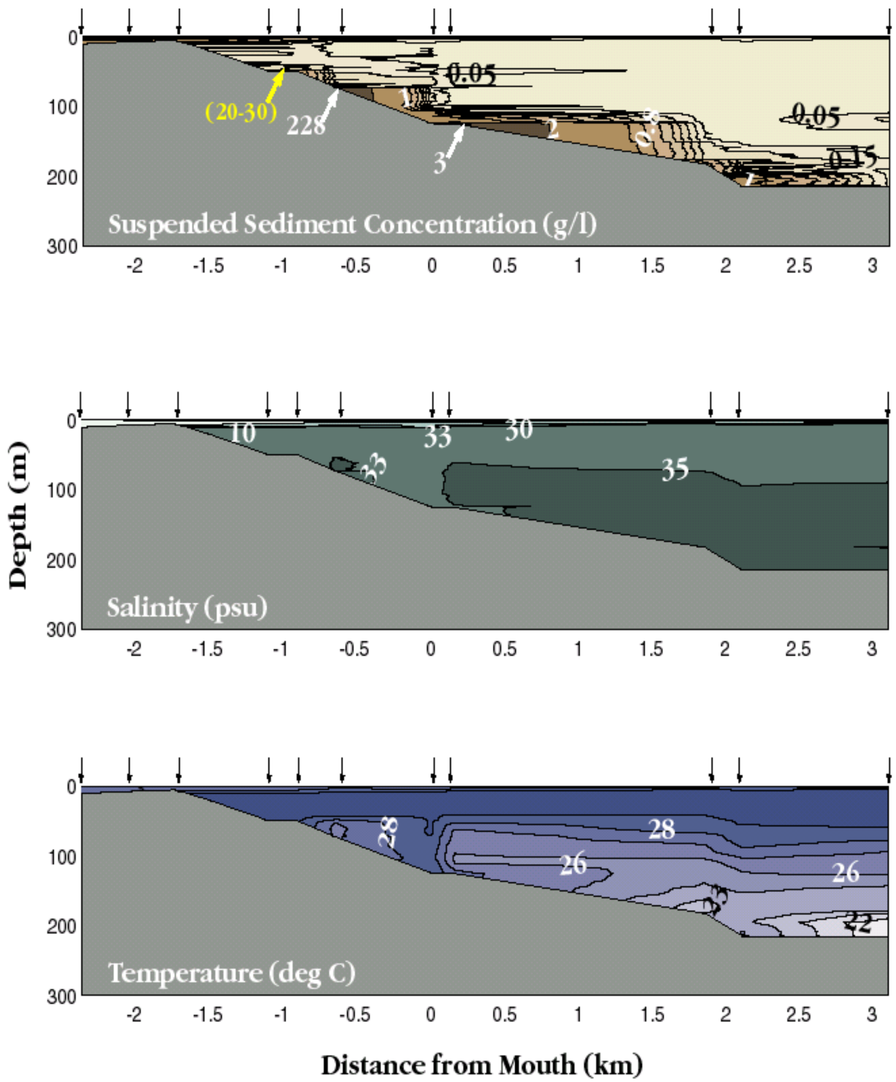
Chezy Equation:

$$h'\rho_p g'\sin\beta=\tau_b+\tau_t=\rho_p u_l^2(C_D+E)$$

Wright et al. 1990

$$h'\rho_p g'\sin\beta=\tau_b+\tau_t=\rho_p u_l^2(C_D+E)$$

Wright et al. 1990



How thick for 10g/l?

~ 20 cm

How long to create?

~ 5.6 hrs

How fast?

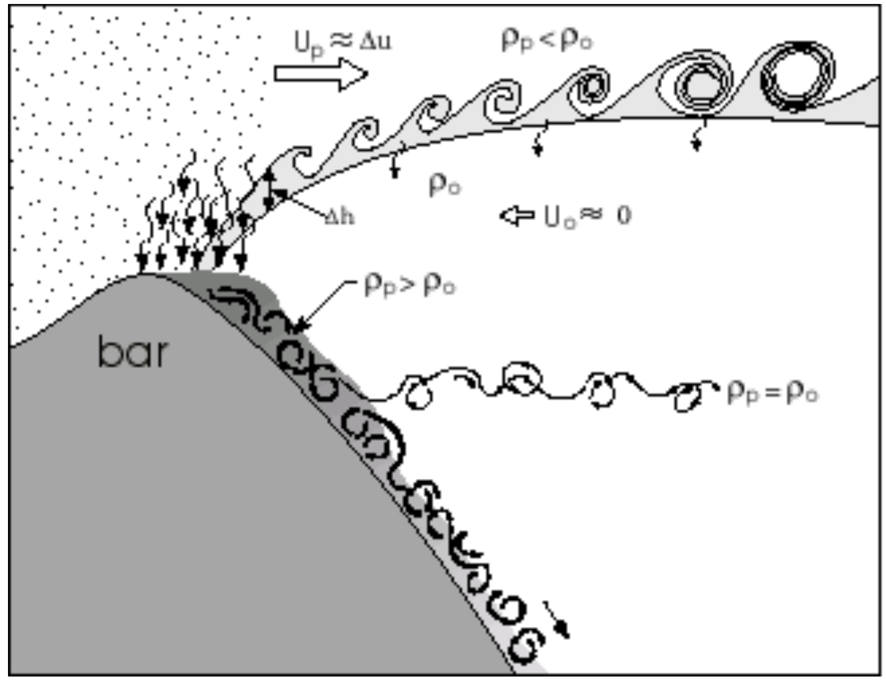
~ 10 cm/s

For 1 g/l, 10 m?

~70 cm/s

Sepik Summary

- ~15% of the river input of sediment is dispersed via the surface plume with a comparable amount in intermediate layers and the remainder in dense nearbottom flows
- Implications for widespread dispersal of particulates
- Rapid delivery to deep sea



•For these examples, high concentration suspensions formed through settling.

•Requires rapid settling flux, $w_s C$, and inhibited mixing (stratification).

Petitcodiac River experiments

Bay of Fundy area -big tides, strong currents, high concentrations, and a stable working platform

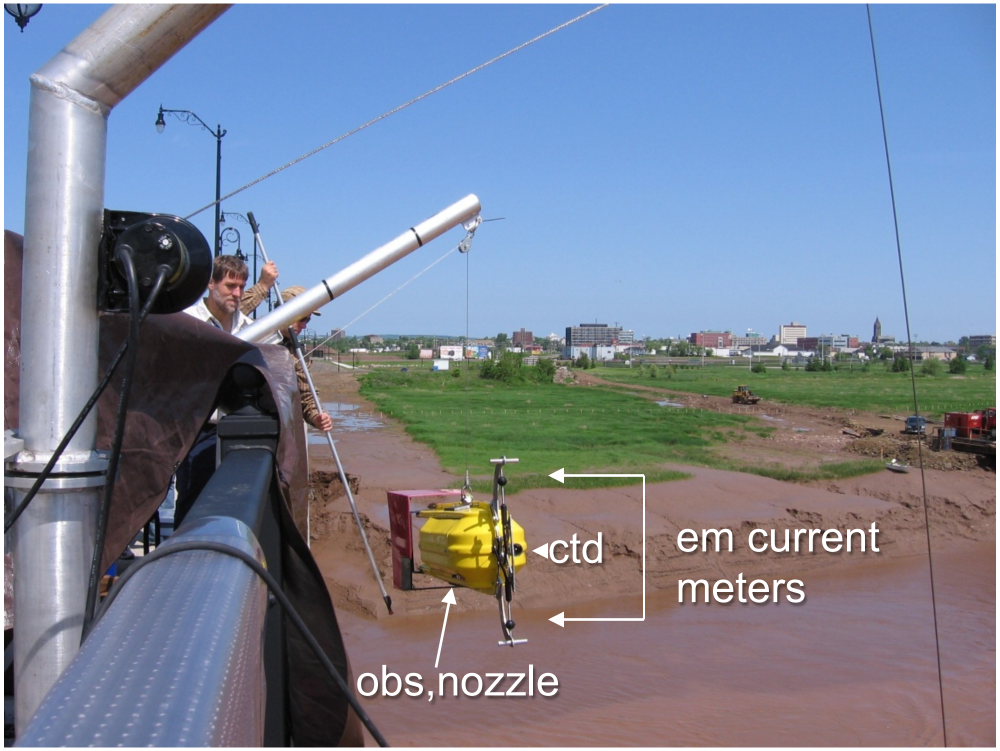
Instrumentation

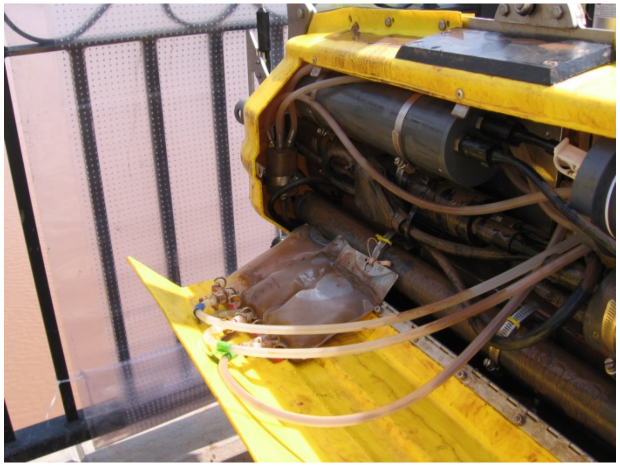
- SUBS profiler
- Surfboard (ADCP, Knudsen)
- ADV profiling tripod

Instrumentation

- SUBS profiler

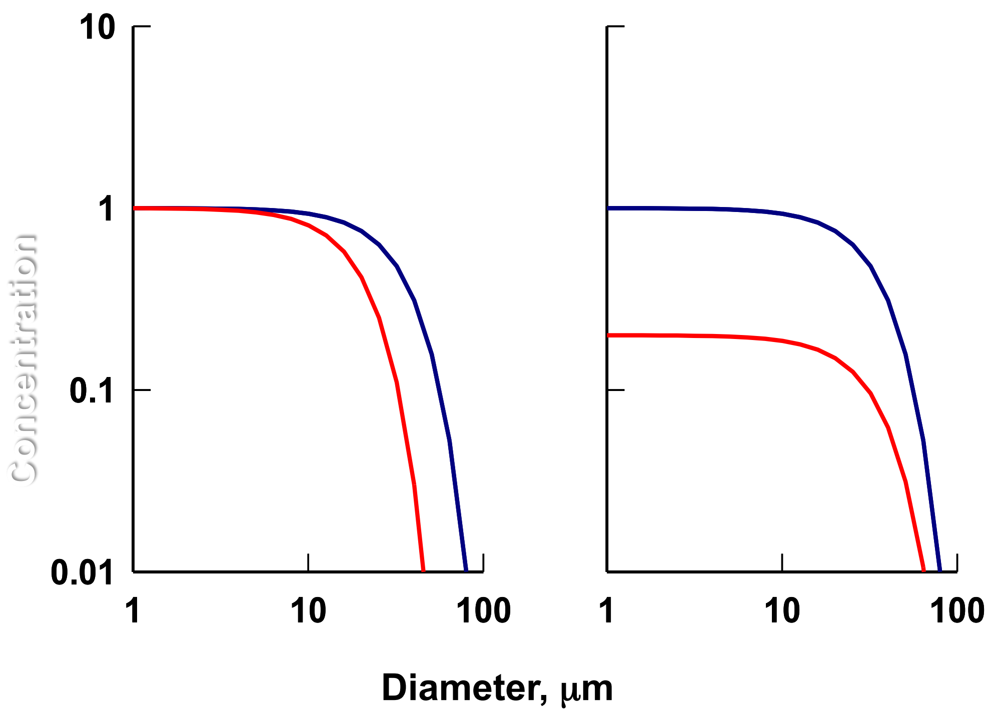
$$\frac{du}{dz}, \rho_z(S,T,C), samples$$





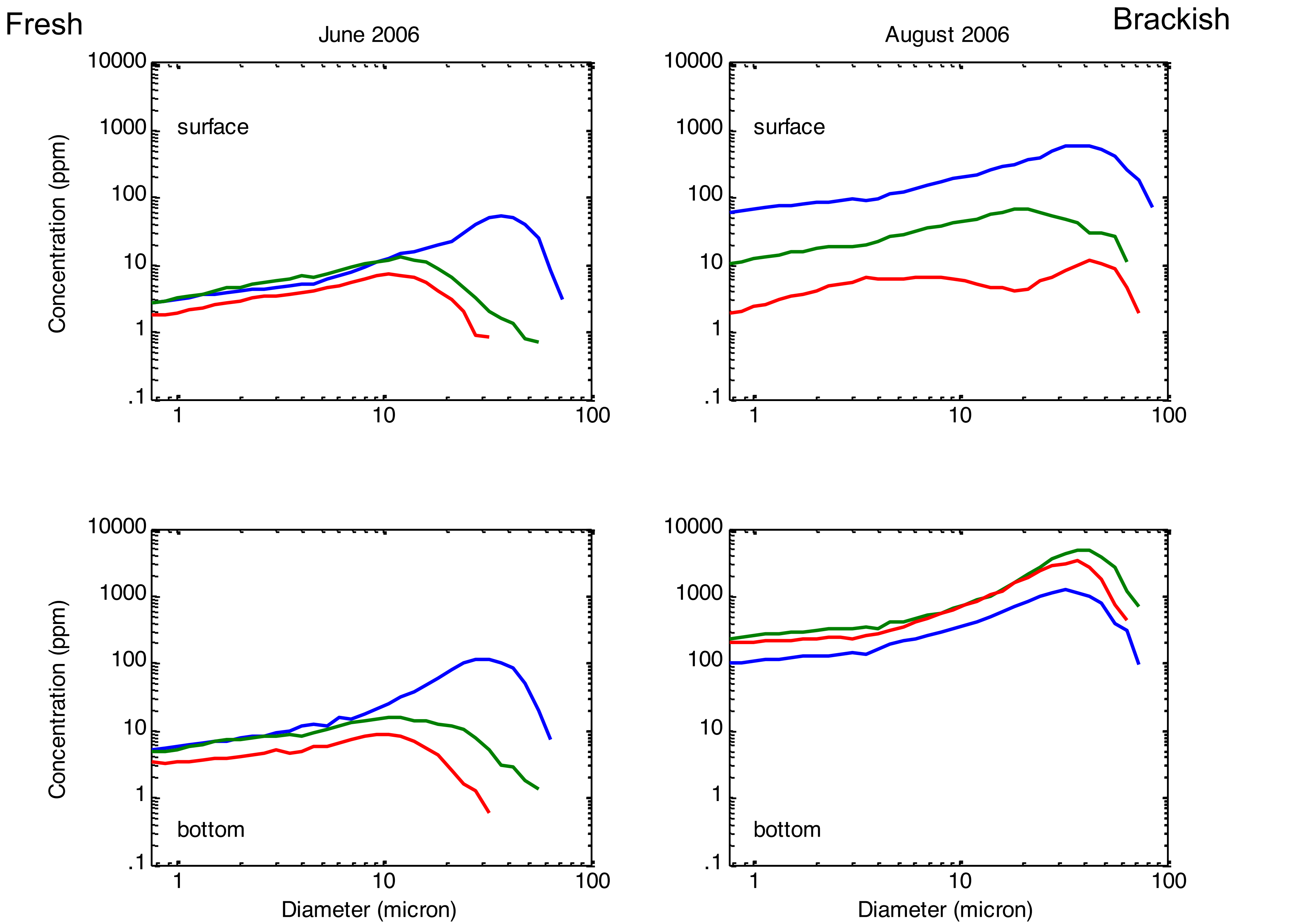
Floc Settling Necessary for Fluid Mud Formation

Single Grains

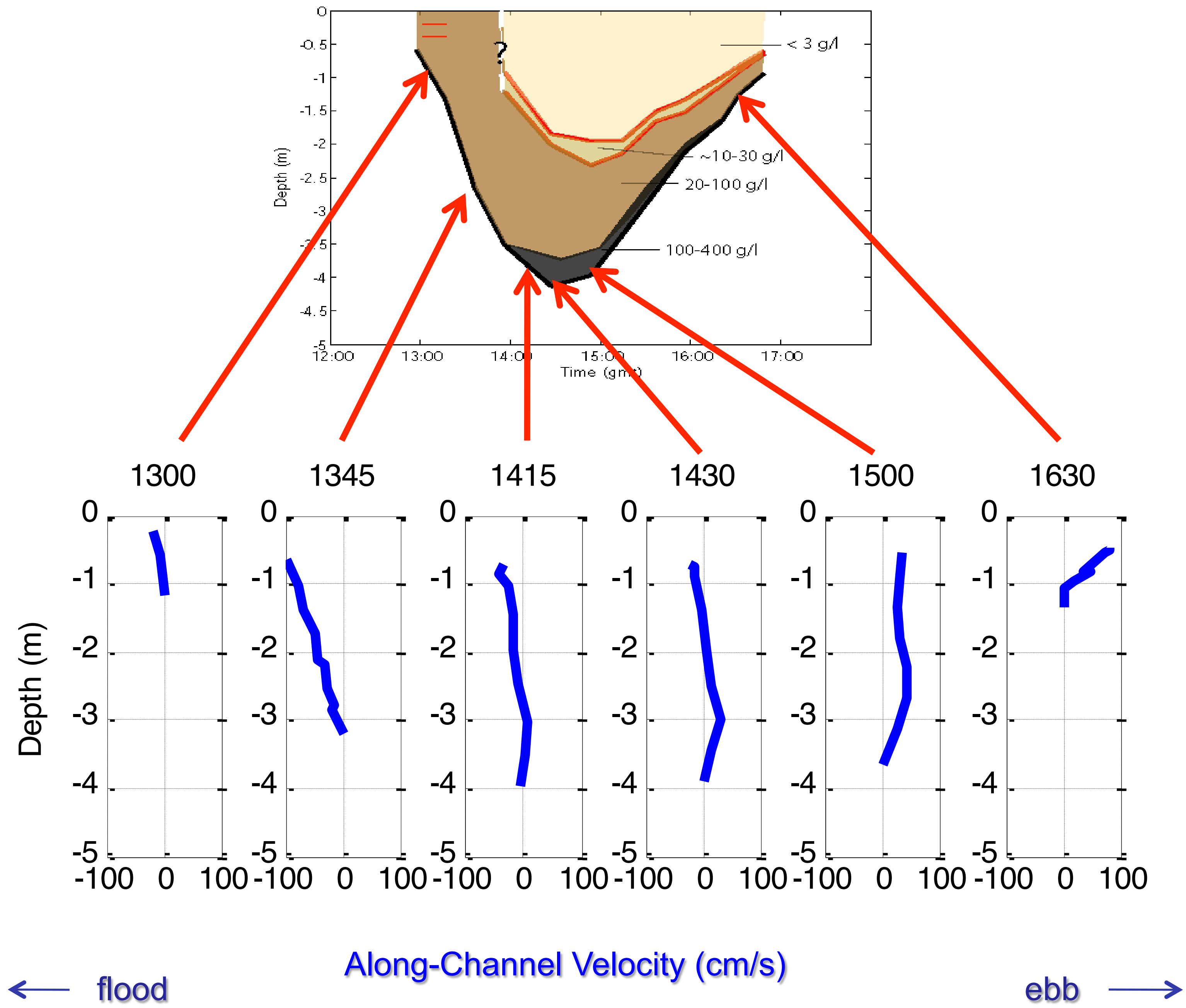


Flocs

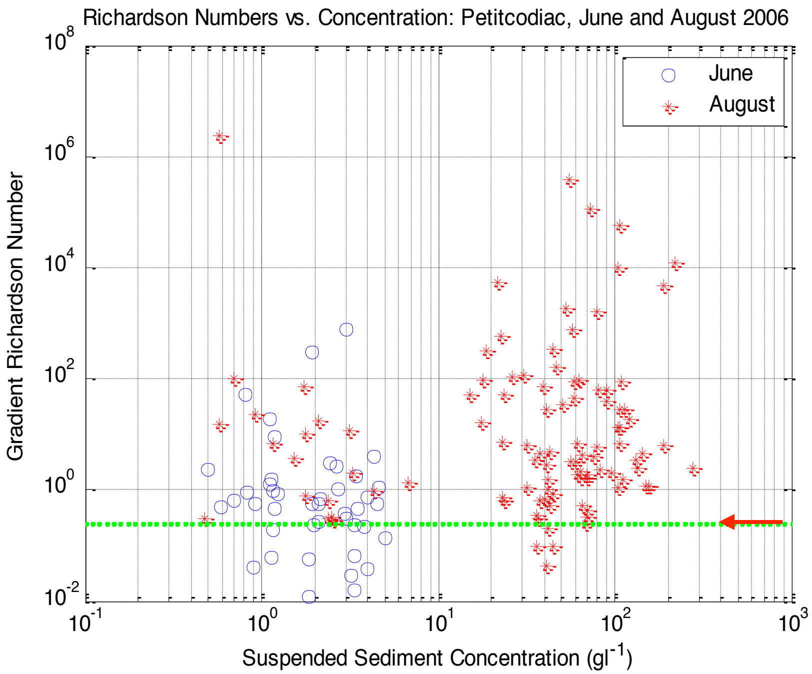
Milligan, BIO

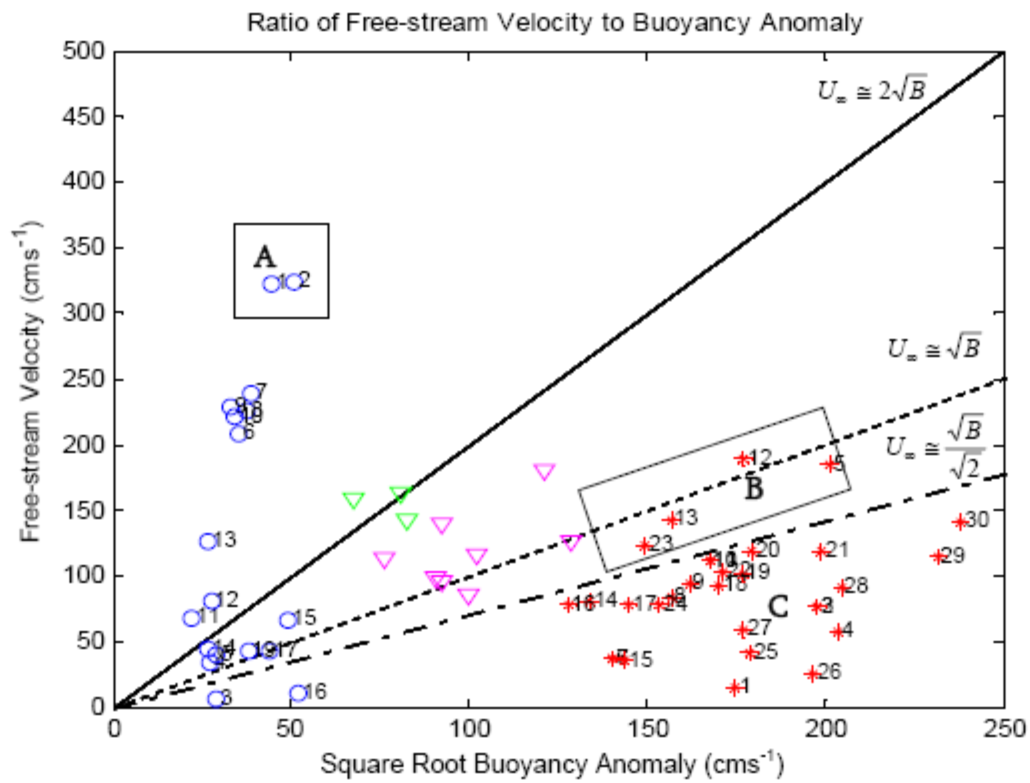


Milligan, BIO



< 3 g/l
~10-30 g/l
20-100 g/l
100-400 g/l
?
Depth (m)
Time (gmt)
1300
1345
1415
1430
1500
1630
Depth (m)
Along-Channel Velocity (cm/s)
flood
ebb





Ri_g vs Suspended Sediment Concentration

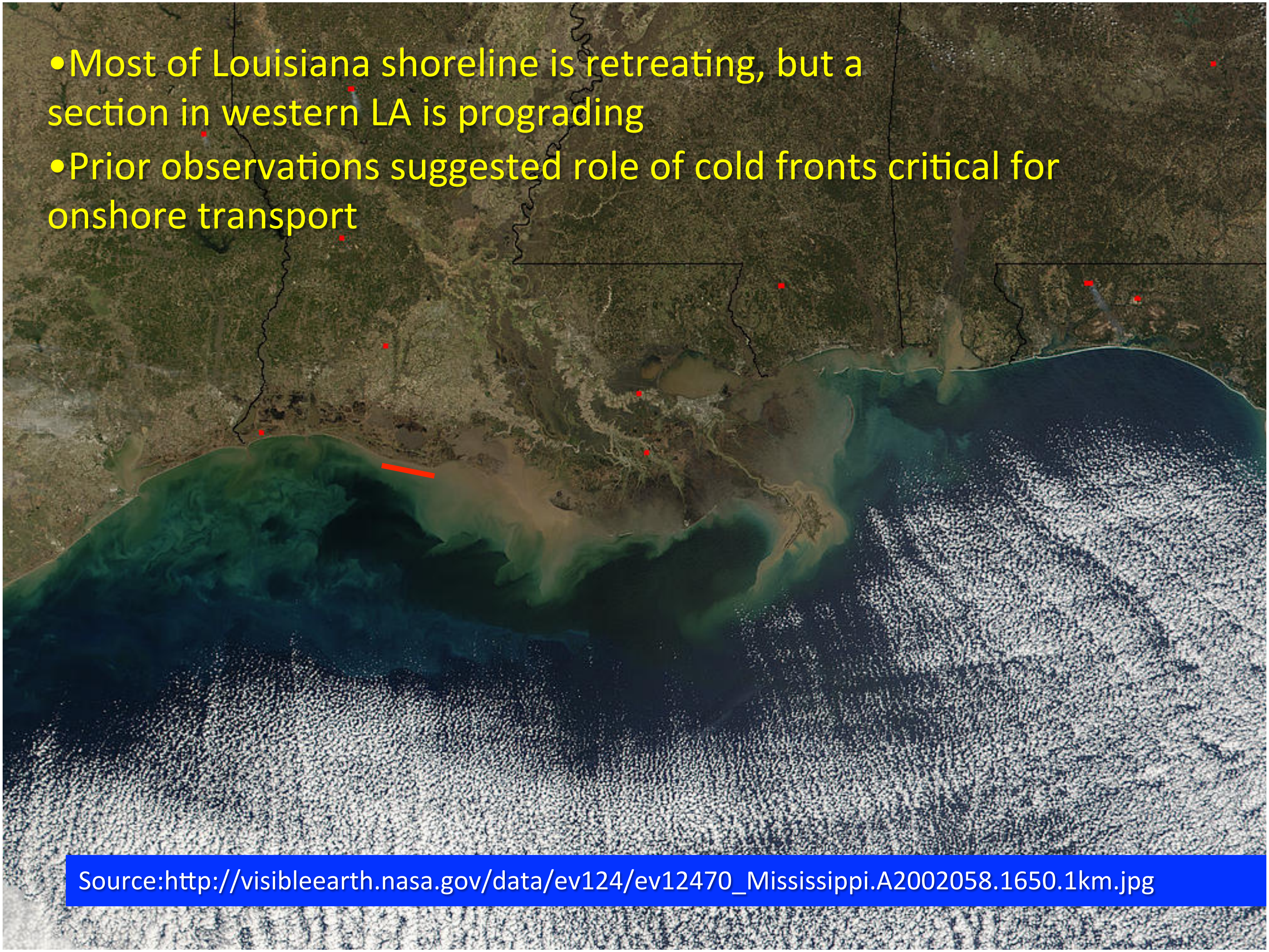
Carrying capacity threshold condition, dependence on Ri_c

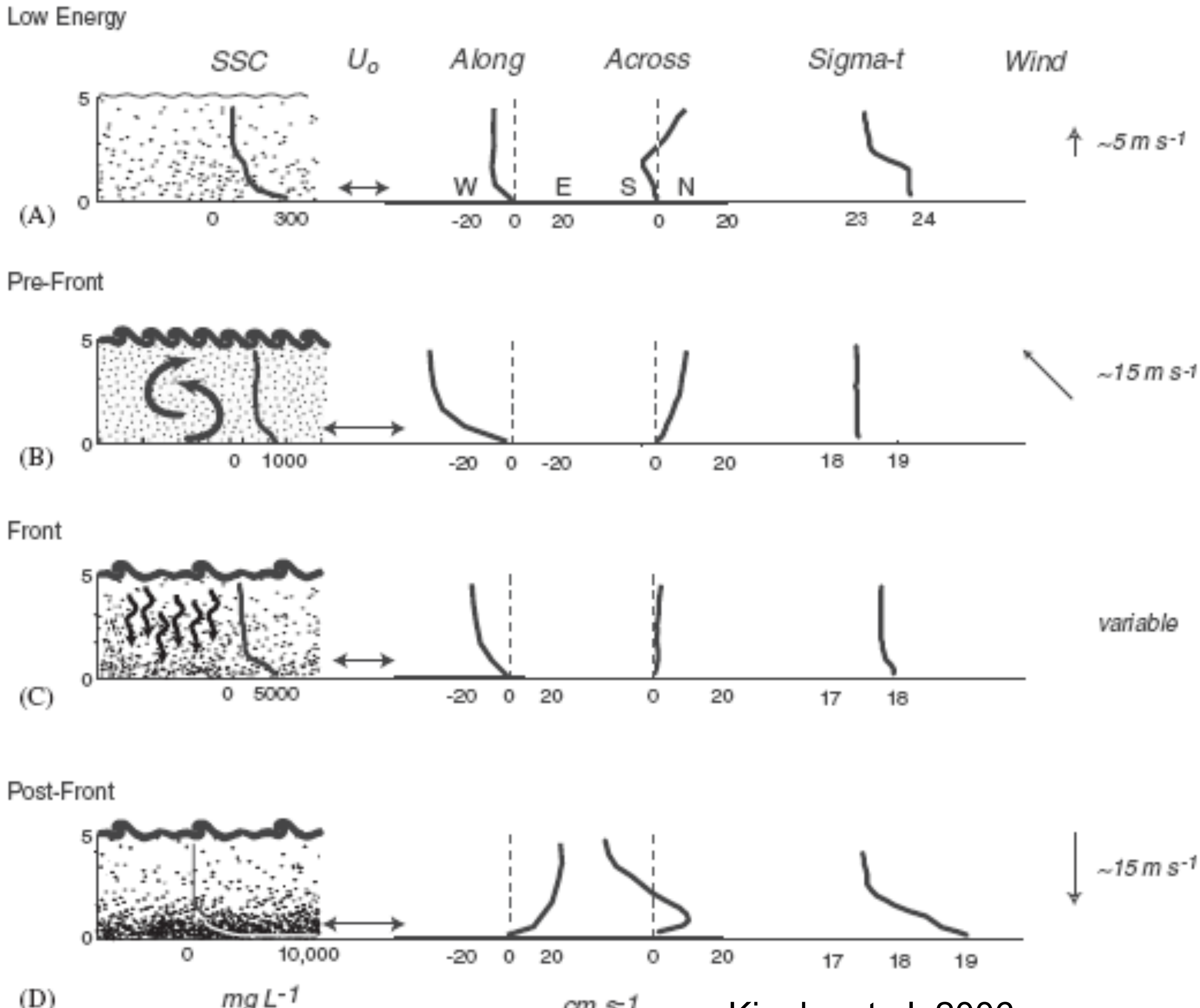
$$\frac{U_\infty}{\sqrt{B}} > or < 2?$$

Heath 2009

Petitcodiac Summary

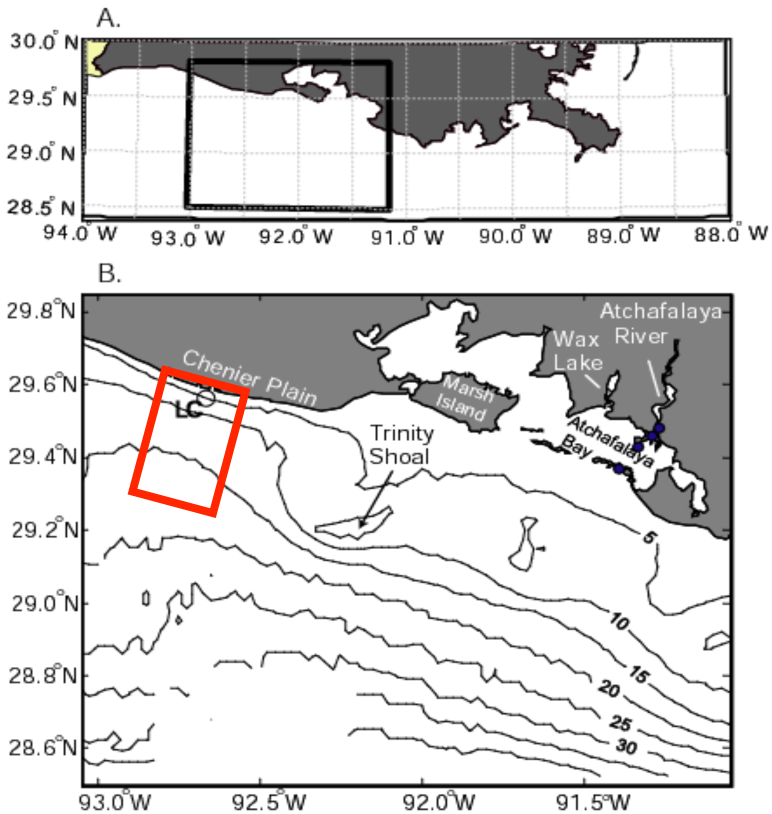
- Floc settling necessary for fluid mud formation
- Ri_c dependence and carrying-capacity threshold noisy but reasonable

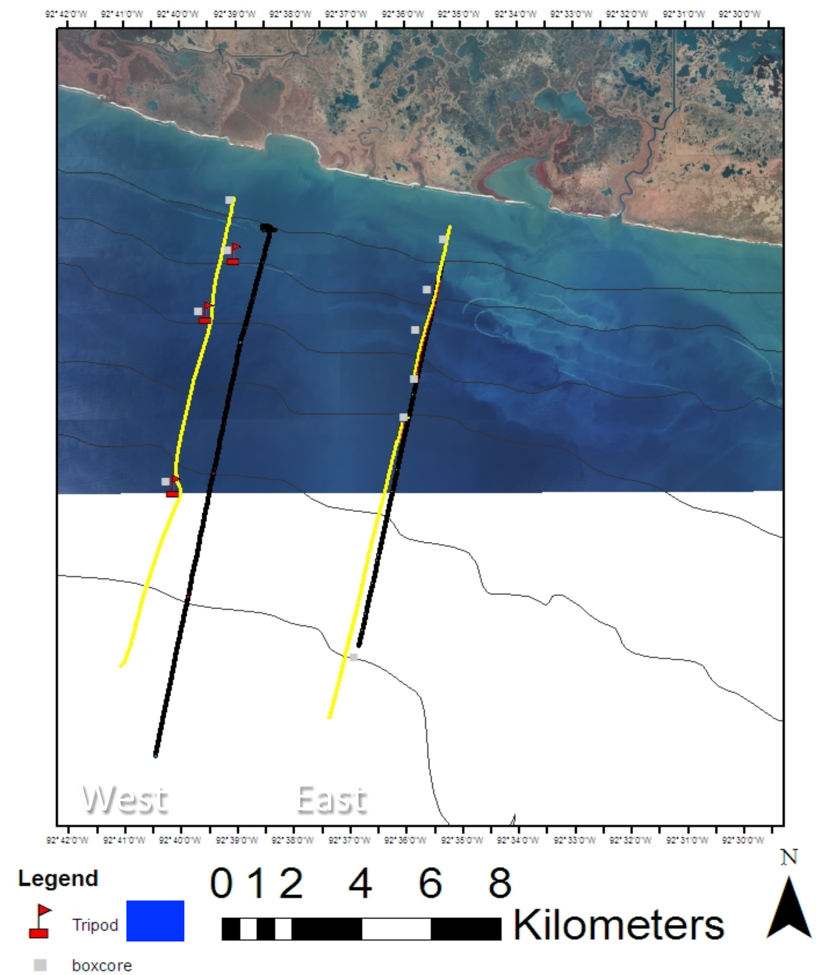

•Most of Louisiana shoreline is retreating, but a section in western LA is prograding
•Prior observations suggested role of cold fronts critical for onshore transport
Source:http://visibleearth.nasa.gov/data/ev124/ev12470_Mississippi.A2002058.1650.1km.jpg



Kineke et al. 2006

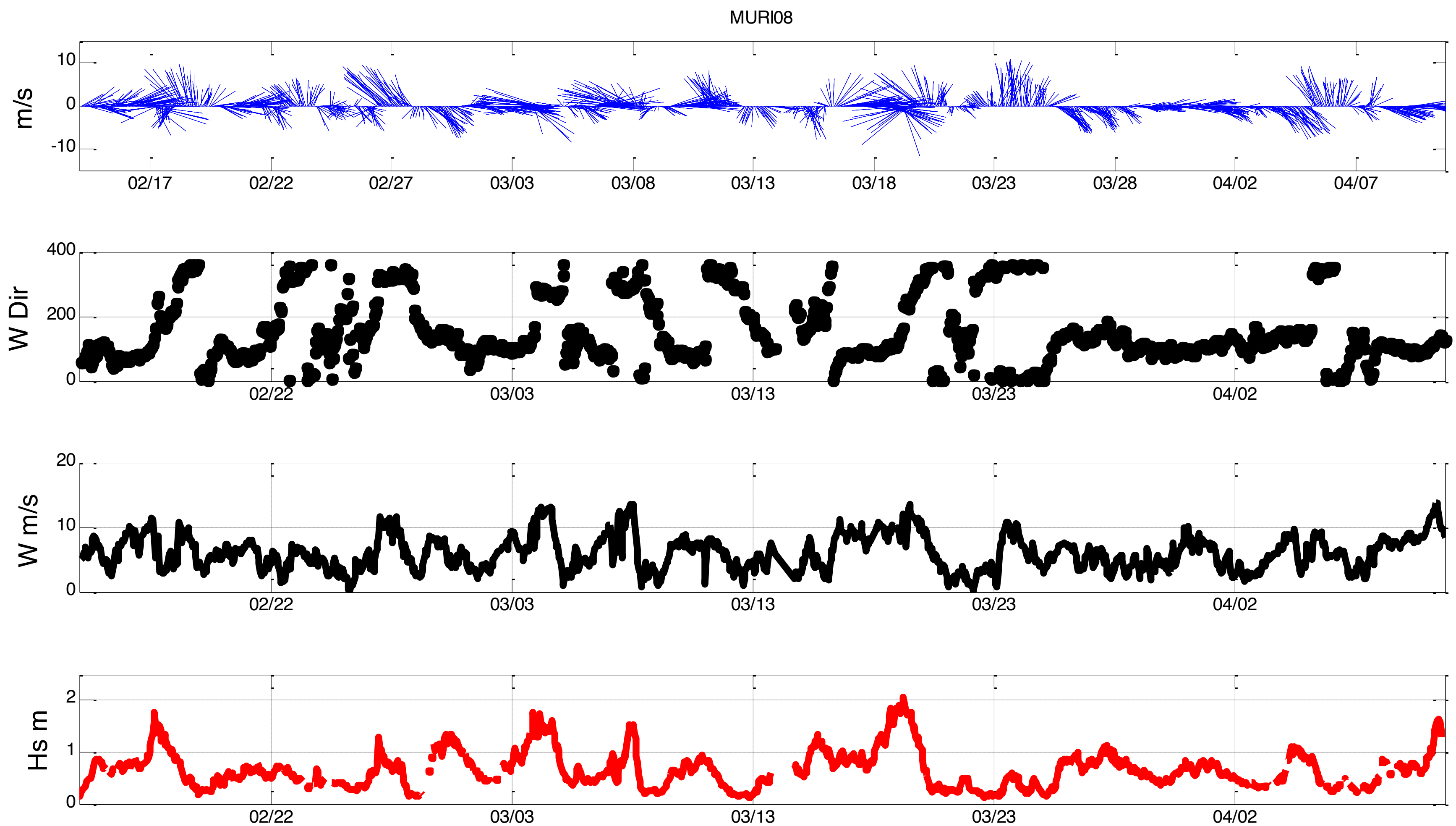
ONR sponsored MURI
JHU, WHOI, BC, MU, MIT



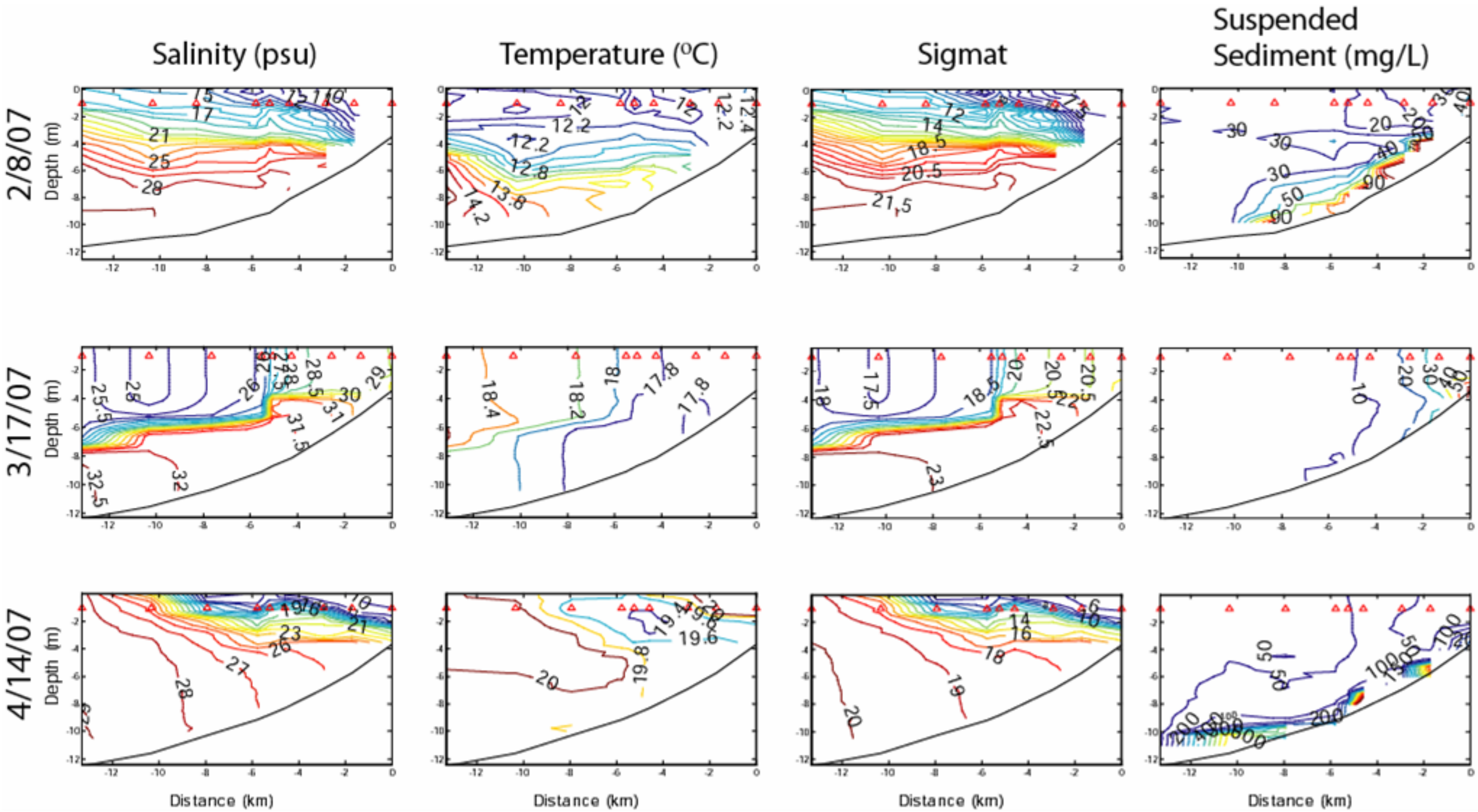


•Water column surveys, coring, bottom boundary layer tripods

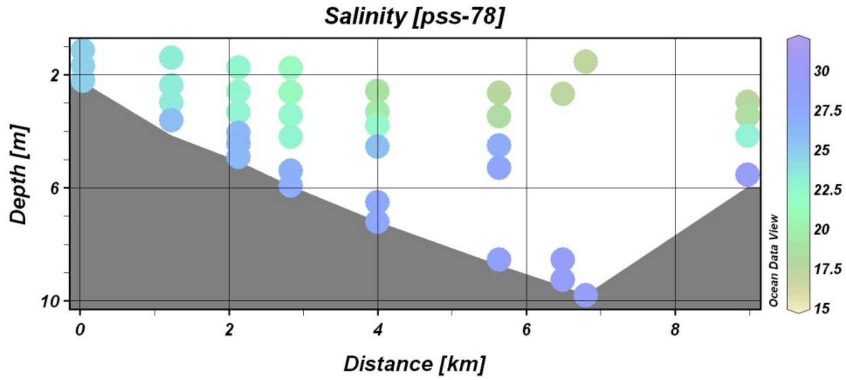
Cold Fronts supply the energy – typical characteristics

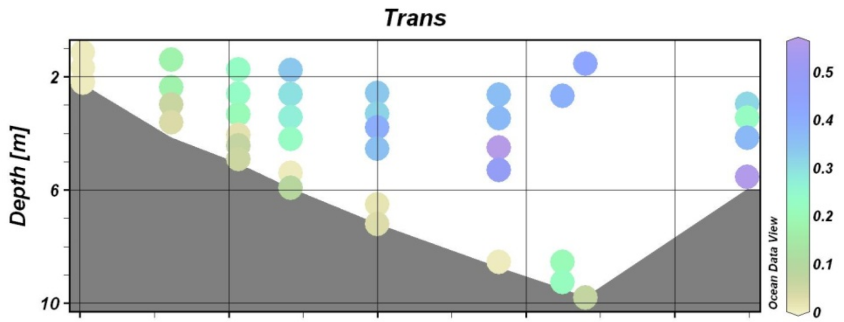


Eastern Transects 2007



LISST

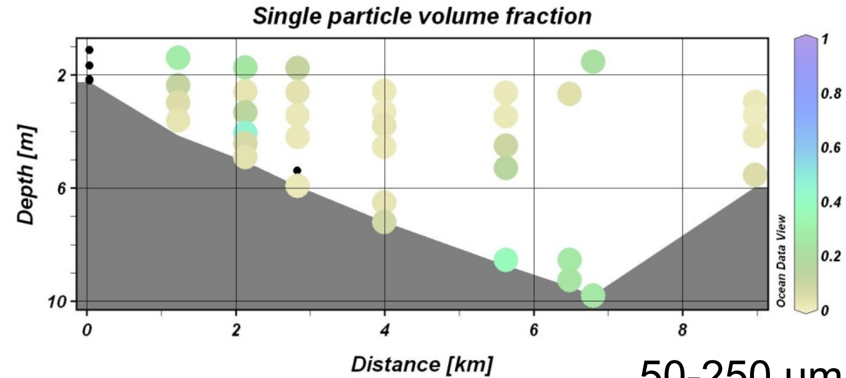




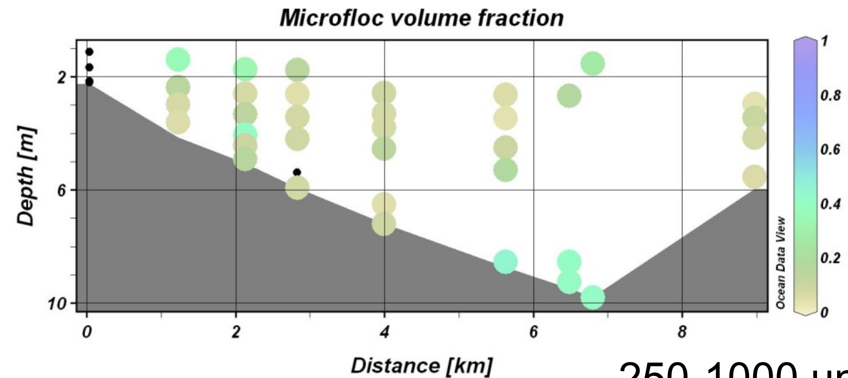
March 2008 East (tripod line)

Mean particle size:
generally 500 – 1000 um
water can clear in < 1.5 hrs

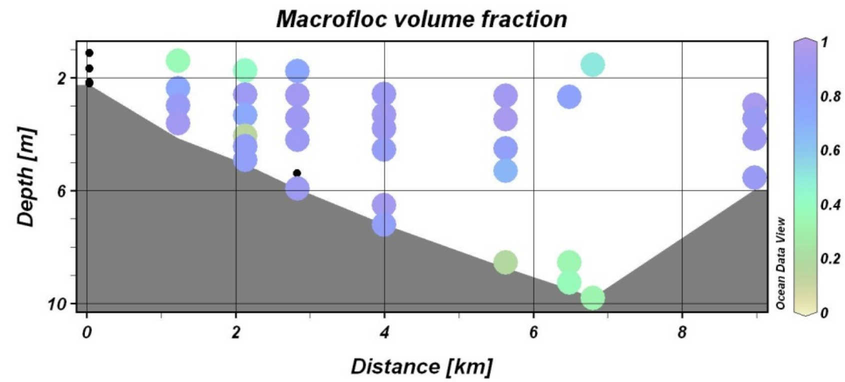
10-50 um



50-250 um



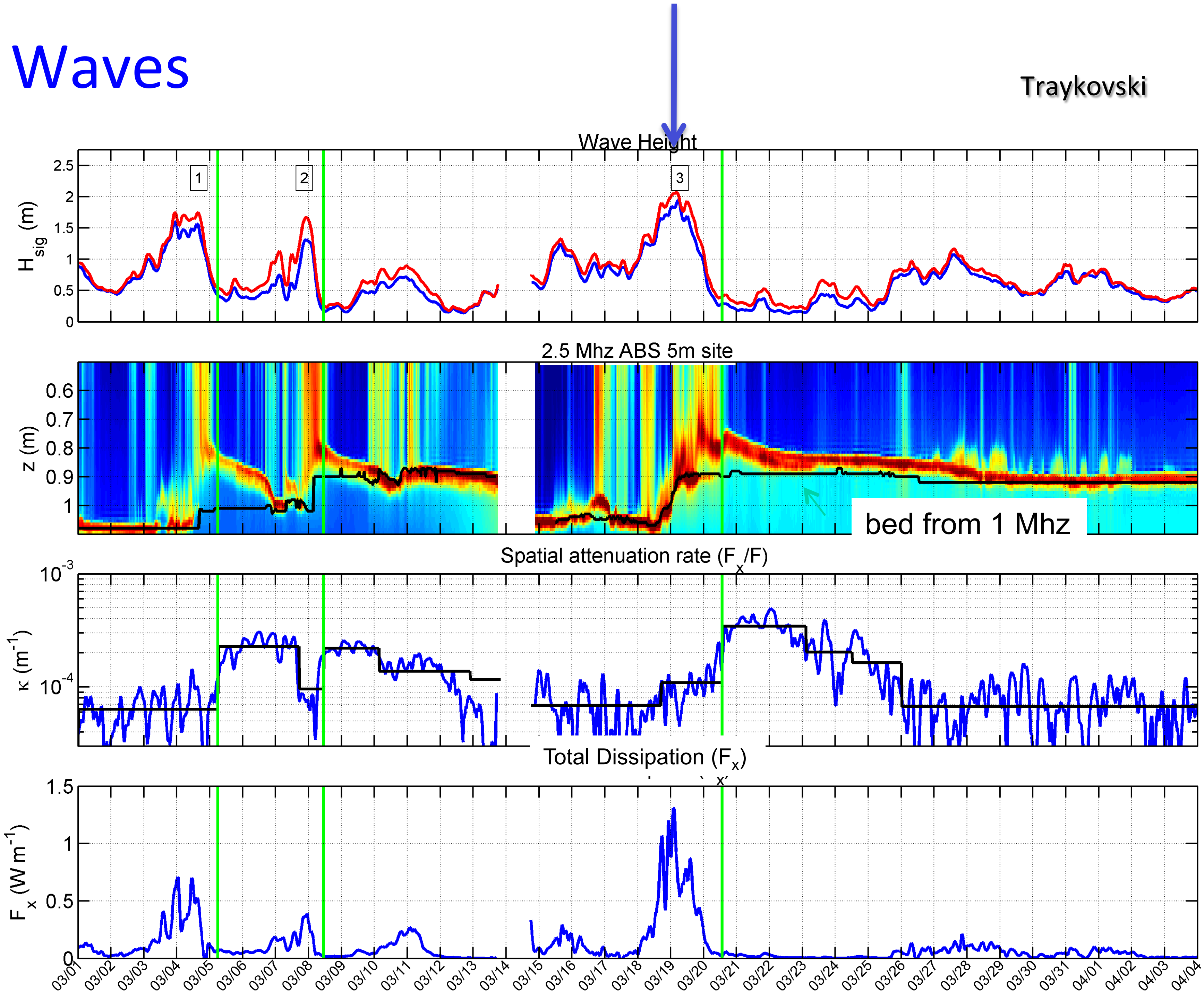
250-1000 um



Meg Estapa

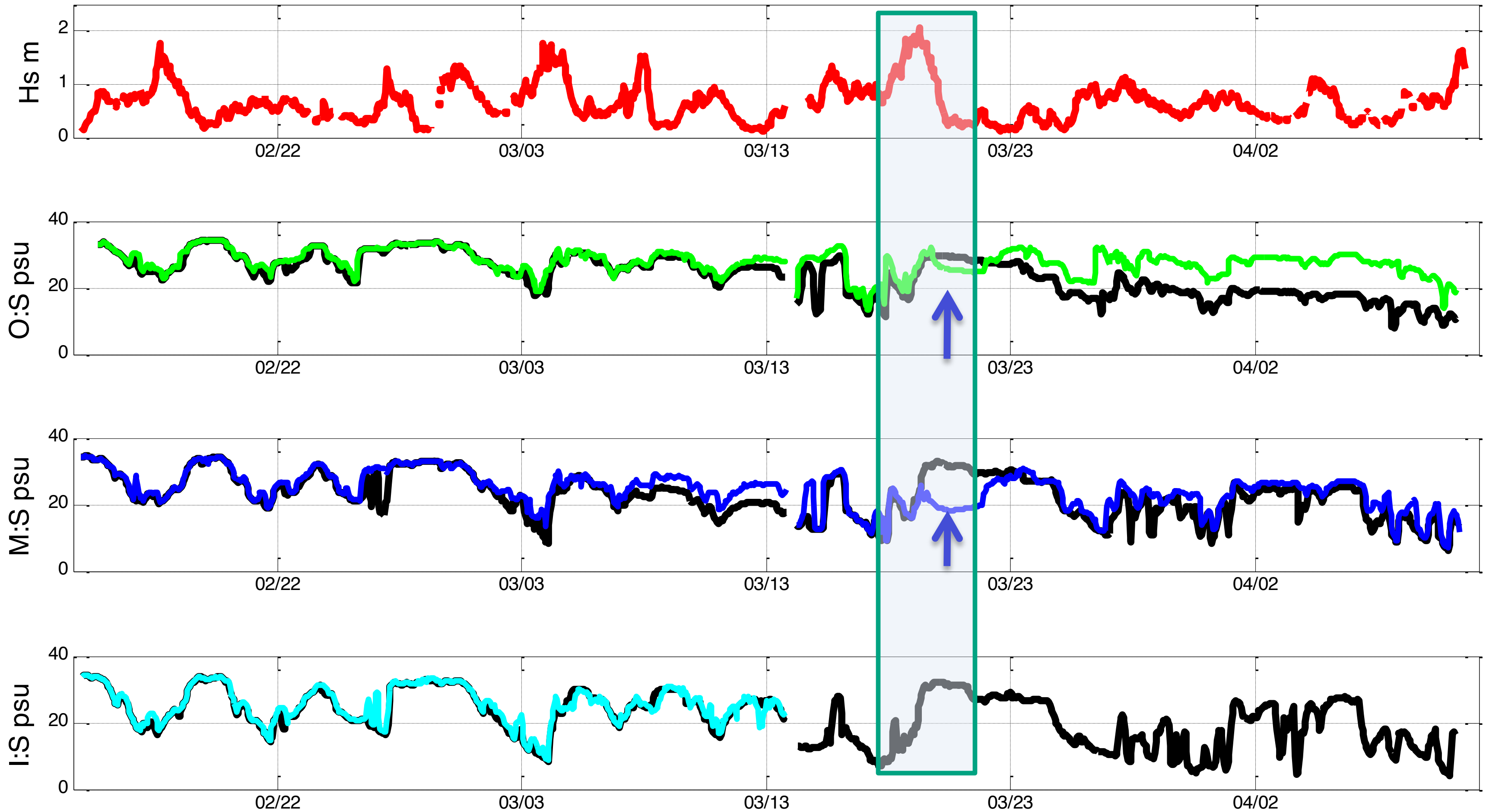
Waves

Traykovski

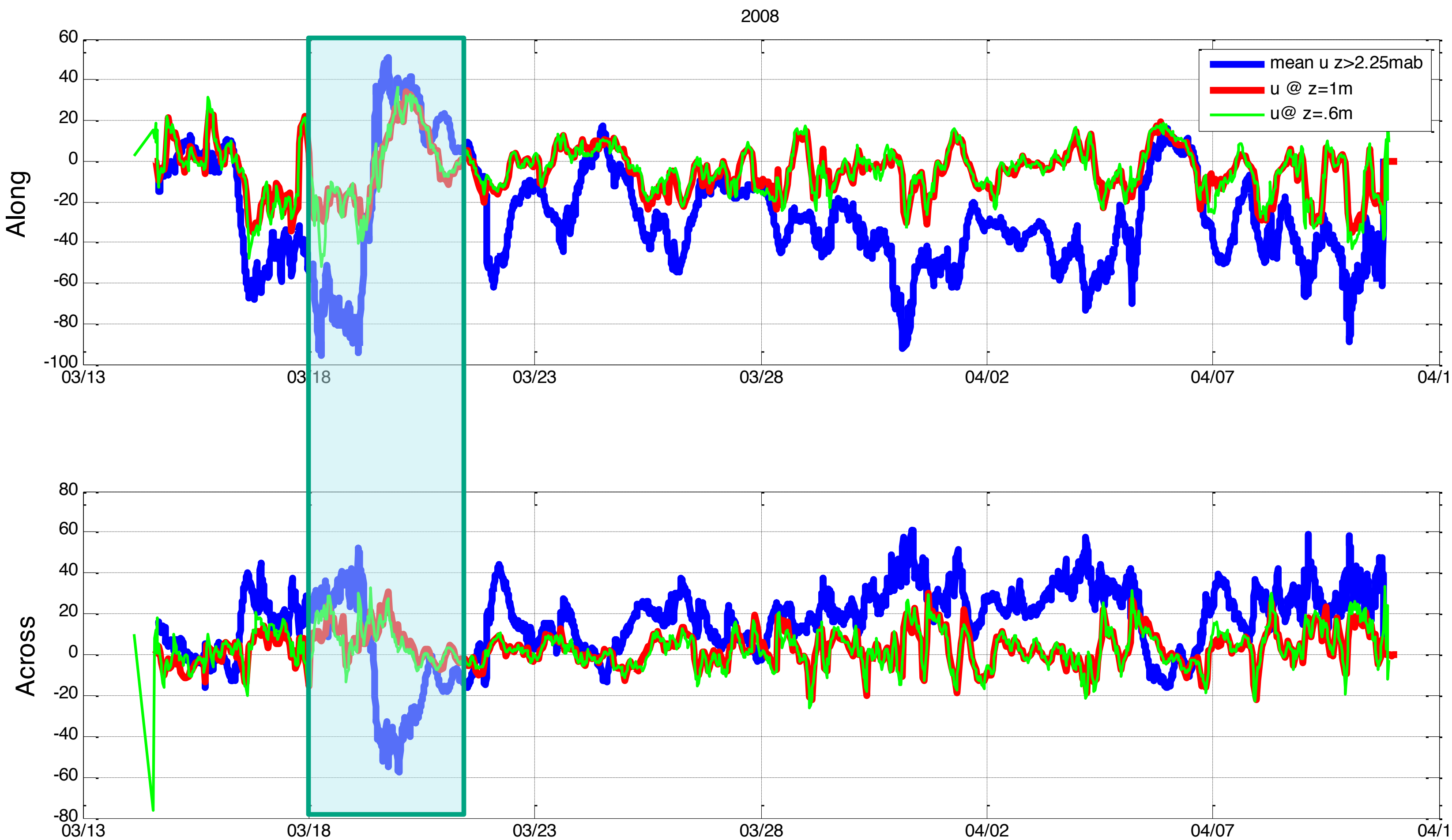


Hs

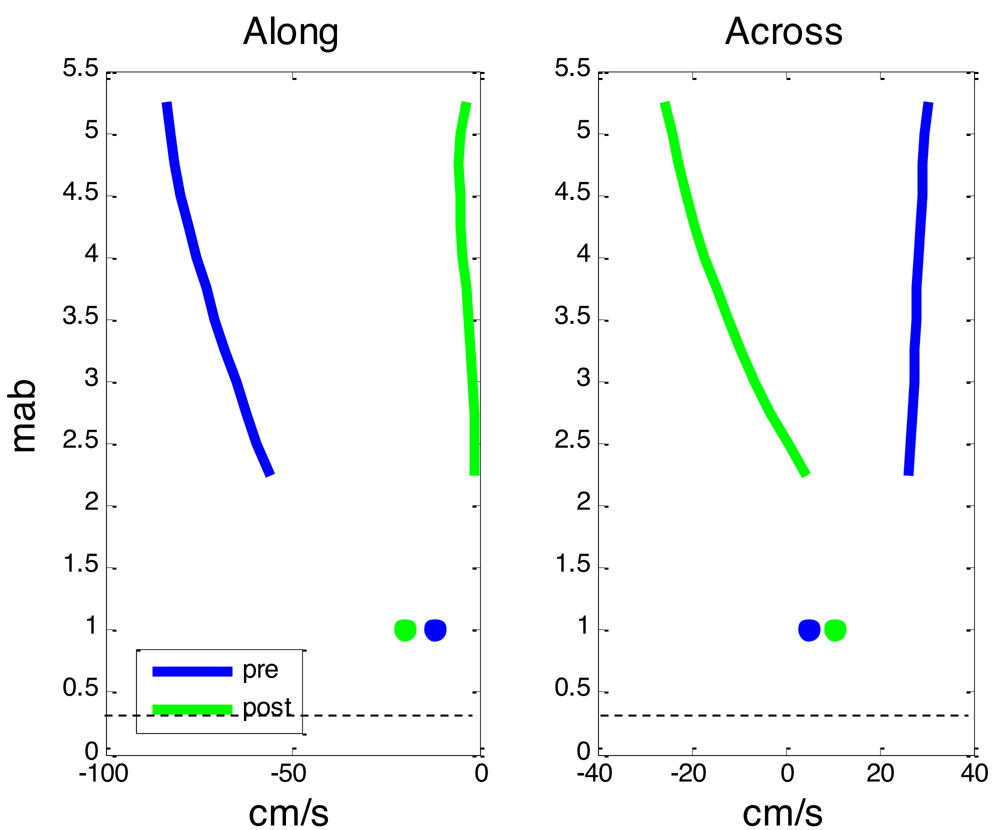
Salinity at 9, 7, 5 m z=1.25 and 0.3 mab



ADV+ADV + ADCP



2008
mean u z>2.25mab
u @ z=1m
u@ z=.6m
Along
60
40
20
0
-20
-40
-60
-80
-100
03/13
03/18
03/23
03/28
04/02
04/07
04/12
Across
80
60
40
20
0
-20
-40
-60
-80
03/13
03/18
03/23
03/28
04/02
04/07
04/12



Post transport estimates

Order 20cm/s * .15 g/l *5 m =
1500 g/s cm

Order 10 – 20 cm/s * 10 g/l * 20 cm (?)=
2000-4000 g/s cm

**interesting caveat…new analysis of ABS observations by Peter Traykovski indicate very weak intermittent offshore gravity flow of very thin mud below the 'bottom' onshore flow…work in progress*

Atchafalaya Summary

- The combination of wave dissipation, event-driven mean currents, water column stratification, and particle characteristics all contribute to net onshore transport and accretion.

- Sediment is delivered in late winter/early spring.

- During passage of CFs, waves initially suspend bottom sediment and mix the water column.

- Post-front, stratification is re-established, rapid settling is enhanced and fluid muds form contributing to wave dissipation.

- Onshore sediment transport of bottom waters is greater than offshore sediment transport in waters column above ~1 m.

Photo courtesy of A. Draut