The Physical Environment of Susquehanna Flats

Larry Sanford

In collaboration with Cassie Gurbisz, Steve Suttles, Michael Kemp, Cindy Palinkas, Jeff Cornwell, Nick Nidzieko, Debbie Hinkle, Angela Cole, Jia Gao, and Alex Fisher

UMCES, Horn Point Laboratory
Cambridge, MD
lsanford@umces.edu

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

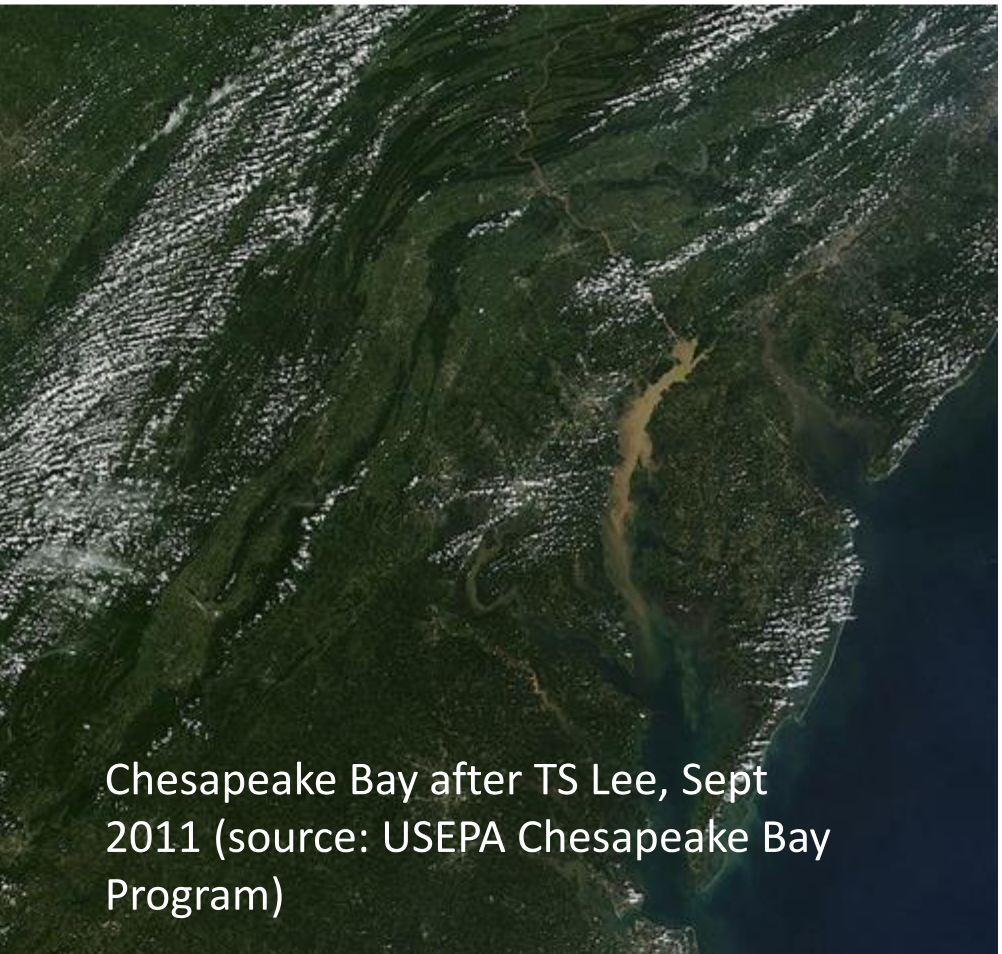
Chesapeake Bay Program

US Army Corps of Engineers
Engineer Research and Development Center

Sea Grant
Maryland

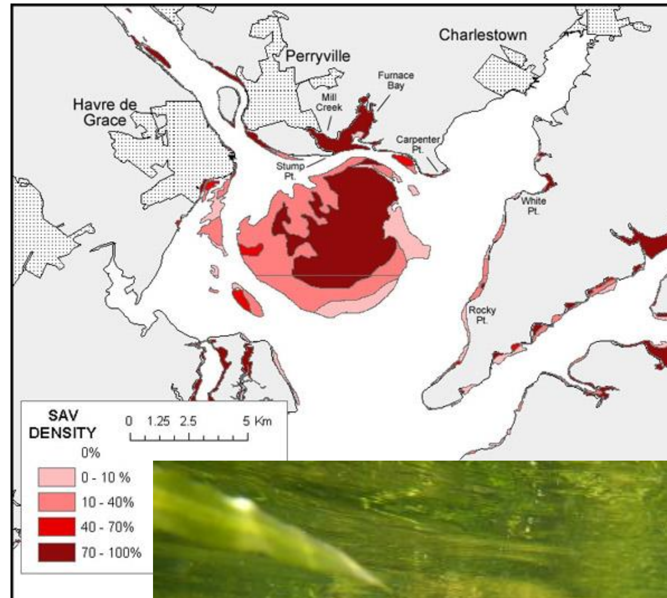
SF is the bay head delta of the Susquehanna River. Its lateral extent is constrained by topography.

Dominated by inputs of fresh water and suspended sediment from the River, but still tidal

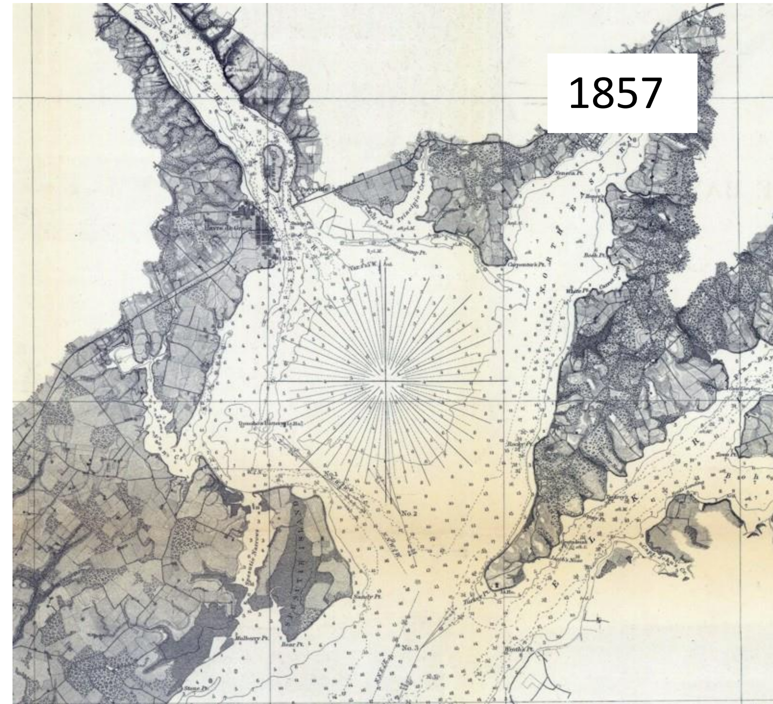


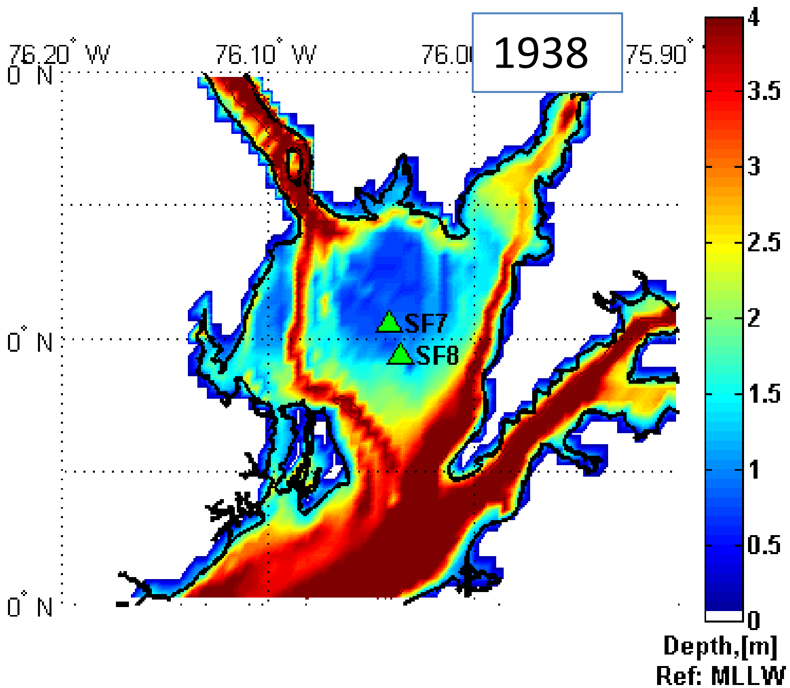
Chesapeake Bay after TS Lee, Sept 2011 (source: USEPA Chesapeake Bay Program)

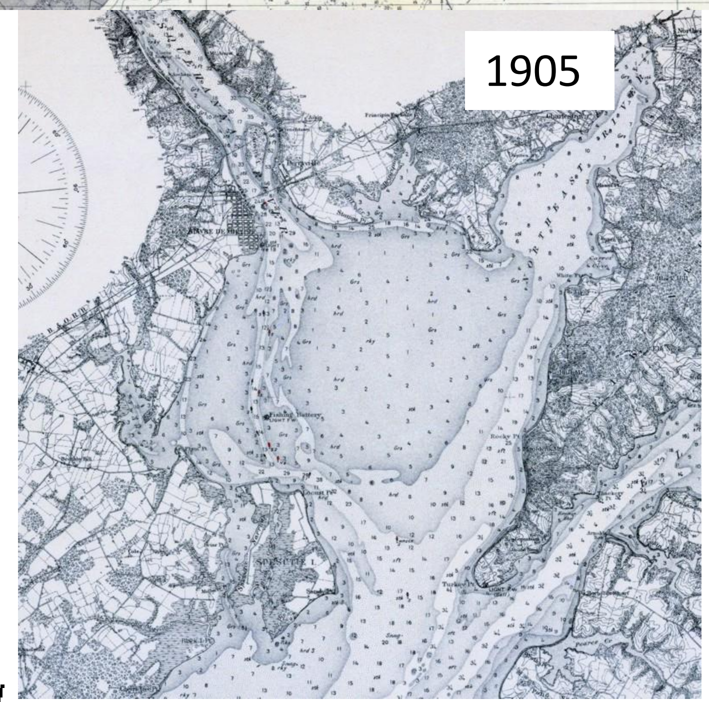
Recent resurgence of large underwater grass bed (source: MD DNR website)



- Expansion of shoal area from 1799 to 1905 due to watershed deforestation and agriculture
- Construction of Conowingo Dam in 1928
- Contraction to 1938?
- Unknown change 1938 to present, collected new bathymetry in 2014.
- Dense grass beds and waterfowl noted except for 1972-2003.

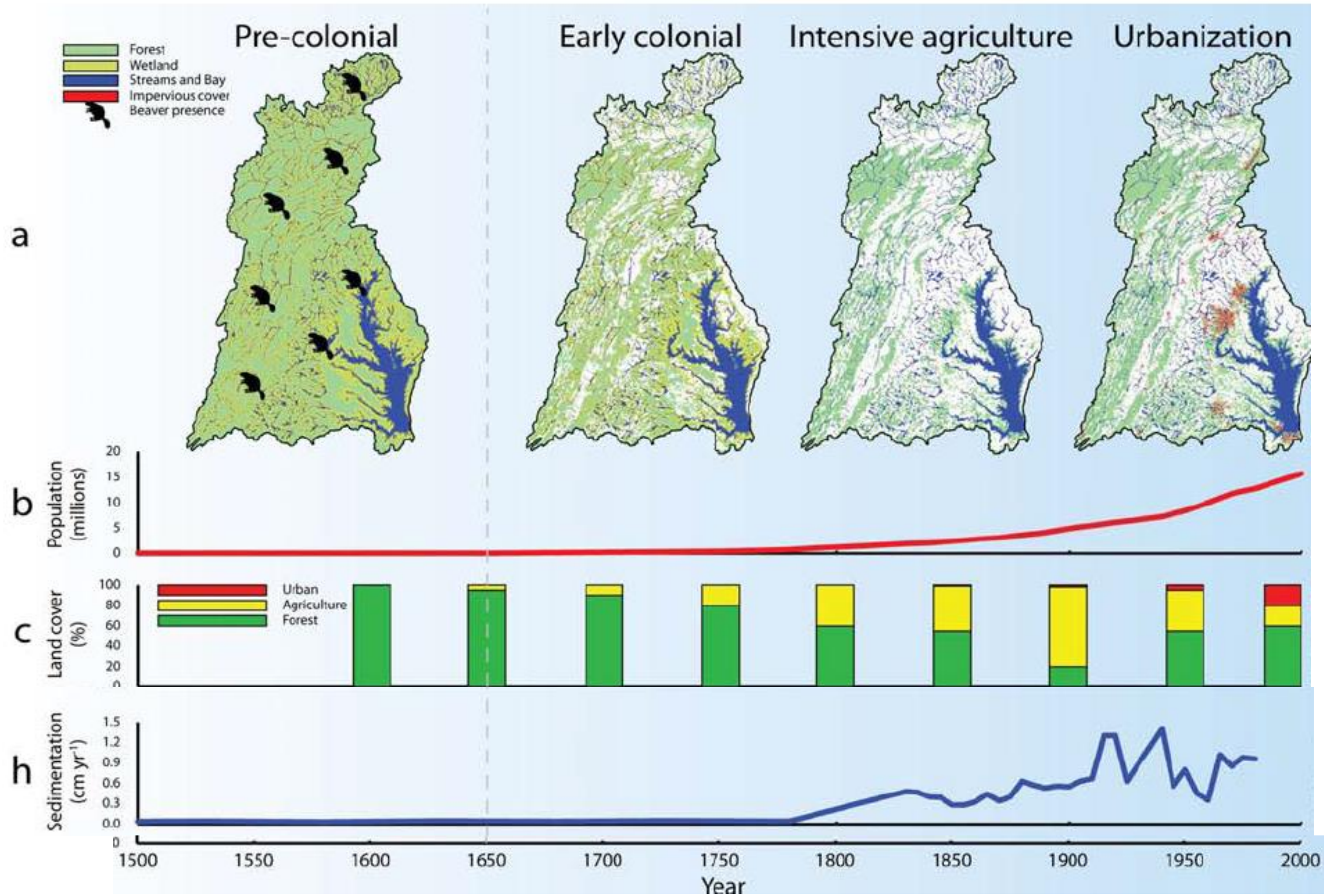




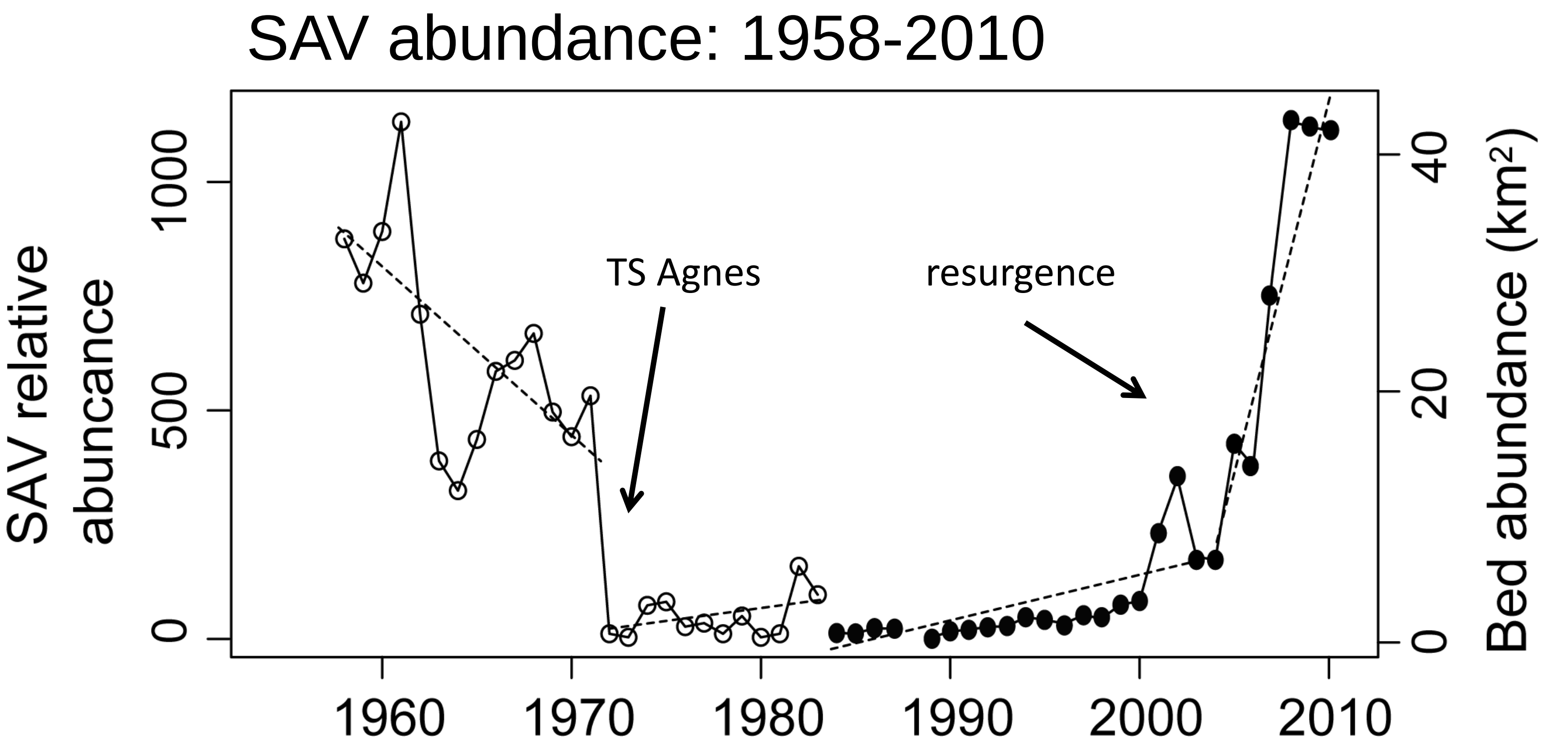


From Brush (2008) – land use and sedimentation estimates in upper Chesapeake Bay

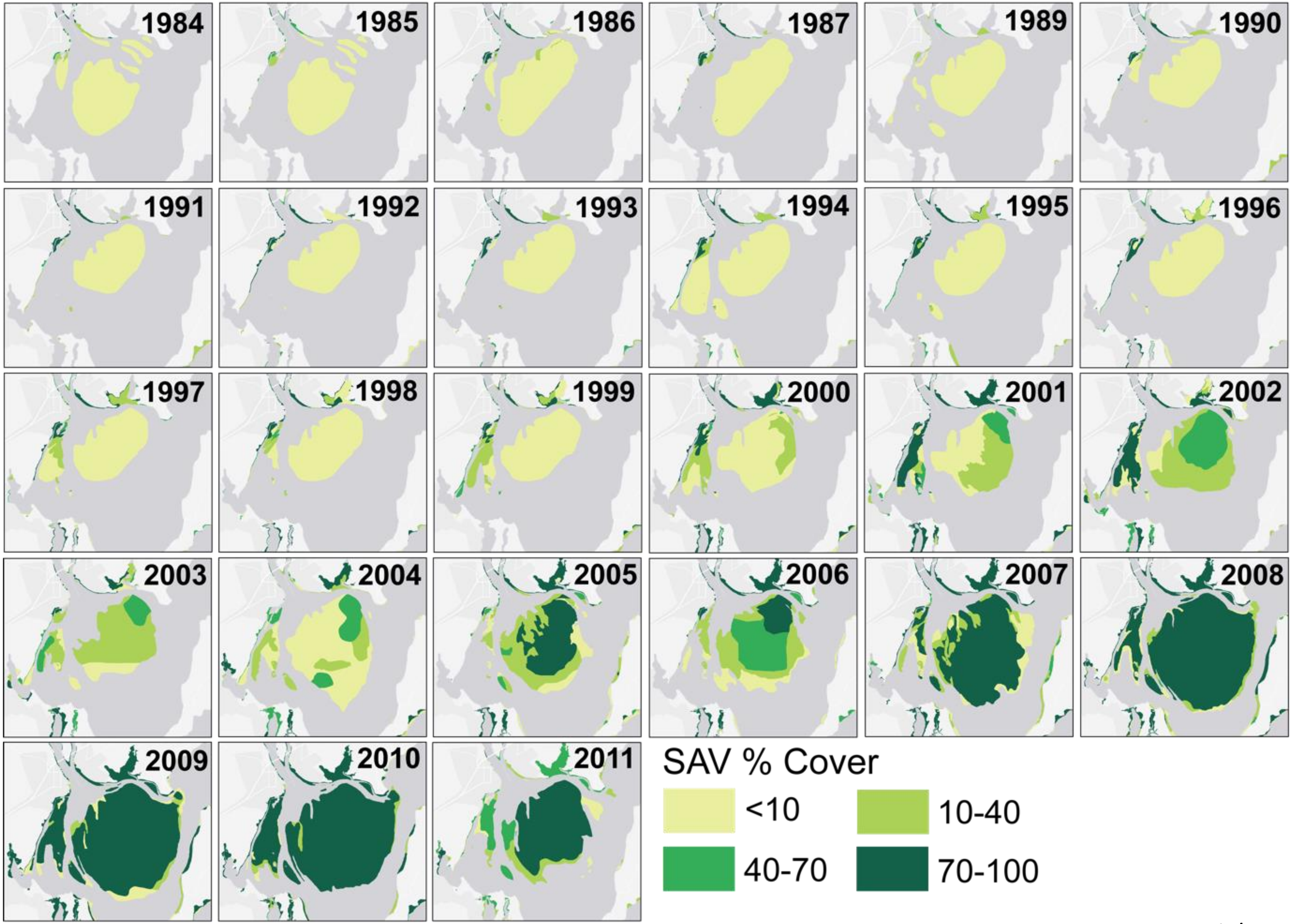
Estuaries and Coasts



SAV bed disappeared after Tropical Storm Agnes in 1972 then recovered suddenly after 30 years



Data: MDDNR, Orth/VIMS



Data: Orth/VIMS

Modern Physical Characteristics

- Approximately 10 km across basin at its widest point, ~9,500 m shallow flats and ~500 m channelized
- Shallow water depths (< 1.5 m) over SF
- Deep (> 6 m) shipping channel on western side
- Spring tidal range ~0.8 m, similar meteorological tides
- Susquehanna River flow averages ~1100 $m^3 s^{-1}$, lower in summer, instantaneous flow controlled at Conowingo Dam 10 km upstream from SF
- Sandy bottom sediments, fining towards south
- Dense submerged grass beds in late summer, absent in winter and early spring

Questions

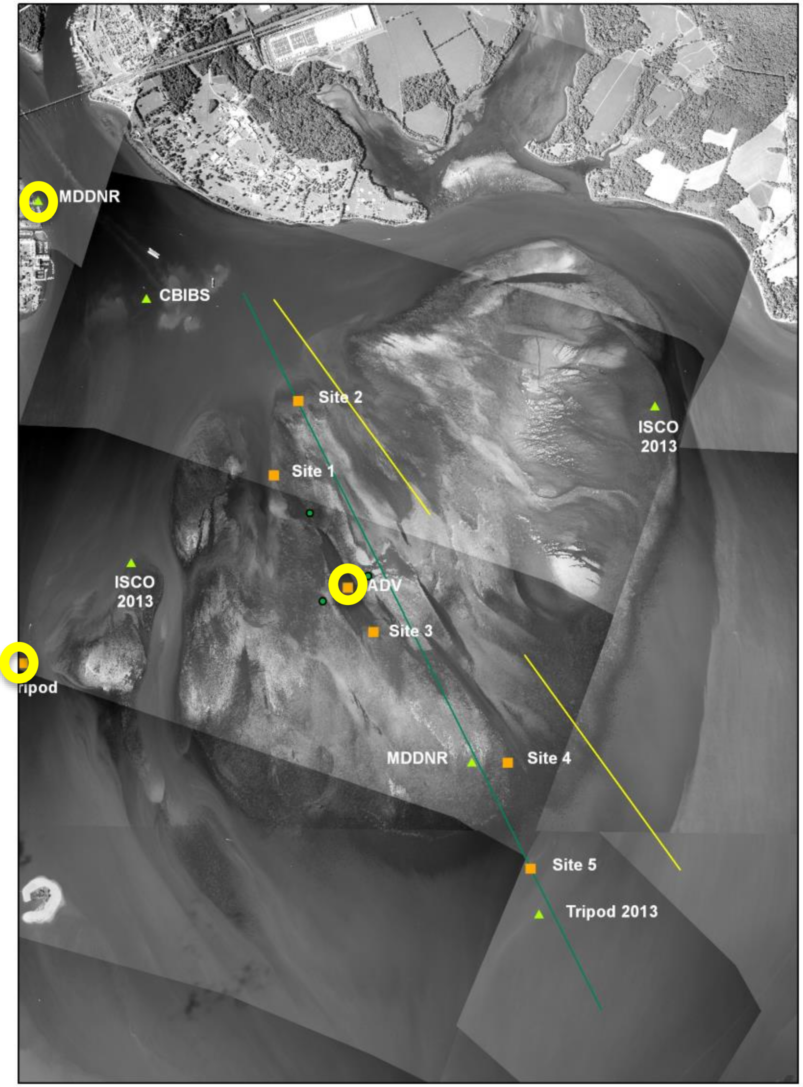
- Underwater grasses in CB are light limited, but at SF the largest grass bed in the CB is directly downstream of the largest source of suspended solids
  - Is reduced turbidity inside the bed because of enhanced sedimentation, or flow diversion around the bed, or both?
  - Do flow and sedimentation patterns change seasonally with changes in grass density?
- The tide rises and falls almost simultaneously inside and outside the bed (shown below).
  - How does exchange with the bed take place?
- This region is both riverine and tidal
  - What is the relative influence of these forcings?

Now let’s look at some data

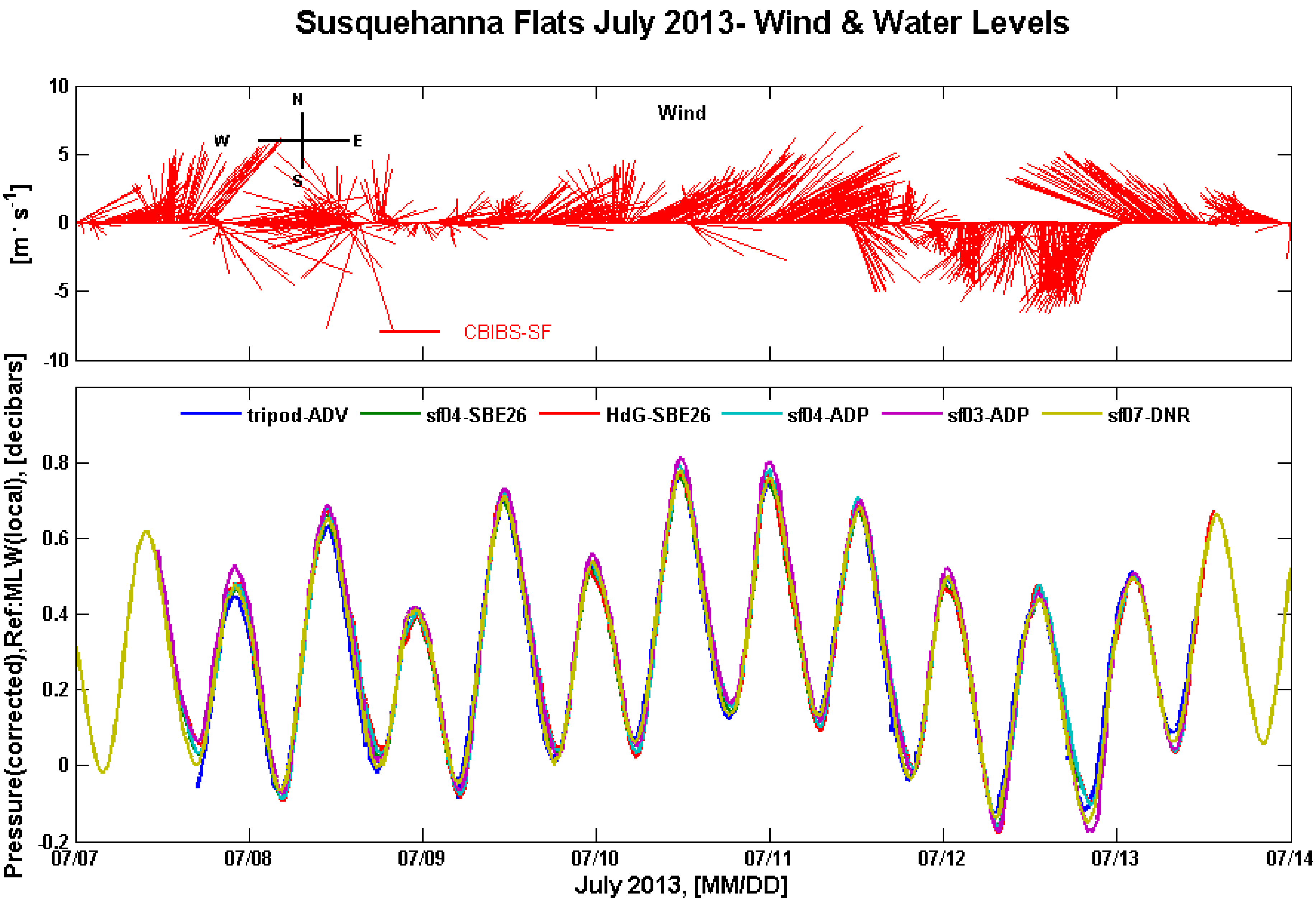
SF Deployment Site Locations :

July & September 2013

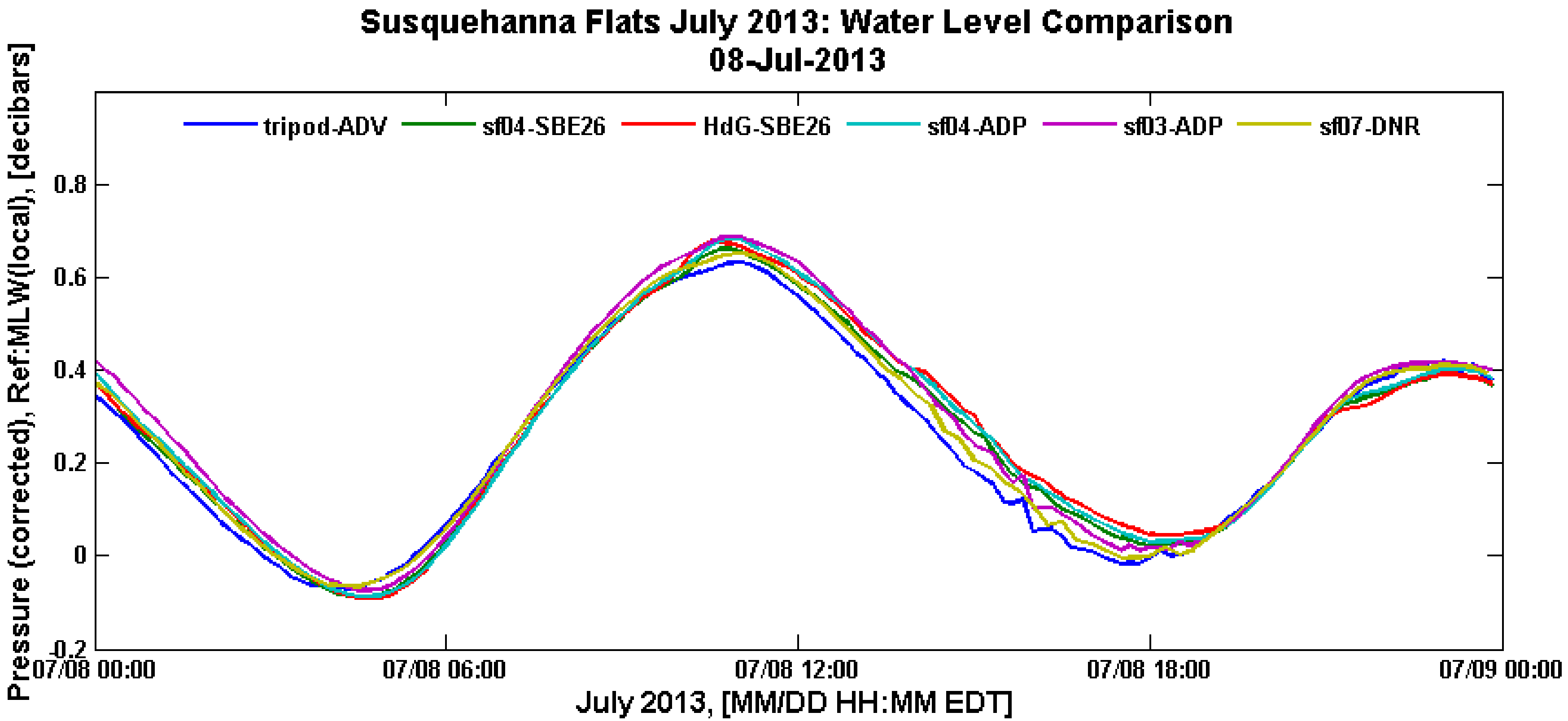
August 2014



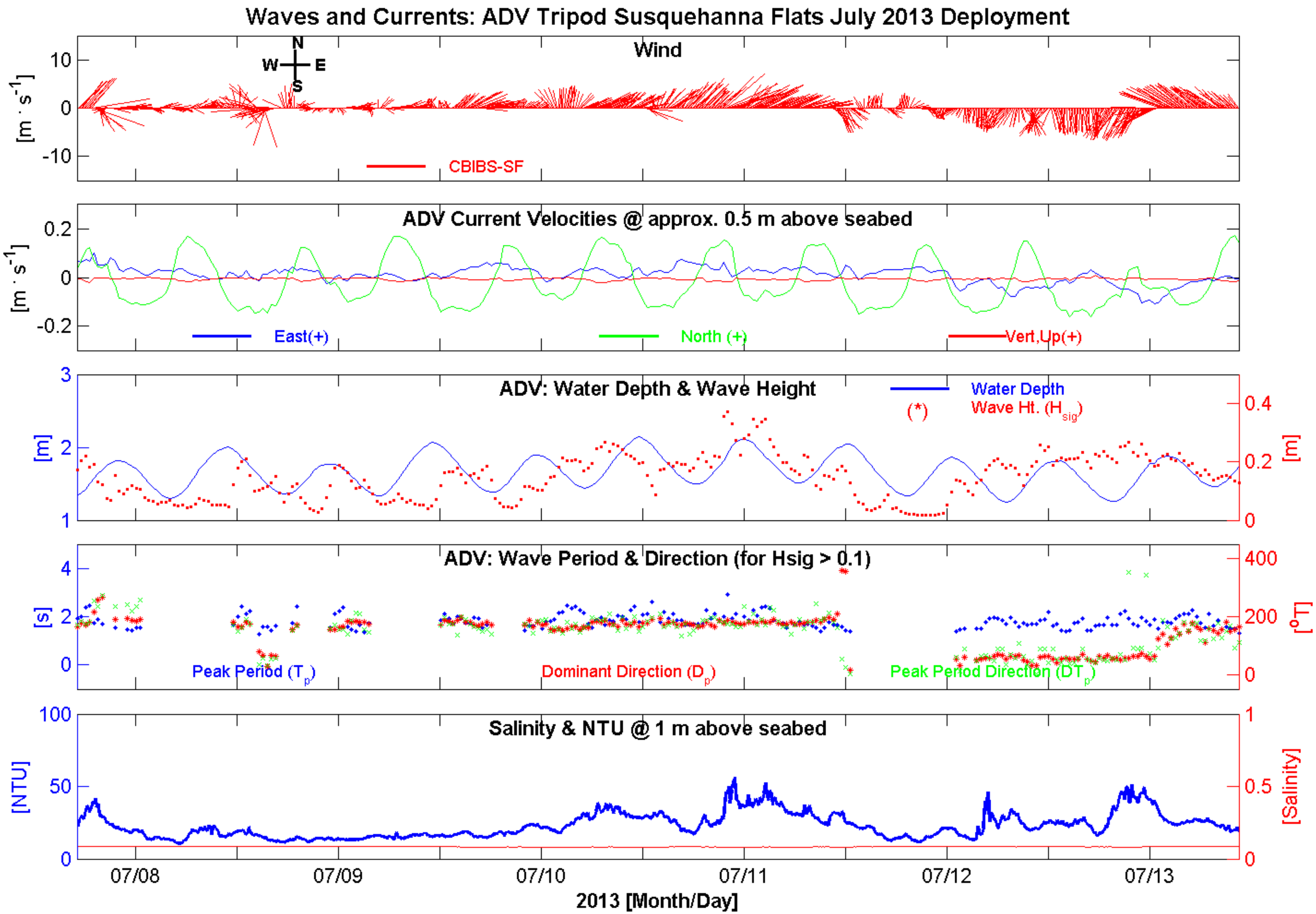
2013 Observations



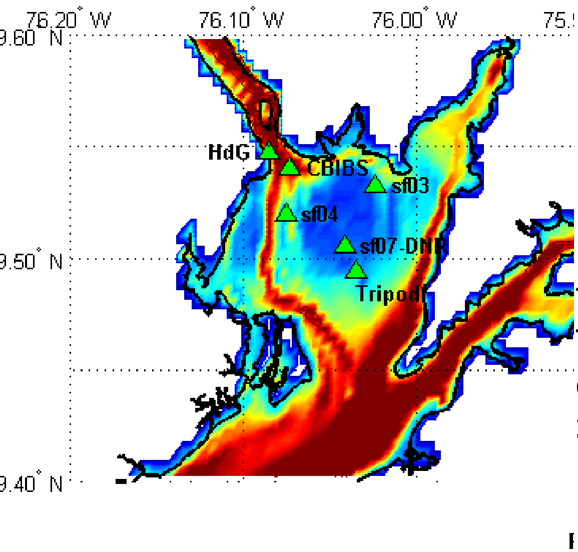
Susquehanna Flats July 2013- Wind & Water Levels
Wind
N
W
E
S
CBIBS-SF
[m · s^-1]
10
5
0
-5
-10
tripod-ADV
sf04-SBE26
HdG-SBE26
sf04-ADP
sf03-ADP
sf07-DNR
Pressure(corrected),Ref:MLW(local), [decibars]
0.8
0.6
0.4
0.2
0
-0.2
07/07
07/08
07/09
07/10
07/11
07/12
07/13
07/14
July 2013, [MM/DD]


Susquehanna Flats July 2013: Water Level Comparison
08-Jul-2013
tripod-ADV
sf04-SBE26
HdG-SBE26
sf04-ADP
sf03-ADP
sf07-DNR
Pressure (corrected), Ref:MLW(local), [decibars]
0.8
0.6
0.4
0.2
0
-0.2
07/08 00:00
07/08 06:00
07/08 12:00
07/08 18:00
07/09 00:00
July 2013, [MM/DD HH:MM EDT]

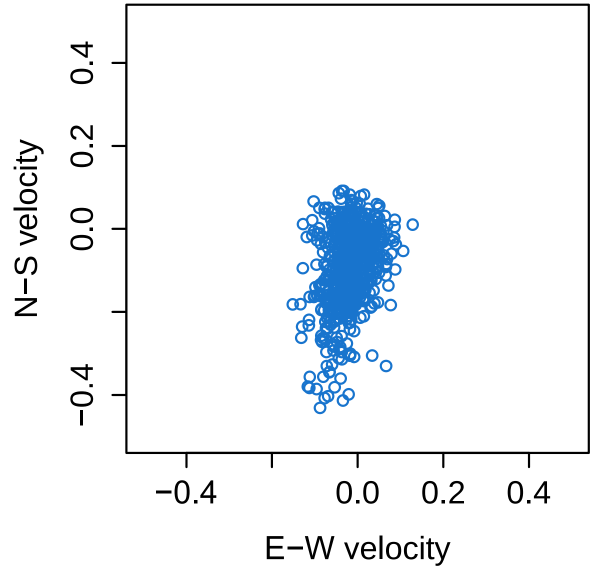
Summary Results @ Tripod Site:



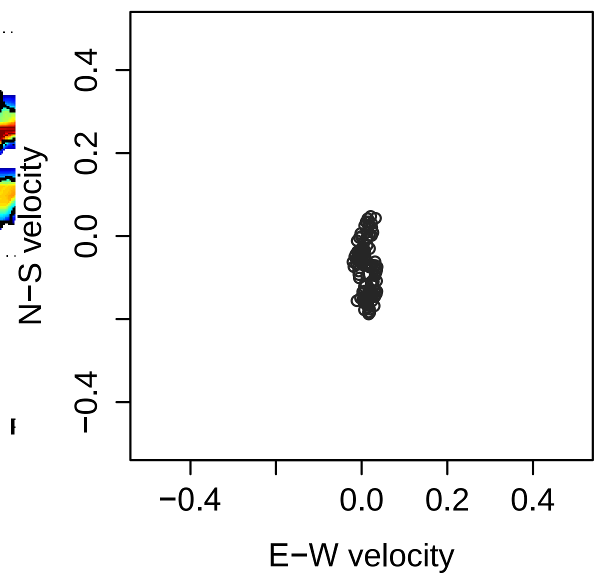
Currents in July 2013



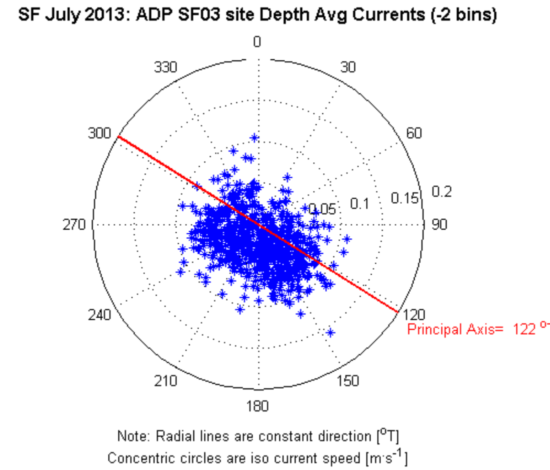
Jul SF4



Jul CBIBS

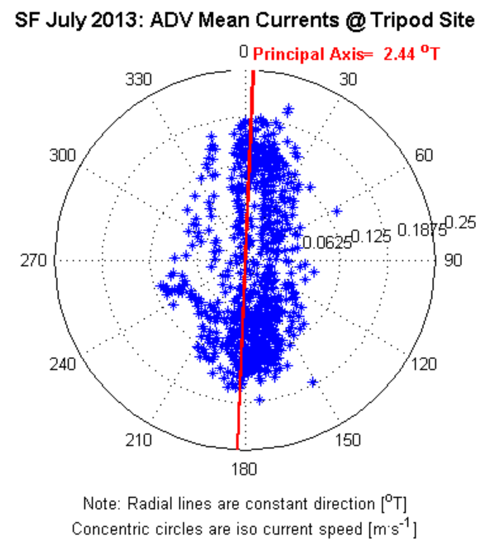


Jul SF3

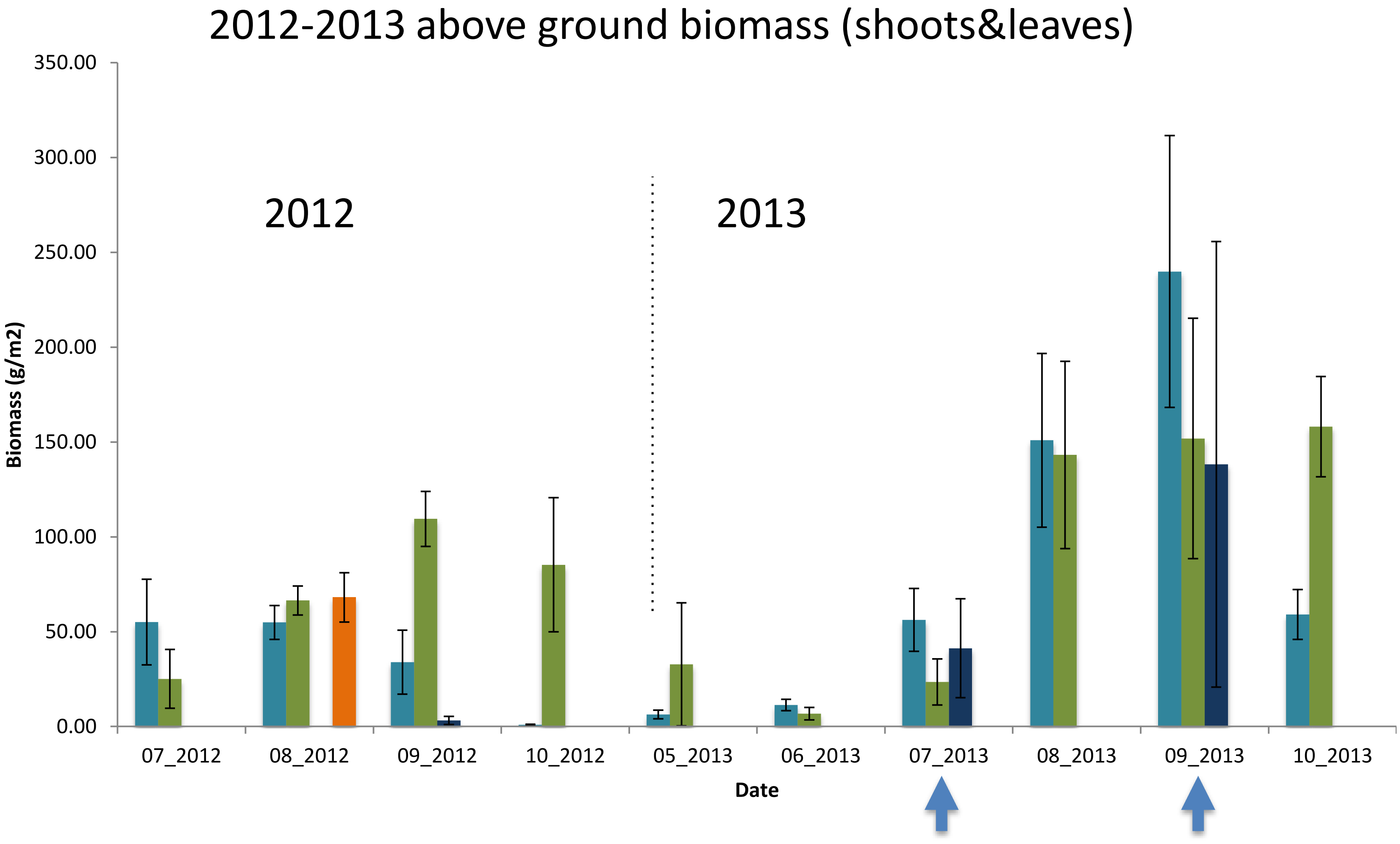


Note ~ 2x zoom on RHS

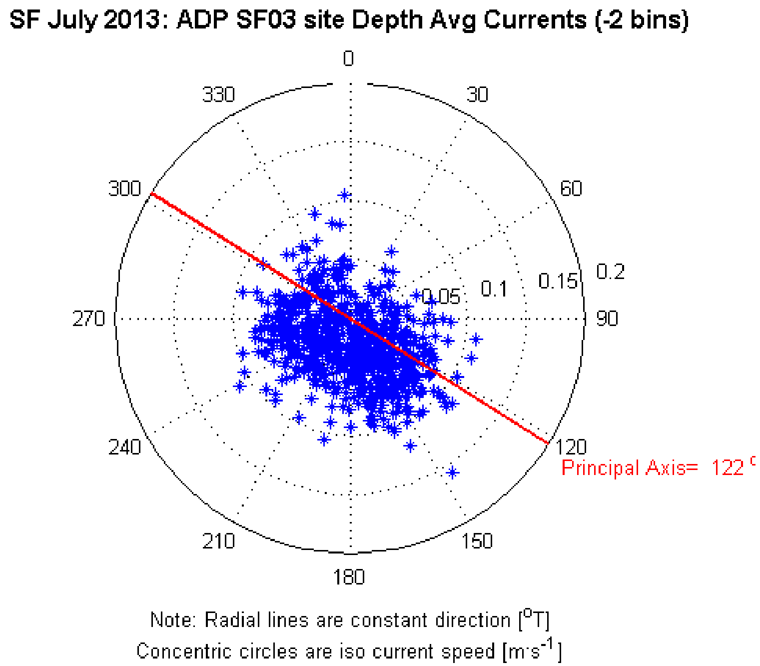
Jul Tripod



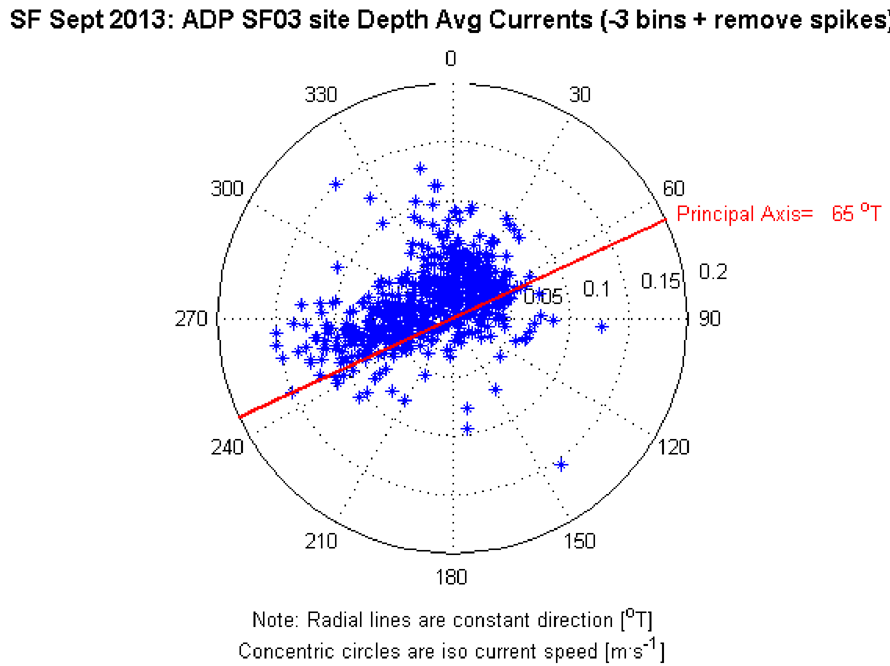
Plant biomass was 4x higher in September 2013 than in July 2013



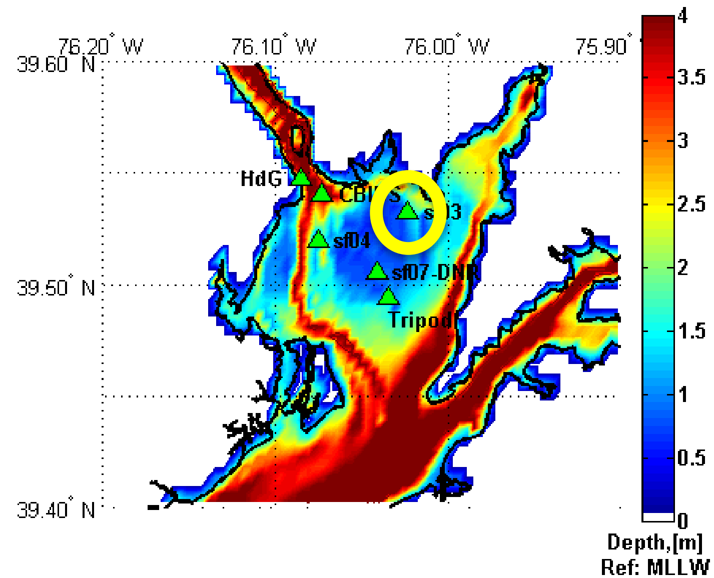
July SF3

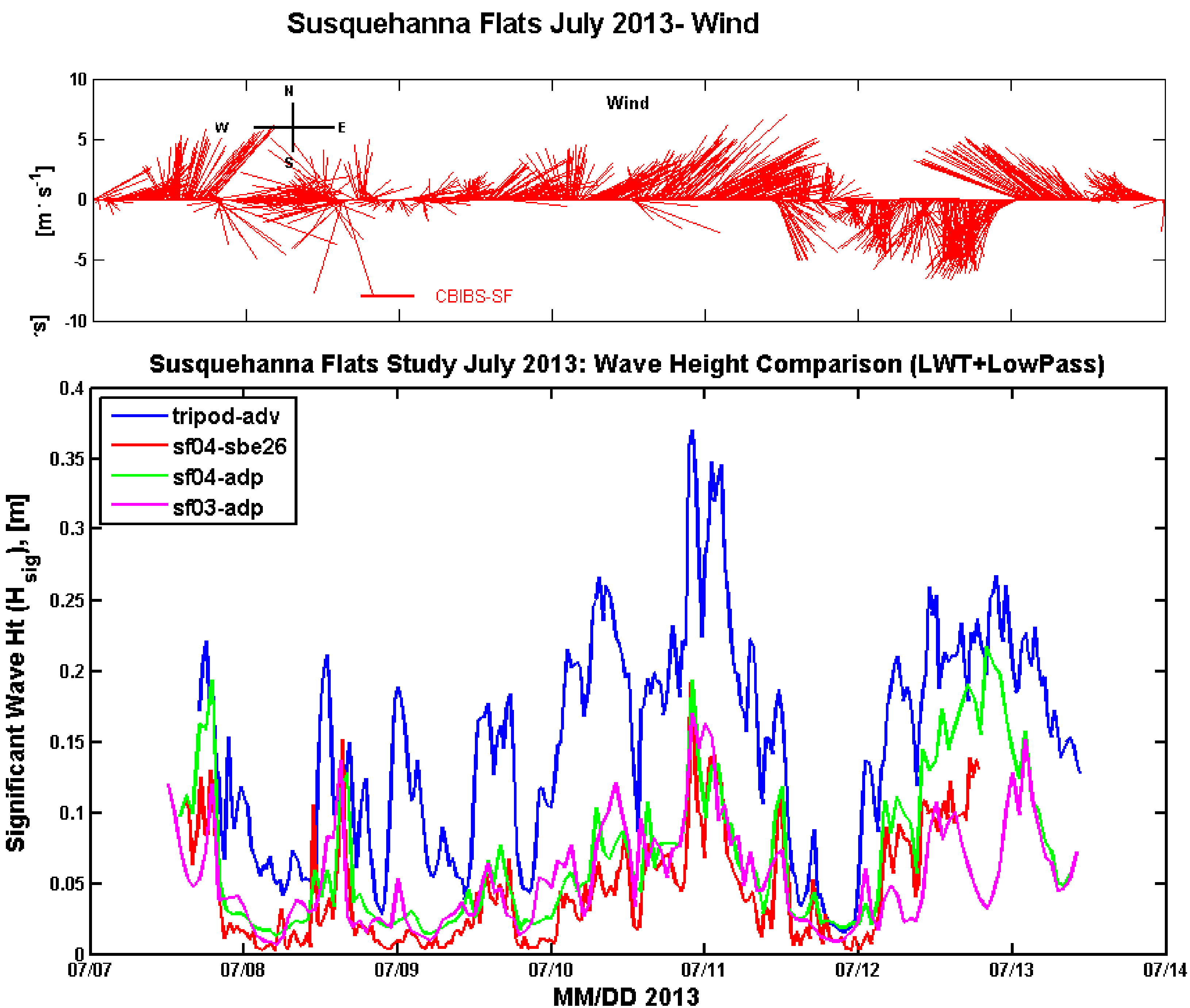


Sept SF3



Tidal currents at SF3, in densest NE corner of SAV bed, changed orientation from July to September and became more on-off shoal oriented

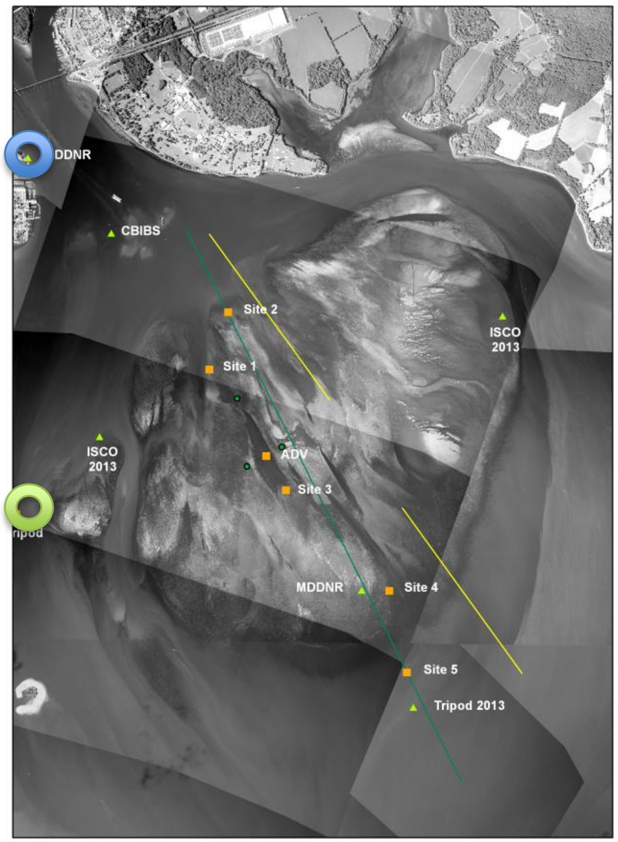


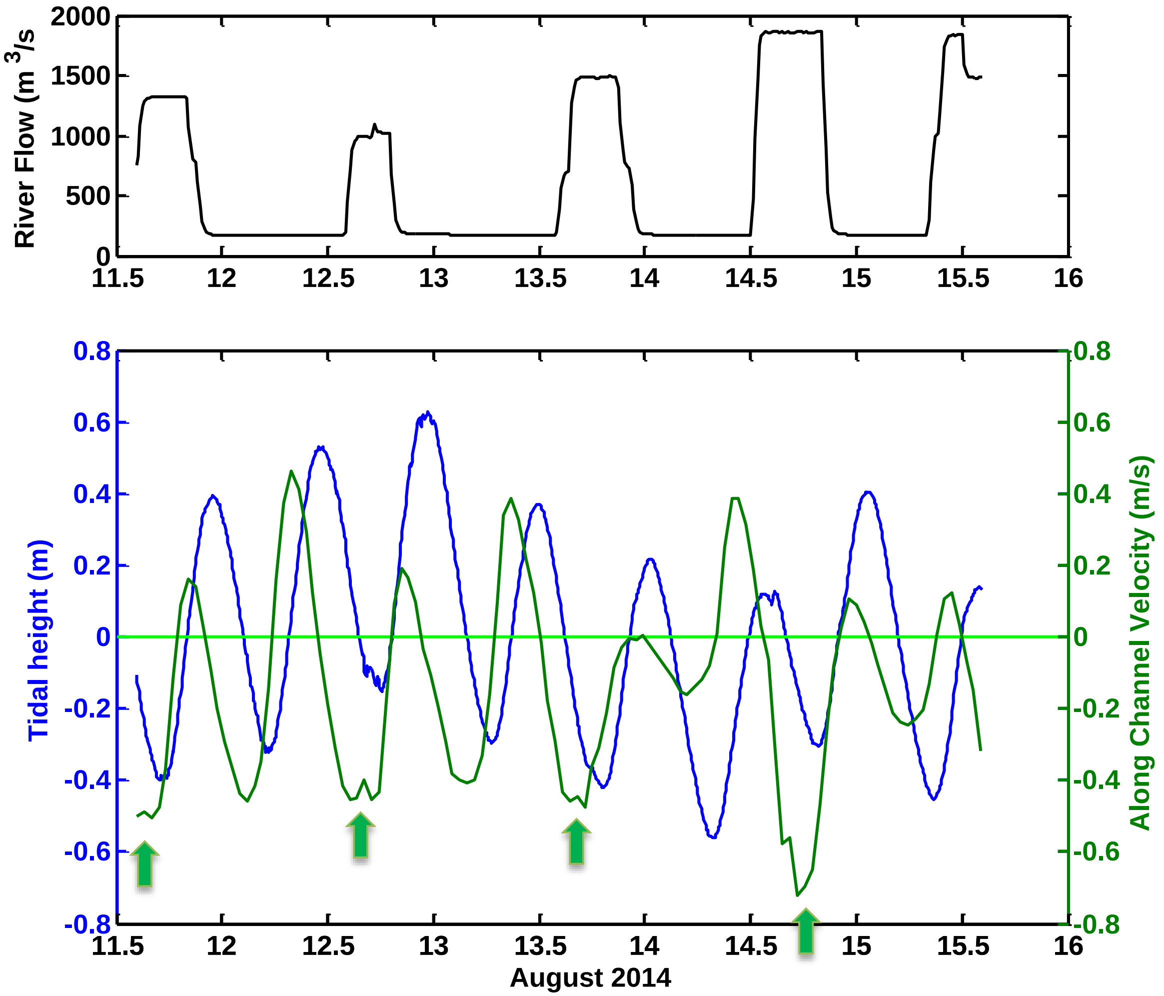


Susquehanna Flats July 2013- Wind
Wind
N
W
E
S
CBIBS-SF
[m · s-1]
10
5
0
-5
-10
Susquehanna Flats Study July 2013: Wave Height Comparison (LWT+LowPass)
tripod-adv
sf04-sbe26
sf04-adp
sf03-adp
Significant Wave Ht (Hsig), [m]
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
07/07
07/08
07/09
07/10
07/11
07/12
07/13
07/14
MM/DD 2013

2014 Observations

Interactions between river flow, tides, and channel currents

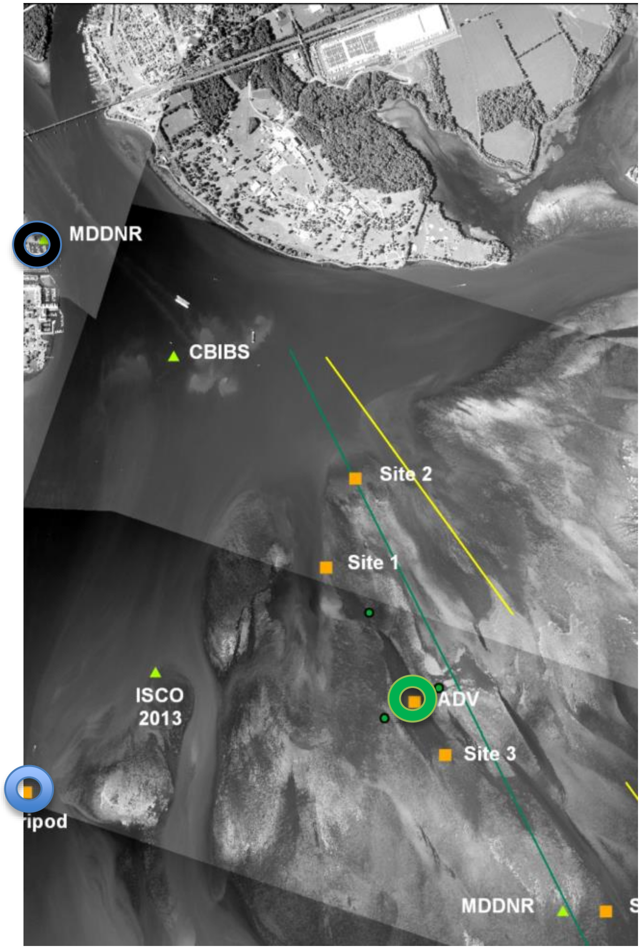


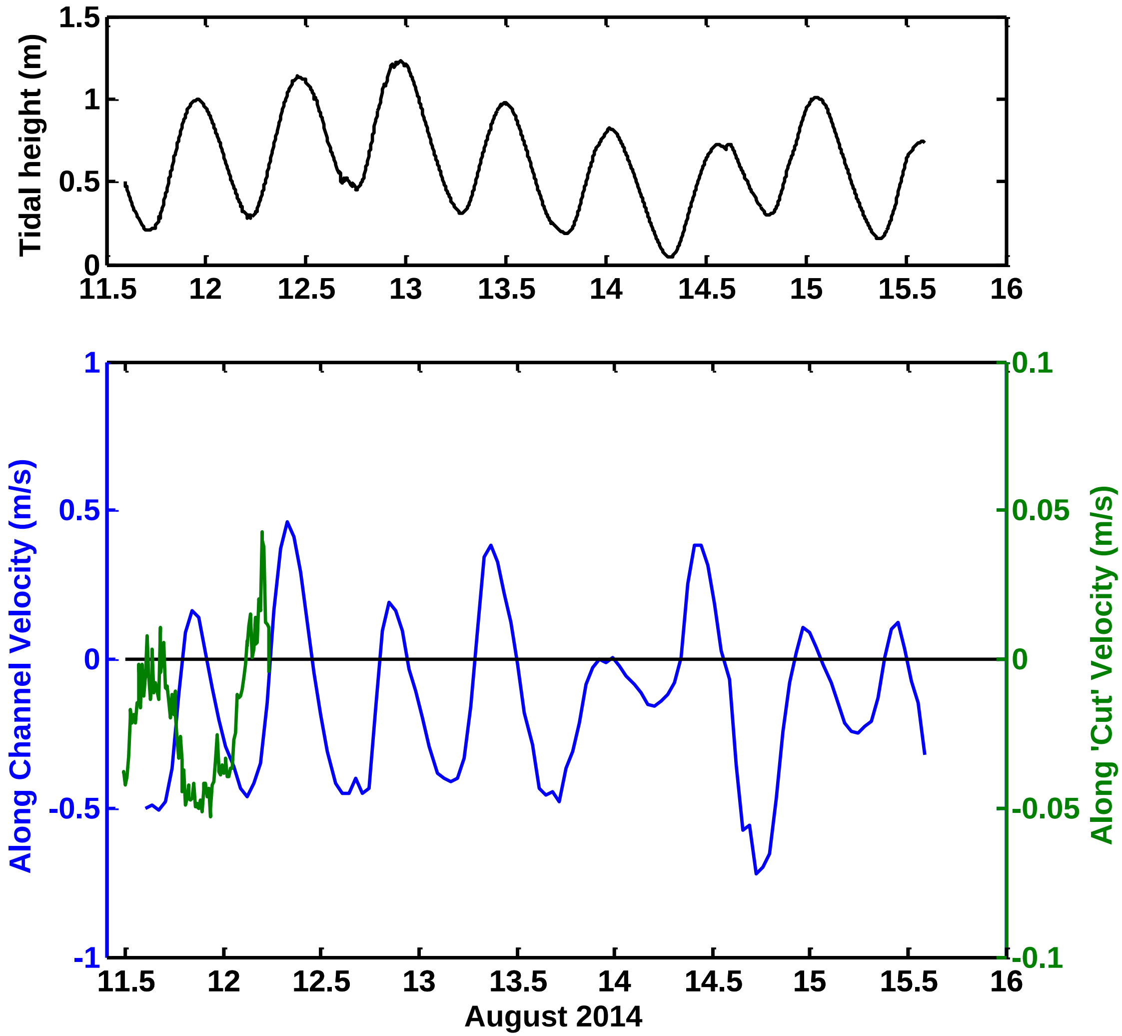


Mean river flow ~ 610 $m^3\ s^{-1}$

Mean channel velocity ~ -0.134 $m\ s^{-1}$ * 200 m wide * 8 m deep = 214 $m^3\ s^{-1}$, ~35% of Q

Interactions between tides, channel currents, and in-bed currents



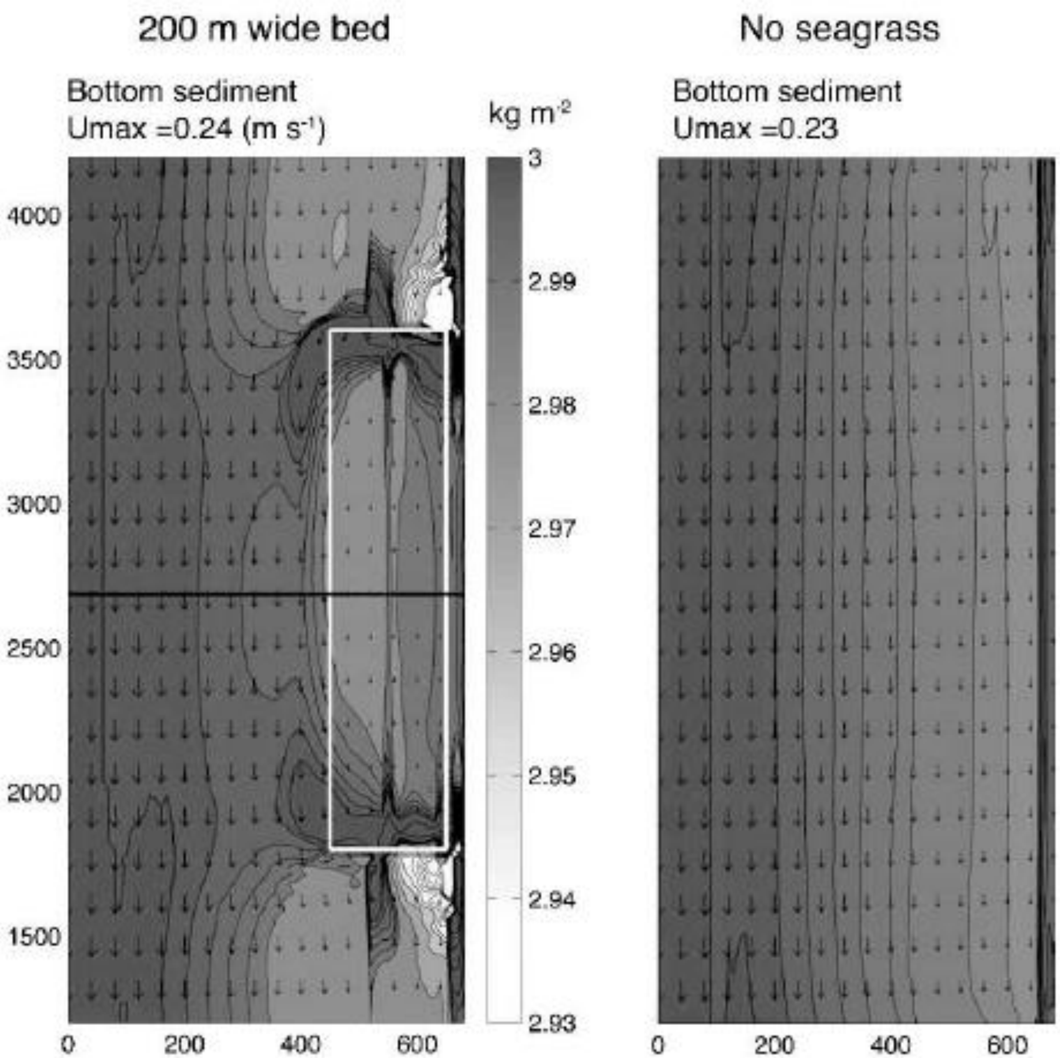


In-bed currents (in a relatively unvegetated, 2 m deep 'cut') are an order of magnitude smaller than channel currents and run in the opposite direction. When the tide is rising, the 'cut' currents run towards the south into the grass bed.

Modeling efforts to date

- Simplified models to illustrate general behavior
- 1 model run as part of LSRWA effort (Steve Scott using CDH)
- Complex new grass resistance model under development by USGS Woods Hole (collaborative effort)
- Future grass ecosystem modeling by Cassie Gurbisz, geomorphological modeling by Matt Biddle (both MEES students at UMCES, Horn Point)

Potential for Seagrass beds to retard flow and change sedimentation patterns



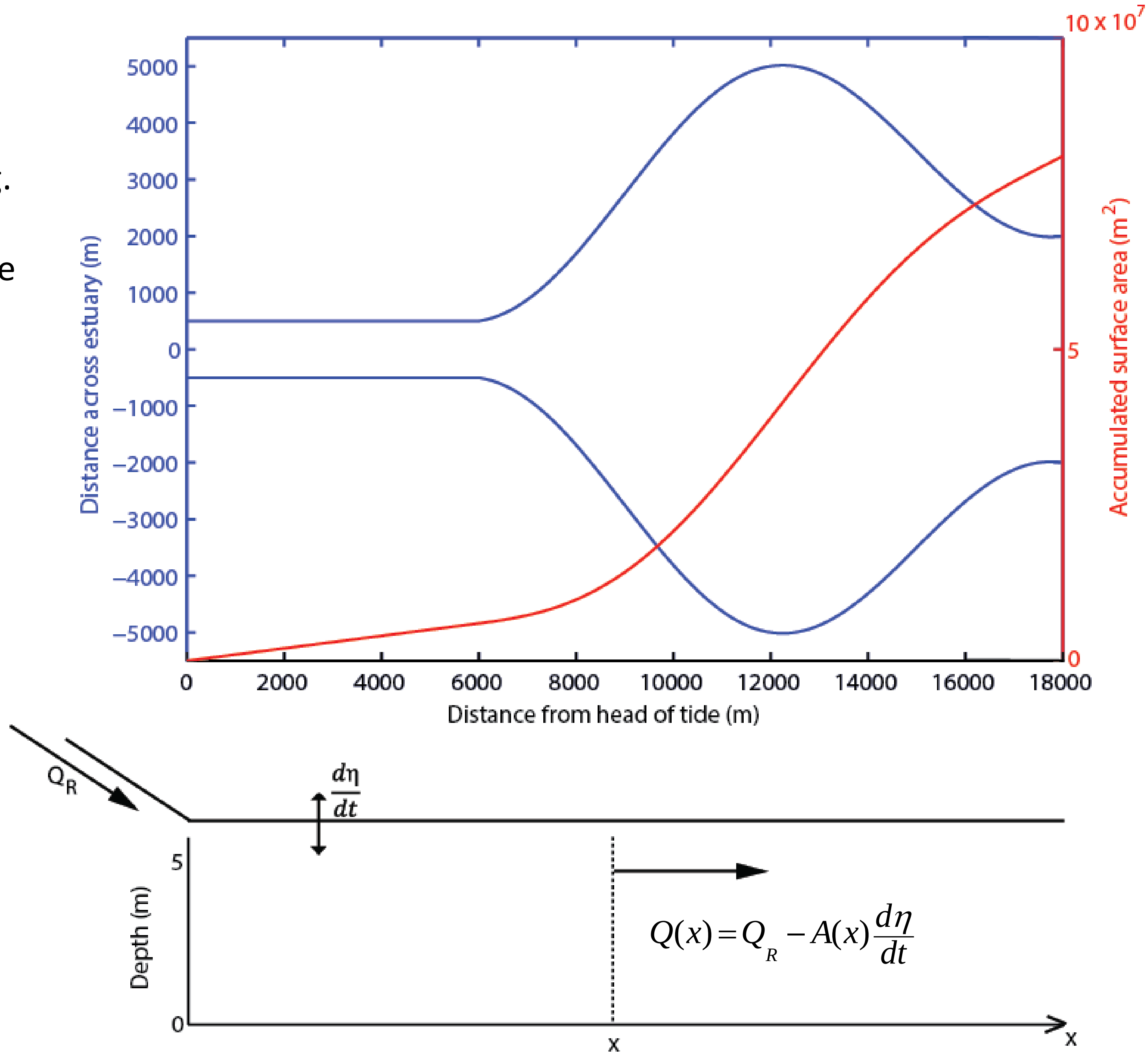
Tidal currents oscillate alongshore, 0.1 m 4 sec waves propagate onshore. Inside the bed, the tidal currents are significantly slowed. Sedimentation patterns near and around the bed are quite different.

From Chen, S. N., L. P. Sanford, E. W. Koch, F. Shi and E. W. North (2007). "A Nearshore Model to Investigate the Effects of Seagrass Bed Geometry on Wave Attenuation and Suspended Sediment Transport." Estuaries and Coasts 30(2): 296–310.

Simplified flow model for river and tidal forcing. Assume quasi-steady state, tide rises and falls uniformly according to

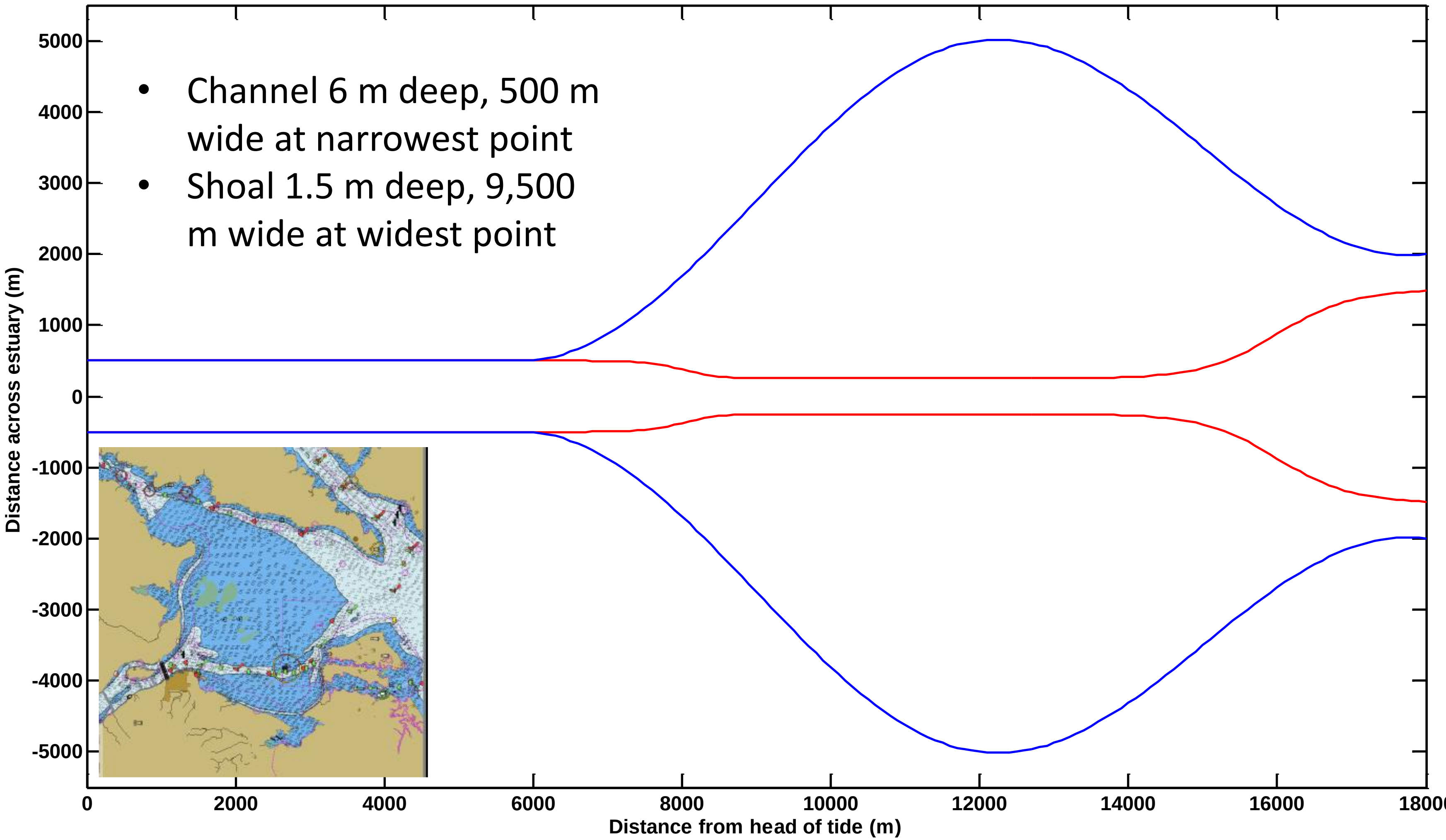
$$\eta = a_T \sin(\omega_T t)$$

Upstream channel width 1000 m, basin 10 km across at widest point, 12 km long, assume constant depth of 5 m. Invoke volume conservation.

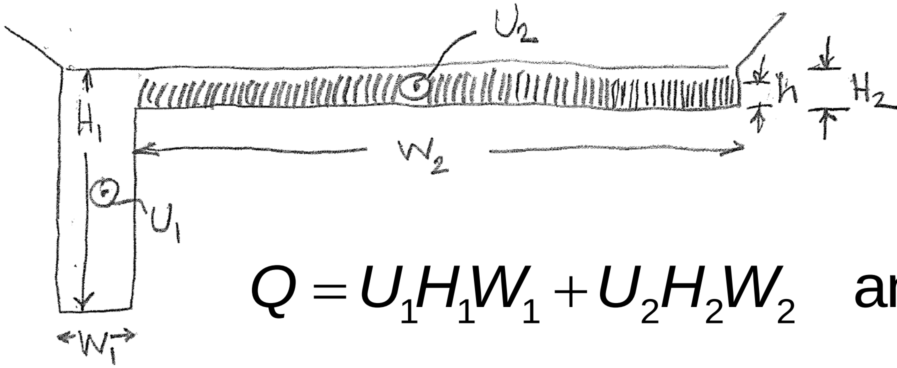


Channel-shoal model geometry

- Channel 6 m deep, 500 m wide at narrowest point
- Shoal 1.5 m deep, 9,500 m wide at widest point



Simplified physical dynamics in a channel-shoal system



Surface slope No grasses Grasses

$$Q = U_1 H_1 W_1 + U_2 H_2 W_2 \quad \text{and} \quad \rho g S = \frac{1}{2}\rho \frac{C_f}{H_i} U_i^2 = \frac{1}{2}\rho \frac{C_d a h}{H_2} U_2^2$$

where Q is total flow, H_i is water depth in zone i, U_i is depth-averaged velocity in zone i, W_i is the width of zone i, S is surface slope (out of the page), ρ is water density, g is gravitational acceleration, C_f is the bottom friction coefficient, C_d is the underwater grass drag coefficient, a is the grass density per unit area of bottom, and h is the meadow height.

Without grass bed

$$\frac{U_2}{U_1} = \sqrt{\frac{H_2}{H_1}}$$

With grass bed

$$\frac{U_2}{U_1} = \sqrt{\frac{C_f}{C_d a h}} \sqrt{\frac{H_2}{H_1}} \approx 0.1 \sqrt{\frac{H_2}{H_1}}$$

Combined with the total flow constraint allows solution for both velocities

Preliminary ADH Model Flow Predictions (Steve Scott, ERDC)

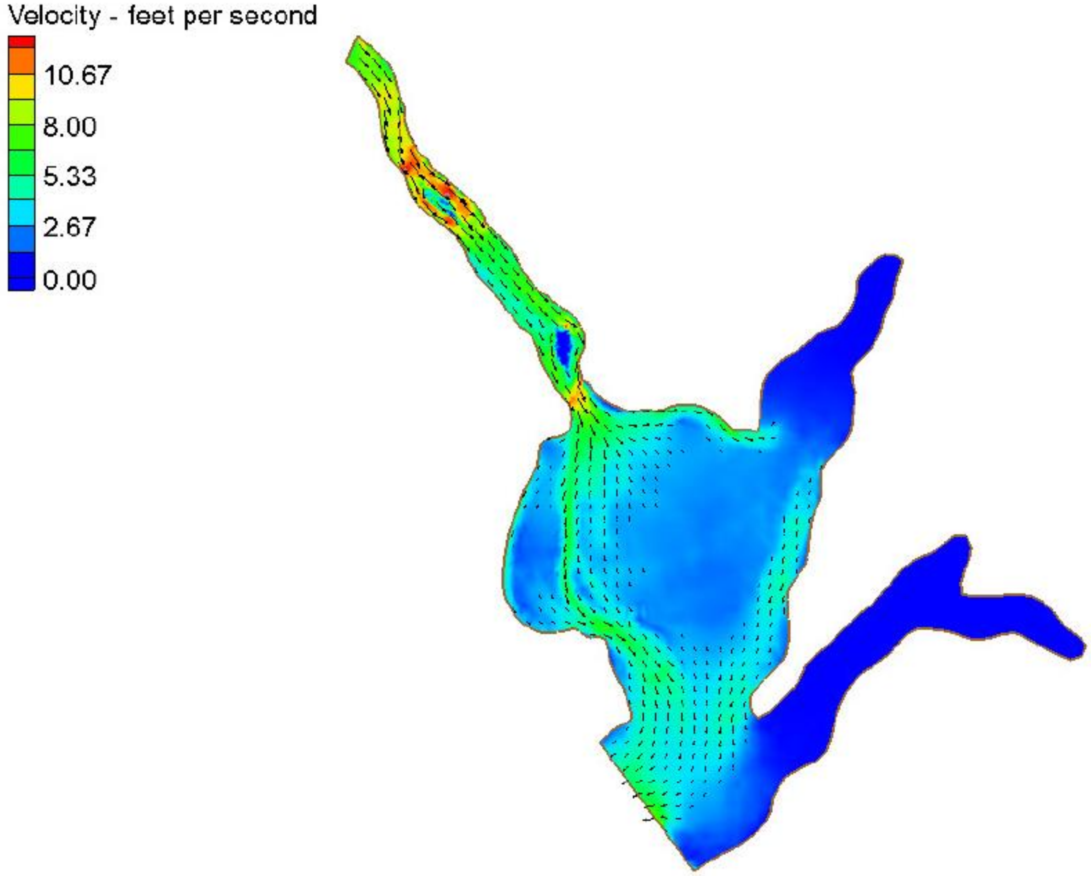
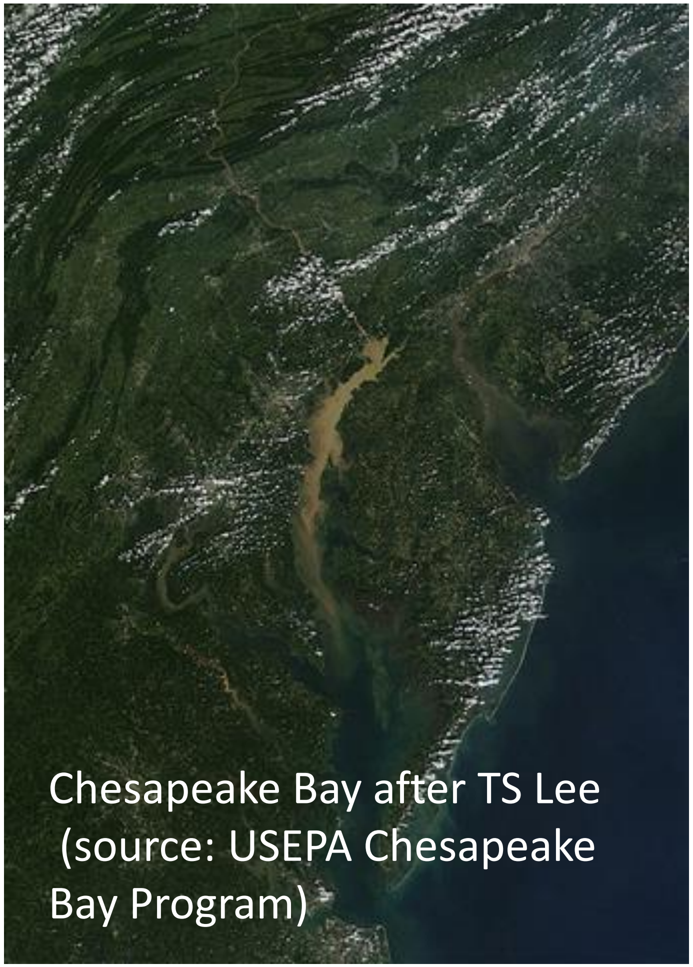


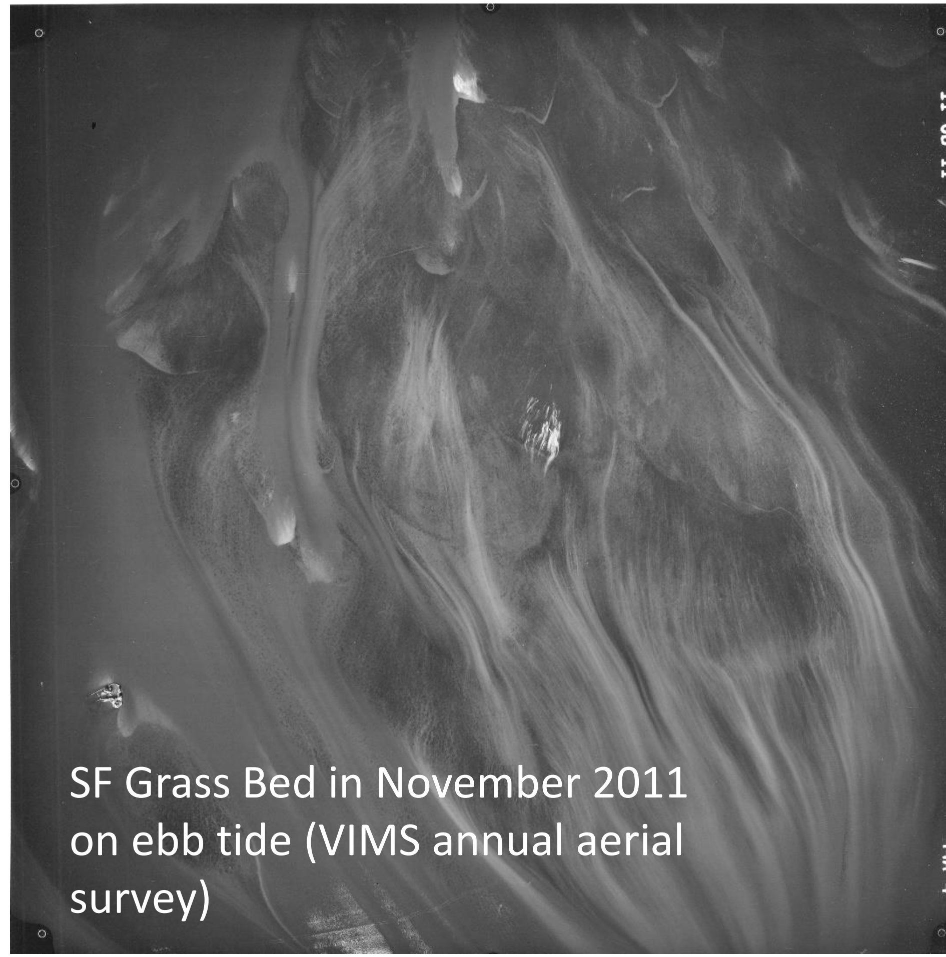
Figure 36 Velocity in Susquehanna Flats for a discharge of 600,000 cfs

Extreme River flows result in deposition on the shoals, but scour in the channel

Tropical Storm Lee in September 2011 was the largest flow event in 40 years

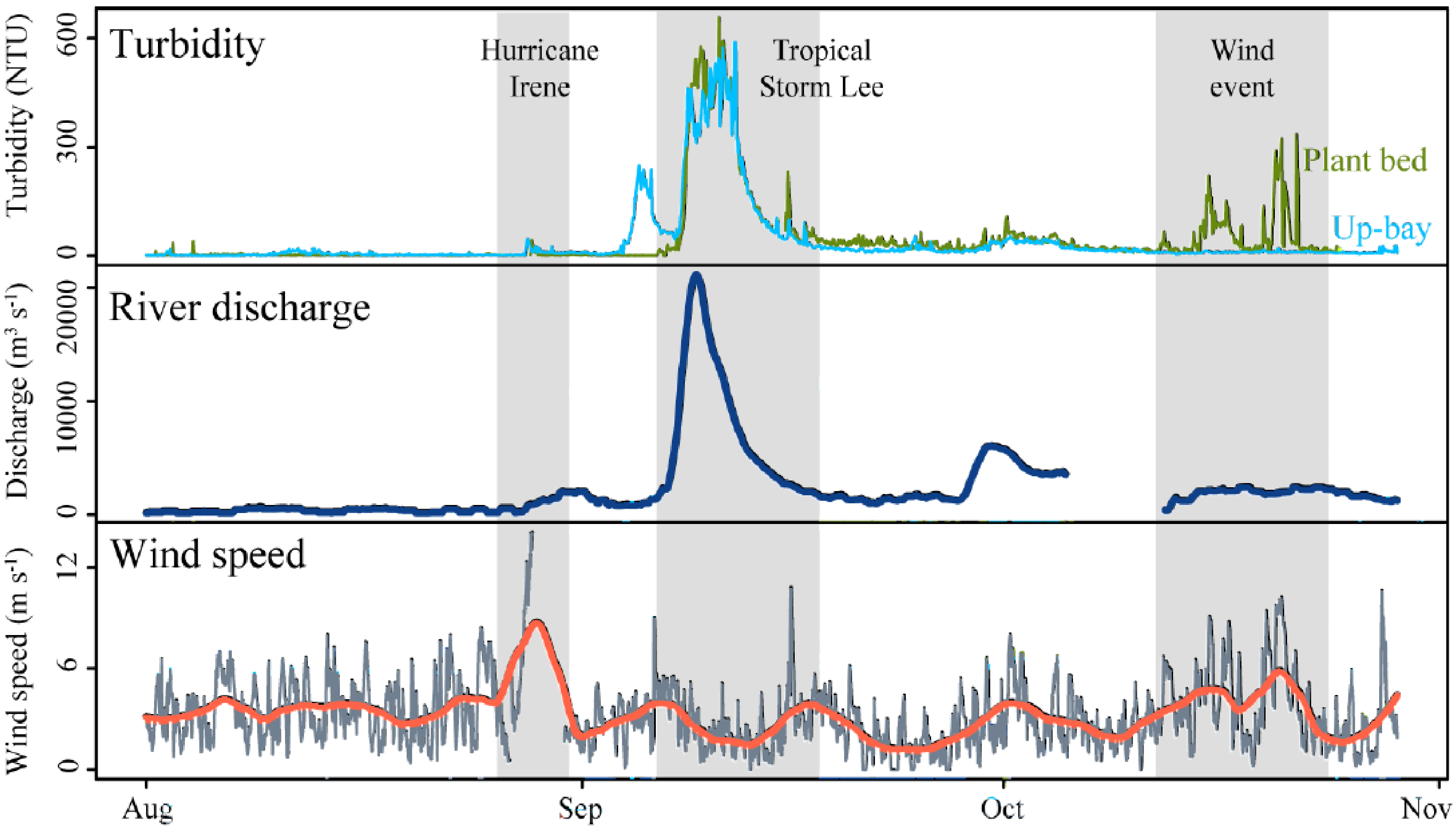


Chesapeake Bay after TS Lee (source: USEPA Chesapeake Bay Program)



SF Grass Bed in November 2011 on ebb tide (VIMS annual aerial survey)

Response to Tropical Storms Irene and Lee in 2011



Conclusions (preliminary)

- SF is a persistent feature at the head of CB
  - varies in size and depth in response to sediment delivery
  - geomorphology constrained by surrounding topography
  - very important to ecology of upper CB
- Resurgent SF SAV bed has a strong influence on flow and sediment delivery
  - resists flow in proportion to grass density
  - diverts large proportion of flow around bed through channel(s)
- Shallow water dynamics control flow around and through the grass bed
  - flows into bed focused into less vegetated, slightly deeper 'cuts'
- Tidal height differences across SF are small but likely dynamically important, need further investigation
- Episodic sediment delivery, seasonal flow blockage and waves appear to dominate turbidity fluctuations inside bed
  - dense grass beds result in greatly reduced turbidity, positive feedbacks

Continuing work

- Additional coordinated hydrodynamic, geological, biogeochemical, and biological studies in 2015
- At least 1 MS thesis and 1 PhD dissertation
- Collaborative modeling with USGS
- Future work on long-term geomorphology?
- Relationship to high flows from Conowingo??