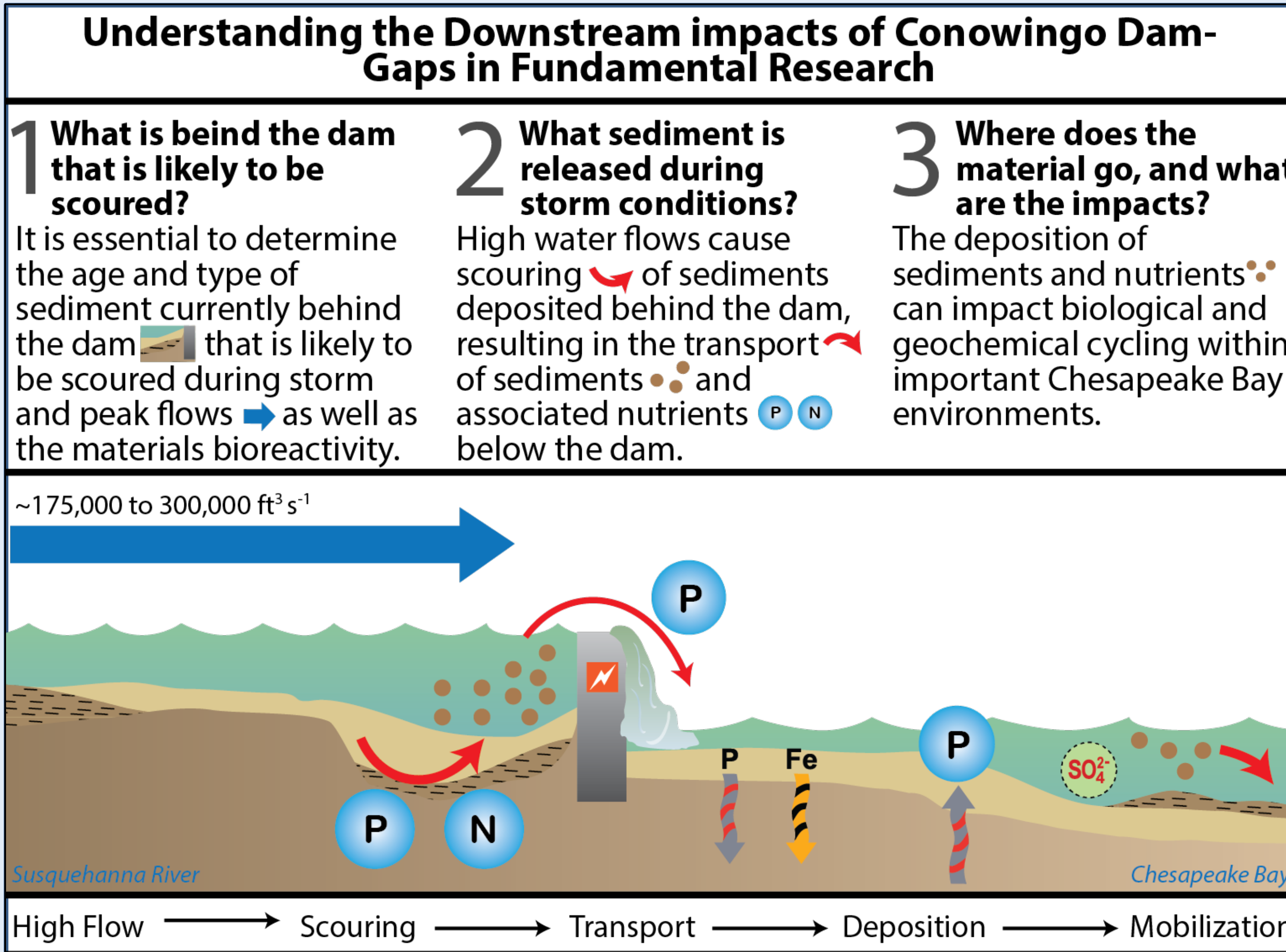
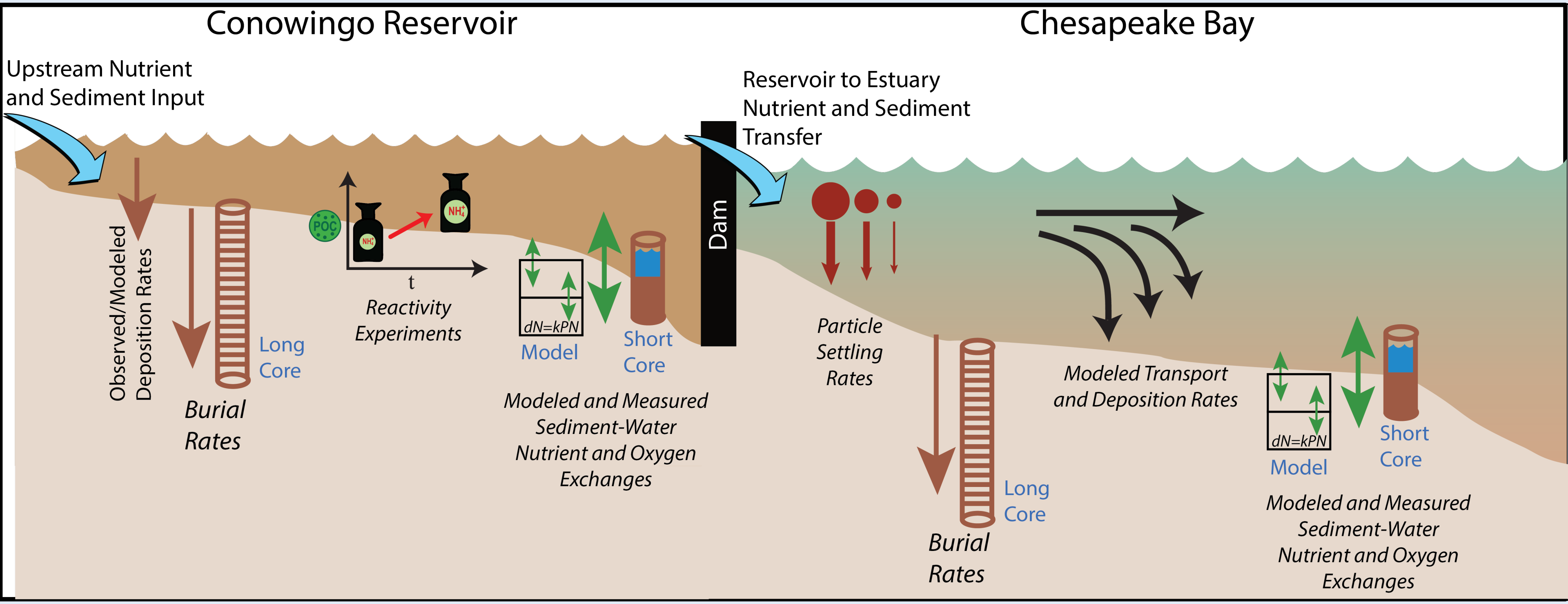
Fundamental Research Gaps Before Our Study



UMCES view at start of project

Coordinated field observations and modeling results from Reservoir to Bay



Separate into two flow conditions (USGS gauge at Conowingo):

“Non-event” = flows less than 86,400 cfs, about when 1st flood gate is opened

“Event” = flows above 86,400 cfs

Sediment dynamics in Conowingo Reservoir

Summary of paper "Spatial and temporal patterns of sedimentation in an infilling reservoir." Published in *Catena*, 2019

Cindy Palinkas, lead author

Emily Russ, PhD student (now at the US Army Corps of Engineers)

UMCES Horn Point Laboratory

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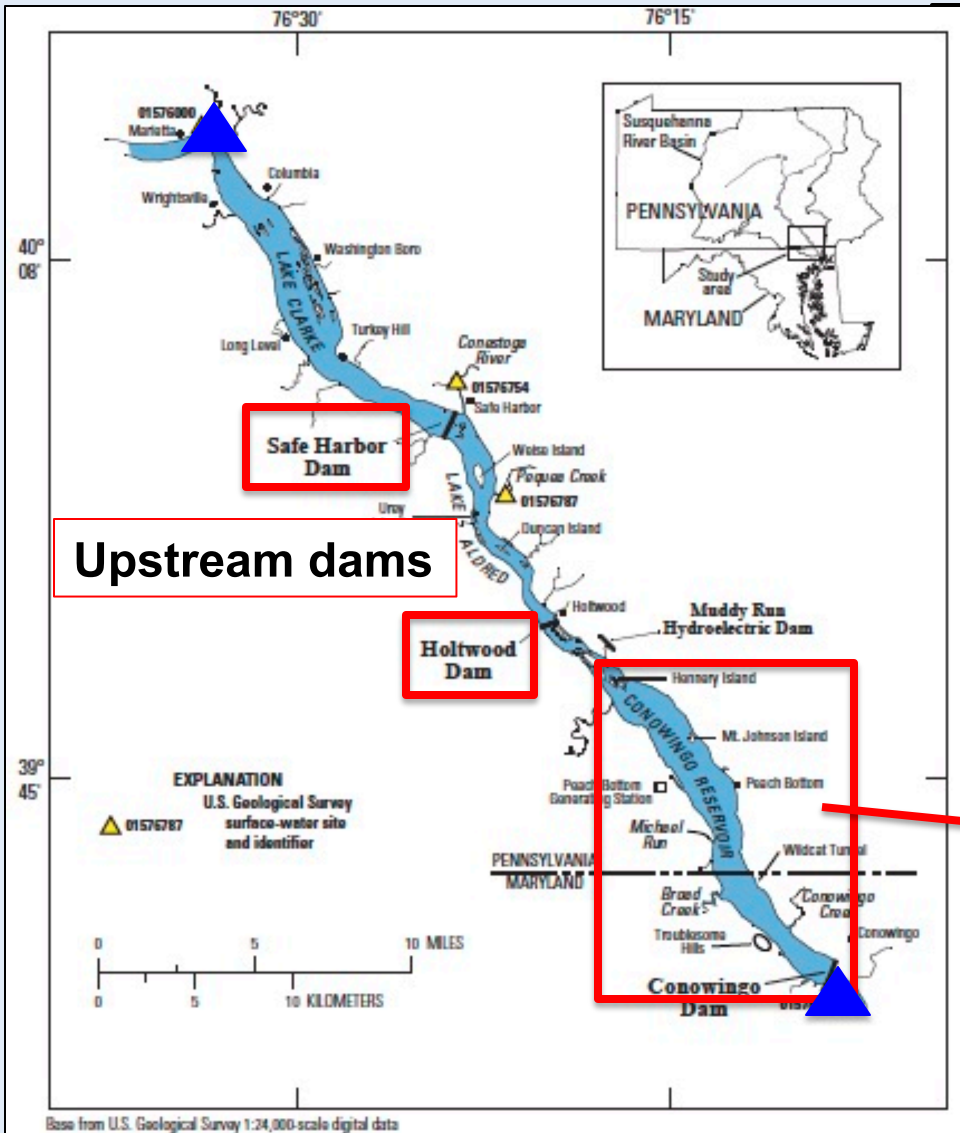
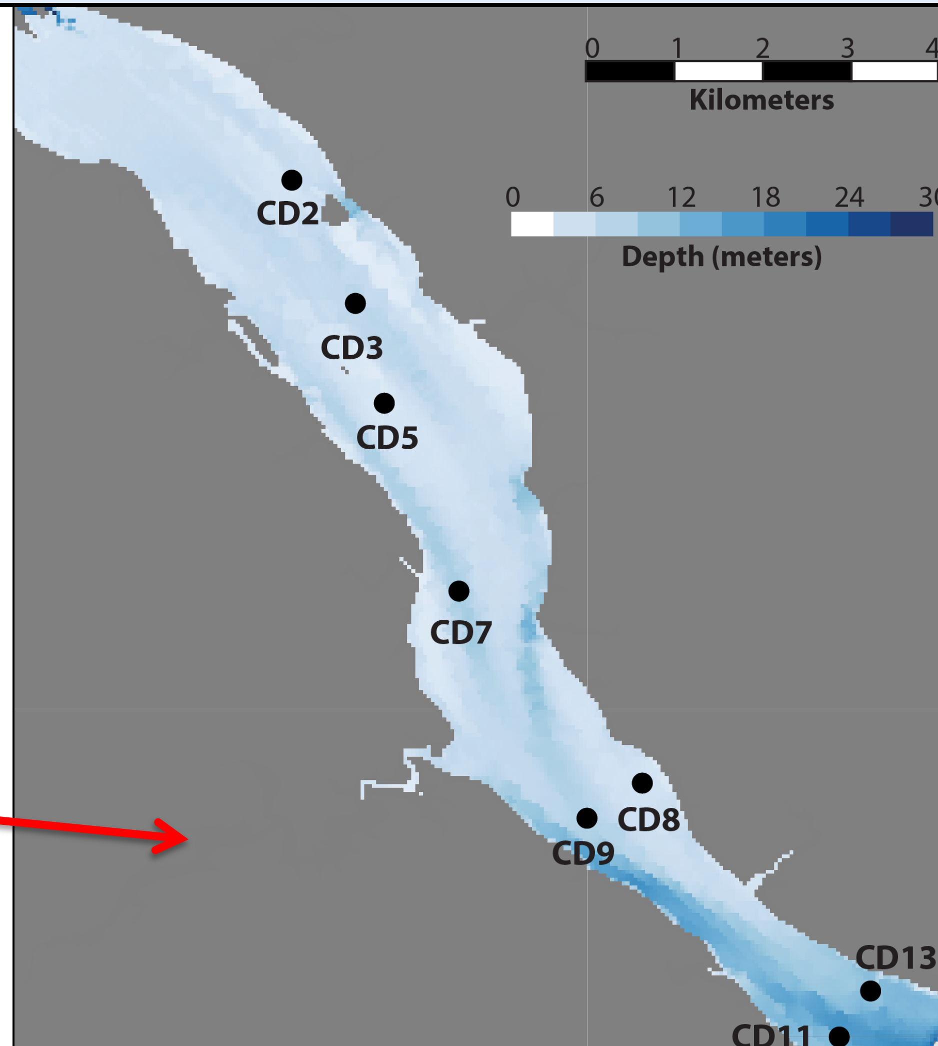
Core Locations



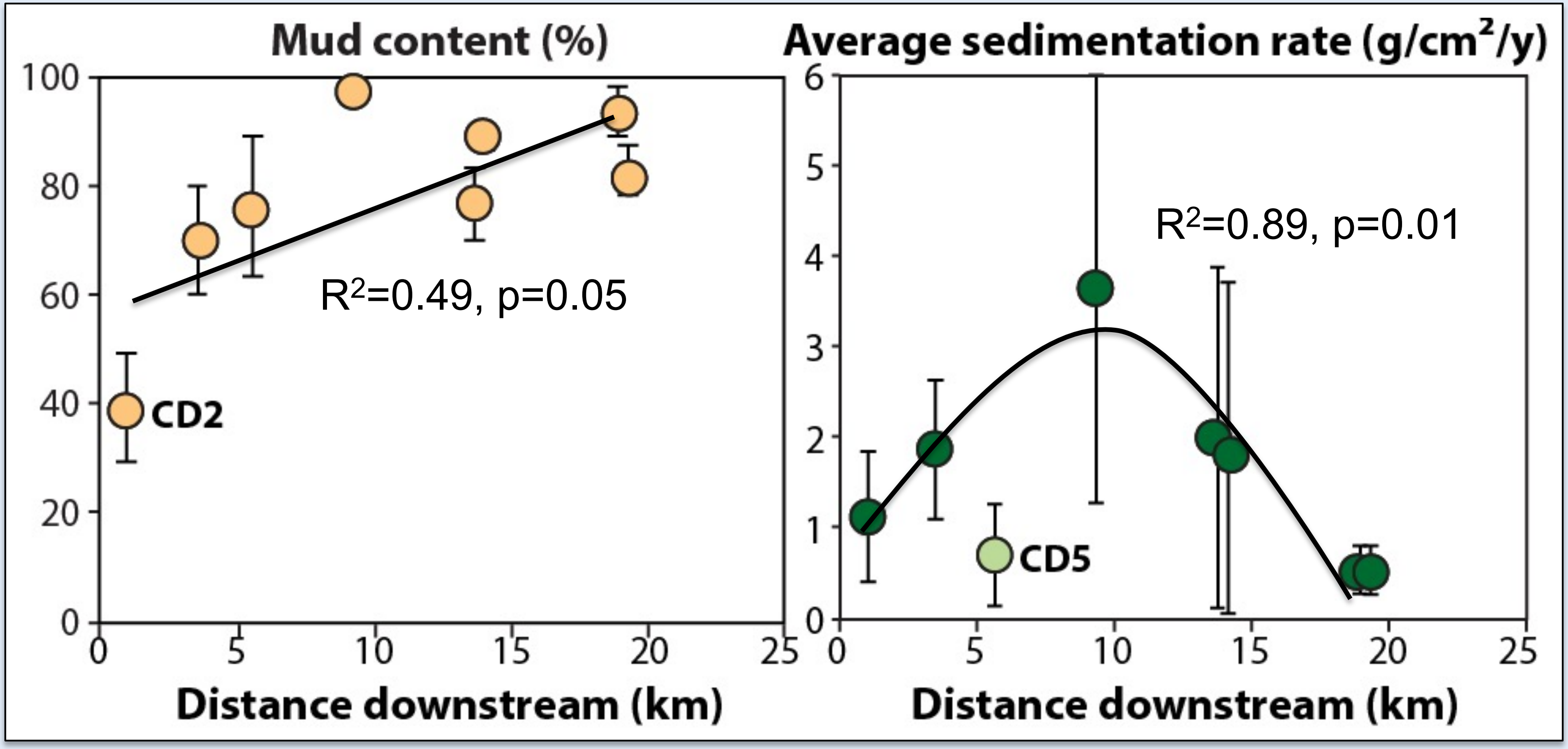


USGS gauges at Marietta (since 1932) and Conowingo (since 1968)

Box cores (May, Jul, Sep, Dec 2015; April 2016); **vibracores** (Aug 2015)

Geomorphic groups: channel, shoals

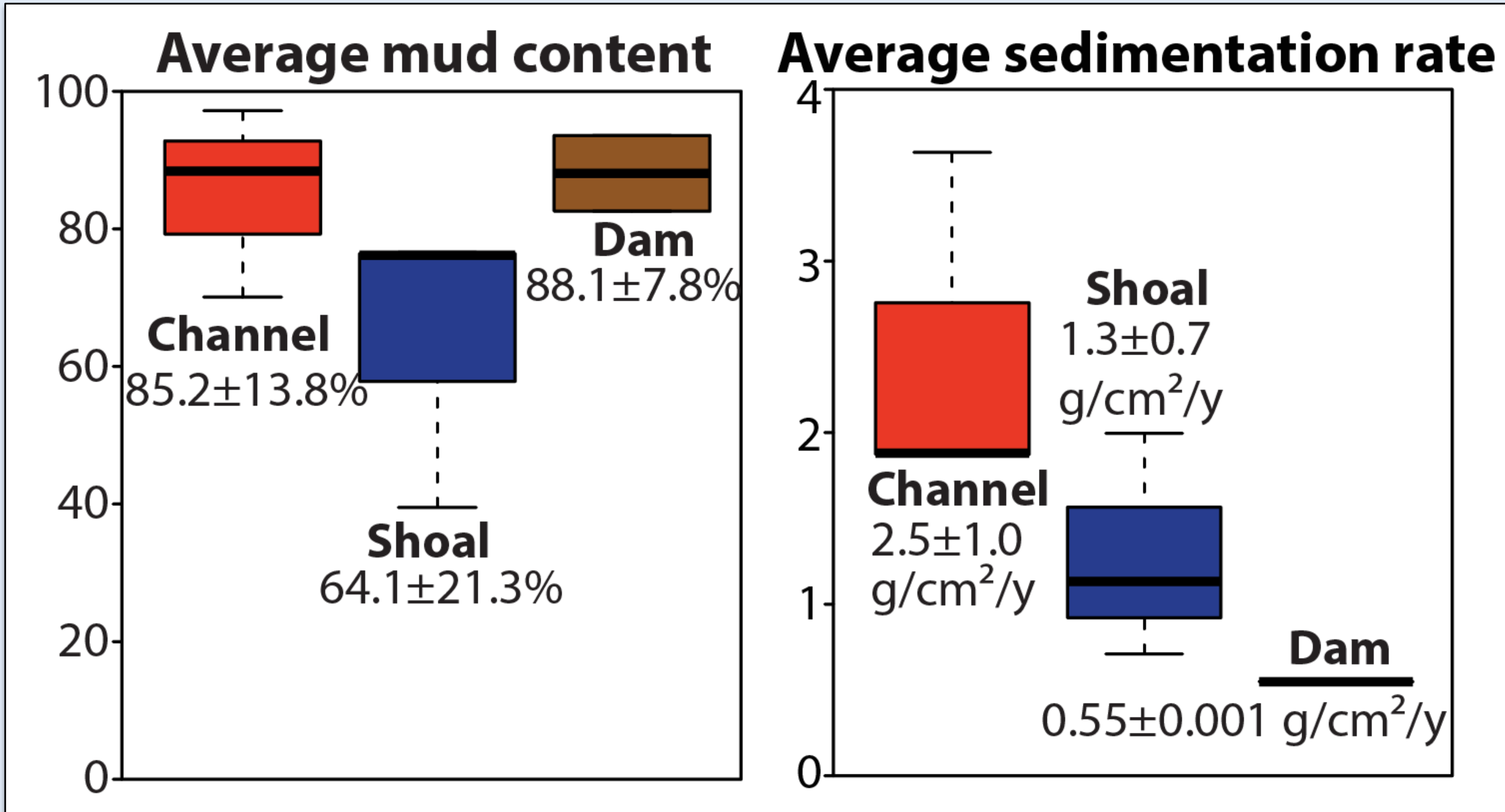
Spatial variability – seasonal scale



Mud: increase downstream but driven by CD2 (R^2=0.25, p>0.1 w/out CD2)

Sedimentation Rates: increase to maximum at CD7, then decrease

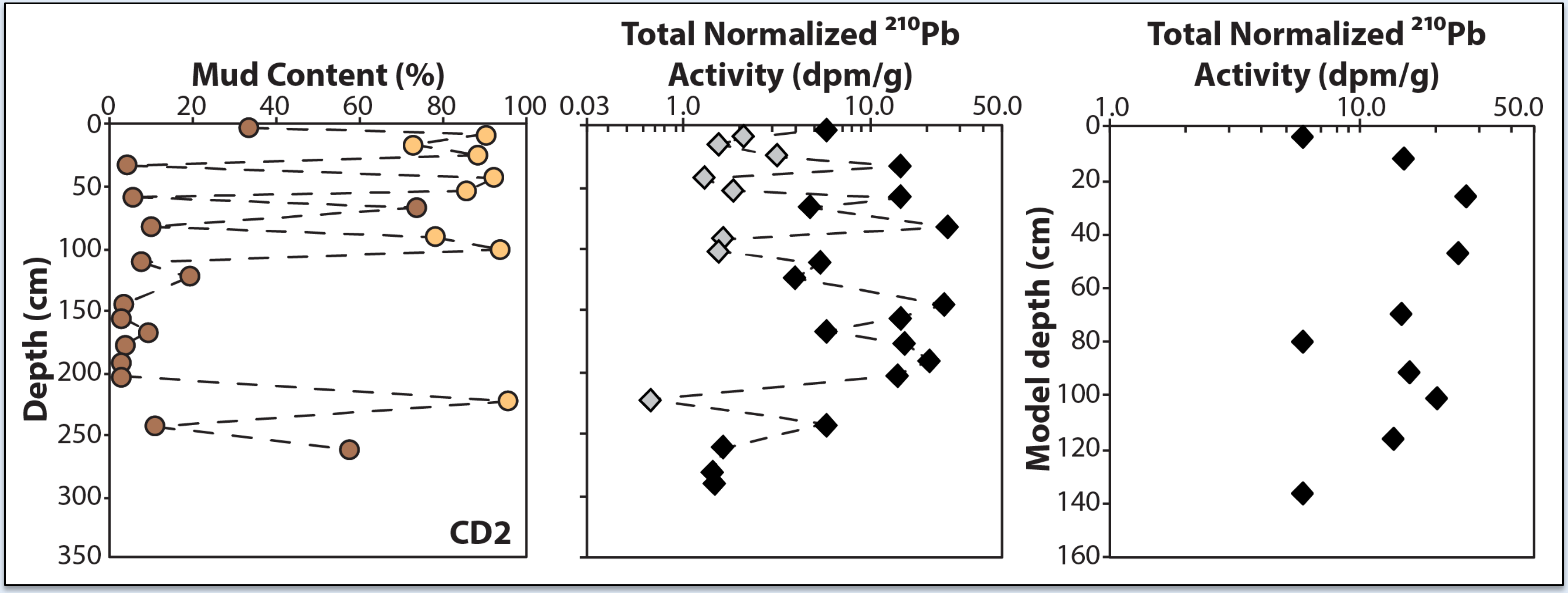
Spatial variability, redux



Seasonal-annual sedimentation follows expectations:

- Highest mud content and deposition rates mid-Reservoir and in channels
- Average rates ~0.5-2.5 $g/cm^2/y$

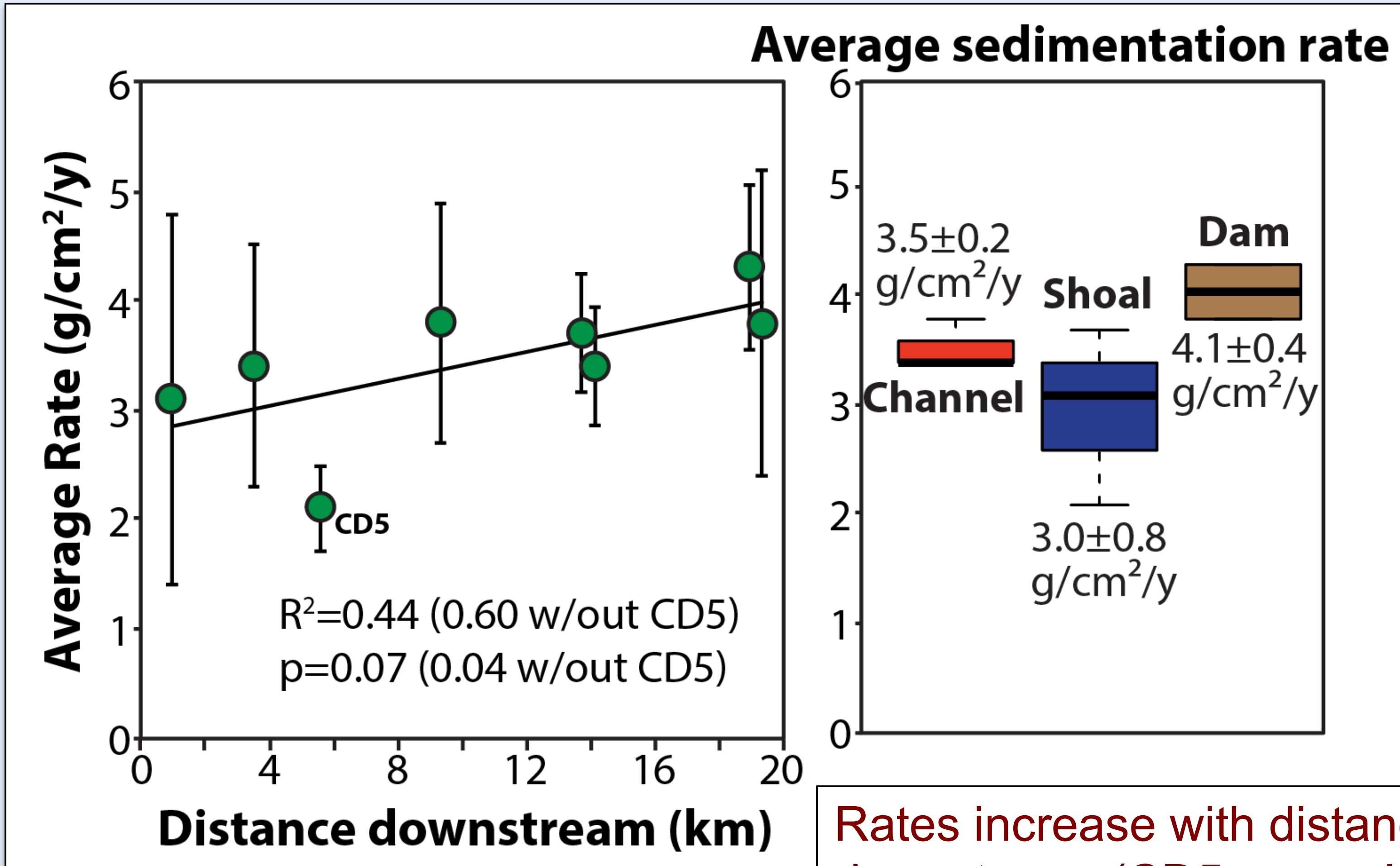
Decadal-scale sedimentation – events!



Variable sedimentation: ^{210}Pb activities vary with depth even after normalization with mud content; high mud content and low ^{210}Pb activity indicative of flood layers

“Remove” flood layers and apply time-varying age-depth model

Decadal-scale sedimentation



Rates increase with distance downstream (CD5 anomalously low)

Rates similar between channels and shoals, a bit higher near Dam

Summary from Reservoir cores

Seasonal scales during "normal" year:

- Preferential deposition of fine material mid-Reservoir and in channels

Over longer time scales:

- Events dominate the sedimentary record, especially in channels – preferential scour?
- Average sediment accumulation rates increase downstream and are similar in channels and shoals

Distance downstream and **geomorphology** key predictors for observations
Time scale key for predicting sediment depocenters

Potential impact of Conowingo Reservoir infill on Chesapeake Bay water quality

Summary of paper “Influences of a river dam on delivery and fate of sediments and particulate nutrients to the adjacent estuary: case study of Conowingo Dam and Chesapeake Bay.” Published in *Estuaries and Coasts*, 2019

Cindy Palinkas[1], lead author

Jeremy Testa[2], **Jeff Cornwell**[1], **Ming Li**[1], **Larry Sanford**[1]

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Major questions addressed

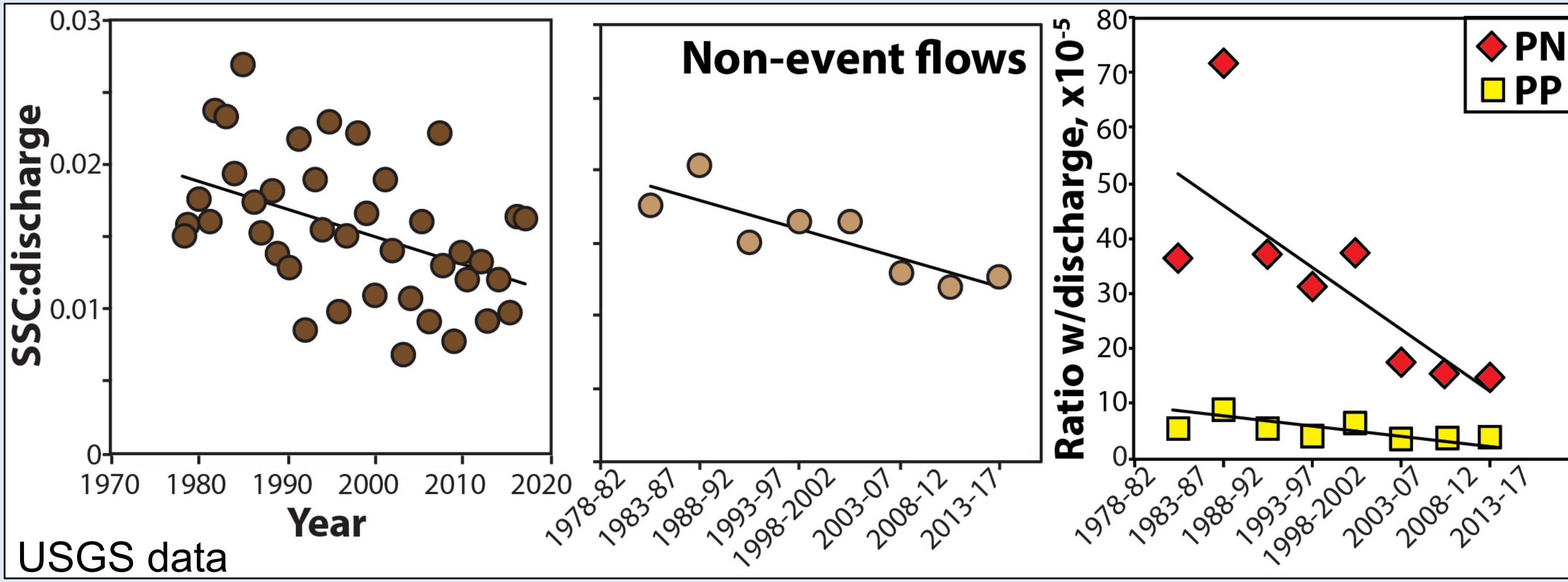
1) How has sediment and particulate loading to the Bay changed over the last 40 years?

2) Are sediments in the Reservoir biogeochemically different from those in the upper Bay, and how might they influence Bay biogeochemistry?

3) What controls the transport and fate of Conowingo sediment in the Bay?

4) What are the likely impacts of watershed and Reservoir-derived particulate material on the Bay's biogeochemistry?

Non-event flows: less suspended sediment and particulate nutrients now than in the past

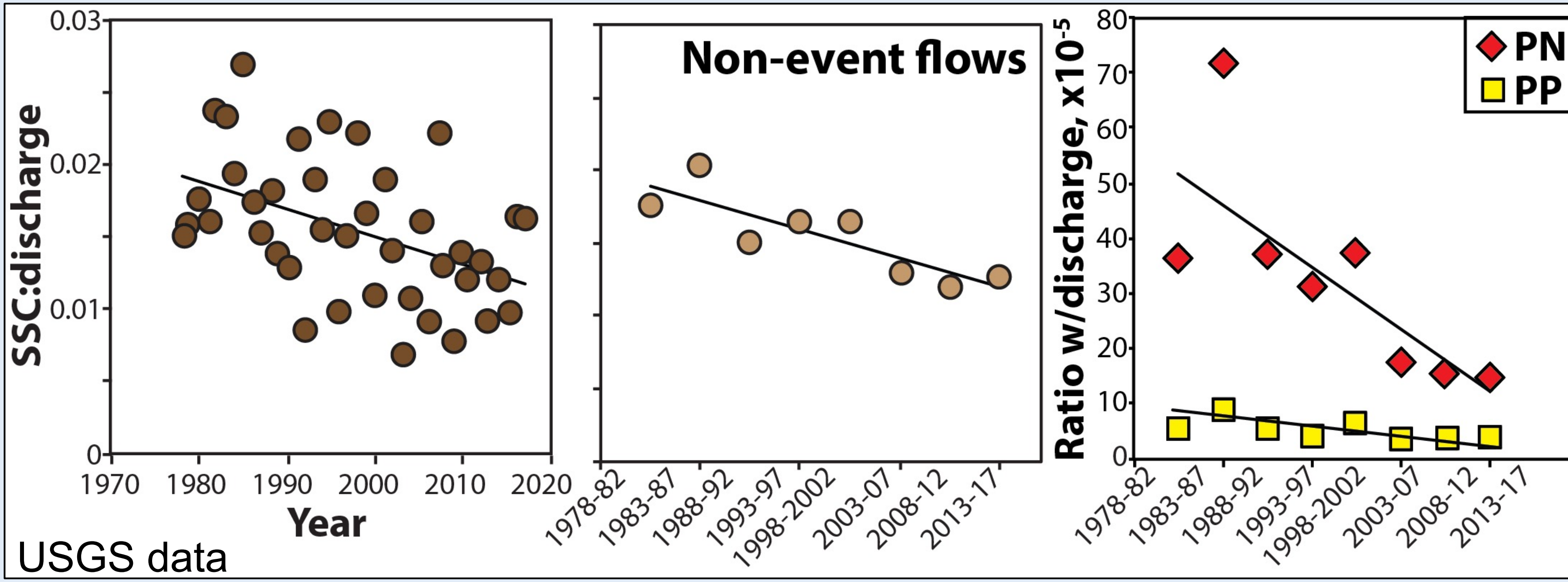


Left: Ratio of suspended-sediment concentration (SSC) measurements to corresponding river discharge, averaged for every year from 1978 to 2017

Middle: Same as the left, but averaged over 5-year intervals

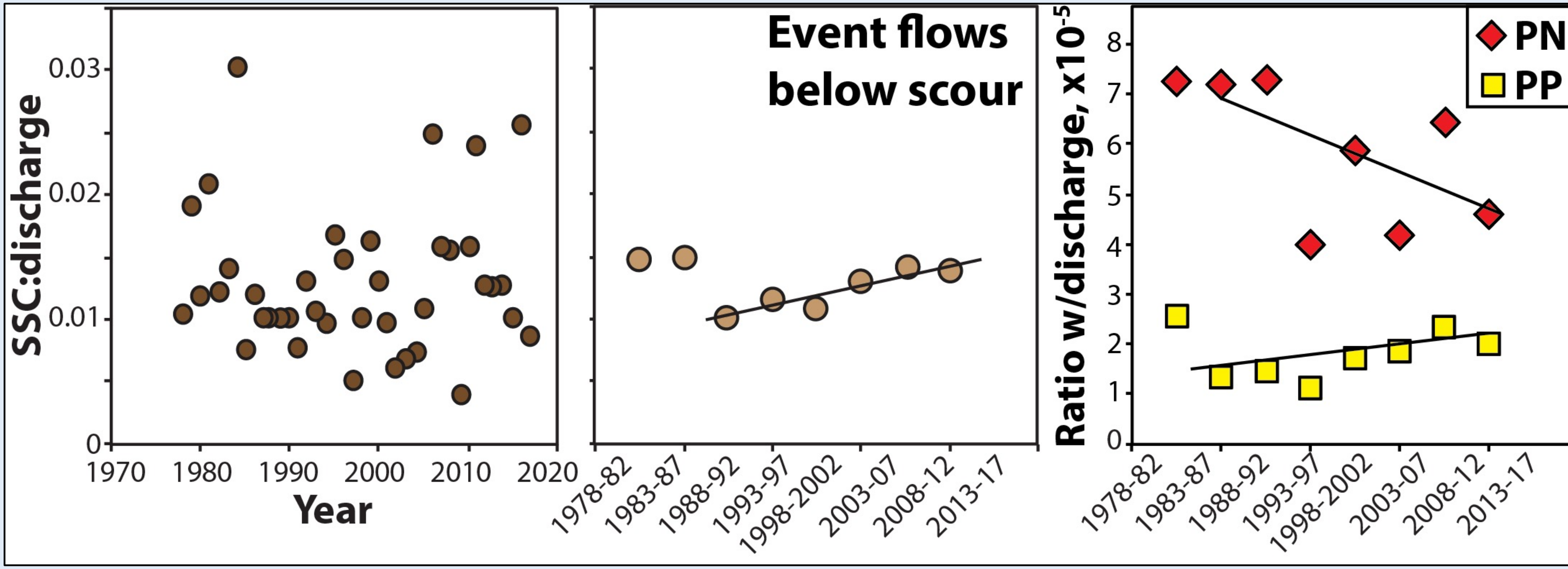
Right: Ratio of particulate nitrogen (PN) and phosphorus (PP) to corresponding river discharge, averaged over 5-year intervals

Non-event flows: less suspended sediment and particulate nutrients now than in the past



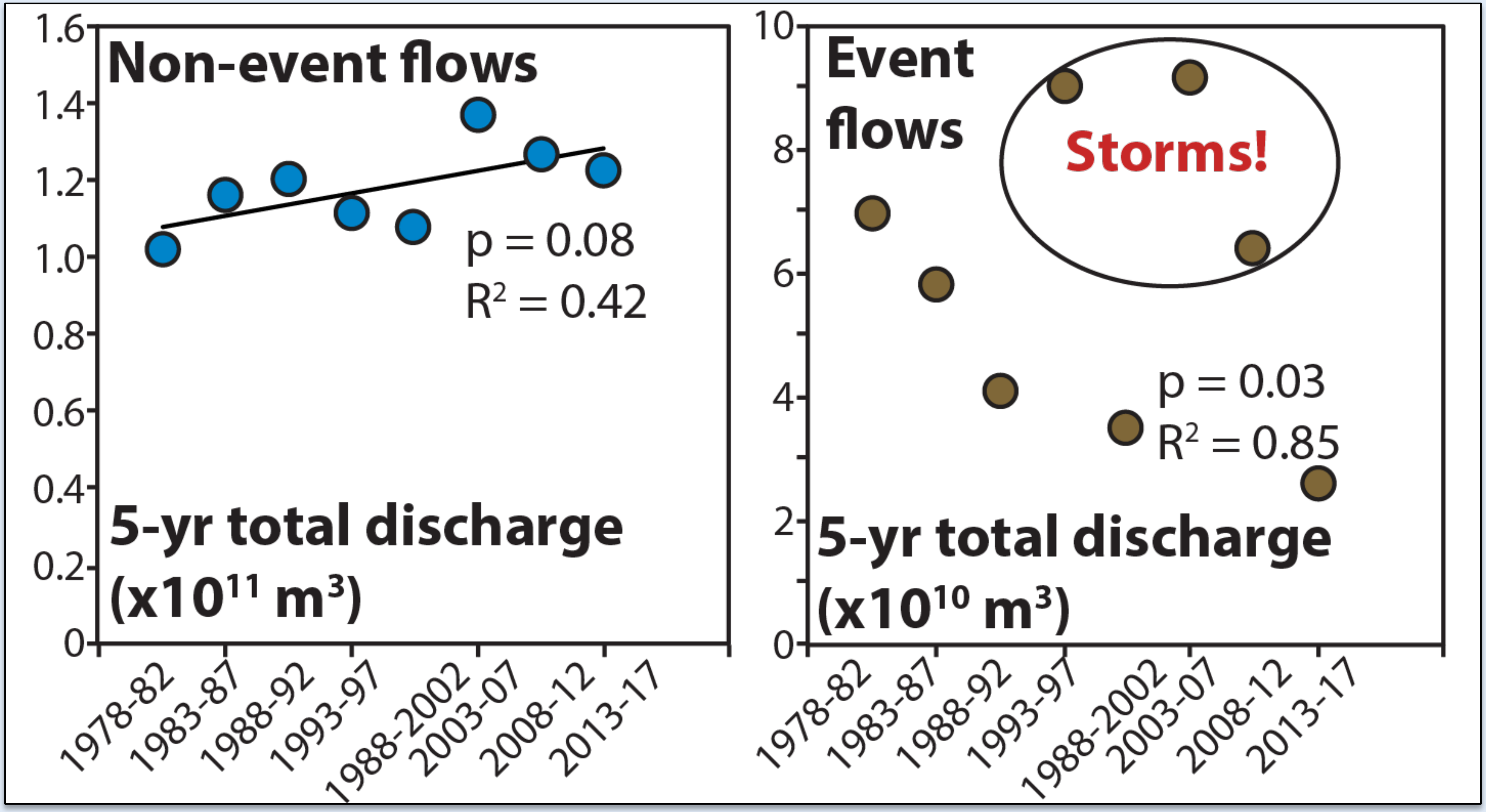
- Occur 90% of the time; represent "every-day" conditions
- Statistically significant decrease in all cases
- Sediment and particulate nutrients from the watershed at these low flows; decrease likely reflects BMP installation in watershed

Event flows: more suspended sediment and nutrients now than in the past for event flows <400,000 cfs



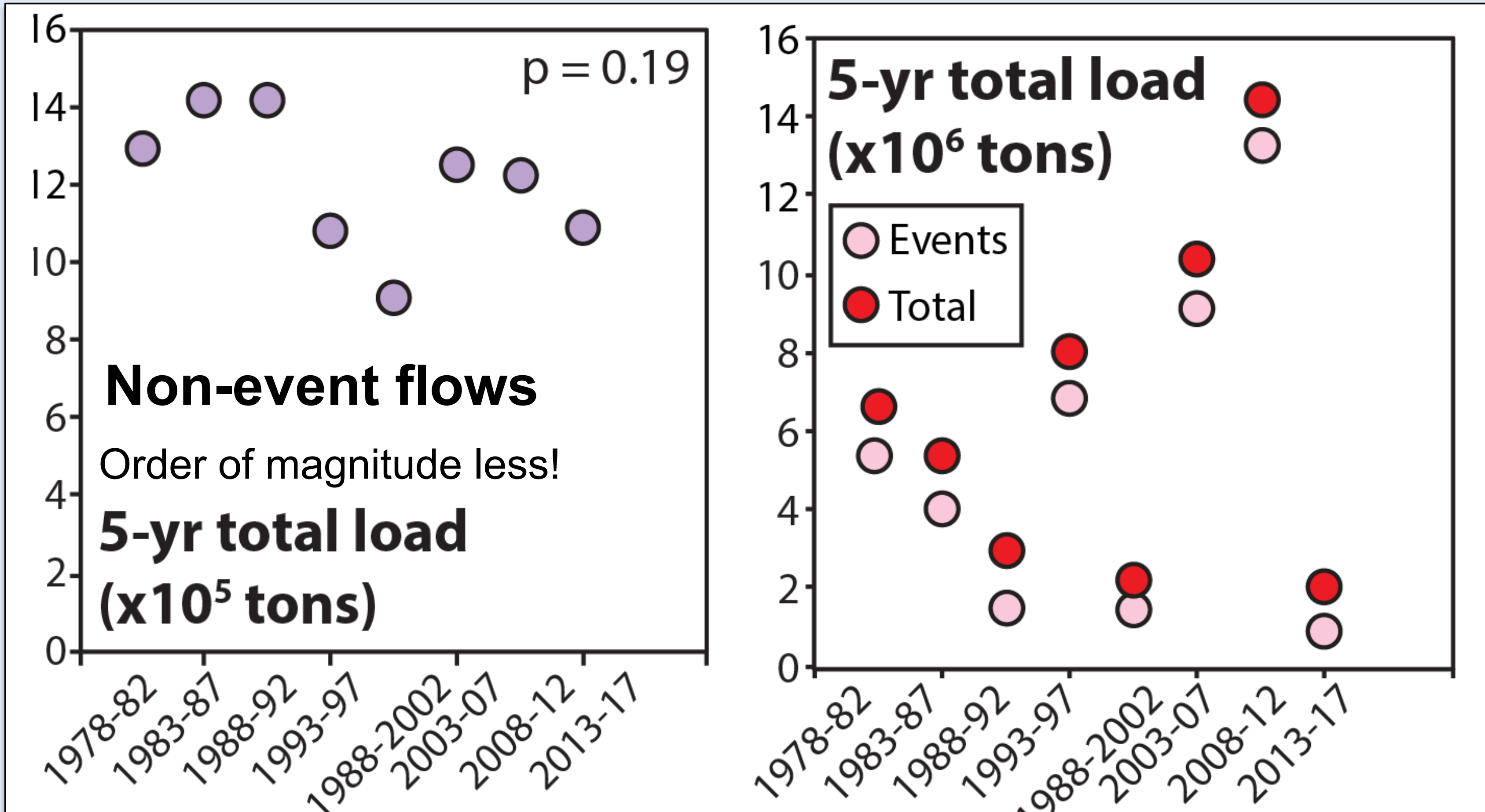
- Increasing sediment and particulate phosphorus loads
- Consistent with decreasing scour threshold AND reduced trapping effectiveness
- Event flows >400,000 cfs occur infrequently (every ~5-7 years); only ~15 observations of SSC and particulate nutrients from 1978 to 2017

Trends in river discharge



- Increase for non-event flows; 1978-1992 much lower than 1993-2017 ($p=0.002$)
- Decrease for event flows (excluding big storms)

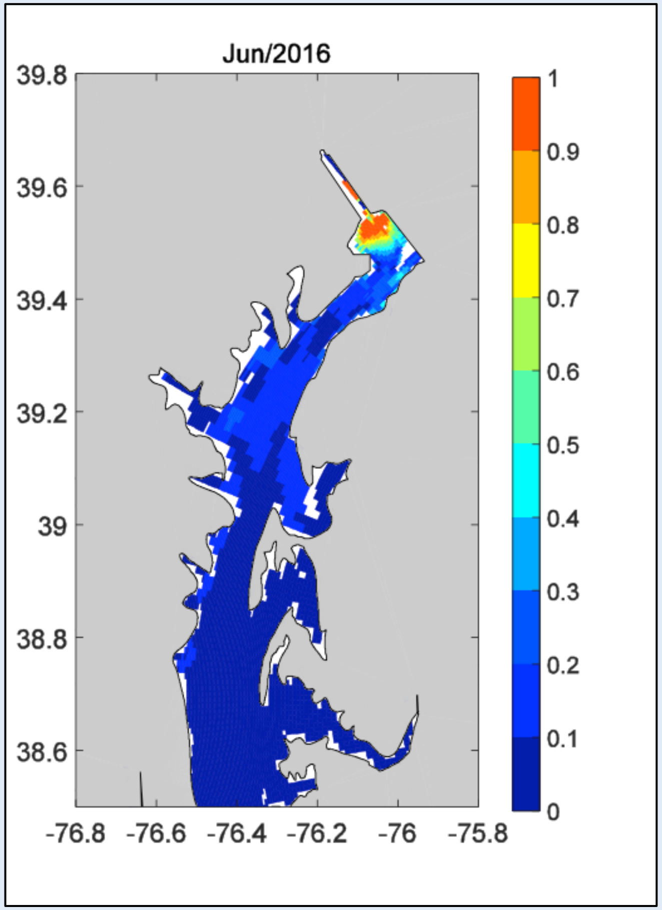
Have sediment loads to the Bay changed?



- Events occur ~10% of the time but comprise ~72% of 5-year loads
- Periods with known big scour events are outliers (1996, 2004, 2011); without them loads declining over time: $p=0.07$, $R^2=0.72$ (total); $p=0.09$, $R^2=0.68$ (events)
- No trend for non-event flows

Potential impact of Reservoir sediments to Bay water quality are limited

- Scoured material has low turnover times and would contribute a small amount of total nutrient loading even in extreme storms
- A large scour event (e.g. Tropical Storm Lee) would contribute 20% of phosphorus loads and 6% of nitrogen loads to the upper Bay
- Most of this material would deposit in the low-salinity upper Bay, where nutrient releases from sediments is minimal

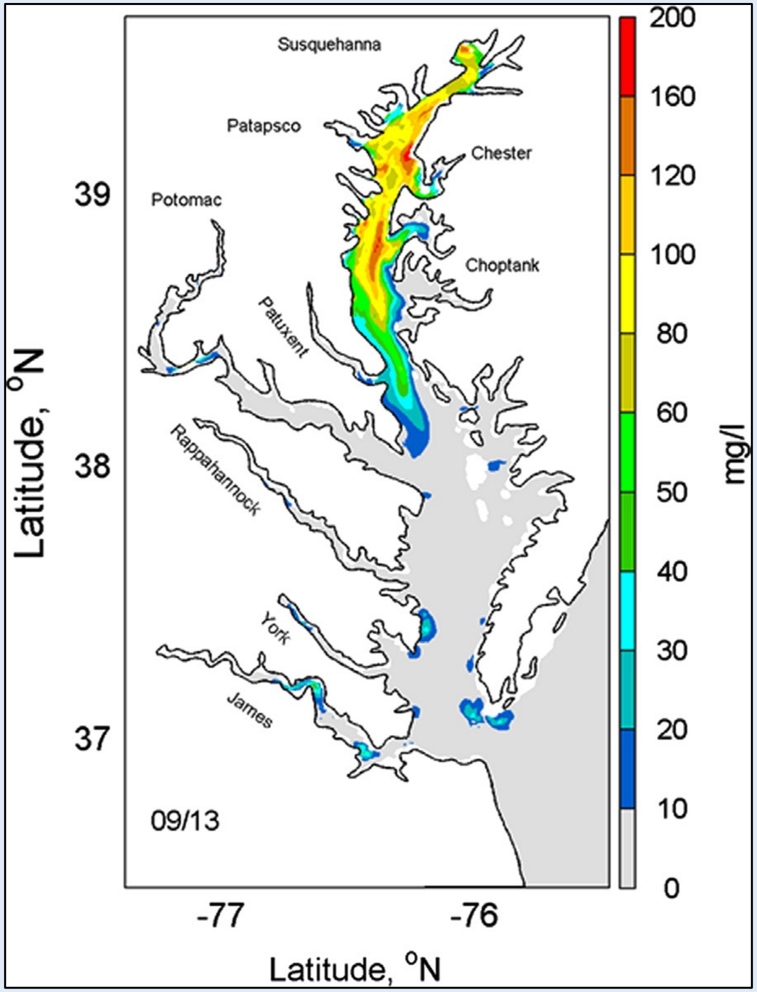


Modeled suspended-sediment concentrations (SSC) for non-event conditions in June 2016; highest SSC is at the mouth of the Susquehanna River with very little sediment transport south of the Susquehanna Flats

Most sediments are deposited in the upper Bay with minimal transport to the mid-Bay possible only during storm events

Event flows can transport fine sediments to saltier waters of the mid-Bay region, where low oxygen in summer could allow for higher rates of nutrient releases from sediments

But, event sediments are redistributed over longer time scales and are not recognizable in sediment cores



Modeled suspended-sediment concentrations (SSC) for event conditions at the peak of Tropical Storm Lee in 2011 (figure from Palinkas et al. 2014)

While large events can have significant short-term impacts, the Bay is resilient over the long run due to ongoing restoration and time gaps between events

Major storm events can deliver enormous amounts of sediment to the Bay, but they occur infrequently (less than 10% of the days since 1978).

Sediment delivery to the mid-Bay region, where waters are saltier and more conducive to nutrient releases from sediment, is relatively small in magnitude, minimizing potential impacts to Bay water quality.

Implications

The resiliency of Chesapeake Bay is likely aided by long time lags between major events and an underlying improvement in watershed management that is evident during non-event periods

Infilling of Conowingo Reservoir over time has changed its effect on downstream waters from a nutrient and sediment sink to a source

Chesapeake Bay will be negatively influenced by continued infilling and the loss of an unintended watershed BMP, but the scale of the potential impact is likely small compared to ongoing reductions in dissolved nitrogen and phosphorus in many regions of the watershed.

Other recent work

Emily Russ, PhD dissertation:
Sediment dynamics in the Susquehanna Flats (non-event)
Sediment provenance study
Updated sediment budget for upper Chesapeake Bay

Matt Biddle, MS thesis:
Modeling event and non-event sediment dynamics in the Flats

Miles Bolton, MS thesis:
Sediment dynamics in small patches on the western side of the Flats and their role in nutrient storage

Summary

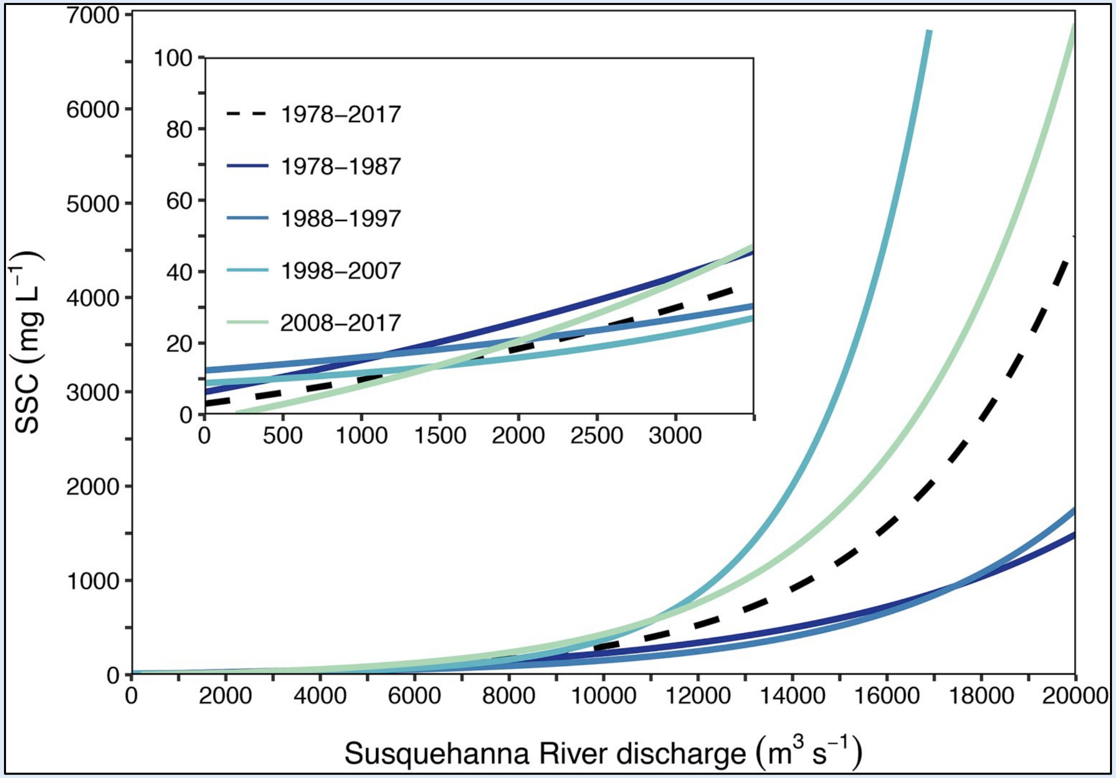
1) For equivalent river discharges, sediment loading has decreased during non-event flows but increased during event flows

2) The potential biogeochemical impacts of these elevated inputs is limited, because scoured particulate nitrogen (N) and phosphorus (P) loads that do enter the Bay are highly refractory (turnover time >> 1 year) and would contribute a relatively small fraction of loading in an extreme storm.

3) Also, these sediments are efficiently retained in the upper Bay due to high sinking rates or trapping in the ETM but can be transported downstream during events.

4) Thus, while high event-flow events are significant and can generate a substantial short-term impact on receiving waters in Chesapeake Bay, the estuary is remarkably resilient to storms.

Changes in sediment delivery to upper Bay



Changing relationship of suspended-sediment concentrations (SSC) and particulate nutrients to river discharge

Increase in particulate loads for a given flow

Sensitivity to inclusion of extreme events

Russ and Palinkas 2020

Questions:

1) What do observations look like for non-event and event flows?
2) What does this mean for sediment delivery to the Bay?

Palinkas et al. 2019

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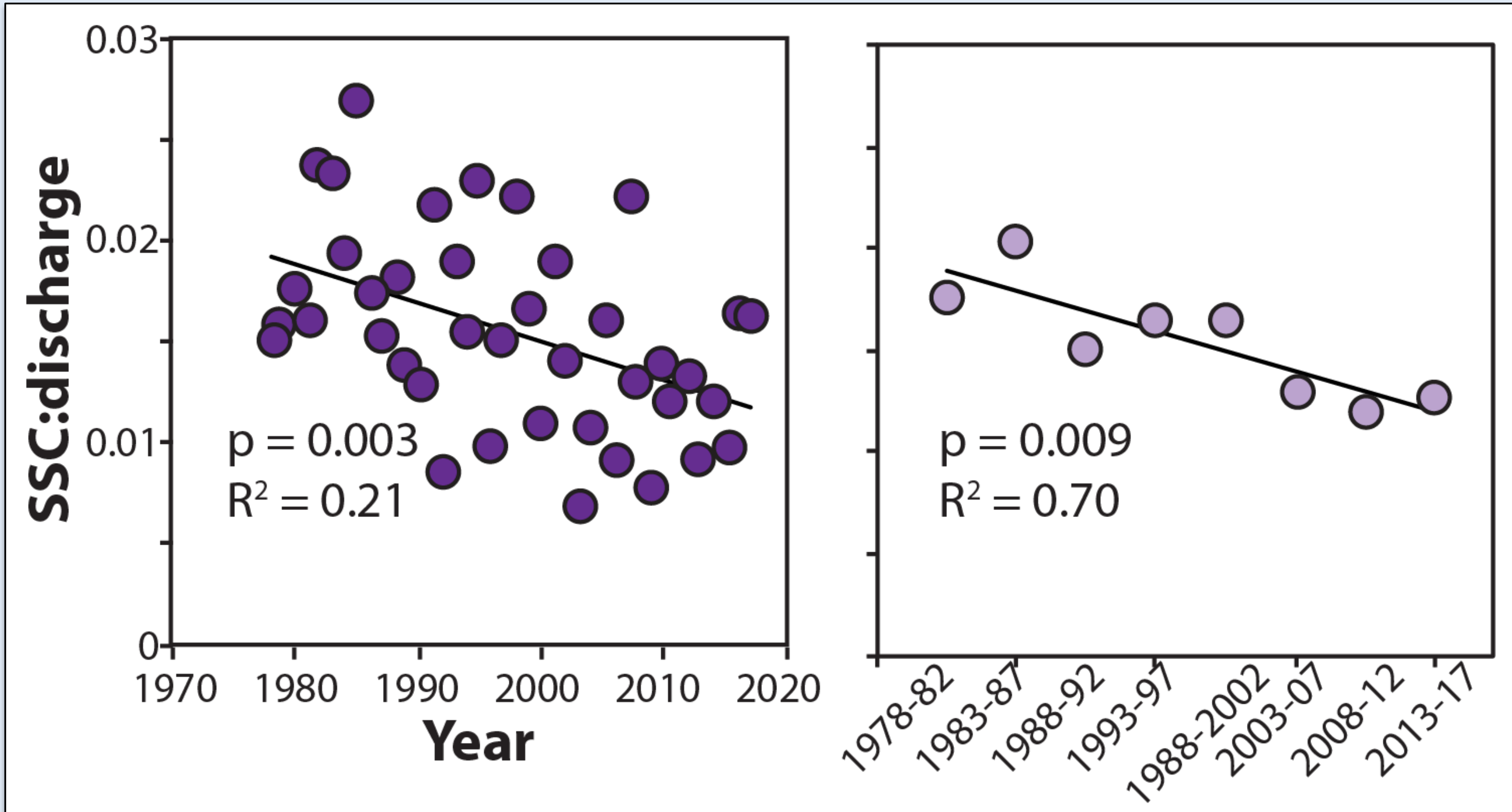
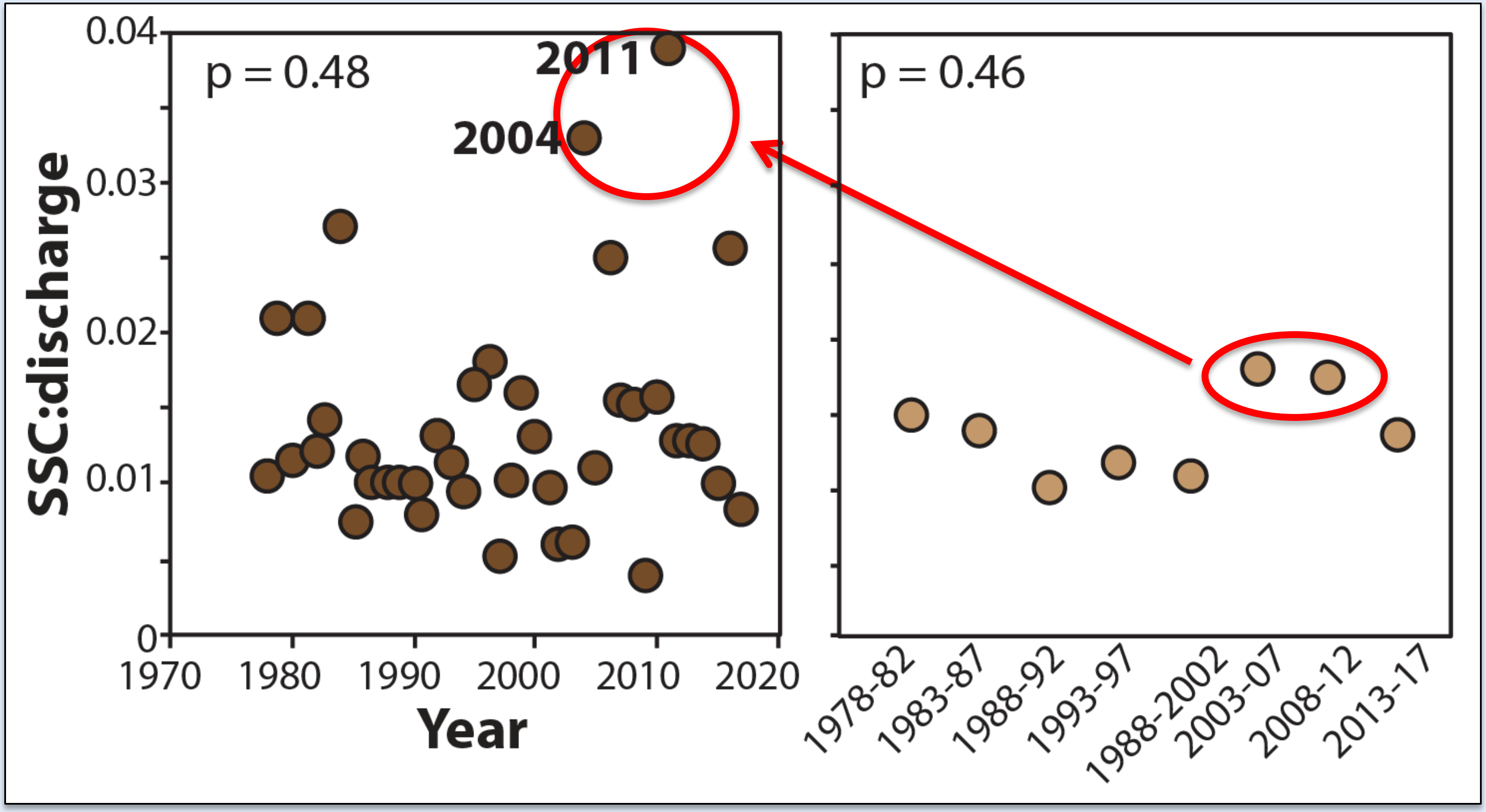
Ratio of SSC to river discharge: non-events (<86,400 cfs)



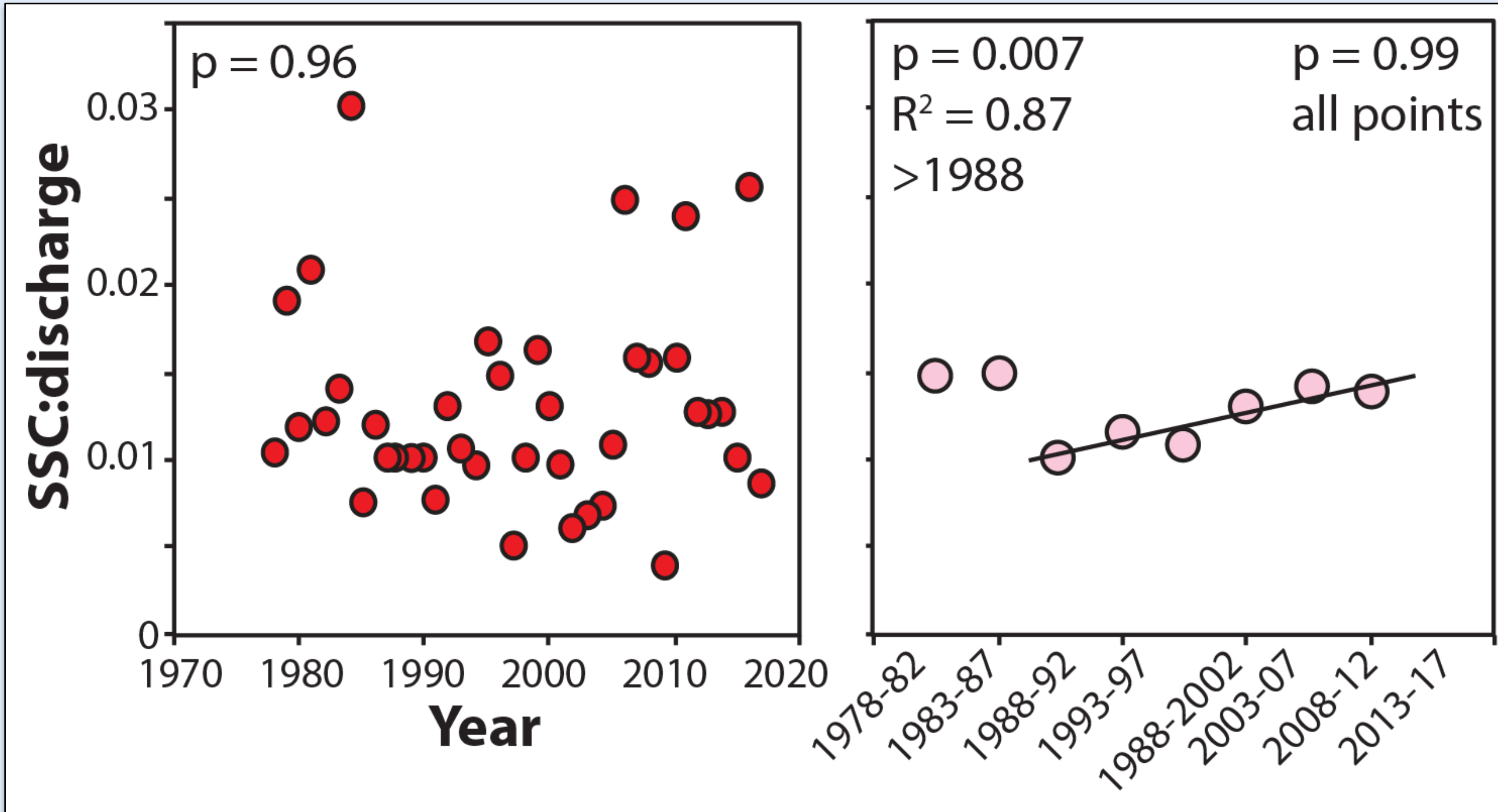
- Annual average: significant decline over time
- 5-year average: time explains 70% of the variability; 3 distinct groups?
- Likely reflects decline in watershed loading also observed at Marietta

Ratio of SSC to river discharge: events (>86,400 cfs)



- Annual and 5-year averages: no trend
- Extreme events have anomalously high SSC – scour!

Ratio of SSC to river discharge: events but not scour (>86,400 cfs but <400,000 cfs)



- No trend at annual scale, strong upward trend after ~1988 – consistent with decreasing scour threshold?
- **CAVEATS:** years arbitrarily chosen, sparse data (some only 1/year)
- What happens above 400,000 cfs? Only 13 observations!

Summary

“While large precipitation and riverine flow events are significant and can generate a substantial short-term impact on receiving waters in Chesapeake Bay, the estuary is remarkably resilient to storms. This recovery potential is likely aided by long time lags between major events and an underlying improvement in watershed management that are evident during low flow periods. The maturation of dams (i.e. infilling) over time shifts these constructed ecosystems from net nutrient and sediment sinks to sources, which changes their effect on downstream waters from that of a nutrient and sediment sink to that of a source. The Chesapeake Bay will be negatively influenced by continued infilling of reservoirs and the loss of an unintended watershed BMP, but the scale of the potential impact of elevated particulate nutrient inputs on the mainstem Chesapeake Bay is likely small compared to ongoing reductions in dissolved nitrogen and phosphorus in many regions of the watershed.”