Characterization of stratified coastal waters in response to a winter Mississippi River flood and the opening of the Bonnet Carré Spillway, Louisiana

Adam D. Boyette

Division of Marine Science
School of Ocean Science and Technology
The University of Southern Mississippi

Gulf of Mexico Oil Spill & Ecosystem Science Conference 2017

New Orleans, LA

09 February 2017

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Acknowledgements

This research was made possible in part by a grant from The Gulf of Mexico Research Initiative. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org (doi).

- Captain Nic Allen and the entire crew of the *R/V Point Sur* for their hard-work, helpfulness & professionalism. Science party performed flawlessly.
  - Division of Marine Science (DMS) and the Gulf Coast Research Laboratory (GCRL) at the School of Ocean Science and Technology (SOST) at the University of Southern Mississippi (USM)
  - Louisiana Universities Marine Consortium (LUMCON), Naval Research Laboratory (NRL), and University of Georgia (UGA) for providing personnel and equipment.

Acknowledgements: Science Party

Adam Boyette (USM)	CONCORDE	CDOM and flow cytometry
Alan Wiedemann (NRL)	CONCORDE	bio-optics/underway AC-S
Wesley Goode (NRL)		bio-optics/underway AC-S
Alison Deary (USM)	CONCORDE	plankton net tows
Hannah Box (USM)	CONCORDE	radium, $\delta^{18}O$
Allison Mojzis (USM)	CONCORDE	chlorophyll, nutrients, and dissolved oxygen
Sergio Derada (NRL)	DEEPEND	numerical modeling, deck ops
Sabrina Para (NRL)	CONCORDE	CTD
Peng Ho (USM)	CONCORDE	Trace metals
Laura Whitmore (USM)		CH_4 (discrete & underway)
Kelia Axler (USM)	CONCORDE	plankton net tows /mesozooplankton gut analysis
Anne Griffis (USM)	ECOGIG	CH_4 and NH_4 oxidation
Inia Soto (USM)	CONCORDE	Satellite Ocean Color

Acknowledgments: Processing & Data Assimilation

Bio-optics (ac-s)

- Inia Soto (CONCORDE)
- Alan Weidemann (CONCORDE)
- Wesley Goode (NRL)

Modeling

- Mustafa Cambazoglu (CONCORDE)
- Peter Spence (CARTHE)
- Brent Bartels (CARTHE)
- Gregg Jacobs (CONCORDE)

Meteorology

- Pat Fitzpatrick (CONCORDE)

Satellite Ocean Color

- Inia Soto (CONCORDE)
- Bob Arnone (CONCORDE)

Biogeochemistry

- DongJoo Joung (CONCORDE)
- Samantha Joye (ECOGIG)
- Kim Hunter (UGA)
- Jeffrey Krause (ACER)

Motivation

Characterize a large plume of Mississippi River (MSR) freshwater entering Mississippi coastal waters via Lake Pontchartrain due to opening of the Bonnet Carré Spillway

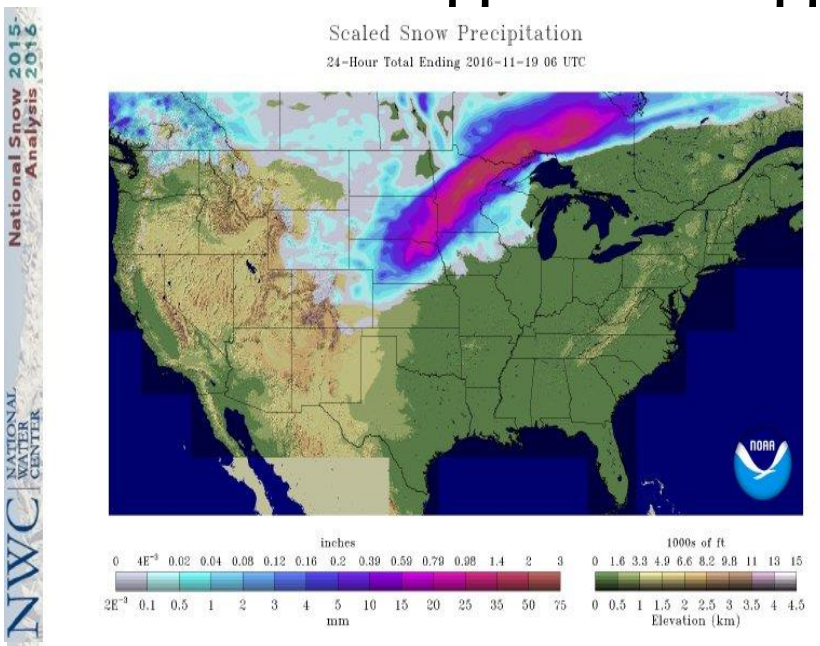
- Unprecedented opening of BCS in winter
  - Historical flooding in MSR valley
    - Climatological patterns during 2015-2016
      - Strong ENSO
    - Mississippi River and tributaries
    - Local rivers
- Effects & Timing
  - Hydrology/physical properties
    - Circulation patterns
  - Biogeochemistry
    - Nutrient stoichiometry
    - Dissolved oxygen
    - Production

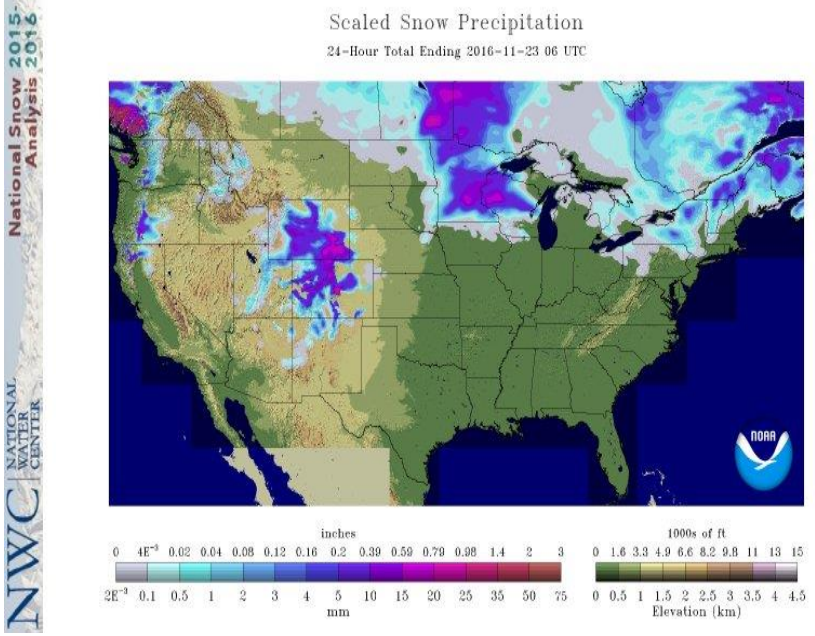
Bonnet Carré Spillway
Opened: 10 Jan. 2016
Closed: 31 Jan. 2016
21 days

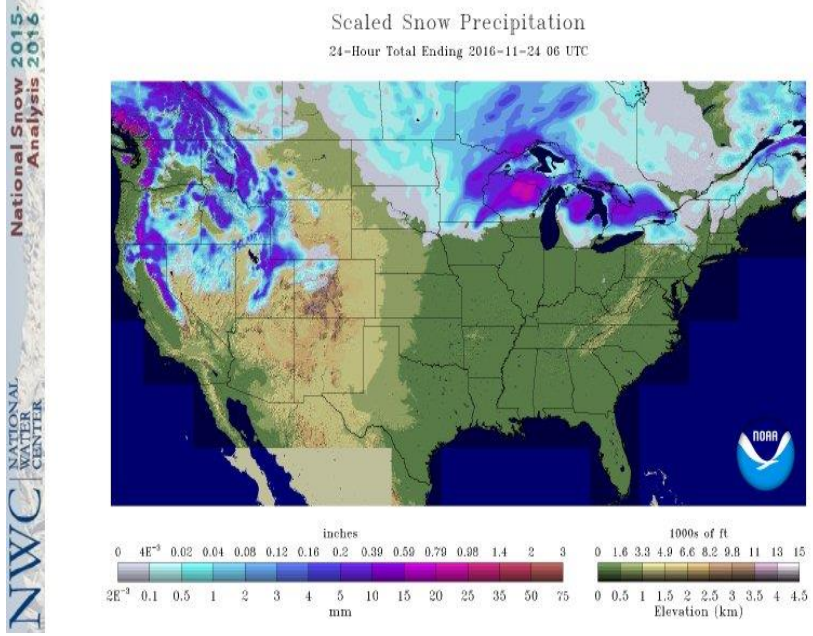
BONCARRES Cruise
Feb. 10-12, 2016 (*R/V Point Sur*)

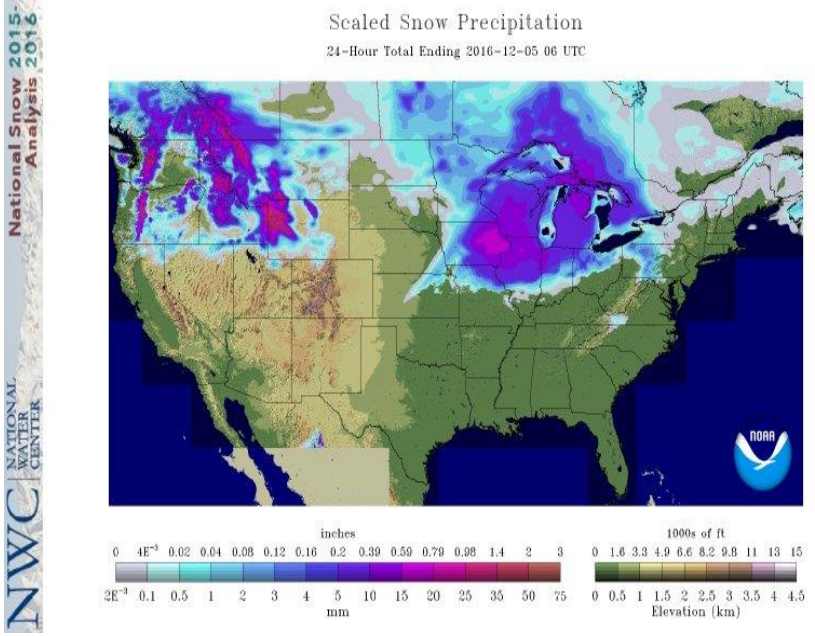

Photo courtesy USACE

Snowstorms in Upper Mississippi Valley in November and earlv December



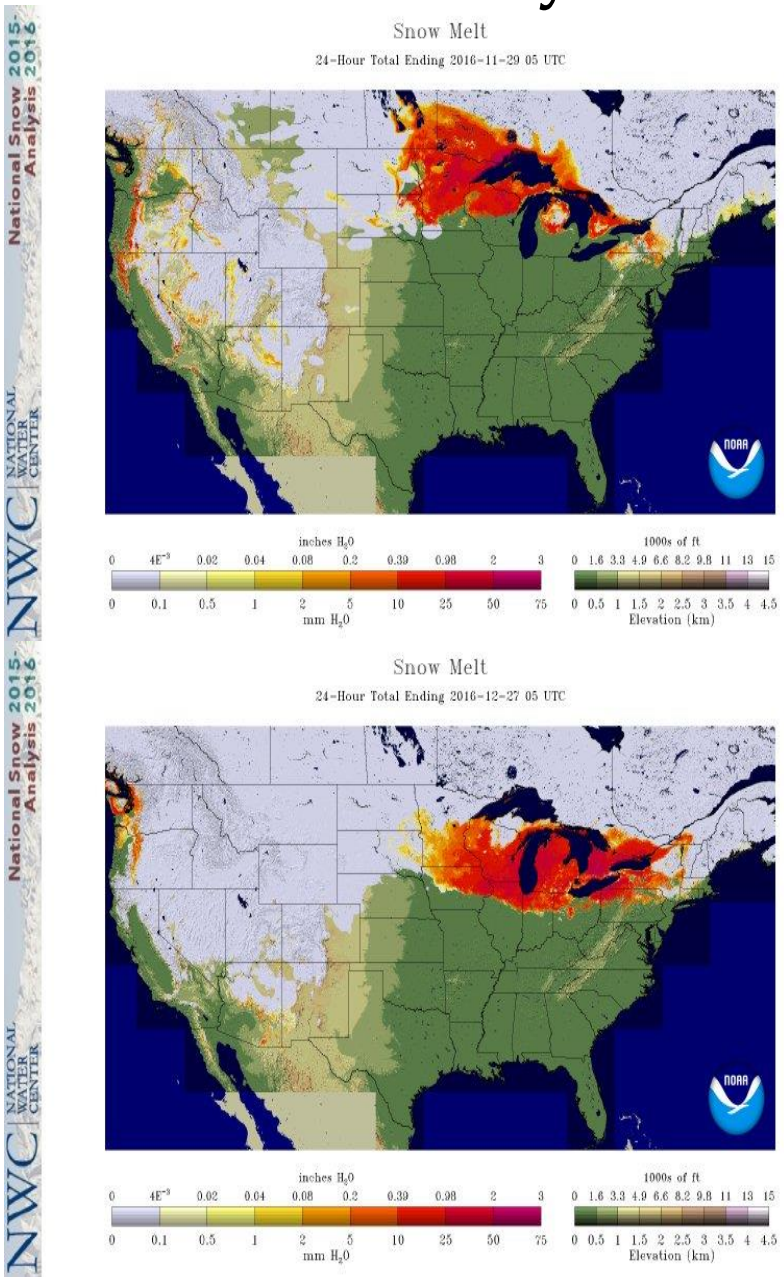


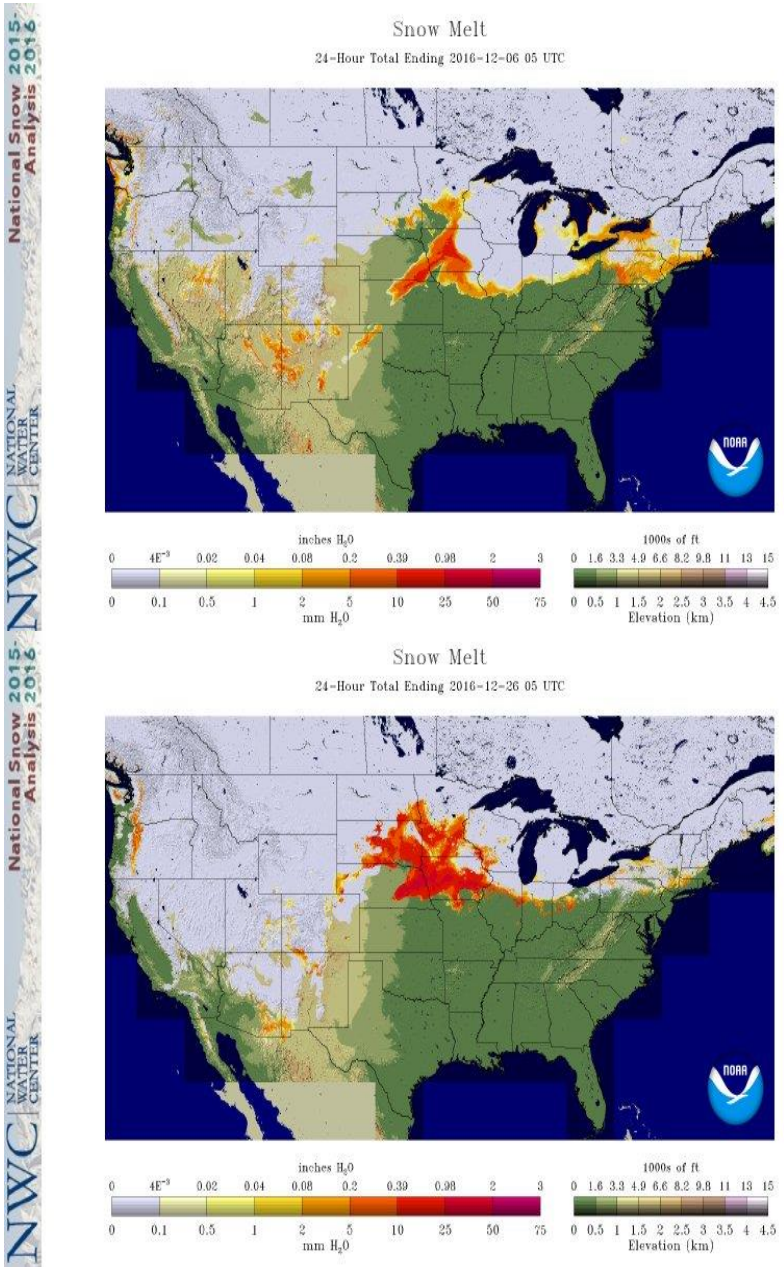




Courtesy Pat Fitzpatrick (MSU)

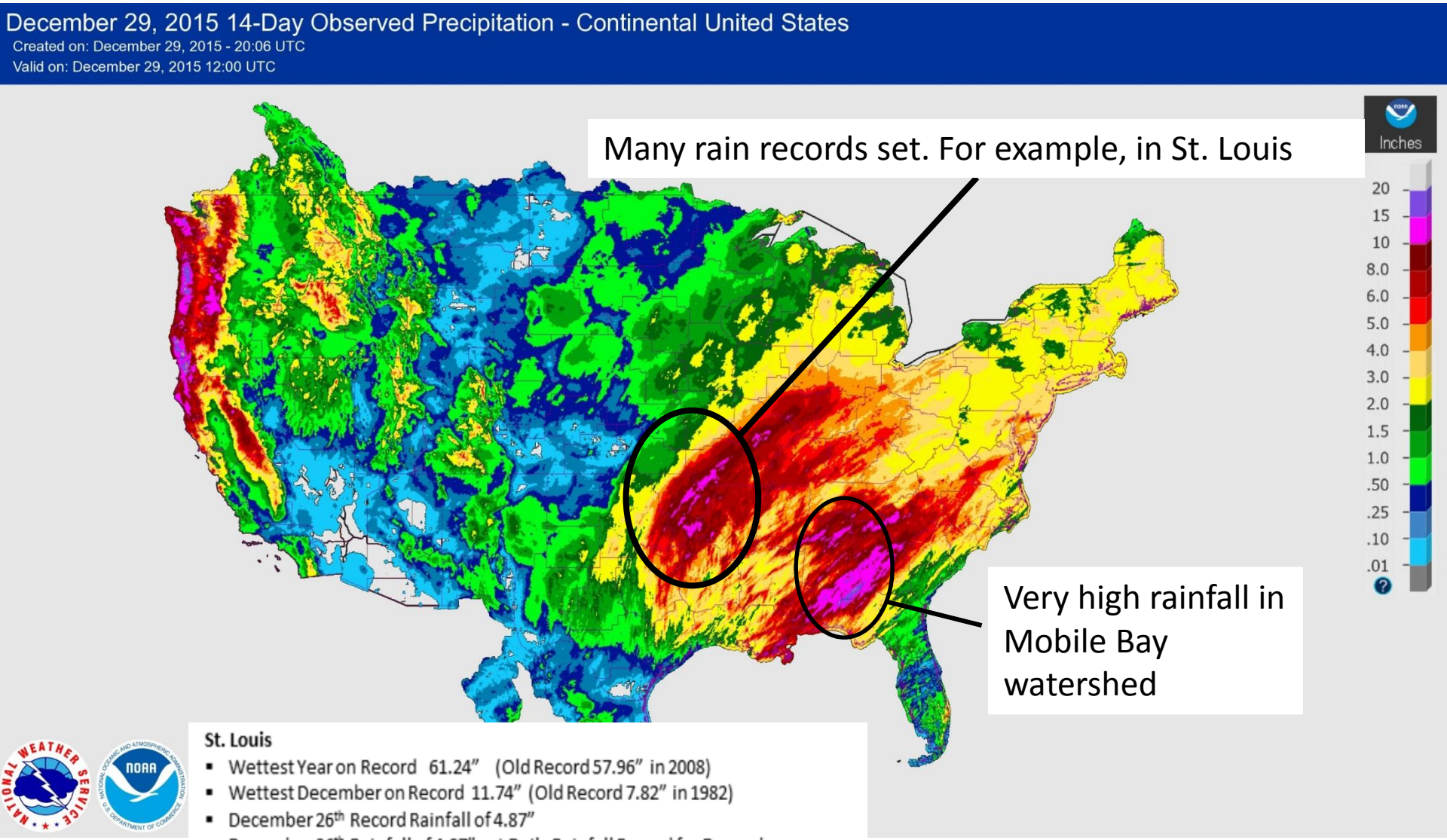
Followed by snowmelt which raised river levels



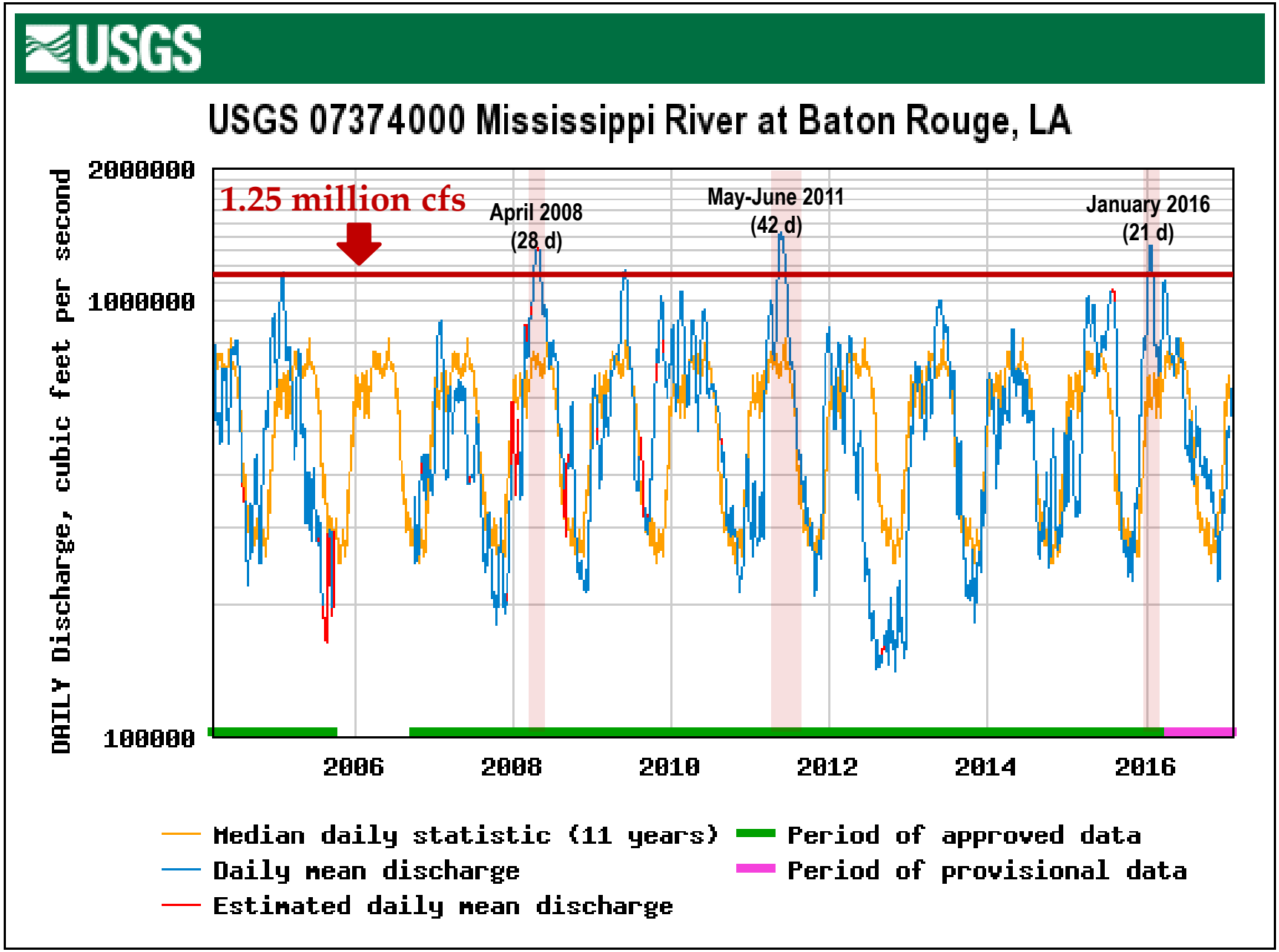


Courtesy Pat Fitzpatrick (MSU)

Followed by two Midwest record rain events during Dec 12-31



Courtesy Pat Fitzpatrick (MSU)


USGS
USGS 07374000 Mississippi River at Baton Rouge, LA
DAILY Discharge, cubic feet per second
2000000
1000000
100000
1.25 million cfs
April 2008
(28 d)
May-June 2011
(42 d)
January 2016
(21 d)
2006
2008
2010
2012
2014
2016
Median daily statistic (11 years)
Daily mean discharge
Estimated daily mean discharge
Period of approved data
Period of provisional data

Bonnet Carré Crevasse (1849-1882)

- 33 miles above New Orleans
- Site of naturally occurring crevasses
- Completed construction following historical Flood of 1927

US Army Corps of Engineers New Orleans District operates the Bonnet Carré Spillway

Spillway opens when local MS river discharge gauges read above 1.25 million cubic feet per second (cfs)

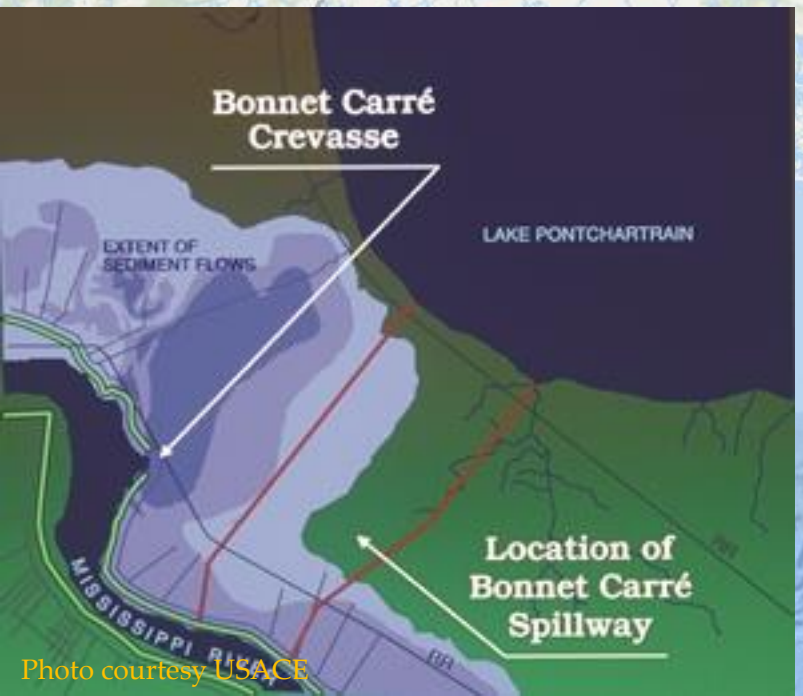


Photo courtesy USACE

Photo courtesy USACE

NASA Visible Earth: Lake Pontchartrain and the Bonnet Carré Spillway, Louisiana (April 29, 2008)

12-Jan

Day 2

Spillway began opening on Jan. 10 (Day 0)

13-Jan

Day 3

16-Jan

Day 7

17-Jan

Day 8

18-Jan

Day 9

19-Jan

Day 10

23-Jan

Day 14

24-Jan

Day 15

26-Jan

Day 17

Spillway began closure on Jan. 25 (Day 16)

29-Jan

Day 20

04-Feb

Day 26

+ 4 days

Spillway closed on Jan. 31 (Day 22)

05-Feb

Day 27

+ 5 days

07-Feb

Day 29

+ 7 days

08-Feb

Day 30

+ 8 days

09-Feb

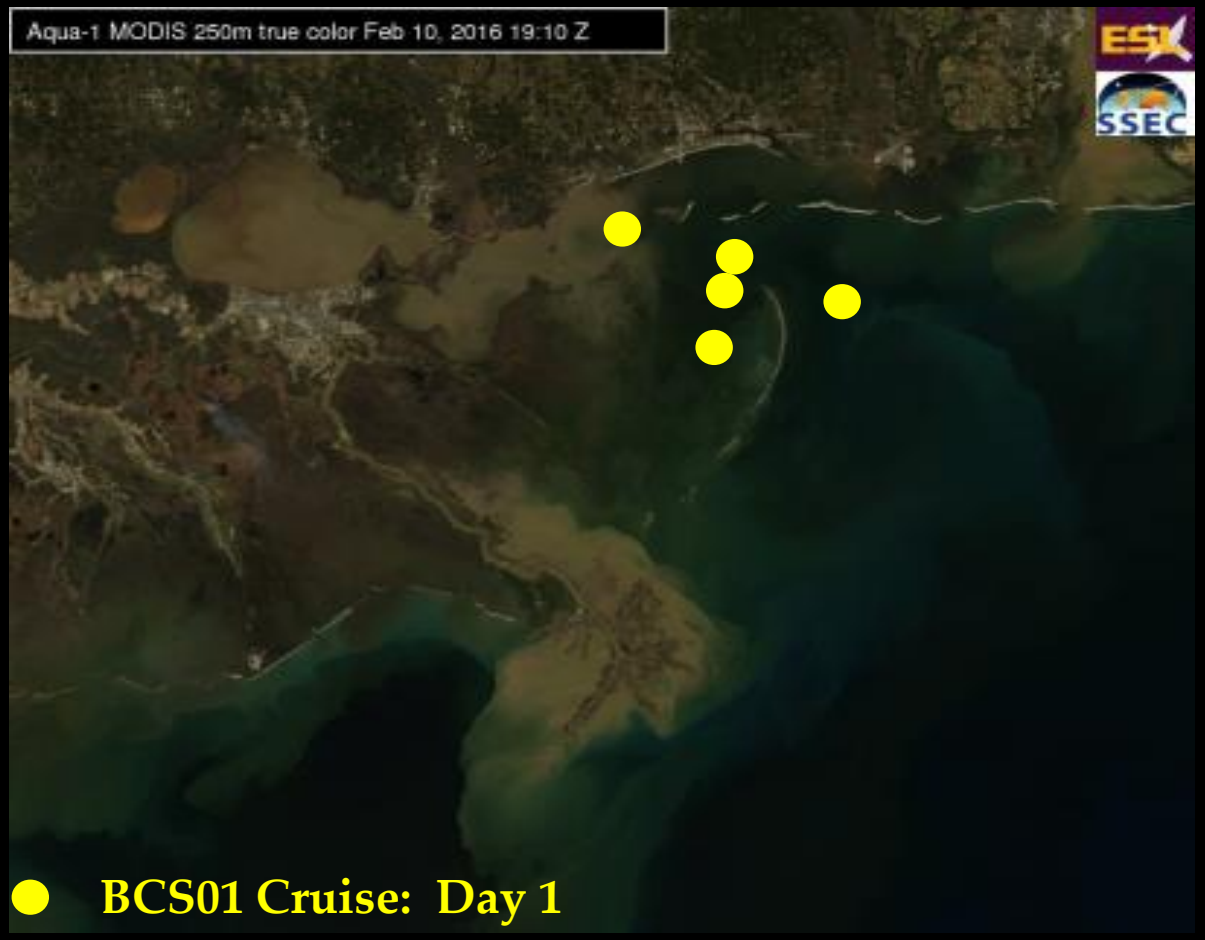
Day 31

+ 9 days

10-Feb

Day 32

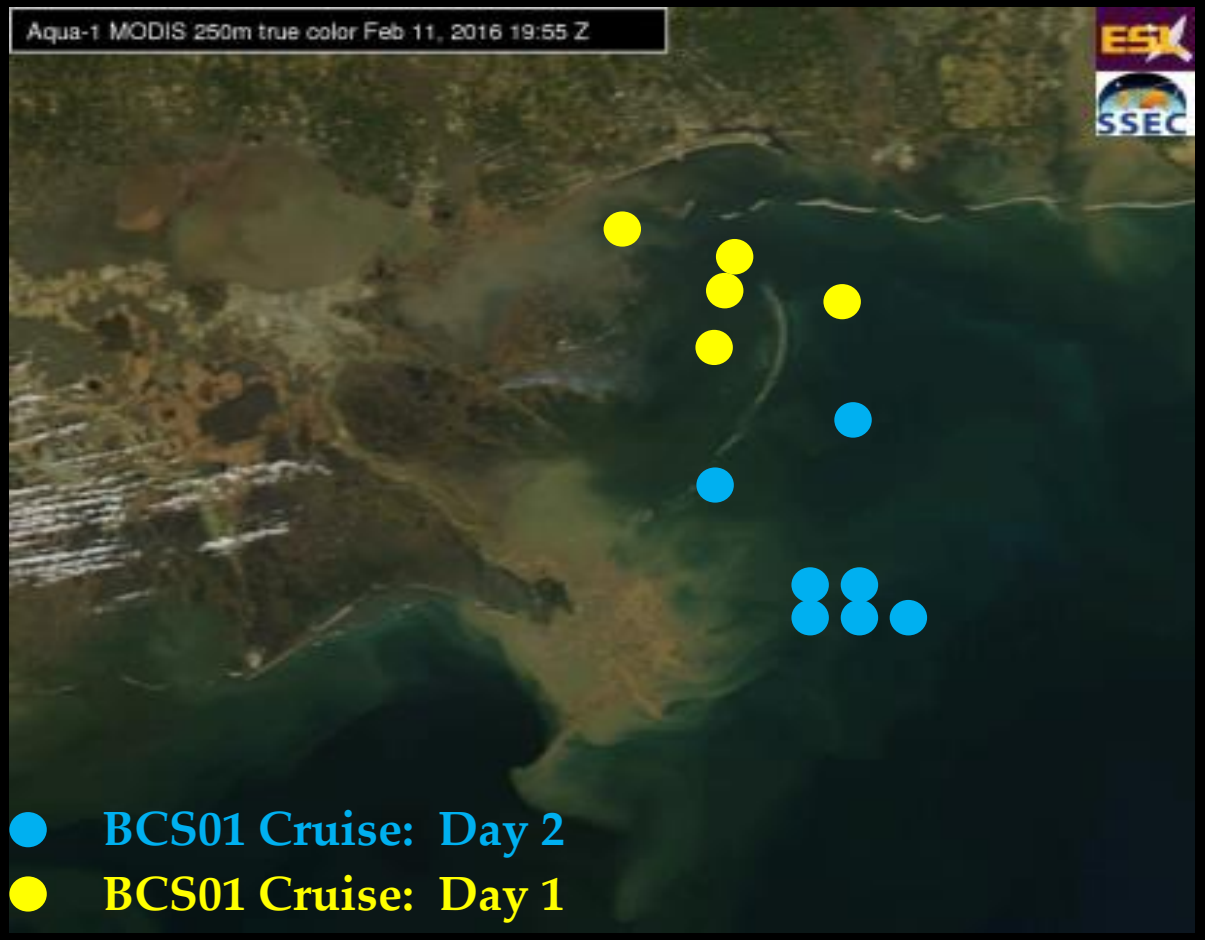
+ 10 days



11-Feb

Day 33

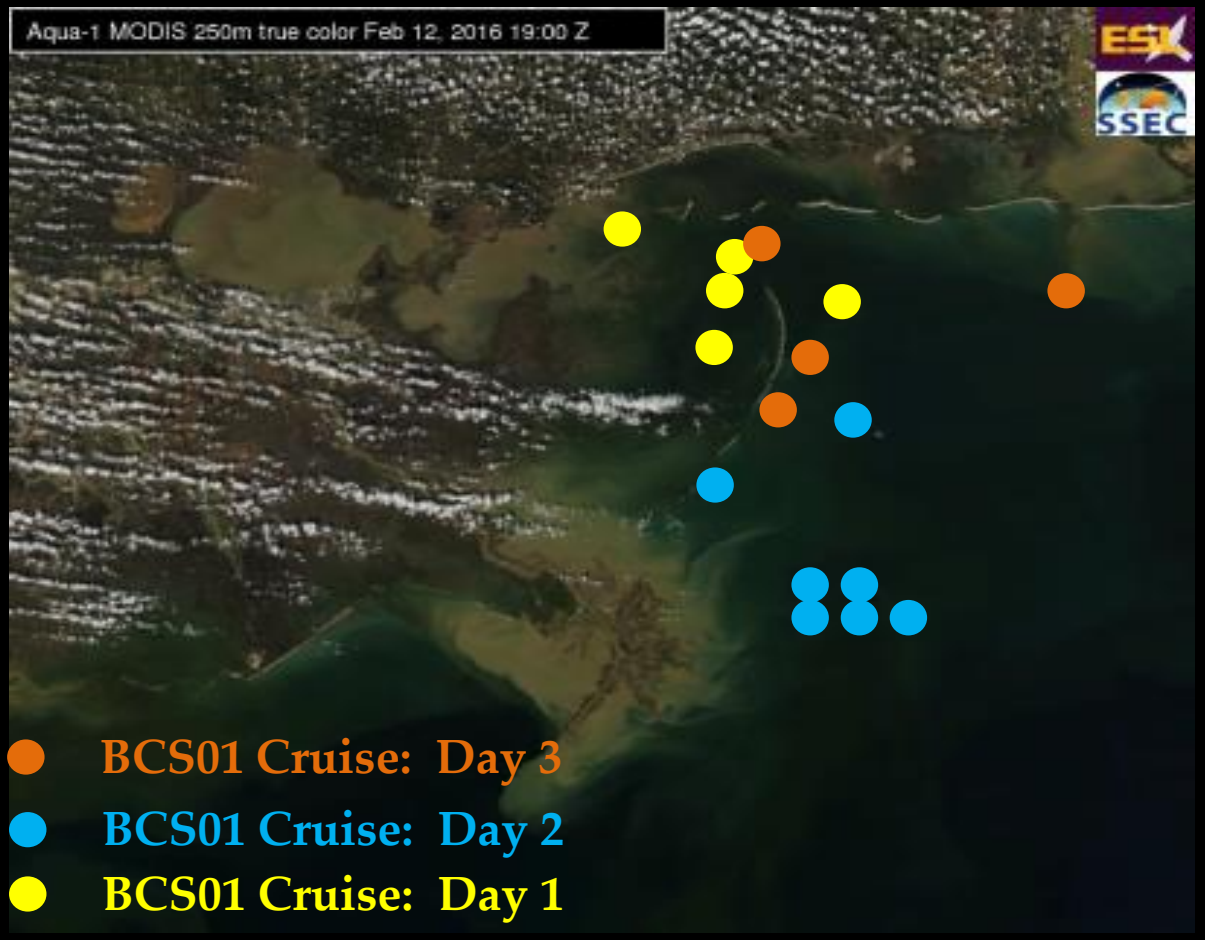
+ 11 days



12-Feb

Day 34

+ 12 days



13-Feb

Day 35

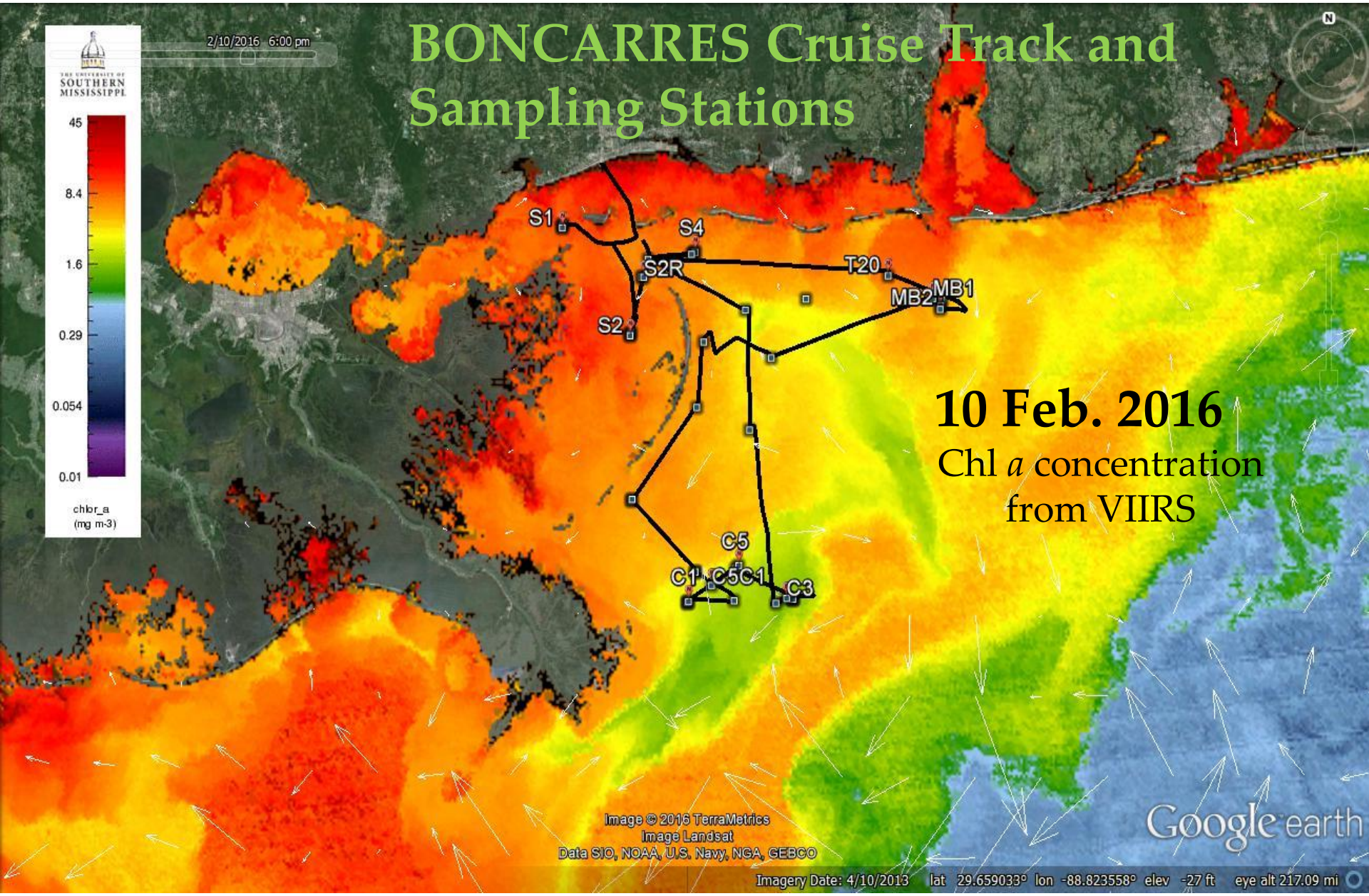
+ 13 days

Accomplishments

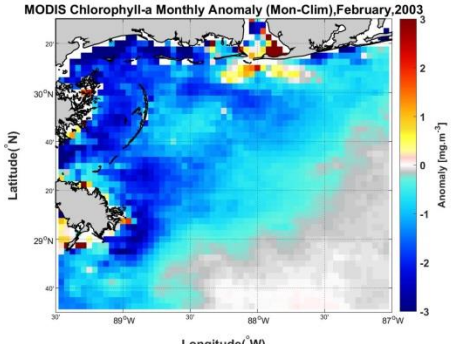
Stations comprising:

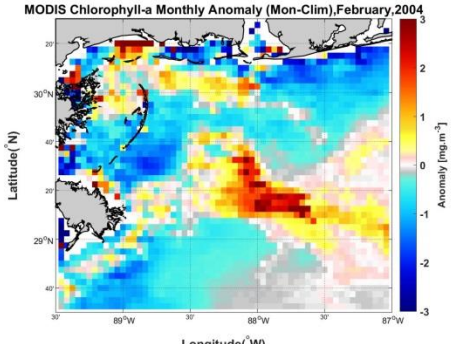
- 15 CTD stations
- 15 trace metal casts & $\delta^{18}O$
- 17 radium pumping casts
- 16 optics (AC-S + CTD) casts
- 34 phytoplankton samples (FlowCAM)
- 30 samples for CH_4 & NH_4 oxidation analyses
- 11 net tows (22 samples)
- Underway optics (AC-S) data
- Underway CH_4 data
- Land-based daily satellite imagery (ocean color) and numerical modeling
- 2 glider deployments/1 glider recovery

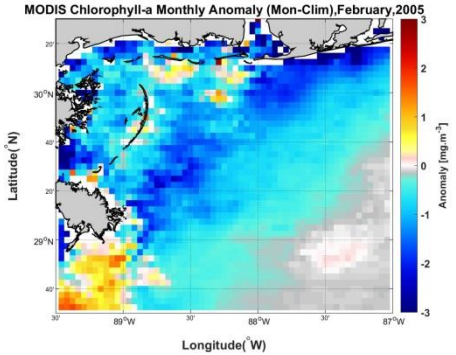
Physical & Bio-optical	Plankton Community
Characterize the physical structure and optical properties of the water column *in situ* • CTD • AC-S (flow-through) & optics package	Quantify plankton biomass using a suite of water sampling and image analysis techniques • Quanitfy meso- & ichthyoplankton abundance and composition • particle size distribution & phytoplankton community composition (e.g. FlowCAM)
Biogeochemistry & Trace Metals	**Remote Sensing & Modeling**
Describe the water chemistry & biomass • nutrients, Chl *a*, CDOM • trace metals, radium (SGD), CH_4 • dissolved oxygen (Winkler titration) • CH_4 conc. and NH_4 oxidation	Apply satellite ocean color and circulation models

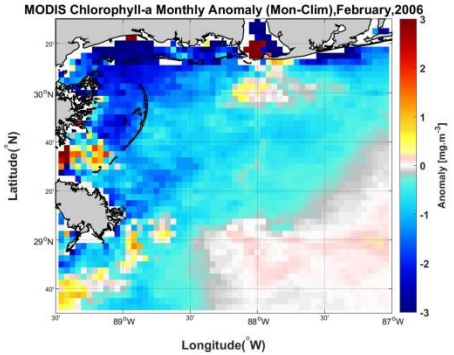

BONCARRES Cruise Track and Sampling Stations
2/10/2016 6:00 pm
THE UNIVERSITY OF SOUTHERN MISSISSIPPI
45
8.4
1.6
0.29
0.054
0.01
chlor_a (mg m-3)
S1
S4
S2R
T20
MB2
MB1
S2
C5
C1
C5C1
C3
10 Feb. 2016
Chl a concentration from VIIRS
Image © 2016 TerraMetrics
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Imagery Date: 4/10/2013 lat 29.659033° lon -88.823558° elev -27 ft eye alt 217.09 mi

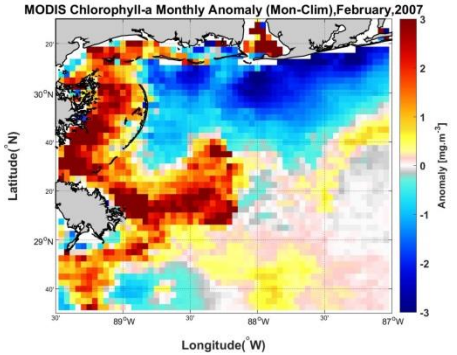
February Chlorophyll-a Anomalies 2003-2016

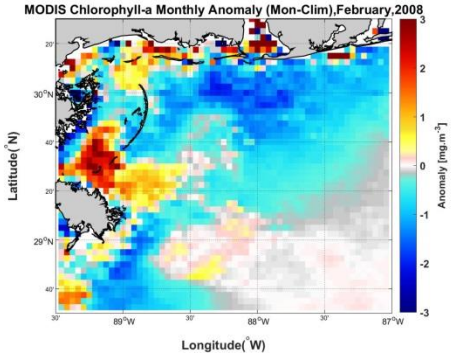


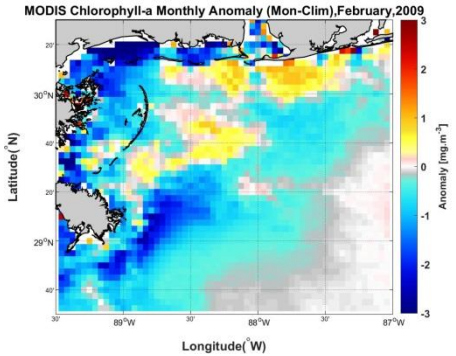


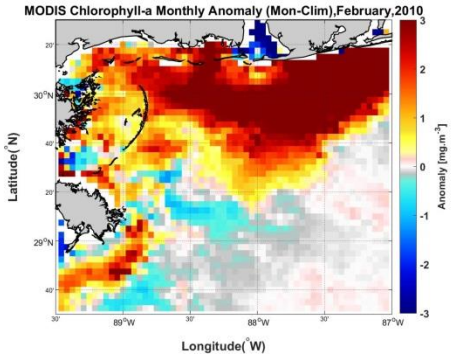


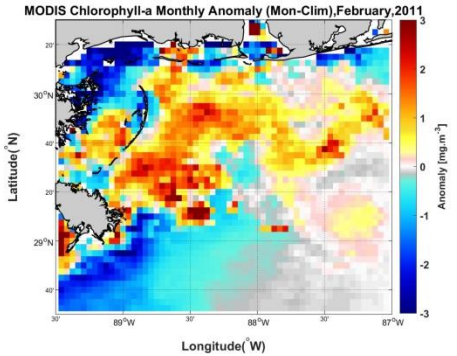


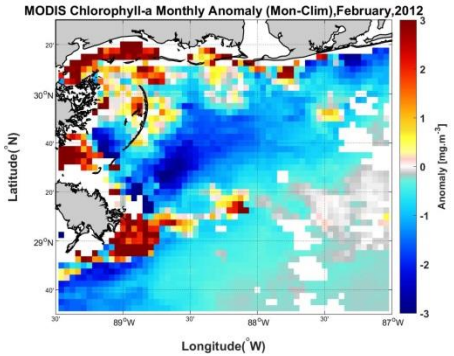


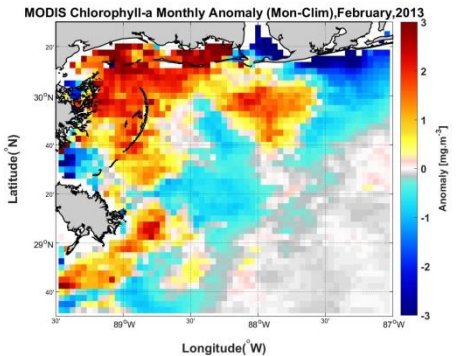


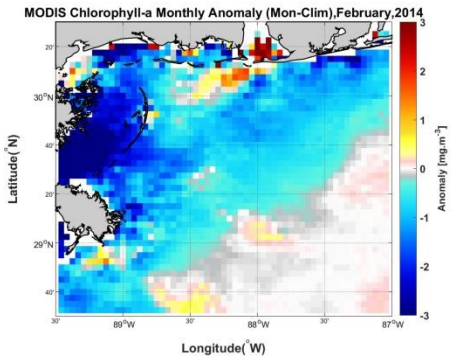


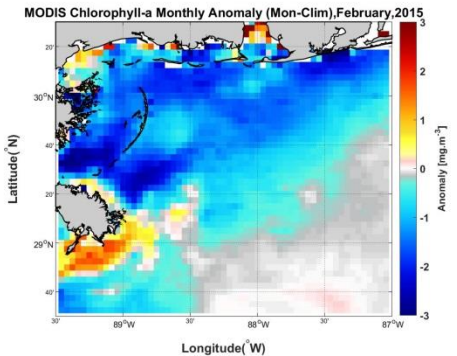


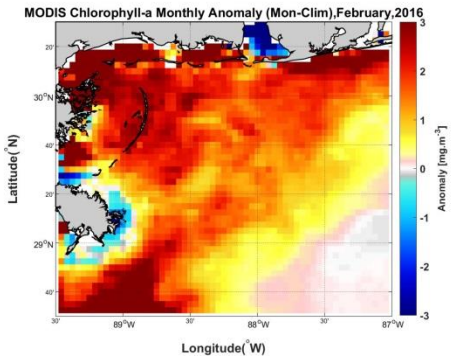


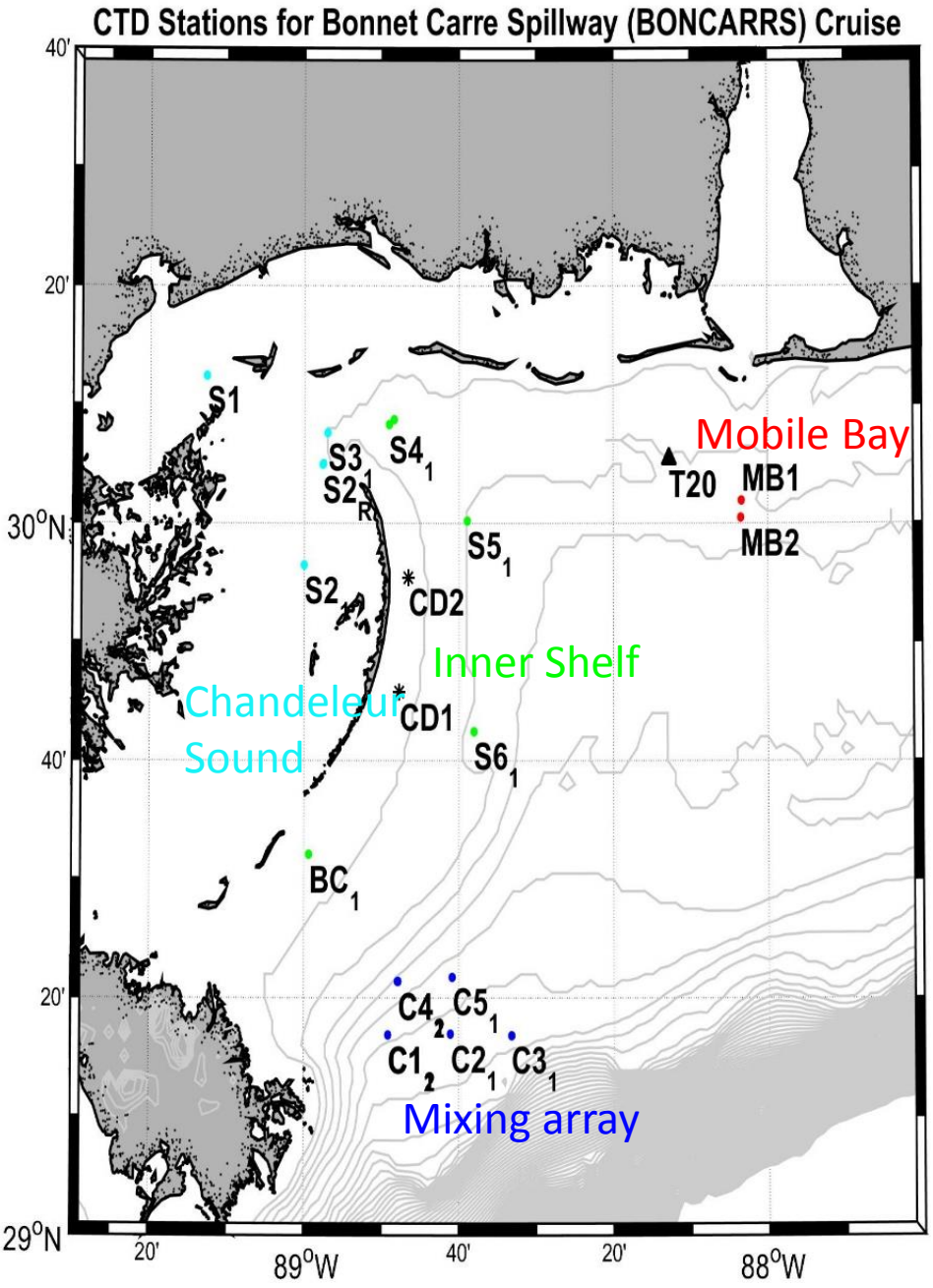


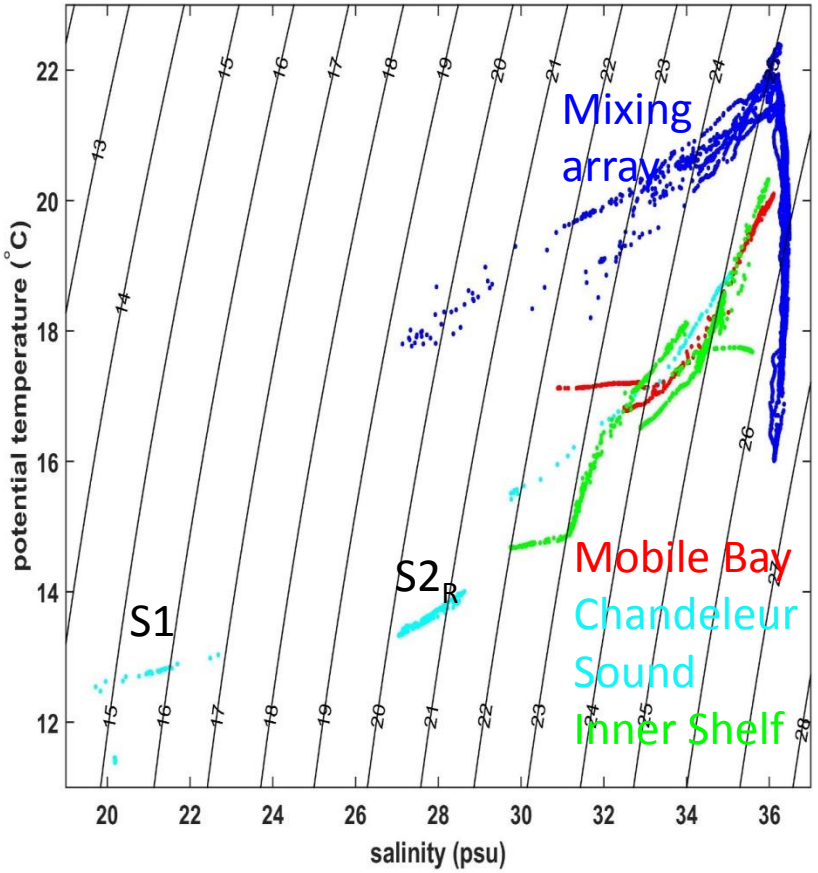




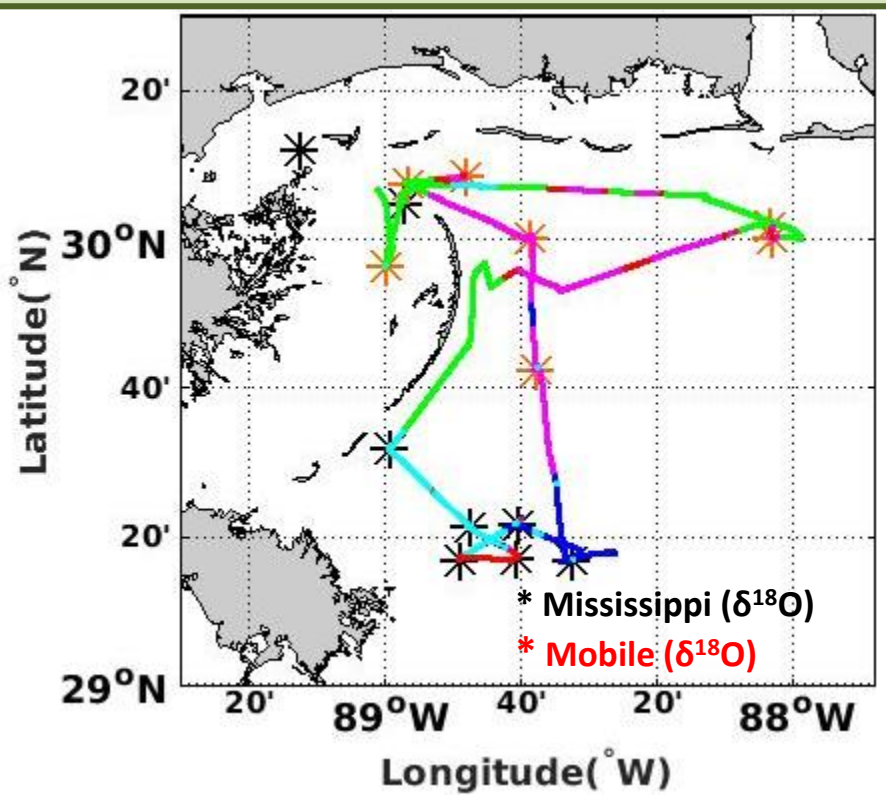





CTD Stations for Bonnet Carre Spillway (BONCARRS) Cruise
40'
20'
30°N
40'
20'
29°N
20'
89°W
40'
20'
88°W
S1
S3
S2R
S4
T20
MB1
MB2
S5
S2
CD2
CD1
S6
BC
C4
C5
C1
C2
C3
Mobile Bay
Inner Shelf
Chandeleur Sound
Mixing array


potential temperature (°C)
salinity (psu)
22
20
18
16
14
12
20
22
24
26
28
30
32
34
36
S1
S2R
Mixing array
Mobile Bay
Chandeleur Sound
Inner Shelf

Optical Water Mass Classification Scheme

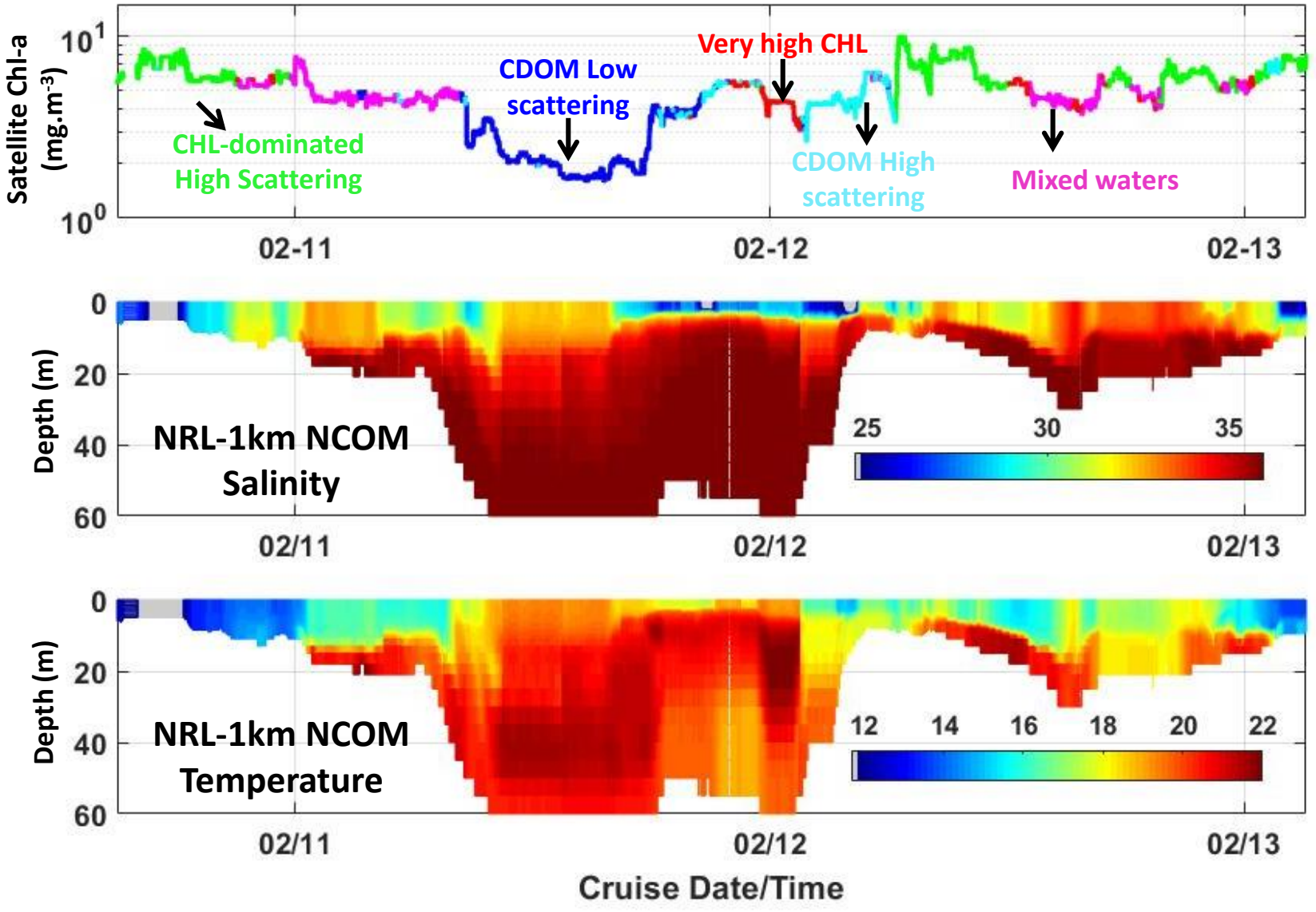


CDOM-dominated Low scattering	CDOM-dominated High scattering	Mixed waters	Very high CHL	CHL-dominated High Scattering	Slope waters

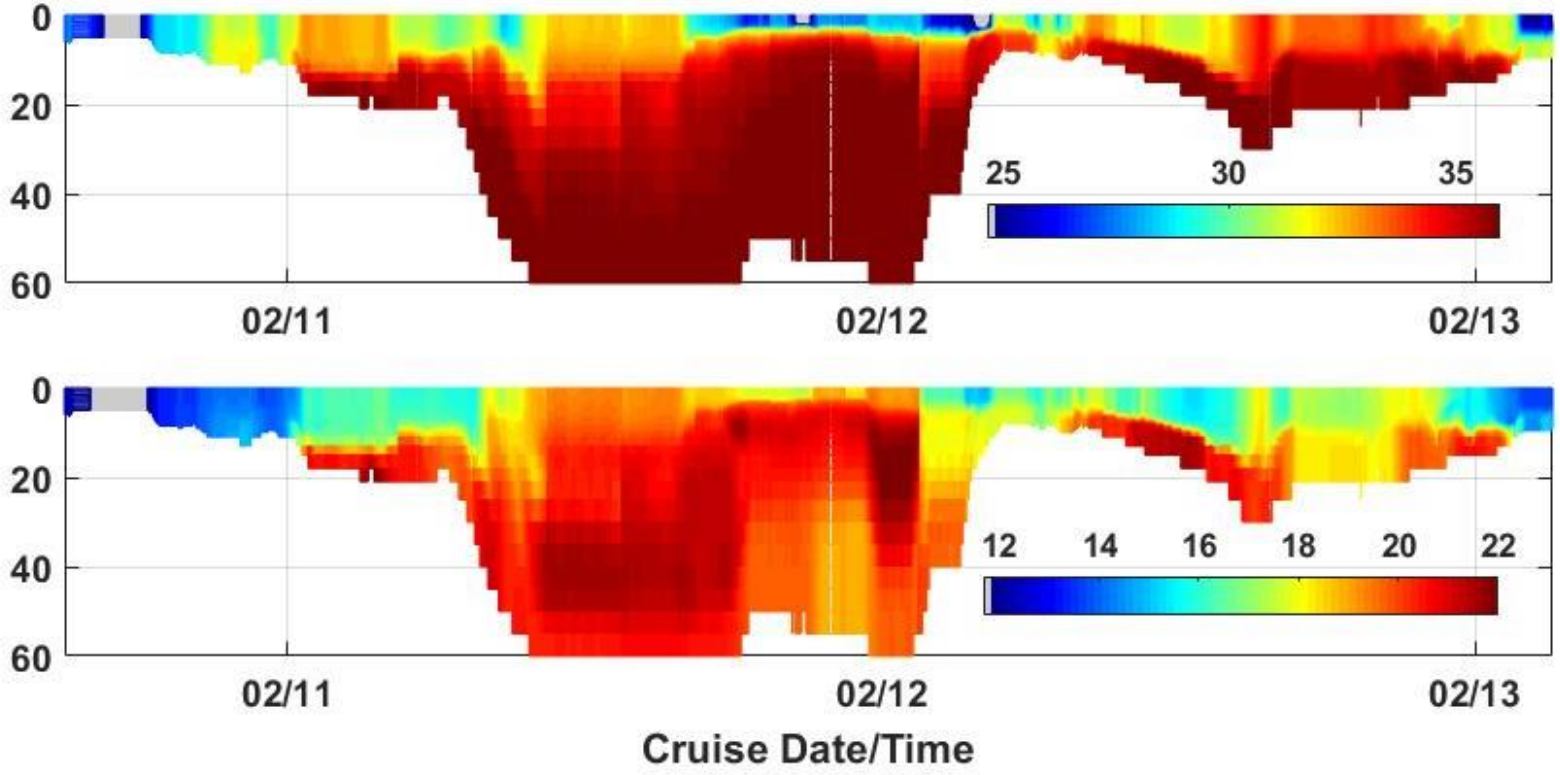
- *In situ* optical data used to create a logic-scheme optical water masses classification that will be eventually transferred to satellite remote sensing.
- **Data used**: Flow-through AC-s, optics profiles, discrete samples, NCOM

- *Soto et al., 2017 (Session 014a) Bio-optical Water Mass Classification of the Mississippi Bight Region: Coupling High Resolution Satellite Data, Circulation Models and In-situ Optics*
- *Joung et al., 2017 (Session 014) Seasonal Dynamics of Trace Elements and Radium Isotopes in Mississippi Coastal Waters*

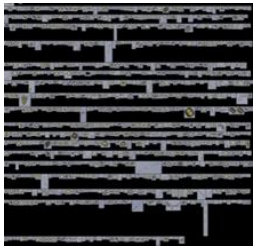
Coupling *in situ* optics, satellite data and high resolution circulation models

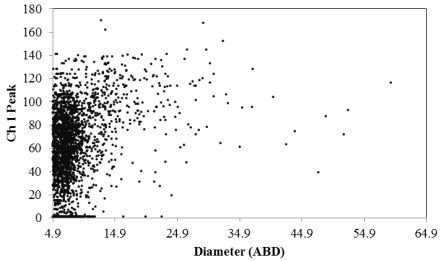


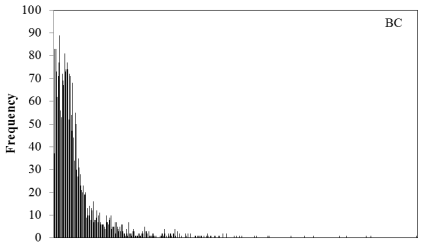
Soto et al., 2017 (Session 014a) Bio-optical Water Mass Classification of the Mississippi Bight Region: Coupling High Resolution Satellite Data, Circulation Models and In-situ Optics


0
20
40
60
25
30
35
02/11
02/12
02/13
0
20
40
60
12
14
16
18
20
22
02/11
02/12
02/13
Cruise Date/Time

FlowCam was used to quantify particle counts and identify phytoplankton taxonomic groups







Level 0
Raw Data

Natural water sample

Level 1
Clean Data

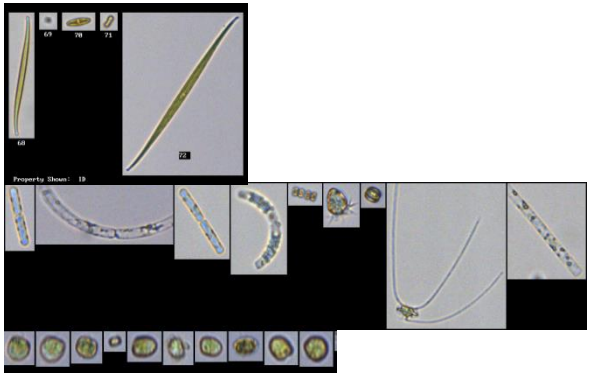
Remove duplicate & artifact images

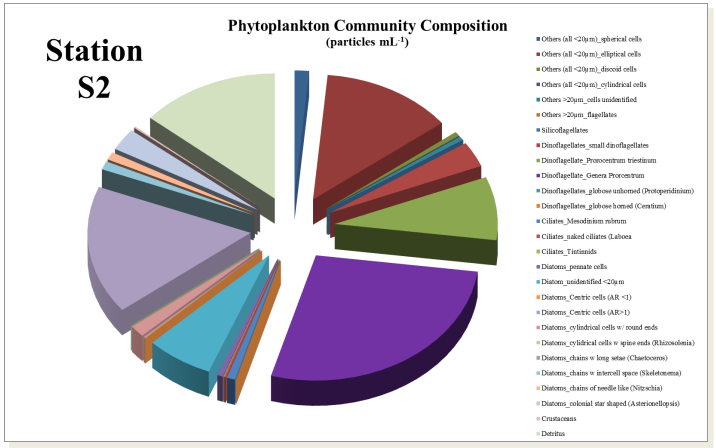
Level 2
Classify

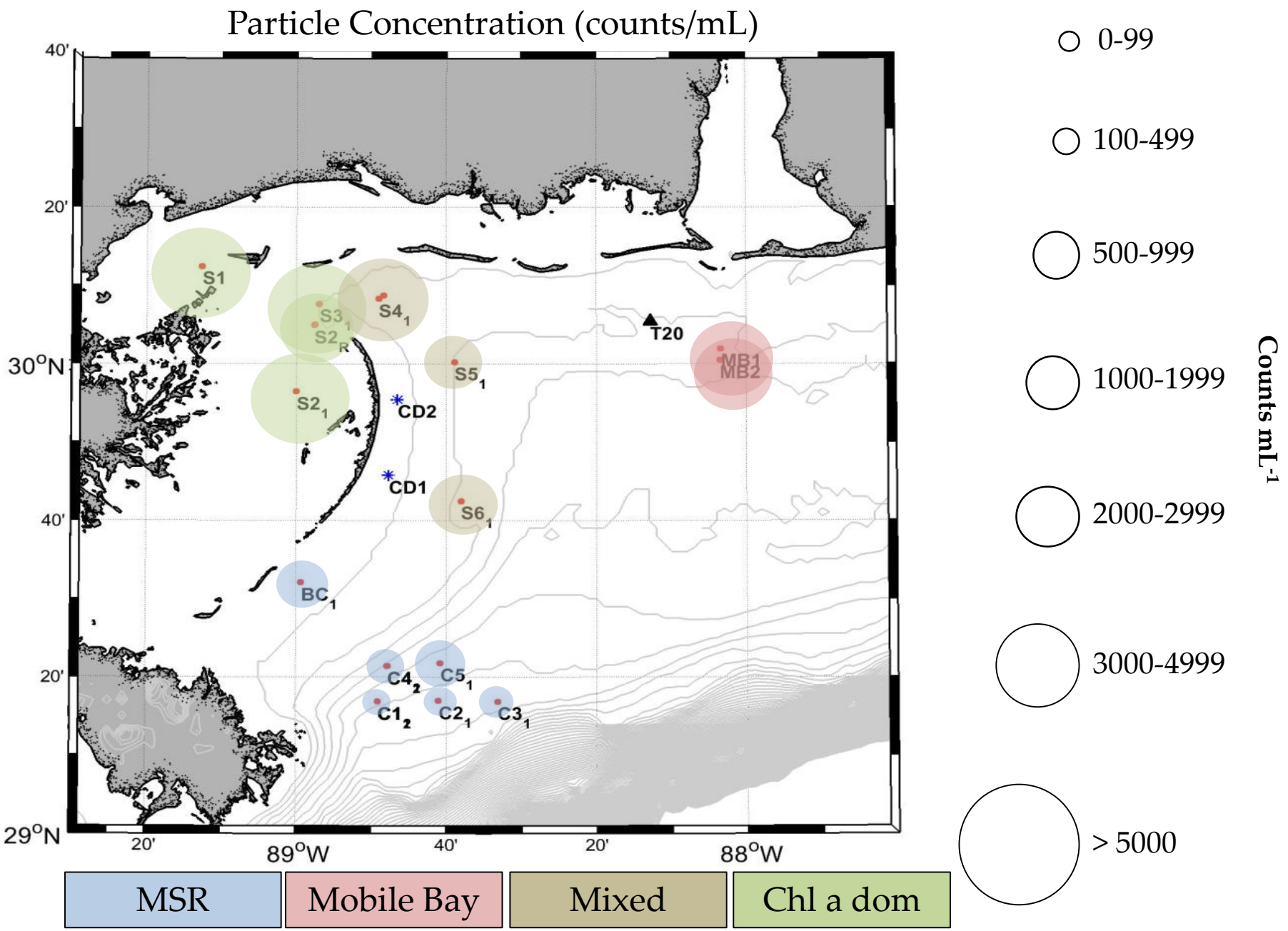
Genera

Abundance & size class

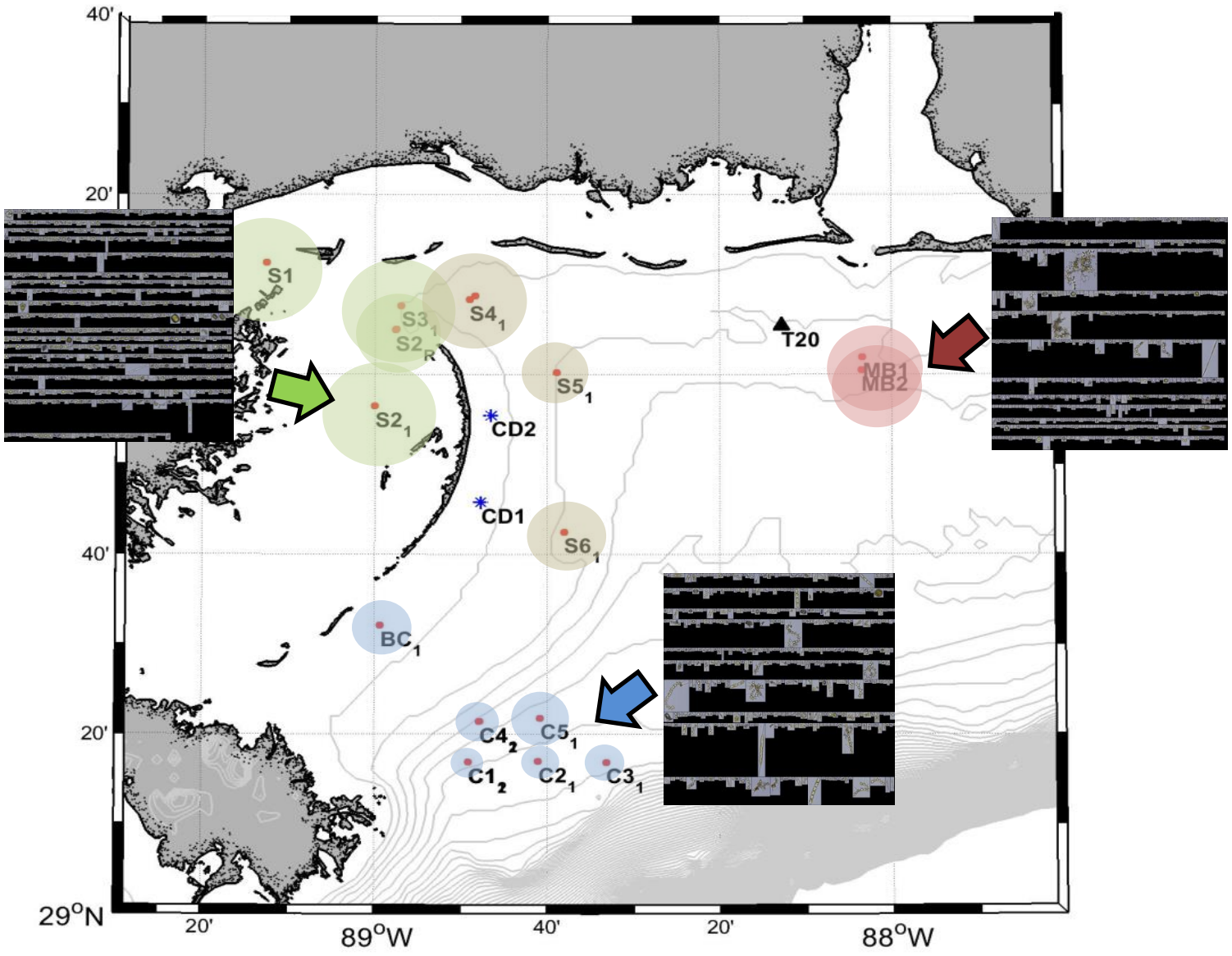
Shape class & biovolume



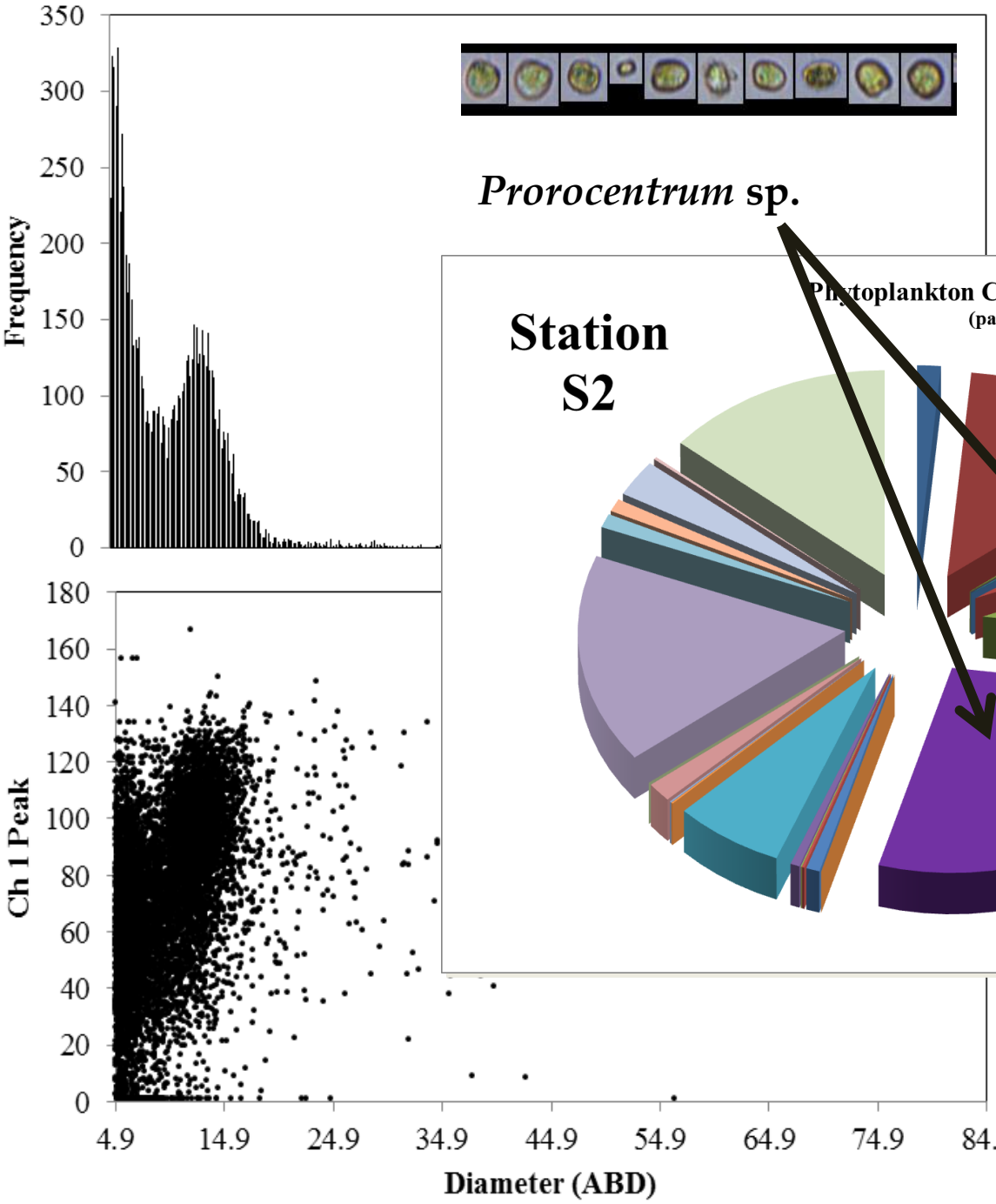



Particle Concentration (counts/mL)
40'
20'
30°N
40'
20'
29°N
20'
89°W
40'
20'
88°W
S1
S3 1
S2 R
S4 1
S2 1
S5 1
T20
MB1
MB2
CD2
CD1
S6 1
BC 1
C4 2
C5 1
C1 2
C2 1
C3 1
0-99
100-499
500-999
1000-1999
2000-2999
3000-4999
> 5000
Counts mL -1
MSR
Mobile Bay
Mixed
Chl a dom

Particle Taxonomic Classification

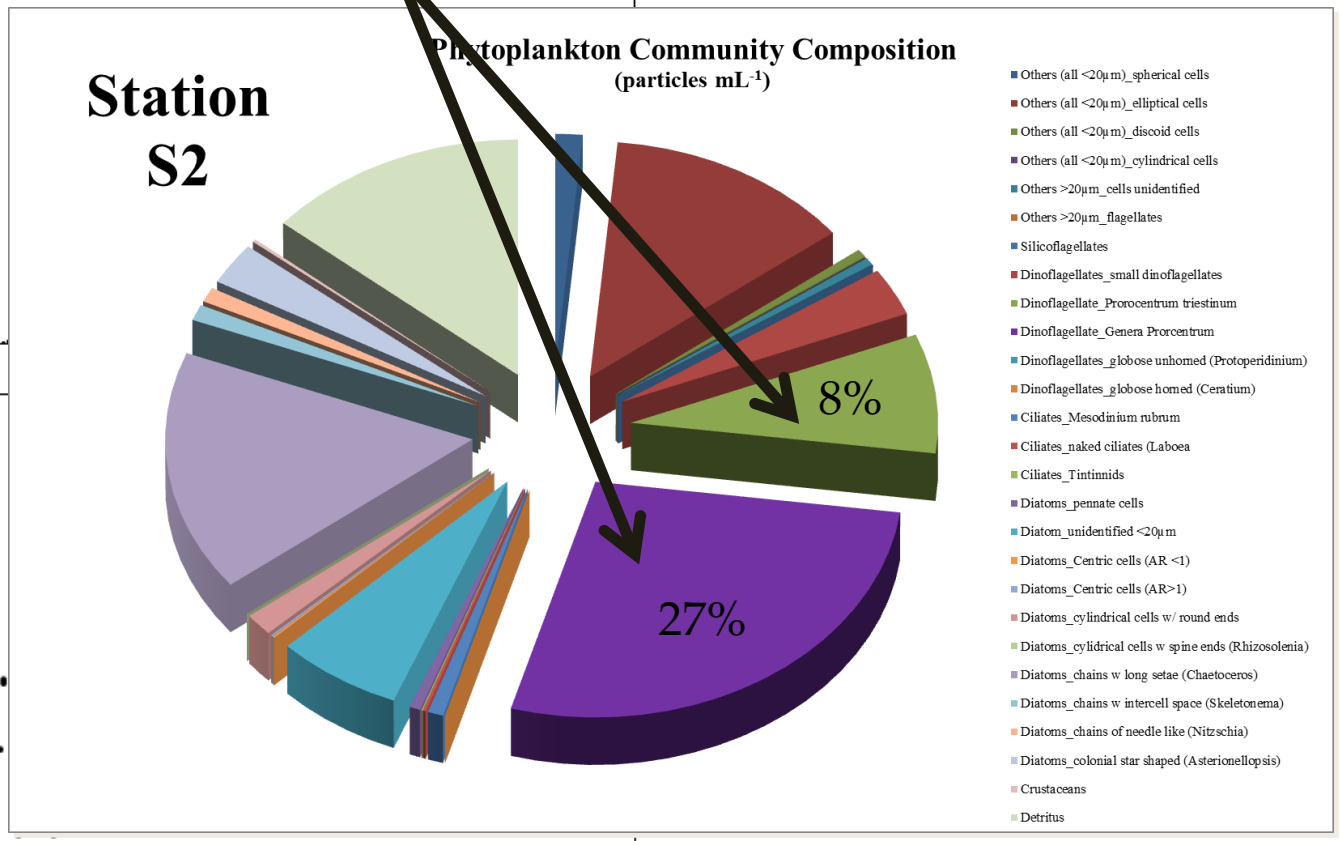


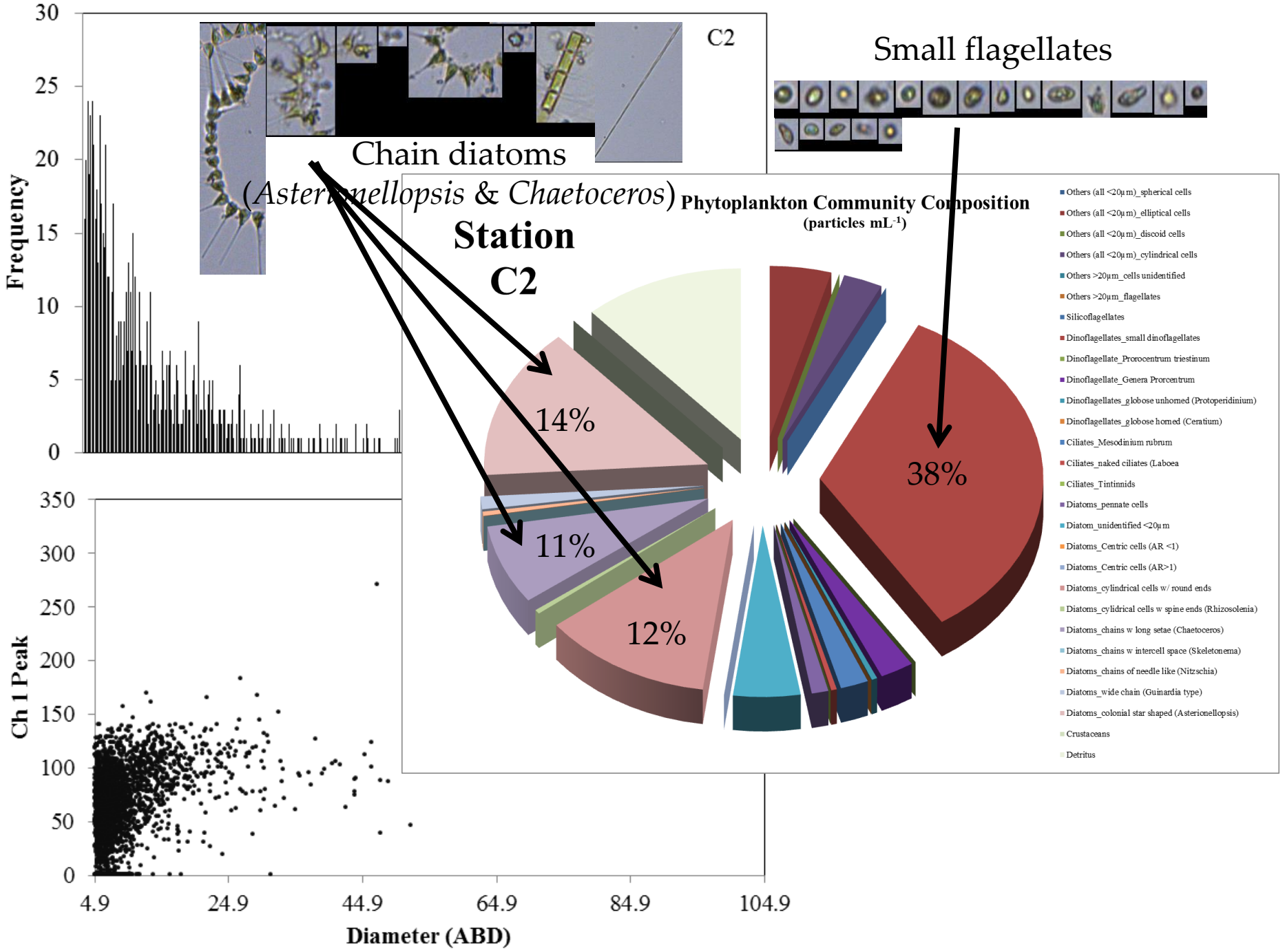
MSR	Mobile Bay	Mixed	Chl a dom

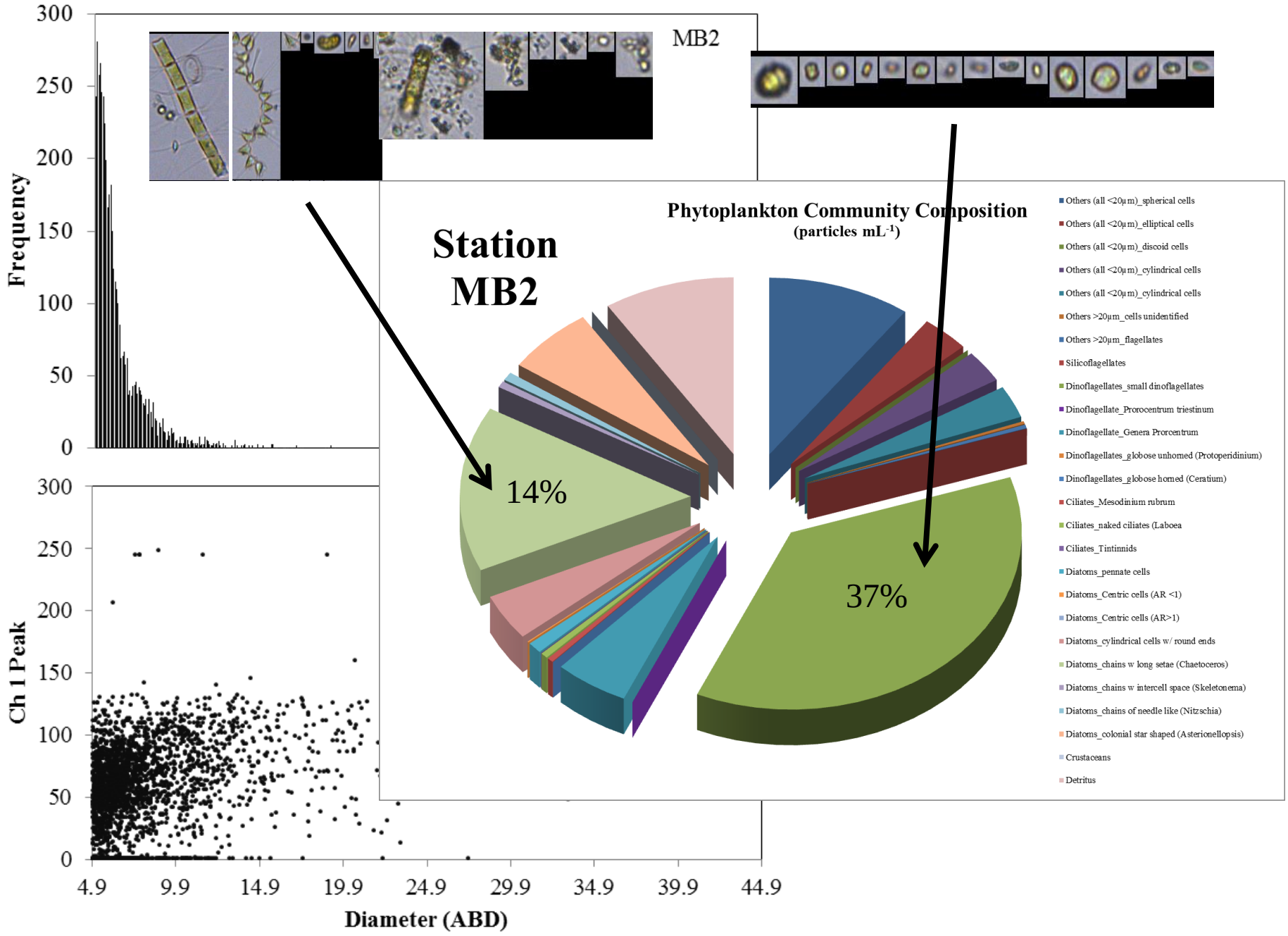


Prorocentrum sp.

Mixotrophic bacteriovore




C2
Small flagellates
Chain diatoms
(*Asterionellopsis* & *Chaetoceros*)
Station
C2
Phytoplankton Community Composition
(particles mL-1)
14%
11%
12%
38%
Others (all <20µm)_spherical cells
Others (all <20µm)_elliptical cells
Others (all <20µm)_discoid cells
Others (all <20µm)_cylindrical cells
Others >20µm_cells unidentified
Others >20µm_flagellates
Silicoflagellates
Dinoflagellates_small dinoflagellates
Dinoflagellate_Prorocentrum triestinum
Dinoflagellate_Genera Prorcentrum
Dinoflagellates_globose unhorned (Protoperidinium)
Dinoflagellates_globose horned (Ceratium)
Ciliates_Mesodinium rubrum
Ciliates_naked ciliates (Laboea
Ciliates_Tintinnids
Diatoms_pennate cells
Diatom_unidentified <20µm
Diatoms_Centric cells (AR <1)
Diatoms_Centric cells (AR>1)
Diatoms_cylindrical cells w/ round ends
Diatoms_cylidrical cells w spine ends (Rhizosolenia)
Diatoms_chains w long setae (Chaetoceros)
Diatoms_chains w intercell space (Skeletonema)
Diatoms_chains of needle like (Nitzschia)
Diatoms_wide chain (Guinardia type)
Diatoms_colonial star shaped (Asterionellopsis)
Crustaceans
Detritus
Frequency
0
5
10
15
20
25
30
Ch 1 Peak
0
50
100
150
200
250
300
350
4.9
24.9
44.9
64.9
84.9
104.9
Diameter (ABD)


MB2
Frequency
300
250
200
150
100
50
0
Ch 1 Peak
4.9
9.9
14.9
19.9
24.9
29.9
34.9
39.9
44.9
Diameter (ABD)
Station
MB2
Phytoplankton Community Composition
(particles mL-1)
14%
37%
Others (all <20µm)_spherical cells
Others (all <20µm)_elliptical cells
Others (all <20µm)_discoid cells
Others (all <20µm)_cylindrical cells
Others (all <20µm)_cylindrical cells
Others >20µm_cells unidentified
Others >20µm_flagellates
Silicoflagellates
Dinoflagellates_small dinoflagellates
Dinoflagellate_Prorocentrum triestinum
Dinoflagellate_Genera Prorcentrum
Dinoflagellates_globose unhorned (Protoperidinium)
Dinoflagellates_globose horned (Ceratium)
Ciliates_Mesodinium rubrum
Ciliates_naked ciliates (Laboea
Ciliates_Tintinnids
Diatoms_pennate cells
Diatoms_Centric cells (AR <1)
Diatoms_Centric cells (AR>1)
Diatoms_cylindrical cells w/ round ends
Diatoms_chains w long setae (Chaetoceros)
Diatoms_chains w intercell space (Skeletonema)
Diatoms_chains of needle like (Nitzschia)
Diatoms_colonial star shaped (Asterionellopsis)
Crustaceans
Detritus

Summary

- Water was impacted by the MSR via BCS, but is also heavily influenced from waters from Mobile Bay, as well as MSR BDC.
- Highly complex physical processes predominantly driven by winds.
- Phytoplankton community spatially & temporally diverse, but small dinoflagellates dominate

Future Work

- Still processing FlowCAM data and will couple with the bio-optical & water classification data.

- Identify patterns in phytoplankton community and compare with distributions of zooplankton & ichthyoplankton taxa

Hoover et al., 2017 (Session 014b) Spatial Variation in Zooplankton and Ichthyoplankton Dynamics during an Atypical Freshwater Discharge Event in the Northern Gulf of Mexico

- *Parra et al., 2017 (Session 014b) Highly-resolved Temporal In Situ Variability of Zooplankton Diel Vertical Migrations in the Mississippi Bight*
- *O'Brien et al. 2017 (Session 014b) Characterizing Spatial and Temporal Changes of the Suspended Particulate Organic Matter in the Mississippi Sound and Mississippi Bight*
- *Pan et al. 2017 (Session 014b) Impact of High Resolution Atmospheric Forcing on Circulation Variability Within a Regional Model of the Mississippi Sound and Bight*

Questions?

Point of Contact:

Adam Boyette

Division of Marine Science

School of Ocean Science and Technology

The University of Southern Mississippi

1020 Balch Blvd.

Stennis Space Center, MS

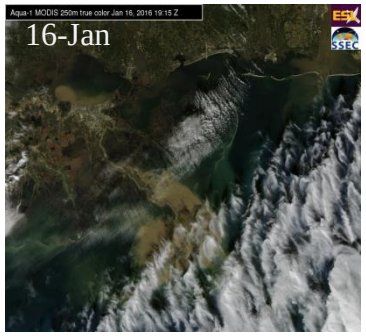
adam.boyette@usm.edu

Thank you!

Plankton (Hernandez Group)


12-Jan


13-Jan


16-Jan

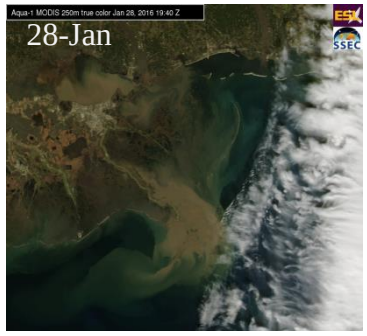

17-Jan


18-Jan


19-Jan


23-Jan


24-Jan


28-Jan


29-Jan

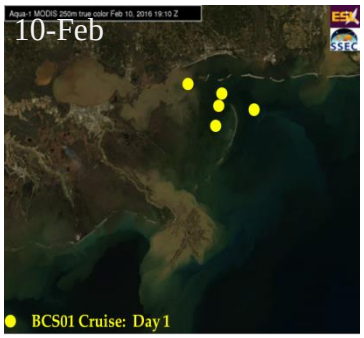

04-Feb

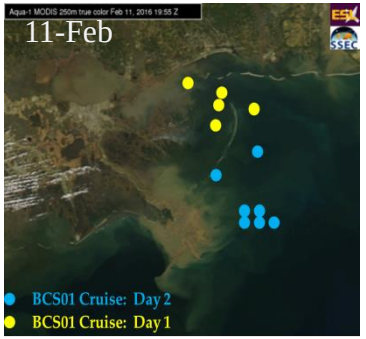

05-Feb

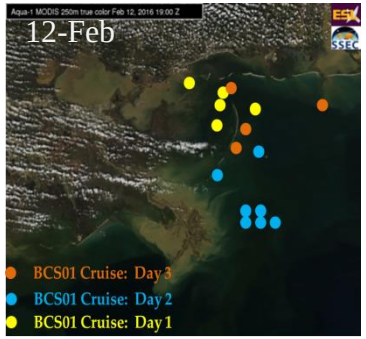

07-Feb


08-Feb

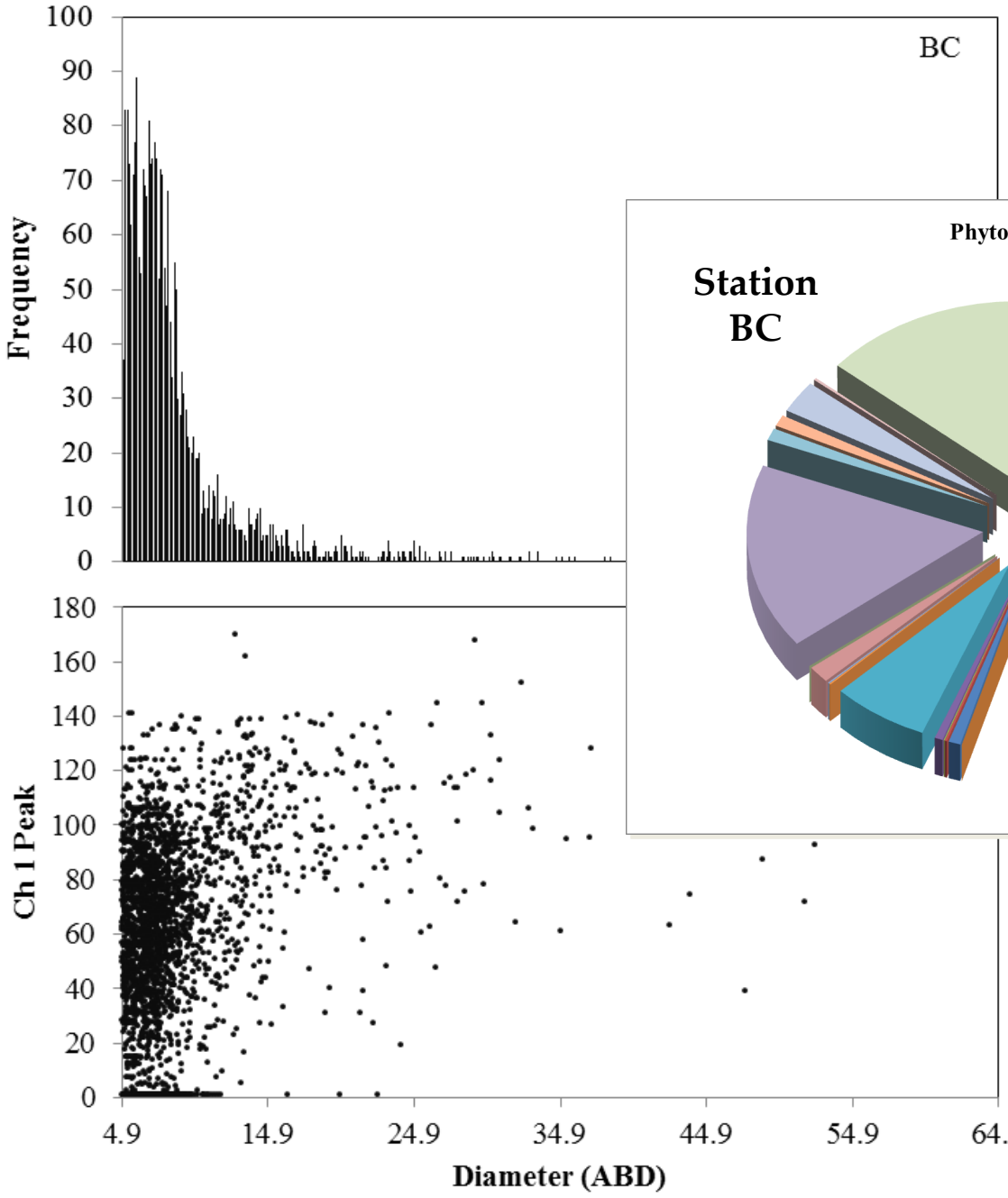

09-Feb

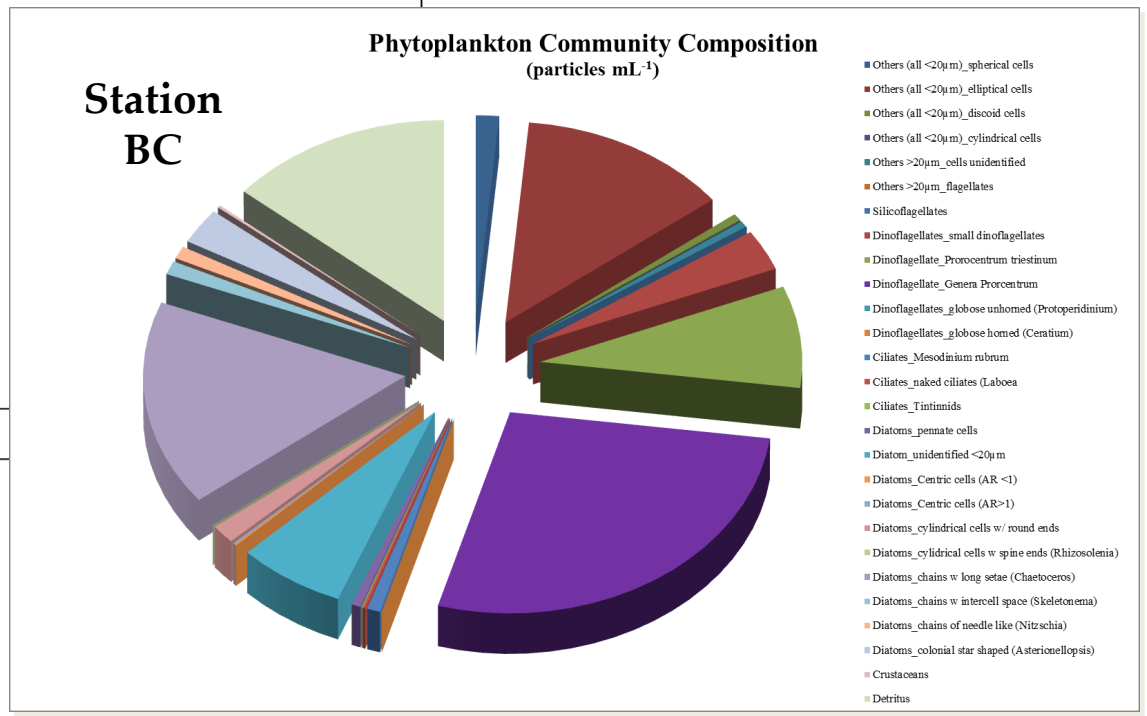

10-Feb
BCS01 Cruise: Day 1

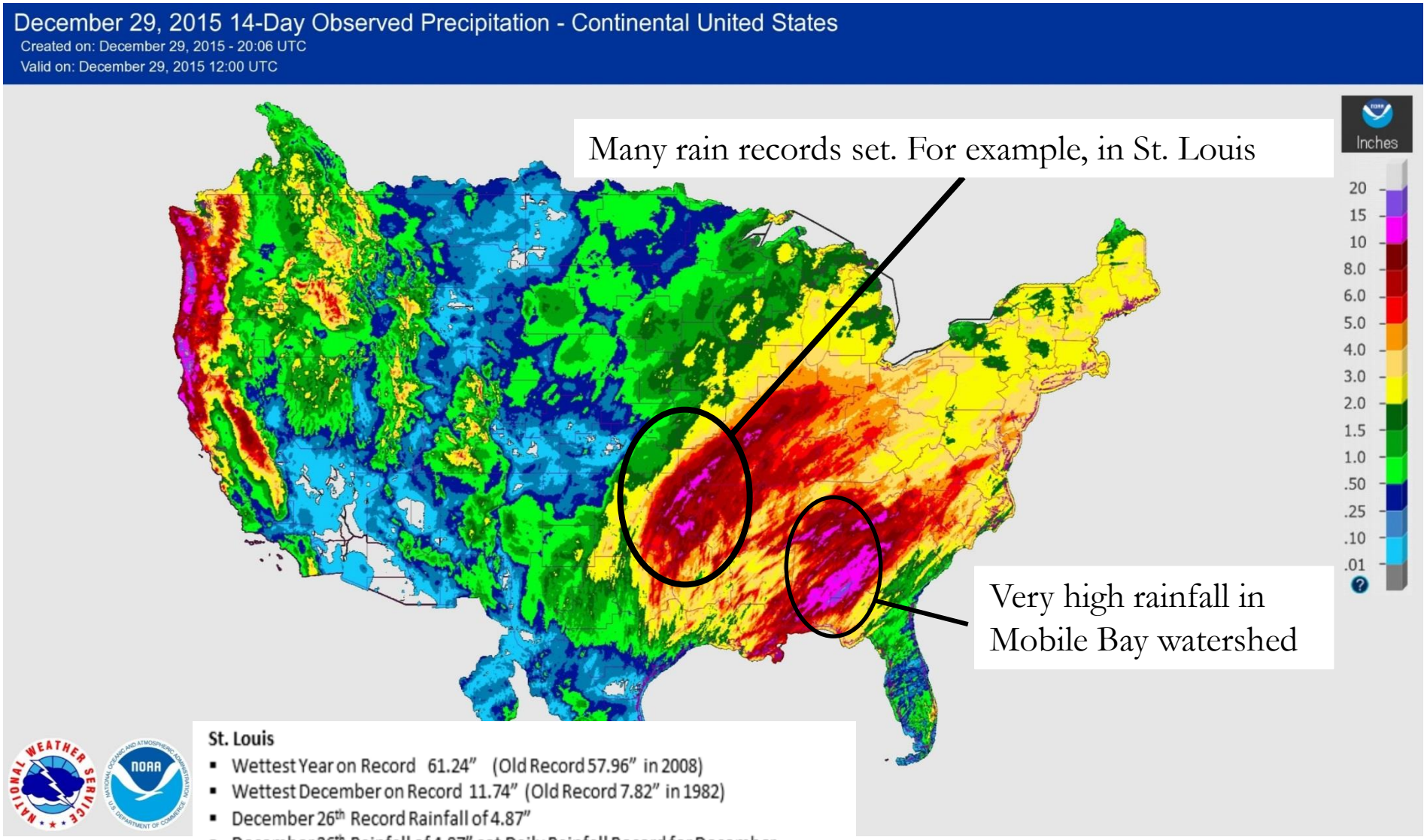

11-Feb
BCS01 Cruise: Day 2
BCS01 Cruise: Day 1


12-Feb
BCS01 Cruise: Day 3
BCS01 Cruise: Day 2
BCS01 Cruise: Day 1


13-Feb

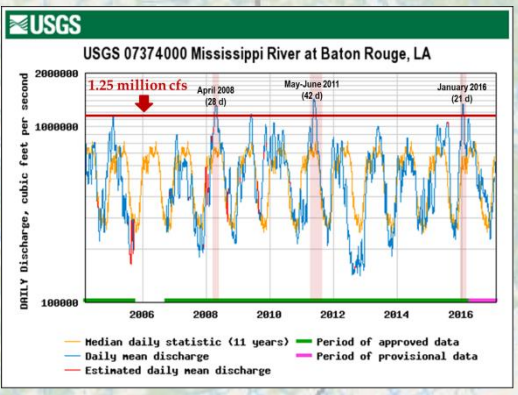

BC
Frequency
Ch 1 Peak
Diameter (ABD)
4.9
14.9
24.9
34.9
44.9
54.9
64.9


Station
BC
Phytoplankton Community Composition
(particles mL-1)
Others (all <20µm)_spherical cells
Others (all <20µm)_elliptical cells
Others (all <20µm)_discoid cells
Others (all <20µm)_cylindrical cells
Others >20µm_cells unidentified
Others >20µm_flagellates
Silicoflagellates
Dinoflagellates_small dinoflagellates
Dinoflagellate_Prorocentrum triestinum
Dinoflagellate_Genera Prorocentrum
Dinoflagellates_globose unhorned (Protoperidinium)
Dinoflagellates_globose horned (Ceratium)
Ciliates_Mesodinium rubrum
Ciliates_naked ciliates (Laboea
Ciliates_Tintinnids
Diatoms_pennate cells
Diatom_unidentified <20µm
Diatoms_Centric cells (AR <1)
Diatoms_Centric cells (AR>1)
Diatoms_cylindrical cells w/ round ends
Diatoms_cylidrical cells w spine ends (Rhizosolenia)
Diatoms_chains w long setae (Chaetoceros)
Diatoms_chains w intercell space (Skeletonema)
Diatoms_chains of needle like (Nitzschia)
Diatoms_colonial star shaped (Asterionellopsis)
Crustaceans
Detritus


December 29, 2015 14-Day Observed Precipitation - Continental United States
Created on: December 29, 2015 - 20:06 UTC
Valid on: December 29, 2015 12:00 UTC
Many rain records set. For example, in St. Louis
Very high rainfall in Mobile Bay watershed
Inches
20
15
10
8.0
6.0
5.0
4.0
3.0
2.0
1.5
1.0
.50
.25
.10
.01
St. Louis
Wettest Year on Record 61.24" (Old Record 57.96" in 2008)
Wettest December on Record 11.74" (Old Record 7.82" in 1982)
December 26th Record Rainfall of 4.87"
December 26th Rainfall of 4.87" set Daily Rainfall Record for December
December 26th Rainfall was 3rd Wettest Day Ever Recorded in St. Louis History
December 28th Record Rainfall of 2.59"

Bonnet Carré Crevasse (1849-1882)

- 33 miles above New Orleans
- Site of naturally occurring crevasses



US Army Corps of Engineers New Orleans District operates the Bonnet Carré Spillway

Spillway opens when local MS river discharge gauges read above 1.25 million cubic feet per second (cfs)

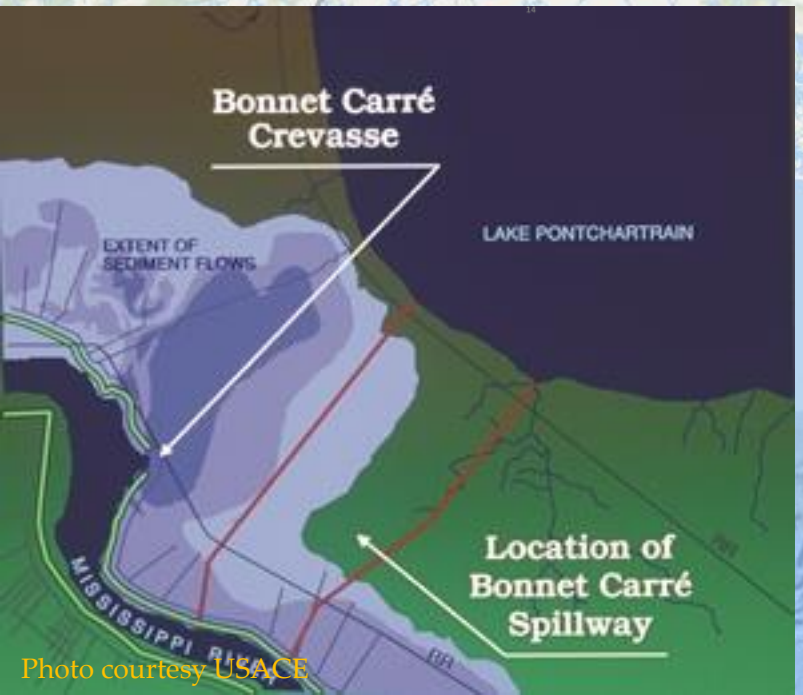


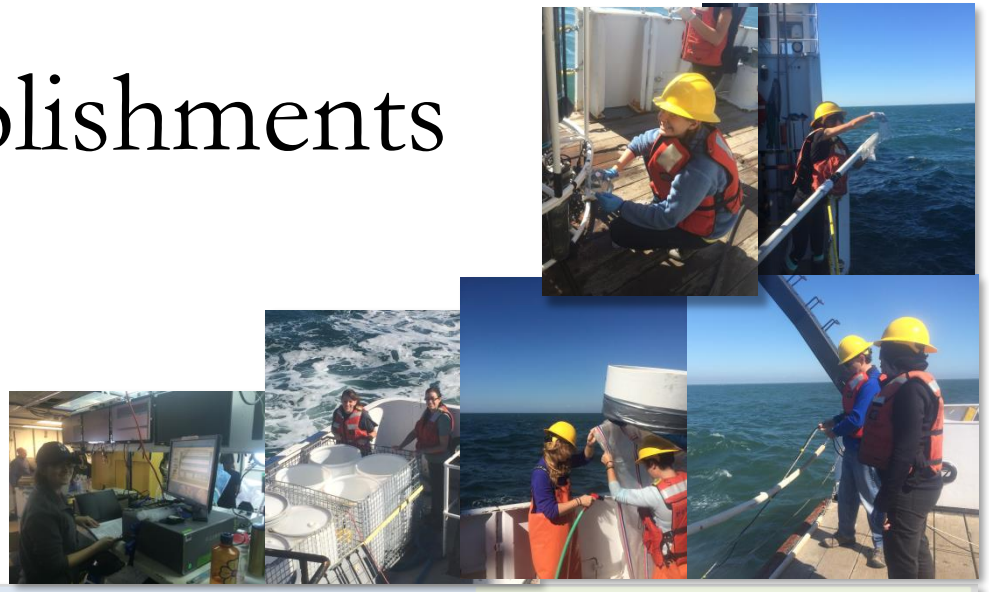
Photo courtesy USACE

Photo courtesy USACE

Accomplishments

Stations comprising:

- 15 CTD stations
- 15 trace metal casts & $\delta^{18}O$
- 17 radium pumping casts
- 16 optics (AC-S + CTD) casts
- 34 phytoplankton samples (FlowCAM)
- 30 samples for CH_4 & NH_4 oxidation analyses
- 11 net tows (22 samples)
- Underway optics (AC-S) data
- Underway CH_4 data
- Land-based daily satellite imagery (ocean color) and numerical modeling
- 2 glider deployments/1 glider recovery



Physical & Bio-optical

Characterize the physical structure and optical properties of the water column *in situ*

- CTD
- AC-S (flow-through) & optics package

Plankton Community

Quantify plankton biomass using a suite of water sampling and image analysis techniques

- Quanitfy meso- & ichthyoplankton abundance and composition
- particle size distribution & phytoplankton community composition (e.g. FlowCAM)

Biogeochemistry & Trace Metals

Describe the water chemistry & biomass

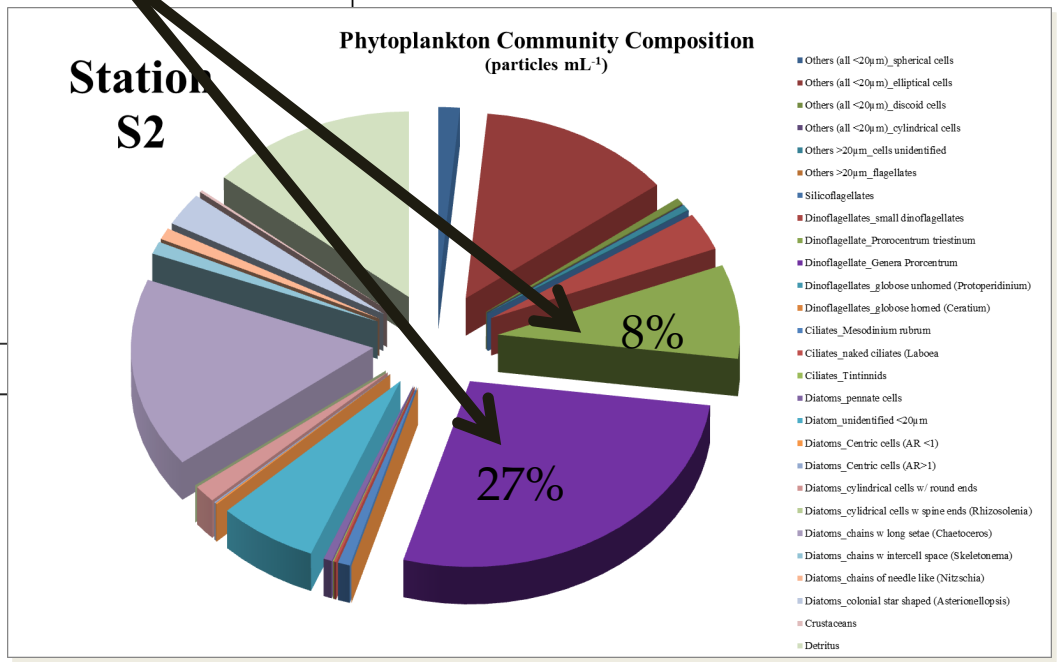
- nutrients, Chl *a*, CDOM
- trace metals, radium (SGD), CH_4
- dissolved oxygen (Winkler titration)
- CH_4 conc. and NH_4 oxidation

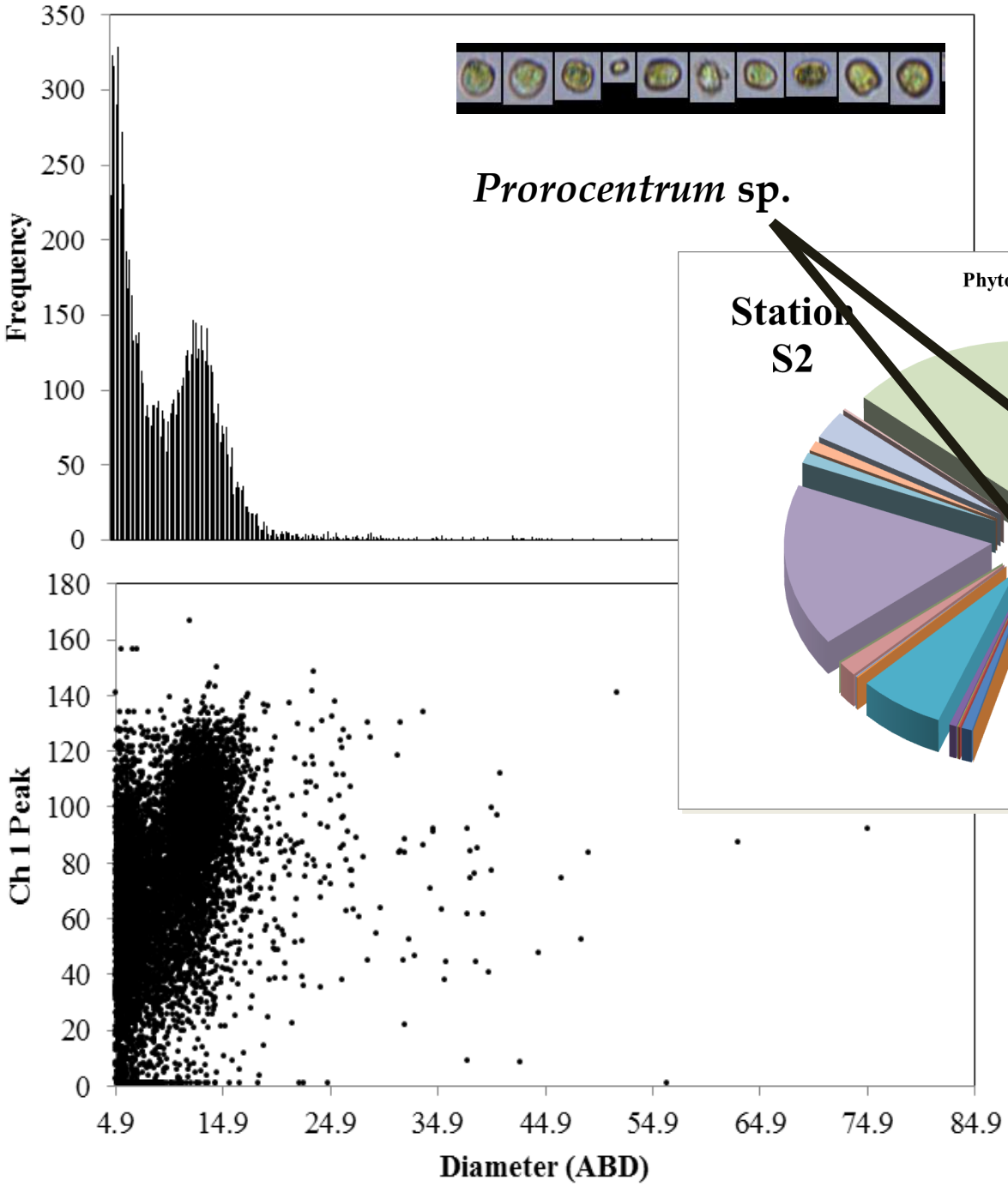
Remote Sensing & Modeling

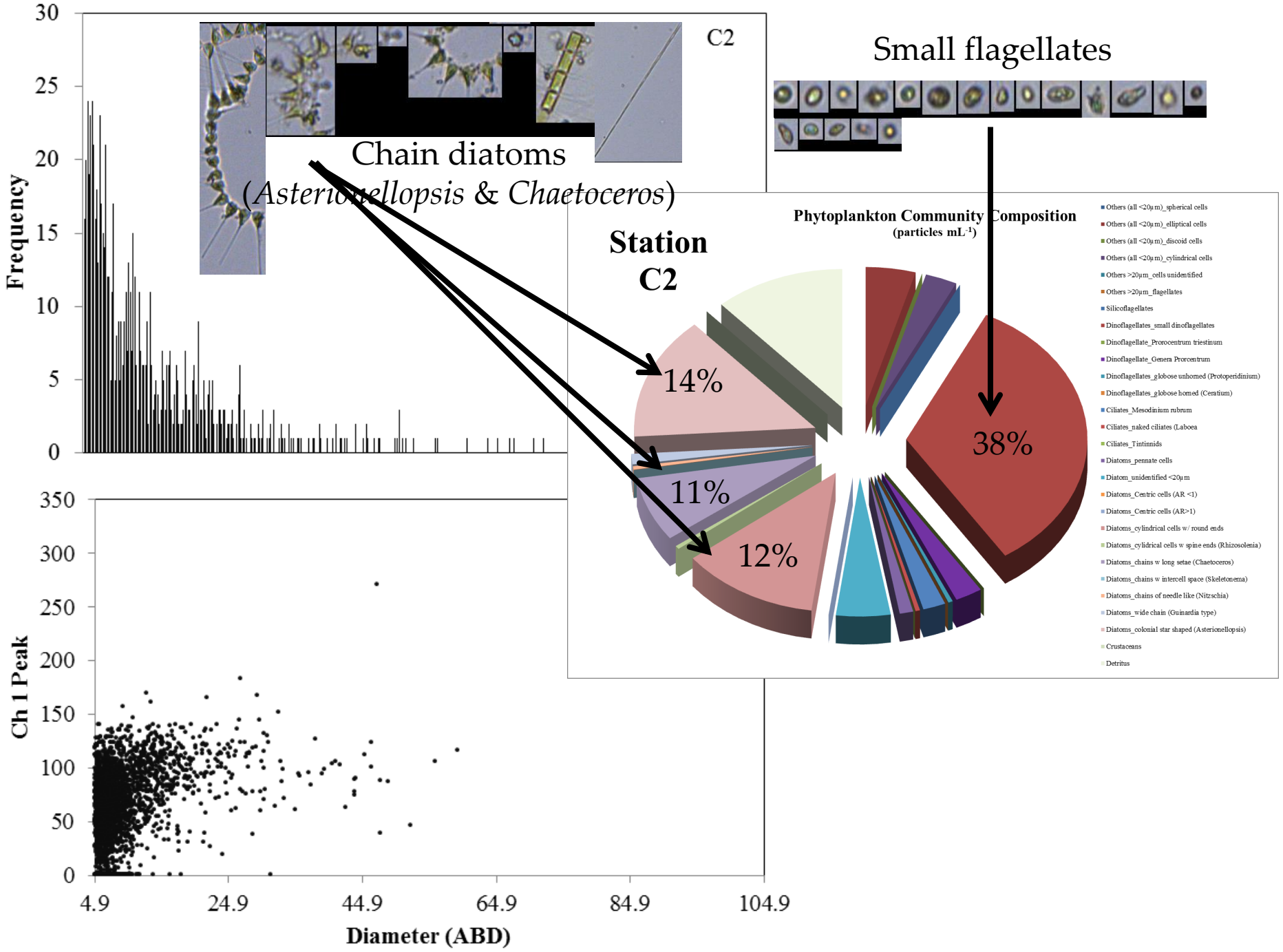
Apply satellite ocean color and circulation models

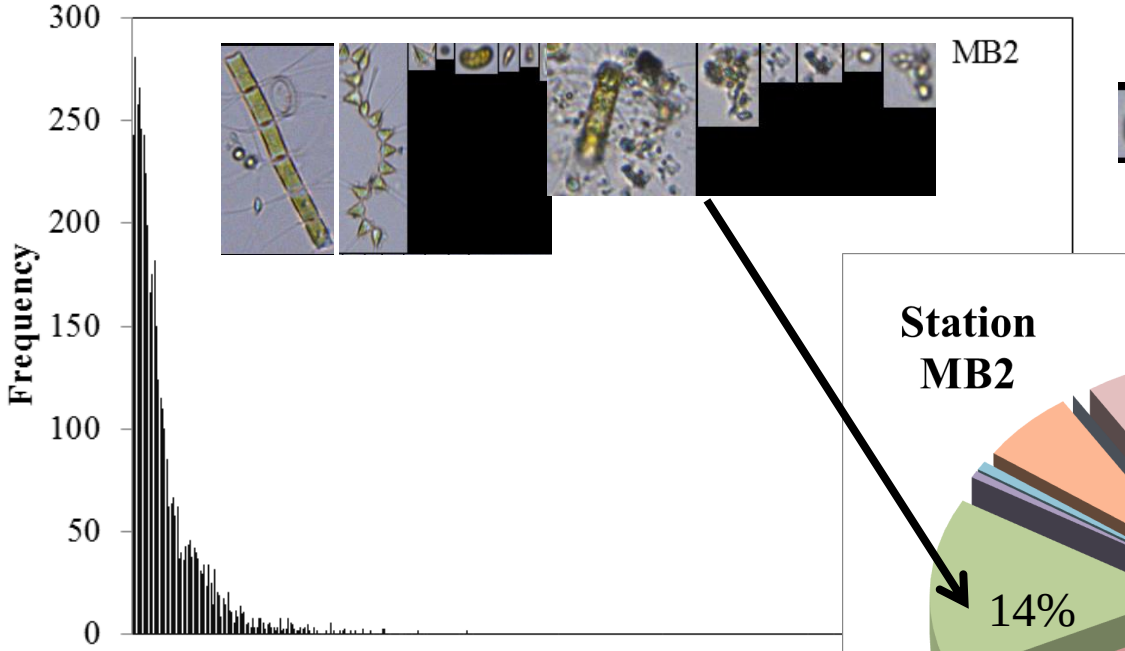
Prorocentrum sp.

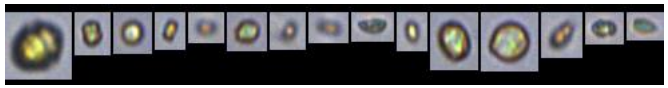
Mixotrophic bacteriovore

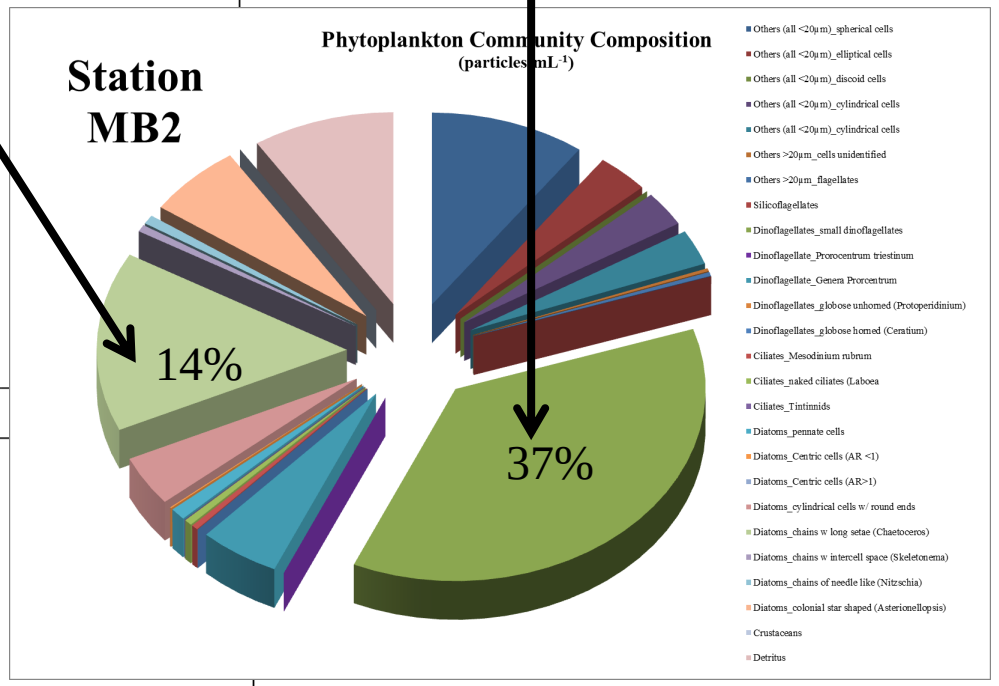


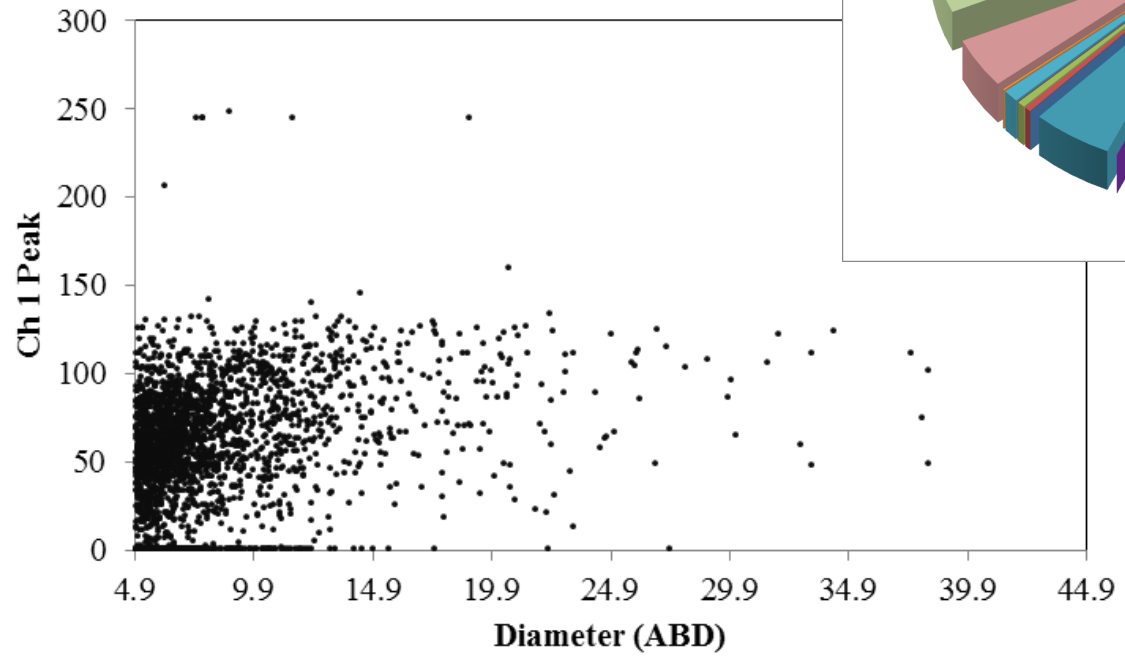


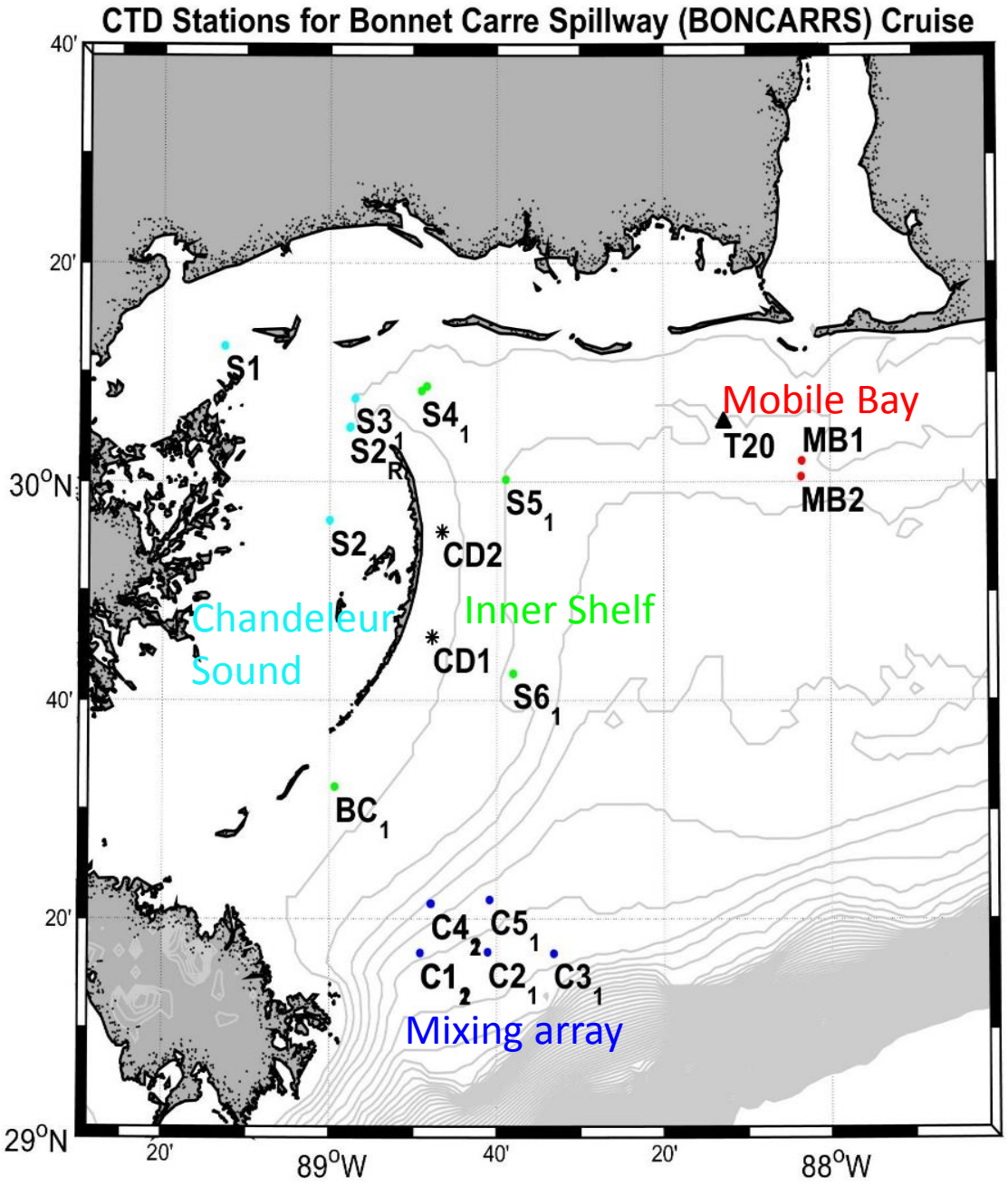

C2
Frequency
Chain diatoms
(*Asterionellopsis* & *Chaetoceros*)
Small flagellates
Station
C2
Phytoplankton Community Composition
(particles mL⁻¹)
14%
11%
12%
38%
Others (all <20µm)_spherical cells
Others (all <20µm)_elliptical cells
Others (all <20µm)_discoid cells
Others (all <20µm)_cylindrical cells
Others >20µm_cells unidentified
Others >20µm_flagellates
Silicoflagellates
Dinoflagellates_small dinoflagellates
Dinoflagellate_Prorocentrum triestinum
Dinoflagellate_Genera Prorocentrum
Dinoflagellates_globose unhorned (Protoperidinium)
Dinoflagellates_globose horned (Ceratium)
Ciliates_Mesodinium rubrum
Ciliates_naked ciliates (Laboea
Ciliates_Tintinnids
Diatoms_pennate cells
Diatom_unidentified <20µm
Diatoms_Centric cells (AR <1)
Diatoms_Centric cells (AR>1)
Diatoms_cylindrical cells w/ round ends
Diatoms_cylidrical cells w spine ends (Rhizosolenia)
Diatoms_chains w long setae (Chaetoceros)
Diatoms_chains w intercell space (Skeletonema)
Diatoms_chains of needle like (Nitzschia)
Diatoms_wide chain (Guinardia type)
Diatoms_colonial star shaped (Asterionellopsis)
Crustaceans
Detritus
Ch 1 Peak
Diameter (ABD)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
4.9
24.9
44.9
64.9
84.9
104.9

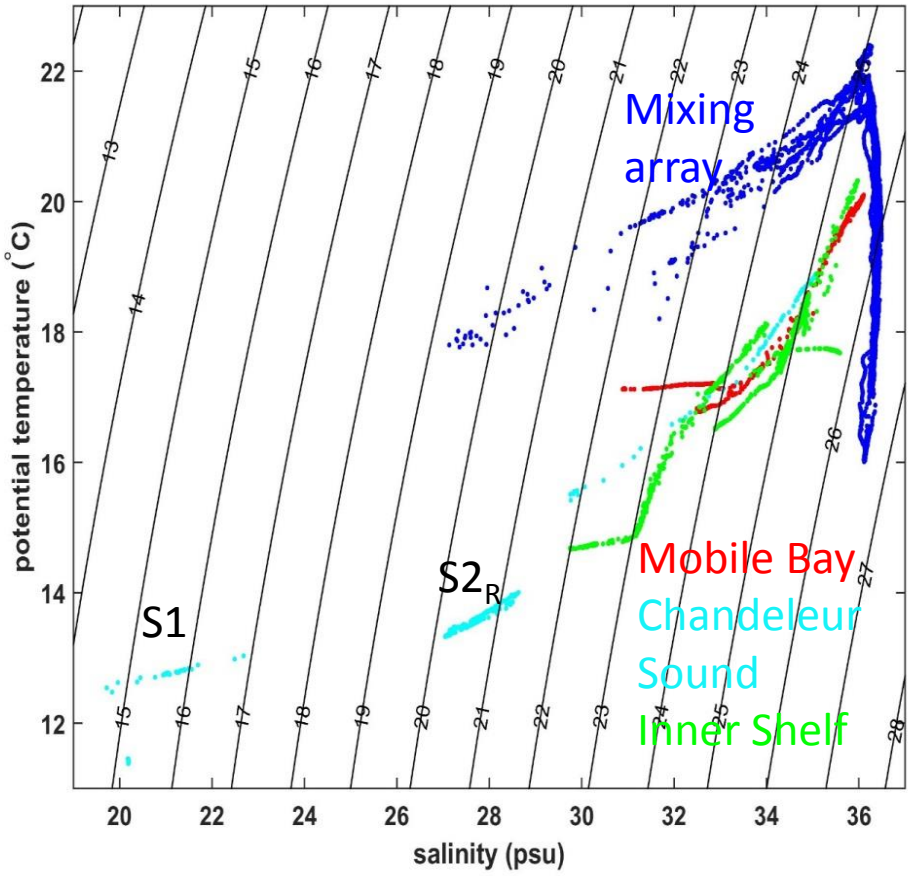

MB2
Frequency
300
250
200
150
100
50
0



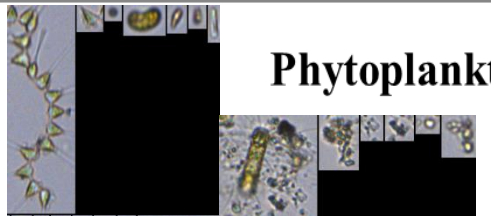

Station
MB2
Phytoplankton Community Composition
(particles mL-1)
14%
37%
Others (all <20µm)_spherical cells
Others (all <20µm)_elliptical cells
Others (all <20µm)_discoid cells
Others (all <20µm)_cylindrical cells
Others (all <20µm)_cylindrical cells
Others >20µm_cells unidentified
Others >20µm_flagellates
Silicoflagellates
Dinoflagellates_small dinoflagellates
Dinoflagellate_Prorocentrum triestinum
Dinoflagellate_Genera Prorocentrum
Dinoflagellates_globose unhorned (Protoperidinium)
Dinoflagellates_globose horned (Ceratium)
Ciliates_Mesodinium rubrum
Ciliates_naked ciliates (Laboea
Ciliates_Tintinnids
Diatoms_pennate cells
Diatoms_Centric cells (AR <1)
Diatoms_Centric cells (AR>1)
Diatoms_cylindrical cells w/ round ends
Diatoms_chains w long setae (Chaetoceros)
Diatoms_chains w intercell space (Skeletonema)
Diatoms_chains of needle like (Nitzschia)
Diatoms_colonial star shaped (Asterionellopsis)
Crustaceans
Detritus


Ch 1 Peak
300
250
200
150
100
50
0
4.9
9.9
14.9
19.9
24.9
29.9
34.9
39.9
44.9
Diameter (ABD)

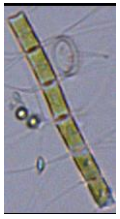

CTD Stations for Bonnet Carre Spillway (BONCARRS) Cruise
40'
20'
30°N
40'
20'
29°N
20'
89°W
40'
20'
88°W
S1
S3
S2R
S4
S5
S2
CD2
CD1
S6
BC
C4
C5
C1
C2
C3
Mobile Bay
T20
MB1
MB2
Chandeleur Sound
Inner Shelf
Mixing array

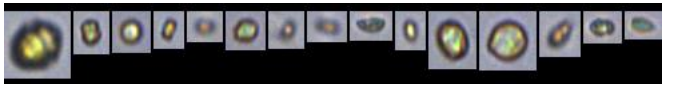

potential temperature (°C)
salinity (psu)
Mixing array
Mobile Bay
Chandeleur Sound
Inner Shelf
S1
S2R

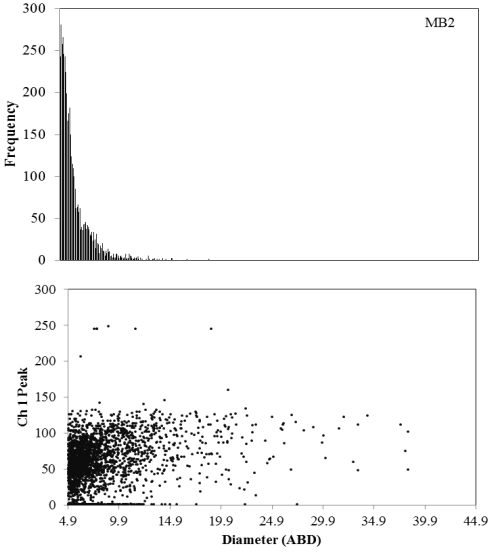
Station MB2



Phytoplankton Community Composition
(particles mL^{-1})

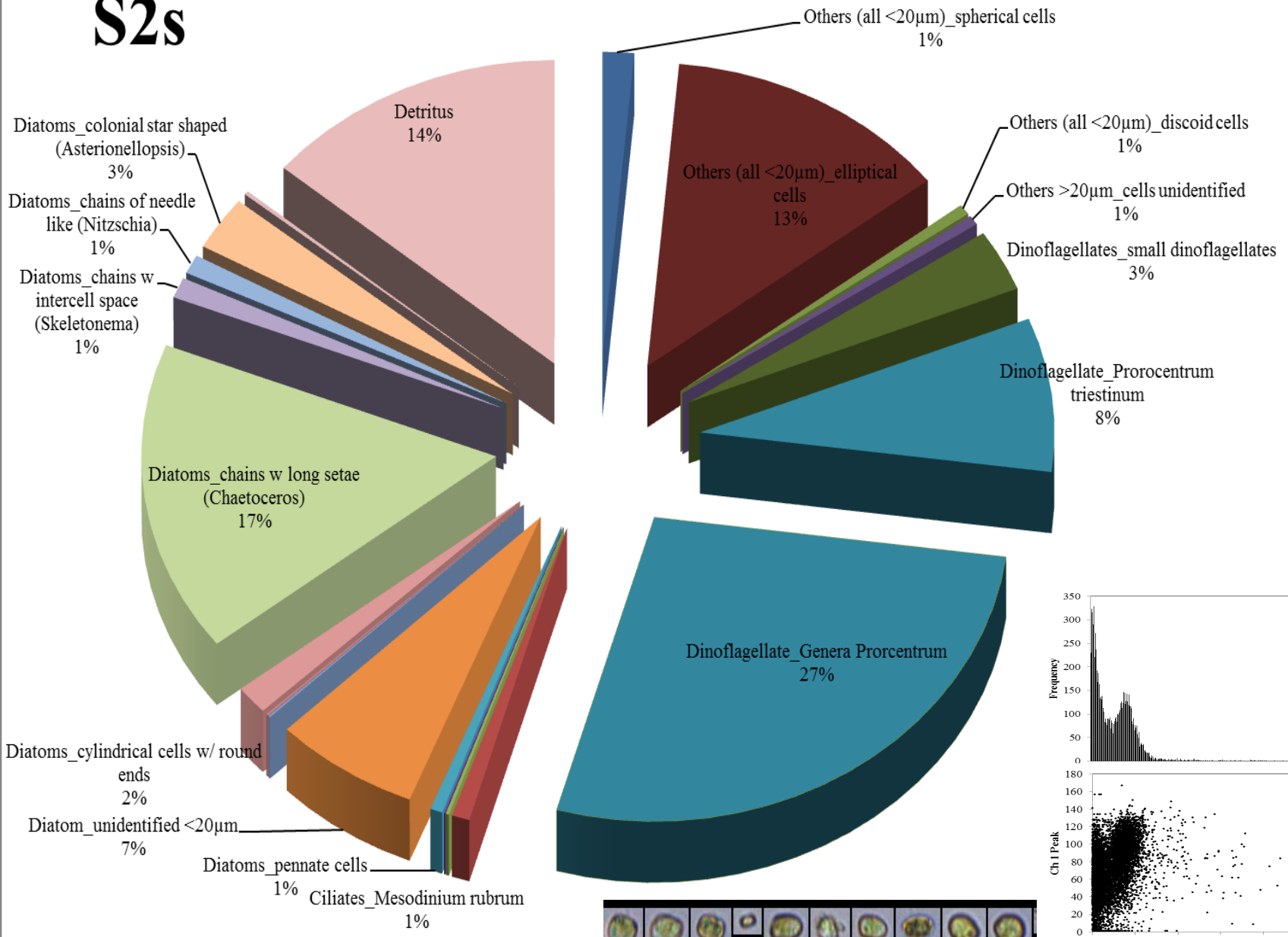


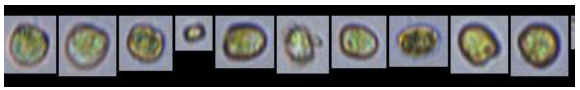


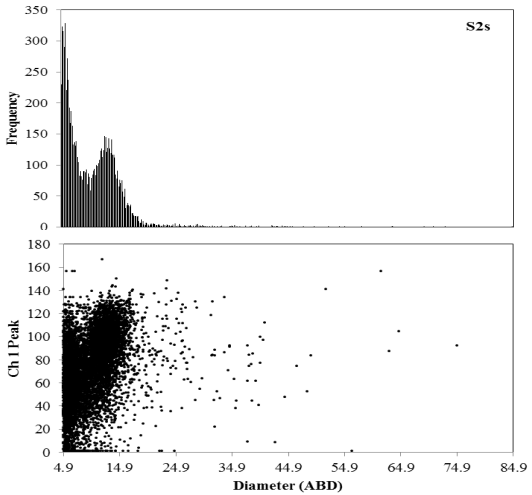


Station S2s

Phytoplankton Community Composition
(particles mL^{-1})

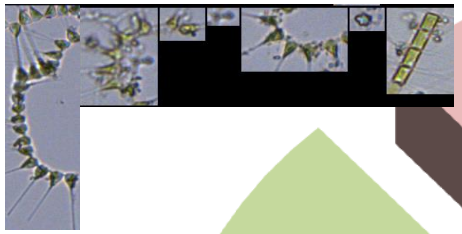






Station C2

Phytoplankton Community Composition
(particles mL^{-1})



Detritus
12%

Others (all <20µm)_elliptical cells
4%

Others (all <20µm)_cylindrical cells
3%

Small flagellates

Diatoms_colonial star shaped (Asterionellopsis)
14%

Dinoflagellates_small dinoflagellates
34%

Diatoms_wide chain (Guinardia type)
1%

Diatoms_chains w long setae (Chaetoceros)
8%

Diatoms_cylindrical cells w/ round ends
12%

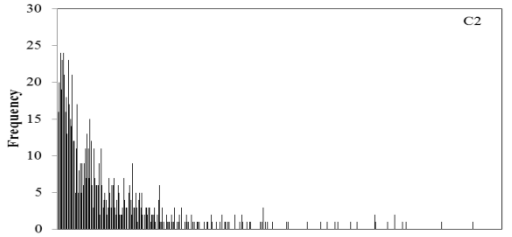
Diatoms_cylidrical cells w spine ends (Rhizosolenia)
0%

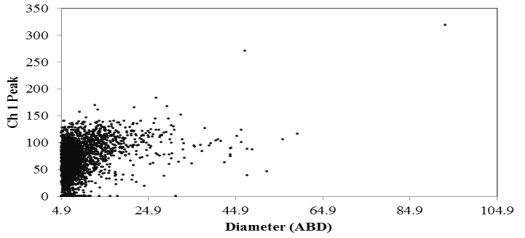
Dinoflagellate_Genera Prorcentrum
2%

Ciliates_Mesodinium rubrum
2%

Diatom_unidentified <20µm
5%

Diatoms_pennate cells
1%





Station BC

Phytoplankton Community Composition
(particles mL^{-1})