Coastal Transport of Organic and Inorganic Matter from Ocean Color Remote Sensing

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1. ABSTRACT

We have developed new algorithms to estimate the concentration of total suspended solids, and to partition the total sediment load into organic and inorganic components. Ocean optical properties are determined by the complex interactions of the dissolved and particulate components in the water, including sediments, phytoplankton and colored dissolved organic matter. Partitioning organic and inorganic components of suspended particles is important from both remote sensing and modeling aspects, particularly in coastal regions where temporal and spatial optical variability is great. The concentration and space/time distribution of the inorganic component, both river-borne and resuspended sediments, can be used to trace plumes and fronts, and can indicate regions of increased turbulence due to wave action and storm events. The distribution of the organic component does not necessarily mirror the distribution of the inorganic component, as they are influenced by different processes (physical vs. biological controls). We apply these new algorithms to SeaWiFS ocean color imagery and use the satellite products to trace coastal features, characterize particle composition, and estimate horizontal and vertical particle flux.

2. INTRODUCTION

The particulate and dissolved material in the ocean determines the ocean color signature. Furthermore, the transport of these materials determines the spatial and temporal distribution of carbon, and their sources and sinks determine the oceanic carbon budget. Through inversion of the spectral ocean color signature (remote sensing reflectance), we can estimate the concentrations of these optically impoprtant components. Here, we focus on only the particulate matter concentration and composition, and not the dissolved components.

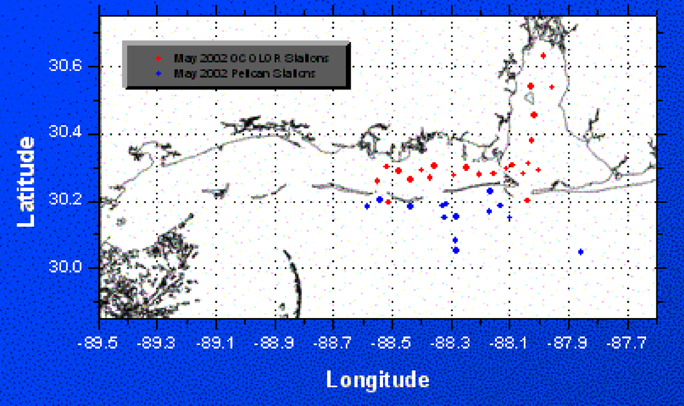
In the northern Gulf of Mexico, there are two main regions of particle injection: the Mississippi River plume and the Mississippi Sound/Mobile Bay region along the Mississippi and Alabama Gulf coasts. We will develop and apply new algorithms for SeaWiFS ocean color imagery, to estimate the total suspended particle load and to partition this load into organic and inorganic components. This will provide insight into processes that affect the distribution patterns of the different particle types (i.e., resuspension, biological growth, settling).

3. OBJECTIVES

- Develop new satellite algorithms to estimate PIM, POM, and TSS.
- Apply these new algorithms to SeaWiFS ocean color imagery in the northern Gulf of Mexico.
- Describe particle composition and dynamics (vertical and horizontal fluxes) in the study region.

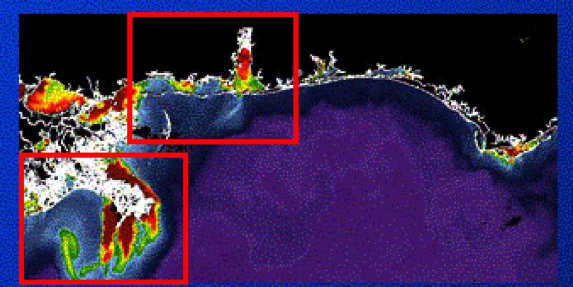
4. STUDY AREA

Station Locations



Imagery Analyzed: Northern Gulf of Mexico (Mississippi River, Mobile Bay), 3/21/03 – 4/1/03

Conditions: High River Discharge Period



Water sample analyses:

- filter pad (a_d, a_{CDOM}, a_φ)
- gravimetric (TSS/PIM/POM)

Terms and Definitions

- TSS – total suspended solids
- PIM – particulate inorganic matter
- POM – particulate organic matter
- a_T – total absorption coefficient
- a_{T-W} – total absorption minus water
- a_φ - phytoplankton absorption
- a_p – particulate absorption
- a_d – detrital absorption
- a_g – CDOM (gelbstoff) absorption
- a_{dg} – combined detrital and CDOM absorption
- b – scattering coefficient
- b_b – backscattering coefficient
- b_o – organic scattering
- b_i – inorganic scattering
- Q – flux (mass/time)
- C – concentration (mass/volume)
- V – velocity (distance/time)
- h - depth
- d – length of transect

5. Algorithm Development

detrital absorption from inorganic scattering

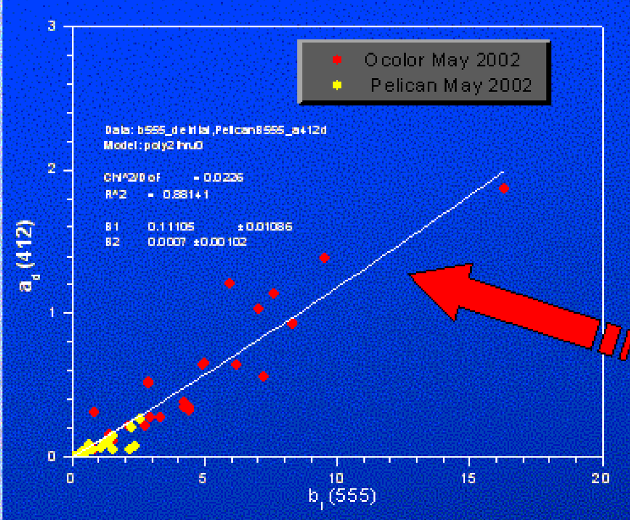
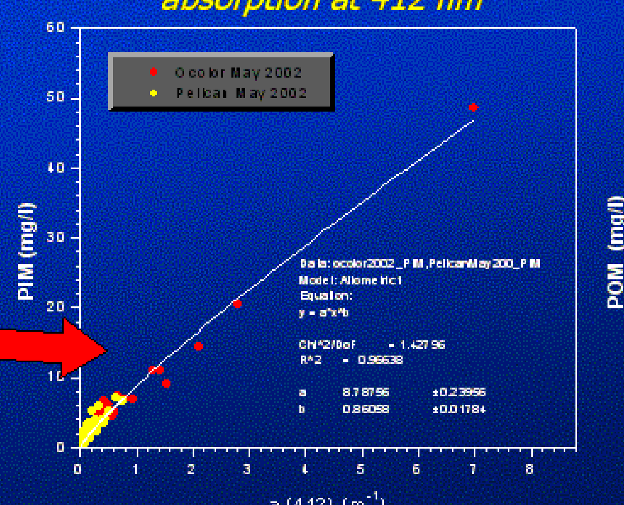


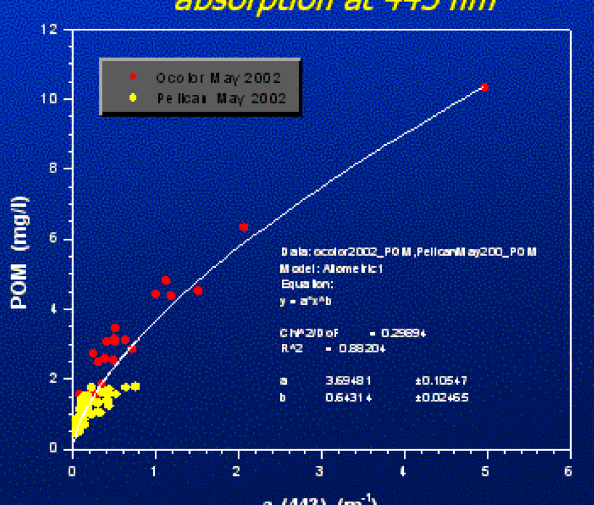
Image Processing Steps

1. Read SeaWiFS chlorophyll, $a_T(\lambda)$, $b_b(555)$, $a_g(443)$
2. Calculate b(555) from $b_b(555)$ – Gould et al. (1999)
3. Calculate $b_o(660)$ from chlorophyll – Loisel & Morel (1998)
4. Calculate $b_o(555)$ from $b_o(660)$ – Gould et al. (1999)
5. Calculate $b_i(555)$ = b(555) – $b_o(555)$
6. **Calculate $a_d(412)$ from $b_i(555)$**
7. Calculate a_{T-W} (remove water absorption)
8. Calculate $a_g(\lambda)$ from $a_g(443)$
9. Calculate $a_{dg}(\lambda) = a_{T-W}(\lambda) - a_\varphi(\lambda)$
10. Calculate $a_g(412) = a_{dg}(412) - a_d(412)$
11. Calculate $a_d(\lambda)$ from $a_d(412)$
12. Calculate $a_\varphi(\lambda) = a_{dg}(\lambda) - a_g(\lambda)$
13. Calculate $a_p(\lambda) = a_d(\lambda) + a_\varphi(\lambda)$
14. **Calculate PIM from $a_d(412)$**
15. **Calculate POM from $a_p(443)$**
16. Calculate TSS = PIM + POM

PIM from particulate absorption at 412 nm

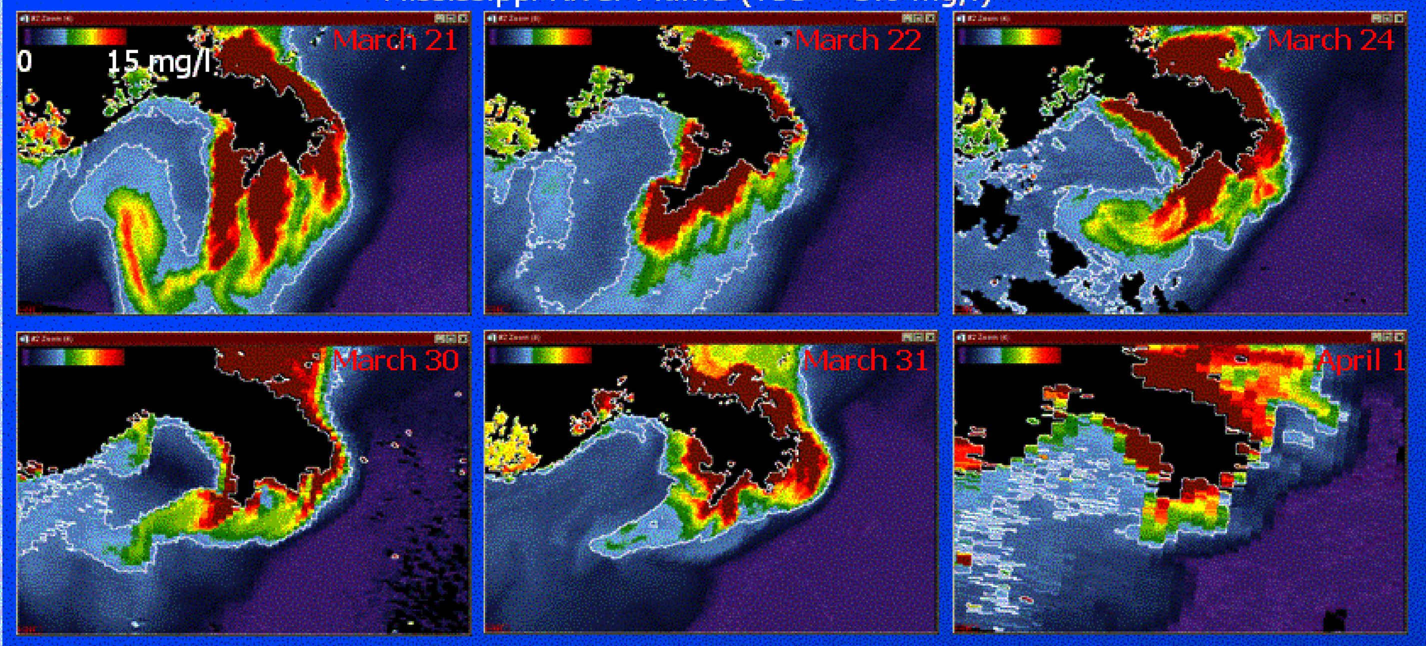


POM from particulate absorption at 443 nm



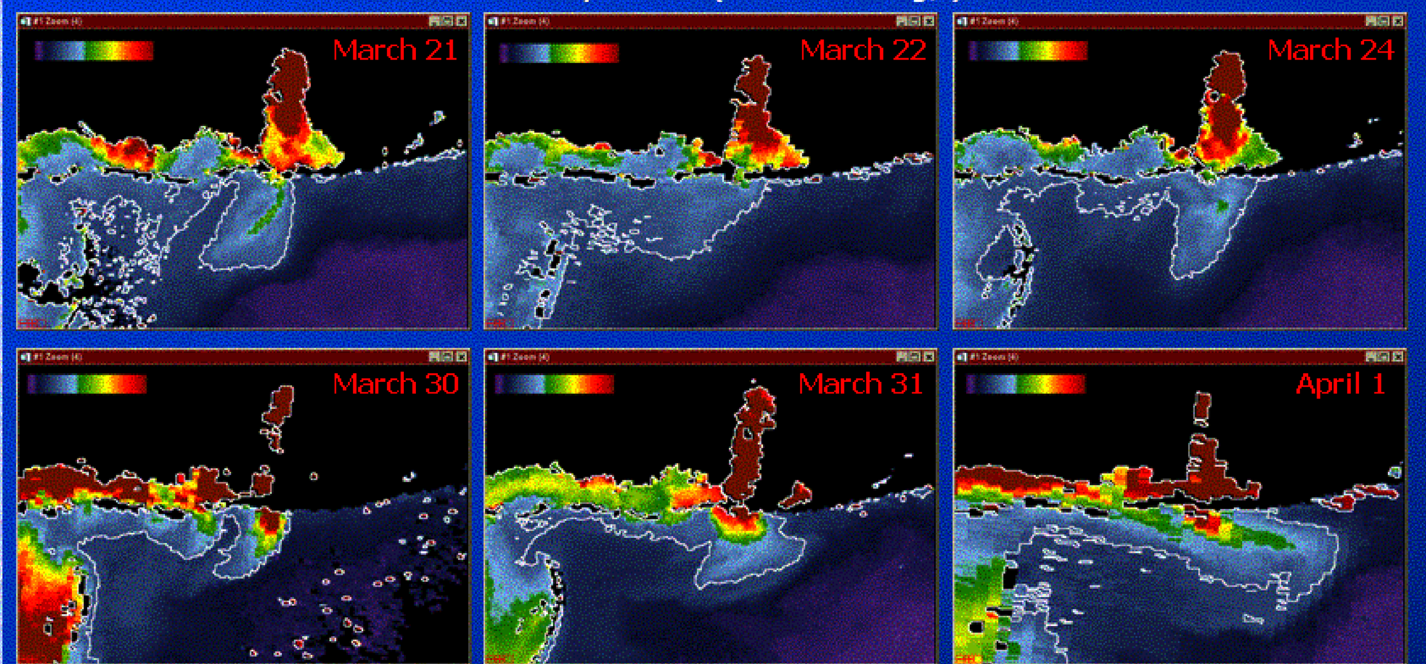
6. Plume Characterization

Mississippi River Plume (TSS > 5.0 mg/l)



Track Plume Changes – contours enclose plume

Mobile Bay Plume (TSS > 3.5 mg/l)



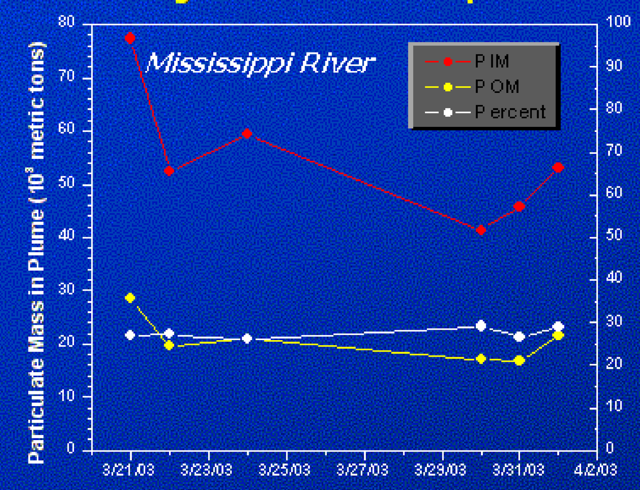
Large changes in plume location, area, and particulate mass in one day.

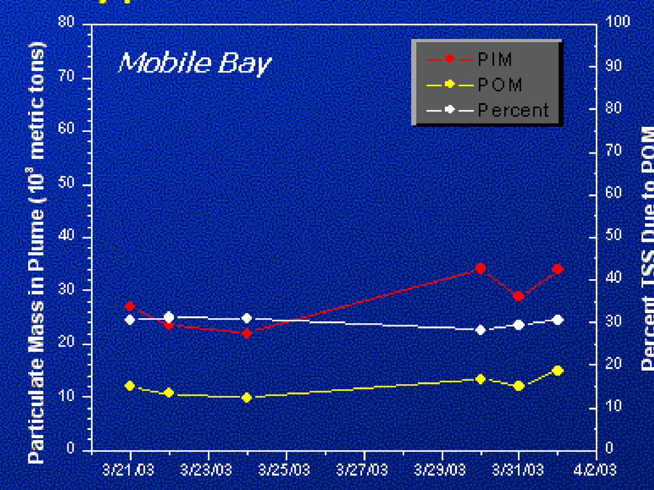
Changes in particulate concentration and mass in plume (organic and inorganic components)

Mississippi River Plume - Total Mass of Suspended Particulate Matter
(Plume defined by TSS concentration ≥ 5.0 mg/l, 1 meter deep)

Date	Plume Area (km^2)	Mean PIM (mg/l)	Mean POM (mg/l)	Mean TSS (mg/l)	Total PIM (metric tons)	Total POM (metric tons)	Total Mass (metric tons)	% of Total Mass due to POM
03/21/03	9,845.2	7.86	2.88	10.74	77,364.9	28,402.3	105,767.2	26.9
03/22/03	7,513.1	6.99	2.61	9.60	52,503.0	19,628.8	72,131.8	27.2
03/24/03	7,657.5	7.74	2.73	10.48	59,304.1	20,942.6	80,246.6	26.1
03/30/03	5,795.2	7.13	2.93	10.06	41,339.4	16,985.6	58,325.0	29.1
03/31/03	5,266.9	8.69	3.17	11.86	45,776.7	16,670.5	62,447.2	26.7
04/01/03	7,252.8	7.30	2.97	10.27	52,925.8	21,527.5	74,453.3	28.9

Total mass of organic and inorganic matter is about two times higher in Miss. River plume than Mobile Bay plume.





Percentage of total particulate mass due to organic matter in Miss. River plume remains fairly constant (around 27.5%)

Percentage of POM in Mobile Bay plume also remains fairly constant (around 30.1%), but is slightly higher than Miss. River plume.

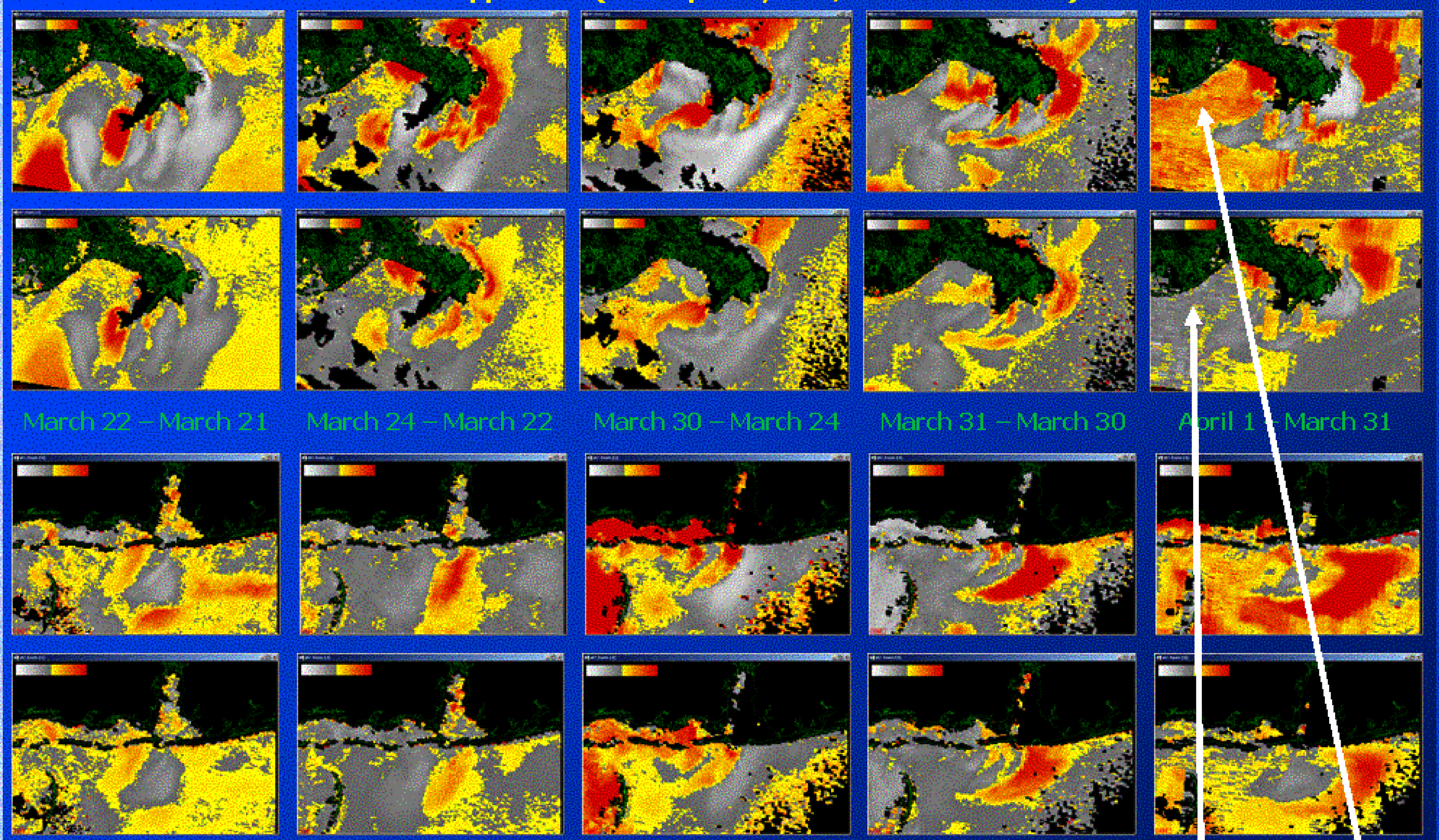
General trend of decreasing particulate mass in Miss. River plume during this 11-day period; slightly increasing trend in Mobile Bay plume.

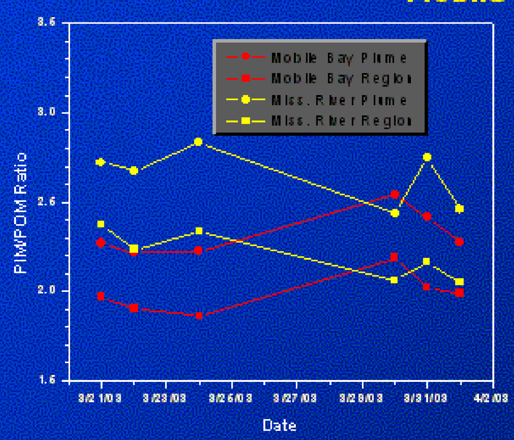
Mobile Bay Plume - Total Mass of Suspended Particulate Matter
(Plume defined by TSS concentration ≥ 3.5 mg/l, 1 meter deep)

Date	Plume Area (km^2)	Mean PIM (mg/l)	Mean POM (mg/l)	Mean TSS (mg/l)	Total PIM (metric tons)	Total POM (metric tons)	Total Mass (metric tons)	% of Total Mass due to POM
03/21/03	5,674.5	4.77	2.10	6.87	27,047.2	11,927.4	38,974.6	30.6
03/22/03	5,533.9	4.26	1.92	6.18	23,571.5	10,642.3	34,199.6	31.1
03/24/03	4,976.4	4.42	1.99	6.40	21,975.6	9,883.3	31,848.8	31.0
03/30/03	4,271.7	7.99	3.14	11.13	34,112.6	13,428.6	47,543.6	28.2
03/31/03	4,736.8	6.06	2.51	8.58	28,725.1	11,906.3	40,641.3	29.3
04/01/03	6,001.8	5.65	2.49	8.13	33,885.2	14,917.6	48,794.9	30.6

7. Particle Composition

Difference images: show % change between two scenes)





Colored pixels indicate where TSS and PIM/POM increased; B&W pixels are where they decreased. Changes can indicate particle settling, biological growth, and advection.

Particle composition in plume is different from regional average (higher PIM/POM ratio in plume), for both Mobile Bay area and Miss. River area.

In general, increase in TSS is coupled with an increase in PIM/POM ratio. EXCEPTION: Miss. River region between 31 March and 1 April.

8. Horizontal and Vertical Flux calculations

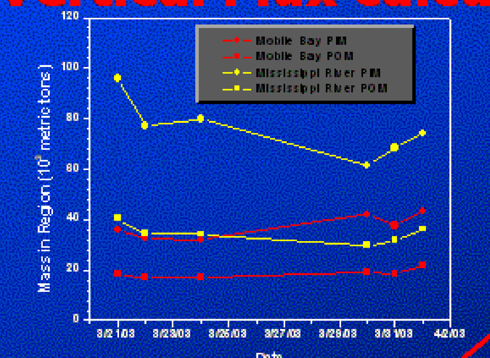
Mississipppi River Plume - Total Particulate Mass (Organic and Inorganic)

Date	Total PIM in Region (metric tons)	Total POM in Region (metric tons)
03/21/03	95,924.3	40,447.0
03/22/03	77,141.0	34,544.3
03/24/03	79,839.9	34,160.4
03/30/03	61,208.1	29,730.0
03/31/03	68,388.8	31,579.0
04/01/03	74,273.7	36,203.2

Mass = Σ (Concentration * Pixel Volume) (all pixels)

COMPARE:
PIM vs. POM
Plume vs. Region
Miss. River vs. Mobile

Vertical flux: PIM decrease between 21 and 22 March in Miss. River region: 18,783.3 metric tons (due to particle settling)

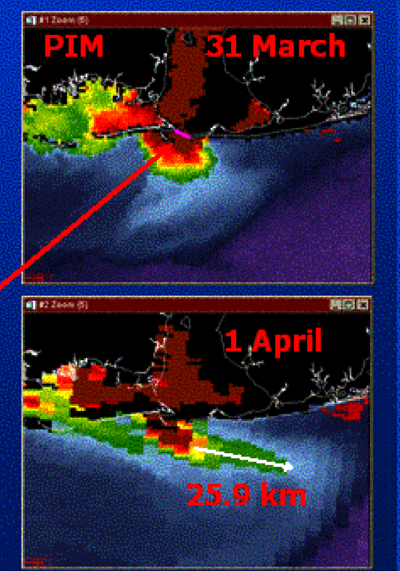


Track changes in particulate mass over time

Horizontal Flux, Q=C*V*h*d

Q=(6.1g/m3)(1.12km/day)(1m)(5.2km)

Q=854.7 metric tons/day



Net change = addition – removal processes

9. Summary

- We developed new algorithms to estimate PIM, POM, and TSS from satellite ocean color imagery.
- We demonstrate the use of these new products to trace coastal plumes and describe particle dynamics and fluxes in two regions in the northern Gulf of Mexico.
- Concentrations of total suspended solids are roughly 30% higher in the Mississippi River plume than in the Mobile Bay plume and total mass is roughly double (due to the larger area covered).
- In both areas, the ratio of inorganic-to-organic particles is higher in the plume than in the entire region
- This ratio decreased over time in the Mississippi River region and increased in the Mobile Bay region.