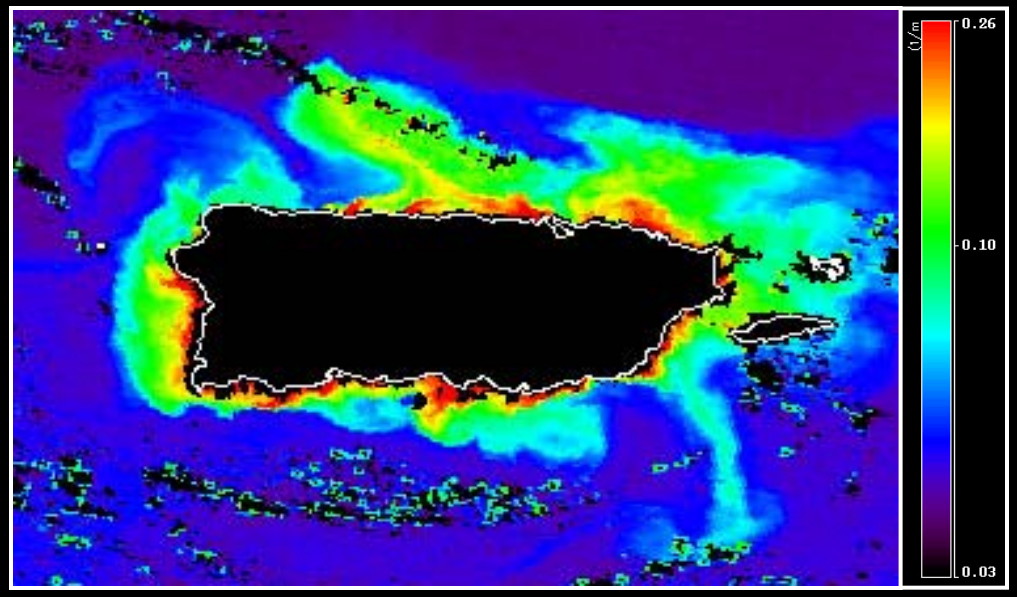
# Remote Sensing of Episodic Rainfall Events Affecting Coral Reefs in Southwestern Puerto Rico

Y. Detrés, R. Armstrong, E. Otero and R. García
yasmin@cacique.uprm.edu
University of Puerto Rico,
Mayaguez Campus




*Sexta Reunión Nacional de Percepción Remota y Sistemas de Información Geográficos (PRYSIG 2008)*

*November 14, 2008*

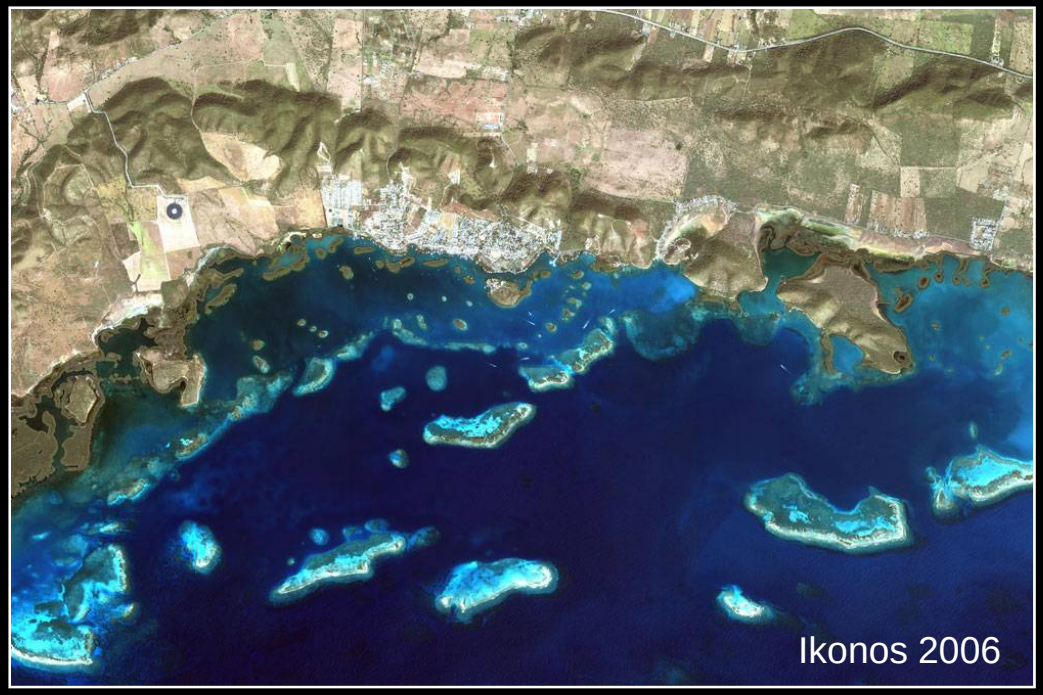
# Southwestern Puerto Rico

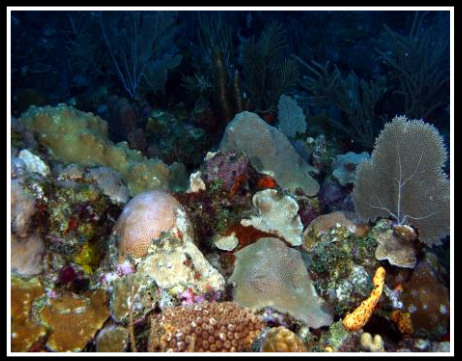

• Southwestern coast is in the lee side of an orographic barrier and receives considerably less precipitation (914mm).

• Absence of riverine discharges on the semi arid southwest coast.

• This optically deep water has high abundance and diversity of corals (fringing, patchy, and shelf-edge formations).

# La Parguera Marine Reserve
## Southwestern Puerto Rico



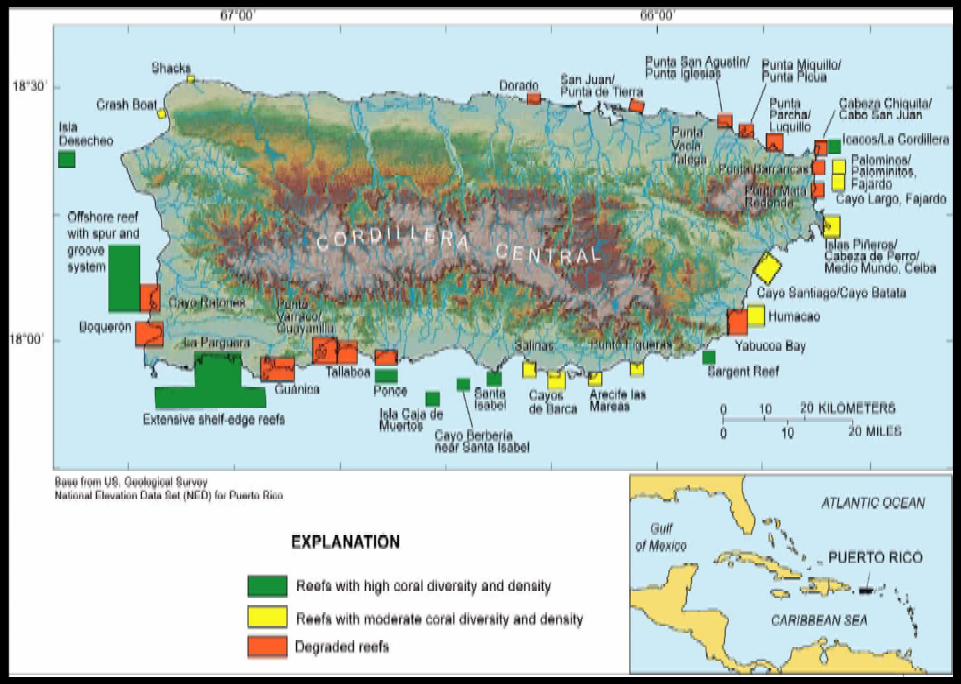
- Low wave energy
- Clear ocean waters
- High abundance and diversity of corals
- Fringing, patchy, and shelf-edge coral reef formations
- Intense and poorly planned urban development
- High load of sediments in runoff

# La Parguera – Coastal Development
## 1936-2007



# Sediment & Nutrient Influx

- Anthropogenic activities (agriculture, industry and coastal urban development) result in increased runoff and increased sediment and nutrient influx to coastal areas.
- Sediment and nutrient discharge to the Puerto Rico shelf are believed to have contributed to widespread degradation of coral reefs in Puerto Rico.
- Negative effects of river-derived sediment and nutrient discharge on coral reefs in nearshore areas of the north, east, southwest, and west coasts of the island.

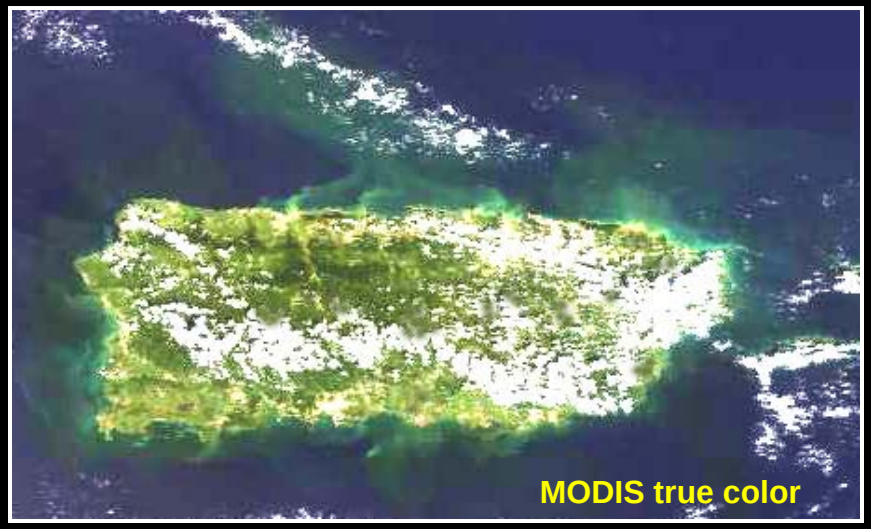



Data from Goenaga and Cintrón (1979) and Simonsen (2000).

Warne, A.G., Webb, R.M.T., and Larsen, M.C., 2005, Water, Sediment, and Nutrient Discharge Characteristics of Rivers in Puerto Rico, and their Potential Influence on Coral Reefs: U.S. Geological Survey Scientific Investigations Report 2005-5206, 58 p.

# Sedimentation & Coral Reefs

- Attenuation of sunlight: affects photosynthetic rates of zooxanthellae and limits coral reefs growth and reproduction.
- Compression of coral depth zonation accompanied by changes in abundance of coral species (Acevedo et al., 1989).
- Reduced coral cover, species diversity and shift to slower growing coral species (Acevedo and Morelock, 1988).
- Reduction of linear extension rates of *Montastrea annularis* (Torres, 2001).
- Death of underlying coral tissue: followed by algal colonization of the smothered portions in the massive coral *Acropora palmata* (Rogers, 1983).

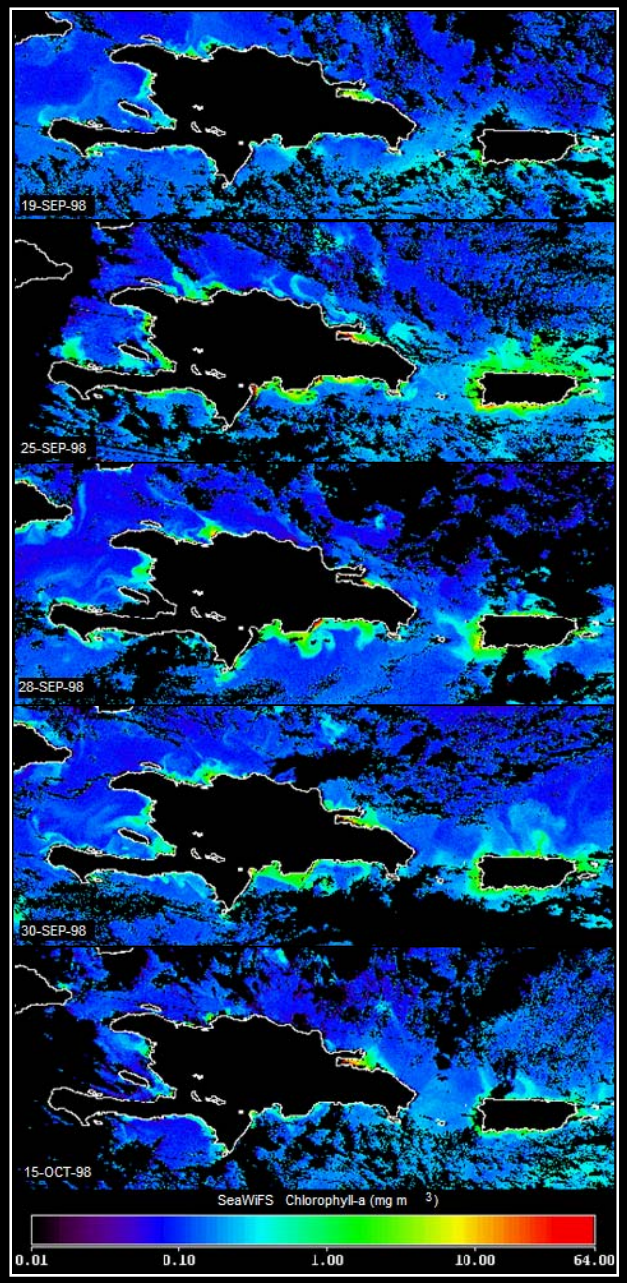




*A. palmata* (elkhorn coral) - coral species more susceptible to sedimentation. First coral listed as threatened under the Endangered Species Act.

# Objective

**To evaluate the application of remote sensing of ocean color to assess the impact of an episodic rainfall event to the coastal marine environments in southwestern Puerto Rico.**




# Previous Work

• Gilbes, et. al. (2001), evaluated the impacts of hurricane Georges (Sept. 21-22, 1998) in the Caribbean region using hydrological and satellite ocean color data.

•Flooding of rivers led to major changes in phytoplankton distribution in coastal and oceanic waters around PR and Hispaniola.

• Proved utility of SeaWiFS imagery (Chl-a) for the rapid and low cost assessment (regional and local scales) of hurricane impacts on coastal water quality.

**Gilbes, F., R. Armstrong, R. M. T. Webb, and F. Muller-Karger. 2001. SeaWiFS Helps Assess Hurricane Impact on Phytoplankton in Caribbean Sea.EOS, Transactions of the American Geophysical Union. Vol. 82 (45). Pg. 529-533**

# Episodic Rainfall Event

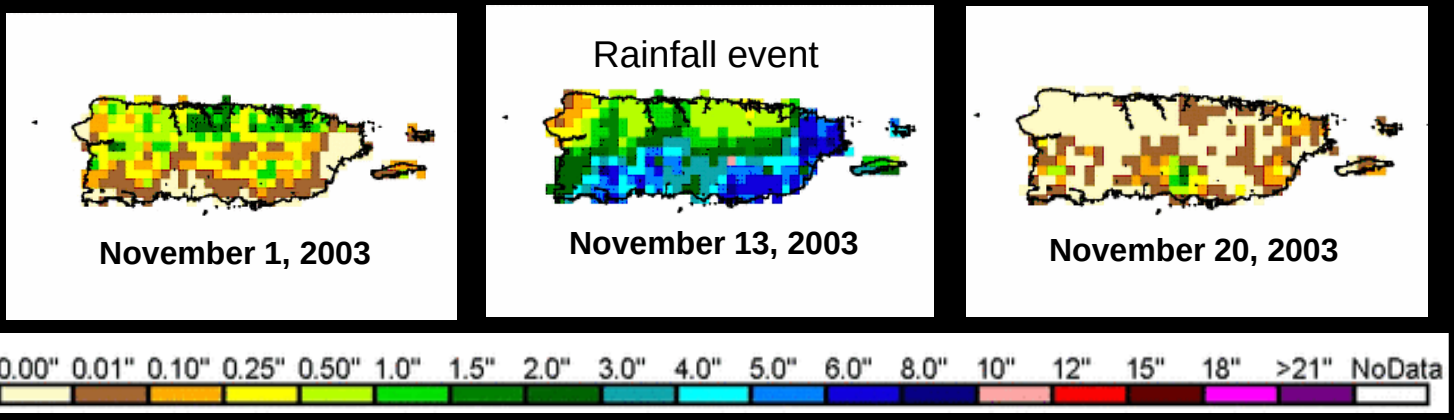
- An extensive area of low pressure developed in the eastern Caribbean from November 13 to 15, 2003, resulting in heavy rains over Puerto Rico and the U.S. Virgin Islands.

- The intense precipitation ranged between 228 to 533 mm and transported a considerable amount of sediments in land runoff to the ocean.

## National Weather Service

**24 Hour – Estimated Precipitation**

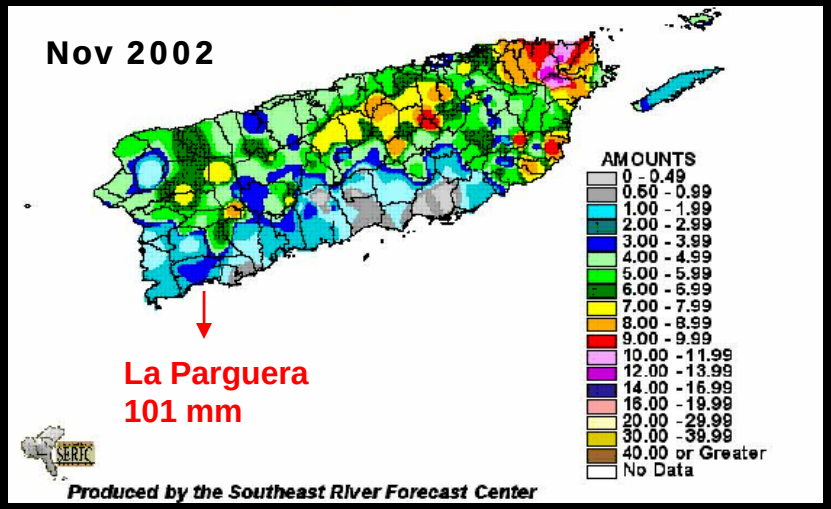
**Puerto Rico**

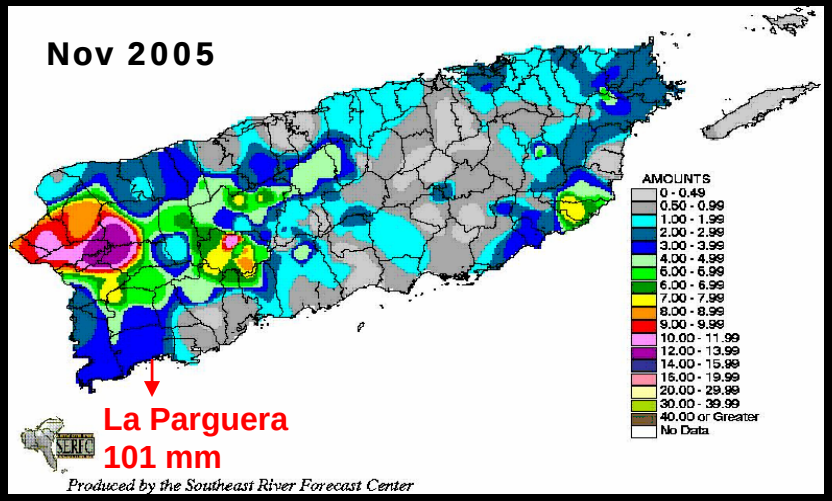


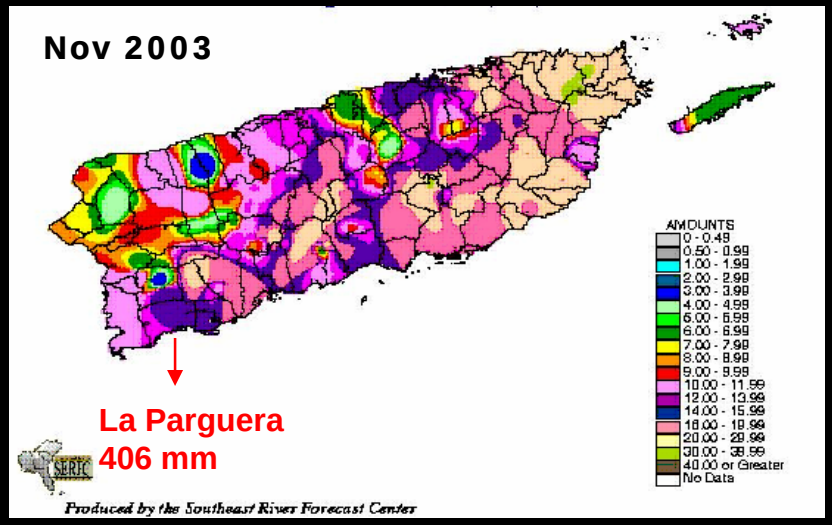

- Estimated precipitation at La Parguera increased from 0.25mm to 228mm during rain event.

# National Weather Service
# Precipitation Gage Analysis For Puerto Rico

## Monthly Precipitation Totals



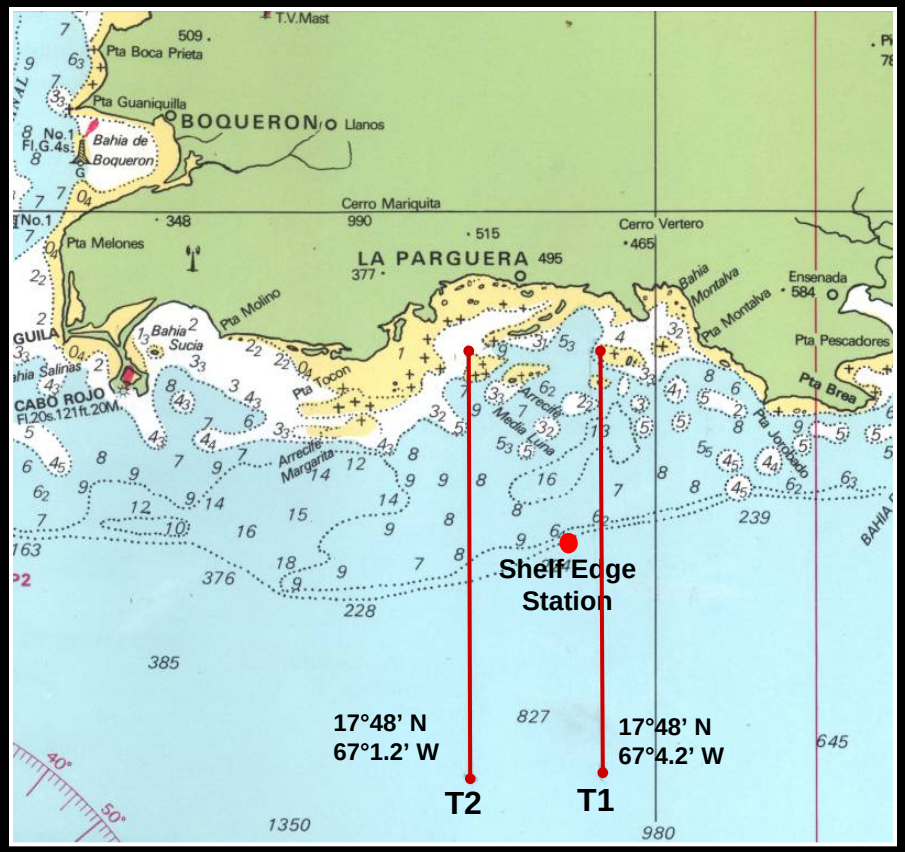



## Remote Sensing Tools

- MODIS Aqua L2 (daily)
- Resolution: 1 km
- Bio-optical products:
  - Chl a (mg $m^{-3}$)
  - $K_{490}$ ($m^{-1}$)
- Data extracted from two parallel transects.

## Field Data (Shelf Edge Station)

- 17°34.8’ N, 67°2.2’W
- Bio-optical parameters:
  - Chl a (18 m & 3 m)
  - Turbidity (18 m & 3 m)
  - Vertical Attenuation ($Kd_{PAR}$)
  - % PAR (10m)




| Transects | T1 | T2 |
|---|---|---|
| Length (nm): | 9.0 (16.2 km) | 9.0 (16.2 km) |
| Distance from coast (nm): | 1.3 (2.3 km) | 1.6 (2.9 km) |
| Distance to shelf edge (nm): | 4.0 (7.2 km) | 4.4 (7.9 km) |
| Distance south of shelf edge (nm): | 5.0 (9.0 km) | 4.6 (8.3 km) |

# Field Data

## Turbidity, Chlorophyll *a* & Vertical Attenuation Coefficient

**SCUFA II (Self-Contained Underwater Fluorescence Apparatus)-Turner Designs:**

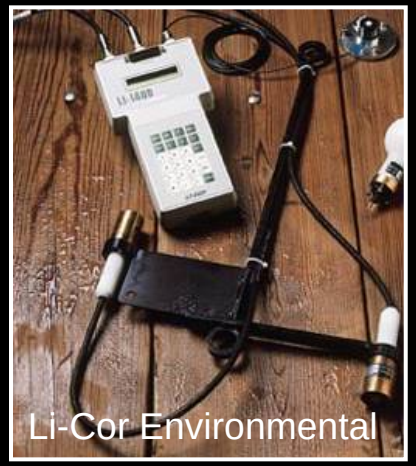
Turbidity: NTU
Chlorophyll a: µg / L
Sampling frequency: 10 minutes
Data was classified in three periods:

- Pre - Rain - Oct 31 to Nov 4
- Post - Rain 1 - Nov 20 to 25
- Post - Rain 2 - Dec 8 to 10

**Li-Cor LI-1400 Light Sensor:**

Vertical attenuation coefficient (Kd $m^{-1}$):

$$Ed_{(z)} = Ed_{(0-)}\, e^{-kd}$$ (Kirk,1994)

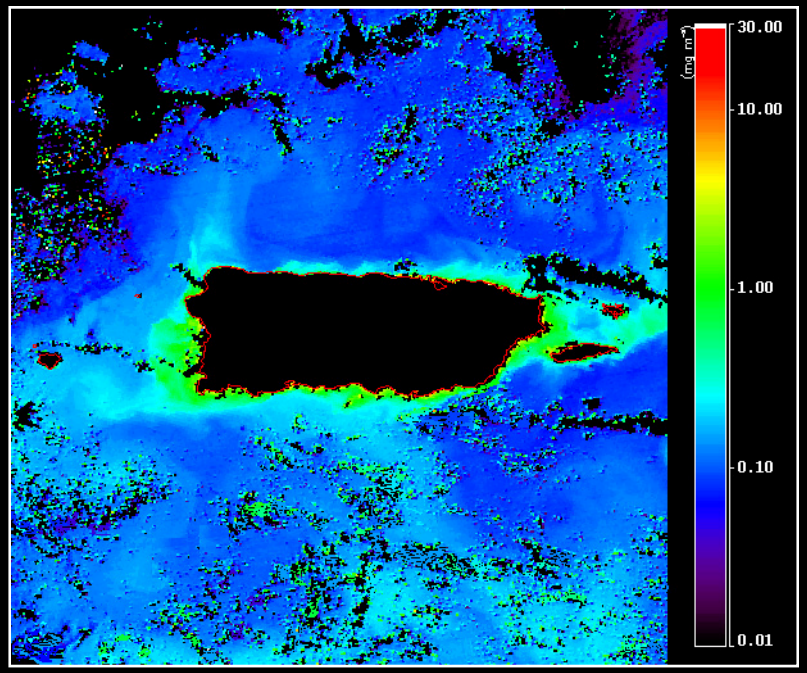


# Baseline conditions

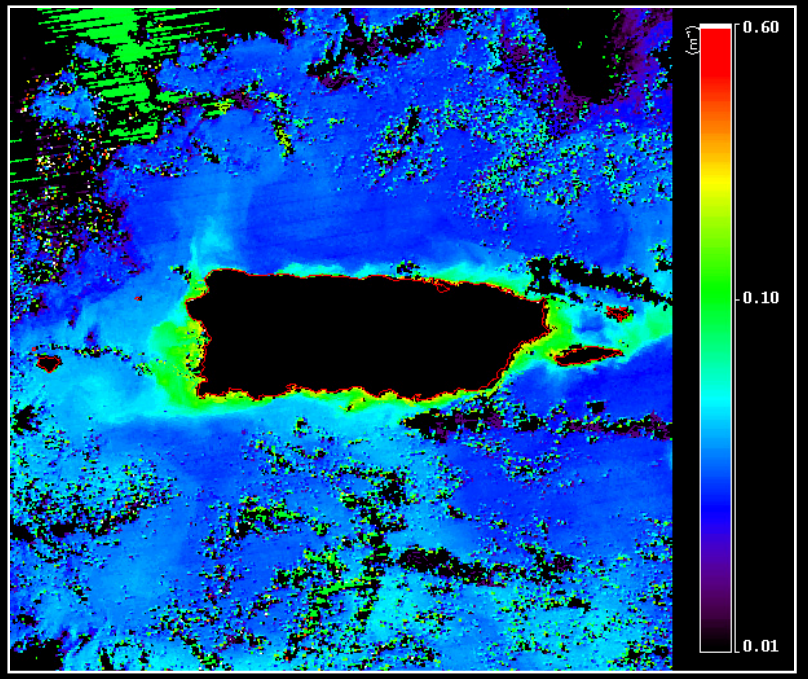
## October 25, 2003

### -19 days

### Chlorophyll *a*




### $K_{490}$




**October 2003**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

**November 2003**

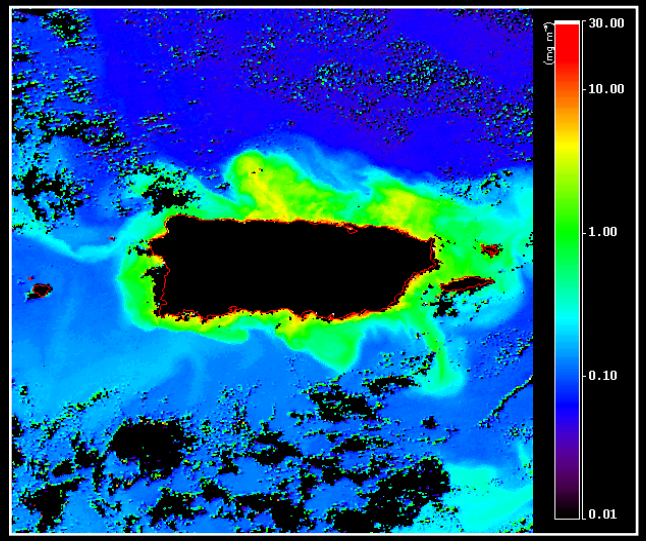
| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | | | | | | |

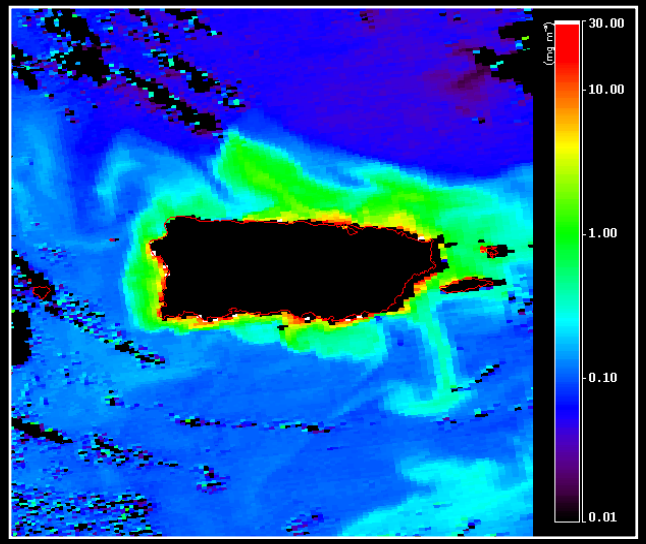
Rainfall Event  Image date

# November 19 & 20, 2003

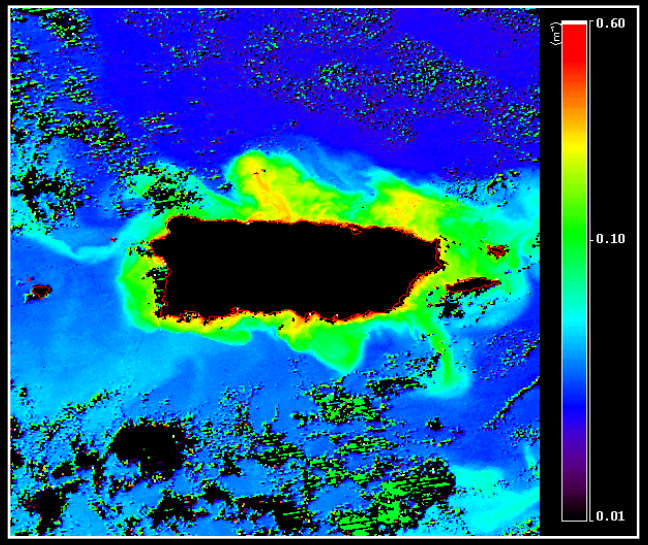
## + 4, +5 days

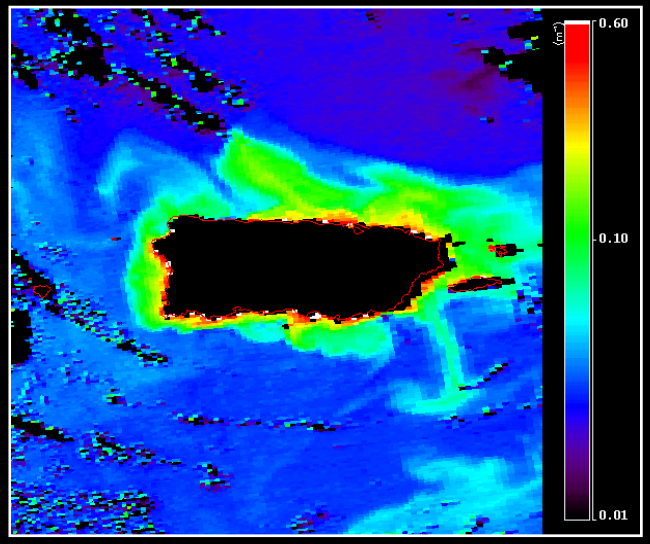
**Chlorophyll *a***




**$K_{490}$**




**November 2003**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | | | | | | |

Rainfall event

Image date

Turbidity plume extended:

13 km south of La Parguera

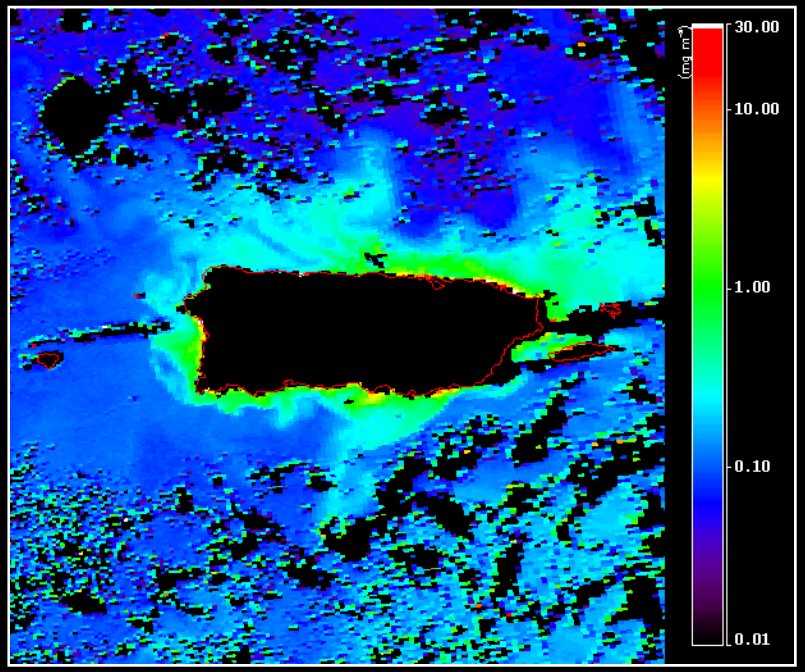
34 km south of Guayama

+40 km in northern PR

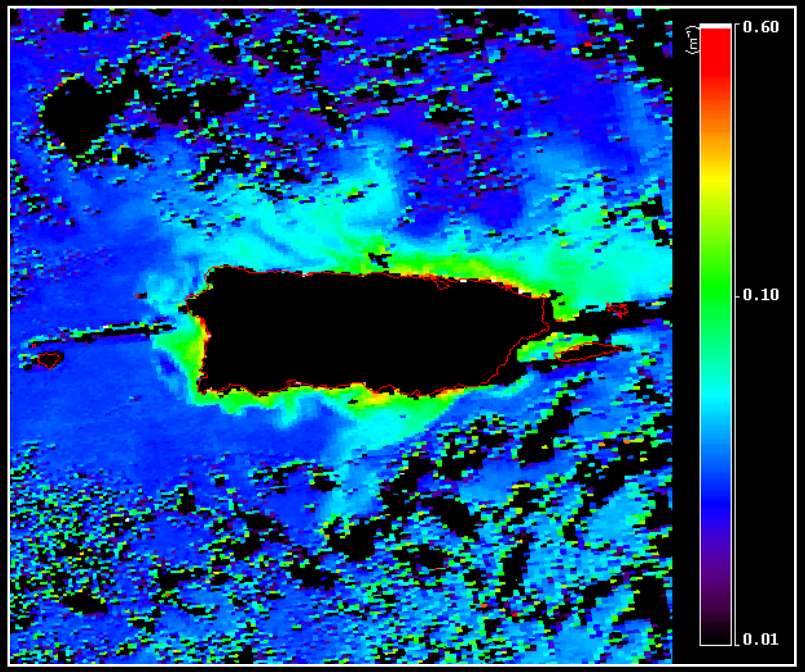
# November 29, 2003

## +14 days

### Chlorophyll *a*




### $K_{490}$




**November 2003**

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | | | | | | |

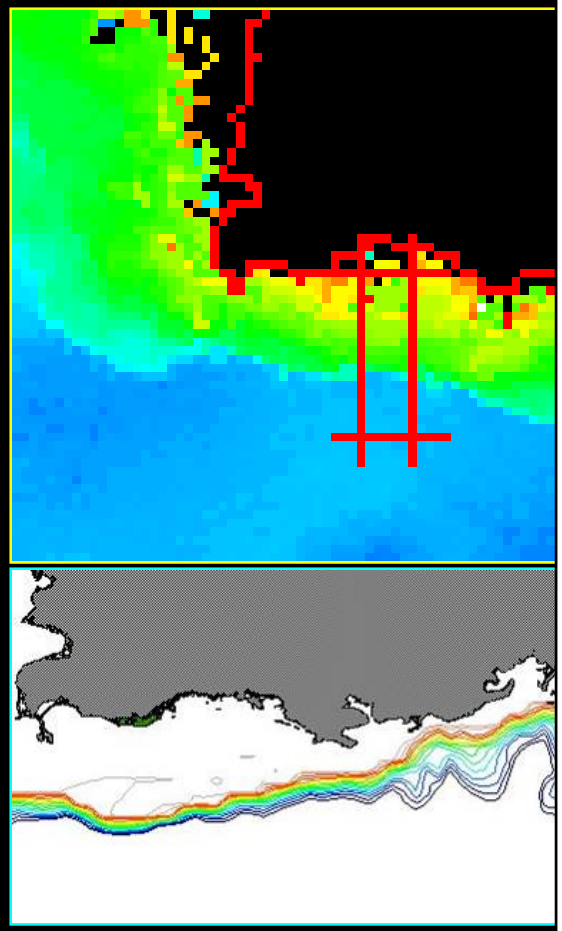
Rainfall event

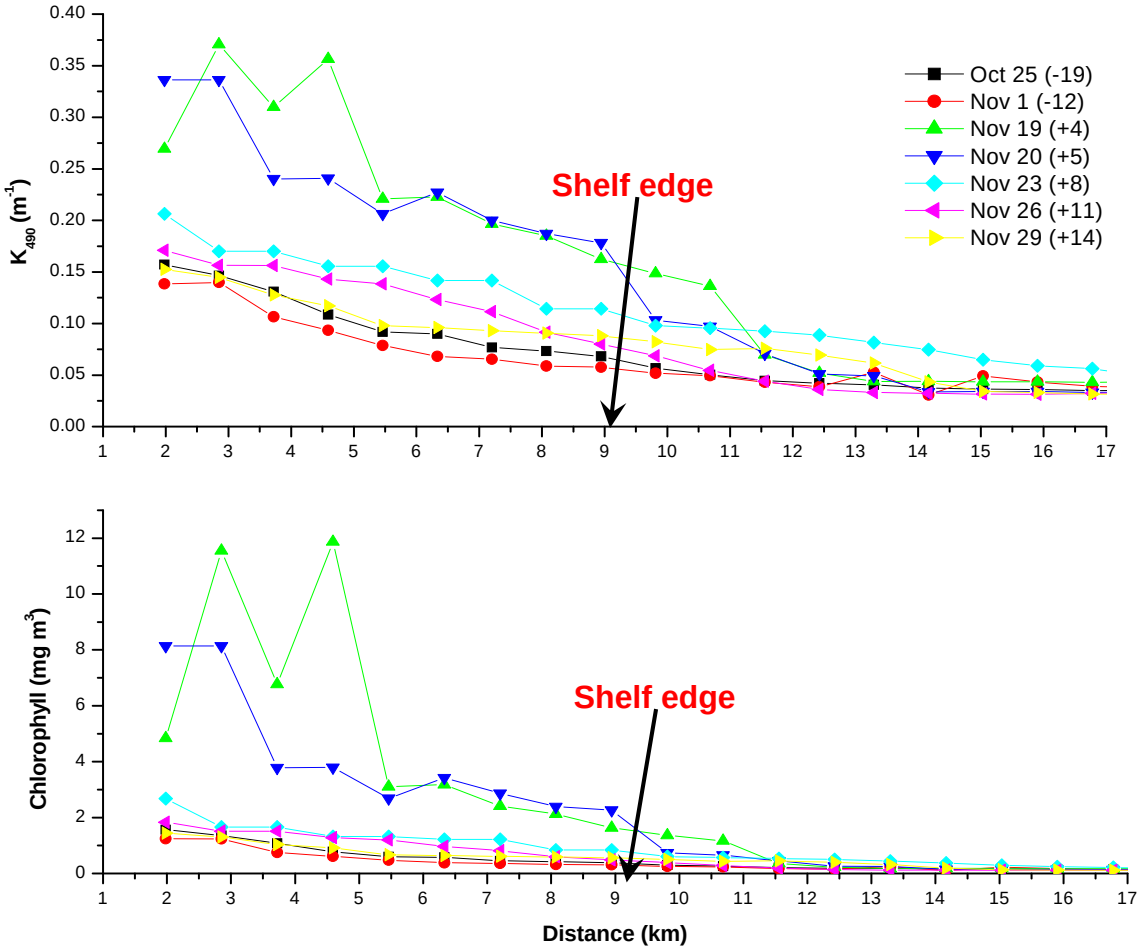
Image date

# MODIS Time Series $K_{490}$ and Chlorophyll a

November 13-15, 2003

Episodic Rainfall Event



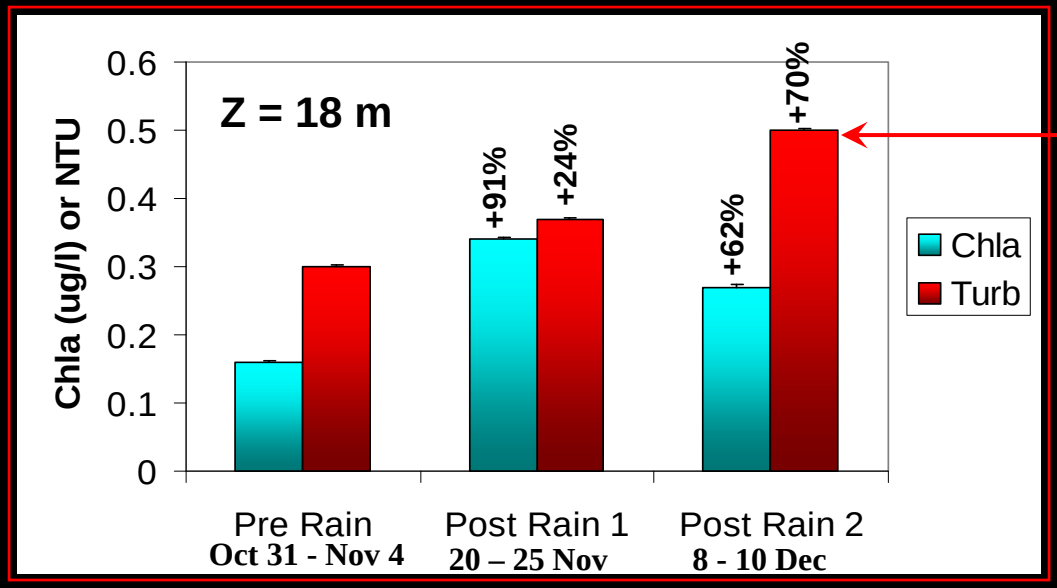


# Hypopycnal Plumes
## Warne et al., 2005

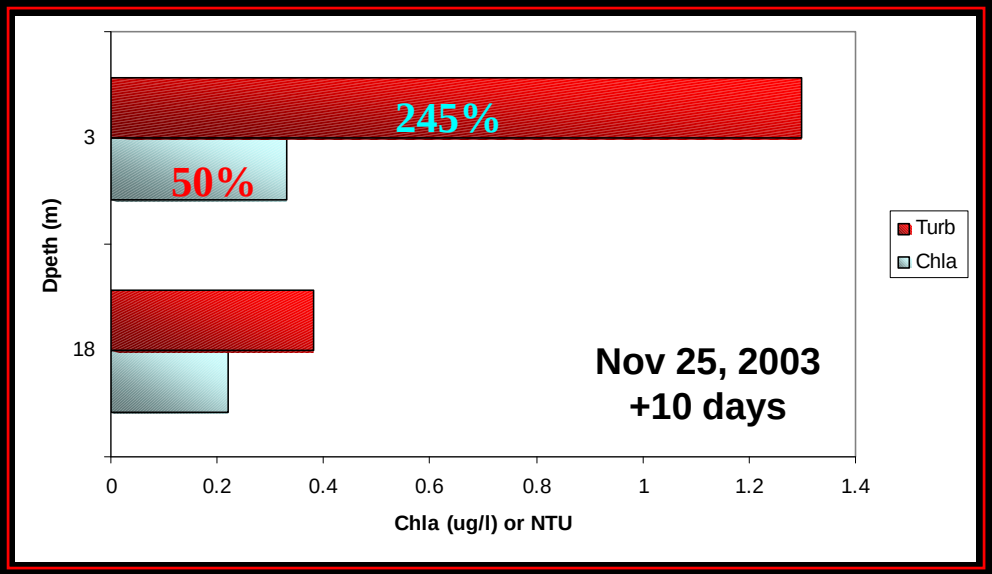
- Buoyant suspension layers formed during intense storms, river water and sediment discharges.
- Mechanisms to distribute suspended sediment over a broad area of the shelf and slope.
- Most coral are able to endure episodic influx of sediment and nutrients, perhaps because during periods of high discharge, the shelf waves and current regime is capable of transporting almost all terrigenous sediment to the shelf edge and slope.

# Field Data

## Shelf Edge Station: Chlorophyll a and Turbidity




Influenced by water masses, with high sediment and chlorophyll content, moving downwind.



# Field Data
## Shelf Edge Station: $Kd_{PAR}$ & % PAR at 10m

| DATE | $Kd_{PAR}$ | %PAR $_{10m}$ |
|---|---|---|
| November 4, 2003<br>-9 days | 0.11 | 32.4 |
| December 10, 2003<br>+25 days | 0.16 | 19.9 |

- After 25 days the Kd remained higher and % PAR at 10m was 12.5% lower.

- Prolonged periods under low % PAR could result in detrimental changes to benthic communities (i.e. reductions in photosynthetic rates).

# Conclusions

- MODIS is a cost effective tool for the assessment of the impact of episodic events in coastal areas and to evaluate the bio-optical parameters that could have direct or indirect impact on coral reef organisms.

- Time series analysis of remote sensing data can be used to identify pathways and temporal patterns of coastal suspended sediments and chlorophyll plumes from land runoff.

- In coastal areas MODIS chlorophyll a values are overestimated due to the influence of CDOM. Therefore, only relative values, rather than absolute values, should be considered in these studies.

- For deeper shelf edge reefs, the high stratification of the turbidty plume limits the potential direct impact of suspended sediments on susceptible corals, such as the *A. cervicornis*.

- Prolonged periods of high turbidity and the resulting light attenuation could have a detrimental effects on coral photsynthesis and growth.