Ecological Assessment of Generalized Littoral Environments: A Decision-Support System (EAGLE/DS)

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD835193010

Frank E. Muller-Karger
Robert Chen
Daniel Otis (Post-Doc)
Pablo Mendez Lazaro (Post-Doc)
Matt McCarthy (Student)

COLLEGE OF MARINE SCIENCE
UNIVERSITY OF SOUTH FLORIDA
ST. PETERSBURG

Institute for Marine Remote Sensing

USF
UNIVERSITY OF SOUTH FLORIDA

Acknowledgements

- EPA STAR program
- EPA National Estuary Programs
  - To date:
    - Tampa Bay Estuary Program
    - San Juan Bay Estuary Program
- NASA
- USGS
- NOAA

Outline

- Overall Objectives
- Methods
  - Approach to obtain environmental obs. time series records
  - Satellite data product algorithm development
- Preliminary Results
    - Spatial patterns seen by satellite
    - Time series of environmental parameters:
      - Historical environmental parameters
      - Satellite data
- Relevance to climate science/USGCRP National Climate Assessment
- Conclusions and Next Steps

Overall Objective

- Develop application to:
  - Advance knowledge of extreme environmental events that impact water quality
  - Help evaluate likelihood of one or multiple extreme events occurring simultaneously in various driving parameters in a given region and evaluate impact on water quality
  - Provide regional-scale of information on extreme events to policy makers, planners, educators and researchers

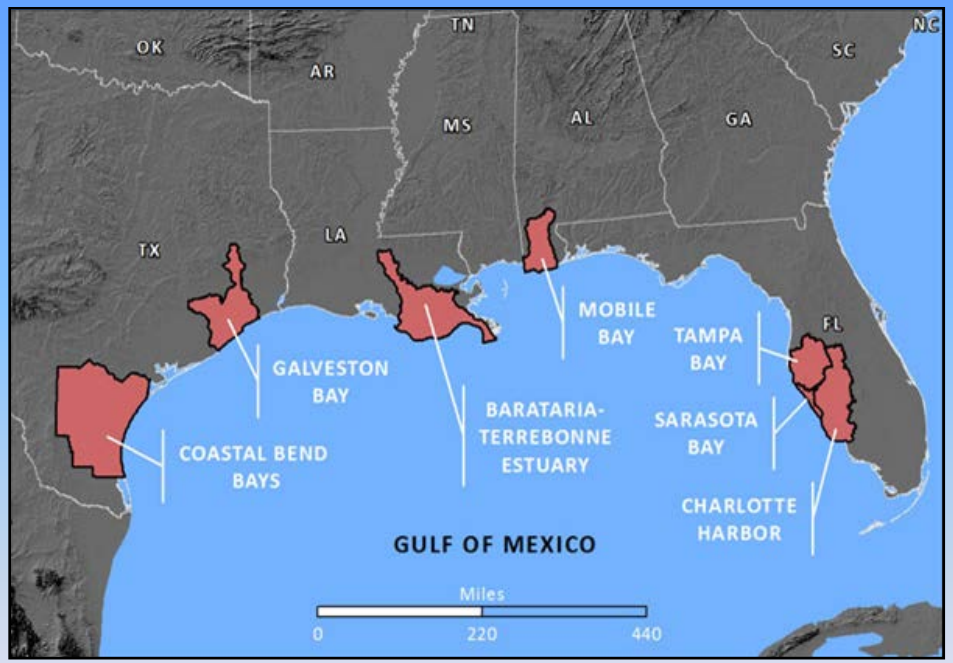
Requirements

- Synoptic, frequent, long-term observations
- Identify:
  - primary drivers of variability in water quality indices of major estuaries (Gulf, PR)
  - frequency of events in each variable
  - whether frequency has changed over time
  - whether synergy between drivers may lead to extreme events

Approach

- Focus: Gulf of Mexico estuaries and Puerto Rico coasts
- Use *in situ* and remote sensing time series data:
  - Evaluate data quality, uncertainty, frequency and magnitude of events, changes in amplitude and period of relevant cycles, evaluate any shift in phase between parameters, etc.
  - Synthesis in the context of local and global environmental change
- Develop decision-support tool:
  - Input and feedback from user community
- Intensive outreach effort

National Estuary Programs: Gulf of Mexico and Puerto Rico



NEP set up under the Clean Water Act amendments in 1987

Partnerships

- National Estuary Programs
  - Actively working with:
    - Tampa Bay Estuary Program (TBEP) / Holly Greening, Lindsay Cross
    - San Juan Bay Estuary Program / Jorge Bauza, Javier Laureano, Pablo Mendez Lazaro
- EPA Puerto Rico Sustainable Communities Program
  - Ross Lunetta and Bill Fisher (EPA National Exposure Research Laboratory, Ecosystems Research Division, Athens, GA)
- EPA Gulf Ecology Division
  - Blake Schaeffer
  - Water quality mobile (Android) app development
    - Test data for five estuaries provided for one year (2003)

Product	Source	Duration	Interval	Parameters
Satellite products MODIS (250 m resolution Band 1: 620-670 nm Band 2: 841-876 nm)	NASA	2000 - Present	Daily, weekly	Rrs(645), other bands *(Index of 'turbidity', Kd)*
River Discharge	USGS	1930's to present	Daily	Discharge
Water Quality	EPA, regional gov't	1970's to present	As sampled	Turb., [Chl], salinity, Secchi depth
Tide Gauges	NOAA	1980's to present	Hourly	Water level (tides, long-term trends)
Meteorological data	NOAA	1890's to present	Hourly/ Daily	Air temp., wind, precip.
Land use data	Various	As available to present	Decadal	Population, policies, water management

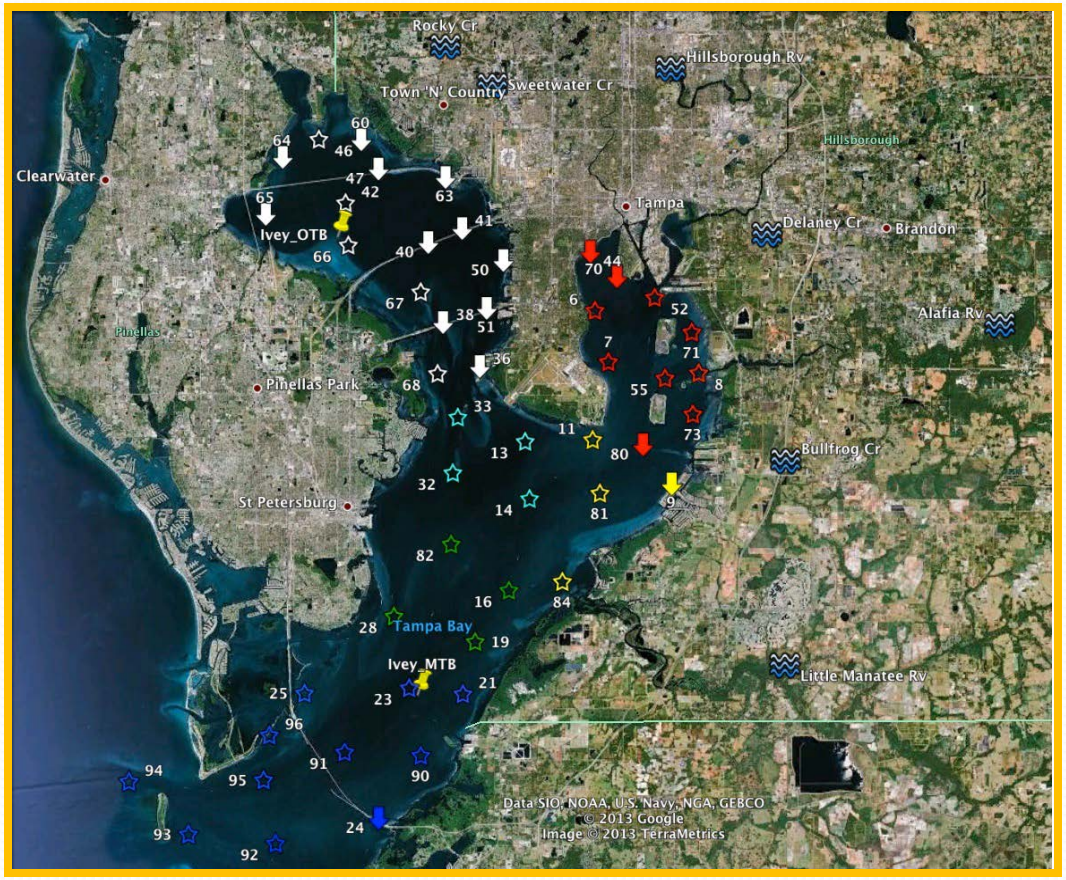
WATER QUALITY

	SJ	TAMPA	GALVESTON	BARATARIA	COASTAL BEND	MOBILE BAY
Heavy metals		X	X	X	X	X
Enterococcus		X	X	X	X	X
Chlorophyll a	?	X	X	X	X	X
Dissolved oxygen (DO)	?	X	X	X	X	X
Inorganic nitrogen (nitrate and nitrite) as N	?	X	X	X	X	X
Light Photosynthetic Active Radiation (PAR)		X	X	X	X	X
Light Photosynthetic Active Radiation At Depth (PAR)		X	X	X	X	X
Nitrogen, ammonium (NH4) as NH4	?	X	X	X	X	X
Nitrogen, Nitrate (NO3) as NO3	?	X	X	X	X	X
Nitrogen, Nitrite (NO2) as NO2	?	X	X	X	X	X
Nutrient-nitrogen	?	X	X	X	X	X
Orthophosphate as PO4	?	X	X	X	X	X
Phosphate-phosphorus as P	?	X	X	X	X	X
Silicate	?	X	X	X	X	X
TSS	?	X	X	X	X	X
Transparency, turb, Secchi disk	X (?)	X	X	X	X	X
pH, Wtemp, salinity, specific conductance	?	X	X	X	X	X

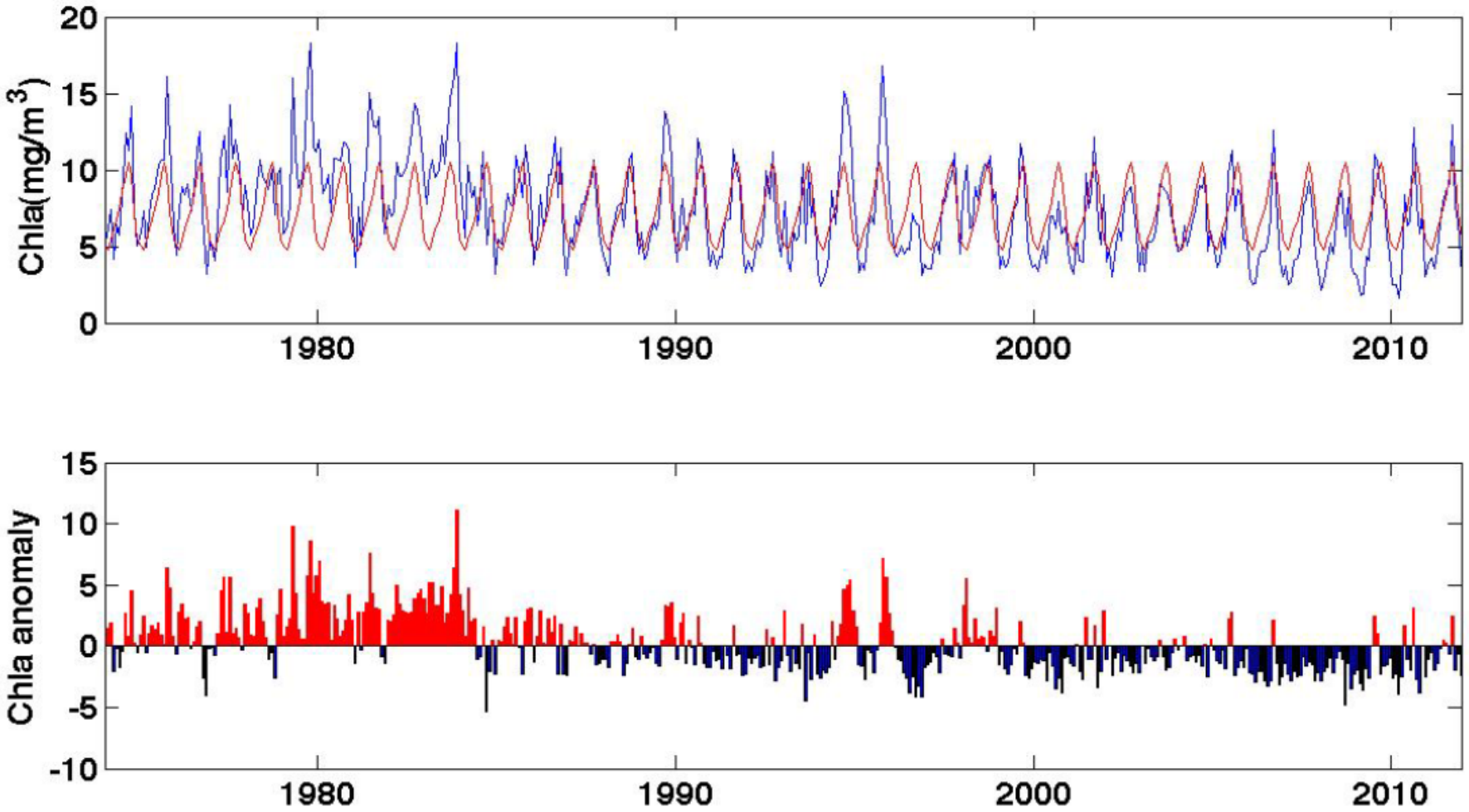
Water quality data varies within and among estuaries: dates, frequency, parameters, quality

Water Quality Monitoring in Tampa Bay

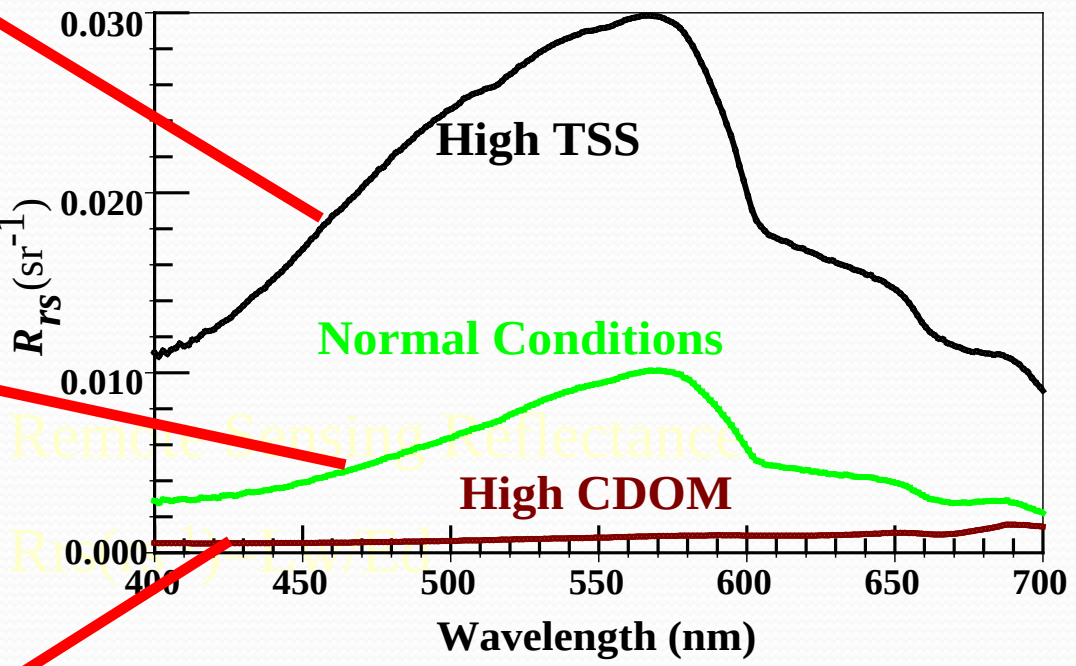
Monthly sampling by: Environmental Protection Commission of Hillsborough County (EPCHC)



Chla – Tampa Bay EPCHC monthly data (1974-2012)
Red line in top graph represents mean annual cycle



Remote Sensing Reflectance (Rrs) in Tampa Bay



Turbidity and transparency from MODIS

- We are examining validity of relationships using *in-situ* turbidity, transparency, TSS from various estuaries
- Turbidity from MODIS Rrs(645) – testing different relationships:
  - from Moreno et al. (2010), Chen et al., 2007b
- Transparency (Secchi depth) from MODIS and SeaWiFS
  - From Chen et al., 2007c (after Mueller, 2000; Lee et al., 2005)

References (partial)

Chen Zhiqiang, ChuanminHu, Frank E. Muller-Karger, Mark E. Luther. 2010. Short-term variability of suspended sediment and phytoplankton in Tampa Bay, Florida: Observations from a coastal oceanographic tower and ocean color satellites. Estuarine, Coastal and Shelf Science. Volume 89, Issue 1, 1 September 2010, Pages 62-72. doi:10.1016/j.ecss.2010.05.014.

Chen, Z., Hu, C., Conmy, R.N., Swarzenski, P., and Muller-Karger, F. 2007a. Colored Dissolved Organic Matter in Tampa Bay, Florida. Marine Chemistry. Vol. 104. 98-109.

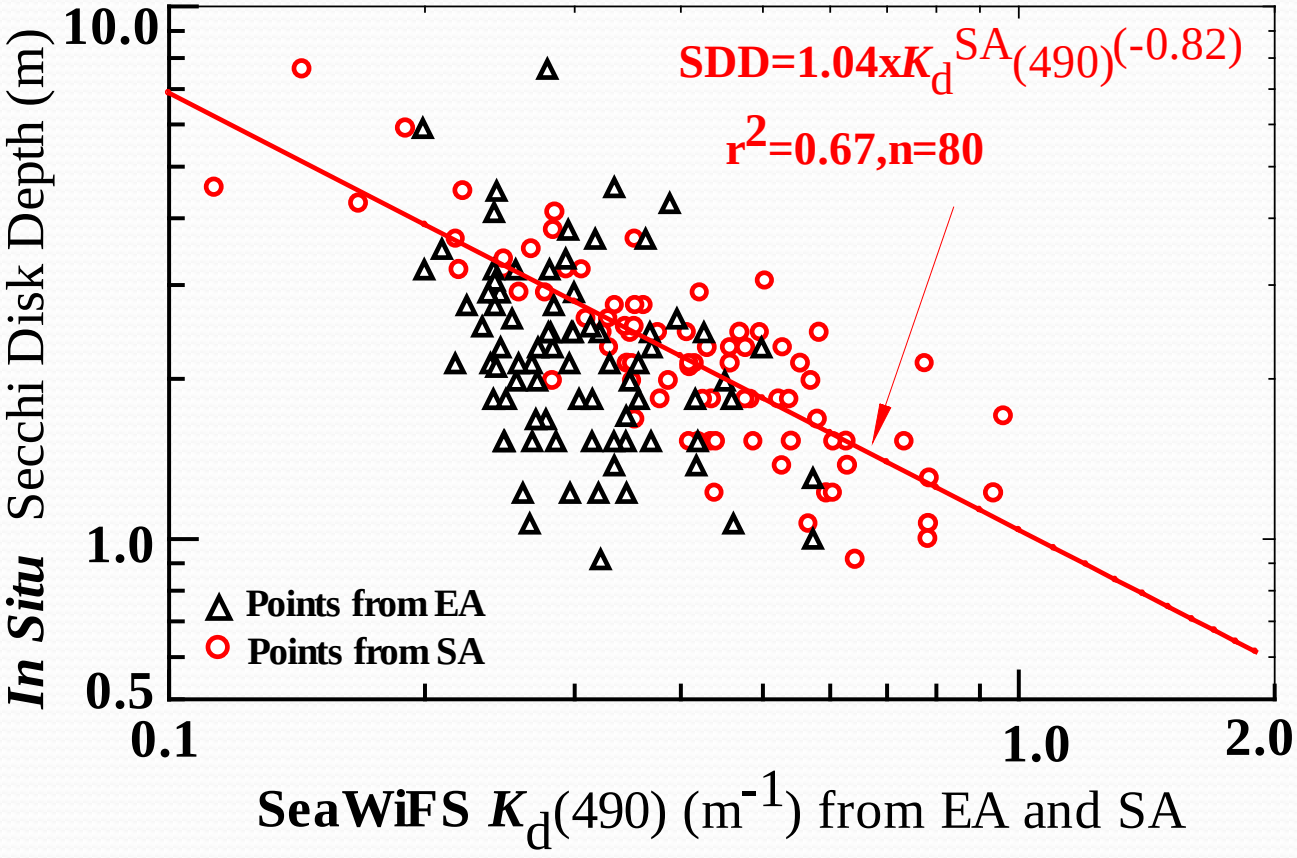
Chen, Z., Hu,. C., & Muller-Karger, F. E.. 2007b. Monitoring turbidity in Tampa Bay using MODIS 250 M imagery. Remote Sens. Environ. doi:10.1016/j.rse.2006.12.019.

Chen, Z., Muller-Karger, F. E., & Hu,. C.. 2007c. Remote Sensing of water clarity in Tampa Bay. Remote Sens. Environ. doi:10.1016/j.rse.2007.01.002.

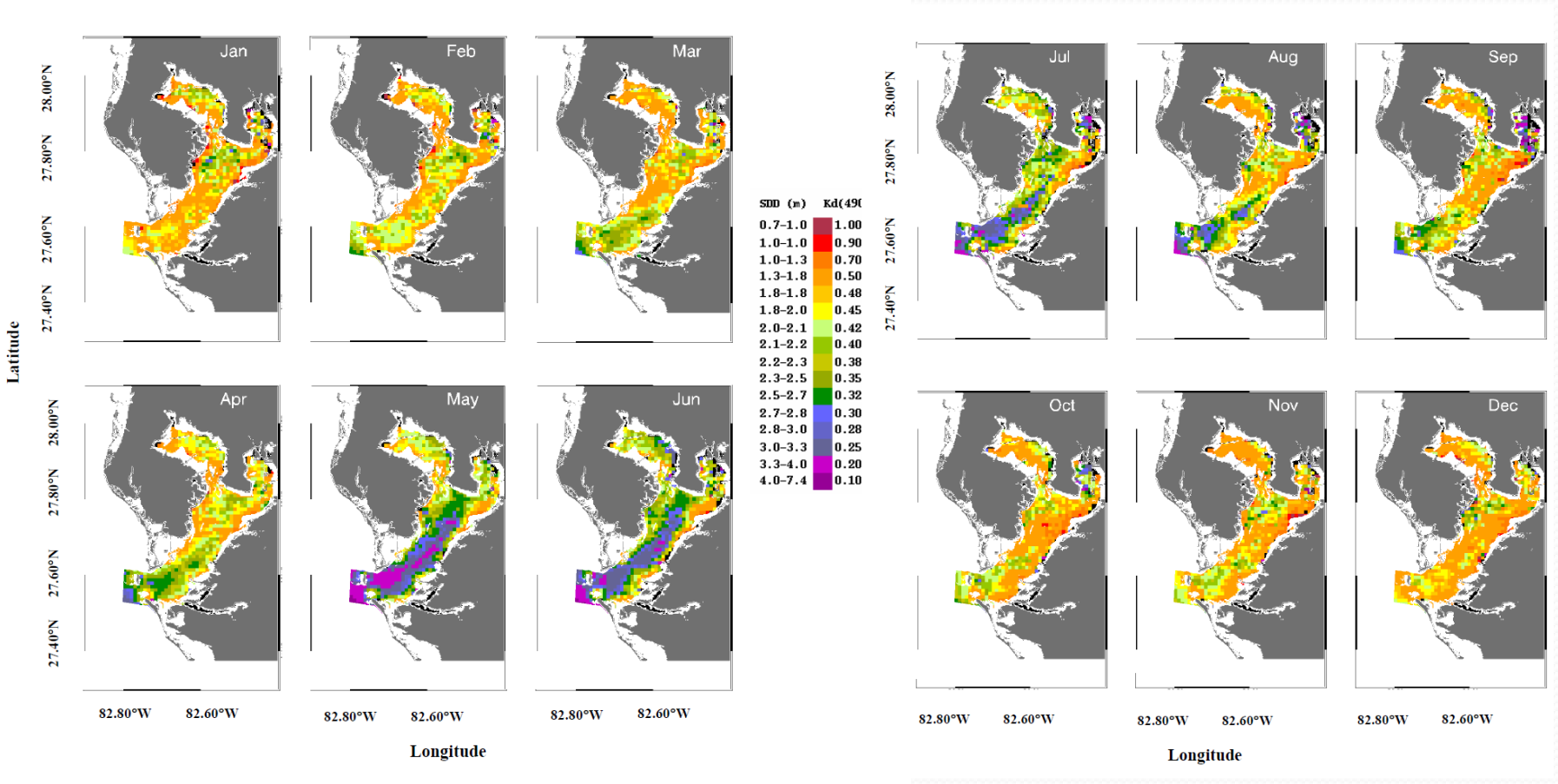
Le, Chengfeng, Chuanmin Hu, Jennifer Cannizzaro, David English, Frank Muller-Karger, Zhongping Lee. 2013. Evaluation of chlorophyll-a remote sensing algorithms for an optically complex estuary. Remote Sensing of Environment. 129. 75–89.

Moreno, Max J., Mohammad Al-Hamdan, Douglas Rickman, and Frank E. Muller-Karger. 2010. Using the Surface Reflectance MODIS Terra Product to Estimate Turbidity in Tampa Bay, Florida. Remote Sensing. 2010, 2(12), 2713-2728; doi:10.3390/rs2122713.

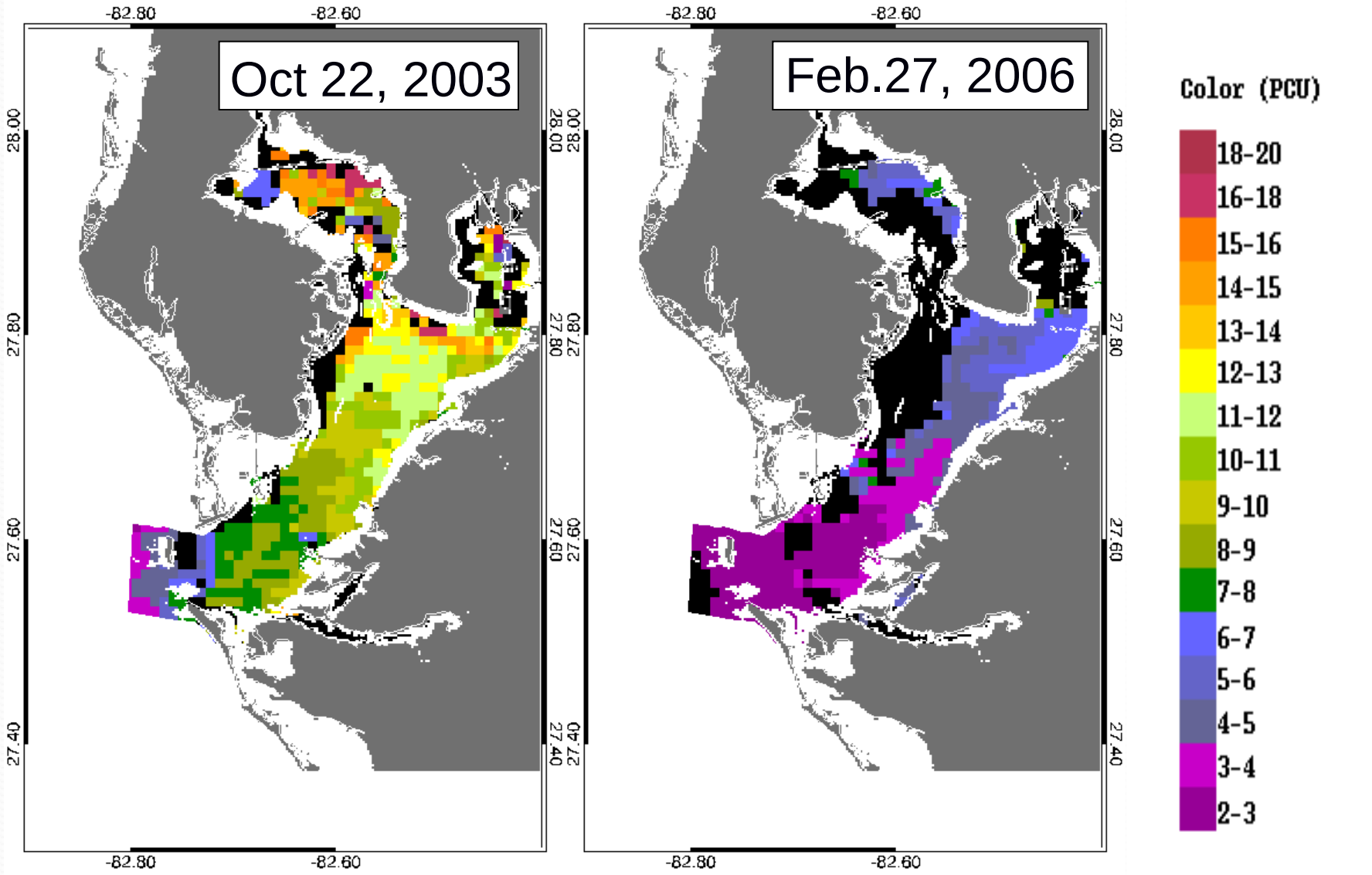
Test Secchi depth comparisons (SeaWiFS)



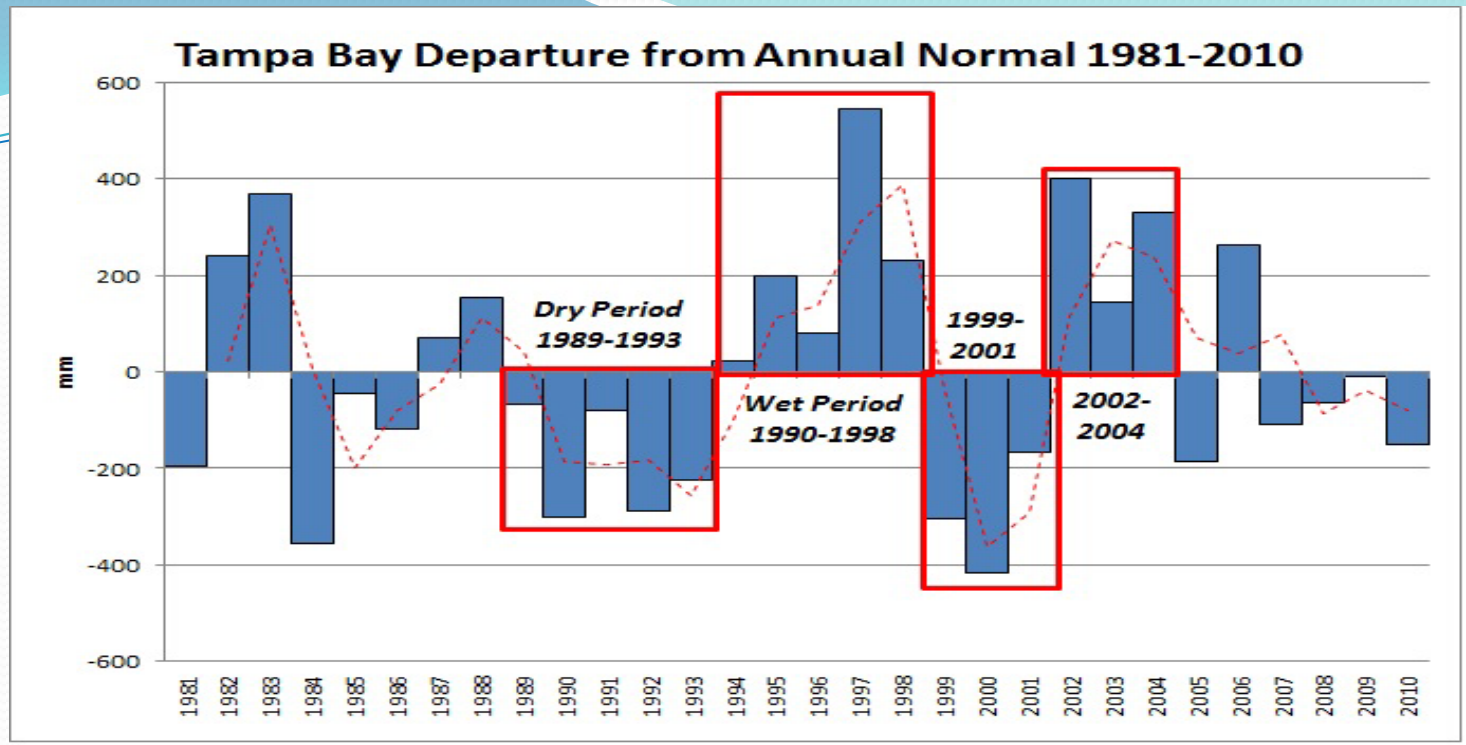
Test Secchi depth monthly composites (SeaWiFS, Sep 1997-Dec 2005)

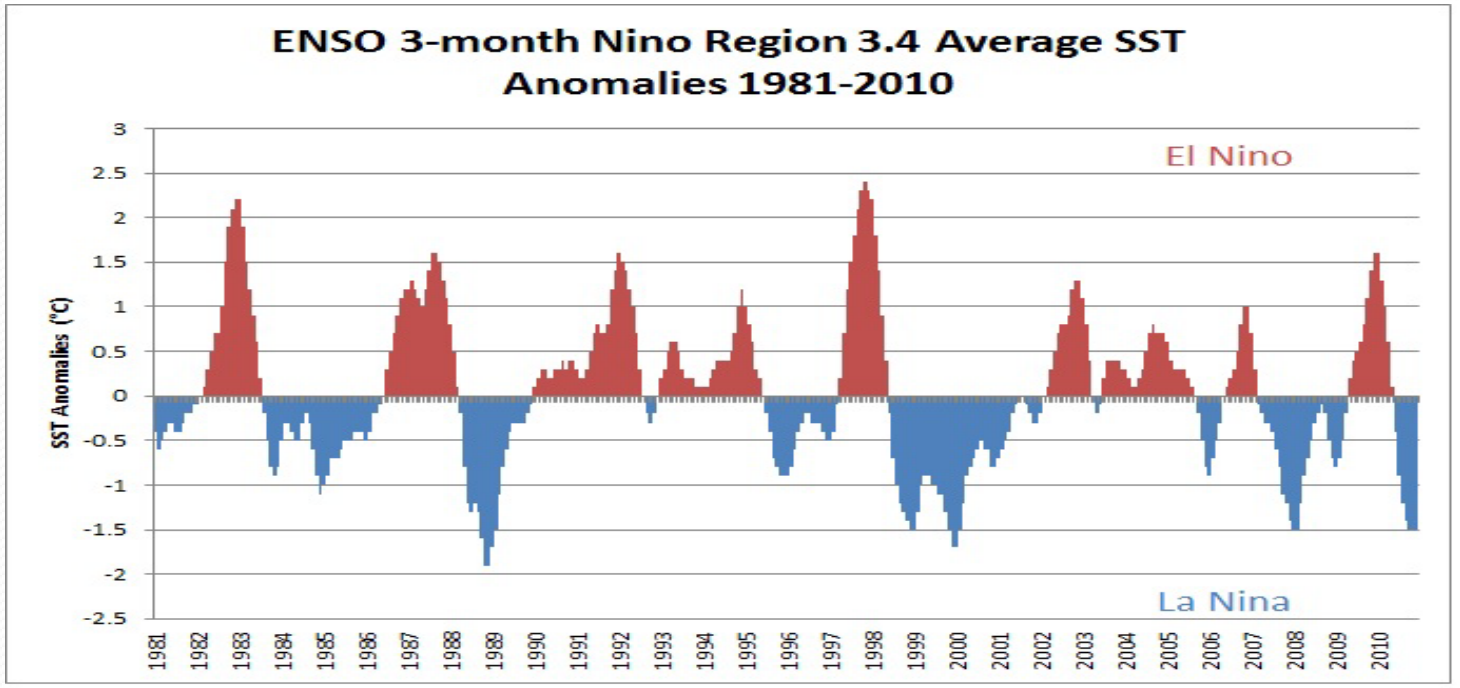


Seasonal Variation of ‘color’ in platinum cobalt units (PCU)

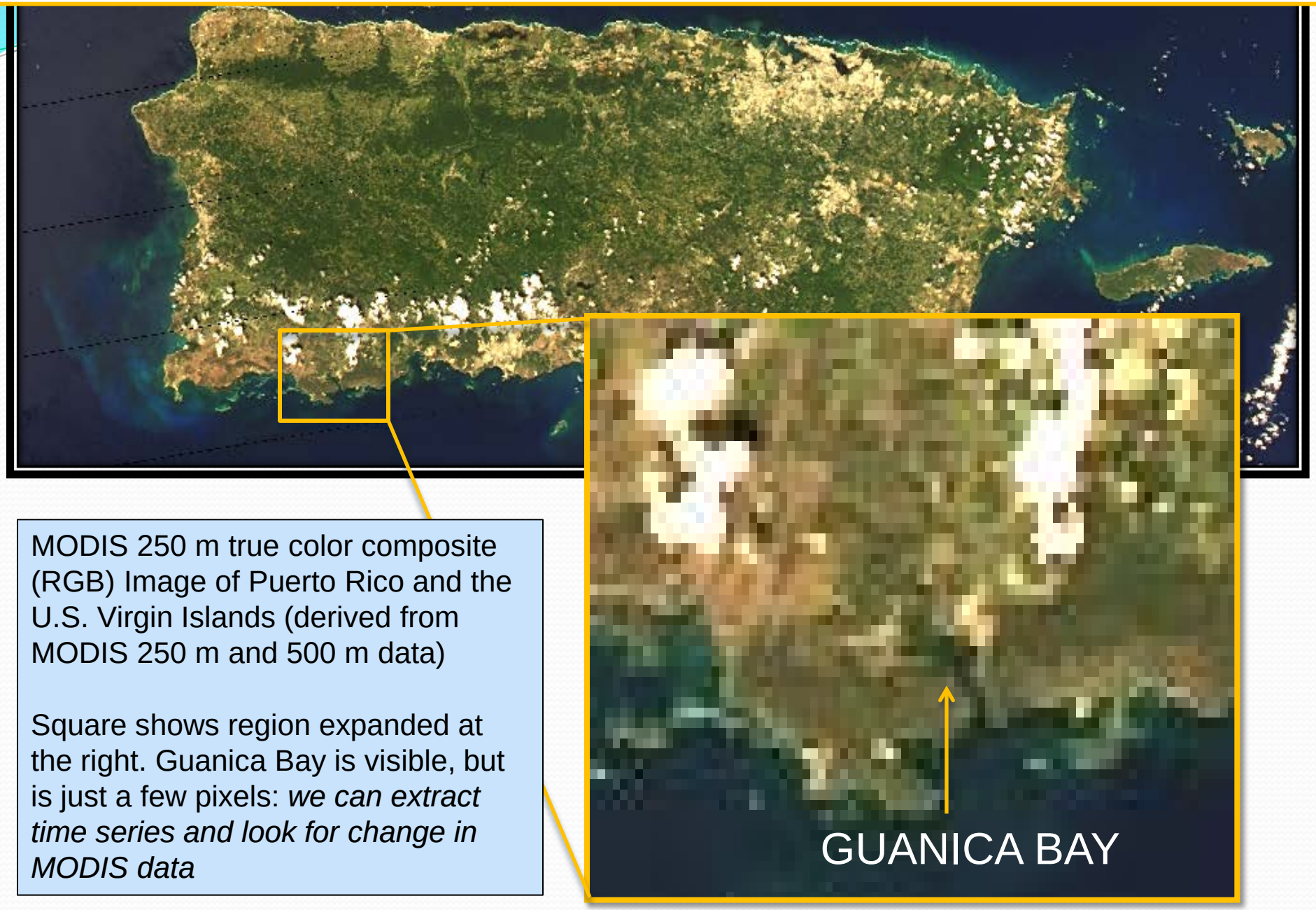


Precipitation



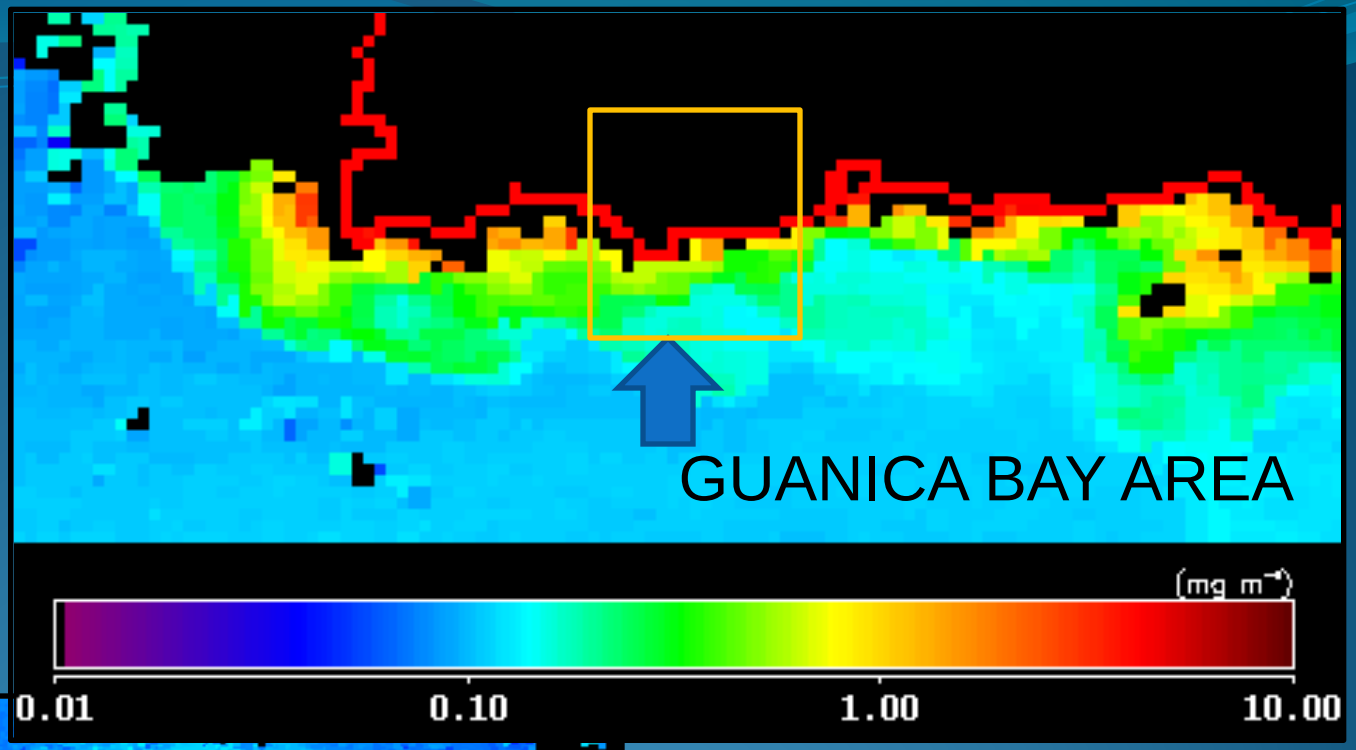


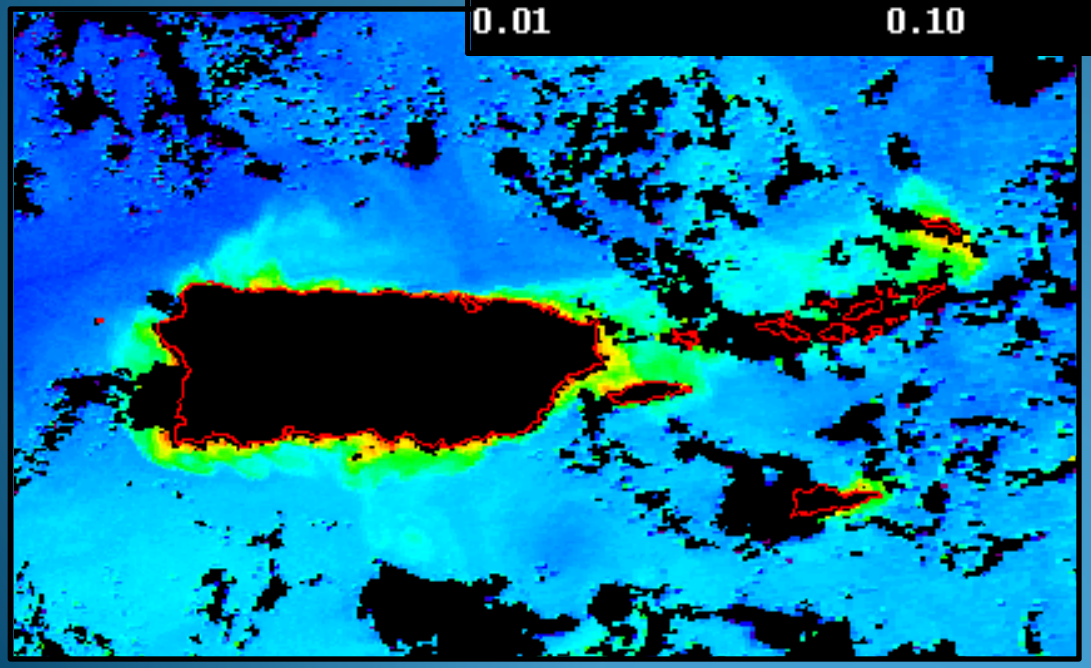
EPA Guanica Bay area (Puerto Rico) study (Lunetta, Fisher, et al.)



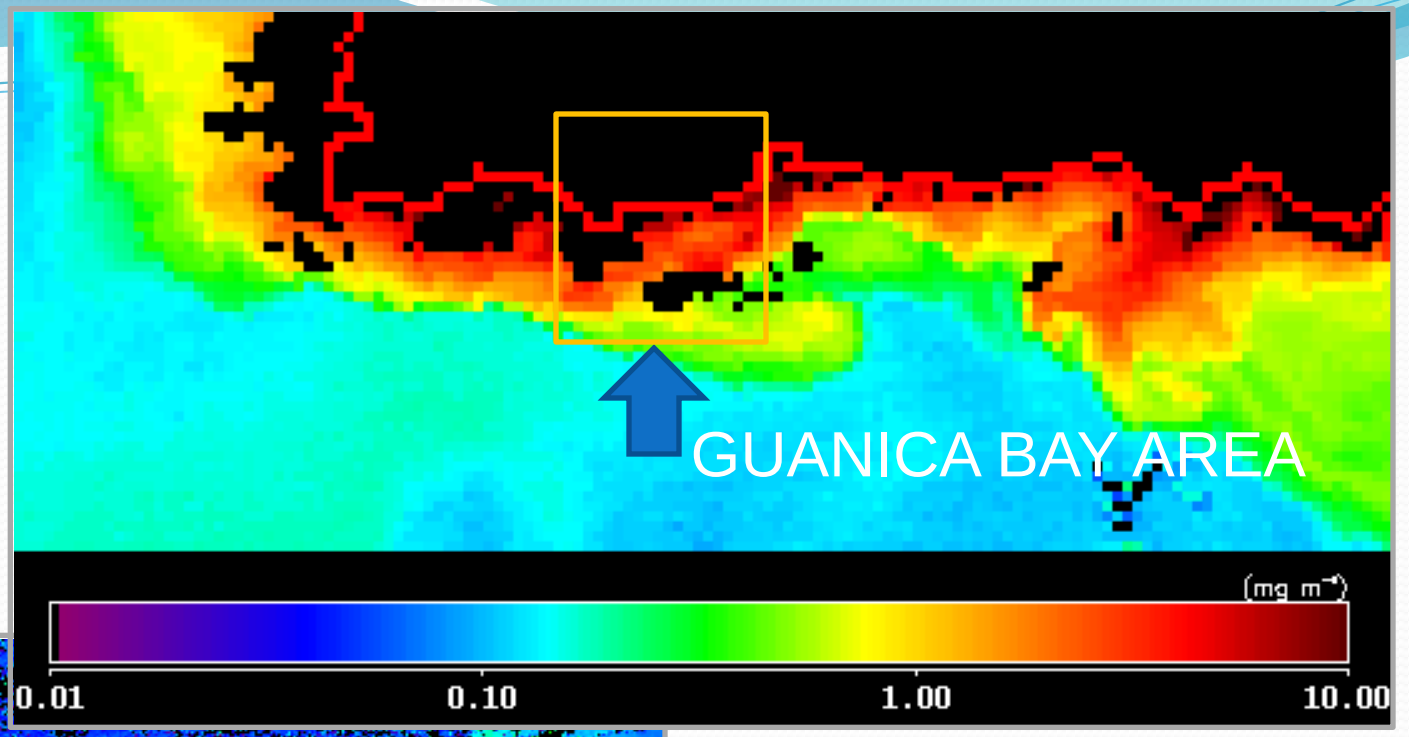
MODIS 250 m true color composite (RGB) Image of Puerto Rico and the U.S. Virgin Islands (derived from MODIS 250 m and 500 m data)

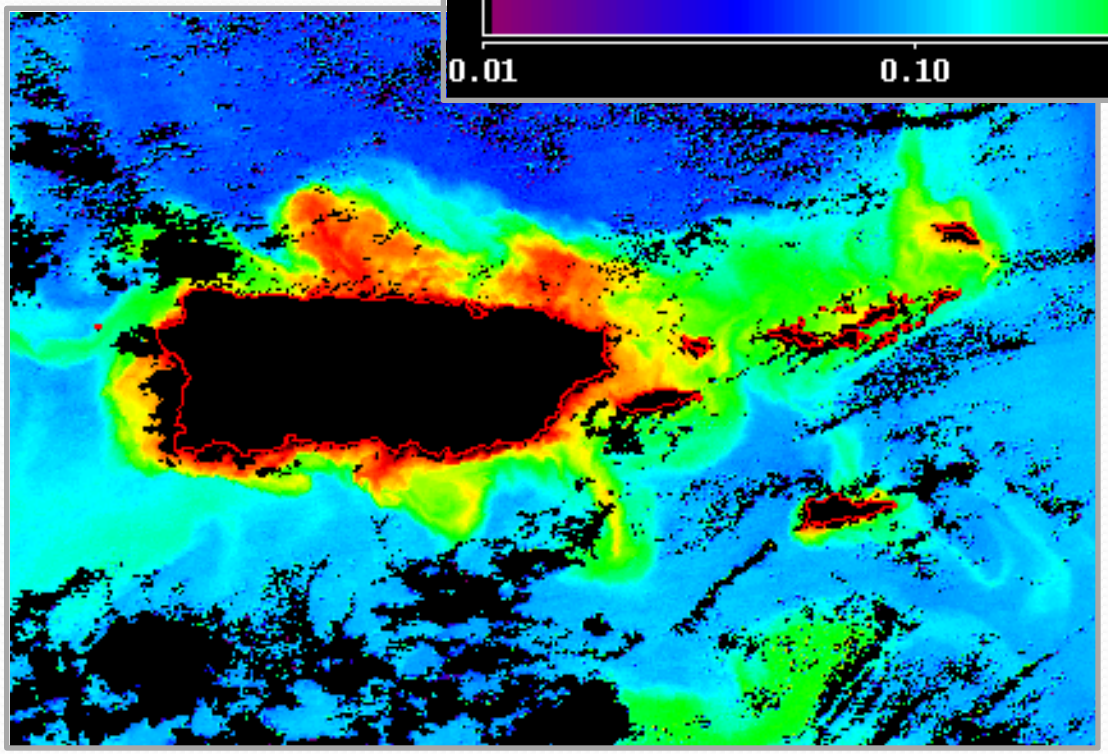
Square shows region expanded at the right. Guanica Bay is visible, but is just a few pixels: *we can extract time series and look for change in MODIS data*





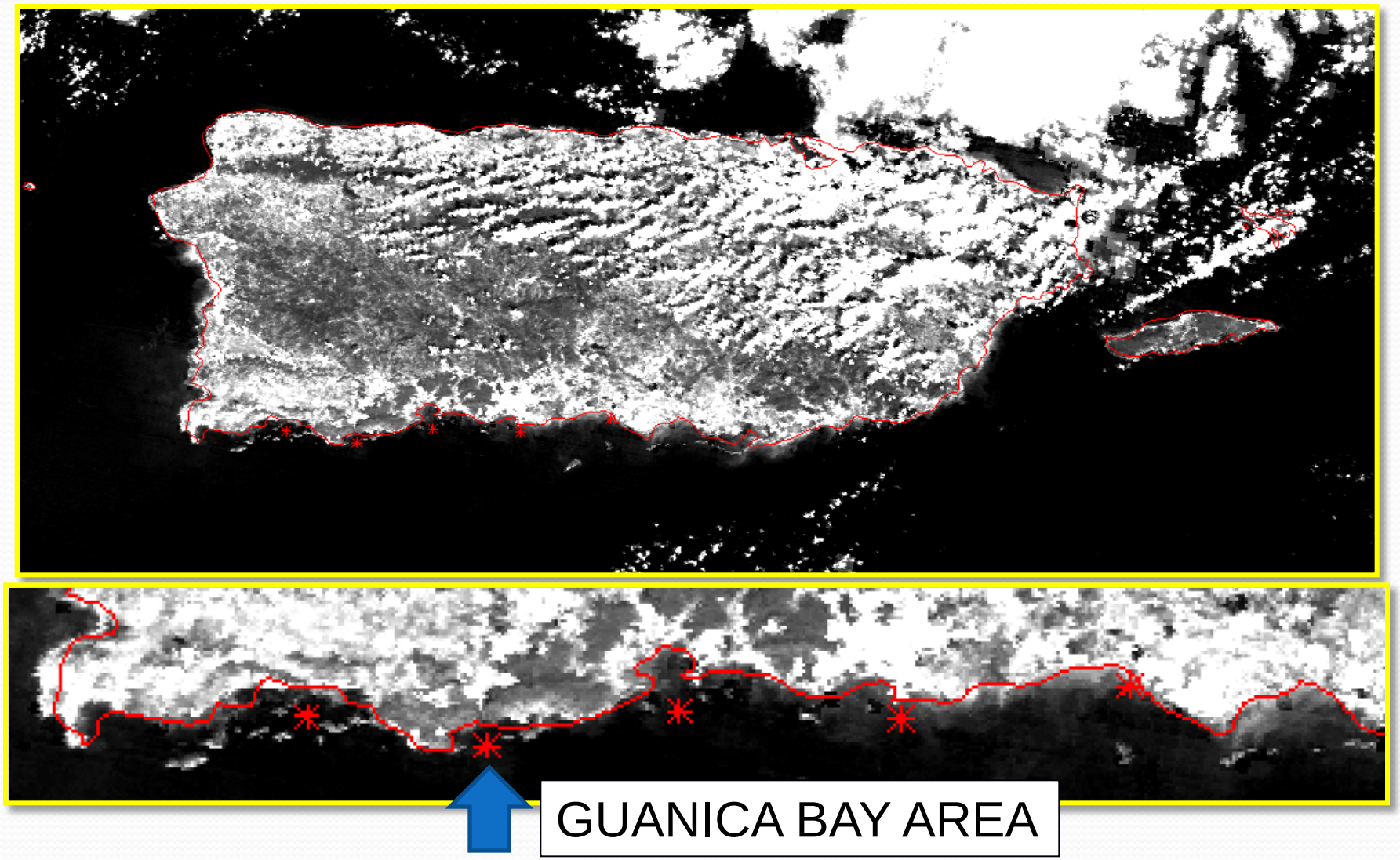
MODIS Aqua
1km, Chl-a
(Default alg.)
05 October 2003



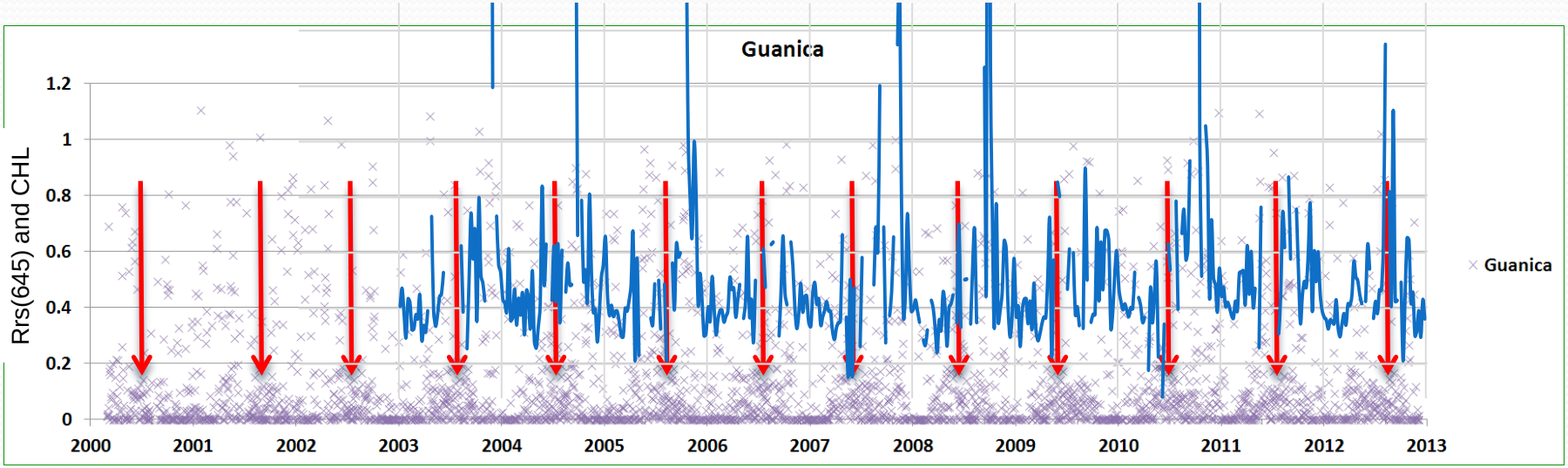


MODIS Aqua
1km, Chl-a
(Default alg.)
19 November 2003

Sample MODIS 250 m reflectance at 645 nm



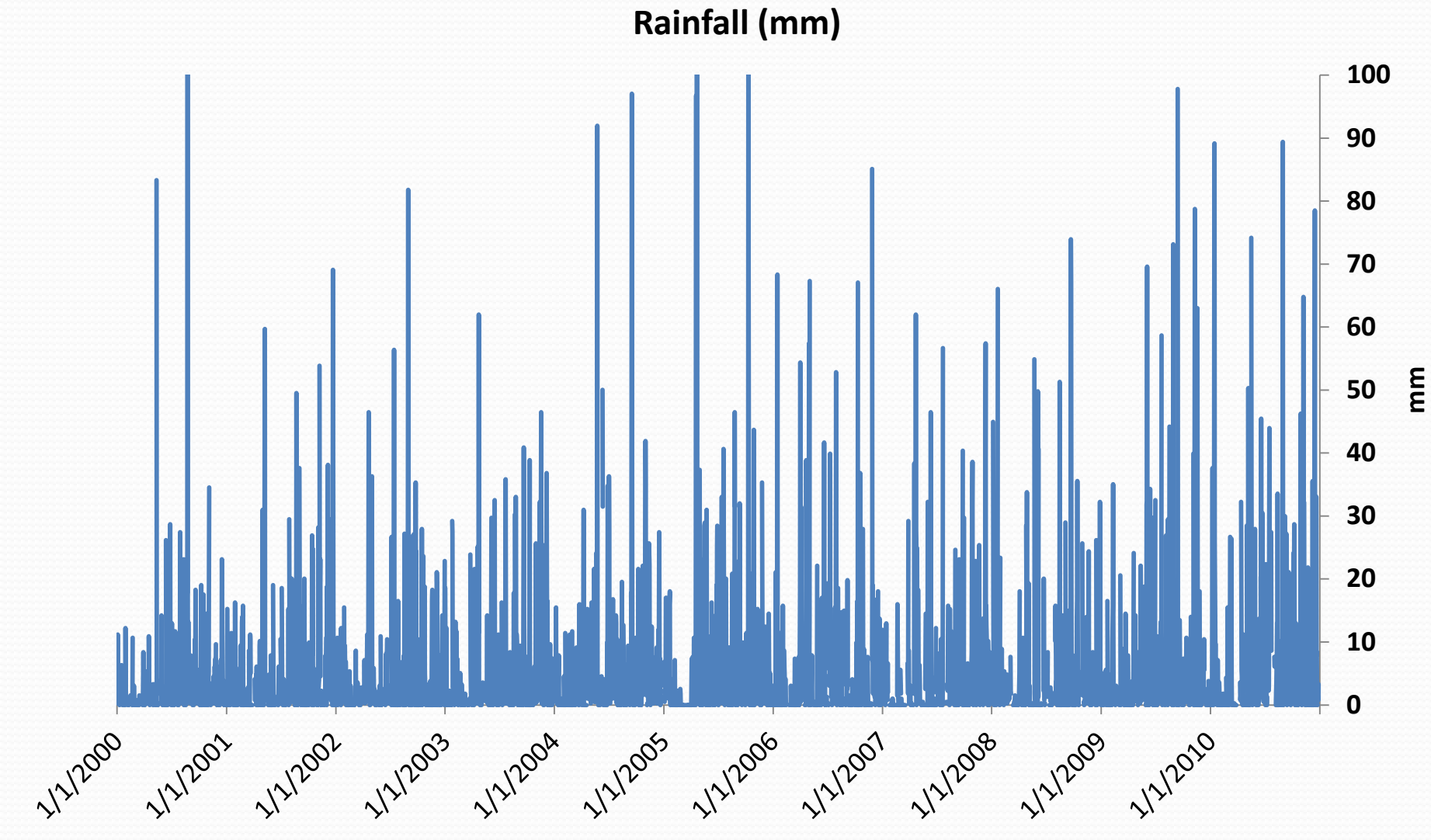
Nearshore Guanica Bay
Rrs(645) and Chlorophyll a concentration



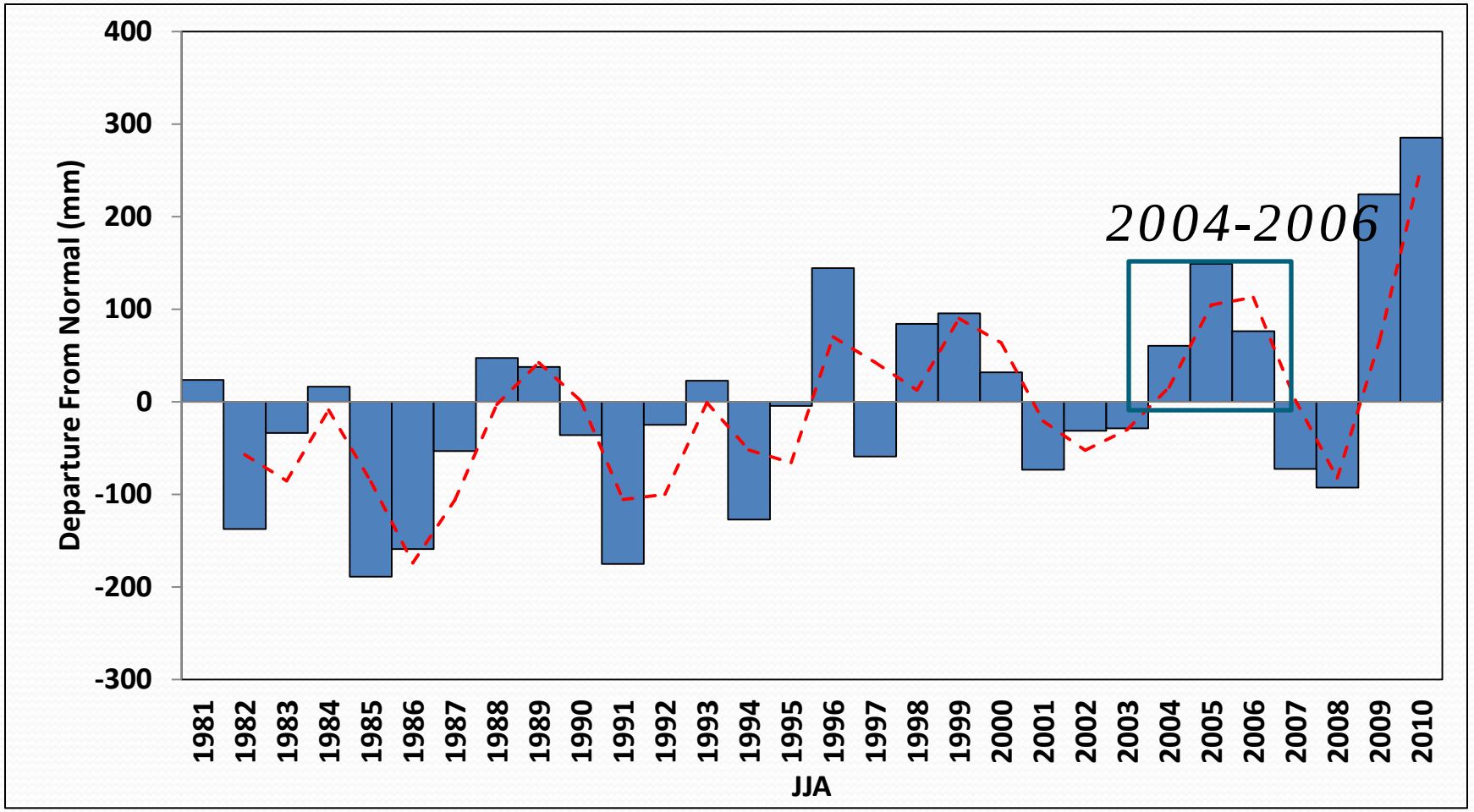
MODIS Terra time series of Reflectance (645nm) 250m resolution and Chlorophyll (1 km) off Guanica Bay

- What drives seasonal pattern in turbidity?
  Is there phase lag between CHL and turbidity?

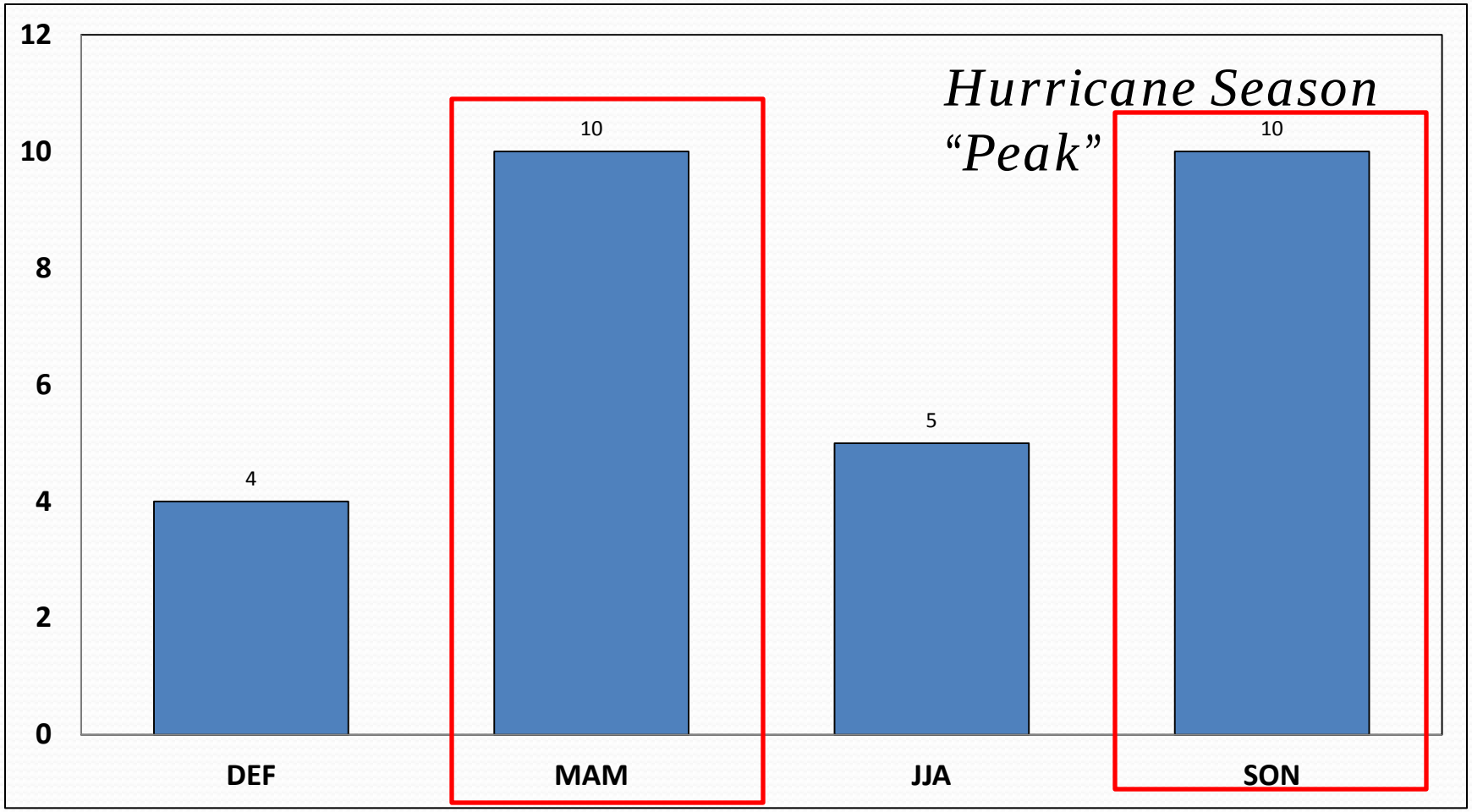
San Juan, PR, Weather Service Forecast Office (WSFO)
DAILY PRECIPITATION REGISTERED DATA: 1981-2010



SAN JUAN: PRECIPITATION DEPARTURE FROM NORMAL
1981-2010 June, July and August

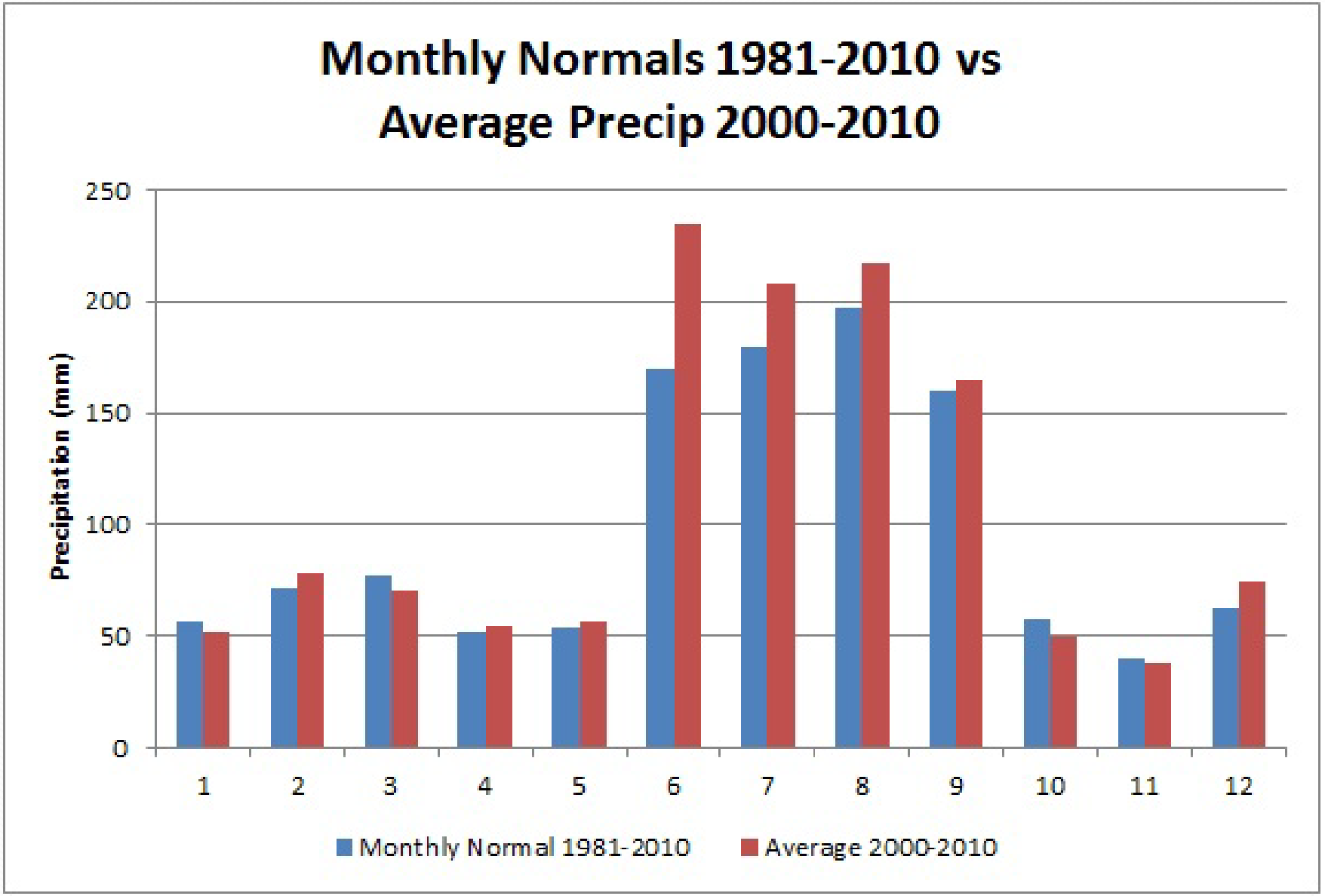


San Juan, PR, Extreme Events:
Seasonal number of days above 78mm/24hrs (1981-2010)



TOTAL: 29 extreme events

San Juan, PR


Monthly Normals 1981-2010 vs
Average Precip 2000-2010
Precipitation (mm)
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
Monthly Normal 1981-2010
Average 2000-2010

Issues

- Very large amount of in situ, meteorological, other environmental data, and satellite imagery
- Different data formats and sampling periods, protocols for each region
- Defining ‘extreme events’ for each variable
  - What statistic best to use, what is ‘commonly’ used?
- Understanding direct human impacts:
  - How to differentiate from ‘natural’ variability
  - Policy changes, land use changes
- Complex optics of each estuary, season
  - Finding adequate cal val / ground truth / match-ups

Relevance to climate science and the USGCRP National Climate Assessment

- National Climate Assessment 2013 does not identify coastal water quality as a major issue (focus is on drinking water, sea level rise)
  - NCA 2013 focuses on rivers, lakes, Great Lakes, the Mississippi River and hypoxic area off delta (dead zone)
  - …but all estuaries are relevant!
- This study will:
  - Inform stakeholders and provide a tool for application in other regions
  - help define how we quantify changes in water quality that are related to climate change

Next Steps

- Organize/standardize environmental data inventories:
  - Assess climate variability
    - Storms, tides, rainfall, winds, etc.
- Understand how best to handle ‘Human Events’
  - Land use and land use change
- Advance algorithms for satellite data:
  - Turbidity
  - Secchi
  - Chlorophyll
- Advance work with EPA on SW Puerto Rico (Lunetta/Fisher)
- Advance application for mobile platforms
  - Work jointly with EPA (Blake Schaeffer)