A Resource Manager's Perspective on Supporting Adaptive Management

U.S. Climate Change Science Program Workshop: Climate Science in Support Of Decision-making

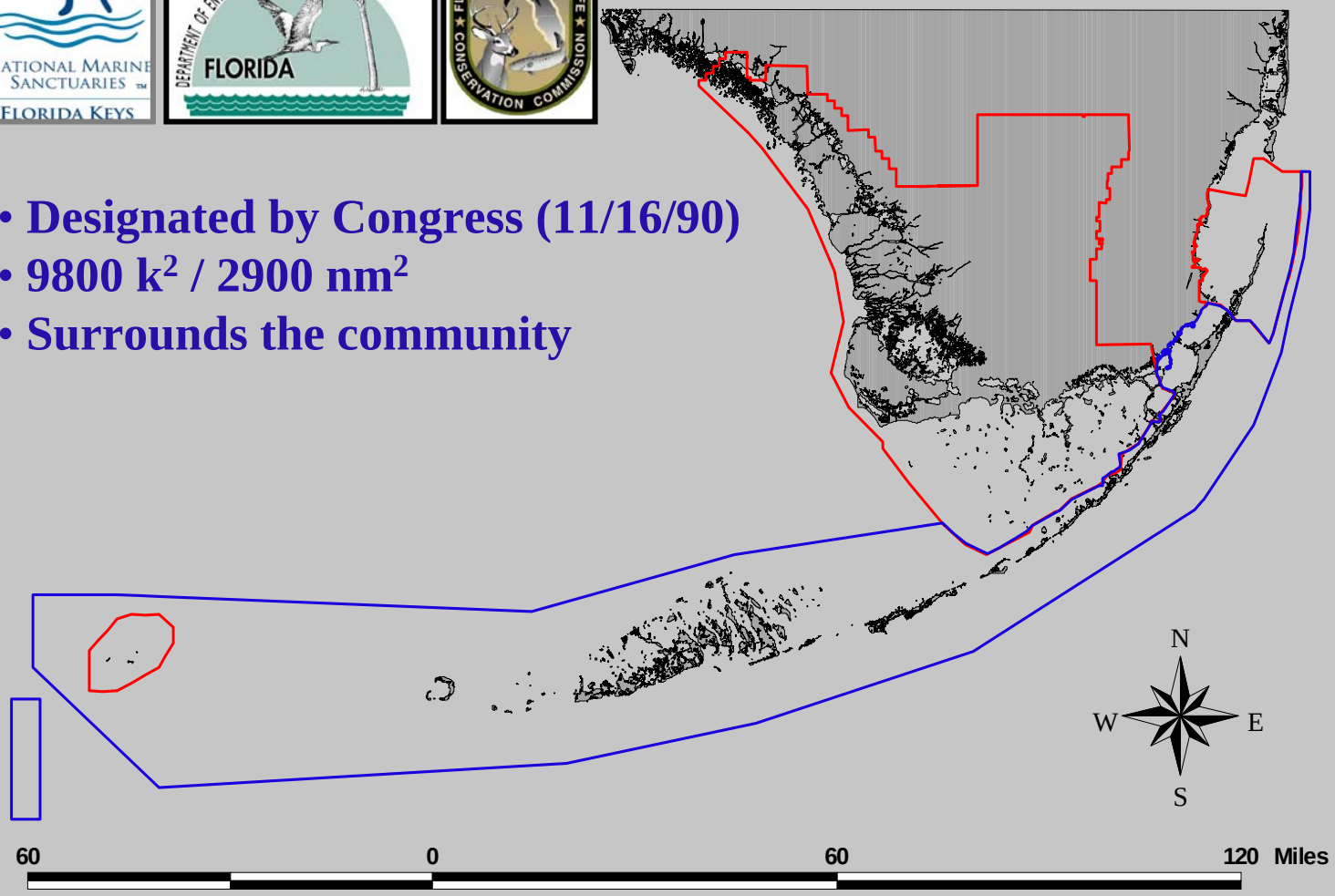
Billy D. Causey, Acting Regional Superintendent
Southeast Atlantic, Gulf of Mexico and Caribbean Region
November 14-16, 2005
Washington, DC

NOAA's National Marine Sanctuary Program: 13 MPAs + NWHI

National Marine Sanctuaries - America's Ocean Treasures

Florida Keys
National Marine Sanctuary

- Designated by Congress (11/16/90)
- 9800 k^2 / 2900 nm^2
- Surrounds the community



Outline of Presentation

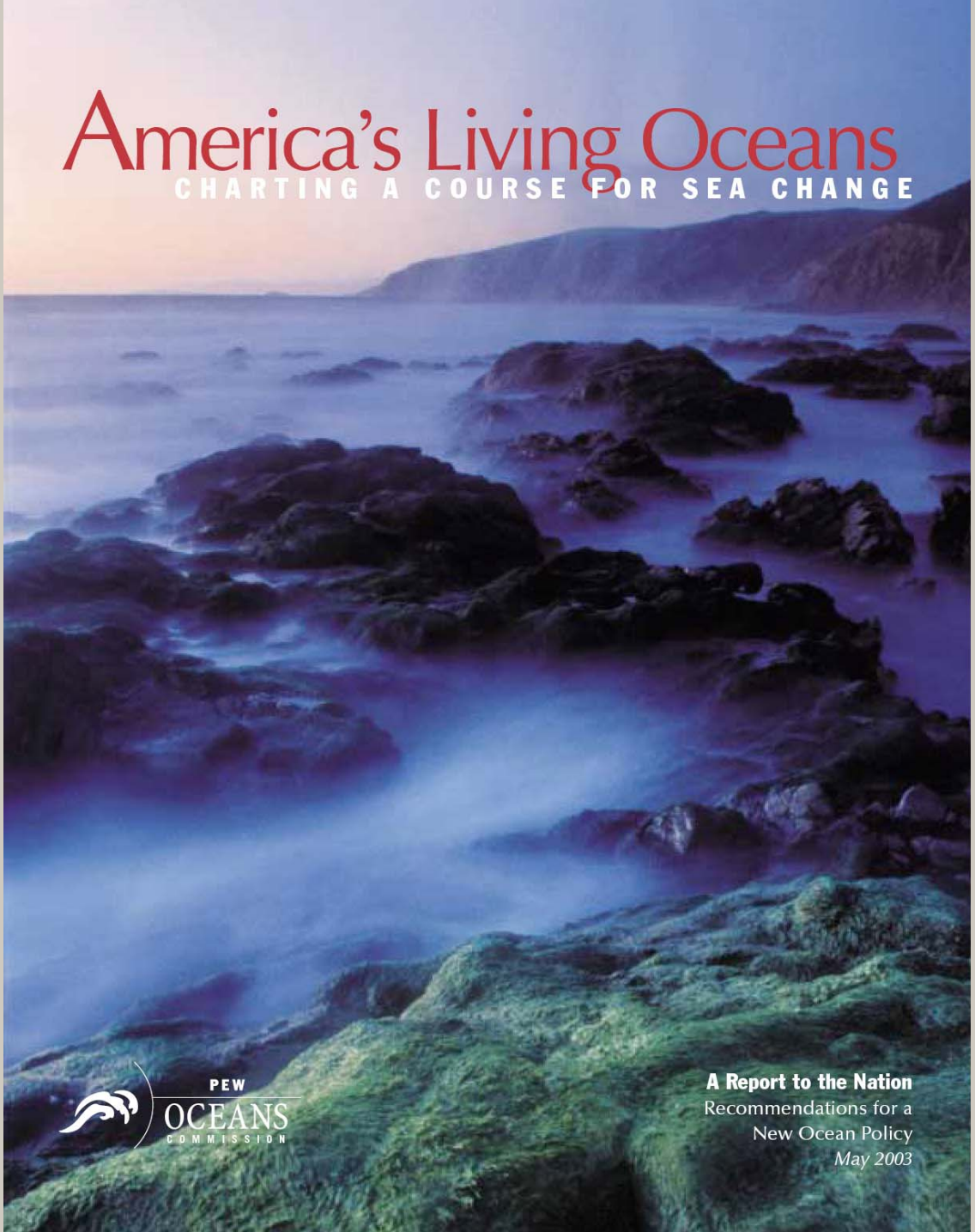
- General Comments
- Early Examples of Broad-scale Climate Change Influences
- Recent History of Climate Change Impacts On the Florida Keys
- Types of information needed / used by managers
  - Use of Remote Sensing Technology
  - *In Situ* Monitoring
  - Use of information
- Summary of Science Needs

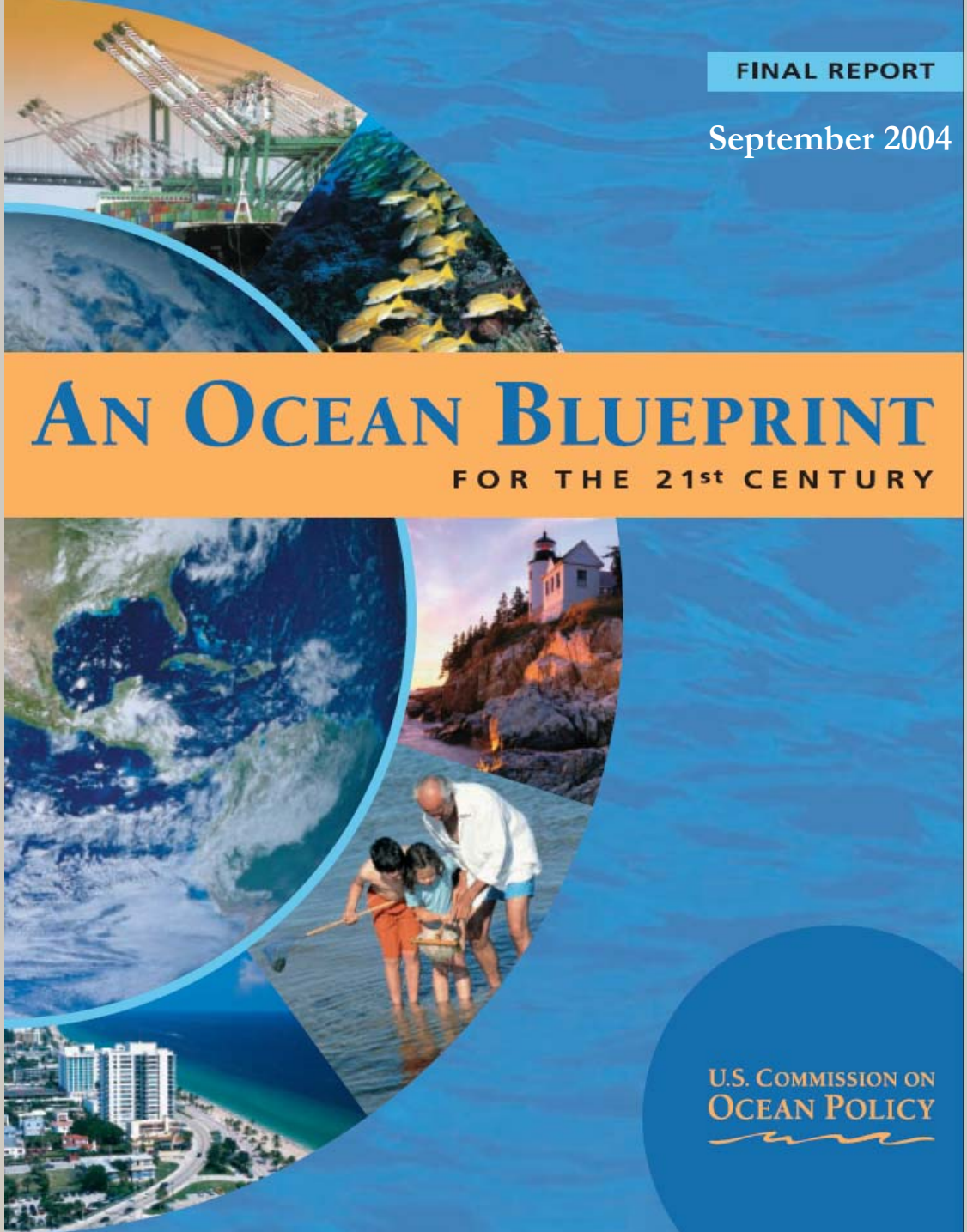
Challenges linked to Climate Change

- Warming Seas
- Rising Seas
- Disease
- Changing Storm Patterns
- Altered Currents

Two Recent Reports Published in the United States Stressed the Need For Climate Change Research

NATIONAL MARINE SANCTUARIES
FLORIDA KEYS


America's Living Oceans
CHARTING A COURSE FOR SEA CHANGE
PEW
OCEANS
COMMISSION
A Report to the Nation
Recommendations for a
New Ocean Policy
May 2003


FINAL REPORT
September 2004
AN OCEAN BLUEPRINT
FOR THE 21st CENTURY
U.S. COMMISSION ON
OCEAN POLICY

In order to address impacts to our ocean and coastal resources

.. Resource managers need to know the spatial scale at which to focus and the tools available to them.

For Example:

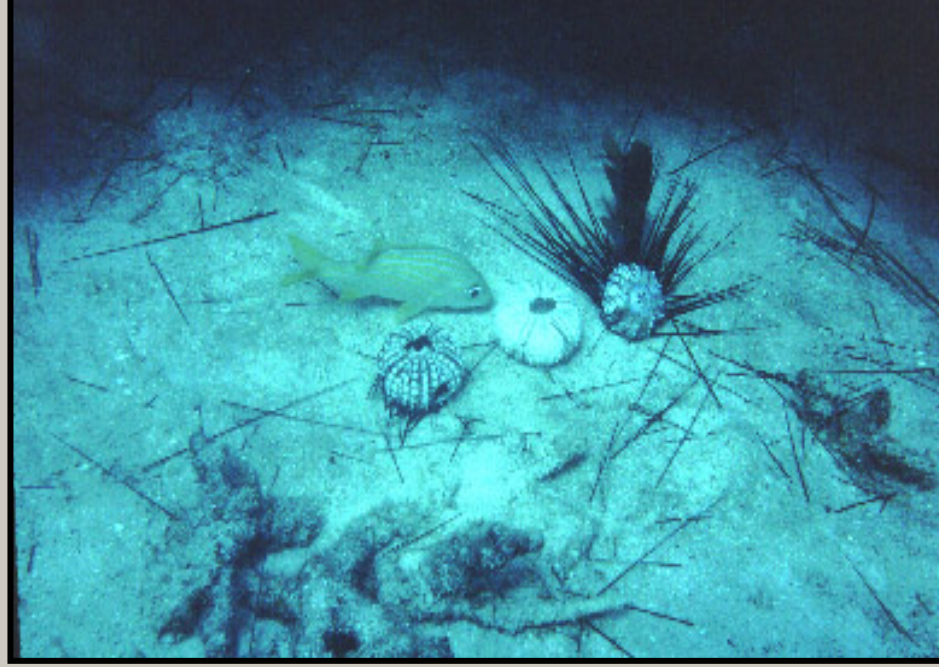
Here are some early examples of how Climate Change has affected marine resources on a large ecosystem scale.

NATIONAL MARINE SANCTUARIES
FLORIDA KEYS

Key Largo National Marine Sanctuary
353 square kilometers - Designated in 1975

Looe Key National Marine Sanctuary
18 square kilometers - Designated in 1981

1983 *Diadema* die-off



1983 Coral bleaching Lower Florida Keys

NATIONAL MARINE SANCTUARIES ™
FLORIDA KEYS

Credit: H.A. Lessios (1984)

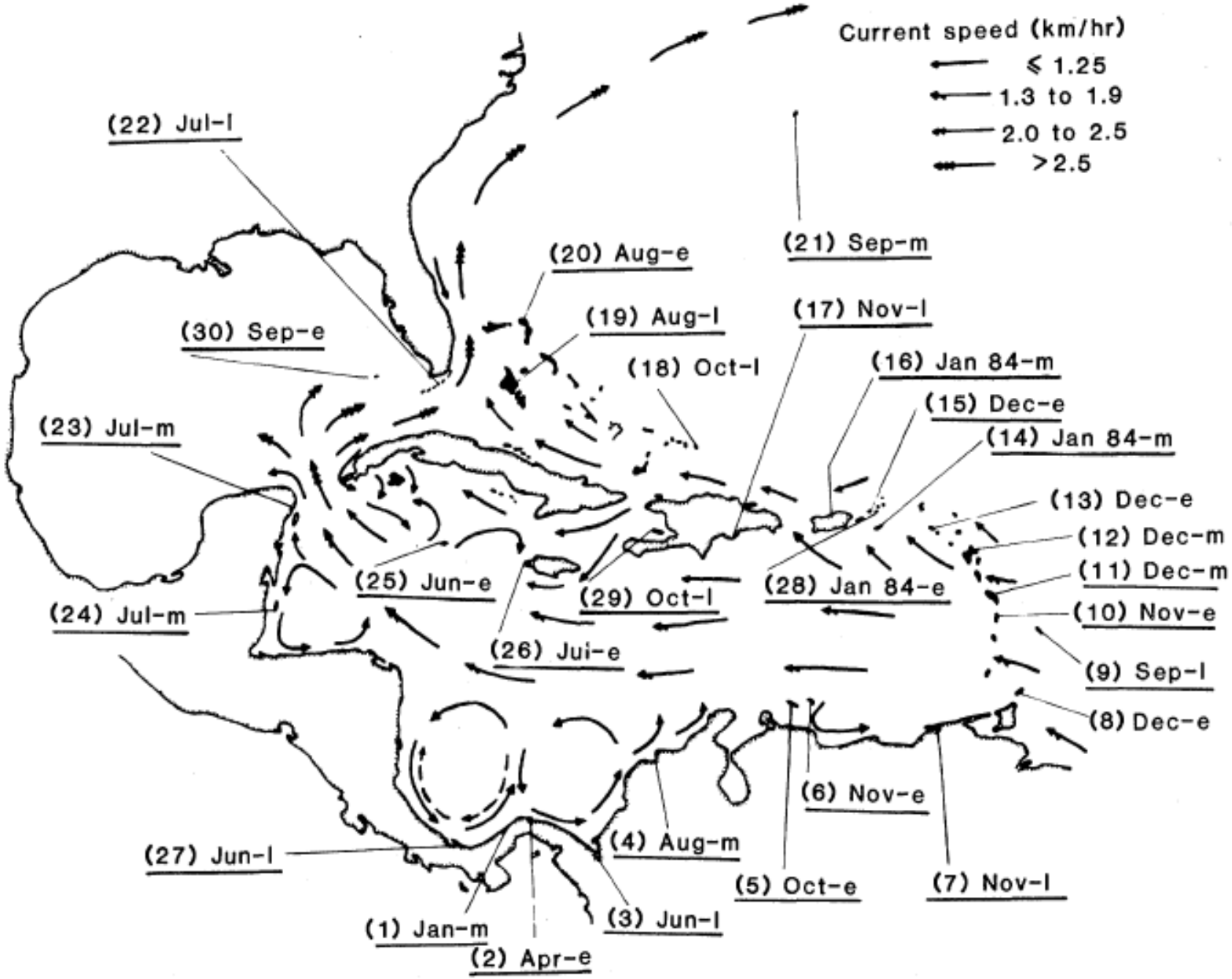
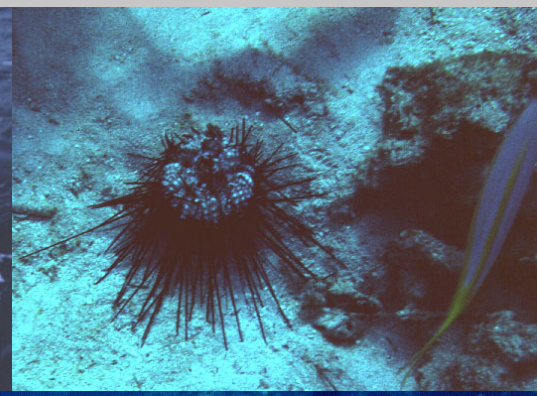
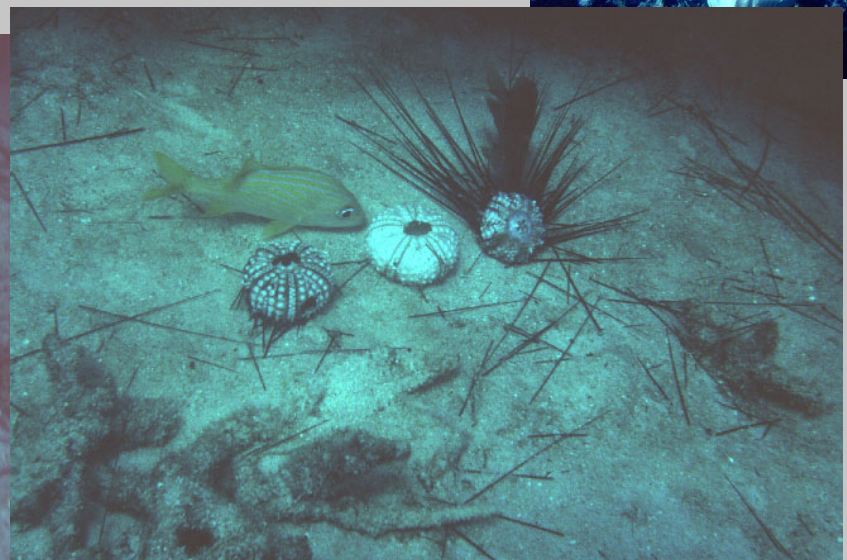


Fig. 2. Spread of *Diadema* mass mortality through the Caribbean and the western Atlantic. Underlined dates indicate the first time mortality was noted at each locality.

Harilaos Lessios - *Diadema* die-off - Looe Key NMS



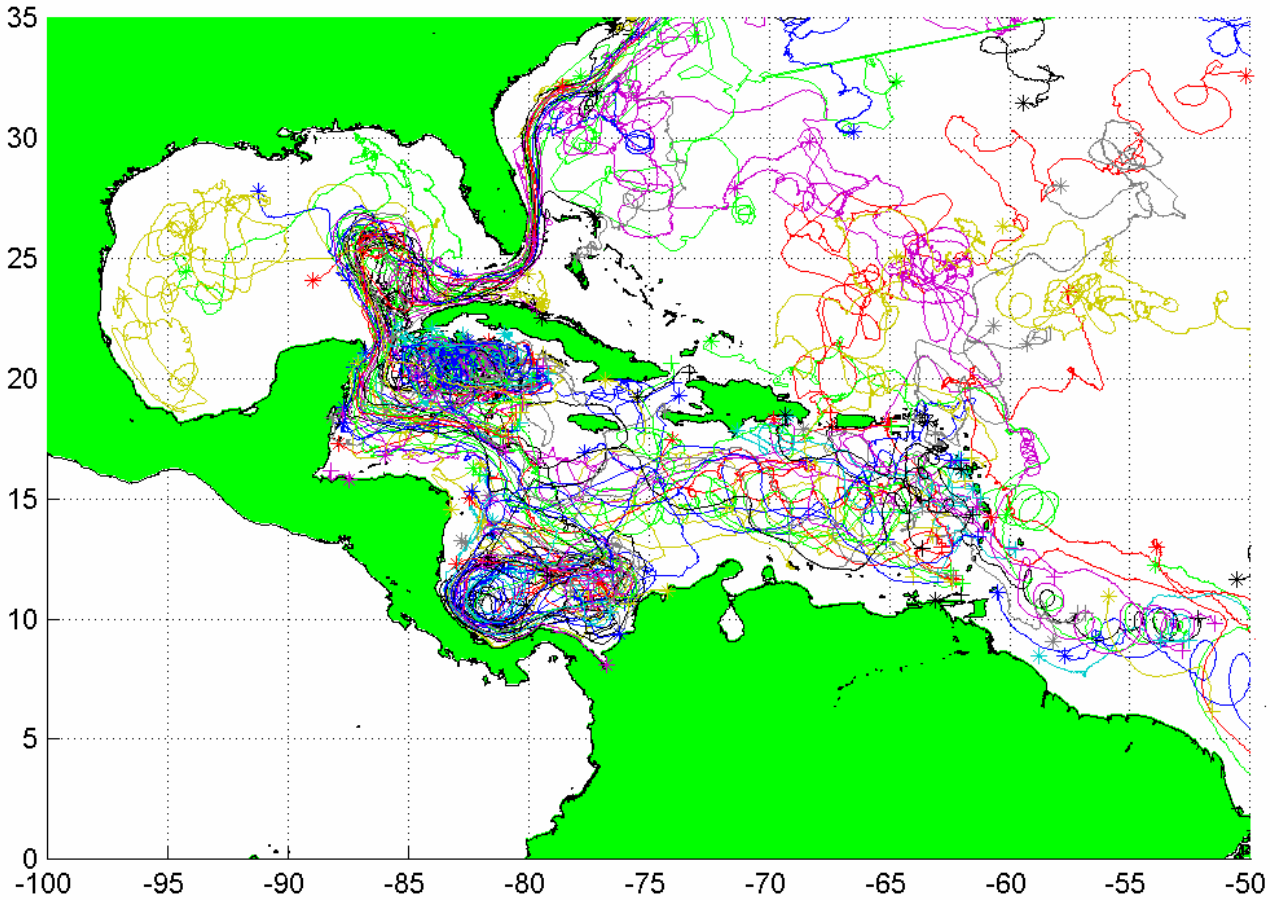


July 1983

NATIONAL MARINE SANCTUARIES

Current Drifters (1998-2000)

Credit: Kevin Leaman (UM/RSMAS)



NATIONAL MARINE SANCTUARIES ™
FLORIDA KEYS

1986 Black band disease
Looe Key Reef

1987 Global coral bleaching event

Looe Key Reef

Multiple Stressors Affecting Coral Reefs

Habitat Destruction

Coral Diseases

Pollution

Global Climate Change

Coral Bleaching

Overfishing

Intense Coastal Development

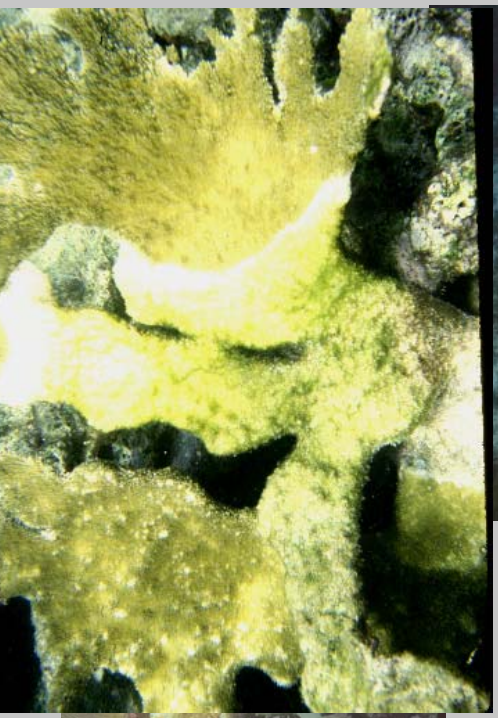
Ocean Dumping

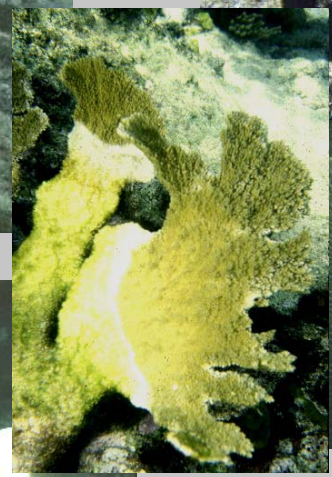
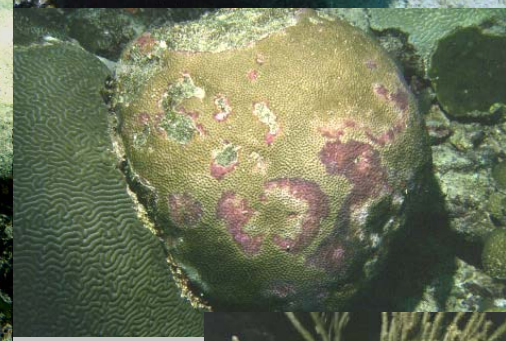
Massive Algal Blooms

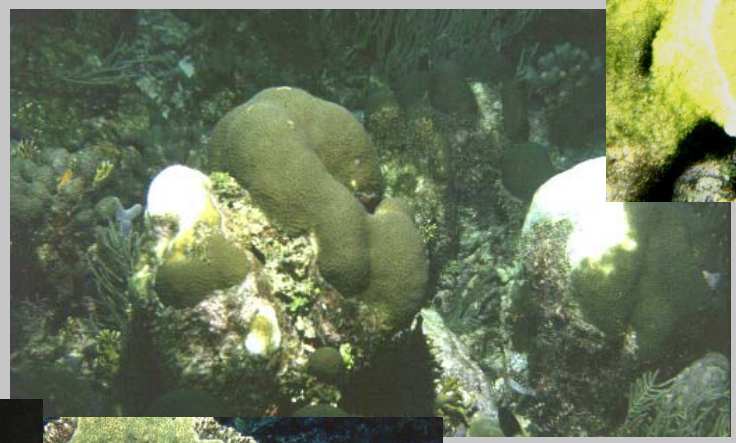
Introduction of Marine Exotics


St Vincent &
the Grenadines
October 1989
Atlantic Ocean
Gulf of Mexico
Caribbean Sea
90°W
80°W
70°W
60°W
30°N
20°N
10°N
Flower Garden Banks
National Marine Sanctuary
Florida
The Bahamas
Cuba
Cayman Islands
Jamaica
Haiti
Dominican
Republic
Navassa
Virgin Islands
Anguilla
Puerto Rico
St. Kitts and Nevis
Montserrat
Guadeloupe
Dominica
Martinique
St. Lucia
St. Vincent and
the Grenadines
Barbados
Grenada
Netherlands
Antilles
Trinidad
and Tobago
Mexico
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Colombia
Venezuela
Guyana

St Vincent & Grenadines - October 1989



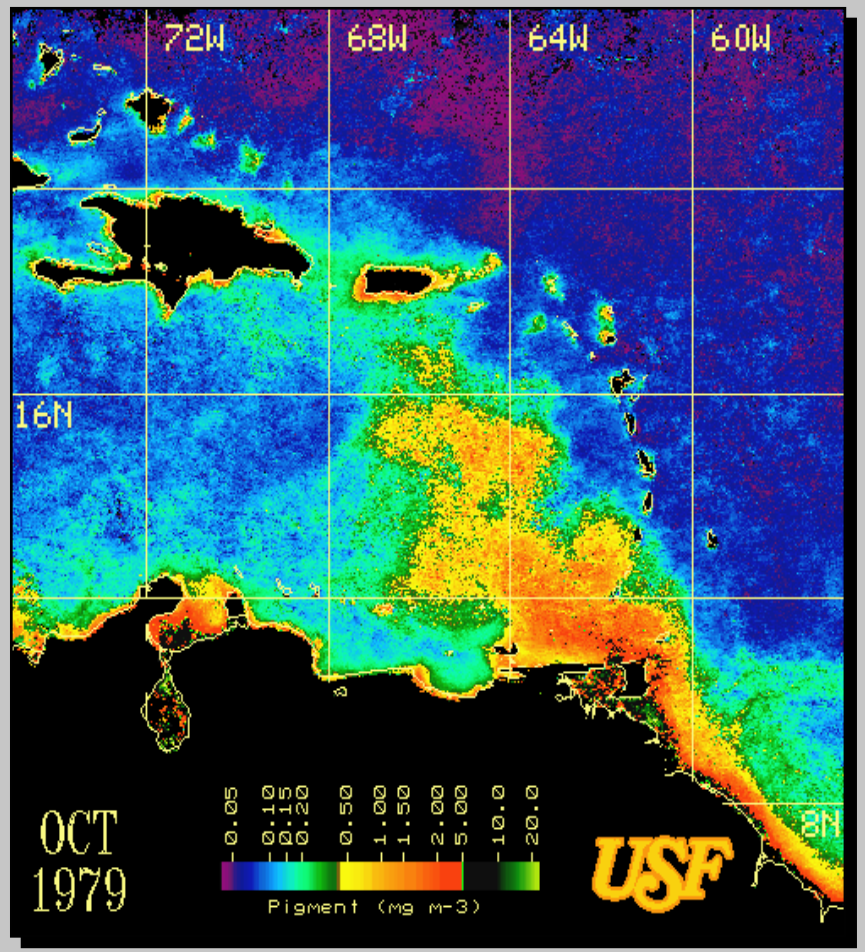




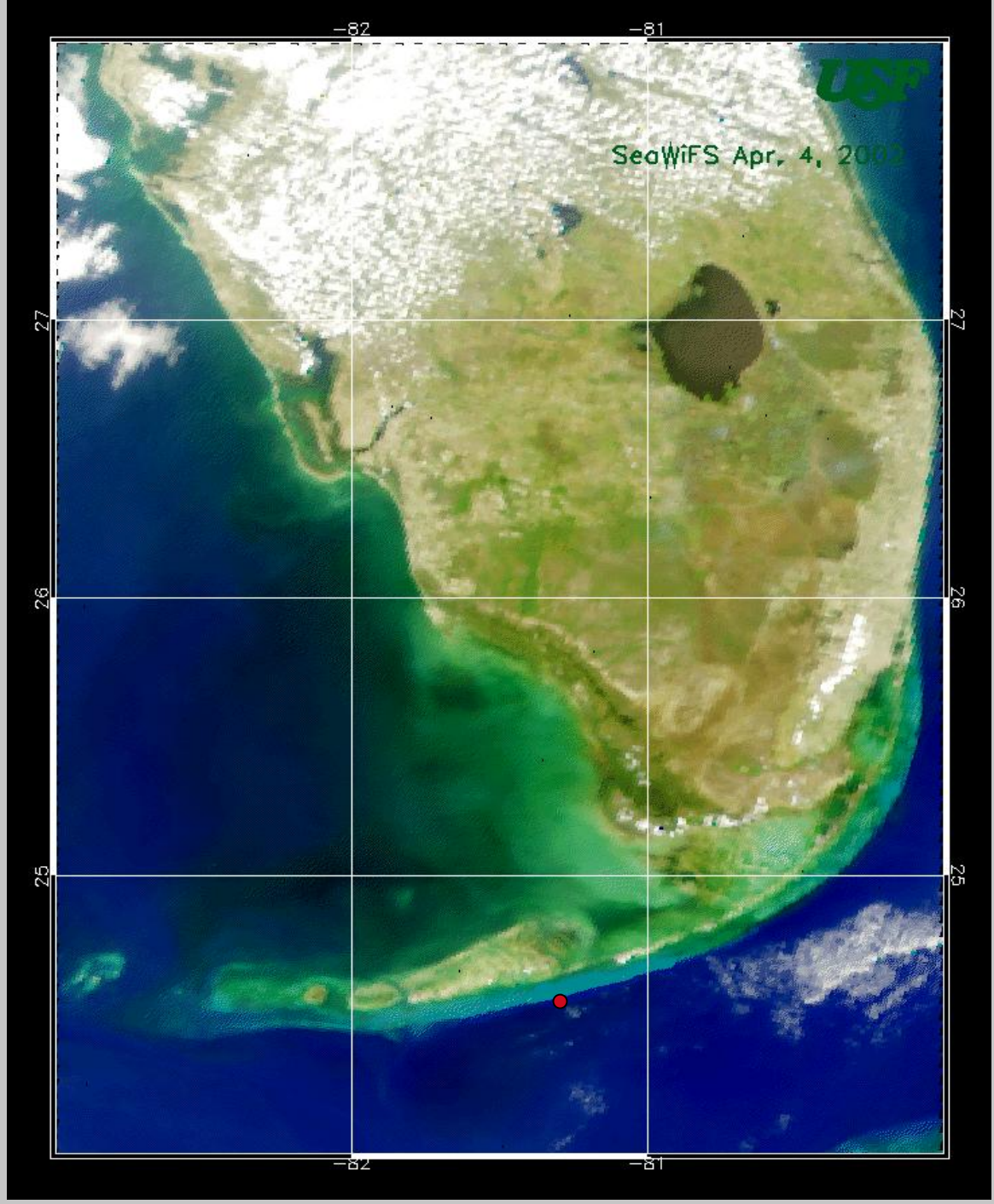


St Vincent & Grenadines - Catholic Rock
October 1989

Terrestrial Run-Off Hypothesis



Credit: F. Muller-Karger & K. Ritchie for slide



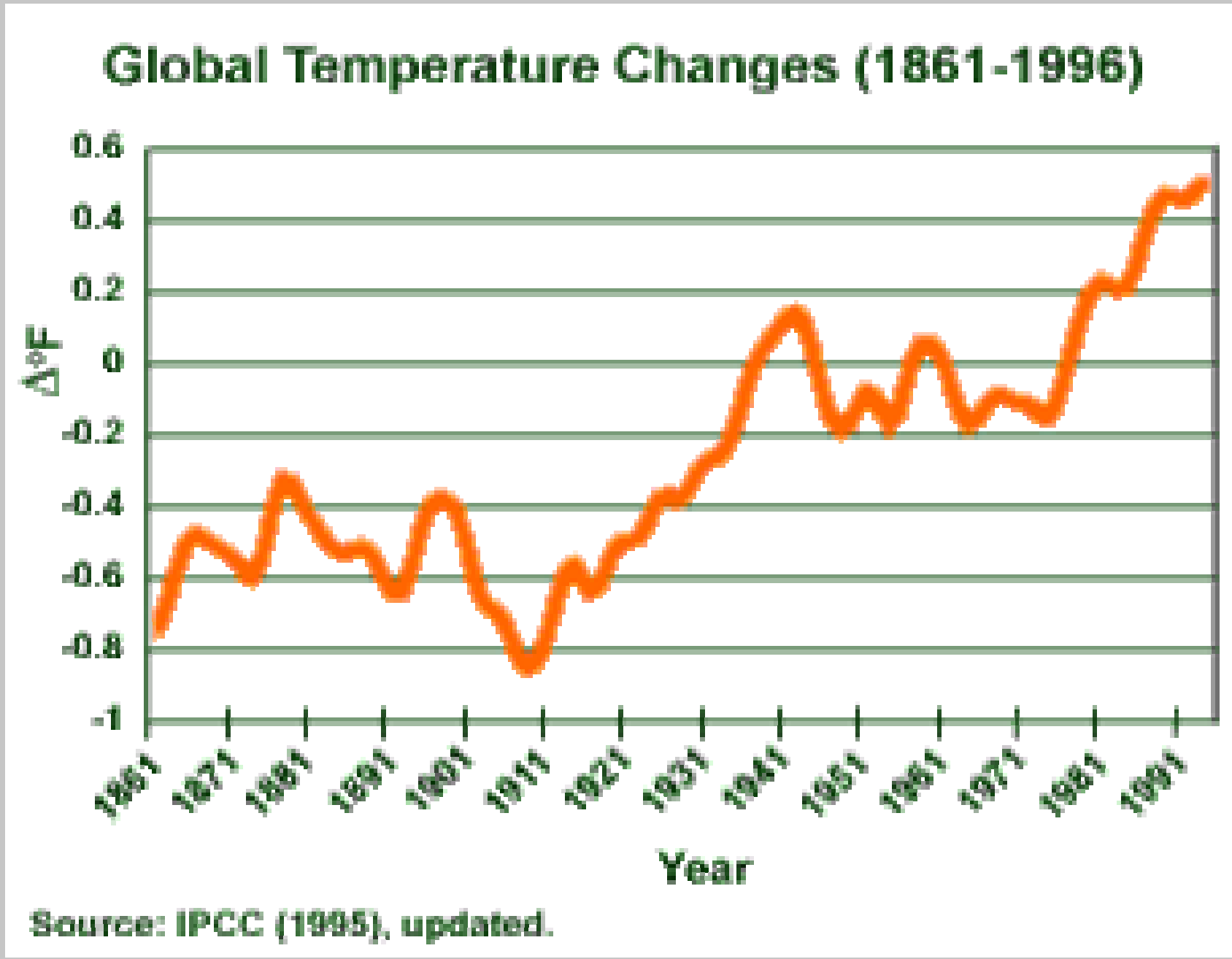
All true color images property of Orbimage.

Collected by Drs. Frank Muller-Karger and Chuanmin Hu using antennas at Univ. of South Florida, St. Petersburg, FL.

Climate Trends

Status

- 16 warmest years on record have occurred since 1980 (1880 - began keeping records)
- 3 warmest years (1998, 2001 & 2002) in the past 5 years
- Fastest global warming rate in 10,000 years



US Environmental Protection Agency (EPA) http://www.epa.gov/globalwarming/climate/trends/temperature.html

Coral Bleaching

- **Intensified over the past two decades**
- **Seems to be synchronized around El Niño events …….(*Peter Glynn, 1984)***
- **Elevated ocean temperatures**
- **Related secondary impacts (e.g. diseases, loss of diversity ….)**

Coral Bleaching Trends

1979

- **Massive die-off of barrel sponges (*Xestospongia muta*) in the Lower Florida Keys**

1980

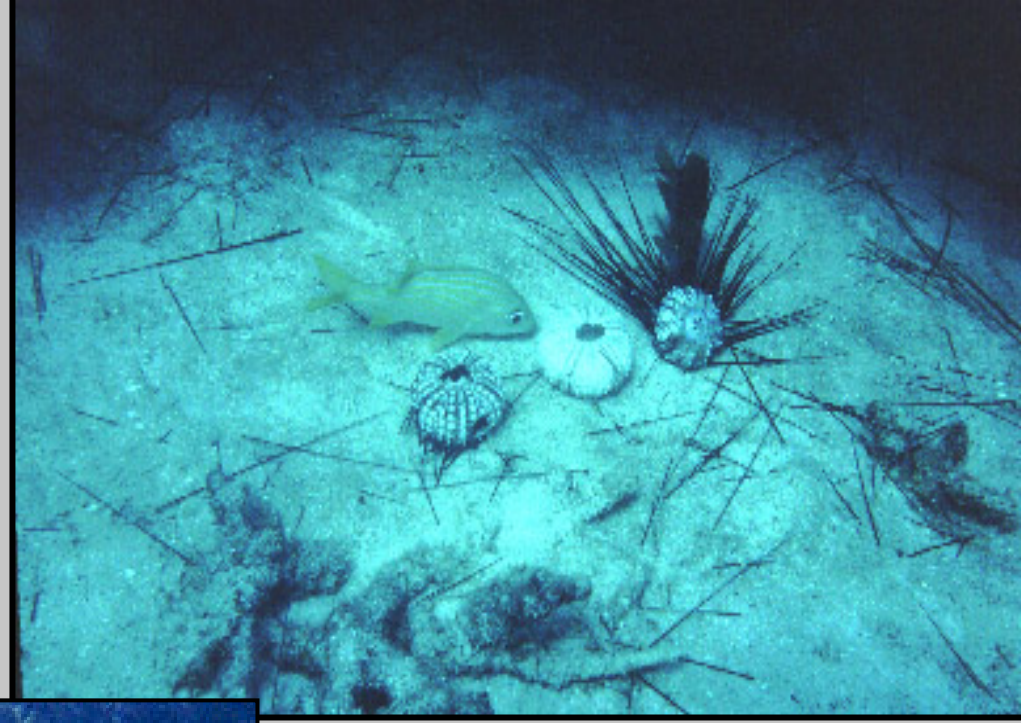
- **6 weeks of doldrum-like weather (slick-calm sea)**
- **Massive fish kill along reef tract**
- **Minor bleaching**

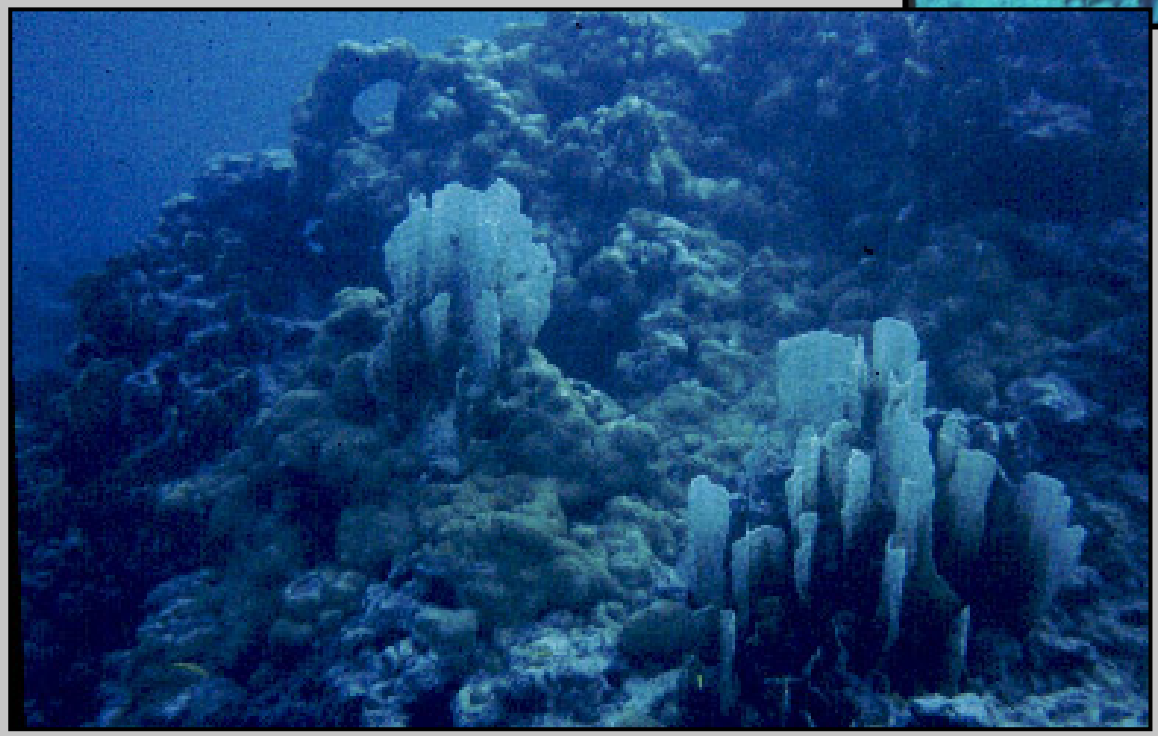
1983

- **4 weeks of doldrum-like weather**
- **Large-scale coral bleaching on Lower Florida Keys outer reefs**
- **Long-spined sea urchin die-off**
- **Yellow Sponge Die-off**

1983 Coral bleaching Lower Florida Keys

"From a distance, spurs looked like snow-draped ridges." …Walt Jaap(1985)





1983 *Diadema* die-off

Coral Bleaching Trends (Cont.)

1986

- **Large-scale black-band disease outbreak in the Lower Florida Keys**

1987

- **Doldrum weather patterns**
- **Massive bleaching throughout the Florida Keys**
- **Restricted to outer reef tract**

* **Local, regional, and global**
* **Atlantic & Pacific bleaching event**

1986 Black band disease
Looe Key Reef

1987 Global coral bleaching event

Looe Key Reef

Coral Bleaching Trends (Cont.)

1990

- Doldrum weather patterns in July
- Massive bleaching

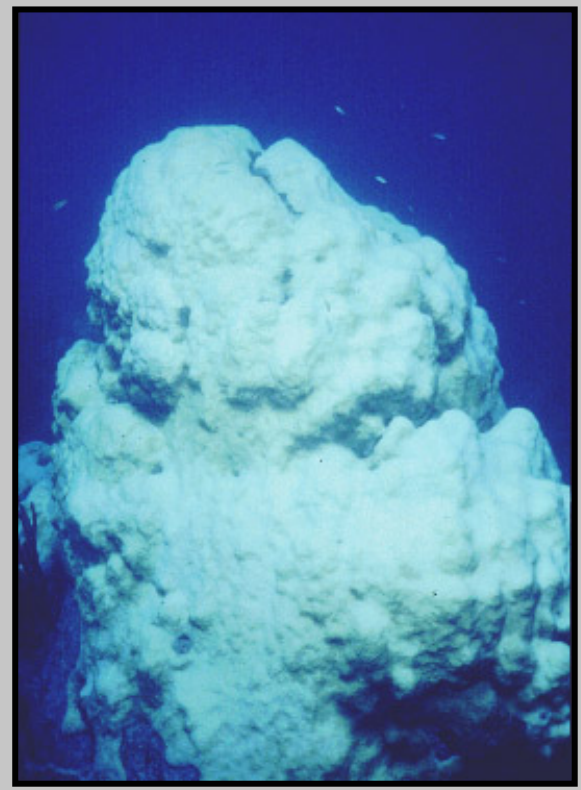
* Coral bleached inshore for the first time

* Large-scale coral mortality for the first time

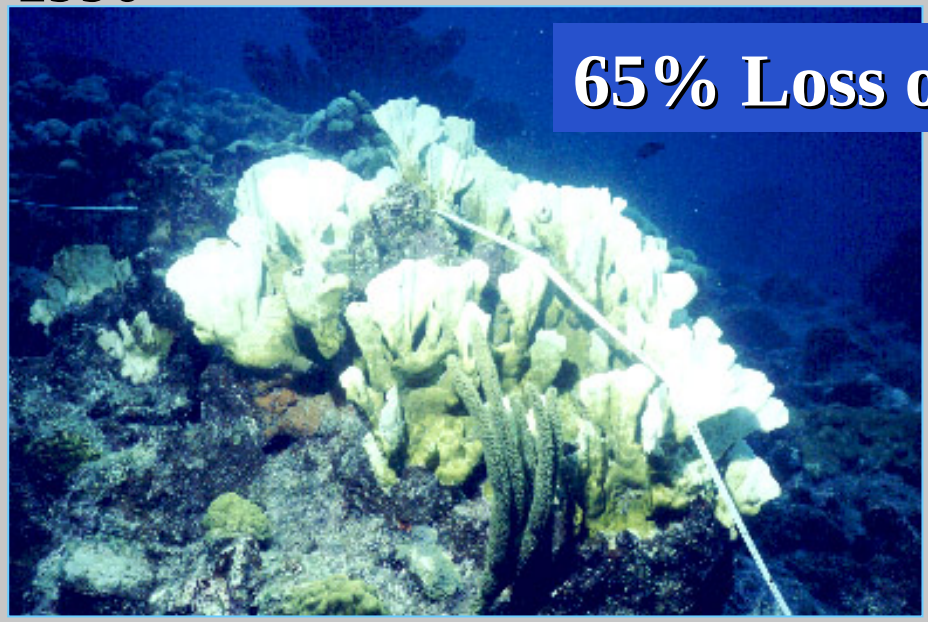
* - Implemented monitoring protocol

- 65% of fire coral on some reefs

- Global bleaching event



1990



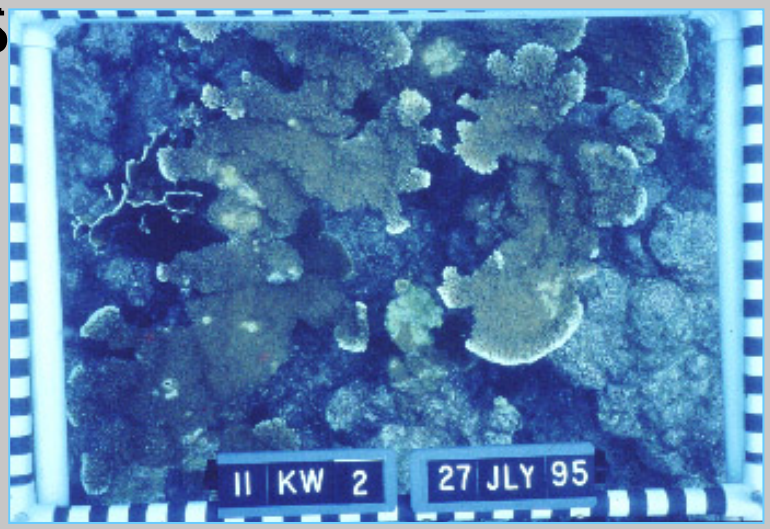
Fire coral bleaching

1990

Fire coral mortality

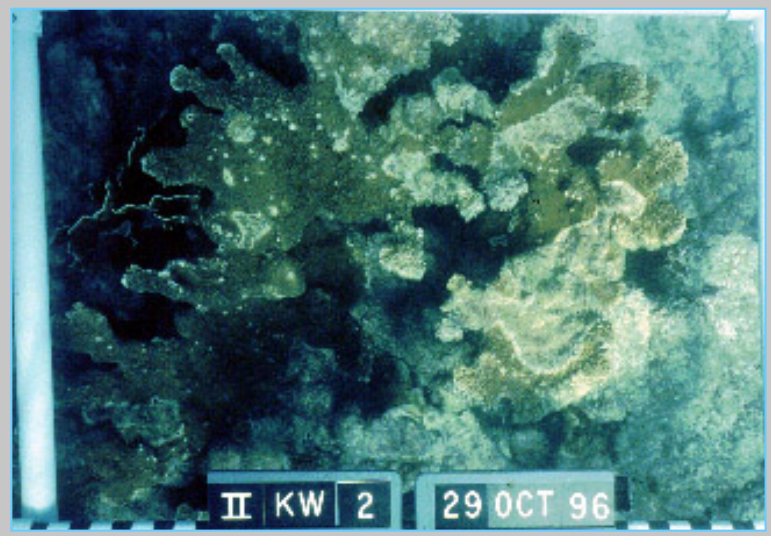
65% Loss of Fire coral

1995



Healthy coral

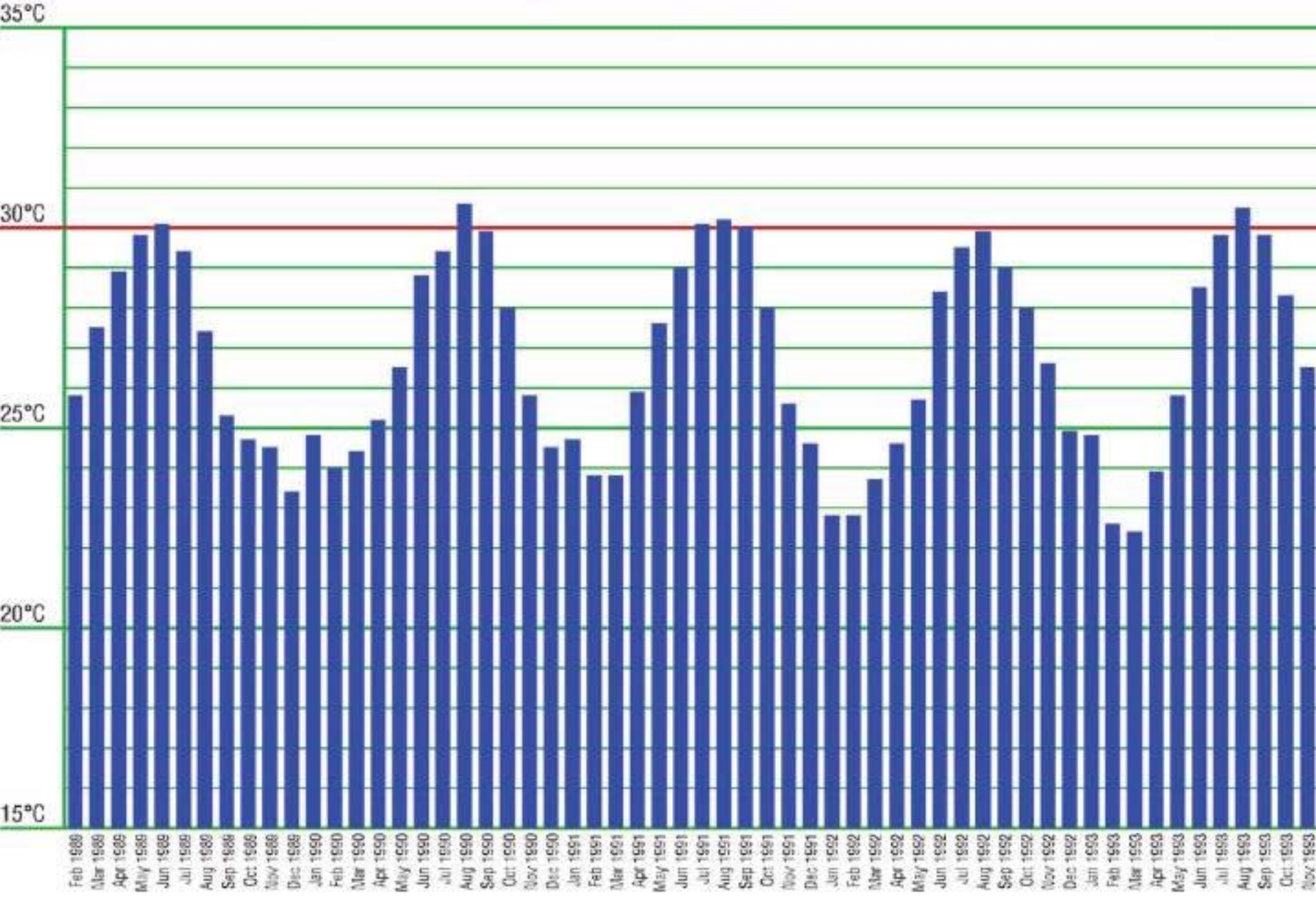
1996



Diseased coral

LOOE KEY REEF February 1989 - November 1993

Average Monthly Temperature



Coral Bleaching Trends (Cont.)

1997

- Doldrum weather patterns
- Massive bleaching
- Inshore and offshore corals affected
- Alerts from 3rd generation Florida Keys residents
- Large loss of living corals
- Global bleaching event

Coral Bleaching Trends (Cont.)

1998

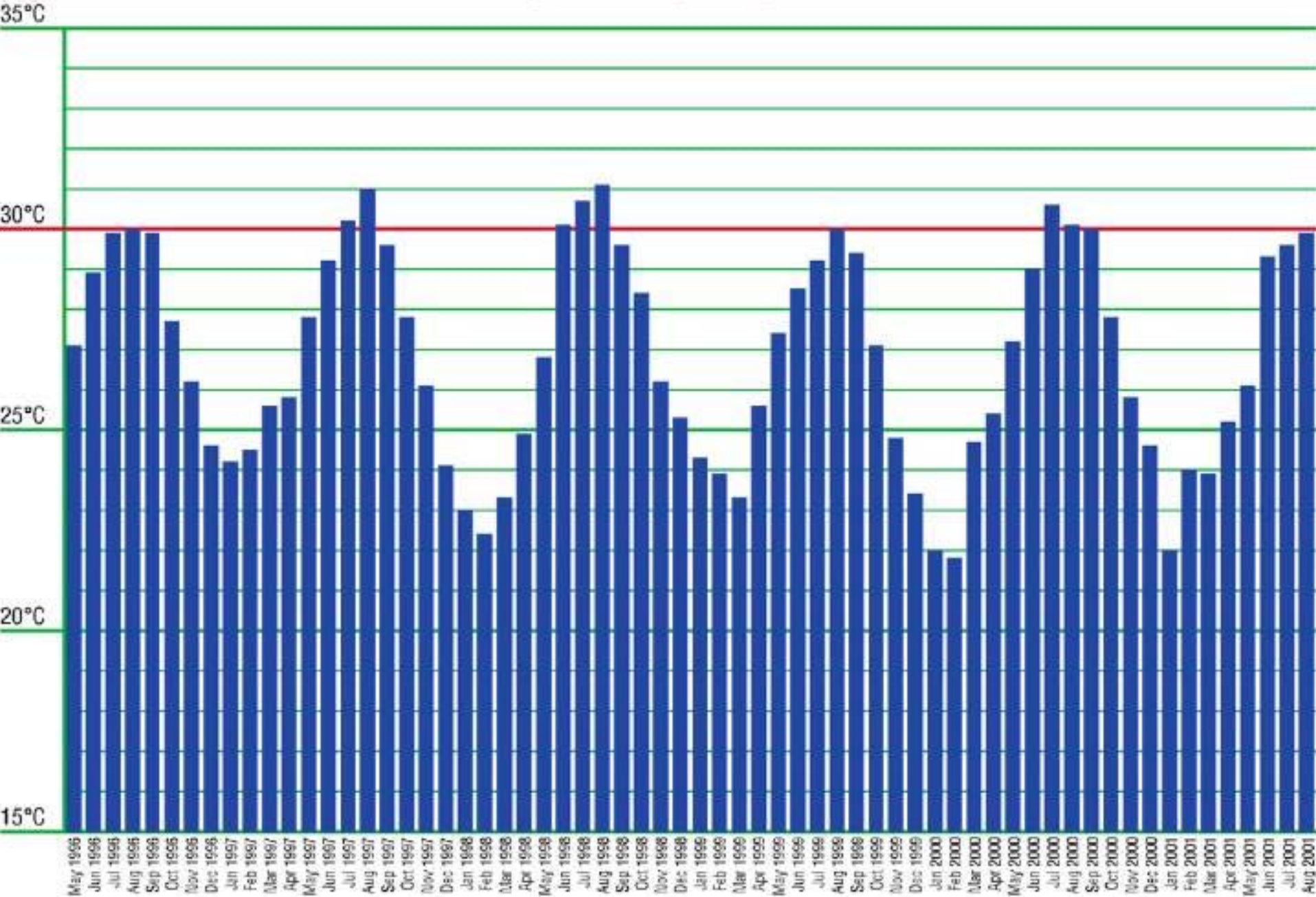
- **Water remained warm from 1997**
- **Massive bleaching continued**
- **Inshore and offshore corals affected**
- **Continued loss of living corals**
- **Global bleaching event**

* **First back-to-back annual coral bleaching**

- **Hurricane Georges**

SOMBRERO REEF LIGHTHOUSE May 1996 - August 2001

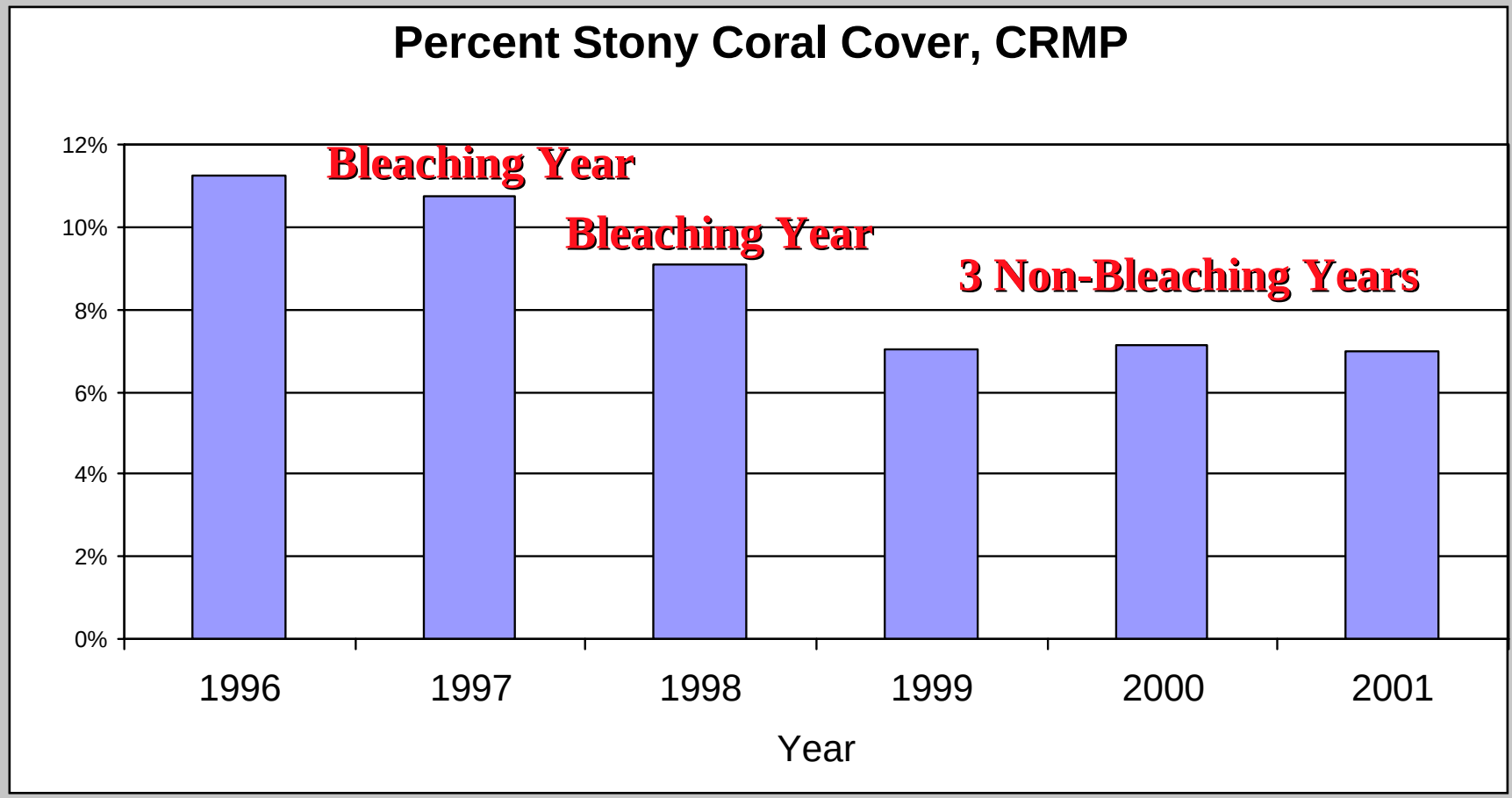
Average Monthly Temperature



Coral Bleaching Trends Summary

- Local patterns of increased duration
- Patterns of geographical expansion
- Coral reefs are responding to warming trends

Scientific Monitoring: Corals

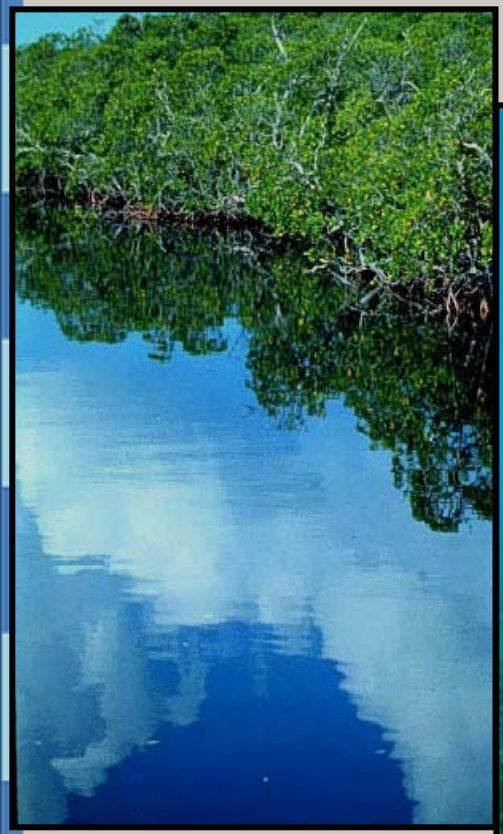


Coral cover declined between 1996 and 1999

and leveled off from 1999 - 2005.

Use of Remote Sensing Technology and *In Situ* Monitoring

Coral Reef Community



Includes the Full Seascape

NATIONAL MARINE SANCTUARIES
FLORIDA KEYS

Full-Range of Habitats

And All of the Marinelife

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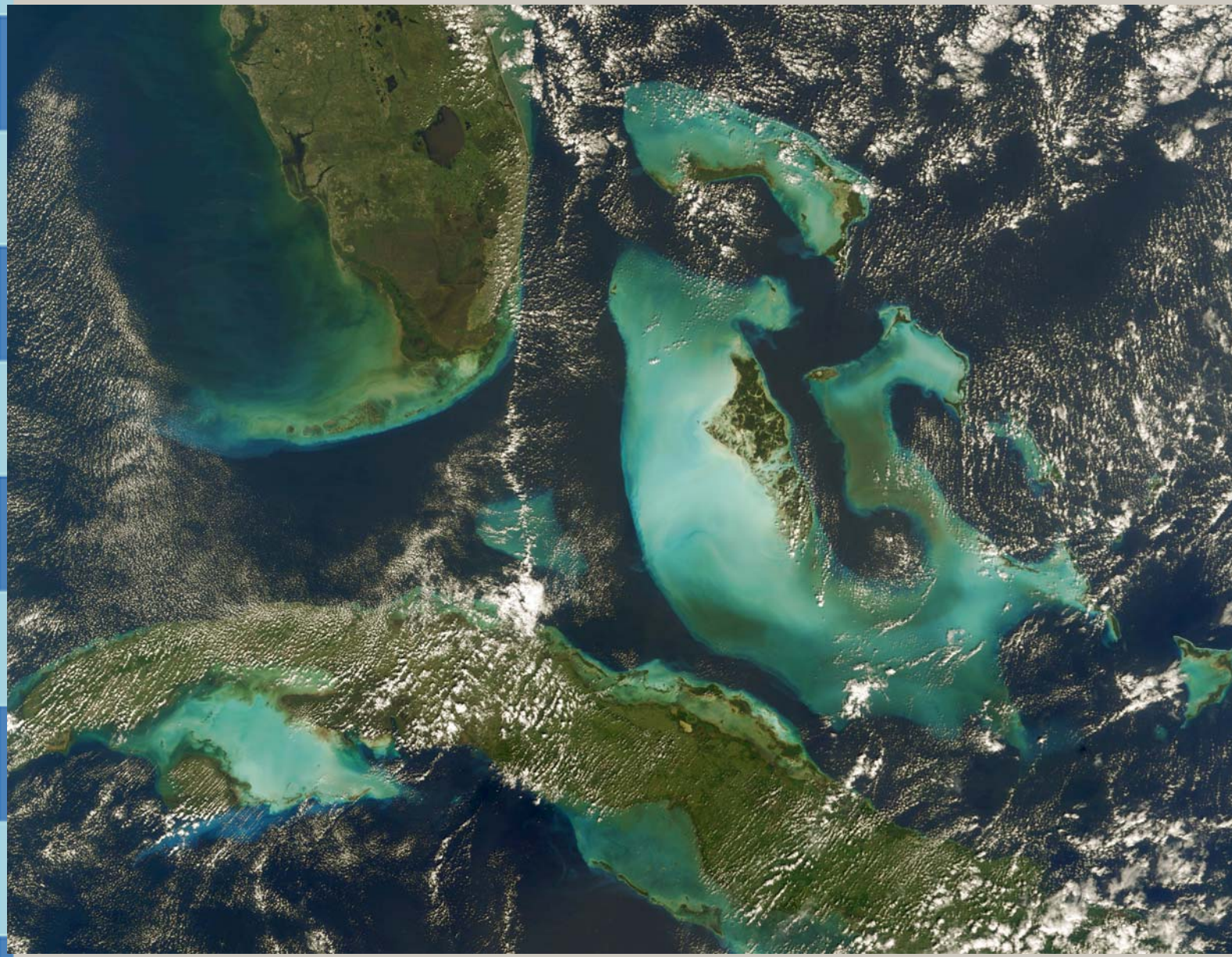
FLORIDA KEYS

South Florida Ecosystem

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

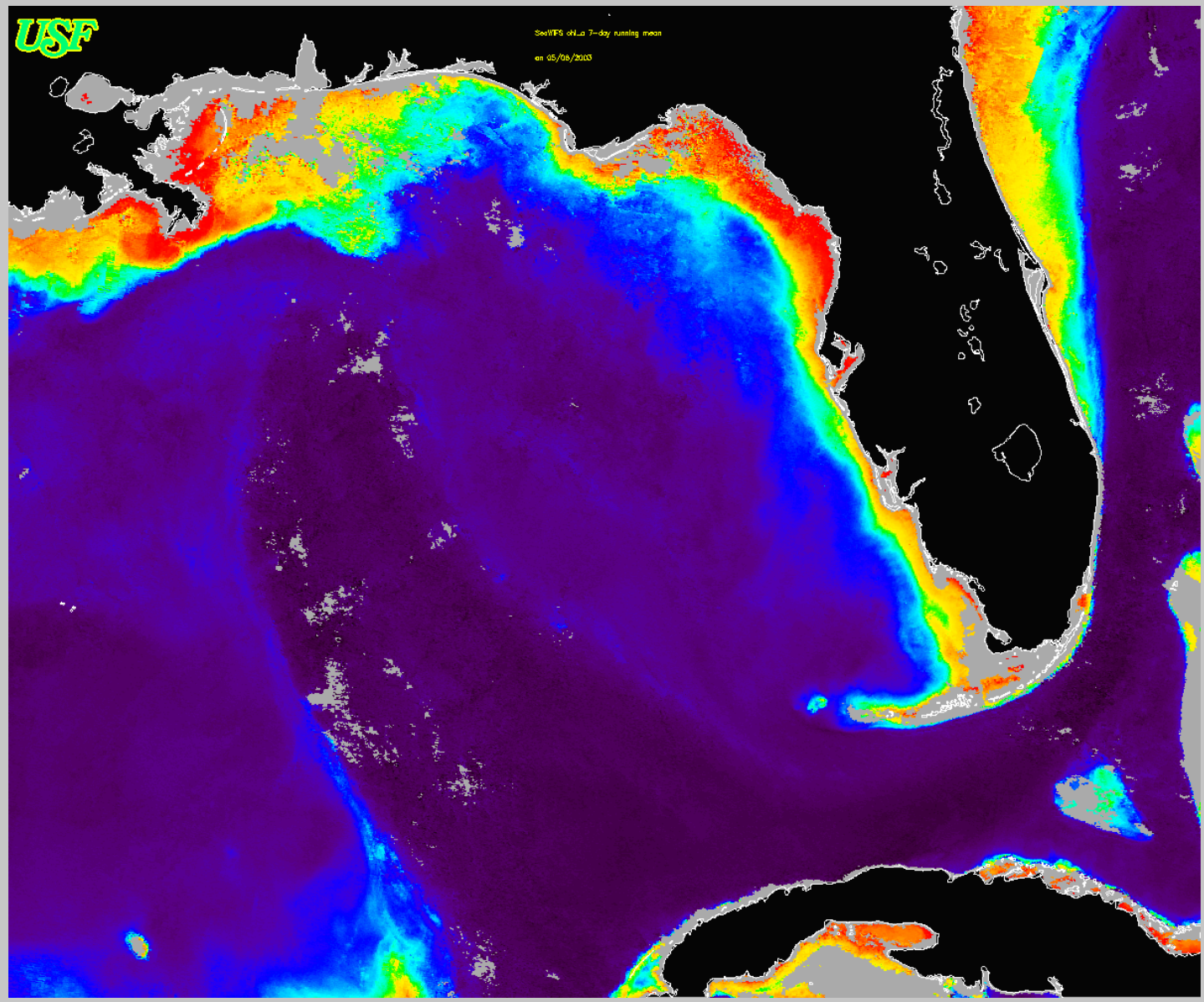
NATIONAL MARINE SANCTUARIES
FLORIDA KEYS



NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

NATIONAL MARINE SANCTUARIES
FLORIDA KEYS

Connectivity: The Loop Current

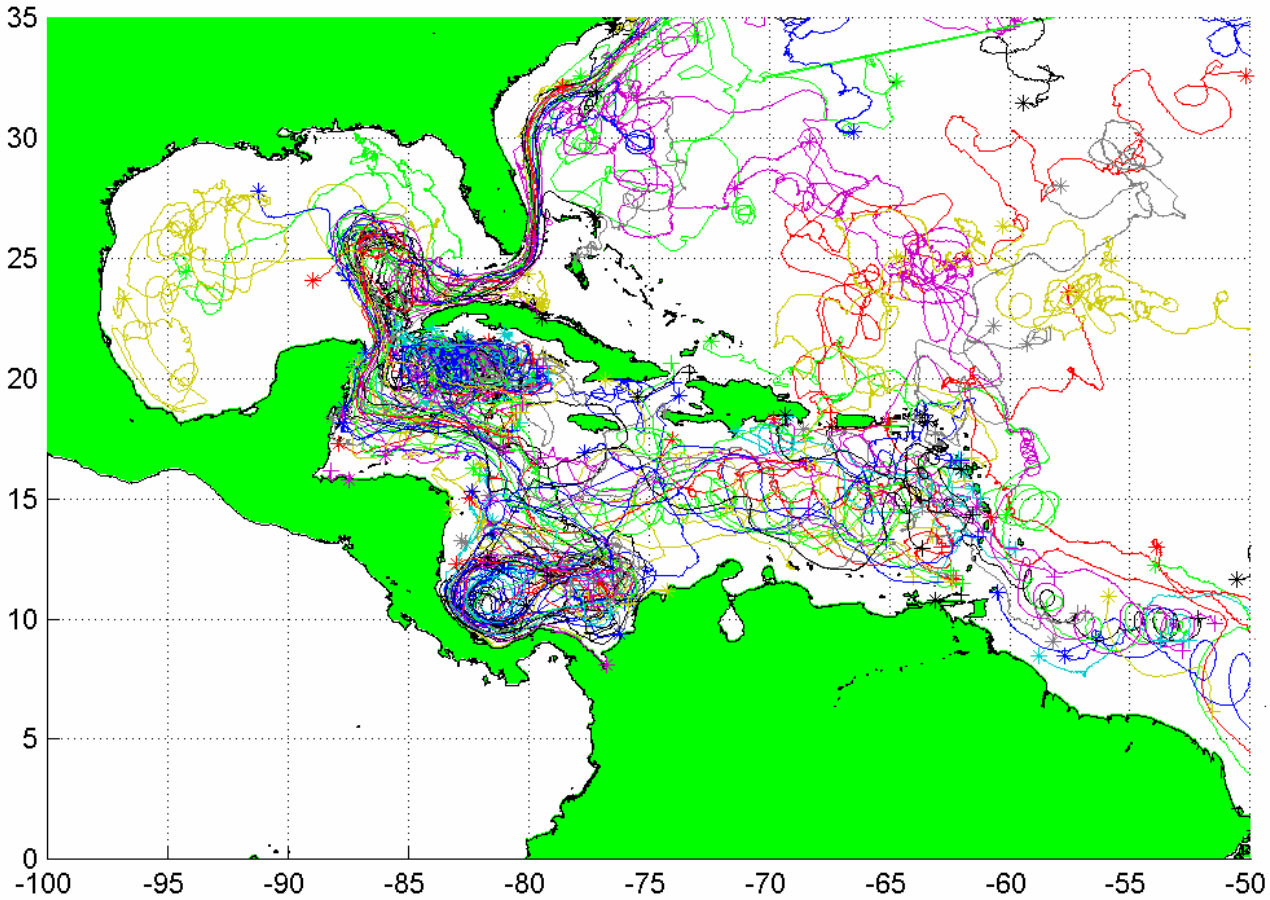


C. Hu
Univ of South Florida

NATIONAL MARINE SANCTUARIES

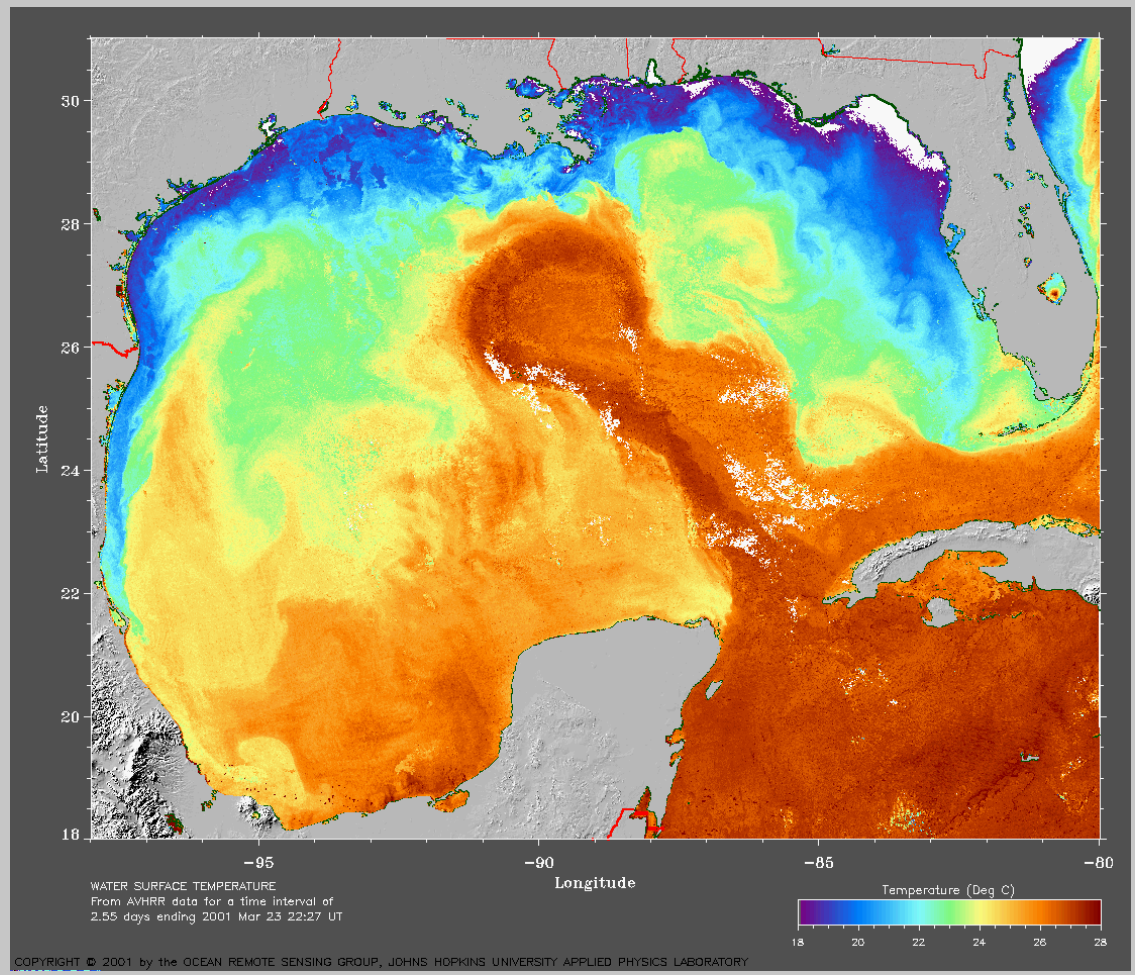
Current Drifters (1998-2000)

Credit: Kevin Leaman (UM/RSMAS)



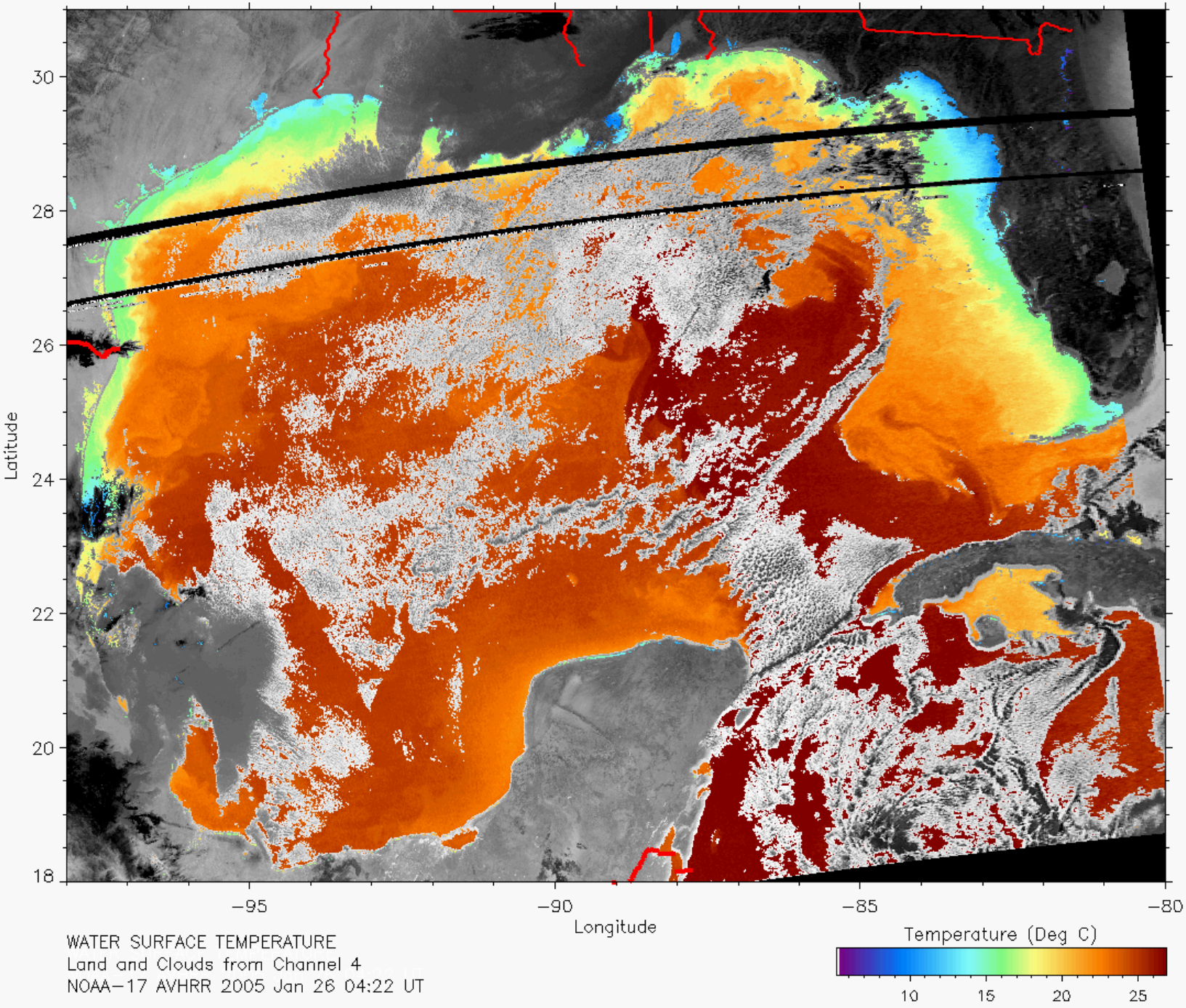
NATIONAL MARINE SANCTUARIES ™
FLORIDA KEYS

The Dry Tortugas, the Florida Keys and Florida Bay are connected to the Loop Current/Florida Current system – and beyond

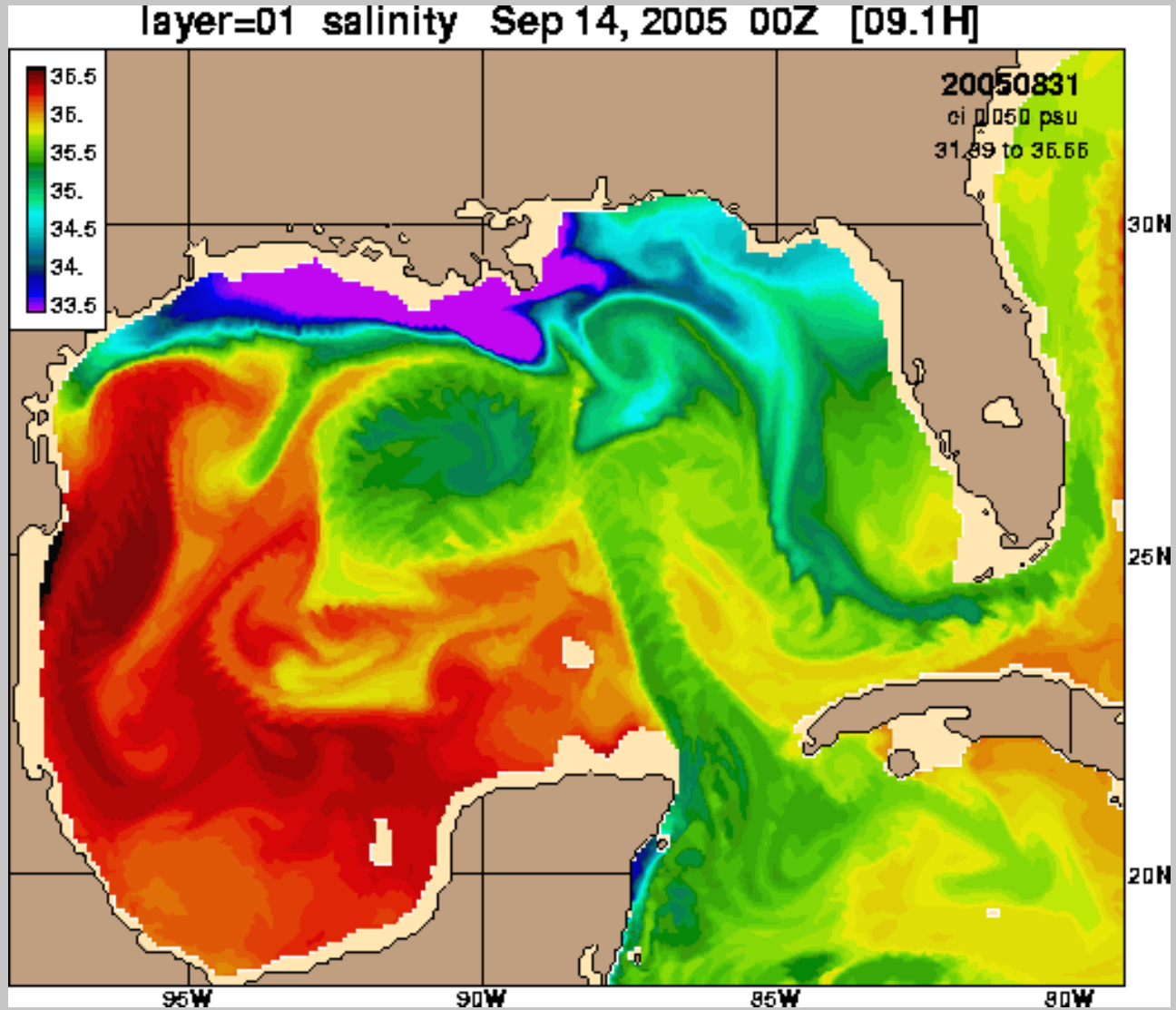


Satellite Sea Surface Temperature March 23, 2001

RSMAS
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE
UNIVERSITY OF MIAMI

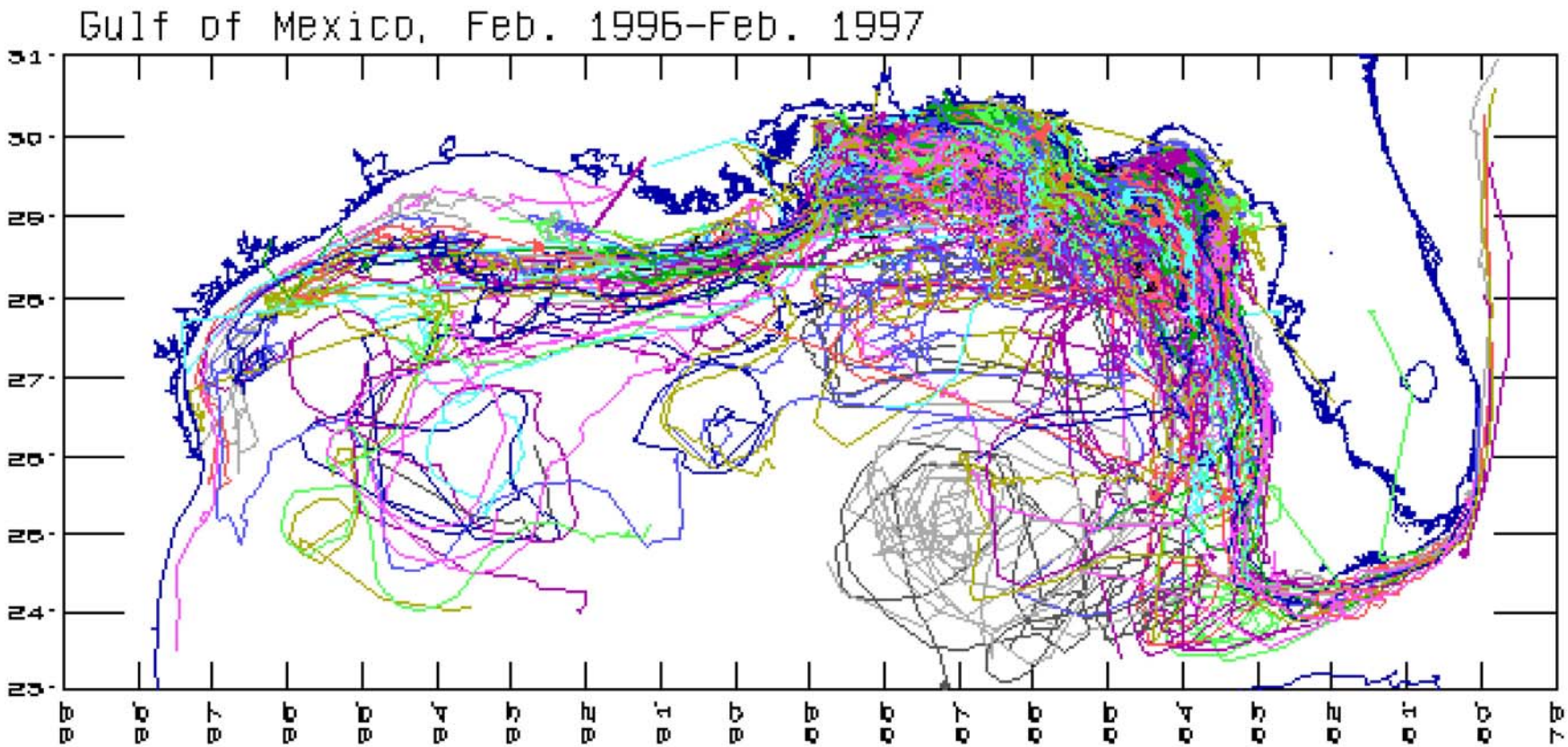


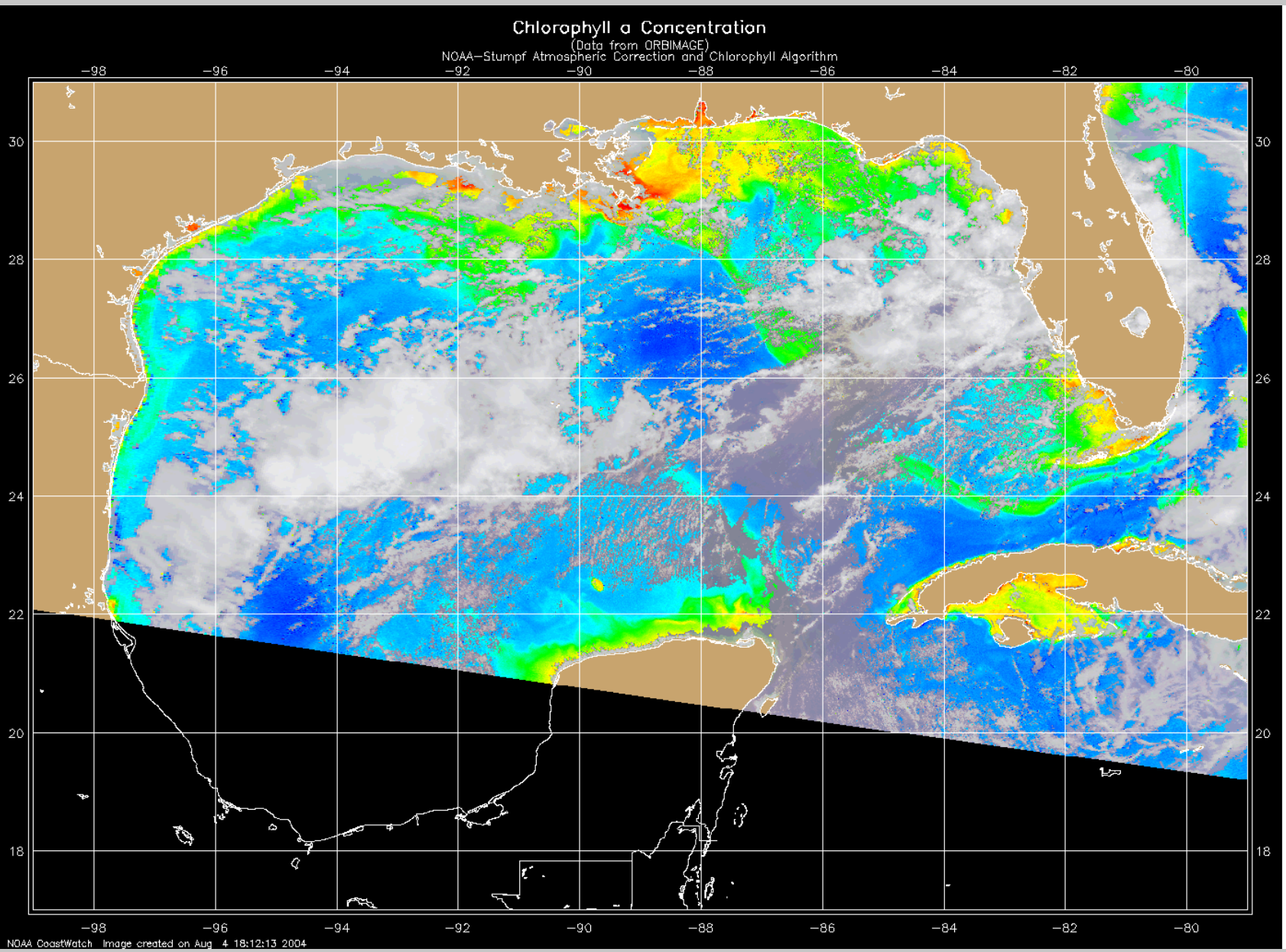
HYCOM computed salinity



Mississippi River Basin

MMS



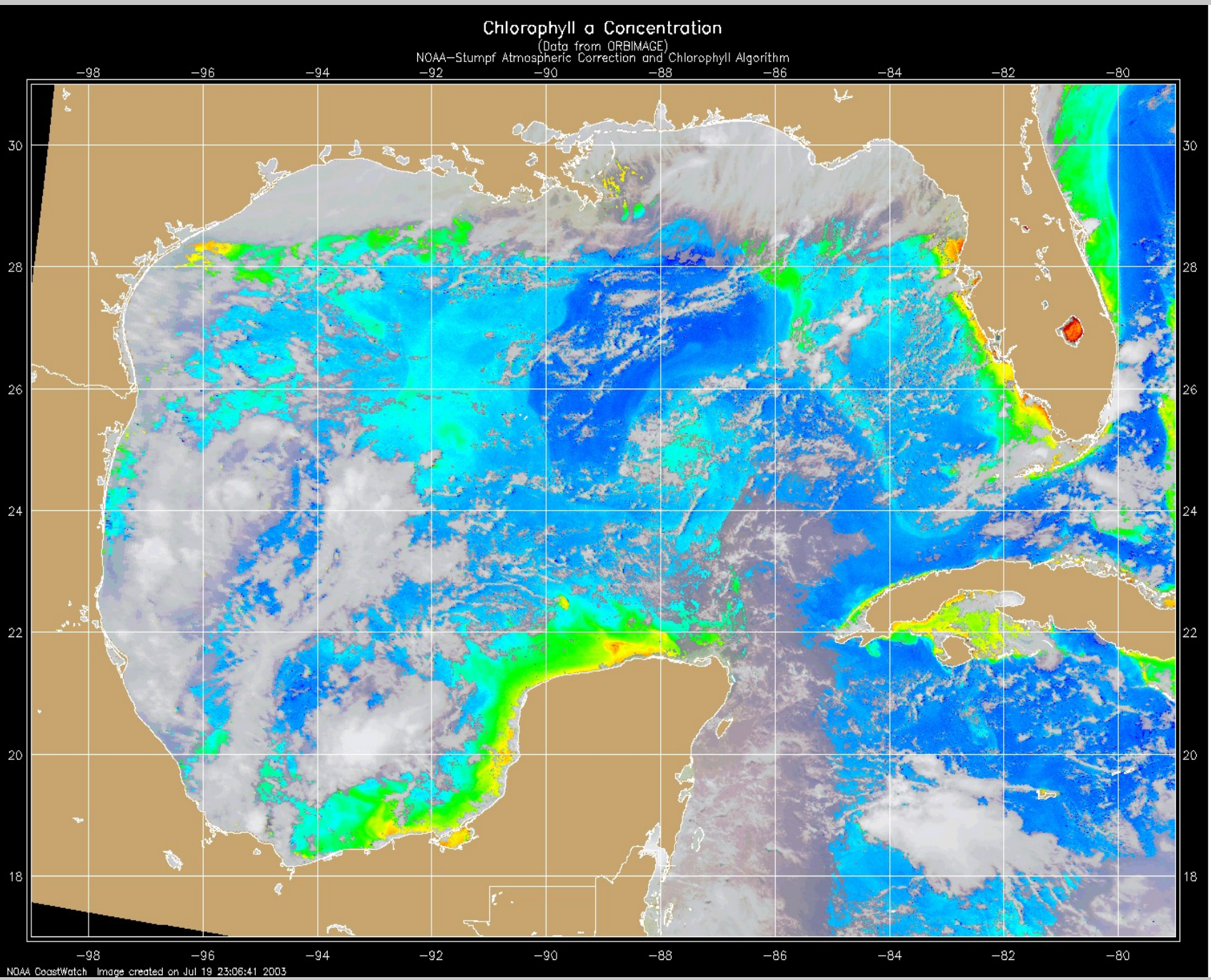


CoastWatch

2004 AUG 4 18:22:18 GMT

Full Region Gulf of Mexic
LAT: 17.00N – 31.00N
LON: 79.00W – 99.00W

Chlorophyll a Concentration
mg m^{-3}
50
30
20
10
5
3
2
1
.5
.3
.2
.1
.05
.03
.02
.01



CoastWatch

2003 JUL 19 18:11:49 G

Full Region Gulf of Mex

LAT: 17.00N – 31.00N

LON: 79.00W – 99.00

Chlorophyll a Concentration
mg m^{-3}

50
30
20
10
5
3
2
1
.5
.3
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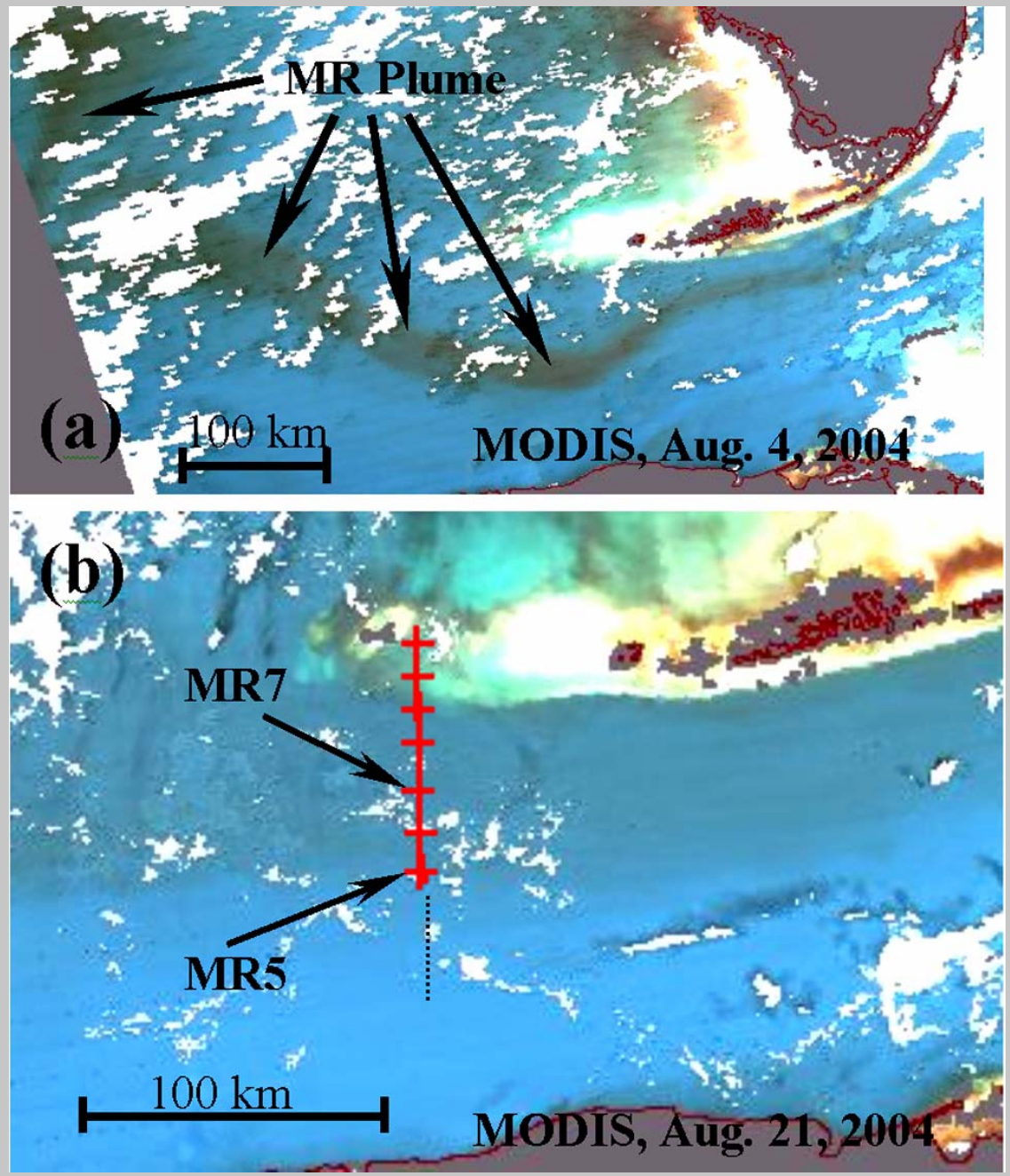
.1
.05
.03
.02
.01

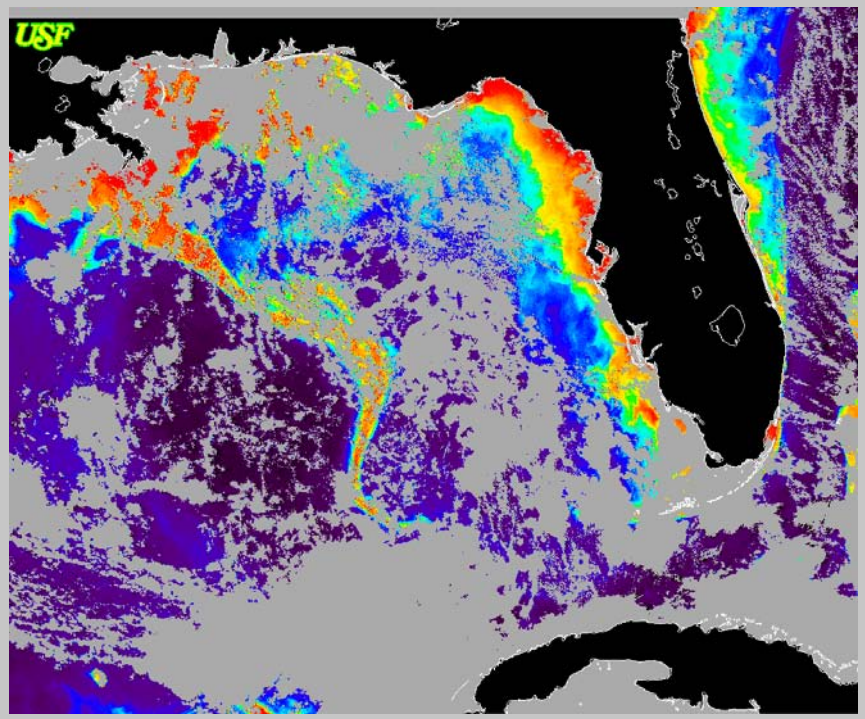
Mississippi River water in the Florida Straits and in the Gulf Stream off Georgia in summer 2004

GRL vol. 12, L14606, July 2005

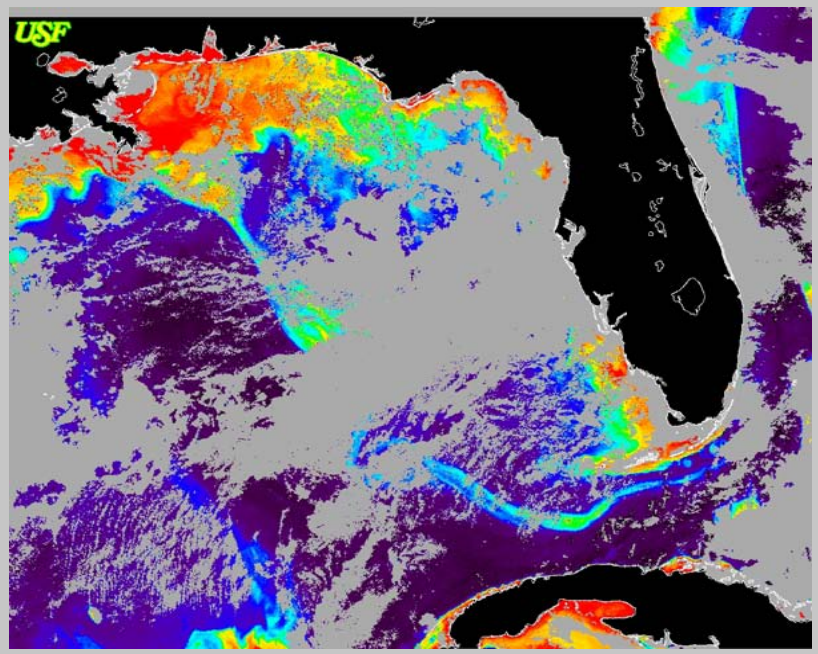
Chuanmin Hu, J. R. Nelson, E. Johns, Z. Chen, R. H. Weisberg, and F. E. Muller-Karger



Mississippi water influence around Florida Bay and the Florida Keys



07/30/2004



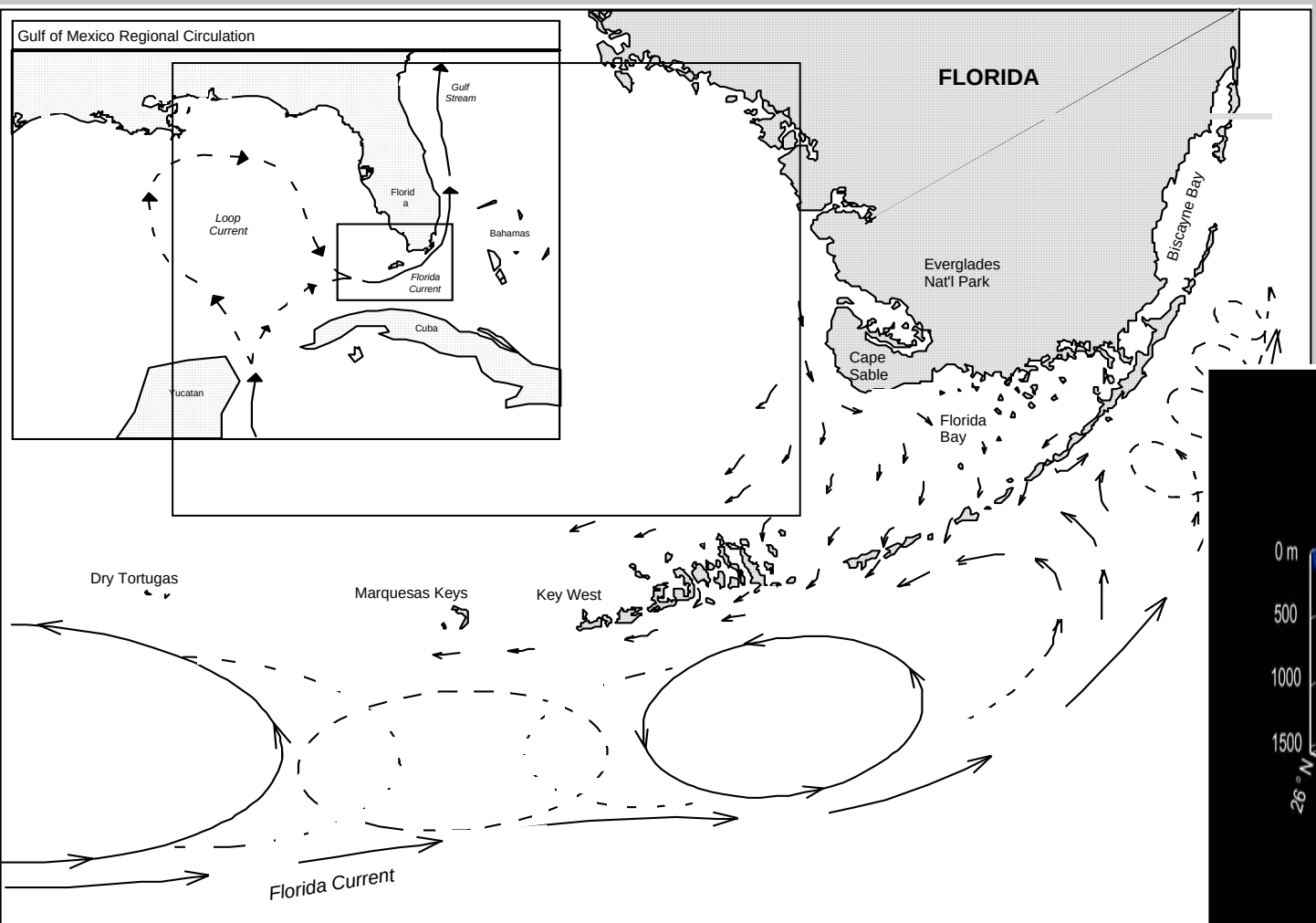
08/04/2004

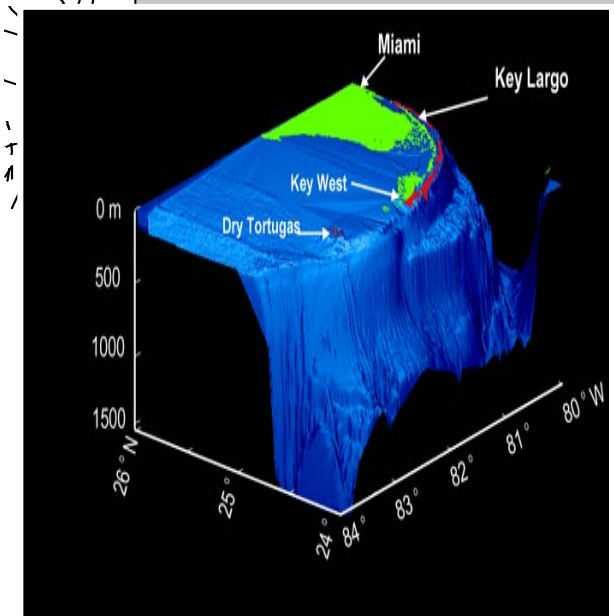
http://imars.usf.edu/

Influence from Ocean Currents

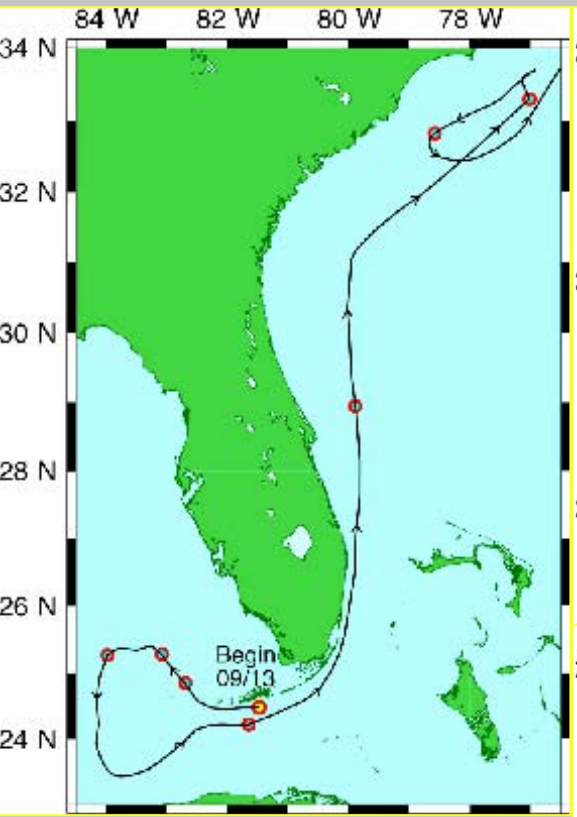
Florida Keys and coral reef are influenced by currents and flows from Florida Bay, Gulf of Mexico, Florida west coast, and Florida Current/Gulf Stream

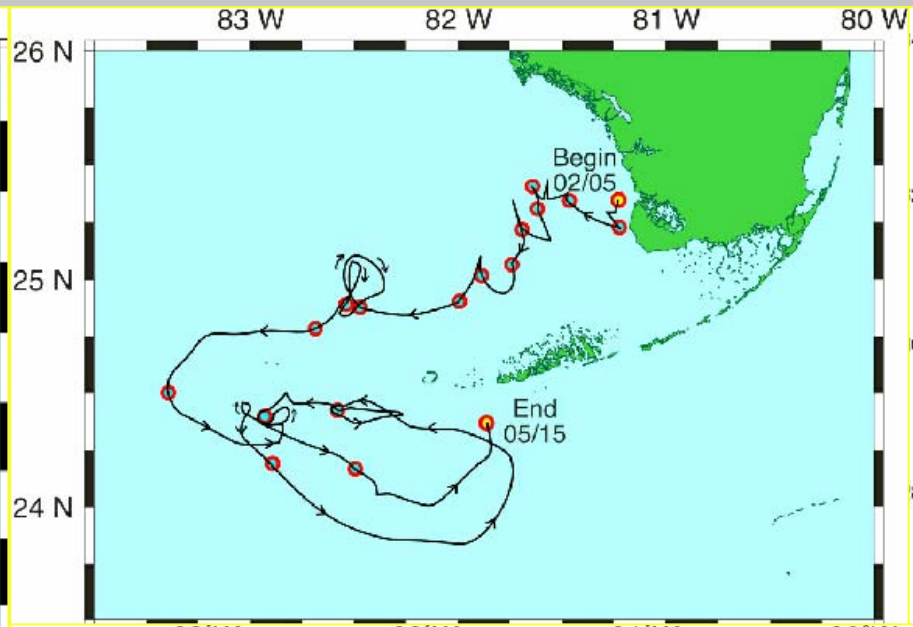
(Lee and Williams - Univ of Miami)

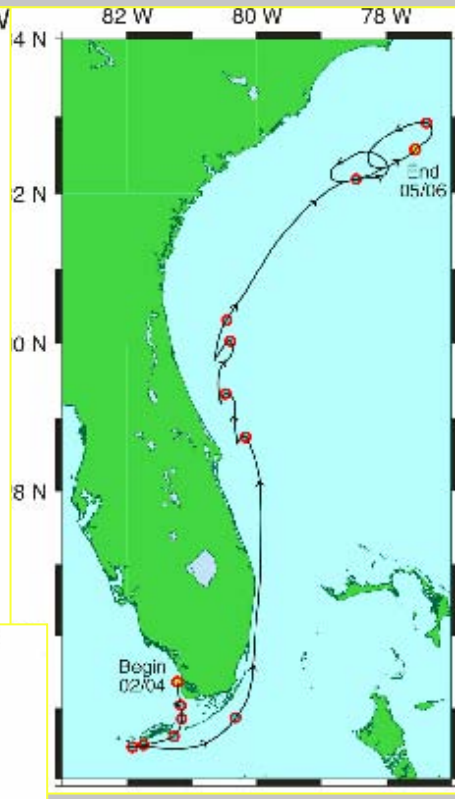


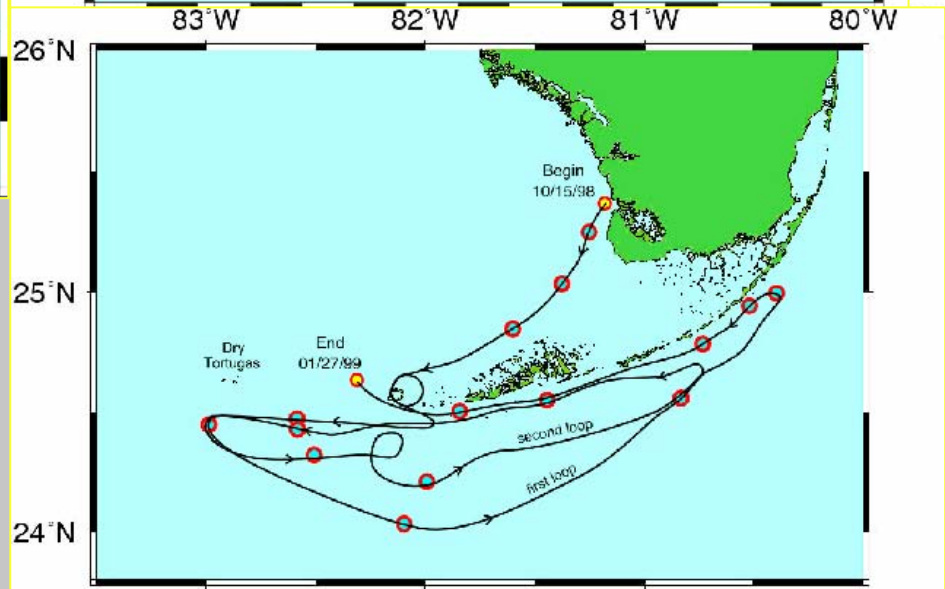


Four Paths of Satellite Current-Tracking Meters









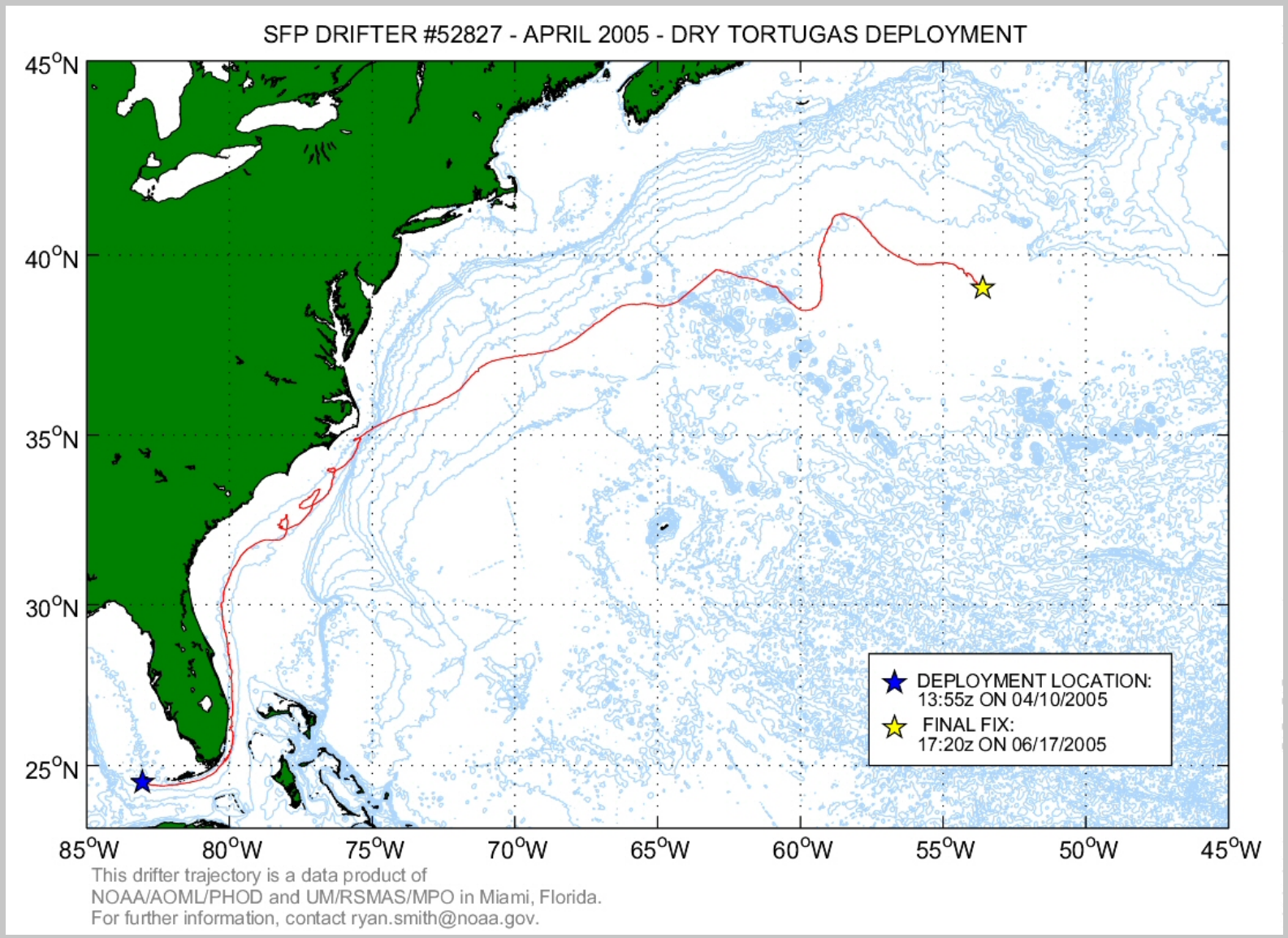
Investigators:

Dr. Tom Lee

Dr. Liz Williams

Univ of Miami

Shark River Slough/ FL West Coast Releases

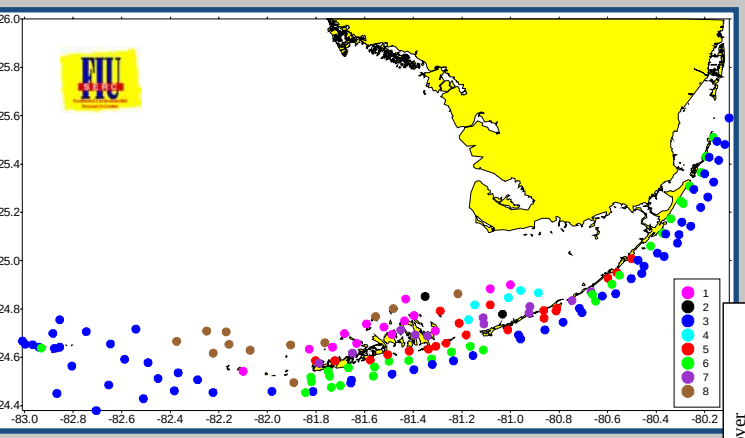


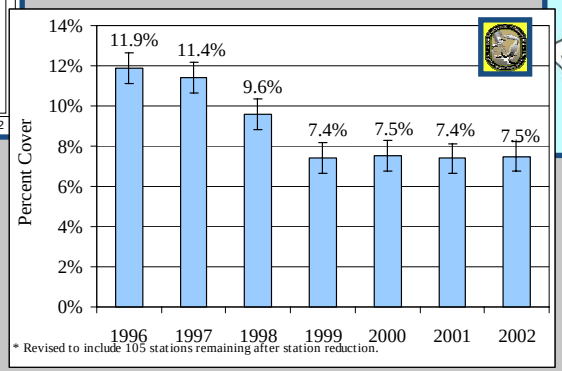
http://www.aoml.noaa.gov/sfcoo/SFP_drifters/

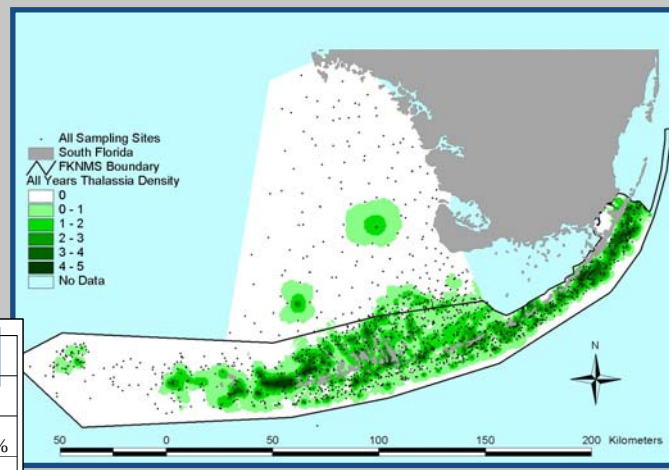
Florida Keys National Marine Sanctuary

Long-term Monitoring Program

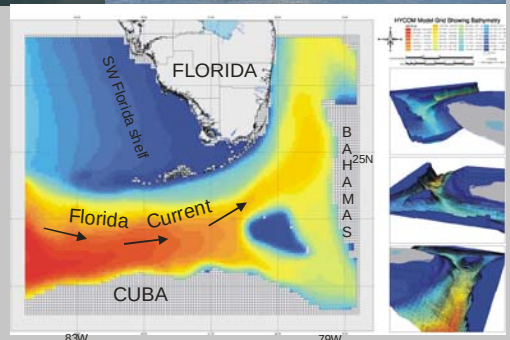
- **Water Quality – FIU- Joe Boyer**
- **Seagrass – FIU – Jim Fourqurean**
- **Coral – FWCC – Carl Beaver**





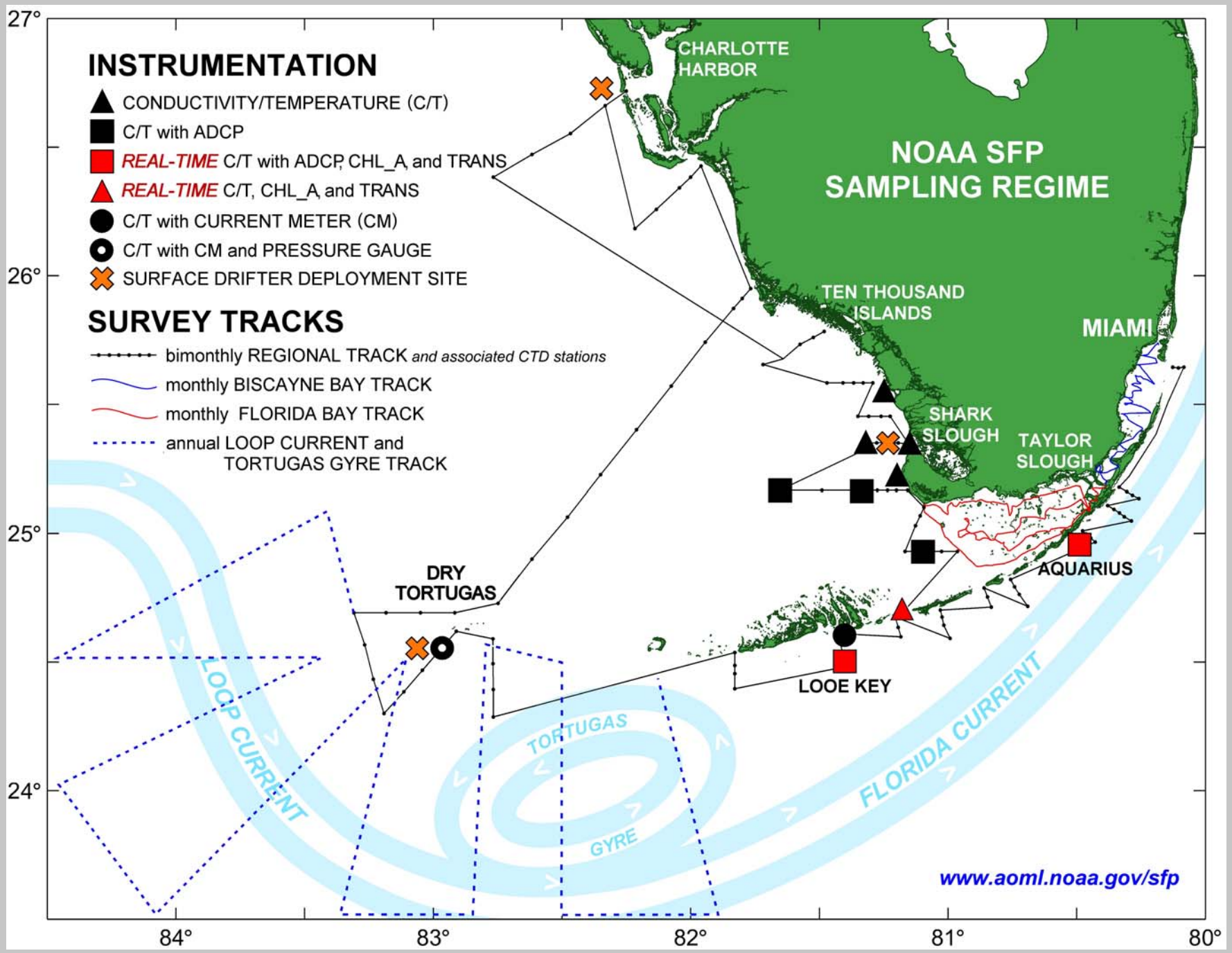


South Florida Ecosystem Research and Monitoring Program



- **Process Studies** — **T. Lee**
- **Interdisciplinary Sustained Observations** — **P. Ortner**
- **Realtime Event Detection** — **E. Johns**
- **Modeling** — **V. Kourafalou**

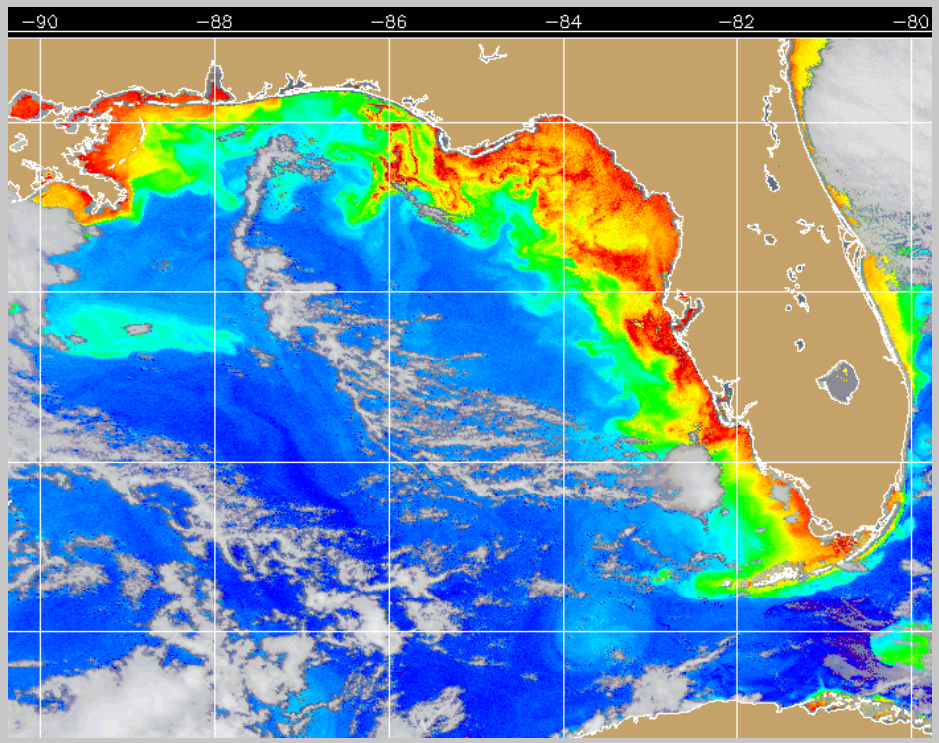
NOAA NOS/NCCOS, OAR/AOML, NMFS/SEFSC & SFWMD


INSTRUMENTATION
CONDUCTIVITY/TEMPERATURE (C/T)
C/T with ADCP
REAL-TIME C/T with ADCP, CHL_A, and TRANS
REAL-TIME C/T, CHL_A, and TRANS
C/T with CURRENT METER (CM)
C/T with CM and PRESSURE GAUGE
SURFACE DRIFTER DEPLOYMENT SITE
SURVEY TRACKS
bimonthly REGIONAL TRACK and associated CTD stations
monthly BISCAYNE BAY TRACK
monthly FLORIDA BAY TRACK
annual LOOP CURRENT and TORTUGAS GYRE TRACK
NOAA SFP SAMPLING REGIME
CHARLOTTE HARBOR
TEN THOUSAND ISLANDS
MIAMI
SHARK SLOUGH
TAYLOR SLOUGH
AQUARIUS
DRY TORTUGAS
LOOE KEY
LOOP CURRENT
TORTUGAS GYRE
FLORIDA CURRENT
www.aoml.noaa.gov/sfp
27°
26°
25°
24°
84°
83°
82°
81°
80°

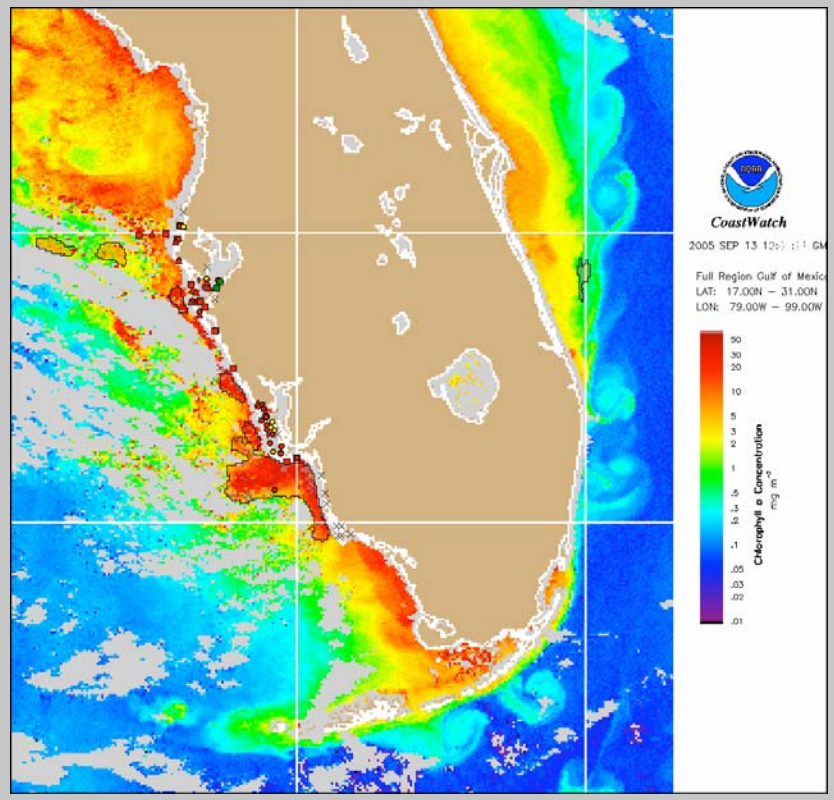
Remote Monitoring Stations

- 32 meters to record water temperature (FKNMS)
- 7 CMAN Stations along reef tract and Florida Bay (FIO)

09/14/05

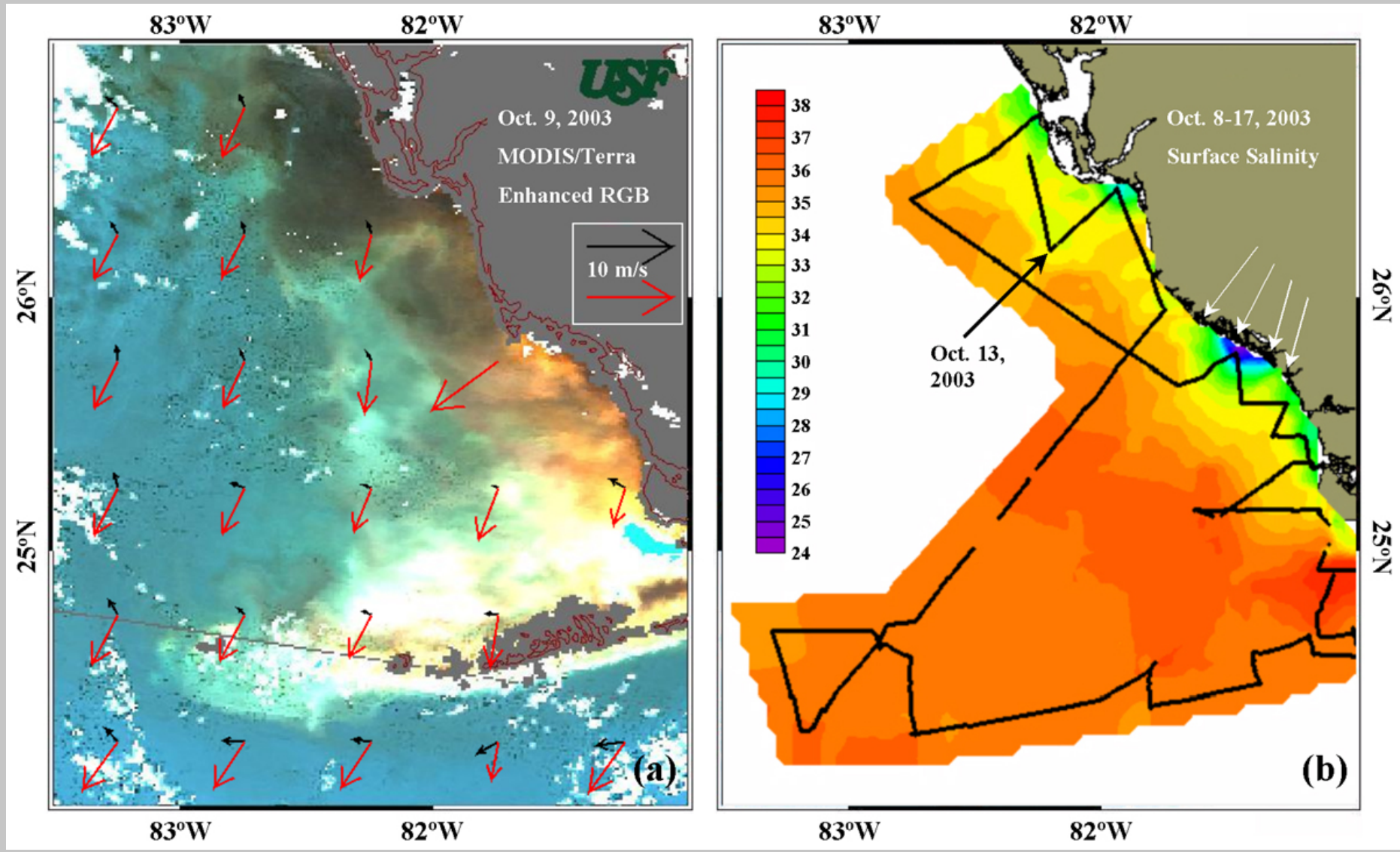


09/15/05



NOAA Harmful Algal Bloom Bulletin

http://coastwatch.noaa.gov/hab/



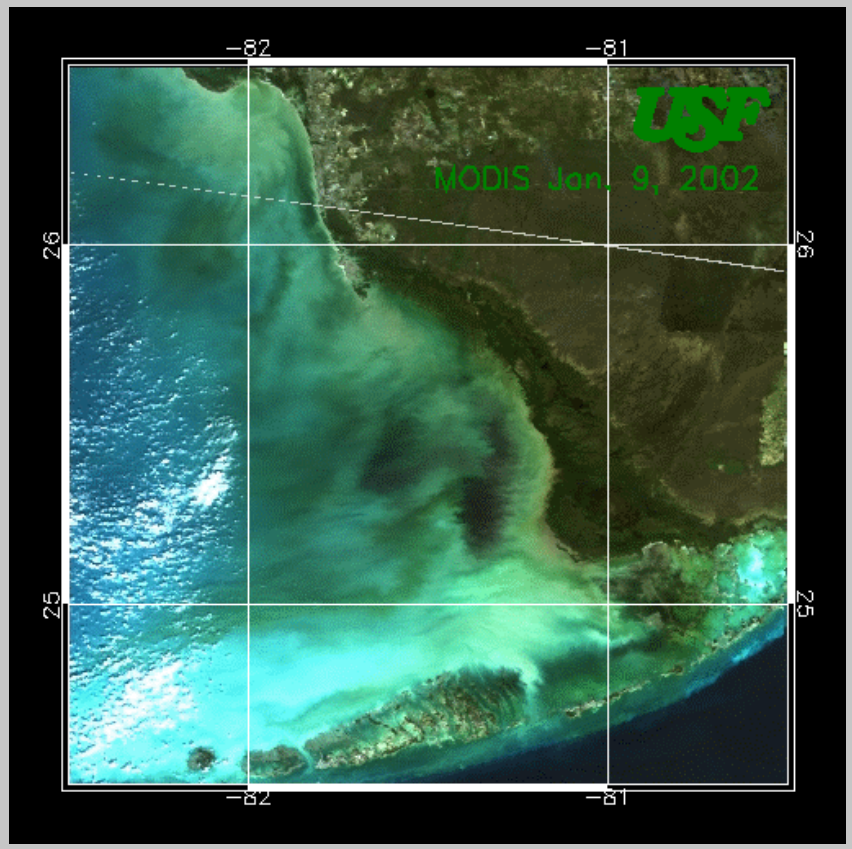
C. Hu, F.E. Muller-Karger, G.A. Vargo, and E. Johns (2004)

Geophysical Research Letters, 31, L15307

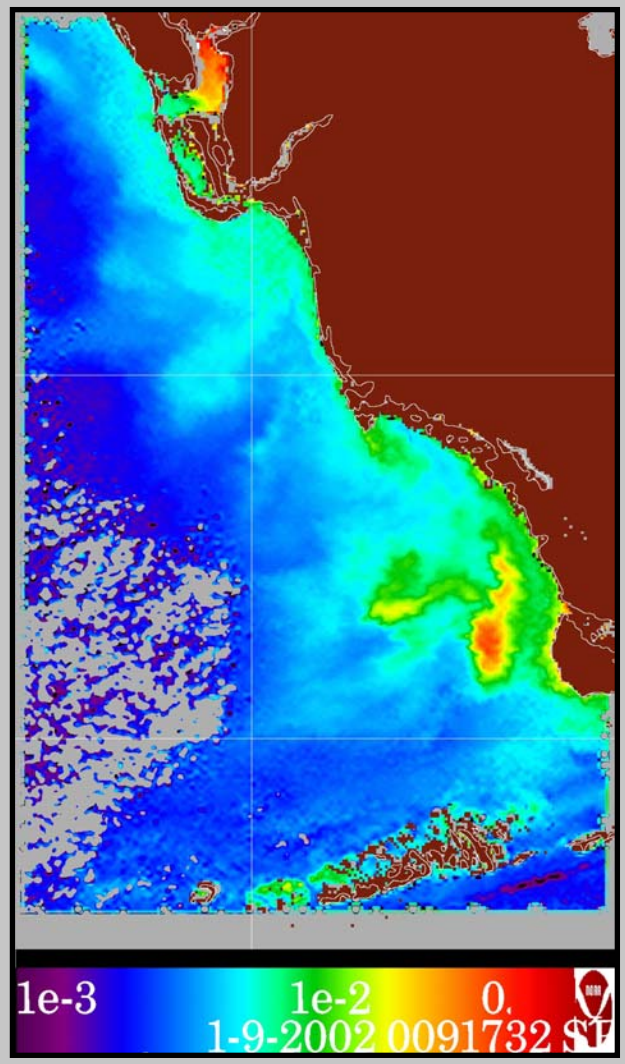
"Linkages between coastal runoff and the Florida Keys ecosystem: A study of a dark plume event"

Blackwater Imagery

9 January 2002

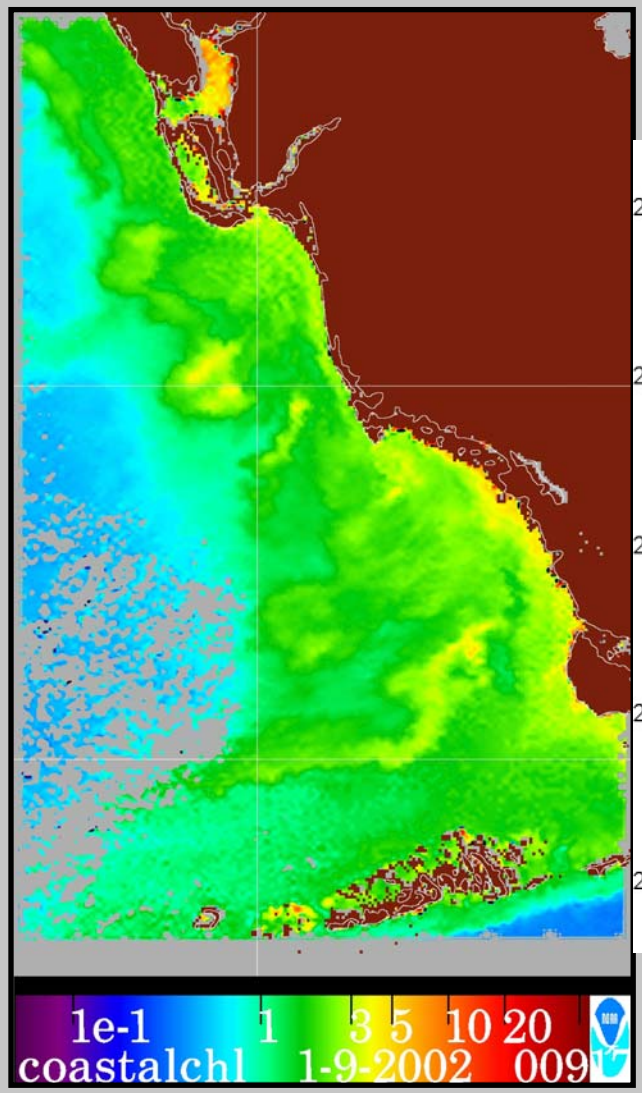


True color image



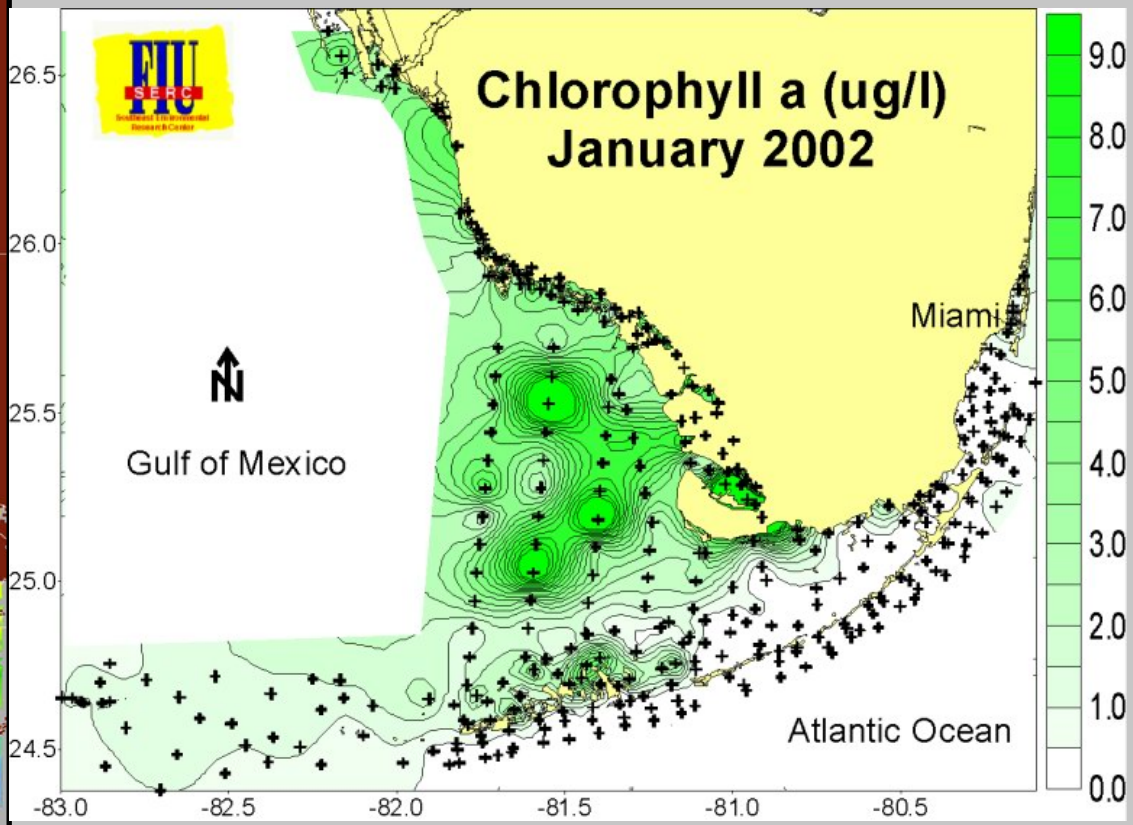
R. Stumpf, NOAA CoastWatch

Image enhanced for blackwater "signal" (tannins, humic acid)

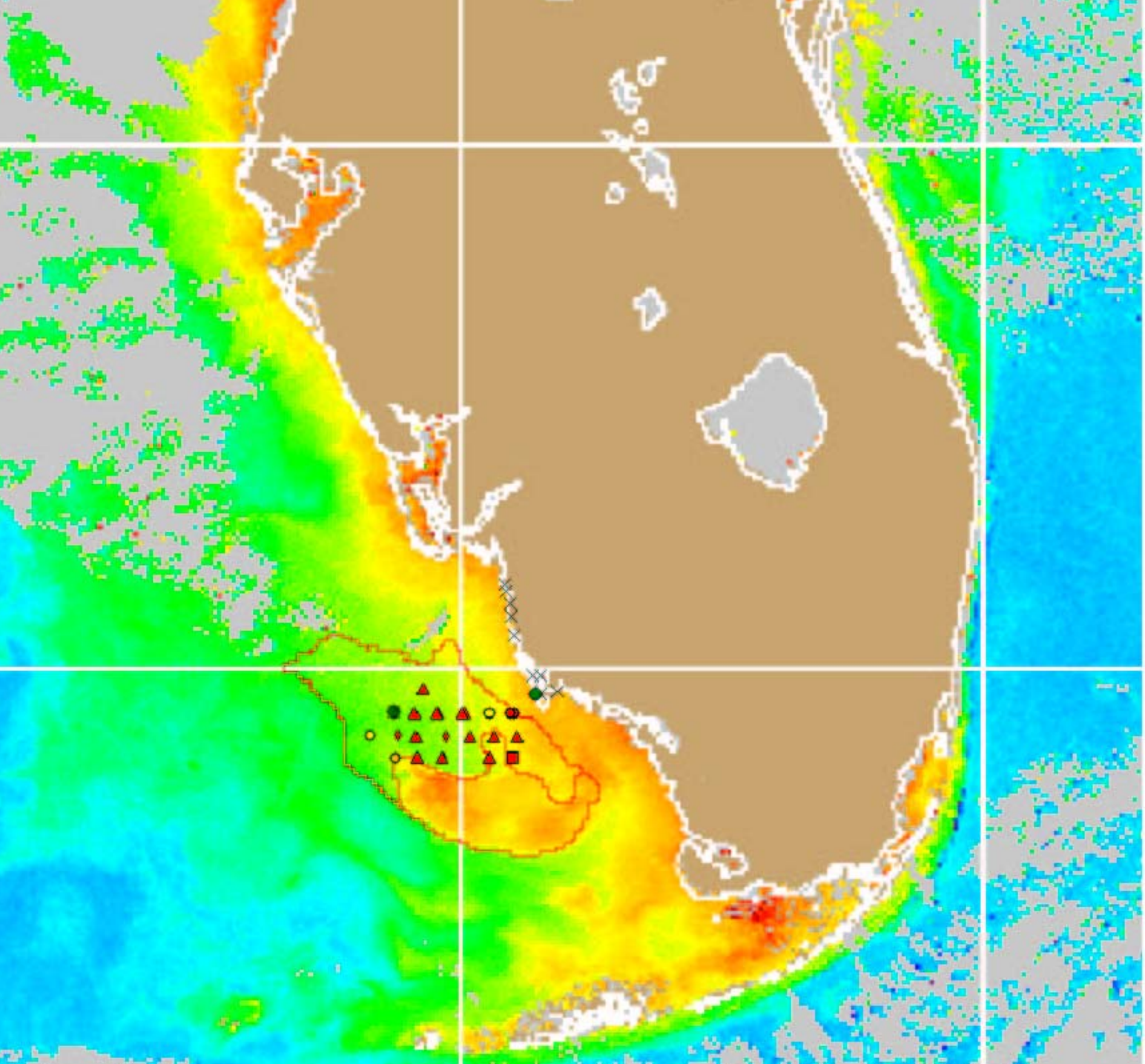


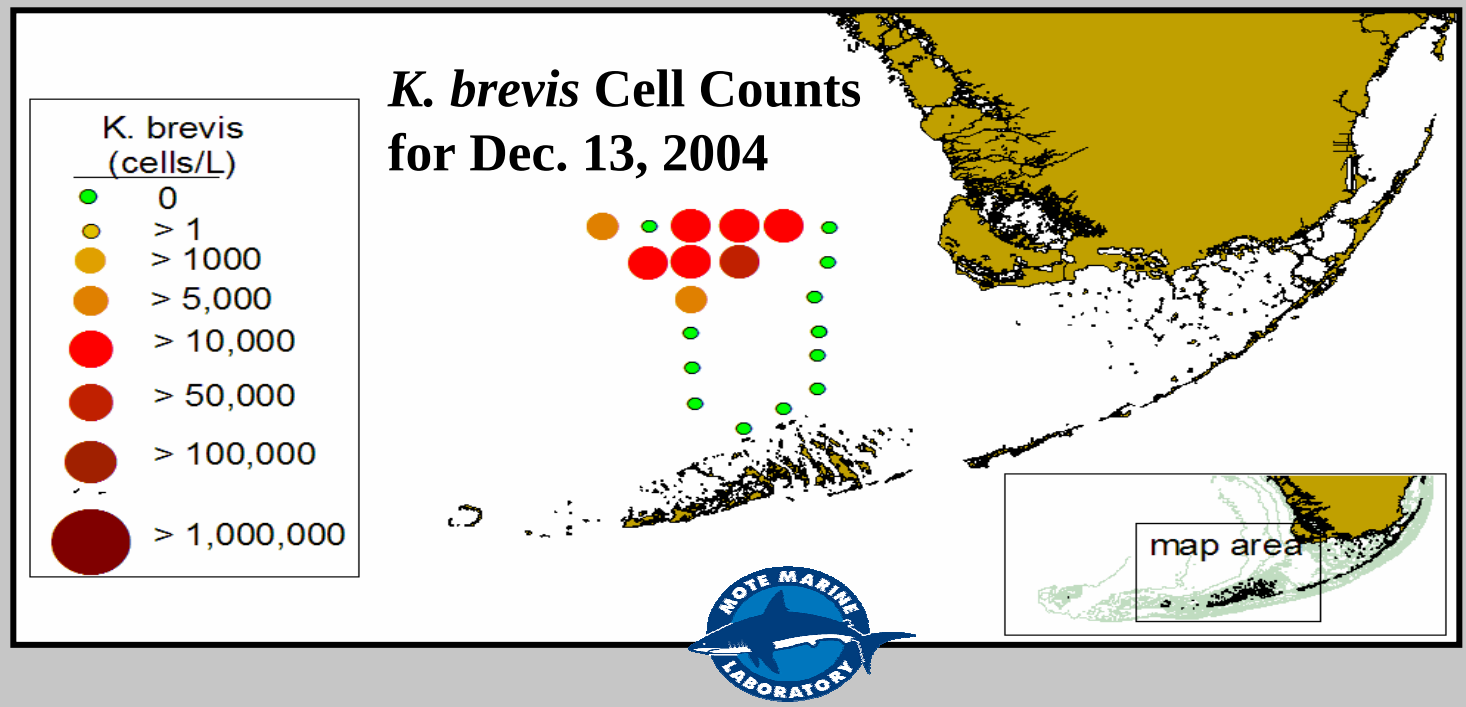
R. Stumpf, NOAA CoastWatch

1/9/02: Image enhanced for chlorophyll concentration (amount of phytoplankton)

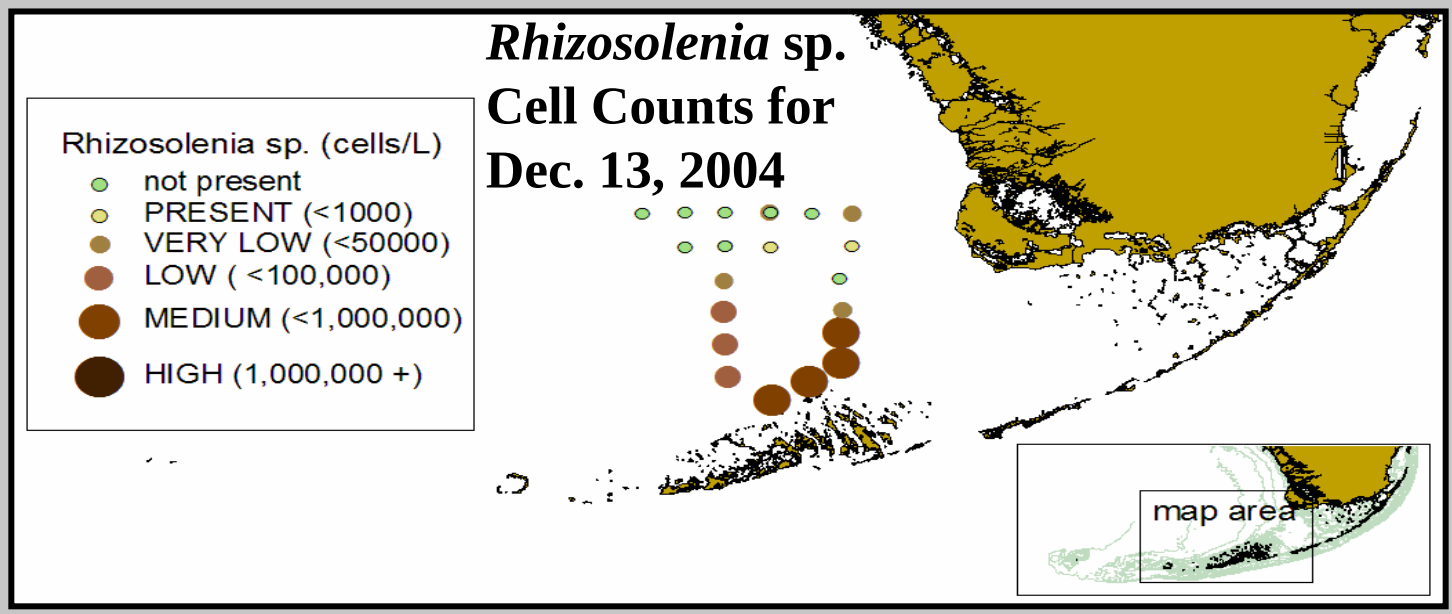


Highest concentration of chlorophyll *a* measured in this region since quarterly monitoring began in 1995


CoastWatch
2004 NOV 28 18:07:18 GM
Full Region Gulf of Mexic
LAT: 17.00N – 31.00N
LON: 79.00W – 99.00W
50
30
20
10
5
3
2
1
.5
.3
.2
.1
.05
.03
.02
.01
Chlorophyll a Concentration
mg m-3



K. brevis Cell Counts for Dec. 13, 2004

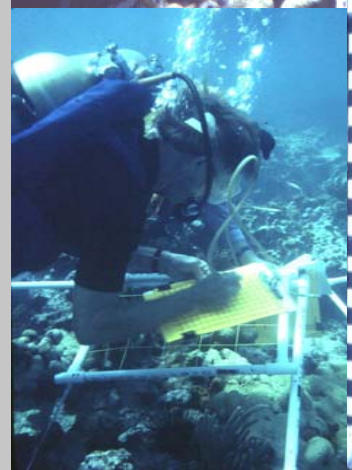


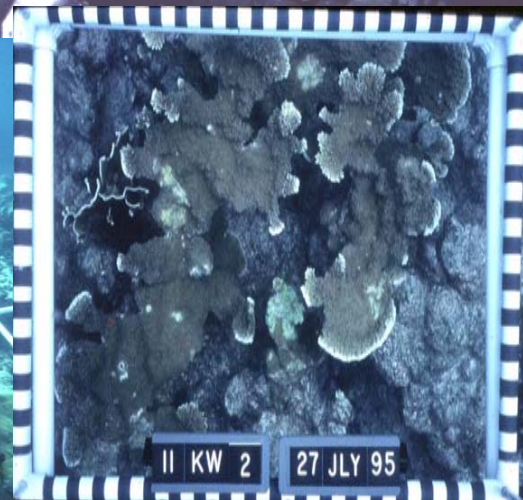
Rhizosolenia sp. Cell Counts for Dec. 13, 2004

Research and Monitoring are necessary tools for helping managers address climate change and coral bleaching issues.

Today we can monitor coral bleaching events at a range of spatial and temporal scales:

- Cellular & tissue level
- *In situ* or at the reef scale
- Local and nearshore
- CREWS - technology
- Coral Reef Watch
- CoRIS - web-enabled, GIS-enhanced info system





Summary of Science Needs:

- **Remote monitoring system**
  - **Regional to Global Scale**
  - **Establish baseline**
- ***In situ* fixed monitoring stations**
  - **Real-time hydrographic data**
  - **Ability to access data readily**
- **Characterize Connectivity**
  - **Local circulation Patterns**
  - **Regional Circulation Patterns**

Summary of Science Needs (continued):

- **Benthic Habitat Map (satellite)**

- **Side-scan/seismic profile of significant benthic features**

- **Long-term monitoring program**
  - **water quality**
  - **seagrasses**
  - **corals**
- **Establish status and trends**

Summary of Science Needs (continued):

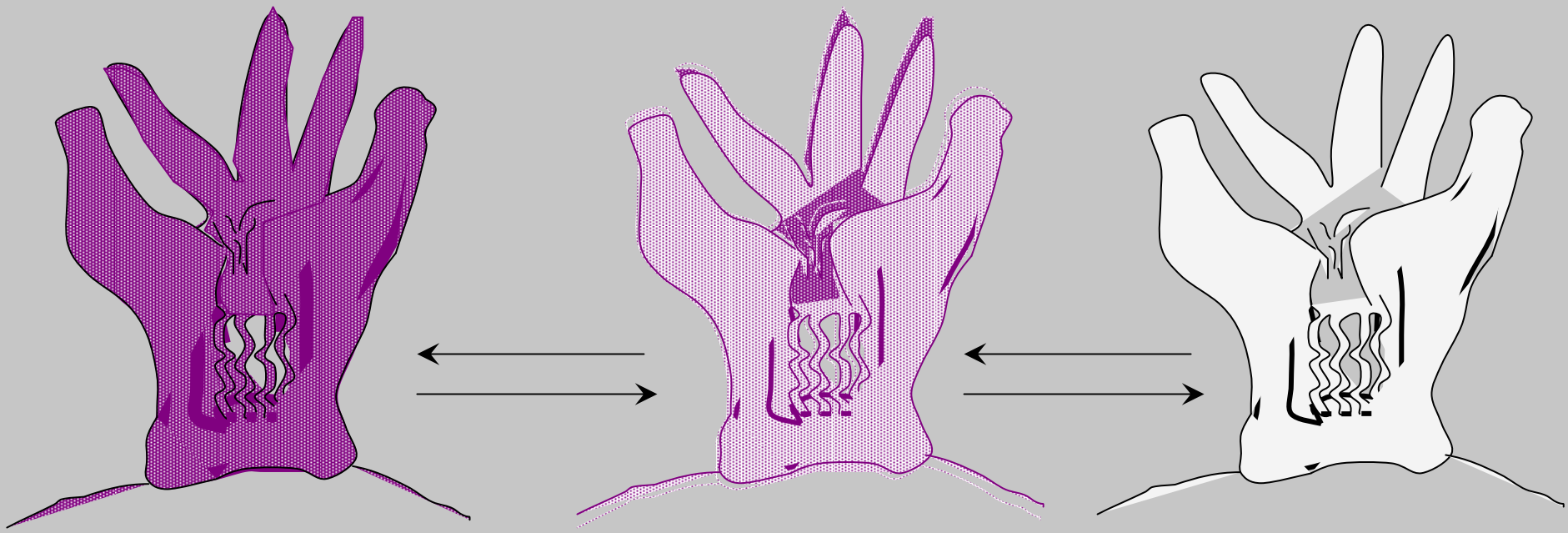
- **Targeted Research**
  - **Role of thermal stress in coastal and marine envionments**
  - **Percent contribution of various stressors in the overall health of ocean and coastal environments**
  - **Characterize healthy corals**
  - **Identify Bio-markers and Bio-indicators**

Resiliency

- **Resilience** is a concept that has been around for a while
- Some coral reefs have **resisted** bleaching
- **Science** will help us understand why & how


Research and monitoring must
range from this scale……

To this scale!!



Healthy Blanched Bleached

Credit: K. Ritchie for slide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NATIONAL MARINE
SANCTUARIES ™