CREON I-CREOS Workshop

Melbourne, Australia *December 10th, 2009*

NOAA *Coral Reef Conservation Program*, and the *Integrated Coral Observing Network* (ICON) project:

Current Capabilities and Vision for the Future

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NOAA / University of Miami – Cooperative Institute for Marine & Atmos. Studies

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NOAA Atlantic Oceanographic and Meteorological Laboratory

A collaborative effort – interagency and international!

noaaresearch

Australian Government

Australian Institute of Marine Science

NOAA'S NATIONAL OCEAN SERVICE

NOAA Fisheries

National Marine Fisheries Service

NOAA Satellites and Information

National Environmental Satellite, Data, and Information Service

CARIBBEAN MARINE RESEARCH CENTER

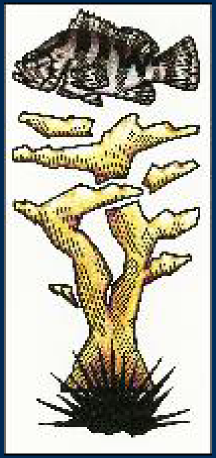
U.S. DEPARTMENT OF THE INTERIOR MARCH 3, 1849

NATIONAL PARK SERVICE

CARICOM

NASA

Remote Sensing Systems



ccmi Central Caribbean Marine Institute

UNIVERSITY OF MIAMI RSMAS ROSENSTIEL SCHOOL OF MARINE & ATMOSPHERIC SCIENCE

CONSERVATION INTERNATIONAL

GREAT BARRIER REEF MARINE PARK AUTHORITY

STATE OF FLORIDA INSTITUTE OF OCEANOGRAPHY FIO

USF UNIVERSITY OF SOUTH FLORIDA

UCAR NCAR UOP

GEORGIA SOUTHERN UNIVERSITY

CCEHBR Center for Coastal Environmental Health & Biomolecular Research

FLORIDA INTERNATIONAL UNIVERSITY MIAMI 1965

NOAA Goals

Coral Reef Conservation Program

PRODUCTS/ACTIVITES

- Improved Understanding of Ecological Processes
  - Physical - biological linkages
  - Causes of Ecological Change
- Online Continuous and Integrated Data
- Baselines and Long-term Climate Trends
- Decision Support Tools
  - Near Real-Time *Ecoforecasts* for Coral Bleaching, Disease, Spawning, Larval Drift, Biological Productivity Changes, etc.
  - Predictive Numerical Models (bleaching, biology, chemistry)
- Local Action Strategy Support
  - Climate
  - Land-based Sources of Pollution

Key Threats to Coral Reef Ecosystems

Coral Reef Conservation Program

Key Threats Addressed

- Climate Change
  - Ocean Warming
  - Ocean Acidification
  - Sea-level Rise
  - Changing Ocean Circulation
- Impacts of Fishing
  - Biological Productivity
  - Larval Transport/Recruitment
- Land-based Sources of Pollution
  - Eutrophication
  - Near-shore Hydrodynamic Processes
- Alien/Invasive Species
- Coral Disease
- Recreational Overuse

NOAA Capabilities

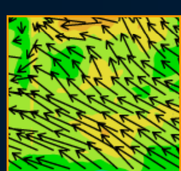
Physical and Chemical Coral Reef Monitoring

CORE CAPABILITIES

Capability 1: *In Situ,* Fixed platform temporal oceanographic and water quality monitoring

Capability 2: Ship-based spatial oceanographic, water quality, and reef fish surveys

Capability 3: Satellite-based synoptic observations, climatologies, anomalies and related products



Capability 4: Regional Physical/Chemical Modeling

NOAA Capabilities

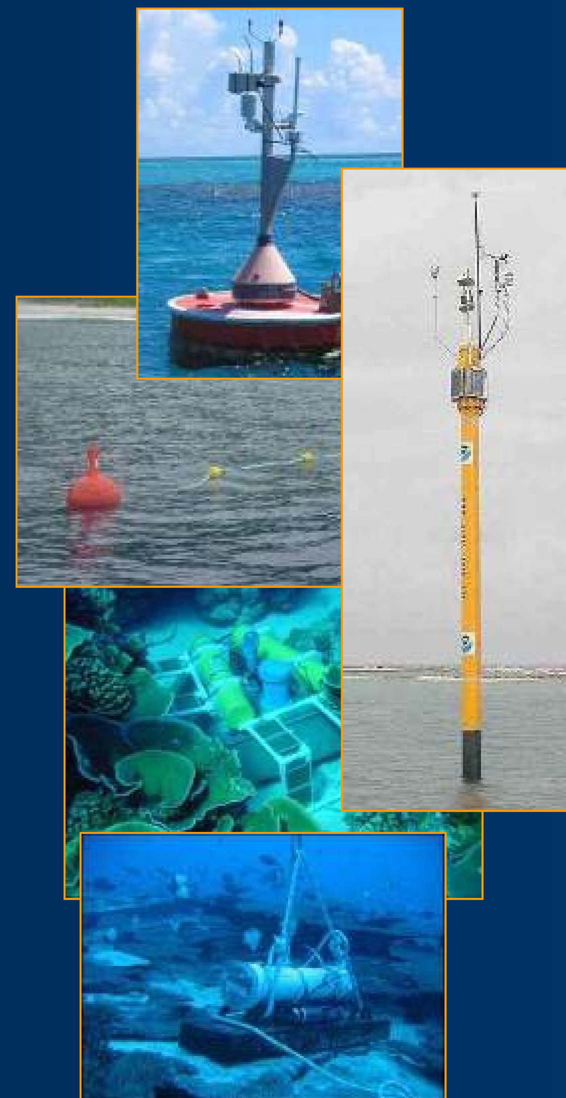
Capability 1: *In situ* Instrumentation

Near Real-time Platforms

- ICON/CREWS Pylons
- Ocean Acidification Moorings
- NDBC Buoys

Subsurface Instrumentation

- Ocean Current Profiles (ADCP)
- Wave & Tide Recorders (WTR)
- Subsurface Temperature Recorders
- Acoustic Fish/Plankton Sensors
- PAM Fluorometers (coral health)
- Ocean Acidification (pH, PCO_2)

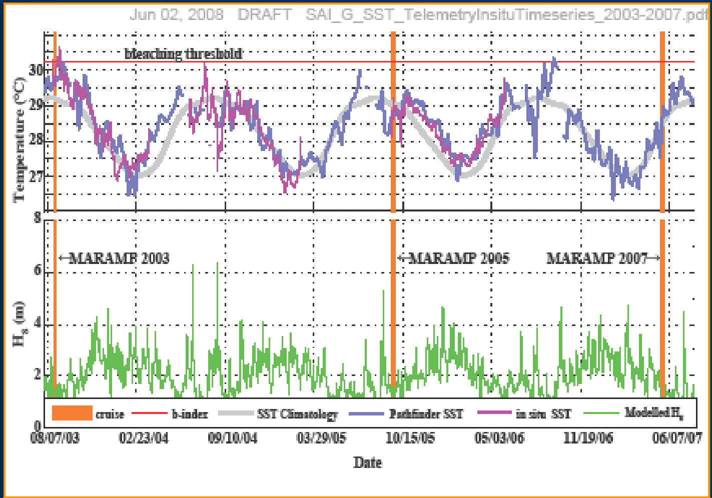


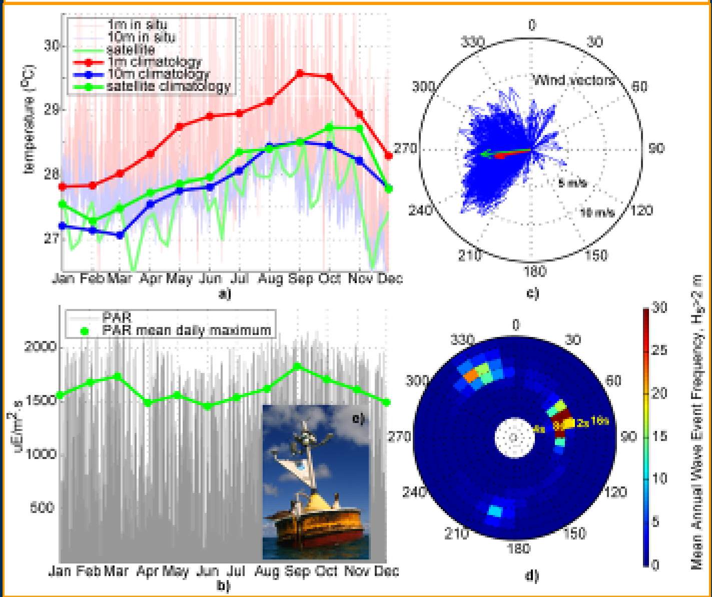
NOAA Capabilities

Capability 1: *In situ* Instrumentation

Variables measured:

- Temperature and Salinity
- Air Temperature, Pressure, Rain, Humidity, Winds
- Currents, Waves, Tides
- Light (PAR, UV, attenuation)
- pCO_2 , pH
- Coral Photosynthetic Efficiency (active fluorom.)
- Nutrients
- Frequency Distribution of Fish and Plankton

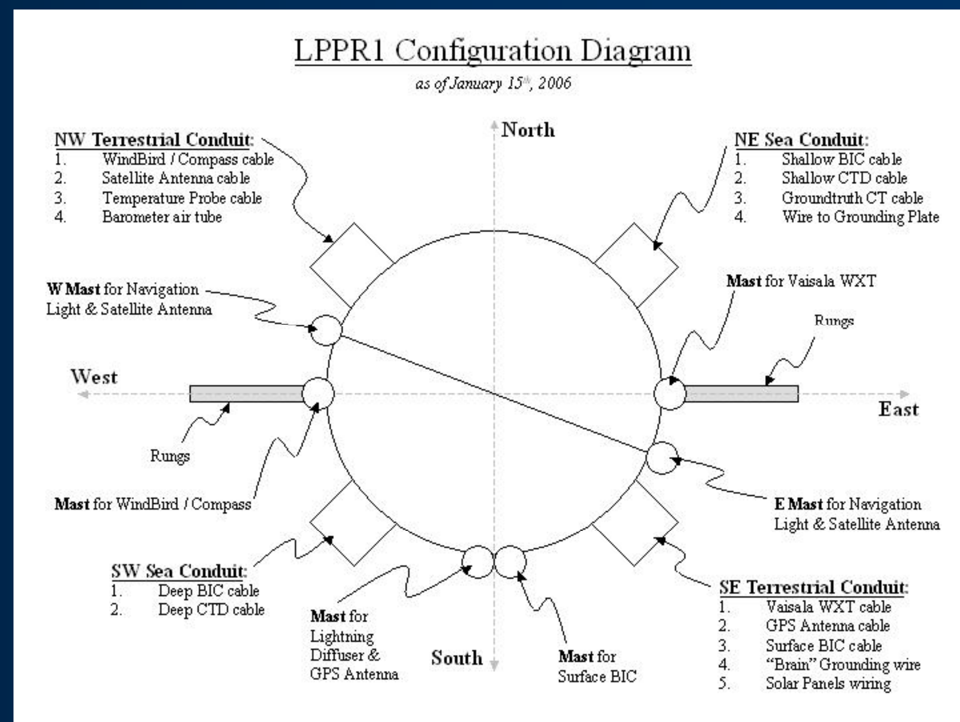




NOAA Capabilities

Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view

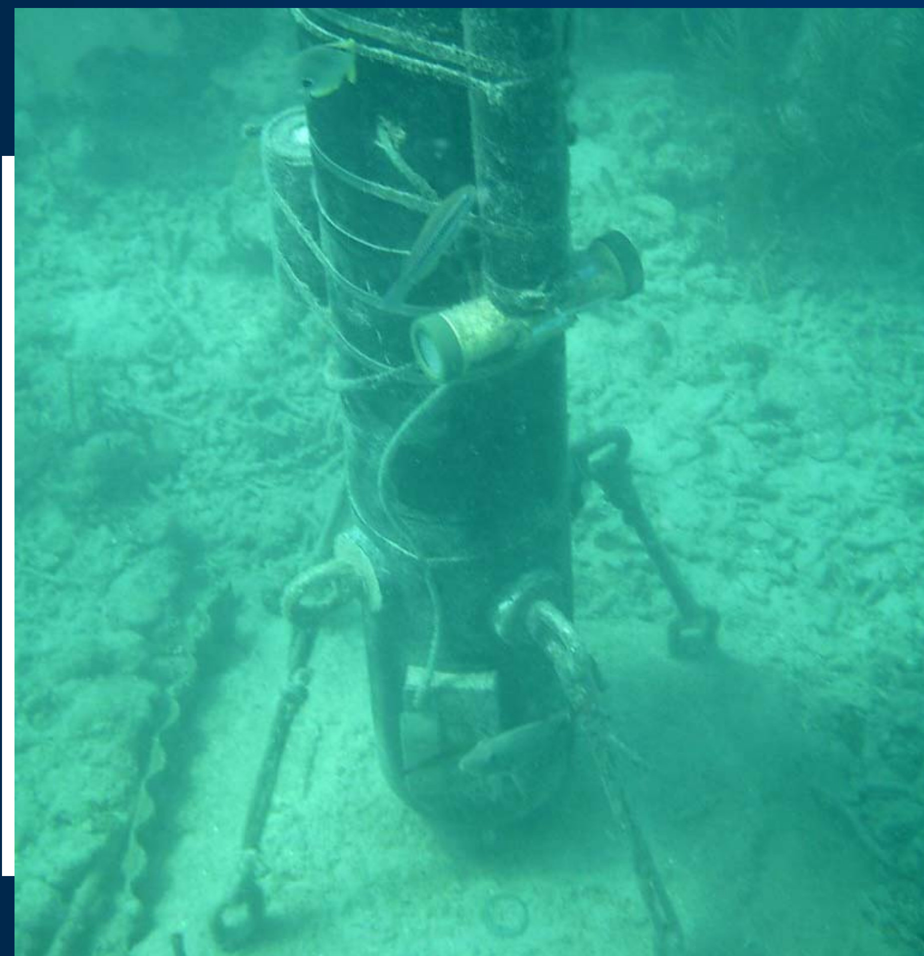


Puerto Rico — US Virgin Islands — Little Cayman

NOAA Capabilities

Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view

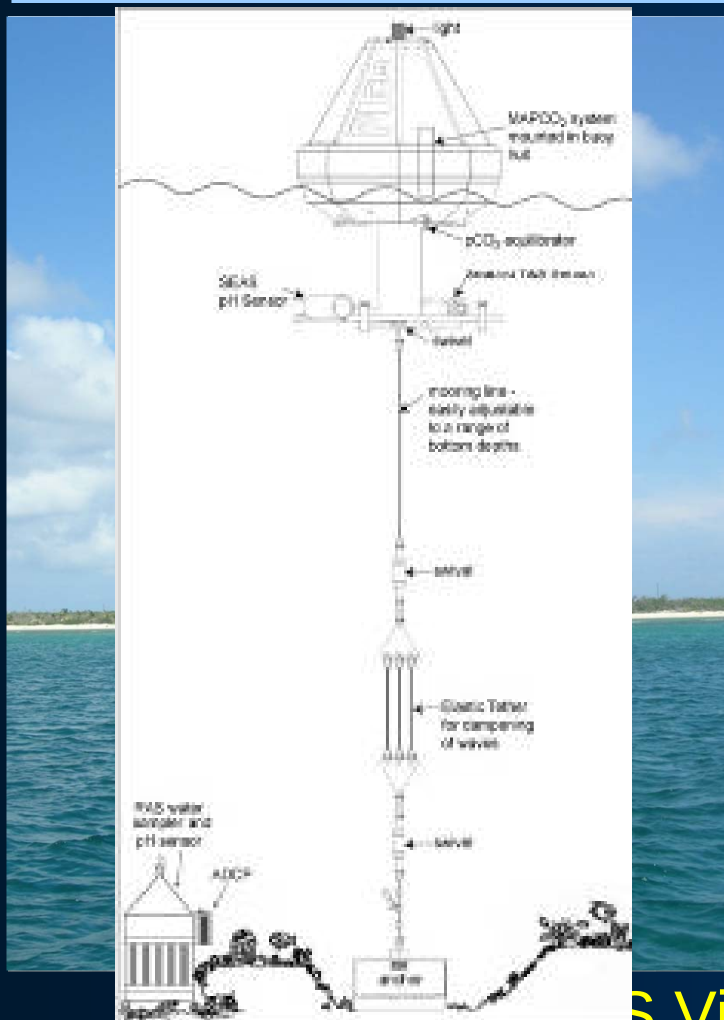


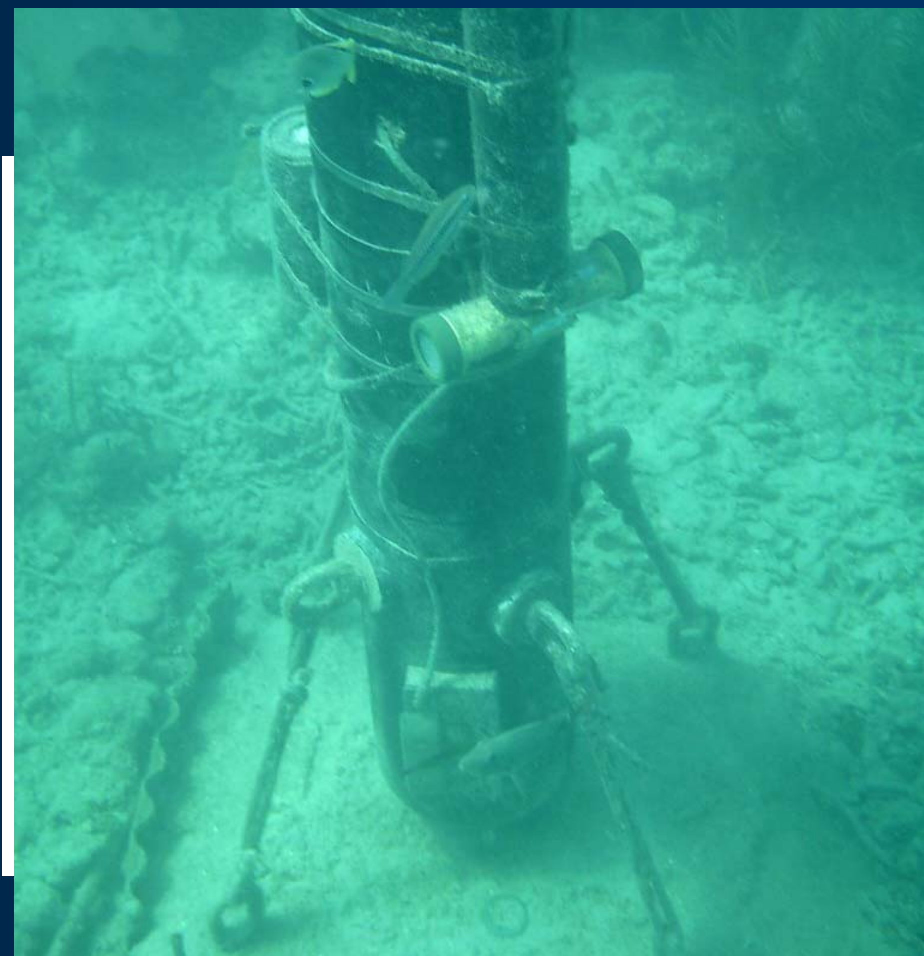
Puerto Rico –– US Virgin Islands –– Little Cayman

NOAA Capabilities

Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view





S Virgin Islands — Little Cayman

NOAA Capabilities

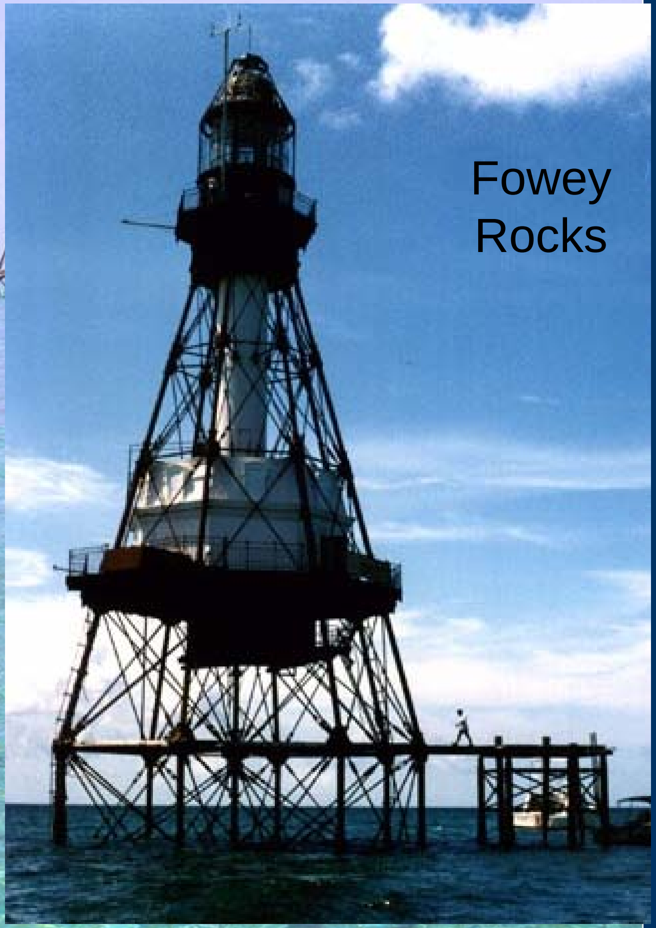
Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view

NOAA Capabilities

Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view



NOAA Capabilities

Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view

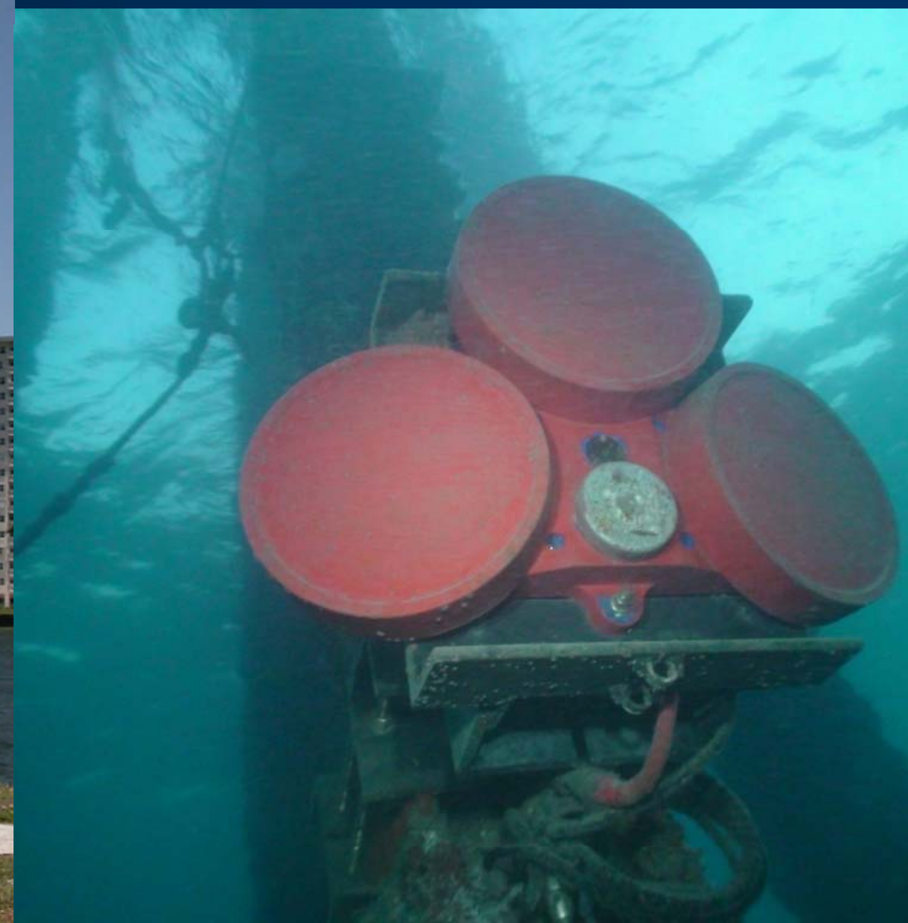
Autonomous hourly, reef-fish and plankton size-frequency distributions: BioSonics DT-X Echosounder

Florida Keys (Tennessee Reef)

NOAA Capabilities

Capability 1: *In situ* Instrumentation

ICON/CREWS Stations – the current view

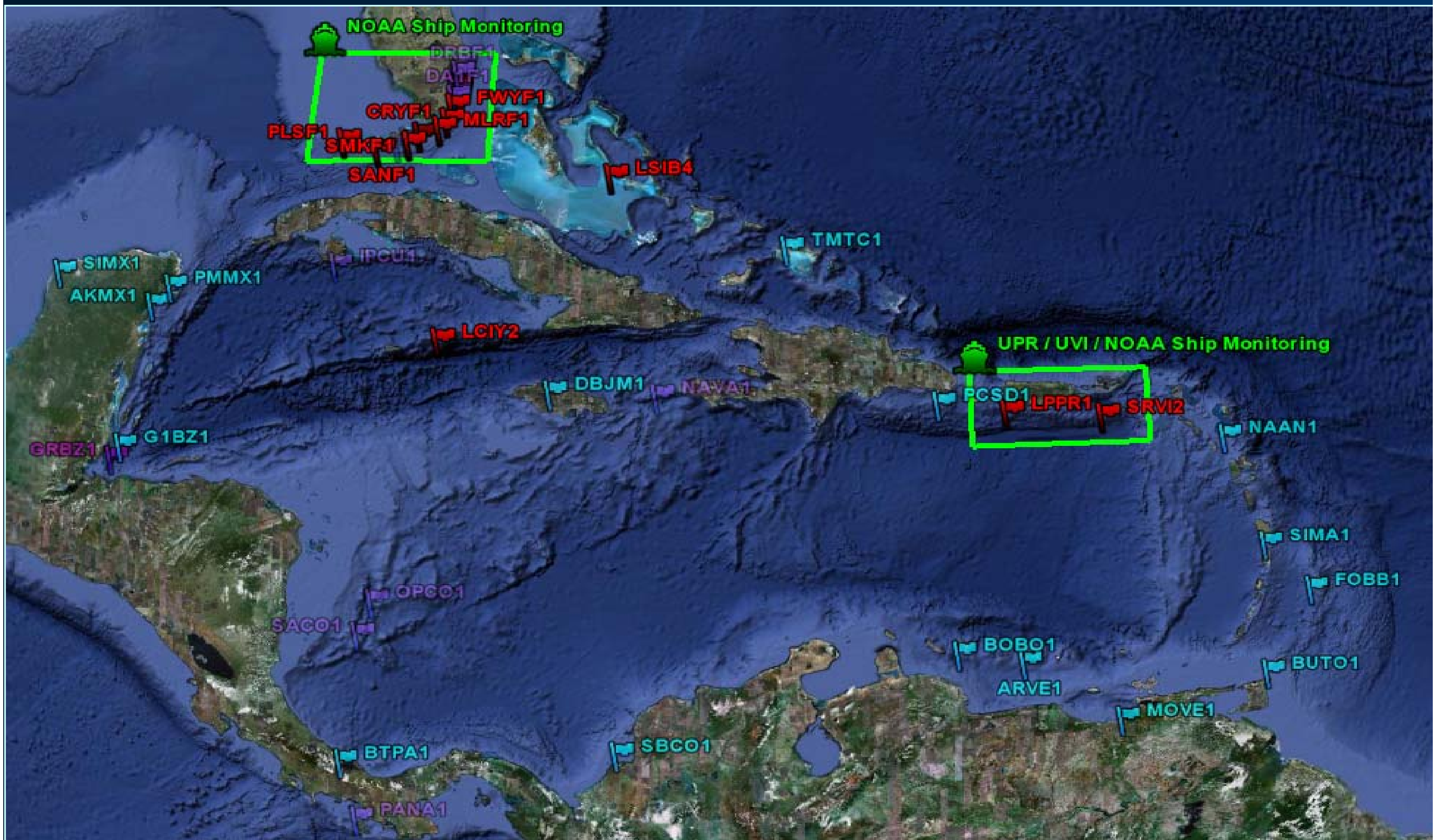


Florida mainland (Port Everglades)

NOAA Capabilities

Capability 1: *In situ* Instrumentation

Caribbean ICON/CREWS Sites (current, proposed):

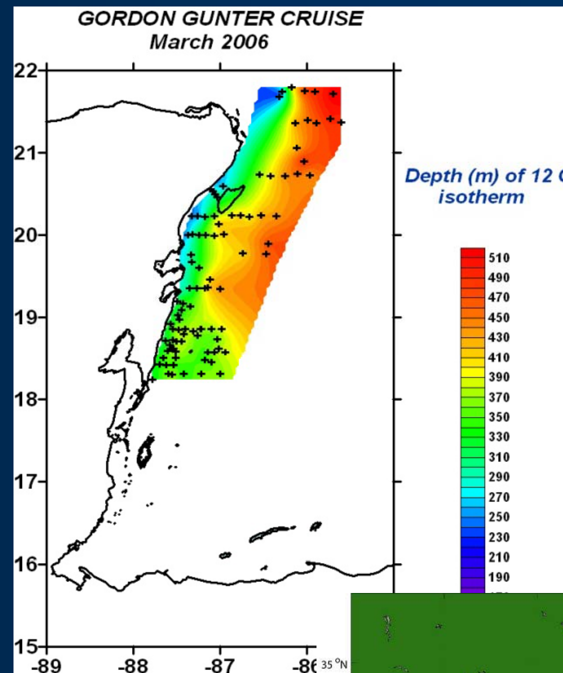


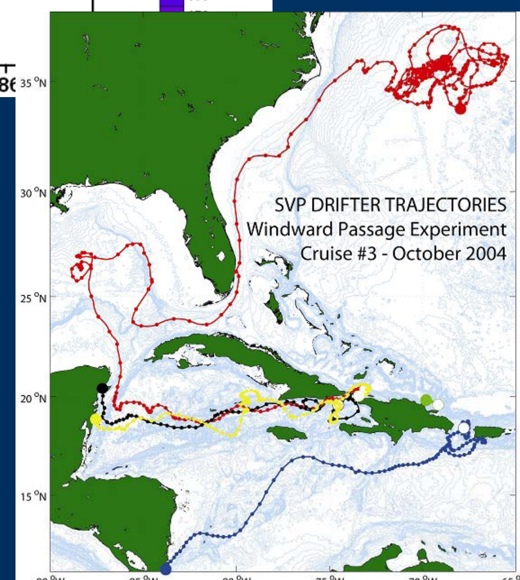
NOAA Capabilities

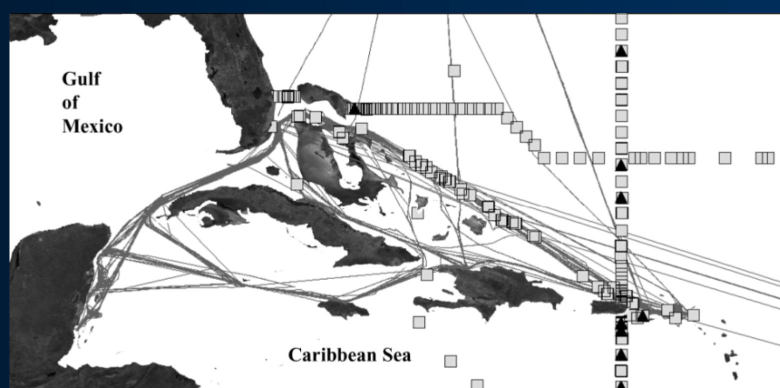
Capability 2: Ship-based Monitoring

Spatial Structure of:

- Sea Temperature
- Salinity
- Ocean Currents
- Nutrients
- Chlorophyll
- Carbon chemistry
- Turbidity / Attenuation

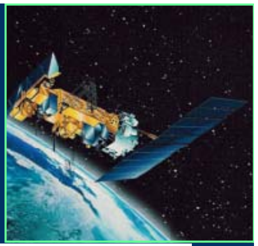




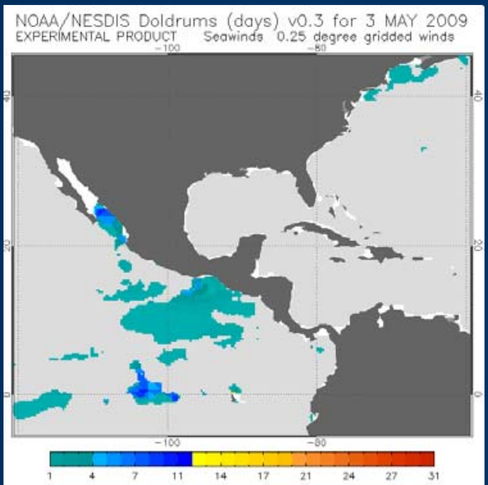


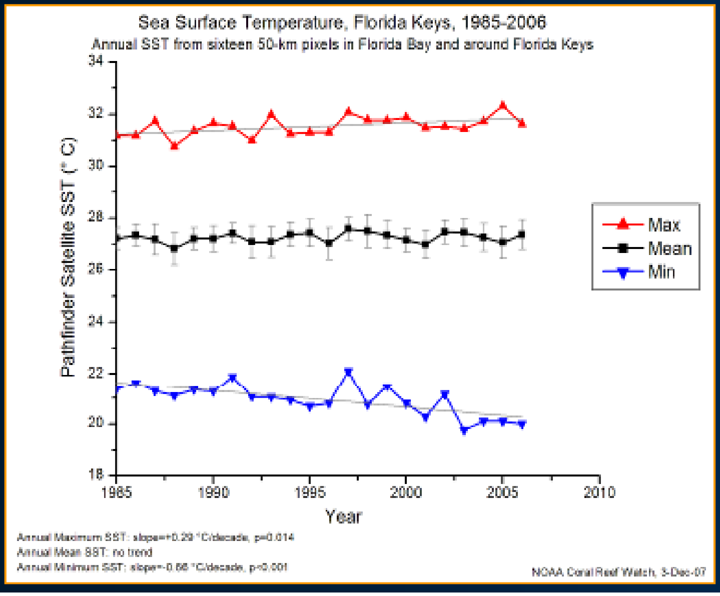
NOAA Capabilities

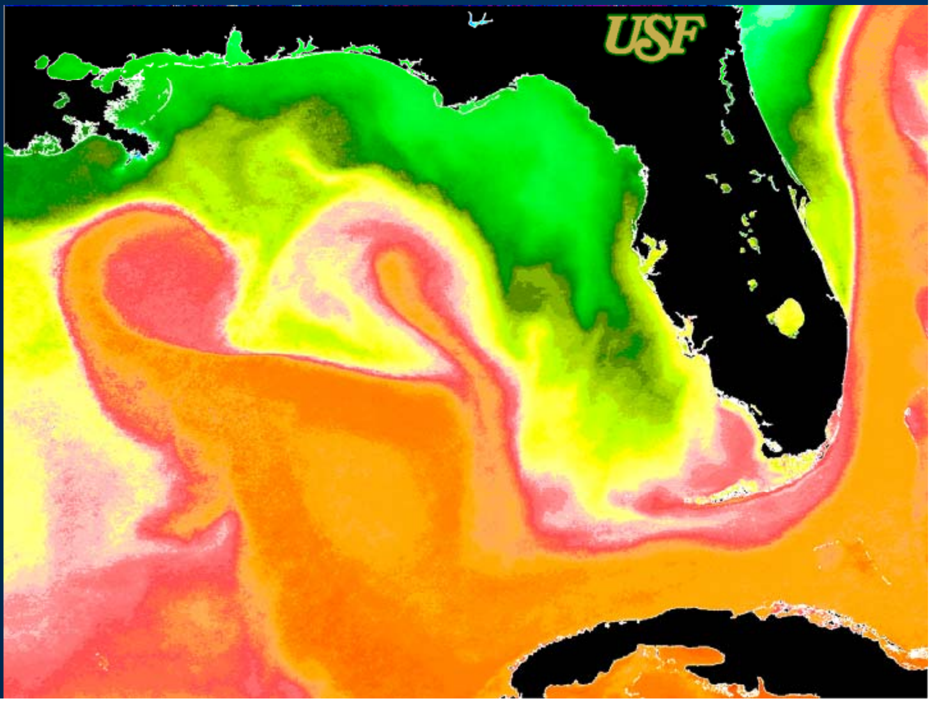
Capability 3: Satellite Monitoring



- **SST**
- **Wind**
- **Ocean Productivity**
- **Sea Surface Height**
- **Light**
- **Coral-Specific**

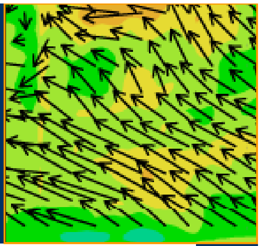






NOAA Capabilities

Capability 4: Physical/Chemical Modeling



NOAA Modeling: Synthesis and product development applications of prior capabilities

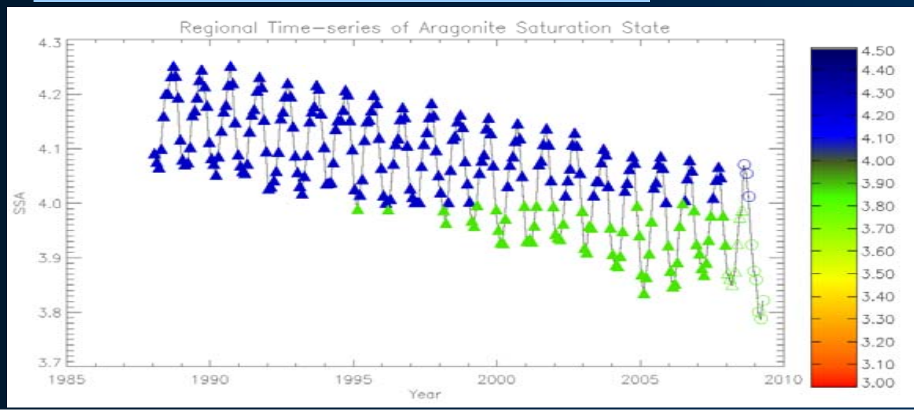
Modeling Products:

- **Bleaching forecasts**
- **Ocean acidification**
- **Hydrodynamic Modeling**
- **Harmful Algal Blooms**
- **Upwelling / productivity changes**
- **Other Ecoforecasting**

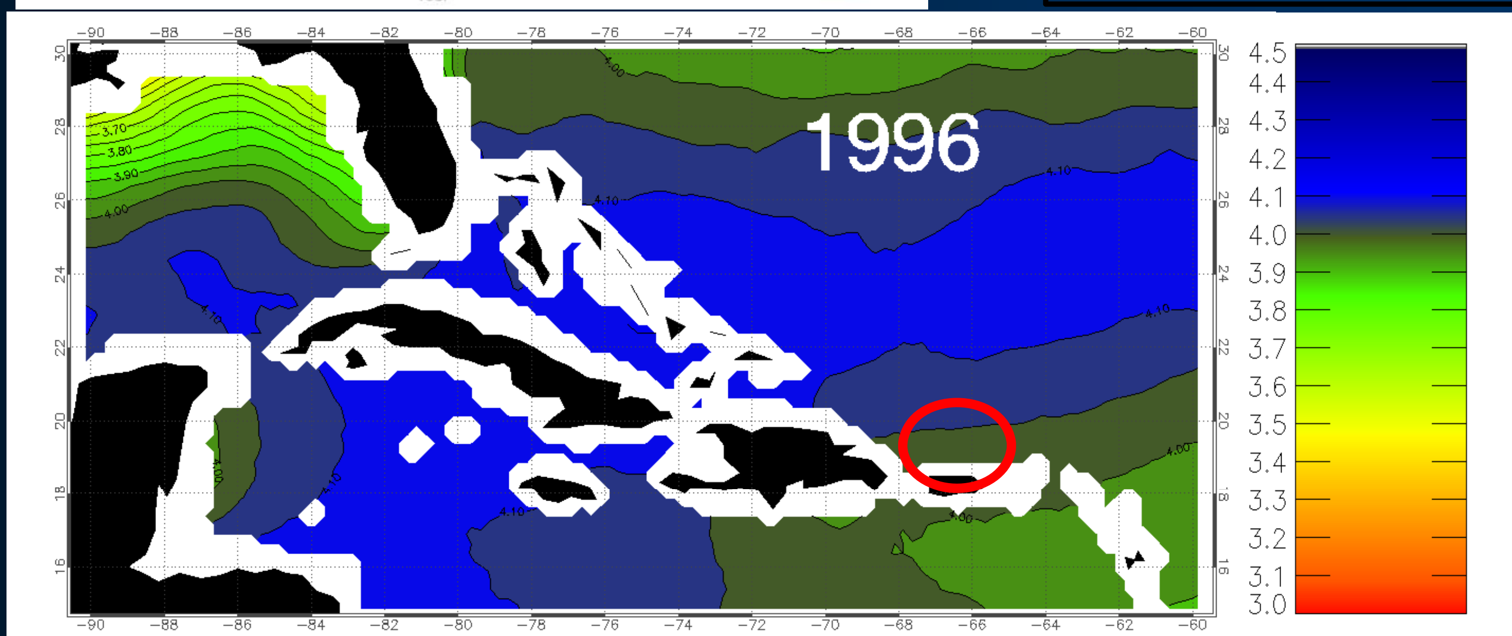
NOAA Capabilities

Capability 4: Modeling

Ocean Acidification:



- Monthly modeled environmental estimates of sea surface carbonate chemistry in the Greater Caribbean.



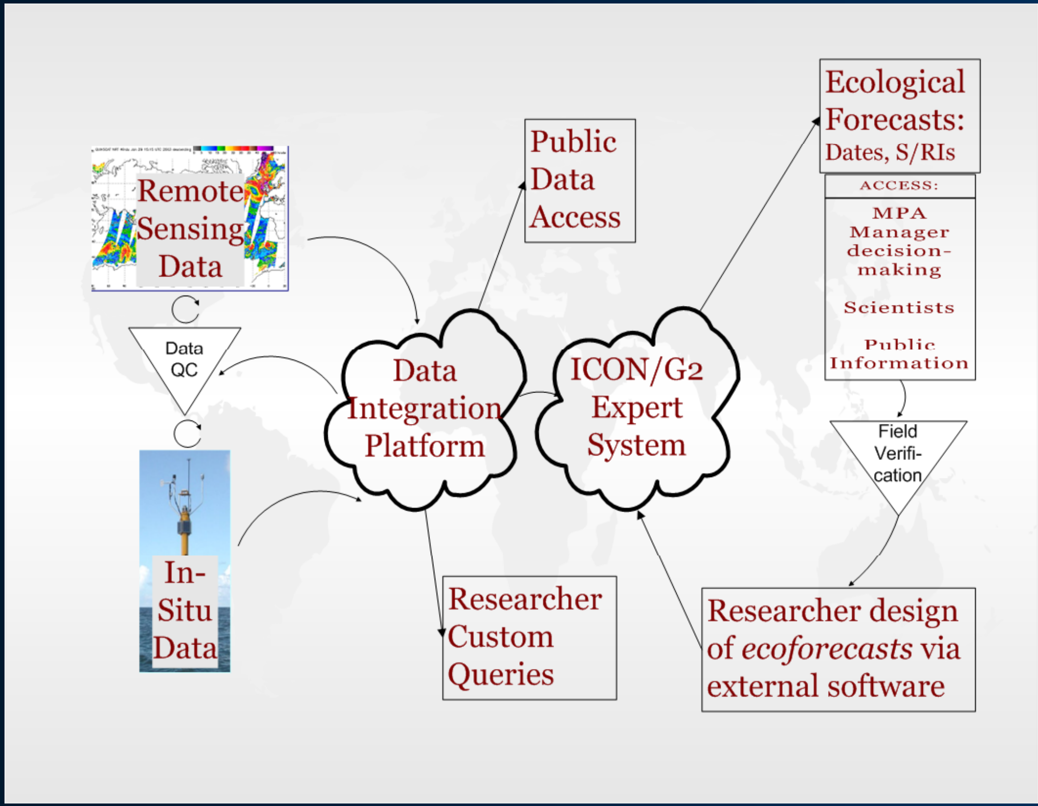
Modeled fields of annual mean aragonite saturation state, Gledhill *et al*. (in press)

NOQA Capabilities

Capability 4: Modeling

Ecoforecasting:

- **ICON/G2 Expert System**



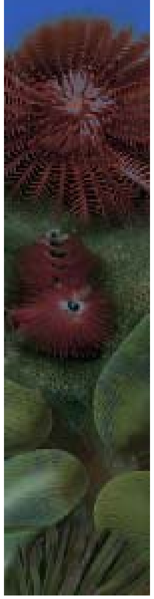
NOAA ICON ecoforecasts use *fuzzy logic* to predict impacts of physical, chemical, biological, and human-induced change on reef ecosystems and their components.

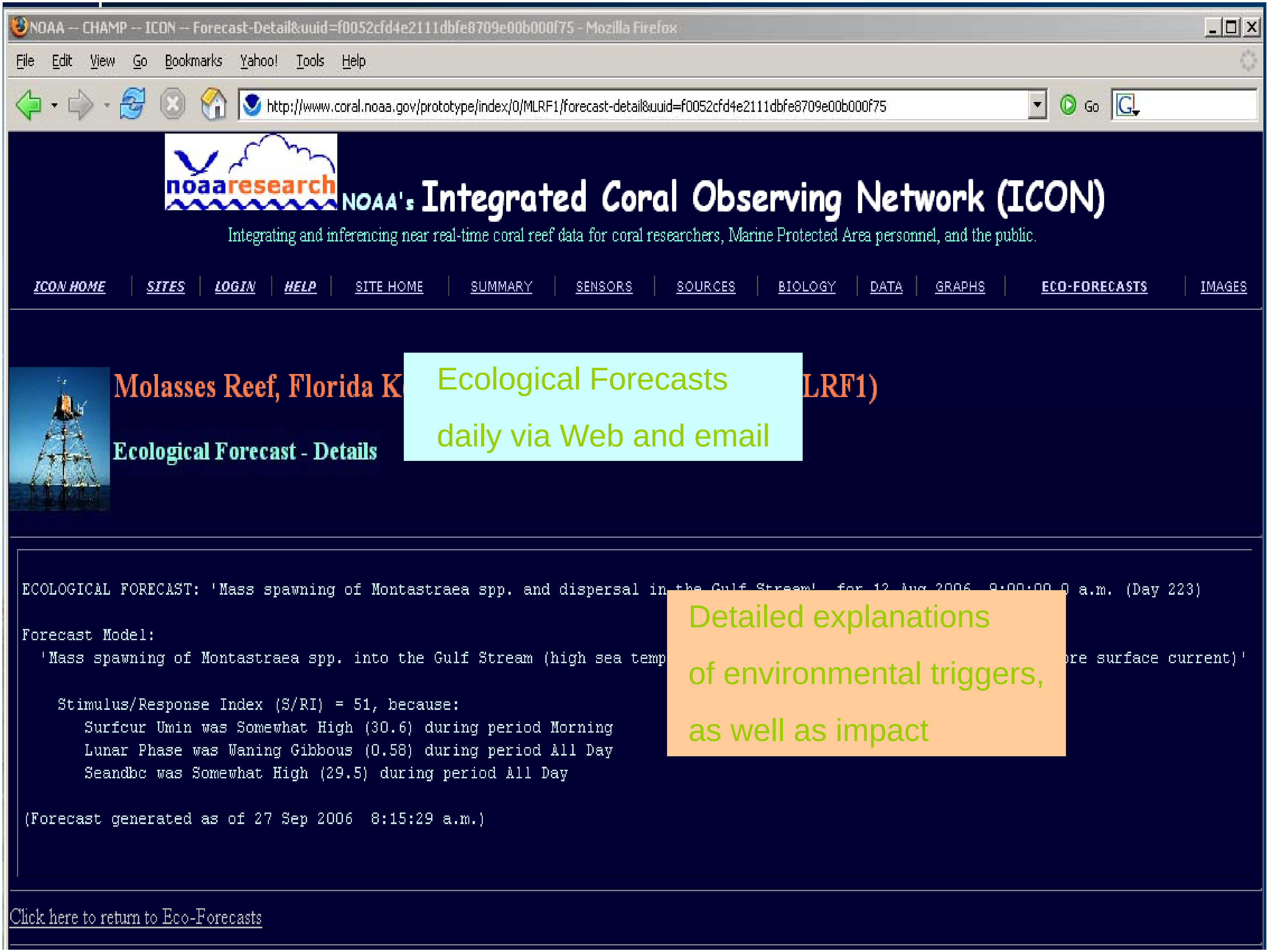
http://ecoforecast.coral.noaa.gov

ICON approach to ecoforecasting

- Environmental sensors are monitored in *near real-time*
- Hourly data or time-series evaluated for ecological significance
- Subjective values assigned for each ecoforecast, each condition
  - "*high*", "*very high*" or "*drastic high*" light for coral stress,
  - "conducive" sea temperature for coral spawning, etc.

- Ecoforecast *alerts* can be triggered by individual conditions…
- …or by multiple conditions that potentiate one another!
- Alerts describe the <u>severity</u> and <u>duration</u> of each condition
  - Stimulus/Response (or stress) index calculated
  - Links provide graphs and maps for key conditions





Ecological Forecasts

daily via Web and email

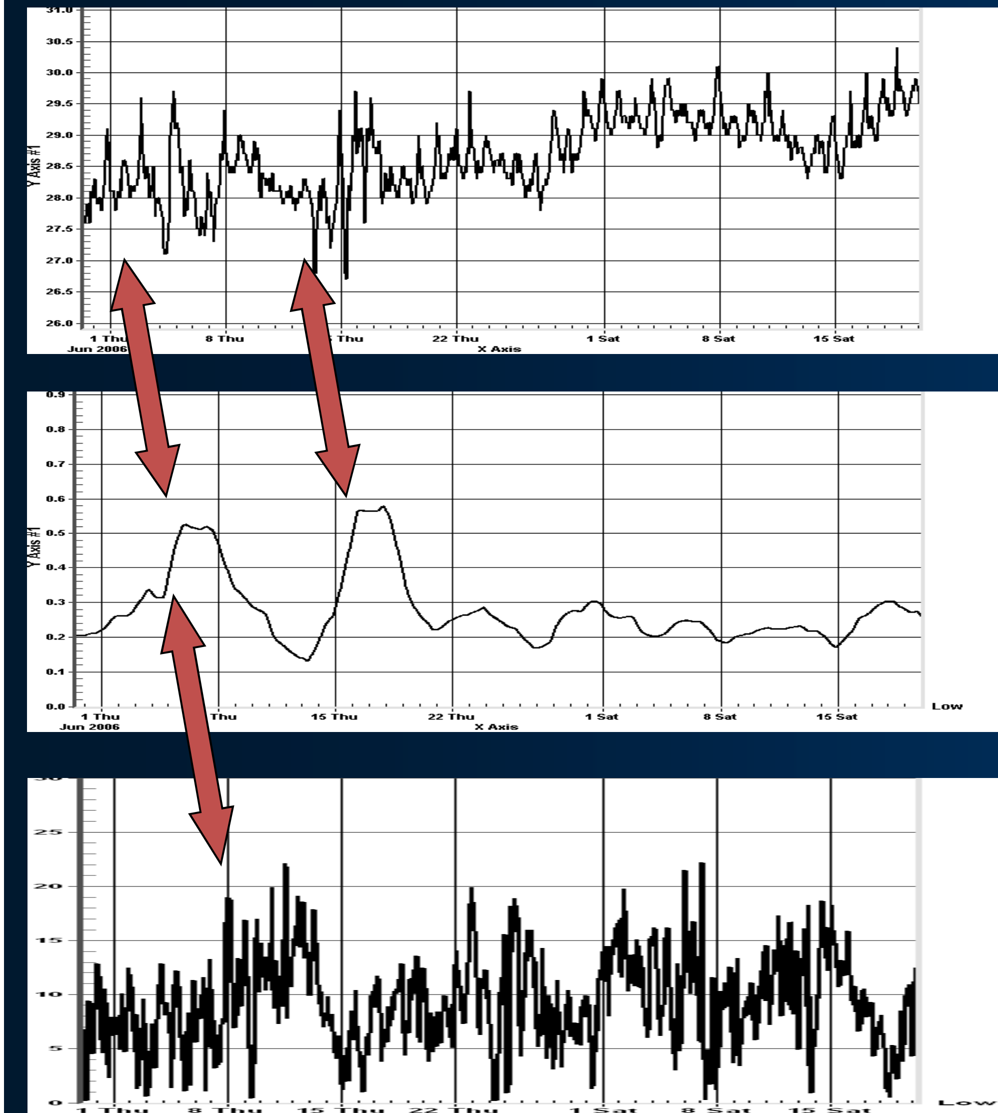
Detailed explanations

of environmental triggers,

as well as impact

NOAA Capabilities

Capability 4: Ecoforecasting



Hourly sea temperature (ºC)

T_{hourly} reported via satellite

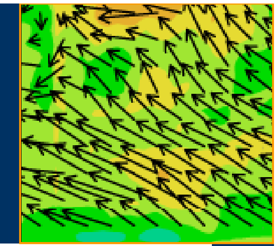
High-frequency T variance

$$T_{var} = \Sigma_{3d} [\sigma_{1d} (T_{hourly})]$$

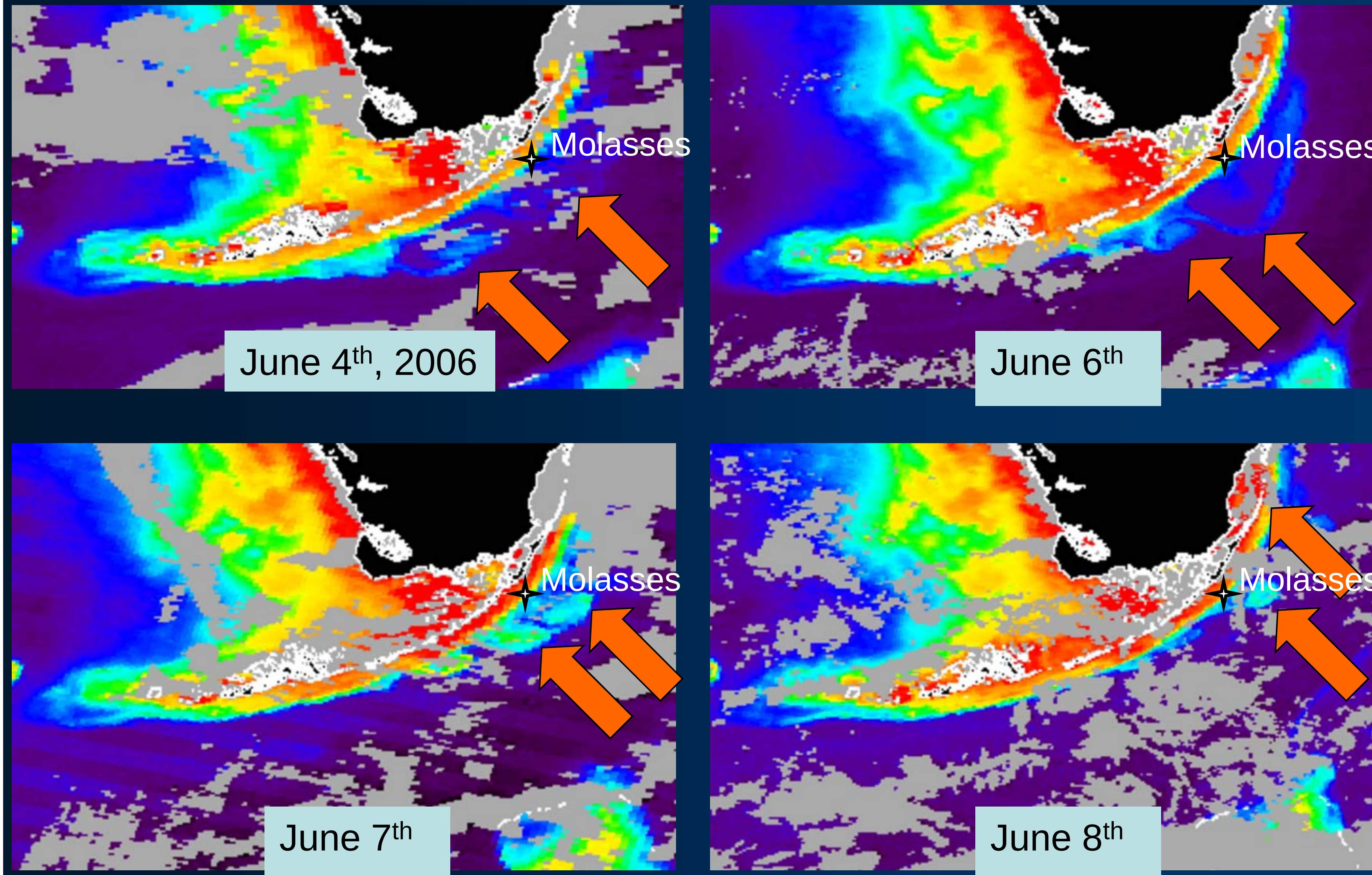
Mean hourly wind (knots)

NB: T_{var} spike *preceded* wind

What is the forcing mechanism?



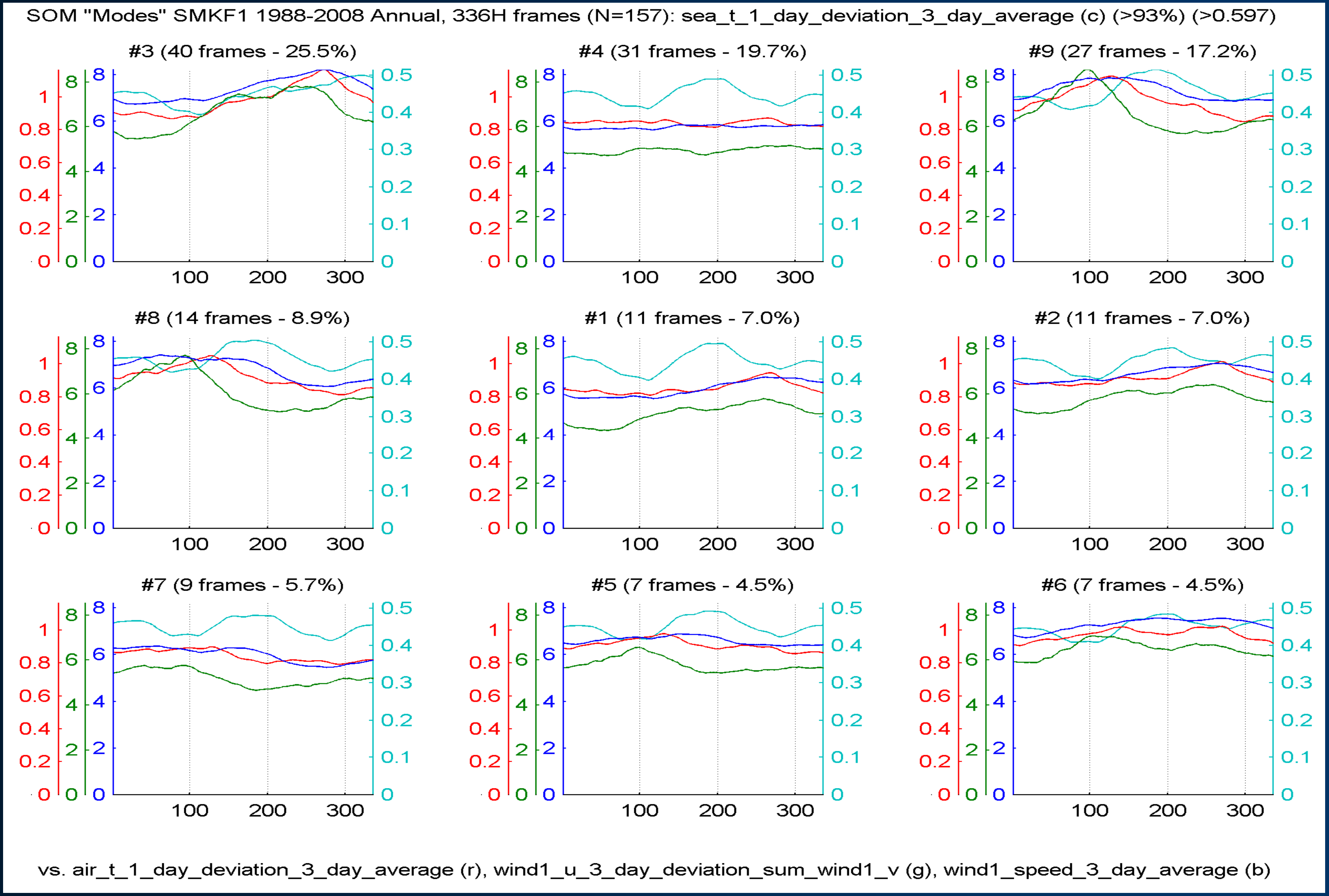
Chlorophyll shows cyclonic circulation



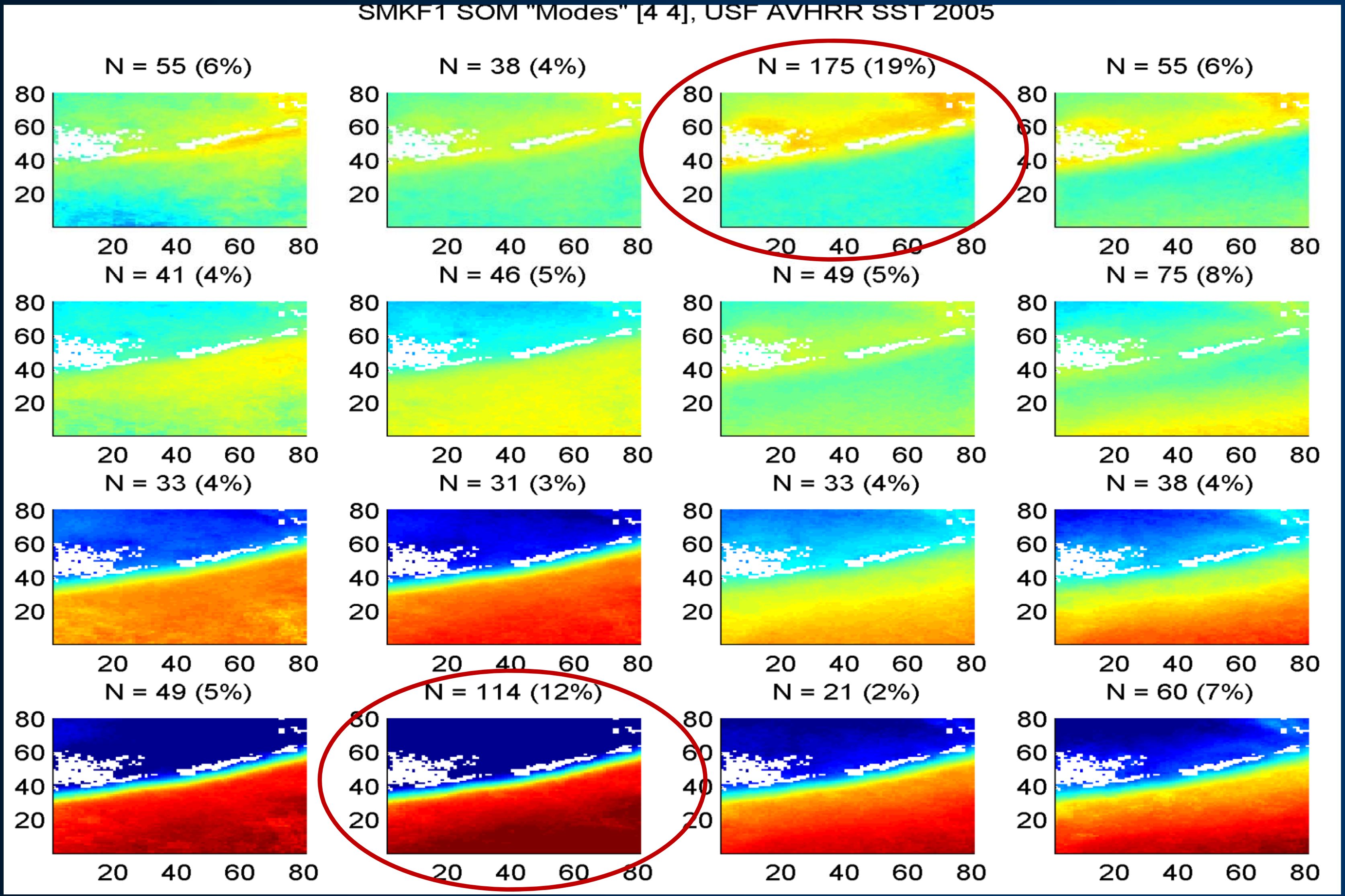
Self-Organizing Maps (SOM)

- A non-linear statistical analysis technique
  - No assumptions about underlying distributions
  - Robust to outliers
- *Unsupervised machine learning* – an Artificial Neural Network ***trained*** to automatically characterize similarities between data vectors
  - Multiple “units” each of same dimension as a data vector; arranged on an (arbitrary-sized) NxM map; initialized at random, or by Principal Components
  - Training: presenting data, one vector at a time to all NxM units; gradually, the set of units organize themselves so similar patterns are adjacent
- Can compare data to SOM units quantitatively – a “Best Matching Unit” is found for each data vector

Extended SOM – *non-linear covariability* between forcing and response (physical, ecosystem)



Spatial SOM of SST fields

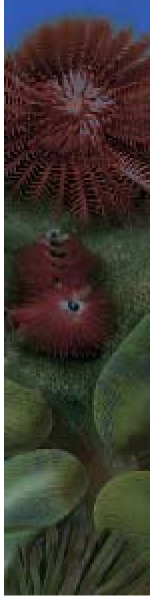


NOAA Capabilities

Coral Reef Monitoring

Challenges:

- **Better integrate data – regional and local; physical, chemical, biological, ecological**
- **Tailor products to management needs**
- **Improved access and more timely delivery**
- **Automate observations**
- **Better serve management**
- **New instruments to address known gaps**
- **Higher space/time-resolution data**
- **More tools for climate change impacts**
- **Model parameterization/validation**



Integrated Coral Observing Network (ICON) project

For more information:

http://ecoforecast.coral.noaa.gov

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Integrated Coral Observing Network (ICON) project

Additional Slides

NOAA Capabilities

Capability 1: *In situ* Instrumentation

Caribbean ICON/CREWS Sites (current, proposed):

Capability 1: *In situ* Instrumentation

Management Requests:

- ✓ Near-real-time monitoring (FL) – CREWS/ICON
- ✓ Currents for larval transport and connectivity (Region) – Drifters/ODP/CM
- ✓ Ocean acidification – MAPCO2 (Region)
- Regional Integration (Region) – CariCOOS and other Regional OOSes
- Continue reef SST monitoring (FL) – FKNMS
- Nearshore salinity (FL)
- Currents and waves for LBSP (PR, USVI)

Satellite and Model Initiation/Validation

NOAA Capabilities

Capability 2: Ship-based Monitoring

Atlantic/Caribbean Oceanographic Cruises

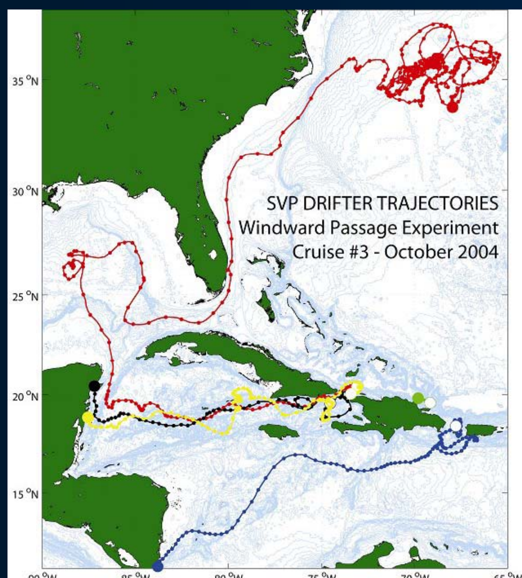
Region	Project	06	07	08	09	10 ?
Caribbean	Reef fish/Larval Fish (NMFS)		x		x	x
GOM	Reef fish survey (NMFS)	x	x	x	x	x
GOM	Flower Garden Banks NMS (NOS)	x	x	x		x
GOM	Deep coral (NMFS)					x
FL	Pulley Ridge reef fish (NMFS)				x	x
FL	Florida Keys NMS (NOS)	x	x	x	x	
FL	Tortugas Ecological Reserve (NOS)		x	x	x	x
FL	Oculina Banks (NMFS)			x		
FL	FACE (OAR)		x	x		x
FL	Benthic habitat mapping (NOS)					x
PR/USVI	Benthic habitat mapping (NOS)	x	x	x	x	x (FL)
PR/USVI	Ocean Obs/fish larvae (OAR, NMFS)		x	x	x	x
PR/USVI	Reef fish recruitment (NMFS)					
PR	Vieques seagrass & coral (NOS)	x	x	x		
Navassa	Navassa NWR (NMFS, NOS)	x			x	

NOAA Capabilities

Capability 2: Ship-based Monitoring

Management Requests:

- ✓ **Currents for connectivity (USVI)**
- ✓ **Currents and waves for LBSP (PR, USVI)**
- **See *in situ* list**

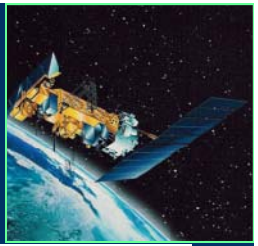


Larval drift around Caribbean

Caribbean CO_2

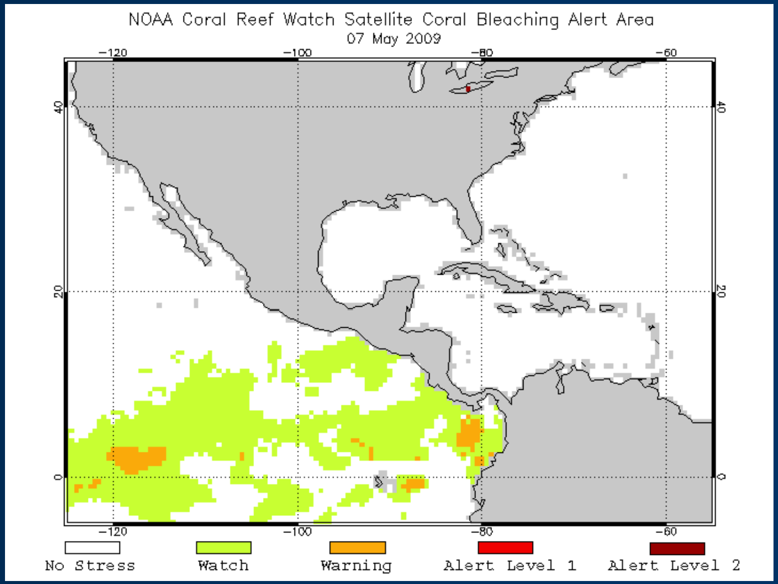
NOAA Capabilities

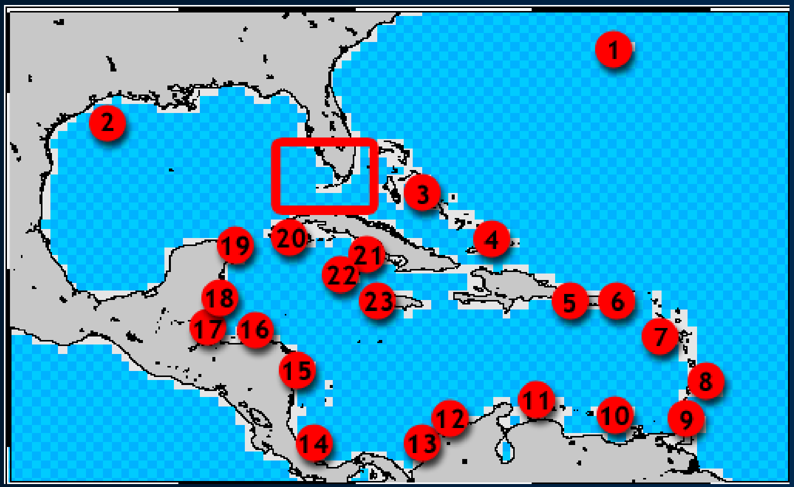
Capability 3: Satellite Monitoring

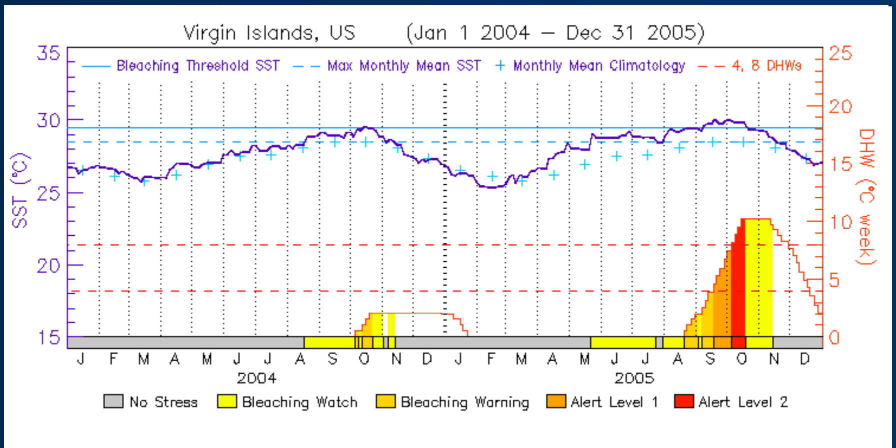


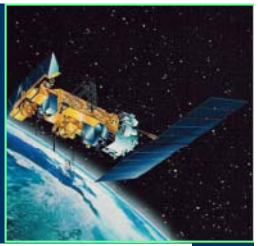
SST-Based Products:

- Coral bleaching nowcasts
- Satellite Bleaching Alerts
- Virtual Stations
- Near-real-time data
- Long-term data



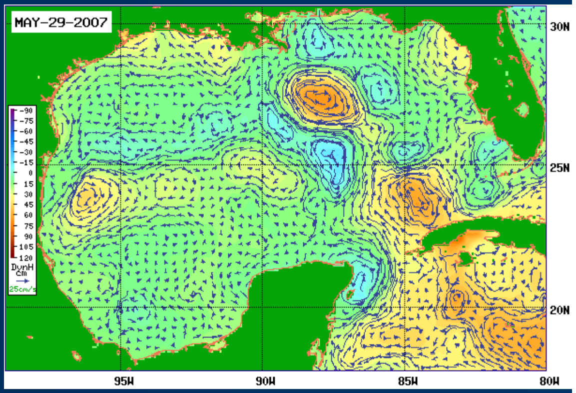






NOAA Capabilities

Capability 3: Satellite Monitoring

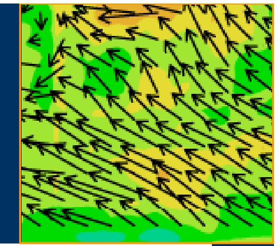


Management Requests:

- ✓ Circulation for:
  - Nearshore processes
  - Connectivity
- ✓ Coastal chlorophyll
- ✓ Bleaching prediction & follow-up
- ✓ Nearshore & higher resolution SST
- ✓ Ocean acidification

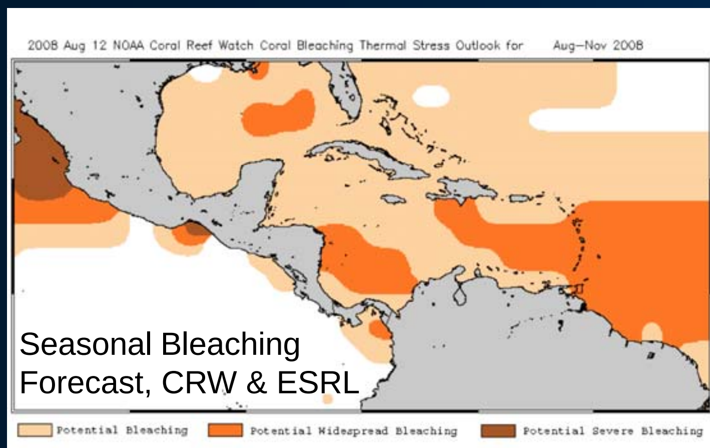
NOAA Capabilities

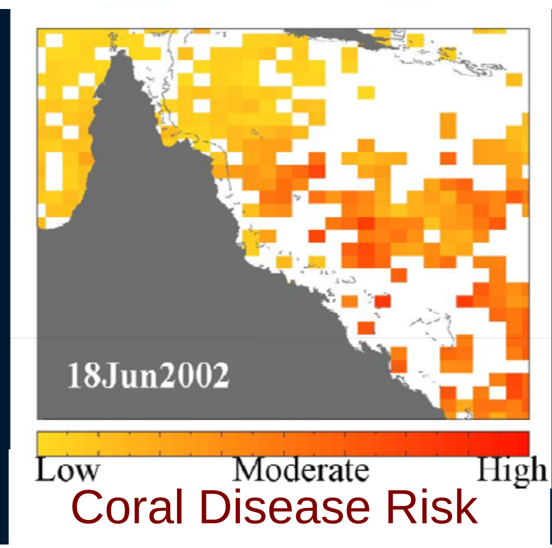
Capability 4: Modeling



Thermal Stress:

Bleaching and disease forecasts





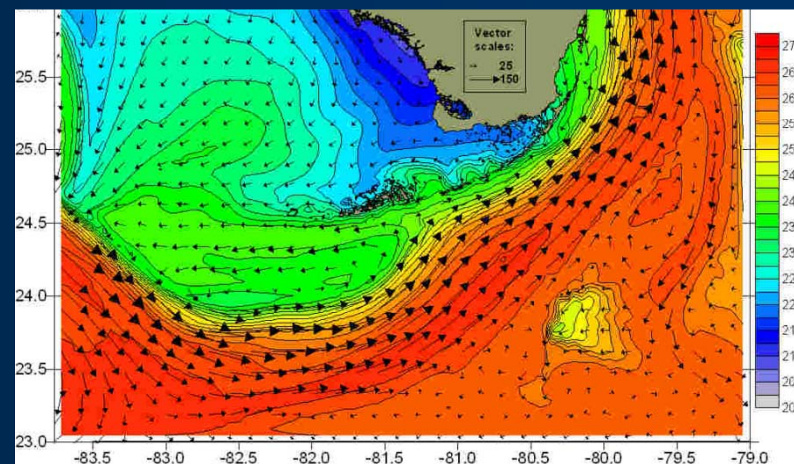
- **A tropical coral bleaching outlook system**
- **NOAA ESRL SST model**
- **Forecast regions of potential thermal stress from one-week to four months**
- **SST-based Disease outbreak potential**

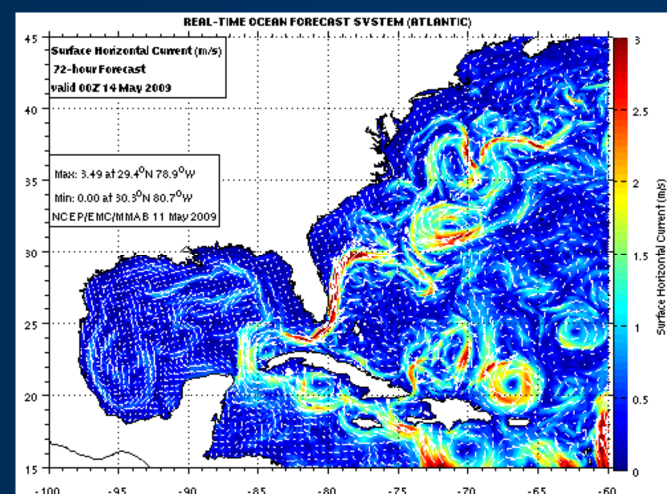
NOAA Capabilities

Capability 4: Modeling

Hydrodynamic Modeling:

- **Multiple scales: bay to basin**
- **Existing examples: S FL HYCOM, PR/USVI ROMS, RTOFS**

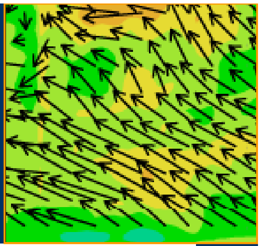




NOAA Environmental Modeling Center Real-Time Ocean Forecast System (Atlantic)

NOAA Capabilities

Capability 4: Modeling



Management Requests:

- ✓ **Bleaching event prediction (Region) - CRW**
- ✓ **Ocean acidification (Region) – CRW/AOML/UPRM**
- ✓ **HAB/Black water events (FL) – NCCOS**
- **Larval transport/recruitment (USVI)**
- **Sea level rise (PR,FL) – Climate & Coastal Program**
- **Near-shore currents for LBSP (PR, USVI)**

NOAA Capabilities

Physical and Chemical Monitoring

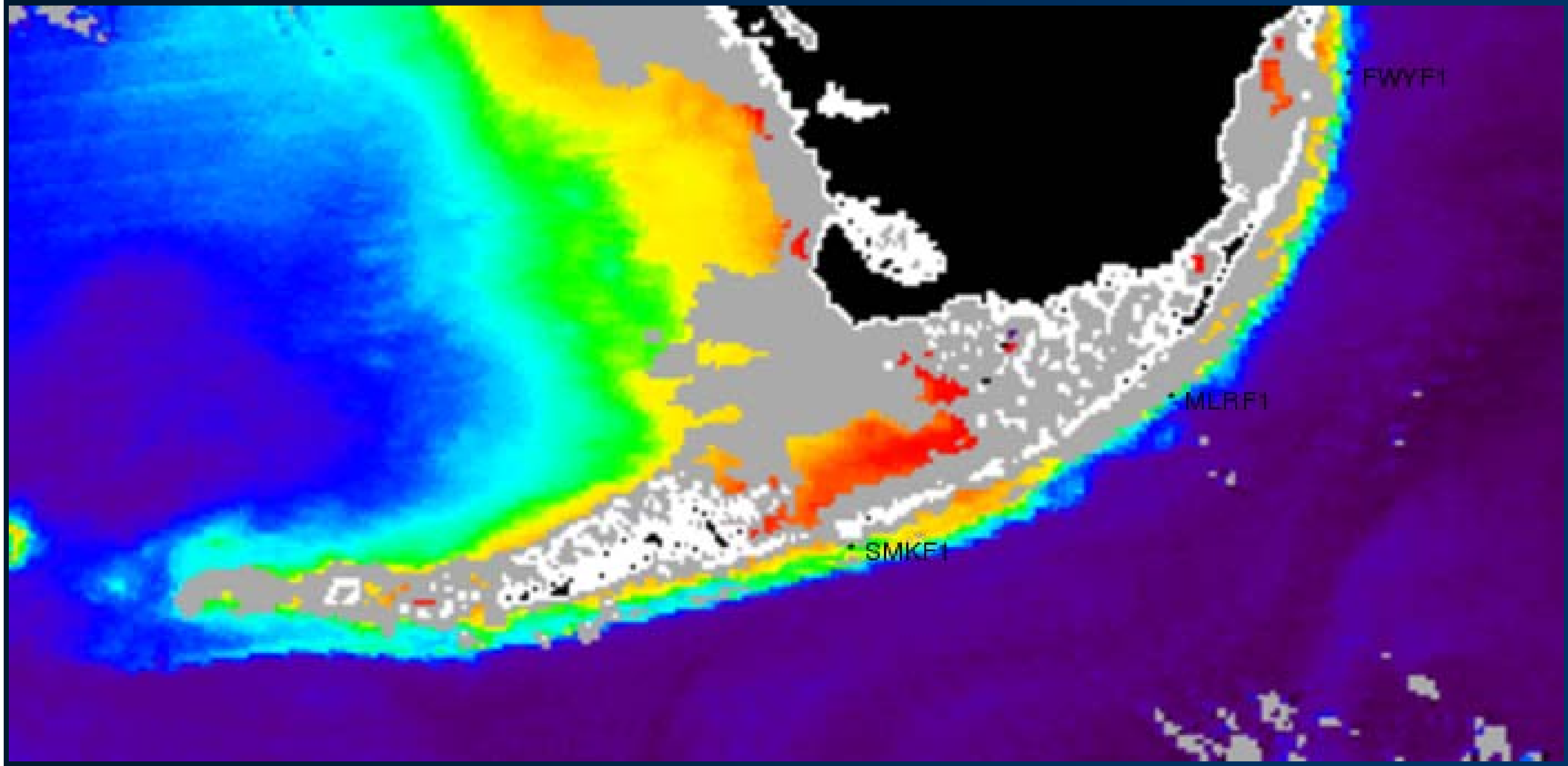
Future Directions – Underway:

- Light and temperature from satellites
- Bleaching and disease prediction
- Higher resolution data
- Standard systems for data access/analysis
- Training for data use and application
- Atlantic OA Test-bed, La Parguera, PR

Future Directions – Down the Road:

- Quantitative water quality and turbidity from satellites
- Ocean Acidification Monitoring Network

SME “street” – 2005 083



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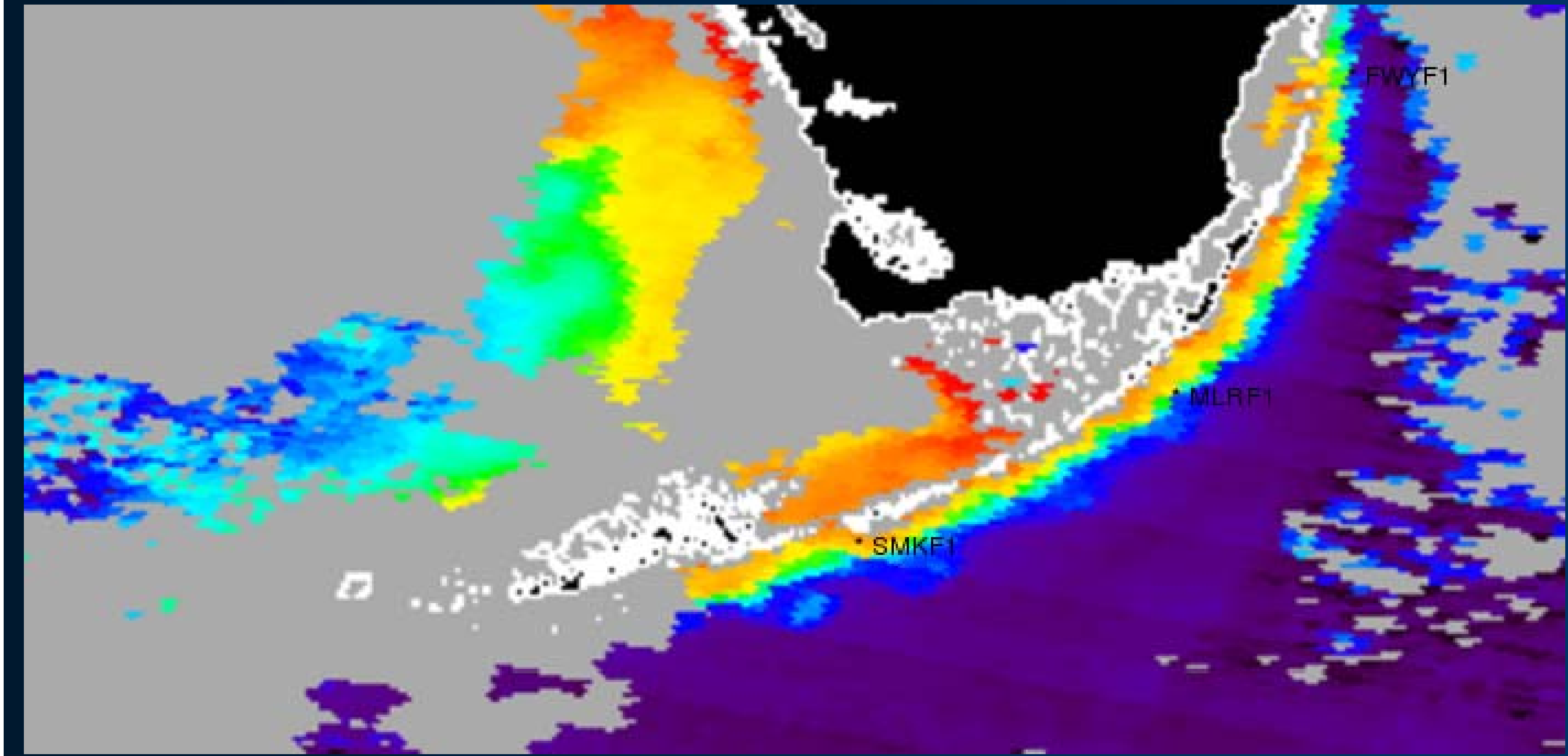

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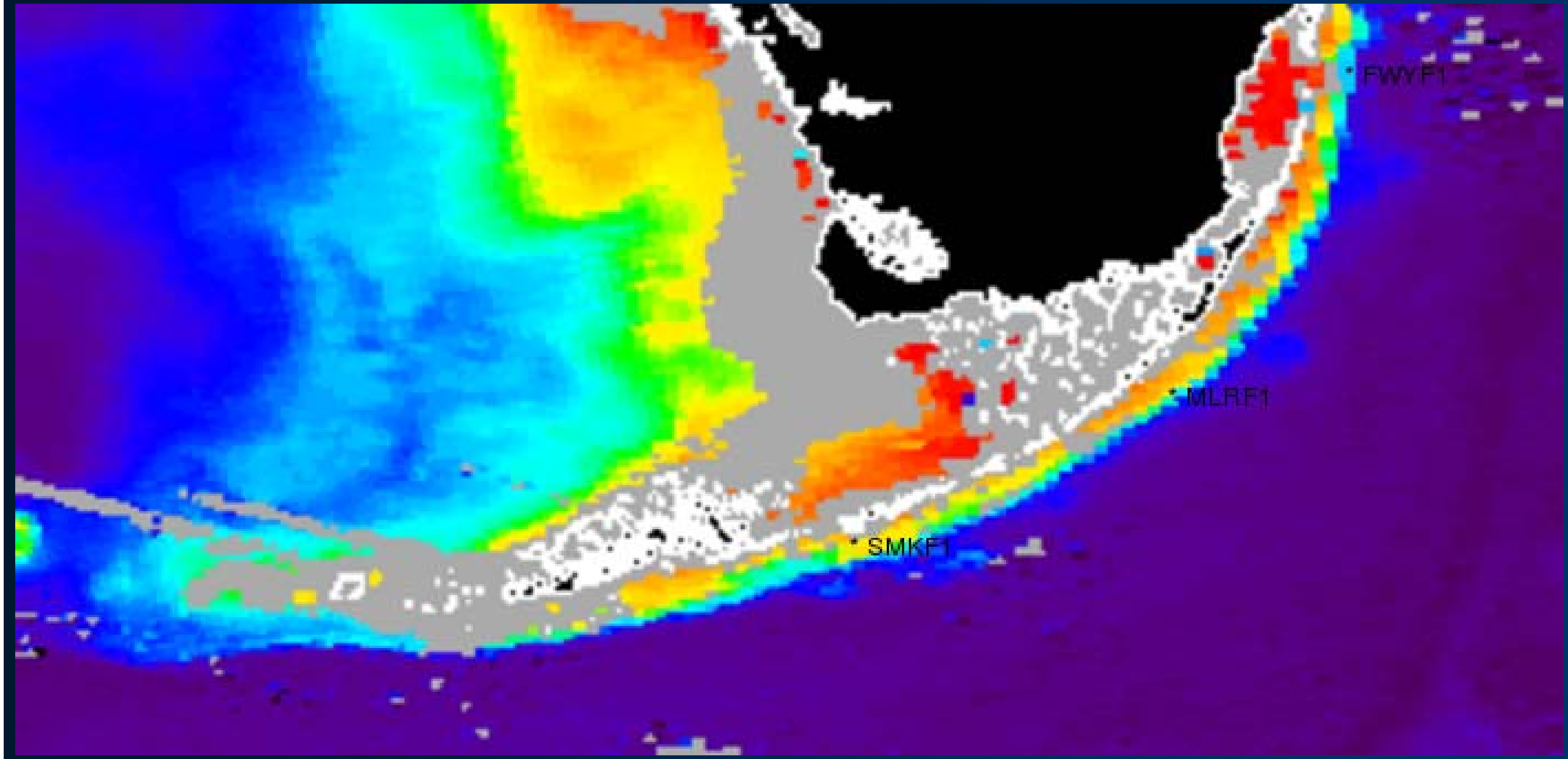

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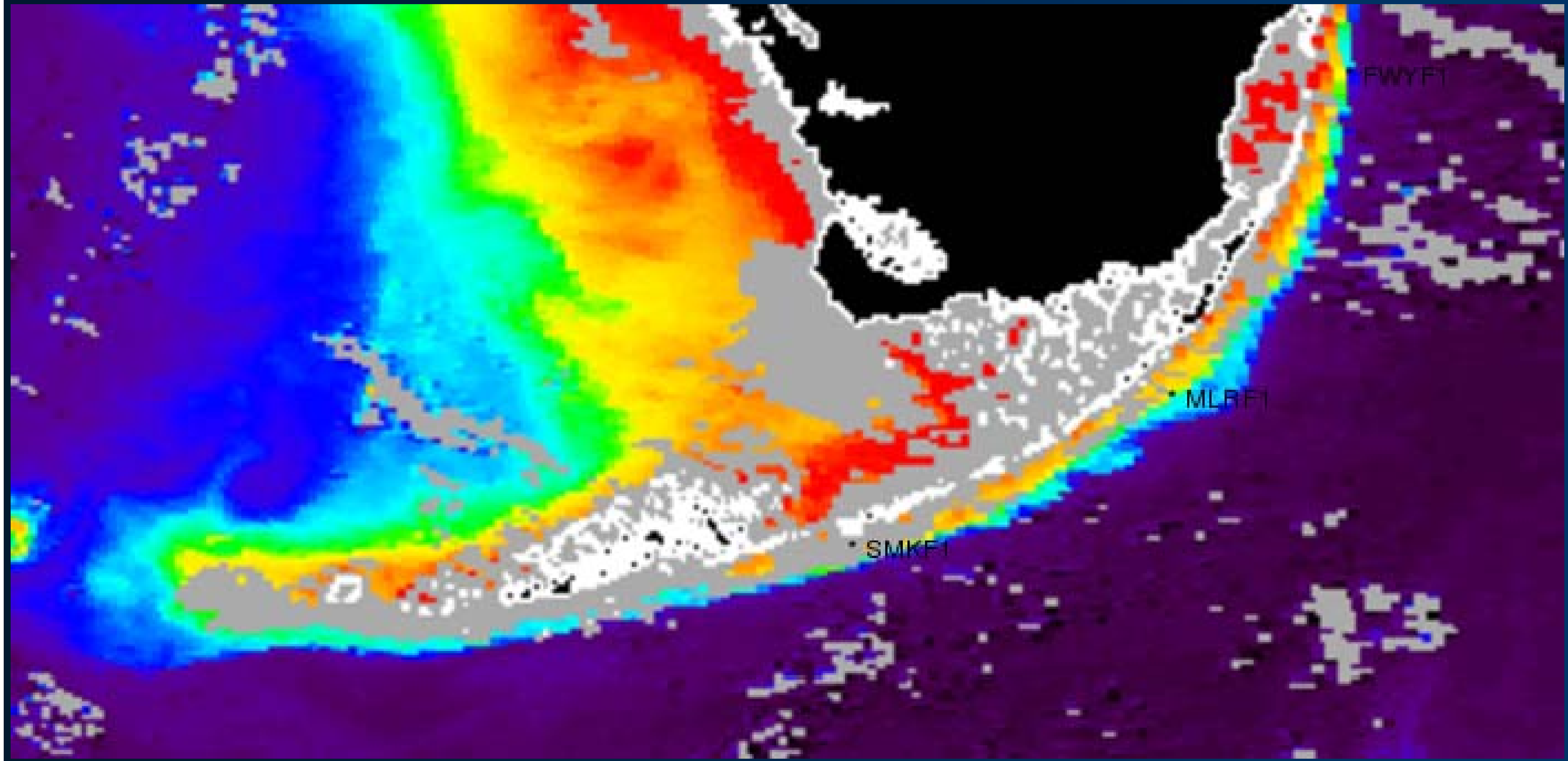

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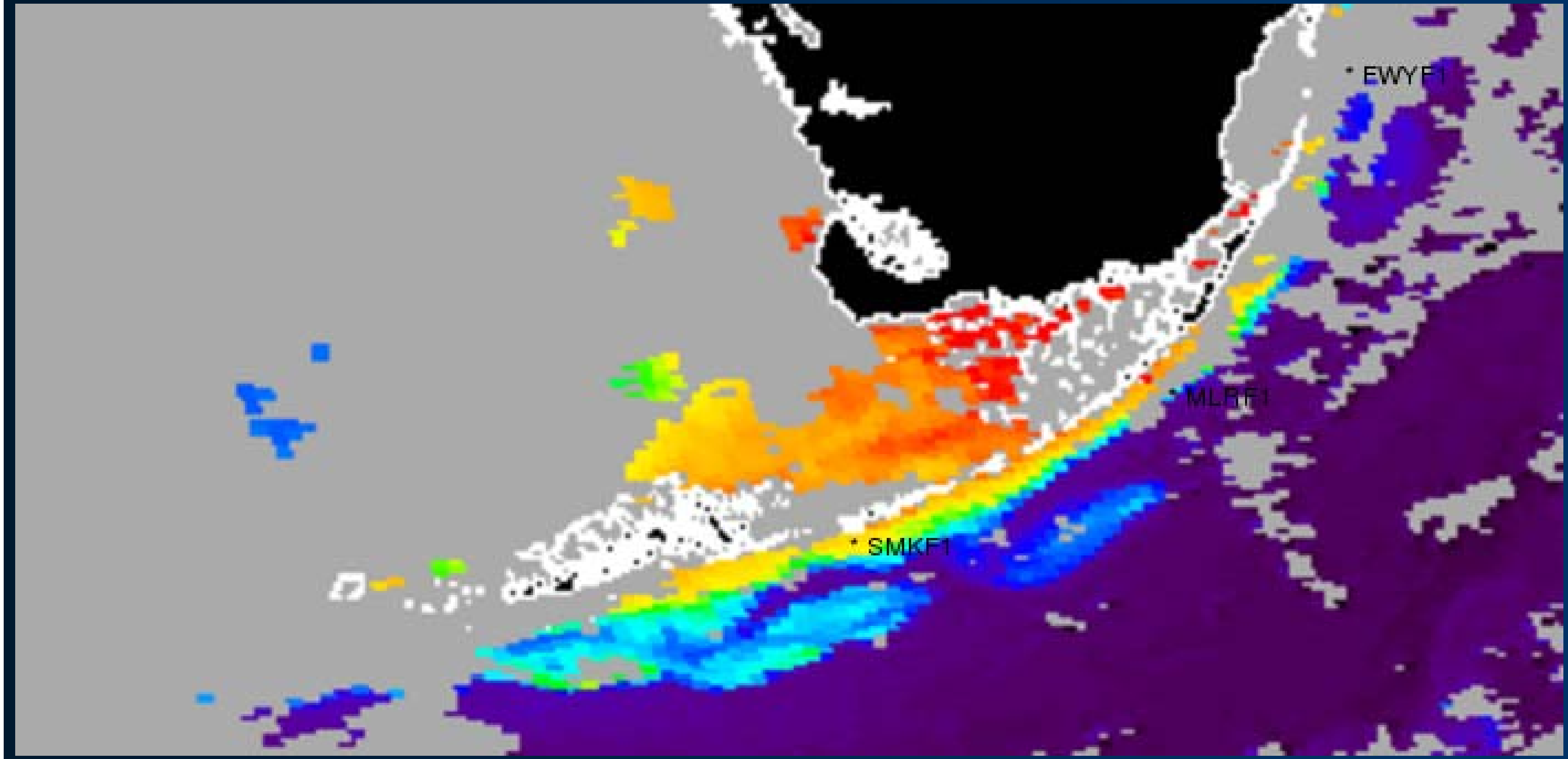
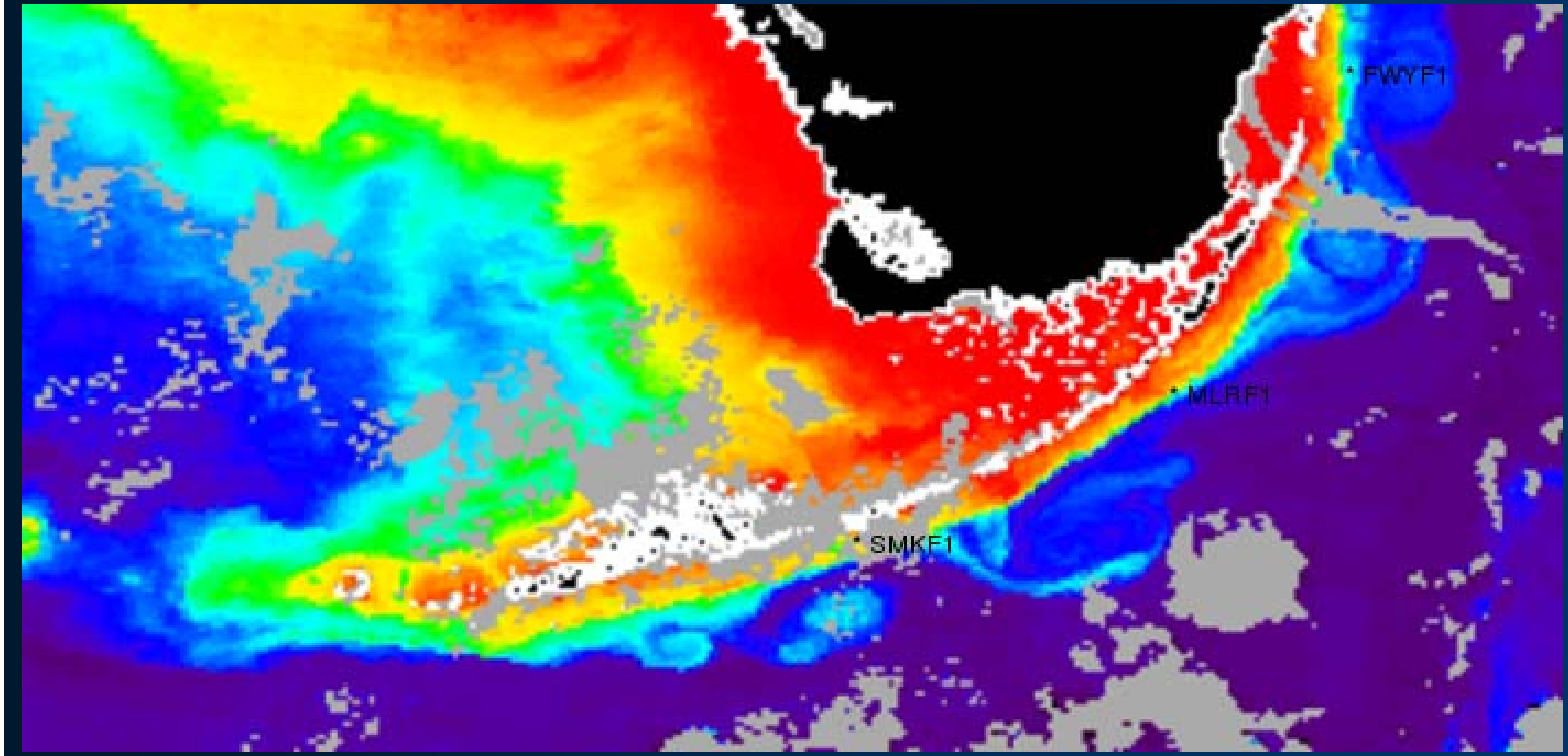


Magnificent – 2005 244



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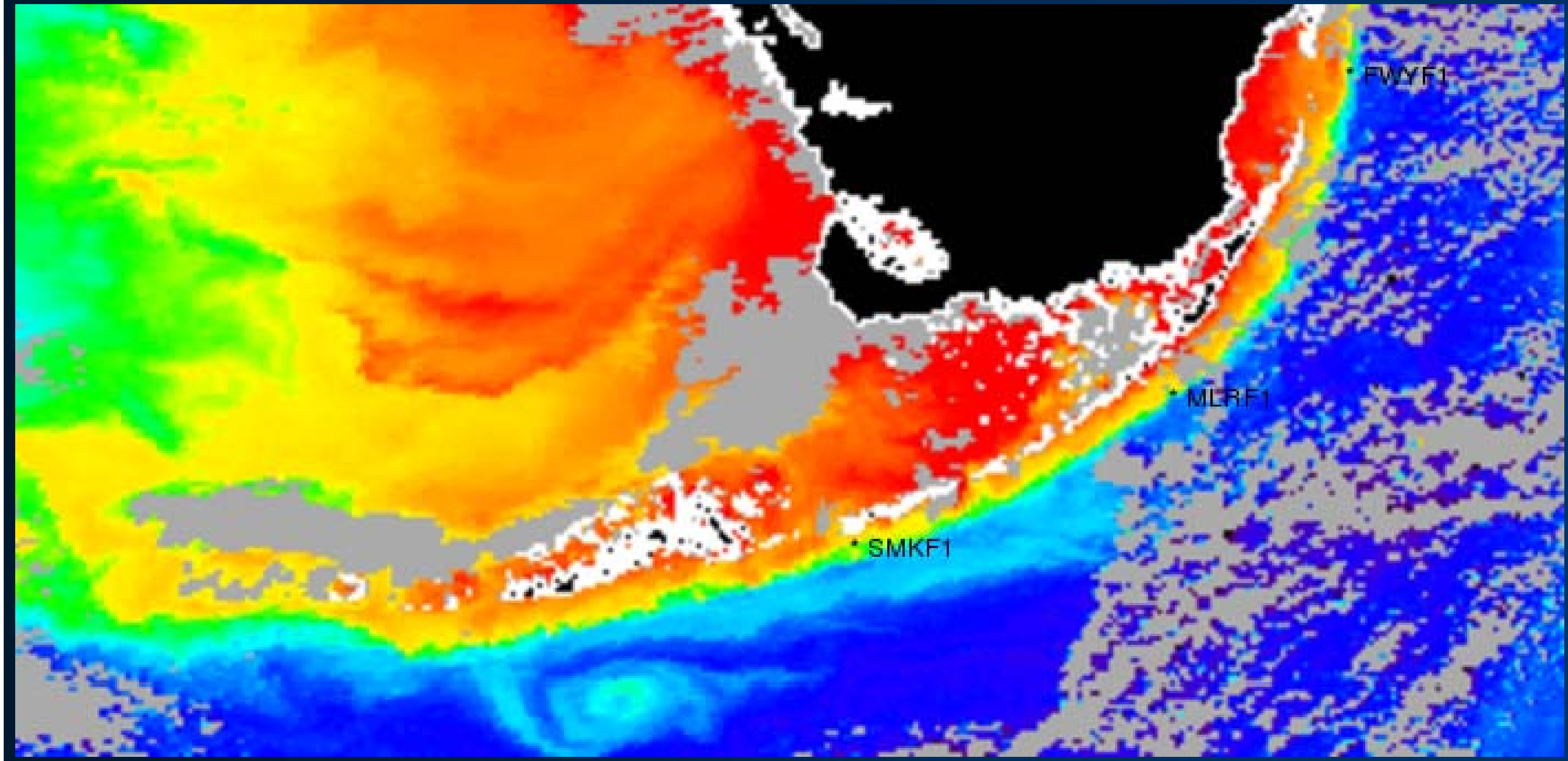

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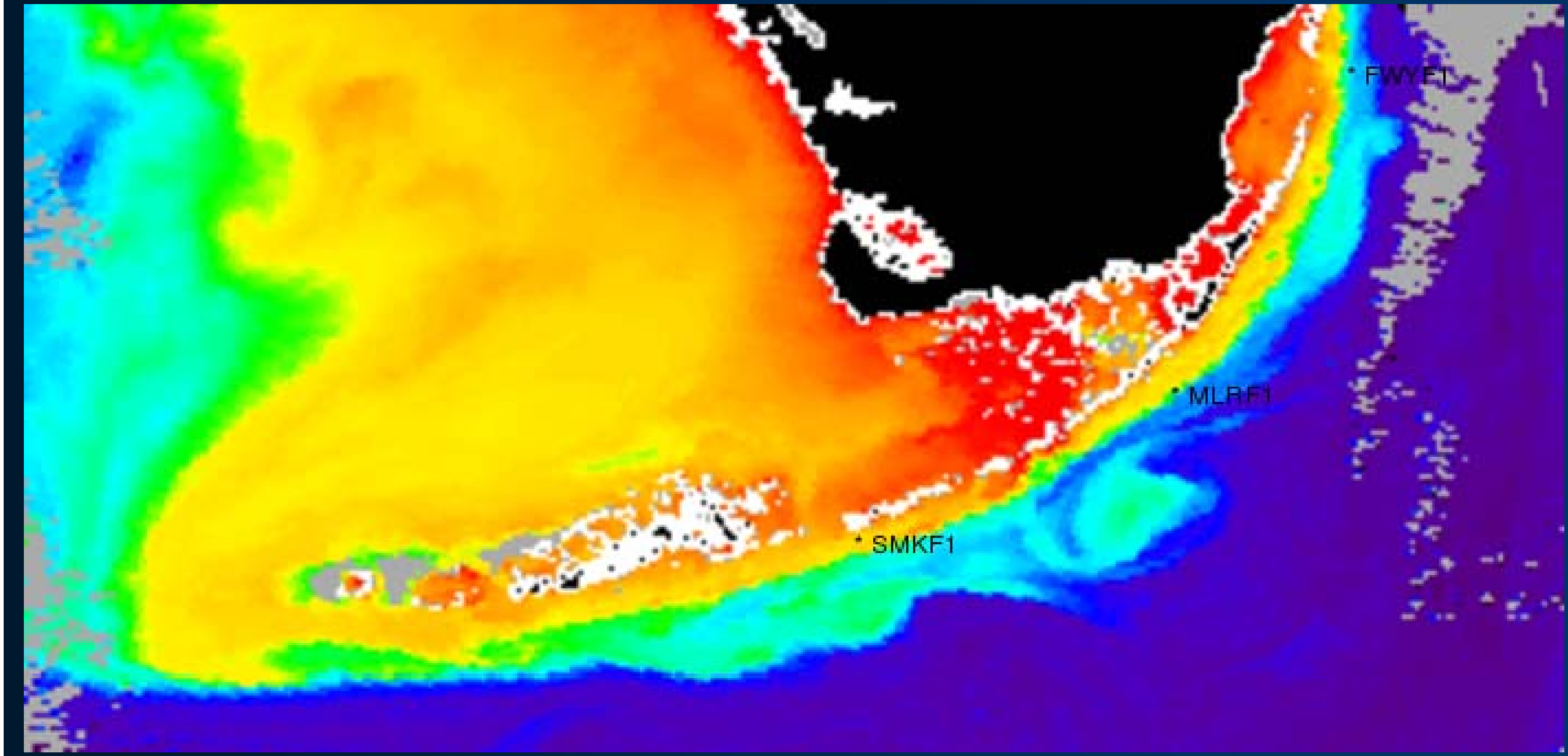
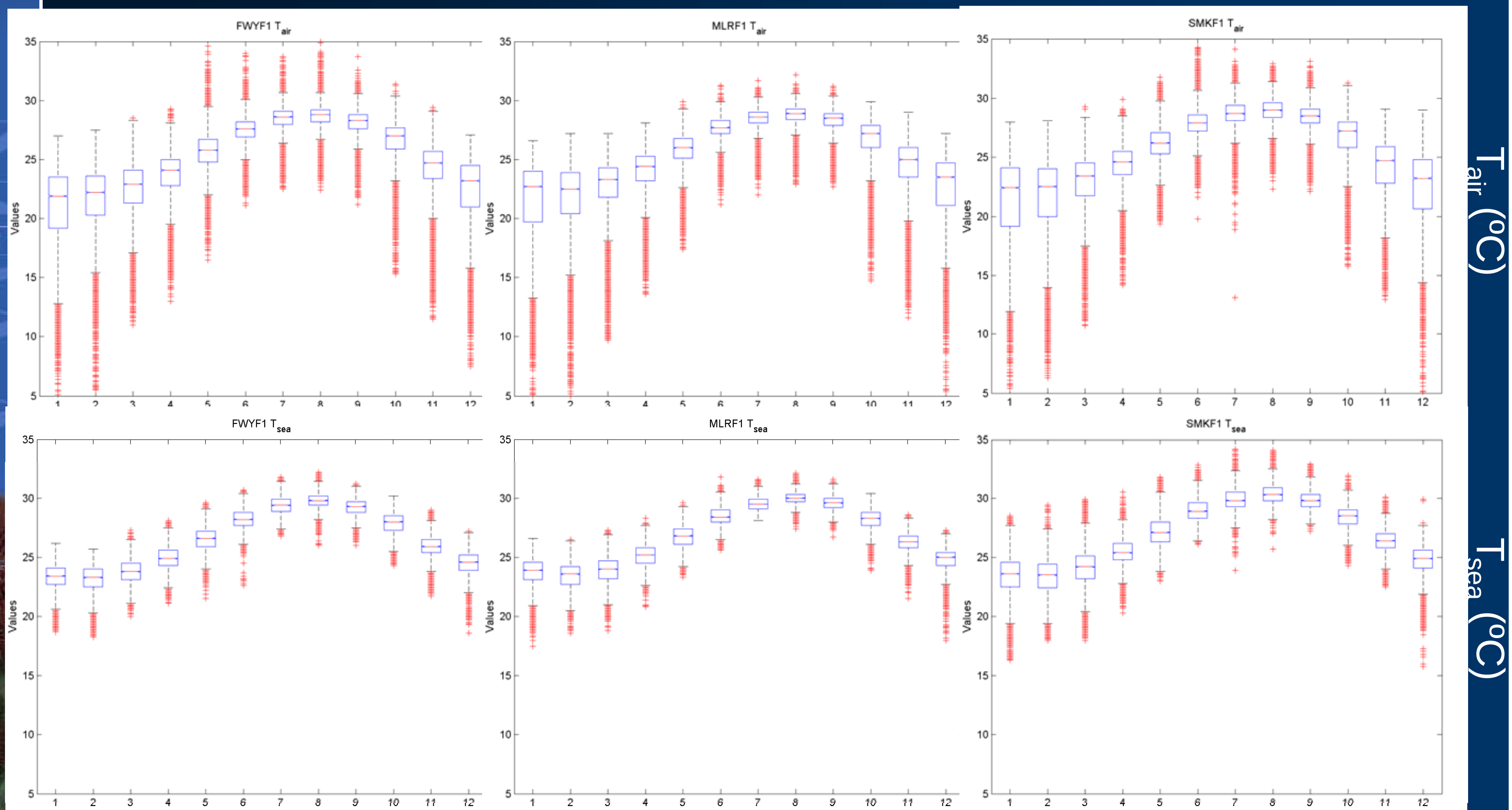


In situ data – T_{air}, T_{sea} seasonal

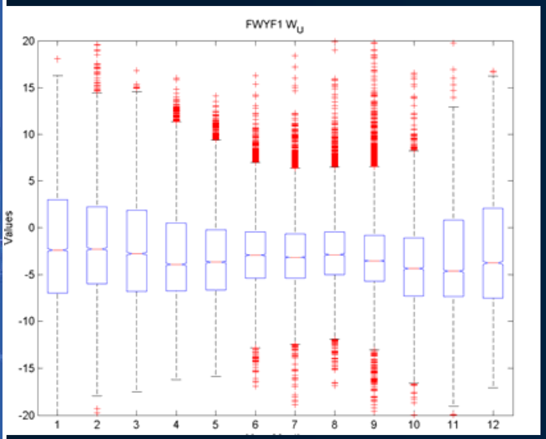


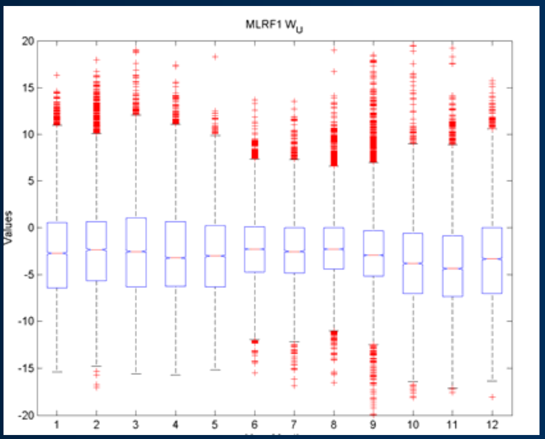
Fowey Rocks

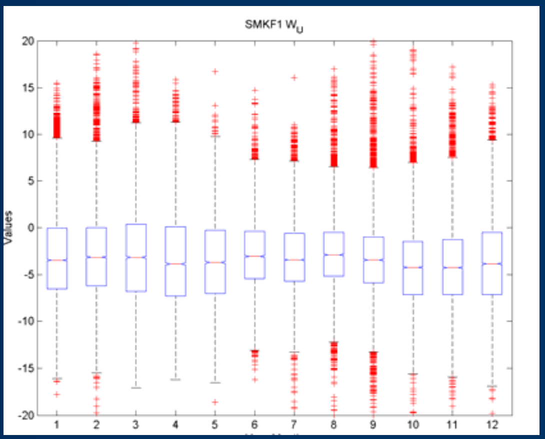
Molasses Reef

Sombrero Key

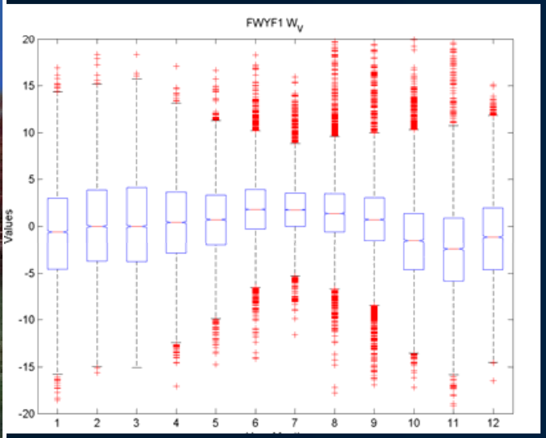
In situ wind - seasonal W_U, W_V

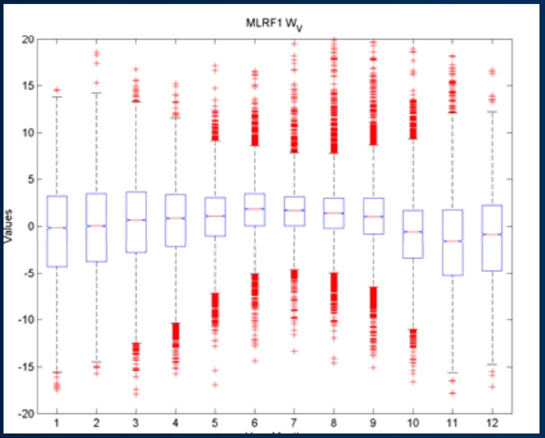


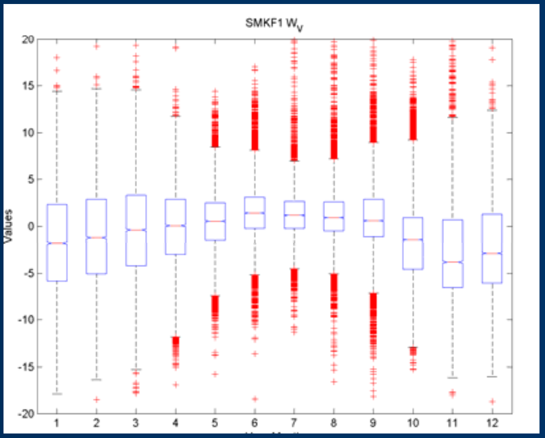




W_U (m/s)







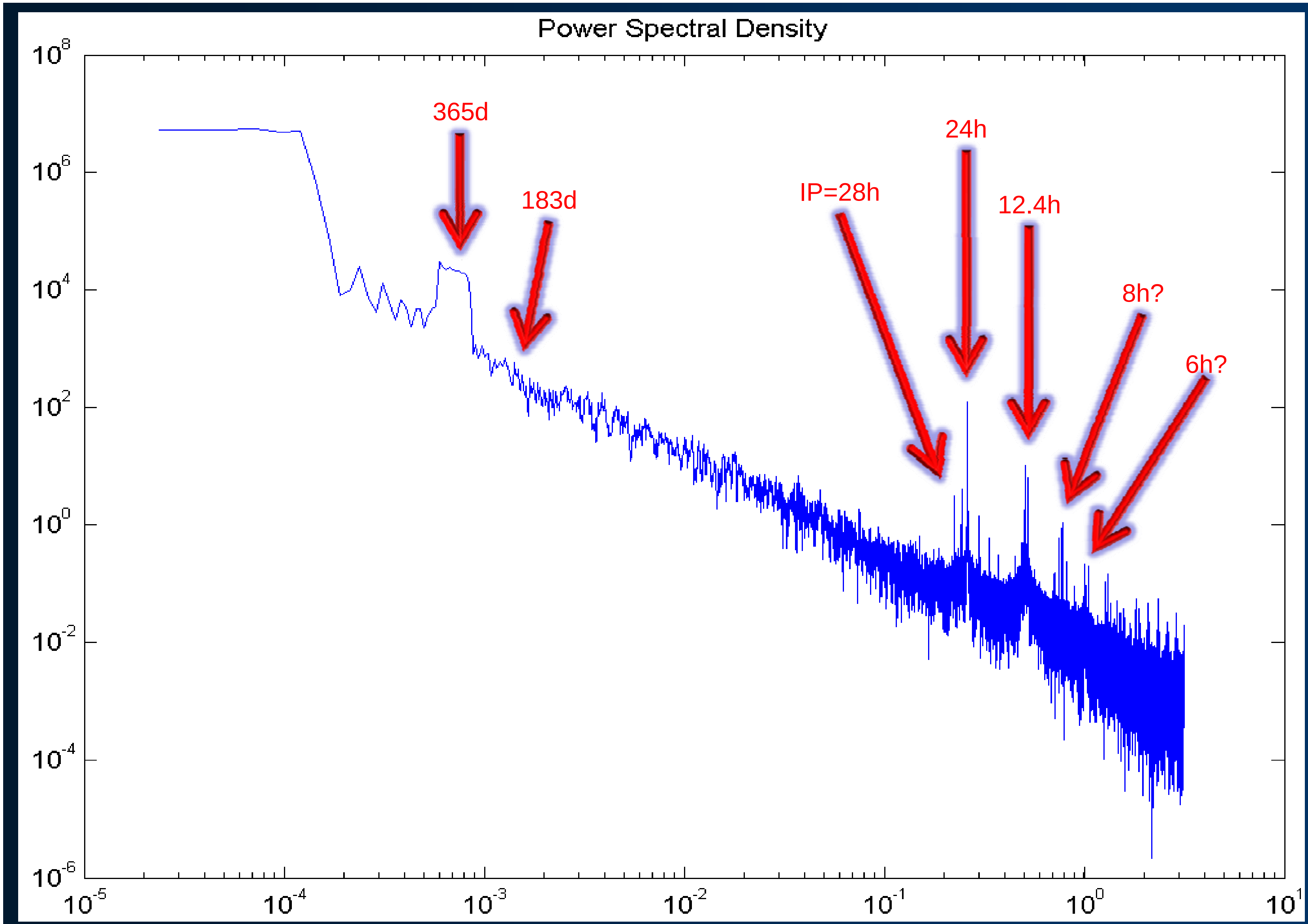
W_V (m/s)

Fowey Rocks

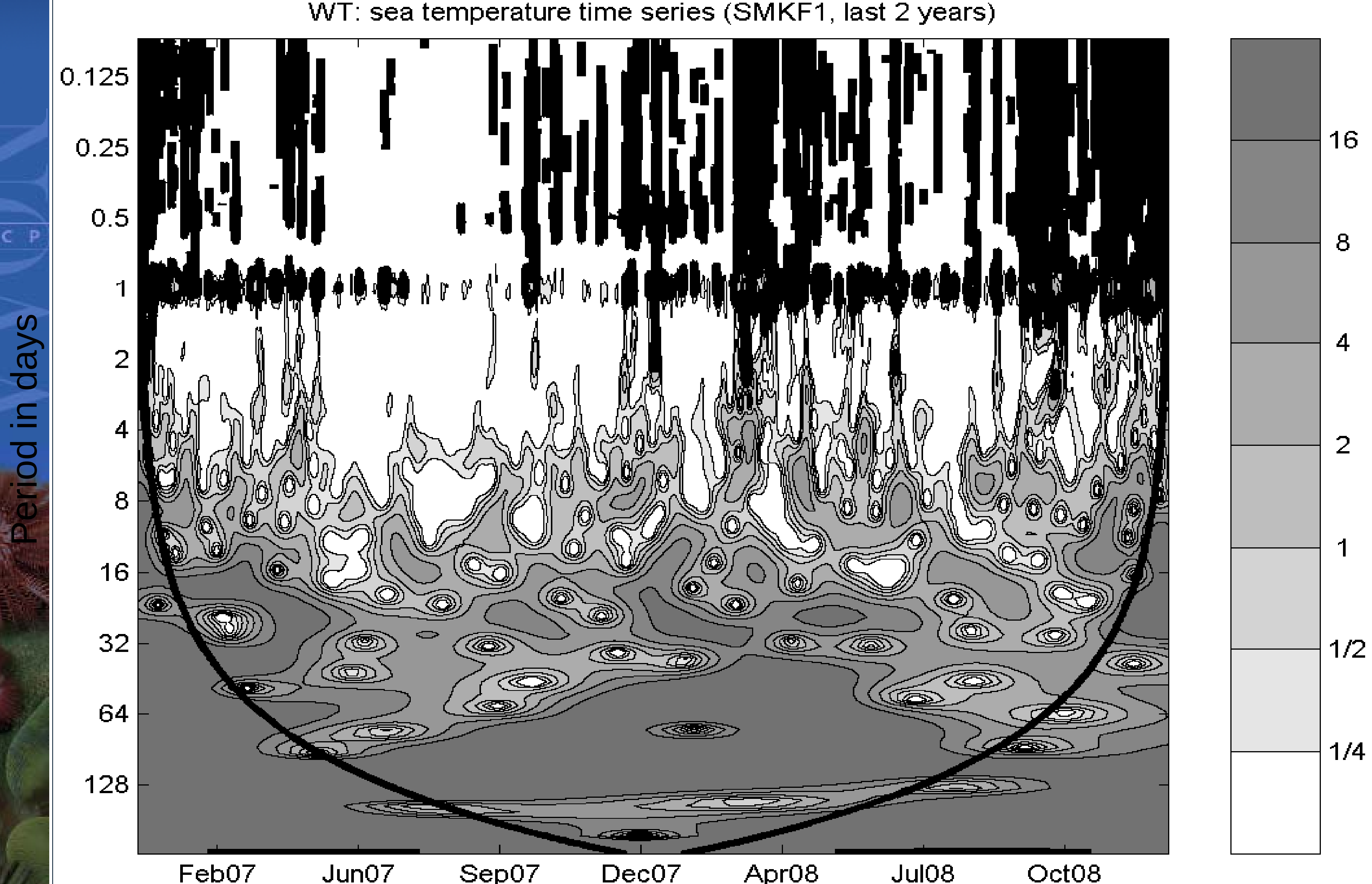
Molasses Reef

Sombrero Key

In situ cycles (Sombrero Reef)



Time-dependent spectrum



Extended PCA – *covariability* between possible forcing and coastal ocean response