The Field Research Facility, Duck, NC

Warming Ocean Observations and Forecast of Effects

- A potential consequence of a warming ocean is more frequent and more intense wind events (Hurricanes & Typhoons)

- Ocean waves are caused by winds

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US Army Corps of Engineers
BUILDING STRONG®

Field Research Facility, Duck, North Carolina

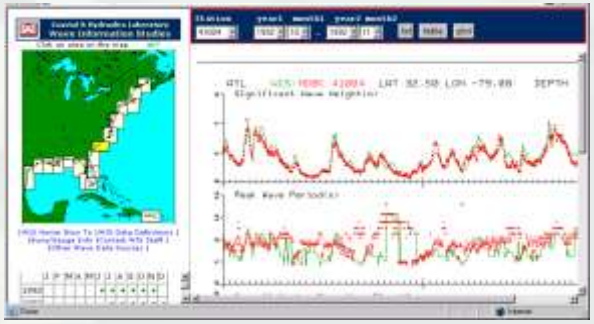
Advancing Coastal Knowledge through Observation, since 1977

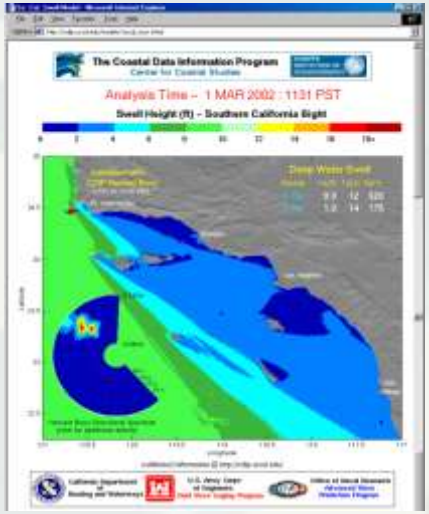
http://frf.usace.army.mil

- **Waves**
  - multiple depths, high resolution
- **Tides**
  - Primary NOAA tide station,
- **Weather**
- **Currents**
- **Morphology**
  - surveys, video

Coastal Field Data Collection Program

- National Wave Observations
  - Coastal Data Information Program
    - Cooperative with Scripps Institution of Oceanography
    - Observations and real-time forecasts
  - NOAA National Data Buoy Center
- Wave Hindcast Data
  - Predict waves from wind observations nationwide
    - 20+ years available
- Participation in the Integrated Ocean Observing System (IOOS)
  - Ties program with other agency partners





Outline

- Wave and Storm Observations & Climate
  - What do we know?
- Useful tools for Ports using wave information
  - High resolution models for wave breaking
  - Enhanced real-time information and delivery system
- National Wave Observation Plan
  - What information exist, what's needed

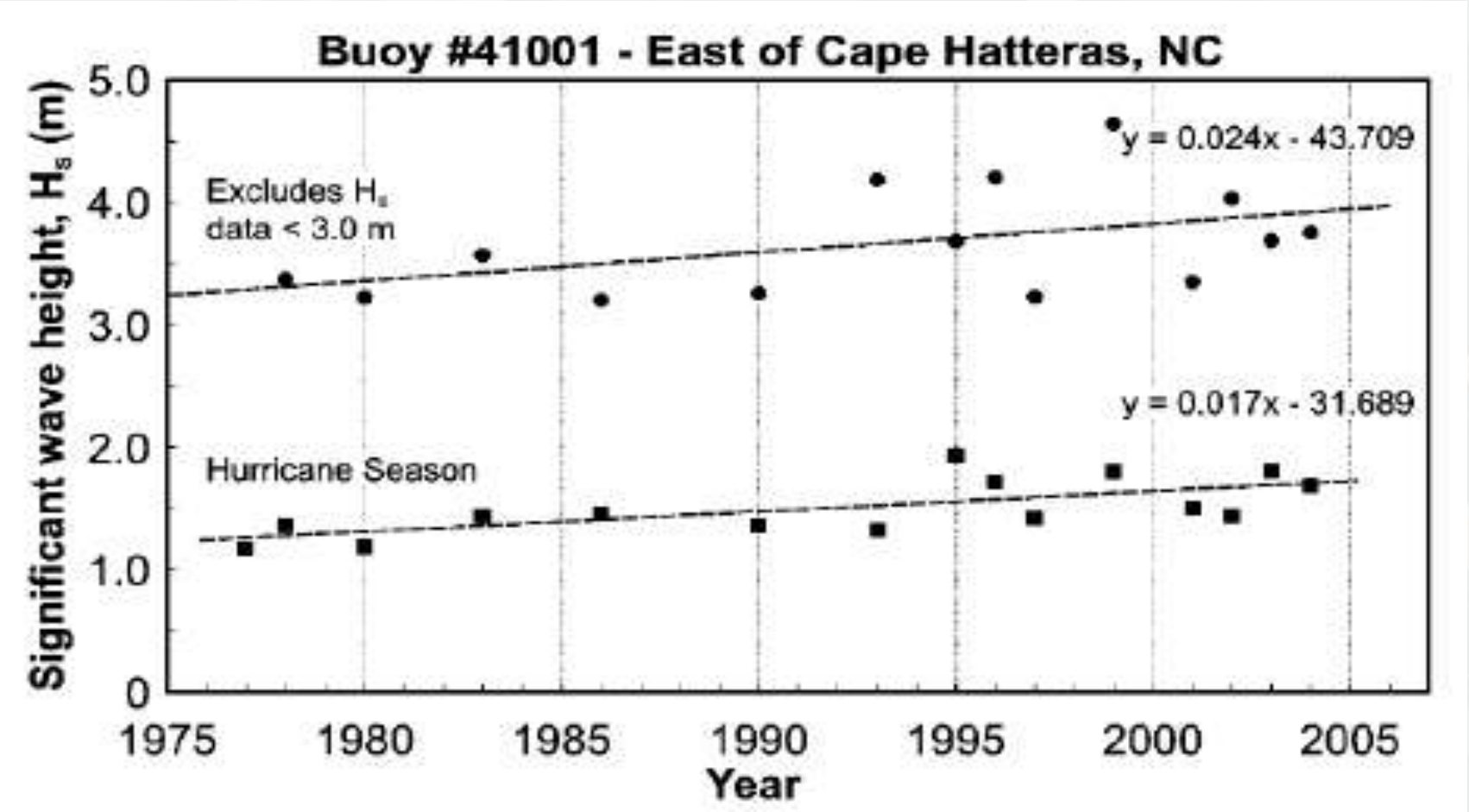
So, has an increase in wave height associated with climate change been observed?

Yes!

But you have to work it:

- A lot of inter-annual variation & infrequent storms to sort out
- Short data records < ~35 years

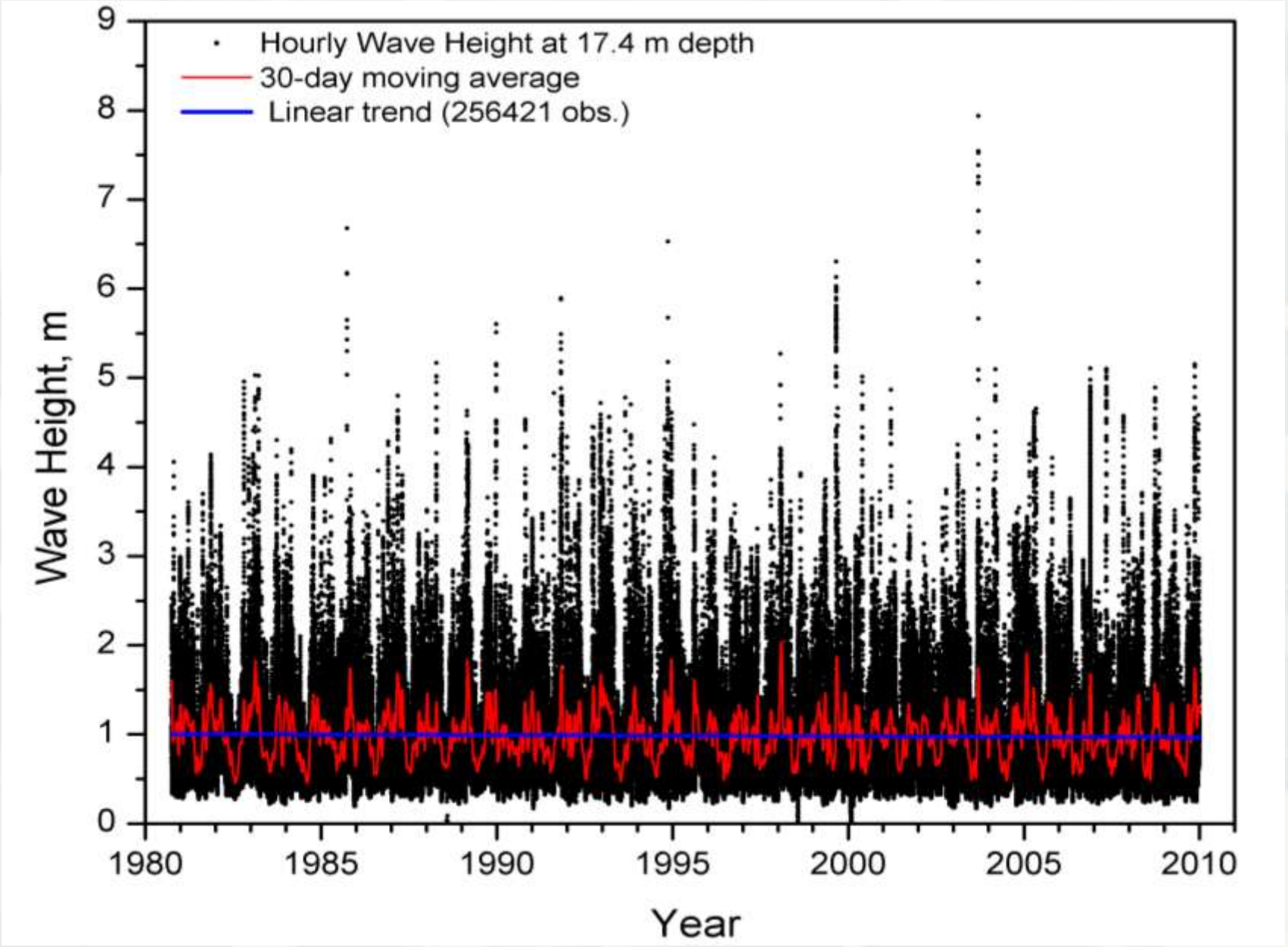
Increasing Wave Heights & Storminess in the North Atlantic



30-yr increase in observed mid-Atlantic Hurricane Season extreme mean wave height of 0.75 m – 2.4 cm or 1” per yr.

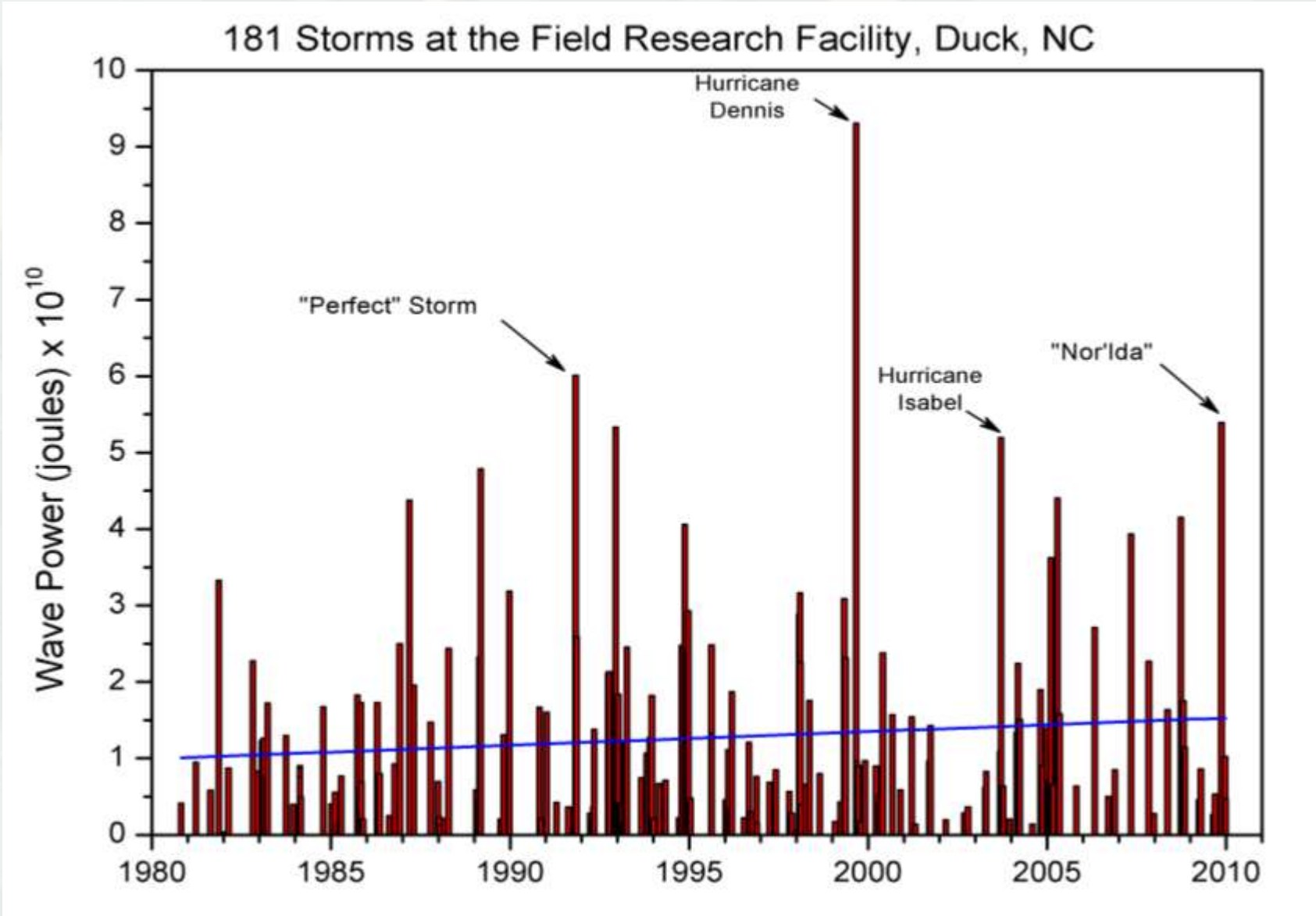
From Komar & Allan, 2007

Wave Height Variation, 28-year record



FRF storm record: H>3 m (10 ft)

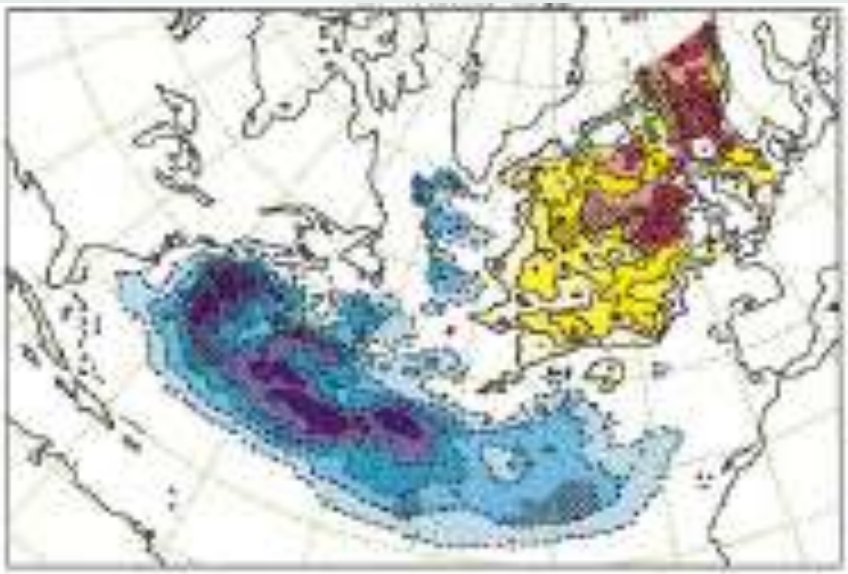
Wave Power – energy delivered, ~H^2x duration



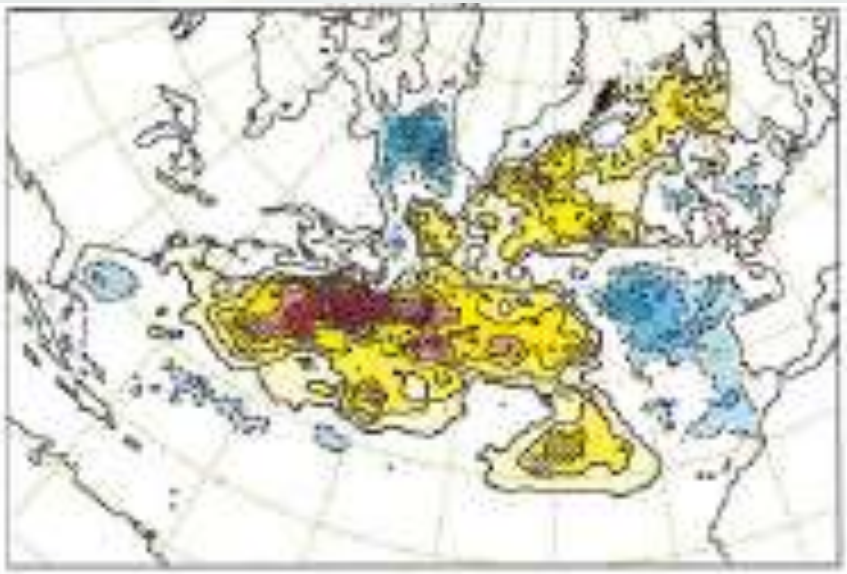
Evidence for increasing wave heights in the North Atlantic

(Wang & Swail 2001)

Winter



Fall



Plot show changes in Significant Wave Height (Hindcasted data)
Contours interval 1 cm/yr
Yellow & Reds indicate increases
Max ~ 6 cm/yr; 1 m (3.3 ft) every 16 years
Not uniform!

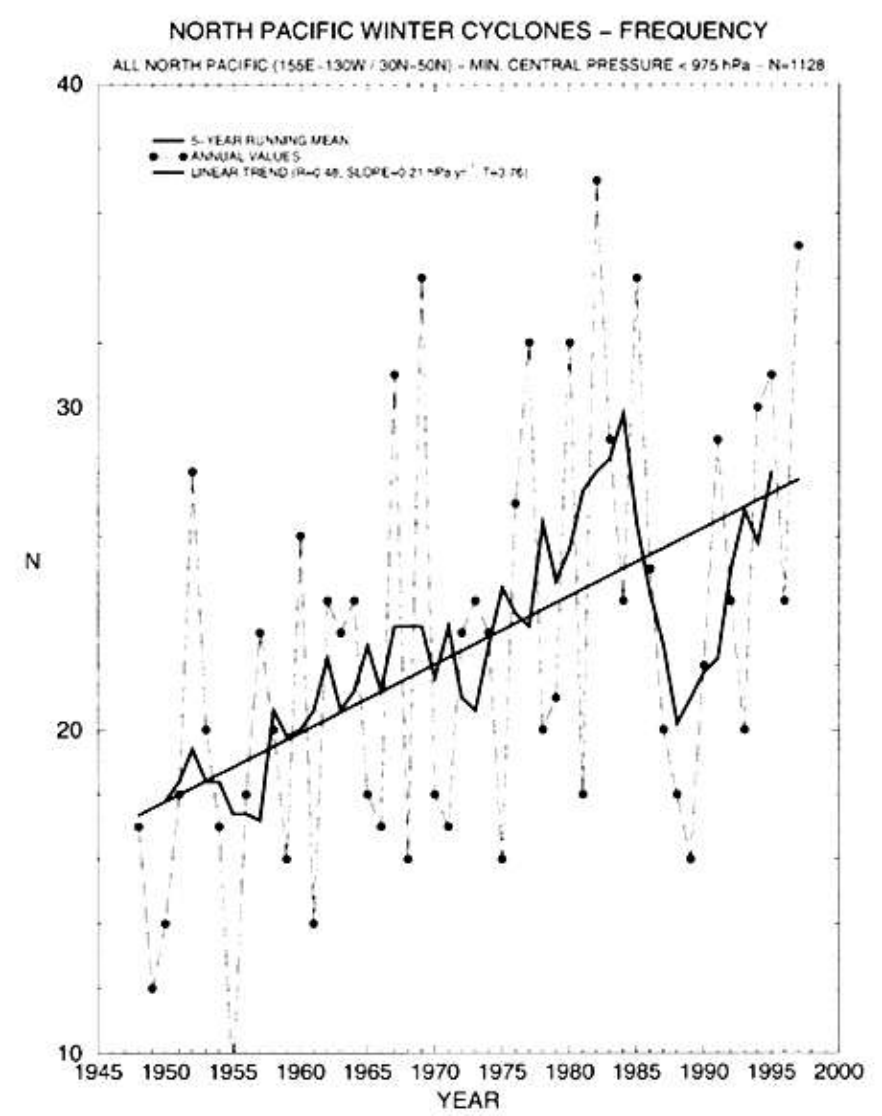
North Pacific: Evidence for Intensification of Winter Cyclones

•Upward trend in cyclone frequency and Intensity during the past five decades.

• The statistical association between cyclone activity and El Nino indices is modest.

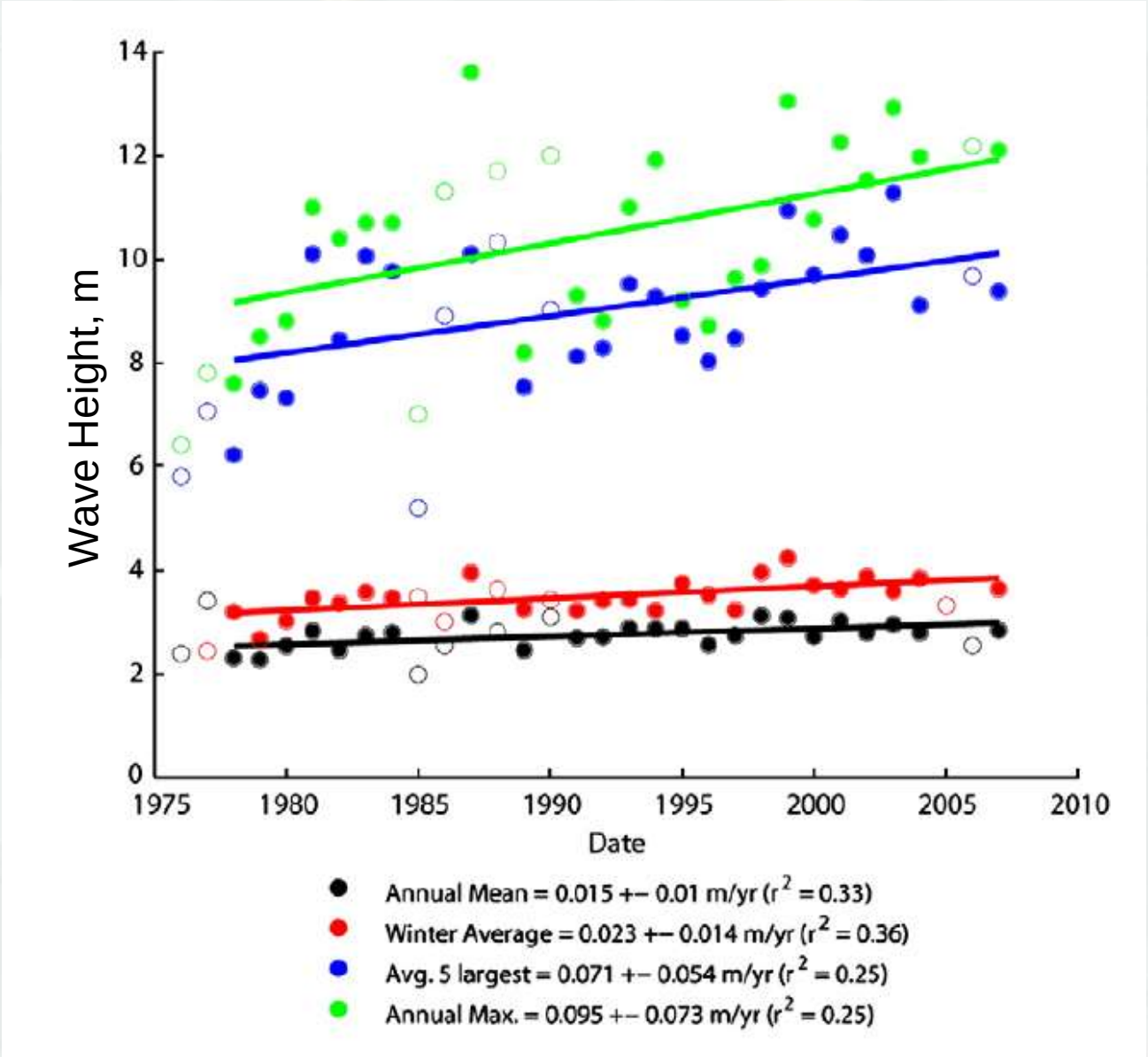
• Hypothesis: Increasing upper-tropospheric zonal winds potentially caused by changes in tropical sea surface temperatures.

Nicholas Graham and Henry Diaz (Scripps and NOAA)

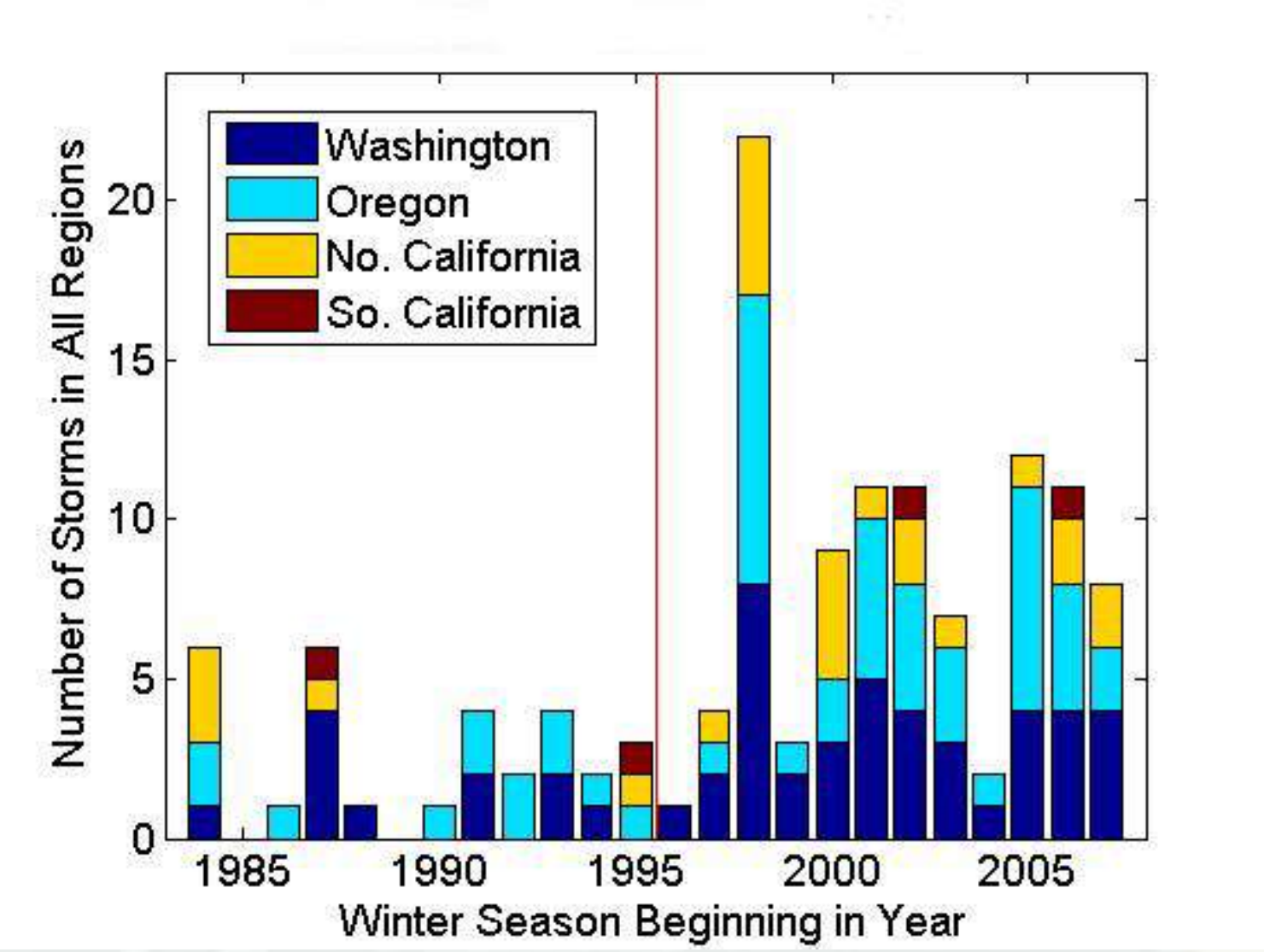


More evidence for the North Pacific

NDBC buoy 46005, Ruggerio, Komar, Allan (in press)



Pacific Storms with H_s >= 6m



Flooding: First impact of Sea Level Rise & Waves

Flood Elevation = Tide + Storm Surge + Wave Runup

Hawaii

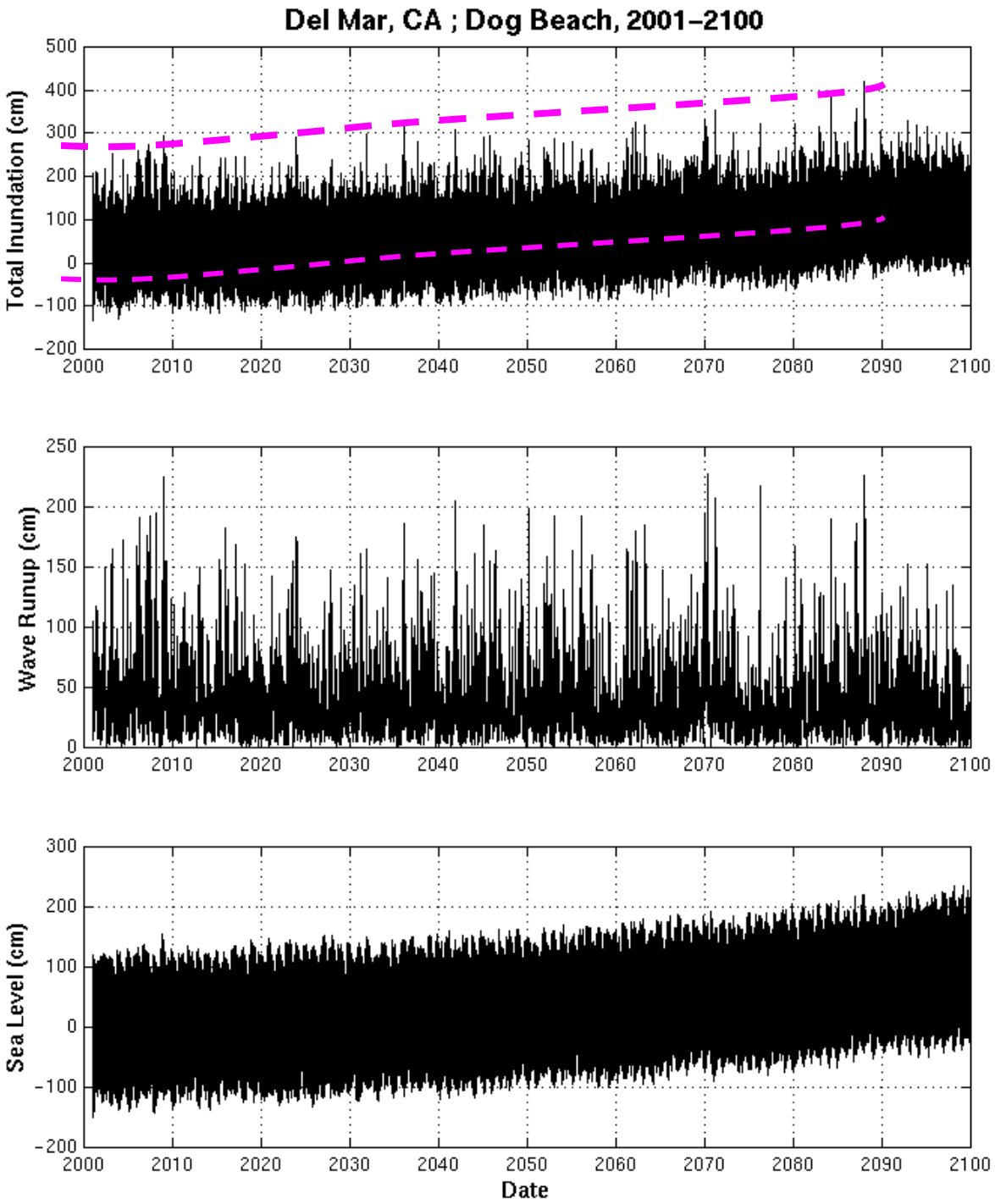
Southern California

North Carolina

100yr Coastal Inundation Forecast

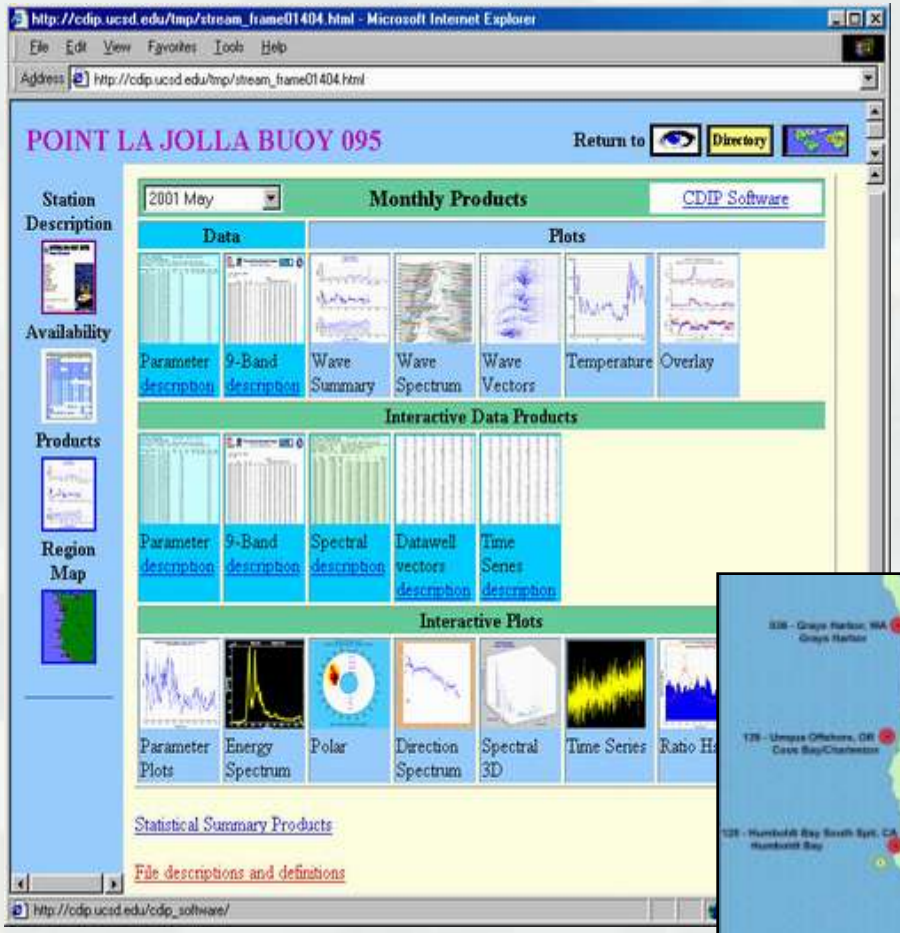
Single Global Climate Model scenario

- SLR impacts first show as increased flooding during events
  - storms & runup important
- In this forecast a calibrated wave model was run using 100 yr forecast winds
- Runup estimated and added to a SLR scenario
- Provides estimate of amplitude & frequency of low-land flooding
- Impact must also account for associated erosion



Coastal Data Information Program

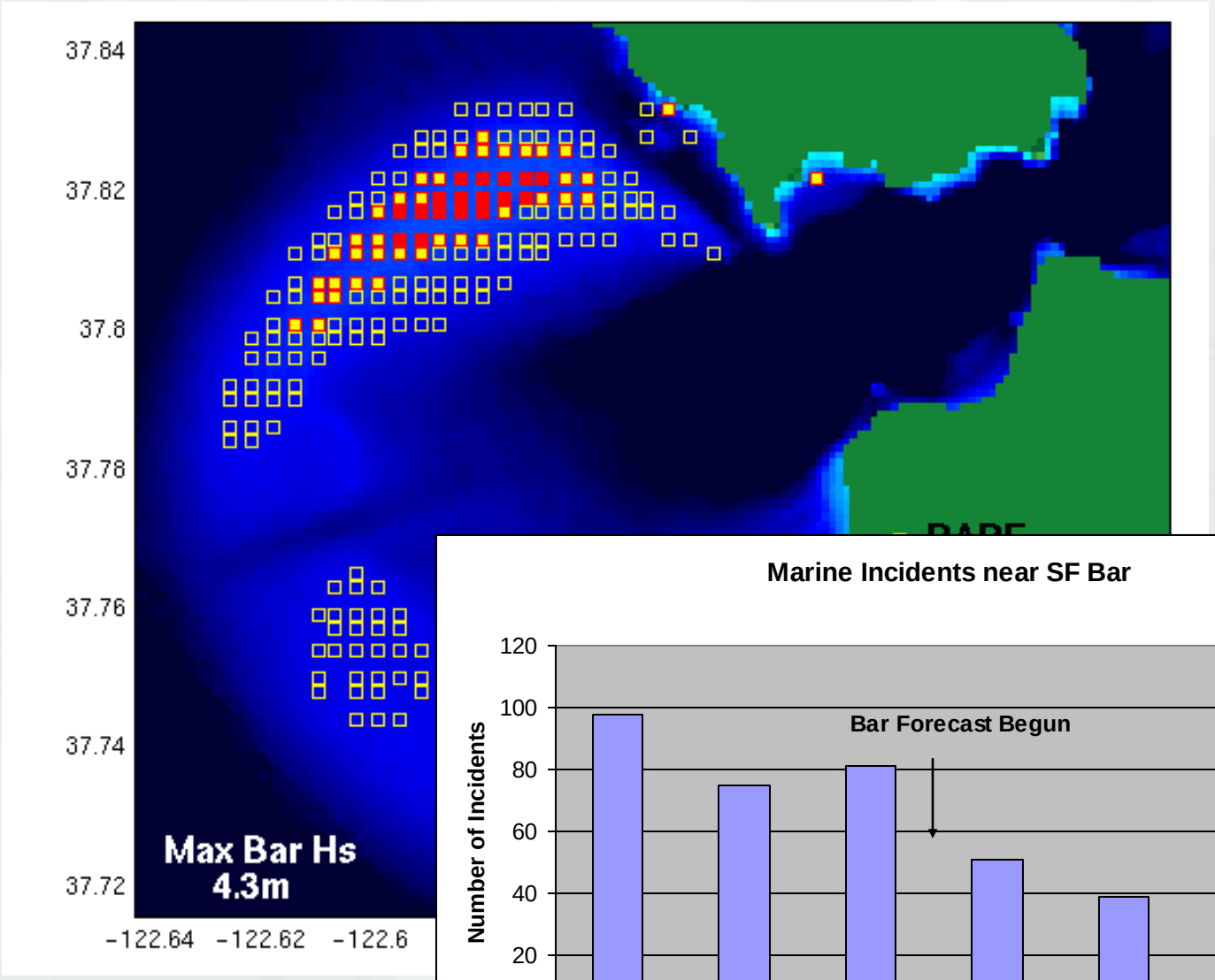
A sustained wave observing system

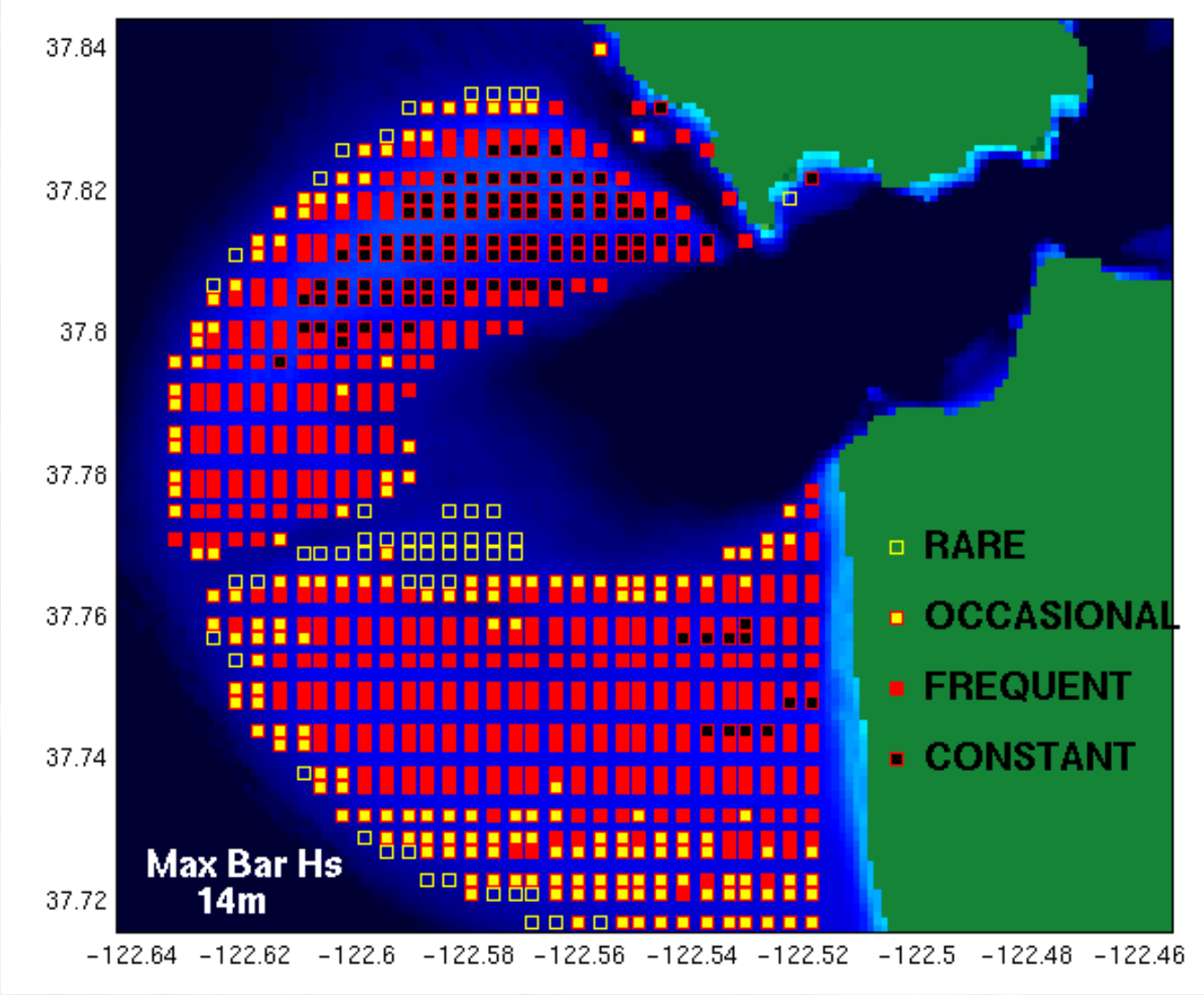


- Corps' and Cal Boating sponsored
- Since late 1970's
- Wave observations & forecasts
- Wide selection of data products
- Operated by Scripps Institution of Oceanography

http://cdip.ucsd.edu

Navigation Safety at the San Francisco Bar – a new application

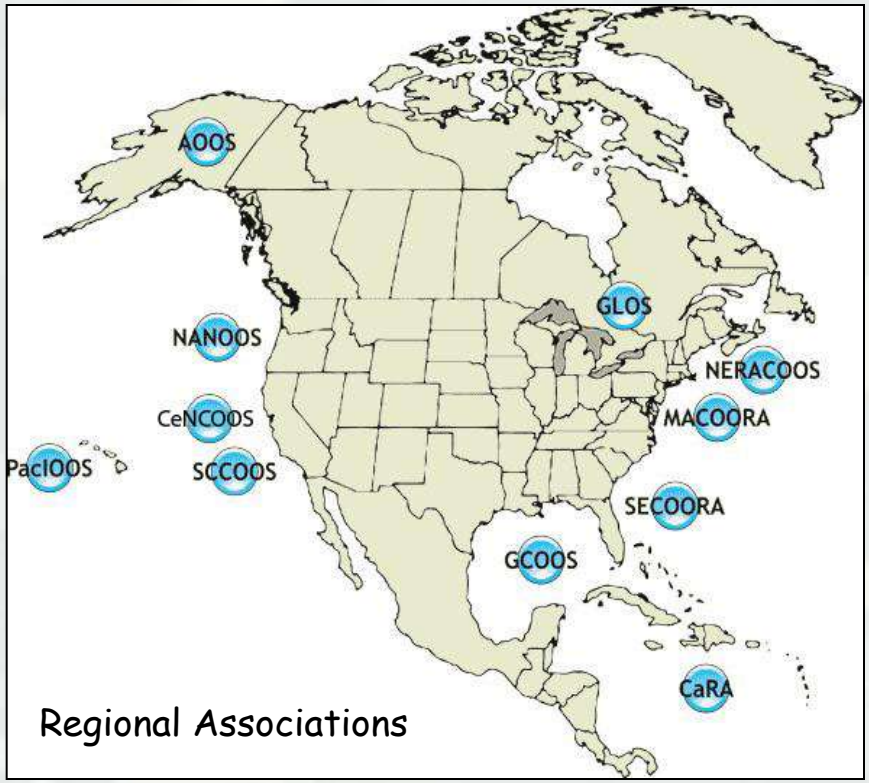



37.84
37.82
37.8
37.78
37.76
37.74
37.72
-122.64
-122.62
-122.6
-122.58
-122.56
-122.54
-122.52
-122.5
-122.48
-122.46
RARE
OCCASIONAL
FREQUENT
CONSTANT
Max Bar Hs
14m

The Integrated Ocean Observing System (IOOS):

Our Eyes on the Oceans, Coasts, and Great Lakes

- 11 Regional Associations (RAs) support local observing systems/products/models
- Data management protocols established *(Discovery & Access)*
- Data being collected and integrated
- NOAA National Data Buoy Center (NDBC) consolidates data
- NOAA is lead agency, of 17.
- Integrated Coastal and Ocean Observing System Act of 2009



IOOS

http://ioos.gov

IOOS: Observation Net

Physical parameters top the list; new knowledge will come from sustained measurements of all variables, most are under-sampled

- Bathymetry
- Sea Level
- Surface waves
- Surface currents
- Salinity
- Temperature
- Ice distribution

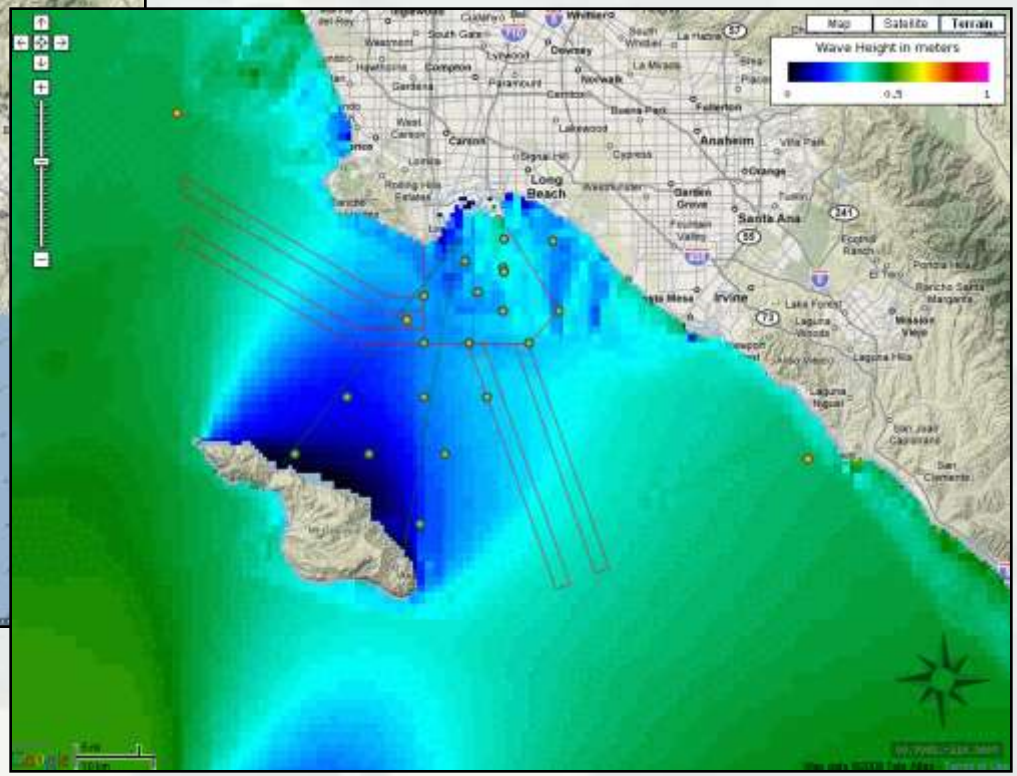
(top 7 of 40 variables)

Map of existing observations

Waves and Currents in the San Pedro Channel

SCCOOS providing currents

CDIP providing wave observations, Nowcasts and forecasts.



http://sccoos.ucsd.edu/themes/harbors

INTEGRATED OCEAN OBSERVING SYSTEM

NOAA IOOS

Site SP001 - info

San Pedro Harbor Site 001

Data Tables
- Parameter
- 9-band energy
- 9-band direction

Daily & Weekly Plots
- Waves - 1 day
- Waves - 1 week
- Wave forecast

Simulated Time Series
- Z displacement values
- Z displacement plot

Latest Model Run
- 9-band plot
- Spectral plot
- Directional spectrum
- Spectral file

Descriptions/Help

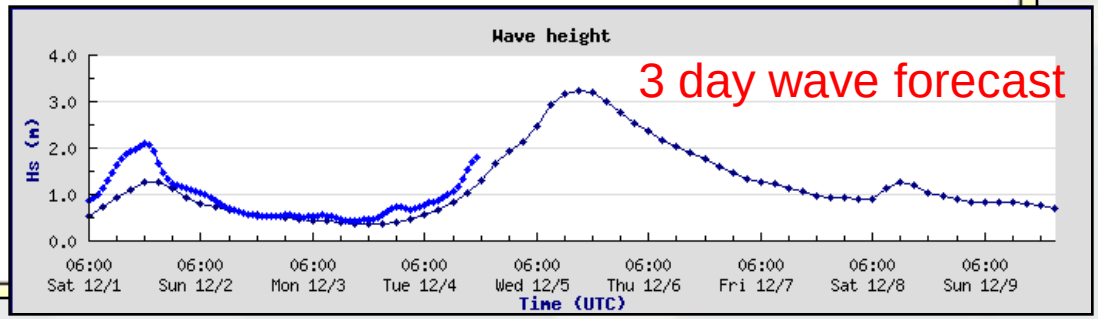
Summary Table

Location Map

Site ID: SP001

- Location:
  33 41.10 N 118 14.22 W
  (33.6850 -118.2370)
- Water depth:
  999.9 m (3281 ft, 547 fm)
- Modeled parameters:
  wave energy, wave direction

SP001 - Location Map



Capability to send automated notification when thresholds are exceeded!

IOOS National Wave Plan: Objectives

- **An integrated plan for wave measurements in the US**
- **Addresses:**
  - Spatial / temporal coverage
  - Accuracy requirements of wave information – tuned to USACE
- **Wave Observing System Design**
  - Four Subnets: Offshore / Outer / Inner / Coastal
  - Identifies gaps/upgrades
  - 296 total, 181 exist, 128 upgrades
- **Integrate wave measurement assets via NOAA/NDBC**
- **Technology development, training activities**
- **Testing and evaluation of existing & new technologies**
  - Wave instrument training/testbed at FRF
- **Long-term, sustainable measurement program**
- **$14-18M annually, USACE $3-4M for the coastal program**

National IOOS Wave Observation Plan

296 sites, 181 exist, 128 upgrades

Summary

- Wave Climate is changing in response to changes in weather (and wind) patterns and ocean temperature
  - Expect increasing conditions
  - Studies continue, stay tuned!
- Sea Level Rise impacts initially appear during “events”
  - high water, high waves, high wave runup
  - Expect increasing frequency
- We depend on, and are limited by existing data
  - Short records (~35 years), gaps, few extremes
  - Climate changing, not stationary
- Integrated Ocean Observing System (IOOS)
  - Need user support for expanded wave observation program
  - Real-time use of data while the long records required for climate study develop