Stockdon Wave Run-Up Equations: Large Battering Waves and Coastal Erosion

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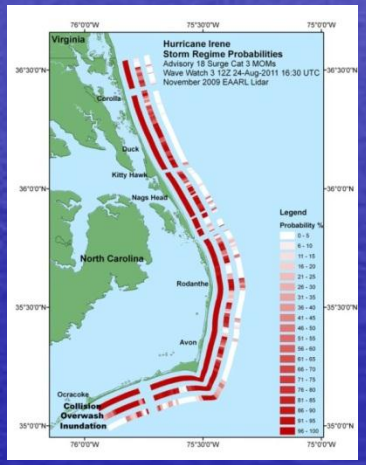
NOAA/National Weather Service
EC/NOAA Marine Services Workshop
February 12, 2014

Partnerships:

NART
NERACOOS
NOS
Wells National Reserve
Maine Geological Survey
City of Hampton and Saco
NOAA in New England Group
ME/NH Emergency Mgrs. & City Officials
Coastal Services Center
Maine Sea Grant
Mass CMZ
NH Coastal Adaptation Workgroup
…And many others…

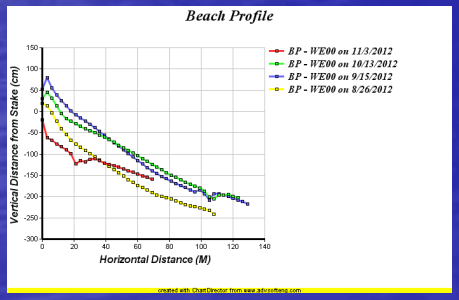
NART Funded Wave Run-up Project

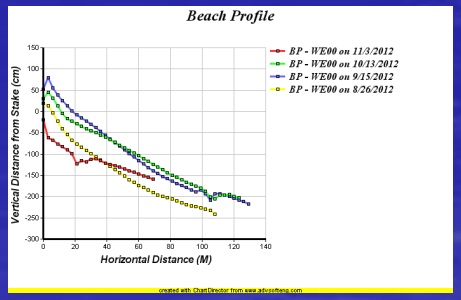
- I. Brief review of wave formation and wave "Battering" (in New England)



- II. Stockdon Run-up Collision Model

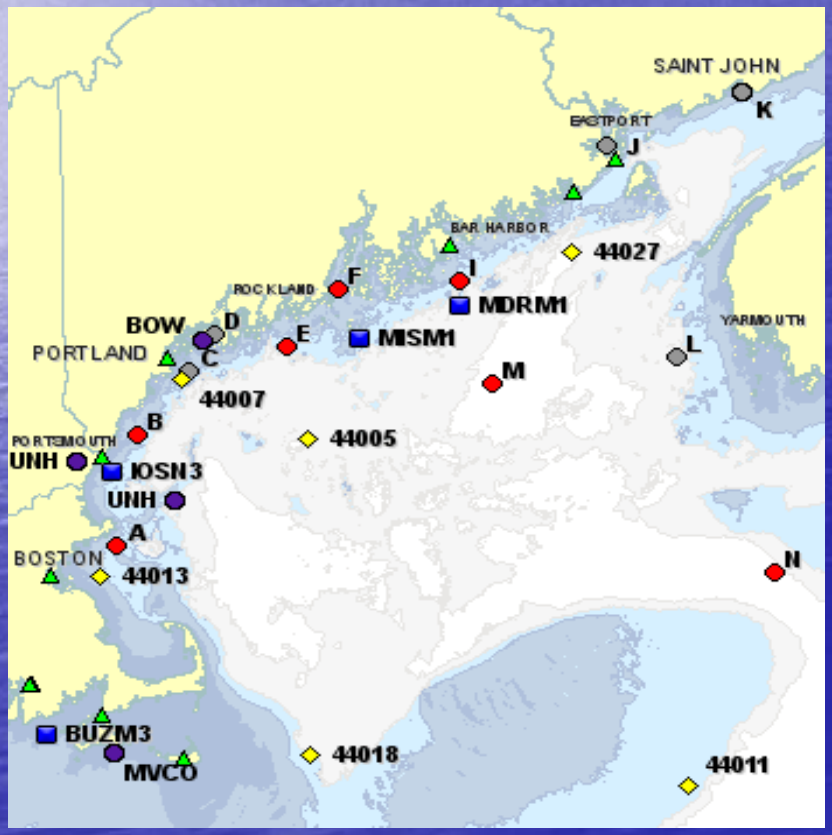
- III. Storm Hindcasts and Verification





I. Wave formation and wave battering in New England

Coastal Hazards: Erosion, Splash-over and Inundation



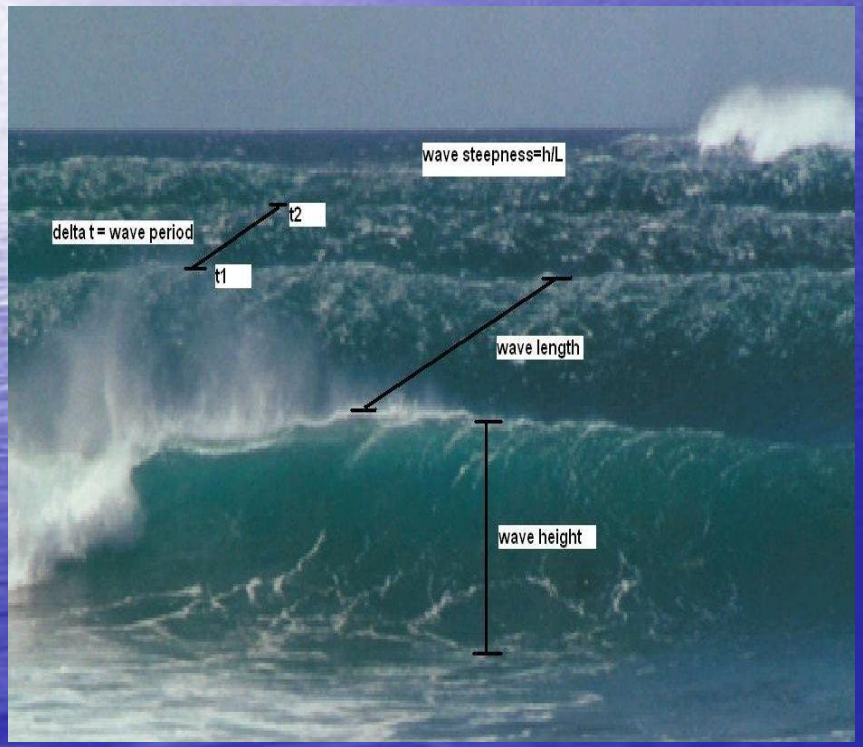
Marine Network(s) Gulf of Maine

The Wave vs. Coastal Inundation Paradox
Which is the greater threat for your location ???

"Wave action is the ultimate cause of most structural damage and beach erosion" (Stockdon)

The Patriot's Day Storm, 2007
Saco, Maine

So Large Waves (combined with high storm tides) Lead to coastal erosion and damage

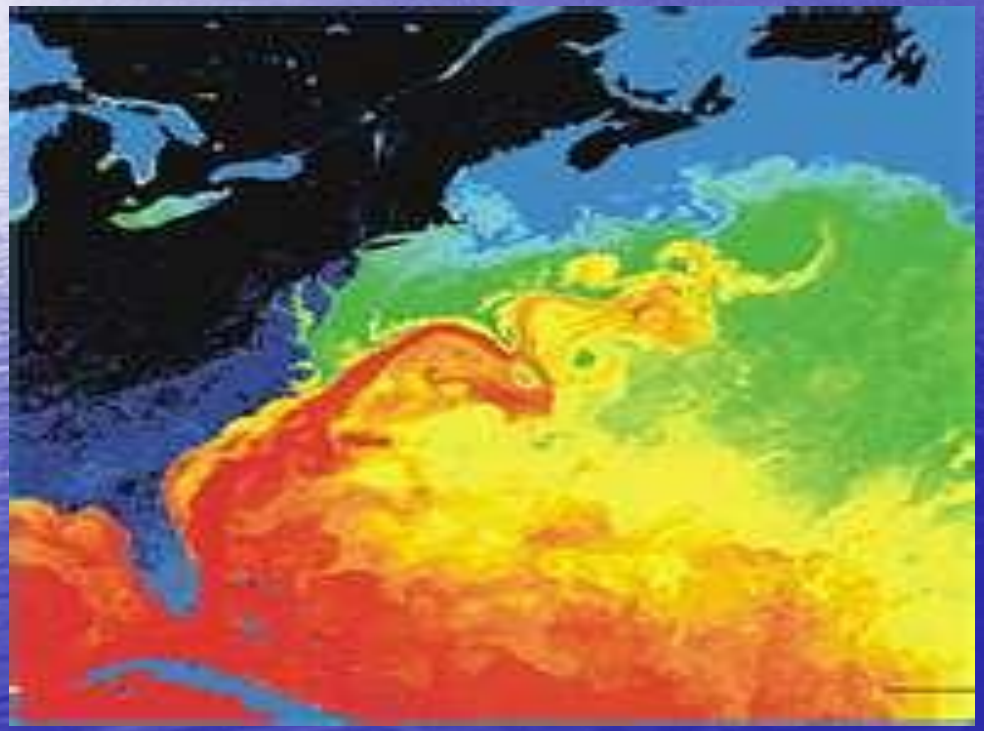


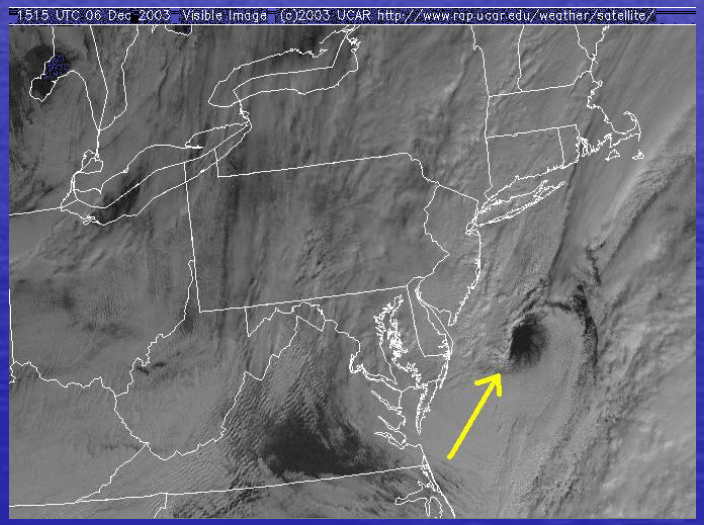
Wave Growth in New England (and all locations) a function of several variables including;

1. Wind speed
2. Fetch
3. Duration

1. Increased Wind Speeds: Allow for Wave Growth

- **East Coast Cyclogenesis can trigger…**
  - **Intense Nor'easters and "Hybrid" storms**

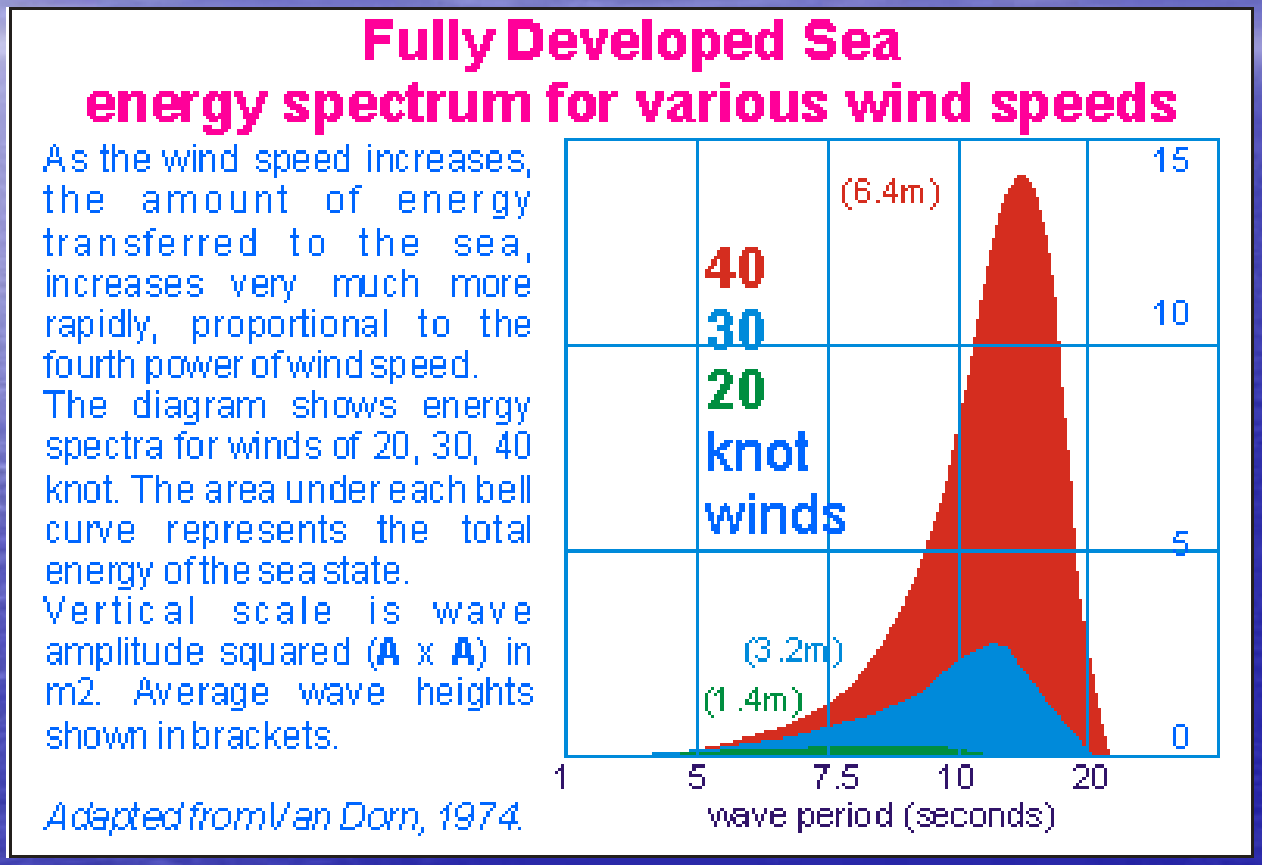




Gulf Stream Serves Important Role in Winter Storms

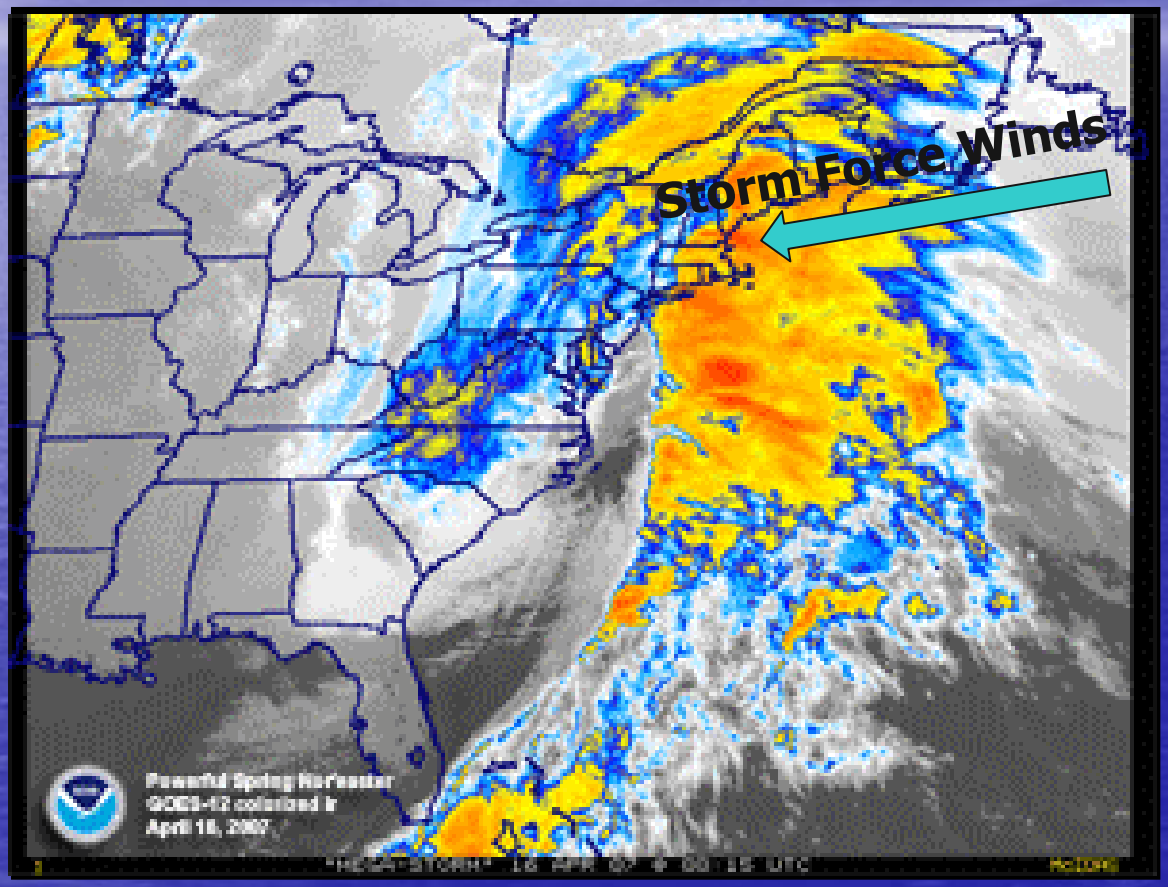
Info on Hybrid Storms See… *http://moe.met.fsu.edu/cyclonephase/*

The Relationship Between Wind Speed and Wave Energy



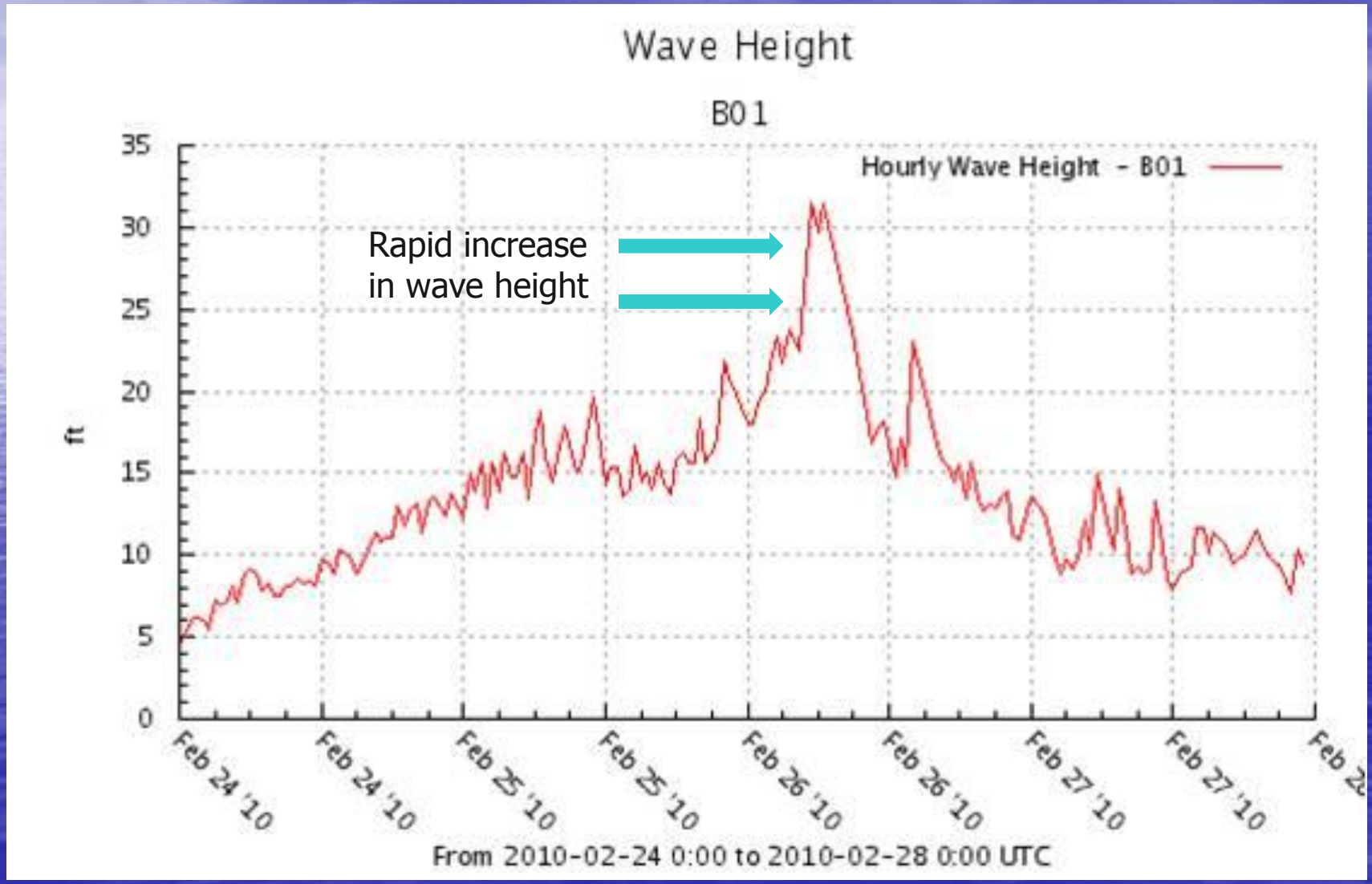
As winds increase…wave energy increases dramatically

2. Fetch: The longer distance winds travel over water, the greater the wave growth (NE, E or SE Flow)



Patriots Day Storm: April 16, 2007

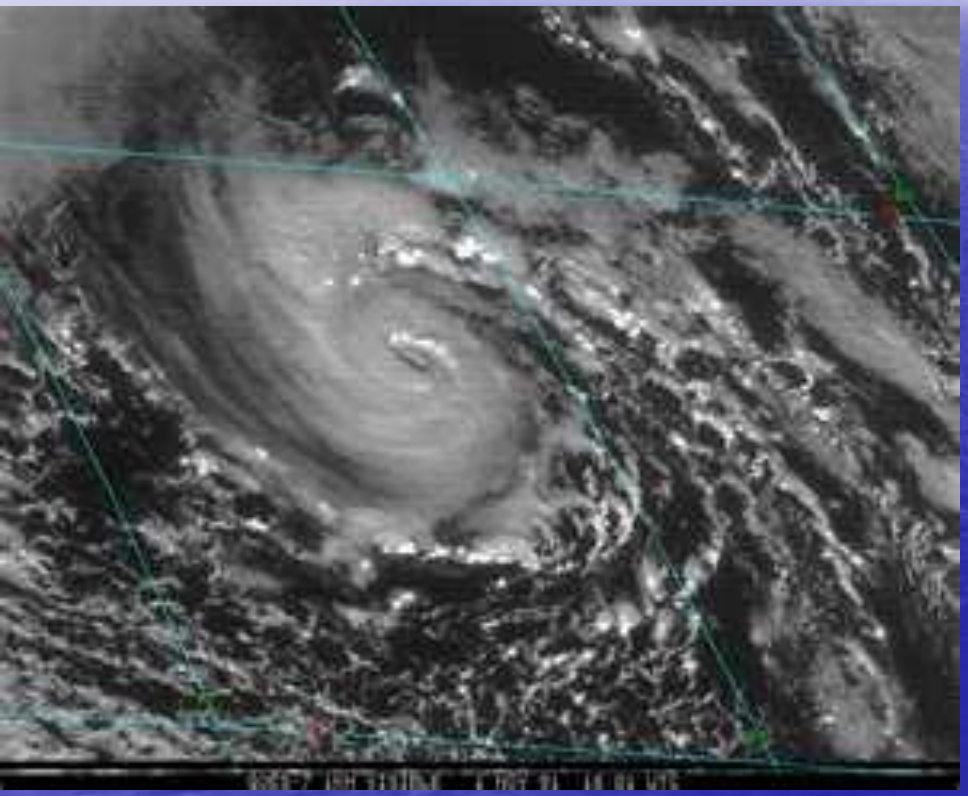
Waves During February, 2010 Nor'easter



February, 2010…
Storm Impact Saco, Wells, Popham

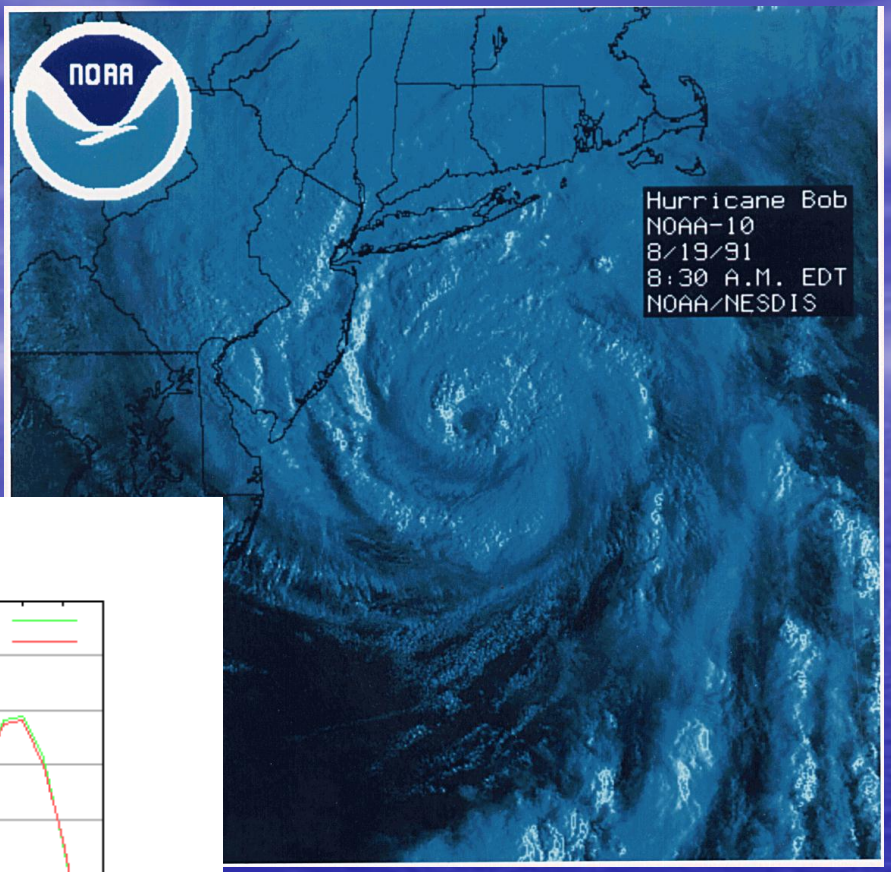
Courtesy P. Slovinsky

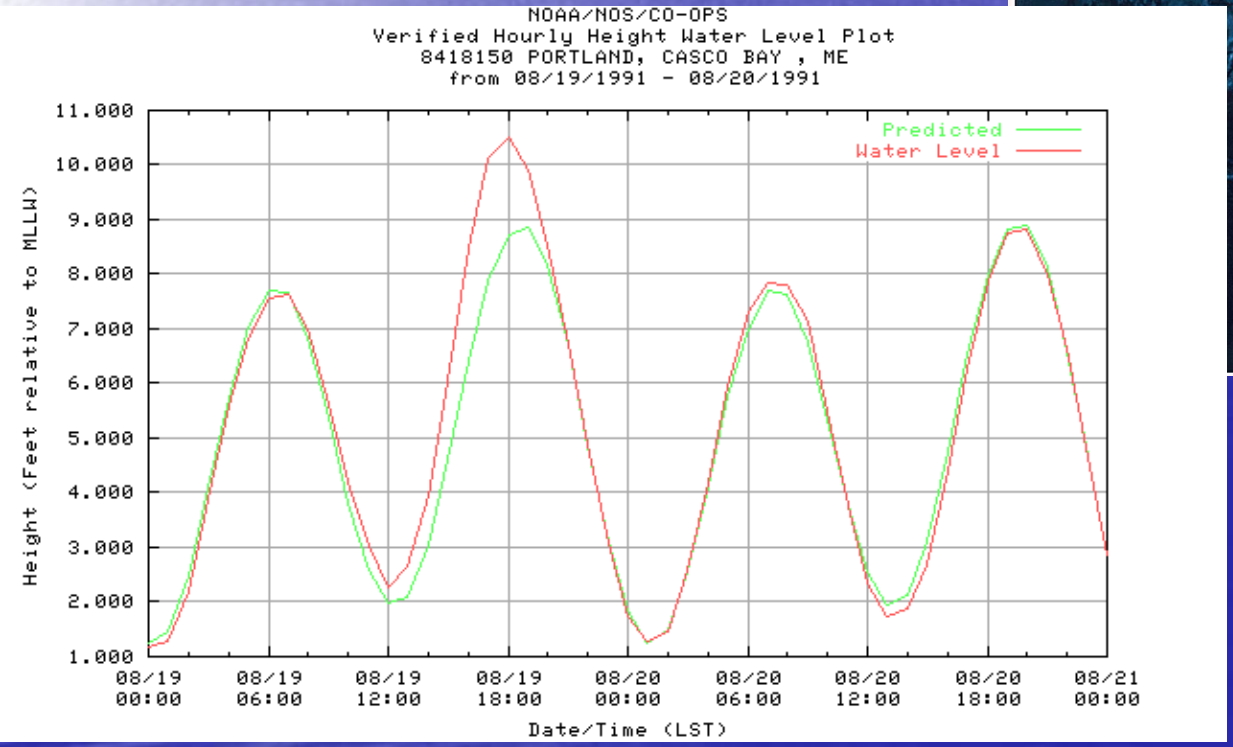
3. Duration: Slow moving, long duration storms tend to produce larger waves (by creating a full sea state)

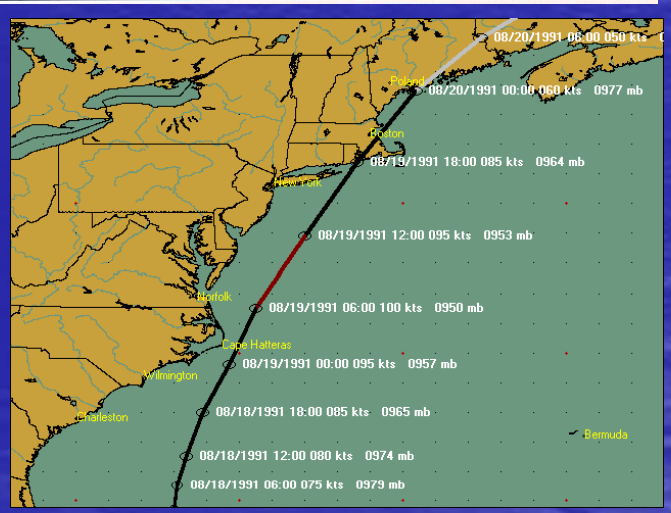


"The Perfect Storm": Time Scale Often Days and Not Hours

Fast Moving Systems: Often do not have time to produce large waves in Northern New England

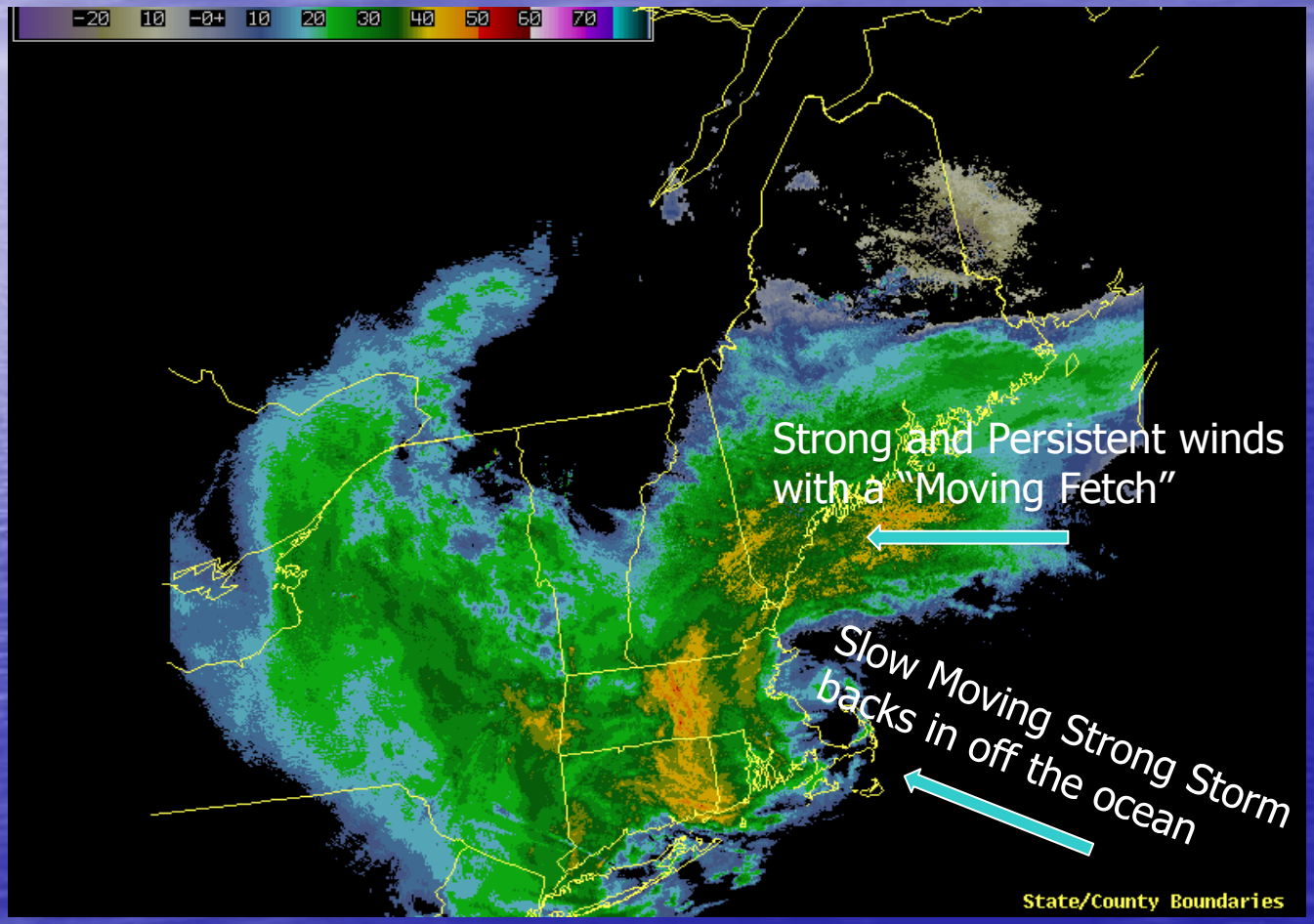






Hurricane Bob: Minimal coastal issues

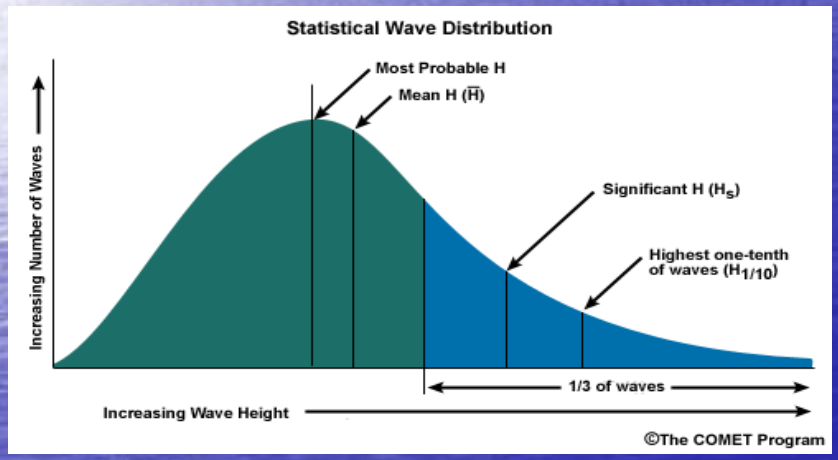
A Conceptual Model of a Storm that Produces Large, Battering Waves in ME/NH



Feb 26th, 2010 Intense Nor'easter Produced Significant Erosion/Damage

"Wave Run-up"

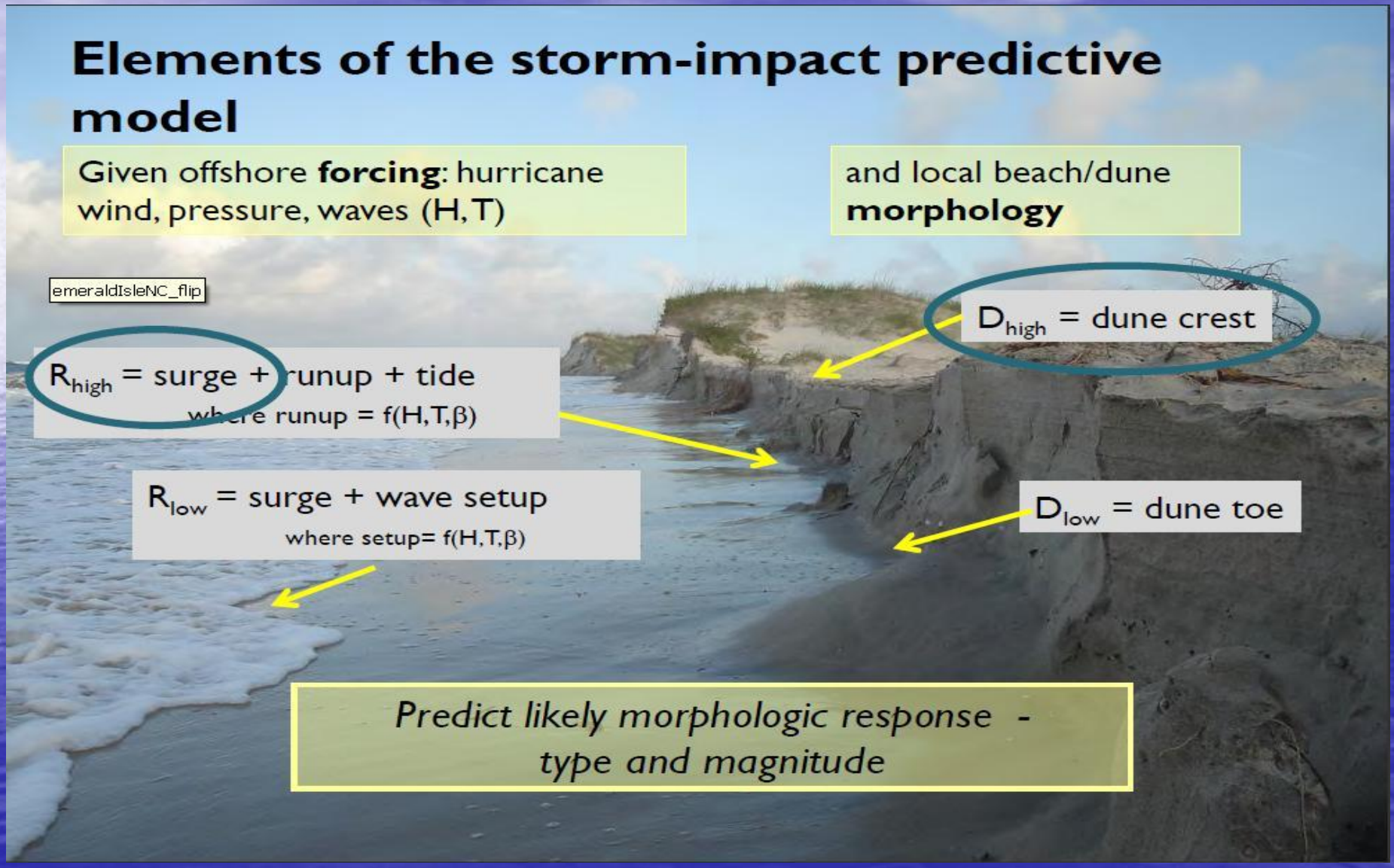
Leads to Erosion Through Wave Battering



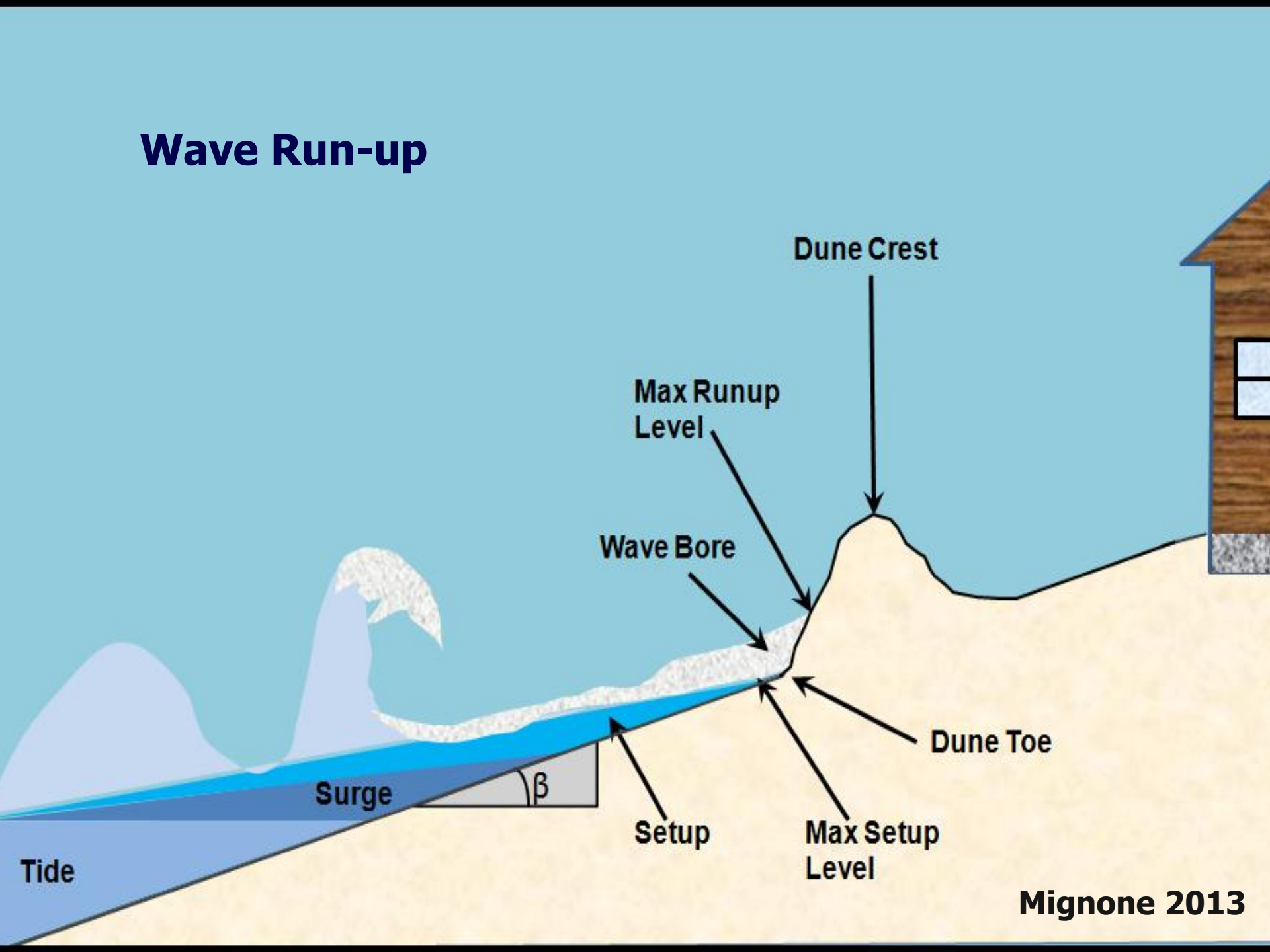
[The highest 2 % breaker run-up can be mathematically computed (Water rise ~ ½ the predicted breaking wave height plus 50 cm)]

York Beach Maine

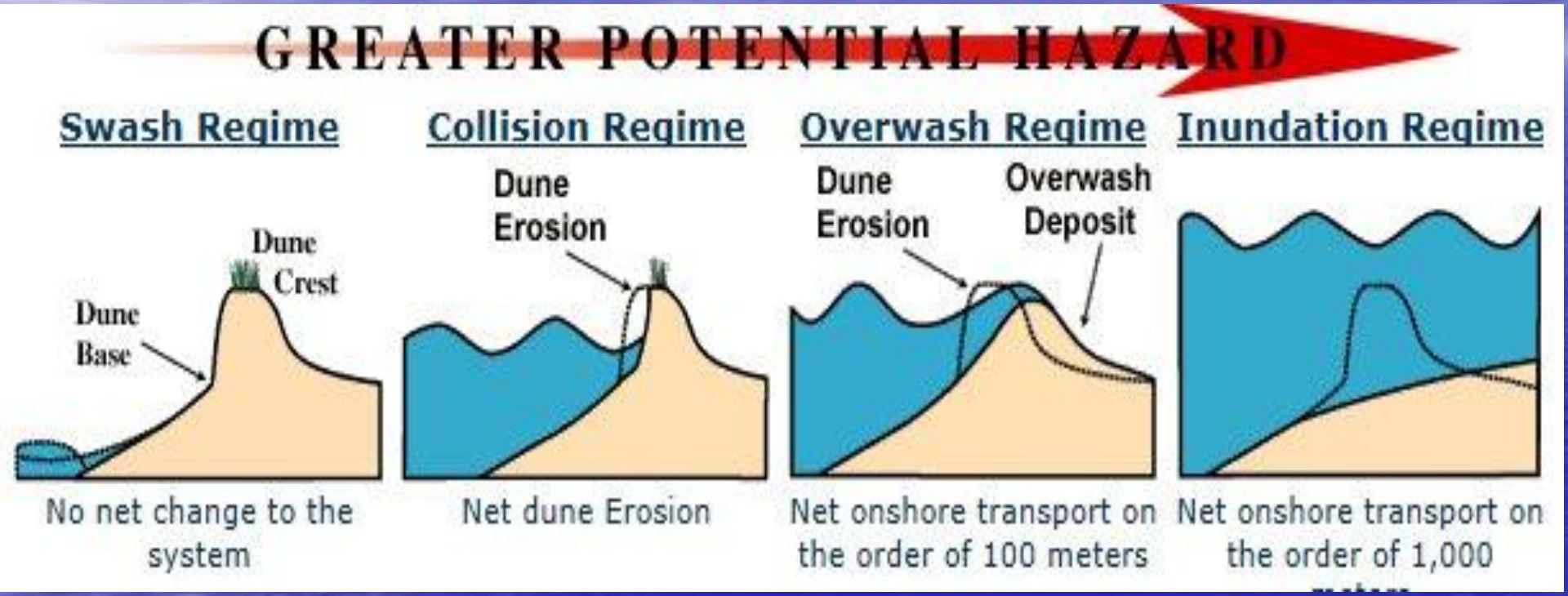
II. Stockdon (USGS) Empirical Collision Model



Wave Run-up


Dune Crest
Max Runup Level
Wave Bore
Dune Toe
Surge
β
Setup
Max Setup Level
Tide
Mignone 2013

Erosion and receding dunes



Parameterizing Runup Elevation

$$R_2 = \left(0.35 B_f (H_0 L_0)^{1/2} + \frac{\left[H_0 L_0 \left(0.563 \beta_f^2 + 0.004 \right) \right]^{1/2}}{2} \right)$$

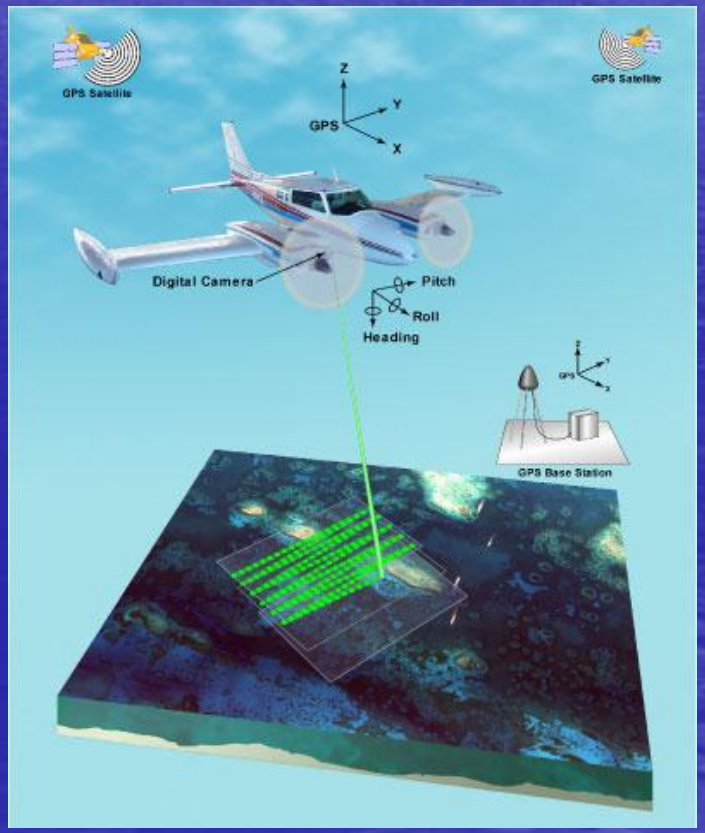
Wave Setup

Swash

- This is a time varying water level
- Large waves making incursions up the beach

Stockdon's Run-up Approach…

- Continuous Array of Run-up calculations
- Leverages use of LIDAR Data



Our "Northeast" Wave Run-Up Approach

- Goal: Establish test sites in coastal "hotspots" to evaluate performance of Stockdon wave run-up equations

- These are vulnerable locations with *complex bathymetry and topography*
  - Therefore: Individual sight surveys were preferred compared to Stockdon LIDAR based surveys
  - Also, Non-Pristine Dune Areas Surveyed
    - Seawalls, Rocky Shorelines, Manmade dune systems etc.

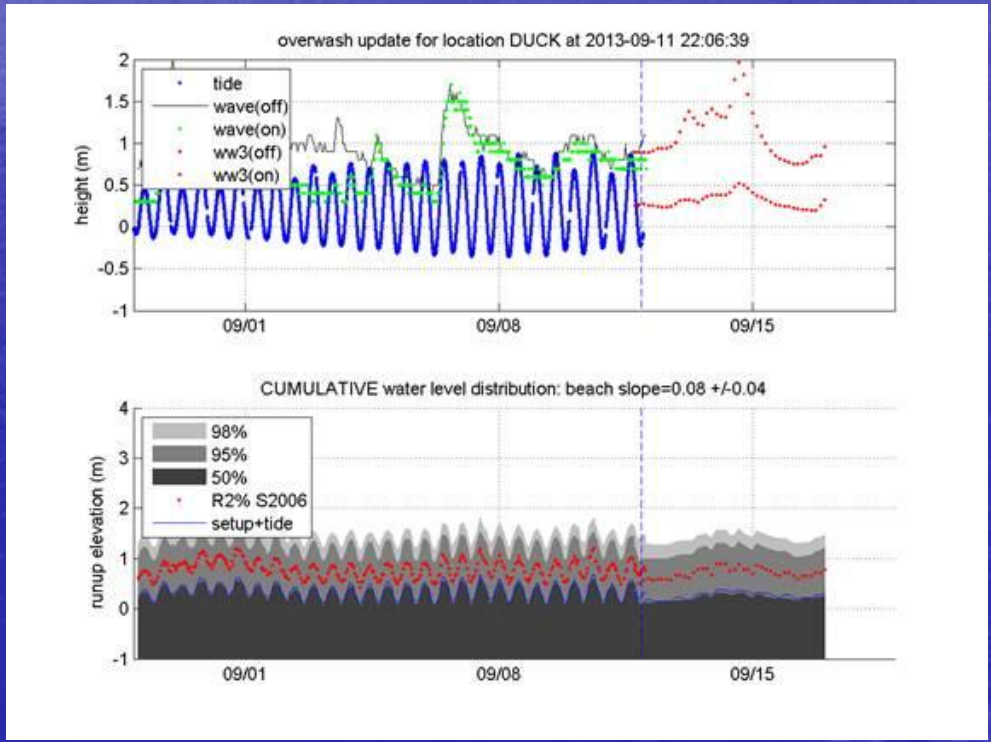
Wave Run-up Study Timeline

- September, 2012: "Wave Run-up" site was surveyed in Saco, Maine
- May, 2013: Several other "Stockdon" sites added
- July, 2013: Hindcasts Created
- September, 2013: Surveys completed and strategies discussed with Dr. Stockdon

Stockdon Visit (September, 2013)

Tour of Maine and New Hampshire Coastline

Stockdon Products



Man-made Barrier Systems, NH Seacoast

Surveying with Hilary Stockdon

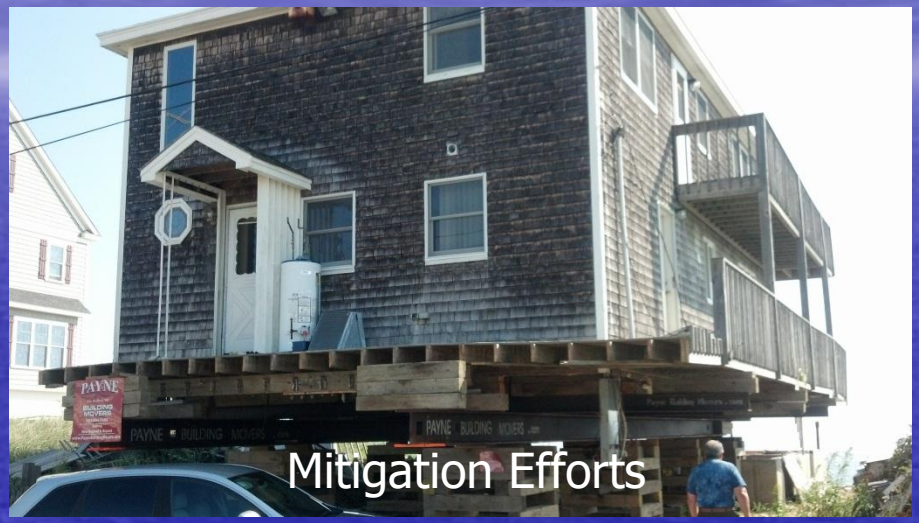
- Camp Ellis Beach
  - Vulnerable location…1st on EMAs list
  - Visited Ferry Beach Ecology School
  - Ferry Beach…natural dune system eroded ~ 1m last yr

Fortunes Rocks Beach

- Organized visit with Biddeford EMA Director
  - Use average of determined slopes
  - Breach occurring between 18-24 Mile Stretch Rd.

High Risk Areas

Newburyport: Plum Island

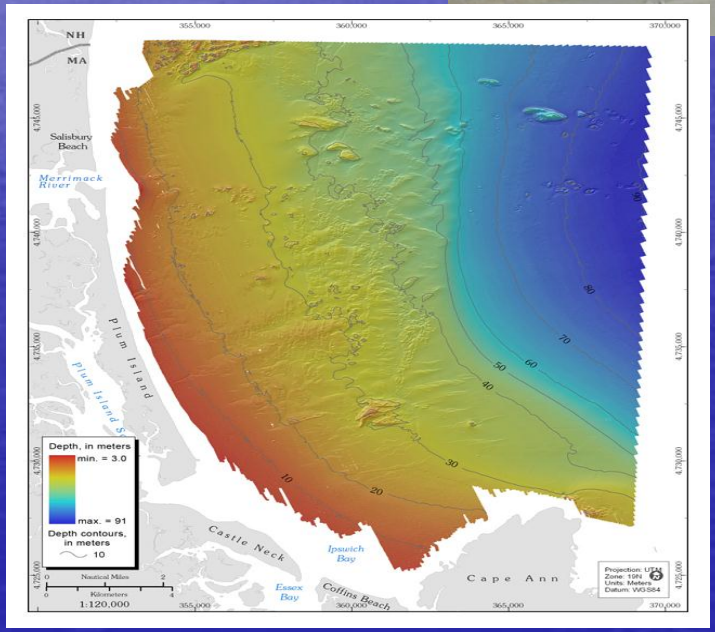


Mitigation Efforts

February, 2013 Storm

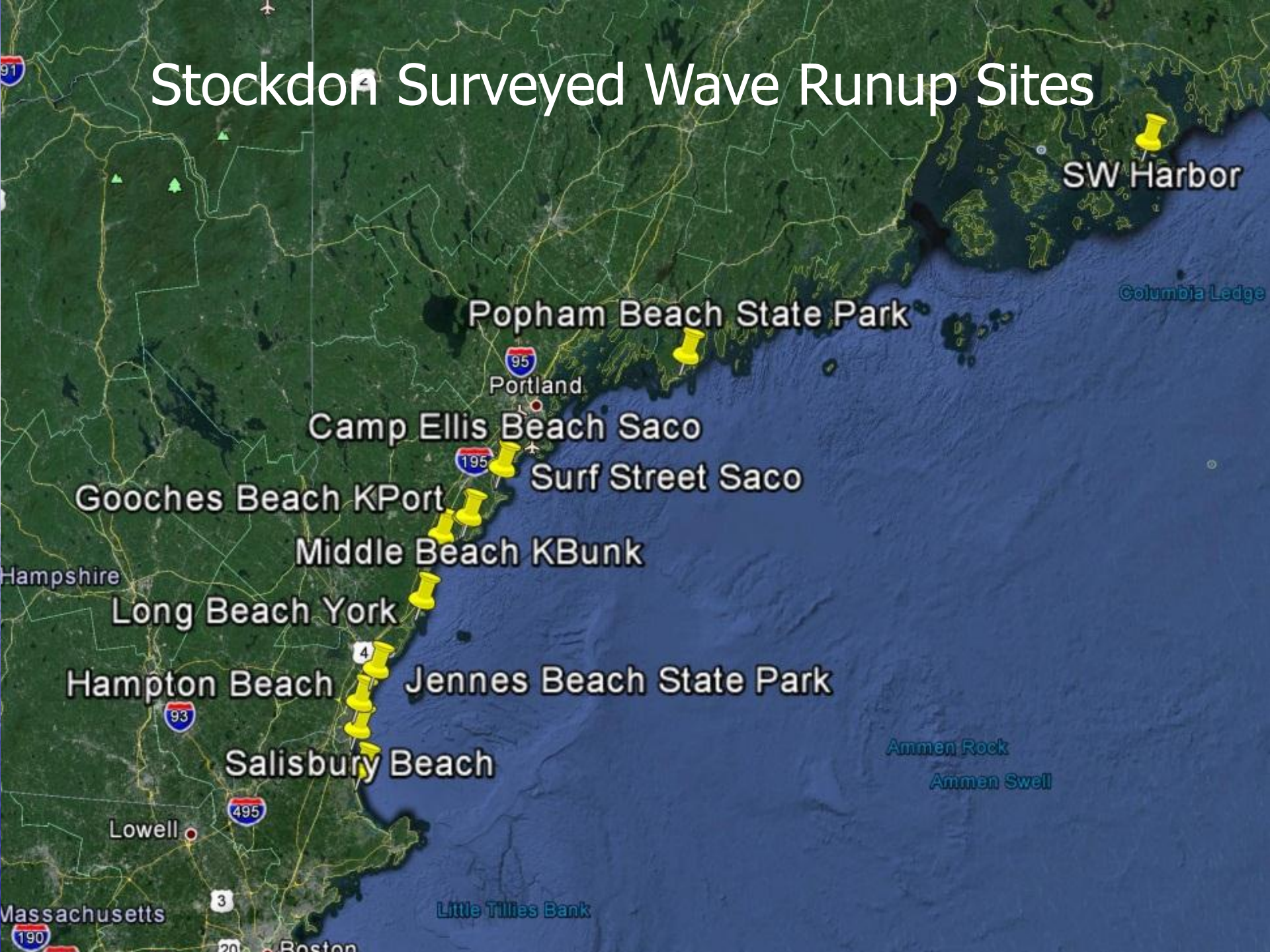
Salisbury Beach

Focused on surveying unique and complex topographical features and included vulnerable sites in Massachusetts



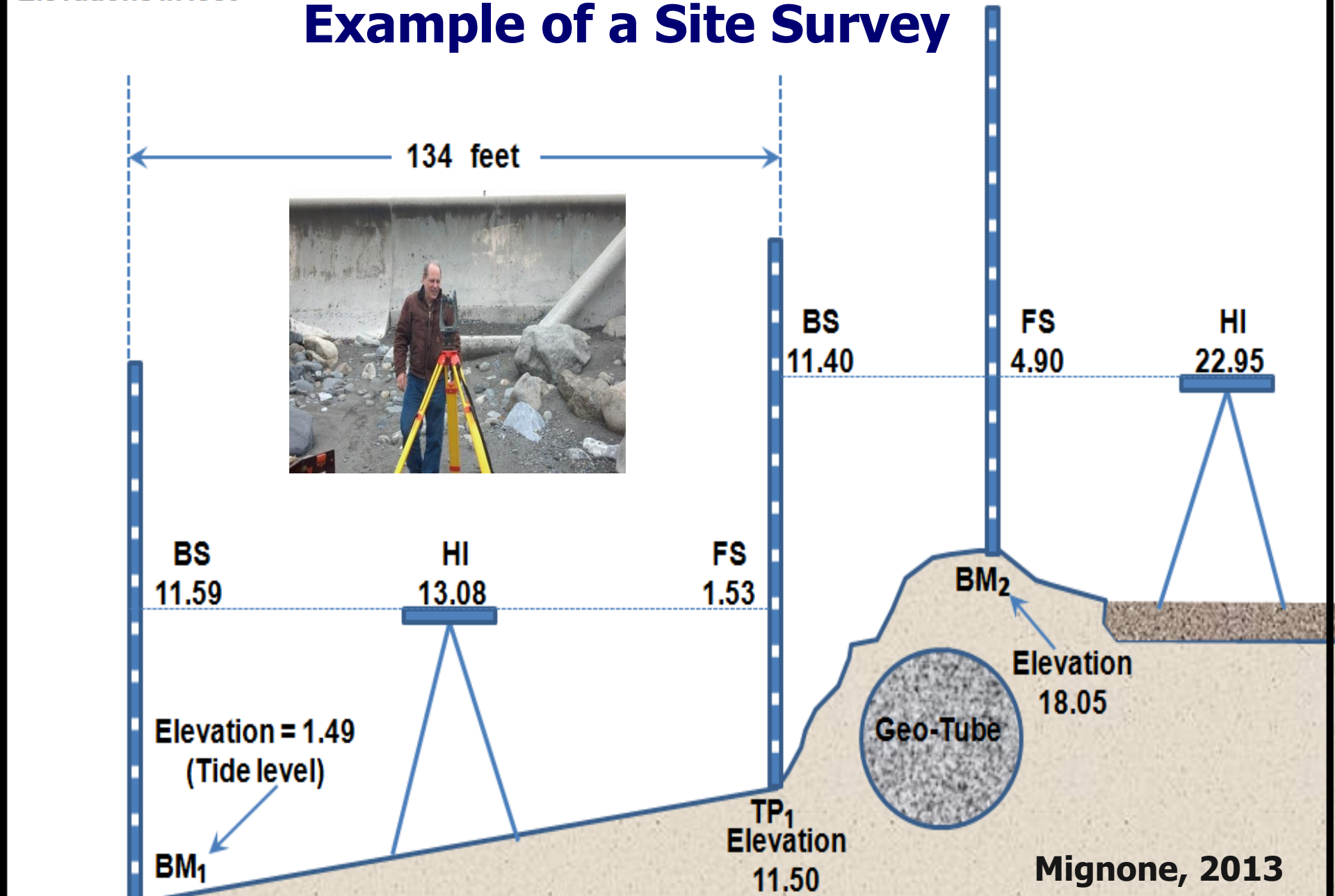
Heat index during survey=100 degrees

CITY	SKY/WX	TMP	DP	RH	WIND	PRES	REMARKS
PORTSMOUTH	SUNNY	94	70	45	SW9	29.96F	HX 100


Stockdon Surveyed Wave Runup Sites
SW Harbor
Columbia Ledge
Popham Beach State Park
95
Portland
Camp Ellis Beach Saco
195
Surf Street Saco
Gooches Beach KPort
Middle Beach KBunk
Hampshire
Long Beach York
4
Hampton Beach
Jennes Beach State Park
93
Salisbury Beach
Ammen Rock
Ammen Swell
495
Lowell
3
Massachusetts
Little Tillies Bank
190
Boston

Latitude = 43.46928° N Longitude = 70.38329° W WGS 1984
Elevations in feet

Example of a Site Survey



Example of Survey Notes

Long Beach Avenue Survey Notes

York, Maine

A site survey was conducted at Long Avenue Beach on Monday May 20, 2013. Differential leveling techniques were employed to determine the elevation of a seawall base and the height of the seawall above MLLW water level.

The water level at the time of the survey (1845 EDT) was determined by averaging tide predictions from subordinate sites at the time of the survey. Tide predictions at the following sites were used:

York Harbor, ME	8.36 feet
Cape Neddick, ME	8.39 feet
Average	8.38 feet

A Tidal anomaly of +0.07 feet was observed at the Fort Point, New Hampshire tide gauge at the time of the survey. This was added to the average tide level resulting in a water level of 8.45 feet which was then used for the bench mark level above MLLW to determine the elevations.

With the elevation of the ocean surface above Mean Low Low Water (MLLW) determined, a backsight (BS) was then taken of a leveling rod at bench mark one

be 18.91 feet. All measurements taken are depicted in Figure 2 and Table 1.

Since there was no discontinuity in the slope of the beach at the mean high water mark the slope of the beach from the base of the seawall to the water level was determined. The beach increased in elevation 4.87 feet over a distance of 79.00 feet for an average slope of 0.06 or 6.0 percent.

In summary the following measurements will be used in the parameterization relative to MLLW:

Base (toe) of seawall = 13.32 feet
Top of seawall = 18.91 feet
Foreshore beach slope = 0.06

Mignone, 2013

Table 1

Long Beach Ave. Survey Notes 2013.05.20

Point	BS(+)	HI	FS(-)	Elevation
BM_1	9.72	18.17		8.45
TP_1	10.39	23.71	4.85	13.32
BM_2			4.8	18.91
check	20.11		-9.65	18.91
	-9.65			-8.45
	10.46			10.46

III. Storm Hindcasts and Verification

Stockdon Hindcast Example #1: Saco, Maine
December 27th, 2012

Stockdon Equations: December 27th, 2012 Storm

- Seas 21-25 feet at high tide (nearshore buoys)
- Astronomical tide only 9.5’ in PWM Harbor + Storm surge 2.5’ = Yields Storm tide 12.0 feet (FS=12.0 ‘)
- On a sunny day, 12.0 feet = minimal issues
  - But not this day

Storm Impact and Surf Tool

Storm Impact and Surf Calculator

Choose one of the buttons below to forecast storm impacts or surf height

Storm Impact Model | Surf Height | Exit

Forecast Storm Impacts at Specific Points

Wave Height (m)
4.87

Period (s)
10

Surge (m)
0.73

Tide (m)
2.93

Dune Base Elevation (m)
5.27425920

Dune Crest Elevation (m)
6.18561120

Slope
0.14000

This is for point forecasting only! Impacts will vary significantly up and down the coast -- See documentation for how to select input for this application

Erosion: Expected

Overwash: Expected

Inundation: Not Expected

Exit

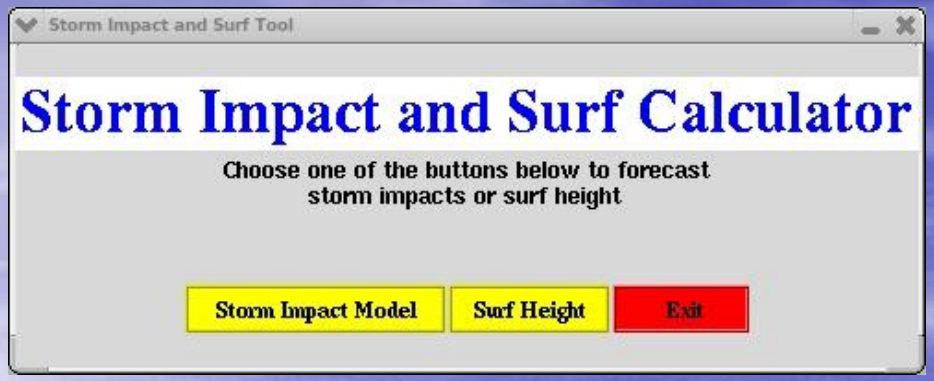
Total Water Level: Rlo 5.01 M

Total Water Level: Rhi 7.004 M

R2% 3.344 M

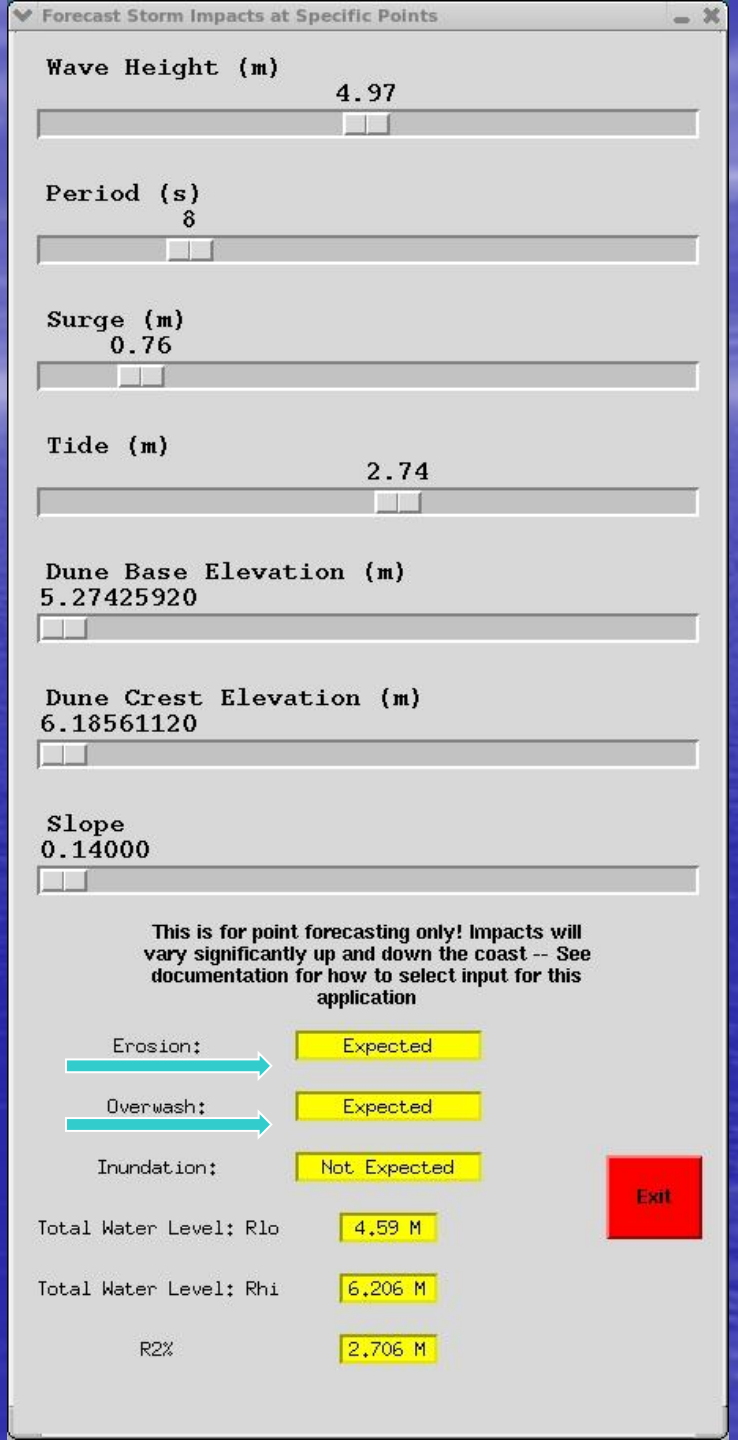

SPEED
LIMIT
15


SPEED
LIMIT
15



Stockdon Hindcast #2: HAMPTON, NH "Sandy"

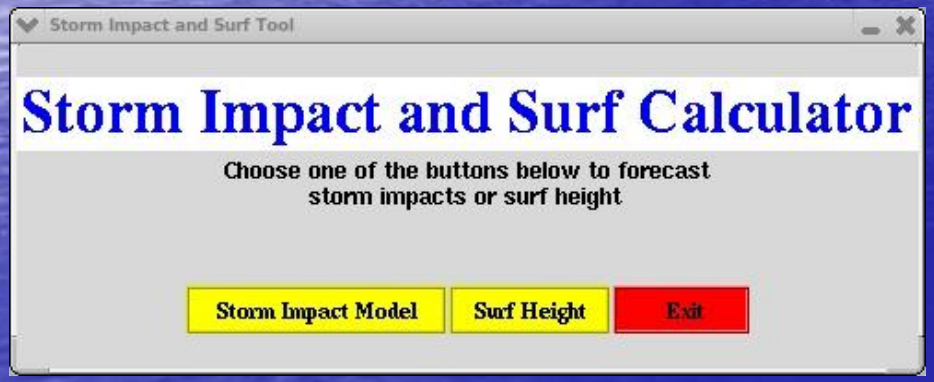
Sandy's Waves 31' at high tide (Buoy "B")

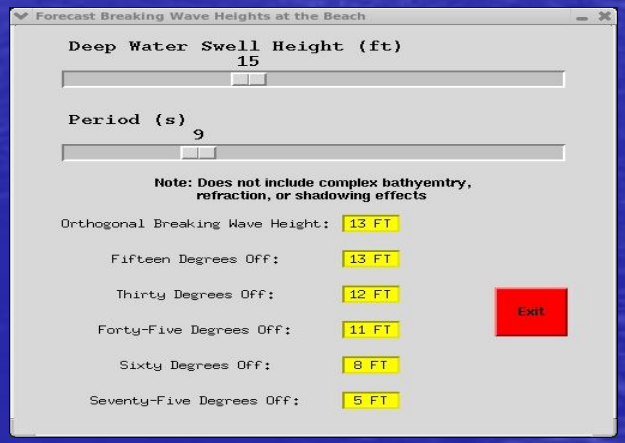


Stockdon Equations and Predicted Nearshore Wave Heights: A Challenge

- Stockdon Equations Relate Wave Heights at 20m ocean depth to wave setup and run-up in the breaker zone
  - Will this relationship always be valid?

- In AWIPS: We use the Surf Height Calculator to estimate breaker zone wave heights (Willis et al. 2009)





- UMaine/NWS GYX Sea Grant Study: Leverage high res. wave models within complex bathymetry to forecast nearshore waves

Next Steps…

- Utilize separate model for rocky shoreline sloped revetments: Allsop (2005)
  - Could be any sloping structure (riprap, seawall etc.)

Future Work…

- Automate Stockdon Output
  - Allow for "one stop shopping" forecaster access & interpretation during storms
- Establish and test new "Stockdon" sites
  - Real-time events and hindcasts
- Hold "Train the Trainer" Workshops (WFO BOX)
- Provide outreach and secure EM Feedback

Stockdon Empirical Equations to Estimate Erosion, Splash-over or Inundation Potential (Use nearshore buoy & Tide gage data):

Stockdon Excel Spreadsheet for Jennes Beach (NH Seacoast)

Stockdon Excel Spreadsheet for Saco

Stockdon Excel Spreadsheet for Ferry Beach Saco

Stockdon Excel Spreadsheet for Long Beach York

Stockdon Excel Spreadsheet for Wells Beach

Stockdon Excel Spreadsheet for Middle Beach KBunk

Stockdon Excel Spreadsheet for Gooches Beach KBunk

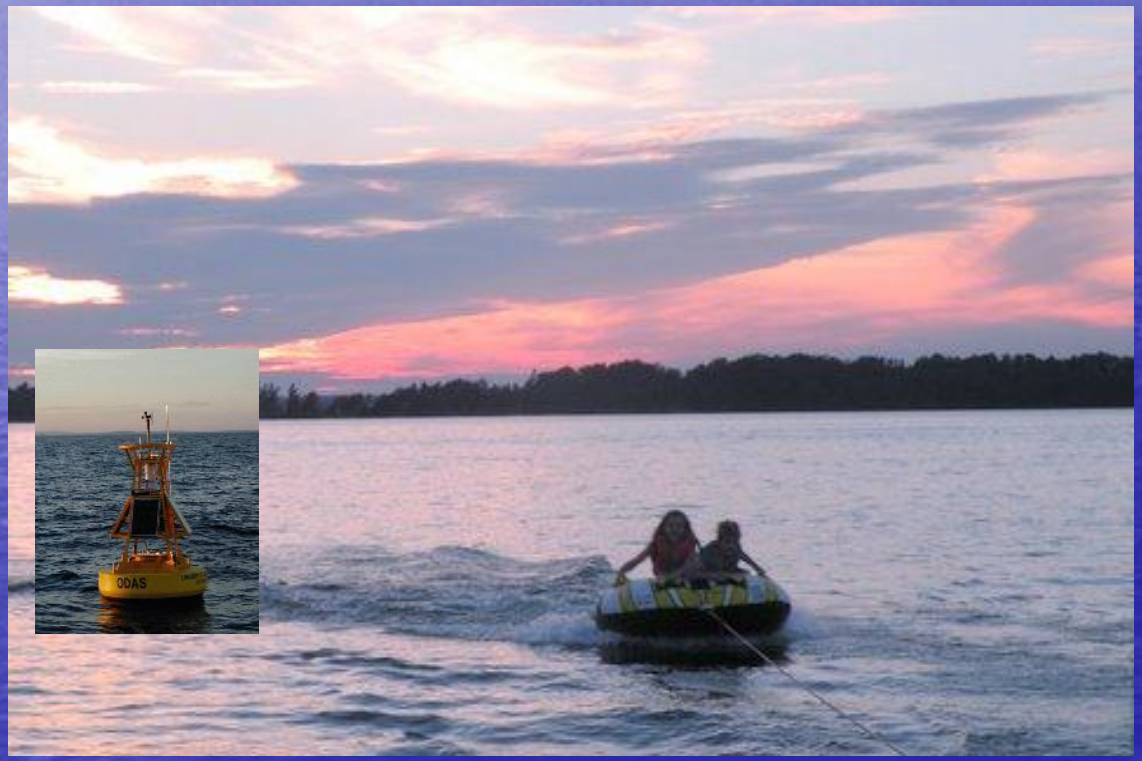
Stockdon Excel Spreadsheet for Hampton Beach

Stockdon Excel Spreadsheet for Popham Beach

How to Run Stockdon Erosion Forecast for Saco in AWIPS

Thank You for your time!!!

Questions/Comments???



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