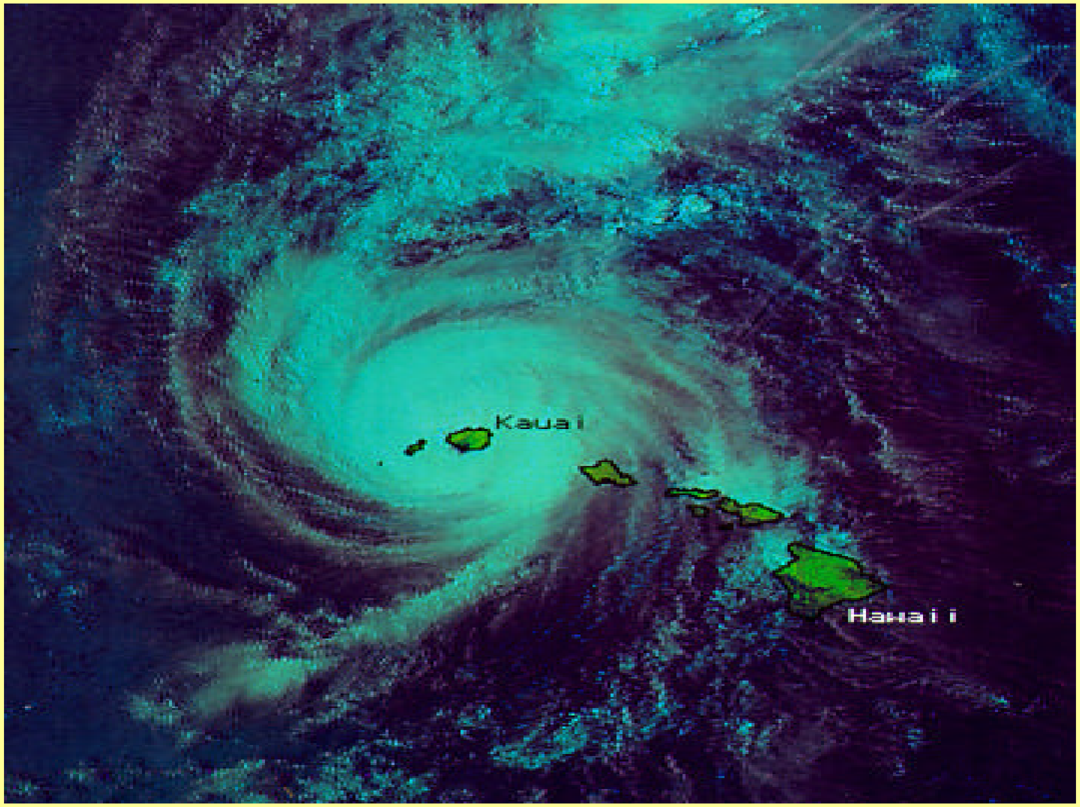
Hurricane induced Wave-Surges at landfall



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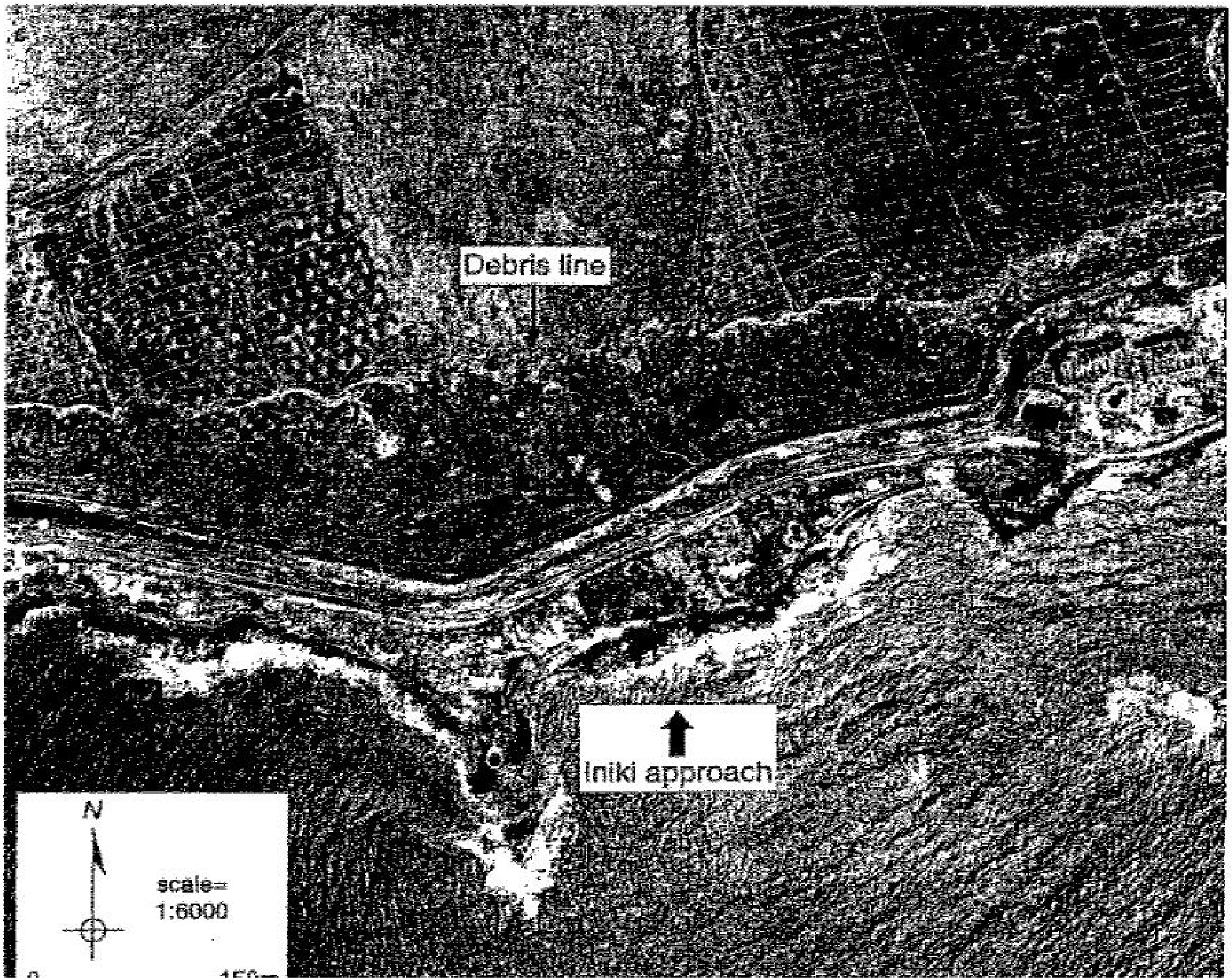
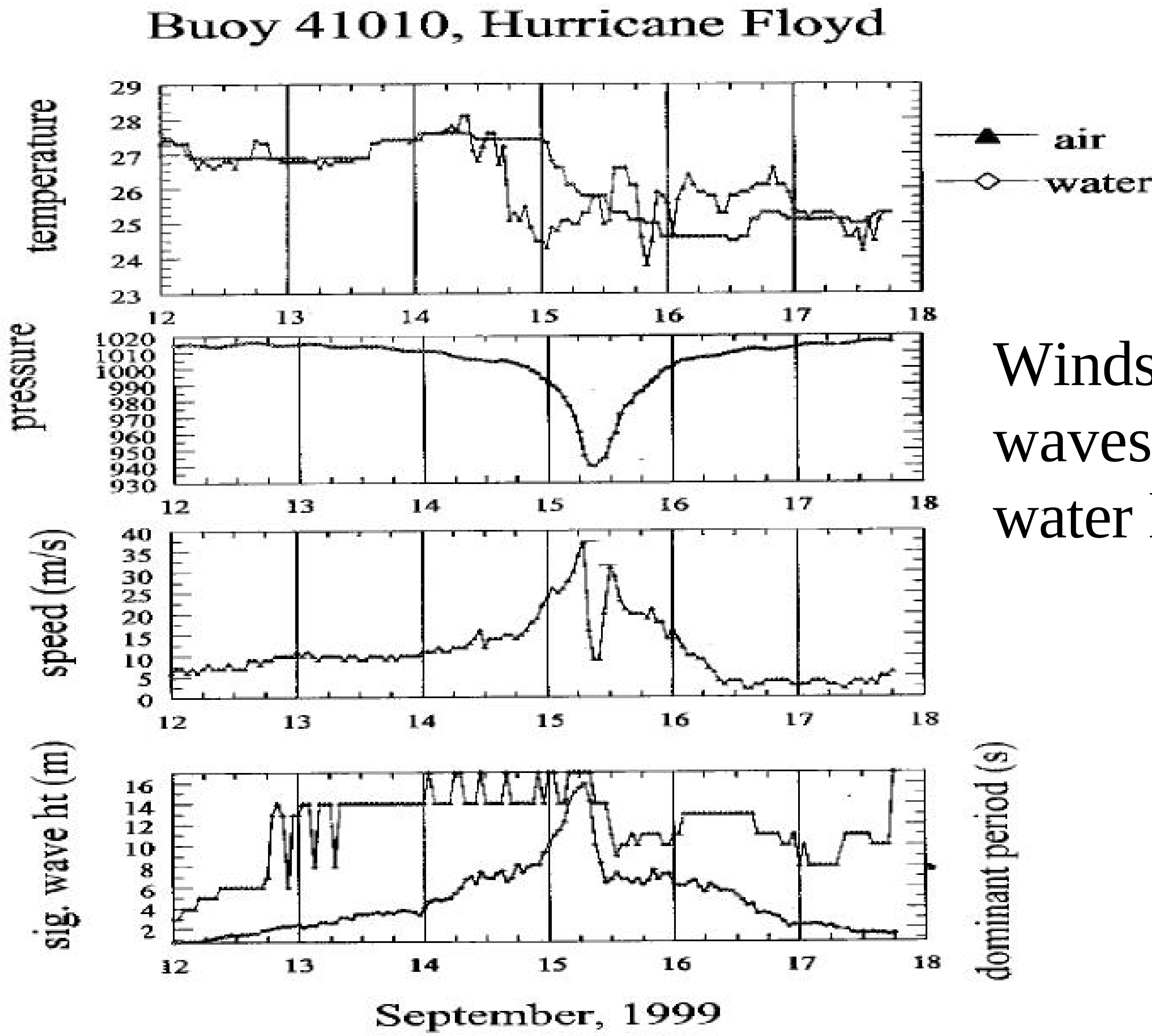
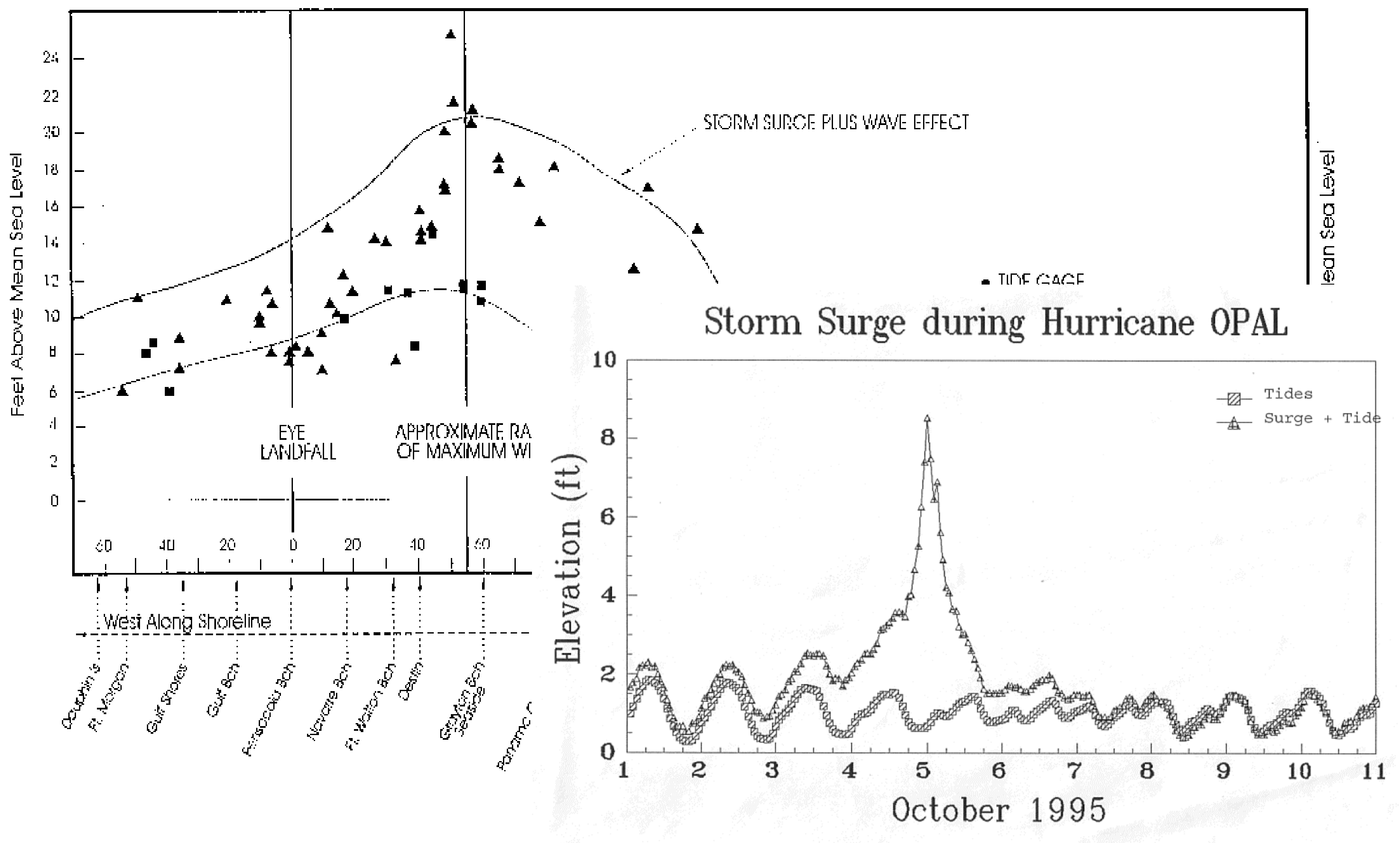

Debris line
Iniki approach
N
scale=
1:6000

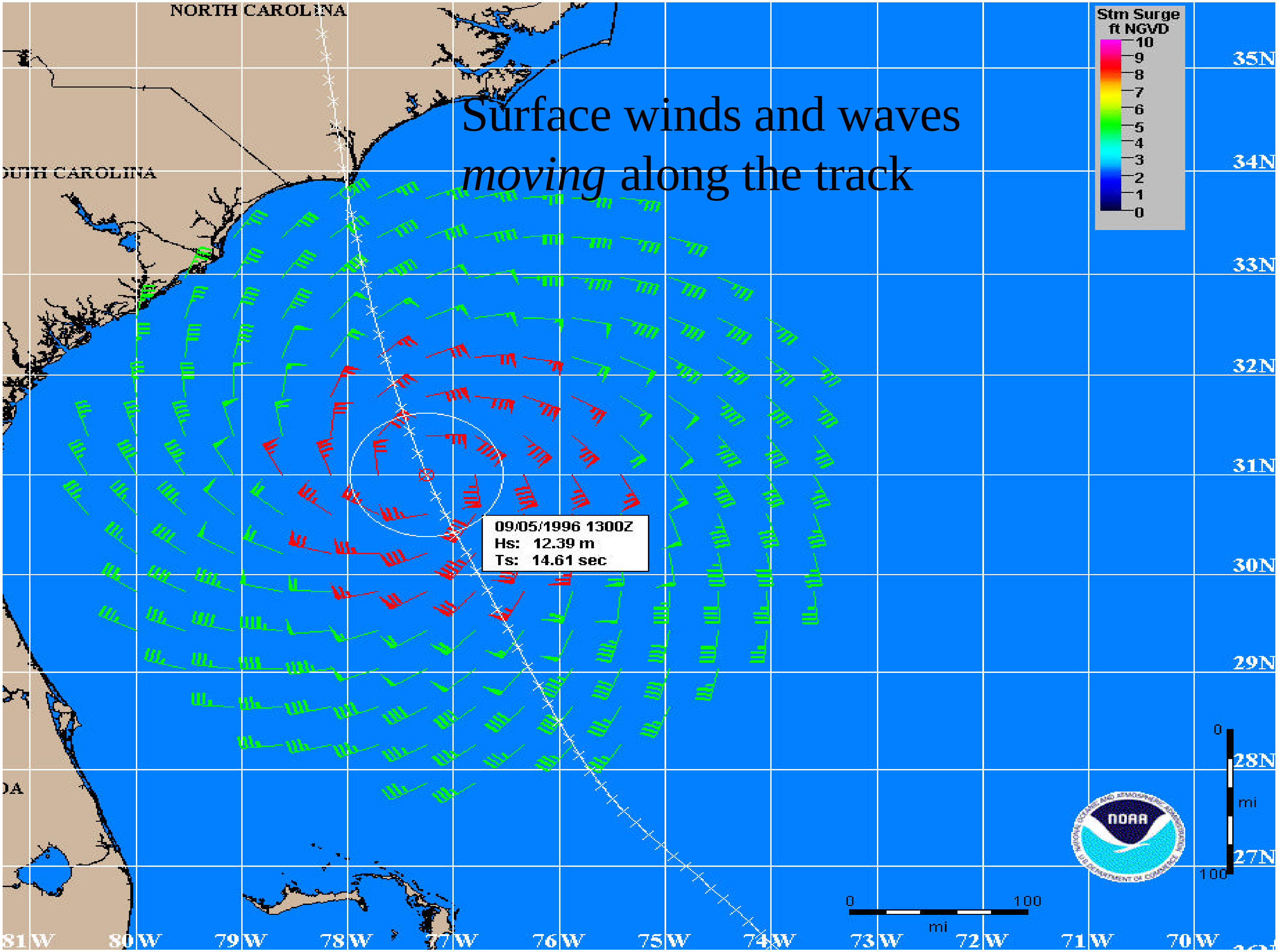


Winds,
waves,
water levels

GULF OF MEXICO SHORELINE PRELIMINARY STORM SURGE and WAVE EFFECT PROFILES FOR HURRICANE OPAL (1995)



Surface winds and waves *moving* along the track



Meteorological Forcing of Ocean Surface waves

- A simple empirical hurricane wind-wave scheme based on JONSWAP fetch-limited wave growth

I. Young (1988) proposed an equivalent fetch, F, such that

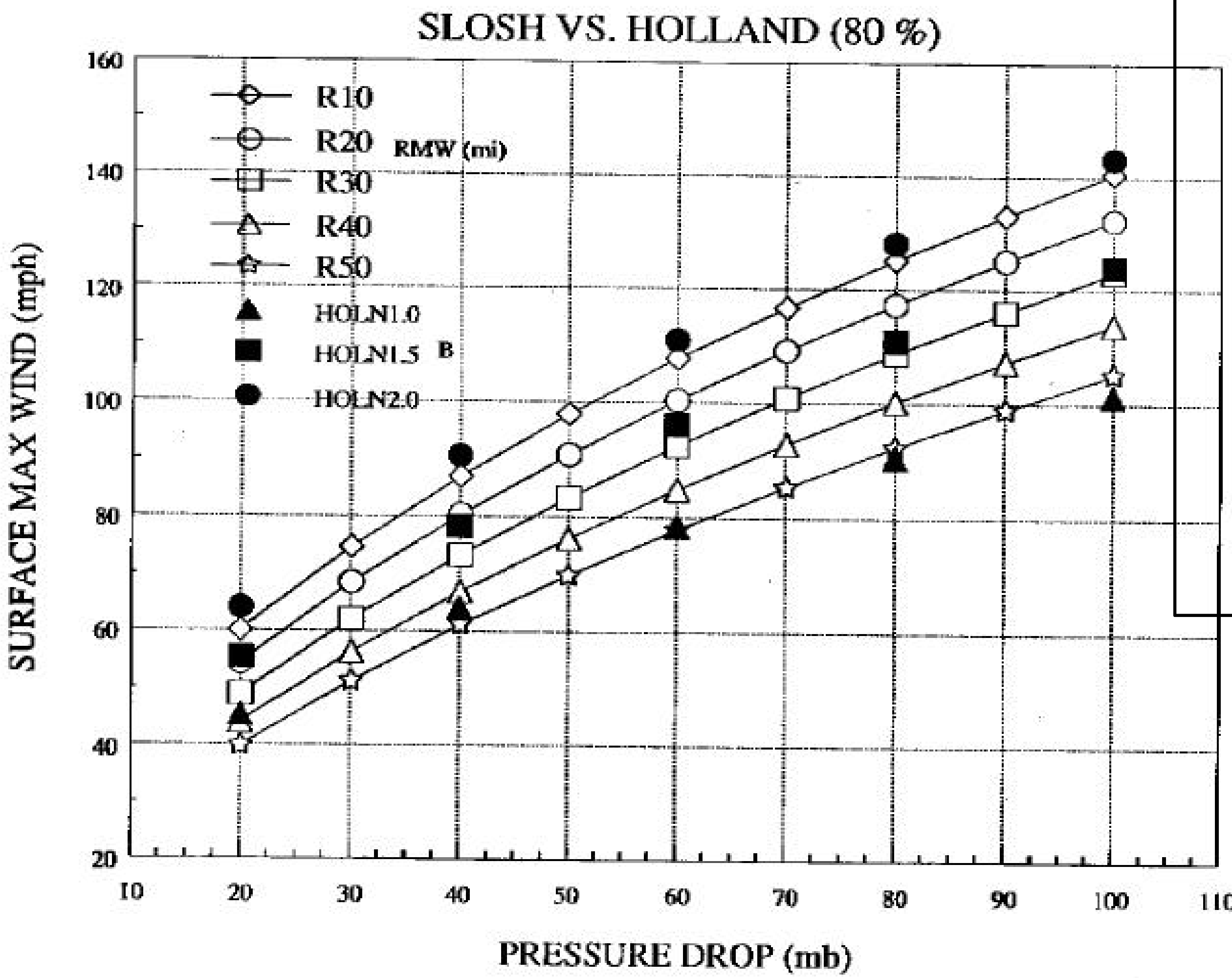
$$Hs = f\,(V_{max}, F), \qquad Tp \sim f\,(V_{max}, F)$$

F is tuned with wave model output and field data.

. Among the sustained winds, V_{max} is the key.

A Parametric cyclonic wind field

Surface wind vs. central pressure drop



A Stationary Storm

Myers & Malkin (1961)

surface wind V

$$\frac{1}{\rho_a}\frac{dp}{dr} = K_s\frac{V^2}{\sin\varphi} - V\frac{dV}{dr}$$

and

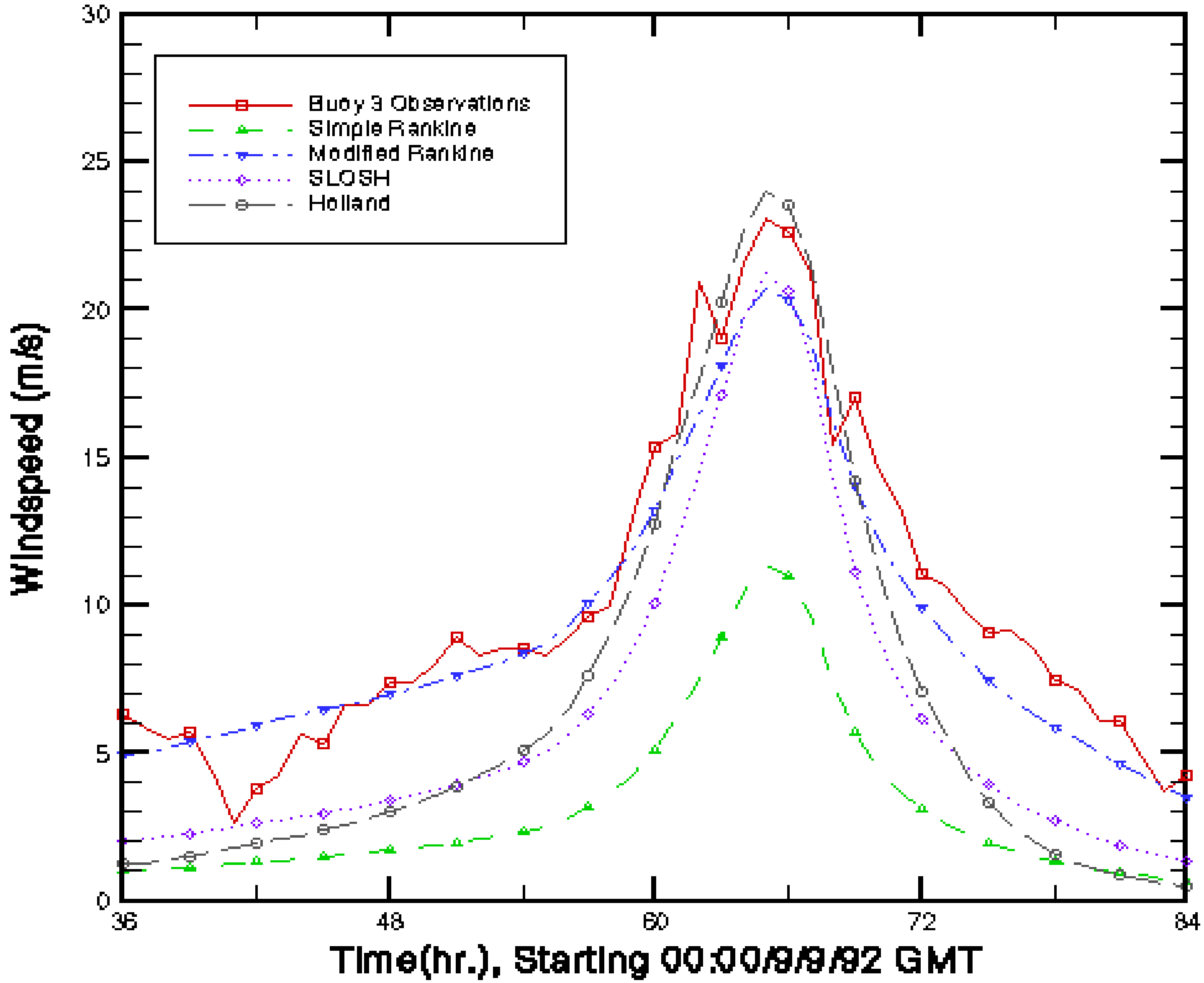
$$\frac{1}{\rho_a}\frac{dp}{dr}\cos\varphi = fV + \frac{V^2}{r}\cos\varphi - \frac{V^2}{\cos\varphi}\frac{d\varphi}{dr} + k_n V^2 . \qquad (1)$$

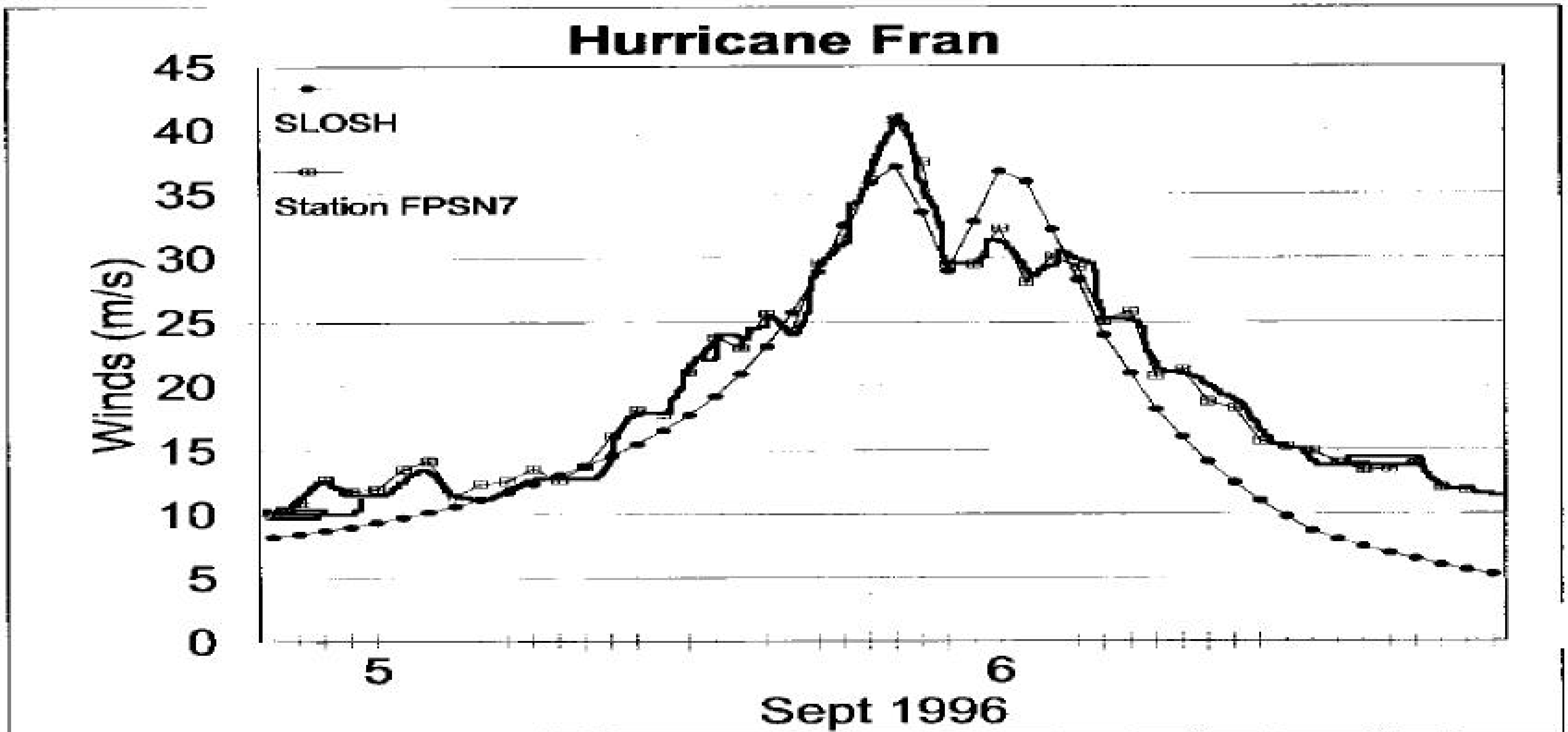
Solve p by assuming

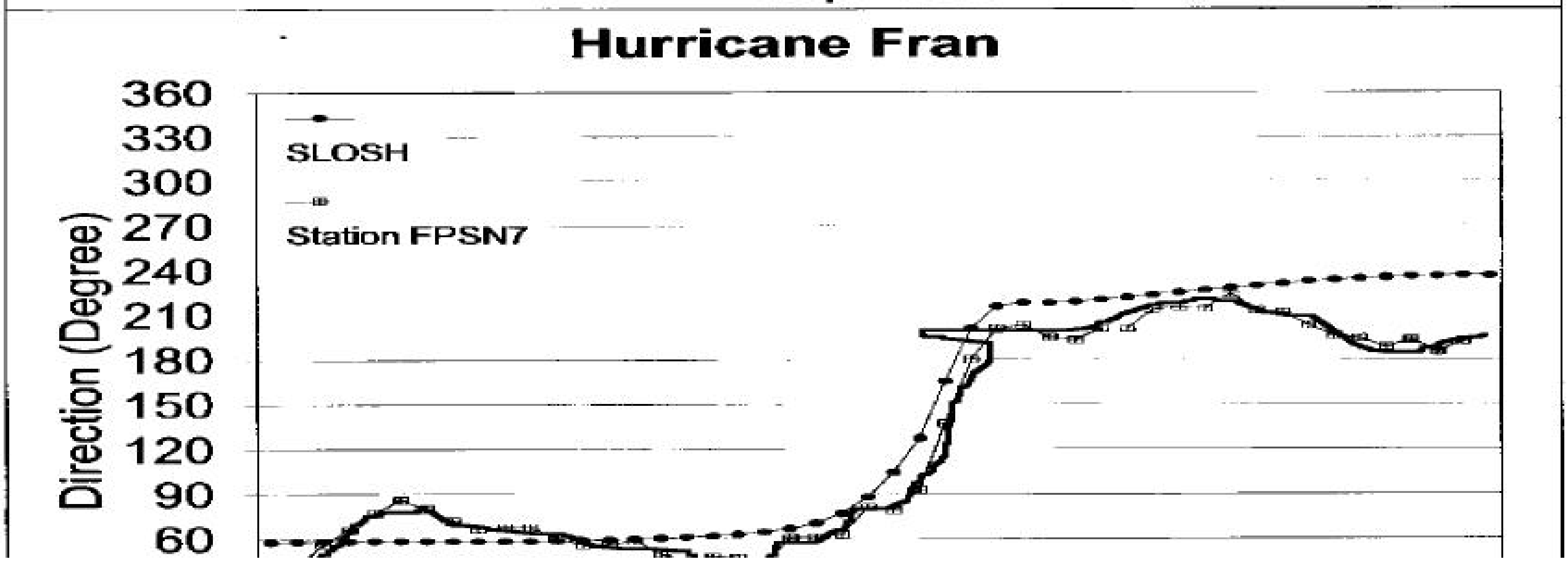
$$V(r) = V_m \cdot \frac{2x}{1+x^2} . \qquad (2)$$

where $x = r/R_{max}$.

Wind Model Comparisons vs. time




Hurricane Fran
Winds (m/s)
45
40
35
30
25
20
15
10
5
0
SLOSH
Station FPSN7
5
6
Sept 1996


Hurricane Fran
Direction (Degree)
360
330
300
270
240
210
180
150
120
90
60
SLOSH
Station FPSN7

Hurricane wave based on equivalent fetch F (Young, 1988)

$$\frac{gH_s}{V_{max}^2} = 0.0016\left(\frac{gF}{V_{max}^2}\right)^{0.5}$$ For fetch-limited seas,

$$\frac{F}{R^l} = aV_{max}^2 + bV_{max}V_f + cV_f^2 + dV_{max} + eV_f + f$$

where $R^l = 22.5 \times 10^3 \log R_{max} - 70.8 \times 10^3$ (meters)

(size of the dominant surface wind field)

Peak frequency f_p,

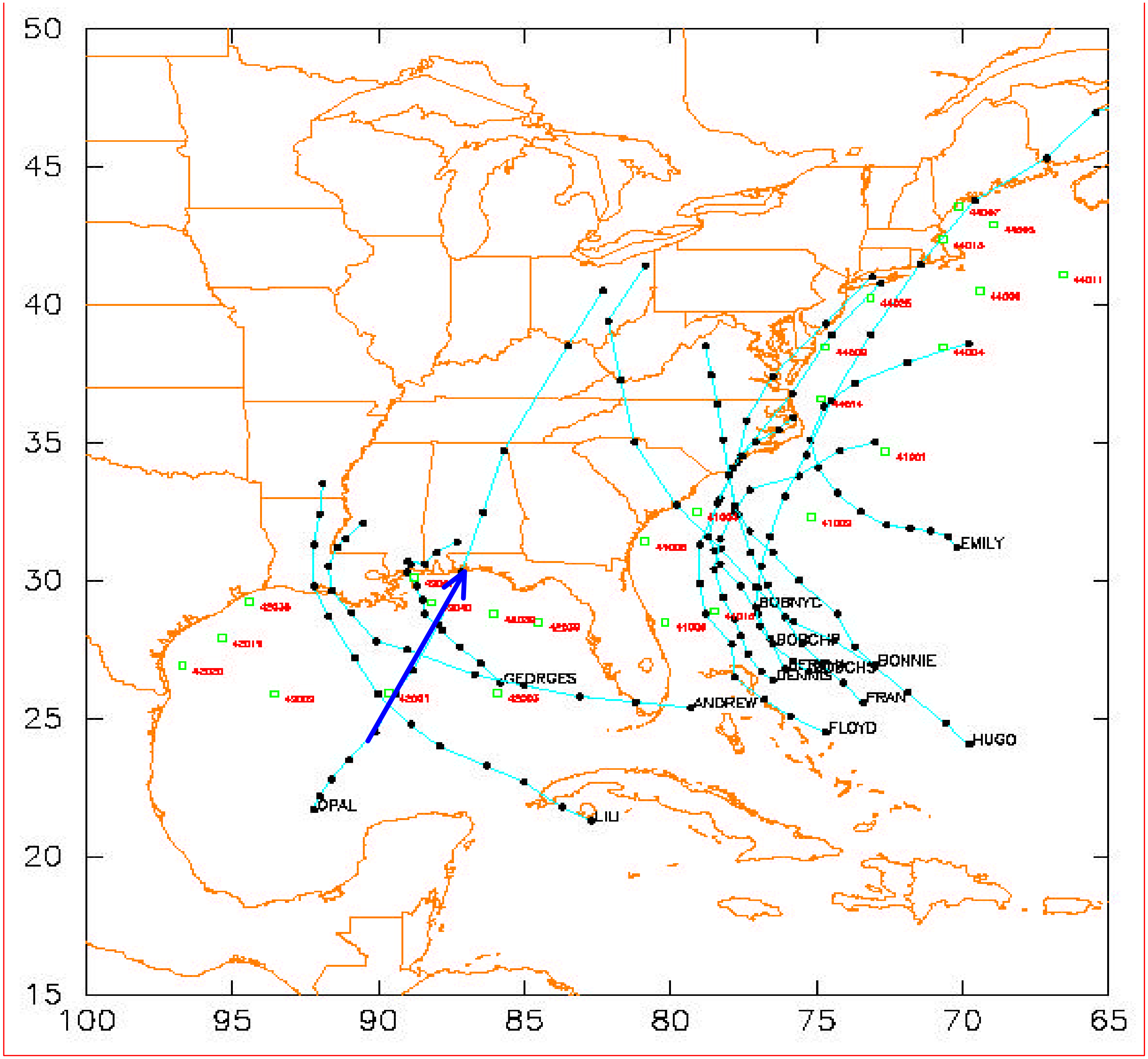
$$\frac{g}{2\pi f_p V_{max}} = 0.045\left(\frac{gF}{V_{max}^2}\right)^{0.33}$$

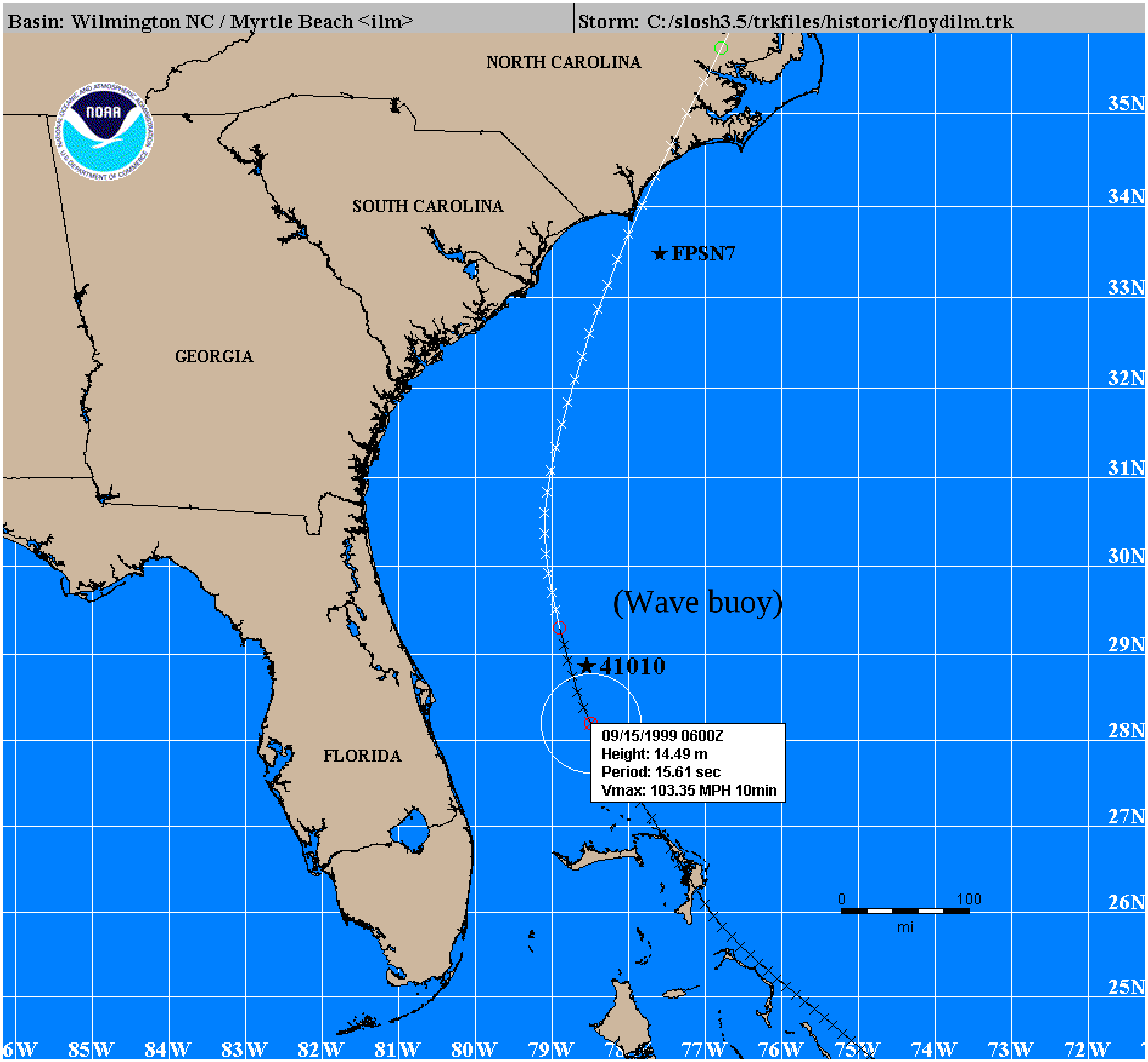
LiLi (2002)

*** Tropical Cyclone WAVES and 12 ft seas radii
RHS,LHS estimates the periphery of 12 ft seas
RHS(the RHS of eye), LHS(the LHS of eye)

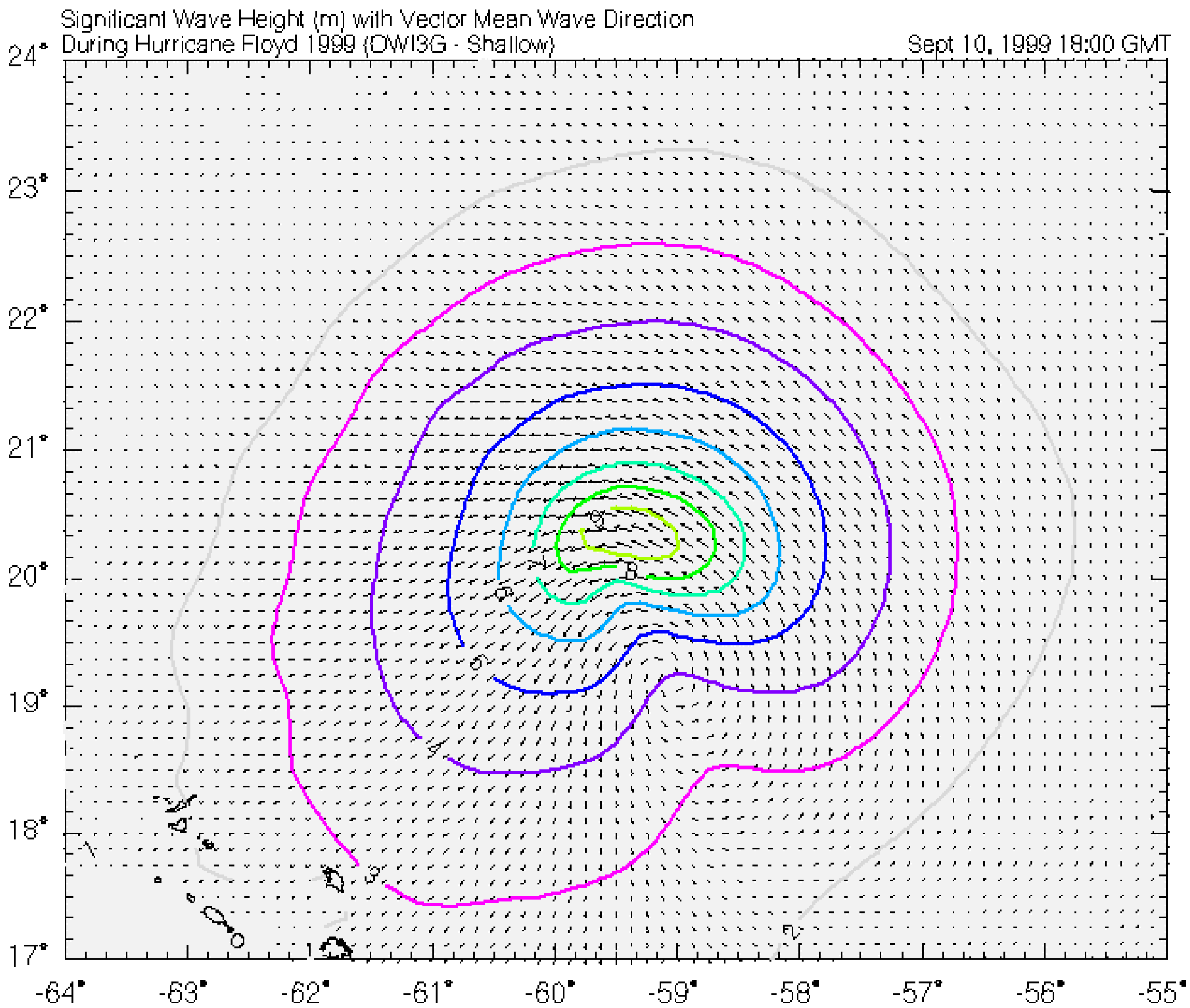
Maximum Waves estimated by calculating Vmax ::

	PDROP (MB)	RMAX (NM)	VF (Knt)	Vmax (Mph)	Wave-Ht (ft)	Wave-T (SEC)	RHS (NM)	LHS (NM)
Seas	72.0	10.0	14.0	99.1	36.4	13.3	82.0	67.0


50
45
40
35
30
25
20
15
100
95
90
85
80
75
70
65
EMILY
BONNIE
GEORGES
ANDREW
FRAN
FLOYD
HUGO
OPAL
LILI
DENNIS



Hurricane Floyd (1999) Choose time, yields Hs, T along the path



2-D wave using hourly winds dx=0.125 degree

2-D waves by E. Walsh (2001, JPO) on NOAA WP-3D. Using scanning radar altimeter.

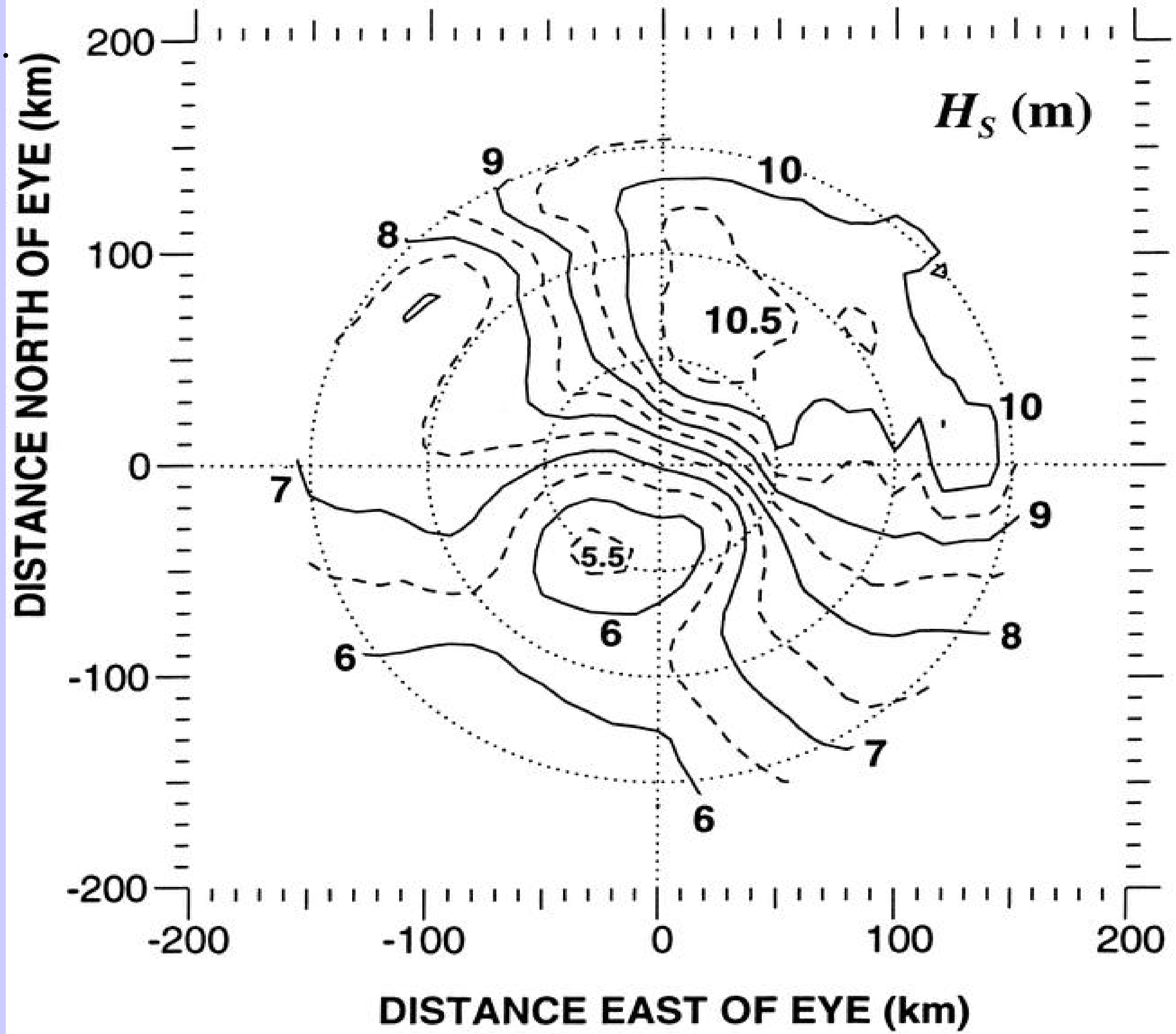
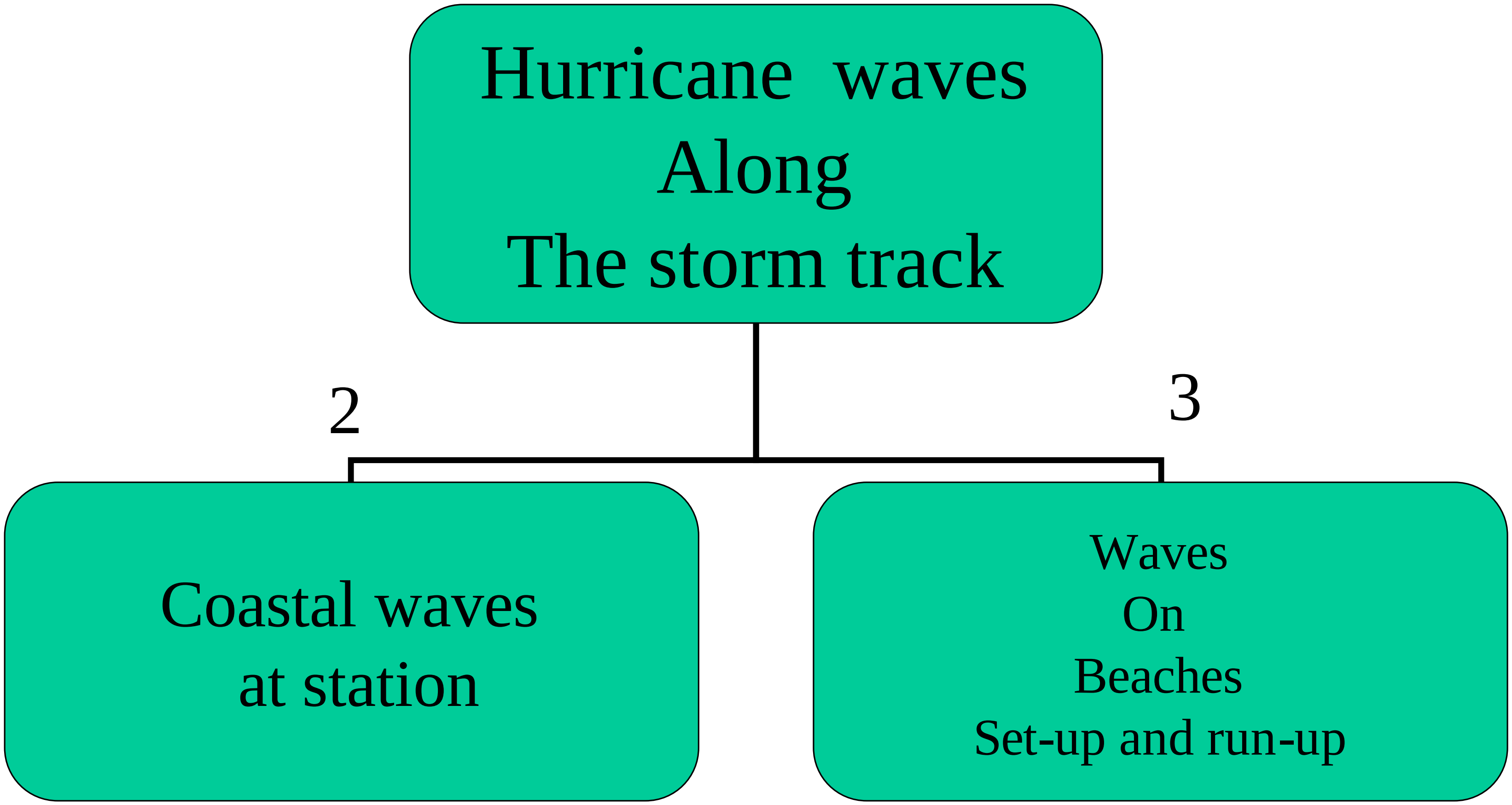
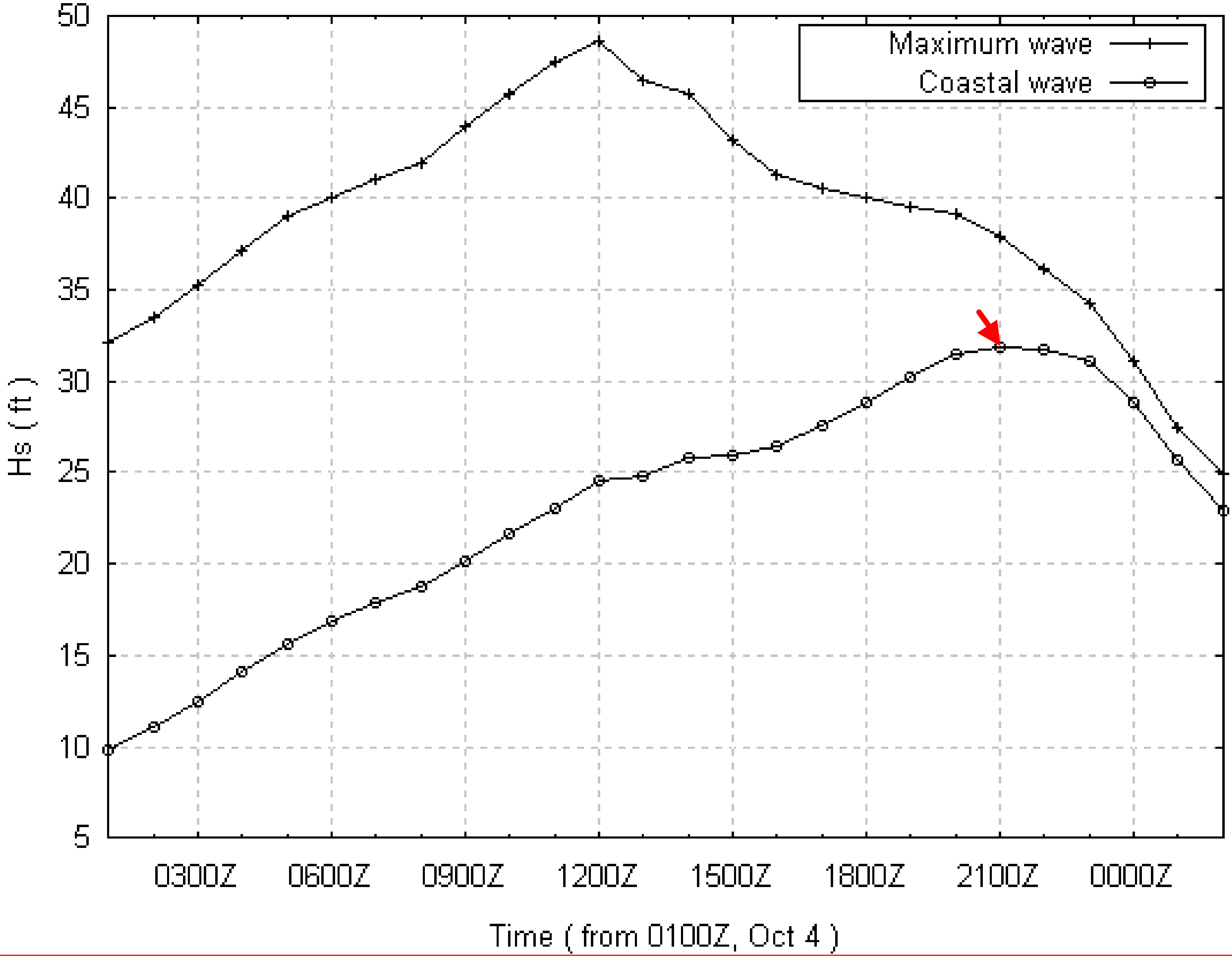


Table 1. Comparisons of wave heights(Hs) and wave periods(T)

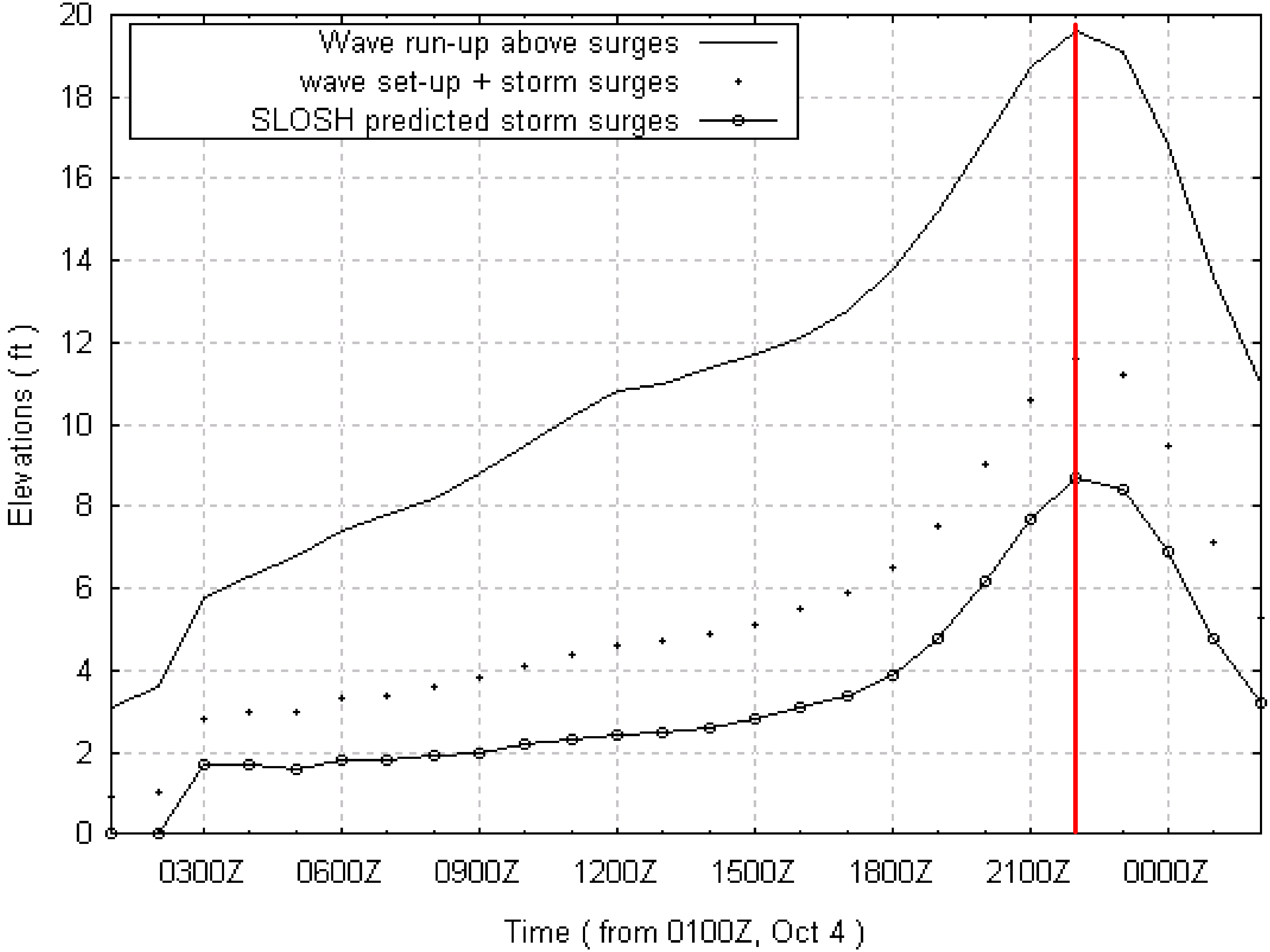
Hurricanes track time	Fran 09/05/96 21Z	Lili 10/02/02 2030Z	Georges 09/27/98 16Z	Floyd 09/15/99 08Z	Bonnie 08/24/98 21Z	Iniki 09/11/92 18Z
Predicted Hs(m)	11.50	11.12	10.48	14.24	10.46	4.95
Observed Hs (m)	11.64	11.20	10.88	14.20	10.70	5.05
Predicted T (sec)	14.22	13.28	13.8	14.95	13.2	9
buoy DMP T(sec)	14.29	13.25	13.2	15.4	12.9	8.4
Data source	FPSN7	42001	42007	41010	Radar	51003

Waves at Landfall site
Computational procedures





Maximum wave
Coastal wave
Hs (ft)
50
45
40
35
30
25
20
15
10
5
0300Z
0600Z
0900Z
1200Z
1500Z
1800Z
2100Z
0000Z
Time (from 0100Z, Oct 4)



Wave run-up above surges
wave set-up + storm surges
SLOSH predicted storm surges
Elevations (ft)
0
2
4
6
8
10
12
14
16
18
20
0300Z
0600Z
0900Z
1200Z
1500Z
1800Z
2100Z
0000Z
Time (from 0100Z, Oct 4)

Remarks for operations:

Wave-surge must be included for slowly moving tropical cyclones making a landfall.

"A parametric hurricane wave model without high resolution grids can give accurate peak wave."

- Wave induced surges ~ storm surge at the shore.
- Parametric model gives quick estimate of waves induced surge effects. The maximum surge occurs at the landfall, but waves are higher prior to landfall.
- The debris line is mostly attributed by wave run-up through the rise of sea water levels.

Waves on Beaches (Kweon and Goda, 1996):

$$\frac{\partial EC_g}{\partial x} = \frac{-K_d}{d_0}\left[EC_g - (EC_g)_S\right] \qquad (1)$$

Where E is the energy density and C_g the group velocity.

Using linear wave theory relationship, it leads to:

$$\frac{\partial\left[H^2 C_g\right]}{\partial x} = -\frac{K_d}{d} C_g\left[H^2 - H_s^2\right] \qquad (2)$$

Where Hs $= \Gamma$ d, $\Gamma = A * (d/L)_o^{-1} * [1 - \exp(-1.5\,\pi\,(d/L)_o)]$.

The wave-induced set-up $\bar{\eta}$ is governed by time-averaged mean momentum equation:

$$\frac{d\bar{\eta}}{dx} = -\frac{1}{\rho g(d+\bar{\eta})}\frac{d\,S_{xx}}{\mathrm{d\,x}}, \; \mathrm{d} = \mathrm{d}_o + \bar{\eta} \qquad (3)$$

And, wave run up follows Mase (1989, CEM)

R = f (beach slope and surf parameter)