Wind Stress over Water Surfaces: Comparisons of Various Estimation Methods

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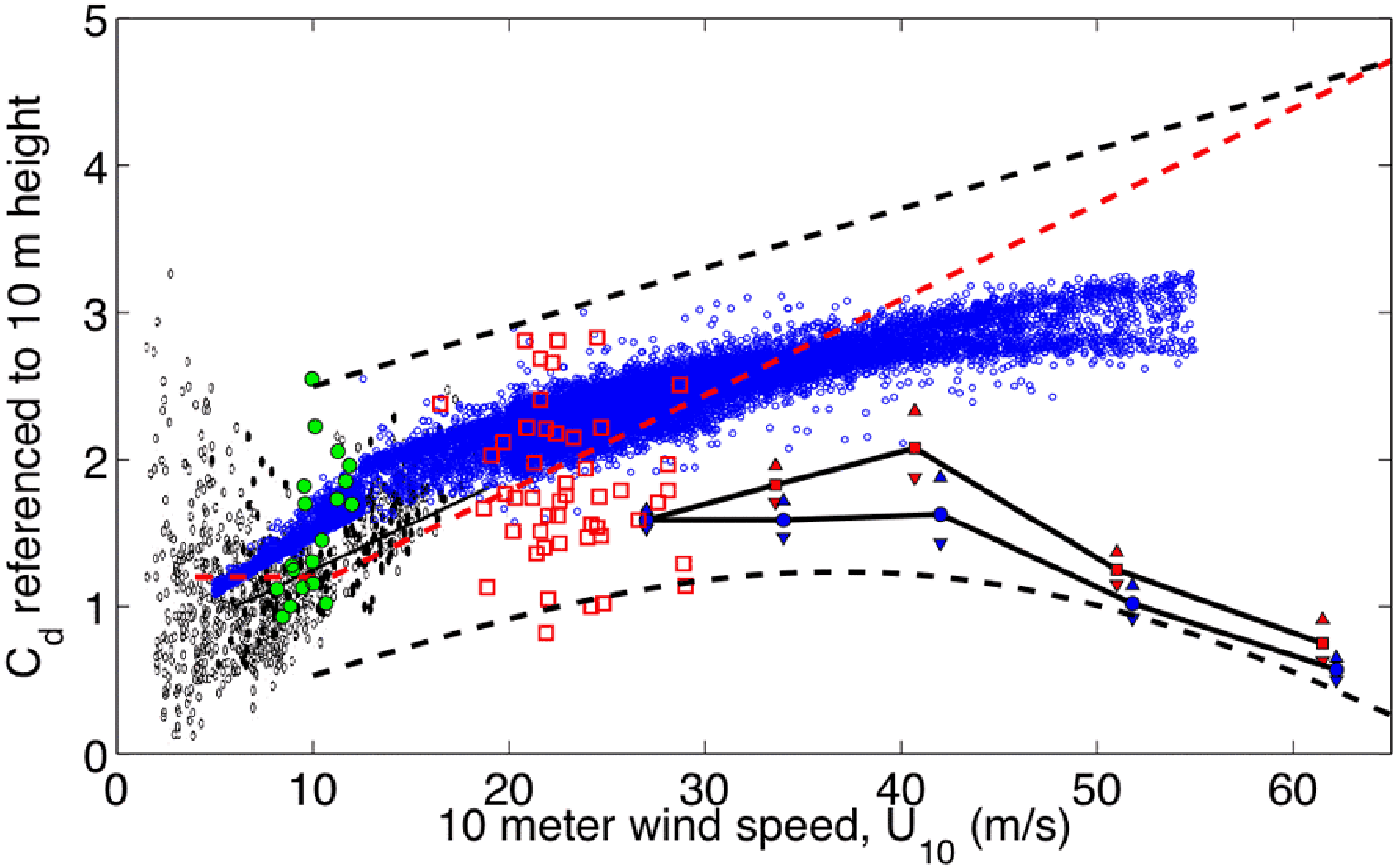
Wind stress $\tau = \varrho U^{*2} = \varrho C_d U_{10}^2$

Where ϱ is the density of air,

U^* is the friction velocity,

C_d is the drag coefficient, and

U_{10} is the wind speed at 10m above the water surface.



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1. Wind-wave Interaction Method

- When U_{10} is less than 7.5 m/s, surface tension and thermal effects dominate the air-water interaction;
- When $U_{10} > 7.5$ m/s, mechanical turbulence takes over, so that the logarithmic wind profile prevails,

$$U_{10} = (U^*/k) \ Ln \ (10/Z_o) \qquad (1)$$

Where k (=0.4) is the von Karman constant,

Z_o is the aerodynamic roughness length.

According to Taylor and Yelland (2001, JPO),

$$Z_o / H_s = 1200 \, (H_s/L_p)^{4.5} \qquad (2)$$

$$L_p = g \, T_p^{\,2} / (2\pi) = 1.56 \, T_p^{\,2} \qquad (3)$$

Where H_s is significant wave height,
L_p is peak wave length, g is gravitational acceleration, and T_p is dominant wave period.

2. Wave Method

According to Csanady (2001) and JONSWAP Wave Spectra (Carter, 1982), for $U_{10} > 20$m/s after wave breaker saturation (Amorocho and DeVries,1980; and Geernaert et al.,1987),

$$g\,Hs/U^{*2} = 0.053\,(g\,T_p/U^*)^{3/2} \qquad (4)$$

Therefore,

$$U^* = 36\,H_s^2/\,T_p^{\,3} \qquad (5)$$

3. Turbulence Intensity or Gust Factor Method

According to Hsu (1988, Coastal Meteorology) And Hsu (2003, Journal of waterway, Port, Coastal, and Ocean Engineering),

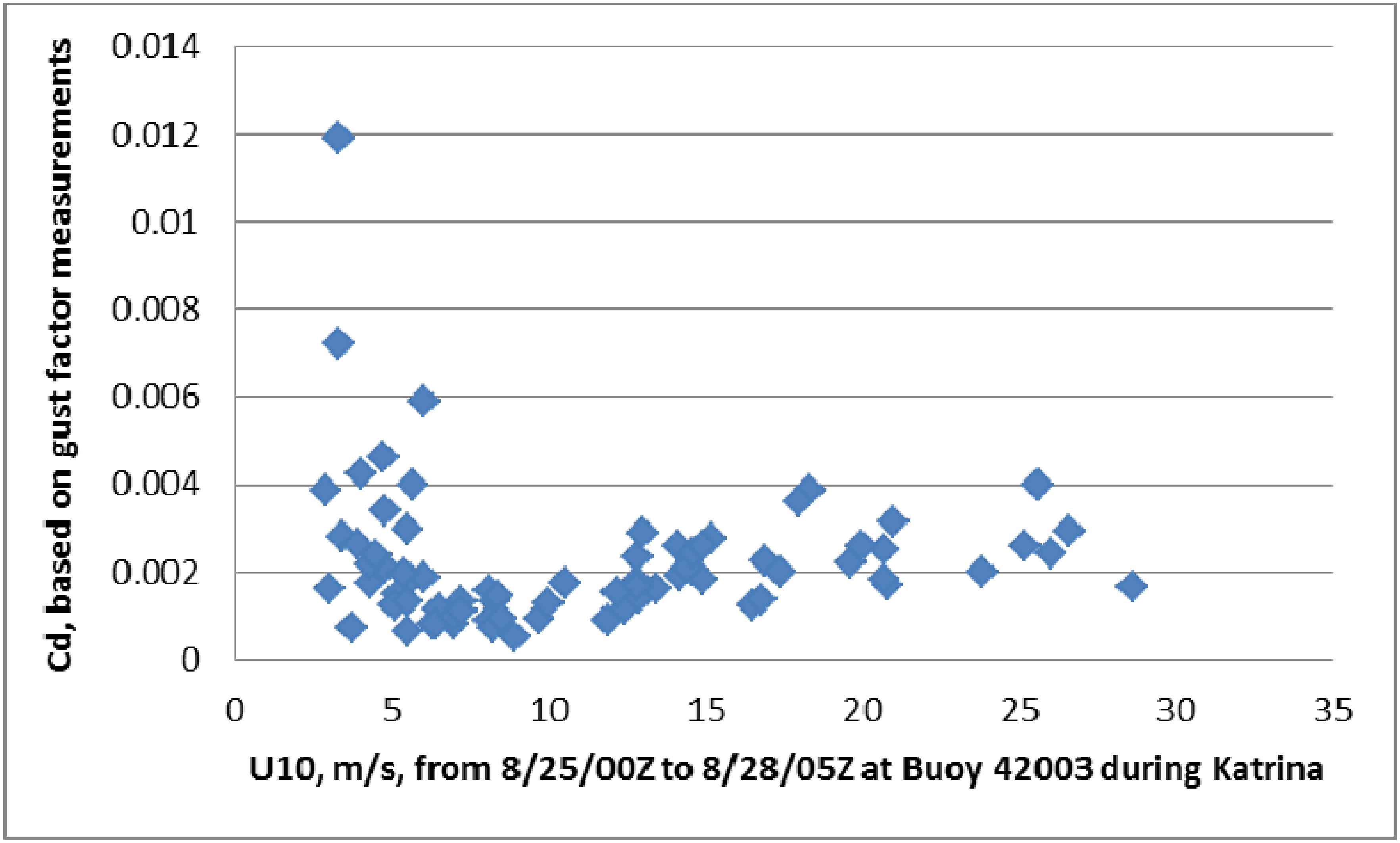
$$U^* = k\ p\ U_{10} \qquad (6)$$

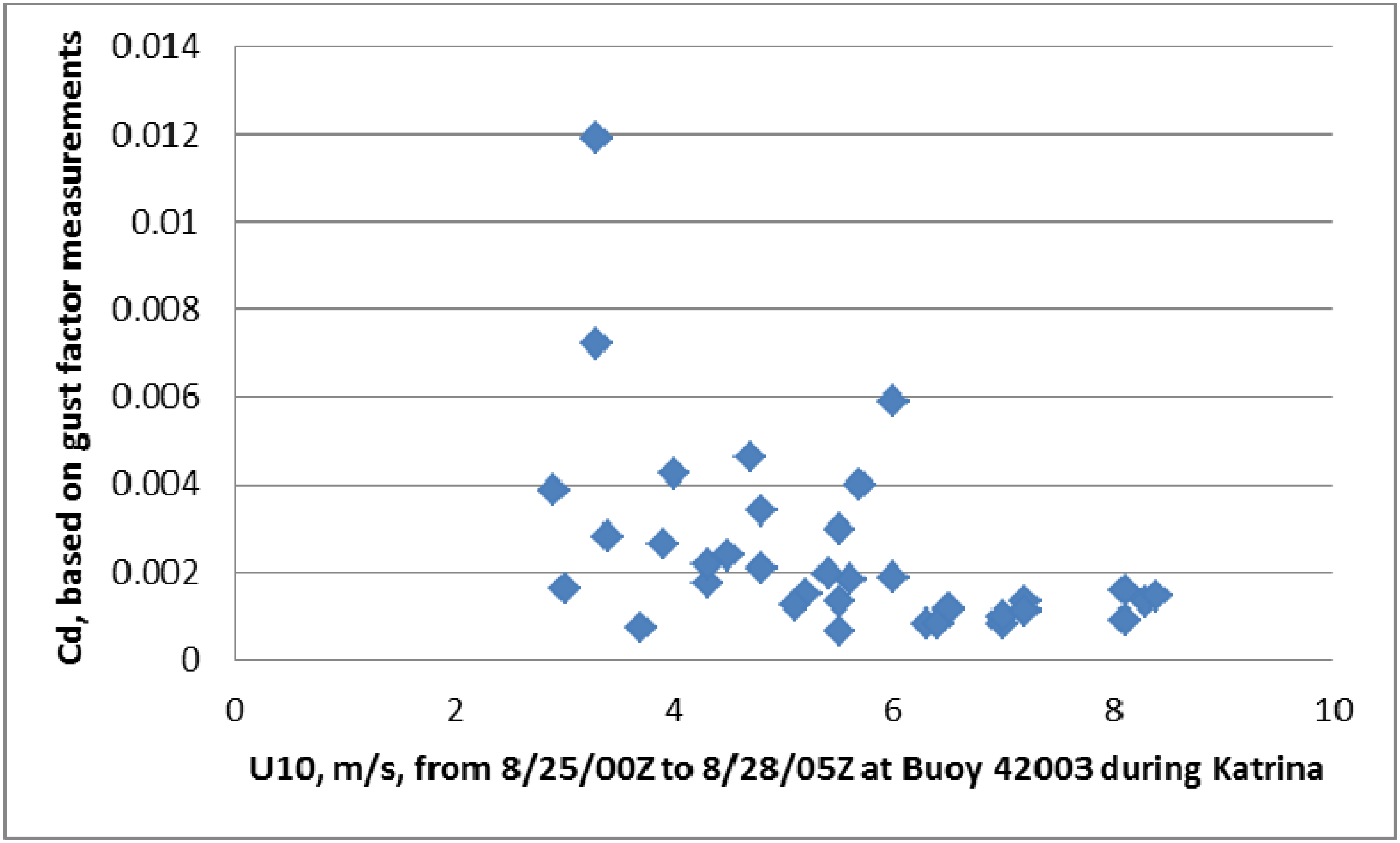
$$G = 1 + 2P \qquad (7)$$

$$U_2 / U_1 = (Z_2 / Z_1)^{p} \qquad (8)$$

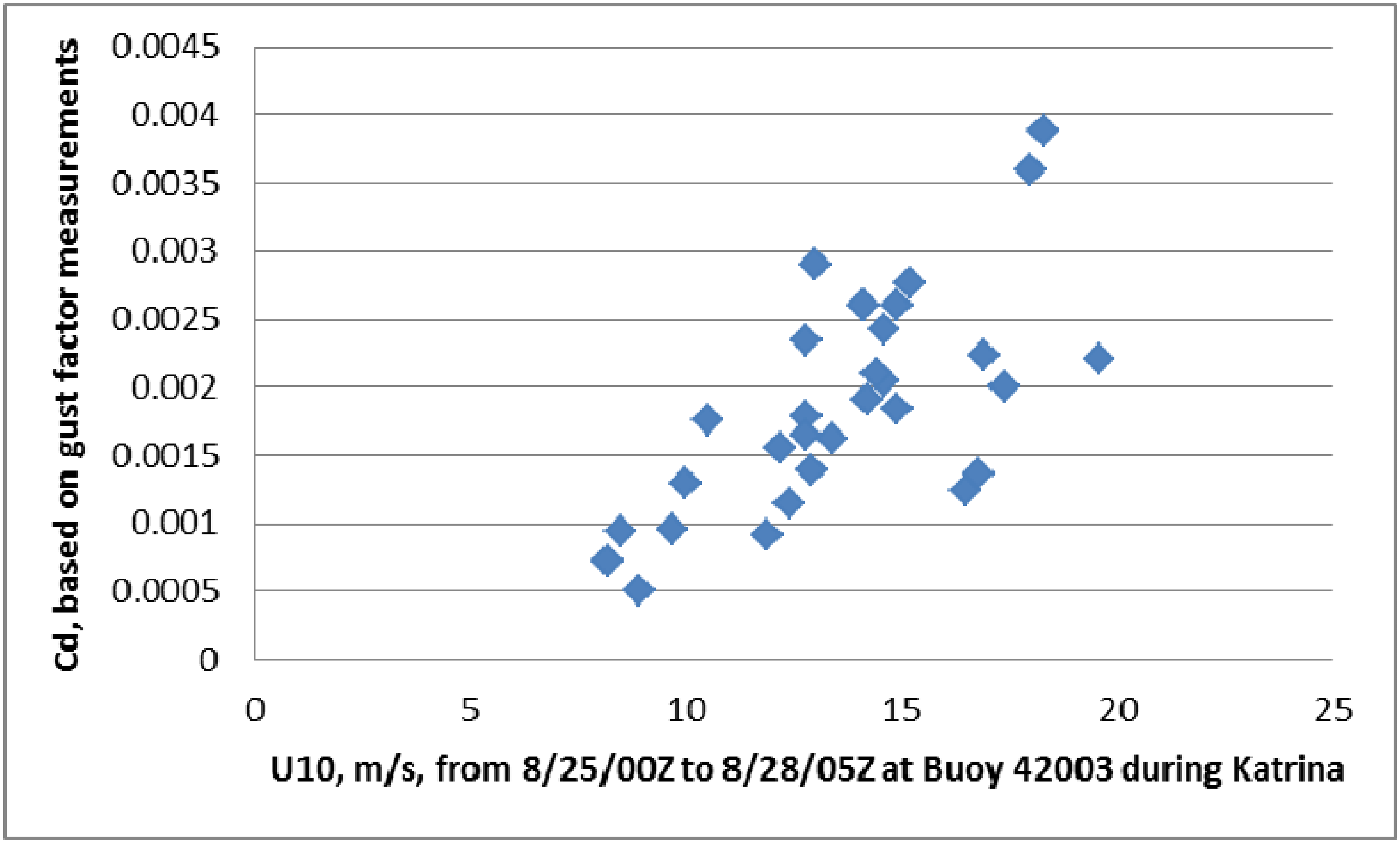
$$P = \sigma u / U_{10} \qquad (9)$$

$$G = U_{gust} / U_{sustained} \qquad (10)$$

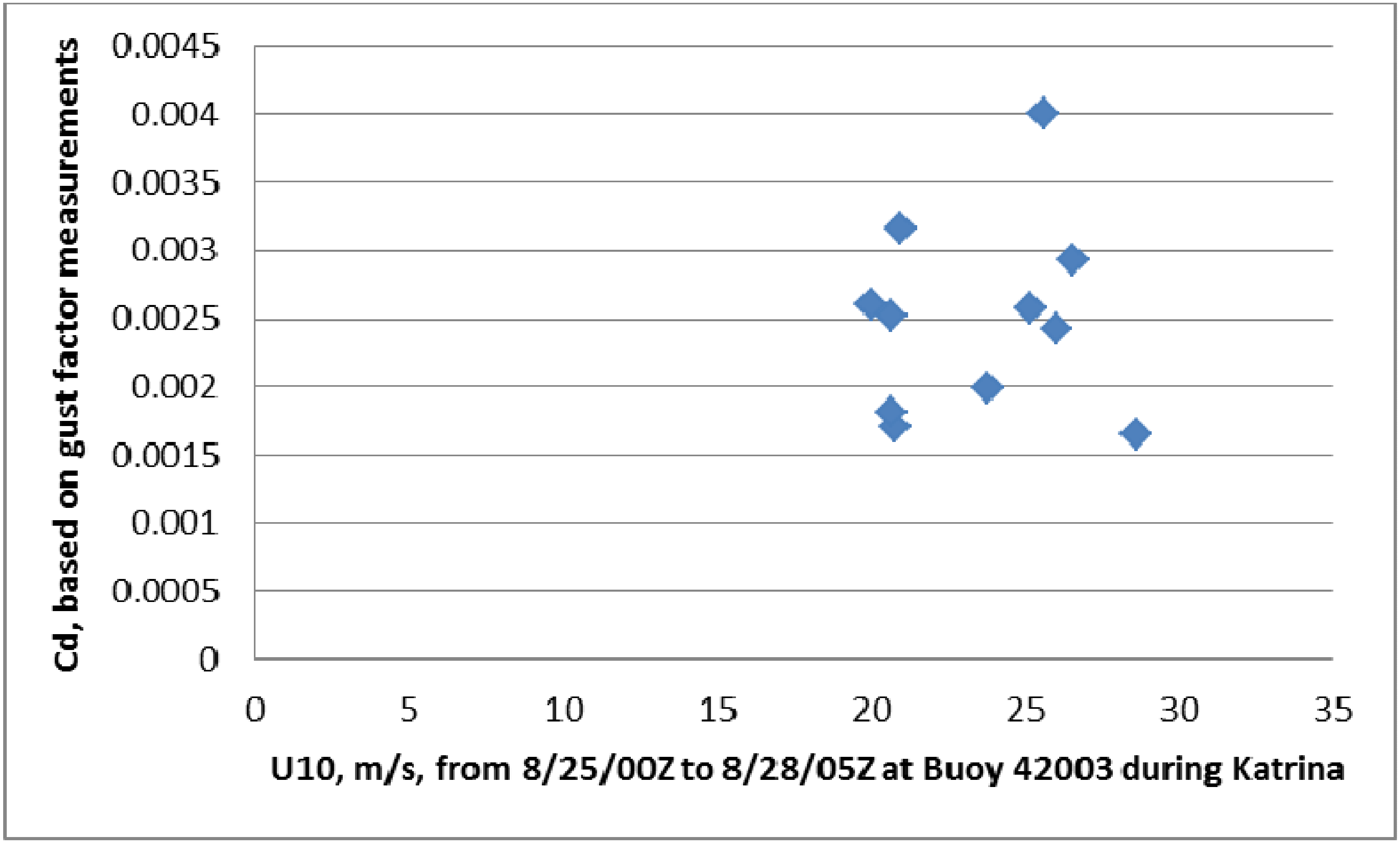

0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Cd, based on gust factor measurements
0
5
10
15
20
25
30
35
U10, m/s, from 8/25/00Z to 8/28/05Z at Buoy 42003 during Katrina



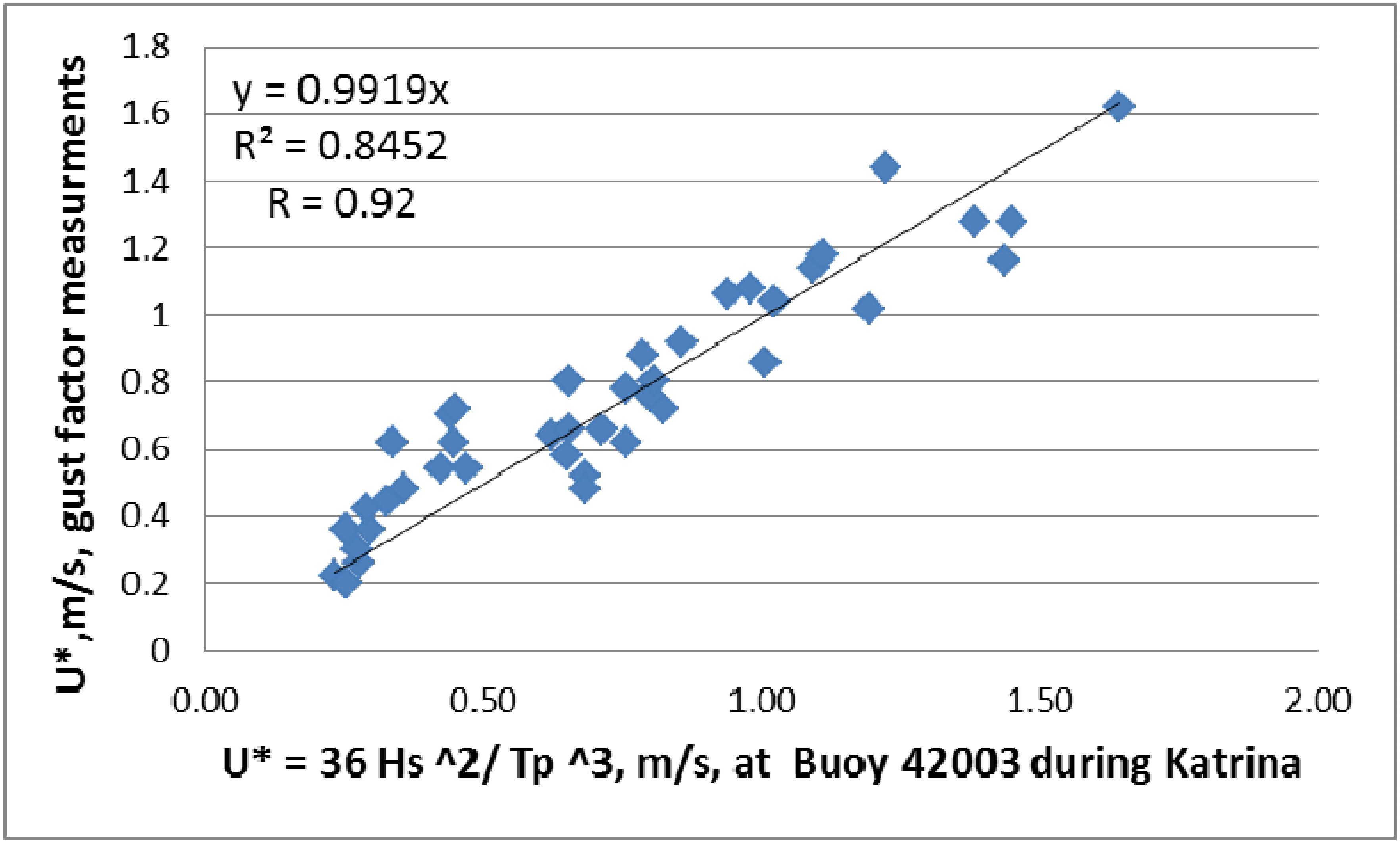
Cd, based on gust factor measurements
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
2
4
6
8
10
U10, m/s, from 8/25/00Z to 8/28/05Z at Buoy 42003 during Katrina



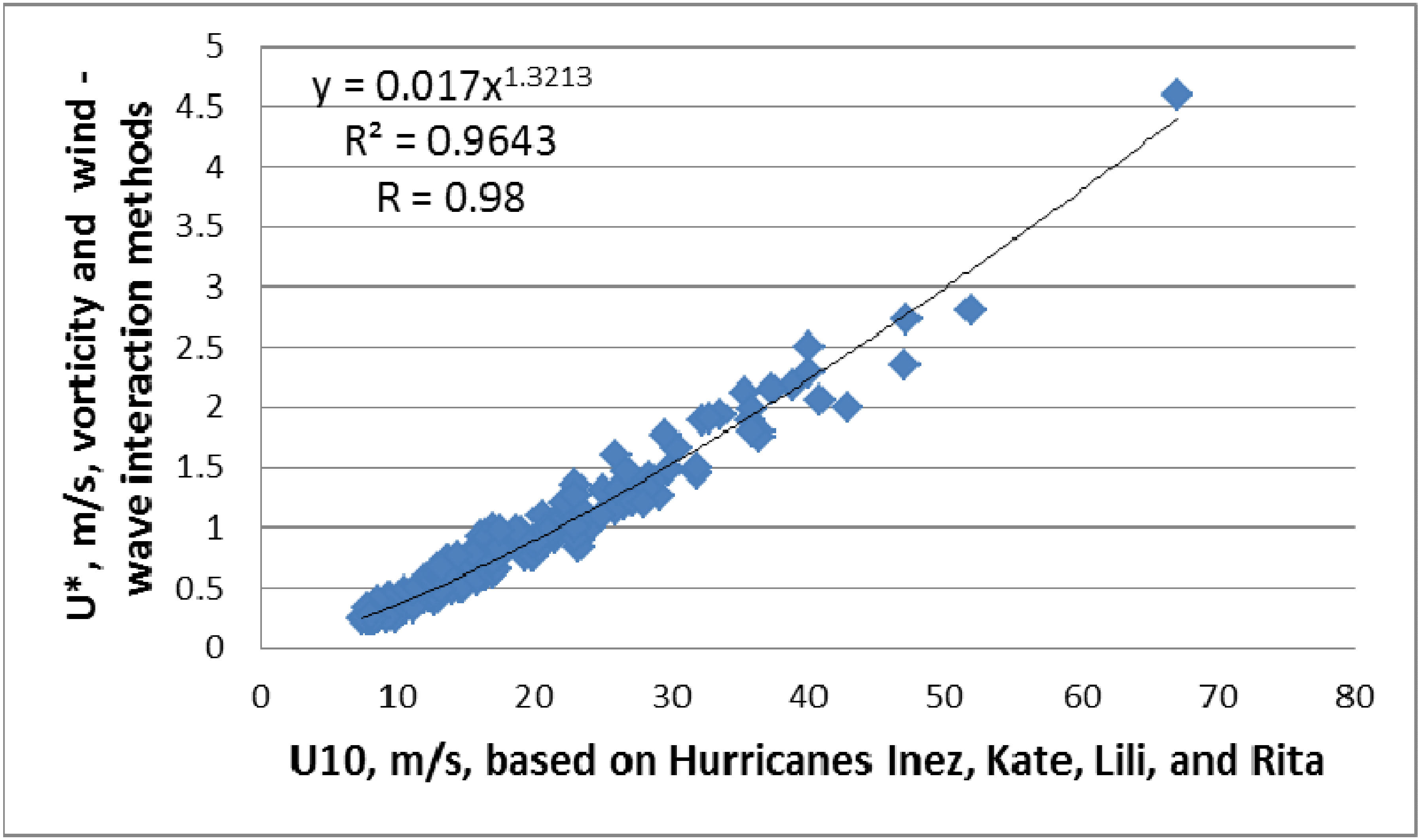
Cd, based on gust factor measurements
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
5
10
15
20
25
U10, m/s, from 8/25/00Z to 8/28/05Z at Buoy 42003 during Katrina



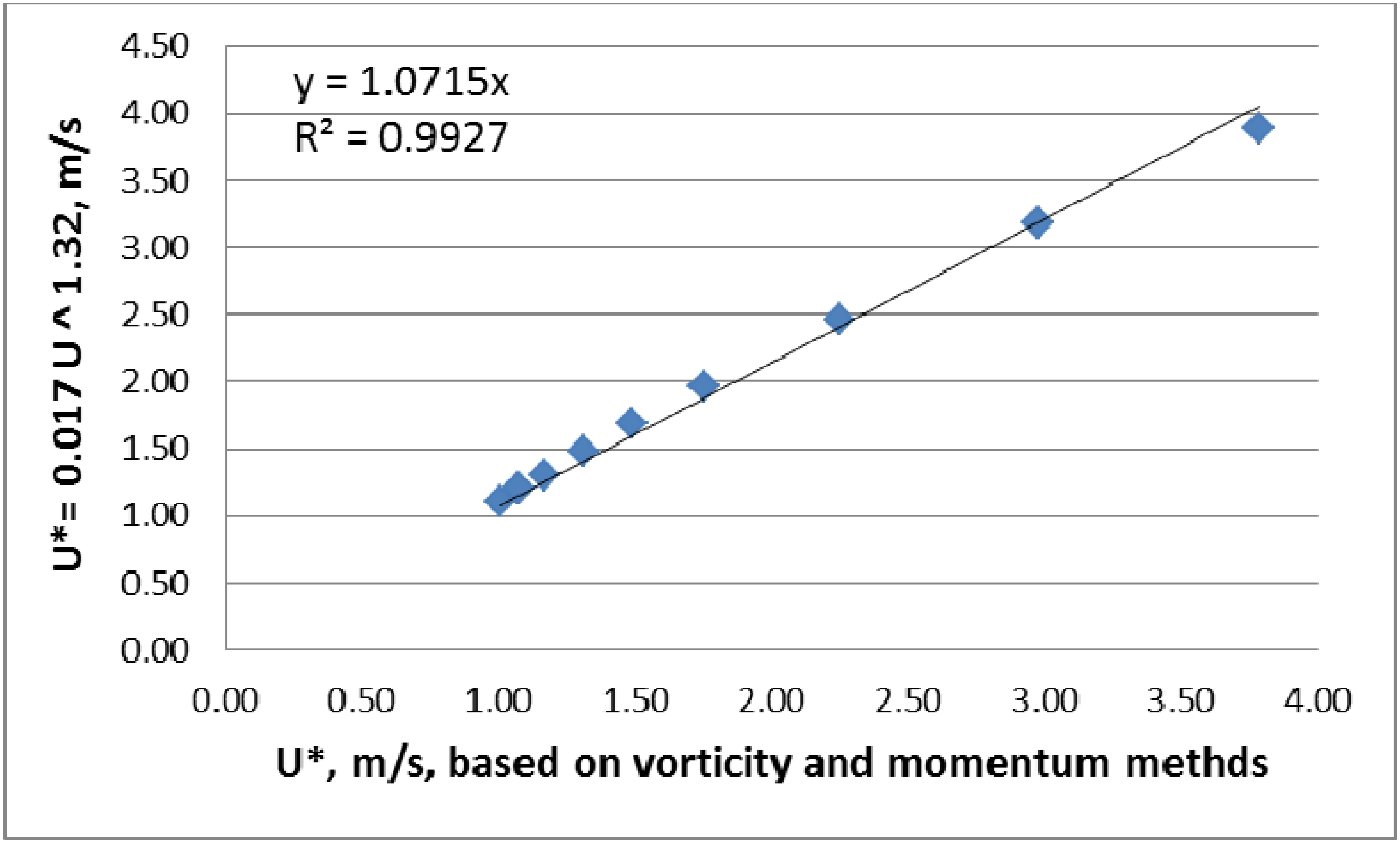
Cd, based on gust factor measurements
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
5
10
15
20
25
30
35
U10, m/s, from 8/25/00Z to 8/28/05Z at Buoy 42003 during Katrina



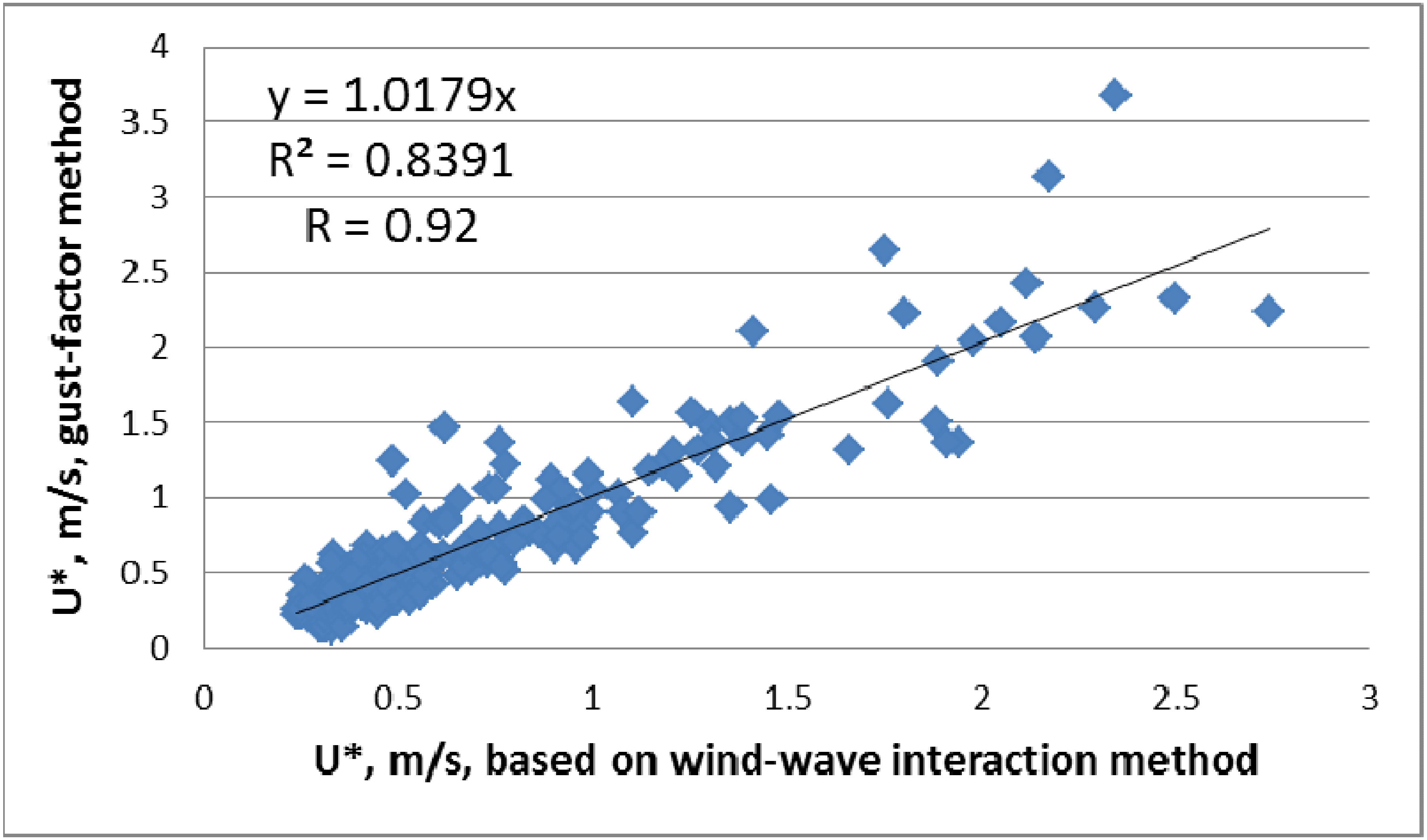
y = 0.9919x
R² = 0.8452
R = 0.92
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.00
0.50
1.00
1.50
2.00
U*,m/s, gust factor measurments
U* = 36 Hs ^2/ Tp ^3, m/s, at Buoy 42003 during Katrina



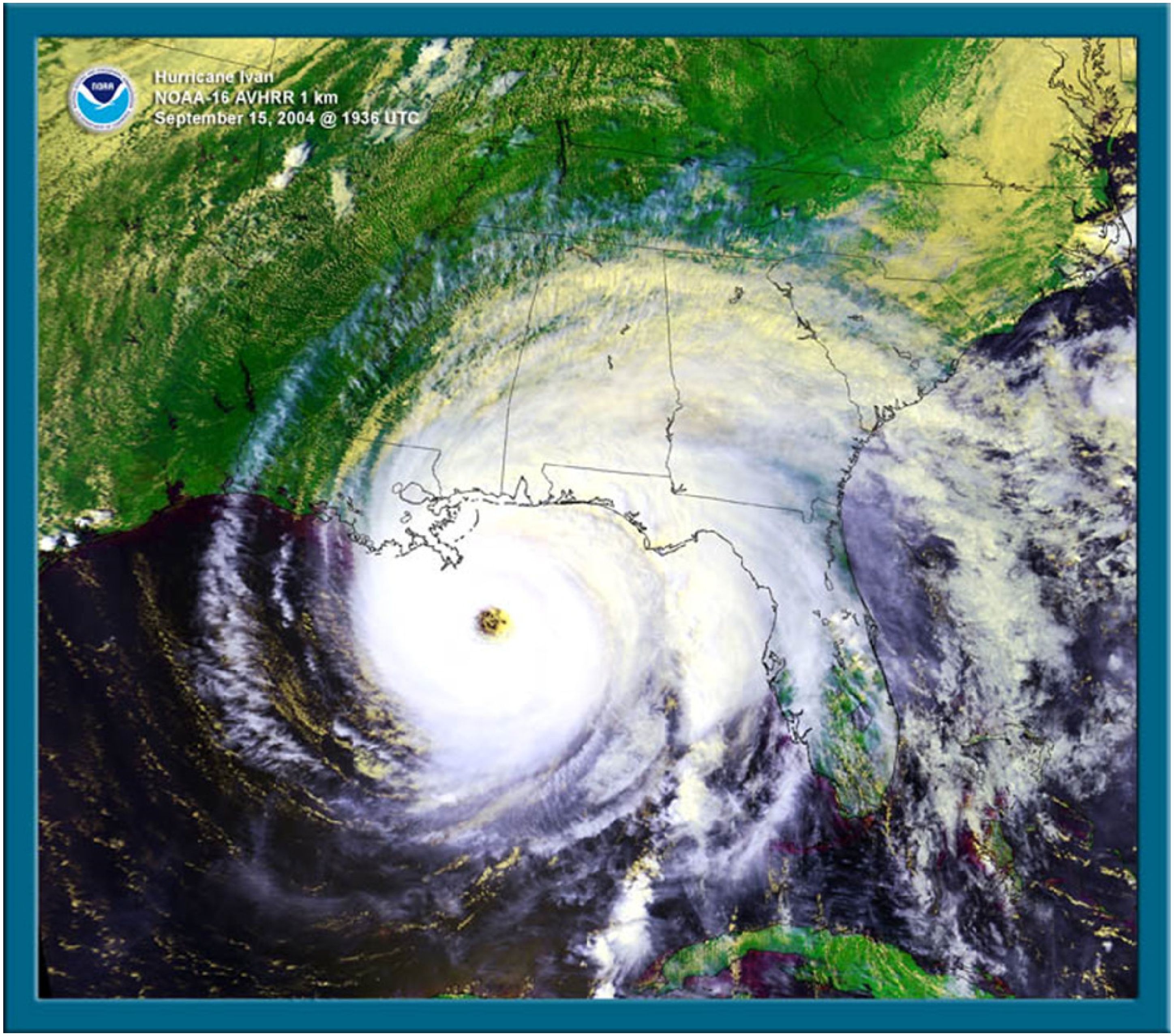
y = 0.017x^1.3213
R² = 0.9643
R = 0.98
U*, m/s, vorticity and wind - wave interaction methods
U10, m/s, based on Hurricanes Inez, Kate, Lili, and Rita
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
10
20
30
40
50
60
70
80

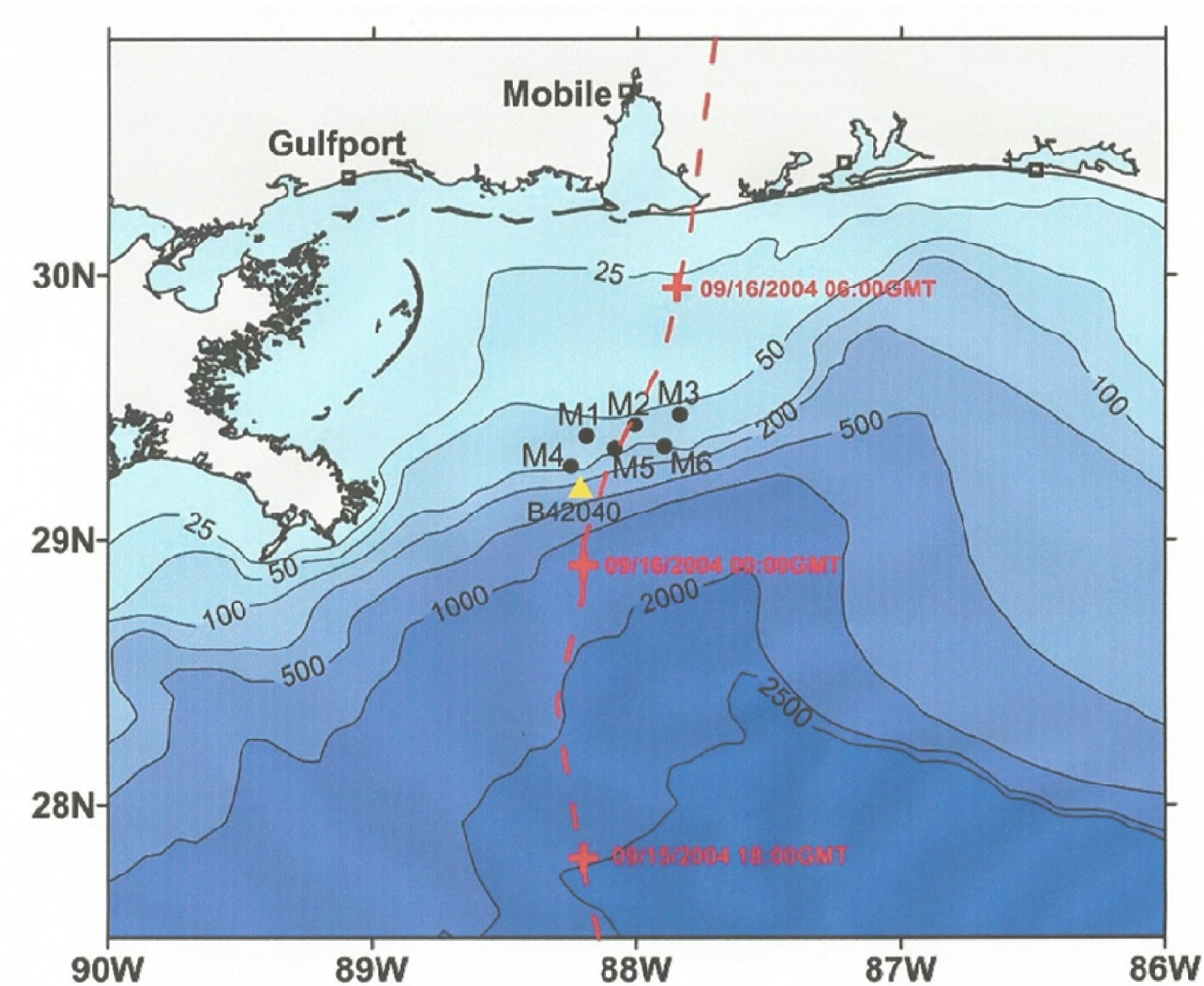


y = 1.0715x
R² = 0.9927
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
U*= 0.017 U ^ 1.32, m/s
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
U*, m/s, based on vorticity and momentum methds

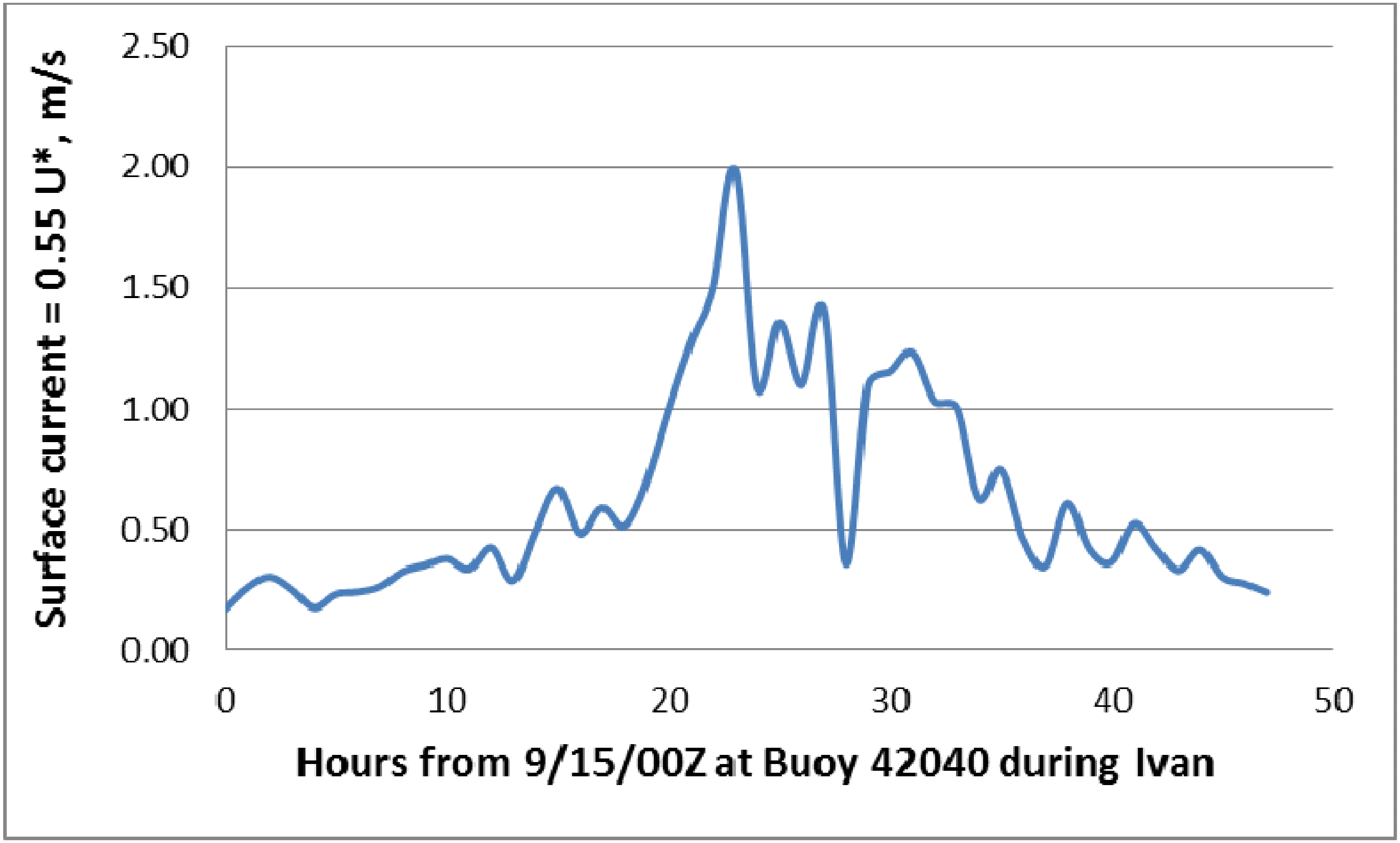


y = 1.0179x
R² = 0.8391
R = 0.92
U*, m/s, gust-factor method
U*, m/s, based on wind-wave interaction method
0
0.5
1
1.5
2
2.5
3
3.5
4

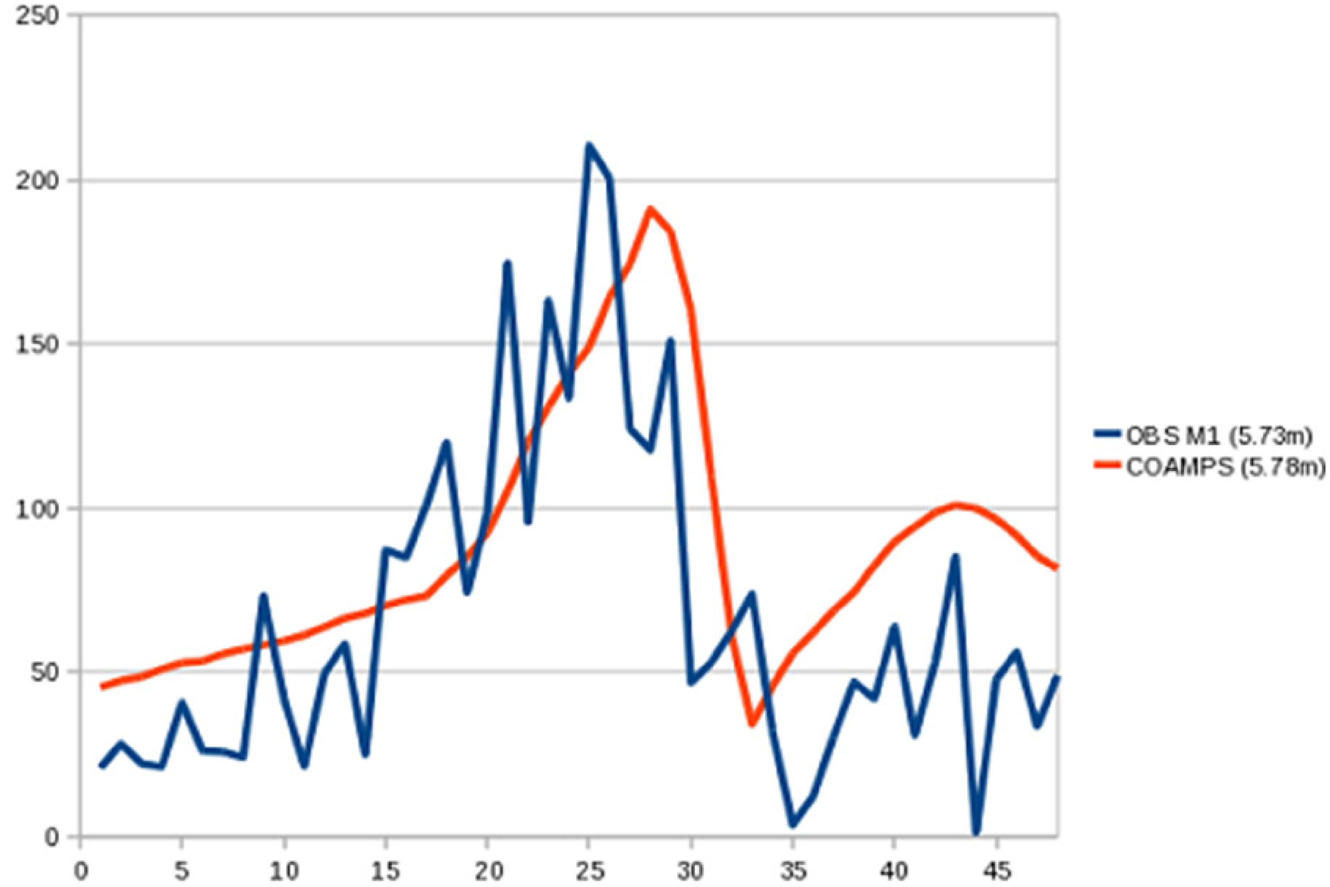

Hurricane Ivan
NOAA-16 AVHRR 1 km
September 15, 2004 @ 1936 UTC



Mobile
Gulfport
30N
29N
28N
90W
89W
88W
87W
86W
09/16/2004 06:00GMT
09/16/2004 00:00GMT
09/15/2004 18:00GMT
M1
M2
M3
M4
M5
M6
B42040
25
50
100
200
500
1000
2000
2500



Surface current = 0.55 U*, m/s
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
Hours from 9/15/00Z at Buoy 42040 during Ivan



250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
OBS M1 (5.73m)
COAMPS (5.78m)