Measuring Surface Stress in Tropical Cyclones with Scatterometers

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Air-sea interaction in TC
Scatterometry in TC
Scatterometer algorithm for stress retrival
Drag coefficient in TC

IHC 2015, Jacksonville

- Wind is air in motion
- Stress is momentum transport of by turbulence generated by wind shear and buoyancy (density gradient)
- While strong wind of TC causes destruction, it is stress that drags down TC
- Practically no stress measurements; stress were almost entirely derived from wind
- An empirical drag coefficient has been used to related stress to wind
- Under the strong winds of TC, wind shear dominates over buoyancy in turbulence generation.

$$\tau = \rho C_D (U - U_S)^2$$

$$\frac{U - U_s}{U_*} = 2.5(\ln \frac{z}{z_0} - \psi_U) = \frac{1}{\sqrt{C_D}}$$

$$H = \rho c_P C_H (T - T_s)(U - U_S)$$

$$\frac{T - T_s}{T_*} = 2.5(\ln \frac{Z}{Z_T} - \psi_T) = \frac{\sqrt{C_D}}{C_H}$$

$$E = \rho C_E (Q - Q_s)(U - U_S)$$

$$\frac{Q - Q_s}{Q_*} = 2.5(\ln \frac{Z}{Z_Q} - \psi_Q) = \frac{\sqrt{C_D}}{C_E}$$

$$U_* = \sqrt{\frac{\tau}{\rho}}$$

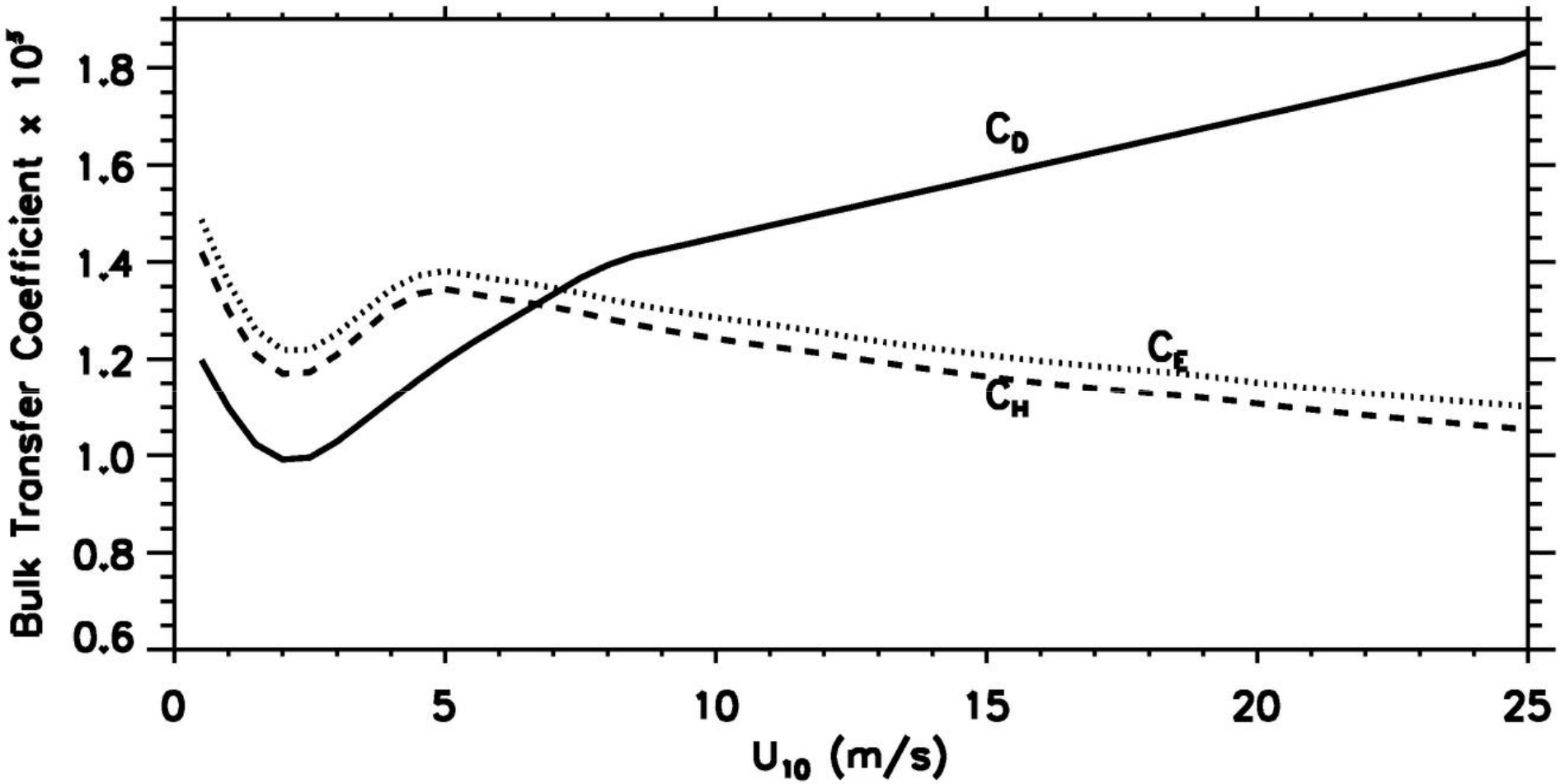
$$T_* = -\frac{H}{\rho U_*}$$

$$Q_* = -\frac{E}{\rho U_*}$$

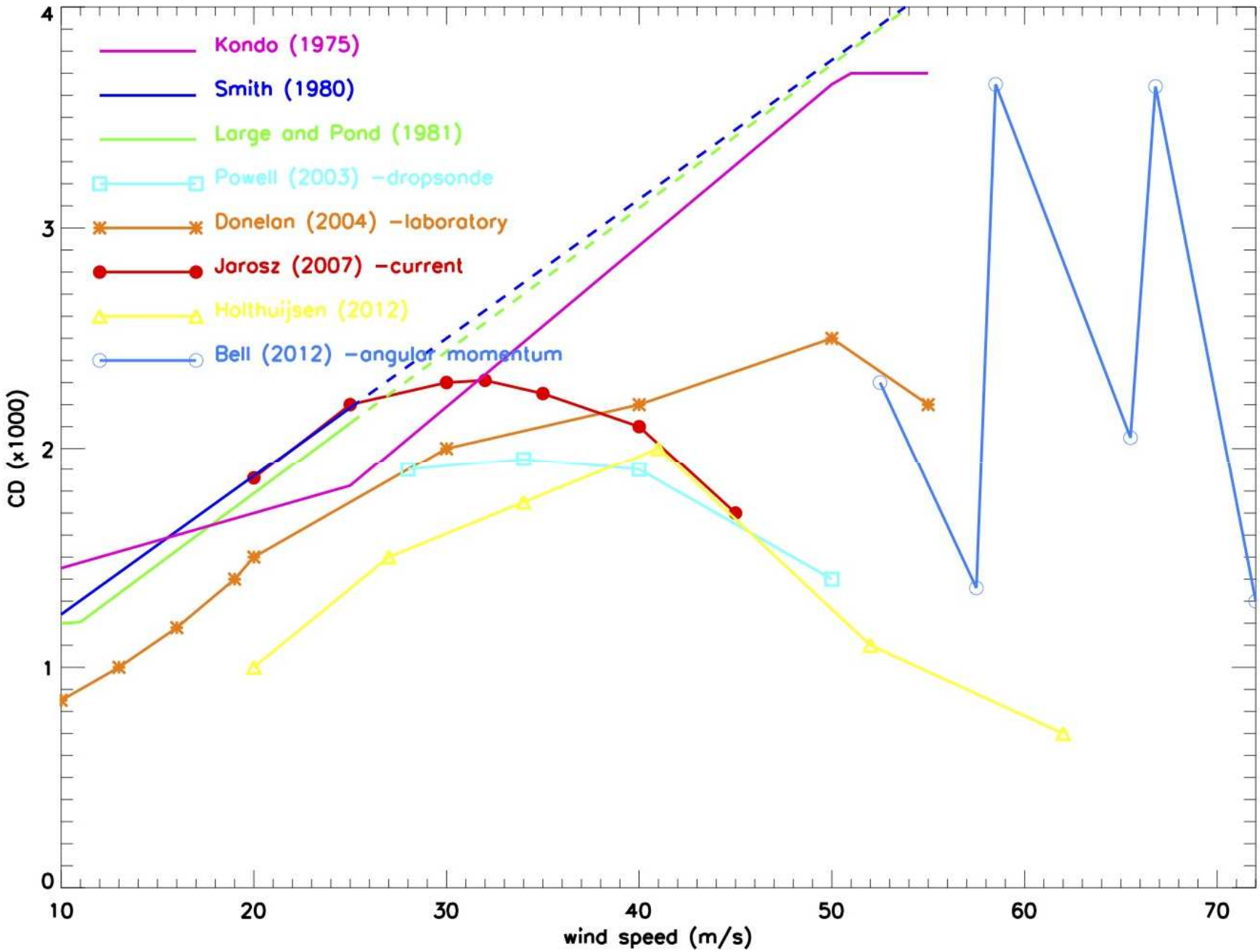
$$Z_o = 0.11 \frac{\nu}{U_*} + 0.011 \frac{U_*^2}{g}$$

Liu et al.(1979) account for stability and surface constaints by solving similarity profiles

Liu, Katsaros, and Businger, 1979



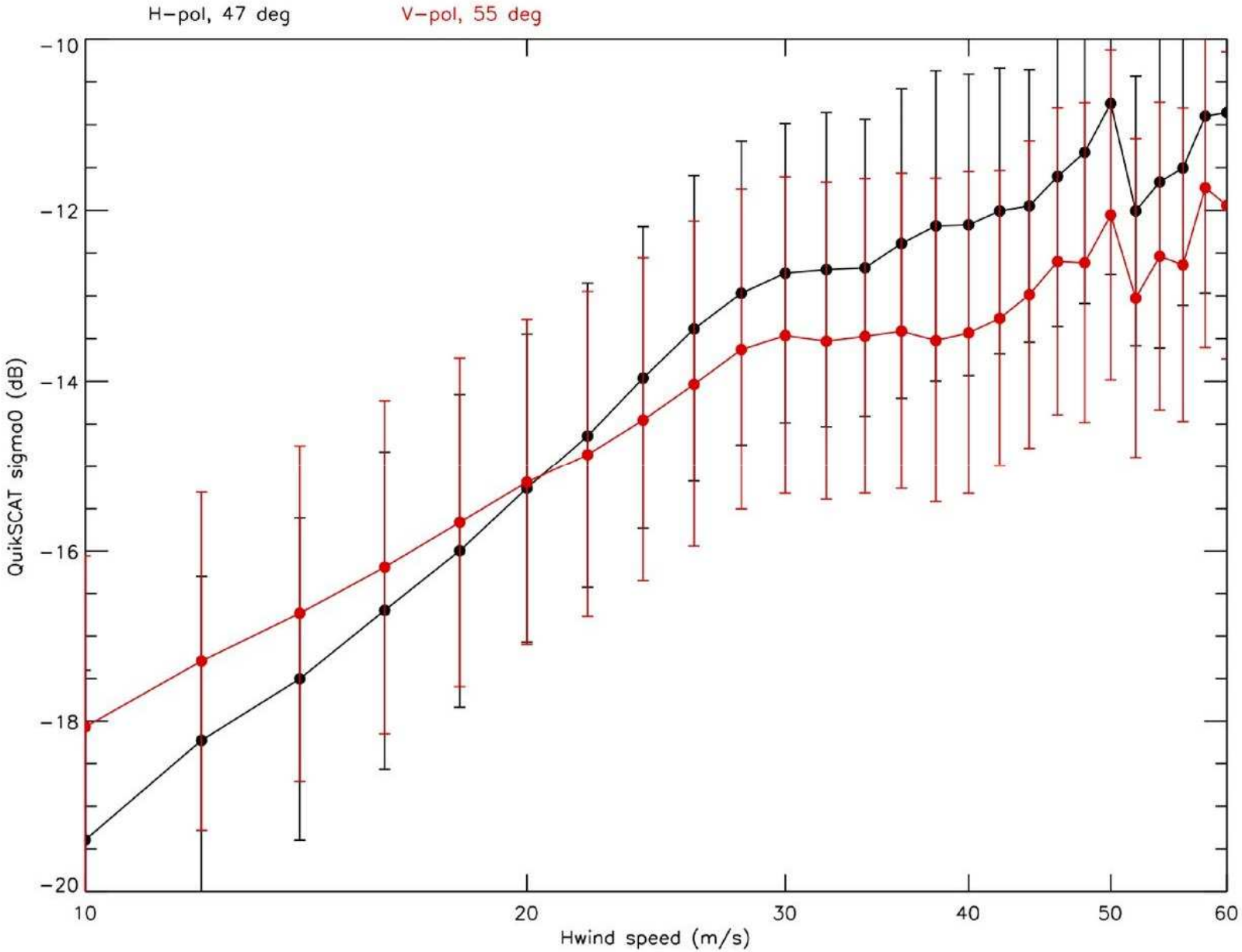
Emanuel (1995) argued that to attain the strong wind of TC, drag cannot keep Increasing while supplies of sensible and latent do not increase


Kondo (1975)
Smith (1980)
Large and Pond (1981)
Powell (2003) –dropsonde
Donelan (2004) –laboratory
Jarosz (2007) –current
Holthuijsen (2012)
Bell (2012) –angular momentum
CD (x1000)
wind speed (m/s)
0
1
2
3
4
10
20
30
40
50
60
70

- **Scatterometers measure backscatter from ocean surface roughness caused by shortwaves that are considered to be in equilibrium with stress.**

$$\sigma_0 = f(U_N, \chi, \theta, p)$$

- **The geophysical product U_N should have a unique relation with $U_* = (\tau/\rho)^{1/2}$, or stress.**
- **But the scatterometer has been promoted as a wind sensor, and U_N has been used as the actual wind.**
- **We can get stress from wind if we know the drag coefficient.**
- **We have problems retrieving strong winds and ascertaining the drag coefficient in TC.**



Number of collocated pairs is around 10^5 for 10 m/s bin, decreases to around 10 at > 50 m/s bin.

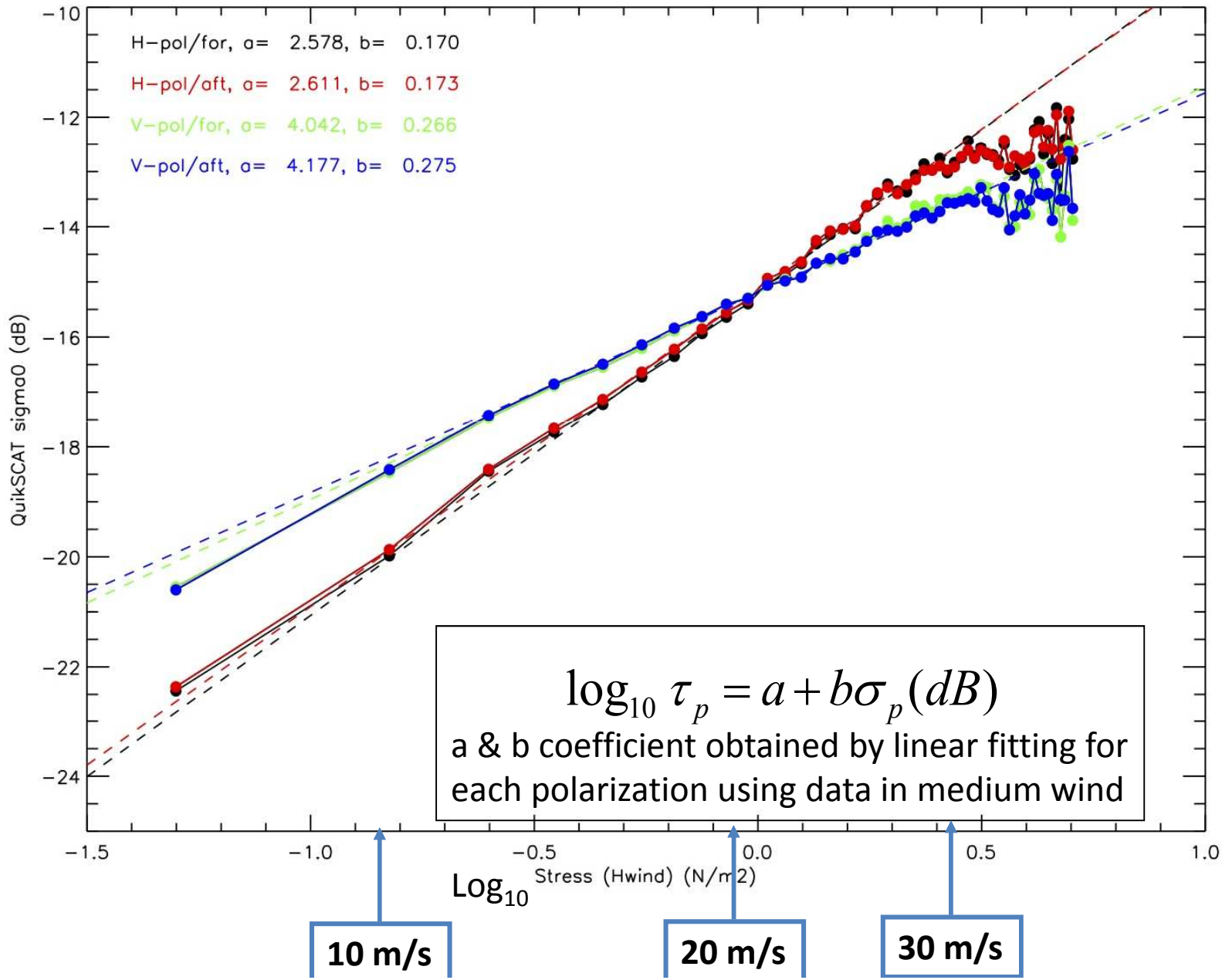
- Conventional wind algorithm at Ku-band and C-band do not apply well to hurricane scale winds.
- Establishing new relations at strong winds is difficult because lack of data

Our hypothesis

- Physics of radar backscatter does not distinguish different weather systems
- The relation between backscatter and surface roughness or stress does not change under hurricanes. The same retrieval algorithm may apply.
- The changes in wind retrieval algorithm in TC is explained through the change of the drag coefficients.
- We will establish an algorithm to retrieve stress over moderate winds, where data are more abundant and the drag coefficient is established and then apply it to the high wind regime in TC

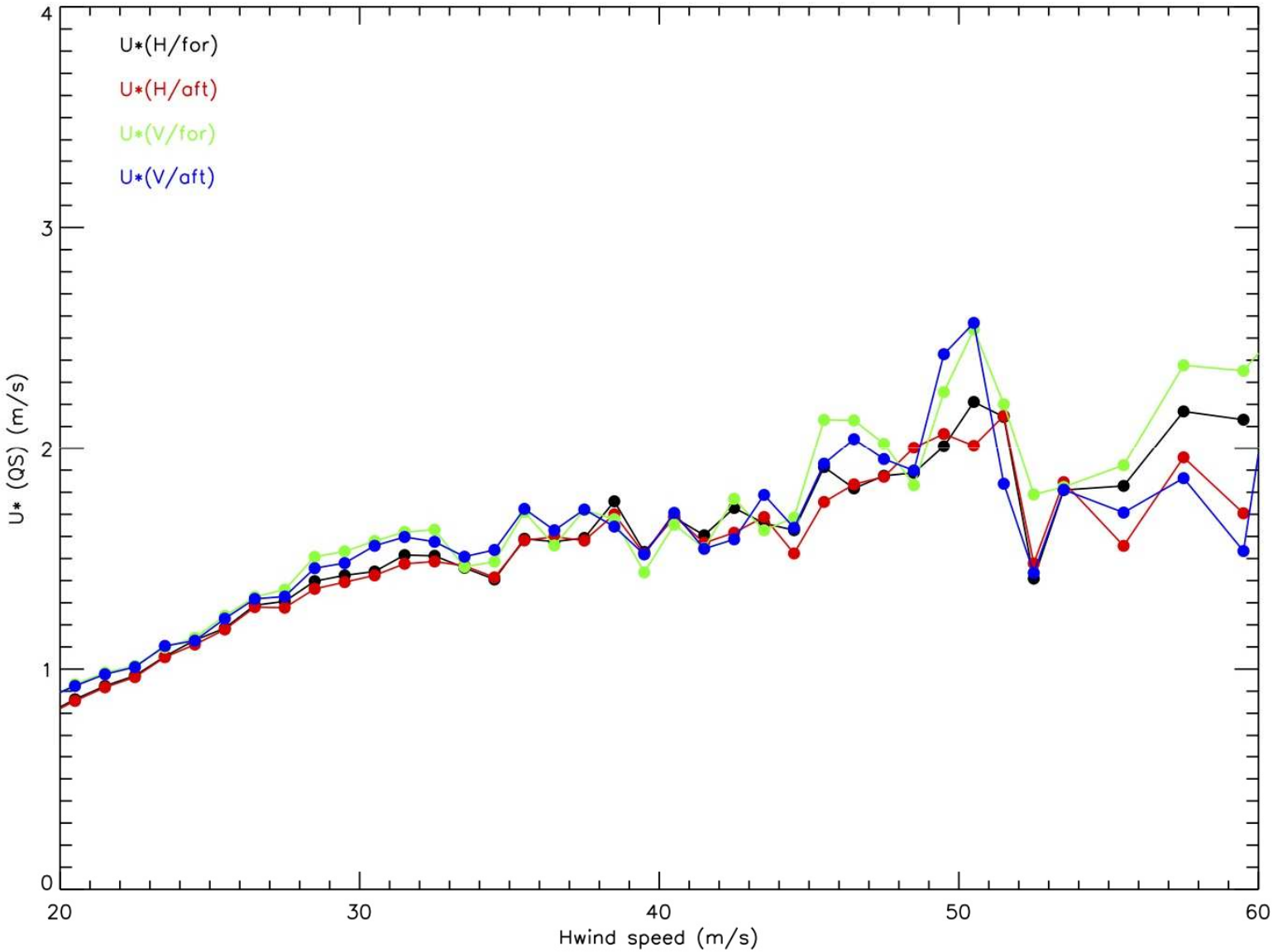
(Separate sensor parameters, e.g., incident angle, azimuth angle, polarization and radar frequency, from secondary factors of the physics of turbulent transport, e.g., air stability, air density, sea states, and sea sprays)

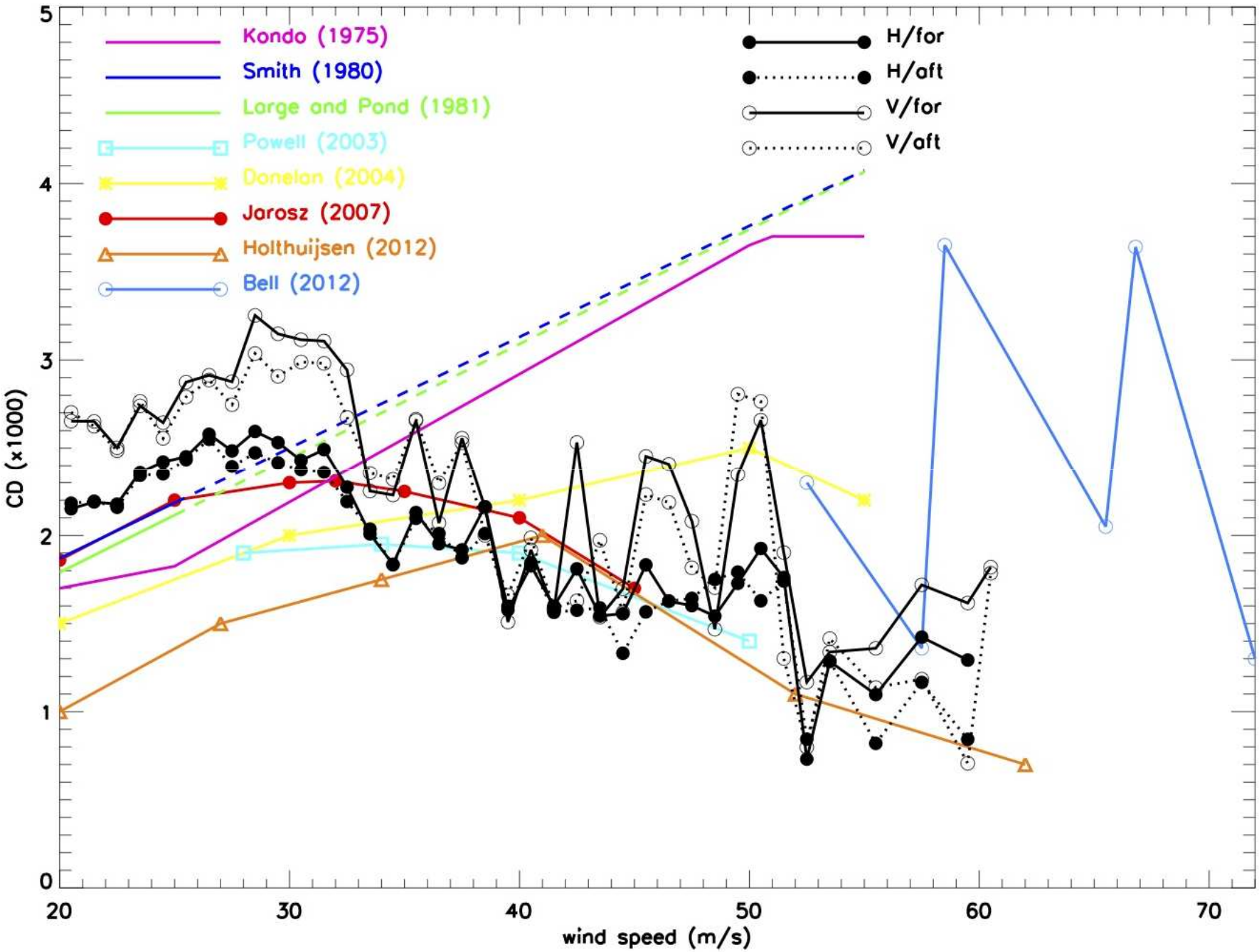
Relation between scatterometer sigma0 and stress



$$\log_{10} \tau_p = a + b\sigma_p(dB)$$

a & b coefficient obtained by linear fitting for each polarization using data in medium wind


U*(H/for)
U*(H/aft)
U*(V/for)
U*(V/aft)
U* (QS) (m/s)
Hwind speed (m/s)
0
1
2
3
4
20
30
40
50
60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Caveats

- **We focus only in the main signal of backscatter and not the full dependence on frequency, polarization, incident angle, and azimuth angle**
- **┤ We brush aside secondary effects of air-sea interation, stability, sea-states, swell, breaking waves, surfectant, density etc.**
- **These are preliminary results of a feasibility study. Continuous work includes**

1 revise our stress algorithm by incorporated buoy, ship, model data over moderate range of wind speed

2 sub-divide our algorithm according to azimuth angle

3 expand high wind data set with dropsonde data