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Air-Sea Exchange in Strong Winds

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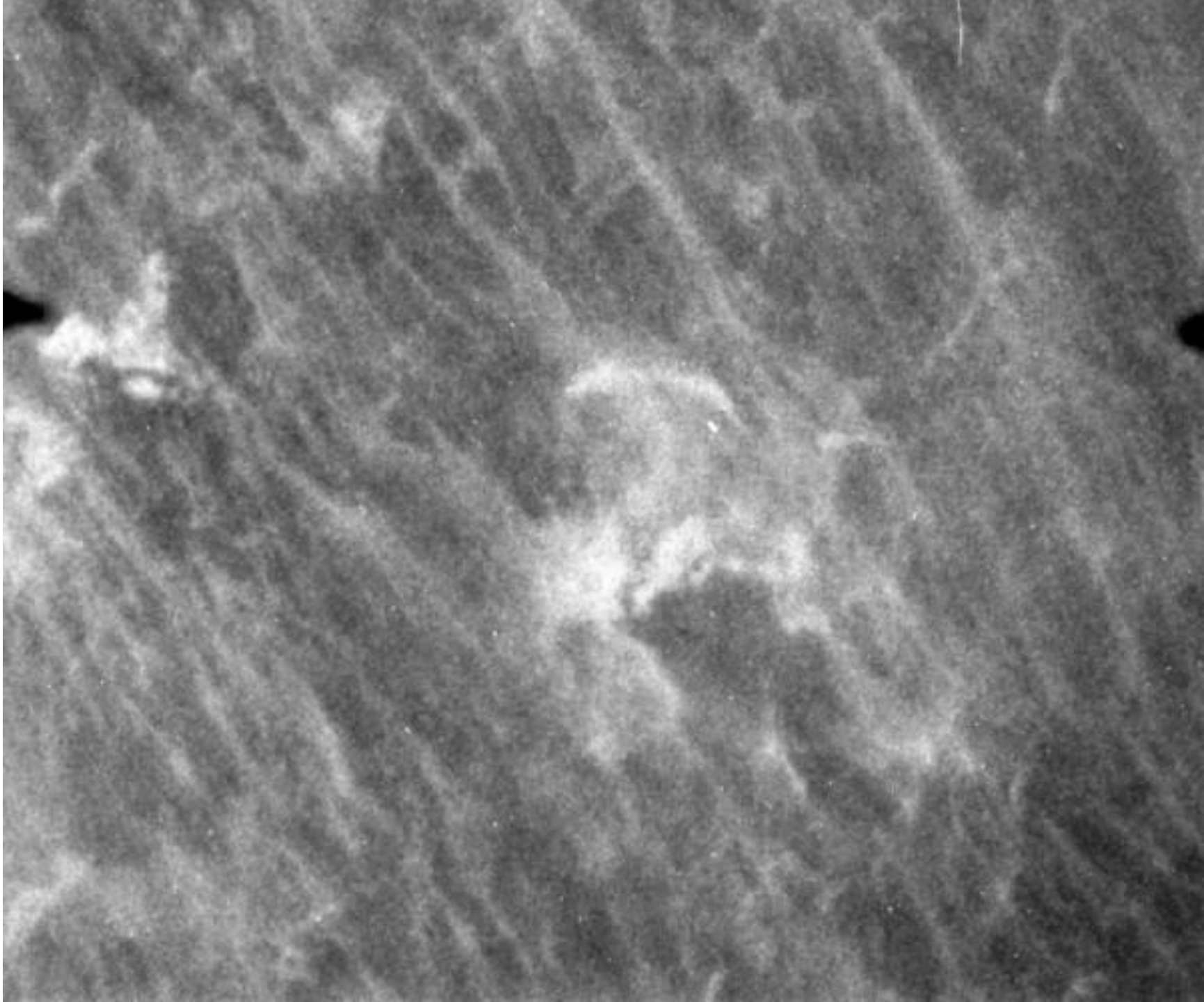
Slippery when windy?



NOAA
Peter Black

Motivation

- Hypotheses

Air-sea exchange in strong winds:

  - Is NOT a simple extrapolation of more moderate conditions, but is genuinely extraordinary
  - Represents a large fraction of exchange averaged seasonally, regionally and globally
  - Can be realistically studied by a range of in situ, remote sensing and (laboratory and numerical) modelling methods

- Conclusion

The topic is:

  - Distinct
  - Important
  - Tractable

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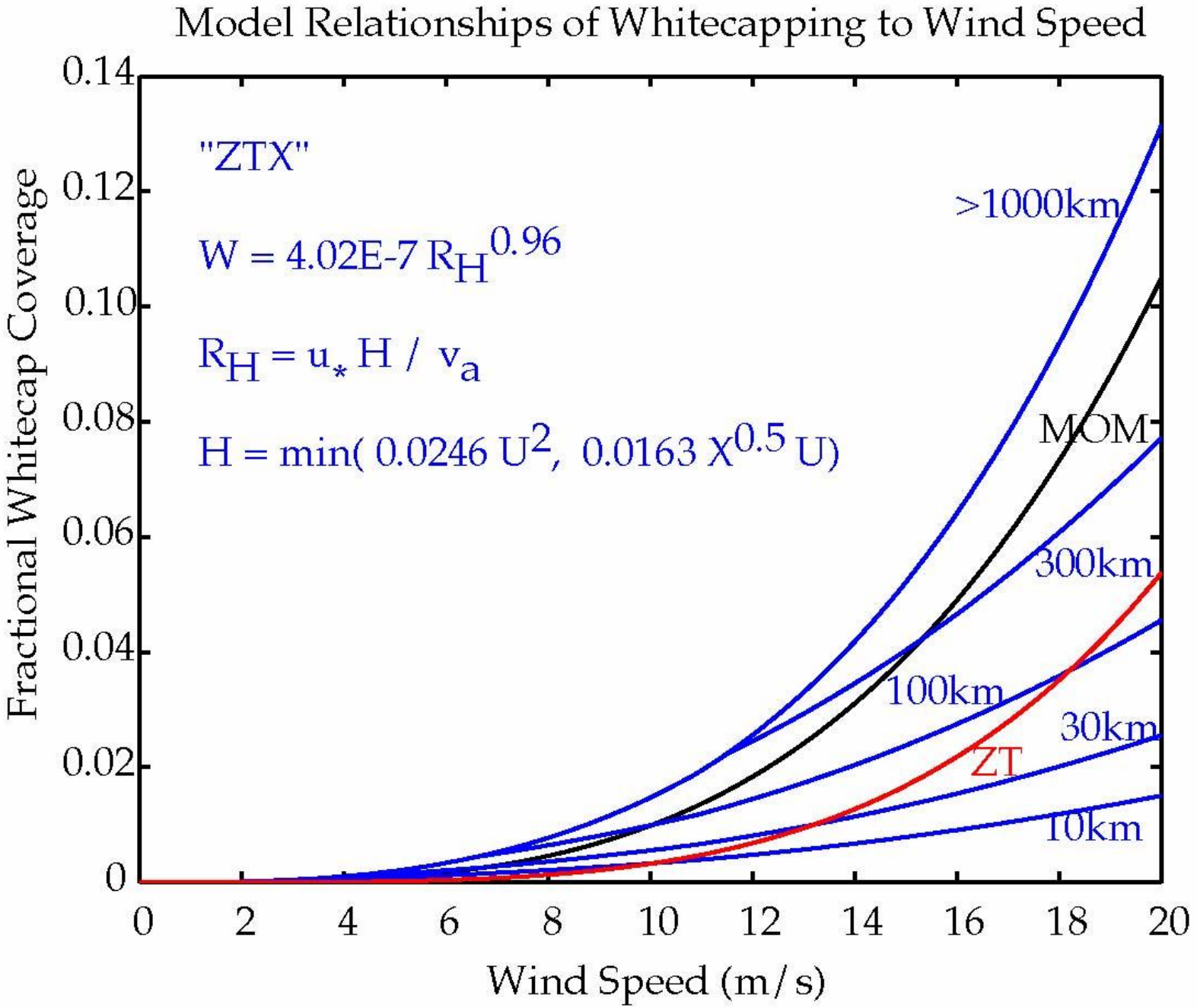
When winds are strong (12 – 25 m/s)


Model Relationships of Whitecapping to Wind Speed
"ZTX"
W = 4.02E-7 R_H^0.96
R_H = u* H / v_a
H = min(0.0246 U^2, 0.0163 X^0.5 U)
>1000km
MOM
300km
100km
30km
ZT
10km
Fractional Whitecap Coverage
Wind Speed (m/s)
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
2
4
6
8
10
12
14
16
18
20

Air-sea gas exchange in a bubbly ocean

$$\text{Net Flux} = K\,(\alpha C_a - C_w)$$

1) Flux IS NOT proportional to air-water concentration difference!

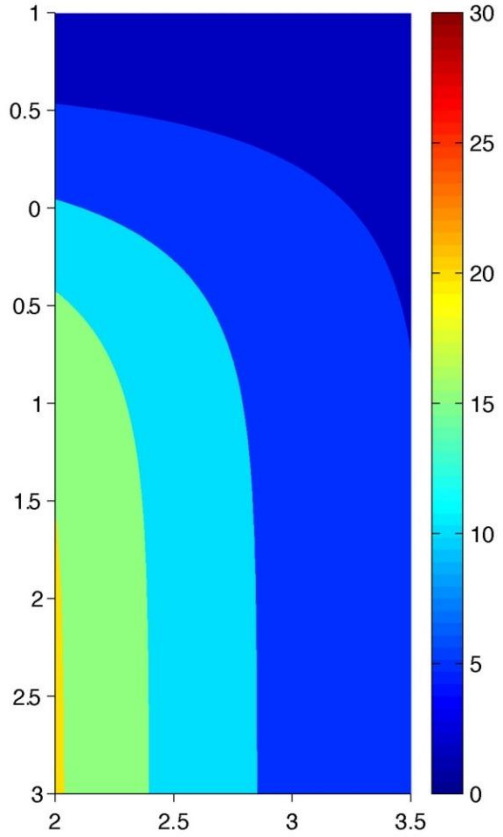
$$K = a\,U_{10N}^{b}\,Sc^{-1/2}$$

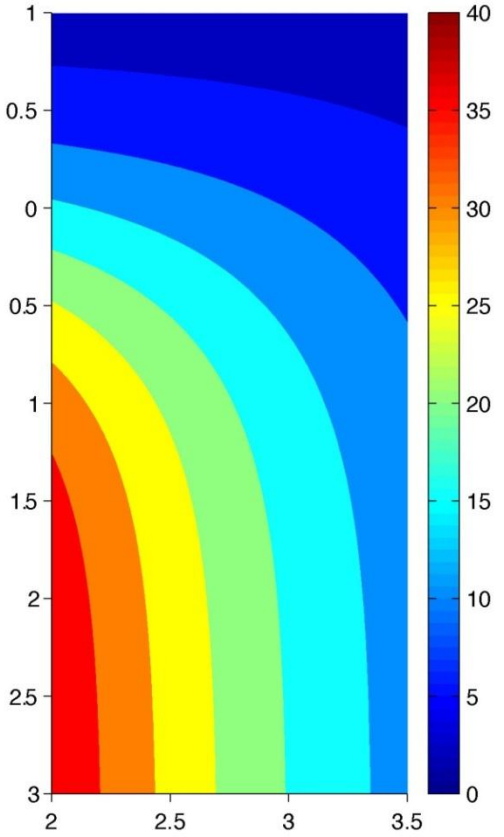
2) Transfer velocity doesn't depend simply on wind speed

3) The dependence on molecular properties involves more than Schmidt Number

Modification of gas transfer velocities due to collective effects

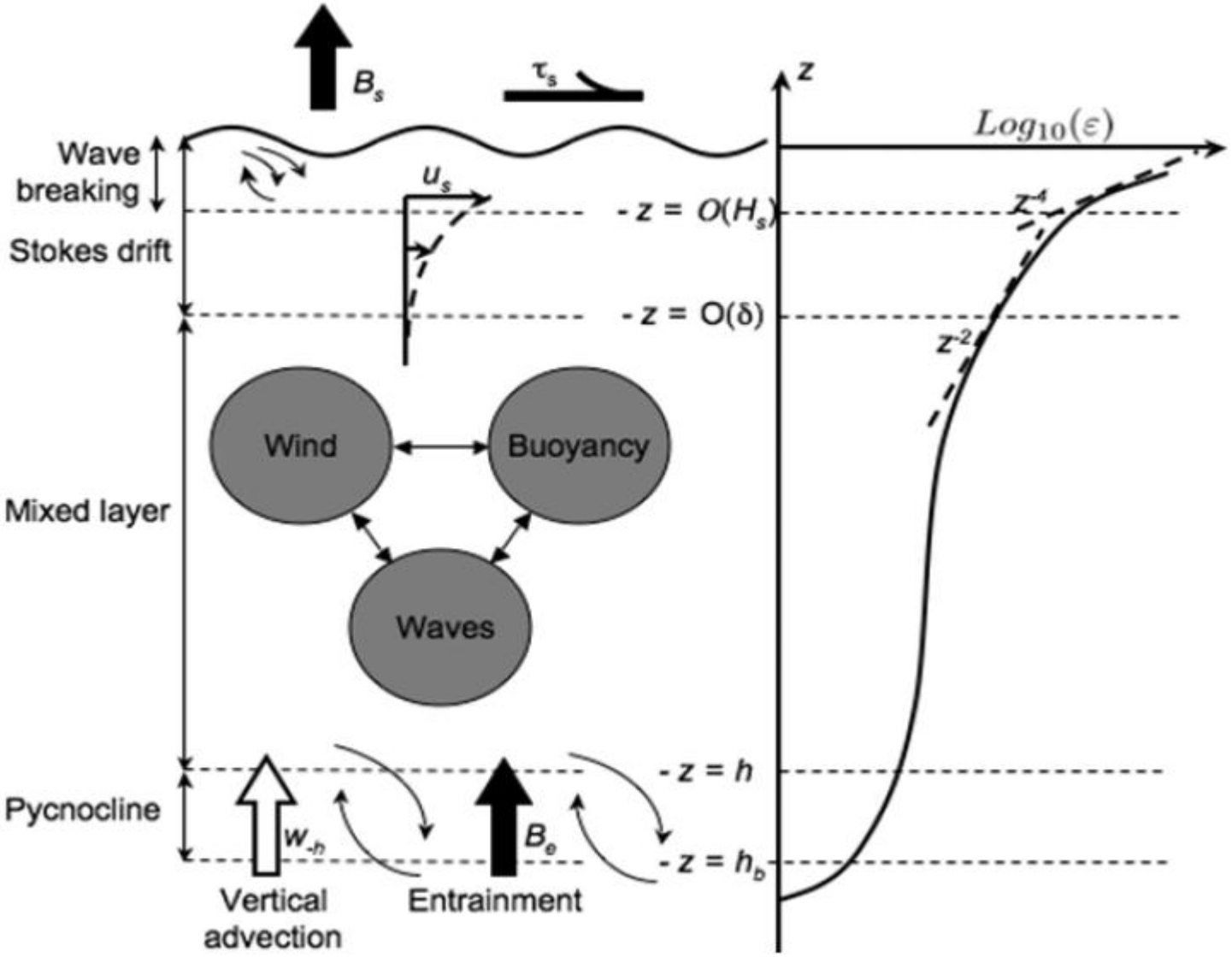
Simple model is modified to include finite plume size. Here void fraction is assumed to be 25%





k_b (cm/h)

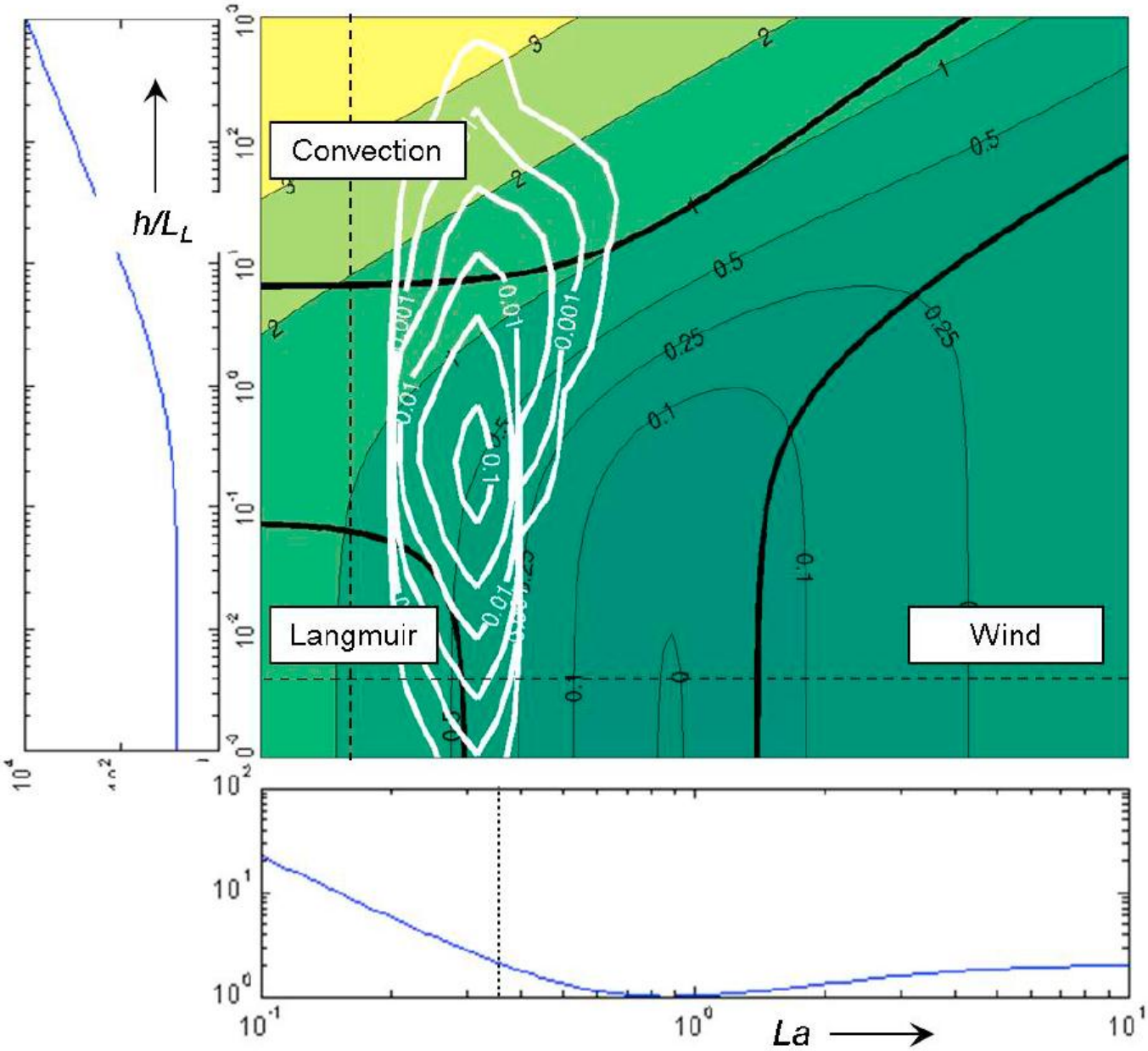
Belcher et al., 2012; deepening of OSBL



Belcher et al., 2012; deepening of OSBL

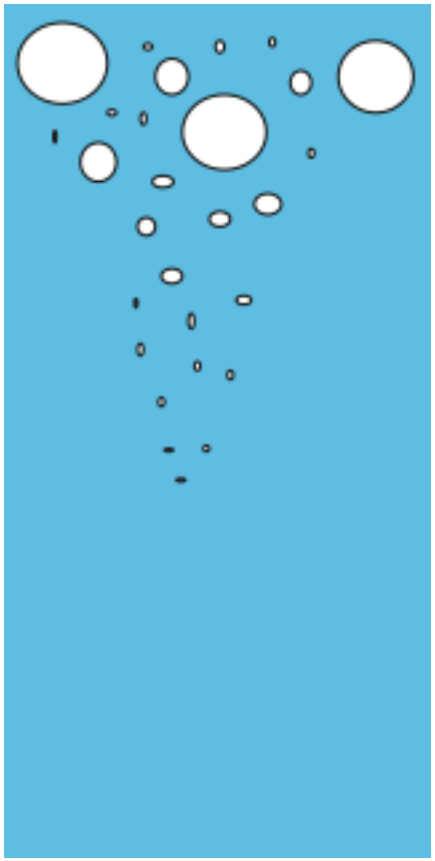
Regime diagram for relative contribution of directly wind-forced, wave-forced and convective forcing to turbulent dissipation.

White contours are the joint pdf for Southern Ocean winter (JJA)



When winds are too strong (> 25 m/s)

Regime change at high mixing?



← Regular

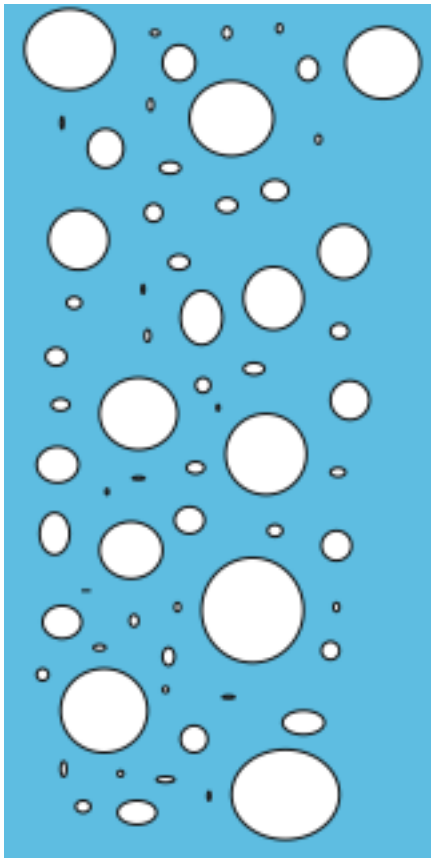
Distribution of bubbles results from a “gravitational sieve”. Partial dissolution is typical

Critical point

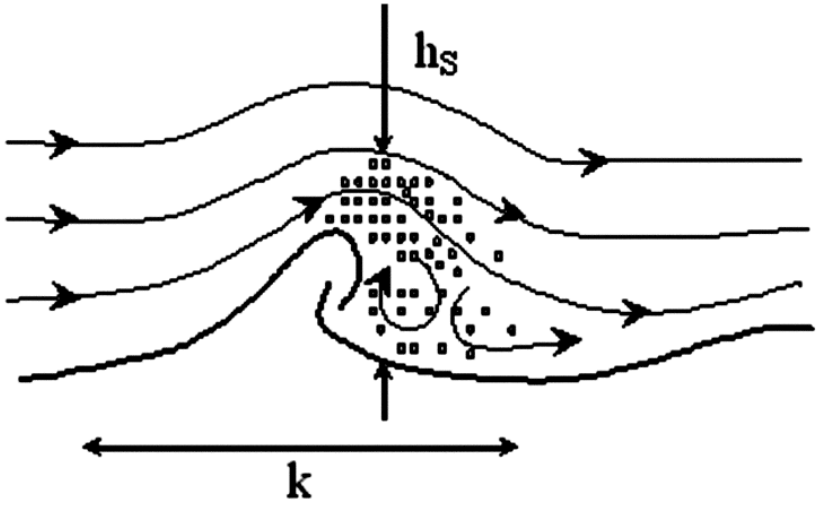
Most of volume flux is in large bubbles, all with similar terminal rise velocity ~0.25m/s

Injection →

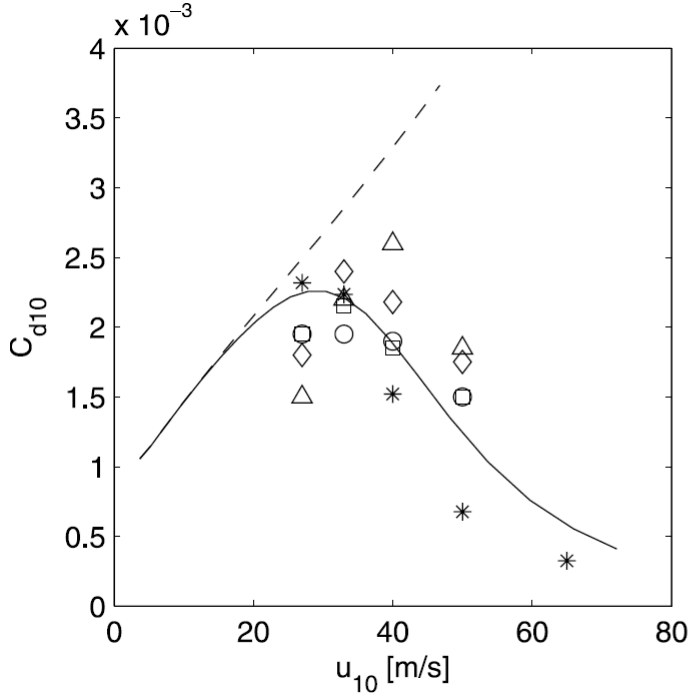
If critical point is exceeded even large bubbles may be submerged to large depths and total solution is typical

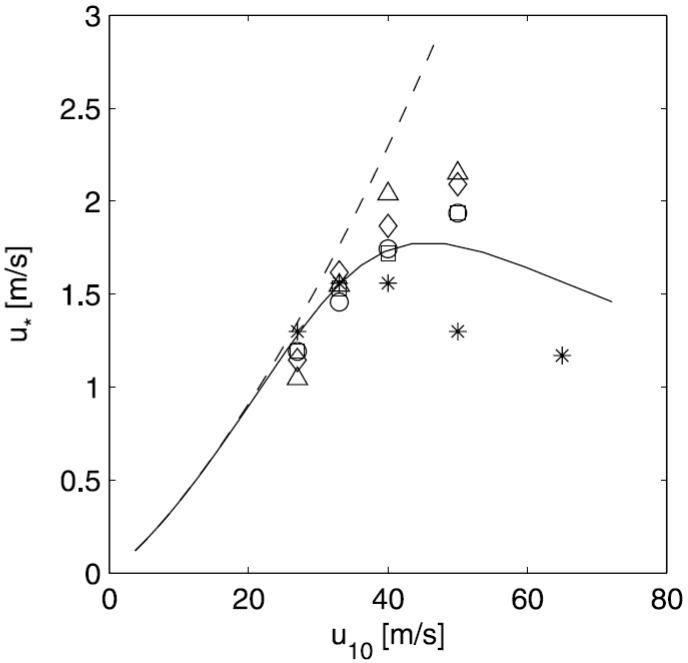


Effect of heavy particles on turbulence? Kudryatsev, 2006

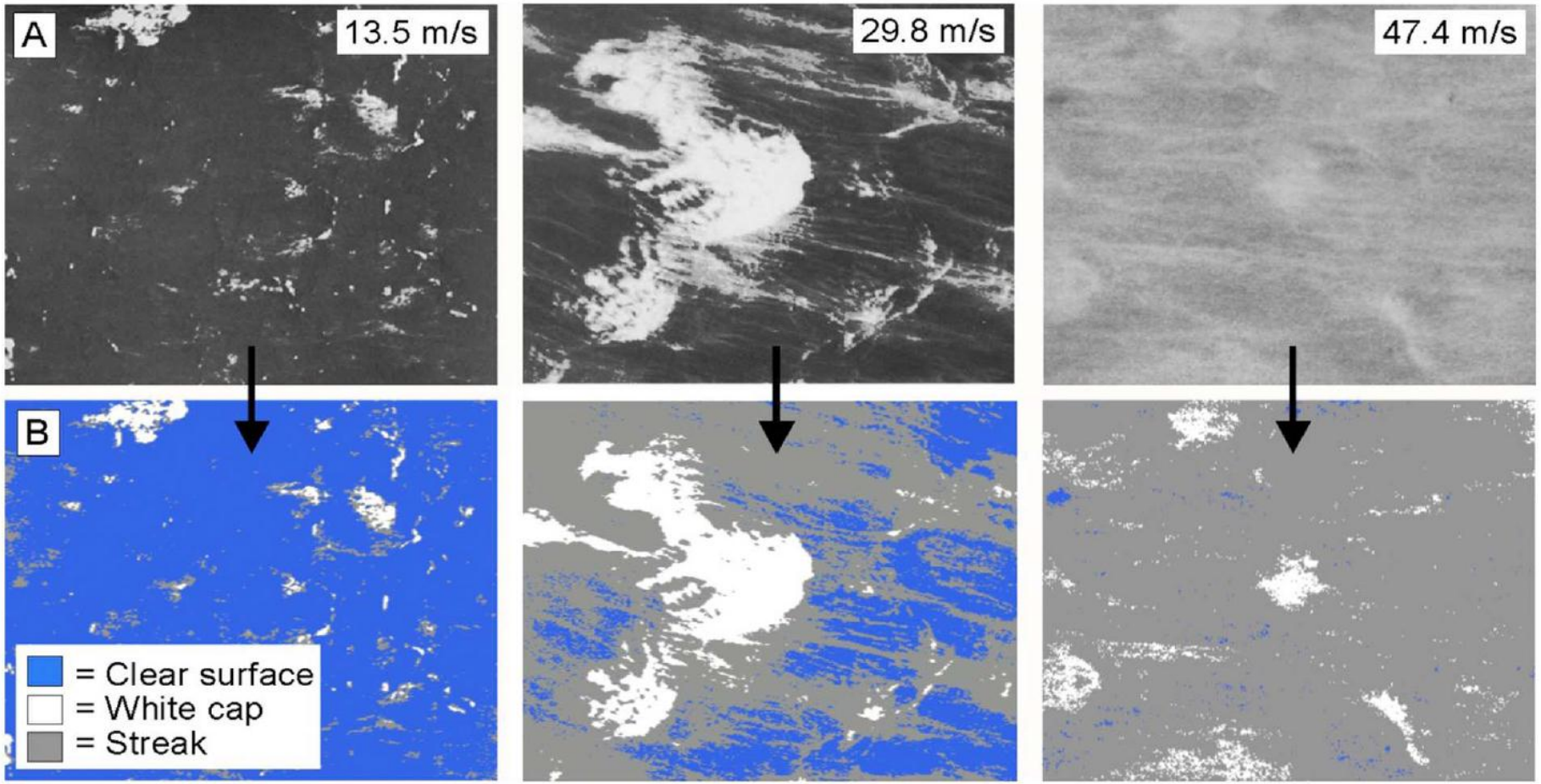


N.B. Spume drops <u>not</u> bubble droplets





Aerodynamically Smooth?
Holthuijsen, Powell and Pietrzak, 2012



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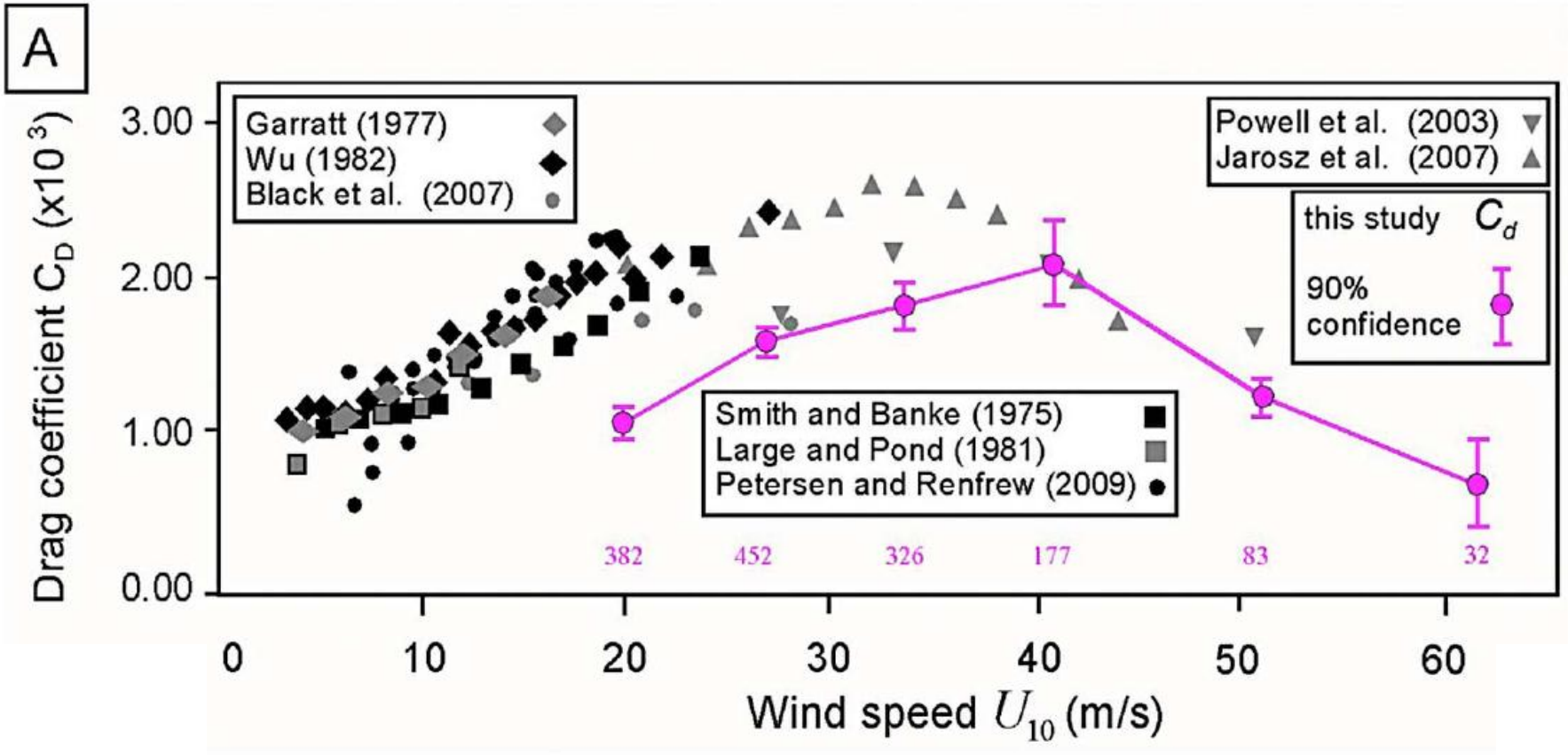

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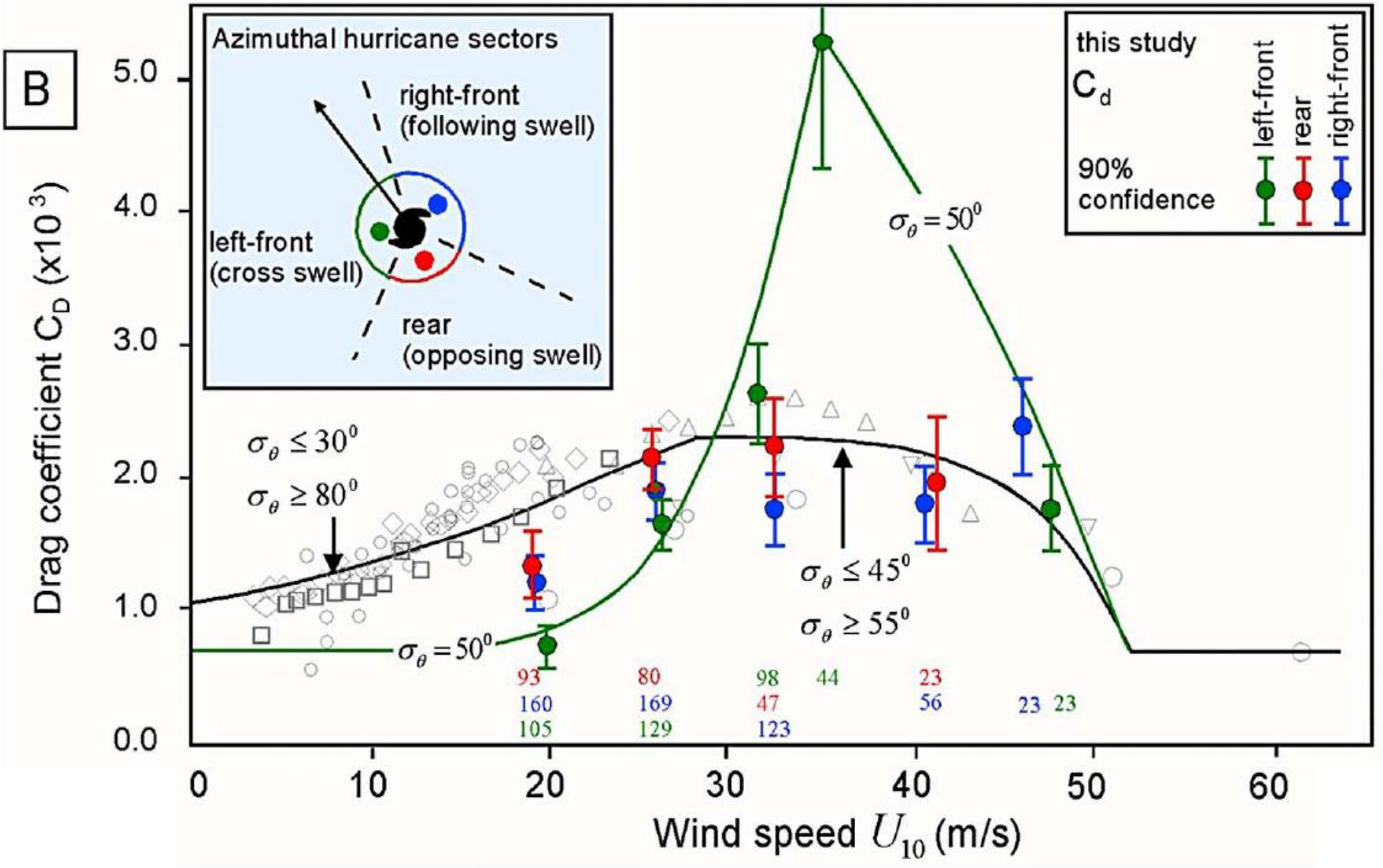

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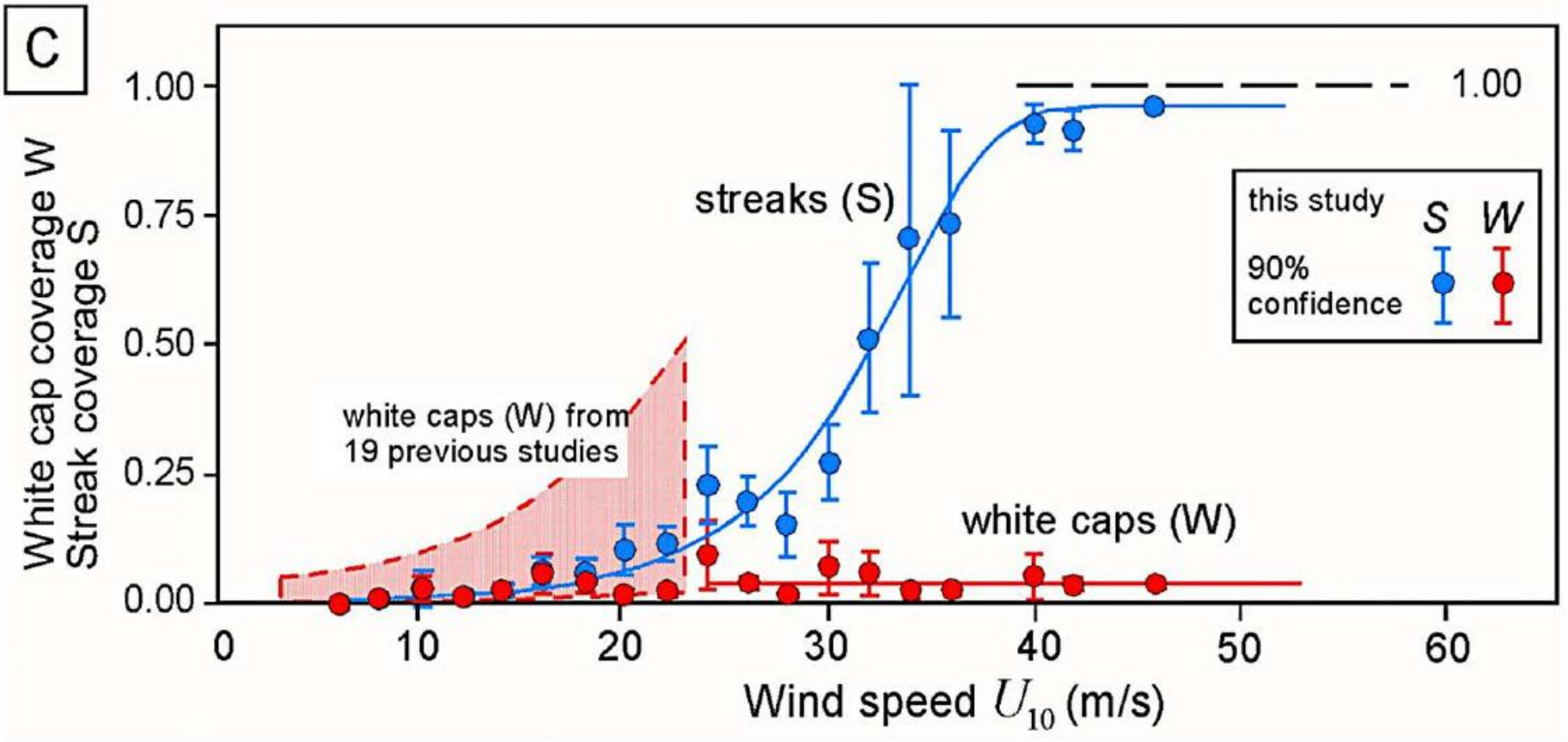

Let us talk