On air-sea fluxes in high winds
- a view from the trenches (troughs)

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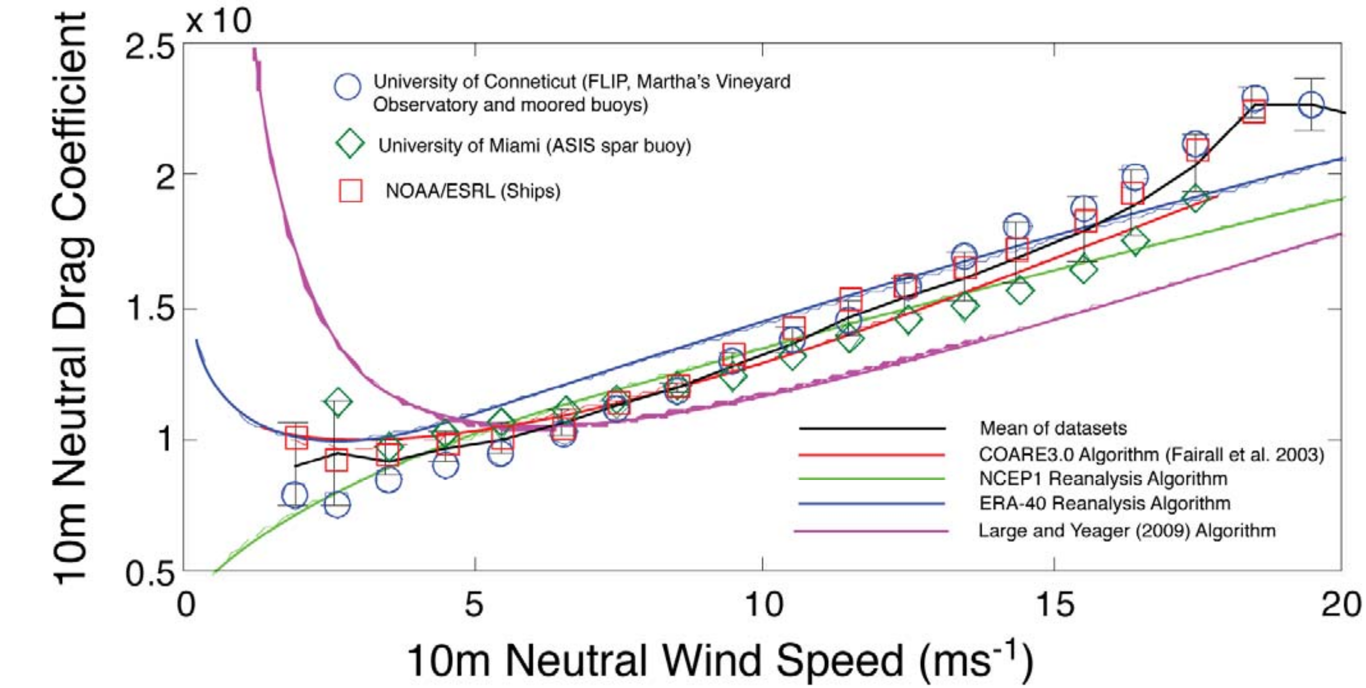
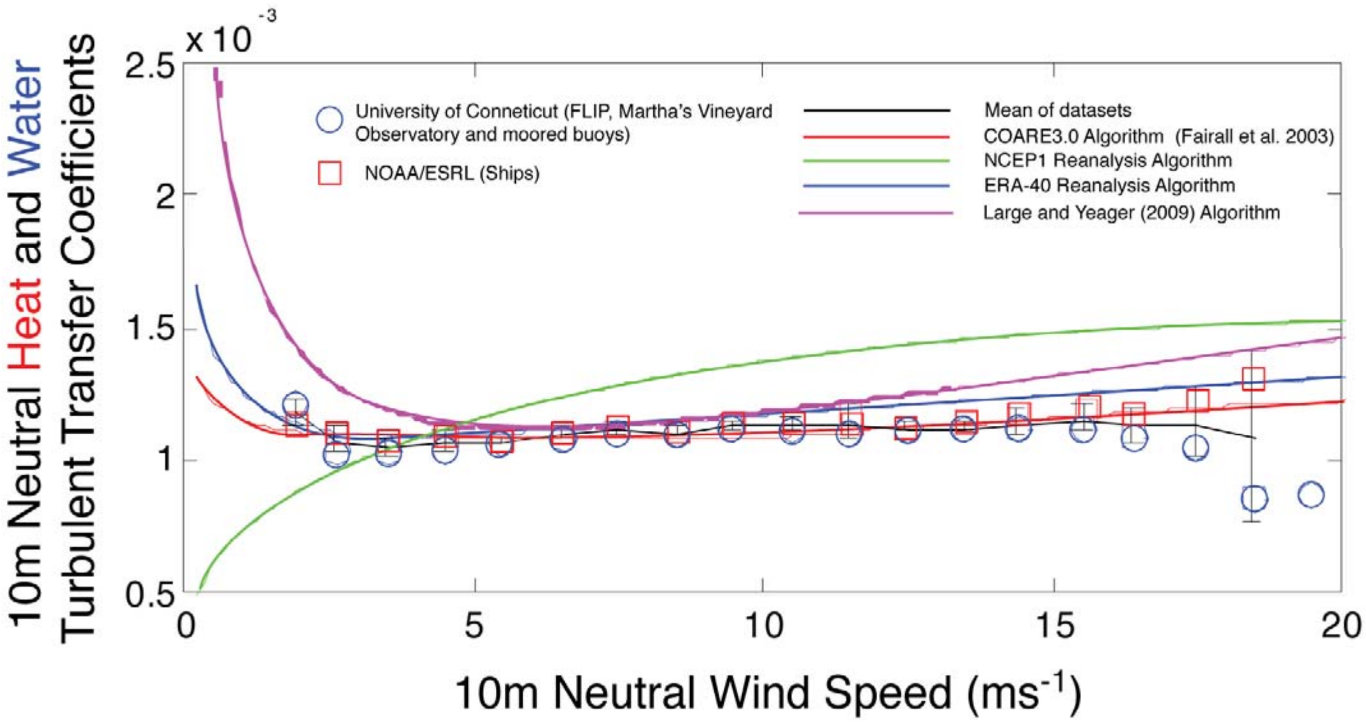
Meteorology, Uppsala Universitet, Uppsala, Sweden

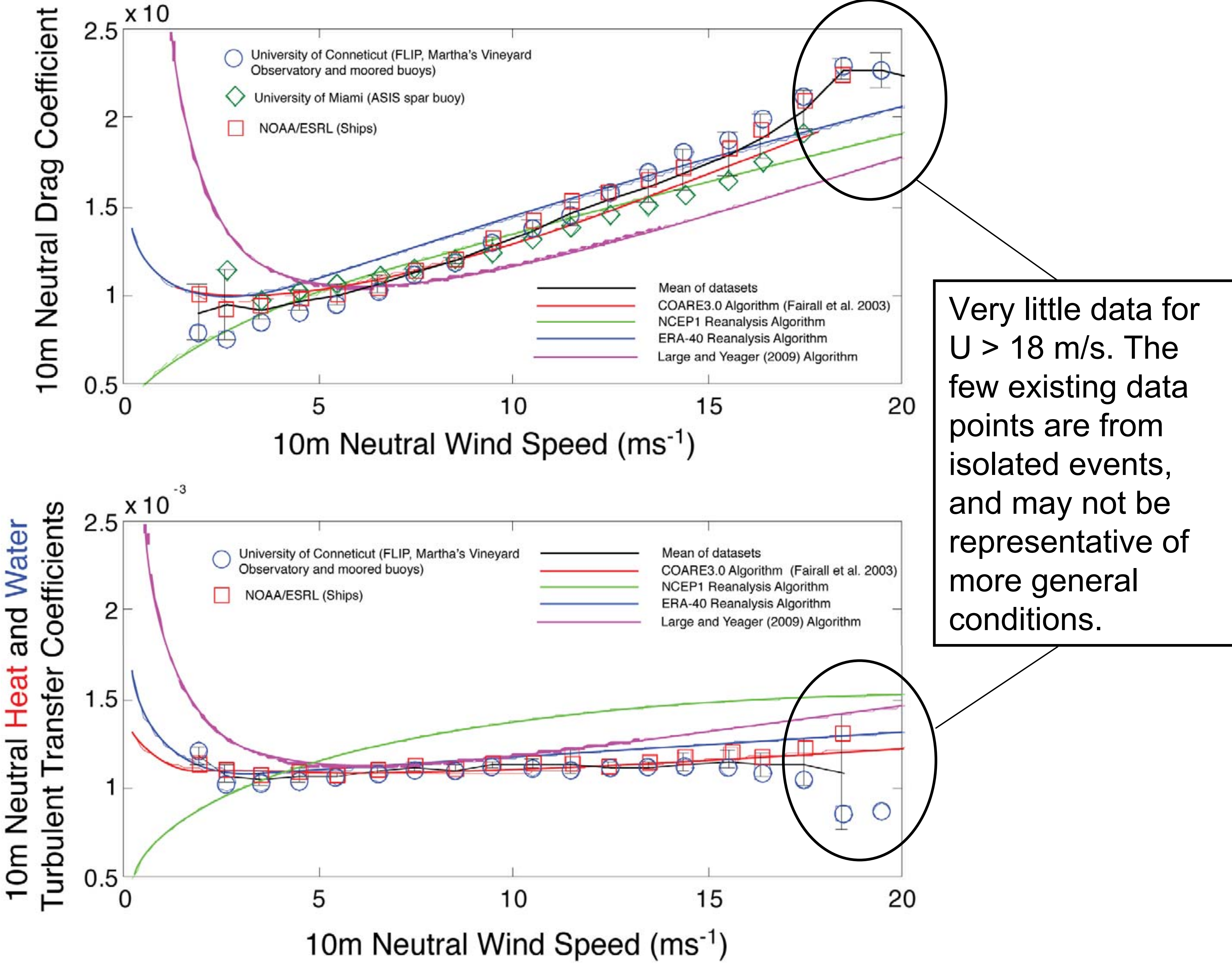
Photo: ASIS direct flux mooring during TS Ernesto



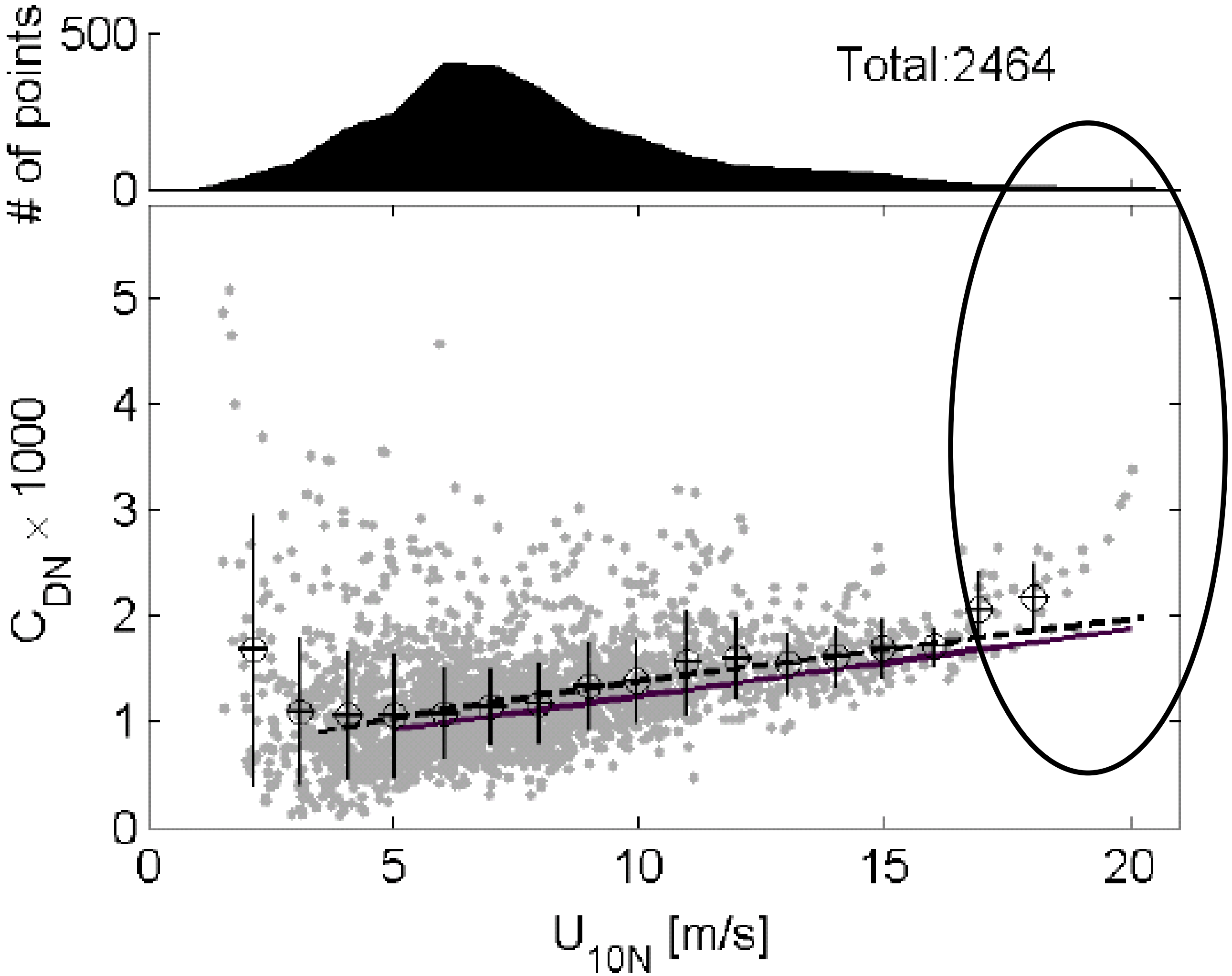


From Fairall et al 2009, OceanObs, Venice.

Very good agreement (in the mean) for data in range 4 – 16 m/s



x 10
2.5
2
1.5
1
0.5
10m Neutral Drag Coefficient
University of Conneticut (FLIP, Martha's Vineyard Observatory and moored buoys)
University of Miami (ASIS spar buoy)
NOAA/ESRL (Ships)
Mean of datasets
COARE3.0 Algorithm (Fairall et al. 2003)
NCEP1 Reanalysis Algorithm
ERA-40 Reanalysis Algorithm
Large and Yeager (2009) Algorithm
0
5
10
15
20
10m Neutral Wind Speed (ms-1)
x 10-3
10m Neutral Heat and Water Turbulent Transfer Coefficients
University of Conneticut (FLIP, Martha's Vineyard Observatory and moored buoys)
NOAA/ESRL (Ships)
Mean of datasets
COARE3.0 Algorithm (Fairall et al. 2003)
NCEP1 Reanalysis Algorithm
ERA-40 Reanalysis Algorithm
Large and Yeager (2009) Algorithm
10m Neutral Wind Speed (ms-1)
Very little data for U > 18 m/s. The few existing data points are from isolated events, and may not be representative of more general conditions.

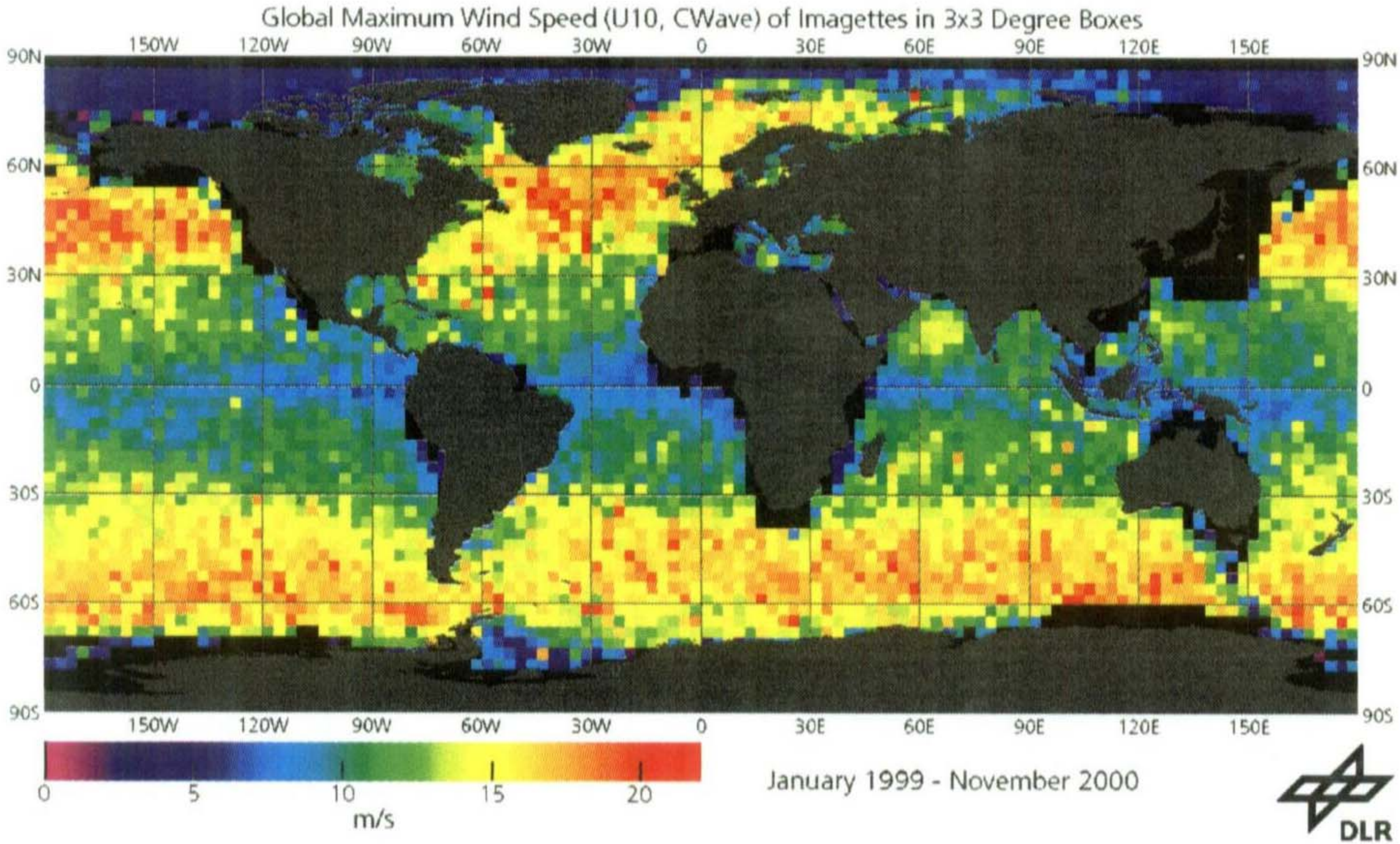


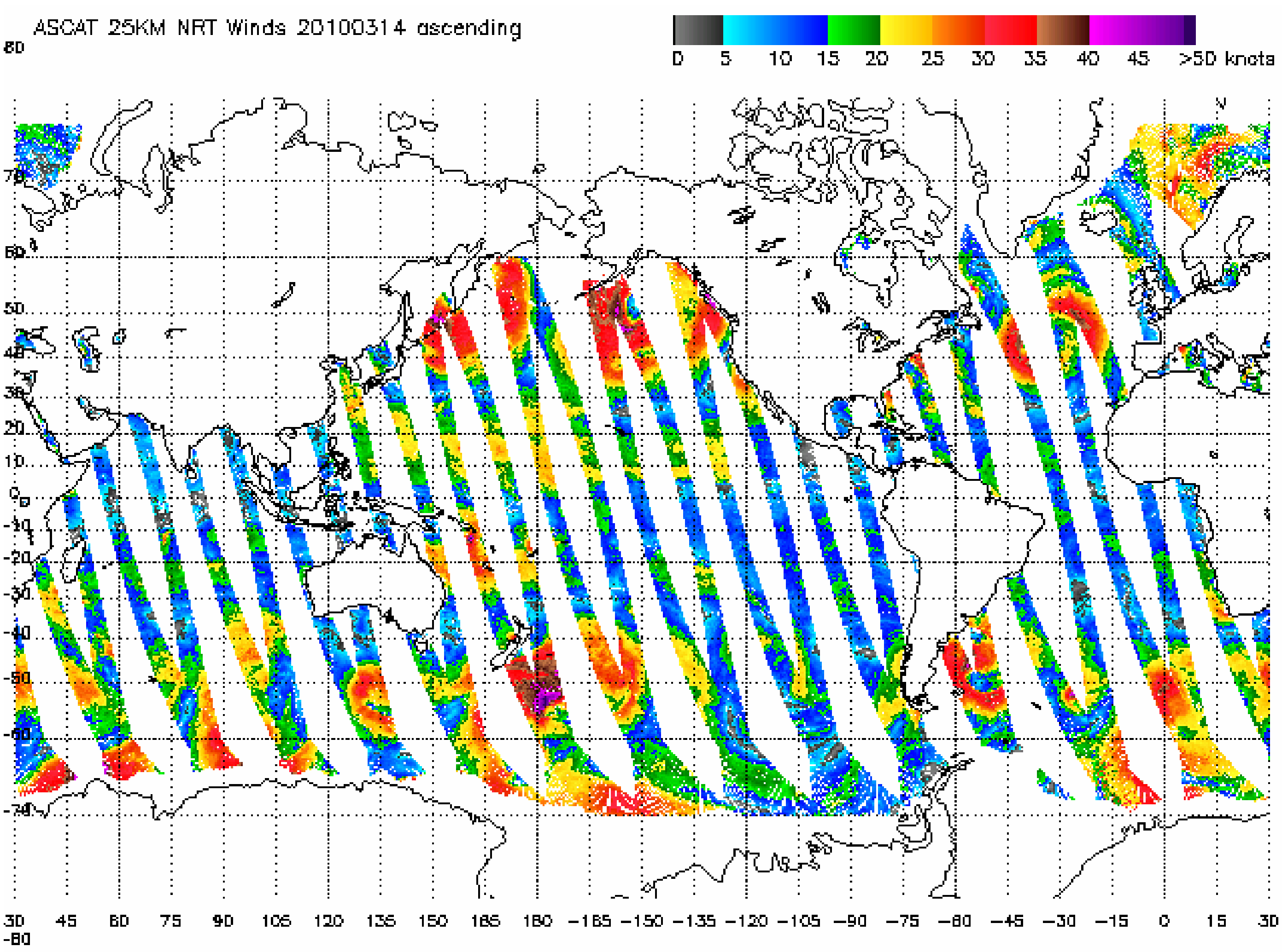
UM-ASIS data pre-2005:

Only 5 out of 1200 hours for U >18 m/s.

Figure 1: 10m neutral drag coefficient versus 10m neutral wind speed for 8 field experiments. Also shown are the bulk relation of Smith [60] (solid) and the drag relation calculated with a constant Charnock parameter of 0.015 (dashed). The circles represent data averaged in wind speed bins of 1m/s, showing 1 standard deviation in U_{10N} and C_{DN}. The wind speed distribution of the data is shown in the top panel.

Why so few flux data for U> 18m/s ? This plots shows maximum annual SAR wind speeds in 3x3 deg degrees boxes.





Scatterometer daily winds:
High wind events are often transient events

Another reason for the paucity of high wind fluxes are that platforms aren't reliable in these conditions.

Sensors are also a problem …

Southern Ocean Gas Exchange Experiment

ASIS drift track in blue
(8 days, 200km)

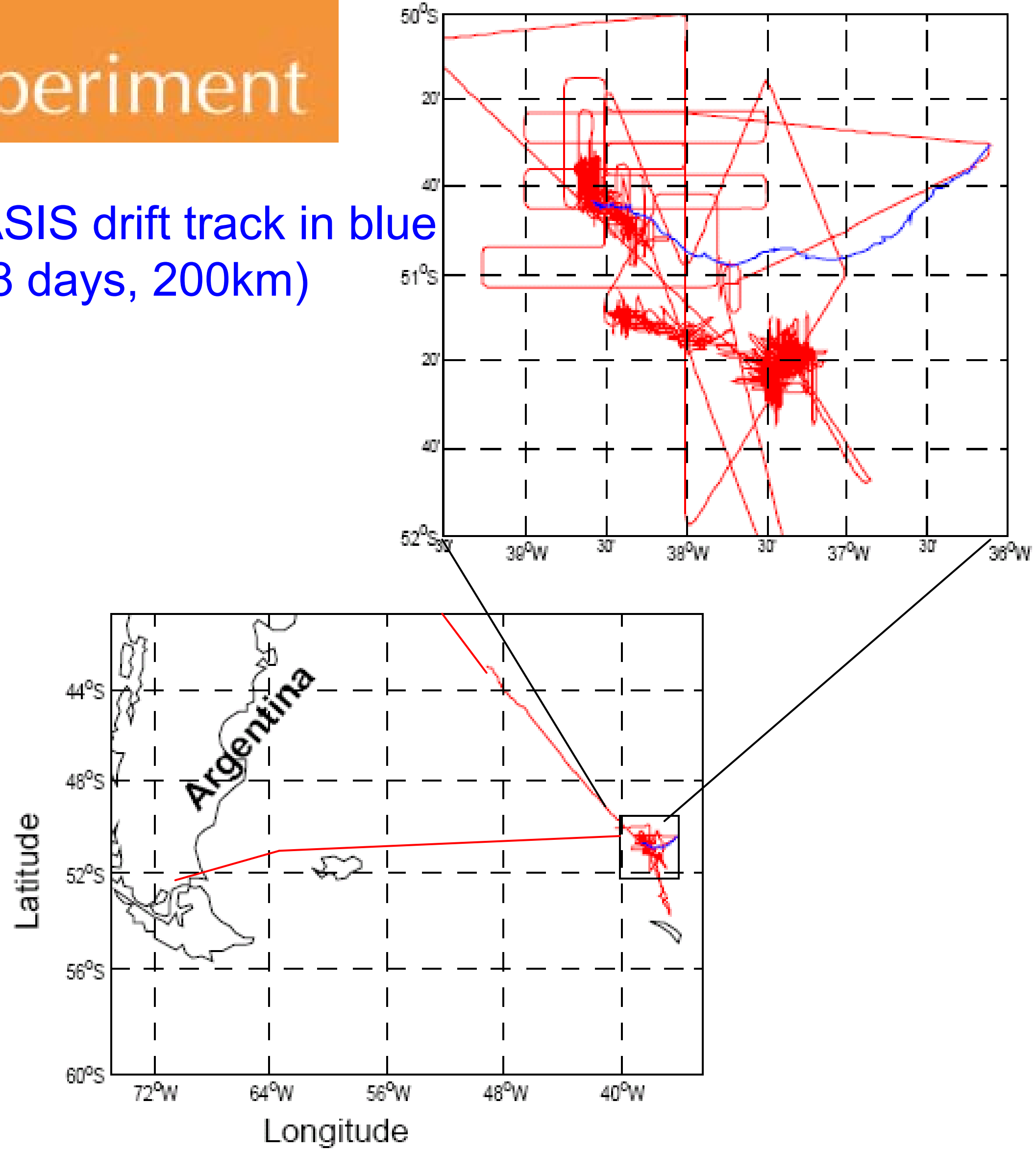
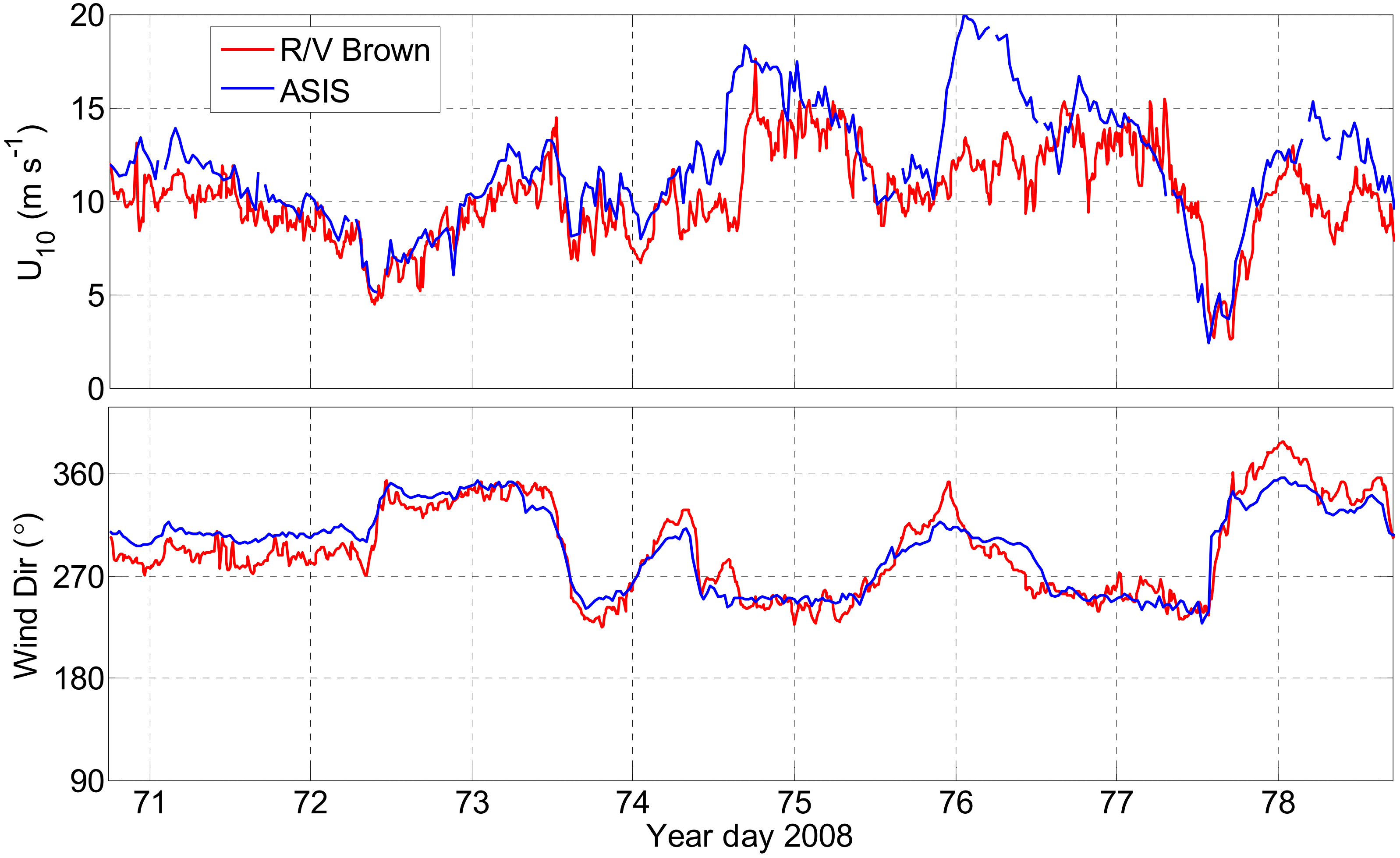
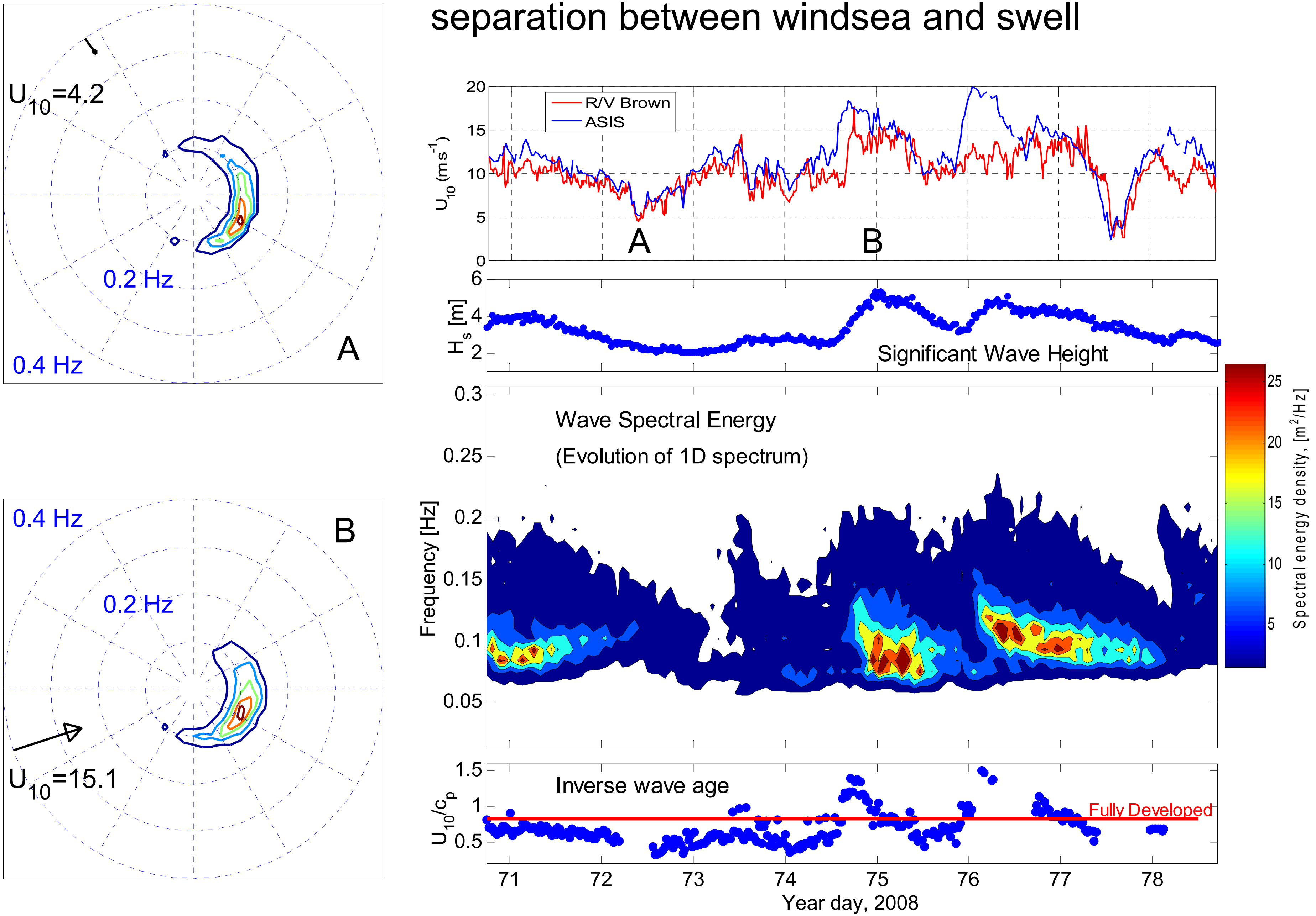


Fig. 2: R/V Ronald Brown ship track (red) and ASIS drift (blue) during the Southern Ocean Gas Exchange Experiment, March 2008.

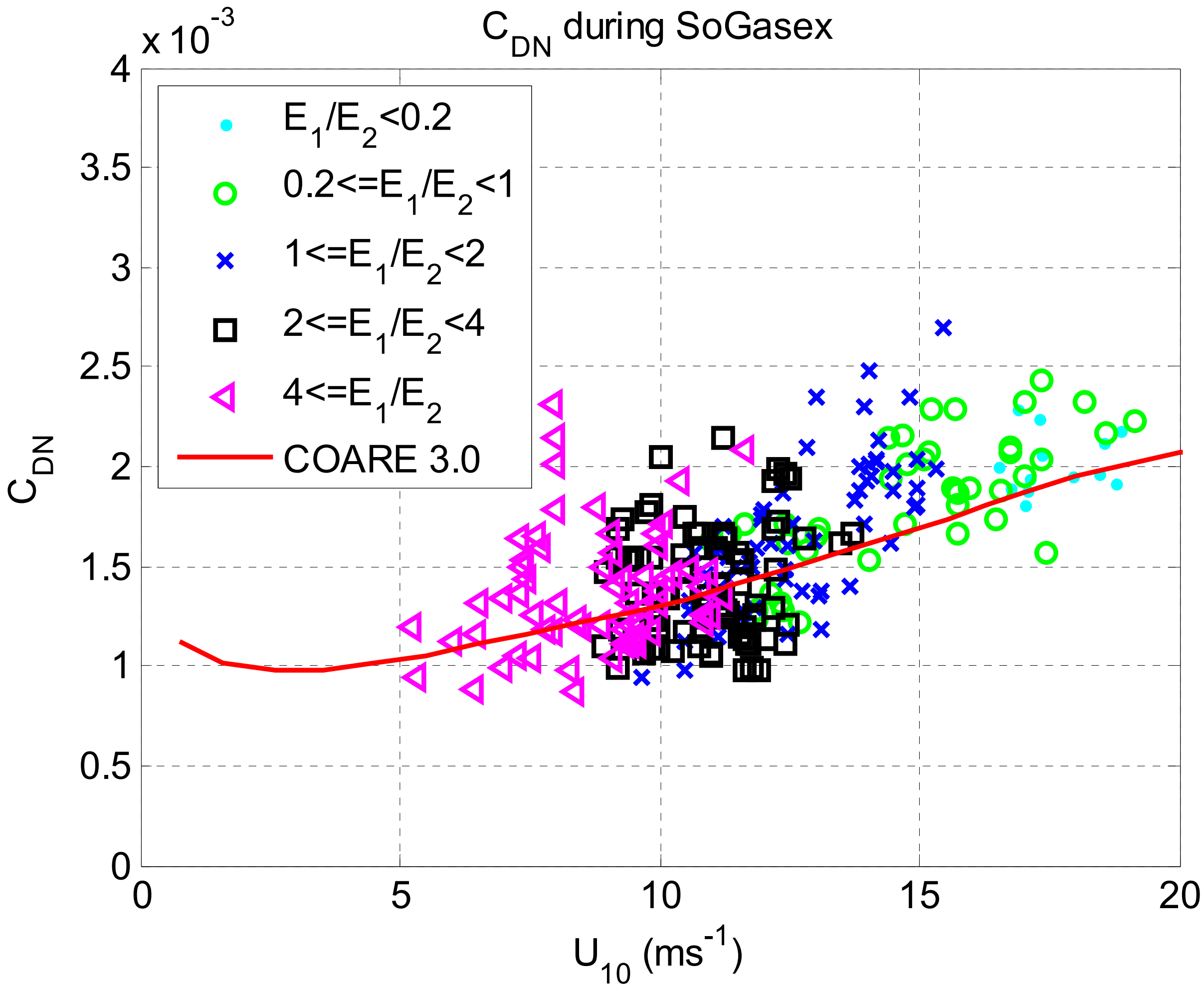


R/V Brown
ASIS
U10 (m s-1)
20
15
10
5
0
Wind Dir (°)
360
270
180
90
71
72
73
74
75
76
77
78
Year day 2008

Southern Ocean waves: Unimodal, with no spectral separation between windsea and swell



Drag coefficient at high winds



E1 = swell energy
E2 = windsea energy

No significant effect of swell on CD in unimodal seas of Southern Ocean

QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY
Q. J. R. Meteorol. Soc. **135**: 2030–2045 (2009)
Published online 13 January 2009 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/qj.355

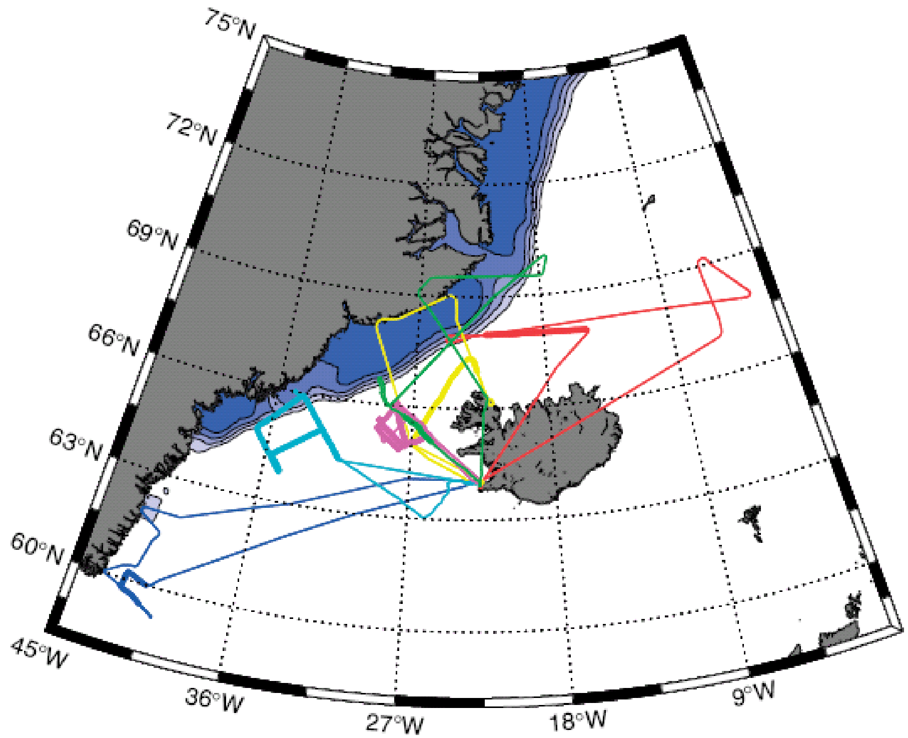
RMetS
Royal Meteorological Society

Aircraft-based observations of air–sea fluxes over Denmark Strait and the Irminger Sea during high wind speed conditions

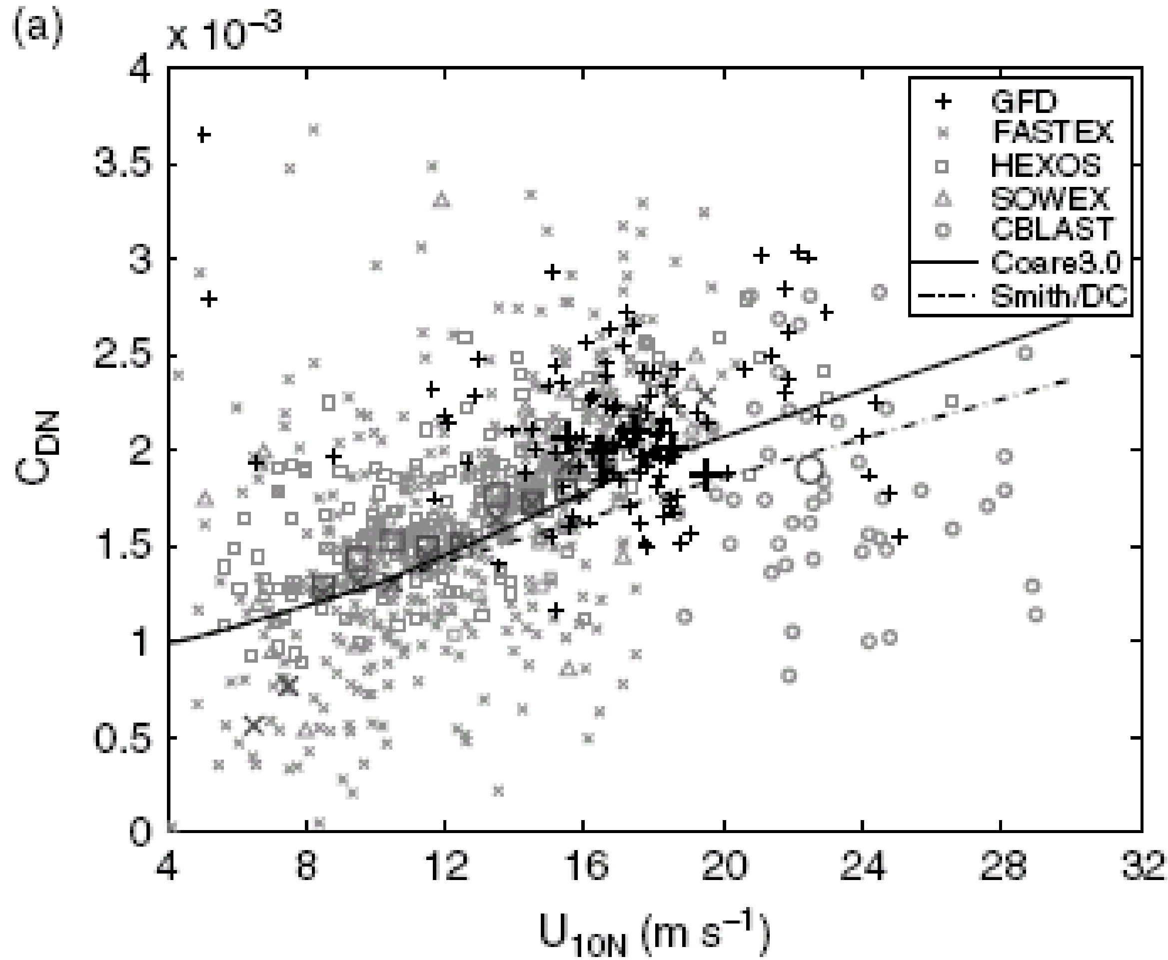
G. N. Petersen* and I. A. Renfrew
School of Environmental Sciences, University of East Anglia, UK

Aircraft data

- Eddy correlation
- Flight altitudes 35 – 45m
- Flights in surface layer
- Fluxes corrected for height using Donelan 1990



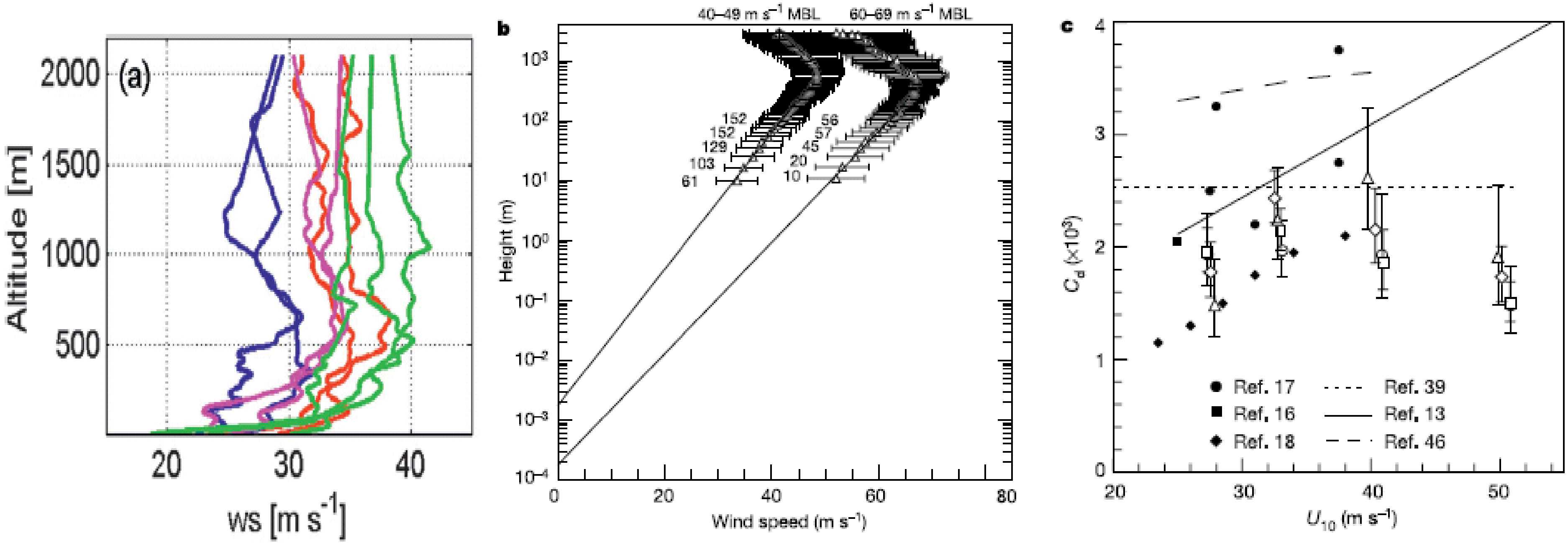
GFD CDs are similar to ASIS-SOGasex CDs, showing enhancement above COARE3 and Smith curves around 16- 20m/s. Above 20m/s, there is no clear trend.



Reduced drag coefficient for high wind speeds in tropical cyclones

Mark D. Powell*, Peter J. Vickery† & Timothy A. Reinhold‡

NATURE | VOL 422 | 20 MARCH 2003 |



1) Group GPS dropsonde profiles by wind speed at mean BL height

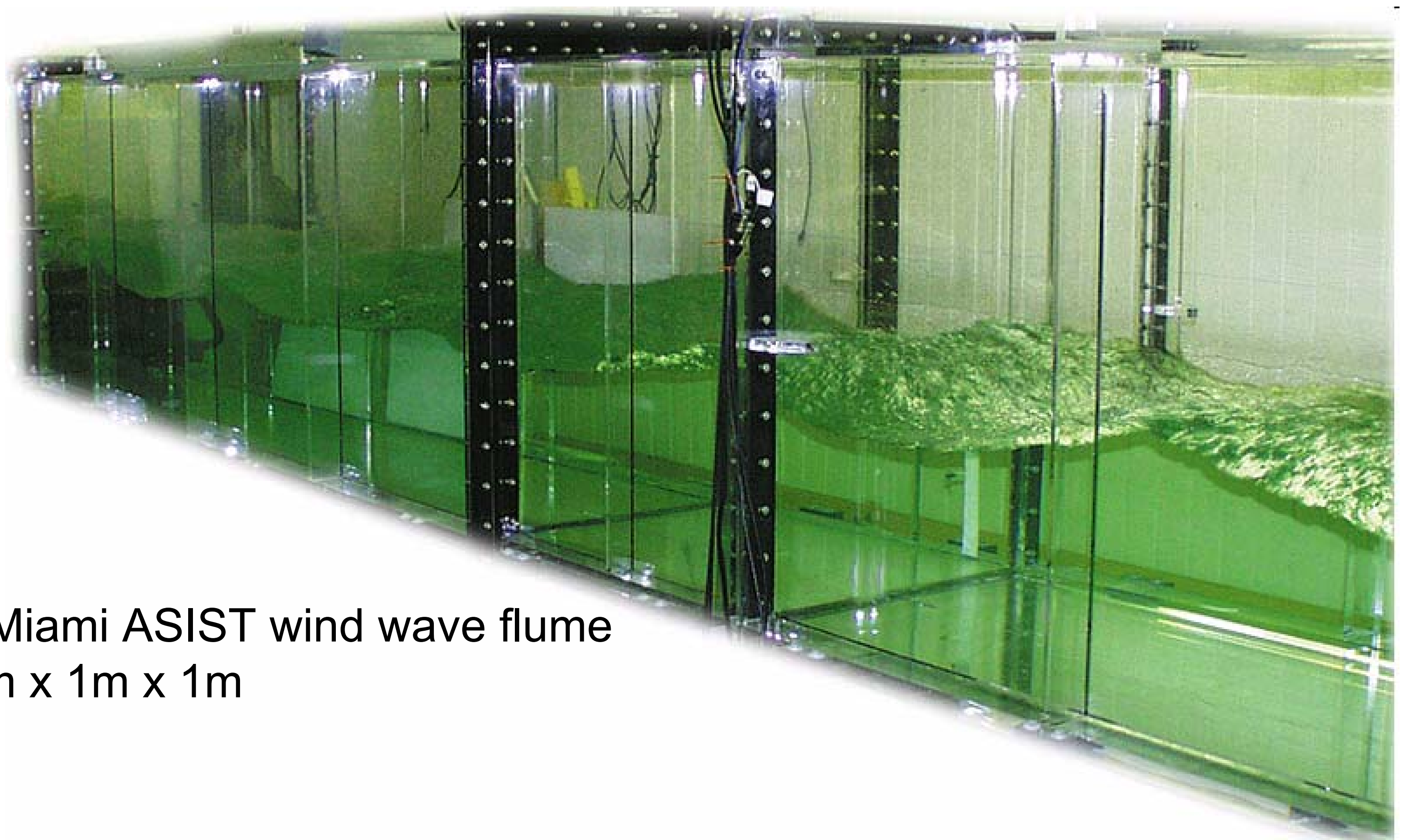
2) Assuming mean log profile, extrapolate mean profiles to find zo, thence CD

→ CD levels off by 40m/s, then decreases at 50m/s

On the limiting aerodynamic roughness of the ocean in very strong winds

M. A. Donelan,[1] B. K. Haus,[1] N. Reul,[2] W. J. Plant,[3] M. Stiassnie,[4] H. C. Graber
O. B. Brown,[1] and E. S. Saltzman[5]

GEOPHYSICAL RESEARCH LETTERS, VOL. 31
L18306, doi:10.1029/2004GL019460, 2004



U. Miami ASIST wind wave flume
15m x 1m x 1m

On the limiting aerodynamic roughness of the ocean in very strong winds

M. A. Donelan,[1] B. K. Haus,[1] N. Reul,[2] W. J. Plant,[3] M. Stiassnie,[4] H. C. Graber
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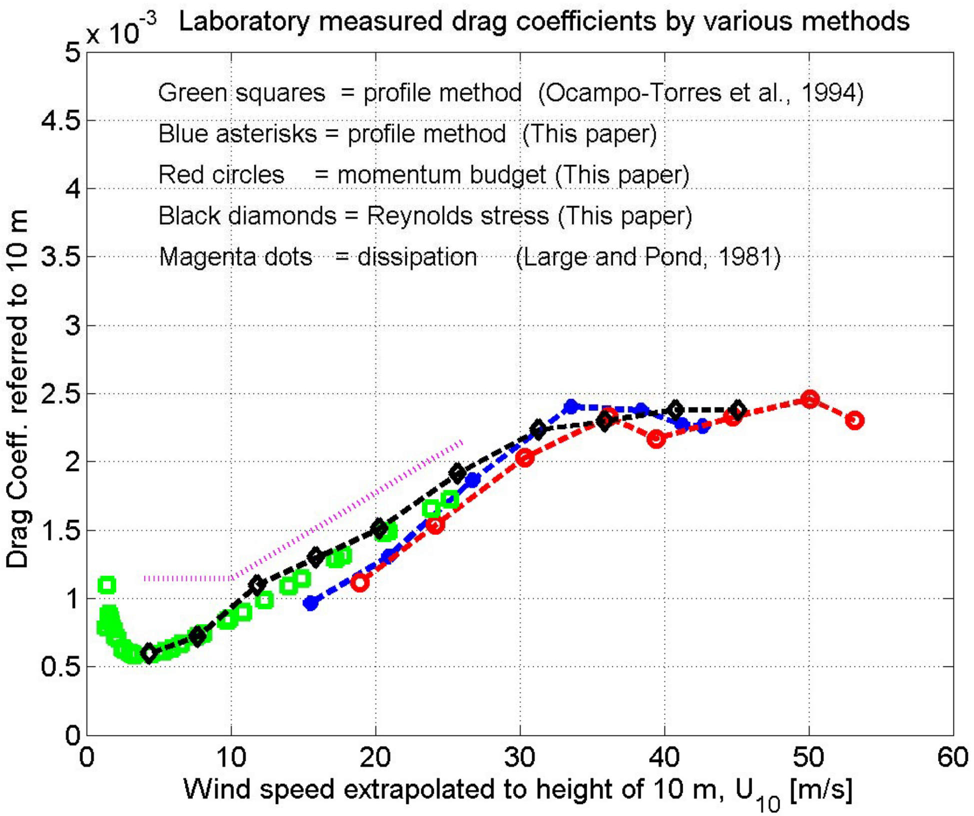

→ Drag levels off at high winds

On the limiting aerodynamic roughness of the ocean in very strong winds

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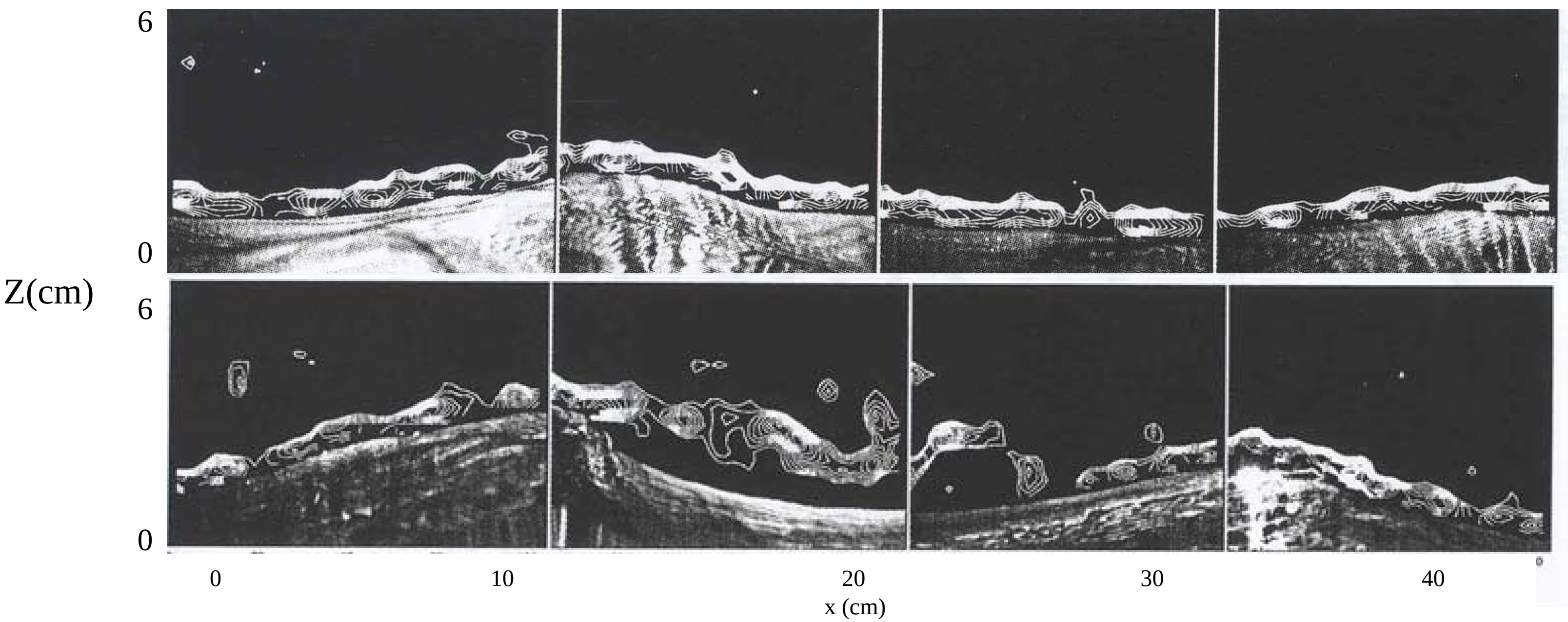


Figure 4. Vorticity contours obtained via Digital Particle Image Velocimetry (DPIV) in the air flow over wind driven waves [Reul, 1998]. Both wave and air flow are from left to right. (Top) waves of gentle slope – non-separated flow. (Bottom) waves of steep slope – separated flow.

→ Hypothesis: Flow separation over steep waves reduces effective roughness and drag

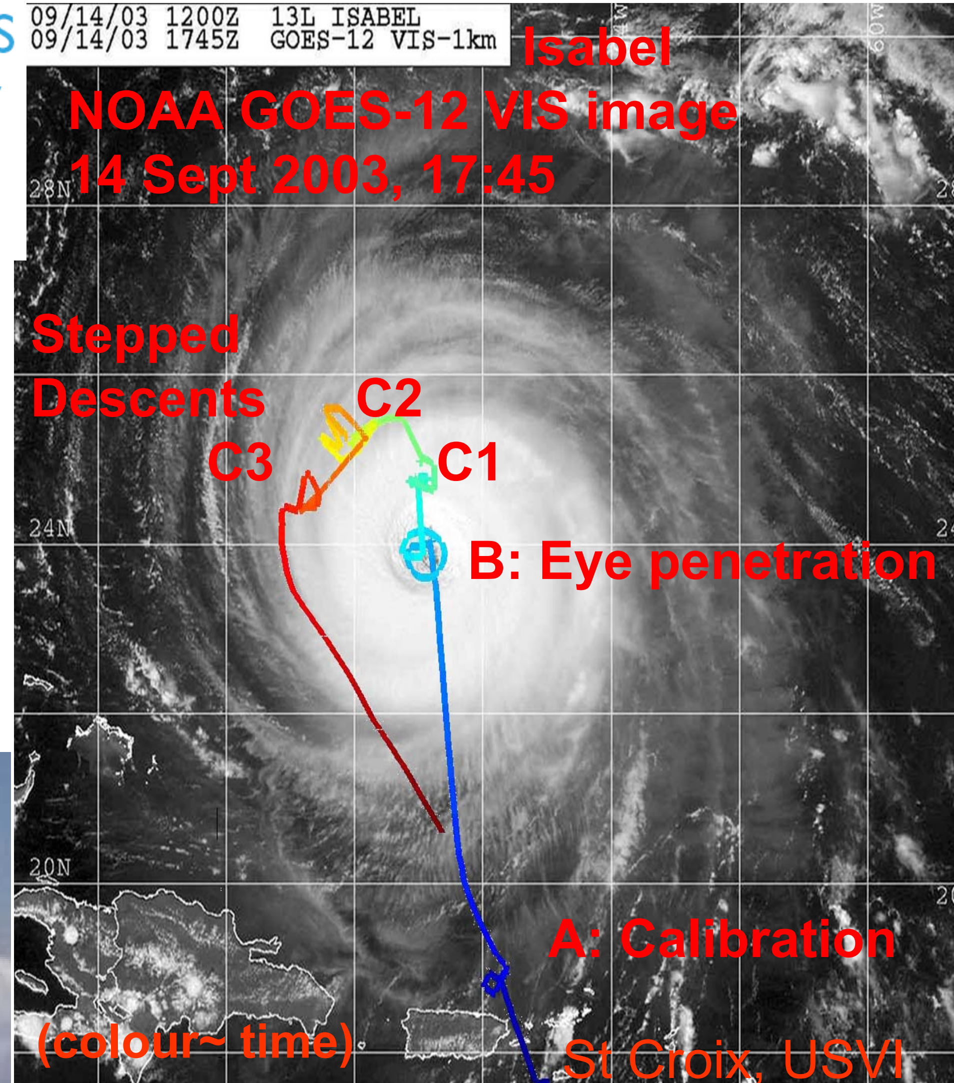
AIR–SEA EXCHANGE IN HURRICANES

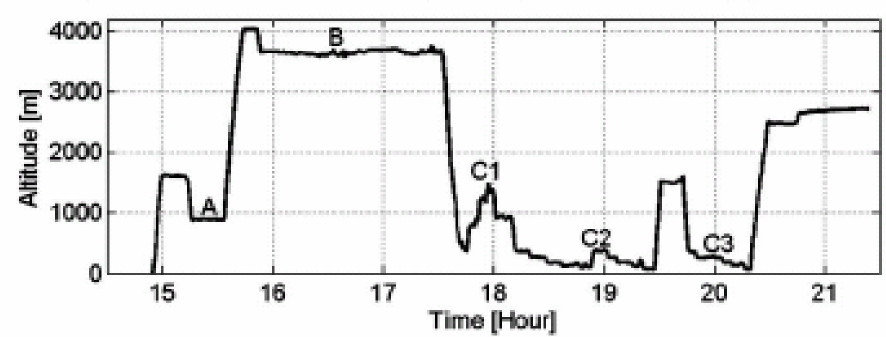
Synthesis of Observations from the Coupled Boundary Layer Air–Sea Transfer Experiment

BY PETER G. BLACK, ERIC A. D'ASARO, WILLIAM M. DRENNAN, JEFFREY R. FRENCH, PEARN P. NIILER, THOMAS B. SANFORD, ERIC J. TERRILL, EDWARD J. WALSH, AND JUN A. ZHANG

BAMS, 2007 "CBLAST". Also:

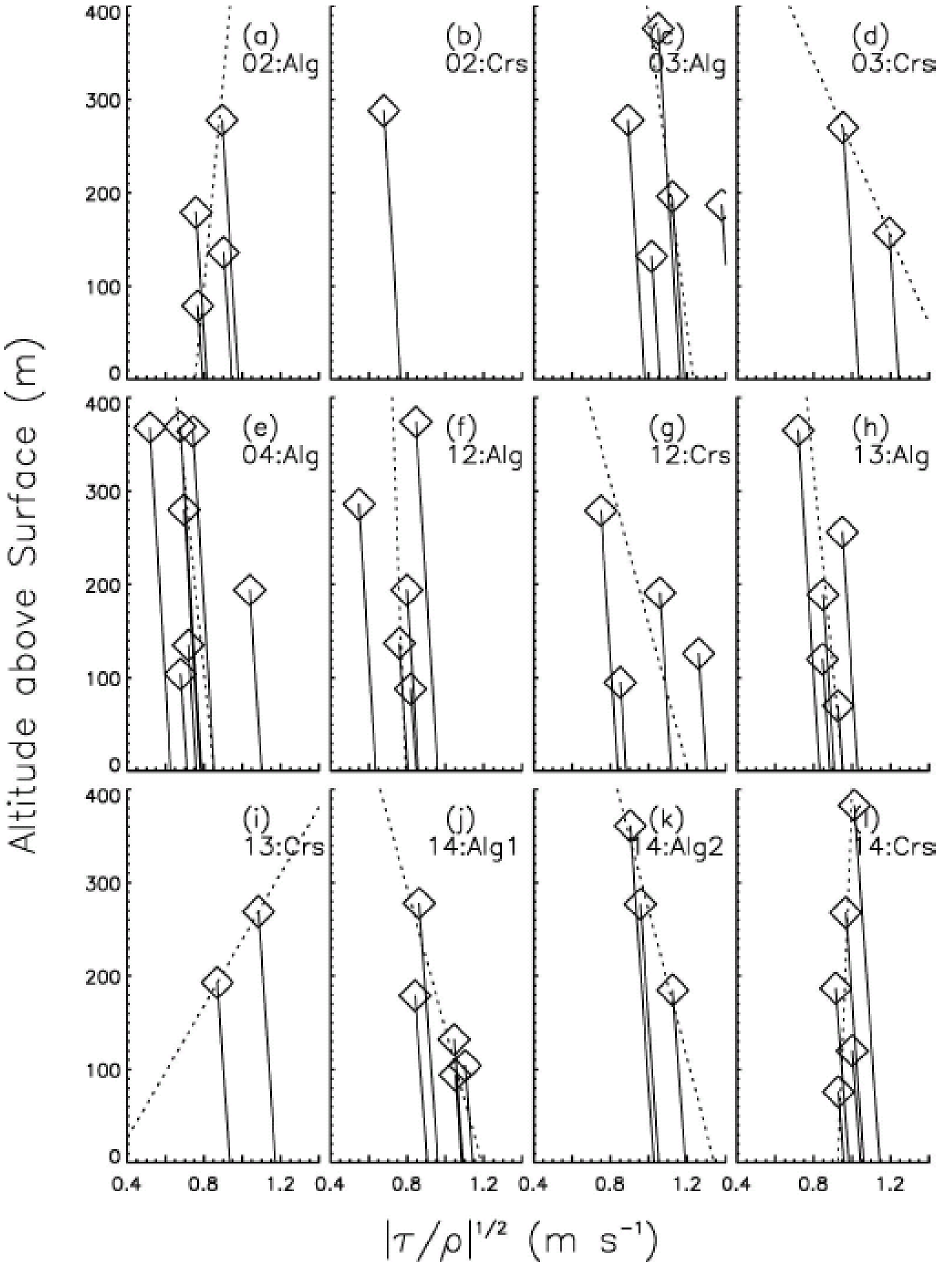
French et al 2007 (JAS)
Drennan et al 2007 (JAS)
Zhang et al 2008 (GRL and BLM)
Zhang et al 2009 (JAS)





CBLAST data

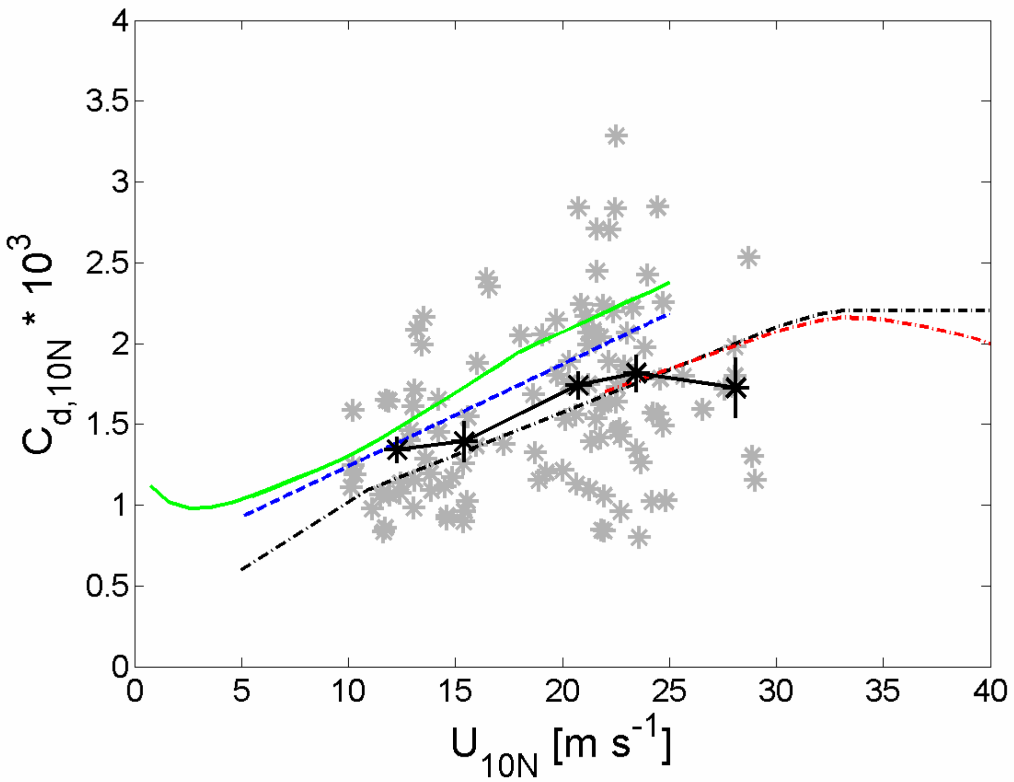
- Eddy correlation fluxes
- Flight altitudes 60 – 400m
- Flights in BL, above surface layer
- Momentum fluxes corrected to surface layer using Donelan 1990



CBLAST data

- Eddy correlation fluxes
- Flight altitudes 60 – 400m
- Flights in BL, above surface layer
- Momentum fluxes corrected to surface layer using Donelan 1990
- Surface winds from SFMR (microwave radiometer)

→ Again, CD levels off at high U



Asterisks: CBLAST .

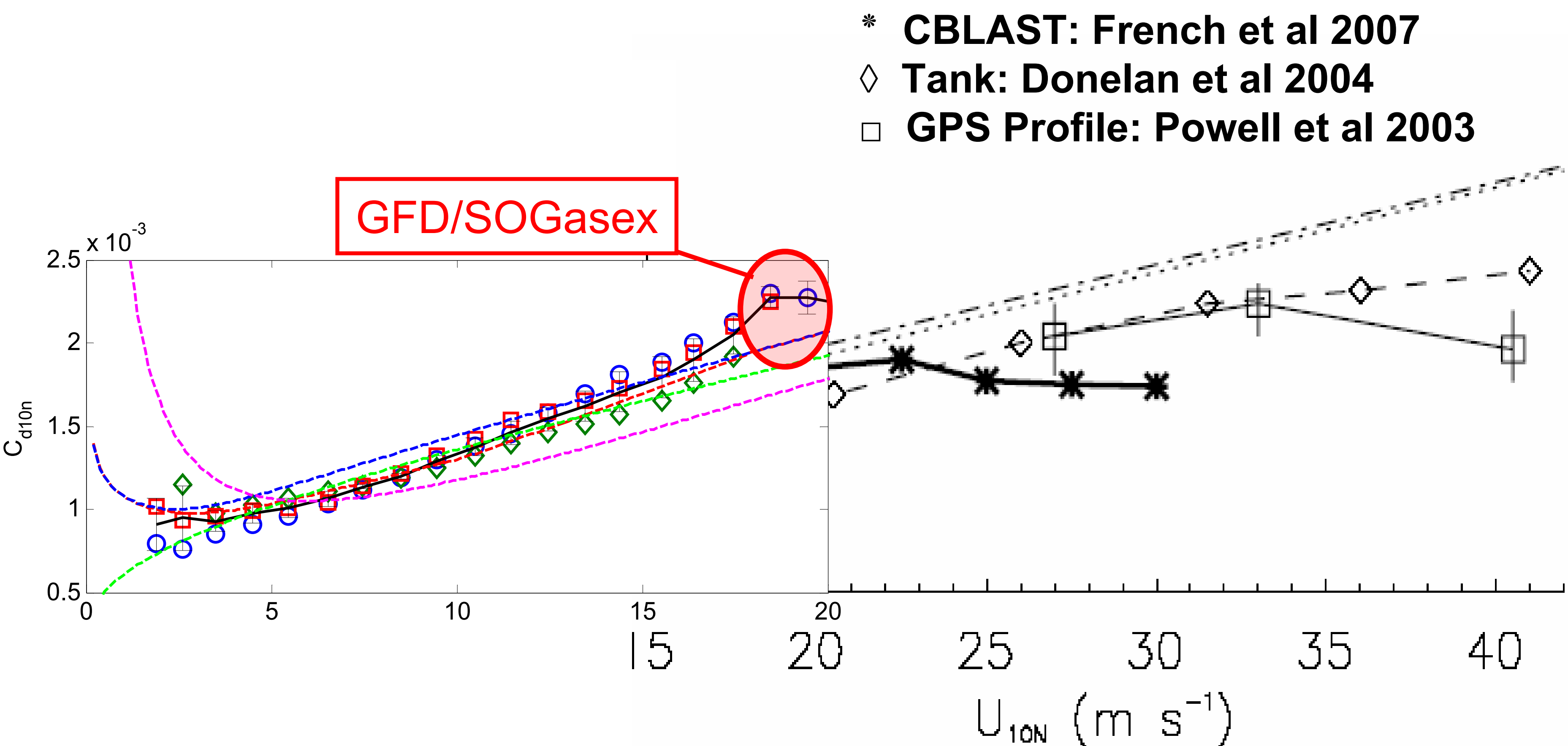
Fairall et al. (2003);

Smith (1980);

Donelan et al. (2004);

Powell et al. (2003)

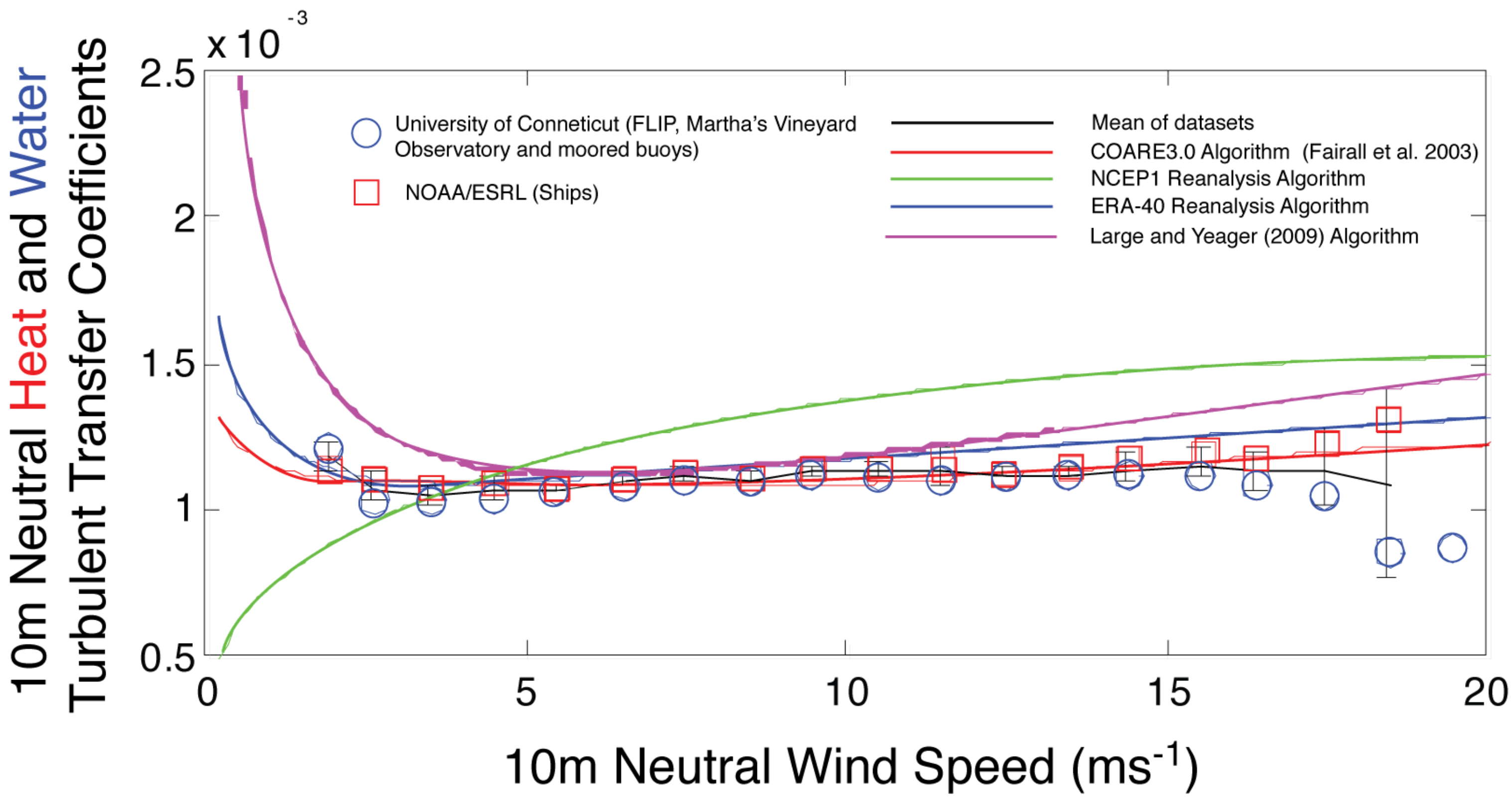
Drag coefficients in hurricanes



The three high wind results are in qualitative agreement: CD levels off at high winds. But all are lower than GFD/SOGasex at 20m/s. These results need to be confirmed with in situ field measurements. Even then, they may not be representative of high latitude conditions, where the wave fields are very different.

What about scalar fluxes ?

10m Neutral Wind Speed (ms^{-1})



Dalton number at high winds

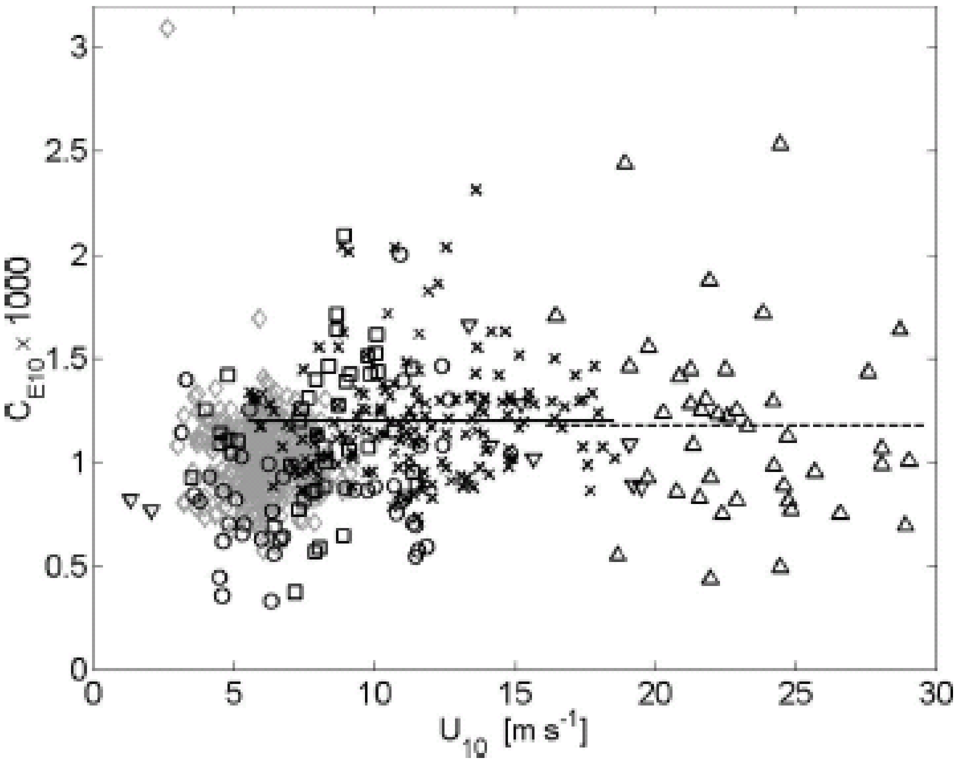


FIG. 11. Plot of Dalton number vs wind speed, both neutral 10 m. The CBLAST data points and mean value are shown with Δ and dashed line, respectively. The HEXOS data (DeCosmo et al. 1996), shown with × and the solid line, have been corrected according to Fairall et al. (2003). Other symbols as in Fig. 2.

O AGILE (Donelan & Drennan 1995)
X HEXOS (Decosmo et al 1996)
◊ GASEX-ASIS (McGillis et al 2004)
∇ SOWEX (Banner et al 1999)
□ SWADE (Katsaros et al 1993)
Δ CBLAST (Drennan et al 2007)

→ C_E (and C_H) independent of wind to 30 m/s

"Extra" scatter attributable to sampling

Dalton number at high winds

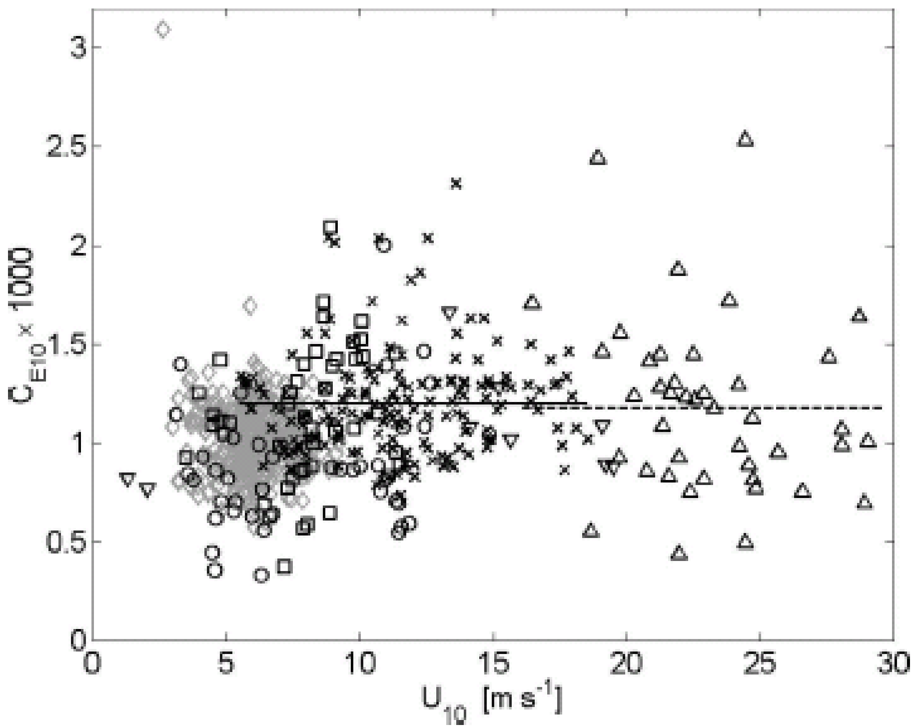
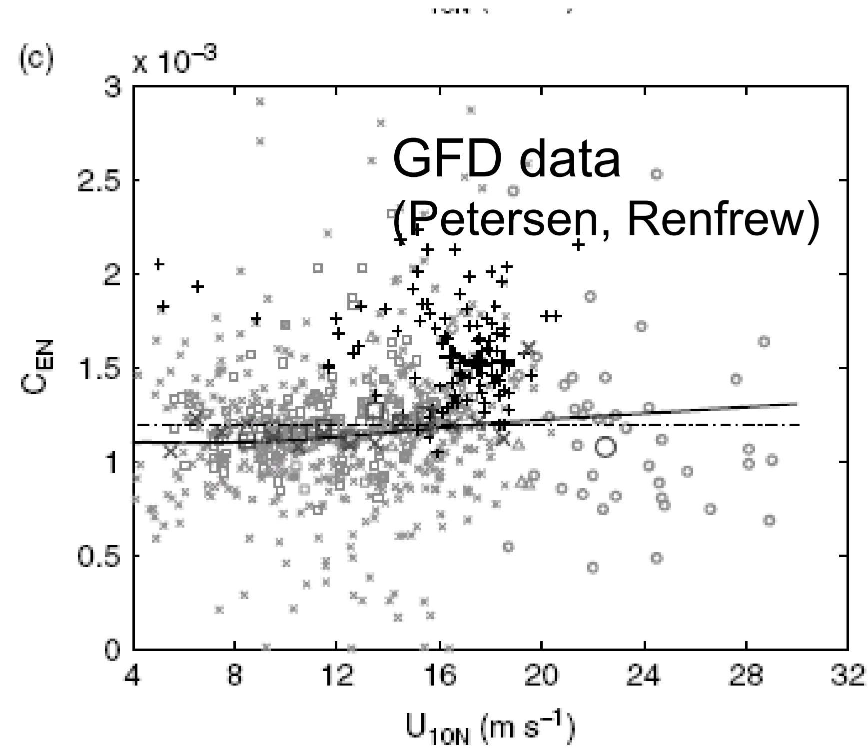


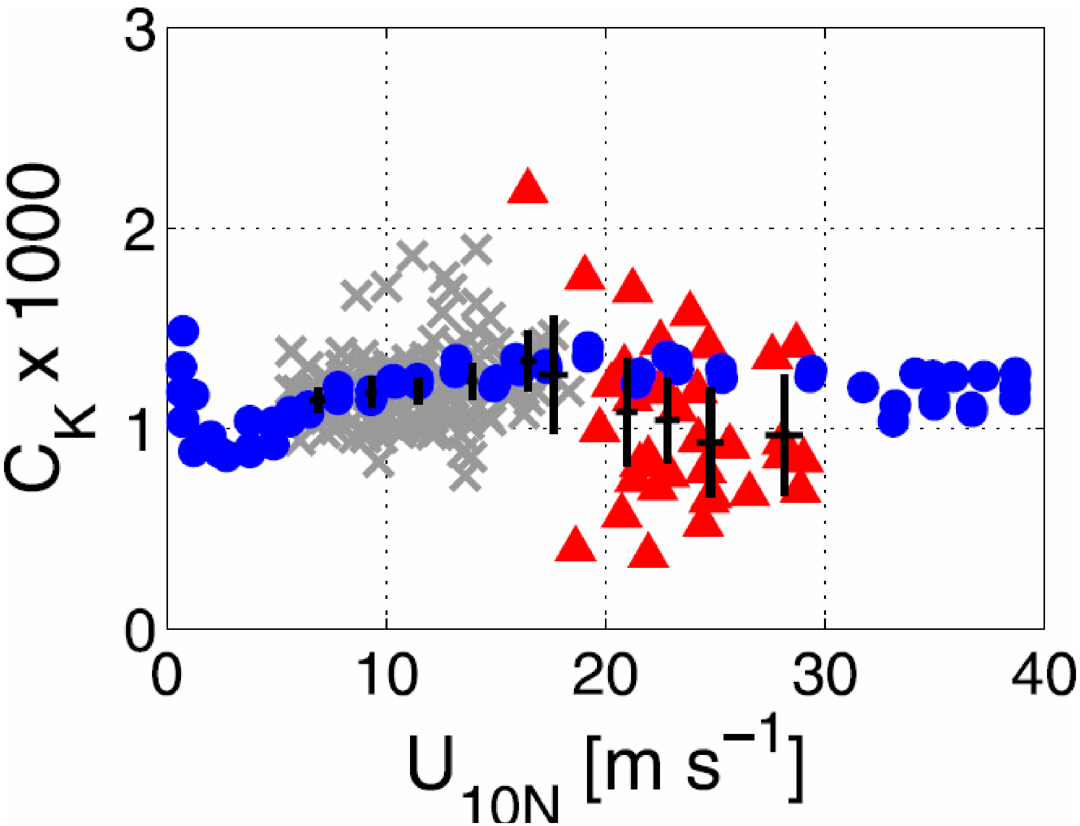
FIG. 11. Plot of Dalton number vs wind speed, both neutral 10 m. The CBLAST data points and mean value are shown with △ and dashed line, respectively. The HEXOS data (DeCosmo et al. 1996), shown with × and the solid line, have been corrected according to Fairall et al. (2003). Other symbols as in Fig. 2.



???

Laboratory data indicate constant bulk heat coefficients to 40m/s.
→ No evidence for sea spray enhancement

C_k = bulk coefficient for moist enthalpy, k



$$k = [c_{pd}(1-q) + c_l q]T + L_v q$$

● ASIST flume
▲ CBLAST aircraft
X HEXOS tower

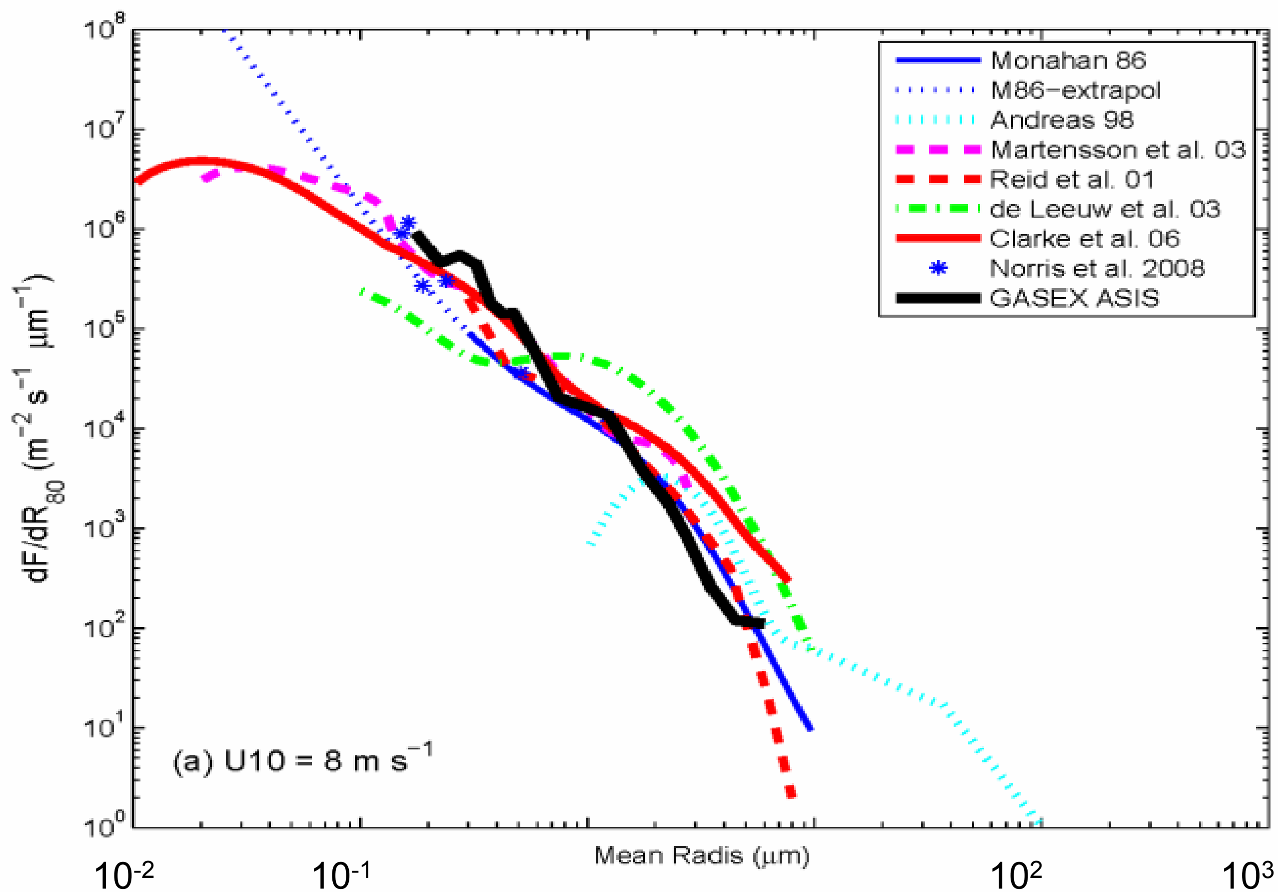
$C_K \sim C_E \sim C_H$

The relative rates of sea-air heat transfer and frictional drag in very high winds

Brian K. Haus[1], Dahai Jeong[1], Mark A. Donelan [1], Jun A. Zhang[2] & Ivan Savelyev[3]

Geophys. Res. Lett, in press

So, what about sea spray ? These are sea spray fluxes (source functions) from the Uni. Leeds CLASP (Compact Lightweight Aerosol Spectrometer – Norris et al. 2008) mounted near the ASIS sonic anemometer during SOGasex.



How to get fluxes at high winds ? We will be deploying 2 direct flux moorings off Taiwan during the “Impact of Typhoons of the Pacific” experiment, June-November 2010. The buoys will measure direct fluxes of momentum, latent and sensible heat, and sea spray, SW and LW radiation, waves, currents, TS, biochemistry). Assuming we have anything left after November, we plan on a long term (1 year) deployment in the Southern Ocean…