Bubble size distributions measured in high wind conditions

(a.k.a. HiWinGS, for the final time!)

Helen Czerski, Ian Brooks, Steve Gunn, Robin Pascal, Adrian Matei, Byron Blomquist

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Ocean bubbles under high wind conditions – Part 1: Bubble distribution and development

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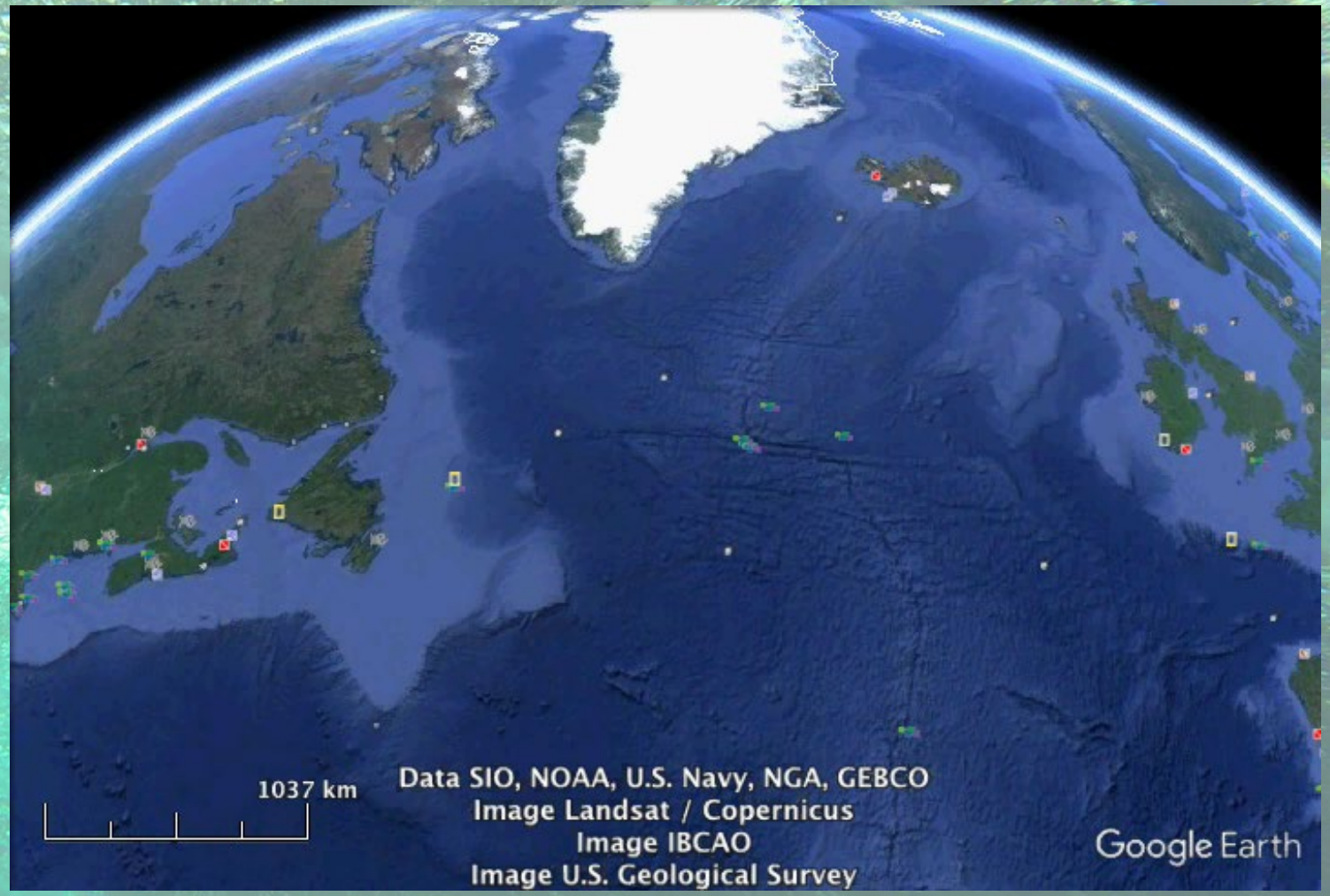
Ocean bubbles under high wind conditions – Part 2: Bubble size distributions and implications for models of bubble dynamics

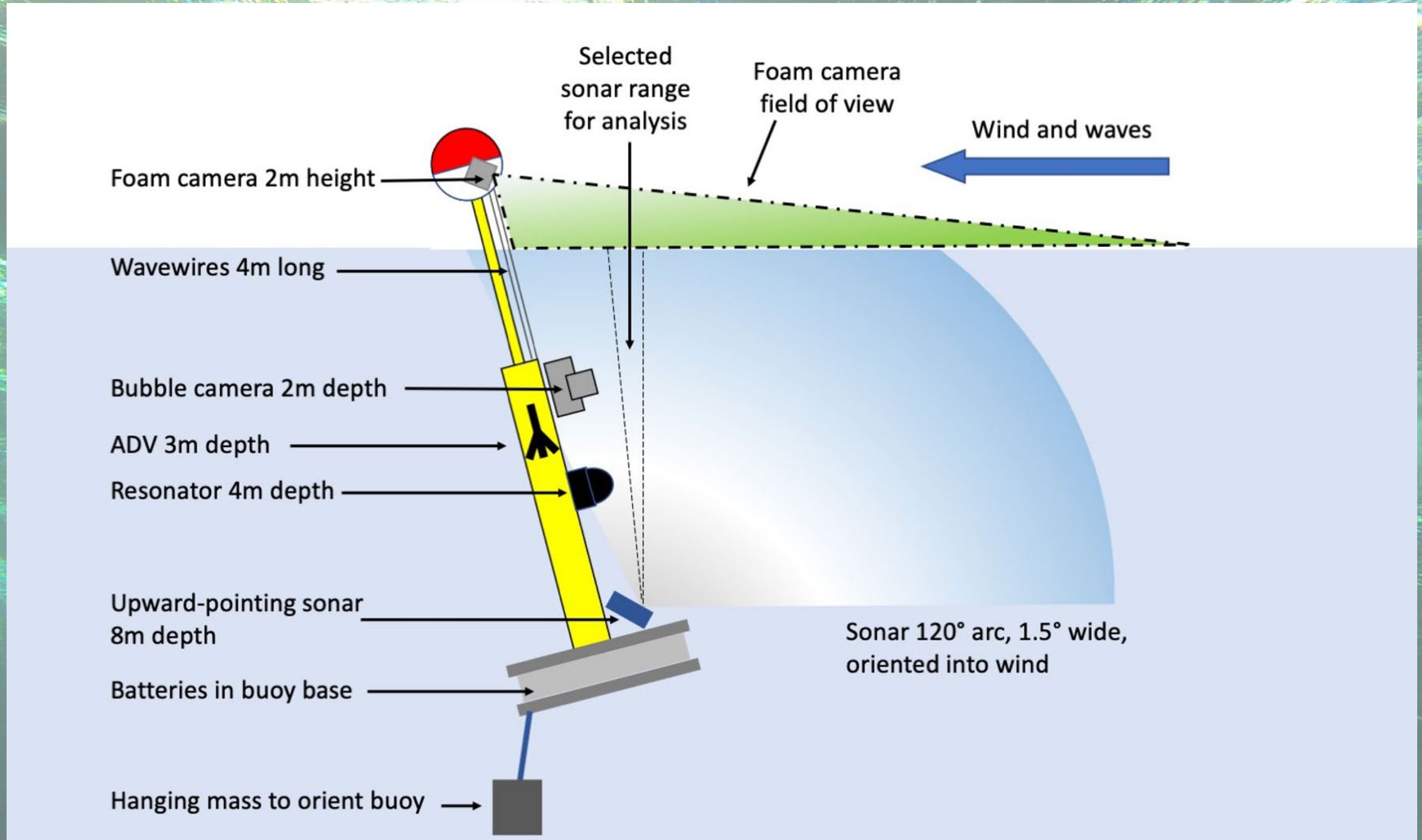
Helen Czerski[1], Ian M. Brooks[2], Steve Gunn[3], Robin Pascal[4], Adrian Matei[1], and Byron Blomquist[5,6]

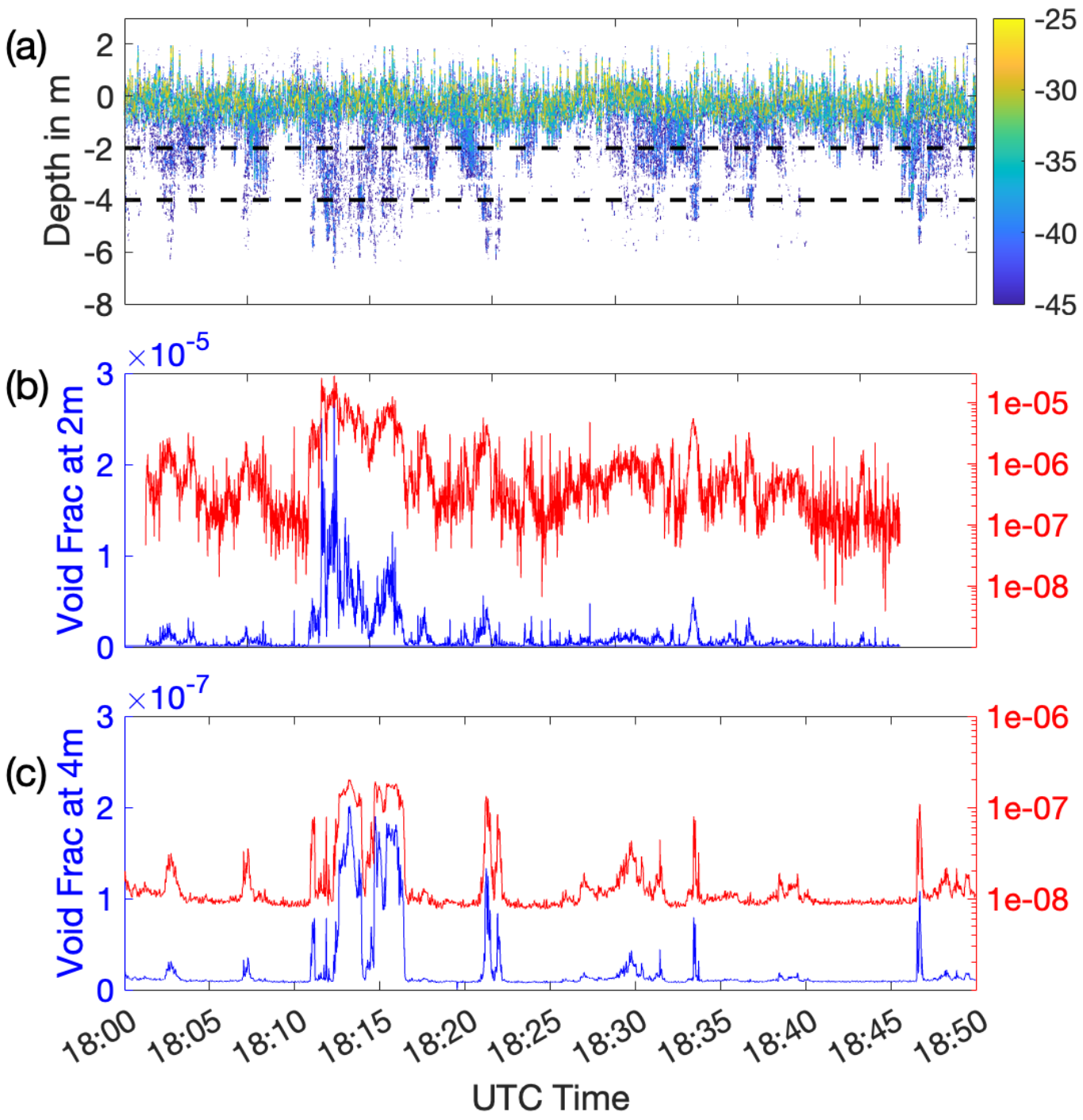
HiWinGS

Oct-Nov 2013
(6 weeks)

Wind speeds 10-27 m/s
(hourly average)



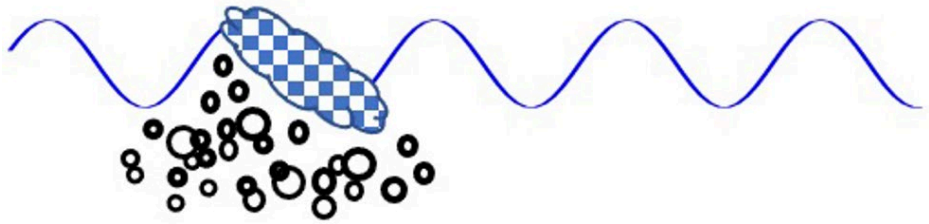

Selected
sonar range
for analysis
Foam camera
field of view
Wind and waves
Foam camera 2m height
Wavewires 4m long
Bubble camera 2m depth
ADV 3m depth
Resonator 4m depth
Upward-pointing sonar
8m depth
Batteries in buoy base
Hanging mass to orient buoy
Sonar 120° arc, 1.5° wide,
oriented into wind



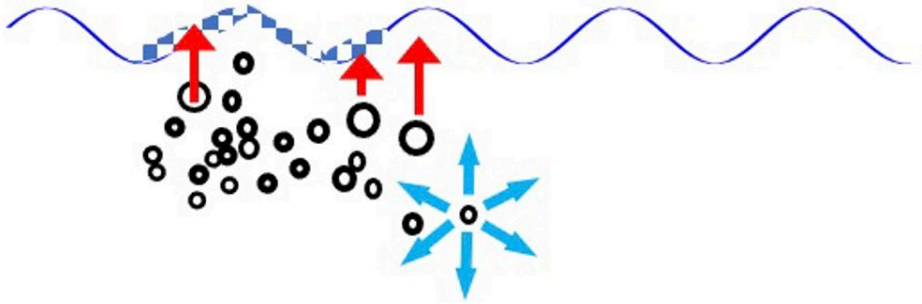
Beware being seduced by sonar images that suggest large deep bubble populations… below 2m, void fractions are almost certainly extremely low.

Framework

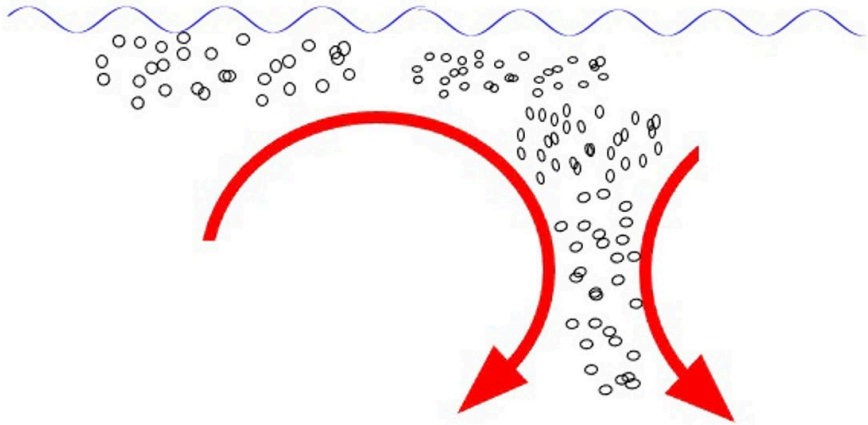
1. Bubble formation



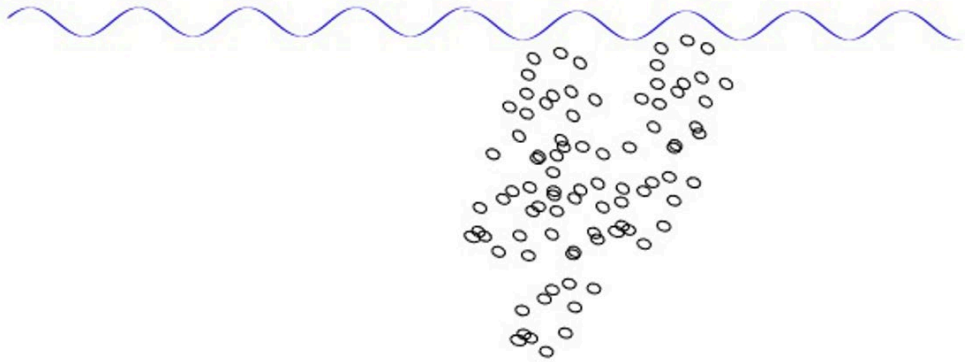
2. Shallow layer evolution



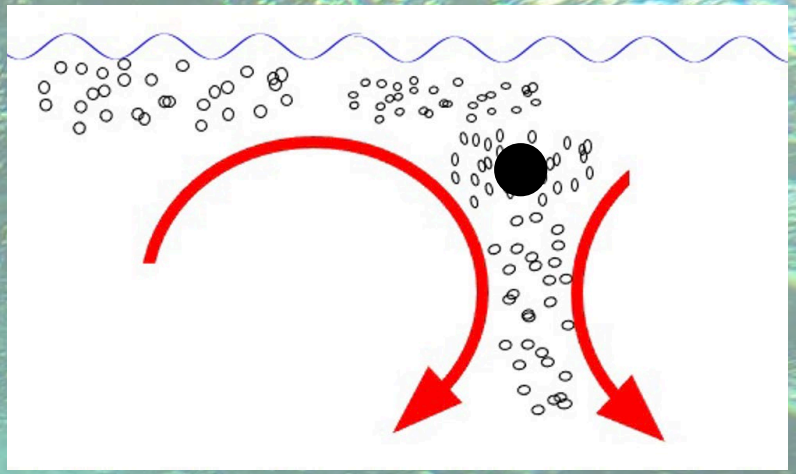
3. Deep plume formation

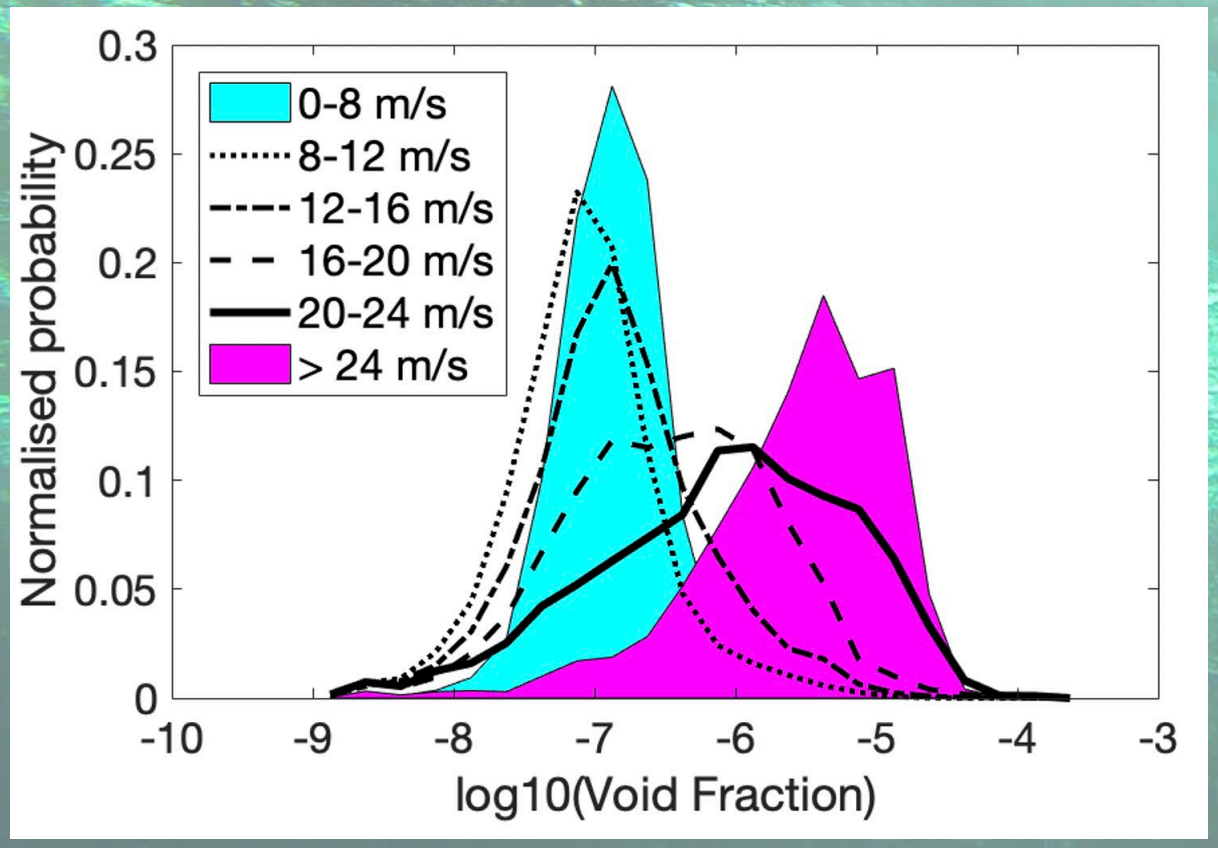


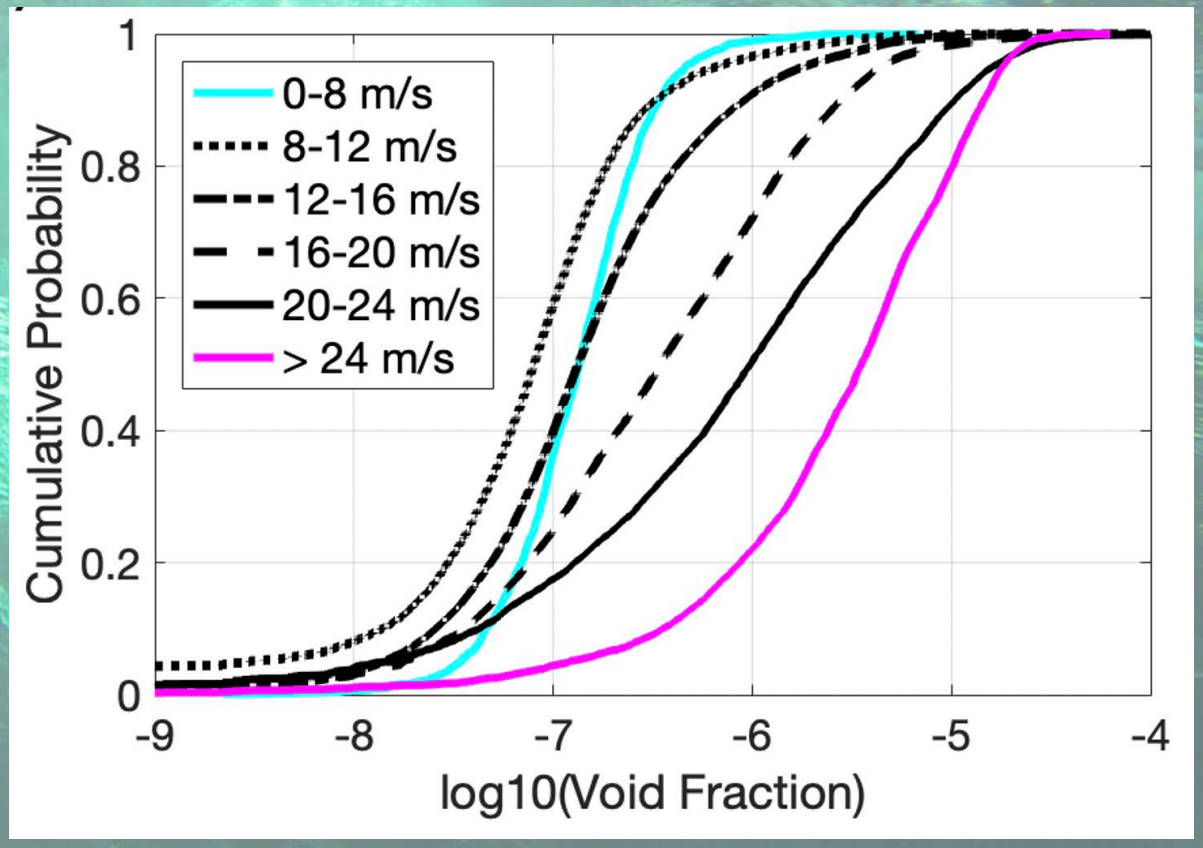
4. Deep plume evolution



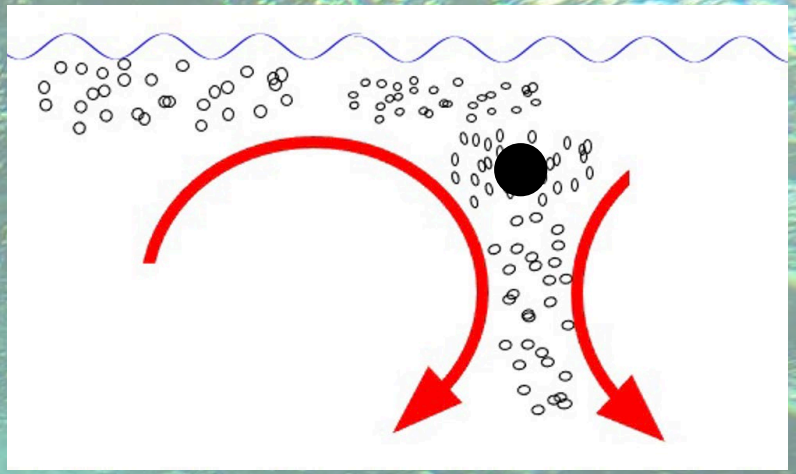
Void fractions at 2m depth

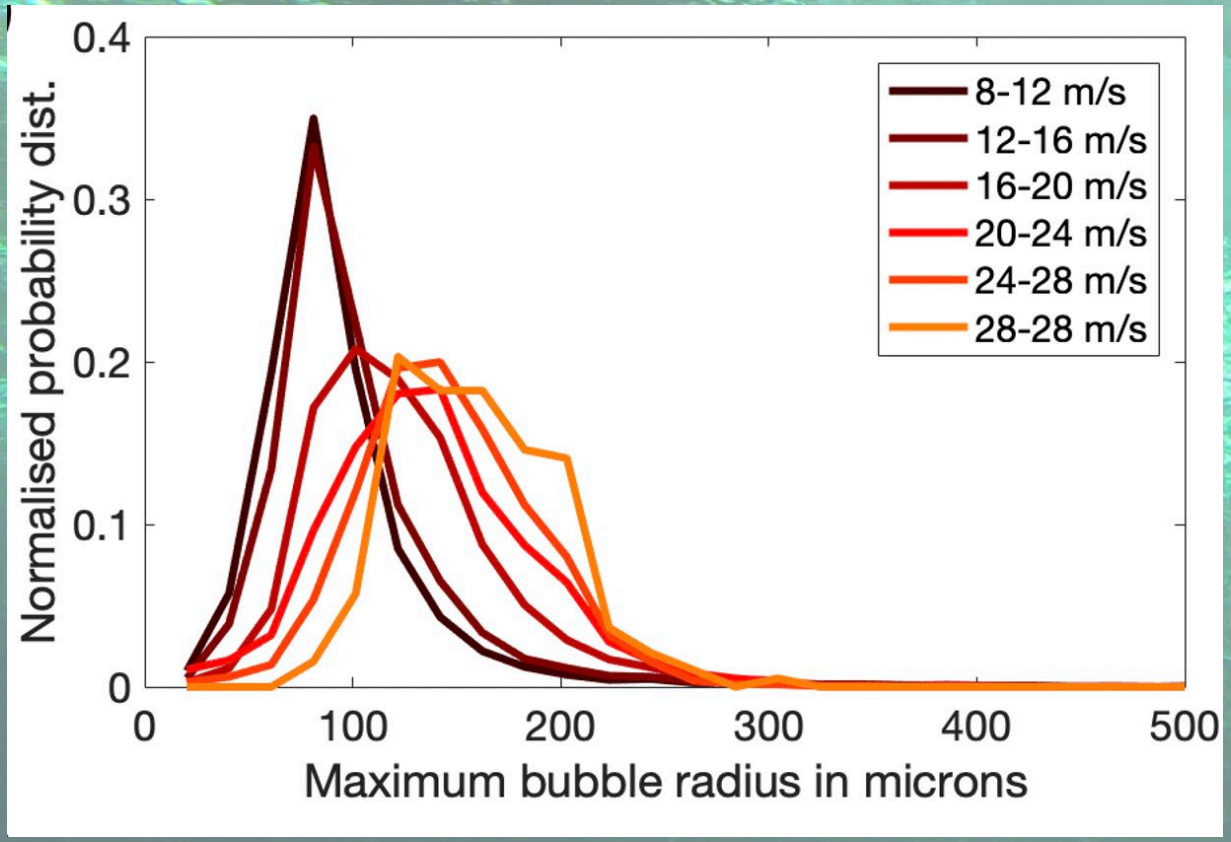


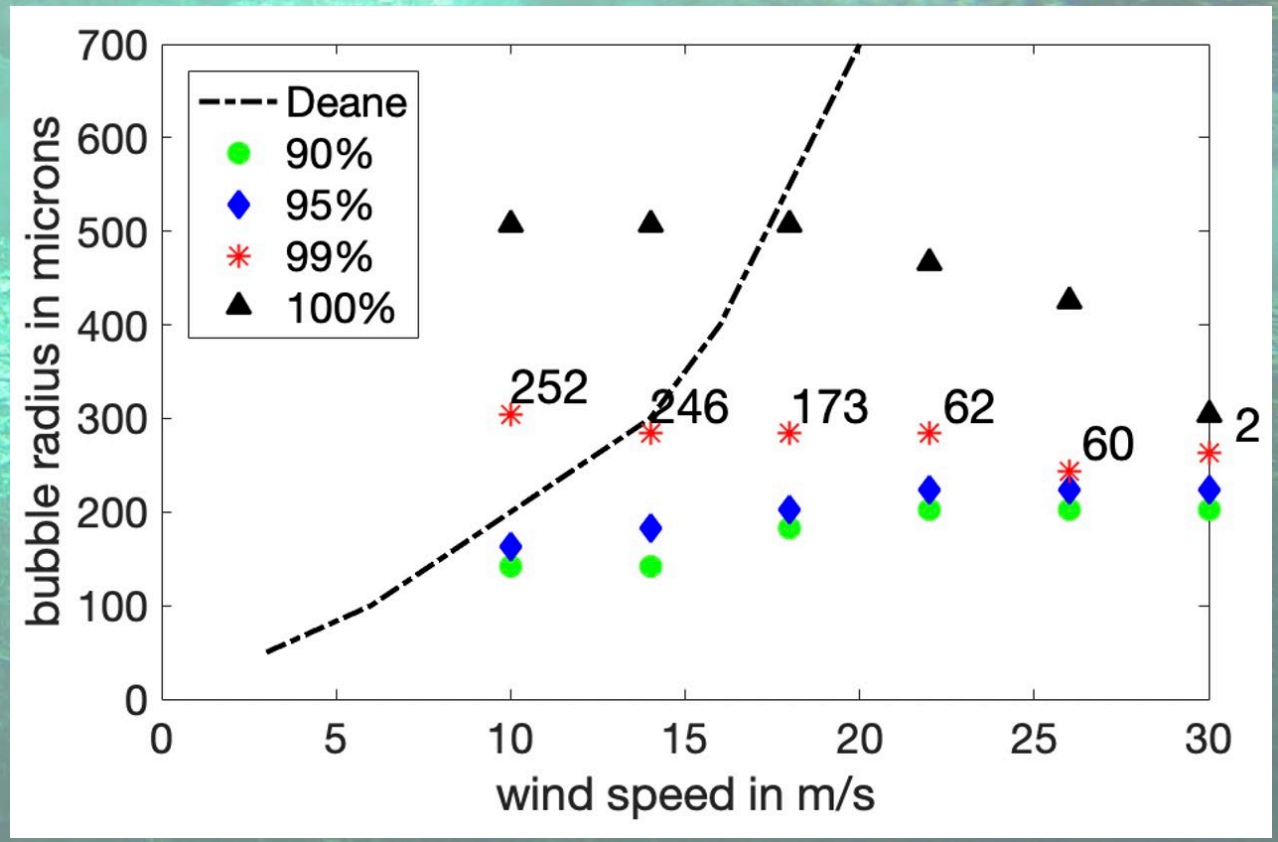




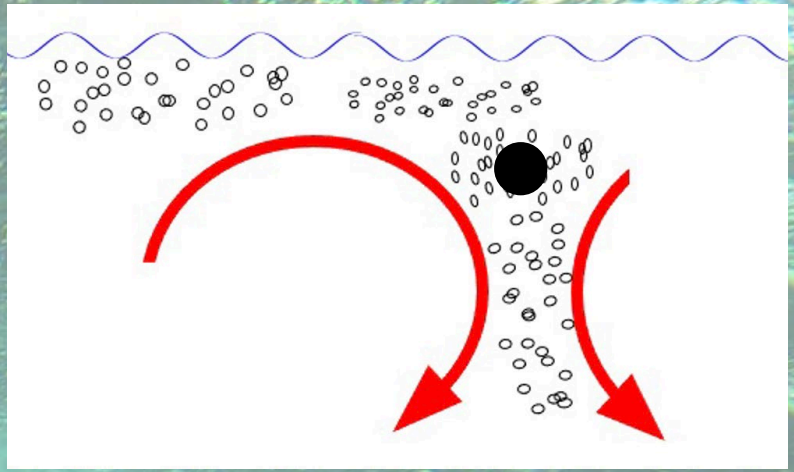
Maximum bubble size at 2m depth

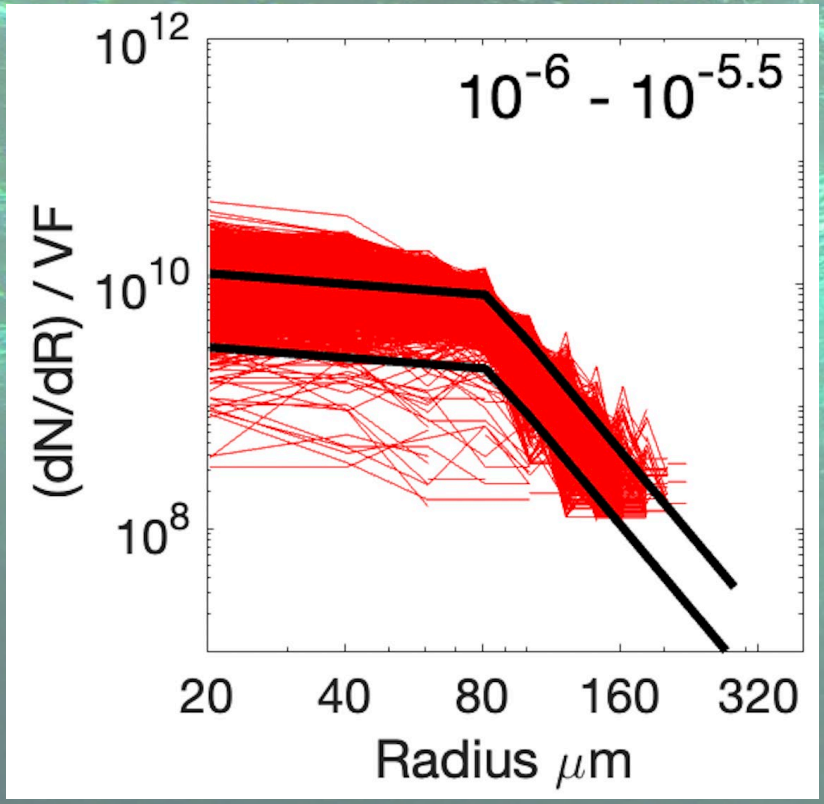


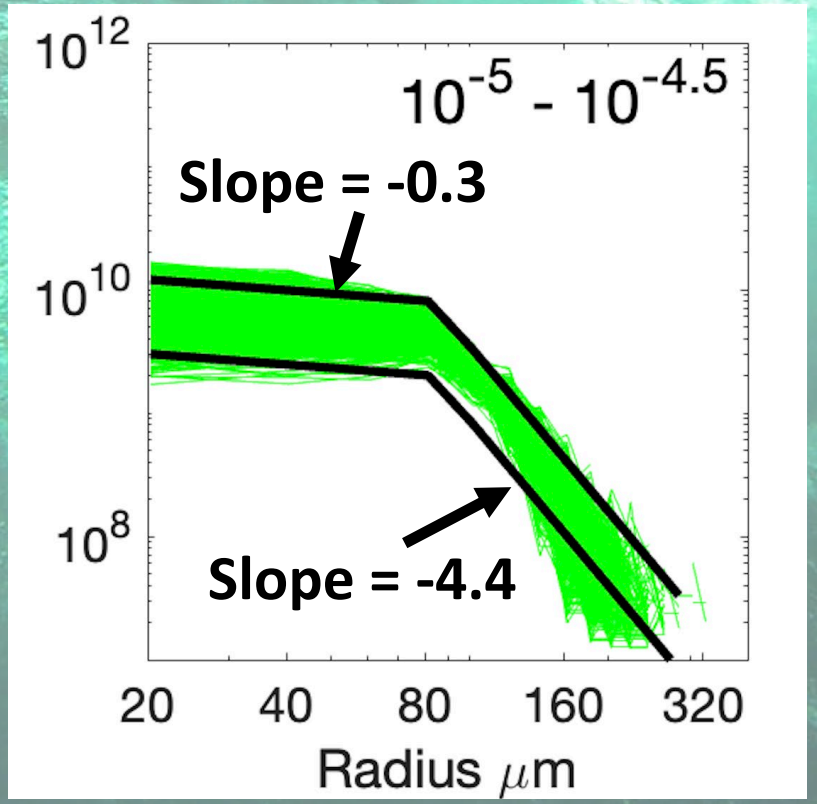


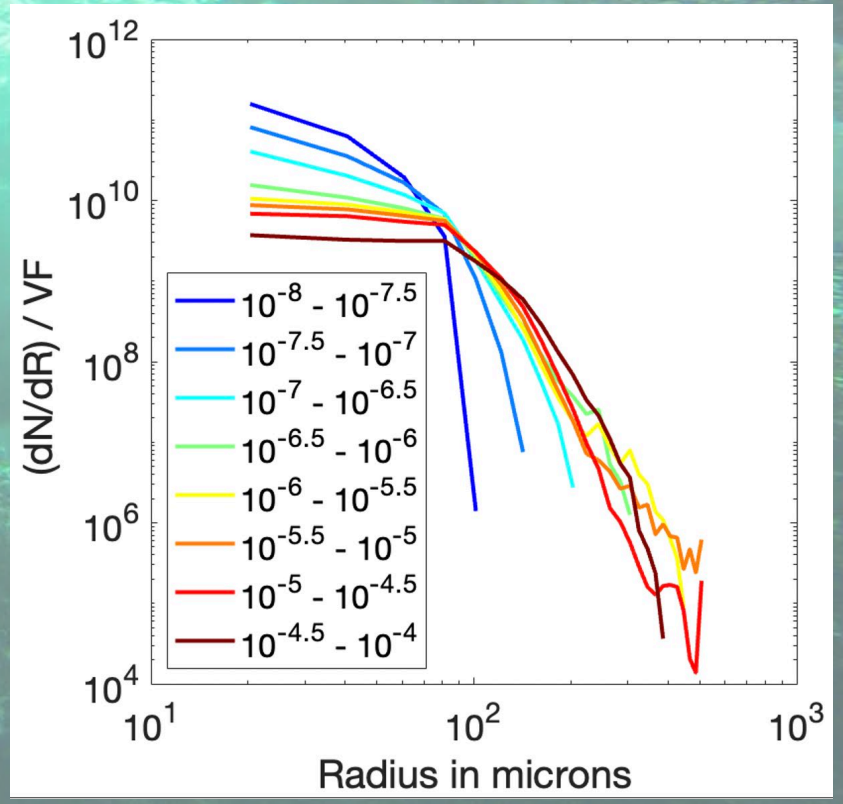


Bubble size distributions at 2m depth

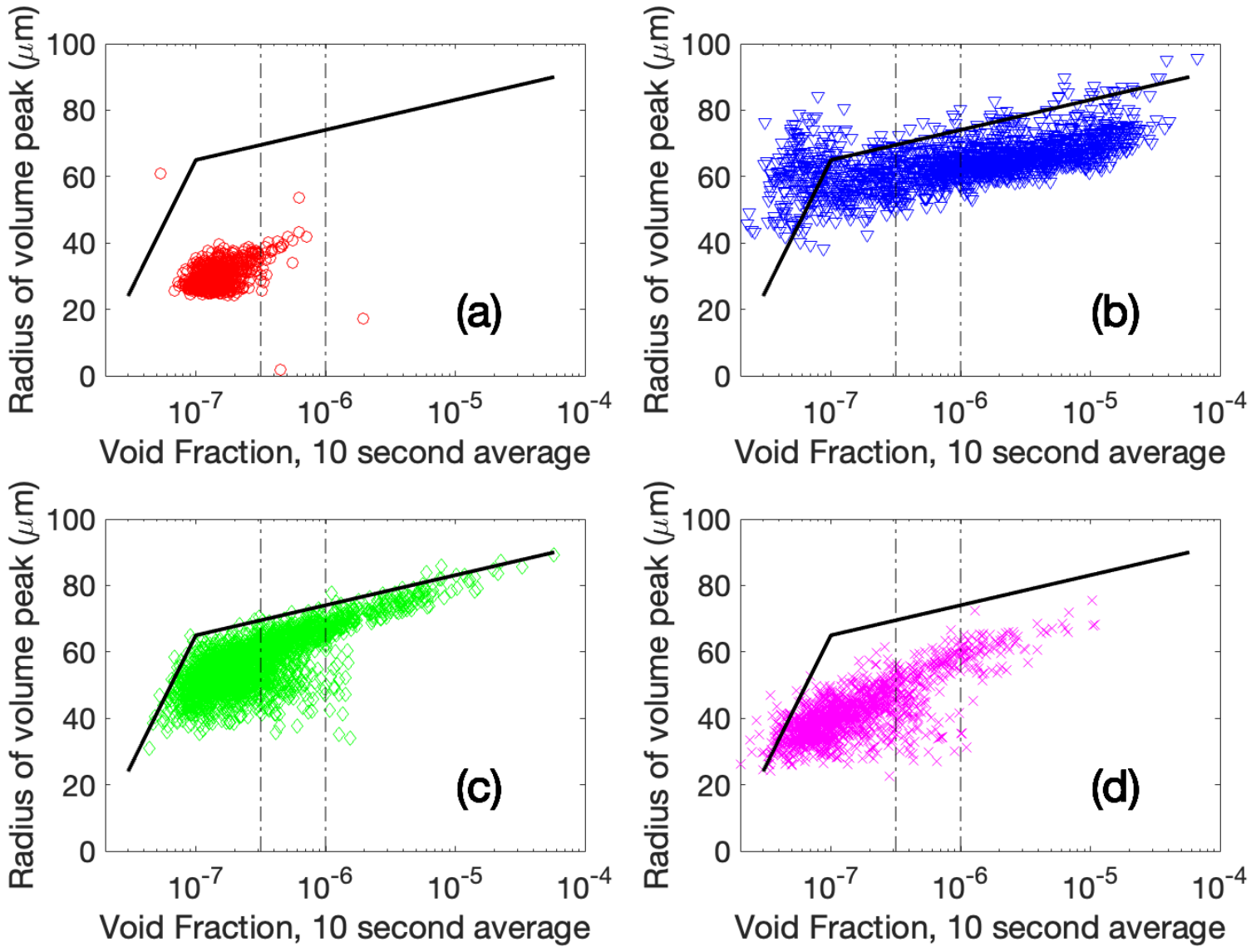








Local environment



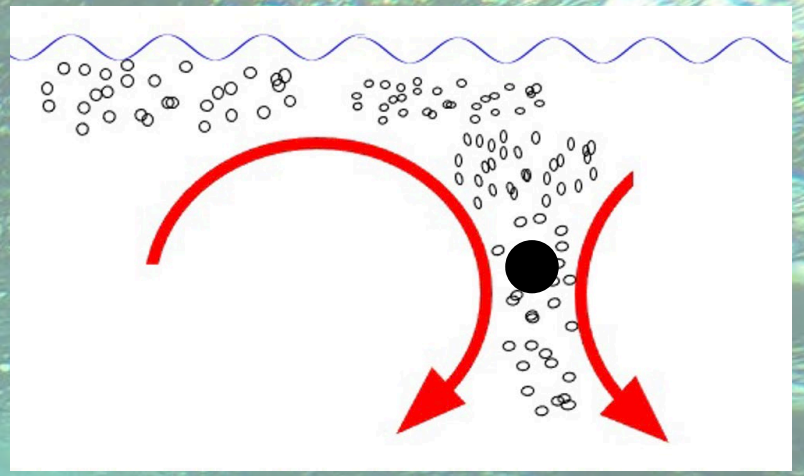
(a) Deployment 3
U_{10}: 6-15 m/s

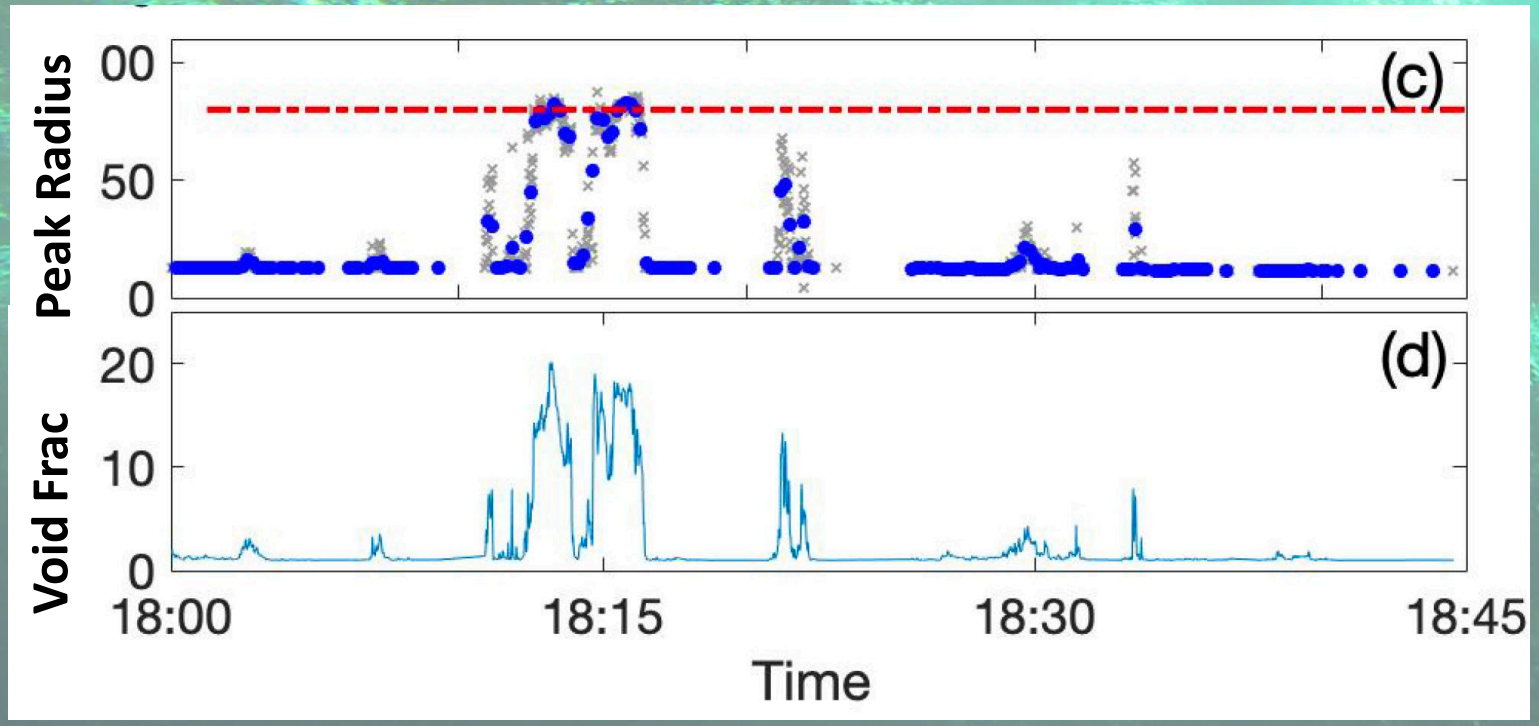
(b) Deployment 4
U_{10}: 8-27 m/s

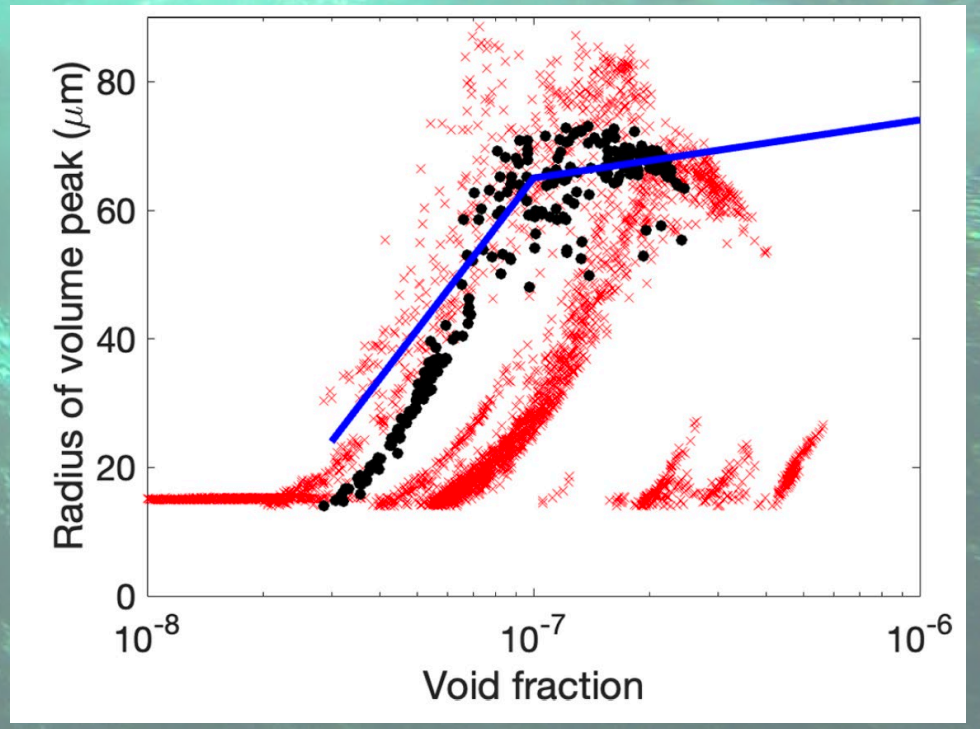
(c) Deployment 6
U_{10}: 11-19 m/s

(d) Deployment 7
U_{10}: 10-18 m/s and warmer water

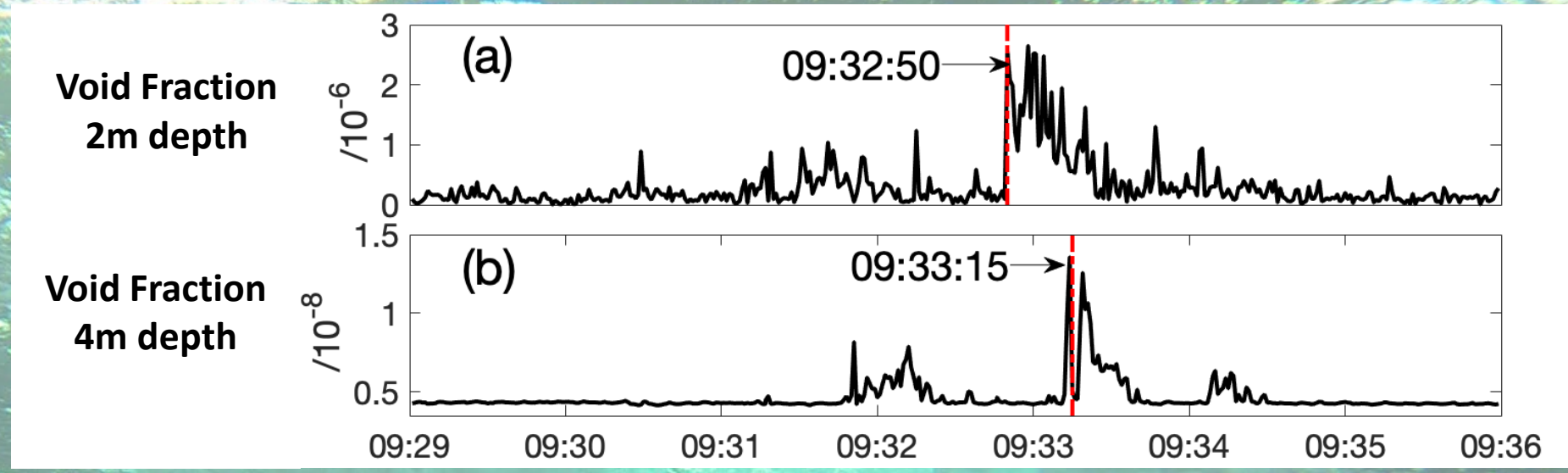
4m depth

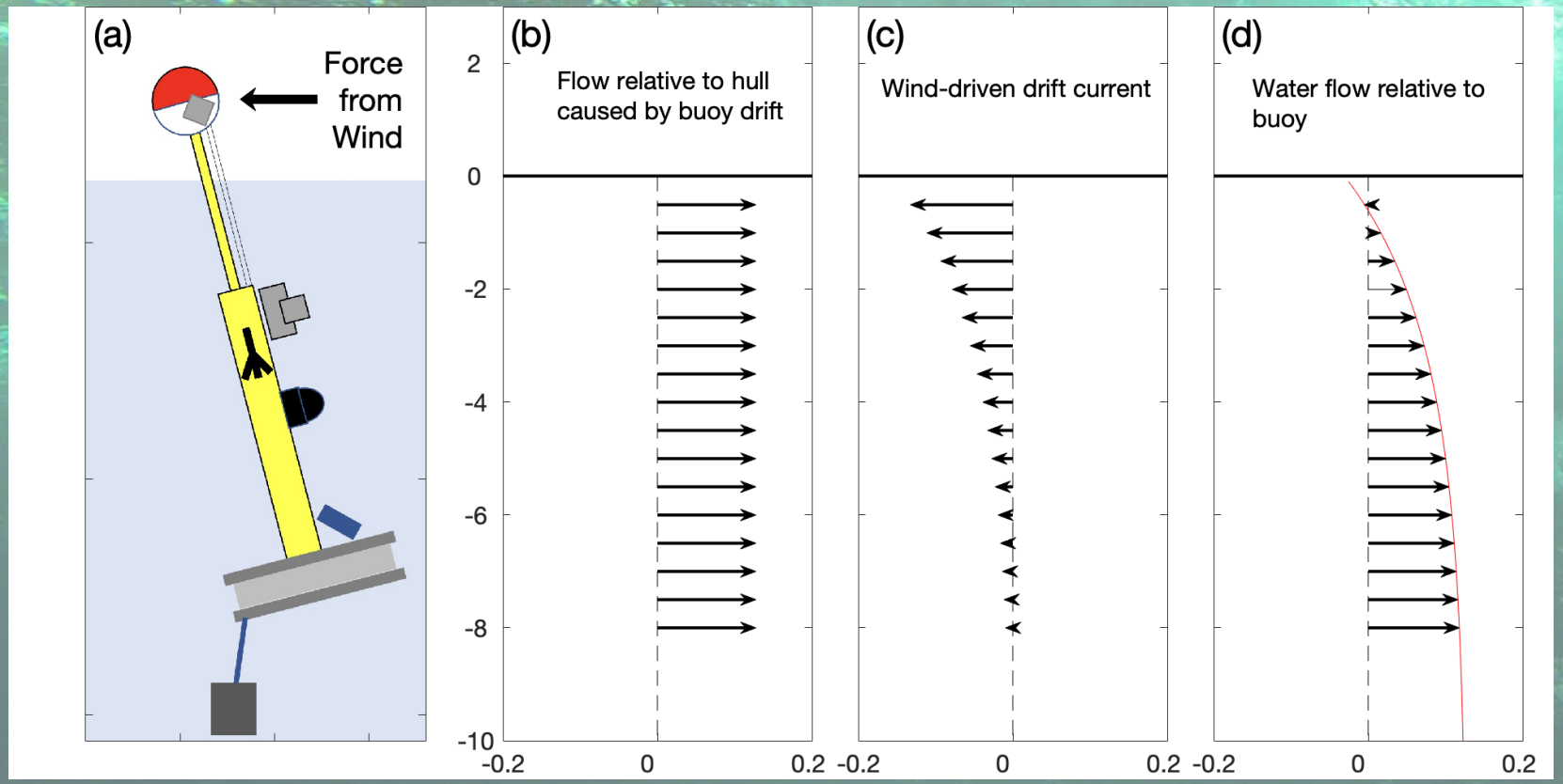



Peak Radius
00
50
0
(c)
Void Frac
20
10
0
(d)
18:00
18:15
18:30
18:45
Time


Radius of volume peak (μm)
80
60
40
20
0
10^-8
10^-7
10^-6
Void fraction

Flow patterns





Oxygen uptake?

Are the bubbles in the deep plumes themselves responsible for enhancing oxygen uptake?

Or are they just tracers for water which already has a higher concentration of oxygen?

If all the oxygen contained in bubbles making up an air void fraction of 10^{-5} dissolved into its local water mass, it would only increase the local saturation state by approximately 0.1 %.

Back-of-the-envelope calculation:

- Assume a void fraction of 10^{-5}
- Assume that it's moving downward constantly at the highest speed our ADV observed (0.1 m/s)
- Assume that this is happening over 25% of the ocean surface

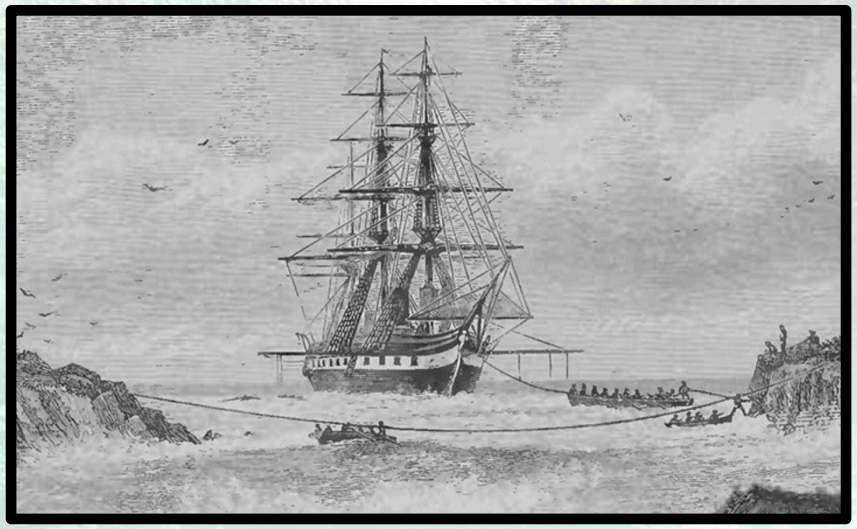
➔ Not enough to match Atamunchuk 2020 observations for O_2 flux

Conclusions

- Bubbles reaching a depth of 2m have already evolved to form a heterogeneous but statistically stable population in the top 1–2m of the ocean.
- Bubble populations differ significantly above and below void fractions of 10^{-6}. Void fraction seems to be a key label.
- Near-surface ocean-side processes are complex & require specific study for a full understanding of gas flux mechanisms.
- This substantial data set in high wind conditions is available to test models.

Future priorities & questions

- Near-surface 3D flow processes: how much do they affect the movement of bubbles & gases around the top 10m of the ocean?
- Possible heterogeneity of gas saturation state – are the gas saturations in downwelling and upwelling regions significantly different?
- Monitoring mechanisms within the top metre is critical.



Challenger 150: The Challenger Society Conference 2022

6-8th Sept, 2022, Natural History Museum, London

T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Session leads: Adrian Callaghan, Helen Czerski

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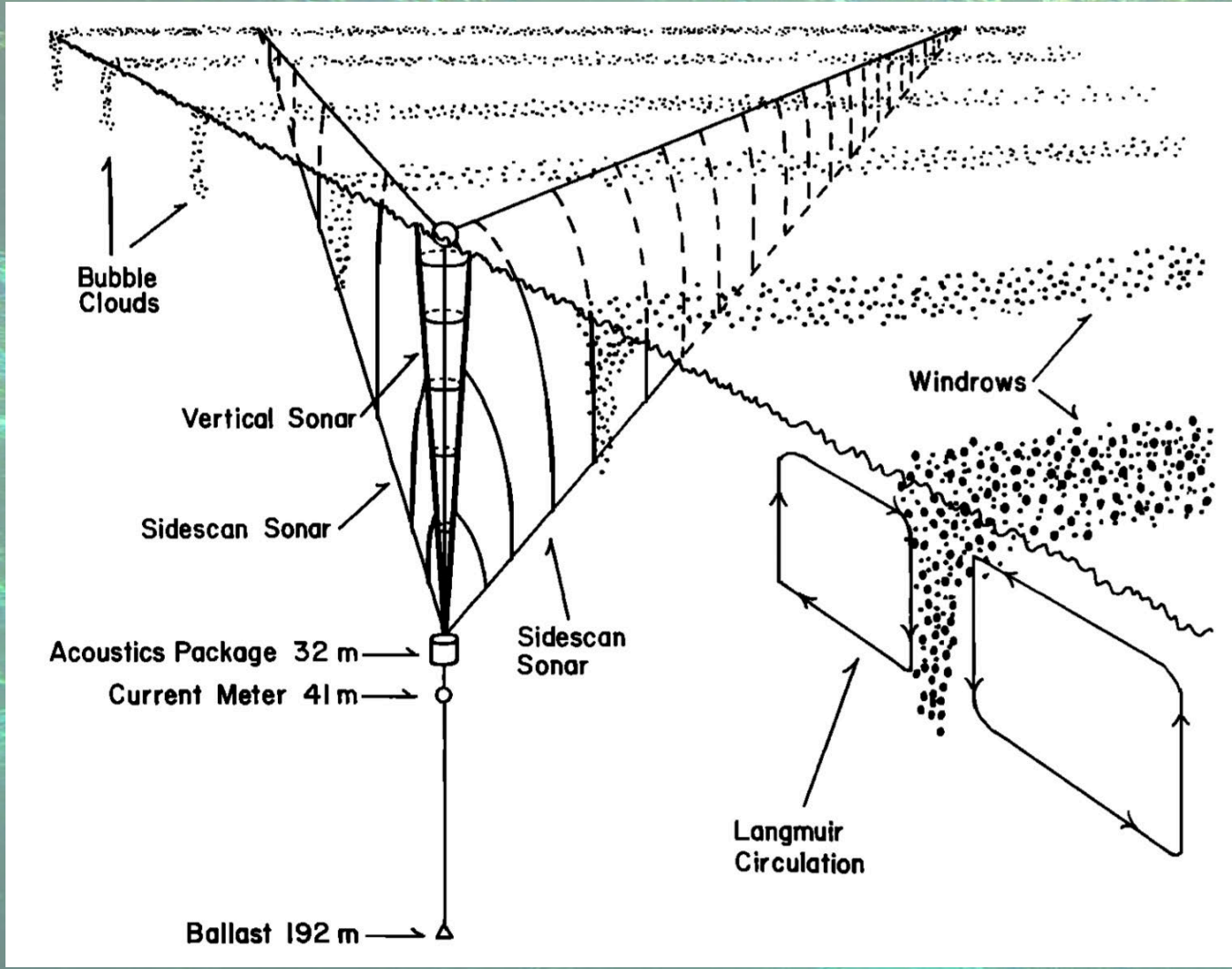

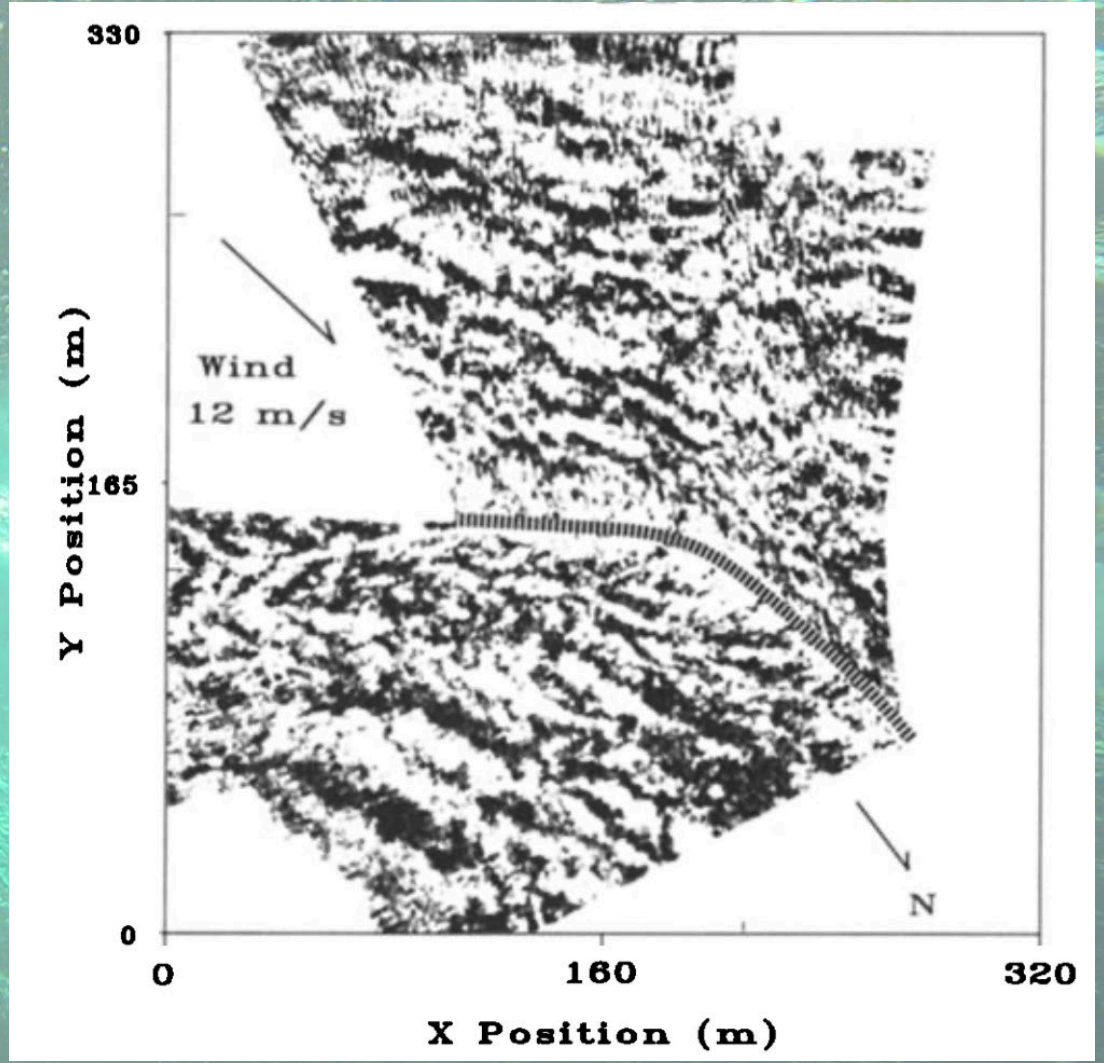

Len Zedel & David Farmer 1991