Imperial College London

Statistical distributions of whitecap variables using a novel remote sensing technique to detect and track individual whitecaps in digital sea surface images

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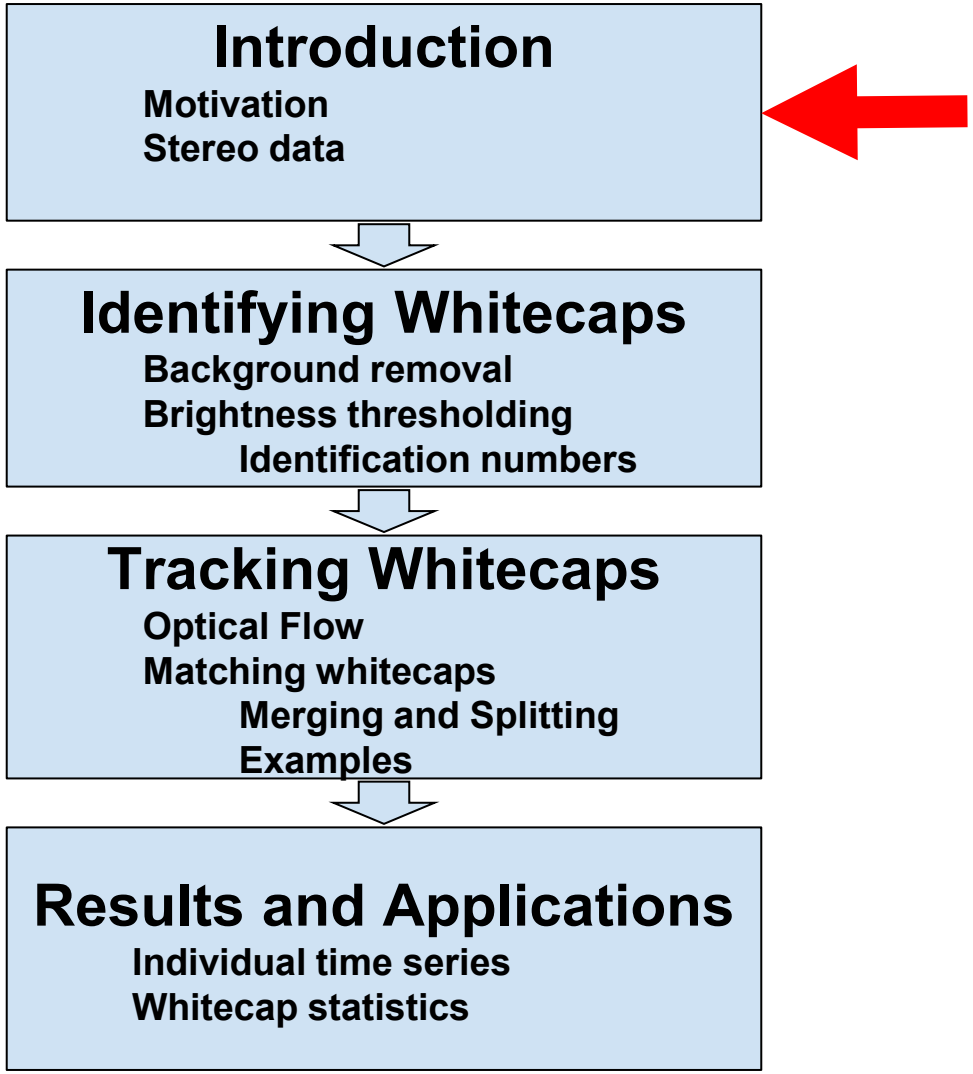
UKRI Natural Environment Research Council

Grantham Institute


Introduction
Motivation
Stereo data
Identifying Whitecaps
Background removal
Brightness thresholding
Identification numbers
Tracking Whitecaps
Optical Flow
Matching whitecaps
Merging and Splitting
Examples
Results and Applications
Individual time series
Whitecap statistics

Introduction

Estimating the energy dissipated by individual surface breaking waves (VTI)

- Callaghan et Al. (2016) energy dissipation model

Observing whitecaps in digital images with a 3D reconstructed sea surface

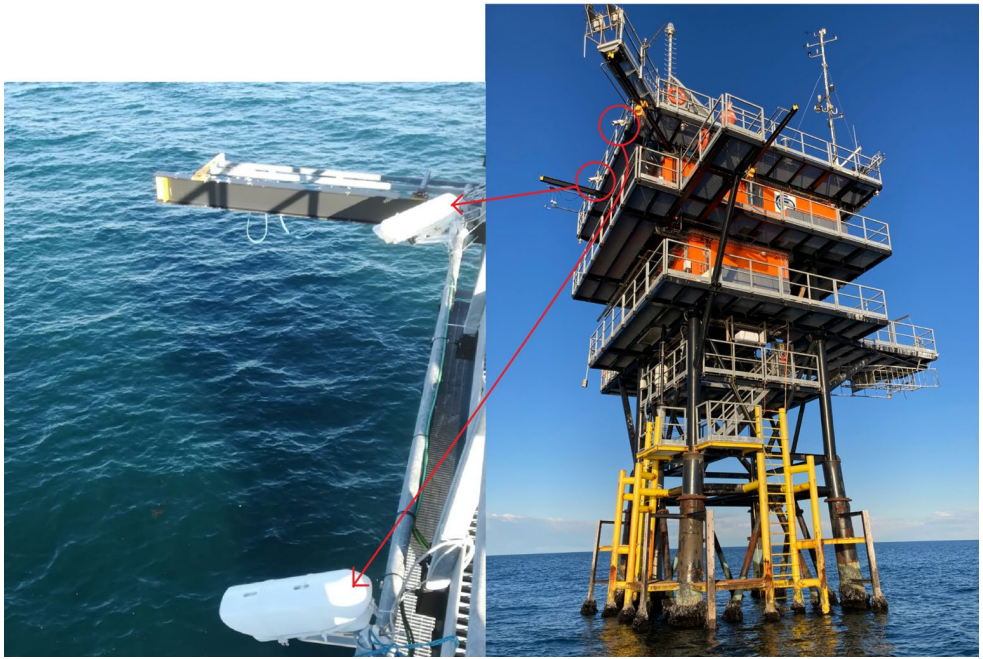
- Wave Acquisition Stereo System (WASS) by Bergamasco et Al. (2017)

Develop an automated remote sensing technique that utilises WASS in order to apply the VTI method to individually tracked breaking waves in the field

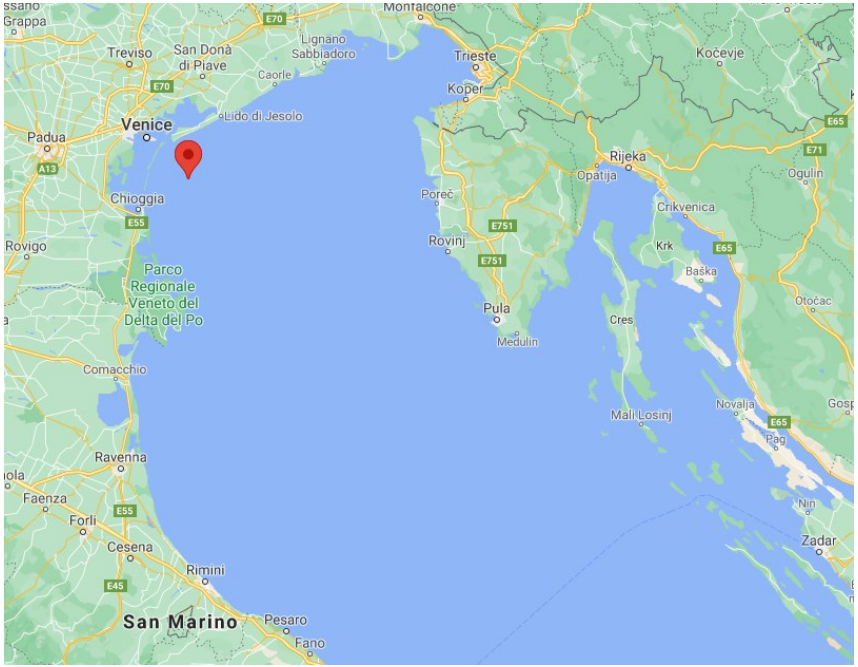
Adriatic Sea - Acqua Alta Tower

Experimental Setup - ICL

New system installed in January 2021



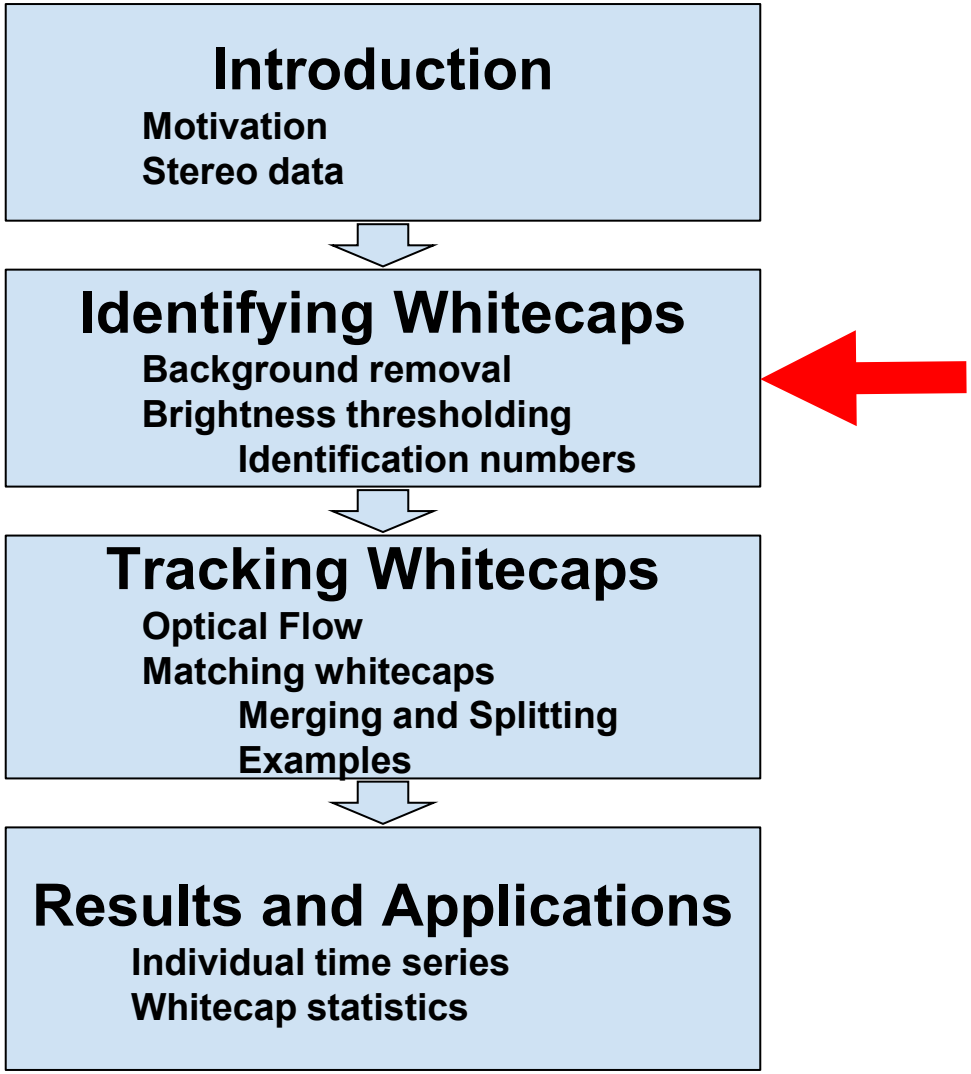
The Acqua Alta Oceanographic Tower in the Gulf of Venice



Location of tower

Stereo data - Acqua Alta Tower (Adriatic Sea)

Reconstructed with the Wave Acquisition Stereo System (WASS) [Bergamasco et Al. 2017]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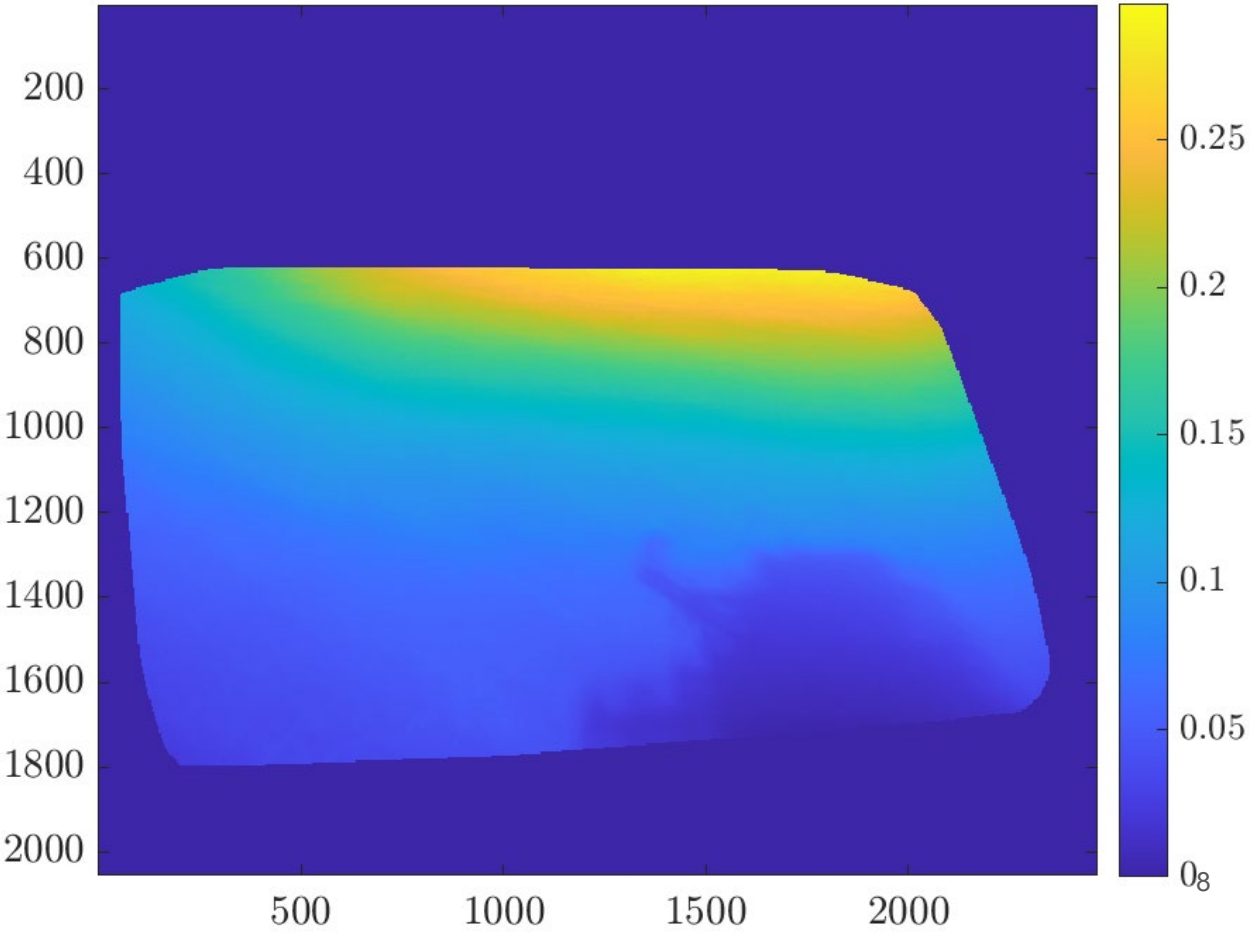
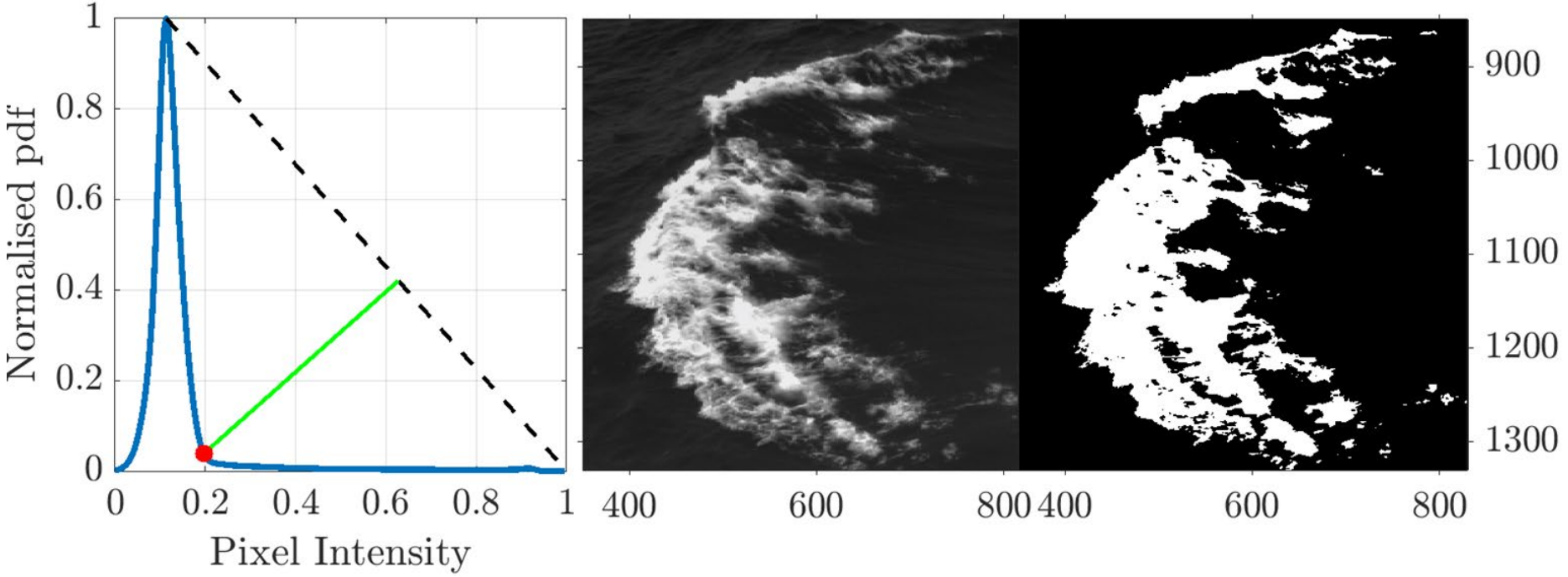
Background Removal - Mean Background

$$I_{L_n} = \frac{1}{L_B + 1} \sum_{i=n-L_B/2}^{n+L_B/2} I_i$$

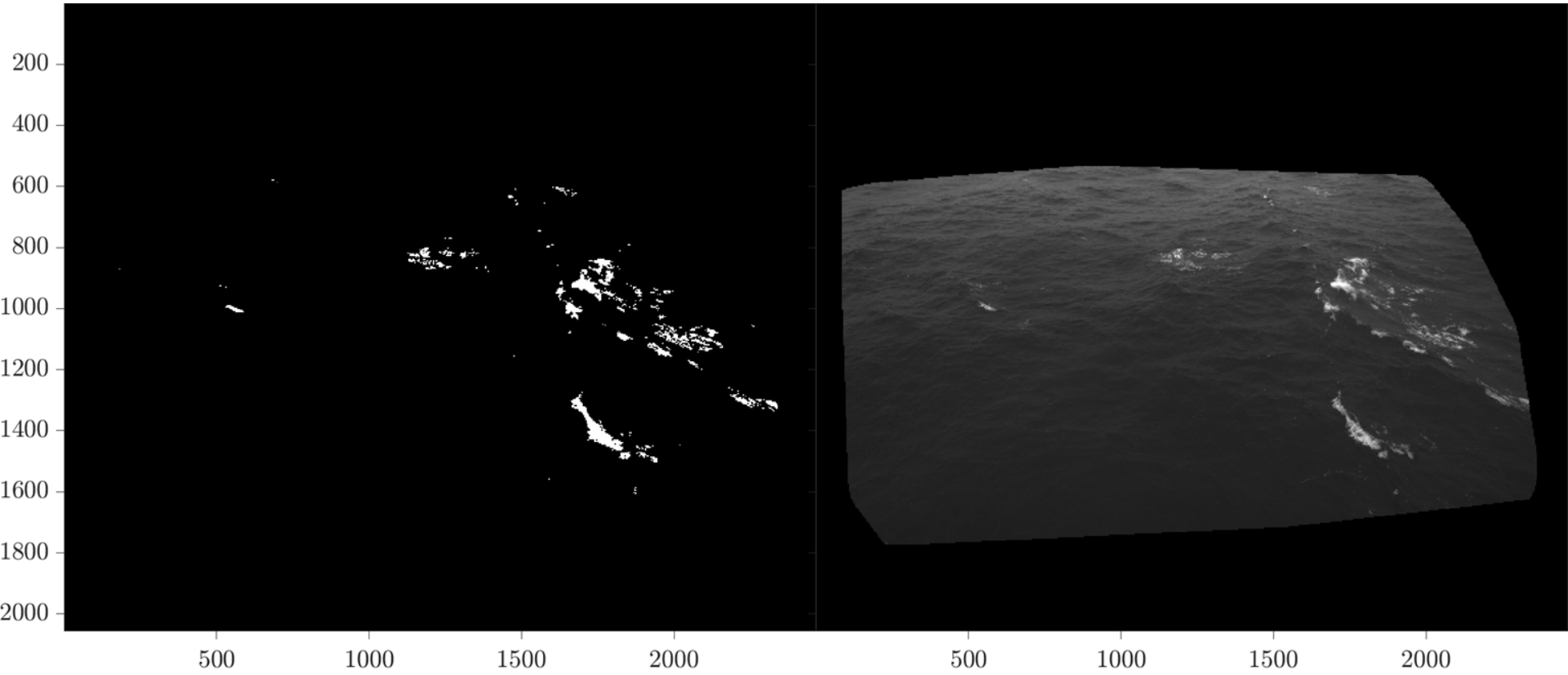
$$I_{B_n} = I_{L_n} - \min(I_{L_n})$$



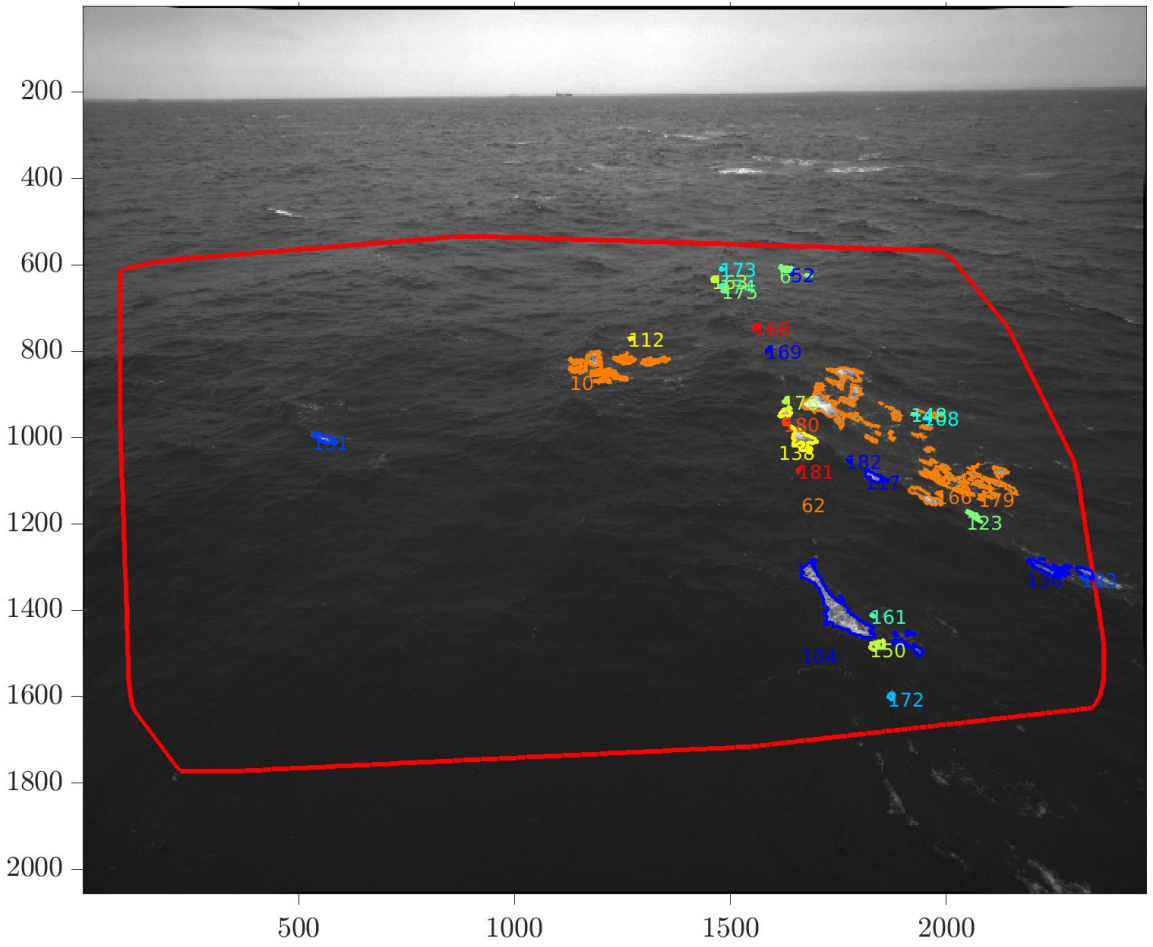
Brightness Thresholding - Modified Adaptive Thresh. Segmentation (MATS)

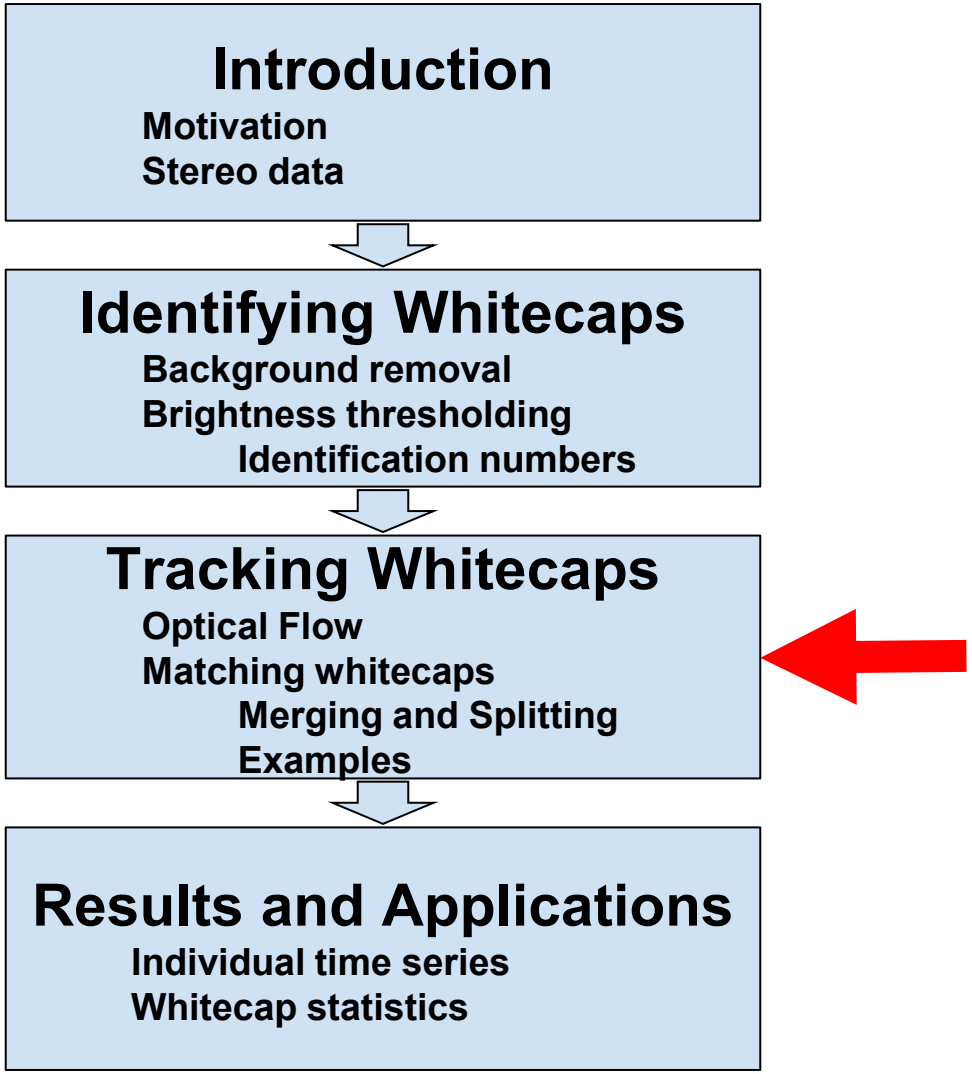


Brightness thresholding - Full image



Unique Identification Numbers

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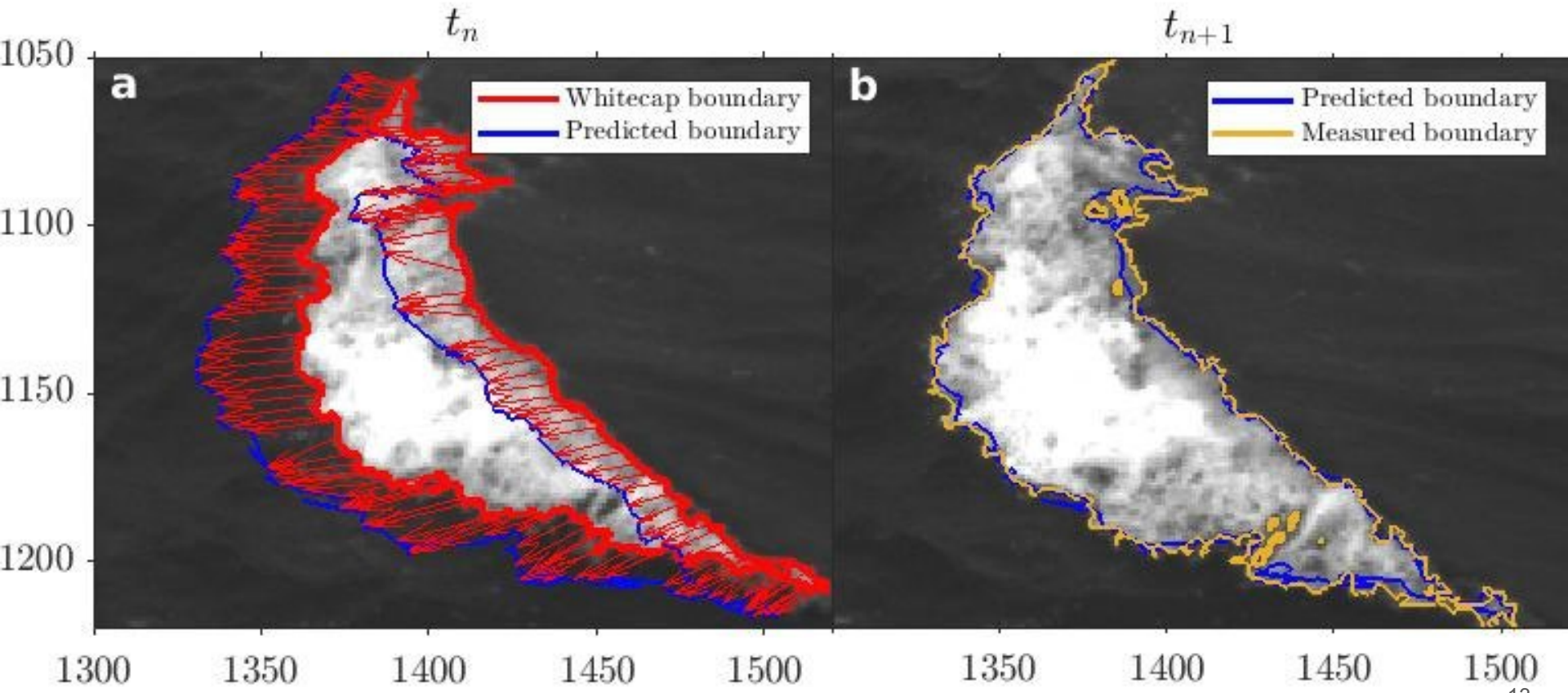
Tracking with optical flow - Lucas Kanade algorithm



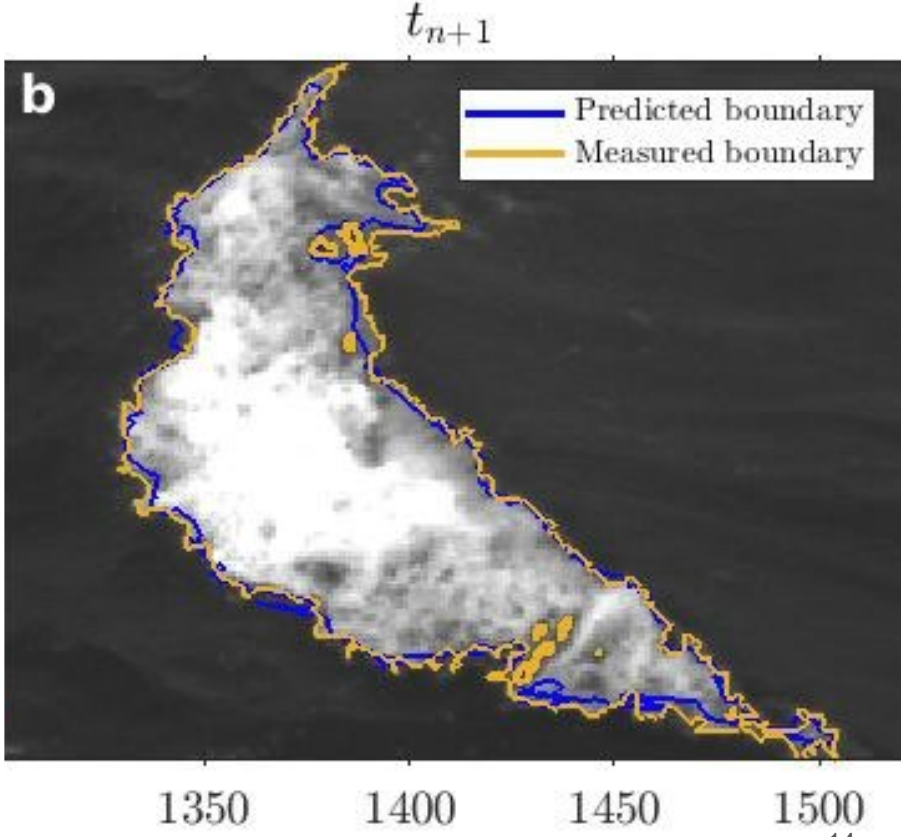
Tracking - Matching whitecaps

- Weighted area threshold

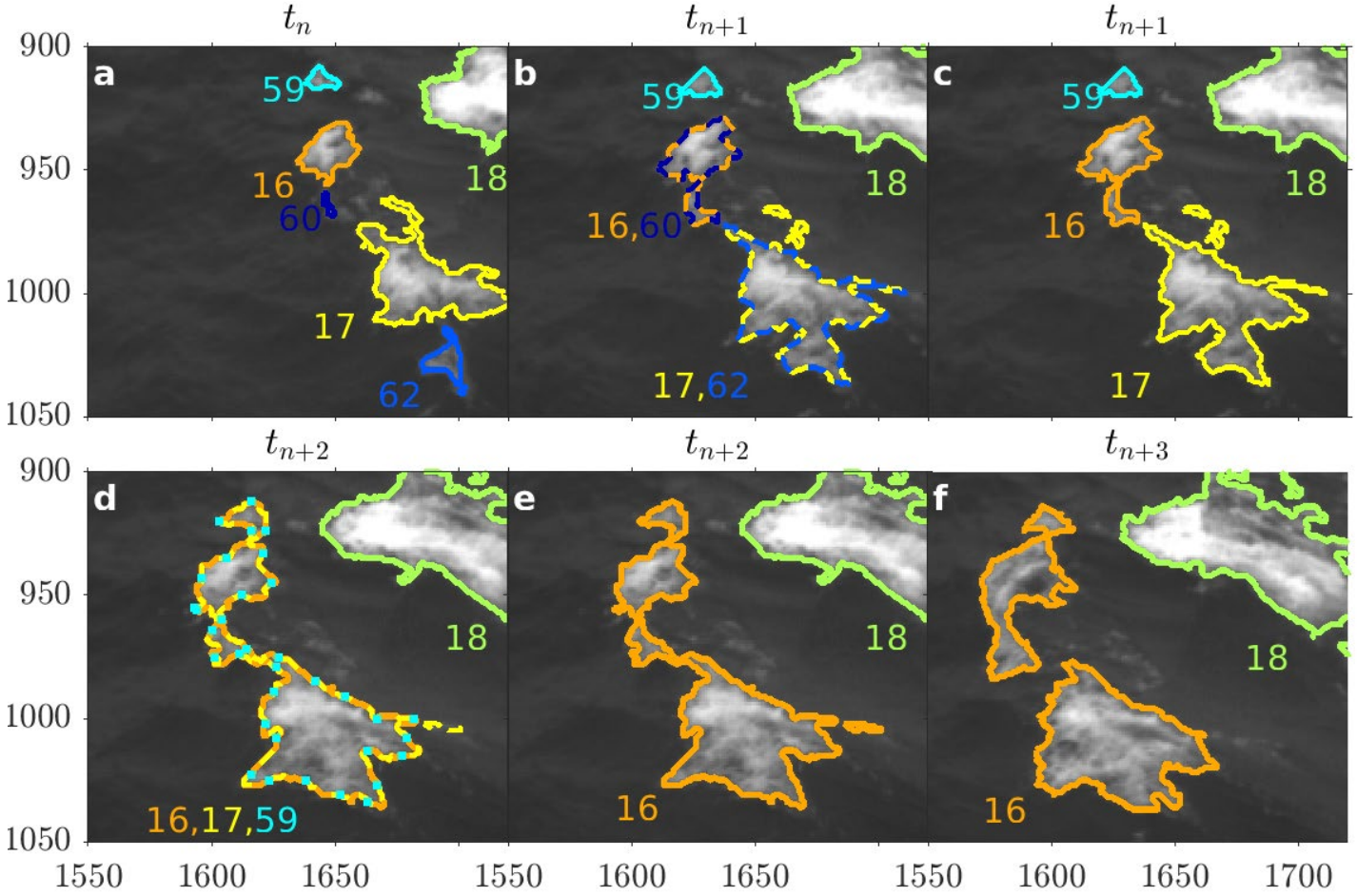
Area [m^2]

$$T_A > \frac{A_{W_j} \cap A_{B_k}}{\min(A_{W_j}, A_{B_k})}$$

Threshold value [0 to 1]



Tracking Illustration - Merging and Splitting



Example cases

- Adriatic Sea (Acqua Alta Tower): 12 frames per second
- Yellow Sea: 10 frames per second
- Black Sea: 12 frames per second
- North Sea (Ekofisk): 5 frames per second

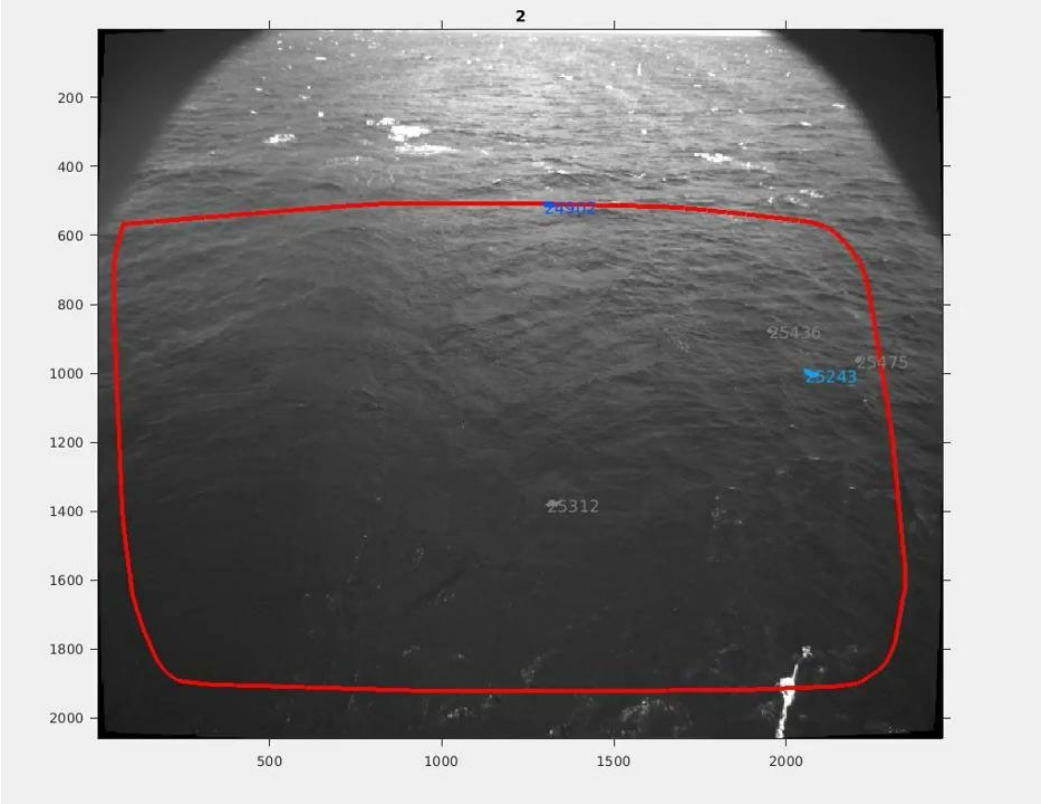
Colour Scheme: 10 possible colors to distinguish between breaking events

Location	Date	Start (UTC)	Minutes	Area $[m^2]$	FPS [s]	f_p [Hz]	H_s [m]
Adriatic Sea	13/04/2021	08:14:56	30	2500	12	0.25	1
Black Sea	04/10/2011	15:30:00	30	1500	12	0.28	0.67
Yellow Sea	13/05/2017	05:00:00	10	5000	10	0.20	1.3

Adriatic Sea

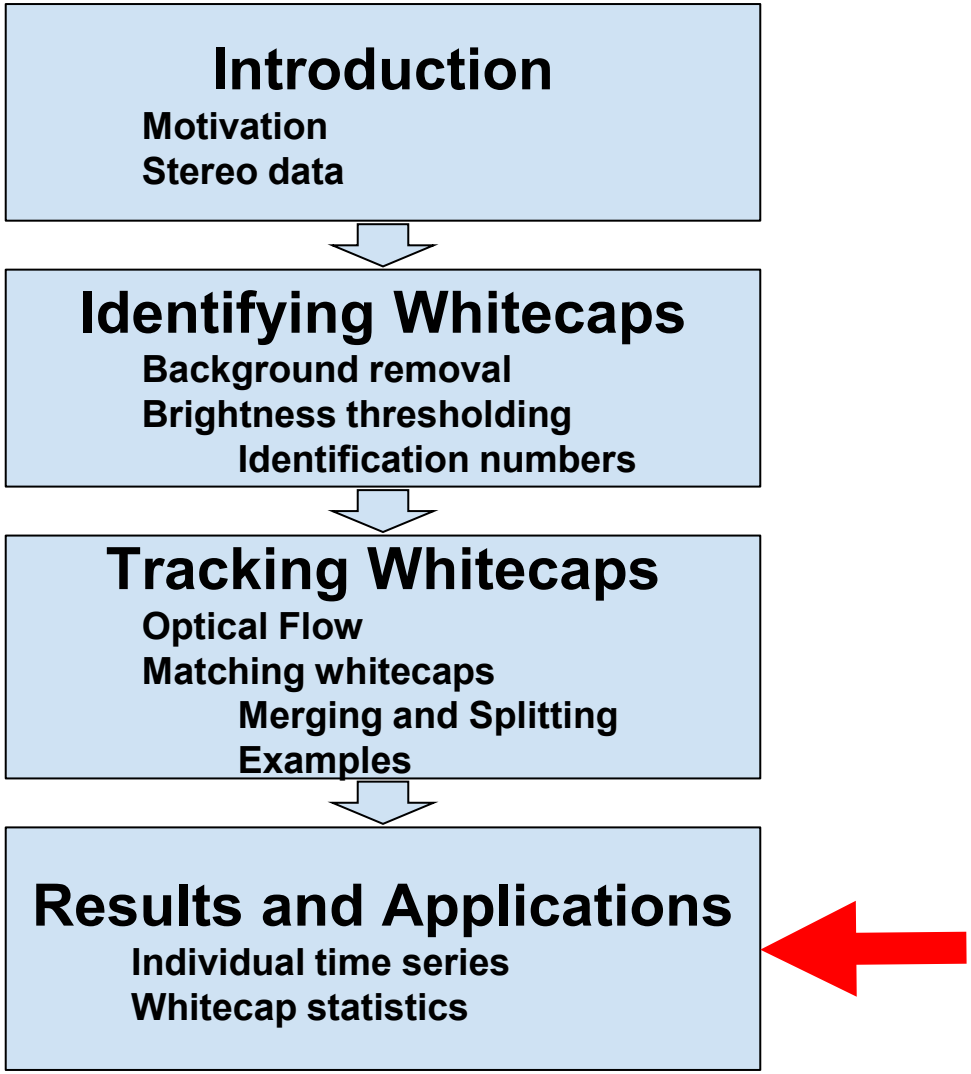
Yellow Sea

Black Sea


2
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000
25436
25475
25243
25312

North Sea (Ekofisk)

Bonus tracker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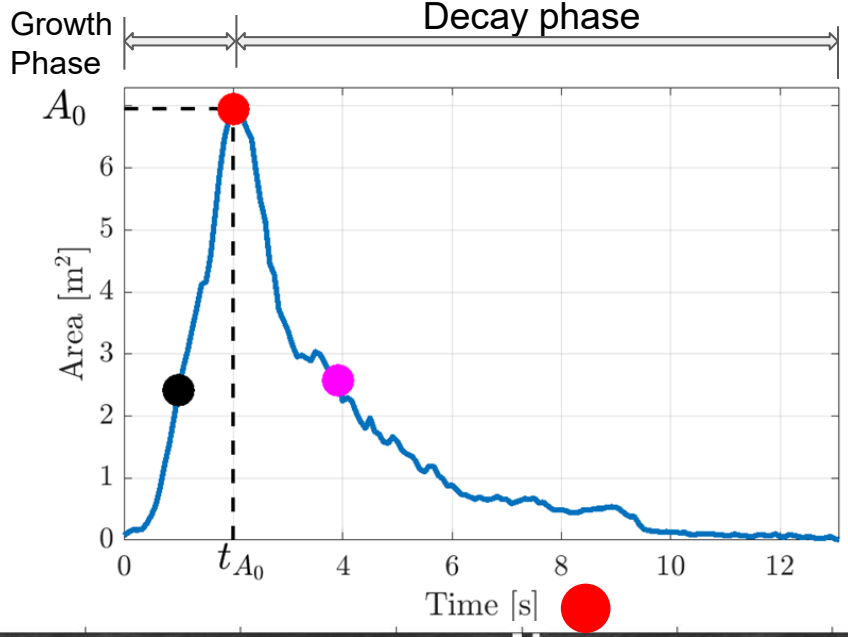
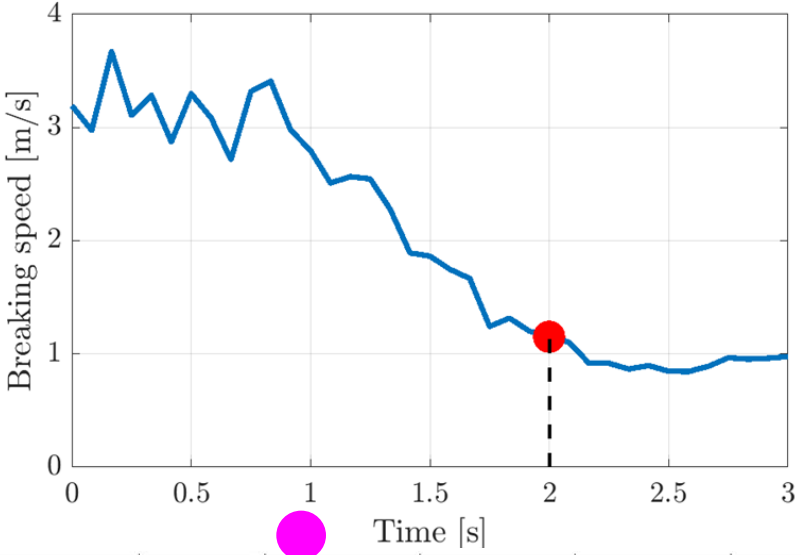
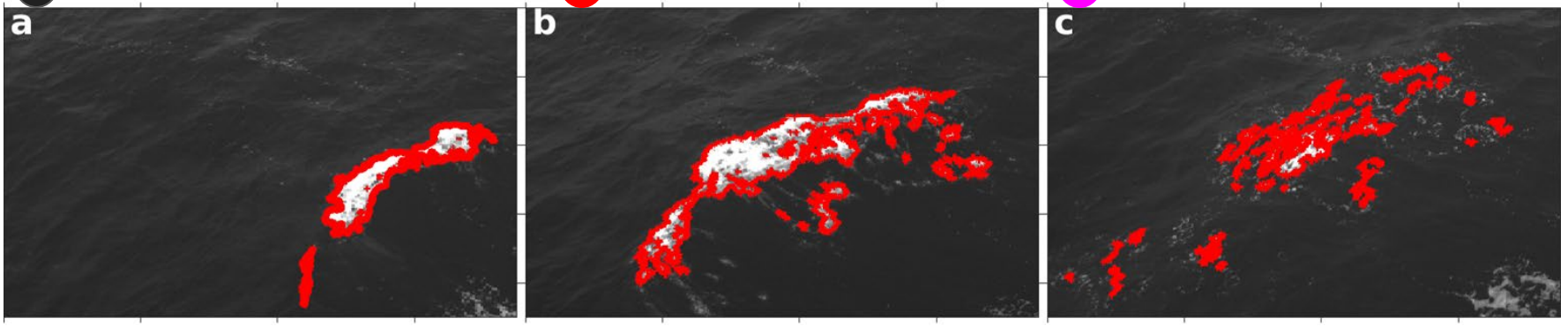
Individual time series - Area & Speed







Application to the volume-time-integral method (Callaghan et Al. 2016)

Energy dissipated for an individual breaking wave: VTI method

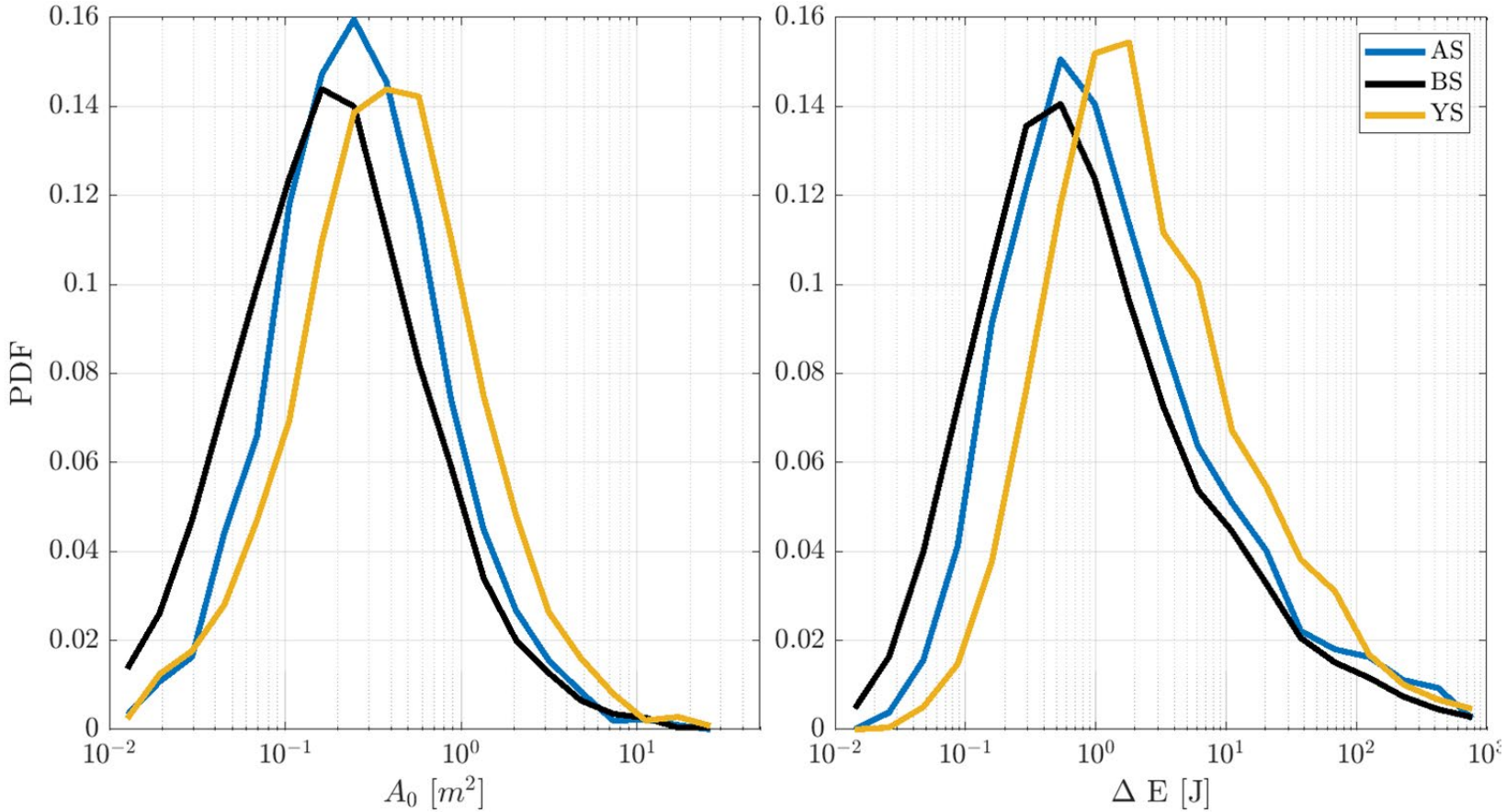
$$\Delta E = \underbrace{\Omega \rho_w}_{\text{constant}} \underbrace{A_0 \hat{z}_p \tau_{growth}}_{\text{measured/ parameterised}} \quad [\text{J}]$$

Application to Callaghan's Energy Dissipation Model of Air Entrainment

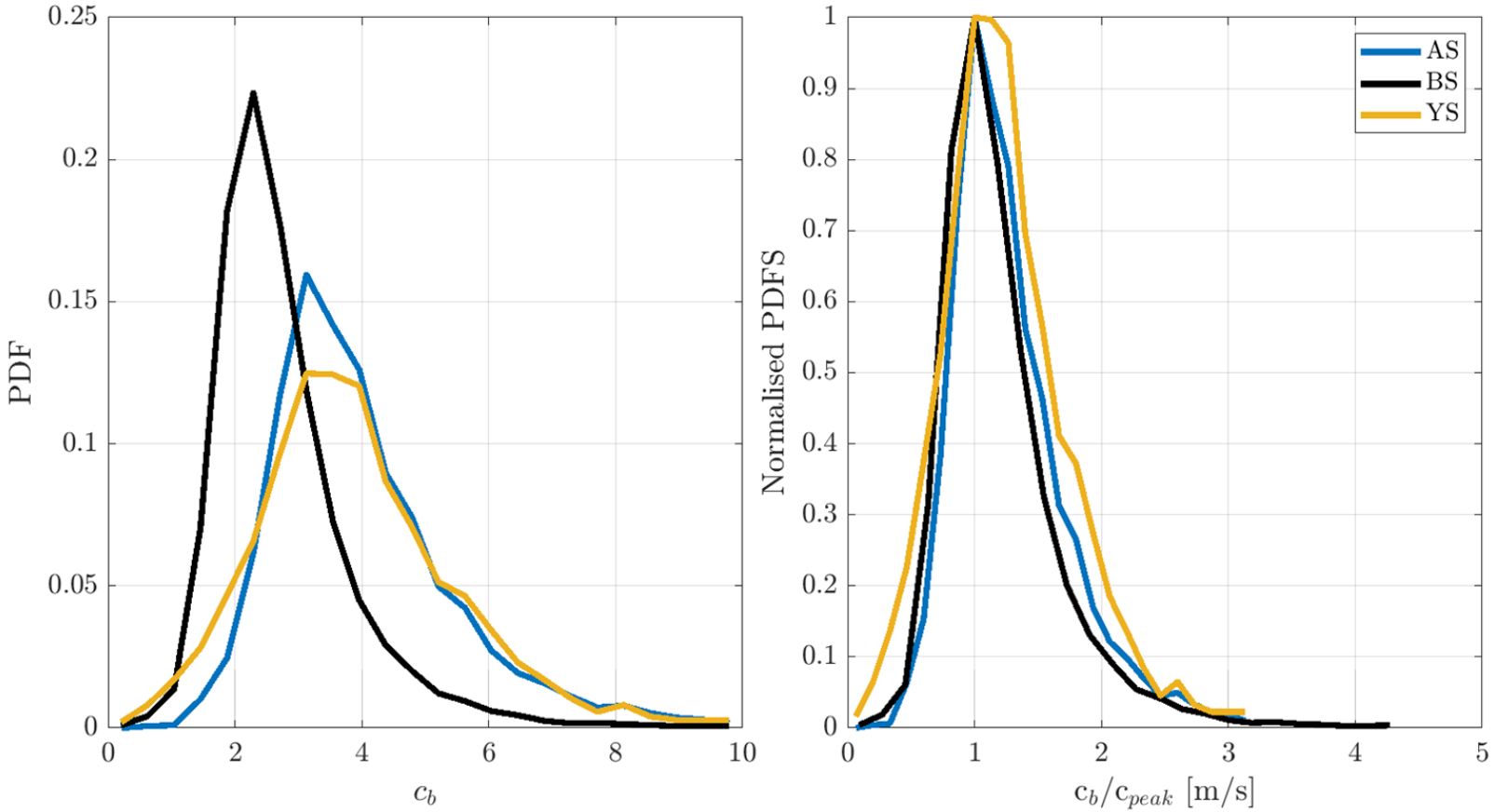
- GTWS presentation from Tuesday at 14:30pm

Air entrainment velocity for an individual whitecap	$w_{ent} = \frac{\hat{z}_p}{t_{A_0}}$	Volume of air entrained by individual whitecaps	$V_{air} = \alpha_{\text{eff}} w_{ent} A_0 \tau_{growth}$ $\alpha_{\text{eff}} \approx 0.2$

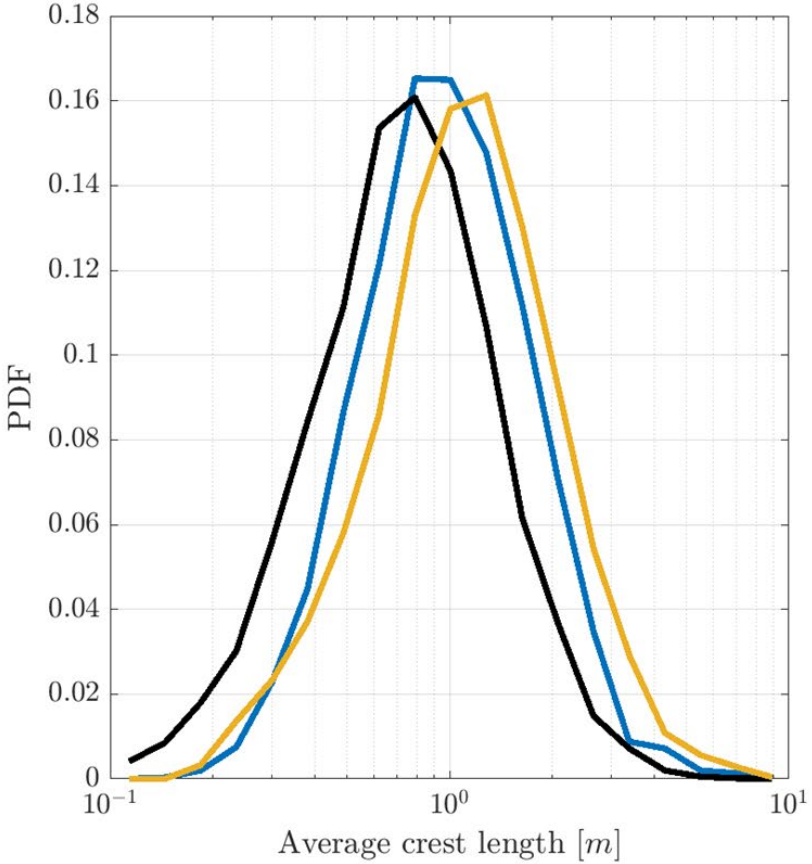
Whitecap statistics - Maximum Area & Energy

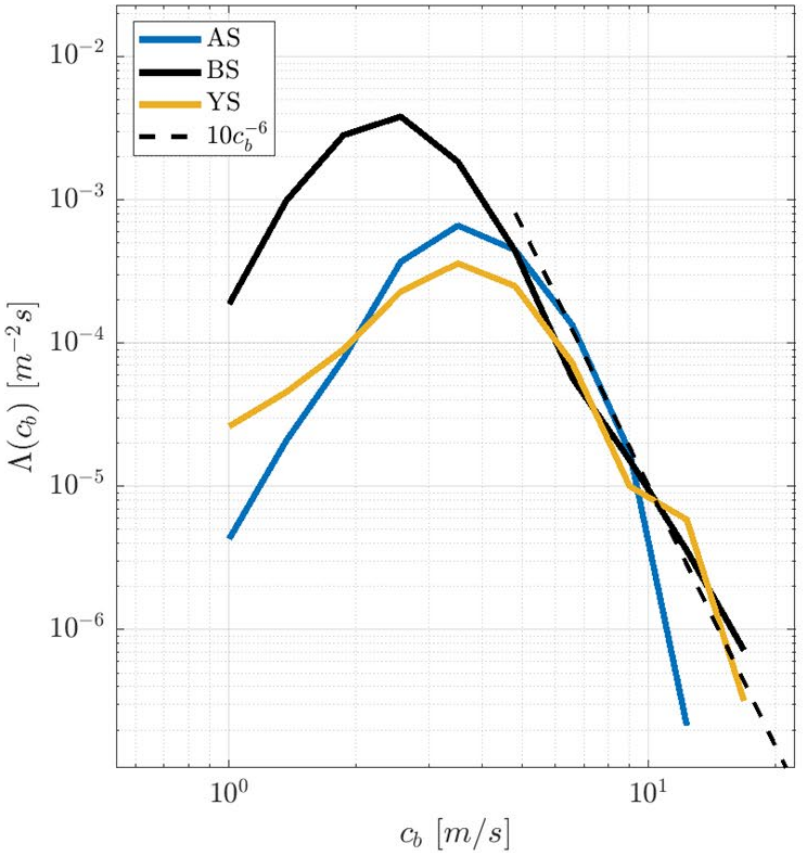


Whitecap statistics - Breaking speed

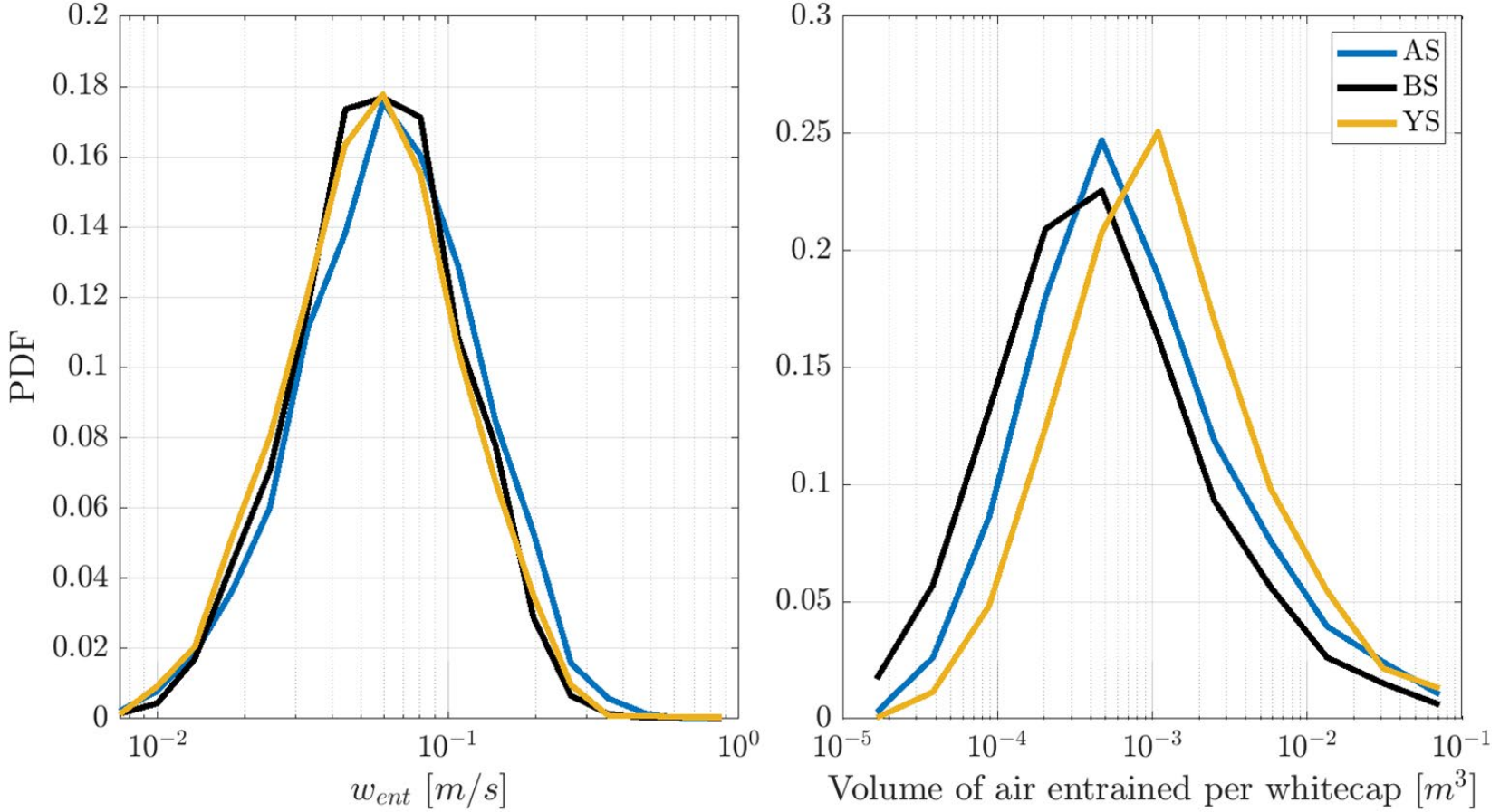


Whitecap statistics - Crest length & Phillips Lambda dist.





Whitecap statistics - Air entrainment for individual whitecaps



Conclusions/Future work

- Developed a whitecap detection and tracking model
- Acquire more stereo data in stormy conditions
- Ongoing analysis of individual whitecap parameters (e.g. area, timescale, speed) in better understanding whitecap statistics
- Development of an empirical dissipation source
- Examine effect of surfactants on whitecap foam using Callaghan et Al. 2017 method