Characteristics and dynamics of crescentic bar events at an open, Mediterranean beach

Rinse de Swart[1*],
Francesca Ribas[1], Daniel Calvete[1],
Gonzalo Simarro[2], Jorge Guillén[2]

*rinse.de.swart@upc.edu

[1]Coastal Morphodynamics Group, Universitat Politècnica de Catalunya, Barcelona, Spain

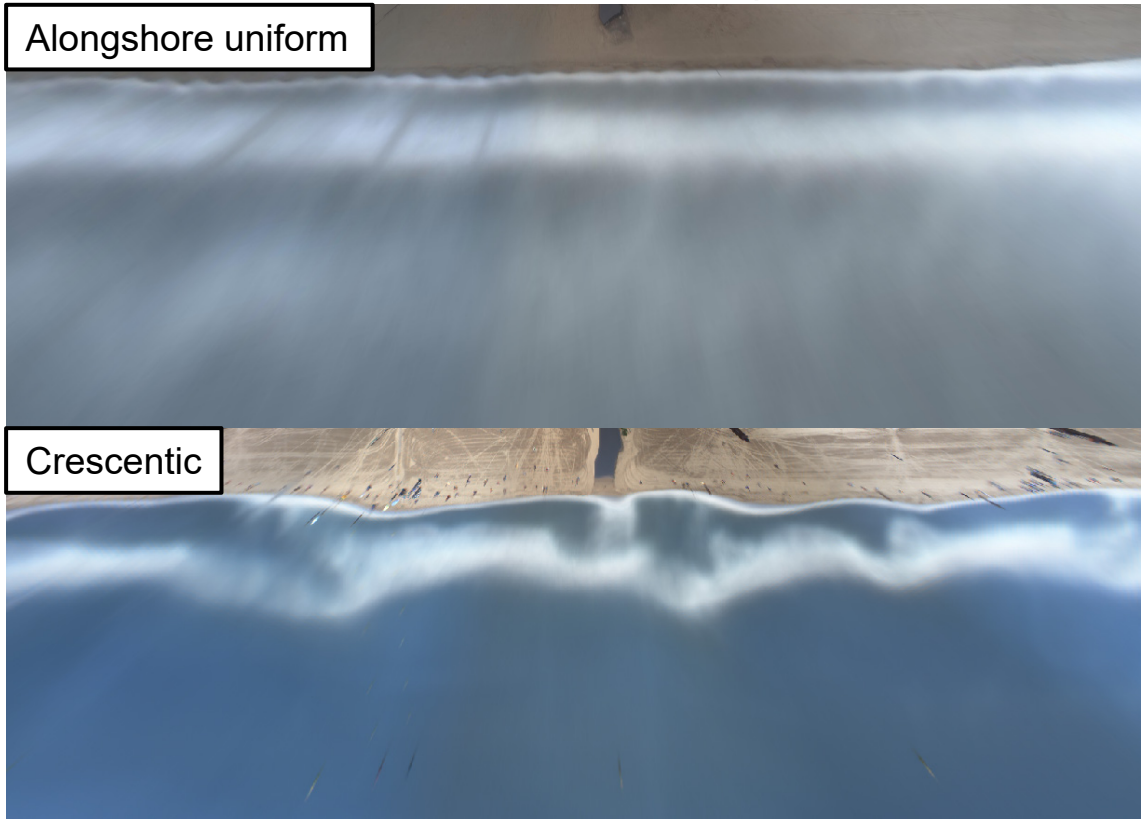
[2]Department of Marine Geosciences, Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Morfos

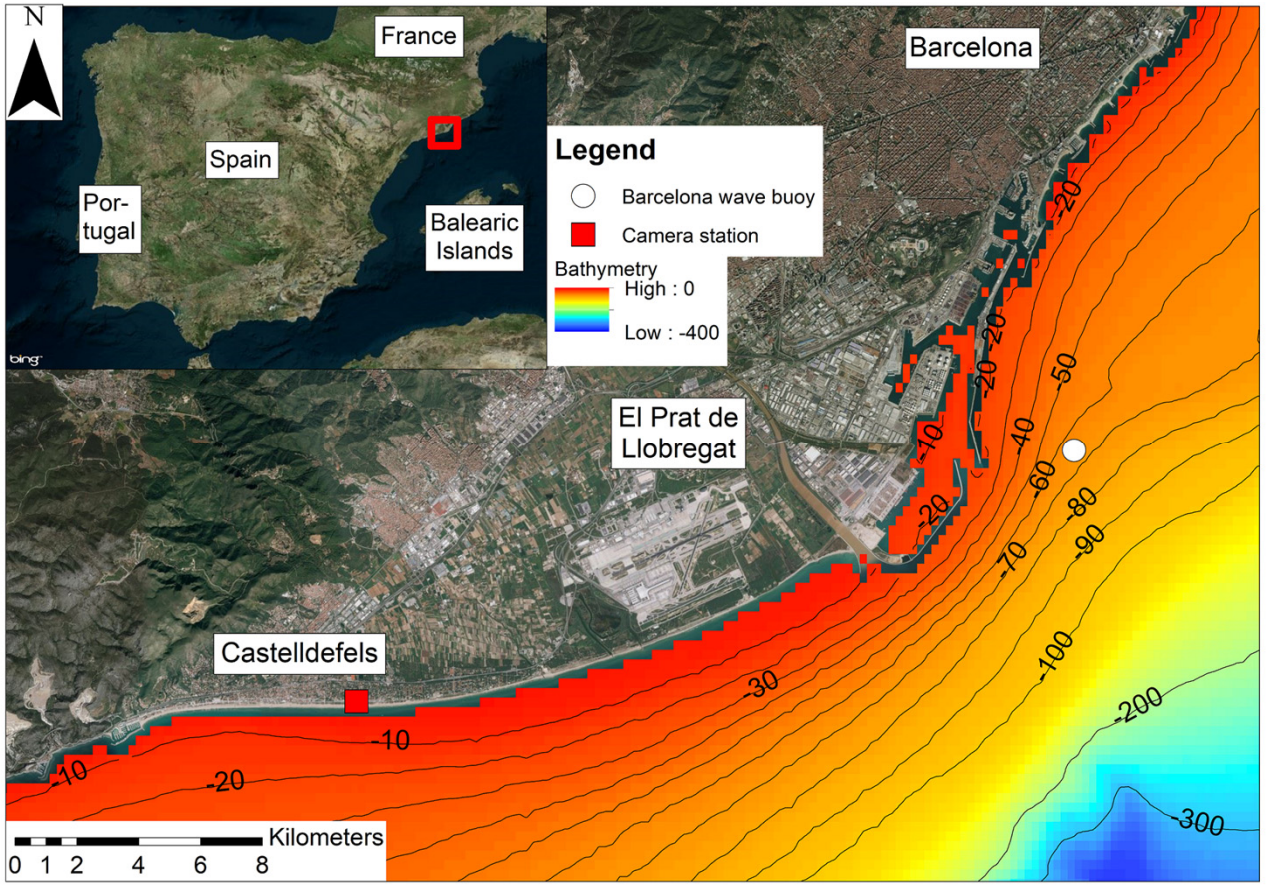
ICM Institut de Ciències del Mar

- Bar observations using time-exposure camera images
  - Foam pattern is a good proxy for bar position
- Shore-parallel bar = alongshore uniform pattern
- Crescentic bar = alongshore variable pattern (undulating)
- Crescentic bars have been observed at various sites worldwide
  - Physical processes well-studied (morphodynamic modelling)



- Motivation
  - No detailed description of environmental conditions during crescentic bar formation and destruction
  - Role of wave obliquity not yet clear
  - Lack of observations in fetch-limited conditions with low tides
- Aim
  - Increase our knowledge on the dynamics of crescentic bars (including formation/destruction moments)
  - Particularly in fetch-limited environments with very low tides
  - Clarify the role of wave obliquity
- NEW
  - Event approach: detect and analyse crescentic bar events
  - Well-validated spectral wave conditions
  - Detailed analysis of environmental conditions during crescentic bar presence and formation/destruction

- Mediterranean Sea, 20 km southwest of Barcelona (Spain)
- Wave conditions taken from Barcelona wave buoy (68 m depth)
- Waves propagated to 10 m depth in front of study site (SWAN)
  - SWAN forcing*: 2D directional spectra complemented with integrated wave parameters (when 2D spectra were missing)

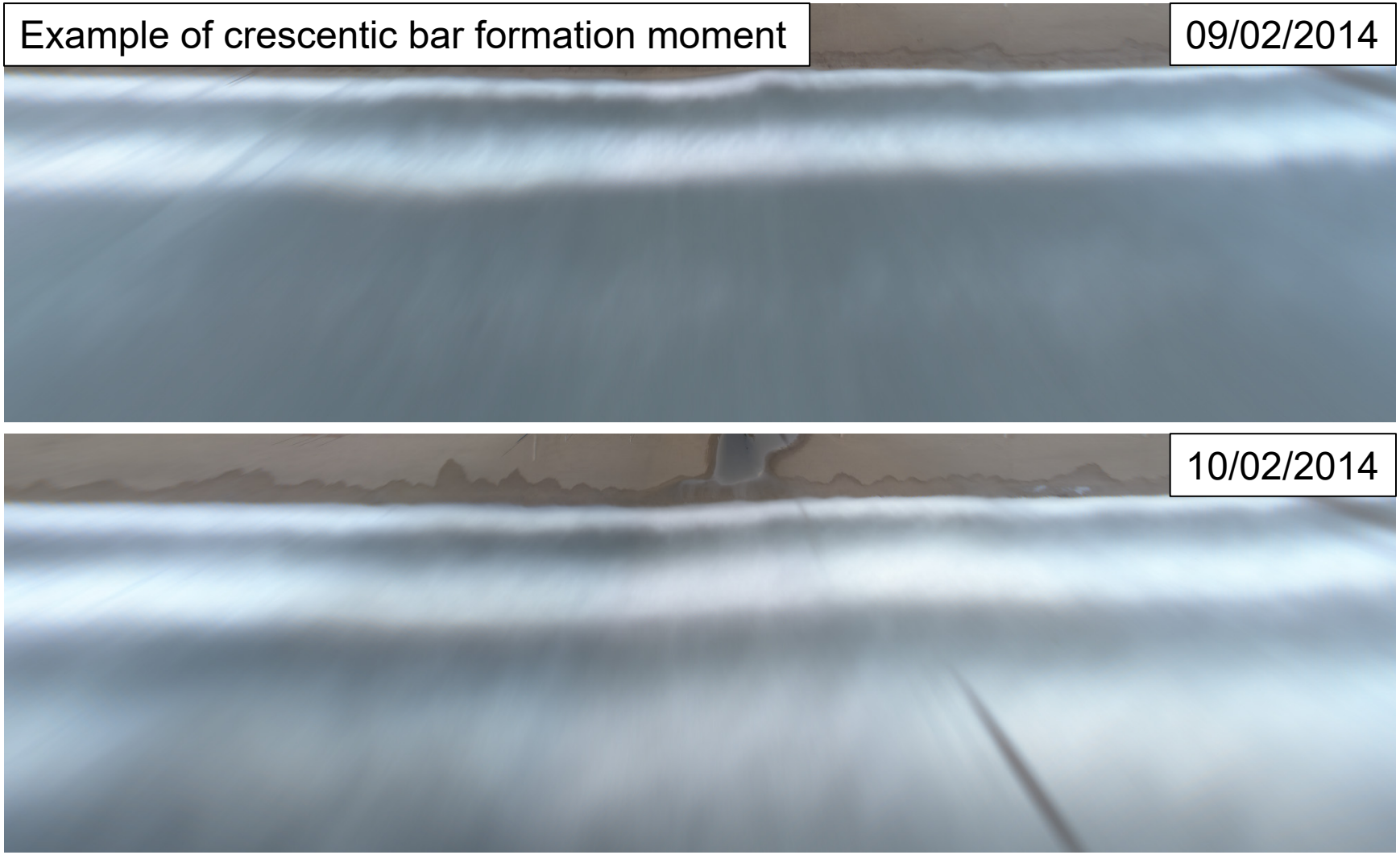


***Note:**
An extensive description and validation of the wave propagation method used in this study can be found in the following article: De Swart, R.L., Ribas, F., Calvete, D., Kroon, A., & Orfila, A. (2020). Optimal estimations of directional wave conditions for nearshore field studies. *Continental Shelf Research*, *196*, 104071, https://doi.org/10.1016/j.csr.2020.104071

- Study site: Castelldefels beach (Plaça de les Palmeres)
  - Open, dissipative beach (tidal range ≈ 10-20 cm)
  - East-west coastline orientation
- Time-exposure images taken every hour using 10 min average
  - Merged in planview (1 km alongshore, 300 m cross-shore)
- Dataset October 2010 – August 2018
  - No camera data from October 2016 – January 2017

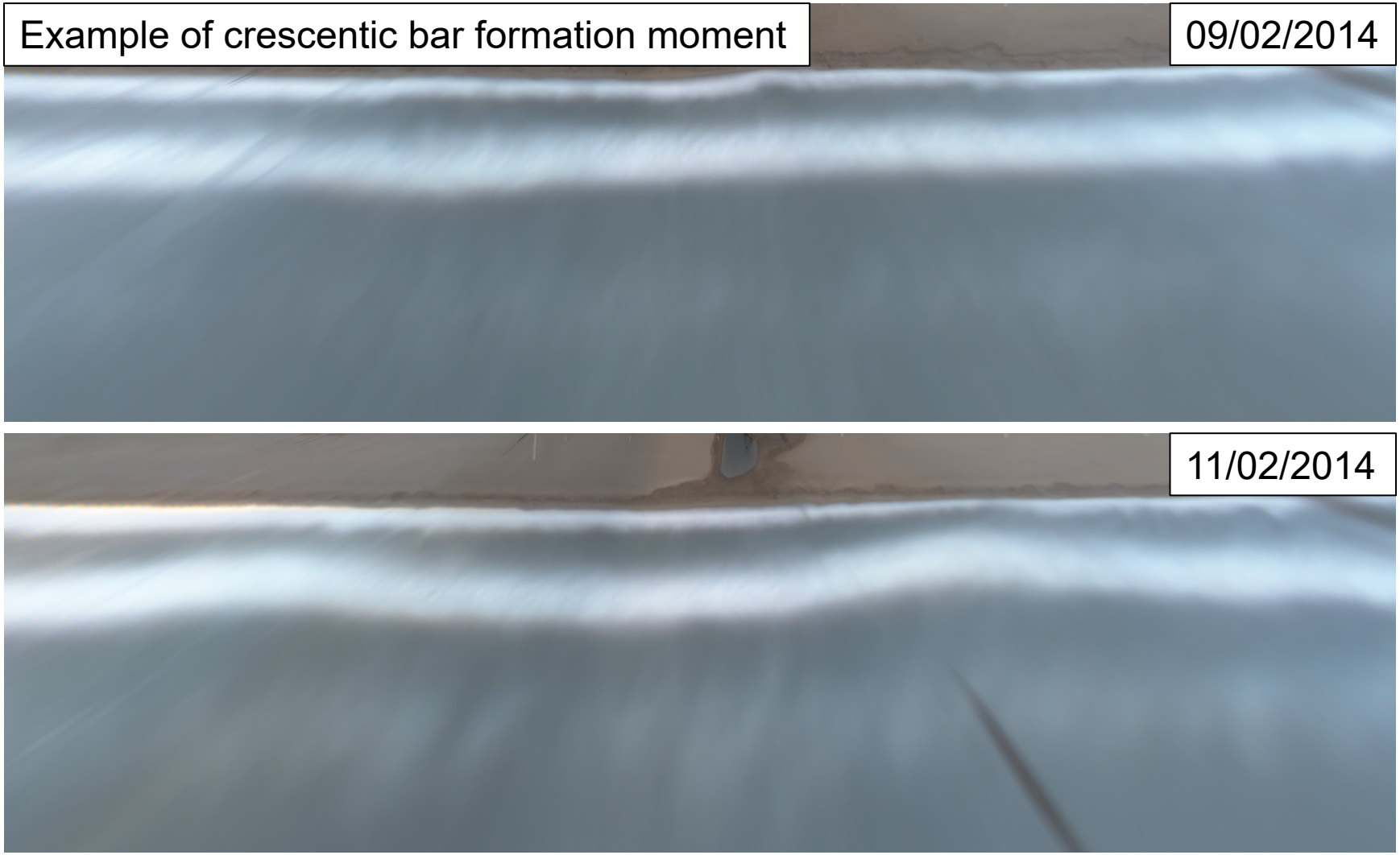
- Visual analysis of images dataset
- Detect crescentic bar events and formation/destruction moments

Example of crescentic bar formation moment



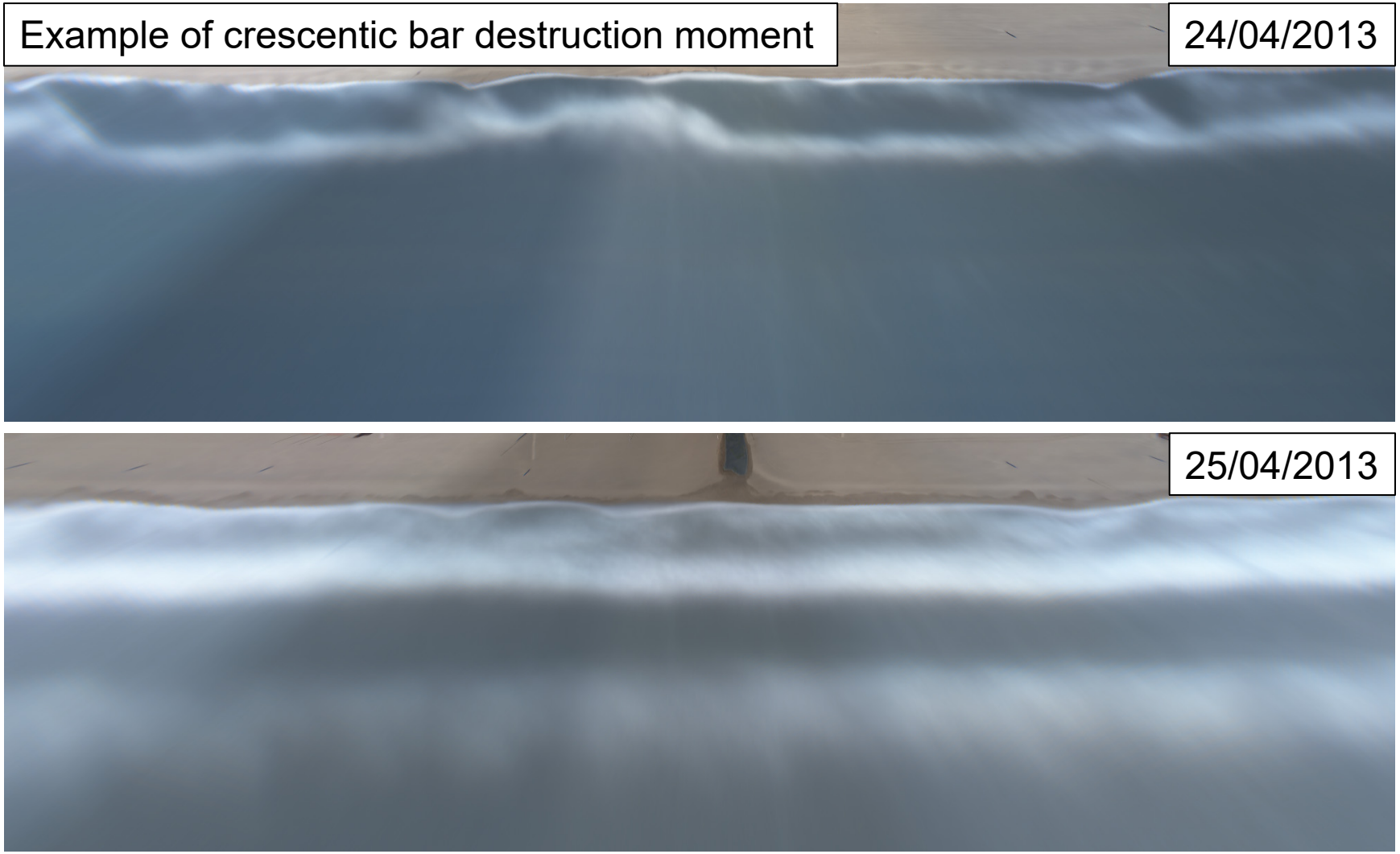
- Visual analysis of images dataset
- Detect crescentic bar events and formation/destruction moments

Example of crescentic bar formation moment



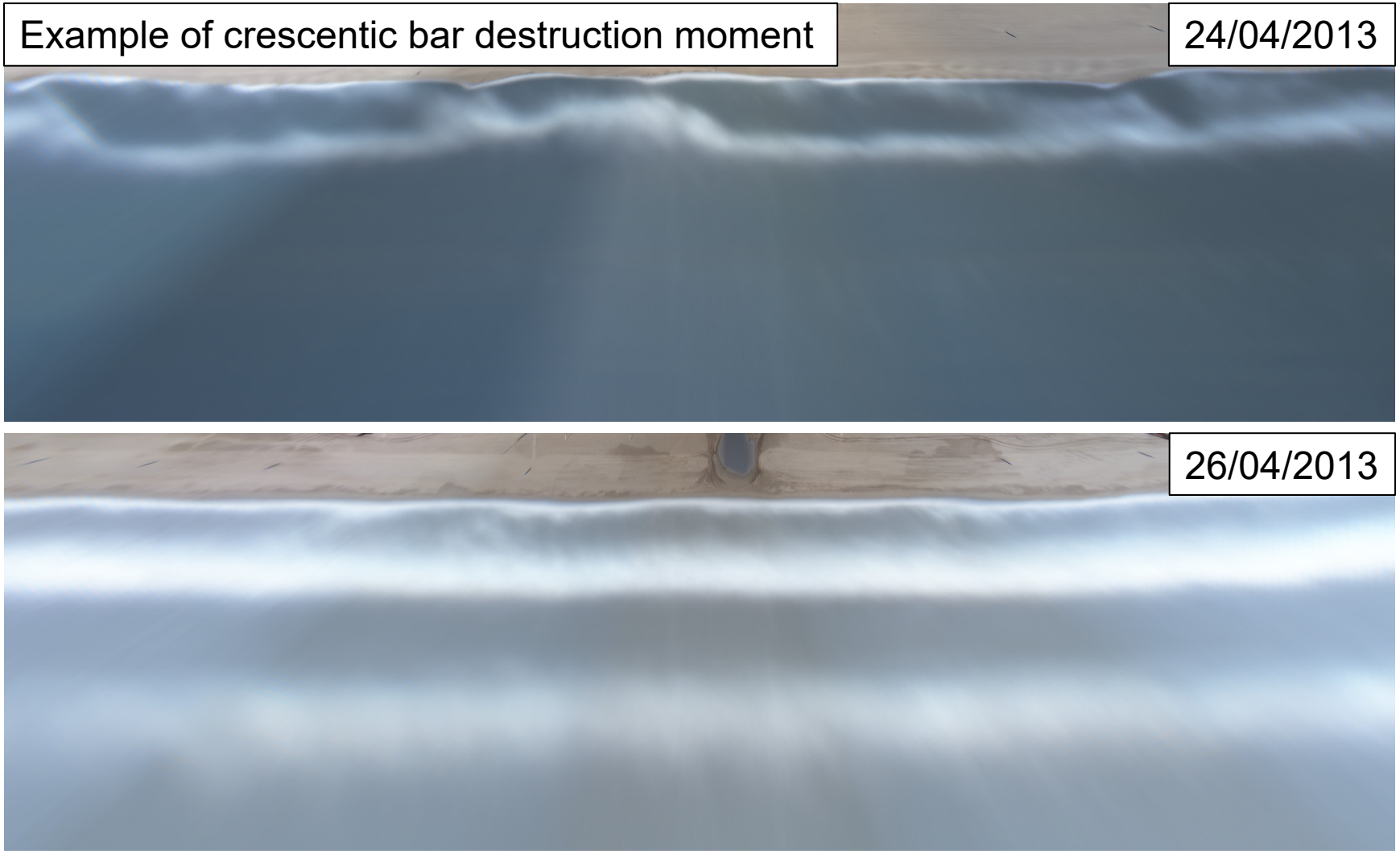
- Visual analysis of images dataset
- Detect crescentic bar events and formation/destruction moments

Example of crescentic bar destruction moment



- Visual analysis of images dataset
- Detect crescentic bar events and formation/destruction moments

Example of crescentic bar destruction moment



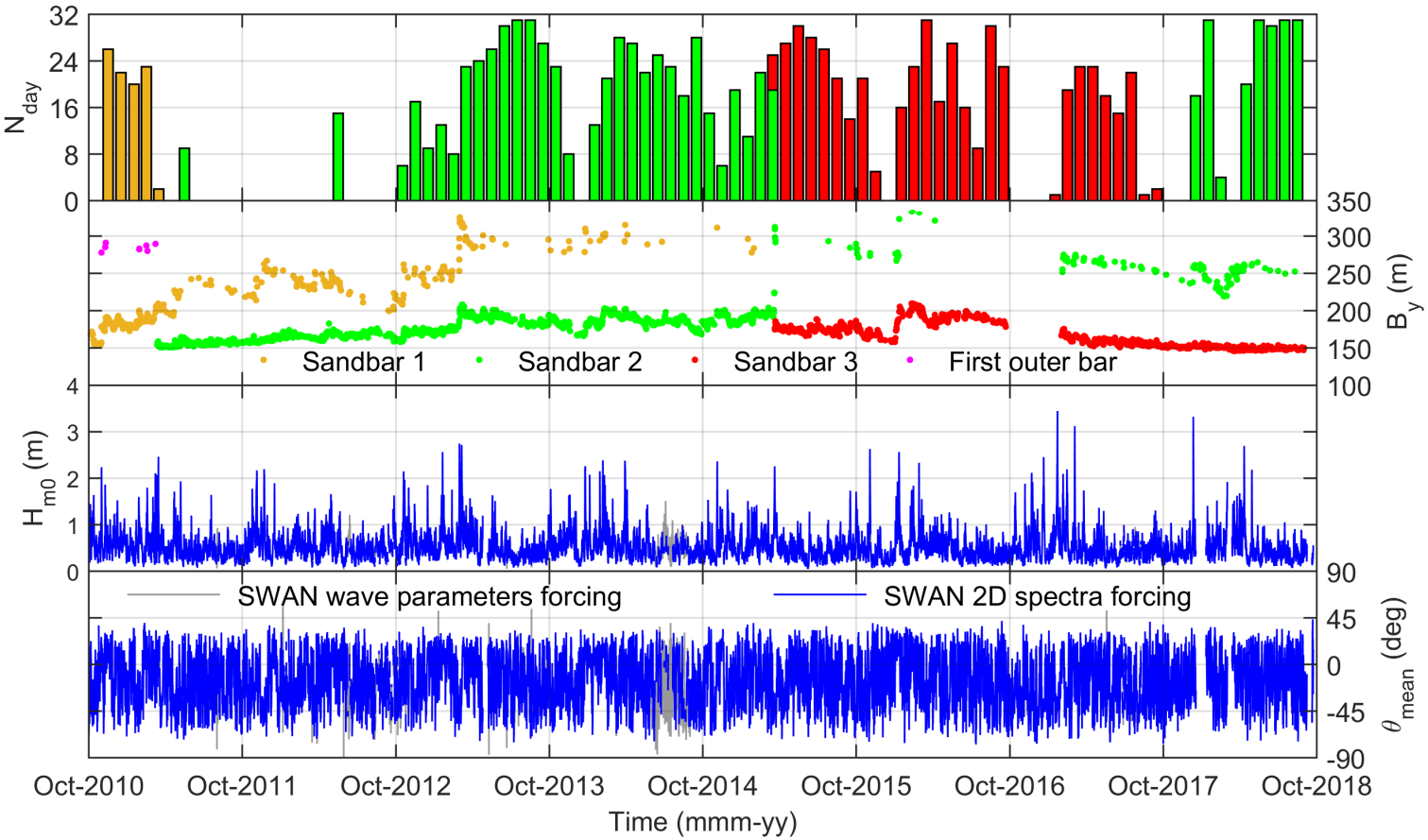
***Note:**
BLIM: A toolbox for the analysis of nearshore time-exposure images. See https://sourceforge.net/projects/blimtoolbox/

- Quantitative analysis of planviews
  - Mostly 1 planview per day (foam pattern should exist)
  - Track barline using BLIM* (detect max foam intensity in image)
- For each barline, find peaks and troughs in barline
- Compute several parameters per barline
  - Alongshore-averaged cross-shore sandbar position, wavelength, amplitude, migration speed

see for definitions Van Enckevort et al., 2004, (https://doi.org/10.1029/2003JC002214)

- Strong variation in crescentic bar presence
  - No seasonal variability in crescentic bar occurrence
  - Crescentic bars normally develop in inner bar (except 2017/2018)
  - Strong correlation between crescentic bar presence and alongshore-averaged sandbar position

Figure explanation:
Time series of (from top to bottom) the number of days per month with crescentic bars N_{day}, the alongshore-averaged sandbar position B_y (shoreline around 140 m), the spectral wave height H_{m0} and the mean wave direction with respect to the shore normal θ_{mean} (positive angles are waves from the west). The colours in the two upper panels denote the different sandbars, whereas the colours in the two lower panels denote the SWAN forcing.

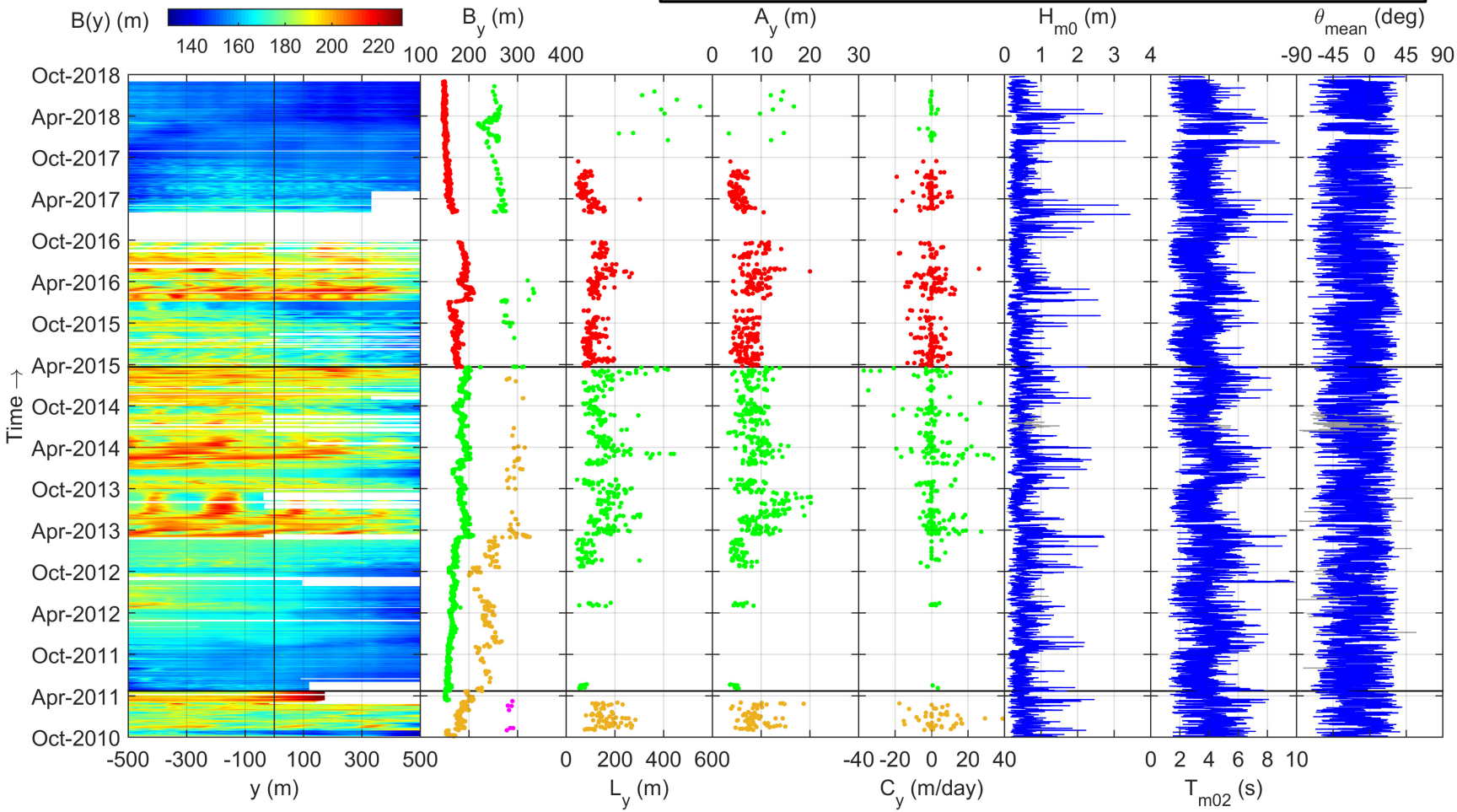


- Overview of crescentic bar events per year
  - Large variability in crescentic bar occurrence per year
  - Duration can vary from a few days to a few months
  - Crescentic bars presence during some years for 66% of the time

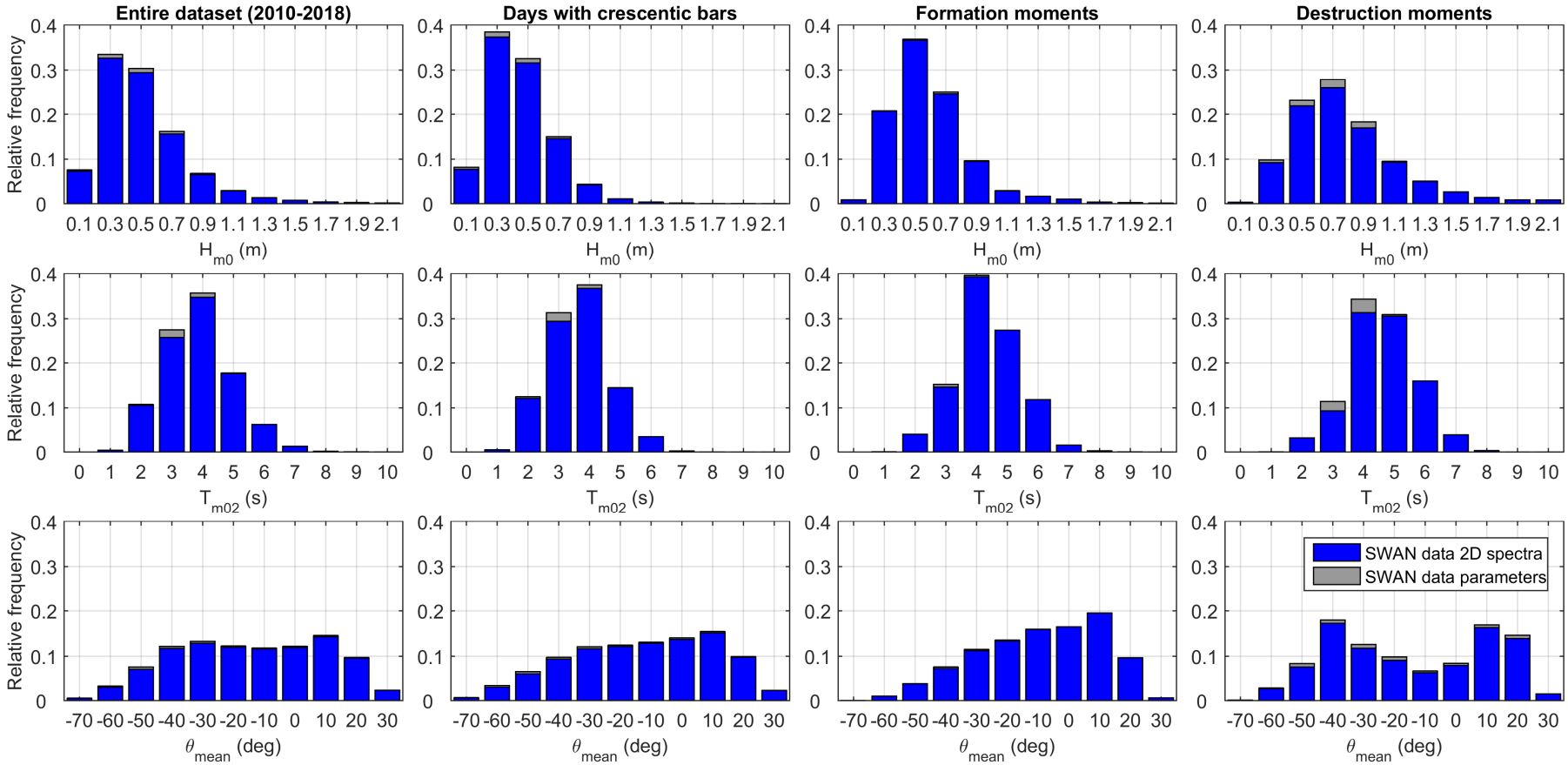
Year	Number of events	Mean duration (days)	Min duration (days)	Max duration (days)	Total duration (days)
2010	6	11	2	25	68
2011	4	9	3	13	34
2012	7	7	1	15	47
2013	14	17	1	117	244
2014	14	18	2	47	245
2015	15	15	3	41	230
2016	9	21	2	49	192
2017	19	9	2	53	177
2018	1	143	143	143	143

- Time-stack entire study period
  - Shore-parallel/crescentic bars
  - Bar arrestment/bar migration

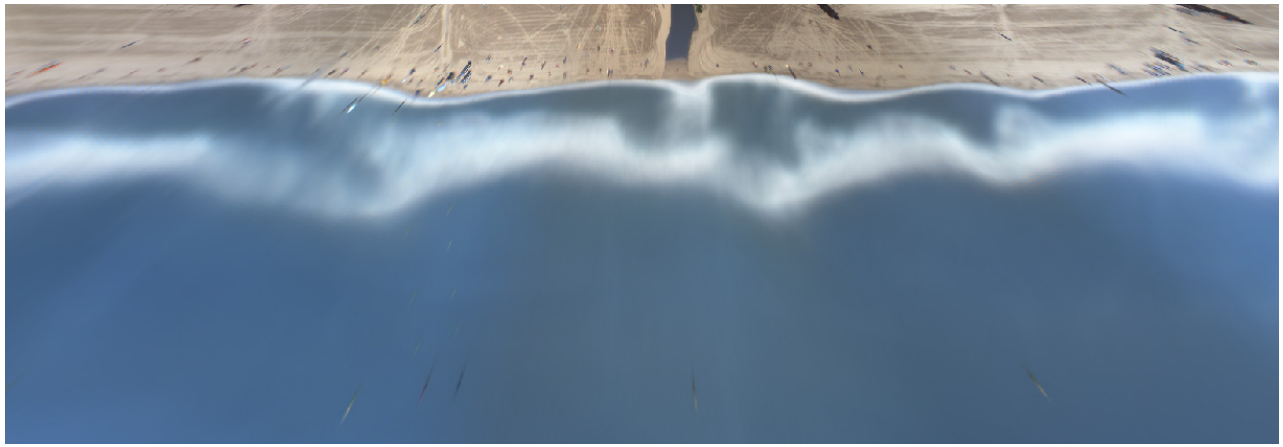
Figure explanation:
Time series of (from left to right) the cross-shore bar crest positions B(y) at each alongshore location (shoreline located around 140 m), alongshore-averaged sandbar position B_y, alongshore-averaged wavelength L_y, alongshore-averaged amplitude A_y, average migration speed C_y (positive for eastward migration), offshore (10 m depth) spectral wave height H_{m0}, mean period T_{m02} and mean wave direction with respect to the shore normal θ_{mean} (positive for waves from the west). Analogous to the previous slide, the colours in panels 2-5 denote the different sandbars and the colours in panels 6-8 denote the SWAN forcing. The horizontal black lines indicate when a new sandbar starts to be plotted in panel 1.



- Wave conditions during crescentic bar events
  - Mainly low-energetic wave conditions with variable wave angles during crescentic bar formation and crescentic bar events
  - Crescentic bar destruction during intermediate energy waves
  - Clear link between destruction and angle of incidence



- Crescentic bars at Castelldefels compared to other studied sites
  - Smaller wavelength, amplitude and migration speed
  - Probable cause: less energetic wave conditions
- Crescentic bar formation
  - Importance of cross-shore bar position
    (bar too close to shore: no crescentic bar formation)
  - Large range of incidence angles
  - Difficult identifying exact formation moment in images
- Crescentic bar destruction
  - Intermediate-energy wave conditions
  - Dominance of oblique wave angles



- Large variability in crescentic bar occurrence
  - Many events in 2010/2013/2014/2015/2016
  - Very few events in 2011/2012/2018
  - Smaller sizes and slower dynamics compared to other sites
- Strong link between crescentic bar presence and barline-shoreline distance
  - No crescentic bar formation when bar is too close to shore
- Crescentic bar development
  - Low-energy conditions
  - Oblique and shore-normal waves
- Crescentic bar destruction
  - Intermediate-energy conditions
  - Oblique wave angles dominate