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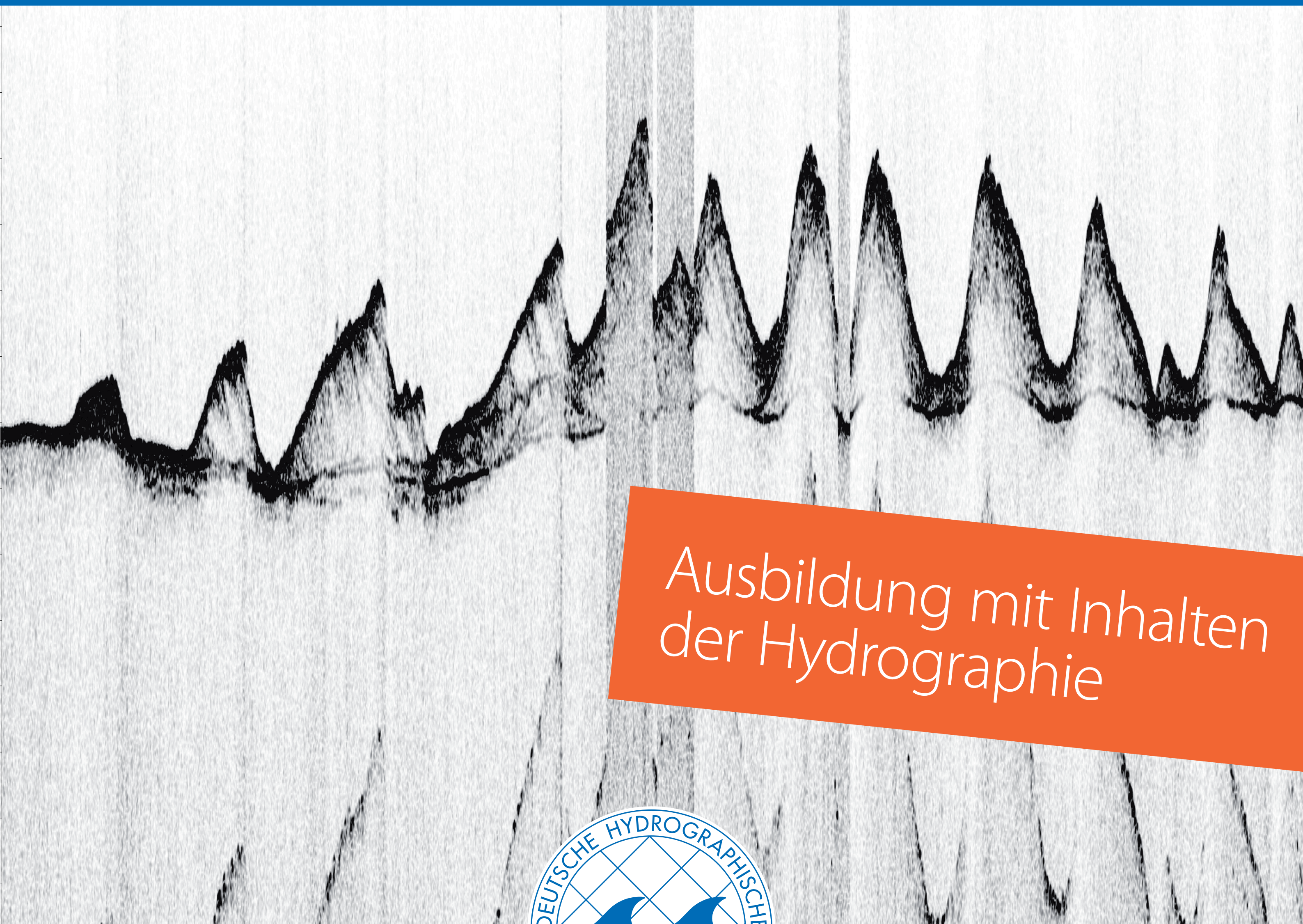

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The Crazy Dunes

An article by NIELS FUCHS

During their doctoral theses in sea ice physics at the AWI, two researchers were given the opportunity to take part in an echo sounding training cruise on the research vessel *Polarstern* in 2018. Instead of sea ice, this time the focus was on sea dunes, in particular an unusual formation they called »Crazy Dunes«. These dunes in the English Channel showed a symmetrical pattern around a central point – an indication of opposing currents. By using multibeam echo sounders and sub-bottom profilers, they were able to analyse morphology and internal structures. The project highlighted the importance of interdisciplinary research and sparked a new enthusiasm for marine geomorphology.

English Channel | dunes | multibeam echo sounder | sub-bottom profiler
Ärmelkanal | Dünen | Fächerecholot | Sedimentecholot

Während ihrer Doktorarbeiten in der Meereisphysik am AWI erhielten zwei Forscher 2018 die Gelegenheit, an einer Echolotungs-Trainingsfahrt auf dem Forschungsschiff *Polarstern* teilzunehmen. Statt Meereis standen diesmal Meeresdünen im Fokus, insbesondere eine ungewöhnliche Formation, die sie »Crazy Dunes« nannten. Diese Dünen im Ärmelkanal zeigten ein symmetrisches Muster um einen zentralen Punkt – ein Hinweis auf entgegengesetzte Strömungen. Durch den Einsatz von Fächerecholot und Sedimentecholot konnten sie Morphologie und innere Strukturen analysieren. Das Projekt verdeutlichte die Bedeutung interdisziplinärer Forschung und weckte eine neue Begeisterung für marine Geomorphologie.

Author
Dr. Niels Fuchs works at the Institute of Oceanography, University of Hamburg.
He was a former PhD student at Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven.

niels.fuchs@uni-hamburg.de

Having committed to a PhD project in sea ice physics at AWI, we were used to spending most of our time in our offices in Bremerhaven, examining existing data from previous expeditions. My colleague Philipp Anhaus worked with acoustic echo sounding data from an ROV diving under the ice to investigate the under-ice topography, while I utilised photogrammetric methods to analyse aerial photographs and study summer features of the ice surface. However, in the middle of our projects, in 2018, we got a unique chance to leave our focus on ice and develop an enthusiasm for marine dunes, leading us to discover the Crazy Dunes at the bottom of the English Channel. More on this dune formation, what made them »crazy«, and what they reveal about dominating currents later. But first, let's start with how we came there:

Looking beyond the horizon is one of the opportunities graduate programmes like POLMAR at AWI provide for PhD students – the chance to step outside their primary research projects and acquire valuable skills that will benefit their future careers as researchers. This often involves venturing into interdisciplinary fields and exploring new areas of study. Exploring what's below the horizon might best describe the technical goal of the yearly »Echosounding Training Cruise« offered by POLMAR on board RV *Polarstern*, benefiting from free berths on the biannual transits, when the German polar research icebreaker switches between the southern and northern hemisphere polar regions.

In November 2018, we, a group of fellow PhD and Master's students from AWI and the University of Bremen embarked on this journey, momentarily stepping away from our regular research projects, ranging from experimental biology to climate modelling. We boarded RV *Polarstern* at the Lloyd's shipyard in Bremerhaven for the research cruise PS116 (Hanfland and König 2019) and faced an intense, week-long introduction to echo sounding techniques aimed at mapping the ocean floor while heading towards the Canary Islands. We were accompanied by experts from AWI's bathymetry department, marine geology specialists and our cruise leader, Claudia Hanfland. As part of our training, we students took turns running daily night shifts to ensure that all instruments and measurements operated continuously, allowing for non-stop 24/7 data collection.

To keep our productivity inevitably high and encourage collaborative exploration outside of our usual environments, we were paired with colleagues to tackle specific research topics. We, the two PhD students from AWI's sea ice section, focused on investigating marine sand dunes on the bottom of the English Channel. Our goal was to identify and analyse dune formations using multibeam echo sounder (MBES) and sub-bottom profiler data, thus learning about them from a multidimensional perspective on the water depth and sediment structure.

While we initially intended to examine how marine dunes are detectable and to track changes since a previous cruise, our findings revealed patterns that unfolded into a more exciting scientific narrative than we had initially anticipated. This experience exemplifies just one of many inspiring projects on student training cruises, where seemingly simple projects can provide profound insights into the Earth's systems and foster the development of academic thinking. Through such initiatives, research schools continue to inspire and equip the next generation of scientists to explore our fascinating planet.

Marine dunes are sandy bedforms commonly found on tide-dominated continental shelves (Franzetti et al. 2013). They form from hydrodynamically-driven particle transport of sea-bottom sediments, like windblown sand and snow behave on land. Both currents and sufficiently fine sediments are abundant in the English Channel, making it a preferable location for dune formation and study. Dunes align perpendicular to the dominant direction of the prevailing current, which in the tidal-influenced English Channel is typically the direction of the tidal residual, often impacted by the more intense flood wave (Ferret et al. 2010). The morphology of dunes and their temporal evolution offer insights into various external hydrodynamic factors, intrinsic sedimentary features, the underlying shelf morphology and long-term fluctuations in sea level (Allen 1968; Franzetti et al. 2013). When moving, dunes can pose significant hazards to offshore installations, shipping routes, gravel extraction activities and scientific equipment deployed on the seafloor (Ferret et al. 2010; Debese et al. 2016). They can also bury or expose remnants of World War ammunition, making them a compelling subject for scientific investigation.

We studied dunes both with MBES and the single-beam sub-bottom profiler Teledyne Parasound P70 onboard RV *Polarstern*. This allowed us to detect the overall morphology of the dunes together with internal sediment stratification, which again gives indicators for formation and evolution. We first focused on the comparison of nine dunes in two areas we mapped again after a four-year period between our and a previous course cruise in 2014 (Fig. 1a). All of them had the morphology of barchan dunes (Fig. 1b). Such crescent-shaped dunes usually form in areas with small amounts of mobile sediment and merely constant prevailing currents. Along our profile line, dunes were between 0.3 km and 1 km long, a maximum of 10 m in height, and some were superpositioning (Fig. 2). None of them showed a strong tendency to move; we found a maximum migration distance of a dune crest by 10 m per year on average, with a range in height change relative to the seafloor measuring ±0.6 m. Most obviously, all dunes were strongly asymmetric with a steeper lee slope. Many became even steeper over the four years, resulting in shorter lee sides and an increased asymmetry parameter for seven of the nine dunes observed. This indicates a consistently prevailing current in the area. An observation that goes in line with the position in the tidal area. Moreover, the steepening also hints towards an intense storm period in the intermediate years or increased currents. One impacting factor could be the height in the long-term tidal cyclicities that happened late 2015 (Peng et al. 2019), and with that exactly between our two visits. A clear first-order reflecting layer in the dunes was visible in the Parasound data at sea-

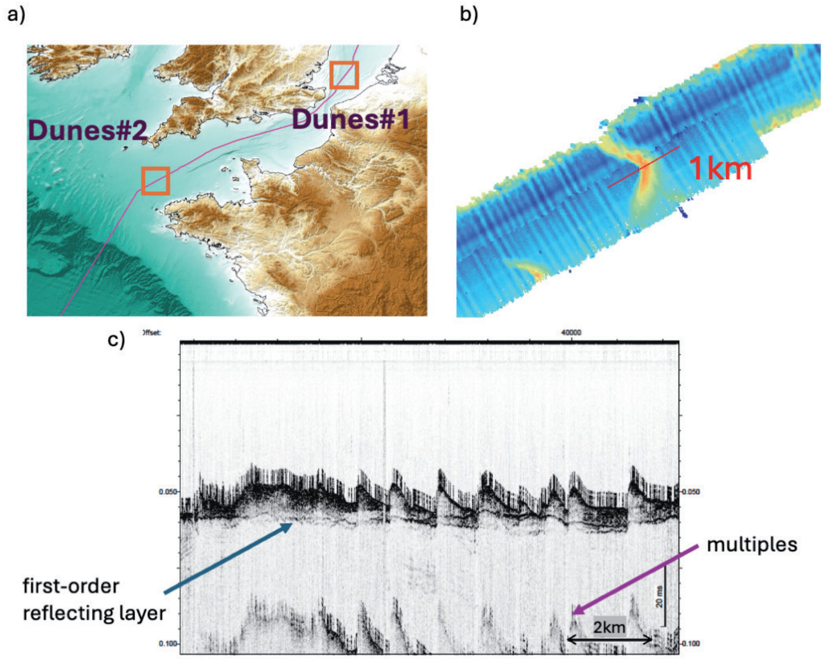

Fig. 1: (a) Map showing revisited study areas #1 and #2 for marine dune evolution in the English Channel. (b) MBES data of one example dune showing the barchan type morphology, the red profile line equals 1 km. (c) Parasound data as shown on the continuous monitoring screen

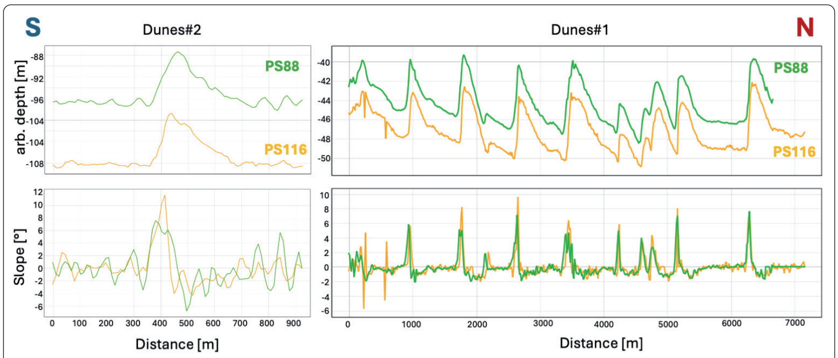

Fig. 2: Dune height and slope angle profiles in the two study areas (Fig. 1a) from RV *Polarstern* cruises PS88 (2014) and PS116 (2018). Dune height is shown on an arbitrary depth axis, with an offset between both measurements for better visibility. Left side of the graphs points toward the southeast

Graduate programme

The POLMAR graduate school at the AWI offers all doctoral students (approximately 220 as of 2025) a structured framework for their doctorate. This includes a comprehensive training programme with scientific trainings, courses in transferable skills and career development as well ship-based trainings. One of the highlights is the »Echosounding Training Cruise« with RV *Polarstern,* which takes place every one to three years.

bottom level, marking the more solid ground on which the dunes are migrating (Fig. 1c). So up to this point, everything was more or less as expected and described in detail in the literature.

A few nautical miles further from our first study site, however, we found a very special dune pattern in the single-beam Parasound data (Fig. 3a). Over more than 5 km, dunes with very distinct asymmetric profiles were visible, yet the direction of their asymmetry changed in between. Meaning that they were symmetrically aligned around a centre point toward which they seemed to migrate. This seemed very exceptional for the observed dune patterns, whose slopes were otherwise clearly aligned to the main current direction through the channel. Our second source of data, the MBES, confirmed the observed pattern (Fig. 3b).

From then on, our guiding questions were: How did these patterns form, what processes are involved, and how can we explain these – Crazy Dunes?

In a first assessment, we found, along-track, six strongly asymmetric dunes with the flat slope facing east and the steep slope facing west. Connected to them were two merely symmetric dunes, followed by seven reversed asymmetric dunes. The morphology of the dunes indicates that the prevailing current impacting the first group is westwards, there is no clearly oriented actor along the centre dunes, and the last group lies in the area of an east-going current.

Sub-bottom profiling data from the Parasound system can help us confirm this suspected system of currents. As part of the redeposition processes and dune migration, compacted layers can form in dunes, which extend from the windward slope into the dune. Originating from compacting processes at the leeside, they are typically aligned parallel to the leeward slope. Their higher density makes them visible in the Parasound data as second-order reflectors. While not being apparent in all dunes, we found distinct layers that clearly confirmed our hypothesis of converging prevailing currents in that area.

Under all the new impressions and spending most time in the bathymetry lab – located virtually in the basement of RV *Polarstern* – to collect data, intensely cleaning the MBES point clouds and performing such first analysis, we had temporarily lost sight of where we actually were on the map. So in the next step, we needed to clarify where the Crazy Dunes were located. A great opportunity to learn about GIS systems, especially the open-source QGIS application. Done with that, we compiled corresponding maps, including our measurement data from the dunes. Fortunately for us, with the theory already in our heads

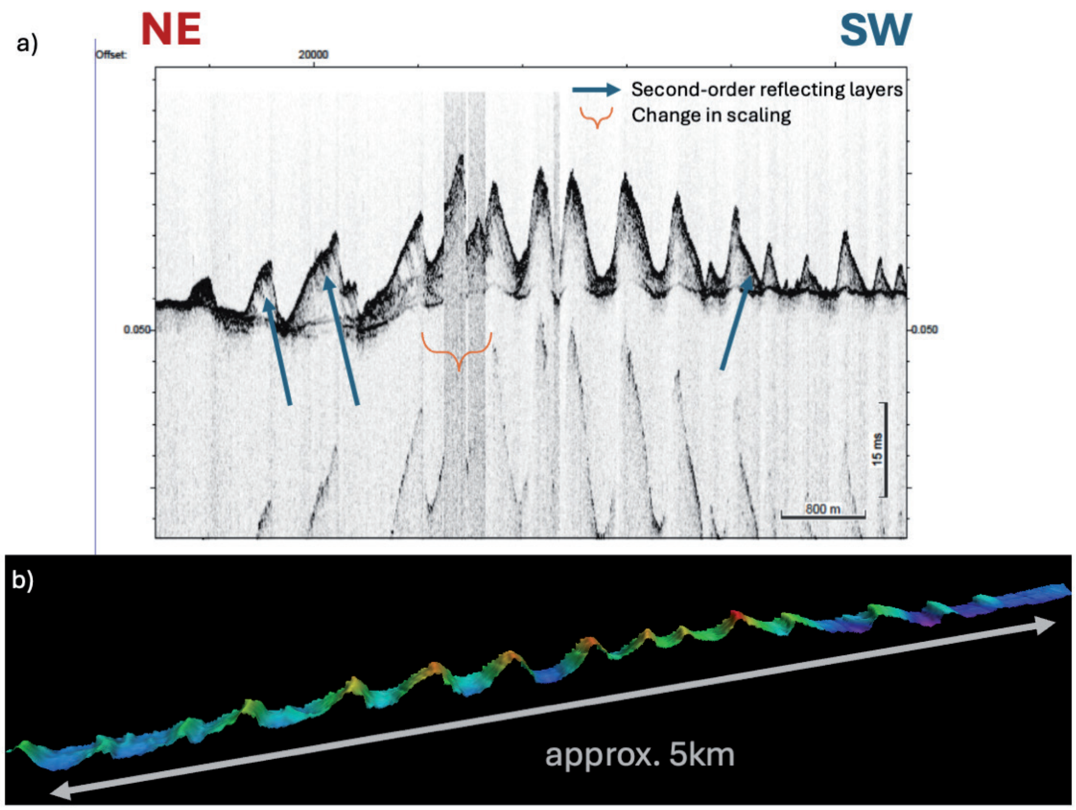

Fig. 3: (a) Parasound image of the Crazy Dunes. Arrows highlight second-order reflecting layers in the dunes. The orange bracket indicates changes in scaling that temporarily changed the vertical axis but did not further impact the measurements. (b) 3D visualisation of the Crazy Dunes from MBES data with exaggerated vertical axis

that we were facing an exciting pattern of ocean and tidal currents, we found out that the Crazy Dunes were located almost exactly in the Strait of Dover, with 32 km the narrowest part of the English Channel.

How can we confirm these current patterns? There must be plenty of studies on the tidal currents. Sitting there, almost seven years ago, we had no idea yet what dozens of small satellites would offer us in the near future in terms of worldwide internet access. So, the options were still limited, and the plan was to be done with our project by the time we entered the harbour in Las Palmas, because well, our sea ice data was already waiting for us back home. So off to the bridge and, thanks to the helpful nautical crew, we got a look at the pilot charts. Lo and behold, they confirmed exactly that we crossed a complex area in the tidal current system, in which the residual of tidal currents oppose at our Crazy Dune location. Extending the analysis of dune patterns on our way through the English Channel, we eventually compiled a map (Fig. 4), which shows the different prevailing currents along our entire track determined from the dune pattern we found, including sinusoidal and trochoial dunes at locations of omnidirectional currents. Different from what we expected, these patterns revealed more variability in the currents than a sole eastward-directed prevailing current through the English Channel.

Fig. 4: Map of the cruise track through the English Channel with estimates of prevailing currents derived from the observed dune morphologies screen

At the point when we had this story together, we were already in the middle of the Biskaya. Any chance to take a closer look at the region had passed. How are the current patterns over a tide? What happens to the North and the South? Can we see where the sediment, which necessarily converges in the centre, is transported away?

However, we had a nice story for the final report, had gained a lot of insights and experience with new tools, especially for the presentation and analysis of geospatial data, and finally went ashore in Las Palmas de Gran Canaria with a new weakness for marine dunes, especially »our« Crazy Dunes. //

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