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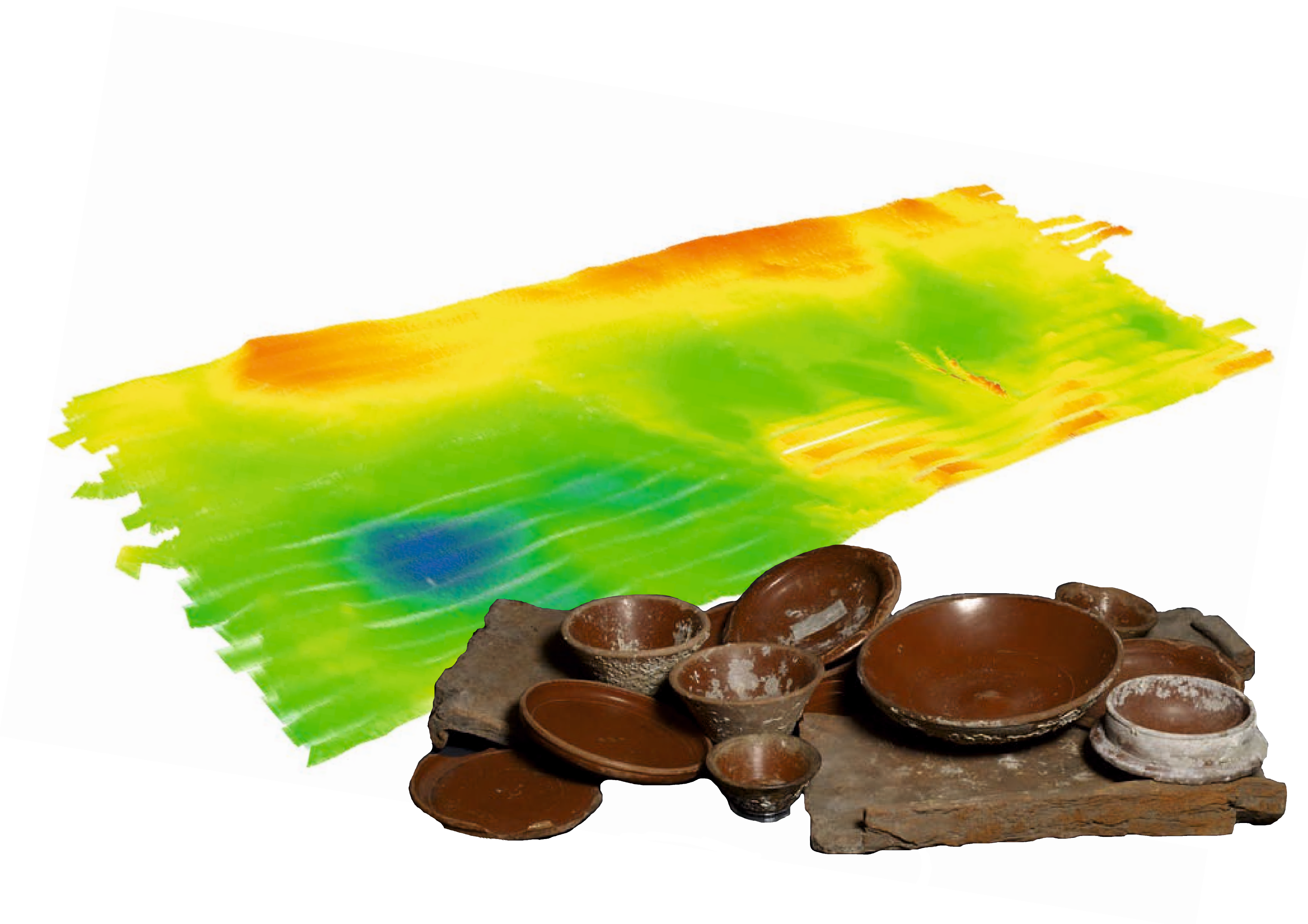
Survey of the potential site of the Roman Pudding Pan shipwreck

Project 7164

February 2017



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Cover image: 3D representation of the MBES Survey of the Study Area and selection of recovered Roman Samian ware pottery from Pudding Pan (photograph © Ashmolean Museum, University of Oxford).

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Summary

Roman artefacts have been recovered from the sea off the north Kent coast, in the oyster dredges and fishing nets of commercial fishermen, for at least the last 300 years. The source(s) of this material continues to elude discovery but finds are closely associated with the areas known as Pudding Pan and Pan Sand. The primary assemblage is unusual as it comprises predominantly a significant consignment of largely intact plain samian vessels dating from c. AD 180-200; no similar assemblage has ever been recovered from a maritime context. Surprisingly, therefore, serious study of this important assemblage had laid dormant since the early twentieth century (Smith 1907; 1909) until an undergraduate dissertation (Watson 1987) and post-graduate research (Walsh 1998; 2006) revived interest through the concerted re-assessment of the site and its unique assemblage. Contact with national and international institutions, and with private collectors, led to a doubling of the size of the known assemblage from the area which now numbers almost 550 samian vessels, in addition to numerous other Roman artefacts. Recent research has shown that the recovery of artefacts relates to two discrete geographically and chronologically separate assemblages. Most, if not all, of the first century AD material has been recovered over a wide area by fishing trawlers operating to the north and west of Pan Sand, whereas the second century AD material is almost exclusively recovered in the oyster dredges that operate in the area of Pudding Pan. Detailed analysis of the wear and damage, coupled with assessment of the rate at which artefacts have been recovered, suggests that the main second century AD source (Pudding Pan) represents a significant and cohesive buried deposit of plain samian wares. It has also been proven that artefacts continue to be recovered by local fisherman from the site, rebuffing the popular belief that the site no longer exists.

The original search area for the wreck associated with the second century assemblage covered an area of c. 30 km^2. Interviews with fishermen and private collectors, and field investigations has resulted in the narrowing of the search area from which finds are likely to have originated. In 2014 the University of Southampton undertook a review of all available marine geophysical survey data from a variety of sources. These were used to identify areas of highest archaeological potential for the preservation of a Roman vessel and associated cargos. Comparison between these survey datasets, and the areas from which Roman artefacts have been recovered, has confirmed the earlier results, redefining a significantly smaller area of Pudding Pan, measuring c. 1.2km^2, which has the highest archaeological potential.

A targeted investigation of this smaller area, using high-resolution geophysical survey (Multibeam Echo Sounder (MBES) bathymetry and Side Scan Sonar (SSS)), would permit an assessment of the archaeological potential by identifying any seabed anomalies that might yield archaeological material of national and international archaeological significance. Geophysical survey was undertaken by the Port of London Authority in July 2015 with the majority of the study area covered within two days. Deteriorating weather conditions on the second day resulted in only 95% multibeam coverage of the study area. A second survey to complete the survey was undertaken in August 2016 ensuring that >100% coverage of the seabed was achieved. Analysis of the SSS, backscatter and MBES data has identified a number of features on the seabed with archaeological potential that warrant further investigation, which is discussed in this report.

Acknowledgements

The geophysical survey was undertaken by the Port of London Authority Hydrographic Service aboard their survey vessel the *Yantlet* in 2015 and *Maplin* in 2016. The crew and staff of the Port of London Authority are thanked for their continuous assistance throughout the project and the collection of high quality data within a very challenging environment. Thanks are notably extended to James Powell, Stuart Leakey and John Dillon-Leetch. The Port of London Authority are also thanked for providing bathymetry data from their jurisdiction.

Chelsea Bradbury (The Crown Estate's Marine Data Exchange) is thanked for assistance with the provision of data and information regarding offshore wind farm developments within the study area. Anne Laking and STV are thanked for their support throughout the project, most notably during the 2014 desk-based assessment which led to the development of the project design upon which this project is based. Historic England are thanked for supporting the project throughout its lifetime – most notably Mark Dunkley for supporting the project team to submit a project design and providing advice throughout, and Jonathan Last as the Project Assurance Officer.

Introduction

Roman artefacts have been recovered from the sea off the north Kent coast in the oyster dredges and fishing nets of commercial fishermen (see for example, Pownall 1778; Smith 1907; 1909; Sealey and Tyers 1989; Walsh 1999; 2002; 2006) for at least the last 300 years (Jacob 1782: 121). These were largely associated with two separate named areas, Pudding Pan and Pan Sand, whose names must reflect the archaeological finds (Figure 1). Pudding Pan and Pan Sand are located c. 4-9km offshore of the north Kent coast, directly north of the settlement of Herne Bay, within the outer Thames estuary.

Despite numerous attempts to locate the sources of this material, including one of the first ever underwater archaeological investigations (Smith 1909), the origin of this material has continued to elude detection. Various theories have been expounded to explain the existence of these Gaulish artefacts in the outer Thames estuary, but the true extent and nature of the assemblage has been obscured as a result of the wide distribution, both nationally and internationally, of the recovered artefacts. Consequently, although the assemblage has been central for the dating of later second century samian assemblages (Willis 2005), until recently the assemblage and likely source(s) have been largely overlooked.

The assemblage is unusual not only as it comprises a significant consignment of largely intact plain samian vessels but also because there is no direct evidence for the shipment of samian wares or indeed any Roman pottery type in northern European waters. Although many major samian studies refer briefly to the site (Hartley 1972; Willis 1997a; 1997b) it has never been discussed in any detail in the context of cross-Channel samian supply.

It is surprising, therefore, that interest in the Pudding Pan assemblage has been so sporadic since the notable studies of the early twentieth century (Smith 1907; 1909), whilst the first century Pan Sand assemblage has been virtually ignored. Within this interlude the assemblage was re-assessed in an undergraduate dissertation (Watson 1987; also see Ferrari 1995) and attempts have been made to locate the site (e.g. Mensikov / Singer 1979; MAS / Redknap 1985; ADU / Dean 1988; 2002), including some limited marine geophysical surveys by the Archaeological Diving Unit (ADU) in 1998 and 2002 (Figure 2).

A thorough re-assessment, begun in the late 1990s, involved contact with national and international institutions, and with private collectors, which revealed several important new lines of inquiry and doubled the size of the known assemblage (Walsh 1998; 2006). The Roman Shipwreck project, a collaboration between the University of Southampton and the British Museum, was borne out of this research in 2000. This project involved the detailed study of all the material recovered or supposedly recovered from the site, along with surveys of the area to try to locate the possible wreck (see below).

Analysis of the enhanced assemblage has confirmed the existence of at least two significant, discrete sources of material. The largest assemblage, dating from c. AD 180-200, now numbers almost 550 complete or near-complete samian vessels as well as a few *amphorae* and lamps. The second assemblage, dating from c AD 65-85, comprises a variety of Roman artefacts including *amphorae*, *mortaria*, *tegulae* and *imbrices*, most of which are intact. A number of artefacts have recently been identified as dating from the early third century AD but they are too few in number to suggest a cohesive deposit.

Recent research (Walsh 2006), including conversations with local fishermen and controlled dredging (conducted by the British Museum and the University of Southampton), has confirmed that, contrary to popular belief (Mensikov 1985; Porter 1978; Singer 1972; *contra* Jefferis and McDonald 1966: 172), material is still being recovered from the area. Local fisherman were able to provide more accurate locational information for the two sources, clarifying the long-standing confusion between the two marine areas of Pudding Pan and Pan Sand to which material has been attributed (see Pownall 1778: 283; Keate 1782: 126; Jacob 1782: 121; Jefferis and McDonald 1966: 172) (Figure 2).

It is now clear that the two discretely dated assemblages have been recovered using two very different fishing methods which are undertaken in discrete and distinct geographical locations. Consequently, the fishing method by which an artefact has been recovered provides a good indication of where the sources might lie. Most, if not all, of the second century material has been recovered in the oyster dredges that operate in the area of Pudding Pan (shown in Figure 2), whereas the first century material has been recovered by trawlers fishing to the north of Pan Sand (Figure 1 and 2).

First century AD Pan Sand assemblage

The location north and west of Pan Sand, from which the first century AD material has been recovered, is less well defined but can be broadly categorised as a linear area extending several kilometres from the north of Pan Sand heading west along the edge of the Princes Channel (Figure 1). The recovered assemblage is closely dated suggesting a cohesive deposit and comprises artefacts that are generally much bulkier than the samian ware assemblage. Two marine geophysical surveys were conducted by the ADU in 1998 and 2002 (including c. 1km^2 of MBES and SSS in the latter survey to the north of Pan Sand, in the broad area where the London 555 amphora filled with c. 6,500 olive pits was reportedly recovered (Sealey and Tyers 1989)). The Pan Sand area was excluded from Roman Shipwreck project surveys owing to budgetary constraints and its location on the edge of the main shipping channel. Pan Sand has been excluded from the current proposal as the search area is less well defined so any search would be more speculative, and it had already been investigated by the ADU in 1998 and 2002. However, contact has been maintained with the fisherman that recovered material from this source who are still working from Whitstable, so they could be re-interviewed to narrow the search area, if this was deemed appropriate.

Second century AD Pudding Pan assemblage

The Pudding Pan area was widely assumed to have been exhausted as it was believed that Roman finds were few (e.g. Evans 1981, 527), which may explain why this assemblage has received such little attention from samian specialists; this assemblage has now reached a statistically significant mass with an unusually high proportion of complete or near-complete plain samian vessels. There is a pressing relevance here, as the stamped samian assemblage from Pudding Pan has been a central reference point for dating excavated second century samian groups and, crucially, sites in Britain and abroad throughout the past one hundred years (e.g. Tyers 1996; Dickinson and Hartley 2000). Detailed analysis of the wear and damage, coupled with assessment of the rate at which artefacts have been recovered, suggests that the main second century source represents a significant and cohesive buried deposit of plain samian wares, thereby forming an important but missing link in the samian supply chain (Walsh 1998; 2006; 2017). The cachet of Pudding Pan is further enhanced not only by the rarity of these site-types throughout the Empire, and complete absence of such sites in northern European waters, but also by the quantities of complete or near-complete vessels that have been recovered. The artefacts, recovered to date, rank the Pudding Pan site as the second most important samian wreck site empire-wide and only the third potential Roman shipwreck from a maritime context ever investigated in northern Europe. Consequently, Pudding Pan can now be considered one of the most significant samian assemblages throughout the Empire.

Since 1998, a series of attempts have been made to locate the second century AD wreck based upon the analysis of literary sources, fishermen's find locations (as stated in Walsh 2006), and most significantly, controlled dredging that recovered four Roman artefacts. This dredging produced the largest number of Roman artefacts ever recovered intentionally from the site throughout 300 years of investigation. In the late 1990s geophysical surveys, using SSS and a marine magnetometer, were conducted within two large target areas (measuring 30km^2) with c. 30 of the most promising anomalies subsequently ground-truthed using diver survey (Walsh 1998) (Figure 6 and 7). The ADU, accompanied by one of the co-authors, undertook a small SSS and marine magnetometer survey (0.32 km^2) in 2002 within this area in tandem with their investigations to the north of Pan Sand (Figure 2).

Significance of the Pudding Pan and Pan Sand sites

The research on the Pudding Pan and Pan Sand sites demonstrates that this area of the seabed still retains high archaeological potential for the recovery of an *in-situ* samian ware assemblage (and associated transport vessel) from the seabed, and any discoveries associated with this site would be of international importance (Dunkley 2012: 5). Such discoveries would directly address a number of key research questions, for the Roman period, highlighted in the recently published Maritime Archaeological Research Agenda for England (Walsh *et al.* 2013):

- Can potential Roman shipwreck sites be identified in northern European waters?
- Could a multidisciplinary approach reveal the full potential of particular sites and areas to yield further finds and thereby reveal further wreck sites?
- Could a corpus of British maritime finds be used to identify concentrations of similarly dated material for further investigation?
- What can be learned from greater investigation of the link between pottery and trade through the discovery of more wrecks / cargoes?
- Was pottery traded in its own right or was its distribution dependent upon the trade in more valuable commodities?
- Pottery is used as a proxy for more valuable trade but is it a true reflection? What evidence is there for the use of other containers?
- Can work practices, spatial organization and material culture onboard be identified? Is it possible to understand Roman shipboard society and even 'mariner' lives and identities?

The archaeological potential of this area, especially the continued recovery of Roman artefacts from the seabed by fishermen, led to a desk-based study of available geophysical datasets conducted in 2014 by members of the University of Southampton (Walsh *et al*. 2014).

2014 Desk-based study – geophysical datasets

Since the limited investigations of the seabed in the late 1990s the area surrounding Pudding Pan has been subject to a series of high-resolution investigations relating to marine infrastructure development (London Array and Kentish Flats Offshore Wind Farms (OWF)) and high-resolution multibeam bathymetry surveys of the coastline for navigational purposes. As a result, a great volume of data has been generated in the last 10 years across the original 30km^2 study area. This provides an ideal resource with which the possible location of the Pudding Pan assemblage can be assessed. A desk based assessment was conducted in 2014 by members of the University of Southampton (Walsh *et al*. 2014). A large body of existing bathymetric datasets was collated covering the study area (Figures 3 and 4). Sources of data include:

- 2010 Maritime and Coastguard Agency (MCA) (HI1339) Thames Estuary and Dover Strait (2m SB);
- Port of London Authority (PLA) main survey data for areas: 201 (1996), 202 (2003), 204 (2005), 218 (1994 & 2010), 219 (1994 & 2010) and Periodic 229 (2012) and 236 (2013);
- Kentish Flats OWF: 2005 swath bathymetry, 2006 post-construction debris survey and 2008 6th bathymetry survey; and
- London Array OWF: 2012, 2013, 2012, 2014 and 2015 export cable swath bathymetry survey.

Previously identified geophysical anomalies with archaeological potential, associated with the construction of the Kentish Flats OWF (array and export cable) and London Array OWF (export cable), were collated, along with geophysical anomalies identified during the 1998 and 2001 SSS surveys of the areas undertaken by University of Southampton. Data from the MCA and Kentish Flats OWF (2006 and 2008 surveys) provided continuous coverage (where surveyed) at 1-2m bin resolutions. Data associated with the London Array OWF is also known to have provided continuous coverage along the export cable corridor, with available bin size resolution 0.25m in later surveys. One hundred per cent data coverage was not available within the remainder of the PLA datasets and some of the Kentish Flats OWF bathymetric data, with datapoint spacing up to 20m (see Figure 5 for examples). The PLA data coverage was generally discontinuous, with survey lines spaced c. 100m apart (due to the shallow water depths) and seabed coverage associated with each line often only 20-30m wide. As a result much of the bathymetry for the PLA area is based upon interpolated data with no survey providing 100% coverage of the central Pudding Pan area.

2014 Desk-based assessment results

Analysis of the available geophysical datasets confirmed a notable reduction in the area within which Roman material might be recovered. The construction of the Kentish Flats and London Array OWFs has resulted in a concerted study of the seabed within their respective areas of impact over a number of years, along with the generation of multiple datasets, seabed installations and dredging programs. None of these interventions have identified any material likely to be Roman in origin. In addition, re-evaluation of the bathymetry data, generated by these two schemes, has not yielded any anomalies likely to be associated with Roman finds. It can therefore be reasonably assumed that the areas around both OWF developments can be classified as having low archaeological potential for the recovery of Roman material associated with the Pudding Pan site. Consequently, a sizeable proportion within the west and south of the Pudding Pan study area can be omitted.

Analysis of the PLA dataset has yielded a number of geophysical anomalies, most frequently on the eastern side of Pudding Pan where data coverage is greatest and additional survey coverage is available from the London Array OWF export cable route. Within the Pan Sand area, where data coverage was available for most of the study area, a series of geophysical anomalies have also been identified in the PLA bathymetry datasets. Several of these coincide with those identified during the

2001 SSS survey conducted (Figure 6) and subsequently dived by members the University of Southampton (Figure 7), including the ‘barrel’ wreck at ETRS89 UTM31N 373500 5703080. The remaining geophysical anomalies from this area are most frequently associated with small targets within the base of bathymetric ‘deeps’ and most probably attributable to non-archaeological geological features protruding above the seabed.

Within the remainder of the Pudding Pan area the PLA data coverage is discontinuous. However within the data available it was still possible to identify a number of clear bathymetric features. Centred on Pudding Pan there is an area of deeper bathymetry (c. -5m Chart Datum (CD)) aligned east-west, while either side the bathymetry rises to c. -3m CD in the north and south. This bathymetric low measures c. 200m wide at its eastern extent, widening to c. 700m in the west where it coincides with the Kentish Flats OWF export cables (as shown in Figure 8). This bathymetric feature coincides with the southern-most area identified from oral accounts as yielding Roman material, including one find spot reported by a local fisherman who is fairly certain of the location from which the material was recovered (Figure 8). The dredging programme, undertaken by the British Museum and the University of Southampton, also yielded a number of Roman artefacts from the margins of this bathymetric low (Figure 9). Diver investigations in the vicinity of this low were focused to the west (drift dives) on the sonar anomalies identified in 1998 (Figure 10). Anomalies investigated along the northern edge of this bathymetric low were predominantly identified as geological rather than cultural in origin. However, one of the drift dives recovered an isolated samian sherd: the first time that divers have located any Roman artefacts on the seabed in this vicinity.

In addition to the cluster of known archaeological finds from this area there are taphonomic reasons to investigate this area of the seabed. The fact that well preserved Roman finds, including samian ware, have continued to be recovered from this area over the centuries implies that there must be a source of material that is, at the very least, partially buried and (to a limited extent) protected from continued dredging. This is attested by the different preservation conditions of the samian ware recovered, showing that pottery is stacked in different orientations with only partial exposure on the seabed. For well-preserved Roman material to have been continuously recovered from the seabed, over a 300 year period, it would suggest that there must have been a slow exposure of the source material on the seabed. For such a process to have taken place it is most likely that this assemblage is associated with an exposed face such as at the edge of a sand bank. Consequently, areas of the seabed where such exposure patterns occur may be considered of higher archaeological potential. As a result, an area of 1.2 km^2 has been identified, coinciding with the greatest concentration of archaeological material [whose location can be estimated] within which *in situ* Roman material might be recovered (Figure 11; coordinates stated in Table 1).

Table 1: Boundary coordinates for area of archaeological interest.

Easting ETRS89 UTM 31N	Northing ETRS89 UTM 31N
368865	5699540
370580	5699540
370580	5700240
368865	5700240

The notable reduction in the area of highest archaeological potential, from an initial 30 km^2 to a well-defined area of 1.2 km^2, informed by interviews with fishermen (Walsh 2006) and analysis of existent geophysical data, means that targeted investigations, to source any Roman assemblages, is now feasible. Progression in techniques for the collection, processing and interpretation of high resolution marine geophysical survey data, since the surveys conducted in the 1990s and early 2000s, has meant that new analytical techniques of multi-sensor datasets can be used for archaeological purposes (Plets et al. 2013).

Current project

Discussions of the results of the desk based assessment with the Historic England Maritime Designation team resulted in an invitation to submit a project design for a targeted survey of the identified study area. The project design was written for Historic England in October 2014 who expressed that they would like to take this project forward, in principle, in November 2014, with commissioning taking place in February 2015.

Aims and objectives

Project aim:

- To investigate the defined study area using the high-resolution geophysical survey techniques in order to identify locations that may be the source of the later 2nd century assemblage.

Objectives

The project will:

1. Obtain high-resolution marine geophysical seabed data from an area of the Pudding Pan where current data coverage is sparse.
2. Analyse all data recovered to identify geophysical anomalies suitable for targeted investigation.
3. Determine the archaeological potential of the identified study area, within Pudding Pan, for the recovery of Roman materials.
4. Outline any recommendations for further investigations at the site.

Survey preparation

The project partner for the study was the Port of London Authority (PLA) who acted as a sub-contractor to undertake the survey and data acquisition. They were chosen as they were best placed to undertake the work as they are locally based, were able to deploy at short notice, and have an intimate working knowledge of the local area including tidal conditions within the relatively shallow waters of the study area.

Due to the shallow water depths over the study area the date for the geophysical survey was determined by the occurrence of favourable tidal and weather conditions at the site. The project team liaised closely with the PLA with conversations typically a week in advance of each survey window to assess the long-range forecasts with reconfirmation made in the final days running up to the proposed survey and the final call made the evening before deployment. Weather conditions during the early summer consisted of a perpetual influx of unseasonal low pressures leading to unfavourable conditions and postponement of the survey on five occasions:

- 20 - 21 April 2015
- 5 - 6 May 2015
- 18 - 19 May 2015
- 4 - 6 June 2015
- 17 - 19 June 2015

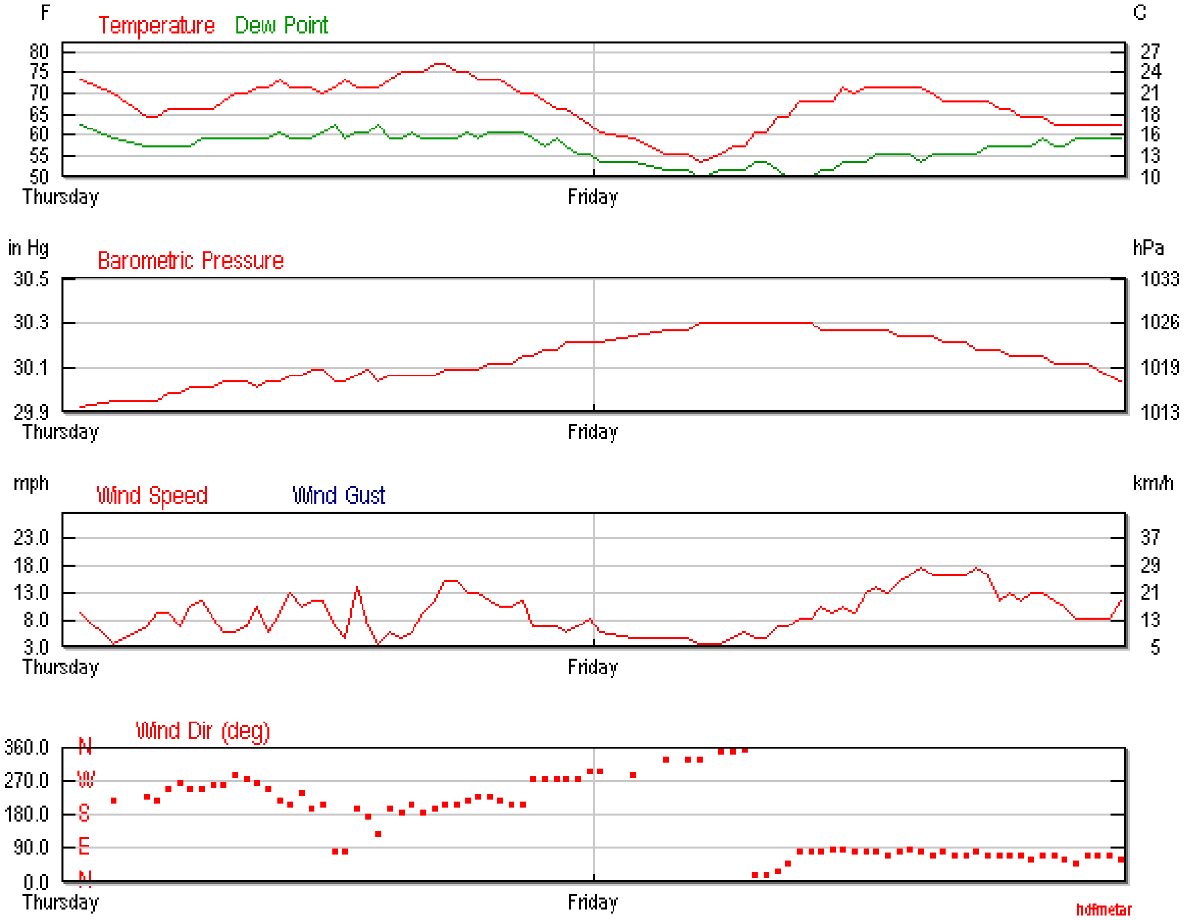
The next window of opportunity occurred 2 - 4 July 2015. On 25 June 2015 the long-term weather forecast promised favourable conditions. On 29 June 2015 the forecasts confirmed that conditions remained within operational parameters so the survey was escalated to 'Go Mode' with further confirmation on the 30 June 2015 as the forecasted conditions remained stable.

July 2015 survey

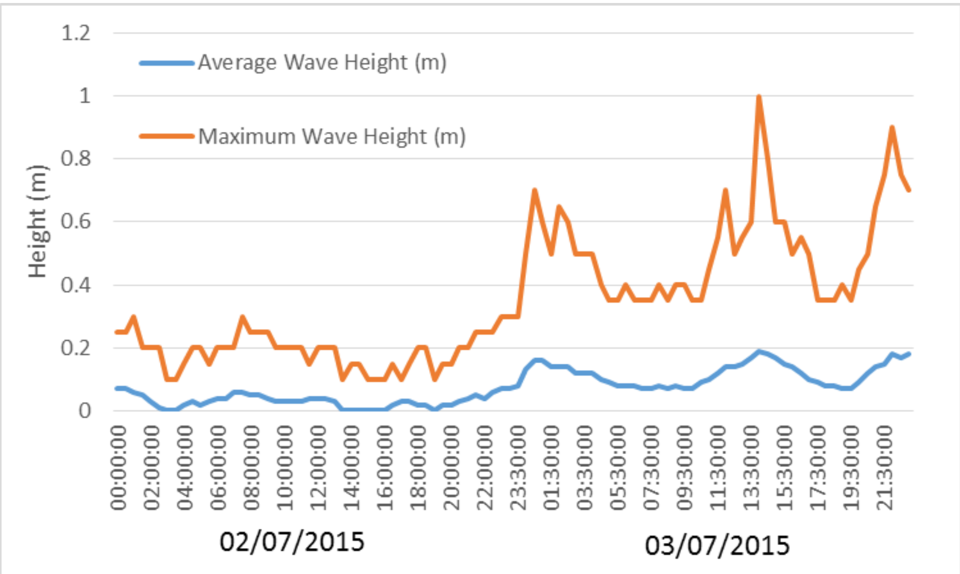
Surveying took place aboard the PLA survey vessel *Yantlet.* Positions were established using an Applanix POS MV-GNSS in PPK mode. The MBES survey was conducted using a Reson Teledyne SeaBat 8125H. The SSS survey was conducted using a dual frequency (325/780kHz) C-Max CM2 Digital EDF towfish. The survey was timed to coincide with high water over the study area timed at 13.15 Greenwich Mean Time (GMT) on 2 July and 14.00 GMT on 3 July. The *Yantlet* was berthed at Gravesend and made passage to the study area on each survey day. Operating times were:

- 02/07/15:- Departed Gravesend 08:48 – Returned 19:06
- 03/07/15:- Departed Gravesend 08:54 – Returned 19:12

The area was initially surveyed with MBES to ensure clear runways for the SSS which was then run to ensure complete coverage (200%; survey lines shown in Figure 12). Weather conditions (see below) and sea state deteriorated through the afternoon of Friday 3 July 2015, as the wind veered from the west towards the east by midday, and it became increasingly difficult to maintain the vessels heading and the wave height was impacting upon the quality of the MBES data quality. At 15.41 a collective decision was reached to terminate the survey, with MBES seabed coverage totalling 1.09 km^2 equating to c. 90% coverage of the study area. Consequently, there were eight survey lines remaining to be surveyed in order to achieve 100% MBES coverage (see Figure 12 and 13 for MBES coverage). Lines were taking 10-15 minutes to run, allowing for infill and ancillary survey operations (i.e. sound velocity profiles (SVP)), meaning that an additional 2.5-3 hours on site would be required to complete survey operations, depending on sea state and tide.



Weather conditions for Whitstable on Thursday 2 and Friday 3 July 2015

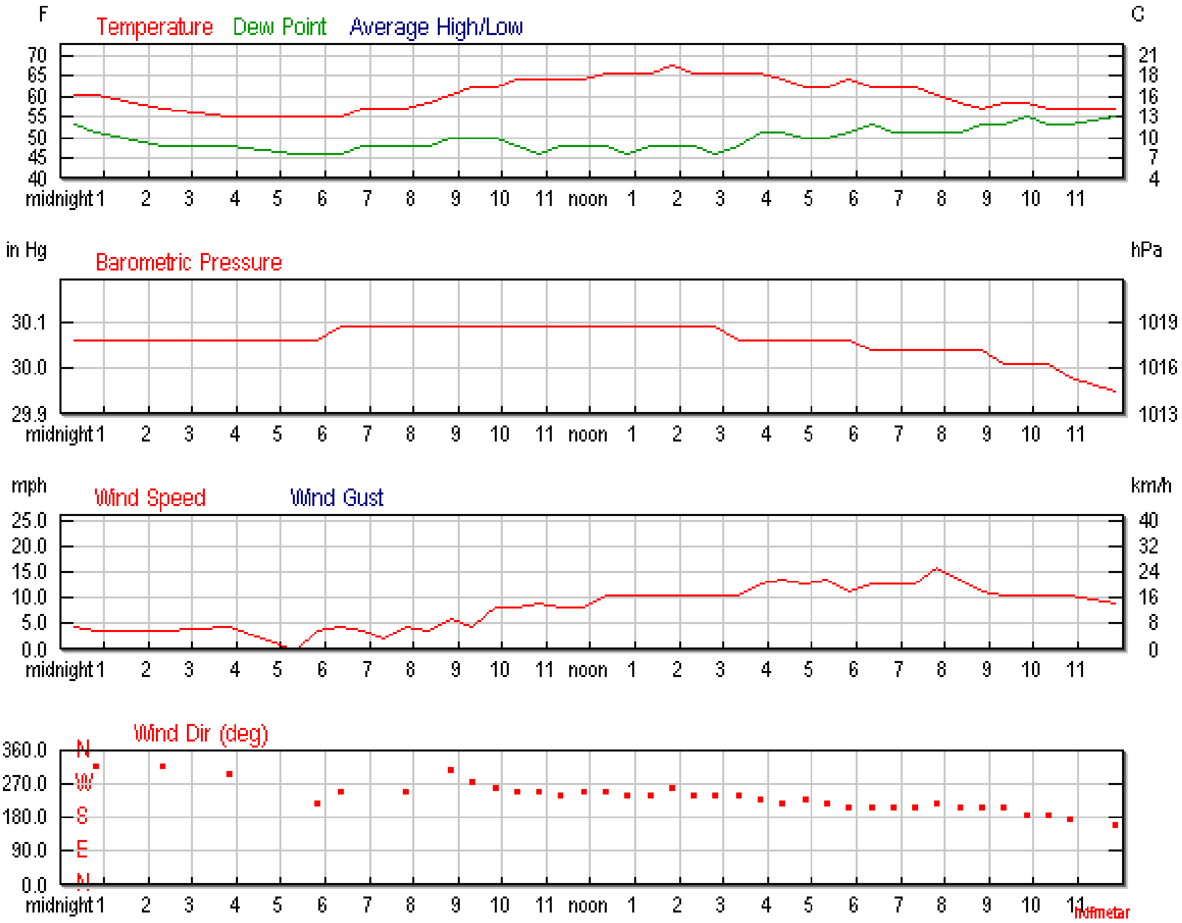


Wave data from the inshore Herne Bay wave buoy (WGS84 51° 22.919' N 001° 06.934' E) on Thursday 2 and Friday 3 July 2015. Data derived from http://www.channelcoast.org

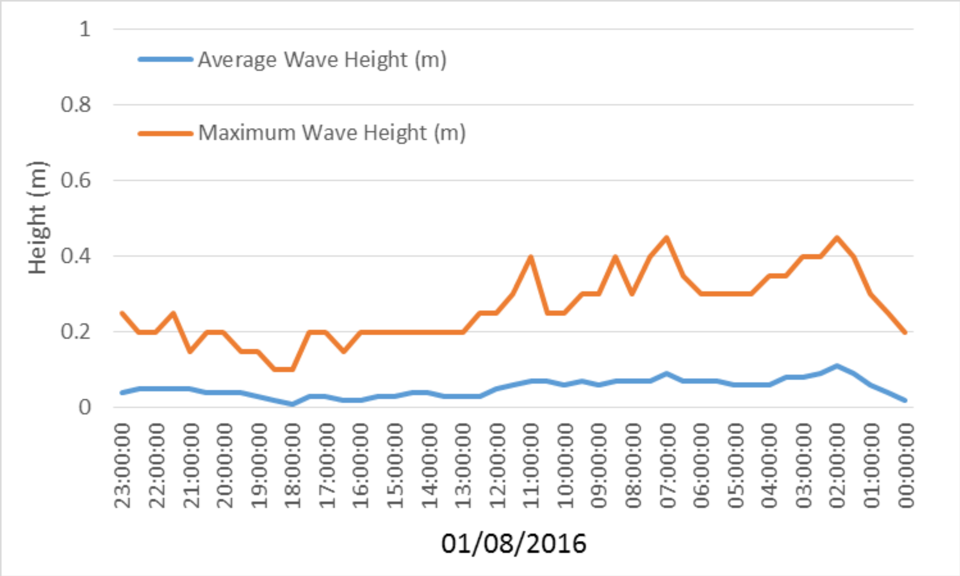
August 2016 survey

The 2016 survey was undertaken aboard the PLA survey vessel *Maplin* on 1 August 2016. Positions were established using an Applanix POS MV-320 in PPK mode. The MBES survey was conducted using a R2Sonic 2024 multibeam echo-sounder. The survey was carried out during daylight hours and timed to coincide with high water over the study area at 10.59 GMT.

Weather conditions (see below) and sea state were good throughout the survey period allowing coverage of the eight outstanding survey lines. This survey provided seabed coverage of 0.64km^2 including 0.43 km^2 MBES overlap with the preceding 2015 MBES survey.



Weather conditions for Whitstable on Monday 1 August 2016



Wave data from the inshore Herne Bay wave buoy (WGS84 51° 22.919' N 001° 06.934' E) on Monday 1 August 2016. Data derived from http://www.channelcoast.org/

Data processing and archive

MBES and backscatter data were processed by PLA hydrographers with SSS processed by COARS, University of Southampton. Primary data manipulation of the bathymetry data included:

- Application of offsets after patch test
- Application of sound velocity profiles
- Tidal corrections
- Data edited for spurious points: water-column noise, depth soundings below the seafloor, navigation errors and invalid motion reference unit values. Points or whole swaths are rejected or adjusted for tidal mismatches. Rejection of low amplitude (noisy) data at the far offsets (outer beams) was also typically necessary.

All data was delivered in ETRS89 UTM 31N. Online global positioning system (GPS) positioning for navigation was corrected using European Geostationary Navigation Overlay Service (EGNOS), reference to ITRF2000 datum, though all survey GPS data was post-processed and referenced to ETRS89. The depth datum was converted to Chart Datum (approximately Lowest Astronomical Tide: LAT) using UKHO Vertical Offshore Reference Frame (VORF).

Archaeological interpretation of the collected marine geophysics dataset has followed the guidelines of Plets *et al*. (2013). The processed marine geophysical data (bathymetry and SSS) has been analysed within Coda Survey Engine v.4.3.3 and ESRI ArcGIS 10.3.1 software. ASCII xyz bathymetry data was converted into raster files, at 0.25m bin size (Figures 13, 15 and 17), to allow additional data manipulation techniques such as hillshade representation, slope analysis, and aspect analysis and display. PLA reported that the survey conditions on the second day of the 2015 survey became severe enough that some motion artefacts started to become apparent in the data. For this reason a combined ASCII xyz of both 2015 survey days was produced in addition to separate ASCII xyz files for each survey day so that the datasets could be interrogated independently.

The SSS was completed with the required coverage on day one of the 2015 survey with data provided in .xtf format together with the online logs providing details of layback. This was processed at COARS within CODA Survey Engine 4.3.3. Processing included:

- initial-signal manipulation to remove the water column;
- addition of a time variable gain (TVG) to increase the signal level at later time offsets from the original pulse;
- slant-range correction to correct to true ground distances;
- speed compensation for survey speed variation; and
- beam-angle correction for compensation from a decrease in beam intensity with range due to decreasing grazing angles and signal attenuation.

SSS coverage is shown in Figure 18. The SSS and bathymetry datasets were carefully studied by a trained maritime archaeologist to identify possible seabed anomalies with archaeological potential. Each anomaly has been cross-referenced between the different datasets, assigned a unique identification, had its position recorded and a description of the anomaly made. Existent datasets, included those from Walsh (2006), have also be compared to each identified anomaly. All positions are given in ETRS89 UTM Zone 31N.

General description of the study area

The bathymetric survey confirms the general form of the seabed bathymetry suggested by the interpolated 2010 PLA survey data. This consists of an east-west aligned area of lower seabed in the middle and east of the study area c. 200-250m wide (north-south), down to -4.8m CD, and c. 1m deeper than the surrounding seabed. In the west of the study area this area of lower seabed altitude both increases in width (c. 475m north-south) and depth, down to -5.5m CD at its deepest point. These two basins are separated by a shallow ridge aligned NW-SE. The seabed consists predominantly of straight to sinuous asymmetrical small ripples aligned north-south and a cross-profile suggesting westward migration (Figure 19). These are most prevalent in the east of the study area.

Within the 2015 survey data there is a large north-south aligned bedform complex within the centre of the study area, centred on 370075 5699775. This measures c. 200 x 20m reaching a maximum elevation of -3.09m CD (Figure 20). This feature generally stands c. 1m proud of the seabed and consists of a central core of 4-5 asymmetrical ripples with an individual wavelength of 4-5m and amplitude of up to 4m. There is only one instance of this feature within the study area. However similar bedform complexes are found further south, beyond the study areas, centred on 370040 5699160 and 369925 5698970 suggesting a discontinuous, probably migratory, natural feature within the wider marine environment. To the west of this feature the seabed becomes predominantly smooth with any bedforms present generally less than 0.1m in height (Figure 19).

Within the 2016 survey data the large bedform is seen to have migrated westwards by up to 30m, now centred on 370044 5699780 (see Figure 21). This is most clearly demonstrated by the bed level change in the area of overlap between the 2015 and 2016 surveys (Figure 22). This westward migration has revealed the seabed below the 2015 position of the bedform, and has shown that there are no geophysical anomalies present in this location. Within the south of the 2016 survey area, centred on

370100 5699560, there appears to be a second large bedform beginning to encroach on the study area with the northern 'tip' measuring 63 x 40m.

A comparison between the previous 2010 PLA survey of the area and the 2015 bathymetric survey also helps to indicate areas where there have been changes in the seabed elevation over this five year period. While the 2010 dataset has sparse coverage compared to the most recent survey, it does seem to suggest that the seabed has remained relatively stable with only minor bed level reductions. The main change in site elevation appears to correlate with the large bedform complex in the centre of the study area which, as demonstrated by the comparison between the 2015 and 2016 datasets, is highly mobile.

Features with archaeological potential

Analysis of the 2015 and 2016 survey datasets has identified nine geophysical anomalies with archaeological potential. The distribution of these anomalies is shown in Figure 23 and consists of four anomalies (UoS_bathy_01-04) derived primarily from the bathymetry data (Figures 24 to 27) and seven from the SSS data (UoS_SSS_01-07: Figures 28 to 36). Each anomaly is described below and summarised in Table 2.

Bathymetric anomalies

UoS_bathy_01 – Figure 24

Centred on 369507 5700016 and observed in the 2015 bathymetry survey. Consists of an east-west aligned depression measuring 6 x 1m and up to 0.15m deep. Towards its western end there is a clearly defined point of elevation measuring 0.9 x 0.9m and up to 0.13m high. The anomaly is visible in the SSS as a small linear dark reflector measuring 2 x 0.3m with a 4m shadow on its southern side. There is no corresponding anomaly visible in the 2015 backscatter data covering this area and there was no coverage in the 2016 bathymetry survey. The seabed is c. -4.2m CD in this location.

UoS_bathy_02 – Figure 25

Centred on 369983 5699559. Consists of a circular depression measuring 7.2 x 6.8m and up to 0.3m deep. On its south-western side is a small point of elevation measuring 0.8 x 0.8m which could indicate the presence of a physical obstruction. It is identified in both the 2015 and 2016 bathymetry surveys and comparison between the two suggests it has not changed its shape or dimensions. Comparison between the 2015 and 2016 surveys also suggests the seabed level has not changed significantly. This is the only circular depression feature located within the study area. The feature is clearly visible in the SSS as an area of disturbance, interrupting the parallel north-south aligned bedforms, with a clearly defined circular depression and area of increased dark reflectors along its western edge corresponding with the raised edge visible in the bathymetry. The clearly defined shape of this anomaly, and apparent absence of any central anomaly, could suggest another possible source for this depression, such as a compaction feature (very similar shape and size to spudcan footprints on the seabed) or possibly a crater left by exploded ordnance. The seabed is c. -3.85m CD in this location.

UoS_bathy_03 – Figure 26

Centred on 369556 5699662. Consists of a linear alignment of at least 12 small geophysical anomalies, no larger than 2 x 1m, spread over an area measuring c. 30 x 6m and aligned WNW-ESE. Elevation of the anomalies above the local seabed is rarely greater than 0.2m. This alignment of anomalies appears to be along a slight promontory of elevated seabed at c. -4.7m CD, with the seabed to its north, east and south typically 0.15-0.20m deeper. It was only covered by the 2016 bathymetry survey. The SSS shows a linear alignment of light reflectors on the seabed coinciding with some poorly defined dark anomalies. No corresponding features are present in the 2016 backscatter. Comparison between the 2015 and 2016 surveys also suggests the seabed level has not changed significantly. These anomalies are near UoS_bathy_04, c. 60m southeast, and UoS_SSS_05, c. 100m southeast, as shown on Figure 34.

UoS_bathy_04 – Figure 27

Centred on 369626 5699583. Consists of a linear alignment of at least six small geophysical anomalies, no larger than 1 x 0.5m, spread over an area measuring c. 7 x 4m and aligned approximately east-west. Elevation of the anomalies above the local seabed is rarely greater than 0.15m. This cluster of anomalies appears to be located at the northern end of a slight promontory of elevated seabed at c. -4.1m CD, with the seabed to its north, east and west typically 0.15-0.20m deeper. It was only covered by the 2016 bathymetry survey. Within the SSS an area of increased seabed surface roughness is visible but no clearly defined protruding anomalies are visible. There were no clearly defined anomalies within the 2016 backscatter. Comparison between the 2015 and 2016 surveys suggests the seabed level has not changed significantly. These anomalies are near UoS_bathy_03, c. 100m northwest, and UoS_SSS_05, c. 40m northwest as shown on Figure 34.

Side Scan Sonar anomalies

UoS_SSS_01 – Figure 28

Centred on 370350 5699833. Consists of a linear alignment of dark reflectors perpendicular to bedforms measuring 1.4 x 0.7m. The anomaly was verified in an adjacent SSS survey line. This anomaly correlates with a localised breakdown in the bedform pattern within the 2015 bathymetry survey and was still present in the 2016 survey, which shows the seabed at c. -4.3m CD. Comparison between the 2015 and 2016 bathymetry surveys indicated a westward bedform migration of c. 2m between the two surveys, but the bathymetric anomaly is visible in both datasets: this might suggest the presence of a small obstruction on the seabed. This anomaly is near UoS_SSS_03, c. 20m north, and UoS_SSS_04, c. 70m west.

UoS_SSS_02 – Figure 29

Centred on 370573 5699713. Consists of a series of interconnecting angular dark reflectors covering an area of 2.2 x 3.6m. The anomaly was verified in an adjacent SSS survey lines. The anomaly is clearly differentiated in the SSS from the surrounding seabed which shows clearly definable north-south aligned bedforms. The 2016 bathymetry survey, which subsequently covered this area, does not show any clearly defined bathymetric features with which the SSS anomalies could be associated. Comparison between the 2015 and 2016 surveys also suggests the seabed level has not changed significantly. The seabed is c. -4.1m CD, dipping to the NW where it deepens to -4.7m CD.

UoS_SSS_03 – Figure 30

Centred on 370353 5699853. Consists of a cluster of small angular dark reflectors, covering an area of 5.3 x 3.6m. Some reflectors exhibit evidence of shadow on their southern side suggesting elevation above the surrounding seabed. This anomaly indicates the presence of an obstruction on the seabed. There is no defined anomaly in either the 2015 or 2016 bathymetry surveys that cover this area. These show a series of north-south aligned bedforms which have migrated westwards c. 2.5m between the two surveys. There are no anomalies in either set of backscatter data. The seabed is c. -4.25m CD in this location. This anomaly is near UoS_SSS_01, c. 20m south, and UoS_SSS_04, c. 70m west.

UoS_SSS_04 – Figure 31

Centred on 370283 5699847. Consists of a dispersed assortment of three angular dark reflectors, the largest and most distinct measuring 3 x 0.2m with evidence of shadow on the southern side suggesting elevation above the surrounding seabed. These anomalies lie on the edge of the 2015 bathymetry coverage but are encompassed by that obtained in 2016. This failed to identify any features on the seabed which might be associated with the SSS anomalies. There are no anomalies in either set of backscatter data. The two bathymetry datasets show a westward migration of bedforms, which between 2015 and 2016 have veered from west to WSW, and have migrated c. 3m over this period. The seabed in this location is c. -4.42m CD. This anomaly is near UoS_SSS_01 and UoS_SSS_03, c. 70m east.

UoS_SSS_05 – Figure 32 and 33

Centred on 369605 5699616. Consists of a clearly defined angular dark reflector, c. 1 x 0.6m, with a large shadow (4m) on its southern side, indicating elevation above the surrounding seabed. This anomaly was located on the edge of the 2015 bathymetry coverage but is fully encompassed within the 2016 bathymetry survey. The SSS anomaly is probably associated with a single rectangular anomaly measuring 2 x 0.8 x 0.2m at 369616 5699616, c. 10m east of the calculated position from the SSS, which is also visible within the 2016 backscatter. To the north and west of this anomaly are a cluster of up to 20 smaller angular anomalies scattered over an area c. 20 x 7m. Along the top edge of this cluster the seabed slopes northwards, declining from c. -4.3 to -4.6m CD. Comparison of the bathymetry either side of these anomalies, where both 2015 and 2016 coverage is available, demonstrates no change in the seabed elevation. These anomalies are near UoS_bathy_03, c. 60m northwest, and UoS_bathy_04, c. 40m southeast, as shown on Figure 34.

UoS_SSS_06 – Figure 35

Centred on 370673 5699693. Consists of a diffuse rounded contact measuring 5.5 x 1.6m. It is located east of the main study area and was encountered at the start of one of the SSS survey lines, outside of the study area. There is no bathymetry coverage of this location from either 2015 and 2016 surveys. There are a number of depressions between bedforms, of similar shape and dimensions, to those identified within the SSS to the east and south within the available bathymetry. However these are orientated north-south, whereas the feature in the SSS appears to be east-west orientated (parallel to the survey line) with no significant depth to replicate the inter-bedform features nearby. The seabed elevation to the south of the anomaly is c. -3.97m CD.

UoS_SSS_07 – Figure 36

Centred on 370290 5699596. Consists of a dark reflector covering an area of 3.9 x 2.5m. The anomaly was verified in an adjacent SSS survey line. Within the 2015 and 2016 bathymetry there is a small depression 8m east of the SSS location (at 370298 5699595) measuring 3 x 2.8m with a small elevated contact in the centre measuring 1 x 0.8 x 0.07m. This anomaly correlates with areas of localised breakdown in the bedform pattern and has a clearly defined contact within its centre visible in both surveys, indicating the presence of a small obstruction on the seabed. Comparison between the 2015 and 2016 surveys also suggests the seabed level has not changed significantly. The seabed in this location is c. -4.15m CD.

Previous finds locations

In addition to identifying new geophysical anomalies with archaeological potential, it has also been possible, for the first time, to reassess the locations of some of the Roman artefacts with good provenance against a high resolution geophysical dataset. These artefacts include material recovered from controlled dredging by the British Museum and the University of Southampton in 2002 and the find spot position provided by a local fisherman. The relationship between these finds and the newly derived bathymetry and identified anomalies is shown in Figures 37 and 38.

The find spot position provided by the local fisherman is located in an area where the MBES is available from both 2015 and 2016 surveys. The accuracy of the location of this find needs to take into account variables such as the precision of the DECCA position obtained and, as is common with all the finds recovered in fishing equipment, the positional accuracy of any material recovered. This results in a possible positional error in the order 10s metres to potentially several kilometres. Using the position with which the fisherman was fairly certain the material was derived from, within the SSS there were no clearly definable geophysical anomalies present within the surrounding area, which is also the case with the backscatter data. The available bathymetry shows a series of sinuous north-south aligned ripples with a total relief of 0.33m across the immediate area. Comparison between the 2015 and 2016 bathymetry data shows there has been negligible change in the seabed over the past year.

The 2015 and 2016 surveys have confirmed the bathymetric pattern of the area derived from the earlier 2010 PLA dataset. This shows the depression in the centre of the study area that becomes wider in the west. It has also shown that the general location of find spots, including controlled dredging, coincide with the margin of this basin. This is also true for a number of the newly identified geophysical anomalies, particularly a cluster at the eastern end of this depression (UoS_SSS_01, 03 and 04), and those associated with the eastern edge of the larger depression in the west of the study area (UoS_bathy_03 and 04 and UoS_SSS_05).

Archaeological potential

While the identified geophysical anomalies have not yet been confirmed as being of archaeological origin through site investigations (e.g. diver surveys), the 2015-16 surveys support the working hypothesis presented within the 2014 desk-based assessment that there may be taphonomic reasons for the distribution and continued recovery of finds from this area. The original hypothesis was that well-preserved Roman material has continued to be recovered from the seabed, over a 300 year period, due to slow exposure of the source material on the seabed. For such a process to take place it is most likely that this assemblage is associated with an exposed face such as at the edge of a sand bank. Such areas were therefore defined as probably having higher archaeological potential than flat areas of the seabed. The list of geophysical anomalies shows that seven of the eleven anomalies can be associated with such settings. While this does not provide direct support for this hypothesis, given no actual material has yet been recovered yet from these locations, it does at the very least suggest that further site investigation of some of the identified anomalies should be undertaken to further test this hypothesis.

The archaeological potential of each of the eleven identified geophysical anomalies is provided in Table 2. UoS_SSS_05 is identified as having high potential as it appears to consist of a spread of angular anomalies spread over c. 20m. This scatter could represent either archaeological material or natural geological features, such as boulders. However the clear concentration of such features in this area (along with UoS_bathy_03 and 04) is in stark contrast to the relatively smooth seabed visible in the surrounding area. As such UoS_SSS_05 is determined to have the highest archaeological potential of all the geophysical anomalies identified within the study area.

There are six anomalies identified as having medium archaeological potential. These consist of the two clusters of anomalies mentioned above, UoS_bathy_03 and 04, which contain smaller scatters of anomalies that appear to be more rounded than the angular anomalies visible in UoS_SSS_05. This set of three anomalies could represent component parts of the same archaeological cluster that have, over the past c.1800 years, become dispersed across this seabed as a result of processes acting upon the seabed including storms and fishing activities. The other anomalies defined as having medium potential are UoS_bathy_01, UoS_SSS_01, 06 and 07. These all consist of single isolated anomalies which may indicate small obstructions on the seabed. However unlike those defined as having low archaeological potential, these have been identified in both the SSS and bathymetry surveys and, where coverage was available, are persistently represented in both the 2015 and 2016 surveys. As such there is a greater prospect that these targets might be identifiable on the seabed during further investigation and not buried beneath bedforms.

Table 2: Location, expected size and archaeological potential of identified geophysical anomalies

Archaeological Anomaly	ETRS 1989 UTM 31N Easting	ETRS 1989 UTM 31N Northing	Depth (m CD)	Expected size / spread	Archaeological potential
UoS_bathy_01	369507	5700016	-4.2	6 x 1m. Small upright anomaly c. 0.9 x 0.9 x 0.13m	Medium
UoS_bathy_02	369983	5699559	-3.85	7.2 x 6.8 x 0.3m	Low
UoS_bathy_03	369556	5699662	-4.7	30 x 6m	Medium
UoS_bathy_04	369626	5699583	-4.1	7 x 4m	Medium
UoS_SSS_01	370350	5699833	-4.3	1.4 x 0.7m	Medium
UoS_SSS_02	370573	5699713	-4.1	2.2 x 3.6m	Low
UoS_SSS_03	370353	5699853	-4.25	5.3 x 3.6m	Low
UoS_SSS_04	370283	5699847	-4.42	5 x 5m	Low
UoS_SSS_05	369616	5699616	-4.3	20 x 7m (extending NW from coordinate)	High
UoS_SSS_06	370673	5699693	-3.97	5.5 x 1.6m	Medium
UoS_SSS_07	370298	5699595	-4.15	3 x 2.8m	Medium

Recommendations

The geophysical survey has identified a series of anomalies with archaeological potential that would warrant further investigations, particularly those rated as having medium to high archaeological potential. The area of greatest focus is likely to be the seabed surrounding UoS_SSS_05/UoS_Bathy_03 and 04. The preference for further investigation would through a diver survey at each of these locations. Unlike the geophysical survey, which required optimal tidal conditions to accomplish the survey (maximum draft under the survey vessel), a dive boat would have a much flexibility to visit the site during periods of slack water. Previous experience indicates that the greatest challenge to any dive on these anomalies is the visibility on the seabed, especially following the winter. As such the optimal time to dive, based upon previous experience in the Thames estuary, is likely to be from late May to early June 2017. The primary objective of the diver survey would be to identify the geophysical anomalies and establish whether they are archaeological, natural or cannot be located upon the seabed. For anomalies UoS_SSS_05, UoS_bathy_03 and 04 the survey will also include exploration of the seabed around the primary anomaly to determine if any of the other geophysical anomalies within the wider area might be archaeological in origin. The purpose of such a dive would be to test the archaeological potential of each anomaly and, if archaeological, assess its significance. No excavation would take place at this time, though material may be recovered for identification purposes if encountered.

Overview of project accomplishments

The project had one principal aim: investigate the defined study area using high-resolution geophysical survey techniques in order to identify locations from which the later 2nd century assemblage may have been recovered. This aim has been exceeded by not only achieving full coverage of the study area using MBES and SSS, but also managing to replicate MBES coverage of c. 36% of the study area through the separate 2015 and 2016 surveys. This study was always going to be challenged by the shallow depths of the survey area and need for suitable weather conditions. This resulted in brief windows of opportunity to survey the area, several of which were missed owing to poor sea conditions in 2015 and early 2016. This was a defined project risk from the outset and why the project was deliberately conceived in conjunction with the PLA to enable maximum flexibility in order to achieve the project aim. The opportunity to carry out two surveys has also been fortuitous as it has revealed the seabed in 2016 that was beneath the large bedform 2015, ruling out any uncertainty that the bedform could have been focused around a buried obstruction.

The high-resolution geophysical survey data obtained from the study area has resulted in the identification of a series of geophysical anomalies with archaeological potential. From the outset of the project it was clear that a fully intact Roman vessel would not be visible on the seabed and instead more subtle features on the seabed, probably of a small size and dispersed, would be the most likely material to be visible in the survey data. The geophysical anomalies visible in UoS_SSS_05, along with UoS_bathy_03 and 04, are more typical of the types of features that might have been expected should any remnant of a Roman vessel, or its cargo, be present as a nucleated assemblage on the seabed (as opposed to a jettisoned cargo across a wider area). There is a possibility that these anomalies may turn out to be natural in origin (such as a cluster of boulders) but, for the first time, they do present the best targets for a diver survey that has been established for Pudding Pan within 300 years of exploration.

It is also worth highlighting the methodology and detailed investigations that went into contextualising this site, eventually leading to the definition of the current study area. The careful work of Walsh (2006; 2017), drawing upon detailed conversations with fishermen and collectors, has significantly enhanced our knowledge of the Pudding Pan assemblage and permitted a redefined spatial awareness of where the assemblage has been derived from. This approach demonstrates how important the study of the existent archaeological collections and local knowledge can be for identifying potential sites within a marine context. The staged approach adopted throughout the life of this project, ranging from careful desk based assessment and review of the existent archive, through to targeted geophysical survey and, in due course, site investigations through divers, demonstrates an exemplar in how to approach the marine historic environment. Other projects, such as the ongoing Historic England sponsored project “Investigating the submerged Pleistocene Landscapes of the Wallet, off Clacton” (also see

Bynoe 2014), are employing a similar staged approach to identifying and investigating key offshore sites where *in situ* archaeological material may be present of international significance.

Data Archive

The bathymetry datasets collected during this project have been deposited with the UKHO national Data Archive Centre (DAC) for bathymetric surveys, accredited by the Marine Environmental Data and Information Network (MEDIN). Access to this dataset is available through the UKHO INSPIRE web portal, and is made available under the Open Government Licence.

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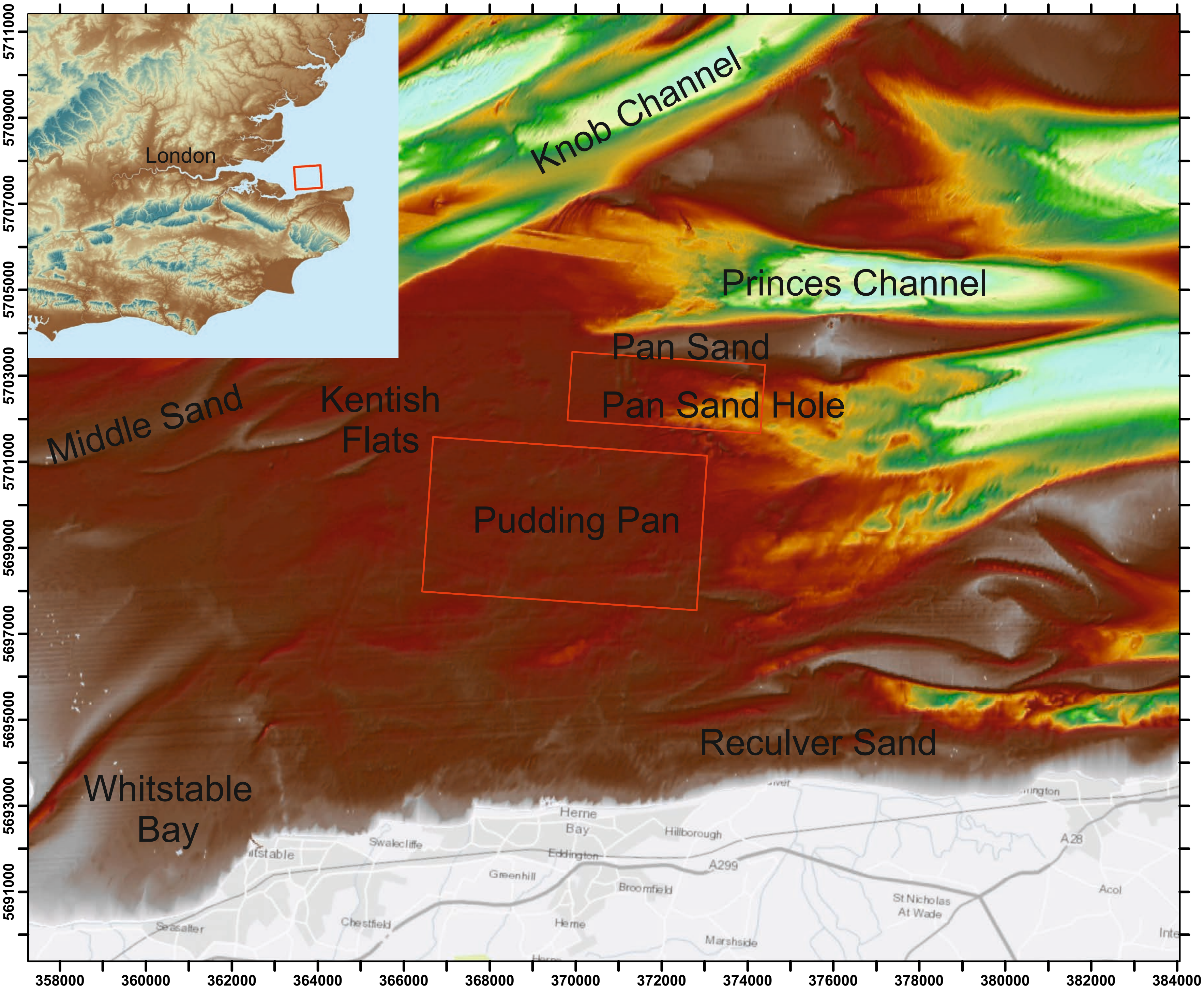

Legend

DBA Study Area

Bathymetry (m CD)
2.5
-19.4

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Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre
Bathymetry derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. Ordnance Survey data © Crown copyright and database right 2016

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Figure 1
Location of Pan Sand Hole and Pudding Pan

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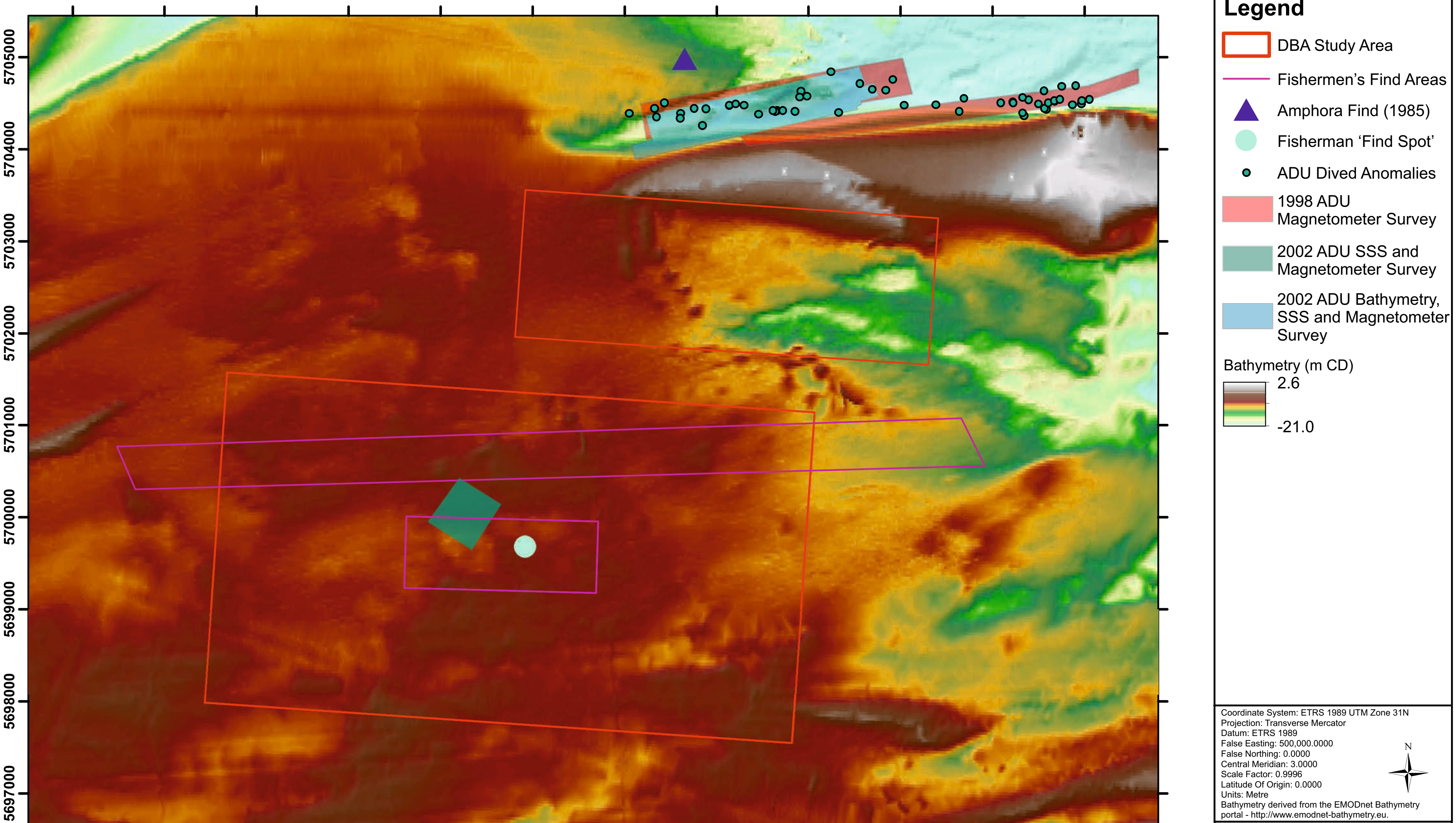

Figure 2: Areas of archaeological potential, based upon known areas of Roman finds, and ADU Investigations in 1998 and 2002

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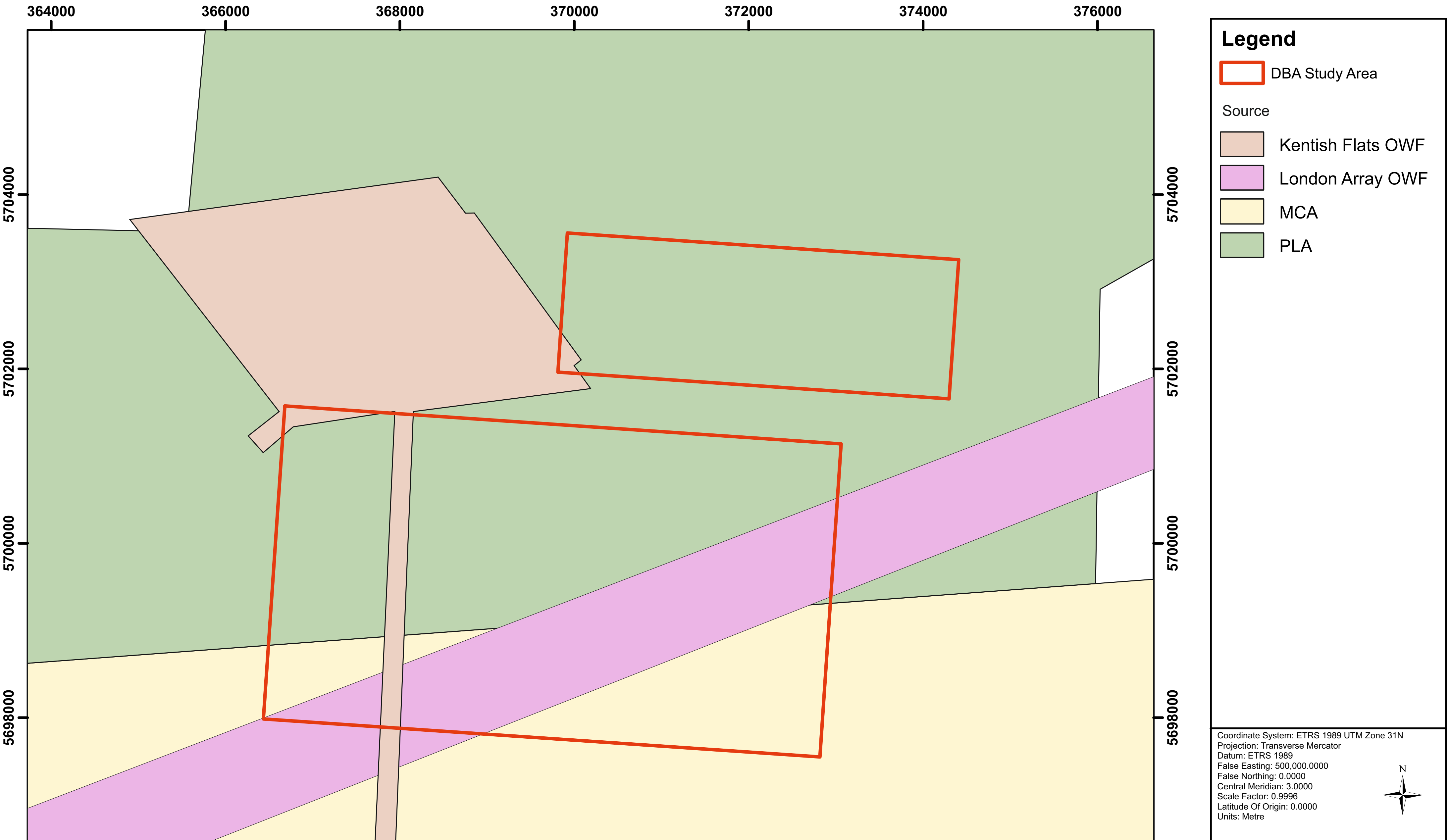

Figure 3

Sources, and coverage, of bathymetric datasets used in the desk-based study

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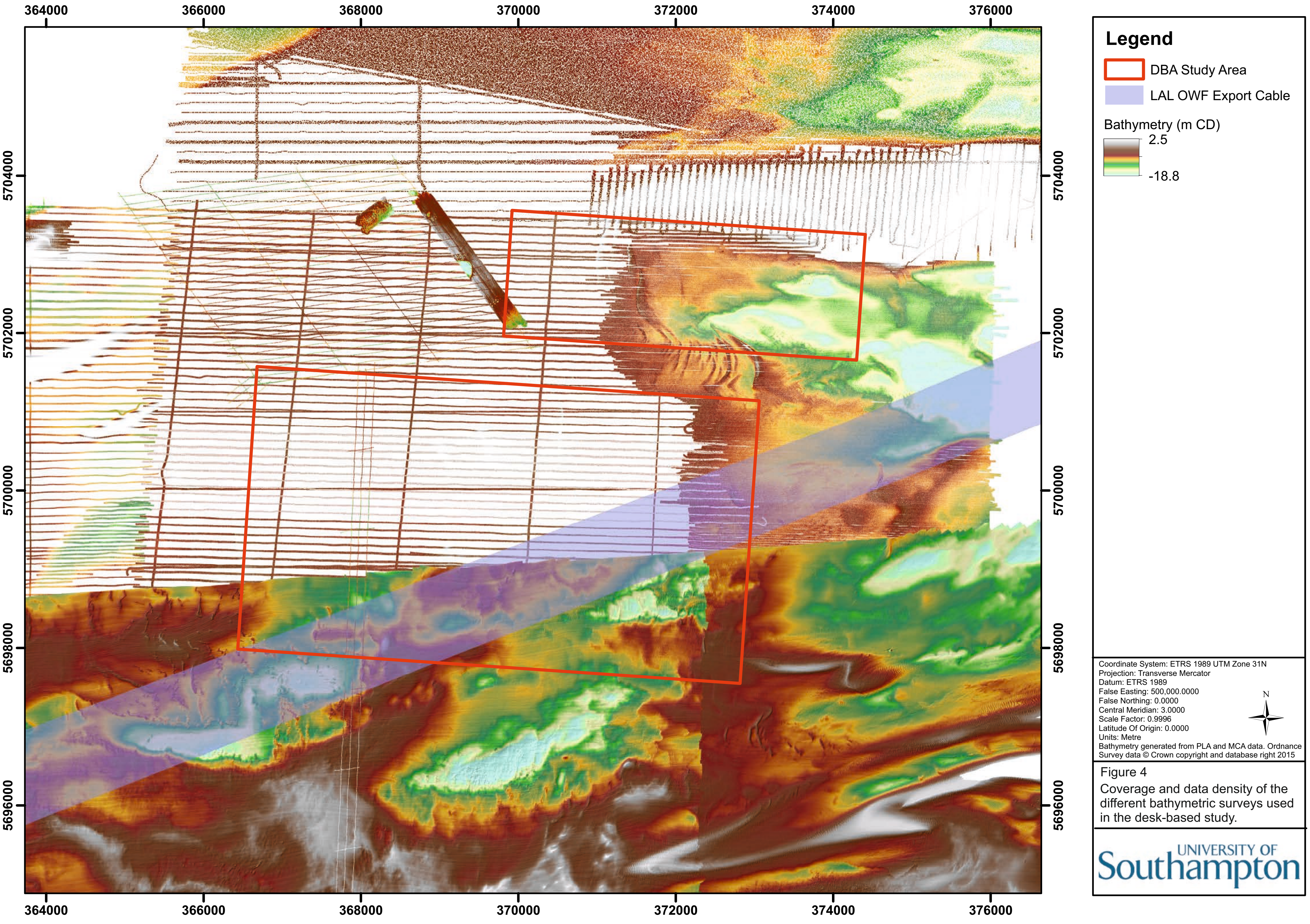

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Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre
Bathymetry generated from PLA and MCA data. Ordnance Survey data © Crown copyright and database right 2015

Figure 4
Coverage and data density of the different bathymetric surveys used in the desk-based study.

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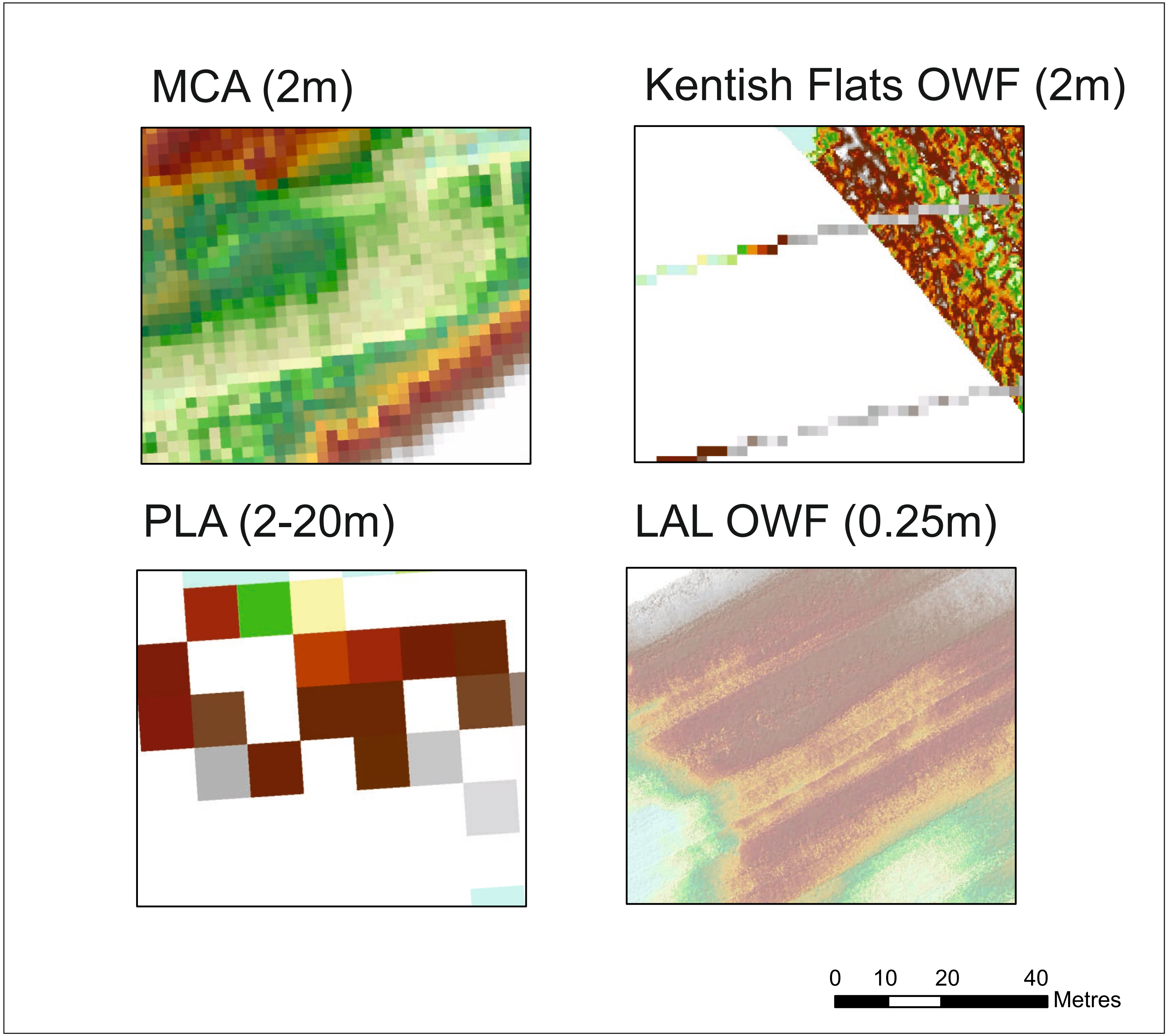

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre
Bathymetry generated from PLA and MCA data. Ordnance Survey data © Crown copyright and database right 2015

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Figure 5
Comparison of data resolution of bathymetric surveys used in the desk-based study

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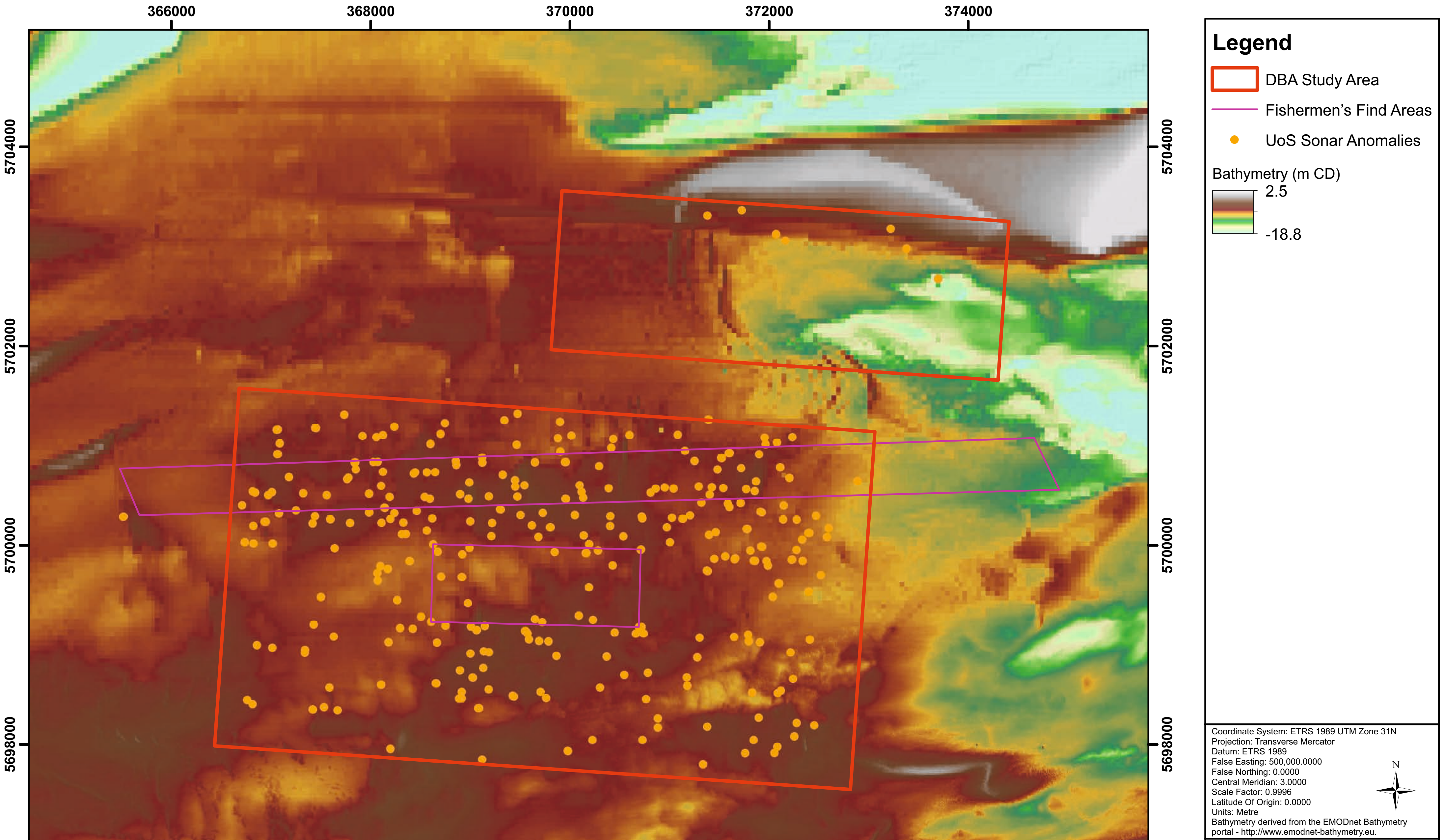


Figure 6
Previously identified sonar anomalies surveyed by the University of Southampton

UNIVERSITY OF Southampton

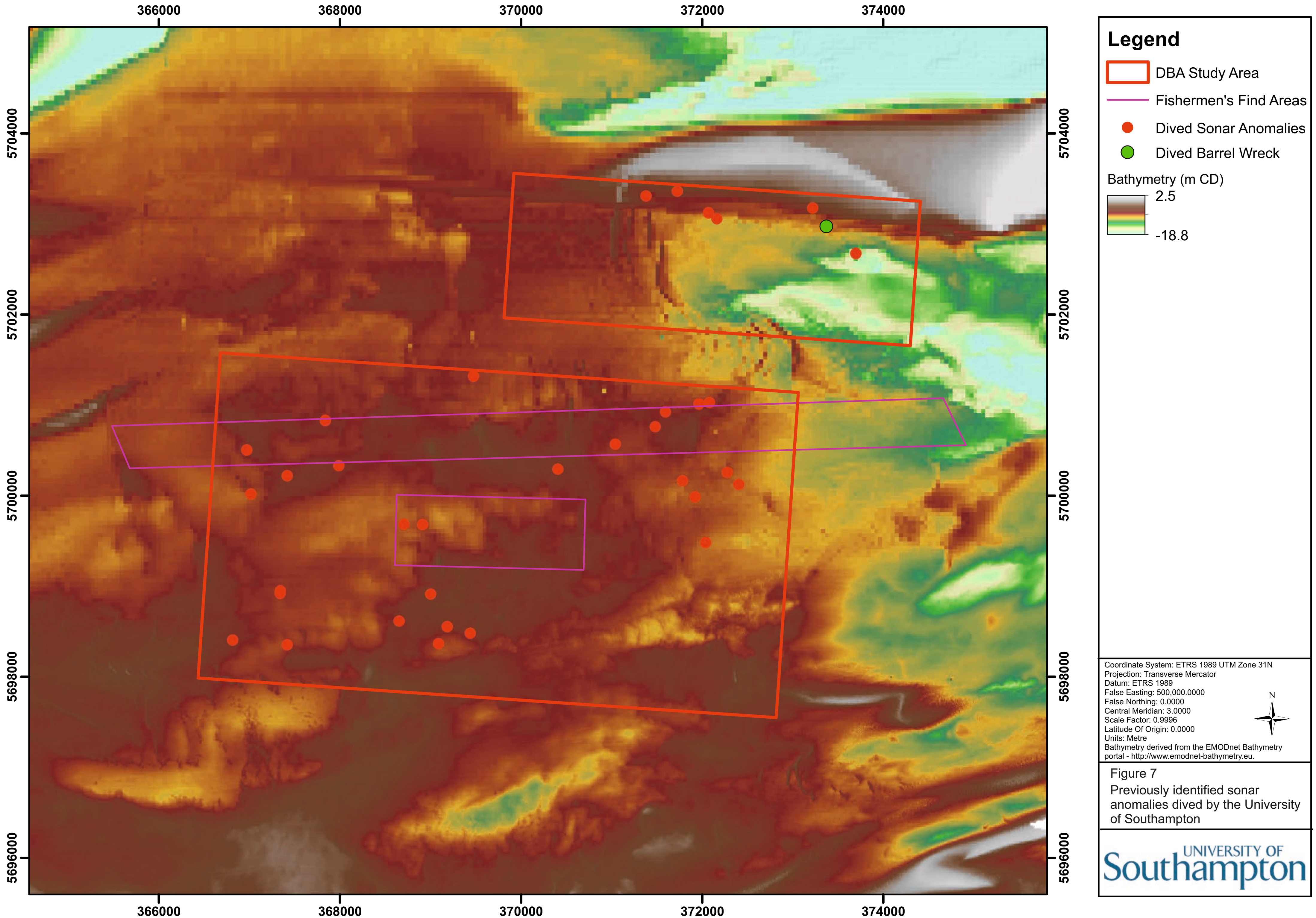


Figure 7
Previously identified sonar anomalies dived by the University of Southampton

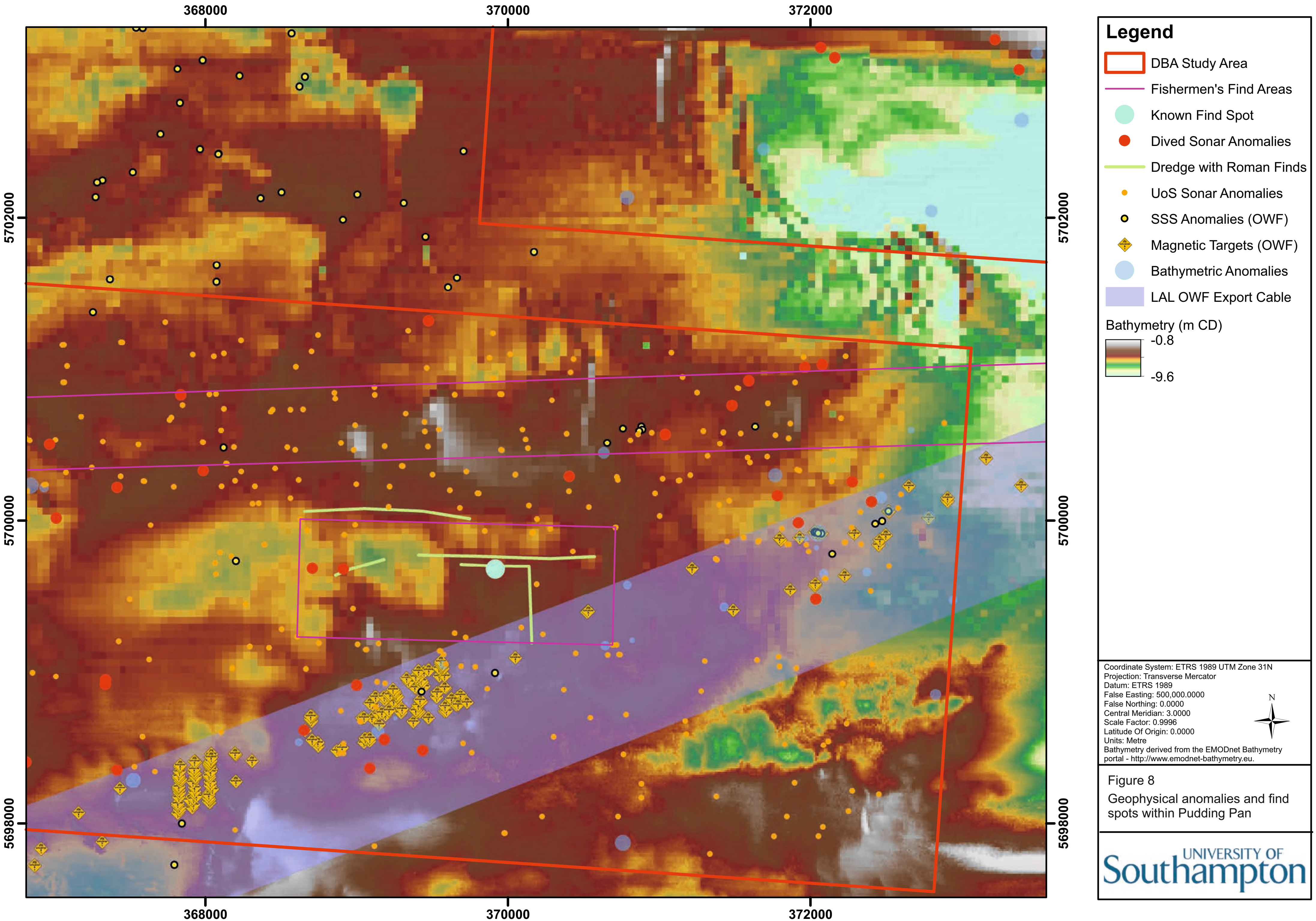
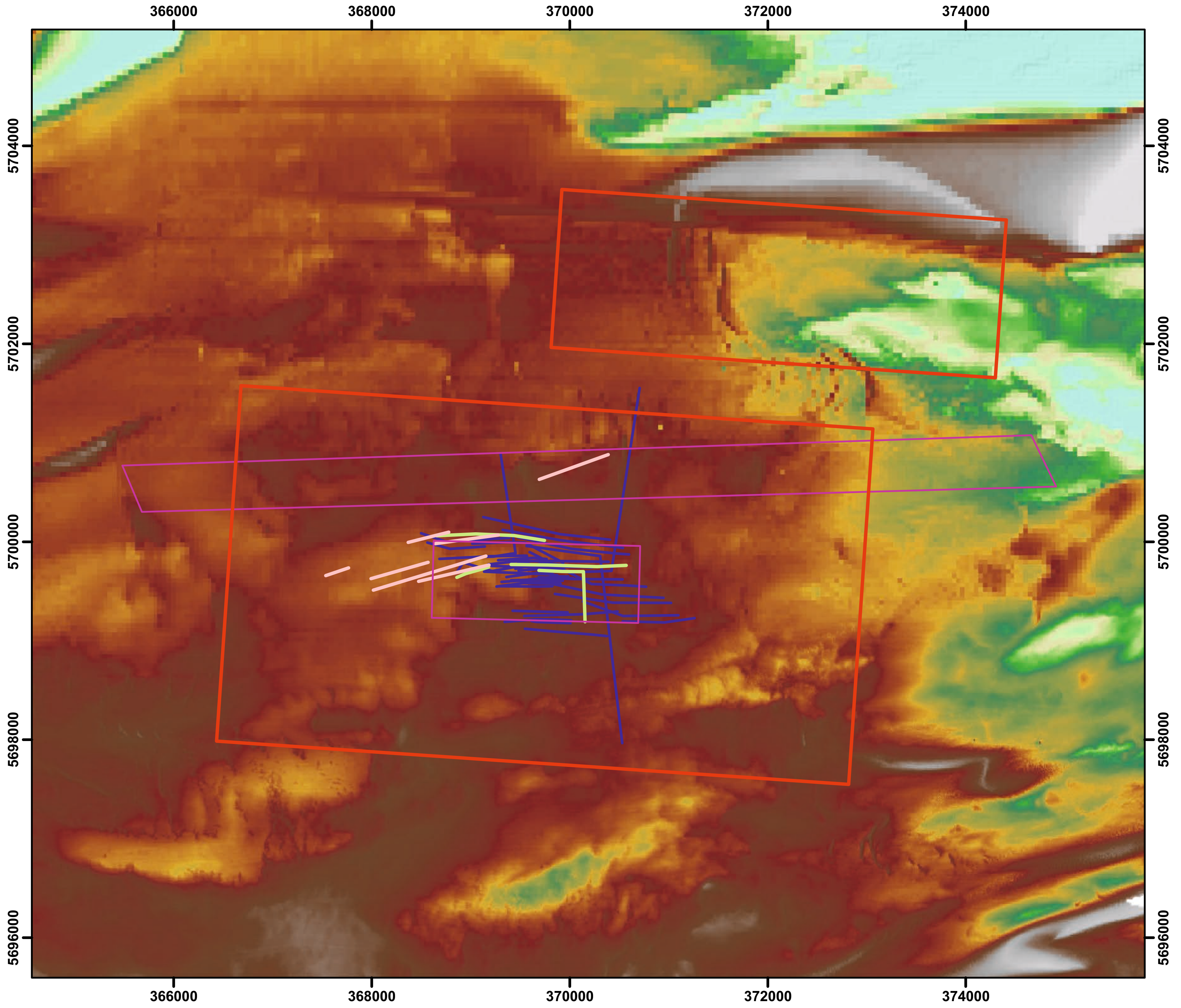


Figure 8

Geophysical anomalies and find spots within Pudding Pan



Legend

DBA Study Area

Fishermen's Find Areas

Drift Dive Survey

Dredge Survey

Dredge with Roman Finds

Bathymetry (m CD)

2.5

-18.8

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre
Bathymetry derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.

Figure 9

Dredge and drift dive surveys of the Pudding Pan area

UNIVERSITY OF Southampton

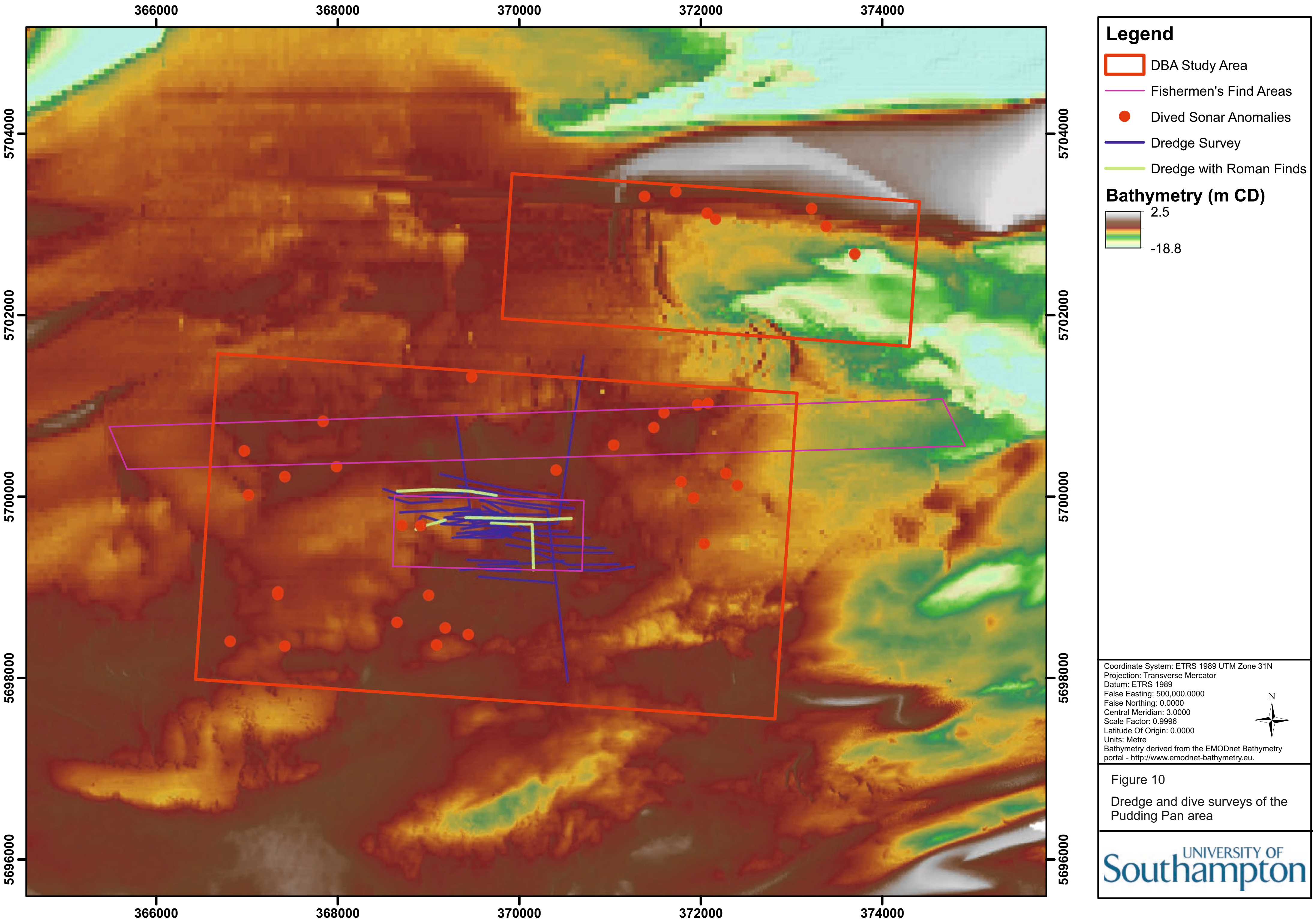
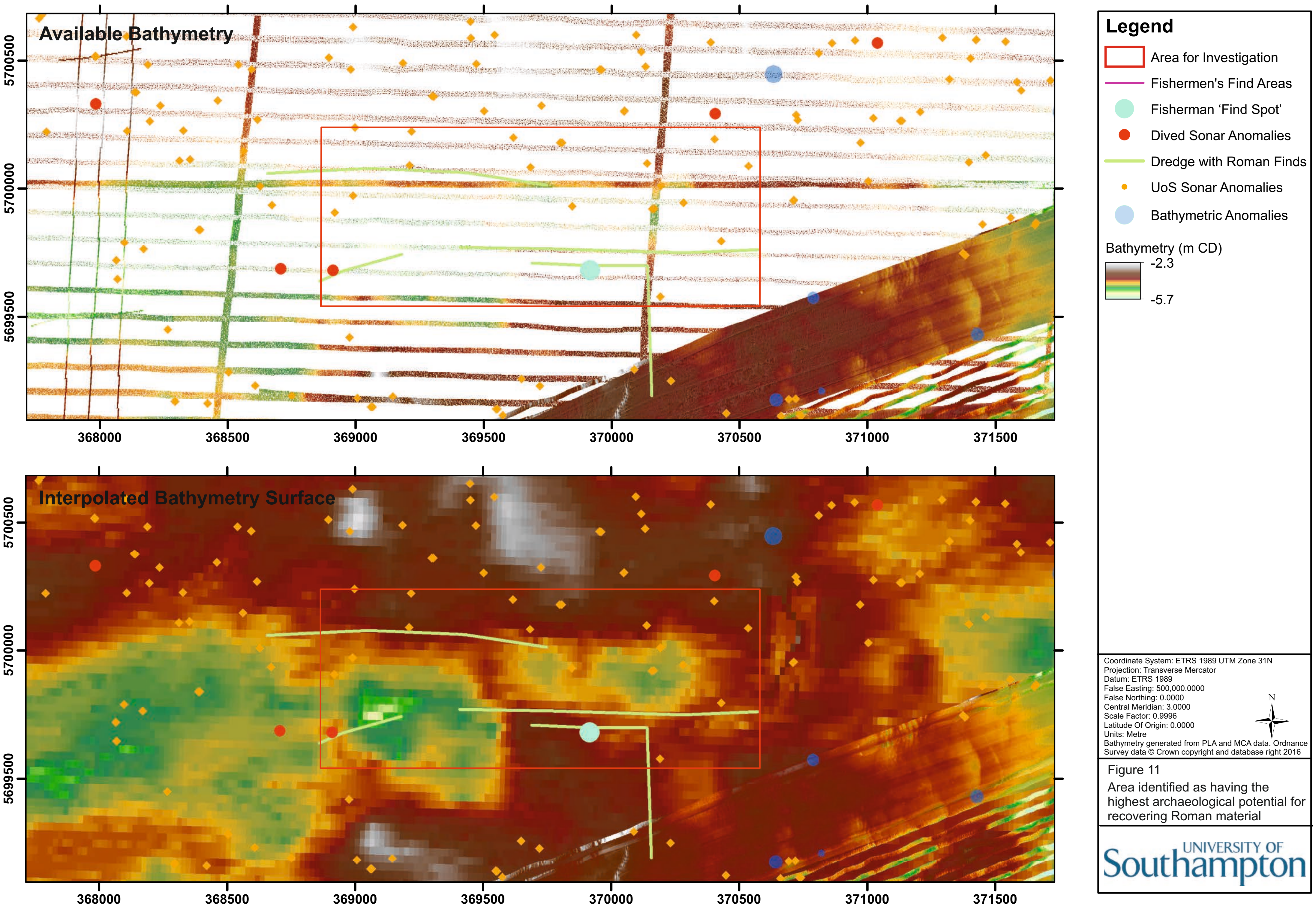


Figure 10

Dredge and dive surveys of the Pudding Pan area

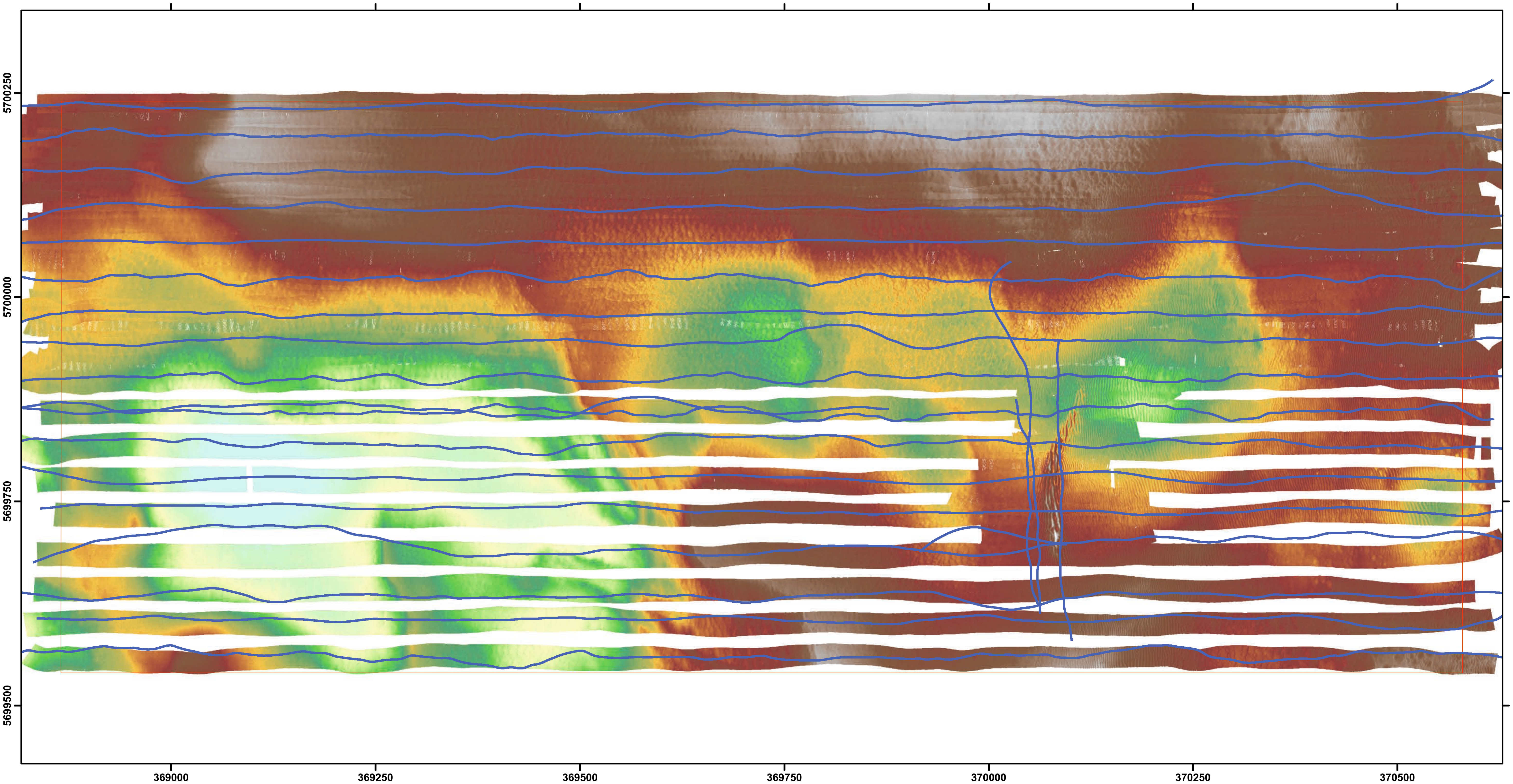
UNIVERSITY OF Southampton

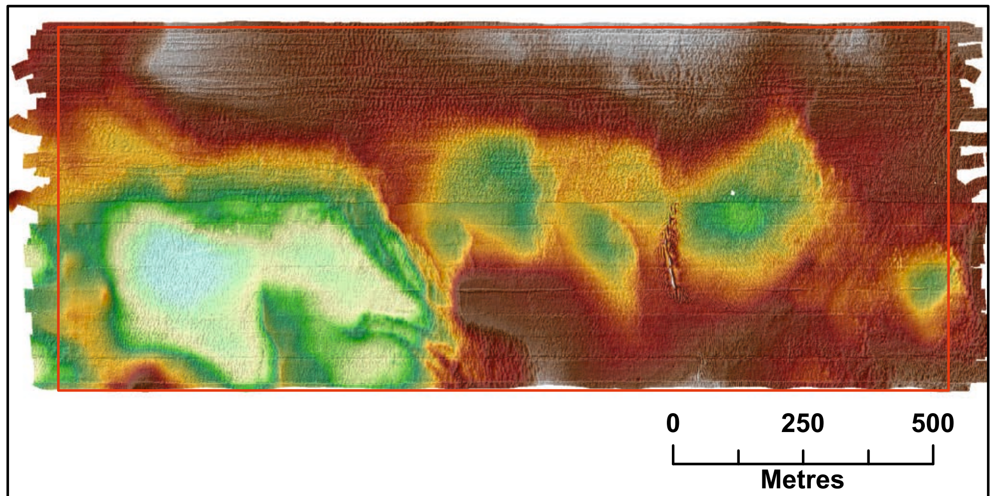


Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre
Bathymetry generated from PLA and MCA data. Ordnance Survey data © Crown copyright and database right 2016

Figure 11
Area identified as having the highest archaeological potential for recovering Roman material

UNIVERSITY OF Southampton





Legend

7164 Study Area

Side Scan Sonar Survey Lines

Bathymetry (m CD)

-3.09

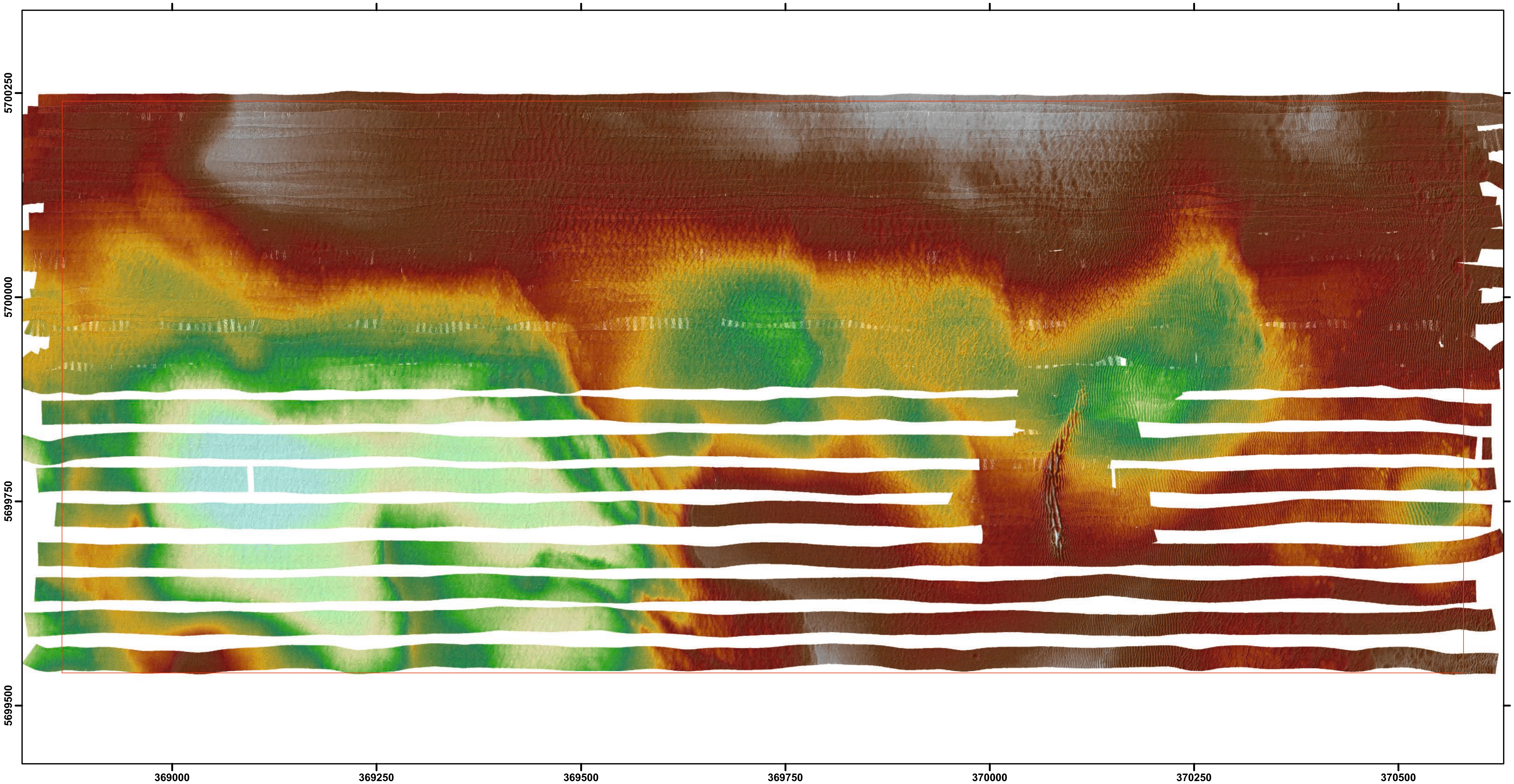
-5.47

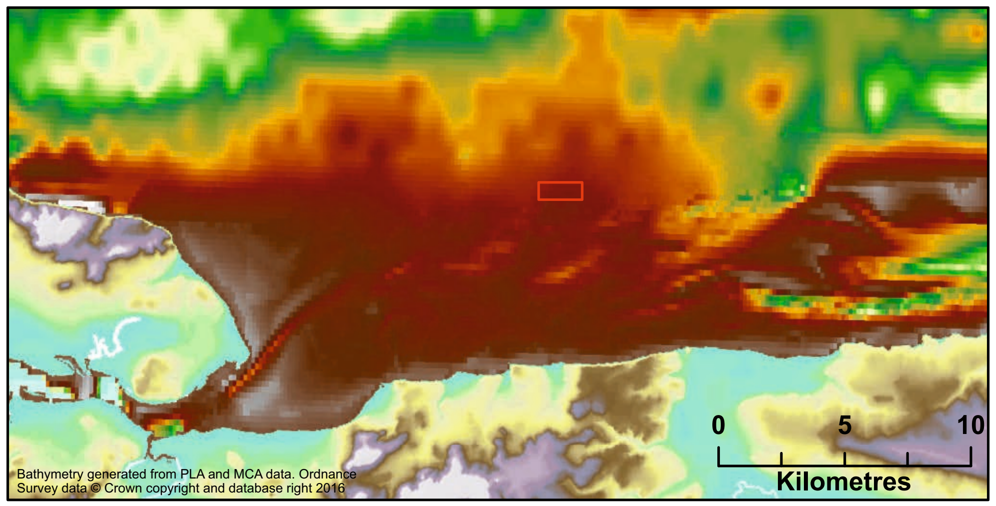
Figure 12
2015 side scan sonar survey lines, shown overlying the 2015 bathymetry survey.

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

7164 Study Area

Bathymetry (m CD)

-3.09

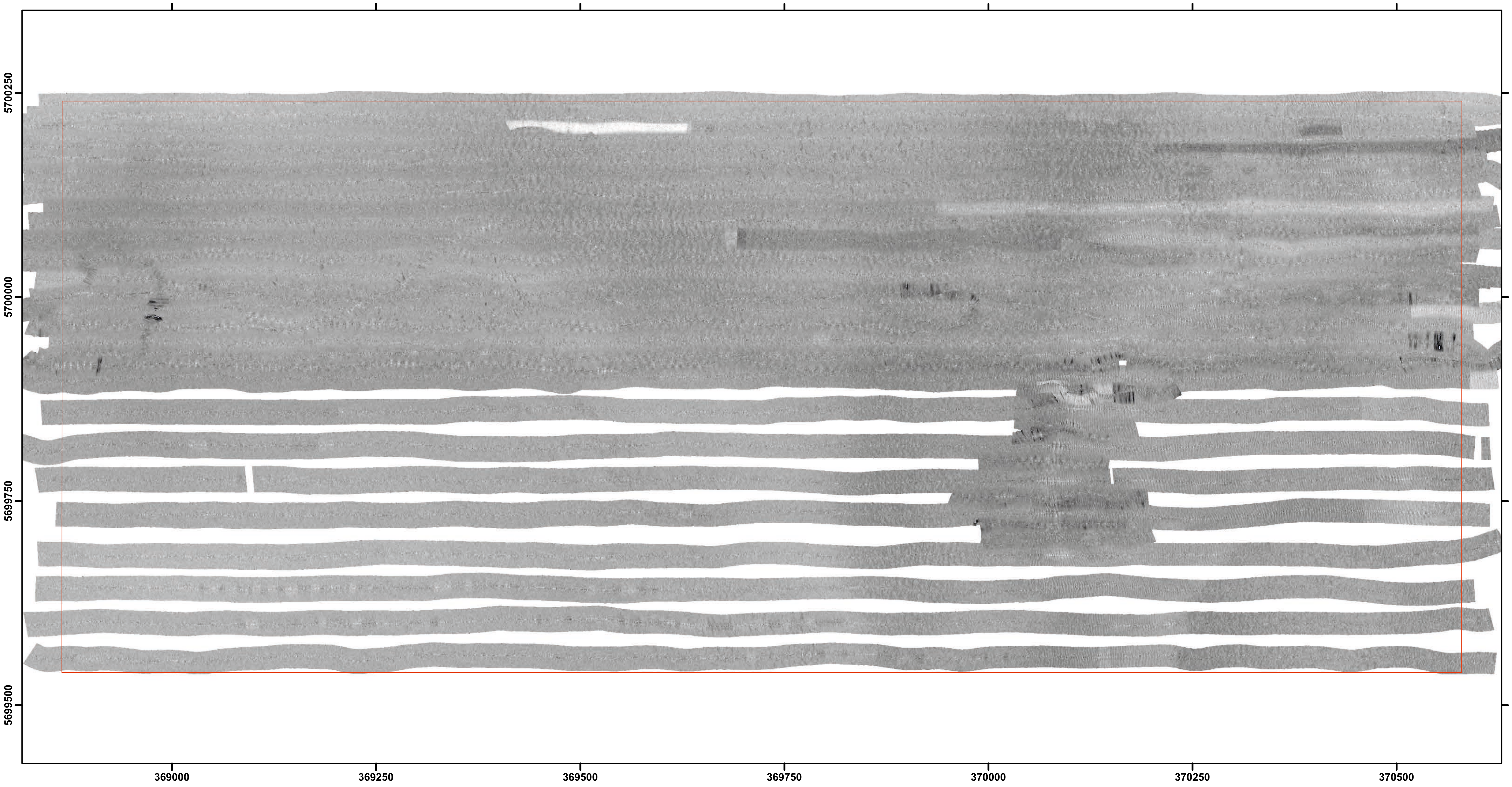
-5.47

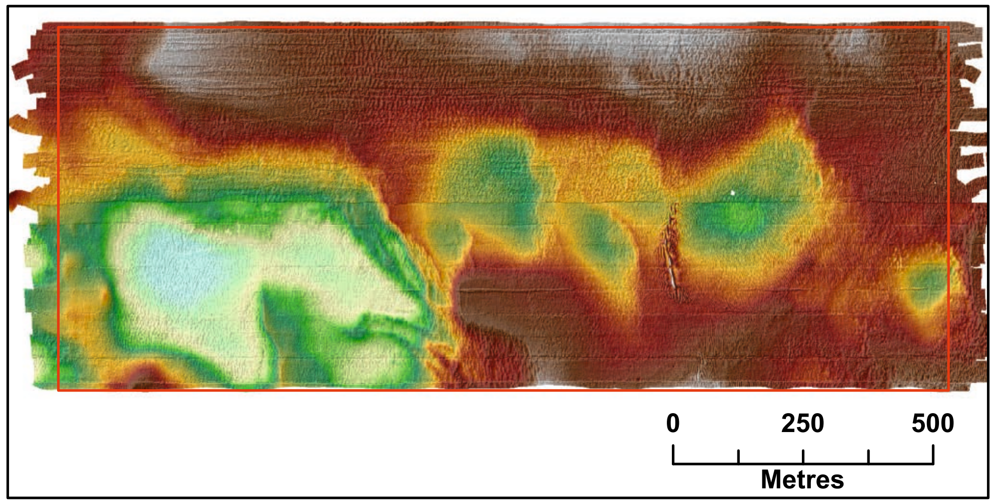
Figure 13
2015 bathymetry survey of study area

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

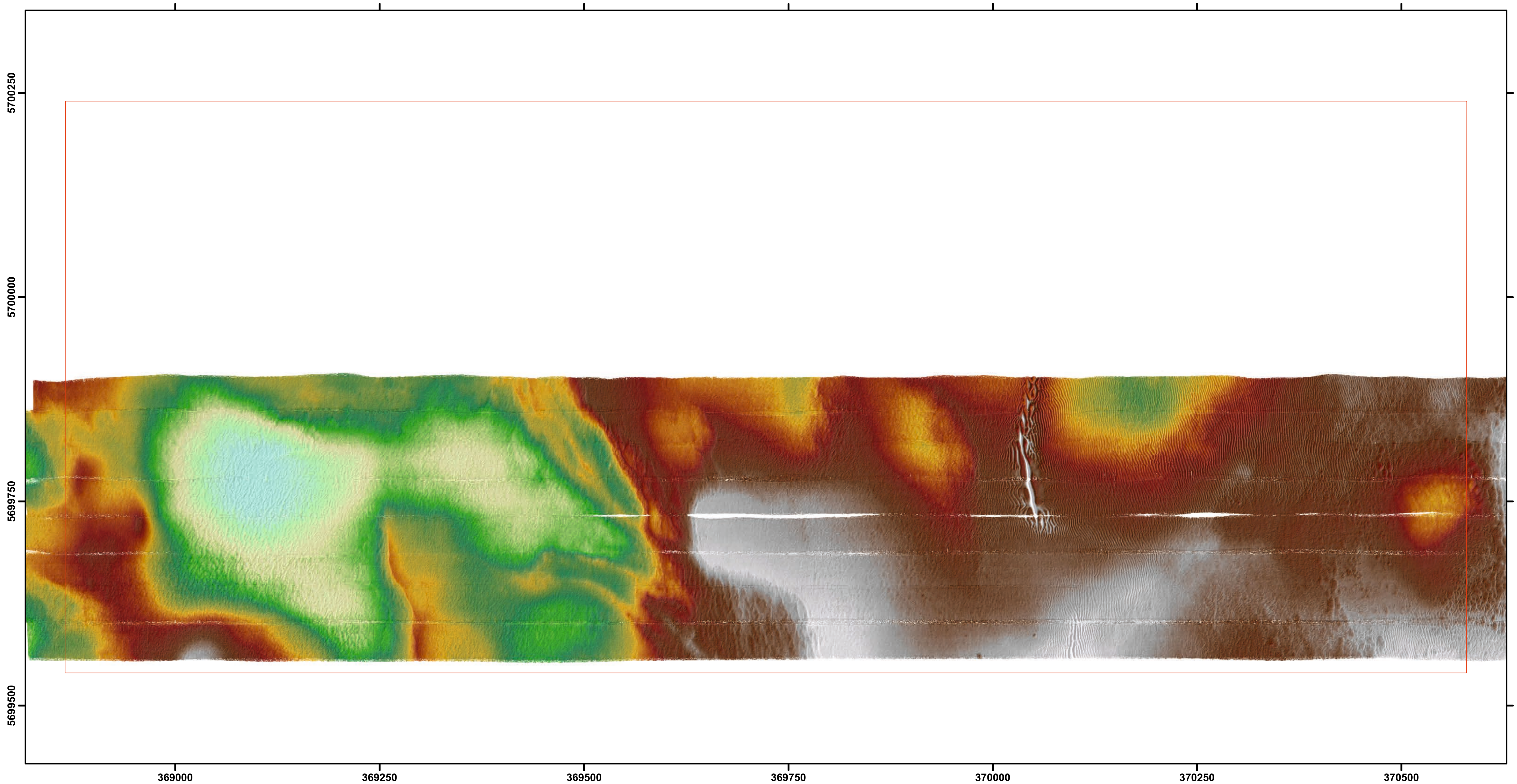
7164 Study Area

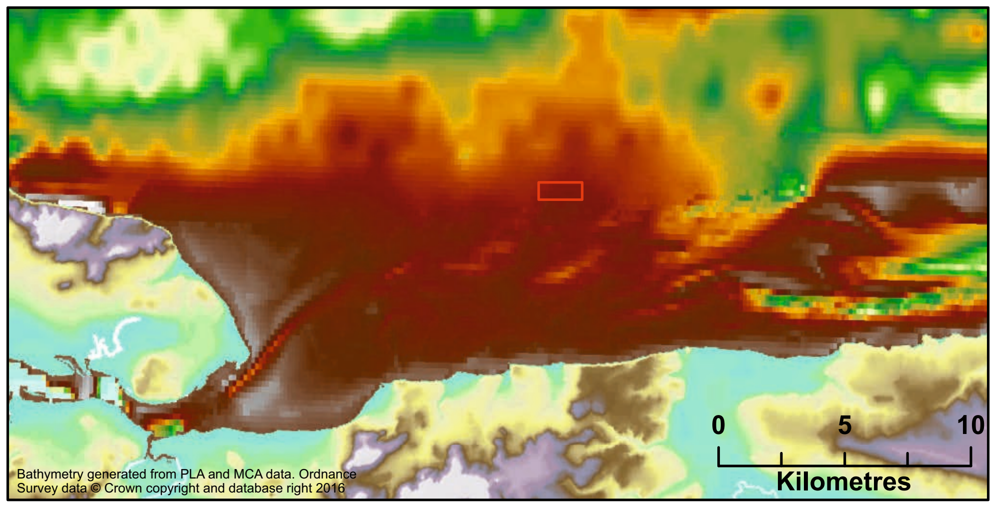
Figure 14
2015 backscatter coverage

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

7164 Study Area

Bathymetry (m CD)

-3.07

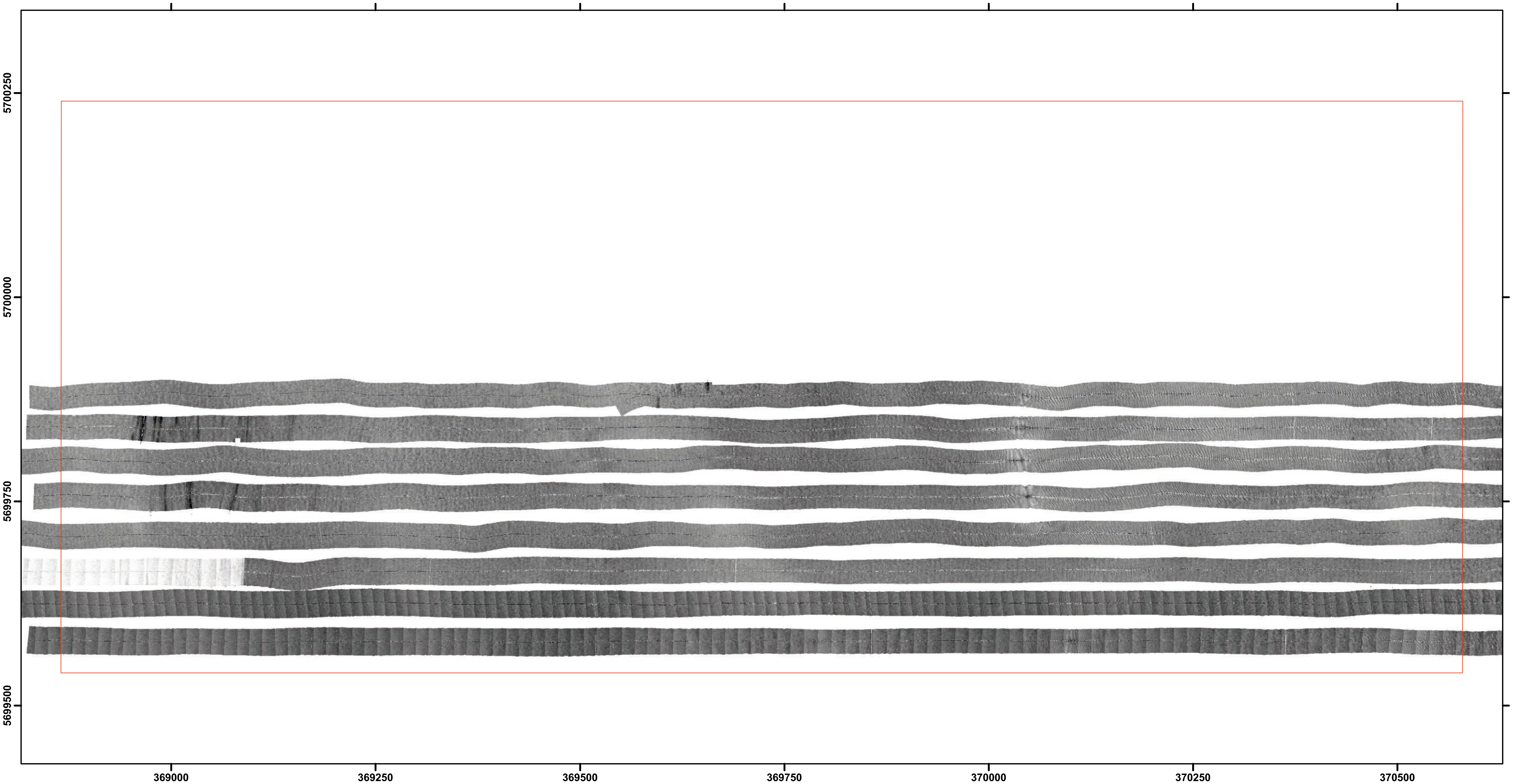
-6.83

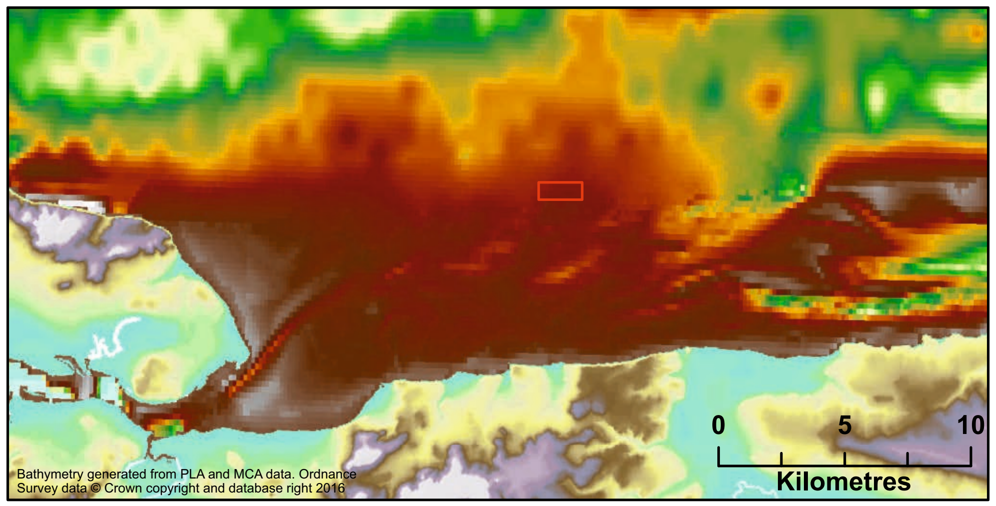
Figure 15
2016 bathymetry survey of study area

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

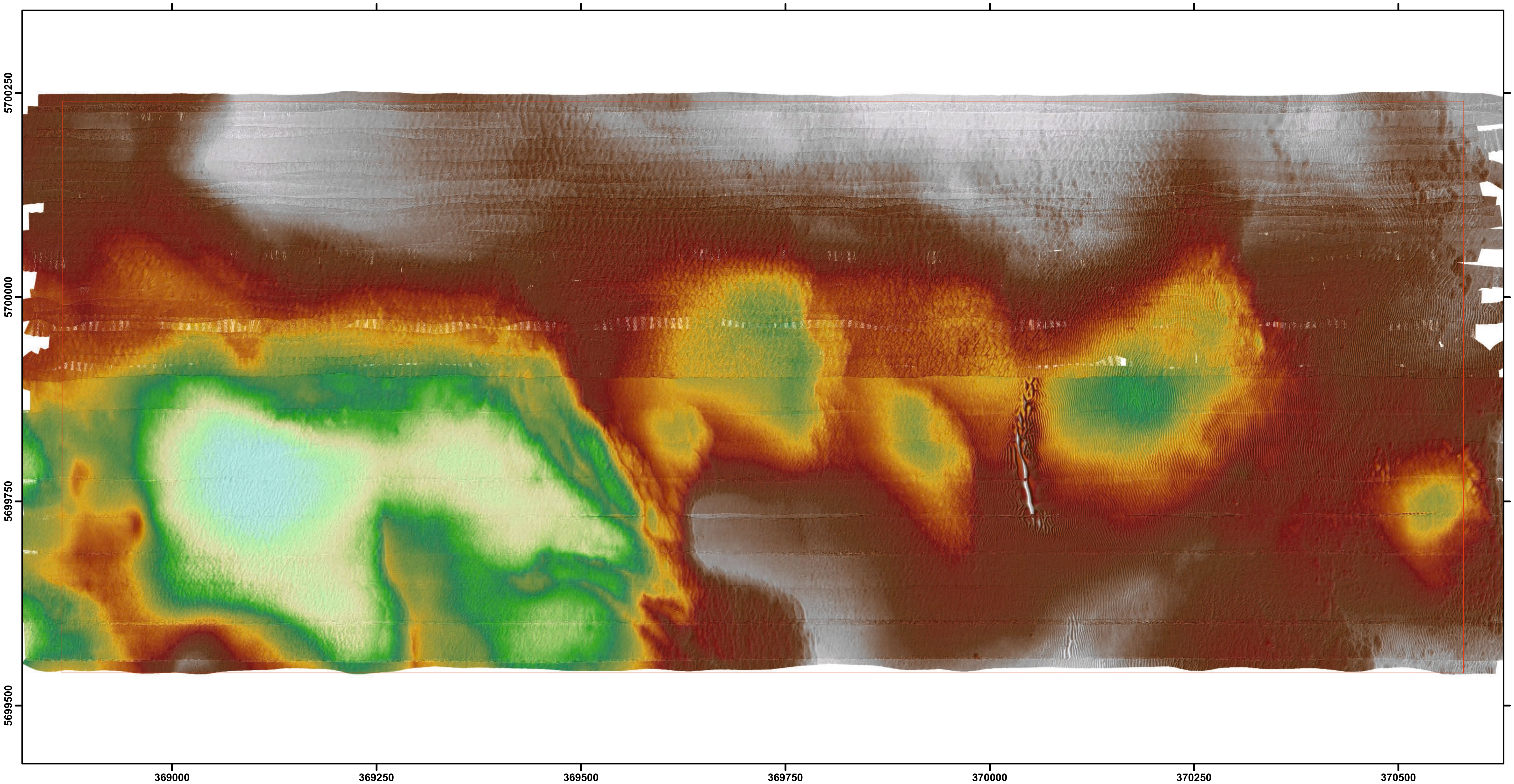
7164 Study Area

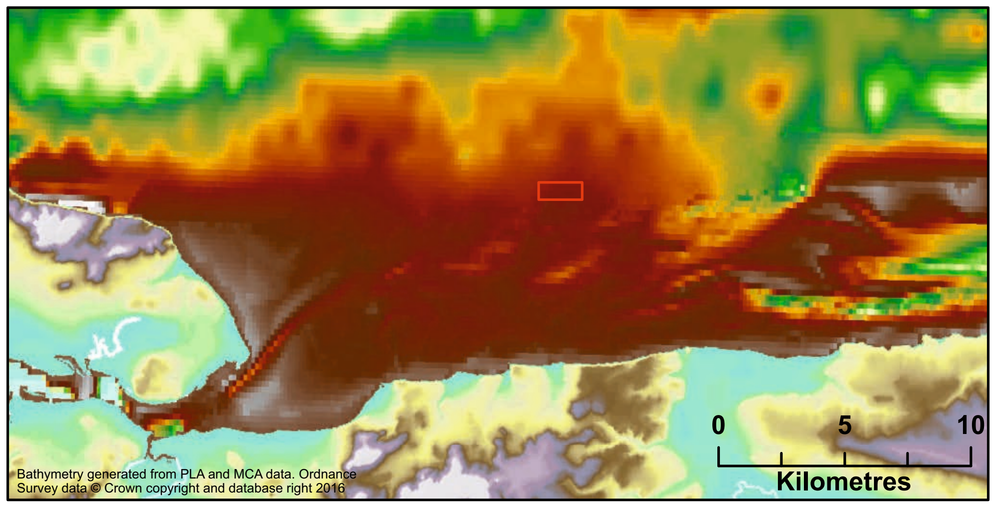
Figure 16
2016 backscatter coverage

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

7164 Study Area

Bathymetry (m CD)

-3.07

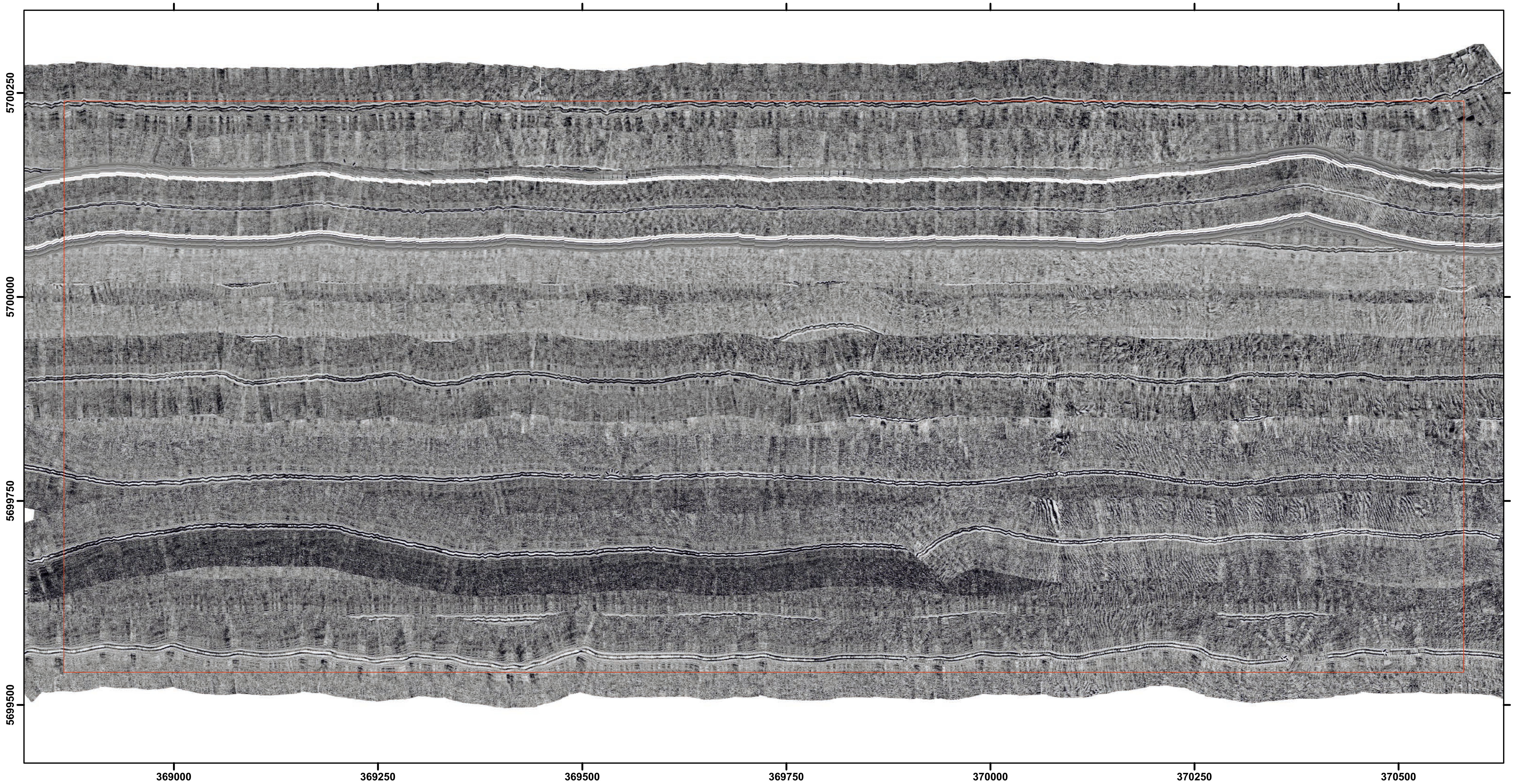
-6.83

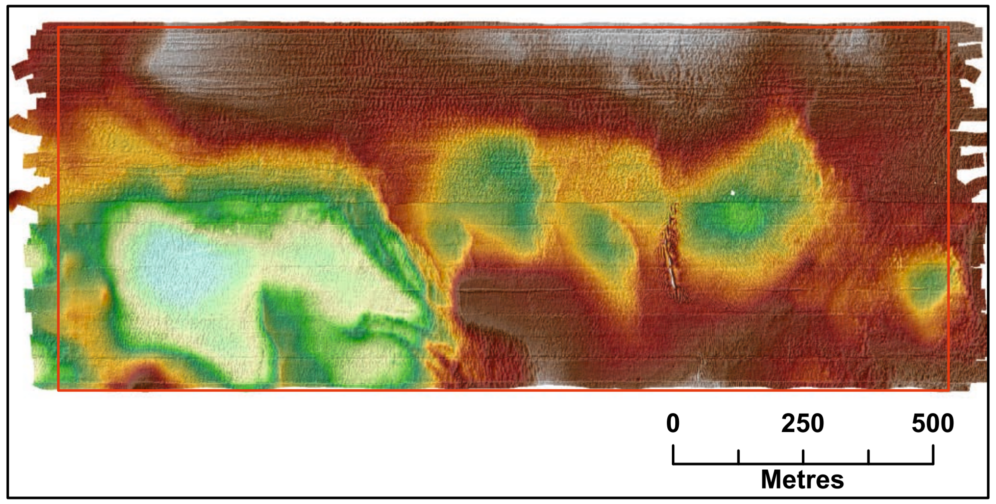
Figure 17
Integrated 2015-2016 bathymetry of study area

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

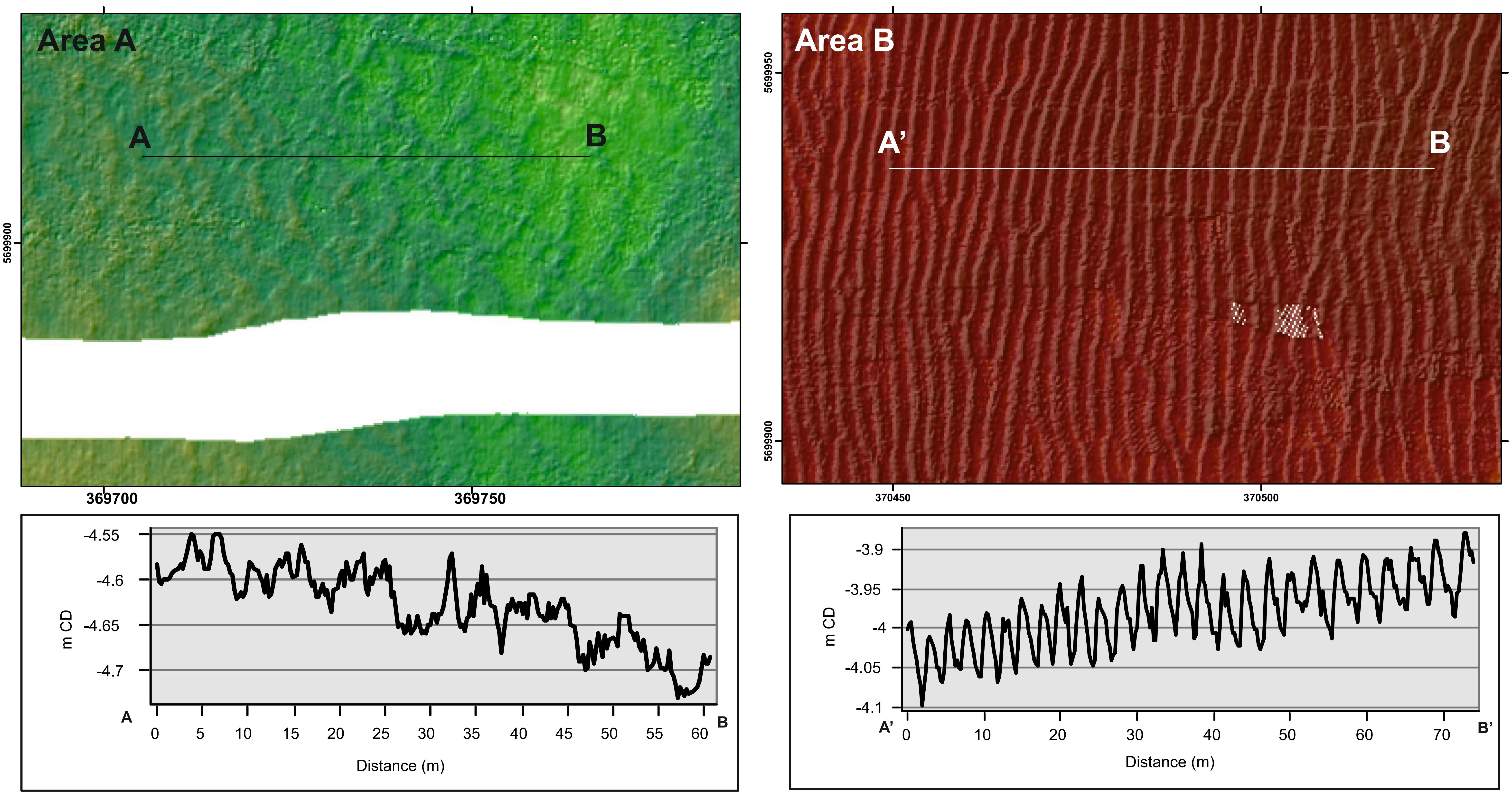
7164 Study Area

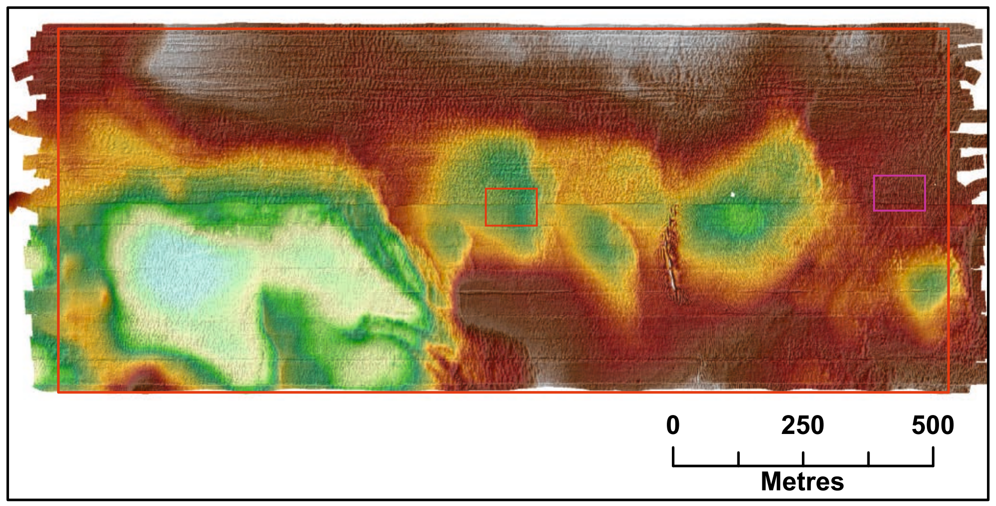
Figure 18
2015 side scan sonar coverage

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

Area 1

Area 2

Bathymetry (m CD)

-3.09

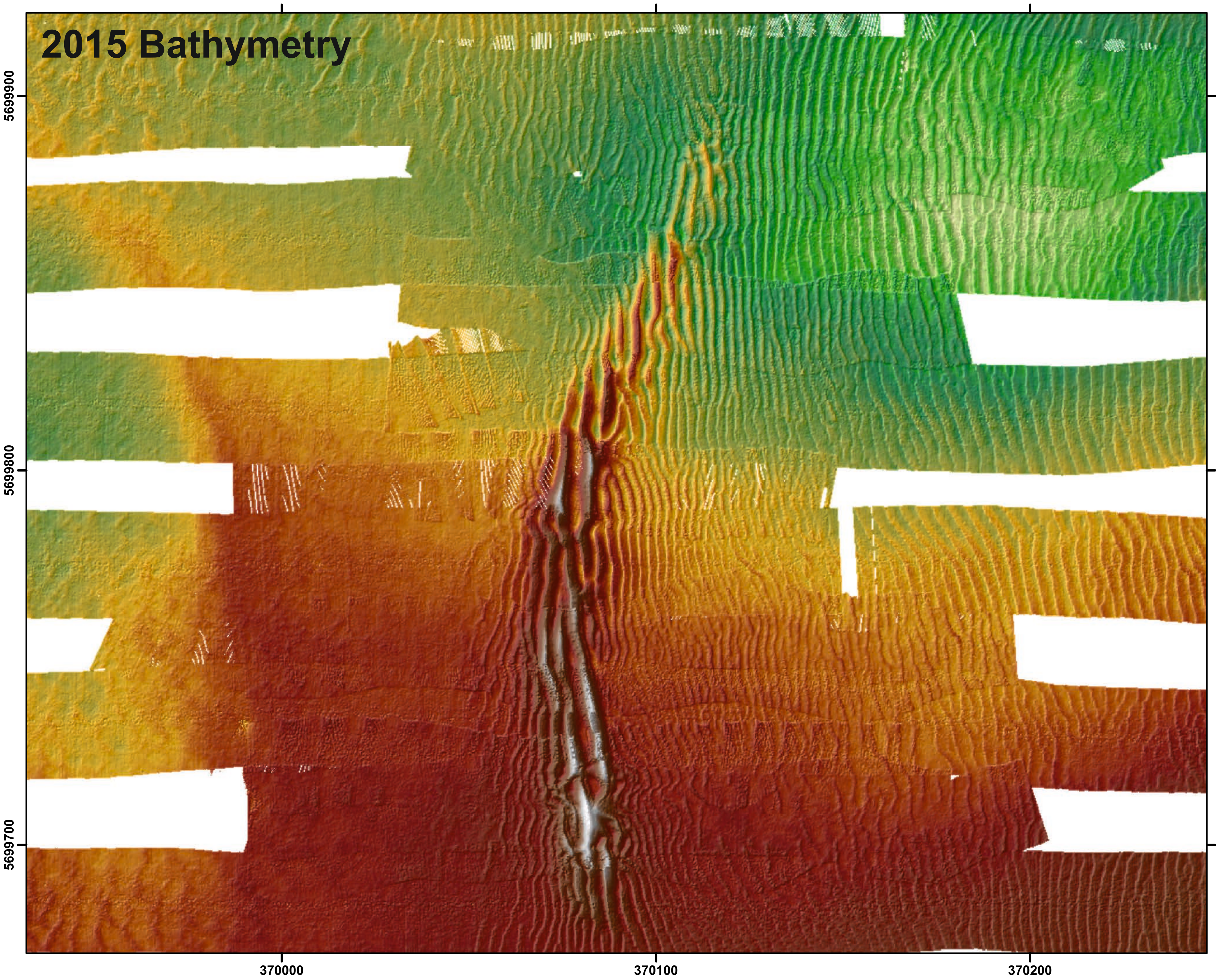
-5.47

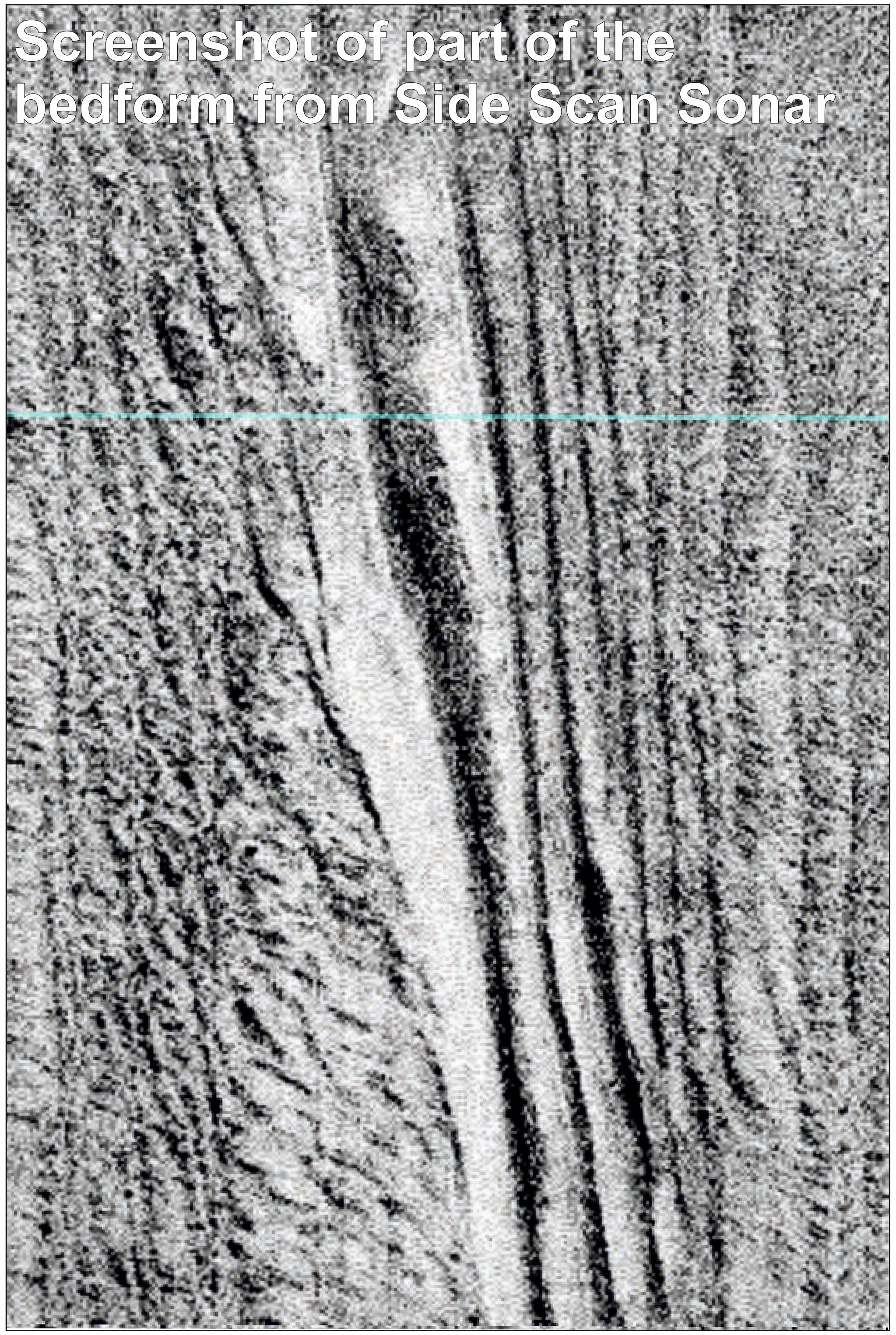
Figure 19
Comparison of bedforms in east and west of study area

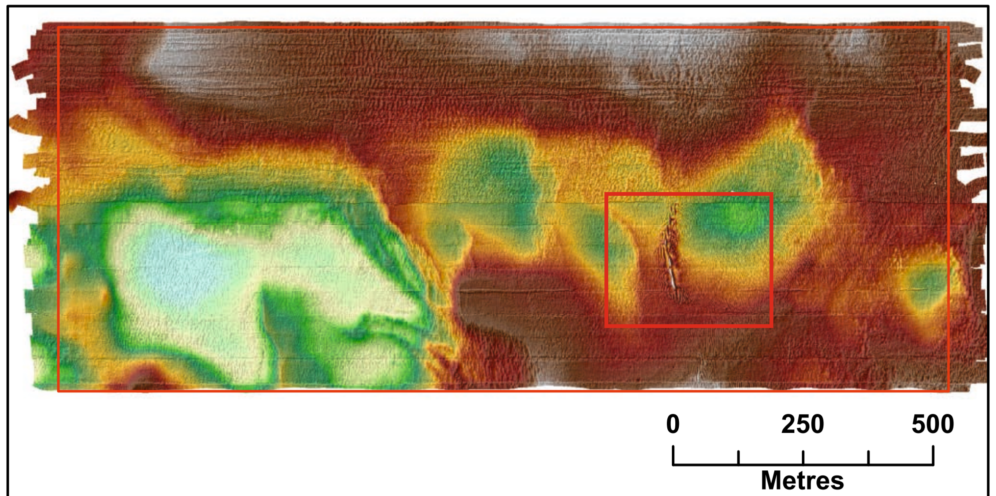
Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 5 10
Metres

UNIVERSITY OF Southampton







Legend

7164 Study Area

Bathymetry (m CD)

-3.09

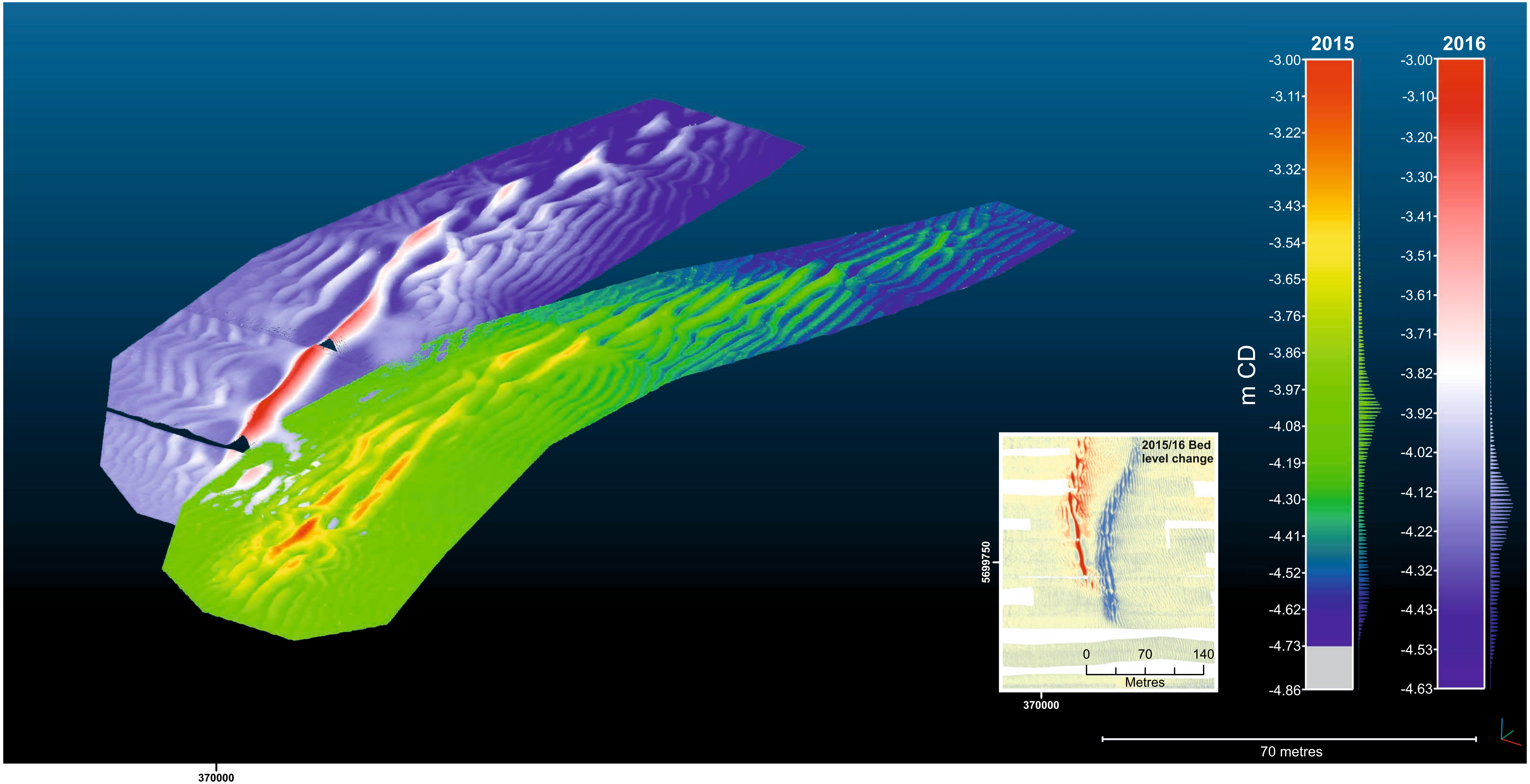
-5.47

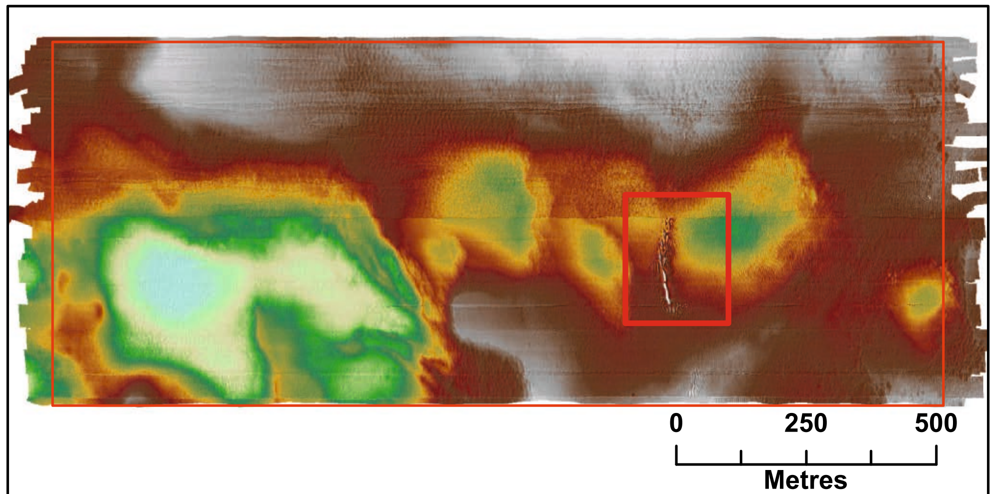
Figure 20
Close-up of the large bedform in 2015 survey

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 20 40
Metres

UNIVERSITY OF Southampton





Legend

Bed Level Change (m) between 2015 and 2016

> + 0.5

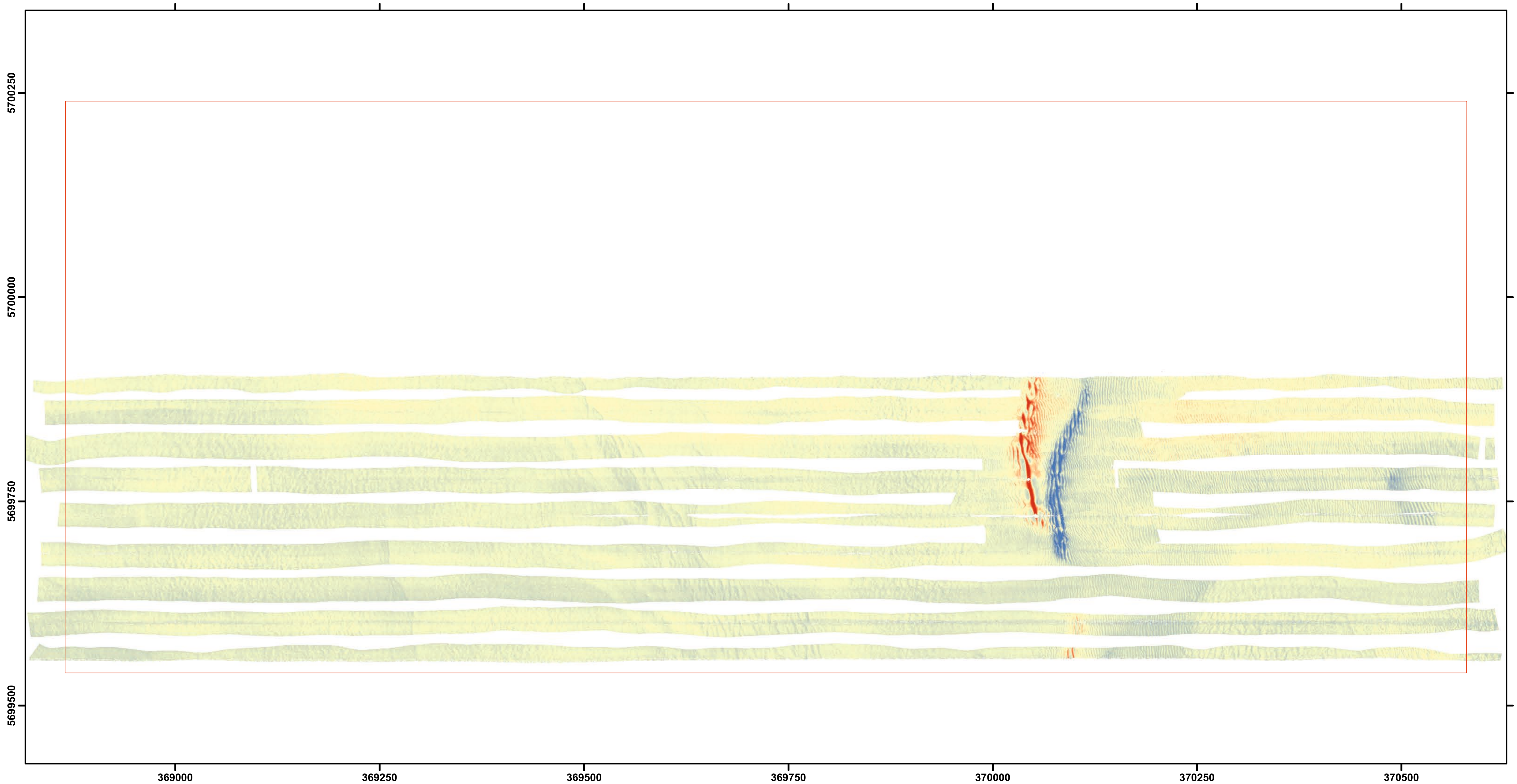
0

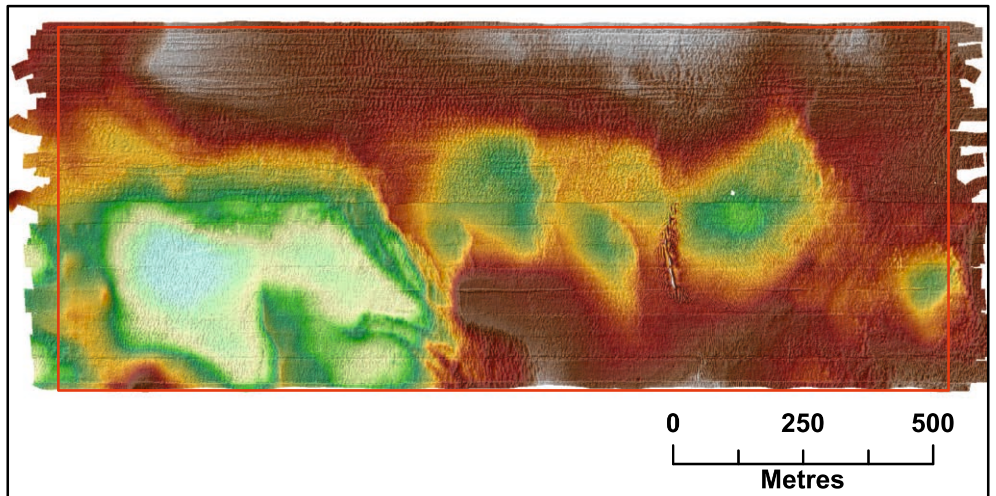
> - 0.5

Figure 21
Westward migration of large bedform between 2015 and 2016 survey.

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

UNIVERSITY OF Southampton





Legend

7164 Study Area

Bed Level Change (m)

> + 0.5

0

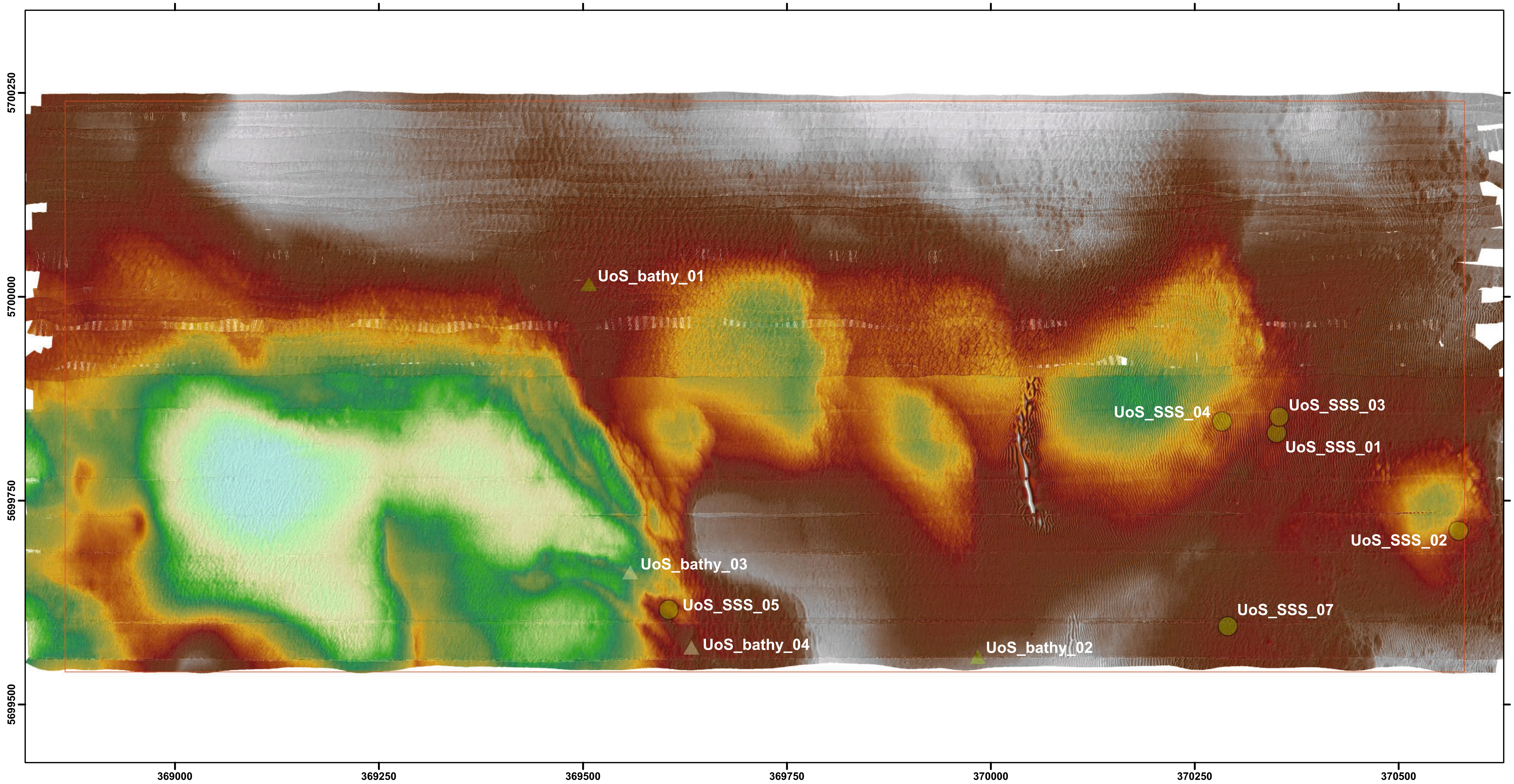
> - 0.5

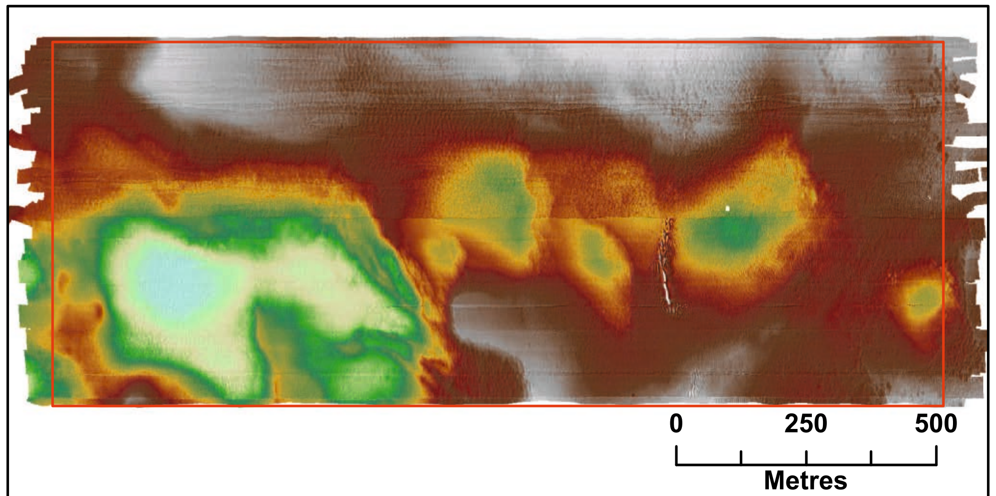
Figure 22
Bed level change in area of MBES overlap between 2015 and 2016 surveys

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 70 140
Metres

UNIVERSITY OF Southampton





Legend

- 7164 Study Area
- 2015/16 Bathymetry Anomalies
- 2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.07

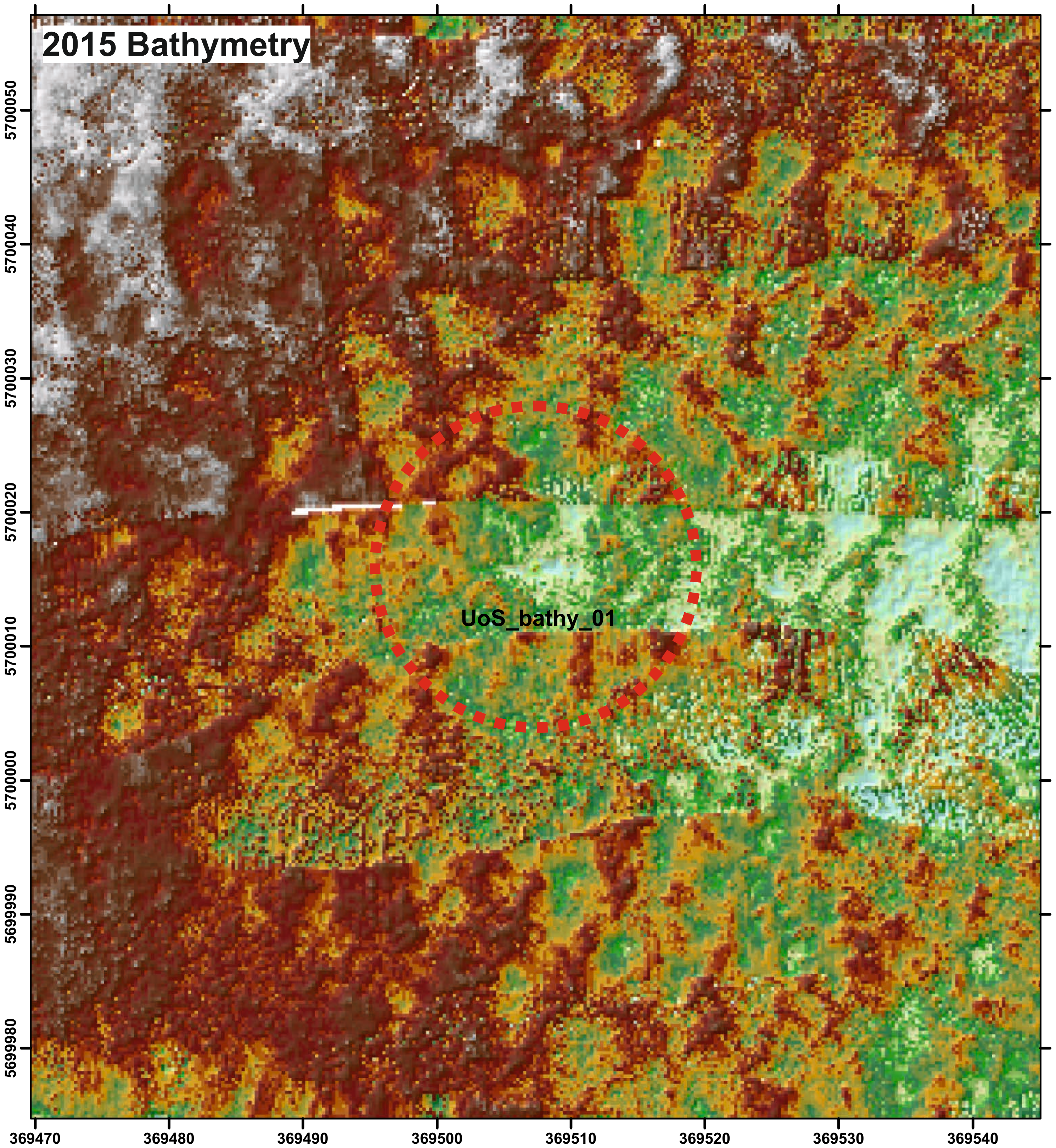
-6.83

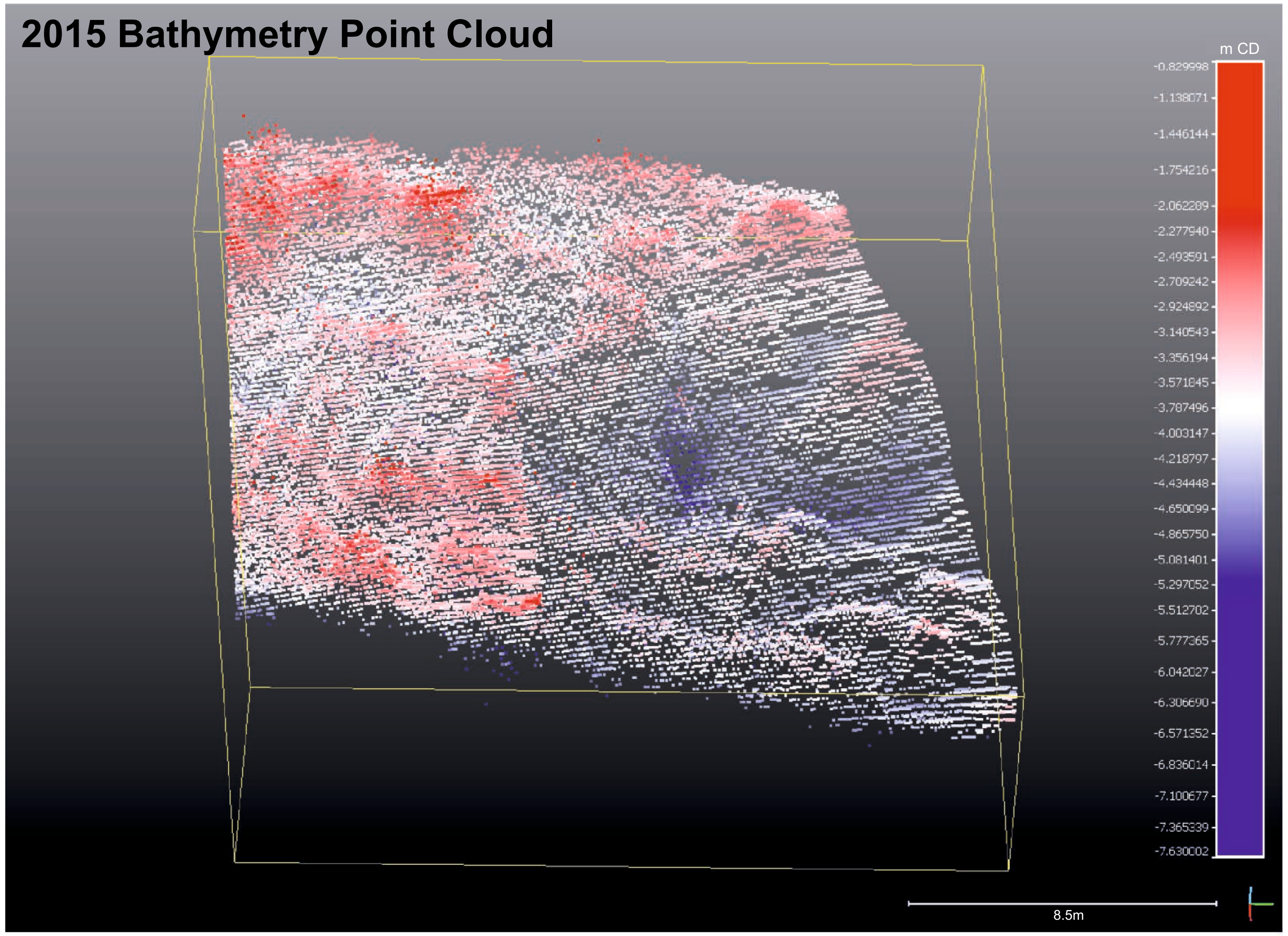
Figure 23
Distribution of geophysical anomalies identified from 2015/16 survey data

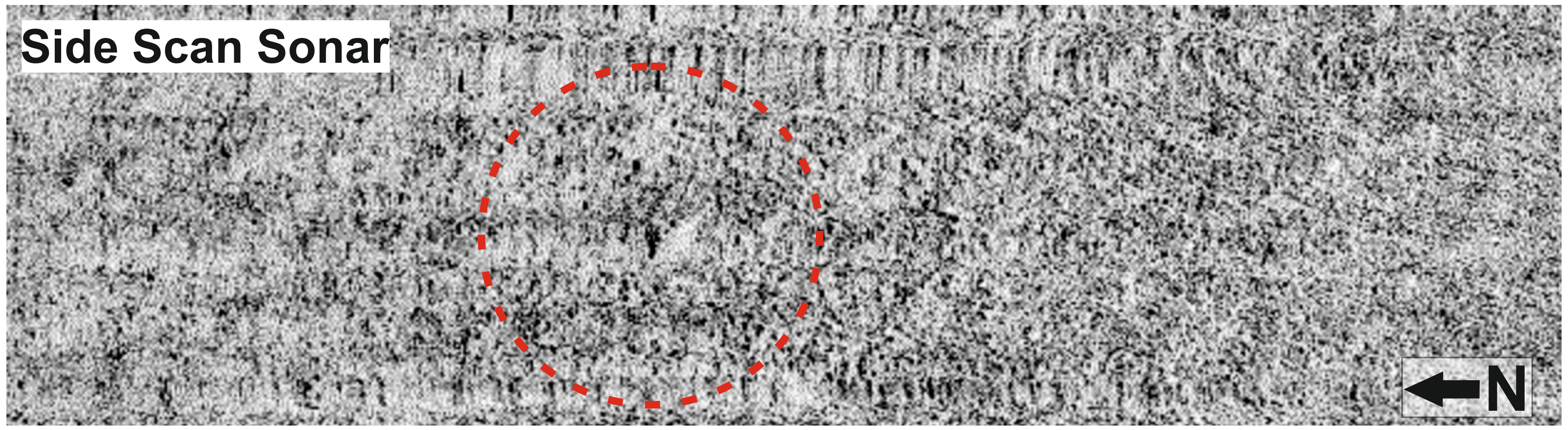
Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

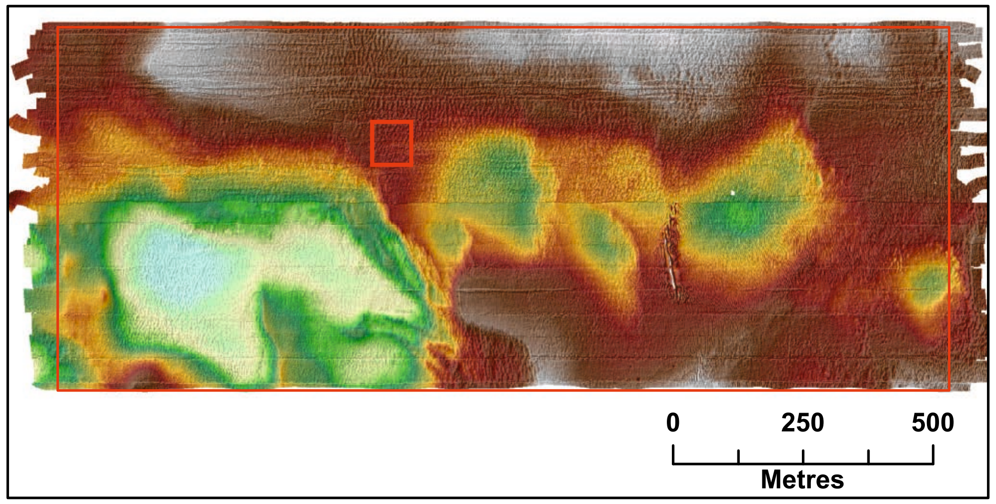
0 75 150
Metres

UNIVERSITY OF Southampton









Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.97

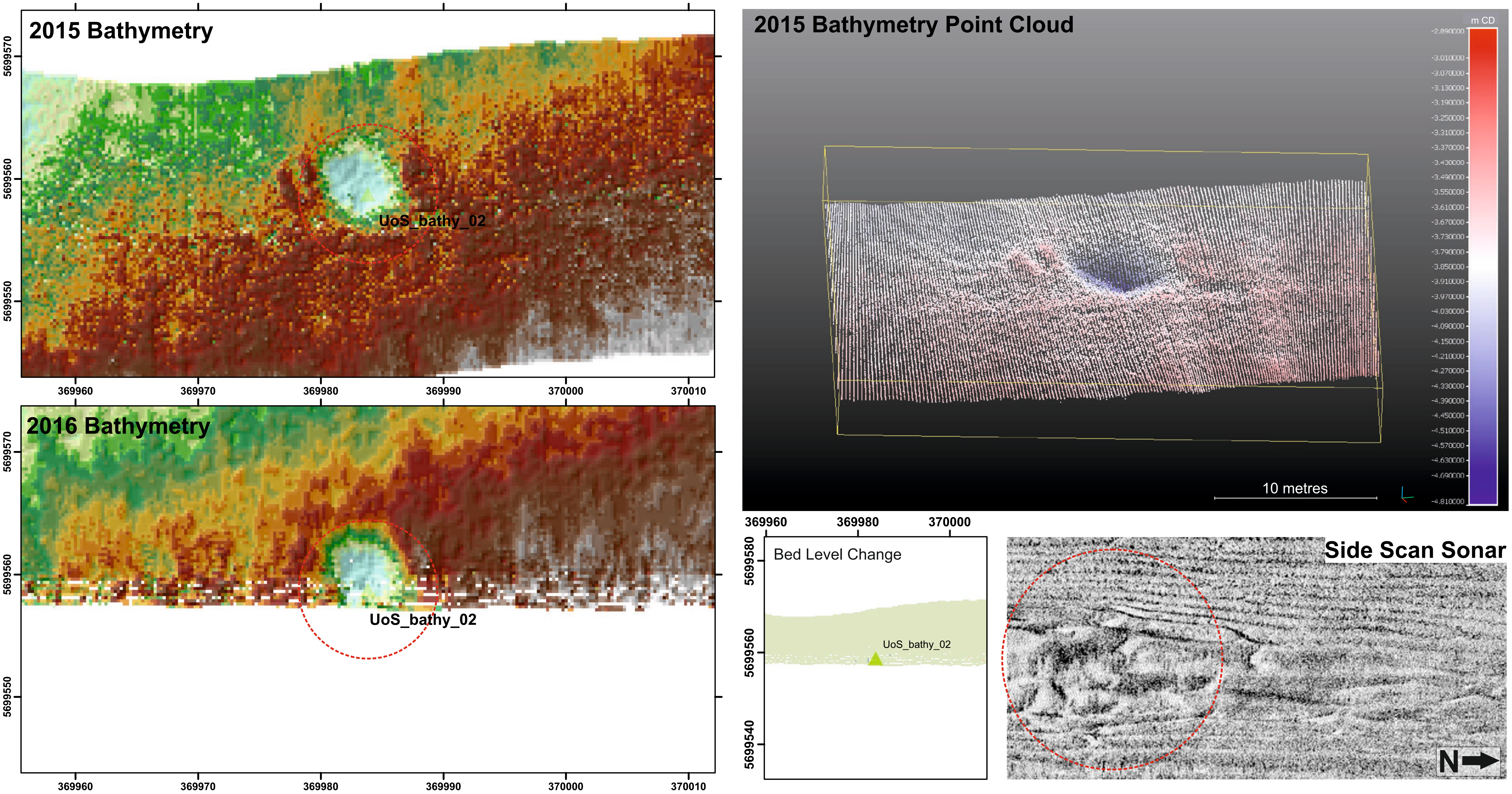
-4.37

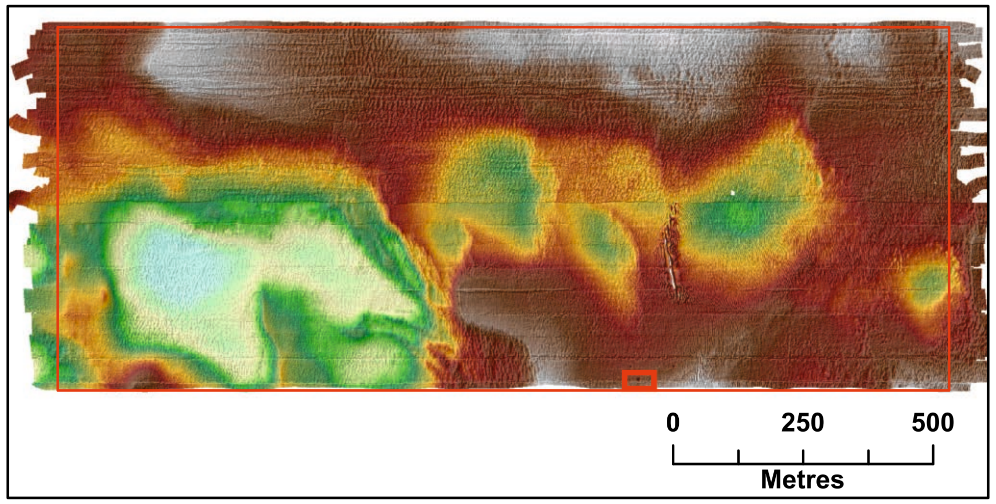
Figure 24
Bathymetry and SSS of UoS_bathy_01

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.75 9.5
Metres

UNIVERSITY OF
Southampton





Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.71

-4.04

Bed Level Change (m)

> + 0.5

0

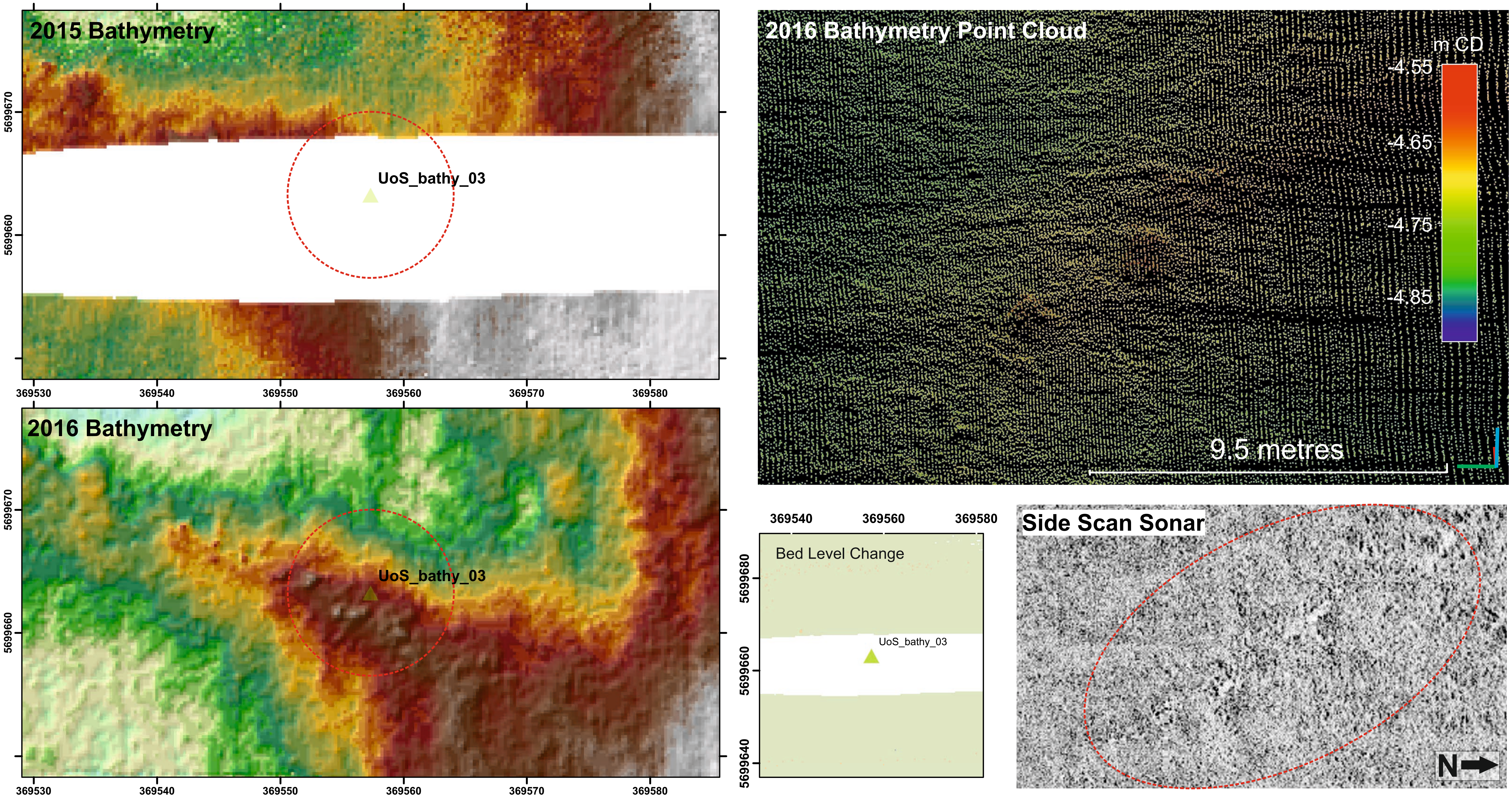
> - 0.5

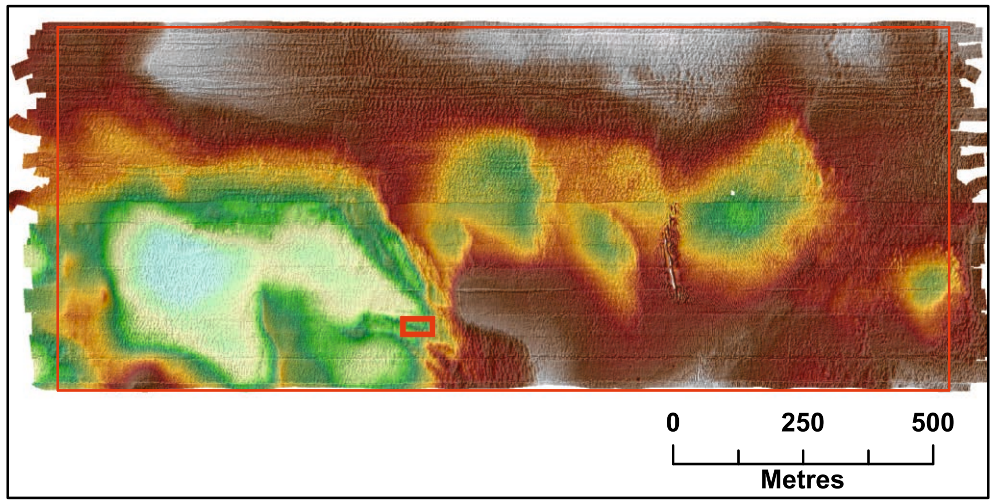
Figure 25
Bathymetry and SSS of UoS_bathy_02

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.75 9.5
Metres

UNIVERSITY OF
Southampton





Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-4.55

-4.9

Bed Level Change (m)

> + 0.5

0

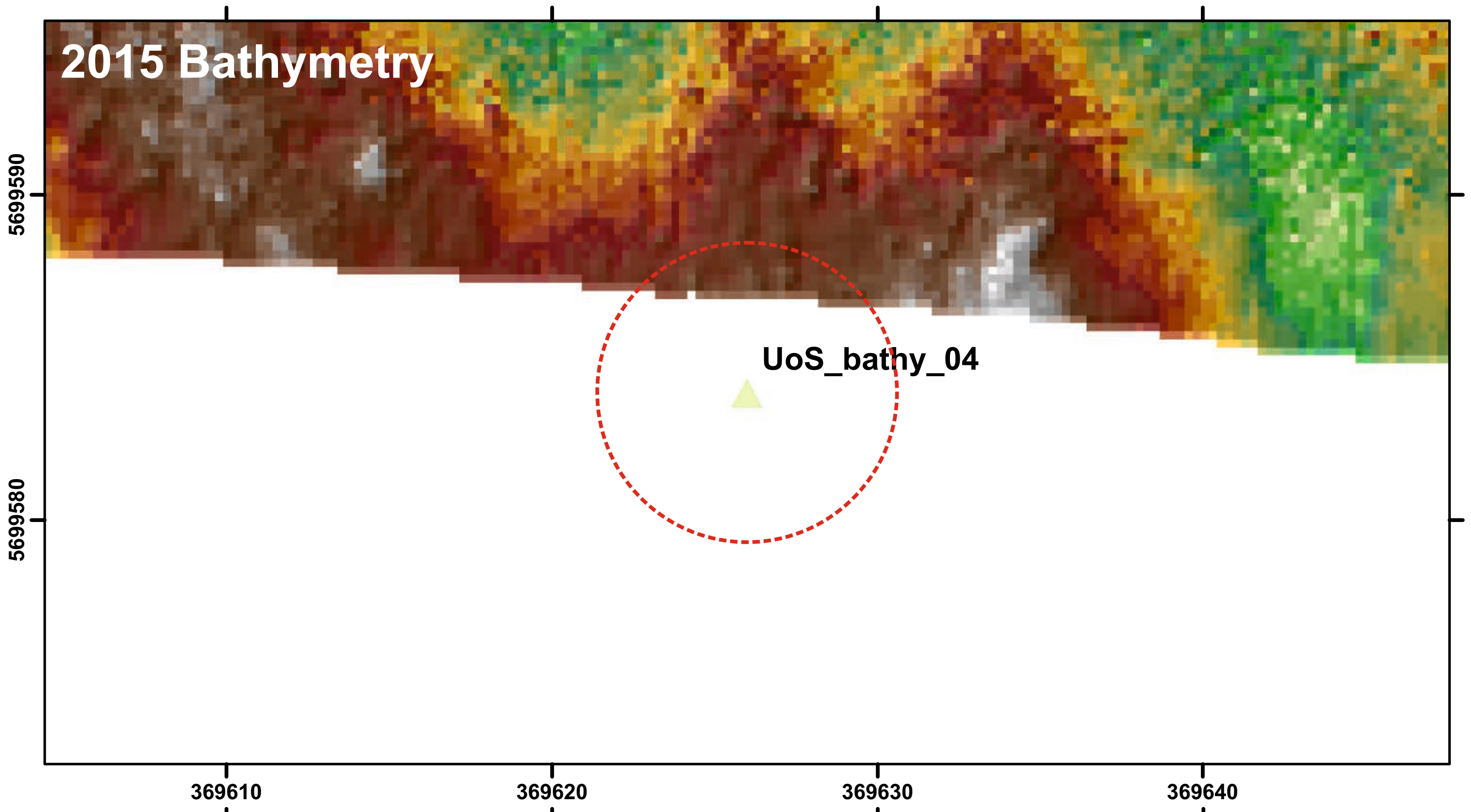
> - 0.5

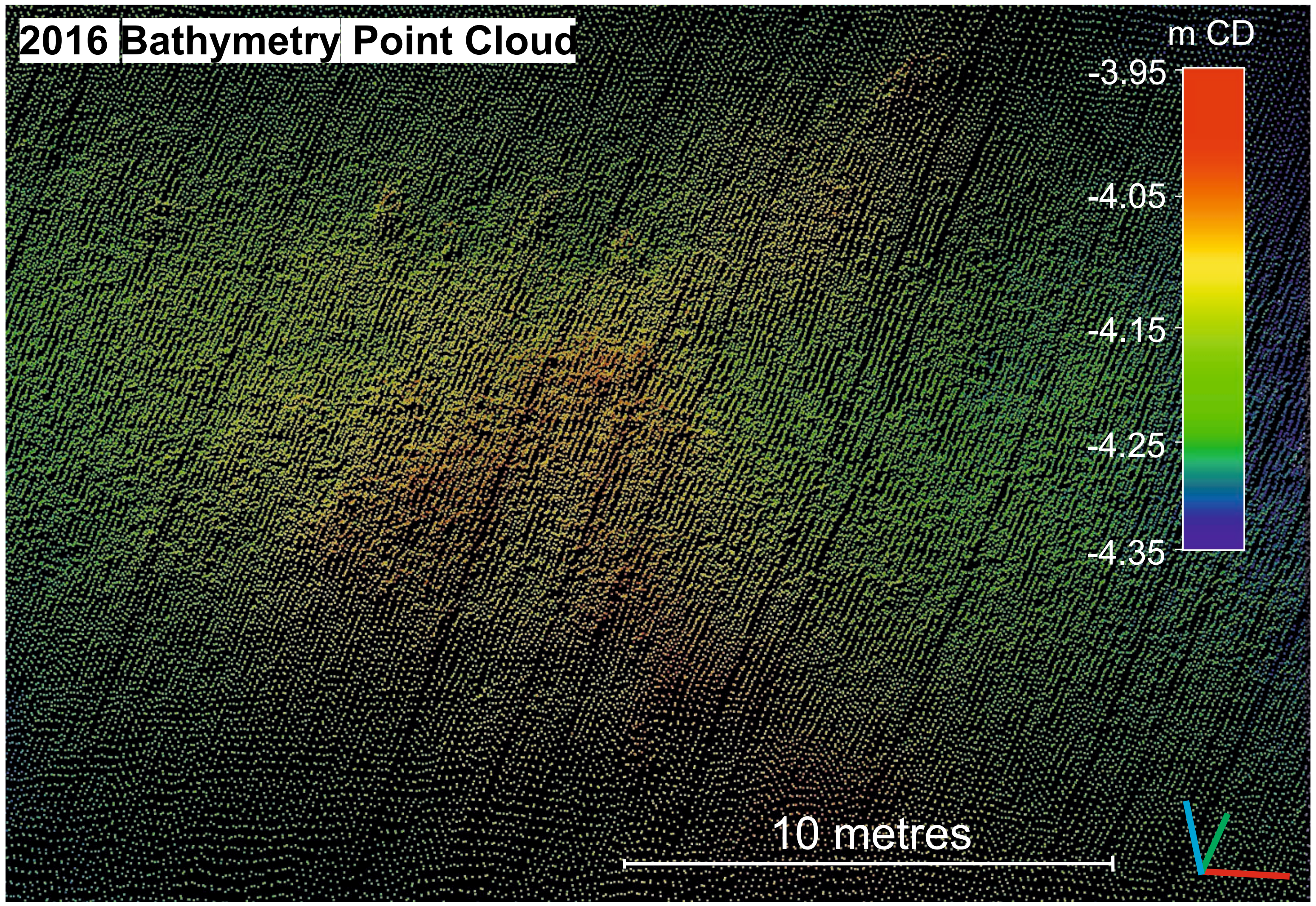
Figure 26
Bathymetry and SSS of UoS_bathy_03

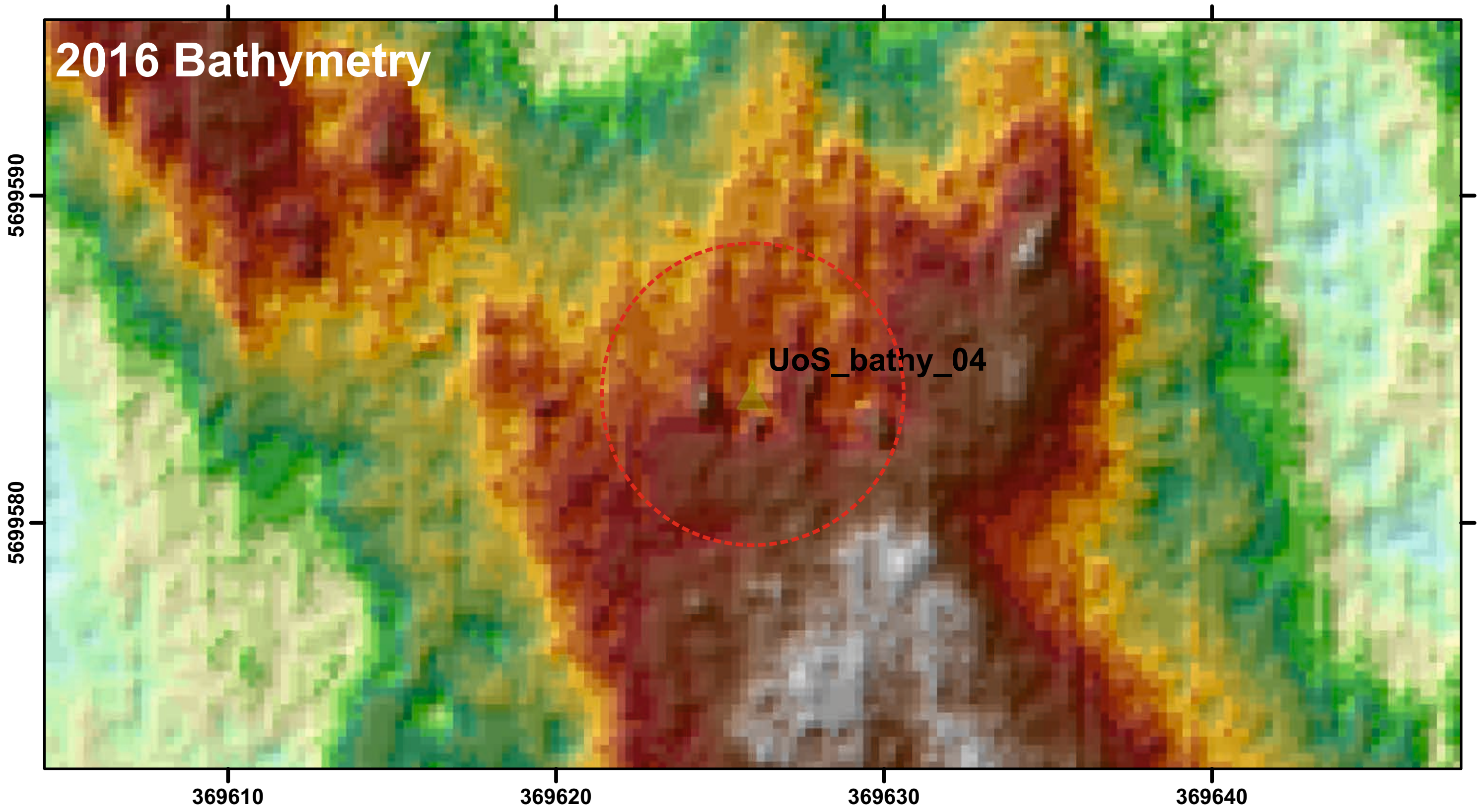
Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

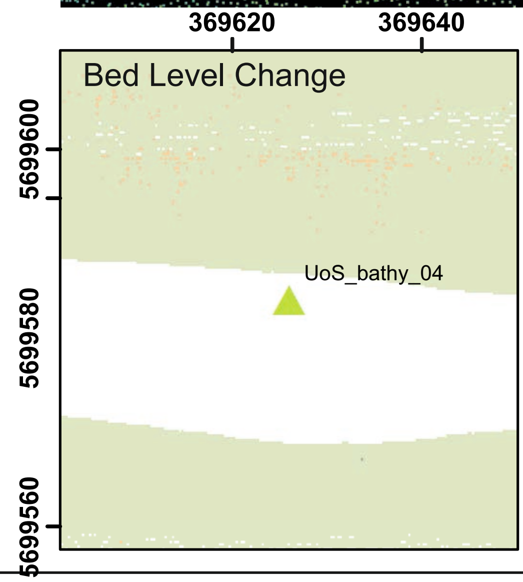
0 4.75 9.5
Metres

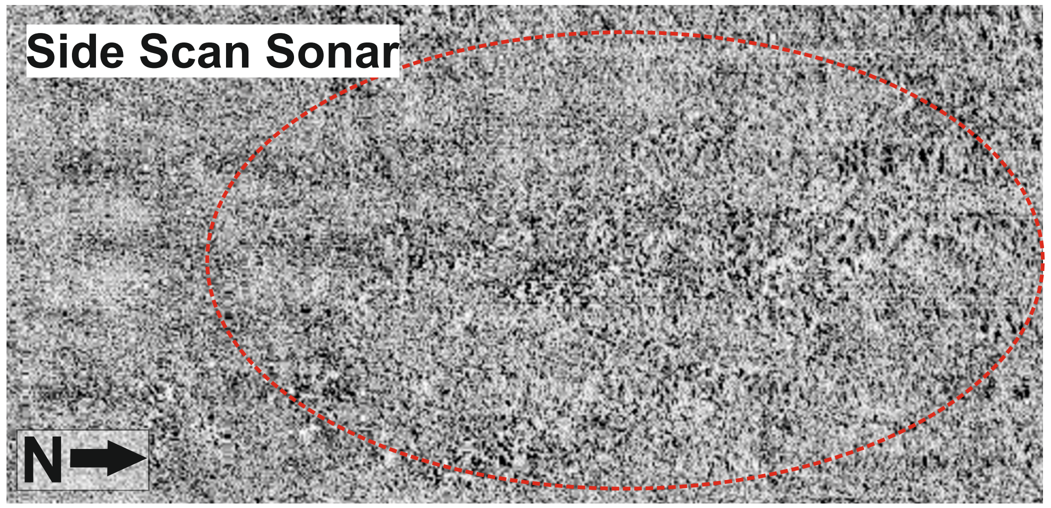
UNIVERSITY OF Southampton

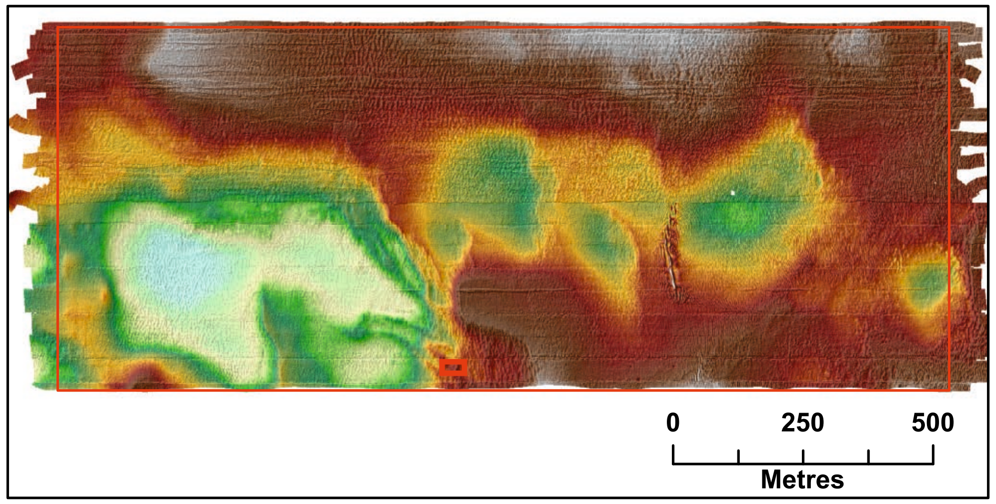












Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.95

-4.3

Bed Level Change (m)

> + 0.5

0

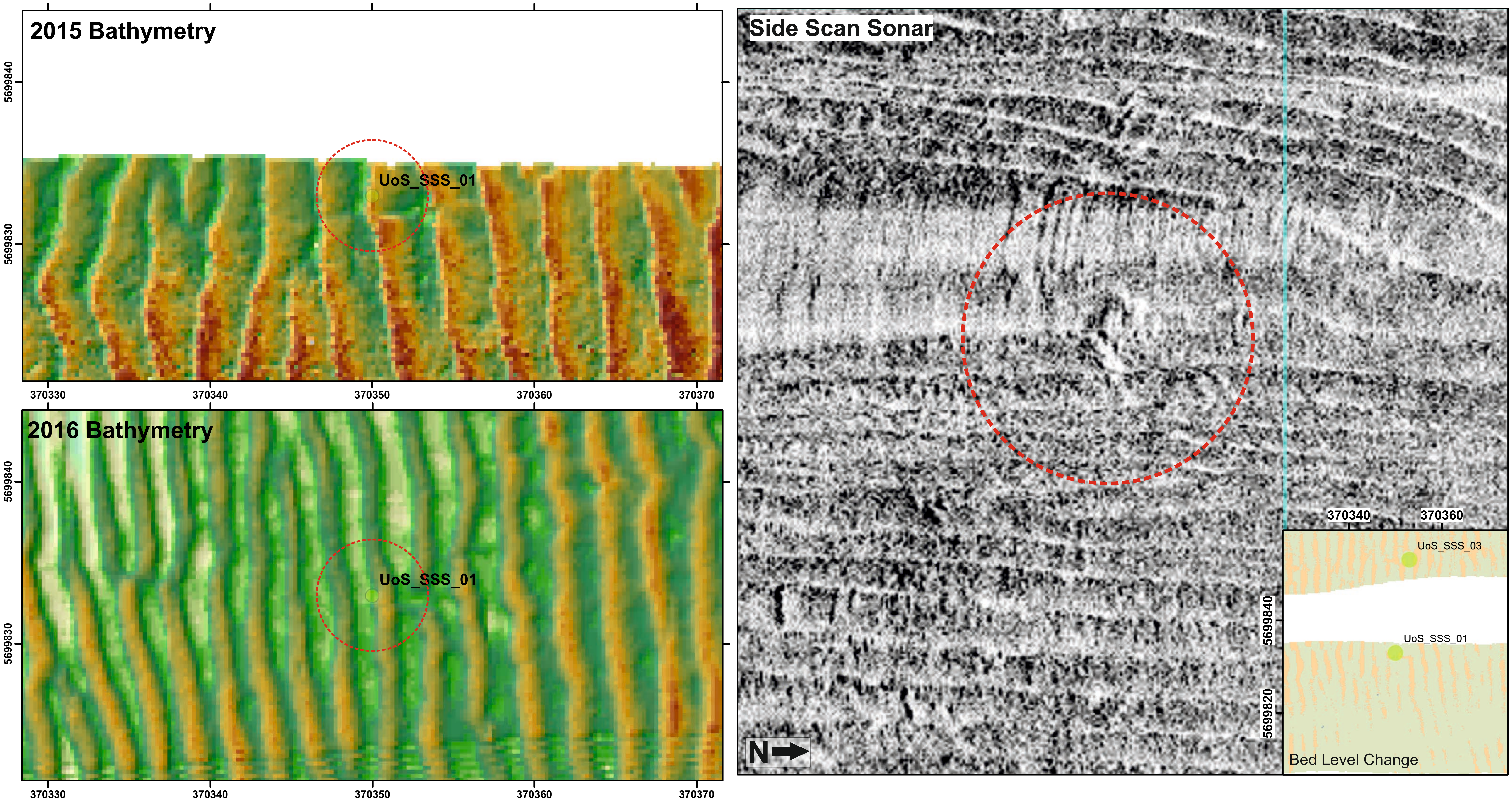
> - 0.5

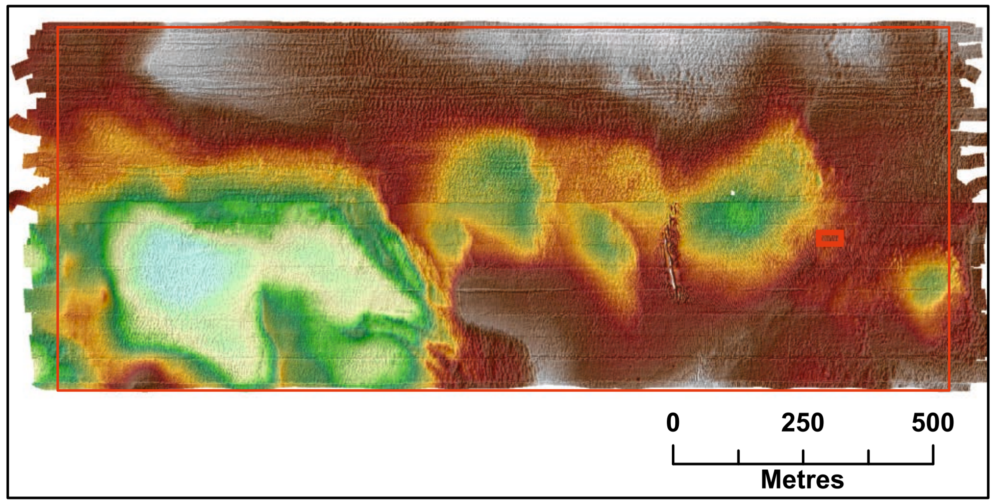
Figure 27
Bathymetry and SSS of UoS_bathy_04

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.75 9.5
Metres

UNIVERSITY OF Southampton





Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.9

-4.4

Bed Level Change (m)

> + 0.5

0

> - 0.5

Figure 28
Bathymetry and SSS of UoS_SSS_01

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.5 9
Metres

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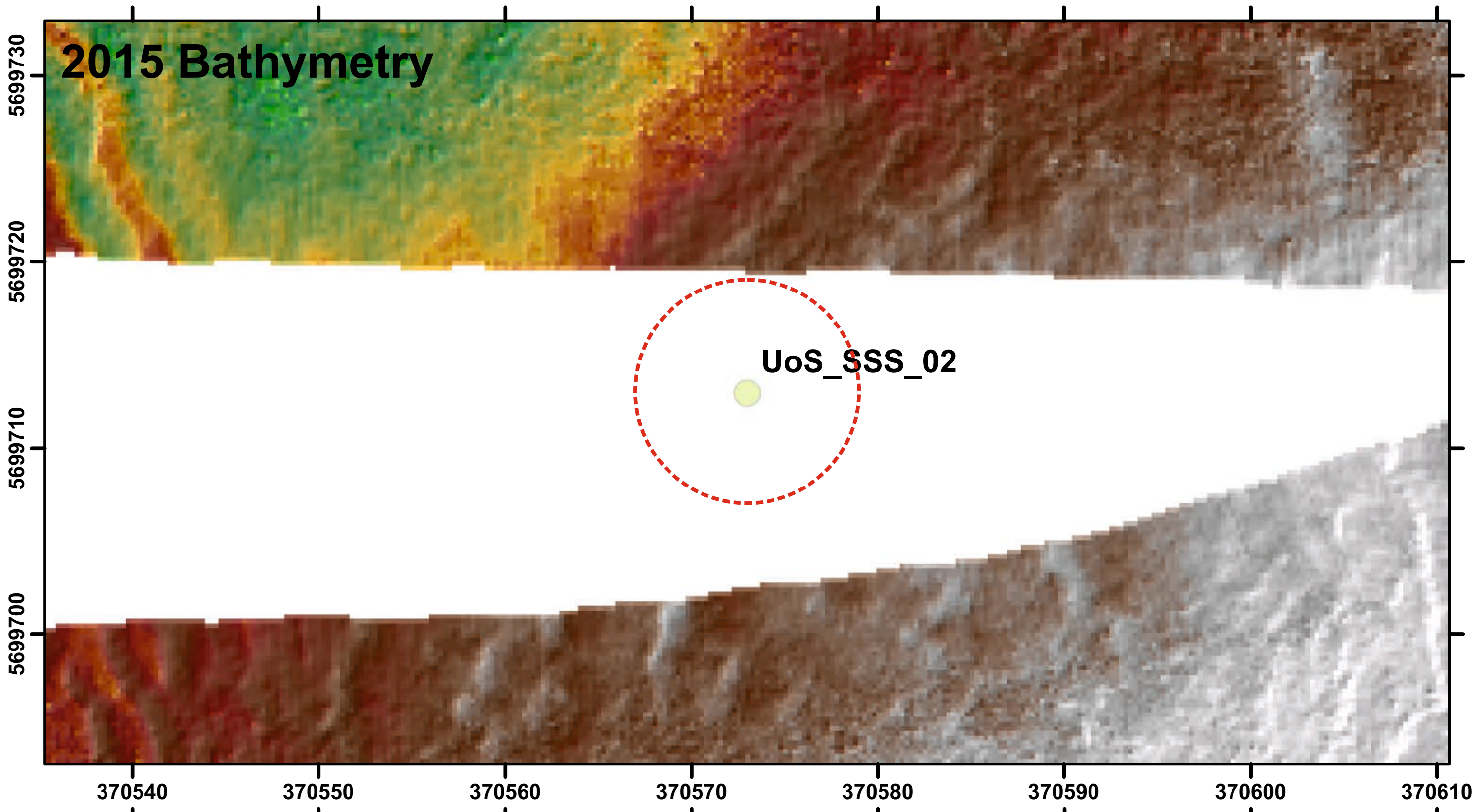

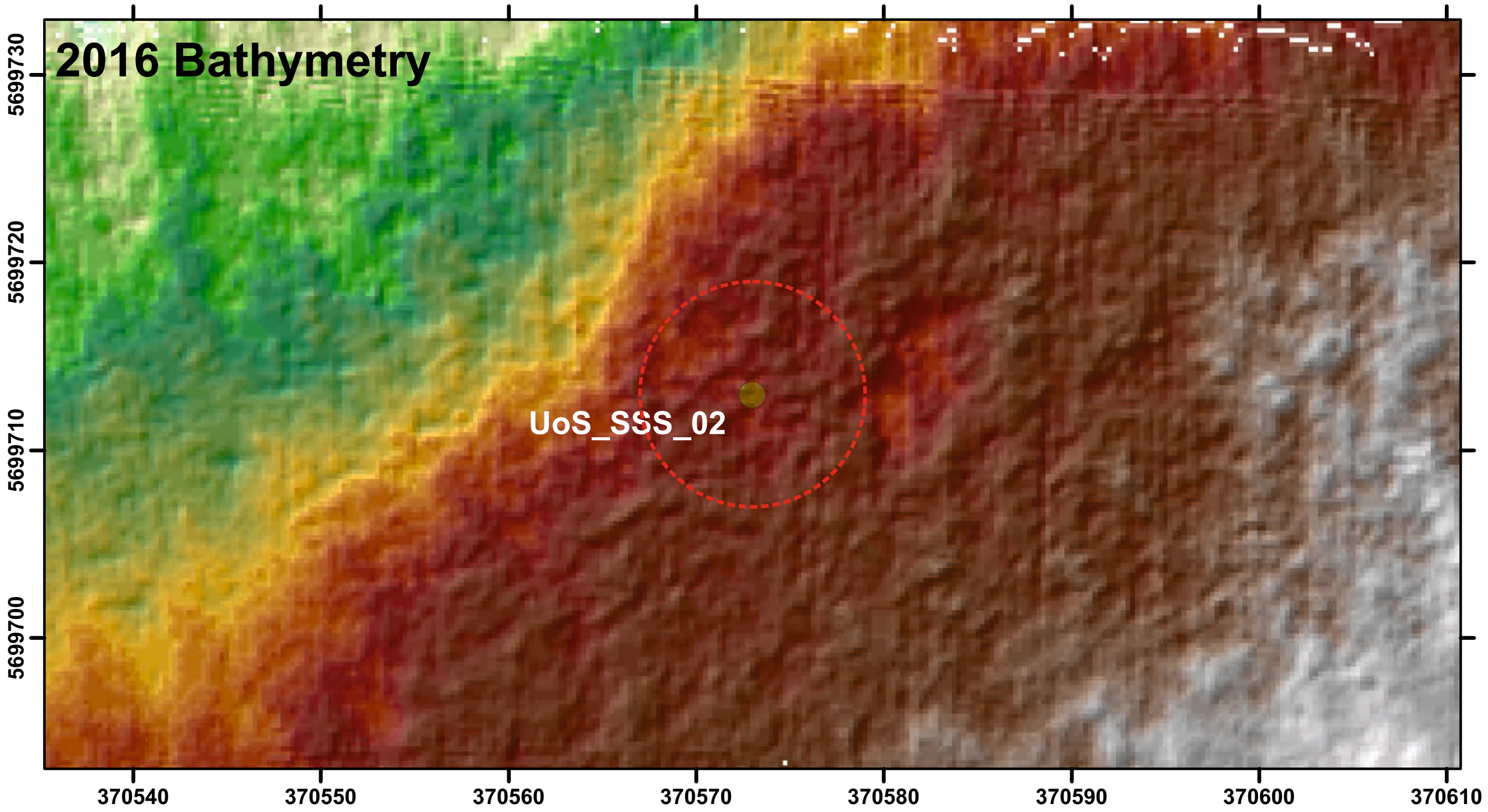

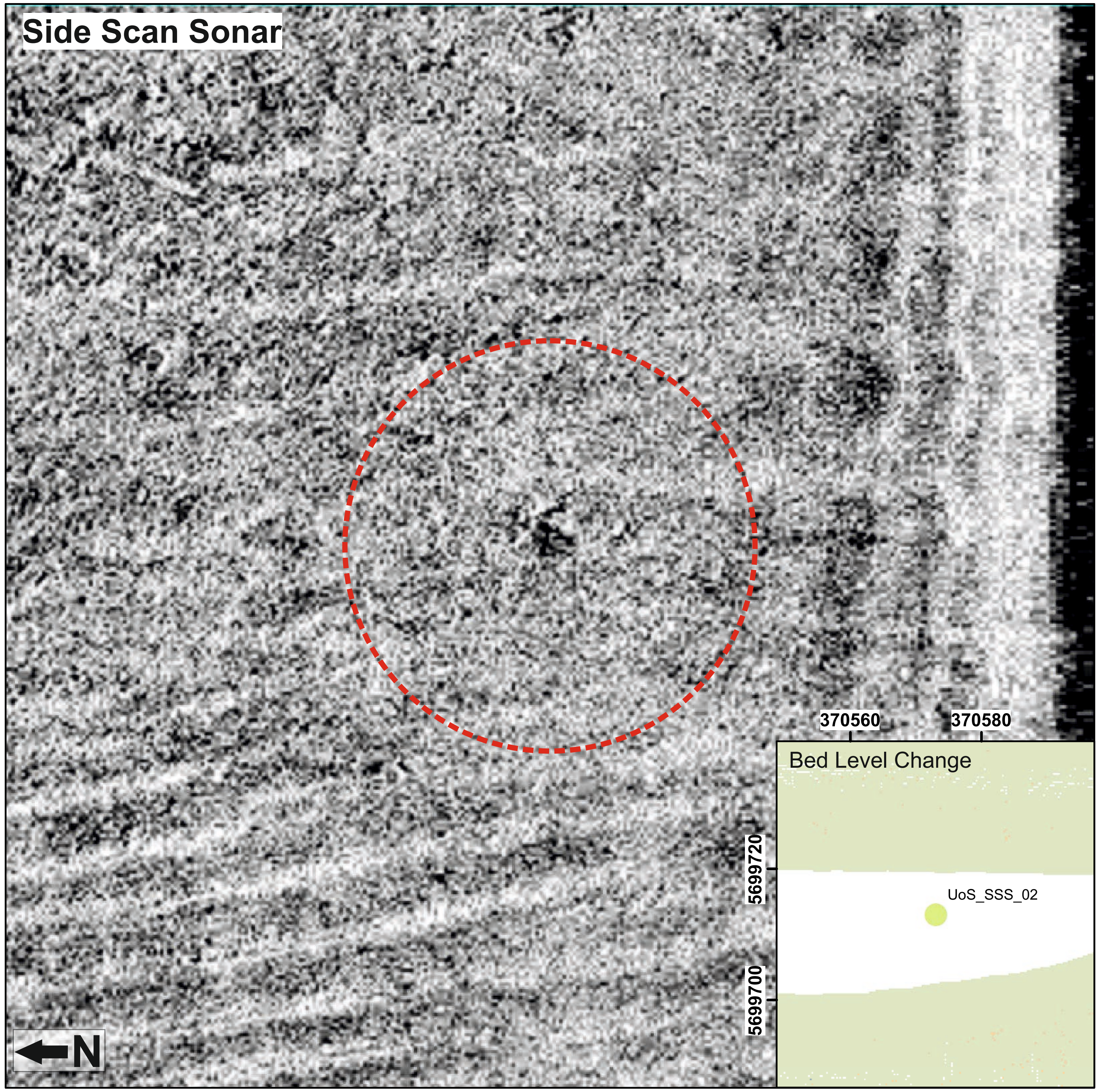

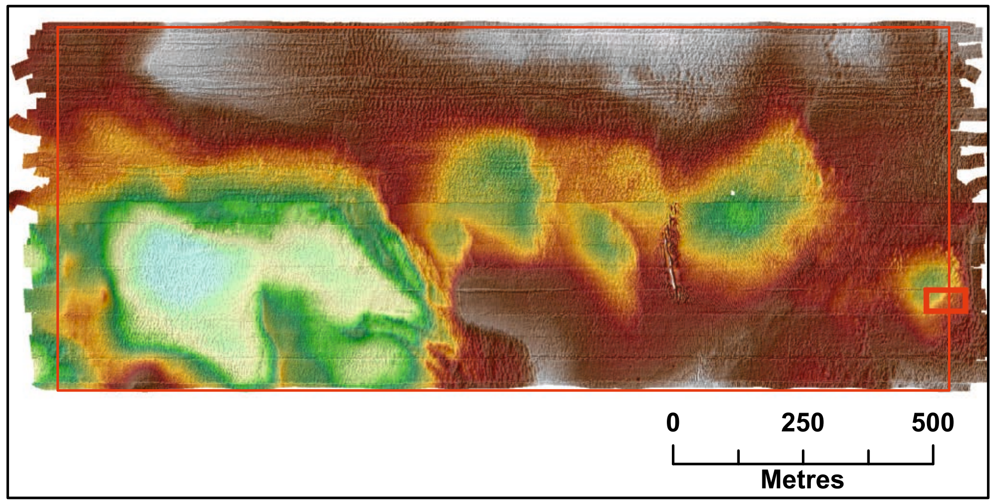

Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-4.1

-4.7

Bed Level Change (m)

> + 0.5

0

> - 0.5

Figure 29
Bathymetry and SSS of UoS_SSS_02

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.5 9
Metres

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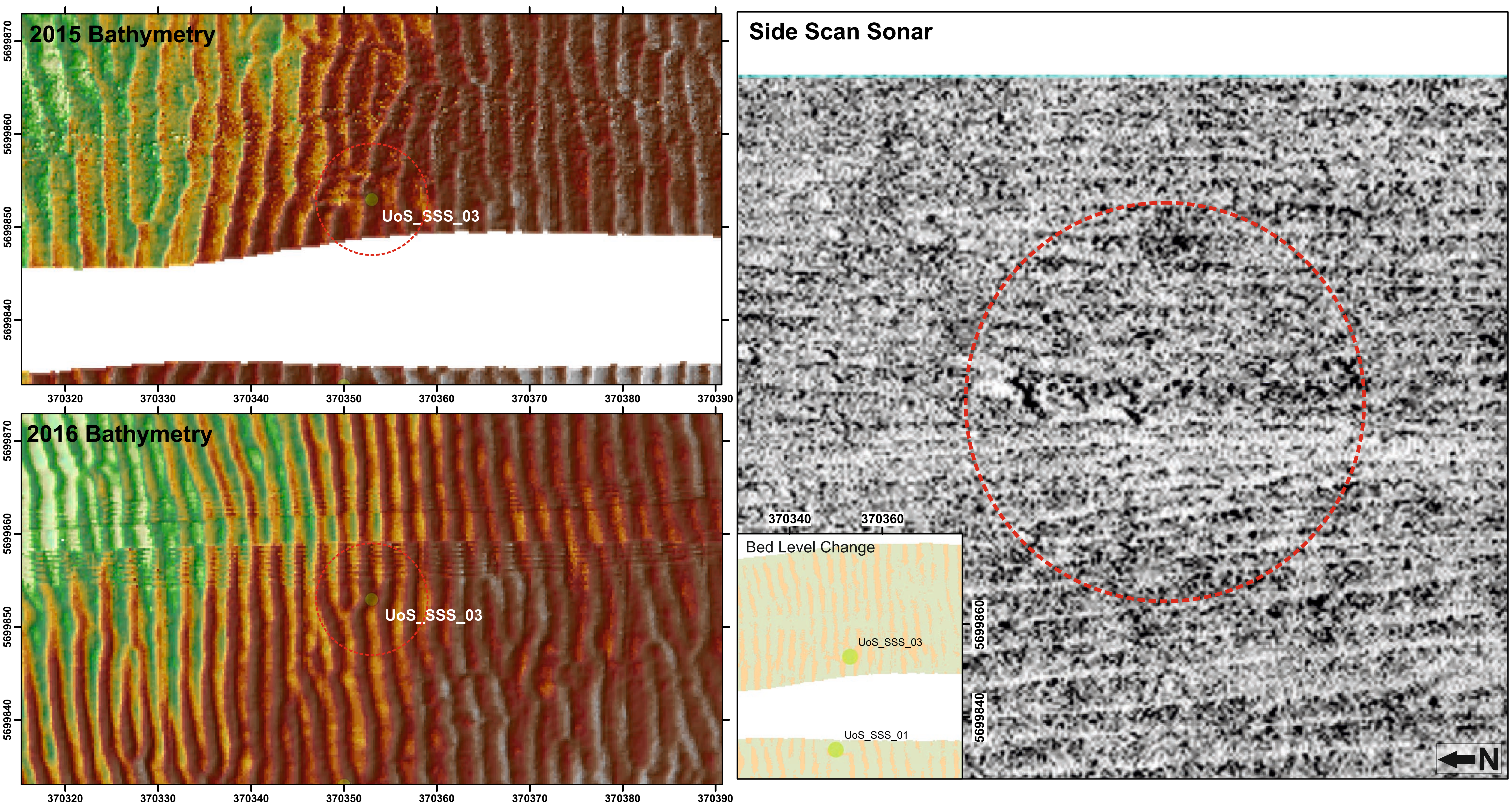

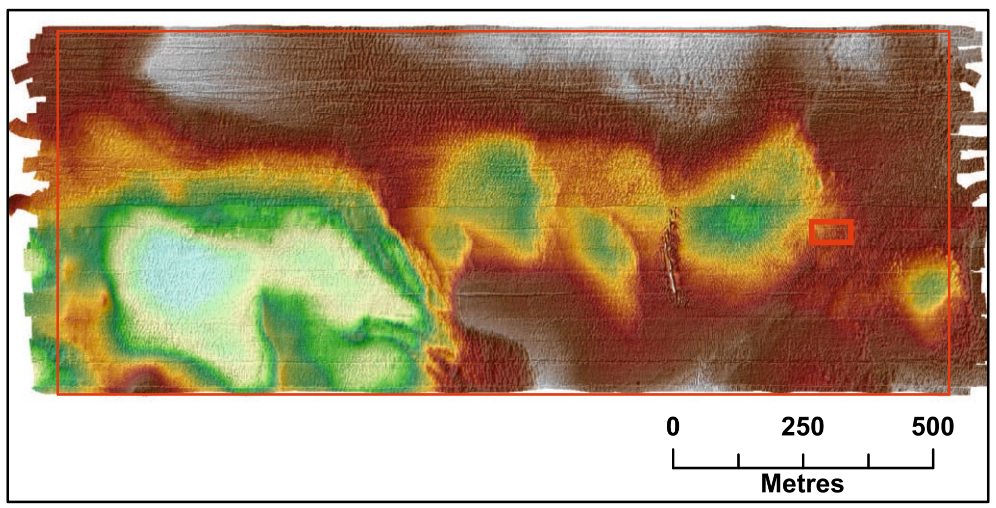

Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-4.1

-4.5

Bed Level Change (m)

> + 0.5

0

> - 0.5

Figure 30

Bathymetry and SSS of UoS_SSS_03

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.5 9
Metres

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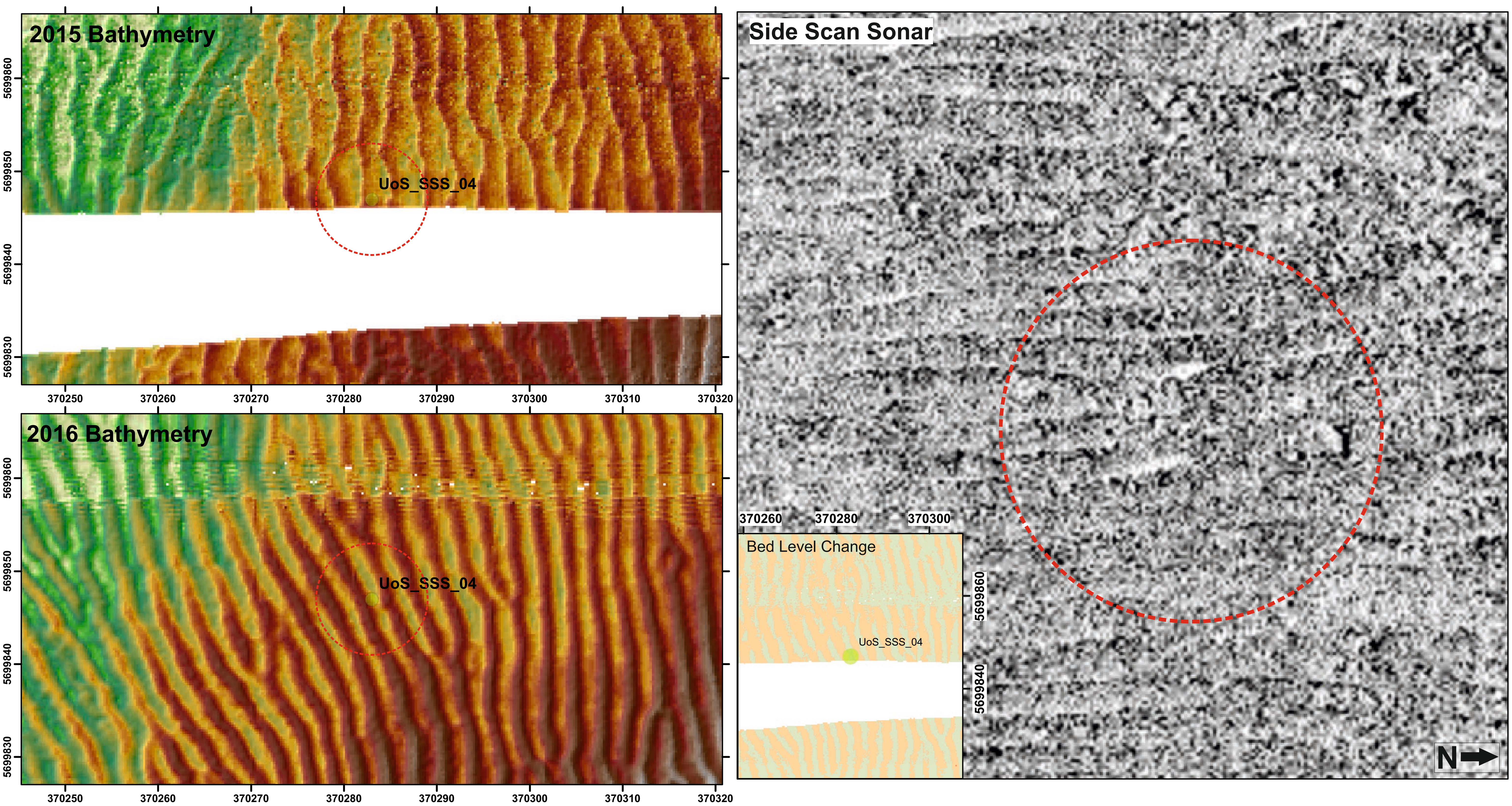

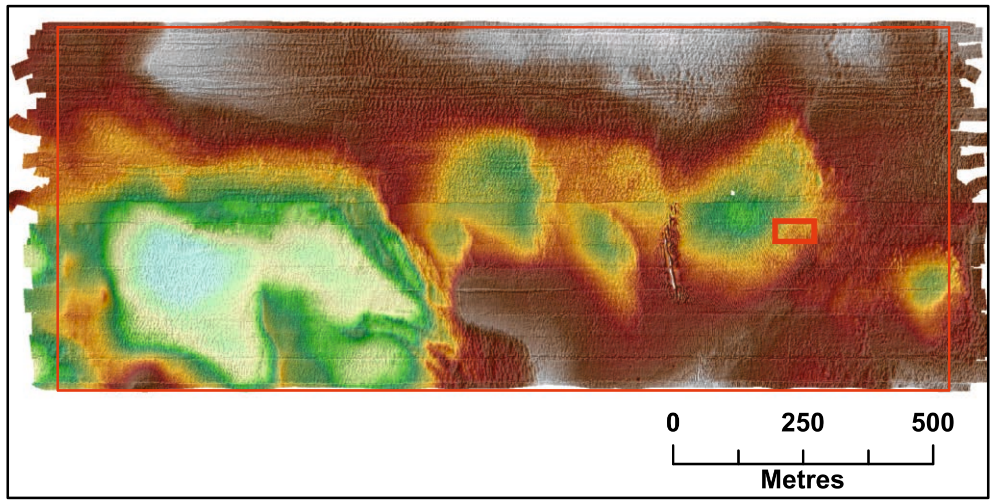

Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-4.1

-4.7

Bed Level Change (m)

> + 0.5

0

> - 0.5

Figure 31
Bathymetry and SSS of UoS_SSS_04

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.5 9
Metres

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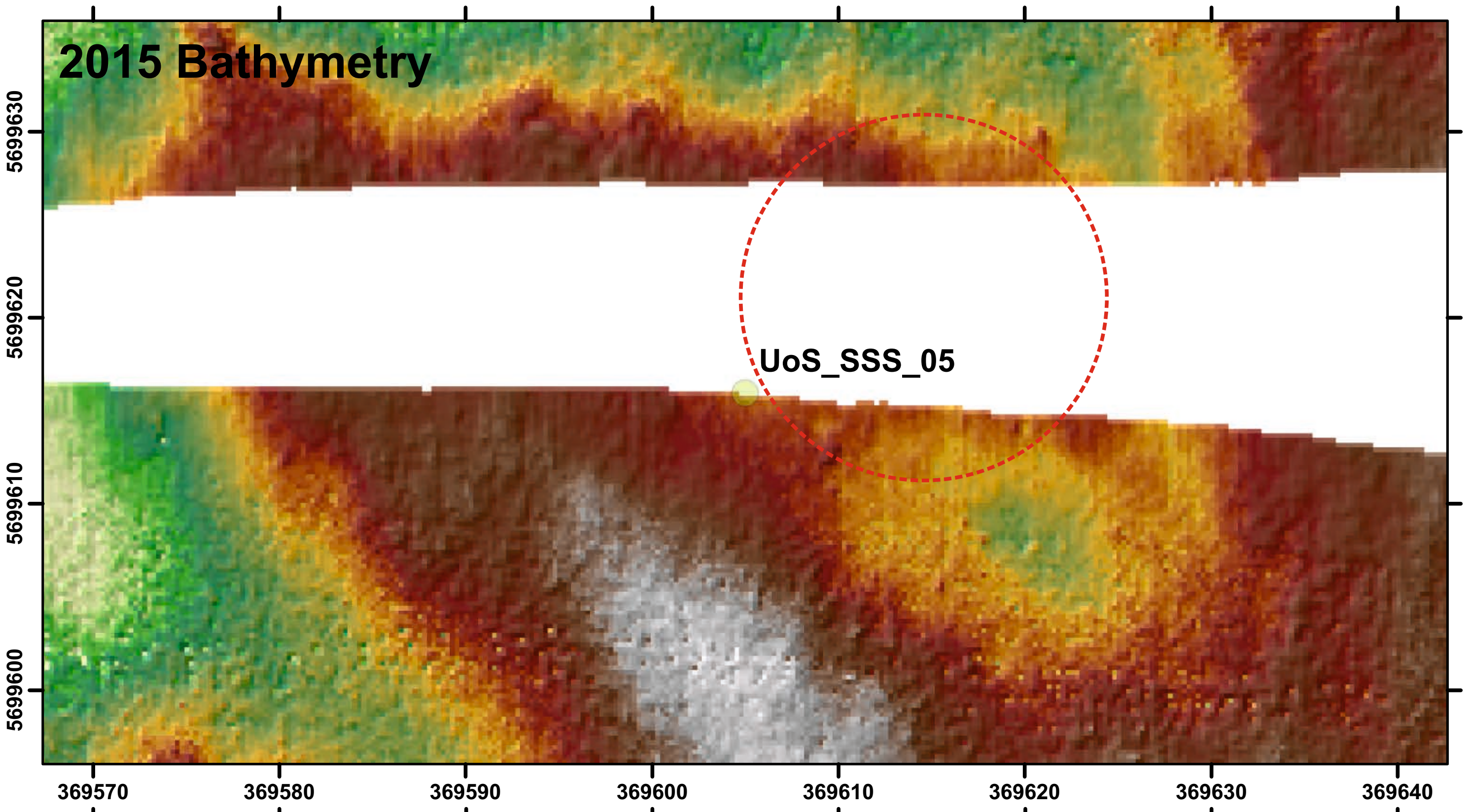

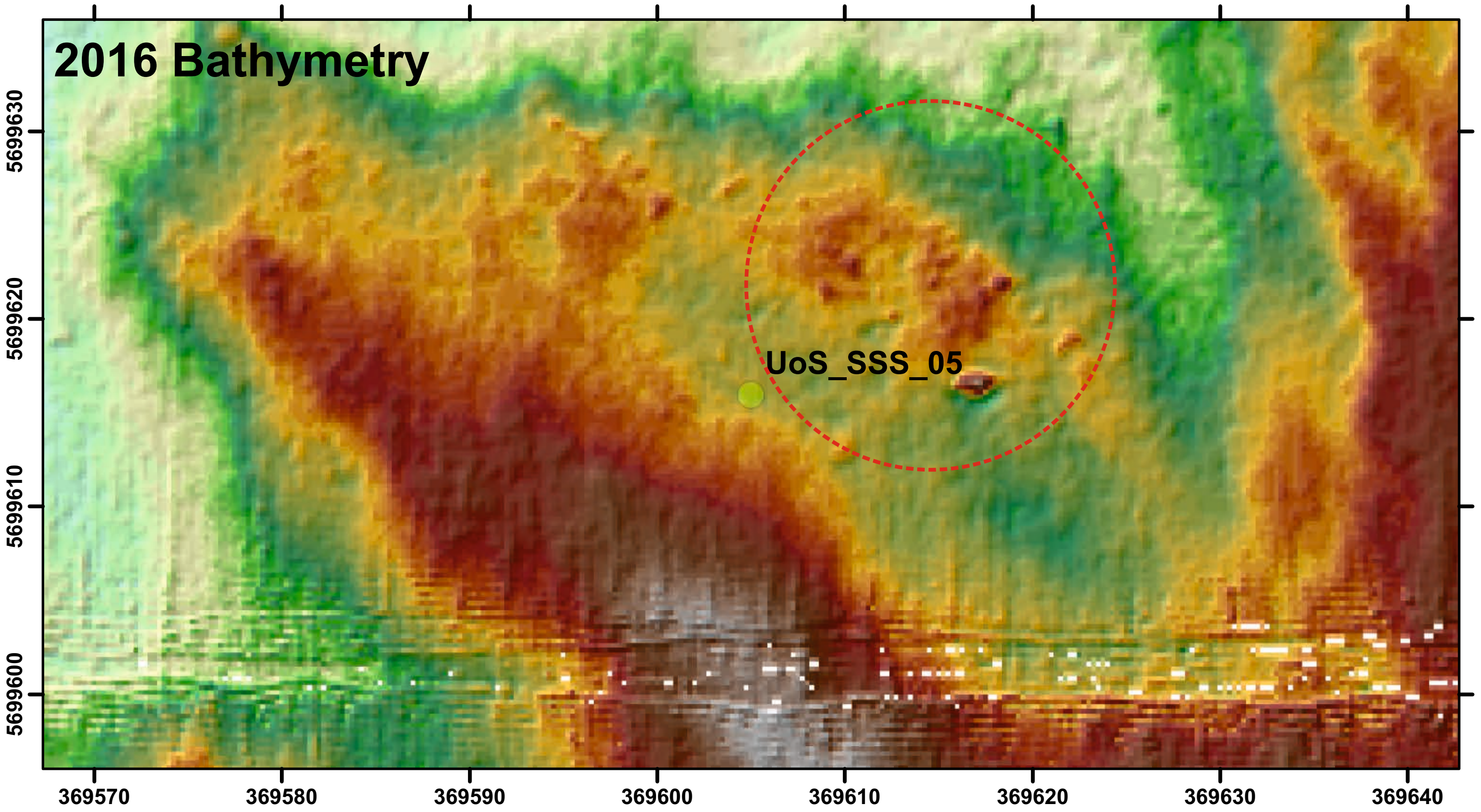

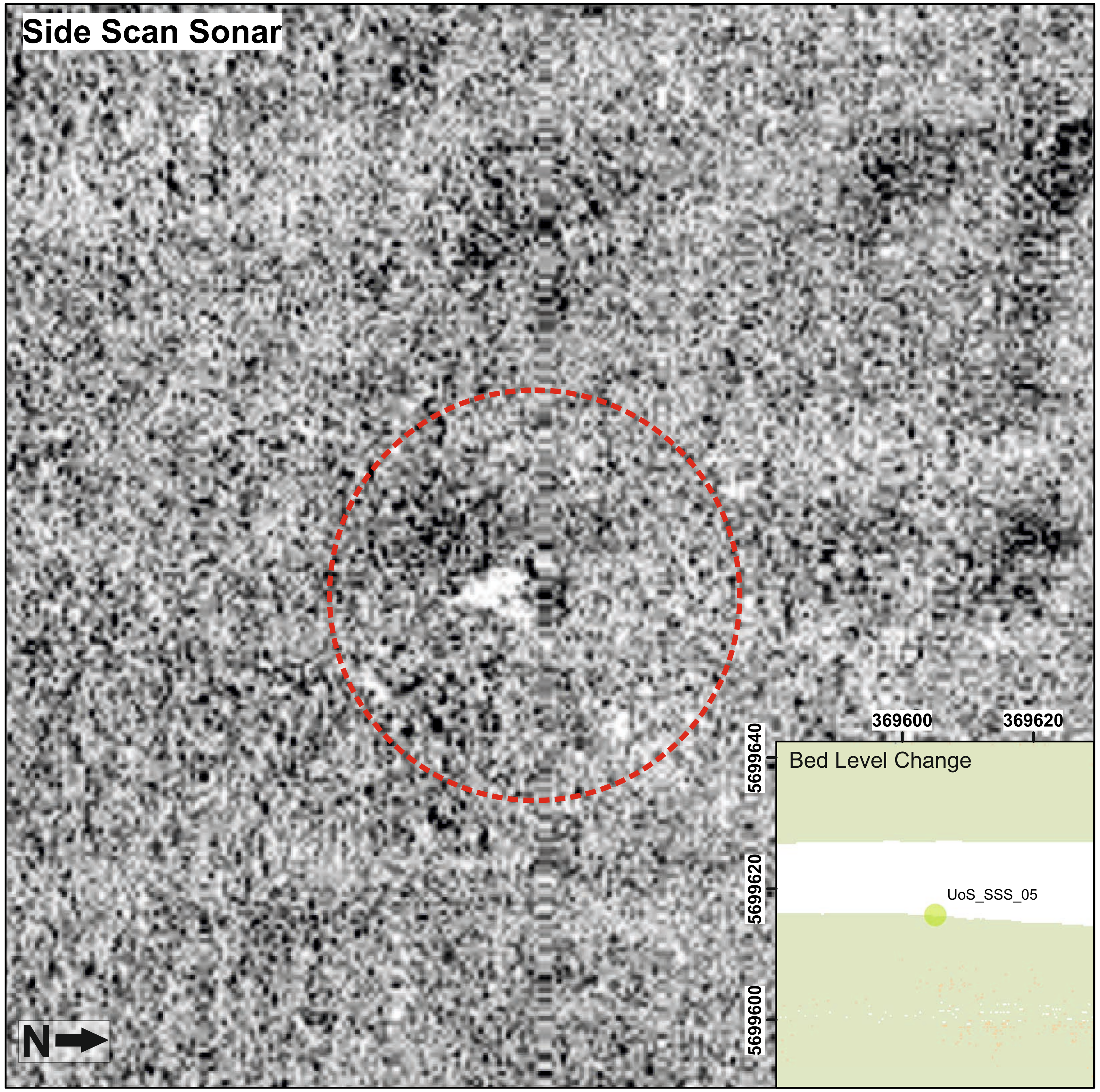

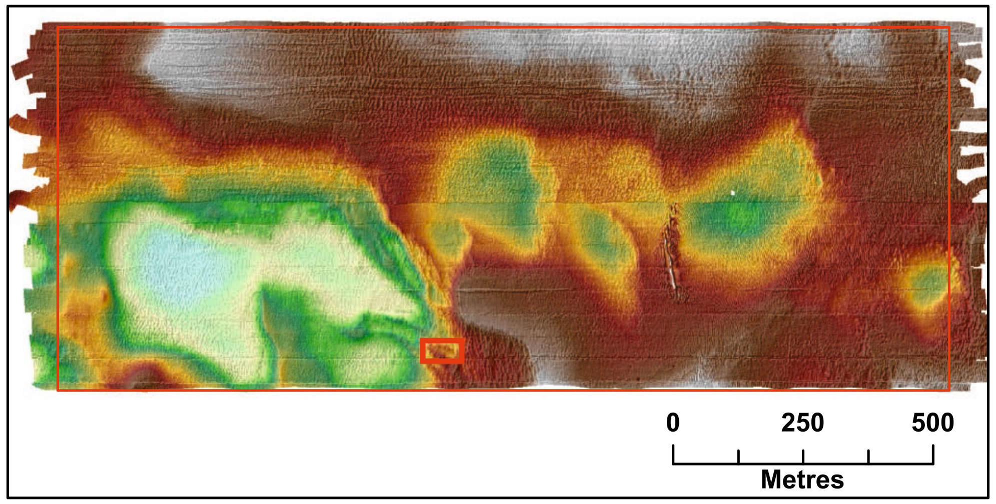

Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-4.0

-4.6

Bed Level Change (m)

> + 0.5

0

> - 0.5

Figure 32
Bathymetry and SSS of UoS_SSS_05

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 4.5 9
Metres

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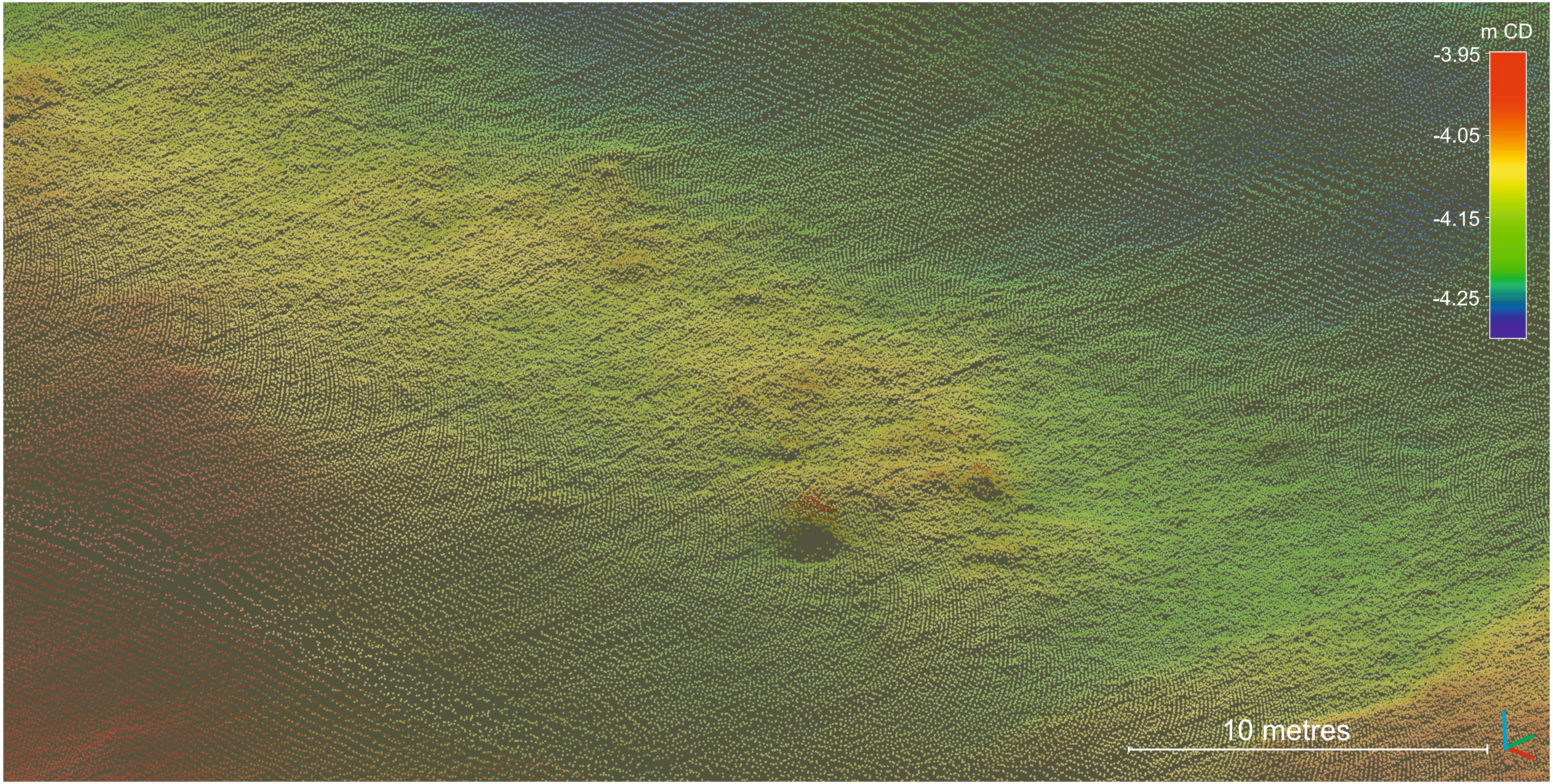
Southampton



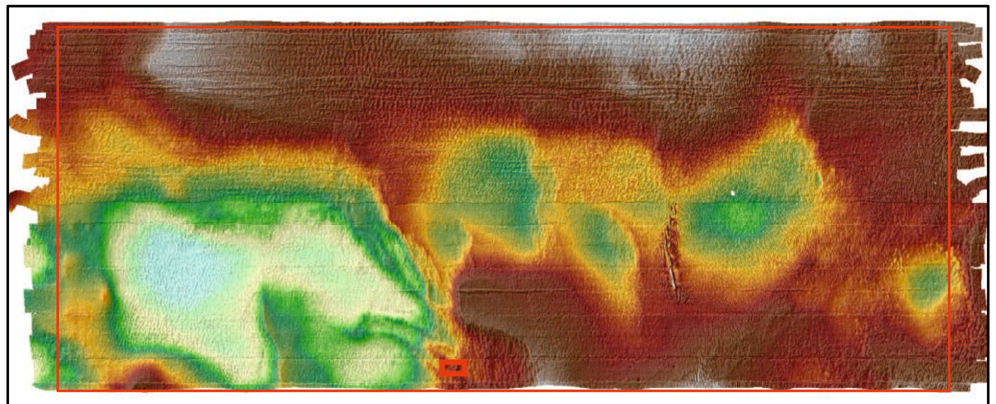


Figure 33
Bathymetry point cloud of UoS_SSS_05.

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

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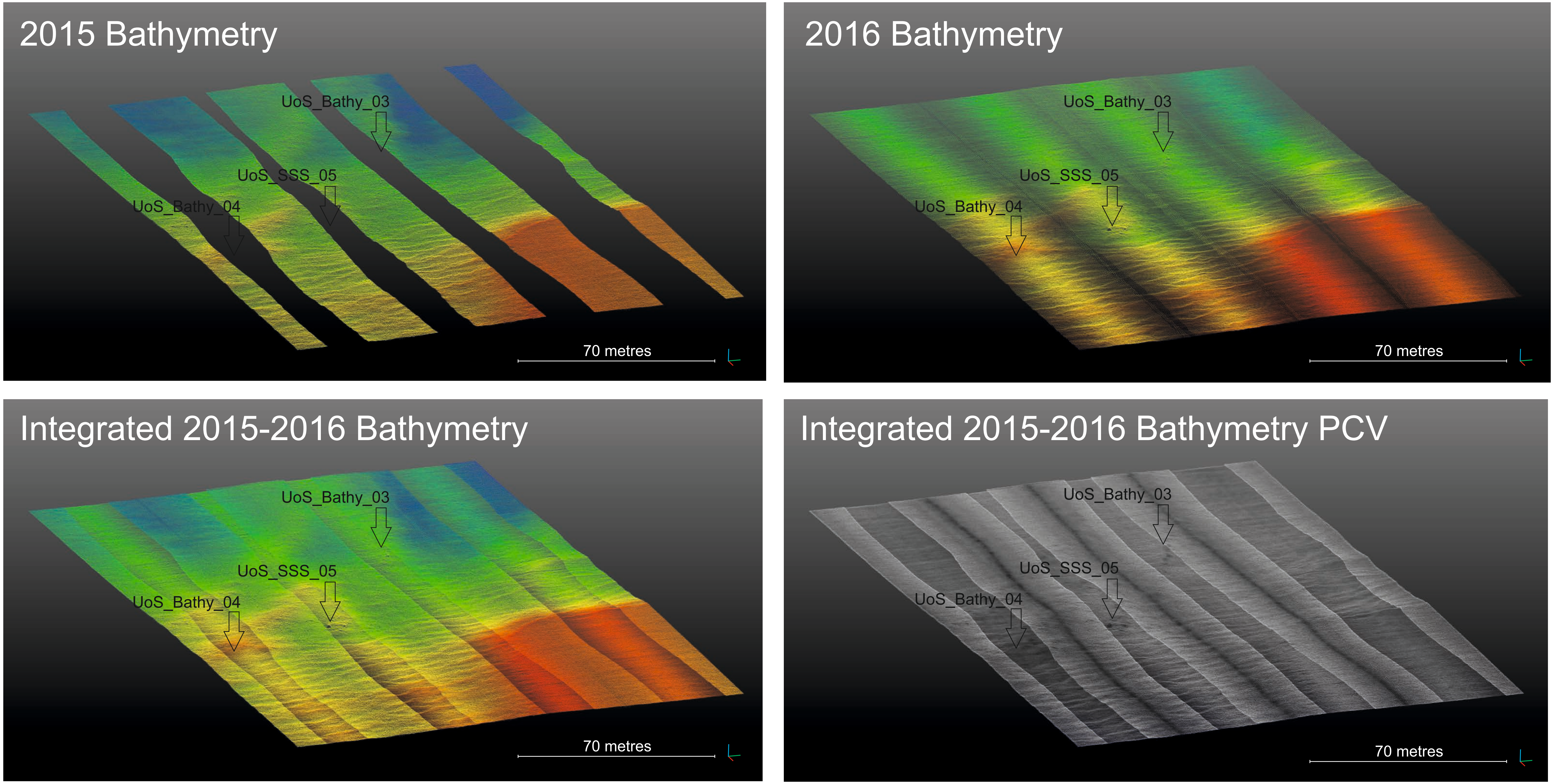
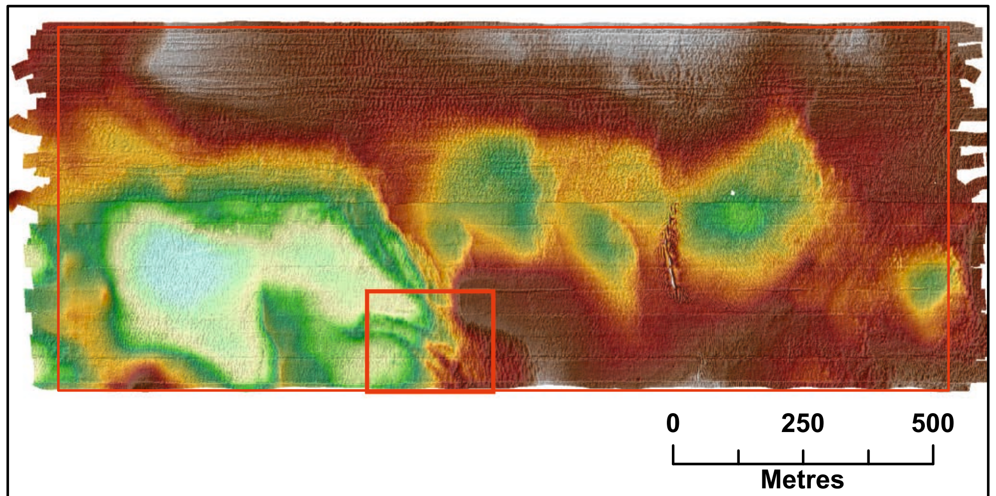




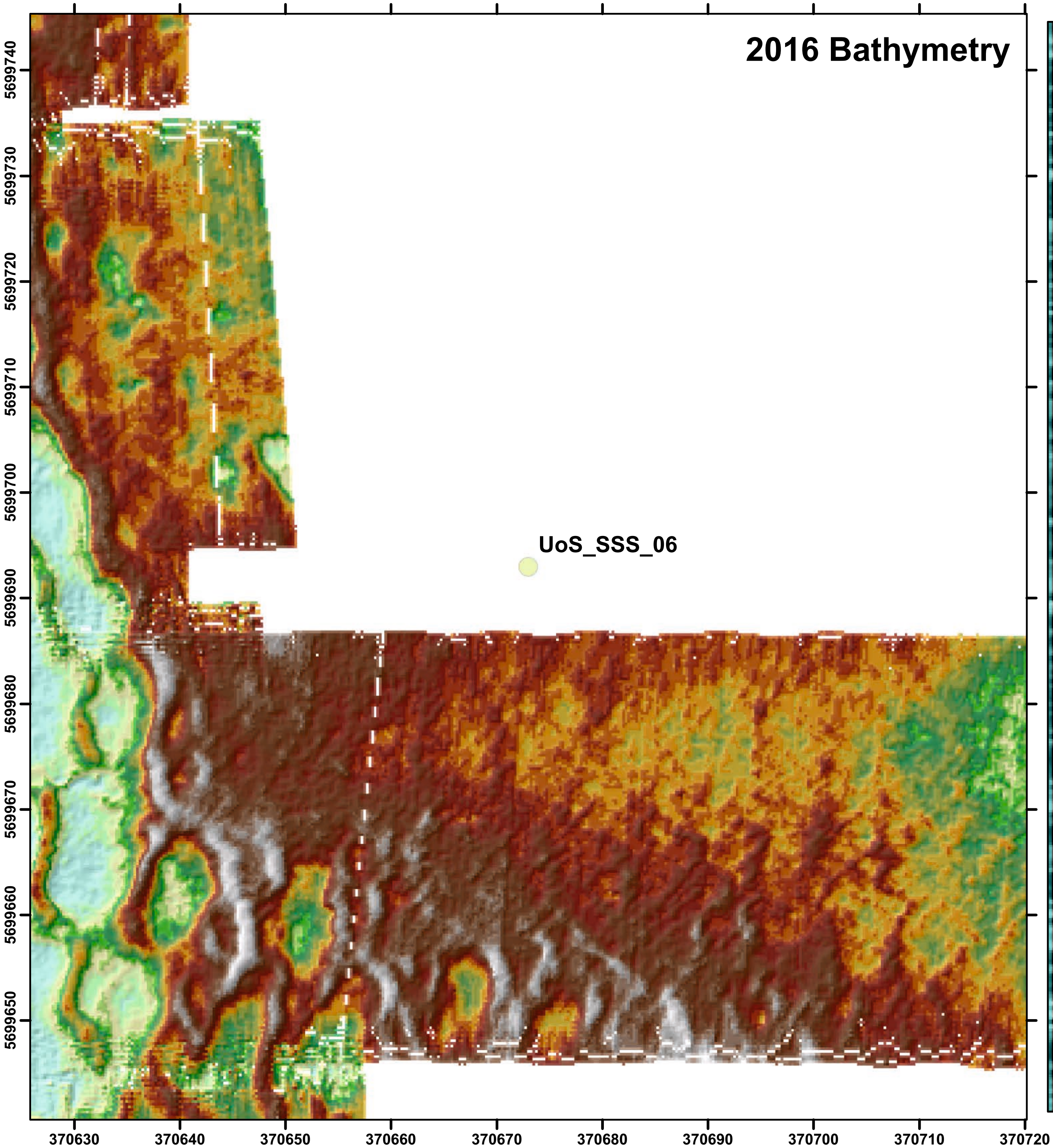
Legend

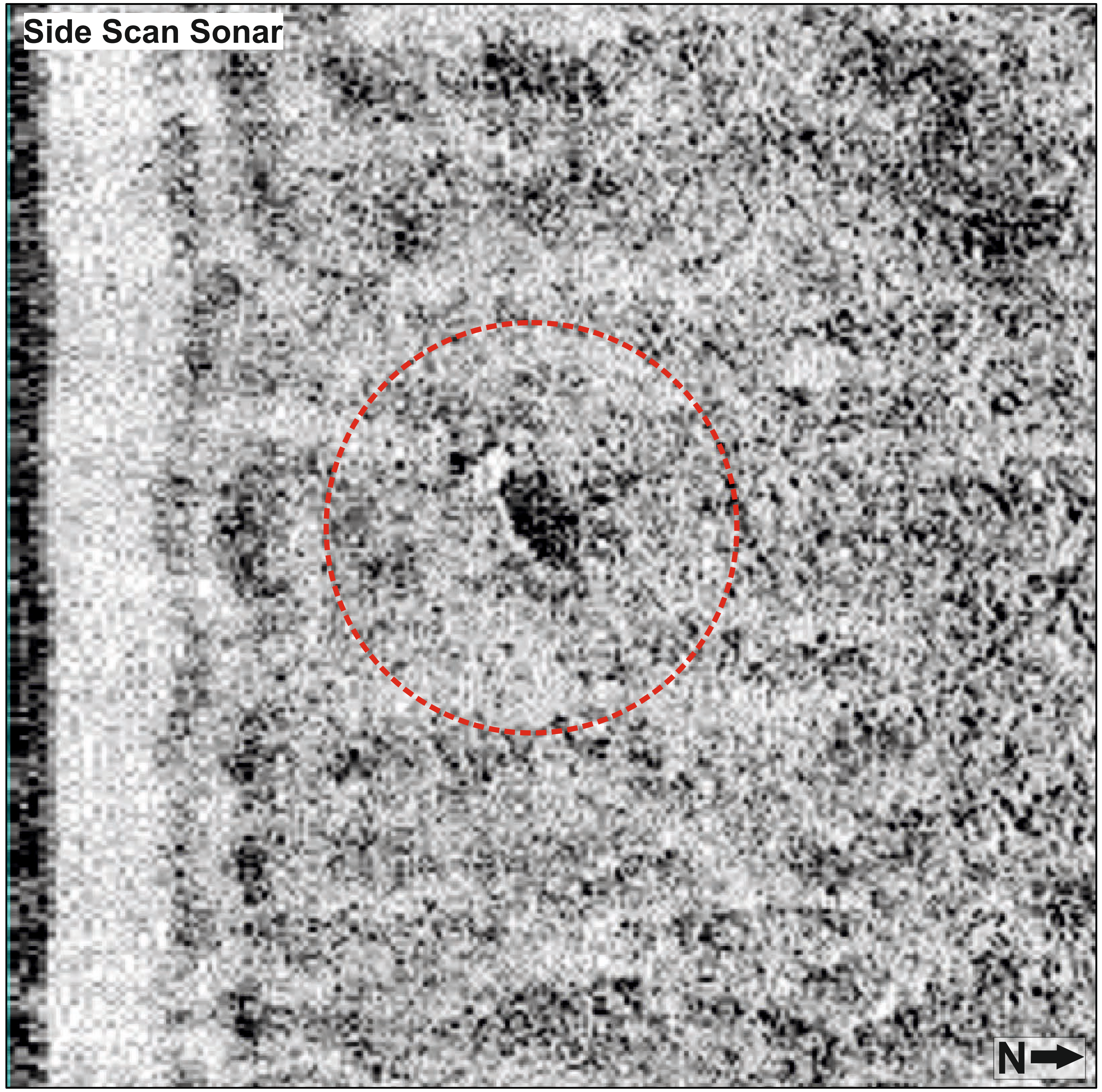
Bathymetry (m CD)

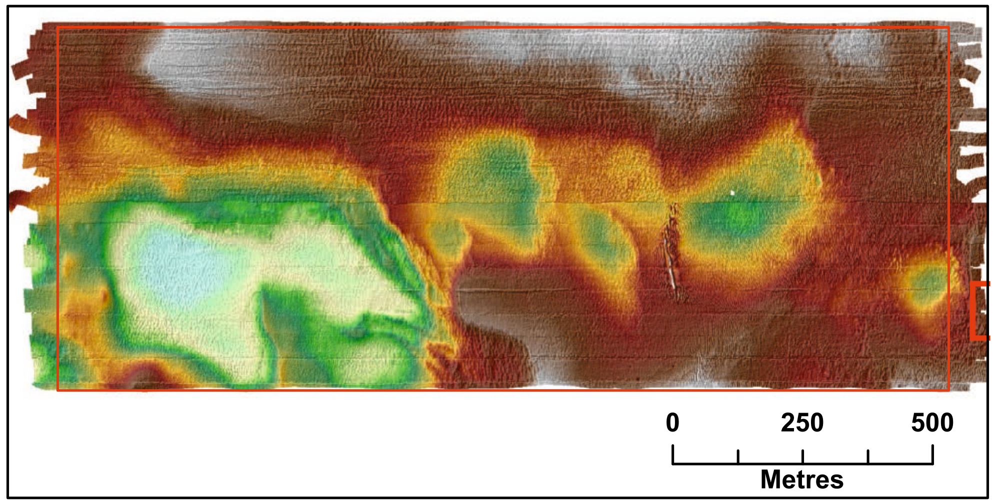
- -3.66
- -4.01
- -4.26
- -4.53
- -4.79
- -5.05

Figure 34
2015 and 2016 Bathymetry point cloud of the area around UoS_Bathy_03 & 04 and UoS_SSS_05

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre







Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.83

-5.48

Figure 35
Bathymetry and SSS of UoS_SSS_06

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 5 10
Metres

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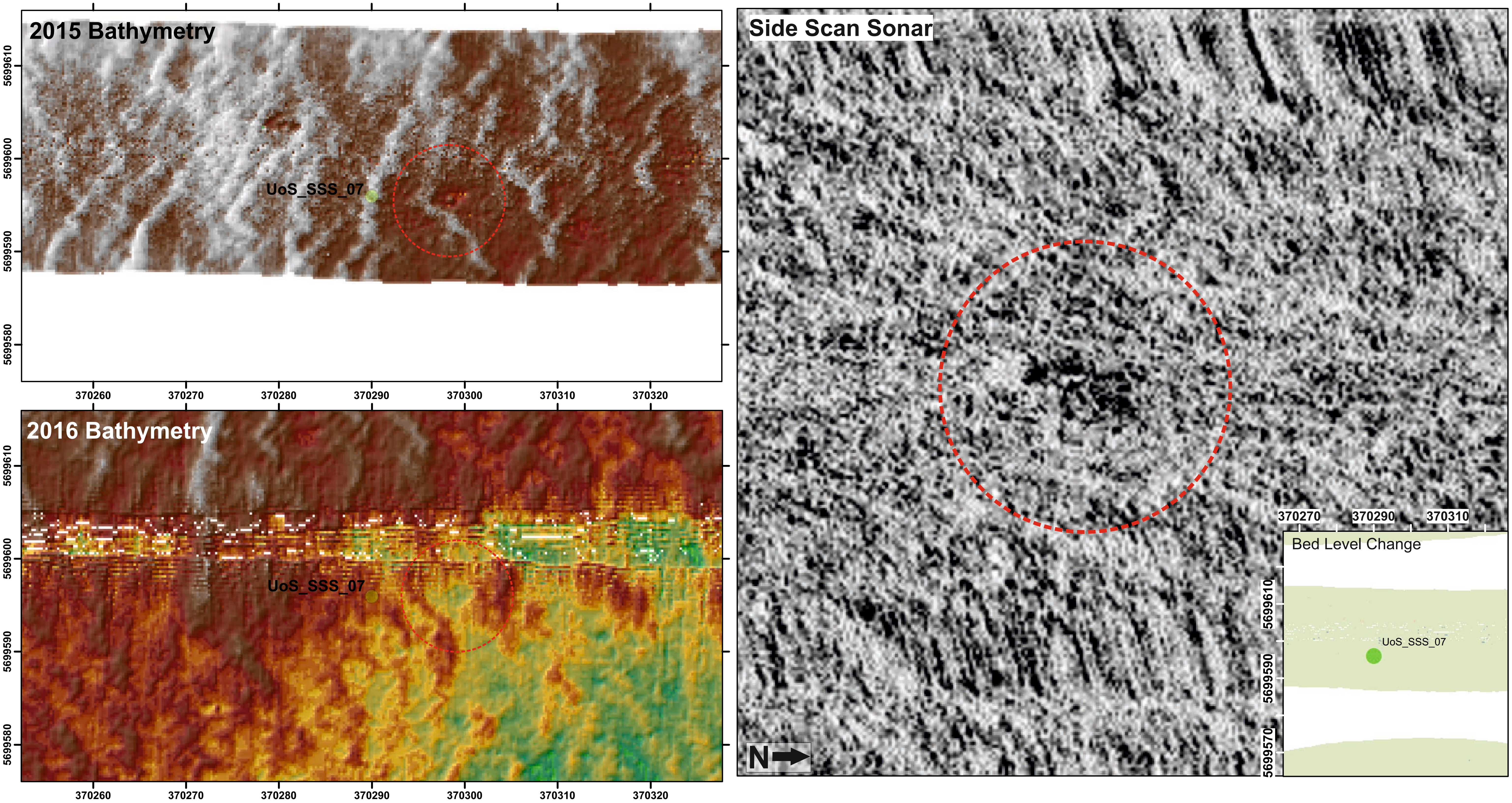

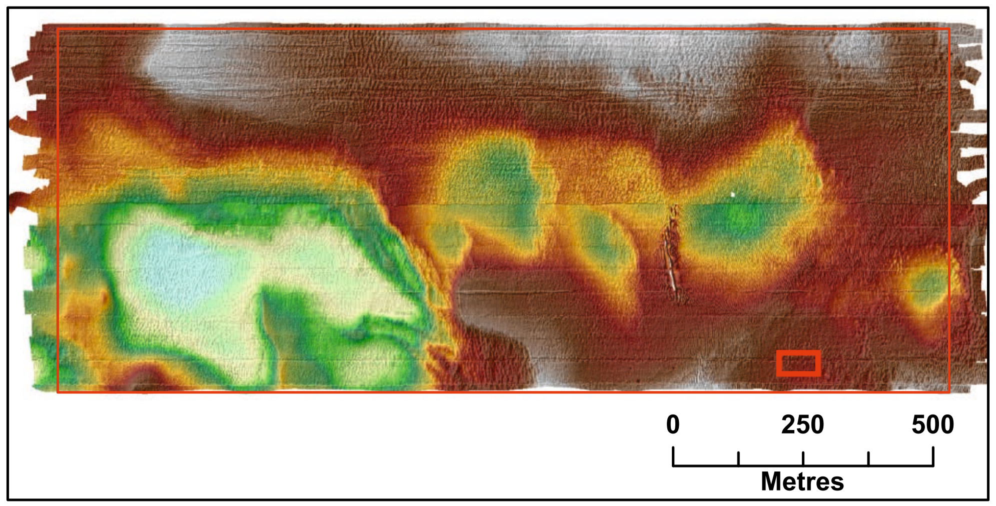

Legend

2015/16 Bathymetry Anomalies

2015/16 Side Scan Sonar Anomalies

Bathymetry (m CD)

-3.95

-4.3

Bed Level Change (m)

> + 0.5

0

> - 0.5

Figure 36
Bathymetry and SSS of UoS_SSS_07

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 5 10
Metres

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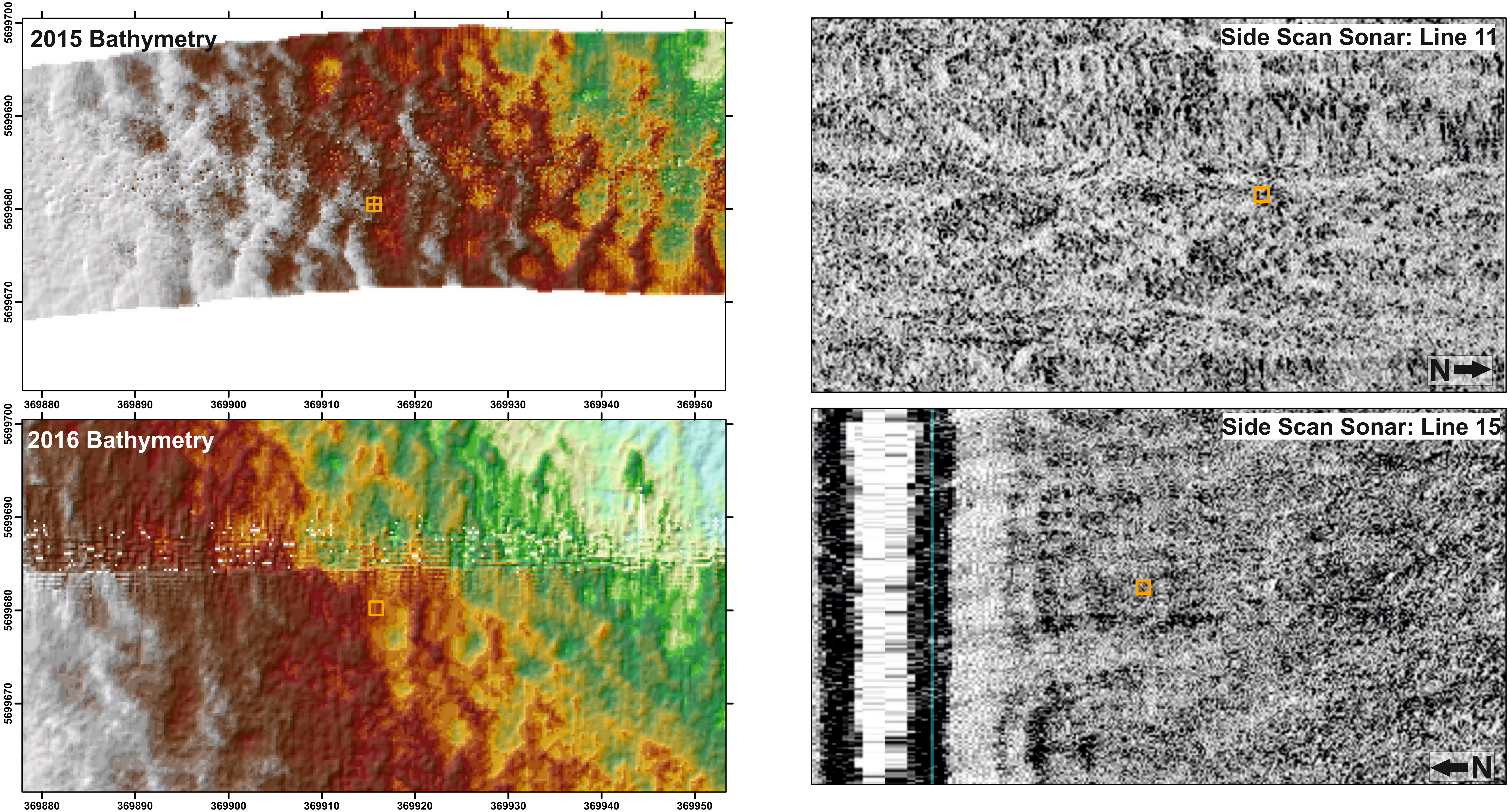

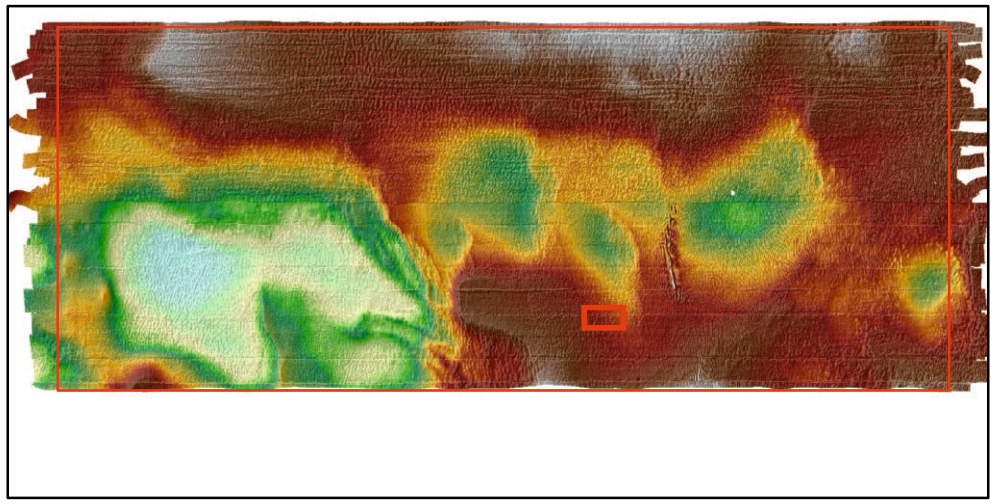

Legend

- 2015/16 Bathymetry Anomalies
- 2015/16 Side Scan Sonar Anomalies
- large_snag

Bathymetry (m CD)

-4.0

-4.3

Figure 37

2015/16 survey data over position of reported fisherman Roman 'find spot'

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

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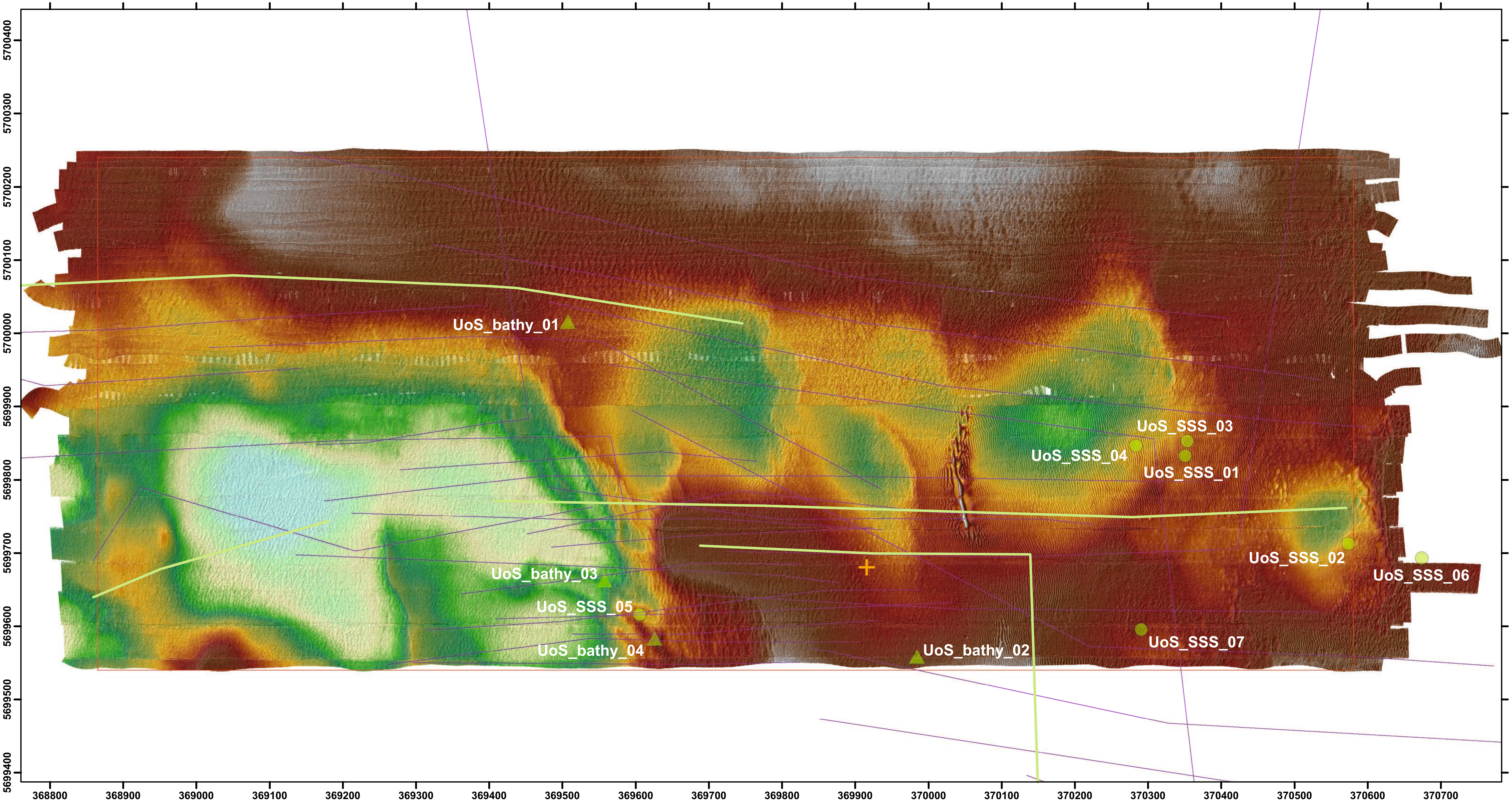

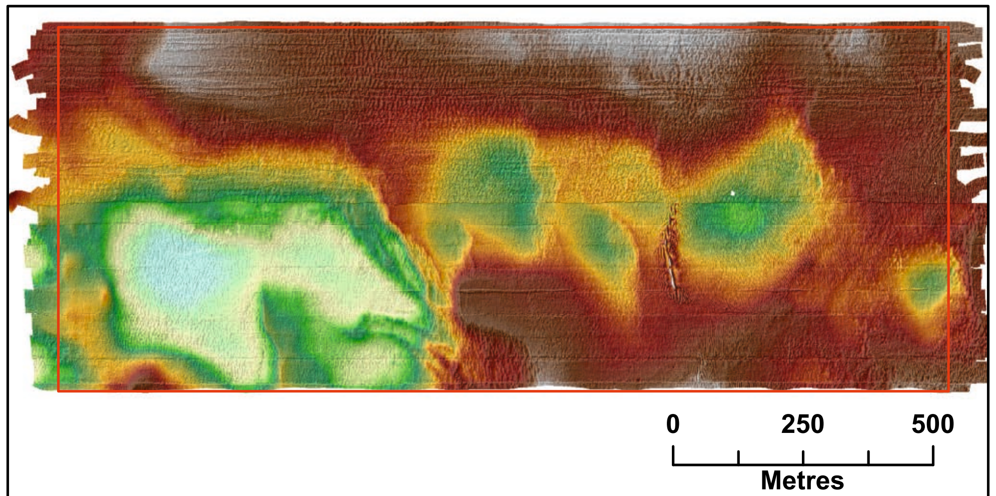

Legend

- 7164 Study Area
- 2015/16 Bathymetry Anomalies
- 2015/16 Side Scan Sonar Anomalies
- Fisherman 'Find Spot'
- UoS 2002 Dredge lines recovering Roman Material
- UoS 2002 Dredge lines not recovering Roman material

Bathymetry (m CD)

-3.09

-5.4

Figure 38

Distribution of 2015/16 survey anomalies and previous known Roman find spots from the study area

Coordinate System: ETRS 1989 UTM Zone 31N
Projection: Transverse Mercator
Datum: ETRS 1989
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 3.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Metre

0 75 150
Metres

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