GIS DETERMINATION OF THE AREAL EXTENT OF OFF-REEF, REEF-DERIVED SURFICIAL SUBSTRATE WITHIN THE PINNACLES POLYGON – BASED ON USGS HIGH RESOLUTION MULTIBEAM SONAR (HRMBS) ACOUSTIC BACKSCATTER DATA ACQUIRED IN 2000

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DWH Attorney-Client Communication

Data Source: HRMBS bathymetric data and co-registered backscatter data used in this briefing are available online at: http://pubs.usgs.gov/of/2002/0006/site/arcex.html

Introduction and Methods

Acoustic backscatter data were acquired by the U.S. Geological Survey (USGS) during a 2000 mapping cruise (Gardner et al. 2000) using a High Resolution Multibeam System (HRMBS) within an area of the Louisiana-Mississippi-Alabama outer shelf (1,926 km^2) populated by elevated fossil worm-algal reef structures originally referred to as the 'Pinnacles' (Ludwig and Walton 1957) (herein termed the 'Gardner Pinnacles polygon'). Backscatter data were acquired and co-registered with bathymetry using a Kongsberg Simrad EM1002 system. At the time, this was the latest generation of HRMBS with a frequency compatible with the depths to be surveyed, with the ability to map large areas at high speed without compromising data, and the ability to simultaneously produce high resolution calibrated backscatter imagery. The Simrad EM1002 system operated at frequencies of 98 kHz (inner ±50° swath centered at nadir) and 93 kHz (the outer ±20°). Depth (z) resolution of the EM1002 is 30 cm or 0.1% of water depth, whichever is larger. Highest horizontal (x, y) resolution is 4 m x 4 m (highest accuracy 0.5 m), but backscatter maps used herein were gridded at 16 m x 16 m resolution. A full description of the system and methodology is provided in Gardner et al. (2000).

The original backscatter data were captured in the field with output values recorded in decibels (dB). Backscatter dB values were converted from decibels (dB) to a non-dimensional 8-bit digital number (DN) using the following conversion:

$$DN = 255 - (dB \times 2)$$

Where DN values range from 0 to 255, corresponding to the dB ranges of -127 to 0 (Dartnell and Gardner 2004).

Without ground-truthing via sediment sampling or in situ imagery, backscatter data cannot be directly correlated to substrates due to multiple factors affecting acoustic backscatter. Training samples would need to be captured in order to accurately classify backscatter values (Gardner et

al 2000). However, while it is not possible to determine a unique geological facies from backscatter data, reasonable predictions can be made based on the known local geology (Gardner et al 2000). It can logically be inferred that the high backscatter values observed from the sediment apron surrounding carbonate platform Pinnacles reefs is coarse carbonate reef-hash and carbonate sand derived from reef erosion and reef invertebrate hard part breakdown, with carbonate particles being transported away from the reefs via bottom currents.

The bathymetric range of 60.00-110.99 m within the Gardner Pinnacles polygon was used as a threshold depth within which mesophotic reefs occur. The total area of interest containing reef and reef-derived off-reef biotope was determined by processing the backscatter imagery (mos.tif) in ESRI ArcGIS 10.2.2. The "RasterDomain" tool in ArcGIS (ArcToolbox\Toolboxes\ 3DAnalyst Tools.tbx\RasterDomain) was used to create a polygon footprint of the backscatter image. The output of the tool is a polygon of the entire image area (feature class: bathyg_RasterArea_orig). The area within the specified bathymetric range was then digitized by processing the imagery bathymetry (bathyg) to derive contour depths and cropping the footprint polygon by tracing isobaths edges. The resultant cropped polygon (yellow outlined area in figures below) was then selected and exported into a new feature class (bathyg_Rasterarea_meso). Areas of the imagery with no data caused by field collection errors were excluded from the area calculations.

The cropped polygon (bathyg_Rasterarea_meso) was then used to determine the area of the backscatter imagery (mos.tif) using the Clip tool in ArcGIS (Raster Processing\clip) to create a spatial subset of the raster (MOS_mesoclip).

To determine the area within the mesophotic depth range with high backscatter. Using the Con tool in ArcGIS (Spatial Analyst Tools\Conditional\Con), a conditional raster for each digital number (DN) value range (DN>100, DN>110, ... DN>200) was created the MOS_mesoclip raster image.

To calculate the area (m^2) for each backscatter threshold value (over the series of increasing DN acoustic backscatter intensities: >100, >110 ..., >200), the pixel cell size of the imagery (16 m x 16 m) was multiplied by the total pixel count for each threshold value.

Results

Areas of potential off-reef biotope determined at sequentially higher backscatter DN thresholds, from DN>100 through DN>200, are presented in Table 1. Overall area and subarea determinations are summarized in Table 2. Correspondingly, a series of figures (arranged in order of increasing DN thresholds) display the estimated area of high backscatter from Table 1. Maps depicting high backscatter interpreted as the probable extent of reef-derived surficial sediments (DN>130) are framed in heavy black outline. The value of DN>130 in Table 1 was chosen by inspection of the serial maps as the threshold above which acoustic backscatter was considered to best represent reef-derived surficial substrate. The previously determined area

(m^2) of reef/reeftop habitat (Table 2, Nash and Randall 2015) was subtracted from total area with DN>130 to arrive at the area (m^2) of reef-derived surficial substrate (Table 2). Area expressed in m^2 was converted as well to km^2 for comparative purposes (Tables 1 and 2).

The total area of high backscatter (at the selected threshold of DN>130) within the Gardner Pinnacles polygon between depths of 60.00-110.99 m was estimated as 355.56 km^2 (Table 2). With the subarea of true reef/reeftop habitat (15.94 km^2) removed, the adjusted off-reef high backscatter area is 339.61 km^2 (Table 2). This represents 24.79% of the total mesophotic area of 1369.94 km^2 within the bathymetrically cropped polygon, an area of coarse, high-reflectivity, off-reef calcium carbonate substrate, a habitat 21.30 times larger than the total area of the carbonate reef reef/reeftop source habitat.

The series of figures below display the high acoustic backscatter regions mapped within the bathymetrically cropped (yellow outlines) Gardner Pinnacles polygon. Reeftop habitat in the Yellowtail-Roughtongue Reef and Alabama Alps Reef subarea figures is denoted in purple outline. Total reeftop area was subtracted from total high backscatter area to arrive at total off-reef high backscatter habitat area. Map figures framed in heavy black outline identify the figures prepared at the acoustic backscatter threshold of DN>130. West to east trending artifacts (light or dark trails) represent low quality backscatter data at the outer margins of individual HRMBS swaths. White areas flanking the AAR and RTR reef platforms, primarily on the western flank – and trending to the southwest, represent current scour depressions (moats), areas from which reef-derived carbonate sediment has been removed by bottom currents. This is illustrated more specifically in the last figure in this report for an area of minor reefs on the shelf edge to the east of RTR.

References (Cited and Additional Relevant Reports)

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Backscatter Quantification Threshold (DN)	DN Min Value	DN Max Value	DN Mean Value	DN Std Dev	Number of Pixels	Area of Backscatter (m^2)	Area of Backscatter (km^2)
Number of pixels >100	102	255	135.15	29.92	2,672,797	684,236,032	684.24
Number of pixels >110	117	255	146.10	27.77	1,956,941	500,976,896	500.98
Number of pixels >120	124	255	151.39	27.00	1,655,945	423,921,920	423.92
Number of pixels >130	**131**	**255**	**156.65**	**26.41**	**1,388,905**	**355,559,680**	**355.56**
Number of pixels >140	146	255	167.61	25.89	931,258	238,402,048	238.40
Number of pixels >150	153	255	173.61	26.28	728,811	186,575,616	186.58
Number of pixels >160	168	255	189.41	28.01	381,308	97,614,848	97.61
Number of pixels >170	175	255	199.08	28.97	262,729	67,258,624	67.26
Number of pixels >180	182	255	209.28	29.07	184,540	47,242,240	47.24
Number of pixels >190	197	255	229.38	25.06	101,527	25,990,912	25.99
Number of pixels >200	204	255	237.73	21.20	80,702	20,659,712	20.66

Table 1: Classification of acoustic backscatter values using ArcGIS and resultant area calculations. Threshold level of DN>130 for quantification of total high reflectivity area is highlighted in gray.

Geographic Area or Subarea	Area (m^2)	Area (km^2)
Pinnacles backscatter polygon (Gardner 2000)	1,924,572,000	1924.57
Pinnacles backscatter polygon cropped to 60-111 m isobaths*	1,369,940,221	1,369.94
Digitized reefs/reeftop area*	15,947,096	15.95
Area of backscatter DN>130	355,559,680	355.56
Area of backscatter DN>130 minus reeftop area	339,612,584	339.61
		Units
Cell size of backscatter image	16 x 16	meters

Table 2: Areal determinations of high HRMBS backscatter (DN>130) within the Gardner Pinnacles polygon (Gardner 2000).

*Gardner Pinnacles backscatter polygon area within the 60.00-110.99 m depth range, and the reef/reeftop biotope area were determined based upon Gardner's bathymetry (Gardner et al. 2000), supplemented by NOAA RV Nancy Foster 2010 multibeam imagery (Nash and Randall 2015).

Figure Legends

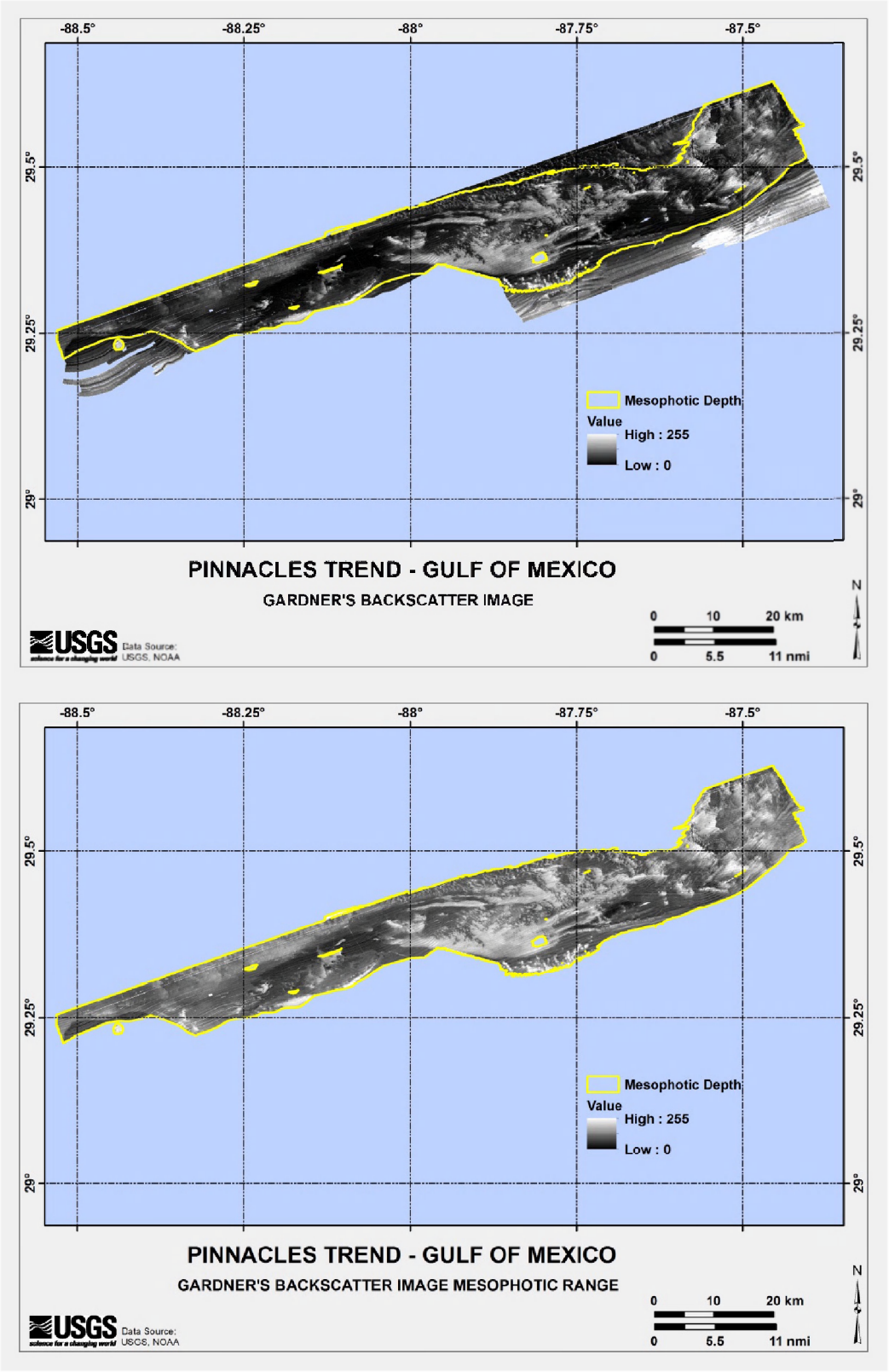
Figure Series 1 (Page 8): Delineation of the study area for determination of high acoustic backscatter interpreted as either hard substrate reef biotope or high reflectivity reef hash off-reef substrate. Top panel: Pinnacles Polygon as mapped by Gardner (2000); Bottom Panel: Subarea (yellow outline) within the Pinnacles Polygon confined between 60.00-110.99 m isobaths. Backscatter is portrayed in grayscale in DN units of 0-255, ranging from lowest to highest.

Figure Series 2 (Pages 9-14): Areas of high backscatter within the overall Pinnacles Polygon Subarea, in 11 sequential panels of 10 DN increments of acoustic backscatter thresholds, ranging from DN>100 to DN>200. The selected threshold for estimation of high reflectivity reef hash off-reef substrate DN>130 is panel 4 in the series (Page 10, bottom panel) identified with a heavy black frame.

Figure Series 3 (Pages 14-19): Areas of high backscatter within the Yellowtail and Roughtongue Reef vicinity, in 11 sequential panels of 10 DN increments of acoustic backscatter thresholds, ranging from DN>100 to DN>200. The selected threshold for estimation of high reflectivity reef hash off-reef substrate DN>130 is panel 4 in the series (Page 16, top panel) identified with a heavy black frame.

Figure Series 4 (Pages 20-25): Areas of high backscatter within the Alabama Alps Reef vicinity, in 11 sequential panels of 10 DN increments of acoustic backscatter thresholds, ranging from DN>100 to DN>200. The selected threshold for estimation of high reflectivity reef hash off-reef substrate DN>130 is panel 4 in the series (Page 21, bottom panel) identified with a heavy black frame.

Figure Series 5 (Page 25, bottom panel): Acoustic backscatter map of a selected shelf-edge subarea of the overall Pinnacles Polygon near its southeastern corner, identifying areas of scour with high backscatter southwest or south of, and adjacent to, areas of high-relief reef.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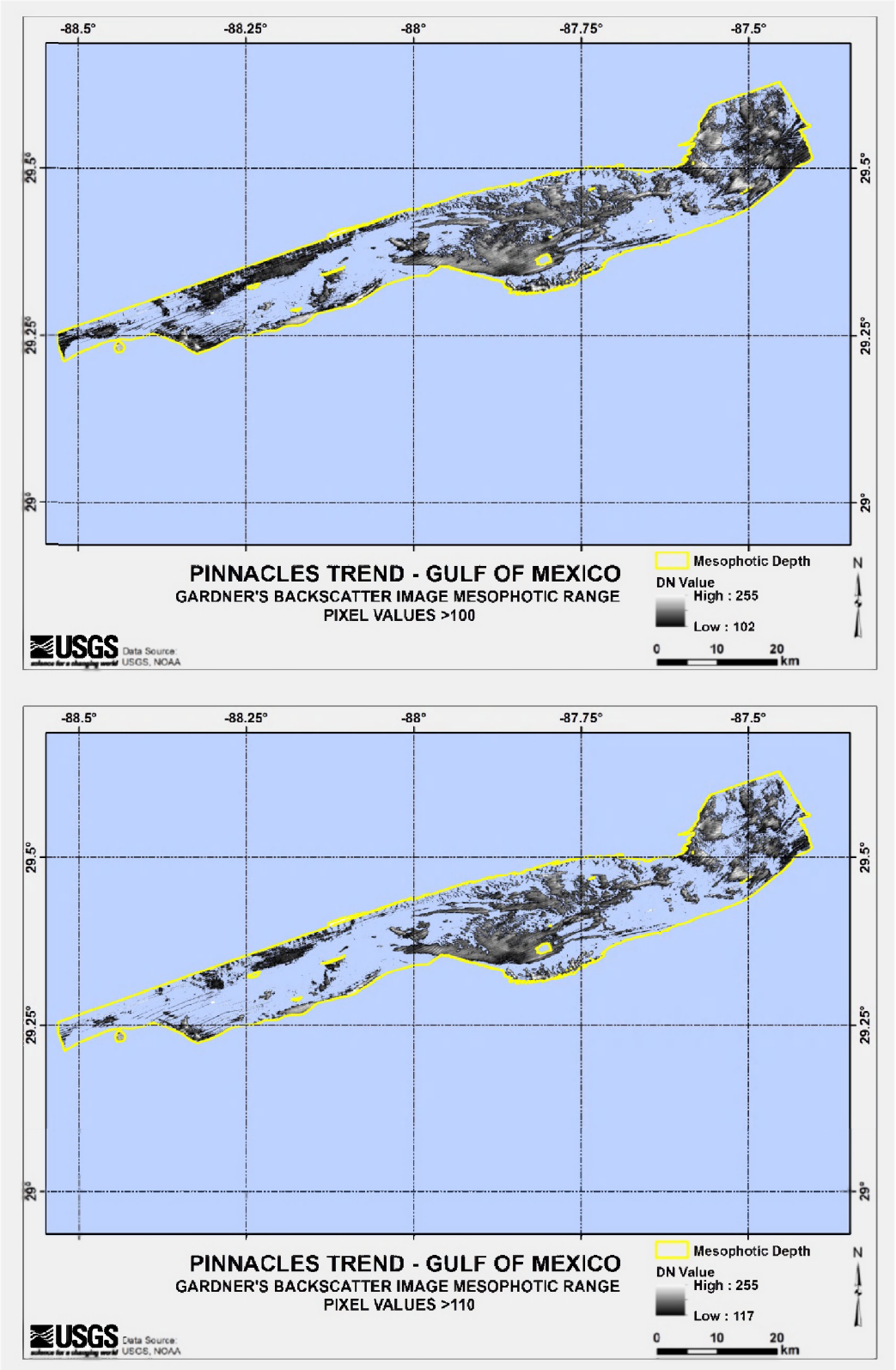
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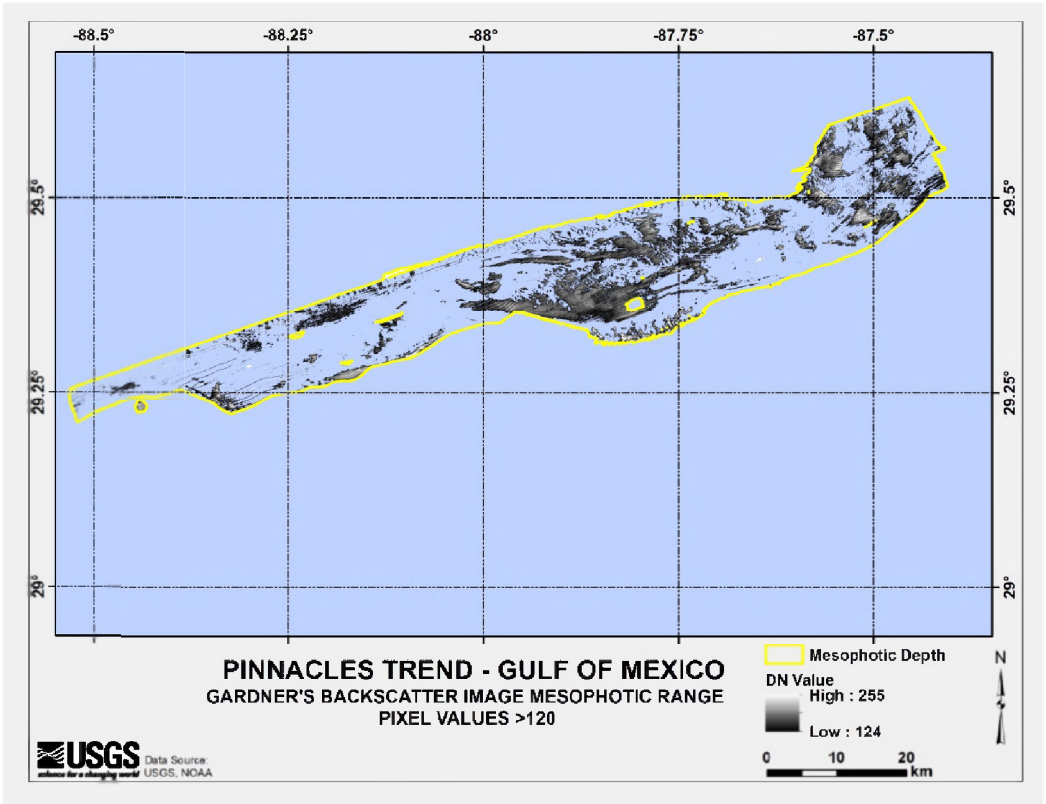
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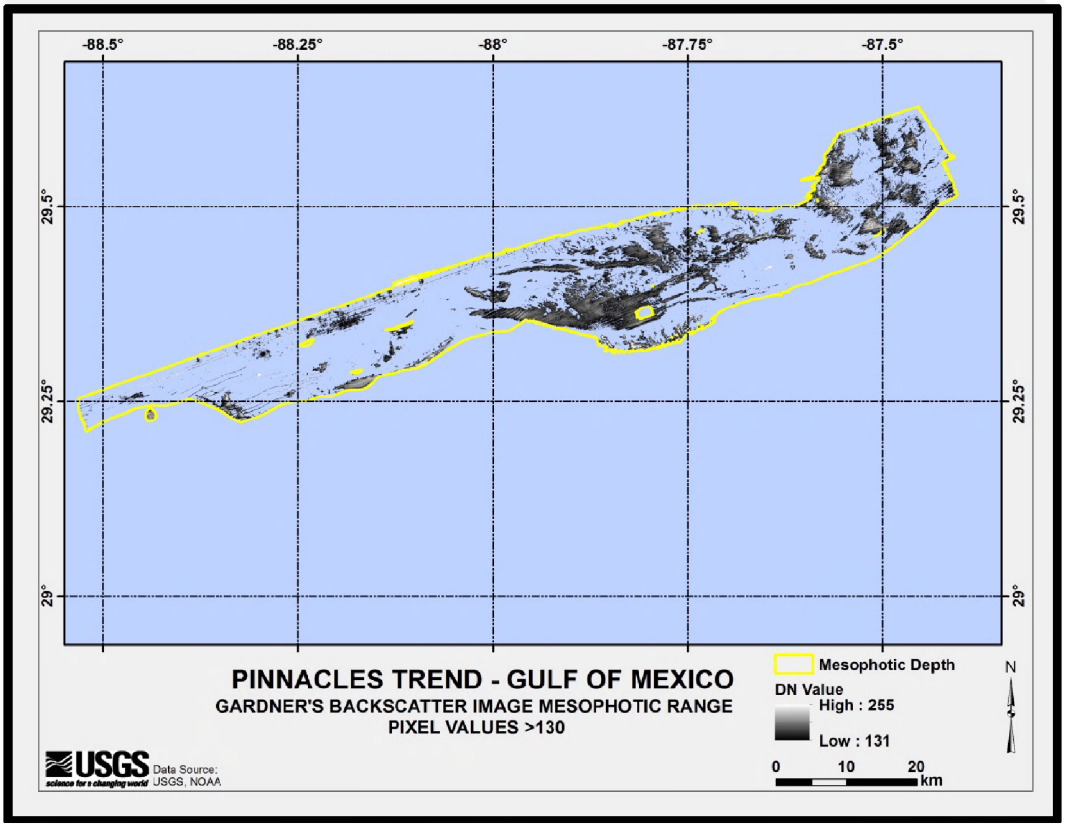
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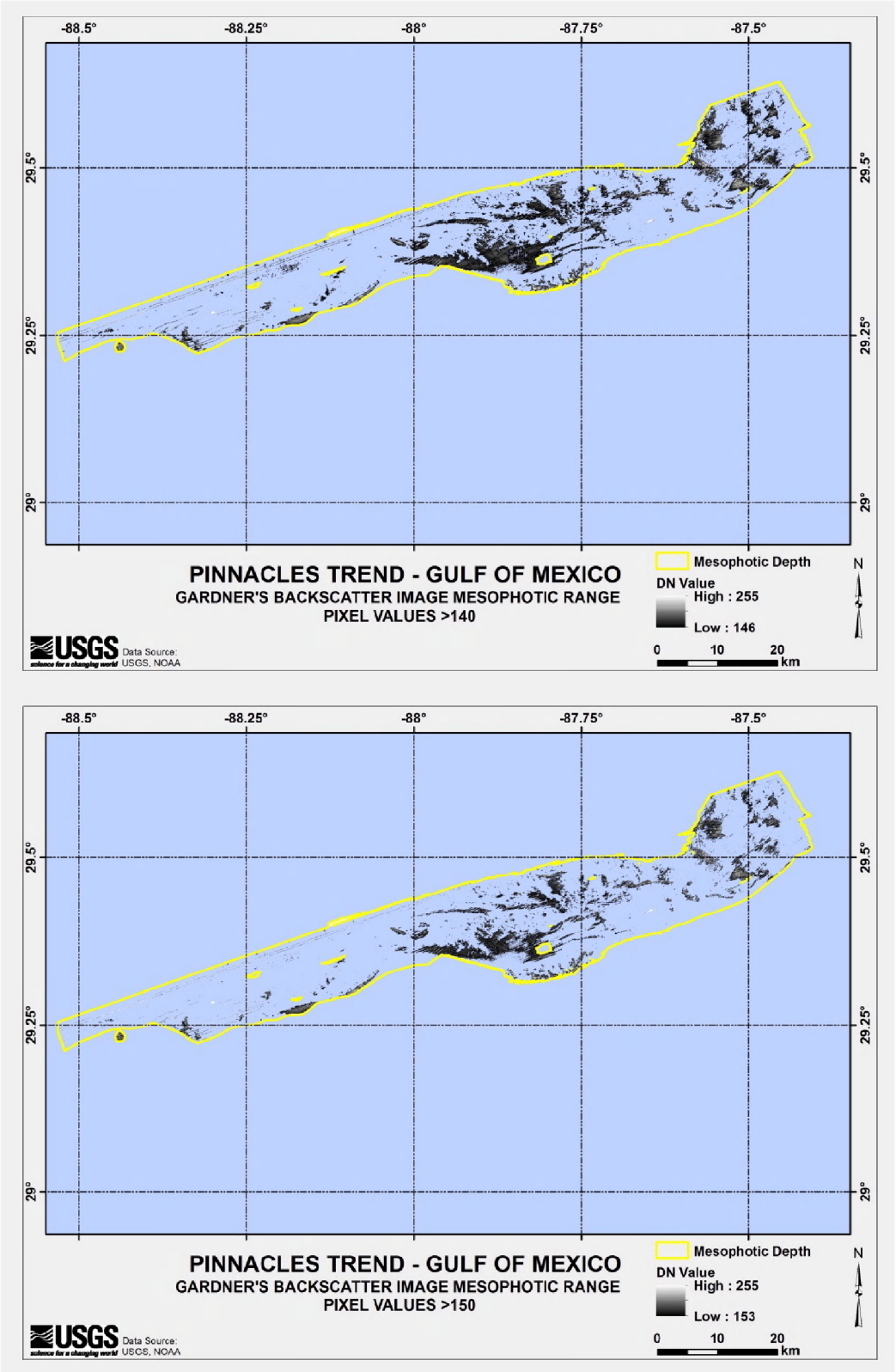
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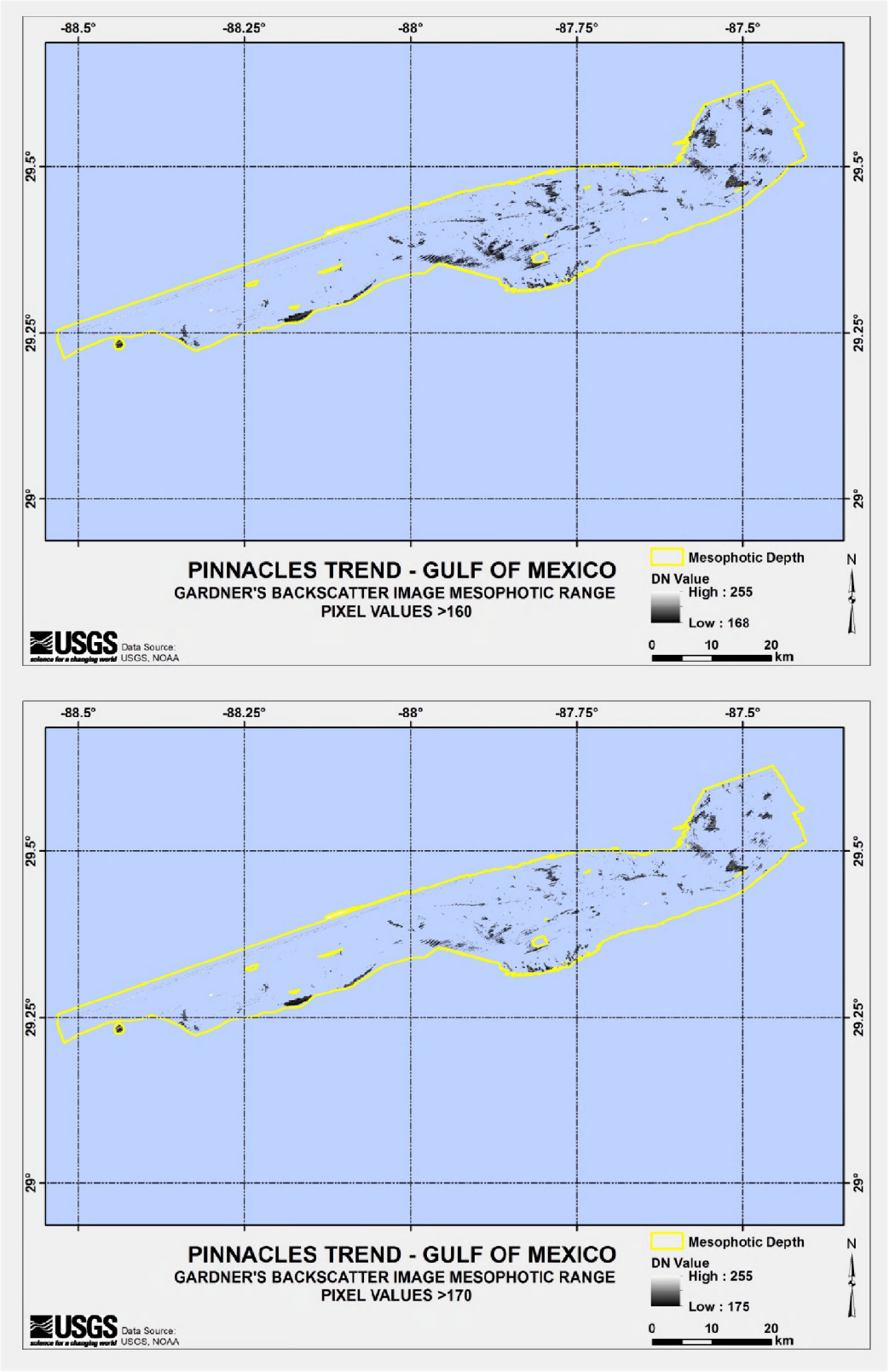
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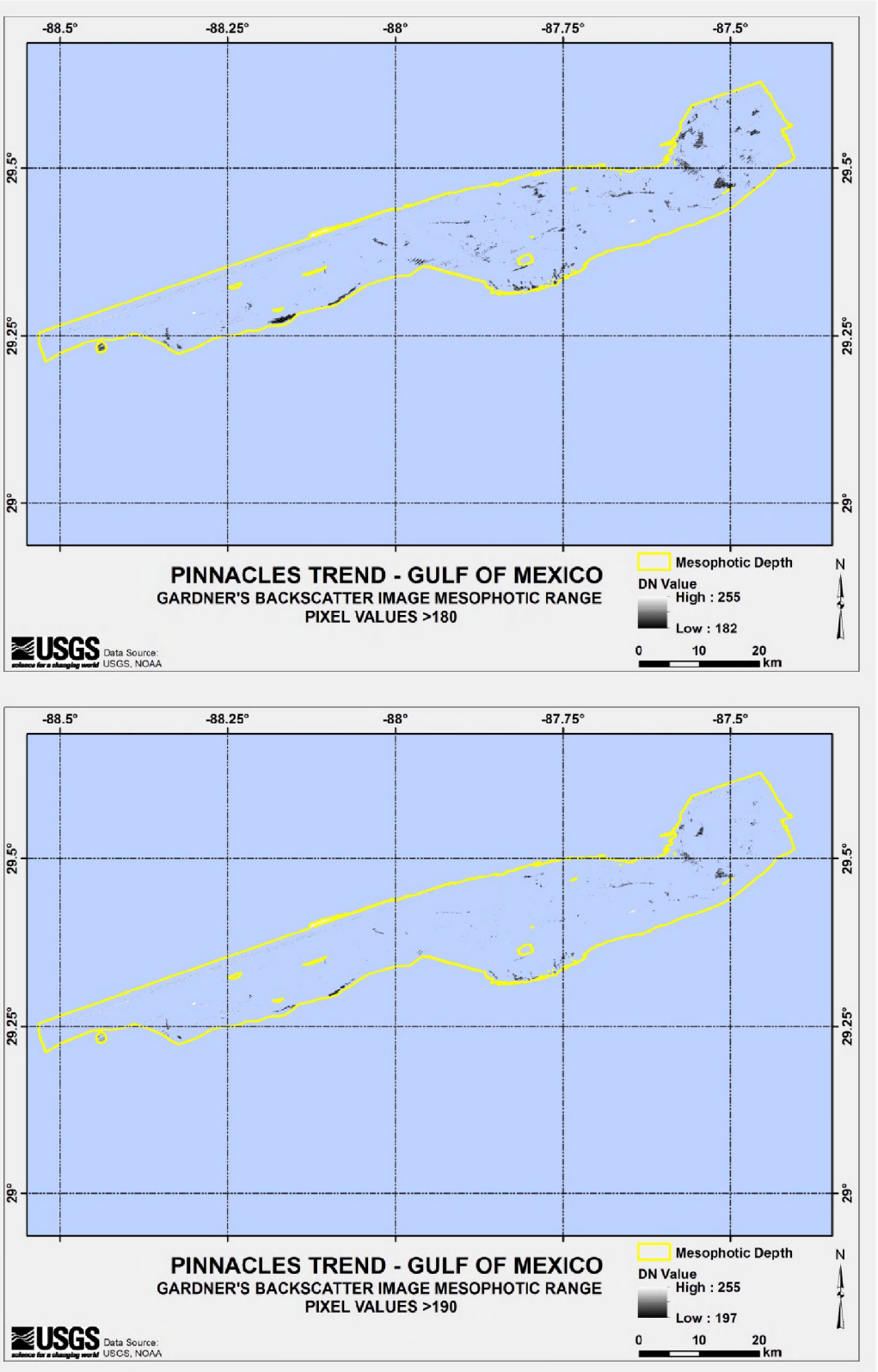
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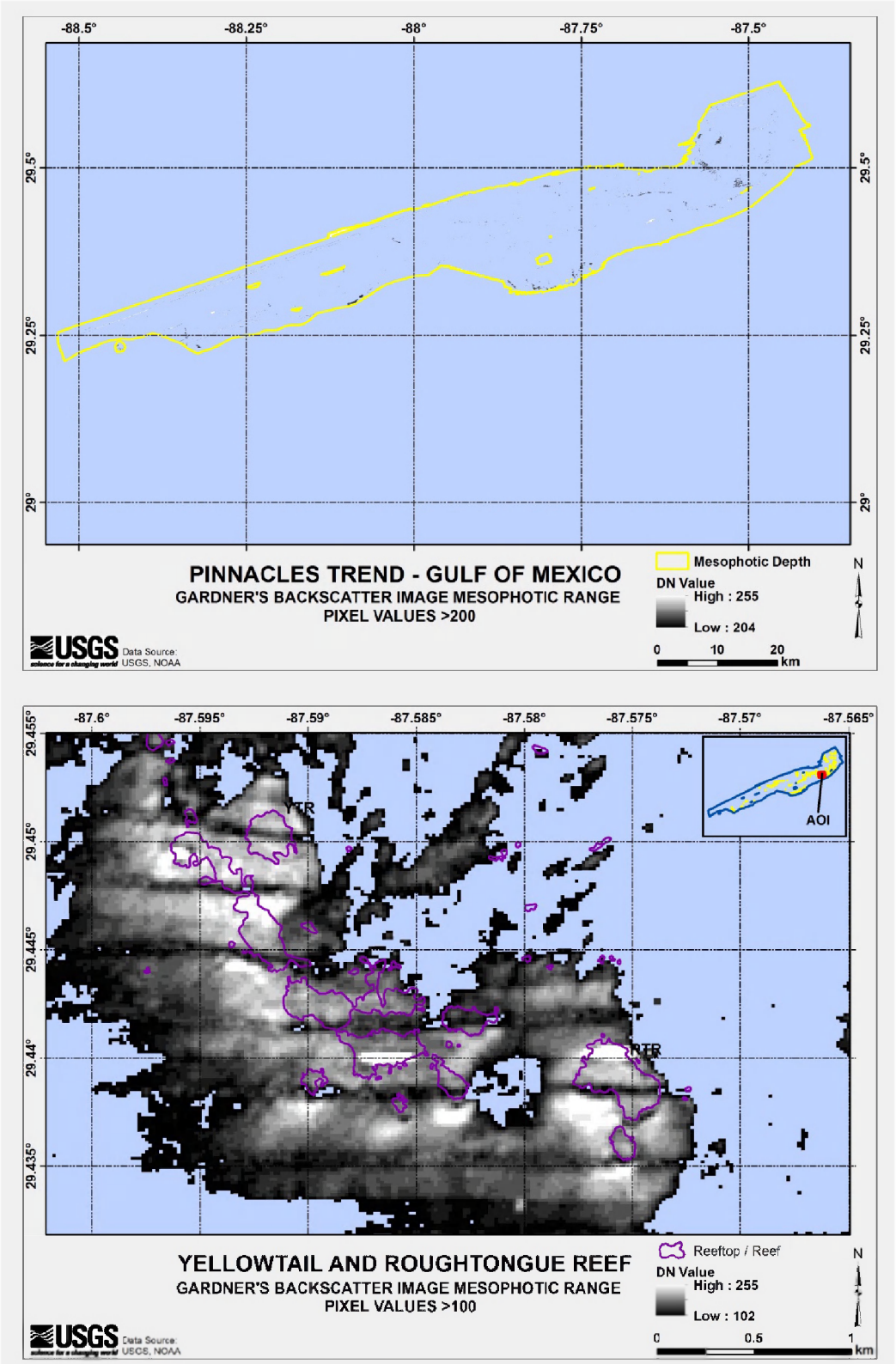
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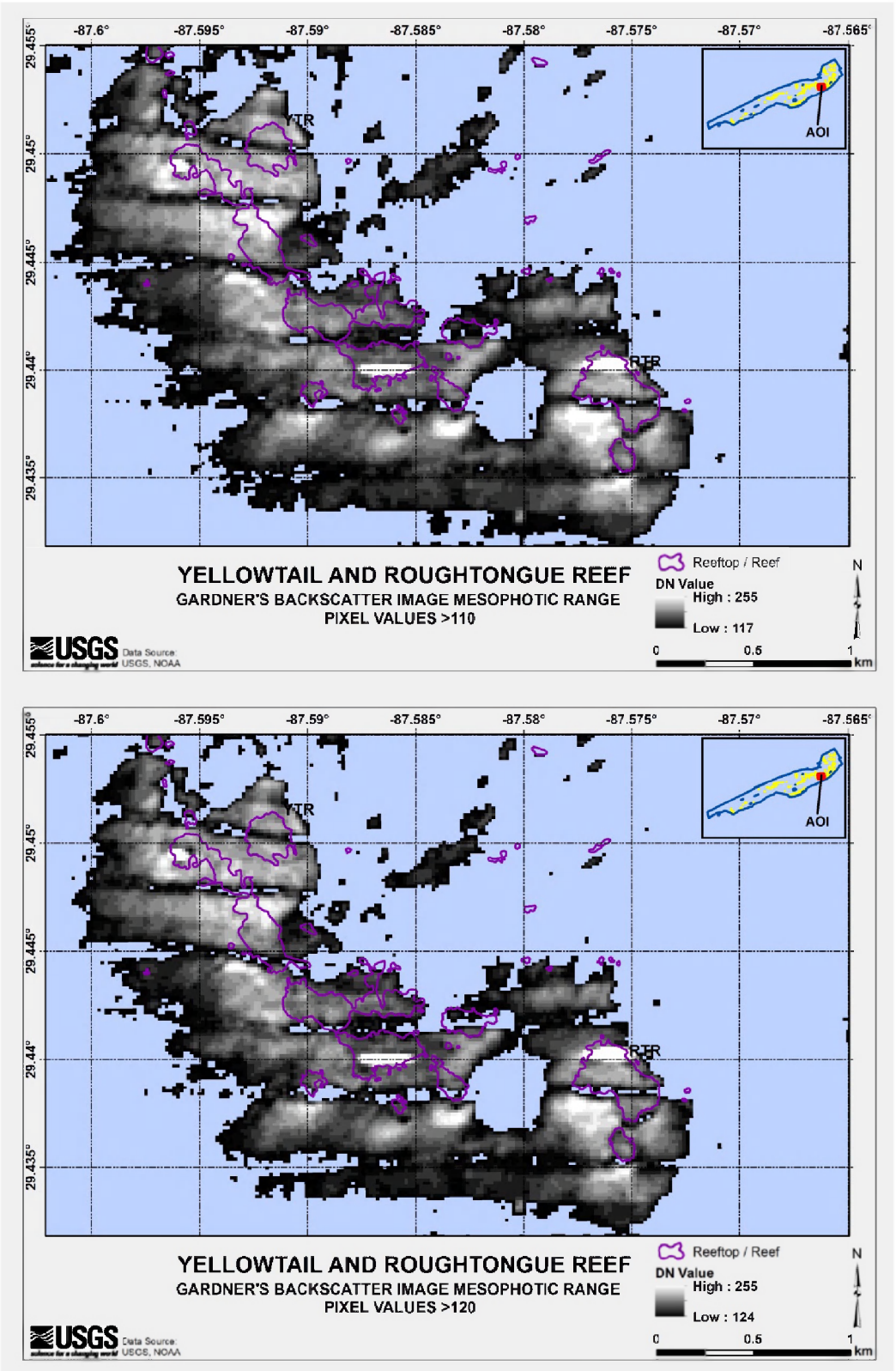
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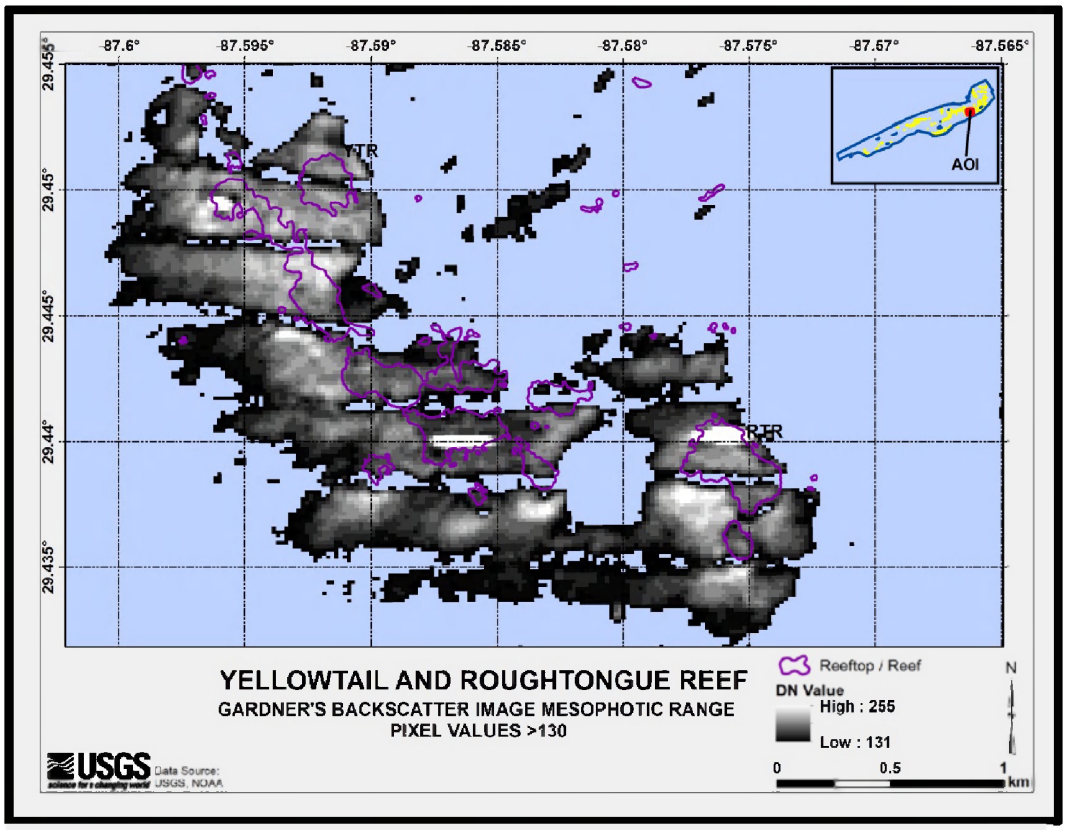
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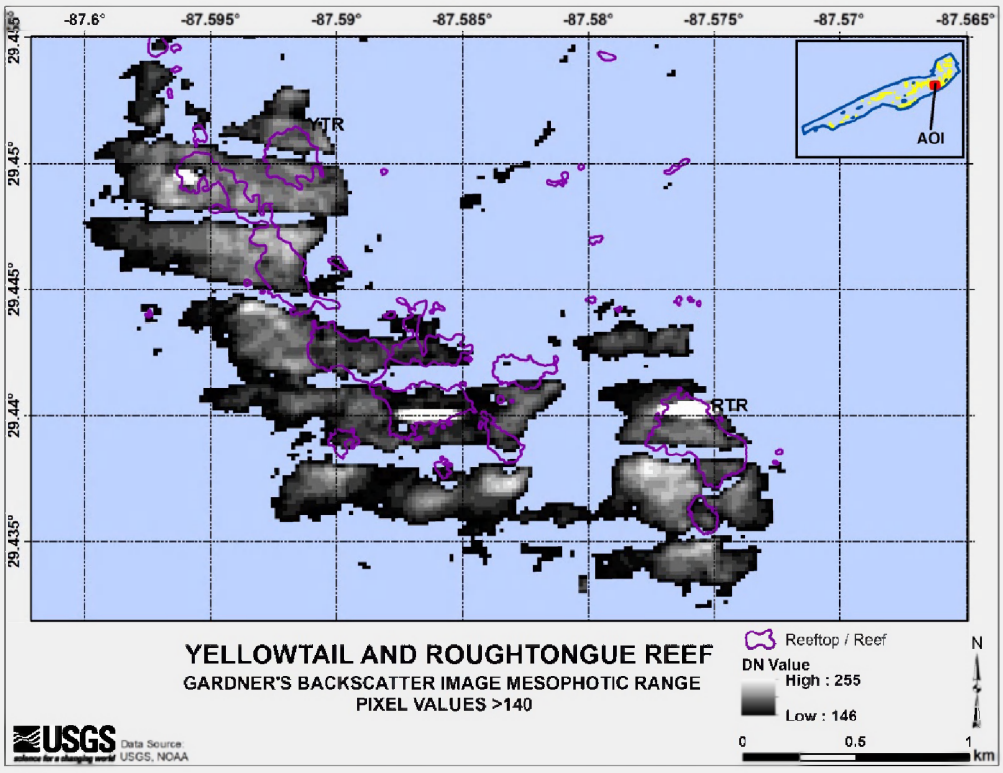
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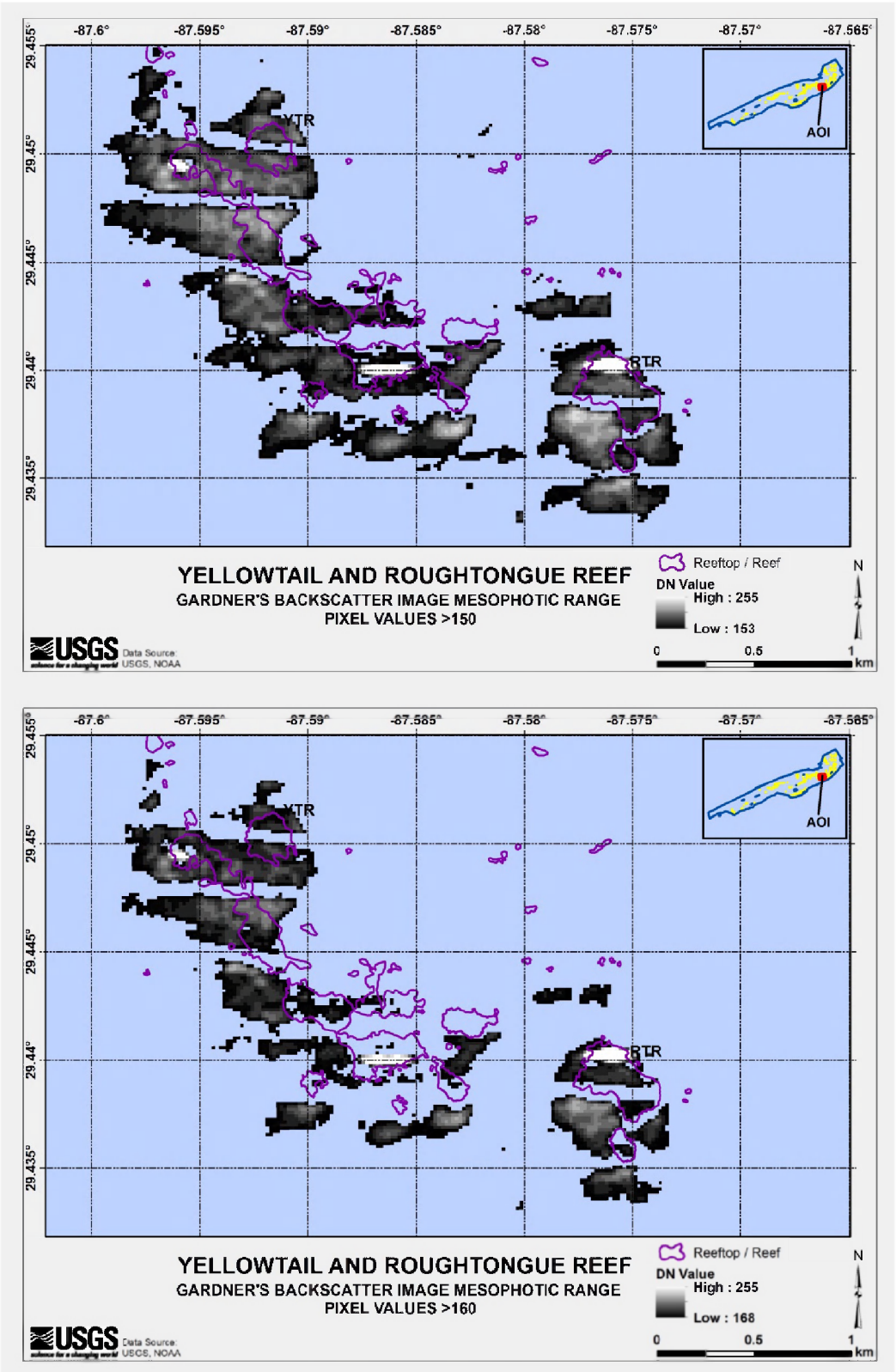
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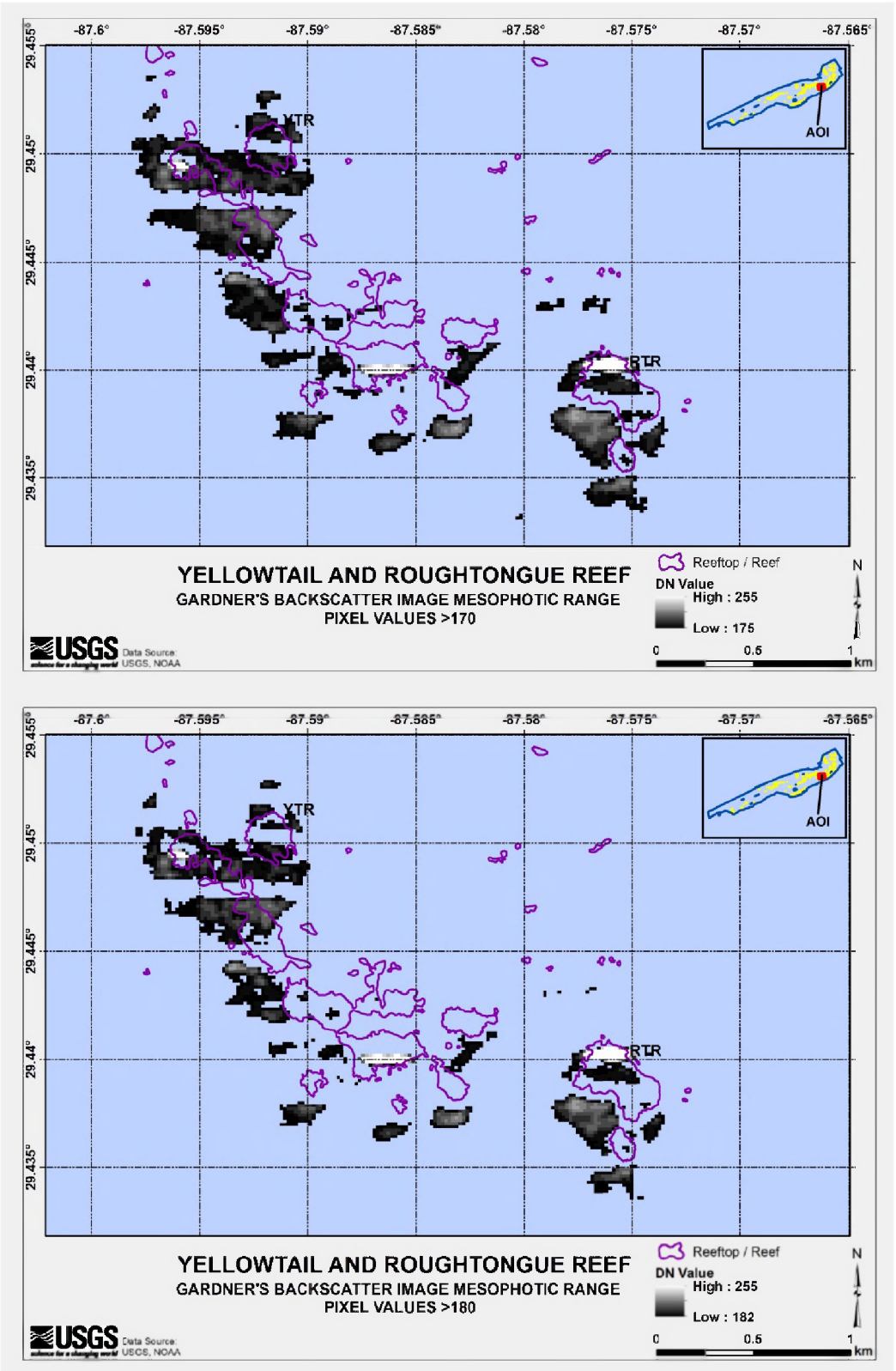
AOI
YELLOWTAIL AND ROUGHTONGUE REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >150
Reeftop / Reef
DN Value
High : 255
Low : 153
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA
YELLOWTAIL AND ROUGHTONGUE REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >160
Reeftop / Reef
DN Value
High : 255
Low : 168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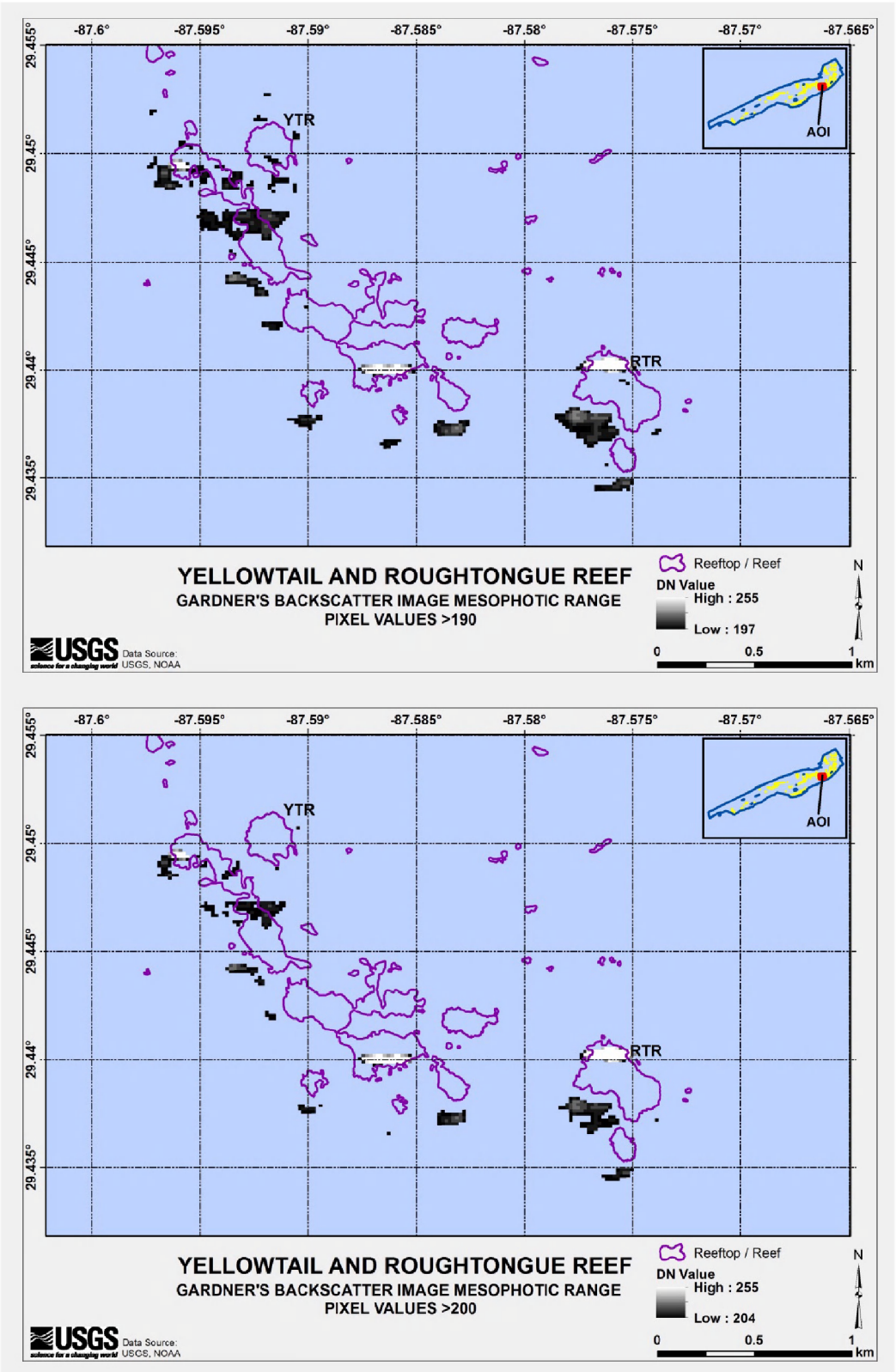
-87.58°
-87.575°
-87.57°
-87.565°
29.455°
29.45°
29.445°
29.44°
29.435°
YTR
RTR
AOI
YELLOWTAIL AND ROUGHTONGUE REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >170
Reeftop / Reef
DN Value
High : 255
Low : 175
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA
YELLOWTAIL AND ROUGHTONGUE REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >180
Reeftop / Reef
DN Value
High : 255
Low : 182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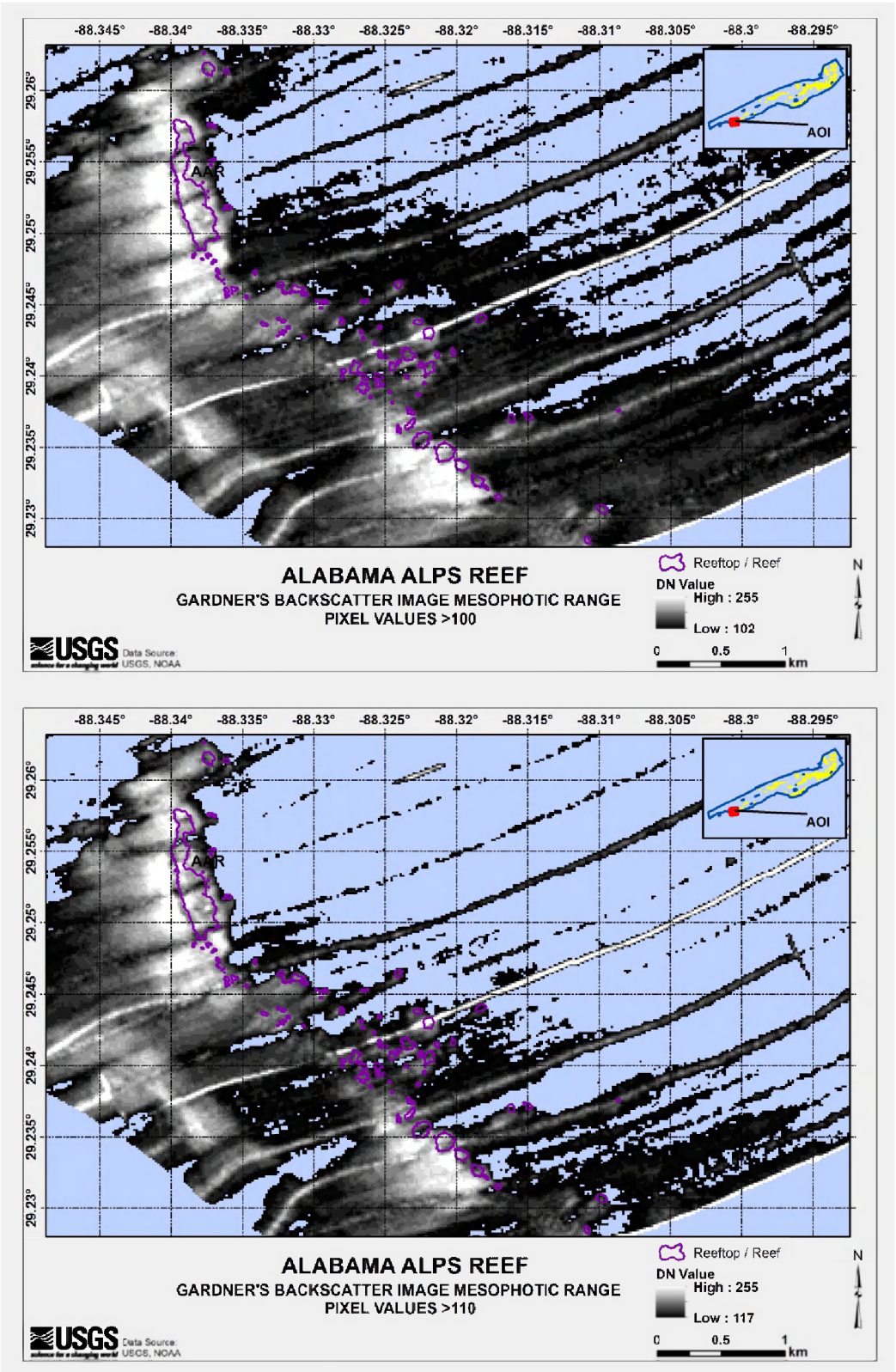
29.45°
29.445°
29.44°
29.435°
YTR
RTR
AOI
YELLOWTAIL AND ROUGHTONGUE REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >190
Reeftop / Reef
DN Value
High : 255
Low : 197
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA
YELLOWTAIL AND ROUGHTONGUE REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >200
Reeftop / Reef
DN Value
High : 255
Low : 204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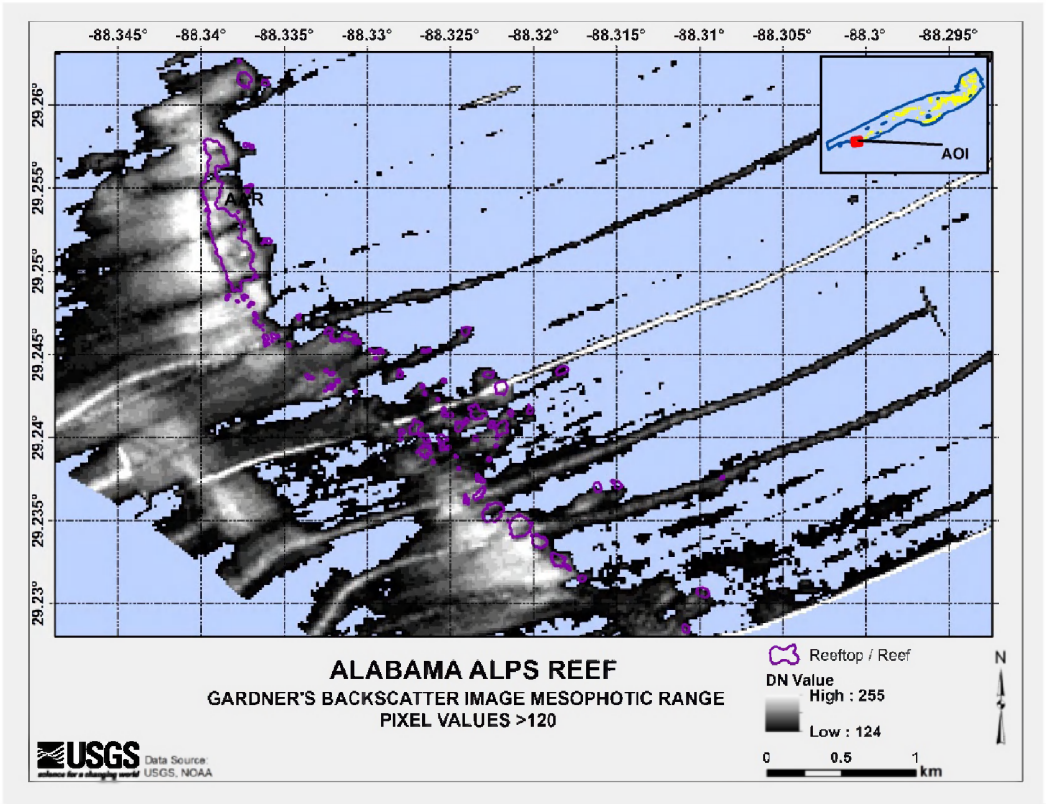
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
AAR
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >100
Reeftop / Reef
DN Value
High : 255
Low : 102
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA
-88.345°
-88.34°
-88.335°
-88.33°
-88.325°
-88.32°
-88.315°
-88.31°
-88.305°
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
AAR
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >110
Reeftop / Reef
DN Value
High : 255
Low : 117
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA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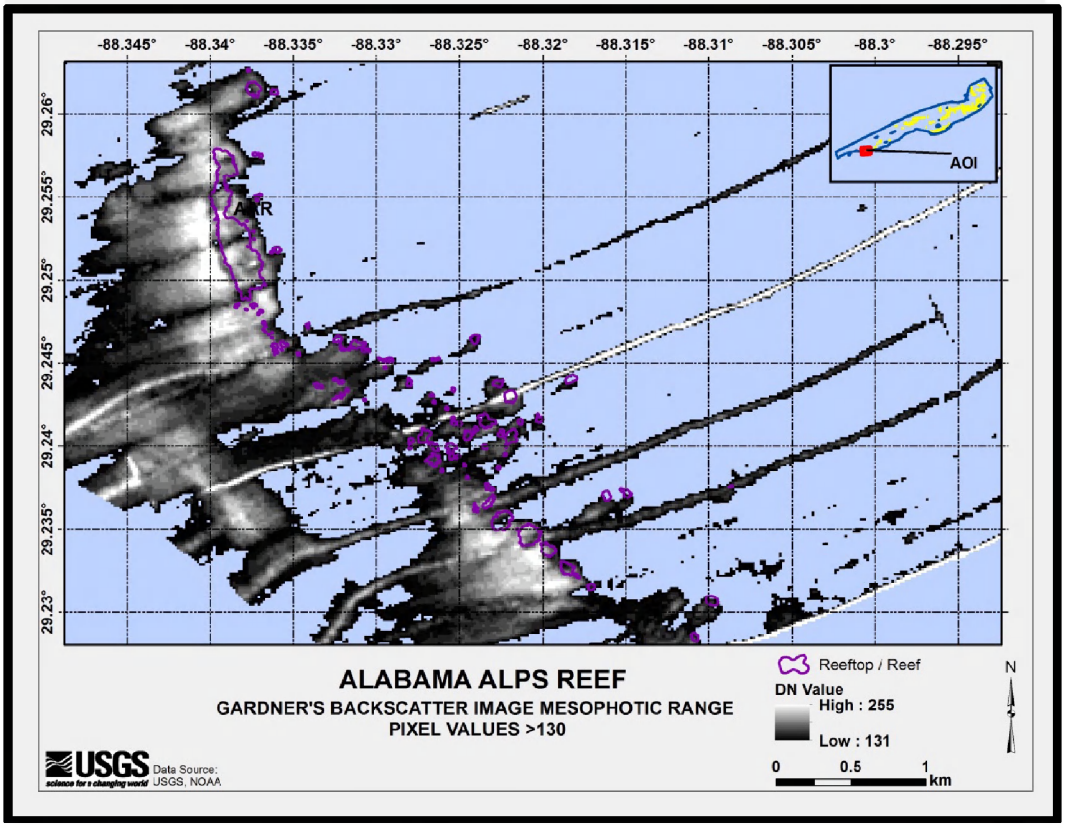
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >120
Reeftop / Reef
DN Value
High : 255
Low : 124
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA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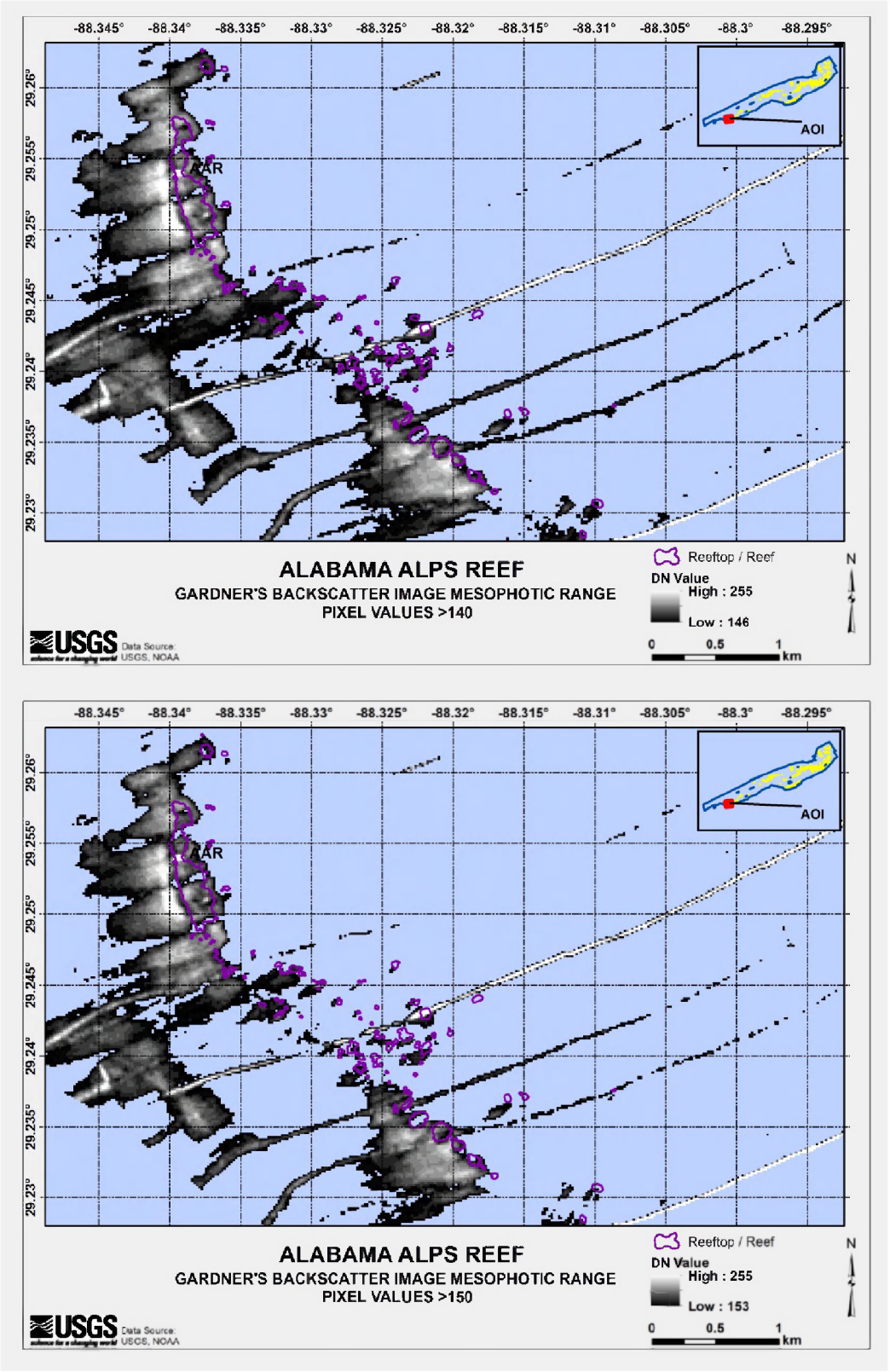
-88.31°
-88.305°
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >130
Reeftop / Reef
DN Value
High : 255
Low : 131
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA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-88.31°
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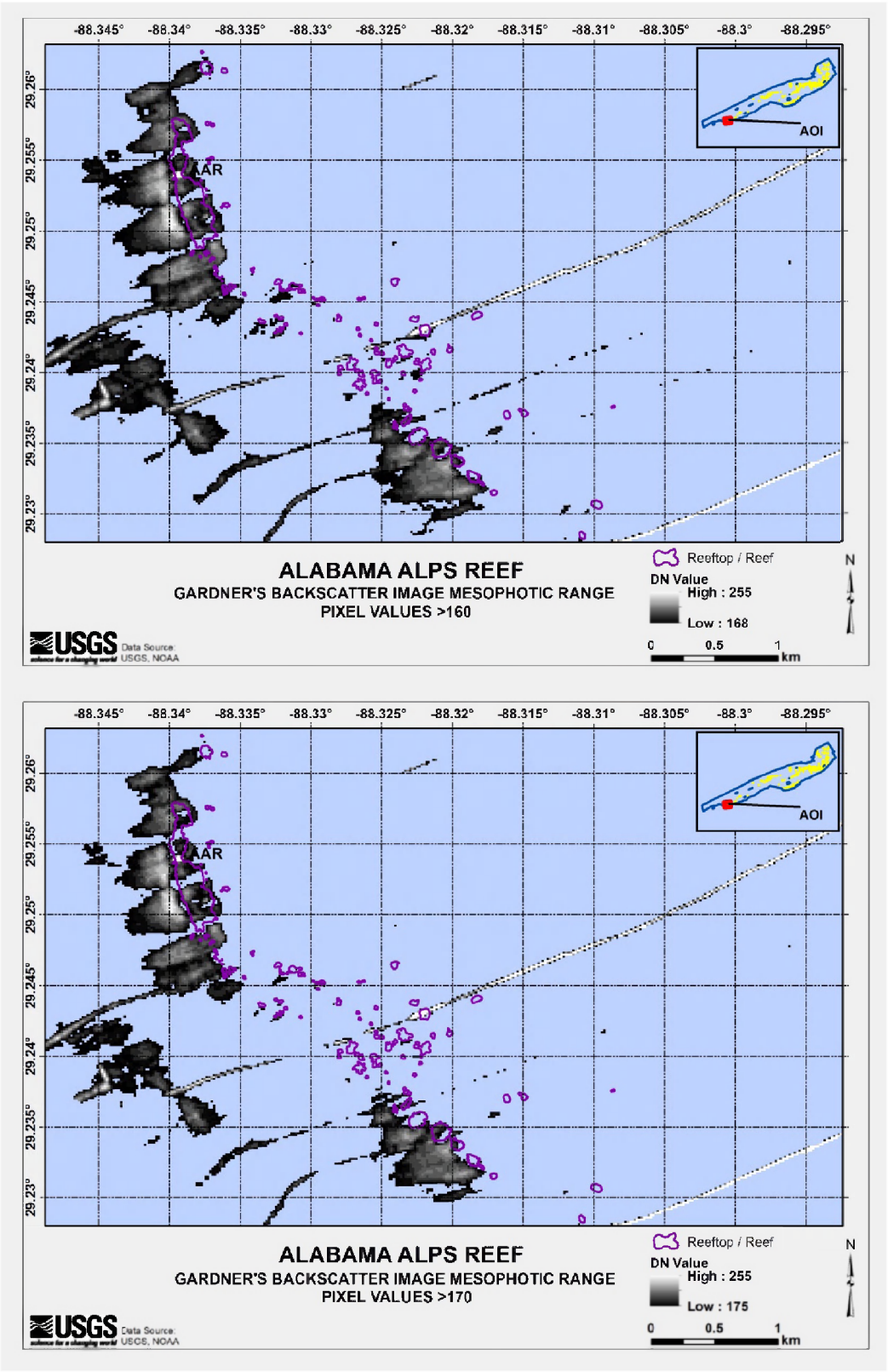
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
AAR
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >140
Reeftop / Reef
DN Value
High : 255
Low : 146
0
0.5
1
km
N
USGS
Data Source:
USGS, NOAA
-88.345°
-88.34°
-88.335°
-88.33°
-88.325°
-88.32°
-88.315°
-88.31°
-88.305°
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
AAR
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >150
Reeftop / Reef
DN Value
High : 255
Low : 153
0
0.5
1
km
N
USGS
Data Source:
USGS, NOAA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-88.31°
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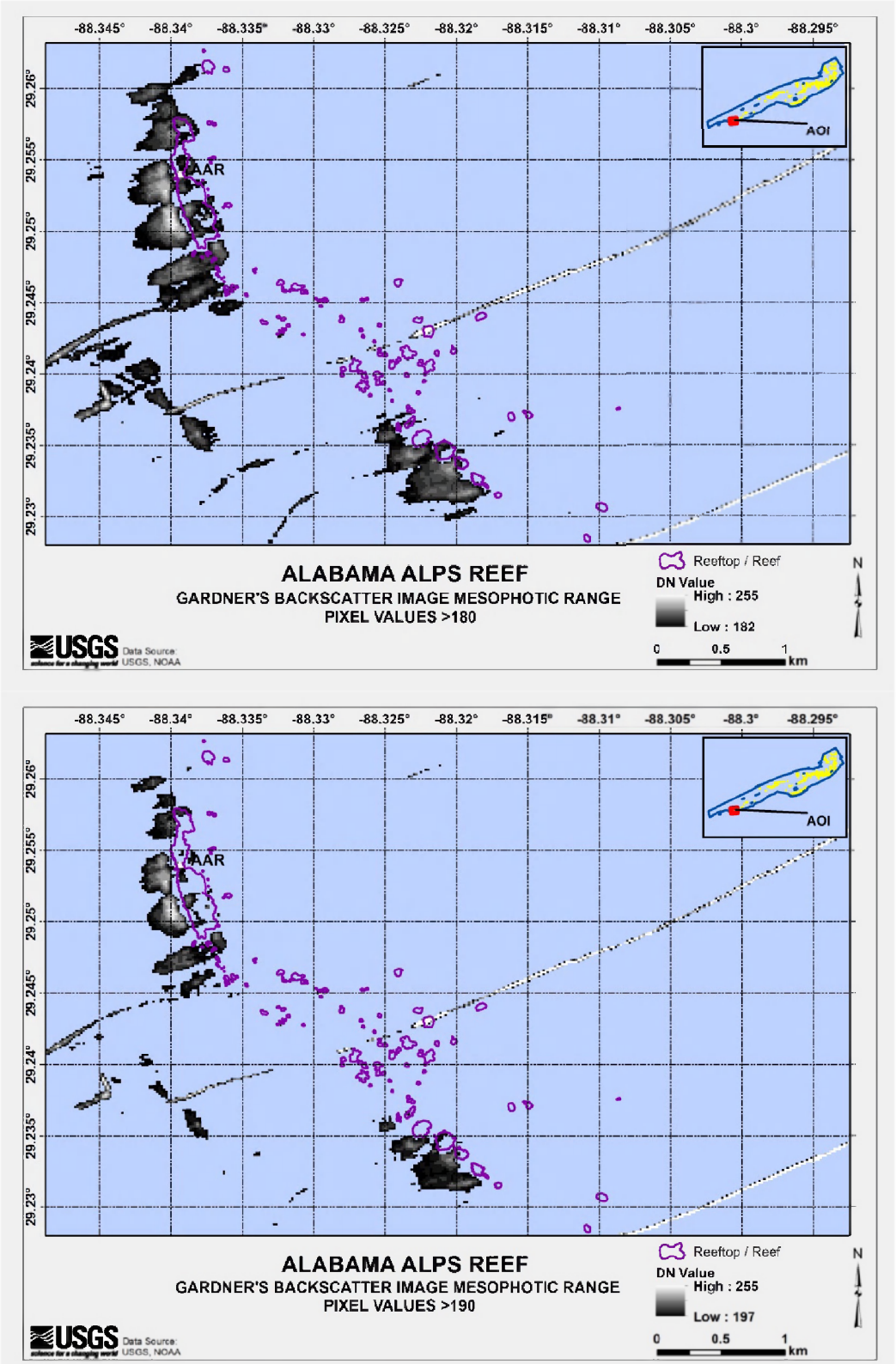
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
AAR
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >160
Reeftop / Reef
DN Value
High : 255
Low : 168
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA
-88.345°
-88.34°
-88.335°
-88.33°
-88.325°
-88.32°
-88.315°
-88.31°
-88.305°
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AOI
AAR
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >170
Reeftop / Reef
DN Value
High : 255
Low : 175
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA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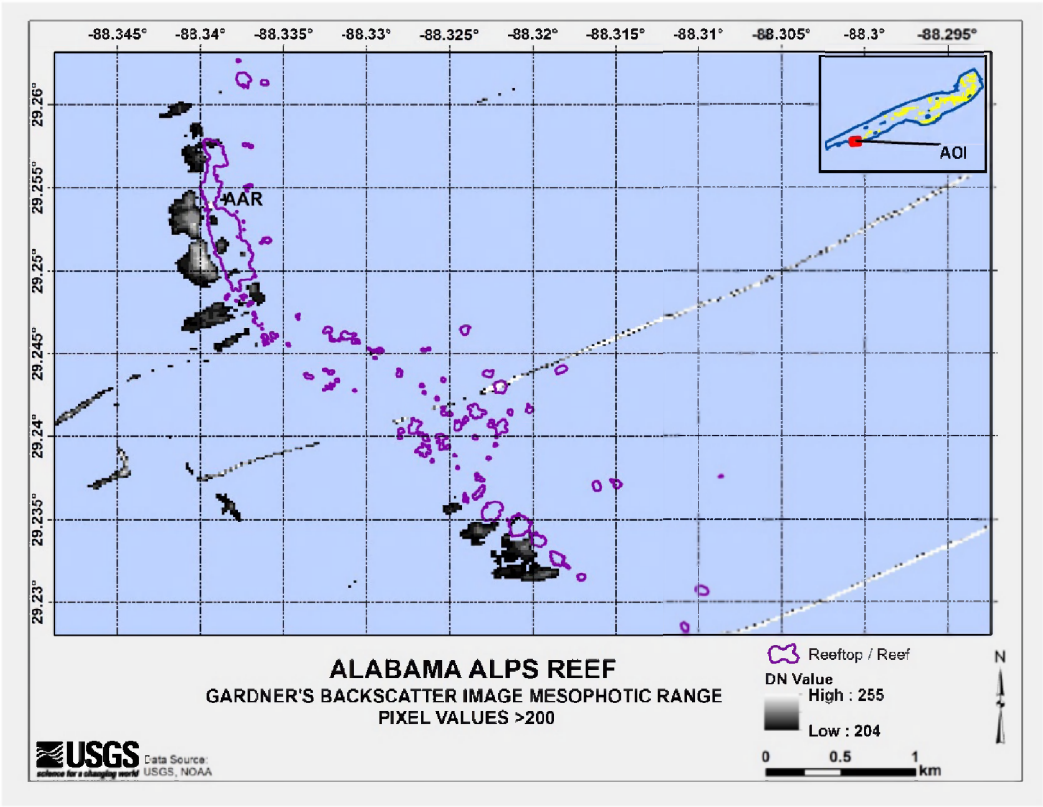
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AAR
AOI
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >180
Reeftop / Reef
DN Value
High : 255
Low : 182
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA
-88.345°
-88.34°
-88.335°
-88.33°
-88.325°
-88.32°
-88.315°
-88.31°
-88.305°
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AAR
AOI
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >190
Reeftop / Reef
DN Value
High : 255
Low : 197
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA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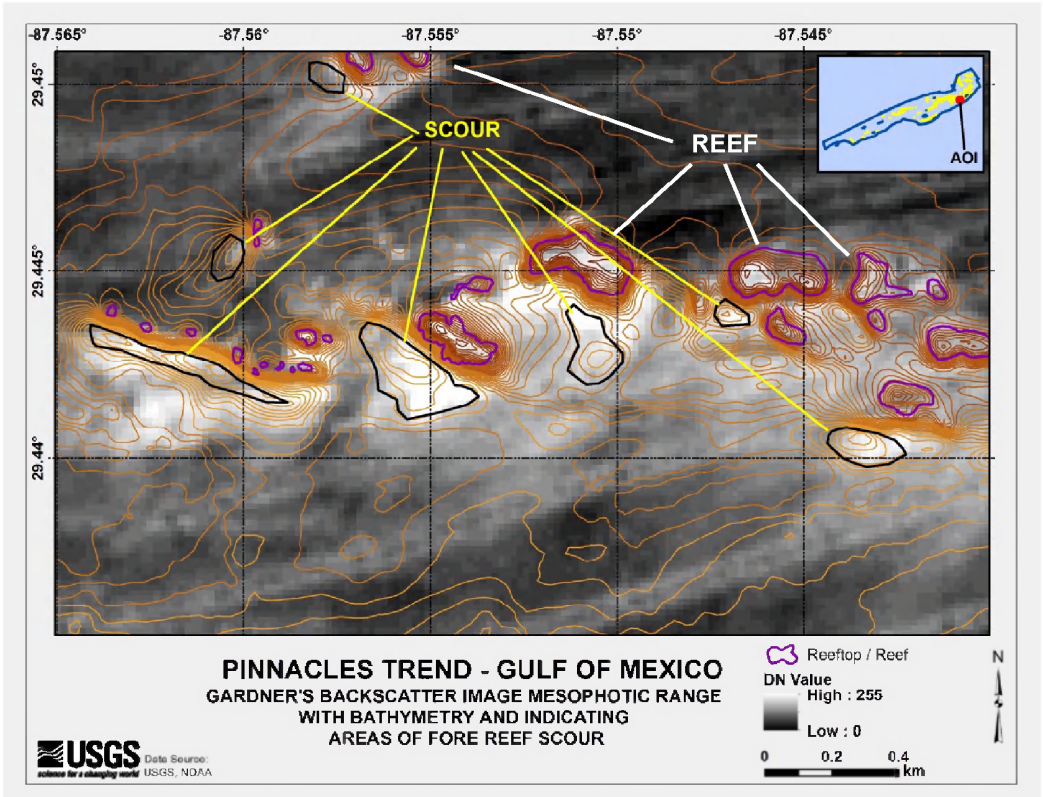
-88.3°
-88.295°
29.26°
29.255°
29.25°
29.245°
29.24°
29.235°
29.23°
AAR
AOI
ALABAMA ALPS REEF
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
PIXEL VALUES >200
Reeftop / Reef
DN Value
High : 255
Low : 204
N
0
0.5
1
km
USGS
Data Source:
USGS, NOAA


-87.565°
-87.56°
-87.555°
-87.55°
-87.545°
29.45°
29.445°
29.44°
SCOUR
REEF
AOI
PINNACLES TREND - GULF OF MEXICO
GARDNER'S BACKSCATTER IMAGE MESOPHOTIC RANGE
WITH BATHYMETRY AND INDICATING
AREAS OF FORE REEF SCOUR
Reeftop / Reef
DN Value
High : 255
Low : 0
N
0
0.2
0.4
km
USGS
Data Source:
USGS, NOAA