EAS
ENVI ANALYTICS SYMPOSIUM

Commercial SAR Change Detection

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Topic Outline

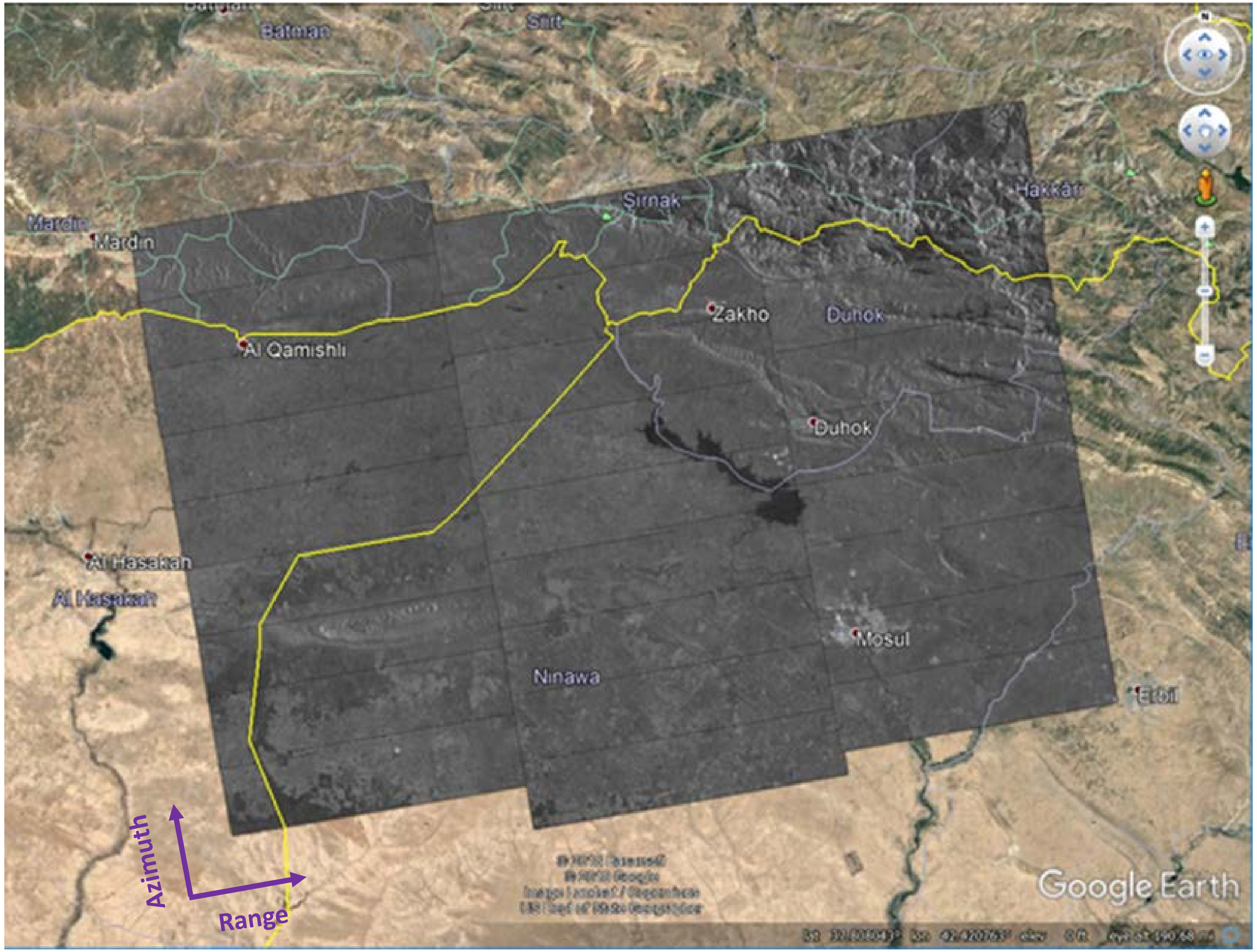
- NGA COMSAR Objectives
- Program Objectives
- Highlights - Current Phase
- Example Results
- Potential Future Efforts

NGA COMSAR Objectives

- Use commercial overhead SAR capability to augment GEOINT analysis
  - Apply large area, exquisite revisit collection systems for activity analysis and cueing
  - Use these as complementary assets to other, heavily-tasked systems
  - Utilize in areas that are not routinely collected by other systems
  - Unclassified data and products offer distribution flexibility and speed
- Demonstrate value of discoverable change information
  - Automatically perform change detection on periodically collected revisit data
  - Extract change detections and attributes from the pixel data
  - Package change information into textual format for querying and analysis purposes

Develop and demonstrate concept to automatically generate queryable change objects from large area overhead SAR imagery

Sentinel-1 Interferometric Wide Swath (IW) mode provides the pixel data



- 12 day revisit (one sat), 6 day revisit (across two sats)
- Near exact imaging geometries between collected pairs
- Each image consists of:
  - 3 Subswaths along Range
  - Each subswath sliced into 9 sections (bursts) along Azimuth
- Nominal Resolution: Rg = 3 m, Az = 22 m

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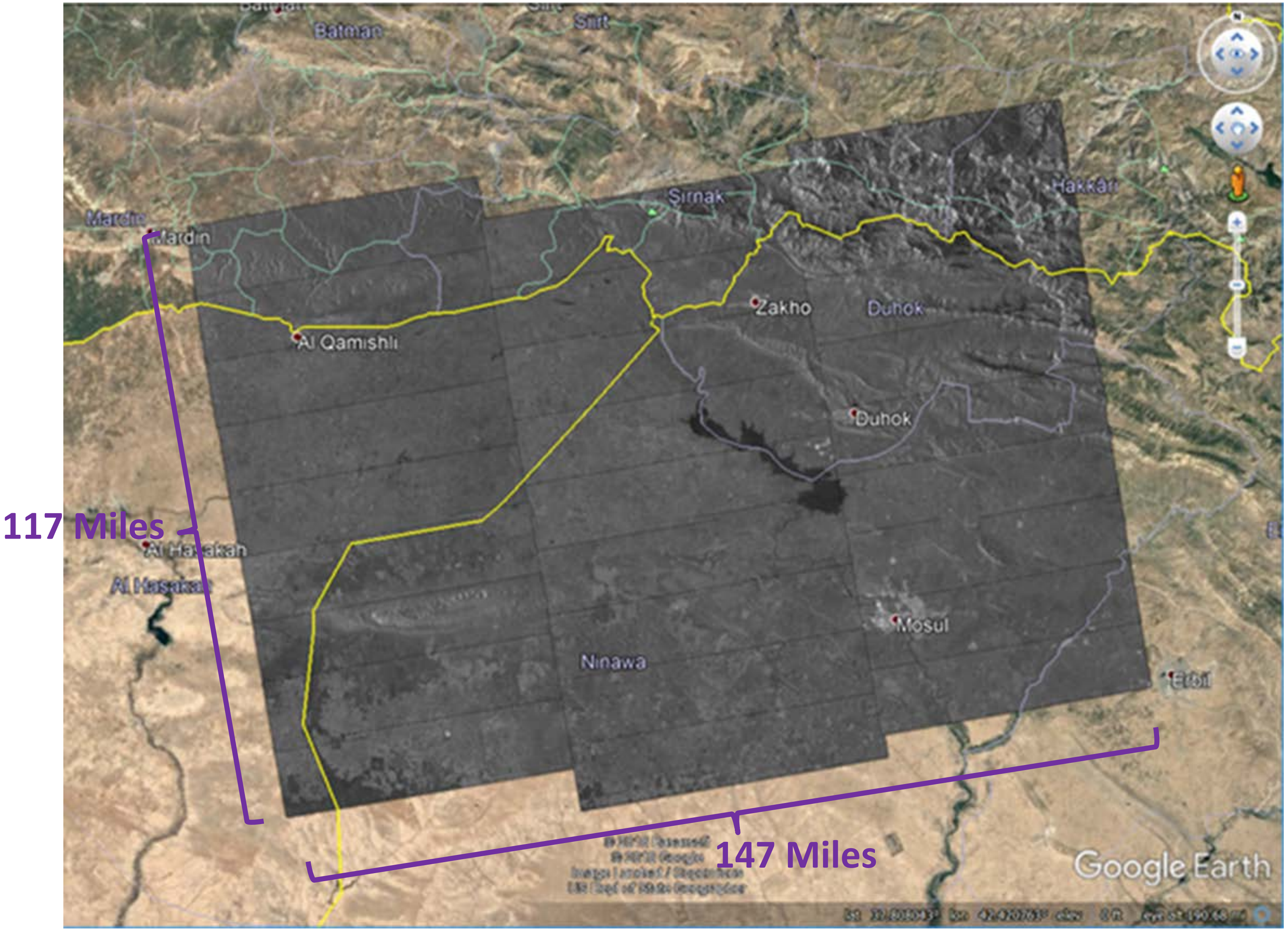
Challenge: Finding a needle in a stack of needles



- Single Image Interpretation
  - 17K square miles
  - 33M pixels to review
  - Delivered in 27 sections
- Search for Change in Pair
  - 34K square miles
  - 66M pixels to review
  - 54 sections
- Perform Change Analytics
  - Massively complicated

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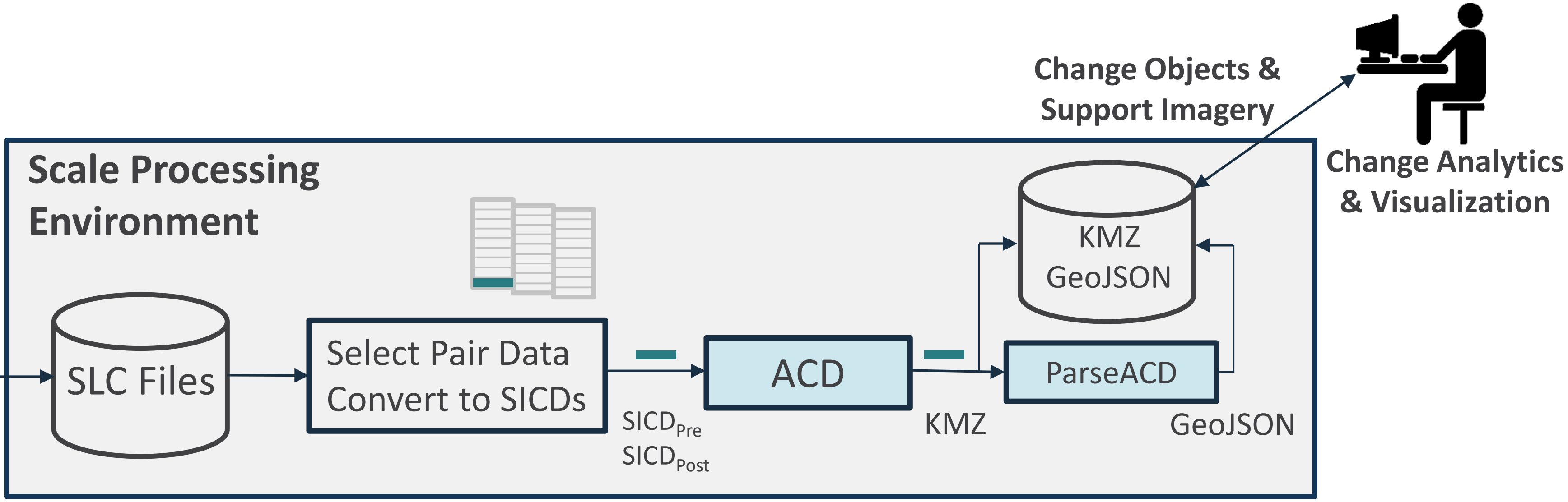
Program Objectives

- Demonstrate automated change detection, information extraction, and change analytics in support of NGA COMSAR Objectives
- Perform on Sentinel-1 imagery within NGA's Scale environment
- Extend and enhance ACD (Amplitude Change Detection) algorithm
- Derive new attributes to be packaged with the change detections within a GeoJSON structure; derive structured observations from the pixel data
- Support, enable, and demonstrate change analytics and visualization using the automatically generated GeoJSONs

Demonstrate utility of deriving queryable change objects from pixel data

Program Highlights – Current Phase

- Added new ACD detection mode; **RCS-Based Detection**
  - Application of Sentinel-1 radiometric calibration parameters
  - Adaptive thresholding algorithm
- Added new **RCS-Based Attributes** to the GeoJSON format
- Ready to provide Google Earth **super-overlays in KMZs**, if desired

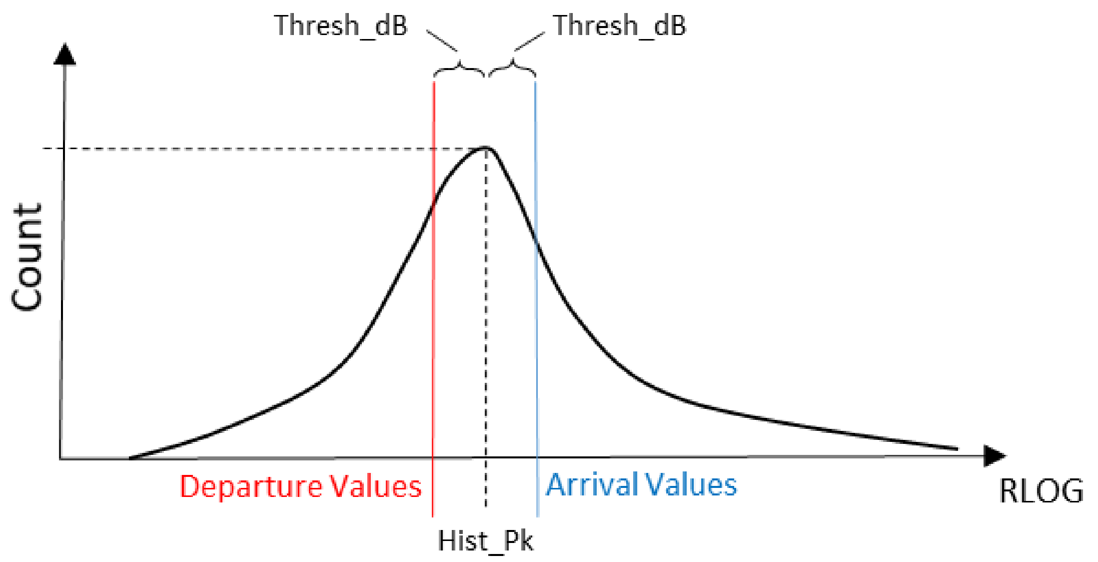


Near Term Emphasis: ACD Enhancements & New Attributes

Legacy ACD Detection Mode: RLOG

- Based on the ratio of pixel intensities between the Pre- and Post- images
  - Creates a *log power ratio* image   RLOG = 10Log(Post/Pre)
  - Detection thresholds are referenced to full scene statistics

- Limitations
  - Local threshold decision is referenced to Hist_Pk (measured over entirety of both images)
  - Detection response is sensitive to low return pixels
  - No physical relation between RLOG measure and Thresh_dB



Better suited for detecting larger area, natural change events

New Detection Mode: RCS-Based Detection

- Use radiometric calibration parameters to scale thresholding in terms of RCS levels (square meters)
  - Removes antenna pattern, slant range, incidence angle variation
  - Results in a RADAR physical quantity – RCS (Square meters)
    - Relates pixel intensity to RCS at target peak
    - Relates expected clutter power to reflectivity
- Advantages
  - Establishes thresholds in terms of target peak RCS
  - Perform independent thresholding on each image
  - Enables more precise measurements of change area
  - Supports measurement of RCS-based attributes

Radiometric calibration

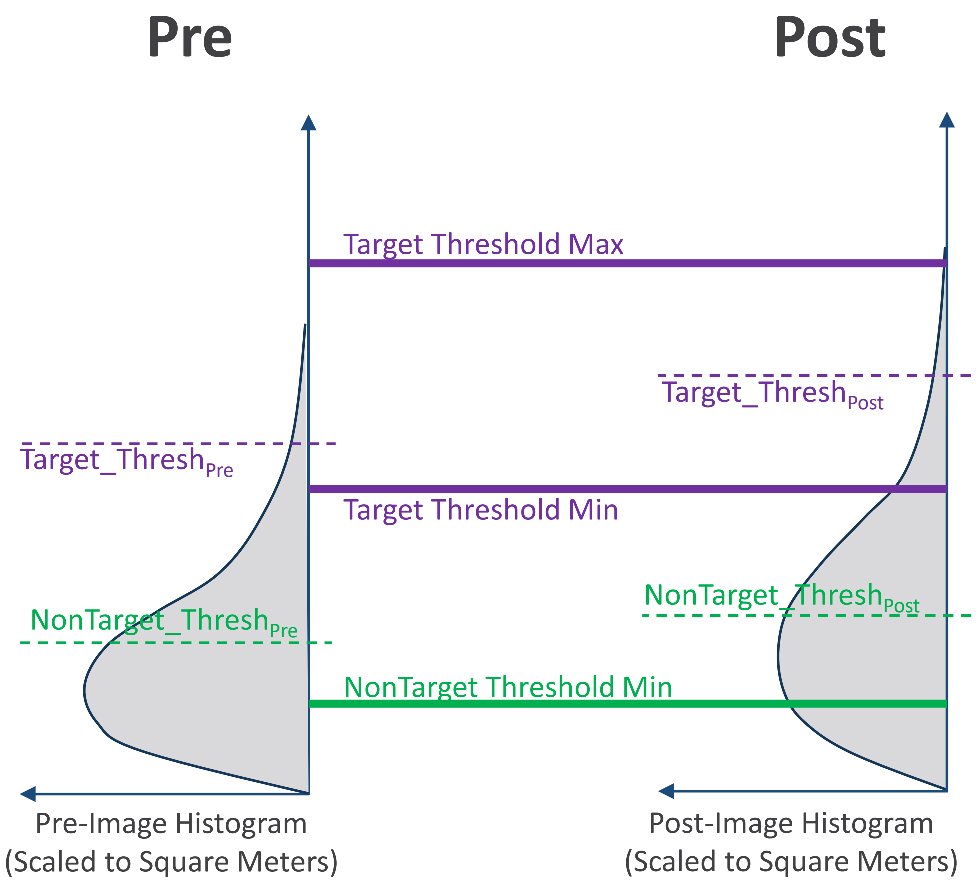
Table 2.2 Typical RCS values for some common targets *

Target	RCS on linear scale	RCS on log scale
Bird	0.001 m²	−30 dB m²
Cruise missile	0.01 m²	−20 dB m²
Person Small boat Small aircraft	1 m²	0 dB m²
Cabin cruiser Fighter–bomber aircraft	10 m²	10 dB m²
Road traffic Large aircraft	100 m²	20 dB m²
Tankers Large passenger ships	1000 m²	30 dB m²

* Introduction to RADAR Systems; M.I. Skolnik, 1981

Designed for detecting changes associated with man-made targets

RCS-Based Detection Description – Adaptive Threshold Determination



Computes thresholds adaptively per image

- $Target\_Thresh_{Pre}$ and $Target\_Thresh_{Post}$
- $NonTarget\_Thresh_{Pre}$ and $NonTarget\_Thresh_{Post}$

Max and Min limits are checked and adopted if exceeded

- Target Threshold Max & Min (Square Meters)
- NonTarget Threshold Min (Square Meters)

Resulting thresholds are translated to intensity levels for the detection process

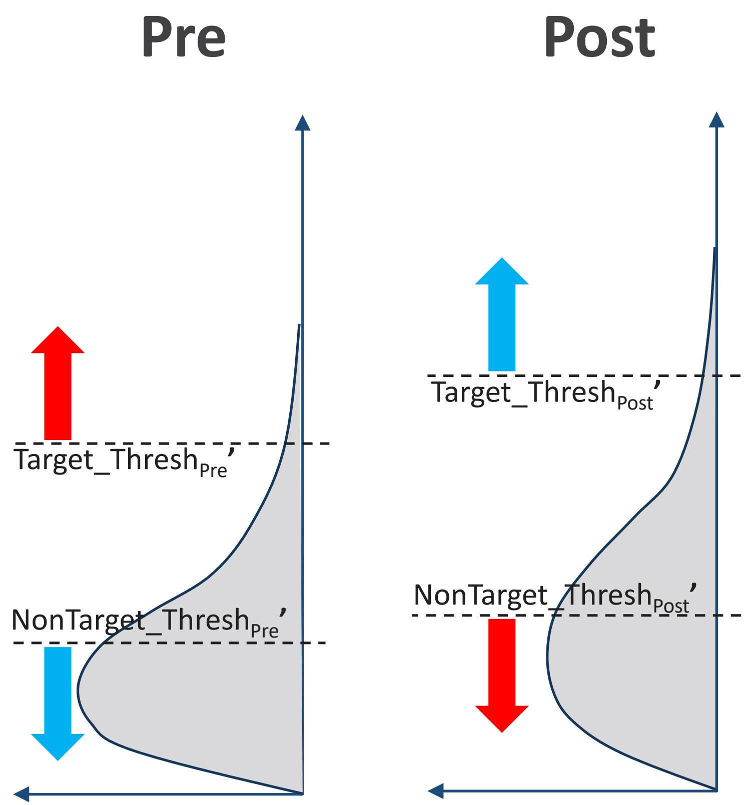
- $Target\_Thresh_{Pre}$’ and $Target\_Thresh_{Post}$’
- $NonTarget\_Thresh_{Pre}$’ and $NonTarget\_Thresh_{Post}$’

RCS-Based Detection Description – Thresholding Concept

For the next pixel, perform the following tests:

If Pix_{Pre} > $Target\_Thresh_{Pre}'$ AND Pix_{Post} < $NonTarget\_Thresh_{Post}'$
Then DEPARTURE CHANGE
Compute RCS_{Pre} and $Clutter_{Post}$
Move to next pixel location and start at top
Otherwise

If Pix_{Post} > $Target\_Thresh_{Post}'$ AND Pix_{Pre} < $NonTarget\_Thresh_{Pre}'$
Then ARRIVAL CHANGE
Compute RCS_{Post} and $Clutter_{Pre}$
Move to next pixel location and start at top
Otherwise
NO DECTECT; Move to next pixel location and start at top



Pre-Image Histogram (for illustration)

Post-Image Histogram (for illustration)

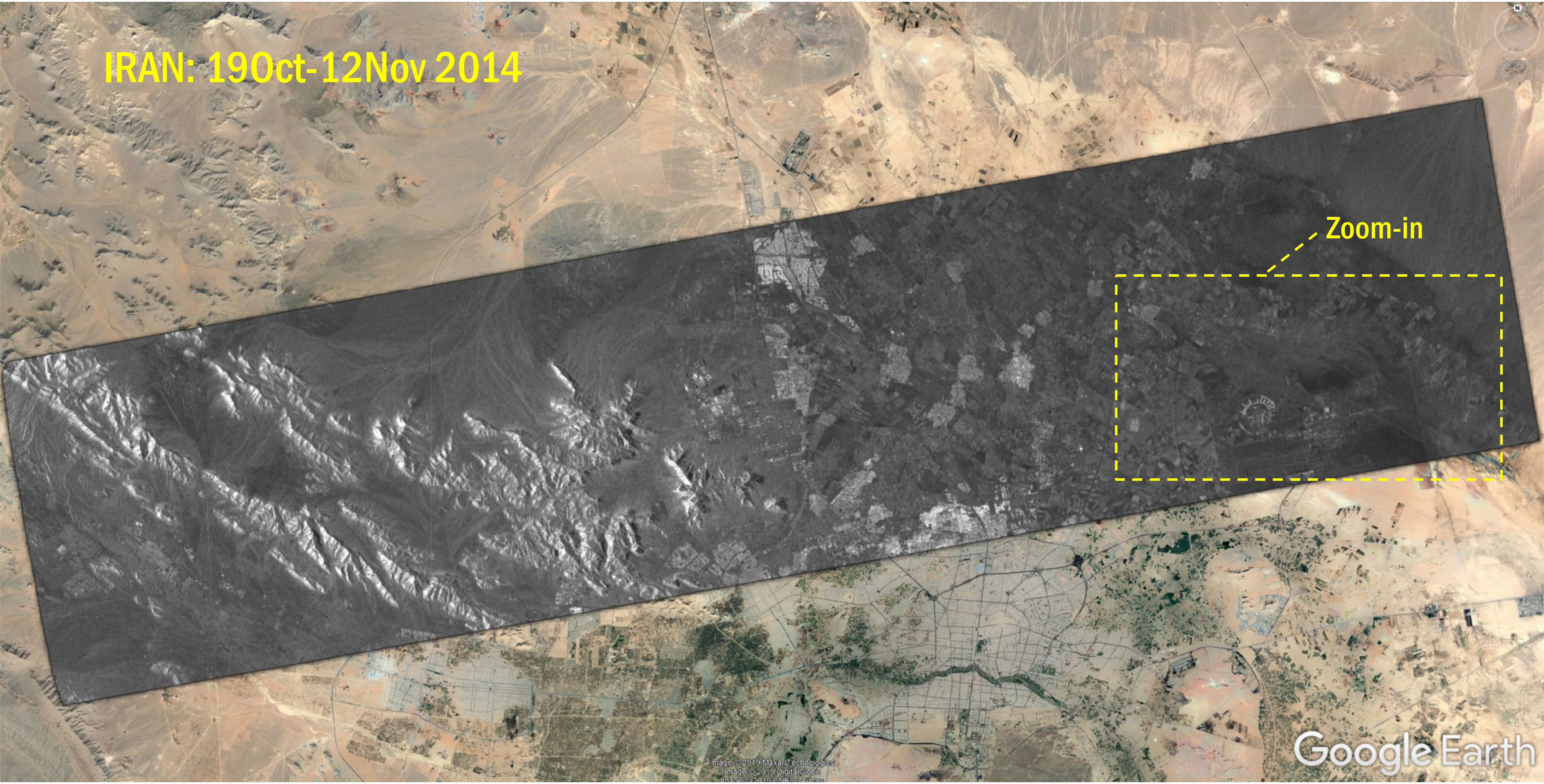
Recorded Information for each change detection

MetaData	Units	Description
Image IDs		Image ID from each SICD
Incidence Angles	degrees	Grazing and Azimuth Angle
Attributes	**Units**	**Description**
Detect Strength	dB	Max RLOG value from change detection pixels (+Arrival, -Departure)
Change Area	$meter^2$	Area span of change detection
Pixel Count		Number of pixels comprising the change
Centroid	degrees	Latitude and Longitude (unweighted and weighted)
Length	meter	Length along major and minor axes
Eccentricity		Ellipse fitting metric
Orientation	degrees	Angular measure from north
Perimeter	meter	Length around the change area
Compactness		Metric relating ratio of perimeter to area
Target Return	$meter^2$ (dB)*	Minimum, maximum, mean, and total target return
Background Return	$meter^2$ (dB)*	Minimum, maximum, and mean background return

New Addition

* Units are dB if derived with RLOG detection mode

Examples



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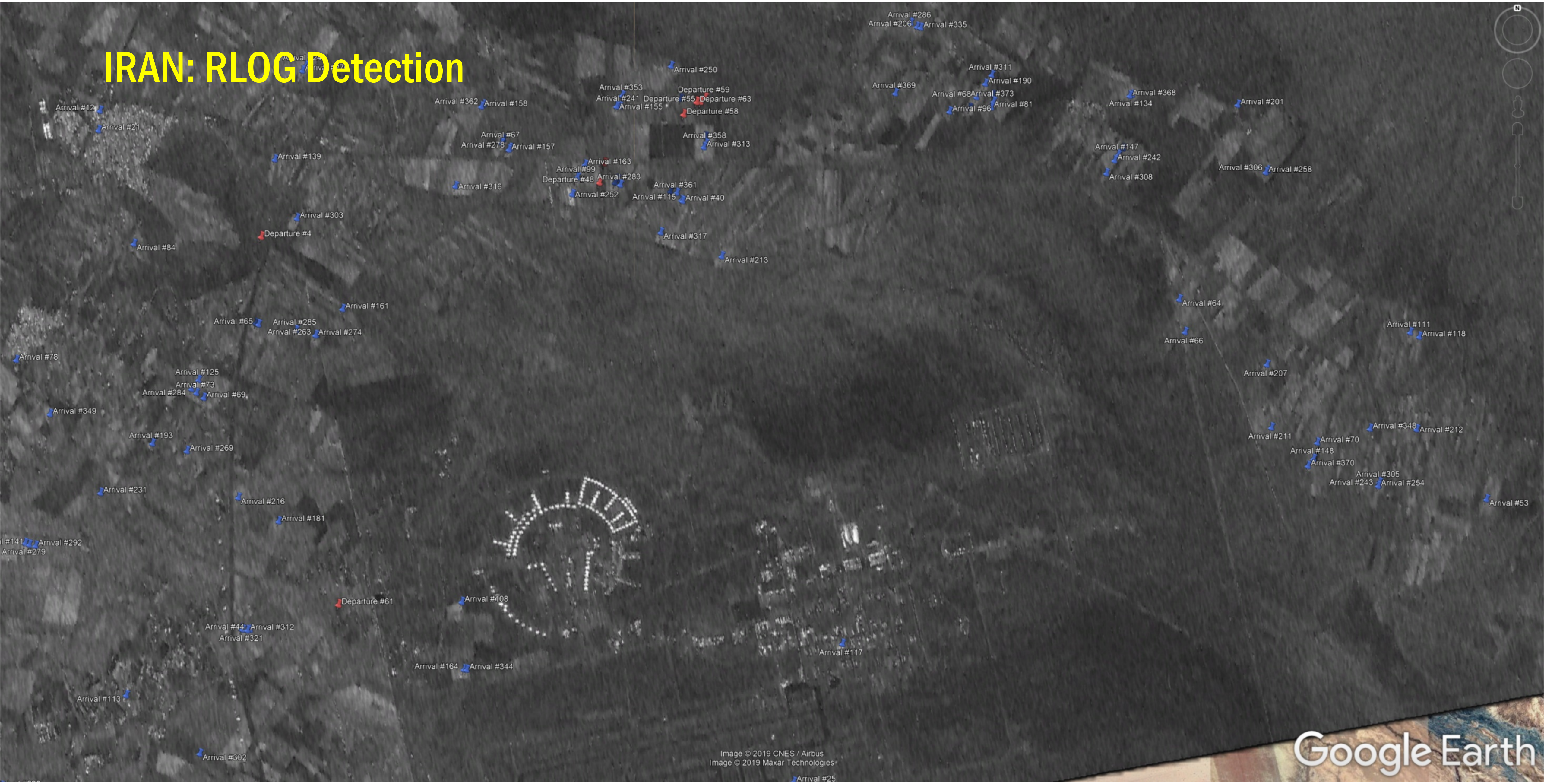
IRAN: EO Image (zoom-in)


IRAN: Pre-Image
Image © 2019 CNES / Airbus
Image © 2019 Maxar Technologies
Google Earth

IRAN: Post-Image

IRAN: RLOG Detection



IRAN: RCS-Based Detection

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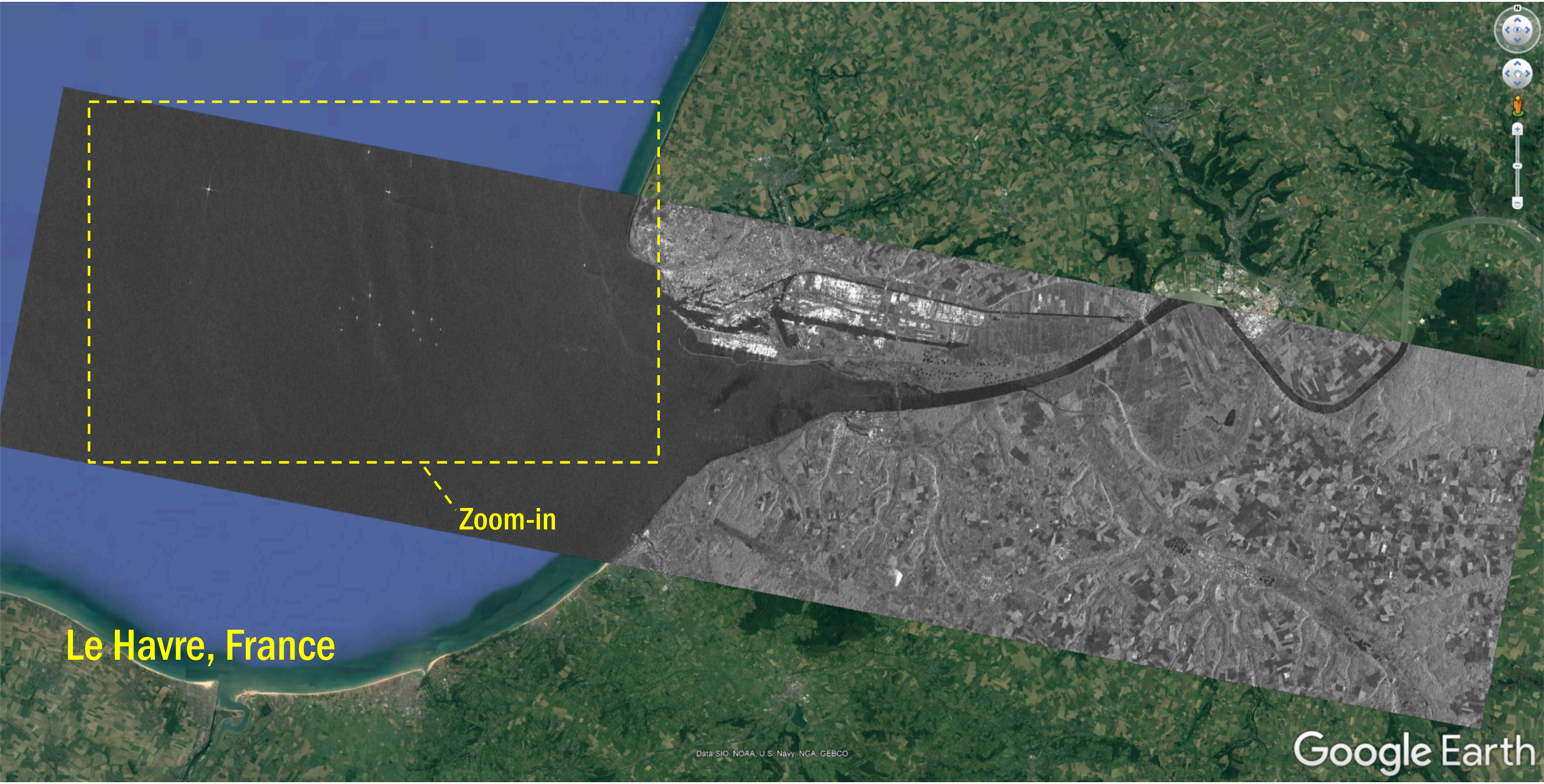
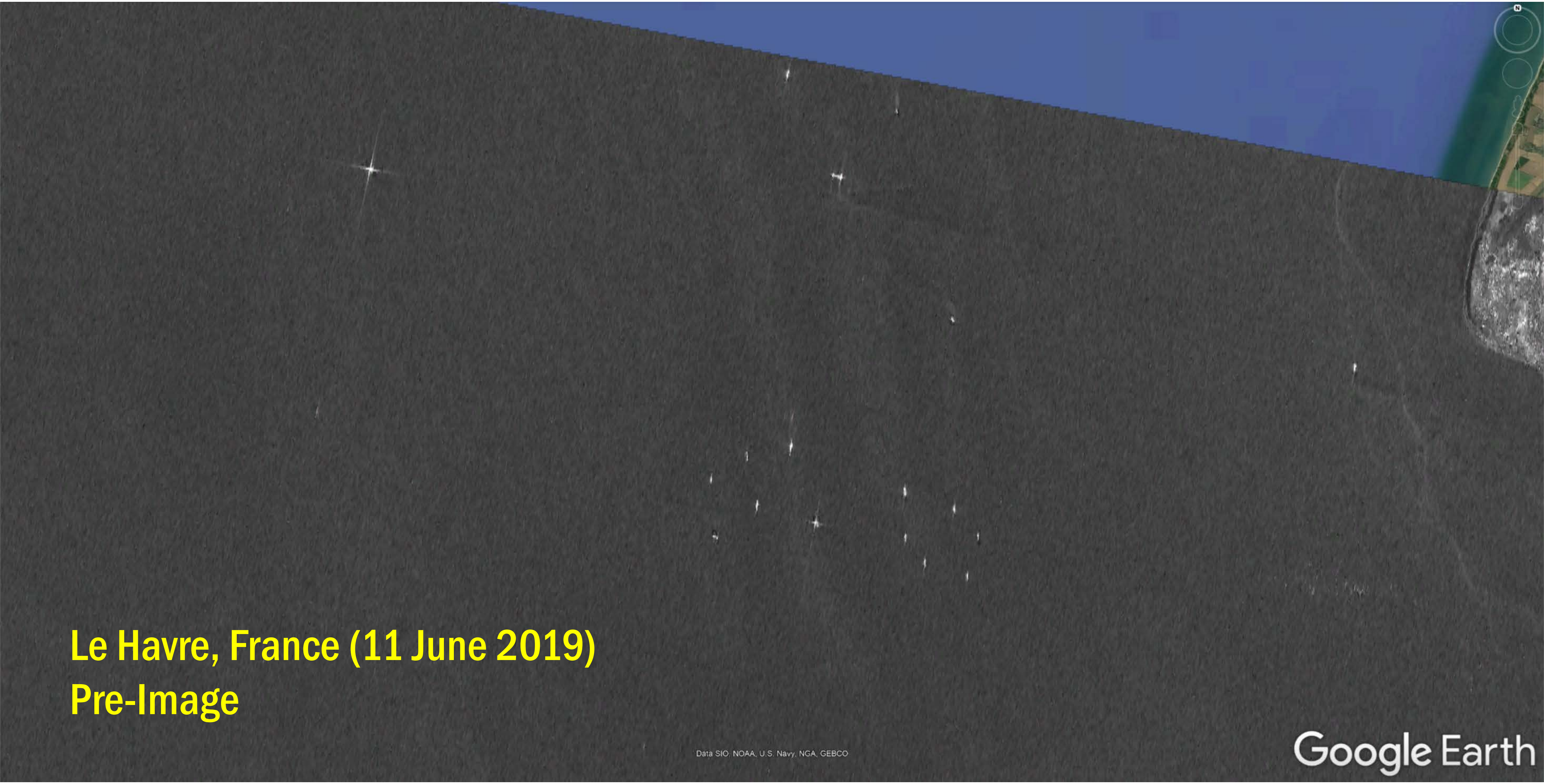
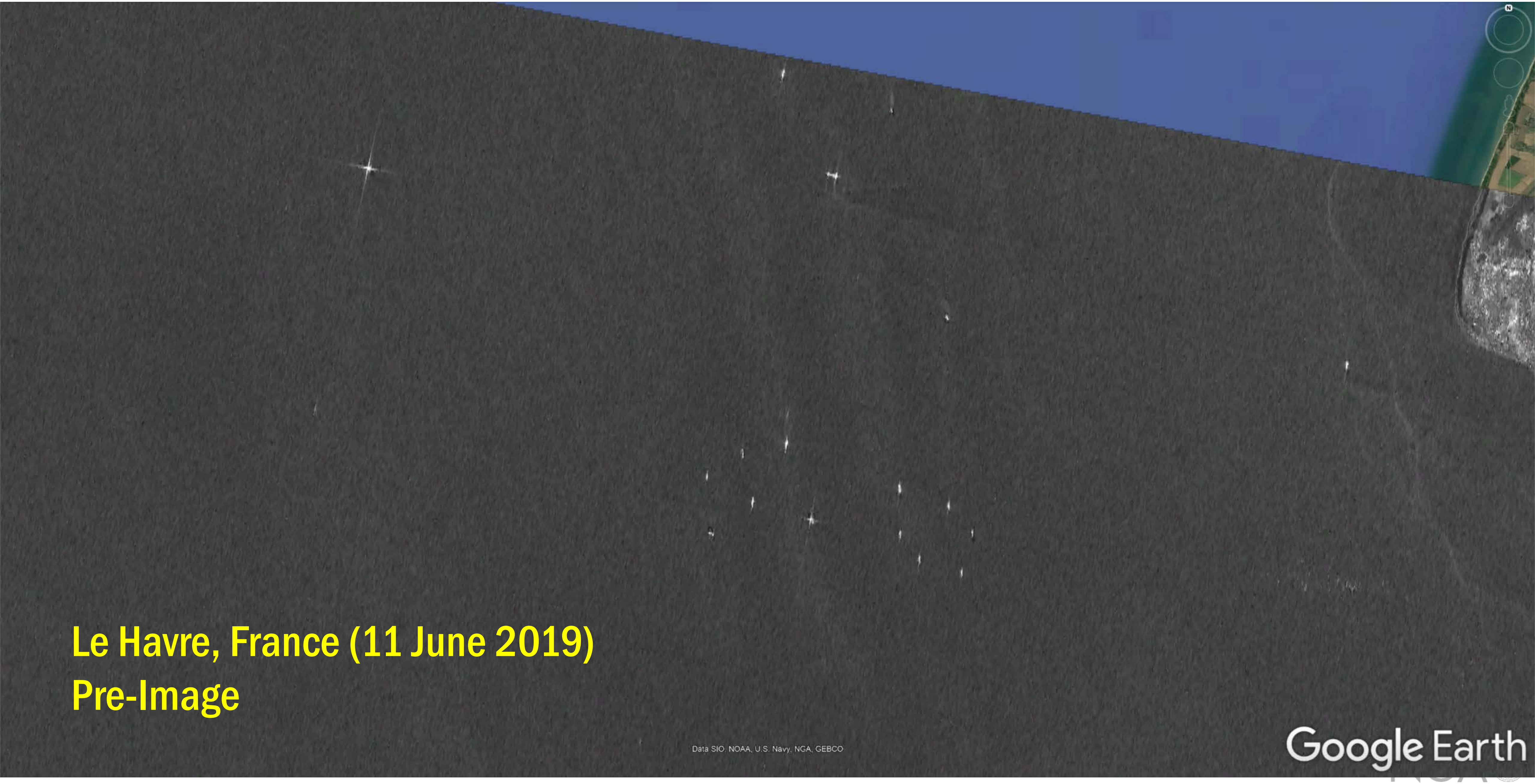
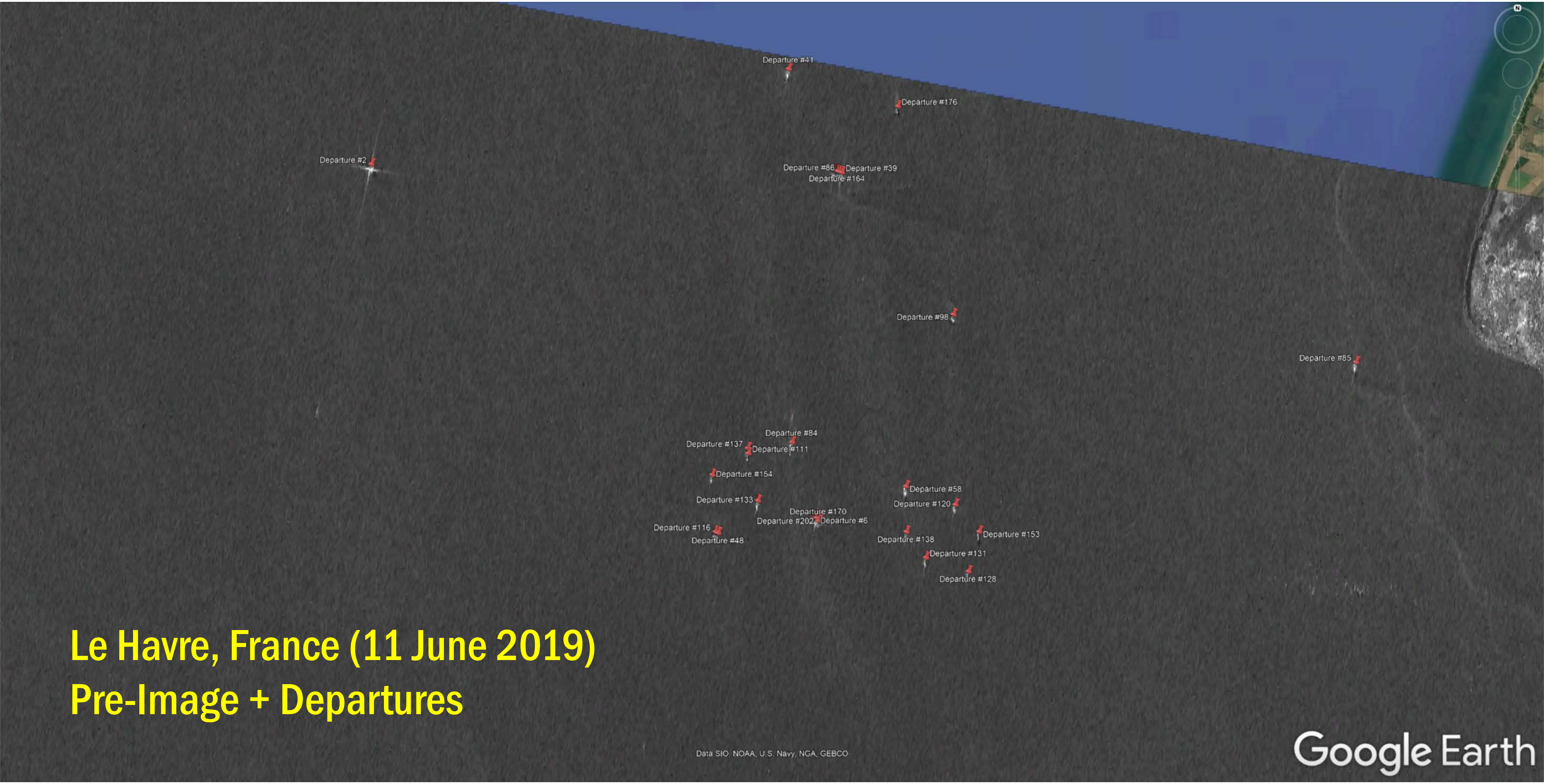
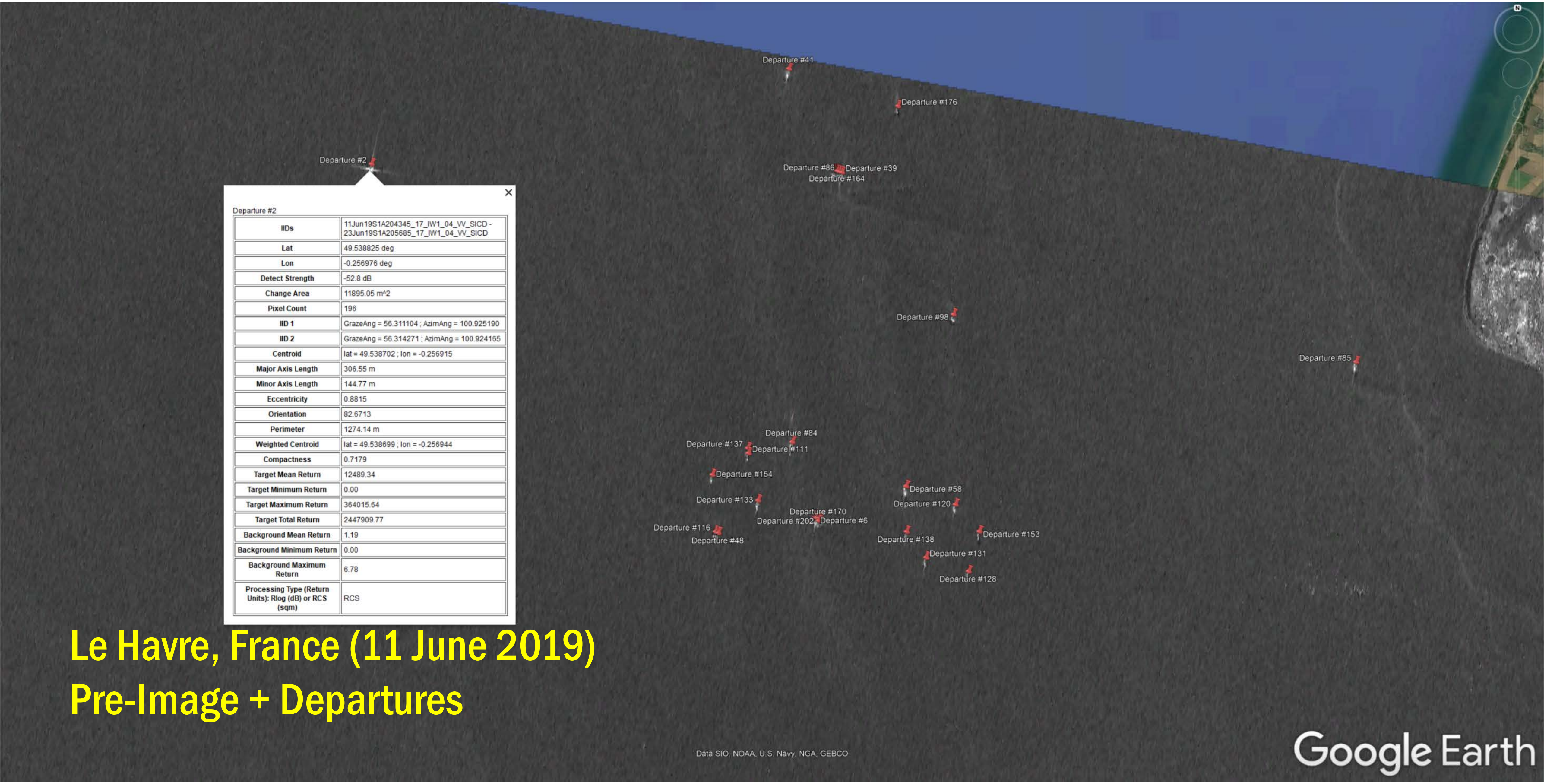

Zoom-in
Le Havre, France
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth


Le Havre, France (11 June 2019)
Pre-Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth


Le Havre, France (23 June 2019)
Post-Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth


Le Havre, France (11 June 2019)
Pre-Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth


Departure #41
Departure #176
Departure #2
Departure #86
Departure #39
Departure #164
Departure #98
Departure #85
Departure #84
Departure #137
Departure #111
Departure #154
Departure #58
Departure #133
Departure #120
Departure #170
Departure #202
Departure #6
Departure #116
Departure #48
Departure #138
Departure #153
Departure #131
Departure #128
Le Havre, France (11 June 2019)
Pre-Image + Departures
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth



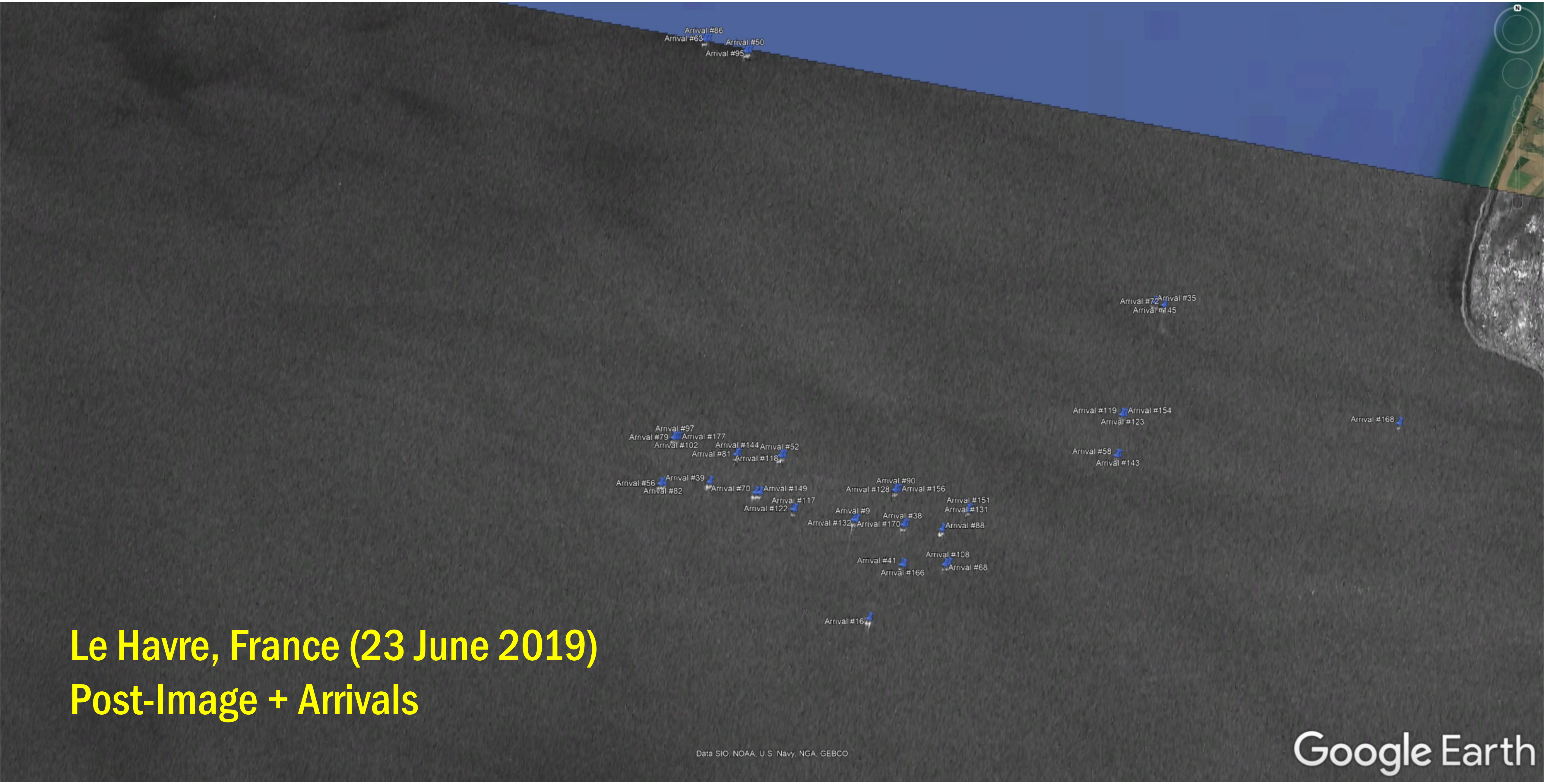
Departure #2

IIDs	11Jun19S1A204345_17_IW1_04_VV_SICD - 23Jun19S1A205685_17_IW1_04_VV_SICD
Lat	49.538825 deg
Lon	-0.256976 deg
Detect Strength	-52.8 dB
Change Area	11895.05 m^2
Pixel Count	196
IID 1	GrazeAng = 56.311104 ; AzimAng = 100.925190
IID 2	GrazeAng = 56.314271 ; AzimAng = 100.924165
Centroid	lat = 49.538702 ; lon = -0.256915
Major Axis Length	306.55 m
Minor Axis Length	144.77 m
Eccentricity	0.8815
Orientation	82.6713
Perimeter	1274.14 m
Weighted Centroid	lat = 49.538699 ; lon = -0.256944
Compactness	0.7179
Target Mean Return	12489.34
Target Minimum Return	0.00
Target Maximum Return	364015.64
Target Total Return	2447909.77
Background Mean Return	1.19
Background Minimum Return	0.00
Background Maximum Return	6.78
Processing Type (Return Units): Rlog (dB) or RCS (sqm)	RCS

Le Havre, France (11 June 2019)

Pre-Image + Departures


Le Havre, France (23 June 2019)
Post-Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth



Le Havre, France (23 June 2019)
Post-Image + Arrivals

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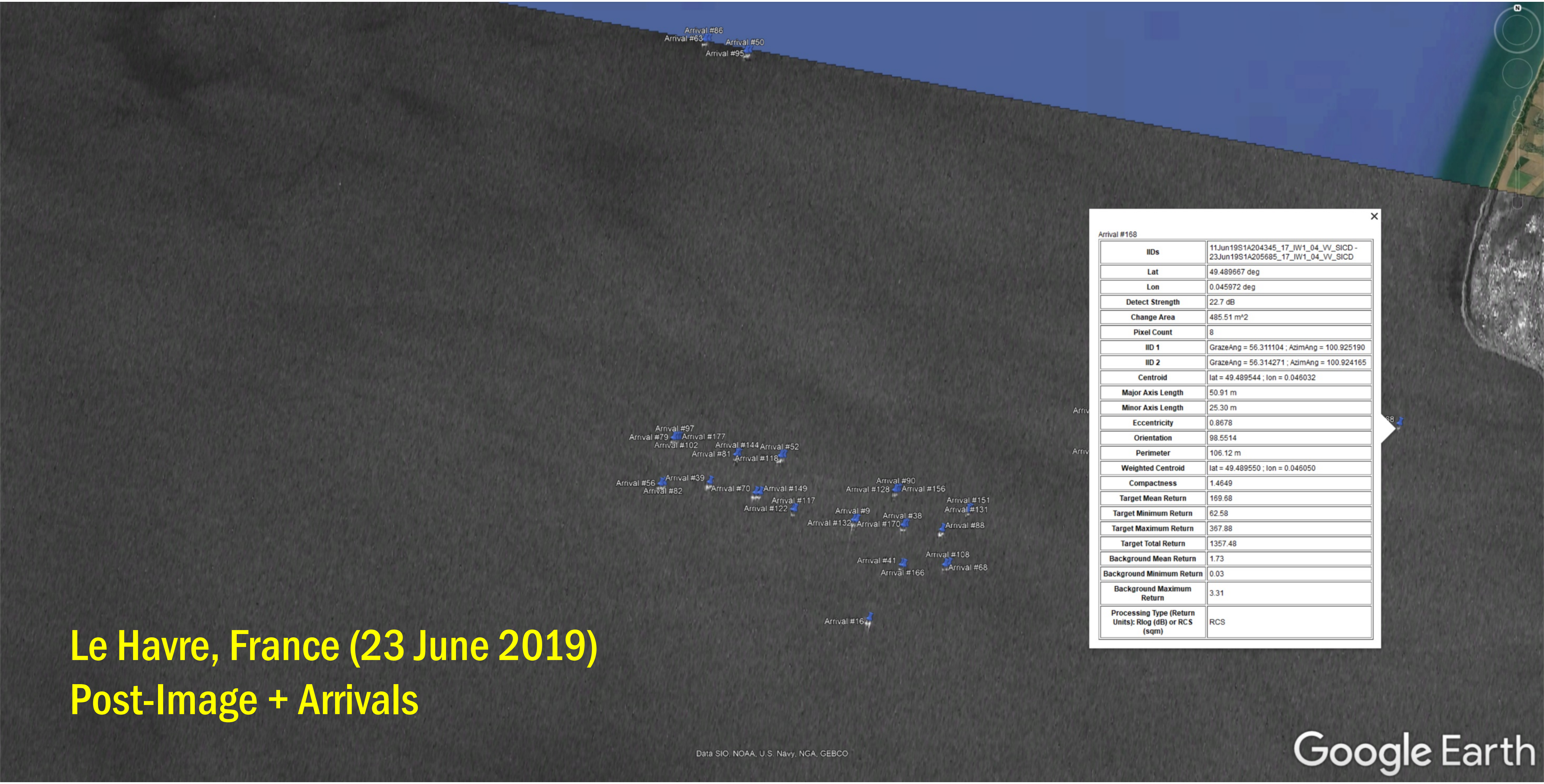
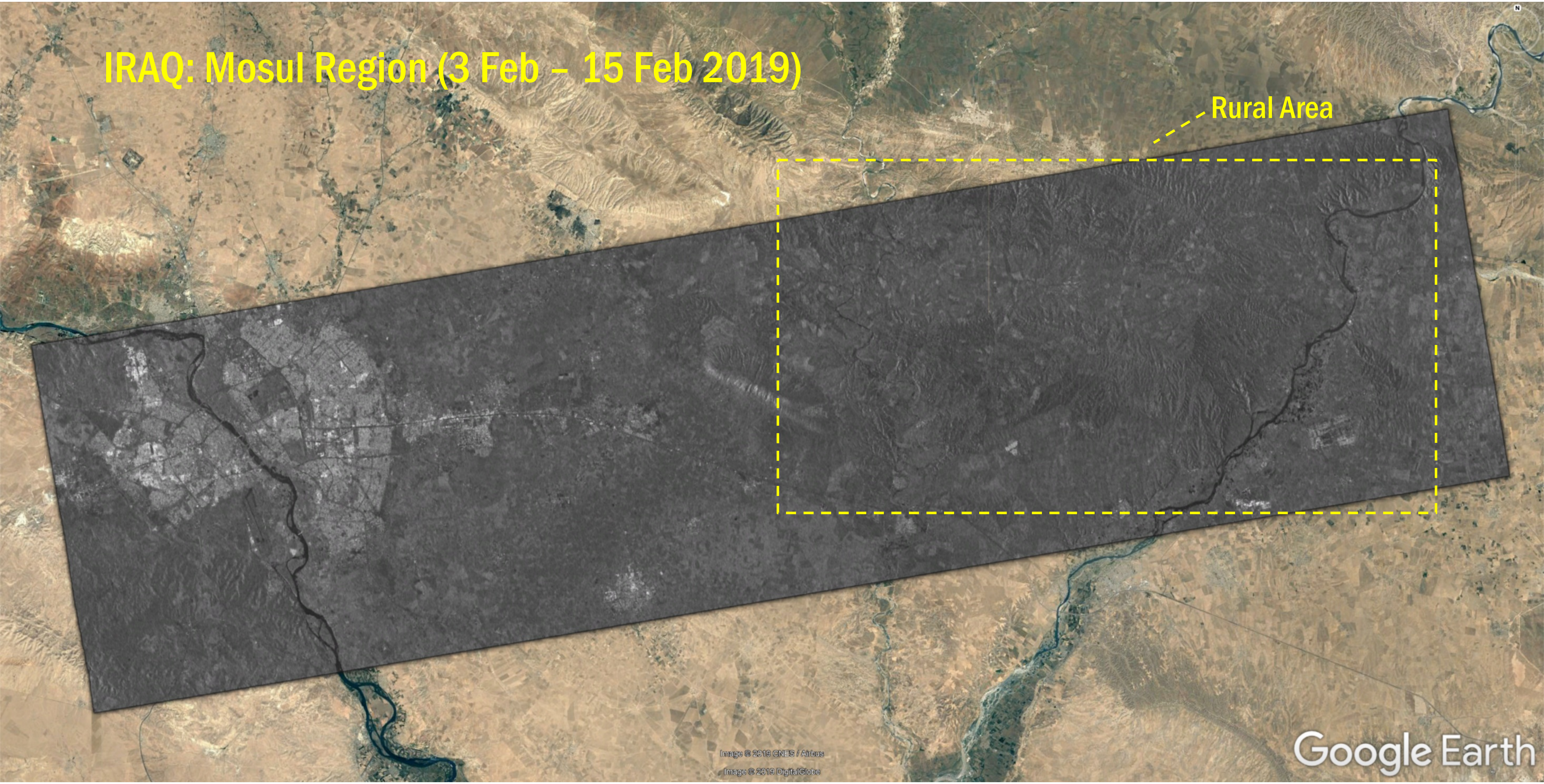


Arrival #168

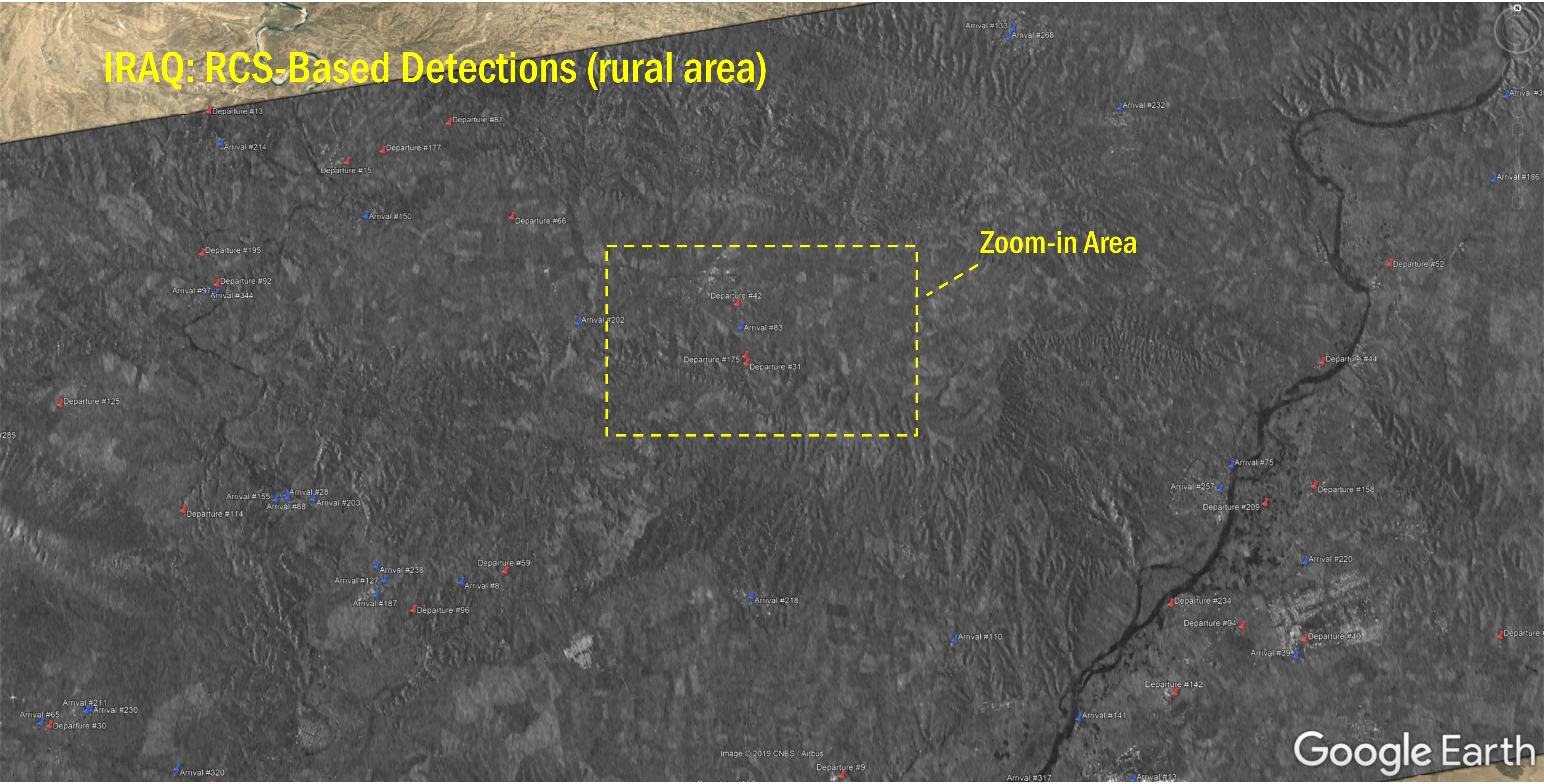
IIDs	11Jun19S1A204345_17_IW1_04_VV_SICD - 23Jun19S1A205685_17_IW1_04_VV_SICD
Lat	49.489667 deg
Lon	0.045972 deg
Detect Strength	22.7 dB
Change Area	485.51 m^2
Pixel Count	8
IID 1	GrazeAng = 56.311104 ; AzimAng = 100.925190
IID 2	GrazeAng = 56.314271 ; AzimAng = 100.924165
Centroid	lat = 49.489544 ; lon = 0.046032
Major Axis Length	50.91 m
Minor Axis Length	25.30 m
Eccentricity	0.8678
Orientation	98.5514
Perimeter	106.12 m
Weighted Centroid	lat = 49.489550 ; lon = 0.046050
Compactness	1.4649
Target Mean Return	169.68
Target Minimum Return	62.58
Target Maximum Return	367.88
Target Total Return	1357.48
Background Mean Return	1.73
Background Minimum Return	0.03
Background Maximum Return	3.31
Processing Type (Return Units): Rlog (dB) or RCS (sqm)	RCS

Le Havre, France (23 June 2019)
Post-Image + Arrivals

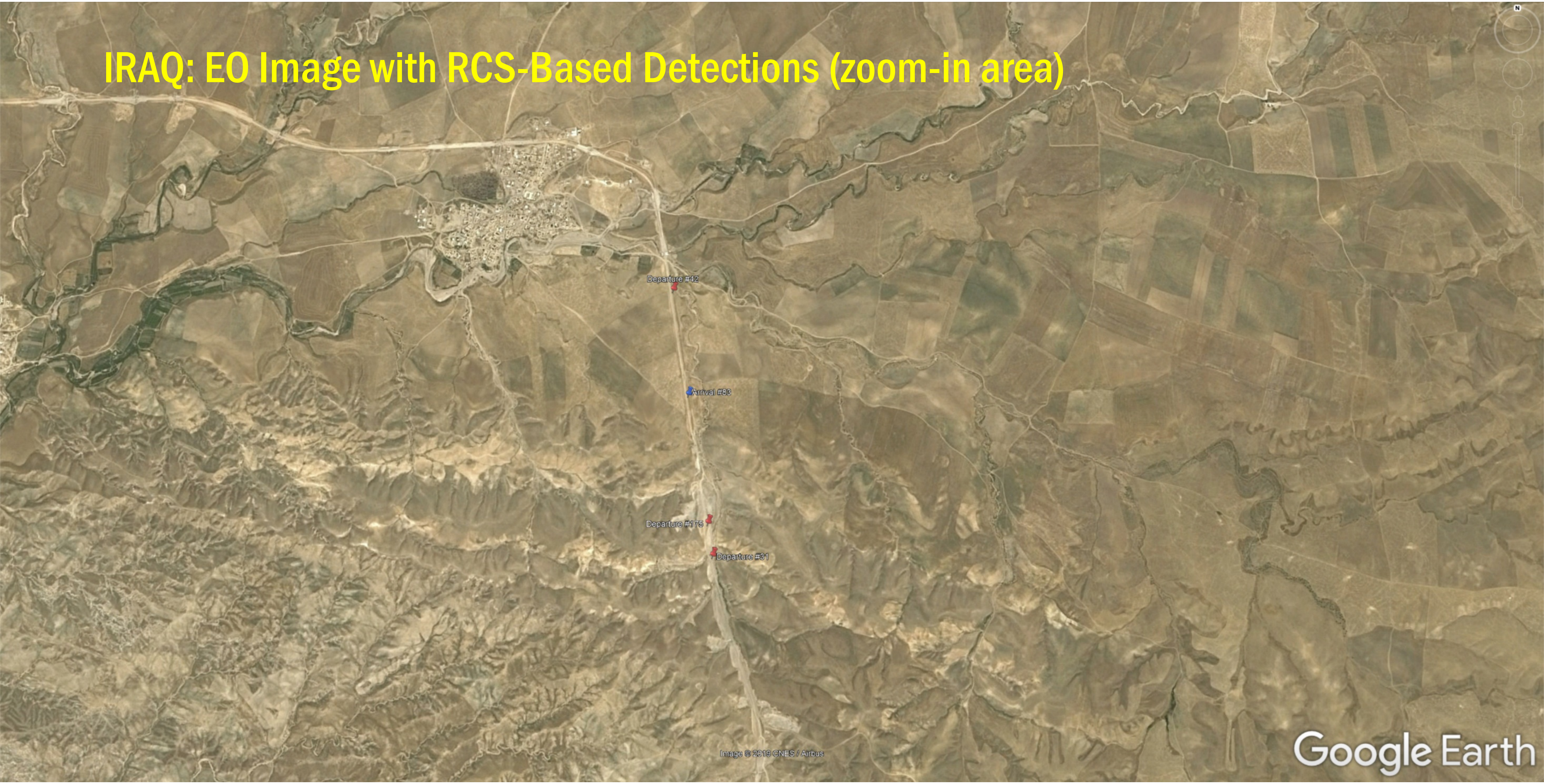
IRAQ: Mosul Region (3 Feb – 15 Feb 2019)

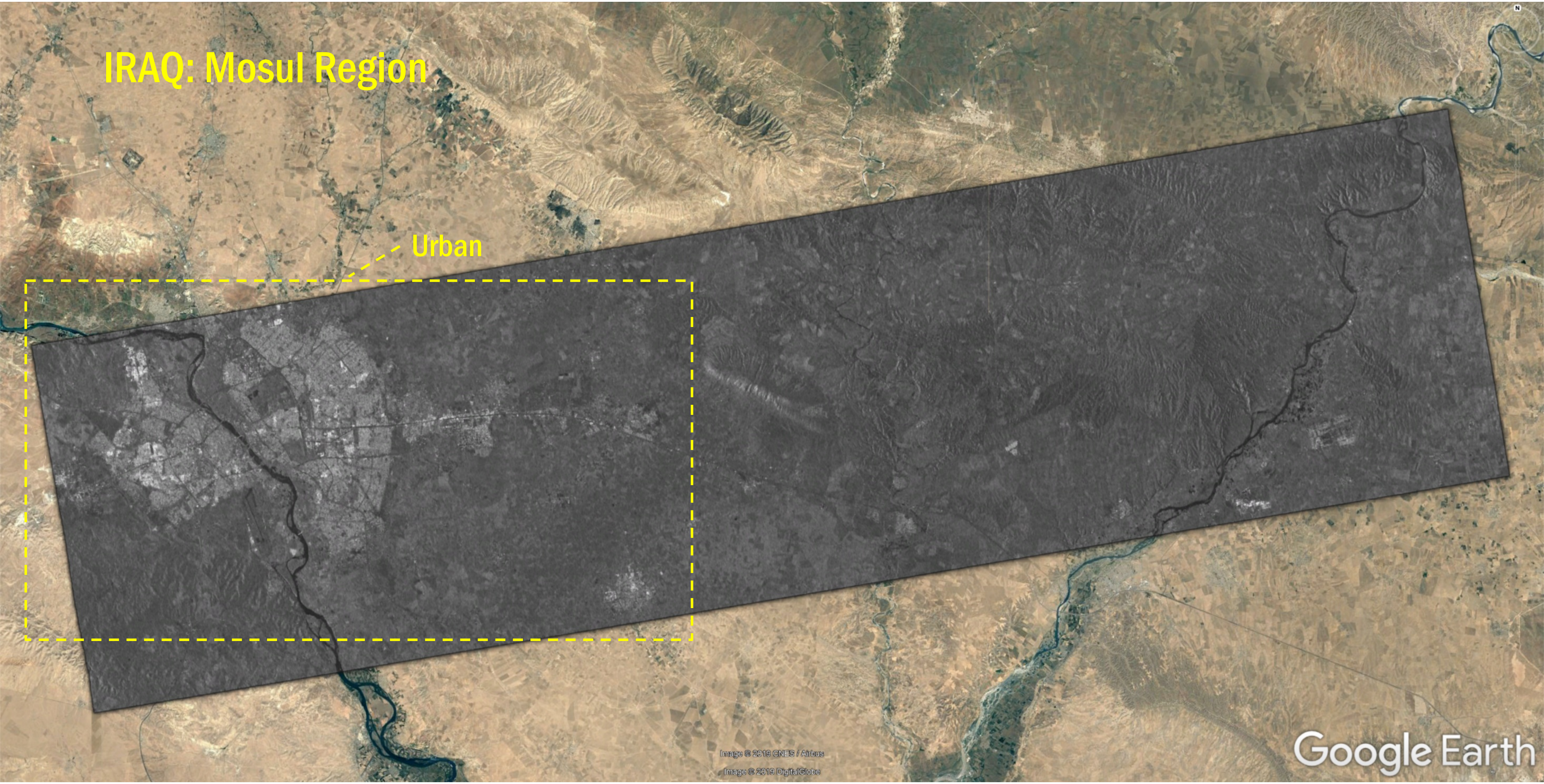


IRAQ: RCS-Based Detections (rural area)

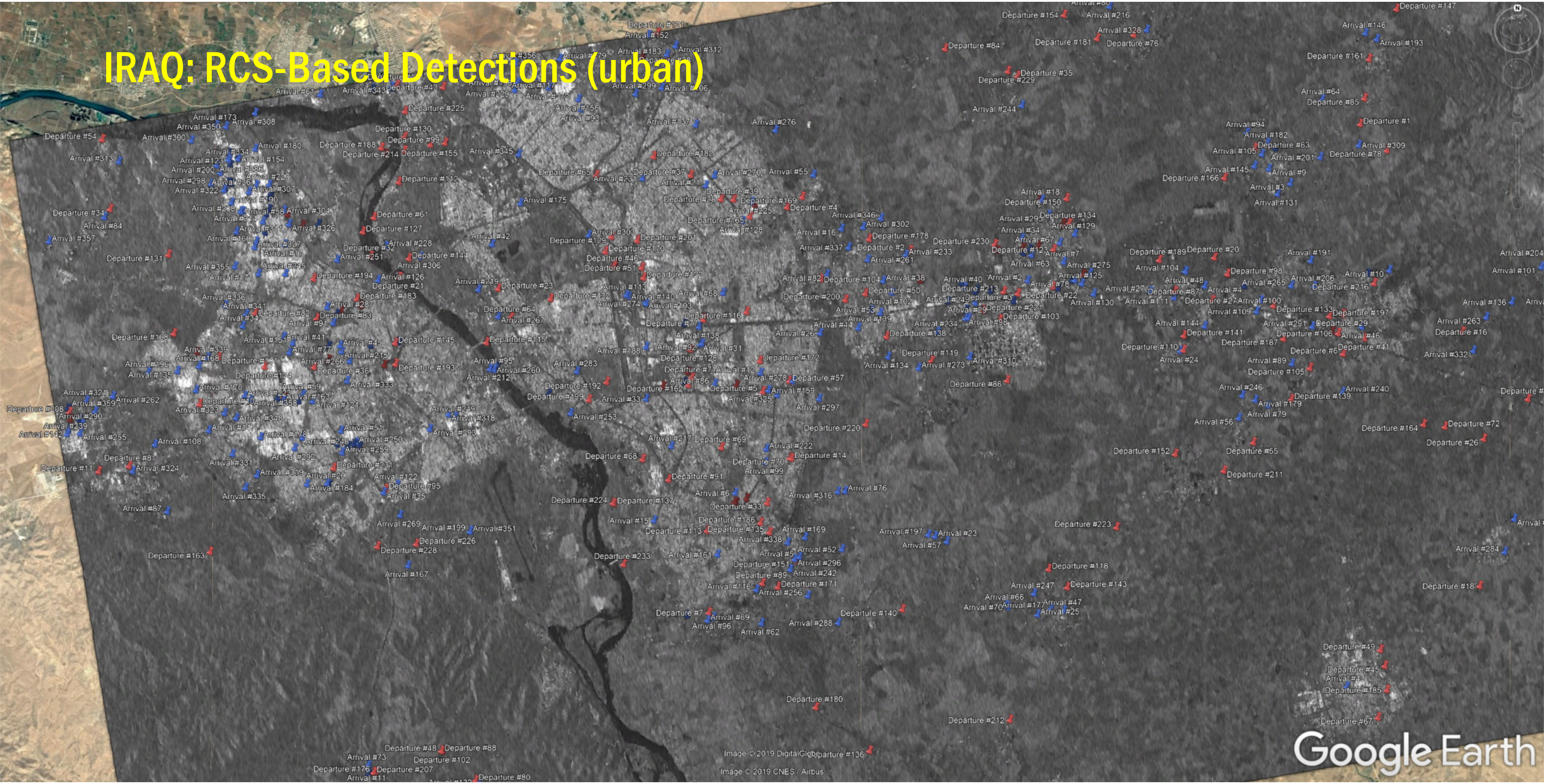


IRAQ: EO Image with RCS-Based Detections (zoom-in area)

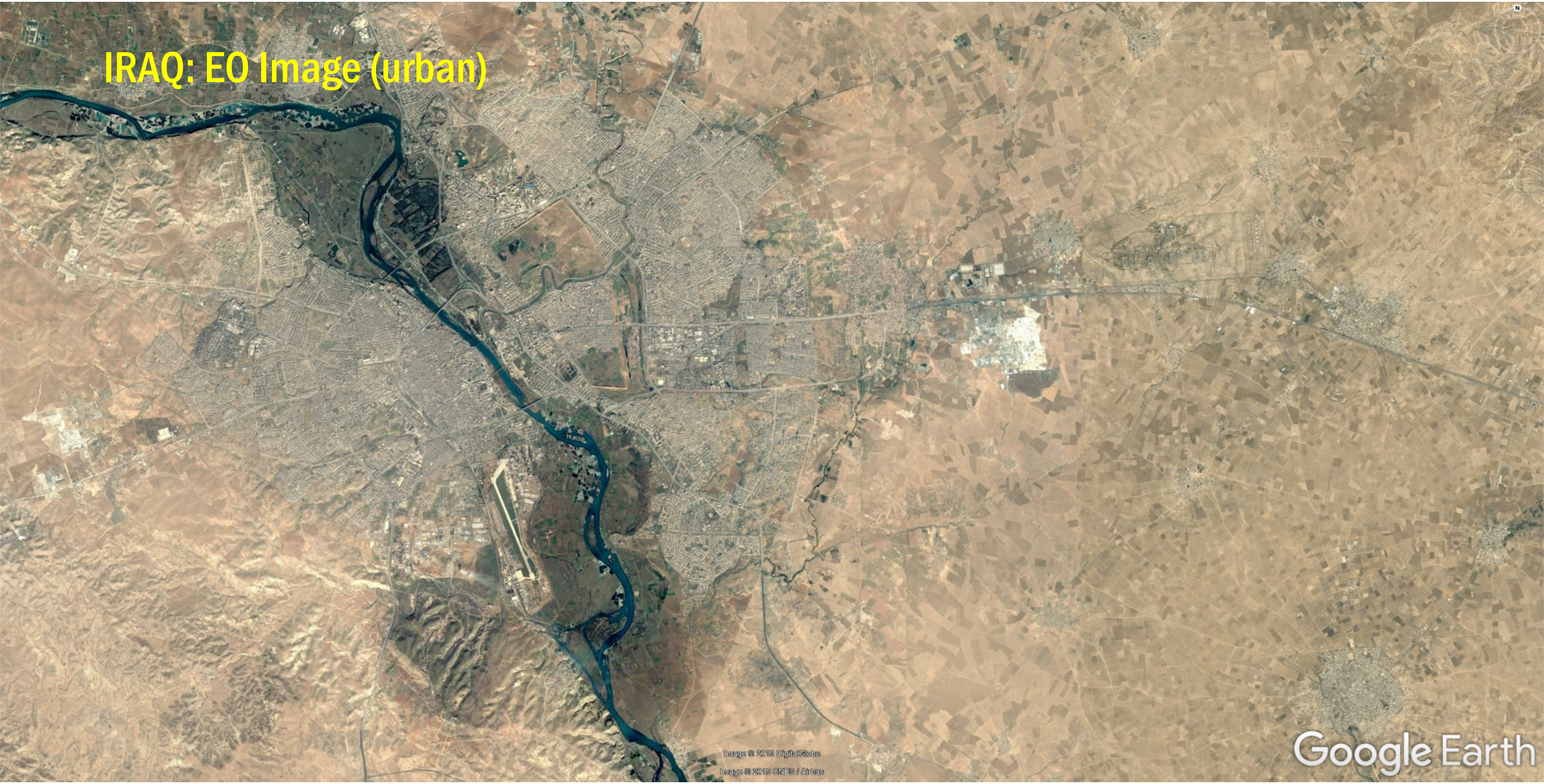



IRAQ: Mosul Region
Urban
Image © 2019 CNES / Airbus
Image © 2019 DigitalGlobe
Google Earth

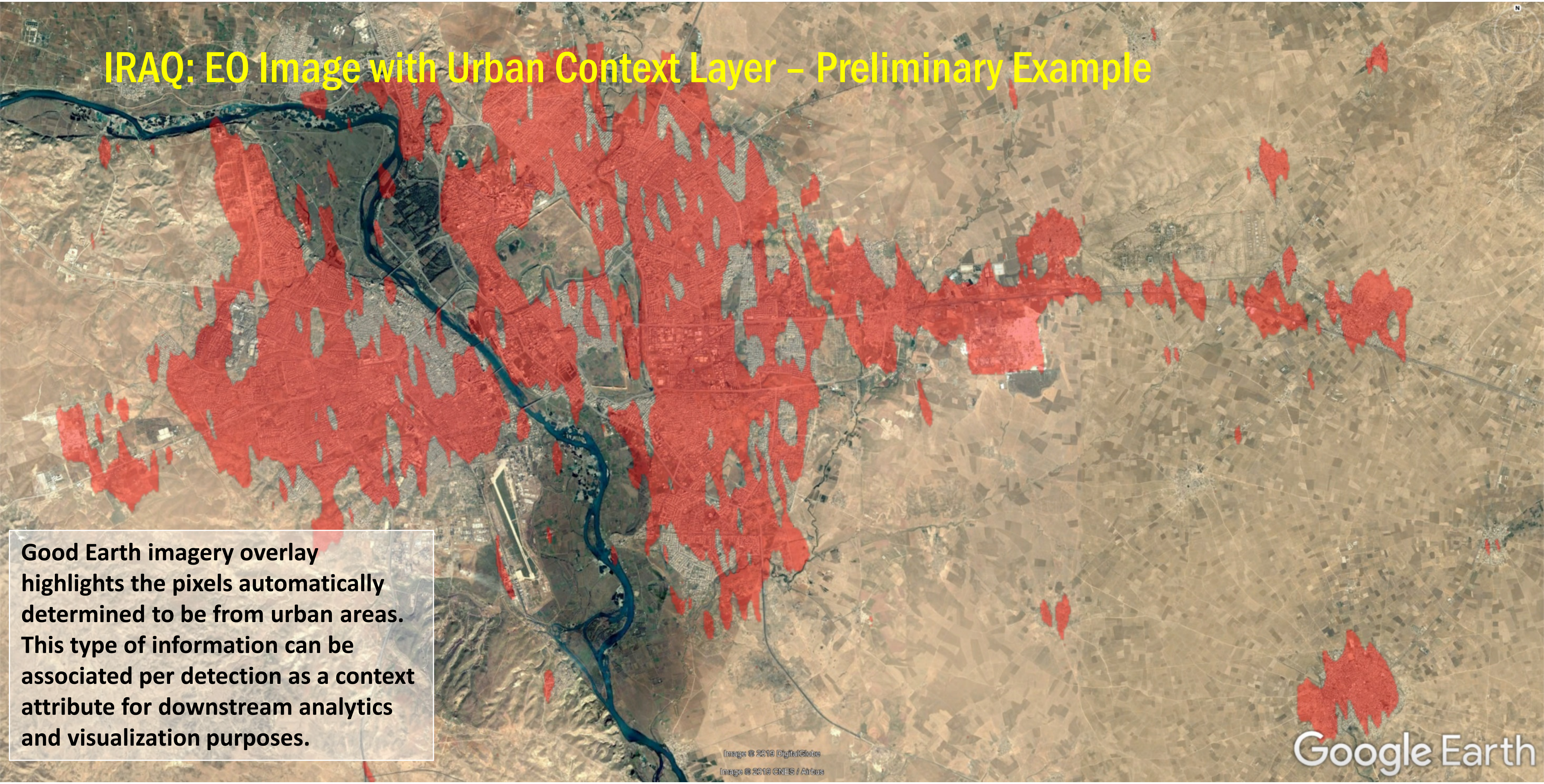
IRAQ: RCS-Based Detections (urban)



IRAQ: EO Image (urban)



IRAQ: EO Image with Urban Context Layer – Preliminary Example



Good Earth imagery overlay highlights the pixels automatically determined to be from urban areas. This type of information can be associated per detection as a context attribute for downstream analytics and visualization purposes.

Potential Future Efforts

- Add scene context attributes with detections to support filtering during analytics or visualization
  - Urban area
  - Terrain slope
  - Water body
- Investigate using both RCS-Based and RLOG techniques for complementary attributes
- Use-case development
- Change analytics demonstrations

Focused on Improvements that Align with NGA Objectives

NGA