Philippine Space Agency SENTINEL ASIA JAXA

Optimizing Optical Satellite Data Analysis: Methods and Strategies

Dr. Saeed Al Mansoori
Director – Remote Sensing Department
Mohammed Bin Rashid Space Centre (MBRSC)

Agenda

- ❑ Introduction and Overview
- ❑ Importance of Optimizing Satellite Data Analysis
- ❑ Data Challenges in Optical Satellite Imagery
- ❑ Workflow for Optical Data Analysis
- ❑ Preprocessing Techniques
- ❑ Advanced Feature Extraction Techniques
- ❑ MBRSC Products: Use Cases
- ❑ Future Trends in Satellite Data Analysis

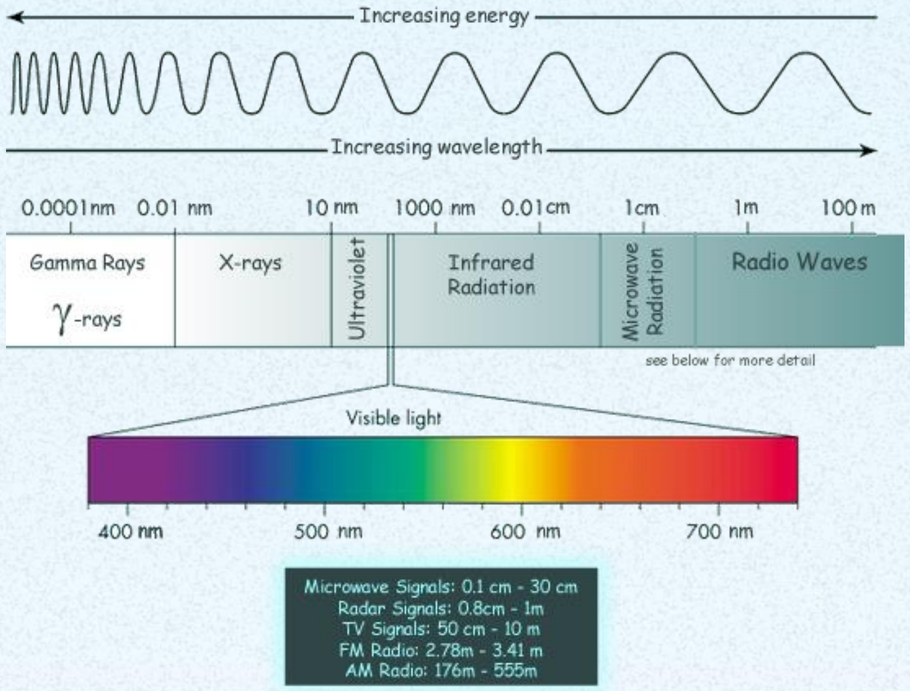
Philippine Space Agency SENTINEL ASIA JAXA

Introduction and Overview

Optical satellite images are taken by sensors that capture visible light, as well as parts of the ultraviolet and infrared spectrums, by detecting sunlight reflected from Earth's surface.

Optical satellite sensors capture sunlight reflected in visible and NIR wavelengths, allowing them to distinguish between materials like vegetation, water, soil, and urban structures. This imaging resembles human vision but extends to wavelengths beyond what we can see.

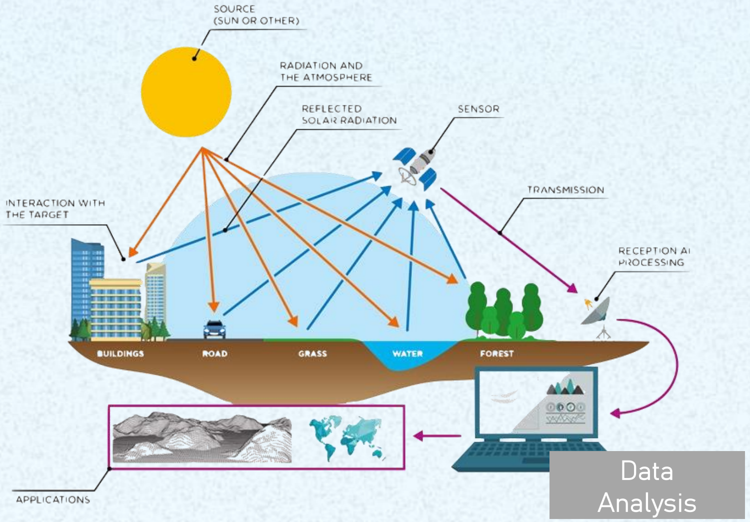
Optical satellite images vary in resolution:



- Spatial Resolution: The detail of the image, ranging from high-resolution images that capture details as small as a few centimeters to lower resolutions that capture larger areas but with less detail.
- Spectral Resolution: The ability to capture data in specific wavelength bands (e.g., red, green, blue, and infrared).
- Temporal Resolution: How frequently images of the same area are captured, useful for monitoring changes over time.

Philippine Space Agency SENTINEL ASIA JAXA

Importance of Optimizing Satellite Data Analysis



- **Enhanced Accuracy**: Improved algorithms lead to better accuracy in interpreting land cover, vegetation health, water quality, etc.

- **Faster Processing**: Optimization reduces processing times, allowing near real-time data analysis, crucial for disaster response and time-sensitive applications.

- **Cost Efficiency**: Efficient data processing minimizes computing costs, especially for high-resolution or large-scale datasets.

- **Scalability**: Optimized processes allow analysis of growing data volumes as satellite networks and data collection expand.

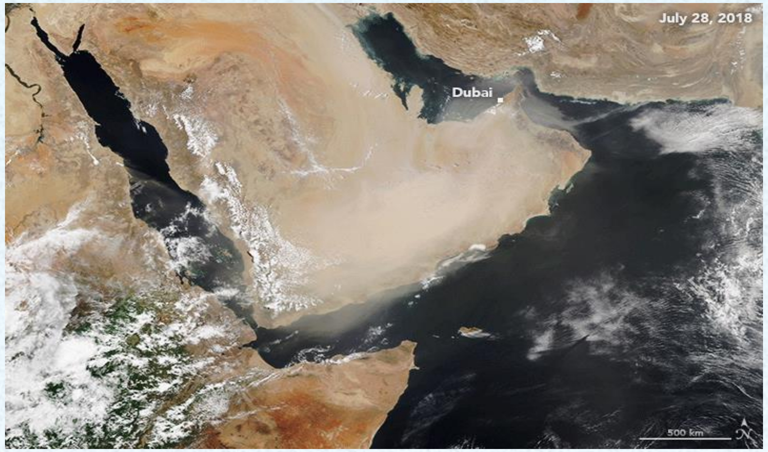
Philippine Space Agency

Data Challenges in Optical Satellite Imagery (1/3)

1. Atmospheric Interference

- Cloud Cover: Clouds obscure large areas of imagery, limiting data collection, especially in tropical and high-latitude regions. Persistent cloud cover can hinder long-term monitoring efforts.
- Aerosols and Dust: Particles in the atmosphere, such as dust, smoke, and pollutants, can distort the captured images, affecting data accuracy, especially in urban and desert areas.

Solution: Atmospheric correction algorithms and multi-temporal imaging can help mitigate these effects, though complete elimination remains challenging.



2. Lighting Conditions

- Sun Angle Variability: Variations in sunlight angle due to time of day or season affect the brightness and contrast in images, making it difficult to maintain consistency across datasets.
- Shadows: Shadows cast by natural or man-made features can obscure underlying details, complicating image interpretation, especially in mountainous or densely built areas.

Solution: Standardizing image acquisition times and employing shadow removal techniques can improve data quality.

Philippine Space Agency
SENTINEL ASIA
JAXA

Data Challenges in Optical Satellite Imagery (2/3)

3. Limited Temporal Coverage

- Daylight Dependency: Optical sensors rely on sunlight, so they cannot capture data at night, limiting temporal coverage for certain types of monitoring.
- Sparse Revisits: Many satellites only capture images of the same location every few days or weeks, which can be insufficient for fast-changing events, such as wildfires or floods.

Solution: Using constellations of satellites or combining data from multiple sources can increase temporal resolution.

4. Spatial and Spectral Resolution Trade-offs

- Resolution Constraints: High spatial resolution (fine detail) often requires lower spectral or temporal resolution due to technical limitations, making it challenging to capture highly detailed images with comprehensive spectral data.
- Spectral Bands Limitations: Most optical sensors capture a limited range of spectral bands, often excluding thermal or additional near-infrared bands that could provide useful data.

Solution: Combining multiple datasets can help balance these trade-offs for more robust analyses.

Philippine Space Agency SENTINEL ASIA JAXA

Data Challenges in Optical Satellite Imagery (3/3)

5. Data Volume and Storage Requirements

- Large File Sizes: High-resolution optical images produce massive amounts of data, requiring significant storage, bandwidth, and processing power to manage effectively.
- Storage and Management Costs: Storing and maintaining these large datasets can become costly, especially for organizations handling extensive archives.

Solution: Cloud-based storage solutions and compression techniques can ease storage demands, while data curation practices ensure efficient data retrieval.

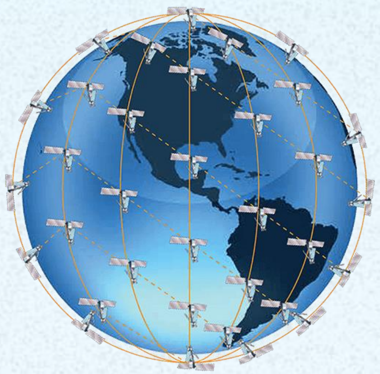
6. Variability in Data Quality

- Sensor Degradation: Over time, satellite sensors degrade, which can reduce image quality and lead to inconsistencies across datasets, particularly in older images.
- Calibration Issues: Differences in calibration between satellite missions and even individual sensors can introduce variations, complicating cross-sensor analysis.

Solution: Regular calibration, radiometric correction, and standardized processing methods help maintain data quality and consistency.

Workflow for Optical Data Analysis

Satellite Observation Network



Data Acquiring and Recording

RS Data Processing

Pre-Processing

- L0 → Radiometric → Atmospheric → Geometric

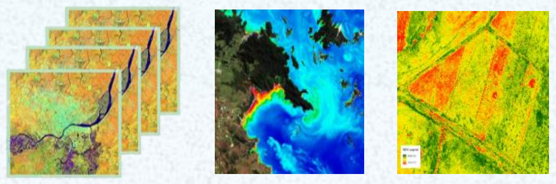
Value-added Processing

- Fine Correction → Fusion, Mosaic
- Orthorectification → Fusion, Mosaic

Information Abstraction

- Classification
- NDVI
- Mineral
- LST
- SST
- Forest

Large Thematic RS Applications



Philippine Space Agency

SENTINEL ASIA

JAXA

Preprocessing Techniques

Pre-processing techniques for optical satellite images are essential for enhancing data quality and ensuring consistent analysis. Here's an ordered list of common pre-processing steps:

Radiometric Correction

Purpose:
Adjusts for sensor-related errors and atmospheric conditions that affect pixel values.

Techniques:
Sensor calibration

Outcome:
Ensures pixel values accurately represent surface reflectance, improving data consistency.

Atmospheric Correction

Purpose:
Removes atmospheric effects such as scattering and absorption caused by aerosols, gases, and water vapor.

Techniques:
Methods like Dark Object Subtraction, Quick Atmospheric Correction (QUAC), and radiative transfer models (e.g., 6S model) are commonly used.

Outcome:
Reduces atmospheric distortions, providing a more accurate reflection of surface properties.

Geometric Correction

Purpose:
Corrects geometric distortions caused by sensor angle, Earth's curvature, and terrain variations, aligning the image to a specific map projection.

Techniques:
Involves ground control points (GCPs) and digital elevation models (DEMs) to adjust the image geometry.

Outcome:
Creates a spatially accurate, map-aligned image, essential for accurate spatial analysis.

(Optional)

Spatial Enhancement

Purpose:
Enhances spatial resolution or sharpness to improve feature visibility, particularly useful for high-resolution analysis.

Techniques:
Includes sharpening filters, resampling, and pan-sharpening (fusing high-resolution panchromatic with lower-resolution multispectral images).

Outcome:
Produces clearer images with enhanced details, though it may introduce artifacts if not done carefully.

Philippine Space Agency

SENTINEL ASIA

JAXA

Preprocessing Techniques

Pre-processing techniques for optical satellite images are essential for enhancing data quality and ensuring consistent analysis. Here's an ordered list of common pre-processing steps:

Noise Reduction

Purpose:
Reduces sensor noise and other image artifacts, especially in images captured under low-light conditions or in specific spectral bands.

Techniques:
Techniques like median filtering, Gaussian filtering, or other smoothing algorithms are applied.

Outcome:
Creates a cleaner image by reducing random pixel variations that could interfere with analysis.

Cloud Masking

Purpose:
Identifies and masks clouds and their shadows, as these can obscure the surface and affect data accuracy

Techniques:
Uses algorithms like Fmask (Function of Mask), cloud probability assessments, or spectral thresholds in visible and infrared bands.

Outcome:
Provides cloud-free images, crucial for applications like land cover analysis where surface visibility is essential.

Image Resampling

Purpose:
Adjusts pixel size to match other images in the dataset or to a desired resolution, aiding in data consistency and alignment.

Techniques:
Common methods include nearest neighbor, bilinear, and cubic convolution resampling.

Outcome:
Ensures uniform pixel sizes across images, useful for multi-temporal analysis and data fusion.

Data Normalization

Purpose:
Ensures uniformity in pixel values across images taken at different times or by different sensors, facilitating comparison.

Techniques:
Normalization methods include relative radiometric normalization, histogram matching, and transforming data to reflectance values.

Outcome:
Produces consistent datasets, ideal for change detection and multi-temporal analysis.

Philippine Space Agency

Advanced Feature Extraction Techniques

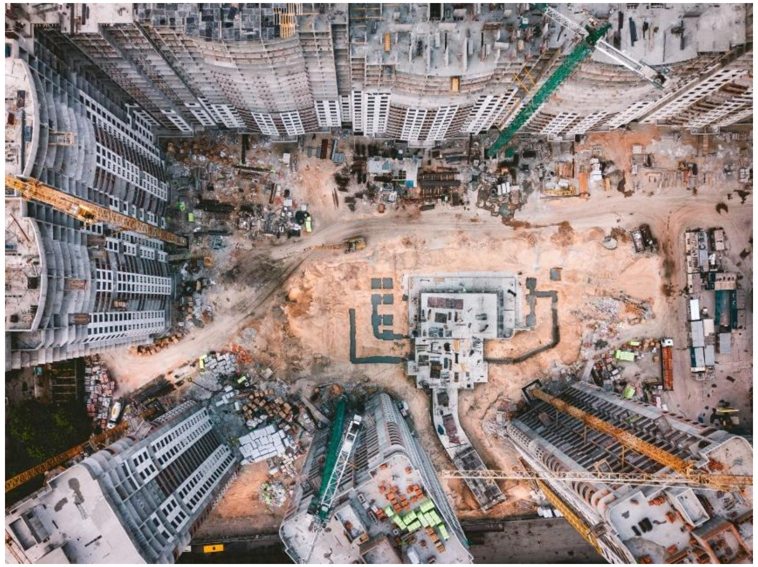
1. Object-Based Image Analysis (OBIA)
2. Machine Learning Classification
3. Deep Learning and Convolutional Neural Networks (CNNs)
4. Spectral Unmixing
5. Change Detection Analysis
6. Texture Analysis
7. Data Fusion Techniques

Philippine Space Agency

مركز محمد بن راشد للفضاء

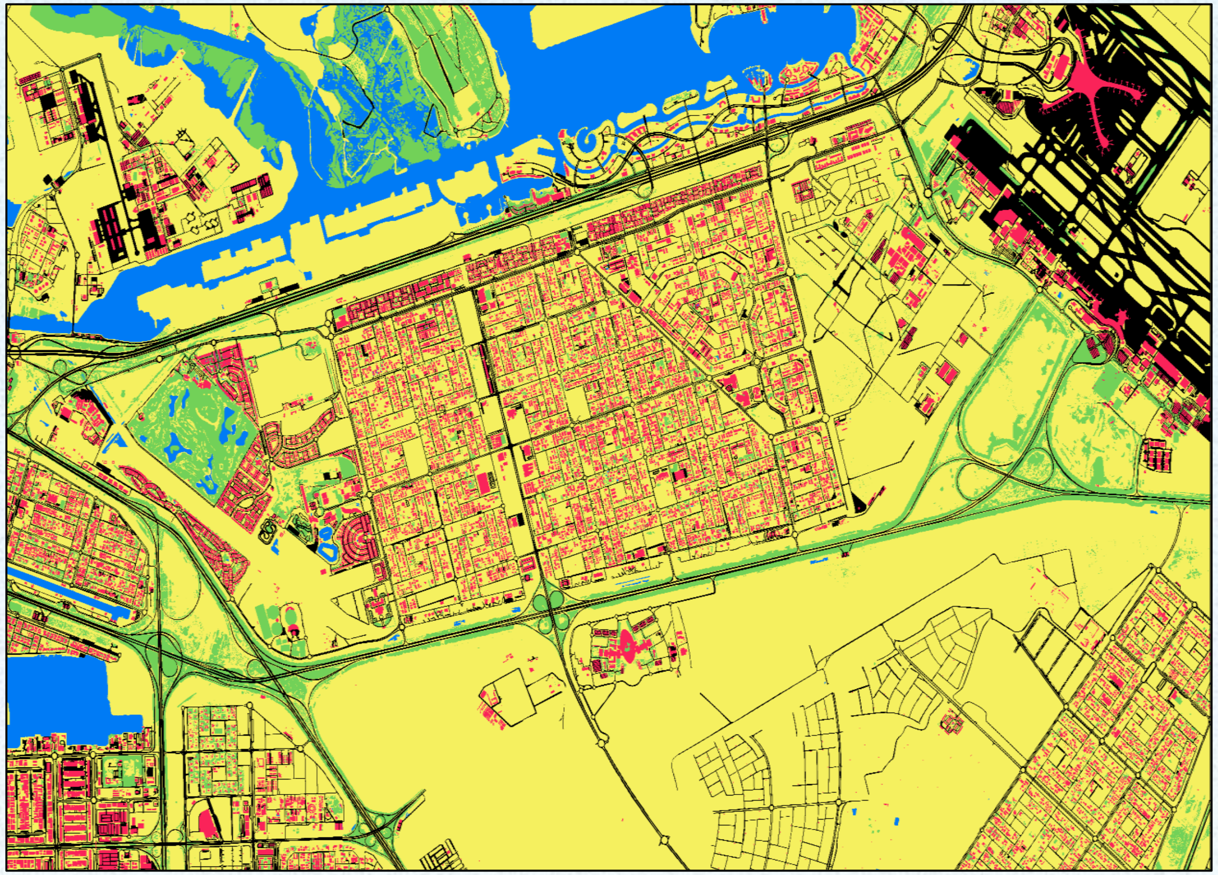
MOHAMMED BIN RASHID SPACE CENTRE

Urban Planning & Development

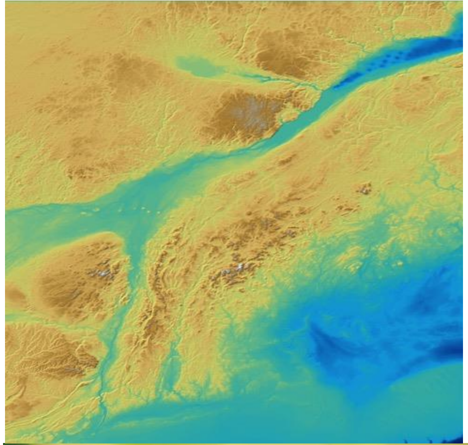


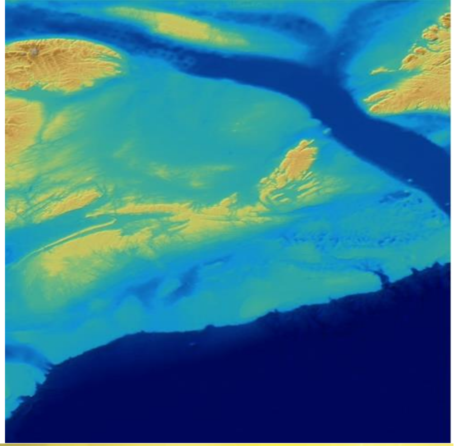
MBRSC Products: Use Cases

Land Use/ Land Cover Mapping



Philippine Space Agency



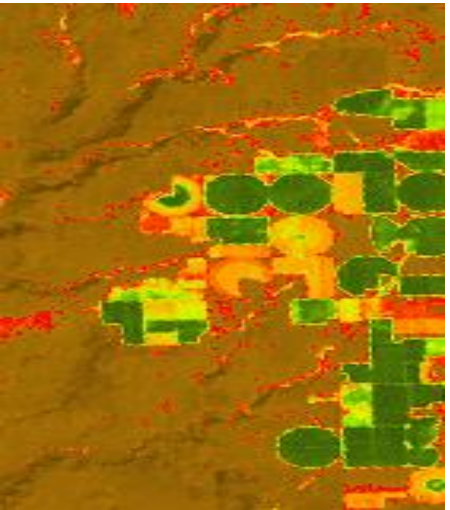


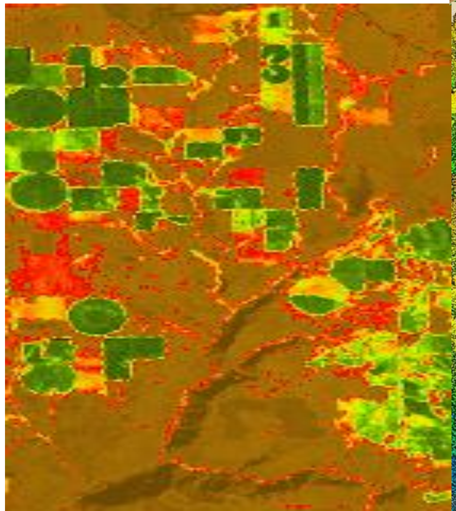
مــــركز محمد بن راشد
للــــــــفــــضــــاء
MOHAMMED BIN RASHID SPACE CENTRE

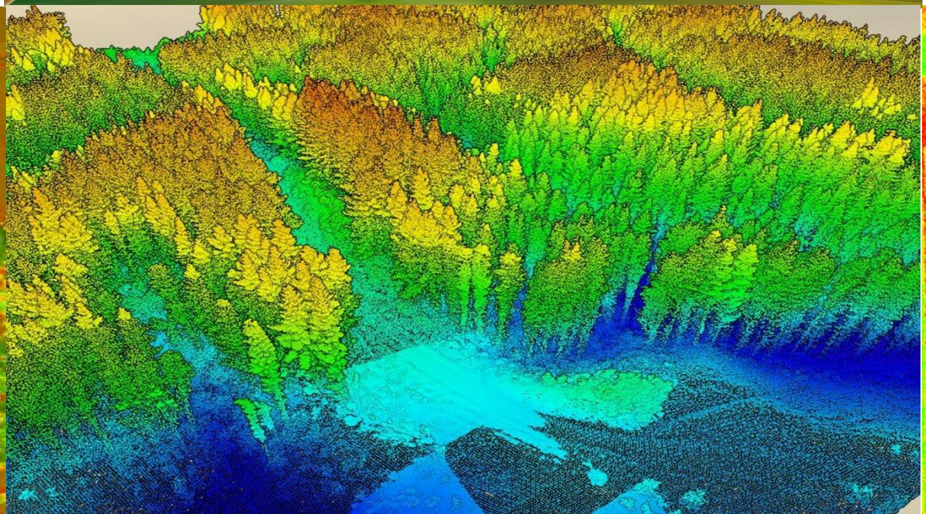
ArcGIS
ESRI

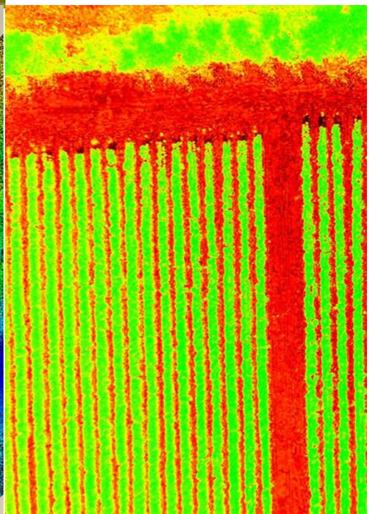
Environmental Studies

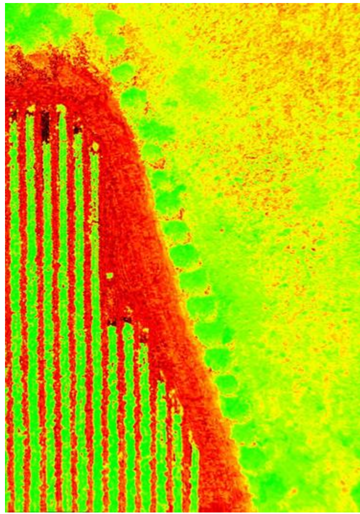
eCognition







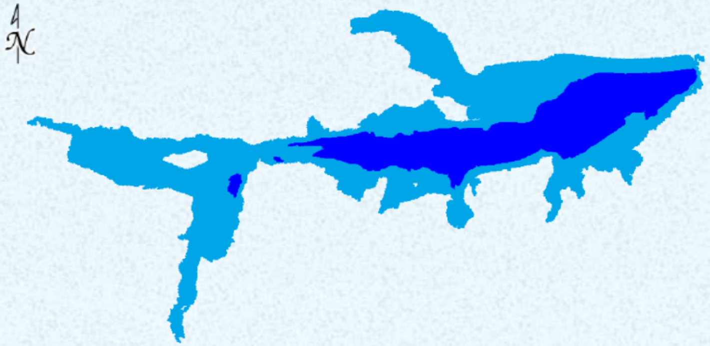




MBRSC Products: Use Cases

Estimate Water Level in Dams: Numerical Analysis

May 2015 – May 2016



May 2016 – Sep 2016

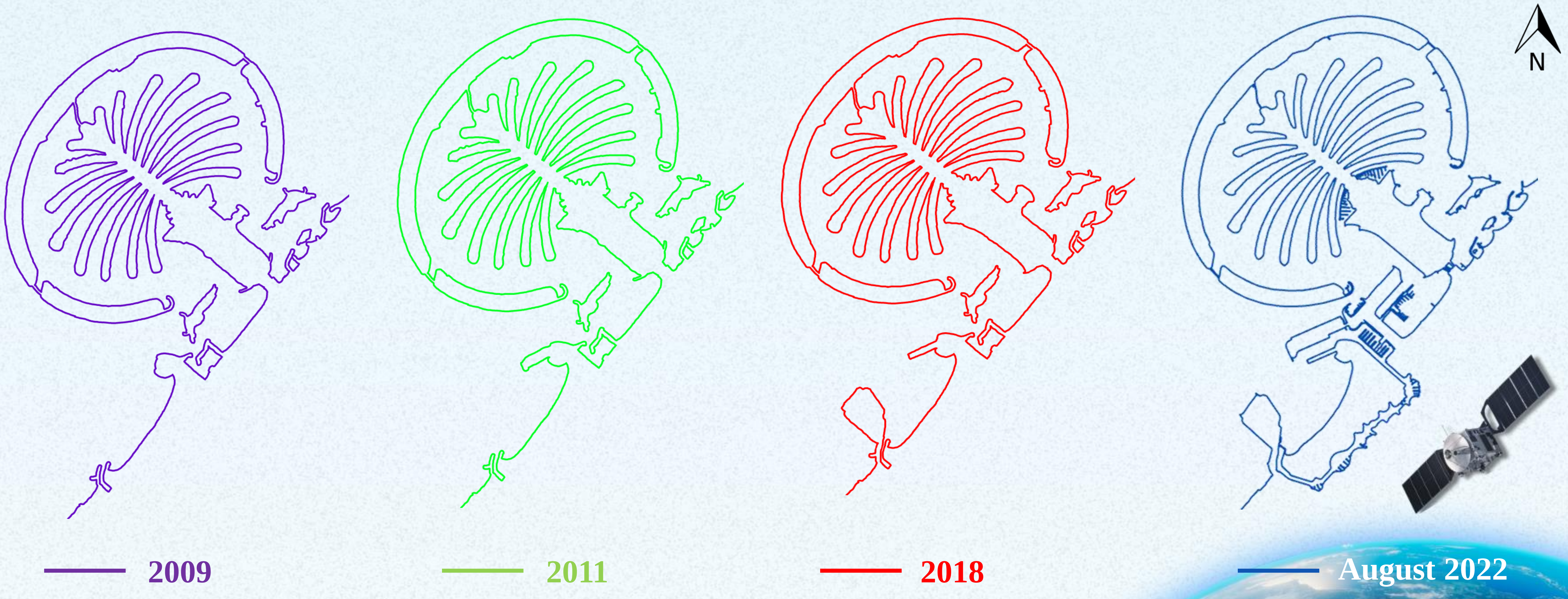
Sep 2016 – Nov 2016

Nov 2016 – Jan 2017

Philippine Space Agency

MBRSC Products: Use Cases

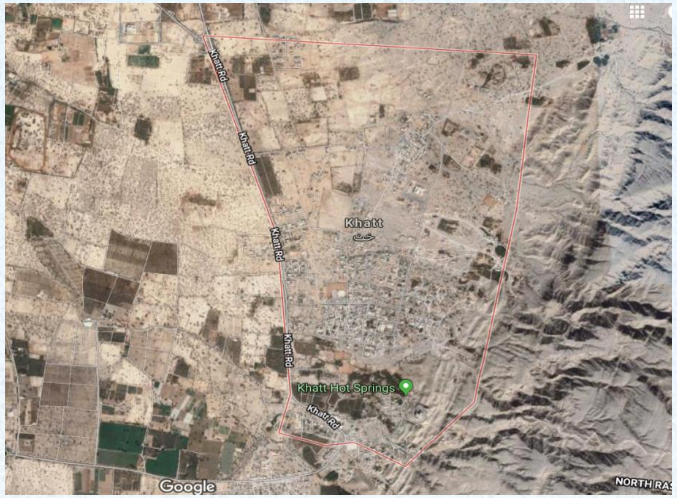
Coastline Monitoring – Dubai shoreline: Case Study



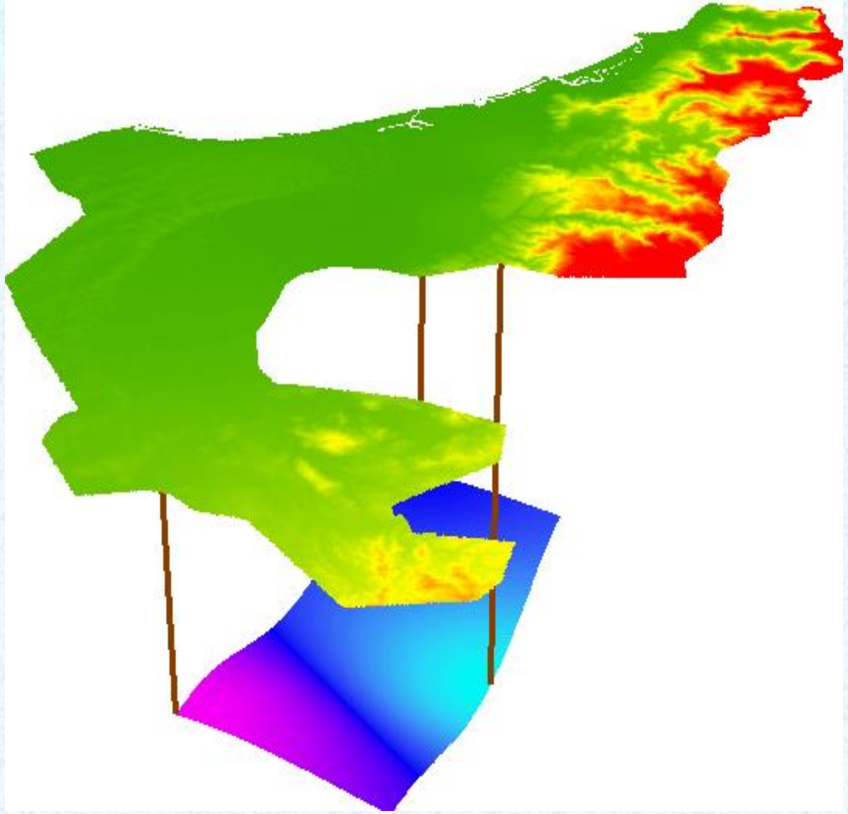
MBRSC Products: Use Cases

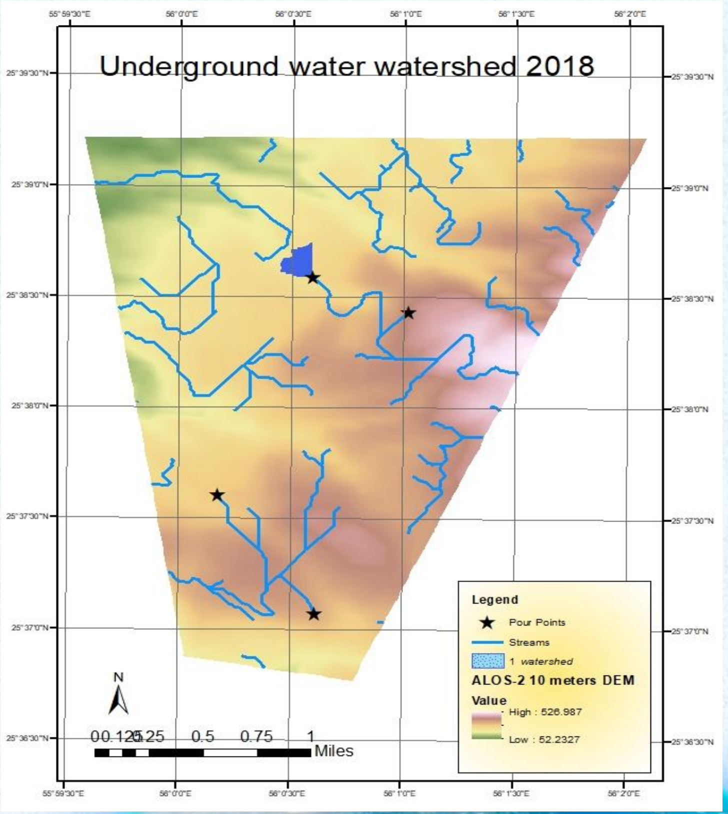
Underground Water Detection using Data Fusion

Study area



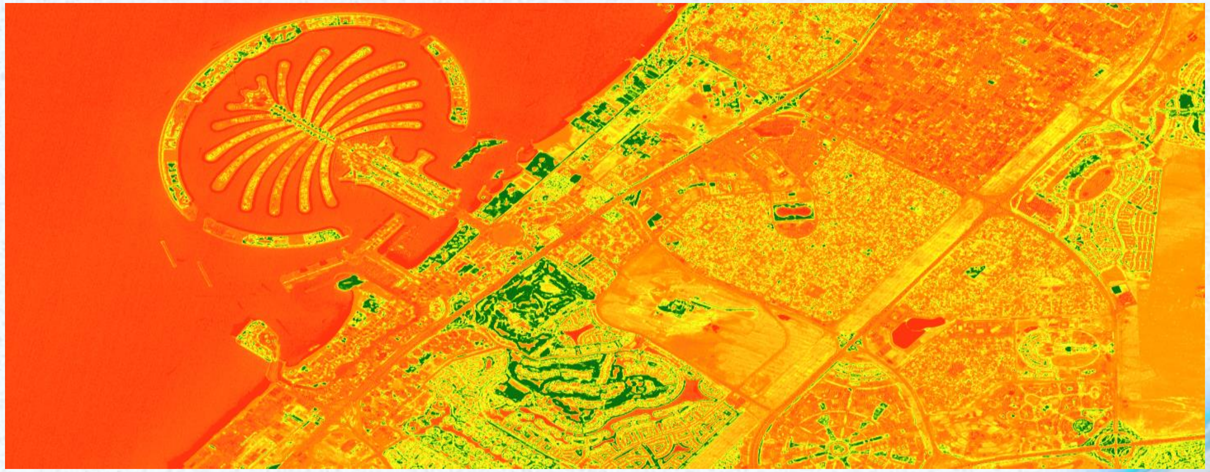
Khatt (RAS AL KHAIMAH, UAE)





MBRSC Products: Use Cases

Vegetation Health Monitoring



MBRSC Products: Use Cases

Palm Trees Detection

Philippine Space Agency



مـــركز محمد بن راشد
للـــــفضـــــاء
MOHAMMED BIN RASHID SPACE CENTRE

Disaster Management

INTERNATIONAL CHARTER SPACE & MAJOR DISASTERS
CHARTE INTERNATIONALE ESPACE ET CATASTROPHES MAJEURES

SENTINEL ASIA
Sentinel Asia




DETECTED FLOOD WATER IN NORTH CENTRAL COAST REGION OF

VIETNAM

As Observed by Sentinel-1 image on 28 October 2024

388 KM^2

OBSERVED FLOOD

0 4 8 16 24 32 km Scale 1:600,000

Coordinate System: GCS WGS 84
Unit: Degree Minutes Seconds

Acquisition Date: 28 October 2024

Description

This map shows flooded area and standing water in North Central Coast Region Provinces on 28th October 2024 after the heavy rainfall. Flood water detected in Quang Tri, Thua Thien Hue, Da Nang city and Quang Nam Provinces in Vietnam.

5
NUMBER OF DEATHS

318
AFFECTED HOUSEHOLDS

143,424
AFFECTED PEOPLE

Source: Reliefweb. 31 October 2024

Legend

- Observed flood water
- Province
- Roads

Credits

Image Courtesy Sentinel Hub

Data Source

Satellite Image:

Pre-Image : Sentinel 1, 22 September 2024
Post-Image : Sentinel 1, 28 October 2024

District Boundary & Roads: opendevelopmentmekong.net

Disclaimer

"Accuracy of this product is not validated by ground truth data"

مــــركز محمد بن راشد للـــــفضـــاء
MOHAMMED BIN RASHID SPACE CENTRE

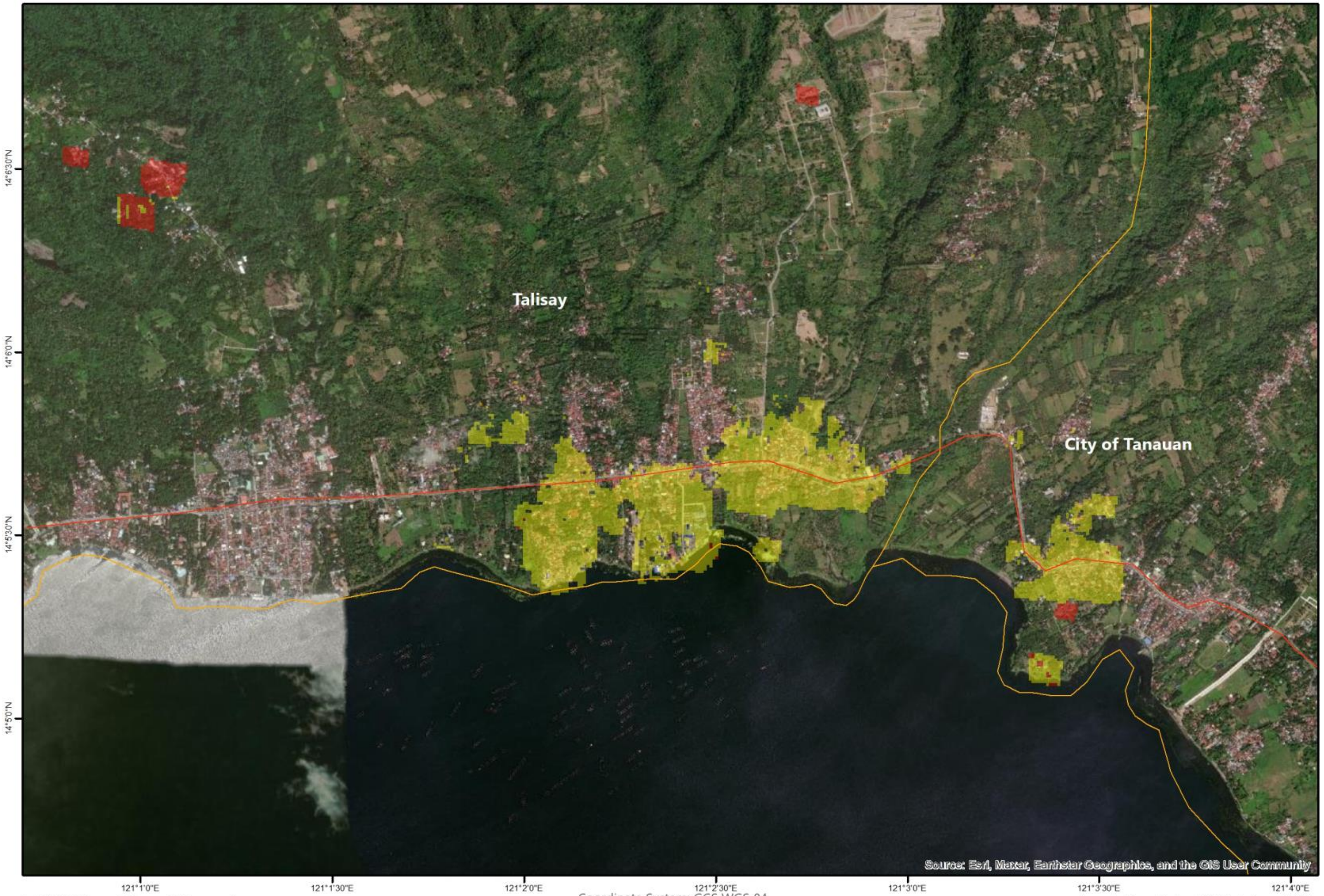
sentinelhub

Sentinel Asia

DETECTED LANDSLIDE AND MUDSLIDE IN BATANGAS PROVINCE

PHILIPPINES

As Observed by Sentinel-1 image on 26 October 2024



0 0.125 0.25 0.5 0.75 1 km

Scale 1:20,000

Coordinate System: GCS WGS 84
Unit: Degree Minutes Seconds

Acquisition Date: 26 October 2024

مــــركز محمـد بن راشـد
للـــــــفضـــاء
MOHAMMED BIN RASHID SPACE CENTRE

sentinelhub

Sentinel Asia

Description

This map shows Landslide and Mudslide area detected by Satellite on 26th October 2024 after Flood, Landslide and Mudslide in Talisay and City of Tanauan Municipalities in Batangas Province in Philippines.

152
NUMBER OF DEATHS

40,000
AFFECTED PEOPLE

Source: npr; 28 Oct: 2024

Legend

Significant Changes/Reflectivity Increment

Significant Changes/Reflectivity Decrement

Province

Roads

Credits

Image Courtesy Sentinel Hub

Data Source

Satellite Image:

Pre-Image : Sentinel 1, 03 August 2024

Post-Image : Sentinel 1, 26 October 2024

District Boundary & Roads: opendevelopmentmekong.net

Disclaimer

"Accuracy of this product is not validated by ground truth data"

DETECTED FLOOD WATER ABU DHABI MUNICIPALITY SELECTED AREA

UAE-ABU DHABI

8.1 KM^2

OBSERVED FLOOD

As Observed by Sentinel-1 image on 10 March 2024

N

0 1 2 4 6 8 km

Scale 1:150,000

Coordinate System: GCS WGS 84
Unit: Degree Minutes Seconds

Acquisition Date: 10 March 2024

Description

This map shows flooded area and standing r
water in the Abu Dhabi Municipality selected
area on 10 March 2024 after the heavy rainfall l

Legend

Observed flood water

Selected Area

Credits

Image Courtesy Sentinel Hub

Data Source

Satellite Image:

Pre-Image : Sentinel 1, 31 August 2023
Post-Image: Sentinel 1, 10 March 2024

District Boundary & Roads: opendevelopmentmekong.net

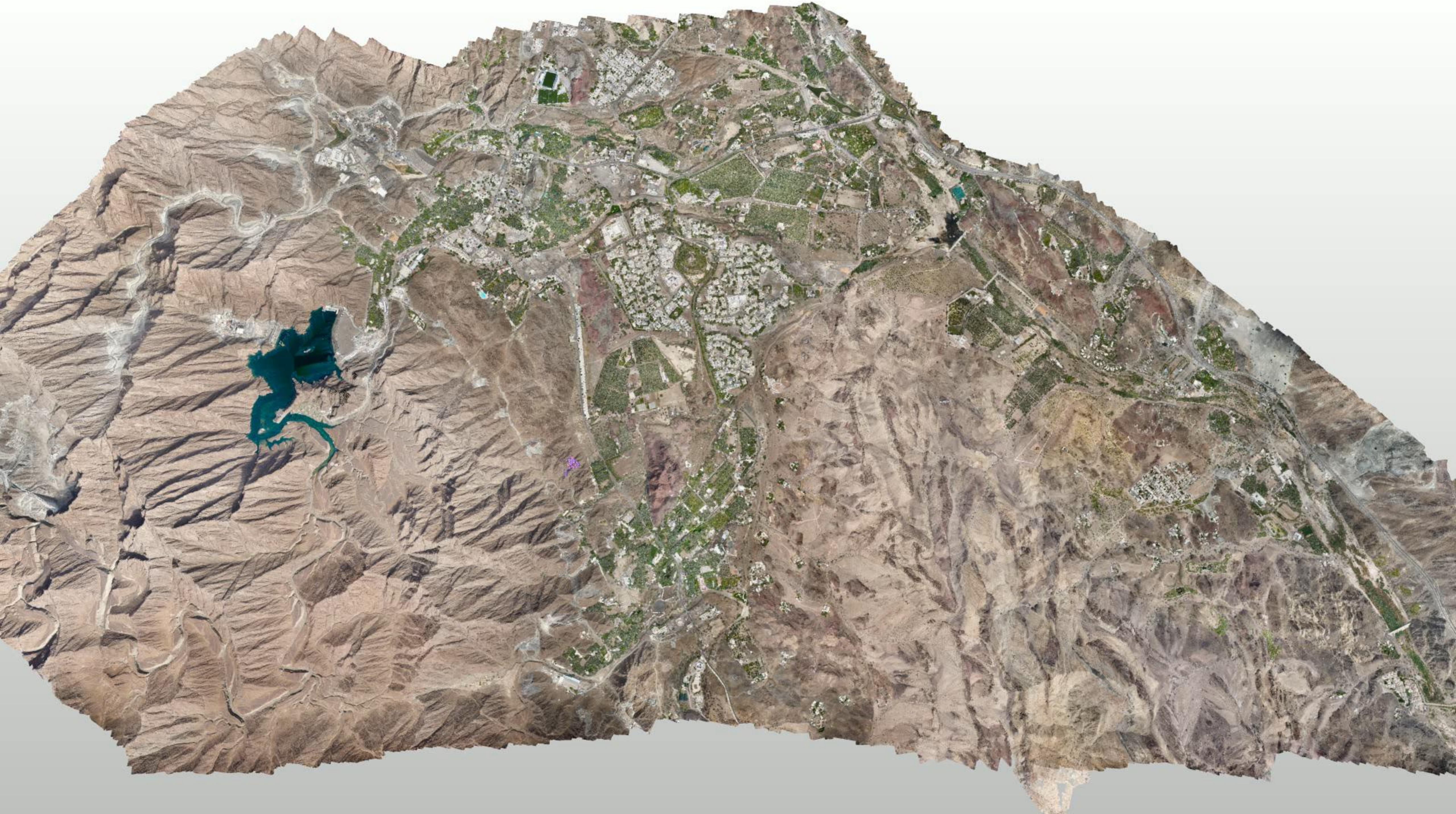
Disclaimer

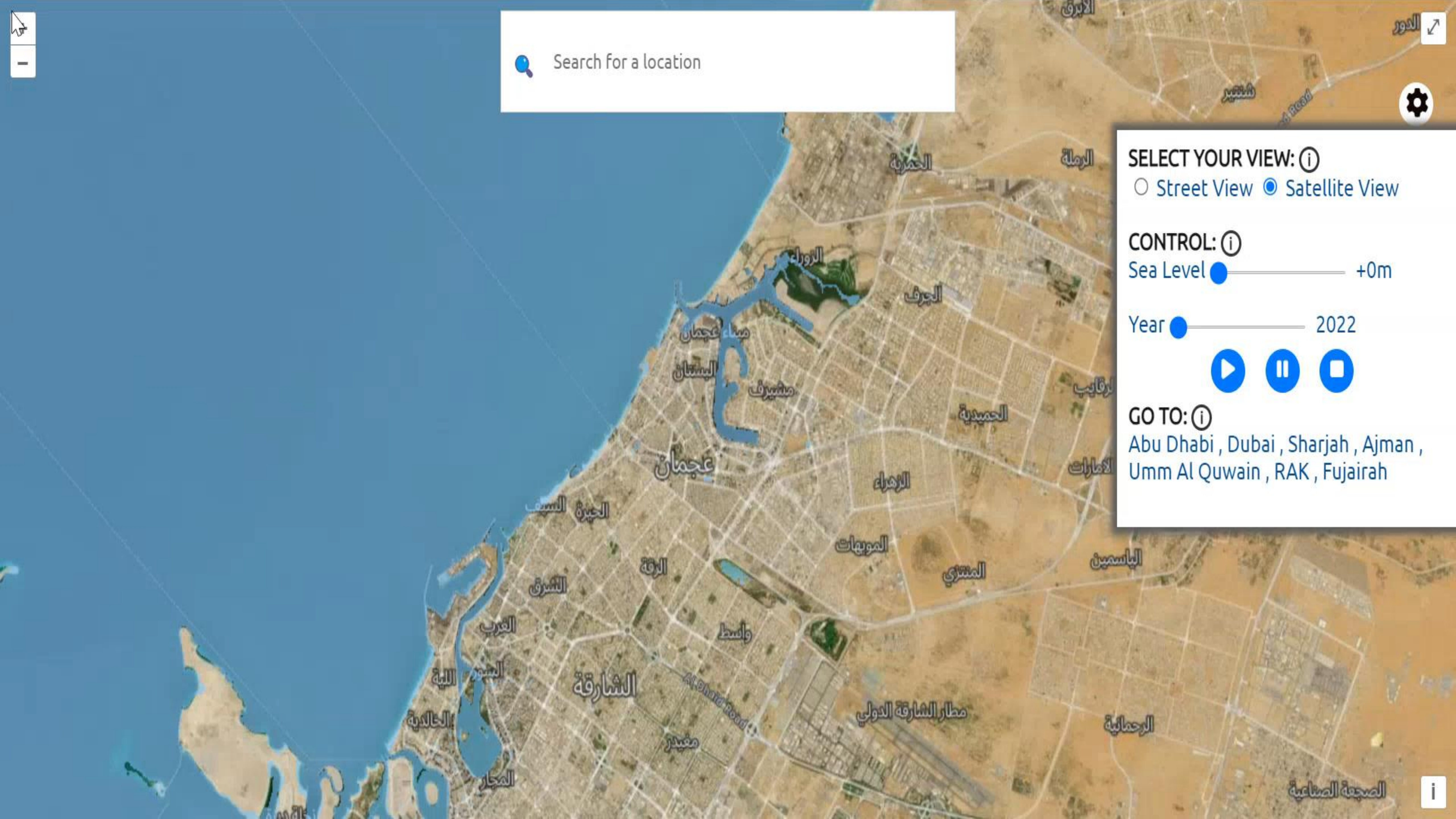
"Accuracy of this product is not validated by ground truth data"

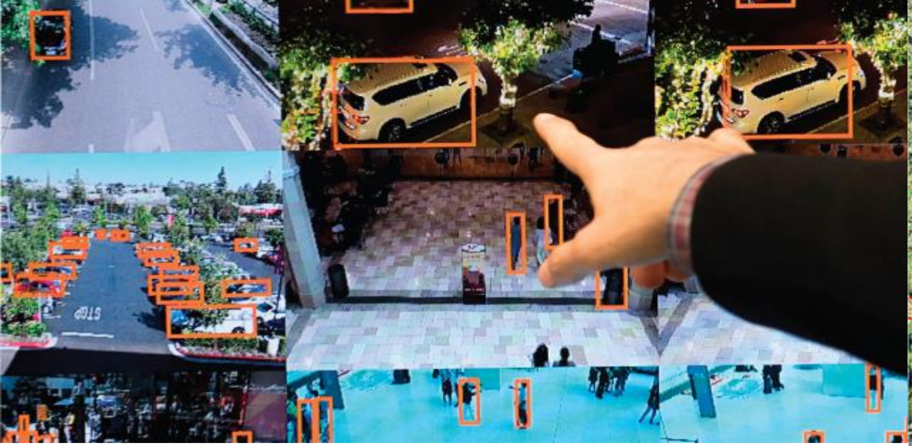
مـــــركز محمد بن راشد للـــــفضاء
MOHAMMED BIN RASHID SPACE CENTRE

sentinelhub

SENTINEL ASIA Sentinel Asia




Search for a location
SELECT YOUR VIEW:
Street View
Satellite View
CONTROL:
Sea Level
+0m
Year
2022
GO TO:
Abu Dhabi , Dubai , Sharjah , Ajman ,
Umm Al Quwain , RAK , Fujairah
عجمان
الشارقة
مطار الشارقة الدولي
الزهراء
الحميدية
الجرف
الرحمانية
الياسمين
المويهات
البستان
مشيرف
الصجعة الصناعية
Al Dhaid Road

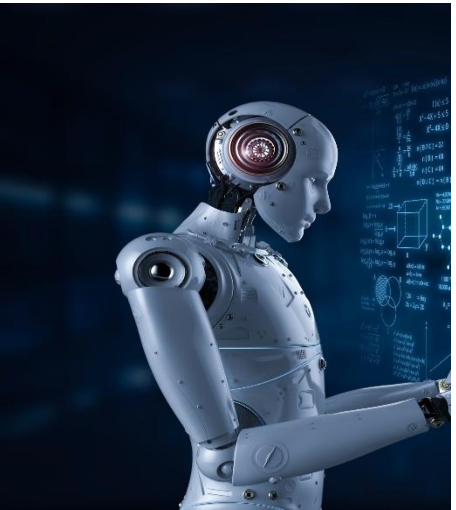


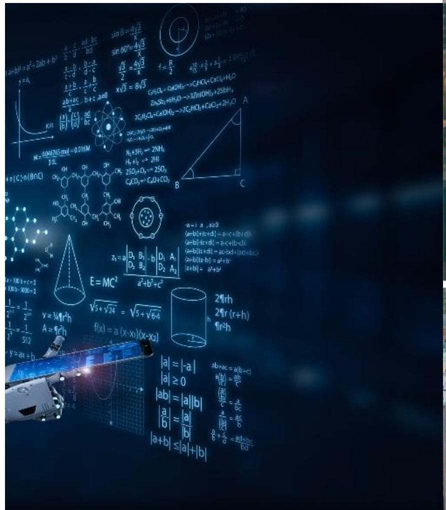
مركز محمد بن راشد للفضاء

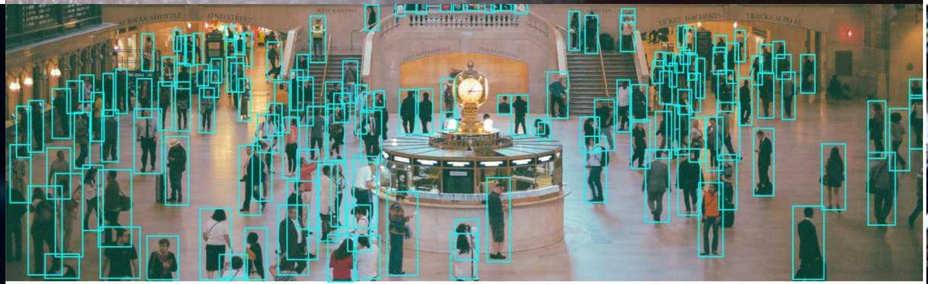
MOHAMMED BIN RASHID SPACE CENTRE

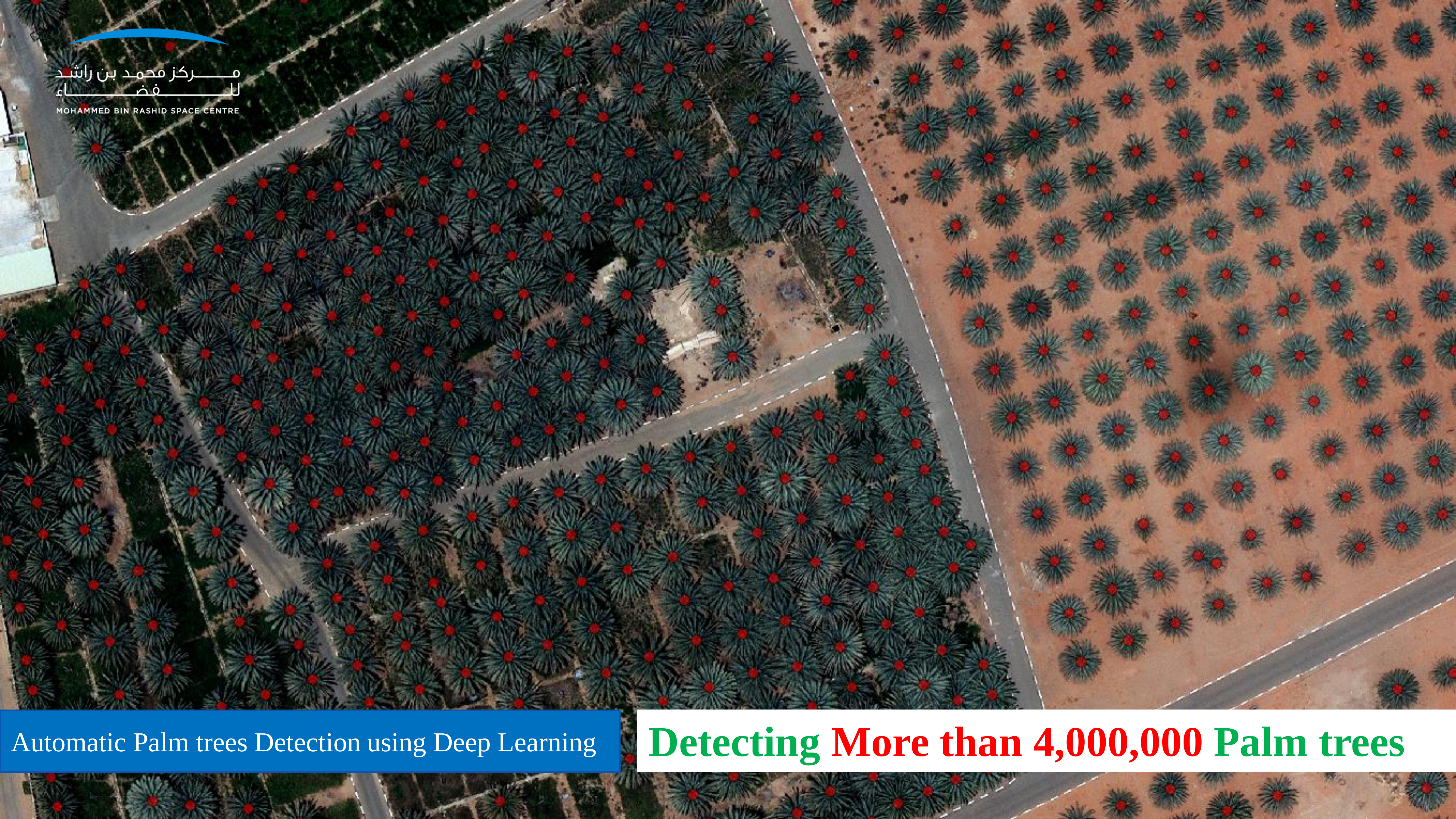
Artificial Intelligence

IBM







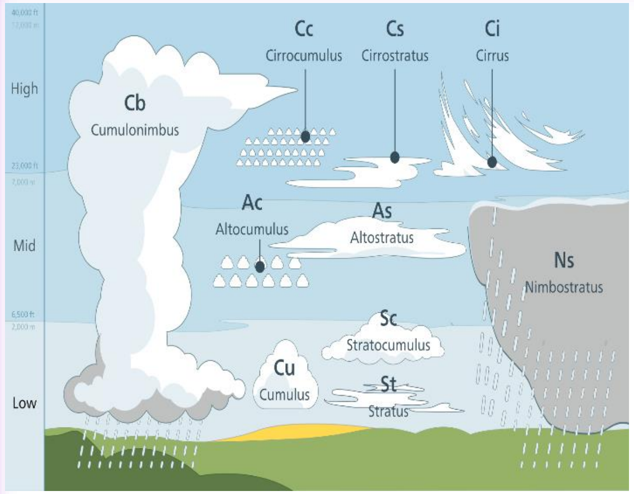

مركز محمد بن راشد للفضاء
MOHAMMED BIN RASHID SPACE CENTRE
Automatic Palm trees Detection using Deep Learning
Detecting More than 4,000,000 Palm trees

Automatic Ships Detection using Deep Learning

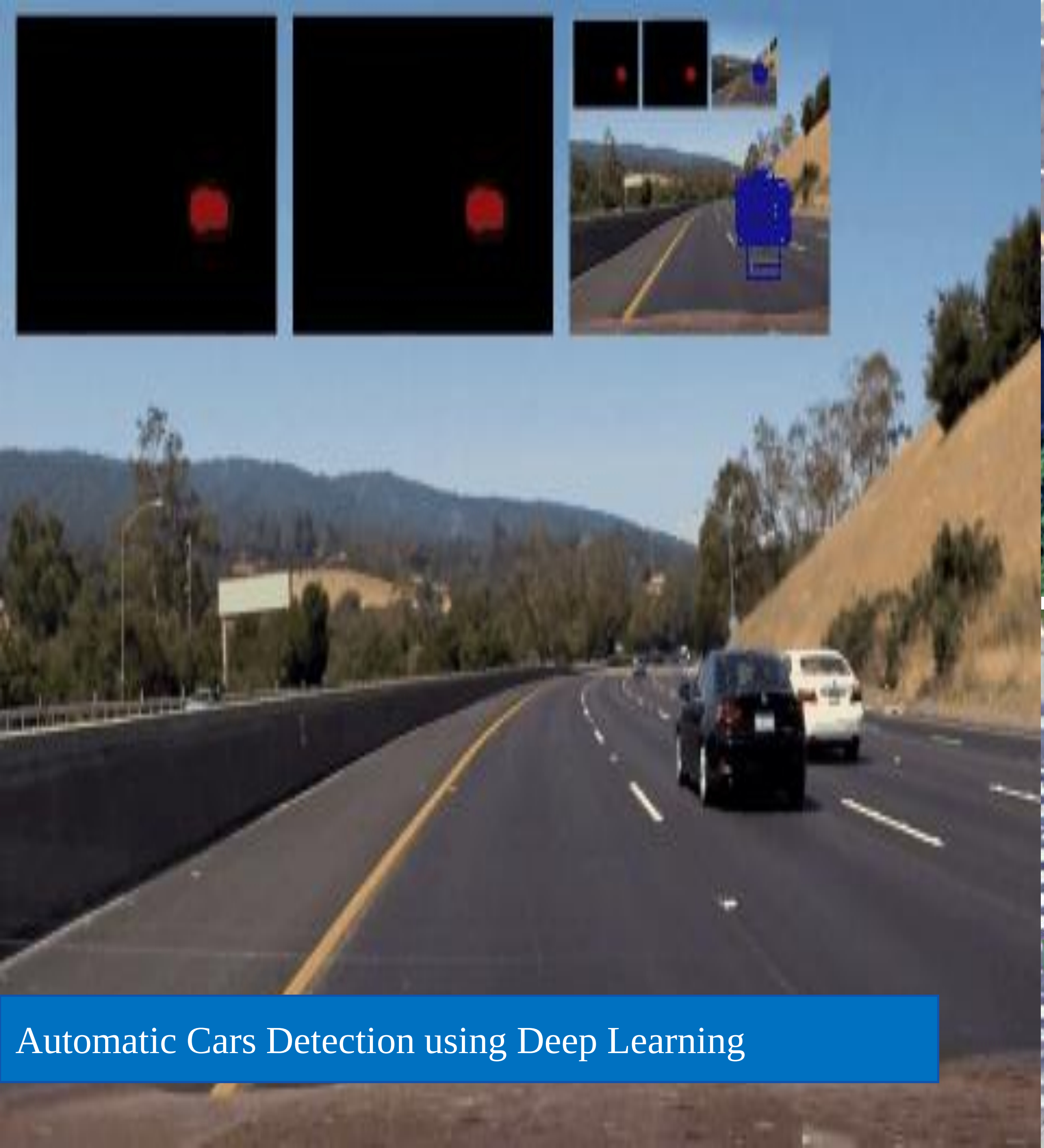
مركز محمد بن راشد للفضاء
MOHAMMED BIN RASHID SPACE CENTRE

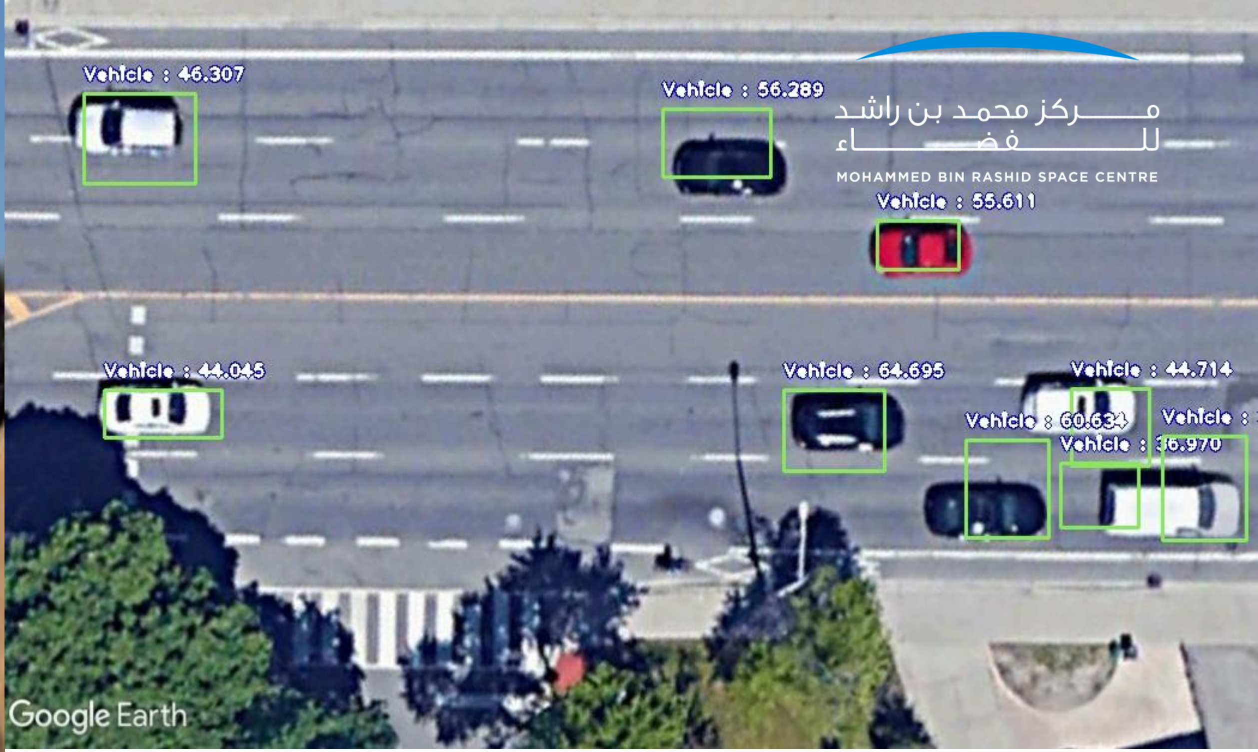
Automatic Airplanes Detection using Deep Learning

Automatic Electric Towers Detection using Deep Learning



Automatic Cloud Detection using Deep Learning





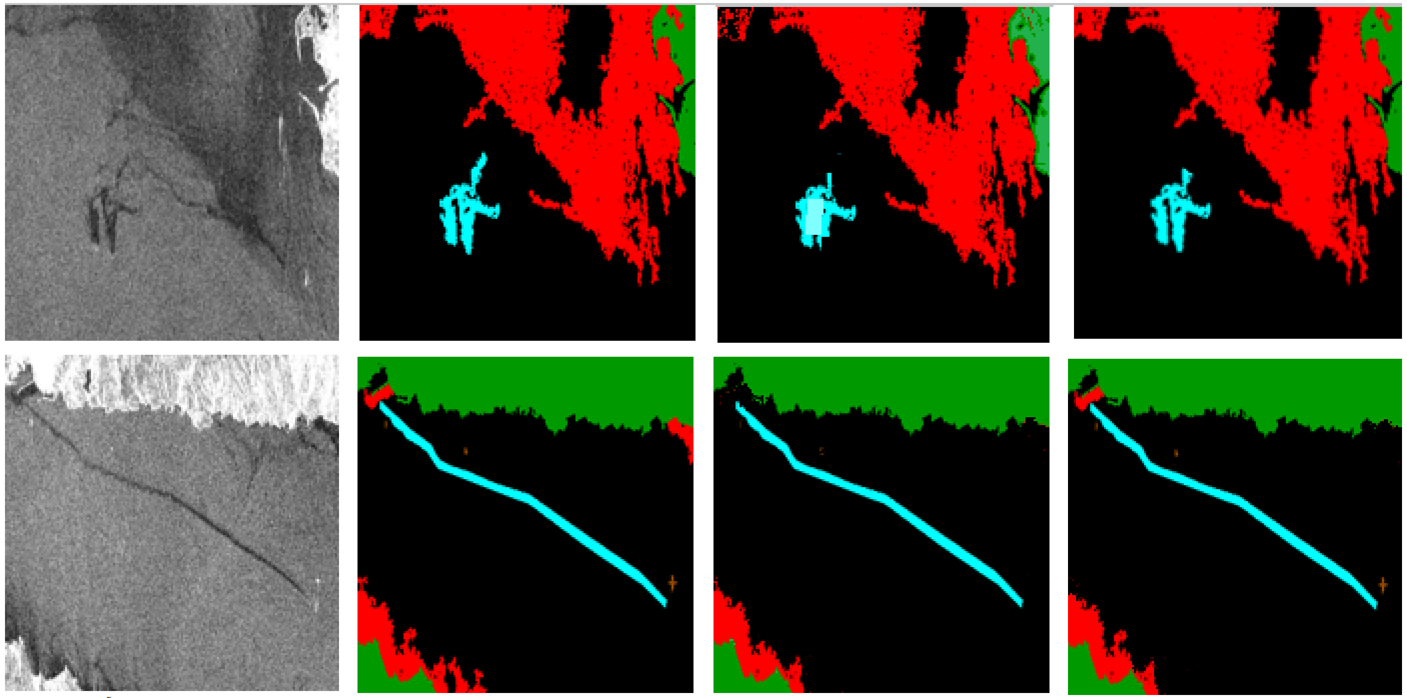
Automatic Cars Detection using Deep Learning

مركز محمد بن راشد للفضاء
MOHAMMED BIN RASHID SPACE CENTRE

Automatic Change Detection using Deep Learning

مركز محمد بن راشد للفضاء
MOHAMMED BIN RASHID SPACE CENTRE

Automatic Oil Spill Detection using Deep Learning



a. SAR image b. Ground Truth c. UNET d. UNET+ACWE

Thank you for your attention…

Any Questions?