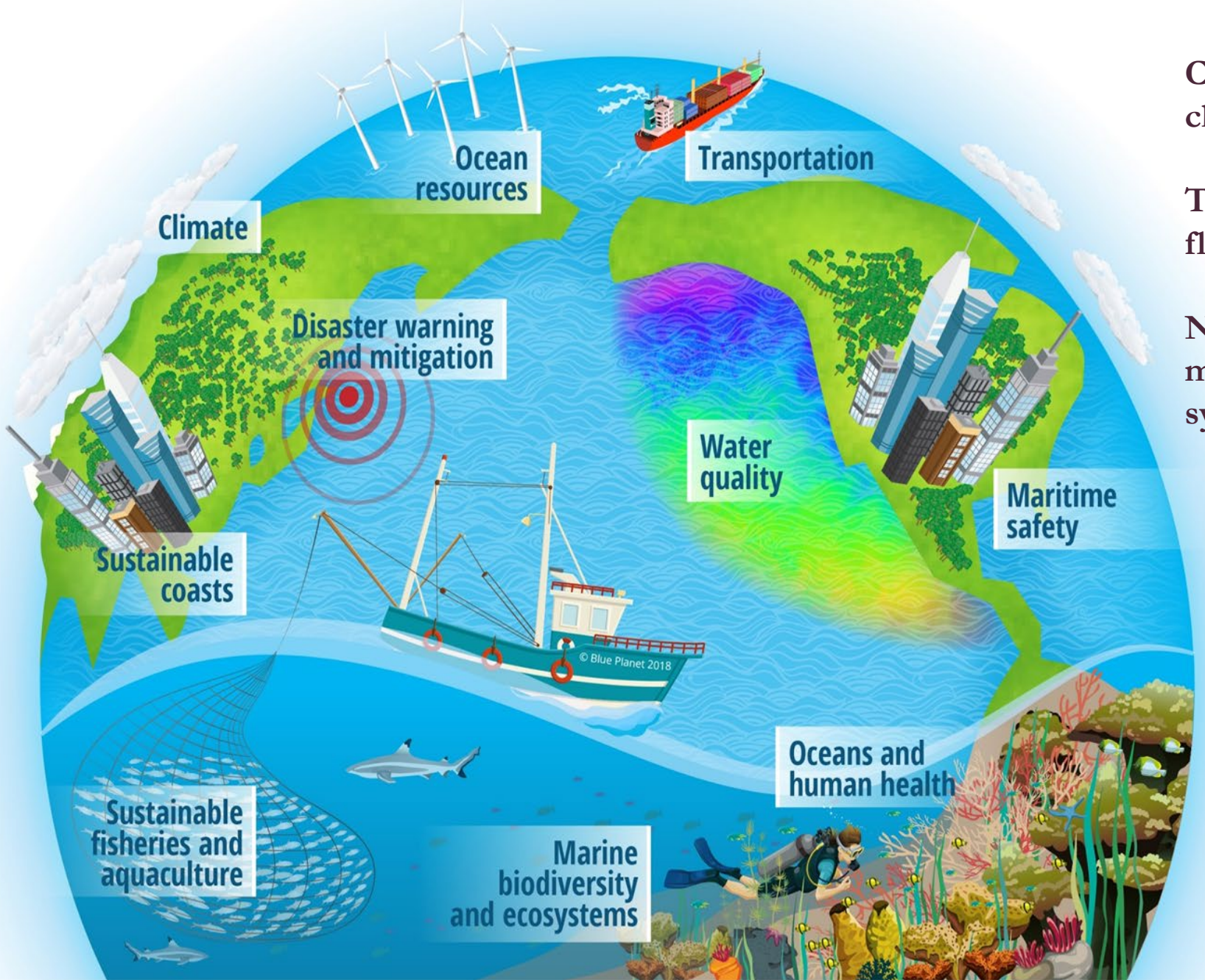
Harnessing Next-Generation Space Technologies for Coastal Resilience and Emergency Management

Dr Rajasekhar Meka

Linking Ocean and Coastal Information with Society



Coastal regions: frontline of climate change

Threats: sea-level rise, storms, flooding, erosion

Need for robust, real-time, scalable monitoring and early warning systems

Harnessing Next-Generation Space Technologies for Coastal Resilience and Emergency Management

Coastal zones, vital for economy, ecosystems, and communities, face rising climate and pollution risks.

Space technologies support:

- Real-time monitoring of floods, storms, erosion & oil spills
- Advanced mapping & modelling for coastal planning & blue carbon
- Rapid oil spill detection & response
- Reliable disaster communications in remote areas
- Data-driven, climate-resilient planning

AI & digital twins boost prediction, emergency response, and pollution control—offering powerful tools to protect vulnerable coasts and enable sustainable development.

The Challenge — Coastal Disasters and Why Speed Matters

- Over 40% of Earth's population and vital economic hubs are along coasts

- Threats: Sea level rise, extreme storms, flooding, erosion — growing with climate change

- Social, environmental, and economic losses are vast; rapid response is critical

- Traditional EO satellites face key gaps:
  - Data delivery latency: Hours or days from satellite to users
  - Infrequent updates: Revisit times of days to weeks may miss sudden events
  -Single-sensor limitations: Gaps in seeing through clouds (optical), chemical/material data (SAR/hyperspectral)

- The world needs: Fast, multi-sensor, real-time data-to-action capabilities

The Role of **Next-Generation** Space-Based Earth Observation

Shift from traditional monitoring to high-resolution satellites

- Frequent revisit times, AI-driven analytics
- Supports informed decision-making and rapid response

Focus Technologies with Public and Private missions of constellation

- Synthetic Aperture Radar (SAR): All-weather, day-night imaging
- Hyperspectral Imaging: Detailed spectral insights for ecosystems
- Integrated with AI and data fusion for early warning

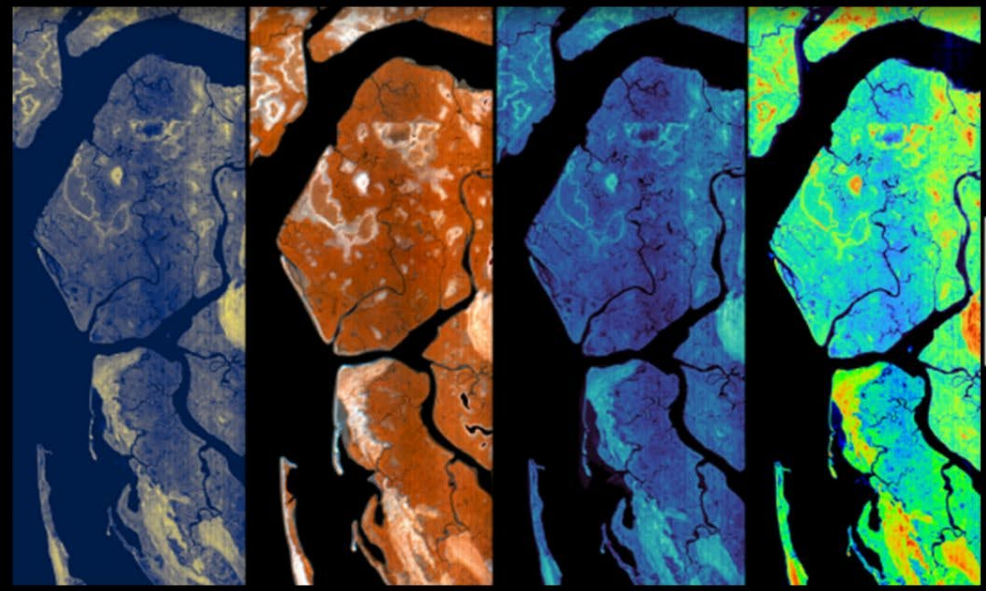
SAR Capabilities

- Flood mapping under clouds
- Shoreline change and erosion monitoring
- Ground deformation (subsidence, tectonics)
- Oil spills and disaster tracking

Hyperspectral Imaging Capabilities

- Water quality: chlorophyll, turbidity, pollution
- Coastal habitats: seagrass, mangroves, coral reefs
- Damage and material assessment

Hyperspectral Eye



pixxel

5m resolution
150+ Spectral Bands

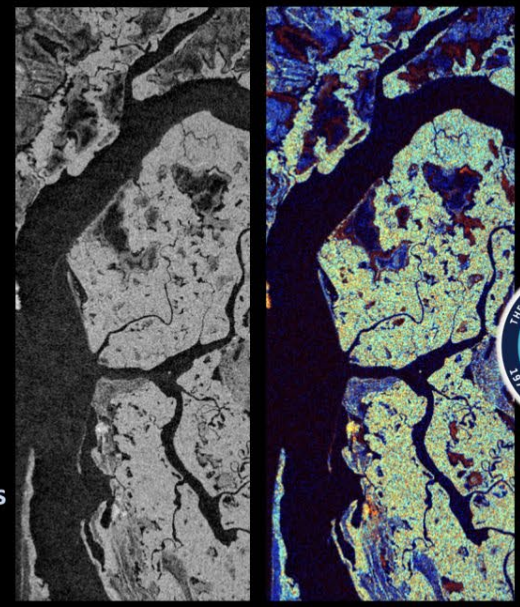
The Real World

Mangrove forests, Ecologic Site at **Saloum Delta National Park**, Senegal.

NASA

15m resolution
8 Spectral Bands

Optical Eye



THE EUROPEAN SPACE AGENCY esa 1975 50 2025

10m resolution
Dual SAR Bands
VV & VH

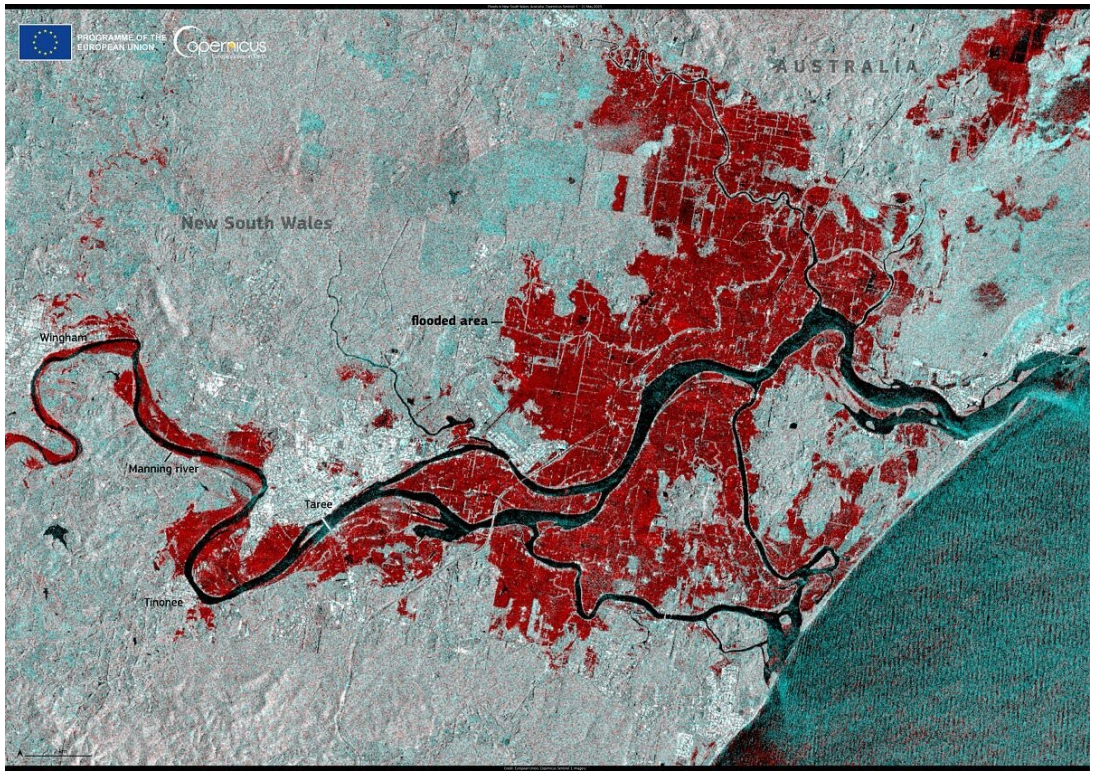
Radar Eye

Extreme Flooding Strikes New South Wales – May 2025

Over three days in May 2025, intense and persistent rainfall led to catastrophic flooding across Smith Town, the Hunter, and Mid North Coast regions of New South Wales — Australia's most populous state.

Meteorologically, the deluge was attributed to a slow-moving coastal low-pressure system, trapped by a blocking high over the Tasman Sea—a setup that funneled tropical moisture inland and resulted in record-breaking rainfall.

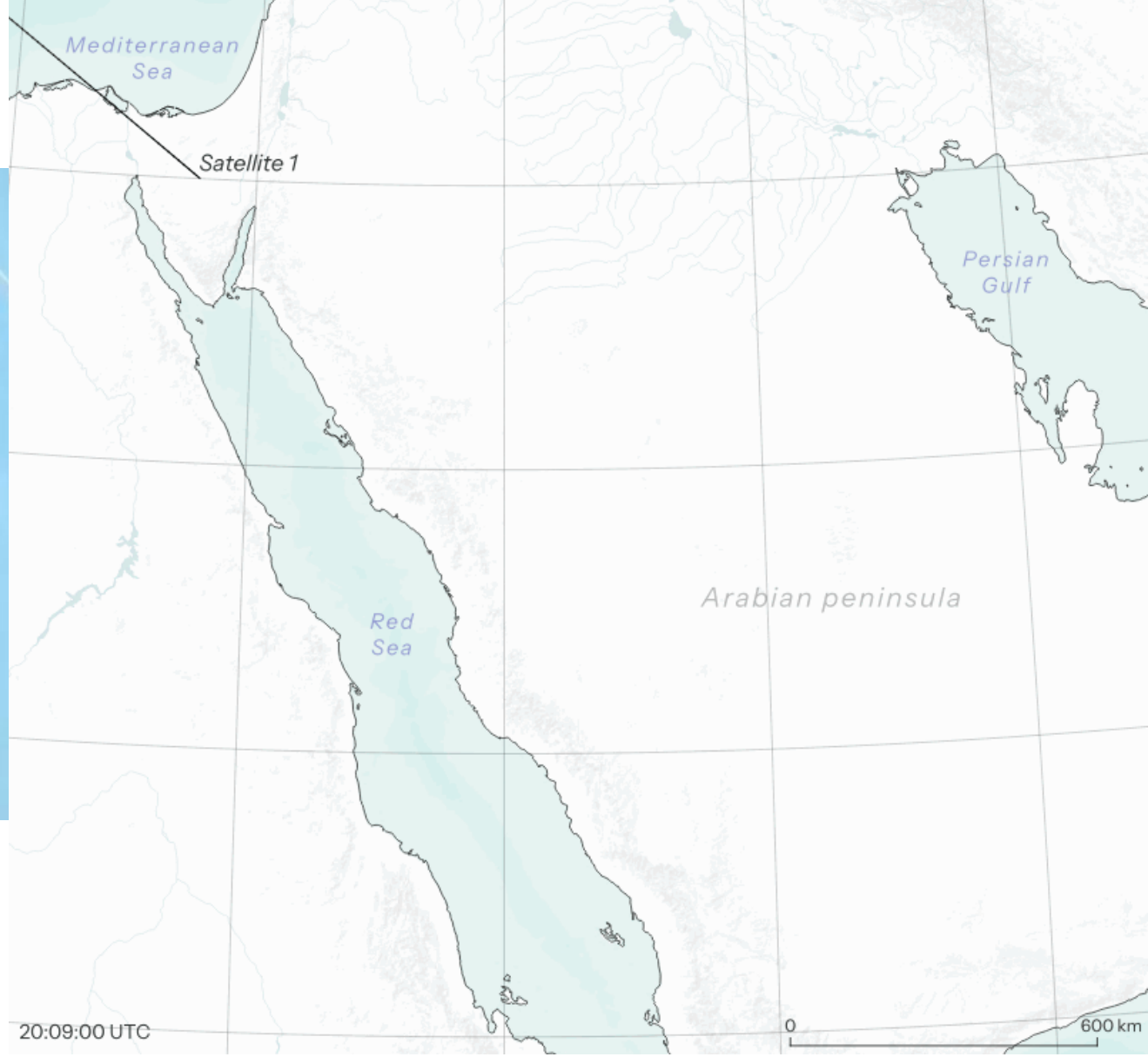
Some of the worst-hit areas including Smith Town, Taree, and Tinonee are clearly shown in this Copernicus Sentinel1 radar image (21 May 2025), compared with pre-flood conditions on 9 May. SAR (Synthetic Aperture Radar) allows us to "see through" clouds and monitor water extent even at night.



Open-access EO data from the CopernicusEU programme is playing a vital role in:

- ✔ Real-time flood mapping
- ✔ Emergency planning & evacuation
- ✔ Post-event damage assessment
- ✔ Supporting evidence-based decisions for recovery


ICEYE
Between Jan - Jul 2025,
ICEYE mapped 9 flood events
totalling 233,870 km² in Australia.


Mediterranean Sea
Satellite 1
Persian Gulf
Red Sea
Arabian peninsula
20:09:00 UTC
0
600 km

Oil Spill Incidents

1

Tanker Accidents

The Strait has witnessed several significant oil spill incidents over the years, often resulting from tanker accidents or operational failures.

2

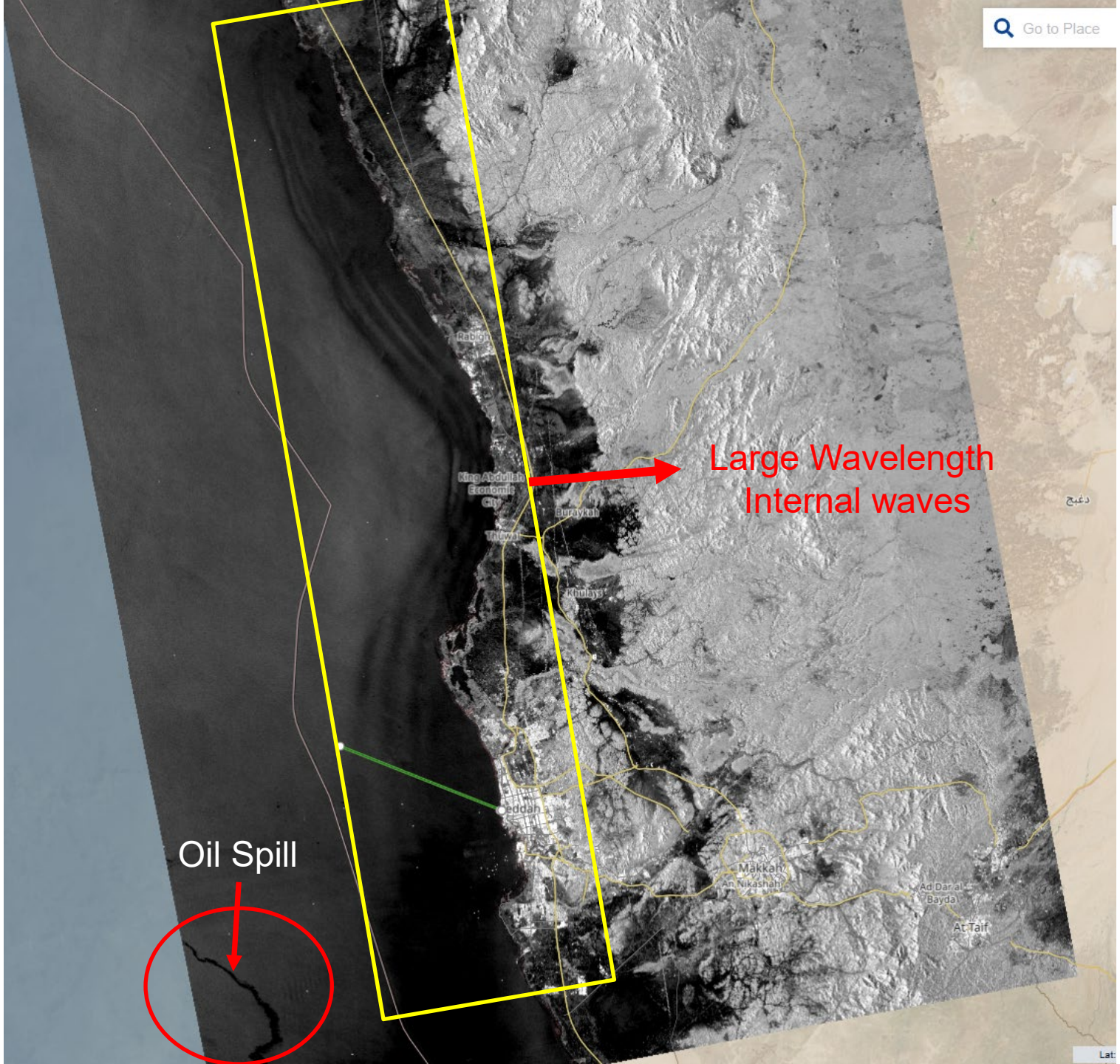
Long-Lasting Impacts

Vj gug"ur kmu"j cxg"hqpi /ncuvkpi "gpxktqpo gpvcnko r cewu."cpf "engcpwr " ghhqtwu"ctg"htgs wgpvn{"unqy "cpf "kpuwhhkekgpv"fwg"vq"vj g"eqo r ngzkv{" qh"vj g"kpekf gpvu0

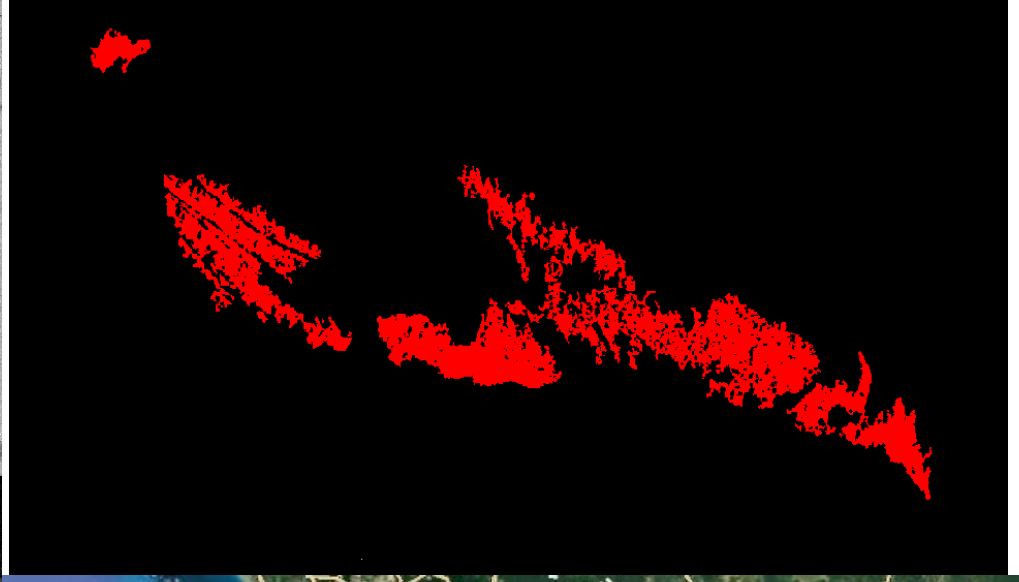
□

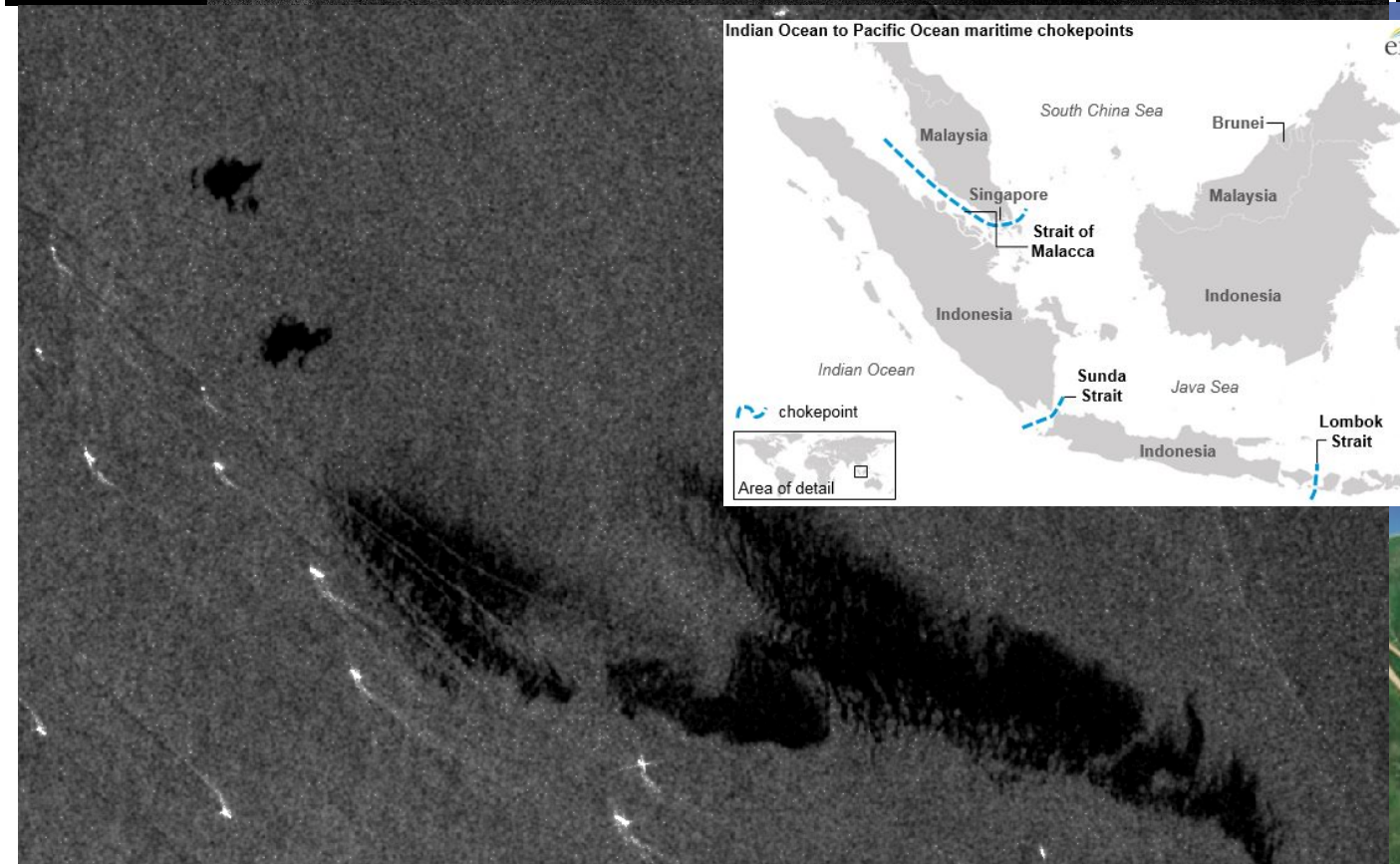
SAR Technology

In recent months, notably in November and December 2024, prominent oil spills have been detected using Synthetic Aperture Radar (SAR) imagery.

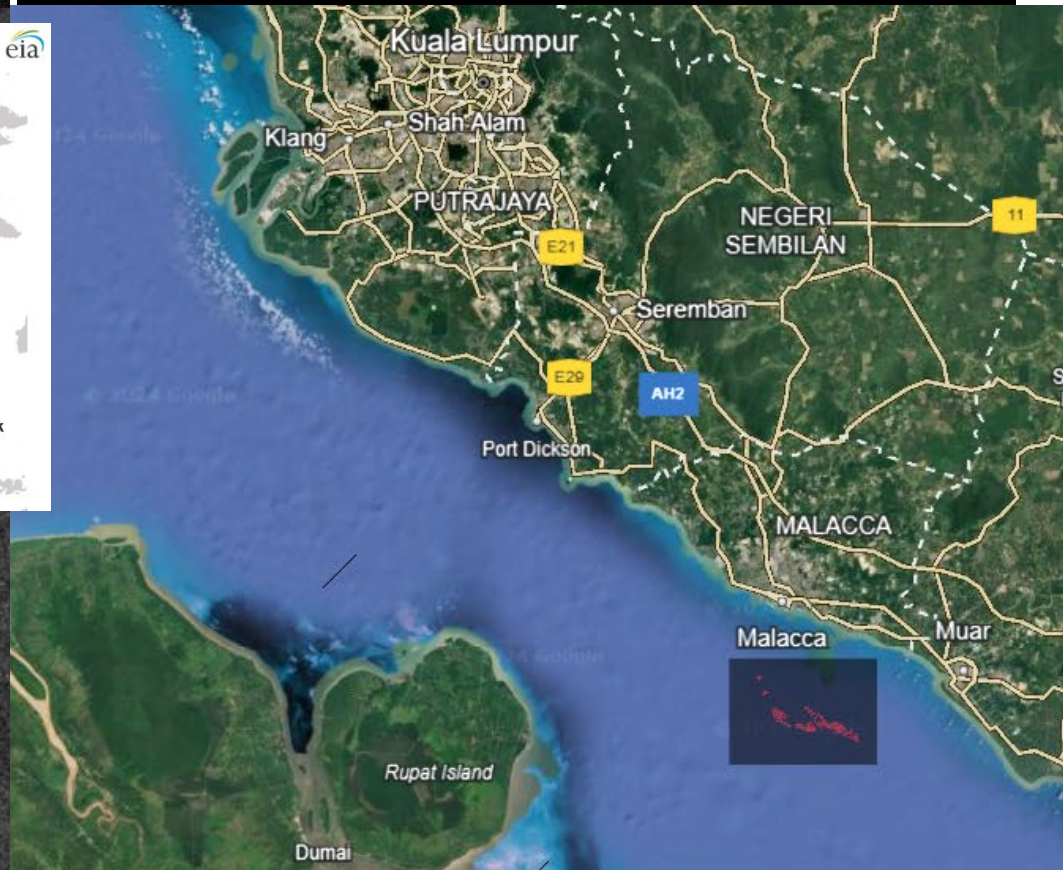

Go to Place
Large Wavelength
Internal waves
Oil Spill
Rabigh
King Abdullah
Economic
City
Thuwal
Buraykah
Khulays
eddah
Makkah
An Nikashah
Ad Dariaal
Bayda
At Taif
دغيج

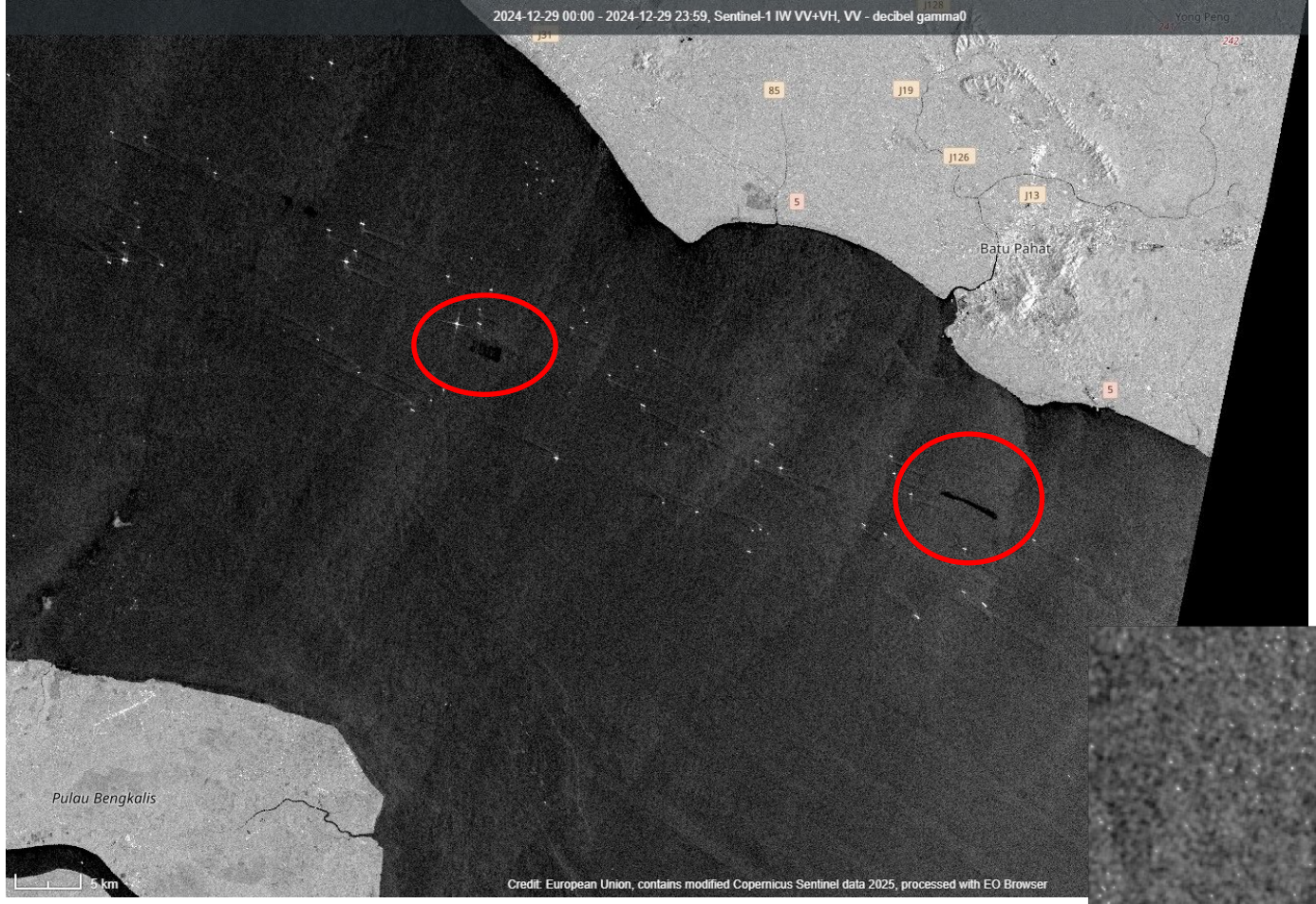

Malacca City
Merlimau
Pekan Rawang
Muar
Bakri
5 km
Credit: European Union, contains modified Copernicus Sentinel data 2025, processed with EO Browser

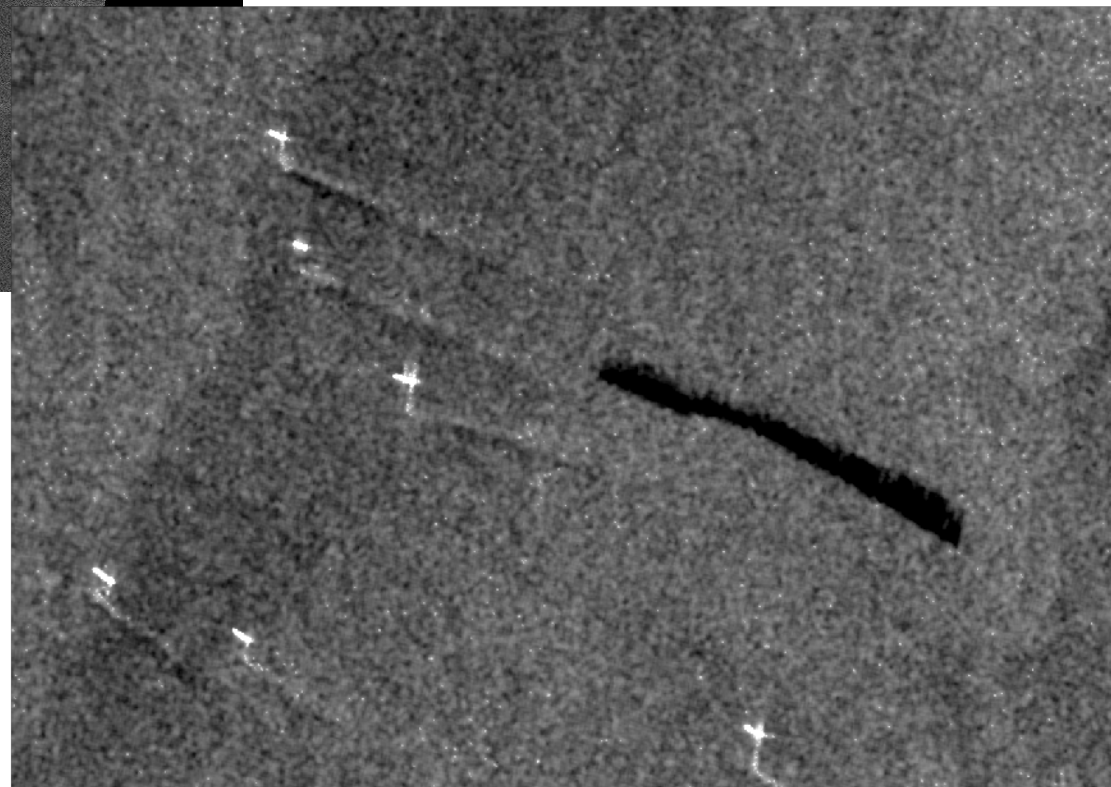




Indian Ocean to Pacific Ocean maritime chokepoints
eia
South China Sea
Brunei
Malaysia
Singapore
Strait of Malacca
Malaysia
Indonesia
Indonesia
Indian Ocean
Sunda Strait
Java Sea
chokepoint
Lombok Strait
Indonesia
Area of detail


Kuala Lumpur
Klang
Shah Alam
PUTRAJAYA
NEGERI SEMBILAN
E21
11
Seremban
E29
AH2
Port Dickson
MALACCA
Malacca
Muar
Rupat Island
Dumai


2024-12-29 00:00 - 2024-12-29 23:59, Sentinel-1 IW VV+VH, VV - decibel gamma0
Batu Pahat
Pulau Bengkalis
5 km
Credit: European Union, contains modified Copernicus Sentinel data 2025, processed with EO Browser



Next-Generation Constellation Approach

Global monitoring using public & private constellations with SAR, hyperspectral, multispectral, and optical sensors

Advantages:

- Ultra-frequent revisits: Sub-hourly to daily coverage for evolving hazards
- All-weather sensing: SAR penetrates clouds, tracks floods and shoreline change night or day
- Chemical/material detection: Hyperspectral spots pollution/algae; multispectral tracks coral/mangroves
- **Immediate disaster maps: AI/edge computing & in-space relay = analysis delivered in minutes**
- - Partnerships: Combining public reliability & private innovation for global coverage and speed
- - Trends: AI for rapid event detection/prediction; IoT-enabled ground networks for local alerts

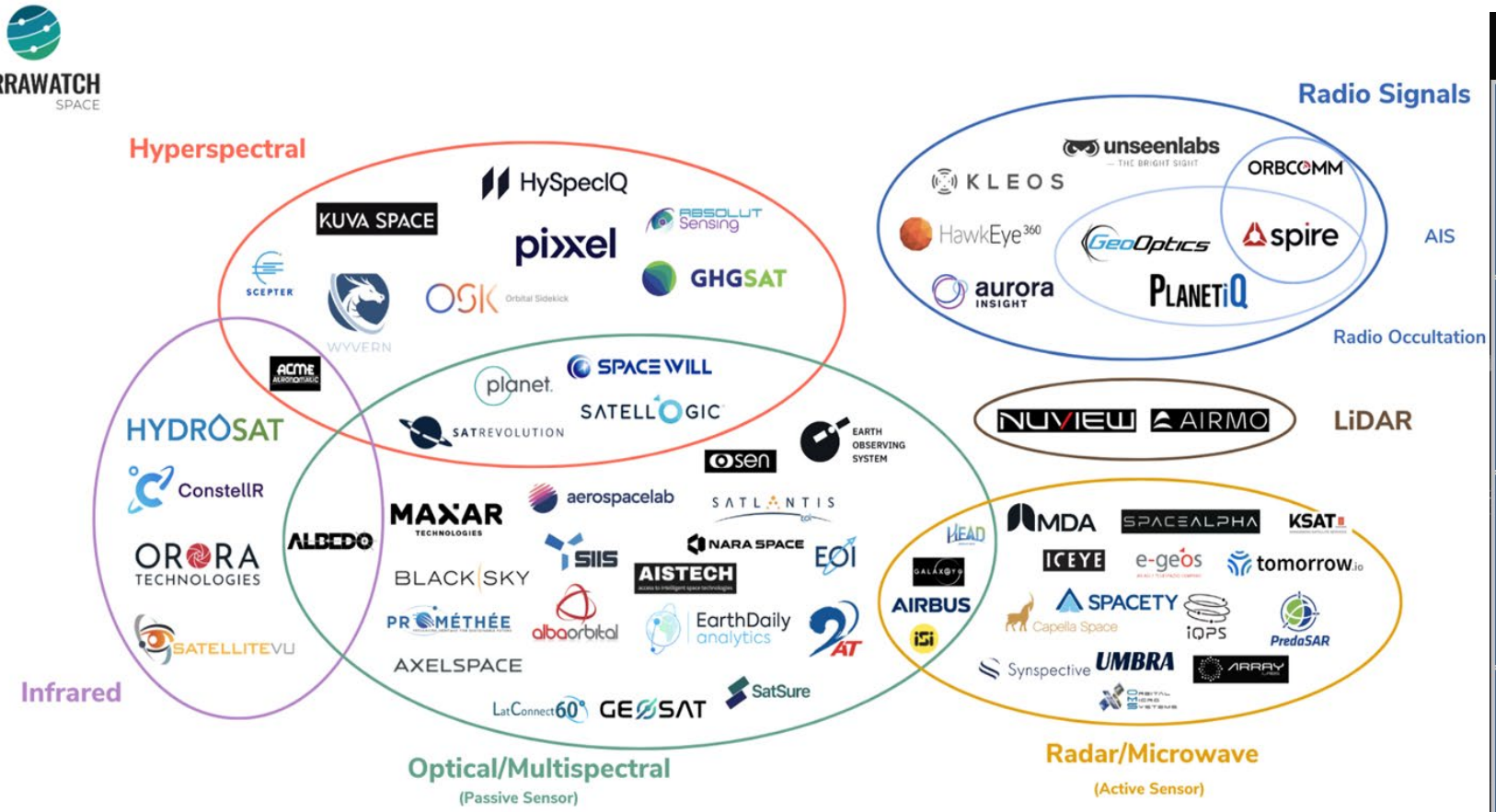
SAR Satellite Missions

Mission	Operator	Country	Band	Sat Count	Launch Yr	Notable Featu..	Revisit Capab..
Sentinel-1A/B/C	ESA (Copernic..	EU	C-band	3+	2014+	Open data, di..	6 days (globa..
RADARSAT Cons..	CSA	Canada	C-band	3	2019	Triple-sat, m..	4 days exact ..
NISAR	NASA/ISRO	USA/India	L & S-band (d..	1	2025	First dual-ba..	12 days (glob..
SAOCOM 1A/1B	CONAE	Argentina	L-band	2	2018/2020	Disaster mgmt..	8 days (with ..
ICEYE Constel..	ICEYE	Finland	X-band, Small..	20+	2018+	First commerc..	20 hours (equ..
Capella Space	Capella Space	USA	X-band, Small..	10+ (scaling ..	2020+	Sub-meter res..	1–6 hours; <1..
Synspective S..	Synspective	Japan	X-band, 1–3 m..	Aim: 30 (plan..	2020+	Affordable, f..	Daily (full d..
Umbra	Umbra	USA	X-band	Growing	2021+	~0.25 m, rapi..	4 times per d..

Hyperspectral Satellite Missions

Mission	Operator	Country	Spectral Res	Launch Year	Satellites	Features	Revisit
PRISMA	ASI (Italy)	Italy	VNIR + SWIR,...	2019	1	Hyperspectra...	~29 days
EnMAP	DLR (German ...	Germany	VNIR + SWIR,...	2022	1	Calibrated h...	~27 days
HysIS	ISRO	India	VNIR, NIR, SWIR	2018	1	Agricultural...	~24 days
GHOSt (Globa...	Orbital Side...	USA	VIS-SWIR, 8 ...	2024 (start)	5+ (planned ...	Methane dete...	Daily revisi...
Pixxel Firef...	Pixxel	India	VNIR-SWIR, ~5 m	2023-2025	3+ (planned 24)	Commercial c...	Daily (plann...
Kuva Space C...	Kuva Space +...	India	Hyperspectra...	Planned 2025+	Constellatio...	Planetary in...	Multi-day re...
HyspIRI (pla...	NASA	USA	VSWIR + Ther...	Future mission	1	Combined spe...	~19 days vis...
PhiSat-1 (AI...	ESA	Europe	VNIR + Therm...	2020	1	AI onboard p...	Nanosat revi...
CHIME (Coper...	ESA	Europe	Hyperspectra...	Planned ~2027	1 planned	Wide-swath h...	Expected day...
HISUI	JAXA	Japan	VNIR + SWIR,...	2019	1	Hyperspectra...	16 days approx.
PRISMA follo...	ASI	Italy	Advanced hyp...	Mid 2020s	Planned cons...	Higher revis...	Planned cons...
LiDAR- and h...	Multiple (NA...	Multiple	Multi-modal ...	Planned future	Multiple pla...	Fusion of hy...	Variable, ai...

EO Satellite Companies



2024 Commercial Remote Sensing Global Rankings

EO Imaging	EO Revisit	EO Video
1 China Siwei SuperView Neo-1	1 Chang Guang Jilin-1	1 Planet SkySat 16-21
2 Airbus Pléiades Neo	2 Satellogic Aleph	2 Zhuhai Orbita Zhuhai OVS-2/3
3 Maxar WorldView-3	3 Planet SkySat	3 Chang Guang Jilin-1 Video

SAR X-Band	SAR Revisit	SAR C-Band
1 Umbra Umbra SAR	1 ICEYE* Constellation	1 SAST Gaofen-12
2 Capella Space Acadia	2 Umbra Constellation	2 Spacety Chaohu-1
3 ICEYE* Generation 3	3 Capella Space Constellation	3 MDA Space RADARSAT-2

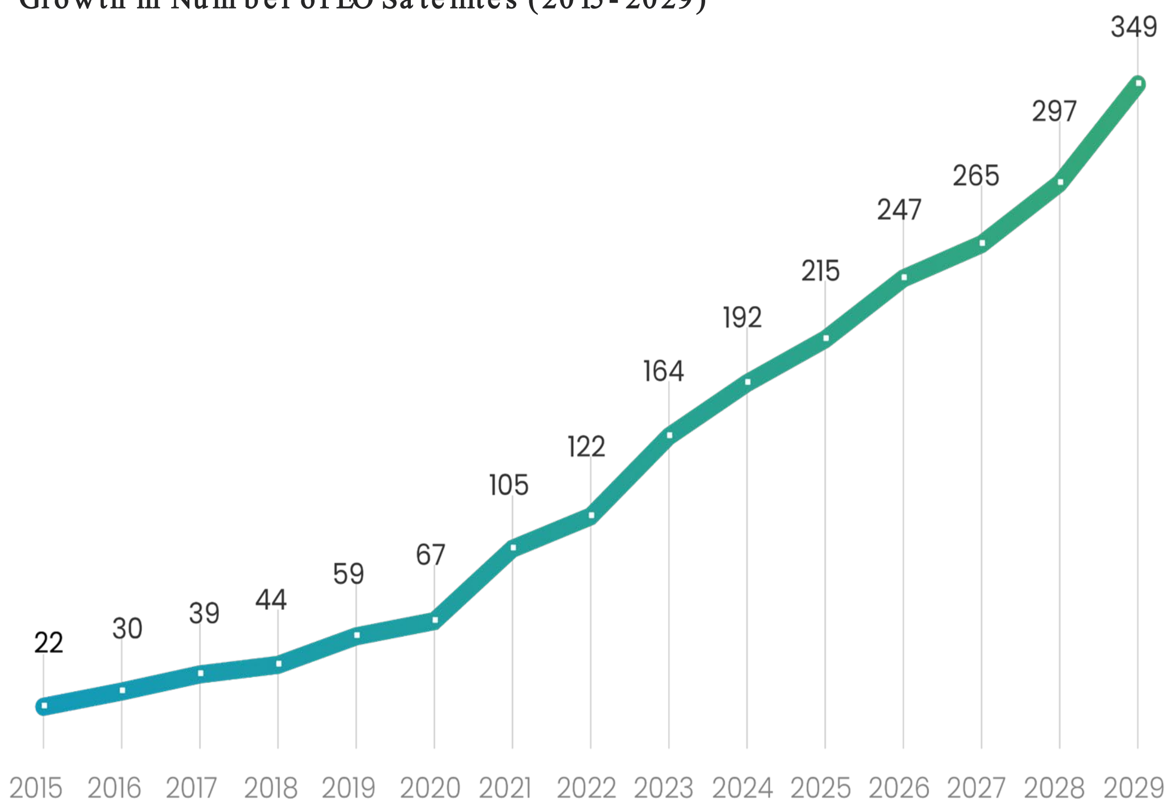
Short-Wave IR	Mid-Wave IR	Long-Wave IR
1 Maxar WorldView-3	1 KARI KOMPSAT-3A	1 CAST Ziyuan-1 02E
2 Satlantis GEISAT Precursor	2 SAST Gaofen-5	2 SAST Gaofen-5
3 SAST Gaofen-5	3 Chang Guang Jilin-1 GP-01/02	3 Chang Guang Jilin-1 GP-01/02

Multispectral	Hyperspectral	Total Medals
1 China Siwei SuperView Neo-3	1 Orbital Sidekick GHOSt	14
2 Satellogic Aleph Mark V	2 Pixxel* Anand/TD-1	12
3 Planet SkySat 16-21	3 Zhuhai Orbita Zhuhai OHS-2/3	RoW 9

EO Satellite Launches

Realistic Projections

Growth in Number of EO Satellites (2015-2029)



2,217 Total # of EO satellites expected to launch in the next 5 years (2026-2029)

44 # of countries with plans to launch an EO constellation (next 5 years)

72 # of companies with existing or future plans for EO constellations (next 5 years)

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אטפ כשט״ קלשאשלע רתכמ,
לותדשאלשטקד
נשכתאשת ר פ ת שאשתד

EO-Powered Predictive Coastal Resilience

The Opportunity:

Harnessing EO satellites, ocean buoys, and climate data for predictive modeling and coastal scenario planning

Digital twins: Real-time virtual models of coastlines for simulating hazards, erosion, flooding, ecosystem shifts

Advantages

Early warnings: High-frequency EO enables anticipation of storms, floods, anomalies

Dynamic adaptation: Data-led guidance on fortification, restoration, retreat, redesign

Onboard EO Processing - Cutting Latency, Maximizing Impact

- In-Space Analysis

➢ Satellites perform onboard processing, classifying risks directly in orbit

➢ Actionable alerts reach responders in minutes; saves bandwidth

- Orbital Supercomputers & AI

Orbital compute nodes process EO streams, training AI for detection & prediction

Enhanced risk modeling: historic + real-time data = live forecasts

- Seamless, Secure, Multi-level Delivery

➢ Secure networks deliver risk maps, forecasts, alerts to agencies & communities

➢ Integrated with IoT buoys, drones, national systems for collaborative response

- From Reactive to Predictive

➢ Anticipate-and-act resilience requires instant, trusted, actionable intelligence

➢ Delivered where and when it's needed most

Policy & Future Directions

- Mainstream next-gen EO into disaster/climate action planning: from reactive to predictive resilience
- Invest in open-access data, capacity building, and cloud/AI analytics for developing regions
- Foster multi-sensor, multinational constellations and rapid public–private data sharing
- Continue research: better event AI, autonomous satellites, high-resolution coastal models