Internal Waves Service

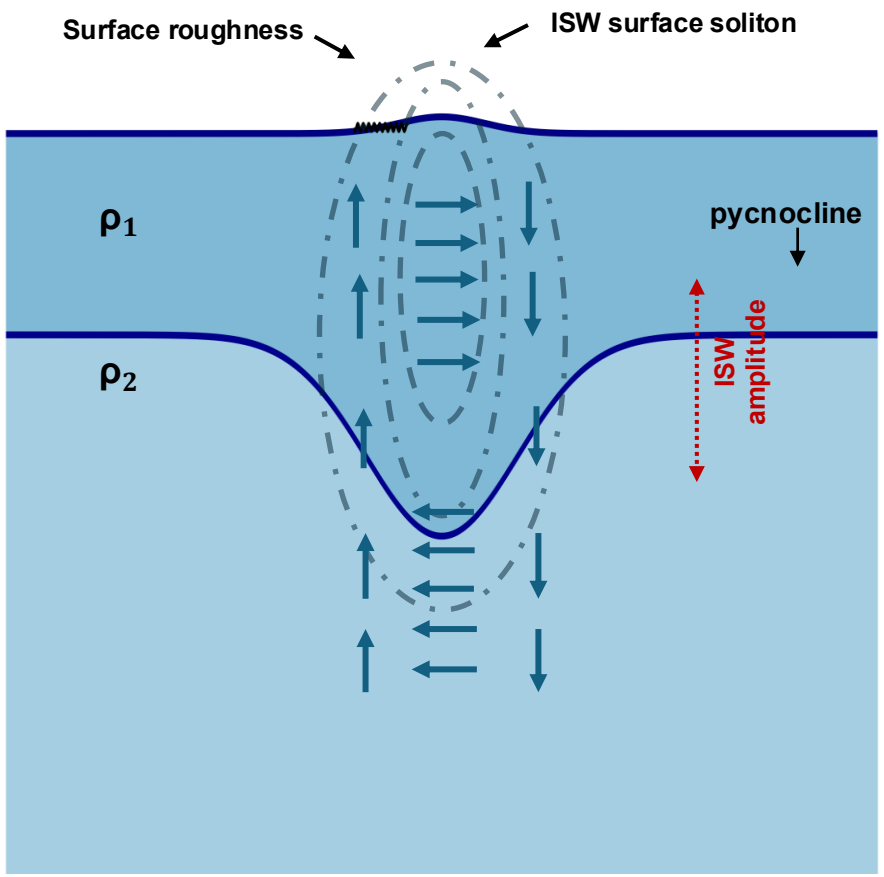
JuliaEO
Global Workshop on Earth Observation with Julia 2026

AIR CENTRE
ATLANTIC INTERNATIONAL RESEARCH CENTRE

Adriana M. Santos-Ferreira, João Pinelo, João Gonçalves and Arun Shukla

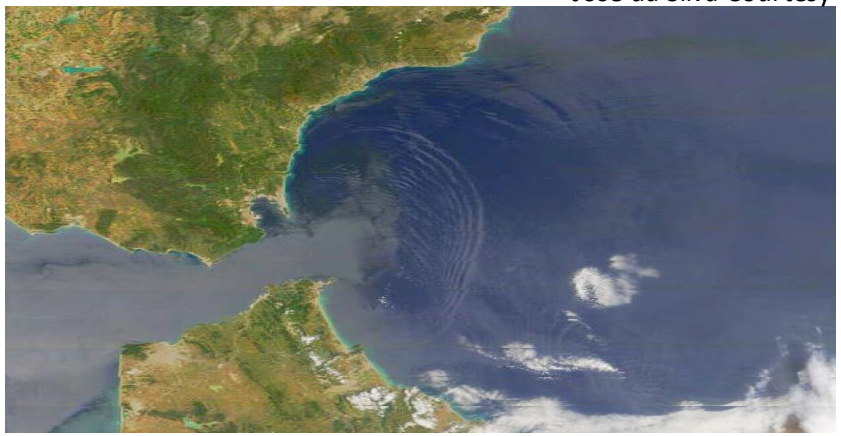
1. Introduction

What are Ocean Internal Waves?



Adapted by Osborne & Burch 1980

José da Silva Courtesy



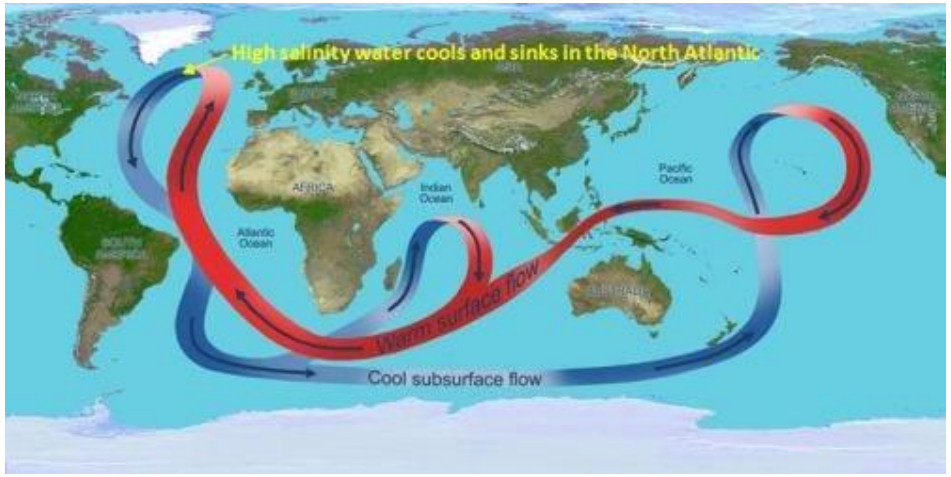
MODIS Image, NASA Courtesy

- Can reach amplitudes of hundreds of meters
- Transport energy efficiently without dispersing
- Generate strong currents (often >2 m/s)
- Leave alternating rough and smooth bands at the surface
- Visible to the naked eye, but much clearer in satellite imagery (SAR/optical)

Scientific and practical importance

Natural Processes

- Energy Transport
- Mixing
- Nutrient Transport
- Climate Regulation
- Global Ocean Circulation



Mark Altaweel 2023

Anthropogenic Activities

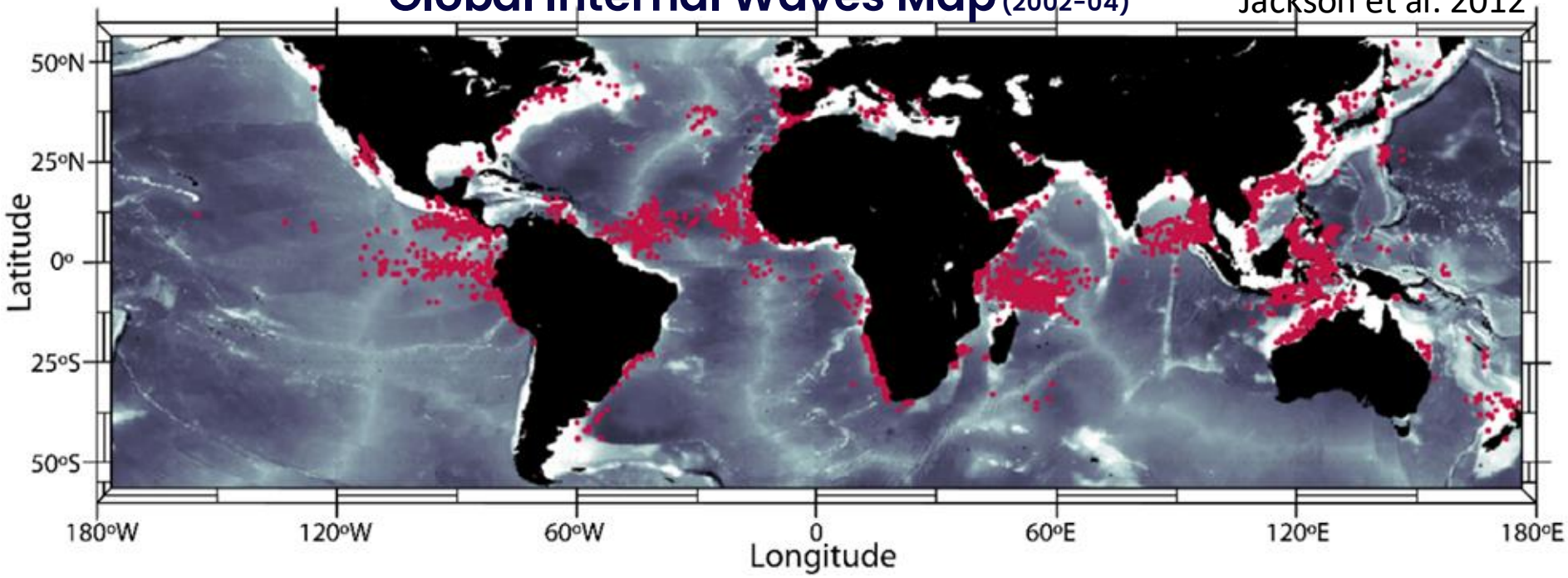
- Infrastructure
- Coastal Impacts
- Submarine Operations/ Navigation

Osborn and Burch 1980

Li et al. 2024

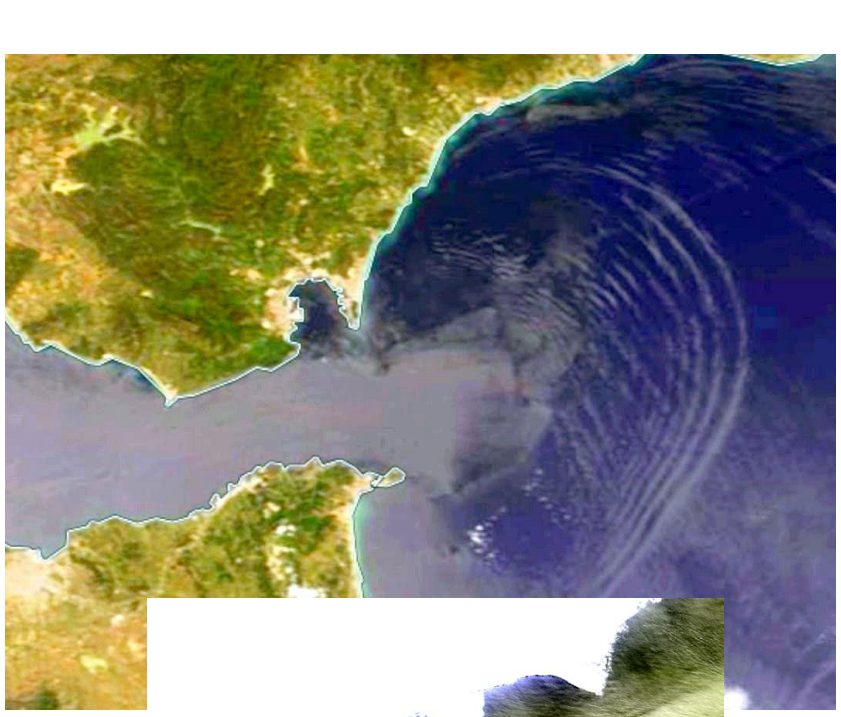
Problem: global observation remains challenging and has been restricted to a few hotspots

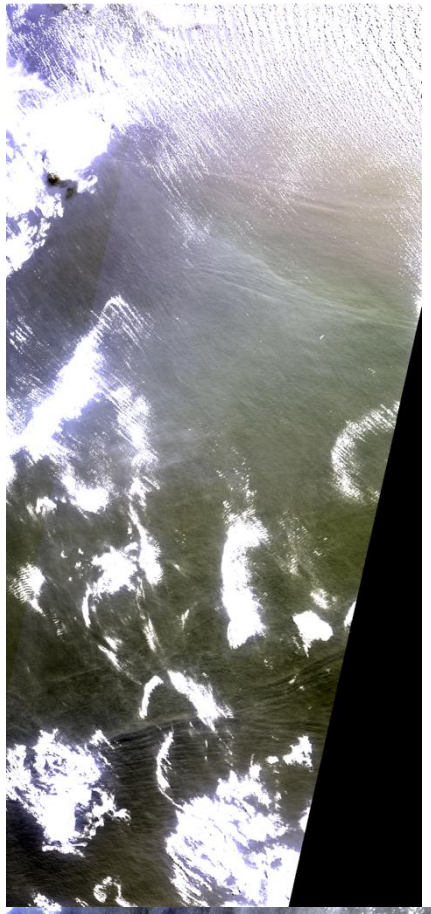
Global Internal Waves Map (2002-04) Jackson et al. 2012

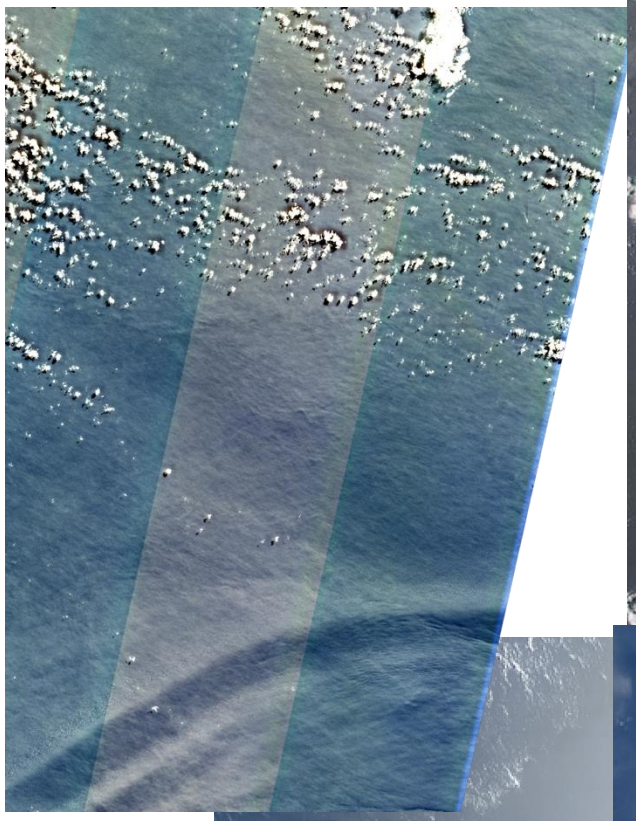


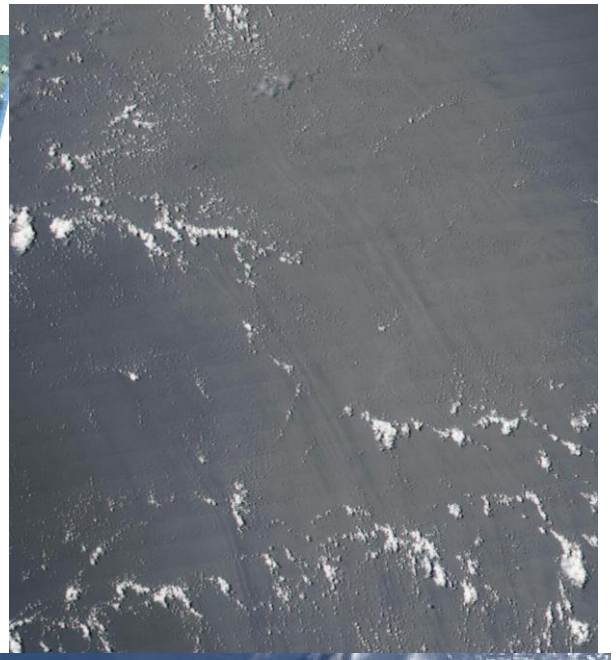
Based on Sentinel-1's Global Coverage > NRT mapping (2014 Onwards)

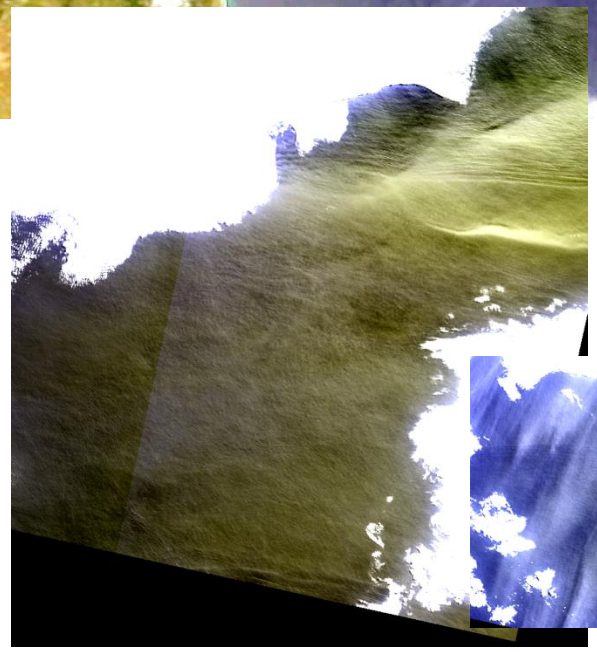
ISWs in Satellite Optical Images

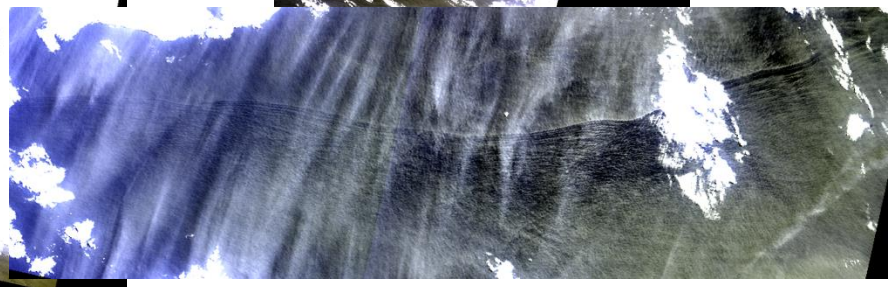


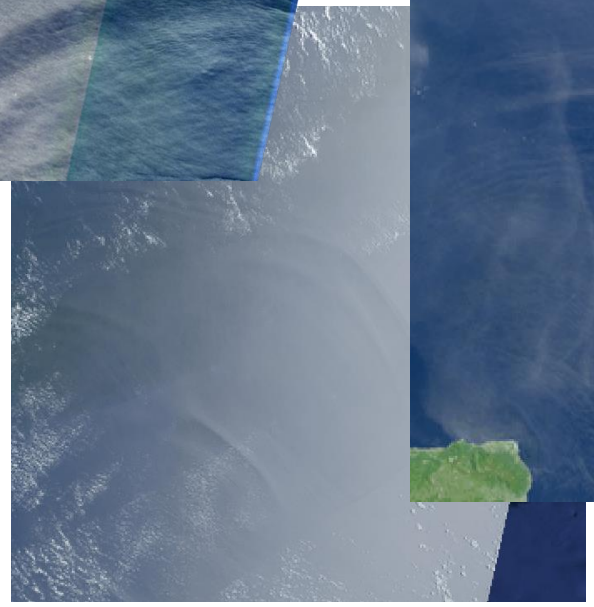


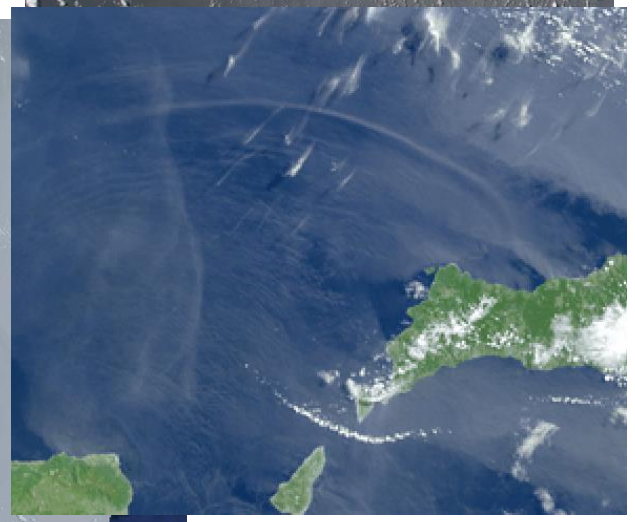




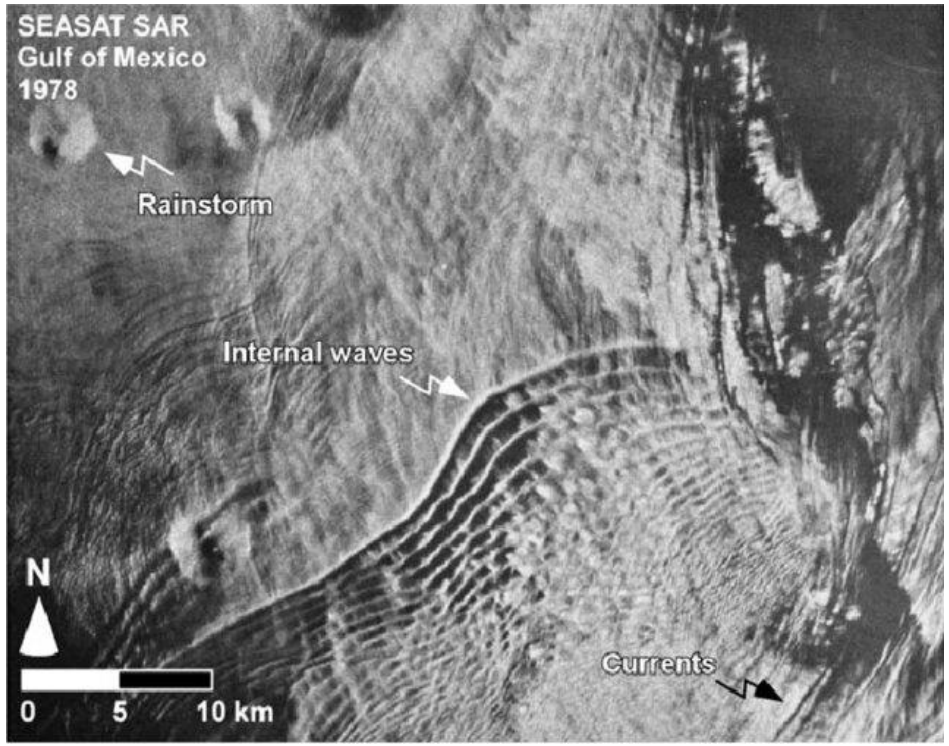




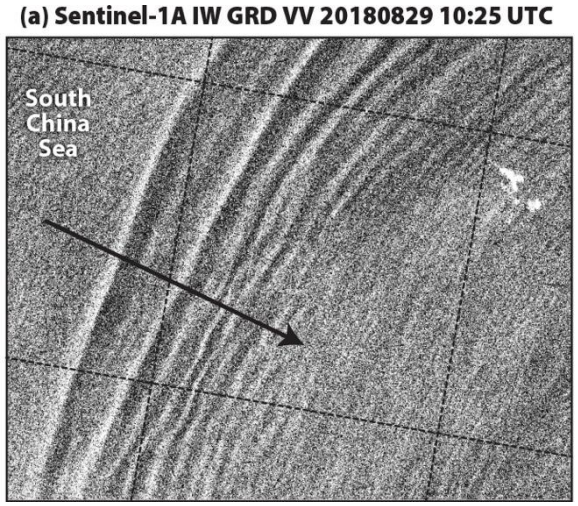




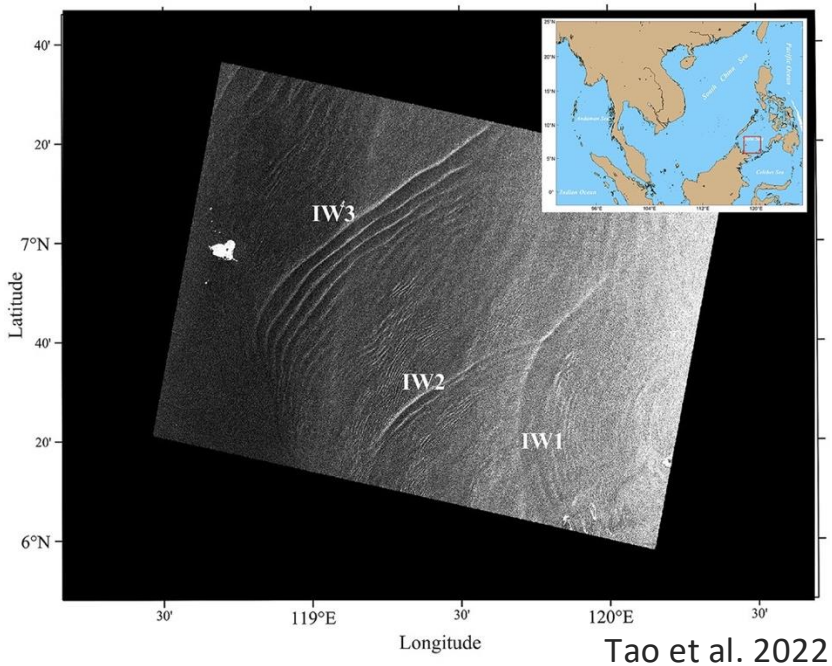
ISWs in Satellite SAR Images



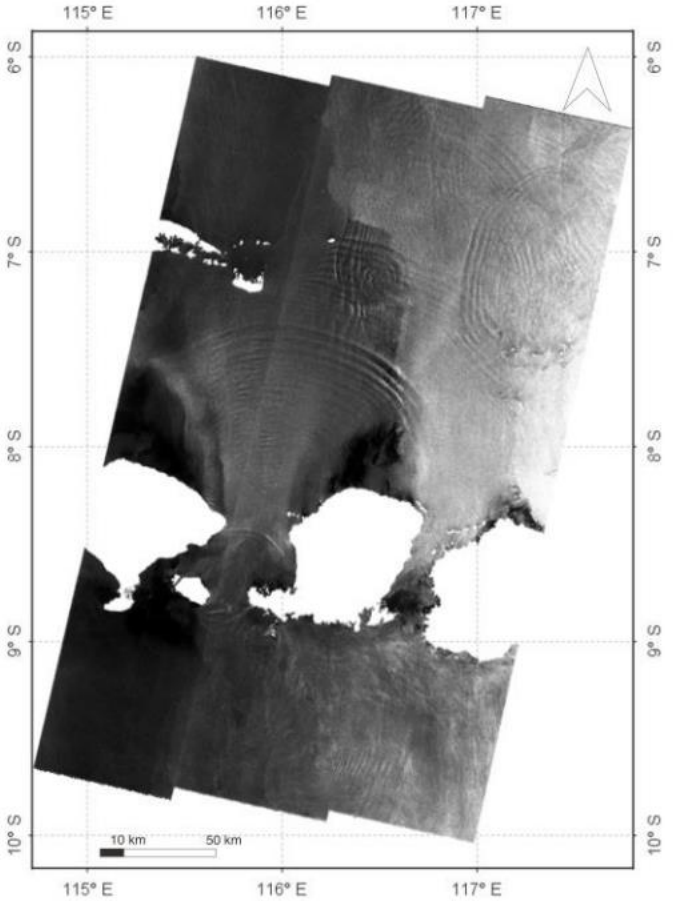
Courtesy: NASA. (Klemas 2012)



Magalhaes et al. 2021



Tao et al. 2022



Lombok, Chonnaniyah et al. 2021

Main objective: Create the first global, NRT service for the detection and monitoring of Internal Waves

Our Goals:

- Support researchers;
- Consolidate IWs as mainstream;
- Find end-users beyond researchers.

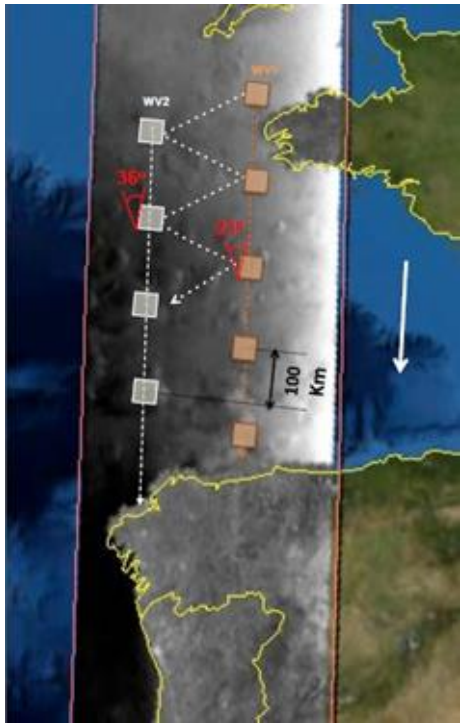
How?

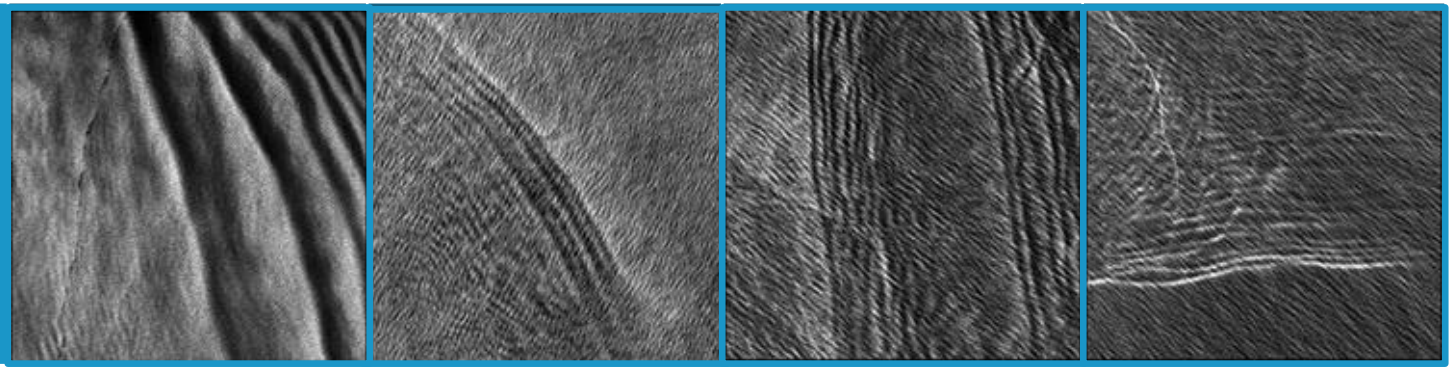
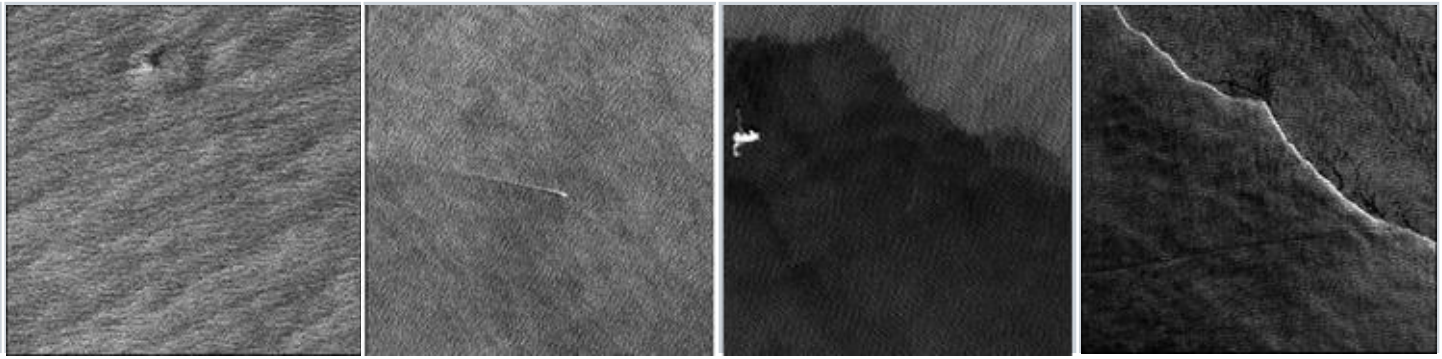
We have created the "Internal Waves Service" (IWS)

https://www.aircentre.org/internal-waves-service/

2. Methodology

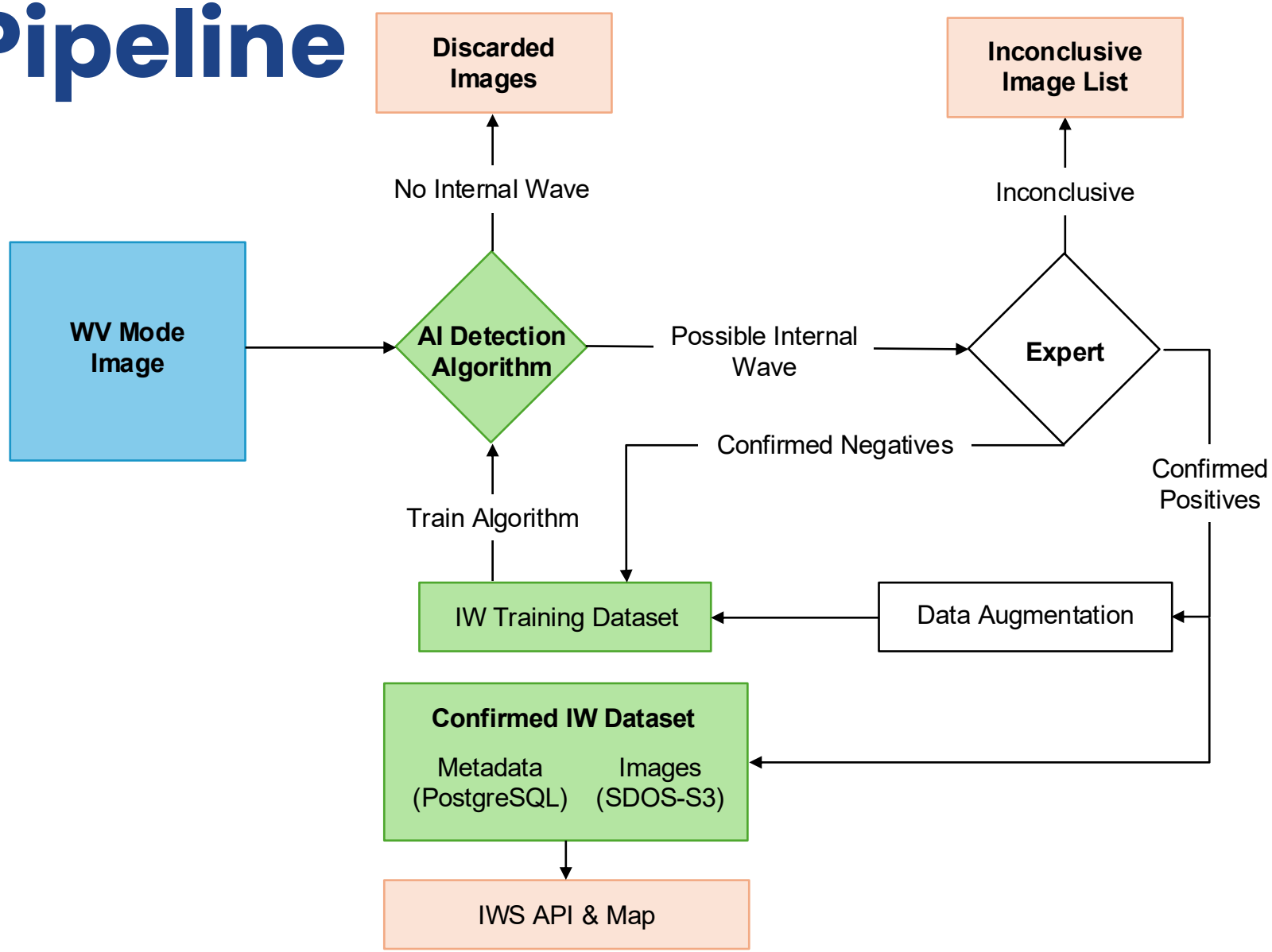
Dataset used by the service



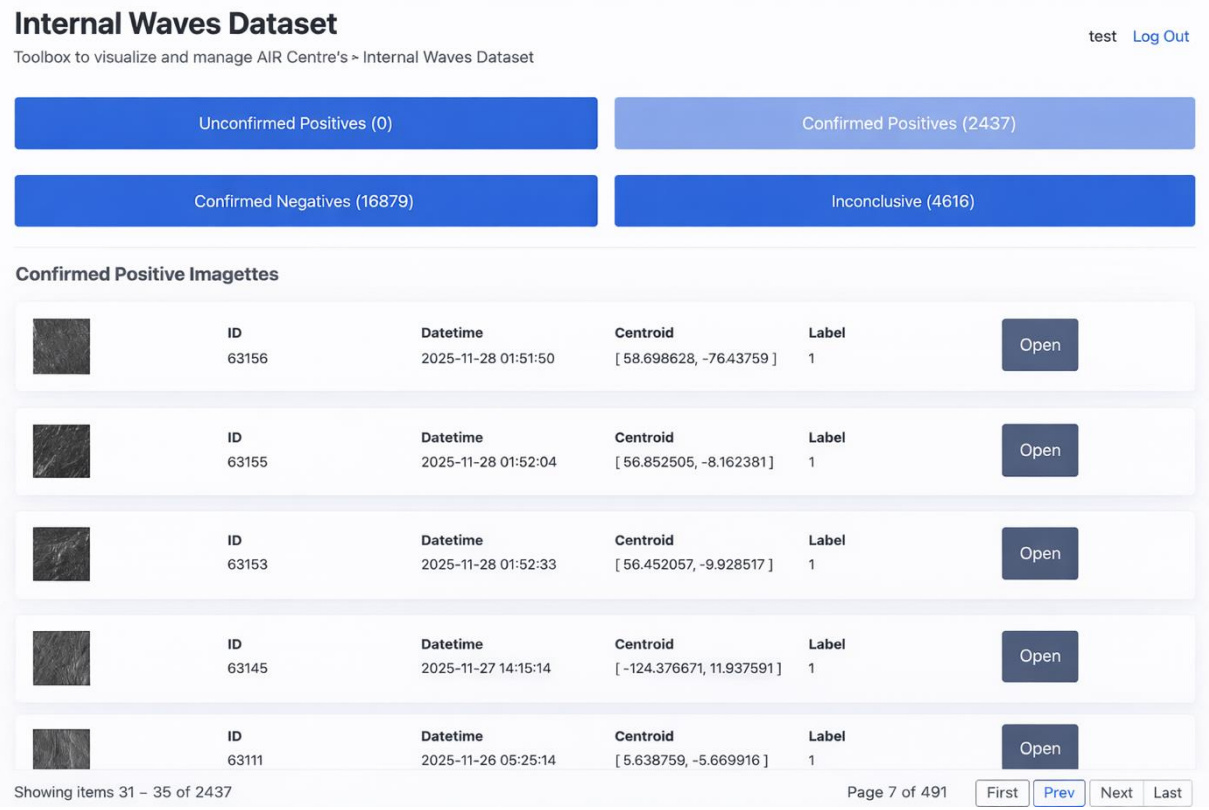
Internal Waves	
Not Internal Waves	

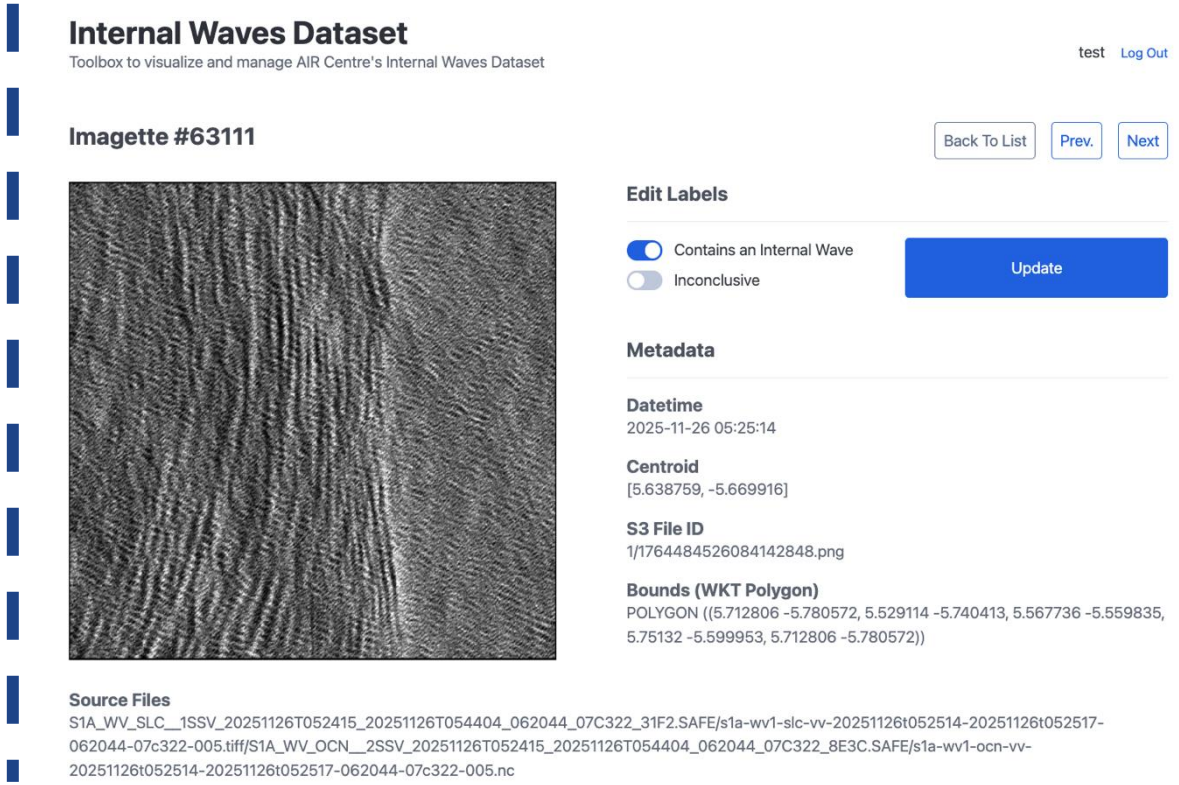
While WV mode does not cover the entire ocean (persistent sampling gaps inherent to the acquisition strategy), its regular acquisitions over wide oceanic areas represent a major leap in both spatial and temporal coverage.

Current Pipeline



Validation Platform (expert use)





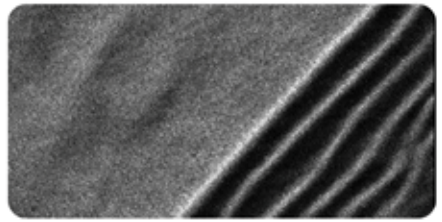
Which ML model do we use?

ATLANTIC INTERNATIONAL RESEARCH CENTRE · COMMUNITY PREDICTION COMPETITION · A MONTH AGO

Late Submission

Automatic Identification of Internal Waves

Probabilistic image classification competition - image classification challenge.



Overview | Data | Code | Models | Discussion | Leaderboard | Rules | Team | Submissions

Overview

Goal

*The **goal** of this competition is to automate the identification of simplified satellite images that have internal waves.*

The exercise consists of an image classification challenge of satellite images from Sentinel 1 (Copernicus Constellation) for the presence of internal waves.

Start
Aug 16, 2024

Close
Oct 31, 2024

Competition Host
Atlantic International Research Centre

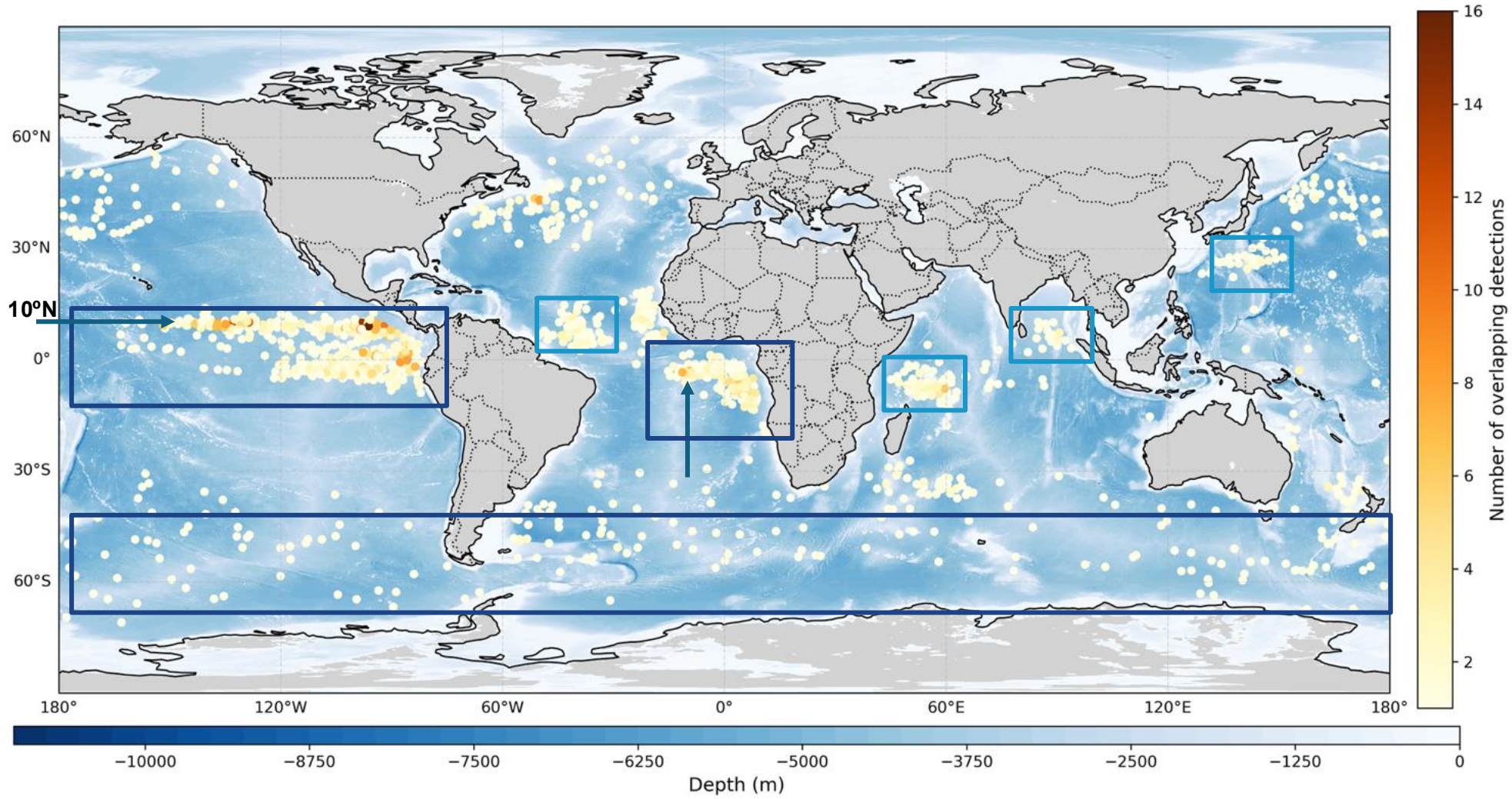
Prizes & Awards
Kudos
Does not award Points or Medals

Participation
67 Entrants
15 Participants
14 Teams
55 Submissions

Tags

3. Results

Current IWS Data (2437 events)



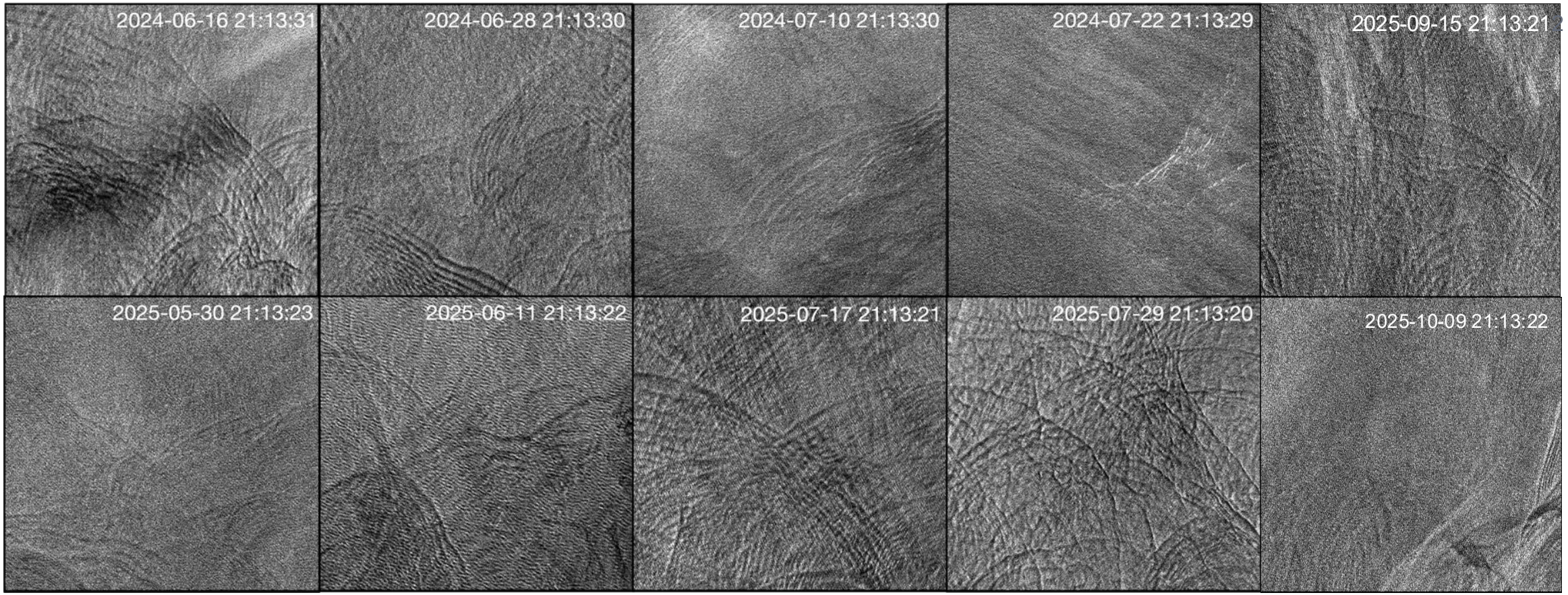
Examples of **known hotspots** seen in the map:

- South China Sea;
- Mascarene Ridge;
- Amazon Shelf;
- Bay of Biscay

New/ unexpected regions identified:

- Sectors of the Southern Ocean;
- Tropical Atlantic near West Africa;
- Central and eastern equatorial Pacific (within ±5° latitude);
- Between 8° and 10°N latitude in the Pacific.

Persistent Internal Solitary Waves activity in the Gulf Stream (43.10°N; 49.93°W)



Pinelo et al., 2025 (conference paper SPIE Imaging + Sensors)

Internal Solitary Waves Community

IWS Internal Waves Service **WORKSHOP 2025**

▼Quick Facts

- Date: 3 - 4 April 2025
- Location: Terceira Mar Hotel, Angra do Heroísmo, Terceira Island, Azores , Portugal
- Timezone: UTC -1; GMT-1
- Event Type: In person only.
- Registration for attendance: by invitation only.

Santos-Ferreira, A. M., Pinelo, J., da Silva, J. C. B., Johannessen, J. A., Chapron, B., Gommenginger, C., Magalhães, J. M., Buijsman, M., Forget, G., Pineda, J., Goh, E., Ávila, M., Diogo, I., & Gonçalves, J. (2025). *The Internal Waves Service Workshop: Observing internal waves globally with Deep Learning and Synthetic Aperture Radar*. **Bulletin of the American Meteorological Society (BAMS)**. https://doi.org/10.1175/BAMS-D-25-0133.1

Next IWS W26 in April 2026, 14-16

An expanding ISW community
24 institutions (12 countries)

In partnership with

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OceanDataLab
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IPMA

4. Discussion and Outlook

IWS – Next Steps 1/2

- **Expand and curate a global ISW dataset** from Sentinel-1 WV mode images (2014 to date; NRT), enabled by Sentinel-1A/1B and the recent launch of Sentinel-1C and Sentinel-1D.
- **Integrate IW mode data** from Sentinel-1 to increase spatial coverage, particularly in coastal and shelf areas.
- **Develop ISW segmentation methods** for precise localization and extraction of physical parameters (e.g., wave crest distances and lengths).
- **Prepare for data assimilation of future missions**, especially **ROSE-L (launching 2028)**, which will enhance WV mode capabilities with higher temporal resolution.
- **Explore synergies between SAR and SWOT** observations to estimate ISW amplitudes and validate phase speeds in key regions (e.g., Amazon Shelf, Banda Sea).

IWS – Next Steps 2/2

- **Establish thematic working groups** focused on data curation, AI model development and science applications. **We applied for a COST Action.**
- **Support collaborative publications** and plan **follow-up workshops** in April 2026.
- **Leverage AI** to revisit archived data (e.g., Envisat) and extract ISW signatures from historical SAR missions.
- **Align with Copernicus programme evolution**, contributing to a long-term, **open-source, scalable platform** for ISW monitoring and applications in forecasting, climate modelling, and marine services.

Joao.Pinelo@aircentre.org

Adriana.Ferreira@aircentre.org