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Environmental Crimes joint workshop with ESA-JRC-UNODC

Earth Observation for Environmental Compliance and Liquid Discharge Detection: Pre-Operational Chime and LSTM Applications

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DISCHARGE SOURCES

- Wastewater treatment plants
- Industrial and urban activities
- Agricultural runoff
- Accidental releases
- **Illegal or unknown pollution events**

POTENTIAL IMPACTS

- Water-quality degradation
- Suspended matter · nutrients · pollutants
- Optical and thermal changes
- Impacts on aquatic ecosystems

MONITORING NEED

- Detect and characterize unusual events
- Map their spatial extent and evolution
- **Support targeted field inspections**
- **Support environmental surveillance & compliance**

MULTISENSOR WATER DISCHARGES (MWD) Project

Developed within ESA's Sentinel User Preparation initiative, MWD investigates the combined potential of simulated CHIME hyperspectral and LSTM thermal observations, together with current multispectral data, for detecting and characterizing potential water-discharge-related anomalies before the future missions become operational.

WHY EARTH OBSERVATION?

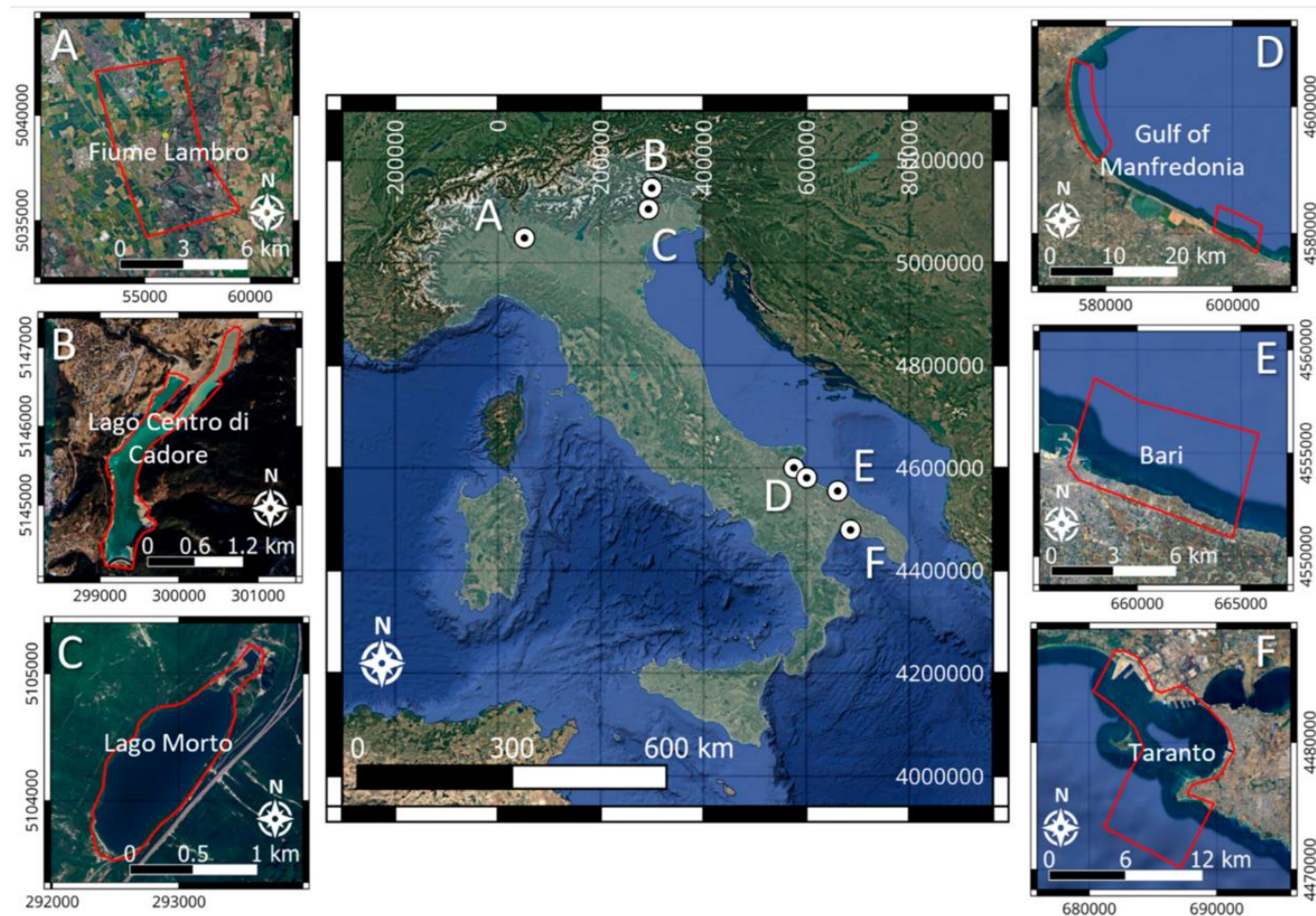
In situ measurements provide accurate information, but their spatial and temporal coverage is limited.

Satellite observations complement conventional monitoring through repeated, spatially distributed observations over large areas.

EO can support the assessment of turbidity, suspended matter, chlorophyll-a and surface water temperature.

**OPTICAL + HYPERSPECTRAL + THERMAL → COMPLEMENTARY
INFORMATION FOR WATER-DISCHARGE MONITORING**

AREAS OF INTEREST



COASTAL AREAS

Manfredonia Gulf
Taranto Gulf
Bari Coast

- Industrial and Urban pressure
- Ports and Maritime traffic
- Wastewater and coastal runoff

MOUNTAIN LAKES

Lago Centro Cadore
Lago Morto

- Artificial Reservoirs
- Hydropower influence
- Constrained water boundaries

METROPOLITAN RIVER

Lambro River

- Densely Populated Area
- Industrial Pressure
- Wastewater Treatment Plant effluents

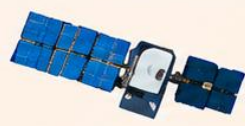
METHODOLOGY

1. Data Selection

Selection of suitable satellite data and preprocessing



Sentinel-2/3
Multispectral
optical data



Landsat-8/9
Multispectral
optical and thermal data

Selection of suitable acquisitions
(date, cloud cover, quality)

Subsetting to the study area
(Gulf of Taranto)

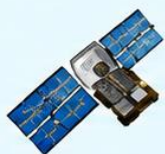
Pre-processing and common grid



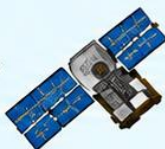
Example: True colour (RGB)

2. Product Generation

Retrieval of optical and thermal products from simulated and operational data



CHIME (simulated)
Hyperspectral data
(VNIR-SWIR)

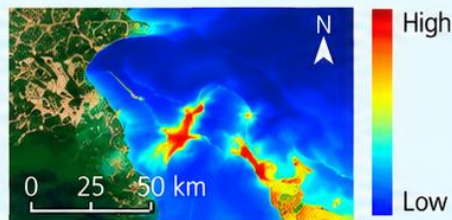


LSTM (simulated)
Thermal infrared data

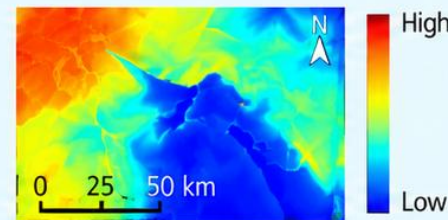
Retrieval of optical indicators
(e.g. turbidity, chlorophyll-a)

Surface water temperature
retrieval

Product generation and masking
(water mask, quality control)



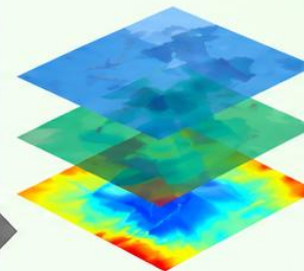
Example: Turbidity map



Example: Surface temperature map

3. Joint Analysis

Integrated analysis of optical and thermal products

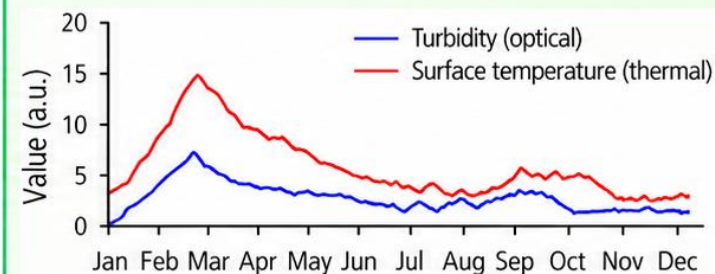


Spatial and temporal comparison

Identification of anomalies

Analysis of spatial patterns
and temporal evolution

Interpretation of potential
discharge-related signals



Example: Temporal evolution at a selected location

METHODOLOGY – DATA SELECTION

MUTISPECTRAL

Sentinel-2 - Landsat-8/9

Initial optical screening

Suitable acquisitions selected around the hyperspectral observation dates.

Coastal analysis

High-resolution multispectral data used for water masking and optical indicators.

Role in MWD

Operational reference for the optical component and later consistency assessment.

HYPERSPECTRAL SIMULATED

**PRISMA/EnMAP → simulated
CHIME**

Source hyperspectral data

VNIR–SWIR imaging spectroscopy with narrow and contiguous spectral bands.

CHIME simulation

**Spectral harmonization according to the
expected CHIME spectral characteristics.**

Role in MWD

Hyperspectral information for detailed analysis of spectral variability.

THERMAL SIMULATED

Simulated LSTM

Thermal observations

Representative LSTM-like products generated from available thermal data.

Key TIR regions

Information around 10.9 and 12.0 μm for surface-water temperature retrieval.

Role in MWD

Thermal information used to analyse spatial temperature patterns and contrasts.

HYPERSPECTRAL SIMULATION WORKFLOW

PRISMA /
EnMAP

Spectral
harmonization

Simulated
CHIME

Hyperspectral
analysis

**MULTISPECTRAL + HYPERSPECTRAL + THERMAL →
COMPLEMENTARY INFORMATION FOR JOINT ANALYSIS**

→ THE EUROPEAN SPACE AGENCY

METHODOLOGY – JOINT ANALYSES

MULTISPECTRAL OPTICAL

Spatial patterns and water-quality variability to identify areas that differ from surroundings waters



HYPERSPECTRAL OPTICAL

Detailed spectral informations, to compare the spectral behaviour of these area with the surrounding waters



THERMAL

Water surface temperature patterns and contrasts



JOINT COMPARISON OF COMPLEMENTARY OBSERVATIONS

Assessment of correspondence in spatial patterns, spectral variability and thermal contrasts

MULTISENSOR CONSISTENCY ASSESSMENT

RESULTS – OPTICAL

Lake Centro Cadore • Landsat-9 vs simulated
CHIME • 19–20 July 2022

WHAT DO WE SEE?

- Comparable spatial patterns of turbidity
- Higher values concentrated in the southern / south-western sector
- Main lake-wide gradients remain recognizable

CONSISTENCY METRICS

Turbidity SSIM

0.923

Turbidity r

0.483

NDTI SSIM

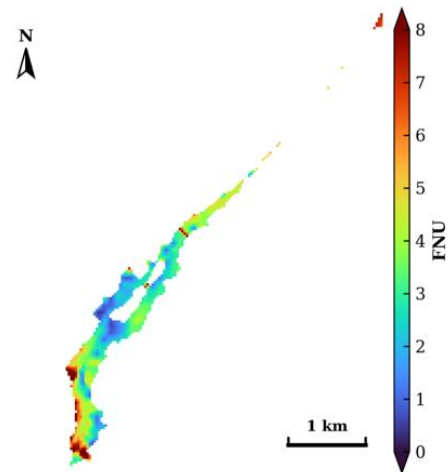
0.921

NDTI r

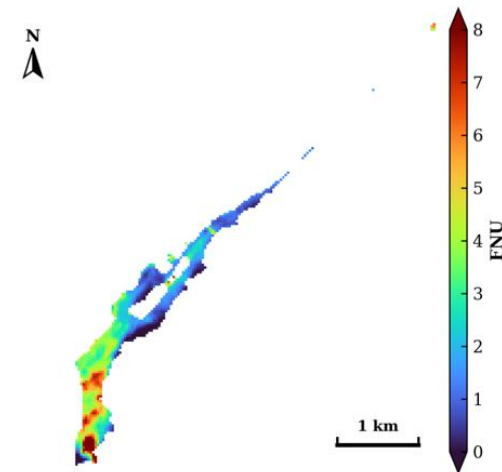
0.300

Absolute values differ, but the dominant spatial structure is preserved. The high structural similarity confirms that simulated CHIME preserves the main spatial patterns observed by Landsat.

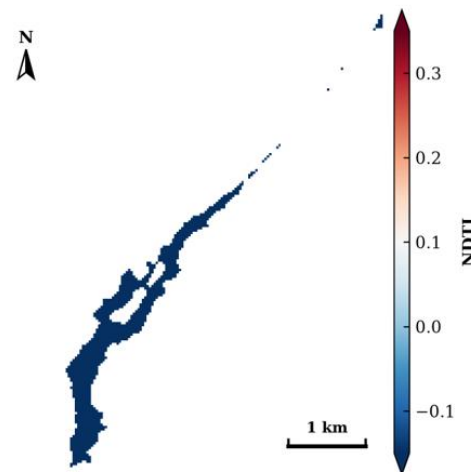
(a) Landsat Turbidity



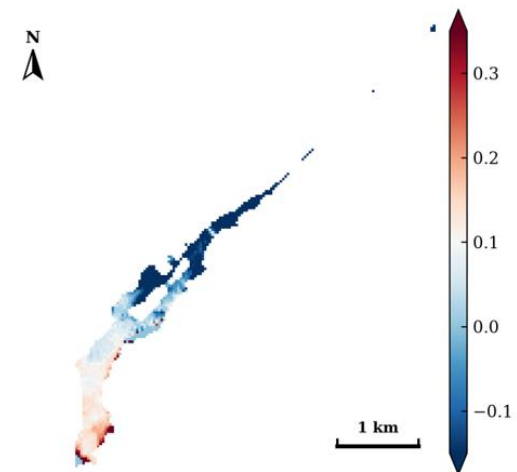
(b) CHIME Turbidity



(c) Landsat NDTI



(d) CHIME NDTI



RESULTS – OPTICAL

Coast of Bari

Sentinel-2 vs simulated CHIME • representative coincident acquisition: 30 March 2021

WHAT DO WE SEE?

- Comparable coastal-to-offshore spatial organization
- Main turbidity pattern remains recognizable
- Good correspondence for NDTI
- Larger differences are observed for NDCI

CONSISTENCY METRICS

Nechad r

0.767

NDTI r

0.672

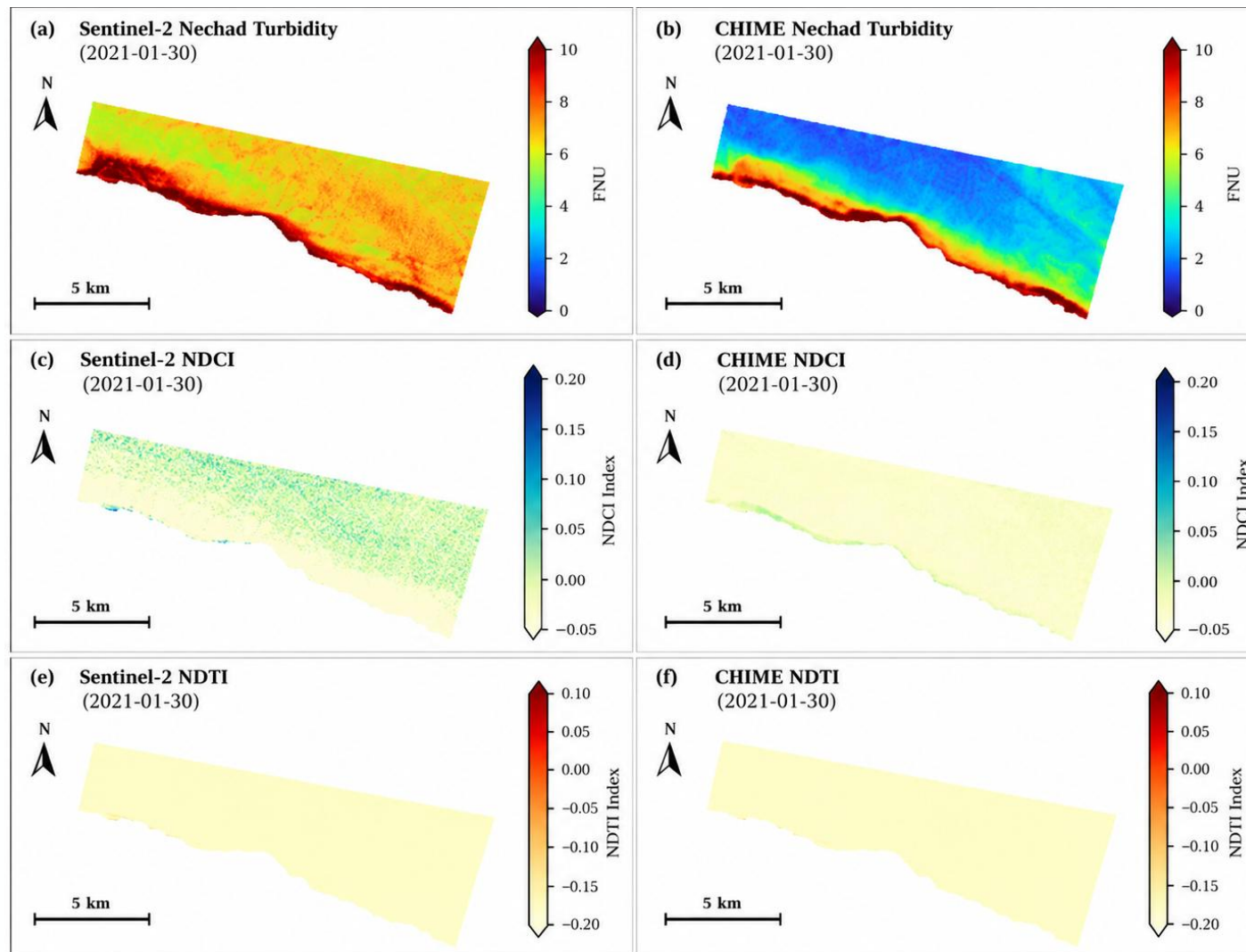
Nechad SSIM

0.670

NDTI SSIM

0.672

Absolute values differ, but the main spatial organization is preserved.



RESULTS – OPTICAL

Coast of Bari –ACOLITE TEST

WHY ACOLITE?

- Sentinel-2 ACOLITE Nechad turbidity was compared with Nechad turbidity simulated CHIME
- Similar turbidity patterns along the coast

CONSISTENCY METRICS

Pearson r

0.816

SSIM

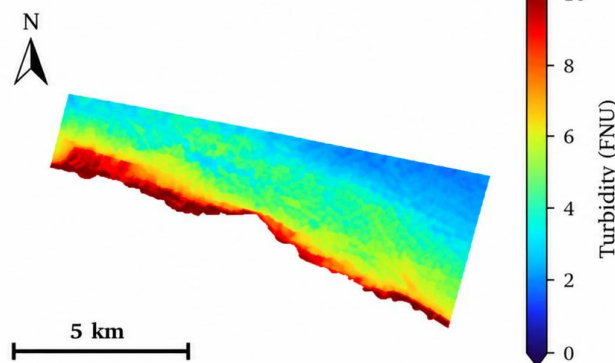
0.948

RMSE

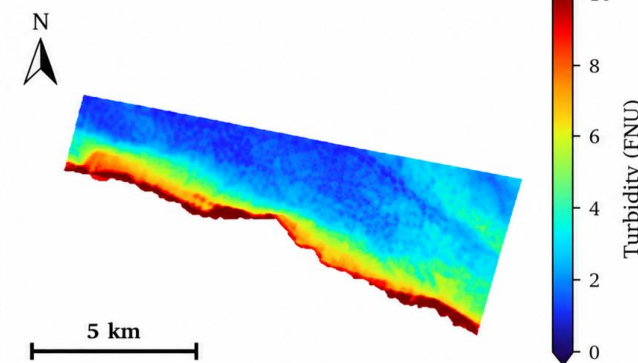
2.04 FNU

Coast of Bari: ACOLITE vs. CHIME Nechad Turbidity (30 March 2021)

(a) Sentinel-1 ACOLITE
(2021-03-30)



(b) CHIME Nechad
(2021-03-30)



**High spatial consistency between ACOLITE
turbidity and simulated CHIME.**

**The results are consistent with the previous
comparison**

RESULTS – OPTICAL

Lambro River

Sentinel-2 vs simulated CHIME • 22 March 2023

WHAT DO WE SEE?

- challenging area because the river is very narrow and the water conditions can change over short distances
- Main along-river variations remain recognizable
- High structural similarity for all three optical products

CONSISTENCY METRICS

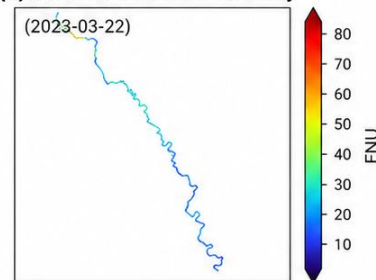
Nechad
SSIM
0.957

NDCI SSIM
0.956

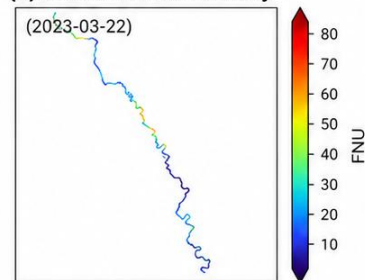
NDTI SSIM
0.960

**Despite the complex geometry,
simulated CHIME preserves the main
spatial organization observed by
Sentinel-2.**

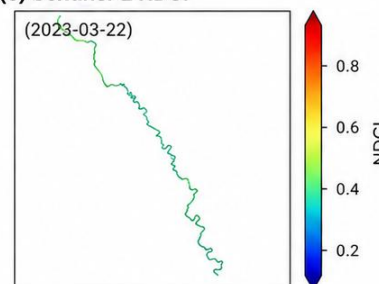
(a) Sentinel-2 Nechad Turbidity



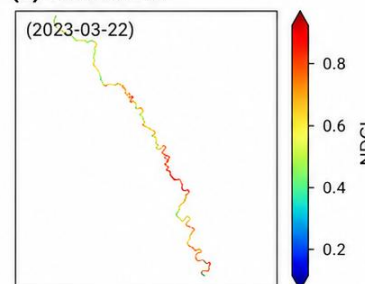
(b) CHIME Nechad Turbidity



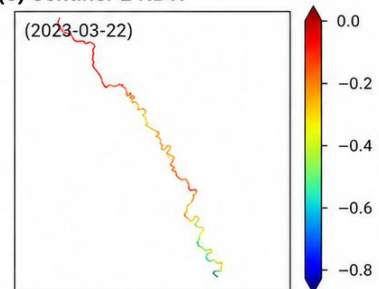
(c) Sentinel-2 NDCI



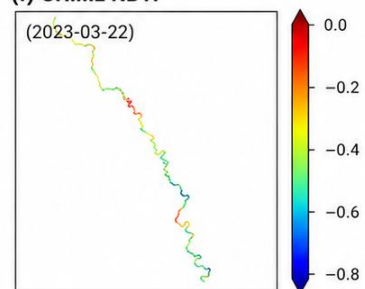
(d) CHIME NDCI



(e) Sentinel-2 NDTI



(f) CHIME NDTI

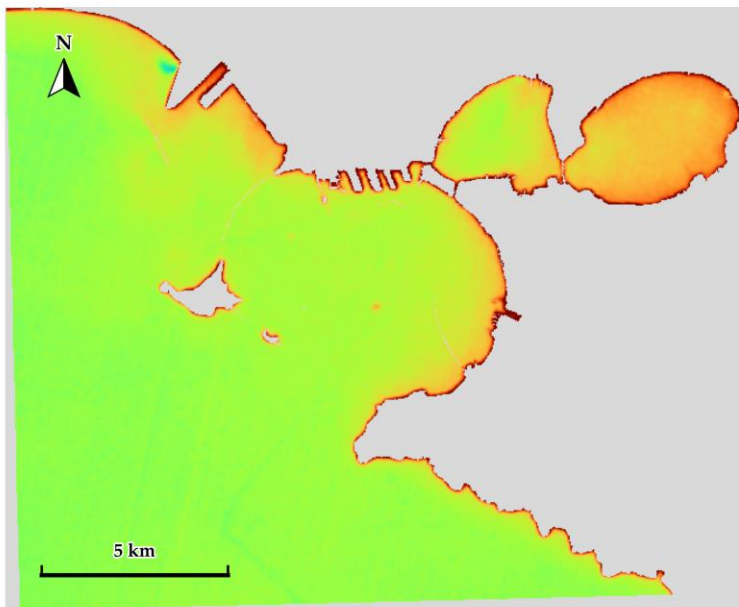


— Lambro River (water mask)

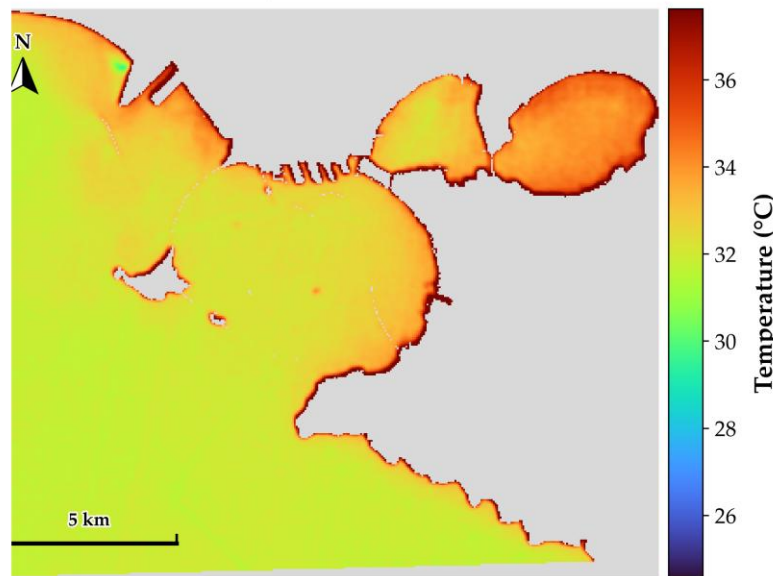
RESULTS – THERMAL

Gulf of Taranto - Landsat-9 Band 10 vs simulated LSTM SST-Q • 6 August 2024

(a) Landsat 8 Band 10 (°C)
Reference



(d) LSTM LC SST-Q (°C)
(Quadratic)



WHAT DO WE SEE?

- Similar spatial temperature organization in both products
- Cooler waters remain recognizable offshore
- Warmer sectors are visible near the coast and within the embayment
- Simulated LSTM SST-Q preserves the main Landsat thermal gradients

SSIM

0.9865

Pearson r

0.9754

RMSE

0.515 °C

Bias

-0.447 °C

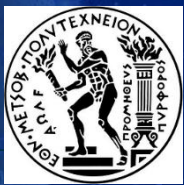
**SST-Q closely reproduces the
Landsat temperature field
while preserving its spatial
structure.**

CONCLUSIONS

MULTISENSOR CONSISTENCY ASSESSMENT

- CHIME and LSTM provide **complementary information** on water conditions.
- Different Earth Observation data can help us **understand changes in water conditions**.
- Observed **anomalies do not directly indicate a water discharge**.
They can show **unusual patterns** or changes **in water quality** that require further investigation and analysis.

Future CHIME and LSTM observations can support environmental monitoring and further investigations, including environmental crime applications.



European
Commission



United Nations
Office on Drugs and Crime



THANK YOU