

LandSeaLot Conference LAND-SEA 2026

Scientific challenges at the land-sea interface & research infrastructure

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What is a Research Infrastructure (RI) in Europe?

A long term, pan-European facility to provide services, data and expertise for research, innovation and society

Definition

A research Infrastructure (RI) is a facility, resource or service of strategic importance for the research communities, providing long-term access to data, services, infrastructure and expertise to address major scientific and societal challenges



Key characteristics



The ERIC legal framework

ERIC = European Research Infrastructure Consortium

A specific legal entity recognised by the European Union



A bridge between research, policy and society



Research Infrastructures

Enabling a connected observing system from rivers and estuaries to coastal seas



ICOS



CO₂

Examples in the environmental domain

A network of complementary RIs



RI for River-Sea Systems
From river source to sea



Joint European Research Infrastructure for Coastal Observation
Coastal seas and shelves regions

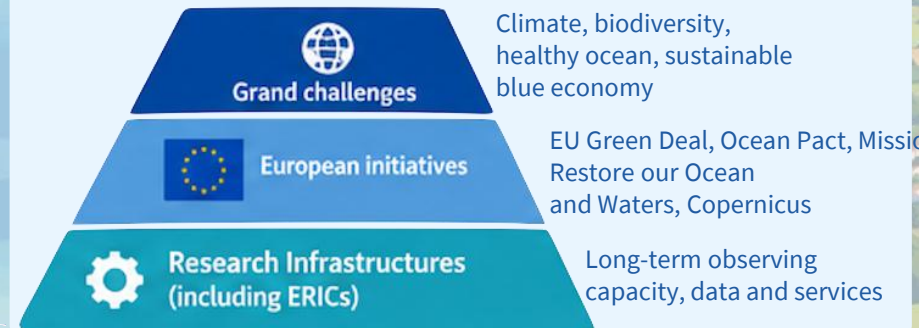
ICOS



Integrated Carbon Observation Systems
Atmosphere, terrestrial and marine carbon cycle

... and many others in Europe (EMSO, Euro-Argo, EMBRC, Elter...)

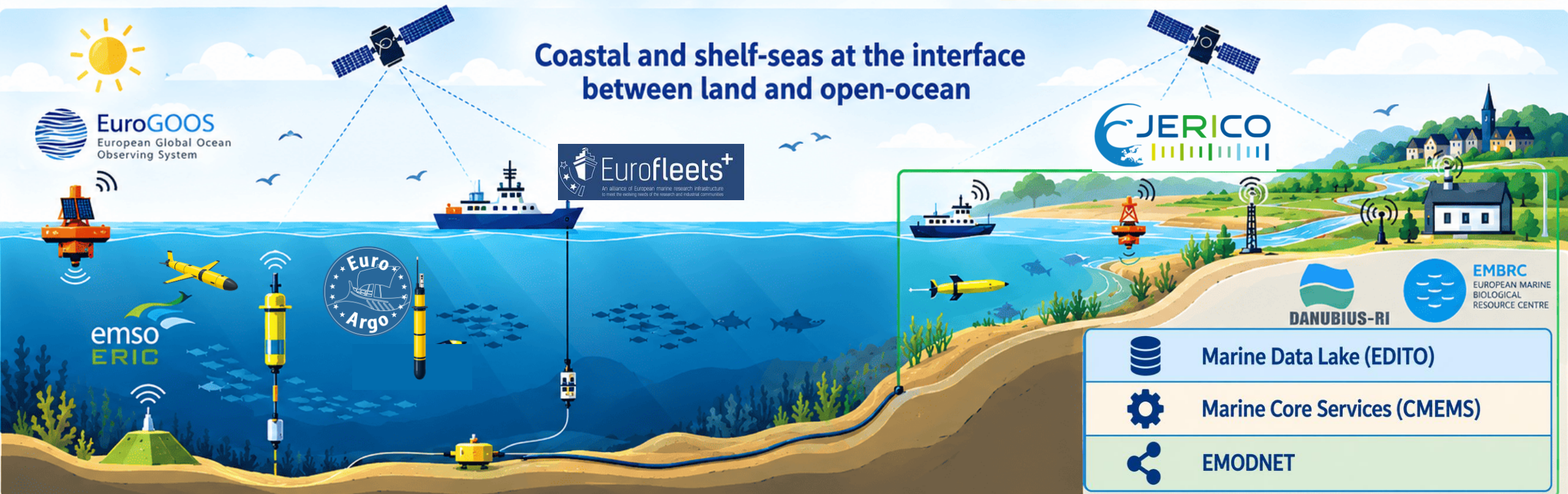
A key pillar of the European research landscape



The European ocean observation landscape

From global commitments to a coordinated European system

From global commitments to a coordinated European system



LandSeaLot societal challenges

Towards healthy and resilient coastal systems for people, climate and nature



Assess lateral carbon fluxes and marine carbon stocks

Quantify carbon pathways, transformations and storage from land to sea



Predict and adapt to climate change threats

From storm surges, floods and heat waves to coastal erosion and saltwater intrusion



Reduce land-based pollution and conserve biodiversity

Address nutrients, eutrophication, plastics and contaminants to protect coastal ecosystems



Support sustainable and resilient coastal communities

Better observations and models for anticipation, adaptation and informed decisions

KEY DRIVERS AND PRESSURES



Land-based inputs
Nutrients, plastics, contaminants, sediment, freshwater



Human activities
Urbanisation, industry, agriculture, maritime activities



Climate change
Sea level rise, storm surges, floods, heat waves, coastal erosion, saltwater intrusion



Ecosystem changes
Habitat loss, biodiversity decline, biogeochemical shifts



Societal demands
Food, energy, recreation, health and well-being

OUR AMBITION



CLEAN WATERS



HEALTHY ECOSYSTEMS



RESILIENT COASTAL COMMUNITIES



KNOWLEDGE FOR ACTION



Rivers & catchments
Freshwater, sediment, nutrients, carbon, plastics



Estuaries & transition zones
Mixing, transformations, fluxes, eutrophication



Coastal seas & human activities
Ecosystem health, biodiversity, multiple uses



Shelf & open ocean
Climate, biogeochemistry, physics, geohazards



The Land-sea interface: a complex and dynamic system

Multiple drivers, processes and feedbacks



Scientific challenges (1/2)

From key questions to solutions



1

Understand processes across extremes and gradients



How do natural and human drivers interact across the land-sea continuum and under extreme events?

- ▶ Freshwater-marine gradients
- ▶ Dynamic systems (tides, discharge, extremes)
- ▶ Multiple spatial and temporal scales

2

Close budgets across the continuum



How do we close the budgets of water, sediments, nutrients, carbon and contaminants?

- ▶ Sources and transformations
- ▶ Transport and fate
- ▶ Resolve sinks and retention
- ▶ Linkages across compartments (land-river-coast-sea)

3

Integrate heterogeneous observations



How can we integrate complementary observations across platforms and disciplines?

- ▶ In-situ and remote sensing (satellite, coastal, airborne)
- ▶ Interoperability and standardisation
- ▶ Multidisciplinary data integration
- ▶ Common methods and shared data services

4

From observations to prediction and decision support



How can we turn observations and knowledge into reliable predictions and actionable information?

- ▶ Data assimilation and modelling
- ▶ Early warning and scenario capacity
- ▶ Indicators and services for users
- ▶ Support for informed decisions and policies



From understanding to actionable knowledge



Harmonised observations



Interoperable data and models



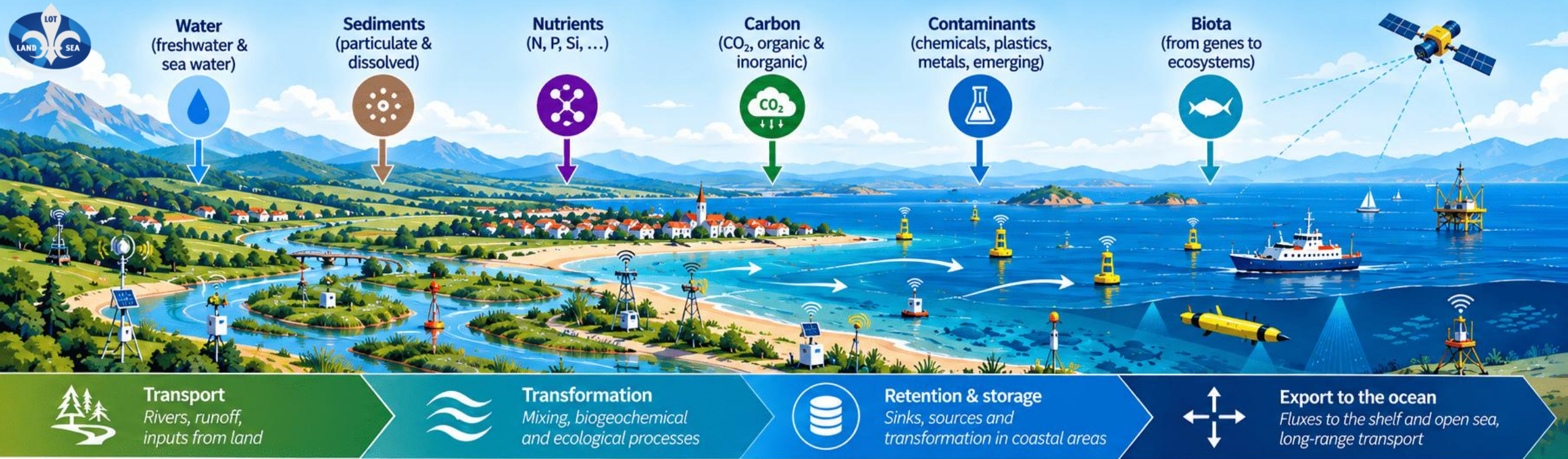
Co-design with users and stakeholders



Innovative solutions for healthy and resilient coastal systems

Scientific challenges (2/2)

From key questions to solutions



KEY SCIENTIFIC CHALLENGES

- 1 Quantify and monitor fluxes**
 - Measure fluxes of water, sediments, nutrients, carbon, contaminants and biota
 - Resolve variability from events to long term
 - Combine in-situ and remote observations
- 2 Understand transformations**
 - Link physical, biogeochemical and ecological processes
 - From compounds to ecosystems and services
 - Address multiple spatial and temporal scales
- 3 Identify thresholds and tipping points**
 - Detect early signals of change
 - Assess cumulative and multiple stressors
 - Improve understanding of resilience and recovery
- 4 Integrate across compartments**
 - Connect land, water column, seafloor and coastal ecosystems
 - Include biotic and abiotic interactions
 - Use harmonised, interoperable data and models
- 5 Support prediction and decision-making**
 - Develop observation-based indicators
 - Feed models and digital twins
 - Provide actionable information for coastal management and adaptation



From complex processes to actionable solutions



Harmonised observations



Integrated data and models



Co-design with users and stakeholders



Evidence for resilient coastal systems

Key variables to observe

A harmonized and interoperable set of essential variable



Rivers & catchments

Estuaries & transition zones

Coastal zone
(people & activities)

Shelf & open sea



Temperature

- ▶ Water, air, surface and deep layers
- ▶ Heat waves
- ▶ Thermal stratification



Dissolved oxygen

- ▶ Oxygen levels
- ▶ Hypoxia events
- ▶ Respiration & biogeochemical processes



Turbidity / SPM

- ▶ Suspended particulate matter
- ▶ Sediment transport
- ▶ Water clarity



Nutrients (N, P, Si, ...)

- ▶ Concentrations and fluxes
- ▶ Eutrophication
- ▶ Sources and transformations



Chlorophyll-a & primary production

- ▶ Phytoplankton biomass
- ▶ Primary production
- ▶ Harmful algal blooms



DOC / CDOM & organic matter

- ▶ Dissolved and particulate organic carbon
- ▶ Origin, reactivity
- ▶ Land-sea exchanges



pH & acidification

- ▶ pH, pCO₂
- ▶ Ocean acidification
- ▶ Impacts on calcifying organisms



Biota (from genes to ecosystems)

- ▶ Phytoplankton, zooplankton, fish, benthos
- ▶ Biodiversity & ecosystems
- ▶ Invasive species
- ▶ Ecosystem health indicators (omics, eDNA)



Contaminants (chemical & emerging)

- ▶ Metals, POPs, nutrients
- ▶ Pharmaceuticals, pesticides, microplastics
- ▶ Sources, pathways, accumulation



Physical forcing

- ▶ Currents, waves, tides, sea level
- ▶ Mixing, stratification
- ▶ River discharge
- ▶ Atmospheric forcing (wind, pressure, heat)

ADDITIONAL PARAMETERS



Salinity



Precipitation



Wind



Air temperature



Atmospheric pressure



River discharge



Bathymetry



Sea state



Sea ice (where relevant)



Particles (size & composition)



Underwater sound



Light / PAR



Other parameters (e.g. meteorological, biogeochemical)

CROSS-CUTTING DIMENSIONS



High temporal variability
(from events to long term)



High spatial heterogeneity
(from local to regional)



Multi-platform observations
(in-situ, remote, models)



Interoperable and FAIR data
(common standards)



Essential for models, services and decision-making

Integrating observations: scale and representativity

Complementary strengths, persistent gaps



In-situ observations

High accuracy and process understanding

- ▶ Point measurements
- ▶ High frequency
- ▶ Vertical coverage
- ▶ Process understanding
- ▶ Cal/val for models and satellites



Earth observation

Wide spatial coverage and synoptic view

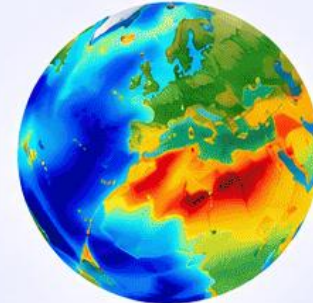
- ▶ Large-scale coverage
- ▶ Regular, repeated observations
- ▶ Multiple variables (ocean, land, atmosphere)
- ▶ Identify patterns and extremes
- ▶ Assess spatial representativity



Models

From data to integrated knowledge

- ▶ Spatially continuous
- ▶ Scenario capability
- ▶ Process representation
- ▶ Data assimilation
- ▶ Predictive capacity
- ▶ Explore future scenarios
- ▶ Assess uncertainty



Local scale
(m – km)

Regional scale
(10 – 100 km)

Basin scale
(100 – 1,000 km)

European to global scale
(> 1,000 km)



PERSISTENT GAPS AND CHALLENGES



Temporal gaps

- ▶ Extreme events
- ▶ Long-term continuity



Spatial gaps

- ▶ Coastal-offshore transitions
- ▶ Under-sampled regions



Methodological gaps

- ▶ Interoperability
- ▶ Harmonisation of products



Integration gaps

- ▶ From observations to knowledge
- ▶ Linking in-situ, satellite and models



User needs

- ▶ Fit-for-purpose indicators
- ▶ Decision-relevant information



From fragmented data
to an integrated observing system



Complementary
observations
in-situ, satellite, models



Interoperable
data and products
common standards (FAIR)



Improved representativity
across scales and compartments



Actionable knowledge
for a sustainable
land-sea interface



The current reality: a fragmented observing landscape

Many data, but still barriers to full integration



Multiple platforms

- Fixed stations, buoys, coastal stations, HF radars, FerryBox, gliders, research vessels, sea-floor observatories, satellites



Multiple communities

- Research infrastructures, national networks, operational services, and thematic projects



Different data flows

- In situ, remote sensing and models
- with heterogeneous repositories, formats, standards and access conditions



Diverse governance

- Different mandates and funding models, with coordination often project-based rather than sustained



- Fixed station (coastal/offshore)
- Moored buoy
- Coastal station / tide gauge
- ▲ HF radar
- ▲ FerryBox (ships of opportunity)
- ▲ Glider / AUV
- Research vessel
- Sea-floor observatory
- Satellite (ocean colour, altimetry, etc.)
- EEZ (indicative)
- Regional sea conventions (e.g. OSPAR, HELCOM, Barcelona, Black Sea)

Fragmentation and gaps

- Weak integration across the land-sea continuum (river-estuary-coastal-marine)
- Limited coupling across processes and domains (sediments, biodiversity, nutrients, carbon, hazards)
- No harmonised Essential LSI Variables and ontologies
- Limited machine-actionable interoperability (heterogeneous repositories, formats and standards)
- EO products widely used but not structurally integrated via sustained Cal/Val pipelines
- Fragmented and project-based governance (rather than sustained cross-RI mechanisms)
- Uneven spatial and temporal coverage of observations across European LSI



Coastal stations
Water level, waves, meteo, water quality



Moored buoys
Meteorology, waves, currents, biogeochemistry



FerryBox
High-frequency, long-term coastal observations



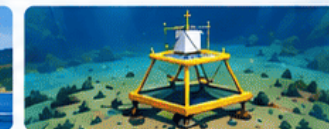
HF radars
Surface currents, waves, sea state



Gliders & AUVs
Water column, biogeochemistry, biology



Research vessels
Multi-parameter observations, process studies



Sea-floor observatories
Long-term, multi-parameter time series



Satellites
Ocean colour, SST, sea level, large-scale coverage

The main gap is not observation capacity —



Need for interoperability, harmonisation and



Interoperable data and open access



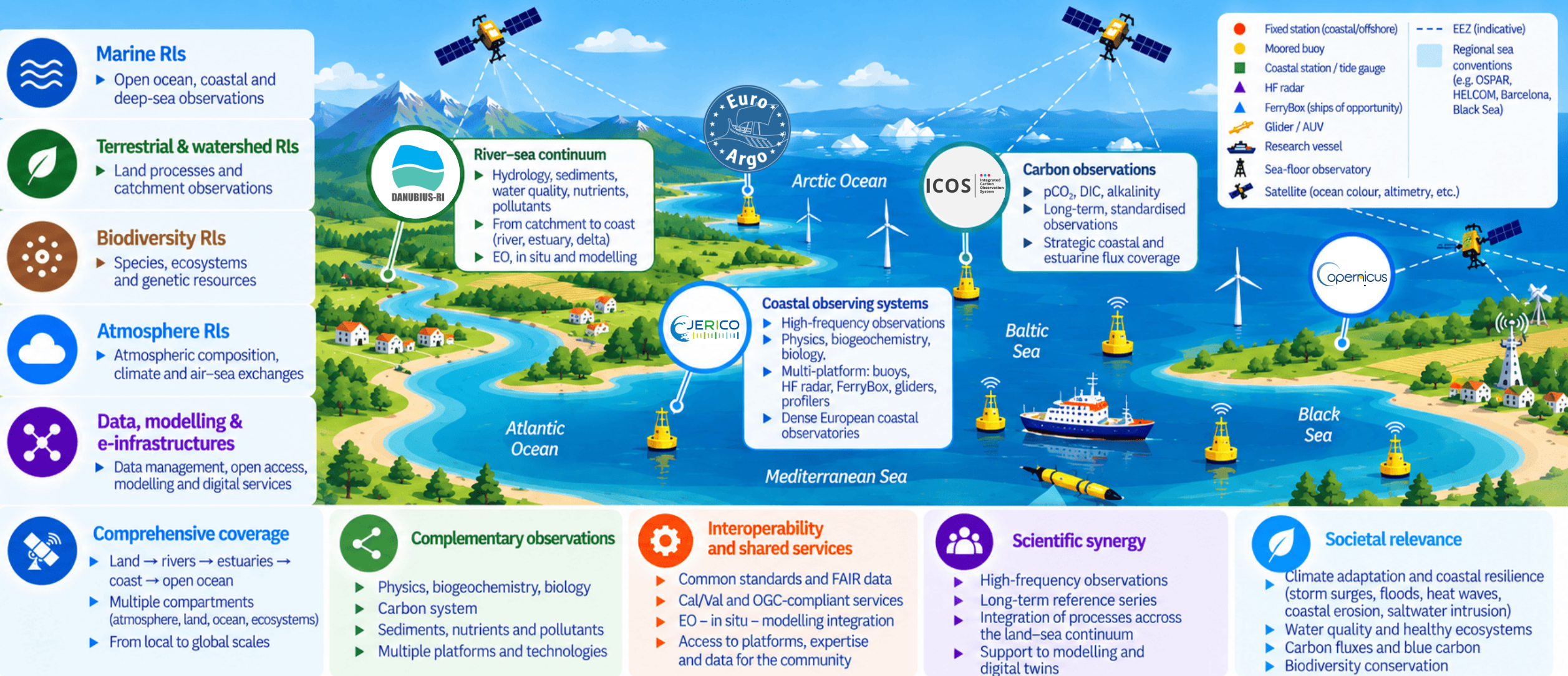
Towards a coordinated



To fully exploit observations

The contribution of European Research infrastructures

A complementary network for integrated land – sea observations



A network of European RIs for a holistic view of the land-sea system



From national observations to a European capability



Interoperable data and open access (FAIR)



Stronger together: complementary strengths and shared services



Knowledge for a healthy and resilient ocean and society



Priorities to maximise the RI contribution

From observations to impact for a healthy and resilient land-sea system



1

Strengthen integration and interoperability

- ▶ Common standards and FAIR data
- ▶ Link in-situ, satellite and models
- ▶ Interoperable services and data infrastructures (e.g. EOSC, EMODnet)



2

Address land-sea continuum as a whole

- ▶ Connect river catchments, coasts and open ocean
- ▶ Observe key fluxes and processes
- ▶ Harmonise observations across compartments and RIs



3

Consolidate long-term, sustainable observations

- ▶ Maintain and upgrade core observing networks
- ▶ Ensure long-term funding and operational capacity
- ▶ Support innovation and new technologies (e.g. gliders, eDNA, HF radar)



4

Enhance synergies across RIs and communities

- ▶ Coordinate RI strategies and roadmaps
- ▶ Share expertise, platforms and services
- ▶ Foster cross-disciplinary and cross-sector collaboration



5

Increase societal relevance and user engagement

- ▶ Co-design with stakeholders
- ▶ Develop fit-for-purpose products and indicators
- ▶ Support policy, blue economy, climate adaptation and biodiversity protection



6

Build a resilient and sovereign European capacity

- ▶ Strategic autonomy in key technologies
- ▶ Human capital, skills and innovation
- ▶ Robust, open and trusted European RI ecosystem



Rivers & catchments

Estuaries & transition zones

Coastal zone

Shelf seas

Open ocean



Working together to unlock the full value of European RIs



Integrated observations



Enhanced services



Greater societal impact



A more resilient and sustainable land-sea system

Conclusion

An integrated European observing capacity for a sustainable future



Key take-home messages



Integration is possible

A complementary network of RIs provides consistent, multi-platform observations across the land-sea continuum.



From data to impact

Open, interoperable data and services enable knowledge, innovation and evidence for decision-making.



Working together

Stronger coordination and synergies between RIs, communities and users maximise value and avoid duplication.



A sustainable and resilient Europe

An integrated observing capacity supports climate adaptation, biodiversity protection, a healthy ocean and thriving coastal regions.



**Together for a better understanding,
management and resilience of the land-sea interface**



Knowledge
for action



Healthy
ocean and coasts



Resilient
communities



A sustainable
and thriving Europe

No single infrastructure,
network or observing system
can capture
the complexity of the land–sea continuum.

Our strength lies in connecting them
from local observations to European Research
Infrastructures,
from land to sea,
and from observations to action.

LET'S OBSERVE TOGETHER!

Thank you



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observe
together!

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