

CONFERENCE PAPER

Ocean observation paradox: UNCLOS, climate change and the future plastics treaty

AuthorTihao Zeng¹

Preamble

The following work was presented at the 12th ABLOS Conference, 7–8 October 2025, Doha, Qatar in the oral session *Advances in ocean governance*.

Abstract

This paper explores the ocean observation paradox undermining global marine plastic governance. While the 2024 ITLOS Climate Change Advisory Opinion affirms a stringent due diligence obligation under UNCLOS Part XII to monitor transboundary pollution according to best available science, UNCLOS Part XIII structurally hinders these efforts. Continuous autonomous systems of ocean observation are physically essential to monitor plastics across the ocean but remain structurally incompatible with rigid coastal State consent regimes in the EEZ. Resolving this jurisdictional friction requires carving out certain ocean monitoring activities from traditional Marine Scientific Research. The emerging Plastics Treaty could embed pragmatic, notification-based exemptions to operationalize the science necessary for effective environmental compliance and litigation.

Keywords

ocean observation · plastic pollution · Plastics Treaty · marine scientific research · law of the sea · UNCLOS · GOOS

1 Introduction

Marine plastic pollution, intrinsically linked to the fossil fuel economy and climate change, has precipitated a severe global environmental crisis. Recognizing this, the 2024 Advisory Opinion by ITLOS affirmed that States possess a stringent due diligence to protect the marine environment using the best available science. Fulfilling this mandate requires continuous, coordinated ocean observation to track the pathways, degradation and accumulation dynamics of marine plastics. However, a profound legal paradox paralyzes these efforts: while UNCLOS Part XII demands proactive monitoring, the rigid Marine Scientific Research consent regimes of UNCLOS Part XIII actively hinder it. Because modern autonomous monitoring systems drift unpredictably across Exclusive Economic Zones, they are not well fit in with

static coastal State consent rules. To unpack this observation paradox, this paper first presents the plastics-climate nexus and evolving State due diligence obligations under ITLOS. It then establishes the scientific needs of the Integrated Marine Debris Observing System as a core tracking mechanism. Subsequent analysis highlights the jurisdictional friction between the physical realities of ocean boundary currents and states sovereignty. Finally, the paper evaluates Part XIII's administrative bottlenecks, particularly the six-month advance notification requirement and assesses pragmatic workarounds like the Argo examples, concluding with a

✉ Tihao Zeng · tihao.zeng@graduateinstitute.ch

¹ Université de Genève, Geneva, Switzerland

call for specific operational carve-outs together with the future Plastics Treaty to support emerging environmental litigation and compliance mechanisms.

2 Plastics production, pollution, and the climate nexus

The crisis of marine plastic pollution has precipitated a multifaceted global emergency, incrementally degrading marine ecosystems, endangering human health, and inflicting devastating socioeconomic costs. Plastics, defined technically as materials containing high polymers that can be shaped during processing, and often compounded with chemical additives (ISO, 2013, n.d.), dominate anthropogenic marine litter primarily due to their extreme environmental persistence. Driven by exponential production and inadequate waste management, these synthetic materials accumulate across all marine compartments, from coastlines and the sea surface to the pelagic water column and the deep seafloor. The scale of this accumulation is so vast that researchers refer to the present epoch as the 'Plasticene', marked by a distinct depositional layer of synthetic debris in the geological record (Haram et al., 2020).

Once in the marine environment, plastics undergo complex physical and chemical degradation, fragmenting from visible macroplastics into microplastics (particles smaller than 5 mm) and nanoplastics (Andrady, 2015). This fragmentation continuously releases both secondary plastic particles and embedded toxic additives into the surrounding ecosystem (Fotopoulou & Karapanagioti, 2017). The resulting ecological damage is twofold: macroplastics inflict direct physical trauma on marine megafauna through entanglement and ingestion, while micro- and nanoplastics infiltrate trophic webs. These microscopic particles act as vectors for persistent organic pollutants, transferring toxins through the food chain to human populations, correlating with severe health risks such as metabolic disorders and potential carcinogenic effects (UNEP, 2016, 2021, 2022b). Beyond these biological impacts, marine plastic pollution imposes catastrophic economic burdens, with global annual losses primarily devastating the fisheries, tourism, and maritime navigation sectors, which estimated between USD 6 billion and 19 billion in 2018 (UNEP, 2021).

This pollution originates from a complex matrix of land- and sea-based sources. Terrestrial leakage, exacerbated by the export of waste to regions with inadequate infrastructure, enters the ocean via surface runoff, riverine transport, wastewater discharges, and atmospheric deposition. Simultaneously, sea-based sources, notably abandoned, lost, or discarded fishing gear (ALDFG) accounts for approximately 10 % of floating marine debris, which directly pollutes critical habitats, particularly in fragile ecosystems like the Arctic (UNEP, 2021). Fundamentally, however, the material source of this pollution is inextricably linked to fossil fuel extraction and climate change. Global

plastic production, which doubled to 460 million metric tons between 2000 and 2019, is projected to nearly triple by 2060 (OECD, 2022). Because 99 % of synthetic plastics are derived directly from fossil feedstocks, their extraction and manufacturing account for immense greenhouse gas (GHG) emissions (UNEP, 2022b).

Consequently, plastic pollution functions as a potent threat multiplier, compounding climate-induced ecological stressors such as ocean acidification, warming, and sea-level rise. By degrading critical habitats like coral reefs and mangroves, plastic debris actively impairs ecosystem resilience, diminishing the natural capacity of coastal environments to withstand climate extremes (Deshpande et al., 2020; UNEP, 2021). Recognizing the indivisibility of these intertwined environmental crises, recent international jurisprudence has progressively interpreted treaty and customary obligations in light of climate change which is linked to the plastics crisis. In its landmark 2024 Advisory Opinion, the International Tribunal for the Law of the Sea (ITLOS) affirmed that anthropogenic greenhouse gases (GHGs) emissions constitute 'pollution of the marine environment' under the United Nations Convention on the Law of the Sea (UNCLOS) (ITLOS, 2024; UN, 1982, 2023). Crucially, ITLOS clarified that Part XII of UNCLOS imposes a stringent due diligence obligation upon States to mitigate such transboundary pollution using the 'best available science' (ITLOS, 2024; Ford et al., 2022; Qiu et al., 2025).

Given the climate-plastic nexus, fulfilling this stringent due diligence obligation requires regulatory means that transcend traditional, siloed sectoral boundaries (Hubert, 2023; IOC, 2021). Because marine plastic pollution is inherently diffuse and transboundary, effective governance relies globally upon robust, harmonized data collection. Consequently, there is a growing consensus among scientific and policy communities regarding the imperative for an integrated global observation system capable of tracking plastic flows systematically across atmospheric, terrestrial, aquatic, and biological compartments (Bank et al., 2021). Deploying such a systemic framework is essential to establish the statistical baselines required to quantify the crisis, attribute pollution to specific sources, and evaluate the efficacy of mitigation strategies (Maximenko et al., 2021; Rayner et al., 2019). Ultimately, sustained and standardized ocean observation serves as the scientific foundation upon which all coordinated international marine governance must be built.

3 Scientific and physical bases of ocean observation for plastics

Before analyzing the legal regimes applicable to ocean observations, it is helpful to first understand its physical and technical basis. Some definitional clarifications are conducive to delineate the scope of discussion. In a narrow technical sense, ocean

observation refers to the routine collection of oceanographic data across all maritime zones, capturing parameters such as temperature, pressure, currents, salinity, and wind (Roach, 2007). Seen more broadly, for example the EuroSea initiative conceptualizes ocean observation as a holistic ‘value chain of marine knowledge’ (Jolly et al. 2021; Reilly et al., 2022). In this framework, observation is not merely the extraction of raw data, but a fully integrated system connecting the initial deployment of platforms and sensors to modeling, forecasting, and the delivery of end user services. In practice, the term ocean observation usually encompasses this entire cycle of measurement, analysis, and data dissemination designed to foster economic value in the blue economy and deliver essential information for sustainable development (Wegelein, 2005; Yu, 2022a; Reilly et al., 2022). Within this context, *data* denotes the unprocessed factual representations of the physical world, whereas *information* refers to the analyzed and interpreted forms of data that are utilized by end users such as governments, port authorities, and environmental agencies, in order to guide governance, mitigate risks, or enforce treaty compliance (ITC, 2001; Reilly et al., 2022).

The ocean observing system worldwide is inherently decentralized, composed of multiple networks and platforms operated at global, regional, and national scales. Conceptually, it functions as an integrated framework comprising inputs based on societal or scientific demands (such as climate obligations or treaty requirements), observing processes executed by various platforms and sensors, and outputs delivered as data products, trend indicators, and hotspot alerts (IOC Task Team, 2012). Despite those observing platforms are fragmented across different jurisdictions and institutions, their activities are increasingly managed as integrated systems to maximize efficiency, avoid duplication, and ensure cross-domain coverage of physical, biogeochemical, and biological variables (Tanhua et al., 2019).

A central coordinating body is the Global Ocean Observing System (GOOS), established in 1991 under the Intergovernmental Oceanographic Commission (IOC) of UNESCO. Supported by partnerships with the World Meteorological Organization (WMO) and the Group on Earth Observations (GEO), GOOS defines standards, sets observing priorities, and coordinates a vast network of ship-based, fixed-point, and autonomous platforms globally. According to the GOOS Status Report 2025, the system’s recent expansion has been heavily driven by technological innovations in autonomous networks, such as the Argo profiling array, which now exceeds 4,000 active floats, and the integration of emerging platforms like uncrewed surface vehicles. These autonomous advancements help offset declines in traditional ship-based observations caused by global budget constraints, while new public-private partnerships, such as the ‘10,000 Ships for the Ocean’ initiative,

increasingly leverage the commercial maritime industry to expand observing capacity (GOOS, 2025). The concerned activities should be considered as part of GOOS ‘as long as the sampled data and the products and forecasts are distributed rapidly’ to end users such as business, government, or regulatory authorities (Bork et al., 2008).

Despite these ongoing advancements and the active integration of biological and ecosystem variables, GOOS reports that the global network remains structurally ‘subcritical’. The system possesses limited resilience to financial or geopolitical disruptions, depends heavily on a few major state contributors, and suffers from critical supply chain vulnerabilities. Introducing the tracking of marine plastic pollution into this already fragile framework presents unique physical, biological, and chemical complexities that challenge traditional oceanographic monitoring (Ryder, 2003; GOOS, 2025). Marine debris varies significantly in its chemical composition, encompassing diverse polymers and additives, as well as in physical properties such as size, shape, and buoyancy. Crucially, approximately 50 % of commercial plastics, such as polyethylene terephthalate (PET) and polyvinyl chloride (PVC), are intrinsically heavier than seawater and sink to the seafloor, effectively eluding surface monitoring. Furthermore, even buoyant microplastics are notoriously difficult to accurately quantify. Standard surface net tows typically capture only the top one meter of the water column, missing deeper layers where plastics are drawn down by biological aggregation, biofouling, and physical processes such as Langmuir circulation. Because of these highly variable transport and degradation dynamics, an estimated 66.7 % of ocean plastics remain currently unmonitable under existing observation frameworks (Isobe & Iwasaki, 2022).

To overcome this fragmentation and bridge the massive data gaps in plastics monitoring, GOOS, GEO Blue Planet, and UNEP Global Partnership on Plastic Pollution and Marine Litter (UNEP-GPML) have jointly proposed the Integrated Marine Debris Observing System (IMDOS, 2023, 2025). IMDOS operates as an overlay designed to harmonize existing, disparate observation networks’ data into a coherent and interoperable framework. This integration includes modelling, *in situ* observations such as water-following drifters and subsurface Argo floats that mimic the vertical movement of debris in pelagic ecosystems, with the synoptic, broader capabilities of remote sensing satellites as well as citizen science. These automated data streams are further augmented by numerical models that optimize field observations and citizen science initiatives, which expand contributions from coastal communities. Given that plastic waste accounts for more than 80 % of the total marine debris, IMDOS acts as a core system in addressing marine plastic pollution (Maximenko et al., 2019; Maximenko et al., 2021). To operationalize this mission, the IMDOS Steering Committee recently

formalized eleven dedicated Task Teams spanning thematic data collection, technical coordination, and policy engagement (GEO Blue Planet, 2025).

Following the recent second part of the fifth session of the Intergovernmental Negotiating Committee to develop an international legally binding instrument on plastic pollution, including in the marine environment (INC-5.2) negotiations, an important direction for monitoring emphasizes a comprehensive life-cycle approach divided into three complementary streams: plastics in the economy (production and trade), plastics in waste (collection and recycling), and plastics in the environment. While IMDOS is most directly relevant to the environmental monitoring stream in specifically addressing marine leakages, its efforts must be designed in close coordination with economic and waste monitoring. This ensures data interoperability across the full plastic life cycle through harmonized indicators, comparable units, and integrated datasets routed through centralized hubs like the UNEP-GPML digital platform. To solidify this role, IMDOS has established a dedicated 'UN Global Plastics Treaty' Task Team (TT10) aimed at actively engaging the INC process, positioning IMDOS as the unified system for marine debris monitoring methodologies, and encouraging the creation of a centralized repository aligned with the treaty's objectives. However, a critical hurdle remains: IMDOS currently operates without a clear legal mandate from an international commitment or an UN organization, making the acquisition of such a mandate and sustained financial commitments a priority for effective treaty implementation (GEO Blue Planet, 2025).

The operational backbone of this integration is the Essential Ocean Variables (EOVs) developed by GOOS. EOVs are defined as the minimal, agreed-upon set of variables whose sustained measurement is indispensable for understanding ocean changes and informing policy (IOC Task Team, 2012). As the emerging plastics treaty ambitions to address the full life cycle of plastics, ocean observation systems must trace both upstream inputs and downstream impacts (UNEP, 2022). To achieve this, a dedicated Marine Plastics EOV is currently at the pilot stage under the guidance of GOOS and IMDOS. The EU-funded EuroSea project (Deliverable D1.5) formally conceptualizes this as 'the first in a new class of EOVs which help the GOOS address the need to monitor human impacts' rather than strictly natural phenomena (Palacz et al., 2022). Deliverable D1.5 provides the foundational EOV Specification Sheet, establishing a Common Sampling Protocol (CSP) aligned with GESAMP Working Group 40 guidelines that augments existing ocean observing approaches to elevate the readiness level of marine debris monitoring globally (EuroSea, 2022; GESAMP, 2019). The scope of this EOV encompasses specific sub-variables, including floating macroplastic patches, size-fractioned microplastics, shoreline litter, seafloor debris, plastics in biota, and polymer identification

through chemical markers.

Beyond the dedicated Marine Plastics EOV, effective monitoring requires the adaptation of existing biological, biogeochemical, and physical variables. Within the Biogeochemistry EOV for Particulate Matter, microplastics are now actively conceptualized as a subclass of suspended particulate matter (Erni-Cassola et al., 2024). Established sampling techniques for particulate organic and inorganic matter such as optical sensors are being adapted to include plastic particle counts, mass, and polymer composition (Othman et al., 2023). Simultaneously, remote sensing under the Ocean Colour EOV is contributing to macroplastic observation. Recent studies utilizing Sentinel-2 and Landsat high-resolution multispectral imagery have demonstrated that aggregated floating macroplastic patches can be detected using spectral unmixing techniques (Papageorgiou et al., 2022; Cerra et al., 2025). Finally, mature physical EOVS such as surface and subsurface currents, wind stress, sea state, sea surface height, and sea-ice extent, remain highly relevant, as they directly govern the transport pathways, degradation dynamics, and accumulation zones of plastics across the global ocean (Maximenko et al., 2019; Maximenko et al., 2021; EuroSea, 2022).

4 UNCLOS and Part XII obligations

UNCLOS Part XII establishes the comprehensive framework for marine environmental protection. Article 192 imposes a general, overarching obligation on all States to protect and preserve the marine environment. This is operationalized through Article 194, which mandates States to take all measures necessary to prevent, reduce, and control pollution from 'any source'. The general obligation of Article 192 is further accompanied by two main categories of procedural obligations: cooperation (Articles 197–201) and monitoring and assessment (Articles 204–206). To ensure compliance and understand environmental impacts, Articles 204 and 206 specify the requirements for States to continuously monitor the risks and effects of pollution and to conduct environmental impact assessments (EIA) when there are reasonable grounds to believe planned activities may cause substantial pollution or significant harmful changes (Dupuy & Viñuales, 2018).

According to Article 1(1)(4) of UNCLOS, 'pollution of the marine environment' is defined as the introduction by humans, directly or indirectly, of substances or energy into the marine environment that results in deleterious effects. In its 2024 Advisory Opinion (Case No. 31), the ITLOS broke this definition down into three cumulative criteria: (1) identification of a substance or energy; (2) introduction by humans; and (3) actual or likely harm. Relying extensively on the 'best available science' from the Intergovernmental Panel on Climate Change (IPCC), particularly the Sixth Assessment Report (AR6) and the Special Report on the Ocean and Cryosphere (IPCC, 2019, 2023), the

Tribunal determined that anthropogenic GHGs constitute marine pollution. Accordingly, ITLOS ruled that Article 194 imposes a stringent due diligence obligation on States to mitigate such pollution, emphasizing that necessary measures must be determined objectively based on the best available science (ITLOS, 2024). This conveys a clear message: protecting the marine environment from complex, transboundary stressors require proactive, science-based governance (Hubert, 2023).

The ITLOS precedent has profound implications for the governance of marine plastic pollution. As 99 % of synthetic plastics are derived from fossil fuels and their production is inextricably linked to GHG emissions, the stringent due diligence standard and the mandate to utilize the best available science directly apply to regulating the full life cycle of plastics. To fulfill their due diligence obligations under Part XII, States are legally obliged to cooperate in good faith to implement robust ocean observation systems that generate baseline, attribution, and compliance data. Integrating new marine technologies for ocean observations, such as smart sensors, remote satellite imaging, and autonomous underwater vehicles (AUVs), may increasingly be understood as a necessity to meeting this due diligence and cooperation obligation.

However, deploying these observing elements raises jurisdictional friction. While States are mandated to monitor pollution under Part XII, Marine Scientific Research (MSR) under UNCLOS Part XIII remains subject to strict coastal State consent regimes, balancing research freedom with coastal sovereignty (Caflisch & Piccard, 1978; Stephens & Rothwell, 2016). The physical reality of ocean dynamics exacerbates this legal uncertainty. Exclusive Economic Zones (EEZs) and continental shelves encompass approximately 40 % of the global ocean, yet their scientific importance regarding plastic transport is disproportionately high. Much of the ocean's flow is physically constrained by the bottom and lateral topography found within these margins. Furthermore, due to the Earth's rotation, the strongest near-surface flows are concentrated at western boundaries, while critical upwelling zones and the primary sources of terrestrial run-off (and thus, plastic pollution) dominate eastern boundaries (Ryder, 2003).

Because oceanographic events and pollutant transport operate across multiple cycles of variability that are entirely unconstrained by maritime boundaries, conducting comprehensive marine monitoring is physically impossible without sustained access to these coastal domains. While Part VII of UNCLOS preserves MSR as a freedom on the high seas, monitoring activities within the EEZ are strictly subject to the Part XIII consent regime. Nevertheless, interpretation of and the interaction between Part XII and Part XIII has been discussed in this context (Hubert, 2023).

5 Ocean observation for plastics and marine scientific research

While UNCLOS Part XIII establishes the global regime for MSR, the Convention notably fails to define the term 'marine scientific research' itself (Caflisch & Piccard, 1978; Stephens & Rothwell, 2016). This seemingly intentional ambiguity is a product of compromise during the Third UN Conference on the Law of the Sea that has generated persistent friction between coastal States and researching States (Birnie, 1995). Coastal States generally favor a broad interpretation that subjects most data collection activities in the EEZ to the consent regime of Article 246, viewing them as potentially related to natural resources or national security (Roach & Smith, 2012). Conversely, researching States often distinguish between 'pure' scientific inquiry and 'applied' research, arguing that the routine, automated monitoring of the marine environment falls under the distinct category of operational oceanography and thus outside the restrictive scope of Part XIII entirely (Stephens & Rothwell, 2016; Yu, 2022a).

While Article 243 encourages States and international organizations to cooperate to create favorable conditions for MSR, the core legal obstacle to an integrated global observation system remains the consent regime. Under Article 245, coastal States have exclusive rights to regulate MSR in the territorial sea. In the EEZ and on the continental shelf, Article 246(2) stipulates that MSR shall be conducted with the consent of the coastal State. While this consent should, in 'normal circumstances', be granted for peaceful research (Article 246(3)), coastal States retain the discretion to withhold it if the research is of direct significance for the exploration and exploitation of natural resources (Article 246(5)(a)). Because tracking marine plastics and climate variables relies on continuous, long-term time-series data, this static, project-by-project consent model is operationally ill-suited (Ryder, 2003). The bureaucratic delays inherent in seeking diplomatic clearance for every sensor or float entering a foreign EEZ create massive spatial and temporal gaps in global datasets (Roach & Smith, 2012).

This operational challenge is acutely exemplified by the European Global Ocean Observing System (EuroGOOS), which coordinates monitoring activities across the highly fragmented maritime jurisdictions of the European seas. Because UNCLOS provides no distinct legal exemption for routine operational oceanography, EuroGOOS members face significant legal precarity when deploying autonomous technologies, such as underwater gliders. These autonomous platforms are essential for tracking transboundary pollutants, such as marine plastic debris, across transition regions between open oceans and shelf seas. However, their unpredictable drift patterns inevitably cross multiple maritime boundaries, rendering them fundamentally incompatible with existing static jurisdictional frameworks. Recent assessments from the EuroSea initiative shows that this incompatibility is

further exacerbated by the fact that Member States possess 'no explicit requirement for consistent interpretation and implementation of international rules' regarding ocean observation (van Doorn & Veloso, 2023). It emphasized that the primary operational bottleneck is UNCLOS Article 248, which requires researching States to submit detailed information to seek coastal State consent at least six months in advance of an observing campaign within a foreign EEZ. Furthermore, if a coastal State does not react by the day the project commences, UNCLOS Article 252 dictates that consent is merely implied, a mechanism that creates 'unnecessary unpredictability for planning marine scientific research' for unpredictably drifting autonomous fleets (van Doorn & Veloso, 2023). To resolve this administrative friction, EuroSea advocates for a harmonized EU-level ocean observing policy, applying the principle of subsidiarity. Specifically, this includes the adoption of standardized clearance request forms and the establishment of a centralized Marine Scientific Research Clearance Office in each Member State, which could act as a single point of contact to effectively compress the diplomatic clearance timeframe from six months to a single month (van Doorn & Veloso, 2023).

Historically, the international scientific community has attempted to bypass these bottlenecks through non-legally binding instruments. Recognizing the incompatibility of Part XIII with free-floating equipment, the IOC and its Advisory Body of Experts on the Law of the Sea (ABE-LOS) formulated Draft Practical Guidelines aiming to build mutual trust through notification procedures for profiling floats (IOC, 1999). While providing certain stability and clarity, these guidelines remain incomplete: they omit emerging technologies like gliders, fail to regulate devices drifting from one foreign EEZ directly into another, and ultimately still build upon the restrictive UNCLOS Part XIII consent regime (Bork et al., 2008). An alternative legal pathway is the application of UNCLOS Article 247, which provides a simplified, implied consent regime for MSR conducted under the auspices of a competent international organization like the IOC. Yet, applying mandatory six-month advance notification and four-month no-objection period to individual, unpredictably drifting platforms remains highly impractical (IOC, 2005). To function effectively for autonomous fleets, this notification timeline would need to apply to an overall project's inception rather than individual float border-crossings. Ultimately, as historical debates over the Ocean Data Acquisition Systems (ODAS) Draft Convention demonstrated, UNCLOS Part XIII was simply not designed for autonomous ocean observation platforms, leaving their legal governance firmly anchored in uncertainty (Bork et al., 2008). Despite the critical global need for operational oceanography to track climate change and transboundary plastic pollution, coastal States remain reluctant to modify the existing MSR consent regime, leaving the legal governance of autonomous ocean

observation platforms in uncertainty.

Nevertheless, the 'Argo approach' offers a pragmatic legal precedent for the future. The Argo program, which maintains thousands of profiling floats globally, operates under IOC Resolution XX-6. It utilizes a notification scheme rather than a strict consent mechanism: researching States notify coastal States of deployments, and if a float drifts into an EEZ, the coastal State can request that data be withheld from the public domain or shared only with them (Ryder, 2003; Yu, 2022b). This approach balances the 'due regard' obligation of Article 58 with the scientific imperative for global coverage. For marine plastics observation, adopting a similar 'notification and transparent data' framework, potentially to be formalized under the new Plastics Treaty or subsequent decisions, could legitimize the use of IMDOS assets in EEZs without abrogating coastal State rights (Stephens & Rothwell, 2016). The routine, automated collection of oceanographic data using autonomous platforms is arguably distinct from traditional MSR (Ryder, 2003; Yu, 2022a). Yet, while frameworks like WMO Resolution 45 (Cg-18; WMO, 2019) support the free operation of certain observing platforms in the EEZ by excluding meteorological tracking from the Part XIII regime, the legal boundary for environmental and plastic tracking remains highly blurred (Yu, 2022b). Furthermore, as the deployment of Maritime Autonomous Surface Ships (MASS) and AUVs expands for pollution tracking, clarifying their legal status and navigational rights under UNCLOS is essential (Venancio, 2025; Xing, 2024; Zou & Telesetsky, 2021). Addressing these jurisdictional ambiguities is paramount, as continuous, unhindered ocean observation is the foundational mechanism through which States can actually operationalize their environmental due diligence obligations under UNCLOS.

6 Conclusion

Sustained and standardized ocean observation serves as the indispensable scientific foundation upon which coordinated marine governance of marine plastics could effectively take place. As this paper has demonstrated, the physical complexities of marine plastic pollution demand a continuous, globally integrated monitoring framework like the IMDOS. Yet, the efficacy of such systems is severely compromised by the legally stringent consent regime of UNCLOS Part XIII. The coastal State consent, particularly the six-month advance notification requirement under Article 248, is operationally incompatible with the unpredictable drift patterns of autonomous gliders and profiling floats essential for modern oceanography (Bork et al., 2008). Consequently, the international community is caught in an observation paradox: legally compelled by Part XII and the ITLOS due diligence standard to monitor transboundary pollution, yet legally restricted from accessing the critical 40 % of the ocean contained within the EEZ.

Beyond informing international policy, the data

generated by these observation systems serves as evidentiary ground for emerging environmental litigations. In the realm of climate change, recent judicial decisions including that of the ITLOS as well as by several domestic courts rely extensively on the 'best available science' compiled by the IPCC. This reliance on empirical data is now extending to a rapidly growing wave of plastics litigation, where stakeholders increasingly seek to hold States accountable for due diligence failures and corporate entities liable for ecological harm and public nuisance (Beresford et al., 2022). Currently, such litigation is heavily constrained by the scientific difficulty of proving complex causation and source attribution within dynamic ocean currents (Swiss Re, 2025). But advancements have been made. For example, the Court of Appeal of Rouen unprecedentedly convicted a vessel of marine pollution based solely on satellite detection in 2025 (CLS, 2025; FNE, 2025). By tracing the lifecycle

pathways of polymers from terrestrial leakage to pelagic sinks and precisely quantifying microplastic accumulation, an unhindered observational framework like IMDOS would provide the objective metrics necessary to attribute transboundary harm, establish legal liability, and enforce compliance.

Resolving this friction requires moving beyond the rigid interpretation and application of MSR. While existing workarounds like UNCLOS Article 247 remain impractical for free-floating platforms, the 'Argo approach' based on deployment notification and transparent data sharing rather than explicit prior consent may prove pragmatic for a broader application. As negotiations for the Global Plastics Treaty continue, policymakers must embed specific legal carve-outs for operational ocean monitoring, ensuring that the rigid jurisdictional limits of the 20th century do not blind the science required to save the oceans in the 21st.

References

- Andrady, A. L. (2015). Persistence of plastic litter in the oceans. *Marine Anthropogenic Litter*, 57–72. Springer.
- Bank, M. S., Swarzenski, P. W., Duarte, C. M., Rillig, M. C., Koelmans, A. A., Metian, M., Wright, S., Provencher, J. F., Sanden, M., Jordaan, A., Wagner, M., Thiel, M. and Ok, Y. S. (2021). Global plastic pollution observation system to aid policy. *Environmental Science & Technology*, 55, 7770–7775. <https://doi.org/10.1021/acs.est.1c00818>
- Beresford, N., Brook, N., Carrigan, D., Haas, K., Kassing, D., Pies, C., Studdert, J. and Verdam, H. (2022). *The price of plastic pollution: Social costs and corporate liabilities (Annex 2: Liability risks arising from the manufacture, distribution, use and disposal of plastics)*. Minderoo Foundation. <https://cdn.minderoo.org/content/uploads/2022/10/13131231/The-Price-of-Plastic-Pollution-Annex-2.pdf> (last accessed 31 March 2026).
- Birnie, P. (1995). Law of the sea and ocean resources: Implications for marine scientific research. *International Journal of Marine and Coastal Law*, 10(2), 229–251.
- Bork, K., Karstensen, J., Visbeck, M. and Zimmermann, A. (2008). The Legal Regulation of Floats and Gliders—In Quest of a New Regime? *Ocean Development & International Law*, 39(3), 298–328. <https://doi.org/10.1080/00908320802235338>
- Caffisch, L. and Piccard, J. (1978). The legal régime of marine scientific research and the Third United Nations Conference on the Law of the Sea. *Zeitschrift für ausländisches öffentliches Recht und Völkerrecht*, 38, 848–901.
- Cerra, D., Auer, S., Baissero, A. and Bacher, F. (2025). Detection and Monitoring of Floating Plastic Debris on Inland Waters From Sentinel-2 Time Series. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 18, 1122–1138. <https://doi.org/10.1109/JSTARS.2024.3502796>
- CLS (2025). *A victory for the oceans: CLS expertise establishes a legal precedent*. CLS, for Earth from Space, Ramonville Saint-Agne, France. <https://maritime-intelligence.groupols.com/a-victory-for-the-oceans-marine-pollution-legal-precedent/> (last accessed 31 March 2026).
- Deshpande, P. C., Phillis, G., Brattebø, H. and Fet, A. M. (2020). Using Material Flow Analysis (MFA) to generate the evidence on plastic waste management from commercial fishing gears in Norway. *Resources, Conservation & Recycling*, 5, 100024. <https://doi.org/10.1016/j.rcrx.2019.100024>
- Dupuy, P.-M. and Viñuales, J. E. (2018). *International Environmental Law* (2nd ed.). Cambridge University Press.
- Erni-Cassola, G., Dolf, R. and Burkhardt-Holm, P. (2024). Microplastics in the water column of the Rhine River near Basel: 22 months of sampling. *Environmental Science & Technology*, 58 (12), 5491–5499. <https://doi.org/10.1021/acs.est.3c08364>
- FNE (2025). *Pollution maritime : Affaire Guardians la détection par satellite retenue comme nouveau moyen de preuve*. France Nature Environnement Normandie, Rouen, France. <https://www.fne-normandie.fr/2025/04/25/pollution-maritime-affaire-guardians-la-detection-par-satellite-retenu-comme-nouveau-moyen-de-preuve/> (last accessed 31 March 2026).
- Ford, H. V., Jones, N. H., Davies, A. J., Godley, B. J., Jambeck, J. R., Napper, I. E., Suckling, C. C., Williams, G. J., Woodall, L. C. and Koldewey, H. J. (2022). The fundamental links between climate change and marine plastic pollution. *Science of The Total Environment*, 806, 150392. <https://doi.org/10.1016/j.scitotenv.2021.150392>
- Fotopoulou, K. N. and Karapanagioti, H. K. (2017). Degradation of Various Plastics in the Environment. In H. Takada and H. K. Karapanagioti (Eds.), *Hazardous Chemicals Associated with Plastics in the Marine Environment* (Vol. 78, pp. 71–92). Springer International Publishing. https://doi.org/10.1007/698_2017_11
- GEO Blue Planet (2025). *1st IMDOS Steering Committee meeting: Meeting report*. https://geoblueplanet.org/wp-content/uploads/2024/10/250108-IMDOS-SC-meeting_report_vf.pdf (last accessed 31 March 2026).
- GESAMP (2019). *Guidelines for the monitoring and assessment of plastic litter in the ocean* (P. J. Kershaw, A. Turra and F. Galgani, Eds.). (Reports and Studies GESAMP No. 99). United Nations Environment Programme.
- GOOS (2025). *Global Ocean Observing System status report 2025* (GOOS Report No. 310). GOOS Secretariat, OceanOPS, GOOS Observations Coordination Group. <https://www.ocean-ops.org/goosreport/> (last accessed 31 March 2026).
- Haram, L. E., Carlton, J. T., Ruiz, G. M. and Maximenko, N. A. (2020). A Plasticene Lexicon. *Marine Pollution Bulletin*, 150,

110714. <https://doi.org/10.1016/j.marpolbul.2019.110714>
- Hubert, A.-M. (2023). Marine scientific research and the protection of the seas and oceans. In R. Rayfuse, A. Jaeckel and N. Klein (Eds.), *Research Handbook on International Marine Environmental Law* (pp. 385–408). Edward Elgar Publishing.
- IMDOS (2023). *Strategy Document*. Integrated Marine Debris Observing System. https://imdos.org/files/page_files/32/imdos-strategy-endorsednov23.pdf (last accessed 31 March 2026).
- IMDOS (2025). *Navigating the Global Plastics Treaty: The Role of IMDOS*. Integrated Marine Debris Observing System. <https://imdos.org/news/inc5-2> (last accessed 31 March 2026).
- IOC (1999). *The Argo Project* (Resolution XX-6). The Intergovernmental Oceanographic Commission (IOC) of UNESCO, Paris, France. <https://unesdoc.unesco.org/ark:/48223/pf0000120502> (last accessed 31 March 2026).
- IOC (2005). *Procedure for the application of Article 247 of the United Nations Convention on the Law of the Sea by the Intergovernmental Oceanographic Commission of UNESCO* (Annex to Resolution XXIII-8). The Intergovernmental Oceanographic Commission (IOC) of UNESCO, Paris, France. https://www.jodc.go.jp/info/ioc_doc/Governing/145407e.pdf (last accessed 31 March 2026).
- IOC (2021). *Ocean knowledge for a sustainable ocean economy: Synergies between the Ocean Decade and the outcomes of the Ocean Panel* (The Ocean Decade Series, 17; IOC/2021/ODS/17). The Intergovernmental Oceanographic Commission (IOC) of UNESCO, Paris, France. <https://unesdoc.unesco.org/ark:/48223/pf0000375969> (last accessed 31 March 2026).
- IOC Task Team (2012). *A Framework for Ocean Observing* (IOC/INF-1284 rev 2). The Intergovernmental Oceanographic Commission (IOC) of UNESCO, Paris, France. <https://unesdoc.unesco.org/ark:/48223/pf0000211260> (last accessed 31 March 2026).
- IPCC (2019). *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegria, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer, Eds.). Cambridge University Press. <https://doi.org/10.1017/9781009157964>
- IPCC (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, H. Lee and J. Romero, Eds.). IPCC. <https://www.ipcc.ch/report/ar6/syr/> (last accessed 31 March 2026).
- ISO (2013). *Plastics — Vocabulary* (ISO Standard No. 472:2013). International Organization for Standardization, Geneva, Switzerland. <https://www.iso.org/standard/44102.html> (last accessed 31 March 2026).
- ISO (n.d.). *ISO/TC 61: Plastics*. International Organization for Standardization, Geneva, Switzerland. <https://www.iso.org/committee/49256.html> (last accessed 31 March 2026).
- Isobe, A. and Iwasaki, S. (2022). The fate of missing ocean plastics: Are they just a marine environmental problem? *Science of the Total Environment*, 825, 153935. <https://doi.org/10.1016/j.scitotenv.2022.153935>
- ITC (2001). *Principles of Remote Sensing*. International Institute for Aerospace Survey and Earth Sciences.
- ITLOS (2024). *Request for an advisory opinion submitted by the Commission of Small Island States on Climate Change and International Law* (Advisory Opinion, Case No. 31). International Tribunal for the Law of the Sea, Hamburg, Germany.
- Jolly, C., Jolliffe, J., Postlethwaite, C., and Heslop, E. (2021). Value chains in public marine data: A UK case study. *OECD Science, Technology and Industry Working Papers*, No. 2021/11, OECD Publishing, Paris. <https://doi.org/10.1787/d8bbdcfa-en>
- Liblik, T., Karstensen, J., Testor, P., Alenius, P., Hayes, D., Ruiz, S., Heywood, K. J., Pouliquen, S., Mortier, L. and Mauri, E. (2016). Potential for an underwater glider component as part of the Global Ocean Observing System. *Methods in Oceanography*, 17, 50–82. <https://doi.org/10.1016/j.mio.2016.05.001>
- Maximenko, N., Corradi, P., Law, K. L., Van Sebille, E., Garaba, S. P., Lampitt, R. S., Galgani, F., Martinez-Vicente, V., Goddijn-Murphy, L., Veiga J. M., Thompson, R. C., Maes, C., Moller, D., Löscher, C. R., Addamo, A. M., Lamson, M. R., Centurioni, L. R., Posth, N. R., Lumpkin, R., Vinci, M., Martins, A. M., Pieper, C. D., Isobe, A., Hanke, G., Edwards, M., Chubarenko, I. P., Rodriguez, E., Aliani, S., Arias, M., Asner, G. P., Brosich, A., Carlton, J. T., Chao, Y., Cook, A.-M., Cundy, A. B., Galloway, T. S., Giorgetti, A., Goni, G. J., Guichoux, Y., Haram, L. E., Hardesty, B. D., Holdsworth, N., Lebreton, L., Leslie, H. A., Macadam-Somer, I., Mace, T., Manuel, M., Marsh, R., Martinez, E., Mayor, D. J., Le Moigne, M., Molina Jack, M. E., Mowlem, M. C., Obbard, R. W., Pabortsava, K., Robberson, B., Rotaru, A.-E., Ruiz, G. M., Spedicato, M. T., Thiel, M., Turra, A. and Wilcox, C. (2019). Toward the Integrated Marine Debris Observing System. *Frontiers in Marine Science*, 6, 447. <https://doi.org/10.3389/fmars.2019.00447>
- Maximenko, N., Palacz, A. P., Biermann, L., Carlton, J., Centurioni, L., Crowley, M., Hafner, J., Haram, L., Helm, R. R., Hormann, V., Murray, C., Ruiz, G., Shcherbina, A., Stopa, J., Streett, D., Tanhua, T., Wright, C. and Zabin, C. (2021). An integrated observing system for monitoring marine debris and biodiversity. *Oceanography*, 34(4), 52–59. <https://doi.org/10.5670/oceanog.2021.supplement.02-22>
- OECD (2022). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*. OECD Publishing, Paris.
- Othman, A. M., Elsayed, A. A., Sabry, Y. M., Khalil, D. and Bourouina, T. (2023). Detection of sub-20 µm microplastic particles by attenuated total reflection Fourier transform infrared spectroscopy and comparison with Raman spectroscopy. *ACS Omega*, 8(11), 10071–10081. <https://doi.org/10.1021/acsomega.2c07998>
- Palacz, A., Telszewski, M., Tanhua, T. and Heslop, E. (2022). *Marine plastics EOv and common sampling protocol* (EuroSea Deliverable D1.5). EuroSea. https://doi.org/10.3289/eurosea_d1.5
- Papageorgiou, D., Topouzelis, K., Suaria, G., Aliani, S. and Corradi, P. (2022). Sentinel-2 Detection of Floating Marine Litter Targets with Partial Spectral Unmixing and Spectral Comparison with Other Floating Materials (Plastic Litter Project 2021). *Remote Sensing*, 14(23), 5997. <https://doi.org/10.3390/rs14235997>
- Qiu, W., Wu, B. and Tai, T. H. (2025). Judicialization and legal implications of international maritime governance in the context of climate change: Insights from ITLOS Advisory Opinion No. 31. *Frontiers in Marine Science*, 12, 1640148. <https://doi.org/10.3389/fmars.2025.1640148>
- Rayner, R., Jolly, C. and Gouldman, C. (2019). Ocean observing and the blue economy. *Frontiers in Marine Science*, 6(330), 1–6.

- Reilly, K., Ros, S., MacManus, C., Manson, S., Cortes, J., Garcia, J. R. and Villa, J. (2022). *Report on economic value of ocean observations* (EuroSea Deliverable D8.6). EuroSea. https://doi.org/10.3289/eurosea_d8.6
- Roach, J. A. (2007). Defining scientific research: Marine data collection. In M. H. Nordquist et al. (Eds.), *Law, Science & Ocean Management* (pp. 541–574). Martinus Nijhoff Publishers.
- Roach, J. A. and Smith, R. W. (2012). *Excessive Maritime Claims* (3rd ed.). Martinus Nijhoff Publishers.
- Ryder, P. (2003). *A possible migration from marine scientific research to operational oceanography in the context of the United Nations Convention on the Law of the Sea (UNCLOS)*. Environmental Information Services.
- Stephens, T. and Rothwell, D. (2016). Marine scientific research. In D. Rothwell, A. Oude Elferink, K. Scott and T. Stephens (Eds.), *The Oxford Handbook of the Law of the Sea* (pp. 559–581). Oxford University Press.
- Swiss Re. (2025). *Plastics: a new wave of litigation?* Swiss Re Institute. <https://www.swissre.com/institute/research/sonar/sonar2025/plastics-new-wave-litigation.html> (last accessed 31 March 2026).
- Tanhua, T., McCurdy, A., Fischer, A., Appeltans, W., Bax, N., Currie, K., DeYoung, B., Dunn, D., Heslop, E., Glover, L. K., Gunn, J., Hill, K., Ishii, M., Legler, D., Lindstrom, E., Miloslavich, P., Moltmann, T., Nolan, G., Palacz, A., Simmons, S., Sloyan, B., Smith, L. M., Smith, N., Telszewski, M., Visbeck, M. and Wilkin, J. (2019). What We Have Learned From the Framework for Ocean Observing: Evolution of the Global Ocean Observing System. *Frontiers in Marine Science*, 6, 471. <https://doi.org/10.3389/fmars.2019.00471>
- UN (1982). *United Nations Convention on the Law of the Sea* (adopted 10 December 1982, entered into force 16 November 1994). 1833 U.N.T.S. 397. United Nations, New York, USA. https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (last accessed 31 March 2026).
- UN (2023). *Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction* (A/CONF.232/2023/4). United Nations, New York, USA.
- UNEP (2016). *Marine plastic debris and microplastics* (UNEP/EA.2/Res.11). UN Environment Programme, Nairobi, Kenya.
- UNEP (2021). *From pollution to solution: A global assessment of marine litter and plastic pollution*. UN Environment Programme, Nairobi, Kenya.
- UNEP (2022a). *Resolution 5/14: End plastic pollution: Towards an international legally binding instrument* (UNEP/EA.5/Res.14). UN Environment Programme, Nairobi, Kenya.
- UNEP (2022b). *Plastics science: Note by the secretariat* (UNEP/PP/INC.1/7). UN Environment Programme, Nairobi, Kenya.
- van Doorn, R. and Veloso, P. F. (2023). *Report on the use of legal frameworks for ocean observing systems* (EuroSea Deliverable D1.7). EuroSea. https://doi.org/10.3289/eurosea_d1.7
- Venancio, D. S. (2025). Challenges in defining the legal status of Autonomous Underwater Vehicles (AUVs). *Ocean Development & International Law*, 56(3), 1–20. <https://doi.org/10.1080/00908320.2025.2531164>
- Wegelein, F. H. T. (2005). *Marine Scientific Research: The Operation and Status of Research Vessels and Other Platforms in International Law*. Martinus Nijhoff Publishers.
- WMO (2019). *Resolution 45 (Cg-18)*. World Meteorological Organization, Geneva, Switzerland.
- Xing, W. (2024). Contemplating Maritime Autonomous Surface Ships (MASS) under the international law on ship-source pollution. *Marine Pollution Bulletin*, 207, 116884.
- Yu, C. (2022a). *Marine Scientific Research and the Regulation of Modern Ocean Data Collection Activities under UNCLOS*. Brill Nijhoff.
- Yu, C. (2022b). Operational oceanography as a distinct activity from marine scientific research under UNCLOS? – An analysis of WMO Resolution 45 (Cg-18). *Marine Policy*, 143, 105131.
- Zou, K. and Telesetsky, A. (2021). *Marine scientific research, new marine technologies and the law of the sea*. Brill Nijhoff.