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Space Technologies and Climate Change
Implications for Water Management, Marine Resources
and Maritime Transport

Chapter 3

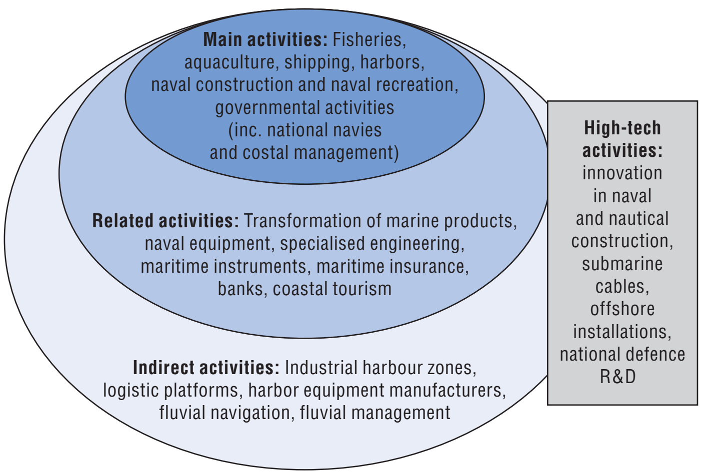
Marine Resources and Maritime Transport: Trends and Outlook

Marine resources management and maritime transport both have strong links with climate change. Both activities can, on their own, lead to adverse environmental effects (i.e. pollution, depletion of marine resources with impacts on ecosystems), but both can be affected by climate change (i.e. extreme weather events, the opening of new sea routes near the poles). This chapter is divided into three main sections. A first introduces the intertwined marine and shipping activities with reference to the law of the sea; a second section focuses on marine resources management, particularly fishing and offshore activities; and a third provides information on maritime transport.

Introduction to marine resources and maritime transport

Marine resources management and maritime transport are two activities strongly linked in terms of their socio-economic impacts (Figure 3.1).[1] More than 90% of world trade involves transport via seas and oceans, while around 1 billion people (one-sixth of the world's population) depend on fishing activities (UNEP, 2007b).

Figure 3.1. **Overview of marine and maritime activities**



Source: Adapted from Kalaydjian, 2006.

Coastal countries have historically attributed significant value to "their" seas. According to the United Nations Convention on the Law of the Sea, a state's territorial sea extends up to 12 nautical miles (22 kilometres) including the airspace over it, its seabed and subsoil (UN Division for Ocean Affairs and the Law of the Sea, 2008).[2] Foreign vessels are allowed innocent passage through those waters. In addition, coastal countries can exercise their sovereignty over their exclusive economic zones (EEZ). The desire of coastal states to control the fish harvest in adjacent waters was a major driving force behind the creation of the EEZs. According to the Convention, the zone extends 200 nautical miles (370 kilometres) into the sea from the coastal baseline (see baseline in Figure 3.2) and forms a territory over which the coastal state has special exploration and

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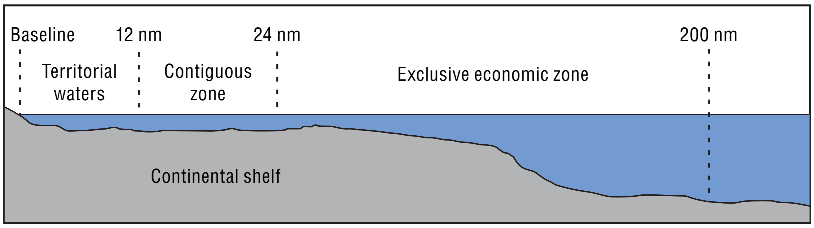
marine resource rights. All other states have freedom of navigation and overflight in the EEZ, as well as freedom to lay submarine cables and pipelines.[3]

Figure 3.2. **Zones of national jurisdiction (Law of the Sea Convention, 1982)**
(nm = nautical miles)



Almost all coastal countries of the world have delimited their exclusive economic zones, although in some cases geography is preventing delimitation, or disputes over specific EEZ boundaries are ongoing (*e.g.* the special case of the Mediterranean Sea).[4] Among the major beneficiaries of the EEZ regime are the United States, France, Indonesia, New Zealand, Australia and the Russian Federation (Table 3.1). The European Union members share their EEZ via the Common Fisheries Policy (CFP); thus vessels from one country can fish in another country's EEZ (with restrictions in territorial waters and protected zones), but must adhere to specific quotas on the amounts and types of fish they catch. The combined zone amounts to 25 million square kilometres, making it larger than those of any single country (EC, 2008a).

Table 3.1. **List of countries with exclusive economic zones (EEZ) by area size**

1	United States 11 351 000 km^2
2	France 11 035 000 km^2
3	Australia 8 148 250 km^2
4	Russian Federation 7 566 673 km^2
5	Japan 4 479 358 km^2
6	New Zealand 4 083 744 km^2
7	United Kingdom 3 973 760 km^2
8	Brazil 3 660 955 km^2
9	Canada 2 755 564 km^2
10	India 1 641 514 km^2
11	Argentina 1 159 063 km^2
12	Madagascar 1 225 259 km^2
13	China 877 019 km^2

In addition to exclusive economic zones, coastal States can under the UN Convention extend their sovereign rights even further over the continental shelf to explore and exploit the seabed up to 350 nautical miles (648 kilometres) from the coast, if this area extends beyond the EEZ. Countries need to follow a rather complex administrative and technical process set out in the Convention to demonstrate that their continental shelf extends beyond their established 200 nautical miles. Australia, France, Ireland, Mexico, New Zealand, Norway, the Russian Federation, Spain and the United Kingdom are among the countries that have launched the process. The United Nations special commission in charge of the procedure expects a high volume of submissions in the coming years (UN Commission on the Limits of the Continental Shelf, 2008).

Finally, more than a dozen regional fisheries management organisations (RFMOs) have been created to manage and conserve fish resources of the open seas. Governments that are members can share information and agree on management tools (*i.e.* quotas, vessel monitoring systems) for large zones outside their direct jurisdiction.

Many of the states that have established their EEZs or that are participating with RFMOs are not, however, in a position to exercise all their rights and perform duties under the Convention (*e.g.* prevent and limit pollution, facilitate marine scientific research). The delimitation of the EEZ, the surveying of its area, its monitoring, the utilisation of its resources and, more generally, its management and development are often seen as long-term endeavours beyond the capabilities of many countries, especially developing ones. But technical advances and new practices, particularly with the growing use of satellite technologies, are changing the situation for some countries, as will be shown in Chapter 4.

Despite technical and financial challenges, monitoring and surveillance of territorial waters and of EEZs have undeniably become crucial in recent years for several countries, particularly in light of the exploitation of natural resources. As marine and seabed resources become increasingly strategic, countries will implement more monitoring and defensive measures to protect those zones.

Marine resources

Marine resources management can be affected – as well as directly affect – climate change (Table 3.2). As mentioned by Ducrotoy and Elliott (2008), the main goal in managing the seas is to allow the sustainable use of its resources by human societies. But marine resources are by nature very diverse and unevenly exploited. They can be found at three different levels in the seas and oceans: the overlying waters, home to numerous biological resources (*e.g.* fish stocks); the top layers of the seabed, with polymetallic and phosphorite nodules (*e.g.* iron, nickel, copper, phosphates); and the underground seabed, with minerals – particularly hydrocarbons (*e.g.* petroleum). The majority of animal, vegetal and mineral resources can be found near the coastlines, as 75% to 95% of the animal and vegetal world exists in a ribbon no larger than 350 kilometres from the coasts, and at depths of less than 200 metres (French

Table 3.2. **Selected climate change connections with both fisheries management and exploitation of mineral resources in sea-floor**

	Possible climate change-induced effects on the activities	Possible effects of the activities on climate change
Fisheries management	• Extreme weather (causing damages to infrastructures and ships) • Introduction of new invasive species (jellyfish, algal bloom) via warmer waters • Acidification of waters in some areas, causing the displacement/ distribution of fish populations	• Endangering of fragile ecosystems through: – Overfishing – Depleting biological and vegetal marine resources, through invasive fishing techniques (*e.g.* destroying coral reefs) – Pollution (*e.g.* fishing vessels)
Exploitation of mineral resources in seafloor	• Extreme weather threatening oil rig installations and transport • New areas to dig for oil and gas (little/no more ice)	• Endangering of fragile ecosystems through: – Contributing to changes via new infrastructures (*e.g.* platform building) – Pollution (from offshore installations, new shipping routes to serve oil rigs, oil and gas accidents)

Academy of Sciences, 2003). This natural richness is endangered in many parts of the world by human activities, pollution and climate change-induced effects. The situation of fish stocks and minerals in the seabed in particular will be explored further in the next two sections.

Focus on fisheries

As stated earlier, around 1 billion people (one-sixth of the world's population) depend on fishing activities for their livelihood; in 2002 over 2.6 billion people received at least 20% of their animal protein primarily from marine sources (Hesse, 2005). Major changes in the fishing value chain have occurred around the world, due to globalisation, the multiplication of bilateral and multilateral agreements concerning EEZ and fishing stock management, fewer natural resources, pollution, and fleets' technological developments (OECD, 2008b). Certain space technologies have contributed to those trends, as will be explored later. One key message, however, is that for the fishing sector to remain sustainable on the regional and global scales, a number of measures are needed.

a) State of the world fisheries

There are no comprehensive data on the global fishing fleet size, but data from the FAO, OECD and other organisations indicate that the figure has increased rapidly between the 1950s and the early 2000s. Fleets have extended their operating range and adopted new technologies, such as advanced electronic fish finders.

Based on existing data, in 2004 the fleet consisted of about 4 million fishing craft; of these 1.3 million were decked vessels of various types, tonnage and power, and 2.7 million were open boats with no deck, including traditional craft operated by sail and oars (FAO, 2007). The data often exclude smaller boats whose registration is not compulsory and/or whose fishing licences are granted by local authorities. About 86% of the decked vessels were concentrated in Asia, followed by Europe (7.8%), North and Central America (3.8%), Africa (1.3%), South America (0.6%) and Oceania (0.4 %). Fishing communities are in general extremely vulnerable to economic shocks and changes in the market and supply. According to the FAO (2007), of the estimated 29 million fishermen worldwide, 5.8 million (20%) earn less than USD 1 a day. Their economic wellbeing therefore greatly depends on fishing abilities, marine resources and adequate weather conditions.

With regard to natural disasters, these events in themselves have led to short-term downturns for the commercial fishing sector. The resulting damage to equipment and infrastructure, however, can compromise the productivity of fishing and aquaculture activities. The 2005 tsunami in the Indian Ocean destroyed fishing boats, aquaculture pens and equipment. Developing countries suffer disproportionately from extreme weather events, as they often have weak response capacities. In 2000 the El Niño disaster reduced the amount of fish to 77-78 million tonnes (excluding China), the same level as in the early 1990s (FAO, 2002).

In terms of fish production, the world total was estimated at 140.5 million in 2004, with growth at 2.6% annually; the average consumption per person doubled since 1960 at the value of 16.2 kilograms per year (OECD, 2008a). This production includes marine capture fisheries, inland fresh water fisheries and aquaculture, all on the rise since the late 1980s. Concerning trade in fish products, the 2000 record of USD 55.2 billion was again topped in 2005 (OECD, 2005). Trade has steadily grown at a rate of 4% per annum in the last decade. China is the world's largest producer of fish products, as shown in Figure 3.3.

Four major FAO fishing areas produce almost 68% of the world marine catch (Figure 3.4). The northwest Pacific is the most productive, with a total catch of 21.6 million tonnes (25% of the total marine catch) in 2004; it is followed by the southeast Pacific, with a total catch of 15.4 million tonnes (18% of the marine total), and the western central Pacific and northeast Atlantic, with 11 million and 9.9 million tonnes (13% and 12%) respectively in the same year.

b) Worrisome trends for fishing activities

The three greatest threats to sustainability of fisheries resources and to the fishing sector are overfishing; illegal, unregulated, unreported fishing (IUU); and climate change impacts. If current trends continue, the world will increasingly face a scarcity of biological marine resources, with the additional challenge that climate change-induced impacts may be amplified.

Overfishing – Overfishing occurs when the number of fish catches in a year exceeds the minimum number of fish necessary for sustainable stock

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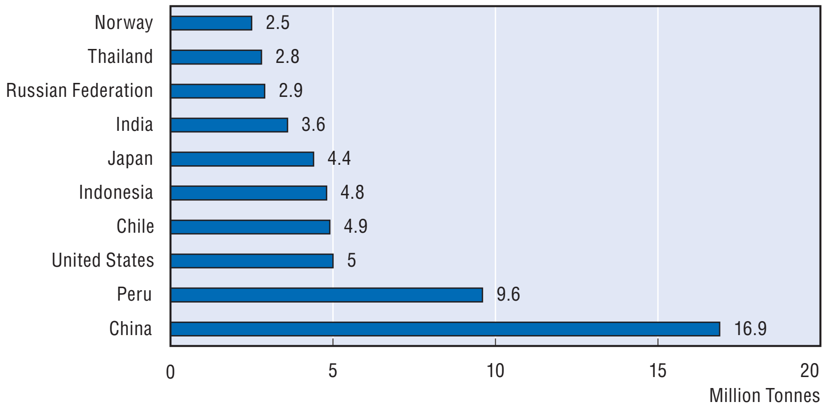
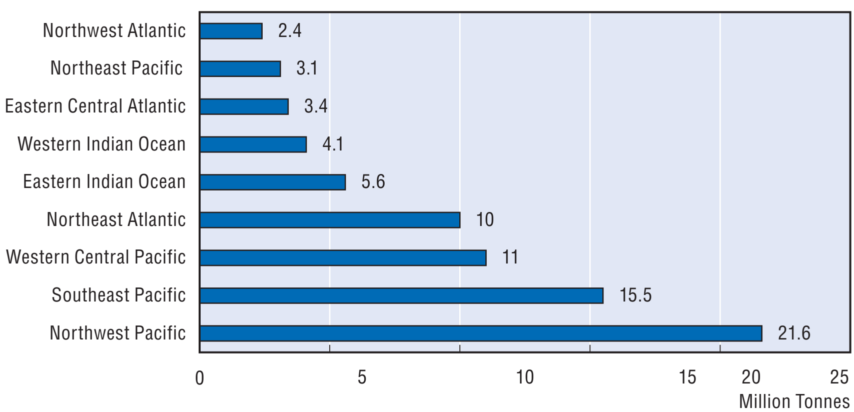
Figure 3.3. **Marine and inland capture fisheries: top ten producer countries in 2004**



Source: FAO, 2007.

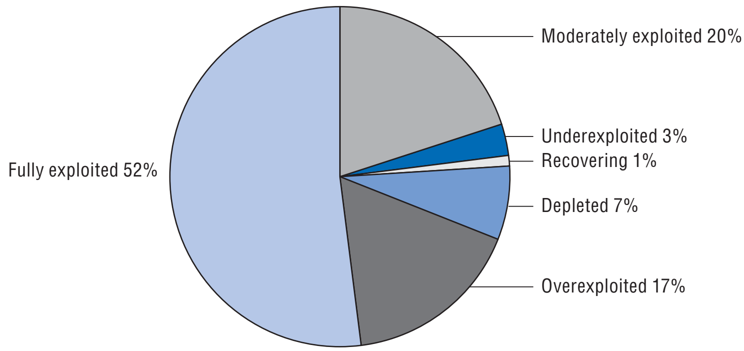
Figure 3.4. **Capture fisheries production: principal marine fishing areas in 2004**



Note: Fishing areas listed are those with a production quantity equal to or more than 2 million tonnes in 2004.
Source: FAO, 2007.

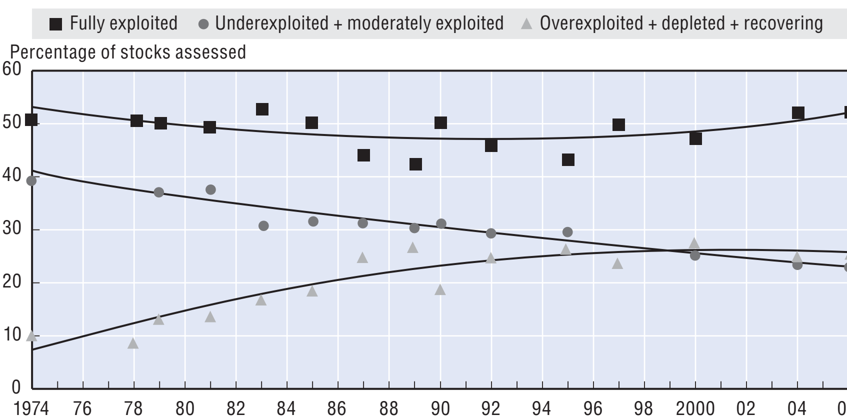
development, hence causing imbalances between species composition in lakes, seas and oceans. By 2030, based on current exploitation trends (Figures 3.5 and 3.6), global individual consumption of fish and marine resources could surpass the current 16.2 kilograms per person, reaching an estimated 20 kilograms (Ifremer, 2007). However, due to the heavy concentration of consumption of a limited number of fish species, the top ten species that make up 30% of total fish consumed are already either fully exploited or overexploited (Hesse, 2005).

Figure 3.5. **Status of world fish stocks in 2005**



Source: FAO, 2007.

Figure 3.6. **Global trends in the state of world marine stocks (1974-2006)**



Source: FAO, 2007.

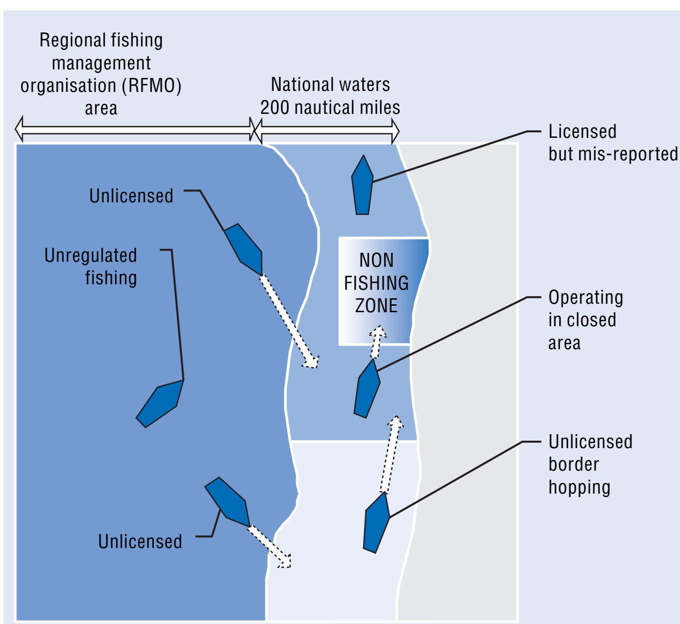
One tool to prevent overfishing is to establish sustainable management practices such as annual catch limits (*i.e.* the amount of fish allowed to be caught in a year). But this not enough. Countries need to make available the resources for developing reliable data on fish stocks and enforce their fishing regulations (OECD, 2008a). Many countries have developed fishing quotas based on scientific assessments of existing fish stocks for the maritime zones under their control, but control is often difficult over large areas and they must contend with pressures from fishing groups.

Illegal, unregulated, unreported fishing – IUU fishing activities constitute a growing worldwide problem that affects both domestic waters and the high seas, and undermines efforts to maintain sustainable fisheries worldwide (OECD, 2008a). The economics of those activities suggest they provide rather high profits to those who perpetrate them. As fish stocks become scarcer, partly because of

IUU fishing, fish quotas tend to decline further for law-abiding vessels, creating further incentives for legal operators to resort to IUU fishing (OECD, 2006). It is difficult to quantify the scale of the problem, as perpetrators can range from licensed fishers to large-scale organised crime organisations. There are several layers of IUU activities, responsibilities and possible responses:

- Illegal fishing activity is understood as fishing without a licence or fishing by contravening the terms and conditions of a licence (*e.g.* using illegal gear, catching over the allocated quota of fish, fishing in closed areas and/or seasons, exceeding by-catch limits). It is the coastal state's responsibility to deter illegal fishing through surveillance, detection, apprehension and the imposition of legal sanctions within its maritime areas (national waters), and to support the actions of its regional fishing organisations.
- Unreported fishing activities can also include a diversity of actors who misreport their fishing to the relevant national authority or regional organisation.
- Unregulated fishing includes fishing on the high seas by "free riders", *i.e.* those who fail to sign up to regional management arrangements and refuse to comply with the measures established by those arrangements. It also includes fishing on the high seas where there are no regional management arrangements in place (Marine Resources Assessment Group Ltd., 2005).

Figure 3.7. **Different types of illegal, unregulated, unreported (IUU) fishing**



Source: Adapted from Marine Resources Assessment Group Ltd., 2005.

Climate change and fisheries – While there are regional differences, climate change will increasingly contribute to the transformation and loss of fishing stocks, notably via changes in sea temperature, acidification of waters and increasing extreme weather. The variability in environmental conditions and processes can have a strong influence on biological systems, which in turn may affect the marine ecosystem (leading to, *e.g.,* eutrophication) (Ducrotoy and Elliott, 2008).

Sea temperature: As the result of anthropogenic climate change, the mean temperature of sea surface waters is expected to increase and mean sea level is expected to rise (IPCC WG2, 2007). Based on current model simulations, there will very likely be a slowdown in the oceans' thermo-haline circulation by 2100, with severe consequences for fisheries and aquatic ecosystems. Already, the distributions of both exploited and nonexploited North Sea fishes have responded markedly to recent increases in sea temperature (Perry *et al.*, 2005). As ocean circulation drives larval transport, the recruitment patterns and population dynamics of marine organisms will be altered worldwide. Warming ocean temperatures influence species composition, breeding and population dynamics of plankton, benthos, fish and other species (UNEP GIWA, 2006). For example, the northeast Atlantic is experiencing an increased inflow of warm water that carries nutrition for cod and herring. These fish may thus increase in numbers as a result of greater nutrition. Nonetheless, since herring prey on other fish such as capelin, an increase in the herring population may decrease the capelin population in the long run. On the other hand, cold water may influence growth rates and force animals to move to warmer waters. Climate change and invasive species have already been implicated in the decline and even collapse of several marine ecosystems (Frank *et al.,* 2005).

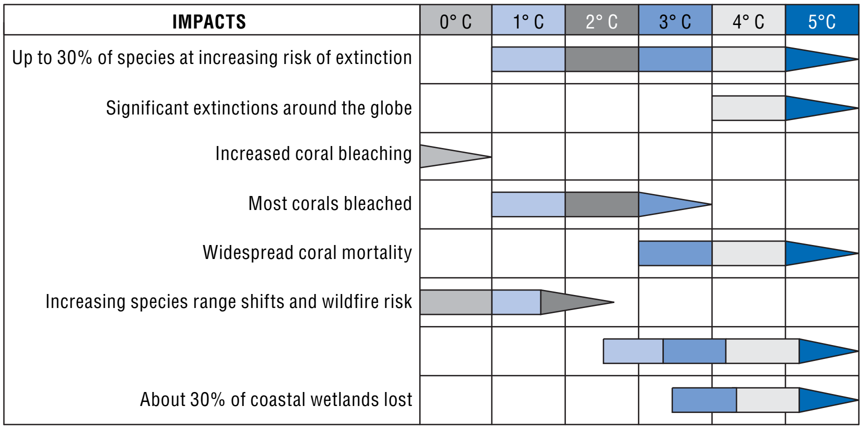
Acidification of waters: The pH of ocean surface waters is projected to fall by 0.14 to 0.35 units by 2100, due to the uptake of rising levels of atmospheric carbon dioxide (IPCC WG2, 2007). The consequent acidification of surface waters will change the saturation horizons of aragonite, calcite and other minerals that are essential to calcifying organisms (Feely *et al.*, 2004). While many aquatic organisms are adapted to thermal fluctuations, the expected changes in pH are higher than any of those inferred from the fossil record over the past 200 to 300 million years (Caldeira and Wickett, 2003).

Exploitation of mineral resources in the sea-floor

Global demand for energy and minerals and increasing geotechnical capabilities are encouraging the exploitation of mineral resources in the seabed. Effects induced by climate change are affecting this industry, while developments of offshore platforms are in turn affecting the environment.

Since 2003, capital and spending for offshore oil and gas operations have grown at unprecedented rates, averaging 15% to 20% per year (Smith, 2008).

Figure 3.8. **Temperature increases and likely impacts on marine and terrestrial ecosystems**



Source: Derived from IPCC WG2, 2007.

This rise is due to increases in the price of energy and to the development of offshore drilling in deep-water environments: exploratory wells are costing on average around USD 40 million, with some reaching as high as USD 100 million in the most demanding regions. Already, 4 500 deep-water wells have been drilled globally since 1990. The first commercial offshore oil well, drilled by a mobile rig out of sight of land, took place in US territorial waters. The well was drilled in October 1947, in 14 feet (4.27 metres) of water in the Gulf of Mexico, off south eastern Louisiana (Gerwick, 2007). There are today over 6 500 oil and gas platforms in the Gulf of Mexico, and the US offshore oil and gas industry employs some 85 000 people.

In addition to the traditional actors in offshore drilling, more countries than ever before are developing their own production. The oil and gas industry is for instance the largest industry in Norway, followed by the maritime sector – and both sectors are still developing rapidly. As of March 2008, Norwegian oil rigs on order represented a value of some USD 10.5 billion for 33 rigs (Bøhler, 2008). To offer an example of a relative newcomer, thirty years ago Brazil was importing all its fuel for internal consumption. Today, using offshore drilling, that country is self-sufficient, and recent discoveries of a large reserve in the São Paulo bay (estimated at 33 billion barrels) could place Brazil among the top ten producers of oil. A technical challenge remains: the need to extract the oil below 2 000 metres of water and at least 4 000 metres of earth and sand.

One significant by-product of climate change is the rapid melting of polar ice caps, which had introduced the possibility of exploiting previously inaccessible territory and the seabed. The Arctic for instance is already becoming the object of competing claims among the five nations bordering that region, since the area could hold as much as one-quarter of the world's remaining undiscovered oil and gas deposits (Bird *et al.*, 2008). As seen in the introduction to this chapter, under the United Nations Convention on the Law of the Sea, a country claiming ownership of a region's ocean floor (generally with a view to developing offshore oil production) must show evidence that the seabed is an extension of their continental shelf. In that context, national scientific expeditions have multiplied in the Arctic region over the past five years (trying to demonstrate geographical claims). The Russian Federation and Denmark are, for example, looking particularly at the large underwater Lomonosov Ridge in the Arctic, to prove that large portions are part of their respective land masses (Borgerson, 2008). As a result of such seabed explorations for oil and gas, more scientific research is being conducted than ever before in the depths of the oceans.[5]

Construction of platforms at sea remains truly challenging due not only to the natural physical environment, but also to the requirements – despite increasing geotechnical capabilities – to dig further in the sea-floor (Gerwick, 2007). In addition, safe, efficient drilling operations depend on an accurate understanding of the current sea state and accurate and timely warning of impending storms. This growing industry is therefore dependent not only on real-time communications, but also on key meteorological forecasts. With regard to accidents, generally due to weather conditions or mechanical failure, there is a long-term trend towards increasingly severe average losses of mobile oil rigs since the early 1990s – even after discounting the loss impact of hurricanes Ivan, Katrina and Rita. But there was a significant increase in the overall insurance claims cost during 2004 and 2005, due mainly to an intense hurricane season in the Gulf of Mexico and strong storms in other regions (IUMI, 2008b).

Climate change-induced effects (*i.e.* extreme weather events, development of new sites for oil and gas production) could also feed on the long-term consequences of increased offshore drilling. The large-scale deterioration of the seas is a relatively recent phenomenon that has accelerated over the past fifty years. The causes of pollution are manifold – chemical, biological and bacterial – and represent an ecological and economic menace still not fully acknowledged. Warmer temperatures and sea rises in parts of the world may worsen the situation, while relatively new activities such as the exploitation of mineral resources in the seabed will also have impacts (Patin, 1999). Despite industry efforts such as banning the use of oil-based drilling fluids since 1992 (OSPAR Commission, 2008), the level of pollution from hydrocarbon spills and other chemicals from offshore oil and gas installations may well be underestimated, perpetuating the difficulty in assessing the scale of environmental effects (Fraser *et al.*, 2008).

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Many scientific data remain to be collected and analysed, in order to understand better climate change's connections with the management of marine resources. As shown in this section, both fisheries management and exploitation of mineral resources in the sea-floor will be increasingly affected by, and may even themselves contribute to the impacts of climate change. One key lesson learned is the need to increase evidence-based knowledge about those specific sectors, particularly through collecting climate and environmental data and monitoring marine zones. The next section will focus on the growing maritime transport sector.

Maritime transport

The seas provide global transportation routes that link ports worldwide and are the lifelines of coastal economies and inland cities. As with marine activities, the links between maritime transport and climate change are sometimes subtle but strong. Maritime transport may both suffer (*e.g.* intensification of extreme weather events) and benefit (*e.g.* the opening of new sea routes) from climate change effects (Table 3.3). Maritime traffic is due to increase over the next two decades, and it will become increasingly important to monitor fleets and the effects of those fleets on ecosystems if seas and oceans are to continue sustaining human activities.

Table 3.3. **Climate change connections with maritime transport**

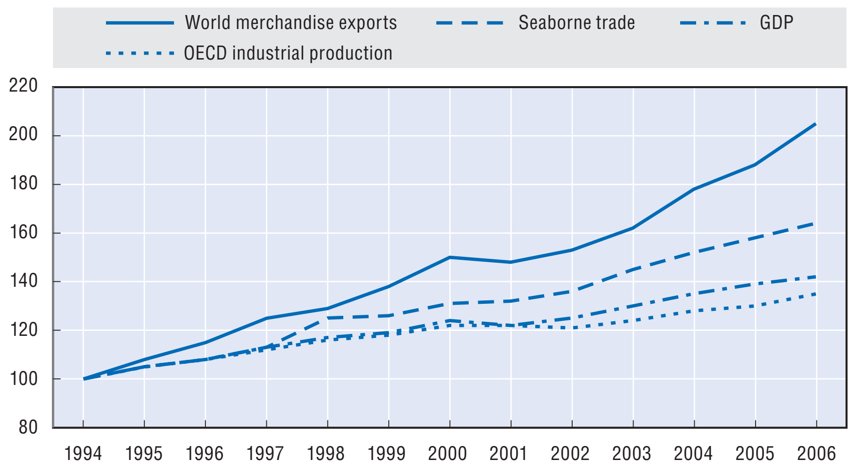
	Possible climate change-induced effects on the activities	Possible effects of the activities on climate change
Maritime transport	• Extreme weather events • Changes in currents • Opening of new sea routes	• Effects on ecosystems • Physical damages (especially to coral reefs) caused by running aground and anchoring • Introduction of invasive species • Marine pollution such as oil spills • Overcrowded shipping lanes • Increased air pollution

Source: OECD/IFP.

Continually growing traffic

The main driver for maritime transport growth is world trade. Maritime trade accounts for approximately two-thirds of merchandise trade (Grossmann *et al.*, 2007). For the past decade, strong world economic growth at an average of 4% has significantly contributed to the growth of the maritime trade. In 2006, GDP grew an average of 3% in developed countries, 6.9% in developing countries and 7.5% in transition economies (UNCTAD, 2007). At the same time, world merchandise trade grew by 8%, highlighting the effect of increasing globalisation and deepening economic integration. This high economic growth rate in 2006 has been encouraged and reinforced by transition economies and developing countries (mainly in Asia) that have been supplying primary commodities and raw materials, and that are emerging as important manufacturing centres. Maritime trade has been primarily driven by the growth in manufactured goods, which reached 72% of the total value of world exports in 2005 (USD 7.3 trillion out of a total of USD 10.1 trillion). Figures 3.9 and 3.10 highlight the positive correlation between world economic growth – particularly growth in merchandise exports – and seaborne trade.

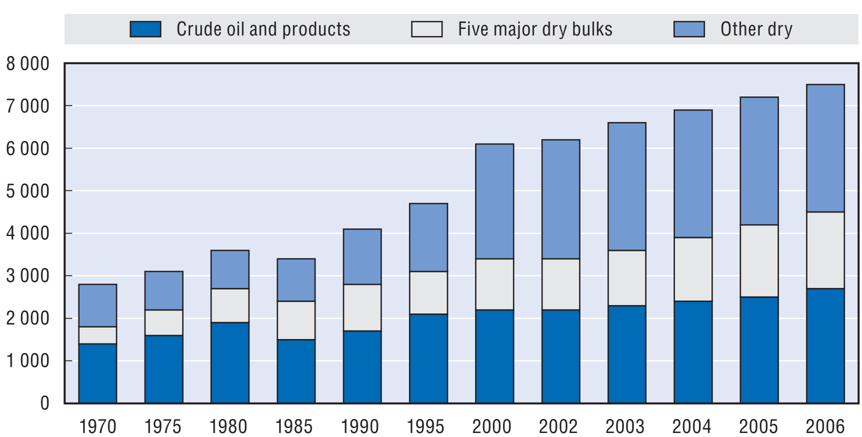
Figure 3.9. **Indices for world economic growth (GDP), OECD industrial production, world merchandise exports (volume) and seaborne trade (volume), 1994-2006**



Source: UNCTAD, 2007.

Figure 3.10. **International seaborne trade for selected years**

Millions of tonnes loaded

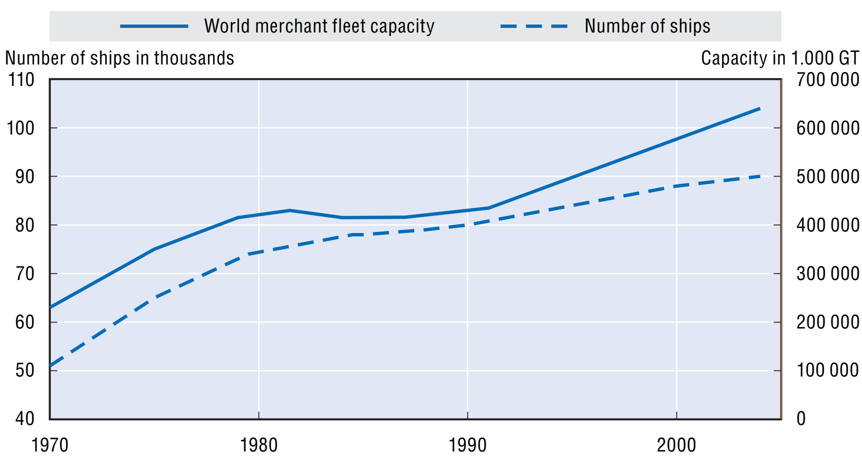


Source: UNCTAD, 2007.

In 2006, the transport volume of seaborne world trade was estimated at 7.4 billion tonnes (compared to 6.78 billion tonnes in 2005) (UNCTAD, 2007). Crude oil accounted for 26.9% of total goods loaded, while petroleum products represented 9.2%. The larger balance of world goods loaded (63.9%) was made up of dry cargo, including bulk and containerised goods. A geographical breakdown of total goods loaded by continent highlights the continued predominance of Asia with a share of 39.1%, followed in descending order by America (21.5%), Europe (19.6%), Africa (10.7%) and Oceania (9.1%).

Both the number of ships and their capacities have continuously increased since the 1970s, in parallel with world economic growth. As Figure 3.11 graphically demonstrates, the number of ships has almost doubled and their capacity almost tripled between 1970 and 2004 (Grossmann *et al.*, 2006). Most shipyards around the world are currently working to full capacity, and the world cargo fleet is set to grow by 243% by 2010 (Frank, 2008). The container fleet has reached 10 742 million TEU (twentyfoot equivalent units, a measurement of container's volume) in 2007, compared with only 3 766 million TEU a decade earlier in 1998. In comparison, scrapping of the tanker and bulker fleets remains very low, about 0.5% of the world fleet for both sectors (IUMI, 2008b).

Figure 3.11. **Development of the world merchant fleet**



Source: Grossman *et al*, 2006.

Certainly, geographical advantages contributed to the growth of maritime transport in particular regions. As the European Union has access to four seas, its main mode of transport for foreign trade has been maritime. As a share of total transportation means for external EU trade, the share of sea trade has been dominant in both euro value and volume in tonnes (Table 3.4).

Table 3.4. **EU external foreign trade by mode of transport, 2004**

Mode of transport	Value in euros	Share in %	Volume in tonnes	Share in %
Sea	859.1	47.1	1 430	71.7
Road	259.7	14.2	100.8	5.1
Rail	25.1	1.4	89.3	4.5
Inland waterway	6.5	0.4	24.9	1.3
Pipeline	53.4	2.9	279.1	14.0
Air	471.7	26.0	9.8	0.5
Other	145.4	8.0	59.7	3.0
Total	1 822.9	100.0	1 993.6	100.0

Source: EC, 2005.

Looking ahead, maritime routes could become even busier. They are corridors of a few kilometres in width linking ports, and determined by a number of obligatory points of passage depending on physical constraints (marine currents, depth, reefs, ice) and political borders. As a result, these routes draw arcs on the earth's water surface. Seaborne trade could continue growing annually by 3.3% until 2020 (Grossman *et al.*, 2006), even if the growth of individual products within the maritime sector (*e.g.* liquid bulk *vs.* dry bulk) varies significantly due to the changing trade patterns of countries.[6]

Forecasts for the European Union alone suggest an increase of approximately 125% in the volume of shipment by sea between 2005 and 2030, a clear indication of the growing importance of maritime transport (Grossmann *et al.,* 2006). Today, 90% of Europe's external trade and close to 40% of its internal trade passes through its ports (EC, 2008b). Overall, global seaborne trade should continue growing more rapidly than the average growth rate, although less quickly than it will after 2015. On the other hand, greater expansion in intraregional trade flow is expected. Coastal and inland waterway shipping are also expected to show high expansion rates, as in many cases they are the focus of political subsidy programmes. This applies to the expansion of rail traffic too, albeit in milder form and regionally differentiated.

New sea routes opening

Sea route traffic is expected to see fundamental changes over the next decades, as climate change is opening new routes to access remote regions more easily.

Sea ice is an early indicator of climate change impacts. Sea ice covers around 10% of the world's oceans, and the measurements of its thickness, extent and composition help scientists understand and predict changes in weather and climate. A warmer earth has significantly contributed to the disappearance of the ice packs in the last decades. Sea ice could disappear in many parts of the world by 2050 if this trend continues.

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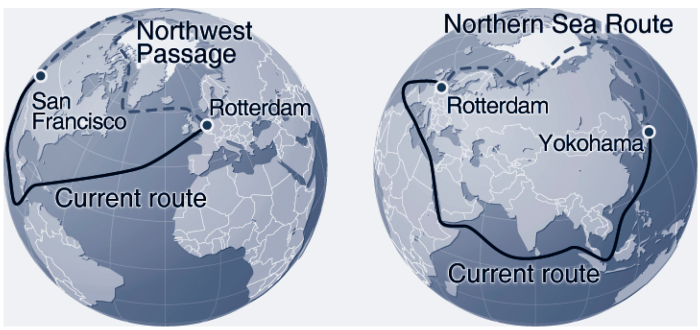
In the Arctic for example, there are already well known recurring openings in sea ice (called *polynyas*), closing within hours or days. However based on the observed changes in the region, two important seasonal waterways circumventing the Artic, namely the Northwest Passage (near the United States' and Canada's coastlines) and the Northern Sea Route (near Norway and Russia's coastlines), are expected to become busier than ever (Figure 3.12). A larger use of the Northwest route for example is attractive, as it shortens transport distances between the Far East and European ports by 40%, allowing savings in journey times, fuel and carbon emission. With the disappearance of sea ice, the Arctic Ocean route would put Europe about 12 000 kilometres from the Far East, reducing for example by half the voyage time between Scandinavia and Japan. It would also cut sailing time from Germany to Alaska by 60%, going through Russia's Arctic instead of the Panama Canal.

Figure 3.12. **Current and future sea routes around the Arctic Basin**



Source: UNEP, 2007c.

Weather constraints remain an important factor when analysing a sea route. In certain meteorological conditions, a ship will not be able to sail or will need to look for shelter while at sea. It then becomes necessary to know the potential time this type of ship would be out of service on those routes, where the wave height recorded exceeds the significant limit (Martinez *et al.,* 2008). So ironically, even if new routes open at least partially thanks to climate change, induced extreme weather events may pose other difficulties for ships at sea, as shown in the next section.

Accidents at sea

Statistics on ship losses are not easily found; many accidents involving small vessels can go unreported, especially small-sized fishing and passenger-carrying ships. The more robust information comes from large commercial ship databases, and those show a rise in accidents, many linked to weather.

General cargo ships in particular run a high risk of accidents. They account for nearly 20% of the world merchant fleet, but suffer over 40% of total losses and almost 40% of the fatalities. These accidents amount to 90 ships lost and the death of 170 seafarers each year worldwide since 1995 (Royal Institution of Naval Architects, 2008). Although numbers of fatalities have been decreasing slightly since the early 2000s, there are still at times significant losses. For example, in the first three months of 2008 there were already more than 300 casualties worldwide (with loss of life for more than 100 seafarers and passengers); 88 of these casualties were caused by bad weather.

Weather remains the single greatest factor behind the total losses of ships, although collision and grounding are also common causes. Those losses have increased markedly in the past four years. The percentage of tonnage lost has almost doubled from 2005 (0.06%) to 2006 (0.11%), with 2007 at 0.08% (data available as of March 2008). However, those percentages still compare favourably with the 0.4% total losses of the early 1990s, thanks mainly to better communications equipment on board ships for emergency signalling. With regard to "partial" losses of ships, machinery is one key reason, followed by collision or contact damage and groundings, although bad weather is often an exacerbating factor. There has been a strong rise in the figures since 1998, with a 270% increase in one decade (from 247 serious incidents in 1998 to 914 in 2007). As a percentage of the world fleet increase, this is equivalent to 0.64% of the fleet suffering a serious partial loss in 1998 compared to 1.73% for 2007.

Pollution from sea traffic

Among the various modes of transport, ships remain by far the most energy-efficient and environmentally friendly means of conveying goods and passengers (Table 3.5). However, despite the enforcement of several international conventions (*e.g.* MARPOL, COLREG), some 20% of sea pollution still comes from the deliberate dumping of oil and other wastes from ships, from accidental spills, and from offshore oil drilling.

While accidental pollution at sea cannot be totally eliminated, operational routine pollution by ships is a common practice that causes major environmental problems in many parts of the world (Table 3.6). The rise in international maritime transportation and the lack of sea and coastal surveillance have led to increases in illegal discharges over the years. In addition, as international sea traffic has been rising rapidly for decades, ocean shipping pollution is also increasingly brought on by efforts to serve that sector through port infrastructure maintenance and fleet modernisation (OECD, 2008c). Another type of pollution, less known, comes from introducing invasive vegetal and biological species transported (*i.e.* in solid and water ballasts, and in hulls) and released by ships; this tips the sensitive species balance that often exists in a given ecosystem. The recent proliferation of

Table 3.5. **Energy use and CO_2 emissions associated with different modes of transport**

Mode of transport	Energy use (MegaJoule per tonne-kilometre)	CO_2 emissions (grams per tonne-kilometre)
Air	7-15	501-1073
Road	1.8-4.5	133-333
Rail	0.4-1	30-74
Inland barge	~0.3	~30-100
Sea[1]	0.1-0.4	3.5-7.7
oil products	0.1	7.7
dry bulk products	0.05	3.9
crude oil	0.045	3.5

1. Value reflects energy use and CO_2 emissions across a wide range of ships, including container ships. Data for non-container ships are estimates; actual energy use and emissions may differ from those shown.

Source: OECD, 2008b.

Table 3.6. **Episodic and routine pollution from ocean shipping activities**

Episodic environmental events	Routine environmental events
Vessel based:	
Oil spills	Engine air emission
Ocean dumping	Invasive species introductions (ballast water/hull fouling)
Sewage discharge	Toxic releases from hull coating
Oily wastewater	Underwater noise
Vessel collisions	
Impacts between ship and marine life	
Port based:	
Dredging	Stormwater runoff
Port expansion	Vessel wake erosion
Ship construction/breaking	Air emissions from cargo handling

Source: OECD, 2008c.

certain tropical algae in the northern hemisphere along main maritime routes, combined with warmer sea temperature, is an example of such pollution. As new sea routes open along the coastline of Siberia, it is expected that ships coming from warmer oceans will be carrying organisms that could become established in the Arctic Ocean (ACIA, 2005).

As mentioned by Saffache (2007), heavy sea traffic recorded in the English Channel, the North Sea (145 000 vessels per year) and the Mediterranean (8 000 vessels per year) accentuates the vulnerability of the coastline in terms of oil slicks. To limit pollution, a number of national and international regulations have been implemented to improve ships' design (*e.g.* double hulls to prevent oil spills, onboard treatment before discharge such as oily water separators) and sometimes new shipping rules (*e.g.* sea traffic separation schemes to avoid collisions). The costs of pollution remain high however, especially for episodic and large-scale accidental discharges. The 1989 Exxon Valdez oil tanker accident is still one of the largest oil spills and environmental disasters. Running aground, the tanker spilled 250 000 barrels into Alaskan water and onto shores. The spill cost has been assessed at around USD 7 billion, including the cleanup costs. More than USD 5 billion of this came from the largest punitive fine ever handed out to a company for corporate irresponsibility. But the social costs, including environmental, were deemed to be much larger, if not easily estimated.

Many hazardous or noxious substances are also carried in bulk form in tankers especially designed for that purpose. For example, half of all materials shipped through US waters are deemed hazardous. Ships carrying dangerous cargo are subject to Chapter VII of the International Convention for the Safety of Life at Sea, which regulates safety measures including such cargo's safe packaging and stowage. Identifying pollution from those ships is challenging, although tracking the ships during their voyage is one avenue pursued by many coastal authorities for prevention purposes. With a rising number of ships of all sizes, and the dependence of many countries on the inexorable growth in world seaborne trade, one key trend is the rise in ship values. Any sort of loss is assessed accordingly and the ship's value is reflected in the size of the ultimate claims.

Notes

1. Work on economic aspects of marine resources and maritime transport is currently being conducted in different divisions of the OECD, including the Trade and Agriculture Directorate and the Environment Directorate.
2. As of May 2008, 155 states have ratified the United Nations Convention on the Law of the Sea (1982). The Convention entered into force on 16 November 1994, and is today a globally recognised regime dealing with all matters relating to the law of the sea.
3. For example, the United States established a contiguous zone by a proclamation dated 2 September 1999,. This newly established zone, drawn according to international law and extending 24 nautical miles from the baselines of the United States, allows the country to exercise the control necessary to prevent infringement of its customs, fiscal, immigration and sanitation laws and regulations, as permitted in Article 33 of the Convention.
4. The Mediterranean, a semi-enclosed sea surrounded by 21 countries, has specific sea delimitation arrangements. Although most of the countries have declared territorial waters, few have claimed economic exclusive zones. As a result, the high seas area in the Mediterranean lies much closer to the coasts compared to most other seas and oceans on the planet.
5. In addition, many nations are currently working together to carry out exploration and monitoring of climate change in the Arctic and the Antarctic until 2009 for International Polar Year (*e.g.* via the Russian-American programme on Long term Census of the Arctic).

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6. The HWWI forecasts are widely used to form predictive models for the future growth of maritime transport and trade. These models are based on past bilateral trade flows (1948-99) and the assumption that economic growth will contribute to an increase in trade relations among countries. Further assumptions include constant shares of cargo shipping by the various modes of transport as supported by historical observations (with the exception of liquid bulks which could be routed through pipelines).

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List of Acronyms

AATSR	Advanced Along Track Scanning Radiometer (instrument on board ENVISAT)
AIS	Automatic Identification System
ASAR	Advanced Synthetic Aperture Radar
ATSR-1 and 2	Along Track Scanning Radiometer (instruments respectively on board ERS-1 and ERS-2)
BRIC	Brazil, the Russian Federation, India and China
BRIICS	Brazil, the Russian Federation, India, Indonesia, China and South Africa
CNES	Centre National d'Etudes Spatiales
CZCS	Coastal Zone Colour Scanner (instrument on Nimbus-7)
DMSP	US Defense Meteorological Satellites Programme
DORIS	Doppler Orbitography by Radiopositioning Integrated on Satellite (instrument on board TOPEX/Poseidon, Jason-1, ENVISAT and the Spot satellites)
DSC	Digital Selective Calling
EEZ	Exclusive Economic Zone
ENVISAT	ENVIronment SATellite
EPIRB	Emergency Position Indicating Radio Beacon
ERS-1 and 2	European Remote Sensing Satellites
ESA	European Space Agency
EUR	Euro (currency of European Union)
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse gases
GMDSS	Global Maritime Distress and Safety System
GMES	Global Monitoring for Environment and Security
GOES	Geostationary operational environmental satellites
GOME	Global Ozone Monitoring Experiment (instrument on board ERS-2)
GOMOS	Global ozone measurement by the occultation of stars (instrument on board ESA's ENVISAT satellite)
GOOS	Global ocean observing system
GSE	GMES Services Element

IFREMER	Institut français de recherche pour l'exploitation de la mer
IMAGE	Integrated Model to Assess the Global Environment
IMO	International Maritime Organization
IMSO	International Mobile Satellite Organization
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOOS	Integrated Ocean Observing System
IPCC	Intergovernmental Panel on Climate Change
ISPS	International Ship and Port Facility Security Code
ISRO	Indian Space Research Organisation
ITU	International Telecommunication Union
LANDSAT	LAND observation SATellite
MARS	Monitoring agriculture by remote sensing
MERIS	Medium resolution imaging spectrometer [per MODIS]
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MODIS	Moderate resolution imaging spectrometer (instrument on board NASA's Terra and Aqua satellites)
MSR	Maritime search and rescue
MWR	Microwave radiometer
NEXRAD	Next generation radar meteorological stations
NOAA	National Oceanic Atmospheric Administration
NOPP	National Oceanographic Partnership Program
NRT	Near-real-time
OECD	Organisation for Economic Co-operation and Development
POES	Polar operational environmental satellite
ROW	Rest of the world
SAR	Search and rescue
SAR	Synthetic aperture radar satellite
SART	Search and rescue radar transponder
SCIAMACHY	Scanning imaging absorption spectrometer for atmospheric cartography
SOLAS	International Convention on Safety of Life at Sea and its amendments
SSAS	Ship security alert system
SSH	Sea surface height
SST	Sea surface temperature
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNESCO	United National Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USCG	US Coast Guard
USD	United States dollar

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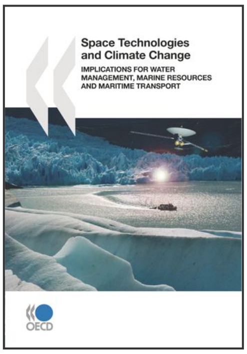
VMS	Vessel monitoring system
WHO	World Health Organization
WMO	World Meteorological Organization
WSIS	World Summit on the Information Society
WTO	World Trade Organization



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