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Ocean Space and the Anthropocene, new notions in geosciences? – An essay•

J.H. Stel

International Centre for Integrated assessment and Sustainable development (ICIS), University Maastricht, P.O. Box 616, 6200 MD Maastricht, the Netherlands. Email: janstel@skynet.be

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Abstract

Two notions, Ocean Space and the Anthropocene, are discussed. The first is occasionally used in legal and governance literature, and in the media. The Anthropocene, however, is widely applied in the global change research community and the media. The notion of ocean space stands for a holistic, system science approach combined with 4D thinking from the ocean, and the processes within it, towards the land. Ocean space is in fact a social-ecological concept that deals with sustainability challenges which are the consequence of the complex interactions between humans and the marine environment on all scales. Ocean space is, on a human scale, impressively large. On a planetary scale, however, it is insignificant, although it has been an ancient feature of the Earth for the last four billion years or so. Yet, ocean space is a critical player in the Earth System; it is central to climate regulation, the hydrological and carbon cycles and nutrient flows, it balances levels of atmospheric gases, it is a source of raw materials vital for medical and other uses, and a sink for anthropogenic pollutants. The notion also encompasses issues such as exploration, adventure, science, resources, conservation, sustainability, etc., and should be an innovative and attractive outreach instrument for the media. Finally, it marks the fundamental change in ocean exploration in the twenty-first century in which ocean-observing systems, and fleets of robots, are routinely and continuously providing quality controlled data and information on the present and future states of ocean space. Advocates of the notion of the Anthropocene argue that this new epoch in geological time, commenced with the British industrial revolution. To date, the Anthropocene has already been subdivided into three stages. The first of these coincides with the beginning of the British industrial revolution around 1800. This transition quickly transformed a society which used natural energy sources into one that uses fossil fuels. The present high-energy society of more than seven billion people mostly with highly improved living standards and birth rates, and a global economy, is the consequence. The downside of this development comprises intensive resource and land use as well as large-scale pollution of the (marine) environment. The first stage of the Anthropocene ended abruptly after the Second World War when a new technology push occurred, leading to the second stage: 'the Great Acceleration' (1945-2015) followed by the third: 'Stewards of the Earth'. Here it is concluded that the notion of the Anthropocene reflects a hierarchical or individualistic perspective, often leading to a 'business as usual' management style, and 'humanises' the geological time scale. The use of this notion is not supported. However, it is already very popular in the media. This again might lead to overestimating the role of humans in nature, and might facilitate an even more destructive attitude towards it, through the application of geo-engineering. The latter could be opening another Pandora's box. Instead we should move to a more sustainable future in which human activities are better fine tuned to the environment that we are part of. In this respect, transition management is an interesting new paradigm.

Keywords: Oceanography, environmental change, anthropogenic pollution, sustainable development, transitions, outreach

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Introduction

'The planet Earth is black!' headed the British newspaper *The Guardian* on December 6, 2012, while showing some pictures from a NASA-NOAA- Suomi National Polar-orbiting Partnership satellite. NOAA stands for National Oceanic and Atmospheric Administration. With a new sensor, the day-night band of the Visible Infrared Imaging Radiometer Suite, three low-light images are simultaneously captured in order to study the Earth's atmosphere, land and oceans at night. The sensor is sensitive enough to detect the nocturnal glow produced by the Earth's atmosphere and the light from a single ship at sea.

Scientists used this sensor to watch superstorm *Sandy*, illuminated by moonlight, when it hit the New Jersey shore on October 29, 2012. It also captured the power outages that plunged the area into darkness as the storm tore into populated areas.

The imagery also underpins a striking difference in human activities: the continents are mostly well illuminated, whereas the ocean surface remains pitch dark (Fig. 1). Moreover, the ocean space interface with the continents – the coast – is mostly highlighted by glowing lights along the shores.

The new pictures came, almost forty years after the crew of Apollo 17, snapped the famous 'blue marble' picture of Earth floating in eternal space. Just a picture; but it can change our perspective on the Earth dramatically. For NASA's 'black marble' video views of the planet by night reference is made to YouTube (www.youtube.com/watch?v=qRiy8V-6UA0).

Ocean Space

It is easy to conclude from these new NASA-NOAA pictures, as well as from many studies and reports, that human activities are now the dominating force which shapes the surface of the planet. One might even conclude that naming our planet 'Earth' was a mistake. But not in the early Middle Ages when Germanic tribes invaded present-day England and founded a number of small kingdoms. They formed a peasant society, and depended on their land for living. In their worldview the sea was not relevant. So, they named their environment 'Earth', which is derived from the Anglo-Saxon word Erda (Erdaz), meaning ground and soil.

Today, a dozen centuries later, we are able to observe our planet from space. That fact has changed our land-dominated or terrestrial perspective. Now, we would name it 'Planet Ocean' or 'Blue Planet' (Earle, 2009) instead of 'Planet Earth'. After all, our planet is dominated by water: some 70% of its surface is covered by it. Today, we can see the Earth as a system, in which atmosphere, land, water, ice and life interact in complex ways at various spatial and temporal scales with numerous positive and negative feedbacks at all levels. But the earth can be seen as 'Spaceship Earth', a machine we can understand, control and change at will by using advanced technology like geo-engineering, or as 'Mother Earth', which we should care about and nurture with great care.

These views concur with the four stereotypical perspectives distinguished within the Cultural Theory (Thompson et al., 1990): the hierarchist, individualist, egalitarian and fatalist (Fig. 2). Perspectives are defined (Van Asselt, 2000) as perceptual

Fig. 1. Composite image of Earth at night, assembled from data acquired by the NASA-NOAA Suomi National Polar-orbiting Partnership satellite, in April and October 2012. The industrialized and newly industrializing countries are clearly seen by the light pollution.

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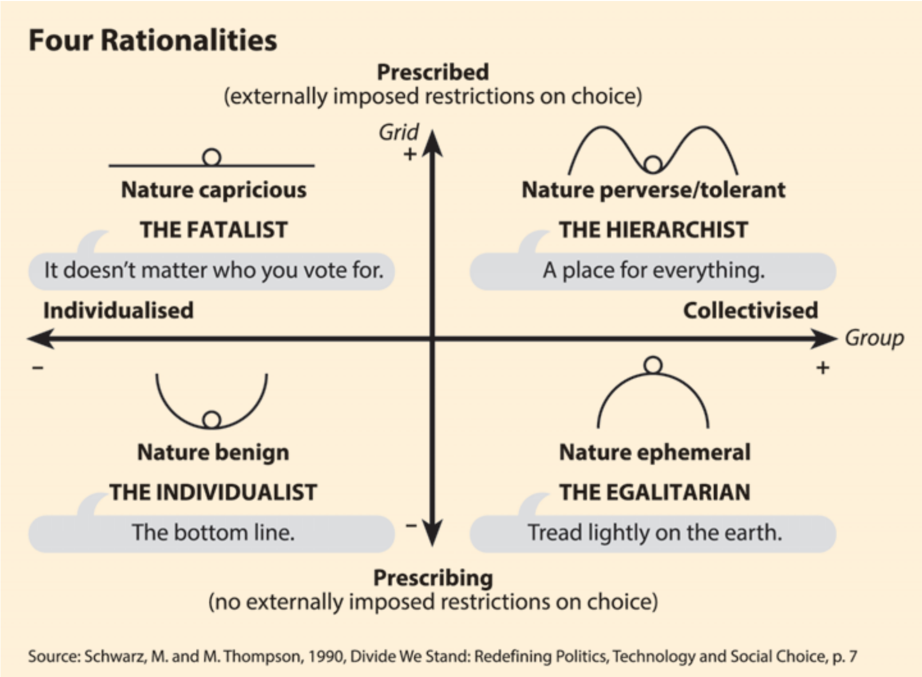

Fig. 2. Characteristics of four of the five perspectives in the Cultural Theory.

screens through which people interpret the world (worldviews) and which guide them into acting (management style). Although the robustness of the idealisations and generalisations of these perspectives is contested, it is used widely to analyse different views on nature and resources, uncertainty, biodiversity, car use, transport risk, religion, climate and water (Offermans, 2012).

The hierarchist (nature is perverse and tolerant) believes that nature is robust within certain limits. Yet, if a threshold – tipping point – is passed in the human-nature relationship, anthropogenic disturbances pose a threat to the functioning of nature. As long as we remain below this threshold, however, we can use the planet for our own benefit. He or she also believes in a strong governmental responsibility, and in decision-making based upon science and expert knowledge. The individualist (nature is benign) is risk-seeking and adheres to a more opportunistic point of view. To address climate change, for instance, he or she relies on laissez-faire markets to spur competition and innovation. The benefits of climate change might at some point even balance out the costs, might they not? Weak sustainability (Williams & Millington, 2004) solutions, with a focus on economic opportunities, adaptation and innovative technology, are preferred.

The egalitarian (nature is ephemeral and fragile) gives priority to nature and ecological recovery, through a preventive, risk-aversing, precautionary management style. In this opinion the needs of animals and plants should also be taken into account. This attitude results in a strong sustainability with room for natural and ecological processes, and a reconsideration of human demands. The fatalist (nature is capricious) is not concerned about the future. Life is a lottery. Everything is determined by destiny and cannot be influenced. Sustainability is just a farce.

A fifth worldview, called 'nature resilient' (Thompson et al., 1990) or 'nature evolving' (Holling et al., 2002) is occasionally pictured at the central intersection of the axes. It is acknowledged that people adhere to one or more stereotypical perspectives on nature, oceans and the way these should ideally be managed.

Ocean perspectives through time: from 2D to 4D

During most of human history we have considered the seas and oceans as a surface – 2D – we had to cross to reach a destination, and as a limitless resource (Huxley, 1932). Trade and fisheries, as well as the collection of seafood from beaches, were the main human activities. Trade interests might lead to maritime domination as was the case in Roman times with the notion of *mare nostrum*. With the discovery of the New World by Columbus in 1492, the Spanish born Pope Alexander VI ruled that unclaimed territories to the west of an imaginary line running north and south through the mid-Atlantic would be Spanish possession. The lands east of it would be owned by the Portuguese. In 1529 this Treaty of Tordesillas was completed by the Treaty of Zaragoza defining a similar line in the Pacific. However, emerging maritime states of those days, such as France, Holland and England, did not agree either with the Spanish and Portuguese monopolies or the ruling of this pope.

The capture of the Portuguese carrack *Santa Catarina* on February 25, 1603, by two vessels of the United Dutch East India Company (VOC) off the coast of Malacca turned out to be a tipping point (Gladwell, 2004) in international maritime law. Although the 750 passengers, among whom a hundred women, were allowed to leave the captured vessel peacefully, the ship and its cargo, were kept as a prize: a valuable jackpot. When

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auctioned in Amsterdam in the autumn of 1604, the profit was around 3.35 million Dutch guilders; more or less the equivalent of the annual revenues of the English government at that time (Vidas, 2010). In today's currency this would be an estimated 250 billion euro. For the Dutch and certainly for the shareholders of the company, the commander of the two VOC-vessels, Admiral Jacob van Heemskerck, was a hero (Fig. 3); for the Portuguese he was a pirate or privateer. But it was Hugo de Groot or Grotius, a brilliant young lawyer, who tipped the international scale in maritime trade and law, by introducing the notion of *mare liberum*, the principle of the 'freedom of the seas'. Even today this notion facilitates a whole range of human activities in ocean space. Yet, and despite these legal changes, the predominant human perception of the ocean was the one of a surface we had to cross for trade, etc.

Ocean exploration slowly turned into a 3D-perspective with the voyages of Louis Antoine de Bougainville on *La Boudeuse* and the *Étoile* (1766-1769), James Cook on HMS *Endeavour* (1768-1779) and Charles Darwin (1831-1836) on board the *Beagle*. The first dedicated ocean exploration voyage was organised by the Royal Society of London and the British government, with HMS *Challenger* from December 1872 to May 1876. The concept of such a marine science expedition was conceived by Charles Wyville Thompson, a professor in natural history at the University of Edinburgh and his student, John Murray. They also defined the term oceanography, which then became a new field of research. An important goal of the expedition was to investigate whether life could exist in the deep sea or not. In those days the general view was that life was impossible below some 550 metres, due to the high pressure and the lack of light. The voyage of the *Challenger* led to a new and overwhelming view of the seas and oceans: a place full of life, with a complex physical structure, and unknown resources, such as manganese nodules, on the deep sea floor. The *Challenger* expedition also sketched the main contours of the ocean basins, and by this, it unveiled the ocean's deeper parts; the third dimension of ocean space. It is of note that the birth of ocean sciences coincided with the beginning of the British Industrial Revolution. This underlines the strong link with, and dependency upon, technological innovation in oceanography.

Since then specialised marine aquaria, laboratories and institutes have been exploring the oceans. The Naples Aquarium, which opened to the public on January 12, 1874, was the first in a series of similar institutes elsewhere in Europe. In 1910 Prince Albert I of Monaco established an oceanographic institute in Paris and the Musée Océanographique in Monaco. Soon this initiative was followed elsewhere in the western world by the establishment of dedicated research institutes, like the Woods Hole Oceanographic Institute (1930) in the USA. This scientific quest for a better understanding of ocean space came into bloom after the Second World War, due to new technology and computerised modelling. Rapidly it became clear that the exploration of ocean space could no longer be addressed by a single country's marine research capabilities; it called for international cooperation. For this, among others, the International Oceanographic Commission, IOC, was established in 1960, within UNESCO.

The largest, most costly, and longest-lasting international research programme in geosciences started in 1968 as the Deep Sea Drilling Project, DSDP. It also marked the transition from 3D to 4D. Within the DSDP and its successors, drilling capabilities have been employed to unlock the information stored in the deep-sea floor. Icons of this successful international research programme are the US drilling vessel or floating universities, *Glomar Challenger* and *Joides Resolution* (Fig. 4). Since 2005 a dedicated Japanese research vessel, the *Chikyu* (meaning Earth in Japanese) has been part of the programme. The programme led to a revolution in geosciences: plate tectonics, a unique and planetary cooling mechanism. Information from ocean sediments ushered in the fourth dimension of ocean space: geological time.

Fig. 3. Jacob van Heemskerck (left), the Heeren XVII of the VOC (centre) and Hugo de Groot (right), players in a lawsuit that changed the world through the introduction of the notion of mare liberum*, leading to the concept of the 'freedom of the seas'. This concept has dominated humanity's relationship with ocean space and its renewable resources ever since. The ever-increasing human activities have, however, put these resources under risk by CO_2 pollution, overfishing, etc. In 2012, UN Secretary-General Ban Ki-moon launched the Ocean Compact initiative to strengthen the current UN Convention on the Law of the Sea, and to create a new momentum for sustainability in ocean space.*

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Fig. 4. Joides Resolution*, leaving Hawaii in May 2008. In 1983, Professor Jan van Hinte and myself initiated a European project under the European Science Foundation to give Dutch scientist regular access to this research facility.*

Another demonstration of the role of time in ocean space is connected with the radioactive fallout of nuclear testing until a ban in 1962. It is also linked to waste from nuclear power plants, and incidental discharges into the sea by plants such as Sellafield (United Kingdom), La Hague (France), Chernobyl (Ukraine) and Fukushima (Japan). The last-named was the largest release in human history. Radioactive tritium, for instance, became a perfect marker for tracking ocean water masses. Scientists, sampling North Atlantic water, found that tritium released into the atmosphere prior to the 1962 nuclear test ban treaty, had mixed downwards by 1973 and moved, by 1980, into deep water off Florida's coast. This water had taken about twenty years to travel 4,800 km, at snail speed, through ocean space. The present boom in ocean exploration and monitoring through innovative technology as observation networks, remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs), gliders and floats, in fact signals the 4D-phase of our understanding of ocean space. It should also be a driver for new ocean governance approaches and regimes (Stel, 2003).

What is Ocean Space?

The notion of ocean space is derived from the Preamble of the United Nations Convention on the Law of the Sea, UNCLOS, 1982. In the third line the following statement is made, '… conscious that the problems of ocean space are closely interrelated and need to be considered as a whole …' This is a reference to the 4D-ocean perspective of today. So far, the notion of ocean space is, however, not (yet) widely applied in ocean sciences. Even in those days the role of new technology in ocean exploration was apparent. Some, like the Maltese ambassador Arvid Pardo (1914-1999) and Elisabeth Mann Borgesa (1918-2002), were worried about a possible widening gap between countries with modern marine research capability and those lacking this.

The notion ocean space is closely linked to Arvid Pardo, who became famous for his Draft Ocean Space Treaty. This was a working paper submitted by Malta to the UN Seabed Committee in 1971. Pardo placed Malta, a developing country, at the heart of the discussion of sustainable use of ocean resources, of ocean space conservation and the transfer of knowledge and funds to developing countries through the concept of the Common Heritage of Mankind. In his draft treaty he distinguished National Ocean Space (now the Exclusive Economic Zone, EEZ) and International Ocean Space (now the High Seas). In a commentary 'Pardo, politics and pollution' in the New Scientist and Scientist Journal of July 8, 1971, the term Ocean Space was introduced to the media. The main issue of the commentary was, however, the fact that Pardo had been fired by the newly elected socialistic prime minister Dom Mintoff (1916-2012). In this way Pardo lost his influence and his visions were frozen in time. In retrospect the visionary Pardo and Mann Borgesa were frontrunners in a transition to sustainable ocean governance; a transition still to come.

In 1967, when Pardo addressed the United Nations General Assembly about the new Law of the Sea, disciplinarity was the common research mode. Then, just as today, most oceanographers were trained in one of the traditional sciences such as physics, chemistry, biology and geology or in a related field of engineering, meteorology etc. (Pinet, 2009). In dedicated research institutes or university departments these disciplinary boundaries mostly blur through multi- and interdisciplinary research efforts. But even today, and in spite of the recognition of anthropogenic forcing in many modern environmental issues, social sciences are mostly not part of or affiliated with, these ocean research institutes.

At the dawn of the third millennium the notion of ocean space still is a challenging one. It nicely fits the way of thinking within modern earth system sciences and an increasing awareness that human activities now also affect the earth system and its subsystems: land, water, air and life or lithosphere, hydrosphere, atmosphere and biosphere. The hydrosphere contains all the solid, liquid and gaseous water of the planet. But, in that view the earth is portrayed as a layered structure, whereas in the notion of ocean space the emphasis is placed on the oceans, a large 'container' with water at the surface of the earth, as such. It extends downwards from the earth's surface several kilometres, with the Mariana Trench as its deepest spot, into the lithosphere and some twelve kilometres up into the atmosphere. It also adds to the fact that 99% of the living space of the planet is made up by ocean space. The other one percent is formed by the land and the narrow band of atmosphere in which life, breathing air, can exist. Its boundaries are blurred at the surface and sea floor by subtle interaction with the atmosphere and lithosphere, respectively.

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Ocean space – 1.37 billion km^3 of water covering some seventy percent of the earth surface – is a different world, which we barely know, even today. Life is everywhere; from microbes in watery cracks in the deep ocean floor to freshwater lakes and streams on the land filled with water temporary on loan from the ocean. It also is home to the greatest abundance and diversity of life in the world, and the known universe. It is a weightless and mostly dark world, like outer space. It is a world alien to us, being ourselves a terrestrial species. In ocean space there is no horizon for orientation. In deep ocean space above is below and below is above. Here, the 600 million years old body plan of a jellyfish, is a perfect adaptation to the ocean world.

Ocean space also is a highly dynamic world with complex currents, waterfalls and cataracts. In a geographical view, ocean space is subdivided by the present oceans and seas. Subtle but intensive and sometimes large-scale interactions, are taking place at its interfaces with the ocean floor and the lower atmosphere. Physical and chemical processes as well as life within ocean space influence human activities and vice versa. Hydrothermal vents and cold seeps indicate zones of active interaction between ocean space and ocean floor. From an ocean perspective, phenomena such as El Niño and La Niña, the thermohaline circulation, and the carbon and water cycles shape life on land, and by this our daily lives, our activities and societies. The ocean is the flywheel of the climate system because of its immense capacity to store heat and it is home of some 1.5 million species (Bouchet, 2006). Last, but not least, it forms the main transport facility for humankind.

Since the Second World War, new and innovative technology developed both by military and civil institutions, has dramatically changed our insights into ocean processes. This has laid the foundation for a transition from basic oceanographic research by academia towards operational oceanography by dedicated organisations often linked to national weather services. The development and implementation of the Global Ocean Observing System (GOOS), an initiative of some UN agencies such as UNESCO/IOC and the World Meteorological Organisation (WMO), forms the backbone of this transition. Just like Integrated Coastal Zone Management (ICZM) it was launched during the 1992 Earth Summit. The implementation takes place mainly through regional initiatives such as EuroGOOS for Europe and SEAGOOS for South East Asia. The first is in turn subdivided into a subregional implementation structure with e.g., the Baltic Operational Oceanographic System (BOOS) and the North-West Shelf Operational Oceanographic System (NOOS). However, all these activities build on a national effort in marine science and monitoring (Stel, 2006, 2007).

A similar global observation system is developed for the earth environment, the Earth System, as a whole. The Group on Earth Observations (GEO) co-ordinates the efforts to build a Global Earth Observation System of Systems (GEOSS). This initiative was launched in Johannesburg after the 2002 World Summit on Sustainable Development. At the European level the Global Monitoring for Environment and Security (GMES) is an earth observation programme launched by the European Commission and the European Space Agency. It is the second flagship programme of the EU after Galileo that establishes a global satellite system. Both GEO and GMES focus on environmental change.

Technology development has also affected our relation with ocean space as a limitless resource. Transport and fisheries are clear examples of this. The transition from sail to steam at the end of the nineteenth century was, just after the Second World War, followed by a transition from steam to diesel (Smil, 2010). Not only did this transition affect the marine shipping sector, but also the fishery sector, as fishing power was markedly increased.

Today, about 90% of global transport is maintained by shipping and in 2010 seaborne trade reached 6.7 billion tonnes. Moreover, the world fleet has expanded over 37% since the financial crises of 2008 (UNCTACT, 2012). In the fishery sector global catches have rapidly increased from some 20 million tonnes in 1950 to about 90 million tonnes around 1990 (FAO, 2010, 2012). Overfishing and an extensive growth of aquaculture, leading to the cultivation of large areas of mangrove forests, are the consequences.

Thus the notion of ocean space stands for a system science approach combined with thinking from the ocean, and the processes within it, towards the land. This includes both human activities that are influenced by ocean space, and human activities, such as the exploitation of ocean resources and pollution, that affect ocean space. Applying the notion of ocean space refers to a holistic approach, the 4D-aspects of this part of the Earth System. It is in fact a social-ecological concept that deals with sustainability challenges that are the consequence of the complex interactions between human activities and the marine environment at all scales; from local to global. So far, the local to regional scale has been addressed in, among others, the concept of ICZM, which was embraced at the 1992 Earth Summit on Environment and Development (Rio de Janeiro). ICZM advocates a holistic approach to coastal zone management to reach sustainable development. Subsequently, it has been widened to the management of regional seas such as the Baltic and EEZs (Stel, 2006, 2012).

Ocean space is also a crucial element of the biosphere, and delivers ecosystem services that dwarf traditional economic returns (Costanza et al., 1997, 2007). But, the ever growing human population and the even faster growing human activities expressed in various footprints (WWF, 2012), nowadays interact strongly with ocean space. It is even worse: we are now able to pollute the ocean in such a way that the characteristics of the system are changing. The main drives in this process are: rapid population growth, increased welfare and consumption, and a large boost in technology development, enabling the first two drivers.

Non-western society's view on ocean space

Perceptions colour our view towards ocean space. Indian Ocean societies and China have viewed the sea as a special place of trade, beyond society and social processes. It was considered as an area to be crossed as quickly as possible; not as territory for control, influence or social power (Steinberg, 2001). This concept is comparable to the present view of western societies when planning a holiday by car in France. Planning the route to take, the highways to use is just focused on how to reach the destination; not on ownership of the highways used.

The perception of the ancient Polynesian society was unique in that their culture was fully adapted to ocean space. They knew how to live, and survive, within the ocean environment. They probably were the only people who really learned to think from ocean space. Their sophisticated navigation system was based on observations of stars, ocean swells, flight patterns of birds and other natural signs. They used charts of sticks and shells to record the interference patterns of waves intersecting with islands (McKay & Walmsley, 2003). And, as they moved further away from the continents, they developed a portable agricultural system, in which domesticated plants and animals were carried in their canoes for transplantation on the islands they encountered. They lived and survived in an immense, undefined ocean world where they could find their way over the open ocean – the surface of ocean space.

Polynesians view the ocean as a multitude of islands connected by short journeys, in a field of cross currents, wave patterns, shifting breezes and flotsam; rich in bird and sea life, all laid out under a series of rotating constellations, whose intersection with the horizon easily marks one's place on the trail between islands (Lewis, 1978). Westerners see the Pacific Ocean as in a window seat on an aeroplane: a blank space speckled with objects that we call islands.

In the wake of European exploration the traditional, holistic worldview of the Polynesians mostly disappeared. Today, inhabitants of small Pacific islands consider themselves to be living on tiny, remote islands, poor in resources. To date, they have a land-trained mind, living on islands with boundaries fixed by Europeans in the nineteenth and twentieth centuries.

Western society's view on ocean space

For four centuries western societies have viewed ocean resources and ocean space in terms of ownership. This is the consequence of De Groot's notion of the 'freedoms of the seas'. In 1982, UNCLOS implemented a traditional solution to an old problem. The old problem relates to intensive and conflicting use of common property marine resource such as fish. The solution was the application of the mechanism of enclosure by the introduction of the concept of the Exclusive Economic Zone, EEZ. This is a marine zone of 200 nautical miles in which states have the right to exploit marine resources in a sustainable way. The present enclosure through the EEZs covers approximately 149 million km^2, an area almost as large as the land surface, and 40% of the world's ocean. They contain 90% of the marine resources. Another new element of UNCLOS was the establishment of the International Seabed Authority for the exploitation of non-marine, ocean resources outside the EEZs. The open waters of the High Seas, however, still are a global common, where the 'tragedy of the commons' in deep-sea fishery is part of daily life (Ostrom et al., 2000). Jointly these measures within UNCLOS should lead to new concepts of ocean and EEZ governance (Stel & Loorbach, 2004).

The concept of 'ocean states' also is an effect of UNCLOS (Stel, 2002, 2010, 2012). The European Union with its 27 member states has a shared EEZ of some twenty-five million km^2. As such, it is by far the largest in the world. The ocean-land ratio for the EU is about five to one. Based on this ratio one could consider the marine domain as the most important feature of the EU-27. Being a terrestrial species, however, we tend to focus on the land rather than the sea (Stel, 2002, 2006; Steffen et al., 2011). Moreover, this ratio also blurs the real situation, as most of the shared EEZ is situated outside Europe and relates to former colonies. From a national perspective the USA has the world's largest EEZ, followed by France, Australia and Russia.

On August 2, 2007 the Russian polar explorer Artur Chilingarov planted a titanium flag at 4,200 metres below the North Pole to underpin the 2002 Russian claim for an extension of the EEZ. What followed was a media hype. The cover of Time Magazine (October 7, 2007) posed the question 'Who owns the Arctic?'. Angry readers reacted by scolding indecisive politicians. Hardly any attention was paid to the rules and regulations within UNCLOS that should take care of the 'problems'. The formal Russian claim is submitted to the UN commission on the Limits of the Continental Shelf, CLCS. Chilingarov's bold action in the Arctic deep sea just fuelled the controversy as most Arctic rim countries have declared an EEZ and are also trying to strengthen their claims for an extension at the CLCS. Similar disputes, however, occur all over the world. The present dispute between China, Japan and Taiwan about eight uninhabited islands – the Senkaku/Diaoyu Islands – in the East China Sea is a prime example of this.

Key message

Most of the ocean was already in place about four billion years ago (Garrison, 2009). So, ocean space is an ancient feature of the Earth. The word 'ocean' is derived from the ancient Greek 'okeanos', referring to a body (3D) of saline water. Humans have, for the sake of convenience, divided the world ocean into the Pacific, Atlantic, Indian, Southern (Antarctic) and Arctic oceans. In reality, however, they are only temporary features of a single world ocean. The word sea mostly refers to a body of saline water, partly or fully enclosed by land. However, sometimes it is used as an interchangeable word for ocean. Recent research

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has shown that the fourth dimension of the ocean – similar to the atmosphere – is time. Therefore the notion of ocean space is re-introduced.

Ocean space is the last physical frontier on Earth. Exploration of ocean space is just starting and will bring twenty-first century ocean research into a completely different modis operandi. The main drivers are new technology (miniaturisation, biomarkers, etc.) and the rapid increase in computer power for modelling. Signals for this change are, among many others, the development in the US of advanced ocean observing systems like the Ocean Observatories Initiative (OOI) which is an offspring of the 1992 GOOS-initiative. The OOI is a long-term, NSF-funded programme to provide 25-30 years of sustained ocean measurements in order to study climate variability, ocean circulation and ecosystem dynamics, air-sea exchange, sea floor processes and plate-scale geodynamics. It will revolutionise our thinking about ocean space and its role in the Earth System.

Today, some 3,600 free-drifting, profiling floats in the upper two kilometres of ocean space, demonstrate the observing power of innovative technology within an international ocean monitoring effort. The US-led Argo-mission started in 2000, reached is target of 3,000 floats in 2007, and currently operates with the support of 23 countries. For the first time in the history of ocean exploration, continuous monitoring of temperature, salinity and velocity of the upper two kilometres of ocean space, is taking place (www.argo.ucsd.edu).

Gliders, floats with wings to provide lift and allow them to move horizontally while profiling, are the natural next step in the exploration of ocean space. Currently, they monitor water currents and temperature, track pollution, watch volcanoes, measure icebergs, reveal the effects from storms on the ocean environment, collect data on human impact on fisheries and monitor water quality. About 400 gliders (The Economist, 2012) are currently used to explore ocean space from deep water to the surface, from the tropics to the poles. Each glider can travel long distances, over long periods without servicing. Due to the rapid advancements in sensor technologies they are rapidly becoming an important tool for collecting ocean data, and, by this, valuable information. They yield a continuous view of what is going on in ocean space and will revolutionise the way we explore and monitor ocean space in the twenty-first century.

On a human scale, ocean space is impressively large. On a planetary scale, however, ocean space is insignificant as its average depth is dwarfed in comparison with the radius of the Earth (Garrison, 2009). There is more water chemically trapped within the Earth's hot interior than there is in ocean space and the atmosphere. Ocean space is a critical player in the Earth System; it is central to climate regulation, the hydrological and carbon cycles and nutrient flows, it balances levels of atmospheric gases, it is a source of raw materials vital for medical and other uses and a sink for anthropogenic pollutants. It is hard to understand that ecosystem services as well as the value of ocean space are not taken into account when we discuss human activities, despite a large and ever-growing literature on these issues (Borgese, 1975, 1986, 1998, 2000; Costanza et al., 1997; Daily, 1997; De Groot et al., 2002; MEA, 2005; Hein et al., 2006; Worm et al., 2006; Beaumont et al., 2007, 2008; Naber et al., 2008; Noone et al., 2012).

The wonders of ocean space are well documented in the media, but mostly without any integrating vision. Public engagement and pre-university education in ocean space issues are needed for many reasons. We need an informed society, a next generation of ocean space explorers, visualisation techniques, etc. But, to understand the role of ocean space in the coupled environment-society system with its numerous human activities, we also need a quantum leap in our understanding of ocean space. For this we have to bring it into the classrooms and to stakeholders, in order to warrant sustained support.

The notion of ocean space could be helpful in this as it reflects a modern, twenty- first century approach, which is part of the modern Earth System Science thinking. Moreover, it also is attractive as an awareness-raising instrument because it encompasses issues such as exploration, adventure, science, resources, sustainability, etc., and reflects 4D-thinking. That is, the ocean as a changing feature of the Earth even in geological time (Stel, 2012).

It is common practice that large, international science programmes have to reach out to the general public. Yet, a sustained education and outreach effort is lacking in Europe. In the US, ocean literacy (http://oceanliteracy.org) is taken seriously by the government and its funding agencies. Their first principle is: 'The Earth has one big ocean with many features'. 'Why don't you take a logical step further?', was my question to their director at the first European Ocean Literacy Conference (Bruges, October 2012). The next step introduces the non-normative notion of ocean space. The answer was: 'Yes, but how?'

Discussing the issue with National Geographic Society, an icon of the US media, signals the problems lying ahead. They already use 'coloured' concepts such as 'Mission Blue' or 'Blue Ocean' (Earle, 2009) and 'Planet Ocean' (Ballesta et al., 2007; Holden et al., 2007). But, in contrast, no one would even think about labelling the exploration of the Amazon and African rainforests or the North American and Eurasian boreal forests, as 'Mission Green' or just 'The Green', 'Green Land' or whatever. Again, this shows that even in the popular media, our land-trained mind, our 'thinking from the land' still blurs our perspectives in a traditional nineteenth-century and terrestrial way.

Another striking example is the way in which the media, with National Geographic Society in the forefront, documented the first solo dive to the bottom of the Challenger Deep in the Marianne Trough by James Cameron in March 2012. As a rule, headlines around the world stressed that this was the first solo dive, the deepest point on Earth, that James Cameron was a film director (*Titanic* and *Avatar*) and that it was like 'hell on Earth'.

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But Cameron also said that he felt lonely. Lonely, despite continuous communication with the surface, and an active outreach through the modern media. According to him, 'It was bleak. It looked like the moon. I didn't see a fish. I didn't see anything that looked alive to me, other than a few shrimplike amphipods in the water'. In my opinion this activity, as many research efforts, should have been presented from an ocean space perspective. In such a view Cameron did not just descend some 10,890 metres to the deepest spot on Earth, like a mountaineer climbing 8,848 metres to reach the top of Mount Everest, the highest mountain top on land. In a modern, ocean space perception, however, he undertook, as the third man on Earth and like the first travellers to Mars in the near future, in a high-tech submersible which was also equipped as a state-of-the art film studio, a widely publicised, adventurous and risky trip to one of the most remote corners of ocean space. Apparently, the media have not yet discovered the outreach 'power' and potential of the notion of ocean space either.

Anthropocene

Today we are well aware of the fact that human activities alter the planet's environment on all scales. Locally, regionally, nationally to globally, we are changing the planet's physical, chemical, biological and geological environments. Our activities have an impact on the composition of the atmosphere globally while we, at the same time, also pollute it on a local or regional scale through urbanisation and industrial activities. Through this we impact the Earth's climate system, its water cycle, its landscape and even its biodiversity.

For practical reasons the 4.5 billion years of Earth history are divided into a number of manageable units. The Quaternary comprises the last 2.58 myr, and includes two epochs: the Pleistocene and Holocene. The first comprises a series of eighteen glacial events, during the icehouse climate of the last two million years. The latter actually is the latest interglacial so far. The term Holocene is derived from the Greek words 'holos', meaning 'whole' and 'kainos', meaning 'recent'. The latter refers to the fact that this epoch is the most recent division of Earth history. It is by far the shortest epoch in the geological record. Based on climate data from a Greenland ice core, it began 11,500 years ago. The Holocene is distinguished as a separate epoch for practical reasons as it relates to the physical environment such as soils, river deposits, deltas, coastal plains, etc., we live on (Zalasiewicz et al., 2011). As such it unconsciously refers to a view that humans have a special place in nature.

The perception that human activities are a new planetary force developed in the late nineteenth century (Marsh, 1864; Stoppani, 1873; Arrhenius, 1896; Chamberlin, 1897). During the early twentieth century this concept was built upon by Hermann Löns (1866-1914), a German writer, journalist and conservationist, and by Vernadski (1926/1998), Teilhard de Chardin and Le Roy (1927). They coined the concept of the noösphere as the third phase of the Earth's development. Just as the emergence of life fundamentally transformed the geosphere (first phase), they argued that the emergence of human cognition fundamentally transforms the biosphere (second phase).

In 2000 Paul Crutzen and Eugene Stoermer coined the notion of the Anthropocene – the Age of Man – within the research community of the International Geosphere-Biosphere Programme. Apparently, the time was right. The notion struck a chord, probably because the effects of human-induced climate change became widely accepted. An internet search in 2011 for the Anthropocene resulted in 520,000 hits. Moreover, the number of scientific papers mentioning the concept of the Anthropocene equalled more than two hundred in 2011, many of them outside the discipline of geology, and this number is steadily increasing.

It is evident that we are living in a time in which the ever-growing human activities are reshaping the natural environment. It is striking how we have altered the surface of the planet by deforestation and land cleaning and reclamation. Infrastructure such as dams, roads, railways, harbours and cities, have a long-lasting and profound environmental impact. Moreover, we are altering the biological and chemical properties in the Earth System by, for instance, overfishing and the introduction of invasive alien species as well as large-scale pollution of both the atmosphere and ocean space. CO_2 pollution is changing the atmosphere and leading to climate change, sea level rise, ocean acidification, coral bleaching and coastal dead zones.

The addition of a third epoch to the Quaternary period is under discussion now in the International Commission on Stratigraphy of the International Union of Geological Sciences (IUGS). A decision is expected in 2016 (Zalasiewicz et al., 2011).

Within the lifespan of a human being, let us say Bert Boekschoten's, the face of the planet has transformed through an unprecedented urbanisation. Cities now dominate our landscape and are easily seen from space at night (Fig. 1). In 1950 only 29% of the world population lived in cities, now more than half occupy cities or megacities. As such, these large concentrations of humans and their activities, create a local to regional micro-climate with many unknown effects. And the number of cities of a million inhabitants is expected to grow from one (Beijing, China) in 1800, to sixteen in 1900, and 378 in 2000, to some 600 or more in 2025. Cities will also grow into megacities with more than ten million inhabitants, and merge into mega-regions. Here cities agglomerate to huge populated areas, such as the present Hong Kong-Shenhzen-Guangzhou region in China, home to some 120 million people. In 2050 about 70% of the world population, a projected 9.2 billion people, will be living in an urban environment. That equals the world's population in 2006.

The world population rose from one billion around 1800, to two billion in 1927. Then, within 33 years it grew to three billion in 1959, to four in 1974, to five, in 1987, six in 1998, and 7 in

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October 2011. Currently, it takes about 13 years to add a billion people. The projected world population for 2025 is eight billion, for 2043 it is nine billion, and the ten billion mark will be reached in June 2083 (http://esa.un.org/wpp/other-information/faq.htm). In consequence, human activities are indeed having an ever-increasing impact on the Earth's environment, inclusive of ocean space.

Stages of the Anthropocene

In the hunter-gatherer society of the pre-Anthropocene humans lived in small groups mostly having a local to regional imprint due to the use of fire and hunting. The latter might even have contributed to the extinction of the Pleistocene megafauna. The next impact of human activity came through the domestication of animals such as dogs, horses, cattle and other farm animals as well as plants. This ushered in the Neolithic or Agricultural Revolution in which a series of agricultural transitions took place. The first use of fossil fuels was during the Chinese Sung Dynasty (960-1279) for the steel industry. From the European late Middle Ages coal was also used for heating in large cities such as London. Mostly, however, wood and charcoal were the main source of energy.

China's forgotten industrial revolution during the Sung Dynasty is comparable to the British or European one, some eight to nine hundred years later. This Dynasty was a period of a rapidly increasing population – it more or less doubled during the eleventh century – as well as urbanisation and innovation in agriculture and technology. As such, it marks the culmination of a history of 1,500 years of innovation by trial and error. Spectacular innovations are the first printed books, the first widespread use of paper currency and credit notes, the first school system, the development of gunpowder, a rapid development of coal, steel and armament industries, a market economy linking the coastal provinces and the interior through new canals, foreign trade with Indian Ocean countries and using large sailing ships with watertight compartments, pivoting sails, and compasses, the first specialised navy, and so on. Chinese engineers developed the spinning jenny and steam engines, which were key to the later British industrial revolution. In the middle of the thirteenth century, China had reached a level of economic and technological development that Europe would only achieve around the turn of the nineteenth century. Moreover, it was a time in which culture and arts prospered through Taoist landscape painting (Fig. 5), calligraphy, poetry and philosophy, with Zhu Xi (1130-1200) as the most influential figure, and leading to Neo-Confucian thought. As Hobson (2004) pointed out, China was by far the most innovative and technologically advanced civilisation until the mid-eighteenth century. Hobson, like Needham (www.nri.org.uk/science.html) and Frank (1998), showed how the East played a substantial role in the rise of the West by the transfer of knowledge and knowhow.

Fig. 5. Taoist landscape painting 'Listening to the wind in the pines' by Ma Lin, a Sung court painter during the first half of the thirteenth century. The title, the four characters in the upper right, was added by emperor Li-Tsung, who received the painting in 1246. In the painting a scholar, with his diminutive servant, concentrates on listening to the strong wind blowing through the pine needles and vines. This sound seems to be echoed in the flowing water and surrounding peaks behind him. The emperor was fond of pine trees and might have been depicted as the scholar. Ma Lin has, in a subjective and masterly way, rendered the look of the scholar intently listening to the wind (National Palace Museum, Taipei, Taiwan).

The first Stage of the Anthropocene coincides with the beginning of the industrial revolution (Fig. 6) in Europe (Steffen et al., 2007, 2011; Zalasiewicz et al., 2008, 2010, 2011). This transition had a relative short incubation period and quickly

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Fig. 6. The first 'Great Exhibition of the Works of Industry of all Nations' or First World Exhibition in London (1851).

transformed society, first in England, later in the rest of the world. Instead of using natural energy sources like wind- and waterpower, plants and animals, the industrial society uses fossil fuels. This caused a transition to a high-energy society of more than seven billion people mostly with highly improved living standards and birth rates and a global economy. The downside of this development is: intensive resource and land use as well as a large-scale pollution of the Earth's environment. The first stage of the Anthropocene ended abruptly after the Second World War when a new technology push materialised, leading to the second stage of the Anthropocene: 'the Great Acceleration' (1945-2015) followed by a third one: 'Stewards of the Earth' (Steffen et al., 2007).

This detailed fine tuning of the Anthropocene 'epoch' towards the growth of human activities, which include a western lifestyle, during the past two centuries, suggests a mismatch with geological time. Instead the timing would much better fit a historical scale. Moreover, it is based mainly upon the destructive side effects of the ever-increasing human activities, which indeed made a large leap since the British industrial revolution and after the Second World War.

Accepting the Anthropocene as a new epoch in the geological record would be a break in the current trend of defining stratigraphic units such as eras, periods and epochs. So far, arranging time in geological units is based upon geological characteristics and criteria. But the Anthropocene, in contrast, is based upon anthropogenic environmental changes that are currently taking place. Compared to the Holocene, in which we live, the proposed Anthropocene encompasses just a few centuries (Crutzen, 2002; Steffen et al, 2007) or at best millennia (Ruddiman, 2007). In the latter case one might argue that the time span of the Anthropocene overlaps the Holocene. So why should we, apart from hubris and an overestimation of humans and human activities, change the name at all?

Anthropogenic pollution

Humans have always caused some environmental pollution. Since prehistoric times, people have created waste that was either burned, thrown into waterways, buried or dumped overground. However, the waste of prehistoric populations mostly comprised food scraps and other substances that broke down

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easily by natural decay processes. Moreover, its number was much smaller and spread out over large areas. As a consequence, pollution was less concentrated and hardly caused problems.

The first organised pollution of the environment in ancient times most likely was the use of human faeces for field fertilisation. In this way the productivity of the alluvial plains were maintained over thousands of years (Borsos et al., 2003). People owning the city channels in China belonged to the richest ones in society, until the twentieth century. But, this use of human excrements also contributed to the pollution of groundwater, making it unfit for consumption in the whole of tropical Asia. Moreover, it could also lead to infections in human society. As a consequence drinking boiled water – tea – became popular in Asia.

Air pollution of living quarters was a consequence of using fuels for heating and cooking. Walls of caves, inhabited many thousand years ago, are covered by thick layers of soot suggesting that breathing was difficult due to the smoke. Lungs of mummified bodies from the Palaeolithic era are frequently black (Makra & Brimblecombe, 2004).

In the wake of the Neolithic Revolution urbanisation started, some 7,000 years ago, to rise in Mesopotamia. Here rural communities formed urban centres or cities such as Eridu and Ur, at the banks of the Tigris and Euphrates rivers. The then coastal town of Ur was the capital of the Sumerian Empire. Between 2,030-1,980 BC it was, with some 65,000 inhabitants, the world's largest city. Urbanisation, however, continued as the city expanded out from the centre and, in time, the once fertile fields which fed the population were depleted. The over-use of the land, combined with a shift in the Euphrates which drew the waters away from the city, finally resulted in abandoning the place around 500 BC.

Other areas where urbanisation occurred very early were the Indus Valley (Harappan civilisation; 3,500-1,500 BC), Nile Valley (Egyptian dynasties and kingdoms) and the great valleys of China (Xia and Shang Dynasty; 2,100-1,600 BC and 1,700-1,046 BC). Urbanisation also developed in Central America, the Maya Aztec area, and the Andean area of South America. It finally reached Europe through Greece. As cities grew, pollution increased. Air pollution caused by a penetrating stink from tainted meat, rotten foods and excrement. Aristoteles (384-322 BC) referred in his *Athenaion Politeia* to a rule that manure should be placed outside the town, at least 2 km away from the town walls (Mészáros, 2001). Moreover, poor sanitation practices and contaminated water supplies often unleashed massive epidemics in early cities. Daily life in ancient Pompeii has been painted vividly by Mary Beard (2009). She described a city with howling dogs, late-night drunks and an overwhelming smell due to the paucity of sanitary facilities. A messy place, where the baths that should provide 'a place of wonder, pleasure and beauty' could be so polluted that 'they might also have killed the visitor' (Beard, 2009, p. 356).

Urbanisation progressed in China, in the Mediterranean Basin and in northwest Africa. From about 1,000 AD onwards, more and more people lived in smoky and sooty surroundings. Maimonides, a Jewish philosopher and physicist (1135-1204), who lived in Cordóba, Fez and Cairo, noted that urban air was, 'stuffy, smoky, polluted, obscure and foggy'. A similar situation occurred in mediaeval cities of northern European such as London, Paris and Bruges.

The ecological footprint of these cities was, however, much larger. Large-scale deforestation and industrial activities were taking their toll. Greenland ice cores show that lead occurs in concentrations four times greater than natural values between ca 500 BC to 300 AD. They also yield evidence of lead pollution from mediaeval and Renaissance silver mines.

Environmental problems became even more serious and widespread at the turn of the nineteenth century. During the early phases of the British industrial revolution, coal powered most factories. Most city homes also relied on coal for heating and cooking. The burning of coal filled the air of London and other industrial cities with smoke and soot. Poor sanitation facilities also allowed raw sewage to pollute water supplies in some cities. The polluted water caused breakouts of typhoid fever and other illnesses. During an unusually hot summer in 1858, the poor sanitation of London triggered the Great Stink (Fig. 7), which eventually led to the construction of a sewage system. Air pollution by industrial human activities also continued to affect daily life in London. The city was often hit by spells of heavy strong fogs, the 'pea soupers'. The toll of the Great Smog or Big Smoke of 1952 was considerable: 12,000 people died prematurely and 100,000 others fell ill (Brimblecombe, 1987).

Fig. 7. Cartoon from 1858, showing Father Thames (right) introducing his children (Diptheria, Scrofula and Cholera) to the fair city of London (left). This just shows how bad the pollution of the Thames had become by the time of the Great Stink (from Punch Magazine).

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In 2010, the total produce of waste resulting from economic activities and households in the EU was 2,570 million tonnes, according to Eurostat. This is, on average, about 5.1 tonnes of waste per person, of which 188 kg were hazardous.

At a global level, the production of Municipal Solid Waste is some 1.3 billion tonnes per annum, and is expected to increase to about 2.2 billion tonnes per annum by 2025. Generally, the higher the economic development and rate of urbanisation, the greater the amount of solid waste produced. Urban residents produce about twice as much waste as their rural counterparts.

The CO_2 emissions in 2011 were, according the International Energy Agency, the highest ever recorded: 31.6 billion metric tonnes (3,483 billion tonnes). This is 3.2 percent above the level of emissions in 2010. This increase is caused mainly by China, the world's largest emitter of CO_2. Due to the extensive use of coal its emissions increased by 9.3 percent. So, it may be concluded that human activities are indeed increasingly affecting the natural environment. Moreover, we might pass the 400 ppm level in the mid of this decennium (see NOAA: http://co2now.org).

In the early 1960s, it rose about 0.7 ppm per year. For the last decade, it has been rising at about 2 ppm per year. That observed increase, independent of the seasonal ups and downs described above, is due to the accelerating pace of emissions from human activities, particularly the burning of fossil fuels.

Key message

Advocates of the notion of the Anthropocene argue that this new epoch in geological time started around 1800 with the Industrial Revolution (Williams et al., 2011). This revolution began in England and, on the continent, in the Low Countries, i.e., the southern part of present-day Belgium. It lasted from ca 1760 to sometime between 1820 and 1840. This transition reshaped society. It dramatically changed daily life and marked a major turning point in human history. The British industrial revolution replaced traditional manual production by new manufacturing processes with machinery and by new chemical manufacturing and iron-producing processes. It improved the efficiency of water power and included the change from wood and other bio-fuels to coal, etc. Some of these innovations were mechanical, while others were based on the applications of science and experiments, leading to, among others, the chemical industry and thousands of new products, unknown from nature.

Since the beginning of the eighteenth century (Ellis et al., 2010), a transition of the terrestrial environment has been taking place in which the early twentieth century marked a turning point. Passing the 50% mark in which more than half of the land has been changed by human activities. Today, most terrestrial ecosystems show the effects of human activities and are predominantly anthropogenic. In other words, the product of land use and other direct human interactions with ecosystems. However, at first glance, the situation in ocean space appears much better (Halpern et al., 2008a, b). Although there are no places where the effects of human activities are not noted, only some forty percent is strongly affected by a cumulative impact. This happens near densely populated coastal areas such as around the North Sea, the Baltic and the South and East China Sea. Lesser to barely impacted areas are situated near the poles. In 2012 Halpern's group (Halpern et al., 2012) published the Ocean Health Index, a tool to measure ocean conditions around the world, for improved ocean management and conservation.

Although the notion of the Anthropocene is under consideration by the IUGS, and is a successful communication tool within the IGBP community and towards the media, it also has some serious side effects. This notion is an expression of hierarchical or individualistic perspective, with a strong belief in present and future technology and geo-engineering solutions to counterbalance the present side effects of human activity. Moreover, the notion is based upon the huge expansion of human activities through new technology. Yet, history has taught us that the side effects of new technology (pollution) are mostly underestimated and generally have led to upscaling of these effects. After all, the present environmental problems, i.e., climate change, ocean acidification, etc., are a consequence of global experiments that humankind, mostly unknowingly, has performed since the beginning of the British industrial revolution. As a consequence, some conclude that, 'It's no longer us against 'Nature.' It's we who decide that nature is what it will be.' (Crutzen & Schwägerl, 2011, p. 1).

Geo-engineering, however, deliberately interferes with a system (or parts of it) that we do not understand fully. It is about taking risks we cannot oversee, about taking measures without knowing the uncertainties, about hubris and not about 'a new global ethos'. With geo-engineering we might easily open another Pandora's box.

Using the already popular notion of the Anthropocene might again, at least in the media, lead to an overestimation of the role of humankind in nature. It might facilitate an even more destructive attitude towards nature. Instead, one should move to a more sustainable future in which human activities are better fine tuned to the (global) environment of which we are part. However, the recent discussions on humankind becoming the steward of the Earth (Steffen et al., 2011), as well as the idea of planetary boundaries (Rockström et al., 2009a, b), once again express a strong belief in future technology. These views again build upon a hierarchical or individualistic perspective; a 'business-as-usual' approach. However, a more open egalitarian approach, such as in transition management, might be a better and more sustainable way forwards.

Sustainability and transitions

Since the early 1980s, the notion of sustainable development (SD) has become an aspiration of most governments, international organisations, etc. A problem is that a single internationally

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agreed upon definition of SD is not available (Williams & Millington, 2004). The most widely cited one, the Brundtland definition, reads, 'SD is a development that meets the needs of present generations without compromising the ability of future generations to meet their own needs.' (WCED, 1987, p. 43). But there are many other definitions, as a result of the difference in human perspectives and values among cultures, society sectors and interest groups. Because of this it might not even be desirable to use just a single specific definition at all (Yin et al., 2000). On the other hand, it is easier to point out what SD is not.

Despite its intuitive appeal, the notion of SD is complex and difficult to put into practice (Grosskurth, 2008), in view of the large variety of definitions. Yet, these definitions also show some general characteristics. Firstly, it is an intergenerational phenomenon with a time scale of 25 to 50 years. Secondly, it covers multiple interrelated scales, varying from global to local levels. As a consequence, sustainable development in one part of the world can cause unsustainable development in another. On a global scale, for instance, unsustainable developments as a result of human activity are expressed in terms of global change, biodiversity loss, ocean acidification and poverty, while at a regional level desertification in the Mediterranean, air pollution in industrialised areas, the shrinking of the Aral Sea and the development of plastic islands in the oceans signal unsustainable human activity. On a national or local level these signs of unsustainability, such as harmful algal blooms, can be even more alarming. Thirdly, it involves, interrelated multiple domains: economy, society, environment etc. (Valkering, 2009). Moreover, SD is a subjective notion, because it depends heavily on personal worldviews; but it is also ambiguous, as it lacks guidance on how trade-offs can be resolved, and normative as even its main principles can be disputed. Finally, SD is related to complex systems (Grin et al., 2010). To sum up: SD problems are difficult and can be described as wicked problems, characterised by complexity, plurality and uncertainty (Rittel & Webber, 1973; Van der Brugge, 2009), unstructured problems which show high uncertainty and low consensus on values (Hisschemöller & Hoppe, 1995) and persistent problems that require a structural societal change (Rotmans, 2005). To evaluate these different views on sustainability, an assessment process is needed such as those developed in integrated assessment, social learning (Tàbara & Pahl-Wolst, 2007), transition management (Rotmans & Loorbach, 2010), reflexive governance (Kemp & Martens, 2007) and sustainability science (Martens, 2006). However, thus far, these concepts have hardly been applied in ocean issues. Yet, both the dynamics of ocean space and the interactions of this system with a wide variety of human activities need approaches that fine tune the unique characteristics of ocean space. Just applying traditional land-based solutions to dynamic ocean-space-based processes and issues is not enough. There is an urgent need for new holistic approaches, such as transition management, in order to explore sustainability in ocean space.

Transitions

One can conclude that our early twenty-first century society is confronted with a large number of complex and unstructured problems such as environmental change and sustainability, that need long-term visions and strategies to be addressed. In the Netherlands this has resulted in a decade of transition-management research (Loorbach, 2010; Rotmans, 2012) to explore new ways of long-term policy making. The present multi-level and multi-actor approach in EU policy making also is a challenge at the national level of the Member States. They have to adapt and fine tune to the often rather complex institutional architecture and decision-making process within the EU. Moreover, the growing involvement of stakeholders both complicates policy making as well as creates the need for an informed society. But how can we create an informed society if the educational system barely takes environmental aspects, ocean issues in particular, into account?

Transitions are well known from the geological record, but the notion of a transition has its roots in biology and population dynamics (Scheffer, 2009). The transition concept is currently also used as a heuristic to describe and explain the complexity of social changes. Here, it builds upon insights gained from integrated assessment studies (Loorbach, 2007). A transition can be defined as, 'a long-term, continuous process of societal change during which society or a subsystem of it, fundamentally changes' (Rotmans et al., 2001, p. 16). These changes are often related to changes in worldviews or paradigms. A transition consists of a set of interconnected changes, which reinforce each other but take place in different areas, such as technology, economy, ecology, etc.

Similar to sustainable development, transitions are intergenerational (25-50 years), because existing structures, institutions and mental frames have to be broken down and new ones have to be developed. By this, they conflict with the normal policy cycles. However, a complete transition theory is not available yet; it is under construction. Moreover, neither is a validated methodology available for the study of transitions. Four interrelated concepts are now distinguished, as follows: multi-level concept, multi-phase concept, multi-pattern concept and the notion of transition management (Van der Brugge, 2009).

The multi-level concept was originally developed by Rip & Kemp (1998) for understanding technological innovations and breakthroughs. Innovation processes are structured in niches, regimes and the socio-technical landscape (Fig. 8), at three interfering levels: micro, meso and macro. At the last-named level, the societal landscape is determined by changes in macroeconomy, political culture, demography, natural environment, worldviews and paradigms. This level responds to relatively slow trends and developments. At the meso-level, with patchworks of regimes, social norms, interests, rules and belief systems operate that underlie strategies of companies, institutions, policies, etc. At the micro- or niche level, individual actors,

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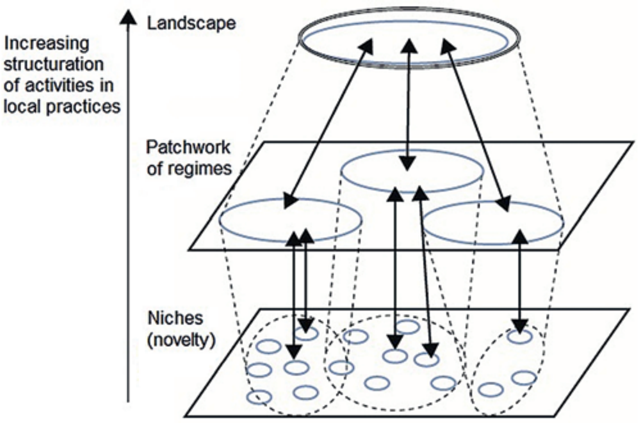

Fig. 8. Multiple levels as a nested hierarchy (from Geels, 2002).

technologies and local practices are addressed. At this level, variations to and deviations from the status quo can occur as a result of new ideas and new initiatives, such as new techniques, alternative technologies and social practices.

The multi-phase concept (Rotmans et al., 2001) distinguishes four different phases in terms of time, in the S-curve of any transition:

- A pre-development phase where there is very little visible change at the macro- or system level, but a great deal of experimentation and innovation takes place at the micro- or individual level.
- A take-off phase where the process of change starts to build up and the state of the system begins to shift because of different reinforcing innovations or surprises.
- An acceleration phase in which structural changes occur in a visible way through an accumulation and implementation of socio-cultural, economical, ecological and institutional transformations.
- A stabilisation phase where the speed of societal change decreases and a new dynamic equilibrium is reached.

All transitions contain periods of both slow and rapid development, caused by processes of positive and negative feedback. One-time events, such as a war, a large accident (*Prestige* oil spill in 2002; BP oil spill in the Gulf of Mexico in 2010) or a crisis (oil crisis in the 1970s; financial crises 2007-2008) can accelerate a transition, but not cause it. An important assumption in the multi-phase concept is that transitions are non-linear and unfold through punctuated equilibria. This means that relatively long periods of stability, alternate with brief periods of instability and rapid change. The idea of punctuated equilibria comes from palaeontology where it provides an explanation of evolutionary patterns that are found in the fossil record. These patterns include a characteristically abrupt appearance of new species, a relative stability of morphology in widely distributed species, the distribution of transitional fossils (if found at all), an apparent difference in morphology between ancestral and successive species and a pattern of species extinction (Gould & Eldredge, 1977). In transition research, the multi-phase concept is not a forecasting tool or blue print. It just helps to identify where we are in the transition process.

There are, however, many possible pathways along which a system can change. A transition is just one of them. Figure 9 shows four of these possible system pathways: the S-shaped transition curve in which niche-level innovations break through (concept of tipping points; Gladwell, 2004), leads to destabilisation and finally to a new stabilisation phase; a lock-in path in which the regime remains stable and blocks up-scaling innovations; a backlash situation in which niche-level innovations break through but do not destabilise the system; and a system breakdown when the system destabilises but lacks niche-level innovations and resilience and dies out.

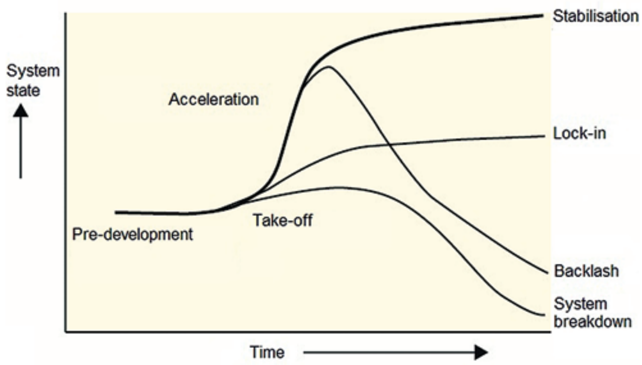

Fig. 9. Four possible system pathways of which the top one leads to a transition. Complexity of the interaction processes limits control over societal developments and may lead to less desired pathways, such as lock-in, backlash and system breakdown (from Van der Brugge, 2009).

The multi-pattern concept describes the way in which a system transforms. Two different approaches are defined (Van der Brugge, 2009). The concept of transition management (TM) is rooted in fields as multi-level governance and adaptive management (Rotmans et al., 2001).

It can be characterised as a joint search and learning process through envisioning, experimentation and the organisation of a coalition of frontrunners in so-called transition arenas. The latter are small multi-actor networks of innovators, experts, strategic and/or original thinkers. Within these arenas a systemic analysis of a complex problem is performed in a participatory manner. The result is a shared problem perception on a systems level. This common ground will then provide the basis for the development of shared visions on the desired future state of the system and leads to a joint transition agenda that contains common problem perceptions, goals, action points, projects and instruments. The latter are used here in the broad sense: from tax measures to public-private arrangements and new instruments. Thus, the transition agenda forms the compass for the transition arena participants, which they can follow straightforwardly during their transition

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journey. They drive the activities and develop a social movement, which will create pressure on current policies and lead to the development of testing grounds for controlled experiments (Loorbach, 2007).

Conclusions

The first modern humans appeared in Africa some 200,000 years ago, a mere wink in Earth's history. They, like our Neanderthal cousin, also lived in coastal areas, collecting sea food. *Homo sapiens* also started to cross the ocean surface to explore the other side; curiosity-driven exploration in short. Up to the Industrial Revolution in Europe, our use of the natural ocean resources was limited and mostly in balance with the natural growth of these resources. During the last two centuries we have both started to explore and study ocean space, with new technology. Especially since the Second World War we have been unlocking the secrets and mysteries of ocean space. At the same time, our societies have grown in an unprecedented way and the impact of our actions has increased staggeringly. We are now among the main triggers of environmental change, also threatening life in ocean space. One can conclude that the British industrial revolution yielded huge benefits, but also caused environmental problems never seen before in human history. So, there is an urgent need for a transition towards sustainability.

The notion of ocean space is reintroduced here. It also marks the transition from the twentieth century science mode towards the twenty-first century one in which we really are able to explore the unexplored. Ocean space is a highly dynamic system which we just are beginning to explore and understand. It is our life support system as well as the cradle of life. Tapping and understanding the fourth dimension, time, permits us to forecast ocean processes for our activities and could promote a sustainable use of its resources. Thus, it is a challenge to connect the results of this exiting field of science with issues such as outreach, environmental awareness and everyone's daily life. Therefore, this notion should be appealing to the public at large and the media as it captures exploration, education, conservation, new scientific approaches from system science to DNA mapping, exiting technological challenges and developments, and last but not least, adventure.

The notion of the Anthropocene has emerged as a popular scientific term used by scientists, the scientifically engaged public and the media. It designates a rather brief period in Earth's history during which humans have a decisive influence on the Earth system. The discussions yield the impression that humans are – especially since the beginning of the British industrial revolution – a geological force on their own; a factor outside the environment. In the near future they will be 'stewards of the Earth' (Steffen et al., 2011). The latter is a rather subjective, normative and even detested view. Yet, most of the arguments (Steffen et al., 2007, 2011) just show the destructive relationship between humans and the (global) environment. It is an increasingly imbalanced social-environmental system, heading to uncharted tipping points and changes that will affect human society itself. The question is not if the Anthropocene is a new epoch or event; the question is how to transform our society, our individual behaviour to a more sustainable one, for us and our children's children. Finally, uncertainty is not often discussed in the literature in favour of the Anthropocene. This is surprising as our knowledge of the Earth System, and certainly the ocean space component of it, is vested in uncertainty.

> 'There are those who will conquer the world, and make of it what they desire.
> I see that they will not succeed, for the world is sacred, a vessel for the spirit.
> It cannot be made by human interference.
> He who tries to change it, spoils it.
> He who holds it, loses it.'
>
> *Lao-tse*

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