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Port Industry Survey on Climate Change Impacts and Adaptation

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Abstract

Ports are critical infrastructure assets that serve as catalysts of economic growth and development. At the same time, they are also exposed to the risk of the impacts of climate variability and change, particularly in view of their location in coastal zones, low-lying areas and deltas. Given the concentration of populations, assets and services associated with ports, the size and value of built infrastructure, and the key role of ports as part of the network of international supply-chains, responding effectively to the impacts of climate change on ports and their land-based access points is of strategic economic importance. Against this background and drawing upon its earlier work, the UNCTAD secretariat carried out an online port industry survey to help improve the understanding of weather and climate-related impacts on ports and to identify data availability and information needs, as well as determine current levels of resilience and preparedness among ports. The present report relates the key findings of the survey, together with some additional information about climate trends and climate-related impacts on seaports and some concluding remarks. The respondent port sample collectively handle more than 16 % of global seaborne trade and can be considered as representative. Although the majority of respondents had been impacted by weather/climate related events, including by extremes, the study revealed important gaps in terms of relevant information available to seaports of all sizes and across regions, with implications for effective climate risk assessment and adaptation planning.

Key words: Climate change, Impacts, Adaptation, Ports, Seaports, Coastal transportation

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1. Introduction and background

Ports are critical infrastructure assets that serve as catalysts of economic growth and development. In addition to playing a key role in international trade, they create jobs, generate wealth and value, contribute to national gross domestic product (GDP) and promote the expansion of related and near-by industries and cities. As a sea-land interface and a point of convergence between various modes of transport, ports act as gateways to trade, providing access to global markets for all countries, including those that are landlocked. With over 80 per cent of global merchandise trade by volume and more than 70 per cent by value being seaborne (UNCTAD, 2017a), ports constitute key nodes in global supply chains and are core to global production processes that rely heavily on manufacturing, outsourcing and low-cost shipping (UNCTAD, 2011).

While ports are at the heart of international trade and globalization, they are also exposed to the risk of climate change impacts, particularly in view of their location in coastal zones, low-lying areas and deltas. They can be particularly affected by rising sea levels, floods, storm surges and strong winds. Given the concentration of populations, assets and services associated with ports - as well as the size and value of built infrastructure - and the crucial role of ports as part of international supply-chains, climate change impacts on ports and their land-based access points, linking the maritime interface with the hinterland, may have serious broader implications; developing effective adaptation response measures is therefore of strategic economic importance.

While the type, range and the magnitude of climate change impacts will vary depending on local conditions, ports are expected to be directly and indirectly affected by climatic changes. Direct impacts are those likely to affect infrastructure, operations and services while indirect impacts include changes in demand for port services resulting from climate change effects on trade, investment decisions, demographics, agriculture production, forestry, energy exploration and consumption as well as fishing activity. Associated risks, vulnerabilities and costs may be considerable, in particular for ports in developing regions with low adaptive capacity, and those in Small Island Developing States (SIDS). With SIDS being sea-locked, climatic factors that may severely impact coastal transport infrastructure and services pose particularly serious threats to national economic development prospects.

Given the strategic role of ports as part of the globalized trading system, adapting ports in different parts of the world to the impacts of climate change and building their resilience is an urgent imperative. A good understanding of the relevant risks and vulnerabilities based on accurate information, including climate and socio-economic data at the local level, is a pre-requisite for informed decision making and well-designed and effective adaptation response measures that enhance the robustness of systems, structures and processes and minimize the adverse effects of climatic factors. In this context, cooperation among a wide range of public and private sector stakeholders at the local, national, regional and international level is required.

Against this background and drawing upon earlier work, the UNCTAD secretariat, in 2014, carried out an online port-industry survey, designed in consultation with port industry stakeholders, including, in particular the International Association of Ports and Harbors (IAPH), to help improve the understanding of weather and climate-related impacts on ports and to identify data availability and information needs, as well as determine current levels of resilience and preparedness among ports. The aim was to gather relevant information which is urgently required for the purposes of risk-assessment and adaptation planning[1], including in particular for ports in developing regions as well as to collate some information on the current state of practice in terms of response measures and adaptation to the impacts of weather and climate-related factors and events.

The present report relates the key findings of the survey, together with some additional information about climate trends and climate-related impacts on seaports. Chapter 2 provides some context on the implications of climate variability and change for seaports, notably by presenting an overview of recent trends and projections on relevant climatic factors as well as an overview of key impacts that climate variability and change

[1] Note that an earlier survey to assess how port administrators felt climate change might impact their operations, what sea-level change would create operational problems, and how they planned to adapt to new environmental conditions found that while respondents agreed that the ports community needed to address the issue of climate change adaptation, most felt relatively uninformed about potential climate impacts (Becker et.al., 2012).

may have. Chapter 3 provides an analytical overview of the key results of the survey and Chapter 4 offers some concluding remarks. Finally, the questionnaire itself and a full summary of results are presented as Appendices A and B, respectively.

1.1. Earlier related activities by the UNCTAD Secretariat

UNCTAD has been working, 'ahead of the curve', on the implications of climate change for maritime transportation, since 2008[2], with particular emphasis on impacts and adaptation needs of seaports and other coastal transport infrastructure. Academic publications include an UNCTAD edited book on "Maritime Transport and the Climate Change challenge", co-published by the UN and Earthscan (Asariotis and Benamara, 2012) and providing detailed insight on a range of the potential implications of climate change for this key sector of global trade; as well as a multidisciplinary academic paper (Becker et. al., 2013), co-authored by experts following an UNCTAD Expert Meeting.

Other relevant initiatives by the UNCTAD secretariat include a number of intergovernmental expert meetings which have focused on the implications of climate change for maritime transport, highlighting in particular the need to adapt to the impacts of climate change. They include an Ad-Hoc Expert Meeting on "Climate Change Impacts and Adaptation: A Challenge for Global Ports", held in September 2011, a Joint UNECE-UNCTAD Workshop on "Climate Change Impacts on International Transport Networks", held in September 2010 - leading to the establishment of a UNECE Expert Group on the subject - and a Multi-year Expert Meeting on Transport and Trade Facilitation with a focus on "Maritime Transport and the Climate Change Challenge", held in February 2009[3]. The implications of climate change for coastal transport systems were also considered at two Expert Meetings with a focus on the transport-related challenges facing Small Island Developing States (SIDS), namely the third session of the Multi-year Expert Meeting on Transport, Trade Logistics and Trade Facilitation, "Small Island Developing States: Transport and Trade Logistics Challenges", held on 24-26 November 2014, and the Ad Hoc Expert Meeting on "Addressing the Transport and Trade Logistics Challenges of the Small Island Developing States (SIDS): Samoa Conference and Beyond", held on 11 July 2014.

Drawing on the above, ongoing and recent work with a particular focus on SIDS includes a technical assistance project on "Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of SIDS" (UNDA 9th tranche)[4], which is being implemented over the period 2015-17. A case-study focusing on two vulnerable SIDS in the Caribbean region (Jamaica and St. Lucia) is being carried out to enhance the knowledge and understanding at the national level and to develop a methodology for assessing climate-related impacts and adaptation options. The methodology will, subject to location-specific modifications, be available for use in other SIDS within the Caribbean region as well as in other geographical regions. Some of the insights gained as part of this technical assistance project, notably regarding the risk of marine flooding in Saint Lucia, are also reflected in Chapter 2 of the present report.

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[2] http://unctad.org/en/Pages/DTL/TTL/Legal/Climate-Change-and-Maritime-Transport.aspx

[3] See UNCTAD, 2009 and UNECE, 2010. Both documents are available at www.unctad.org/ttl/legal. Following the joint UNCTAD-UNECE workshop on the subject, a UNECE Expert Group on Climate Change Impacts and Adaptation for International Transport Networks and Nodes was established. UNCTAD continues to participate actively in this work.

[4] http://unctad.org/en/Pages/DTL/TTL/Legal/Climate-Change-Impacts-on-SIDS.aspx.

2. Climate variability & change implications for seaports

Maritime transport is a most important global industry that facilitates the movement of goods and people (Fig. 2-1). It forms the lifeline of world's trade, as about 80 % of goods have at least one maritime transport 'leg (UNCTAD, 2017a) Transport requires operational and efficient transport networks, with seaports forming the key nodes (Fig. 2-2). Climate Variability and Change (CV & C)[5] could have significant implications for a broad range of seaport operations, infrastructure and assets, requiring well-targeted response measures; efficient, integrated and resilient international transport nodes/networks are of paramount importance for the further economic development, particularly for SIDS and for other groups of vulnerable countries.

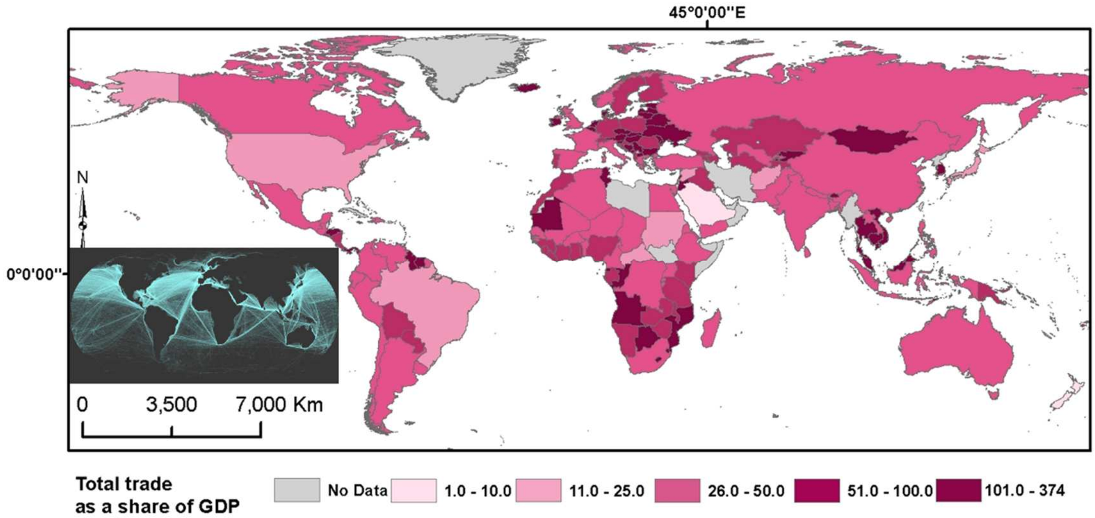


Figure 2-1 Total Trade as a share of GDP in 2012, i.e. the sum of goods and services exports and imports divided by the value of GDP (in 2005 U.S. dollars), aggregated from two World Bank datasets (Merchandise Trade (% of GDP) - 2005-2012; and Services Trade (% of GDP) - 2005-2012 (UNECE, 2015). Inset: Major maritime routes which facilitate this trade are shown[6]

Transportation accounts for a significant fraction of global Greenhouse Gas (GHG) emissions, which are now considered as a most significant forcing for a range of observed climatic changes; high atmospheric concentrations of GHGs absorb large parts of the heat reflected back from the Earth's surface and, thus, increase the Earth's heat storage (IPCC, 2013). Fossil fuel emissions have been increasing steadily since the 1950s and, with the exception of the mildest future climate scenario (RCP 2.6 scenario[7]), are projected to continue growing at least until 2050.

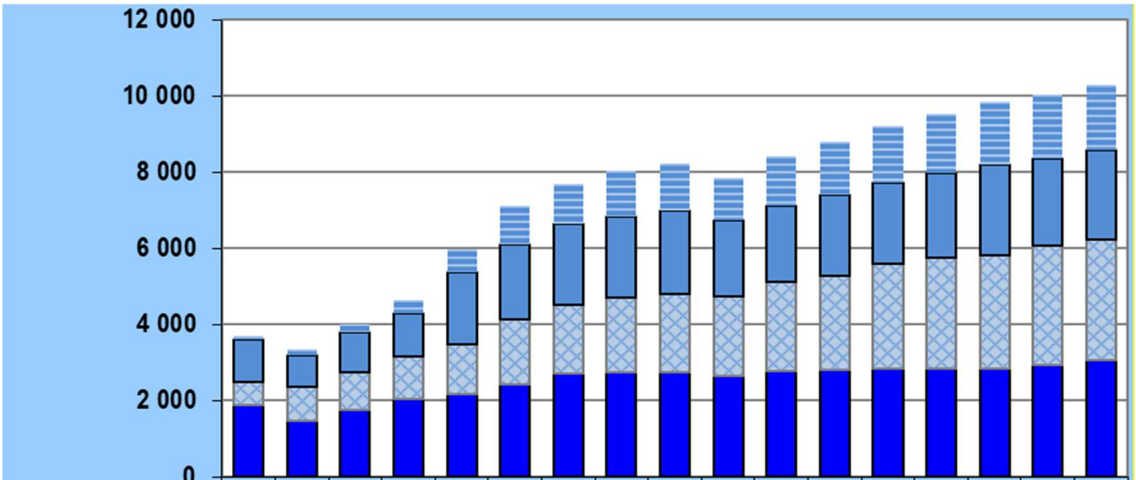
Transport CO_2 emissions show significant spatial variability, with the highest emissions found in the United States of America, the Russian Federation, China, Japan and Brazil, with western Europe, Australia and India also associated with high emissions; by comparison, Africa is characterized by the lowest transport-generated emissions (UNECE, 2015). Despite the key role of maritime transport for international transport and trade, GHG emissions from international shipping presently form only a small part of the total; international shipping

[5] Climate Variability and Change (CV & C) refers to the variability and sustained change of climatic factors relative to a reference period, e.g. the first period with accurate records (1850s-1860s) or periods with widespread, good quality and comparable climatic observations, during which most of the transport infrastructure used today was constructed (e.g. 1961-1990 or 1986-2005).

[6] P. Bridge, WMO, presented at UNECE Expert Group meeting, 2016

[7] In the last IPCC Assessment Report AR5 (2013) forecasts are made on the basis of Representative Concentration Pathways-RCP scenarios. In these scenarios, the CO2 equivalent concentrations for 2100 have been set as (Moss et al., 2010): RCP 8.5, 1370 ppm C02- equivalent; RCP 6.0 850 ppm CO2-equivalent; RCP 4.5, 650 ppm CO2-equivalent; and RCP 2.6, peaking at 490 ppm CO2-equivalent.

contributes only 2.2 % of global CO2 emissions from fuel combustion, being the most energy efficient mode of transportation. Nevertheless, emissions are rising and are projected to grow up to five-fold by 2050 (IMO 2015). In addition, seaports form complex systems and multimodal transport nodes. In the case of larger ports, these are mostly integrated within large coastal urban agglomerates; consequently, ports are associated with a range of environmental effects[8].



	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Container	102	152	234	371	598	1 001	1 076	1 193	1 249	1 127	1 280	1 393	1 464	1 544	1 640	1 661	1 720
Other dry cargo	1 123	819	1 031	1 125	1 928	1 975	2 112	2 141	2 173	2 004	2 022	2 112	2 150	2 218	2 393	2 310	2 339
Five major bulks	608	900	988	1 105	1 295	1 711	1 814	1 953	2 065	2 085	2 335	2 486	2 742	2 923	2 985	3 121	3 172
Oil and gas	1 871	1 459	1 755	2 050	2 163	2 422	2 698	2 747	2 742	2 642	2 772	2 794	2 841	2 829	2 825	2 932	3 055

Figure 2-2 International seaborne trade in millions of tons loaded at seaports (selected years), (UNCTAD, 2017a, Review of Maritime Transport 2017)

As mentioned earlier, the location of seaports makes them vulnerable to a range of hydro-meteorological hazards which are influenced by CV & C. In the following sections, recent trends and projections regarding the climatic factors that influence seaports (and their connecting transport networks) are presented, together with their impacts on seaports.

2.1 Recent trends and projections on relevant climatic factors

2.1.1 Climate factor trends

Globally-averaged, near-surface temperature is the most cited climate change indicator, as it is directly related to the planetary energy balance and increases in Greenhouse Gas-GHG emissions, as well as many climatic impacts and risks (IPCC, 2013). Although global temperature has not increased in each consecutive year (or decade), a long-term warming trend is clearly observed, mostly in the past 40 years (Fig. 2-3a). Atmospheric temperatures have increased, whereas oceans also show significant increases in heat content (Dieng et al.,

[8] Fuel combustion emits directly Carbon monoxide (CO), volatile organic compounds, Sulfur and Nitrogen oxides ((SOx and NOx) that could generate 'photochemical smogs' and acid rains, as well as carbon particulates that cause respiratory problems. At seaports, road freight vehicle loading/unloading can increase pollution, particularly as vehicles tend to pollute more during the first few km of their journey (UNECE, 2015). Although new technology/cleaner fuel formulations will continue to cut emissions, the increasing number of loading/unloading vehicles in seaports and connecting road networks may counterbalance these benefits. Transportation noise in and around ports can also have harmful health effects at seaport urban agglomerations; low-noise road surfaces, effective noise barriers and low noise tyres can help reduce noise levels. Seaports can also have major environmental impacts during their construction, upgrading and maintenance. Generally, the environmental effects of seaports on their local environment is an issue to be tackled. In recent years, several initiatives from the industry as well as relevant environmental regulation have appeared that take these issues into consideration (Inoue, 2012).

2017) which has resulted in their thermal (steric) expansion and, thus, in sea level rise[9]. Sea ice covers have been declining, with the Arctic sea ice extent having decreased by more than 40 % since the first satellite records (1979) (NOAA, 2017). 2016 was the warmest year in the instrumental record, breaking the previous records of 2015 and 2014, with observations being consistent with a steady trend in global warming superimposed on random, short-term variability (Rahmstorf et al., 2017)[10]. In early 2016, the global temperature was about 1.5 ^{0}C above that recorded in the early industrial revolution and more than 0.4 ^{0}C higher than that recorded in 1998 which was a strong El Niño year (Simmons et al., 2017)[11]. Although 2015 and 2016 temperatures could have been influenced by El Niño conditions (NASA, 2016), land surface temperatures in 2014 (a neutral El Niño year) were also 0.88 ± 0.2 ^{0}C higher than the 1961–1990 average (WMO, 2014).

Global mean sea-level rise (MSLR) has increased sharply above its background rates of the past 2000 years (e.g. Horton et al., 2014). Since 1860, global sea level increased by about 0.20 m (average period rate of 1.3 - 1.8 cm per decade), but with a discernible acceleration in recent decades (Fig. 2-3b). Currently, satellite and tide gauge observations suggest a global sea level rise of 3.3 ± 0.25 cm per decade since 1993 (Church et al., 2013). There is however, regional variability, with some regions experiencing greater sea-level rise than others as, for example, in the western Pacific. In these regions, seaports and other transport coastal infrastructure are vulnerable particularly when their high rates of mean sea level rise combine with extreme storm surges/waves, as was the case along parts of the Philippines coast during the (2013) typhoon Haiyan (Esteban et al., 2015).

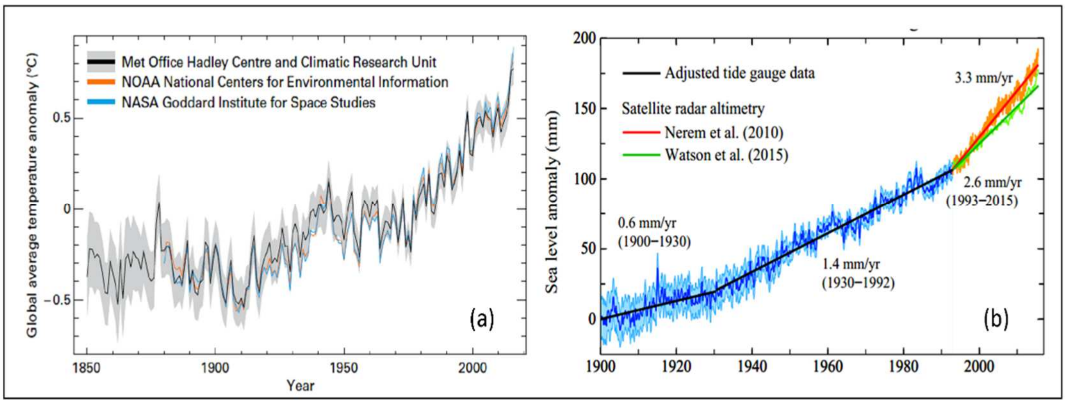


Figure 2-3 (a) Global average temperature anomalies for the period 1850-2016 relative to the reference period 1961–1990 for 3 major datasets[12]. Grey shading indicates the uncertainty in the HadCRU dataset, UK Met Office Hadley Centre (From WMO, 2017). (b) Estimated sea level change (mm) since 1900. Data through 1992 are tide-gauge record (Hansen et al., 2016).

Global land precipitation observations show mixed long term trends and strong regional variability, with an increasing trend being discerned in middle and high latitudes (IPCC, 2013; EPA, 2015). With regard to mean wind intensity, trends are not easily discerned in the instrumental record; in any case, wind impacts are mostly

[9] Mean sea level increases due to the combination of (a) ocean thermal expansion, (b) ocean water mass increases from the melting of the continental Greenland and Antarctic ice sheets (GIS and AIS), glaciers and ice caps; (c) isostatic adjustment; and (d) changes in land water storage (Hanna et al., 2013).

[10] Since the 2000s, there appears a slowdown in the rate of the global mean surface temperature rise, termed as 'the global warming hiatus'. In 2003–2013, both global land and sea surface temperatures (LSTs and SSTs) increased at a lower rate than in the previous decades (Dieng et al., 2017). The slowdown was attributed to uncertainties related to other temperature change forcing: volcanic eruptions, changes in atmospheric water vapor and industrial aerosol concentrations, heat redistribution in the oceans, solar activity and the variability of ocean climate (e.g. El Niño and La Niña events (Yan et al., 2016). Recent research (e.g. Karl et al, 2015; Simmons et al., 2017) has, however, questioned the occurrence of the trend hiatus, suggesting that re-analysis of corrected/updated datasets indicate that higher global temperature trends in this period than those reported in previous studies.

[11] An alarming development in view of the 2015 Paris Agreement the aim of which is to 'hold' the global average temperature increase to well below 2 ^{0}C above pre-industrial levels (UNFCCC, 2015).

[12] In the WMO (2017) analysis, the latest versions of the datasets GISTEMP, NOAAGlobalTemp and HadCRUT of NOAA, the NASA and the UK Met. Office Hadley Centre, respectively, have been used. The combined dataset extends back to 1880 (http://library.wmo.int/opac/doc_num.php?explnum_id=3414).

associated with extreme events like tropical and extra-tropical storms. Arctic sea ice (minimum) extent has rapidly declined since 1979 (13.3 ± 2.6 % per decade), whereas Antarctic sea ice extent has remained mostly stable in the same period (WMO, 2017). Most minimum extent records occurred in the last decade, with the 2016 sea ice extents dropping to record lows (NSIDC, 2017). Finally, permafrost temperature has increased in northern regions by up to 2 ^{0}C since 1980 and its thickness decreased by 0.32 m since 1930 (IPCC, 2013), leading to permafrost thaw and significant transport infrastructure damage (UNECE, 2013).

Extreme events (e.g. storms, floods/droughts and heat waves) constitute particularly dangerous climatic hazards. Societies are rarely prepared to face extreme weather events efficiently, as they have become reliant on predictable, long-term climatic patterns (MetOffice, 2014). Currently, climate extremes show patterns consistent with global warming. In many regions, observations show increases in both the intensity and frequency of hot temperature extremes and decreases in cold extremes (IPCC, 2013). Tropical and extra-tropical storms may also respond to a warming climate by becoming even more extreme (MetOffice, 2014). Their impacts on coastal transport infrastructure could be very severe, particularly due to the extreme sea levels (ESLs)[13] they induce (Hallegate et al., 2013). In recent years, storms have been particularly devastating. In 2013-2014, the highest storm surge levels since 1953 were recorded along the coasts of the Netherlands and the UK (WMO, 2016), whereas the effects of the catastrophic 2017 hurricane season (e.g. Harvey, Irma and Maria hurricanes) have yet to be fully accounted for.

A clear trend regards the increasing frequency and intensity of heavy precipitation events (and associated floods) in many parts of Europe and North America (IPCC, 2013). Between 1980 and 2014 river floods accounted for 27 % of fatalities and 32 % of the economic losses related to natural disasters (Munich Re, 2015). In Europe, annual water discharges have been observed to increase in the north and decrease in the south, a trend projected to hold in the future (EEA, 2015c). Heat wave frequency and intensity have also increased: a 3-fold increase since 1920s has been observed in the ratio of the observed monthly heat extremes to that expected in a non-changing climate (Coumou and Rahmstorf, 2012).

2.1.2 Climatic factor projections

By 2100, mean atmospheric surface temperature is projected to increase by up to 3.7 °C, depending on the Representative Concentration Pathway (RCP) scenario (IPCC, 2013). The ocean will also warm under all RCP scenarios. The highest ocean surface warming is projected for the subtropical and tropical regions resulting in conditions that can force/maintain stronger tropical storms. By 2100, ocean warming in its upper 100 m is projected at about 0.6 °C, under RCP2.6, to 2.0 °C, under RCP8.5; thus, ocean warming will continue for centuries (due to the long time scales of heat transfer from the surface to the deep ocean waters) even if GHG emissions were to be stabilized. Climate will not change uniformly. Temperatures close to the poles are projected to rise faster than at the equator; temperature rises relative to the reference period of more than 10 °C are predicted for arctic areas in 2100 under the RCP8.5 scenario (IPCC, 2013).

Predictions of mean sea-level rise are constrained by uncertainties regarding, for example, the response of the