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The Opening of the Northern Sea Route

Joshua Ho*

Long neglected and dismissed as scientifically unfounded, global warming has now been accepted as a new reality that will have a direct impact the safety, security and the environment of human habitats. If global warming due to greenhouse gas accumulations is expected to be severe world-wide, it is enhanced in the Arctic regions. The coupled climate models used by the Intergovernmental Panel on Climate Change (IPCC) in 2007 predicted that the warming in the Arctic over the next 50 years is in the range of three to four degrees Celsius, more than twice the global average, suggesting that the Arctic may be where the most rapid and dramatic changes will occur during the 21st century. With the warming of the Arctic comes the possibility of the opening of Arctic sea routes for commercial navigation which will tremendously cut down transit times between Europe and Asia. However, maritime infrastructure and services along the routes will have to be improved before navigation along these routes will become a reality.

Introduction

Long neglected and dismissed as scientifically unfounded, global warming has now been accepted as a new reality that will have a direct impact the safety, security and the environment of human habitats. The effects of climate change due to global warming include the increase in frequency and intensity of adverse weather events,

*Joshua Ho is a Senior Fellow at the S. Rajaratnam School of International Studies, Nanyang Technological University. He can be reached at ISHHHo@ntu.edu.sg

water shortages, sea level rise and as a consequence, flooding and resultant destruction of coastlines. This will be accompanied by a decrease in crop yields due to increasing temperatures, reduction in water supply and an increase in temperature-related illnesses and deaths.[1] Traditional industries such as agriculture, fisheries and tourism might be reduced or even disappear altogether in regions that are heavily affected by climate change. Port cities located in the deltaic regions, mostly in Asia, will have to endure detrimental effects from climate-linked storm surges and rises in sea level within its vast coastline and densely populated areas. Hundreds of millions of people living near low lying coasts will be displaced. Asia may soon be faced with disappearing states and loss of livelihood due to inundation. If societies are not able to adapt to climate change, great human suffering will occur.

If global warming due to greenhouse gas accumulations is expected to be severe world-wide, it is enhanced in the Arctic regions. Climate model studies of increasing atmospheric greenhouse gas scenarios confirm that anthropogenic global warming will be more severe in the high northern latitudes due to complex feedback mechanisms in the atmosphere–ocean–ice system.[2] The coupled climate models used by the Intergovernmental Panel on Climate Change (IPCC) in 2007 predicted that the warming in the Arctic over the next 50 years is in the range of three to four degrees Celsius, more than twice the global average. However, the models also indicate a large spread in the results, suggesting that the Arctic may be where the most rapid and dramatic changes will occur during the 21st century.[3]

Latest Findings on the Rate of Climate Change

Recently, the Tyndall Centre for Climate Change Research at the University of Oxford, UK, and the Hadley Centre at the UK Met Office jointly sponsored an International Climate Conference in Oxford, UK, on September 28–30, 2009 titled ''4 Degrees & Beyond''. The key message at that conference was that global warming of up to 4 degrees Celsius average was likely. A 4 degree Celsius increase translates to a 2 degree increase in some places, and a 12 degree or more increase in others, making these places uninhabitable for plants, animals and humans. Relying on the Hadley Centre's HadCM3 model, which is an ensemble of climate models, Dr Richard Betts, Head of Climate Impacts at the UK Met Office's Hadley Centre, mentioned that current emissions are already at the upper end of the IPCC models and we are now

faced with the prospect of dealing with the worst case scenarios developed by the IPCC. The models are based on human emissions alone and exclude heat-amplifying feedbacks from melting ice or changes in carbon sinks. When those are factored in, the timeline will move forward. As Dr Betts puts it, ''reaching four degrees by 2060 is a plausible, worst-case scenario'' with the median year being 2070. By 2100, an average global temperature rise of 5.5 degrees is possible.[4]

Hence, the previous notion of limiting emissions so that global warming does not increase globally beyond 2 degrees Celsius average is increasingly indefensible due to the limited reductions on the part of all stakeholders to date. If emissions reductions are not implemented soon there is also the possibility of a limited runaway ''greenhouse effect'' and the less likely ''Venus effect'', a situation where the Earth would heat up uncontrollably, which would eventually make it uninhabitable, like the planet Venus.[5] Basically, once global warming reaches a certain threshold – estimated to be at about 3 degrees Celsius average global rise in temperature – natural warming feedback cycles will take-over and accelerate the warming process. The natural positive feedback mechanism includes the reduction in oceanic carbon dioxide uptake, the release of methane from thawing permafrost and peatland, the release of methane from oceanic methane hydrates as well as the albedo effect arising from Greenland and Antarctic ice melting. These positive feedbacks will increase average global temperatures quickly to about 8 degrees Celsius. Hence, the longer emissions reductions are postponed, the harder it is to even defend this 4 degree limit.

As far as the Arctic is concerned, the thawing of permafrost and peatland is a critical positive feedback that will increase the rate of warming. Scientists have discovered that even a modest thaw of the perennially frozen soil that lies under the lakes surrounding the Arctic as well as the caps on the dry land around them could trigger a vicious warming cycle as the methane gas released will trap 25 times more of the sun's heat than carbon dioxide does.[6] A complete thaw will discharge 10 times the current amount of methane already in the atmosphere. Simply put, thawed permafrost releases methane and carbon dioxide, and when these gases reach the atmosphere, they help to heat the earth via the greenhouse effect. The trapped heat thaws more permafrost, thus exacerbating the entire warming cycle. Already, the air temperature in the Arctic has increased at double the rate of the global average over the last 100 years with the total ice extent decreasing at a rate of 3% to 5% per decade, the older multi-year ice decreasing twice as fast, river discharge from Russia

increasing, the tundra permafrost thawing and snow cover on land decreasing.[7] These observations and analysis of current warming trends indicate that global warming is happening at a quicker rate and that the Arctic sea ice is melting at a faster rate than the median case.

The Impact of Climate Change on Ports in Asia

According to the latest World Wide Fund for Nature report on the impacts of climate change on mega-cities released in November 2009, Asia is arguably the most vulnerable continent. The report focused on the climate variability and adaptive capacity of 11 key Asian cities, namely Dhaka, Jakarta, Manila, Calcutta, Phnom Penh, Ho Chi Minh, Shanghai, Bangkok, Hong Kong, Kuala Lumpur and Singapore. The report states that there is widespread evidence of climate change in Asia and includes overall temperature increases from 1 to 3 degree Celsius over the last 100 years, changing precipitation patterns, increasing number of extreme weather events and rising sea levels. Many of the largest cities in Asia are extremely susceptible to the impacts of climate change as they are located along the coast and within major river deltas. Excessive carbon dioxide in the atmosphere also contributes to the acidification of the oceans, the shifting in climate zones and the reduction of water availability. The acidification of the oceans endangers calcifying organisms such as corals, which are the cradle for sea life. In addition, de-oxygenation due to excessive carbon dioxide absorption by the ocean causes a reduction in fisheries habitats. As a result, those depending on fish and seafood as a source of food and livelihood in South and Southeast Asia, especially the artisanal fishers, will be threatened with food shortages and a decline in fish population. A shift in climate zones in the tropics and semi-arid regions will affect the agricultural and crop yields, and ultimately affect livestock production and food security at the national level. The Himalayan glaciers that feed the great rivers of Asia and supplies millions of people with drinking water are also at risk of drying up and this change, to a certain extent, has already happened.[8]

The key finding in the report was that the vulnerability of Asia to climate change is relatively high as millions of lives will be affected, including the reduction of a countries natural assets and a reduction of gross domestic product (GDP). The overall vulnerability score is calculated by taking the average of three categories: the

countries' exposure, sensitivity and adaptive capacity. For example, the less developed cities like Dhaka (Bangladesh), Jakarta (Indonesia) and Manila (Philippines) rank high on the most vulnerable list because they are susceptible to extreme weather events such as tropical cyclones, flooding and drought. Compounded by the size of the cities and low adaptive capacity, the WWF urges the government, businesses and influential scientists to implement immediate adaptation and mitigation strategies and policies.[9]

Importantly, many of these coastal cities in Asia will be affected by sea level rise, which is projected by the IPCC reports to increase from 0.17 metres in the 20th century to between 0.18 to 0.59 metres by the end of this century. However, this projection excludes the uncertainties in climate–carbon cycle feedback and the full effects of changes in Greenland and Antarctic ice sheet flow due to the paucity of published literature.[10] Already scientists gathering at a climate change summit in Copenhagen, in December 2009, warn that global sea levels will increase by an amount that is more than previously projected by the IPCC AR4 models. Even if the world manages to cut the emission of greenhouse gases, the best estimate of possible sea level rise was about 1 metre, or in the range of 0.75 to 1.90 metres, by 2100, as noted Professor Stefan Ramstorf of the Potsdam Institute for Climate Impact Research in Germany.[11] Their latest report, entitled ''Copenhagen Diagnosis'', was compiled by 26 researchers, most of whom were also authors of the IPCC report, estimated that the global sea-level rise could exceed 1 metre by the year 2100, with the upper limit estimated at 2 meters. This is at least twice as much as that projected by Working Group 1 of the IPCC AR4.[12]

Asia will be a region which will be seriously affected with this increase in sea level as large numbers of people will be displaced. An analysis conducted by the Tyndall Centre for Climate Change Research, University of Oxford, UK, calculated that by end of this century, a one metre increase in sea level will displace over 100 million people and inundate close to 900,000 square kilometres of land in Asia.[13] Similarly, the OECD had estimated that 15 of the top 20 port cities that will be affected by coastal flooding by 2070 will be in Asia. These 15 cities are projected to have a combined flood exposed population of nearly 95 million and include the cities in the countries of India (Kolkata and Mumbai), Bangladesh (Dhaka, Khulna and Chittagong), Vietnam (Ho Chi Minh and Hai Phòng), Thailand (Bangkok),

Myanmar (Yangon), Indonesia (Jakarta), Japan (Tokyo) and China (Guangzhou, Shanghai, Tianjin and Ningbo).[14]

According to the Stern Review, the expected costs for stabilisation at 500–550 ppm CO2e is likely to average around 1% of annual global GDP with a range of between −2% to +5% by 2050, with the variability of estimates diverging strongly thereafter and especially by 2100. Through cost–benefit analysis, the Review also concluded that the benefits of strong early action will outweigh the costs and tackling climate change was the pro-growth strategy as ignoring climate change will eventually damage economic growth.[15]

The Impact of Climate Change on Sea Lanes – The Opening of the Northern Sea Route

Besides sea level rise affecting port cities, the maritime industry will also be affected by the effects of climate change, particularly in the Arctic, where a reduction in the sea ice will result in the opening up of the Northern Sea Route (NSR) for ship transportation. During the last 75 years, the Soviet Union and Russian Federation have operated in the Northern Sea Route. Maritime transport has been extensive and reached its peak of 6.6 million tons in 1987, mainly in the form of the regional export of natural resources and to a lesser extent of cargo to the communities along the Siberian coast.[16] After the collapse of the Soviet Union, much optimism was envisaged in the 1990s with respect to the increased use of the Northern Sea Route for maritime transport between Europe and Asia. This optimism has yet to become a reality, mainly because of the fact that the Northern Sea Route has never been ice free, even during the summer months, to allow for significant maritime transportation between Europe and Asia. The current volume of shipping appears to be 2.13 million tons in 2007 and the transportation of hydrocarbons within the Barents and the White Seas reached 8.5 million tons in 2006.[17]

The Arctic Marine Shipping Assessment (AMSA) assesses that shipping in the coming decades will remain dominated by an increase in regional transportation in waters close to Norwegian interests, namely in the Barents, Pechora and Kara Seas.[18] Coastal and port access in all these areas will experience immediate seasonal improvements due to the reduced appearance of sea ice. From around 2025, AMSA

assesses that transit traffic in the Northern Sea Route may be more regular. Even though the sea routes along the Siberian coast may open up earlier, the depth of water along the coast may limit the size and freight capacity of ships that can transit the route. AMSA estimates that regular trans-polar summer transport (four months) may not occur until towards the middle of this century, from 2040 onward.

However, the AMSA assessment is likely to be conservative, given the current rates of global warming. Consistent with the increasing rate of global warming, the observed maritime activities along the Northern Sea Route have also changed over the last five years. Previously, no non-Russian ships traversed the Northern Sea Route along the Siberian coast, but now merchant, research and expedition vessels have journeyed through the Northern Sea Routes during the summer seasons since 2004 and this volume is set to increase. For example, the predicted volume of transport in the Northern Sea Route, primarily associated with transporting natural resources, gas and oil, may increase by up to 5.5 million tons in 2010, and by up to 12.8 million tons by 2020.[19]

There have also been other maritime activities that indicate that the trans-Arctic passage may open up much earlier than expected. For example, in 2008, the Arctic Ocean experienced for the first time ever an ice-free and navigable Northern Sea Route along the Siberian coast.[20] This occurred during a summer melt season after a winter in which the maximum ice extent was greater than had been observed in the previous five years, suggesting that seasonal temperature fluctuations have increased and that future ice-free passages during the summer months along the Siberian coast is highly likely. Recently on September 9, 2009, it was reported that two German merchant vessels were the first ever to make through the formerly impenetrable Northeast Passage or the Northern Sea Route, departing from Ulsan in South Korea to Novy Port in Russia.[21] The ice-class ships were to eventually sail around the Yamal Peninsula, cross the Barents Sea to Murmansk and head on to Rotterdam. Advance Microwave Scanning Radiometer–Earth Observing System (AMSR-E) sea ice maps also highlight the possibility of a clear route through the Northern Sea Route (see figures 1–3). For example, since 2008, a clear passage of the NSR along the Siberian coast has opened up. Although the sea ice coverage has not declined as rapid as the previous two years, it is still the third lowest since data was collected.

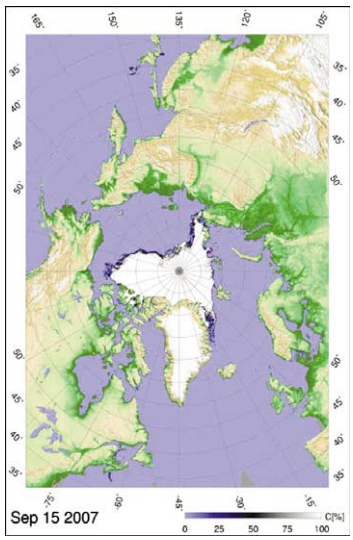

Fig 1. Arctic sea ice concentration in September 2007.
Source: Daily Updated AMSR-E Sea Ice Maps, IUP Universitat Bremen Website, http://www.iup.uni-bremen.de:8084/amsr/amsre.html.

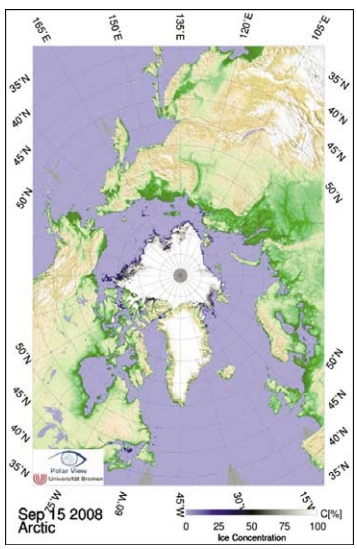

Fig 2. Arctic sea ice concentration in September 2008.
Source: Daily Updated AMSR-E Sea Ice Maps, IUP Universitat Bremen Website, http://www.iup.uni-bremen.de:8084/amsr/amsre.html.

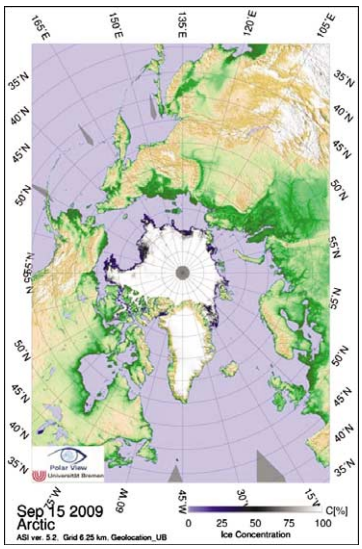

Fig 3. Arctic sea ice concentration in September 2009.
Source: Daily Updated AMSR-E Sea Ice Maps, IUP Universitat Bremen Website, http://www.iup.uni-bremen.de:8084/amsr/amsre.html.

Future Shipping in the Arctic

The Centre for High North Logistics in Norway, a private sector funded centre, has embarked on studies that should have been completed in June 2009 on the business case for trans-Arctic container shipping. The size of ships being examined include 100,000 tonne LNG carriers and up to 5,000 TEU container ships for deployment by 2015.[22] There is also the possibility that the city of Adak, located in the Aleutians, Alaska, United States, could serve as a possible international hub port for Arctic shipping.[23] Both these developments seem to indicate an earlier ice-free passage via the Northern Sea Route. The US National Intelligence Council, in its study *Global Trends 2025*, has suggested that the date for a seasonally ice-free Arctic could even be as soon as 2013.[24]

That being the case, tremendous shipping benefits would accrue as transiting the Northern Sea Route above Russia between the North Atlantic and the North Pacific would trim about 5000 nautical miles and a week's sailing time compared with the use of the Suez Canal and through the Malacca Straits. This may have an adverse impact on existing regional container hub ports like Singapore, which sits astride the

main east–west transportation thoroughfare and is a major regional trans-shipment port. When container ships use the Northern Sea Route, it would make more economic sense to stop at new or existing ports in Northeast Asia and use these ports as trans-shipment centres to the Southeast Asian region, instead of the port of Singapore. Possible ports that could be used in Northeast Asia may include Hong Kong, Shanghai, and Tokyo. If this were to occur, the container volumes handled by the port of Singapore may decrease for four months of the year.

Despite the fact that a 'blue' Arctic Ocean is predicted in summertime (four months) to occur from the middle of this century, current rates of warming indicate that this may occur much earlier. However, even before trans-polar navigation is feasible, routes along the coast of Siberia will be navigable much earlier. Already there are plans to build trans-Arctic ships and plans for hub port development in north-east Asia that will take advantage of this ice-free passage. Such plans indicate that the Northern Sea Route may be opened up for ice-free passage as early as 2013, given current accelerated rates of global warming. The opening up of the Northern Sea Route will have an adverse impact on the operations of current regional hub ports. Not only that, it will also have an impact on the profitability of the current liners operating between Europe and Asia. Both liner and terminal operators, including those in Southeast Asia, will have to factor the early opening of the Northern Sea Route into their plans if they are not to be caught off guard.[25]

Improvements Needed before Shipping in the Arctic can become a Reality

However, before the Northern Sea Route can reliably be used as a transit route between Europe and Asia, several issues will need to be resolved. For example, for vessels operating in the Arctic part of the world oceans, it is crucial for navigation to have access to synoptic environmental observations of the weather, sea ice and ocean conditions and their forecasts. Such information will be essential in both strategic and tactical navigation support and help to ensure safe and efficient operation in ice-covered waters. In particular though, six issues will need to be resolved. Firstly, environmental monitoring and forecasting services providing meteorological, oceanographic and sea ice information to support shipping all year round will need to be significantly enhanced. Secondly, search and rescue as well as ice-breaker

support services, with seasonal and regional increased access, will need to be provided in a comprehensive manner. Thirdly, experienced mariners who are trained for Arctic operations are needed to operate the ships. Fourthly, new ship technology is required for independent ship operations in ice covered waters, which will remain present for most of the year. Fifthly, when traffic gets heavier, it may be necessary to implement vessel traffic systems (VTS) along narrow straits that may end up as choke points, like the Barents Straits. Lastly, an integrated governance and regulatory framework based on the United Nations Convention on the Law of the Sea (UNCLOS) is needed.

When it comes to governance, there may be a need to adopt a more inclusive approach when it comes to the management of the Arctic routes. Currently, the Arctic Council provides the forum for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic Indigenous communities and other inhabitants, of common Arctic issues, in particular of sustainable development and environmental protection in the Arctic. It is a non-treaty intergovernmental ministerial level forum established by the Ottawa Declaration of 1996.[26] Members of the Arctic Council include Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States, five of whom have Arctic Ocean basin coastlines and three of whom have no coastlines in the Central Arctic Ocean. As issues regarding the Arctic, especially shipping issues, may impact on other stakeholders who are not members of the Arctic Council, a more inclusive approach may be required. Models exist where stakeholders are included in discussions for the management of a critical waterway used for international navigation. For example, the Malacca Straits Cooperative Mechanism was established in 2007 under the principles of UNCLOS Article 43 to deal primarily with the safety and environmental protection issues along the Malacca Straits.[27] Security issues can be addressed but were secondary. The Cooperative Mechanism is led by the littoral states of Indonesia, Malaysia and Singapore, but includes other stakeholders like the International Maritime Organization (IMO); the Nippon Foundation; the shipping industry, like INTERTANKO, INTERCARGO, BIMCO, the International Chamber of Shipping (ICS); and other interested non-littoral states in its Forum for Cooperation discussions.

Conclusion

Global warming and its resultant climate change is occurring at a rate that is much quicker than the median projections of previous IPCC models and current global emissions of global greenhouse gases are already at the upper end of the IPCC model projections. The likelihood of global warming occurring above current expectations is high if nothing is done to curb greenhouse gas emissions. If this were to happen, there will be severe consequences, including loss of habitat and arable land due to sea level rise, which will reduce crop yields. Fish stocks are also expected to diminish as a result of ocean acidification and the degradation of coral reefs. Water resources are expected to diminish due to contamination by salt water as a result of sea level, a reduction in precipitation, and the drying up of the Himalayan glaciers which supply water to many Asian countries. Temperature related illnesses and deaths are also expected to occur more frequently, with the extent of damage to physical infrastructure expected to be larger due to the increasing frequency and intensity of extreme weather events. As a secondary consequence, climate change is expected to exacerbate local conflicts, especially in regions where the governance structure is weak and thus unable to effectively redistribute the scarce food and water resources equitably or quickly enough, resulting in a rush for these scarce resources for survival.

In the area of shipping, many hub ports will have to either readjust their operational activities or to upgrade existing infrastructure to accommodate a sea level rise which is expected to affect cities like Shanghai, Ningbo, Tokyo and Singapore. The Arctic will be where warming will be the greatest, which will consequently result in the opening up of new sea lanes, like the Northern Sea Route. These new sea lanes will enable shorter transit times between Europe and Northeast Asia, which will reduce sailing times by about a week, resulting in substantial cost savings for ship operators. However, although climate change may result in some benefits, in this case, the opening new sea lanes, there will also be negative impacts on others. For example, with the opening up of the Northern Sea Route, current hub ports which lie along the east–west transportation thoroughfare, like Singapore, might be adversely affected as ship operators may decide to use the ports in Northeast Asia as transhipment centres instead.

Despite the fact that there will be regional variation in the costs and benefits resulting from climate change, the net global effect will be negative. Hence, tackling

the effects of climate change is a true transnational issue and a global common problem which requires substantial leadership commitment at the global level before it can be resolved. The Stern Review mentioned that there was no distinction in terms of impacts between developed and less developed countries and everyone will be affected, hence everyone will have to contribute towards limiting greenhouse gas emissions to within an acceptable limit.

Governments will have to overcome their deeply embedded shorter-term planning cycles and start embracing a longer time horizon as some of the negative effects will be felt much sooner than expected, even if the full negative consequences will only be felt in 40 to 50 years. There is an urgency to substantially reduce carbon emissions urgently because the longer the delay, the more difficult it is to reduce carbon emissions, either because the reduction target may become too high and costly to implement economically, or it may be technologically impossible to remove such large amounts of carbon dioxide and its equivalents from the atmosphere. If we fail to act decisively soon, it will be doubtful whether we can avert this disaster on a global scale, and when that happens we would have committed acts against humanity, essentially committing global genocide on our children and grandchildren, who are not represented at the elite levels or in government.

Notes

1. Simon Tay, Phir Pangmalit and Elaine Teng, ''Special Report on Climate Change Challenges in Southeast Asia,'' Report of Shell–SIIA Expert Roundtable on Climate Change Challenges in Southeast Asia, 2008.
2. Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report* (Switzerland: World Meteorological Organisation, 2008).
3. Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report* (Cambridge: Cambridge University Press, 2007).
4. Richard Betts et al., ''4°C of Global Warming: Regional Patterns and Timing'' (presentation at International Climate Conference, Oxford, UK, September 28–30, 2009). http://www.eci.ox.ac.uk/4degrees/ppt/1-2betts.pdf (accessed November 30, 2009).
5. Professor H.J. Schellnhuber, ''Terra Quasi-Incognita: Beyond the 2°C Line'' (presentation at International Climate Conference, Oxford, UK, September 28–30, 2009). http://www.eci.ox.ac.uk/4degrees/ppt/1-1schellnhuber.pdf (accessed December 1, 2009).

6. Sarah Simpson, ''The Arctic Thaw Could Make Global Warming Worse,'' *Scientific American*, June 29, 2009. http://www.scientificamerican.com/article.cfm?id = the-peril-below-the-ice (accessed September 15, 2009).
7. Leonard P. Bobylev, Kirill Ya. Kondratyev and Ola M. Johannessen, *Arctic Environment Variability in the Context of Global Change* (New York: Springer-Praxis, 2004), p. 470.
8. World Wide Fund for Nature, ''Mega-Stress for Mega-Cities: A Climate Vulnerability Ranking of Major Coastal Cities in Asia,'' WWF Report, 2009. http://assets.panda.org/downloads/mega_cities_report.pdf (accessed November 26, 2009).
9. *Ibid.*
10. Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report.*
11. Stefan Rahmstorf, ''A Semi-Empirical Approach to Projecting Future Sea-Level Rise,'' *Science*, 315, January 19, 2007. http://www.pik-potsdam.de/~stefan/Publications/Nature/rahmstorf_science_2007.pdf (accessed November 29, 2009).
12. I. Allison et al., *The Copenhagen Diagnosis: Updating the World on the Latest Climate Science* (Sydney: The University of New South Wales Climate Change Research Centre (CCRC), 2009). http://www.ccrc.unsw.edu.au/Copenhagen/Copenhagen_Diagnosis_HIGH.pdf (accessed December 1, 2009).
13. David Anthoff et al., ''Global and Regional Exposure to Large Rises in Sea-Level: A Sensitivity Analysis,'' Tyndall Centre for Climate Change Research Working Paper 96, October 2006. http://www.tyndall.ac.uk/sites/default/files/wp96_0.pdf (accessed November 29, 2009).
14. R.J. Nicholls et al., ''Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates,'' OECD Environment Working Papers No.1, November 19, 2008. http://are.berkeley.edu/courses/EEP151/fall2008/wordpress/wpcontent/uploads/2008/09/hellegateetal_oecd.pdf (accessed November 30, 2009).
15. Nicholas Stern, *The Economics of Climate Change: The Stern Review* (Cambridge: Cambridge University Press, January 2007), pp. 168 and 239. http://www.hm-treasury.gov.uk/stern_review_report.htm (accessed December 4, 2009).
16. I.E. Frolov and B.A. Krutskih, ed. *Hydrometeorological Supplying of Arctic Navigation in XX and Beginning of XXI Centuries: Federal Survey on Hydrometeorology and Environmental Monitoring* (St. Petersburg: Arctic and Antarctic Research Institute, 2008).
17. *Ibid.*
18. Arctic Council, *Arctic Marine Shipping Assessment 2009 Report*, April 2009.
19. Frolov and Krutskih, ed. *Hydrometeorological Supplying of Arctic Navigation.*
20. Ola M. Johannessen and Lasse H. Pettersson, ''Arctic Climate and Shipping,'' in *High North, High Stakes: Security, Energy, Transport, Environment*, ed. Rose Gottemoeller and Rolf Tamnes (Norway: Fagbokforlaget, 2008), pp. 95–114.

21. ''First Through Northeast Passage,'' *The Barents Observer*, September 9, 2009. http://www.barentsobserver.com/first-through-northeast-passage.4629485-116320.html (accessed September 15, 2009).
22. Felix H. Tschudi, ''Norwegian Commercial Perspective'' (presentation at the Conference on Energy Security in Asia organised by the Norwegian Institute for Defence Studies (IFS) and the China Foundation for International and Strategic Studies (CFISS), Beijing, May 21–22, 2009). http://www.mil.no/multimedia/archive/00123/Tschudi_Energy_Secu_123699a.pdf (accessed September 17, 2009).
23. Hiromitsu Kitagawa, ''Japanese Perspective'' (presentation at the Conference on Energy Security in Asia organised by the Norwegian Institute for Defence Studies (IFS) and the China Foundation for International and Strategic Studies (CFISS), Beijing, May 21–22, 2009). http://www.mil.no/multimedia/archive/00123/Kitagawa_Beijing_Co_123695a.pdf (accessed September 17 2009).
24. National Intelligence Council, *Global Trends 2025: A Transformed World* (Washington, DC: US Government Printing Office, November 2008), p. 53. http://www.dni.gov/nic/PDF_2025/2025_Global_Trends_Final_Report.pdf (accessed September 17 2009).
25. Joshua Ho, ''Arctic Meltdown Could Hurt Singapore,'' *The Straits Times*, July 6, 2009.
26. Arctic Council Secretariat, ''About the Arctic Council,'' Arctic Council Webpage, October 22, 2007. http://arctic-council.org/article/about (accessed September 18 2009). See also ''Declaration on the Establishment of the Arctic Council.'' http://arctic-council.org/filearchive/Declaration%20on%20the%20Establishment%20of%20the%20Arctic%20Council-1..pdf (accessed September 18 2009).
27. Joshua H. Ho, ''Enhancing Safety, Security and Environmental Protection of the Straits of Malacca and Singapore: The Cooperative Mechanism,'' *Ocean Development & International Law*, 40, no. 2 (2009), pp. 233–47.