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The Melting Arctic and New Trade Routes

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THE MELTING ARCTIC AND NEW TRADE ROUTES

by

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is accepted in partial fulfillment of the requirements
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Abstract

This paper postulates that climate change will lead to historic shifts in population centers that are employed in the shipment of goods. Recent evidence suggests that global warming may result in substantial melting of the Arctic Ocean's sea ice. Indeed, at the end of summer's light in September 2012, warming had shrunk the ice cap that covers the North Pole to the smallest size ever recorded. This remarkable measurement signifies a sea change. Ice-free, navigable open water in what is called the *High North* may make way for routine shipping during the long days of the northern summer months. Traveling via the North Pole trims 3,000 miles off a trip through the Panama or Suez Canals. Surveying the savings the shorter path could bring, shipping companies are plotting the prospects of navigating through the fabled Northwest Passage bordering Alaska and Canada on the one side, and the Northeast Passage bordering Russia and Europe on the other. Obviously, the shipping industry brings its own needs—supply depots, fueling stations, navigation charts, radio facilities, and emergency services, among others. Supplying these needs brings economic opportunity and economic opportunity grows human settlements.

Transport itself drives the patterns of human settlements. Towns begin at seaports and along navigable rivers. Cities extend their boundaries, stretching inland along highways and railways, and connect to new towns that sprout at new intersections, like the railway junction that became Atlanta. Major cities grow at the intersection of trade routes and cities fade when trade departs. When one route opens, another one often closes, as people migrate into areas with economic opportunity. As global warming opens pathways across the Arctic Ocean, new settlements will follow.

Introduction

As global warming leads to melting the northern ice cap, melting will open corridors for shipping, and new trade routes will lead to historic shifts in population centers that are employed in the shipment of goods.

This paper ties historical perspectives of trade routes to new assessments of climate change and of maritime commerce. The argument focuses on three thematic areas: an appraisal of trade routes and human settlements in history, an assessment of the science of warming, and a survey of maritime commerce connected to the Arctic. Finally, the paper supposes the kinds of changes that may be expected in future shipping and settlements there.

How is the climate of the Arctic changing? This paper presents work by the Intergovernmental Panel on Climate Change (IPCC) and the United States Global Climate Change Research Program (USGCRP) both of which give recent evidence of global warming and the rapid rate of change there. Climate scientists and geographers provide insight into the impact of climate change on the diminishing ice cap. What does new transport imply for people, policy, and provisions? Possibly the most comprehensive study on the Artic transport today, the Arctic Marine Shipping Assessment (AMSA) gives views of the broader global maritime community. Sociologists, economists, and marine transport experts comment on possible new industry and commerce that will accompany the new climate. The Arctic Council, a high level intergovernmental body that collaborates on protecting the environment through sustainable development, commissioned the AMSA particularly to discuss "issues related to the human dimension" of sustainable development there (AMSA). Fittingly,

their work devotes an entire chapter to the history of Arctic explorers. Likewise, this paper also includes historical accounts of trade routes along camel caravans, capes and canals to demonstrate that when transport routes change, human settlements change along with them.

A word about the paper's organization: There are four main sections: transport and patterns of settlement comes first, which includes discussions of the early U.S. frontier, camels, capes and canals, and how ports-city communities supply the trade routes with labor and services. The second section relates the latest scientific findings on climate change, with particular attention to the sea ice conditions. The shipping industry's possible reactions to the diminishing ice cover are found in the third section. It explains how ice and other factors influence route economies. Finally, the last section considers coincident factors that affect shipping, besides the new paradigm of melting ice. The section looks ahead and imagines scenarios of new trade and industry that may develop as the ice continues to melt, and notes on how governments are preparing even now for a new future in the High North.

Transport drives the patterns of human settlements.

Shipping is in the news.

When scientists at the National Snow and Ice Data Center first confirmed unprecedented melting of the Arctic ice cap in August 2012, they fueled speculation about shipping by the popular press. Some fifty news outlets such as the Financial Times, Christian Science Monitor, Slate Magazine, the Guardian, NBC News, CNN International, and the BBC issued major stories in summer 2012. With great enthusiasm, they reported on record numbers of ships traversing the pole with traffic spiraling upwards at rates up to 400% (NSIDC, Brahic, MacKanzie). According to the Northern Sea Route Administration, only two ships had sailed across the Northern Sea Route in 2009, four in 2010, and 46 in 2012 (NSRA, Staaleen), small numbers compared to the 20,000 ships travelling through Suez Canal in a year, but the increase is significant. As a Tschudi Shipping Company representative says, "There are key commercial challenges, but . . . a large variety of vessels sailed. It's about to be internationally commercial" (ASF).

Early U.S. settlements

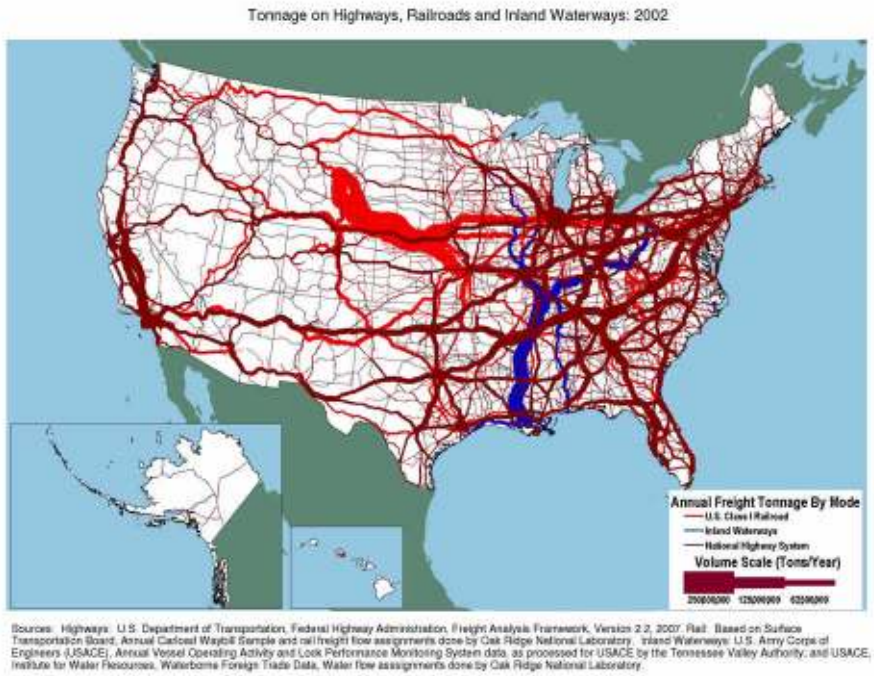
Because the Arctic is relatively unfamiliar, it is difficult to imagine how new transport would affect the area. Precedent from more familiar territory helps predict the changes that might occur there. Clearly, transport drove the pattern of growth within the U.S, growth that began at ports. From the Pilgrims' first coastal landings, transportation systems determined where people lived and where commerce developed.

Two hundred years ago, nearly all new Americans lived along the Atlantic Ocean's

coast. Villages hugged the shores at Jamestown near present-day Norfolk and stretched north and south, clustering around seaports at Boston, New York, Philadelphia, and Charleston. Merchants in colonial towns imported luxury goods from England and exported timber, grain, and animal pelts eastward to Europe. Lumberjacks, farmers, and trappers, harvesting stocks to bring to eastern seaport markets, made their way westward. They plodded along trails, rode in covered wagon trains, and paddled up rivers creating thoroughfares that in due course transformed into roadways, railways and canals. By one hundred and fifty years ago, towns had spread along the coastlines of rivers as well as the sea. Goods travelled by ship among the early towns along the eastern seaboard, and by barge and riverboat to hamlets along the Mississippi, Ohio and Missouri rivers. In the mid 1800's, miners pushed further west to dig California gold. Speculators, merchants, and settlers took passage on covered wagon caravans and on clipper ships that sailed from New York around South America's Cape Horn to San Francisco, a three-month journey. When the 3,000-mile transcontinental railroad opened in 1869, pioneers began to homestead in places along the railway. People could travel coast-to-coast in three days. Forts built every 100 miles or so at water stops where steam locomotives re-fueled, protected the water tanks, depots, coal stations and other facilities provisioning trains (McGuirk 2009 86). Forts became towns. Fort Wayne, Chicago, Omaha, Cheyenne, Denver, Salt Lake City, and Sacramento became populous freight centers. When automobiles individualized travel fifty years ago, the newly paved Interstate Highways connected those same centers, and today less than half of Americans live along coasts; instead living along major transport lines (see figure 1). The rate of population growth in the U.S.'s interior now matches that of the coasts (Crossett 1, Crowell ii). As international consultant Michael Grant points out, transport corridors provide livable, sustaina-

ble, economically viable communities (1-4). Today, it is difficult to remember that America began at coastal towns, from an accidental consequence of explorers trying to discover passages from Europe to Asia.

Figure 1 Major transportation routes in the U.S.



Source: U.S. Department of Transportation. Major settlements are along shipping routes including rivers, highways,and railways. See also time lapse video *U.S. Population Growth from 1790-1990*, University of Kentucky Appalachian Center, Lexington http://www.outragegis.com/animations/population-growth.htm

Of the Arctic.

Will similar growth patterns develop in the Arctic? Will towns cluster around harbors on the shores of the circumpolar nations? Will communities that supply provisions connect along railways and rivers that eventually carry goods inland? In the view of historian John Short, such patterns are common in all human hamlets and eventually trade encourages people to move nearby. Ports "existed to support trade through which the natural mineral and agricultural resources of the colonies were shipped to home markets in Europe" (Short 241). A regular "summer sealift of cargoes" should be expected with consumer goods delivery to settlements that will emerge in Canadian and Russian "Arctic communities" with

newly increased shipping (AMSA 11). Future activity from "tankers, bulk carriers, offshore supply vessels, passenger ships, tug/barge combinations, fishing vessels, ferries, research vessels and government and commercial icebreakers" will emerge (AMSA 11). Will people move to the High North? Yes, if, in fact, the Age of Discovery is any guide.

Navigating the far north

From the 1490's European explorers endeavored to navigate the northern seas. Determined to find a water strait that joins the Atlantic and Pacific Oceans, they looked "to find a more direct route to the Orient and the lucrative trade with India, Southeast Asia and China" (AMSA 37). Adventurers' names label the seas and straits on the North Pole map and lend a human dimension to the unfamiliar territory. John Cabot, William Barents, Henry Hudson, William Baffin, Vitus Bering, Dmitri and Khariton Laptev, John Davis, James Cook, and John Ross explored in turn until the mid-19th century. Impenetrable ice blocked their efforts. Norwegian explorer Roald Amundsen, also looking for a shorter path from West to East, maneuvered through the Northwest Passage between 1903 and 1906. Had the ice bound seas of the harsh climate not blocked earlier explorers, would pioneers have colonized the Arctic's coasts six hundred years ago instead of the Atlantic's two hundred years ago?

Arctic geography

A map (see figure 2) shows an ocean nearly surrounded by land, with Canada on the left and Russia on the right, and the Pacific and Atlantic oceans at the top and bottom. With the North Pole at the map's center, all points from it are south. The sun rises and sets in the south, and at the Summer Solstice (21 June), the sun appears to circle the horizon for 24 hours. The Arctic, the smallest of Earth's oceans, is about one and a half times the area of

Figure 2 Map of the Arctic region.

the U.S. A

Source: UT Perry-Castaneda Library from CIA map file 803536AI (G01486) 6-12

Great Circle Route from Nome, Alaska to Reykjavik, Iceland (both cities are at 64° North) measures 3,200 miles, about the length of the transcontinental railway. It is also mostly shal-

low. National Geographic's bathymetry map shows a wide continental shelf 40 meters deep extending out from Russia's shore and from Canada extending under the Queen Elizabeth Islands and Greenland. The ocean plunges to a depth of 4,000 meters at the North Pole. The map outlines an area that bulges into the Bering Sea to include Alaska's Aleutian Islands. (Traditionally, the Arctic zone includes the area where the average temperature for the warmest month is below ten Celsius.) The Aleutian Islands sit along the Great Circle Route between the west coast of the U.S. and China. From the Bering Sea, a narrow strait separates Alaska from Russia and funnels the Pacific Ocean into the Arctic. Starting at the Bering Strait, the Northwest Passage hugs Alaska's coast and wends through the Archipelago of Canada's northern shore on the one side, and the Northeast Passage follows Russia's and Europe's coasts on the other. These are not precise pathways but represent a variety of conduits depending on ice and meteorological conditions as polar expert Jan Drent explains (2). The Russian portion of the Northeast Passage is called the Northern Sea Route and it extends from the Bering Sea to Novaya Zemlya in the Barents Sea. While only the narrow Bering Strait connects the Arctic to the Pacific Ocean, three straits on either side of Greenland and Iceland channel Arctic and Atlantic waters, the Davis Strait, Denmark Strait and the Norwegian Sea.

Arctic people

The majority of Arctic people live near coasts of the eight littoral nations comprising the Arctic Council: Canada, the Kingdom of Denmark (with Greenland), Finland, Iceland, Norway, the Russian Federation, Sweden and the United States (see figure 3). The Council notes that four million people live in the region today, though indigenous societies inhabited it well before Greek navigator Pytheas discovered Iceland in 325 BCE and Viking explorer

Erik the "Red" discovered Greenland in 981 AD (AMSA History 37). Six indigenous tribes representing half a million people sit alongside the eight nations on the Council (CIA). About 100,000 people, 40% of them indigenous, live in Canada north of the tree line in the archipelago region. A few towns near zinc, lead and iron mines on Baffin Island and Little Cornwallis Island, and dwellings on Mackenzie King Islands have long sustained indigenous peoples. Other key coastal places on the map include Prudhoe Bay on the north slope of Alaska in the Beaufort Sea and Churchill in Canada's Hudson Bay. Known as the polar bear capital of the world, Churchill is also the only deep-water port in Canada's High North, and importantly, links to the national railway.

Most Arctic people live in waterfront towns, the *World Fact Book* indicates. About 60,000 people live in Greenland. Of the 300,000 people who reside in Iceland, a third live near the port of Reykjavík. Both Helsinki, Finland and Stockholm, Sweden house roughly 700,000 people. In Norway, about 400,000 live north of the Arctic Circle. Kirkenes, at the tip of Norway's mainland, houses the Center for High North Logistics, where Norway helps Russia patrol the Northern Sea Route traffic. Norway's Svalbard at 78 degrees latitude is the most northerly permanently inhabited place on Earth with 2,400 people. China maintains an unusually large embassy and a science center there. The largest city north of the Arctic Circle is Murmansk with a population of 330,000. Located near Russia's border with Finland, Murmansk is pivotal to Arctic shipping. Thanks to the Gulf Stream, it is the most northern port in the world that is ice-free all year long. From Murmansk, the Northern Sea Route connects to marinas at Dickson, Tiksi, and Pevek, small towns totaling about 25,000 inhabitants, on the Kara, Laptev and East Siberian Seas. Just off the right top edge of the map is Russia's port Vladivostok. It sits on the eastern edge of the Trans-Siberian railway, near the

borders of China and North Korea

Called the Russian San Francisco, Vladivostok is the largest Russian seaport on the

Figure 3 Population in the Arctic

Source: U.S. Census Bureau.

Pacific, home to Russia's Pacific fleet as well as 600,000 people. Just below the bottom of the map is the Dutch city of Rotterdam, one of the largest ports in the world, and a gateway to Europe with its extensive intermodal transport networks. Rotterdam's population is roughly twice that of Murmansk. The map shows that these and other isolated communities dot the coastal zone. Just as in the early history of the U.S., the Arctic's population is concentrated along the coasts around at ports.

Trade routes shape the course of history

Historically and globally, the largest cities are those built around transportation hubs. Tertius Chandler's *Four Thousand Years of Urban Growth: An Historical Census History* says the largest cities are built where goods are traded (as quoted by Pullen), even cities one thousand years ago.[1] As professor of geography, Cliff Ellis so eloquently writes on-line, "Throughout history, cities have been founded at the intersections of transportation routes, or at points where goods must shift from one mode of transport to another, as at river and ocean ports." Moreover, sociologist Kingsley Davis observes that "Compared to most other aspects of society – e.g., language, religion, stratification, or the family – cities appeared only yesterday, and urbanization, . . . has developed only in the last few moments of man's existence" (429). In earliest times, as in the Arctic today "The only means of conveying bulky goods for mass consumption was by boat." Davis continues to say that oxcart, pack animals and human bearers were "all short-distance means of transport, the only exception being the camel caravan" (430). In frontier zones, "Long-distance transport was reserved largely for goods

[1] The largest cities 1,000 years ago: Constantinople, Turkey (at present-day Istanbul), was founded on a natural harbor. Kaifeng, China was on the southern bank of the Yellow River. Cordova, Spain linked pilgrims along Roman Roads. Neyshabur sits on the main east-west railway line through Iran, strategically positioned astride the old Silk Road that linked Anatolia and the Mediterranean with China. (Source: Herodotus).

which had high value and small bulk . . . The size of the early cities was therefore limited by the amount of food, fibers, and other bulky materials that could be obtained from the immediate hinterland by labor-intensive methods . . . a severe limitation which [cities] . . . had to escape before they could attain their full size." With suitable technology, short hauls eventually lead to long hauls and cities, "become centers of power and influence throughout the whole society" (429-430).

All major cities are located where trade corridors meet—at seaports, river-banks, and even railway junctions. Starting from the Pilgrims' coastal landings, to river beds to the westward train tracks, the largest cities in the U.S. today are transport hubs, as at ocean ports and inland rivers.

And indeed, Davis' "yesterday" has barely arrived for the indigenous populations of the High North, many of whom live in isolated clusters and continue to fish, hunt muskoxen, narwhals and walrus, herd reindeer, and ply native trade to subsist. No map can describe the vast, stark, boundless beauty of this circum-polar world nor explain the intricate ecosystems there, as scientists Barry Lopez and Alum Anderson so aptly do in their work. Nor does a map show what a warming world may look like as tundra and tall shrubs zones nudge northwards, as climatologist Song Feng notes. Life in this map's zone will be forever altered.

Trade routes have "shaped the course of history" maintains historians Irene Franck and David Brownstone in *The Great Travel and Trade Routes of Human History* (xi). Among dozens of historic accounts, they examine camel caravan treks across the Sahara desert, as well as two great sea trade courses around Cape Horn at the southern tip of South America and Cape of Good Hope around the southern tip of Africa. The long and dangerous voyages along these three routes, the "world's great natural highways" ultimately led to

building the Panama and Suez Canals (xi). Maritime enterprises will surely compare efficiencies of the Cape and Canal corridors to the northern passages. These three historical conduits give insight into the sorts of effects that are possible with the opening of polar sea-lanes.

Camel caravans

Presenting a broad sweep of empires' rise and fall, professor of urban development and historian Joel Kotkin contends that "the creation of sacred place, the provision of basic security, and the host for a commercial market" characterize human villages (xvi). The Egyptian city of Cairo expanded, for example, as it "controlled transcontinental markets" in its "golden age" linking Africa, China and India (48).

With nearly the same dimensions as the continental U.S., the vast Sahara desert spans most of northern Africa, from Sudan in the south to the Mediterranean Sea in the north. In Arabic, Sahara means *wilderness*. As inhospitable and barren as the polar region, the desert wilderness' topography is rugged, containing mountains, plains, and valleys. Before the camel caravan was introduced, 4,000 years ago, the Sahara was impassable for trade. In a sense, the desert was as insurmountable a barrier as the Arctic's blockade of ice. After camels were introduced from Arabia, steady trade between north and south set up along trails that became more regular and established with time. Gold from the south was exchanged for salt from the north and "the earliest routes followed streambeds . . . where water and vegetation were most likely to be found" (Franck 339). By 500 BCE, the seaports of Carthage and Leptis likely traded "skins, timber, ivory, ostrich feathers" as well as salt and gold (339).

Making their headquarters at Carthage, Romans discovered "new roads" as domesticated camels "could last far longer without water, and could also travel faster" than the few

other beasts of burden (Franck 340). Indeed, "Camels seem to have begun transforming travel and political relations." Romans, in 100 A.D. "traveled further than ever before" carrying their technical know-how with them, building roads, dams and aqueducts. One aqueduct "brought water to Carthage from nearly 90 miles away" (340). Roman roads brought food and other goods into Carthage, enough to nourish a city of half a million people, declares technology historian L. Sprague De Camp (201). Trade flourished from Leptis to Rome's port at Ostia. The many early camel treks merged into main lines of regular caravan traffic, like a pony express, by the arrival of the Moslems in the 7th century. The Arab towns also expanded the gold trade. Bringing Islam with them, Moslem traded with Moslem, so the conversion of people to Islam followed.

Trans-Sahara travel, however, continued to be dangerously dependent on the supply of water in the wadis. Caravans often travelled by night to avoid the worst of the heat of day (Franck 343). (Similarly, many of today's long-distance aircraft depart at night in Denver to avoid the worst of the hot, thin air at the high altitude airport (Peterson 27)). In 1805, "lack of water cost the lives of all 2,000 men and 1,800 camels of a caravan en route home to Fez from Timbuktu," the main crossroad for Sahara trade (Franck 342). That main crossroad began contending with the tracks around the Capes Horn and Good Hope because, though longer, the shipping lanes were proving to be safer than the overland caravans. About the same time, nomads were becoming nationalized and the automobile was becoming more common concurrently with the trade in oil. Eventually, the camel caravan traffic collapsed completely with the advent of the automobile and oil trade. In the Sahara, "A traffic flow of only one vehicle per day over a road . . . would indicate a surprisingly well-traveled 'main-highway' (Franck 349). The comparison with the situation in the Arctic is clear: the numbers

of ships passing over it have been small, yet significant.

James Newman, professor emeritus of African geography, explores trade across the Sahel and the Sudan, beginning with an analysis of Western Africa four thousand years ago. Trade was "the major compelling force" that started villages and population growth and "re-defined comparative locational advantage" (106). Trade in iron-making and copper, for examples, "provided the impetus for the formation of states" (107) and led to population centers with "walled villages in secure locations" (109) and a gradually expanding trade network. Timbuktu, for example, was a center for "Luxury goods, such as glass and copper wares, and cloth" that grew as a scholarly center for "astrology and astronomy, medicine . . . history and geography, in addition to the Quran" (115). When drought and blight weakened trans-Saharan trade in the 17th century, coastal trade took its place. Newman notes that "cities in the Sahel and Sudan went into "decline" and the "pattern of urbanization shifted," sprouting a "whole new coastal urban network" (125) provisioning the new trade centers.

The Capes

The great shipping routes of history surfaced through the courage of intrepid sailors and explorers compelled to discover a way to reach spice markets faster than going overland. In 1498, seeking to find a passage over water from Europe to the East, Vasco da Gama pioneered a pathway around the Cape of Good Hope. Navigating around Cape Horn Sir Francis Drake set the course in 1578, benefitting from earlier exploration by Ferdinand Magellan in 1519. The Dutch towns of South Africa, French posts in eastern Africa, and Portuguese and Spanish colonies in South America are but a few of the landings that resulted from cape voyages. Later, as Franck puts it, "Because the Horn route was difficult" it was "little used in the 16th century" and indeed the "Spanish found it easier to break apart ships in the Caribbe-

an, transport them overland at the Isthmus of Panama . . . and reassemble them on the west coast" rather than sail around South America (65). The journey became less perilous in 1855 after Navy Lieutenant Maury published "a book of wind charts and sailing directions based on analysis of logs from many ships over the years" (Franck 70). Using the Maury collection, sailors traveled further south to pick up more favorable winds and the Horn causeway became more passable. The California gold rush beginning in 1848 made it a commercial success. In the first year of gold's discovery, "over 300 ships of all sizes and descriptions" sailed from the east coast to harbor in San Francisco (Franck 70). So many ships made that one-way trip that there was a dearth of vessels and crews in New York; so ship builders designed and set about building new, faster vessels, the clipper ships.

In their heyday, the clipper ships outpaced all other vessels at both Capes. They shortened the sail time from New York to San Francisco from 200 to 90 days. The fastest one, the Cutty Sark was built in 1869, the same year as the opening of the Panama Canal; a replica anchors at its homeport in England. As fast as they were though, clipper ships could not outpace either the railway, or the steam ships that came after. This was about the time of Amundsen's successful voyage through the Northwest Passage, and it was during the time of construction of the great canals. Passage via the capes would decline in favor of canals.

The Canals

The Cape routes were eclipsed by the opening of the Suez Canal (built between 1859 and 1869) and the Panama Canal (built between 1881 and 1914). Historian David McCullough describes how building a canal causes a migration of people and how great sums of money flow into the region and stimulate the entire economy. However, Ferdinand de Lesseps and Barthélemy Prosper Enfantin, promoters of the Suez and Panama Canals,

were not seeking riches; by cutting the ground to make the canals, they were creating pathways to link the East to the West.

The canals were engineering feats of wonder. The Suez Canal was cut at sea-level through the Isthmus of Suez, joining the Mediterranean to the Red Sea. One hundred miles in length, the Suez reduces the travel from Europe to India by 5,800 miles compared to the alternate around the Cape of Good Hope. In Panama, fresh water raises boats in locks to the level of the sea, which differs by 20 feet on either side of its 48 miles from the Atlantic to Pacific Ocean. The locks could "raise or lower a ship in a chamber in about fifteen minutes" and were 1,000 feet in length as "of all the oceangoing ships in the world at that time, approximately 95% were less than six hundred feet long" (McCullough 595-596). The Panama Canal cut the travel from New York to San Francisco by more than half; 5,000 miles compared to 12,000 miles via the Cape Horn. Both canals followed work of previous builders. Great powers designed, built, and controlled the canals; Great Britain at Suez and the U.S. at Panama. (Later each power relinquished authority to the respective sovereign State.) Construction at both canals used labor that immigrated to the economic opportunity, a workforce so numerous, a new word was coined for them—"navvys." The government of Egypt went bankrupt in the process and the Panamanian government did not fare much better. (Yet, in Panama at least, a widespread effort to combat malaria amongst the workers, benefited the entire country.) The year the Suez Canal opened in 1869, 5,000 ships made passage. When the Panama Canal opened in 1914, 1,000 ships passed through. Both canals permitted ships of any flag. Now, the Suez and Panama Canals handle 50 and 30 ships daily, respectively.

Caravans, capes, and canals

How might the remarkable history of camel, capes and canals apply to new Arctic

routes? *Merchants quickly adjust from one mode of transport to another.* Historian Giles Milton details how towns and cities grew at the points where goods were loaded onto ships and at points where those ships had to land for resupply of water and food, and the extensive efforts to create the spice trade. As an oasis served camel caravans, Cape Town provided fresh supplies to ships rounding the Cape of Good Hope. *Transport routes compete with each other.* Just as the ancient caravans from Fez to Timbuktu waned in favor or the safer travel around the Capes, those same routes themselves faded when the canals were built. When the transcontinental railway was completed in 1869, and "the most lucrative freight [was] being shipped by rail, the clipper ships were left with bulky goods", economists Noel Maurer and Carlos Yu Maurer say, and the Cape Horn Route consequently "passed into decline" (72). *When one route opens, another falls in importance.* By caravan or by sea, alterations in trade routes led to changes in population centers. As Franck claims, "empires built on trade" decline and retreat "as new routes pass them by" (xi).

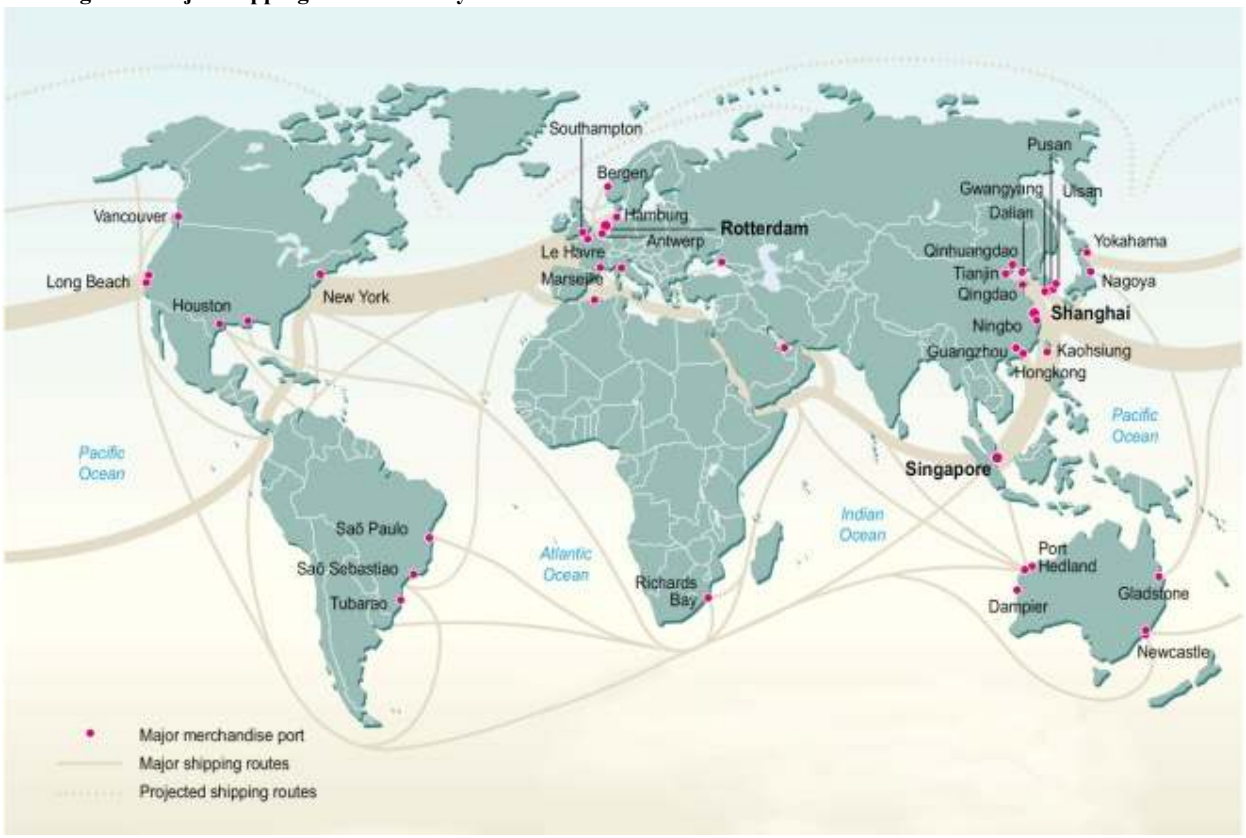
Shipping routes link East and West.

The vantage point of an airplane flight shows the patterns of city and urban development; cities connect to each other by rail and road, like spokes from central hubs of activity. Coastal cities bulge at their sea edges fed on the sea side by supplies coming in from deep water ports, and accessed on the land side by rail lines and pipelines. Facilities for fuel suppliers, maintenance, crew quarters, dispatch offices, docks, supply depots, and ship building all become part of the industry that connects one town to another. Seeing the city-port interface from an aerial point of view reveals the logistics of moving goods by land, sea and air.

Where are major shipping lanes today? Geographer John Rennie Short says contemporary municipalities develop in "areas that offer opportunities for economic growth" specif-

ically in “strategic locations” such as “at the meeting point of major transportation routes” (10). Coastal cities like Rotterdam, Sydney, Tokyo, and Los Angeles illustrate this theory; they grew to meet the needs of the expanding trade industry. Rotterdam, for example, with its extensive intermodal networks and its “continuing transformation from a bulk port to an industrial complex will generate added value and jobs by providing . . . [needed] facilities” (121).

Figure 4 Major shipping routes of today.



Source: WorldShipping.org. See also *Trade Routes 1925* by Richard Natkiel, 1986

Just as airlines move passengers, ship lines move goods. A map (see figure 4) indicates the major shipping routes with the volume of goods indicated by the width of the arrows; with a hint at the vestiges of cape travel. *Transit shipping* goes long distances from major port to port whereas *destination shipping* goes shorter distances and engages commerce locally at alternate ports in a manner similar to long haul and short haul trucking.

Merchant ships broadly divide into two categories; containerships that carry prepackaged goods and ships that carry bulk goods.

Shipping lines

Shipping lines, like airlines, follow routine itineraries. For example, an Alaskan cruise ship might depart every Monday. Like a camel caravan crossing the Sahara stopping off at wadis, a procession of ships crosses the ocean on a course through a predetermined set of ports of call on a regular schedule. The number of travel days for each voyage varies by line. Table 1 shows port-to-port travel days for several destination of interest, by courtesy of American President Lines. (See table 1).

Table 1 – Number of days of transit on major shipping routes.

Days to transit on American President Lines			
09	AEE	Americas Europe Express	New York to Rotterdam
18	PS5	Pacific South 5	Los Angeles to Shanghai
25	CIX	China India Express	Beijing to Pipavav (India) via Singapore
27	CEC	China East Coast	New York to Hong Kong via Suez Canal
31	NYE	New York Express	New York to Shanghai via Panama Canal
45	LP7	Asia Europe Loop 7	Rotterdam to Shanghai via Suez Canal

Source: Data extracted from American President Lines, Vessel Schedules. Web. 13 October 2013. Number of days of transit for ship line itineraries.

Are these transit routes candidates for a Polar Express? New York to Europe and Los Angeles to China are quite direct and northern lanes have no distance advantage. Interesting-ly, New York to China is about the same distance via either canal. The longest transit time is between Asia and Europe: Rotterdam to Shanghai via the Suez Canal (and the Malacca Strait), takes 45 days. In contrast, Rotterdam to Shanghai via the Northern Sea Route could be as short as 22 days.

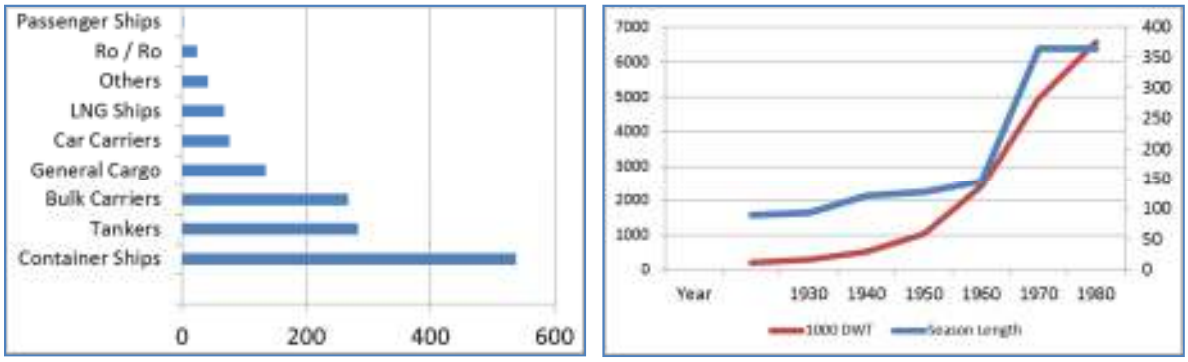
These are containership lines with weekly departures, thus there are several ships on each line simultaneously, like greyhound busses on inter-city service. The World Shipping

Council claims 6,000 containerships work some 200 lines carrying 30 million twenty-foot equivalent units (TEUs) each weighing 10 – 30 tons, depending on the cargo.

Besides containerships, other lines carry goods in bulk. As economists Wouter Jacobs, Cesar Ducruet, and Peter De Langen explain, there are many sorts of carriers. Bulkers carry liquid bulk (crude oil, liquid nitrogen gas, chemicals), agri-bulk (grain, corn, soya, fruits), break bulk (ore, coal, scrap, aggregate material, other dry goods), RoRo stock (roll-on, roll-off such as automotive cargo), and general cargo (forestry, iron, steel products) (Jacobs 97). Bulkers, classified by the weight they carry in Dead Weight Tons (DWT), make up 20% of the world's fleet.

Could a portion of containership lines and bulk freight move north? A count of the types and numbers of vessels using the Suez Canal in a month and the amount of freight using the Northern Sea Route since 1930 is shown below. (See figure 5)

Figure 5 Ship traffic on the Suez Canal and Northern Sea Route .



Sources: Left Suez Canal Authority Web. Right Daamen. Left graph shows number and type of ships sailing through the Suez Canal in September 2012. Right graph shows for the Northern Sea Route in blue the mount of cargo in 1,000 dead weight tons passing through route per year and in red, the number of navigation days.

Bulkers and containerships account for most of the Suez's traffic, (results are similar for Panama) and the volume of bulk passing through the Northern Sea Route has grown steadily as ice has retreated. Both containerships and bulk vessels have gotten larger since the time the Panama and Suez Canals were built. Panamax vessels are of the maximum size

that will fit into a Panama lock. Capesize vessels are too big to go through either Canal – traveling instead around the Capes, the same passages found in the Age of Discovery. Moving even a portion of the container, bulk, or oversized traffic from the lines to the north would be revolutionary.

Table 2 World Fleet Vessel Counts.

Total World Fleet approximately 80,000 vessels		
	Containerships	Bulkers
Total Number	6,000	12,000
Number at average size	4,000	6,000
Max size	18,000 TEU	400,000 DWT
Average size	5,000 TEU	10,000 DWT

Source: Extracted from World Shipping Council databases. The largest bulkers are 400,000 DWT. The largest containerships (owned by Danish company Maersk Line) have a carrying capacity of 18,000 TEUs, but most containerships, about 4,000 of them carry 5,000 TEUs or less.

The shipping lines carry 90% of all consumer goods, reports the International Maritime Organization, and most of that is trade between China, the U.S., and the EU. Counting containerized shipping alone, the EU exports more than the U.S. (see table 3). The largest container shipping lines, the Danish Maersk Lines, Switzerland's Mediterranean Shipping Company and France's CMA control about 30% of the world's container market. Greece[2], Japan and China own over half of the largest bulkers. If northern tracks were to open for routine container shipping, Europe and Russia could become the major trade partners with China, at the U.S.'s loss.

Table 3 Millions of TEUs in 2010

Country	Export	Imports	Total
China	31.3	12.0	43.3
EU	14.8	16.8	31.6
US	11.2	17.6	28.8

Source: Data compiled from World Shipping Council information.

Shainghai, Singapore, and New York handle the most containers, 30-32 million

[2] See Thomas Cahill's splendid story of the long history of Greece's seafaring and its importance to international trade today.

TEUs. Singapore also acts as a transfer station, moving containers from one ship line to another, just as Atlanta's airport moves baggage from one airline to another. In terms of overall tonnage, Shanghai is the number one exporter and second largest importer of goods. Its rival, New York places second in exports and first in imports. A shift in the East-West flow of goods would threaten the standing of New York's port.

Port-city commerce

Port cities "are historically commercial centres with considerable geo-economic and political power" in Jacobs' view (110). Warehousing, logistics, ship repairs, provisioning, and stevedoring are some of the services ports provide. During the second half of the 20th century, banking centers began handling the seaports' commodity trade in what is called *advanced producer services*. Part of a larger industry, these centers offer financial services, maritime law and arbitration, maritime insurance and brokerage, charterers liability, engineering, ship finances, and personnel services, as well as maritime education and research (Jacobs 97). By a count of the numbers of firms linked to the ports, London, Houston, New York, Oslo, Rotterdam and Geneva (yes, land-locked Geneva) offer the most services (Jacobs 105). More shipping lines means more advanced producer services, even in areas beyond the ports themselves, explains maritime broker Athanasius Pallis (10-13).

Shipping is big business. A look at traffic[3] on an ordinary day, 13 October 2013, reveals 80,000 vessels sail world-wide, counting all water craft— containerships, bulkers, fishing boats, cabotage vessels, trawlers, lighters, as well as cruise vessels on tours, and freighters—whether steaming or mooring, or queuing at canals. The largest concentration is at Eu-

[3] All ships report location through the Automatic Information System by agreement with the International Maritime Organization. The position, track, departure and destination ports are displayed in real time at marinetraffic.com

rope's gateway to the Arctic. Any shift in global maritime commerce has enormous consequence for new business and tele-connections worldwide. As the Chair of the Committee on Climate Change and U.S. Transportation, Hank Schwartz, puts it, "the greatest impact of climate change . . . seen through the lens of transportation professionals would be that which would alter the movement of goods and people on a global scale. And that would be the melting of the Arctic sea ice" (Schwartz).

Global warming is melting the Arctic Ocean's ice cap.

Climate matters.

Climate change is underway. The world is warming up. North Dakota is taking on aspects of North Carolina's present-day climate even as North Carolina is becoming warmer, more like the climate of Puerto Rico. The further north, the faster the rate of warming; North Dakota is warming up faster than Puerto Rico, and the poles are warming fastest of all.

Climate and weather

Weather is what people experience day to day and climate is the collective of that experience in an area over a lifetime. Notionally, climate is to weather what the forest is to a tree, or what history is to the nightly news. Climate influences how communities feed, clothe, and shelter themselves. Climate shapes the design of towns (housing, water and waste facilities, hospitals, schools) and the design of transportation infrastructure (airports, railways, bridges, roadways, pipelines, subways, and storage facilities), and determines where people can live (McGuirk 2009 83, 2012).

Wherever people live or travel, they feel the climate of that place and time. As an-

thropologists Sarah Strauss and Ben Orlove explain, people "understand that each season is characterized by particular attributes – weather, length of day and night, stages of plant growth" (126). A temperate climate like North Carolina experiences four seasons. People clear roads of winter's snow; wear shorts and sandals in sweltering summers; and build their houses with wood from forests. North Dakota's continental climate is too dry for most deciduous trees, and the cold freezes the ground so deeply that architects design foundations four to five feet below ground level, to brace a building against frost heaves. Houses have steep roofs designed to shed heavy snow. Trucks and trains must lighten their loads in spring there, as road and rail beds soften when the ground thaws with summer's approach. Frost depth has become shallower over the last decades and the growing season has lengthened. Close to the Equator, Puerto Rico's tropical climate has not four seasons but two, wet and dry, and fruit, herbs and spices grow year-round. Open atrium buildings need no heating or air conditioning. White, flat roofs collect rainwater and storage tanks mounted on stilts supply water for households. Far from the Equator, the Arctic also has two seasons, but its seasons are light and dark. At the North Pole, daytime lasts from 21 March through 21 September. The sun appears above the horizon to any viewer north of the Arctic Circle (the land of the mid-night sun) and the other six months of the year, the moon and the eerie glow of the aurora borealis provide the only light.

In every place, words people use for seasons, such as planting season, mud season, holiday season, fall, monsoon season, Indian summer, January thaw, etc., "stress a temporal dimension of human activity and experience" and identify the climate where they live (Strauss 136). In the Arctic, indigenous people used to speak of the season of *polynyas,* or area of open water. Today, they use a new word for seasons: *navigation season.*

IPCC and USGCRP

Scoping the future climate nature of "navigation season" begins with a close review of the primary literature collected by the Intergovernmental Panel on Climate Change (IPCC) and by the United States Global Climate Research Program (USGCRP). Remarkably, thousands of scientists contribute their work to the IPCC and hundreds to the USGCRP, including experts from thirteen federal agencies (e.g., Departments of Defense, State, Transportation, and the Department of Commerce's National Oceanic and Atmospheric Administration, with its National Climatic Data Center in Asheville). The IPCC will publish the Fifth Assessment Report on global climate change in early 2014 and the USGCRP will publish the Fourth Assessment Report on national climate change in late 2013[4]. Peer-reviewed papers submitted to the assessments describe current climate, quantify the rate of warming and of melting ice, and draw conclusions about global warming and shipping in the Arctic. This prodigious science underlies the extraordinary future for the High North.

Unequivocal and unprecedented

Climate scientist Thomas Karl and colleagues state conclusively that "global warming is unequivocal and primarily human-induced" (Karl 12). The rate of global warming is "unprecedented in human history" and "Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850" (IPCC SPM 3-10). "Currently rare extreme events are becoming more common" with greater danger of

[4] Though both IPCC and USGCRP have circulated drafts of their newest assessments, they restrict use, attribution, and quotes. The IPCC Fifth Assessment report was released for public review in March 2013 but only the Summary for Policy Makers is to be quoted or referenced until final publication expected in the latter part of 2014. The USGCRP 3rd Assessment report was released for public review in early 2013 but it is not to be quoted or referenced until final publication later in spring 2014, excepting for leeway under the "suitable use for educational purposes" clause of U.S. copyright.

droughts, floods, more intense storms, extreme windiness, and higher ocean waves (Karl 14). Sea-level will inevitably continue to rise and "thresholds will be crossed leading to large changes" in ecosystems with possibly abrupt loss of sea ice cover and "rapid ice sheet collapse" in Polar Regions (Karl 12-26). Many phenomena that have already been observed "are unprecedented over decades to millennia," are irrevocable, and their "effects will persist for many centuries" (IPCC SPM 3-10).

The IPCC explains that greenhouse gas discharged into the atmosphere causes global warming. Indisputably, "Human influence on the climate system is clear" and the "concentrations of carbon dioxide (CO2), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years" (IPCC SPM 3-10). Greenhouse gas pollution absorbs long wave energy emitted from the earth's surface and heats the atmosphere, much as water molecules absorb energy emitted from a microwave oven and heat up coffee in a cup. Short wave energy comes from the sun; clouds scatter it, snow and ice and other light-colored, high albedo[5] surfaces reflect it, and oceans and ground absorb and re-emit the energy as long wave energy. In a non-polluted atmosphere, much long wave energy would escape back to space, keeping Earth's temperature steady. Instead, the earth's energy budget is off-balance. Extreme weather, previously beyond human experience, has occurred already and the IPCC warns that future "Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system" (IPCC SPM 14).

The USGCRP examines the changing climate of Alaska and finds rapid sea ice loss, shrinking glaciers, and a shortened snowfall season (Stewart 33). Thawing permafrost there upheaves the ground, tilts roads, and ruins structures and houses that were built on top of it,

[5] Albedo is a measure of how much light a surface reflects, from the Latin for white.

as it is impossible to dig foundations below frost line as in North Dakota. Based upon the results of models that integrate ocean, land, and atmosphere mathematically, T.S. Rogers and others evaluate future marine access (Rogers, Pullen). As Paul Edwards explains it, global circulation models combine the physics of oceanic and atmospheric circulations with heat balance equations. Depending on the emissions of future greenhouse gas, the fidelity of the models, and given correct initial conditions, the models project a range of future temperature conditions for the atmosphere. The temperature will determine the seasonal presence of ice. The IPCC and USGCRP source's papers quantify the rate of melting and predict that ice conditions will make way for shipping midcentury.

The Arctic warms at twice the global rate.

Arctic climate

As previously stated, the Polar Regions are warming faster than other regions of Earth and the North Pole is warming fastest of all. Climatologist Thomas Wilbanks and others explain that energy is carried by air currents from the warm Equatorial band towards the poles. Because the atmosphere, specifically the troposphere, is shallower at the poles than at the equator, less energy is needed to warm the mass of air there. Ocean currents also move warm water pole-ward mixing it with north seas. Primarily though, a darkening albedo, or surface reflectivity, causes the warmth. Flying over the pole in fall 2012, a passenger would see a dark sea below, not the white of frozen ice. Thirty years ago, a passenger would have seen a white mass of ice. Dark seas absorb more incoming solar energy than white ice does. In effect, melting ice causes global warming as much as global warming causes ice to melt.

The angle that the earth tilts on its axis (23½ degrees) relative to the plane of its rota-

tion around the sun causes the seasons. Global warming does not disrupt the earth-sun geometry. It is excessive warmth that has caused excessive melting. Indisputable evidence for the ice cap's retreat comes from visual imagery and from inferometers sensors on satellites that detect the radiation signals emitted from Earth. Modern satellite altimetry can even estimate sea ice thickness. Yes, the Arctic has warmed in every season, and sea ice has "decreased in every season, and in every successive decade since 1979" (IPCC SPM 4). The Arctic has already warmed at about twice the rate as the lower latitudes.

NOAA 2012 and NSIDC

The official *State of the Climate Report for 2012* issued by NOAA's Asheville office states that record melting shrunk the ice cap to its smallest size ever recorded. The press release highlights the historical context of the record retreat of the Arctic Ocean's ice cap:

> Minimum Arctic sea ice extent in September . . . reached new record lows. Arctic sea ice minimum extent (1.32 million square miles, September 16) was the lowest of the satellite era. This is 18 percent lower than the previous record low extent of 1.61 million square miles that occurred in 2007 and 54 percent lower than the record high minimum ice extent of 2.90 million square miles that occurred in 1980. (NOAA press release 2013).

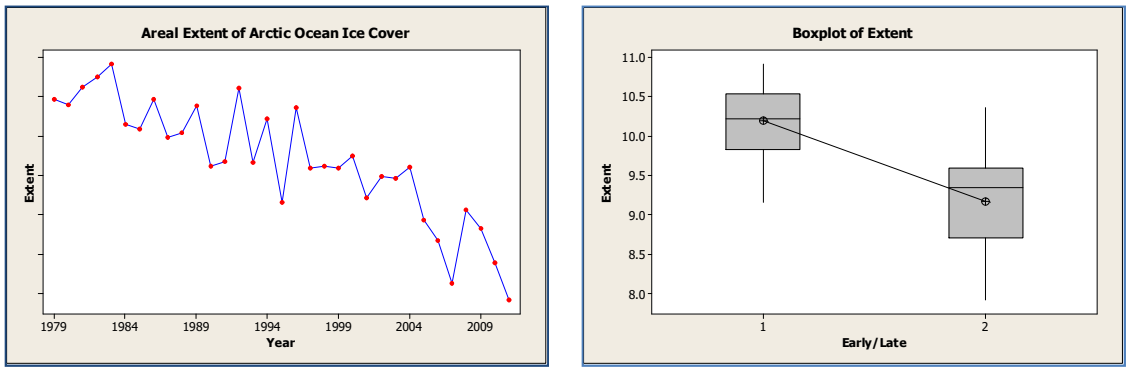
Data from the National Snow and Ice Data Center show sea ice cover dropping steadily since 1979 at a linear rate of approximately 13% per decade (measured annually close to the September[6] equinox) (NSIDC). Splitting the values by time into two groups compares the amount of ice in the early years to more recent years and proves that ice cover

[6] P*erennial ice* survived summer melting. It may refreeze over winter and become second year ice. The World Meteorological Organization defines ice that has survived two summers or more as multi-year ice.

has fallen remarkably (see figure 6). A simple statistical test confirms with a T-Value of 5.16 and a P-Value of 0.0 that there is very high confidence (greater than 95%) that the melting ice is statistically significant and not a chance occurrence.

Scientists analyzed this extraordinary melting at the ice cap's margins. They estimate that more ice melted in 2012 than as far back in time as they could verify through submarine tests, ship logs, and ice core samples. From this extended period-of-record, the IPCC concludes, "the decline of sea ice over the last few decades has been unprecedented over the past 1450 years" (IPCC WGI 4-5)[7].

Figure 6Arctic sea ice minimum per year



Source: Left NSIDC, minimum sea ice coverage yearly. Right Author. sea ice averages in early years (1979-1996) compared to more recent years (1997-2010).

Scientists forecast Arctic ice melt will accelerate.

The rate of global warming at the North Polar Region is accelerating, and at a pace that is faster than previously predicted. The IPCC states that the "Arctic region will warm more rapidly than the global mean" and is "*very likely* that the Arctic sea ice cover will continue to shrink and thin year-round in the course of the 21st century as global mean surface temperature rises" (IPCC SPM-17). One of the model projections indicates "a nearly ice-

[7] IPCC source paper Kinnard, C., C. M. Zdanowicz, D. A. Fisher, E. Isaksson, A. De Vernal, and L. G. Thompson, 2011: Reconstructed changes in Arctic sea ice over the past 1,450 years. Nature, 479, 509-U231.

free[8] Arctic Ocean in [every] September before mid-century is likely" (IPCC SPM-17).

More than sea ice will dissolve. Snow cover will diminish and glaciers on Greenland's west coast will calve at higher rates as warming accelerates. Large ice floes carried by winds and huge icebergs carried by currents circulate clockwise, causing hazards on the seas.

Moreover, the IPCC measured extensive permafrost and fresh-water ice sheet warming. As NOAA's study says, "The temperature of permafrost, or permanently frozen land, reached record-high values" and "on the Greenland ice sheet. . . 97 percent of the ice sheet showed some form of melt, four times greater than the average melt this time of year" (NOAA press release 2013). Because "warming over land will be larger than over the ocean" it is "*virtually certain* that near-surface permafrost extent at high northern latitudes will be reduced as global mean surface temperature increases" (IPCC SPM-18). Thawing permafrost makes rail beds and roadways unstable and renders Alaska's and Canada's ice roads too soft for heavy loads (Prowse 277, Peterson 36). A sampling of a few scientists' views on the trends in sea ice follows next.

Julienne Stroeve synthesizes numerous studies and explains that melting varies year to year and is more pronounced in some seas than others. Swings in the jet stream push areas of low and high pressure and alter the normal flow of clouds, winds and wind-driven waves, all of which alter the rate ice melts. Solar energy, "entering through leads and polynyas" warms the ocean more. Sea ice in the Kara and Laptev seas largely disappeared in 2010, but returned slightly just when more ice was lost in the Beaufort and Chukchi seas. Overall, there is 50% less ice in September today than there was 30 years ago (1024). The rate sea ice is melting is accelerating and "the system may be poised to undergo rapid change." There

[8] Conditions are ice-free when the sea ice extent is less than 10 km2 for at least five consecutive years

may be “dramatic summer ice loss” (1025).

Muyin Wang and James Overland use the latest findings from the most recent model runs on USGCRP supercomputers. The analysis combines six climate models, ice extent and ice volume parameters, and weather and climate mathematics with the darkening of the albedo. The study confirms that “Arctic sea ice loss is very likely to occur in the first rather than the second half of the 21st century, with a possibility of loss within a decade or two” (Overland 2013). The study concludes that, by the 2030s, the North Pole will be nearly ice free in the summer (Wang 3-4).

Studies by Steffen Tietsche et al. also conclude the region will be ice-free in summer by mid-century, but also predict that winter ice should return for the foreseeable future. Excess heat in oceans “that had built up during the ice-free summer is rapidly returned to the atmosphere during the following autumn and winter, and then leaves the Arctic” escaping to outer space. The ocean in winter, without its cover of ice, can chill rapidly and reform and a “so called tipping point, which would describe the sudden irreversible loss of summer sea ice during warming conditions, is unlikely to exist” (1, 4). Even if sea ice does not vanish altogether, its loss in the summer months is probably the most extraordinary climate change signal of all time.

Melting Arctic ice opens shipping lanes.

The U.S. National Research Council (NRC) investigates the impacts of climate on means of transport and support facilities, with ships, planes, trains, barges, ports, and piers among them. Weather phenomena can exceed thresholds for the safe operation of marine

vessels; gale force winds create heavy seas and larger waves near shore inhibit portage; calving glaciers cascade into the sea and create more icebergs; icing on structures destabilizes ships. Whereas weather affects the operation of transport infrastructure, climate affects the overall design of transport systems (McGuirk 2009 85-87). In the view of climate scientist and transport specialist J. Titus, the pattern of development goes far beyond the life cycle of the road, or rail, or bridge. The ability to adapt to climate change may be helped or hindered by the decisions that transportation officials make today (Titus).

Ice was as an impenetrable barrier to the seafaring explorers as the desert was to the early nomads. When pack ice froze his ship fast overwinter, Henry Hudson's expedition ended in mutiny. When icebreakers calved off Greenland's west coast, William Barents's expedition at Novaya Zemla was forced to turn back. Large pieces of icebergs called growlers can sink a ship. It was a growler from Greenland that, carried southward by the Labador Current, floated down the Davis Strait, struck and sank the Titanic off the coast of Nova Scotia. Lasseure warns that as more ice falls off Greenland, the risk of more ships colliding with growlers in the Baffin Bay rises. Modern ships, designed with ice-reinforced hulls, strengthened bows, and ice-avoidance radars can better weather the hazards at sea, but ice still matters to shipping.

As ice shrinks at least partially from the shores of Russia and Canada, sea lanes have opened up. In the last decade, dozens of vessels sailed through each year, some without the need for icebreakers. Shippers (see Arctic Shipping Forum section ahead) exude optimism saying, "The winter is a fairly narrow season" and **"**From mid-August to mid-September, there is practically no ice – easiest for conventional vessels to maneuver." Another shipping company offers, "With proper icebreaker support, the Northern Sea Route can be used almost

year round" (ASF). While ice is still an obstacle to travel, its disappearance brings the promise of trade.

Ice matters.

Both the area and thickness of sea ice matter to mariners. The area of ice matters because seas that have lost ice by the end of September will have only first year ice in the next spring's navigation season. First year ice is typically less than 1.5 meters in depth; it is thinner and softer than multi-year ice. Multi-year is harder, pressurized into more solid blocks. Mostly pack ice blown about by the wind, multi-year ice breaks into floes that collide into each other forming rafts that can stack up to four meters above the sea surface and eight meters below. Along the coasts, *shore fast* ice forms in waters less than 30 meters deep. Offshore winds push deeper-depth sea ice just beyond the shorefast ice, and open lanes of ice-clear water called *leads*. Sailors steer their way along the leads to navigate in open water. Russian Academy scientist V. C. Khon explains that open water is defined as areas with sea ice concentration less than fifteen percent. At that volume, light ice-class ships can transverse without icebreaker escort. With warming oceans, "high-seas ice formations will become thinner and smaller" and more pack ice will break into floes creating a need for "more accurate ice-floe forecasts and improved technology for mapping ice migration" argues Russia Academy scholar Alexei Konovalov.

Ships go faster in areas where there is less ice – either thinner ice or few ice floes. Interestingly, the normal cruise speed for liner vessels was 24 knots before the 2008 economic slowdown. A decline in demand for containerized goods and a need to decrease fuel consumption dropped speeds in open water. Liners today travel at *slow steaming* near 19 knots or *extra slow steaming* near 14 knots, depending on the ship size and load. Reviewing on-

line databases of actual ship voyages shows the average cruise speed there is about ten knots. Some ships have crossed the north seas in open water at speeds approaching slow steaming, making speed less of an issue than before.

Of ice and ships

With upgrades in construction, modern ships can navigate in thicker ice. However, structures added to a vessel to harden it against ice take away from cargo space. The International Maritime Organization classifies vessels by their suitability for open water, first year, or multi-year ice. Vessels move up in class primarily as a function of the amount of ice reinforcement they have. The more reinforced, the higher the class. Open water vessels have little to no ice-reinforcement. Icebreakers, particularly nuclear-powered ones, are at the top of the class. Russia has a fleet of six. They can go anywhere.

The speed of an icebreaker is of course slower in thick ice cover, and faster in medium or thin ice. Significantly, icebreaker fees, unlike taxi fares, depend not on the length of service but on which part of the sea service is used, as well as the escorted vessel's gross tonnage, and the ice-class of the vessel as explained by Norwegian geographer and member of the Secretariat of the Northern Sea Route Administration, Claes Ragner (NSRA, Ragner 552). Icebreakers may tow ships, or cut channels or lanes in the ice, and then return to port to pick up a convoy of ships or even a single cargo ship for a tandem voyage to the next port of call.

The breadth of a vessel also constrains its passage. Supertankers are too wide to follow the channel cut by today's icebreakers, nominally 30 meters in width.[9] However, ship-

[9] The Suez can handle ships 70 meters at the beam; although most of the vessels passing through are more narrow (Ranger, 552).

builder Aker Arctic Technology recently announced that they had developed a class of ice-breaker that can cut through ice 1.5 meters deep, forward and aft, and, very unusually, can also move sideways, cutting a 50-meter wide channel, and all but the largest 65-meter beam ultra-tankers could follow in its path. Calling it "game changer" technology, Aker will bring "new capability in terminal operations, ice management and oil spill response in freezing seas" (Synder). Finland and Russia collaborate in this shipbuilding venture and expect to deliver a polar class 7 icebreaker to the Russian Ministry of Transport in mid-2014.

On the other hand, Finland and Norway's ships are already equipped with special hulls that can break up first year ice themselves, without the need for icebreaker service (Titley). Though there are some sections, like the Matochkin Shar Strait beside Novaya Zemlya, that will still be ice bound in summer, since 2007 most of the Polar ice cap is less than one year old and much easier to break up. The ice is substantially different from before 2005, when most of the Polar ice cap was multi-year, thicker ice and much harder to break through (Titley 2013).

Navigation season

Calculating the length of the navigation season is complicated, but advanced computer models can help. Models include both the area and the thickness of sea ice in the calculations that yield future ice conditions. Geographer Scott Stephenson and colleagues calculate the length of the navigation season along the Northern Sea Route, the Northwest Passage, and along a Trans Arctic Route. Season length varies by vessel's "high, medium, and no ice-breaking capability" (Stephenson et al. 2). The research determines that of all three paths, the Northern Sea Route will have "the longest navigation season of the Arctic routes" and that "At early-century" open water vessels may navigate there for more than 90 days, and

medium reinforced vessels "may navigate reliably for nearly a full summer" by mid-century (11). Heavy ice-reinforced vessels may cross the entire Northern Sea Route all summer. Furthermore, Stephenson's calculations show that although the Northwest Passage and the Trans-Arctic Route over the top of the globe will "remain less accessible" than the Northern Sea Route, "until the latter half of the century", polar class 6 vessels will be able to navigate over the North Pole even sooner. The season for weaker polar class 3 vessels can be as short as ten days along the Canadian Arctic Archipelago part of the Northwest Passage, "severely shorter" than the Northern Sea Route. Stephenson calculates that polar class 6 vessels should eventually be able to steer directly across the North Pole in summers. The "season" referred to of course, is navigation season. In 2011, there were 141 days where the entire Northern Sea Route was ice clear. Overall, sea ice thickness has declined and the "older and thicker ice types" are declining at even faster rates than perennial ice (IPCC WGI 4-11).

A shorter ice season means a longer navigation season. As the National Strategy for the Arctic asserts "The reduction in sea ice has been dramatic, abrupt, and unrelenting. The dense, multi-year ice is giving way to thin layers of seasonal ice, making more of the region navigable year-round" (5). Can icebreakers ensure year-round routine transit and make northern circuits profitable? Other factors besides ice type and extent of vessel reinforcement go into the calculation of the cost effectiveness. Weather is a factor as well; heavy seas are dangerous and accidents are unforgiving. The Suez Canal expenses include an inventory cost during the wait time, and other fees, what shippers call *demurrage*. Rising demurrage rates have triggered interest in alternates. Similarly, at the Panama Canal, tolls figure into the cost efficiency. The toll, which differs for passenger and containerships, is based on the time a vessel takes to go through the canal, or *Canal Waters Time,* including wait time. Traffic

jams cost money. The price for a bulker depends on the DWT and for a containership depends on the type of cargo, the tonnage, and the vessel's size.

Obviously then, much more than distance determines cost effectiveness. Nonetheless, a few useful comparisons on distances are presented, (see table 3), with an orientation map (see figure 7).

Table 3 Some comparison figures on different Sea Routes.

Number of Ships on Routes		Travel Distance & Time		
		Rotterdam Shanghai	Murmansk Vladivostok	New York Shanghai
Northwest Passage	21	8,000	xxx	xxx
Northern Sea Route	500	8,000 22 days	6,000	xxx 29 days
Panama Canal	13,000	13,000	14,000	xxx 31 days
Suez Canal	21,000	11,000 45days	xxx	xxx 27 days
Cape Horn		xxx	14,000	xxx
Cape Hope		xxx	xxx	xxx
Malacca Straits	70,000			

Source: Numbers derived from various sources

.

Figure 7 Earth orientations.

It is apparent that the Europe-to-Asia distances are much shorter via the north than the canals. Many merchants speculate that Russia will gain part of the Europe-to-Asia traffic.

Destination and transit shipping will increase.

There is consensus among the broader, global maritime community that global warming is melting enough sea ice to lengthen the navigation season substantially. The communi-

ty has moved beyond discussing *if* shipping through the Arctic corridor will occur more frequently to arguing about whether the *type* of shipping will be destination or transit shipping, and about whether the more viable *route* will be the Northern Sea Route or the Northwest Passage. A majority of ship owners, as noted in a survey business economist Frédéric Lasserre and Sé Pelletier Frederic conducted, say that bulk destination shipping on the Northern Sea Route is the most likely scenario.

Arctic Marine Shipping Assessment

According to the AMSA, the Northern Sea Route is more accessible as a transit corridor than the Northwest Passage. Indeed, a recent account showed that more ships cruised the Northern Sea Route rather than the Northwest Passage, largely due to highly variable ice conditions there (21-27). They asserts that "the last regions of the Arctic Ocean with sea ice coverage in summer would be in the northern waterways of the Canadian Archipelago and along the northern coast of Greenland" (32), making Russia's lane more reliable than Canada's for transit.

Besides long distance transits, different sorts of local shipping will be needed. Local short sailing "to and from Arctic ports, is likely to have more direct influence on communities . . . allowing for a higher standard of living" adding that much would be needed in terms of "port facilities, search and rescue . . . and mechanisms of governance" which may in turn provide employment for growing local communities (AMSA 123). An innovative shuttle service could possibly develop where a port authority shifts loads from open-water vessels to polar class vessels that rapidly cross the pole, shifts the load back to conventional vessels on the other side. Additional passenger cruises will launch as tourism continues to trend upwards. Cabotage services and inter-Arctic commercial services between larger ports to

smaller terminals at towns and mines will continue to increase. Extra-wide loads normally carried on ice roads in northern Canada may shift to sea lines. (As permafrost thaws in northern Canada, the season for using ice roads is shortening drastically). There will be more demand for freight delivery from lower latitudes. Feeders, smaller sized containerships less than 6,000 TEUs, from northern cities will carry goods to locals within the Arctic, e.g., Vancouver to Finland, or Shanghai to Murmansk and Rotterdam. Views from maritime experts about future Arctic shipping follow next.

Polar professionals forecast shipping will increase.

Writing for the Russian Academy of Sciences in 2008, V.C. Khon estimates that by the late 21st century, the navigating season on the Northern Sea Route will be three to six months and two to four months on the Northwest Passage. Khon specifies in his 2010 analysis that climate model results match actual sea ice extent as observed by satellite. He uses the observations and model predictions of sea ice concentration to forecast the length of seasons of ice-free conditions, and uses that to quantify cost savings for both transit and destination shipping. Analyzing model projections of sea ice volume, Khon argues that "development of transit maritime freight traffic should be expected" on the Northern Sea Route and, "in the more distant future" the Northwest Passage (18). He reasons that opening Arctic trade will bring economic opportunity to the north, as it shifts opportunity from elsewhere. Khon expects that goods that normally go through the Suez Canal will go via the Northern Sea Route, as "year-round transit . . . may be 15% more profitable." He projects that this traffic will be "more economically viable" than the Suez Canal "even in the winter months by the end of the 21st century" (18). A longer season of ice-free navigation can cut not only icebreaking costs but also the cost of ice reinforcement of individual ships. Decreasing the time of deliv-

ery of goods lowers costs and "can significantly enhance the commercial attractiveness of the Arctic transport systems in relation to southern shipping routes (through the Suez or Panama Canals)" (18).

Companies calculate many factors besides transit distance in formulas for cost efficiencies, explains Stephen Carmel, the Senior Vice President at Maersk Line, the largest containerized shipping company in the world (2013). Transit time, canal costs, icebreaker assistance fees, port fees, inventory costs (which is a function of cargo type), construction of ice-capable vessels, relay trips (from international hub ports to ports with difficult ingress), price per ton, labor costs, and tariffs are all part of the cost/benefit ratio. Nonetheless, he writes that opening of the northern passages may have as large an impact on the shipping industry as when container shipping started in the 1950s a small difference in the initial conditions can cause a paradigm shift (see Paradigm section ahead). As Carmel writes, "the transport sector coevolves with the industries it supports" (2009 27) and "Large and discontinuous shifts in transport costs and attendant shifts in routes have in the past been the source of conflict" (2009 33).

In *U.S. Naval Proceedings*, Carmel states that there will be more destination shipping to support and supply logistics for the oil and gas industry, but argues that transit shipping is not likely to increase appreciably. There could be a cost advantage of haulage from the east coast of the U.S. to Shanghai or other cities in northern China, at the expense of the more southern cities; but, with the economics of scale of shipping lines, the advantages of voyages via the northern passages do not add up. Three factors explain his assertions: the climate's incompatibility for regular scheduling; the high capital cost of building ice-class vessels; and the slow speed of the vessels in icy waters.

Keeping regular schedules is a big issue. Hence, Carmel concludes that for transit shipping " It is very unlikely, then, that the Northern Sea Route across the top of Russia will become a major pathway for the global flow of commerce, and it is virtually certain the Northwest Passage across the top of Canada will never be useful for international trade" (2013 1). Other experts disagree, and "never" is a long time.

In a major study, Claes Ragner assesses future needs for ports, cargo fleets, and ice-breakers. Writing in 2000, Ragner analyzes historic and current cargo flows for both delivery to Arctic communes and transit freight traffic, tracing the volumes of timber exports from Port Tiksi, coal from Port Pevek, nuclear waste from Europe and reprocessed fuel from Japan. It is possible to picture a future scenario where the volume of mineral fertilizers and fabricated metals moved *from* Russian ports to the Far East compares to the volumes moved *to* Russia for a two-way exchange (544-553), thus avoiding a one-way pile up of ships as in the California gold rush. Following the collapse of the Soviet Union in 1991, fuel and food deliveries to Arctic localities almost completely stopped, yet facilities along the way are now prepared to enlarge. Transit cargo volumes rose and fell, the study suggests, while competing with other conveyance modes, such as the trans-Siberian railway, river vessels (as opposed to sea vessels), roads, and pipelines. Ragner presumes that both transit and destination shipping are on the horizon.

Furthermore, Ragner states that infrastructure will be necessary to support operations of ship lines and also to keep crews safe and healthy. The Northern Sea Route is "undoubtedly shorter and normally faster than the Suez" (551). It is important to note that "vessels will sometimes select routes close to the mainland, other times routes through the many archipelagos, and sometimes routes north of them" adding that optimal courses vary with the

"highly variable" ice conditions (542). Despite the variation, he estimates that using the Northern Sea Route instead of the Suez Canal reduces the distance between Germany's major port at Hamburg and Japan's port at Yokohama by 40%, but asks "is it also more profitable?" (551). Cost accounting includes constructing ice-class vessels, icebreaker fees, transit tariffs, ice-pilot charges, and insurance premiums in case of cargo freezing. Among the factors, icebreaker service fees seem to be most critical in the cost accounting. If the fees, for example, were to be no more than $1,000 per container, the analysis would conclude the route is economically feasible.

Although the "international shipping industry thus far has not utilized the route for transit traffic", Ragner expects that to change soon, given "new icebreaking technology and climatic change" (541). He confirms that the International Northern Sea Route Programme (beginning from 1993) is studying the "potential for commercially and environmentally sustainable shipping" with oil extracting and increased "import of pipes and other oil-industry equipment from Japan" along with "nuclear cargoes" (551-576). As it is, Rangner's thorough analysis concludes that economic potential for increased shipping over the Northern Sea Route is not viable unless the ice continues to diminish. And since he made that assessment in 2000, that is exactly what has happened to the Arctic sea ice.

Russian Polar expert, Eduard Sarukhanian, exclaims that global warming is bringing "very much a huge social change" both politically and economically. The circumpolar nations are vying for political control and economic advantage. He continues, saying, "The prospect of open trade routes, increased traffic on the Northern Sea Route gives Russia unprecedented maritime commerce" adding that Russian "economists know that this will be an advantage economically, and the national perspective is well in tune to the possibilities."

Russia's icebreakers will accompany cargo ships, break up even thick ice, and guarantee that ships can stay on regular schedules; transforming the possible to the probable.

Arctic Shipping Forum

The Arctic Shipping Forum convened 200 maritime firms in 2012 and recorded interviews with directors of several shipping companies—Tschudi, Rosatomflot, Sovcomflot, and Nordic Bulk Carriers—who speak about future commercial activities. A representative from Tschudi claims "We bought into northern Norway mining company in 2006. That investment was not done because of the mine but because of the port facilities connected to the mine… because we expect a market for trans-shipment of Russian cargo in the future where we will be able to offer a deep sea and ice free port" (ASF). Tshudi boasts "the Russian presence is light years ahead of the rest of the U.S. . . . Russian companies have invested over one billion Euros into super Arctic vessels. They will be the major market in the years to come."

The company Rosatomflot continues the conversation:

> Northern Sea Route transit shipping has been developing for last few years. Before 2009 there had been no Northern Sea Route (NSR) shipping from one European port to Asian port without calling at a Russian port in between. In 2010, we had four transit voyages, each of which proved a point. First, the NSR is suitable for tankers. Second, it is open for any flag ship, that is, for non-Russian vessels and cargos. Third, it is suitable for passenger cruises. We took a passenger vessel from the Baltic Sea to the Pacific Ocean. And lastly, four, the season has lengthened. We repositioned an icebreaker vessel from Alaska back to the Atlantic in the middle of winter December 2010. This was done after the official end of transit navigation which usually ends at the end

> of October or beginning of November depending on ice conditions. This particular transit was done in 9 days. (ASF).

A competing company, Sovcomflot is also preparing for transit voyages; "At this stage we see the demand for cargo transport. Ship owners have to get ministers to pay attention." Pointing to the need for search and rescue capability and emergency preparedness, the representative adds "We do not think the Arctic is for everyone just for those with long term commitment." As Nordic Bulk puts it, "twenty days savings is a lot. Transit shipping is a reality."

The broader, global maritime community looks ahead.

Paradigms

The AMSA admits few studies reveal the real possible social transformations from rapidly opening seas but suggests that the trade lessons of history can guide future conjecture (122-132). To fill this void, scenarios help visualize what things may be like by mid-century – when there will be reliable open water navigation in summer and reliable ice-reinforced navigation in winter. Markets will adapt and fresh opportunities will open, with different paradigms. Stephen Aguilar-Millan, a director at the European Futures Observatory cautions against overly bounding future visions with what he calls paradigm blindness. Global warming is a high probability, high impact, highly credible emergent future (Aguilar-Millan 148). When speculating on human dimensions in the Arctic, it is important to not only include implausible but credible futures, but also include farfetched, wild card scenarios.

Natural resources

Melting sea ice may be as great a paradigm shift to transportation as hydraulic fracturing is to energy. When fracking increased natural gas supplies, many effects followed. A less-expensive energy supply turned the U.S. into a net exporter of energy. Natural gas companies expanded industrial faculties at the pipeline[10] terminus in North Dakota, and an influx of workers reminiscent of the California Gold Rush doubled the population of towns like Williston. A supply of cheaper U.S. energy cut the demand for natural gas imports and shelved plans for developing Russia's Shtokman fields. Russia's Gazprom company expected to liquefy gas on site – the process uses less energy in cold air than in warm, and less sea ice makes field access easier – and sell the product to the U.S. But fracking was a black swan that brought unanticipated alterations in energy markets just as retreating ice brings unanticipated variations in the shipping markets.

Other natural resources could surface. Though highly speculative, one possible scenario involves collecting methane from thawing permafrost underwater in the shallow bays of Russia's continental shelf in the Laptev Sea. When subsea permafrost thaws, plumes of melting methane ice crystals rise to the surface as gas. Sometimes called clathrates, methane hydrates could become industrially significant (Connor).

Bulk shipping for the mining industry and natural resource exploration could trigger increased shuttle traffic between Murmansk and the Kara Sea to Dikson and up river to Dudinka near Norli'sk as cold regions research Nathan Mulherim describes (1). An influx of people into mining towns could result just as happened in North Dakota or Colonial Jame-

[10] Pipelines are regulated by the Department of Transportation as a mode of transport, as are rails, roads, and canals. Pipelines in the U.S. carry natural gas, crude oil, and fertilizer, among other commodities.

stown. Konovalov sees prospects for gold, chromium, and titanium mining in the Murmansk region, lead and zinc in Novaya Zemlya, and platinum, palladium, nickel, and coal in Norilsk. He anticipates an increase from half a million to 42 million DWT in mining freight and expects westbound traffic seven months a year and eastbound traffic five months by 2030. Agreeing with him, U.S. scientists write that oil platforms will be leased and with gas exploration, even more infrastructure will be developed, growing a workforce with all its attendant needs (Carl Markon, Sara Trainor, and Stuart Chapin). Art Pine, Shashi Kumar and John Marcario lend weight to the scenario, asserting in naval trade journals that additional facilities will be necessary to support destination shipping for mining and the natural resource industry and settlements associated with the new industries. Pine argues that the needs speed past the current pace of action.

Increased shipping certainly has "potential for environmental impact, depending on cargo carried . . . and thus for affecting local societies that depend on a healthy marine environment" (AMSA 122). However, as environmental sociologist Peter Hall argues, "Ship transportation is cheaper, less polluting, and less energy intensive than air- and truck-based transportation alternatives. Switching to cleaner, more highly regulated ocean-based transport that is connected to predominantly rail-based distribution systems may be part of decoupling continued economic growth from increased transportation impacts" (88). Transport by ship will grow in relative terms to freight transport by other means: Adaptations in transport systems caused by climate change may well initiate "creative seaport and port-city adaptation in response to the climate and energy change" (88).

Global climate change and local impacts

Climate change alters not only the Arctic but drives shifts in maritime markets global-

ly. As professional planner Scott Shuford and colleagues write, decisions made for one area must anticipate future climate conditions in other areas (Shuford 4th Symp 2009). He also introduces the concept that population centers move due to environmental stressors (Shuford APA 2009). Effects in one part of the world can have an impact locally. Just as global warming opens possibilities in the Arctic, it may limit opportunities for existing ports elsewhere. The impact of climate change on transport infrastructure is noteworthy in the U.S.

Climate-change induced extreme events like intense, widespread droughts or the 2013 "biblical" flooding in Boulder can disrupt the entire inter-modal network. With some 40,000 miles of navigable waterways along the coasts, rivers, and lakes, moving goods by ship and barge is essential, especially given that half the grain exported from the U.S. rides on barges on the Mississippi (McGuirk 2009 88-90). Climatic shifts affect entire networks, as goods move alternately by train, truck, ship and barge.

Sea-level rise already threatens coastal ports. Seas at Boston, New York, Atlantic City, and Norfolk, are rising at two to three feet per century. The rate is accelerating most at Norfolk, where "a rise of 1.5 feet by 2050 is likely and is the basis of the advice and planning for engineering purposes" according to Laurence Atkinson, an expert in sea-level and national security, and director of the Center for the Study of Sea-level Rise at Old Dominion University. The Norfolk area is home to the largest naval base in the world and has two civilian airports, a military transportation control center, and Marine, Coast Guard, Army, and Air Force military bases. Extensive bridge and tunnel networks connect people to the places they live and work, and fully half the population's work is associated with the military bases. A generally weaker and slower Gulf Stream offshore, combined with sea-level rise is causing record high tides in Norfolk. High tide "crept up into the streets over 300 work hours in

2010" and most of the area around the bases gets flooded regularly to the point that "Workers can't get to their jobs" (Atkinson). Climate change "is not only opening the Arctic to trade routes" it is also "changing the game on how we maintain our present ports" when one notes that the cost of replacing a single wharf at the Norfolk Naval Base approaches $50 million (Atkinson, AMS).

Storm surge coupled with flooding from extreme precipitation inland caused massive damage in recent years, notably in New Orleans and the greater New York area. Levees, dams, bridges, subways, boardwalks, businesses and homes were destroyed. As global warming causes coastal storms to become more intense, more infrastructures will be at risk (Karl). The design life of many coastal structures is 50 years or less, the "time concrete wastes away in seawater" (Atkinson). A list of these structures includes levees and canals, seaports, port structures, navigation channels, turning basins, docking areas, and navigation gates, piers and wharfs, dray and wet docks, storm drains, pipelines, and upstream flood control systems (Peterson, Titus). All these sorts of engineered structures are at risk at current ports and all will be needed in the High North. Jobs to design, build, repair, replace, maintain, and operate them will become part of the industry.

Ports that will "likely be most impacted by climate change" are studied by the Organisation for Economic Co-operation and Development (Nicholls). In terms of *assets exposed* by coastal storms, wind damage, and sea-level rise (including local land subsidence), the study signals out Norfolk, New York, Tokyo, and Rotterdam among others.[11] The study surveys 136 of the most populous ports and estimates population growth to the year 2070 and

[11] In terms of assets exposed, the ports that will most likely be most impacted by climate change are Norfolk, New York, New Orleans, Osaka-Kobe, Tokyo, Amsterdam, Rotterdam, Nagoya, and Tampa-St-Petersburg.

concludes that in terms of *population at risk*, climate change will most impact ports in the U.S. and China[12] (Nicholls 25), which are the largest importer and exporter nations. These threatened global ports affect the possible scenarios of shipping over the pole.

Risks, operating costs, and damages to already established ports alter the relative economies of High North operations. Inter-Arctic commercial services between hub ports and small terminals at towns and mines may become not only physically possible with re-treating ice, but also economically viable. The Arctic Bridge, between Murmansk and Churchill, Manitoba, Canada is one example (see figure 8). The circuit is the shortest connection between East and West economic centers. Lasseure relates that Churchill, with its national rail links, was a possible gateway port for "hinterland markets" to North America, a "new niche market" (1469) though how stable the rail bed is questionable..

Strong economic ties between Canada and Russia could develop based on regular trade. Canada could exchange sand, gravel, fertilizer, and manufacturing equipment for Russia grain crops. (Siberia's long hours of daylight could yield cereal crops, theoretically, as permafrost thaws and just as increased dryness lowers the U.S. Corn Belt crop yields, confirms some climate change models). One, perhaps far-fetched, scenario involves a logistics supply line from Canada's Hudson Bay inland through Manitoba southward to the U.S. through the Midwest and on to Mexico, and, on the other side from Murmansk, Canada exports could travel inland via railways and reach Eurasia markets, even into countries like Afghanistan (Lemmon 79-89, 409, Mulherin 4-5). Less far-fetched, paths inland to the Sea of Okhotsk via Siberia's great rivers (e.g., the Lena and Kolyma) may develop (Mulherin 1-60).

[12] In terms of population in year 2070, ports most at risk from climate change are Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, Greater New York, Osaka-Kobe, Alexandria and New Orleans.

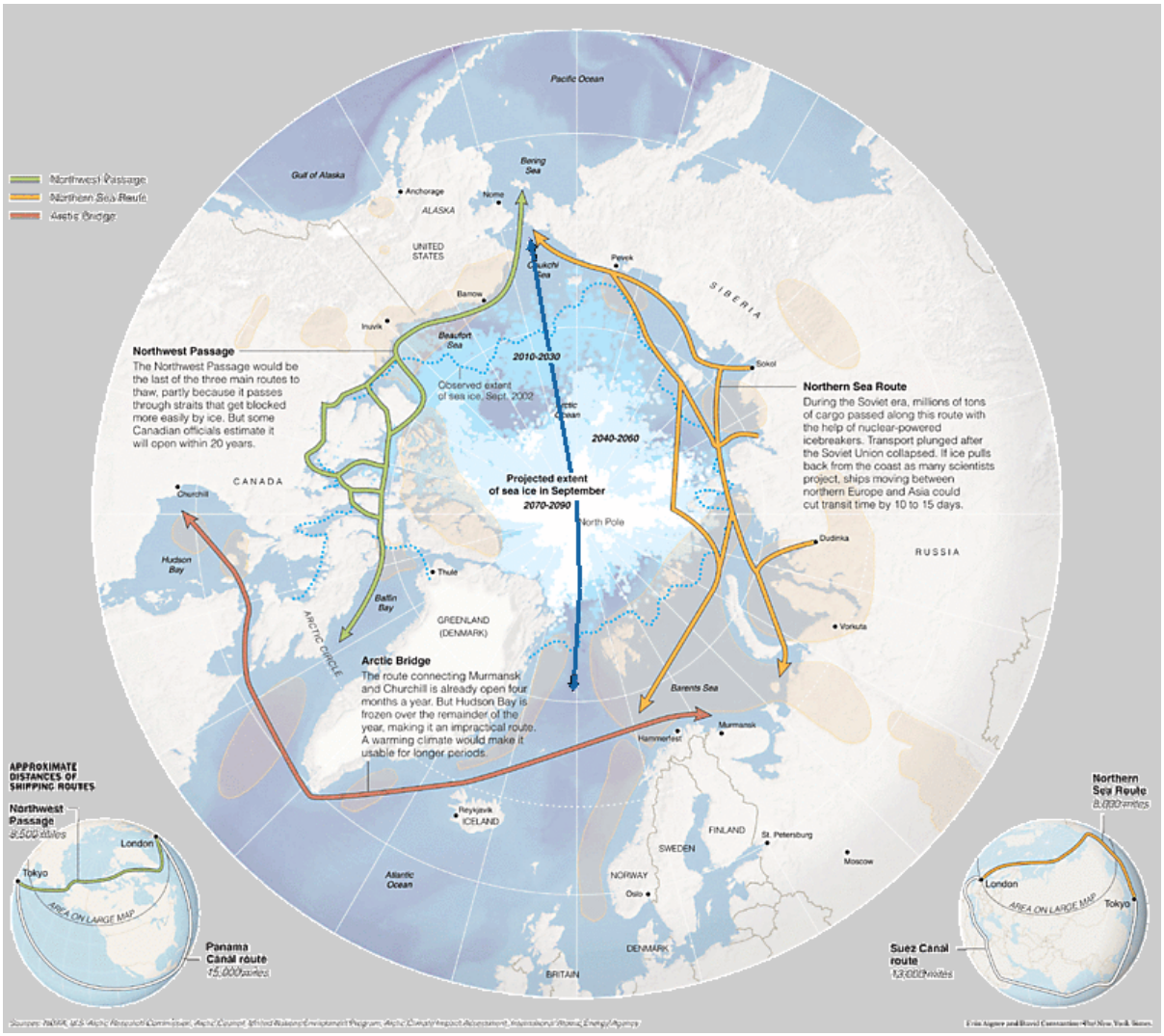
Little factual evidence backs up this scenario but fantastical growth has resulted from trade in the past. Theoretically, once regular trade between the Russian and Canadian ports begins, commerce will expand, if history is any guide. Roger Morton insists that inland facilities develop concurrently with coastal ports. Sociologists Tom Daamen, and Tom and Isabelle Vries explain that infrastructure grows between the port facility outward to connect to other cities and trade centers (4-5). Trade, Kotkin argues, spurs growth as it needs infrastructure and advanced producer services. Just as countries "benefited mightily from the rapid expansion of world trade" in the Age of Discovery, small towns can grow with trade, explains historian John Short. Small towns like Churchill? Remember that Amsterdam began as a fishing village in the 13th century but its "vast fleet of 1,800 seagoing vessels" served to "expand their trading capabilities" and transformed the small town into a "civic culture centered around trade and commerce" today (77).

Canals expand

Complicating the global paradigm, today both canal corridors are expanding. Panama is cutting a third channel while Egypt is proposing another pathway from the Red Sea to the Mediterranean by rail (Williams). China and Israel agreed in 2013 to build a railway up the west side of the Arabian Peninsula, the opposite side of the Sinai from the Suez Canal.

When completed, this $4 billion railway will connect the Red Sea to the Mediterranean, an alternative to the Suez. Goods would unload from ships at a newly built inland canal port in Eilat for transfer to rail. News articles speculate that the rise of Islam within the government of Egypt played a role in this decision motivated by China's desire to strengthen and stabilize tracks for trade (Williams).

Figure 8 Arctic sea routes.



Source: Modified from AMSA. Northern sea routes are indicated by color: yellow Northeast Passage, green Northwest Passage, red Arctic Bridge, blue Trans-Arctic Route. See seasonal ship traffic at NSRA http://www.arctic-lio.com/nsr_transits

Whatever the motivation at Suez, Panama's locks limit the size of vessels; the maximum size ship that fits into the locks, called a Panamax, is 320 meters long, 33 meters wide and 12 meters deep. These dimensions are smaller than "the largest aircraft carriers, cargo ships, and supertankers" which "must find alternative routes, among them the Cape of Good

Hope Route and the Cape Horn Route" (Franck 73). The third lane of the Panama Canal due to open in 2015 can handle crafts 427 meters long, 55 meters wide and 18 meters deep. And port cities are preparing to accommodate these larger, post-Panamax ships.

Port authorities in the U.S. are preparing for the Panama's additional channel. Houston's Port is dredging to accommodate deeper drafts. The Port of Savannah, Georgia, which moves the most cargo for Home Depot, Lowes, and WalMart, is also deepening the berths to accommodate the draft and beam sizes of the larger, post-Panamax ships and is purchasing 24-story gantry cranes to handle the containers. Gulf and east coast ports, however, are already at risk with stronger hurricanes and storm surge (which Karl confirms is also a consequence of global warming). Inter-modal transfer of goods or deliver to other more competitive ports may overtake the dredging efforts in Georgia. New York, Norfolk, and Baltimore ports are already deep enough to handle ships with a draft of 15 meters. But the Port Authority of New York, for example, has to raise the Bayonne Bridge so post-Panamax ships can pass under it.

Sea-level rise complicates even decisions about bridge clearances. Pilots steer heavily-laden ships with sometimes only two feet separating the mast and keel from the bottom of the bridge and the bottom of the sea (AMS). With a heavier load, the ship sits lower in the water and the draft—the distance from the waterline to the keel—restricts larger ships from shallower waters. One inch of draft equates to a five million dollar cargo of 58,000 pairs of sports shoes or a three million dollar value of 1,500 televisions (AMS). Rising seas means less cargo, more dredging, or higher bridge spans. Sea-level rise upsets even the best-laid plans for shipping through the expanded canals.

Even while the expansions of the two great canals are underway, trajectories over the

pole are becoming possible. How will the Canals compete with the northern seas? When asked about the relationship between the Northern Sea route and the Panama and Suez Canals, a Rosenflot president said, "We don't see them as our direct competitors as they are well established and prominent trade routes. We see them as a good support and good alternative for part of the year" (ASF).

Is it possible that Russia will carve out a share of the Asia-Europe-Suez traffic? With icebreakers, transit shipping could be regular and reliable enough to compete economically with the Asia Europe Loop lines. Ships circuits between Murmansk and Vladivostok, would have intermodal connections inland to China, Siberia, and Europe. As a wild card, perhaps, small volume, high value cargo, like nuclear waste from Japan, could travel to Europe during the summer months via a Trans-Arctic path, minimizing time at sea (Ragner 551). Remembering that most containerships have a capacity of 6,000 TEUs or less, there are plenty of smaller sized containerships that can take advantage of cost economies of saving twenty days sail by using the Northern Sea Route.

Furthermore, many crude oil tankers and dry bulk containerships are too big for even Panama's third channel. Ultra large (Capemax) tankers move crude oil from the Persian Gulf by rounding the Cape of Good Hope on their way to Europe or the Malacca Straits on their way to East Asia. Would these vessels find shorter seas over the top of the world? Most of China's oil arrives in tankers that navigate from the Middle East through the Malacca Straits and the South China Sea, seas that the U.S. Navy patrols. Fears that the U.S. Navy will interdict passage of these tankers has piqued China's interest in the northern passages suggests Carmel (2013) and in possibly obtaining their oil from Russia instead.

As if to test a regular circuit from Asia to Europe, the Chinese company Cosco Group

dispatched in the fall 2013 the *Yong Sheng*, across Russia's coast, reports several news outlets[13] . The 19,000 DWT freighter carried steel from northern China's port Dalien to Rotterdam on a 35 day voyage that would have taken 48 days via the Malacca Straits and the Suez Canal. The ship steamed across the Northern Sea Route in 7.4 days, with the help of Russian icebreaker service in the Laptev Sea (NSRA). *Yong Sheng's* voyage prompted the Alaska Dispatch to speculate "Goods and resources like Alaska seafood, or zinc and lead from the Red Dog Mine in Northwest Alaska near Kotzebue, may one day find their way to previously infeasible markets in Europe via the Northern Sea Route, like some modern-day spice road" (Anderson). According to marinetraffic.com, the 8.4 meters draught, 19,000 DWT general cargo ship is currently resting in the warm water of Venice. Its maiden Arctic voyage tests commercial and strategic value of an Asian Europe loop via the Northern Sea Route.

It is expected and desirable then that the ports of Dikson, Tikst, and Pevek will open permanently for foreign vessels. These would be used in "service offerings" (icebreaker, ice pilots) for transit vessels moving across the Russian seas. Since the icebreaker service depends not on the length of time it is used, but on the section of the sea in which it is used, the port of service really matters. The prime detriment to increased traffic is no longer the rate of ice loss, but instead the speed of gaining infrastructure along the way, especially these three ports. In Soviet times, these were very well equipped, mostly serving as supply depots for settlements along northern Siberia (Sarukhanian). Efforts to revamp these ports and plans to open them to foreign vessels on a permanent basis are underway (Ragner 569). Russia President Putin is very strong on pursuing commerce along the Northern Sea Route and cites an-

[13] Barents Observer, Russian news service Platts, Alaska Dispatch, UK's Independent – http://www.alaskadispatch.com/article/20130901/yong-sheng-why-arctic-voyage-chinese-cargo-ship-business-usual

other advantage; avoiding piracy in the waters near the Suez Canal.

Containers

New trade routes cause a "paradigm shift" in the global supply chain, explains environmental sociologist Peter Hall. Even converting the *technique* of moving goods, such as containerized cargo, can transform population centers employed in moving goods. Before a North Carolina trucker invented the container in the 1950's[14], most cargo was roped into bundles. Longshoremen and stevedores grappled bundles from ship to shore. Hall traces the fantastic growth of the Port of Los Angeles as it transformed into the largest container port in the U.S. Containers extensively converted equipment, facilities, and the workforce. In addition, "urban seaports shifted from serving as gateways to their respective regions . . . to functioning as logistics hubs that facilitate widely dispersed and accelerating global trade flows." Hall states that "This has brought a significant redistribution of costs and benefits among port workers, neighboring communities, local industries, and global manufacturers and distributors of goods located in Asia (e.g., Toyota), Europe (e.g., IKEA) and North America (e.g., WalMart)" (88). Because importers could safely and predictably discharge containers, the switch to containers opened another paradigm shift of modern life, just in time shipping.

The Arctic has, obviously, a formidable climate. Yet people who consider that the climate will prevent operating there should look to the past challenges able-seafaring countries have conquered, as McCullough describes. The Panama Canal's locks, for example, were "colossal machines" and one of the "engineering triumphs of all time" (591). McCullough says that "In their overall dimensions, mass, weight, in the mechanisms and in-

[14] Malcolm McLean, according to Wikipedia. Lifted off ships by gantry cranes, containers ride piggyback on flatbed railcars to freight rail yards, where cranes fit them onto 18-wheel trucks for highway hauling.

genious control apparatus incorporated in their design, they surpassed any similar structures in the world" (590). Besides technical challenges, Panama also delivers lessons of building in an extreme climate. In Panama "what was built had also to hold up in a climate wherein almost everything, concrete included, could go to pieces rapidly" (594). Panama brought social benefits in the way of superb "application of modern medical science [and] the methods of financing" used (598). He also points out the impacts miles away in the city of Pittsburgh, where some "fifty different mills, foundries, machine shops, and specialty fabricators were involved in the canal, making rivets, bolts, nuts (in the millions), steel girders, [and] steel plates" (598). No less, he credits the Canal with the rise of an industrial giant, the General Electric Company. The company produced "virtually all the motors, relays, switches, wiring, and generating equipment" including more than one hundred huge electric motors (599). Before the canals, "Nothing even approaching the size" had been attempted (592). The canals created technology, skills, and inventions. Entrepreneurs will meet the challenges of the Arctic with the Canal's spirit of inventiveness, and the Age of Discovery's spirit of adventure.

Government plans

Northern passages will need infrastructure that supports operations and that keeps crews safe and healthy (Grant, Ragner, Daamen, Kumar). Infrastructure typically grows between the port facility and the city that necessarily grows around it (Hall). Social structures like schools, health clinics, and civic centers will be needed, as several social scientists discuss (among them Joshua Ho, Daniel Cressey, John Gowlett and Maurice Perret). As climate change becomes more obvious, government planning is shifting into high gear. Actions taken by the U.S. are reviewed next, with a mention of Russian and Canadian actions as well.

The U.S. Department of Defense is preparing.

"The opening of the Arctic is the most immediate national security challenge presented by climate change" asserts Rear Admiral David Titley, then the director of the Task Force on Climate Change and also the Oceanographer of the Navy. Titley, while releasing the Navy's *Roadmap for the Arctic* report. The *Roadmap* pinpoints many matters facing Navy operations in the Arctic. These include: "incomplete charting, limited infrastructure to support operations, limited ice-breaking capability, weak systems for communicating between vessels, limited experience in the Arctic's harsh operating environment, insufficient search and rescue assets, and high cost of operations" (Titley 2010). The Admiral cautions that the Bering Strait, which separates Russia and Alaska, may become a channel filled with international tensions, like the Persian Gulf's Strait of Hormuz or the Strait of Malacca, as traffic increases. He advises that there is "potential for climate change to be a threat multiplier as we look for populations to relocate to areas with shifting economic opportunity" (Titley NPR 2013). Agreeing with the consensus viewpoint about the lack of long-term global economic value of the Northwest Passage, Titley says, "I liken it to U.S. Route 66: storied, almost mythical, but not of significant commercial use." And he adds that "the Northern Sea Route will ultimately become an established, but secondary route, that is, bulk trade with Asia, destination shipping along the route, etc. Certainly it will be a 'real' international trade route, but not in the first tier" (Titley 2013).

Meanwhile, the U.S. Coast Guard is conducting exercises "in an effort to figure out what resources will be needed to establish a permanent presence along Alaska's North Slope" (Marcario 38). Among the exercises are Unmanned Aerial Vehicles (UAV or drones) test flights. UAVs take off from a ship's deck and fly five to ten miles out transmitting high-

resolution images of the sea state. They scout for ice leads and measure winds and waves, helping ships navigate safely. Though the program is in a test phase, emphasizes specialist and retired Admiral Philip Kenul, UAVs helped the U.S. Coast Guard Cutter *Healy* escort Russian tanker *Renda* on an amazing emergency voyage in January 2012 to provide fuel for icebound Nome, Alaska.

In testimony to a House Subcommittee, the Coast Guard advocates for investing in polar icebreakers, for search and rescue and for environmental concerns. Opportunity in mineral extraction, for example, will drive need for environmental recovery. The needs extend to "Energy development activities, increasing maritime transportation . . . expanding tourism . . . [and] services for communities in the Arctic" (United States 2011). An icebreaker would act as a mobile base, patrolling offshore to provide "helicopters, boats, cargo space, heavy-lift cranes . . . control and communications facilities . . . and other infrastructure that would "allow the Coast Guard to operate above the Arctic Circle" as the "Arctic is the future of this country" (United States 2011). At the same time, military policy experts Peter Ohotnicky, Branden Hisey, and Jessica Todd caution that the U.S. needs to act soon in these areas or lose global advantage to other nations (60).

The U.S. Department of State is debating.

Canada and Russia declare the Northwest Passage and the Northern Sea Route as internal national waters. While no nations contest Russia's claim, the U.S. and the European Union argue that the Northwest Passage is an international transit waterway. Disputing Canada's claims of sovereignty put the U.S. into a difficult position. As foreign policy specialist Scott Borgenson says, many policy and security issues loom. The U.S. is the "only major country that has failed to ratify UNCLOS [the United Nations Convention on the Law of the

Sea], and Washington is therefore left on the outside looking in as a nonmember to various legal and technical bodies" (75). Borgenson suggests that Canada and the U.S. should agree bi-laterally to manage traffic in Canada's seaway. Together the two countries could use transit tolls to pay for search and rescue, establish harbors of refuge, institute hazardous waste management systems and provide similar services that would guard both human health and the environment (76). Finnish research law professor Timo Koivurova recommends governance measures among all the bordering nations, possibly progressing towards a treaty. Geophysicist George Bacus warns, however that "Commercial advances will likely outpace both diplomatic efforts to resolve sovereignty rights and military preparedness investments in the Arctic" (4).

As for diplomacy, in May 2013, Secretary of State John Kerry travelled to Sweden for a meeting of the Arctic Council. There, China, India, Italy, Japan, Singapore and South Korea sought and received observer status on the Council. (The EU did not gain status on the Council, likely due to disputes with Canada over seal hunting, though individual European countries have status.) Separately, China agreed to import fish duty-free from Iceland and to plan a golf course for Iceland. These are clear signals that they intend to embark on business within the sphere. Canada will chair the Council following Sweden's term, and the U.S. follows Canada. The Council signed agreements on search and rescue and on oil spill procedures. The Council furthered efforts with the International Maritime Organization developing codes for safe operations in the zone. For its part, the State Department released the *National Strategy for the Arctic Region*. In her remarks, the Special Assistant to the President for Homeland Security, Patricia Cogswell anticipates more commerce, infrastructure, and exploring for natural resources:

> The Arctic is rapidly changing . . . As sea ice diminishes, ocean resources are more readily accessible. This accessibility, along with recent scientific estimates indicating the presence of significant energy and other resources, have inspired strong interest for new commercial initiatives in the region, including energy production, increased shipping, scientific research, tourism, and related infrastructure development. As an Arctic nation, the United States must be proactive and disciplined in addressing changing regional conditions and in developing adaptive strategies to protect its interests. An undisciplined approach to exploring new opportunities in this frontier could result in significant harm to the region, to our national security interests, and to the global good. (White House).

With this proclamation, Federal agencies have launched their work to adapt to the astonishing transformations underway in the North Polar Region's climate.

NOAA is charting new Arctic shorelines.

The significance of sea ice loss is evident in the February 2013 NOAA report*, Arctic Nautical Charting Plan: A Plan to Support Sustainable Marine Transportation in Alaska and the Arctic*. The plan is to "improve inadequate chart coverage for Arctic areas experiencing increasing vessel traffic due to ice diminishment," to quote a NOAA official, who continues, "As multi-year sea ice continues to disappear, vessel traffic in the Arctic is on the rise" (NOAA Press Release 2013). The official says that maritime companies have "concerns about adequate charts, especially in areas increasingly transited by the offshore oil and gas industry and cruise liners." Pointedly, the officer adds that some "regions of Alaska's coastal areas . . . haven't had more than superficial depth measurements since Captain Cook ex-

plored the northern regions in the late 1700s."

NOAA's charting plan describes the existing facilities at Alaska's northern ports, beginning with Barrow, which is the most northern settlement in the U.S. It is the "economic, transportation and administrative center for the North Slope Borough." The report continues, "Vessel traffic, in Barrow, heaviest during the summer after the subsistence whaling season ends, consists of tugs carrying fuel and supply barges." Importantly, "Barrow has no pier facilities" and "cargo bound for Barrow is lightered from barges to landing craft. Anchorage can be had 1200 yards off Barrow in 30 feet of water to receive supplies and to transfer personnel by small boat. . . Barrow is a destination for small cruise ships carrying as many as 400 passengers." (24). Facilities are even rougher at the port of Kotzebue, which "serves as the transportation hub (both air and sea) for the whole of the Northwest Alaska." The NOAA mapping report continues, saying, "There are 11 villages that require barge shipments and the large transport ships must be anchored at least 14 miles out in the Kotzebue Sound due to shallow waters, inadequate charts and navigational aids. The transport ship's freight must be lightered by smaller barges to Kotzebue. Our port of call is the second most costly in the world with the exception of Antarctica" (26).

Despite the cost and rough conditions, these facilities are commercially successful. Take the Delong Terminal, for example: NOAA describes it as "a shallow draft port with an open shipping season of approximately 100 days." Delong was "constructed to service the Red Dog Mine" more than two decades ago. Even as remote as it is, the mine is "the world's largest producer of zinc concentrate, representing 79% of all U.S. zinc mine production. It is also the second largest lead producing mine in the country, accounting for a third of all U.S. production. The mine uses self-loading barges to pick up the ore and lighter it to vessels an-

chored offshore" (25). With dwindling ice, access to the mine will be more frequent.

The choke point of the Northern Sea Route is at the Bering Strait, "44 miles wide between Cape Prince of Wales, Alaska, and Cape Dezhneva, Siberia," as NOAA puts it. "It is the gateway from the Bering Sea in the Pacific Ocean to Chukchi Sea in the Arctic Ocean." Important from a security standpoint, "the Russian island of Big Diomede and the American island of Little Diomede lie just three nautical miles apart." Ships navigate through either of the two sections, east or west of the islands. Most ships "cling[s] close to the shore, rounding Cape Prince of Wales" (27). With no U.S. harbor nearby, traffic will make way towards the Russian side.

Canada and Russia open the Northwest Passage and Northern Sea Route for Business.

Even though the consensus view is that the Northern Sea Route will be more viable for trade, Canada has instituted tariff rates, travel restrictions, and regulations along the Northwest Passage. As if to prove the vitality of their coastal seaways, the Canadian government underwrote a test voyage of the commercial vessel *Nordic Orion,* a 15,000 DWT dry bulk vessel that moved a load of coal from Vancouver to Finland in September 2013 in a journey that was fully two weeks faster than travel through the Suez Canal (NSRA). Canada continues to assert its sovereignty claims, and the *Nordic Orion's* expedition is proof of the country's seriousness. Prowse's study of economic opportunity is one of many analyzing risks and suggesting means of adapting to climate change sustainably there (271-281). Further research by geographers James Ford and Tristan Pearce underscore Canada's commitment to a viable Northwest Passage commerce. If Canada's sovereignty were assured, the country would move forward developing facilities for safe and environmentally sound operations along the Northwest Passage. Otherwise, Canada may find more opportunity in align-

ing efforts with Russia (as in Arctic Bridge efforts).

While Canada hovers on a diplomatic framework, Russia, in contrast, is actually operating a business through the Northern Sea Route Administration. Ships entering the passage travel with permission. Captains apply for permits to travel the 3,000 miles across the Barents, Kara, East Siberia, Laptev, and Chukchi Seas. The captain declares the dimensions, gross tonnage, draught, fuel consumption statistics, cargo types, and number of crew on board. The captain requests icebreaker support for heavy, medium, or light ice conditions, and specifies the ship's ice reinforcement class, which can range from one for lightly reinforced ship hulls, to nine for icebreakers. Depending on the navigating season, the Administration can withhold permits for transit. For example, oil and gas tankers and vessels lacking hulls reinforced for ice can navigate only in open water from July to mid-November with icebreaker support, and not at all from mid-November through June. The Administration requires captains not only to have experience navigating in northern ice, but also to take on an ice pilot for the duration of the transit. By law, fees for ice pilots (and icebreakers) are set by the Russian Federation, and "determined in accordance with . . . monopolies taking into account ship's capacity, ice-class, the distance of pilotage, and the navigation period." Tariffs are roughly set in Rubles[15]: with standard containers at 1,000 Rubles per ton for the icebreaker support, vessels carrying cars and car parts at 2,500 per ton, and 1,000 per ton for standard containers. Icebreaker tariffs that support vessels delivering general cargo supplying the northern ports is much less expensive, about 500 Rubles per ton with bulk liquid cargo at about half that rate.

Yes, Russia's tariffs are exorbitant. For example, the *Baltic Ice*, a marine vessel that

[15] See Northern Sea Route tariffs http://www.arctic-lio.com/nsr_tariffsystem

sank in December 2012 near the port of Rotterdam, weighed in at 7,700 dead weight carrying its cargo of 1,400 cars from Japan to Europe. The transit tariff would have amounted to 1.9 million Rubles, or at today's (inflated) exchange rate about half a million dollars. Had the *Baltic Ice* not sunk, and travelled instead via the Suez Canal, what would have been the cost? The voyage from Yokohama to Rotterdam is 31 days via the Suez versus 25 days across the Northern Sea Route. That is a 24% reduction in time. The tariff through the Suez calculates to about $75,000[16]. Obviously, Russia's ice tariffs are lucrative, and will undoubtedly, fall naturally, once volume increases and the Ruble value stabilizes.

Conclusion

No matter how fast or slow nations move forward with planning, clearly, more vessels will move across the top of the world. Towns and villages will develop to support that traffic. From viaducts carrying water to modern roadways carrying cars, thoroughfares link human settlements. These crossroads began with the history of the camel caravans in the Sahara desert, the adventurous sailing about the capes, and the building of the great canals. Each endeavor overcame what were then insurmountable obstacles, such as the torrid desert, treacherous seas, and great distances between the East and West. Even the best analysis can be wrecked by the black swans of unanticipated paradigms, like fracking, unusual national alliances, or future markets for cold storage. The loss of the final barrier to East-West transport–the ice–is only one new paradigm.

Before concluding, this paper presents one speculative story about the possible future

[16] See Suez Canal tariffs http://www.suezcanal.gov.eg/calc.aspx

on the Arctic's frontier, shown in italics below.

What might a frontier in the High North look like? With the melting of the Arctic, the Northern Sea Route becomes an attractive alternative to the Suez Canal as an East-West route. Competition really takes off as Egypt's political disarray disrupts access to the Suez Canal and ships come under attack by pirates. Even though well-armed and able to ward off the force of attacks, especially with the aid of the U.S. Navy, companies see security and economic advantages of repositioning businesses to the High North. The Northern Sea Route is devoid of ice much of the year. Scientists, who had anticipated an ice-free pole since the IPCC began its work, forecasted an increase in shipping but they had not anticipated an unconventional energy source.

A market develops for clathrate, which, like fracking, is an unanticipated energy source. Clathrate is a frozen form of natural gas. As the ice layer of the Arctic continues to melt, the increasing sea temperatures melts frozen clathrate and it fizzes to the surface as methane gas. Methane is easy pickings as natural gas tankers only have to collect the gas, like a shop vacuum collecting sawdust off the garage floor. Ships deliver the gas to newly installed pipelines at the Russian ports of Dikson, Tikst, and Pevek. Railways extending from these three port cities connect to municipalities located further inland.

Communities of migrants from China and beyond populate the towns that grow around the areas where gas moves from pipeline to rail lines to trucks and to storage facilities. Businessmen, accountants, and lawyers establish advanced producer services surrounding the clathrate economy. Engineers and technicians build, modify and maintain machines and engines that are optimized to suit the fuel and centers of technology and innovation develop. Murmansk and Vladivostok grow as population centers supporting the two terminus

of East-West trade. Korea, China, Japan, Finland, Norway and Russia form a central command overseeing the Arctic resources. Much of the traffic moves from the clathrate fields across the Northern Sea Route towards the teeming population of China. On their return trip, the tankers carry containerized cargo on their decks. They anchor at Russia's ports and unload the goods manufactured in China for distribution to the growing Siberian cities. The balance of ships sails westward in sovereign areas of Europe and Alaska. Narrowly passing through the Bering Strait, these ships find their way to the Port of Los Angeles. Unloading there, transcontinental rail carries the oil to the heavily populated cities of the eastern U.S.

As shipping becomes reliable in the Arctic, "cold" itself becomes a business commodity along the coastal towns, attracting industry where cold surroundings is an advantage. Besides liquefying natural gas, other cold-friendly industries include food storage, seed grain storage, preservation, and industrial dehydration plants. The cold temperature speeds processing and cuts the cost of dissipating the heat that computers generate. An industry for data servers arises. Companies and agencies with large data server banks, like Google and the National Security Administration, realize savings on data storage and processing costs. Accessing data servers for maintenance will become routine.

Meanwhile, a coalition of Arab and African countries continues to trade Middle East oil. The small port of Liberia, once used as a center for the trade's camel caravans, becomes a large port-city. From there, trade in coffee, maize, raw minerals, and bulk grains moves in the opposite direction. The spread of Islam picks up where it left off in the 17th century as businessmen from the Middle East travel north and spread their culture.

From imaginative scenarios to present-day reality, this conclusion fittingly returns to the all-important fact that the Arctic ice cap is melting. Scientific literature from both inter-

national and national assessments of climate change gives a current consensus view of the status of the Arctic Ocean. Global warming is causing unprecedented melting of sea ice. Warming climate will melt enough ice each summer to allow significant numbers of vessels to transit the Arctic with high-value-low-volume goods. Destination shipping with freight and bulk cargo will supply the growing villages and towns that provide the labor force. Forecasts of continued melting are such that navigating across the Arctic Ocean will become routine, particularly along the Northern Sea Route.

Mariners are looking forward to new Arctic routes that could provide significant cost savings in time and distances travelled as well as opening additional markets. Traffic would prompt new marine infrastructure and other facilities. New routes will be accompanied by new marine services to support increased traffic and provide the potential for economic growth in new areas. Marine, rail, and river terminals will develop, with towns then cities growing around them, like cities around the train refueling stations in America's west.

As global warming melts the Arctic's ice caps and opens passages for shipping, the world will witness the resulting great impacts on transport and settlements. A navigable Arctic will lead to shifts in population centers; and like America's Wild West, a new frontier will open as people that are employed in the transport of goods migrate into areas with new economic opportunity, leaving flagging centers behind. The human drive to explore, stake new territory, invent, and overcome obstacles makes this so. Because transport drives the patterns of human settlement and trade routes shape the course of history, new settlements will grow in the Arctic along new trade routes. The Arctic will no longer be a desolate, isolated place, a sad but inevitable ending.

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