The Science and Technology Innovation Report on the Ocean Big Data Application along the ice silk road

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Abstract: Over the past twenty years, the National Marine Environmental Forecasting Center (NMEFC) has carried out safety and security tasks for a total of 9 batches of Arctic science and technology navigations and 22 voyages of merchant ships along the North East Arctic waterway. The paper summarizes their successful experience and technology innovation achievements of applying on big data, focusing on the infrastructure innovation construction of the ocean forecast big data: creating an autonomous Arctic observation system, exploring the Arctic international cooperation model, participating in the global regional observation plan; scientific and technological business innovation: research method innovation, security technology innovation, super-computing innovation; as well as science innovation achievement: science research achievements, application technology achievements, computer technology achievements. Finally, a brief prospect for the future of the Arctic is given from the perspective of prediction.

1. Introduction

The Silk Road on Ice (hereinafter referred to as the Ice Silk Road) extended the traditional Maritime Silk Road of the eastbound ocean lane [1], and it starts from Vladivostok, Russian, goes across the Bering Strait northward into the Arctic Ocean, and flows westward through the North-East Arctic channel [2] and the Barents sea to the coastal ports of northwestward Europe. The accelerated melting of Arctic ice and snow caused by global warming, the modernization of marine ships brought about by the rapid development of science and technology, the rich resources to be developed under the Arctic ice sheet, the international obligations of energy conservation and emission reduction undertaken by our country consciously, the scientific cognition and the responsibility of developing the Arctic people jointly bear, etc., all foreshadow that the ice road will become a sea highway. The National Marine Environment Forecasting Center (hereinafter referred to as the Forecast Center) has realized the innovation of big data infrastructure and innovation of scientific and technological methods along the ice silk road in the long-term practice of business scientific research and foreign cooperation by applying big data and other technologies.

2. Ice Silk Road Ocean Forecast Big Data Infrastructure Innovation

2.1. Creating a fully autonomous Arctic Ocean observation system

Before 2012, satellite remote sensing monitoring data and Arctic science test data were the main sources of data for Arctic Ocean forecasting at that time. Since 2012, the forecasting center, along with China's fifth and sixth Arctic science and technology team undertake safety and security tasks of science and
technology, use the ocean hydrologic-sea ice-meteorological-atmospheric boundary layer stereoscopic observation model consisting of air-sighting and sounding instrument, ocean buoys and submarine, as well as automatic weather stations to collect and accumulate the ocean observation data, and make application demonstration products of marine forecast on site through participation in navigation observation, ice station operations, aerial exploration and other work processes [3]. The two business innovations of on-site observation and forecasting of Arctic science examination are realized. During the seventh and eighth Arctic science examinations in 2016-2017, the forecasting center team with supporting service personnel crossed the Central Arctic Passage for the first time (Figure 1.) and obtained a large amount of valuable key information on ocean hydrology and space atmosphere in the main functional area of the Arctic marine environment on the basis of completing the Arctic Science and Technology Survey on Ice Survey.

2.2. Exploring the inter-State cooperation mode in Arctic Ocean observations
Through cooperation with the Finnish National Meteorological Service on science research in polar sea ice and meteorological field observation, data analysis and data assimilation, numerical simulation, the “China/Finland Polar Atmosphere-Snow Sustainable Joint Monitoring and Numerical Simulation Research” was approved for implementation by the National Oceanic Administration in 2013 [4], and a series of important results were achieved in the cooperation. In December 2014, a memorandum of understanding on polar forecasting cooperation was signed with the Alfred Wegner Polar Research Institute of Germany, agreeing to strengthen cooperation in the field of marine and polar research, to jointly optimize the use of polar observation networks, develop data assimilation techniques and improve polar forecasting models [5]. In October 2018, the national key R & D plan "The intergovernmental key project of international innovation cooperation-Research on multi-factor space observation and information service of Arctic environment" [6] participated by the prediction center and cooperated with the EU 2020 plan "integrated Arctic observation system (INTAROS) " entered the substantive research stage.

2.3. Participation in the global ocean observation regional plan
As a member of the Scientific Steering Group of the Polar Prediction Program (PPP) organized by the World Meteorological Organization (WMO), the Centre collaborates with other member countries in polar forecasting studies based on observational data (Figure 2.) and numerical models [7]. As a member of Northeast Asia Regional Ocean Observing System (NEAR-GOOS) of the Global Ocean Observing System (GOOS), we will work with Russia, Japan, South Korea and other member countries to promote the free sharing of ocean observation data and other international cooperation in the field of ocean [8]. We have participated in the International Arctic Rafting Ice Station Program, relying on the German "Polar Star" icebreaker, with sea ice, ocean and atmosphere within 50 kilometers of the icebreaker as the main observation object, and rafted along the direction from the East Siberian Sea to the North Pole under the action of "crossing the pole flow". Through a year of artificial observation, the understanding
of the central Arctic ocean atmosphere-sea ice-ocean-ecosystem coupling process is deepen during the
collection of a large amount of ocean data at the same time, to investigate the physical characteristics of
arctic sea fog and the mechanism of extinction, thus exploring the Arctic sea fog numerical simulation
[9].

Figure 2. Real-time observation data of the north-polar waves of the global ocean.

3. Ocean Forecast Business Innovation on Big Data Technology along the Ice Silk Road

3.1. Innovation in the research method of ocean forecast along the Ice Silk Road

In 2013, the Center was successfully elected as a member of the Arctic University Organization (UArctic)
[10], which opens the path of Arctic Ocean forecasting innovation in the combination of “production,
learning and research”. The UArctic includes eight Arctic countries (Canada, Denmark, Finland, Iceland,
Norway, Sweden, Russia, and the United States) and China, the United Kingdom, Belgium, France and
Japan, the strong teaching and research team of which promotes the simultaneous development of
research and education in Arctic Ocean prediction. In 2015, senior experts from the research and
development of polar sea ice numerical simulation and forecasting systems of the National
Environmental Prediction Center of the United States were invite
[358x324]d to lecture in Beijing to offer a series
of lectures on polar climate models, sea ice models, data assimilation, collection forecasting, predictive
testing, and to cooperate in the use of the Climate Prediction System (CFSv2) to carry out the mid-
and long-term numerical prediction tests of Arctic sea ice, and the Arctic scientific research and merchant
ship's first voyage was successfully applied [11]. Six Arctic prediction seminars were jointly organized
with foreign scientific research institutions to discuss and develop the Arctic sea ice ocean integrated
prediction system and the current-atmosphere-wave-sea ice coupling system.

3.2. Technology Innovation of Safety and Security Services along the Icy Silk Road

In December 2018, the China Ocean Forecast net developed by the Forecasting Center will be
operational [12]. This is China's only national marine forecasting professional website, marking China's
future-oriented marine forecasting services enters the "Internet +" and "mobile Internet +" era, this
website is China's professional information platform of marine forecasting and early warning, which is
responsible for issuing storm surge, waves, sea ice (Figure 3.), tsunami, red tide, green tide and sea
temperature, sea currents and other marine disaster warning (forecasting) information to the external in
authority, and gathers information, public science, professional marine forecasting and protection
services. Experts’ replies and question-and-answer interaction are achieved through mobile applications
and WAP services, and the service surface seamlessly covers the global oceans and poles. Immediately
thereafter, the Marine Environment Prediction and Guarantee System of the Maritime Silk Road was
put into operation and the Marine Environment Forecast products along the Maritime Silk Road were
released in Chinese and English (more languages will be added in the future) through the China Marine Forecasting Network's "Marine Silk Road Special Channel" [13].

Figure 3. Big data for 120-hour numerical forecast of North-polar sea ice.

3.3. High-performance Computing Clusters and Supercomputing Innovations
Ocean observation data is traditional data; ocean forecasting products are big data. Global ocean forecasting, especially Arctic ocean forecasting, is depending more and more on high-performance computing, it can be said that without high-performance computing there is no modern ocean forecast, high-performance computing technology and research has changed from the past ocean forecasting auxiliary role to the same role as the ocean forecast science and technology. Driven by innovation, the forecasting center has formed a computing resource mine consisting of Sunway 3000 + high-performance computing system, IBM blade cluster, ocean real-time data center, ocean supercomputing center, ocean forecast numerical model software set, global ocean monitoring and forecasting data lake, global marine environment forecasting business network, ocean cloud computing and big data visualization intelligent platform, etc., which is sufficient to ensure the sustainable development of ocean forecasting technology innovation along the Ice Silk Road. In August 2017, the Forecasting Center joined the National Supercomputing Innovation Alliance and served as a member of the Technology and Standards Group of the Alliance, since then it has joined the ranks of China's top-level supercomputing innovation teams.

4. Innovation results on ocean forecast big data application along the Ice Silk Road

4.1. It has won the first prize of China Marine Science and Technology Award in the Global Business Oceanographic Forecasting System
The global operational oceanographic forecasting system, which is developed mainly by the forecasting center, is the first independent marine environment numerical forecasting system nested by the global-ocean and polar-offshore (Figure 4.). It achieves the full coverage of the integrated ocean forecasting business of space resolution from 100 km to kilometer, and the advent and application of the forecasting system has completely reversed the long-term use of foreign ocean forecasting products in China, thus becoming one of the few countries after the United States and Europe to carry out the global business-oriented ocean forecast. In December 2017, the project passed application evaluation, and it’s believed that the scientific and technological achievements have reached the international advanced level as a whole, and is in the international leading position in the physical parameterization scheme, the assimilation of autonomous power satellite data, and the application of environmental forecasting technology [14]. It is evaluated as one of China's top ten marine science and technology progress in 2013, the first prize of the 2015 China Marine Science and Technology Award, and in June 2016, it was selected to join the exhibition of the national "12th Five-Year Plan" scientific and technological
innovation achievement exhibition with the theme of "Innovation-driven development and science and technology leading the future".

Figure 4. Big data for near-sea 500hPa forecast of the North Pole.

4.2. The key technologies of China's merchant ship polar routes won the China Marine Science and Technology Award

After entering the 21st century, the Forecasting Center took the initiative to face climate change, intervened in the Arctic seaway trade navigation marine forecast ingress and guarantee service research in advance, successfully completed 9 batches of China's Arctic science and technology ocean forecast safeguard mission, and has provided forecast guarantee for China Ocean Shipping Group and other 15 merchant ships and a total of 22 voyages of the Arctic Northeast Seaway ever and again (Figure 5.). In 2016 alone, the "Yongsheng Wheel +" project of six Arctic voyage ships saved a total of 32,137 sea miles, 108 days of sailing time, 4077 tons of power fuel, which greatly reduced the operating costs of enterprises, carbon emissions and environmental pollution [15]. The normalization of commercial shipping in the Northeast Arctic Seaway has made the traditional "Sea Silk Road" route extend naturally northward and directly to Europe via the Arctic Ocean. The "Research and Application of Polar Marine Meteorological Support Technology" project the Forecasting Center participated in, won the first prize of the 2008 China Marine Science and Technology Award and the project "Research and Application of Key Technologies of The Polar Route of Chinese Merchant Ships", as well as the Special Prize of the 2018 China Maritime Science and Technology Award.

Figure 5. Big data for sea wave and sea ice forecast in the eastern section along the Northeast Passage of the North Pole.
4.3. Numerical forecast over-calculation results has won the National PAC Final Bronze Award for four consecutive years

The Forecasting Center is a member of the International Operational Ocean Forecasting Organization (GOV) in the field of numerical models, and has achieved new progress and achievements in data assimilation, business process optimization and other fields of global operational ocean forecasting system (CGOFS), especially in the field of polar science and ice silk road commercial shipping, such as the research and application of "sea current-atmosphere-wave-sea ice coupling forecasting system", marine monitoring forecast cloud, big data application and global ocean forecast visualization human-machine dialogue. The research results of “Research on the application of NEMO in the global marine environment forecasting model”, “the optimization of the computational performance of the NEMO-based global marine environment forecast ingress in the supercomputing cluster”, “the coupling line of the global atmospheric-wave numerical calculation model” (Figure 6.), “the parallel optimization of the typhoon-coupled numerical calculation model” and 4 related theme papers have participated in the 2016, 2017, 2018 and 2019 National Parallel Application Challenge (PAC) respectively and won the Bronze Award of the Challenge Final for four consecutive years, and all the theme papers were awarded the outstanding thesis award in the competition at the same time.

Figure 6. Effect diagram of Global Atmosphere-Sea Wave optimization coupling model.

5. Conclusions

According to the latest estimates by scientists, the global warming rate of the upper ocean within 2000 meters is 0.36-0.39 Wm$^{-2}$ from 1971 to 2010, which accelerated significantly in the 1990s and increased to 0.55-0.68 Wm$^{-2}$ after 1991, and the phenomenon continues [16]. At the same time, studies have found that between 1901 and 2012, the rate of warming in the Arctic was twice the global average, and it is noted that Arctic warming occurred mainly in the winter of the 1990s [17]. As with the growth of the Ice Silk Road (North-East Arctic Channel), the Northwest and Central Passage of the Arctic are also ushering in the dawn of commercial shipping. We will strive to “improve the level and capacity of scientific research in the Arctic, deepen scientific cognition and understanding of the Arctic, explore objective laws of arctic change and development, and create favorable conditions for enhancing human capacity to protect, utilize and govern the Arctic [18].”

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