Technology for Forecasting the Global Environment and Human Society

Akira Koyama, Xiaoxi Zhang, Masaki Hisada, and Minako Hara

Abstract

NTT Space Environment and Energy Laboratories aims to contribute to achieving sustainable corporate growth and a resilient society by proactively adapting to changes in the social and natural environment on the basis of highly accurate forecasts of the global environment and human society. In this article, we introduce two technologies. One is global environmental futures forecasting technology for clarifying Earth's regeneration process by linking global-scale observations and modeling of the physical, biological, and chemical processes of Earth and simulating these processes. The other is management science and technology on environmental, social, and governance (ESG) for supporting the formulation of corporate ESG management strategies by predicting the future of human society and environmental impact.

Keywords: global environment, ESG management, future prediction

1. Introduction

The Sustainable Development Goals adopted by the United Nations in 2015 encourage private sector actors to solve social problems as businesses, and attention is being paid to corporate responses to social problems such as poverty, greenhouse gas emission reduction to mitigate climate change, and adaptation measures to reduce the impact of climate change. To achieve sustainable growth under these conditions, financial indicators as well as non-financial indicators need to be considered. We are also witnessing the emergence of previously unforeseeable events such as disasters caused by extreme weather, global pandemics, and armed conflicts. With this background, the NTT Group has set an ambitious environmental and energy vision to achieve both economic growth and zero environmental impact. To contribute to this vision, this article introduces the global environmental futures forecasting technology and management science and technology on environmental, social, and governance (ESG) that enable proactive and flexible responses to the rapidly changing global environment and global situation on the basis of highly accurate forecasts of the global environment and human society.

2. Global environmental futures forecasting technology

Global environmental futures forecasting technology reveals the potential regenerative processes of the global environment and enables the global environment to be forecast through observations, modeling, and simulating physical phenomena such as climate, weather, and physical processes in the ocean, as well as biological and chemical phenomena such as ecosystem circulation and carbon cycles over large areas. The ocean, which covers about 70% of Earth's surface, is a largely unexplored area that has not been directly observed in real time, despite its great effect on extreme weather such as typhoons and liner

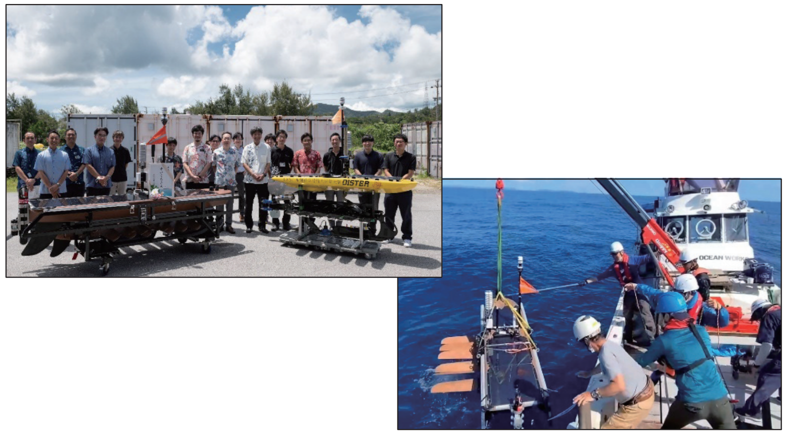


Fig. 1. Atmospheric and ocean autonomous observation system (Seiuchi-san) and dropping it into the sea.

rainbands. We are working on observing and modeling physical phenomena such as weather using satellite Internet of Things (IoT) technology [1]. This article introduces an experiment involving atmospheric and oceanic observations conducted with the Okinawa Institute of Science and Technology Graduate University (OIST) to improve the accuracy of extreme weather forecasting and a modeling study of marine ecosystems incorporating biological and chemical processes.

2.1 Efforts to forecast extreme weather

Extreme weather events, such as typhoons and linear rainbands, have been occurring frequently. To improve accuracy in extreme weather forecasting, it is important to observe the interaction between the atmosphere and ocean as well as improve the accuracy of numerical forecasting models. Ocean temperature and humidity as well as ocean surface and underwater temperature need to be directly observed to improve forecasting accuracy, but the number of sensors is insufficient, making observations along the path of typhoons very difficult. The area directly under a typhoon is very difficult to observe because of the harsh environment in which storms and high waves occur. To conduct real-time ocean observations directly under typhoons, we developed the atmospheric and ocean autonomous observation system "Seiuchi-san" that can autonomously record observations for long periods without human intervention. In July 2022, we commenced observations offshore of Okinawa in collaboration with OIST (**Fig. 1**). We observed the area near the center of Typhoon Hinnamnor in August 2022. For future work, we will analyze the experimental data to improve accuracy of typhoon forecasts and research real-time continuous observation techniques in the ocean near Japan to improve the accuracy of extreme weather forecasts. We will attempt to broaden the scope of observations in the ocean near Japan as well as in distant oceans where typhoons occur through joint research with the Japan Agency for Marine-Earth Science and Technology.

2.2 Efforts to model marine ecosystems

Marine ecosystems are constantly transforming due to the effect of air temperature, water temperature, and changes in sunlight intensity, which is exacerbated by climate change. The results of human activities, such as agricultural runoff carrying various nutrients and chemicals, flow into the ocean through rivers. It is also difficult to observe ecosystems and quantify changes when we do not fully understand the role of individual organisms in nutrient cycling. Therefore, we aim to observe and model marine ecosystems, including plankton and other microorganisms, fish, and mammals, using new observation technologies that use satellite IoT technology, and to forecast marine ecosystems using simulations of environment changes. We are currently studying ecosystem-cycle forecasting technology that models ocean-ecosystem circulation processes and predicts the effects of climate change and human activities, fish-ecosystem monitoring technology that restores the ecosystem balance by constructing indicators of fish well-being, and microorganism-diversity-modeling technology that models the diversity of millions of microbial species and forecasts changes due to climate change (**Fig. 2**).

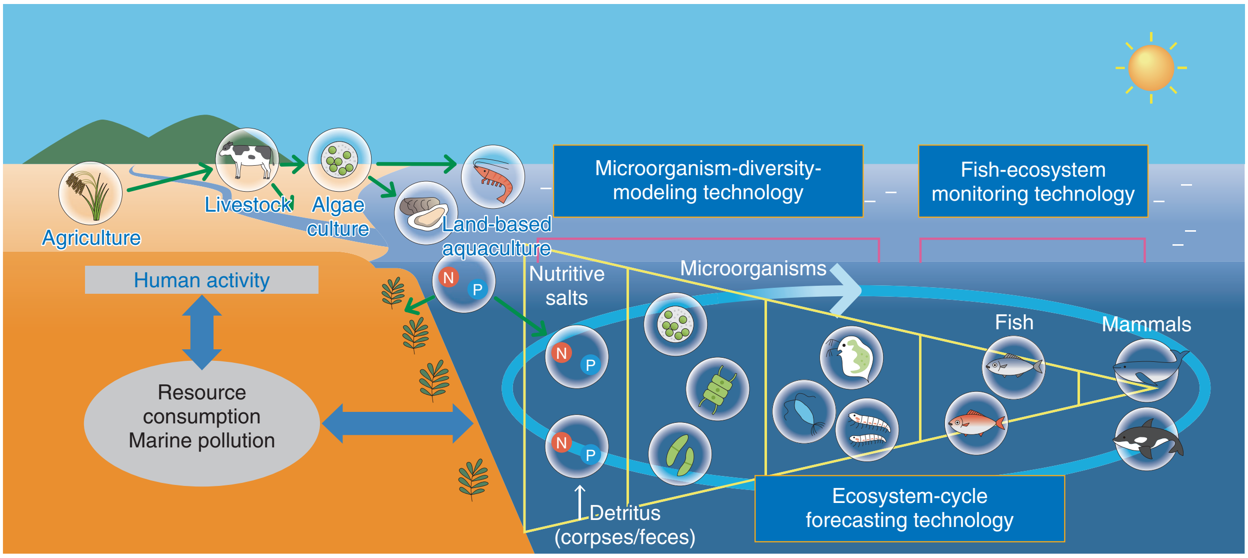
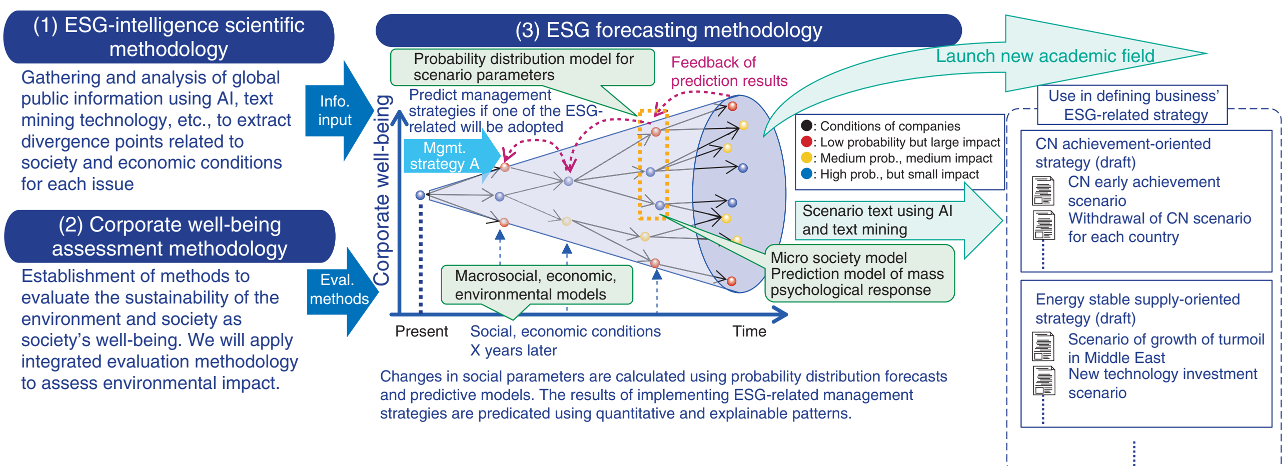


Fig. 2. Marine ecosystem model.



CN: carbon neutral

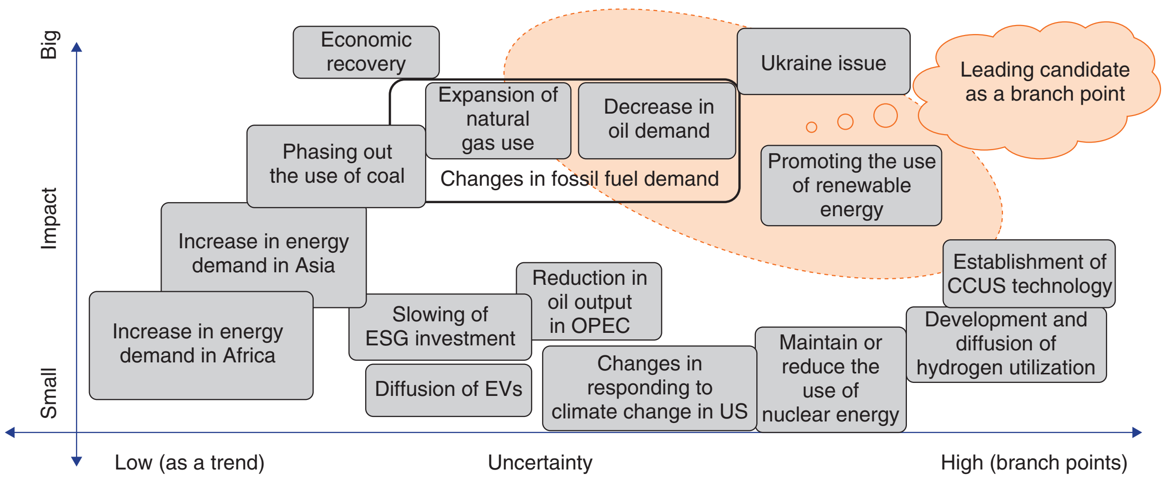
Fig. 3. Overview of management science and technology on ESG.

3. Management science and technology on ESG

Management science and technology on ESG is used for establishing scientific-prediction methodology on human society and global environmental impact to scientifically support the formulation of corporate management strategies related to non-financial values such as ESG. We are currently investigating an ESG-intelligence scientific methodology, corporate well-being assessment methodology, and ESG forecasting methodology (**Fig. 3**).

3.1 ESG-intelligence scientific methodology

We collect global information on politics, economy, society, technology, and environment using artificial intelligence (AI) including text mining technology, etc., and scientifically analyze them as information that contributes to the formulation of management strategies regarding ESG. For example, we are collecting and analyzing information necessary to



CCUS: carbon capture, utilization, and storage
EV: electric vehicle
OPEC: Organization of Petroleum Exporting Countries

Fig. 4. Attribution analysis using conventional method.

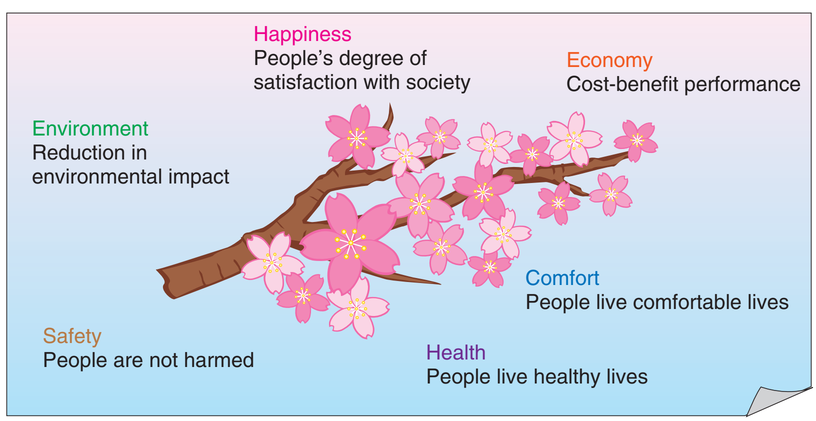


Fig. 5. Overview of the GSF Index.

formulate business strategies related to carbon neutrality and energy, in light of the latest efforts to decarbonize around the world and the energy crisis caused by the conflict in Ukraine. To create multiple possible future scenarios, important influencing factors are extracted on the basis of the collected information and set up as branch points in the creation of future scenarios. **Figure 4** shows an example of manual analysis with the conventional method. For the same information sources as in the conventional method, by applying AI text mining technology to the aforementioned series of analysis processes, we are attempting automatic information collection and analysis so that the bias of manual information analysis can be eliminated and branch points can be extracted objectively.

3.2 Corporate well-being assessment methodology

To evaluate the contribution of information and communication technology (ICT) to achieve a sustainable society, NTT developed the Gross Social Feel-good Index (GSF Index) [2] for quantitatively evaluating the positive and negative effects of ICT services and solutions in terms of their impact on the global environment, society, and economy (**Fig. 5**). The corporate well-being assessment methodology is an extension of the GSF Index to establish a method for quantitatively evaluating the sustainability of the global environment and human society in terms of societal and corporate well-being. This methodology is an attempt to evaluate the contribution of corporations toward a well-being society that people desire, particularly for multiple stakeholders and considering non-financial impact. In FY2021, in a joint research project with Kyoto University, we conducted a quantitative evaluation of employee satisfaction in companies by identifying priority issues on the basis of findings from a questionnaire survey.

3.3 ESG forecasting methodology

The ESG forecasting methodology is used to establish a set of scientific-prediction models to quantitatively predict the results of implementing a single ESG-related management strategy in multiple possible futures using the branch points obtained using the ESG-intelligence scientific methodology. The set of scientific-prediction models consists of a macroeconomic model that predicts economic, social, and environmental changes at the macro level by using input-output analysis [3] and a micro-social model that predicts changes in individual behavior related to environmental impact. By combining these models, the risks and effects of implementing corporate ESG-related management strategies can be predicted that cannot be predicted manually on the basis of changes in social conditions output from the models. The results of the quantitative forecasts are output as scenarios, and the forecast results are evaluated using the corporate well-being assessment methodology. We aim to develop scientific technology that will be useful in the formulation of ESG-related management strategies that can lead to a better future for companies and society as a whole.

4. Future work

This article introduced global environmental futures forecasting technology and management science and technology on ESG. Regarding global environmental futures forecasting technology, we aim to develop technologies for simulating the regeneration process of the global environment by modeling the physical, biological, and chemical processes of the global environment using the results of ultra-wide-area observations. For management science and technology on ESG, we aim to develop technology for forecasting human society and environmental impact. These two technologies will be linked using Digital Twin Computing [4] technology and implemented on a simulation platform for forecasting the global environment, which will enable the mutual influences of the global environment and human activities to be taken into account. On the basis of forecasting, we aim to proactively adapt to changes in the social and natural environment.

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