Forefront Initiatives of NTT Space Environment and Energy Laboratories

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Abstract

Having established unconventional research themes that had not been targeted at NTT laboratories, NTT Space Environment and Energy Laboratories is taking on various challenges to change the future of the global environment. By looking at the Earth from the perspective of space, we are aiming to regenerate the global environment and create an inclusive and sustainable society. In this article, the latest activities and future prospects of NTT Space Environment and Energy Laboratories, which has existed for three and a half years, are introduced.

Keywords: space, environment, energy

1. Introduction

NTT Space Environment and Energy Laboratories was established in July 2020 to contribute to the revitalization and reform of the global environment. We will achieve this by reviewing the Earth and social environment we live in from the broad perspective of space above the Earth in a manner that is not bounded by the conventional framework of environment and energy. Three and a half years after our establishment, we have revised our vision as follows: "With the ultimate goal of regenerating the global environment and creating an inclusive and sustainable society, we aim to create innovative next-generation energy technology and resilient environmental adaptation technology and contribute to achieving zero environmental impact."

The specific image of society that we hope to create through this new vision is the "sustainable and resilient society" described in the title of the Feature Articles. This is a society in which the impact of the society we live in on the global environment is reduced to zero and the varying impact that global environment changes have on society can be mitigated flexibly. This society will be based on the following innovations (i) next-generation energy technologies such as nuclear fusion and space power generation; (ii) zero power outages through local production and local consumption of clean energy, and autonomous, decentralized, and coordinated energy networks; (iii) reduction of carbon dioxide (CO_2) in the atmosphere and oceans through circular agriculture, forestry, and fisheries; and (iv) the use of highly accurate future prediction to not only prevent damage caused by natural disasters but also extract energy from typhoons and lightning ("disaster green energy").

We have been working hard to establish research systems, increase the number of researchers, collaborate with many research institutions, and quickly generate research results. We have frequently updated our owned media "Beyond Our Planet" [1] to raise awareness of the Laboratories and strengthen our acquisition of external human resources. The number of page views of articles on linear rainbands, in conjunction with sudden rainstorms and typhoon strikes, has increased significantly to about 18,000 per month (out of about 81,500 per month in June 2023 for the entire owned media), and our organization and activities have been highly ranked by search engines in a manner that shows we are gaining social recognition.

To accelerate the digital twinning of the global

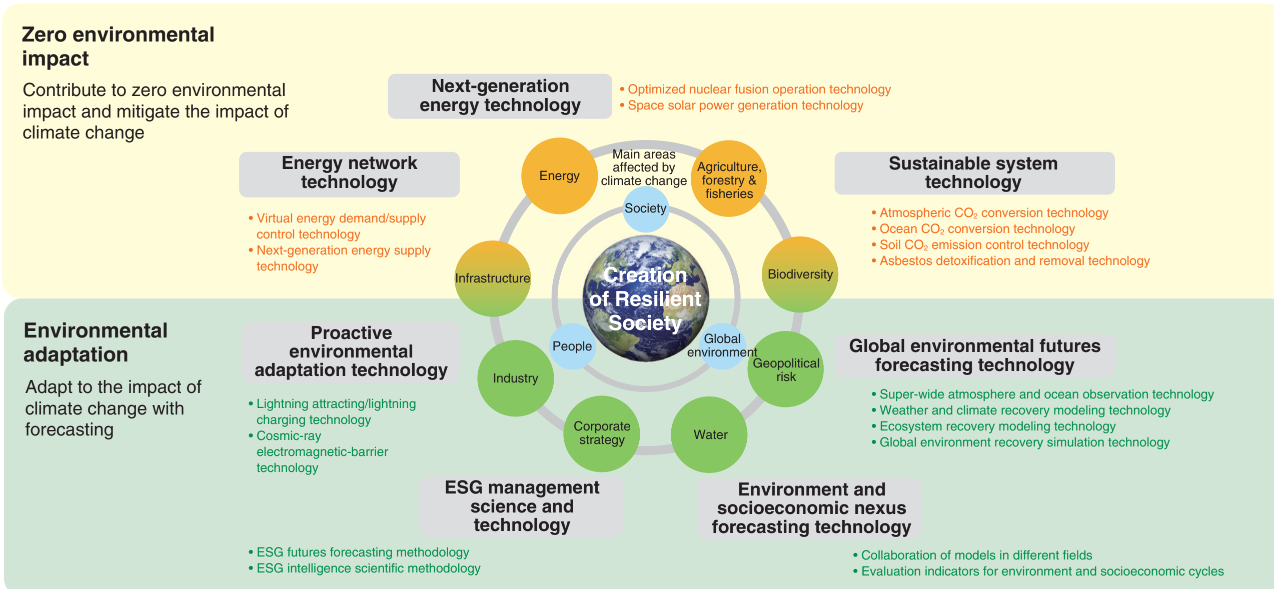

Fig. 1. Overall view of research themes.

environment and establishment of highly accurate future-forecasting technology, the Environment and Socioeconomic Nexus Forecasting Technology Group was established in October 2023. The number of researchers has increased 1.8 times since the establishment of the Laboratories, and more than 40 collaborations with external organizations and universities, including startups, have begun to produce a variety of results.

The research themes we are currently focusing on are shown in **Fig. 1**. NTT Space Environment and Energy Laboratories has separated these themes into two projects: the Zero Environmental Impact Research Project (at the top of the figure) and the Resilient Environmental Adaptation Research Project (at the bottom of the figure). Three research groups are involved in the Zero Environmental Impact Research Project, and four groups (including the newly established Environment and Socioeconomic Nexus Forecasting Technology Group) are involved in the Resilient Environmental Adaptation Research Project, and each group is pursuing research in collaboration with the others.

As shown in the center of Fig. 1, we aim to apply the results of our research to eight areas affected by climate change. Therefore, we hope to reach our goal of creating a sustainable and resilient society by regenerating the global environment and reducing the effects of climate change while maintaining a balance among the global environment, society, and people. Each project and its current status are described hereafter.

2. Forefront initiatives of Zero Environmental Impact Research Project

To contribute to NTT Group's vision of zero environmental impact, this project is focused on researching the following three technologies: (i) next-generation energy technology that is overwhelmingly clean and innovative, (ii) energy network technology that efficiently handles supply and demand of renewable energy, and (iii) sustainable system technology that reduces atmospheric and marine CO_2 through circular agriculture, forestry, and fisheries.

We are currently working on two themes regarding next-generation energy technology. The first is "optimum fusion reactor operation technology" for fusion power generation, a dream energy source. Fusion power generation is a safe and clean energy source that reproduces—on the Earth—the physical phenomenon occurring on the Sun, and it is being researched worldwide with the aim of commercialization by 2050. In collaboration with the National Institutes of Quantum Science and Technology (QST) and the ITER Organization, we are pursuing research on using NTT's Innovative Optical and Wireless Network (IOWN) to control the stability of

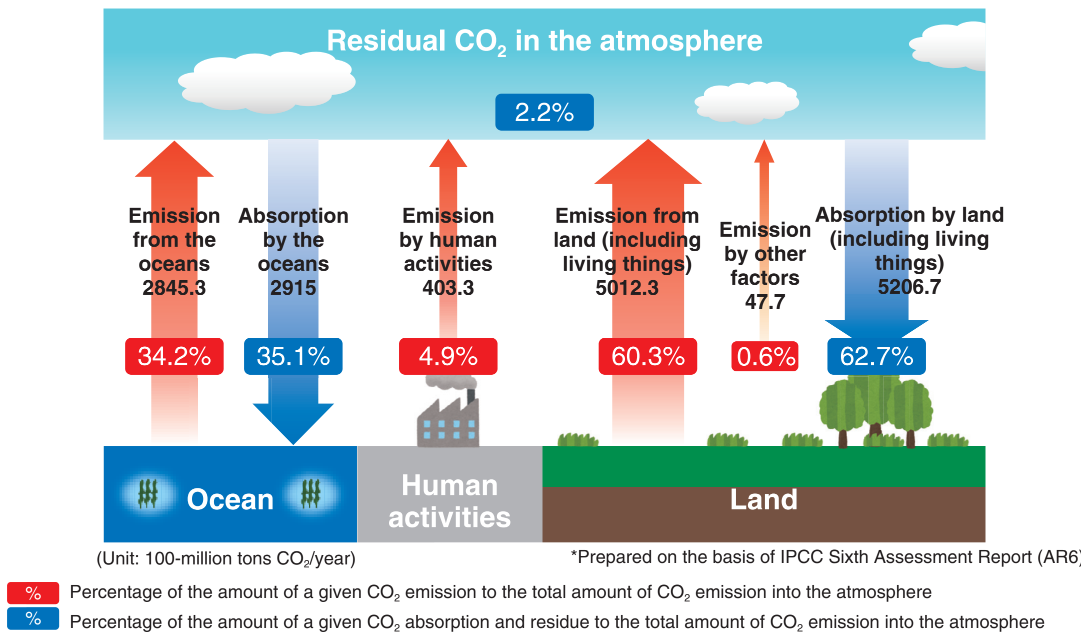

Fig. 2. Overall picture of global CO_2 flux.

plasma in fusion reactors. Venture companies are currently playing a prominent role in this field, and while exploring global trends, we are looking to form new partnerships with ventures and institutions that can use our technology. As the first step of such collaborations, we have started a joint experiment on anomaly prediction with the ITER Organization [2].

The other is "space solar power technology," which enables large amounts of energy obtained in space to be transmitted wirelessly to the ground in an efficient manner. As a grand research theme, space solar power generated from sunlight captured by geostationary satellites (about 36,000 km above the Earth) is wirelessly transmitted to the ground day and night via laser beams and microwaves. This theme is explained in detail in an article in this issue titled "Long-distance Laser-energy Transmission for Space Solar Power Systems and Their Application on Earth" [3].

To maximize the use of renewable energy regarding energy network technology, we are researching two technologies: (i) virtual energy-demand/supply control technology that absorbs fluctuations in renewable energy output through integrated control of information processing by information and communication technology (ICT) devices in NTT's datacenters, storage batteries, and electric vehicles (ii) and next-generation energy supply technology that enables local production for local consumption and ultra-resilient supply of renewable energy by using safe and highly reliable direct-current power supply.

Virtual energy-demand/supply control technology is beginning to attract attention as a new concept called "power to data", namely, surplus power from renewable energy is replaced with data (information processing) for efficient consumption. In collaboration with NTT operating companies, we have started to experimentally demonstrate this technology by connecting our laboratory to an actual datacenter. We plan to increase the number of connection sites and proceed with verification of this technology for practical use.

Regarding sustainable system technology, we are researching CO_2-conversion technology to reduce CO_2 in the atmosphere and oceans through circular agriculture, forestry, and fisheries. Carbon neutrality is often thought of as the reduction of CO_2 emitted from human activities, mainly from energy sources; however, the amount of CO_2 emitted from human activities account for only 4.9% of the global CO_2 emissions.

The latest data on the global CO_2 cycle is shown in **Fig. 2**. We have previously referred to the figures in the draft version of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), but Fig. 2 shows the figures prepared with

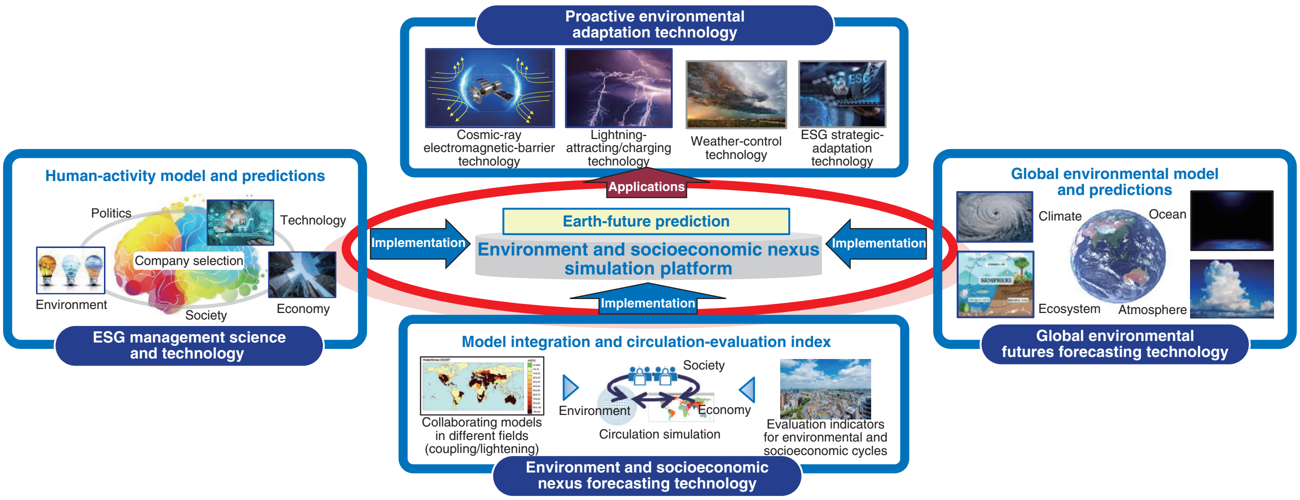

Fig. 3. Resilient Environmental Adaptation Research Project.

reference to the final version. The land (including living things) emits the largest amount of CO_2 (60.3% of the total annual amount of CO_2 emission into the atmosphere), and the oceans emit 34.2% of the total of CO_2 emission. The land (including living things) absorbs 62.7% of the total amount of CO_2 emission into the atmosphere, and the oceans absorb 35.1%. In other words, it is, of course, important to reduce emissions from human activities to virtually zero; however, in consideration of the balance and cycle of the entire planet, it is important to approach the land and oceans at the same time as reducing emissions from human activities. We need to reduce CO_2 emissions from human activities while simultaneously stopping or tackling deforestation, soil pollution, and ocean destruction and pollution. Given those needs, we are researching technologies to reduce CO_2 emissions through circular agriculture, forestry, and fisheries.

We are researching ways to increase the amount of CO_2 fixed in the long term in the ground as well as in living things and organic matter. We are applying genome editing to plants and algae to increase the amount of CO_2 that they absorb during photosynthesis. These genome-edited plants and algae are then fed to seafood and livestock. Thus, the amount of CO_2 in the atmosphere and oceans can be reduced by fixing it in the food chain and cycle.

Although we call this process "genome editing," we are not involved in genetic modification but rather selective breeding, which is safe. As an outcome of this research, we have succeeded in identifying a gene that dramatically improves the CO_2 absorption of algae [4]. As a regional revitalization business based on land-based aquaculture, NTT Green & Food, Inc., which uses the gene-edited algae that absorbs a large amount of CO_2 as feed, started business in July 2023 [5]. Producing new results and expanding our business has therefore become urgent. From now onwards, we will promote the use of marine and terrestrial plants with dramatically increased CO_2 absorption and extend their use to carbon credits.

These technologies are introduced in the article titled "Zero Environmental Impact Technology to Achieve a Clean and Sustainable Society" [6].

3. Forefront initiatives of Resilient Environmental Adaptation Research Project

An overall picture of the Resilient Environmental Adaptation Research Project is shown in **Fig. 3**. This project is researching environmental adaptation, namely, predicting the future by taking into account the mutual influences of human activities and the global environment, supporting proactive management decisions on the basis of the prediction results and avoiding or taking advantage of damage caused by natural phenomena. We are working on establishing four technologies: (i) ESG (environmental, social, and governance) management science and technology that predicts future scenarios (such as climate change) that will affect corporate management from a wide range of publicly available information;

(ii) global environmental futures forecasting technology that predicts the future of the global environment through observation and modeling of physical, biological, and chemical processes in the global environment; (iii) environment and socioeconomic nexus forecasting technology that predicts social and environmental cycles by integrating models from a variety of fields and creating new cycle-evaluation indicators; and (iv) proactive environmental adaptation technology that combines these three technologies and uses the results of future prediction to proactively adapt to the social environment.

With the ESG management science and technology, we aim to establish a future forecasting technology that contributes to the formulation of management strategies by combining two methods: ESG intelligence scientific methodology and ESG futures forecasting methodology. The ESG intelligence scientific methodology collects and analyzes global public information (such as government documents, academic conferences, and news) worldwide by using artificial intelligence (AI), text-mining techniques, and other methods. Information is analyzed by first removing human-thinking biases then generating multiple possible scenarios by extracting causal relationships between events and plans. The ESG futures forecasting methodology quantitatively predicts social and environmental changes on the basis of multiple scenarios. For this quantitative forecasting, we use a macroeconomic model called the computable general equilibrium (CGE) model. The CGE model is used for mathematically predicting changes in an overall market on the basis of production and consumption by industry and the interactions among industries. For example, fluctuations in energy prices can affect the sales volume and CO_2 emissions in industries that use a large amount of energy (e.g., steel manufacturing and transportation). By calculating these effects by using the CGE model, we can quantitatively predict future economic and environmental impacts while taking into account the interactions between industries. Using these methods, we can continuously forecast the combined impact of environmental and social changes on management over the short and long terms. With the ESG futures forecasting methodology, in collaboration with research organizations such as the National Institute for Environmental Studies since 2020, we have been conducting assessments regarding the impact of ICT development on society* and disseminating the results at international conferences. We will focus on the ESG intelligence scientific methodology and collaborate with the management divisions of operating companies with the aim of achieving more practical results.

To create a flexible society that can adapt to change, it is necessary to establish technologies for predicting the future of the global environment. These technologies involve observation of the atmosphere and oceans over an ultra-wide area to model weather and climate on the basis of the Earth's physical processes and model ecosystems on the basis of the Earth's biological and chemical processes. Meteorological and environmental observations are currently limited to land and near-shore waters, that is, real-time observation in the distant parts of the oceans from land has not been established. Therefore, satellite observation is the main method of such observations. However, it is difficult for satellites to measure water vapor, the energy source of extreme weather events, such as typhoons and linear rainbands, as well as environmental information about the ocean. With these difficulties in mind, we are attempting real-time observations in these unexplored areas by using satellite Internet of Things (IoT) [7] while upgrading weather and climate models. Since it is difficult for us to establish such sophisticated ocean observations and models on our own, we are also working with a variety of organizations to study this issue. Some of our recent accomplishments include (i) the world's-first successful simultaneous observation of the atmosphere and ocean under a Category 5 typhoon in the northwest Pacific Ocean in collaboration with the Okinawa Institute of Science and Technology Graduate University (OIST) [8] and (ii) the world's-first development of millimeter-wave radio frequency identification (RFID) tags to improve drone-navigation accuracy for advanced weather observation in collaboration with the University of Tokyo [9].

The aforementioned newly established Environment and Socioeconomic Nexus Forecasting Technology Group is working on technology for forecasting environmental and socioeconomic nexuses. To achieve inclusive sustainability, we are (i) constructing a global-scale simulation environment that reproduces the interaction between environmental and economic activities related to the global water cycle and (ii) researching large-scale coupled simulation technology to link simulation systems in different fields of expertise. These activities are described in detail in the article titled "Forecasting Technologies

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Fig. 4. Experimental demonstration of a lightning-resistant drone flight on a beach in a snowstorm.

for Environmental and Socioeconomic Cycles for Attaining Inclusive Sustainability" [10].

The proactive environmental adaptation technology predicts the future by coupling the three abovementioned technologies (ESG management science and technology, global environmental futures forecasting, and environment and socioeconomic nexus forecasting) and adapts business practices to the environment in accordance with the prediction results. However, it will take time to establish these three technologies. Therefore, we have started research on lightning and cosmic rays, which can be predicted to some extent even now. We are researching technology for preventing lightning-induced damage to important equipment by capturing lightning by drones equipped with lightning rods, guiding it to the desired location, and using lightning energy. We are researching lightning-resistant drone technology, lightning induction technology, lightning prediction technology, and lightning charging technology.

We have completed verification of lightning-resistant drones using artificial lightning and natural lightning in the winter of 2022/2023 on the coast of Uchinada Town, Ishikawa Prefecture, which is an area with the most winter lightning in Japan. Unfortunately, we were unable to capture natural lightning. However, we gained much knowledge during the demonstration in the extreme cold and quite-hazardous winter storms (**Fig. 4**). For example, we developed technology for predicting lightning-induction areas by combining information on thunderclouds and lightning strikes with information from our observations and technology for operating drones under extremely bad weather conditions. Our challenge is not over yet, and to be the first in the world to capture natural lightning with a lightning-resistant drone, we will continue to refine this technology in winter 2023/2024.

We have been working to improve the technology for evaluating soft errors, namely, malfunctions of semiconductors in communication equipment due to cosmic rays. To further develop this technology, we are researching cosmic-ray electromagnetic-barrier technology for evaluating the effects of cosmic rays on space equipment and the human body and reducing the effects of strong electromagnetic fields. This topic is explained in detail in the article titled "Forefront Research Initiatives on Environmental Adaptation to Enhance Societal Resilience to Environmental Changes" [11].

4. Conclusion

The latest information on the efforts of NTT Space Environment and Energy Laboratories were explained in this article. The Feature Articles in this issue will discuss some of the themes that have achieved success. We hope you will keep abreast of the growth of the Laboratories as it takes on the challenge of creating innovative technologies in the environment and energy field from a space perspective.

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