Japan Academy Prize to:

Ayako Abe-Ouchi
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for "Understanding Mechanism of the 100,000-Year Period Glacial Cycle"

Outline of the work:

In the last several hundred thousand years in the history of the Earth, glacial and interglacial periods have appeared alternatingly with ice sheet coverage across the Eurasian and North American continents. This fact has been observed since the late 19th century and has generated discussion on the driving force of climate change among several geologists and scientists. Although Milankovitch's study (1941), proposing the importance of Earth orbital change and its influence on summer insolation, was a crucial step toward a complete solution, the big question is how the small orbital change drove the glacial–interglacial cycle, primarily with 100 kiloyear (ky) periodicity retrieved from ocean sediments.

Milankovitch and other scientists analyzed the variability of the solar insolation at high-latitude regions in summer because of the variation of Earth orbital elements which is critical for seasonal climate and the multiyear persistence of the snow cover. According to Milankovitch hypothesis, most of the variability is due to 23 and 41 ky components, while the 100 ky component remains small. Several studies were conducted to discuss the dominance of the 100 ky glacial cycle which appeared in oxygen isotope concentration data from ocean sediment. Some found correlations between the intensity of solar insolation and ice sheet volume despite utilizing simple models that cannot be directly compared with the actual world.

Dr. Ayako Abe-Ouchi attempted to simulate the climate of the entire Earth under ice age boundary conditions using MIROC (Model for Interdisciplinary Research on Climate), a climate model developed at the University of Tokyo. She then attempted to reproduce the growth and decay of ice sheets using the ice sheet model, IcIES (Ice sheet model for Integrated Earth-system Studies), developed by her research team. This was done by taking relevant input parameter values calculated from the findings of climate model runs since it is time-consuming, expensive, and practically impossible even with the recent supercomputer resource. The utilization of various snapshot experiments of high resolution from comprehensive climate models using different ice sheet sizes, carbon dioxide concentrations, and orbital configurations, is unique to this study.

Another crucial factor is the effect of the bedrock movements. The Scandinavian Peninsula is currently rising gradually as the recovery process from the sinking of the bedrock due to the weight of the ice sheet covering the peninsula during the LGM period. This movement of Earth surface toward isostasy is included in the model calculation.

The reproduced change in the entire ice volume during the previous 400 ky correlated with the observational counterpart (inferred from the oxygen isotope concentration). It is surprising that not only the outstanding component with 100 ky periods but also the lower peaks with 20 and 40 ky period correlate with the observation. The geographical distribution of the ice sheet at the glacial maxima is well simulated in the Northern Hemisphere, which is comparable with the geomorphological and geochemical data from the field. Across the North American region, the ice sheet is generated first at the northernmost locations at the beginning of the cold phase; subsequently it spreads southward with time along with the thickening of the ice sheet. During the melting phase, the top surface of an ice sheet lowers and subsequently, the environmental air temperature increases to produce rapid melting. Model simulates the asymmetry between thickening and thinning known as saw-tooth pattern in the time series of oxygen isotope data, which is another remarkable feature. This study demonstrates the minimal change in orbital parameters sufficient to change the large North American ice sheet since the ice sheet behavior demonstrates hysteresis around the climatic conditions of the glacial–interglacial cycle, resulting in exceeding ice being a "tipping point" and the entire system acting like a watering device in a Japanese garden called "Shishiodoshi" or "Souzu."

As previously stated, Dr. Abe-Ouchi has provided the first answer to one of the most difficult and long-standing questions in geoscience: What is the mechanism to generate the 100,000-year period glacial cycle? Dr. Abe-Ouchi has demonstrated that changes of the solar insolation can actually produce a glacial cycle with dominant periodicity, inferred from observed evidence using a conventional developed ice sheet model combined with a global climate model. Furthermore, she continued to lead several paleoclimate modeling studies on the glacial, deglaciation, and other periods in Earth history applying a coupled atmosphere-ocean model MIROC developed as a Japanese community climate model. Dr. Abe-Ouchi also contributed to numerous international projects and reports in the United Nations to help in understanding climate change in the past, present, and future. Dr. Ayako Abe-Ouchi is worthy of the Japan Academy Prize for her outstanding achievement.

List of Main Publications

1. Abe-Ouchi A. and Blatter H. (1993) On the initiation of ice sheets. Annals Glaciol. **18**, 203–207.
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3. Huybrechts P., Payne T., Abe-Ouchi A. and the EISMINT Intercomarison Group (1996) The EISMINT benchmarks for testing ice sheet models. Annals Glaciol. **23**, 1–12.
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7. Abe-Ouchi A., Segawa T. and Saito F. (2007) Climatic conditions for modelling the Northern

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9. Blatter H. Greve R. and Abe-Ouchi A. (2010) A short history of the thermomechanical theory and modeling of glaciers and ice sheets. J. Glaciol. **58**, 1087–1094.
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12. Braconnot P., Harrison S. P., Kageyama M., Bertlein B. J., Masson-Delmotte V., Abe-Ouchi A., Otto-Bleisner B. and Zhao Y. (2012) Evaluation of climate models using paleoclimatic data. Nature Clim. Change **2**, 417–424.
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15. Abe-Ouchi A., Saito F., Kawamura K., Raymo M. E., Okuno J., Takahashi K. and Blatter H. (2013) Insolation-driven 100,000-year glacial cycles and hysteresis of ice-sheet volume, Nature **500**, 190–193.
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