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Japan Agency for Marine–Earth Science and Technology

Harmful UV is likely to Increase in Later 21st Century - Long-term simulation using a new Earth system model reveals -

Introduction
Shingo Watanabe and his colleagues at JAMSTEC, Nagoya University, National Institute for Environmental Studies, and Kyushu University found that harmful ultraviolet radiation reaching the Earth's surface is projected to increase in northern mid-latitudes, including Japan, in the latter half of the 21st century despite the expected recovery of the stratospheric ozone layer. The projections were obtained from comprehensive long-term simulations of Earth's environment including UV radiation, using a new Earth system model MIROC-ESM-CHEM.

In contrast to previous studies that only considered the effects of long-term change in stratospheric ozone to project UV radiation, researchers added those in tropospheric ozone, aerosols and clouds as well to project the long-term evolution of surface UV radiation. The results revealed a significant influence of these tropospheric factors on the future behavior of UV radiation. This suggests that the recovery of the stratospheric ozone layer alone, expected to be achieved by the emission regulations on halocarbons (HCFCs), would not necessarily result in a global decrease in surface UV radiation.

The study was supported by the "Long-term Global Environmental Projection using an Integrated Earth System Model," a research program funded under the government's Innovative Program of Climate Change Projection for the 21st Century. The numerical simulations in this study were performed using JAMSTEC's super computer Earth Simulator.

Their work has been published online on the Journal of Geophysical Research-Atmospheres on 1st June, and will also be presented in the general assembly of the International Union of Geodesy and Geophysics (IUGG) to be held in Australia from 27th June to 7th July.

Title: Future Projections of Surface UV-B in a Changing Climate

Authors: Shingo Watanabe[1], Kengo Sudo[1,2], Tatsuya Nagashima[3], Toshihiko, Takemura[4], Hiroaki Kawase[3],, and Toru Nozawa[2,3].

1. JAMSTEC, 2. Nagoya University, 3.National Institute for Environmental Studies, 4. Kyushu University

Model and results

The study aims to form projections of climate change not only in terms of atmospheric temperature, precipitation and sea level, but also in terms of changes in complex processes in the Earth's system. These include carbon cycle, atmospheric environment and UV radiation, which are intricately interrelated with ecosystems and human activity on the planet. The simulation results are expected to contribute to international climate research initiatives, including the Fifth Assessment Report of IPCC (*1) to be released in 2013. The newly developed model is based on a global climate model consisting of component models of tropospheric atmosphere, ocean, sea ice, river, and land-surface. The new model further includes stratosphere, ocean and terrestrial biosphere, aerosol and atmospheric chemistry.

Using this model, researchers calculated effects of long-term anthropogenic changes in aerosols and atmospheric chemistry, particularly ozone in the troposphere and stratosphere, to project the long-term evolution of global surface UV radiation. The results showed that harmful UV-B radiation (*2) reaching Earth's surface is likely to increase in north low and mid-latitudes in the latter half of the 21st century. Over Japan, the average surface UV-B radiation is projected to increase by 10 percent by the end of this century (Fig. 1). This means that the area surrounding Tokyo would experience UV radiation equivalent to that observed in the southern part of Japan today (Fig. 2).

Such increase in UV radiation contradicts previous projections, in which the reduction of HCFCs was expected to recover the stratospheric ozone layer, therefore, reducing the amount of surface UV-B radiation globally. The study revealed that, in addition to the stratospheric ozone change, anthropogenic changes in the tropospheric environment would also increase UV-B radiation. These changes include 1) improvement in air quality through the reduction of human-induced aerosols (*3) and tropospheric ozone (*4) downstream of industrial regions and regions with drastic deforestation, and 2) a decrease in cloudiness associated with global warming and aerosol decline. The resulting clearer-sky conditions would allow UV radiation to pass through the troposphere much easier than they do with today's skies.

Background

Since the discovery of the Arctic ozone hole, there have been growing concerns over the depletion of the stratospheric ozone layer caused by HCFCs. Concerns are also mounting over the associated increase in UV-B radiation - the radiation known to have harmful effects on human health, plants and animals. To respond this, the international community adopted the Montreal Protocol on Substances That Deplete the Ozone Layer in 1987, which regulates the production and use of HCFCs. Regulations under this international framework brought some success, showing a year by year decrease in atmospheric HCFC concentration since its peak levels at the end of 20th century. This had led to the theory that the recovery of the stratospheric ozone layer, by the reduction of HCFCs, would reduce global surface UV-B radiation throughout this century.

However, previous projections did not consider long-term changes in tropospheric ozone, aerosols and clouds, and thus ignored their effects on UV radiation. The simulation results, therefore, have contained large uncertainty (Fig.3).

Future Perspectives

The use of the advanced Earth system model has enabled, for the first time, the quantitative projection of harmful UV-B radiation that takes account of long-term tendencies of both stratospheric and tropospheric components. The findings are expected to facilitate research and advance measures against UV radiation in a wide variety of fields, including health, medical treatment, agriculture and fisheries, housing, and urban and work environments. Further advances in the research fields of UV radiation projection around the world will allow for developing more reliable projections.

***1. IPCC (Intergovernmental Panel on Climate Change)** is an international body for the assessment of climate change. It provides scientific views and compiles reports on climate change, which serve the world as a basis for addressing global warming.

***2 Harmful UV-B:**

Ultraviolet is found in sunlight. Its wavelength is shorter than that identified as the color violet. It is invisible and the wavelength of ultraviolet reaching the Earth's surface is in the range of 280 to 400 nm. Ultraviolet radiation in the spectrum between 280-315 nm, called UV-B radiation, is biologically hazardous and causes damage to DNA. It is known to be responsible for melanoma and cataracts.

***3. Human-induced aerosols:**

Anthropogenic aerosols are suspended fine particles composed of sulfate and carbonaceous compounds (soot and organic matters), which are originally emitted from fossil fuel burning or biomass burning and photo-chemically altered in the air. They are typical atmospheric pollutants. Their trans-boundary transport from the Asian continent to Japan has become a concerning issue in recent years. Aerosols are known to scatter and absorb UV radiation, thus reducing the amount found on the Earth's surface.

***4. Tropospheric ozone:**

Unlike the stratospheric ozone layer, tropospheric ozone is formed through photochemical reactions involving hydrocarbons and nitrogen oxides. It is an atmospheric pollutant and the chief constituent of photochemical oxidant. As in the stratosphere, UV radiation is also absorbed by ozone in the troposphere, which reduces the amount of UV radiation reaching the Earth's surface.

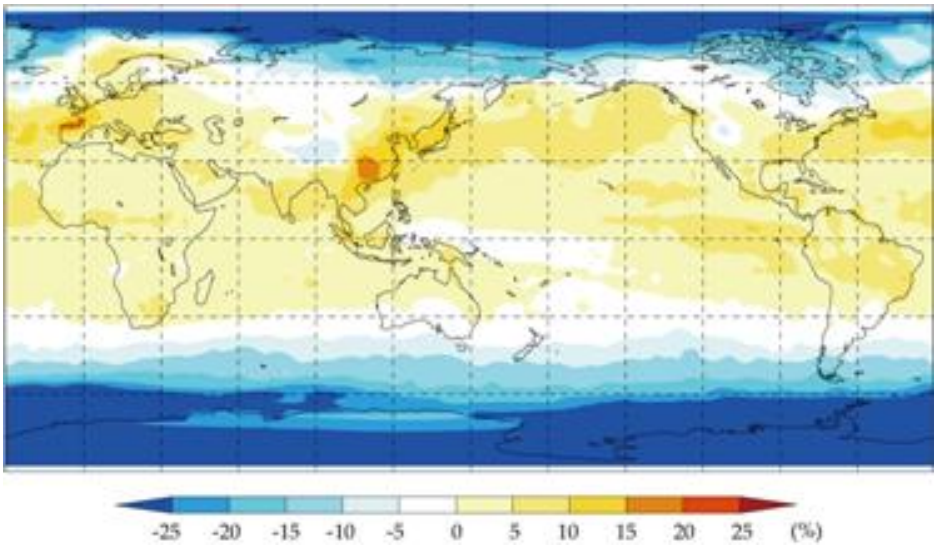

Figure 1: Long-term projection of UV-B radiation
Projected changes in average UV-B radiation between the early 21st century (2000 to 2009) and late 21st century (2090 to 2099). UV-B radiation will decrease in mid- and high latitudes in the southern hemisphere due to the recovery of the ozone layer. The decrease is also evident in the Arctic region (except for north Europe), which is due to decreasing sea-ice and snow as well as increasing clouds and aerosols. On the other hand, a UV increase of 5 % or more is projected downstream of industrial regions and regions of drastic deforestation.

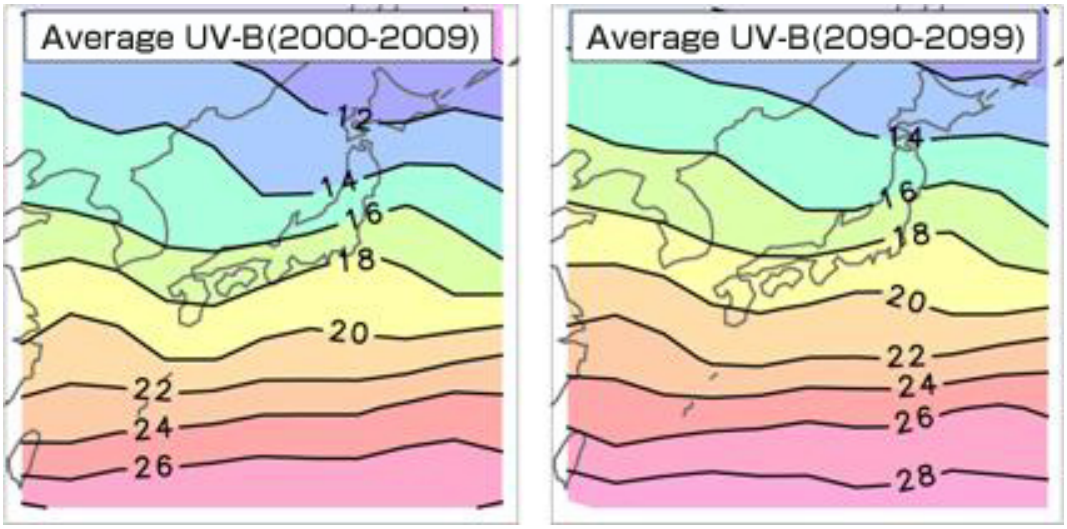

Figure 2: UV-B simulations around Japan (daily UV-B exposure: kJ/m2)
The comparison of these simulations shows a northward shift of the UV radiation gradient, indicating a nationwide increase in UV radiation. Take a look at the yellow zone for instance the UV radiation observed in the southern part of Japan in the early 2000's, is estimated to occur in areas covering the east to south pacific coasts of Japan.

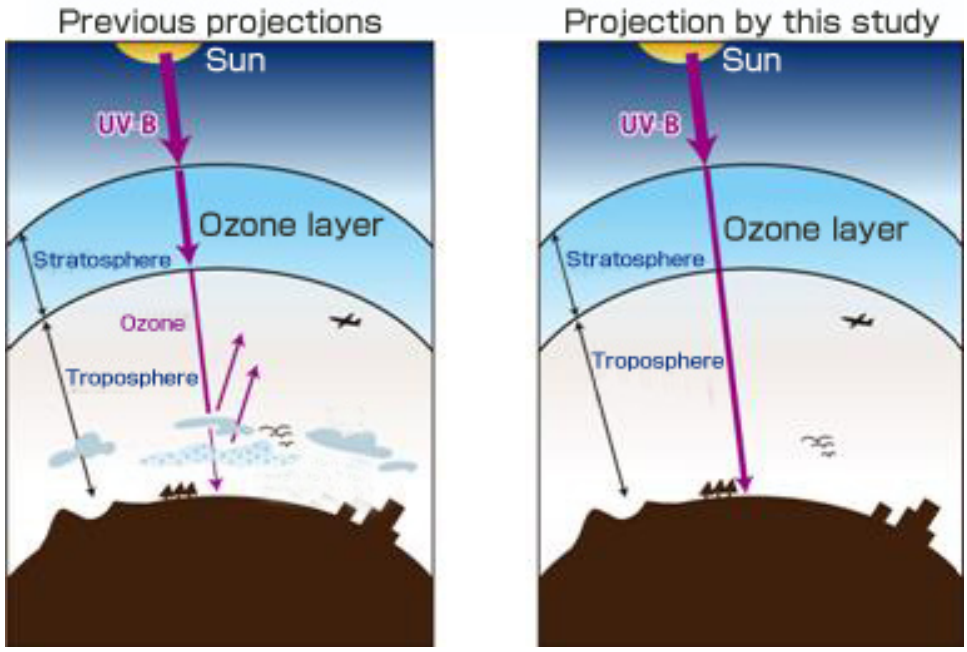

Figure 3: Components affecting UV-B radiation projection
Long-term changes in components affecting the absorption and scattering of UV radiation (e.g. ozone, aerosols and clouds in the troposphere) were not included in the previous projections.

Contacts:
Japan Agency for Marine-Earth Science and Technology
(For the study)
Shingo Watanabe, Senior Scientist
Long-term Climate Projection Research Group
Global Warming Research Project for IPCC-AR5

(For publication)
Hikaru Okutsu, e-mail: press@jamstec.go.jp
Senior Administrative Specialist, Planning Department Press Office