Ozone-climate coupling: an attribution study based on MIROC-ESM-CHEM

Alessandro Damiani[1], Shingo Watanabe[1], Hideki Okajima[1], Michio Watanabe[1]
[1]*Japan Agency for Marine-Earth Science and Technology, Japan*

We describe a recent attribution study focused on the response of the climate to the temporal evolution of the ozone hole. In this analysis we employed the Earth System Model for Interdisciplinary Research on Climate with interactive chemistry (MIROC-ESM-CHEM) comprehensive of a coupled atmosphere-ocean general circulation model as well as sea ice, marine ecosystem and land ecosystem components. Because of the prohibitive computational cost of the interactive chemistry, only few previous experiments adopted a similar complex configuration to investigate this topic, while the majority of them included the ozone hole climatology in the atmospheric component. Nevertheless, the standard configuration causes the dynamics of the model evolving without being coupled with the ozone chemistry feedback and this potentially prevents a correct evaluation of the feedbacks.

Two ensembles covering the period 1960-2050 are examined: the first ensemble includes all forcings as prescribed in the standard historical Coupled Model Intercomparison Project Phase 5 simulations while the other ensemble is analogous but with ozone depleting substances held fixed at 1960 levels. Here we show their difference that represents the response of the climate to ozone forcing. According to previous studies, our results point to a driving influence of the ozone hole on the climate of the Southern Hemisphere with an evident impact on all the components of the climate system in summer during the *historical* period (i.e. 1960-2005) and an overall effect counteracting the greenhouse gas forcing during the *future* decades (i.e. 2006-2050) under the RCP 4.5 scenario.

During the historical period the atmospheric cooling caused by the ozone depletion caused a temperature decrease in the lower stratosphere and a reduction of the geopotential height at high southern latitudes. These changes move down toward lower altitude affecting also the surface climate in summer. Indeed, summertime surface zonal winds are found to be intensified and shifted poleward, surface temperature on the east Antarctica decreased and the pattern of the surface pressure clearly reproduced the positive phase of the Southern Annular Mode. In addition, changes in both low and high clouds are coupled with variations in the radiation fields over the Southern Ocean. The poleward intensification of the westerlies also strengthens the meridional overturning circulation in the ocean, then reduced sea ice extent and changes in sea surface temperatures are associated with enhanced offshore Ekman transport and pumping. In contrast, such changes do not occur in winter. On the other hand, in spring the strong increase in the top of the atmosphere albedo caused by the ozone depletion is roughly mirrored by a contemporaneous slight increase of the surface albedo which tends to offset the increment of the downwelling shortwave/ultraviolet radiation at ground.