Abstract for the Workshop on Perspectives in Computational Climate Science
and 7th OFES International Workshop on Oct. 2-3, 2014
(University of Aizu, Aizuwakamatsu, Fukushima)

# Why do we need to consider snow-darkening effect in global models?

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NASA Goddard Space Flight Center has developed a system for Earth System Modeling, called Goddard Earth Observing System Model, version 5 (GEOS-5) (see at: http://gmao.gsfc.nasa.gov/GEOS/). Recently, the snow-darkening module for the land surface model (LSM) of NASA GEOS-5, called **GO**ddard **S**no**W** **I**mpurity **M**odule (**GOSWIM**), has been developed (Yasunari, T. J., et al., 2014, SOLA, 10, 50-56, doi:10.2151/sola.2014-011; available at: https://www.jstage.jst.go.jp/article/sola/10/0/10_2014-011/_article). The GOSWIM in the LSM can simulate the degree of seasonal snow contamination over the land surface (currently excluding glaciers, the ice sheets, and snow over sea ice) and its snow albedo reductions by the depositions of dust, black carbon (BC), and organic carbon (OC), which are known as light-absorbing aerosols (LAAs) and originate in various sources.

In this presentation, we introduce the current status of the implementation of snow-darkening effect (SDE) calculations in global models, which was recently summarized as a part of a review paper by Yun Qian, Teppei J. Yasunari, et al. (2014, Advances in Atmospheric Sciences, submitted). Moreover, based on Yasunari et al. (2014) above and a paper in preparation, we also show some examples from offline LSM/GOSWIM and online global GEOS-5/GOSWIM simulations. In addition, we further show a comparison of BC mass concentrations in snow from the review paper above among a global GEOS-5 simulation and other global model simulations.

During snow melting season (e.g., March-May in the mid-latitudes in the northern hemisphere), the land surface heating became stronger over some regions because of increased net shortwave heating caused by the existence of BC+dust+OC SDE. This suggests that if the SDE treatment is not included in global models, it may cause an underestimate of surface heating during the melting period over some regions, where stronger SDE caused by BC, dust, and OC were actually seen in our results. Hence, we encourage more global models to incorporate SDE. However, based on the review paper above, only a limited number of global models can currently simulate SDE: Of this limited number, all include BC SDE; some consider BC+dust SDE; a few incorporate BC+dust+OC (or BC+dust plus another LAA) SDE. This indicates that the comprehensive treatment of SDE in the global models is still poor. One issue that creates uncertainty of SDE in the melting season is the flushing effect on the snow impurities caused by liquid water in snowpack. A comparison in the review paper among three global models with different degrees of the flushing effect showed a wide range of BC mass concentration in the top snow layer. To reduce this uncertainty, process-oriented observational studies are essential. Therefore, the SDE-incorporated global models need more sophisticated SDE parameterizations based on future observations. In addition, the global models without any SDE implementations would be encouraged to incorporate SDE to reduce uncertainties of modeled quantities especially in the snow melting period.

## Acknowledgment

This research was supported by NASA Modeling, Analysis, and Prediction (MAP) program. The output of simulated BC mass concentration by OsloCTM2 was obtained from Ragnhild B. Skeie (CICERO). We appreciate proofreading of this abstract by Jan Angevine (ARTS at NASA/GSFC).