Cloud-boundary layer interactions over the Antarctic ice-sheet: Implications for the surface energy budget

Authorship: Manisha Ganeshan[1], Yuekui Yang[2].

[1]Goddard Earth Sciences Technology and Research Studies and Investigations, USRA, Greenbelt, MD 20771, USA; email: mganeshan@usra.edu;
[2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

Abstract

Polar regions are under increasing scrutiny owing to accelerated changes in properties of the ice and the atmosphere. Coupled land/ocean and atmospheric models are expected to represent not only the current state of the Antarctic ice-sheet, but also its evolution under varying atmospheric radiative forcing. Changes in clouds, water vapor, and the boundary layer temperature gradient (lapse-rate) can individually and/or collectively alter the surface radiation balance. Turbulent mixing in the atmospheric boundary layer can influence cloud properties (including their occurrence frequency and cloud base height). In polar regions, moreover, the surface-based temperature inversion contributes to surface warming through the lapse-rate feedback, which individually can be more significant than the positive cloud radiative forcing (Pithan and Mauritsen 2014). Yet, the mechanisms that erode the surface-based inversion have not been adequately explored. They may vary over differing cryospheric surfaces and on seasonal and diurnal timescales. During the sea ice melt season in the Arctic Ocean, the surface-based inversion appears to be eroded by mechanical turbulent mixing due to wind shear (Morrison et al., 2012; Shupe et al., 2013). When coupled with low-clouds, the mixed layer can extend up to the cloud top height where convective turbulence due to radiative cooling helps maintain the negative boundary layer lapse rate (Morrison et al., 2012; Shupe et al., 2013). This type of cloud-boundary layer coupling is expected to have a combined influence on the surface energy budget of the Arctic Ocean which needs to be duly incorporated in coupled climate models. The nature of cloud-boundary layer interactions over the Antarctic ice-sheet remains to be explored. For instance, the surface-based mixed layer in Figure 1 is not associated with mechanical or convective fluxes as indicated by positive values of the Richardson number. It is possible that horizontal temperature advection influences the boundary layer lapse rate in this case. Based on dropsonde observations from the Concordiasi campaign during spring 2010, we explore processes that influence the boundary layer lapse rate over the Antarctic ice-sheet. In particular, we investigate the role of water vapor and the influence of the solar elevation angle (including diurnal and seasonal variability). We also highlight the differences between coastal and continental boundary layer processes. The findings of our study has implications for accurate modeling of the Antarctic surface radiation and ice-sheet mass balance.

Keywords: Atmospheric boundary layer, Antarctic ice-sheet, water vapour

References

Morrison, H., Zuidema, P., Ackerman, A. S., Avramov, A., Boer, G., Fan, J., Fridlind, A. M., Hashino, T., Harrington, J. Y., Luo, Y., Ovchinnikov, M., and Shipway, B. (2011). Intercomparison of cloud model simulations of Arctic mixed-phase boundary layer clouds observed during SHEBA/FIRE-ACE, J. Adv. Model. Earth Syst., 3, M05001, doi:10.1029/2011MS000066.

Pithan, F., & Mauritsen, T. (2014). Arctic amplification dominated by temperature feedbacks in contemporary climate models. *Nature Geoscience*, *7*(3), 181.

Shupe, M. D., Persson, P. O. G., Brooks, I. M., Tjernström, M., Sedlar, J., Mauritsen, T., Sjogren, S., and Leck, C. (2013). Cloud and boundary layer interactions over the Arctic sea ice in late summer, Atmos. Chem. Phys., 13, 9379–9399, doi:10.5194/acp-13- 9379-2013.