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Summary

Arctic boundary layers - Gunilla Svensson

Large part of the Arctic is and almost circular ocean surrounded by land. The region is defined by a very large annual cycle that leads to almost completely sea-ice cover during winter and substantial ice-loss during summer. The currently changing climate is manifesting in a declining summer sea-ice minimum, at least over the satellite observed era (1979 - present). The Arctic loses about 100 Wm^{-2} to space annually, a climate in balance thus receives an equal amount from lower latitudes. The sea-ice accumulates the net fluxes at the surface and melt/freezes, a sustained net bias of 1 Wm^{-2} corresponds to 0.1 m annual melt of sea-ice (Bourassa et al., 2013).

The presence of sea-ice leads to the formation of the well-known Arctic inversion. However, this does not mean that the boundary layer always is stably stratified. There is no diurnal cycle for most of the year, transitions between different stability regimes is instead controlled by synoptic changes and clouds play an important role through their interaction with long-wave radiation (e.g. Stramler et al. 2011). Statistics from the year-long SHEBA experiment (Persson et al. 2002) show that the inversion is ground based about half of the time, while in summer it is elevated about 90% of the time (Tjernström and Graversen 2009).

There are three main challenges for modeling the Arctic boundary layer i) the heterogeneous surface conditions; ii) the clouds and their interaction with the radiation; and iii) the theoretically difficult stably stratified turbulence conditions. The Arctic boundary layer can only be correctly described if the surface energy balance and the surface fluxes of energy are well described. In the Arctic challenges concerning this are characterization of the time evolution of the albedo, the changing surface roughness, the aggregation of fluxes from open water (leads) in sea-ice covered areas etc.

The clouds are very important for the surface net radiation, with an opaque atmosphere the net radiative balance at the surface is close to zero. In clear sky conditions (or radiatively very thin clouds) the surface radiates strongly (Engström et al., 2014). The Arctic atmosphere tends to be in either of these states and it is important for the net energy in the region that these states are correctly described and that they occur with the right frequency for the energy budget at the surface (e.g. Pithan et al., 2014). The optical properties of the clouds and their presence and lifetime is the balance of many small-scale processes that are difficult to model (e.g. Morrison et al., 2012).

Modeling the stably stratified boundary layer is challenging; a subject that has been attended to by the GABLS (a part of GEWEX Global Atmospheric System Studies) for more than ten years (Holtslag et al., 2013). Most problems are found in the strongly stable regime, above a Richardson number of about 0.2 - 1 where observations still show substantial momentum fluxes (Mauritsen et al., 2007). The problem is that these fluxes are not related to the local gradient which is the standard way of parameterizing turbulence. Another problem is that these layers can be extremely shallow and are thereby not resolved by the vertical discretization of the numerical grid. In long-lived stably stratified layers, when the atmosphere is stably stratified from the surface to the free atmosphere, gravity waves are able to pass through and may also contribute to momentum transport and turbulence, for a review on this topic see Sun et al. (2015). Some recent efforts of improving modeling of the stably stratified regime (e.g. Mauritsen et al., 2007; Lazeroms et al., 2013) are not able to fully take into account the non-local nature of weak turbulent situations.

These complicated processes to capture right in models all contribute to the variability that is found in how climate models represent the Arctic climate (e.g. Karlsson and Svensson, 2011; Svensson and Karlsson 2011; de Boer et al., 2012 ; Barton et al., 2014) and how the modeled climate is changed (e.g. Karlsson and Svensson, 2013; Pithan et al., 2013). New approaches, maybe stochastic representation, and model development in the coupled system is needed to be able to better describe the Arctic Boundary Layer. For additional information on challenges in polar prediction on time scales from hours to seasons see the science plan for WWRP Polar Prediction Project (available at: www.polarprediction.net).

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