Papers

The impact of a non-uniform land surface on the radiation environment over an Arctic fjord – a study with a 3D radiative transfer model for stratus clouds over the Hornsund fjord, Spitsbergen*

doi:10.5697/oc.54-4.509
OCEANOLOGIA, 54 (4), 2012.
pp. 509–544.

KEYWORDS
Monte Carlo modelling
Stratus
Solar radiation
Spatial variability
Solar flux anomaly due to the uniform surface assumption
Nadir radiance
Hornsund
Spitsbergen
Arctic

Anna Rozwadowska⋆
Izabela Górecka⋆⋆

Institute of Oceanology,
Polish Academy of Sciences,
Powstańców Warszawy 55, Sopot 81–712, Poland;

e-mail: ania@iopan.gda.pl;

⋆corresponding author,

⋆⋆former affiliation

Received 10 June 2011, revised 18 April 2012, accepted 9 October 2012.

Abstract

This paper estimates the influence of land topography and cover on 3D radiative effects under overcast skies in the Arctic coastal environment, in particular in the

* This research was carried within the framework of Polish Research Project NN307315436 funded by the Polish Ministry of Science and Higher Education in 2009–2011.

Hornsund fjord region, Spitsbergen. The authors focus on the impact of a non-uniform surface on: (1) the spatial distribution of solar fluxes reaching the fjord surface, (2) spectral shortwave cloud radiative forcing at the fjord surface, (3) the solar flux anomaly at the domain surface resulting from the assumption of a uniform surface, i.e. the error due to plane parallel assumptions in climate models, and (4) remote sensing of cloud optical thickness over the fjord. Their dependence on spectral channel, cloud optical thickness, cloud type, cloud base height, surface albedo and solar zenith angle is discussed. The analysis is based on Monte Carlo simulations of solar radiation transfer over a heterogeneous surface for selected channels of the MODIS radiometer. The simulations showed a considerable impact of the land surrounding the fjord on the solar radiation over the fjord. The biggest differences between atmospheric transmittances over the fjord surface and over the ocean were found for a cloud optical thickness $\tau = 12$, low solar zenith angle ϑ, high cloud base and snow-covered land. For $\tau = 12$, $\vartheta = 53°$, cloud base height 1.8 km and wavelength $\lambda = 469$ nm, the enhancement in irradiance transmittance over the fjord was 0.19 for the inner fjords and 0.10 for the whole fjord ($\lambda = 469$ nm). The land surrounding the Hornsund fjord also had a considerable impact on the spectral cloud radiative forcing on the fjord surface and the solar flux anomaly at the domain surface due to the uniform surface assumption. For the mouth and central part of the fjord the error due to the use of channel 2 of the MODIS radiometer ($\lambda = 858$ nm) for cloud optical thickness retrieval was < 1 in the case of low-level clouds (cloud base height 1 km, nadir radiance, $\vartheta = 53°$, cloud optical thickness retrieved solely from MODIS channel 2). However, near the shoreline (up to 2 km from it), especially over the inner fjords, the cloud optical thickness was then overestimated by > 3 for $\tau = 5$ and by > 5 for $\tau = 20$.

1. Introduction

Precise determination of solar radiation fluxes at the Earth's surface is crucial for a wide range of scientific problems, from primary production in the sea to climate change. Although the solar zenith angle is high in the Arctic, solar radiation is still an important source of heat there. Model studies of the sensitivity of the annual cycle of ice cover in Baffin Bay to short-wave radiation showed that during spring and summer the short-wave radiation flux dominated other surface heat fluxes and thus had the greatest effect on ice melt (Dunlap et al. 2007). Simulated ice cover is sensitive to the short-wave radiation formulation during the melting phase. According to Perovich et al. (2008) solar heating of the upper ocean was the primary source of heat for an extraordinarily large amount of melting at the bottom of the ice in the Beaufort Sea in the summer of 2007.

Solar radiation is also crucial for marine and sea ice algae. Light was considered to be the most probable factor controlling the onset of the spring ice-algal bloom in the lower part of the pack ice around Svalbard (Werner et al. 2007).