Is there a positive feedback between Arctic stratus and diminishing sea ice?
Master thesis

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Contents

0.1 Abstract

This will be my abstract.
Write it later....
No more than a page and should contain:
- main findings - how it compares to others - a conclusion?

Chapter 1

Introduction

Here I will write my introduction. Something about how low clouds in the Arctic have a warming affect as opposed to the cooling effect they have on lower latitudes. This warming is due to the lack of SW radiation flux to reflect, and the emission of LW radiation flux to the ground therefore makes a greater difference.

(Something citing the IPCC report 2013 on the ice conditions in the Arctic, and something about Arctic clouds and radiation?)

1.1 Main goal

1.2 My contribution

The findings in my thesis have been achived with some of the most recently developed code (by Greg Thompson) for cloud microphysics and their effects on radiation, in modelling. The results build further on the work of many researchers @name-some-and-cite and contribute and may raise some questions for further research within the field.

1.3 Structore of the thesis

In the following chapter **??** Background I willpresent the background for my thesis; what work I hope to compare with and relate my thesis to. Also I will touch upon why the subject of my thesis is important. In chapter 2 Theory the most important theory and basic knowledge needed to understand some of the processes in clouds and their possible effect on the sea ice. Chapter 3 Model and methods is where I explain how I have worked with different

tools to get the results presented in chapter **??** which are further discussed in chapter **??**. A summary of main findings and conclusions are presented in the last chapter **??** Summary and conclusions, before the lists of figures and references at the very end.

Chapter 2

Theory

2.1 Arctic clouds

The Arctic cloud cover is dominated by low clouds @cite. Most high amounts of stratus clouds are over the oceans Klein1993. The Arctic is the only region where the season of maximum stratus does not correspond to the season of greatest lower troposphere static stability Klein1993, which could be due to lack of evaporation during the cold winter months. According to [?] stratus in the Arctic basin peaks during summer at nearly 62%, while during the winter season the stratus only accounts for 18% of the cloud cover. This leads them to conclude that the seasonal cycle of stratus in the Arctic is driven by the temperature cycle, thereby moisure content in the atmosphere, rather than the static stability.(, as opposed to other areas.)

The air in the Arctic is very stable in winter (polar night) and clean as there are not many sources for pollution. In Autumn the sea ice extent reaches a minimum after the summer melting and leave open water to influence low clouds and their properties.

Low clouds have bases below 2000 m. Stratus (St) are layered clouds that form when extensive areas of stable air are lifted. Stratus clouds are normally between 0.5 and 1 km thick, whereas they can be several km wide (@citeAguadoBurtpage188?).

2.2 Radiation and clouds

How clouds scatter and absorb SW and LW radiation. Explain something about blackbodies, clouds and blackbodies? Stefan–Boltzmanns law states that the flux density emitted by a blackbody is proportional to the fourth

power of the absolute temperature @citeLiou2002page12. For a greybody, like a cloud, the equation can be written

$$F = \epsilon \sigma T^4 \tag{2.1}$$

where the emissivity of the greybody, $\epsilon(units?)$, is included. $F(units)$ is the flux density emitted by the greybody, and $\sigma = 5.67 \cdot 10^{-8} Jm^{-2} sec^{-1} deg^{-4}$ is the Stefan–Boltzmann constant.

Write about optical depth from Wallace and Hobbs: Normal optical depth or optical thickness, τ_λ is a measure of the cumulative depletion that a beam of radiation directed straight downward (zenith angle $\theta = 0$) would experience in passing through a defined layer WallaceHobbs2006.

$$\tau_\lambda = \int_z^\infty k_\lambda \rho r dz \tag{2.2}$$

where k_λ is the mass absorption coefficient, which has units of $m^2 \ kg^{-1}$, ρ is the density of air, which has units of $kg \ m^{-3}$, and r is the mass of the absorbing gas per unit mass of air.

How do clouds reflect radiation? What is the effect of more water? Or more ice? What about the droplet size? (effective radius)
How do clouds absorb and emit radiation? Effect of more or less water or ice? Droplet size?

Ice is more effective in reflecting SW than water. Snow has a higher albedo than rain. Is there any use in presenting some albedo values for water, snow, ice? Or open water versus sea ice? New ice versus old sea ice?

2.3   Aerosol affect on clouds

2.3.1   The first indirect effect

Twomey 1974?
By increasing droplet concentration and hence the optical thickness of a cloud, pollution acts to increase the reflectance clouds Twomey1977. The optical thickness is increased when the number of CCN is increased. Although the changes are small, the long term effects on climate can be profound Twomey1974.

Meg: The optical depth will change with changes in aerosol number concentrations (aerosol content?) and changes in clouds and their properties. For instance if a cloud has many small droplets, the optical depth will be

higher. Where as fewer cloud droplets will yield a lower optical depth, resulting in more SW radiation reaching the ground — possibly having a warming effect on the area.

2.3.2   The second indirect effect

Albrecht 1989

Chapter 3

Model and methods

3.1 Model description

To produce results for the thesis, a formulation of the Weather Research and Forecasting (WRF) Model called the Advanced Research WRF (ARW) has been used, version 3.6.1. The model is developed at the National Centre for Atmospheric Research (NCAR) in Boulder, Colorado. The ARW model is the first fully compressible conservative form nonhydrostatic model designed for both research and operational numerical weather prediction (NWP) applications Skamarock2008.

3.2 Model setup

I run ARW with a horisontal resolution of 4 km, and 72 vertical layers. This resolution is sufficient to resolve clouds @citation.
The vertical layers in the ARW model are called eta levels. These levels have uneven vertical spacing, defined by @insertequation @citaion. Since the level is dependent on pressure, the height varies in both time and space. Consequently the levels in the lower troposphere are closer to each other than higher up in the troposphere. Therefore the low clouds in the area can be resolved. (@How close? what heights??)
@Area description. Sea names: Beaufort and ??. By Canada and Alaska, this is because data from the area has been used for research by others @citations. The area is not ice free any part of the year @cite, and provides a good place to simulate cloud and sea ice interaction.
The sea ice in the area was removed by editing the input file constructed? built? by WPS and real.exe, to get results to compare with results from runs

with ice.

From diminishing sea ice we might experience an increase in sea traffic, which would lead to an increase in aerosol content in otherwise clean air @citation. To include increase in aerosol concentrations due to lack of sea ice I used the microphysics scheme developed by Greg Thompson and Trude Eidhammer described in [**?**].

The scheme uses a monthly mean for aerosol number concentrations derived from multi-year (2001-2007) global model simulations @citationColarco2010??(det har de cita) in which particles and their precursors are emitted by natural and anthropogenic sources and are explicitly modeled with multiple size bins for multiple species of aerosols by the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model (@desiterteGinoux2001).

Choice of schemes and reasons should be presented. As should hos WPS and real.exe and wrf.exe works. At least short about what they do and contribute with to get to the end results. Explain some of the improvements in the micro physics scheme in combination with the revised radiation schemes (RRTMG for SW and LW).

3.3   Model runs

3.3.1   Manipulation of input files

Elaborate on removal or placing of sea ice. Elaborate on multiplying the aerosol number concentration with a factor 10. By use of ncap2 from NetCDF (NCO).

3.3.2   Changed ice run

Removed ice from the input file for the model run by using NCO and ncap2. The point of this is to compare the run with no ice to the control run, and see if there are any changes to the cloud properties.

3.3.3   Changed aerosols run

Multiplied the aerosol number concentration fields at all levels with a factor of 10 by using NCOs ncap2, using the same tool I also changed the belonging..? (tilhørende..) variables in the bdy input file (is this a building file.. or what?). The goal is to find changes in cloud properties compared to those in the control run.

3.4 Input data

E.... (ECMWF) ERA-Interim reanalysis... used as input for initial and boundary?? conditions. Downloaded by python scripts provided by Anne (more names) at the IT-help ??? at section for Meteorology and Oceanography at the University of Oslo.

3.5 Processing of the results

Figures presented in my thesis, I made (unless other is stated) by use of National Centre for Atmospheric Research (NCAR) Command Language (NCL), with a lot of help and inspiration from the example scripts for WRF-users available at (URL for examples).