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Chapter 1

Model and methods

1.1 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.

1.2 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.

1.3 Model runs

1.3.1 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).

1.4 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.

1.5 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).

Chapter 2

Theory

2.1 Arctic clouds

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?) But how high does the top of a cloud with a low base reach??

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.

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.

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?

2.3 Aerosol affect on clouds

2.3.1 The first indirect effect

Twomey 1974

2.3.2 The second indirect effect

Albrecht 1989