NUMERICAL STUDY OF AEROSOL EFFECTS IN ARCTIC MIXED-PHASE CLOUDS VIA THE LIQUID PHASE

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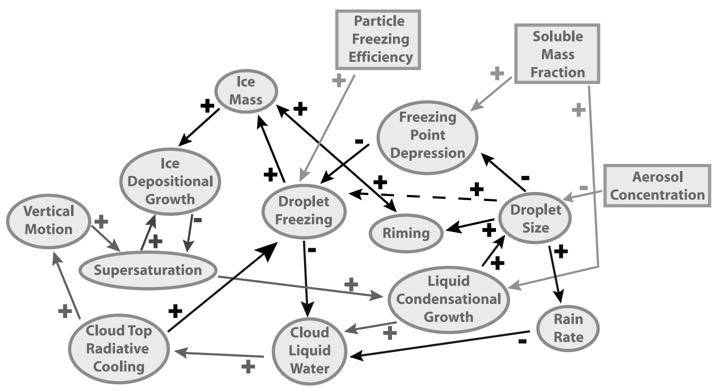
Mixed-phase stratiform clouds are commonly observed at high latitudes (e.g. Shupe 2011) and have significant impacts on the near-surface atmospheric energy budget. Observational and modeling studies (e.g. Harrington et al., 1999; Shupe et al., 2008) demonstrate strong connections between ice amount and cloud liquid lifetime. Active ice formation mechanisms in given atmospheric conditions are sensitive to aerosol properties. Arctic aerosol observations often reveal mixed particles containing both soluble and insoluble mass (Leaitch et al., 1984). Particle soluble mass fractions have been shown to be as high as 60-80% and are often made up of sulfates (Zhou et al., 2001; Bigg and Leck, 2001).

In this work, we present a model study focusing on aerosol impacts on liquid-dependent processes (e.g. droplet size distribution, droplet freezing, drizzle formation) in mixed-phase stratiform clouds. High-resolution simulations are based on a 12-hour period from the Surface Heat Budget of the Arctic (SHEBA) campaign. This time period was the focus of a recent GCSS-WMO mixed-phase stratiform cloud model intercomparison (Morrison et al., 2011) and simulations are completed using the University of Wisconsin Non-Hydrostatic Modeling System (Tripoli, 1992) in combination with advanced bin microphysics (AMPS, Hashino and Tripoli, 2008). We demonstrate the impact of aerosol properties (e.g. soluble mass fraction, concentration, freezing efficiency) on cloud lifetime, cloud water budget, and provide a general overview of the complex interactions between aerosols and liquid and frozen hydrometeors. Additionally, thoughts on the climatic relevance of these interactions will be discussed.



G7–P2

BJERKNES COMPENSATION AND ITS ROLE IN THE ARCTIC

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A vital component for maintaining Earth's climate is the meridional transport of heat through both the ocean and atmosphere, and understanding the decadal to multi-decadal changes of these transports can provide an insight into the natural variability of the climate system. In 1964, Jacob Bjerknes proposed that the total energy transported by the climate system should remain approximately constant if the ocean heat storage and fluxes at the top-of-the-atmosphere were unchanging. This would mean that large anomalies in the oceanic heat transport should be balanced by opposing variations in the atmospheric heat transport; a process later named Bjerknes Compensation.

Bjerknes compensation has been identified in the 600 year control run of the Bergen Climate Model by examining the anomalies of the implied meridional heat transports in both the ocean and atmosphere (Figure 1). These anomalies show strong anti-correlation ($r = -0.72$, $p \leq 0.05$), and a multi-decadal variability with a period of approximately 70 years. By regressing this Bjerknes Compensation signal onto maps of sea level pressure, we have identified a dipole pattern which results in strong meridional flow into the Arctic over the Greenland Sea. Similar regressions onto maps of sea ice concentrations, surface air temperatures, and ocean surface fluxes highlight part of the mechanism by which the compensation occurs through changes in the sea-ice cover. The anomalies in heat transport are found to be highly correlated ($r = 0.73$, $p \leq 0.05$) to the anomalies in Arctic sea-ice area.

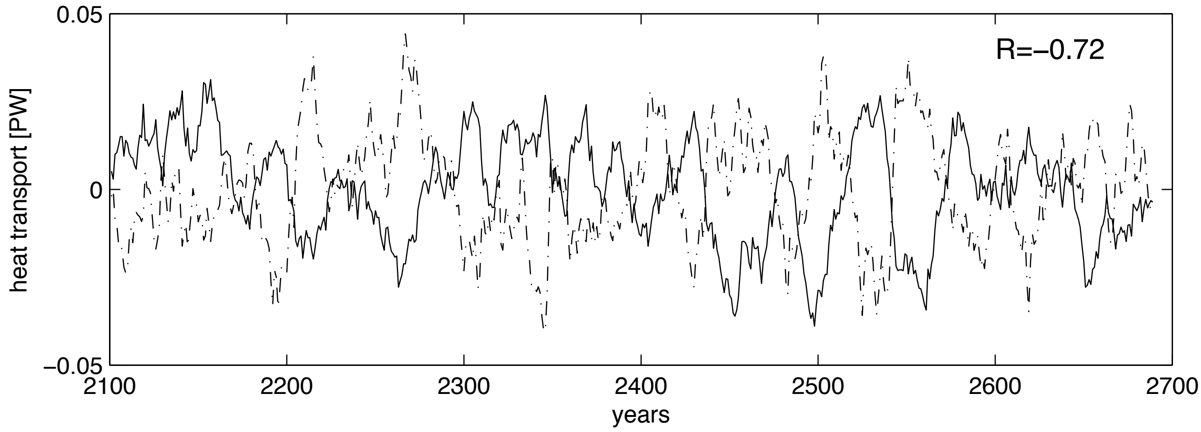

Figure 1: Meridional heat transport anomalies at 67N in the atmosphere (solid) and ocean (dashed), for the 600 year control run of the Bergen Climate Model. An 11-year running mean has been applied to highlight multi-decadal signals. The anomalies have a correlation of $r = -0.72$, $p \leq 0.05$.

G7–P3

The role of atmospheric circulation for sea ice on the Arctic by applying the CMIP3 model

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Recently the decreasing trend of sea ice extent (SIE) on the Arctic was observed and the record-low Arctic SIE was observed in September 2007. Using the NCEP/NCAR reanalysis dataset, Ogi and Wallace [2012] suggested the reason that the record-low Arctic SIE in September 2007 was lower than the SIE in September 2011 is the strong anticyclonic circulation over the Arctic which dominated in September 2007 and it isn't characterized in September 2011.

The purpose of our study is to research the role of atmospheric circulation that relates to the loss of sea ice by CMIP3.

Figure 1 shows the 925-hPa wind anomalies that regress the time series of sea ice area using CMIP3. This result shows the anticyclonic circulation over the Barents Sea and the cyclonic circulation dominating over the Laptev Sea. Furthermore it shows the flow of wind from the Chukchi Sea across the Arctic toward Fram Strait. This result is the similar pattern of atmospheric circulation that data analysis shown in Ogi and Wallace [2012].

We have analyzed that in the event of global warming, anticyclonic circulation influence decreasing the SIE or a rise in temperature by global warming influences anticyclonic circulation. We will also discuss the phenomenon influence to the mid-latitude includes Japan.

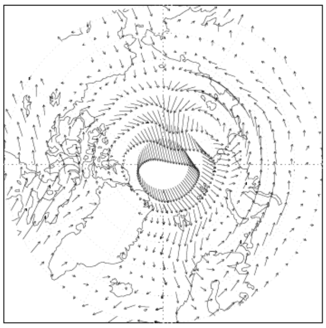

Figure 1: The 925-hPa wind anomalies that regress the time series of sea ice area in September by miroc3_2_medres (1979-2011) of CMIP3.

G7–P4

Influence of retreating sea ice on cloud cover over the Arctic Ocean during recent global warming period

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Sea ice area over the Arctic Ocean has been reducing in recent decades. Coupled atmosphere-ocean general circulation models (GCMs) also have simulated retreat of sea ice in 20th century simulations, although the reduction rate is not consistent with the observations. The Ice-Albedo Feedback is thought to have a main role in the Arctic Amplification (AA). On the other hand, the AA is affected by a feedback of downward longwave radiation at surface enhanced by an increasing cloud over the Arctic region. Observed cloud cover in the Arctic region during cold season (autumn-winter) increased due to the reduction of sea ice (e.g.,Liu*, et al.* 2012). Further, increase in cloud cover over the Arctic Ocean is related to the reduced sea ice in simulations with a GCM (Vavrus*, et al.* 2011). Therefore, understanding a relationship between the reduced sea ice and cloud cover change leads to unraveling a mechanism of the AA in the future. In this study, we investigated the relationship during recent global warming period in simulations with coupled GCM, MIROC5.

Resolution of atmosphere of the MIROC5 is T85L40, and the horizontal resolution of the ocean is approximately 1 degree. The detail of MIROC5 is described in Watanabe*, et al.* (2010). The current study used monthly mean data during 1976-2005 in 20th century simulations, in which reality-based greenhouse gas, aerosol, volcanic eruption and solar variation were prescribed.

In the simulation during 1976-2005, as the Arctic sea ice decreases with global warming, decreasing trends of sea ice area over the Arctic Ocean are found in all months. The maximum reduction of sea ice area occurs in September. On the other hand, the low-level cloud cover averaged over the Arctic Ocean increases during autumn-winter. The maximum occurs in October. In August, although retreat in sea ice appears to be similar to that in September, significant increasing trend in cloud cover is not found. From September, increasing trend of low-level cloud appears over girds with reduced sea ice. During autumn (September-November), surface air temperature increases more largely than the upper air temperature due to the reduced sea ice. Thus, stability of low-level atmosphere is weakened. This effect results in increase in low-level cloud. Also, surface water vapor increases with expanding open water surface. This can contribute to the increased low-level cloud cover.

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G7–P5

MODELING HIGH WIND EVENTS IN A REGIONAL ARCTIC SYSTEM MODEL

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As climate model resolution increases from the order of 100 km to the order of 10 km the details of high wind events, such as Greenland tip jets, are becoming increasingly well resolved in these models. Observations from these events indicate localized large heat, moisture, and momentum transfer between the atmosphere and underlying ocean or sea ice. To better understand the role of high wind events in forcing ocean and sea ice processes, such as deep ocean convection, a series of uncoupled and coupled model experiments have been designed. The model used for these experiments is the Regional Arctic System Model (RASM), based on the Weather Research and Forecasting (WRF) atmospheric model, the POP ocean model, the CICE sea ice model, the VIC land model, which will include dynamic vegetation, and the CISM ice sheet model.

Initial efforts to characterize the impact of increased resolution on high wind events has focused on several case study simulations of high wind events along the southeast coast of Greenland. In these experiments a stand-alone version of WRF was run with horizontal grid spacing of 100, 50, 25, and 10 km. The 10 km resolution simulations best matched available in-situ observations collected as part of the GFDex field campaign. For the 10 km simulation wind speeds were up to 150% greater, sensible heat fluxes were up to 340% greater, and latent heat fluxes were up to 225% greater than in the 100 km simulation. Multi-year WRF simulations on a large pan-Arctic model domain with horizontal grid spacing of 50 and 10 km have also been performed and the climatology of high wind events across this domain will be presented.

Future work will include stand-alone ocean-ice model simulations forced with ERA-Interim, WRF 50 km, and WRF 10 km atmospheric data. These simulations will be analyzed for differences in mixed layer depth and deep ocean convection occurrence. Finally, fully coupled RASM simulations at 50 and 10 km atmospheric model grid spacing will be performed and analyzed for feedbacks between the atmosphere, ocean, and sea ice during high wind events.

G7–P6

DEVELOPMENT OF AN ENSEMBLE DATA ASSIMILATION SYSTEM WITH WRF FOR THE LAND-ATMOSPHERE INTERACTION IN ARCTIC

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We are developing an ensemble data assimilation system with regional climate model WRF-ARW. This data assimilation system is focusing to reanalyze atmospheric and land components in Arctic. In this system, we employed the Maximum Likelihood Ensemble Filter (MLEF) (Zupanski, 2005) for the data assimilation method. In this presentation, we show the description of the system and a preliminary result from the developed data assimilation system.

G7–P7

LARGE SCALE VARIATIONS OF THE ENERGY-WATER BALANCE AT THE LAND SURFACE USING A WETNESS INDEX

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The large-scale distribution of energy-water balances at the surface has been examined by indirect measures, such as river discharge or evapotranspiration estimated from the atmospheric water budget. We attempted to examine the large-scale distributions and variations of the energy-water balances at the land surface using a wetness index (WI), calculated as a ratio of precipitation to potential evaporation, on annual basis. A global gridded precipitation data (GPCC) and a reanalysis data (NNRP), to calculate the potential evaporation from the energy-water balance equation, were used.

The global distribution of WI climatology from 1951-2010 (Fig. 1) agree well with the climate zones of wet and dry, as indicated in Xu et al. (2005). The interannual changes in WI had strong positive correlation with precipitation in all regions over the globe. It reveals that small changes in precipitation could result in large changes in WI in high latitudes (Fig. 2).

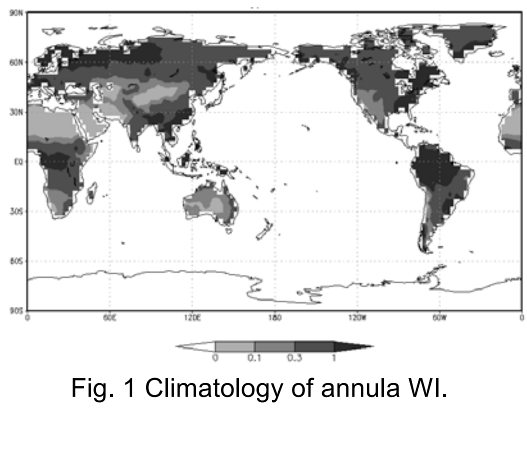

Fig. 1 Climatology of annula WI.

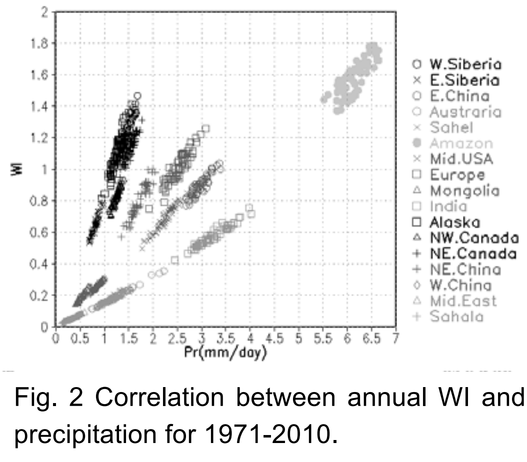

Fig. 2 Correlation between annual WI and precipitation for 1971-2010.

Reference: Xu et al. (2005) Hydrol. Processes, 19,2161-2186.

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G7-P8

Toward Hierarchical Modeling and Prediction of the Arctic Climate System

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Arctic sea ice is a key indicator of the state of global climate because of both its sensitivity to warming and its role in amplifying climate change.
Accelerated melting of the perennial sea ice cover has occurred since the late 1990s, which is important to the pan-Arctic region, through effects on atmospheric and oceanic circulations, the Greenland ice sheet, snow cover,
permafrost, and vegetation as well as it affects the global surface energy and moisture budgets, atmospheric and geosphere-biosphere feedbacks.

We evaluate available results from CMIP5 models against limited observations for their skill in representing recent decadal variability of Arctic sea ice area, thickness, drift and export. We also intercompare results from CMIP5 models with selected CMIP3 models and a hierarchy of regional ice-ocean and fully coupled climate models to demonstrate possible gains or outstanding limitations in representing physical processes of potential importance to past and present climate variability in the Arctic. We argue that the limited ability of global models to realistically reproduce some of the critical processes affecting recent warming and sea ice melt in the Arctic Ocean distorts predictability of EaSMs and limits the accuracy of their future arctic and global climate predictions. To better understand the past and present states and estimate future trajectories of Arctic sea ice and climate, we argue that it is critical to advance hierarchical arctic regional climate modeling and coordinate it with the design of an integrated Arctic observing system to constrain models.