Investigating Associations of Arctic Surface Radiation with Cloud Properties and Sea Ice Coverage based on DOE MOSAIC Campaign

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ABSTRACT

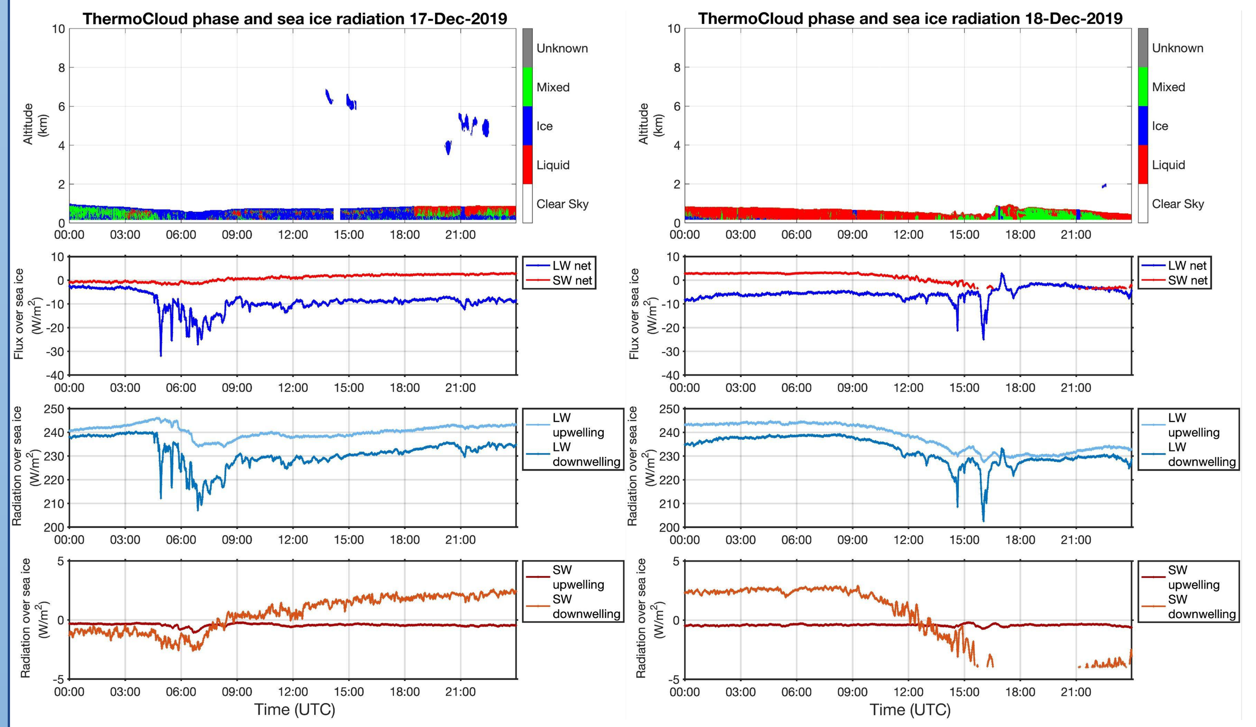
The Arctic is rapidly changing due to climate change. In fact, a unique characteristic reported for that remote region is that the Arctic air temperature increases twice as fast as the global average. Until recently, there have been gaps in knowledge in understanding the radiative effects of Arctic clouds under different sea ice conditions in various seasons, as well as how these radiative effects are related to the microphysical and macrophysical properties of clouds.

The objective of our work is to use observations from the MOSAIC field campaign to improve the understanding of the relationships among surface radiative forcing, cloud macrophysical and microphysical properties, and sea ice coverage. Specifically, we investigated how shortwave (SW) and longwave (LW) surface net radiation are affected by different cloud types (i.e., stratiform, convective, and high clouds) and different cloud phases (i.e., ice, mixed, and liquid phase). In addition, the correlations between cloud properties and surface radiation are examined for different seasons as well as different sea ice coverage. These results will ultimately improve the understanding of cloud radiative effects and their role in the future changes of Arctic sea ice coverage.

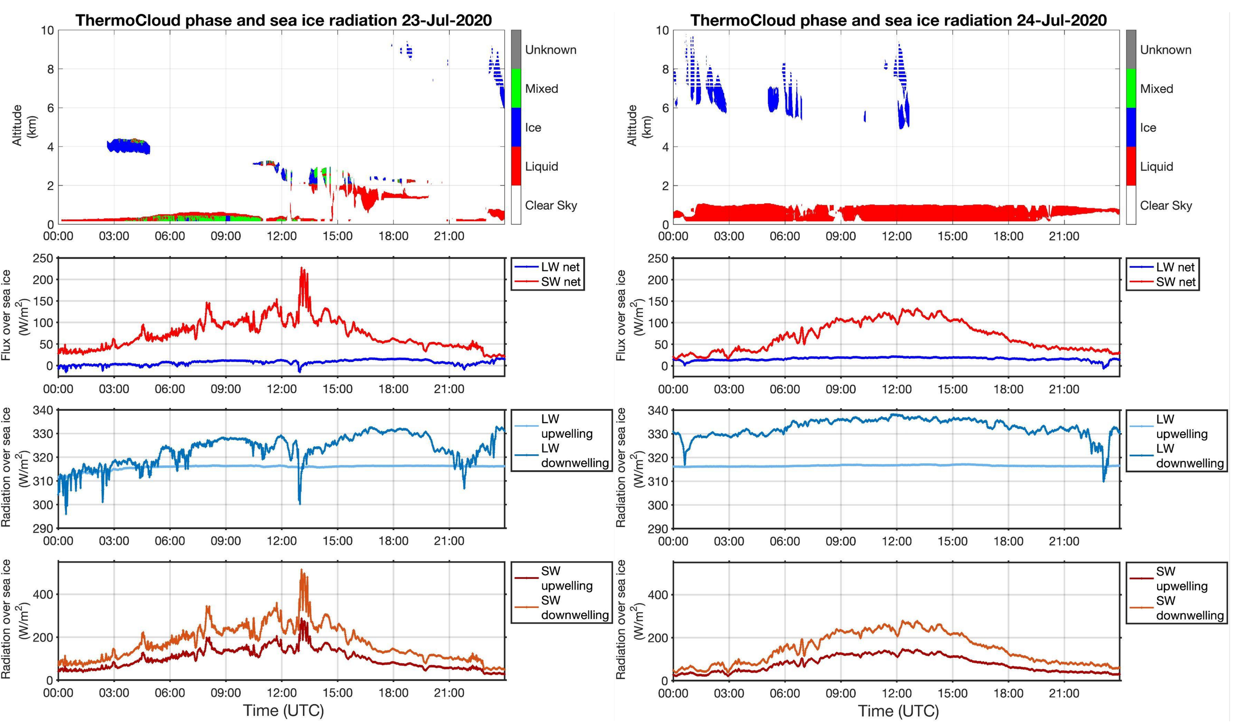
DATASET

This study used three separate data sources: MSR-E/AMSR2 Unified L3 Daily 12.5 km for sea ice concentration, Ice radiation data was obtained from an on ince instrument during the MOSAiC campaign that measured LW and SW radiation, and a Value Added Product (VAP) which was on board the campaign vessel, and it combines lidar, radar and temperature measurements to give a combined thermocloud phase data set

CASE STUDY OF CLOUD PHASE AND RADIATION IN DEC & JUL

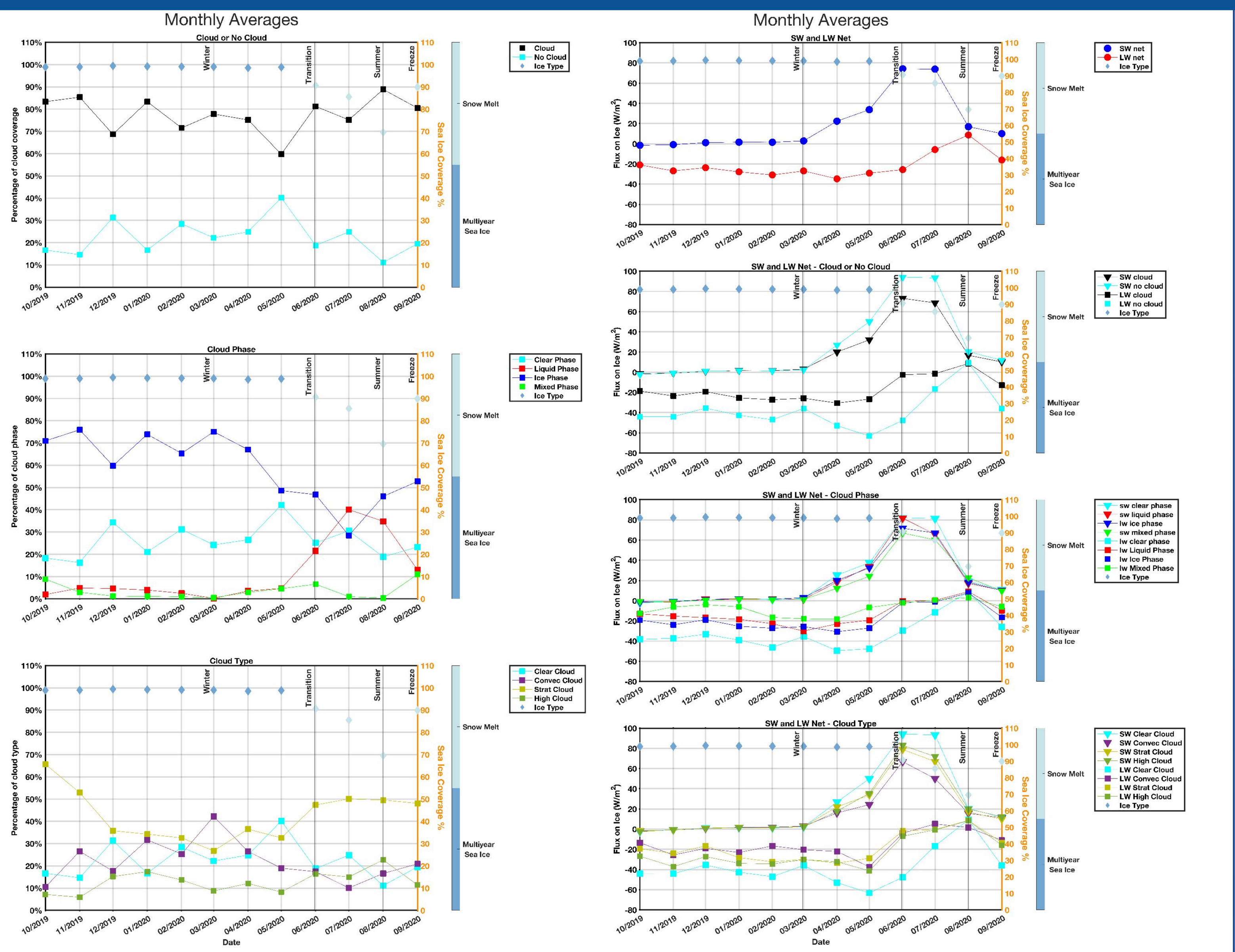


Top Left: Stratiform ice cloud. Top Right: Stratiform Liquid Cloud. This analysis shows that mixed phase clouds have a higher insulating effect on LW radiation. It also shows that liquid phase clouds have a greater warming effect than ice phase clouds

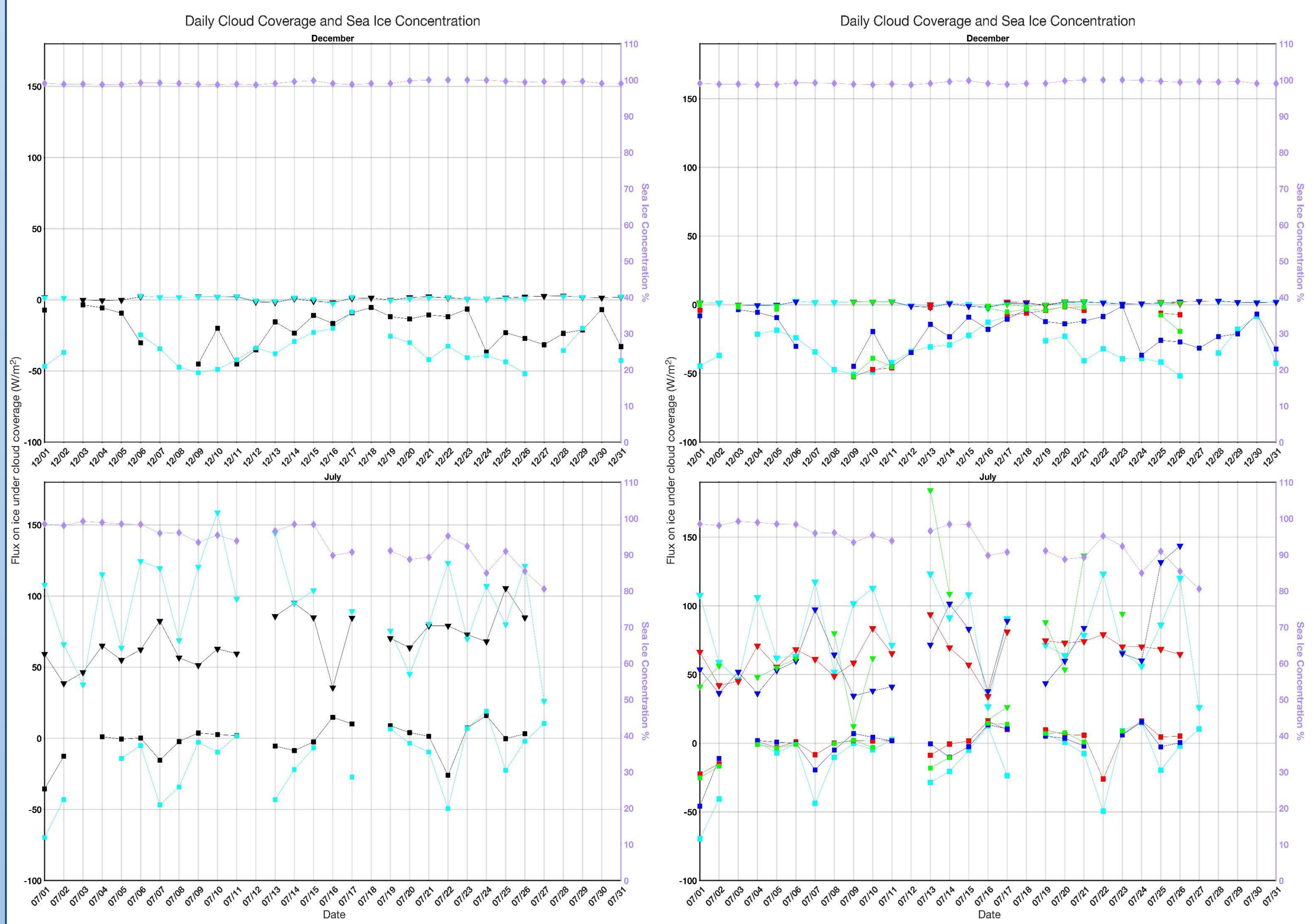


Bottom Left: Mixture of high clouds and stratiform clouds with mixed, ice and liquid phase. Bottom right: Majority liquid phase startiform cloud. The graphs show that the cloud coverage traps greater LW than the the graph on the right and reflects more SW radiation

MONTHLY AND DAILY CORRELATION BETWEEN CLOUD PROPERTIES AND SURFACE RAD

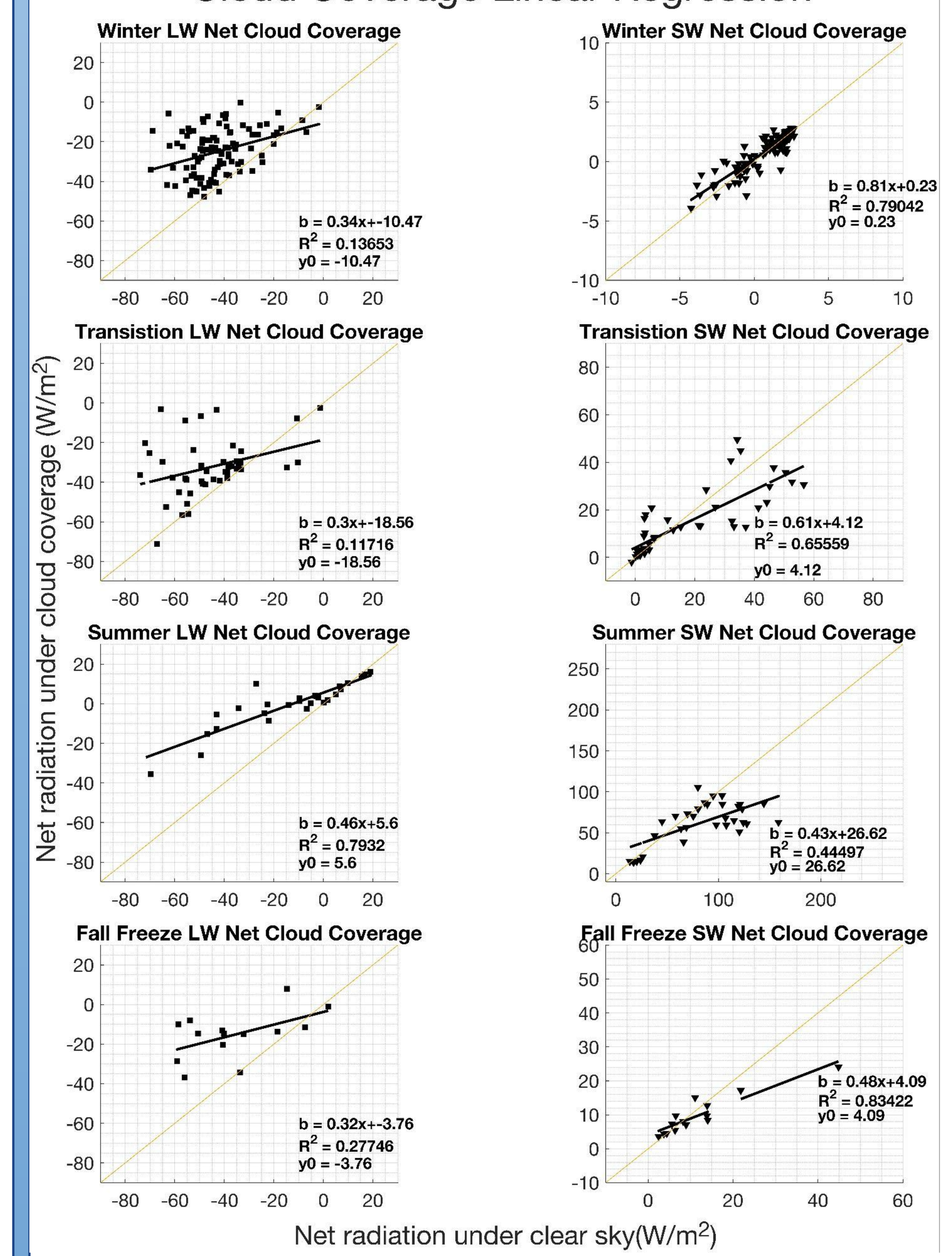


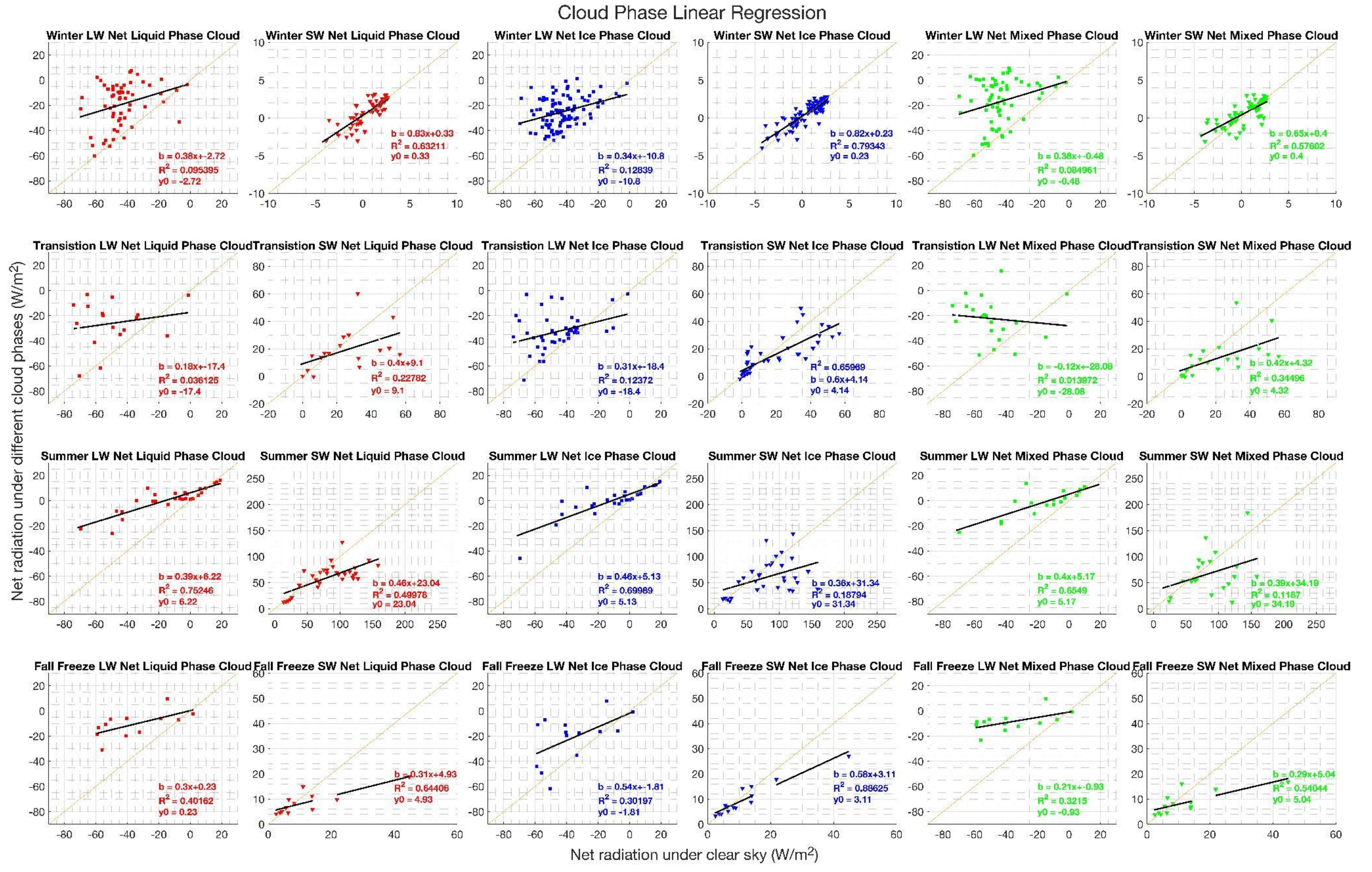
Top Left: Cloud coverage, clear sky percentage of each month during the MOSAiC campaign. Middle Left: cloud phase throughout the year. Bottom left: Different cloud types throughout year. Top right: Net LW and SW radiation throughout the year. Right Top Middle: Cloud coverage and clear skies effect on flux over sea ice. Right Bottom Middle: Cloud Phase effect on flux over sea ice. Bottom Right: Cloud type effect on flux over sea ice



Left: Daily effects of cloud coverage and clear sky on radiation over sea ice. The data shows how clouds affect LW and SW radiation. Right: Daily effects of cloud phase on radiation over sea ice. The data shows how each phase effects LW and SW radiation. The data shows that each phase can have a varied effect from day to day.

CLOUD RADIATIVE EFFECT UNDER VARIOUS CLOUD FRACTIONS AND PHASE





Left: Net cloud coverage radiation compared to net radiation under clear sky. Right: Net cloud coverage of ice, mixed and liquid phase compared to net graduation under clear sky

CONCLUSIONS

1. There is a higher percentage of cloud coverage than clear sky throughout the year,, which plays a critical role trapping LW radiation on the surface.
2. Ice clouds are the most dominant type of cloud phase with liquid clouds becoming more dominant during the summer months.
3. Mix-phased clouds on average have a higher insulating effect on LW radiation.Mix-phased clouds make up less than 10-15% of overall cloud coverage in any given month.
4. Second most common type of cloud is the liquid phase cloud, which has the second highest insulating property of LW radiation. This is important as liquid phase clouds are more common in the summer months when solar radiation and temperatures are higher. As temperatures in the arctic continue to rise, there is a possibility of having a greater amount of liquid phase clouds which trap more LW radiation.

FUTURE WORK

1. Study the linear regression between clear skies and the type of cloud type and cloud phase.
2. Compare our observed data with MOSAiC with the Energy Exascale Earth System Model (E3SM), which will allow us to compare our radiation and cloud results over sea ice to what is being modeled in climate change models.
3. Investigate difference in radiation and cloud effects over sea ice and open water during vessel transit
4. Research secondary ice production in clouds and study the transition between ice and liquid phase clouds

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