What Causes the Low-Level Cloud Increase from April to May Over the Arctic?

Ryan Haas[1,2], Paquita Zuidema[1], Will Bertrand[2], Jonah Shaw[2], Jen Kay[2],

[1]Rosenstiel School of Marine and Atmospheric, and Earth Science, University of Miami

[2]Department of Atmospheric and Oceanic Sciences, University of Colorado at Boulder

Introduction

- Knowing how Arctic clouds change throughout the year is crucial for understanding their impact on Arctic amplification.
- Understanding the spatial and vertical extent of Arctic clouds in May is very important, as May marks the onset of the melt season.
- Research suggests a link between enhanced Arctic cloud cover and sea ice loss in the fall (Kay et al., 2016). Does a similar relationship exist in the spring?

Methods

- This research focused on analyzing average variations in Arctic cloud cover from April to May and searching for changes in corresponding cloud-controlling factors
- Arctic cloud data from 2006 to 2019 was collected from the 3S-GEOPROF-COMB product created by Bertrand et al. (2024). This globally gridded data product contains cloud vertical structure data from the CloudSat radar and CALIPSO lidar. Together, this monthly dataset provides a comprehensive climatology that is perfect for visualizing patterns in Arctic clouds that emerge throughout the year.
- Arctic sea ice data (Figure 3a) is from the National Snow and Ice Data Center (Meier et al., 2021).
- Vertical potential temperature data (Figure 3b) is from NOAA Physical Sciences Laboratory, website at https://psl.noaa.gov.

Acknowledgements

This work was supported by the National Science Foundation and the University of Colorado Boulder ATOC department. The 3S-GEOPROF-COMB product created by Bertrand et al. (2024) was critical for the Arctic cloud climatology research conducted in this study. I would like to thank Jen Kay, Jonah Shaw, and Will Bertrand for their extensive support and incredible guidance throughout the research process. I appreciate the insightful contributions from Paquita Zuidema as the project continued throughout my final academic year at the University of Miami.

Results

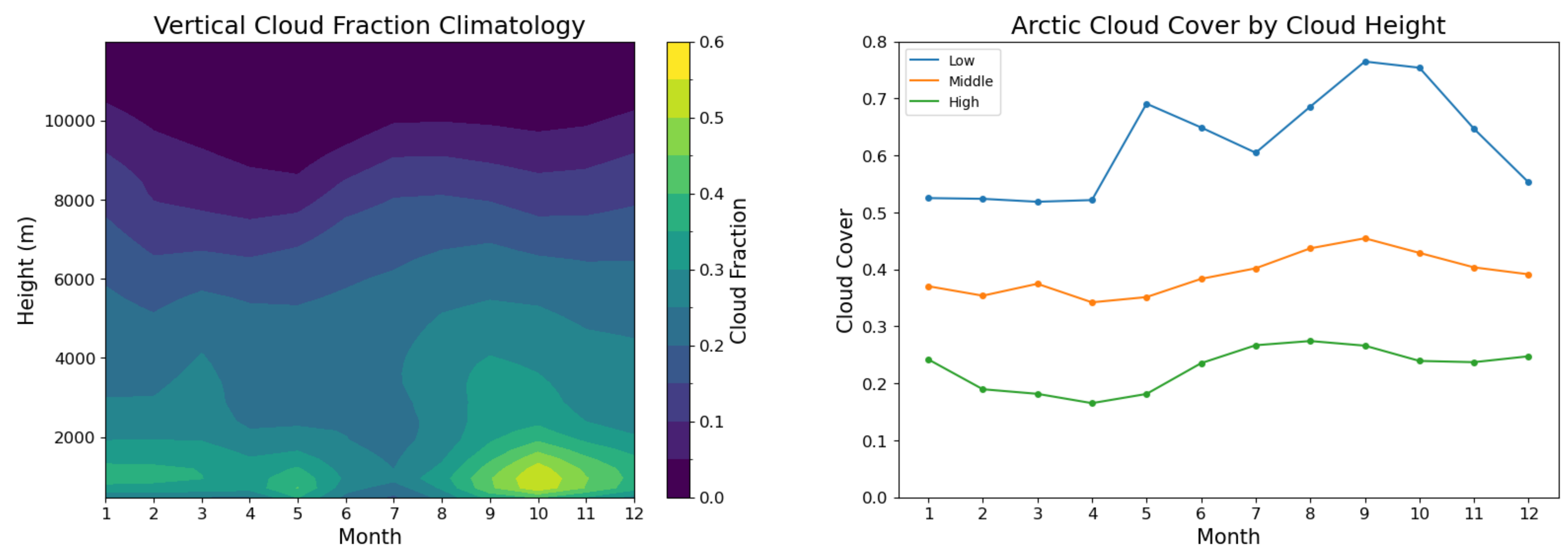


Figure 1: The figure on the left shows a vertical profile of the cloud fraction throughout the year from 360m to 12km over the Arctic (70-82N). The figure on the right shows the Arctic cloud cover throughout the year as a function of cloud height, where 'low' indicates a cloud base below 3.2km, 'middle' indicates a cloud base between 3.2km and 6.6km, and 'high' indicates a base above 6.6km.

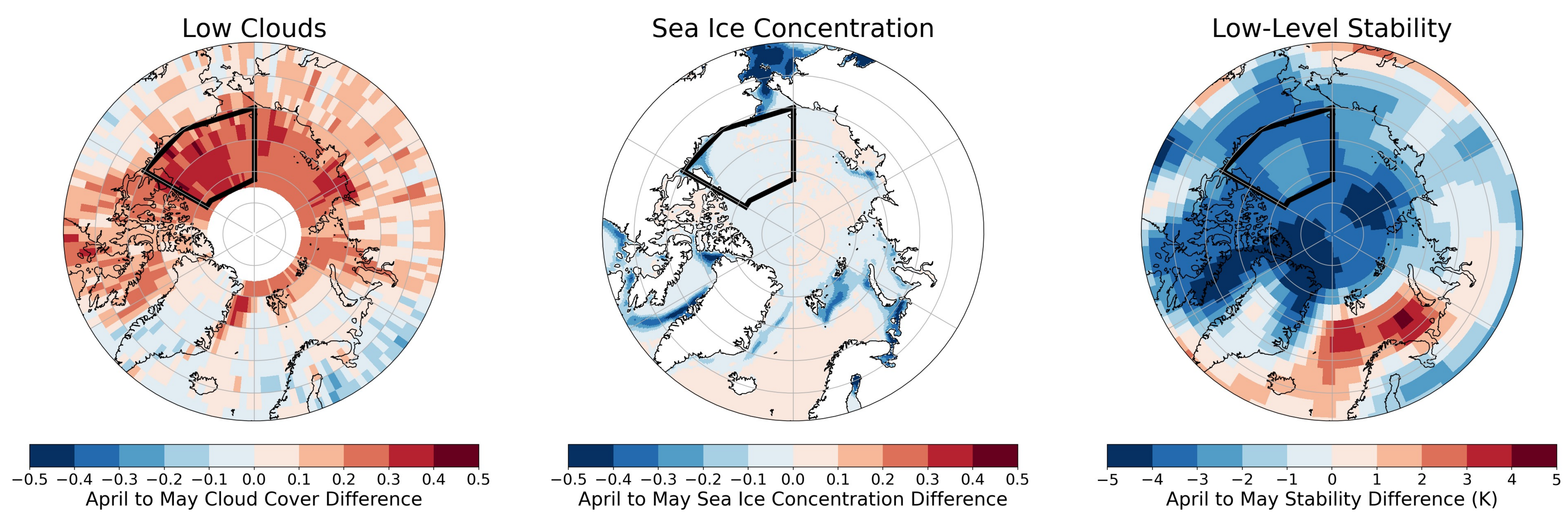
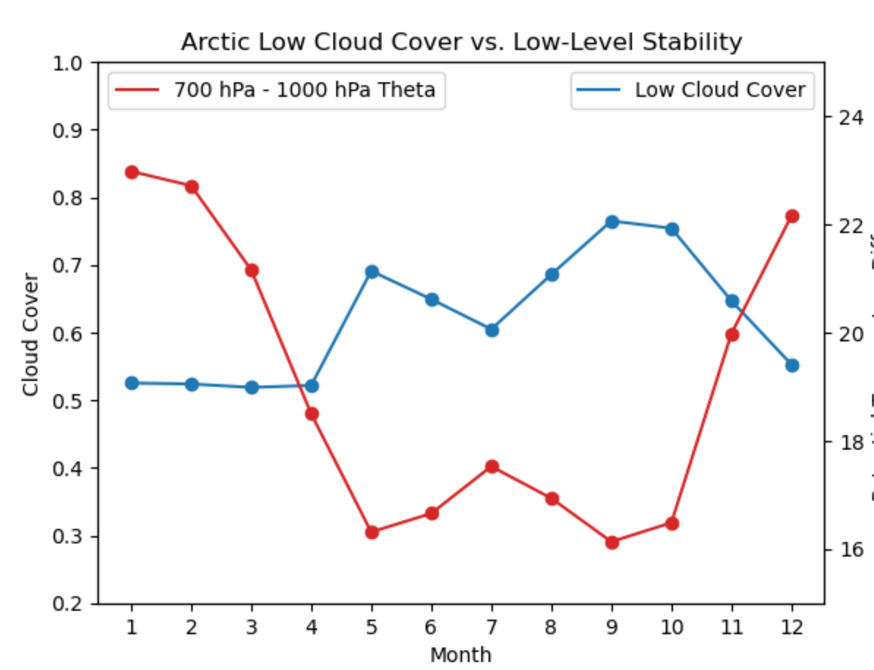


Figure 2: The map on the left shows the difference in low cloud cover between April and May. The central figure shows the May minus April difference in sea ice concentration. The figure on the right portrays the difference in low-level stability between the two months, which is represented by the potential temperature difference between 700 hPa and 1000 hPa. The black box outlines the area with the most significant low cloud cover increase.

Figure 3: The figure illustrates the variation in low cloud cover and low-level stability throughout the year across the Arctic.



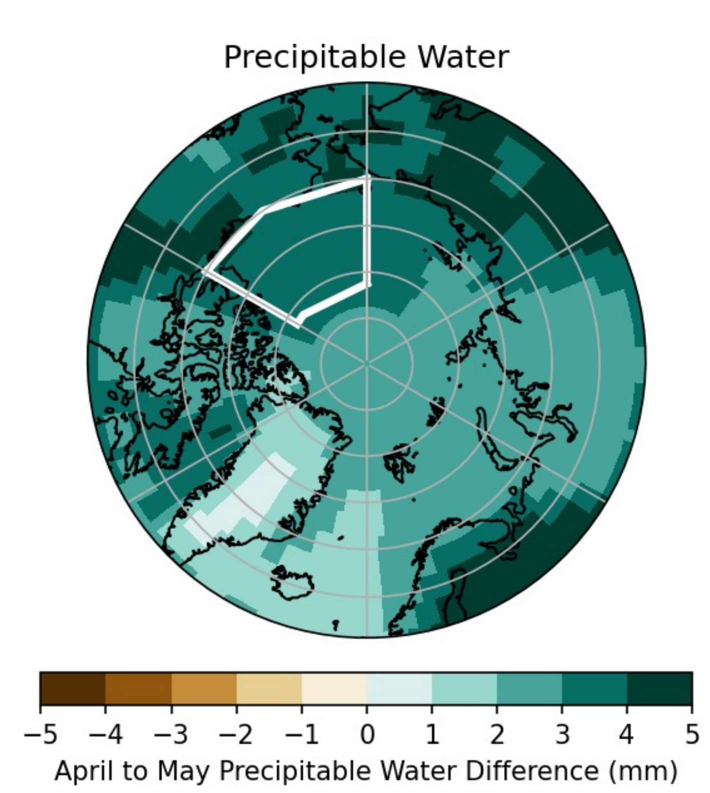


Figure 4: The figure shows the May minus April difference in precipitable water values. The white box outlines the area with the greatest low cloud cover increase.

Conclusion

- There is a notable increase in low cloud cover from April to May throughout the Arctic Ocean, which coincides with a decrease in low-level stability. This May cloud blip is not correlated with sea ice unlike in early autumn. Throughout the year, there is a negative correlation between low cloud cover and low-level stability in the Arctic.
- From April to May, the Beaufort High shifts eastward and weakens, leading to decreased subsidence over the Beaufort Sea in May. There is a southerly wind reversal at 925 hPa over Canada and the Arctic Ocean, resulting in enhanced low-level moisture advection during May.

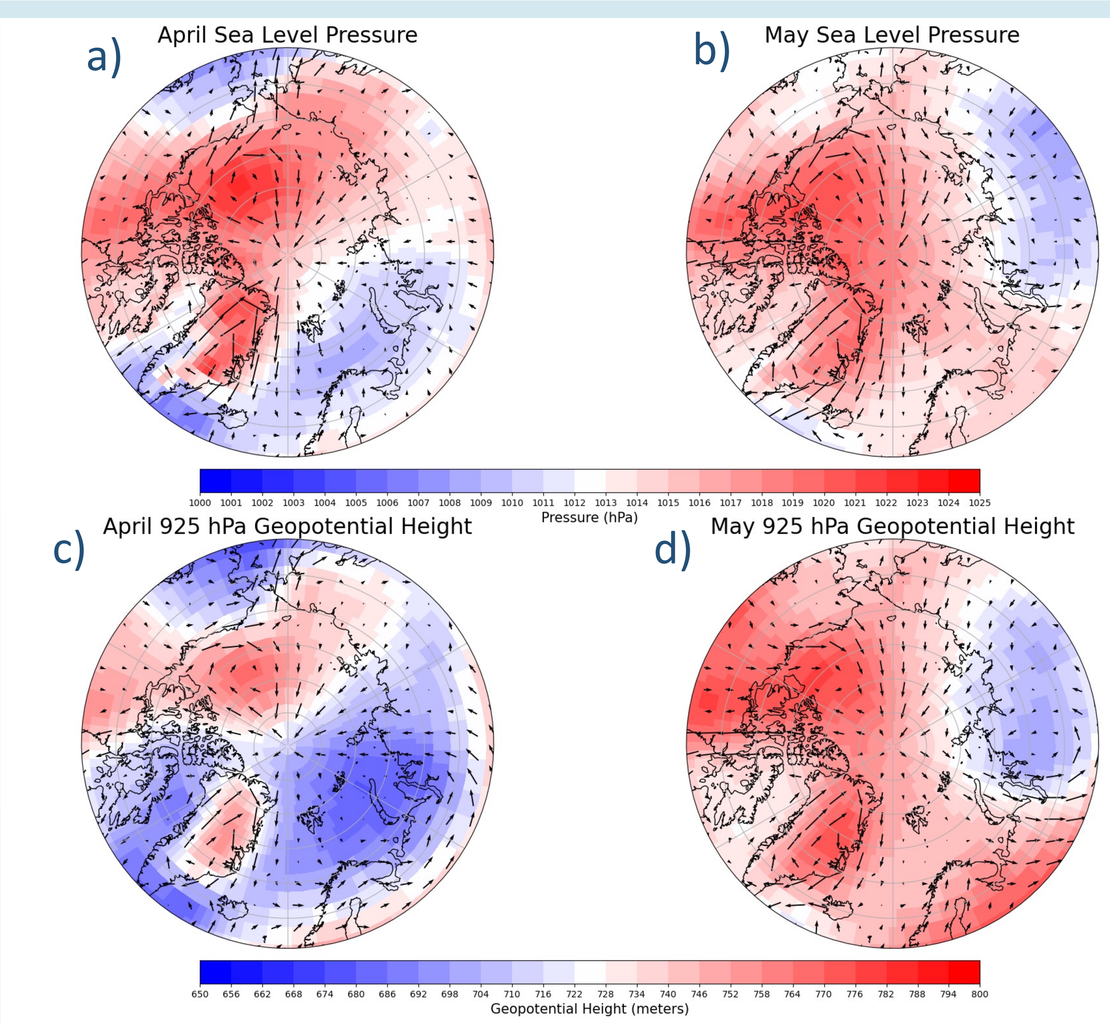


Figure 5: Figures a) and b) show the mean sea level pressure for April and May, respectively. Figures c) and d) display the 925 hPa geopotential height. The arrows indicate the wind speed and direction at 1000 hPa for a) and b), and at 925 hPa for c) and d).

References

Bertrand, L., Kay, J. E., Haynes, J., and de Boer, G.: A global gridded dataset for cloud vertical structure from combined CloudSat and CALIPSO observations, Earth Syst. Sci. Data, 16, 1301–1316, https://doi.org/10.5194/essd-16-1301-2024, 2024.

Dong, X., Mace, G., Minnis, P., & Young, D. (2000). Arctic stratus cloud properties and their effect on the surface radiation budget; Selected cases from FIRE ACE. NASA. https://www-pm.larc.nasa.gov/data/fire3/publications/xdong.JGR_FIRE99_comp_new.pdf.

Huang, Y., Dong, X., Bailey, D., Holland, M., Xi, B., DuVivier, A., J. E. Kay, Landrum L. and Y. Deng (2019), Thicker clouds and accelerated Arctic sea ice decline: The atmosphere-sea ice interactions in spring, Geophysical Research Letters, DOI: 10.1029/2019GL082791.

Kay, J. E., and A. Gettelman (2009), Cloud influence on and response to seasonal Arctic sea ice loss, *J. Geophys. Res.*, 114, D18204, doi:10.1029/2009JD011773.

Kay, J. E., L'Ecuyer, T., Chepfer, H., Loeb, N., Morrison, A. and G. Cesana (2016), Recent advances in Arctic cloud and climate research, *Current Climate Change Reports*, 2:159, DOI: 10.1007/s40641-016-0051-9.

Kalnay et. al., The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470, 1996.

Liu, Z., and A. Schweiger, 2017: Synoptic Conditions, Clouds, and Sea Ice Melt Onset in the Beaufort and Chukchi Seasonal Ice Zone. *J. Climate*, **30**, 6999–7016, https://doi.org/10.1175/JCLI-D-16-0887.1

Morrison H, de Boer G, Feingold G, Harrington JY, Shupe MD, Sulia K. Resilience of persistent Arctic mixed-phase clouds. *Nat Geosci.* 2012;5:11–7. doi:10.1038/ngeo1332.

Meier, W. N., F. Fetterer, A. K. Windnagel, and J. S. Stewart. (2021). NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 4 [Data Set]. Boulder, Colorado USA. National Snow and Ice Data Center. https://doi.org/10.7365/efmz-2t65

Yu, Y., Taylor, P. C., & Cai, M. (2019). Seasonal variations of arctic low-level clouds and its linkage to sea ice seasonal variations. Journal of Geophysical Research: Atmospheres, 124, 12,206–12,226. https://doi.org/ 10.1029/2019JD031014