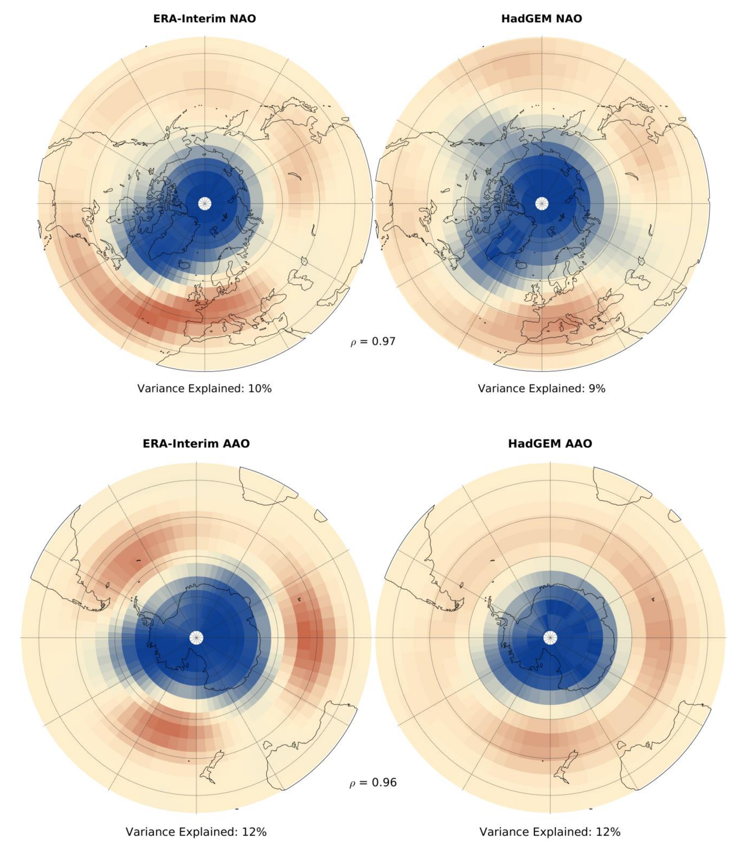
Observed and Modeled Cloud Responses to the Annular Modes

Andrew Geiss (avgeiss@gmail.com) and Roger Marchand (rojmarch@u.washington.edu) -- University of Washington, Seattle, Washington

1. Background

Clouds play a crucial role in Earth's radiative energy budget, but remain a major source of uncertainty in climate predictions. Studying how clouds respond to internal climate variability can improve our understanding of how clouds change on monthly and inter-annual time scales, provide insight into how clouds and cloud feedbacks might be altered in a changing climate, and provide a validation metric for climate models. Here, cloud responses to the Southern Annular Mode and the North Atlantic Oscillation are examined using 15 years of observations and a 25 year historical climate simulation. We use regression and clustering techniques to identify regions of the globe with distinct cloud responses to these sources of climate variability in the context of cloud occurrence histograms.



Right – Normalized loading patterns for the Southern Annular Mode and the North Atlantic Oscillation derived independently from reanalysis and from HadGEM 700hPa geopotential height anomalies.

2. Data

MISR Cloud[1] – The Multi-angle Imaging Spectro-Radiometer retrieves cloud top height and optical depth using multi-angle imaging. We use 5-degree gridded monthly global cloud fraction joint histograms between 2000-2015.

HadGEM 2 / COSP Cloud[2] – The CFMIP Observation Simulator Package was run alongside the Hadley center Global Environment Model v. 2 during a historical simulation forced by prescribed SST as part of the CFMIP 2 experiment. COSP samples the model's cloud fields by emulating MISR's cloud property retrieval algorithms. We use 5-degree gridded monthly simulated cloud fraction joint histograms from 1983 to 2008.

SAM and NAO indices are derived by applying an empirical orthogonal function decomposition to HadGEM and ERA-Interim 700hPa geopotential fields poleward of 20 degrees.

3. Method

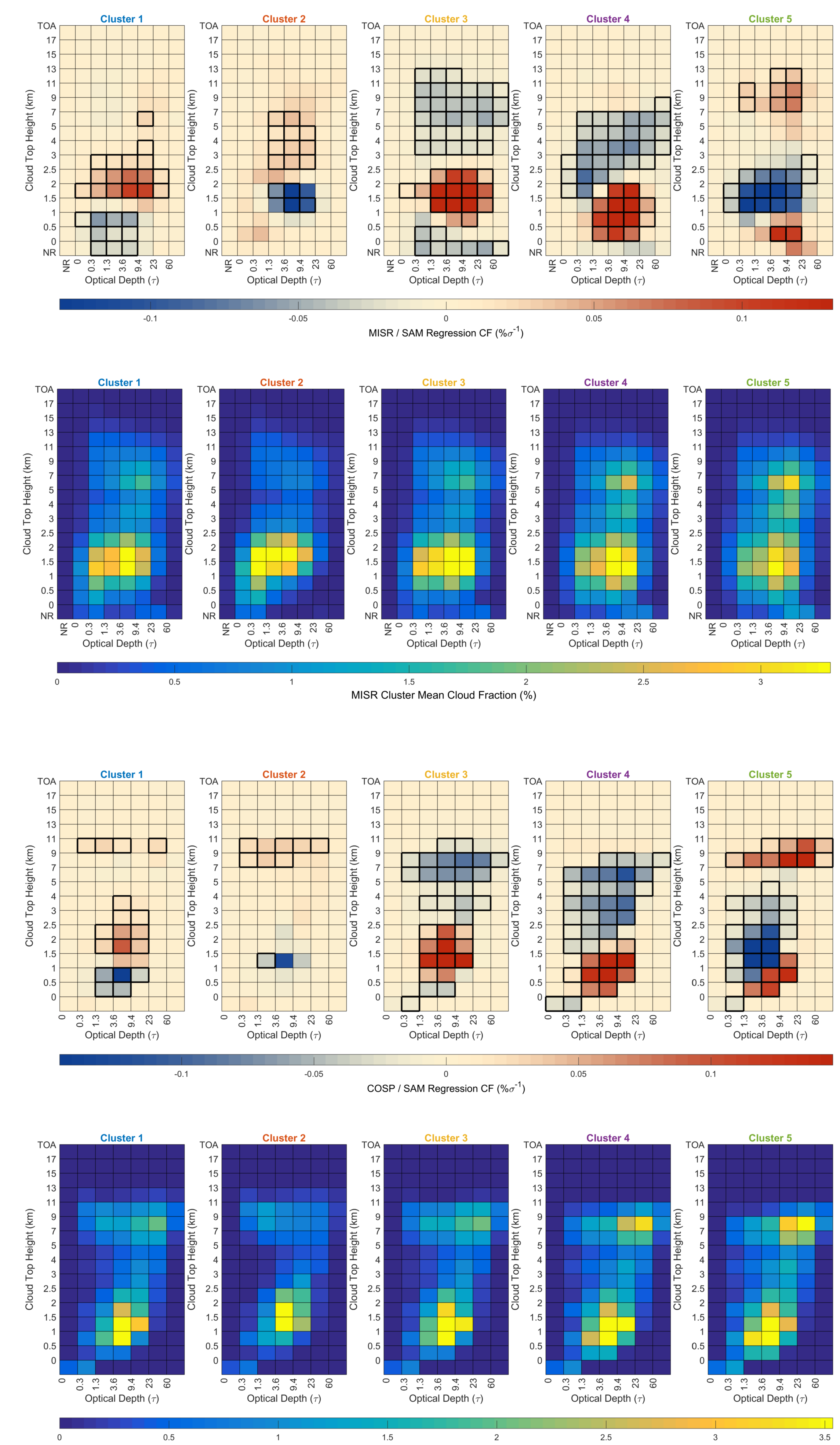
The annular modes are the primary modes of monthly to inter-annual extratropical climate variability, and different regions in each hemisphere have unique cloud responses/ interactions with these modes. Cloud fraction joint histograms are useful for evaluating these responses because they separate cloud occurrence with respect to cloud optical depth (which strongly influences shortwave cloud radiative effects) and cloud top height (which influences longwave effects).

We compute regression coefficients between the annular mode indices and cloud occurrence in each of the joint-histogram bins at each grid-point. Next we apply a k-means clustering algorithm to identify regions with similar cloud interactions with the index. The averaged regression coefficients and mean cloud occurrence for each of the clusters are shown to the right for the NAO and SAM.

4. Southern Annular Mode

Right – Cluster assignments for the SAM. Different colors are regions with unique cloud responses. Shading represents distance to cluster mean, dark shading indicates a poor match to the mean.

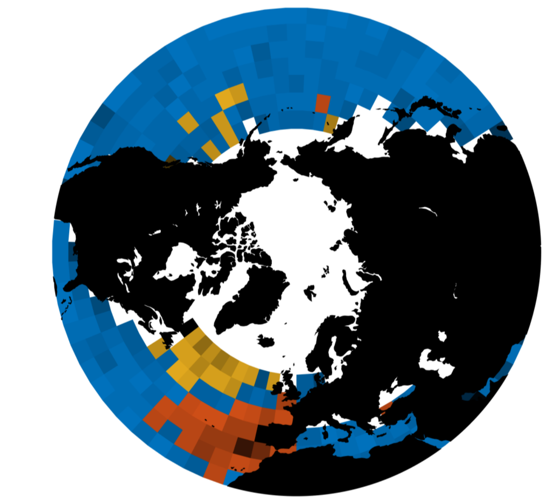
Below – SAM/Cloud regression coefficients for each cluster and cluster averaged cloud occurrence. Bold bordered bins pass a 99% confidence test.

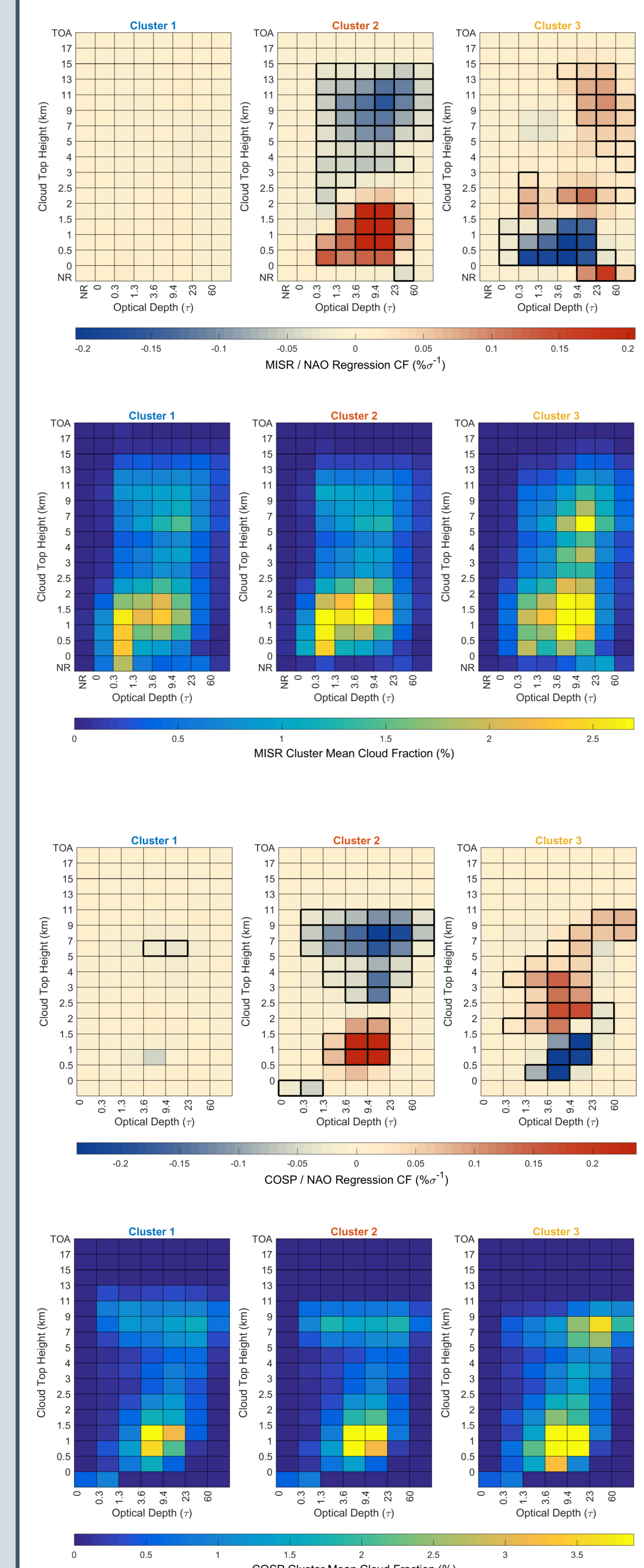


5. North Atlantic Oscillation

Right – Cluster assignments for the NAO.

Below – NAO/Cloud regression coefficients and mean cloud occurrence.

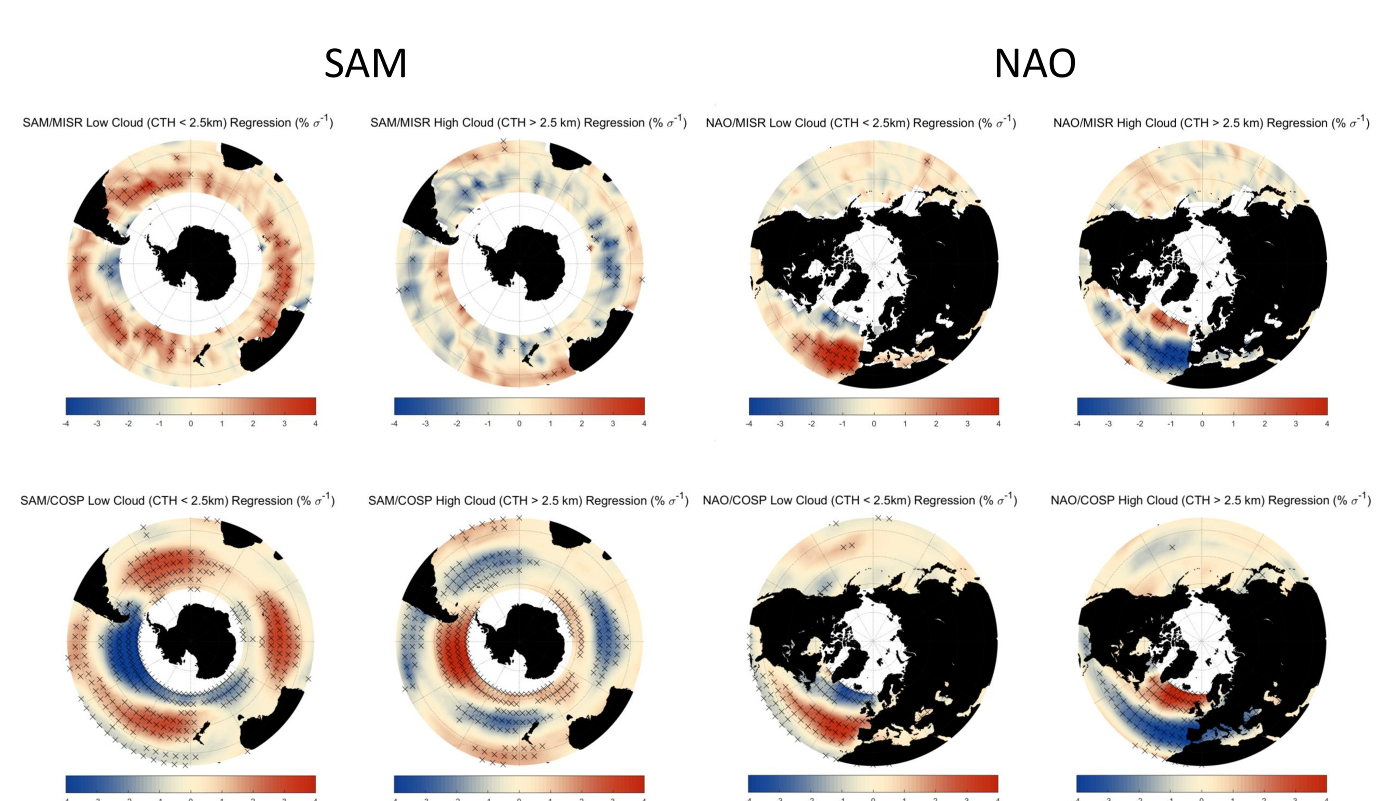




6. Conclusions

The annular modes are primarily associated with regional changes in the relative distribution of cloud with respect to cloud top height over the extratropical oceans on monthly-yearly time scales, with some small changes with respect to cloud optical thickness.

HadGEM's cloud fields respond to these modes of climate variability in a manner very similar to observed cloud, and many of the discrepancies seen in panels 4 and 5 are actually present in the model climatology or are due to differences between MISR and COSP joint histograms.



Right – Regression maps between high and low cloud (CTH greater or less than 2.5km) and the NAO and SAM, derived from MISR and HadGEM.

[1] Diner, D.J. and Coauthors (1998). "Multi-angle Imaging SpectroRadiometer (MISR) description and experiment overview." *IEEE Trans. Geosci. Rem. Sens.*, **36** (4), 1072-1087.

[2] Thank you to Dr Alejandro Bodas-Salcedo at the UK Met Office for providing this data.