# Cluster Analysis of Cloud Regimes and Characteristic Dynamics of Mid-Latitude Synoptic Systems

*N. D. Gordon and J. R. Norris*
*Scripps Institution of Oceanography*
*University of California*
*San Diego, La Jolla, California*

*C. P. Weaver*
*Center for Environmental Prediction*
*Rutgers University*
*New Brunswick, New Jersey*

*S. A. Klein*
*Geophysical Fluid Dynamics Laboratory*
*Princeton University*
*Princeton, New Jersey*

## Introduction

This study uses a clustering algorithm to group meteorological regimes by cloud properties and then identifies the attendant dynamics that have created the observed cloud field. Clustering of clouds properties is not new; Jakob and Tselioudis (2003) used a clustering routine on International Satellite Cloud Climatology Project (ISCCP) histograms of optical depth and cloud-top pressure to look at dominant modes of tropical clouds. We chose ISCCP data because of its global extent. Even though our study focuses on clouds over Oklahoma, we would like to be able to extrapolate the results globally. Our study focuses on cool season (November-March) mid-latitude clouds over land. The partitioning of meteorological regimes based on satellite-derived cloud properties has been used to examine frontal clouds (Lau and Crane 1995, 1997; Klein and Jakob 1999). Our study differs from these in that we use more than just optical depth to identify a particular regime and we are treating clouds as they would be simulated by a general circulation model (GCM). Also, we are attempting to provide a complete picture of the types of clouds present at mid-latitudes, even though frontal clouds are an important subset.

After partitioning clouds into different regimes, we can examine the meteorology that is coincident with the cloud fields to gain a better understanding of the dynamics that give rise to various cloud systems. The Constraint Variational Analysis (CVA) (Zhang et al. 2001), which is a heavily constrained reanalysis product, provides a comprehensive picture of the atmosphere over the Atmospheric Radiation Measurement Program's Southern Great Plains site.

The motivation for this study is to provide the basis to better examine model fidelity by developing an algorithm for grouping meteorological regimes by grid-box mean cloud properties. We can then focus on the shortcomings of models for each regime. We compare the cloud properties from satellite data to those simulated by the Geophysical Fluid Dynamics Laboratory Atmospheric Model (AM2), as well as individual cases simulated by the regional atmospheric modeling system. We are attempting to develop a partitioning that is more comprehensive, namely that the groups are more homogeneous and still physically based, and that it concentrates on the dynamics and thermodynamics that are important for cloud development.

The cloud regimes that are picked out by the clustering algorithm are patchy cirrus, broad cirrus, stratus/stratocumulus, nimbostratus, clear/cumulus, and mixed. Figure 1 displays the mean ISCCP histograms for each of the clusters. For each of the clusters, besides having distinct cloud properties, there are identifiable differences between the meteorology associated with each regime (not shown). To utilize this technique for analyzing model performance, we can look at the mean cloud properties as simulated by the AM2 single-column model, which is being forced by the CVA. By taking the mean cloud properties from the single-column model at the time points that fall into each ISCCP cluster, we can compare observed forcing to simulated cloud properties (Figure 2). For the clusters with the strongest forcing, the nimbostratus and stratus/stratocumulus are the most accurately simulated regimes. The clusters that are more indicative of weaker synoptic forcing, the two cirrus clusters, and the clear/cumulus, are poorly simulated.

We have demonstrated a technique for grouping regimes with identifiable meteorology, based on GCM-sized grid-box mean cloud properties as detected by a satellite. Each cluster has distinct cloud properties that can be explained by utilizing the detailed information on the atmospheric state obtained from the CVA data. Even though the sole criteria for being partitioned in a given cluster are the grid-box mean cloud fraction, cloud-top pressure, and reflectivity, there is consistent meteorology associated with these mean cloud properties.

## Corresponding Author

Neil D. Gordon, ndgordon@ucsd.edu, (858) 822-4611

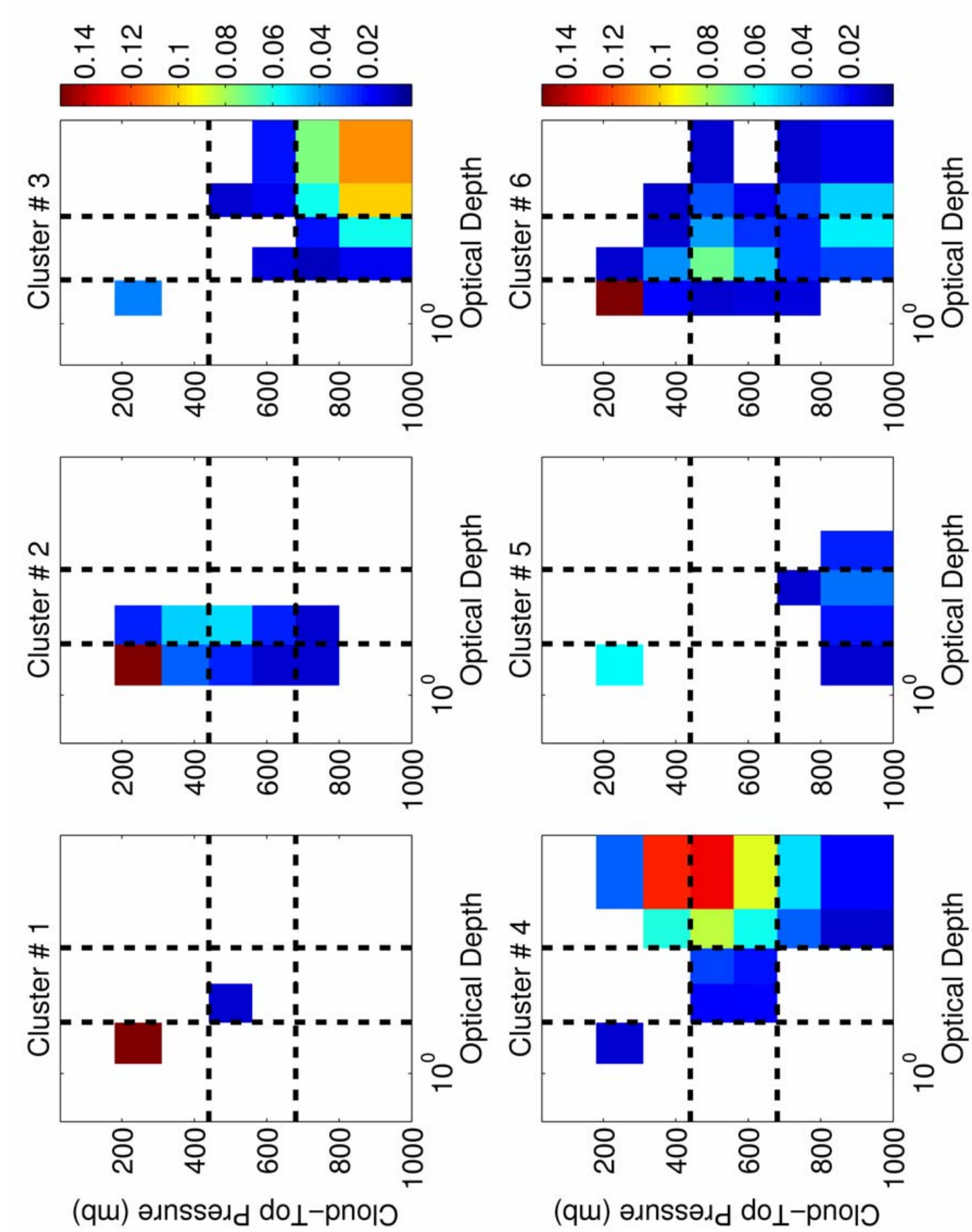
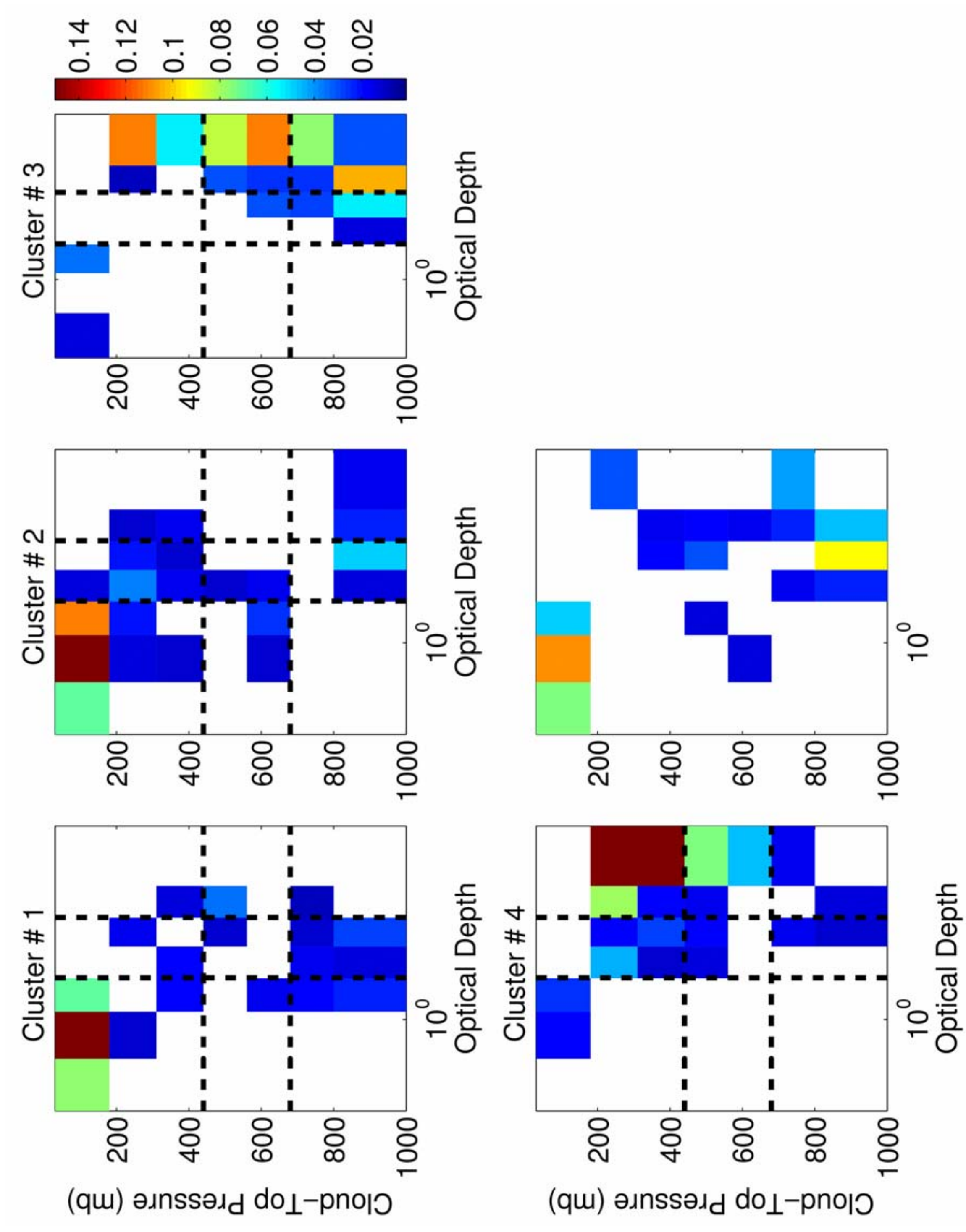

Cluster # 1
Cluster # 2
Cluster # 3
Cluster # 4
Cluster # 5
Cluster # 6
Cloud−Top Pressure (mb)
Optical Depth
$10^0$
200
400
600
800
1000
0.14
0.12
0.1
0.08
0.06
0.04
0.02

**Figure 1**.


Cluster # 1
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Optical Depth
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**Figure 2.**