N91-10497

A CLOUD CLASSIFICATION SCHEME APPLIED TO THE BREAKUP REGION OF MARINE STRATOCUMULUS

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1. Introduction

A major goal of the marine stratocumulus (MSc) segment of FIRE is to describe and explain the temporal and spatial variability in fractional cloud cover. The challenge from a theoretical standpoint is to correctly represent the mechanisms leading to the transitions between solid stratus, stratocumulus and trade wind cumulus. The development and testing of models accounting for fractional cloudiness require an observational data base that will come primarily from satellites. This, of course, is one of the missions of the ISCCP.

There are a number of satellite cloud analysis programs that are being undertaken as part of FIRE. One that has already produced data from the FIRE MSc experiment is the spatial coherence method (Coakley and Baldwin, 1984). This method produces information on fractional cloud coverage and cloud heights. It may be possible, however, to extract more information on cloud structure from satellite data that might be of use in describing the transitions in the marine stratocumulus cloud deck. The purpose of this research is to explore potential applications of a cloud analysis scheme relying on more detailed analysis of visible and infrared cloud radiance statistics.

For this preliminary study we examine data from three days during the 1987 FIRE MSc field work. These case studies provide a basis for comparison and evaluation of the technique. Later studies will involve a more extensive data set.

2. Satellite Data Set

The data used in this analysis came from the AVHRR instrument aboard the NOAA polar orbiting satellites. Daytime passes of NOAA-9 over the eastern Pacific between approximately 20° and 40° N were selected for 7 July, 10 July and 13 July. A wide variety of cloud conditions are represented in these days.

A nearly solid status deck is found on the 13th. A wide spectrum of broken cloud conditions is found on the 10th and the 7th was chosen because of coincident LANDSAT and SPOT passes on this day.

Visual (AVHRR Chan. 2, 0.8 μm) and IR (AVHRR Chan. 4, 11 μm) data are used, both having a horizontal resolution of 1.1 km at the subsatellite point.

3. Cloud Classification Method

Parikh (1977) demonstrated that spectral and textural features of visible and infrared satellite images could be used for cloud classification. Tournadre and Gautier (1988) have developed a method that uses a set of ten spectral and textural parameters to classify subscenes according to the cloud features that they contain.

For the FIRE data the method is applied to scenes of 512 by 512 pixels. Each scene is divided into subscenes of 8 x 8 pixels. The ten parameters are then derived from the visible and IR data for each subscene.

There are six spectral parameters and four textural parameters derived for each subscene. The spectral parameters are the minimum, maximum and mean for both visible and IR channels. The textural parameters are based only on the visible data. They are derived from the statistics of the differences between adjacent pixels within the subscene. The parameters are: the first and second moments of the differences (the "mean distribution" and "contrast"), and the angular second momentum (ASM) and entropy of the distribution of differences. The first two textural parameters measure the magnitude of the differences within a subscene while the latter two textural parameters are functions only of the frequency distribution of the differences.

Each parameter is normalized by the respective mean and standard deviation computed over all subscenes. The set of ten normalized parameters then defines a "profile" that may be used to classify the subscene. For display purposes the ten parameters are ordered as follows: 1-minimum value visible, 2-maximum value visible, 3-mean value visible, 4-mean distribution visible, 5-contrast visible, 6-ASM visible, 7-Entropy visible, 8-minimum value IR, 9-maximum value IR, 10-mean value IR.

A principal component analysis is then performed on all the profiles for a given scene. The method used follows that of Jalickee and Ropelewski (1978) who developed the technique for classifying atmospheric temperature profiles. Their method, which they call Typical Shape Function (TSF) analysis, is equivalent to a rotated Empirical Orthogonal Function (EOF) analysis. It produces a set of independent eigenvectors or TSFs that best represent the various profiles occurring within the scene.

After the TSFs have been found, each profile is classified by finding which TSF it is best correlated with. Each subscene is assigned a number corresponding to the TSF for which its profile matches best. Because information on the magnitudes of the variations in the parameters relative to each other has been lost in the process of normalization, it is only the "shape" of the profile that matters in the process of classification.

The classification procedure outlined above was repeated for several scenes on a given day. The TSFs from one scene are not in general identical to the TSFs from another scene. Therefore, in order to compare the classifications of multiple scenes, a common set of TSFs is required. This is accomplished by finding which TSFs are most highly correlated and therefore probably representative of the same cloud type. The regrouped TSF set consists of averages of these common types. Each scene is then reclassified on the basis of this new set of TSFs.

4. Results

The discussion here will focus on data from 10 July 1987. The area chosen for analysis (Fig. 1) was selected for its wealth of different cloud types and range of fractional cloudiness. Within the four 512 x 512 pixel scenes that make up the area, both open and closed cell clouds are evident (Fig. 2). What we seek to determine from this preliminary analysis is how well the TSF cloud classification scheme can discriminate these various cloud types.

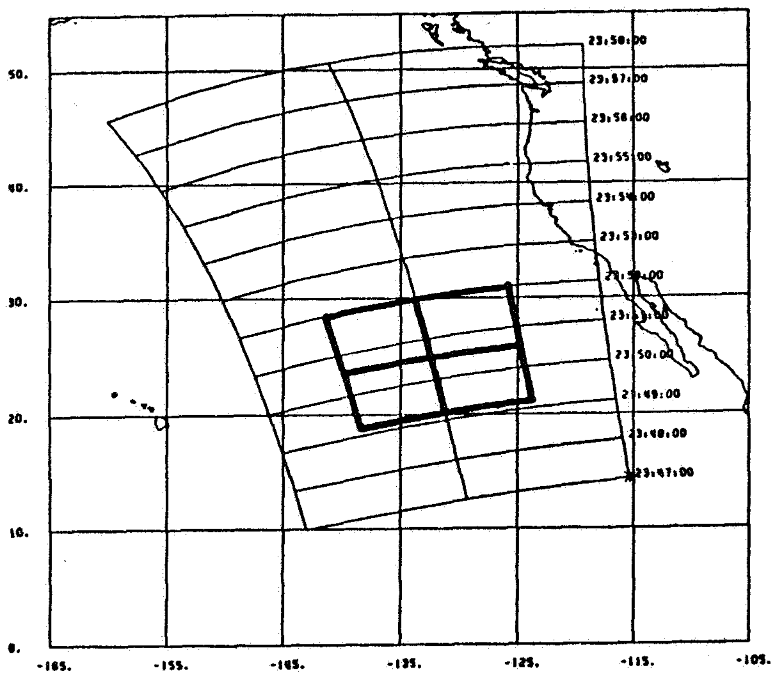

Figure 1. Location of the four scenes (bold boxes) used in the analysis for 10 July 1987.

The results are displayed in image format where each subscene is shaded according to the TSF that its profile most closely matches. A monochrome rendition of the regrouped classification of Fig.2 is given in Fig. 3.

There are nine classes in the regrouped classification. The TSFs for 3 of these classes are shown in Fig. 4. Regions of unbroken low cloud are shaded white in Fig. 3 and correspond to TSF class 1. There appears to be a band that is clear of clouds running horizontally in the lower half of Fig. 2. From Fig. 3 we see that this corresponds to class 4. Class 3 occupies a large fraction of the upper right quadrant. Examination of Fig. 2 shows that these are partly cloudy regions with small cloud sizes.

The class 1 profile (Fig. 4) has high visible spectral parameters and low IR parameters, as expected for radiation from a solid cloud. The texture parameters all indicate relatively homogeneous conditions. Class 4 has low visible and high IR spectral parameters as would be expected for radiation

Figure 2. Channel 4 (IR) imagery for the four scenes shown in Fig. 1.

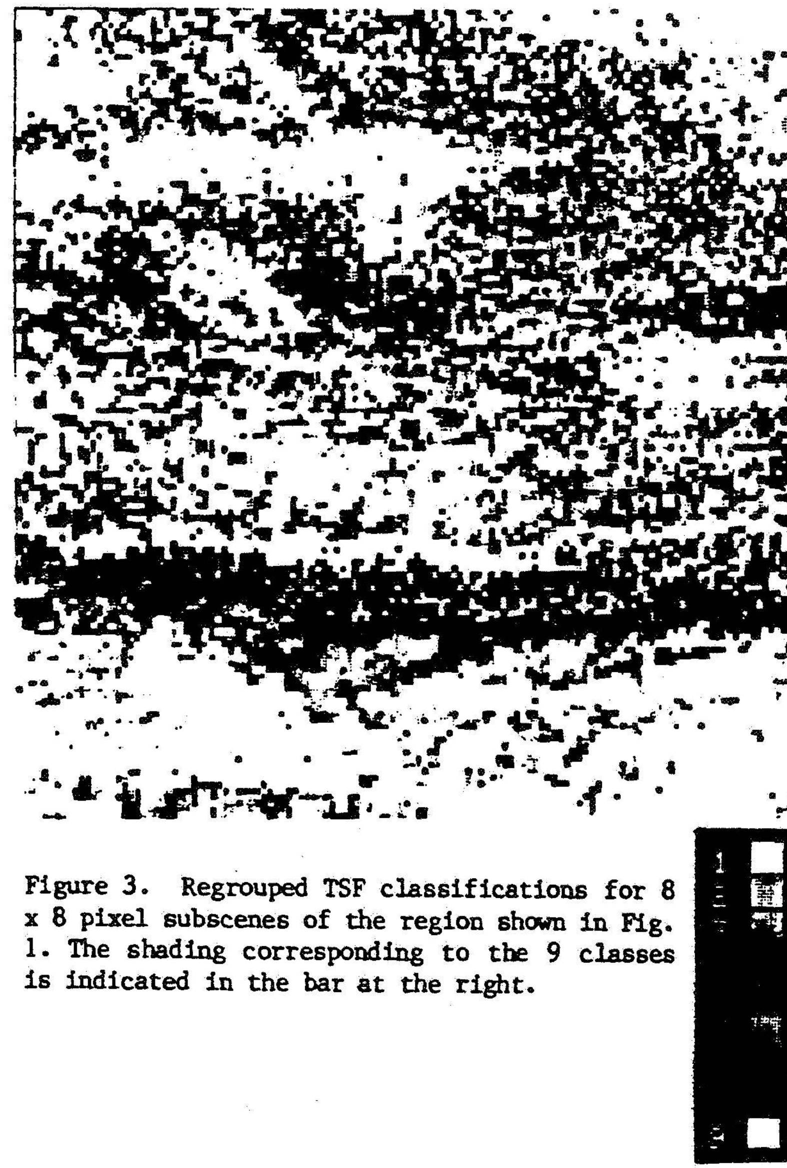

Figure 3. Regrouped TSF classifications for 8 x 8 pixel subscenes of the region shown in Fig. 1. The shading corresponding to the 9 classes is indicated in the bar at the right.

from the ocean surface. The textural parameters indicate even more homogeneous conditions than for the unbroken cloud case (very high ASM and very low entropy). Class 3, the small broken cloud cover case, has a low normalized visible minimum like the clear case, but higher normalized maximum and mean, comparable to the unbroken cloud case. IR spectral parameters are midway between the clear and unbroken case. What most distinguishes this class from the other two is the magnitude of the textural parameters. In all, this profile indicates a subscene containing some clear areas but one that is largely filled with low inhomogeneous clouds of small size.

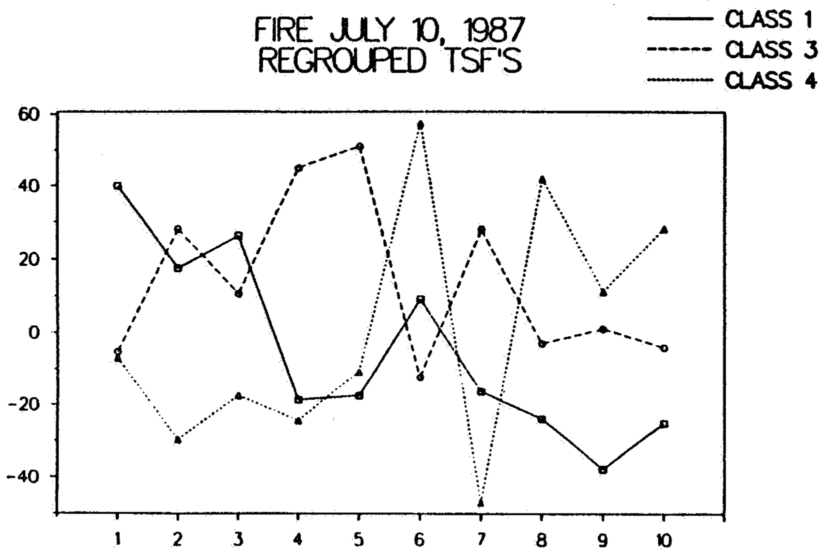

Figure 4. Profiles of the TSF parameters for three of the classes in Fig. 3. Class 1 is solid low cloud, class 3 is small broken cloud and class 4 is clear.

5. Summary

The marine stratocumulus regime, as represented in the small sample examined for this study, contains a sizable number of distinctly different cloud types. We have demonstrated that a TSF analysis can objectively discriminate a number of these cloud types on the basis of spectral and spatial statistics.

One application of this technique that we foresee is a description of the stages that the cloud layer goes through as it breaks up. Such a description will help in developing models of this process. Through intercomparisons with in situ measurements it may be possible to relate these cloud types to the thermodynamic properties of the cloud layer.

In the future we plan to incorporate observations from FIRE aircraft and other satellites in refining the technique. Eventually, the TSF cloud signatures identified in this study will be added to a TSF data base being developed from analyses done with data from various cloud regimes around the globe.

6. Acknowledgments

This work is support by the Marine Meteorology Program of the Office of Naval Research. We wish to thank P. Collard, J. McPherson and D. Hooper for their assistance.

7. References

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