A New Method to Evaluate Cloud Fraction within Marine Stratocumulus Clouds

Poster ID A53M-0334

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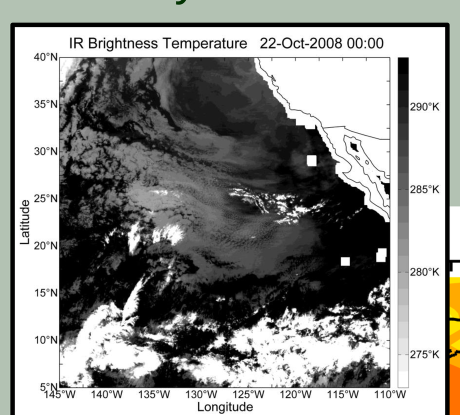
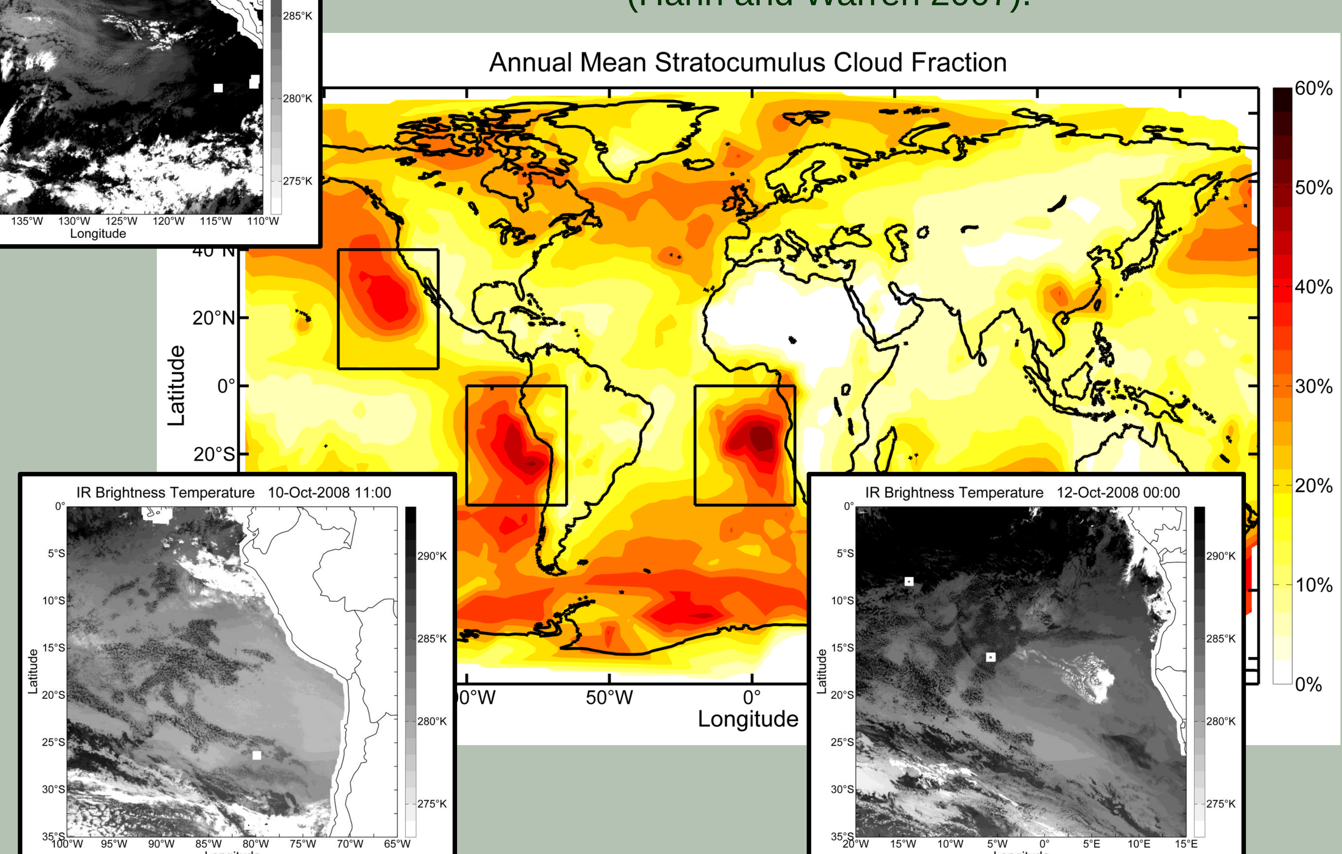
I) Motivation

Cloud fraction is the largest determining factor in the radiative impact of marine stratocumulus (de Szoeke et al. 2012). Analysis of the causes of cloud fraction variability in each of the three dominant marine stratocumulus regions (subtropical oceans in the Southeast Pacific, Southeast Atlantic, and off the southern coast of California) will help to clarify similarities and differences between the regions. By identifying the time and space scales across which cloud fraction varies, we hope to isolate and understand the relative roles of specific processes thought to be important in transitioning between broken and unbroken cloudiness.

Our ability to perform a consistent analysis of cloud fraction across all regions is currently limited by lack of a uniform data set. Visible satellite imagery is not a viable method at night when processes that might impact cloud fraction, such as precipitation, are most active. We are proposing a new methodology to determine pixel scale cloudiness using infrared brightness temperatures. This new method can be uniformly applied to all three regions and functions well across the diurnal cycle.



Annual mean stratocumulus cloud fraction and examples of the stratocumulus cloud decks in each of the three primary regions. Cloud fraction data are from the cloud atlas database (Hahn and Warren 2007).



II) Data

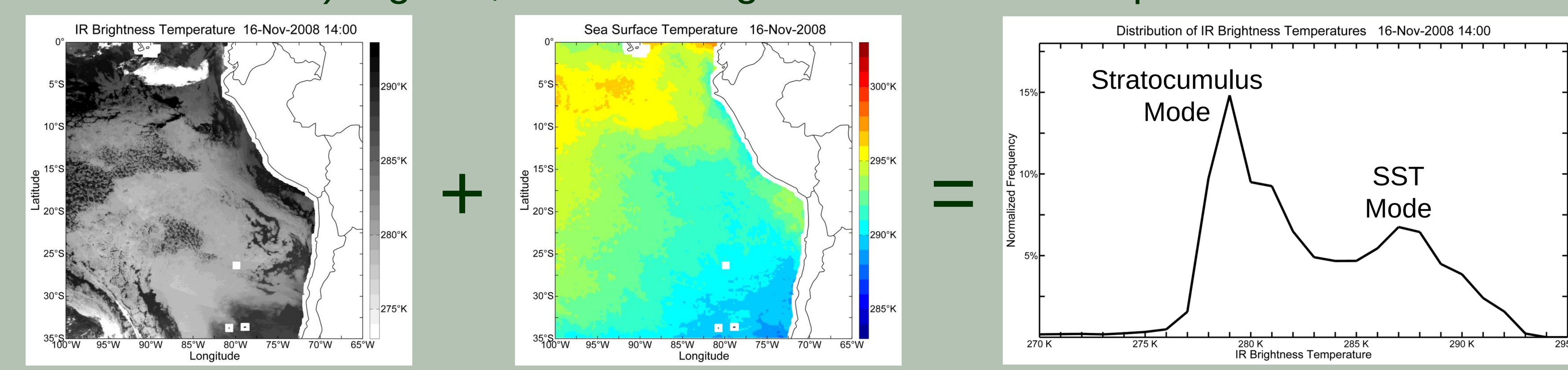
The primary dataset for this project is the NCEP/CPC 4-km Global IR Dataset. This product merges IR brightness temperature observations from multiple geosynchronous satellites (GOES, METEOSAT, and GMA) into a uniformly gridded product, correcting for the zenith angle dependence to minimize spatial discontinuities at the seams between satellite coverage areas.

Availability	February 2000 – Current
Spatial Coverage	60°S - 60°N,180°W - 180°E
Spatial Resolution	4 km x 4 km
Temporal Resolution	30 min

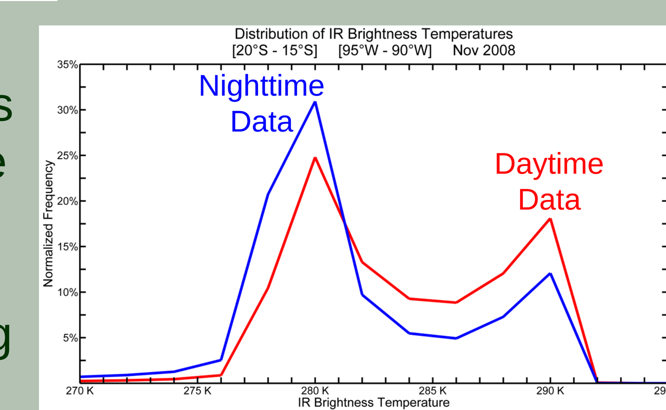
This research was supported by a NASA Earth and Space Science Fellowship NNX10AP43H, DOE grant DESC000701, NASA grant NNX11AE98G, and NOAA grant GC08-252b. Contact: cdburley@ncsu.edu

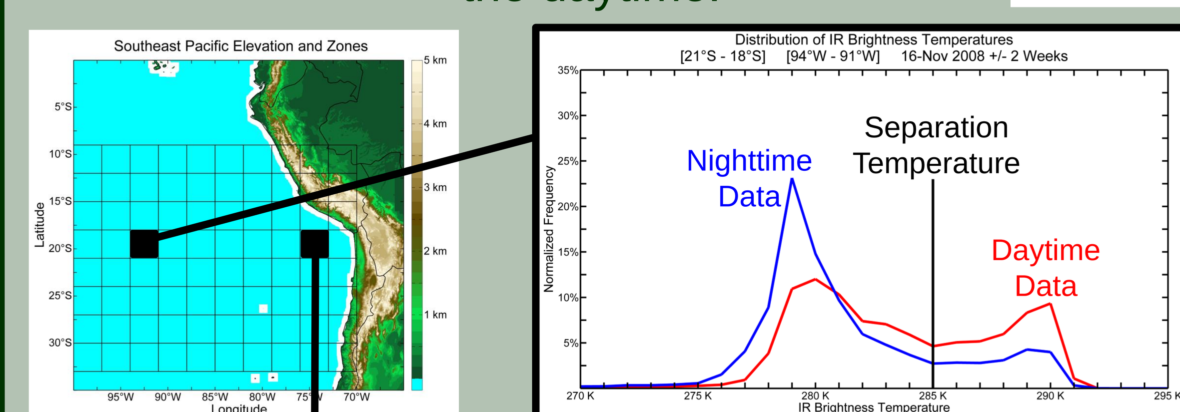
III) Cloud Fraction Methodology

The nearly uniform emission temperature of the stratocumulus cloud deck combined with relatively homogenous underlying sea surface temperatures yields a bimodal distribution of IR brightness temperatures for most scenes. By finding the temperature that separates the two modes, we can split the brightness temperature field into cloud (pixels colder than the threshold) and ocean (pixels warmer than the threshold) regions, thus creating a cloud fraction map for each scene.

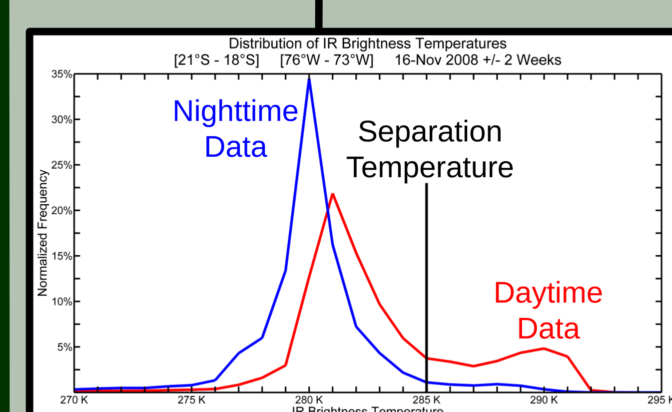


Aggregating the single scene distributions in space and time allows for a cleaner separation between the two modes. A diurnal transition in cloudiness also becomes apparent as more ocean shows through during the daytime.

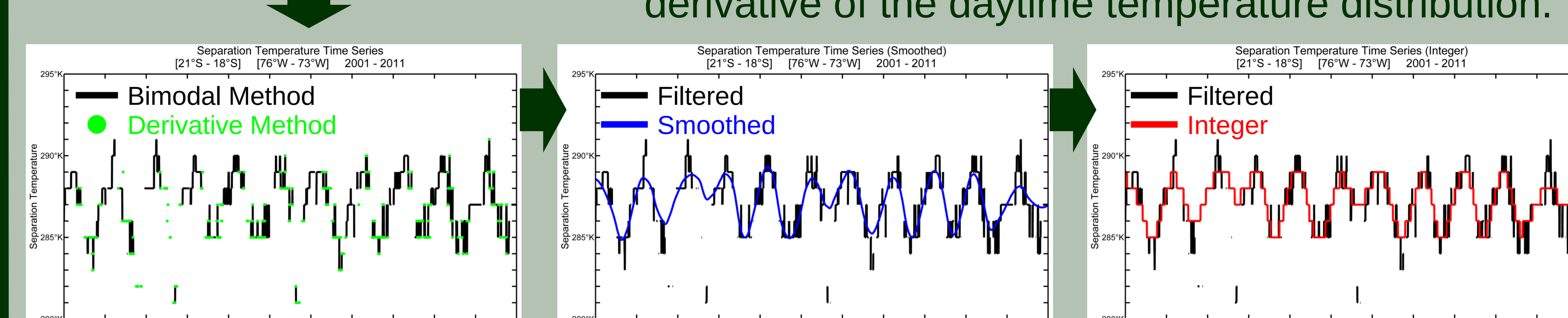




Distributions were created over a moving 4 week window for 3°x3° boxes that covered the largest stratocumulus areas within each of the three regions.

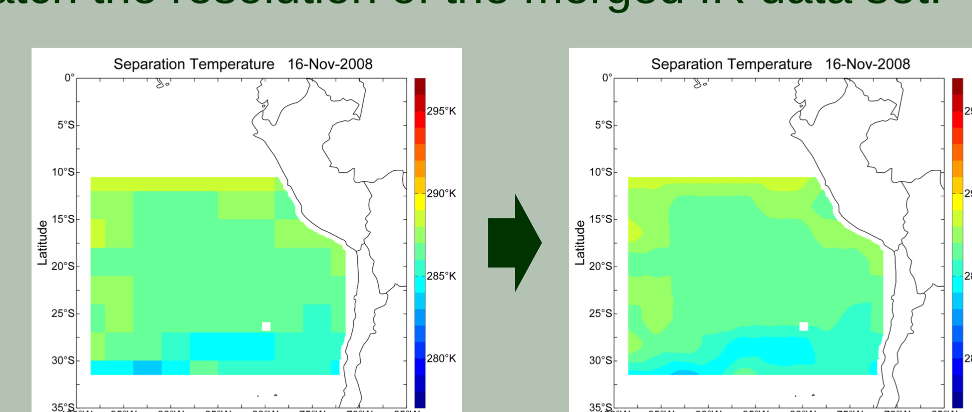


If the distribution showed a clear bimodal structure (such as in the example on the upper right), the separation temperature value was defined to be the minimum in the daytime brightness temperature frequency between the two modes. If two modes were not apparent (such as in the example on the lower left), the separation temperature was defined as the inflection point identified by taking the derivative of the daytime temperature distribution.



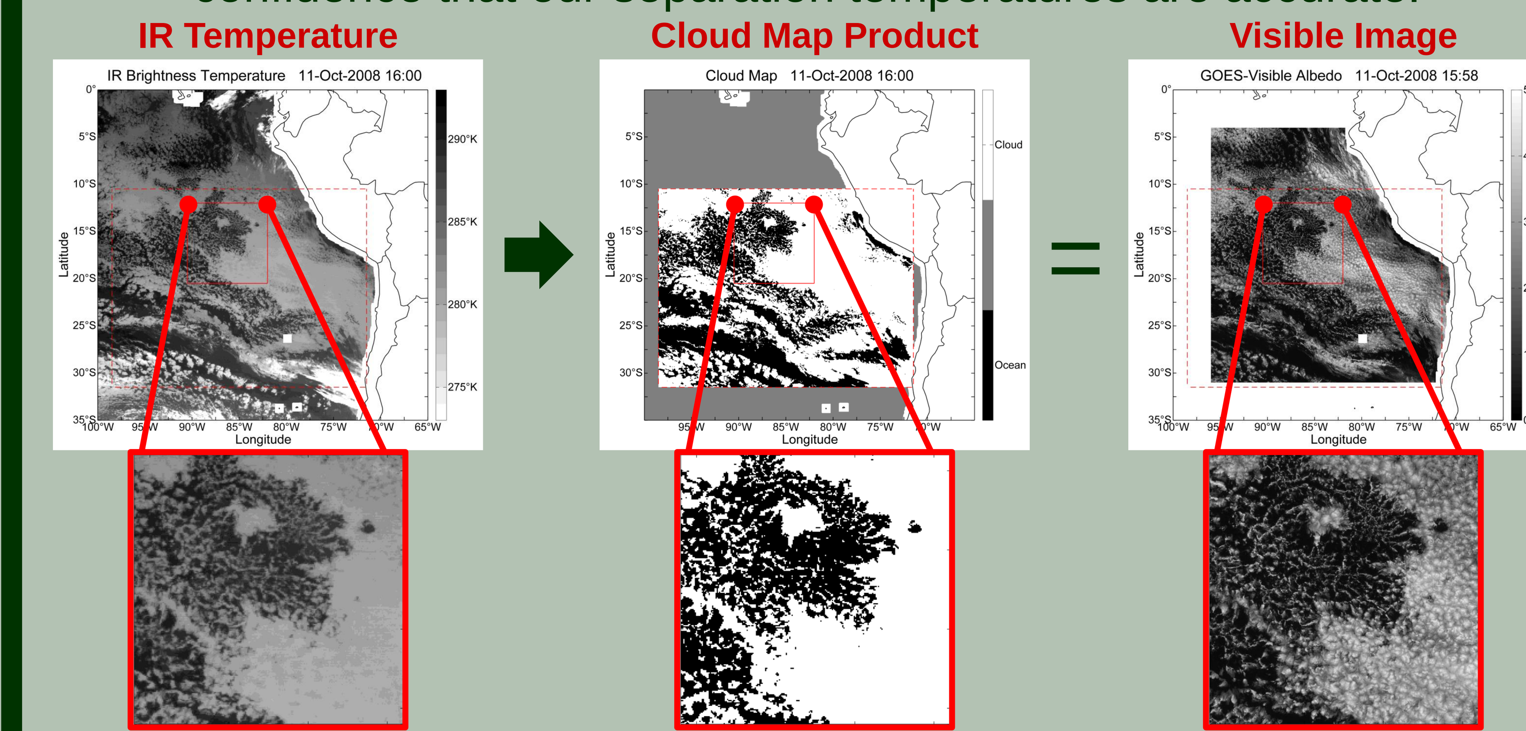
The time series of separation temperature values for each zone is first filtered to remove outliers and then smoothed to prevent discontinuities and fill in gaps where the automated method fails to find a valid separation temperature. The final time series is rounded to integers to match the resolution of the merged IR data set.

The time series for each zone is finally mapped back into their respective coordinates and the field is spatially smoothed to minimize discontinuities at the boundary between adjacent zones.

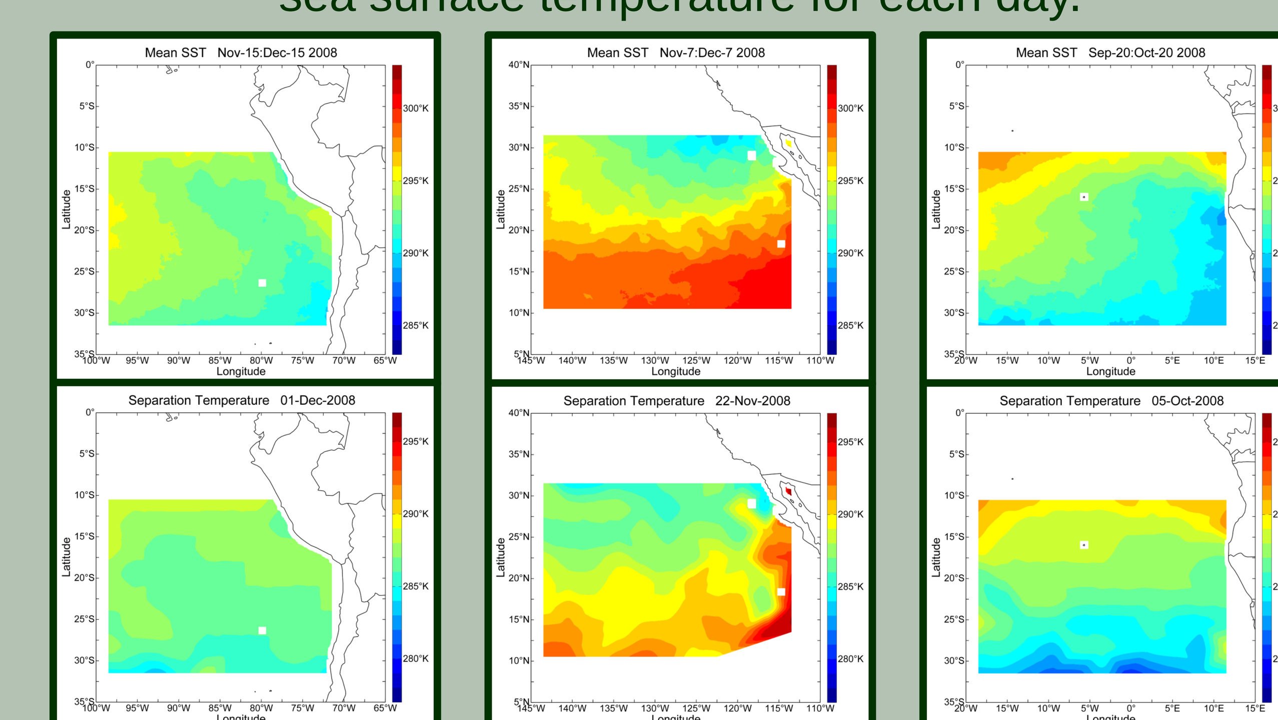


IV) Evaluation

There are two methods to measure our product's performance against other observations. For a more direct validation, the cloud maps can be compared to visible satellite imagery during daytime scenes. Our product's ability to reproduce the cloud field from visible data gives us confidence that our separation temperatures are accurate.

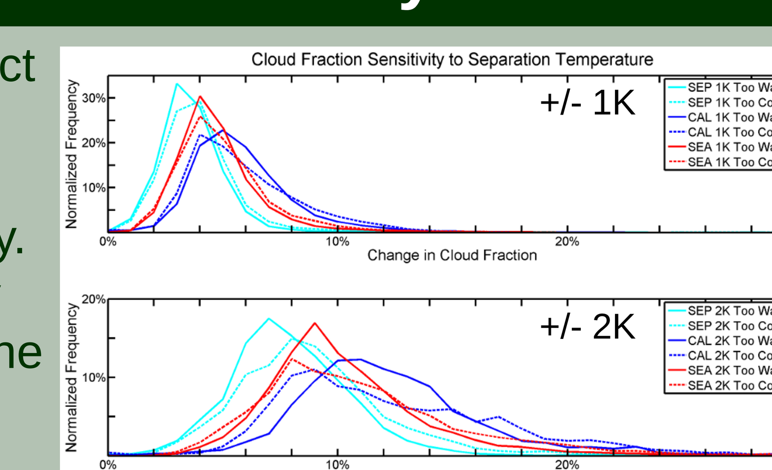


Secondly, because the separation temperature is meant to isolate the cloud emission from the sea surface emission, spatial patterns in the separation temperature maps should resemble the spatial patterns in sea surface temperature for each day.



V) Threshold Sensitivity

Because our cloud fraction product depends solely on finding the correct separation temperature, there is some inherent uncertainty. Analysis shows this to be roughly 10-12% for every 2 K of error in the separation temperature. For this reason, all future analysis using the cloud fraction product will be done with a +/- 2 K ensemble approach to produce a reasonable range of possible cloud fractions.



VI) Future Work

1) Examine the relative magnitudes of the diurnal, seasonal, inter- and intra-annual variability for each of the three regions.
2) Examine how cloud fraction varies in response to changes in SST, large scale subsidence, and other macro-environmental variables.
3) Develop a method to track cloud fraction in a Lagrangian framework to better understand the transition between mesoscale broken and unbroken cloud regions.