Relationships Between Boundary-layer Cloud Property Pairs

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Data and Methods

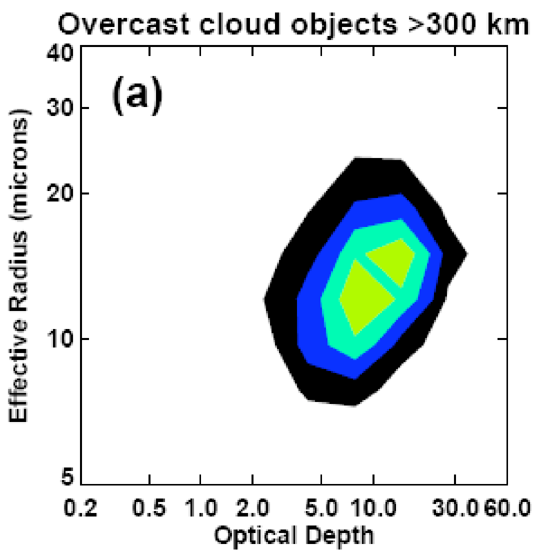
- The cloud object data were taken from CERES-TRMM, over Jan-Aug 1998. Each boundary-layer cloud object is a contiguous region of SSF footprints that have cloud tops < 3 km, and a cloud fraction of: 99-100% (overcast), 40-99% (stratocumulus), or 10-40% (shallow cumulus). The cloud objects in this work were all observed over the ocean, and within 30 degrees of the Equator.
- The k-means cluster algorithm is used for detailed analysis of joint distributions of cloud properties. The clusters are formed using these quantities, calculated for individual cloud objects:
  - Slope of $\ln(Re)$-$\ln(\tau)$ line for Re- τ relationship
  - W_{700} (precipitable water above 700 mb) for OLR and SST
  - 2-D position of LW CRF and SW CRF

Relationship between R_{eff} and τ

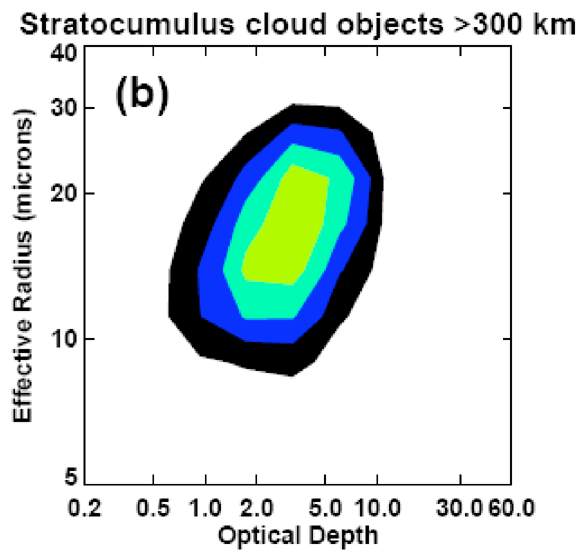
- Using AVHRR data, Szczodrak et al. (2001) noted that R_{eff} tended to be proportional to $\tau^{0.2}$ for boundary-layer clouds over the northeast Pacific. This agrees with theory, if:
  - Liquid water content increases linearly with height
  - Cloud droplet number concentration is constant with height
- However, there were exceptions in the Szczodrak study, and many different correlations between R_{eff} and τ were noted by Nakajima and Nakajima (1995), also using AVHRR data.

Joint PDFs of R_{eff} vs. τ

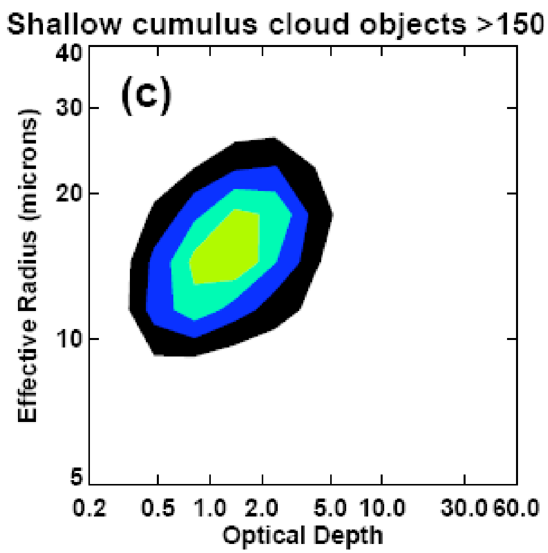
Overcast



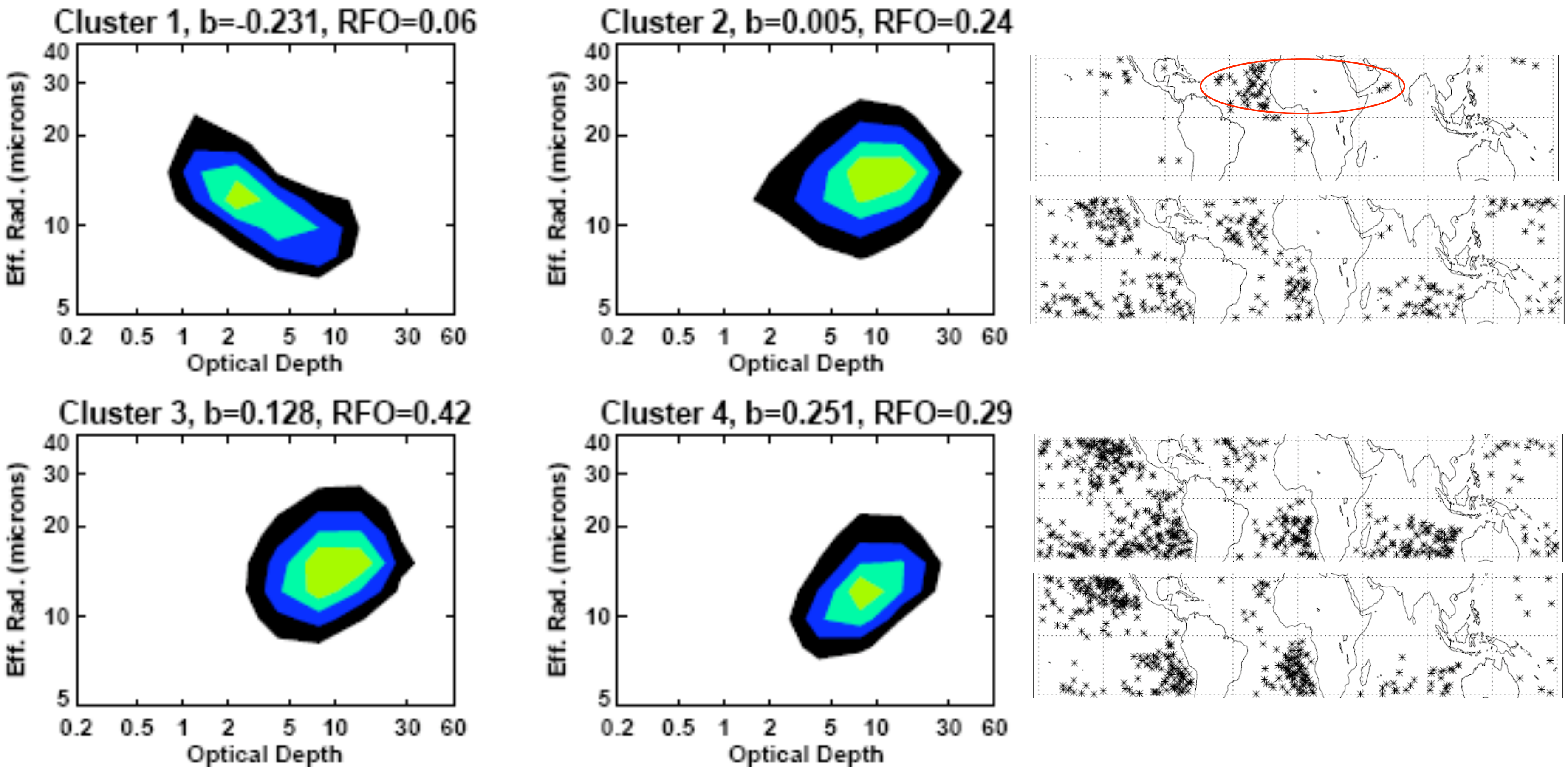
Stratocumulus



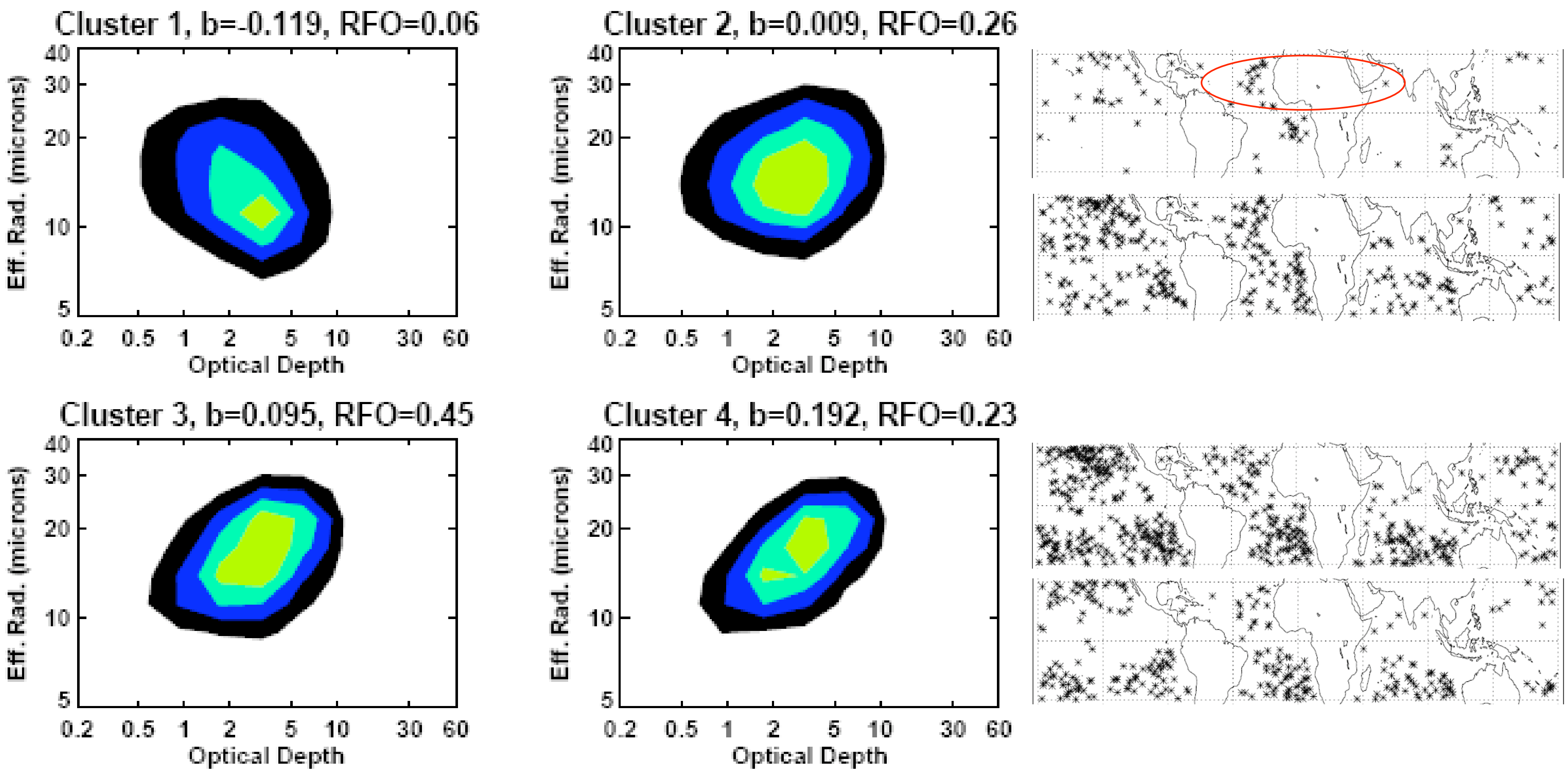
Shallow cumulus



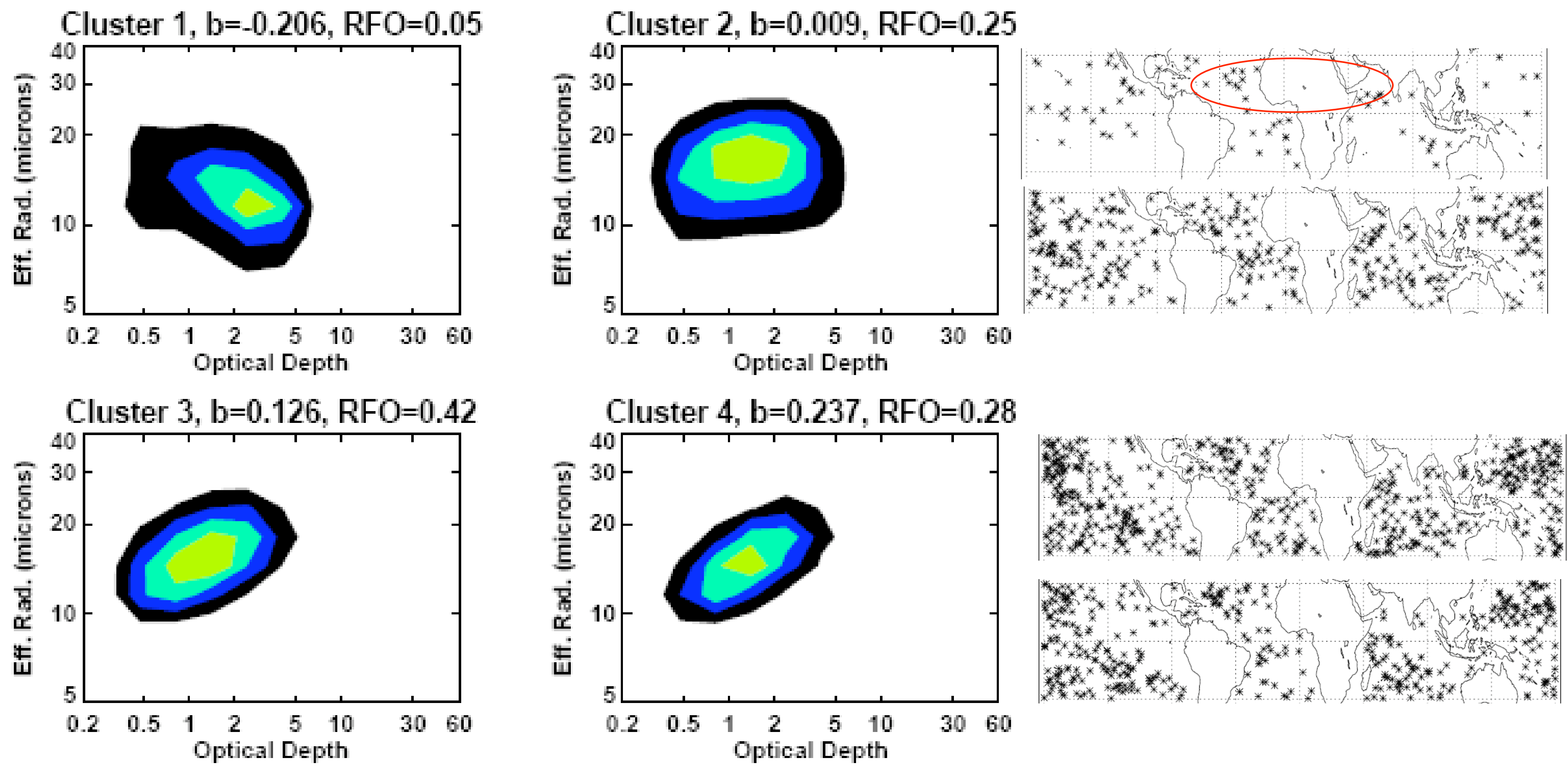
Cluster Analysis – Stratus



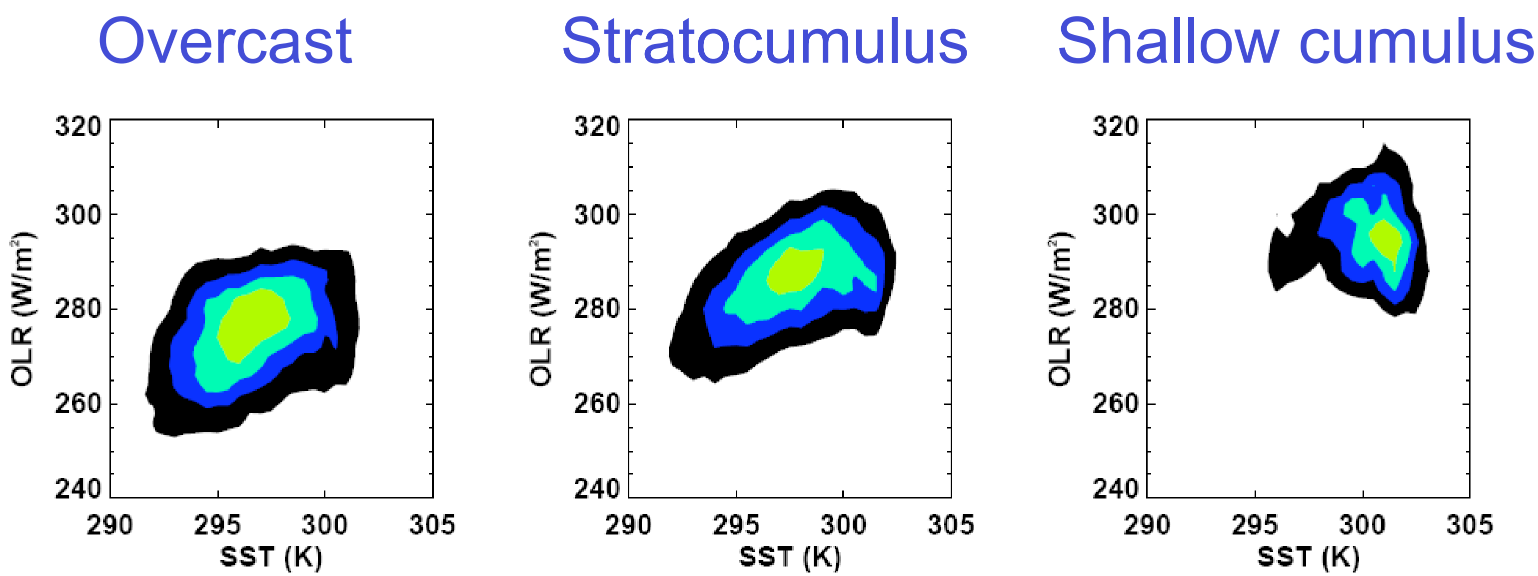
Cluster Analysis – Stratocumulus



Cluster Analysis – Shallow Cumulus

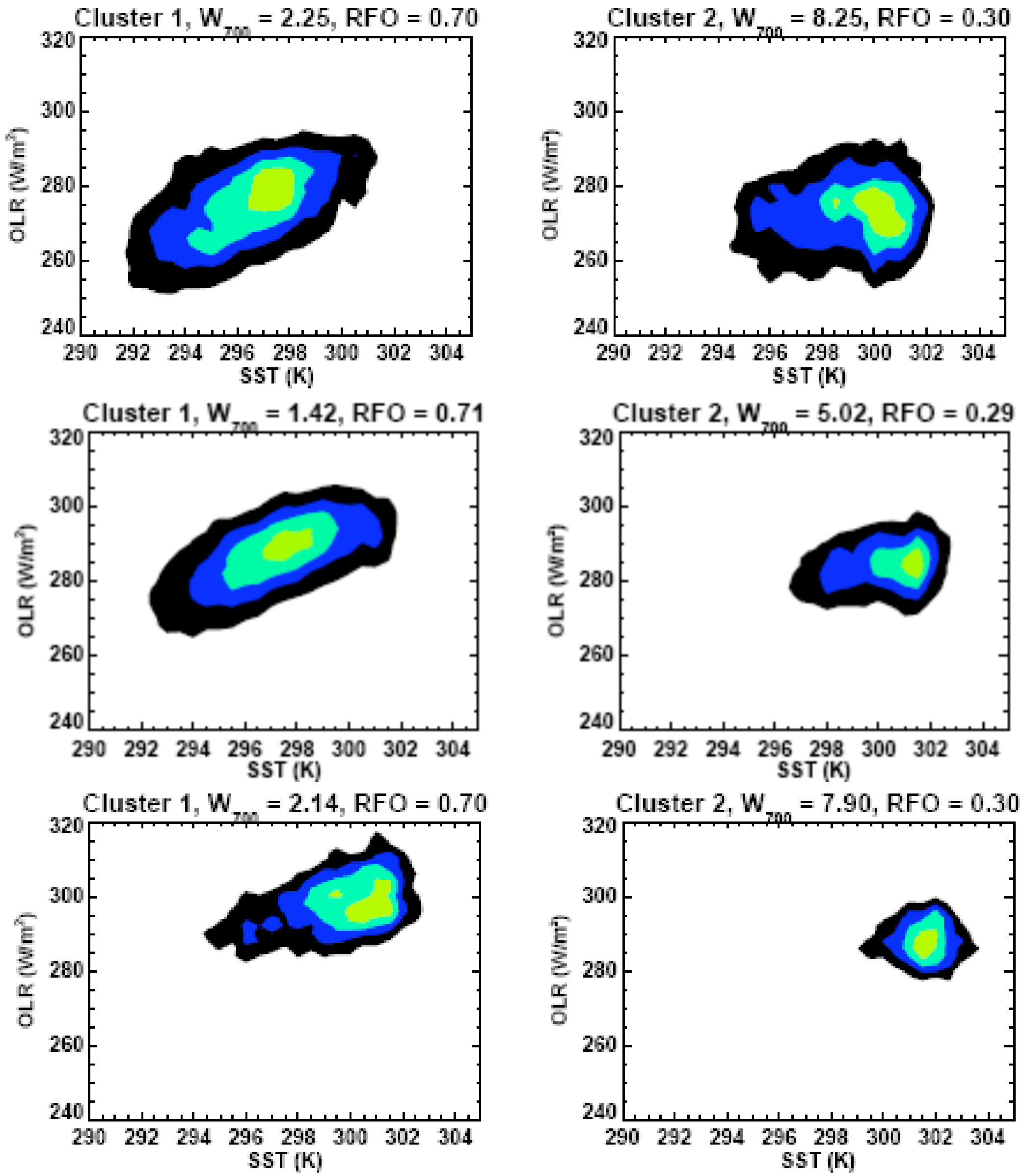


Joint PDFs of OLR vs. SST

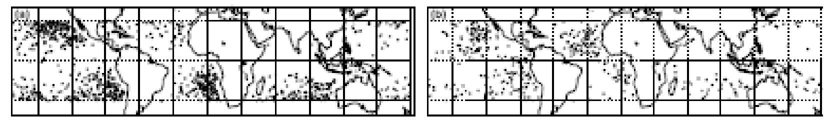


Note the decrease of OLR with SST at high SSTs ("super-greenhouse effect" seen with clear-sky OLRs).

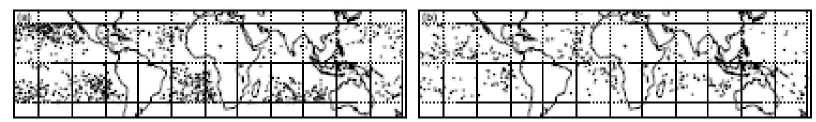
Cluster Analysis – OLR vs. SST



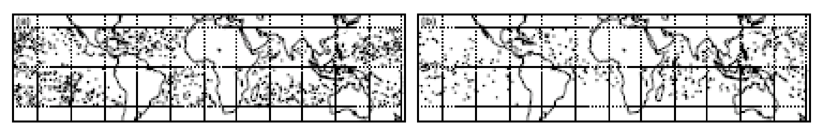
Stratus



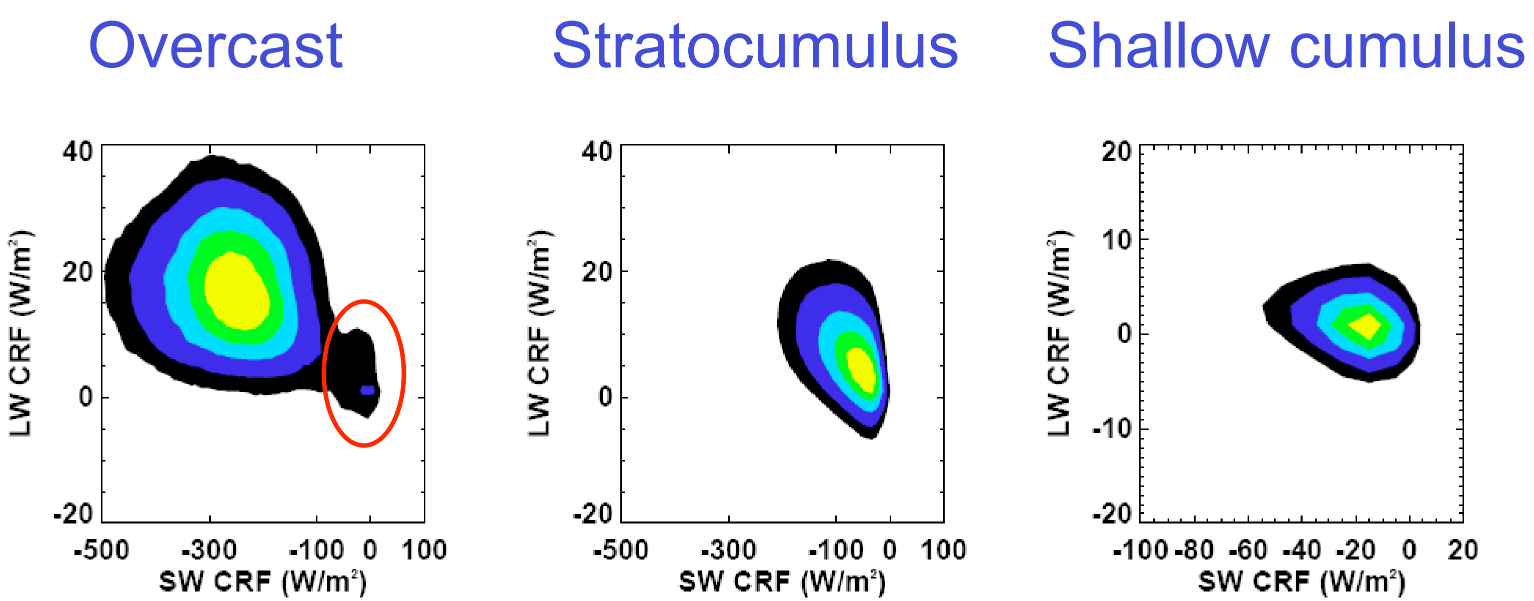
Stratocumulus



Shallow cumulus



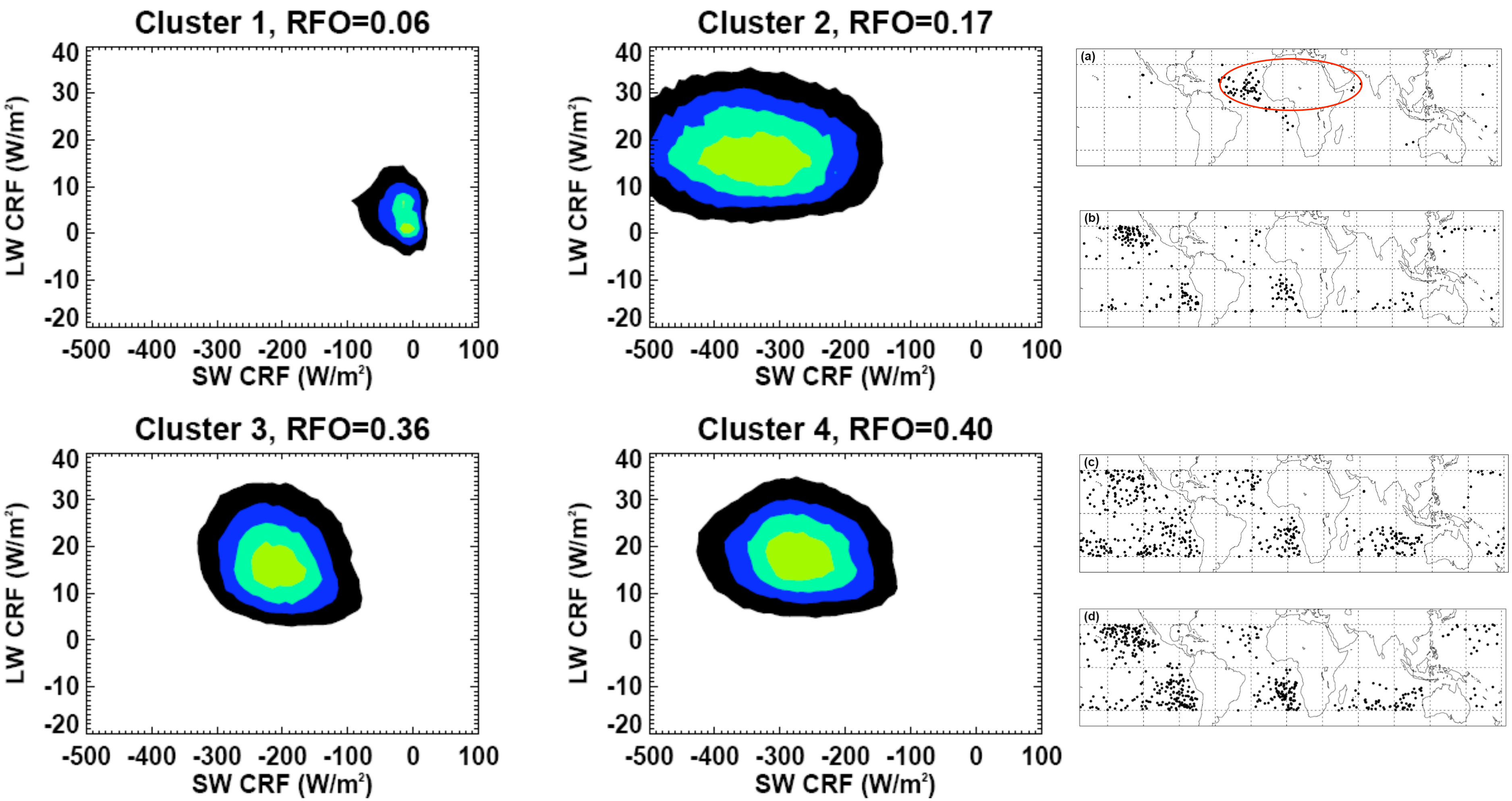
Joint PDFs of LW CRF vs. SW CRF



Magnitude of LW and SW CRF decreases with cloud cover.

Strange feature to overcast joint PDF.

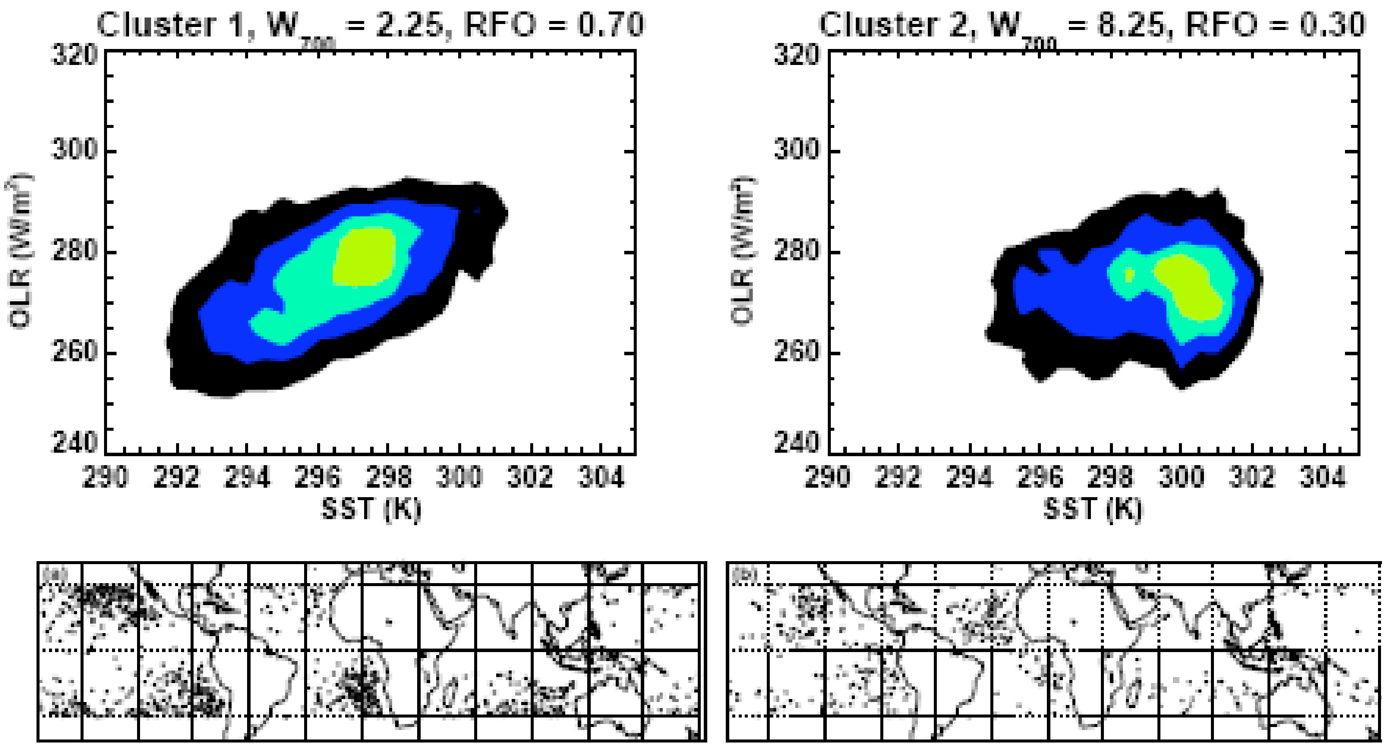
Cluster Analysis: LW CRF vs SW CRF, Overcast Clouds



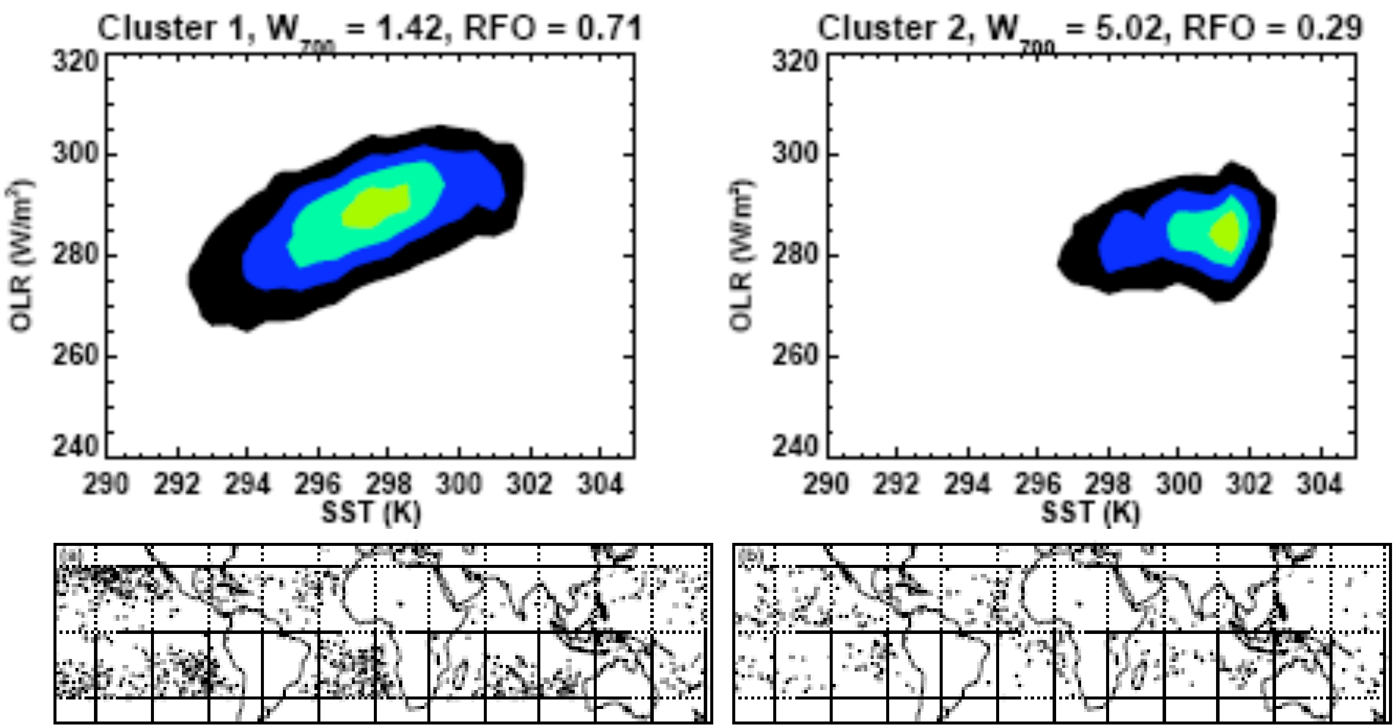
Summary

- Analysis of the relationship between τ and r_e revealed that for each cloud type, there is a cluster associated with negative slopes, one with slopes near zero, and two positive slopes. The cluster with negative slopes for overcast clouds may be associated with dust, while this does not appear to be the case for other types.
- Using W_{700}, there appear to be a “moist” and a “dry” cluster for each boundary-layer type, and the relationship between SST and OLR is roughly linear throughout the SST range for the dry cluster, while the OLR stays in a roughly constant range for the moist cluster. The sum of these clusters produces a decrease in OLR with SST for high SSTs, which has been seen in clear-sky results by Hallberg and Inamdar (1993) and others.
- A cluster in the LW CRF – SW CRF relationship for overcast clouds has low values of CRF; this cluster has many of the same members as the “dusty” cluster in the τ and r_e relationship.

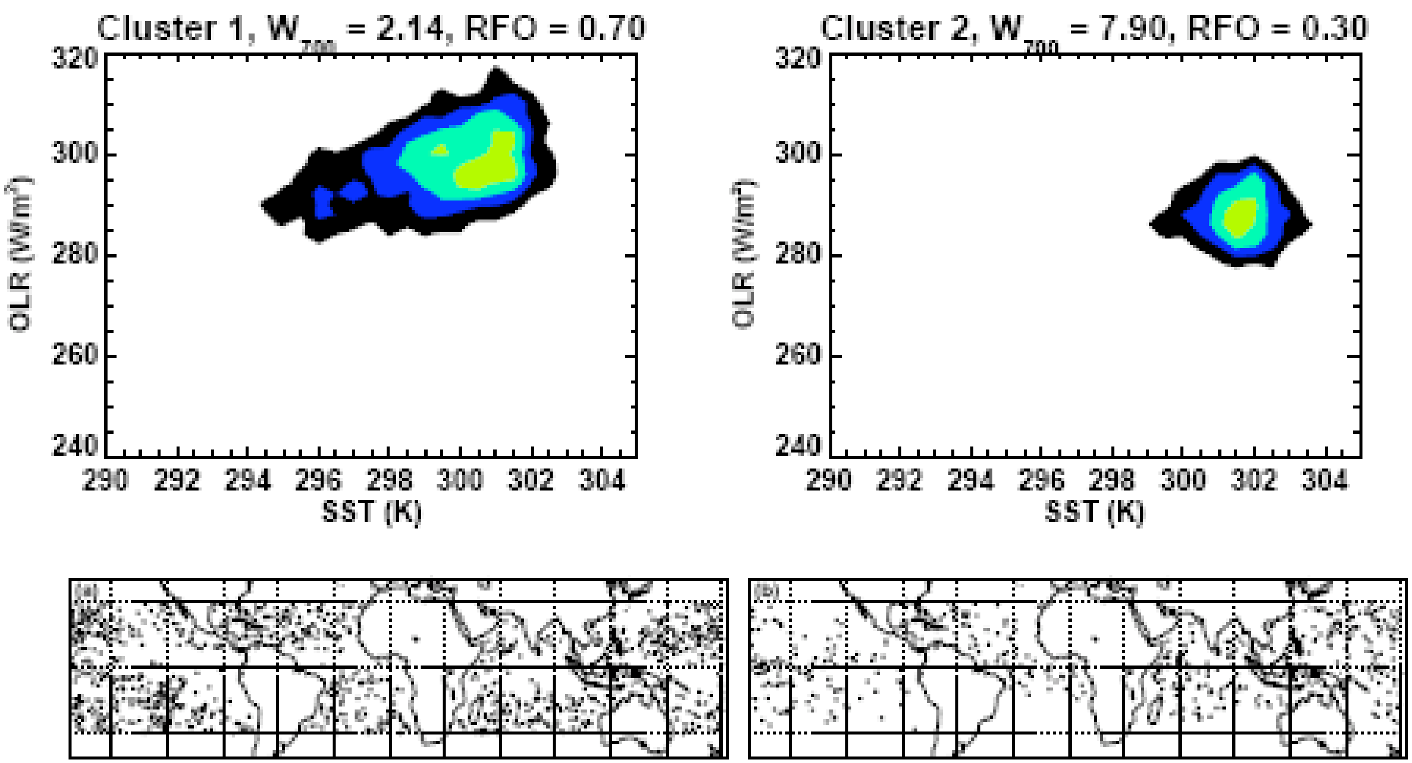
Cluster Analysis – OLR vs. SST, Overcast Clouds



Cluster Analysis – OLR vs. SST, Stratocumulus Clouds



Cluster Analysis – OLR vs. SST, Shallow Cumulus Clouds



Correlation Tables - Microphysics

Stratus (1272 objects, 2.4 M footprints)

	τ	r_e	albedo	SWCRF
r_e	0.245			
albedo	0.919	0.153		
SWCRF	-0.869	-0.082	-0.753	
LWP	0.921	0.574	0.814	-0.752

Stratocumulus (1209 objects, 1.6 M footprints)

	τ	r_e	albedo	SW CRF
r_e	0.316			
albedo	0.771	0.164		
SW CRF	-0.850	-0.181	-0.829	
LWP	0.920	0.638	0.677	-0.743

Shallow cumulus (1448 objects, 0.4 M footprints)

	τ	r_e	albedo	SW CRF
r_e	0.290			
albedo	0.328	-0.053		
SW CRF	-0.563	-0.083	-0.473	
LWP	0.940	0.572	0.270	-0.500

Correlation Tables - Macrophysics

Stratus (1272 objects, 2.4 M footprints)

	CTT	OLR	LW CRF
OLR	0.616		
LW CRF	-0.658	-0.651	
SST	0.597	0.300	-0.131

Stratocumulus (1209 objects, 1.6 M footprints)

	CTT	OLR	LW CRF	SST
OLR	0.529			
LW CRF	-0.528	-0.594		
SST	0.730	0.422	-0.219	
cld frac	-0.119	-0.243	0.345	-0.044

Shallow cumulus (1448 objects, 0.4 M footprints)

	CTT	OLR	LW CRF	SST
OLR	0.183			
LW CRF	-0.267	-0.330		
SST	0.689	0.088	-0.025	
cld frac	-0.075	-0.080	0.211	-0.015

Correlation Tables - Mixed

Stratus (1272 objects, 2.4 M footprints)

	τ	r_e	albedo	SW CRF
CTT	-0.248	-0.158	-0.339	0.275
OLR	-0.159	-0.203	-0.199	0.096
LW CRF	0.192	0.173	0.253	-0.189
SST	-0.159	0.078	-0.236	0.184

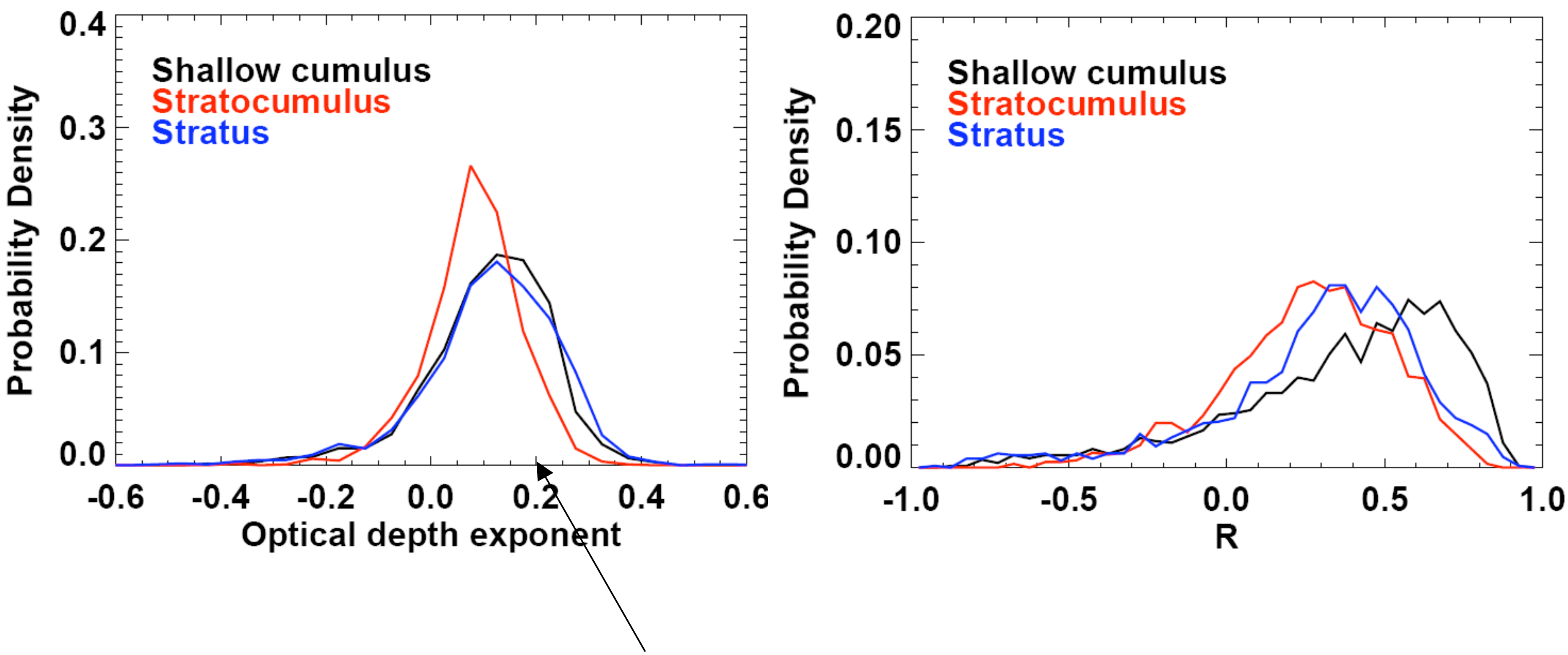
Stratocumulus (1209 objects, 1.6 M footprints)

	τ	r_e	albedo	SW CRF
CTT	-0.220	-0.252	-0.273	0.242
OLR	-0.249	-0.244	-0.302	0.255
LW CRF	0.341	0.201	0.408	-0.403
SST	-0.166	-0.215	-0.176	0.173
cld frac	0.408	0.044	0.593	-0.592

Shallow cumulus (1448 objects, 0.4 M footprints)

	τ	r_e	albedo	SW CRF
CTT	-0.006	-0.043	-0.151	0.094
OLR	-0.169	-0.256	-0.029	0.040
LW CRF	0.178	0.096	0.143	-0.210
SST	0.058	-0.010	-0.160	0.042
cld frac	0.162	0.041	0.347	-0.488

Results of log(R_{eff})-log(tau) regression within cloud objects



Ideal value

Data and Methods

- The cloud object data were taken from CERES-TRMM, over Jan-Aug 1998. Each boundary-layer cloud object is a contiguous region of SSF footprints that have cloud tops < 3 km, and a cloud fraction of: 99-100% (overcast), 40-99% (stratocumulus), or 10-40% (shallow cumulus). The cloud objects in this work were all observed over the ocean, and within 30 degrees of the Equator.
- We calculate the Spearman rank correlation between each pair of cloud properties. It is more resistant to outliers than the standard linear correlation.

Summary

- The correlations between most microphysical variables are statistically significant, if not always large.
- Positive correlations between R_{eff} and optical depth are consistent with results of Szczodrak et al. (2001), although these results show a somewhat flatter relationship between the two.
- Cluster analysis indicates something interesting is going on in “dusty” regions for overcast cloud footprints.