Spearman Rank Correlations Between Boundary-layer Cloud Properties

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1. Cloud Object Data

The cloud object data were taken from CERES-TRMM, over Jan-Aug 1998. Each boundary-layer cloud object is a contiguous region of CERES footprints that have cloud tops below 3 km, and a cloud fraction of: 99-100% (stratus), 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.

2. Joint PDFs and Correlations

We are not only interested in 1-D distributions of cloud properties (see Xu et al. 2007), but also how they change with one another. One way to examine this is with 2-D (joint) PDFs. However, with a large number of cloud properties, a simple correlation coefficient summarizing each pair is useful. Spearman rank correlation has the advantage of being less sensitive to outliers than the standard Pearson correlation.

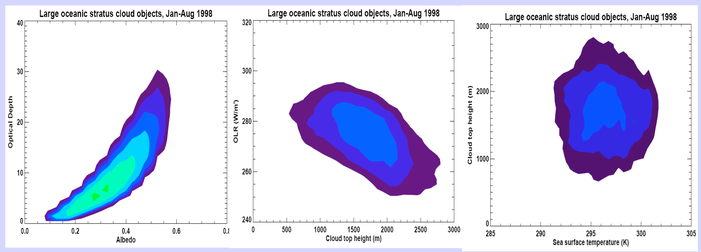

Fig. 1: Examples of joint PDFs between variables that have a strong positive correlation, a weak negative correlation, and a very weak correlation.

3. New measure of Stability

In a paper by Wood and Bretherton (2006), the EIS (Estimated Inversion Strength) is defined as an estimate of the jump in theta at the PBL top, rather than the LTS (lower-tropospheric stability) estimate of stability based on the difference in theta between 700 hPa and the surface. EIS has been found to have a closer correlation to cloud fraction than LTS.

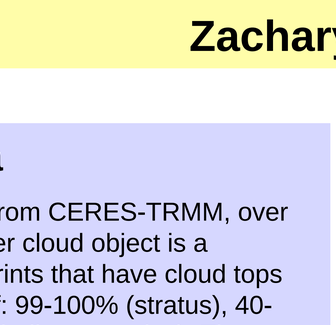

Fig. 2: EIS and LTS defined (taken from Wood and Bretherton (2006)

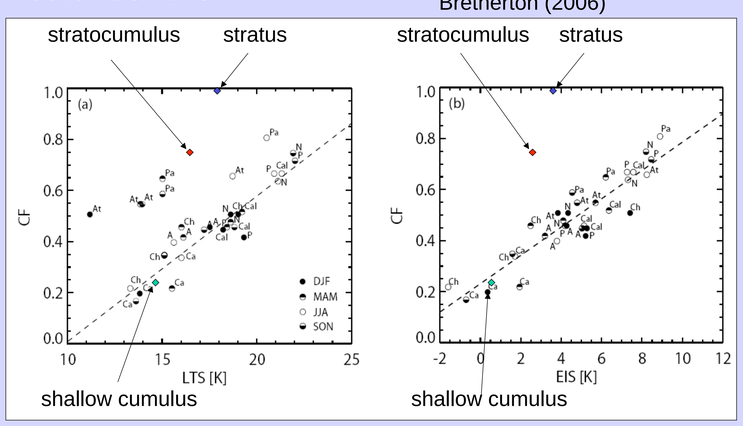

Fig. 3: Relationship between low cloud amount and LTS, EIS (a,b, respectively) from Wood and Bretherton (2006) with averaged cloud object data added.

Summary

- Correlations are generally high (strongly positive or negative) among pairs of cloud properties that are in the same category (microphysics, macrophysics, or thermodynamics). Many correlations are statistically significant, but small in magnitude.
- The correlations between cloud properties tend to be stronger among stratus clouds than shallow cumulus, due to the larger cloud fraction.
- The vertical velocity at 700 hPa was not strongly correlated to other cloud properties.
- The small correlations between LTS/EIS and cloud fraction may increase when seasonally averaged over regions as in Klein and Hartmann (1993) and Wood and Bretherton (2006).

4. Correlation Tables

Table 1: Spearman rank correlations of cloud object averaged data for stratus cloud objects >300 km. N=1272.

	Microphysics			Macrophysics			Thermodynamics		
	τ	albedo	SWCRF	CTT	OLR	LWCRF	SST	EIS	LTS
albedo	0.755								
SWCRF	-0.649	-0.265							
CTT	-0.244	-0.390	0.264						
OLR	-0.190	-0.203	0.021	0.576					
LWCRF	0.194	0.258	-0.156	-0.658	-0.523				
SST	-0.180	-0.336	0.217	0.694	0.352	-0.154			
EIS	0.075	0.230	-0.315	-0.450	0.075	0.059	-0.616		
LTS	0.031	0.130	-0.292	-0.213	0.031	-0.116	-0.485	0.943	
ω_{700}	-0.034	0.030	-0.069	-0.108	0.116	-0.037	-0.111	0.216	0.185

Table 2: Spearman rank correlations of cloud object averaged data for stratocumulus cloud objects with equivalent diameters >300 km. N=1209.

	Microphysics			Macrophysics				Thermodynamics		
	τ	albedo	SWCRF	cld frac	CTT	OLR	LWCRF	SST	EIS	LTS
albedo	0.574									
SWCRF	-0.809	-0.304								
cld frac	0.303	0.351	0.749							
CTT	-0.331	-0.416	0.352	-0.202						
OLR	-0.178	-0.203	0.102	-0.204	0.457					
LWCRF	0.315	0.324	-0.300	0.200	-0.584	-0.368				
SST	-0.245	-0.337	0.319	-0.231	0.836	0.416	-0.291			
EIS	0.248	0.230	-0.388	0.267	-0.509	0.034	0.122	-0.619		
LTS	0.263	0.135	-0.398	0.271	-0.240	0.171	-0.069	-0.433	0.915	
ω_{700}	-0.008	0.130	-0.065	-0.029	-0.392	-0.053	0.203	-0.318	0.190	0.020

Table 3: Spearman rank correlations of cloud object averaged data for shallow cumulus cloud objects with equiv. diameters >150 km. N=1448.

	Microphysics			Macrophysics				Thermodynamics		
	τ	albedo	SWCRF	cld frac	CTT	OLR	LWCRF	SST	EIS	LTS
albedo	0.164									
SWCRF	-0.612	0.046								
cld frac	-0.085	0.138	-0.026							
CTT	0.105	-0.135	0.047	-0.094						
OLR	-0.223	-0.007	-0.049	-0.025	0.109					
LWCRF	0.159	0.012	-0.114	-0.001	-0.275	-0.145				
SST	0.114	-0.192	0.062	-0.095	0.788	0.081	-0.060			
EIS	-0.099	0.087	-0.142	0.089	-0.339	0.320	-0.032	-0.441		
LTS	-0.032	0.043	-0.196	0.052	-0.147	0.301	-0.117	-0.309	0.904	
ω_{700}	-0.028	0.028	0.019	0.016	-0.236	0.003	0.034	-0.195	0.114	0.026

5. Cloud Radiative Forcings

Cloud radiative forcings (CRFs) are defined as the all-sky value of OLR or reflected shortwave subtracted from the clear-sky value. They were calculated using the CERES footprint data for the all-sky fluxes, and nearby clear footprint data for the clear-sky estimate when available, and Fu-Liou model estimates when no nearby clear footprints existed.

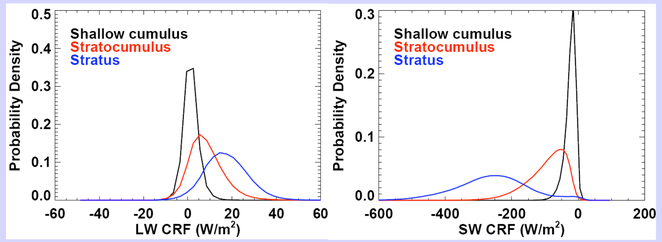

Fig. 4: Distributions of longwave and shortwave CRF for shallow cumulus, stratocumulus, and stratus cloud objects.

6. Distributions of LTS, EIS

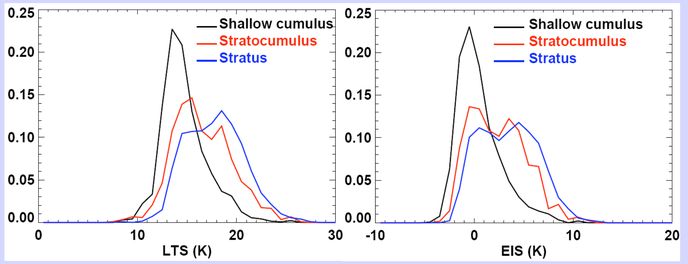

Fig. 5: Distributions of LTS and EIS for shallow cumulus, stratocumulus, and stratus cloud objects.

Both LTS and EIS tend to increase with cloud fraction, but the distributions are quite wide. This is somewhat similar to the variability of LTS with cloud fraction on short time scales found by Klein (1997).

References

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Website: http://cloud-object.larc.nasa.gov