P1.1 MESOSCALE STRATOCUMULUS CLOUD PATTERNS AROUND SAN FELIX ISLAND.

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1. INTRODUCTION

The southeastern Pacific has been largely recognized as the site of the most persistent subtropical stratocumulus (SC) cloud deck (e.g. Klein and Hartmann, 1992). However, this area is comparatively void of *in-situ* observations compared to other subtropical west coasts, with very few field campaigns (e.g. Bretherton et al., 2003; Garreaud et al., 2001).

An important feature of this subtropical SC cloud deck is its meso-scale cellular structure (e.g. Agee, 1973) whose origin and connection with air-sea interaction processes is largely unknown. However, any detailed description of the SC variability must consider changes in their cellular morphology and the associated forcing mechanisms. San Felix Island (SFI) is located at about (26º16'S, 80º05'W) 850 km off the north-central Chile coast, under the influence of the southern edge of the area with maximum persistence of the SC in austral spring-summer. Besides SFI location, its small size, small orography and good exposure to the SE trades constitute ideal features as an observation platform (e.g. Bahamonde, 1987), well isolated from continental influences.

During the first semester of 2003 a laser ceilometer and an automatic weather station at SFI provided a unique opportunity to characterize the *in-situ* SC cloud cover variability and its comparison with satellite-derived information on cloud-cover patterns around SFI.

2. DATA

A Campbell automatic meteorological station was installed at SFI in December 2002, recording 30-min averages of air temperature and relative humidity, wind speed and direction, atmospheric pressure, solar and net radiation. A CT12K laser ceilometer was also installed at that time, recording low-cloud base heights every 15 minutes. Unfortunately during February and most of March 2003 nighttime measurements were not performed due to electric power restrictions.

The characterization of synoptic weather fields was obtained from NCEP/NCAR reanalysis (Kalnay et al., 1996). Satellite retrievals from MODIS-TERRA were used to characterize SC cloud patterns.

Sea-surface temperature was recorded in a tide-gage station and regular weather observations were performed every three hour by meteorological observers from the Chilean Navy.

3. RESULTS

Consistent with the southernmost location of the SE Pacific SC deck, the maximum in the frequency of cloud bases below 2000 m derived from ceilometer data occurred in austral summer. The diurnal cycle in low-cloud frequency, defined as the ratio AM/PM in SC frequency, also peaked in austral summer (Fig. 1a). SC cloud base heights did not show any significant diurnal cycle throughout the 6-month period with ceilometer recordings (Fig. 1b). Ceilometer SC frequency and SC cloud cover estimates from MODIS VIS-channel data, were positively correlated (r = 0.75).

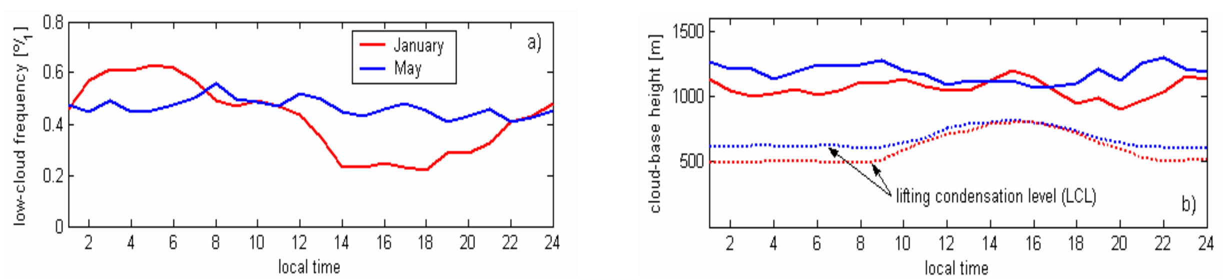

Figure 1: Mean diurnal cycles of ceilometer-derived a) low-cloud frequency and b) cloud-base height, for January (solid red) and May (solid blue) 2003. Lifting condensation levels are indicated in dashed lines.

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When considering a large-scale meteorological parameter representing the local daily SC variability in terms of ceilometer-derived cloud frequencies, the lower-troposphere bulk stability (LTS, Fig. 2), defined as the difference between potential temperatures at 700 and 1000 hPa (Klein and Hartmann, 1993), correlated at r = 0.40.

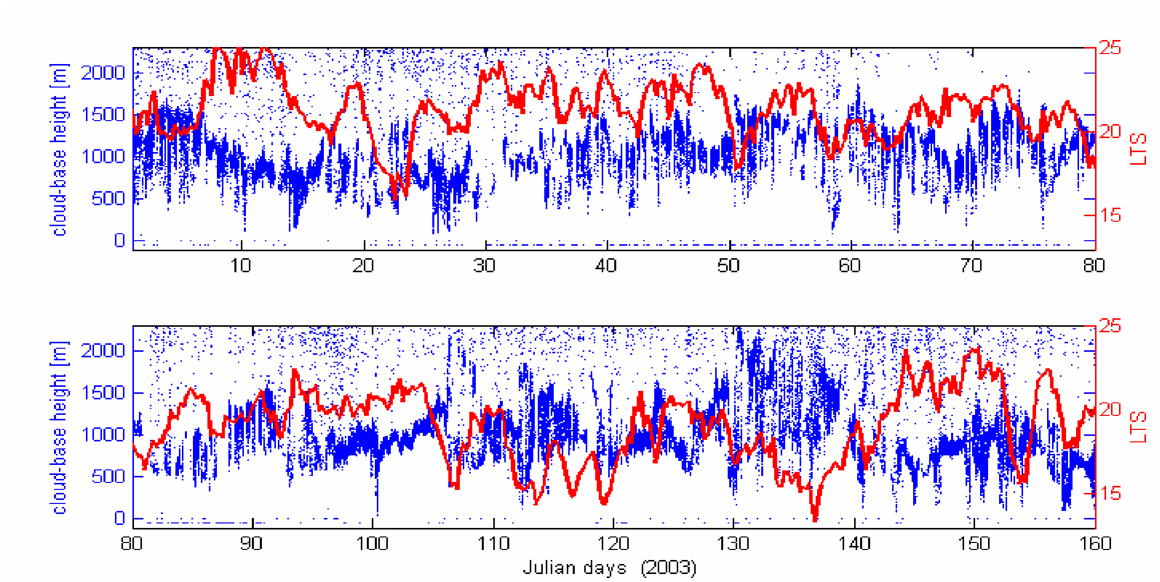

Figure 2: 15-minute averages of ceilometer cloud-base heights (blue) and low-troposphere stability index (red) from NCEP/NCAR reanalysis (LTS: 4 values per day), for the period January-June 2003. Dashed line at the bottom indicates nighttime periods (2-6 AM) when electric power was not available.

A similar but negative value (r = -0.41) was obtained when correlating the LTS with daily-averaged cloud base heights, though these coefficients raised to 0.7 when the daily values were low-passed with a 20-day cutoff filter (Fig. 3).

Cellular mesoscale structures in the SC deck were defined from the MODIS-TERRA satellite data. This information was classified into four groups, two of them corresponding with closed-cell (small/large) structures. The third group consisted of open-cell structures, while the fourth group included all structures that could not clearly fit into the cellular structure (Fig. 4 and Table 1). While the largest occurrence of large closed-cell structures during 2003 was found in austral spring and summer (75 %), the small ones occur mostly in austral fall and winter (81%). Open-cell structures can be found in all seasons, although they tend to concentrate in austral fall and winter (68%).

Large closed-cell structures were associated with mean cloud base heights above 1200 m, the ceilometer return signal showing in many cases precipitation coming off the cloud base. This feature was absent during the occurrence of small closed-cell structures, when cloud bases were typically below 1000 m and close to the lifting condensation level, indicating a good degree of coupling between the cloud base and the ocean surface. Conversely, a lower degree of coupling was observed for large closed-cell structures, in which the lifting condensation level was around 400 m below the cloud base.

No characteristic time sequences in the size of closed-cell cloud patterns were evidenced. However, 40% of the closed-cell patterns occurred before or after open-cell ones. No clear relationships were evidenced in terms of characteristic large-scale weather patterns being associated to particular cellular-structures, suggesting that even short-lived significant weather disturbances influence cloud patterns in such a way that they can only be classified within the fourth group.

An automatic cloud-structure identification scheme was tested using probabilistic neural networks (PNN). Each image was reduced to six statistics (Tian et al. 1999) and the network was trained with 190 images. The PNN showed a classification skill of about 83%. In spite of the small size of the training sample, these results are promising. An increase of the training set of images should improve this skill.

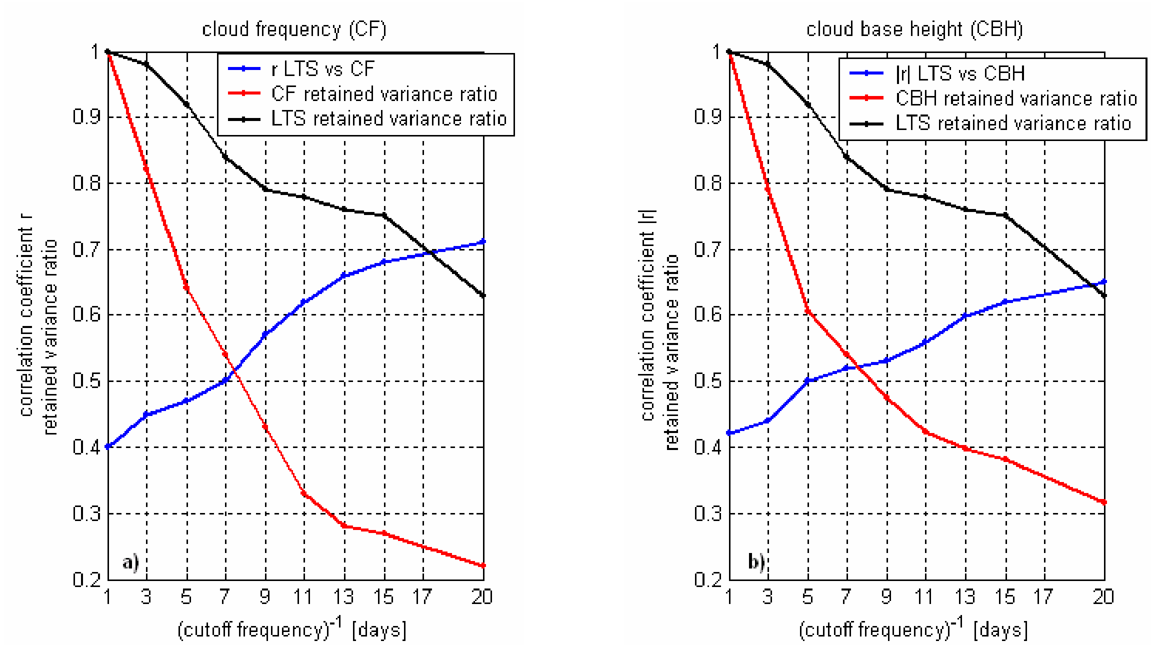

Figure 3: Linear correlation coefficients (blue lines) between LTS and low-pass filtered morning (8-12 AM) series of a) cloud frequency and b) cloud-base height, for variable cutoffs in days (horizontal axis). The corresponding retained variance of the time series (red line) and LTS (black line) as a function of the cutoff period of the filter are also shown for each variable.

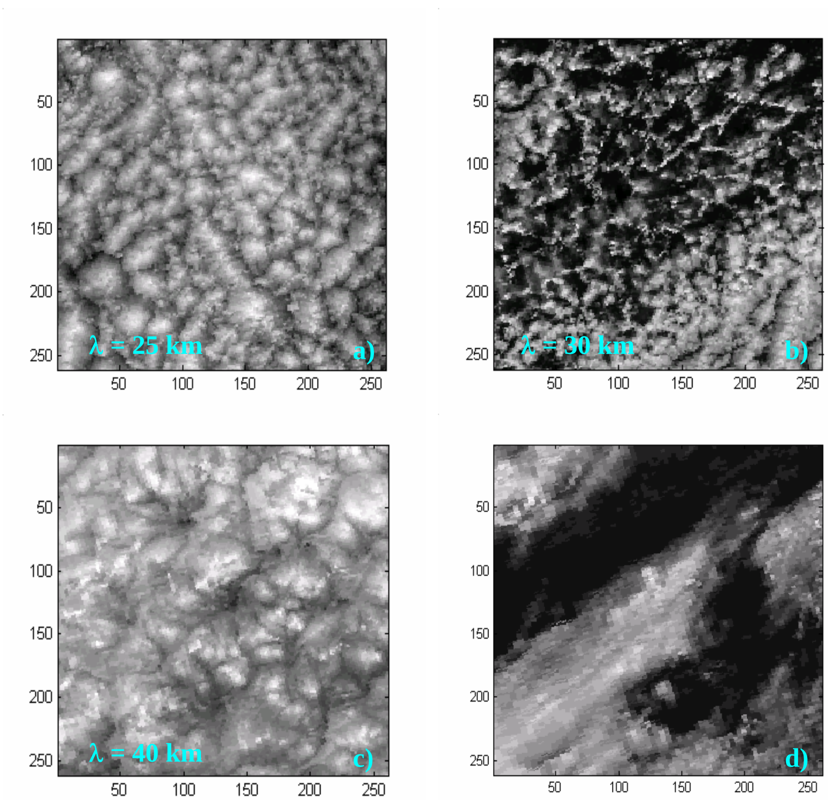

Figure 4: Examples of cell patterns in 250km x 250km boxes with their characteristic length (λ) resulting from bi-spectral analysis: a) small closed cells, b) open cells, c) large closed cells, and d) no-cellular pattern.

a)

Structure	ocurrence [%]
Cellular patterns	55
clear	15
High clouds	1.5
Undefined pattern	28.5

b)

Cellular patterns	ocurrence [%]
Open cells	29
Small closed cells	12
Large closed cells	14

Table 1: Occurrences in percent of a) cellular patterns and other cloud structures, and b) different types of cellular patterns:

4. DISCUSSION

Results on the correlation between ceilometer-derived variables, namely low-cloud frequency and cloud-base height, and the bulk stability of the lower troposphere obtained from the NCEP/NCAR reanalysis, compare well with those obtained by Klein (1997) for the northern hemisphere. Wood and Hartmann (2005) obtained similar correlation coefficients for the subtropical South Pacific using satellite-derived estimates of cloud top height (instead of cloud base heights) and low-cloud cover, using a smaller data base. These authors also found a relationship between the characteristic cell-size (λ) and the marine boundary layer depth, consistent with our results.

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5. REFERENCES

Agee, E. M., T. S. Chen, K. E. Dowell, 1973: A review of mesoscale cellular convection. *Bull. Amer. Meteor. Soc.*, **54**, 1004-1012.

Bahamonde N., 1987: Islas oceánicas chilenas: Conocimiento científico y necesidades de investigación. *Ediciones Universidad Católica de Chile*, 85-100.

Bretherton, C. S., Taneil Uttal, Christopher W. Fairall, Sandra E. Yuter, Robert A. Weller, Darrel Baumgardner, Kimberly Comstock, Robert Wood and Graciela B. Raga, 2004: The EPIC 2001 stratocumulus study. *Bull. Amer. Meteor. Soc.*, **85**, 967-977.

Garreaud, R., J. Rutllant, J. Quintana, J. Carrasco y P. Minnis, 2002. CIMAR-5: A snapshot of the lower troposphere over the subtropical southeast Pacific. *Bull. Amer. Meteor. Soc.*, **82**, 2193-2220.

Kalnay, E. and coauthors, 1996: NCEP/NCAR 40-years Reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437-471.

Klein, S. A.., D. L. Hartmann, 1993: The seasonal cycle of low stratiform clouds. *J. Climate*, **6**, 1587-1606.

Klein, S. A.. 1997: Synoptic variability of low-cloud properties and meteorological parameters in the subtropical trade wind boundary layer. *J. Climate*, **10**, 2018-2039.

Tian B., Mukhtiar A. Shaikh, Mahmood R. Azimi-Sadjadi, Thomas H. Vonder Haar, and Donald L. Reinke, 1999: A study of cloud classification with neural networks using spectral and textural features. *IEEE Transactions on Neural Networks*, **10**, 138-151.

Wood, R., D. L. Hartmann 2005: Spatial variability of liquid water path in marine low clouds: Part II. Geographic distribution and dependence upon large-scale parameters. *J. Climate*. In press.