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CHANGES IN SURFACE AND UPPER-AIR TEMPERATURE ALONG THE ARID COAST OF NORTHERN CHILE

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Introduction

Monthly records of minimum and maximum daily temperature from 6 meteorological stations and daily vertical temperature profiles from one rawinsonde station are analyzed to assess long-term changes in temperature at the surface and higher levels along the arid coast of northern Chile. Climate in this region is mainly influenced by the subtropical anticyclone in the SE Pacific, by the presence of the Andes cordillera that isolates this region from the warm and moist continental air masses, and by the stabilizing effect of the relatively cold adjacent ocean. A marked temperature inversion layer separates the well mixed and humid boundary layer from the subsiding dry air aloft. Stratiform clouds in the upper part of the boundary layer stretch over a large oceanic region west of Peru and Chile. The analysis of changes in the temperature regime at middle levels in the troposphere is particularly relevant for understanding the accelerated retreat of glaciers in the central Andes.

Methodology

Linear trends during the period 1961-2004 were calculated for annual mean values of daily temperature extremes (Max/Min) at 6 stations in northern Chile: Arica (18.3ºS), Iquique (20.5ºS), Antofagasta (23.4ºS), Copiapó (27.3ºS), Vallenar (28.6ºS), and La Serena (29.9ºS).

Vertical temperature profiles obtained from daily radiosoundings (12 UTC) at Antofagasta from 1958 to 2005 were analyzed to assess long-term changes in the temperature regime in the troposphere and lower stratosphere. The height of the low-level inversion layer, the freezing level and the tropopause were also examined.

Results

The evolution of surface and upper-air temperature in the coastal region of northern Chile is characterized by a relatively abrupt increase in the mid-1970´s that coincides with a change in the Pacific Decadal Oscillation from the negative (cool) to the positive (warm) phase. This behavior is revealed in Table 1, where linear trends in annual values of daily minimum and maximum temperatures are presented for 1961–2004, and for two partial periods before and after the increase in the mid-1970`s. The significant positive trend revealed for minimum temperature at most stations during 1961-2004 does not characterize the partial periods, when non-significant, and in some cases negative trends prevailed. This situation is illustrated in Fig. 1 where composites of annual mean anomalies of daily extreme temperatures are presented for four stations from 23ºS to 30ºS (Antofagasta, Copiapó, Vallenar and La Serena). According to results presented in this figure the maximum temperature regime exhibits a weak negative trend during both sub-periods, before and after the shift in the mid-1970's, while the minimum temperature has remained nearly stationary in recent decades.

Table 1. Linear trends (ºC/dec) in annual mean values of extreme daily temperature.

Max. | Min. Temp.	1961-2004	1961-1976	1977-2004
Arica	-0.06 | 0.35	-0.38 | -0.33	-0.55 | 0.25
Iquique	-0.11 | 0.26	-0.18 | 0.20	-0.61 | -0.04
Antofagasta	0.00 | 0.39	-0.28 | -0.16	-0.17 | -0.05
Copiapó	0.07 | 0.39	-0.46 | -0.14	-0.02 | -0.02
Vallenar	-0.03 | 0.34	-0.44 | 0.07	-0.20 | -0.20
La Serena	-0.01 | 0.27	-0.39 | 0.00	-0.26 | -0.03

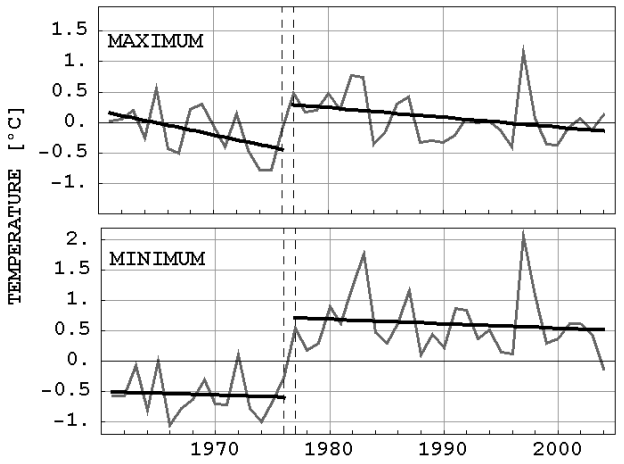

Figure 1. Composites of annual mean of daily maximum (top) and minimum (bottom) temperature anomalies at four stations in northern Chile (Antofagasta, Copiapó, Vallenar and La Serena) with respect to 1961-1990. Thick lines indicate trends for the periods 1961-1976 and 1977-2004.

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The evolution of temperature at different levels in the troposphere and lower stratosphere above Antofagasta (23.4ºS) is presented in Fig. 2. Similar to the surface regime, a pronounced shift occurred in the mid-1970s, with warming below 200 hPa and cooling aloft. The impact of El Niño events is well defined in the boundary layer in the form of positive temperature anomalies reaching considerable magnitude during major episodes such as those in 1982-83 and 1997-98.

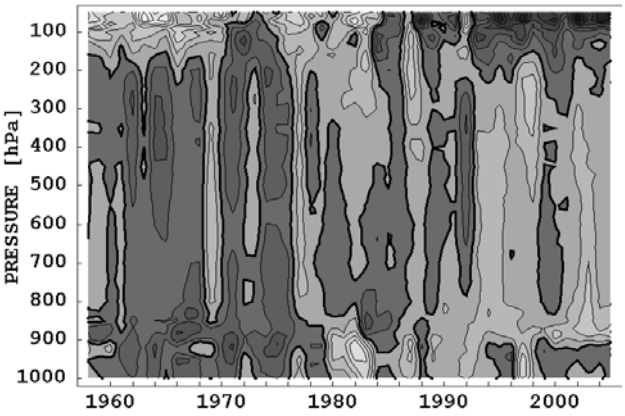

Figure 2. Annual mean temperature anomalies from 1000 hPa to 50 hPa over Antofagasta, with respect to the 1958-2005 mean value at each level. Dark gray areas indicate negative anomalies. Contours are drawn every 0.5ºC. The thick line indicates 0°C anomaly contour.

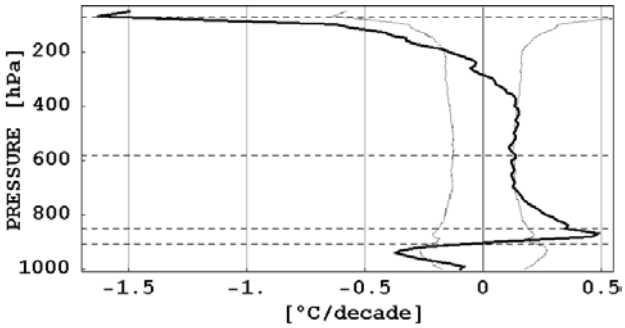

Figure 3. Linear trend in temperature from 1000 hPa to 50 hPa over Antofagasta during 1977-2005 (thick line). The 95% significance levels for positive and negative trends are indicated as thin lines, based on a Montecarlo test. Dashed lines indicate the mean levels of the base and top of the temperature inversion layer, the 0ºC isoline and the tropopause.

Linear trends during most recent decades (after 1977) are presented in Fig. 3. Consistent with the evolution of surface temperature in northern Chile during recent decades, temperature over Antofagasta shows a negative trend in the boundary layer since the mid-1970's, in contrast with a positive trend at levels from the inversion layer to around 400 hPa (Fig. 3). Consistent with this trend the freezing level (0ºC) has increased at a rate of 13.4 m/dec. A significant negative trend characterizes the temperature regime in the upper troposphere and the lower stratosphere during the same period (see Fig. 3). This feature was also detected at other radiosonde stations along the extratropical West coast of South America (Quintero, 33°S; Puerto Montt, 42°W and Punta Arenas, 53°S).

This study confirms earlier results documenting the occurrence of a significant upward displacement of the temperature inversion layer and associated stratus cloud deck during El Niño episodes (Rutllant *et al*., 2003). Overall, the height of the inversion layer has been decreasing in recent decades (Fig. 4). Specifically, negative trends of the order of 40 m and 15 m every 10 years were calculated for the top and base of the inversion layer, respectively, during austral summer in the period 1977–2004. Smaller changes were detected for other seasons. These results are consistent with recent findings showing a lowering of the base of the stratus deck resulting in an increased frequency of flight restrictions at coastal airports in northern Chile due to low cloud ceiling (J. Quintana and J. Carrasco, National Weather Service, personal communication).

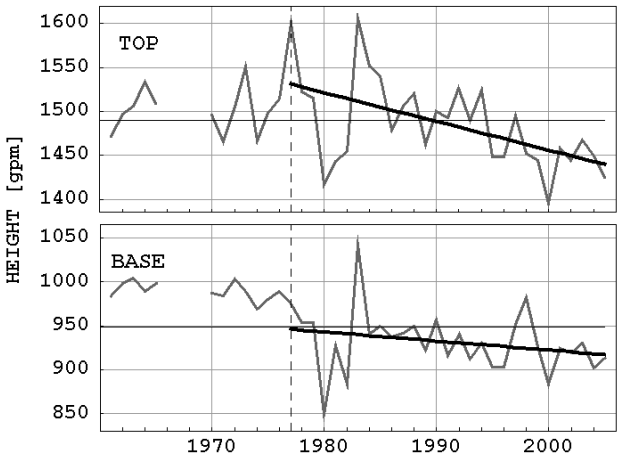

Figure 4. Annual mean elevations of the top and base of the temperature inversion layer over Antofagasta (23.4ºS). Thick lines indicate trends since 1977.

Acknowledgments

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Reference

Rutllant, J., H. Fuenzalida, and P. Aceituno, 2003: Climate dynamics along the arid northern coast of Chile: The 1997–1998 Dinámica del Clima de la Región de Antofagasta (DICLIMA) experiment. J. Geophys. Res., 108, NO. D17, 4538, doi: 10.1029/2002JD003357, 2003