1. Introduction

This work shows a cross-correlation analysis between the NCEP/NCAR Reanalysis data and the Paranal ground station observations of surface temperature and pressure for the period from 1985 to 1999.

The data obtained from the NCEP/NCAR Reanalysis is explained in a previous work of Bustos, R. [1]. The NCEP/NCAR Reanalysis project uses a state-of-the-art analysis/forecast system to perform data assimilation using all data available from 1948 to the present. The output archives contain basic upper-air parameters on standard pressure levels. Data fields are saved on a 2.5º lat x 2.5º long grid (144 x 73) in multiple vertical levels. It contains four times per day at 00, 06, 12, and 18 UTC, daily and monthly averages, and long-term mean data. The reanalysis gridded fields are classified into four classes. An A-class indicates that the analysis variable is strongly influenced by observational data, and hence it is the most reliable class (temperature, wind). B-class indicates that, although there are observational data that directly affect the value of the variable, the model also has a very strong influence on the analysis value (relative humidity, surface temperature, surface pressure, precipitable water vapour). C and D class do not depend on observational data (clouds, precipitation, plant resistance, albedo, geopotential height).

The NCEP/NCAR reanalysis data used for this study is surface temperature (B-class) and surface pressure (B-class), both obtained every 6-hours (00, 06, 12, and 18 UTC) during the period 1985 to November 2000. This data is referred to a grid point located at 25.0º S, 70.0º W, and 1,843 m.a.s.l, 60 [Km] southeast of Paranal.

The Paranal ground stations data used for this study are surface temperature and pressure obtained from a ground meteorological station every 20 minutes approximately, from 1985 to December 1999. Paranal is located at 24.62º S, 70.40º W, and 2,635 m.a.s.l.

The purpose of this study is to estimate the data reliability of the NCEP/NCAR Reanalysis data, comparing it with actual Paranal ground station data.

2. Surface temperature analysis

2.1 NCEP/NCAR data

NCEP/NCAR surface temperature data gives values at a site located 25.0º S and 70.0º W, at 1,843 m.a.s.l. It is considered as a B-class variable, partially defined by observations but strongly influenced by the model characteristics.

The temperature of a dry air parcel decreases with its altitude at the *dry adiabatic lapse rate* $\mathbf{\Gamma_d}$ = 9.8 [ºC/Km]. Under saturated conditions, the saturated parcel's temperature decreases with altitude at the *saturated adiabatic lapse rate* $\mathbf{\Gamma_s} \cong$ 6.5 [ºC/Km] [2]. Different mixing ratio due to dynamical processes such as solar radiation and wind can produce different lapse rate near the surface and the time of the day and year [3]. If we consider an average lapse rate for Paranal of 8 [ºC/Km], the average temperature difference between the grid point and Paranal should be of 6.3 [ºC].

Computing the NCEP/NCAR and the Paranal ground station average temperatures for the complete period, a 0.7 [ºC] difference is obtained. The 5.6 [ºC] difference is probably due to an underestimated NCEP/NCAR surface temperature rather than the 8 [ºC/Km] lapse rate estimation. NCEP/NCAR surface data differences have been previously found in a Visviri comparison work of Aceituno and Montecinos [4] and also in Bustos et al [3]. In order to compare both datasets, a 0.7 [ºC] has been subtracted from the NCEP/NCAR temperature data.

2.2 Ground station data

The ground meteorological station at Paranal is located 24.62º S, 70.40º W at 2,635 m.a.s.l. The data shows some relatively long periods with no data when instruments were malfunctioning and in 1992, when works were performed at the top of the hill.

For the ground station data at Paranal, a one-hour average value for 00, 06, 12, and 18 UTC has been considered (30 minutes before and after). From 1985 to 1999, 32.4% of the data has not averaged due to errors or nonexistent data at those hours.

2.3 Cross-correlation analysis

The Paranal ground station temperature data are cross-compared with the NCEP/NCAR temperature data. The datasets analyzed are:

1. NCEP/NCAR Reanalysis temperature data. (Temp. 1)
2. Paranal ground station temperature data. (Temp. 2)

Four times per day data cross-correlation:

	Temp. 2
Temp. 1	0.7321

Daily averages cross-correlation:

	Temp. 2
Temp. 1	0.7300

Monthly averages cross-correlation:

	Temp. 2
Temp. 1	0.7875

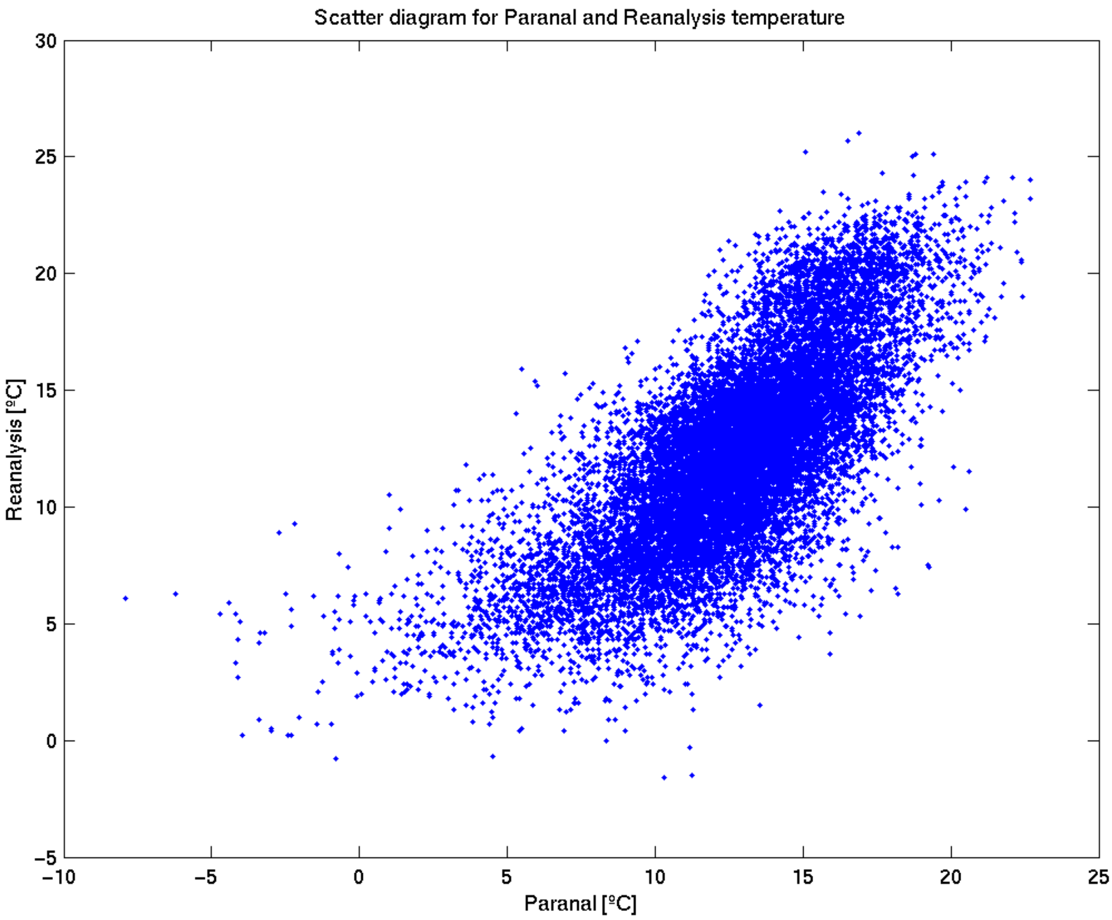

Figure 1: Scatter diagram for the Paranal and NCEP/NCAR Reanalysis temperature data. The four times per day data is depicted for the complete period 1985-1999.

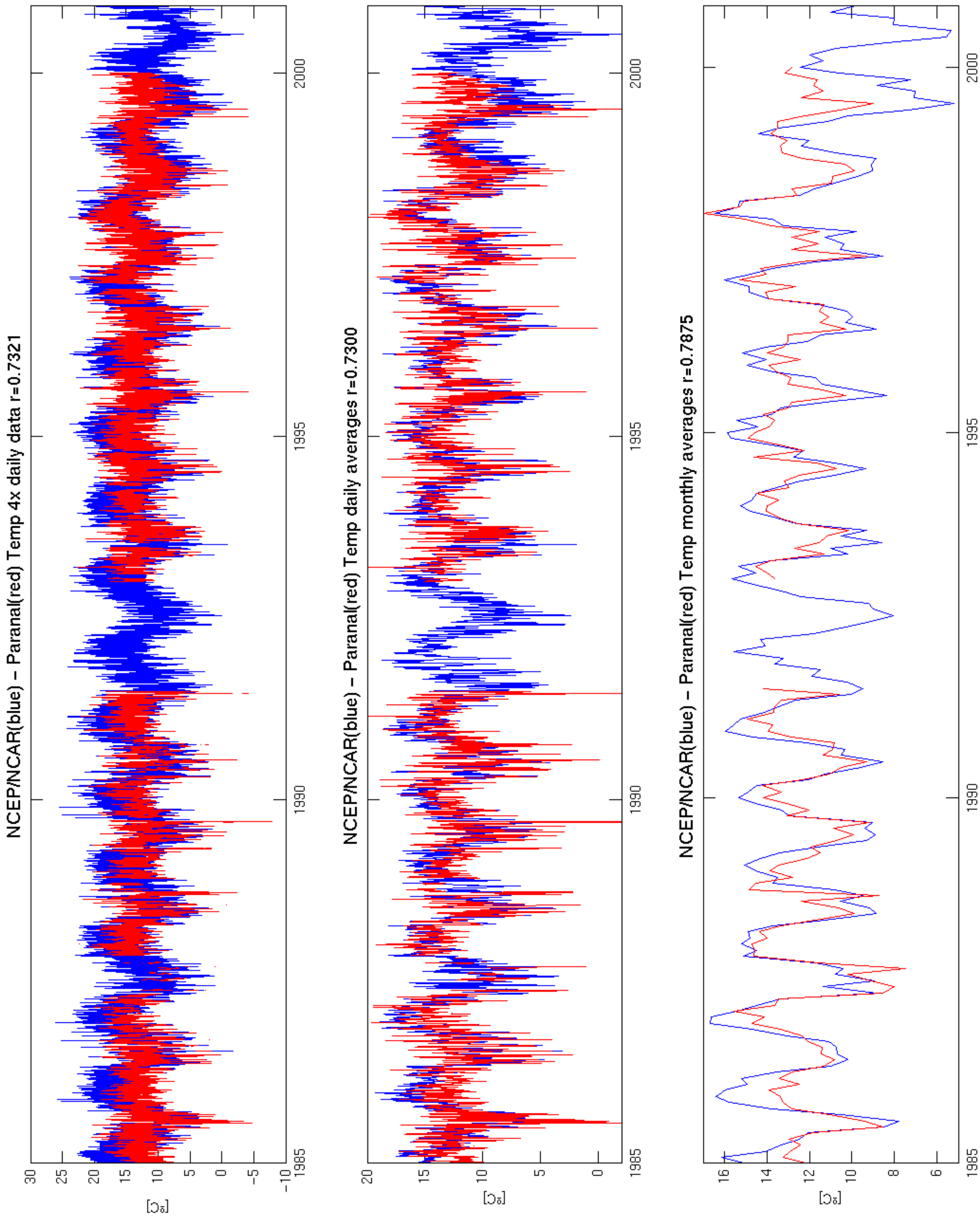

Figure 2: NCEP/NCAR temperature data are in blue and Paranal ground-based temperature data in red. 0.7ºC has been subtracted from the NCEP/NCAR temperature data in all graphs. The upper graph is four times per day (00, 06, 12, and 18 UTC), the middle graph shows daily averages, and the lower graph shows monthly averages.

On figure 1, the scatter diagram is shown for the four times per day data for the complete period (1985-1999) for both datasets.

On figure 2, the lower graph shows monthly averages from 1985 to the present. It can be seen that NCEP/NCAR Reanalysis data has very similar tendencies with the observed at Paranal. In fact, a cross-correlation value of 0.7875 indicates a good reliability of the reanalysis data. Descending tendencies of average temperatures during summer of 1999 and 2000 are captured in both cases. For the complete year 2000, it would be interesting to compare the cold temperature tendency seen in Reanalysis with the Paranal observations.

3. Surface pressure analysis

3.1 NCEP/NCAR data

NCEP/NCAR pressure at the surface data is a B-class variable, partially defined by observations but strongly influenced by the model characteristics.

For the case of pressure, an exponential decay with a scale factor H [2] is assumed:

$$p(h) = P_0 e^{-\int_0^h \frac{1}{H(h)} dh} \qquad \text{Eq. 1}$$

$$H(h) = \frac{RT(h)}{M_d g} \qquad \text{Eq. 2}$$

Where P_0 is the pressure at the ground level [mb], R is the molar gas constant, M_d is the molecular weight of "dry" air, and g the gravitational constant. Using an H_0 value near the surface for H(h) of 8 km [2], the correction factor obtained using an altitude difference of 792 m is 0.9057.

$$p_{2635} = 0.9057 \cdot p_{1843} \qquad \text{Eq. 3}$$

Computing the NCEP/NCAR and the Paranal ground station average pressures for the complete period, a 0.9105 factor is obtained. The difference with the previous altitude correction factor is only 0.53 %, probably due to the use of an estimated scale factor H of 8 [km]. In order to compare the datasets, a 0.9105 factor has been multiplied from the NCEP/NCAR pressure data.

3.2 Ground station data

The ground meteorological station at Paranal is located 24.62º S, 70.40º W at 2,635 m.a.s.l. The data shows some relatively long periods with no data, especially before 1992, when instruments were malfunctioning or not working. From 1985 to 1999, 43.7% of the averaged data is not available.

3.3 Cross-correlation analysis

The Paranal ground station temperature data are cross-compared with the NCEP/NCAR temperature data. The datasets analyzed are:

1. NCEP/NCAR Reanalysis pressure data. (Press. 1)
2. Paranal ground station pressure data. (Press. 2)

Four times per day data cross-correlation:

	Press. 2
Press. 1	0.3745

Daily averages cross-correlation:

	Press. 2
Press. 1	0.3996

Monthly averages cross-correlation:

	Press. 2
Press. 1	-0.0345

On figure 1, the scatter diagram is shown for the four times per day data for the complete period (1985-1999) for both datasets.

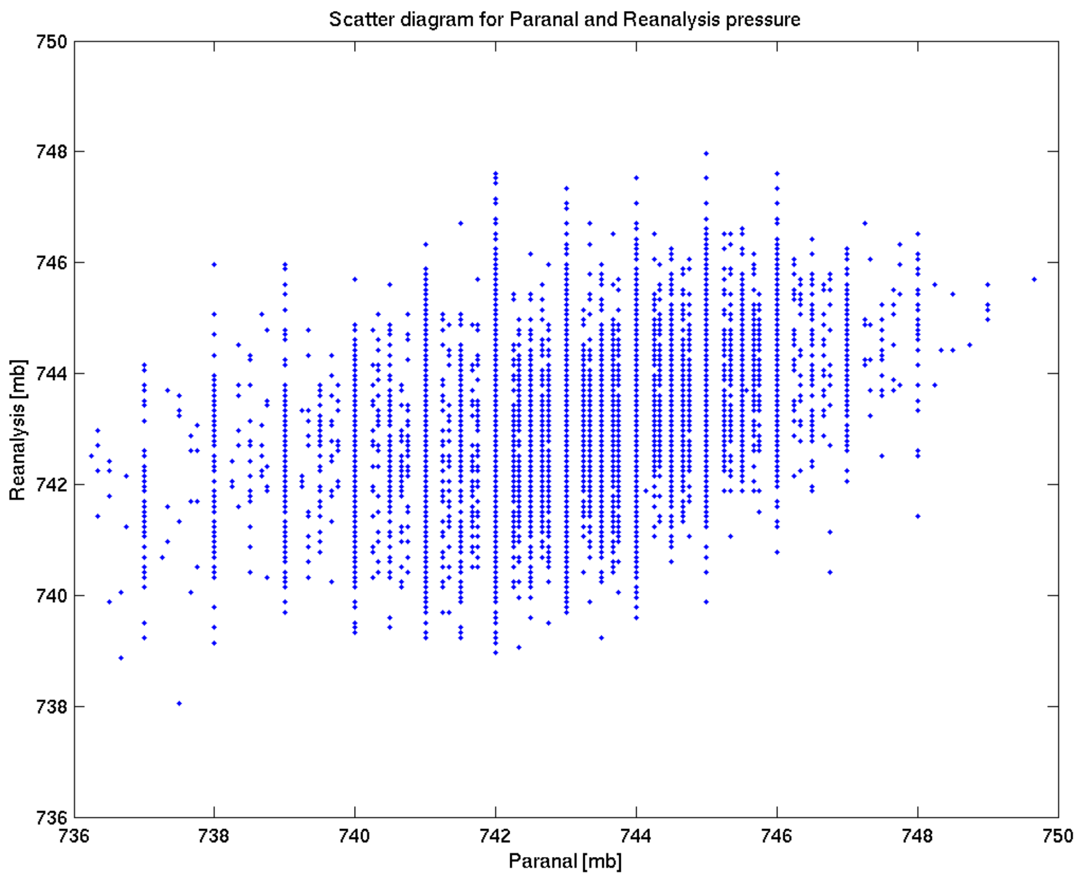

Figure 3: Scatter diagram for the Paranal and NCEP/NCAR Reanalysis pressure data. The four times per day data is depicted for the complete period 1985-1999.

On figure 4, the lower graph shows monthly averages from 1985 to the present. It can be seen that NCEP/NCAR Reanalysis data does not have similar tendencies with the observed at Paranal. In fact, a cross-correlation value of –0.0345 indicates a poor reliability of the Reanalysis pressure data even that the four times per day and daily averages show better results. For the last 5 years, it can be seen that anomalies are similar for both monthly averages.

If we remove the mean value and the annual cycle for the last 5 years independently, a cross-correlation value of 0.5491 is obtained for the four times per day datasets and 0.6461 for monthly averages as depicted on figure 5. This result has a significant improvement from the previous comparisons.

It can be seen that Reanalysis does not well follow the annual cycle on this grid point probably attributed to local effects of Paranal (top of a mountain) and to the atmospheric tides (diurnal and semi-diurnal pressure cycles) that Reanalysis does not consider. In this case, the data averaged at 00, 06, 12, and 18 UTC coincides approximately when the atmospheric tides are zero, but this needs to be calculated for the time of day and year and the latitude of Paranal [5].

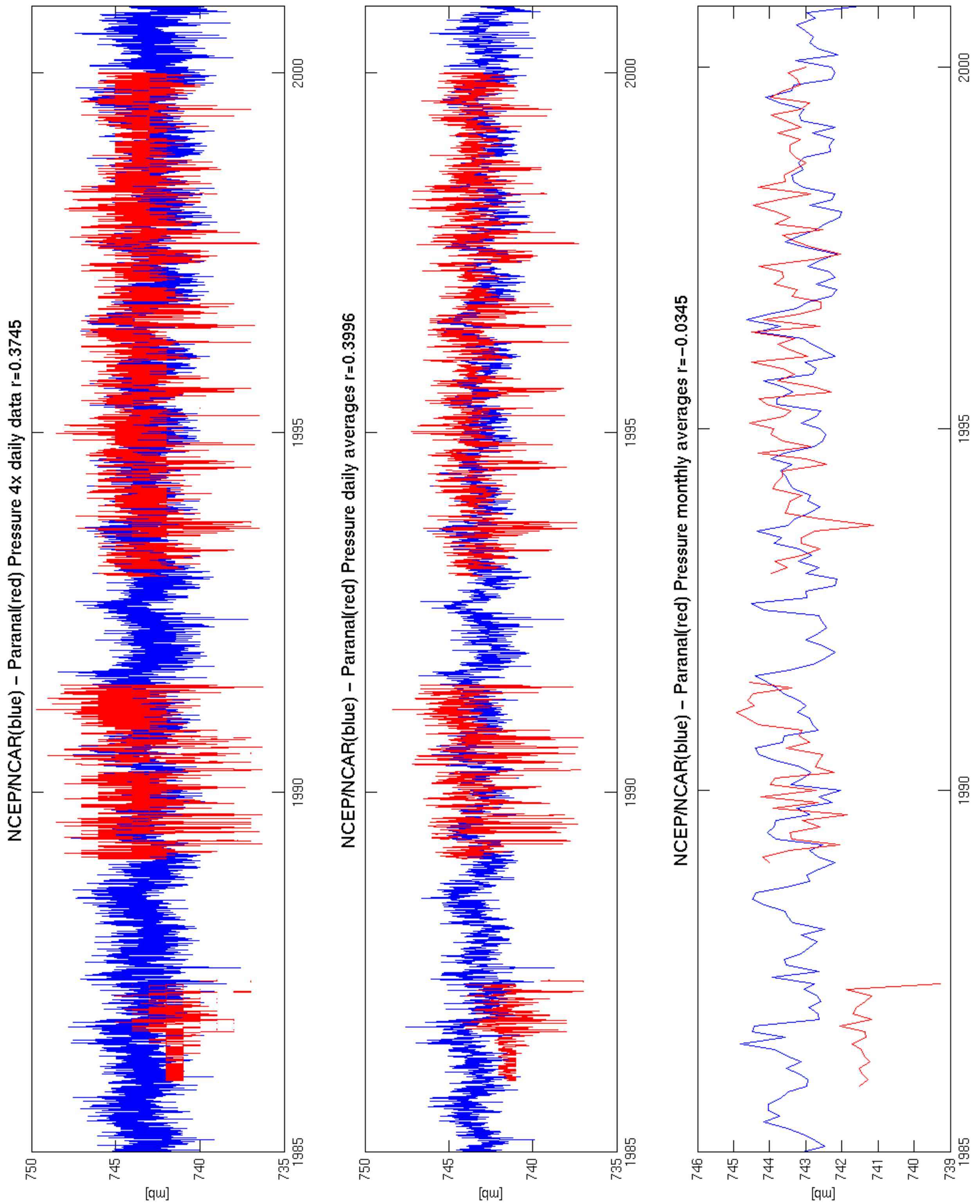

Figure 4: NCEP/NCAR pressure data are in blue and Paranal pressure data in red. The upper graph is four times per day (00, 06, 12, and 18 UTC), the middle graph shows daily averages, and the lower graph shows monthly averages.

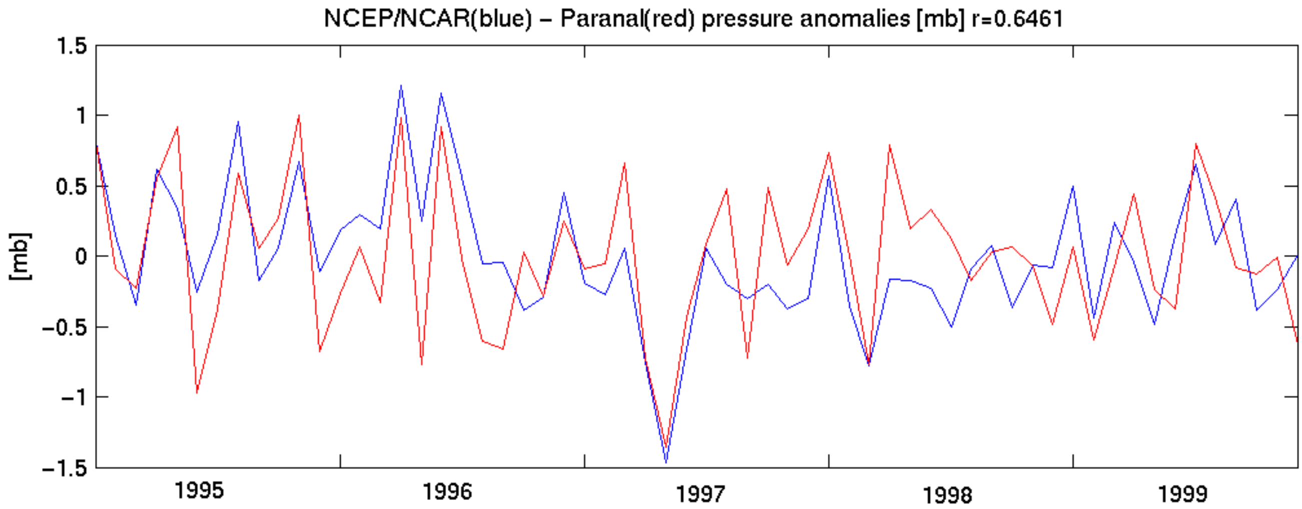

Figure 5: Pressure anomalies (the mean value and the annual cycle are removed independently) for Reanalysis (blue) and Paranal (red) data.

4. Conclusions

For a 15 year period between 1985 and 1999, the monthly tendencies observed in the NCEP/NCAR reanalysis data for surface temperature presents similar patterns with the ones observed with ground stations at Paranal. For the case of pressure, only for the last 5 years similar anomalies can be seen.

Considering the 792 [m] difference in altitude and the 60 [Km] difference in distance between the two points analyzed, cross-correlation values of 0.7875 for surface temperature gives a good reliability of the NCEP/NCAR data. The 5.6 [ºC] surface temperature difference obtained for the two points is probably due to an underestimation of NCEP/NCAR surface data. Previous works have also noted these differences for NCEP/NCAR surface data [3, 4].

Significant discrepancies are observed between monthly averages of Reanalysis and the observed in Paranal. However, if the annual cycle and the mean value in both datasets for the last 5 years are removed, the reliability of the Reanalysis data improves to a cross-correlation value of 0.6461. The altitude correction factor of 0.9057 obtained for pressure values at 1,843 [m] to compare both datasets is consistent with the NCEP/NCAR data and the observed values.

Considering the site differences and the cross-correlation values obtained for surface temperature for the 15-year period studied here, it is concluded that the NCEP/NCAR data can be used to study long-term climatological variations for Paranal. It is also concluded that Reanalysis surface pressure can not be used to study long-term climatological variations for Paranal, unless considerations are taken with the annual cycle, the local effects of Paranal, and the atmospheric tide phenomena.

Acknowledgments

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Paranal meteorological data provided by Marc Sarazin (European Southern Observatory / Paranal Observatory).

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A 15-Year Cross-correlation Analysis of NCEP/NCAR Reanalysis Data with Paranal Ground Stations

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