100 YEARS OF SURFACE WEATHER OBSERVATIONS AT ORCADAS ANTARCTIC STATION:

A LOOK AT VARIABILITY AND CHANGE IN THE ANTARCTIC PENINSULA

Walter E. Legnani [1], Pablo O. Canziani[2], Javier Barletta[1], Gustavo Gil[1], Federico Ibañez[1]

1. Departamento de Ingeniería Eléctrica. Facultad Regional Buenos Aires.
Universidad Tecnológica Nacional.
2. Programa de Estudios de Procesos Atmosféricos en el Cambio Global (PEPACG).
Departamento de Investigaciones Institucionales
Pontificia Universidad Católica. Buenos Aires. Argentina

1. INTRODUCTION

The temporal tendency of the monthly mean meteorological observations from the Argentine Antarctic Station Orcadas (60º45'S / 44º43'W), Laurie Island or Orcadas del Sur Archipelago is analysed for the period 1904-2003, i.e., 100 years of continuous observations. Most other available Antarctic datasets for surface climate trend analysis span shorter periods, beginning in the mid to late 1940's, if not later (van de Broecke, 2000). Jones (1990) studied the temperature recors obtained by early expeditionary groups in the late XIX and early XX centuries, and pointed out the relevance of such early records in order to understand the Antarctic temperature evolution. Jones noted a 1ºC warming between those early observation and the 1957-1975 mean temperatures at different Antarctic locations. In recent years there has been a debate on the origin of the warming and temperture change in Antartica. While it has be argued that the warming in late spring-early summer is due to the large ozone depletion within the ozone hole with samples that begin in 1980 (Thompson and Solomon, 2002), others have pointed out that the current warming trend at least considering the Southern Annular Mode index evolution the present warming process in the Antarctic Peninsula at least date backs to the early 1970´s (Marshall et al, 2004). Hence the warming could be due to the enhancement of GHG. Other authors have argued that both ozone depletion and GHG enhancement could be responsible (e.g. Shindell and Schmidt, 2004). In consequence the detailed analysis of the Orcadas surface dataset provides a truly longterm perspective on the evolution of climate in the Antarctic Peninsula region practically throughout the complete XXth century, ad provide insights for the debate onthe underlying causes of such changes.

2. DATA AND METHODOLOGY

Surface monthly mean temperature and pressure and monthly precipitation totals,

[1] Corresponding author: W.E. Legnani Address: Avda. Medrano 951. 1179 Buenos Aires. Argentina
e-mail: walter@secyt.frba.utn.edu.ar

from the weather station at Orcadas station were used in the present study. The datasets had few gaps, the best coverage over the full period corresponding to the temperature records. During the pre-processing stage, the gaps were completed by linear interpolation and the quality of the fit tested in all cases to ensure the quality of the now equally spaced samples, a requirement of the wavelet analysis methodology (Torrence and Compo, 1998, Foufoula-Georgious and Kumar, 1995]. In the case of pressure and precipitation the samples do not span the full period due to a more important lack of data during the beginning and end of the samples, which resulted in an interpolated dataset with a lower quality at those times (ref Table I). Nevertheless these two variables still span lengthy periods where they remain the only such observations available for Antarctica.

Table I

Dataset	First Year	Last Year
Temperature	1903	2003
Pressure	1903	1991
Precipitation	1909	1982

Figures 1, 2 and 3 show the raw datasets for monthly mean temperature, pressure and monthly total precipitation respectively. Visual inspection of these plots shows both the annual cycles as well as the significant variability in different scales over the period studied. Temperature shows a strong annual cycle with an interannual variability which appears to span a number of years. Monthly pressure total precipitation plots do not yield as clearly defined an annual cycle and have significant variability from one year to the next.

The pre-processed time series were deseasonalized, using an additive model, based on the observed mean annual cycle. The deseasonalized anomalies were then analysed using a filter based on wavelets. In particular the filters were chosen to analyse the longterm trend evolution. More specifically the wavelet base used was the daubechies order 3, which was applied in a decomposition based on a discrete transform algorithm for hierarchical decomposition. Scuh an approach allows the determination of the turning points in the tendency, and thus a much better evaluation of changes in comparison to a simple linear trend. The flow diagram in figure 4 shows the applied work methodology.

The anomaly evolutions calculated in this work correspond to the anomaly signal with the slowest rate of change in the samples. In other words the wavelet filter was applied so as to maintain only the lowest frequencies in the sample. The wavelet filter base chosen for such an analysis does not influence the results (Mallat, 1999). Rather the wavelet filter base was chosen is this case because of its efficiency, its quality as a filter tool and its computational characteristics, in particular computational speed.

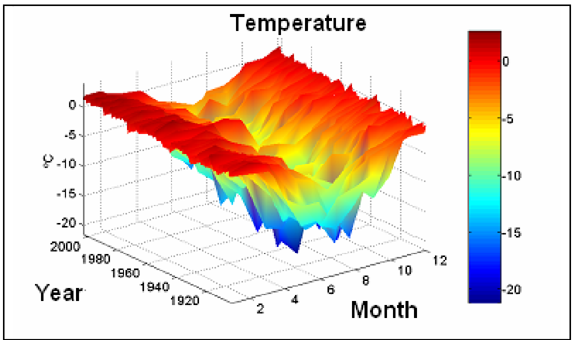

Figure 1: Raw monthly mean temperature observations (ºC)

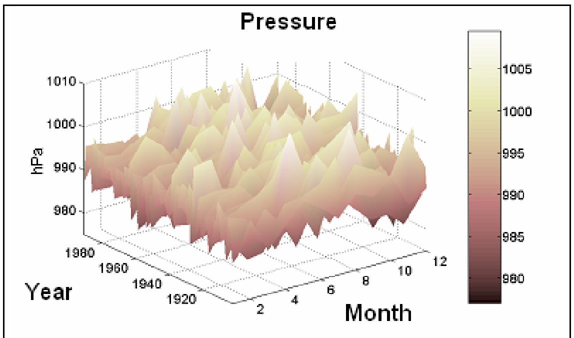

Figure 2: Raw monthly mean pressure observations (hPa)

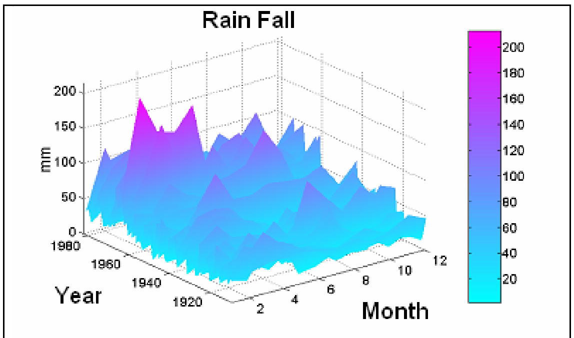

Figure 3: Raw monthly accumulated precipitation (mm)

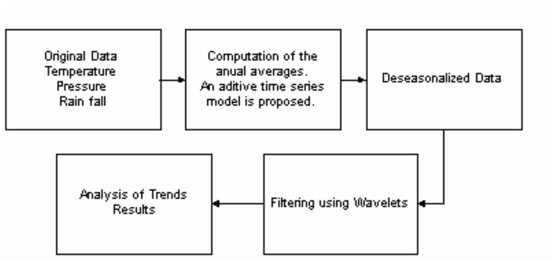

Figure 4: Methodology

3 RESULTS

Wavelet analysis results are shown in figs. 5 to 7. In the case of temperature (fig. 5) a temperature increase is observed for all months and for the whole sample. Changes range, depending on month, from under 1°C to 2°C. Uch results agree well with obserations carried ut during early Antarctic expeditions (Jones, 1990). A particularly strong temperature increase can be seen for the late winter and spring (August though October), which grew more rapidly since 1970 approximately. The rate of warming appears to have increased since 1980 for the months of July, August and September, in coincidence with the appearance and growth of the Antarctic ozone hole. This plot suggests an overall increase of about 2°C over a 100 year period in mid to late winter and early spring, albeit with varying but sustained positive tendency over that timespan.

Another period of sizeable warming can be observed between March and July since 1903 up till approx. 1940. After that the temperature increase during the autumn months slows down, peaking in the early 1970’s and between March and June, there even appears to be a cooling processes during the 1990’s. The most prominent cooling appears in June.

There appears to be some warming throughout the summer months (DJF), which does not show such strong tendencies during specific periods as those previously described. There appears to be an increase in the warming rate since the early 1970’s in agreement with the conclusions of Marshall et al. (2004) based on the study of SAM. There does not appear to be an enhancementin the warming since 1980, which would occur ozone deletion at high latitudes were contributing significantly. Such an enhacement is observed during the late winter months and early spring. However current theory on the contribution of ozone depletion does not refer to these months.

Considering the full sample, the largest changes since 1903 have occurred in July and August, i.e. mid winter. The month with the weakest temperature increase and least variability in the tendency is November. In other words there has been a sizeable warming during winter months, the earlier part of the winter warming during the first half of the 20th century and the later part and spring warming during the last 30 to 25 years.

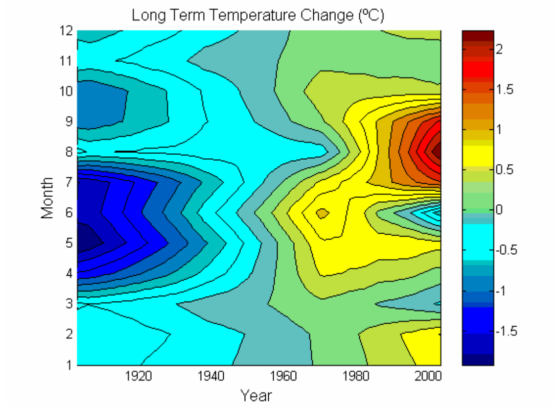

Figure 5: Temperature anomaly longterm evolution

Pressure changes are not as well defined. A quick overview of fig. 6 shows significant changes in tendency from one month to the next between June and November during the second half of the sample. Note that similar oscillatory behaviour, albeit with a weaker amplitude, also occurs for the same months during the earlier part of the sample. At any rate, summer and early autumn months, show an overall 3hPa pressure increase. December does not show any significant pressure change over the 20th century, though there is a very weak increase, whose significance needs to be evaluated, and which begins the mid 1970’s approximately. Note that inspection of pressure linear trends at other stations aslo yield a similar intermonthly difference in trend behaviour (e.g. http://cdiac.ornl.gov/epubs/ndp/ndp032/ndp032.html)

Precipitation (in terms of monthly accumulated precipitation shows a sizeable increase, in particular during the first half of the year (summer and autumn). Overall figure 7 suggests an increase of the order of 40-50 mm for February and April-May, i.e., a 40 to 50% increase over a 75 year period. The

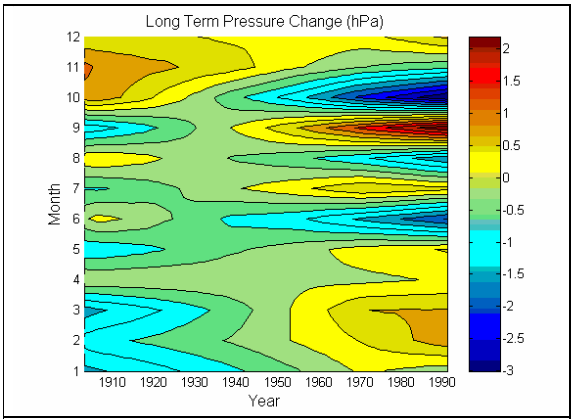

Figure 6: Pressure anomaly longterm evolution

precipitation tendency increased during those months in the late 1950's/early 1960's.
The rest of the year has a more moderate increase, of the order of 20mm, with no discernible enhancement or decrease in the rate of precipitation change.

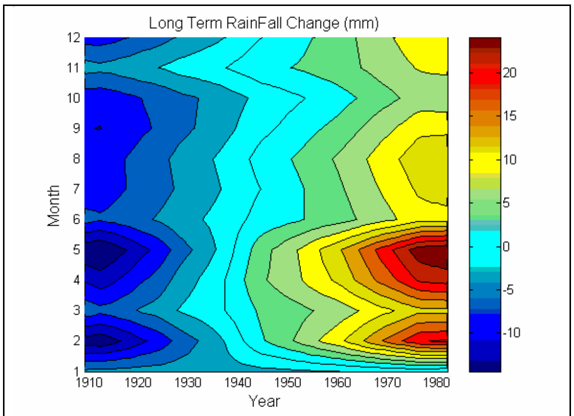

Figure 7: Accumulated precipitation anomaly longterm evolution.

Changes in precipitation occurred mostly at times of the year with limited temperature change, except in June in the early decades of the sample, Little can be said of the relationship with pressure changes given the aforementioned variability of the pressure dataset.

4 CONCLUSIONS

Antarctic weather datasets were analysed here for the first time with the wavelet filter technique. In particular the evolution of 100-year long anomaly time series has been studied. The Orcadas Station timeseries is the longest available for Antarctica, and most other continuous timeseries started only after WWII. Thus this analysis provides a first glimpse on climate evolution in the vicinity of the Antarctic Peninsula almost 50 years before other sites.

A significant warming tendency is detected with increases of less than 1°C up to approximately 2°C. Such tendencies depend on the month of the year as well as on the temporal segment of the timeseries. For example the analysis points to a significant warming in autumn and early winter up to 1940 approximately, followed by a weaker tendency afterwards or even sizeable cooling, e.g. in May/June. On the other hand, during the 1970's a strong warming begins in late winter and spring, which appears to be lasting to this day. This time of the year exhibits the months where a sustained and largest, if variable, positive tendency is observed.The pressure anomaly timeseries analysis does not provide conclusive results except for a pressure increase in summer and autumn, but the behaviour is in agreement with shorter time series for this Antarctic region.

Precipitation changes are large, with increases close to 50% over a 75 year period, during the summer and autumn months. Changes are significant but not as large for the rest of the year.

These results evidence large changes in the climate in the region of the Orcadas Station during the 20th Century, with a large warming and increase in precipitation. The relationship between such changes andthe evolution of circulation patterns needs to be assessed.

5 REFERENCES

Foufoula-Georgious, E. Kumar. "Wavelets in Geophysics". Academic Press. 1995

Jones, P.D., Antarctic Temepratures over teh Present Century – A Study of the Early Expedition Record, J. Clim., 3, 1193-1203, 1990.

Mallat, S., "A wavelet Tour of Signal Processing".*Academic Press*. 1999.

Marshall, G. J., P. A. Stott, J. Turner, W. M. Connolley, J. C. King and T. A. Lachlan-Cope, Causes of exceptional atmospheric circulation changes in the Southern Hemisphere, Geophys. Res. Lett., 4 31, L14205, doi:10.1029/2004GL019952, 2004.

Shindell, D. T. and G. A. Schmidt, Southern Hemisphere climate response to ozone changes and greenhouse gas increases, Geophys. Res. Lett., 31, L18209, doi:10.1029/2004GL020724, 2004.

Thompson, D., Solomon, S., Interpretation of recent Southern Hemisphere climate change, Science, 296, 895-899, 2002.

Torrence, C. and G. P. Compo. "A practical Guide to wavelet analysis". Bull. Amer. Meteor. Soc. **79**, 61-78, 1998

van den Broecke,*M.* On the Interpretation of Antarctic Temperature Trends J. Clim., Vol. 13, No. 21, pp. 3885–3889, 2000

ACKNOWLEDGEMENTS

This research has been possible thanks to grant CONICET PIP 5276.