SNOW AND AVALANCHES FORECASTING OVER THE ANDES MOUNTAINS

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ABSTRACT: During the last three years (1998-2000), the University of Chile and CODELCO-ANDINA has directed significant research towards the implementation and evaluation of an operational regional weather forecast over the Andes Mountains (Vergara et. Al, 1999). The implementation is designed to provide traditional synoptic forecasts at high-resolution grid spacing and local weather forecasts for providing warning of avalanches during winter time.

The current analysis uses data based on daily snow precipitation in Lagunitas (2670 m above msl), located in the central part of Chile of the Andes Mountains, as well as daily model forecasts. For this station the period study covers the last years. The 1997 and 2000 winter was one of the wettest winters during the last 30 years.

This paper explores the performance of snow and avalanches forecasts during several cases of strong weather conditions over the Andes Mountains (Figure 1) during El Niño year of 1997 and compares the model results with snow observations. The results show that the 24 hour forecasts explain about 80% of the variance in snow depth data. The study demonstrates the operational capability of the model to forecasts total snow depth during the storm. Finally, the model is shown to be an effective tool for support of avalanches forecasts over the Andes Mountains due to the strong relationship between snowfall and avalanches.

KEYWORDS: Snow, avalanches, meteorology, Andes Mountains, Chile

1. INTRODUCTION

The Andes mountains, the longest chain of mountains in the south hemisphere, shows a strong and complex variations in the snow and meteorological conditions as one move from east to west, because the Andes is the narrows and longest mountains in the world. The annual mean snowfall in the Andes central part Chile is close to 10 meters, with a strong interannual variability from 2.2 meters on la Niña year of 1998 to 21.44 meters on the el Niño years of 1972 (Figures 2 and 3), and the snow may fall in the any time on the winter from April to September with a maximum in June/July (Figures 3 and 4). During the winters the means minimum temperatures is close to –10C and the maximum mean temperature is close 12C (Figure 5). The high temperatures on the mountains usually take place immediately following the storms associate to anticyclone subsidence, and the avalanches formation on the study area (Figure 1) is proportional to the number of hours of closed roads due to avalanches (Figure 6), them the maximum avalanches formation are maximum in June-July (Figure 7). But the ratio of the number of avalanches to the total snowfall of the storm increase during the second part of the winter and spring time because the temperature increase dramatically and them melting (Figure 7).

Because the strong relationships from the since of the storm and the number of avalanches (Figures 6 and 8). The weather observation a forecasts are the primary tools for predicting the total snow precipitation on the storm, the avalanches potential and hours of roads are close due to the avalanches.

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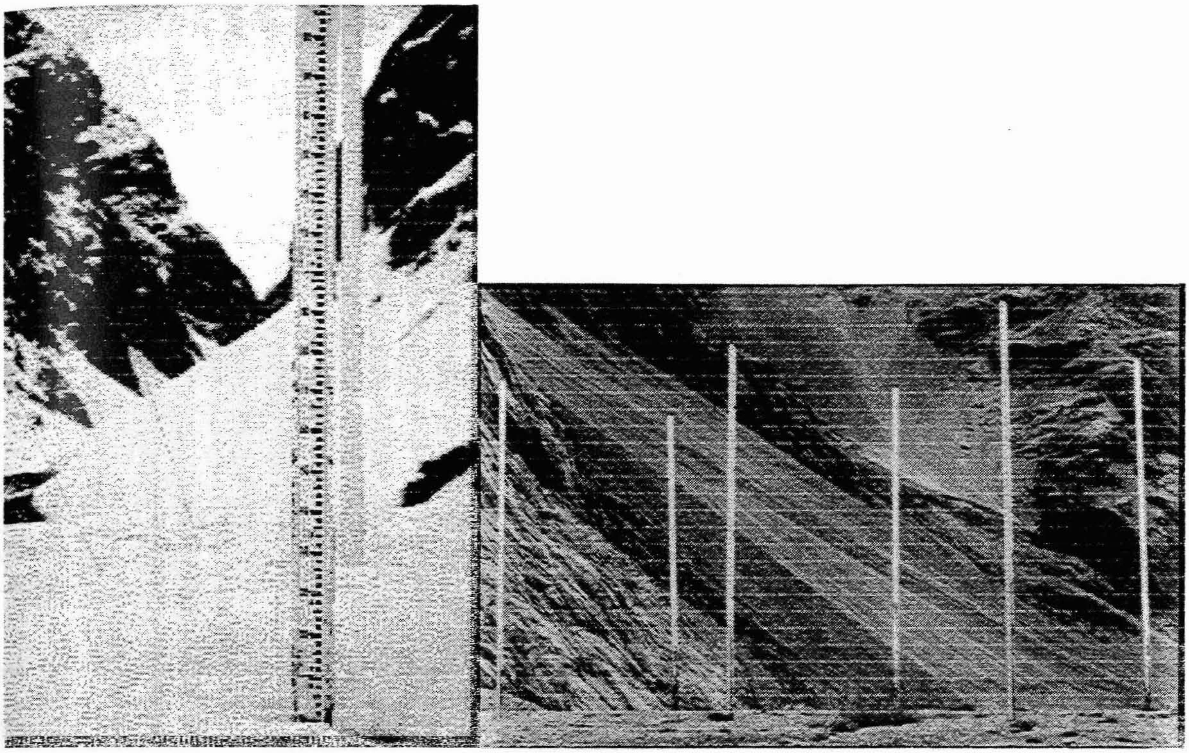

Figure 1: Snow depth stake at Lagunitas stations (2670 m above msl); From September of 1998 at the end of the winter (right), one of the driest winters of the last one hundred years and September of 2000 (left) one of wettest last thirty years.

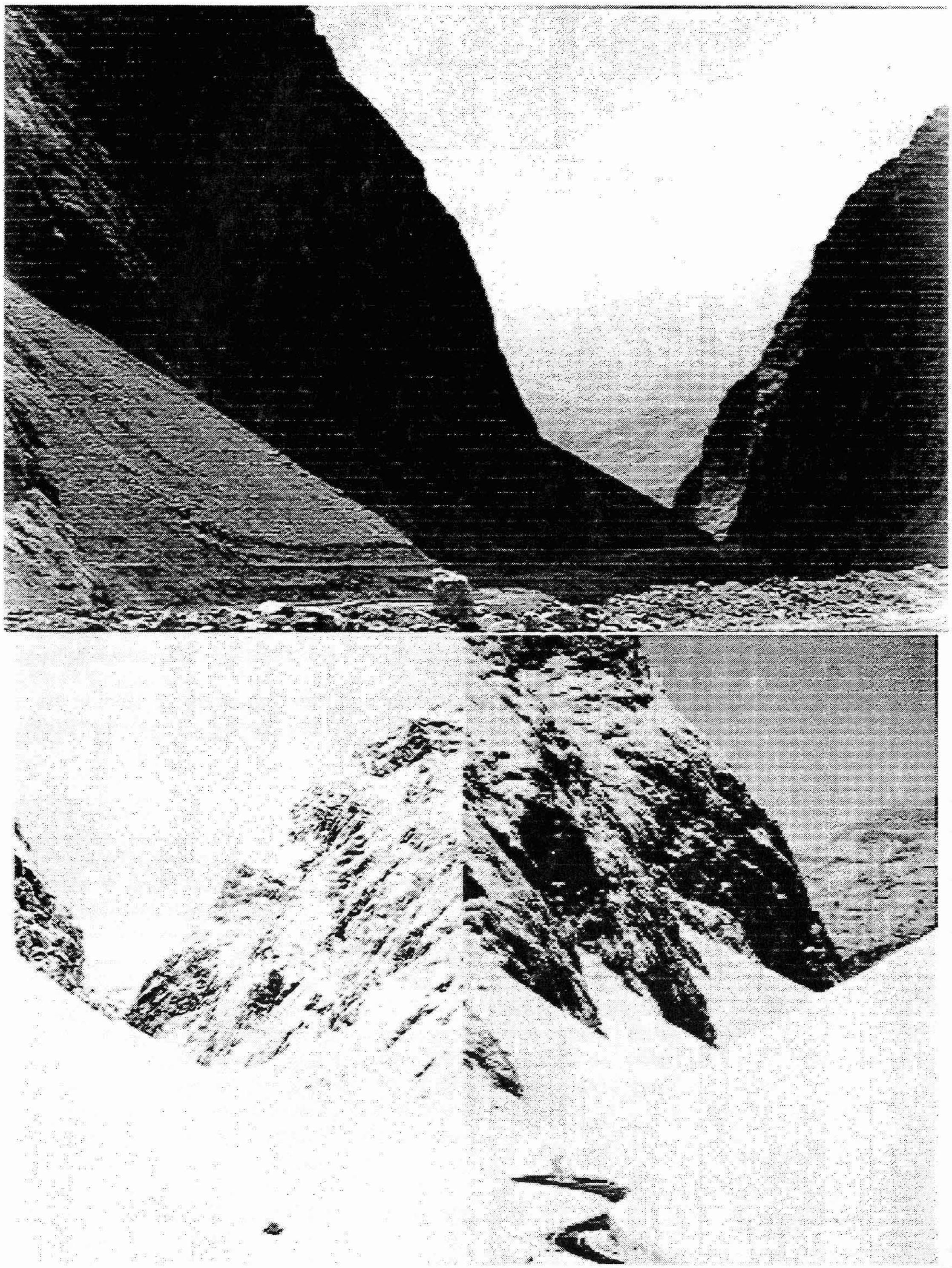

Figure 2: Piuquenes to Haulage Roads though the avalanches area, during of year 1998 winter (top), and 2000 (bottom).

2. RESULTS

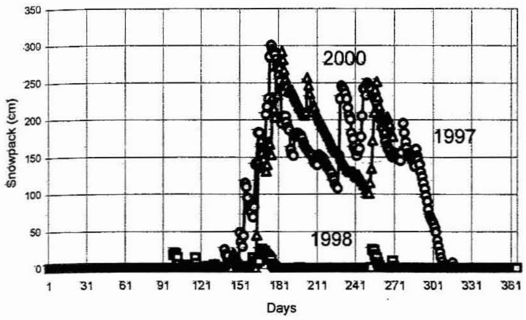

Figure 3: Time evolution of snowpack depth during the El Niño year 1997 (circle) and La Niña year 1998 (squared) and 2000 year (triangle) at Lagunitas station central part of Chile (Figure 2).

This paper explores the performance of the NCEP Regional Spectral Model (Vergara, et .al, 1998) during winters of 1997 (El Niño) and 1998 (La Niña). The winter of 1997 one of the wettest on record is important in terms of precipitation. The 1998 winter was one of driest winters of the last one hundred years (Figure 2) and no important rainfall events occurred. During both years the RSM was run operationally and several cases of extreme weather events occurred during these years (in particular during the 1997 winter).

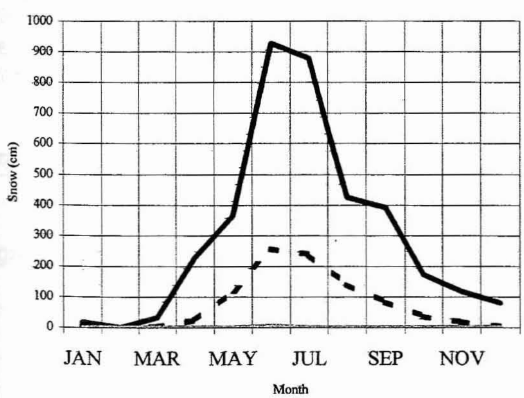

Figure 4: Annual cycle of maximum (continues line) and mean (dots line) snow precipitation in the Lagunitas station.

In order to evaluate the model performance, model outputs for the two-years are correlated with observed precipitation data. The RSM precipitation forecasts over the Andes Mountains in the central part of Chile explain about 70% of variance in the observed daily rain data, with explained variance of 78% for the 24 hour forecasts and 66% for the 48 hour forecasts with a mean error close to 25 mm (Vergara, 2000). Snowfall forecasts at Lagunitas local station explain about 81% (24 hour forecasts, Figure 9a) and 78% (48 hour forecasts, Figure 9b) of the snowdepth, with a mean error close to 20cm (24 hours) and 30cm(48 hours). The RSM provides accurate forecasts of the heaviest rainfall and snowfall events over Chile and the Andes Mountains. These forecasts of heavy events are of particular interest since they can provide better avalanches forecasts and warning due to the strong relationship between snowfall and avalanches (Figures 6 and 8). The high resolutions weather forecast, is able to provide better forecasts for local weather conditions because of its ability to resolve small scale weather features and the complex and strong slope over the Andes topography.

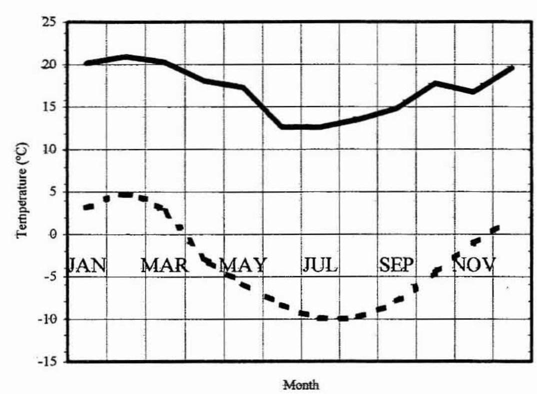

Figure 5: Annual cycle of maximum (continues line) and mean (dots line) temperature in the Lagunitas station.

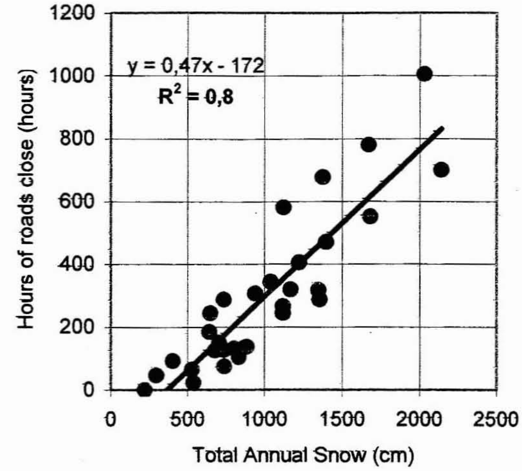

Figure 6: The annual number of hours of closed roads due to avalanches as a function of total annual snow at Lagunitas station (2670 msnm).

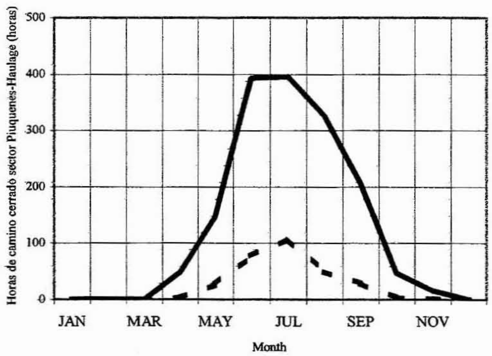

Figure 7: Annual cycle of the number of maximun (continues line) and mean (dots line) hours of closed roads due to 1997 at Lagunitas station.

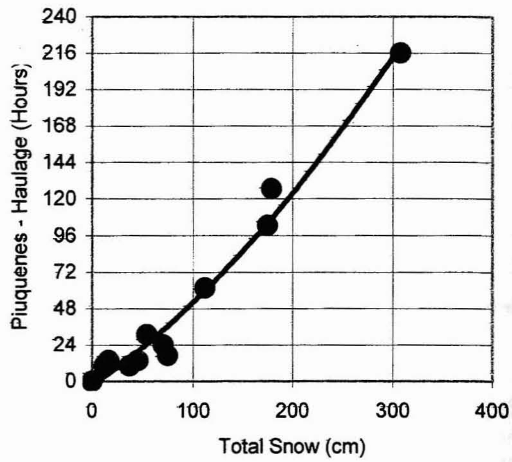

Figure 8: The number of hours of closed roads due to avalanches as a function of total snow during 1997 at Lagunitas station (2670 msnm).

3. CONCLUSIONS

Performance of the operational forecast system over the Andes Mountains in the central part of Chile was presented. The objective of the system is to provide better snowfall forecasts for synoptic and mesoscale phenomena. The model demonstrated an operational capability to run successfully over South America (in particular Chile) and successfully simulated strong rainfall events, especially during the El Niño event of 1997/1998. The model proved to be an effective tool for the support of mountains weather snowfall and rain forecasts over the chilean mountains.

4. ACKNOWLEDGEMENTS

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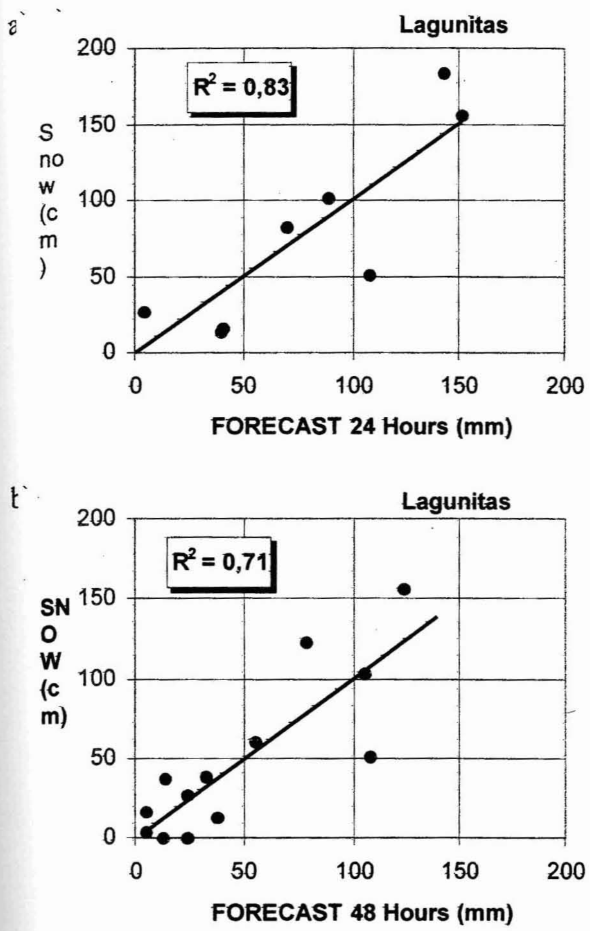

Figure 9a,b: Regression of 24 (top) and 48 (bottom) hour snow forecasts on control station observations. The solid line represents the linear regression.

5. *References*

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