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REGIONAL CIRCULATION FEATURES ASSOCIATED WITH PRECIPITATION EVENTS LEEWARD THE ANDES

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1. INTRODUCTION

Synoptic and regional-scale conditions associated with precipitation events leeward the Andes in Argentina are studied. Anomaly patterns of mid-tropospheric circulation in conjunction with local precipitation are analysed from Tartagal (about 20ºS) to Ushuaia (about 55ºS) mainly along the longitude 70ºW east of the Andes Cordillera in order to examine the anomaly circulation behaviour and seasonality, and also to detect spatial coherence and geographical differences in anomaly patterns having place in precipitating situations.

A number of studies have described the circulation features in subtropical and mid-latitudes around South America and associated anomalies with precipitation (Aceituno, 1988; Minetti and Sierra, 1989) Garreaud and Rutllant, 1996). In this study, the circulation features in the South American troposphere associated with precipitation occurrence events east of the Andes are analysed using biserial-composite fields prepared from ECWMF operational numerical analyses. Emphasis has been placed on the geopotential anomalies in the middle troposphere in the austral cold and warm seasons and the distinct circulation patterns that appear in the north–south direction. A variable wavetrain pattern of anomalies extends from Western South Pacific Ocean to the north or northeast depending on the specific site examined.

It is worth noting that each one of the regional synoptic map-pattern classifications investigated is appropriate or of exclusive use for the corresponding surface station. There exist separate classification systems for each in situ precipitation, thereby, different responses for each station. Notwithstanding, north of Malargüe (about 40ºS) there seem to be regional anomaly patterns in connection with precipitation occurrence substantially different, and perhaps independent from an orthogonal technique point of view, from those occurring to the south. This influence may affect the hydrological environment and the runoff of Cordillera rivers. So, this work addresses a climatologic diagnosis study of circulation patterns linking mid-tropospheric dynamics, cyclonicity and anticyclonicity conditions, and wavetrain pattern of anomalies to the local precipitation and in what a way these patterns are evidenced as significantly different with latitude affecting different runoff regimes. These atmospheric patterns are responsible of precipitation production, both liquid and solid, which feeds and controls the Cordillera rivers. Consequently, depending on what hemispheric and large-scale factors are acting this would affect or favour a determined anomaly pattern associated which in turn is associated with precipitation at a given locality, and, hence, the runoff variability.

2. DATA AND METHODOLOGY

The data used consist of daily 500-hPa geopotential height fields at 1200 UTC from ECMWF for the South American region between 15°S to 70°S and 120°W to 20°W. Daily precipitation data at the following meteorological stations of Argentina are used: Tartagal (22º30´S, 63º50´W), Tucumán (26º50´S, 65º12´W), Catamarca (28º27´S, 65º46´W), Mendoza (32º50´S, 68º47´W), Malargüe (35º30´S, 69º35´W), Neuquén (38º57´S, 68º08´W), Bariloche (41º09´S, 71º10´W), Maquinchao (41º15´S, 68º44´W), Esquel (42º54´S, 71º22´W), Lago Argentino (50º20´S, 72º18´W) y Ushuaia (54º48´S, 68º19´W). The precipitation is accumulated from 1200 UTC of day *i* to 1200 UTC of day *i+1*. The data cover the period 1983-1987.

A synoptic climatological approach provides a means to identify relationships between synoptic-scale conditions and the surface environment. Among the types of synoptic climatological studies (Yarnal, 1993), the one used here is the environment to circulation perspective. Atmospheric circulation patterns are identified following and depending on surface conditions. Surface data are

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already present and contained when fitting the classes of atmospheric patterns. The biserial correlation-based methodology used seeks to find key interactions between the atmospheric circulation and the precipitation occurrence as a surface variable with categorical behaviour (Yarnal, 1993; Wilks, 1995). A classification of atmospheric circulations is obtained. The derived climatology is exclusive for each location.

3. RESULTS

The South American circulation features associated with precipitation events identified in the biserial correlation fields (Ruiz, 2002) are presented and contrasted. Biserial correlation coefficients with an absolute value larger than 0.17 and 0.15 are statistically significant using a *t-Student* test at 99 % and 95 % level, respectively. The patterns obtained may be interpreted as anomalous configurations present when local precipitation occurs, or, inversely, when it does not, with the daily variability taken into account.

The geopotential anomaly patterns are discussed and compared in order to detect similar behaviour types. The study of the daily variability circulation shows the anomaly patterns that generate precipitation in different regions of Argentina, north-western, central-western and south-western regions, independently on whatever large-scale anomaly or low-frequency process is acting (ENSO, interannual or decadal variabilities). If a large-scale process activates the regional anomalies favouring local precipitation, then this may influence precipitation excess or deficit at the specific related sites, and hence, the Cordillera river runoff regime.

In order to take into account the seasonal cycle, the total sample was separated into the cold months (May to October) and the warm months (November to April). Firstly, the discussion focuses on the austral cold semester. In the north-western subtropical region of Argentina as in Tartagal (Fig. 1), it may be clearly seen anomalously low geopotential heights between 20°S and 30°S over the adjacent Pacific Ocean and, particularly, a positive height anomaly covering the south-eastern Pacific region from 30°S to the Patagonia coast. This pattern is a striking feature of the atmospheric circulation in relation to precipitation occurrence in leeside, north-western locations of Argentina. The axis of anomalies has SW–NE direction. The circulation index reverses. Westerlies are blocked at mid-latitudes, and shift southwards. Anomalies are mainly observed over the Pacific side. The Atlantic Ocean does not appear to have an important role, at least through this regional analysis.

Going to the south, Tucumán (Fig. 2) shows an anomaly geopotential pattern similar at a first sight to that of Tartagal; however, the negative anomaly center is located about 30°S over the Cordillera de los Andes and the highly significant positive anomaly is now about 50°S to the southwest of the Patagonia, clearly breaking up the westerly regime. Another high anomaly may be seen over the Gulf of Santa Catarina in Brazil. For Catamarca (Fig. 3), a similar anomaly configuration is found, though the low anomaly center is outside the continent over the Pacific Ocean. All these stations are characterized by a SW–NE direction in the dipole height anomaly pattern. Distinctively Mendoza (Fig. 4) presents a somewhat more defined S–N direction in the markedly evident dipole configuration. The anomalously low height center associated with precipitation at Mendoza is a dominant fact with a clear preferential position to favour precipitation at the central-western region of Argentina, the Cuyo region, in winter. Anyway, the positive height anomaly in the south-eastern Pacific Ocean between 100°W and 60°W is also evidently necessary. In Malargüe (Fig. 5), the anomaly pattern is rather similar, but shifted southwards. Therefore, high height anomalies over the Drake Passage about 60°S begin to appear important to produce precipitation in north-western Patagonia. The latter is markedly evident for Neuquén (Fig. 6), where the positive anomaly is precisely between the southern continent and Antarctica and the anomaly low center is about 35°S adjacent to the central Chilean coast. It may be noted that the axis of this dipole configuration is in the SSE–NNW direction. At Maquinchao (Fig. 7), it may be observed a fairly similar behaviour, although shifted just a little westwards and southwards. It may be said that the Mendoza area is some like a transition zone, as Malargüe and Maquinchao exhibit a rather different anomaly pattern. Notwithstanding, it is in Bariloche (Fig. 8) where the geopotential height anomalies in association with precipitation are completely different and clearly obey to another circulation regime. Therefore, the Comahue region may be affected in a different way by large-scale anomalies in both spatial and temporal terms. The anomalously low negative center about 45°S west of the continent is the most notable feature which dominates Bariloche precipitation. Then circulation anomalies there determine in a great extent precipitation leeward the Andes south of 38°S. Esquel (Fig. 9) is another example of the mentioned above. Nevertheless, at 50°S Lago Argentino (Fig. 10) presents again a rather different anomaly pattern connected with precipitation. Negative anomalies are clearly embedded in the west of Tierra del Fuego in the south-eastern Pacific Ocean, and an anomalous high center begins to insinuate around 30*S in the subtropical Pacific Ocean. At Ushuaia (Fig. 11), the anomaly pattern again changes. An important negative anomaly center is evidenced now in the south-western Atlantic Ocean, adjacent to the continent.

4. SOME DISCUSSION AND CONCLUSIONS

Atmospheric circulation associated with precipitation events leewards the Andes in Argentina between 22ºS to 55ºS are studied in order to examine latitudinal and mountain barrier effects on transient disturbances, and consequently on precipitation.

It is worth noting that each one of the regional synoptic map-pattern classifications investigated is appropriate or of exclusive use for the corresponding surface station. There exist separate classification systems for each in situ precipitation, thereby, different responses for each station. However, it may be established some preferential ensemble atmospheric circulation configurations according to spatial coherence of anomaly geopotential patterns in different regions.

The circulation anomalies associated to precipitation in the north-western region of Argentina leeside the Andes up to Mendoza show a configuration with a negative anomaly nucleolus to the north or northeast and a positive one to the south, mainly over the Pacific Ocean, which does not go south of 60°S. The Mendoza region may be considered as a transition zone (the behaviour in summer resembles that of Neuquén), while the Neuquén region evidences a different behaviour. Positive anomalies may be found over the Drake Passage in the southernmost part of the continent. The Patagonic Andes leeside the Cordillera exhibit a markedly different circulation regime in relation to precipitation with the negative height anomaly nearly at the same position where the positive anomaly is found for north-western precipitation. This important feature indicates a practically orthogonal behaviour between leeside precipitation anomaly north of about 38°S and south of it. The Cordillera river runoff may be distinctly affected depending on the region and source of precipitation (Poblete et al., 2005).

Southernmost stations of the continent are also affected by a different anomaly circulation pattern in some extent.

The analysis for the warm semester, not shown here, reflects that the interseasonal variability is not too large.

The synoptic-scale patterns identified represent the atmospheric circulation conditions leading to supplying rainfall through the meridian about 70ºS leeward the Andes, and a sort of typification is achieved.

Acknowledgements

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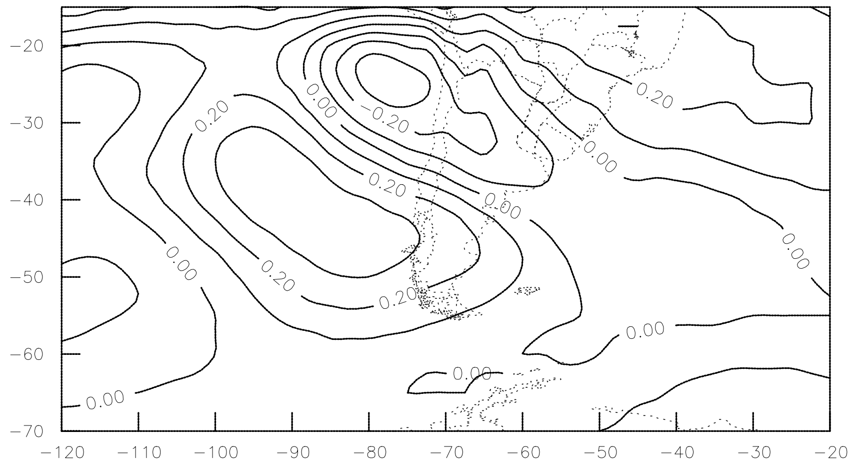

Fig. 1. Biserial correlation field between 500-hPa geopotential heights and precipitation occurrence at Tartagal, for the cold semester.

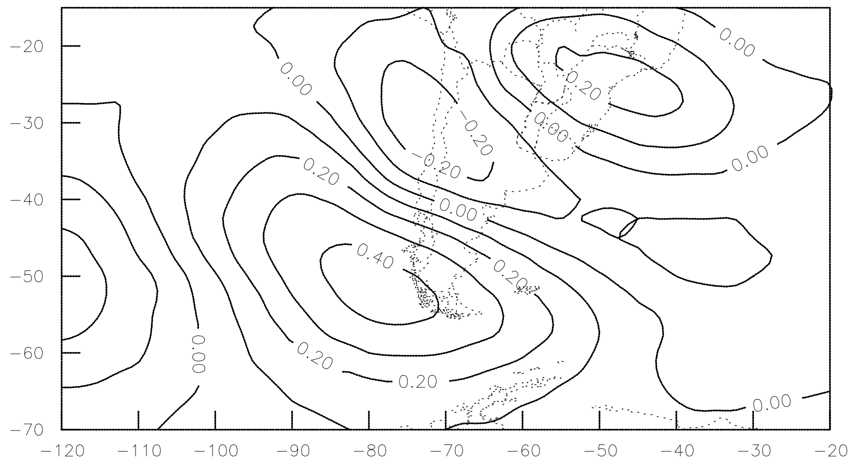

Fig. 2. Idem Fig. 1, but Tucumán.

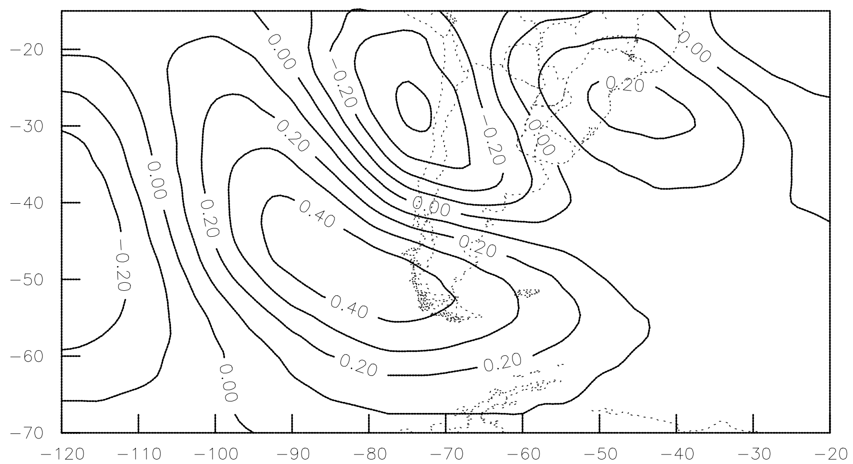

Fig. 3. Idem Fig. 1, but Catamarca.

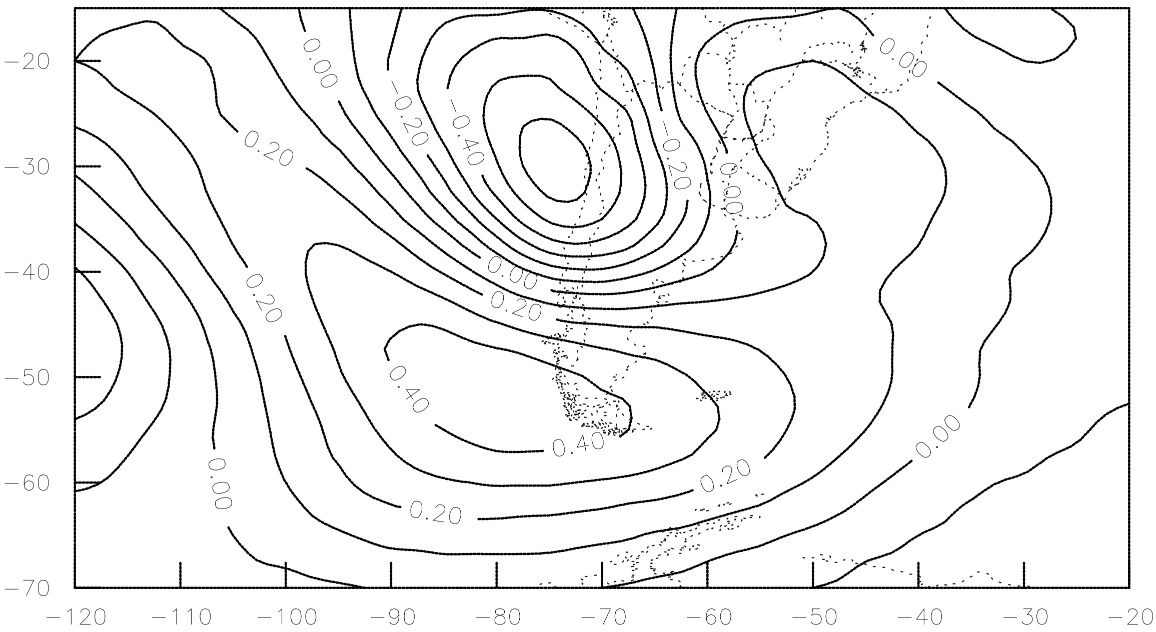

Fig. 4. Idem Fig. 1, but Mendoza.

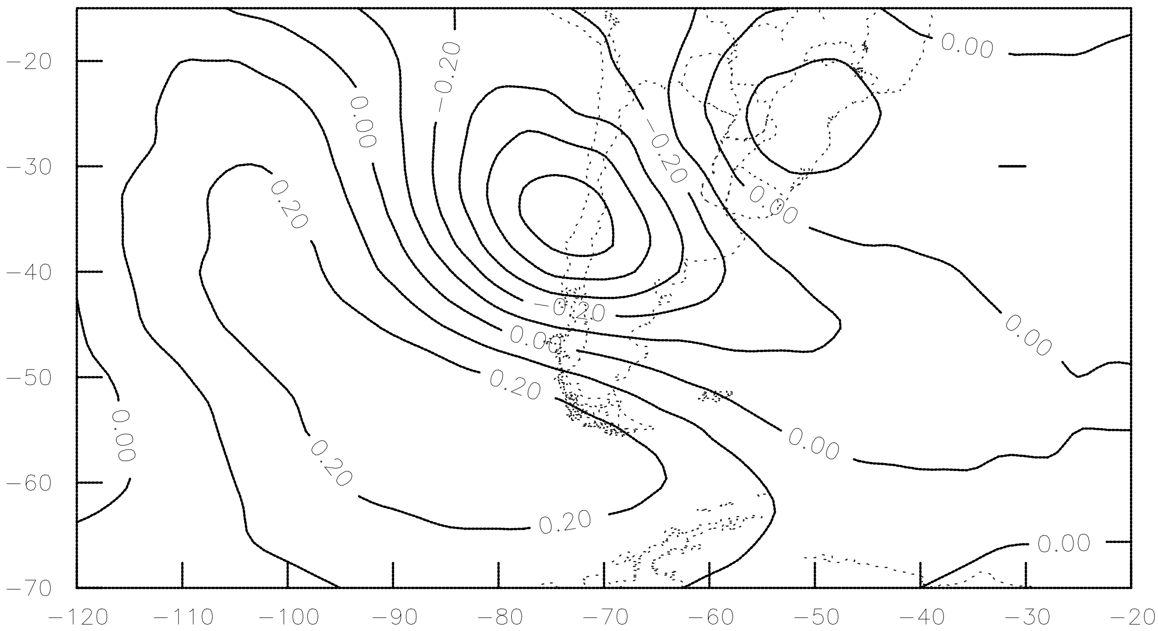

Fig. 5. Idem Fig. 1, but Malargüe.

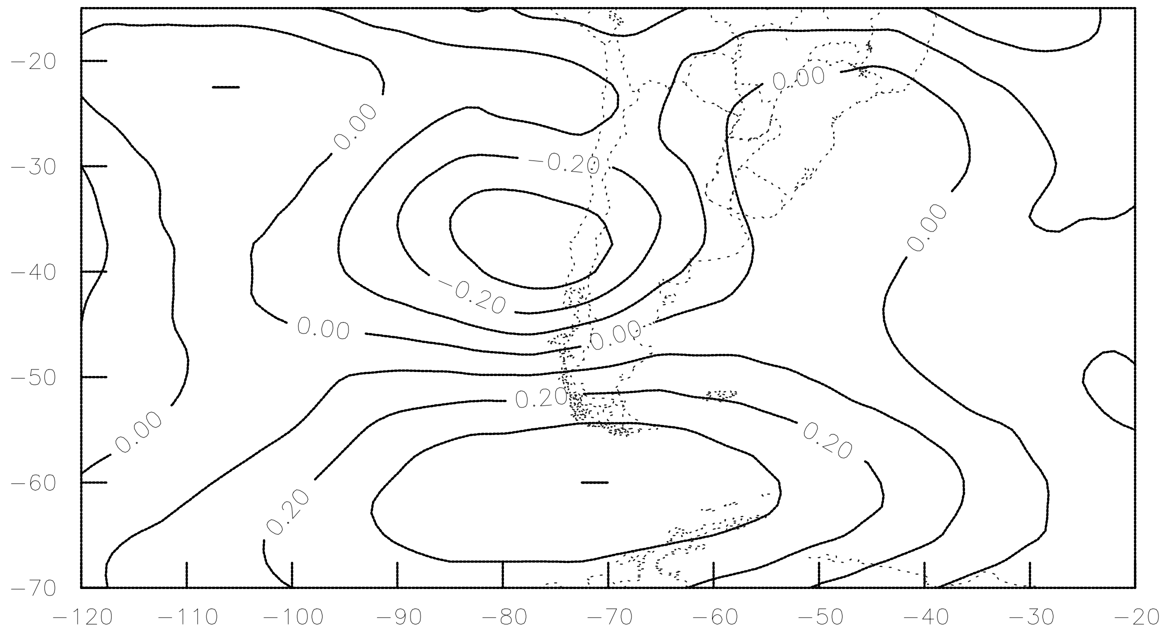

Fig. 6. Idem Fig. 1, but Neuquén.

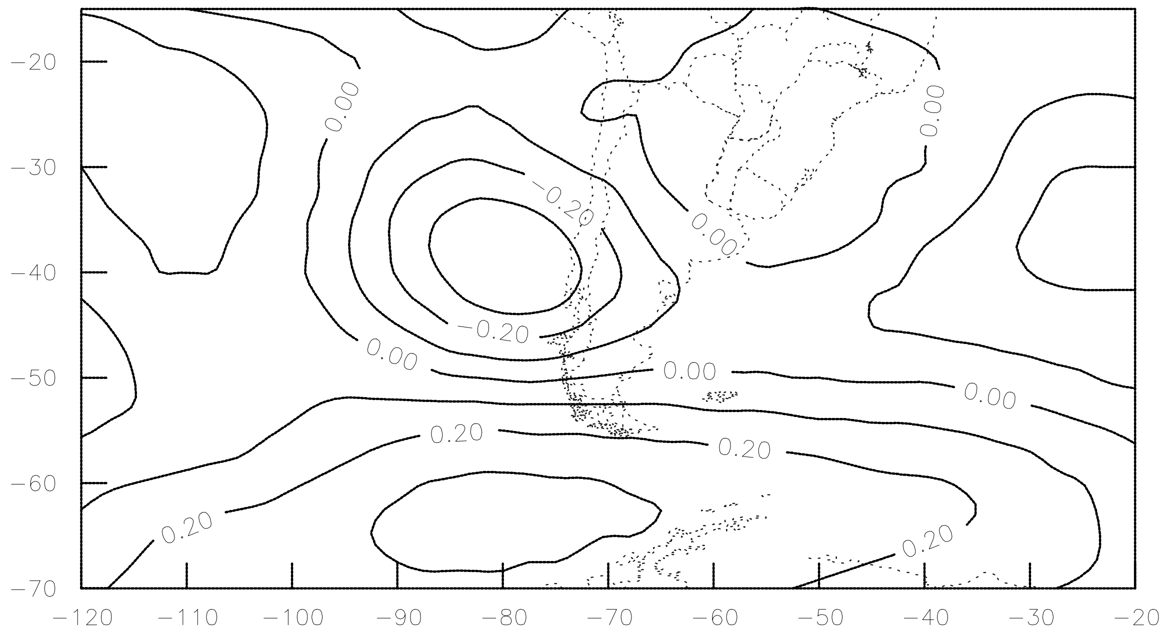

Fig. 7. Idem Fig. 1, but Maquinchao.

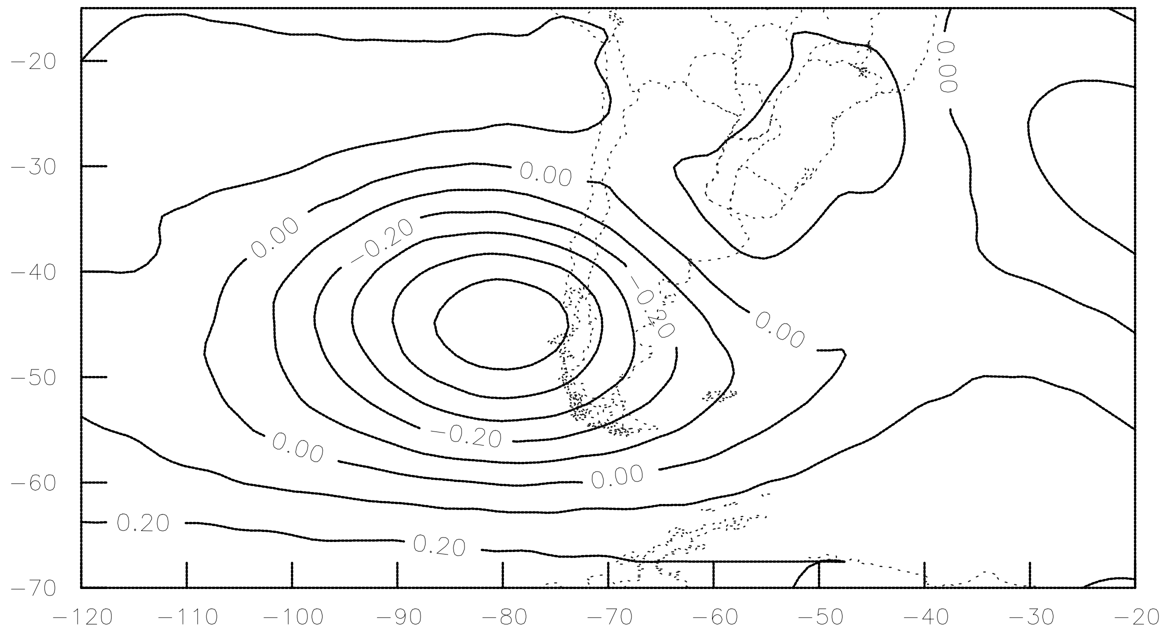

Fig. 8. Idem Fig. 1, but Bariloche.

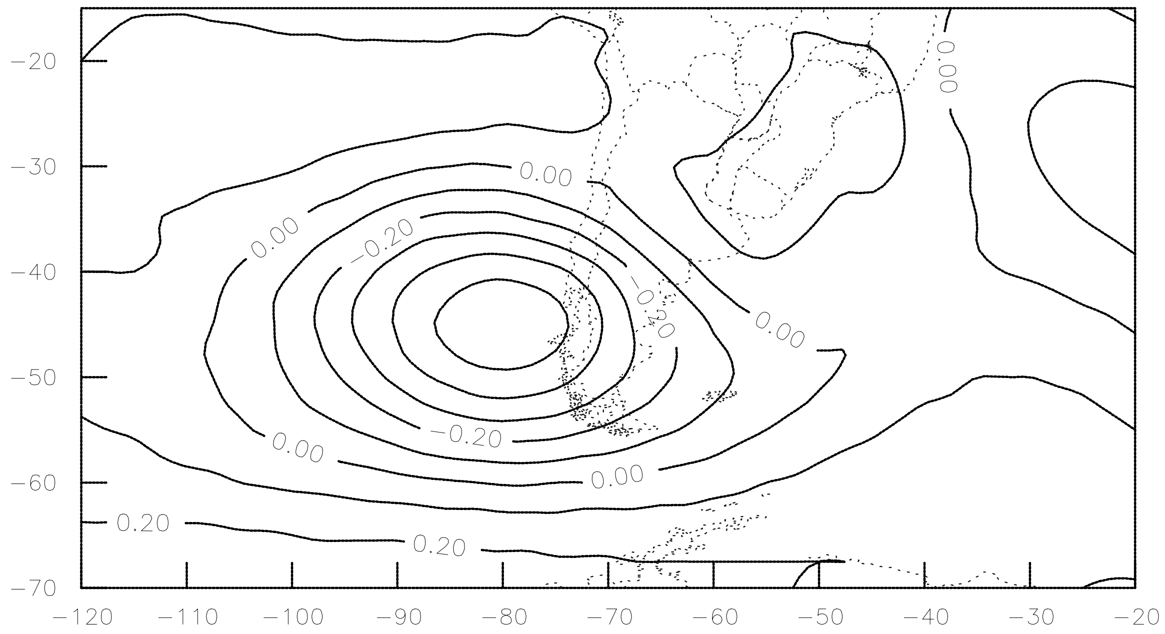

Fig. 9. Idem Fig. 1, but Esquel.

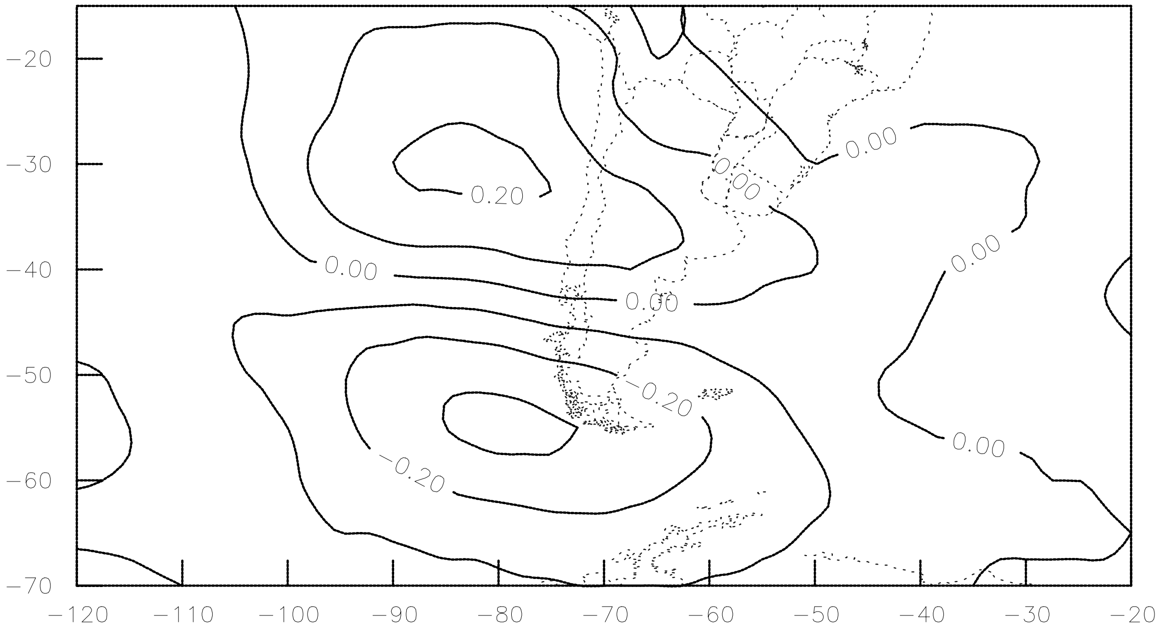

Fig. 10. Idem Fig. 1, but Lago Argentino.

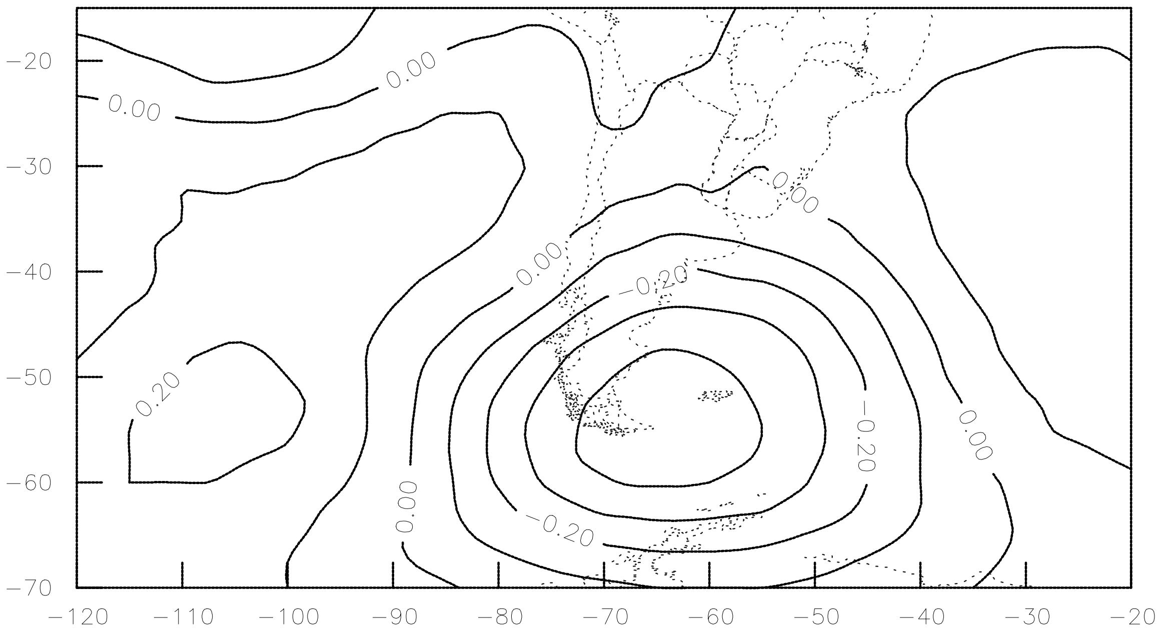

Fig. 11. Idem Fig. 1, but Ushuaia.