Recent (2004-2010) variations of surface displacements in an Andean permafrost-glacier environment (Chile, 33° S.)

1 - Introduction and methods

In the semi dry central Andes (Chile, 33° S) glaciers, debris-covered glaciers and rock glaciers constitute the three main components of the cryosphere. Recent studies in the Laguna Negra area (Bodin et al., 2010) have shown, for the last 50 years, a shrinkage of uncovered glacier leading to an extension of debris-covered glacier area, frequently associated to thermokarst development. This work presents the main results of a 6-year GPS monitoring of the annual ground surface displacement of a debris rock glacier and a debris-covered glacier, a 2-years GPS monitoring (measurements in Dec. 2008, Apr. 2009, Jan. 2010 and Apr. 2010) of seasonal surface displacement of a talus rock glacier.

2 - Interannual kinematics of glacial and periglacial landforms (2004-2010)

Using a bi-frequency differential GPS (Trimble R6, centimetric positional accuracy; Lambiel & Delaloye, 2005), 43 points were marked on metric blocks at the surface of the glacial and periglacial complex of the Punta Negra Alto complex. Each point was measured in April 2004, April 2009 and April 2010 on the debris-covered glacier (lines C and D) and the debris rock glacier (lines A and B).

Between 2008 and 2010, the mean seasonal horizontal surface velocity (Tab. 2) ranged from 0.32 m/yr (sd. = 0.15) to 0.56 m/yr (sd. = 0.47), whereas the mean vertical surface velocity ranged from -0.07 m/yr to -0.23 m/yr (sd. = 0.04 to 0.12). The measurements show a fastly moving unit overriding the lower terminal tongue which deforms at slower rates.

If the spatial patterns of the surface velocity is regular from one season to another (Fig. 3), the amount of deformation measured varies significantly, especially the vertical rate. This latter was more than 3 times higher between January 2010 and April 2010 than the two preceding seasons and a lower Rito D_horiz/D_vert was also observed during summer 2010.

The part of the austral summer component (from Dec. 2008 to Apr. 2009) in the total oblique displacement reaches on average 27-31% which, reported to the mean seasonal horizontal rate, yields 2 to 5 times more movement during austral winter (from Apr. 2009 to Jan. 2010) period.

3 - Intra- and interannual kinematics of a talus rock glacier (2008-2010)

Using a bi-frequency differential GPS (Trimble R6, centimetric positional accuracy), 43 points were marked on metric blocks at the surface of the Punta Negra Alto talus rock glacier. Each point was measured in December 2008, April 2009, January 2010 and April 2010 along three main transverse lines and one U shape line above the terminus of the rock glacier.

4 - Discussion & conclusion

Recent studies in the Laguna Negra area (Bodin et al., 2010) have shown, for the last 50 years, an extension of debris-covered glacier area. In this latter, a mean lowering rate of 0.21 m/yr has been measured using DEMs of 1955 and 1996 which is in good agreement with the DGPS measurements on line D. The low values of Ratio D_horiz/D_vert on that line might hence be related to high melting rates, especially strong in 2009-2010, which would account for a higher proportion of the total surface movement than the creep of ice. High melting rate might also be responsible of the strong lowering rates associated to low Ratio values observed on the rock glacier between 3300 and 3400 m a.s.l during summer 2009-2010.

Between 1961 and 2008, the air temperature at the closest meteorological station (Embalse El Yeso, 2475 m a.s.l.) has risen by 0.037°C/yr, pushing the Zero Isokthermal Altitude by almost 500 m (4150 m a.s.l in 2003). This warming has probably set many of the glacier and permafrost ice masses close to the melting point. Fluxation of air temperature and solid precipitation, especially under the influence of ENSO, might explain the interannual variability of both the creep and the melting of ice which depend on, but also partly influence, ground temperature and liquid water content (Meda et al., 2008).

DGGS survey of surface movements on talus and debris rock glaciers and on debris-covered glacier was performed at an annual and seasonal frequency between 2004 and 2010. A distinct behaviour can be observed between rock glacier and debris-covered glacier, the latter being probably affected by high melting rates.

Inter- and intrannual variation of horizontal and vertical surface changes is probably due to the variability of ground temperature, liquid water content. To better understand the climatic control, a monitoring of the ground temperature has been implemented in 2008 (Fig. 4).

References:

- Bodin E., Rajoa F. & Brenning A. - 2010 State and recent evolution of the cryosphere in the Andes of Santiago (Chile, 33.5°). Geomorphology. 10.1016/j.geomorph.2010.02.016

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