



Hasty retreat of glaciers in northern Patagonia

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Mapping glacier extent from optical satellite data has become a most efficient tool to create or update glacier inventories and determine glacier changes over time. A most valuable archive in this regard is the nearly 30-year time series of Landsat Thematic Mapper (TM) data that is freely available (already orthorectified) for most regions in the world from the USGS. One region with a most dramatic glacier shrinkage and a missing systematic assessment of changes, is the Palena province in Chile, located south of Puerto Montt in northern Patagonia. A major bottleneck for accurate determination of glacier changes in this region is related to the huge amounts of snow falling in this very maritime region, hiding the perimeter of glaciers throughout the year. Consequently, we found only three years with Landsat scenes that can be used to map glacier extent through time.

We here present the results of a glacier change analysis from six Landsat scenes (path-rows 232-89/90) acquired in 1985, 2000 and 2011 covering the Palena district in Chile and neighbouring regions. Clean glacier ice was mapped automatically with a standard technique (TM3/TM band ratio) and manual editing was applied to remove wrongly classified lakes and to add debris-covered glacier parts. The digital elevation model (DEM) from ASTER (GDEM2) was used to derive drainage divides, determine glacier specific topographic parameters, and analyse the area changes in regard to topography. The scene from the year 2000 has the best snow conditions and was used to eliminate seasonal snow in the other two scenes by digital combination of the binary glacier masks and neighbourhood analysis.

The derived mean relative area loss over the entire study area is 25%, showing a large spatial variability and a strong dependence on elevation. While small mountain glaciers at high elevations and steep slopes show only little change over the 26-year period, ice at low elevations from large valley glaciers shows a dramatic decline (area and thickness loss). Some glaciers retreated more than 3 km over this time period or even disappeared completely. Typically, these glaciers lost contact to the accumulation areas of tributaries and melted away as dead ice. Furthermore, numerous proglacial lakes formed or expanded rapidly, increasing the local hazard potential. On the other hand, some glaciers located on or near to (still active) volcanoes have also slightly advanced over the same time period. Observed trends in temperature (decreasing) are in contrast to the observed strong glacier shrinkage, indicating that also other factors must play a role.