What influences climate and glacier change in the southwestern China?

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The subject of climate change in the areas of the Tibetan Plateau (TP) and the Himalayas has taken on increasing importance because of available water resources from their mountain glaciers (Immerzeel *et al.*, 2010). Many of these glaciers over the region have been retreating, while some are advancing and stable (Yao *et al.*, 2004, Scherler *et al.*, 2011). Other studies report that some glaciers in the Himalayas show acceleration on their shrinkage (e.g., Fujita and Nuimura, 2011). However, the causes of the glacier meltings are still difficult to grasp because of the complexity of climatic change and its influence on glacier issues. However, it is vital that we pursue further study to enable the future prediction on glacier changes.

The paper entitled "Climate and Glacier Change in Southwestern China during the Past Several Decades" by Li *et al.* (2011) provided carefully analyzed, quality controlled, long-term data on atmospheric temperature and precipitation during a period from 1961-2008. The data were obtained from 111 Chinese stations. The researchers did systematic analyses of temperature and precipitation over the whole southwestern Chinese domain. They discussed those changes in terms of other meteorological components such as atmospheric circulation patterns, radiation, and altitude difference, and then showed how these factors could contribute to climate and glacier changes in the region.

Air temperature and precipitation are strongly associated with glacier mass balance because of heat balance and the addition of mass when it snows. Temperature warming trends over many places in the southwestern China were unequivocally dominant in all seasons and at higher altitude. This indicates that the heat contribution to the glaciers has been increasing. On the other hand, precipitation has a wider variability in time and space. It is more difficult to clearly understand precipitation's effect on the climate and glacier melting characteristics in the whole southwestern China as a collective view.

However, the precipitation patterns are probably modulated by climate feedbacks through many factors in southwestern China. Precipitation seasonality may also affect climatic sensitivity of glacier mass balance (Fujita, 2008).

In addition to the authors' main focus above, other factors, also probably directly and indirectly, influence the climate and glacier mass balance changes. Those factors are: (1) debris-covered effect which heats (if it is thin) or insulates (if it is thick) the ice below the debris and it probably causes no uniform response on glacier meltings (Scherler *et al.*, 2011); (2) interaction between glacial lakes and exposed ice parts on glaciers (e.g., Sakai *et al.*, 2009, Fujita *et al.*, 2009); (3) atmospheric heating effect over the foothills of the Himalayas due to the Atmospheric Brown Cloud (ABC), including absorbing aerosols such as black carbon, dust, and organic matters (Ramanathan *et al.*, 2007), the so called *Elevated Heat Pump* (EHP) effect suggested by Lau *et al.* (2006, 2010); (4) snow darkening effect over non debris-covered parts of glaciers as the absorbing aerosol depositions reduce snow albedo and accelerate snow meltings by absorbing more solar energy at the snow surface (Warren and Wiscombe, 1980, Flanner *et al.*, 2007, 2009, Yasunari *et al.*, 2010, Qian *et al.*, 2011); (5) another kind of snow darkening effect over non debris-covered glacier due to the growth of biological activities with dark-colored materials on glacier also reducing snow albedos (Takeuchi *et al.*, 2001); (6) Other factors on snow albedo reductions such as snow grain size, specific surface area, and depth changes, melt-water effect on snow, and changes in solar illumination conditions (e.g., Wiscombe and Warren, 1980, Flanner *et al.*, 2006, Yasunari *et al.*, 2011, Aoki *et al.*, 1999, 2011); and finally, (7) feedbacks via interactions between the snow surface and atmosphere including all the factors above.

What I'd like to emphasize is that the atmospheric warming trend indicated by Li *et al.* (2011) is robust and very likely associated with the dominant characteristics of glacier shrinkage across southwestern China, as discussed by the authors. However, the shrinkage rate of sub-regional scale variability is probably due to the modulations of precipitation, as well as other factors identified above. Further, the atmospheric warming is not limited to only southwestern China, but is also probable in the surrounding Tibetan and Himalayan regions (Gautam et al., 2010).

Comprehensive studies, including international projects discussing all the contributors above by a) field observations, b) global or regional modeling, and c) satellite data analyses, are essential to assess the future climate change and glacier retreat in/around TP and the Himalayas. The authors' findings showed robust information on atmospheric warming trends and some wider variety on precipitation during 1961-2008 in the southwestern China. In addition, they indicated some possible connection between these findings and atmospheric circulation, altitudinal difference, and meteorological conditions. Future studies should promote a deeper discussion and understanding of the relationships.

Hereafter, we must make a committed effort to study climate and glacier issues in/around TP and the Himalayas involving the existing warming trend. This trend fluctuates, year-by-year. The fluctuation of the warming and precipitation changes may directly contribute to climate change and glacier retreats. But the seven factors noted above likely modulate the climate change and glacier melting patterns in southwestern China on the warming trend in intra- and inter-annual timescales. The temperature and precipitation data in this study offers a terrific asset for future studies on climate and glacier issues in/around this region.

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