Glacier mass balance modelling of the Tibetan Plateau – mesh dependence issues

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The Tibetan Plateau is an extraordinary topographic feature which exerts a major impact on regional and global climate. Its glacierised mountain ranges attain extreme altitudes and represent an important water resource for more than a billion people in Asia. Understanding the past glacial history of the Tibetan Plateau therefore is important to understanding global and regional climate and glacier hydrological evolution. A regional glacier modelling study has been initiated as part of an umbrella project aiming towards reconstructing the Quaternary palaeoglaciology of the Tibetan Plateau. On the basis of field studies which includes cosmogenic exposure-age dating, it is now generally recognised that former glaciers on the Tibetan Plateau, while more extensive than today, were still restricted to individual mountain areas. In contrast, a handful of previous modelling studies (Kuhle et al. 1989; Calov & Marsiat 1998; Bintanja et al. 2002; Casal et al. 2004) yield a bifurcated result with either 1) the growth of plateau-wide ice sheets (thus overshooting field evidence) or, 2) virtually no ice (which undershoots field evidence).

We apply and test a positive degree day (PDD) model across the Tibetan Plateau to explore the parameter sensitivity and potential issues of grid-dependence. Utilising the 1km mean monthly (1950 – 2000) distributions of temperature and precipitation from the WorldClim database as a contemporary reference climatology, a suite of PDD experiments are run to predict present day ice cover. At a resolution of 1 km the algorithm nicely identifies zones of positive mass balance (accumulation) across most major contemporary glaciarised areas. Unsurprisingly increased grid resolution yields a significant decrease in the predicted accumulation area with a 40 km grid completely failing to predict accumulation across the domain. Such mesh dependence with larger grid-resolutions yielding less accumulation illustrates a major flaw in large-scale, low resolution ice modelling in areas of high topographical relief where adequate sub-grid parameterisation of accumulation/flow/melt processes have not been accounted for in a meaningful manner (e.g. Marshall & Clarke 1999). The result of the 20 km resolution PDD model can be manipulated to converge by applying extreme perturbations in temperature (c. -10 K) or precipitation (c. + 8000 %) but this yields plateau-wide accumulation areas far exceeding field evidence of glaciation. Our results indicate that the bifurcation in Quaternary ice extent identified in previous ice sheet modelling studies of the Tibetan Plateau are very likely a consequence of grid-resolution related issues implicit to the models applied.

References

Bintanja R., van de Wal R.S.W., Oerlemans J. 2002: Global ice volume variations through the last glacial cycle simulated by a 3-D ice-dynamical model. *Quaternary International*, 95-96, 11-23.

Calov R, Marsiat I. 1998: Simulations of the Northern Hemisphere through the last glacial-interglacial cycle with a vertically integrated and a three-dimensional thermomechanical ice-sheet model coupled to a climate model. *Annals of Glaciology*, 27, 169-176.

Casal T.G.D., Kutzbach J.E., Thompson L.G. 2004: Present And Past Ice-Sheet Mass Balance Simulations For Greenland And The Tibetan Plateau. *Climate Dynamics*, 23, 407-425.

Kuhle M., Herterich K., Calov R. 1989: On the Ice Age Glaciation of the Tibetan Highlands and its Transformation into a 3-D Model. *GeoJournal*, 19, 201-206.

Marshall S.J., Clarke G.K.C. 1999: Ice sheet inception: subgrid hypsometric parameterization of mass balance in an ice sheet model. *Climate Dynamics*, 15, 533-550.