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Glacier fluctuations of Jostedalsbreen, West Norway, during the past 20 years – an example of detailed documentation of sensitively responding maritime mountain glaciers

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Mountain glaciers are acknowledged as high-resolution indicators of short-, medium-, and long-term climate changes. In the context of discussing causes, signals, and consequence of the present climate change, mountain glaciers have received an increasing attention. Variations in glacier mass, area, length, and frontal position have important effects upon freshwater resources, hydro electrical power generation, natural risk management, and sustainable development in mountain regions. Due to their high mass turnover, maritime mountain glaciers react especially sensitive to changes of the predominant weather and climate conditions.

The steep outlet glaciers of Jostedalsbreen, western Norway, are good examples of sensitively reacting maritime mountain glaciers. Their changes in length, frontal position, and lower tongue's morphology during the past 20 years have been well documented. During the 1990s they received considerable attention because of a substantial ice mass increase, resulting in a strong frontal advance. This glacier advance was exceptional in a global context with only a few other regions (e.g. New Zealand) experiencing comparable advances in the same period. At many outlets of Jostedalsbreen,

that advance terminated around (or slightly prior) to the year 2000. Since then, most of those glaciers have experienced a remarkable strong retreat, leading even towards partial disintegration of their lower glacier tongues in some cases.

During the whole observation period between 1961 and 2006, there was a total increase in ice mass of 17 m w.e. at Nigardsbreen. However, that mass increase was concentrated between 1988 and 1995 (+10 m w.e.). The glacier was in summary close to balance between 1995 and 2006 (+ 0.1 m w.e.), but a mass lost of c. -2.5 m w.e. was recorded between 2000 and 2004. The positive net balance of 2005 (+1.1 m w.e.) was followed by a marked negative balance in 2006 (-1.4 m w.e.). The mass balance of 2007 is expected to be positive again, caused by a snowy winter followed by a summer characterised by cold and moist conditions after Mid-July.

Whereas the cause of the advance during the 1990s seems to be well known, the interpretation of the most recent retreat still leaves some uncertainties. Any change of the frontal position of a glacier tongue is the response to a sufficient change of the glacier ice mass. The glacier advance of the 1990s can be related to the period of considerable positive net balances after 1988. However, a terminus response time of three to four years has to be applied for the short and steep outlets of Jostedalsbreen. The precipitation record shows increased winter precipitation during the last two decades of the 20^{th} century. In addition, the precipitation maximum shifted from autumn into winter during the 1990s. Until around 2000, there were no significant deviations of the summer air temperatures from the long-term means. Therefore, below-average summer air temperatures can be ruled out as forcing factor for the glacier advance. Influence of strong zonal circulation is demonstrated by a high correlation between the NAO index and winter balances of maritime glaciers.

Empirical relations between mass balance parameters and glacier front behaviour previous applied cannot explain the retreat after c. 2000 in full. The timing of the onset and the magnitude of the retreat cannot fully be explained by the existing mass budget data! Not only the amount of the ice mass deficit since the budget year 2000/2001 is hardly large enough to explain the strong retreat. The onset of the retreat and the proceeding period of stationary glacier fronts occurred “too early” if compared with the cumulative net balance data series, especially if the terminus response time is considered. After 2001 (partly already since 1997), length change and net balance data miss similar trends. Summarizing the analysis of the meteorological parameters, the most obvious deviation regarding the most recent glacier retreat is an air temperature rise during summer/late summer (July, August, and September). However, it is not obvious why this meteorological conditions have been not been documented correspondingly in the annual mass balance record, although there is little doubt that the lower glacier tongues were strongly affected by this excessive ablation. One hypothe-

sis is the occurrence of a disturbance of ‘normal’ mass transfer due to special weather conditions causing extreme summer back melting. Another hypothesis is a temporal, or even permanent change in glaciological regime towards a more “continental” one.

These findings underline the sensitivety of maritime glaciers to climate change and the need for regional differentiation with the use of glaciers as climate indicators.