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Geodetic point surface mass balances: A new approach to determine point surface mass balances on glaciers from remote sensing measurements

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Mass balance observations are very useful to assess climate change in different regions of the world. As opposed to glacier-wide mass balances, which are influenced by the dynamic response of each glacier, point mass-balances provide a direct climatic signal that depends on surface accumulation and ablation only. Unfortunately, major efforts are required to conduct in situ measurements on glaciers. Here, we propose a new approach that determines point surface mass balances from remote sensing observations. We call this balance the geodetic point surface mass balance. From observations and modelling performed on Argentière and Mer de Glace glaciers over the last decade, we show that the vertical ice flow velocity changes are small in areas of low bedrock slope. Therefore, assuming constant vertical velocities in time for such areas and provided that the vertical velocities have been measured for at least one year in the past, our method can be used to reconstruct annual point surface mass balances from surface elevations and horizontal velocities alone. We demonstrate that the annual point surface mass balances can be reconstructed with an accuracy of about $0.3 \text{ m w.e. a}^{-1}$ using the vertical velocities observed over the previous years and data from Unmanned Aerial Vehicle images. Given the recent improvements of satellite sensors, it should be possible to apply this method to high spatial resolution satellite images as well.