Seasonal velocity variations of 12 outlet glaciers from the Greenland ice sheet derived from in situ GPS instruments

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Abstract
We present 14 velocity records derived from in situ, single-frequency GPS (Global Positioning System) instruments placed on 12 marine terminating outlet glaciers in South, West, and East Greenland, covering various parts of the annual cycle (2009 to 2013). The results show that the seasonal variations are highly variable, but generally characterized by a pronounced summer maximum with a minor winter minimum. The seasonal variations are of the order of 1 to 2 m s⁻¹ for individual glaciers, and the average seasonal range is approximately 4 m s⁻¹. The seasonal variations are strongly correlated with the surface mass balance of the glaciers, indicating that the seasonal variations are mostly driven by changes in the amount of ice lost to the ocean.

The Problems
- Dynamic mass loss from calving outlet glaciers still poorly understood.
- Modelling calving outlet glaciers requires observational data.
- In situ observations provide the detailed seasonal variations in outlet glacier velocity.

The Instruments
- Stand-alone GPS receivers from Risø and Dr. A. Behra, respectively.
- High-frequency GPS (1-2 Hz) data for accurate determination of the seasonal variations.
- Borehole GPS (10-15 Hz) data for accurate determination of the seasonal variations.
- In situ measurements of the seasonal variations.

The new data - fresh off the instrument

The GPS data consist of hourly or even shorter time intervals and show the same geographical position, whereas the remote (GPS) cannot capture the changes in the sea ice and the ice shelf. The analysis of the seasonal variations requires a rigorous processing to remove the effects of the sea ice and the ice shelf.

The Processing
The data processing involves a rigorous filtering to remove the effects of the sea ice and the ice shelf. The analysis of the seasonal variations requires a rigorous processing to remove the effects of the sea ice and the ice shelf.

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The GPS velocity records support the idea of a pronounced seasonal variation, with a minor summer maximum, followed by a larger winter minimum.

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Sample: Velocity of KNS in Southeast Greenland
One use: Satellite-derived velocities vs. GPS velocities

Horizontal error bars:
St. dev. of 7-day averaged GPS velocities in the period of the acquisition window

Vertical error bars:
Formal error from processing added to a 3% max. error due to slope-depending effects