Long-term monitoring of the glaciers in Wordie Bay, Antarctic Peninsula, using multi-mission SAR time series

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1. Overview of the Study Area

2. Motivation & Research Questions

3. Velocity Measurements
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   b) Results

5. Summary
1. Overview of the Study Area: Wordie Ice Shelf

Surface velocities were derived from Sentinel-1 acquisitions (2015/08/28 and 2015/09/09).
Background image: mosaic of Landsat-8 LandsatLook „Natural Color“ images from 2015/09/16 ©USGS
2. Motivation & Research Questions

- What we know from other studies: acceleration of Fleming Glacier after disintegration of the ice shelf and dynamic thinning (Rignot et al. 2005, Wendt et al. 2010)

- No long-term studies which address the adaption process of the former tributary glaciers to the loss of the buttressing ice shelf

- How can multi-mission SAR data be used in order to derive long time series of datasets of glaciological parameters (e.g. velocities, ice elevation, mass balances,...) at Wordie Bay?

- How did these parameters change after the disintegration of the ice shelf exactly over time and how long do these changes last?

- Are there differences in the behavior of the single glaciers?
3. Velocity Measurements

a) Data & Methods

- **440 scenes** from **8 SAR-sensors**, covering a timespan from **1994 – 2016** were processed
- Glacier surface velocities were derived by applying SAR-feature tracking to image pairs with suitable temporal baselines
3. Velocity Measurements
b) Results: Fleming Glacier

- Stable velocities from 1994 to 2008
- In the end of 2008 sudden acceleration of the glacier and strong upstream propagation of high velocities
- At the same time the glacier front remained comparatively stable
- Rapid retreat of the grounding line due to oceanic melt (+1°C at 150 m, Cook et al. 2016), continuous dynamic thinning and a retrograde bed topography
- Big part of the tongue can freely float → loss of drag, highest speeds on floating parts
3. Velocity Measurements
b) Results: Prospect Glacier

- Area loss between 1995 and 2010 → increase in ice velocities and an upstream extension of higher velocities due to diminished buttressing
- In the end of 2011 pronounced acceleration on the first 4 km of the profile
- Area and front distance remain quite stable at the same time
- In contrast to Fleming Glacier, loss of buttressing force as possible reason
• Before the acceleration took place, the 3 branches of Prospect Glacier shared 1 front
  → tongues were interconnected

• When the acceleration took place, the interconnection got lost, 3 unconfined tongues
  developed, flow direction changed → buttressing got lost
4. Elevation Change
a) Data & Methods

- Differencing of two interferometric DEMs, generated from 8 TSX-TDX bistatic acquisitions in December 2011 and December 2013
- The 2013 DEM was vertically referenced to the 2011 DEM on sea level, tide differences were compensated by using the TPOX8 tide model (Egbert & Erofeeva, 2002)
4. Elevation Change

b) Results: Fleming Glacier

- The maximum height change rate increased from $-3.5 \pm 0.2 \text{ [m/yr]}$ to $-5.1 \pm 0.4 \text{ [m/yr]}$, and can now be found at approx. 380 m.
- Highest thinning rates have propagated inland, maybe together with the migration of the grounding line.
- Above 800 m, the ice thinning rates for 2011 – 2013 are smaller than for 2004 – 2008 → increase in snow accumulation.
• Since ice thinning rates on Fleming Glacier may be highest upstream of the new grounding line due to more horizontal stretching caused by the faster flow \(\rightarrow\) delineation of the possible new grounding line
• The delineated floating part of the tongue coincides with the extent of the highest velocities on the velocity profile
• Prospect Glacier shows the highest thinning rates of the area (up to 12 ma\(^{-1}\)). Together with the increase in flow speeds this can be interpreted as a sign of pronounced dynamic thinning.
After the complete loss of the buttressing ice shelf and an acceleration, the flow speeds of Fleming Glacier remained stable for decades.

Continuous dynamic thinning and ocean melt in connection with an appropriate bed topography may have caused a sudden retreat of the grounding line of Fleming Glacier.

This may have caused a big part of the ice tongue to go afloat and therefore to accelerate.

The glaciers at Wordie Bay seem to be at different stages in response to the loss of the former ice shelf.

Prospect Glacier was still influenced by the buttressing effect of the remains of the former ice shelf → additional acceleration and strong dynamic thinning after recent ice break ups.

Fleming Glacier however had already to adapt to new boundary conditions which were not solely connected to the disintegration of the former ice shelf anymore.
Thank you for your attention!

Paper on the presented results in preparation!

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• Positive yearly trend of the median velocity for Fleming (≈ 8 cm/day), Prospect (≈ 4 cm/day), Harriot (≈ 3 cm/day)

• Carlson Glacier shows no velocity-trend

• Fleming Glacier lost approx. 350 km² of its unconfined tongue between 1998 – 2000 => no effect on velocities

• All Glaciers lost area, but glacier extents seem to be more stable at least since 2010

• Air temperatures at Rothera Station (170 km from Wordie Bay) show just a small positive trend

• Ocean temperatures at 150 m depth rose at up to +1°C at Wordie Bay (Cook et al. 2016) => dominant driver for the glacier front behavior
4. Elevation Change

a) Results

Prospect Glacier

**dh/dt 2011 - 2013**

**Cubic Function**

max. dh/dt 2011 - 2013

-10.8 ± 0.4 [ma⁻¹]