Quantifying Ice Sheet Dynamics and Variability with Meter-scale DEM and Velocity Products

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Abstract

We are using complementary satellite and airborne data to investigate ice-sheet/grounding line retreat and thinning in the Antarctic and Greenland ice sheets. Preliminary results are presented for Jakobshavn Isbrae, Greenland and Pine Island Glacier (PIG), West Antarctica – two outlet glaciers where rapid acceleration and thinning are well-documented in recent decades. Our preliminary results show large seasonal elevation variations at Jakobshavn and grounding line retreat accompanied by ice shelf thinning at PIG.

Introduction

• From ~1990-2010, outlet glacier velocity increases of 50-150% [1,2].
• Thinning ~10-25 m/yr in Greenland.~4.9 m/yr in W. Antarctica [3].
• Increased discharge and negative mass balance [4,5].
• ICESat altimeter failed in 2009, ICESat-2 not operational until ~2016, IceBridge spatial/temporal coverage limited.
• Repeat observations necessary to measure ice sheet mass loss and understand processes driving observed changes.

Data & Methods

Commercial stereo imagery

• DigitalGlobe/Geoeye: 5 polar-orbit satellites.
• 0.46 m/pixel panchromatic. ~17 km swath width.
• Along-track stereo acquisition, ~1 min apart.
• 1000s of cloud-free pairs, high-priority locations with ~10°x10° orthoimages.
• Meter-scale surface texture (e.g. sastrugi) can be captured with high-res data.

DEM Generation

• ~2-4 m/pixel output DEM resolution.
• Automated, open-source, command-line workflow.
• NASA Ames Stereo Pipeline core.
• Multithreaded. ~48 hours per pair on 8-core workstation, depending on setup/inputs.
• Python utilities (GDAL/OGRE, NumPy/ScPy/MapToolKit) for pre/post-processing and analysis.

DEM Alignment and Correction

• Unconnected greengrading error typically <5 m.
• Horizontally/vertically co-register “keystone” DEM to ATM/ICESat altimetry data over control surfaces (bedrock).
• Algo/mosaic additional DEMs with reference “keystone” over control surfaces or low-velocity ice (<200 m/yr).
• Ongoing efforts to automatically co-register individual along-track CCD “striping” artifacts of ~4-5 m.

Velocity Map Generation

• Input aligned DEM products or orthomages.
• Seed search window with low-res velocity products.
• Sub-pixel (~1/100) correlation provides X/Y offsets for every input pixel.

Elevation Change Map Generation

• Eulerian elevation difference (dz) for fixed reference frame.
• Lagrangian elevation difference (dz) using pixel offsets from concurrent velocity maps to track parrots.
• dz = 0 for grounded ice in steady-state.
• dz > 0 for floating ice with no melting/stretching.

Summary/Conclusions

• Automated, open source processing pipeline for 0.5 m/pixel commercial imagery.
• High-res (2-4 m/pix) DEM/velocity timeseries provide unprecedented observations of ice sheet dynamics, with optimal sub-meter horizontal/vertical accuracy.
• Preliminary timeseries capture:
  • Seasonal elevation changes of ~+50 m/yr for lower Jakobshavn between 2010-2012.
  • Apparent PIG grounding line retreat since 2009, ice shelf thinning in 2011.
• Data for complete timeseries has been ordered.

References