Quantification of the Impact of Supraglacial Lakes and Slush on Surface Energy Balance of Ice Shelves

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The majority of grounded ice in Antarctica is buttressed by fringing ice shelves, making them a critical mass balance component (Smith *et al.*, 2019). Rapid collapse of Antarctic Peninsula ice shelves demonstrated sensitivity to recent warming, exacerbated by the formation of surface meltwater features (Berthier *et al.*, 2012). Supraglacial lakes (SGLs) and slush have lower albedo than that of surrounding snow, increasing radiation absorption and generating melt (Jakobs *et al.*, 2019). Quantification of the energy balance of supraglacial features is essential for confirming the significance of the melt-albedo feedback. Nivlisen Ice Shelf (70°S, 11°E) is illustrative of the increasingly prevalent surface melt on the EAIS.

Study Aims

(1) Calculate **lake and slush area** of Nivlisen Ice Shelf
(2) Develop a **Surface Energy Balance (SEB) model** in Earth Engine using Landsat 8 and Sentinel-2 imagery as appropriate
(3) Quantify **extra energy** absorbed by different supraglacial features, 2017 – 2020
(4) Validate modelled energy absorption at lakes with observed lake volume

Principal Components Analysis for SGL and Slush Extraction

- Previous NDWI methods for lake extraction generate errors of commission (cloud cover) and omission (slush) (Williamson *et al.*, 2017).
- **PCA-histogram method** (Fig. 1) applied here.
- Method performs well for SGL and slush delineation
- Visual inspection of RGB images shows **Sentinel-2 masks more accurate** (lower sensitivity to each band threshold)

Surface Energy Balance Model in Earth Engine

- Equations following Buzzard et al., 2017; Law et al., 2020 to quantify extra energy transferred to Nivlisen at SGL and slush
- Earth Engine provides rapid processing, availability of Landsat 8 and Sentinel-2 imagery, and Global Forecast System Data (6 hourly meteorological data, including shortwave radiation)

Results

- **Shortwave flux** dominates net SEB – corroborates Law et al., 2020
- **No inter-annual trend of average energy** absorbed at SGL or slush
- 2017 – high net energy absorption by SGLs (Fig. 3)
- 2019 – high net energy absorption by slush (Fig. 3)
- **High slush** extent years have **similar** significance to high SGL extent years for energy absorption

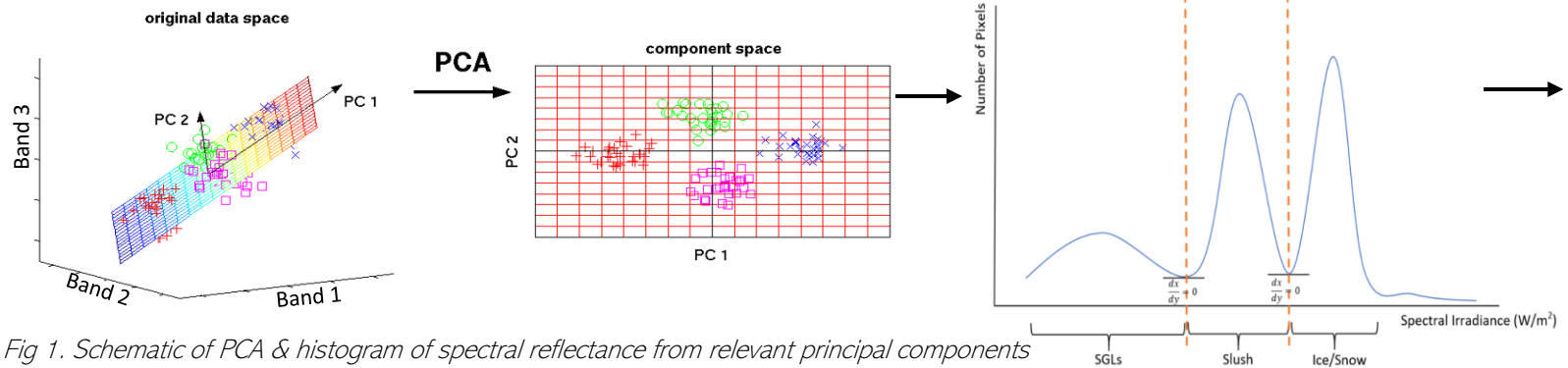

Fig 1. Schematic of PCA & histogram of spectral reflectance from relevant principal components

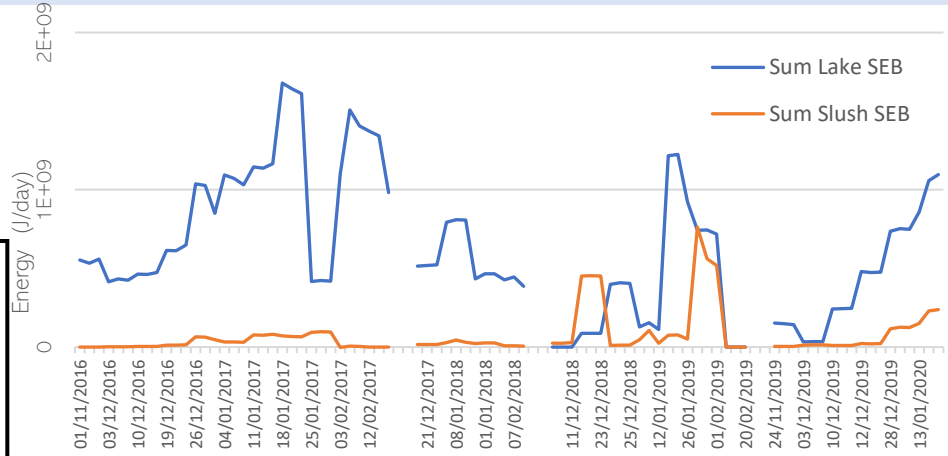

Fig 3. Daily sum of total energy balance slush and SGLs for summers 2017-2020.

Conclusions

The PCA-histogram method is confirmed to be **successful** for supraglacial feature extraction used with different satellite sensors and advantages for future research of hydrology evolution. SEB model results confirm and quantify energy contribution of SGLs whilst indicating **previously under-estimated implications of slush in particular years**. Inter-annual modelled extra energy absorbed at lake pixels is validated by comparison to inferred energy transfer derived from total SGL volume ($R^2 = 0.813$).

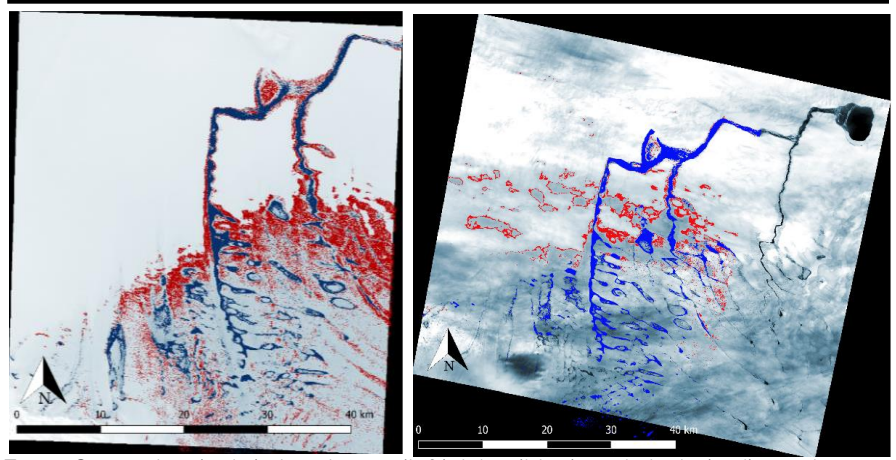

Fig 2. Sentinel-2 (right), Landsat 8 (left) lake (blue) and slush (red) masks 2019

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- PCA Schematic image (left hand image) accessed at www.nlpca.org/pca_principal_component_analysis.html on 06/04/2020.