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Characterizing Greenland Ice Sheet seasonal dynamics using ice velocity mosaics based on Sentinel-1 SAR data

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May 26th 2022, Living Planet Symposium

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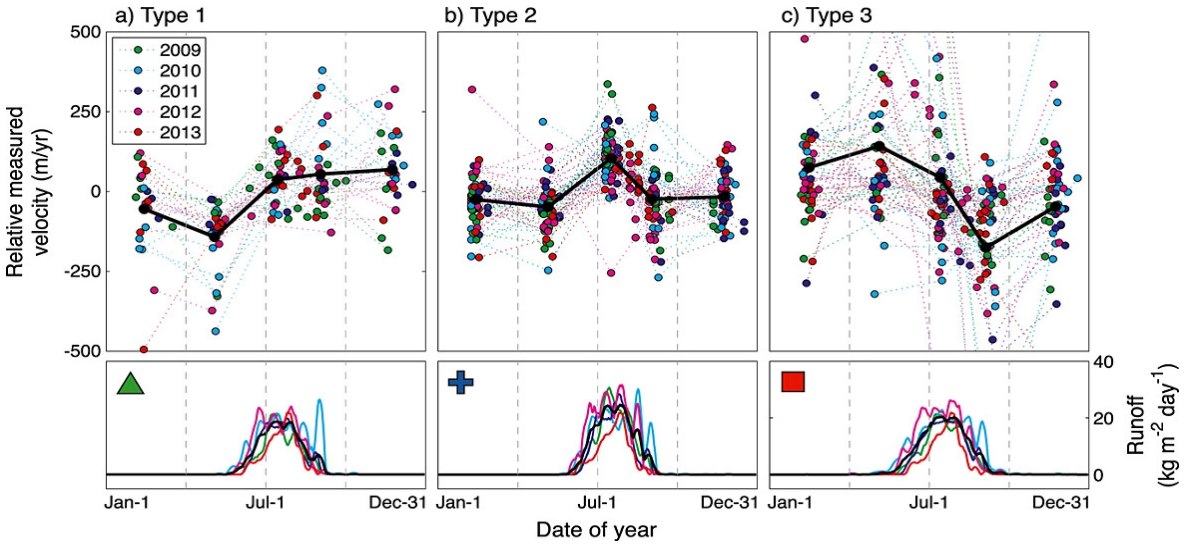
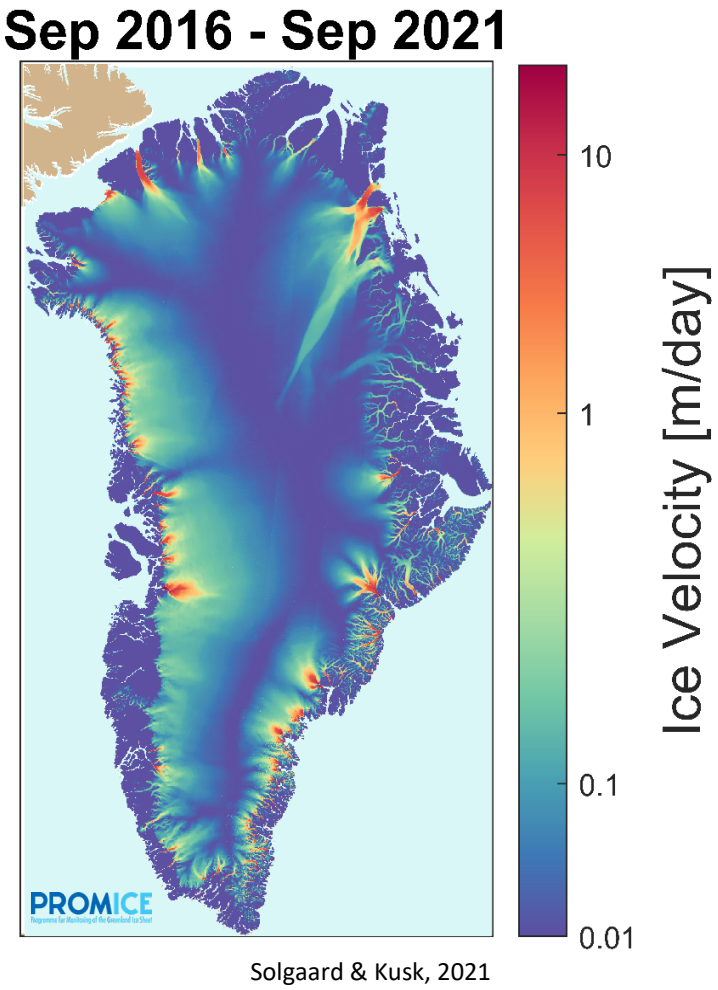
Seasonal flow patterns

- Surface melt penetrating to the base of the ice sheet modulates seasonal flow through the subglacial hydrological system.
- Numerous studies of seasonal flow patterns and the processes coupling surface runoff, the subglacial hydrological system and surface velocity: point observations using GPS, numerical modelling, larger areas/multiple glaciers using EO data, …



Moon et al., 2014



Solgaard & Kusk, 2021

Introduction

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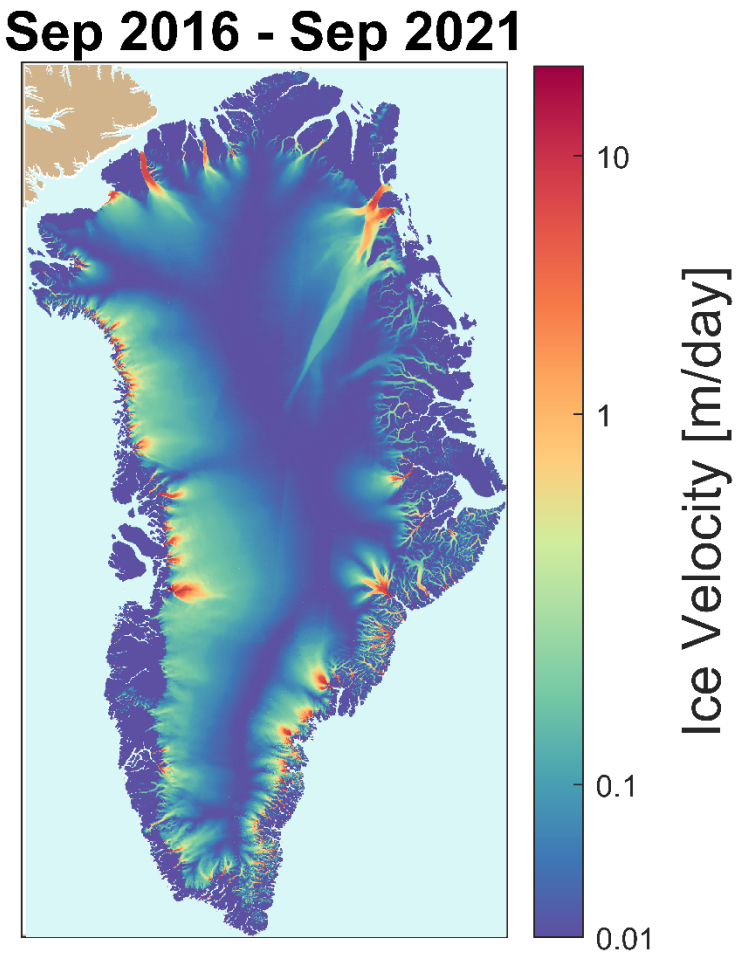

Solgaard & Kusk, 2021

Aim:

Characterize seasonal patterns ice flow on the Greenland Ice Sheet:

- Spatial and temporal overview
- Inter annual variability
- Seasonal patterns and surface runoff

PROMICE
Programme for Monitoring of the Greenland Ice Sheet

Greenland Ice Velocity mosaics

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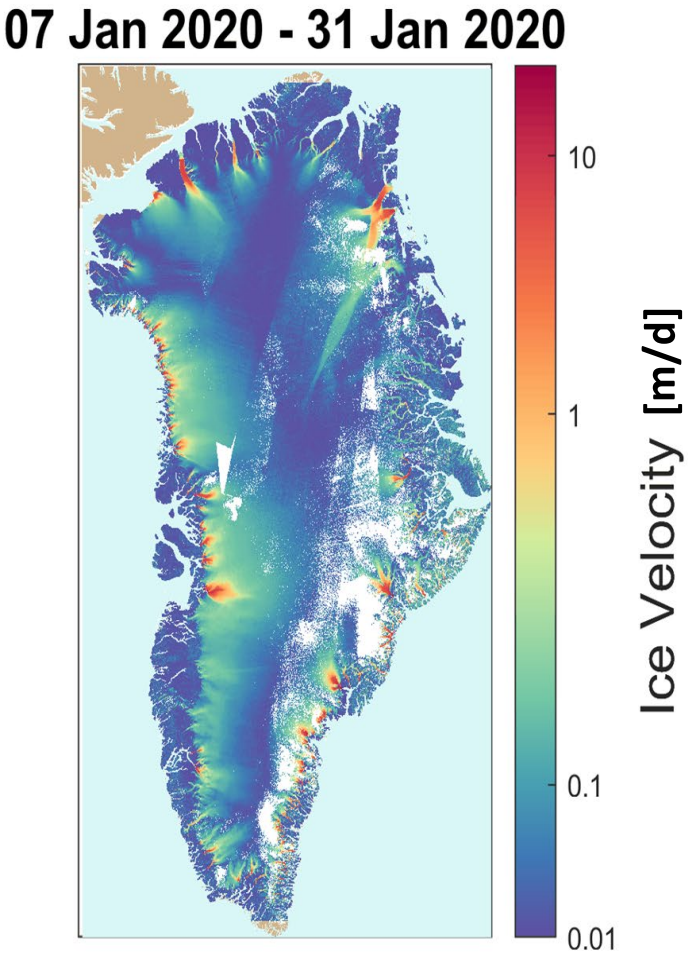

Solgaard & Kusk, 2021

We use the PROMICE ice velocity product:

- A time series of Greenland ice sheet wide ice velocity mosaics at 500 m resolution.
- Product based on Sentinel-1 SAR offset tracking
- Includes both 6 and 12 day pairs.
- Time series span September 2016 - present
- A new mosaic is available every 12 days spanning 24 days (2 Sentinel-1 cycles)
- Updated continuously

https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/overview

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Time series of Ice Velocity

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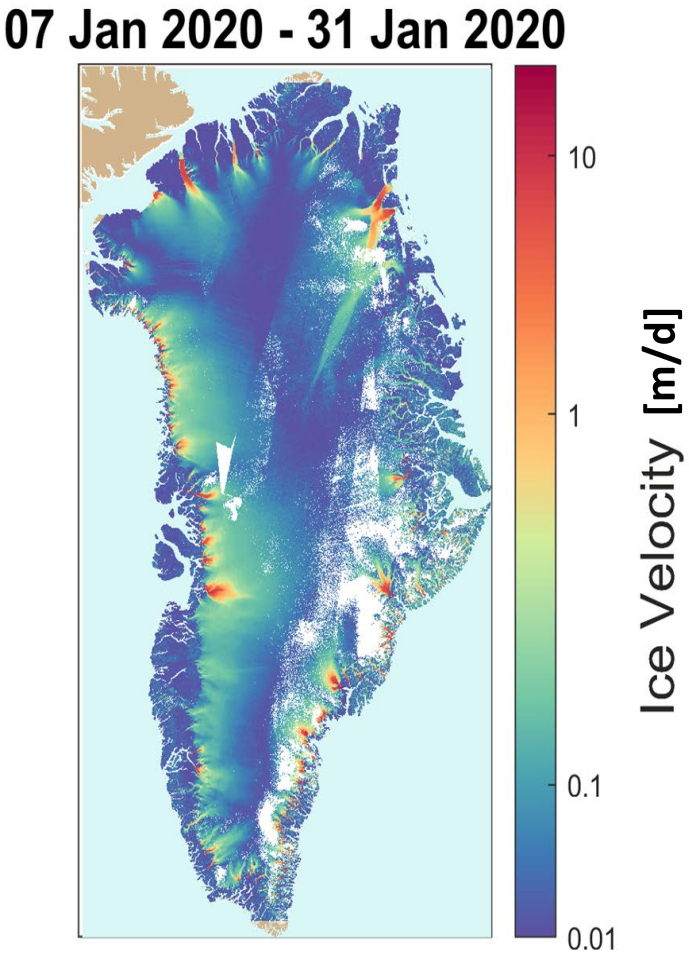
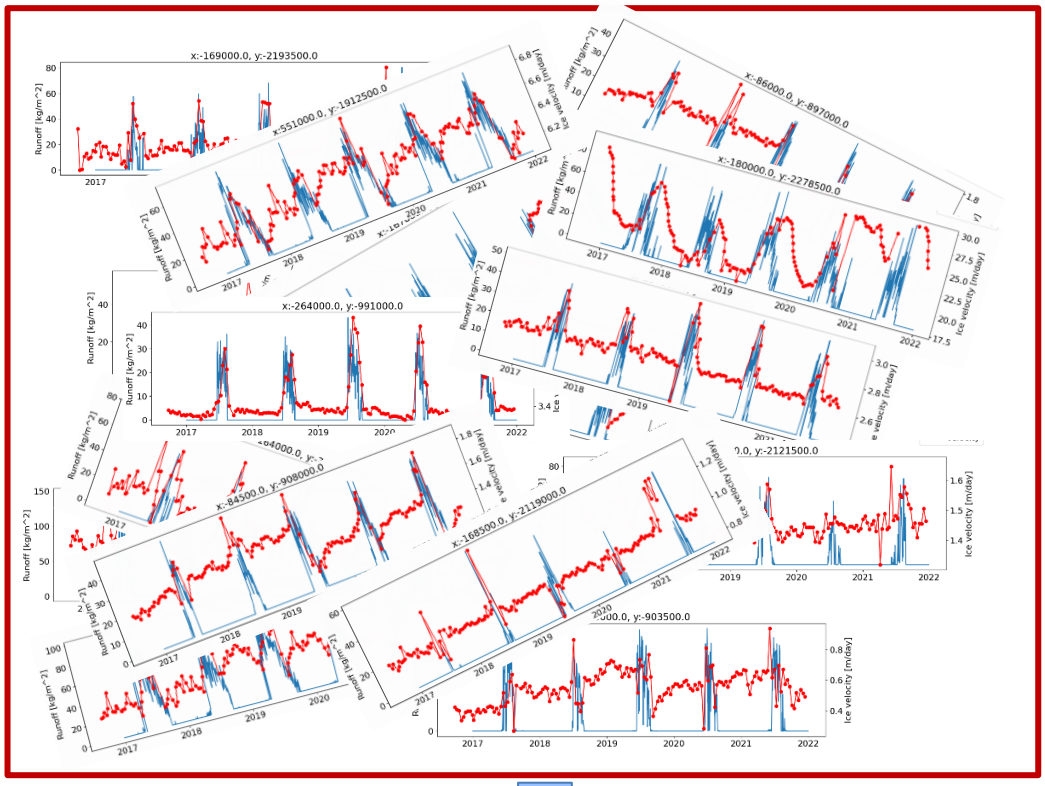


Solgaard & Kusk, 2021



We use **K-Means clustering** on annual time series of ice velocity to identify Greenland wide seasonal patterns of flow.

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Clustering Algorithm + Data Filtering

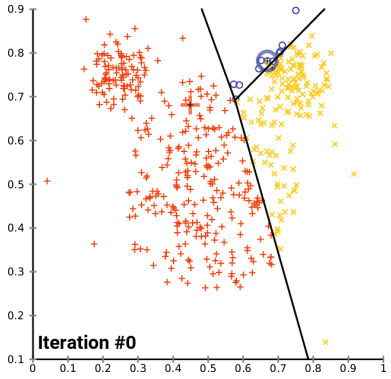
K-means clustering:

- K-Means is an **unsupervised machine learning algorithm**, meaning that there is no labeled data given to teach the algorithm what the different clusters should look like.
- The K-means algorithm seeks to group time series with similar signal shapes by minimizing the within-cluster variance while separating them by maximising the between-cluster variance.

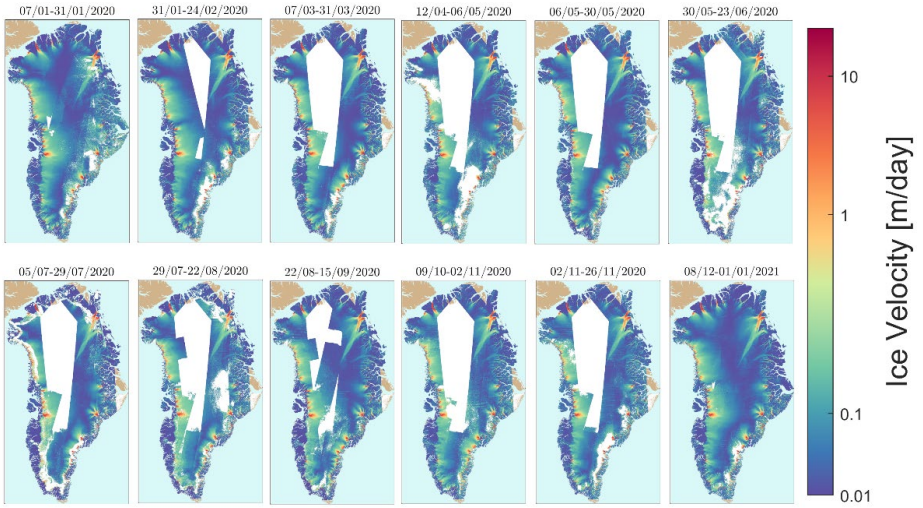
Use data spanning Jan-Dec 2017-2021 -**5 full years.**

1. In each grid point: divide into annual time series
2. Discard timeseries < 0.3 m/d
3. Discard timeseries where the estimated uncertainty is >50%
4. Discard incomplete timeseries
5. Normalize each time series by its max to be in the range [0 1]

→ > 668 000 time series included in the analysis



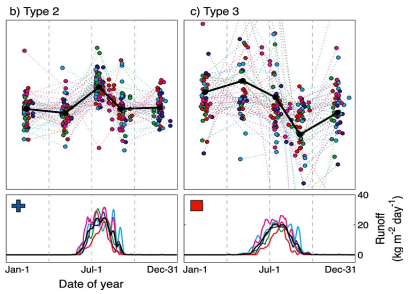
https://commons.wikimedia.org/wiki/File:K-means_convergence.gif



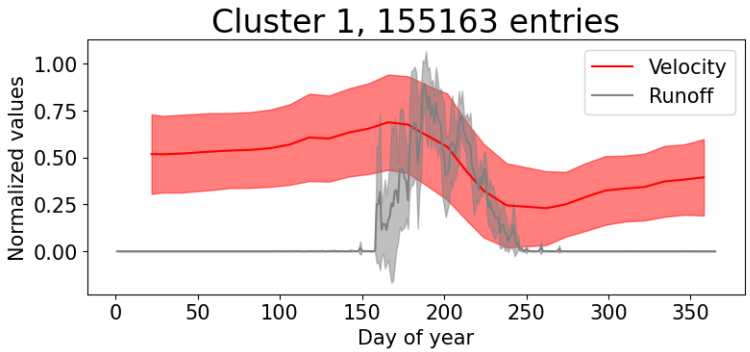
Results

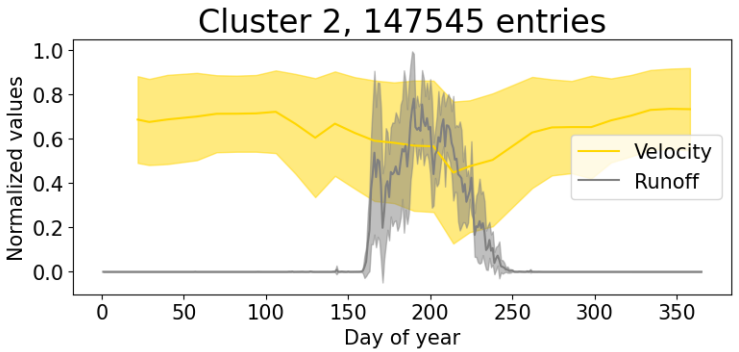
Results for k=4.

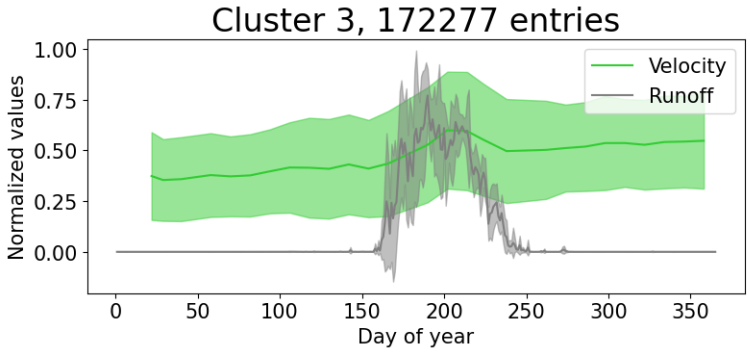
Compare each ice velocity time series with the time series of runoff from the regional climate model, RACMO (Noël et al. (2019)), in the nearest grid point.

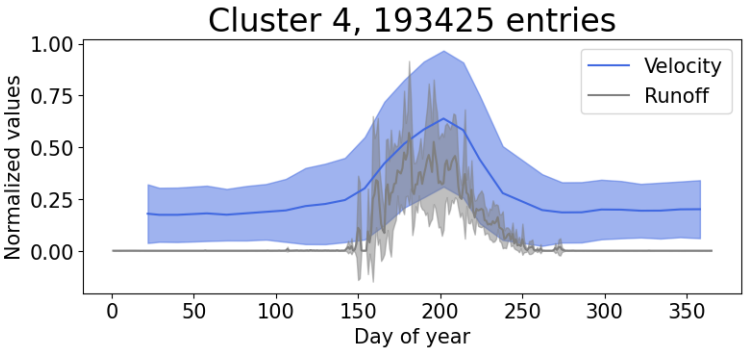


Moon et al., 2014

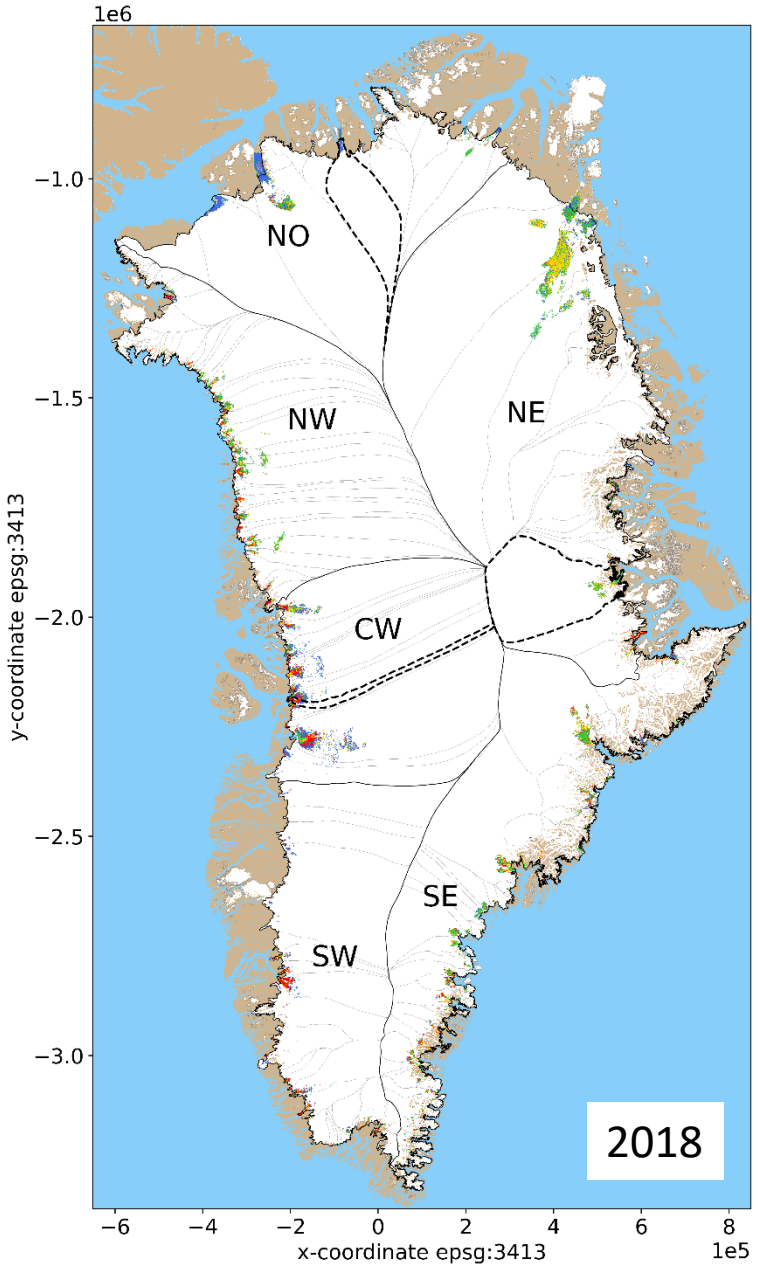


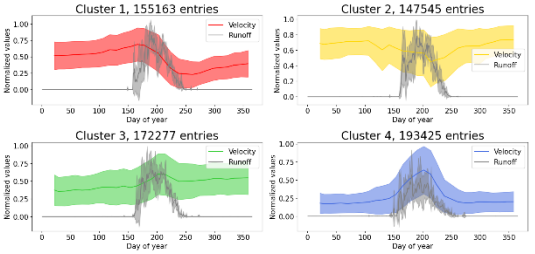






Results: spatial view





Results: spatial view

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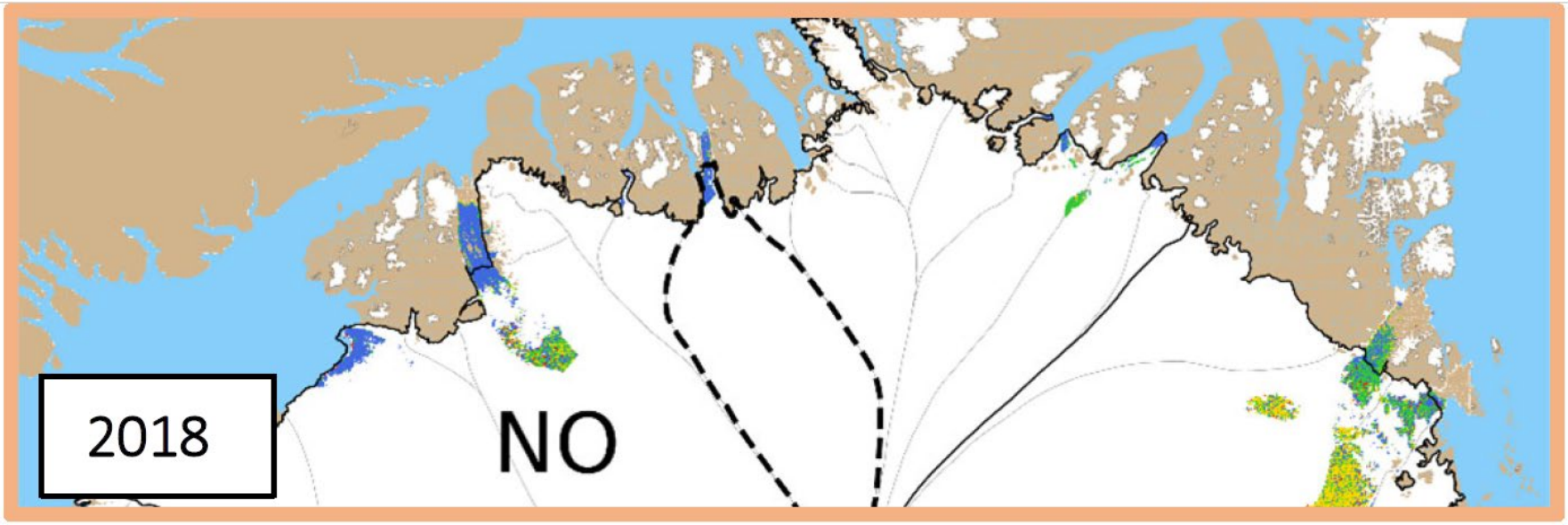
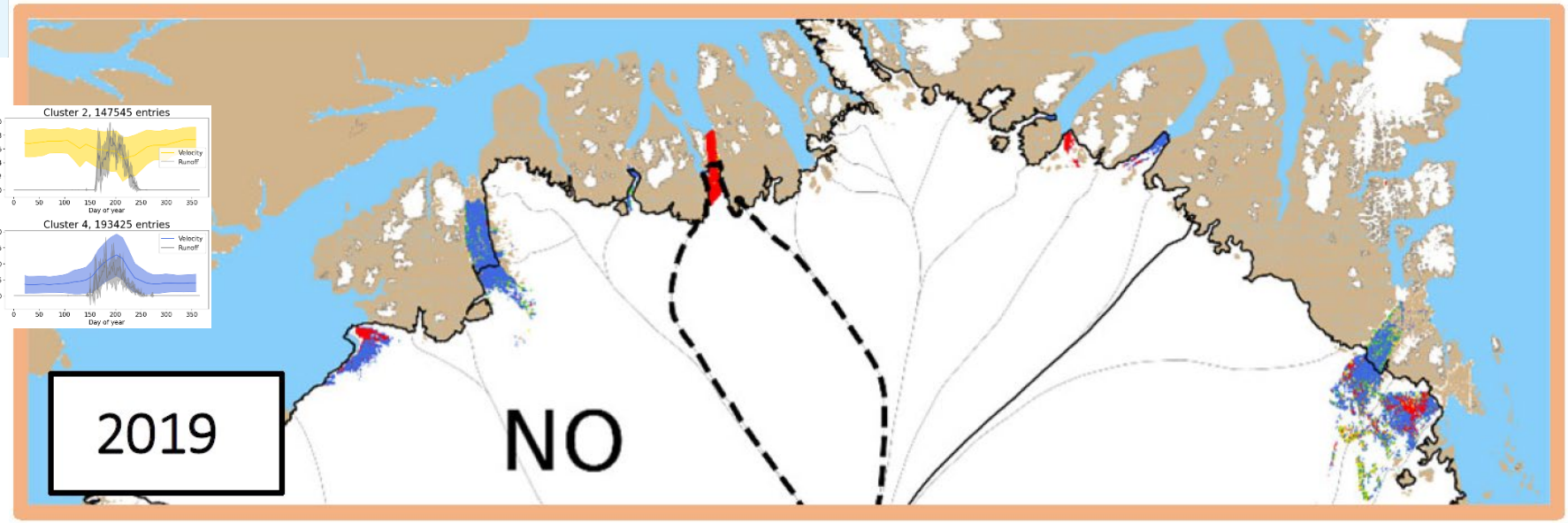
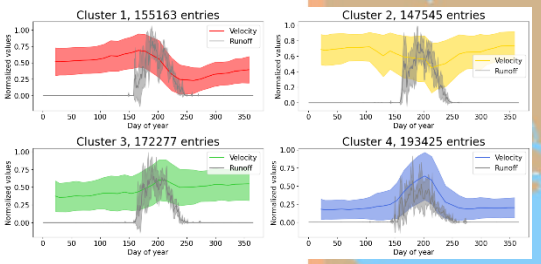




- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4



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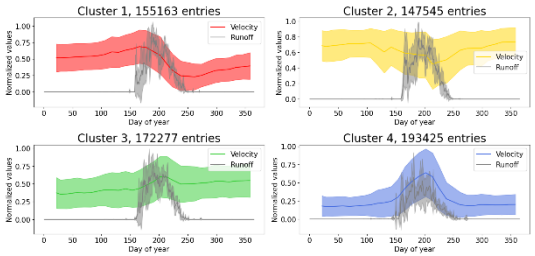

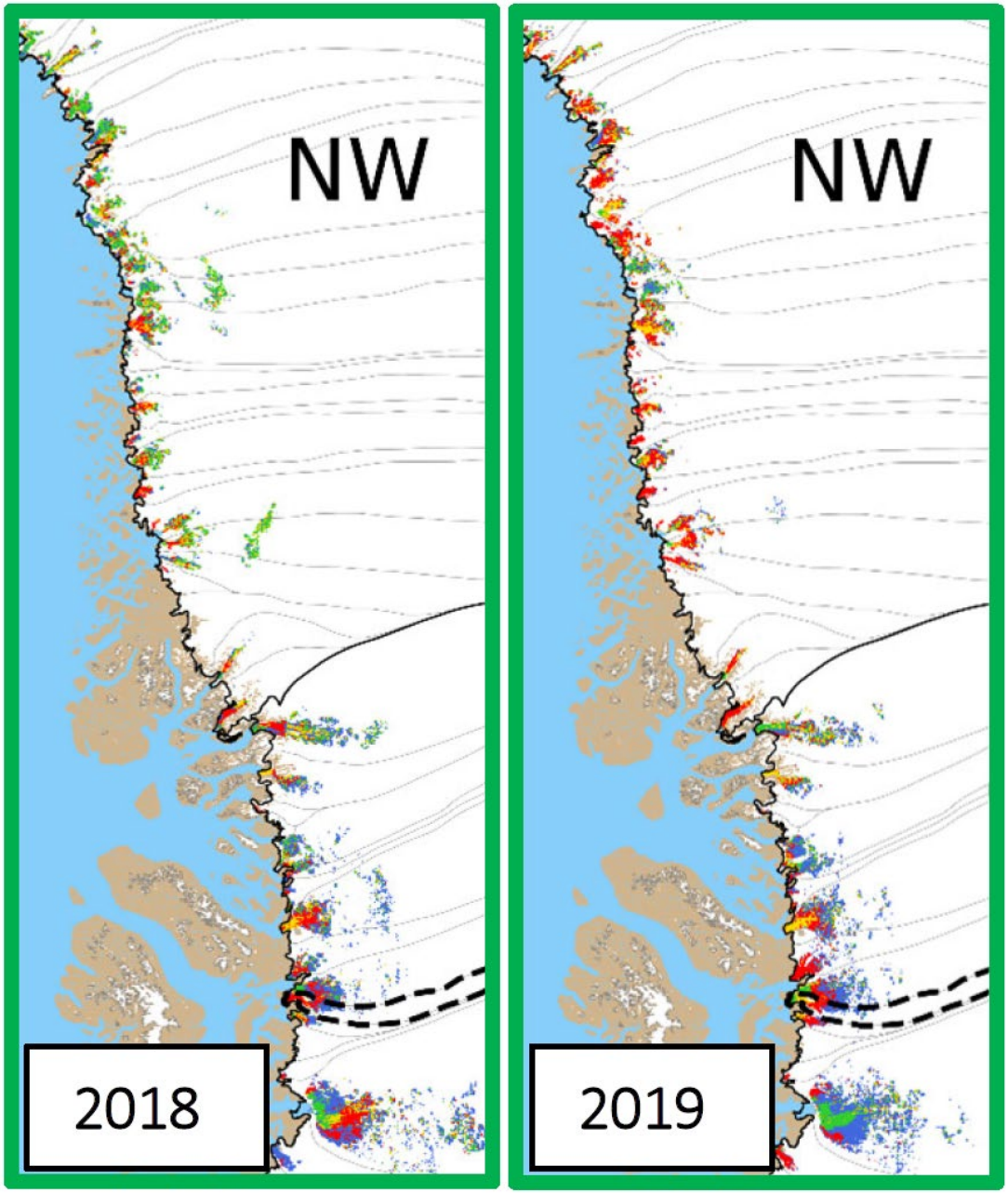

Results: temporal view

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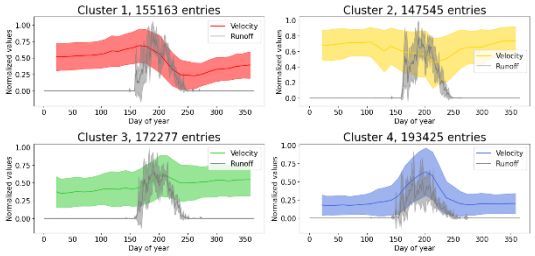

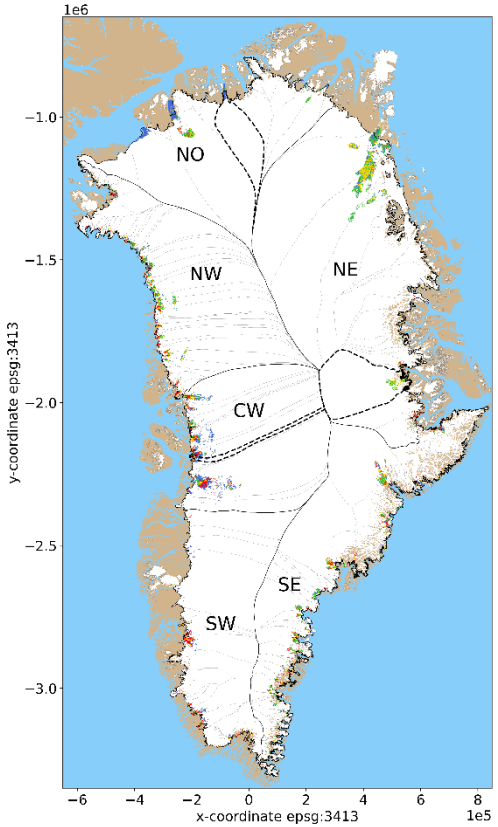

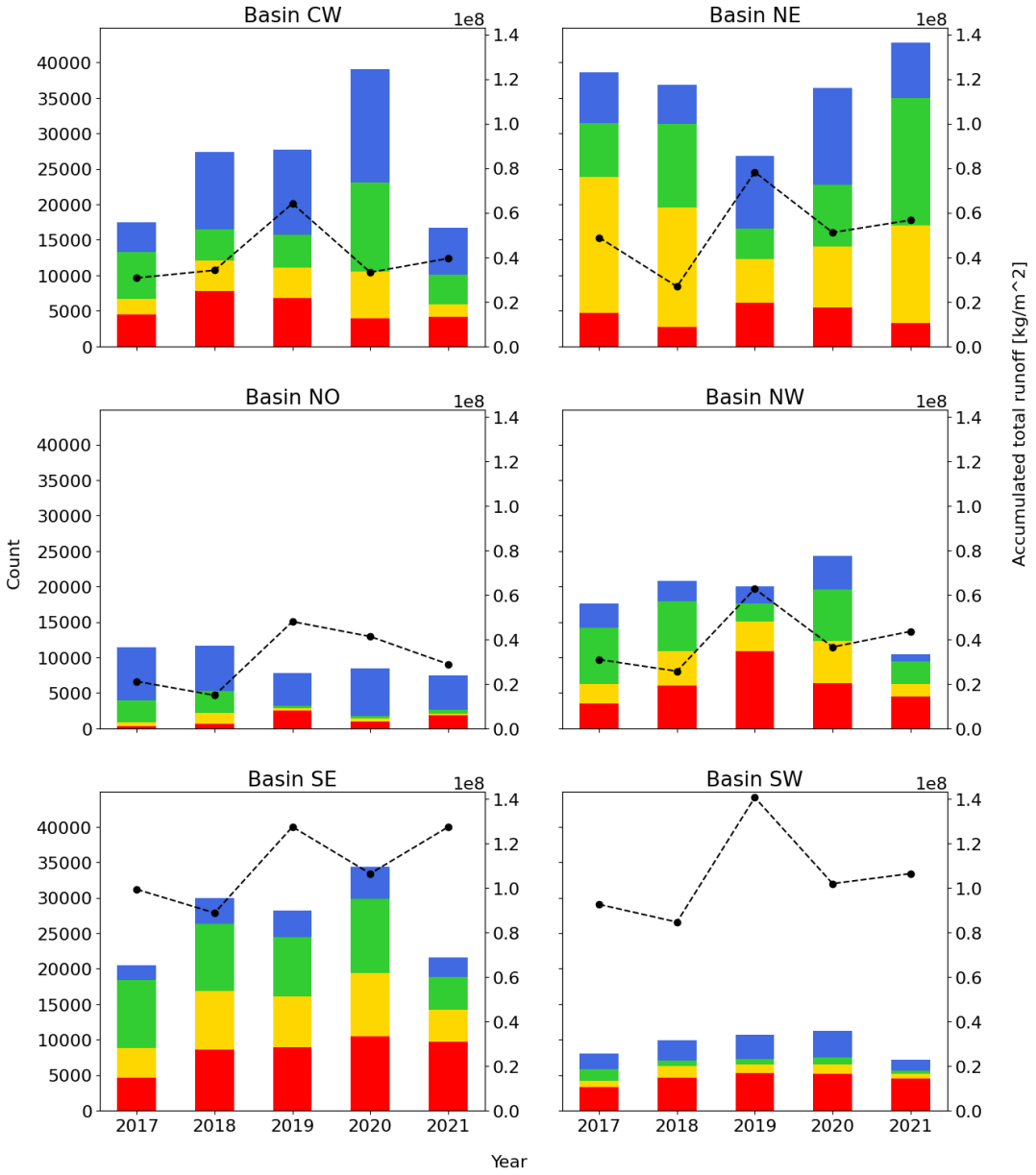

Summary and Conclusions

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- Using an unsupervised clustering method to group similar seasonal flow patterns we are able to gain a spatial overview.
- The resulting patterns are similar to those identified by e.g. Moon et al, 2014.
- The results show both inter annual variations as well as along glacier variability.
- During years of high melt, more time series are classified as Cluster 1 (type 3). This is most pronounced in the northern basins, while the southern basins largely are insensitive.
- Important tool for further development of our understanding of the hydro-dynamical coupling of ice flow and surface melt on multi-seasonal scale.

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References

Moon, T., Joughin, I., Smith, B., van den Broeke, M. R., van de Berg, W. J., Noël, B., and Usher, M. (2014), Distinct patterns of seasonal Greenland glacier velocity, Geophys. Res. Lett., 41, 7209– 7216, doi:10.1002/2014GL061836.

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B. Noël, W. J. van de Berg, S. Lhermitte, M. R. van den Broeke, Rapid ablation zone expansion amplifies north Greenland mass loss. Sci. Adv. 5, eaaw0123 (2019).

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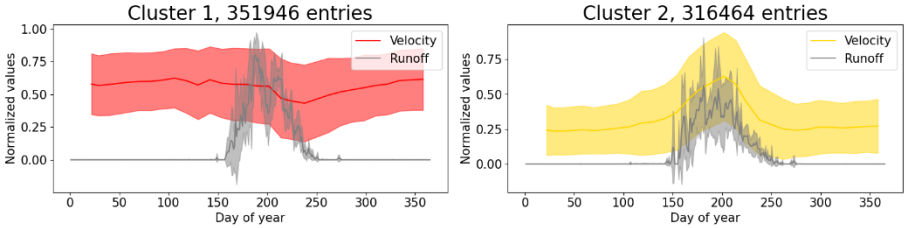
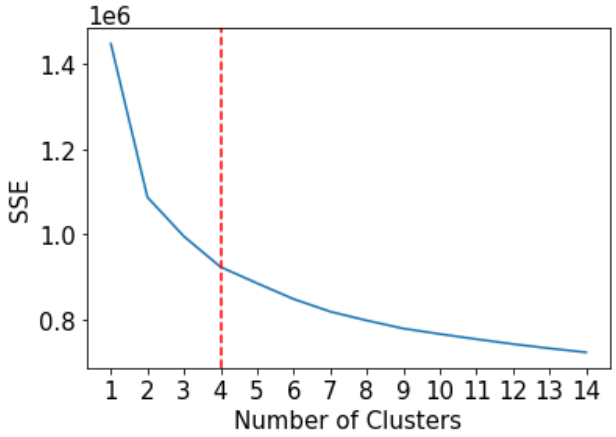
Results

Results for k=2





Results for k=7