

40 Years of Föhn Winds on the Antarctic Peninsula: Impact on Surface Melt from 1979-2018



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Introduction

- Warm and dry föhn winds cause surface melt that can destabilize vulnerable ice shelves
- Topographic funneling of these winds leads to localized wind-induced melt which is difficult to identify without direct measurement
- Automatic Weather Stations (AWS) provide in-situ meteorological observations with limited spatial representation
- ERA5 reanalysis and RACMO2 modeled data can expand the spatial understanding of föhn winds

We use AWS observations to train a machine learning (ML) model to identify the föhn signature in ERA5 reanalysis and RACMO2 output. We quantify the spatial and temporal extent of föhn-induced surface melt from 1979-2018.

Approach

Data

- 12 AWS: (AAWS)** - University of Wisconsin-Madison, (IMAU)- Utrecht, University, Netherlands, National Snow and Ice Data Center (NSIDC) (Figure 1)
- ERA5:** Satellite derived reanalysis data, 30 km x 30 km resolution, 25 variables
- RACMO2.3p2:** Regional Climate model data, 5.5 km x 5.5 km resolution, 19 variables

Föhn Detection and Machine Learning

- Created a **Föhn Detection Algorithm (FonDA)** to identify föhn wind events in AWS data.
- We use **XGBoost Gradient Boosting** decision tree Machine Learning.
- We use AWS identified föhn events to train two Machine Learning models to identify föhn in ERA5 and RACMO2 output.

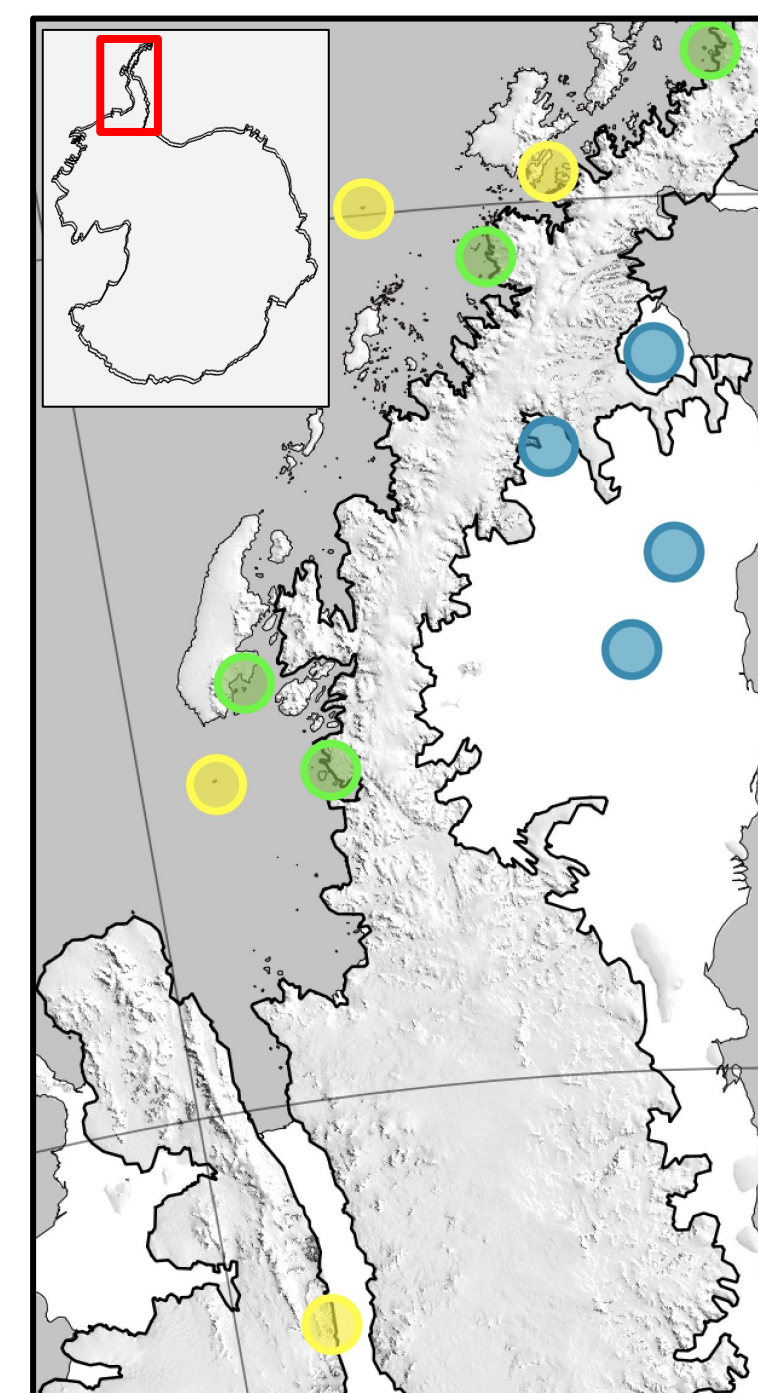


Figure 1: Study Domain and AWS locations. White shading indicates ice shelves, Grey shading indicates the ocean. The Antarctic Peninsula is a composite MODIS mosaic (125m).

★ **Table 1:** ML Model performance showing each models ability to identify föhn-induced melt compared to AWS identified events and concurrent melt. Event classification is dependant on temperature; Strong (>7 °C), Moderate (>3.5 °C, <7 °C), Weak (<3.5 °C).

ERA5 föhn classification				
AWS classification	Model classified correct	Föhn melt	Occurrence	Melt captured
Strong	100.0%	7.1%	3.6%	7.1%
Moderate	98.9%	20.5%	23.1%	20.3%
Weak	87.8%	72.4%	73.3%	63.5%
Total föhn-induced melt captured				90.9%
RACMO2 föhn classification				
AWS classification	Model classified correct	Föhn melt	Occurrence	Melt captured
Strong	100.0%	6.8%	3.0%	6.8%
Moderate	95.9%	19.5%	19.0%	18.7%
Weak	93.5%	73.7%	78.0%	68.9%
Total föhn-induced melt captured				94.4%

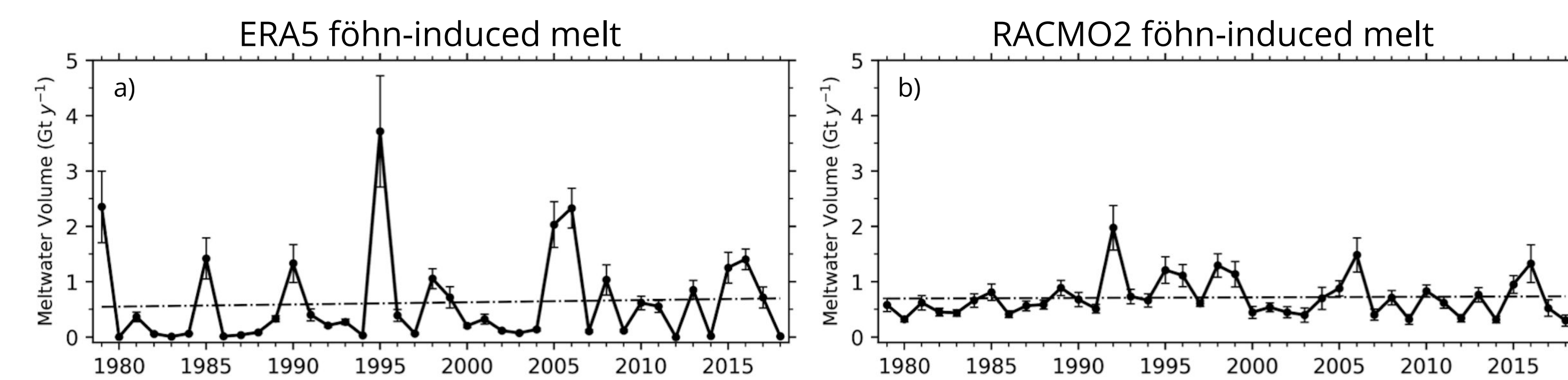
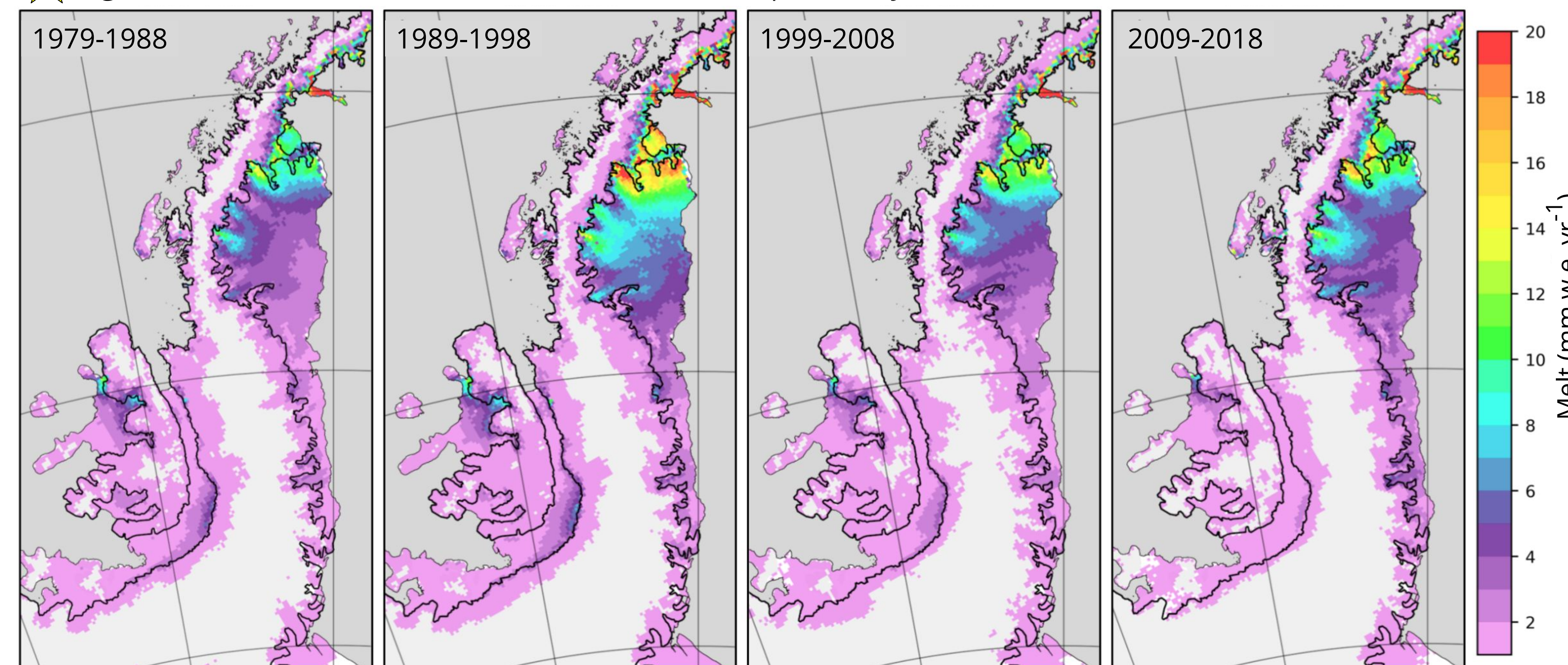
Surface Energy Budget and Melt

- Combine föhn events identified with Machine Learning models and the surface energy budget to create a climatology of surface melt and the surface energy budget.

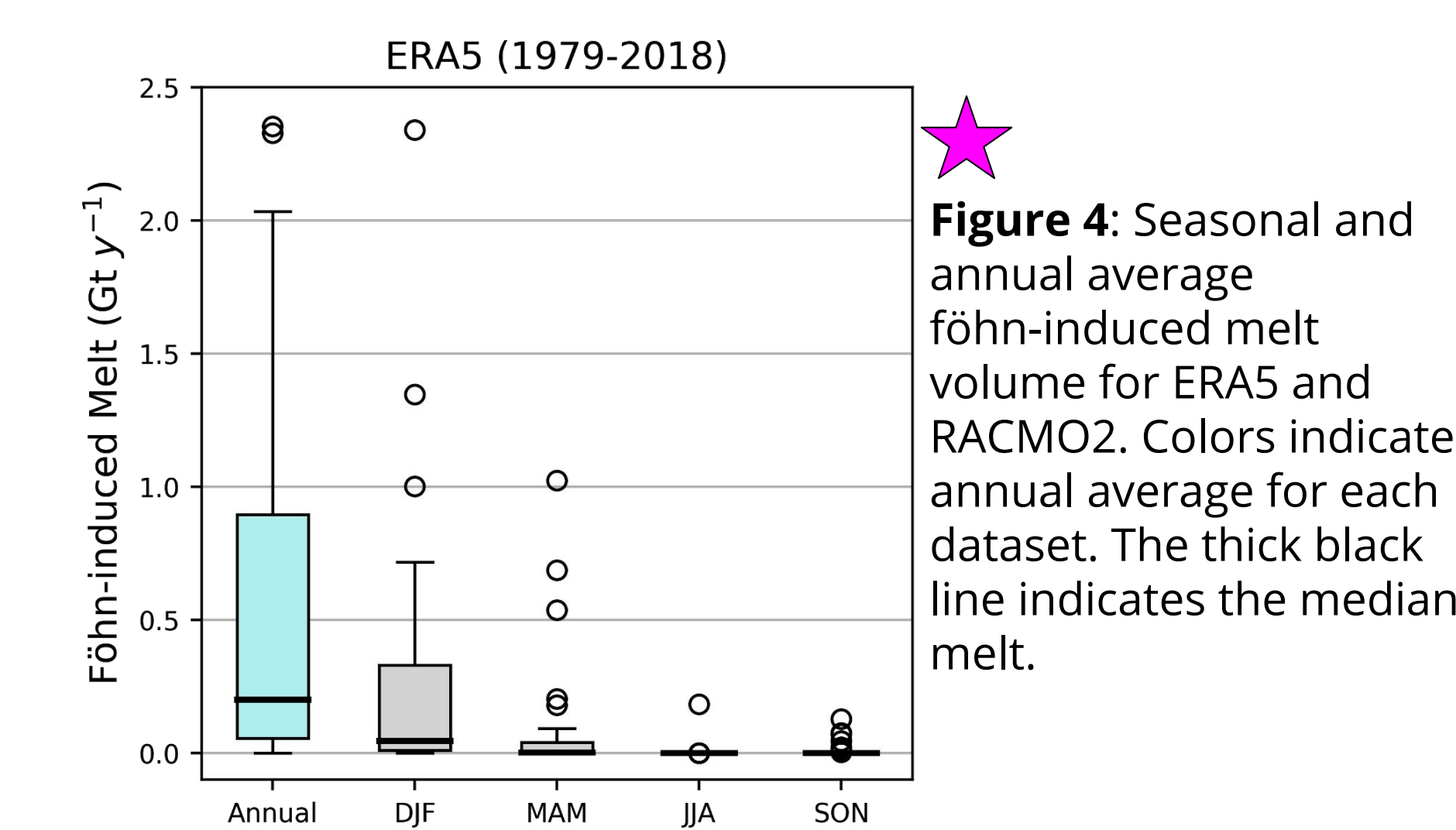
$$\text{Energy} = \text{SW}_{\text{net}} + \text{LW}_{\text{net}} + \text{H}_S + \text{H}_L \text{ (W m}^{-2}\text{)}$$

Results

★ **Figure 2:** Annual RACMO2 föhn-induced surface melt pattern by decade



★ **Figure 3:** Annual average föhn-induced melt for a) ERA5, b) RACMO2. Dashed line represents the long-term trend.



★ **Figure 4:** Seasonal and annual average föhn-induced melt volume for ERA5 and RACMO2. Colors indicate annual average for each dataset. The thick black line indicates the median melt.

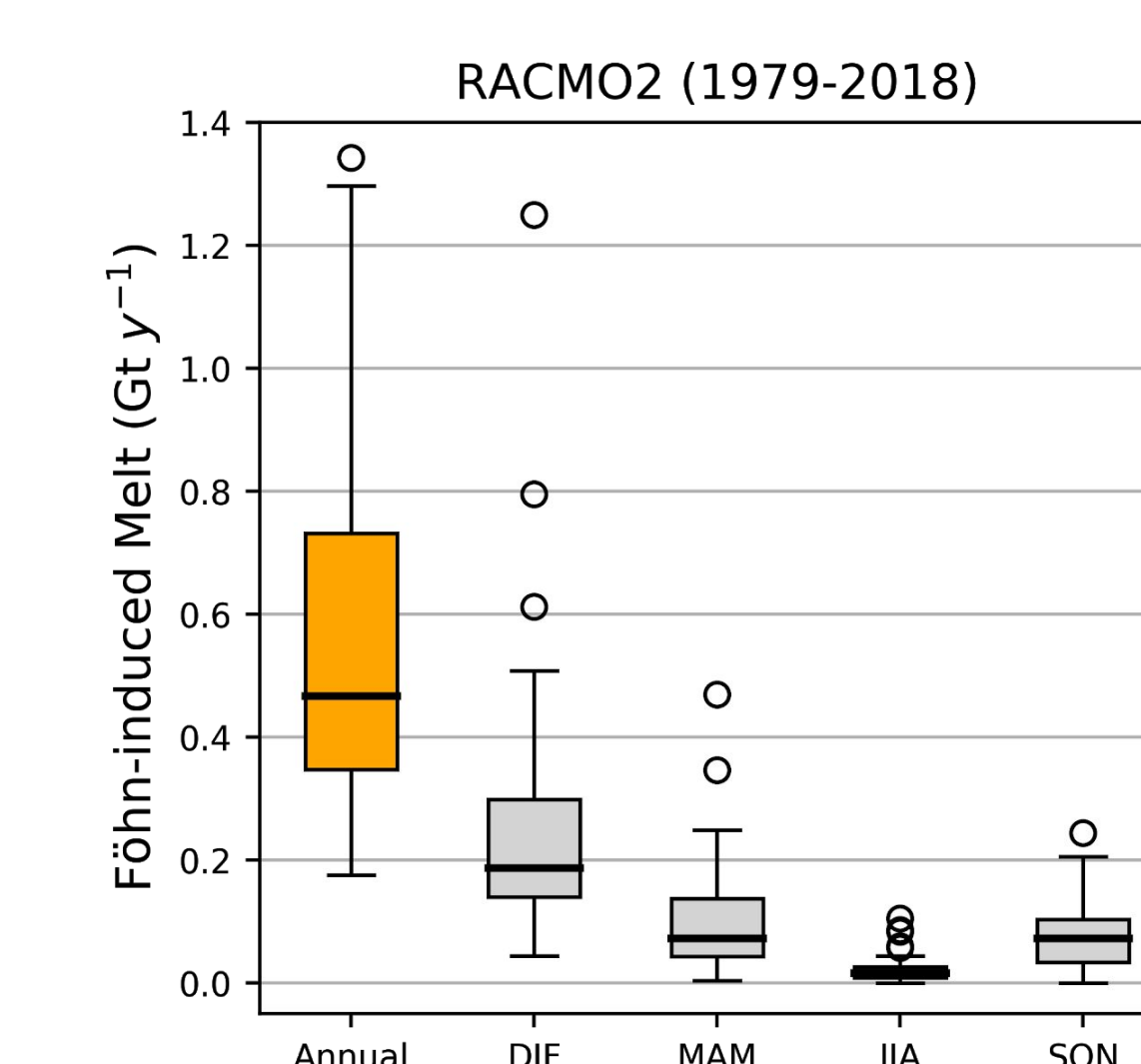
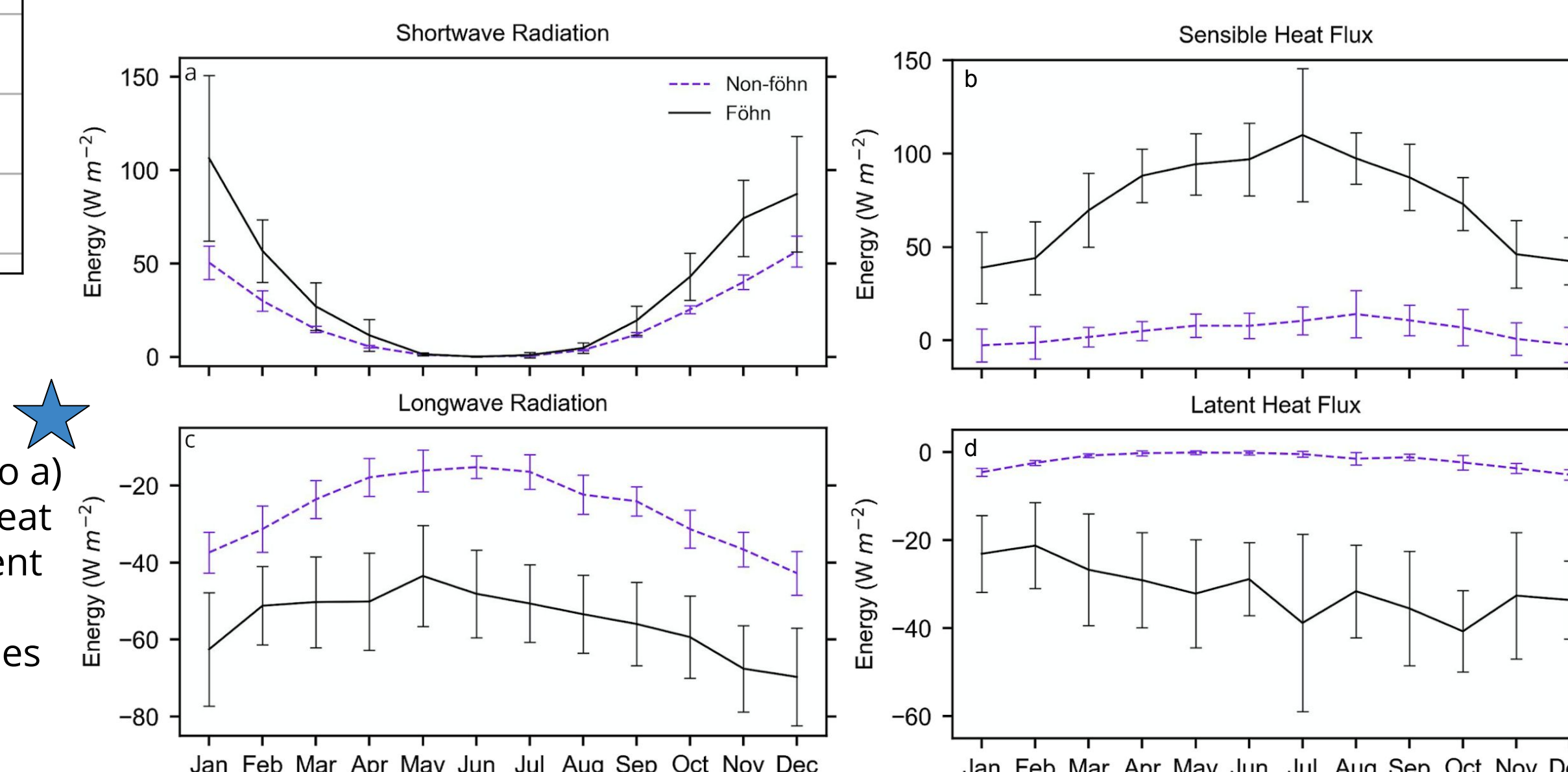


Figure 5: Monthly föhn-induced melt volume for a) ERA5, b) RACMO2.



Figure 6: RACMO2 surface energy budget components separated into a) Shortwave radiation, b) Sensible heat flux, c) Longwave radiation, d) Latent heat flux. Solid lines indicate föhn conditions while purple dashed lines indicate non-föhn conditions



Research Summary

Problem: Gaps in knowledge exist regarding the effect föhn winds have on surface melt for a large part of the Antarctic Peninsula through time because föhn winds often occur on local sub-grid scales.

Solution: We use in situ observations to train a machine learning (ML) model to identify föhn winds in reanalysis and regional climate model datasets.

Data: We use Automatic Weather Stations, ERA5 Reanalysis and modeled RACMO2.3p2 output.

Result: We combine the ML identified föhn winds with the surface energy budget for both datasets and create a föhn-induced surface melt climatology from 1979-2018

Conclusions

Föhn Detection

★ The ML models identify 90.9% (ERA5) and 94.4% (RACMO2) of AWS identified surface melt concurrent with föhn events (**Table 1**).

★ The ML models identify 79.9% (ERA5) and 81.3% (RACMO2) of AWS identified föhn events (**Table 2**).

Melt Climatology

★ The föhn influence is strongest at the eastern base of the AP mountains and propagates across the Larsen C ice shelf (**Figure 2**).

★ Both datasets indicate an insignificant increase in föhn-induced melt through time (**Figure 3**).

★ Föhn-induced melt occurs in all seasons but predominantly in the summer (**Figure 4**, **Figure 5**).

★ Sensible heat exchange is more important during winter föhn-induced melt events while increased shortwave radiation is more important during summer melt events (**Figure 6**).

★ **Table 2:** ML Model detection performance

ERA5 model prediction accuracy	
F1-score	79.9 ± 3.48
Recall	81.2
Precision	78.6
Improvement in	
F1-score over null model	27.4
RACMO2 model prediction accuracy	
F1-score	81.3 ± 3.84
Recall	84.1
Precision	78.5
Improvement in	
F1-score over null model	23.1

Acknowledgements

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