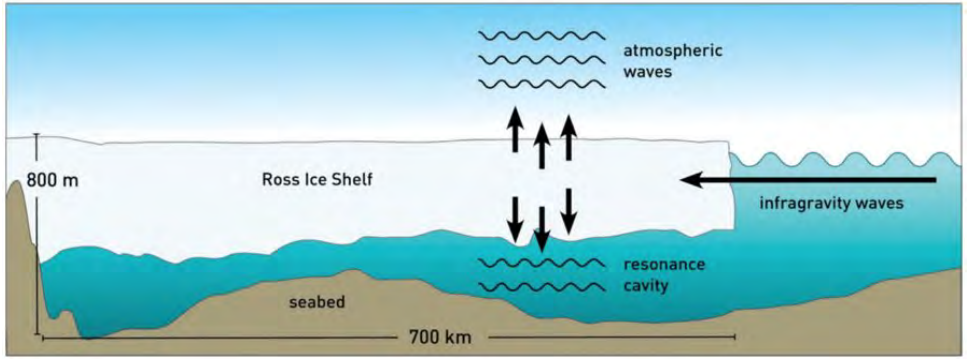
Automatic Event Detection in Antarctic Ice Shelves

Linnea Wolniewicz

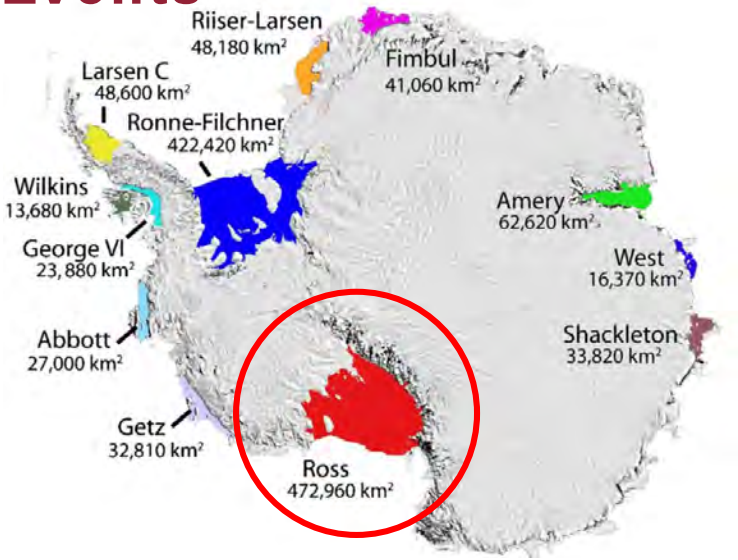
Mentors: Dhiman Mondal, Pedro Elosegui, John Barrett, Chester Ruszczyk

Background

Antarctic Ice Shelves & Ocean Forcing Events

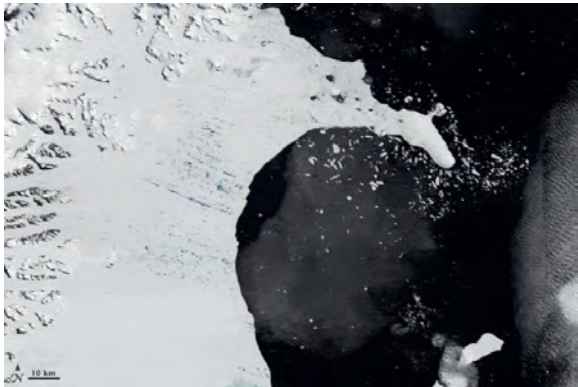


[Kotary, 2017]



[Scambos et al., 2007]

- Ice shelves buttress land ice
- Climate change has weakened ice shelves
- Ocean forcing contributes to the collapse of an ice shelf
- Larsen B Ice Shelf collapse in 2002 (right)



[NASA's Earth Observatory]

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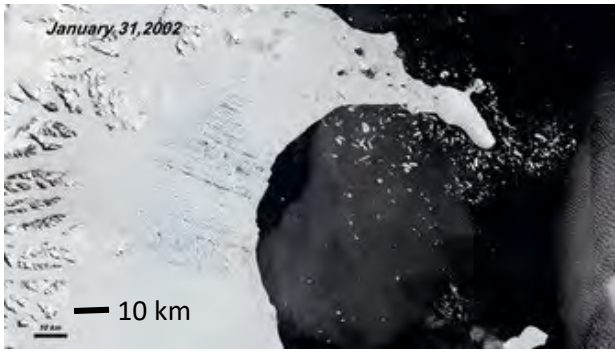
[Scambos et al., 2007]

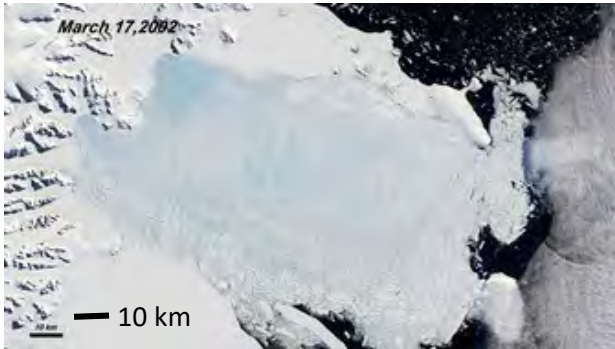
Why do we detect ocean wave events?

- Ice shelves susceptible to ocean forcing
- Ocean wave events contribute to calving events
- RIS collapse = 3.3 m rise in *global* sea level [Independent UK]
- Detecting ocean wave events is important!

Before: 1/31/2002



After: 3/17/2002



[NASA Hyperwall]

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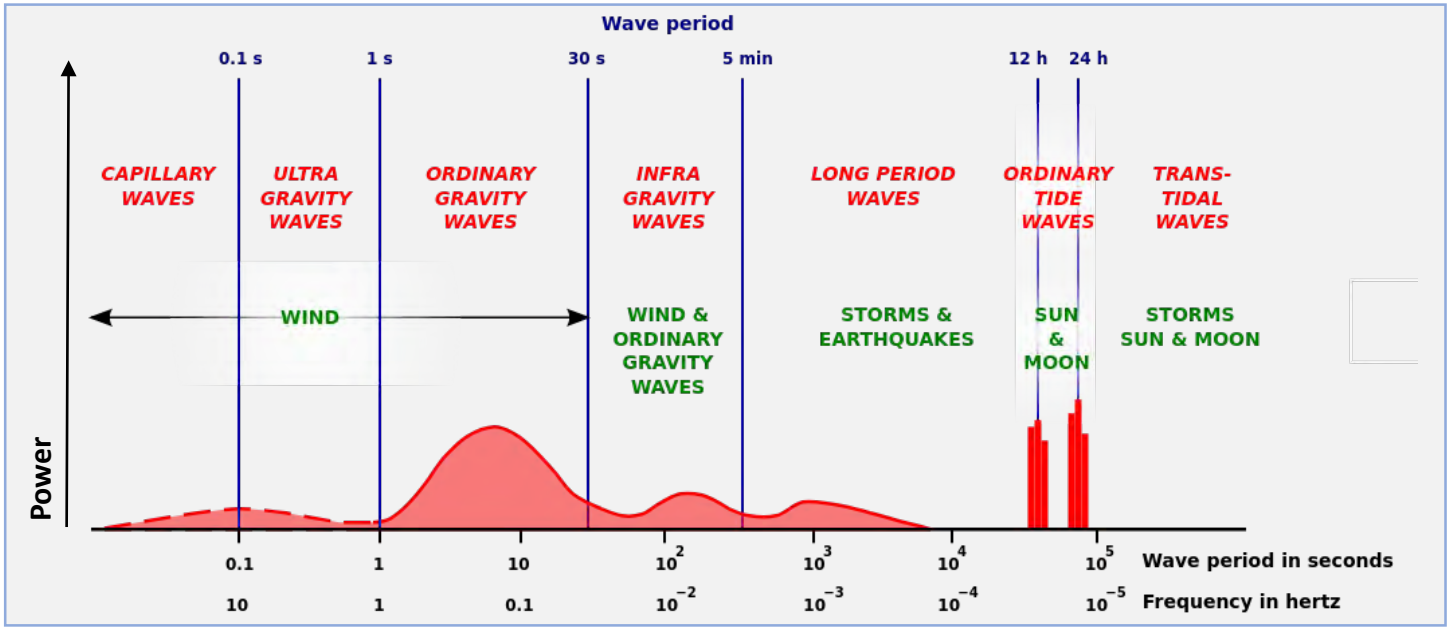
What are ocean wave events?

Major 3 waves:

- Swell (30- 100 mHz, ~10 s)
- Infragravity (3 - 30 mHz, ~1 min)
- Very Long Period (< 3 mHz, ~5 min)



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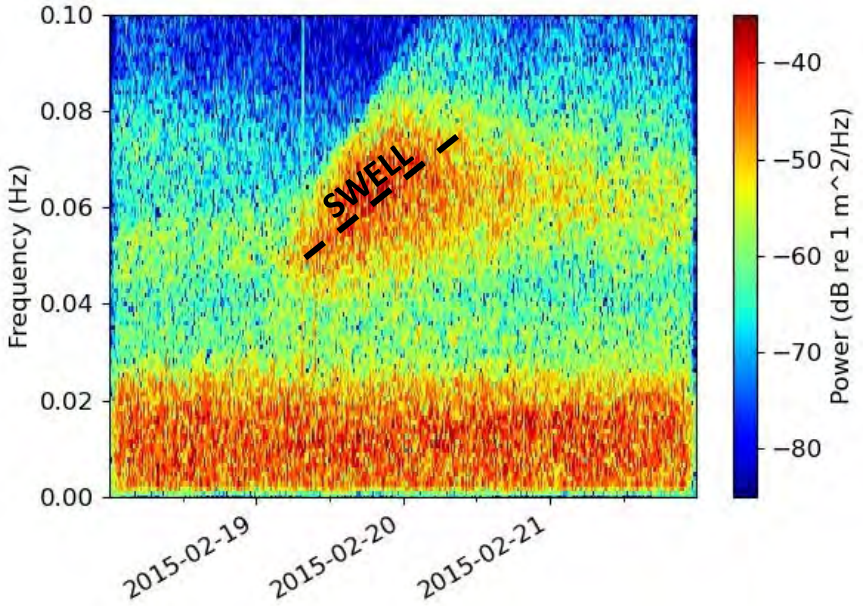
How do we detect ocean wave events?

- Ocean forcing causes ice shelves to vibrate
- Seismometers embedded in the ice shelves monitor vibrations
- Ocean wave events are dispersive and easy to distinguish in spectrograms
    - Phase velocity varies with frequency



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My Research

My research goal: automatically detect ocean wave events impacting the ice shelves

1. Seismic spectrograms
2. Cluster spectrograms
3. Identify dispersive events

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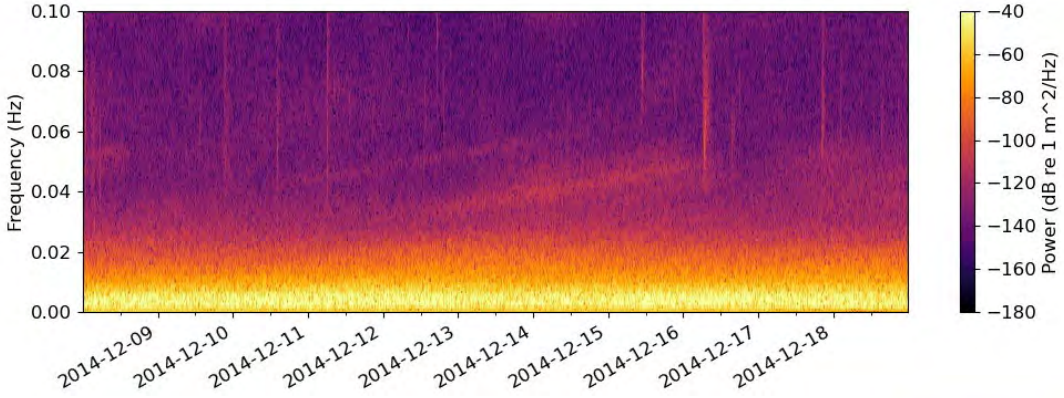
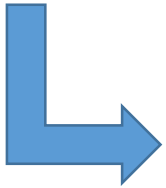
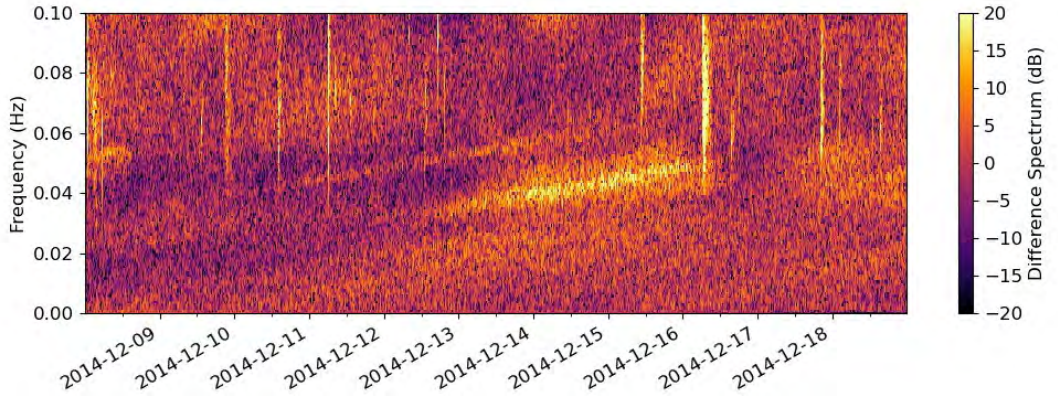
Step 1: Seismic spectrograms







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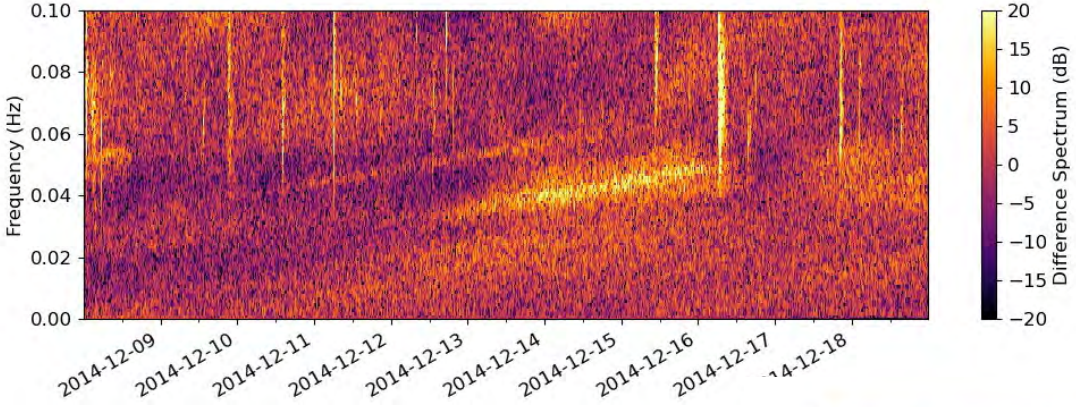
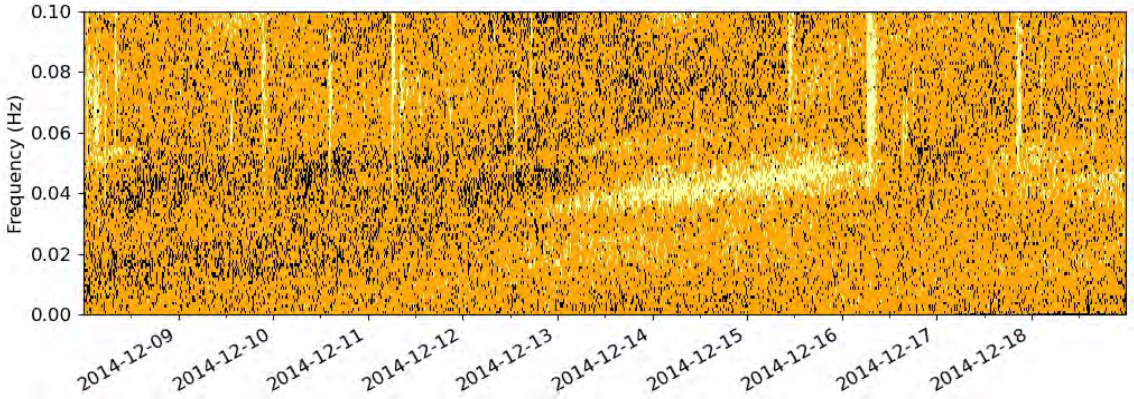
Step 2: Cluster spectrograms



1. Signal cluster
2. Noise cluster
3. Quiet cluster



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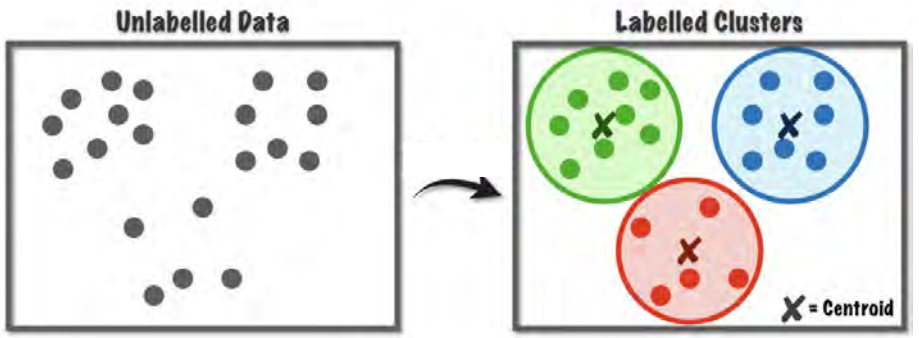
What is a Gaussian Mixture Model (GMM)?

- Unsupervised machine learning model
- Clustering algorithm
- Unlabelled data => k-clusters labelled data
  - Identifies cluster centroids and Gaussian distributions
  - Predicts cluster for each datapoint
- In image segmentation, pixel intensities used to define clusters



[Medium, K-means/GMM clustering with Python]

[Medium, K-means/GMM for Image Segmentation]

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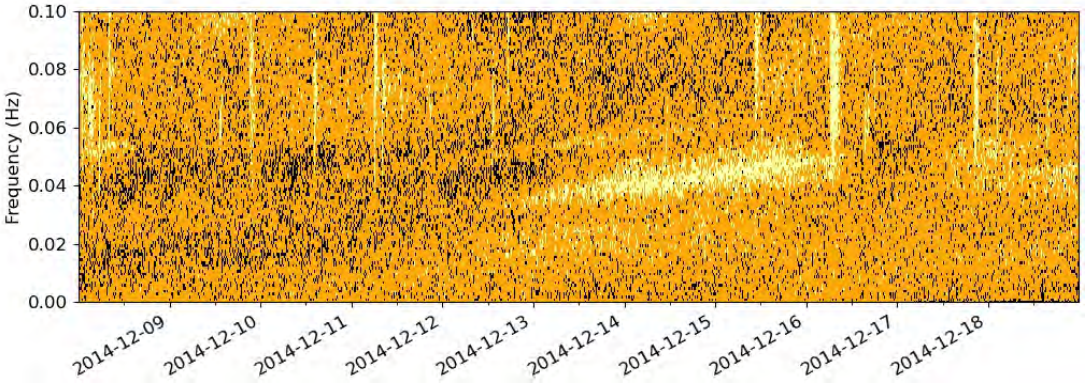
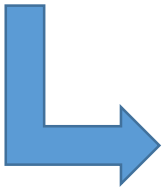
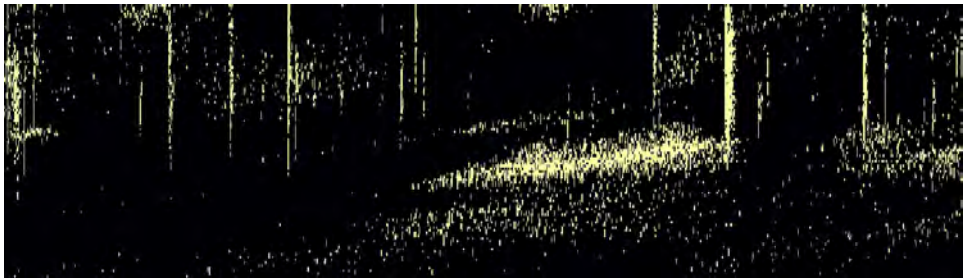
Step 2 (cont.): Cluster spectrograms







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Step 3: Identify dispersive events

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A few other example results:

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Conclusions

Summary

- Raw data => images with detected events
- ~90% accuracy
  - Accuracy = % True Positive and True Negatives
- Pros: removes vertical noise spikes and identifies events
- Cons: identifies multiple ellipses for one event

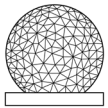
Data is 87 10-day spectrograms Data spans 100 days (11/21/2014-3/1/2015) Data from station DR10 on the RIS
True Event Detections: 115
Accurate Noise Removal: 45
Missed Detections: 15
Missed Noise Removal: 4

Implications

- Create a labelled dataset with my software
  - Use labelled dataset to train a Convolutional Neural Network to automatically detect *and* classify events
- Open door to discoveries of new ice shelf responses to ocean wave events
  - Only a few ocean wave events have been documented; detecting more events will greatly increase our understanding of ice shelves and their response to ocean forcing
- Detecting ocean wave events allows us to explore ice shelf stability
- Learn new physics from the data through Machine Learning

Acknowledgments

- My research group
  - Without the constant help of Dhiman Mondal, Pedro Elosegui, John Barrett, Chet Ruszczyk, and Tyler Landsparger this work would not have been possible
- MIT Haystack Observatory
  - For all their helpful advice and supportive network
- Haystack IT
  - For all their help and answers to my questions
- NSF
  - For funding the project



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