Waves in the marginal ice zone: insights from in situ observations and modeling

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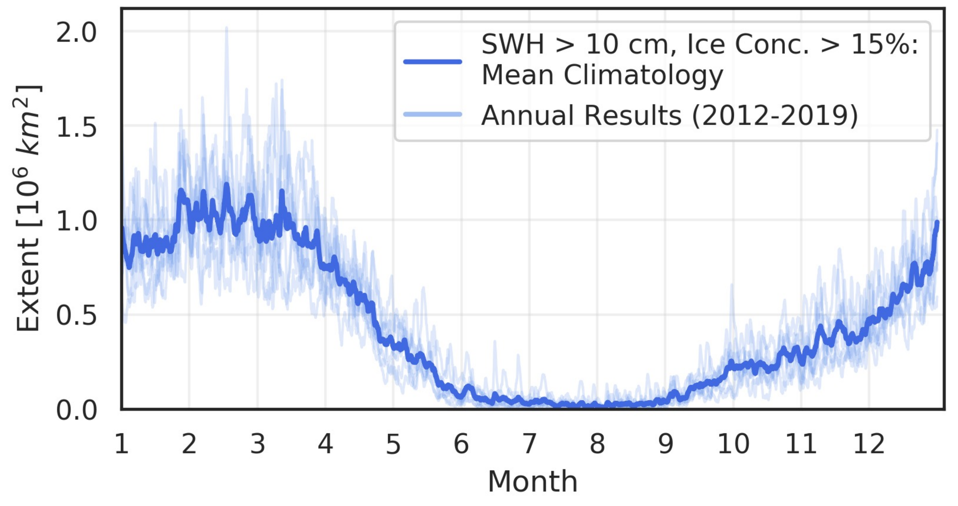
INTRODUCTION

- **Ocean waves control formation and fracture of sea ice**
- Arctic climate warms → sea ice retreats → remaining ice cover exposed to bigger waves
- **Observations of wave-ice interaction are rare** → finding constraints for a new global coupled wave-ice model is a major challenge

Model Climatology of Wave-Affected Ice Extent in the Artic

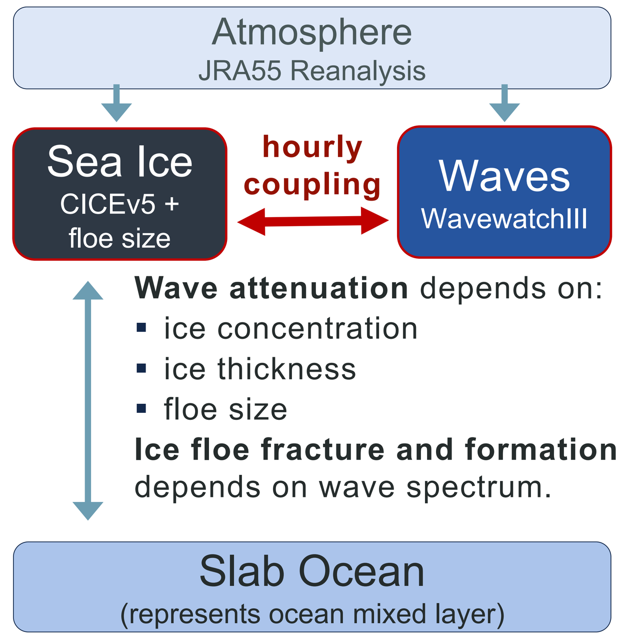
2012-2019 from Roach et al. (2019) Coupled Wave-Ice Model



OVERVIEW OF MODEL AND IN SITU OBSERVATIONS

Model Configuration

Roach et al. (2019) Coupled Wave-Ice Model

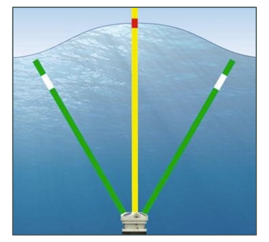


Wave attenuation depends on:
- ice concentration
- ice thickness
- floe size

Ice floe fracture and formation depends on wave spectrum.

1° global grid

Challenge of Observing Waves in Ice



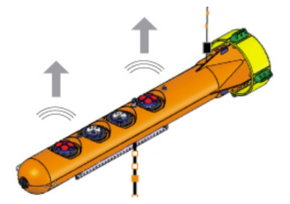
Source: Nortek website

- When mooring is under partial ice cover, **wave signal must be sufficiently energetic relative to noise and ice roughness** to yield valid wave measurements

2 BGOS moorings Nortek AWAC

Adapted from Thomson (2020)

3 SODA moorings Nortek Signature-500



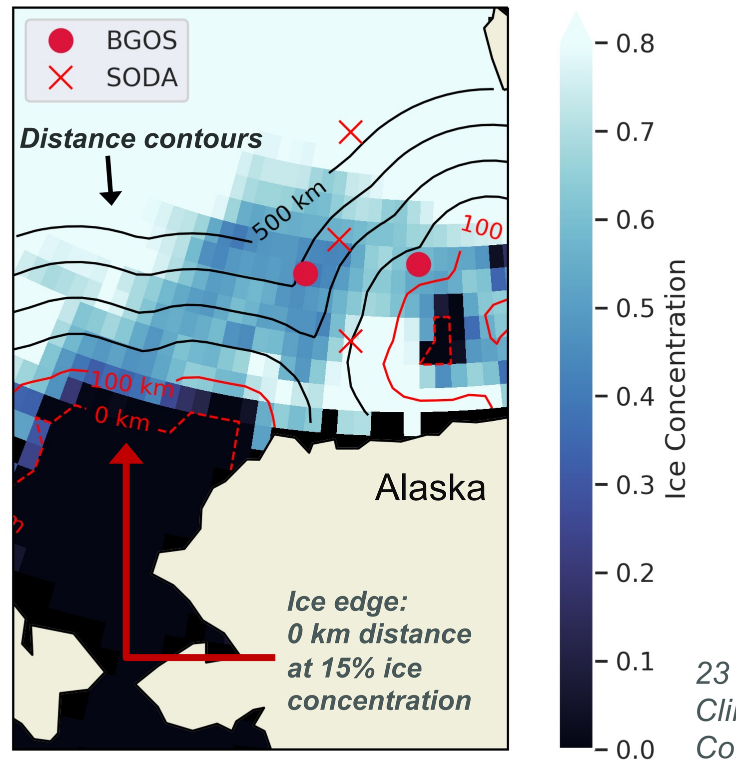
Adapted from Lee et al. (2016)

SWIFTs Surface buoys

APL Sea State website (2015)

METHOD OF COMPARISON

Illustrative Distance and Ice Concentration



23 July 2018 Ice Concentration from NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration (Meier et al. 2020)

Point Observations vs. Gridded Model Data

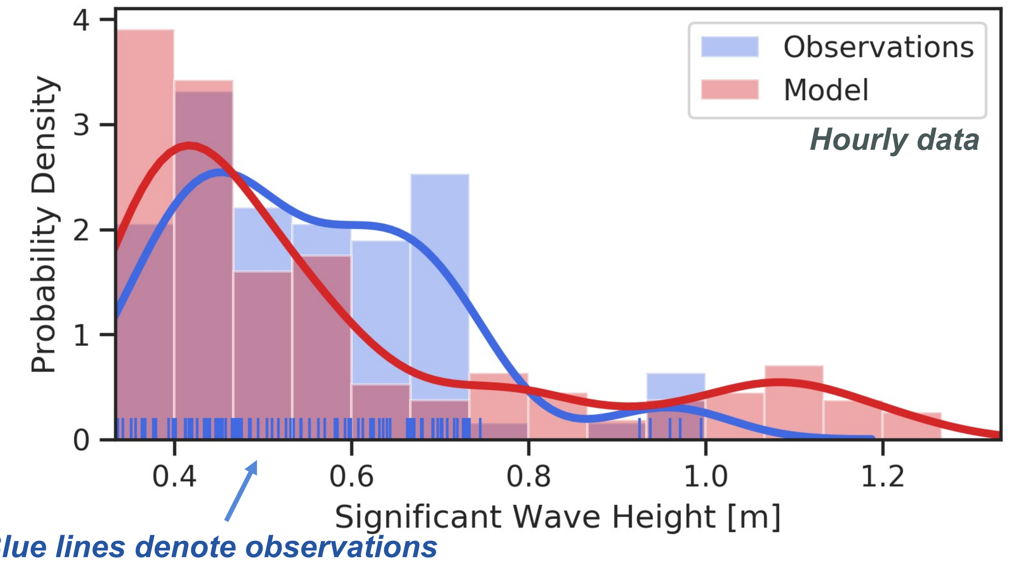
- Group results based on "**distance from the ice edge**"
- Domain of comparison limited to Beaufort Sea region near in situ observations

RESULTS: SIGNIFICANT WAVE HEIGHT

Distribution of Significant Wave Height at 100+ km Inside MIZ

Model Results span 2012-2019 in the Beaufort Sea Region

- At 100+ km inside the ice edge:
  - Observations show prevalence of mid-size (0.4 - 0.75 m) waves
  - Model shows more waves exceeding 1.0 m
- Differences in distributions: model bias or sampling challenges?

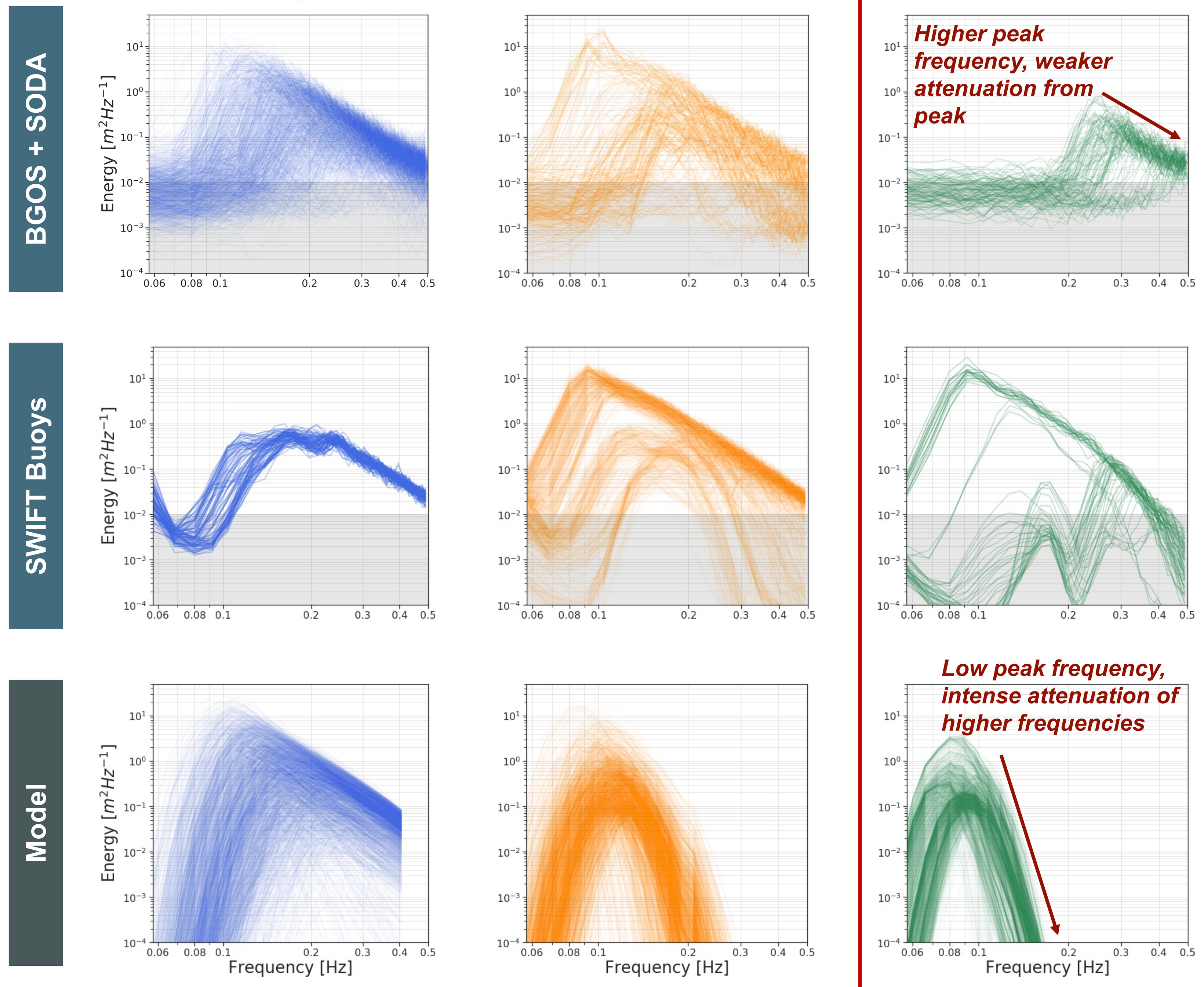


Blue lines denote observations

Low end of domain shown is set above the signal-to-noise threshold for all instruments

RESULTS: WAVE SPECTRA

Hourly data



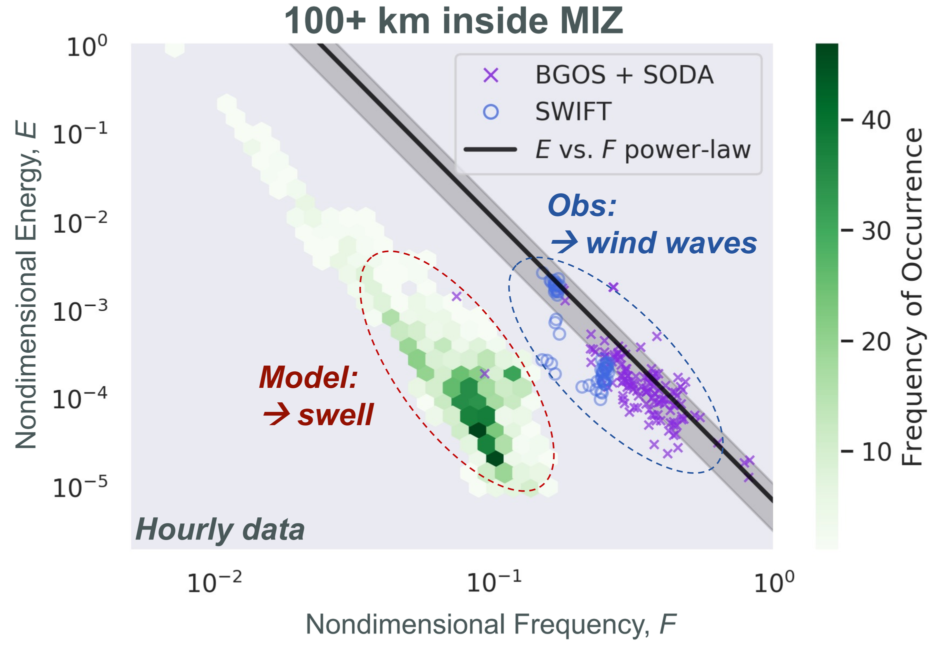
At 100+ km inside the ice edge:
- Model only has wave energy at low frequencies
- BGOS + SODA moorings observed short waves at high peak frequencies

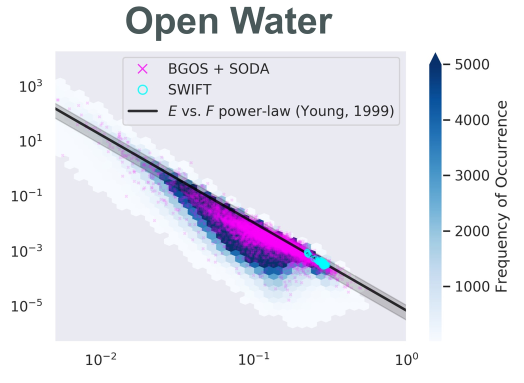
RESULTS: NONDIMENSIONAL WIND WAVE SCALING

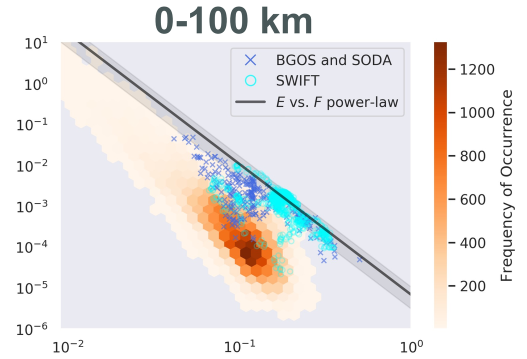
Wind Wave Theory Applied to Waves in Ice

Model Results span 2017-2019 in the Beaufort Sea Region

- Observations report *wind waves*
- Model reports *swell* but no *wind waves*



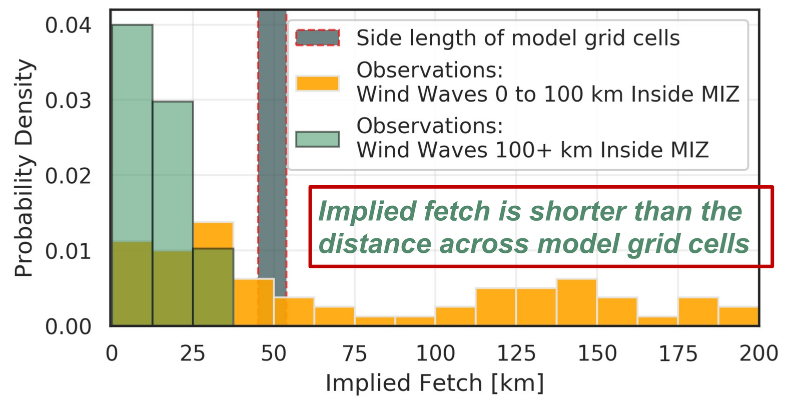




DISCUSSION: IMPLIED FETCH AND CONCENTRATION BIAS

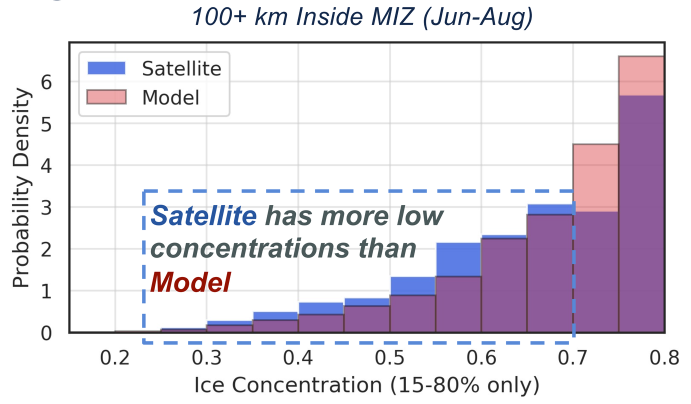
- Estimate ***implied fetch*** for observed wind waves using power-law relations
- At 100+ km, **waves are locally generated over fetch shorter than distances across model grid cells**
- **Satellite observations show more low ice concentrations** at 100+ km inside ice compared to model
- *Horvat & Tziperman* (2015) parametrization suggests **observed local wind waves are strong enough to fracture ice**

Histogram of Implied Fetch



Histogram of Intermediate Ice Concentrations

100+ km Inside MIZ (Jun-Aug)



CONCLUSIONS AND FUTURE RESEARCH

- Model and observations have differences in wave height distributions at 100+ km inside the ice edge
- **Wind waves in ice** present in *Observations* but not in *Model*
  - Model resolution not fine enough for short wind waves, and…
  - Too-high ice concentration bias in model at 100+ km inside ice edge hinders wind wave generation
  - Local wind waves are strong enough to fracture ice
    - → New model experiments will investigate local wind wave generation in ice
- **Swell waves in ice** present in *Model* but not in *Observations*
  - Swell waves excluded from mooring observations because wave signal too weak to overcome instrument noise floor and ice roughness
  - Model is not sufficiently attenuating low frequency energy, but swell has less impact on floe fracture

References

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