Modelling the Backscattering Properties of Anisotropic Rough Snow Surfaces: Implications for the Evolution of Near Surface Features on the Ice Sheets

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Abstract

Understanding the near-surface roughness is paramount for the evolution of surface features and its contribution to the ice sheet dynamics. In regions experiencing the transition from dry snow to melt conditions, the surface becomes rough which along with liquid water content influences the radar backscatter. Such surfaces are driven by wind resulting in the formation of features oriented at different azimuth directions, ranging from ripples to dunes. Different scales of roughness also induce depolarisation in the radar signal, thereby making it difficult to infer the effective contribution of densification process on total backscatter. Here, we present a physical understanding of a wind-induced snow surface having anisotropic roughness from the modelled radar backscatter. As part of the approach, we propose to model the horizontal component of roughness (autocorrelation length) as a function of azimuth direction in the surface scattering model, i.e. Integral Equation Model. We performed our experiments for strongly anisotropic ($a < 0.2$), weakly anisotropic ($a > 0.7$), and isotropic ($a = 1$) surfaces, where a is the anisotropy, tuned for C-band frequency. Also, the minima of backscatter intensity varied over entire range of azimuth angles at a particular incidence angle is derived for retrieving the most dominant wind direction. From our analysis, significant azimuth modulation occurs in the radar backscatter at low incidence angles. Moreover, we found that the most dominant wind direction at 30-deg incidence angle changes from a strongly anisotropic surface (i.e. 0-deg) to a weakly anisotropic surface (i.e. 90-deg), however it remains unaltered for 45-deg and 60-deg incidence angles (i.e. 90-deg). Our modelled results are in strong agreement with wind scatterometer data of ice sheets and further show the potential of 30-deg incidence angle for tracking the changes in wind flow pattern based on directionality of roughness. In this regard, we foresee the importance of azimuth modulation for understanding the properties and orientation of surface features in the ice sheets, with particular application to wind flow. As a future scope, we plan to apply our model on radar images for the retrieval of wind directions and compare the directionality of roughness with the katabatic wind flow patterns and AWS measurements.

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AGU Fall Meeting, New Orleans, LA and Online Everywhere

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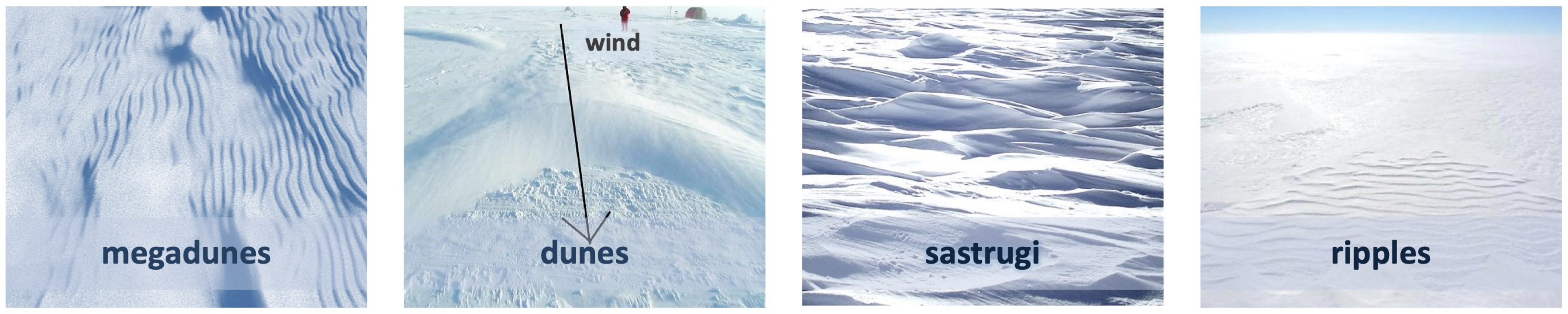
Rationale

Understanding the near surface roughness is paramount for the evolution of surface features and it's contribution to the surface mass balance of upper few meters



km-scale → **cm-scale**

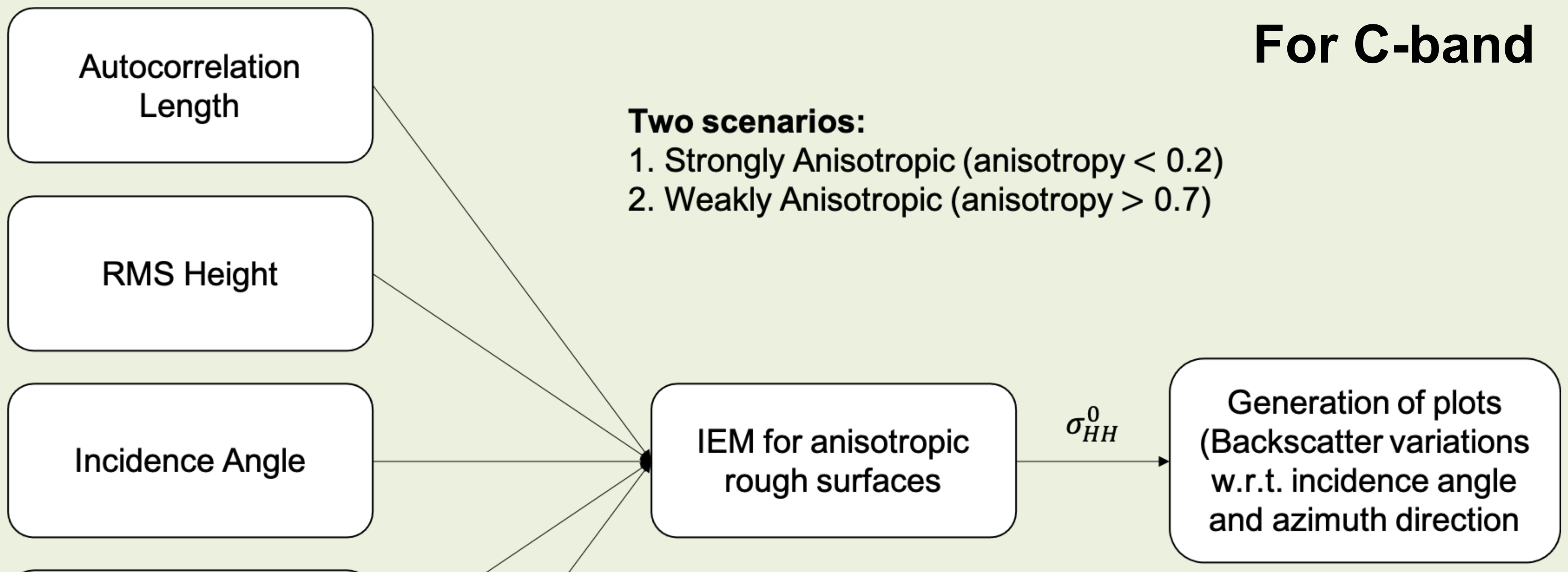
Near surface of ice sheets contains more than one scale of roughness, mostly shaped by wind, thereby introducing anisotropy

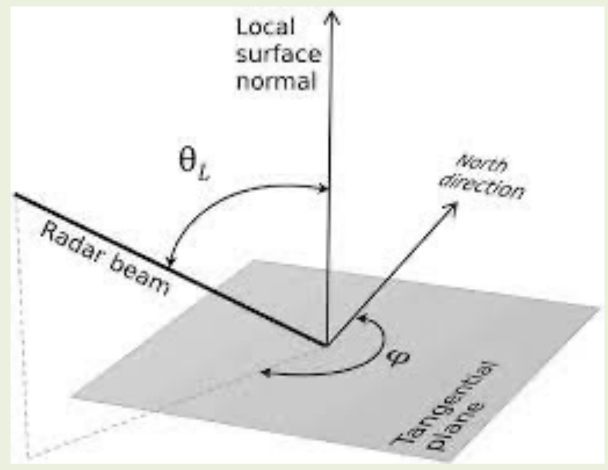
Anisotropy in roughness is also caused due to gravity on tilted surface, especially when melting or rainfall on snow occurs

Approach

For C-band

Two scenarios:
1. Strongly Anisotropic (anisotropy < 0.2)
2. Weakly Anisotropic (anisotropy > 0.7)





Dominant wind direction = Minima of backscatter, plotted w.r.t. azimuth angle

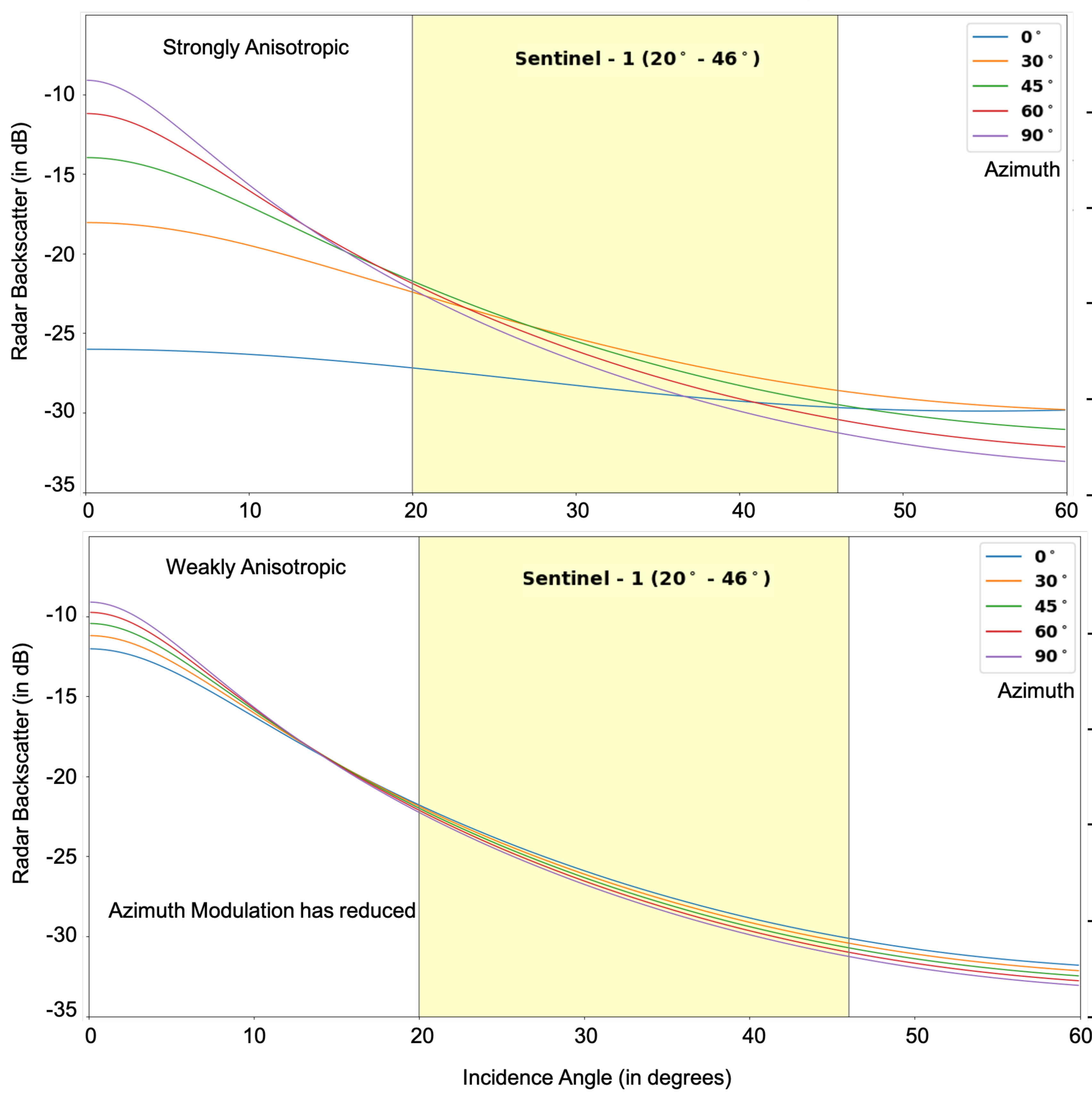
What we are doing?

- ✓ Simulating the backscatter response from anisotropic rough surface and quantifying the most dominant wind direction at different incidence angles
- ✓ We parameterize Integral Equation Model (IEM) for rough snow surfaces, introducing anisotropy
- ✓ Roughness is quantified by RMS height and Autocorrelation length
- ✓ When anisotropy is considered, autocorrelation length is a function of azimuth direction
- ✓ C-band radar configuration; different incidence angles (30°, 45°, 60°)

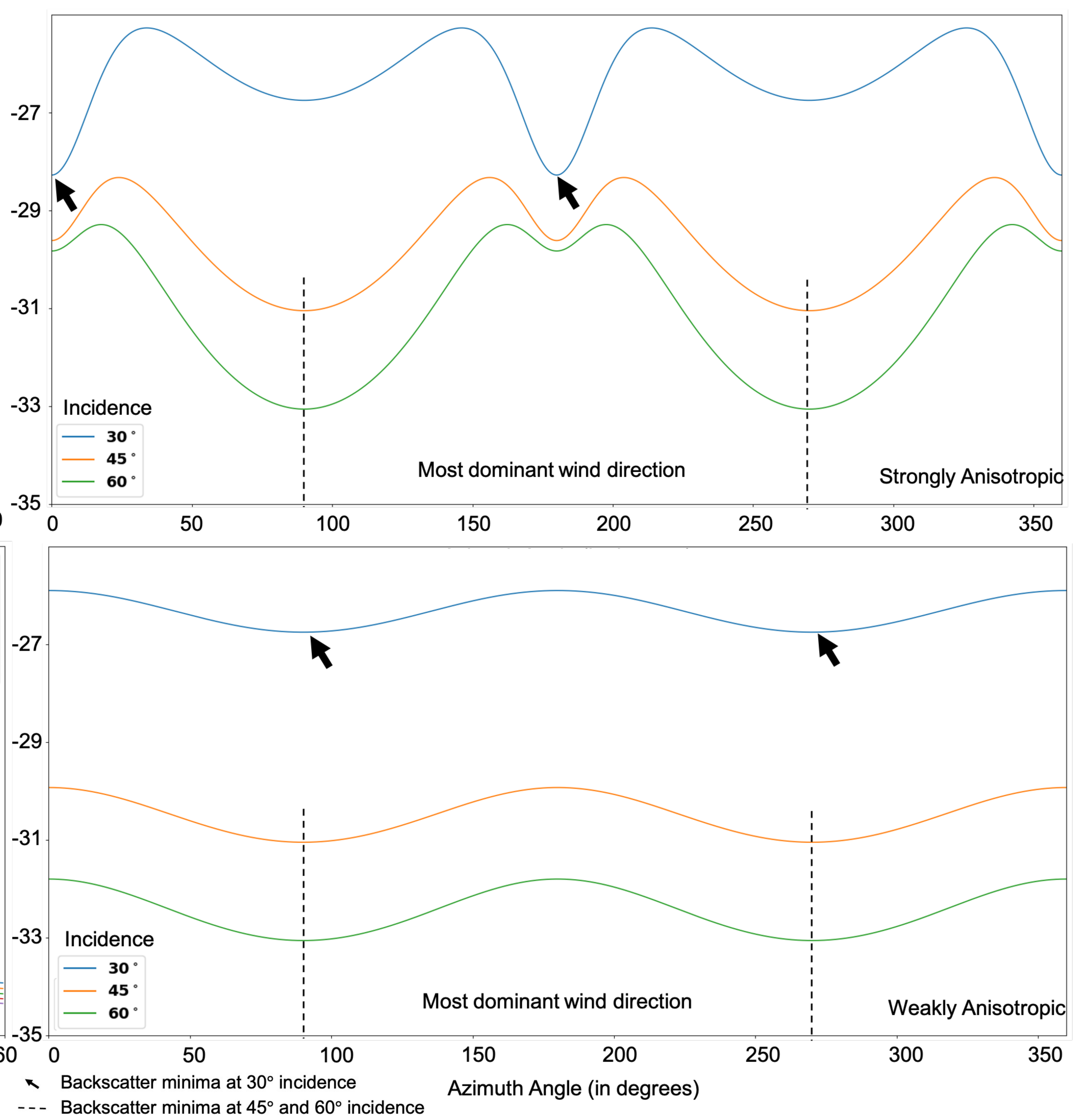
Limitations

Lack of roughness field data (RMS heights and autocorrelation length)

Variations in backscatter w.r.t. incidence angle



Variations in backscatter w.r.t. azimuth direction



Results

- ✓ Significant azimuth modulation is observed at low incidence angles
- ✓ Most dominant wind direction changes from 0° to 90° azimuth direction for 30° incidence angle when the surface transforms from strong anisotropic to weakly anisotropic
- ✓ Potential of backscatter at 30° incidence angle for tracking the changes in wind flow pattern based on the degree of roughness anisotropy

Future Scope

- ✓ Applying our model on radar images for retrieval of dominant wind directions
- ✓ Comparing the directionality of roughness with katabatic wind flow patterns and AWS measurements
- ✓ Calibration of our model with in-situ roughness data

Take Away Home Message

Roughness anisotropy is important for modeling near-realistic backscatter and for understanding the orientation of surface features in the ice sheets, with particular application to wind flow