Detecting and Estimating Position Biases due to Ice in GNSS Antennas

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Abstract:

GNSS velocity estimates are essential for geophysical studies ranging from glacial isostatic adjustment (GIA) to plate tectonics. The ANET-POLENET network in Antarctica includes GNSS sites designed to measure GIA deformation and provide constraints for modern ice mass change derived from satellite measurements. While servicing GNSS stations in Antarctica, we found ice within the radome antenna. We only observe the presence of ice in the antenna when we service a station, which happens in Antarctica annually at best. Ice enters the antenna as snow driven by ground blizzards into the basal holes in choke ring antennas. Internal ice likely builds up through time and, at cold-weather sites, may not be cleared by melting. Time series at such sites indicate that when ice remains in or on the antenna over long periods without being removed, it introduces a bias in the position, translating into a bias in the station's estimated velocity.

GNSS receivers collect code and phase measurements after they have passed through the Earth's atmosphere from GNSS satellites. After modeling the propagation, positioning software estimates the position, receiver clock bias, zenith wet delay, east and north troposphere gradients, and the phase ambiguities. It is unclear how ice can affect the code and phase measurements but assuming ice or snow in the antenna causes a similar delay to water in the atmosphere, it would be comparable magnitude to the zenith wet delay. Ice frozen to an antenna will affect the signals that pass through it. However, since position software models for code and phase observations lack a term that captures the bias introduced by icing, it could leak into any of the estimated parameters. If the ice were uniform around the entire antenna, it would be absorbed by the receiver clock delay. Likewise, if the ice were only on the north side of the antenna, it could make the antenna appear further south than it is. Any non-uniform ice distribution will change the position solution of the receiver. We have set up experiments in Antarctica and on campus, where we packed the radome antenna with snow and ice to approximate how the antenna has been found in the field. This project aims to detect icing in the experiment data and then adjust the position estimation to include a parameter that captures the icing signal.

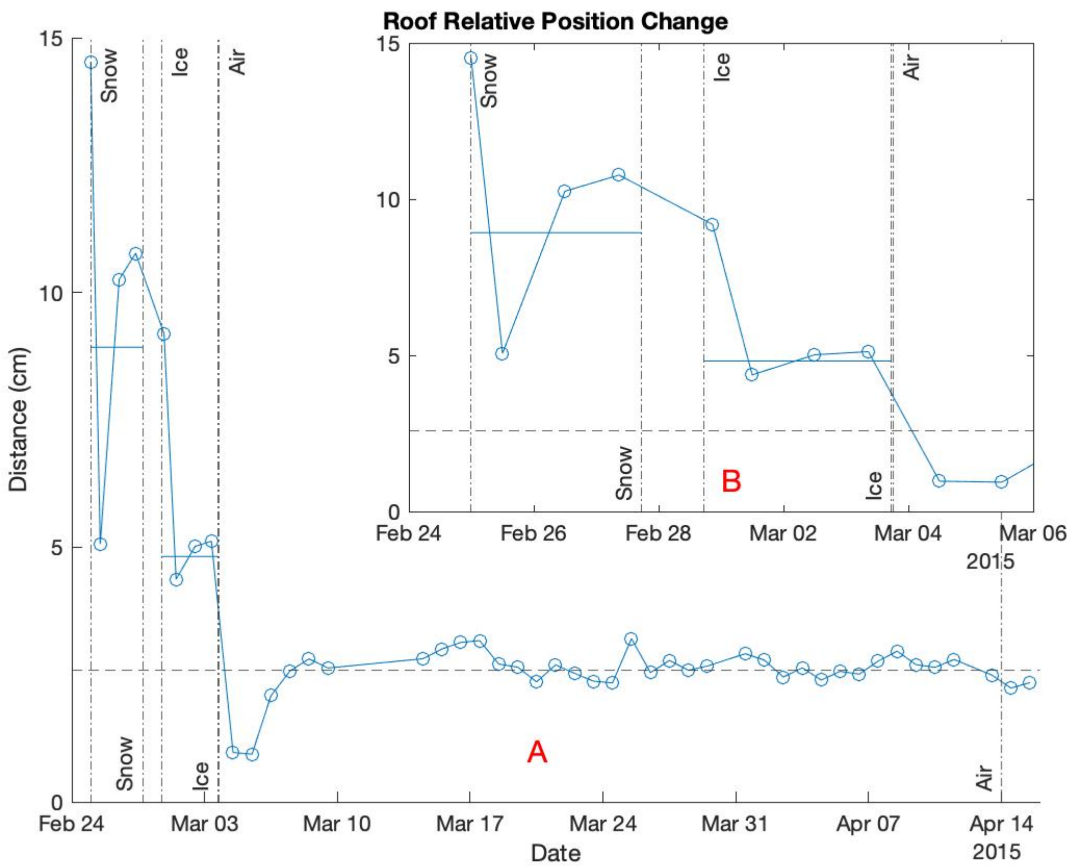

Figure A shows the estimated change in position, while inset B shows a zoomed-in version for the beginning of the time series where most of the position change occurred. The vertical bars bound periods when snow/ice was added or removed. The horizontal dashed line shows the weighted mean position offset after March 4th, 2015, of 2.5910 centimeters. The other two horizontal lines correspond to the weighted mean during the snow and ice periods. During the snow period, the weighted mean is 8.926 centimeters, and the weighted mean is 4.817 centimeters during the ice period.