Monitoring Snow Accumulation in the Askaryan Radio Array Using DAQ Temperature Data

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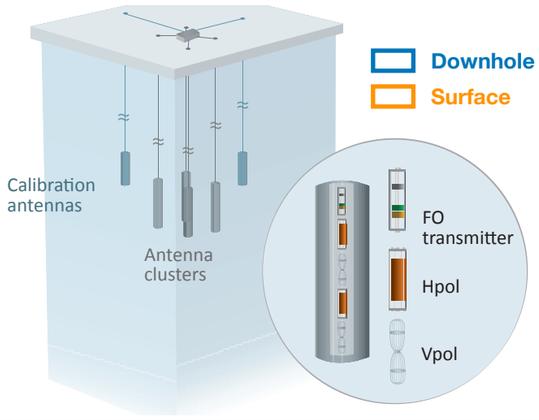
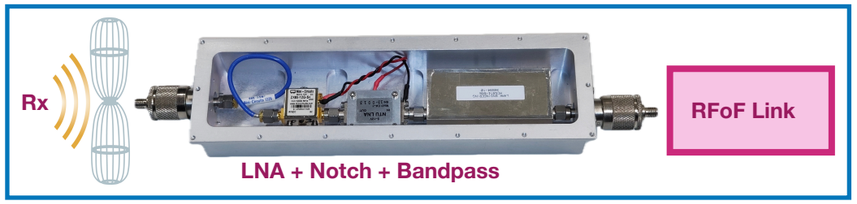
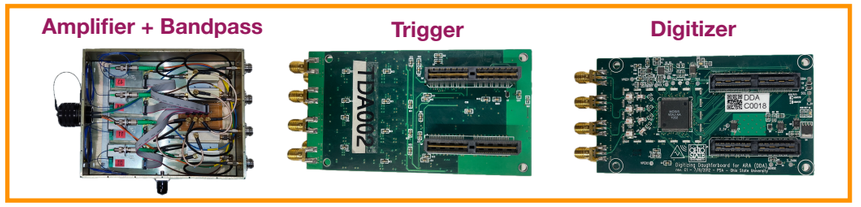
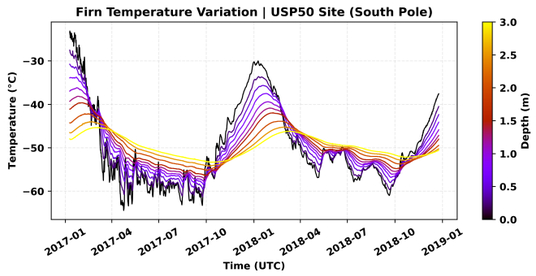
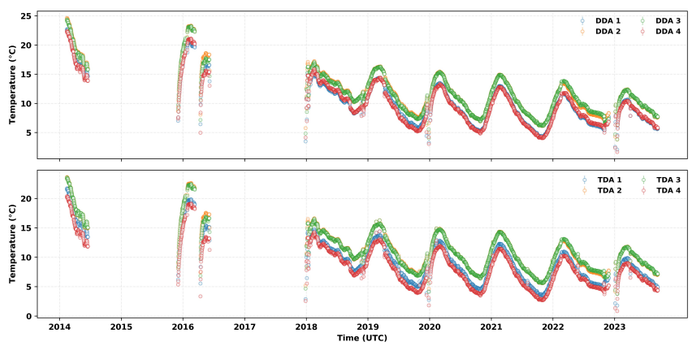


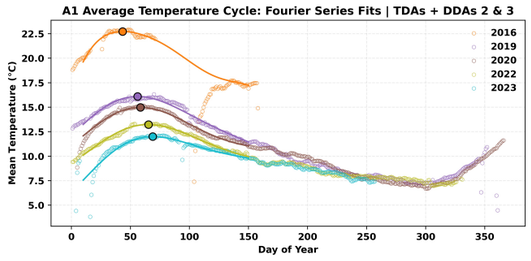


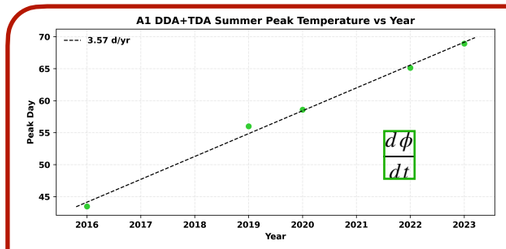


ARA DAQ enclosure gets buried under accumulating snow each year. DDA (digitizer board) and TDA (trigger board) temperature sensors capture this effect. The warm season peak shifts later in the year, and the peak amplitude decays. A third-order Fourier series fits these data well [3].







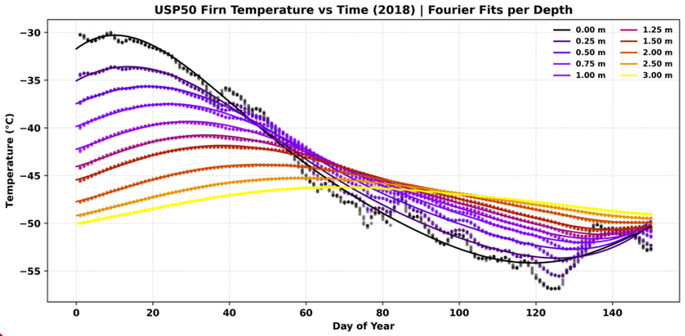


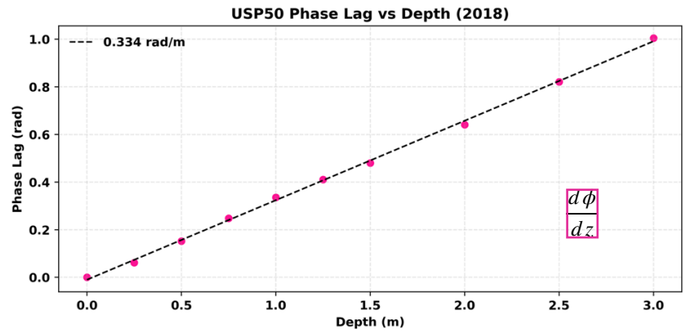
Accumulation Rate From Peak Shift

Periodic thermal wave in a semi-infinite diffusive medium [2]: $T(z,t) = T_0 + A_0 e^{-z/\delta} \cos\left(\omega t - \frac{z}{\delta}\right)$

Phase increases linearly with depth and time as: $\phi(z) = \frac{z}{\delta}, \quad \frac{d\phi}{dz} = \frac{1}{\delta} \simeq 0.321 \text{ rad/m}$ **and** $\phi(t) = \omega\, t_{\text{peak}}, \quad \frac{d\phi}{dt} = \omega \frac{dt_{\text{peak}}}{dt} = 0.0615 \pm 0.0026 \text{ rad/yr}$

Inferred snow accumulation rate: $\frac{dz}{dt} = \frac{(d\phi/dt)}{(d\phi/dz)} = 0.192 \pm 0.008 \text{ m/yr}$

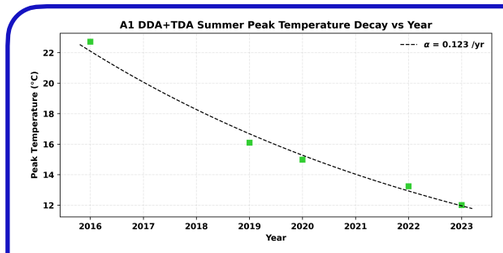




Consistent with independent South Pole accumulation estimates [4][5].

We used average gradient $\frac{d\phi}{dz}$ from 2017 and 2018 USP50 [1] data.

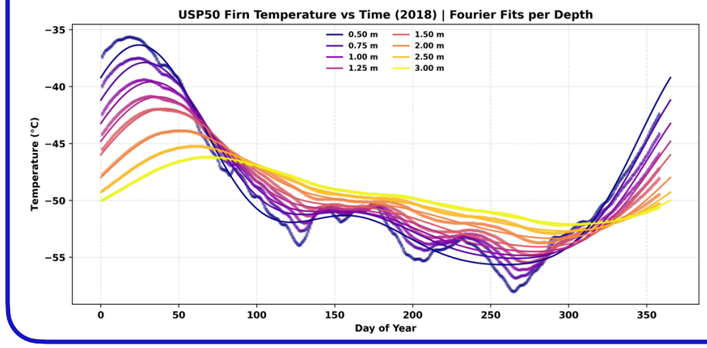
Accumulation Rate From Peak Decay

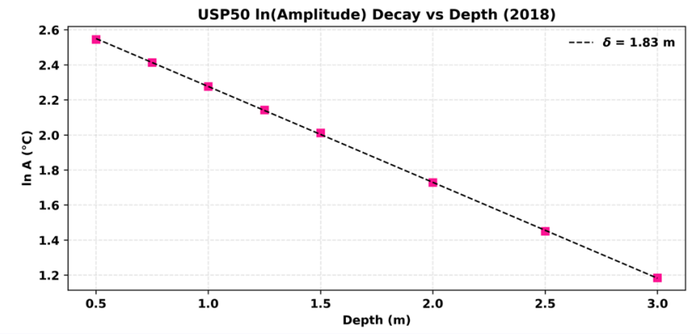


Amplitude damping of thermal wave happens as: $A(z) = A_0 e^{-z/\delta} \quad \Rightarrow \quad \ln A(z) = \ln A_0 - \frac{z}{\delta}$

ARA DAQ temperature annual decay: $T_{\text{peak}}(t) = T_\infty + A_0 e^{-\alpha t} \quad \Rightarrow \quad \ln(T_{\text{peak}}(t) - T_\infty) = \ln A_0 - \alpha t$

Temporal damping rate α and skin depth δ gives snow accumulation rate: $\alpha t = \frac{z}{\delta}, \quad \frac{dz}{dt} = \delta\alpha = 0.227 \pm 0.015 \text{ m/yr}$





Consistent with independent South Pole accumulation estimates [4][5].

We used average α and δ from 2017 and 2018 USP50 [1] data.

ARA DAQ board temperatures track annual snow burial. The annual thermal peak shifts later and weakens with time, giving an inferred accumulation rate of 19–23 cm/yr, consistent with independent measurements.

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References
1. USP50 Data Source: Kahle et al. https://doi.org/10.15784/601396, 2020.
2. Carslaw and Jaeger, Conduction of Heat in Solids, 1959.
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