Towards an improved ice model for the Radio Neutrino Observatory Greenland (RNO-G).

Bob Oeyen for the RNO-G collaboration

Knowing the radio optics of ice allows for more precise antenna position calibration of RNO-G

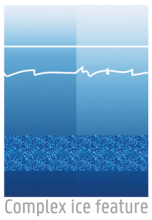
- Index of refraction at each point
- Internal reflections
- Absorption length
- Birefringence

single exponential, double exponential, exponential polynomial

Radio Neutrino Observatory - Greenland

In-ice askaryan radio detection of ultra-high-energy astrophysical neutrinos at Summit Station (Greenland)

Simple exponential



Complex ice feature

We discovered an exponential ice model to be incompatible with pulser data → which can be resolved by modelling the ice data more carefully

First principles suggest $n(z) \sim \rho(z) \sim \exp(-z / z_0)$

$n(z) = 1 + cst \cdot \rho(z)$ AND

1. Densification due to stress of weight snow — Simple exonential

$$\frac{d\rho}{\rho_{Ice} - \rho} = cst \cdot \rho \cdot dz \quad \Rightarrow \quad \rho(z) = \rho_{Ice} - (\rho_{Ice} - \rho_{snow}) \exp(-z / z_0)$$

2. Steepening of densification at $\rho(z_{crit}) = 550$ kg/m^3 — Double exponential

$$\rho(z) = \rho_{Ice} - (\rho_{Ice} - \rho_{snow}) \exp(-z / z_{01}) \quad \text{for } z \le z_c$$
$$\rho(z) = \rho_{Ice} - (\rho_{Ice} - \rho_{crit}) \exp(-(z - z_{crit}) / z_{02}) \quad \text{for } z > z_{crit}$$

3. Higher order features ?? — Exponential polynomial

$$\rho(z) = \rho_{Ice} + a_1 \exp(-z / z_0) + a_2 \exp^2(-z / z_0) + \ldots + a_i \exp^i(-z / z_0) + \ldots$$

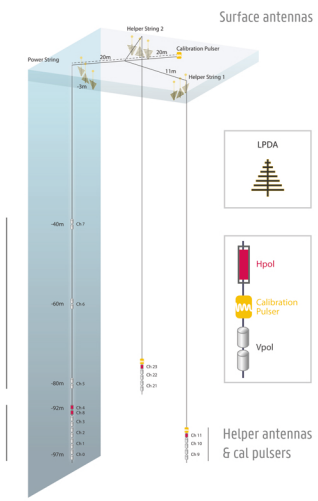
RNO-G antenna position calibration depends on ice optics

Minimize the difference between observed & expected time delays by moving antenna

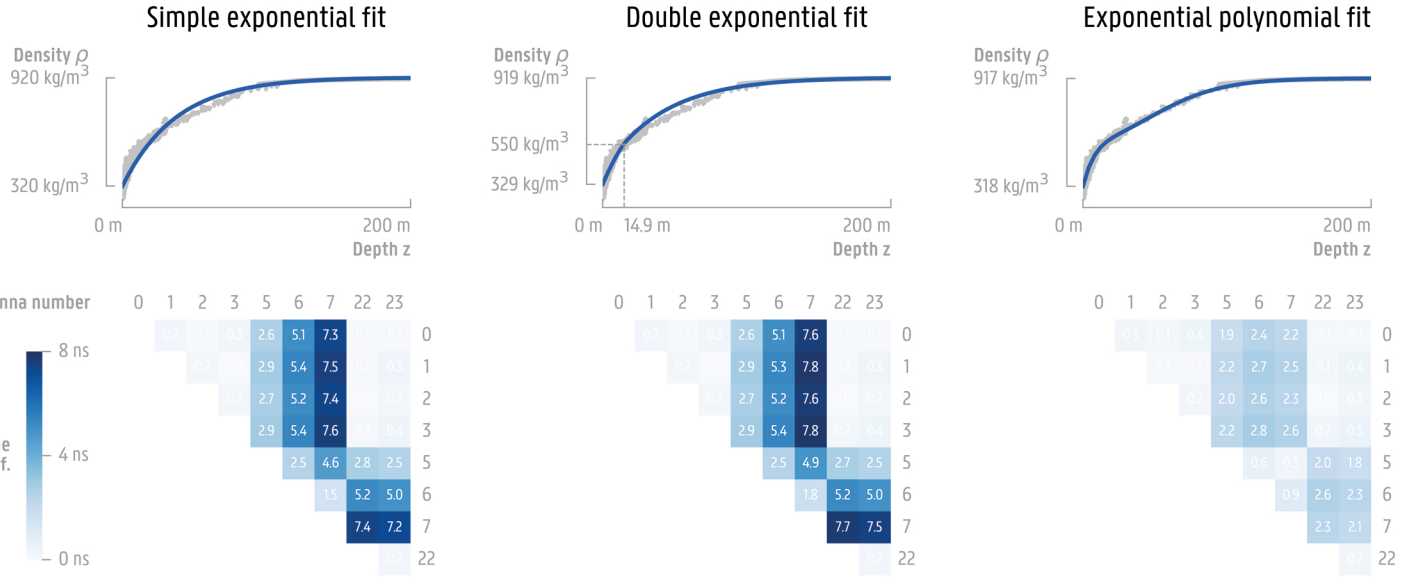
Δt_{obs} ← cross-correlation signals

$\Delta t_{exp} \sim n_{avg}$

$$n_{avg} = \frac{\int_{z_{pulser}}^{z_{antenna}} n(z)dz}{(z_{antenna} - z_{pulser})}$$



An exponential polynomial fit describes the upper ice better, resulting in more accurate timing



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