The Neglcted Middle Child

Temperature and Water Content in the Percolation Zone

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Eric Steig
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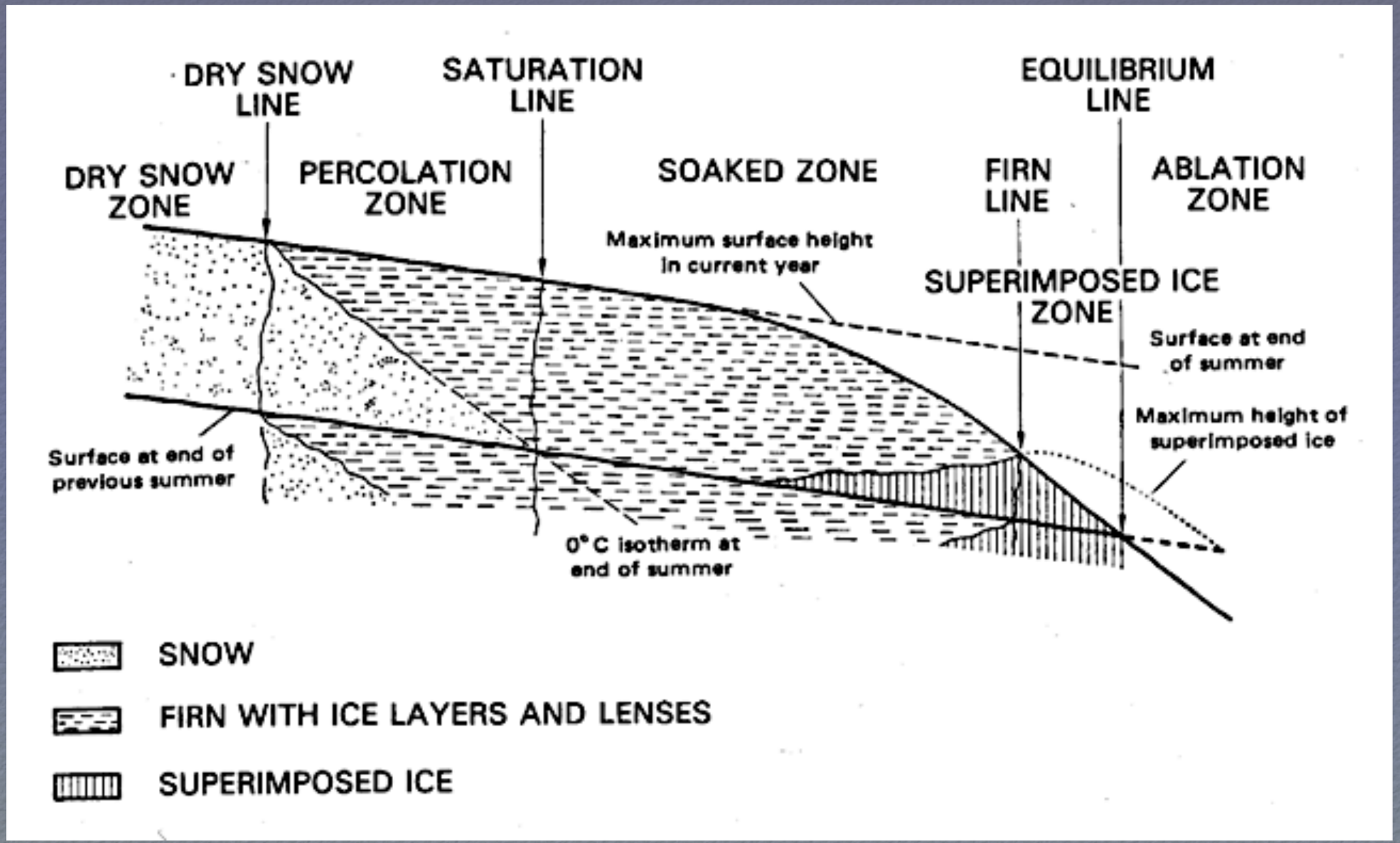
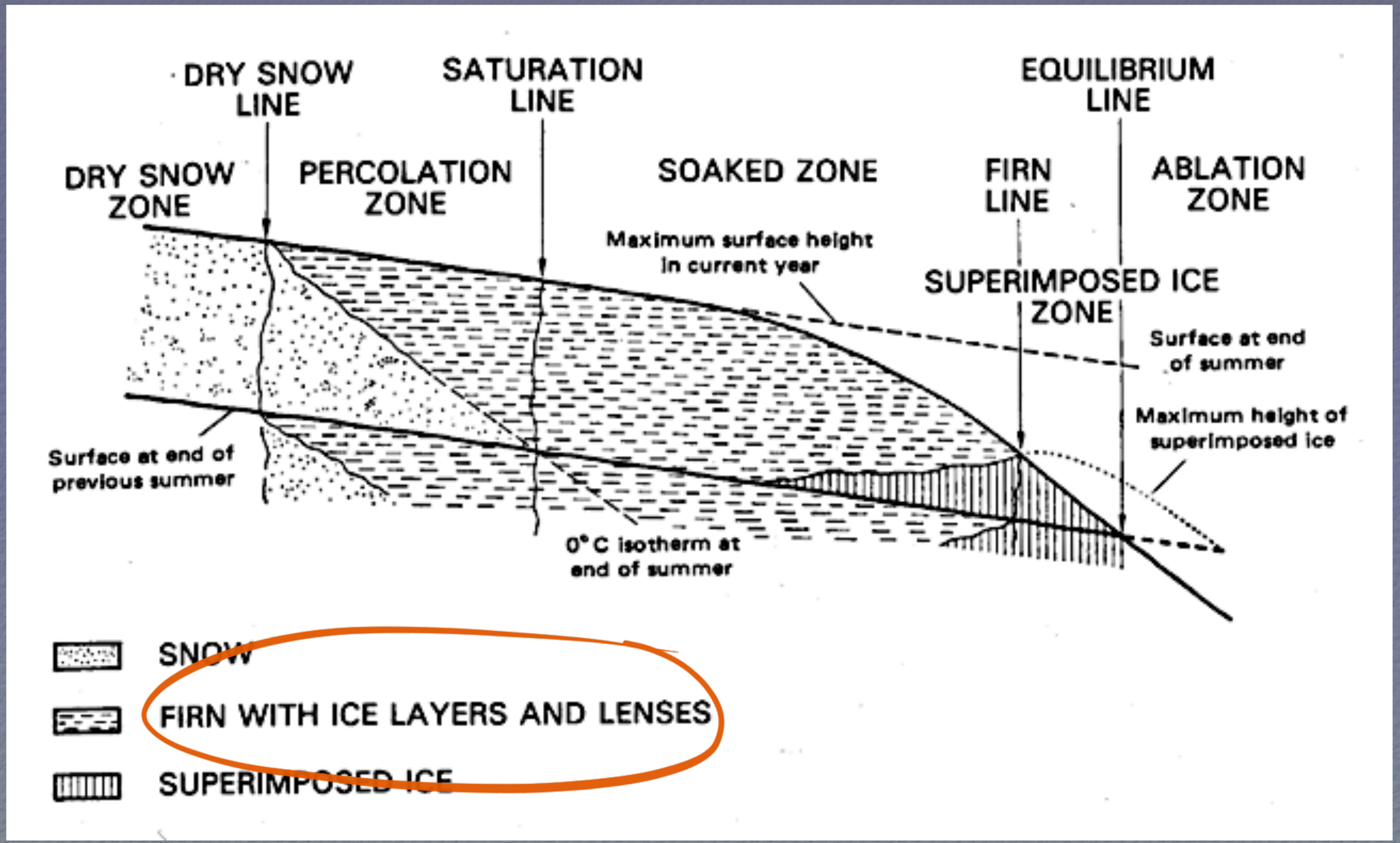
Joe McConnell DRI

The Percolation Zone



The Percolation Zone



MOTIVATION

The percolation zone - may be large, but we seem to often ignore it.

Greenland radar reflections

firn “water table”

Ice shelf bre

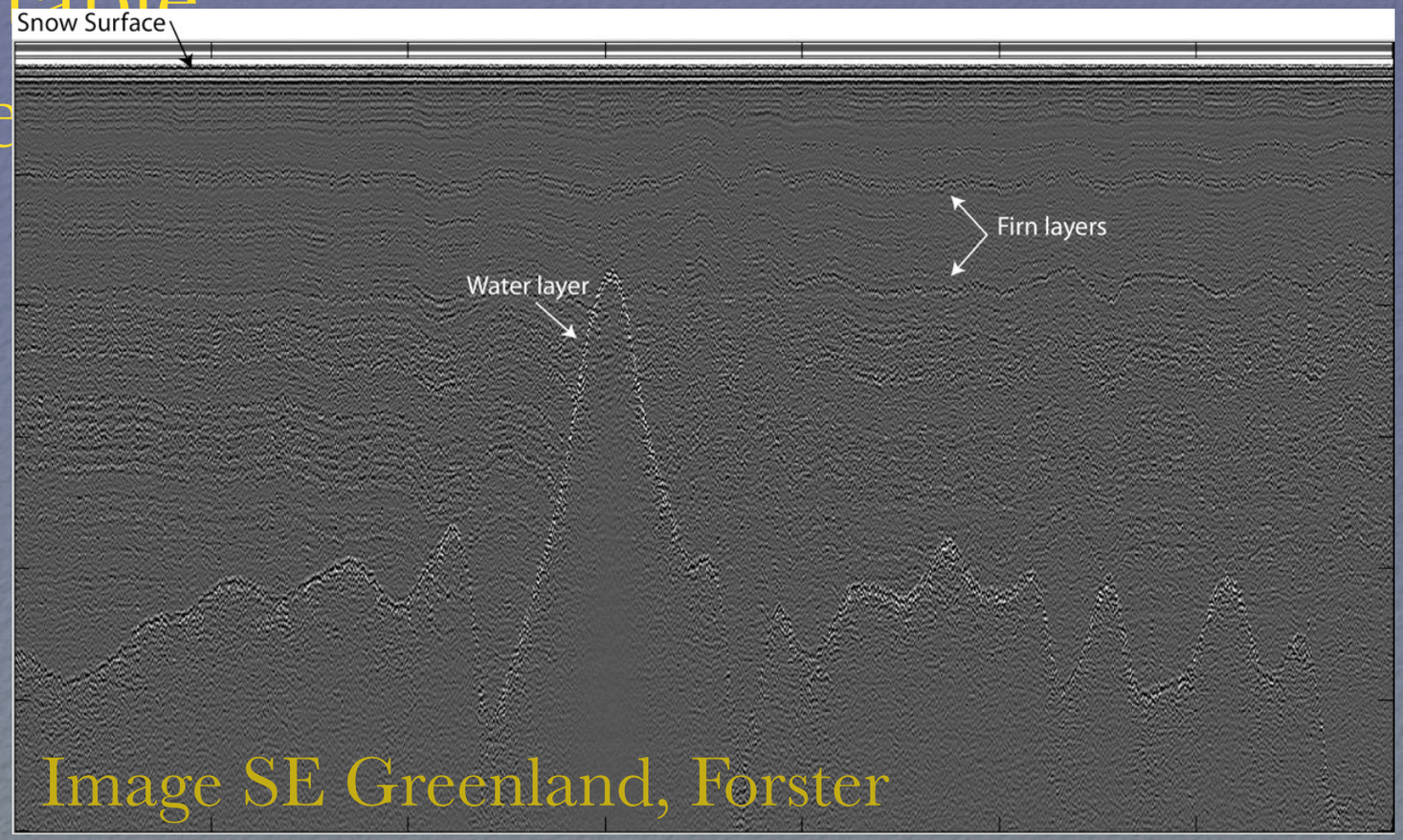


Image SE Greenland, Forster

KEY POINTS

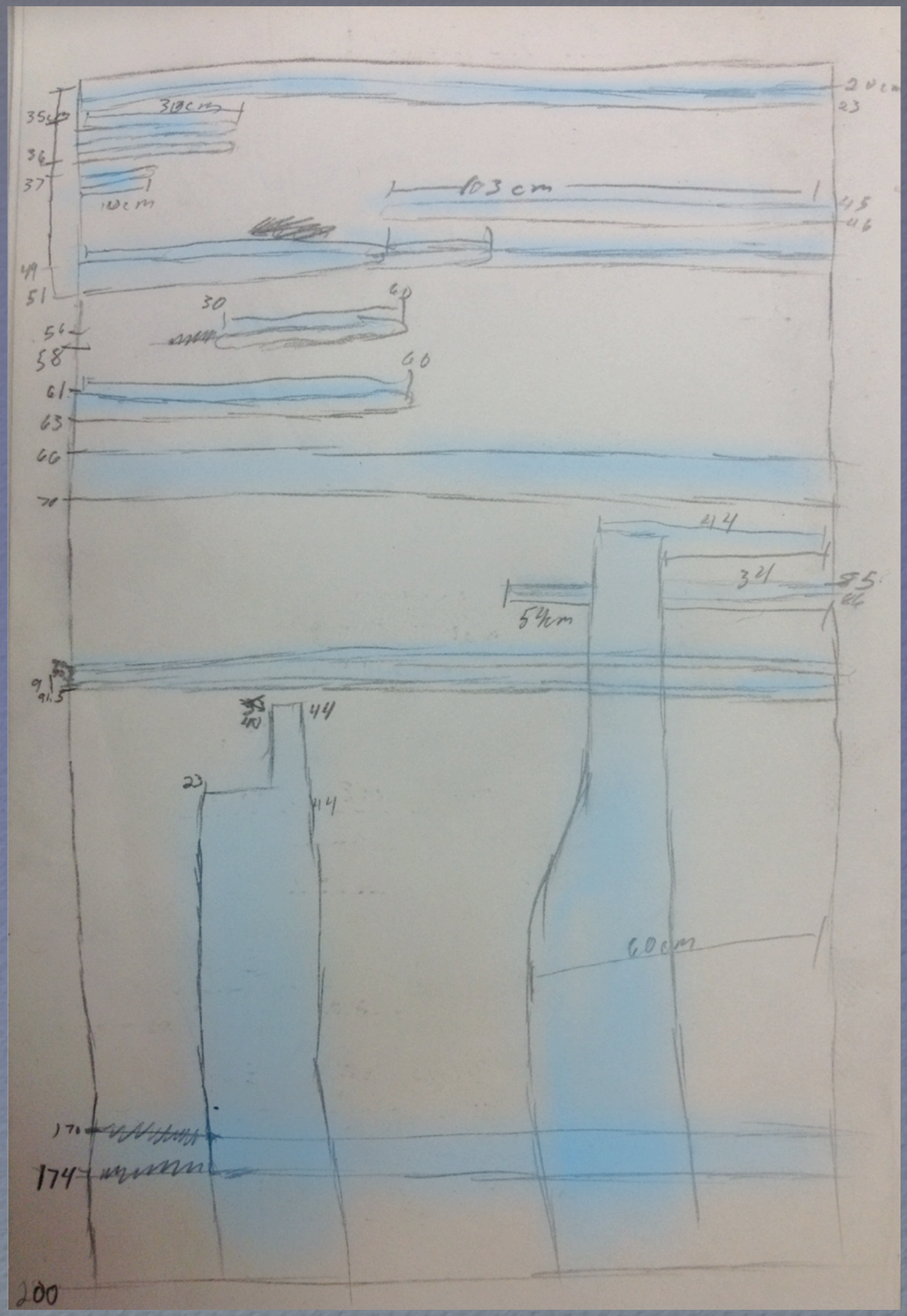
- two "bubble close-off" depths.

- noise in surface temperature can mimic past temperature signal in borehole

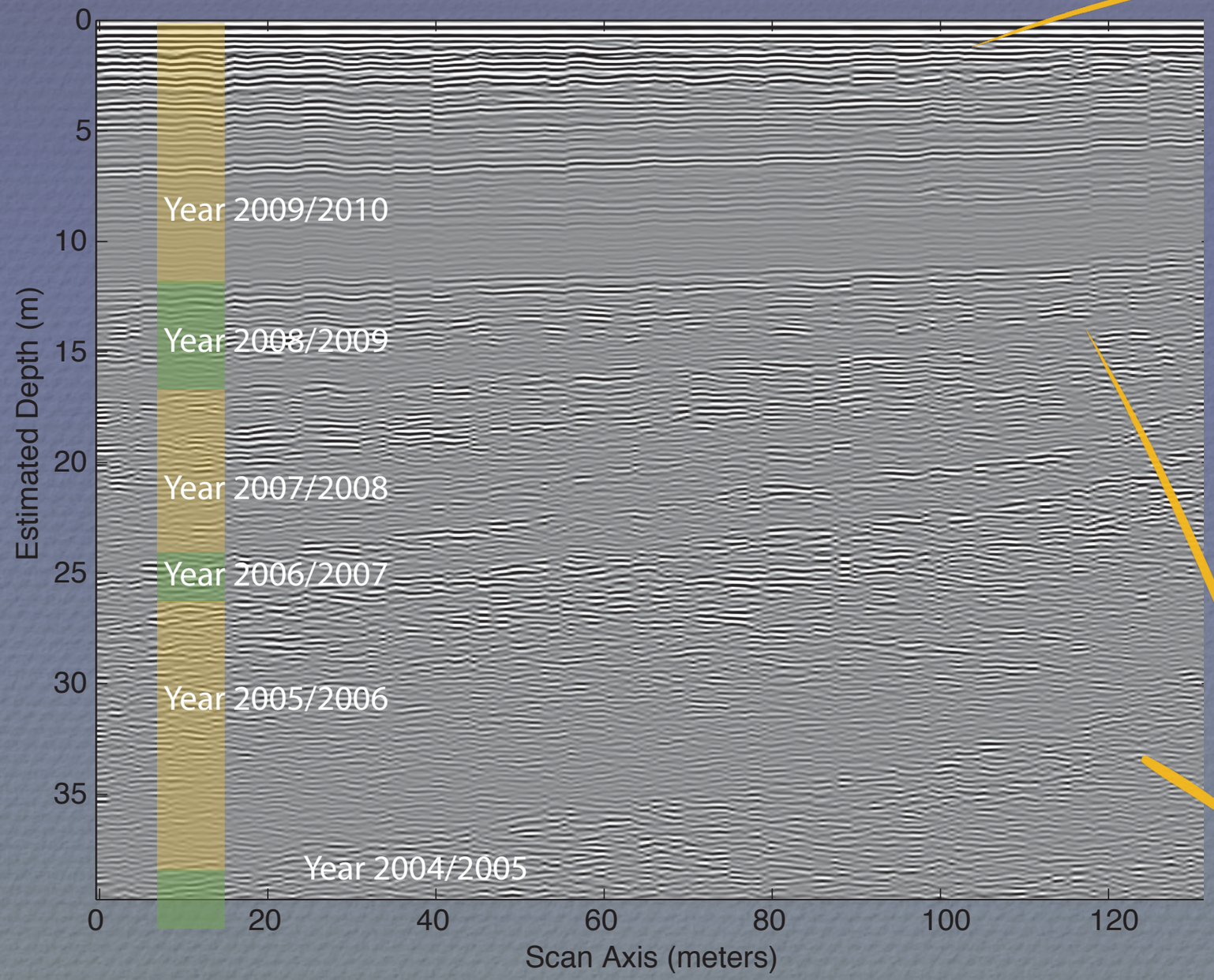
- percolating meltwater does not necessarily freeze: creating perched aquifers.

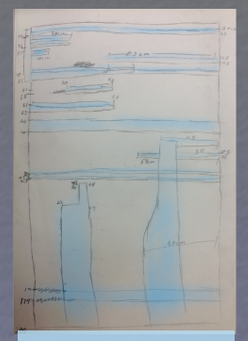
The Observations

Refrozen Melt Layers
Recrystallized Ice
Vertical Pipes



The Observations

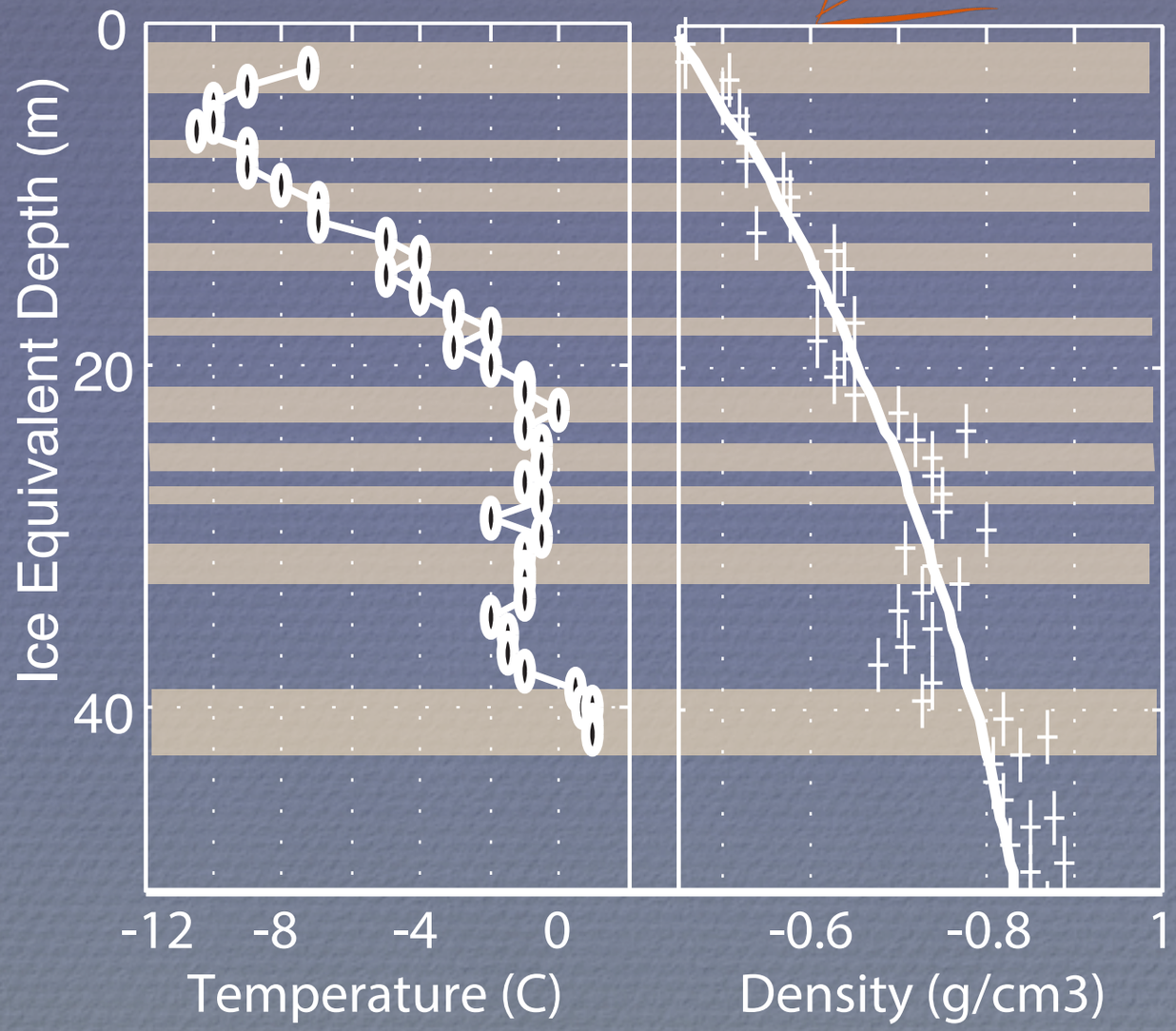




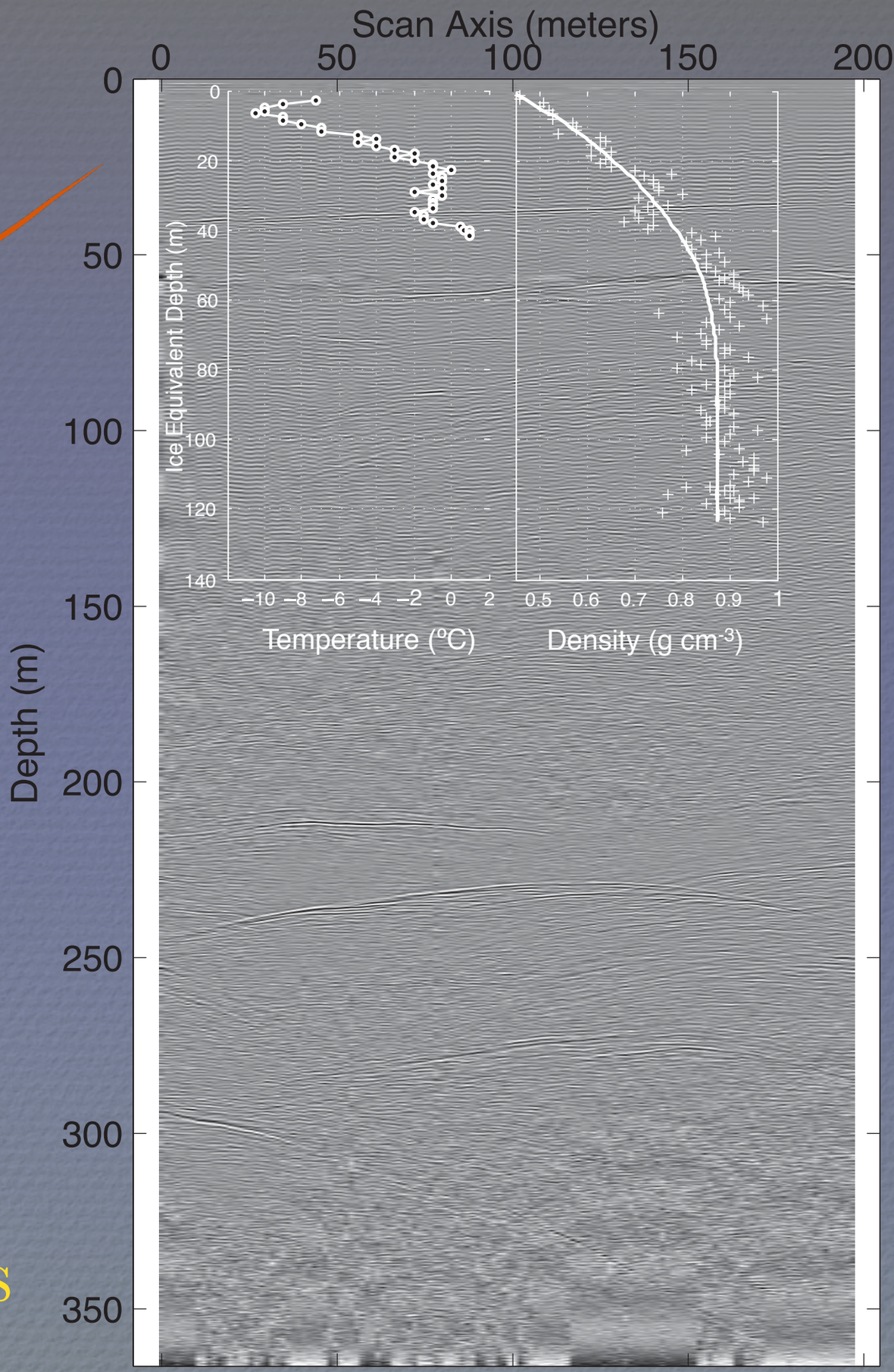
3m
Last Evidence of
Water Percolation

11m = 12C
Last Summer Surface

The Observations



Two bubble Close off depths



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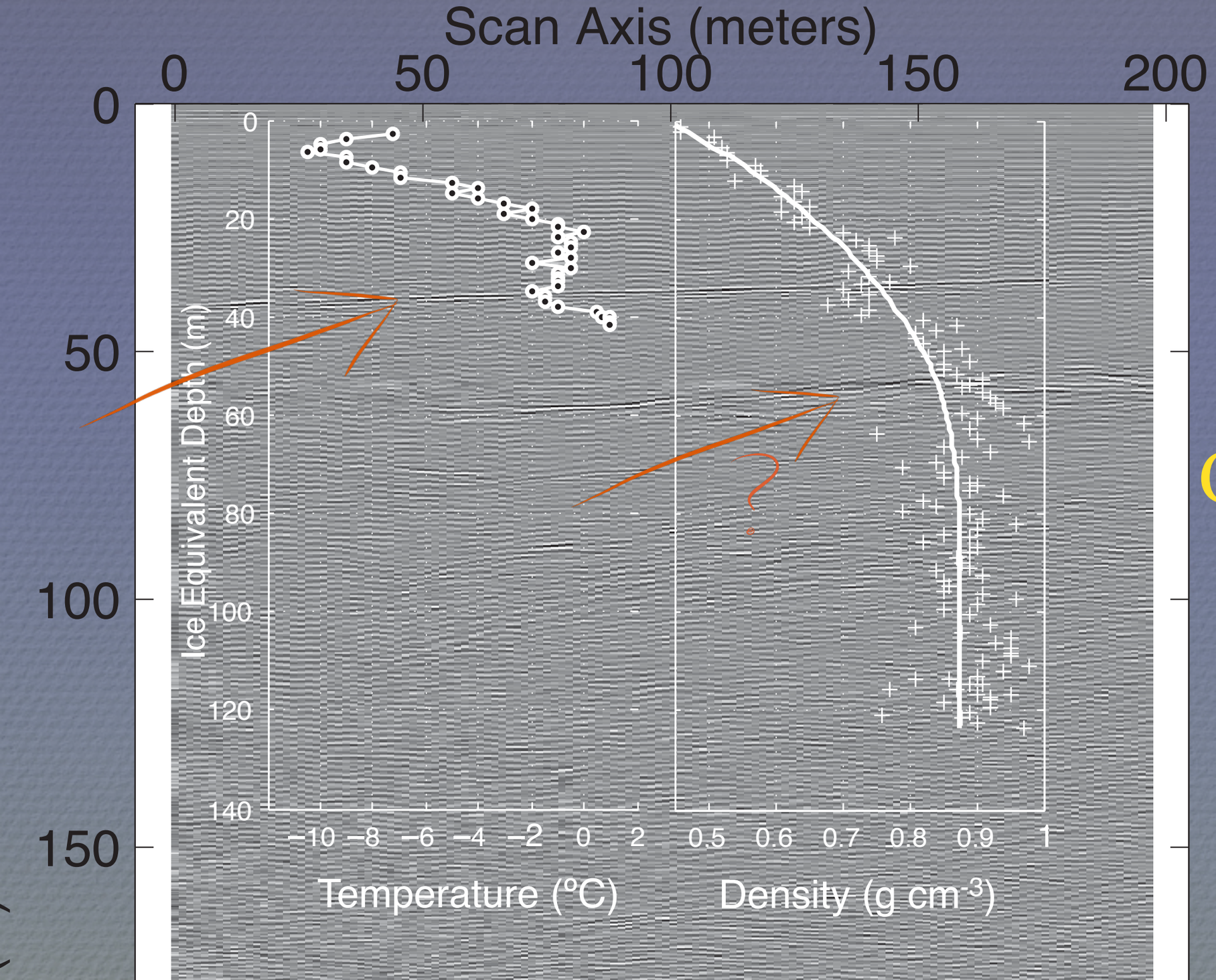


Bright radar reflector at ~40m

Cold Sink Below

Conservation of Energy (Enthalpy Formulation)

$$\rho \frac{\partial H}{\partial t} = \underbrace{\rho k \frac{\partial^2 H}{\partial z^2}}_{\text{Diffusion}} - \underbrace{\rho w \frac{\partial H}{\partial z}}_{\text{Advection}} + \underbrace{\dot{Q}}_{\substack{\text{Source} \\ \text{(Strain heating)}}}$$

Downward Velocity

$$H = U + P/\rho$$

Enthalpy

Internal Energy

Conservation of Energy (Enthalpy Formulation)

$$\rho \frac{\partial H}{\partial t} = \underbrace{\rho k \frac{\partial^2 H}{\partial z^2}}_{\text{Diffusion}} - \underbrace{\rho w \frac{\partial H}{\partial z}}_{\text{Advection}} + \underbrace{\dot{Q}}_{\substack{\text{Source} \\ \text{(Strain heating)}}}$$

Downward Velocity

$$H = U + P/\rho$$

H: Enthalpy

U: Internal Energy

Assumptions

1. 1-D
2. Density Constant (assuming ice properties)
3. Constant Accumulation Rate
4. Sinusoidal + Noise Surface H
5. No Source Term
6. Simple Method of Generating Surface Melt

Assumptions

7. Effective Diffusivity of Water << Diffusivity of Heat

Conservation of Energy (Enthalpy Formulation)

$$\rho\frac{\partial H}{\partial t} = \underbrace{-\rho K\frac{\partial^2 H}{\partial z^2}}_{\text{Diffusion}} \underbrace{-\rho w\frac{\partial H}{\partial z}}_{\text{Advection}} + \underbrace{\dot{Q}}_{\substack{\text{Source} \\ \text{(Strain heating)}}}$$

Downward Velocity

Diffusivities

$$K = \begin{cases} k/\rho c & \text{Cold} \\ 0 \end{cases}$$

k → Conductivity; c → Specific Heat

Temperate Ice

$$\Delta H = LW \qquad T = T_m$$

W → Water Content; L → Latent Heat

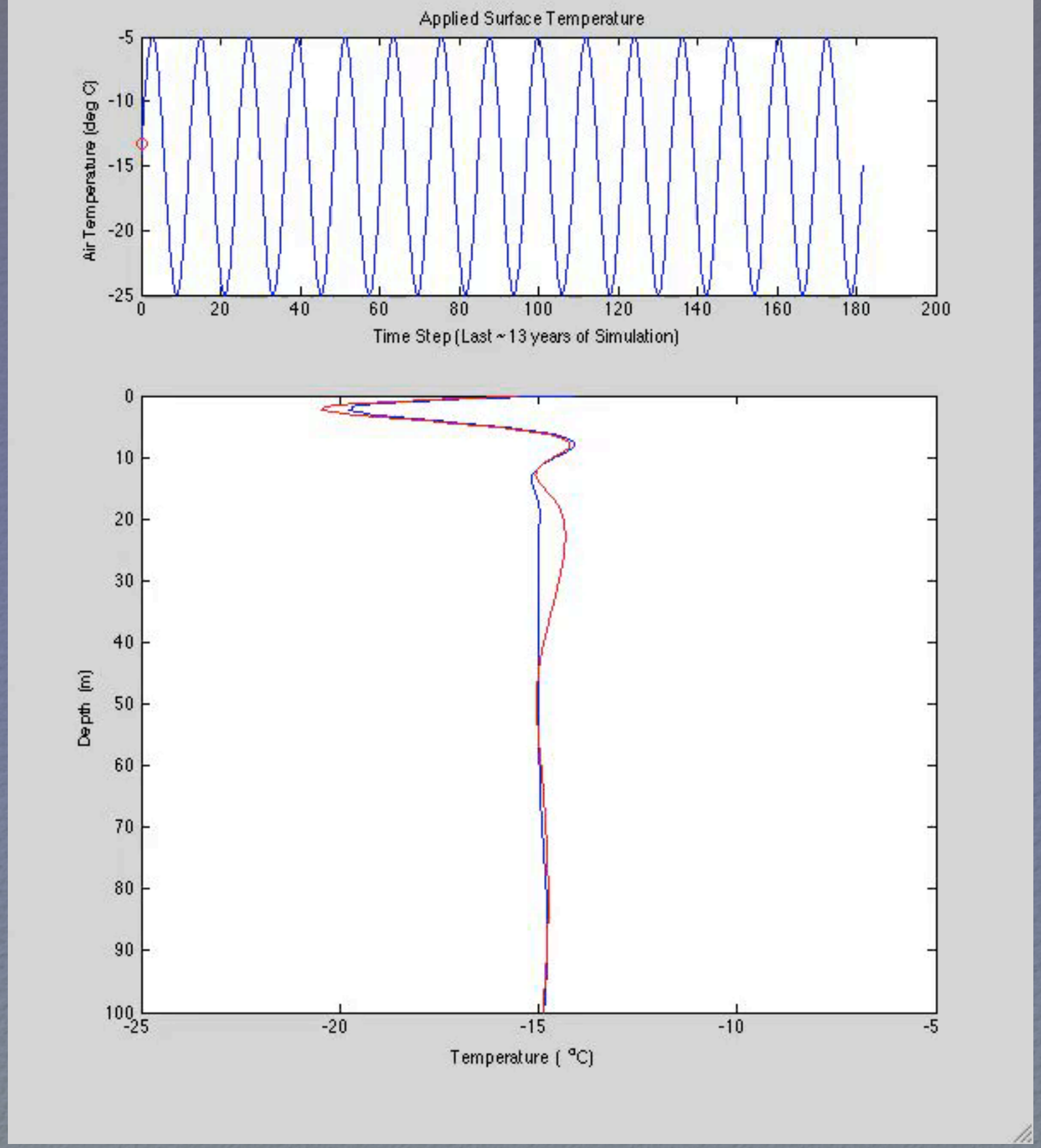
Cold Ice

$$\Delta H = c_p \Delta T$$

COLD ICE

7m/yr accum

T=-15+15sin(year)
+noise



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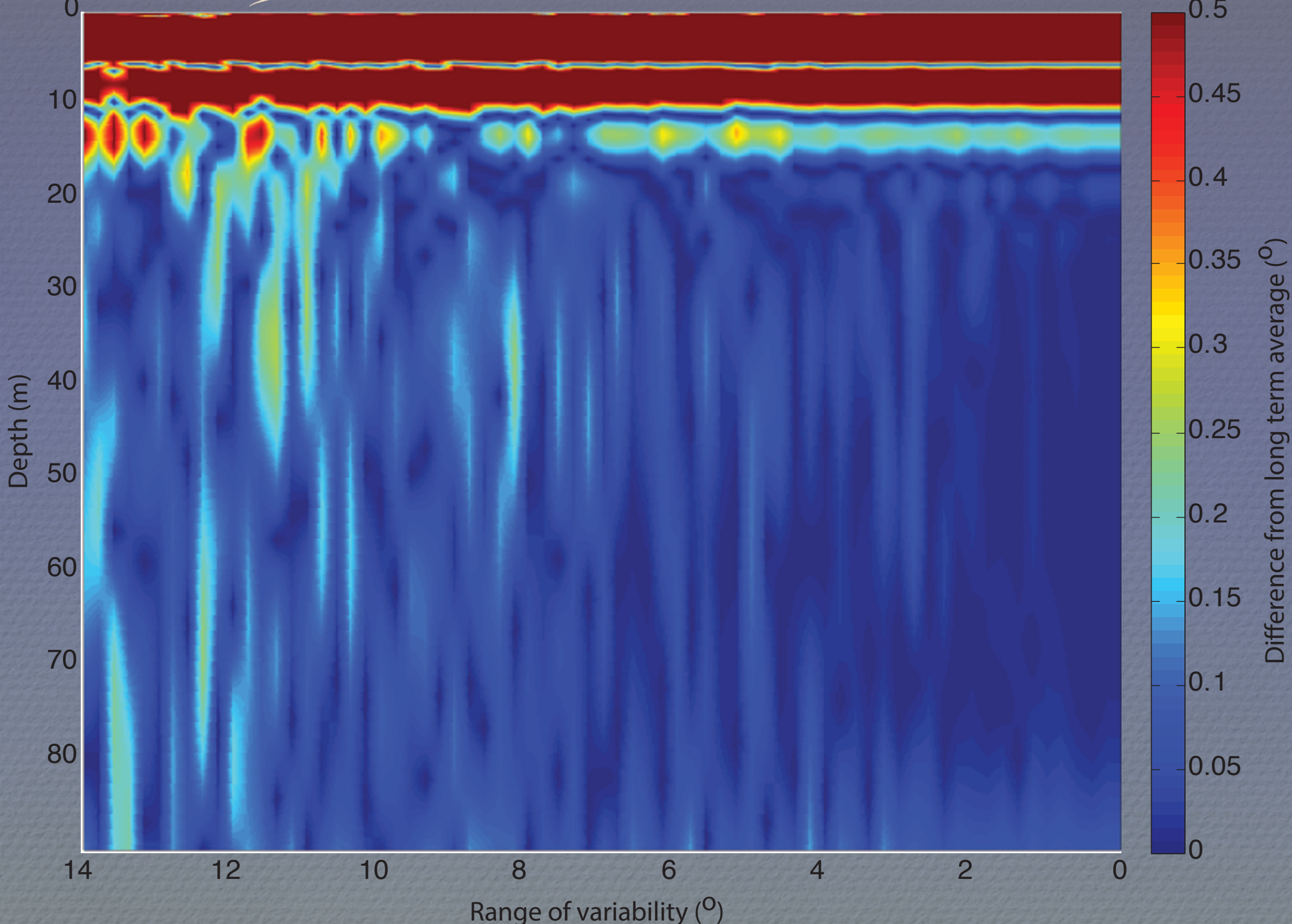
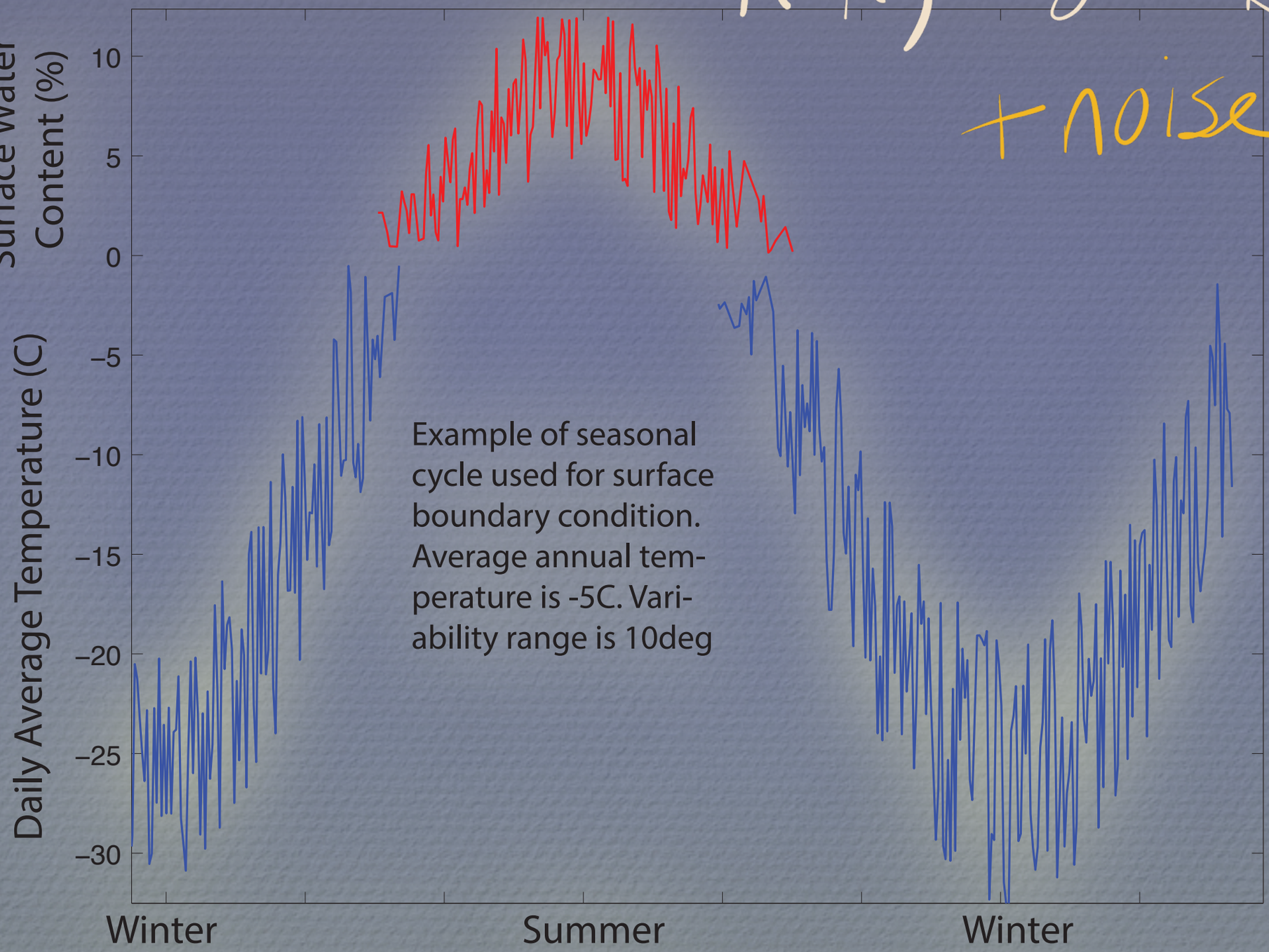


POLYTHERMAL

$$T(0,t) = T_0 + T_R \sin(\omega t)$$

+ noise

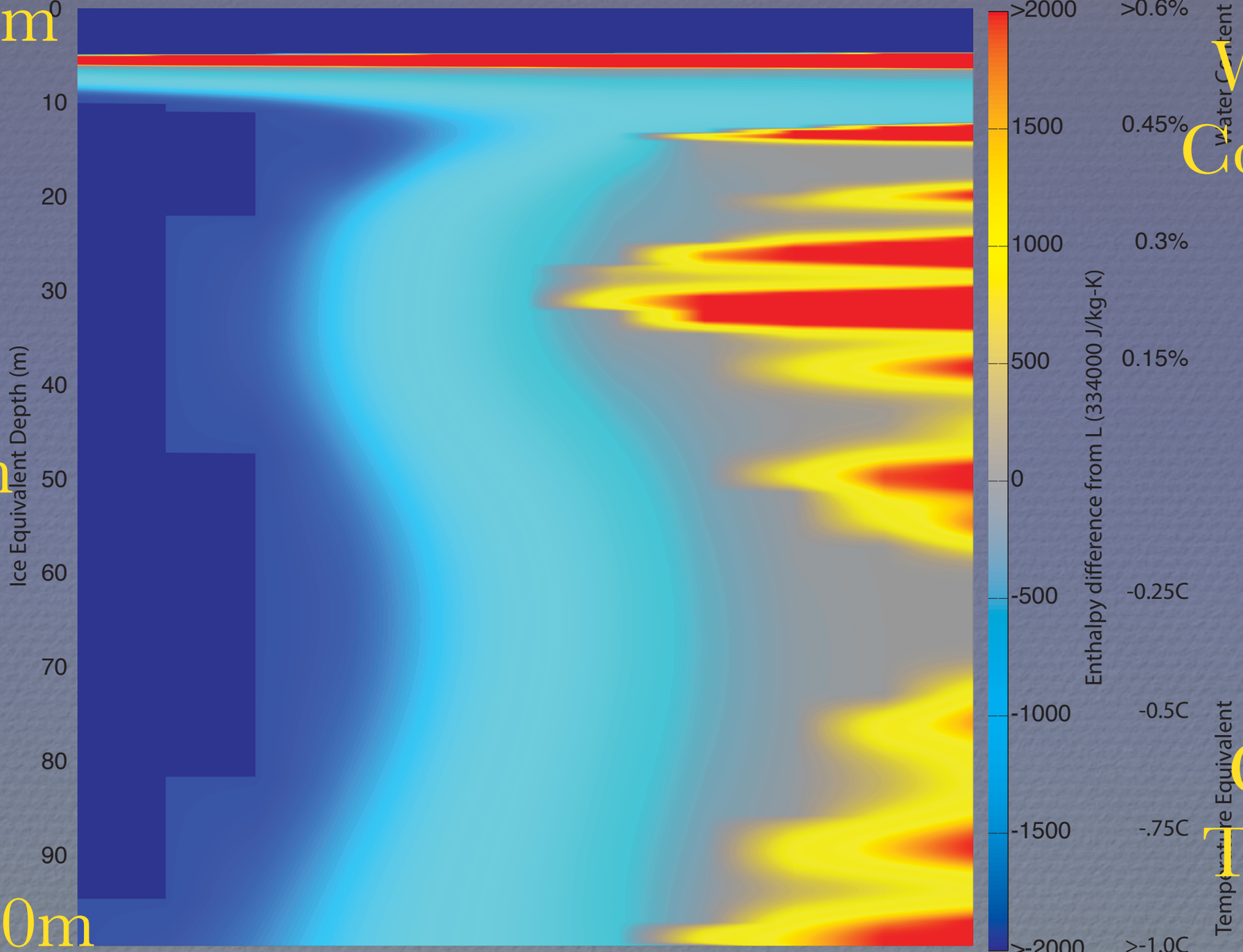


Example of seasonal cycle used for surface boundary condition. Average annual temperature is -5C. Variability range is 10deg

POLYTHERMAL

7m/yr (Mt Waddington, BC)

0m



Water Content

Depth

100m

Cold Temps

Less Melt

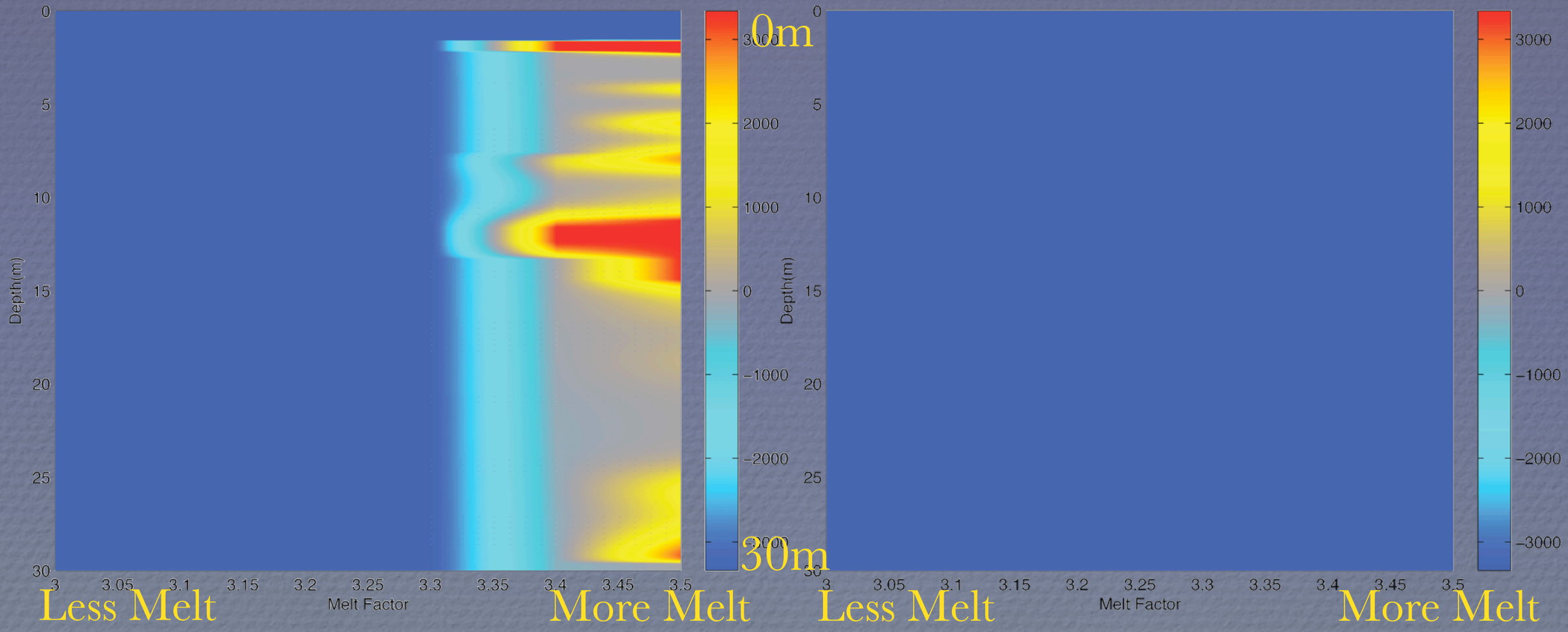
More Melt

POLYTHERMAL

WAIS

2m/year

1m/year



Less Melt More Melt Less Melt More Melt

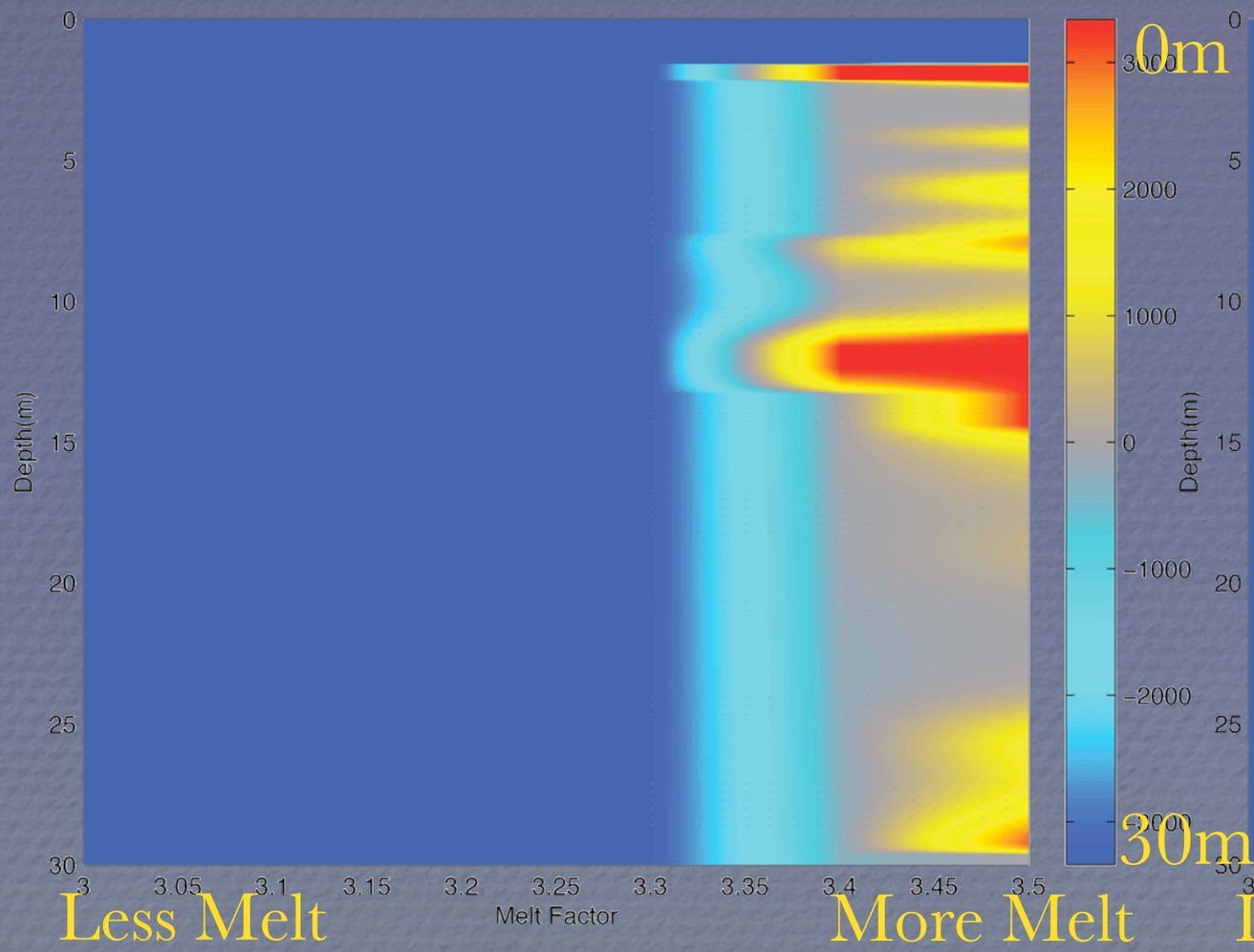
Surface Melt is increasing in
West Antarctica (especially on Peninsula!

POLYTHERMAL

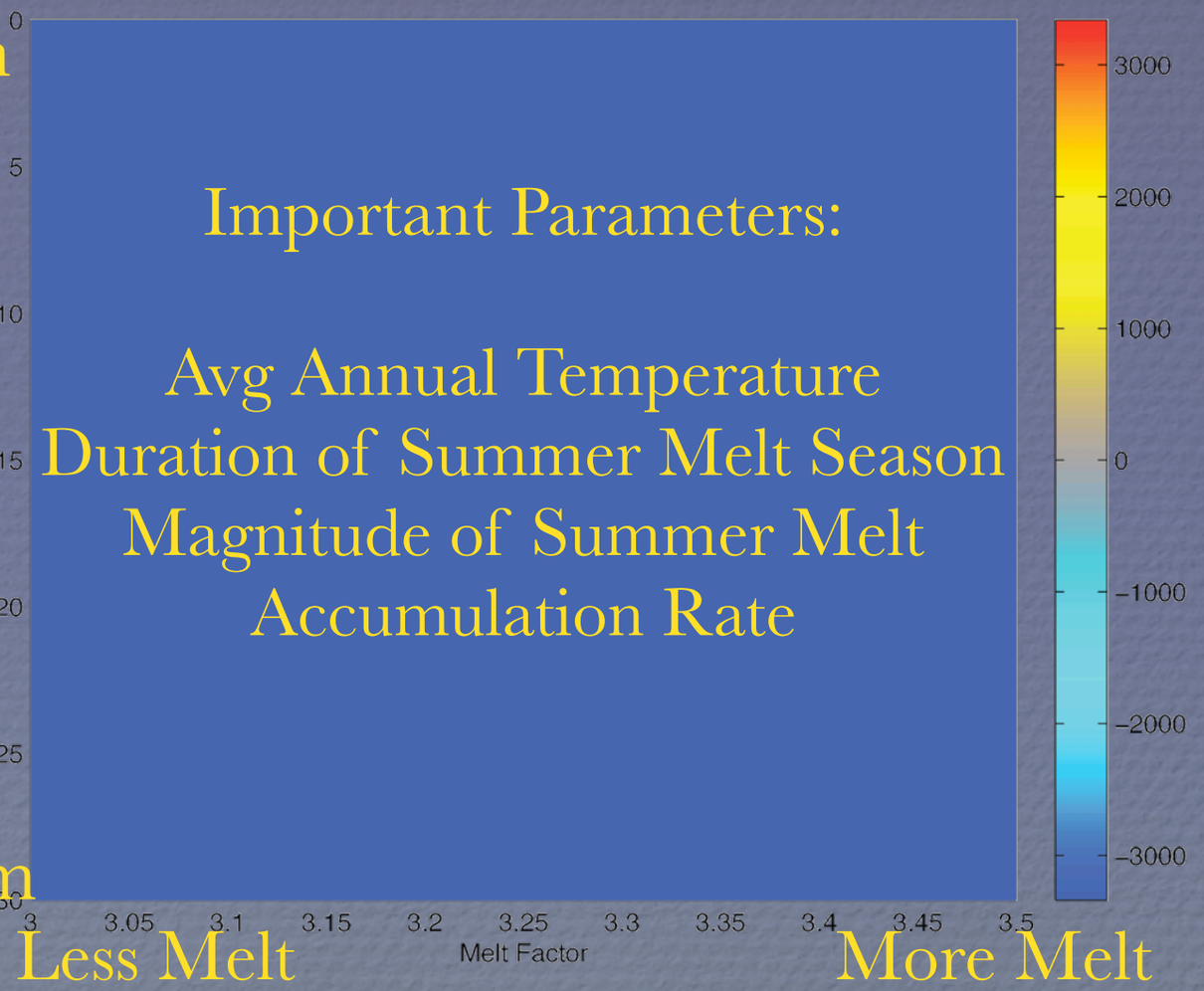
WAIS

2m/year

1m/year



Less Melt — More Melt



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