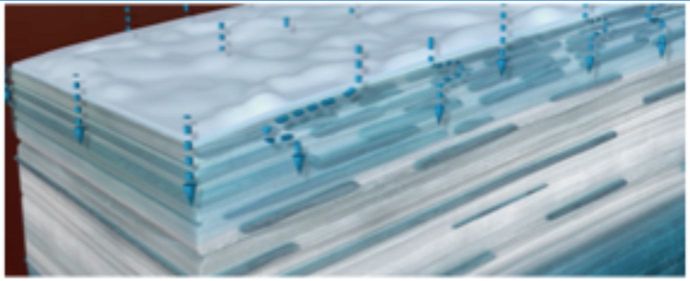
# Inferring Firn Permeability from Pneumatic Testing on the Greenland Ice Sheet

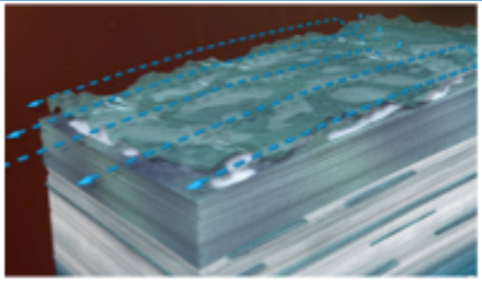
Aleah Sommers
Harihar Rajaram

CESM Land Ice Working Group
June 22, 2016

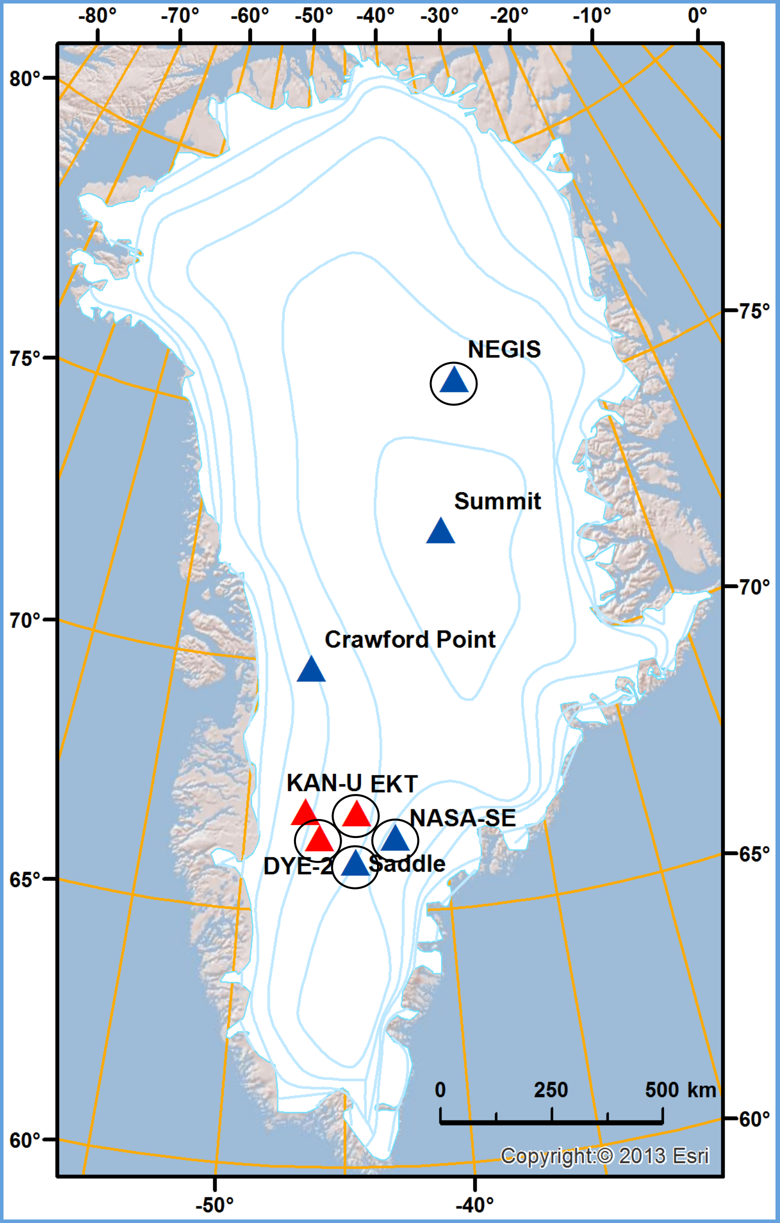
# Background

- Meltwater percolation is an important piece in surface mass balance estimation
- Permeability is key for accurately modeling percolation through firn
- Previous work has mainly focused on vertical permeability through firn core segments
- Refrozen ice lenses in firn create an anisotropic porous medium
    - Need to understand horizontal *and* vertical permeability at different scales
    - How will this change with increased meltwater or more/thicker ice lenses?

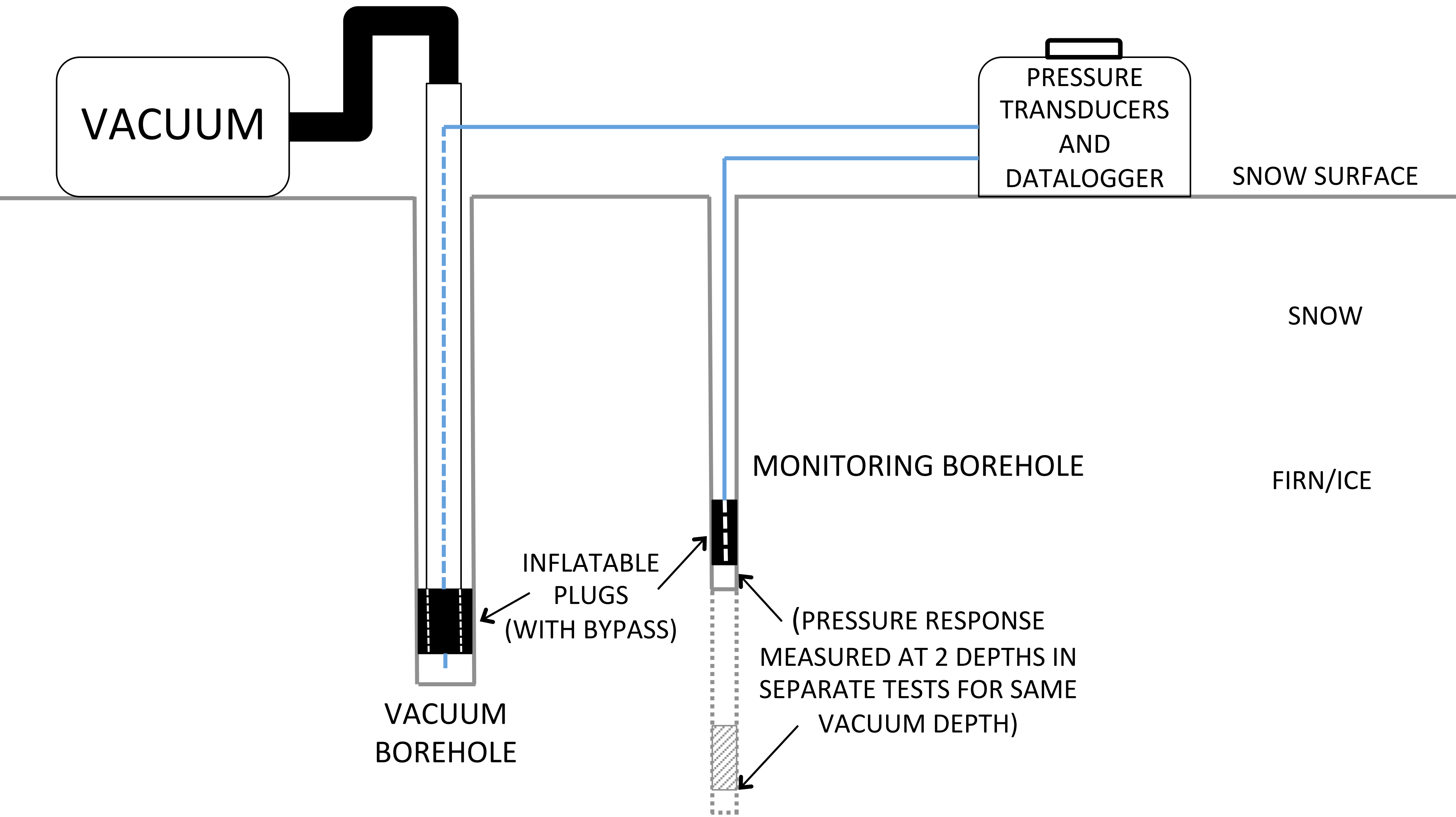


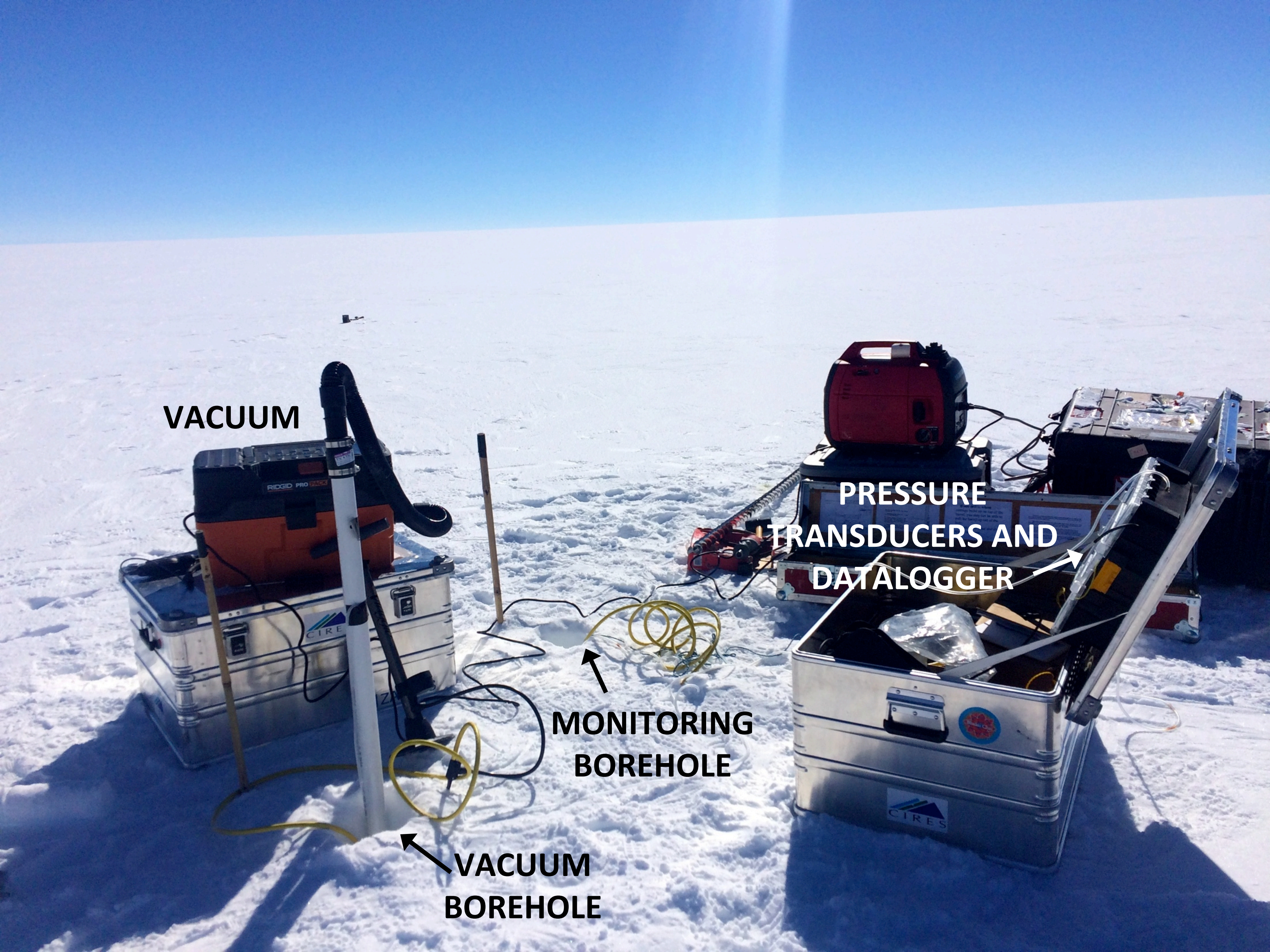


# Field sites – Spring 2016



# Method: Pneumatic testing




VACUUM
PRESSURE TRANSDUCERS AND DATALOGGER
MONITORING BOREHOLE
VACUUM BOREHOLE

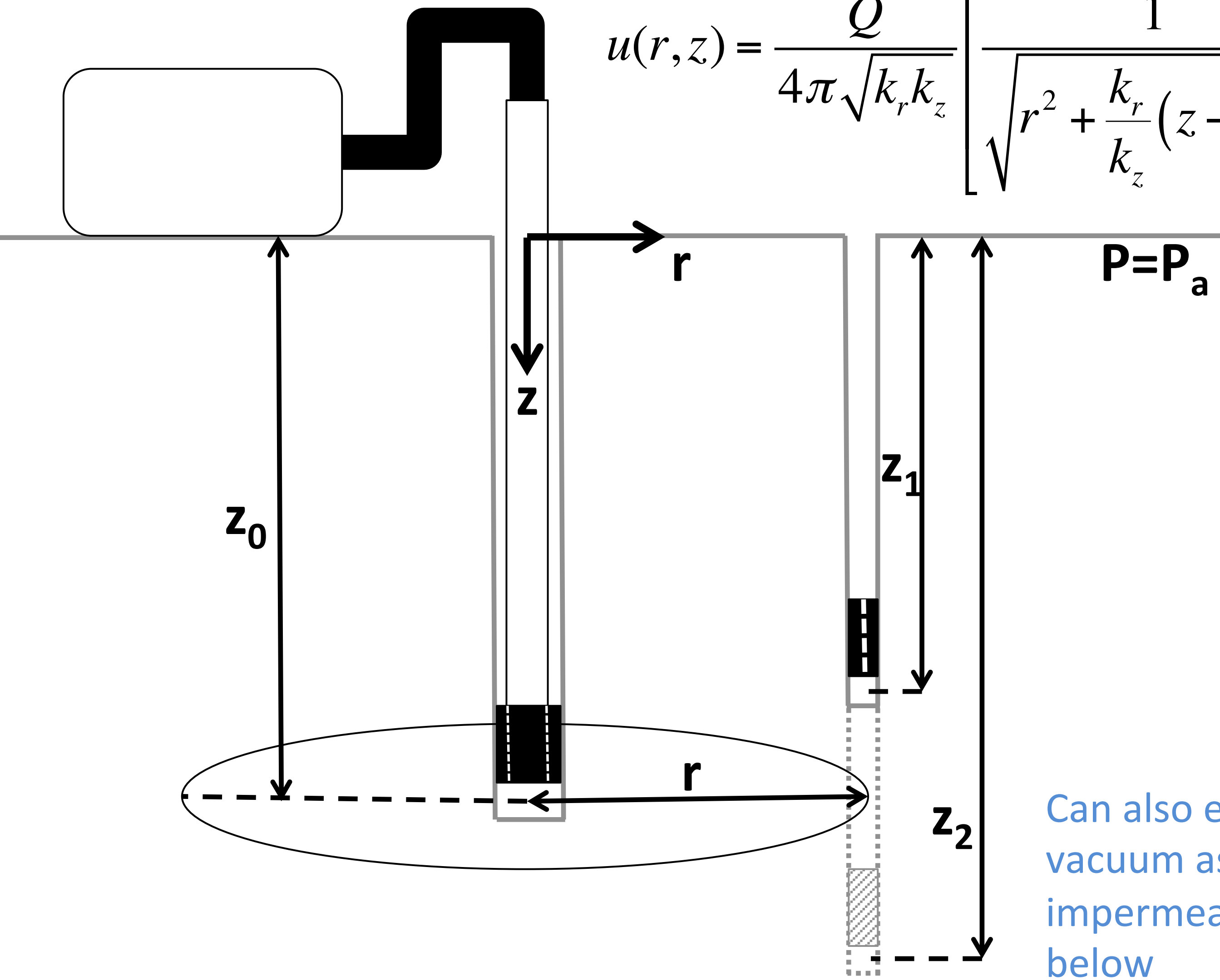
# Pneumatic Test Analysis

- Approximate permeability tests using an analytical solution for air flow through anisotropic porous medium
- Snow surface open to atmosphere (constant pressure b.c.)
- Solve for radial and vertical permeabilities ($k_r$ and $k_z$) by fitting pressure response at monitoring depths to observed differential pressure responses

# Solution – Laplace equation with method of images for point sink

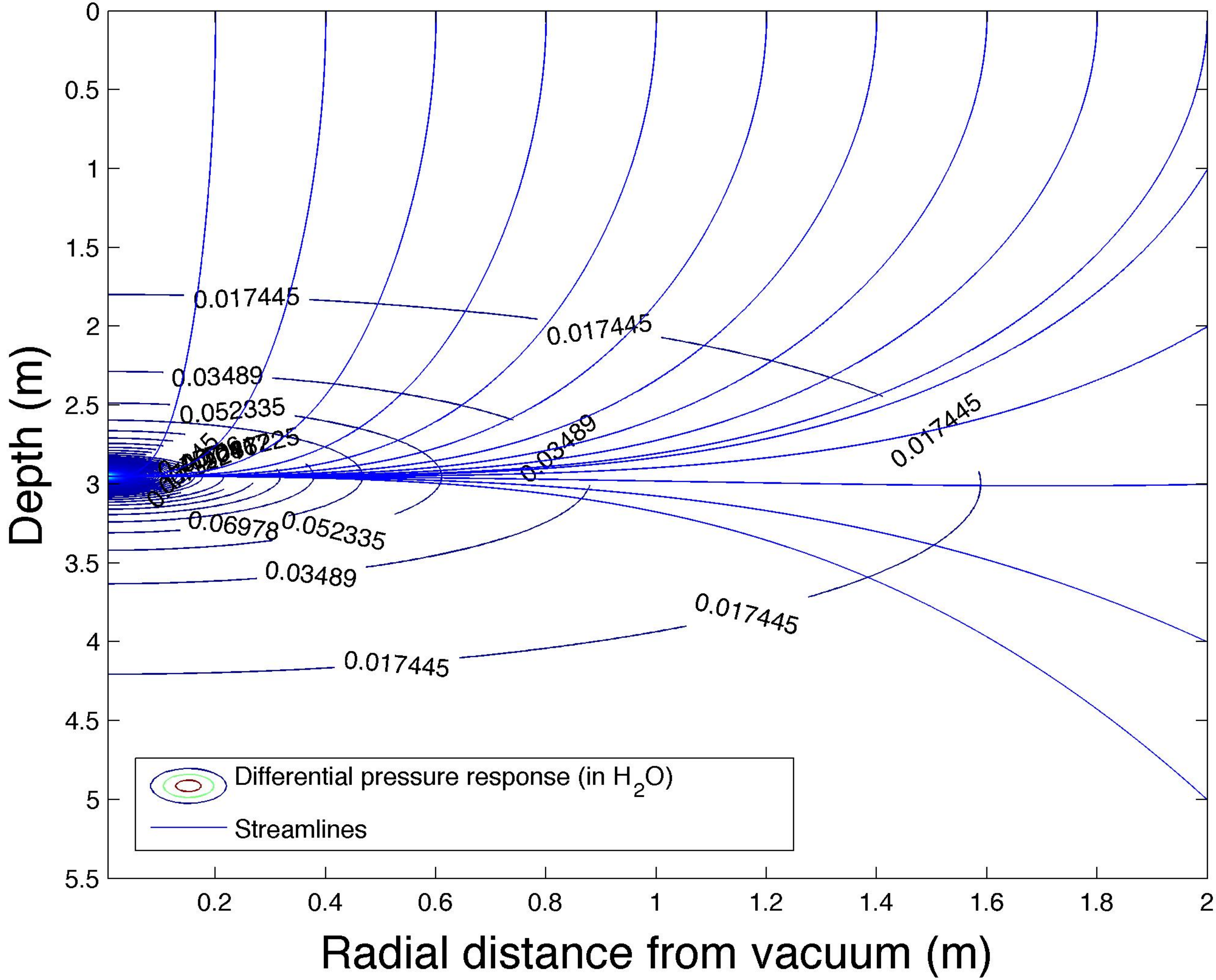
$$u = P_a^2 - P^2$$

$$u(r,z) = \frac{Q}{4\pi\sqrt{k_r k_z}}\left[\frac{1}{\sqrt{r^2 + \frac{k_r}{k_z}(z - z_0)^2}} - \frac{1}{\sqrt{r^2 + \frac{k_r}{k_z}(z + z_0)^2}}\right]$$

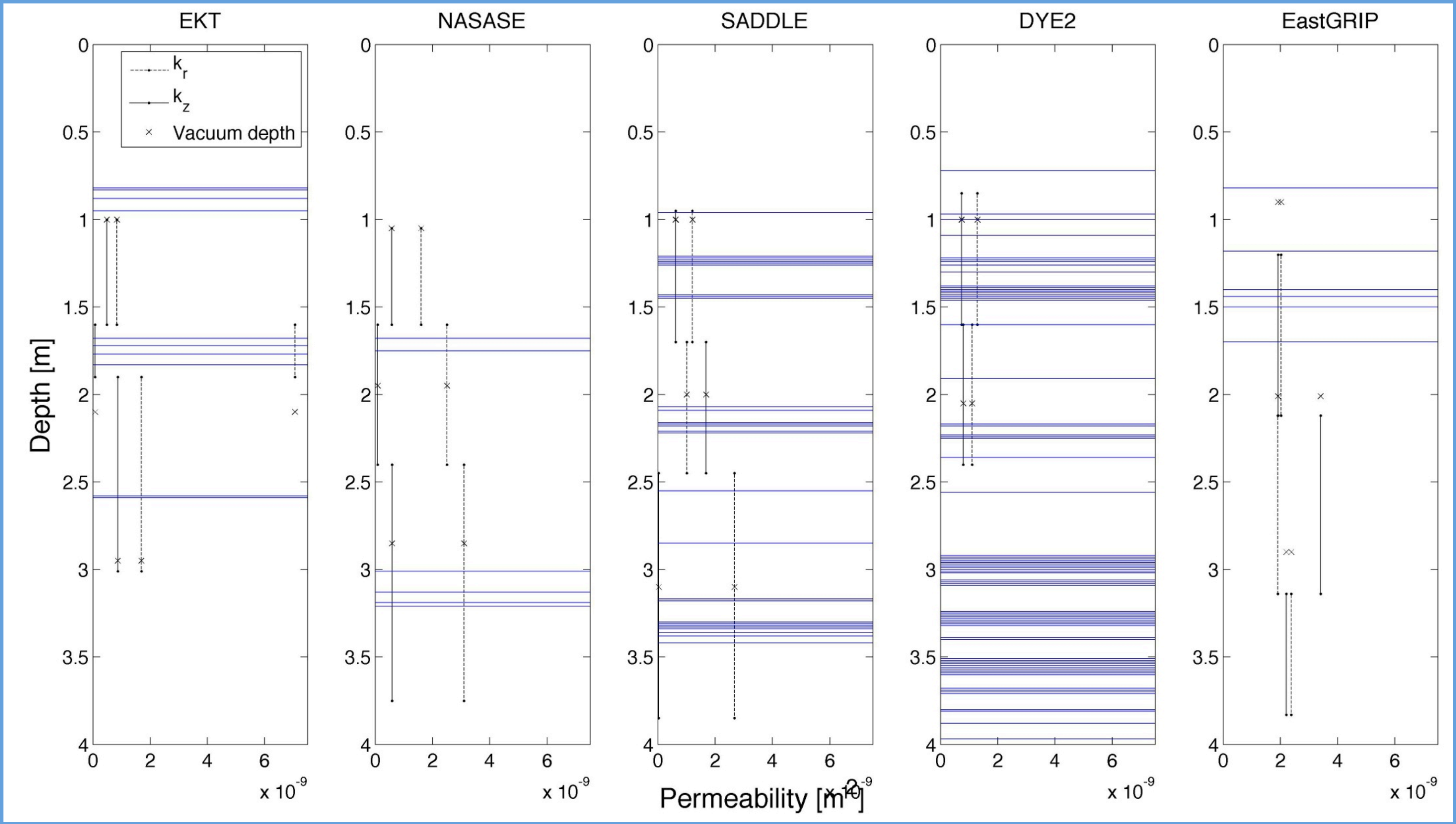



Can also extend solution to treat vacuum as a line sink, or consider an impermeable boundary ice layer below

## Sample pressure response field and streamlines



# Preliminary results: inferred permeability profiles




- In most cases, $k_r > k_z$
- Higher anisotropy ratio ($k_r/k_z$) for tests that span several ice lenses – ice layers reduce vertical permeability
- Range of inferred permeability values is comparable to that previously reported for Greenland firn at Summit (e.g., *Adolph and Albert, 2014*)

# Future Directions

- **This method can be used to characterize horizontal and vertical firn permeability at the field scale**

- Recommendations for further work:
  - More pressure monitoring transducers at various depths and distances for each vacuum test
  - Stronger vacuum motor to stimulate pressure responses farther away
  - Examine in detail the change in permeability over multiple years in locations with increasing meltwater percolation

# Many thanks to

University of Colorado Graduate School Dean's Graduate Research Grant

AGU Cryosphere Student Innovation Award

Eli Weber

FirnCover 2016 – Mike MacFerrin, Max Stevens, William Colgan, Baptiste Vandecrux, Darren Hill, Shawn Marshall, Samira Samimi, Achim Heilig, Bastian Gerling, Leander Gambal

CH2MHill Polar Field Services