Ice Layer Detection from RADAR Depth Sounder Data using Novel Approach based on Theory of Electrostatics

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Introduction

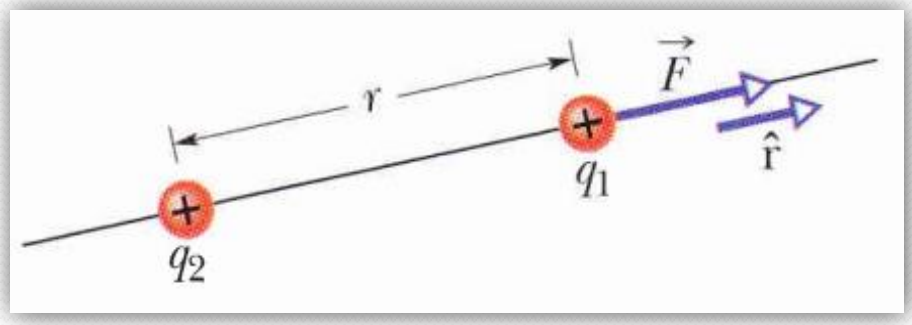
Radar Depth Sounder

- The Radar depth sounder is an important instrument that can provide relevant information about changes to polar ice sheets.

- Ice thickness can be determined by distinguishing layers of different dielectric constants such as air, ice, and rock in radar images.
- Manual layer identification is very time consuming and is not practical for regular, long-term ice-sheet monitoring.
- The development of automated techniques is thus fundamental for proper data management.

The proposed method

Three steps:



- **Anisotropic diffusion**
- **Electric field**
- **Projection profile**

Anisotropic diffusion

- A technique aiming at reducing image noise without removing significant parts of the image content, such as edges, etc.

From Isotropic to Anisotropic

- Gaussian filtering (isotropic diffusion) could remove noise but it would blur images as well

Isotropic diffusion: $I(x, y, t) = I(x, y, 0) \otimes G(t)$

scale

A Gaussian filter with zero mean and variance of t

- Ideally, we want
  - Diffusion within the object boundary
  - No filtering across the edge orientation

Perona-Malik's Idea

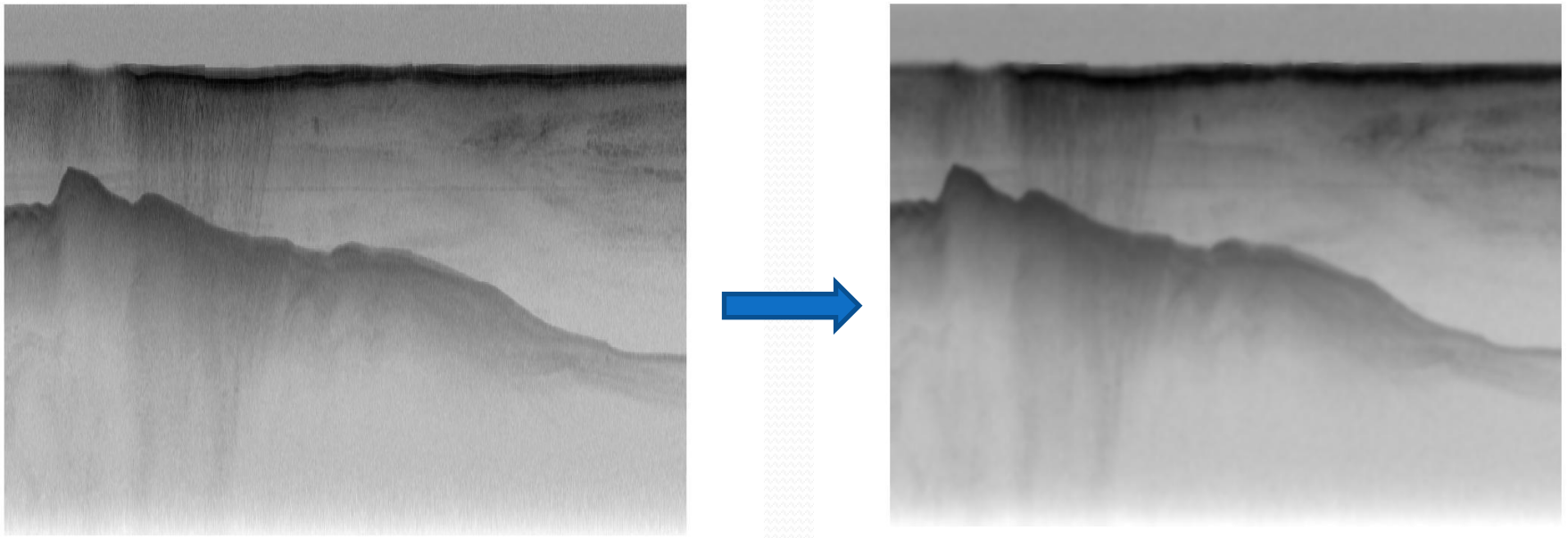
Isotropic diffusion:

$$\frac{\partial I(x,y,t)}{\partial t} = div[\nabla I]$$

$$\frac{\partial I(x,y,t)}{\partial t} = div[g(\| \nabla I \|)\nabla I]$$

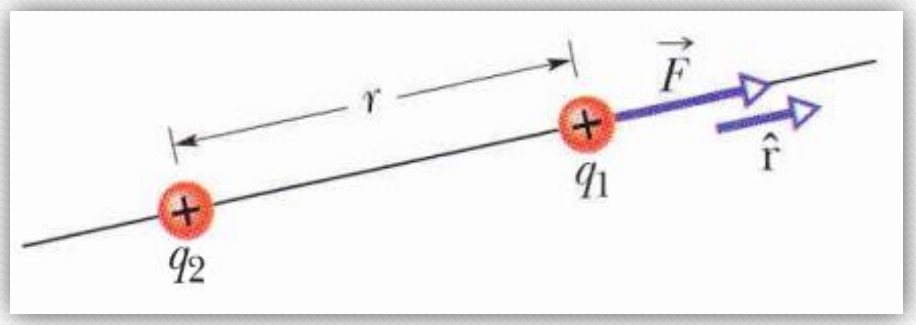
edge stopping function

Anisotropic diffusion



Layer detection by means of Electric field

- Coulomb's law: *the magnitude of the electrostatic force between two charged particles is directly proportional to the scalar multiplication of the magnitudes of charges and inversely proportional to the square of the distances between them*



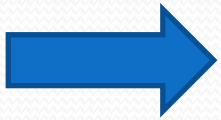
Layer detection by means of Electric field

- Every pixel is assumed to be an electrically charged particle which has electrostatic interaction with other neighboring particles/pixels.

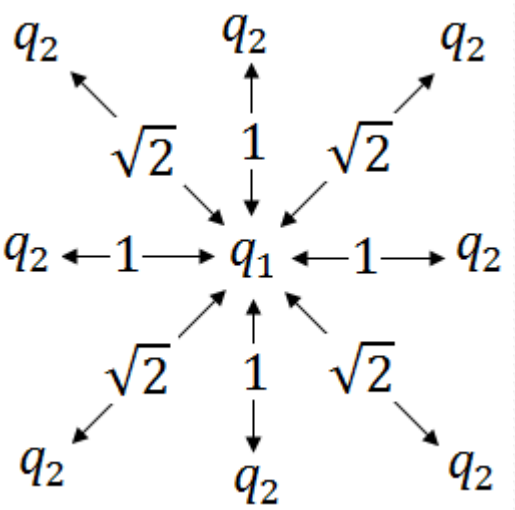
- the image is considered to be a grid of particles, where the horizontal or vertical space between every pair of consecutive positions is 1.

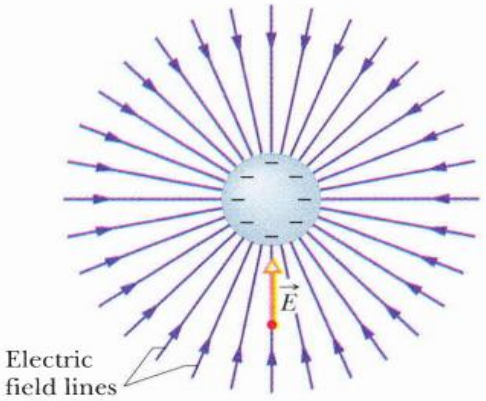
Layer detection by means of Electric field

- The electrical charge of each particle is represented indirectly by the grayscale intensity of the pixel
- pixel signs are always positive, therefore the electrostatic force between them would be repulsive.
- To have both repulsive and attractive force between pixels, pixels are transformed so that they have small values with positive and negative sign.

- $[0\ ,255]$  $[-0.5\ ,0.5]$

Layer detection by means of Electric field



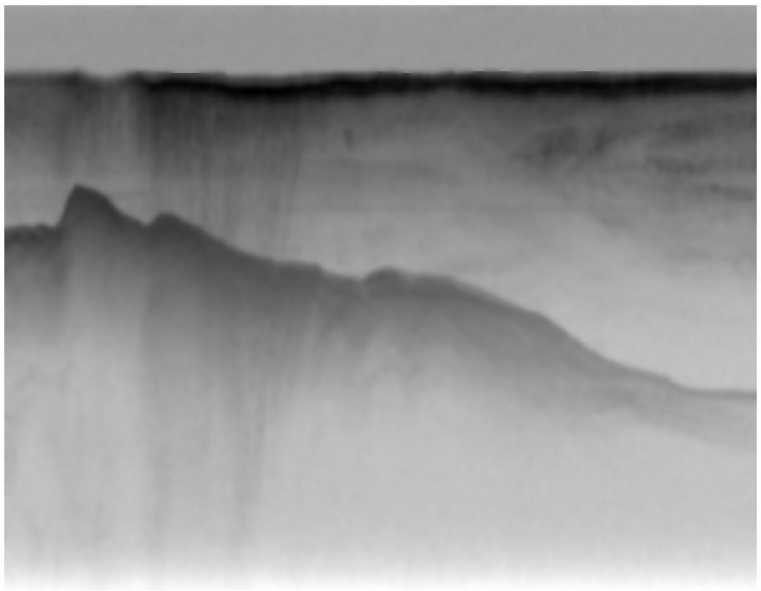


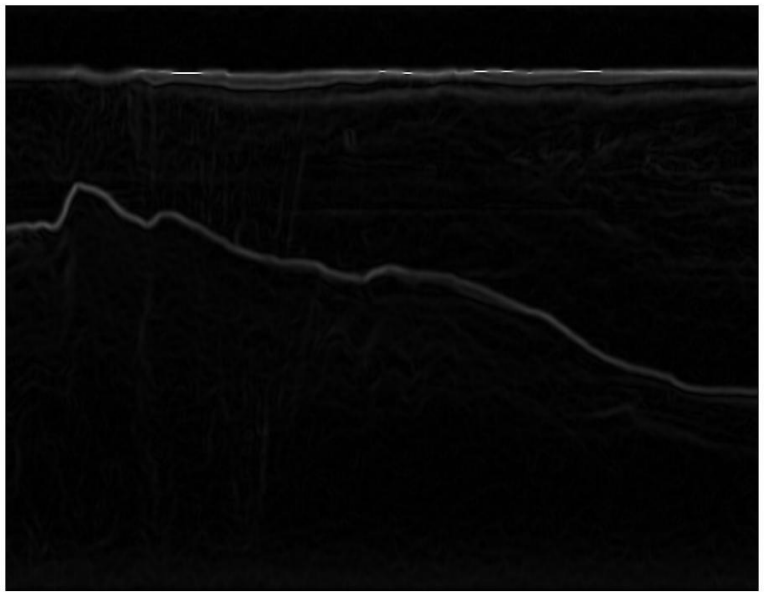
$$\vec{E} = k\frac{q_2}{r^2}\frac{\vec{r}}{|r|}$$

Layer detection by means of Electric field

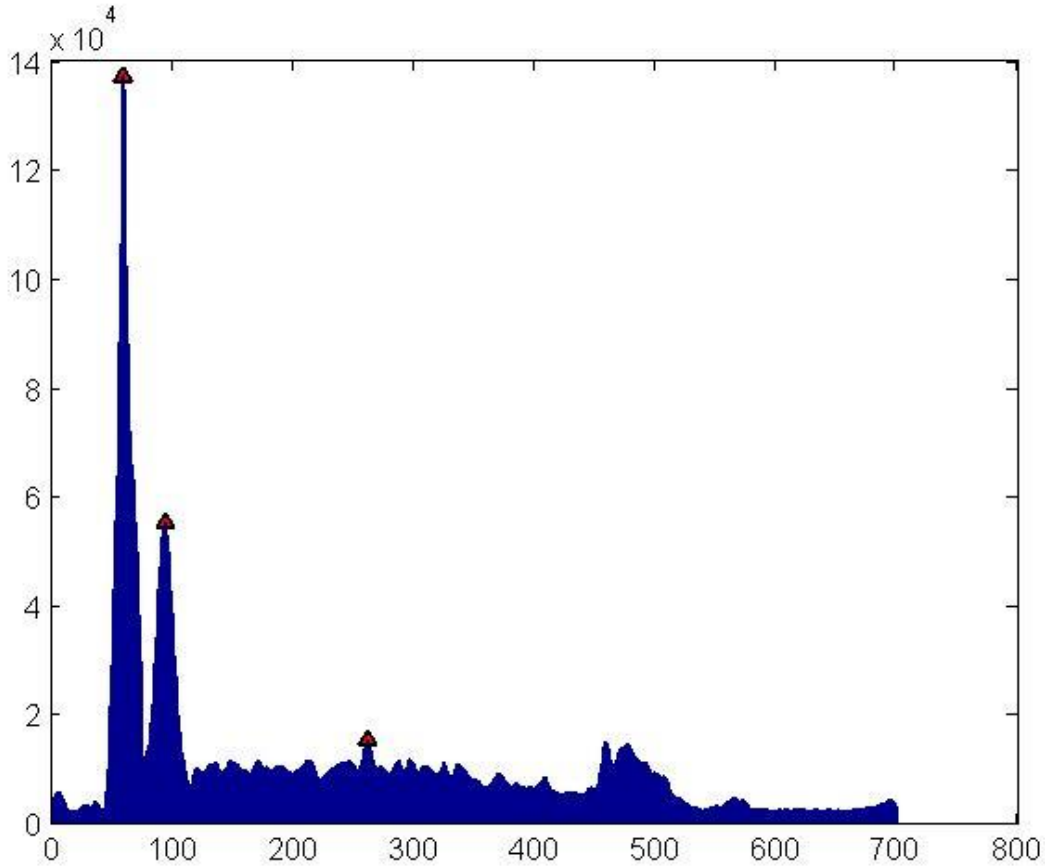
$$\begin{bmatrix} \frac{|Q_{i,j} - Q_{i-1,j-1}|}{2} & |Q_{i,j} - Q_{i-1,j}| & \frac{|Q_{i,j} - Q_{i-1,j+1}|}{2} \\ |Q_{i,j-1}| & 0 & |Q_{i,j} - Q_{i,j+1}| \\ \frac{|Q_{i,j} - Q_{i+1,j-1}|}{2} & |Q_{i,j} - Q_{i+1,j}| & \frac{|Q_{i,j} - Q_{i+1,j+1}|}{2} \end{bmatrix}$$

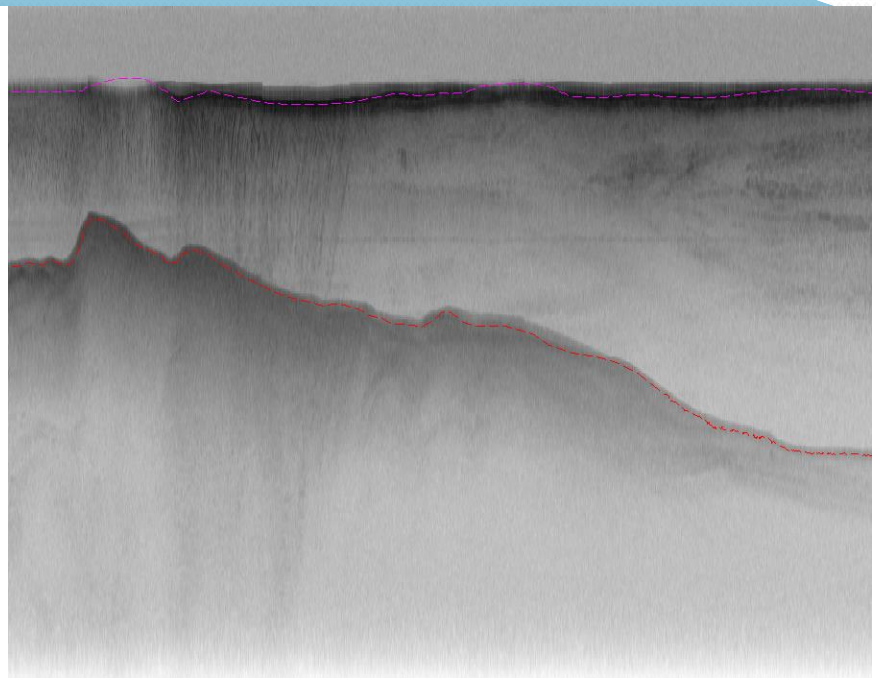
Electric field



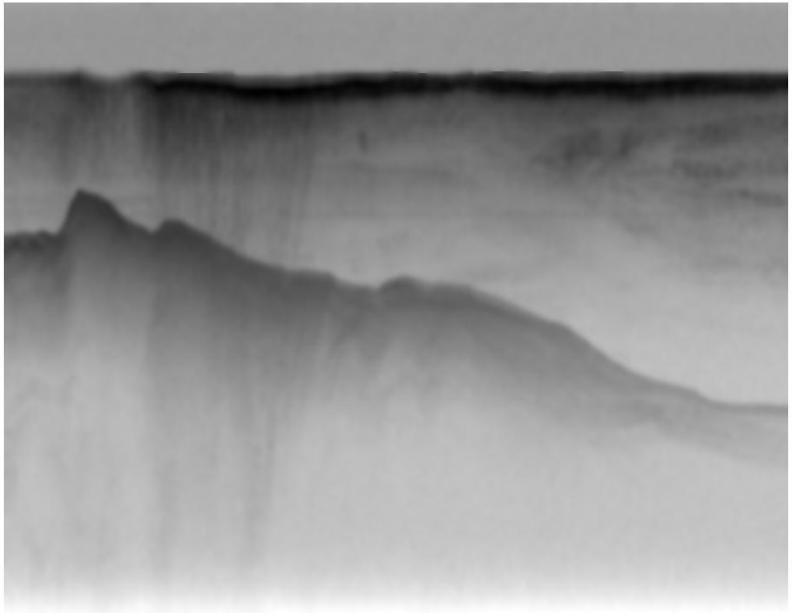


Projection profile

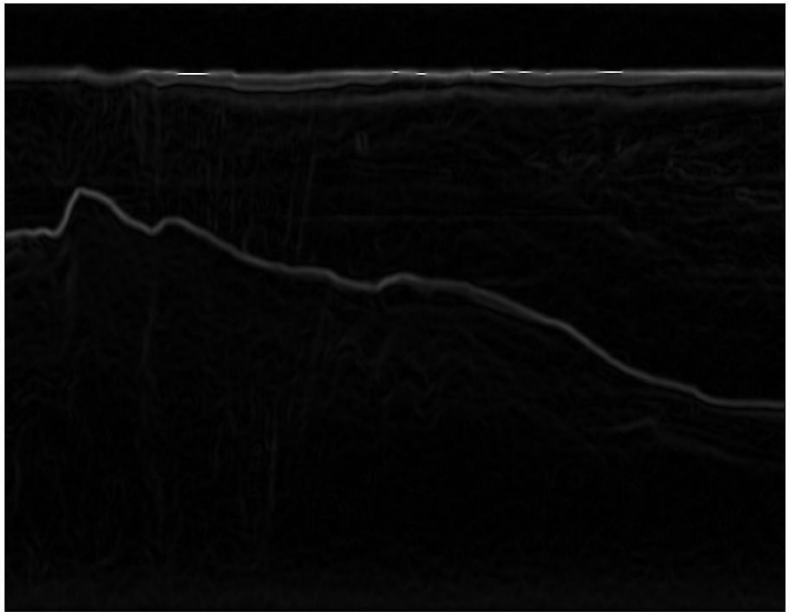




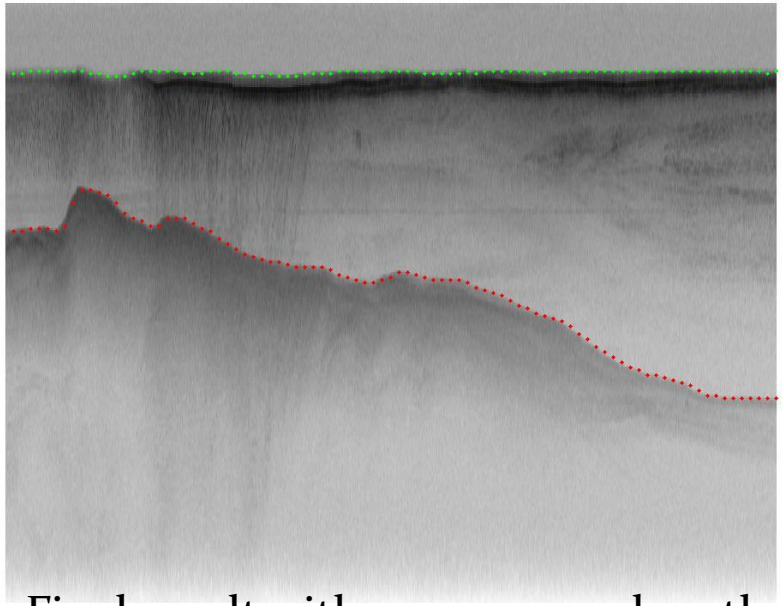
Ground-truth



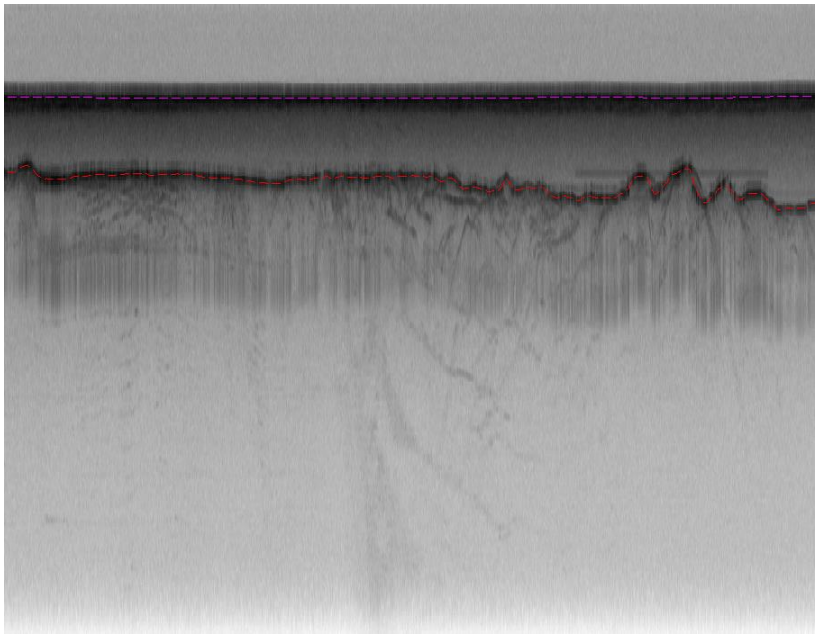
Anisotropic Diffusion



Electric field



Final result with our proposed method



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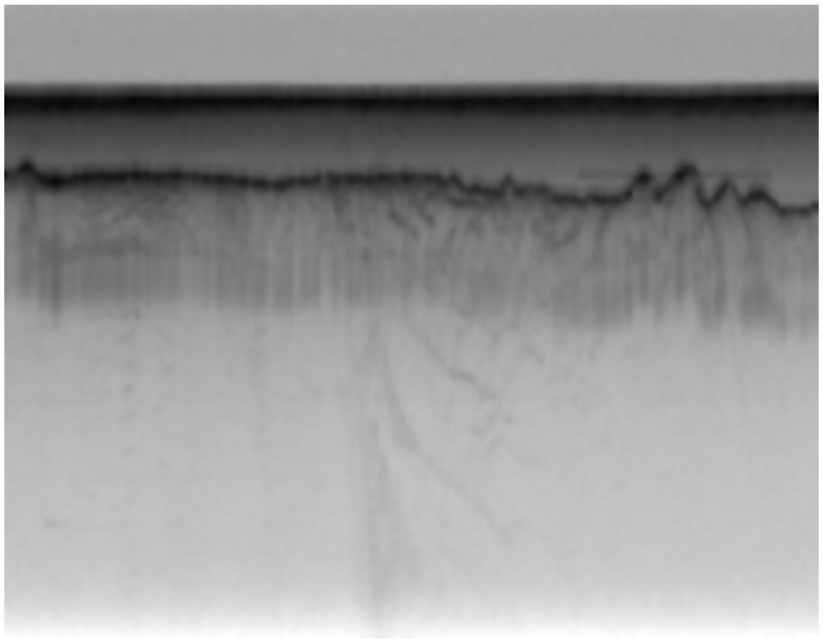
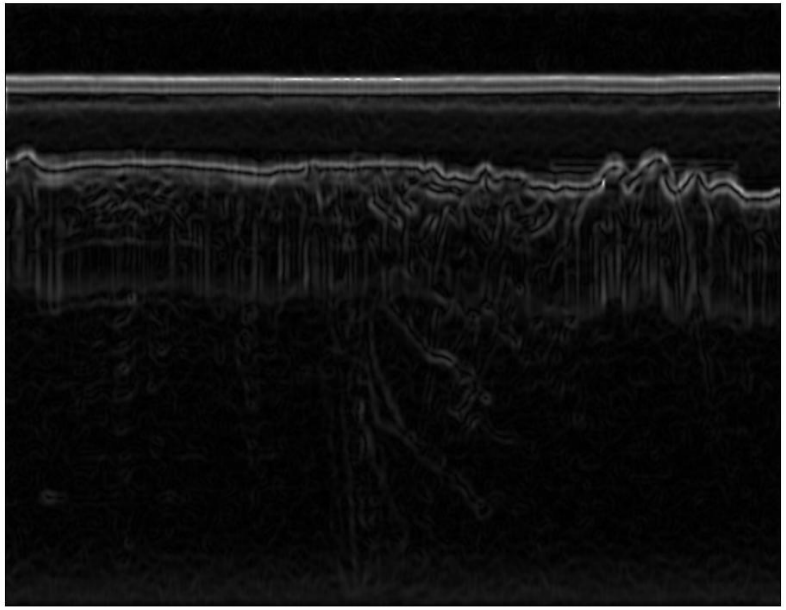
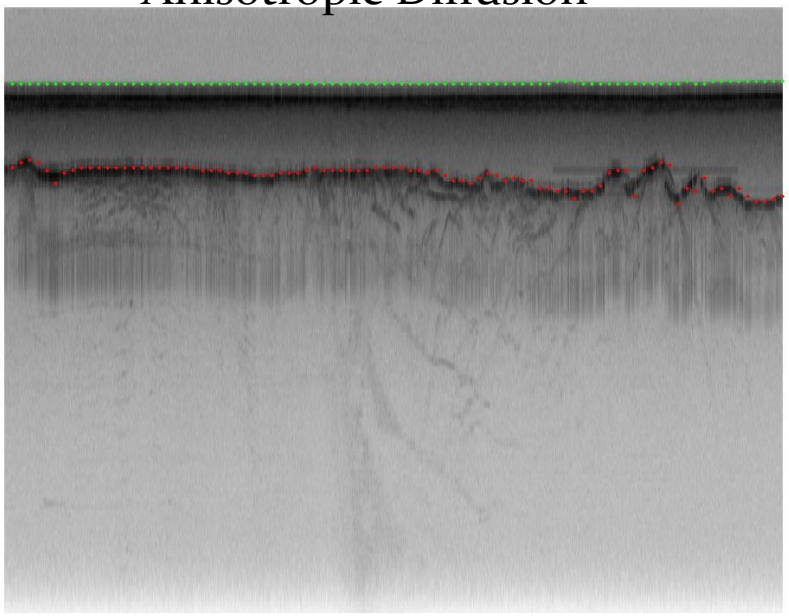


Anisotropic Diffusion



Electric field



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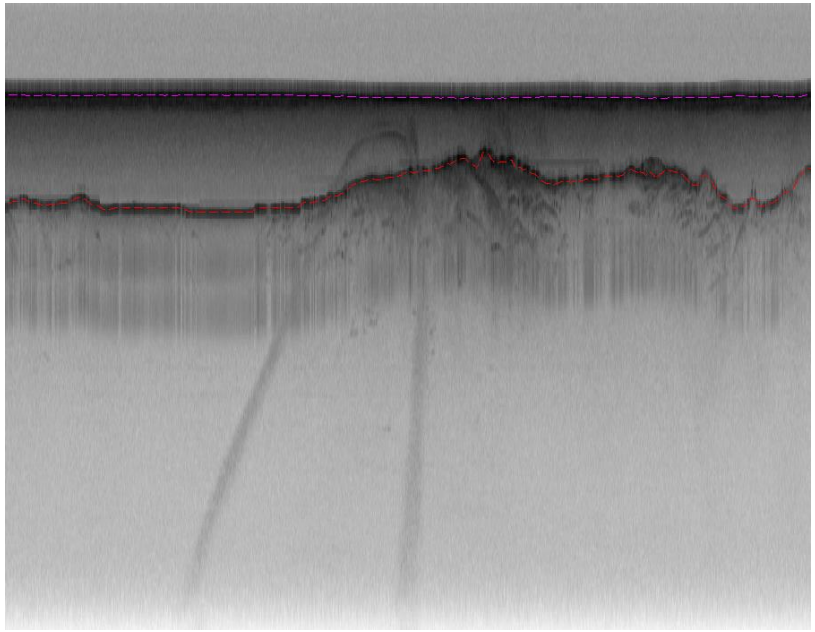

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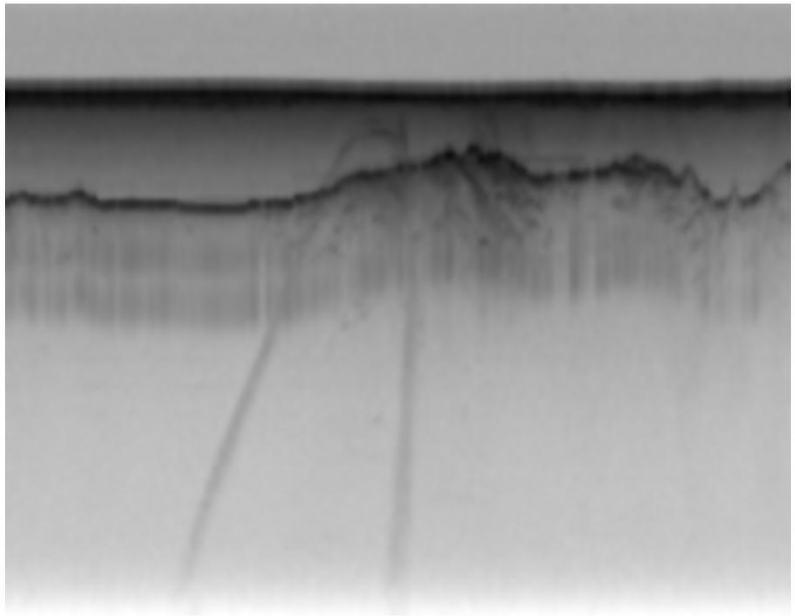
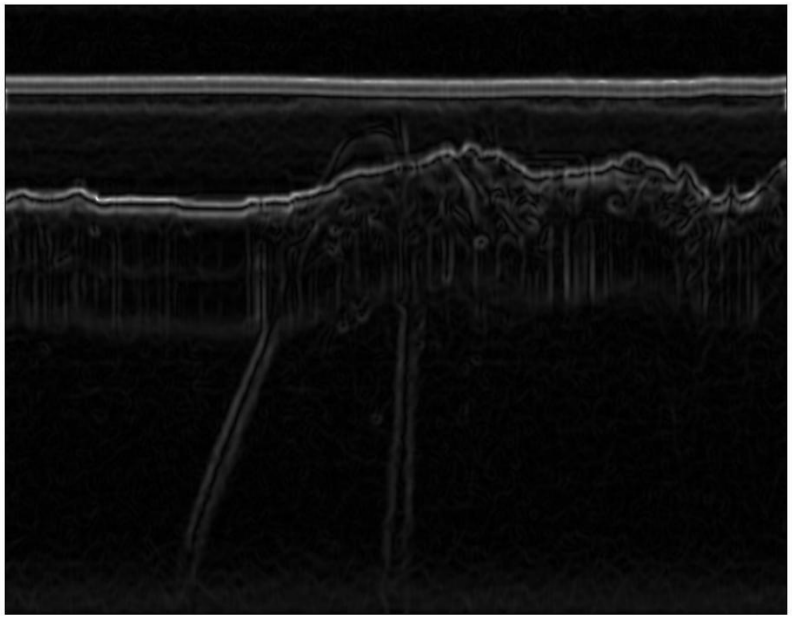


Anisotropic Diffusion



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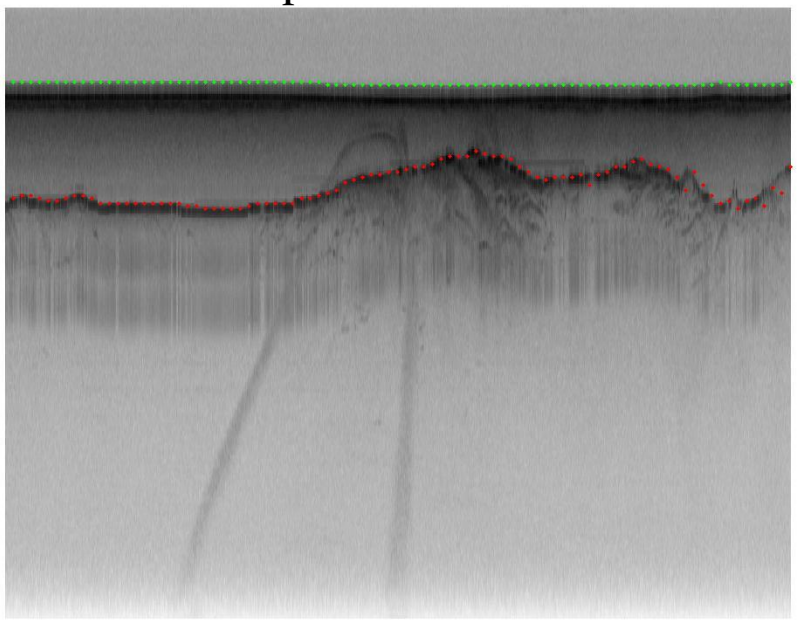

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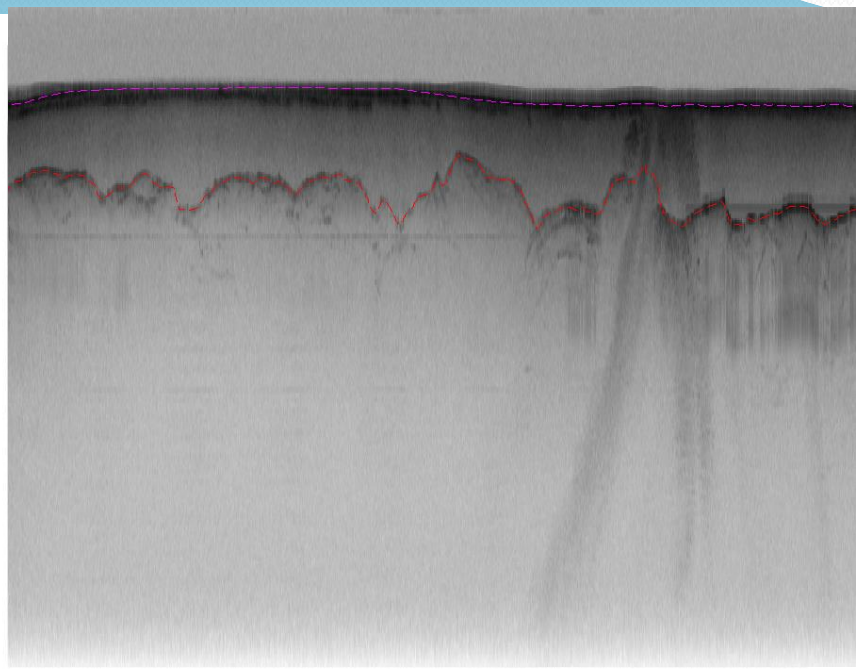

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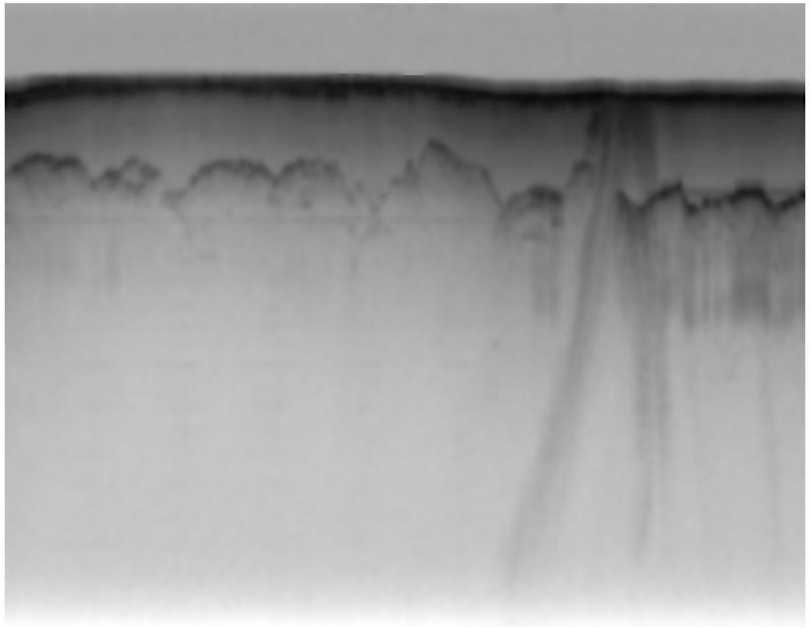

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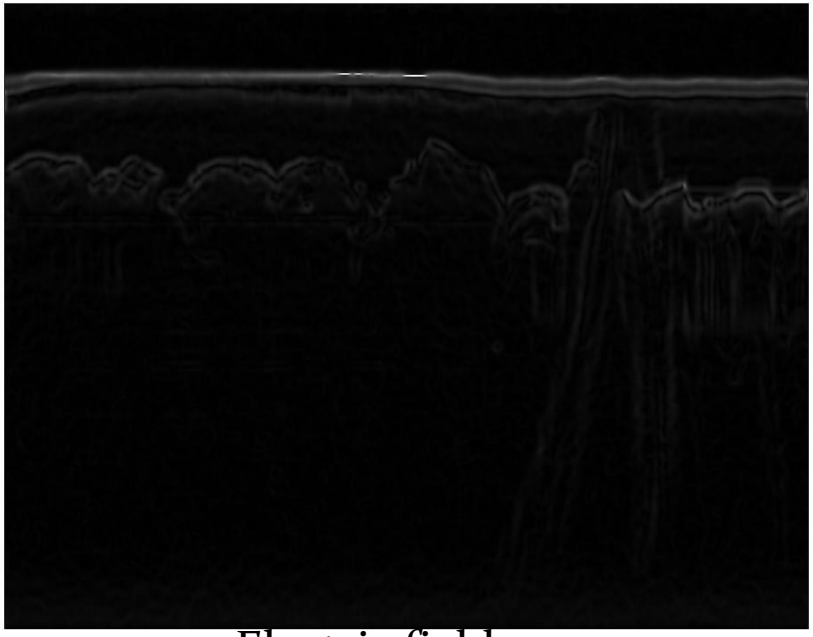

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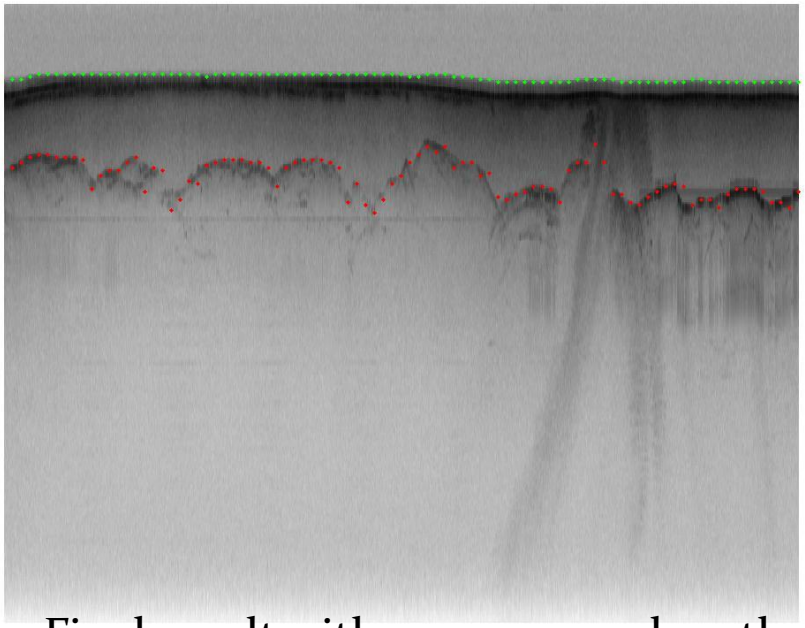

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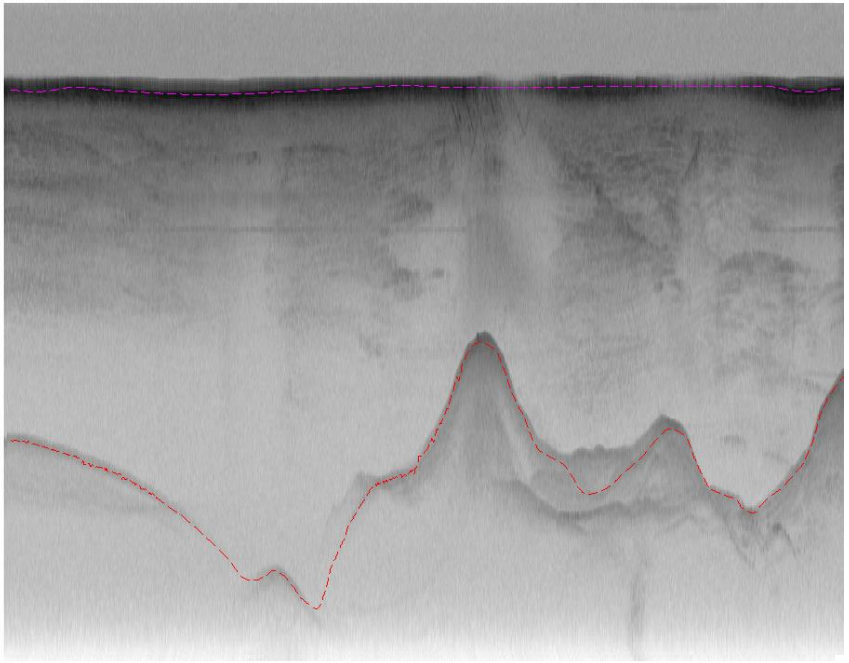

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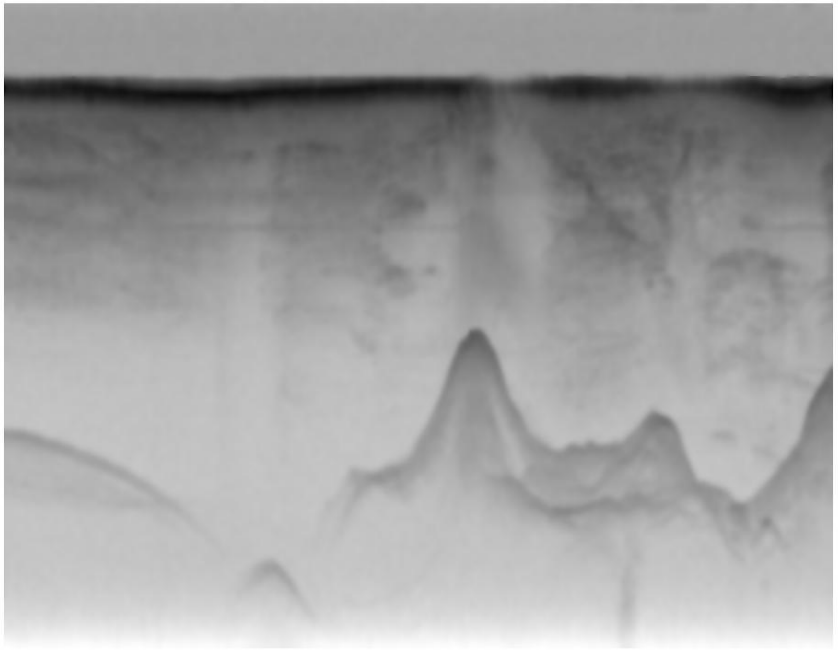

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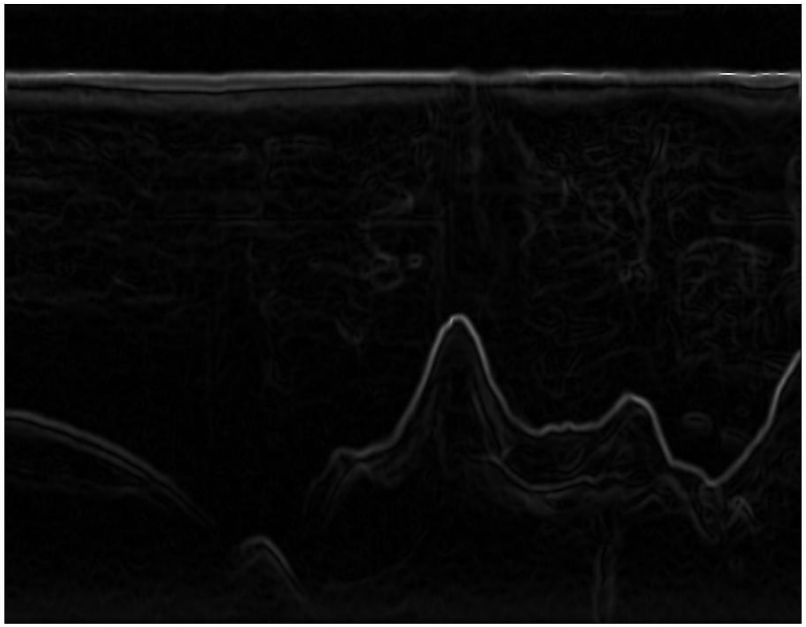

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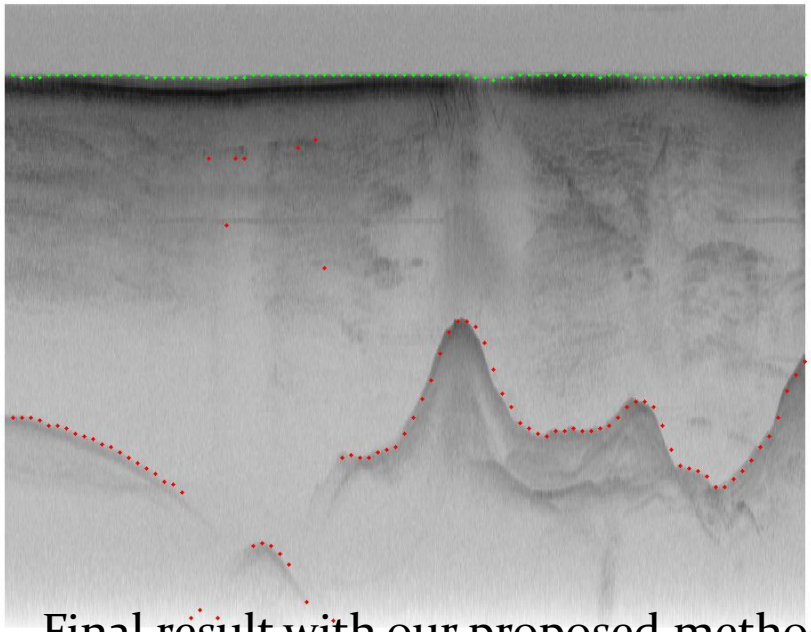

Final result with our proposed method

Conclusion and future works

- We presented a technique for automatic layer finding using electric field
- Fully automatic without any user interference
- Does not need any training data

- Apply this method for internal layers detection (more than 2 layers)

Thank you!