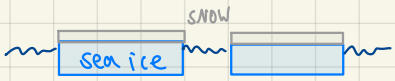
Induction Method

Sea ice = frozen ocean
Land ice = precipitation



$\rho_{ice} = 900 \frac{kg}{m^3}$
$\rho_W = 1000 \frac{kg}{m^3}$

What about conductivity? σ salt water ↑
σ ice ↓
→ good contrasts

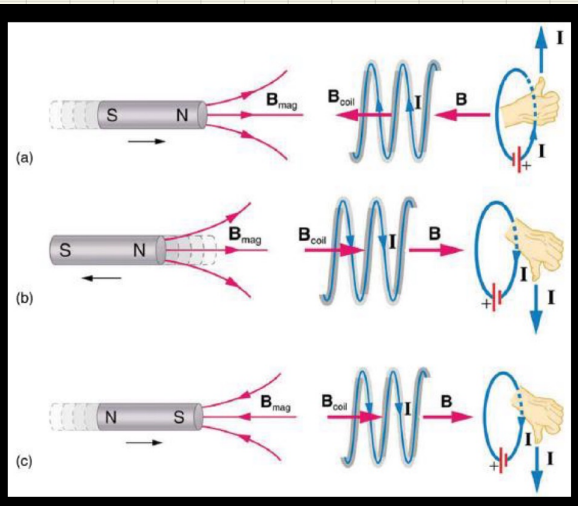
↯ sea ice = positive feedback = interception of energy

⇒ Induction method

*measuring
- Extent → Albedo
- Thickness → Albedo resilience
- Dynamics → Albedo resilience

[satellites: optical, radar (day/night capacity)]
⇒ geophysical method without ground coupeing of sensors

Company: DRIFT and NOICE → Praktikum (Bremen)



Reference:
LibreTexts Physics CC-BY SA 4.0.

Induction

→ time variability of $\vec{B}$
→ Lorentz-force
→ Induction of current in loop
→ Lentz-Law: $\vec{B}$ field in loop opposite of original $\vec{B}$-field
→ Transfer mechanical energy into electrical energy

$$\nabla \times \vec{E}(\vec{x},t) = -\frac{\partial}{\partial t}\vec{B}(\vec{x},t)$$

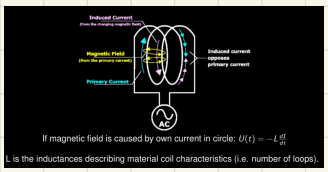
$$\oint_{\partial z} \vec{E}(\vec{x},t)\cdot d\vec{l} = \int_z \frac{\partial}{\partial t}\vec{B}(\vec{x},t)\cdot d\vec{A}$$

Maxwell equation

Line integral
EMF (induced potential different)

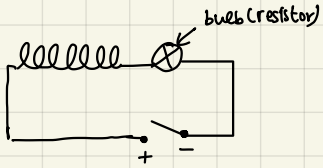
Area Integral → Fluxterm
→ Fluxchange per time unit

Self Inductance



Koyle = Spule

Simple induction circuit:

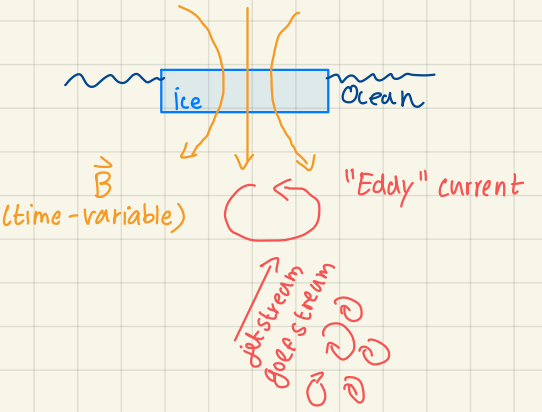


① Lamp will turn on slowly
② Current flow starts apruptly at $t=0$ $\left(\frac{dI}{dt} > 0\right)$
③ Current creates a magnetic field B which is time variable (because I is time variable)
④ Magnetic field in coil works against the imposed I (Lenz)
⑤ Consequently the bulb is at first until I is equilibrium $\left(\frac{dI}{dt} = 0\right)$
(⑥ Furthact switch off $\frac{dI}{dt} \neq 0$)

Electromagnetic Induction (EMI)

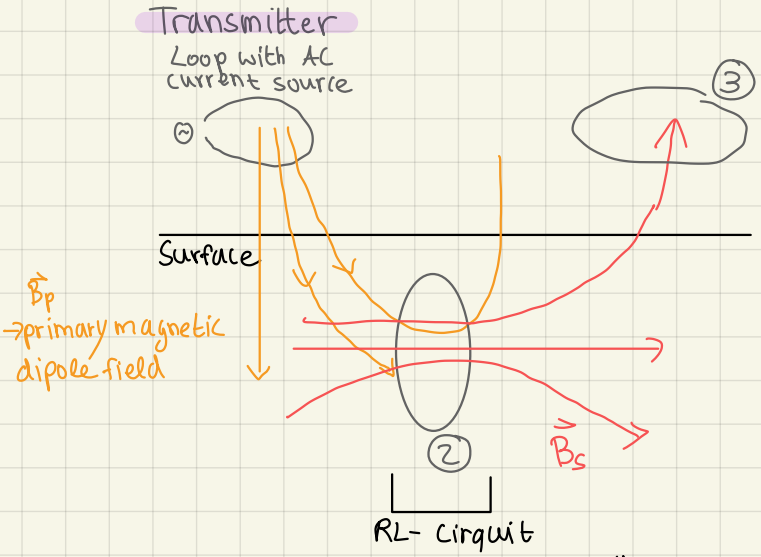
Principle: EMI uses time variable magnetic fields to induce "Eddy" currents in the subsurface, which in turn create a secondary time variable magnetic field which can be detected at the surface
The geophysical target parameter is the (AC) conductivity.

What are Eddy currents?



Conceptually: Eddy currents are represented with an inductor (Spule)

Measurement Setup



② Subsurface Eddy currents are represented as an Inducter

③ Receiver loop recieves both, $\vec{B}_p$ and $\vec{B}_s$ which will induce potential / currents representing transmitter and supsurface properties.

⇒ the variable of interest is $\frac{U_s}{U_p}$

⇒ In order to understand what $\frac{U_s}{U_p}$ entails we model the subsurface as a R-L circuit
(There are other ways, e.g. RLC (if polarizible), but R-C is most important)

Goal in the following: What is $\frac{U_s}{U_p}$?

Start with transmitter: $I(t) = I_1 e^{i\omega t}$ (ω: frequency of AC source)

I_1: peak current; Index 1 depicts loop 1

In loop ② (subsurface) $U_{e2} = -L_{12} \frac{dI_1}{dt}$ (Farraday's law)

$= -L_{12} I_1 i\omega e^{i\omega t}$

L_{12}: coupling factor describing orientation of loop 1 relative to loop 2

→ What kind of current will this induce in subsurface?

In loop ③ (reciever) $U_p = -L_{13} \frac{dI_1}{dt} = -L_{13} I_1 i\omega \exp(i\omega t)$

Extension of Ohm's law:

[of to induced polarization)

$$I = \frac{1}{R} U + C \frac{dU}{dt}$$ RC-cirquit

with an inductor L

$$I = \frac{1}{R} U - L \frac{dI}{dt}$$ RL-cirquit

The extension transfers the resistance of Ohm's law to the concept of impedence Z.

$$Z_{e2} = R_{e2} + \underbrace{i\omega L_{12}}_{\frac{dI}{dt}}$$

$$U_{e2} = Z_{e2} \underbrace{I_2}_{\text{unknown}} \Rightarrow I_2 = \frac{U_2}{Z_{e2}} = \frac{-L_{12} I_1 i\omega e^{i\omega t}}{R_{e2} + i\omega L_{12}}$$ | Erweitern mit $\cdot \frac{1}{R_{e2}}$

$$= \frac{-i\omega \frac{L_{12}}{R_{e2}} I_1 e^{i\omega t}}{1 + i\omega \frac{L_{12}}{R_{e2}}}$$ now: $\alpha = \omega \frac{L_{12}}{R_{e2}}$ "induction parameter"

$$I_{e2} = \frac{-i\alpha I_1 e^{i\omega t}}{1 + i\alpha}$$

$$U_p = -L_{13} \frac{dI_1}{dt} \quad V$$

$$U_s = -L_{23} \frac{dI_2}{dt}$$