JOINT INVERSION OF LAND AND MARINE ELECTRICAL RESISTIVITY TOMOGRAPHY FOR IMAGING SUBMARINE FRESHWATER DISCHARGE

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FRESH-/SALTWATER INTERFACE

SALTWATER INTRUSION (SI)

INfiltration on the beach slope

FRESH SUBMARINE GROUNDWATER DISCHARGE (FSGD)

LEGEND

- Pumping well
- Rainfall-Evapotranspiration
- Tidal ocean water level
- Ground surface
- Regional flow system
- Local flow system

Fresh groundwater
Seawater
Unsaturated zone
Up-coning

modified from Werner et al. 2013
ERT ON LAND

Zone detected by EM

Seawater
Fresh (brackish) water discharge
Saltwater lens
Saltwater infiltration pond
Freshwater aquifer

Resistivity directly related to water salinity
Relatively high resolution
Limited to the intertidal zone
Resistivity directly related to water salinity

Fast acquisition (5 to 6 km/h)

Influence of the water layer

Lower resolution and depth of investigation
HOW TO COMBINE BOTH?
CAN WE GET A SINGLE MODEL?

Qualitative coherence between the two images, but:
- Difference in resolution
- Resistivity values are not similar

Data should correspond to the same resistivity distribution, but
- Presence of the water layer on marine data
- Influence on the inversion results
The difference between the two conditions is the presence of the water layer during high tide for marine ERT.
Both data sets are able to detect the presence of freshwater

- Land ERT does not get the sea extension
- Marine ERT has a lower resolution
OPTION 1: LAND ERT AS A REFERENCE MODEL

Improvement of the image
- Discontinuity in the freshwater discharge
- No guaranty that land data remains fitted

Marine ERT at high tide with land as reference
Low weight

Marine ERT at high tide with land as reference
High weight
OPTION 2: DATA CORRECTION

Collected data \( d_{\text{land, lw}} \) from \( m_{\text{true}} \)

What would be the data at high tide \( d_{\text{land, hw}} \)?

\[ \Delta d = d_{\text{est land, hw}} - d_{\text{est land, lw}} \]

\[ d_{\text{land, hw}} = d_{\text{land, lw}} + \Delta d \]

\( d_{\text{land, hw}} \) is used with \( d_{\text{sea}} \) for a joint inversion

See Hayley et al. (2010, Geophysics) : data correction for temperature variations in time-lapse ERT
OPTION 2: QUALITY OF CORRECTION

A - Absolute resistance correction

B - Relative resistance correction

C - Quality of the estimated high water data

D - Quality of the estimated correction
**OPTION 2: JOINT INVERSION**

Joint model
- Data correction ensures land data is still fitted
- Reference model counteracts the apparent loss of resolution for land data due to the water layer

**Marine ERT at high tide with land as reference**

**Marine ERT at high tide with data correction and reference land model**
FIELD APPLICATION


- Reference model is needed
- Fitting both data sets leads to small differences
- Inadequacy between data sets?
CONCLUSIONS

- New approach to jointly invert land and marine data with overlapping
  - Data correction to simulate land data with water layer
  - Estimated correction is well estimated
  - Reference model to maintain higher resolution from land data

- Combined resistivity model enables finer interpretation
- Risk of data inadequacy ?

- Immediate extension to monitoring tide processes (time-lapse)
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OPTION 2: DATA CORRECTION

1) Measured land data at low tide: \( d_{\text{land},\text{lw}} = G(m_{\text{true}}) + \epsilon \)

2) Fictional land data at high tide: \( d_{\text{land},\text{hw}} = G(m_{\text{true}} + \Delta m) + \epsilon \)

3) Taylor’s approximation: \( G(m_{\text{true}} + \Delta m) = G(m_{\text{true}}) + \frac{\partial G(m_{\text{true}})}{\partial m} \Delta m \)

4) Taylor’s for data: \( d_{\text{land},\text{hw}} = d_{\text{land},\text{lw}} + \frac{\partial d_{\text{land},\text{lw}}}{\partial m} \Delta m \)

5) Estimating: \( d_{\text{land},\text{lw}}^{\text{est}} = G(m_{\text{est}}) = d_{\text{land},\text{lw}} + e \)

6) Estimating: \( d_{\text{land},\text{hw}}^{\text{est}} = G(m_{\text{est}} + \Delta m) \)

7) Estimating the derivative: \( \frac{\partial d_{\text{land},\text{lw}}}{\partial m} = \frac{d_{\text{land},\text{hw}}^{\text{est}} - d_{\text{land},\text{lw}}^{\text{est}}}{\Delta m} \)

8) Estimating: \( d_{\text{land},\text{hw}} = d_{\text{land},\text{lw}} + (d_{\text{land},\text{hw}}^{\text{est}} - d_{\text{land},\text{lw}}^{\text{est}}) \)

9) Joint inversion of \( d_{\text{land},\text{hw}} + d_{\text{sea},\text{hw}} \)

See Hayley et al. (2010, Geophysics) : data correction for temperature variations in time-lapse ERT
NOISE CONSIDERATION

Before correction

After correction

Apparent increase of the relative noise level, because the average resistance decreases

Land data, noise 3%, eRMS = 1.8

Land data, noise 5%, eRMS = 1.1

Noise level of land data must be adapted during inversion to reach the expected noise level
But few variations are observed in the resistivity model
VALIDATION OF THE FRESHWATER DISCHARGE

Apparent electrical conductivity (mS/m)

700 650 600 550 500 450 400

0 100 200 300 m