FACULTY OF SCIENCES

DEPARTMENT GEOLOGY
RESEARCH GROUP HYDROGEOLOGY AND APPLIED GEOLOGY

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

T. Hermans and M. Paepen

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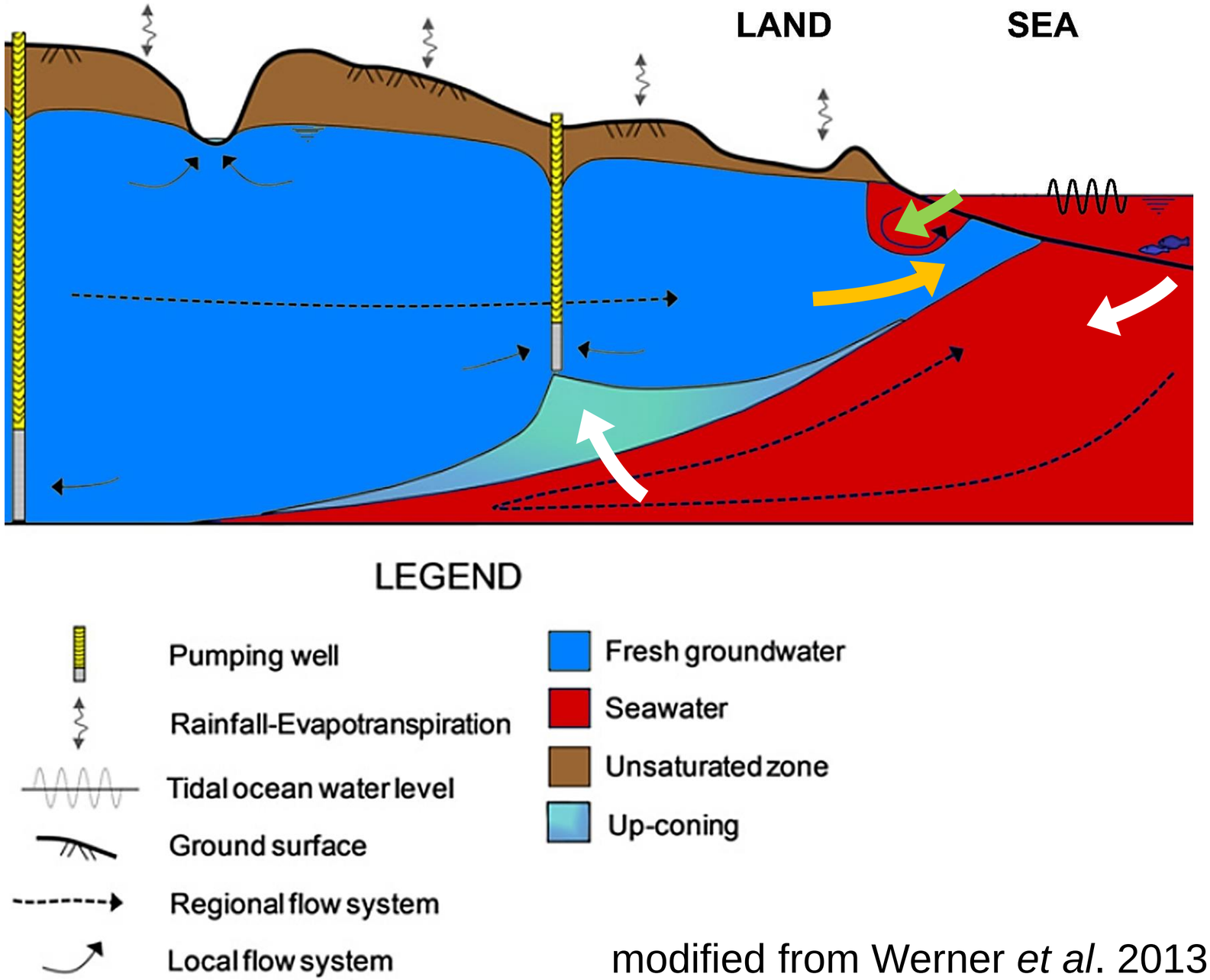
FRESH-/SALTWATER INTERFACE

SALTWATER INTRUSION (**SI**)

INFILTRATION ON THE BEACH SLOPE

FRESH SUBMARINE GROUNDWATER DISCHARGE (**FSGD**)



modified from Werner *et al*. 2013

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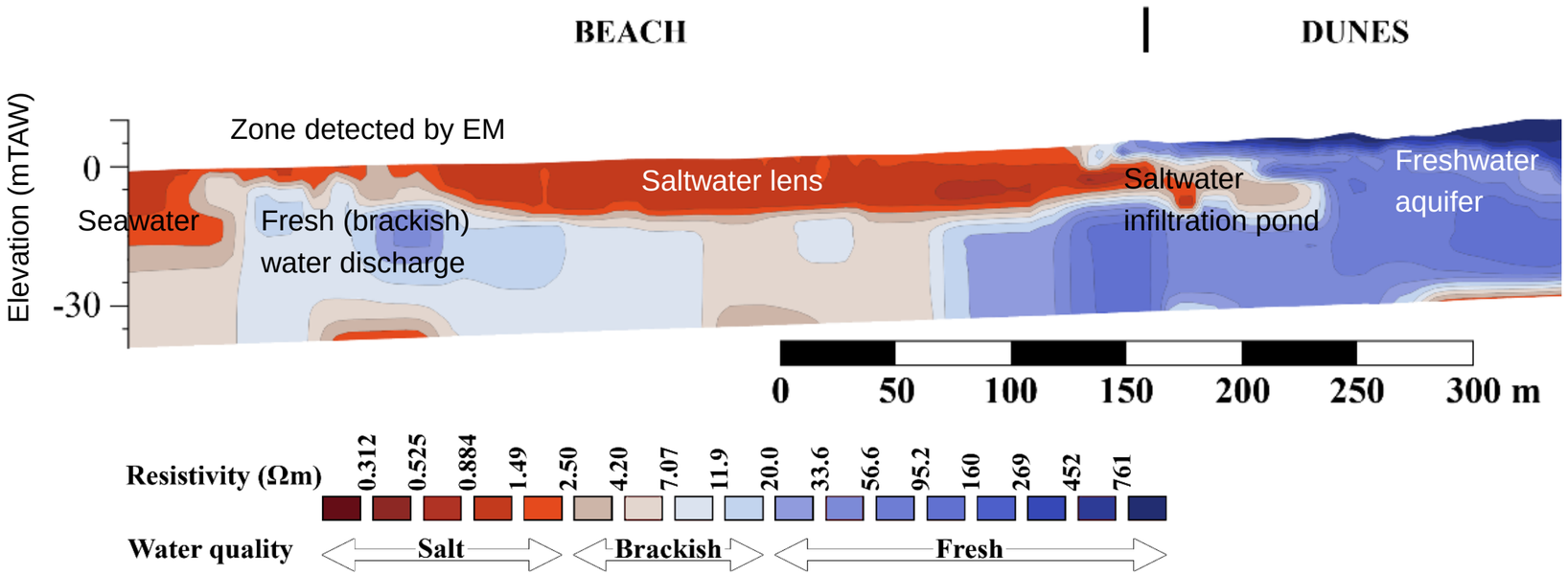
ERT ON LAND



Resistivity directly related to water salinity

Relatively high resolution

Limited to the intertidal zone

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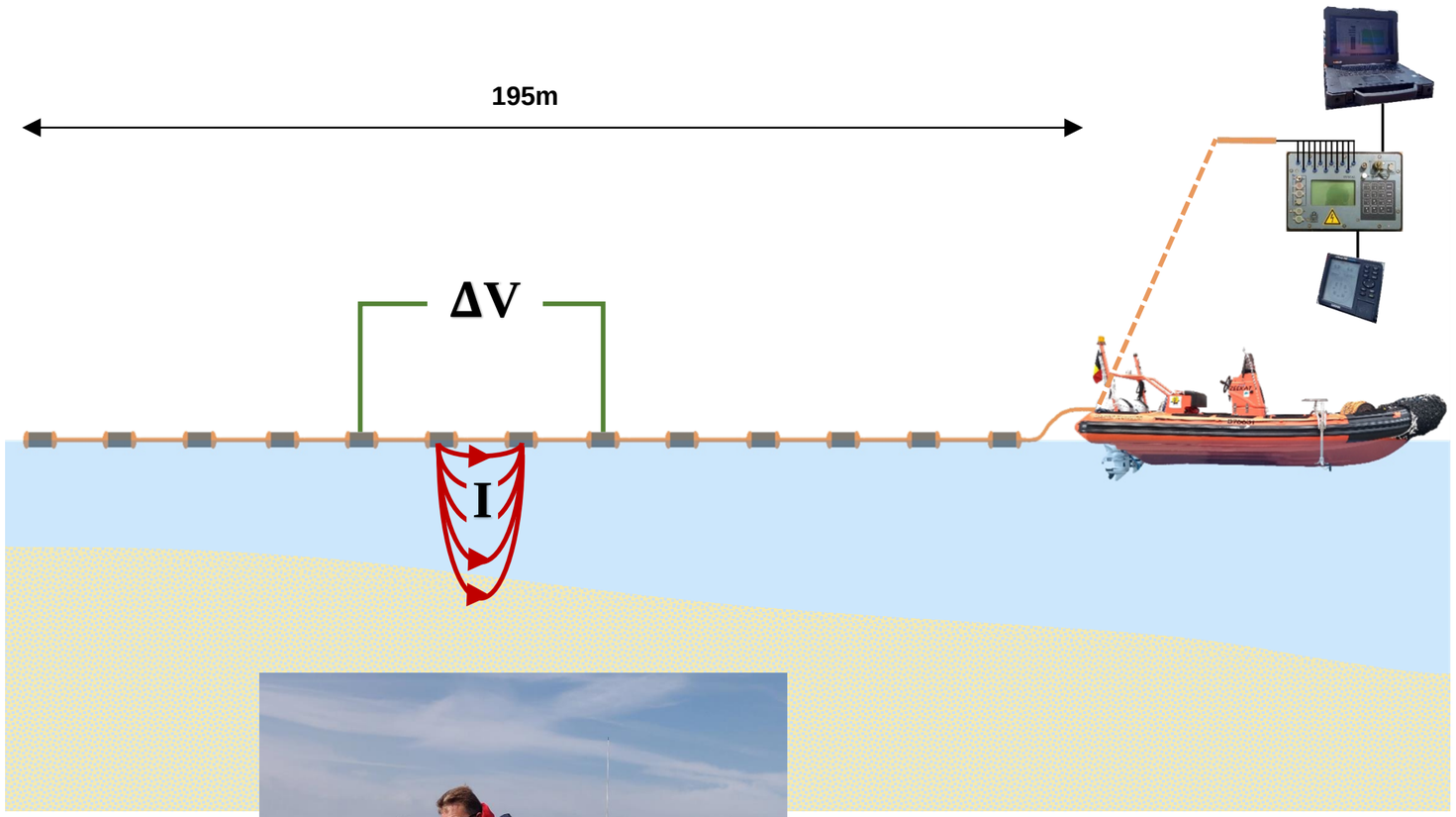
MARINE ERT

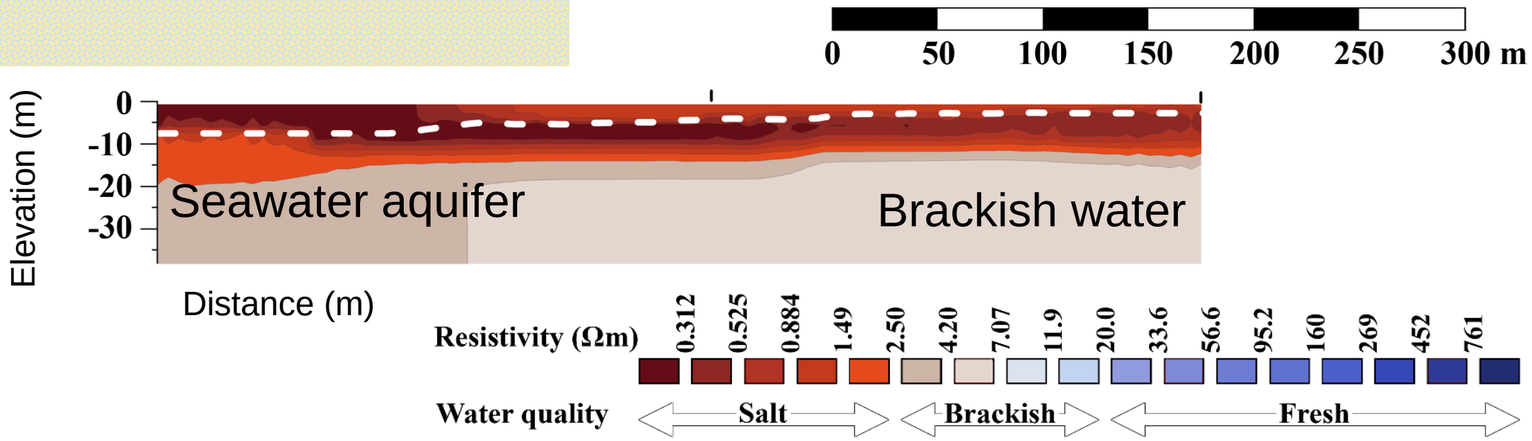


Resistivity directly related to water salinity

Fast acquisition (5 to 6 km/h)

Influence of the water layer

Lower resolution and depth of investigation



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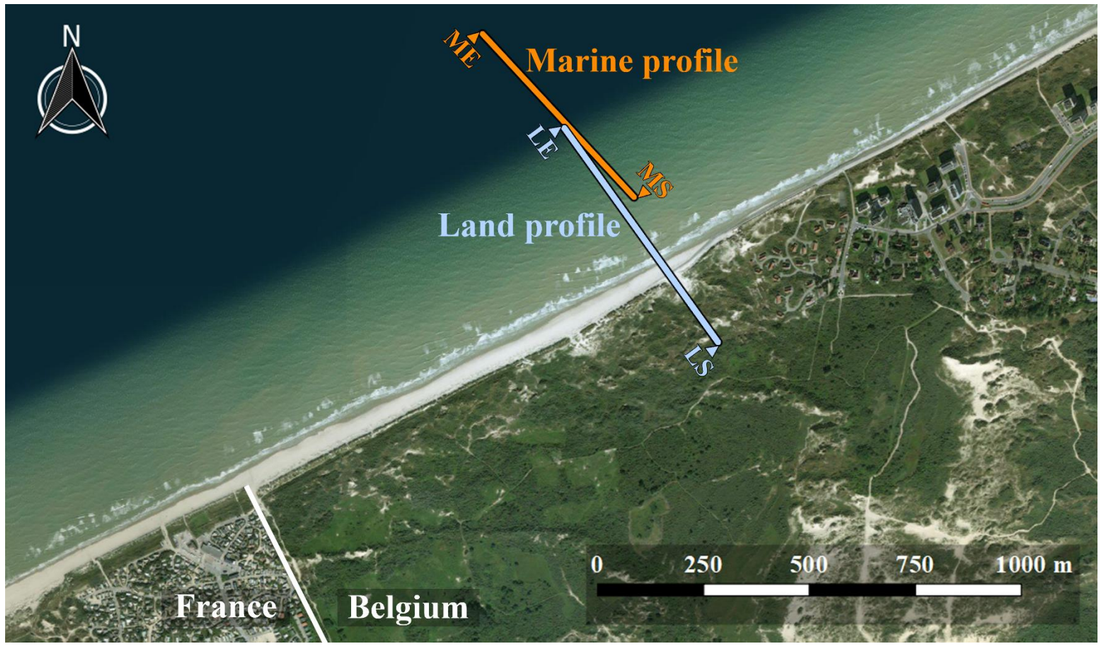
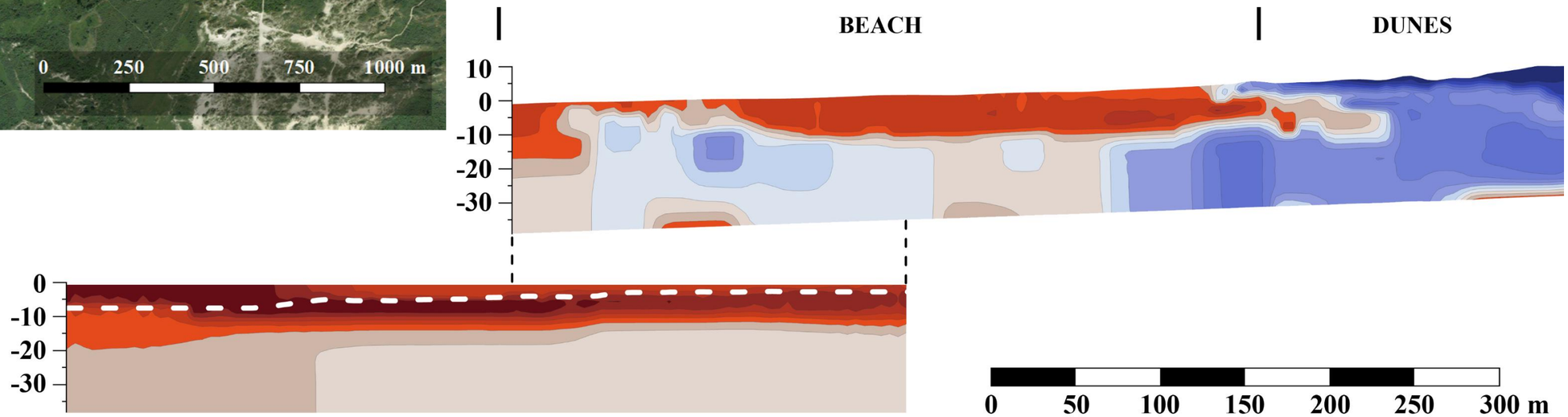
HOW TO COMBINE BOTH ?



Land profile



Marine profile

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Resistivity (Ωm)

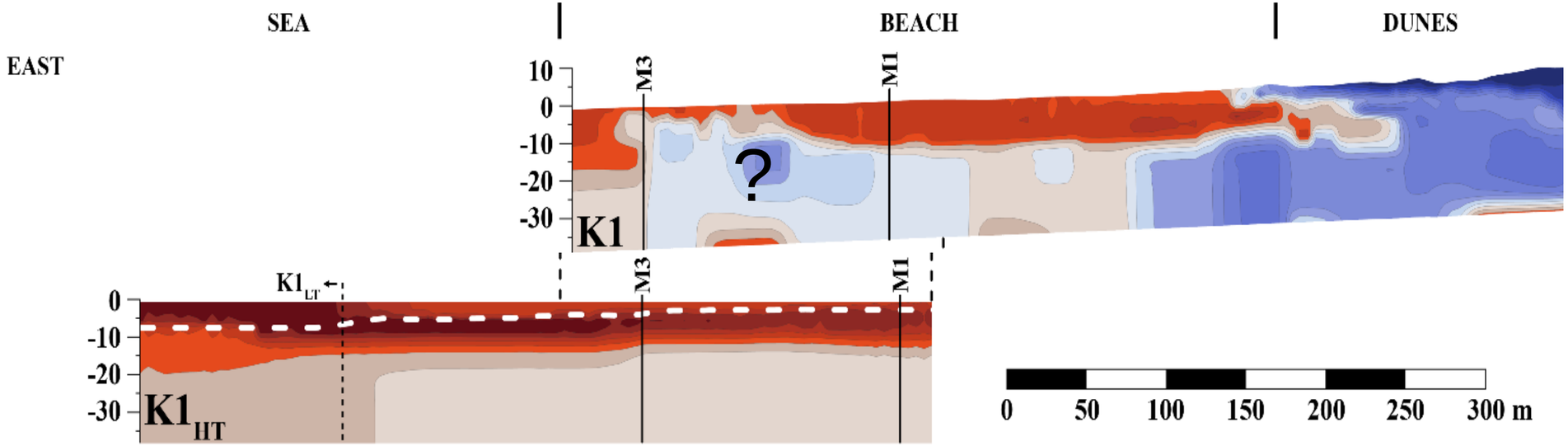
CAN WE GET A SINGLE MODEL ?

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



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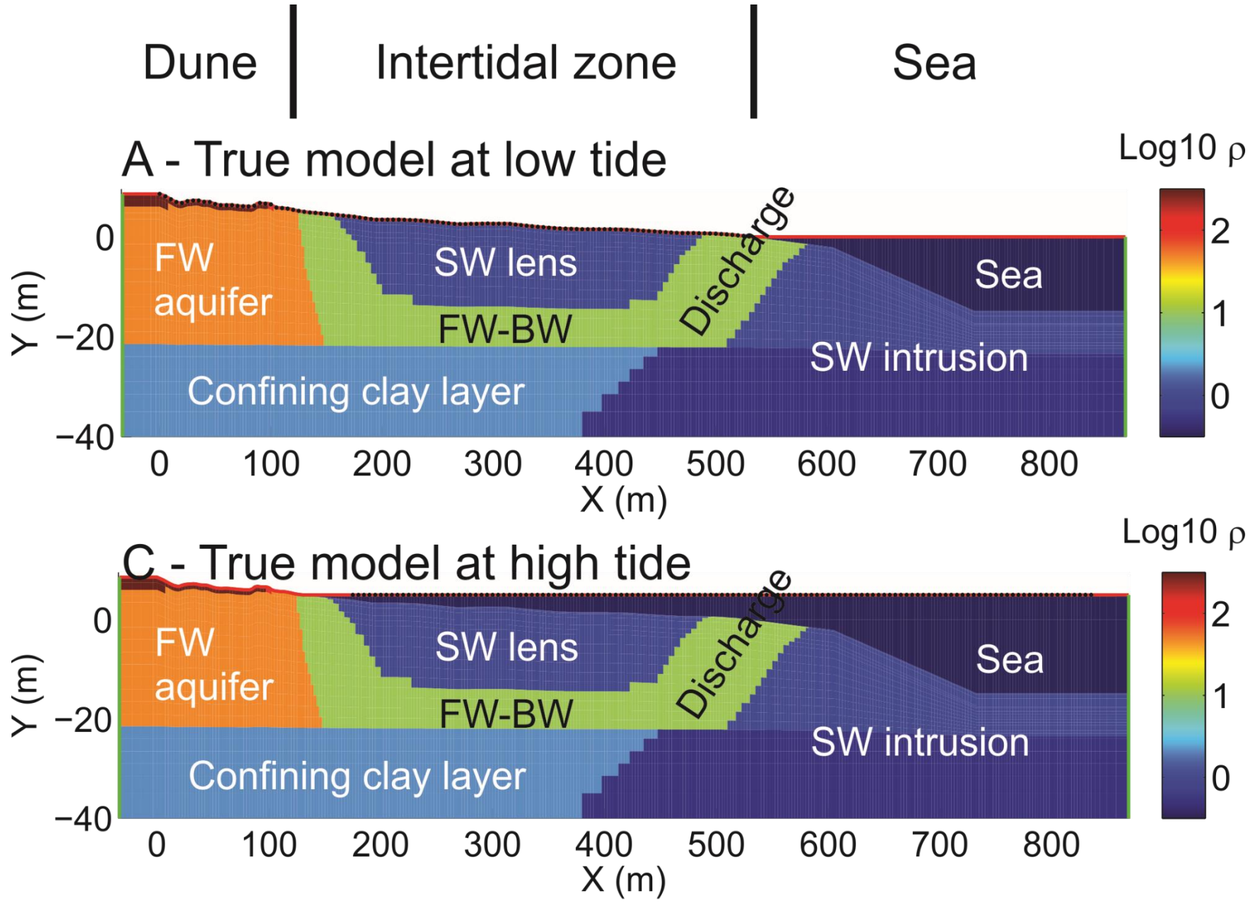
Resistivity (Ωm)

ACCOUNTING FOR THE SEAWATER LAYER



Land ERT at low tide

Marine ERT at high tide

The difference between the two conditions is the presence of the water layer during high tide for marine ERT

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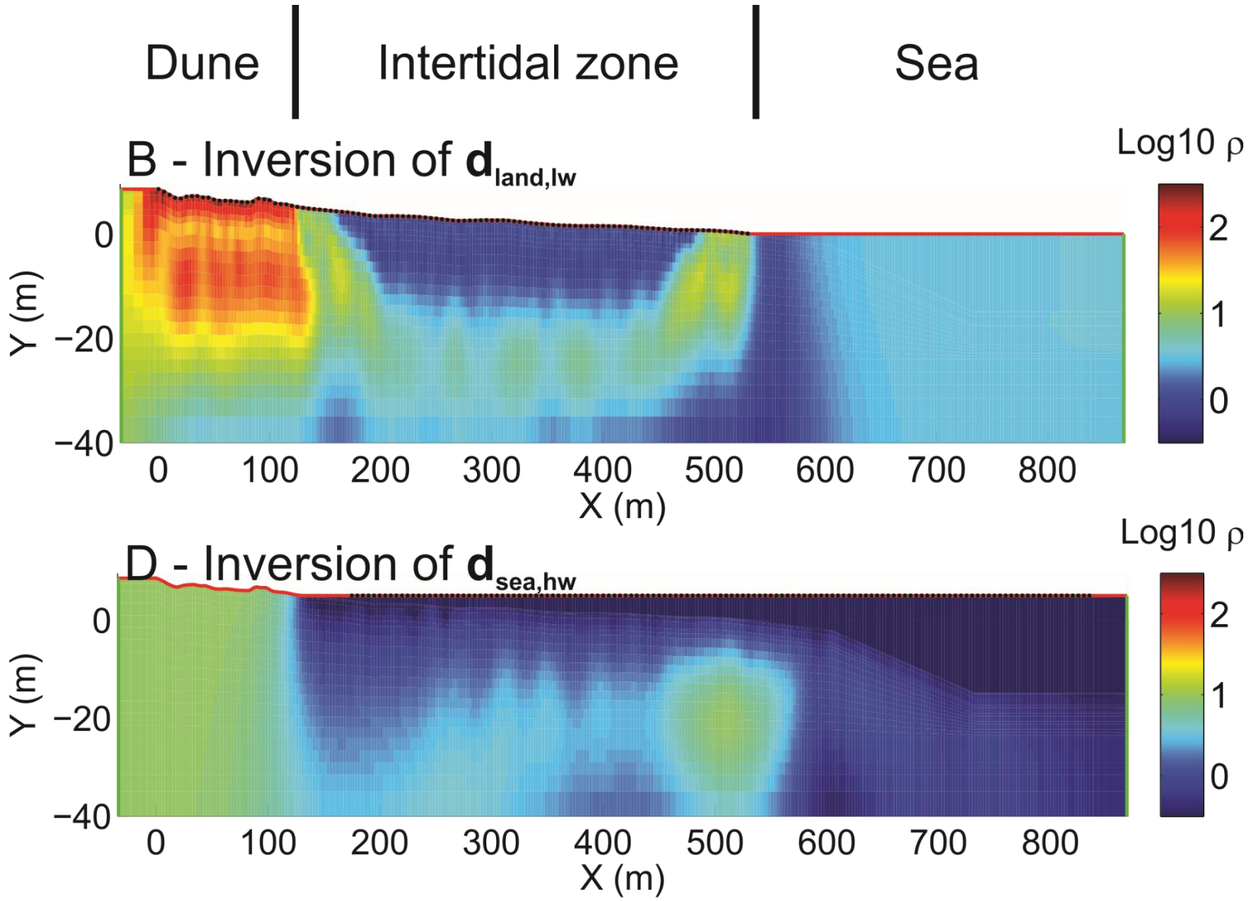
INDIVIDUAL INVERSIONS



Land ERT at low tide

Marine ERT at high tide

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

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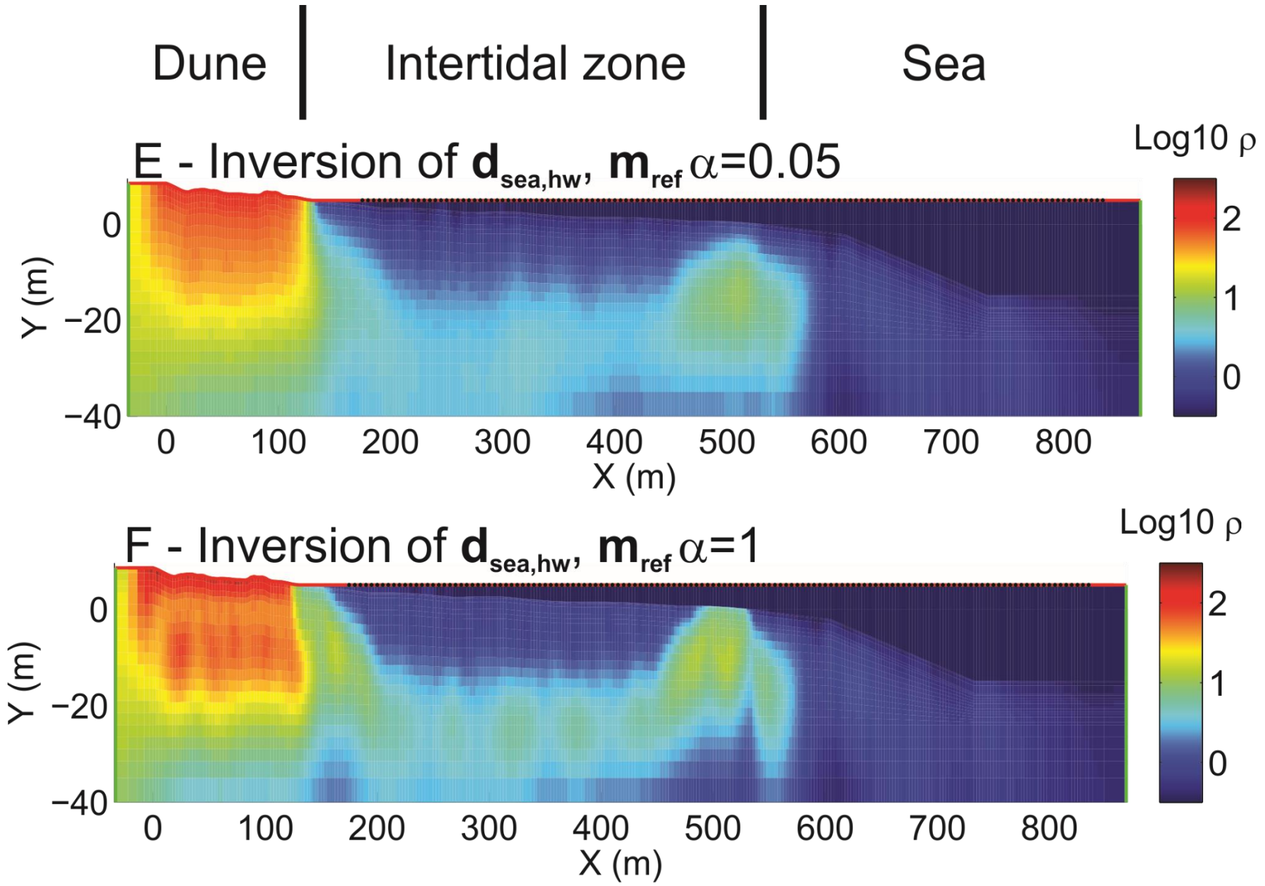
OPTION 1: LAND ERT AS A REFERENCE MODEL



Marine ERT at high tide with land as reference
Low weight

Marine ERT at high tide with land as reference
High weight

Improvement of the image

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

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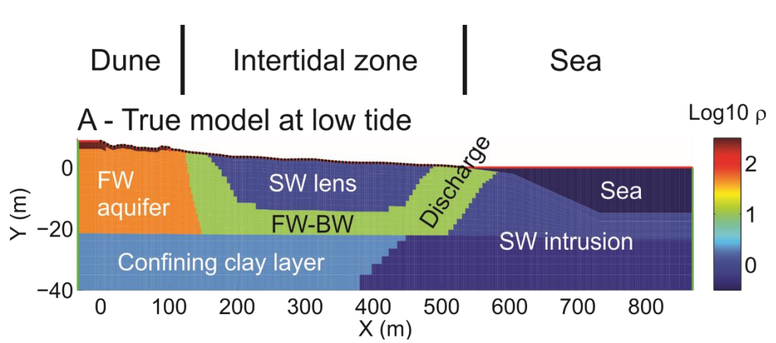
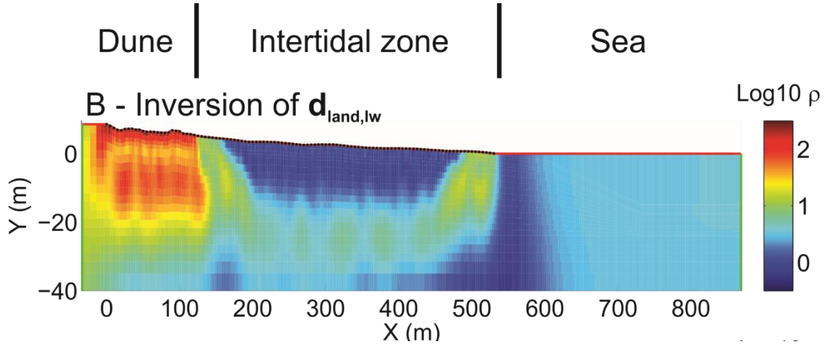
OPTION 2: DATA CORRECTION



1. Inversion

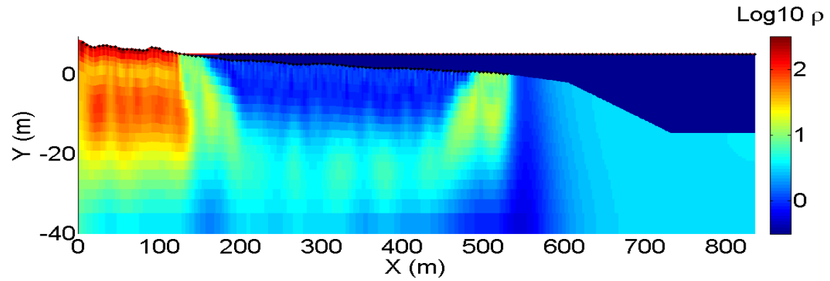


Collected data $\boldsymbol{d_{land,lw}}$ from $\boldsymbol{m_{true}}$

What would be the data at high tide $\boldsymbol{d_{land,hw}}$?

$$\boldsymbol{m_{est} \rightarrow d^{est}_{land,lw} = d_{land,lw} + \epsilon}$$

2. Simulate presence of water layer Forward model



$$\boldsymbol{d^{est}_{land,hw} = G(m_{est} + \Delta m)}$$

3. Data correction

$$\boldsymbol{\Delta d = d^{est}_{land,hw} - d^{est}_{land,lw}}$$

$$\boldsymbol{d_{land,hw} = d_{land,lw} + \Delta d}$$

$\boldsymbol{d_{land,hw}}$ is used with $\boldsymbol{d_{sea}}$ for a joint inversion

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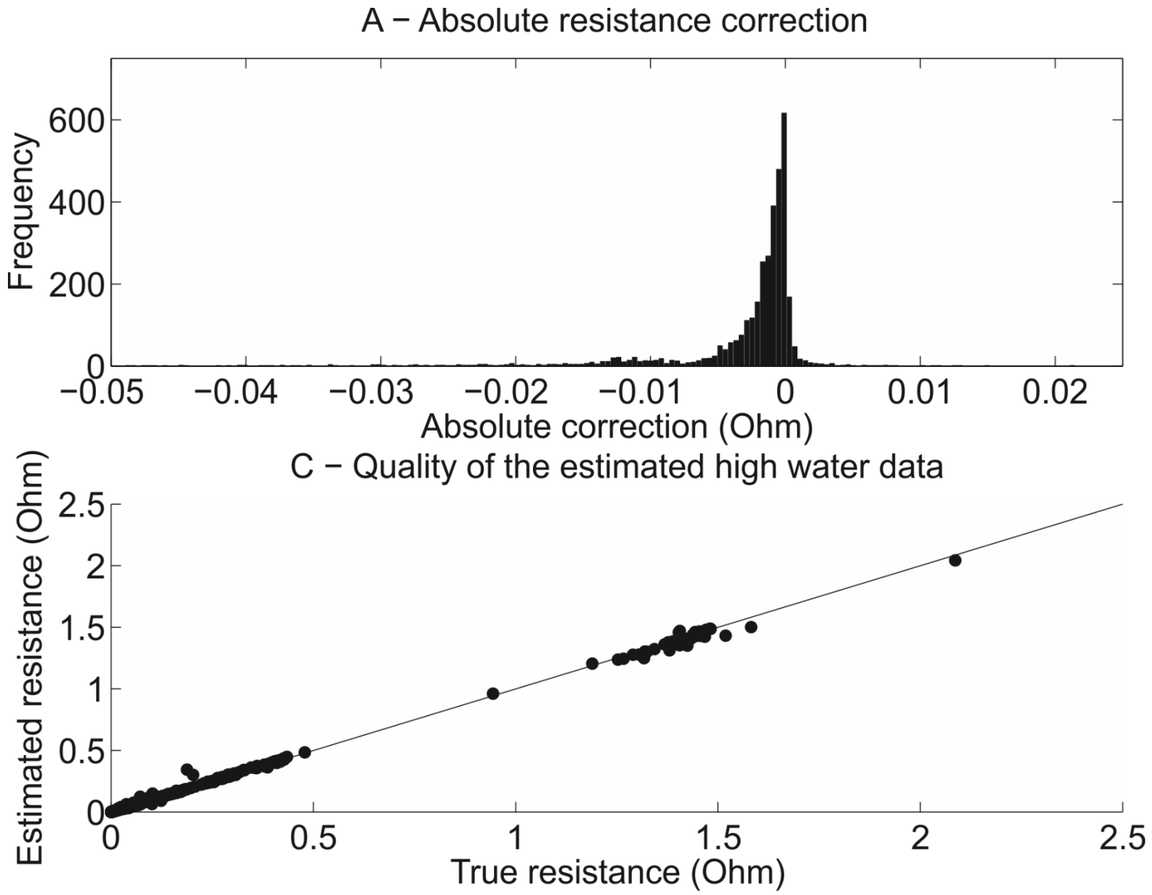
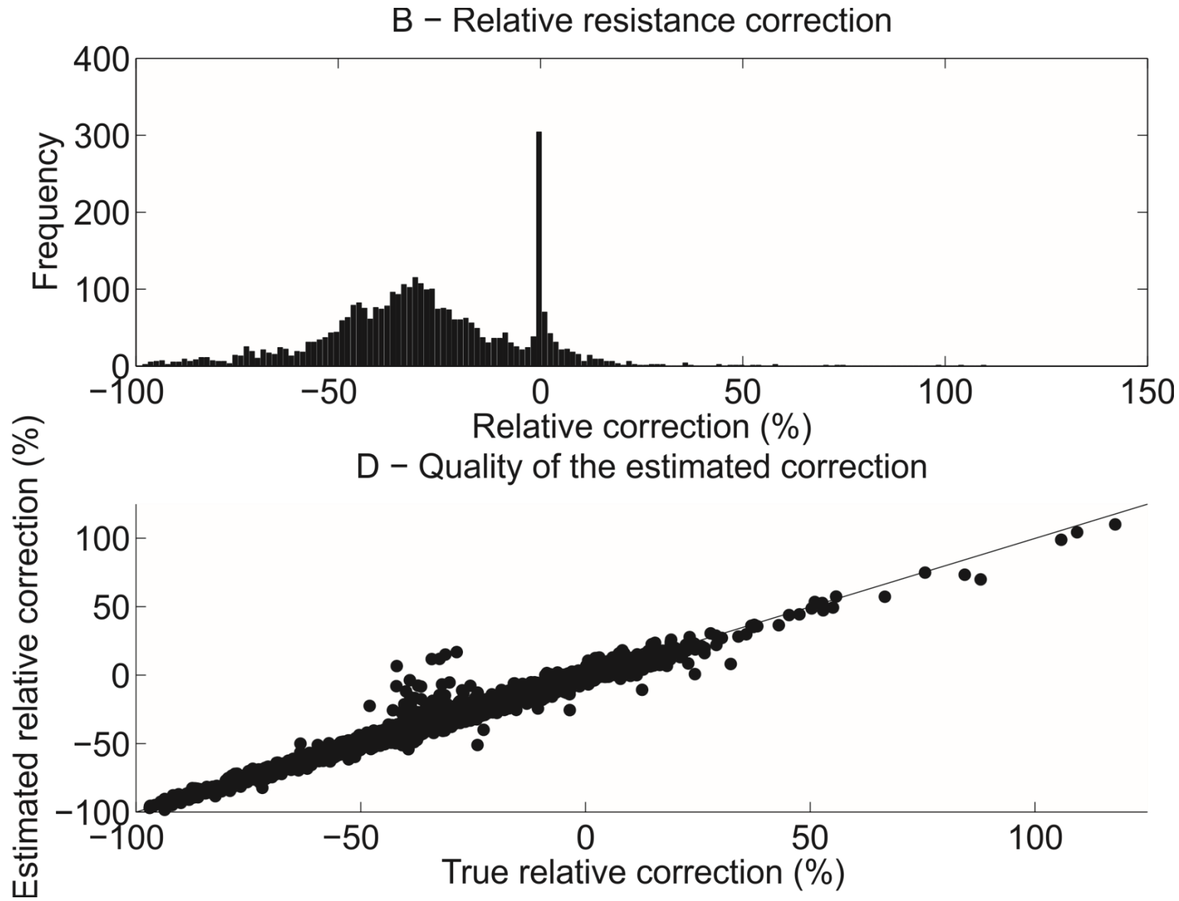
See Hayley et al. (2010, Geophysics) : data correction for temperature variations in time-lapse ERT

OPTION 2: QUALITY OF CORRECTION





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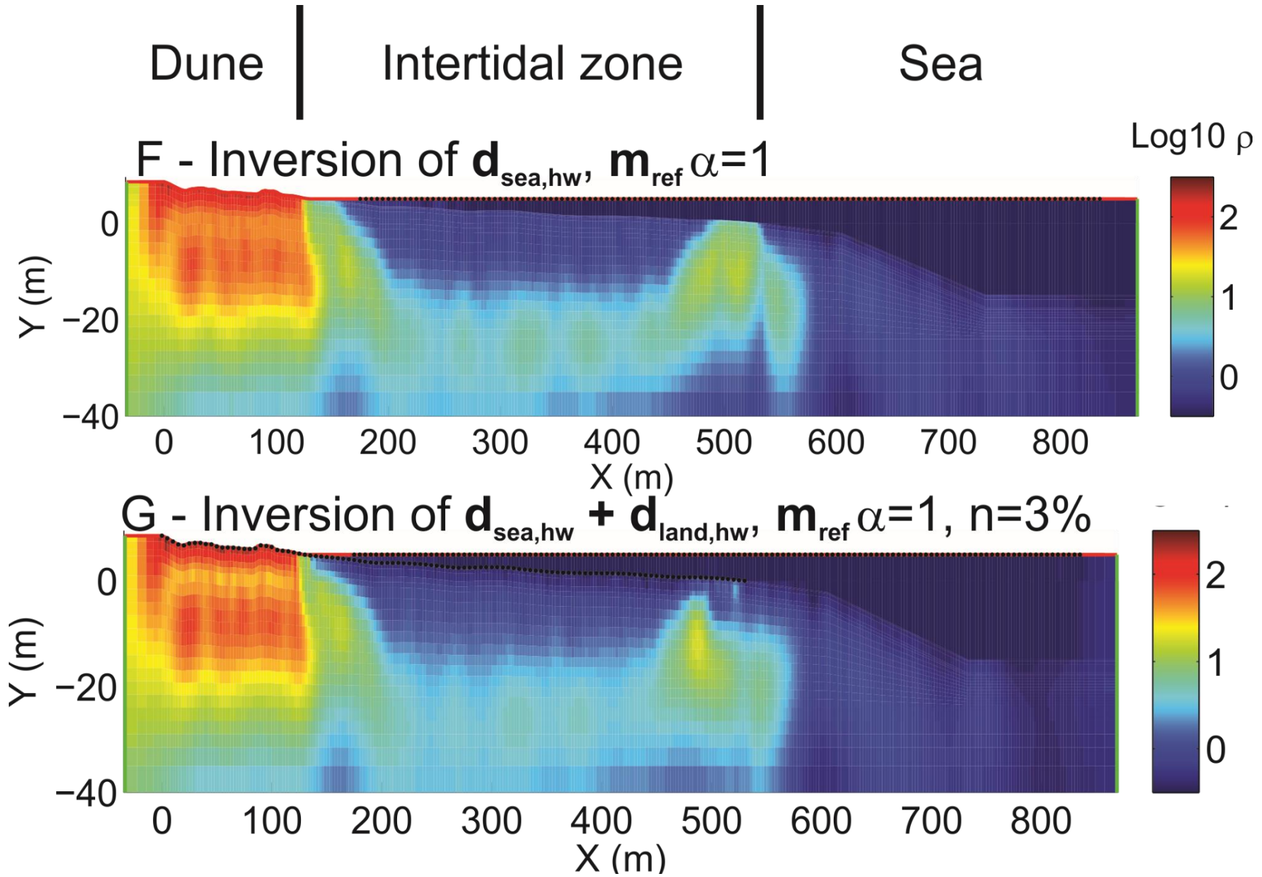
OPTION 2: JOINT INVERSION

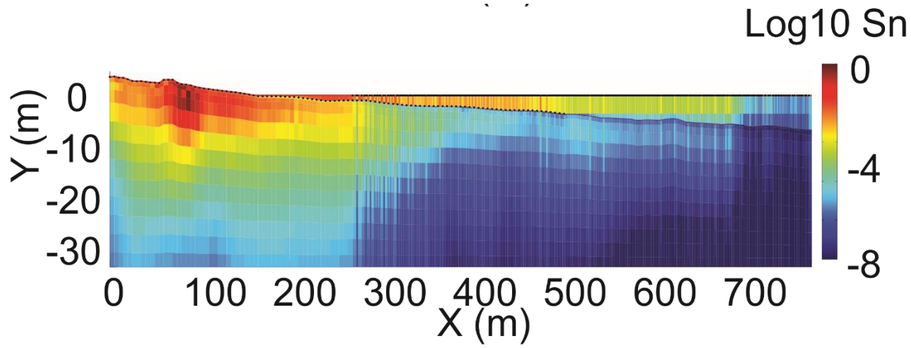


Marine ERT at high tide with land as reference

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

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



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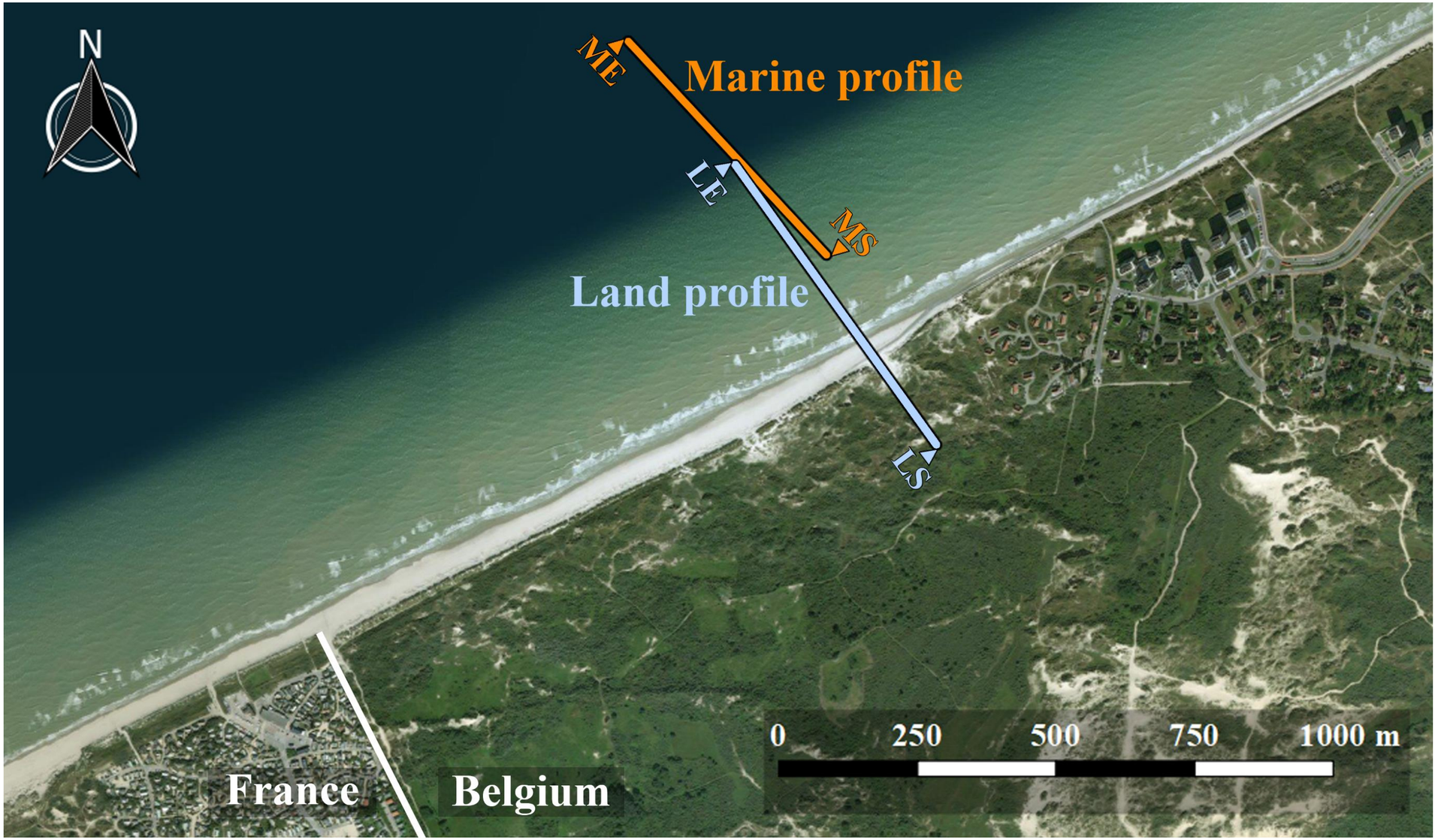
FIELD APPLICATION



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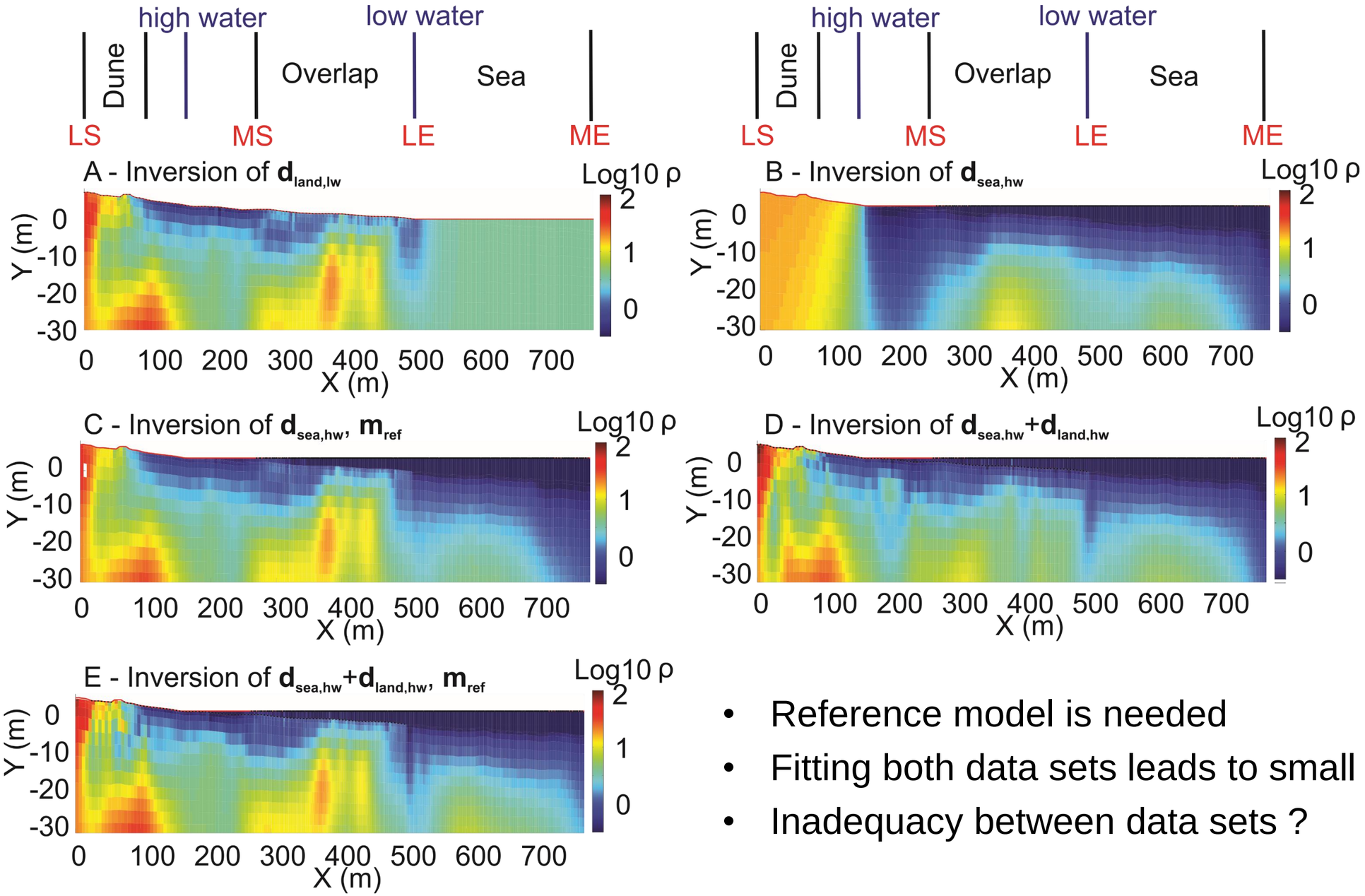
FIELD APPLICATION



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

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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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Hermans and Paepen. 2019. Geophysical Research Letters, pending revisions

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

- Immediate extension to monitoring of tide processes

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OPTION 2: DATA CORRECTION

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

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

3) Taylor's approximation: $\boldsymbol{G(m_{true} + \Delta m) = G(m_{true}) + \frac{\partial G(m_{true})}{\partial m} \Delta m}$

4) Taylor's for data: $\boldsymbol{d_{land,hw} = d_{land,lw} + \frac{\partial d_{land,lw}}{\partial m} \Delta m}$

5) Estimating: $\boldsymbol{d^{est}_{land,lw} = G(m_{est}) = d_{land,lw} + e}$

6) Estimating: $\boldsymbol{d^{est}_{land,hw} = G(m_{est} + \Delta m)}$

7) Estimating the derivative: $\boldsymbol{\frac{\partial d_{land,lw}}{\partial m} = \frac{d^{est}_{land,hw} - d^{est}_{land,lw}}{\Delta m}}$

8) Estimating: $\boldsymbol{d_{land,hw} = d_{land,lw} + (d^{est}_{land,hw} - d^{est}_{land,lw})}$

9) Joint inversion of $\boldsymbol{d_{land,hw} + d_{sea,hw}}$

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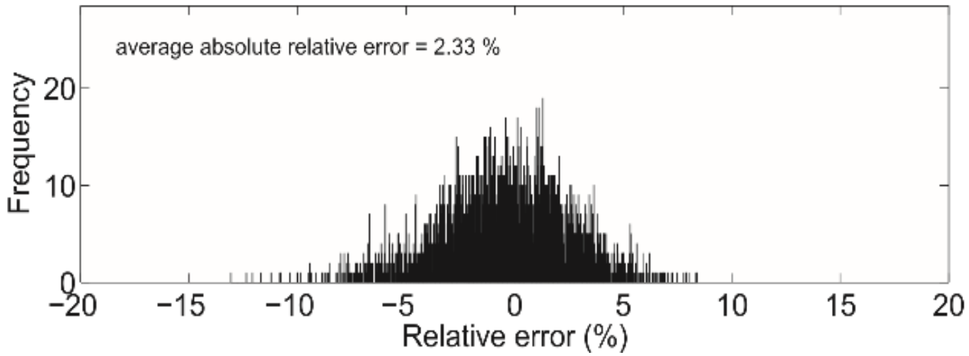
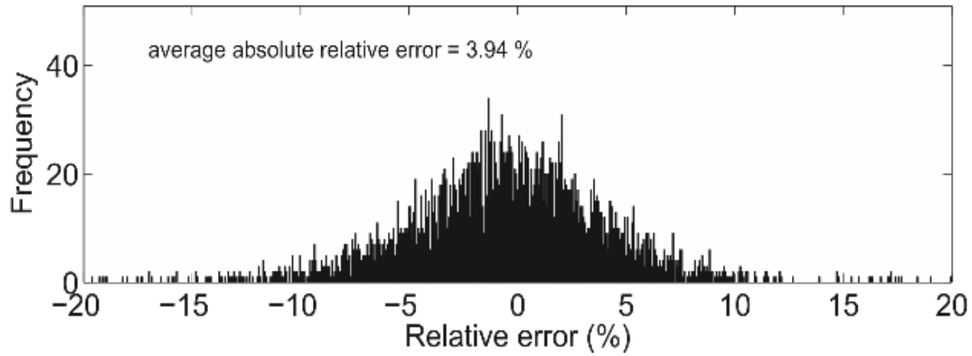
See Hayley et al. (2010, Geophysics) : data correction for temperature variations in time-lapse ERT

NOISE CONSIDERATION

Before correction

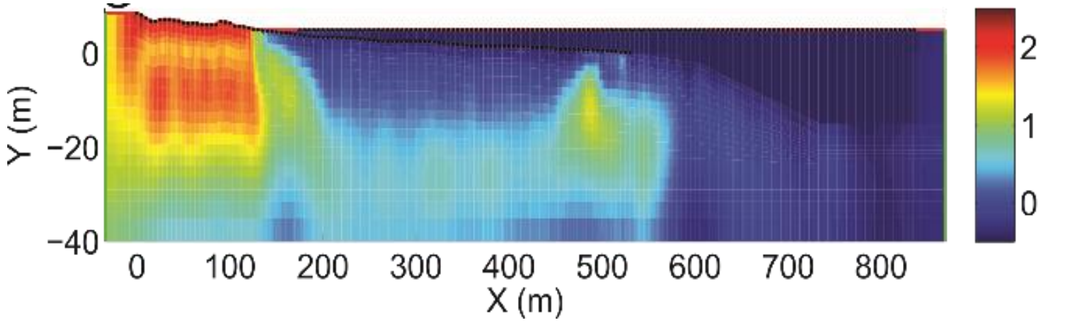


After correction

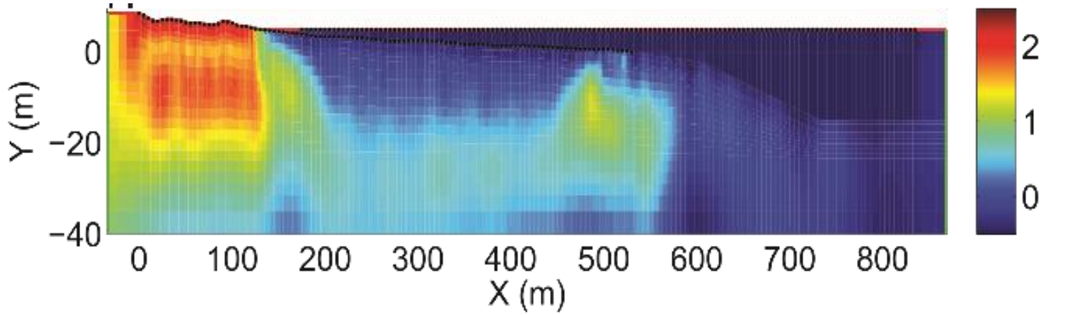


Apparent increase of the relative noise level, because the average resistance decreases

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

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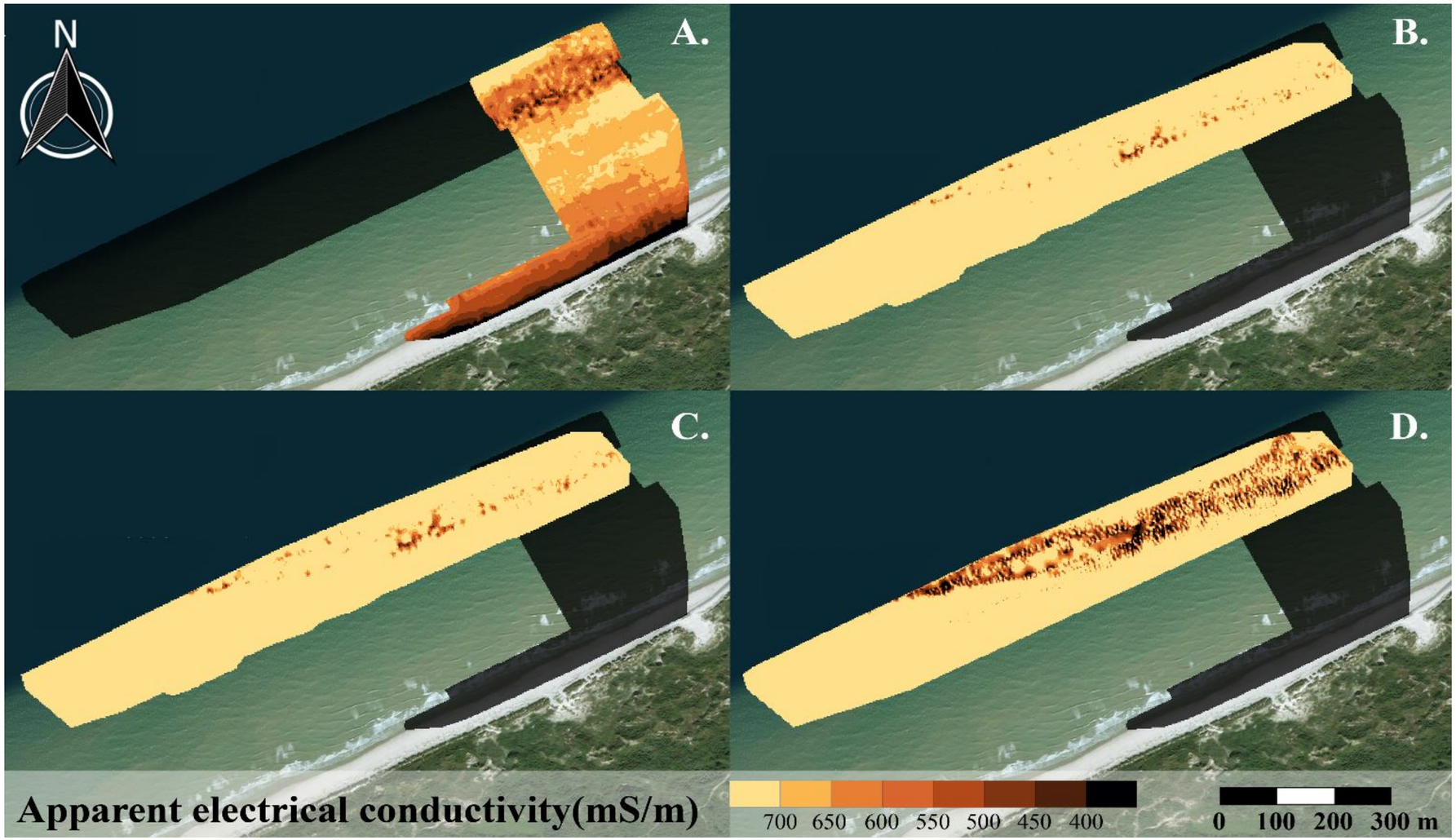
VALIDATION OF THE FRESHWATER DISCHARGE



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