Ocean effect correction in global inversion of geomagnetic observatory data

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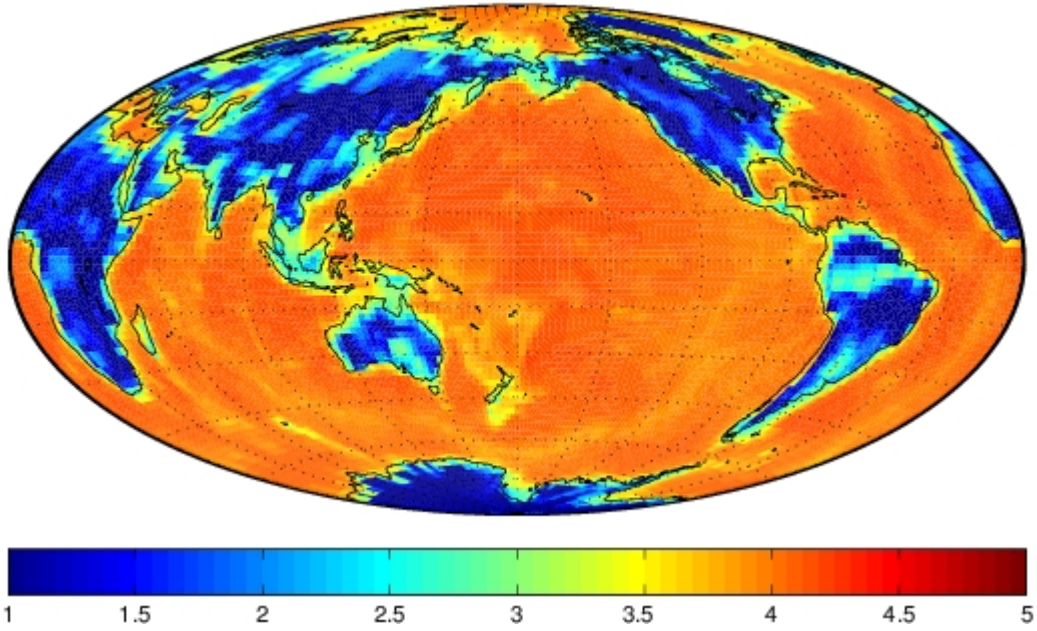
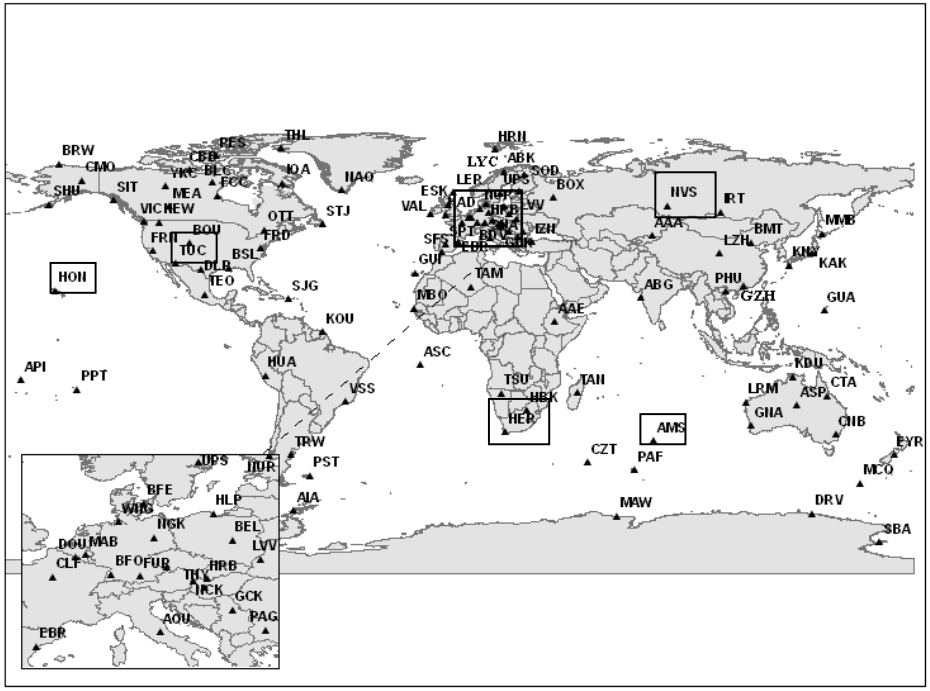
Introduction

- High-contrast between conductive sea water and water-rich ocean sediments vs. resistant igneous rocks from continents
- Sparsity of observations doesn't allow to reconstruct the global near-surface conductivity by EM inversion methods
- Empirical surface conductance based on bathymetry, topography, sediment thickness, and a-priori estimates of electrical conductivity of individual materials has been assembled (Everett et al. 2003)

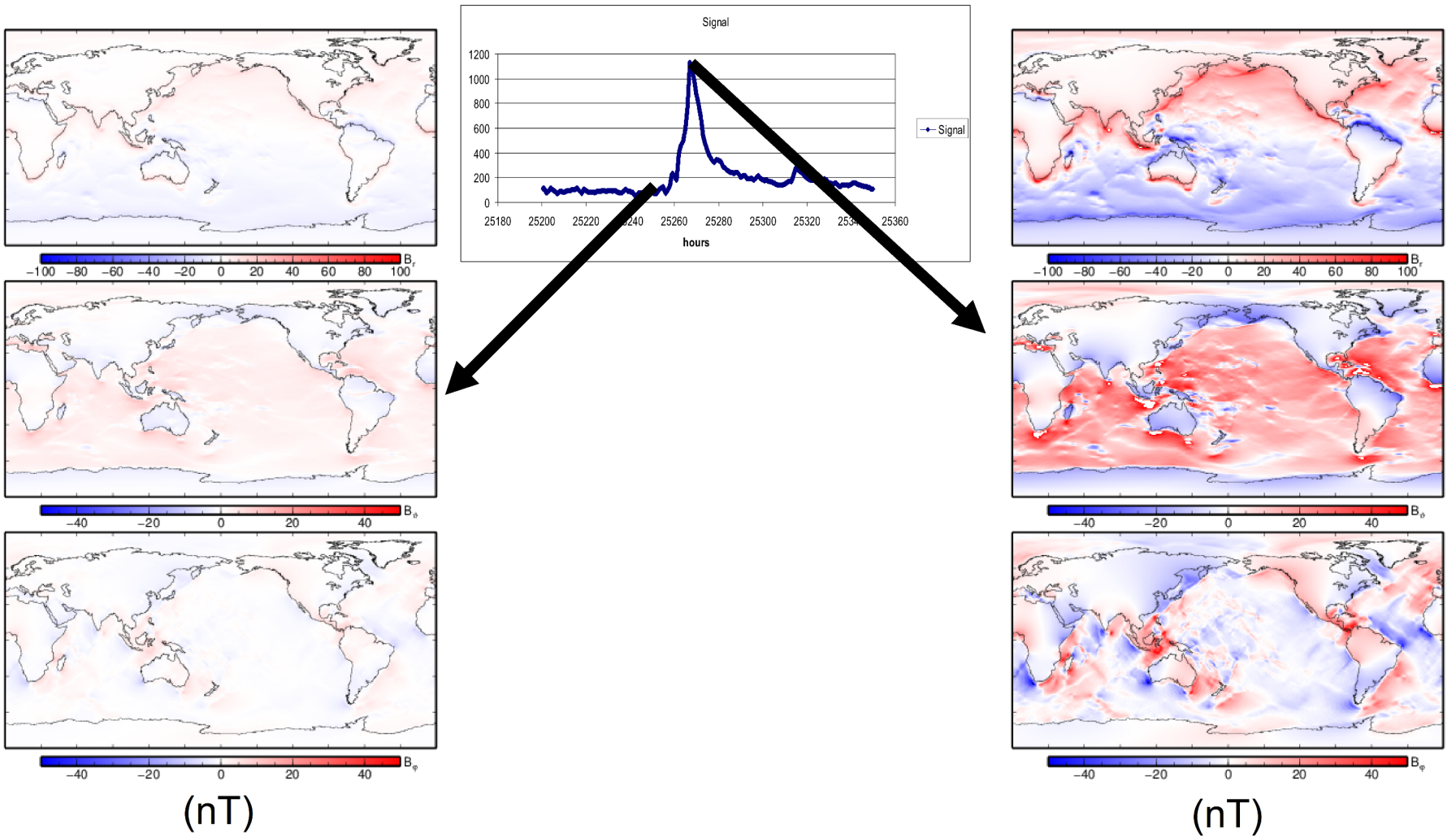


Introduction

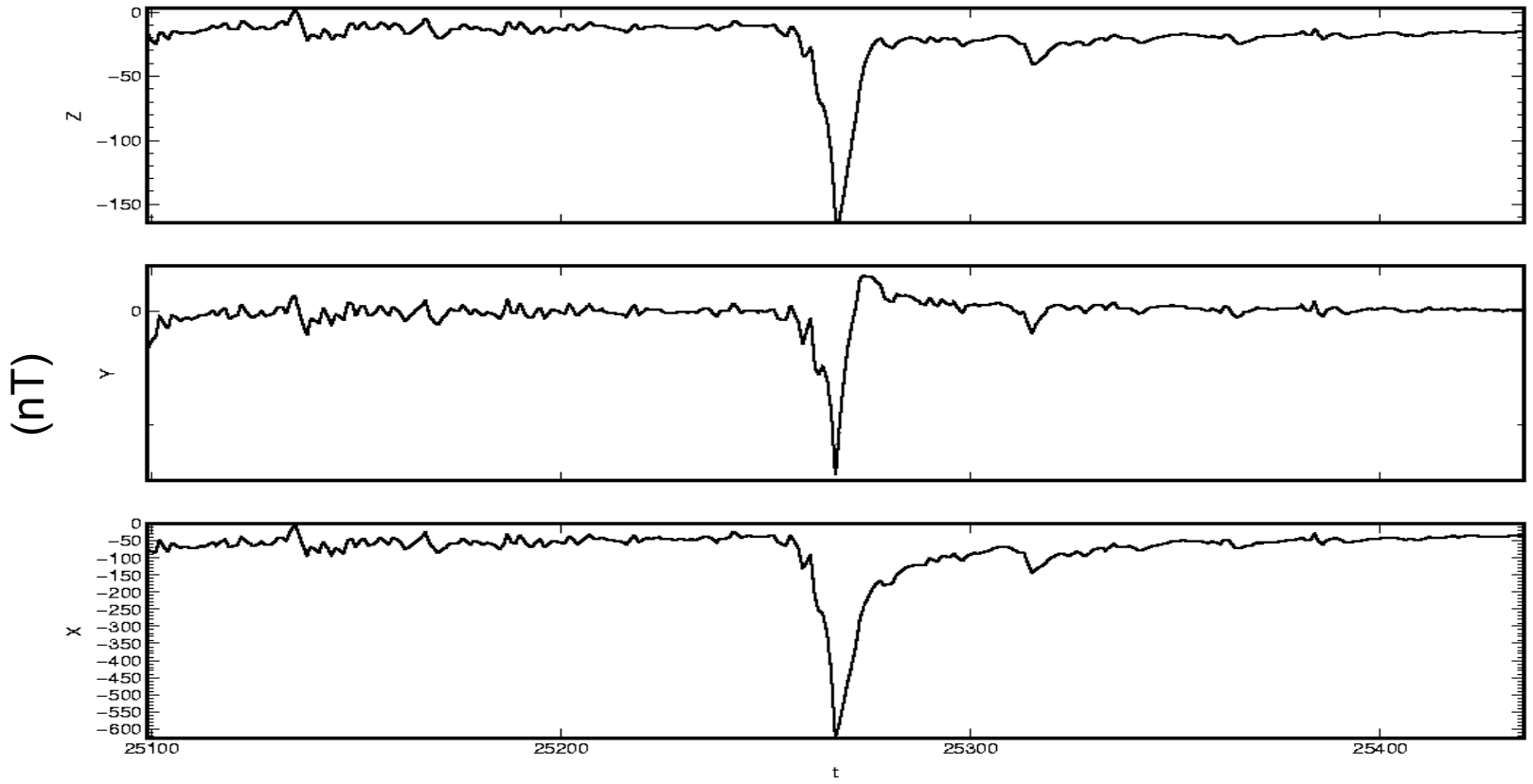
- Effect of large lateral conductivity contrasts is strongly manifested at the coastal observatories
- It has to be removed from data prior 3-D inversion for deep mantle conductivity structures
- Frequency-domain approach based on C-responses: Kuvshinov & Olsen 2006
- Time-domain approach: this study



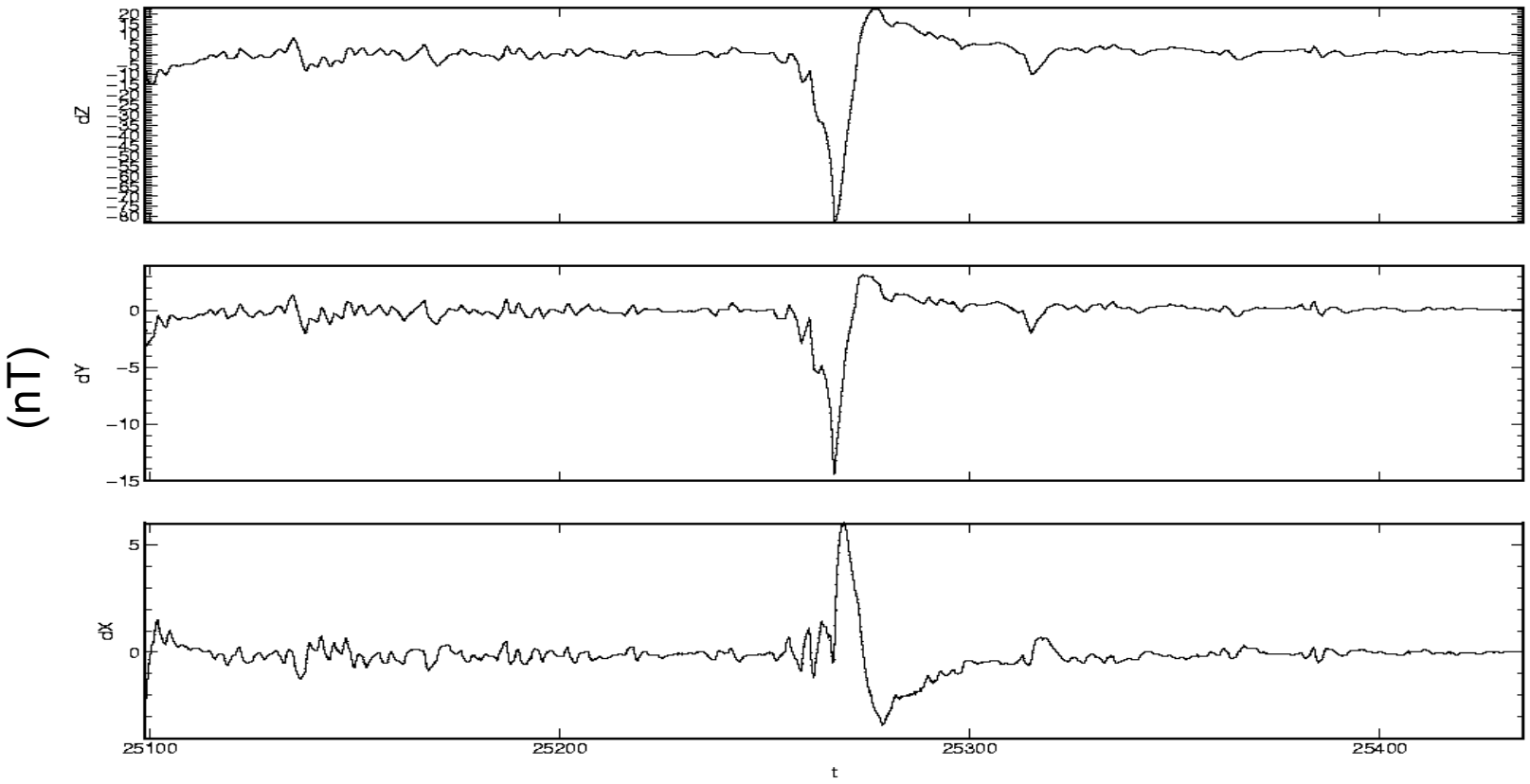
Difference maps before and at the signal peak



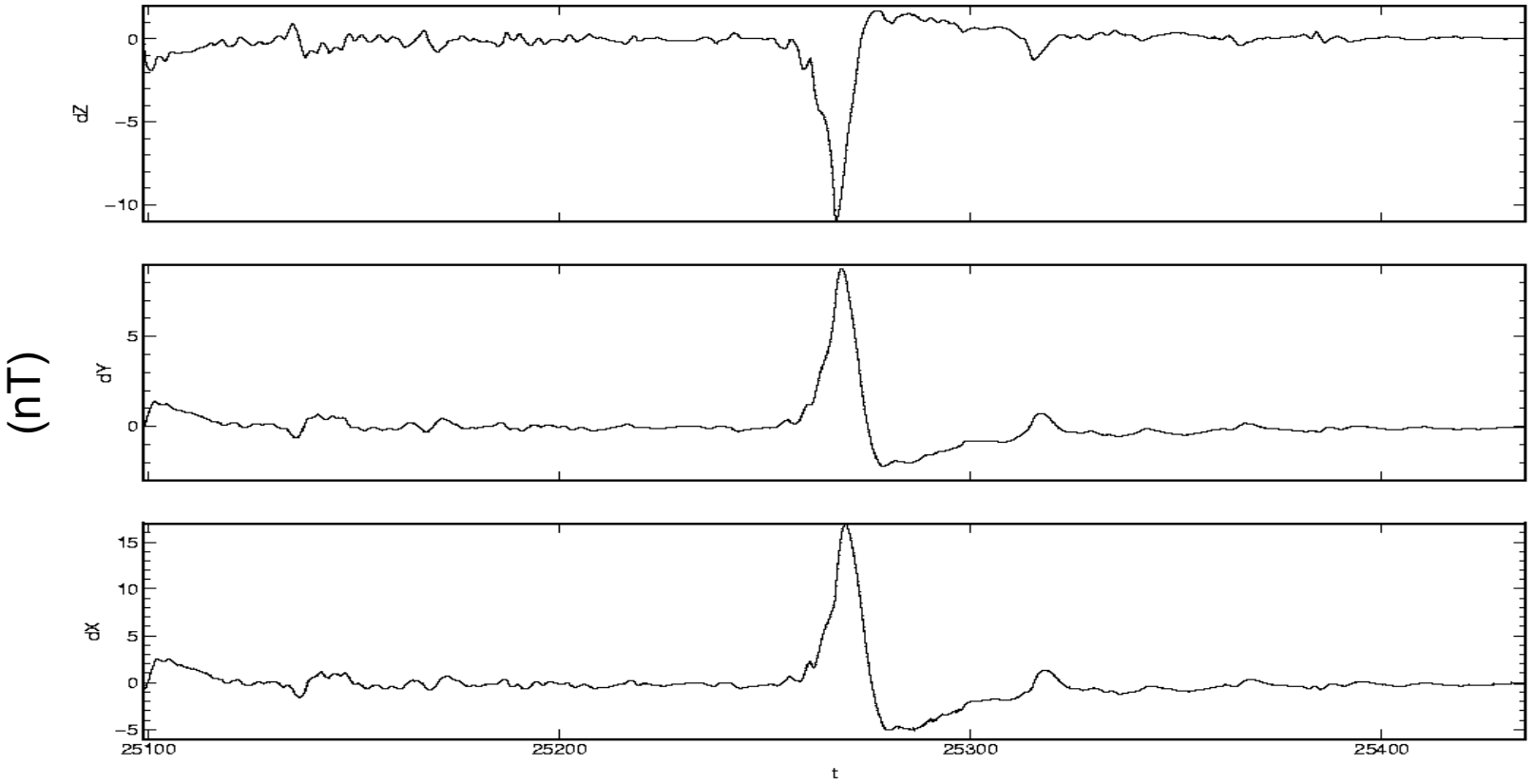
Time series for HER observatory (coastal)



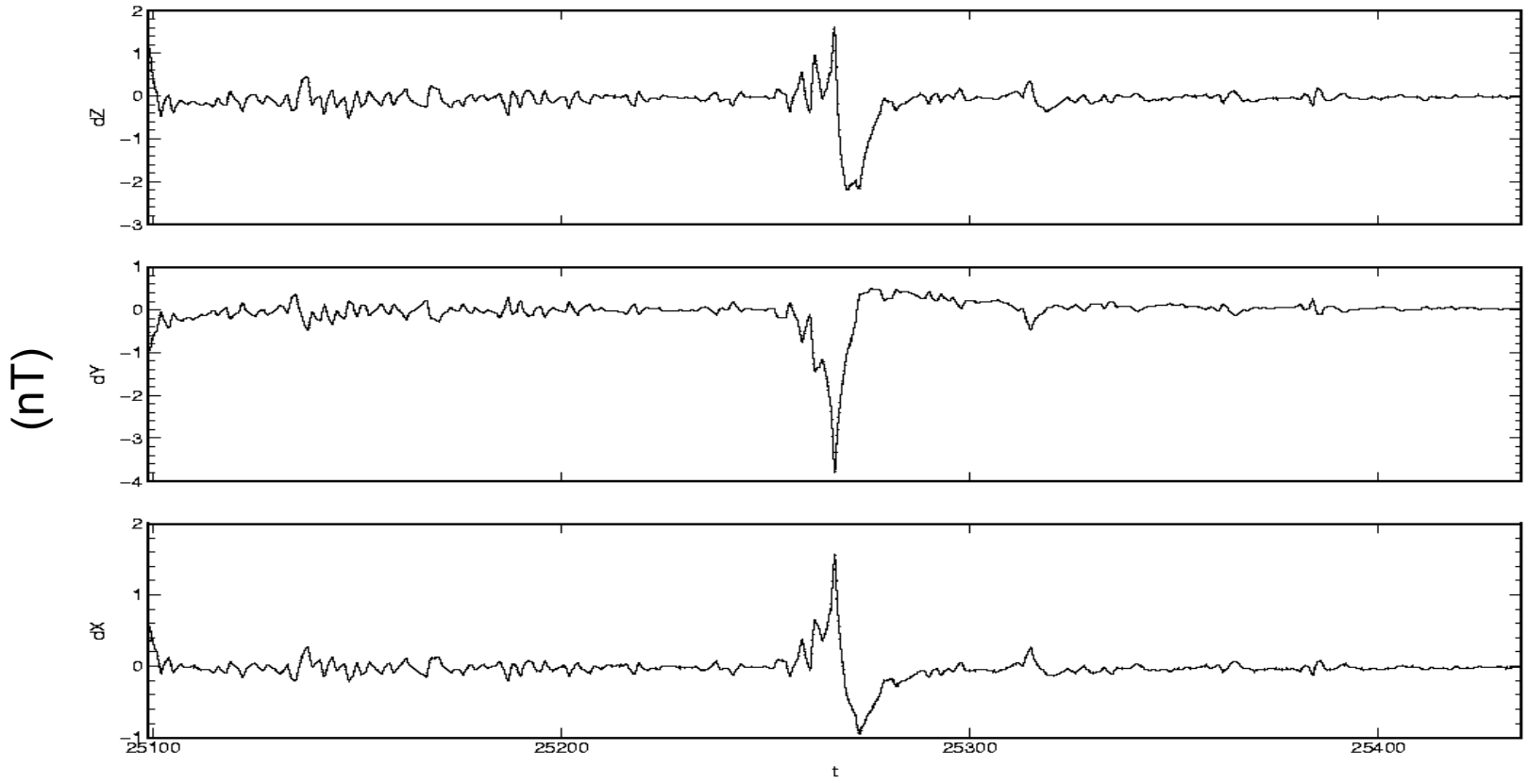
Difference for HER observatory (coastal)



Difference for HON observatory (oceanic)



Difference for NVS observatory (continental)



Inverse problem with an approximate forward operator

- We have a non-linear forward problem d = F(m), where d is vector of predicted data and m is vector of parameters.
- F(m) is computationally expensive, we can afford only few runs.
- F'(m) is a low-resolution approximation of F(m). It is fast and can be computed many times in the inversion scheme.
- $m = F'^{-1}(d)$ is a non-linear regularized inverse problem, which uses the approximate forward solver F'(m).

Inverse problem with an approximate forward operator

We introduce following iterative scheme:

- select a starting model m_0
- predict the error caused by use of approximate forward operator and correct the observed data: $d^{corr} = d^{obs} – (F(m_i) – F'(m_i))$
- invert corrected data: $m_{i+1} = F'^{-1}(d^{corr})$
- repeat until $|m_{i+1} - m_i| < \varepsilon$
- if the operators F, F', F'^{-1} were linear, we could write $m_{i+1} – m_i = F'^{-1}(d^{obs} – F(m_i))$
- then if $m_{i+1} – m_i \rightarrow 0$, also $m_i \rightarrow F^{-1}(d^{obs})$

Synthetic test

- High-resolution forward solver F:

j_{max} = 80, Δt = 0.01 h, implicitly includes the surface conductance map

- Low-resolution forward solver F':

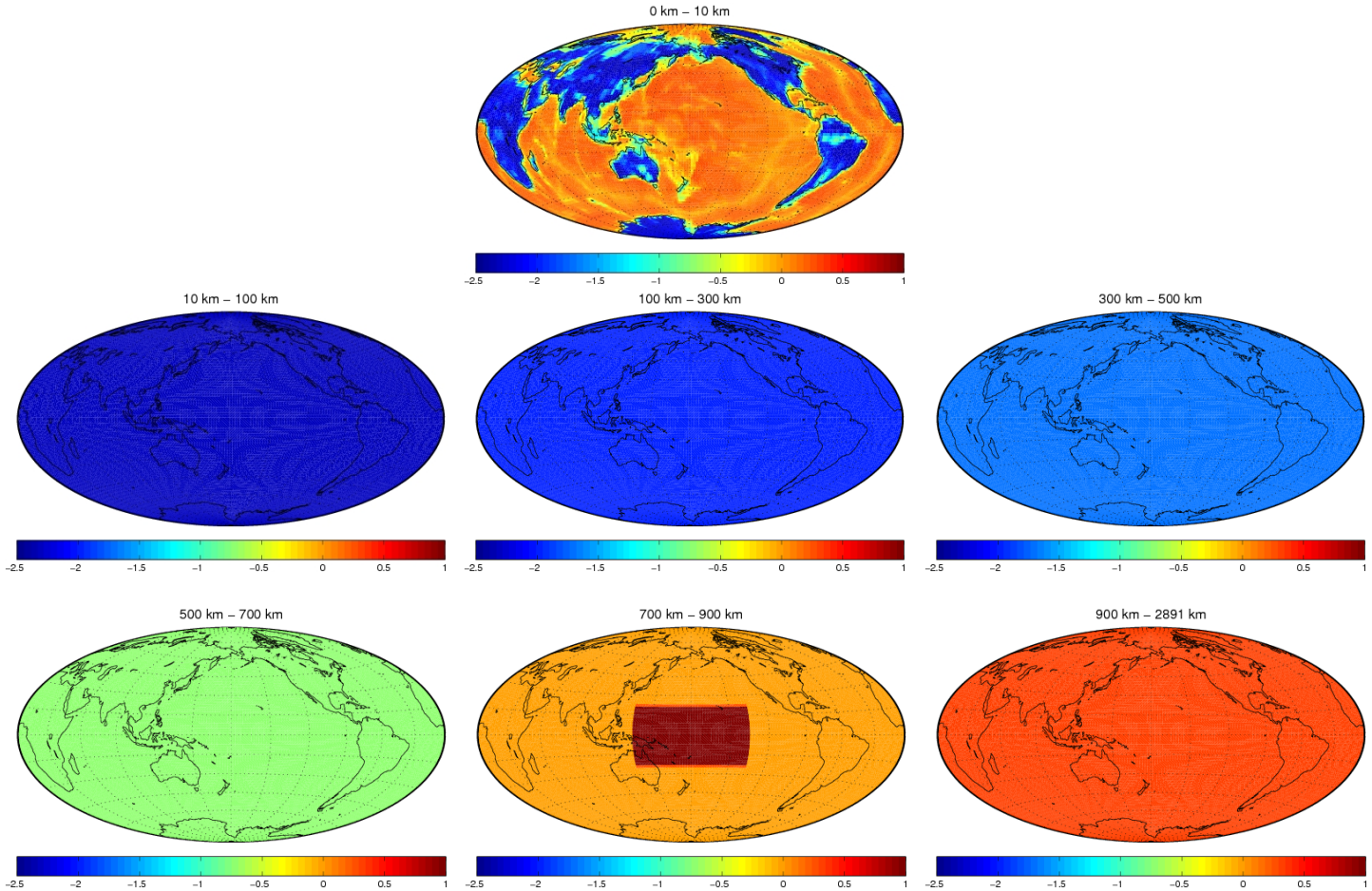
j_{max} = 8, Δt = 1 h, surface conductance map not included.

We make one iteration of our scheme to test its formulation.

Synthetic dataset

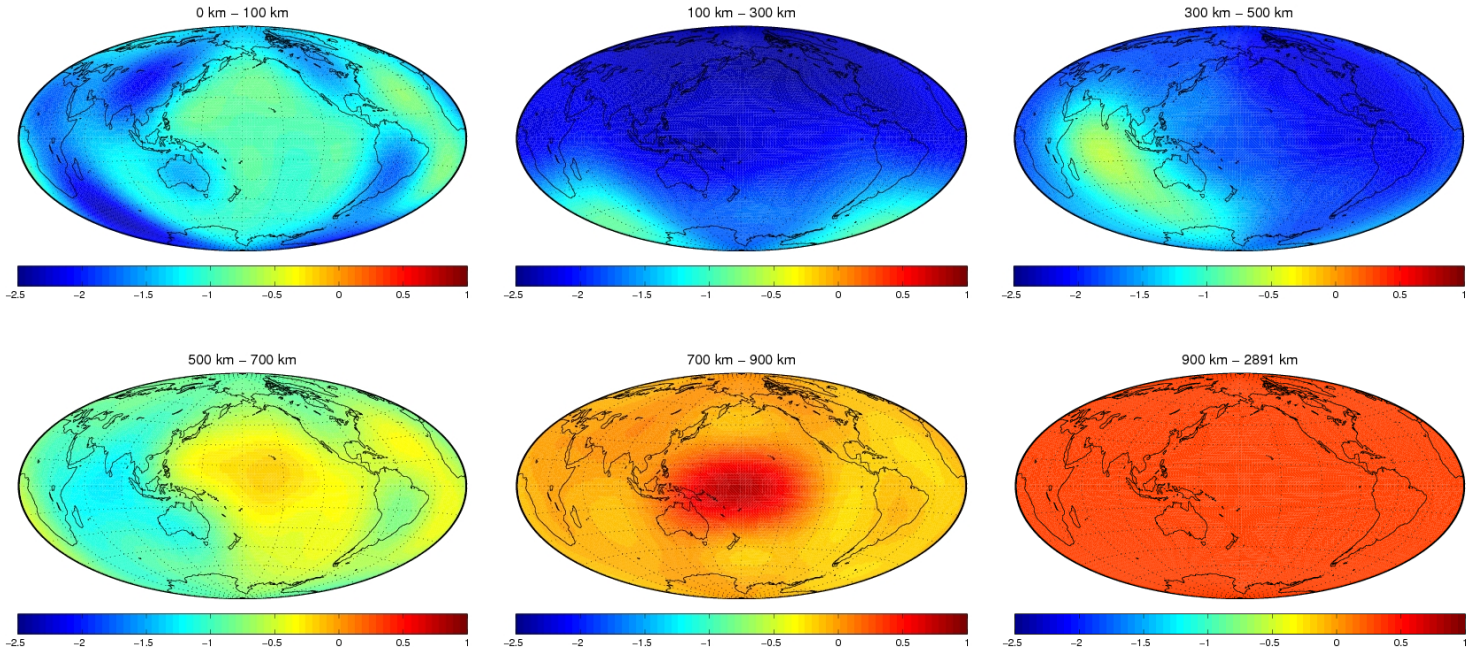
- 1-D background conductivity profile with an 45° x 90° conductive block of 200 km thickness positioned at the depth of 700 km

1-D + block → F → $G_{jm}^{(i,obs)}$

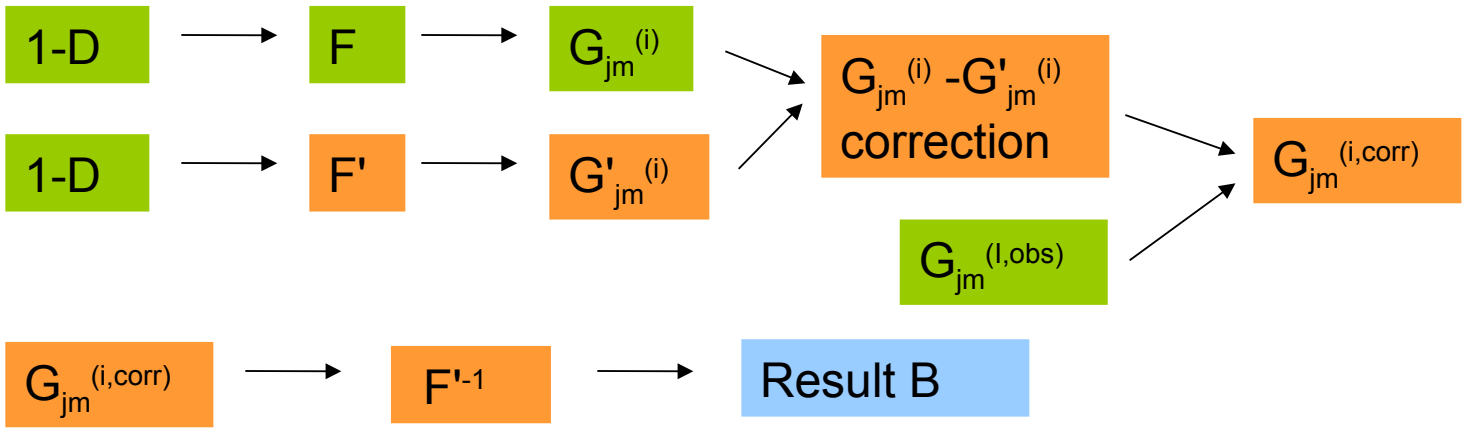


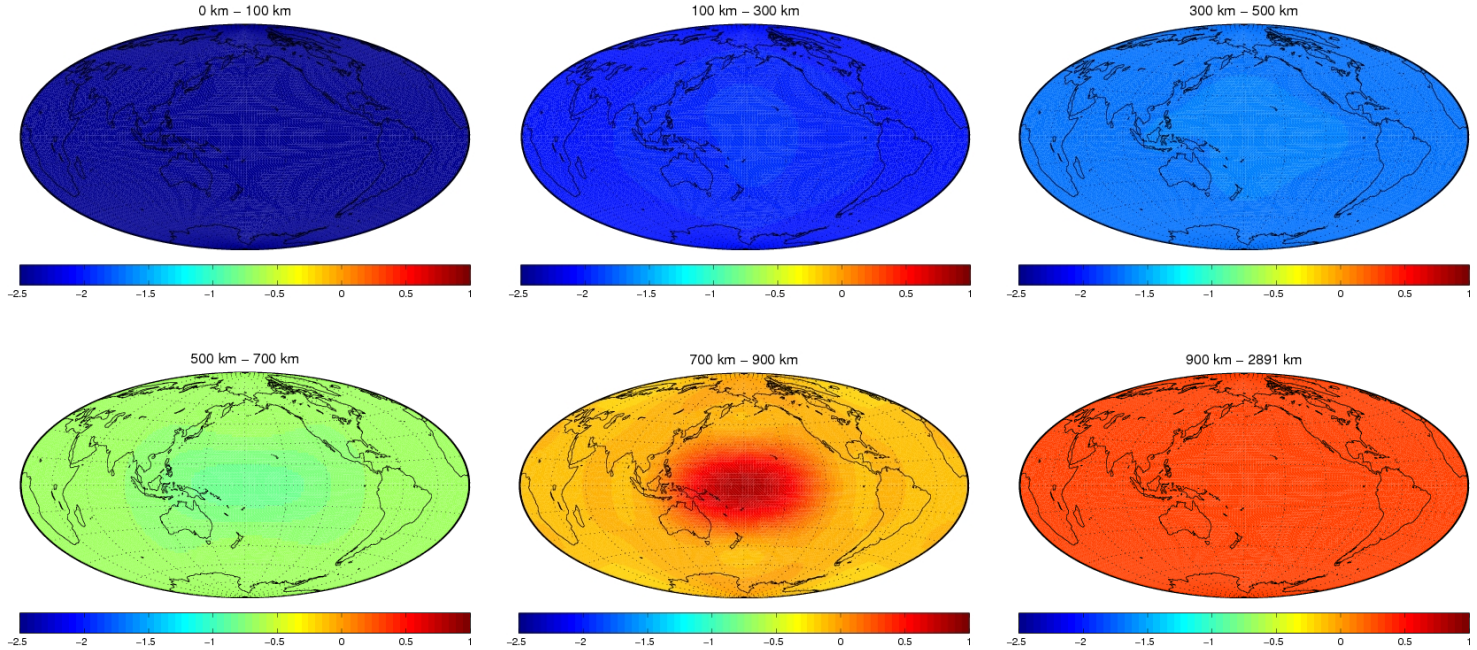
Inversion without correction

$G_{jm}^{(i,obs)}$ → F'^{-1} → Result A



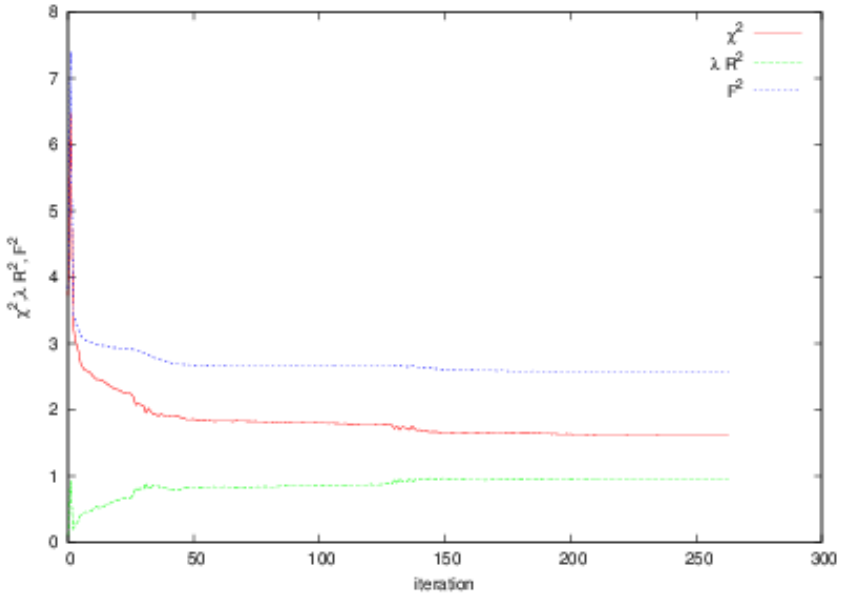
Inversion with correction



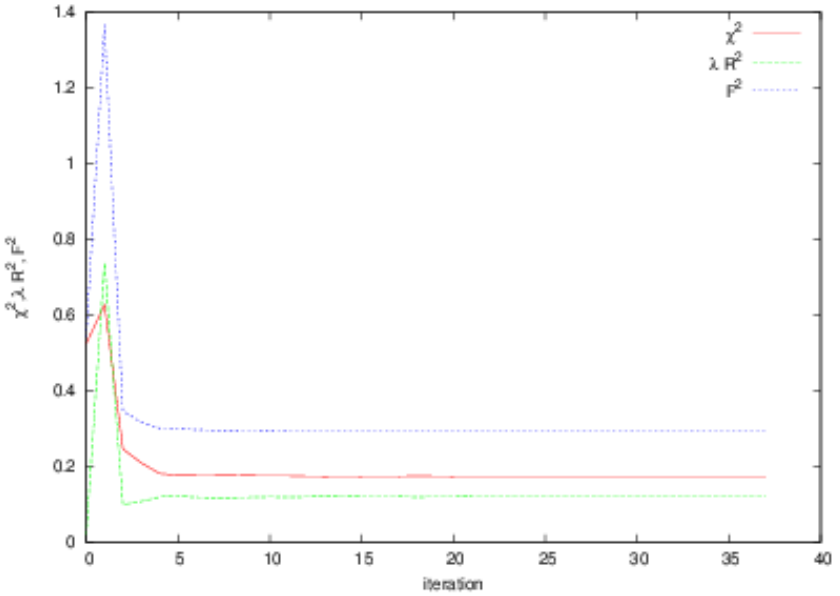


Convergence rates of the inversions

Uncorrected data



Corrected data



Conclusions

- Ocean effect is crucial for inverse EM modelling
- Ignoring it can lead so significant spurious lateral conductivity variations in the upper mantle
- For synthetic model the iterative scheme built on HR and LR forward solution is able to remove these artifacts
- Only one step of our iteration scheme was sufficient in the case of synthetic test model

Work in progress

- Ocean effect corrections will be applied directly to observatory data
- Spherical harmonic analysis (SHA) and synthesis (SHS) will be incorporated in the scheme