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Topographic Distortions of Magnetotelluric Transfer Functions: a High Resolution 3-D Modelling Study using Real Topography

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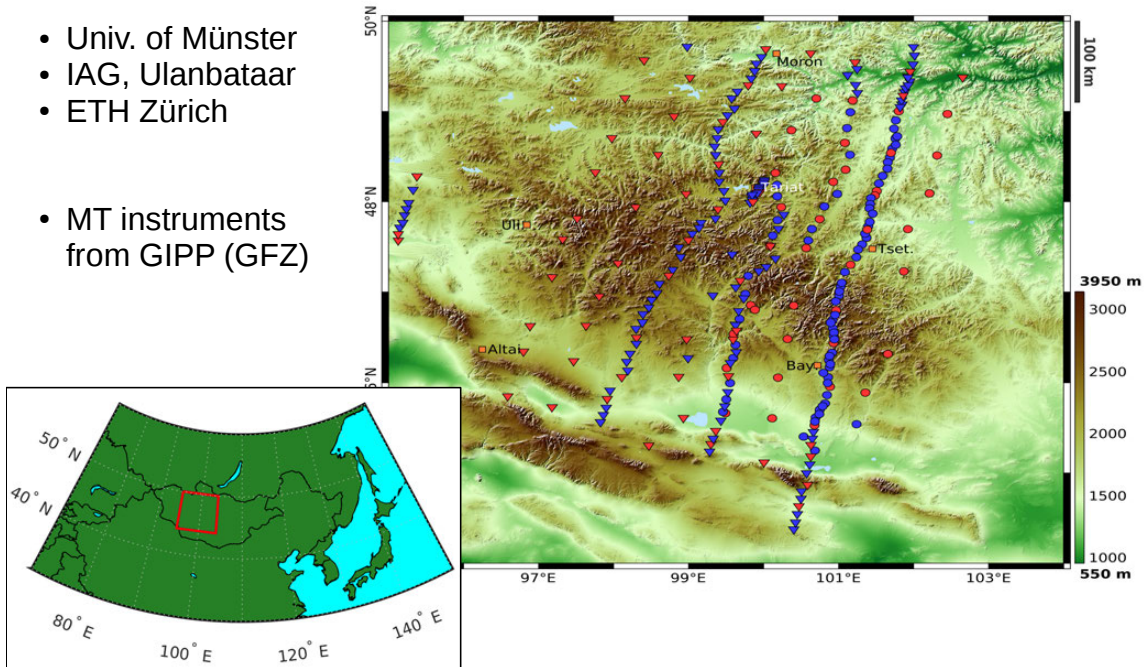ETH Zürich, Switzerland

| 12.12.2014 | 1

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Topographic Distortions of MT TF

3D MT survey to understand volcanism and uplift mechanisms in the Hangai Mountains (Mongolia)

- Univ. of Münster
- IAG, Ulanbataar
- ETH Zürich

- MT instruments from GIPP (GFZ)

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Central Questions

- What are the physics behind topographic distortions?

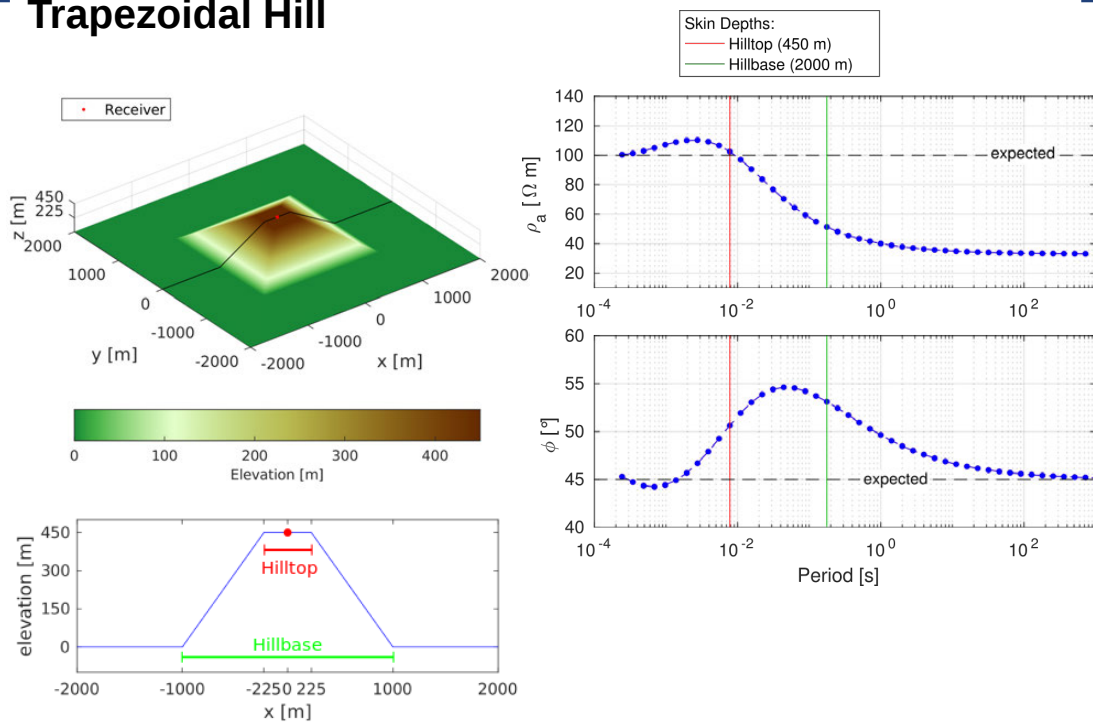- What is the effect of real topography on MT TF?

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Methodology

- Modelling of transfer functions
  - homogeneous subsurface: $\rho = 100\ \Omega\text{m}$
  - topography at the surface
  - **GOFEM:** FEM with 2nd order Nedelec elements & locally refined meshes (Grayver & Kolev, 2015)

- Transfer Functions:
  - impedance **Z**: $\vec{E}_h = \mathbf{Z}\,\vec{H}_h$
  - tippers **T**: $H_z = \mathbf{T}\,\vec{H}_h$
  - phase tensor: $\boldsymbol{\Phi} = \Re\mathbf{Z}^{-1}\,\Im\mathbf{Z}$

- Analytical values:

  $\rho_a = 100\ \Omega\text{m and } \phi = 45^o$

  $\mathbf{T} = (0\ 0)$

  $\boldsymbol{\Phi} = \mathbf{I}\ \text{ with e=0, } \theta = 0 \text{ and } \Psi = 0$
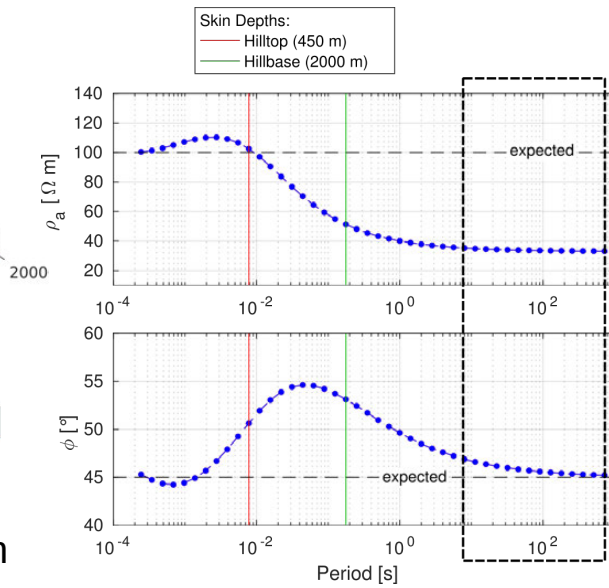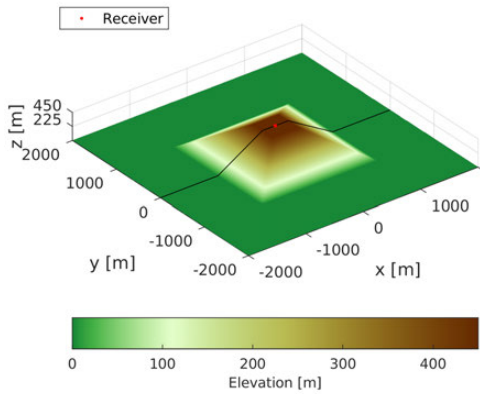
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Trapezoidal Hill
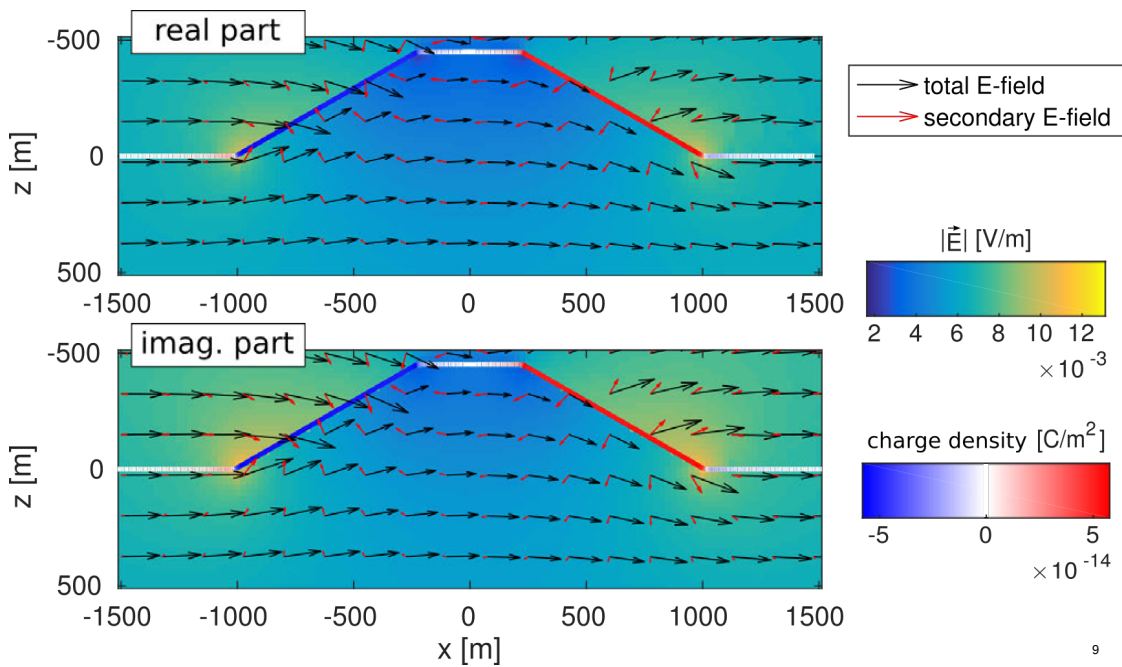

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Galvanic Distortions

- Charge accumulation on slopes
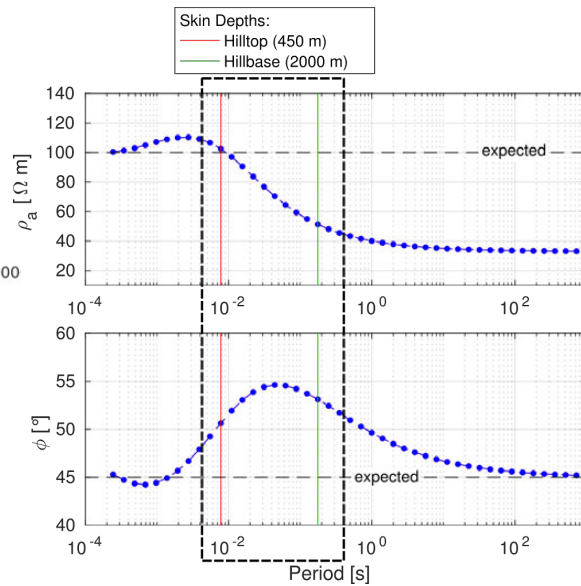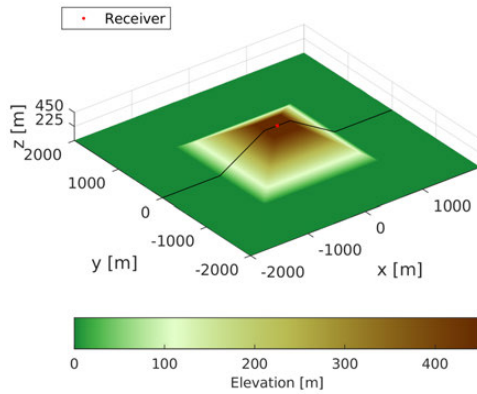- Only the amplitude of **Z** is distorted

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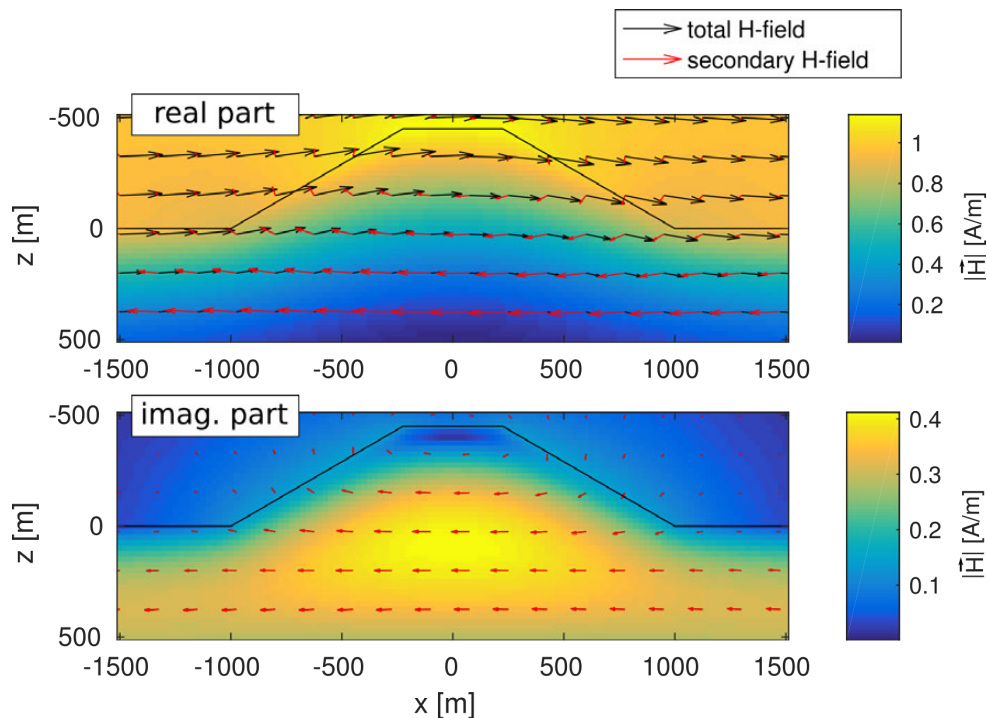## Electric Field in x-direction & surface charge density at 10 s

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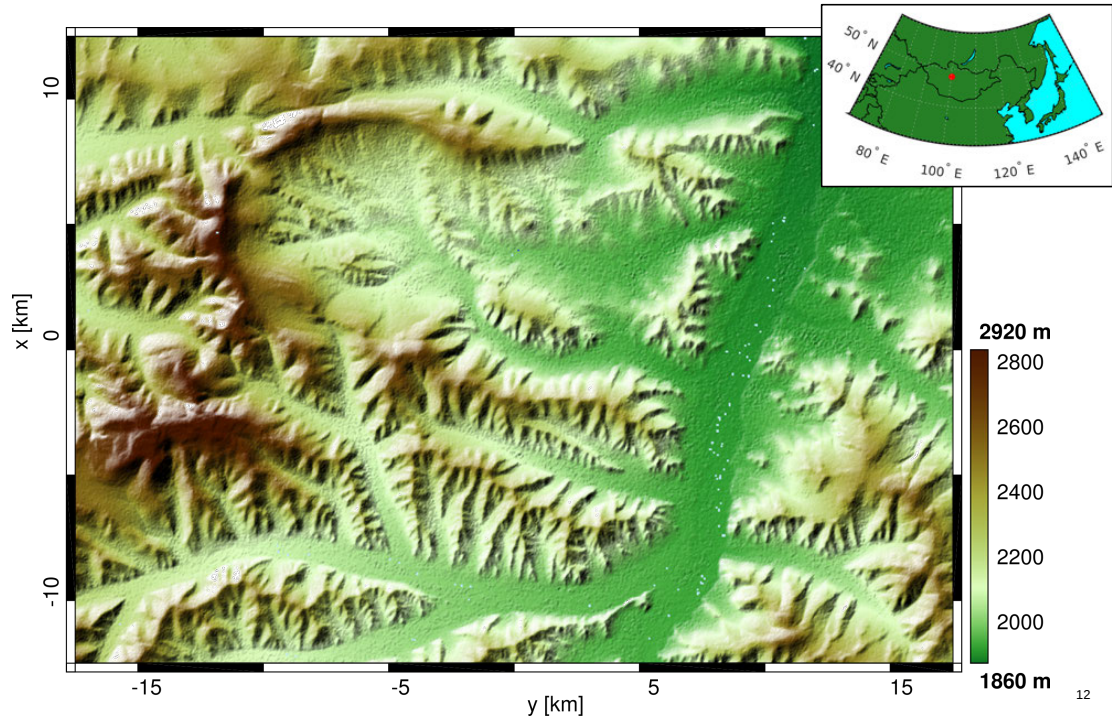## Inductive Distortions

- EM induction
- Amplitude and phase of **Z** are distorted

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Magnetic Field (x-polarisation) at 100 Hz
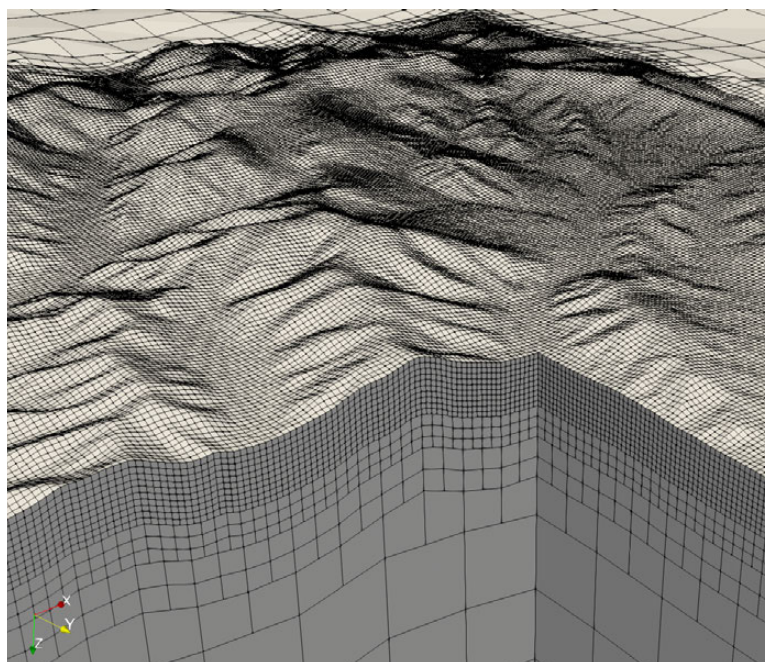

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Real Topography – Hangai Mountains, Mongolia

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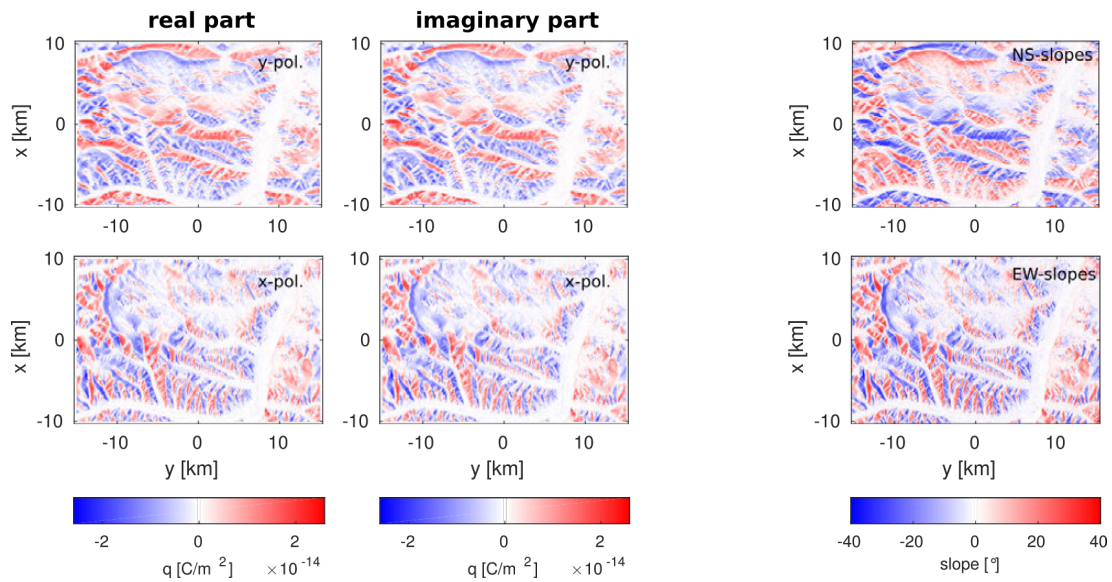# Modelling Mesh

- $2.4 \cdot 10^6$ cells

- min. edge length: 80 m

- $1.2 \cdot 10^8$ unknowns

- solved on Piz Daint (CSCS)
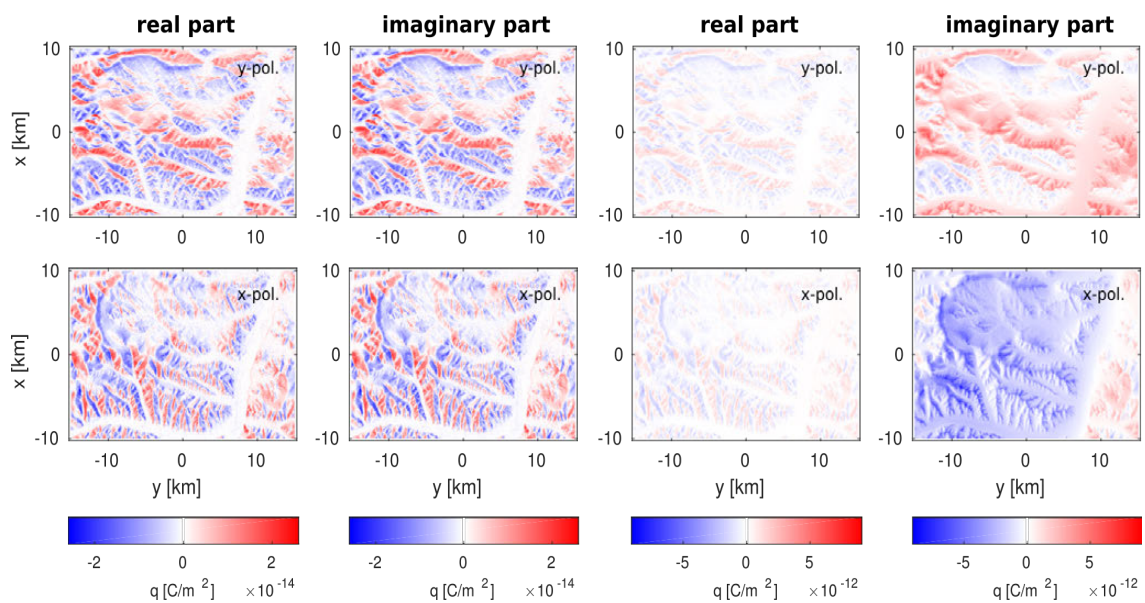
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Surface Charge Density

T=100 s

real part   imaginary part   NS-slopes / EW-slopes

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Surface Charge Density

T=100 s   **T=10 ms**

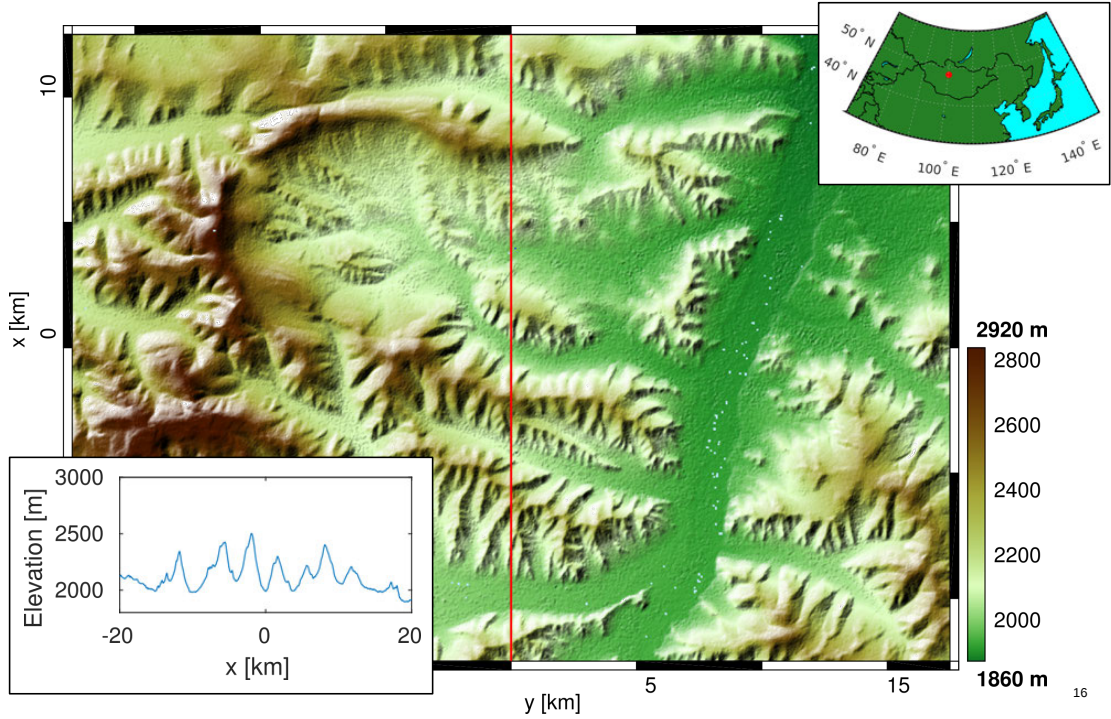real part   imaginary part   real part   imaginary part
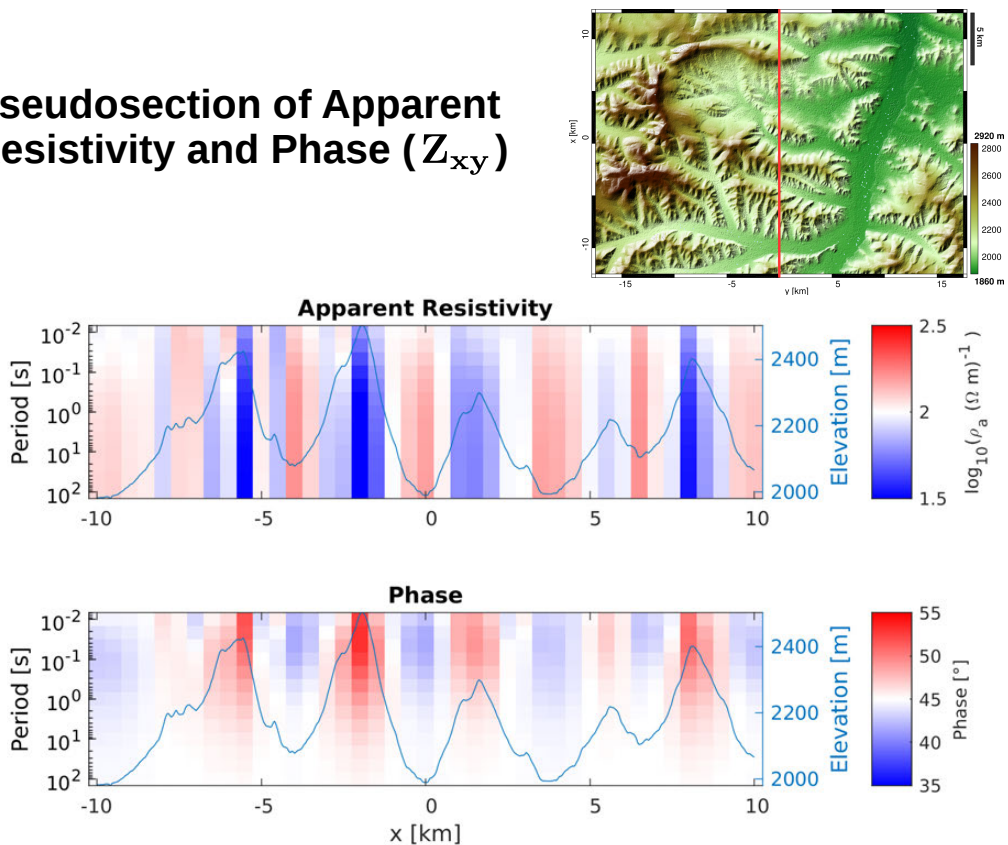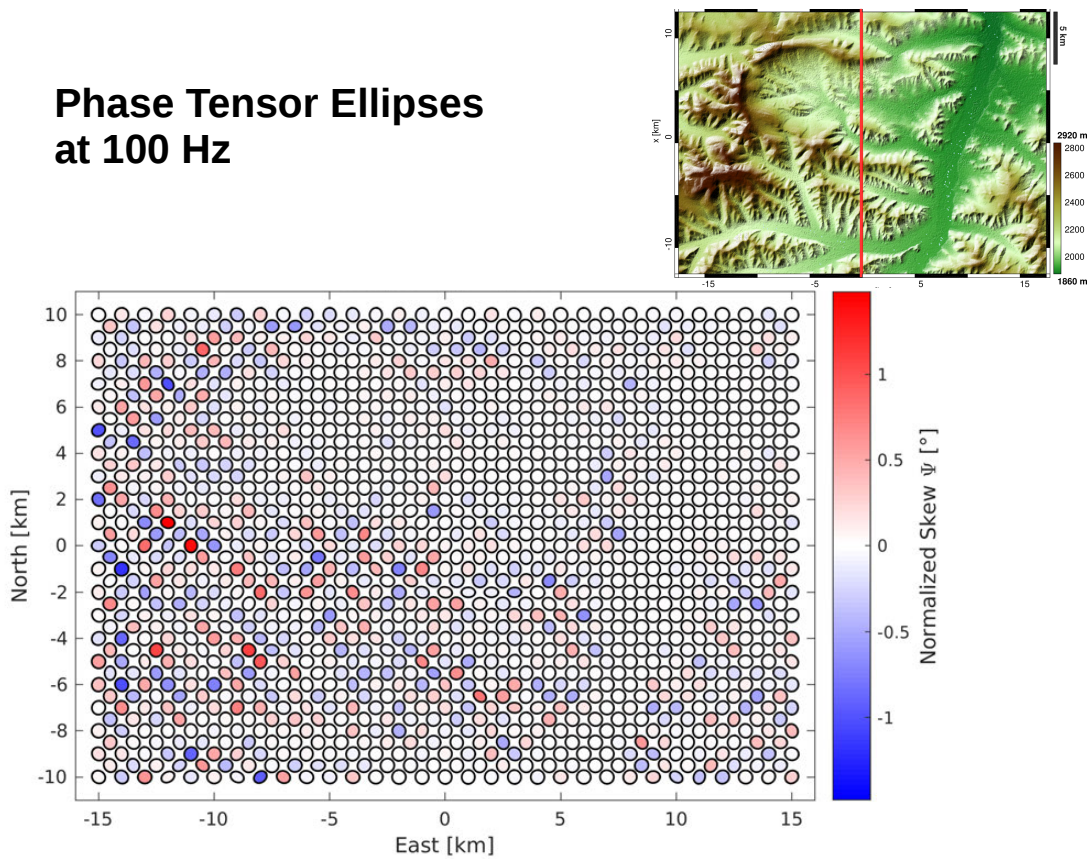
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Real Topography – Hangai Mountains, Mongolia

Pseudosection of Apparent Resistivity and Phase (Z_{xy})
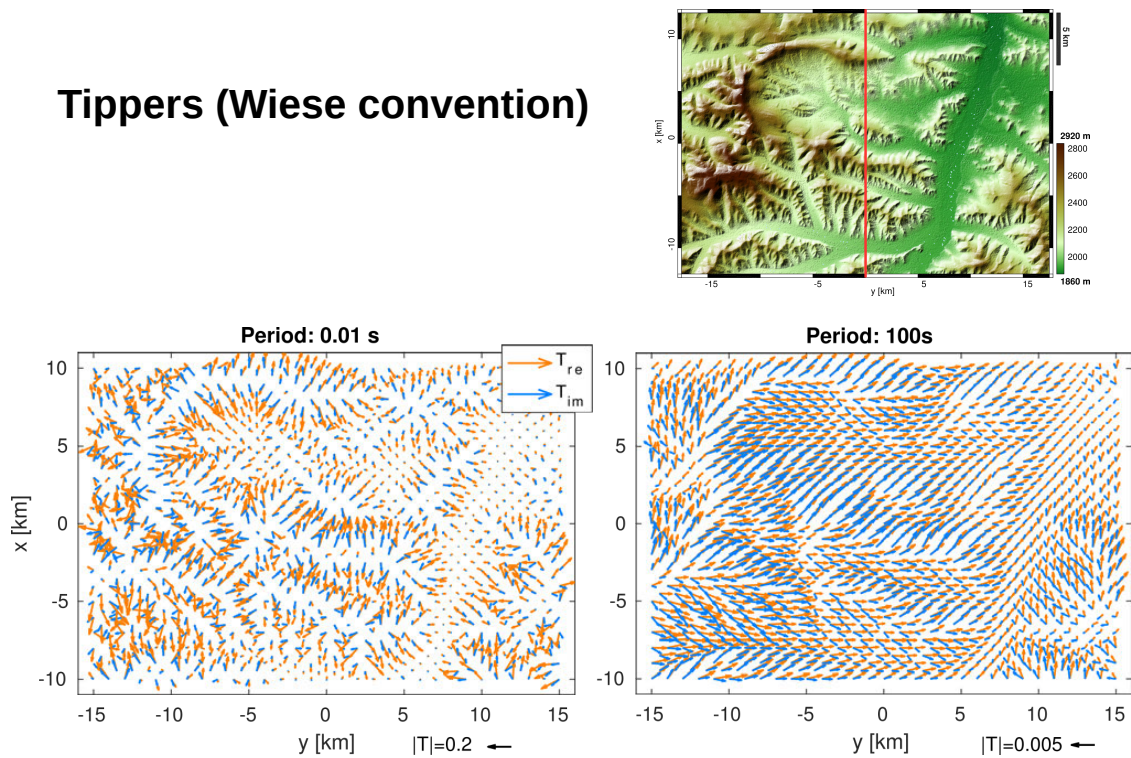
**Phase Tensor Ellipses
at 100 Hz**

Tippers (Wiese convention)

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Conclusions

- What are the physics behind topographic distortions?
  - galvanic distortions: periods > 10 s
  - inductive distortions: periods < 1 s
  - period range depends on skin depth & size of the topographic features
- What is the effect of real topography on MT TF?
  - phase tensor and tippers are affected to a lesser degree
  - impedance: $\delta\rho_a = 70\%$ and $\delta\phi = 5^o$
  - 5% error floor on impedance:
    $$\delta\rho_a = 7\% \text{ and } \delta\phi = 2^o$$
- inclusion of topography in the forward modelling step of the inversion
  - additional computational cost
  - improves the recovered conductivity structure

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