Preliminary work on topographic effect of Sabalan Volcano on MT transfer functions

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Introduction

Topographic effect on Magnetotelluric data and consequently on its transfer functions are important factors to be considered since its neglect may lead to severe misinterpretations. In this study we aim to show the topography effect of Sabalan Volcano on MT data; this inactive stratovolcano, located in northwest of Iran, has been discussed several times in the literature due to its geothermal resources, without taking into account the topographic influence. For that, at first the deviation of the apparent resistivity and phase which are calculated on the surface are shown (using COMSOL Multiphysics) and then the effect of slope is estimated at specific site locations in order to be comparable with responses from 1998-2007 field measurements, for further study.

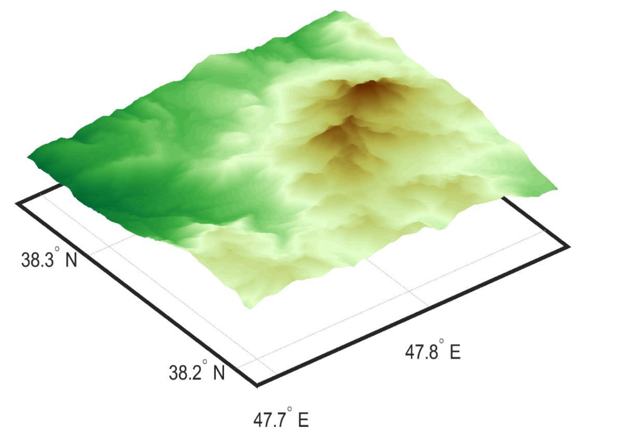


Fig 1. Topographic map of the study area (peak elevation of 4,811 m)

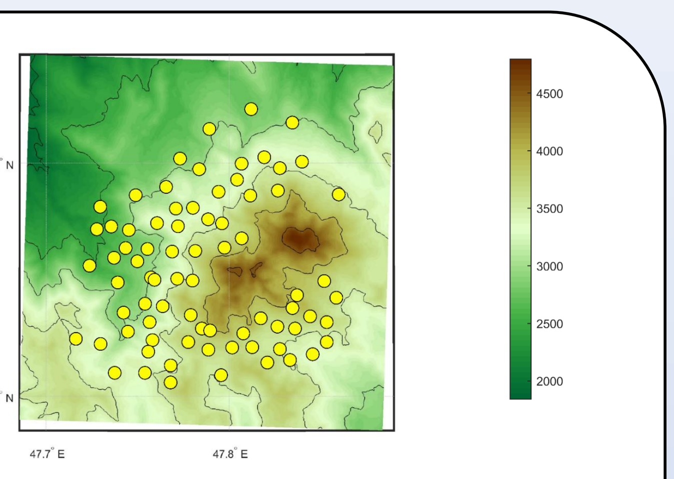
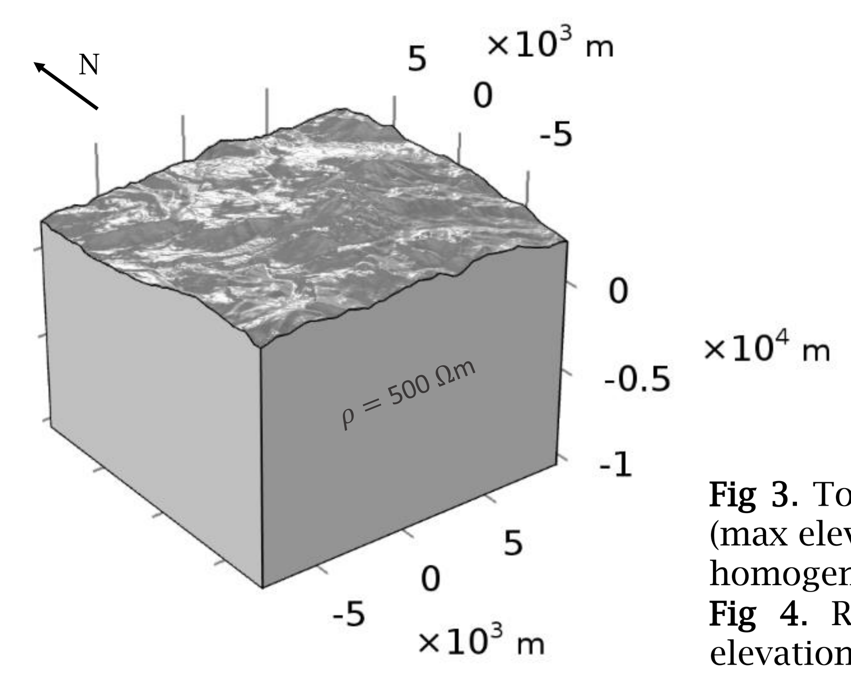


Fig 2. Station setup in measurement area (The sites' elevations range from 2400 to 4058)

Topographic effect of the whole area on apparent resistivity, phase and tipper



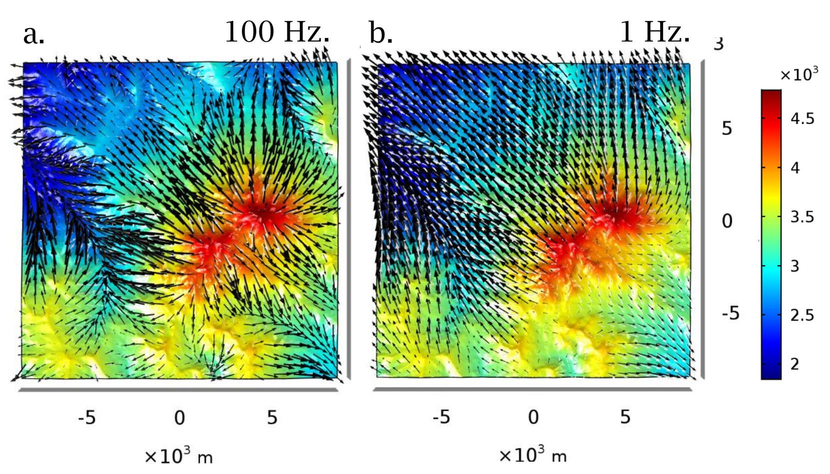


Fig 3. Topography model. The model includes Sabalan topography (max elevation: 4.8 km, horizontal extension: 17.3x17.3 km) above a homogeneous half-space with a resistivity of 500 Ωm
Fig 4. Real (black) and imaginary (white) parts of tipper over elevation map. a. freq. 100 Hz. b. freq. 1 Hz.

Steep topographic features can lead to significant distortions since the steepness of the slope is an important factor for the accumulation of charges. These distortions are frequency dependent at large frequencies and have static behavior at low frequencies.
Considering Sabalan Volcano as a real topographic model (fig. 3), we can see that tippers (Fig. 4), with the max absolute magnitude of 0.3 for 100 Hz and 0.038 for 0.01 Hz., sense the local top areas as conductive bodies.
Apparent resistivities are distorted to higher values in valleys and lower values on tops. Fig. 5 shows that for a 500 Ωm homogeneous subsurface model, the ρ_a values change from approx. 30 Ωm to 2500 Ωm, depending on the freq., for y-pol (primary E-field points to North) and x-pol (primary E-field points to East).
For the phases, the topography creates most distortions at freq. 100 Hz ranging from 29 ° to 72 °.

At low frequencies, phases are approx. 45°, while values for ρ_a are shifted by a value which remains nearly constant for frequencies lower than 0.1 Hz, as a galvanic effect. For higher frequencies, where the inductive effect prevails, both phase and apparent resistivity show a frequency-dependent behavior.

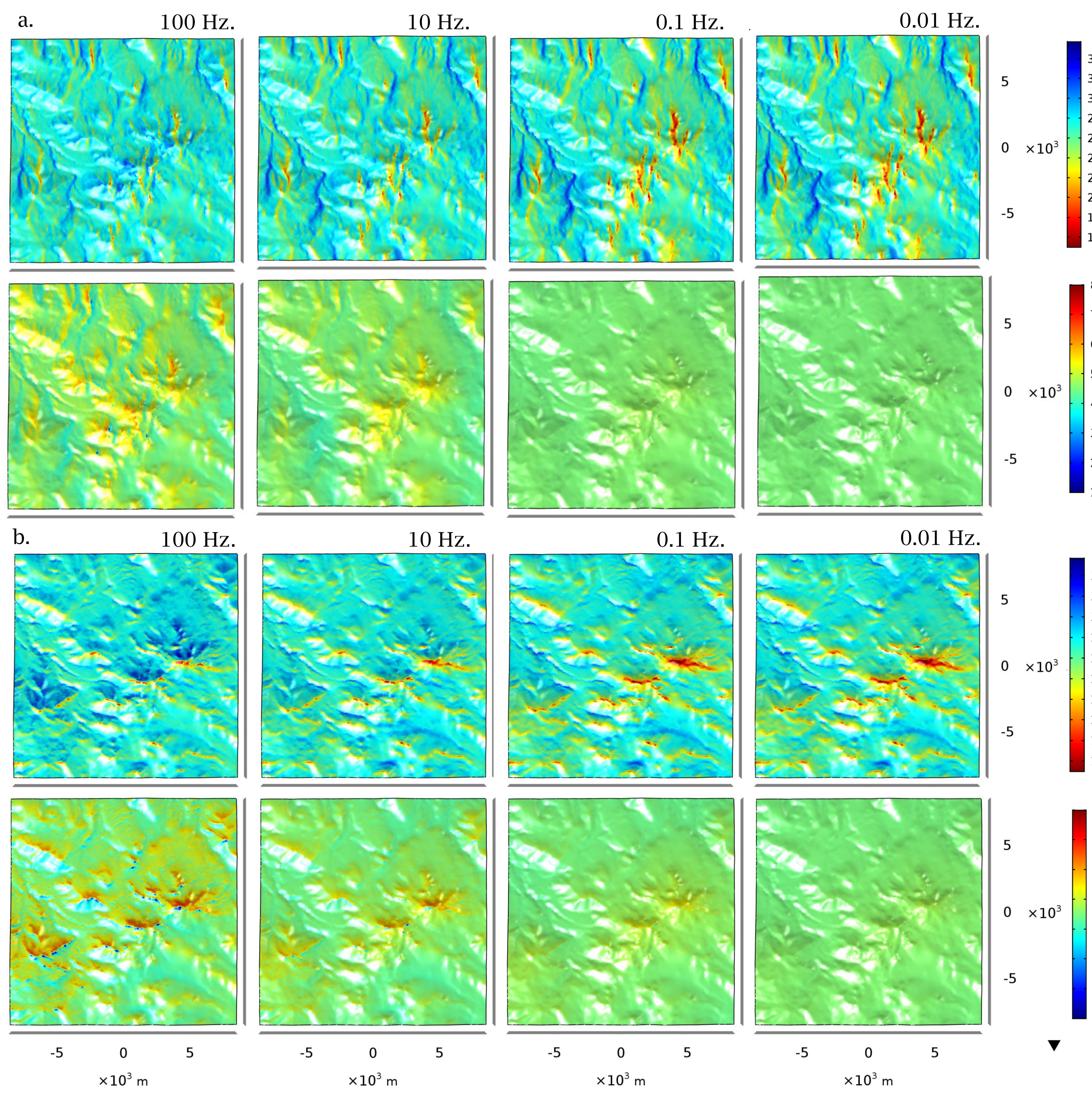
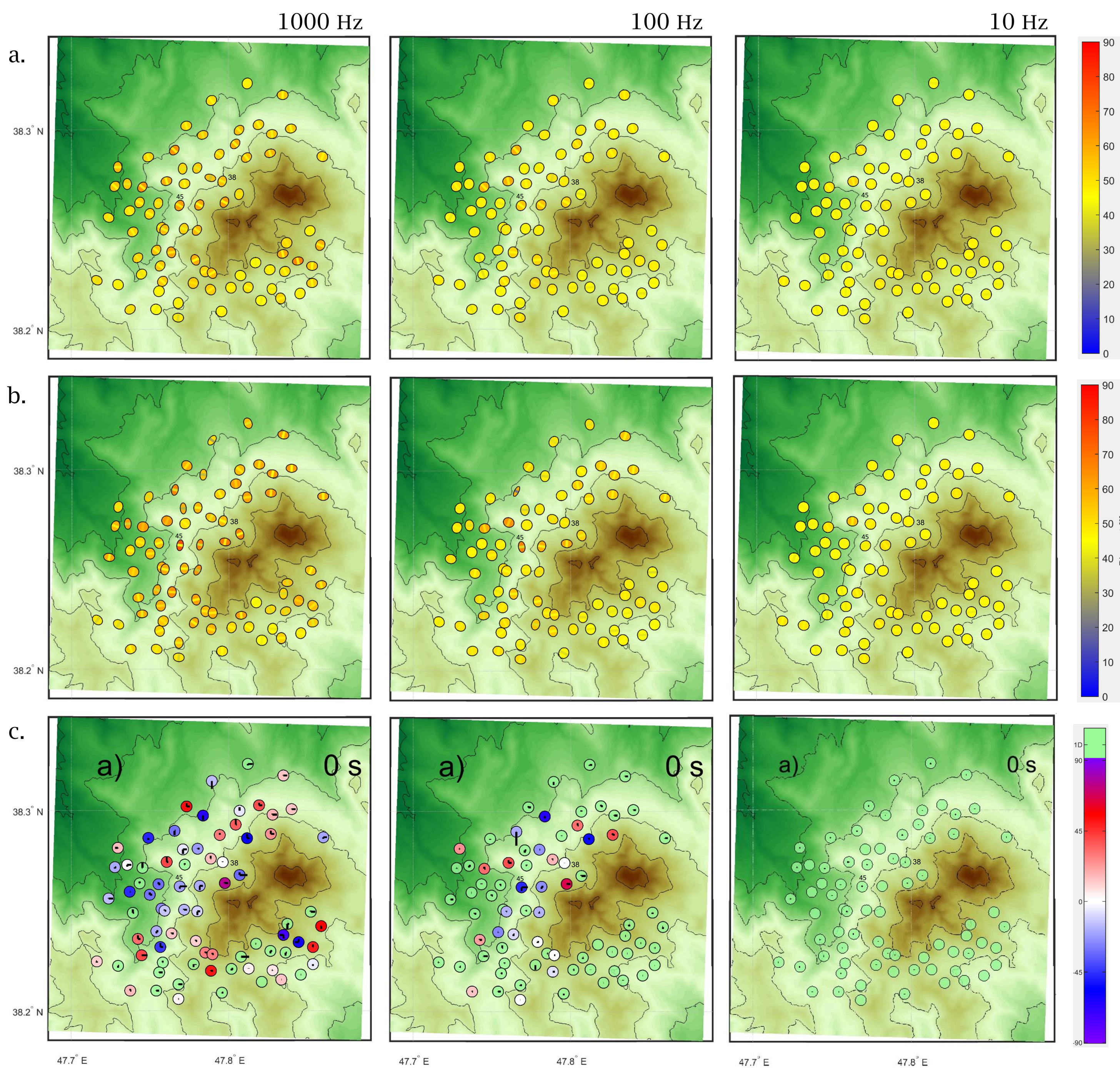


Fig 5. (a) log10($\rho_{a,yx}$) in Ωm & Φ_{yx} in degree, (b) log10($\rho_{a,xy}$) in Ωm & Φ_{xy} in degree, at the topographic surface for freq. 100, 10, 0.1 and 0.01 Hz.

Slope effect on phase tensors at site locations



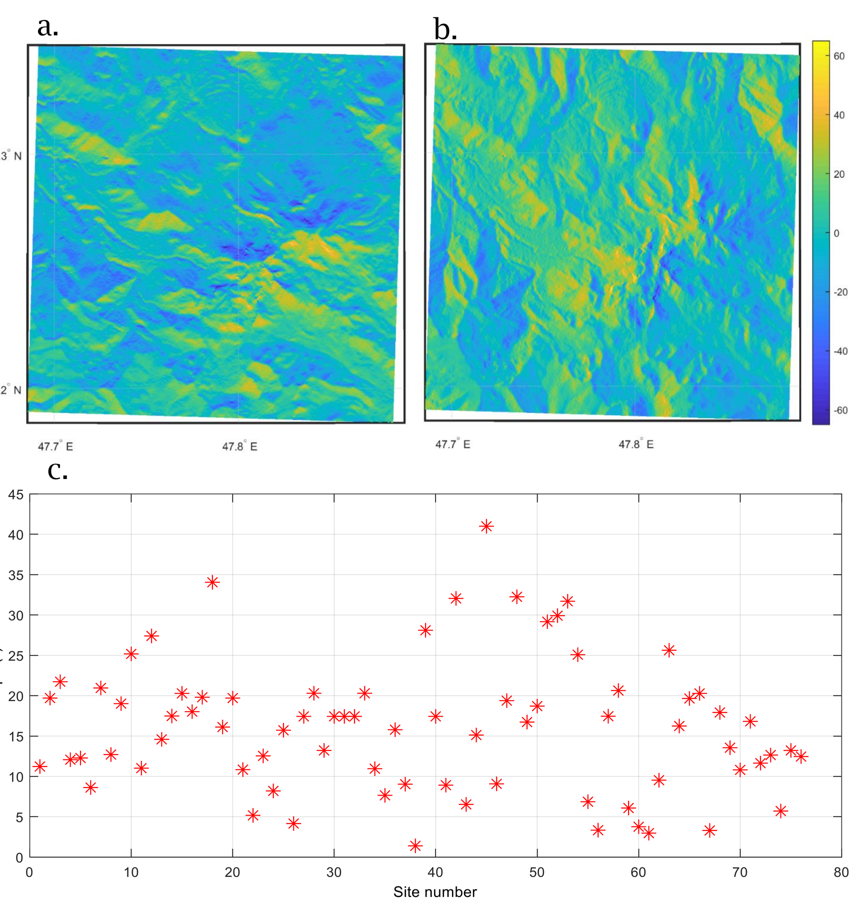


Fig 6. Slopes (°) in (a) north–south and (b) east–west directions. (c) Slope magnitude at all stations which ranges from 2° to 42°.
Fig 7. Phase tensor ellipses calculated with regard to (a) Horizontal E-fields and (b) slope-parallel E-fields, for 1000 Hz, 100 Hz and 10 Hz. (c) Phase tensor differences between a and b. Green circles denote stations with 1-D character (where the ellipses turn to circles). This figure shows there are notable slope effects on high frequencies for stations with slopes more than 25°.

In order to be able to assess results of previous studies on Sabalan, the effects shown in fig. 5 are calculated for the same stations as those in terms of phase tensor ellipses (fig. 7a). Also, the effects of the vertical electric fields on slopes, which is the result of not using perfectly horizontal electric dipoles when acquiring field data, are calculated for the same stations by considering slope-parallel E-fields (fig. 7b).
In fig. 7c, the differences between the maximum resp. minimum phases ($\Delta\Phi max$, $\Delta\Phi min$) are represented by horizontal resp. vertical black bars with the length illustrating the phase difference. The bars' origin equals the origin of a unit circle whose circumference marks the phase difference of 10°. This means, for a phase difference of 10° of $\Delta\Phi max$ the length of the horizontal bar equals the radius of the circle. If the end of the bar is located inside the circle, the misfit will be <10°. For bars crossing the circumference the misfit is >10°. The color of the 10°-circle shows the clockwise difference between the orientation of the fig. 7a and fig. 7b phase tensor $\Delta(\alpha-\beta)$. For phase differences less than 5° the orientation is found hard to define and a green color is chosen, denoting a 1-D like situation.

Slope effect on phase tensors at site locations

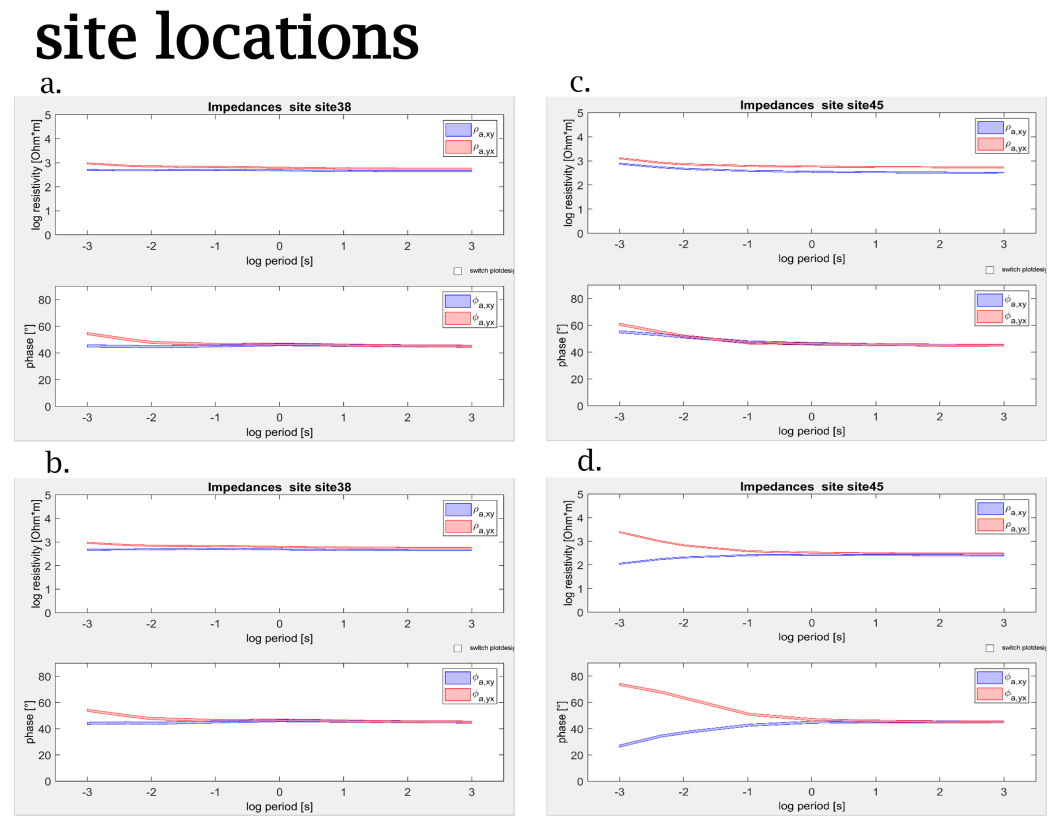


Fig 8. Impedances for the site 38 (a and b), as an example of the location with the least topography distortions, and site 45 (c and d), with the most distortions (see fig. 7).
Fig. a and c show ρ_a and Φ with considering horizontal E-fields and in fig. b and d, with considering slope-parallel E-fields. As fig. d clearly indicates, site 45 has the most effects.

Conclusion

Galvanic and inductive topography distortions in Sabalan Volcano can be considerable and have to be addressed. Not considering slope-parallel E-field influences the high-frequency results, depending on study target can be negligible for lower frequencies.
Providing more detailed quantitative aspects and performing forward modelling by including topographic effects, are left for further studies.

References

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