APPENDIX E: TITAN INVERSION RESULTS

This appendix contains a description on the TITAN DCIP and MT data processing and inversion, as well as an outline on the inversion results for each individual model, including Quality Control and Assurance (QC/QA) comments.

GLOSSARY OF TERMS

SMDC SECTIONS : SMOOTH DIRECT CURRENT RESISTIVITY SECTIONS

SMIP SECTIONS: SMOOTH INDUCED POLARIZATION CHARGEABILITY SECTIONS

NULLCON: UBC INVERSION MODELS USING THE HALF SPACE CONDUCTIVITY AS STARTING REFERENCE MODEL

MT: MAGNETOTELLURIC

RLM: RODI, W., AND MACKIE MT INVERSION CODE

LINE#_PUM_HRP_IT#: CONJUGATE PW INVERSIONS DERIVED FROM INVERTING THE 1D FITTED AND INTERPOLATED DATA, WITH NO ROTATION OF THE PRINCIPAL COMPONENTS. THESE MODELS USED THE HALF SPACE RESISTIVITY (250 OHM-METERS) AS STARTING MODELS, AND WERE CONSTRUCTED USING TM (PHASE + RESISTIVITY) AND TE (PHASE + RESISTIVITY) DATA.

LINE#_PUM_HTM_IT#: CONJUGATE PW INVERSIONS DERIVED FROM INVERTING THE 1D FITTED AND INTERPOLATED DATA, WITH NO ROTATION OF THE PRINCIPAL COMPONENTS. THESE MODELS USED THE HALF SPACE RESISTIVITY (250 OHM-METERS) AS STARTING MODELS, AND WERE CONSTRUCTED USING TM (PHASE + RESISTIVITY) DATA.

PW: PHIL WANNAMAKER MT INVERSION CODE

IT#: ITERATION NUMBER USED FOR PRESENTING THE MODEL

DCIP DATA PREPROCESSING:

For the inversions, the raw data were edited, including adjustment of data errors and removal of poor quality data, allowing the program to reach appropriate model misfits and consistent inversion models. The editing and preprocessing of the datasets included:

1. Filtering the raw data[1] using the ***DCIPSuper.exe*** program with the following "Quantec[2]" input parameters:
   - All negative Vp values were excluded for the inversions
   - All apparent resistivity values <500 000 Ohm-meters were included
   - Small apparent resistivity values <0.001 Ohm-meters were excluded
   - All phase values <300 milliradians where included
   - All phase values >-50 milliradians were included
   - High Vp errors <20% were included
   - High phase errors <10% were included
   - Apparent resistivity limits: from 0.001 Ohm-meters to 500 000 Ohm-meters
   - Phase limits: from -50 milliradians to 300 milliradians
2. Exclusion of the data points (for both the voltage and phase) with Vp errors higher than 20%.
3. Exclusion of negative phase data points (>50 %)
4. Exclusion of data points with phase errors (>10%).
5. Starting Error floor of 0.5 milliradians added to the final phase data files for inversions.

[1] *Raw data contained in the digital files "Line#.csv".*
[2] *Quality Control Process passes all data thru except dipoles straddling current electrodes.*

2D DCIP UNCONSTRAINED INVERSIONS:

In general, the quality of the DCIP raw data is good. Pre-processing of the DC Resistivity & Induced Polarization (DC/IP) data involved adjustment of data errors and removal of poor quality data. The DC Resistivity and IP unconstrained inversion models were calculated using the ***UBC DCInv2D***^{TM} ***& IPInv2D***^{TM} ***2D***[3] algorithm (Oldenburg & Li, 1994) and ***IPView-IIC***[4] platform. Multiple unconstrained inversion models were produced in order to arrive at the final 2D inversion models. Smooth inversions were executed for both the DC resistivity and IP datasets. The Smooth DC and IP Inversion Models[5] were derived from setting the ***chi***[6] factor to the programs default (NULL). The αs[7], αx and αy[8] parameters were set to the inversion code default (NULL). The data was further edited as necessary to achieve convergence with a final resulting misfit equal to or approximately equal to the number of data points input to the inversion code. No Sharp Inversion Models were produced or presented in this interpretation report.

The inversions were generally run with successive removal of poorly fitting data and error adjustment before arriving at the final 2D models. Some data acquired with large transmit-receiver separations were not of high quality and were removed prior to inversion.

One set of Smooth IP inversion models was derived assuming a homogenous half-space (conductivity distribution set to NULL). This IP model (apparent chargeability distribution) was useful for defining and/or improving the interpretation of the chargeability models when the resulting IP inversions were distorted by incorporating a DC model with high resistivity contrasts.

Three basic DC and IP inversion models were calculated as follow:

1. ***L#N_smDC***: Smooth DC "Resistivity" inversions from inverting the voltage data (contained in the raw *L#N.csv* file). The Smooth DC inversions were topographically corrected according to the Quantec inversion mesh (*L#N_meshPLDP.txt*), and the elevation file (*L#N.topo*) from the GPS survey files.
2. ***L#N_smIP***: Smooth IP "Chargeability" inversions from inverting the phase data (contained in the raw *L#N.csv file*). The Smooth IP inversions used the Titan 2D conductivity model (derived from the Smooth DC "Resistivity" inversions), and were topographically corrected according to the Quantec inversion mesh (*L#N_meshPLDP.txt*), and the elevation file (*L#N.topo*) from the GPS survey files.
3. ***L#N_smIP_nullcon***: Smooth IP "nullcon Chargeability" inversions from inverting the phase data (contained in the raw *L#N.csv file*). The Smooth IP "nullcond" inversions used the half-space conductivity, and were topographically corrected according to the Quantec inversion mesh (*L#N_meshPLDP.txt*), and the elevation file (*L#N.topo*) from the GPS survey files.

3D DC RESISTIVITY & INDUCED POLARIZATION INVERSIONS

Three dimensional inversions were executed for both the 2D DC resistivity and IP chargeability data. The 3D DC and IP inversions were executed with the objective to minimize the effect of 3D structures and other 2D linear features that may affect the data and 2D inversions, and also to reduce the uncertainty on the interpretation of the 2D data. Only one set of inversion models was produced for the DC data. Several models were produced for the IP data using different combination of the inversion parameters and starting conductivity models. Details on the inversion parameters and alternate inversion models of the 3D inversions are available in the digital archive.

---

[3] *UBC-Geophysical Inversion Facility (GIF): Department of Earth and Ocean Sciences at the University of British Columbia.*
[4] *IPView: Version 2.1.5 beta (Industrial imaging Co., Inc.); Written by B. Petrick and Licensed to Quantec Geoscience Ltd.*
[5] *The inversion models presented in this report are the most consistent models according to the degree of association with the DC and MT results and the available geological information. Additional inversion models are available in the Digital Archive attached to this Interpretation Report.*
[6] *The* ***chi*** *parameter controls the inversion misfit.*
[7] *The* αs *parameter controls the degree of closeness between the constructed model and the initial model.*
[8] *The* αx *and* αy *parameters control the horizontal and vertical smoothness of the model respectively.*

MT DATA PREPROCESSING:

The initial data input into the Geotools database were line-station data, taken directly from the EDI archive9. The raw impedance tensor data span the 0.1 Hertz to 10000 Hertz bandwidth, with a data density of approximately 6-8 points per decade. Data points with high noise levels were removed from the Apparent Resistivity and Phase curves prior to inversion. In some cases, low frequency data <1 Hertz was not included in the inversion due to low signal-to-noise levels. High frequency (>10000 Hertz) phase data, not consistent with the resistivity data, was also excluded.

1D MT MODELS:

One-dimensional (1D) inversions (L#_unr10) were generated for the acquired lines. The TM and TE curves were fit to the raw data to ensure that the apparent resistivity and phase are smooth and consistent. The apparent resistivity and phase from the fit data are then interpolated to obtain 12 frequency responses per decade. Stitched 1D Determinant sections (L#_det11) were also calculated to supply an alternative starting models for the 2D inversions. Phase curves or intervals with gradient exceeding 45 degrees where not included in the inversions. These intervals are inconsistent with the MT theory and are considered as no MT signal originated from local sources and/or noise.

2D MT UNCONSTRAINED INVERSIONS:

The MT inverse models were calculated using the GeotoolsTM MT processing and model-inversion platform. Two (2) sets of 2D PW models (pum_hrp[12] and pum_htm[13]) were derived from inverting the unrotated data using different combinations of datasets (TM phase, TM resistivity, TE phase and TE resistivity). The PW inversion mesh parameters used 100 single rows, and a regularization width/depth ratio of 0.01. The finite element and regularization meshes were constructed using frequencies at 10k, 1k, 100, 10 and 0.1 Hertz, a column width of 50 meters, 100 rows maximum and a minimum row-thickness of 10 meters. The MT inversion models were calculated using the interpolated resistivity and phase curves, in the 10000 Hertz to 0.1 Hertz bandwidth, assuming a maximum of 5% error for the resistivity and 3 degrees for the phase, at a minimum of 12 equi-spaced frequencies per decade.

The PW models were derived as follow:

1. ***Line#_pum_hrp_it#***: Conjugate PW inversions derived from inverting the 1D fitted and interpolated data, with no rotation of the principal components. These models used the half space resistivity (250 Ohm-meters) as starting models, and were constructed using TM (phase + resistivity) and TE (phase + resistivity) data.
2. ***Line#_pum_htm_it#***: Conjugate PW inversions derived from inverting the 1D fitted and interpolated data, with no rotation of the principal components. These models used the half space resistivity (250 Ohm-meters) as starting models, and were constructed using TM (phase + resistivity) data.

For QA/QC the inversion results, it is useful to review the actual data input into the 2D inversions and all the raw data, which is available in the Project Logistical Report submitted previously. Only the final models of the DC, IP and MT inversion results used for the interpretation are shown in this appendix. Note that the inversion models presented are not always derived from the final iteration of the inversion program.

---

[9] *Data contained in the "Geophysical Survey Logistics Report" Digital Archive.*
[10] *1D Unrotated Inversion Models.*
[11] *Stitched 1D Determinant Inversion Models.*
[12] *MT 2D PW TMTE resistivity & phase Unrotated Inversion Models, starting from the half-space ~250 Ohm-metres.*
[13] *MT 2D PW TM resistivity & phase Unrotated Inversion Models, starting from the half-space ~250 Ohm-metres.*

The following pages will present set figures containing the 2D DCIP and MT raw data and the inversion results, and the 3D inversion results from 2D data, in ascending order as:

a) 2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models.

b) 2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models.

c) 2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models.

d) 2D MT unrotated Interpolated Raw Data input to the inversions.

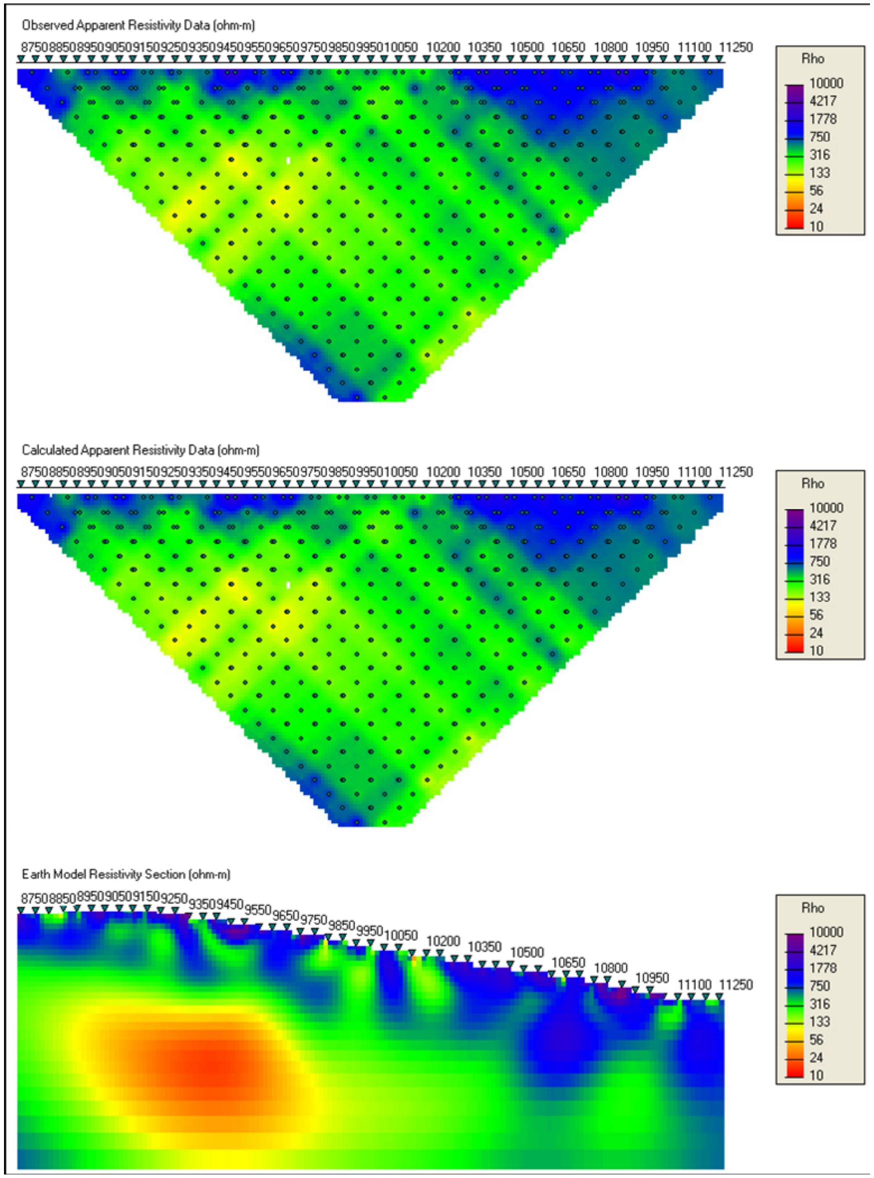
e) 2D PW MT Resistivity Inversion Model (left = "*Line#_pum_hrp_it#*") and calculated Data (right).

f) 2D PW MT Resistivity Inversion Model (left= "*Line#_pum_htm_it#*") and calculated Data (right).

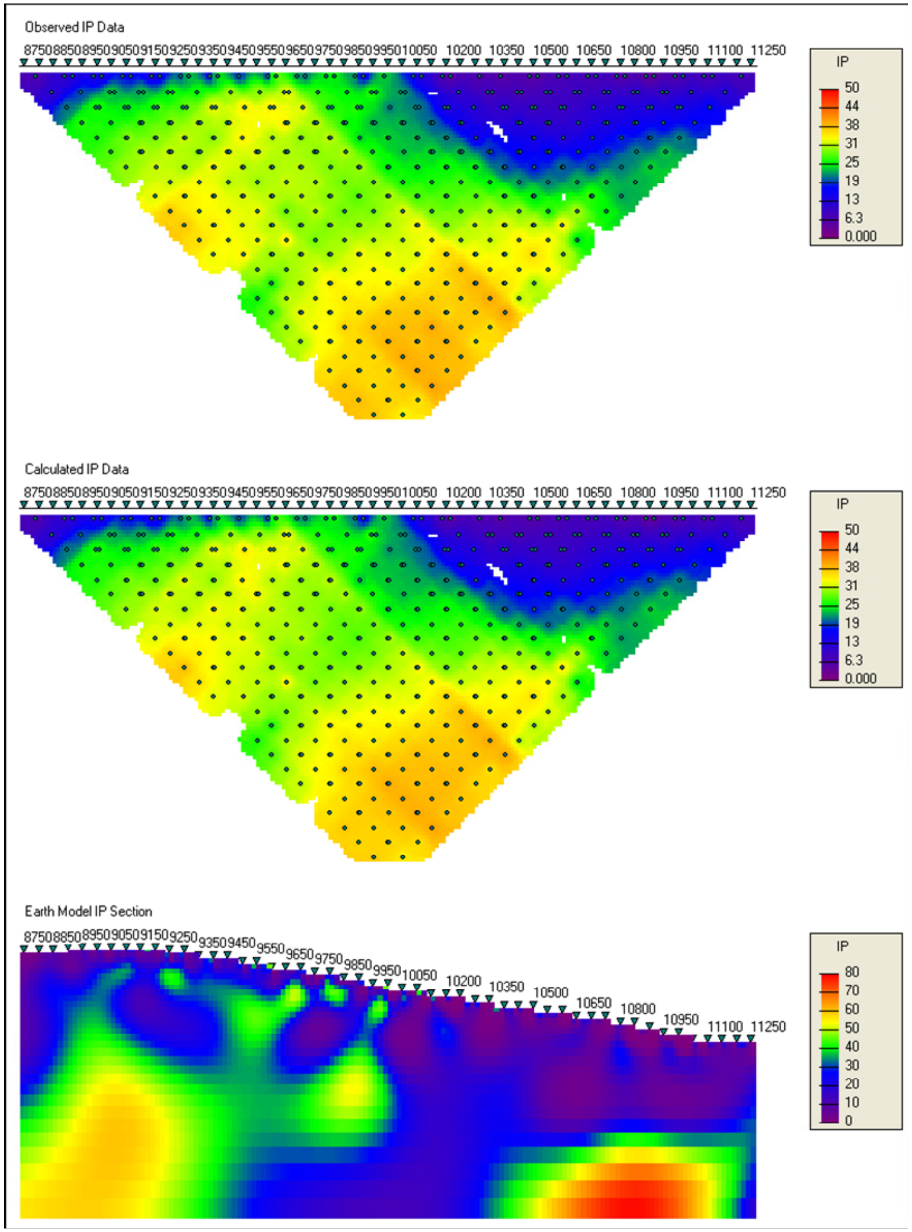
g) 3D View of the 3D DC Resistivity Unconstrained Inversion Results.

h) 3D View of the 3D IP Chargeability Unconstrained Inversion Results.

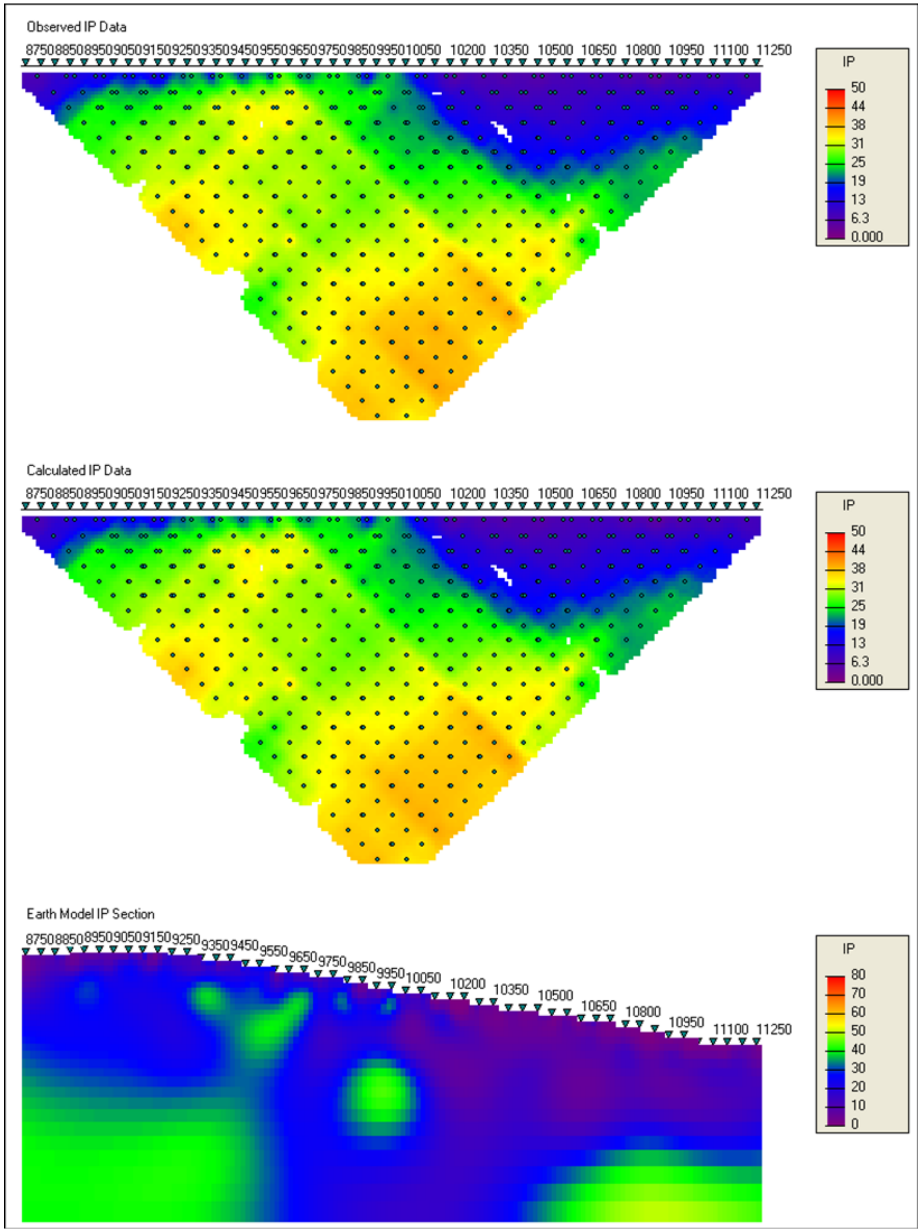
Line L10000N



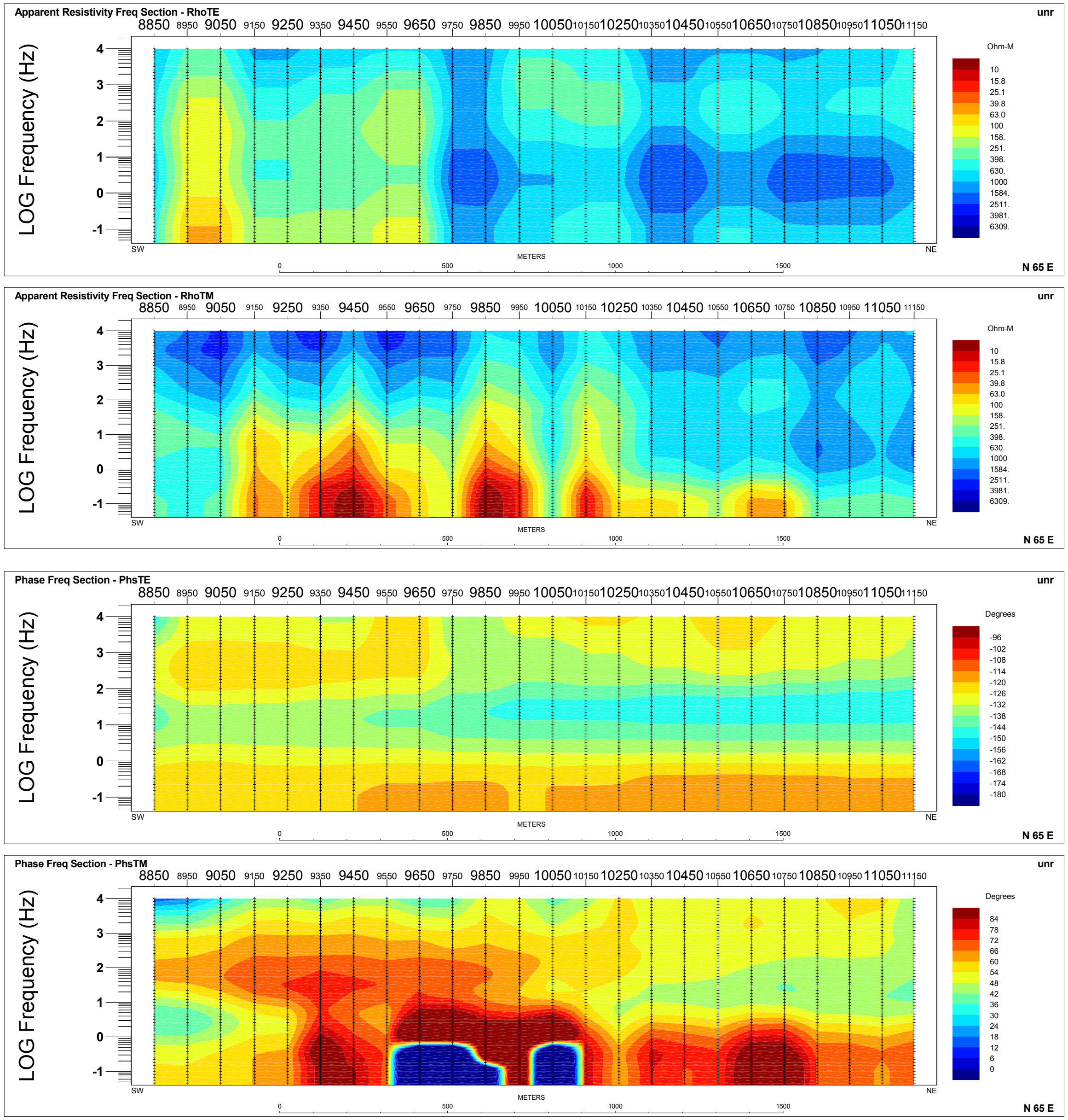
a) 2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models



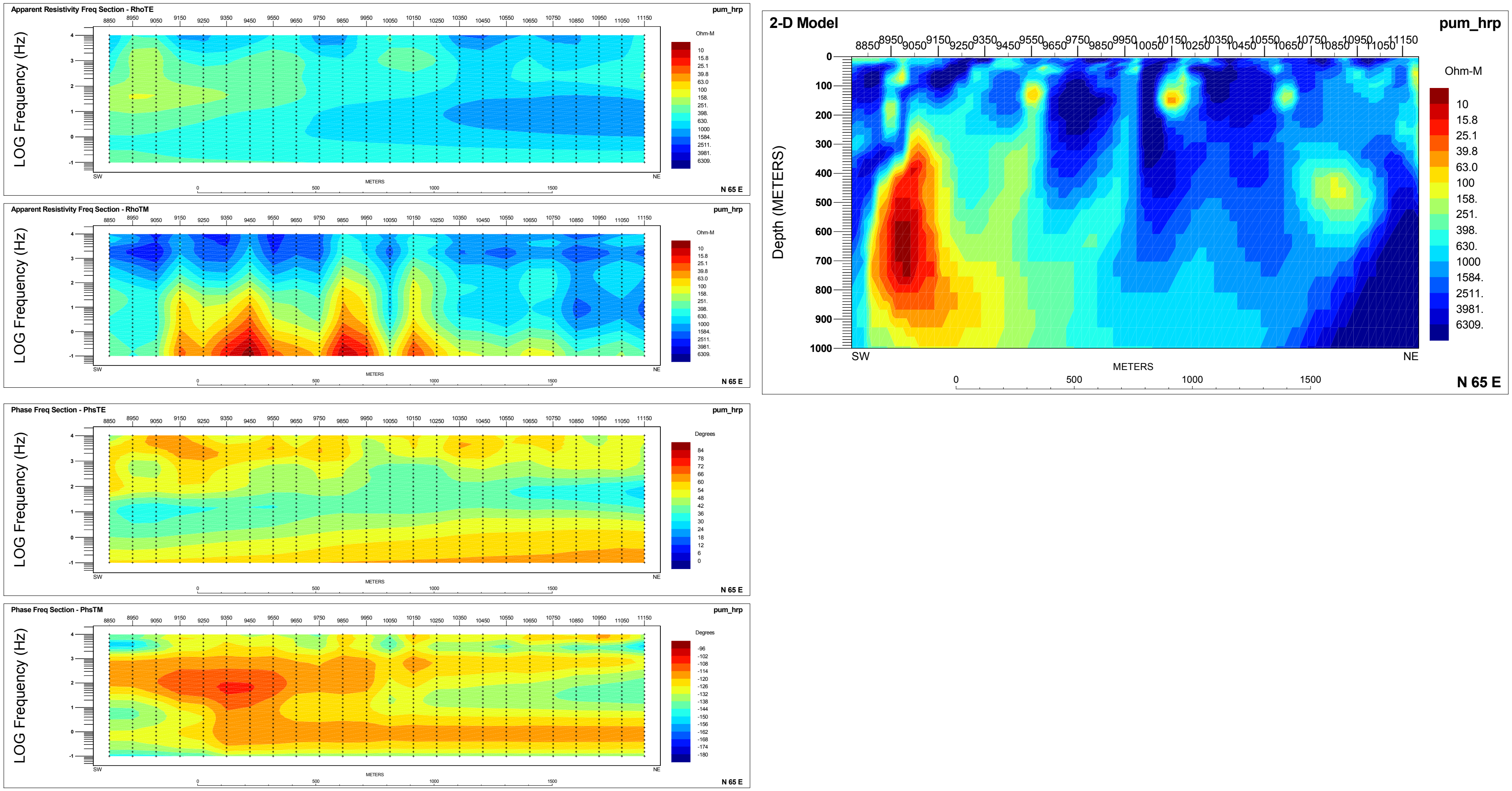
b) <u>2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models</u>



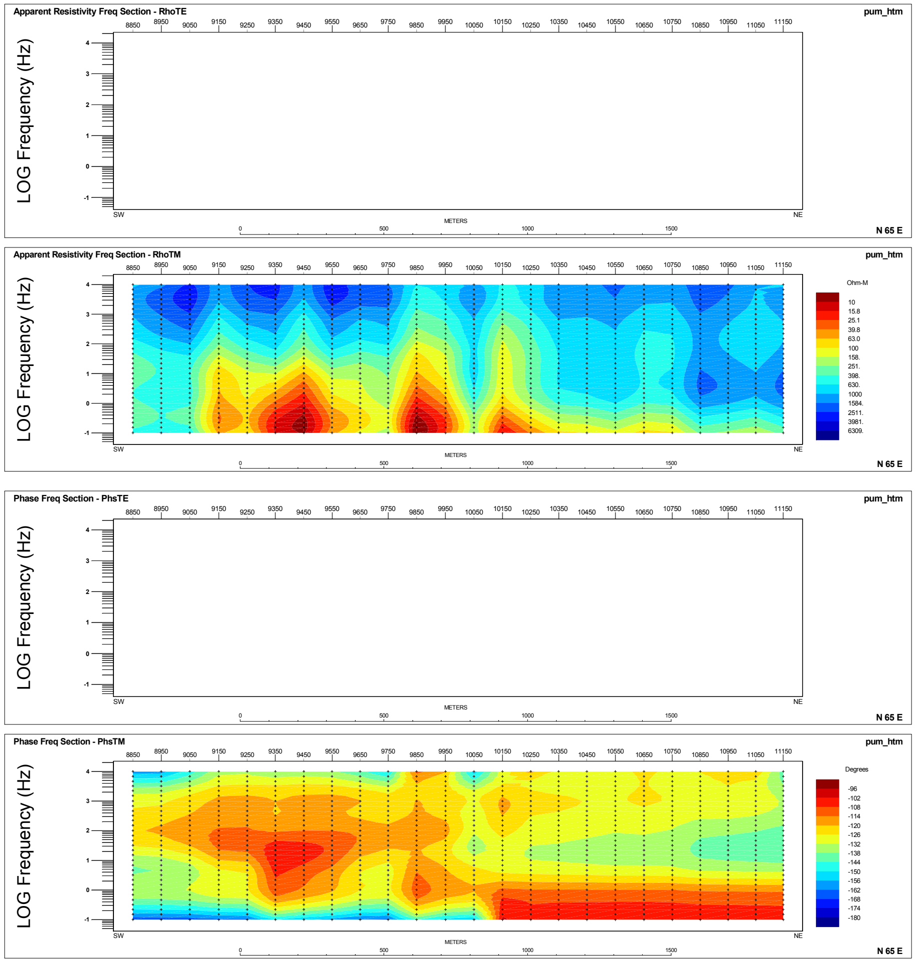
c) 2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models

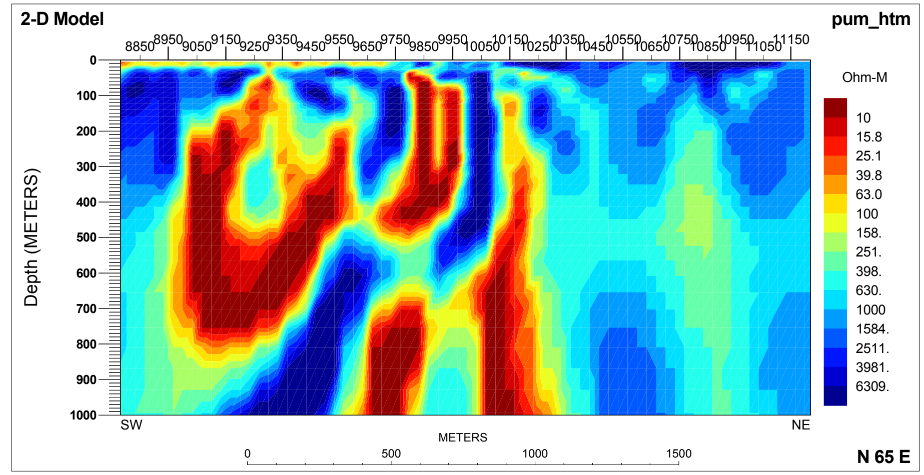


d) 2D MT unrotated Interpolated Raw Data input to the inversions



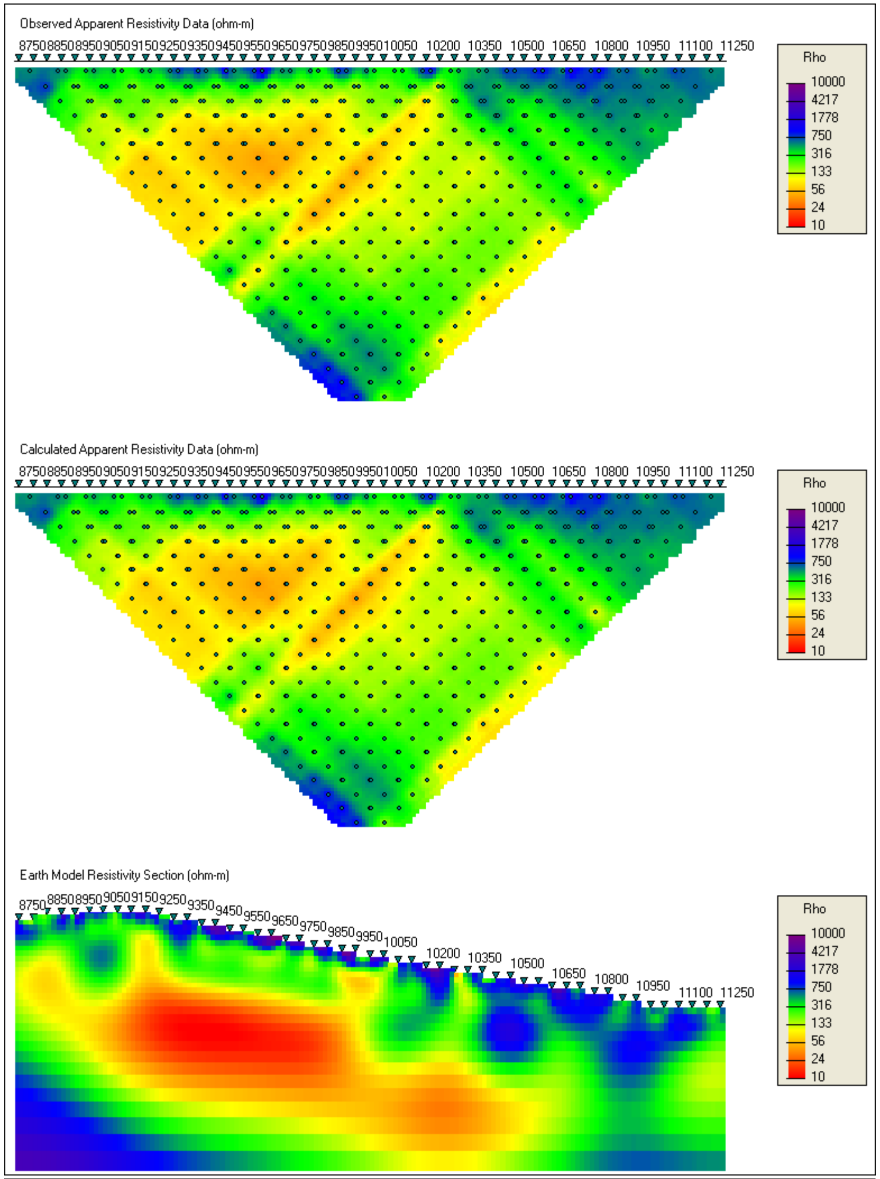
e) 2D PW MT Resistivity Inversion Model (left = "Line10000N_pum_hrp_it15") and calculated Data (right)



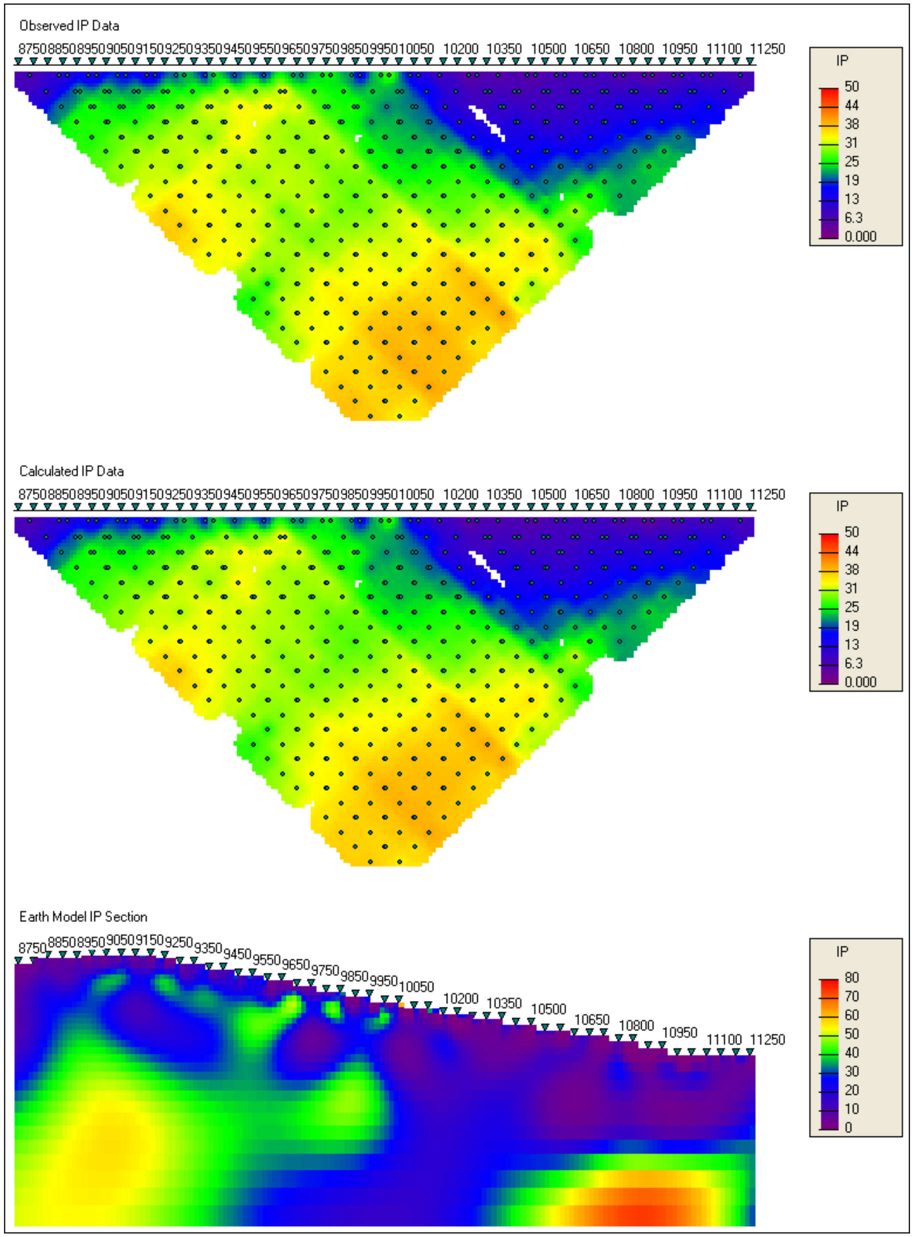


f) 2D PW MT Resistivity Inversion Model (left= "Line10000N_pum_htm_it49") and calculated Data (right)

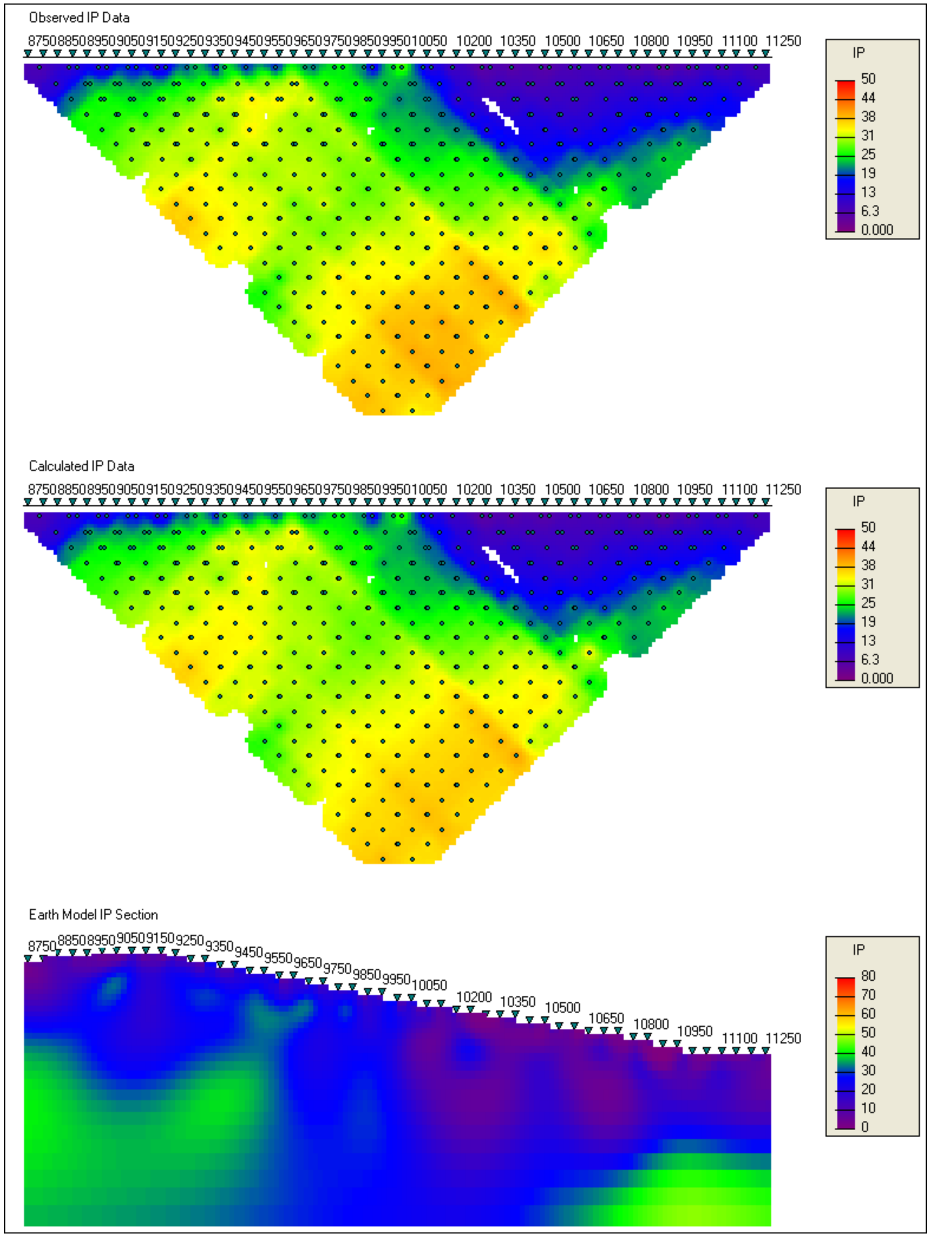
Line L10300N



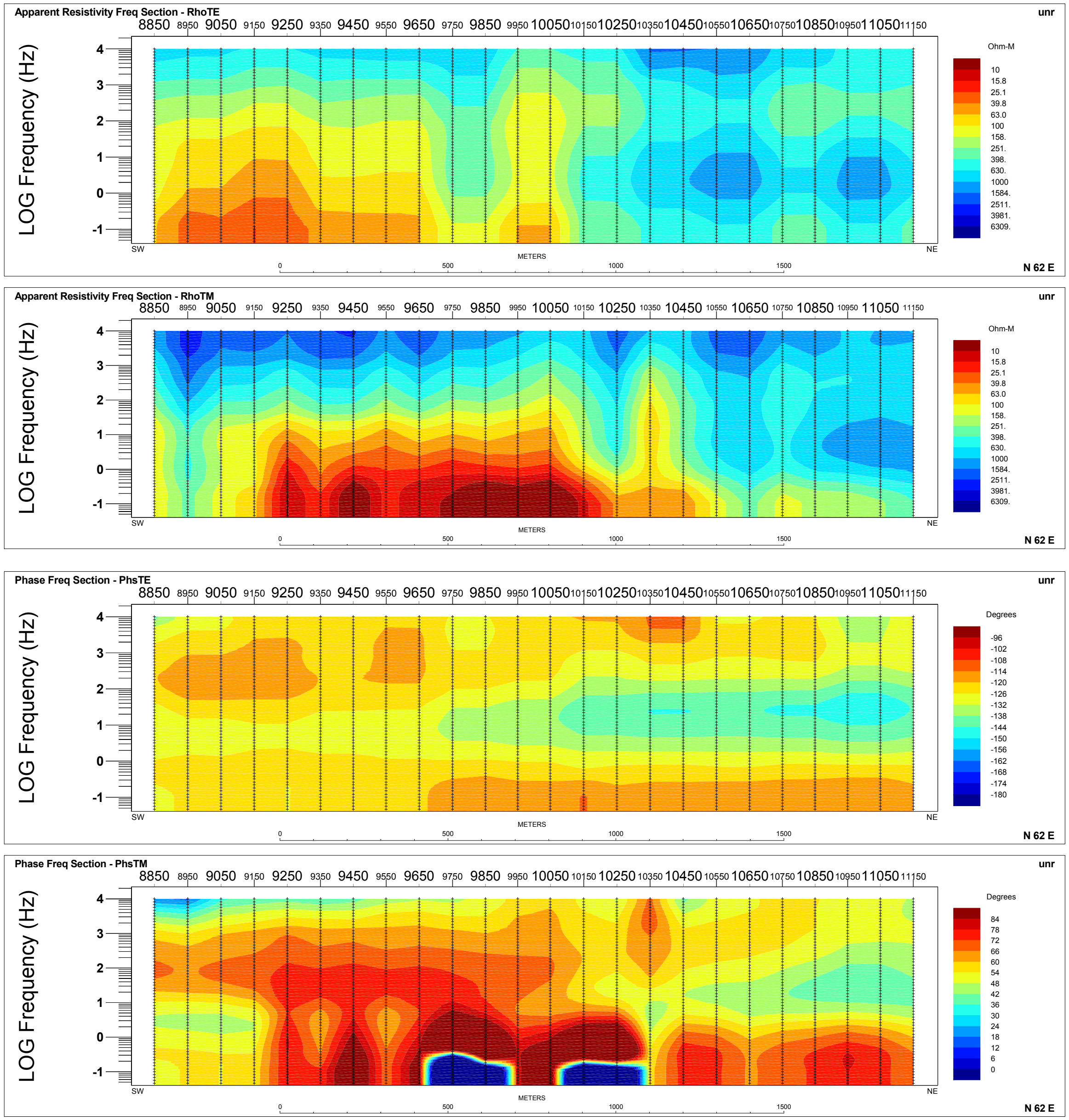
a) 2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models



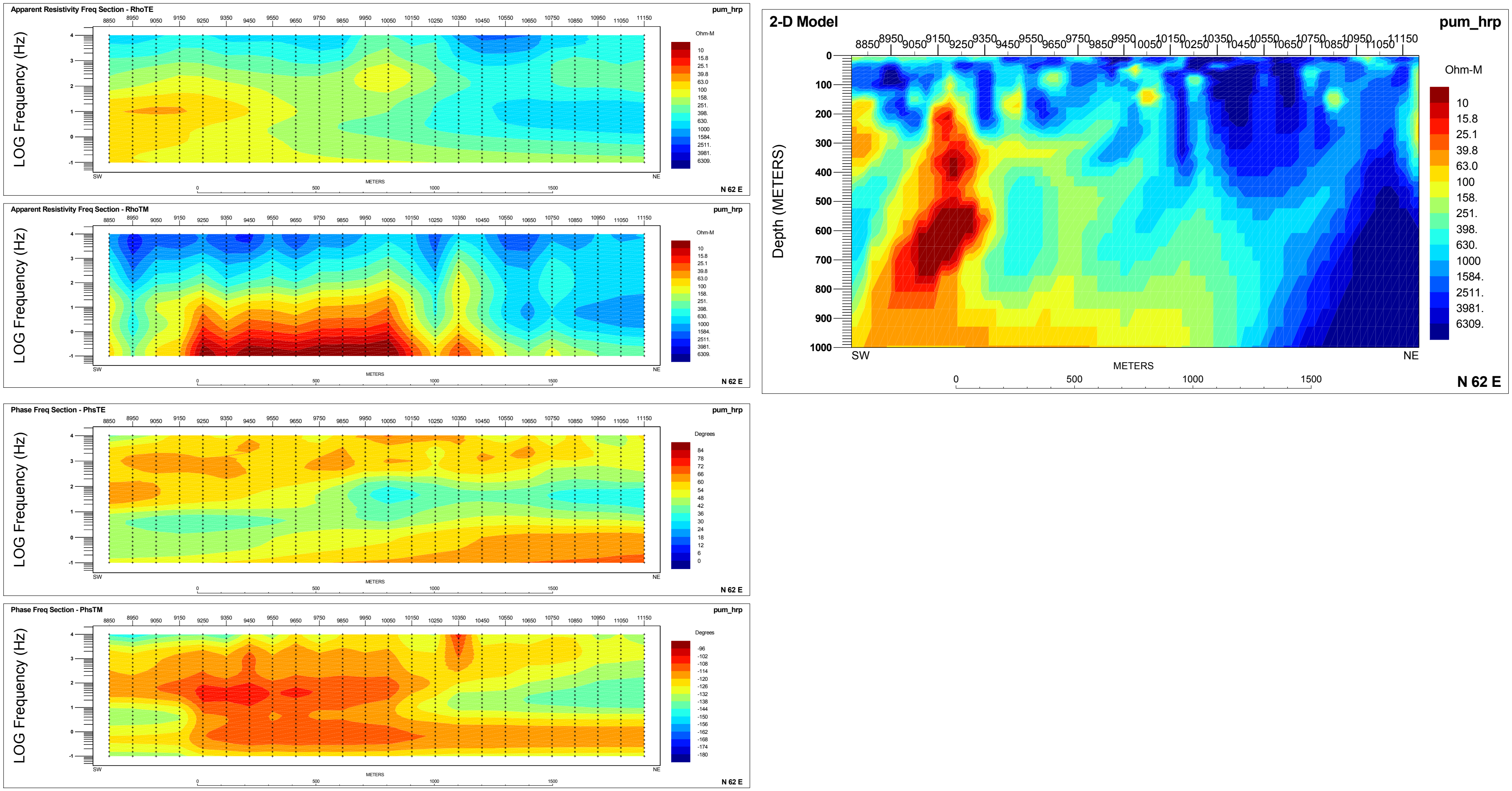
b) <u>2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models</u>



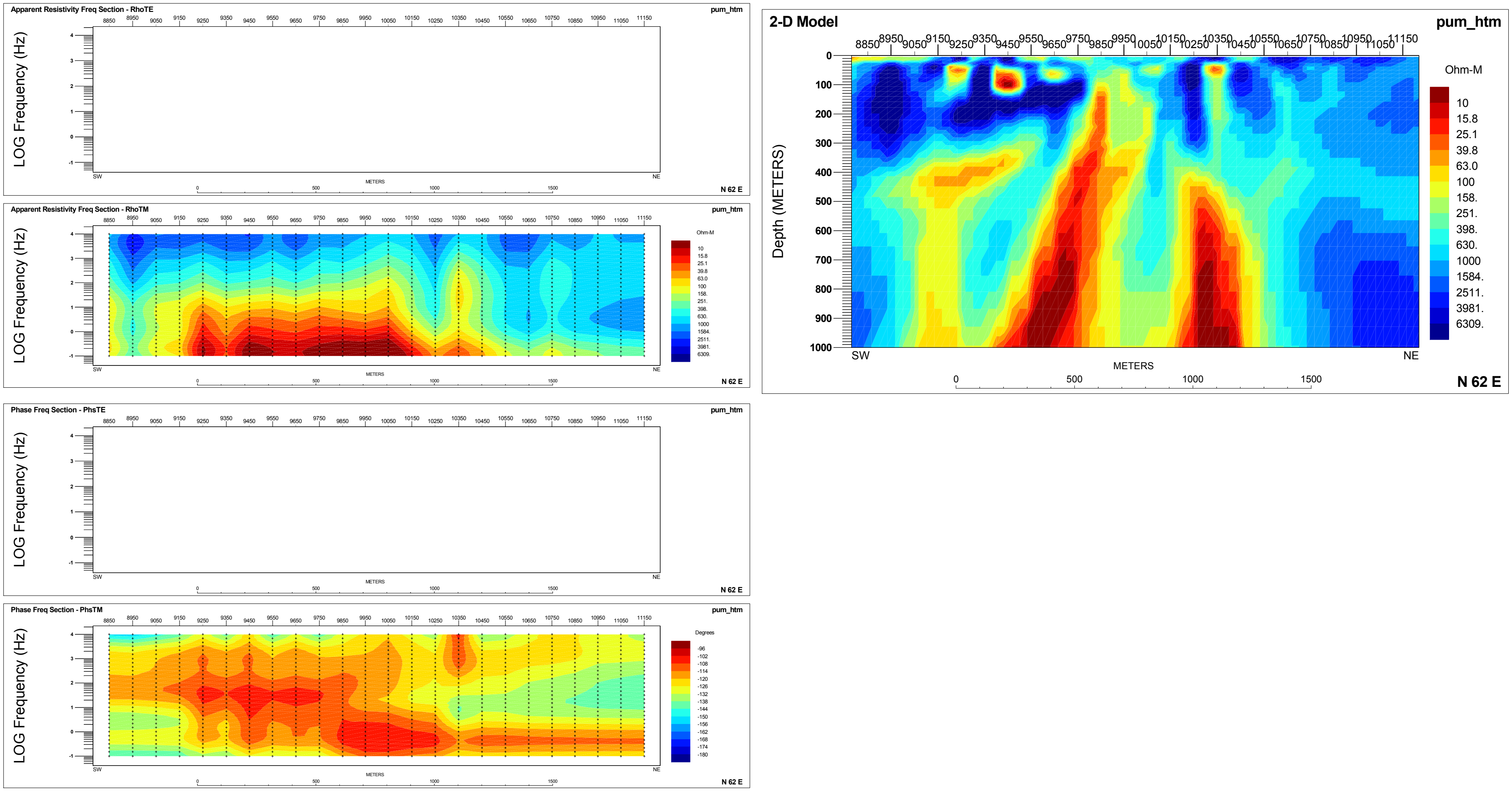
c) ***2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models***



d) <u>2D MT unrotated Interpolated Raw Data input to the inversions</u>

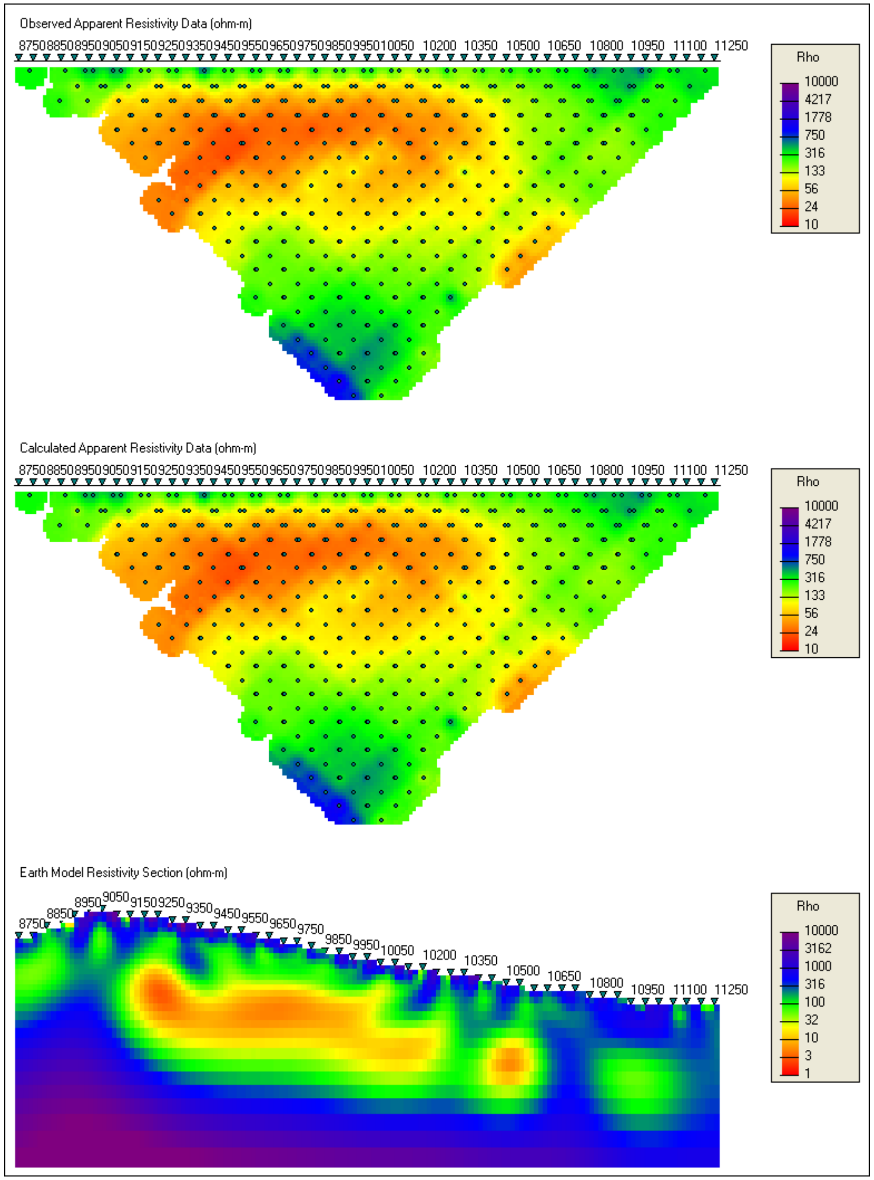


e) ***2D PW MT Resistivity Inversion Model (left = "Line10300N_pum_hrp_it36") and calculated Data (right)***

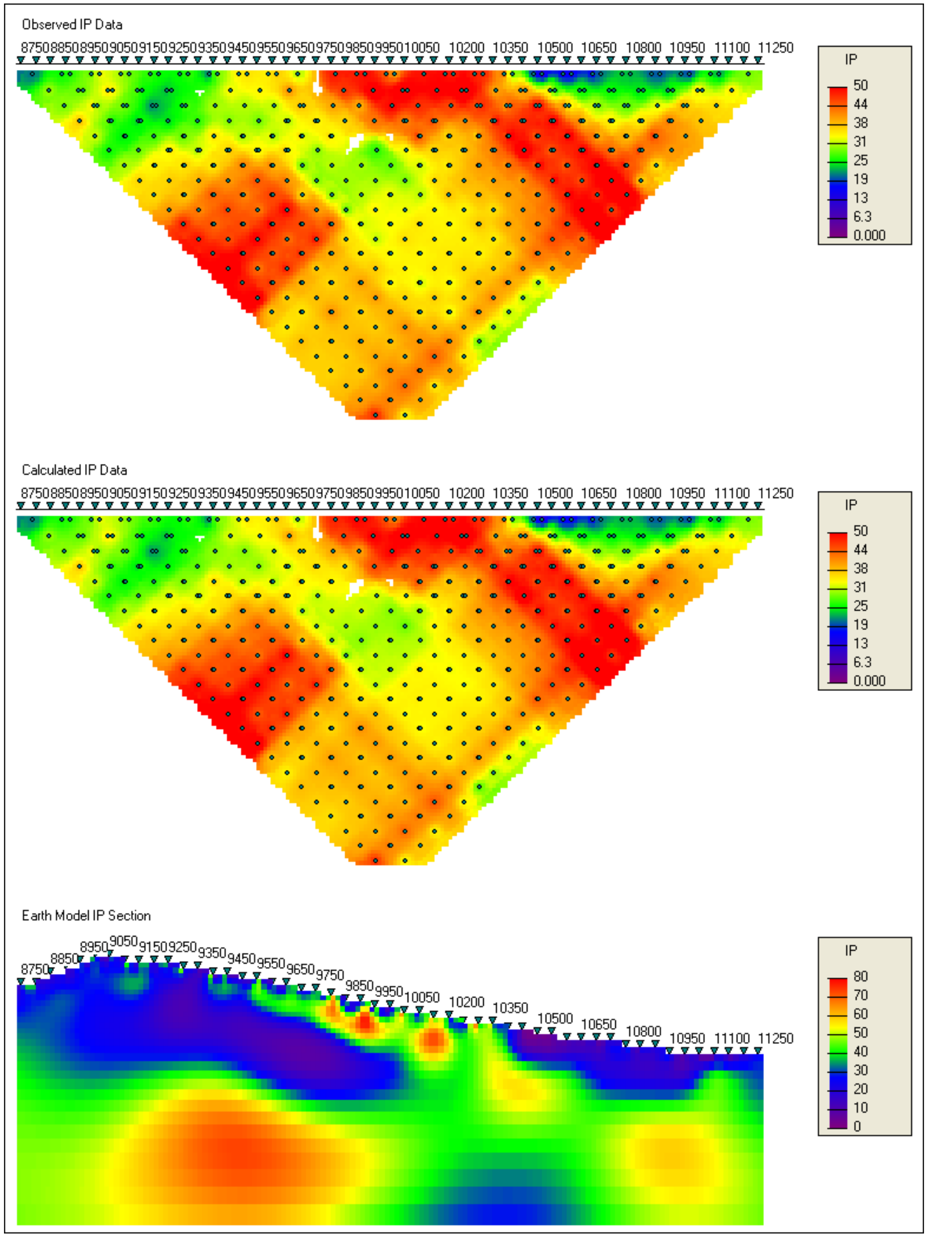


f) 2D PW MT Resistivity Inversion Model (left= "Line10300N_pum_htm_it49") and calculated Data (right)

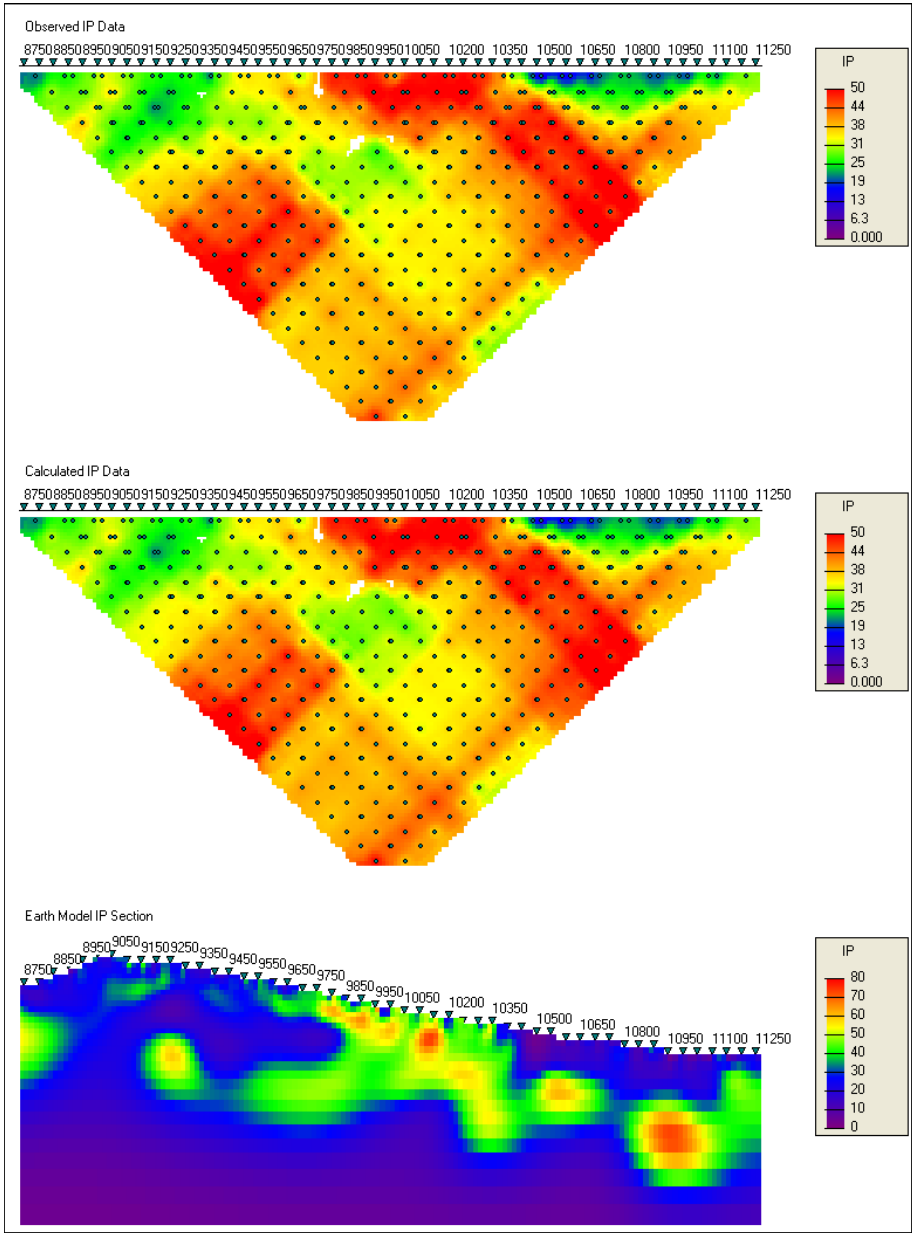
Line L10600N



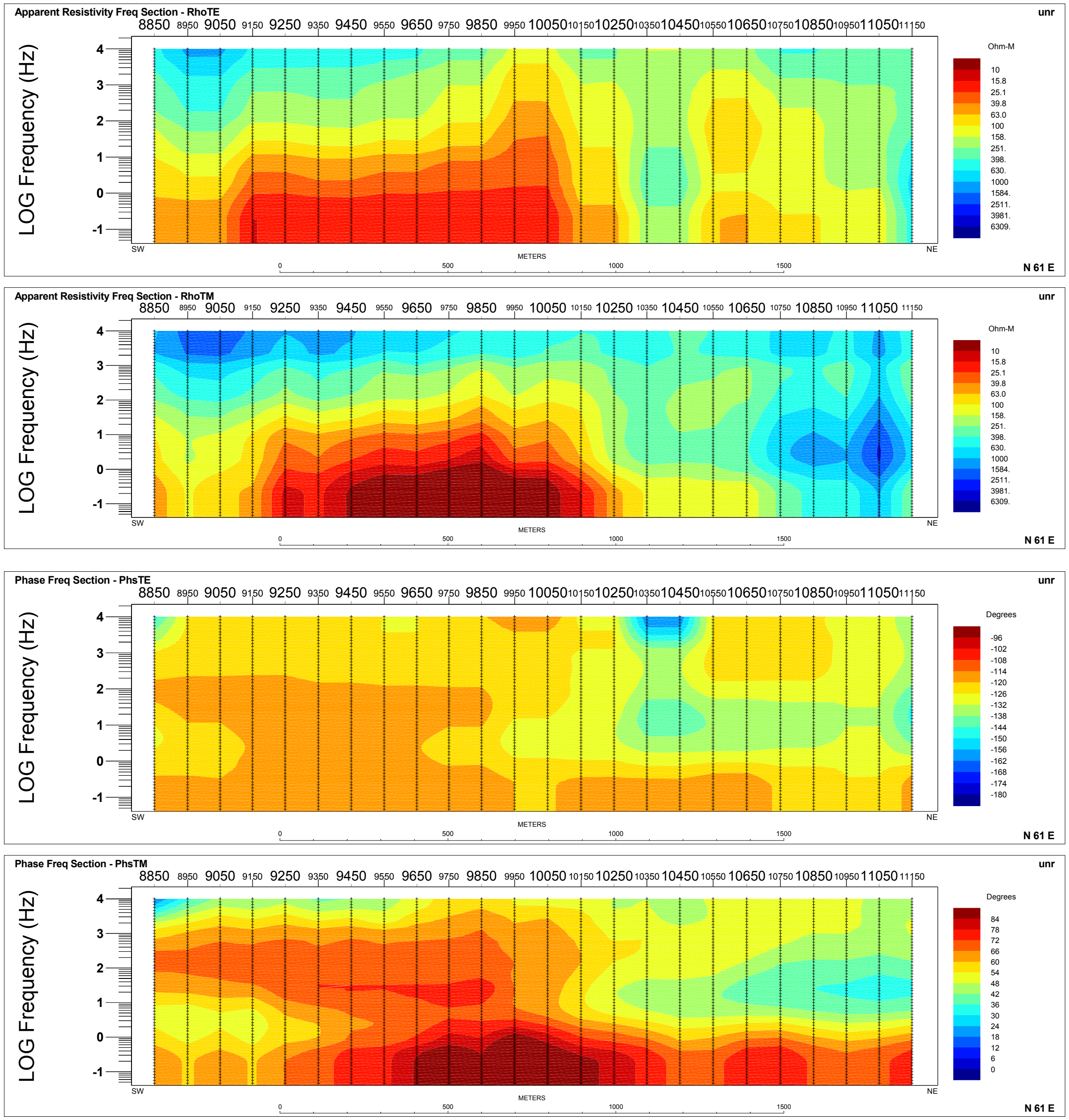
a) ***2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models***



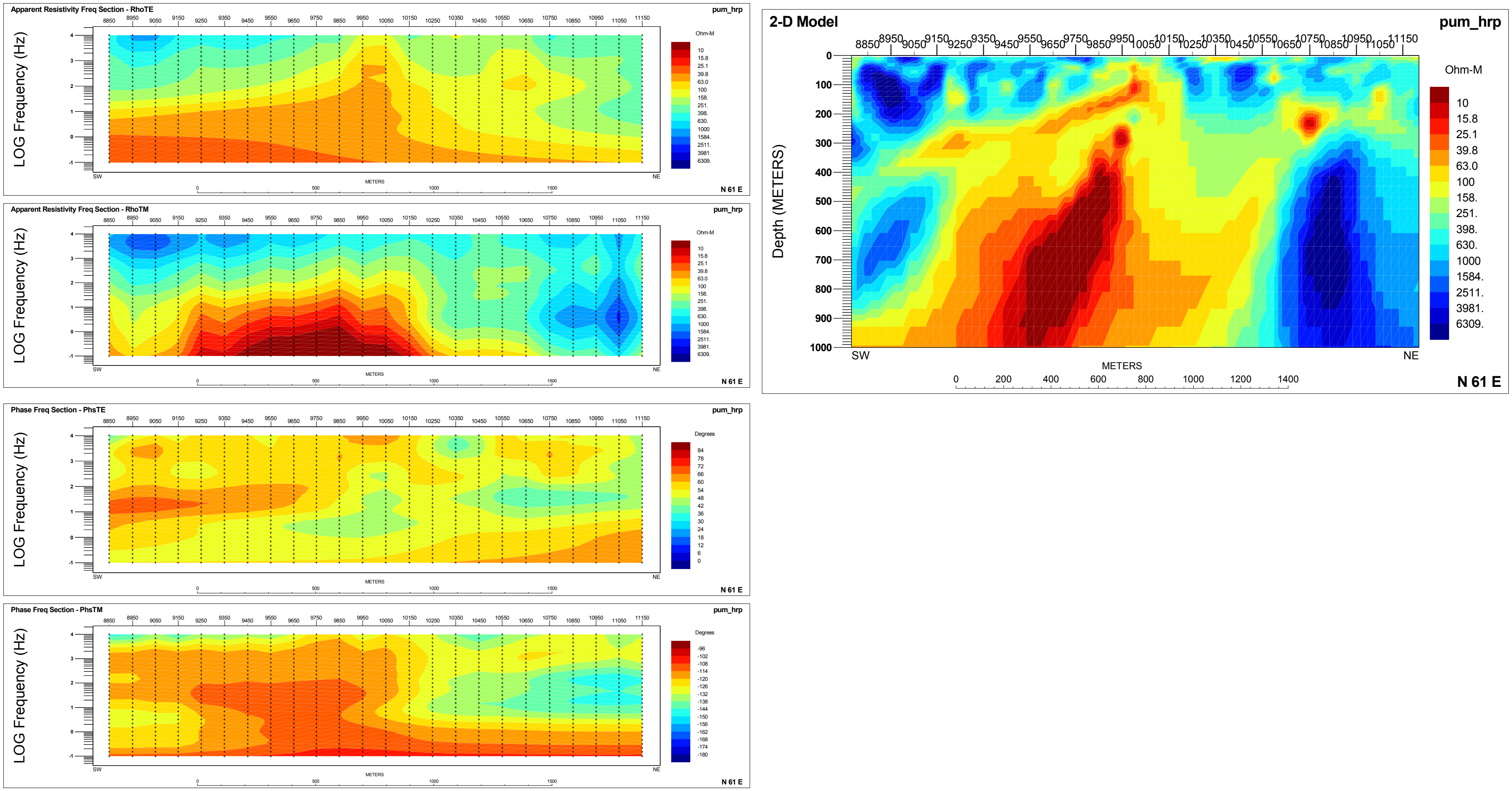
b) 2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models



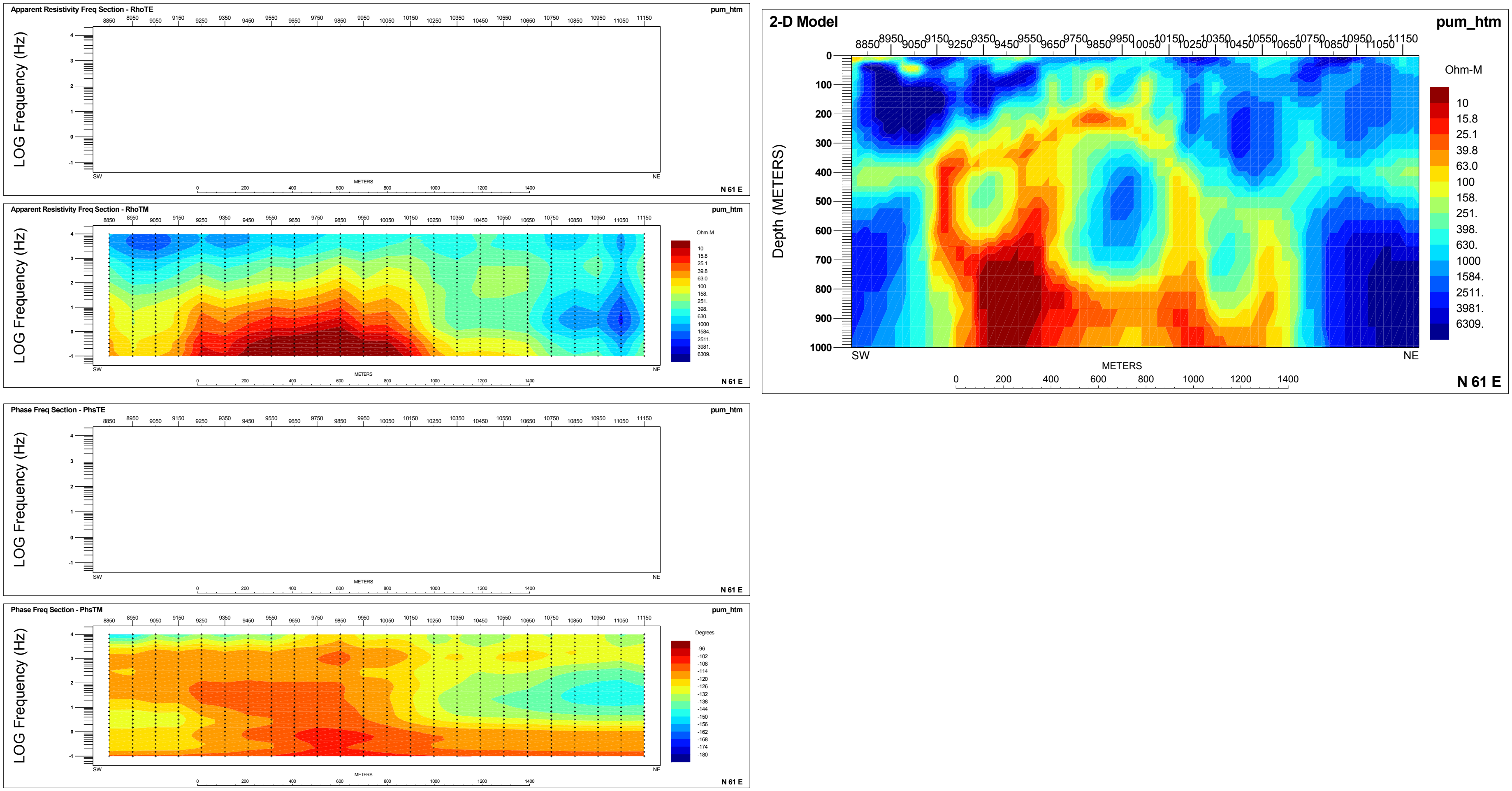
c) <u>2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models</u>



d) 2D MT unrotated Interpolated Raw Data input to the inversions

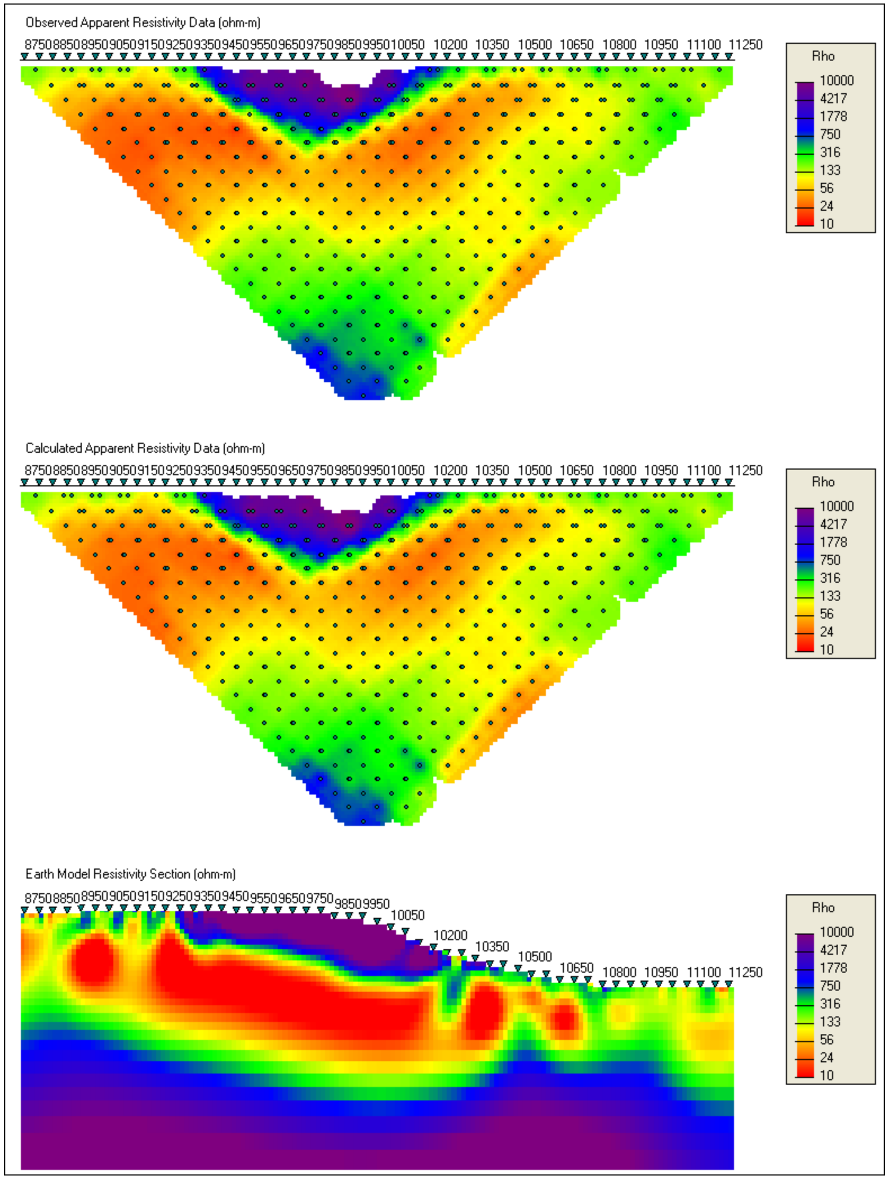


e) ***2D PW MT Resistivity Inversion Model (left = "Line10600N_pum_hrp_it19") and calculated Data (right)***

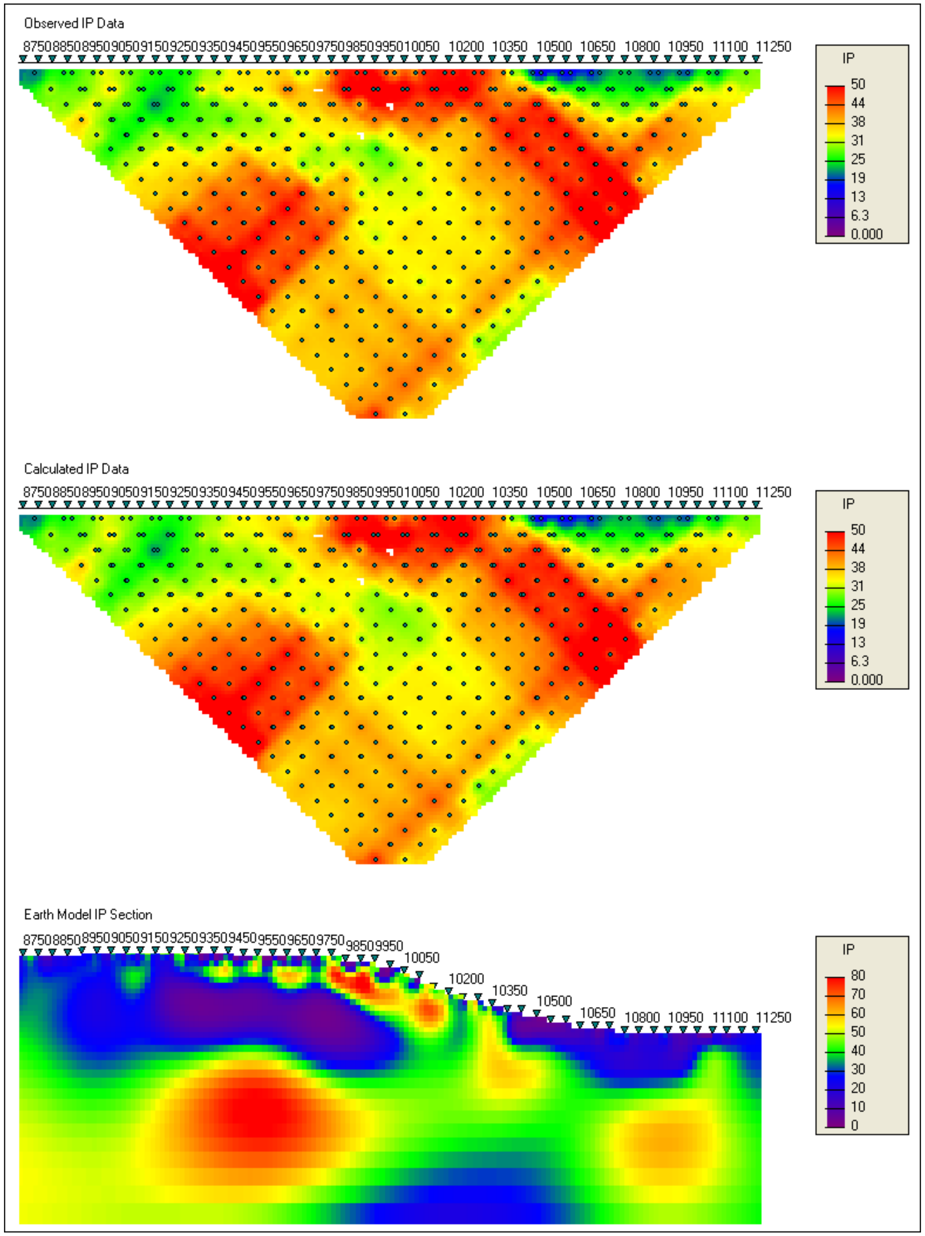


f) ***2D PW MT Resistivity Inversion Model (left= "Line10600N_pum_htm_it49") and calculated Data (right)***

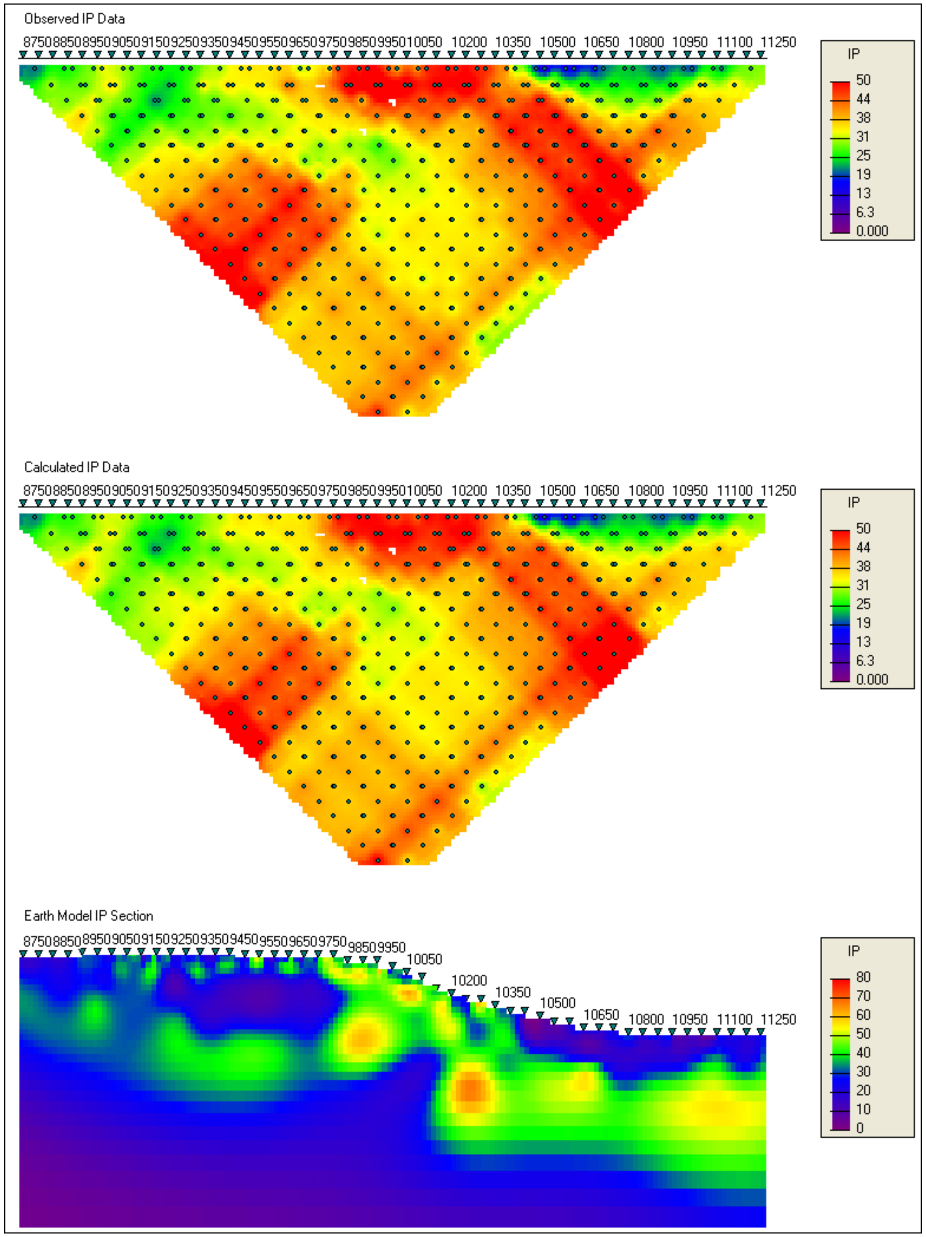
Line L10900N



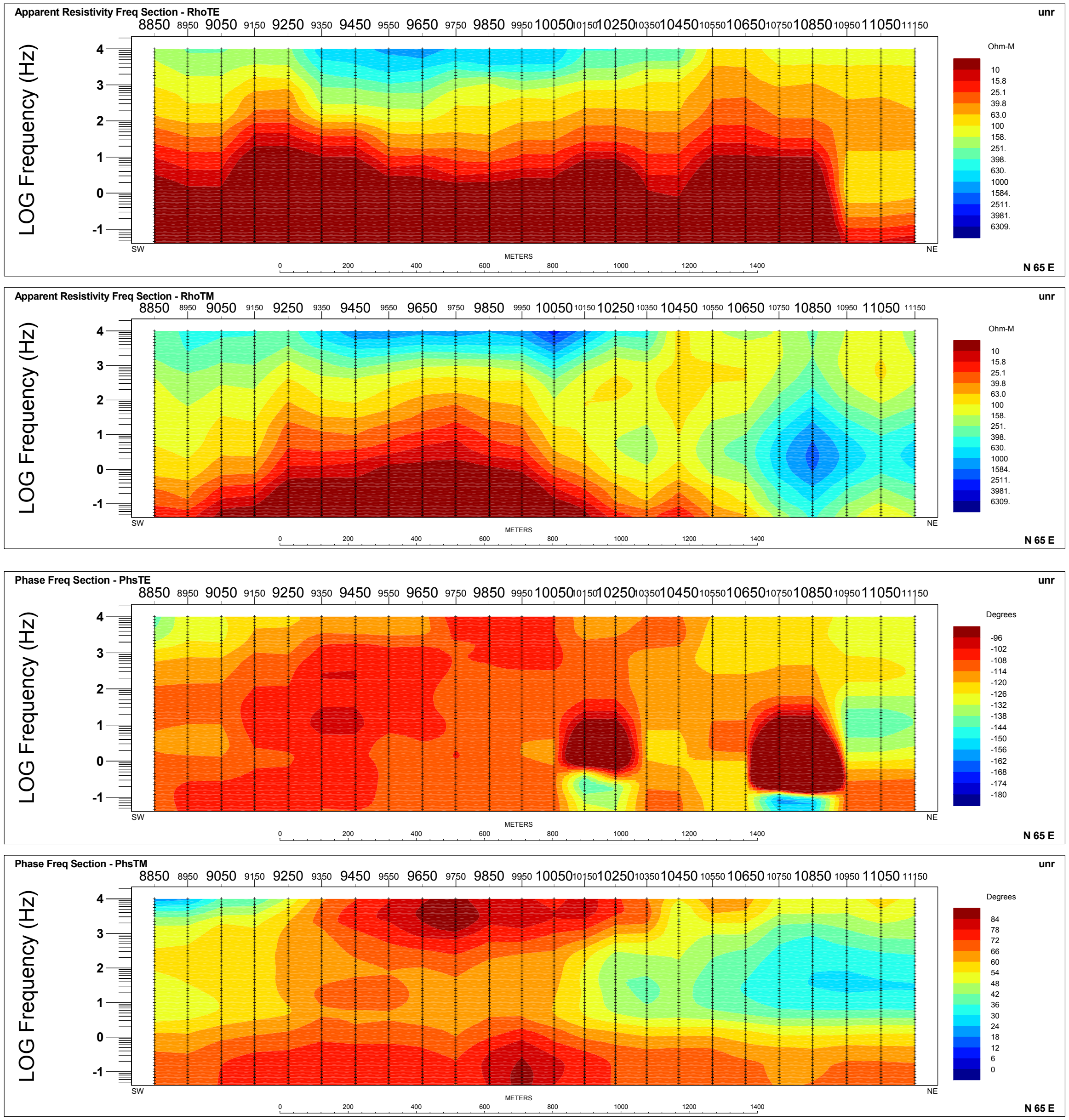
a) *2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models*



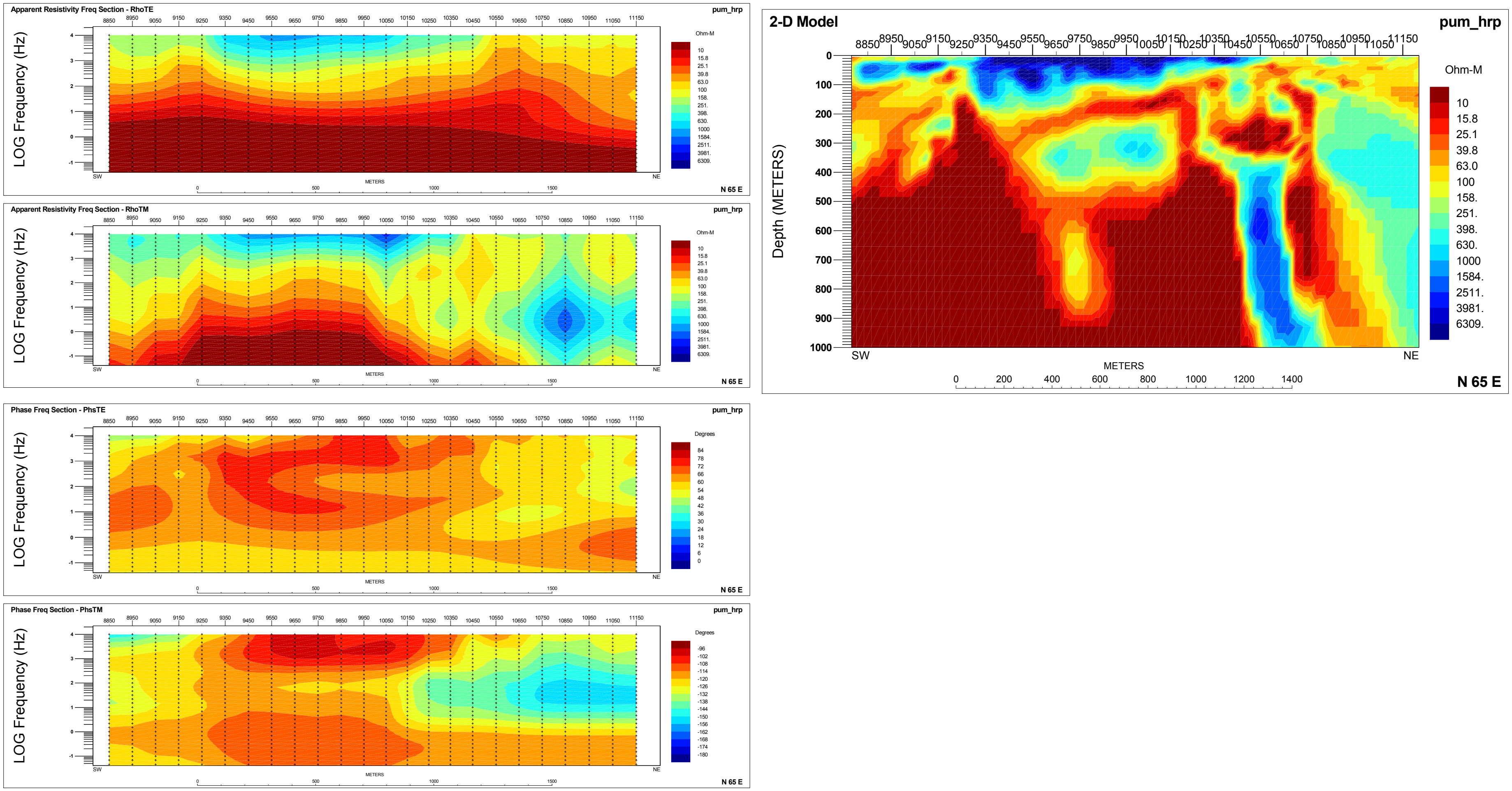
b) 2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models



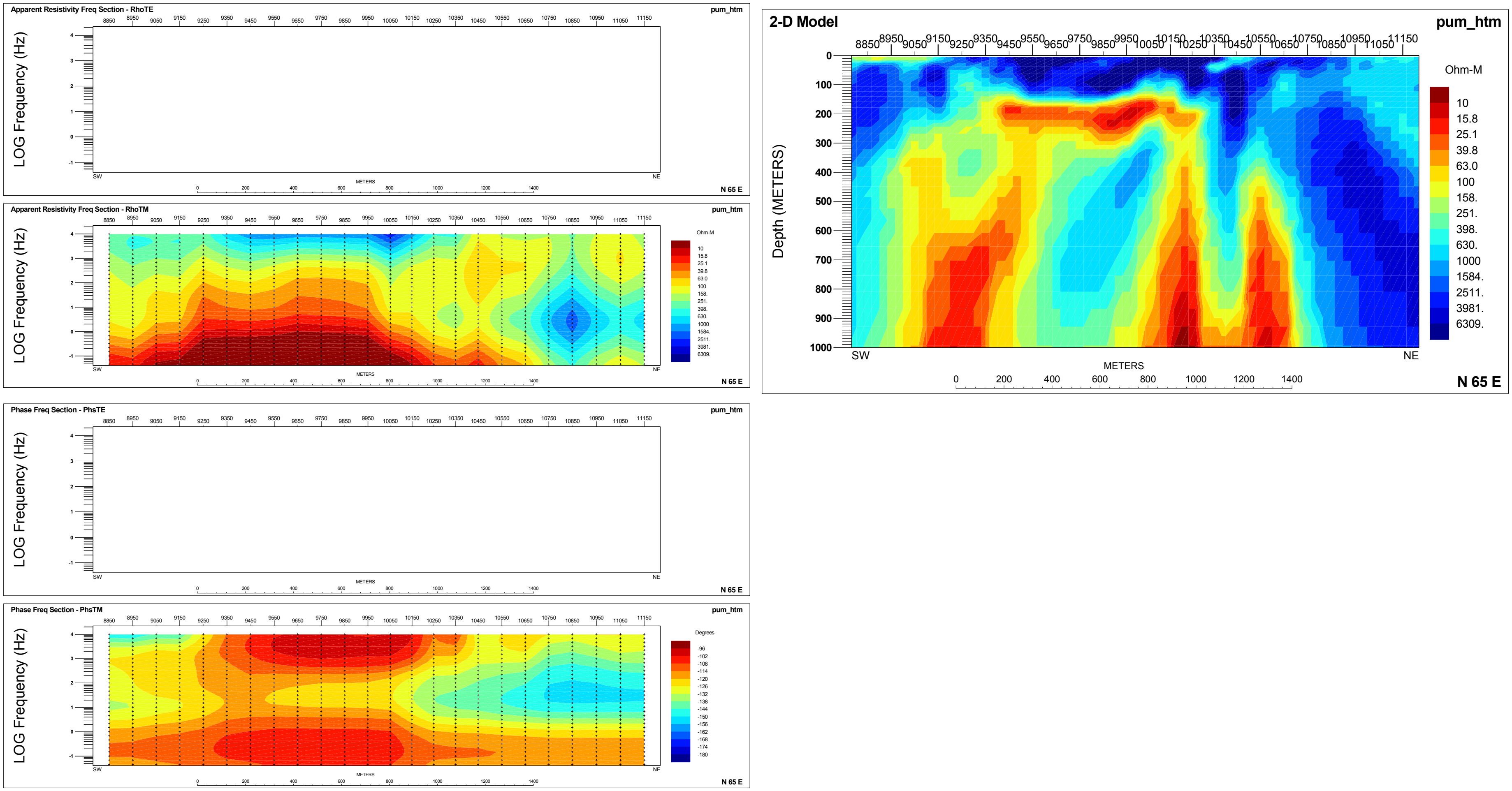
c) 2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models



d) <u>2D MT unrotated Interpolated Raw Data input to the inversions</u>

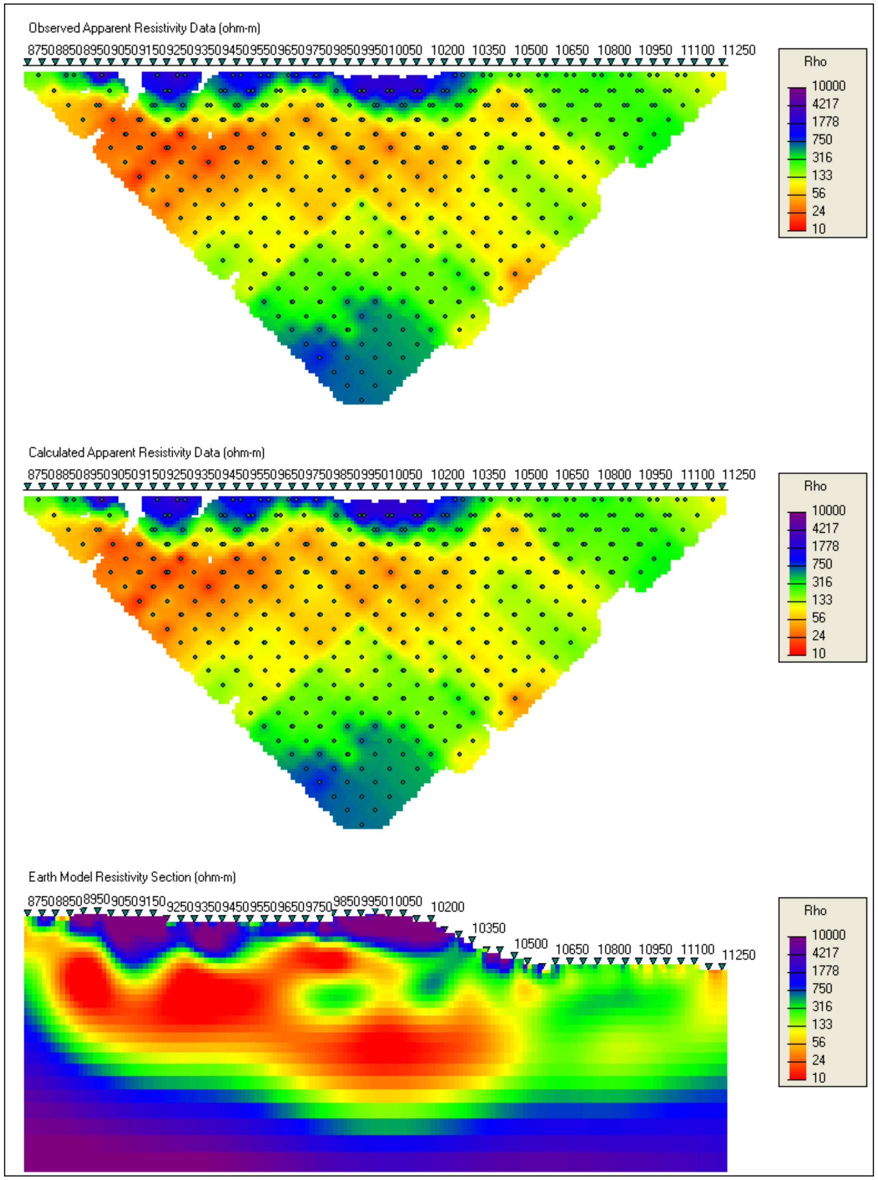


e) ***<u>2D PW MT Resistivity Inversion Model (left = “Line10900N_pum_hrp_it49”) and calculated Data (right)</u>***

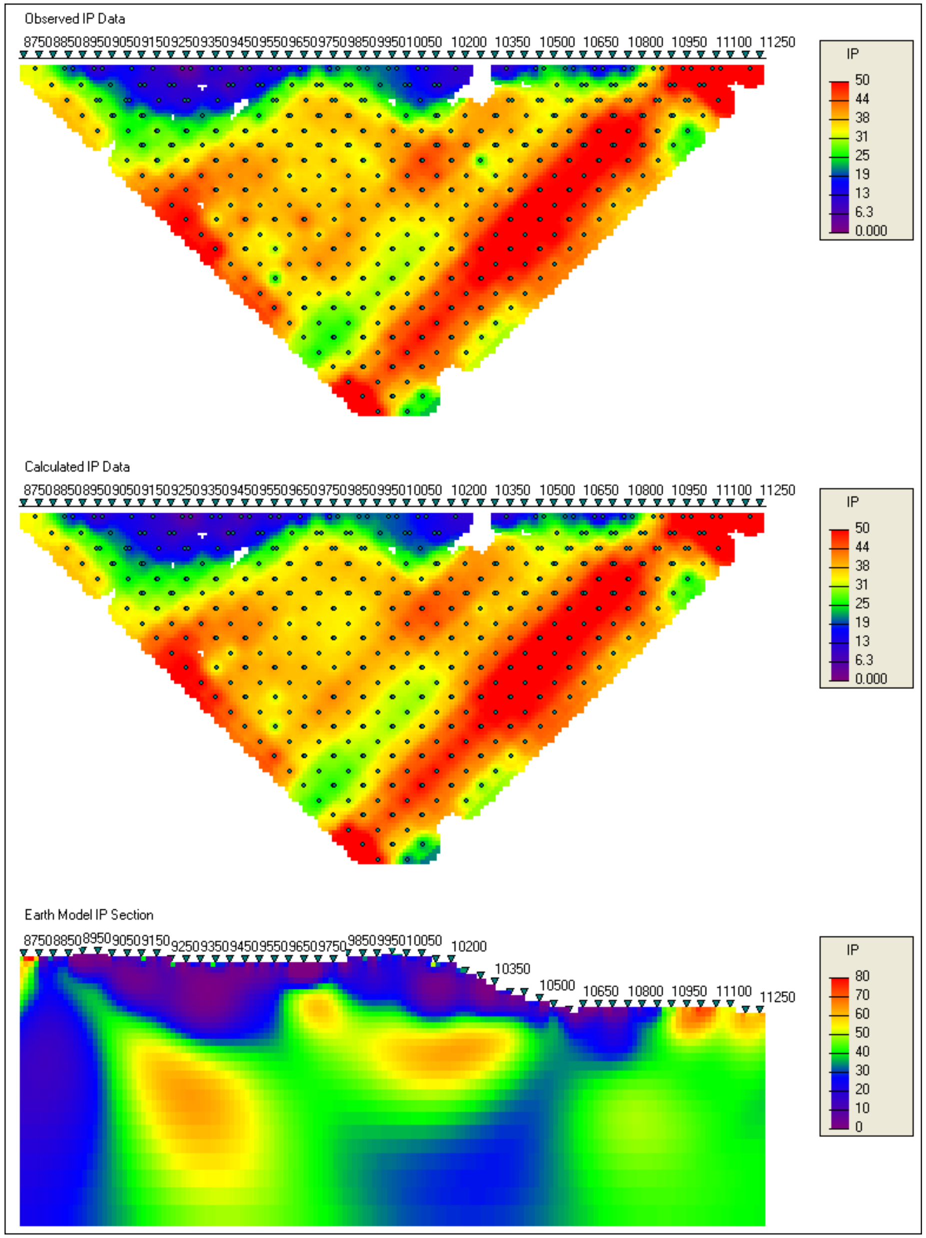


f) ***2D PW MT Resistivity Inversion Model (left= "Line10900N_pum_htm_it49") and calculated Data (right)***

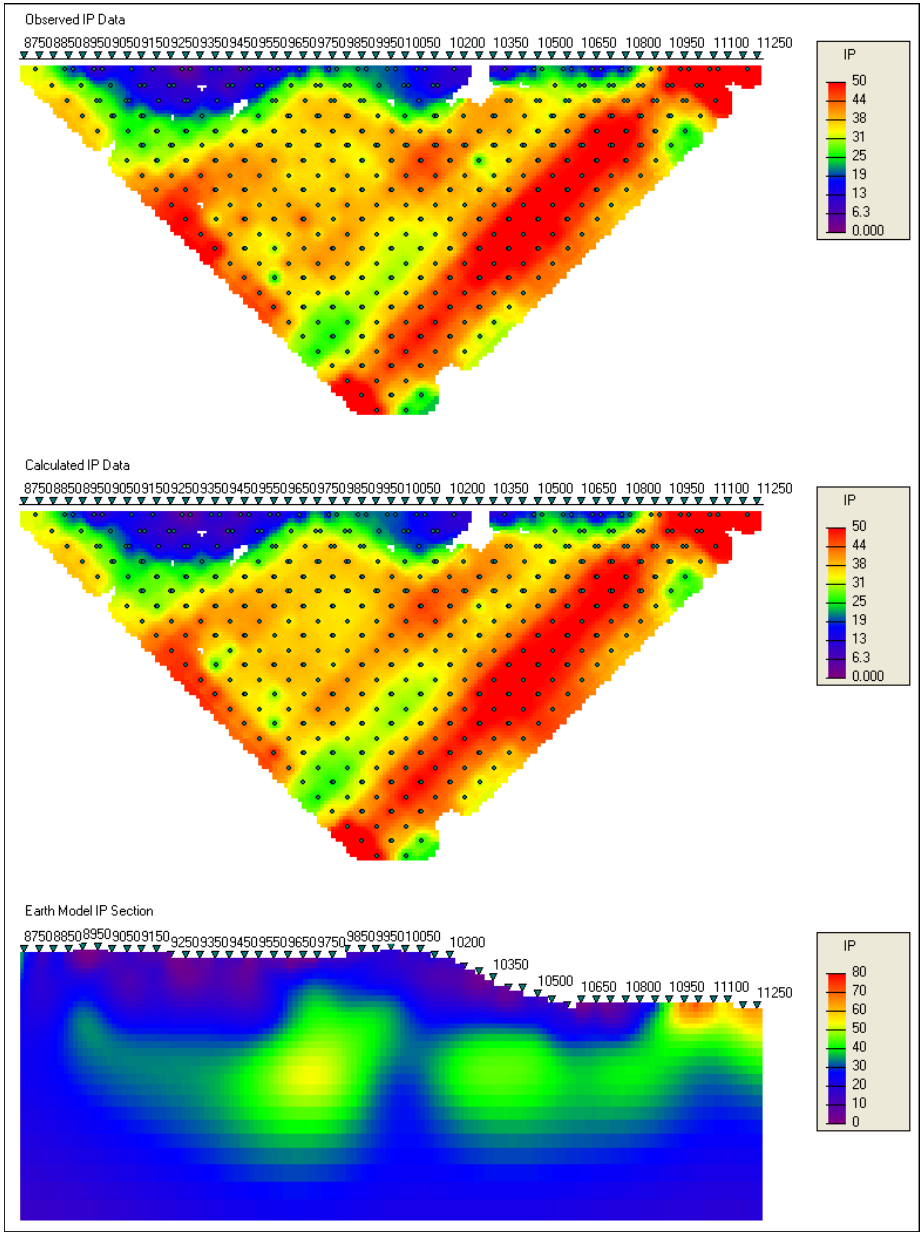
Line L11200N



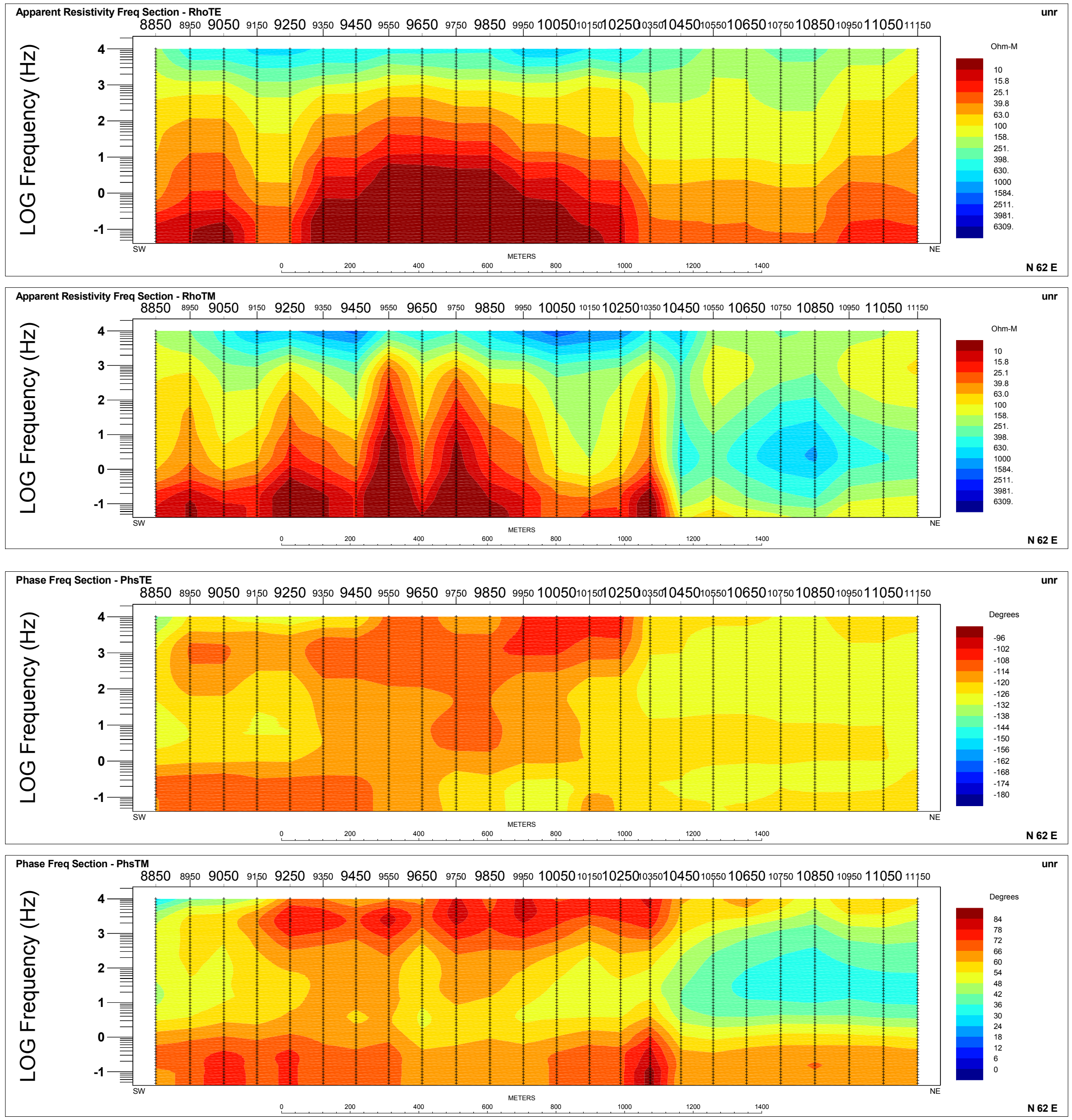
a) ***2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models***



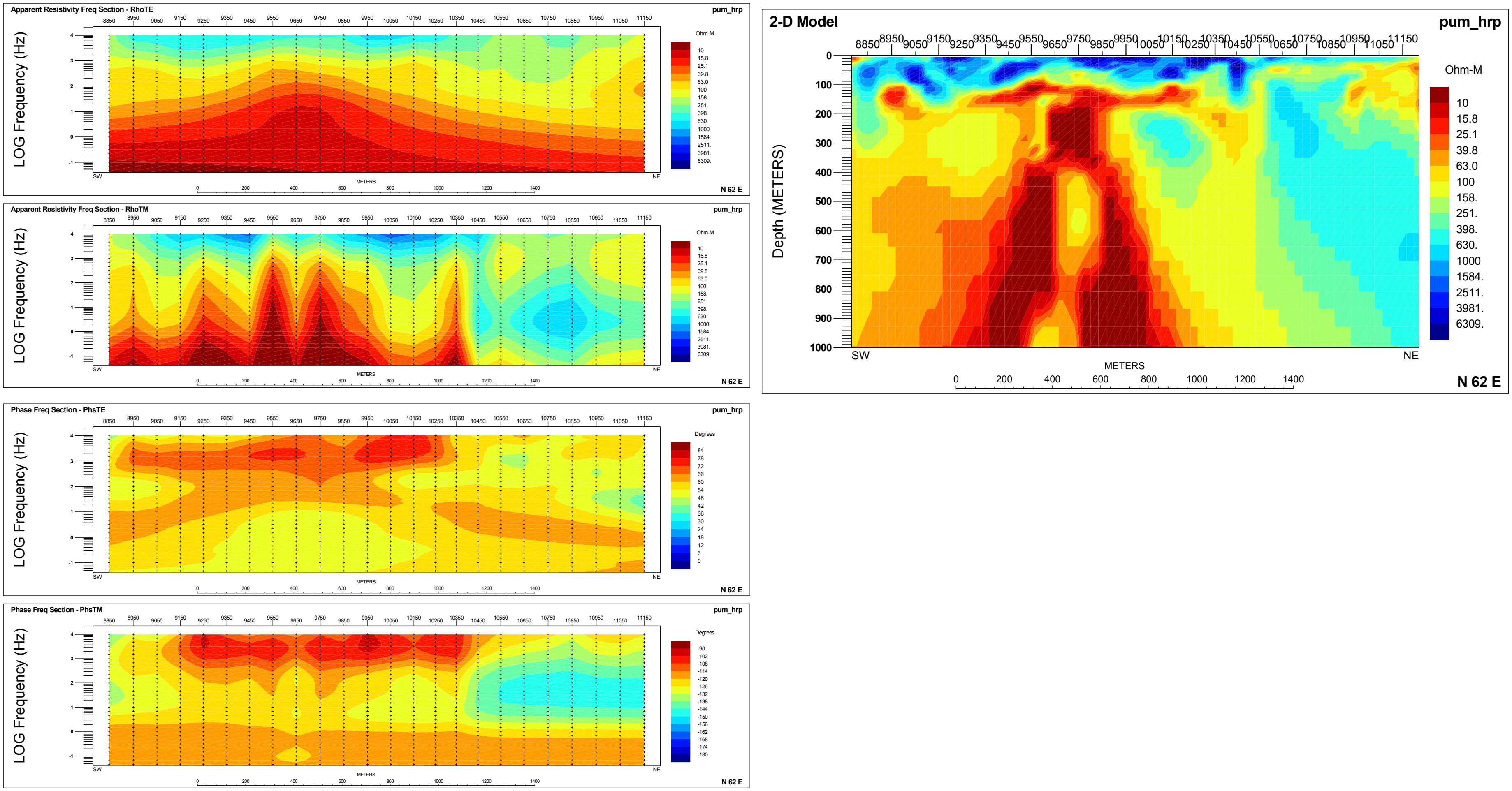
b) ***2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models***



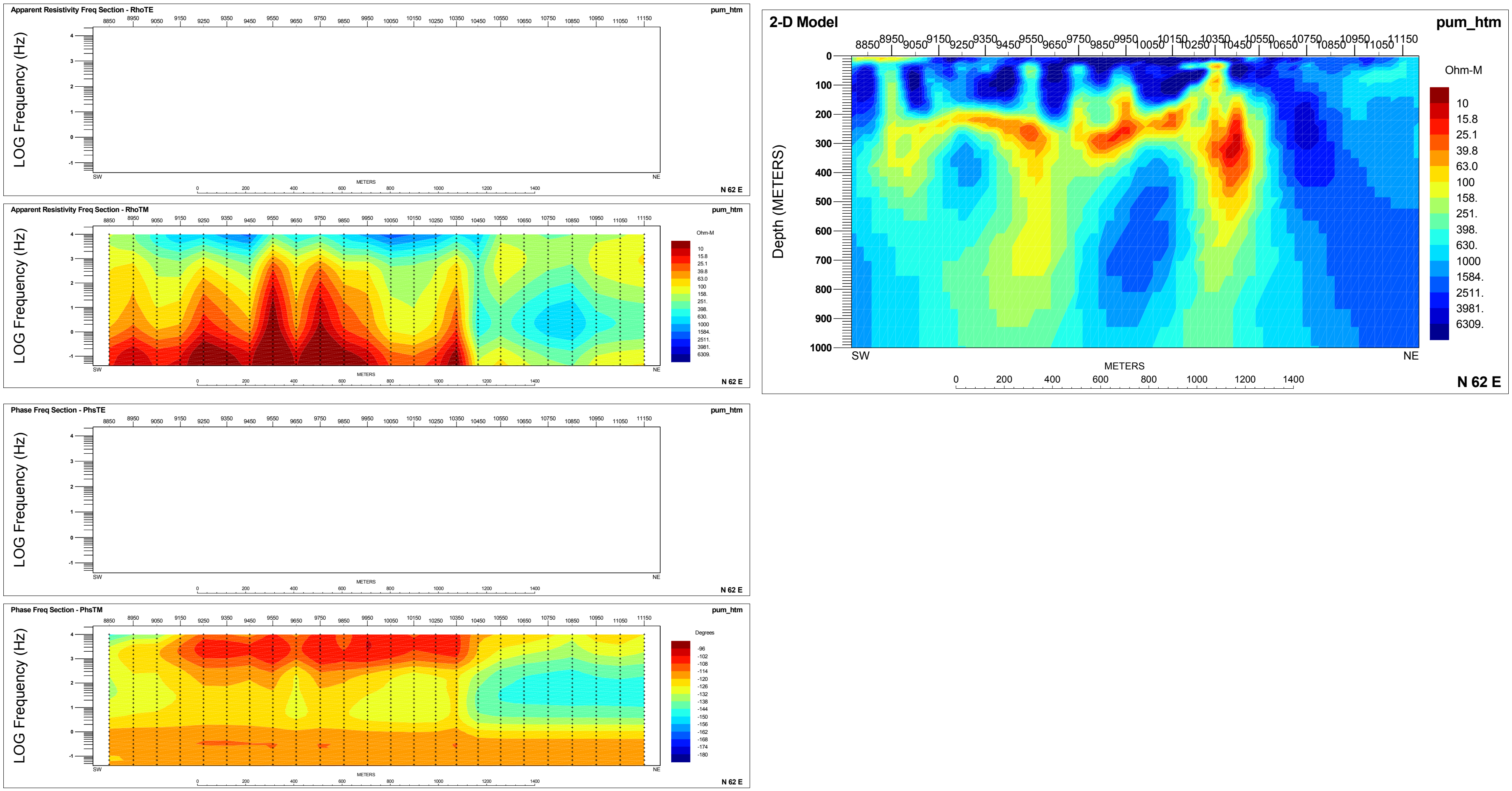
c) 2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models



d) <u>2D MT unrotated Interpolated Raw Data input to the inversions</u>

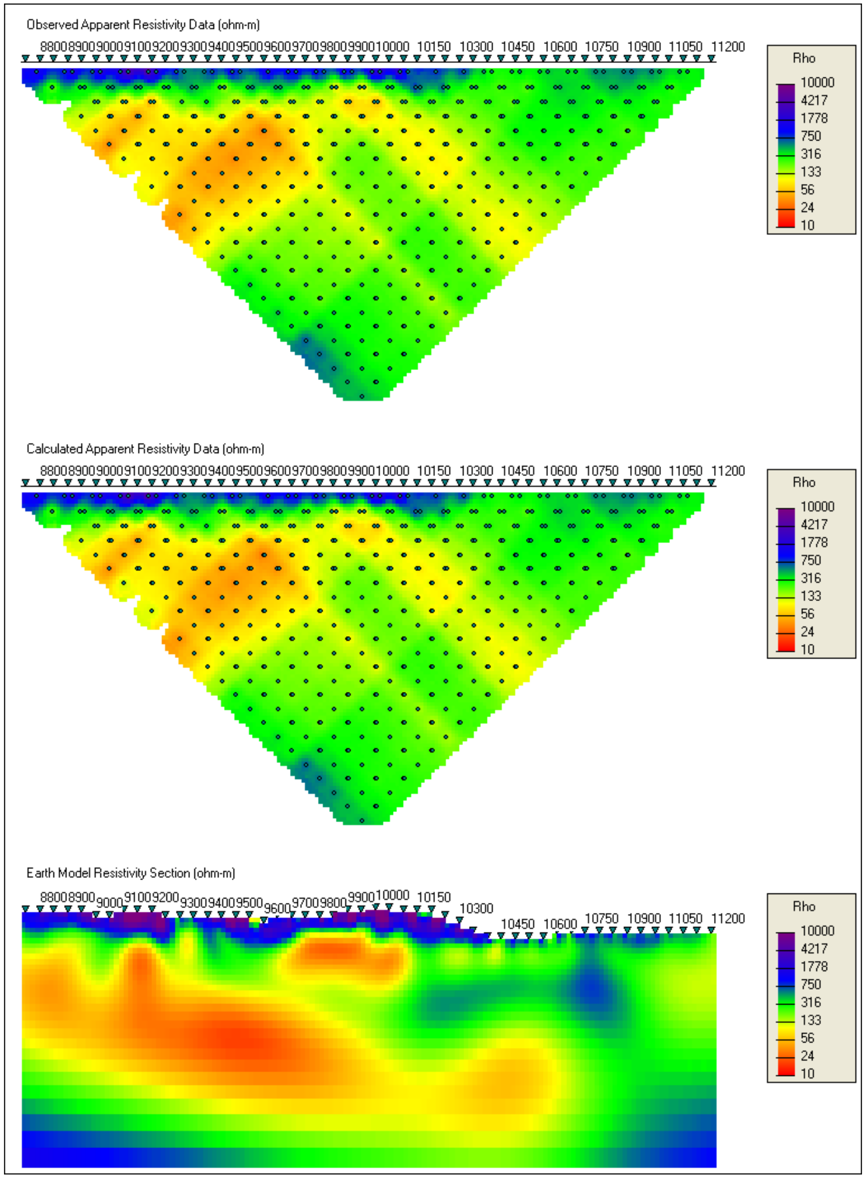


e) ***2D PW MT Resistivity Inversion Model (left = "Line11200N pum hrp it32") and calculated Data (right)***

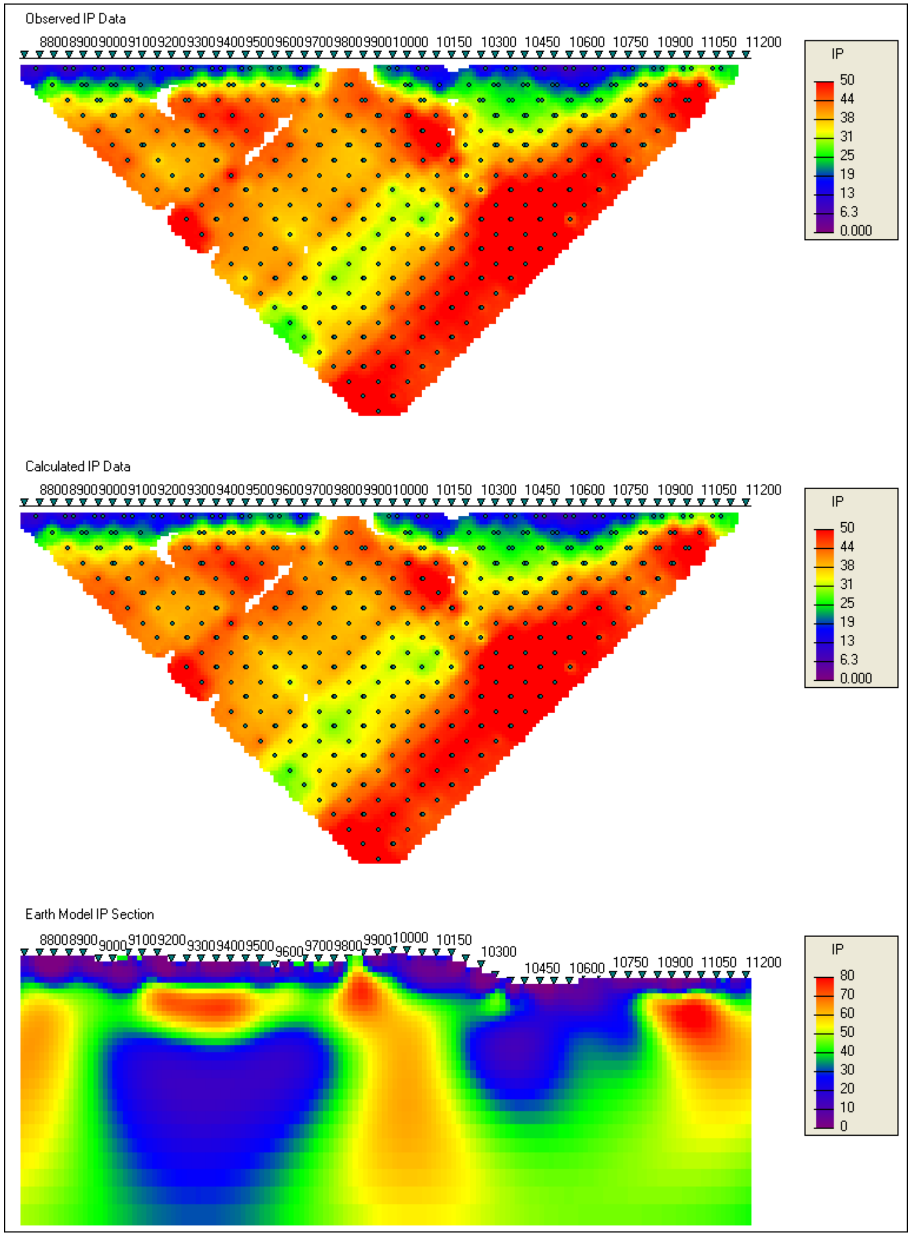


f) 2D PW MT Resistivity Inversion Model (left= "Line11200N_pum_htm_it49") and calculated Data (right)

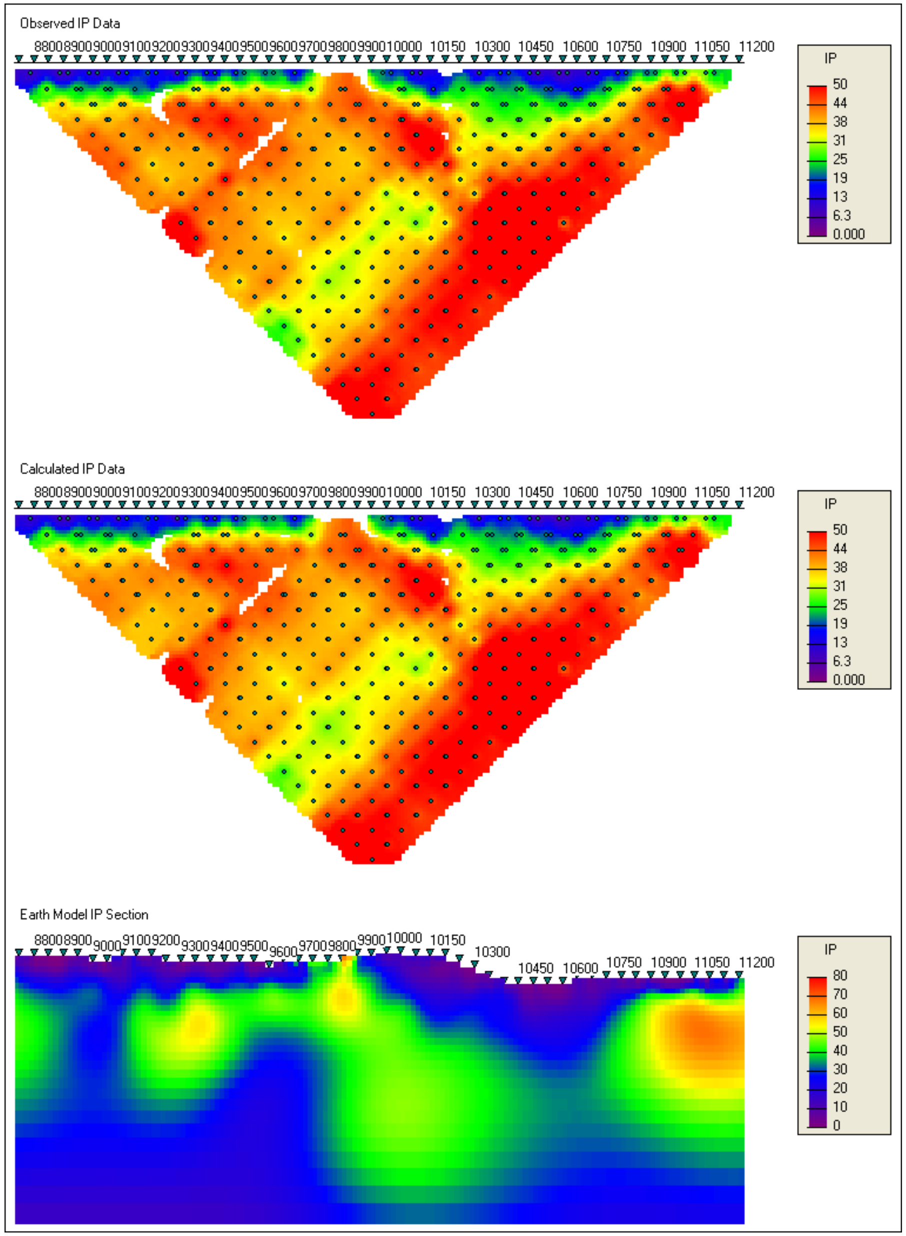
Line L11500N



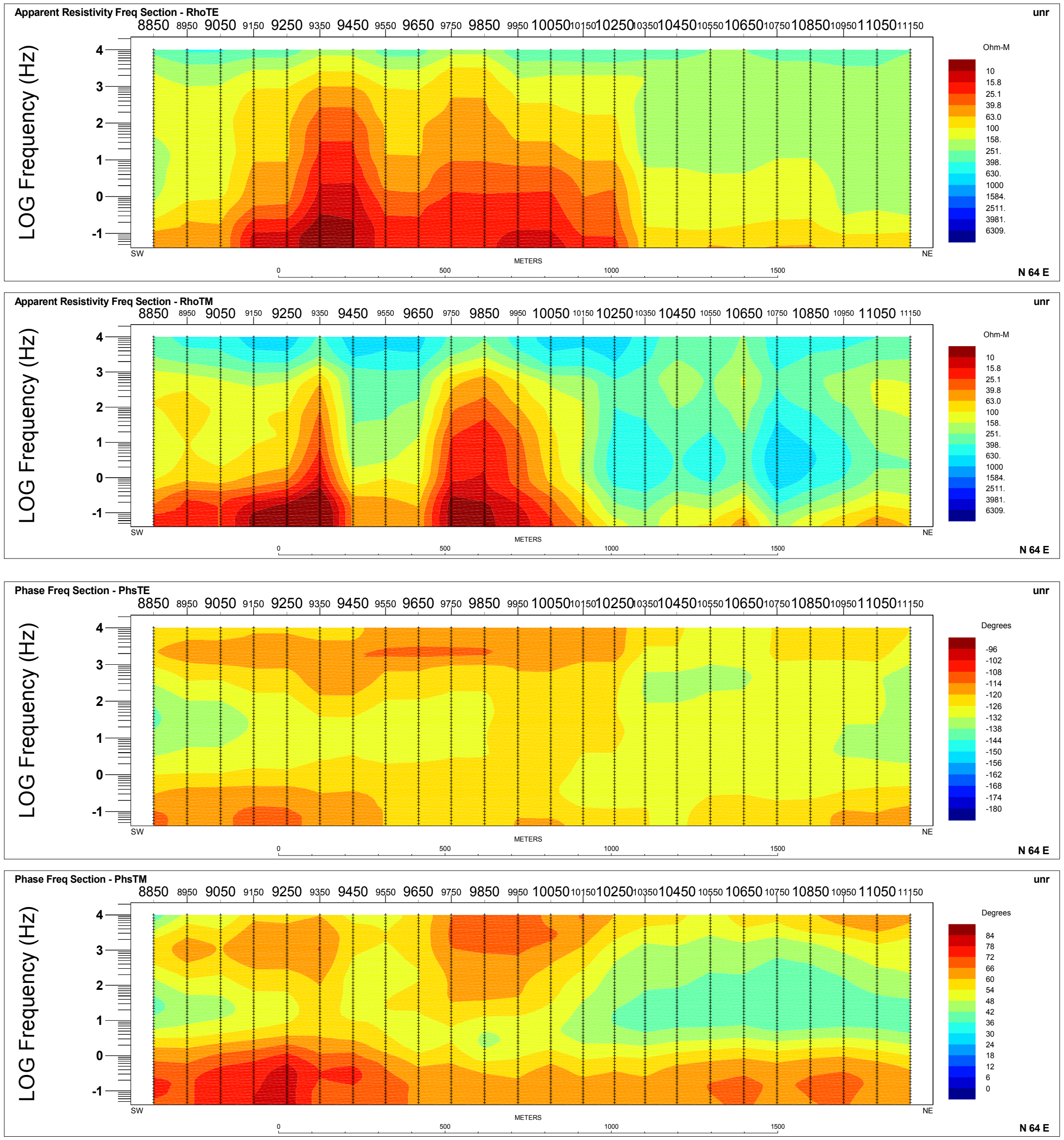
a) ***2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models***



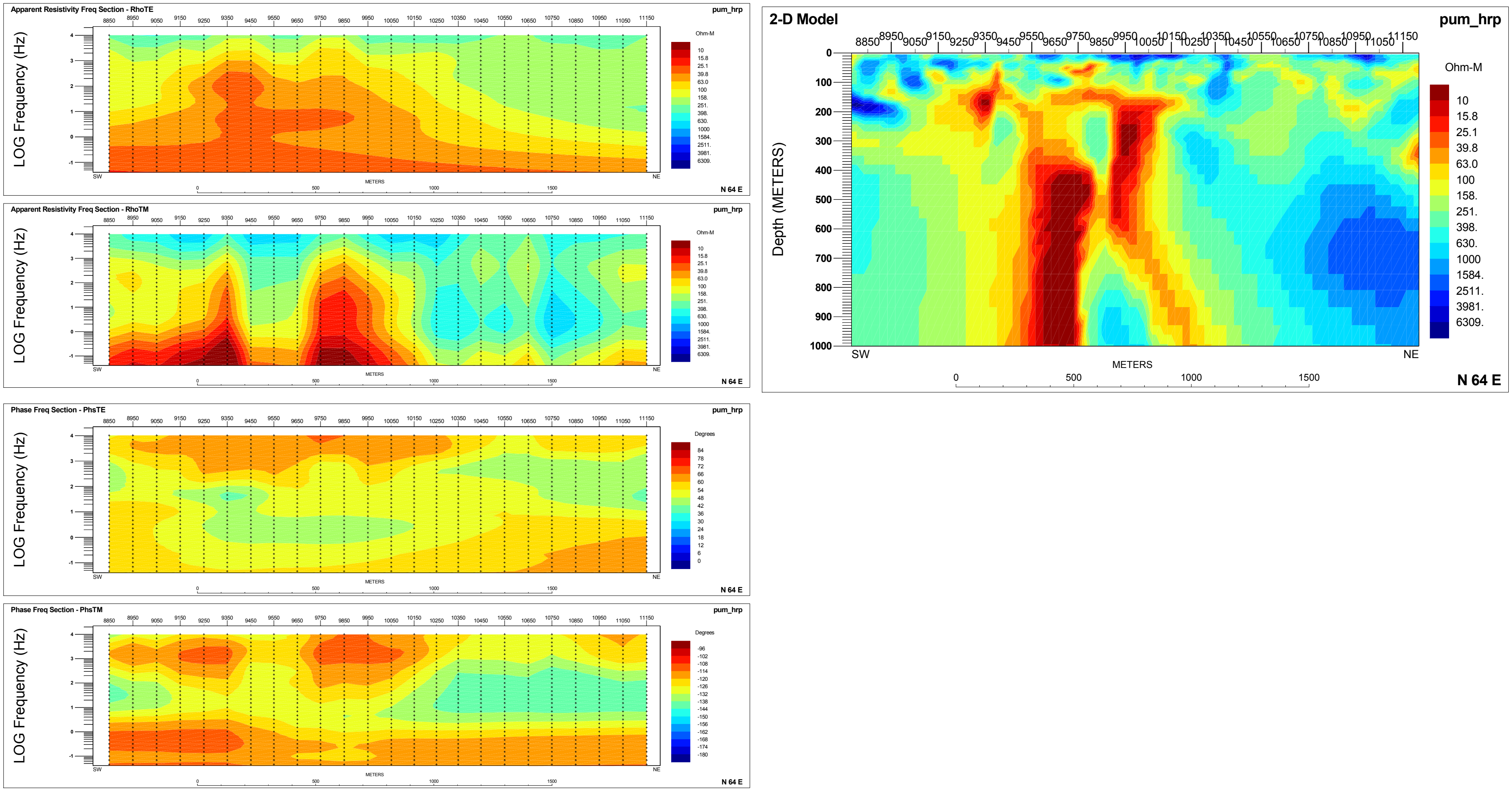
b) ***2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models***



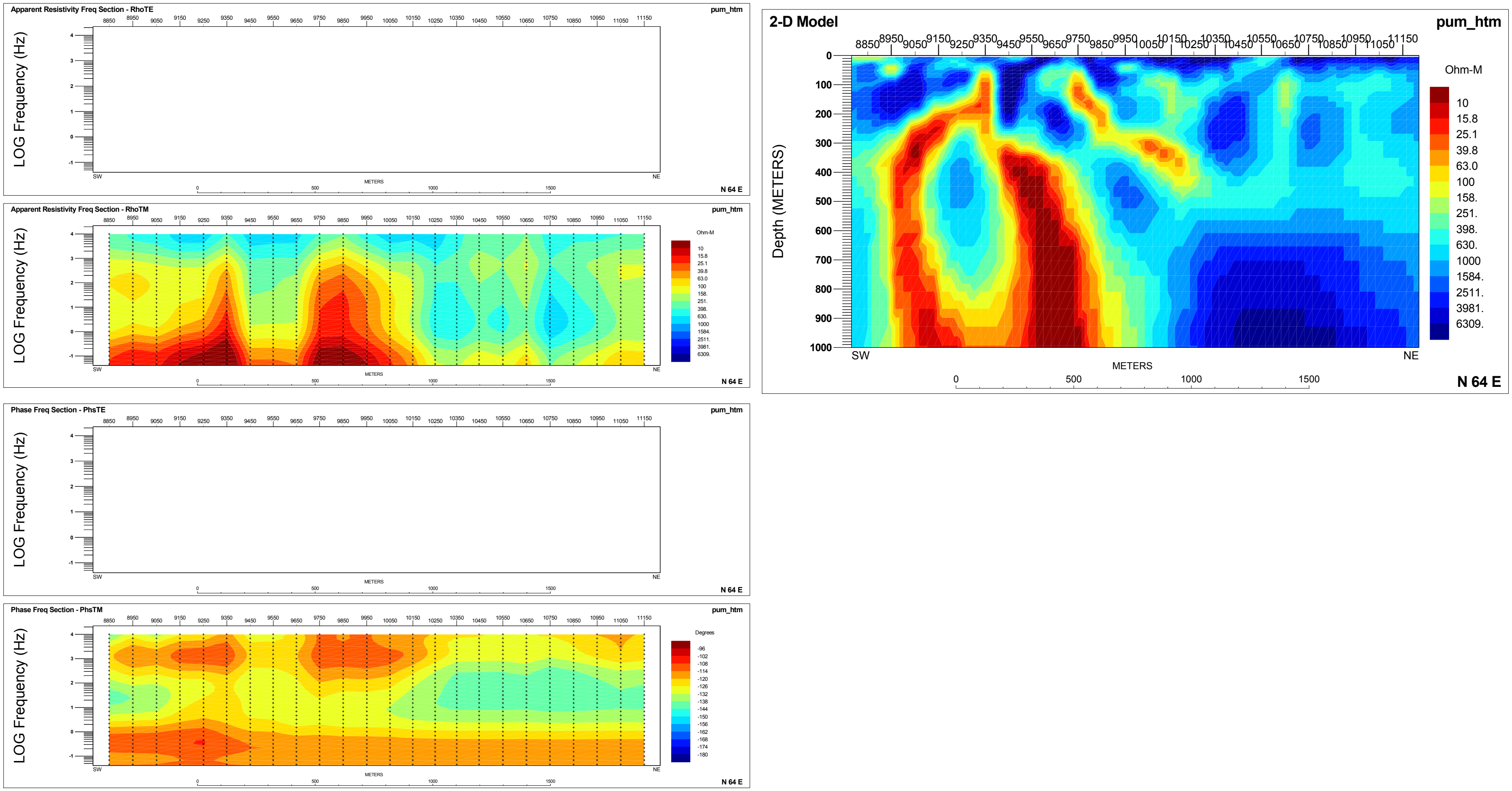
c) <u>2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models</u>



d) ***2D MT unrotated Interpolated Raw Data input to the inversions***

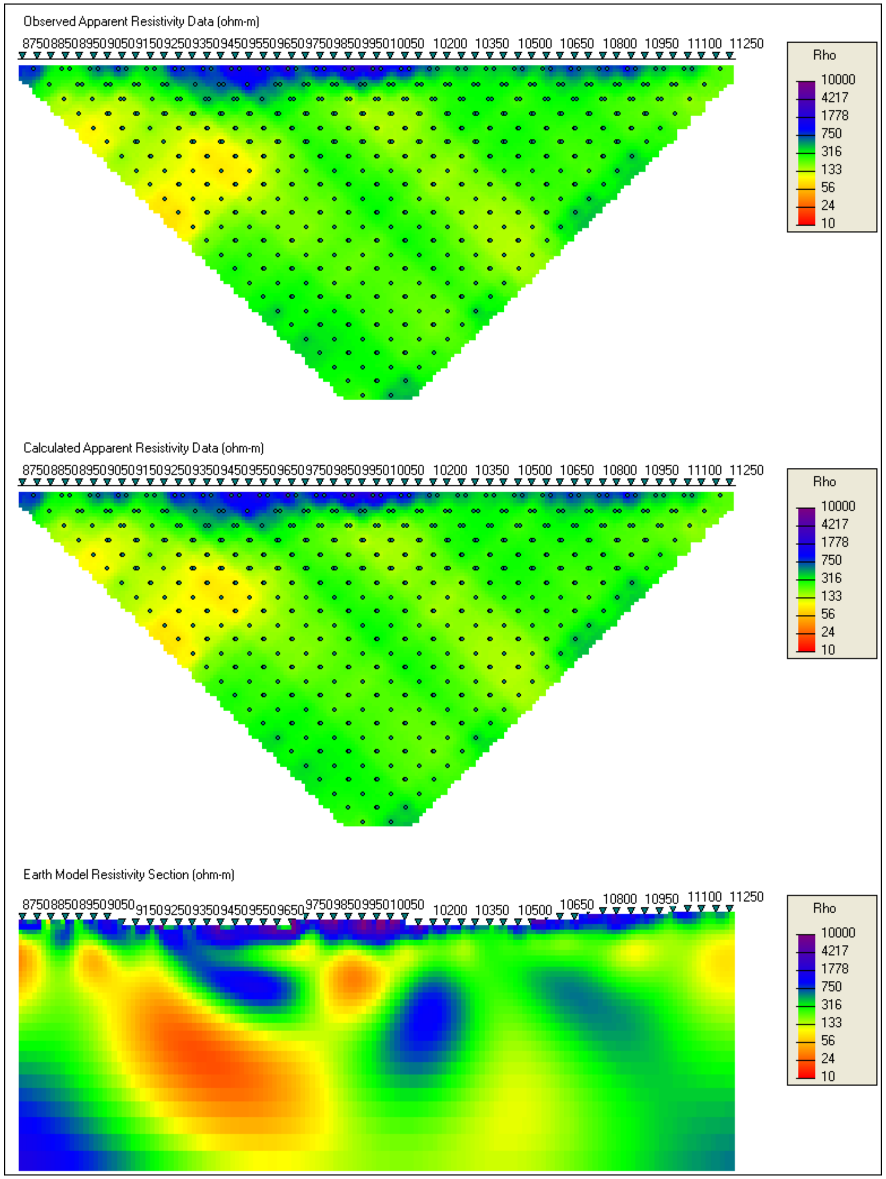


e) 2D PW MT Resistivity Inversion Model (left = "Line11500N_pum_hrp_it33") and calculated Data (right)

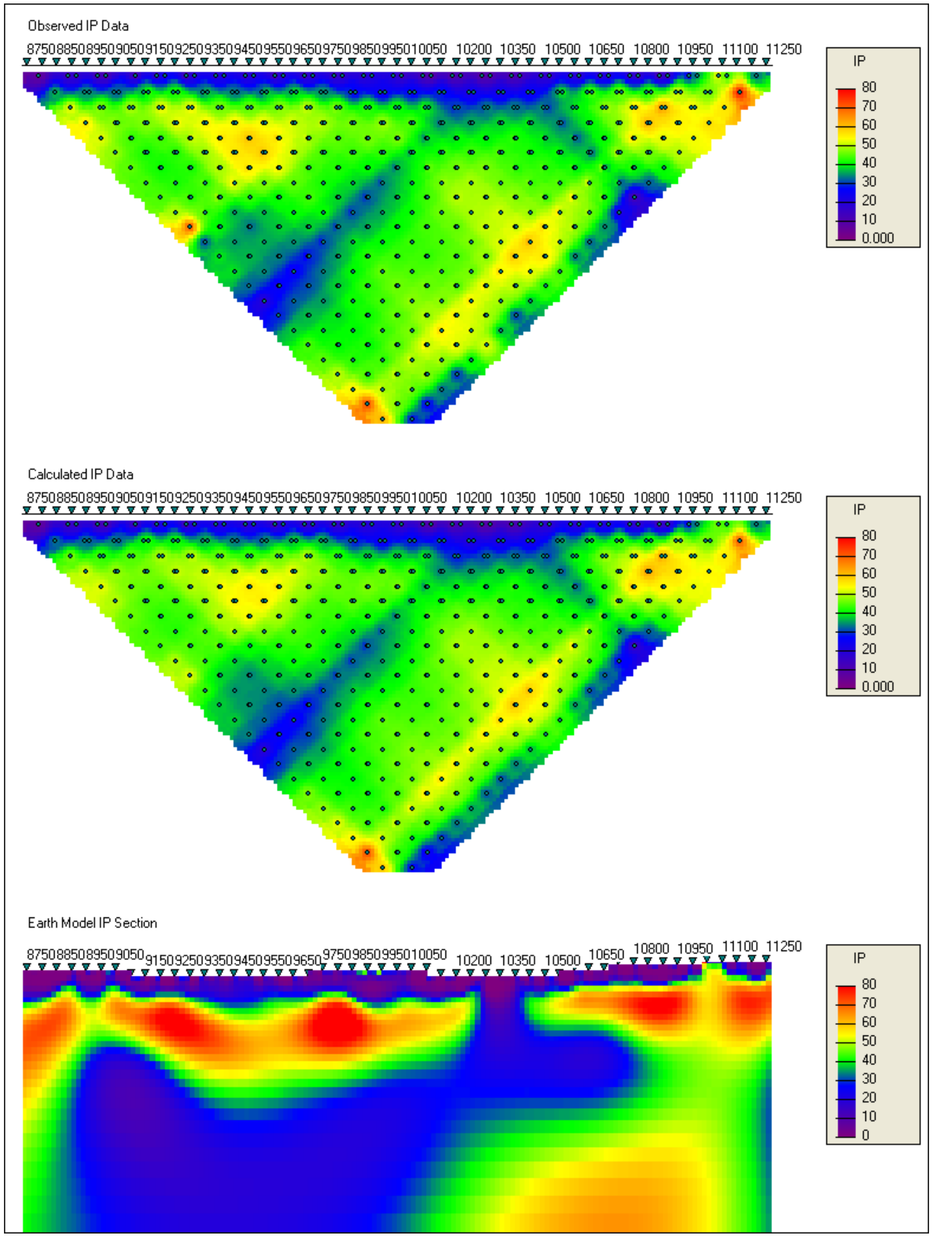


f) 2D PW MT Resistivity Inversion Model (left= "Line11500N_pum_htm_it49") and calculated Data (right)

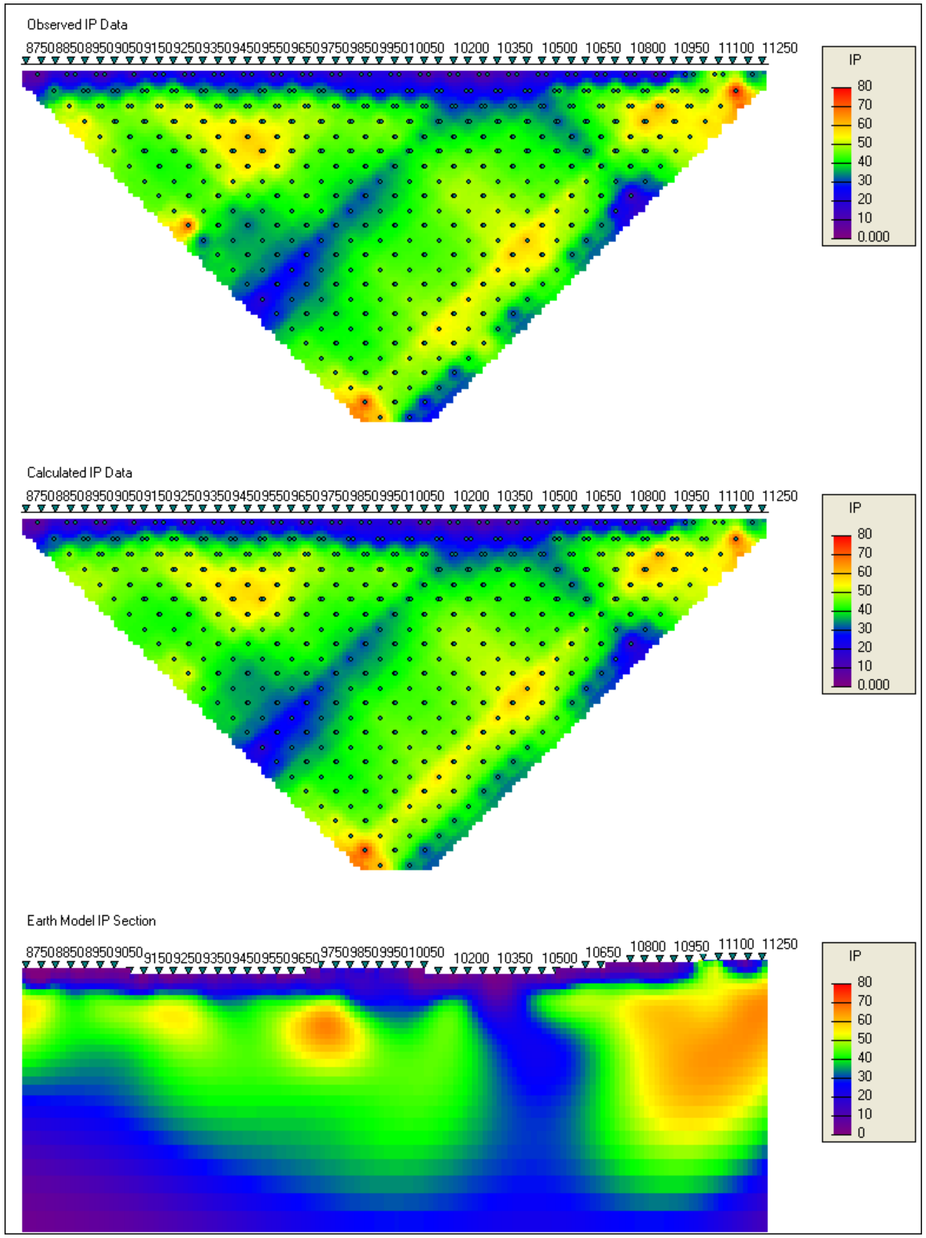
Line L11800N



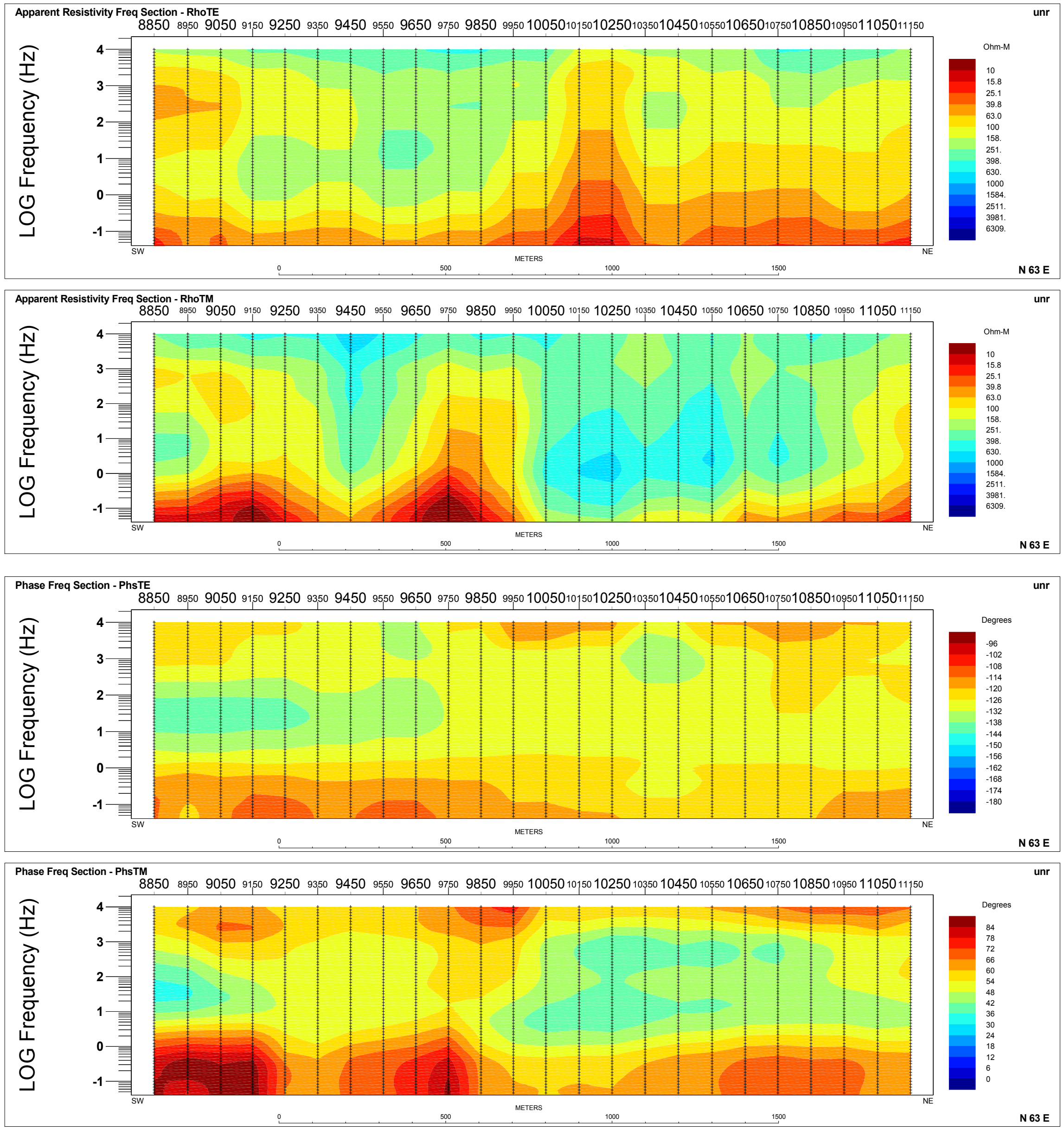
a) 2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models



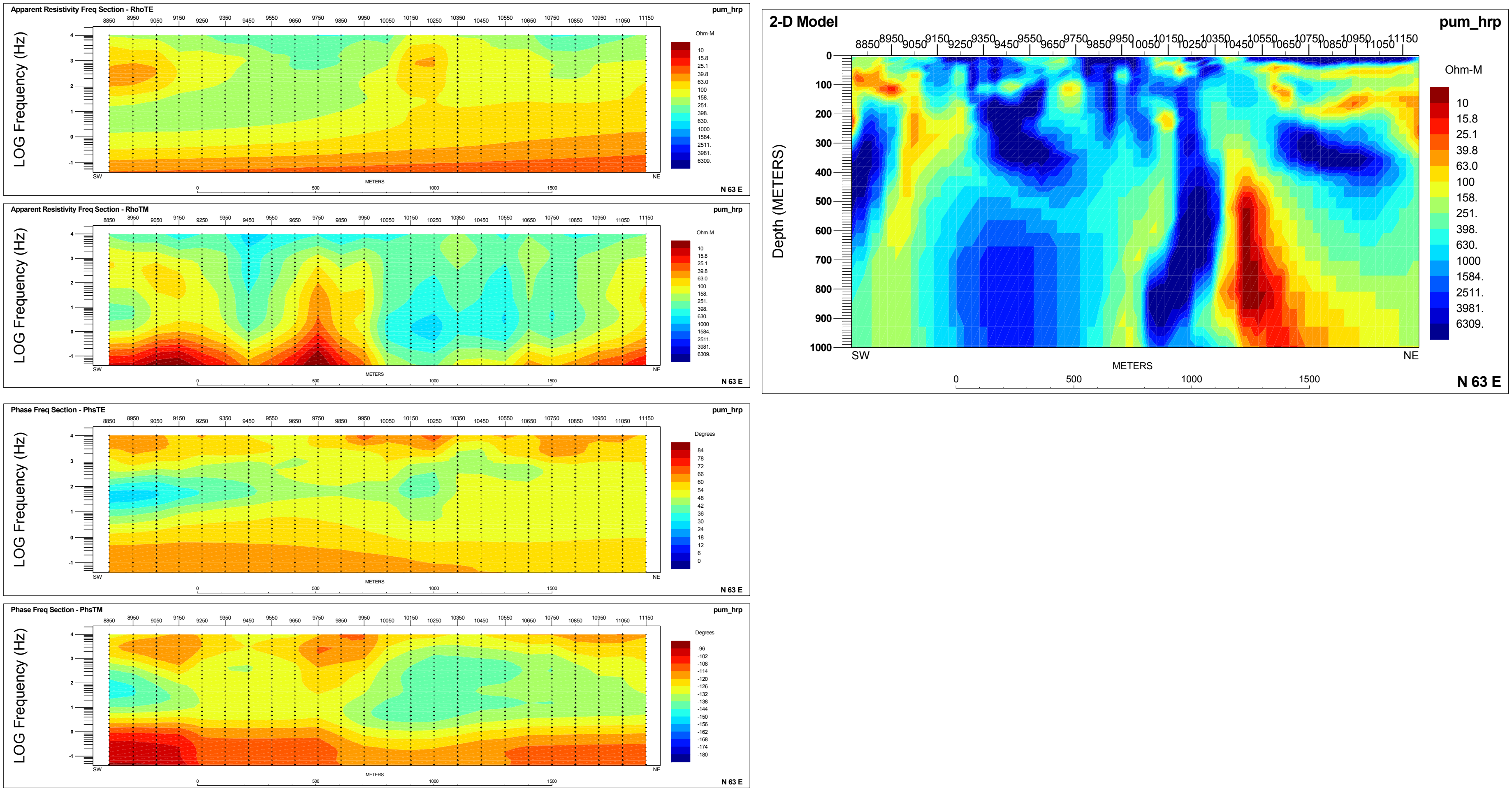
b) ***2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models***



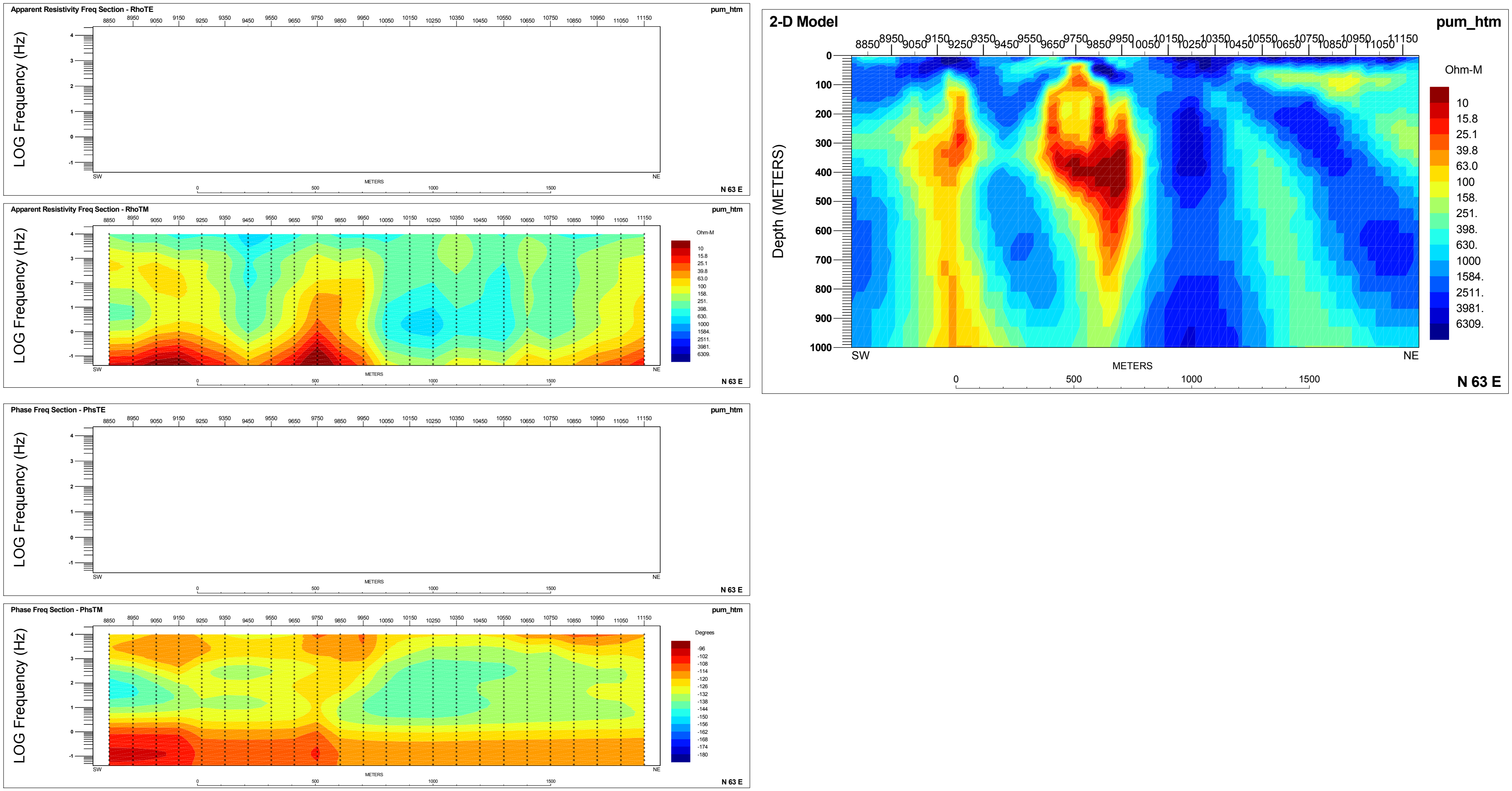
c) ***2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models***



d) 2D MT unrotated Interpolated Raw Data input to the inversions

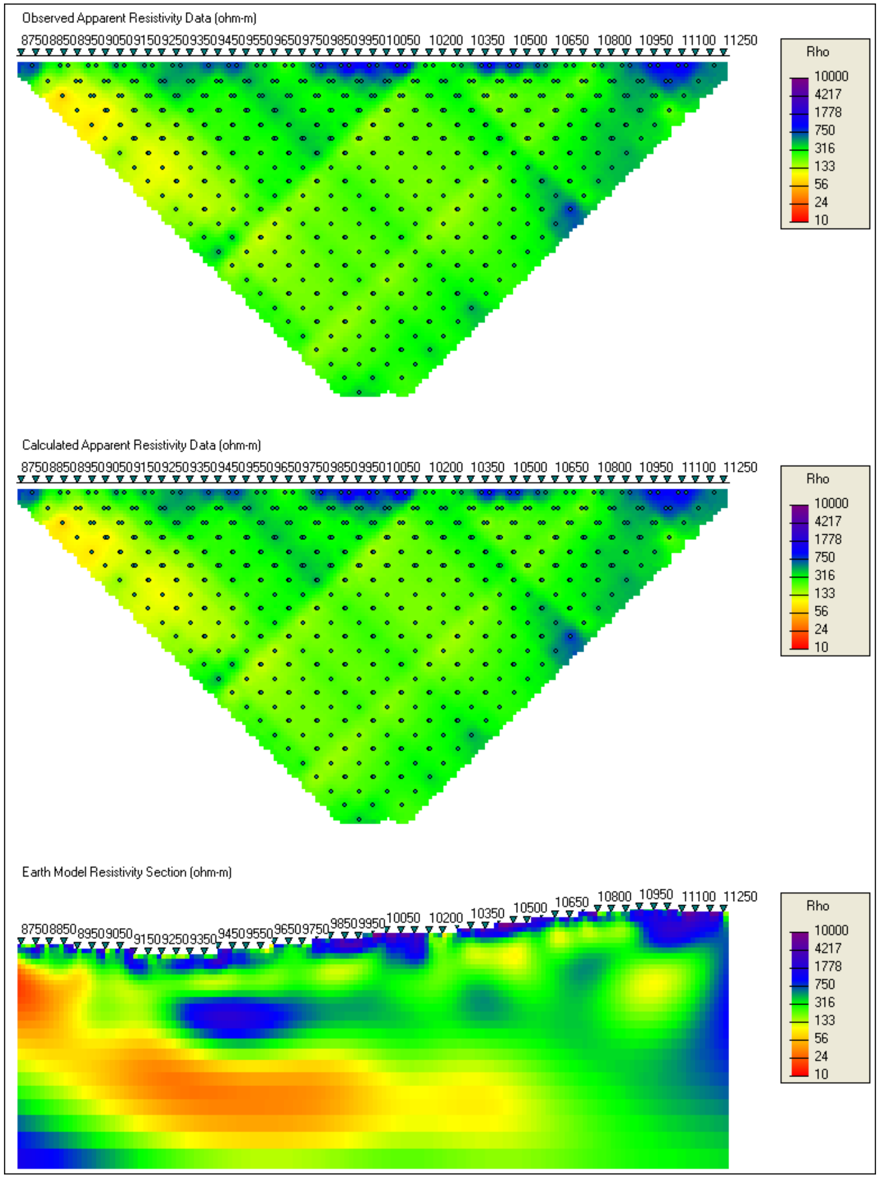


e) ***2D PW MT Resistivity Inversion Model (left = "Line11800N_pum_hrp_it49") and calculated Data (right)***

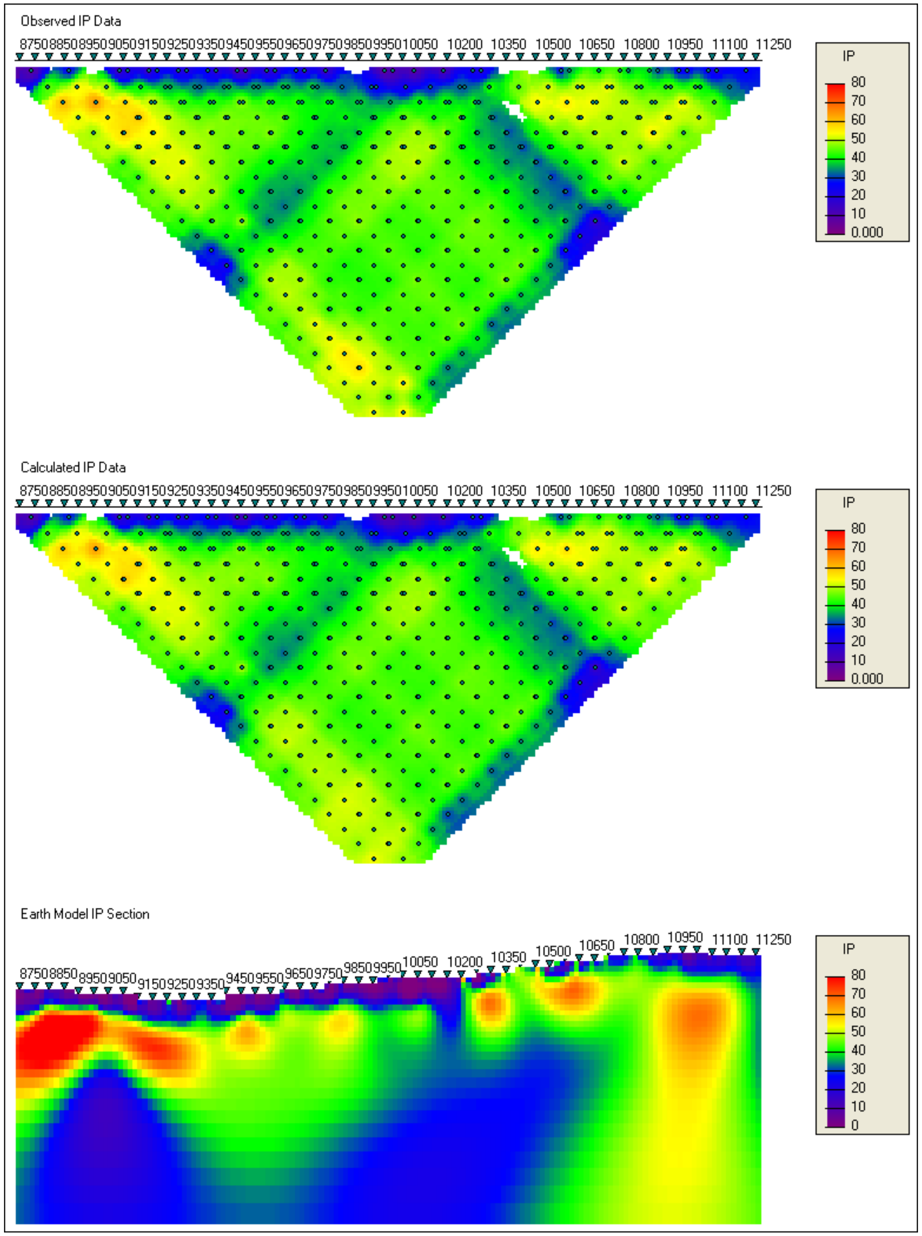


f) 2D PW MT Resistivity Inversion Model (left= "Line11800N_pum_htm_it49") and calculated Data (right)

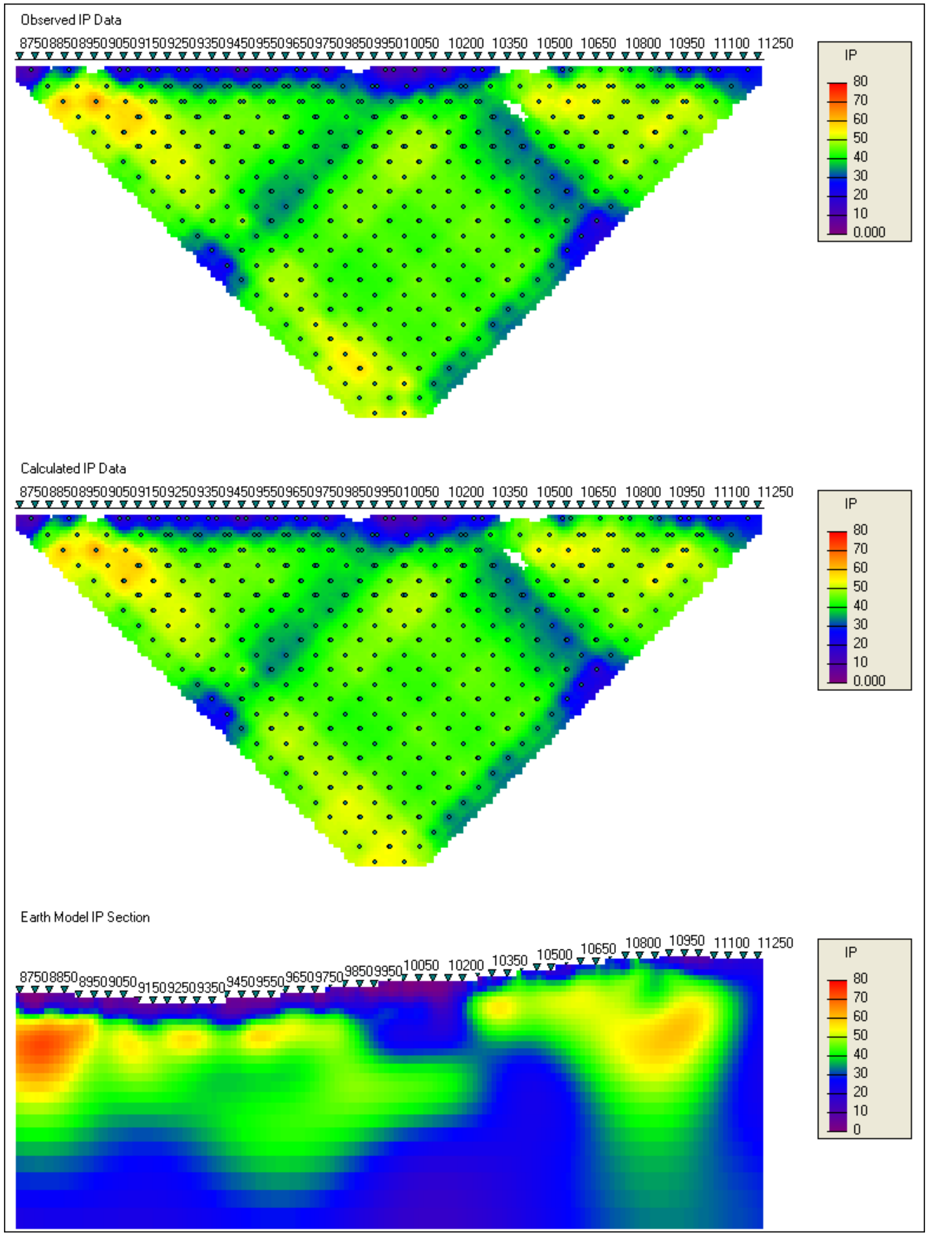
Line L12100N



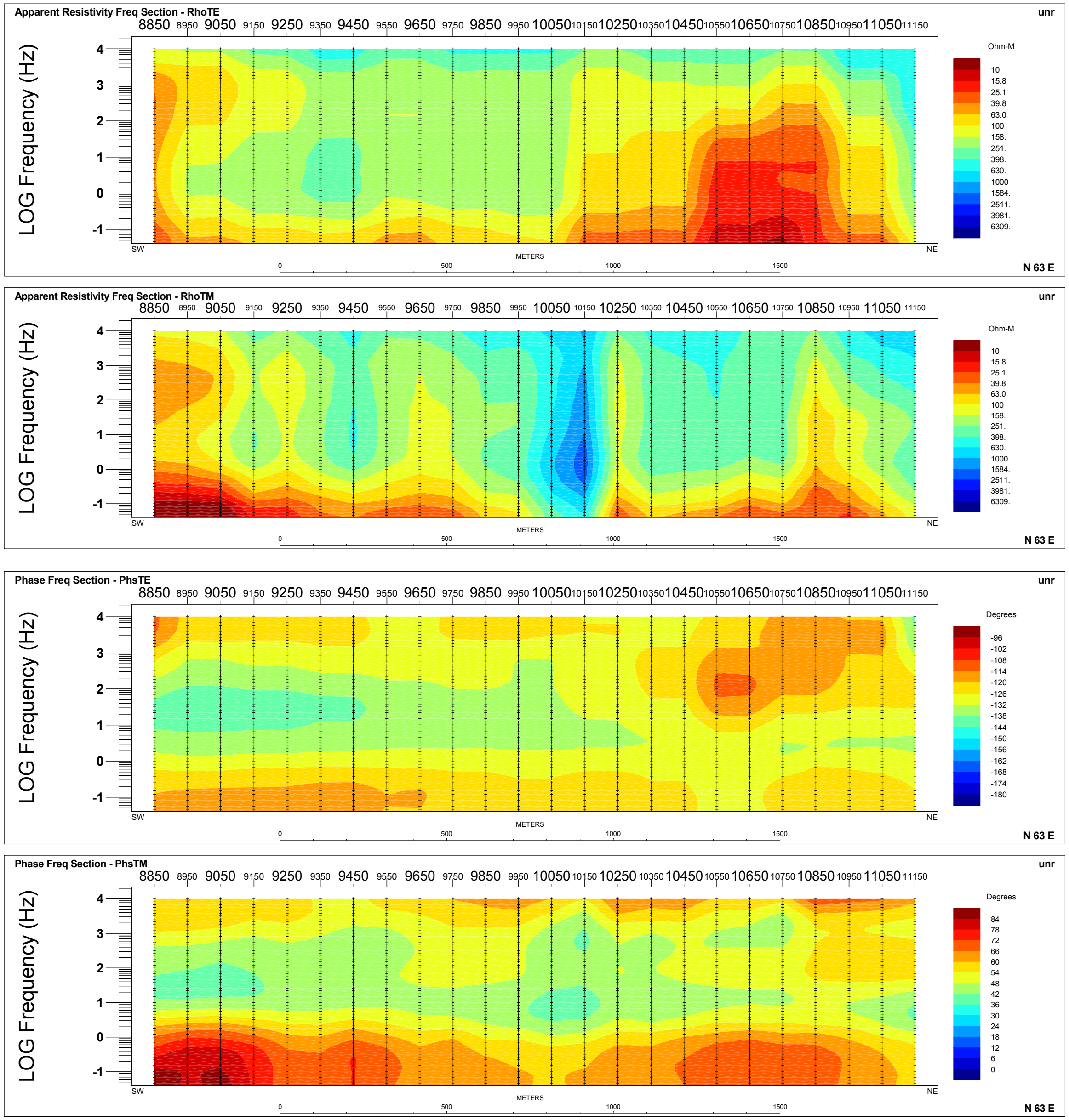
a) 2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models



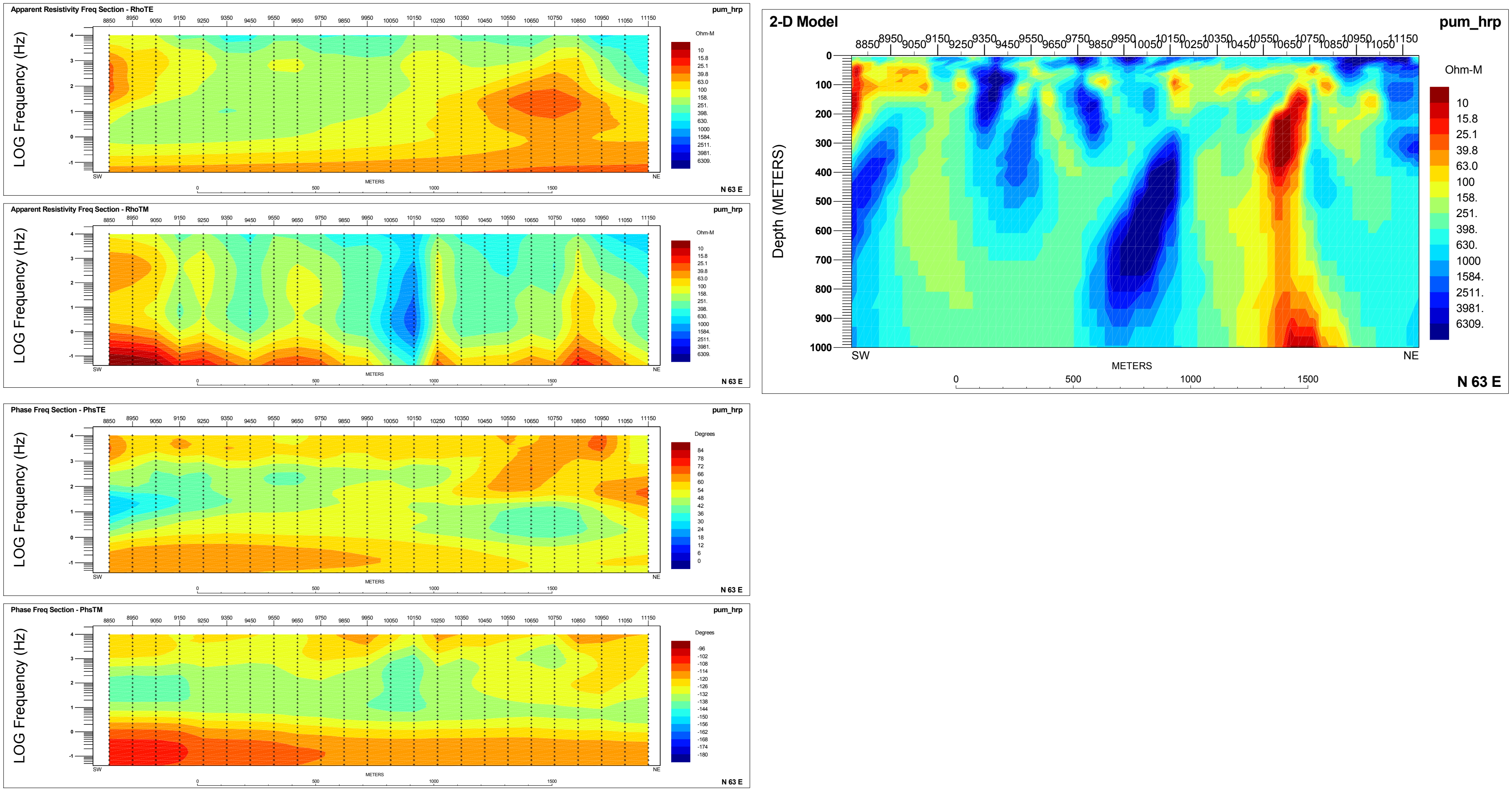
b) 2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models



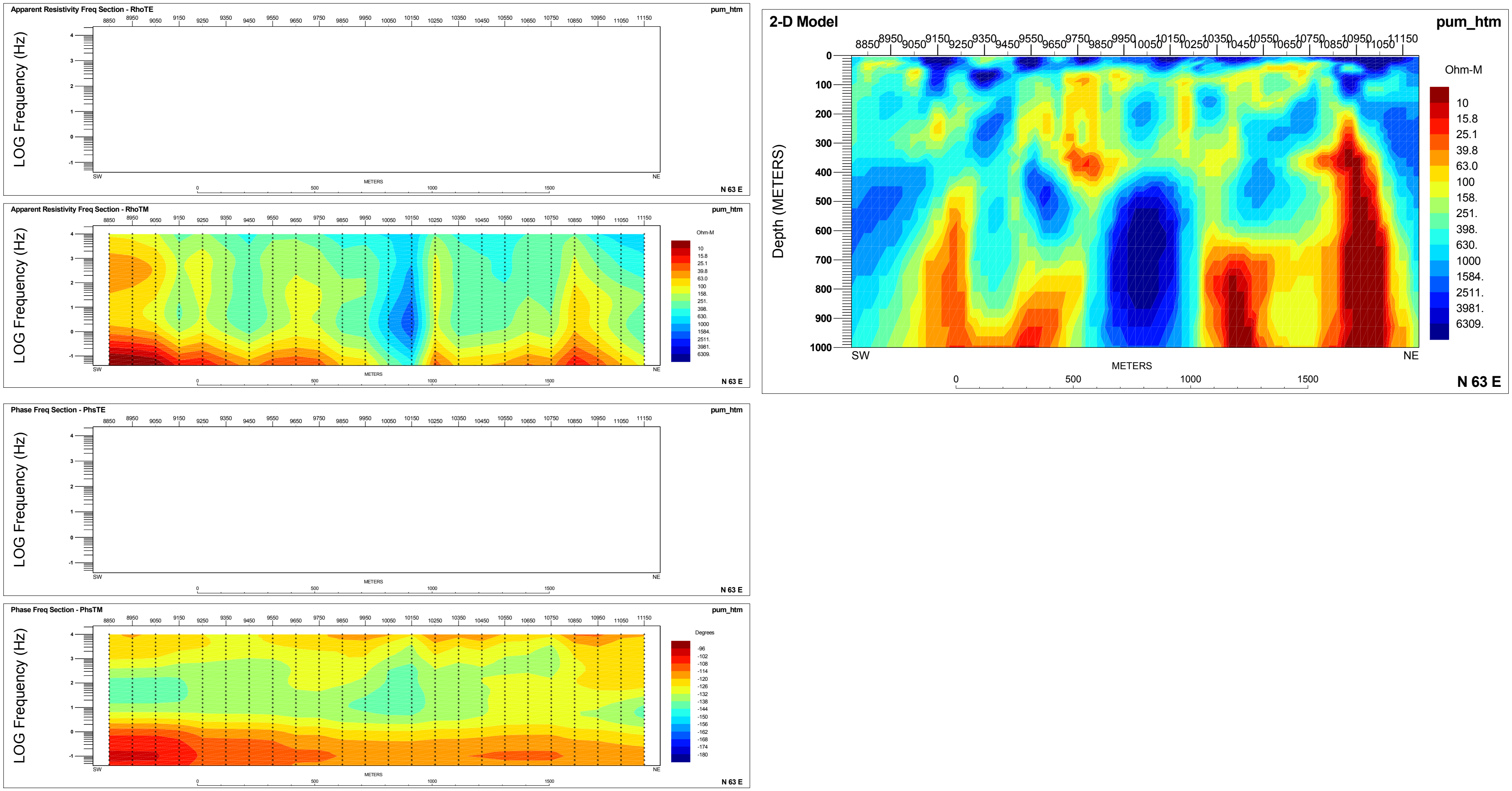
c) <u>2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models</u>



d) 2D MT unrotated Interpolated Raw Data input to the inversions

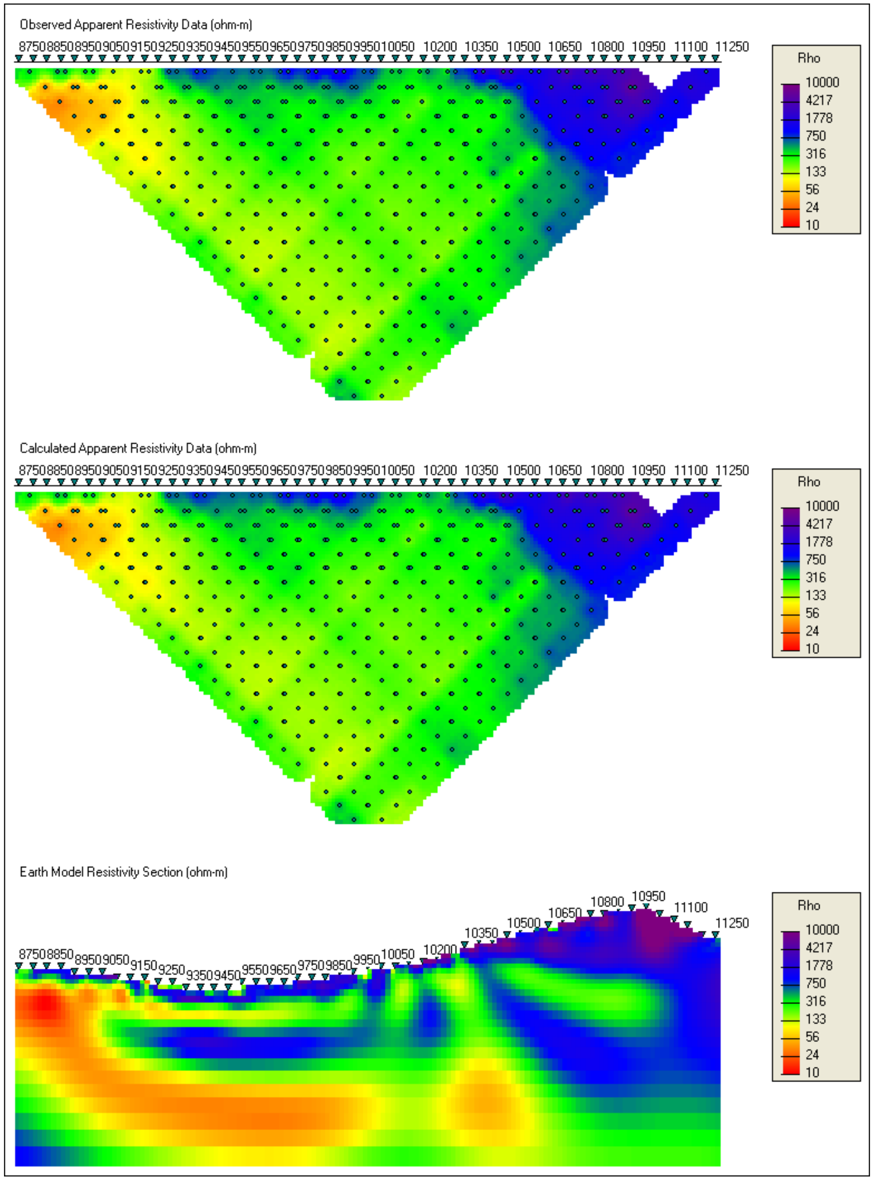


e) 2D PW MT Resistivity Inversion Model (left = "Line12100N_pum_hrp_it43") and calculated Data (right)

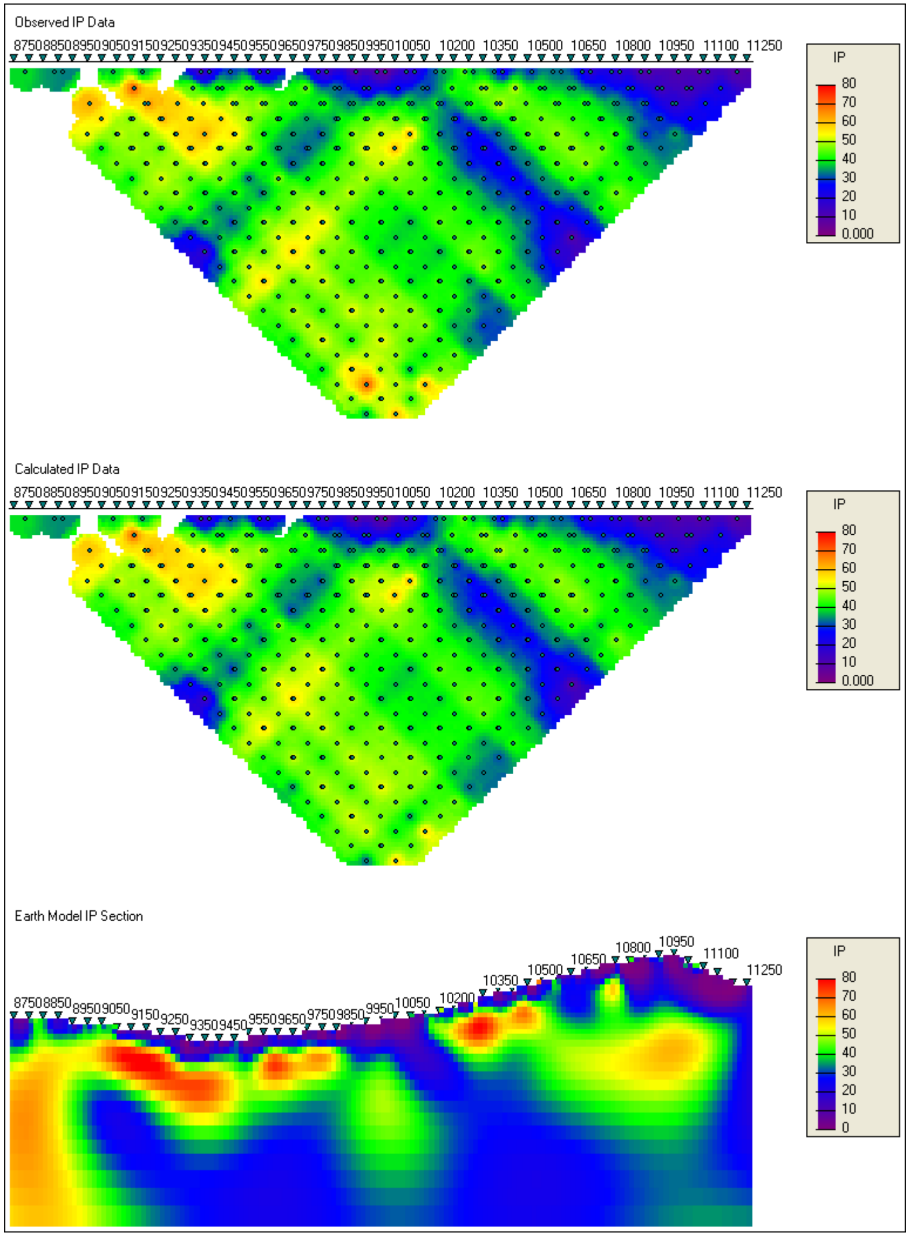


f) <u>2D PW MT Resistivity Inversion Model (left= "Line12100N_pum_htm_it49") and calculated Data (right)</u>

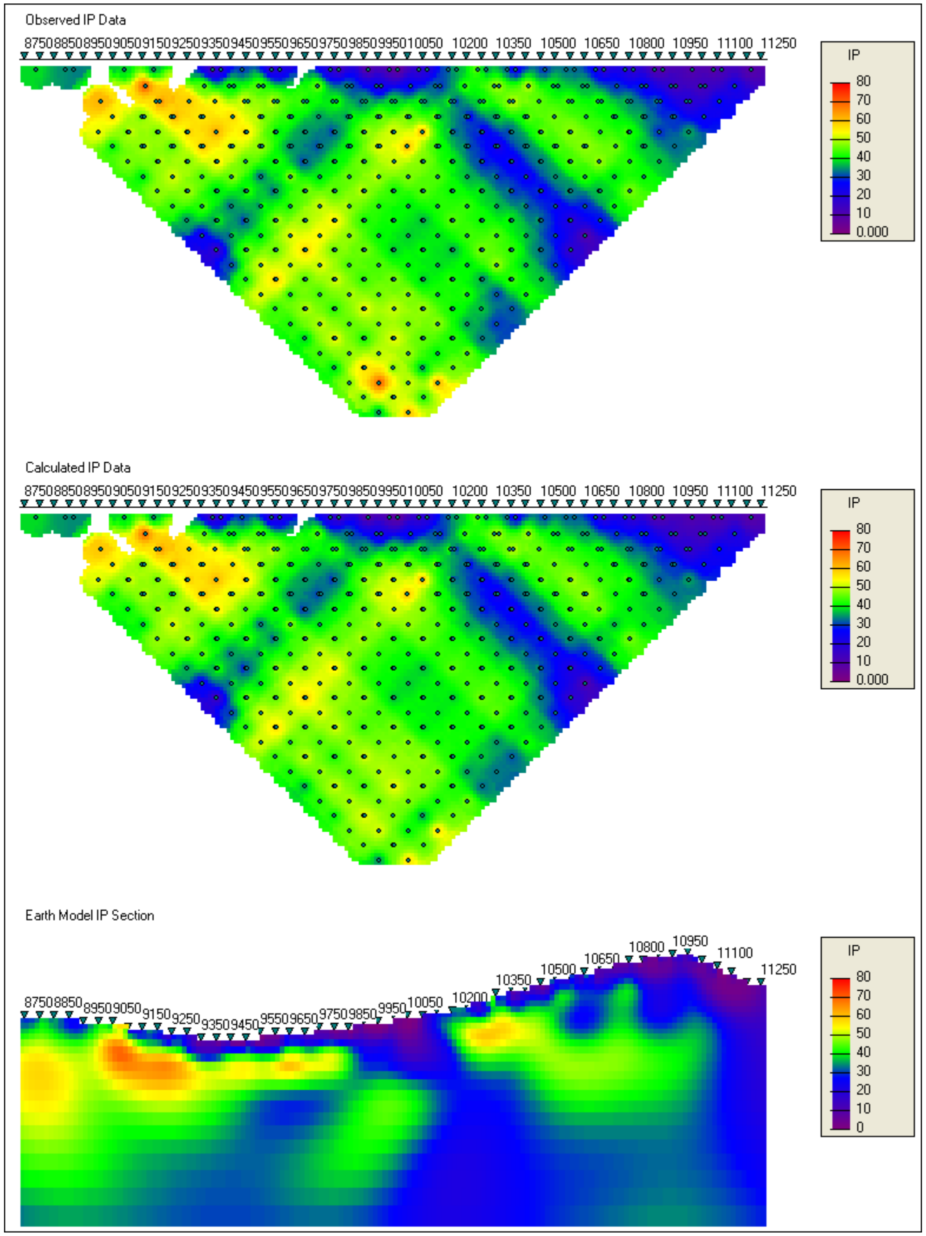
Line L12400N



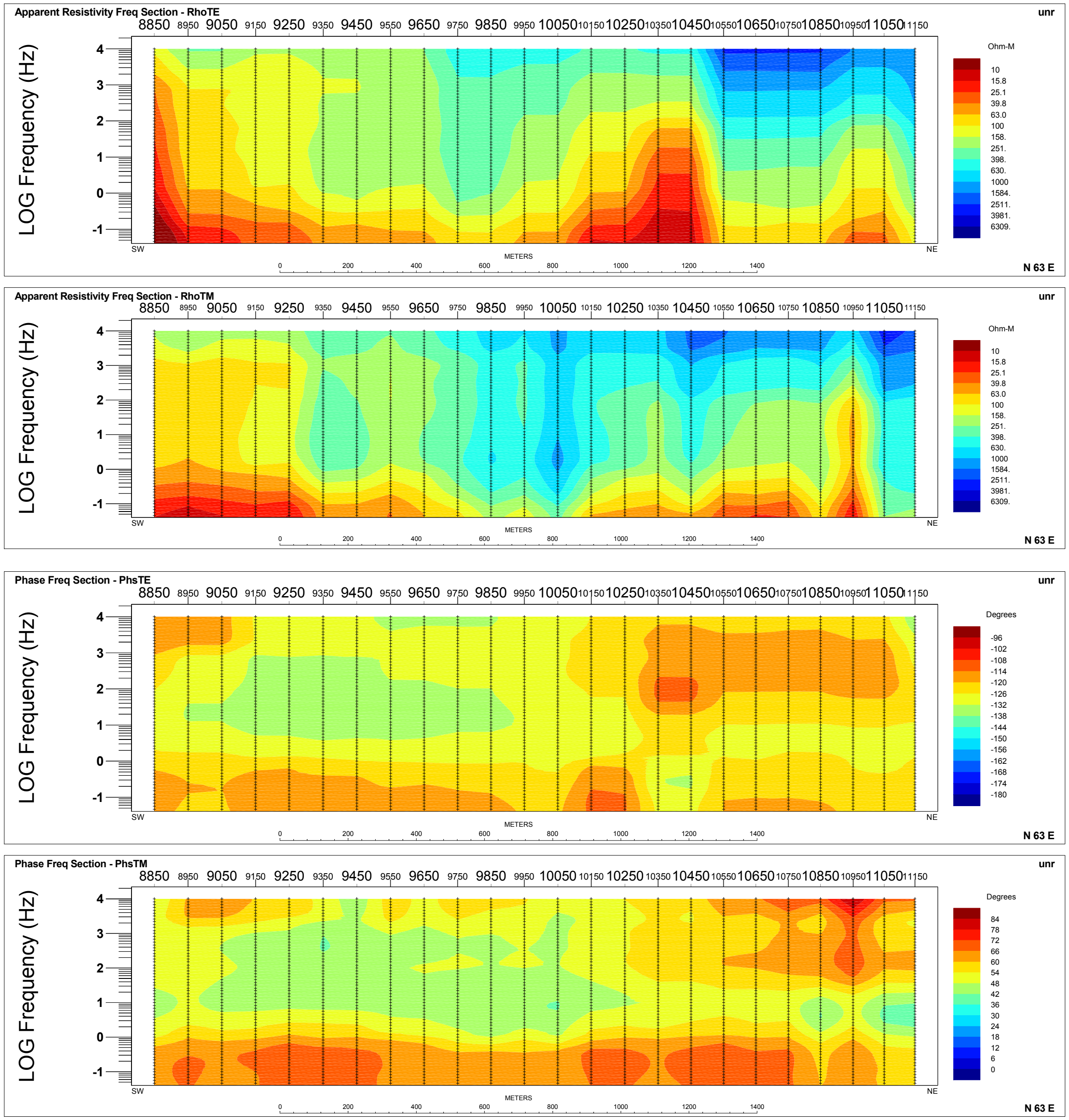
a) 2D DC Resistivity Unconstrained Inversion Results with Observed Data and Calculated Models



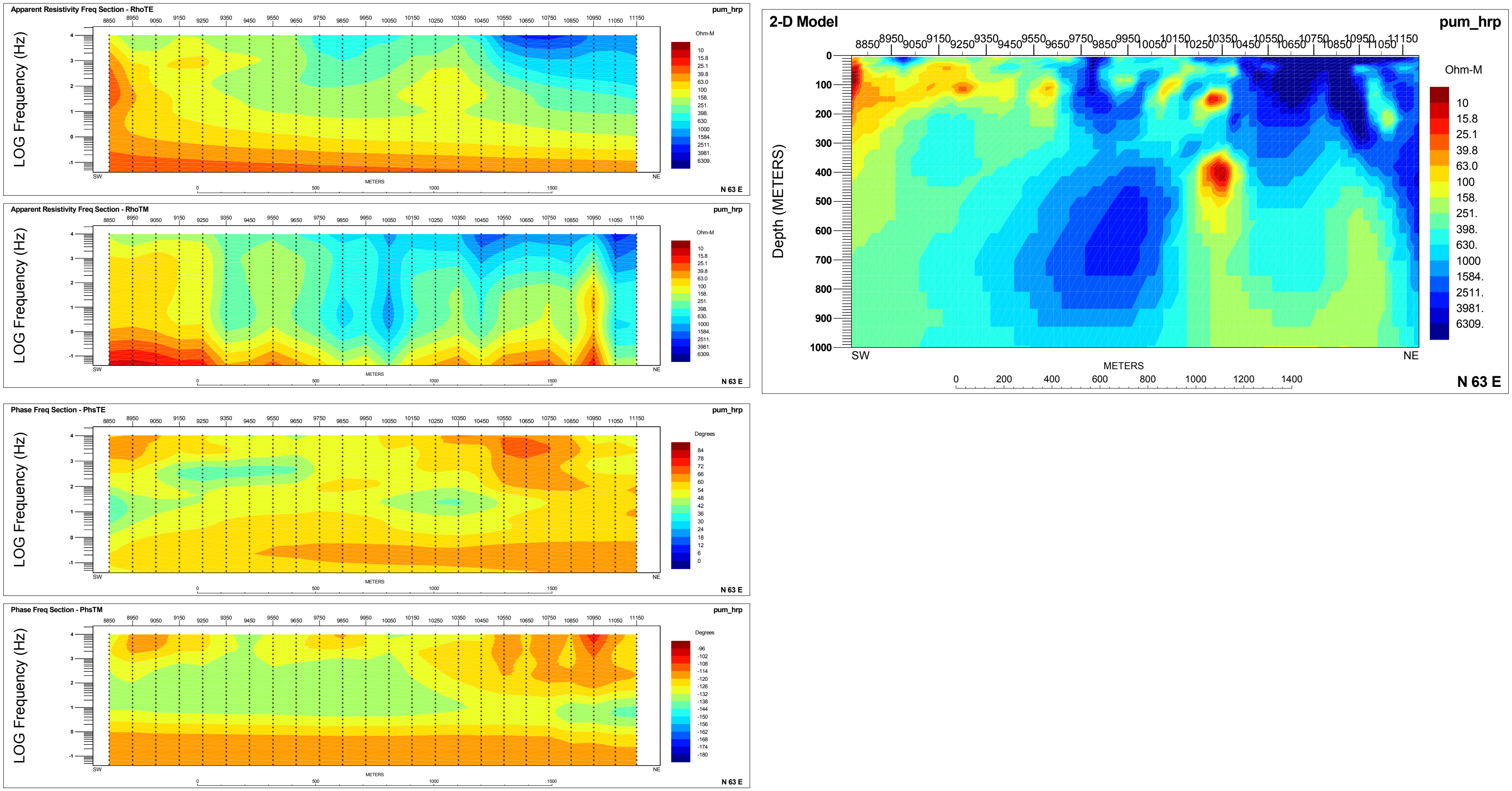
b) ***2D IP Unconstrained Inversion Results (using homogeneous conductivity model) with Observed Data and Calculated Models***



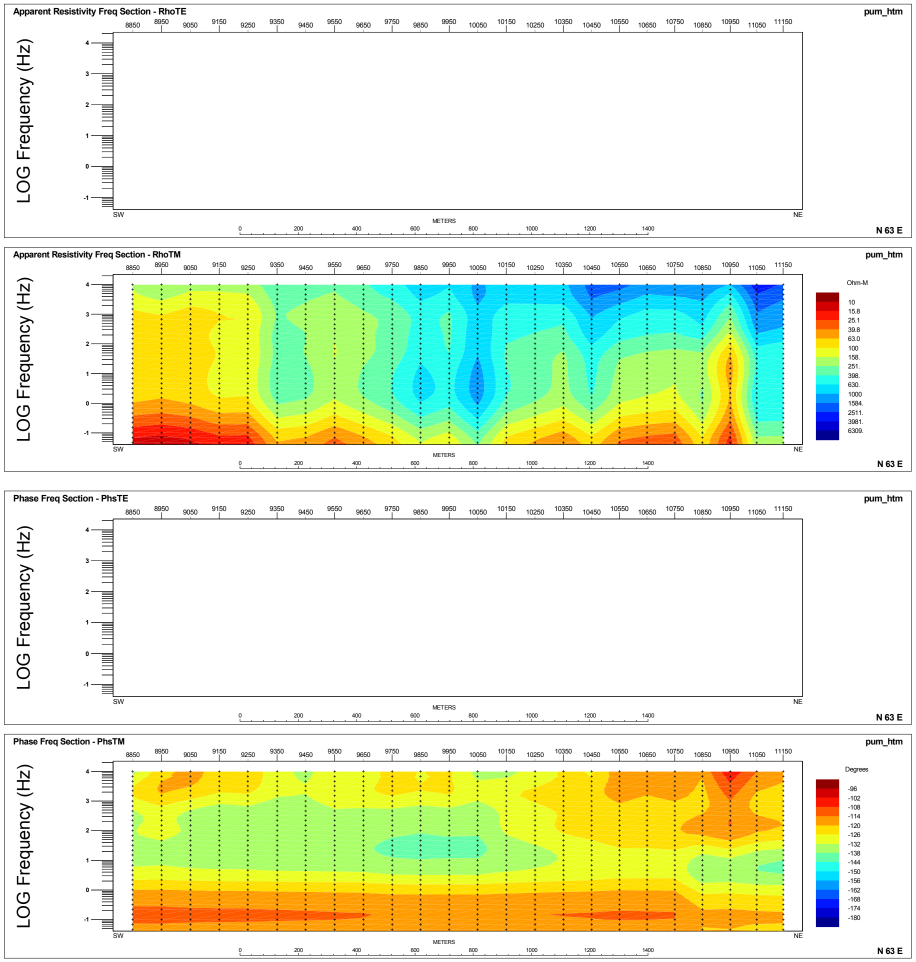
c) 2D IP Unconstrained Inversion Results (using the Titan conductivity model) with Observed Data and Calculated Models

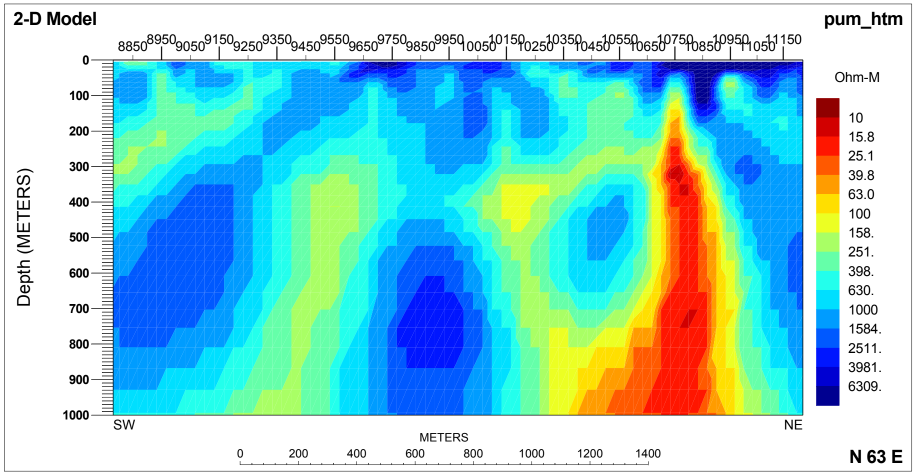


d) <u>2D MT unrotated Interpolated Raw Data input to the inversions</u>



e) 2D PW MT Resistivity Inversion Model (left = "Line12400N_pum_hrp_it33") and calculated Data (right)





f) 2D PW MT Resistivity Inversion Model (left= "Line12400N_pum_htm_it49") and calculated Data (right)