

The UBC
Geophysical Inversion Facility



MT3D: Forward modeling and inversion of trial geometry

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Mesh Design Considerations

Grid Spacing

- Range in periods that we need to model 10000s - 0.1s
- Calculate skin depths to give an approximate mesh spacing
- Multiple meshes for difference frequencies?
- Station spacing
- Block geometry

Dimensions of Core Region

- Site locations of the provided data
- Where does the data approach the halfspace value
- Computational abilities



Mesh Design Considerations

Padding

- Padding distance - skin depth
- Satisfies boundary conditions
- Expansion factor
- Computational considerations

Verification

- Check halfspace response
- Compare with other meshes
- Compare with other users



How we tackled those considerations

Core Region Design

Period (s)	Background skin depth (km)	1Ωm block skin depth (km)
10000	500.00	50.00
1000	158.11	15.81
100	50.00	5.00
10	15.81	1.58
1	5.00	0.50
0.1	1.58	0.16

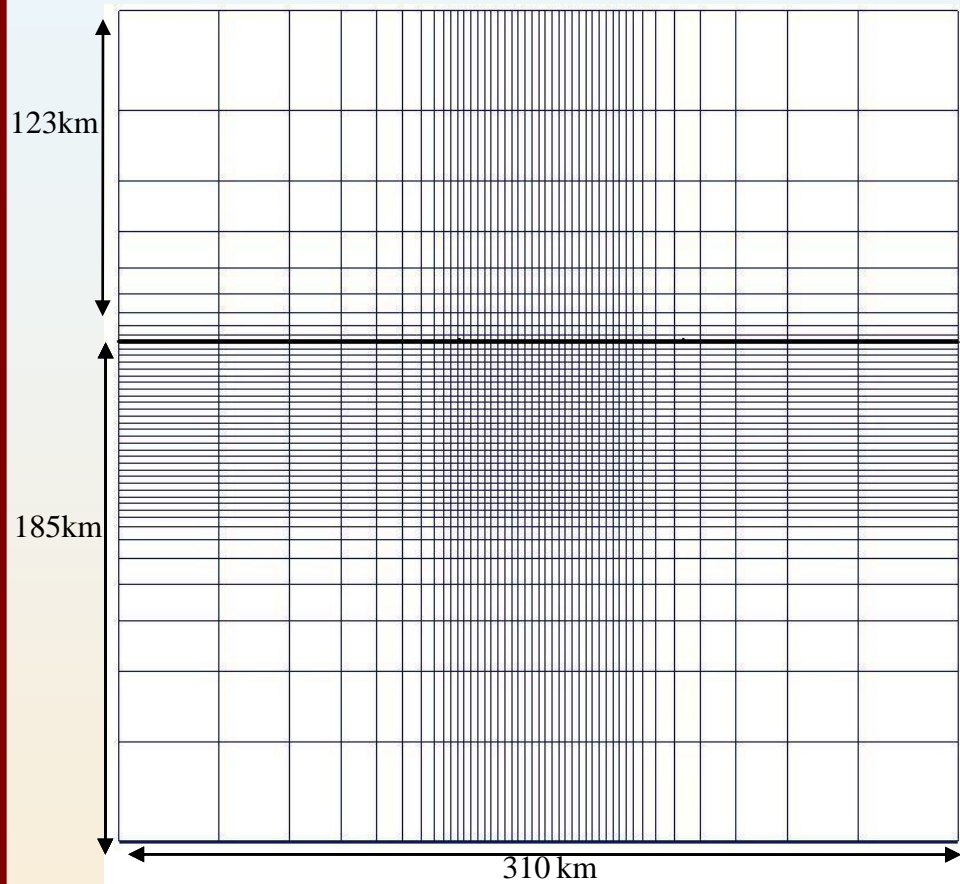
- Fine mesh had 500 m cells
- Coarse mesh had 2500 m cells

Further Parameters

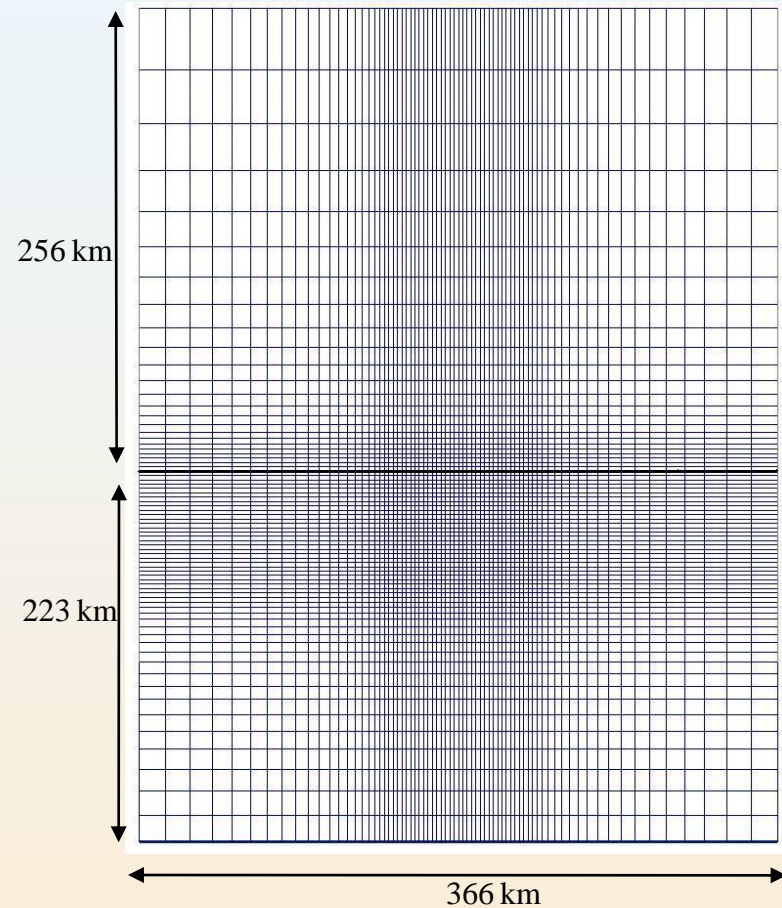
- Expansion factor of 1.4
- Fine mesh had $104 \times 114 \times 46 = 545,376$ cells
 - Core region had $84 \times 94 \times 34 = 268,464$ cells
- Coarse mesh had $44 \times 52 \times 43 = 98,384$ cells
 - Core region had $28 \times 36 \times 27 = 27,216$ cells



Effects of Mesh Design on 560s Period

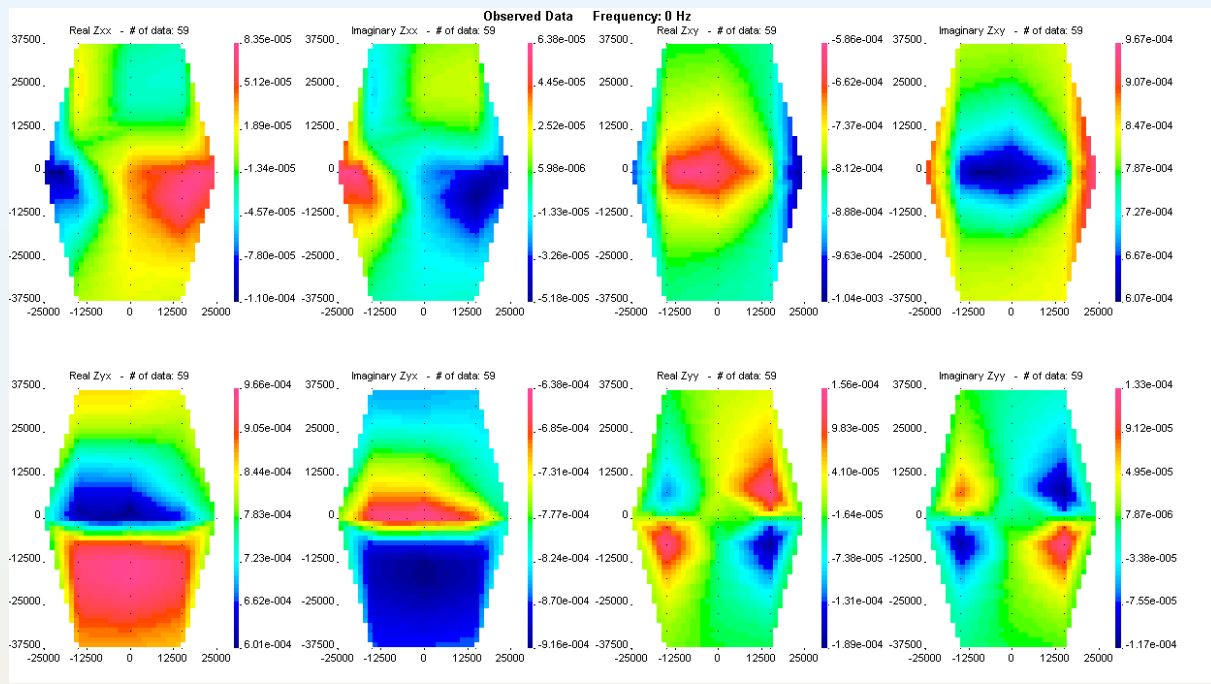


- Cross section of 44 x 52 x 43 cell mesh with an expansion factor of 1.4
- 98,384 cells - 16 min

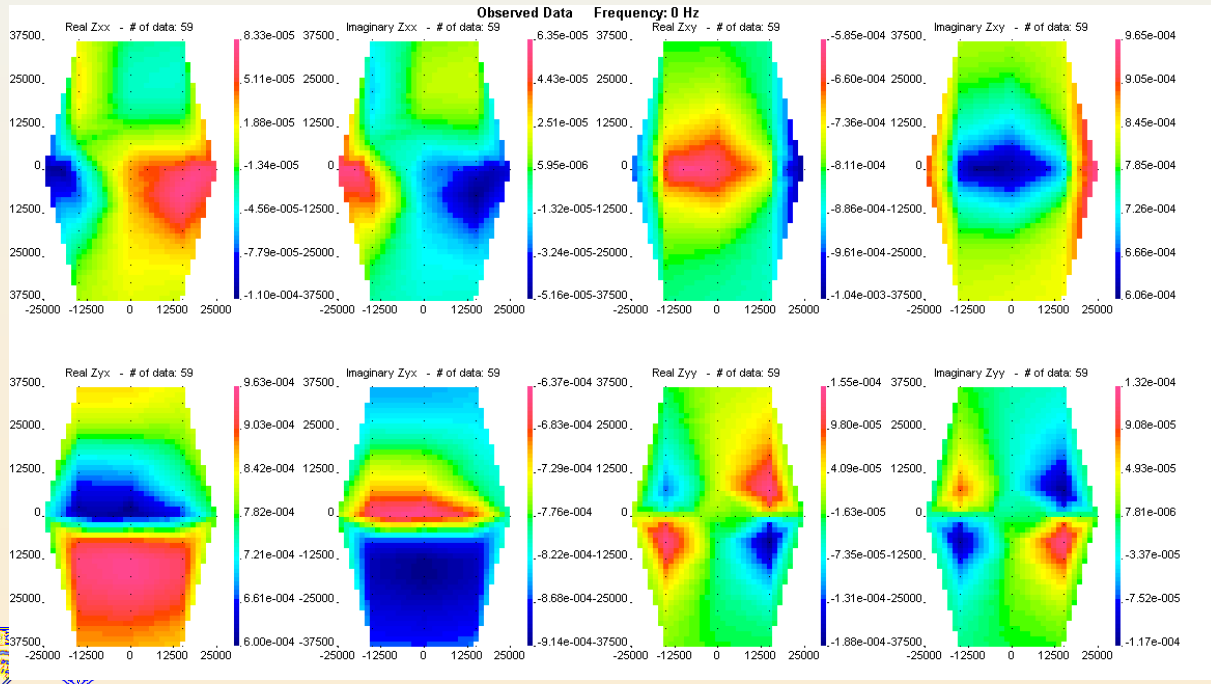


- Cross section 72 x 72 x 72 cell mesh with an expansion factor of 1.1
- 373,248 cells - 1 hour 40 min





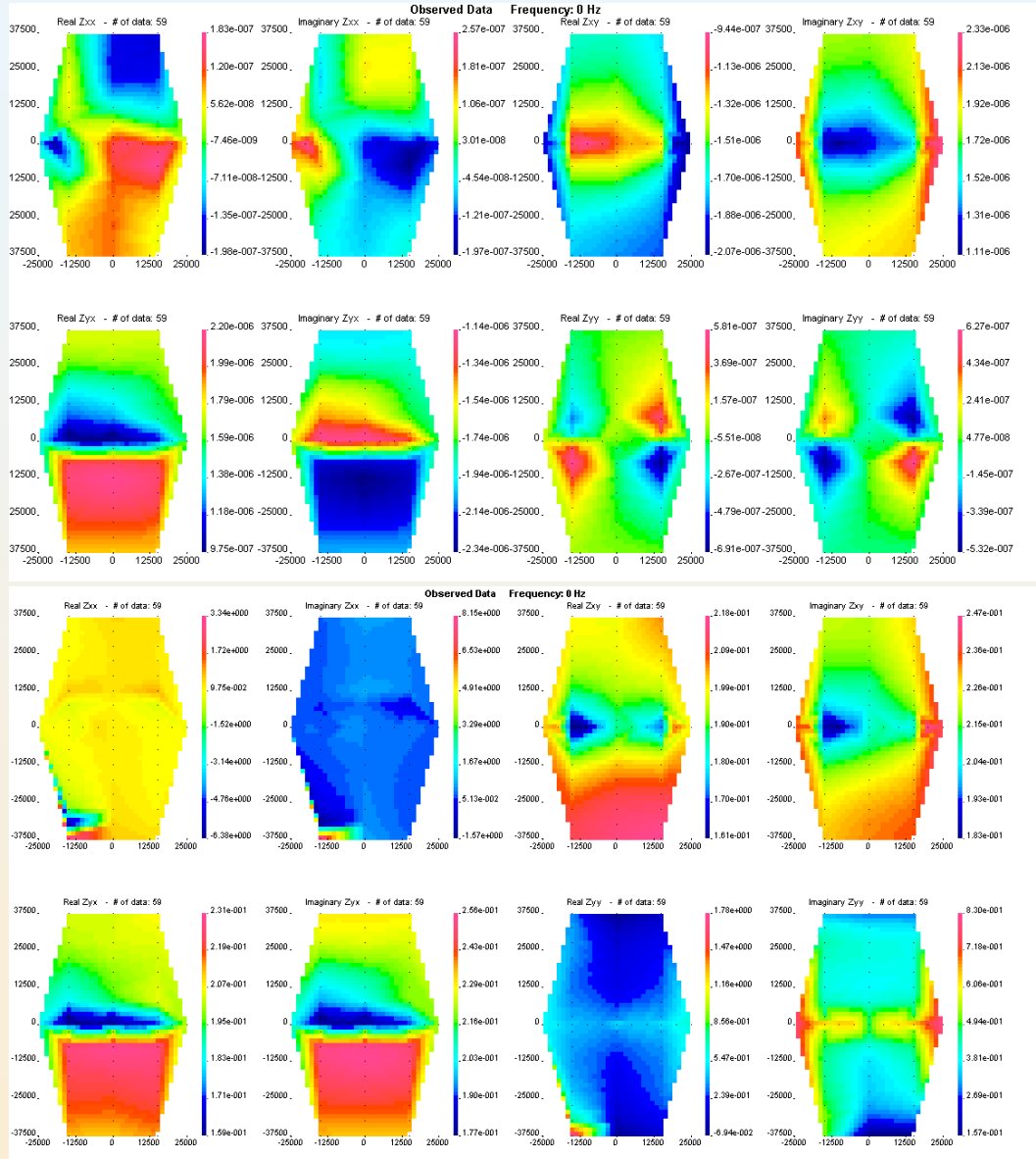
- 560 s Period
- Expansion 1.4
- 44 x 52 x 43
- 98,384 cells
- 16 min



- 560 s Period
- Expansion 1.1
- 72 x 72 x 72
- 373,248 cells
- 1 hour 40 min



Effects of Mesh Design on 560s Period

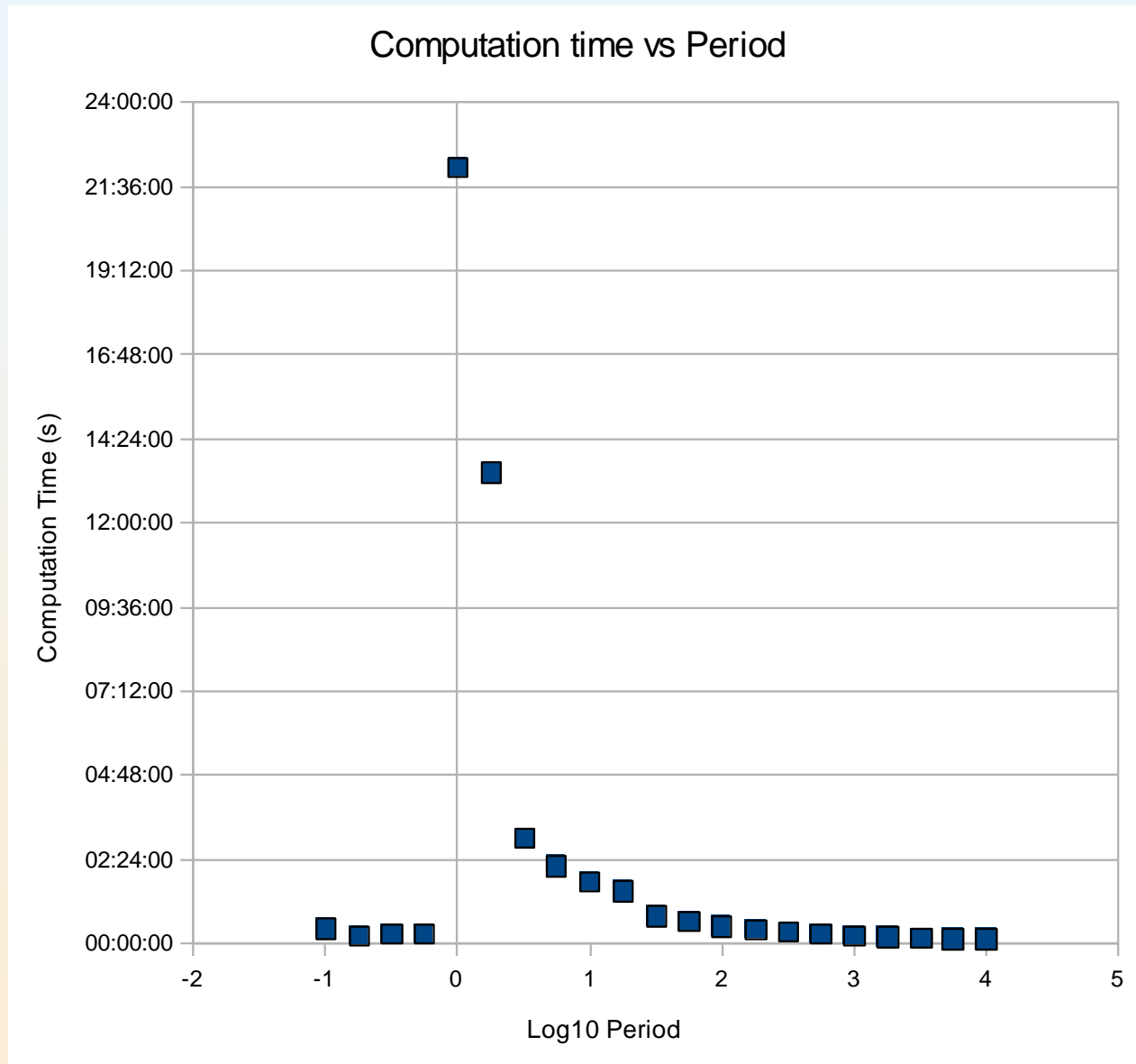


Difference between the solution on each mesh

Percent difference between the solution on each mesh



Speed Considerations

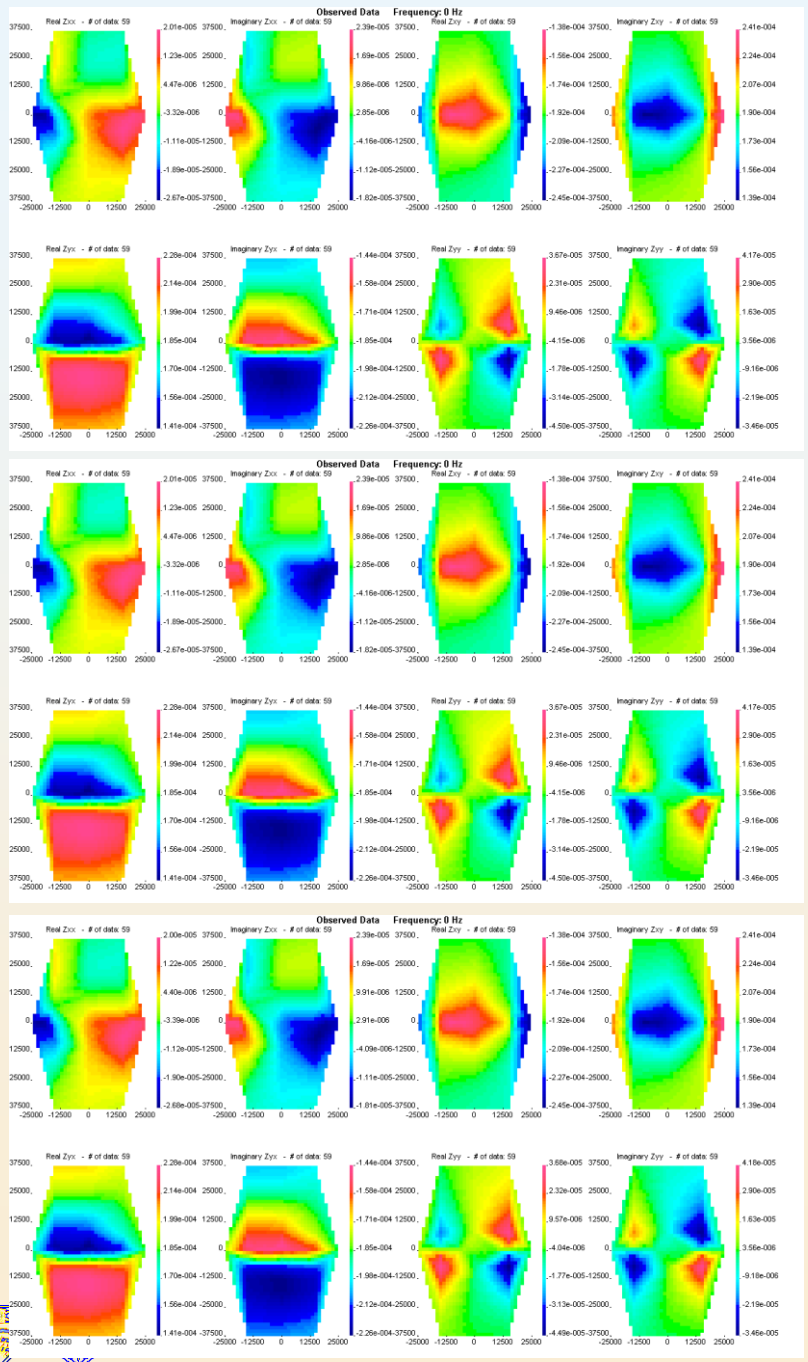


10000s Solver Tolerance

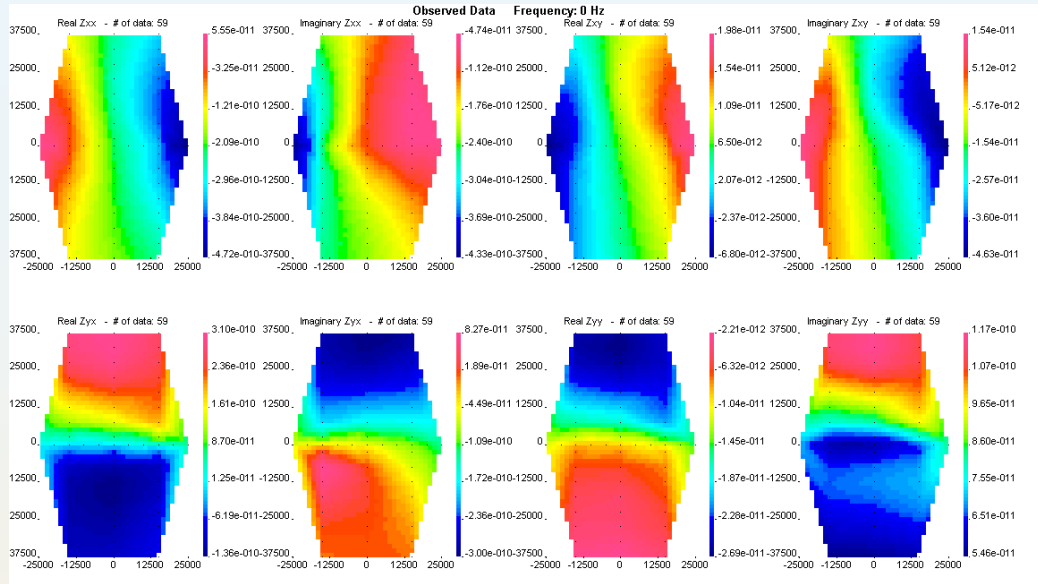
- Tolerance 10^{-10}
- 3 min 11 sec

- Tolerance 10^{-6}
- 2 min 20 sec

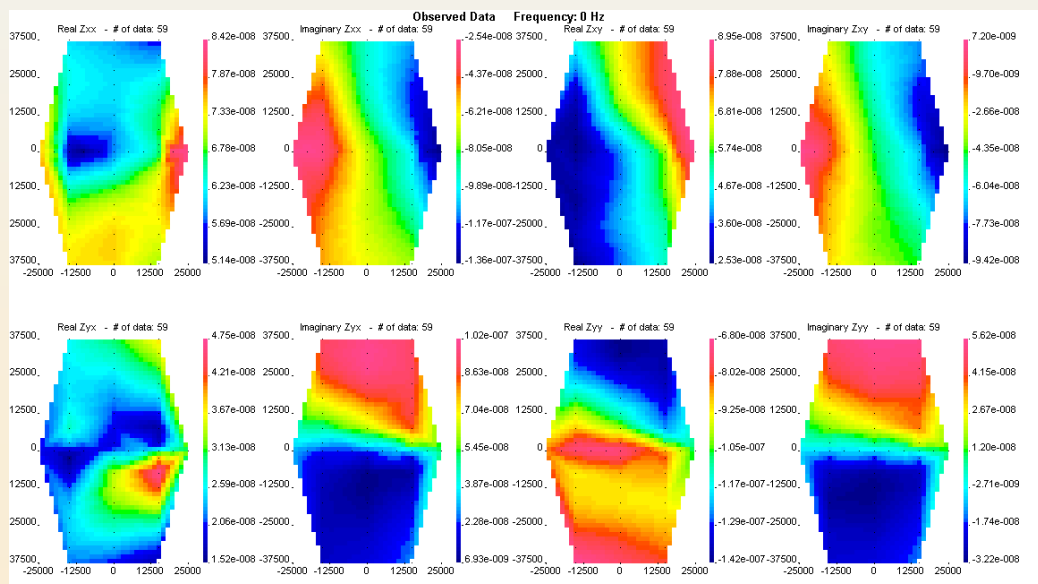
- Tolerance 10^{-4}
- 1 min 34 sec



10000s Solver Tolerance - Differences



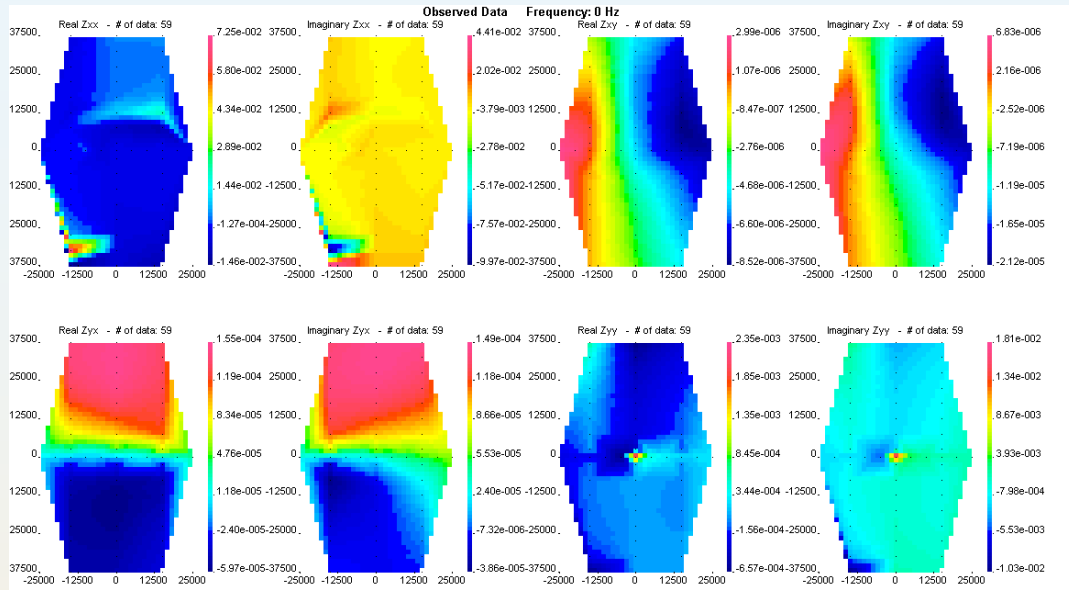
Solution difference between tolerance of 10^{-6} and 10^{-10}



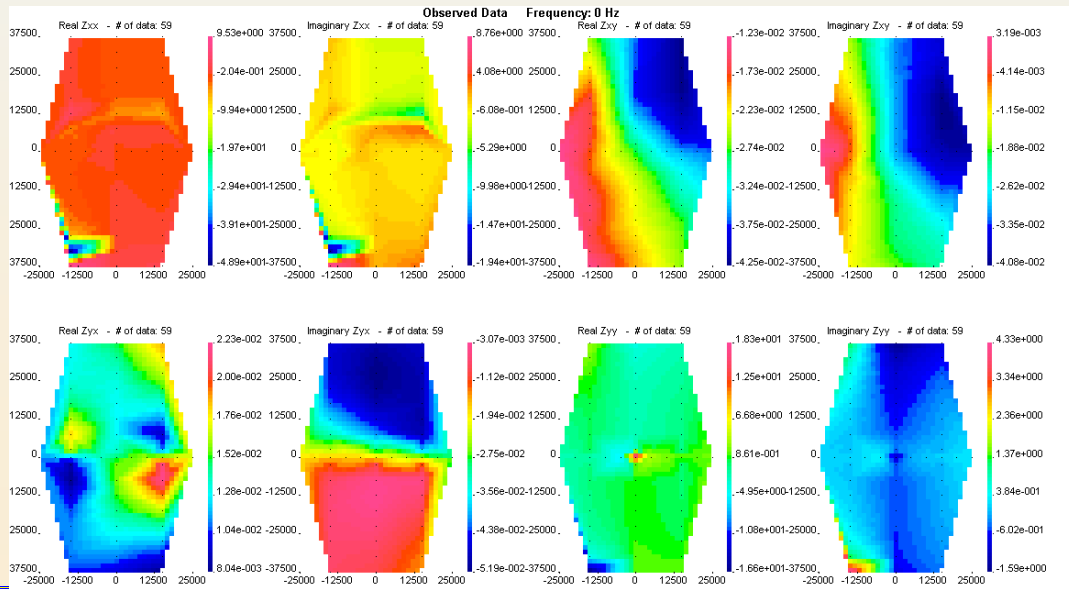
Solution difference between tolerance of 10^{-4} and 10^{-10}



10000s Solver Tolerance Percent Differences



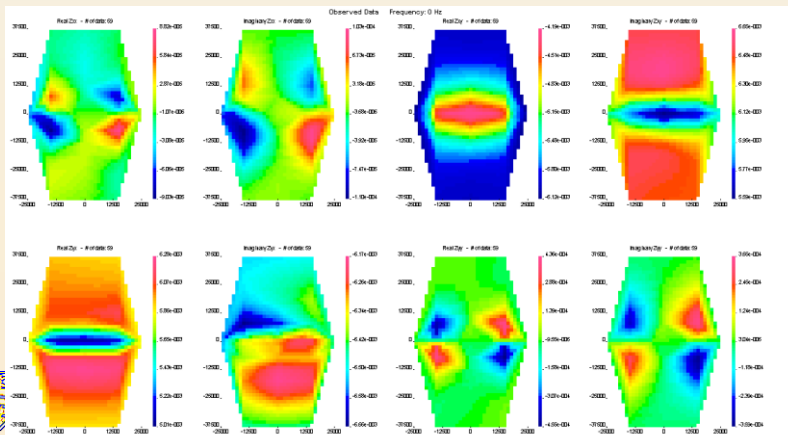
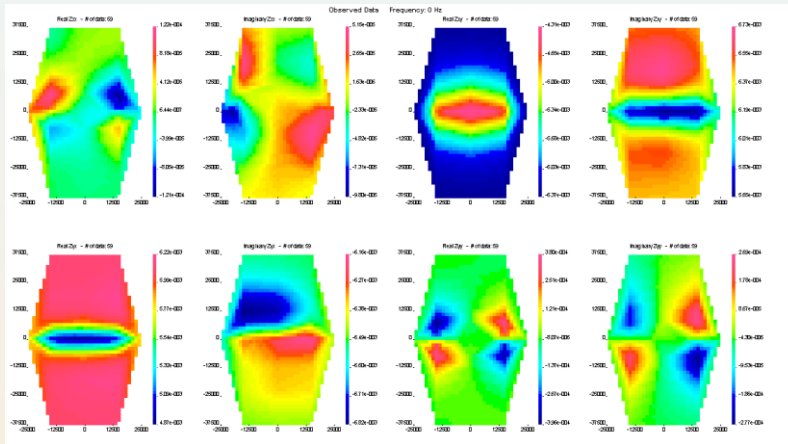
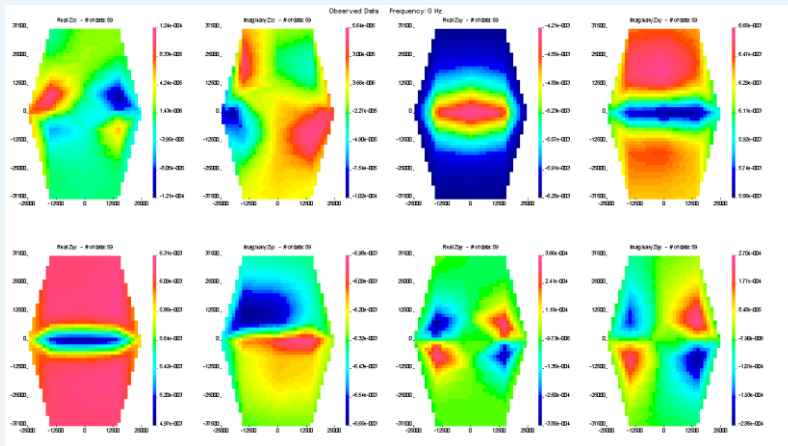
Percent solution difference between tolerance of 10^{-6} and 10^{-10}



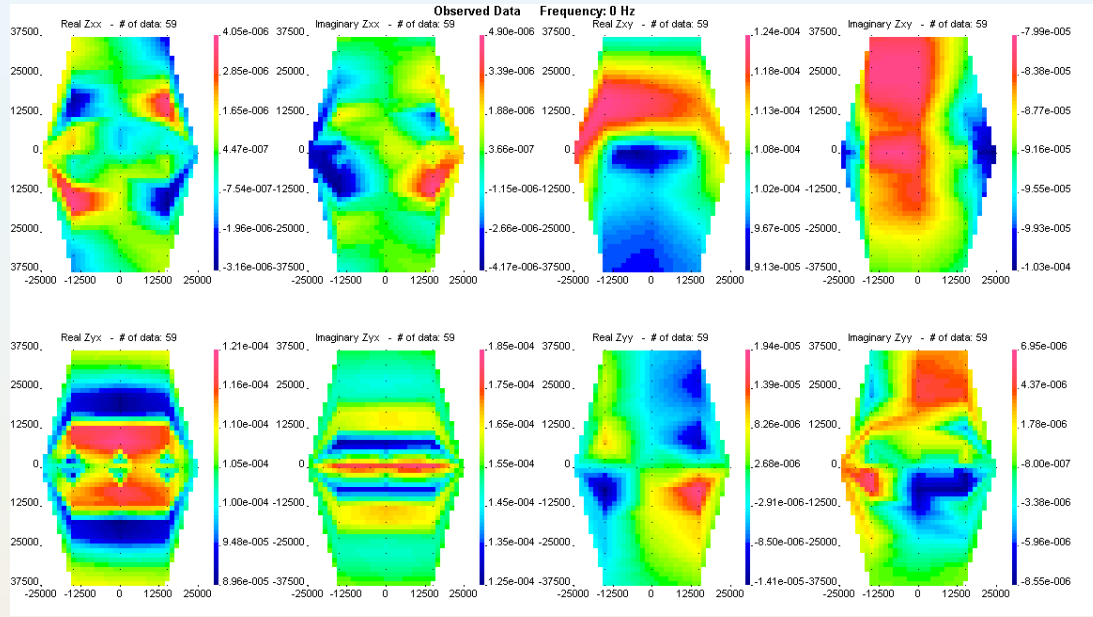
Percent solution difference between tolerance of 10^{-4} and 10^{-10}

10s Solver Tolerance

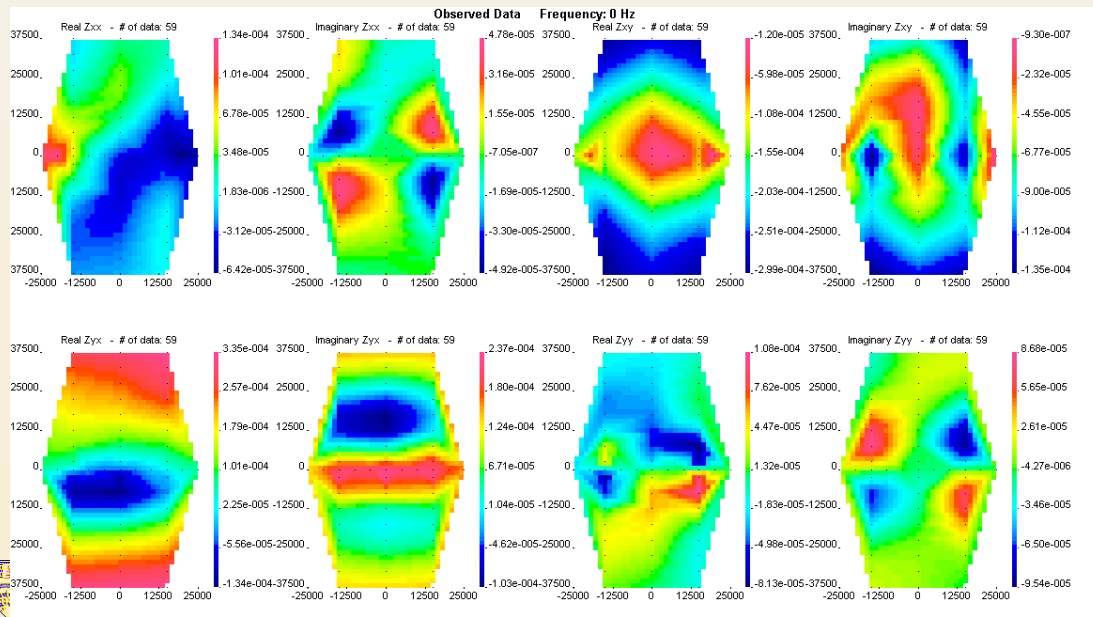
- Tolerance 10^{-10}
- 1 hour 44 min
- Tolerance 10^{-4}
- 21 min
- Tolerance 10^{-3}
- 1 min 30 sec



10s Solver Tolerance - Differences



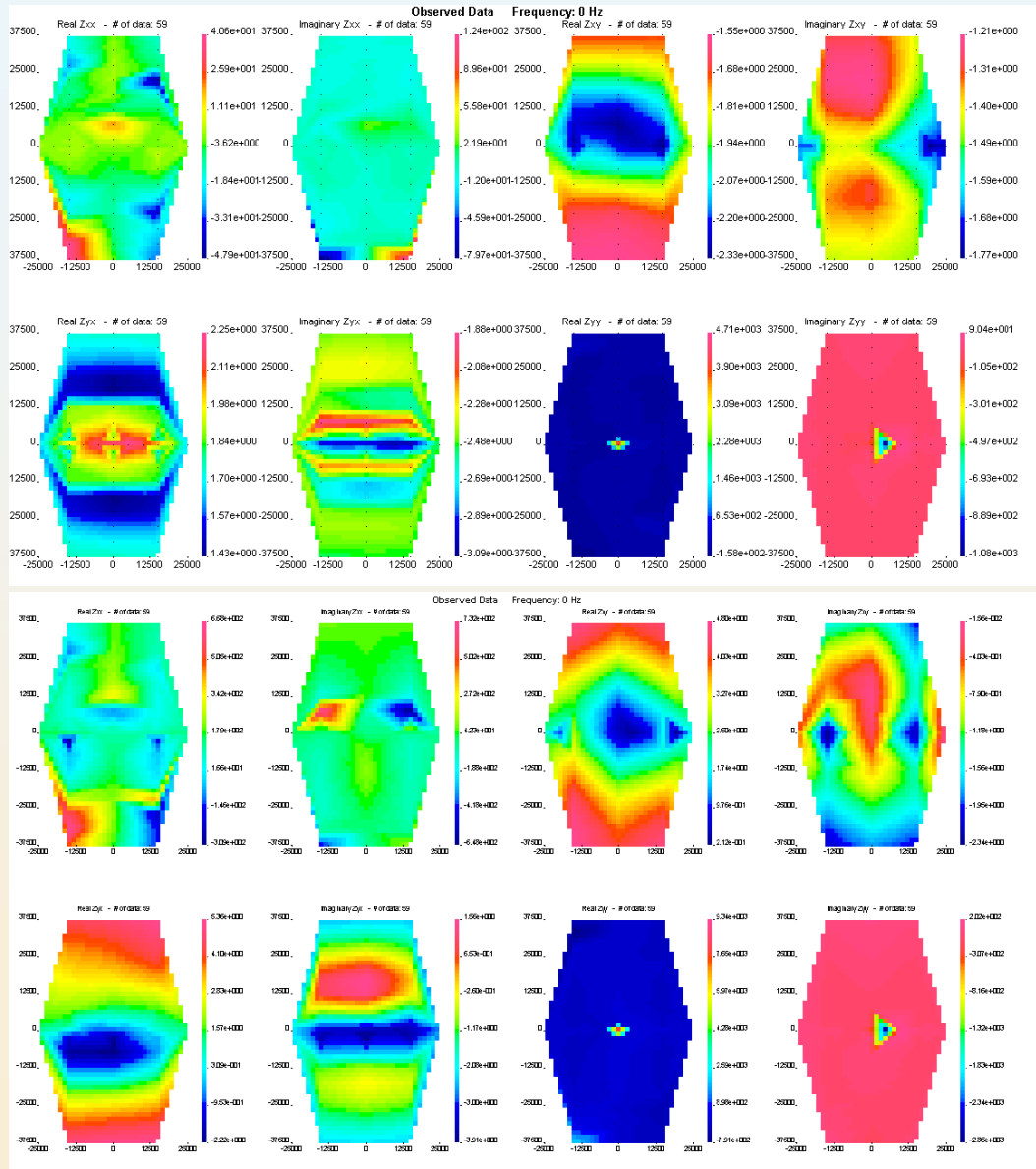
Solution difference between tolerance of 10^{-4} and 10^{-10}



Solution difference between tolerance of 10^{-3} and 10^{-10}



10s Solver Tolerance Percent Differences



Percent solution difference between tolerance of 10^{-4} and 10^{-10}

Percent solution difference between tolerance of 10^{-3} and 10^{-10}



Inversion of data

Periods to invert

- Invert each frequency individually: start at 10000s period
- Joint 10000, 1000, 100s
- Joint 10000, 1000, 100s, 10s
- Computational considerations since the higher frequencies are much quicker to solve

Noise

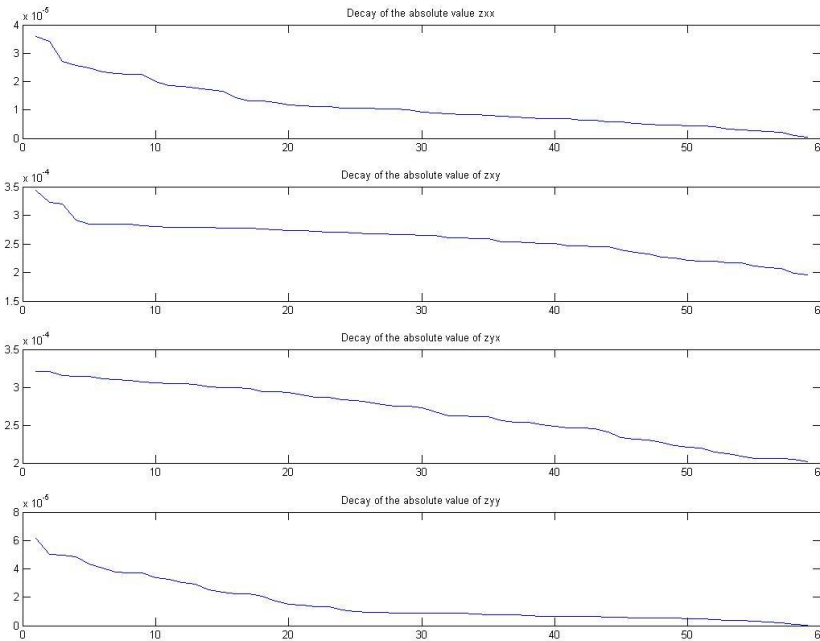
- Various noise schemes were examined
- Standard deviation of the noise was a percentage of the data plus a floor
- Many ways to come up with a floor
 - Same floor for everything or should it be element specific
- Relative sizes of diagonal vs off-diagonal elements may change depending on the geometry



Inversion of data

Determining an appropriate floor

- Examine the decay of $|Z_{xx}|$, $|Z_{xy}|$, $|Z_{yx}|$, $|Z_{yy}|$



$$\sigma_{xx} = 0.05 * Z_{xx} + 0.05 * |\bar{Z}_{xx}|$$

$$\sigma_{xy} = 0.05 * Z_{xy} + 0.05 * \min|Z_{xy}|$$

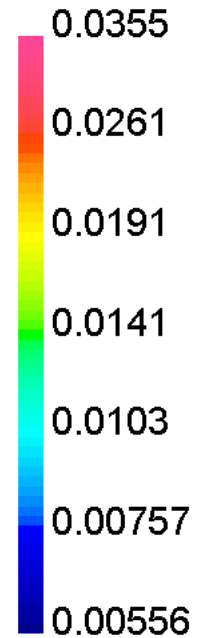
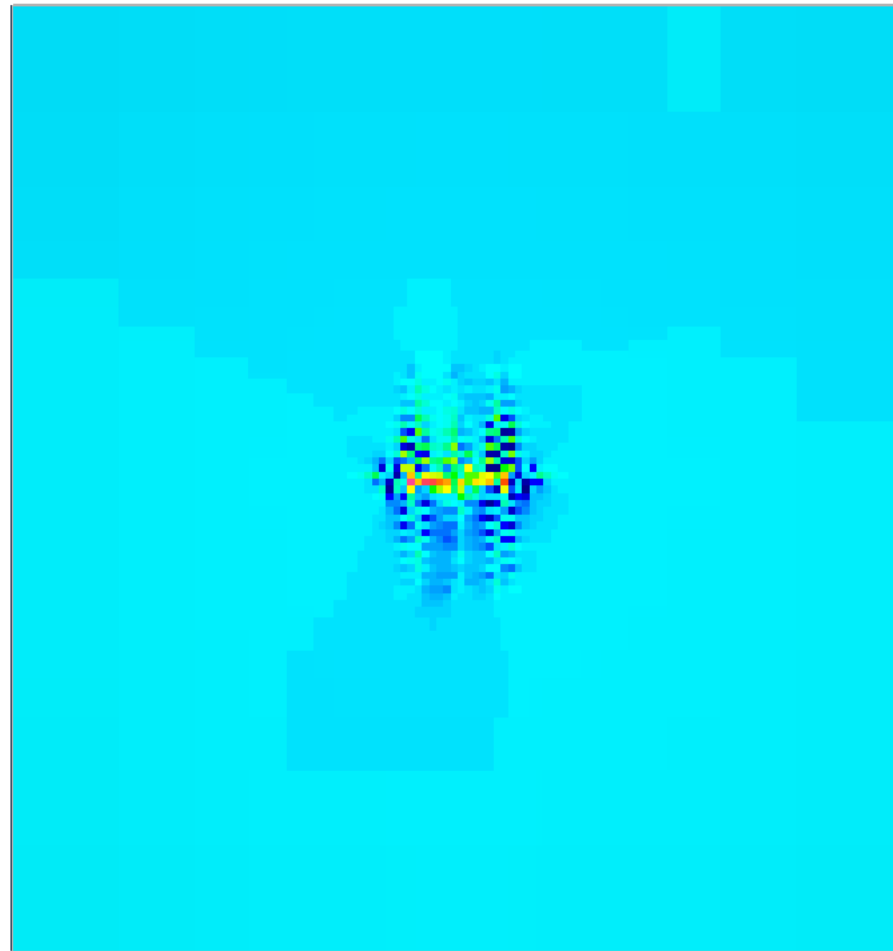
$$\sigma_{yx} = 0.05 * Z_{yx} + 0.05 * \min|Z_{yx}|$$

$$\sigma_{yy} = 0.05 * Z_{yy} + 0.05 * |\bar{Z}_{yy}|$$

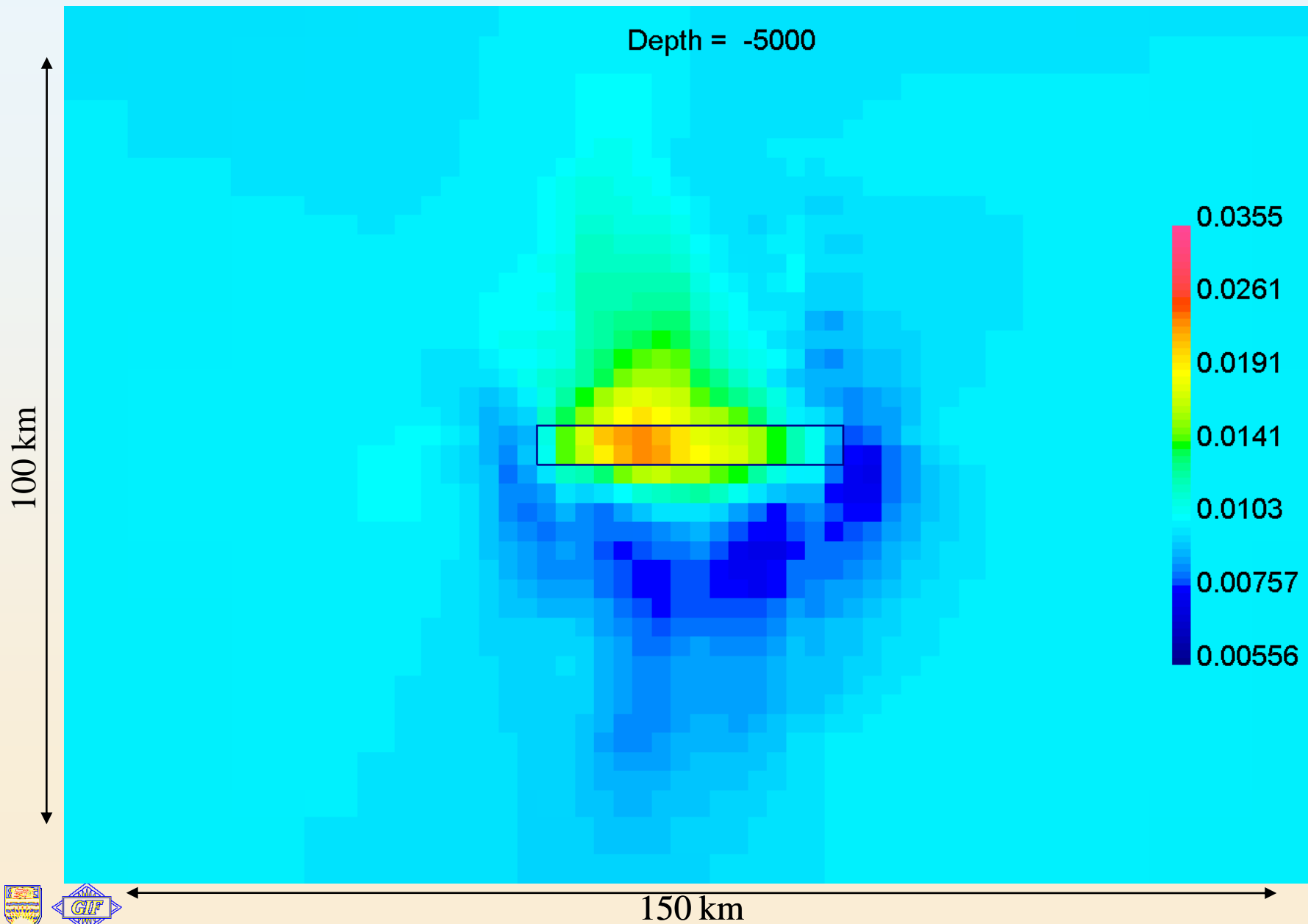
Decay of $|Z_{xx}|, |Z_{xy}|, |Z_{yx}|, |Z_{yy}|$ for 10000s period

10000s period Inversion

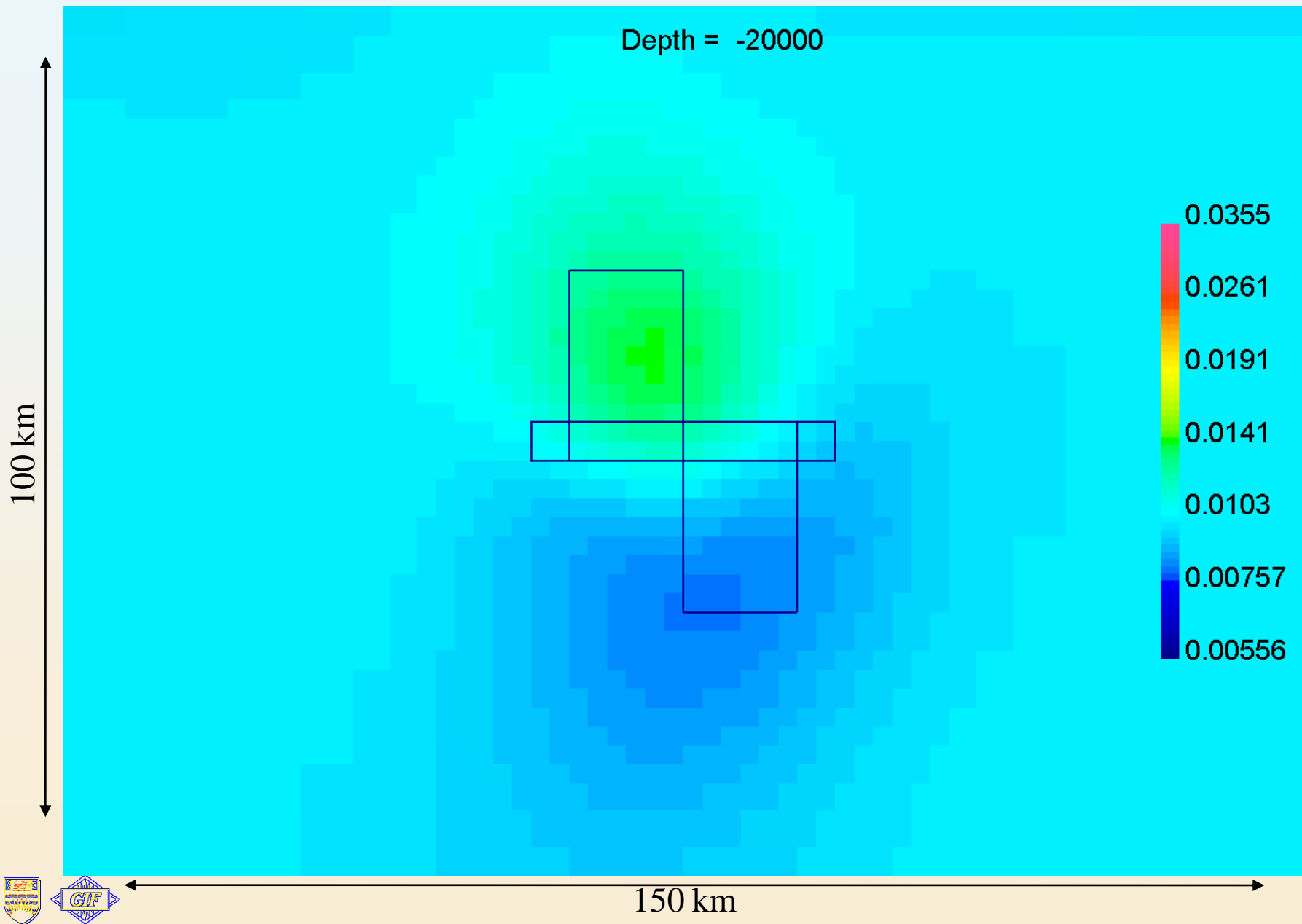
Depth = 0



10000s period Inversion

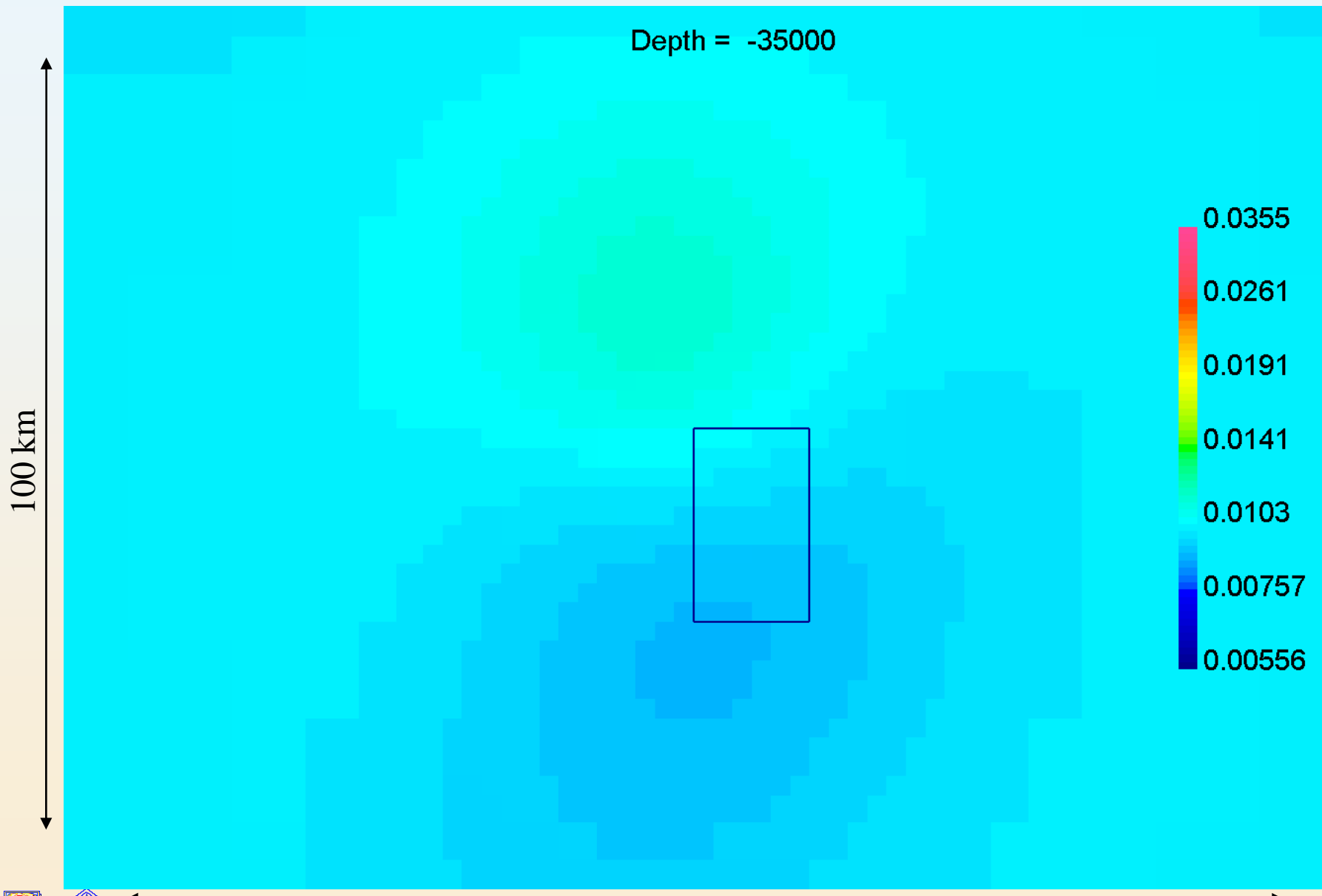


10000s period Inversion



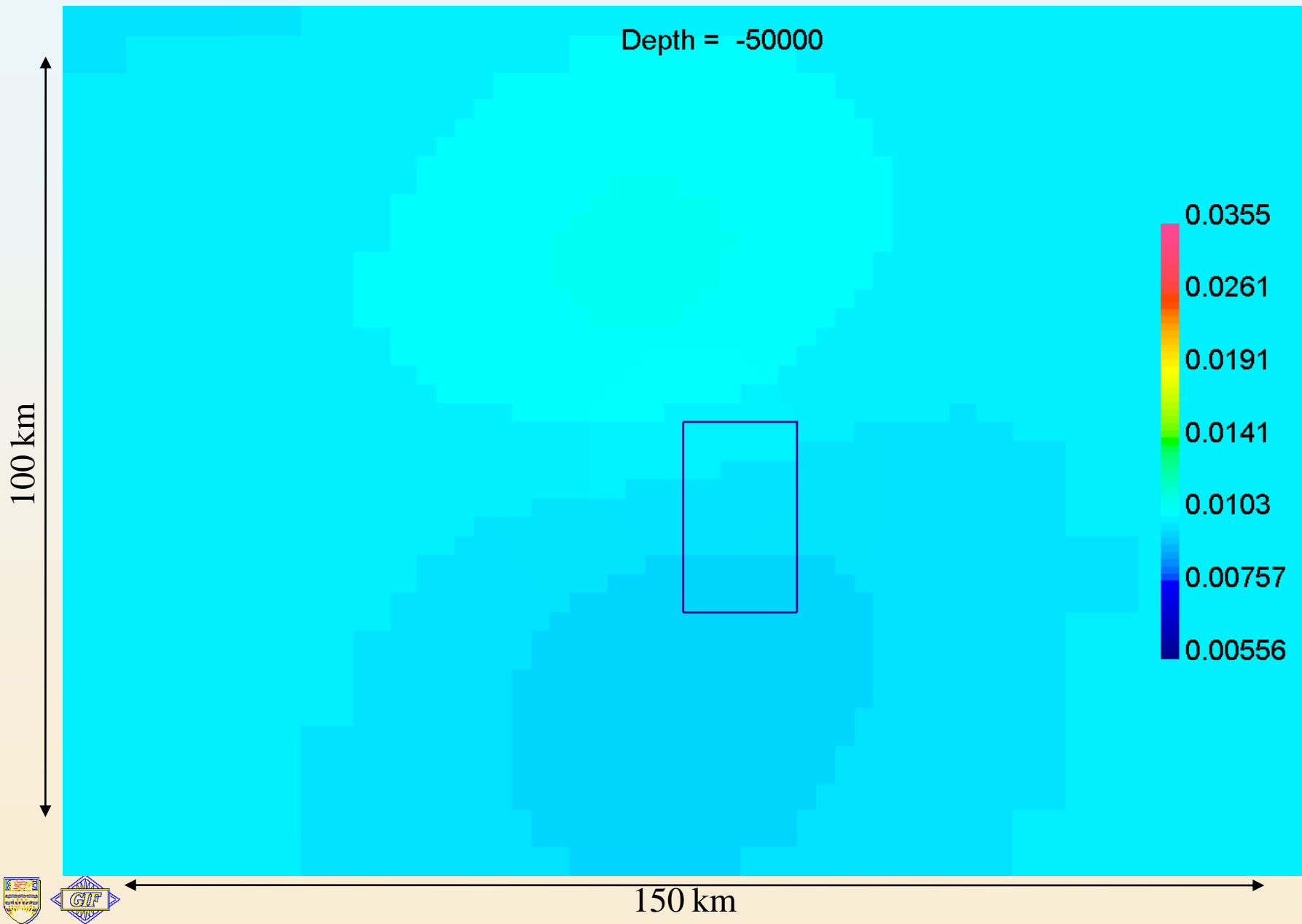
10000s period Inversion

Depth = -35000



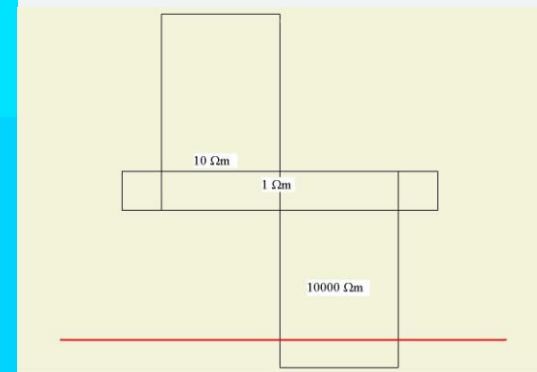
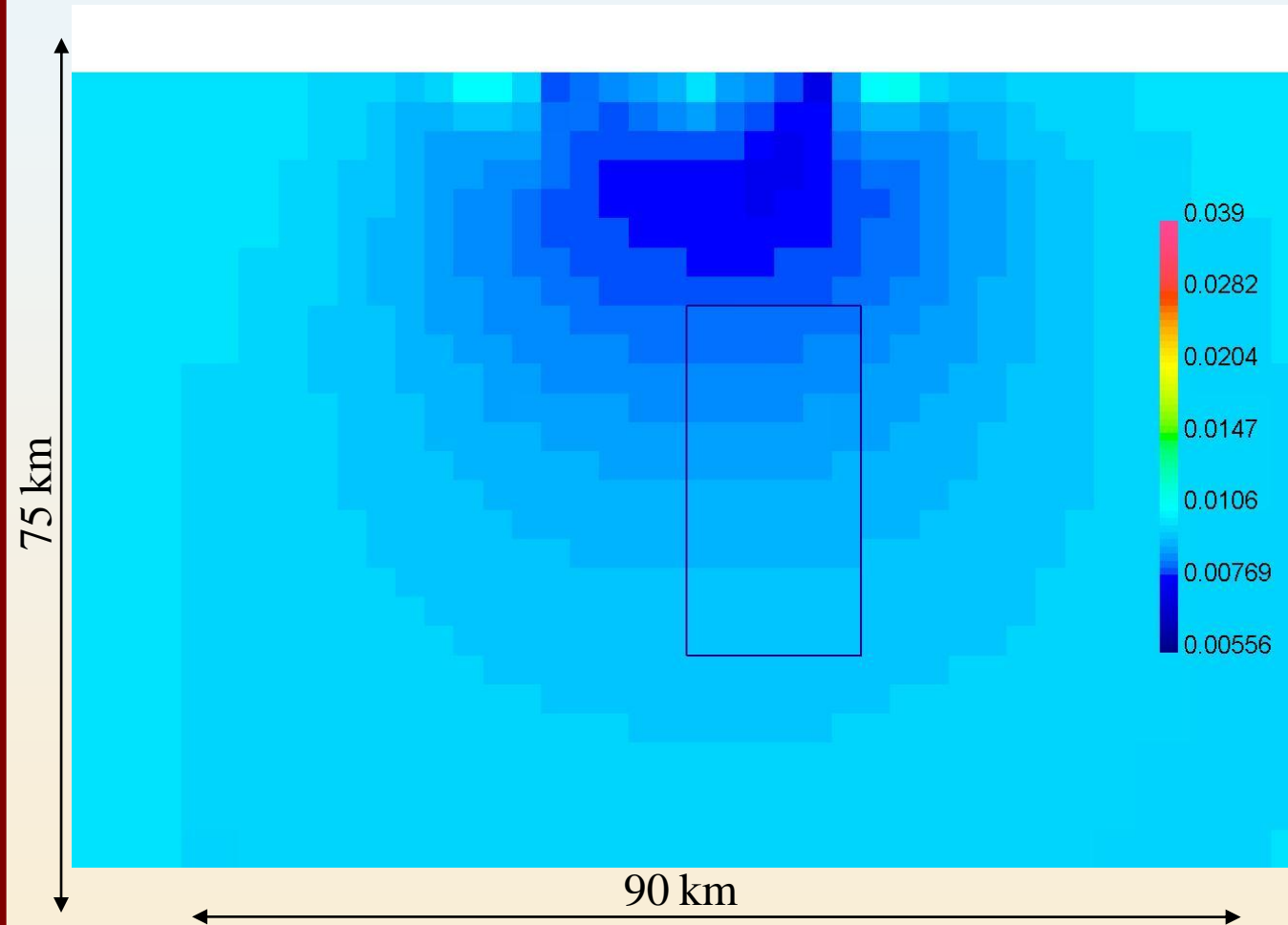
150 km

10000s period Inversion



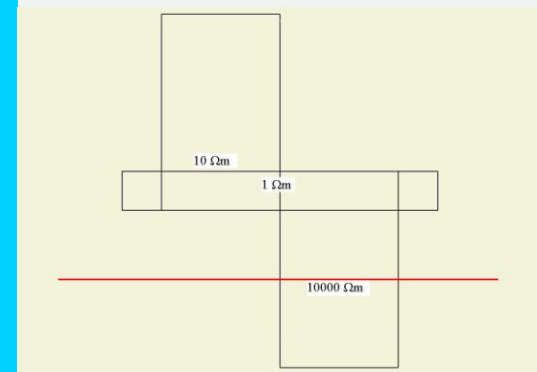
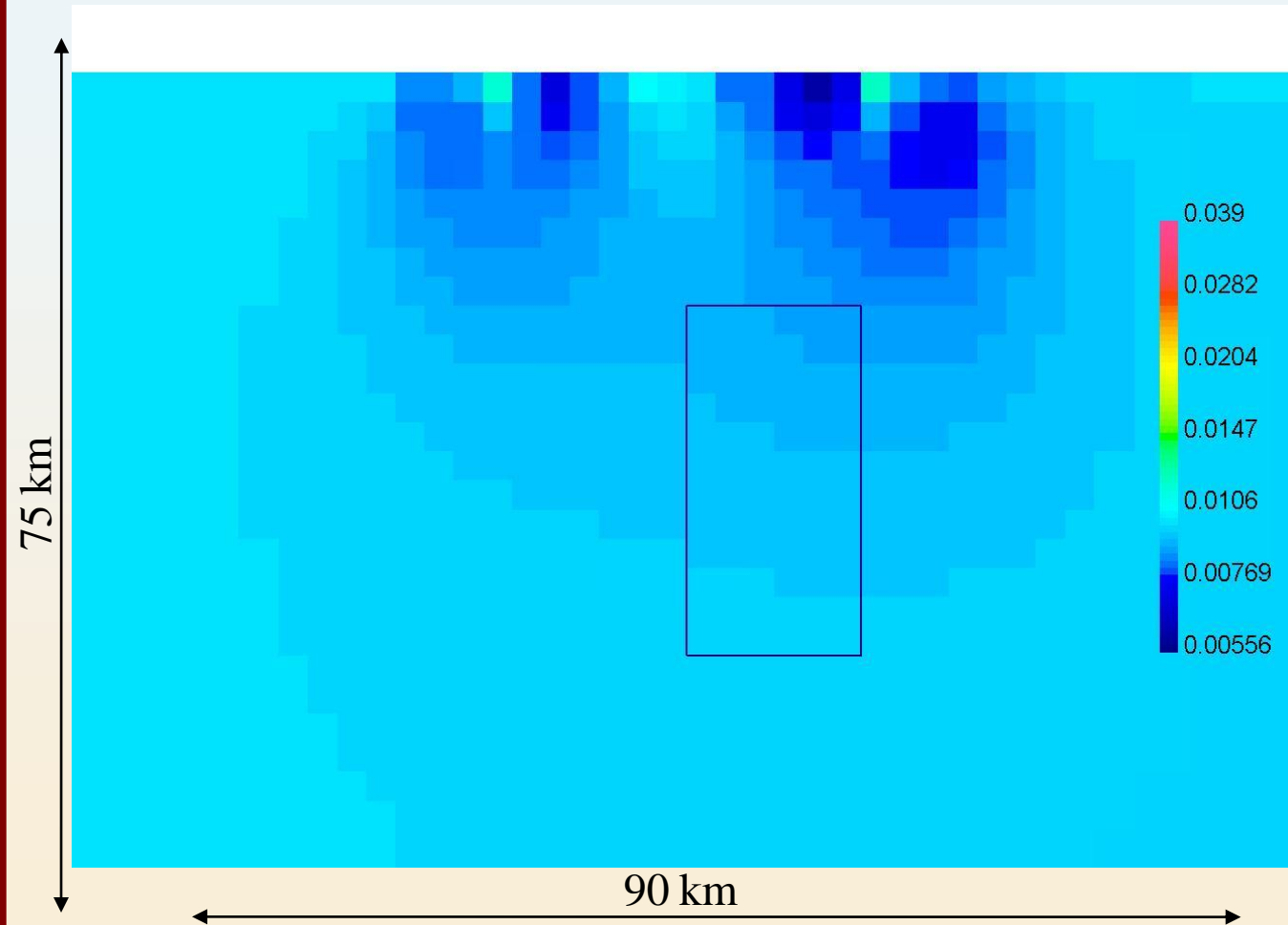
10000s period Inversion

$y = -20000\text{m}$



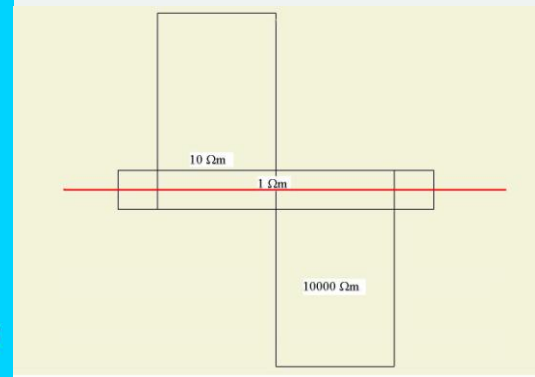
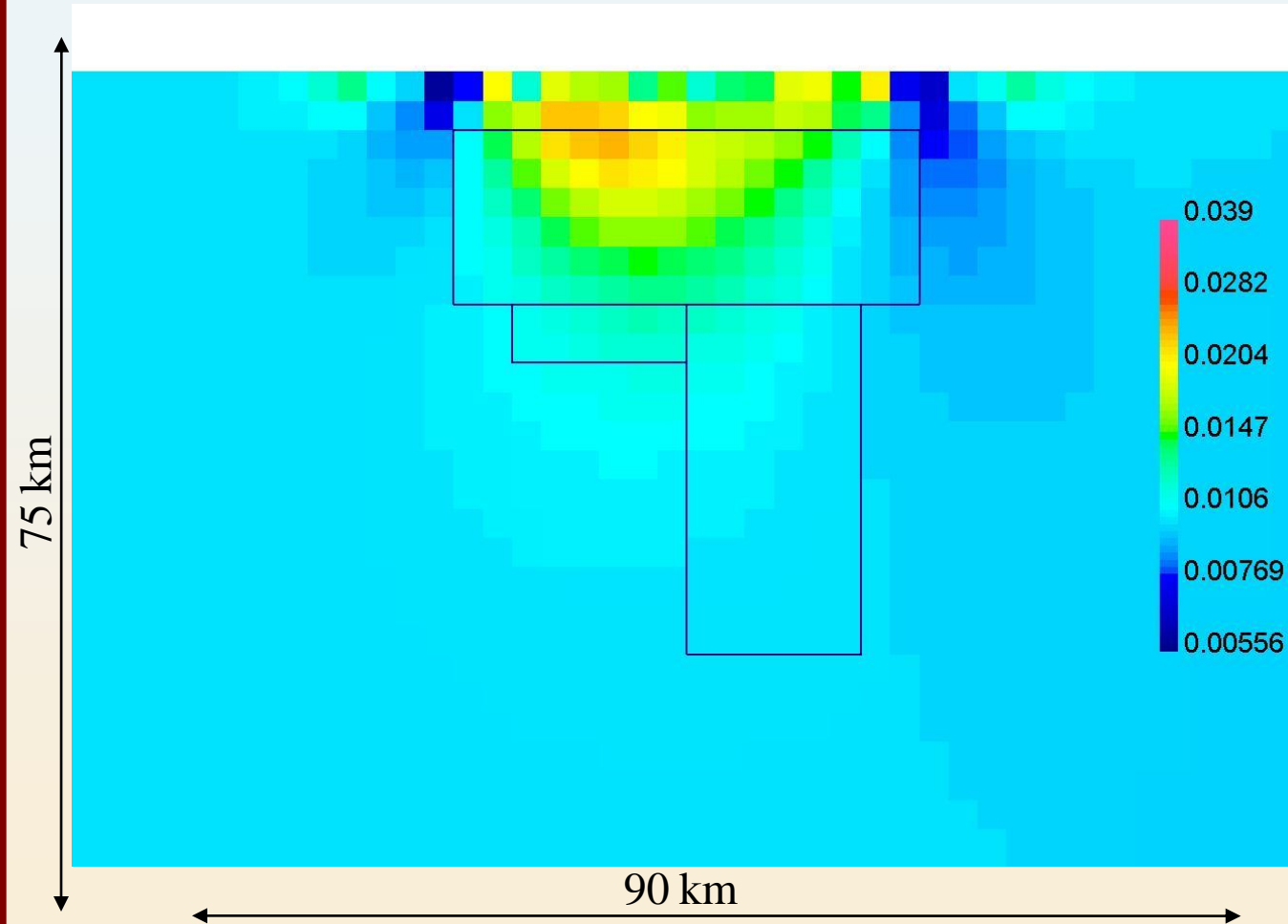
10000s period Inversion

$y = -10000\text{m}$



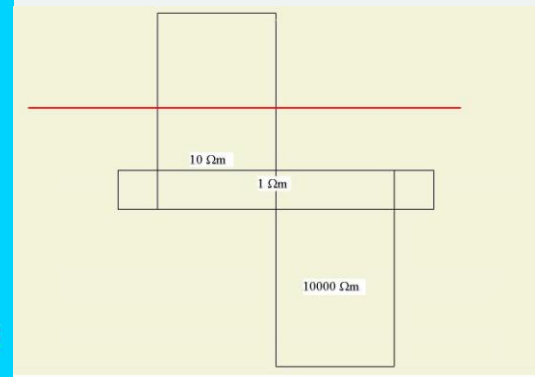
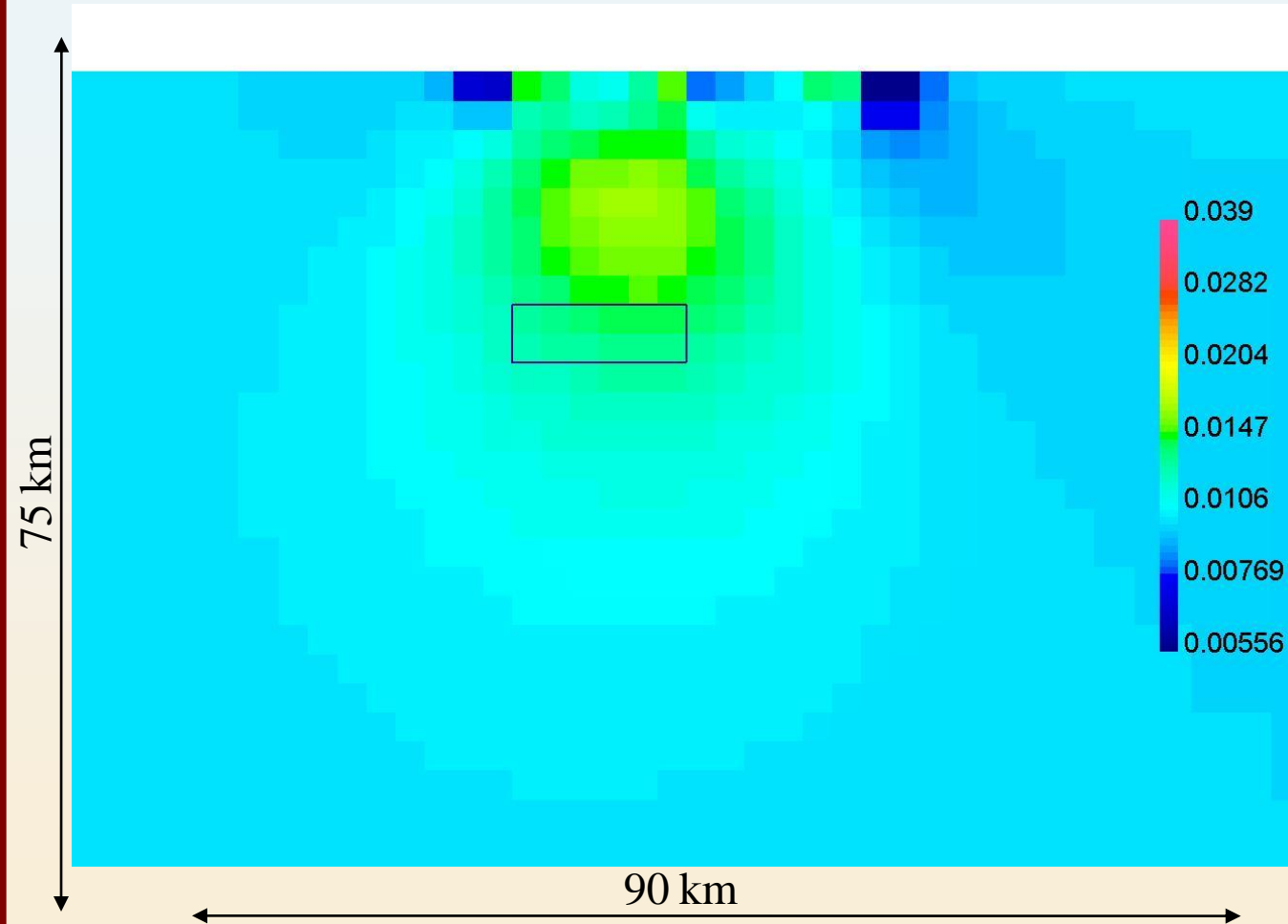
10000s period Inversion

$y=0\text{m}$



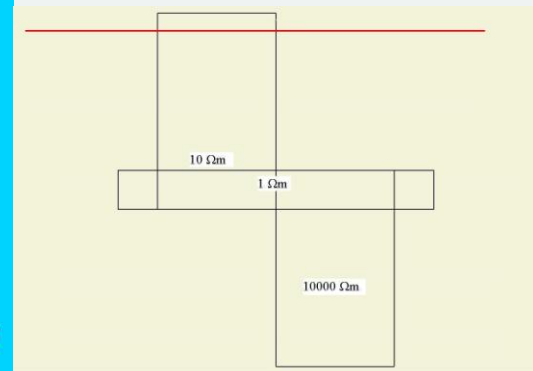
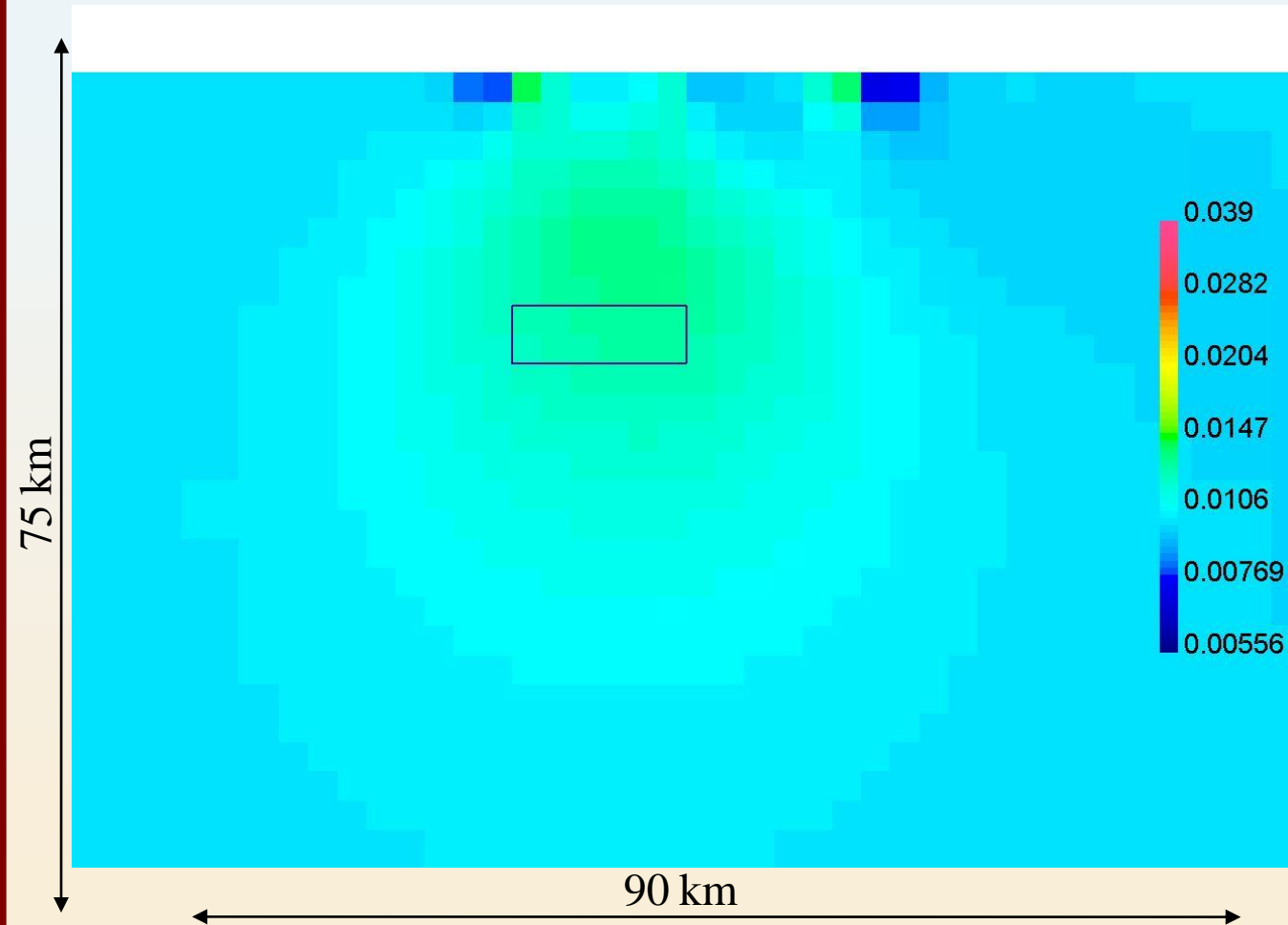
10000s period Inversion

$$y=10000\text{m}$$

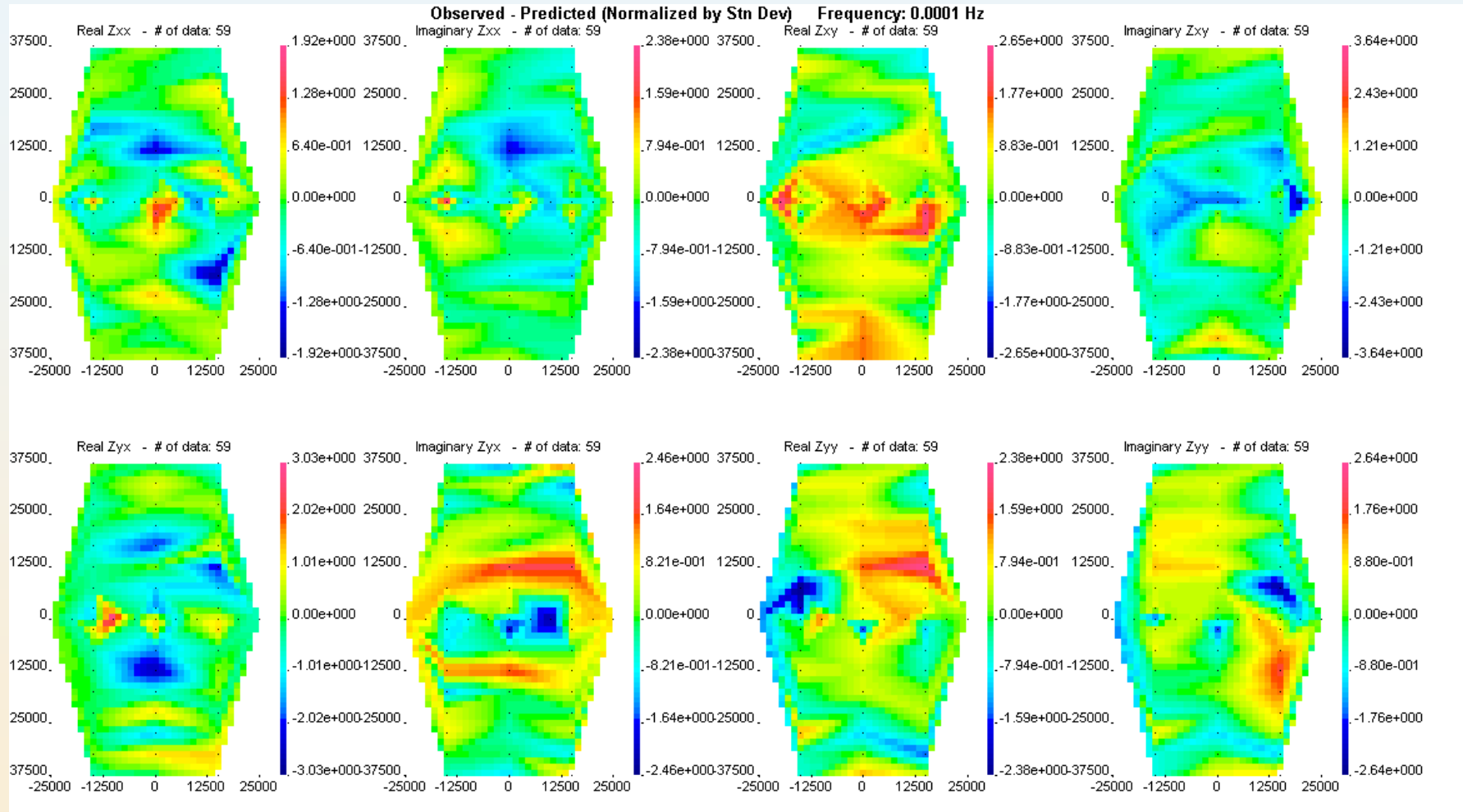


10000s period Inversion

$y=20000\text{m}$



Data Misfit of 10000s period data

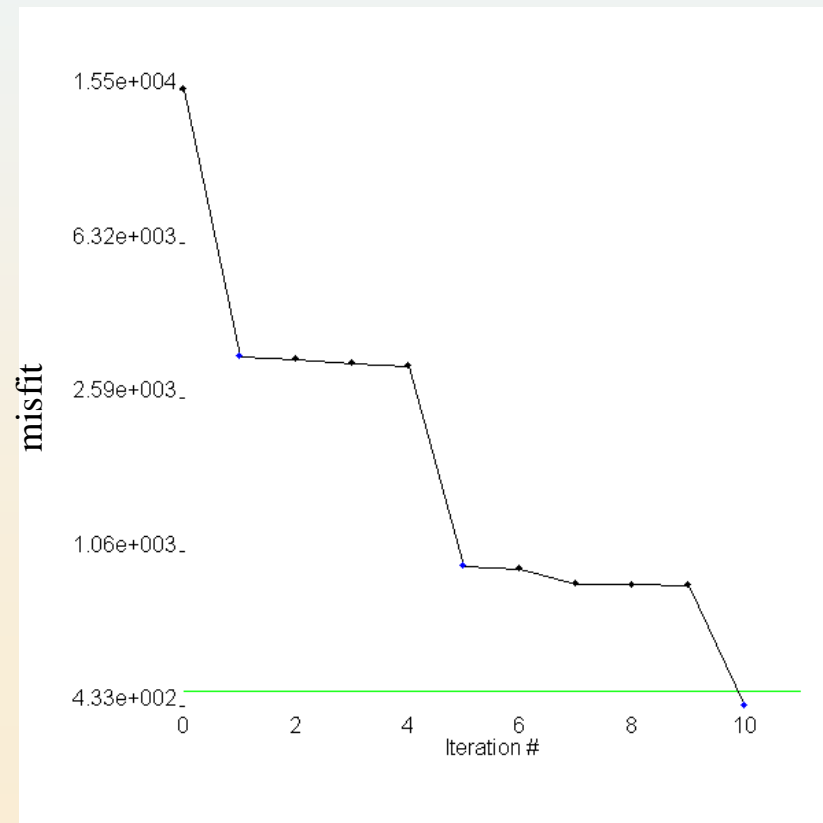


Convergence of 10000s period data

target misfit: $4.72\text{E}+02$

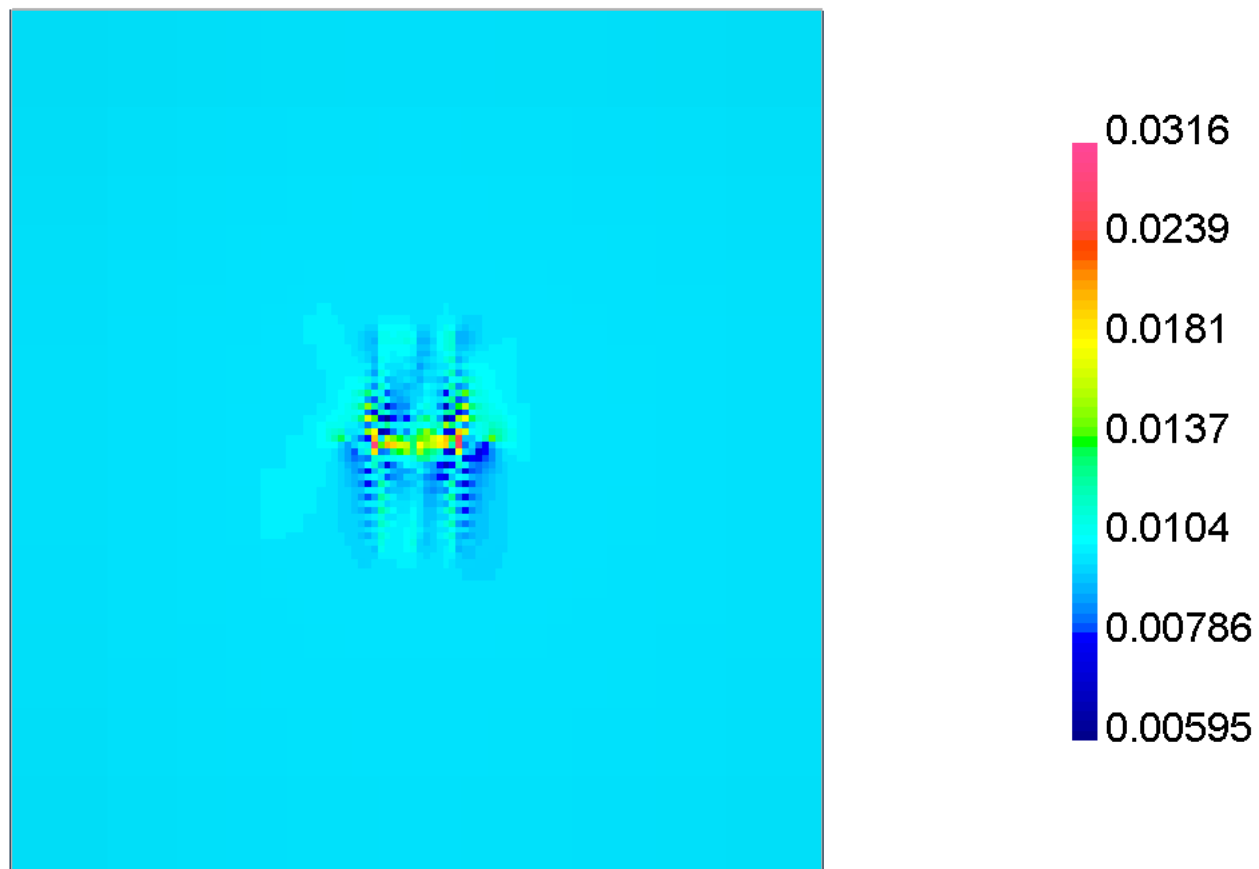
final misfit: $4.33\text{E}+02$

TOTAL cpu time: 15:35:55

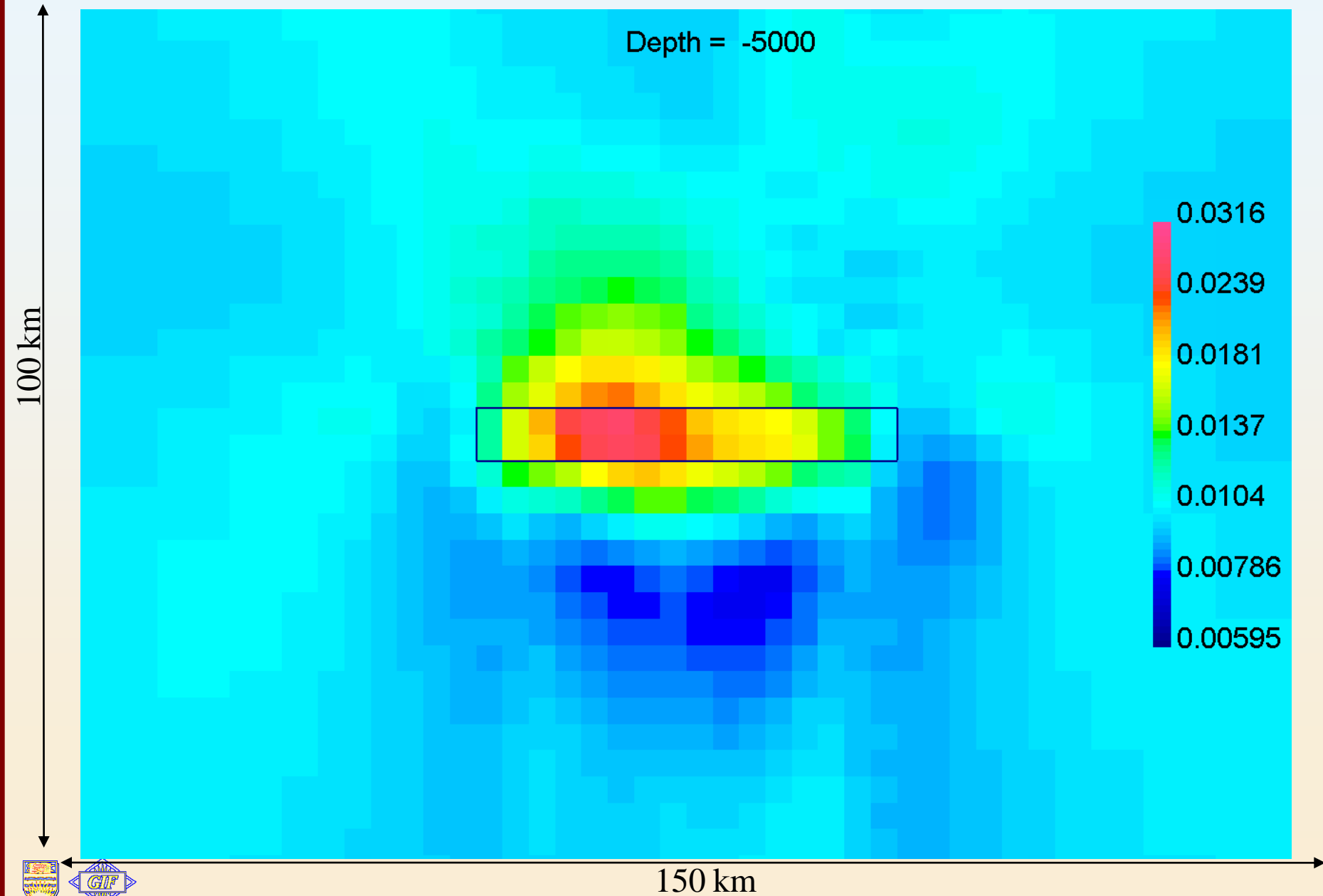


Inversion of 10000s, 1000s, 100s period data

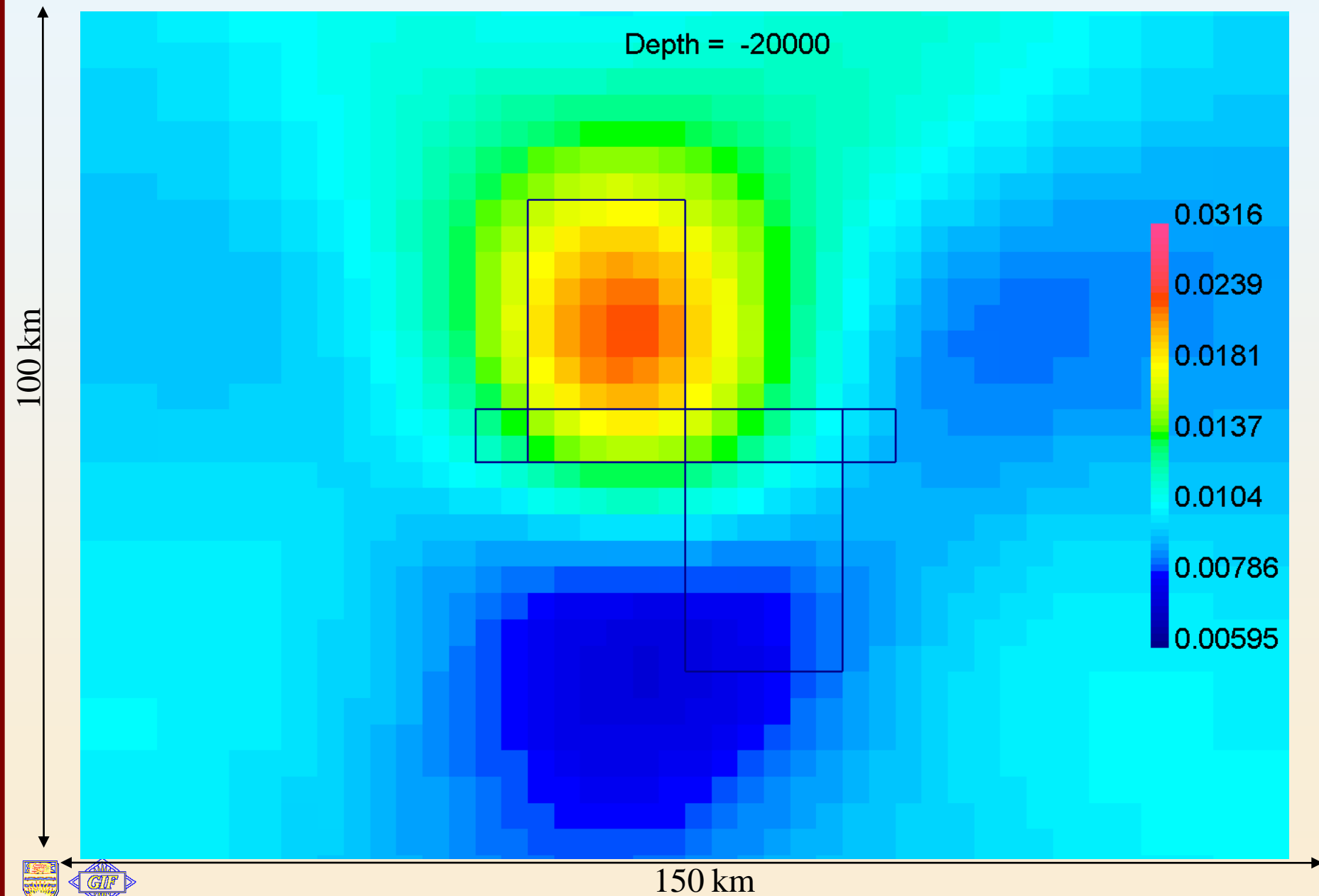
Depth = 0



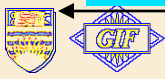
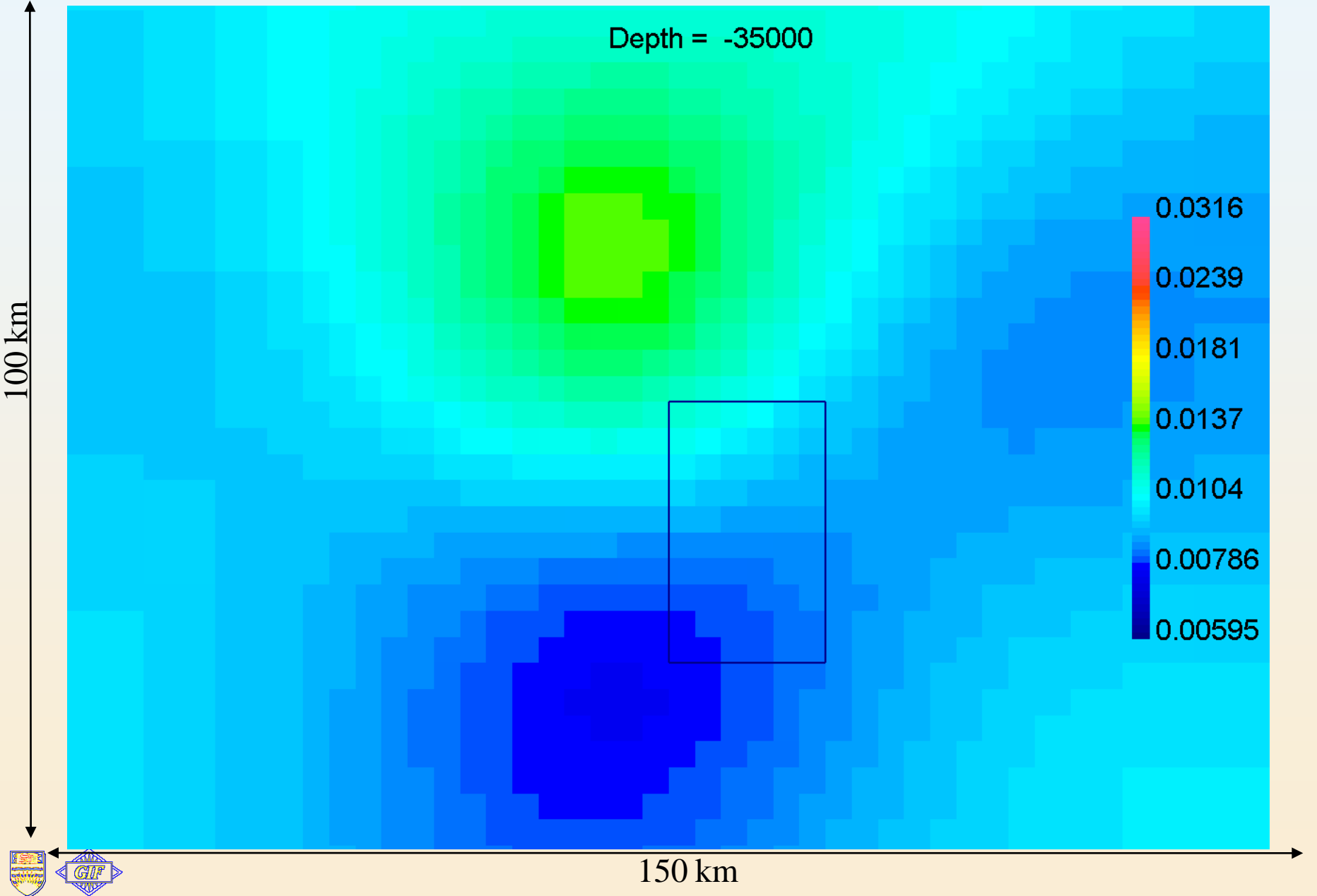
Inversion of 10000s, 1000s, 100s period data



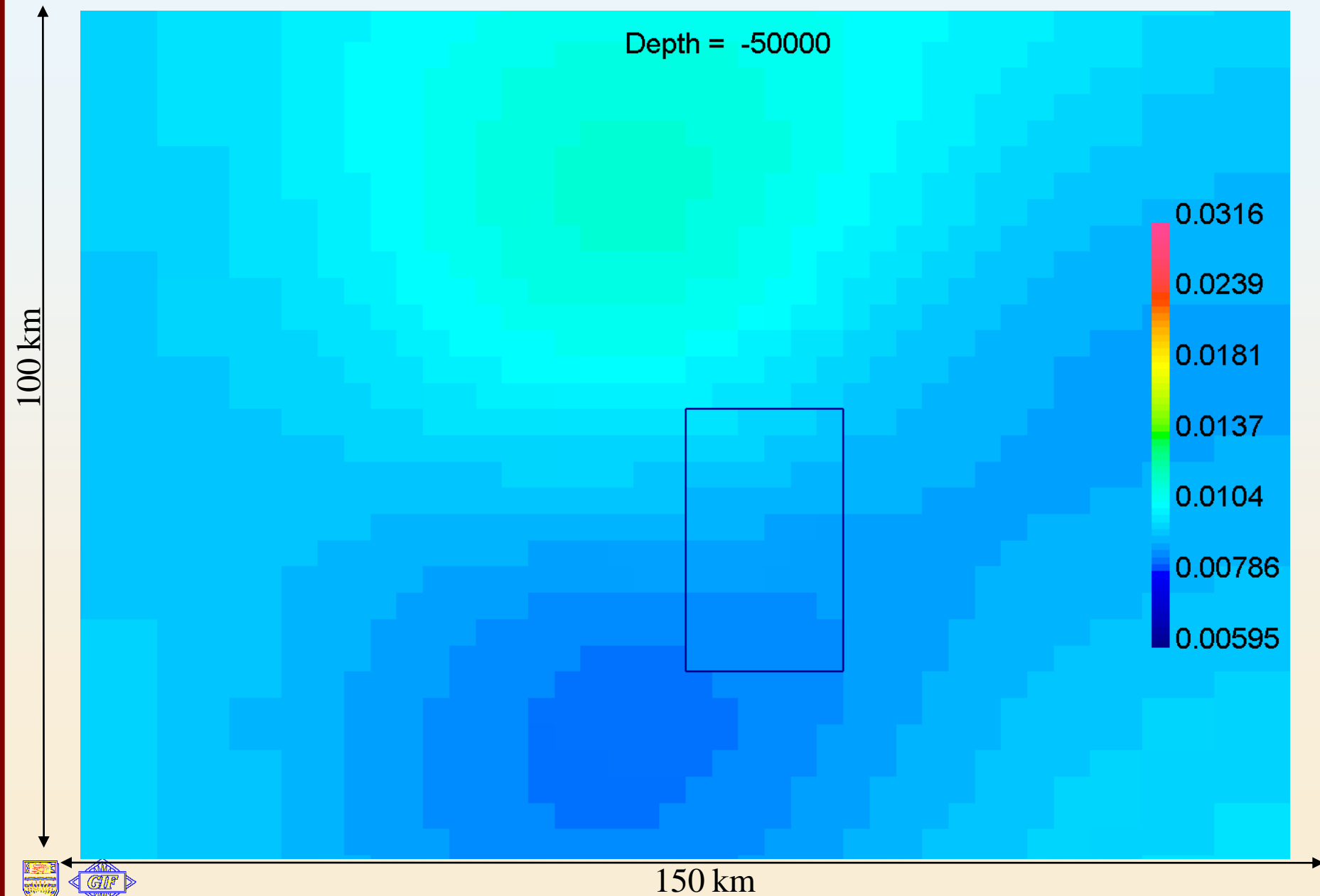
Inversion of 10000s, 1000s, 100s period data



Inversion of 10000s, 1000s, 100s period data

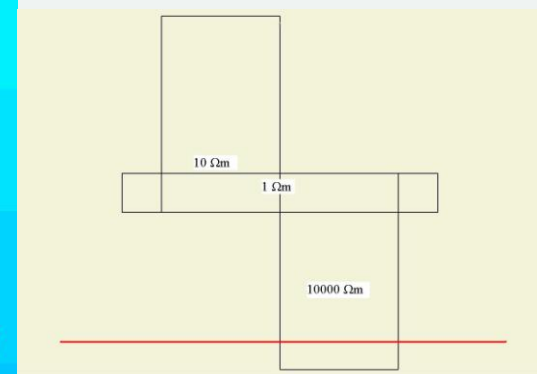
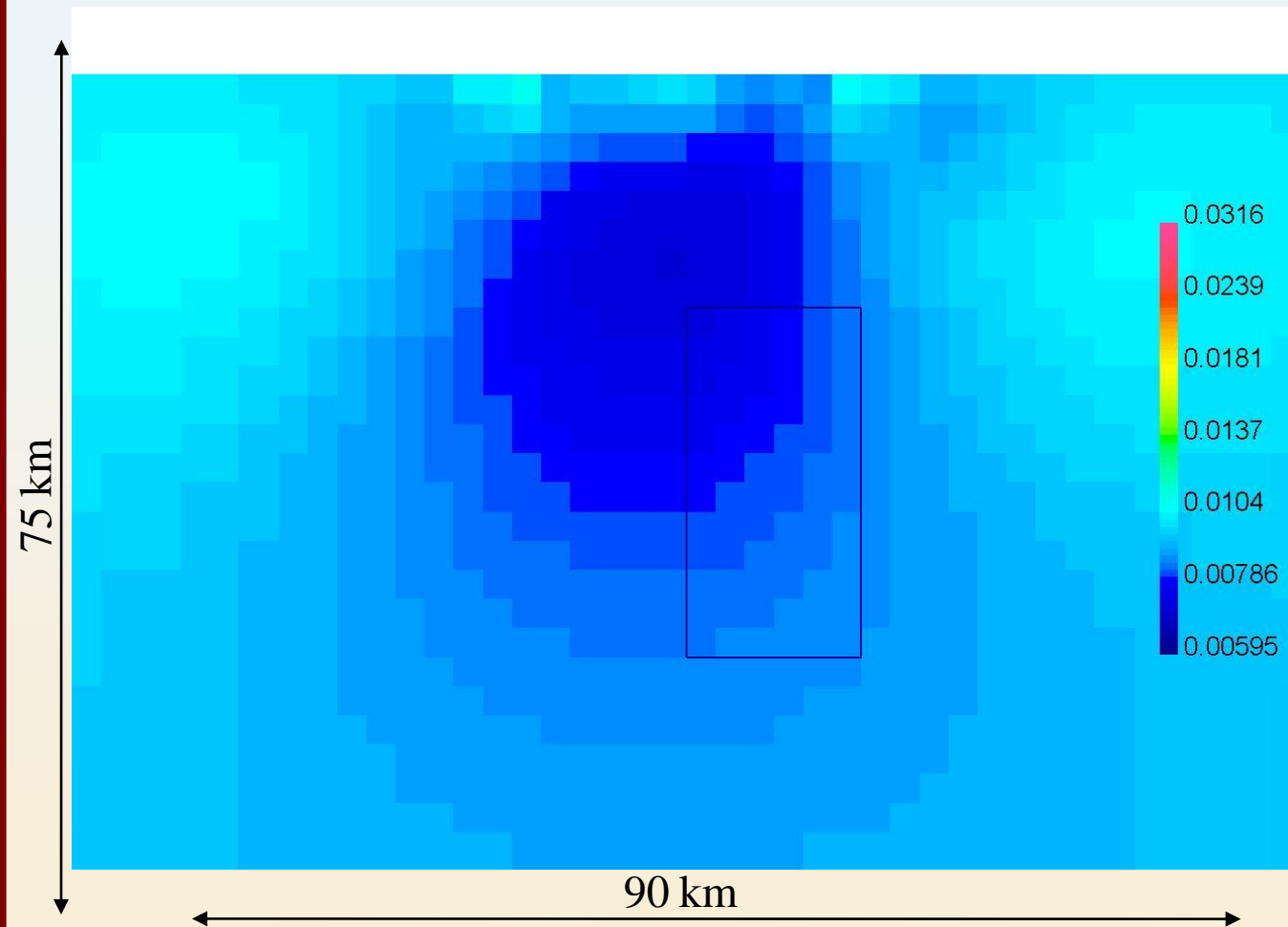


Inversion of 10000s, 1000s, 100s period data



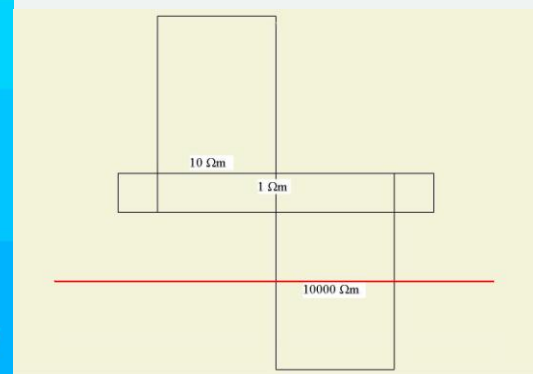
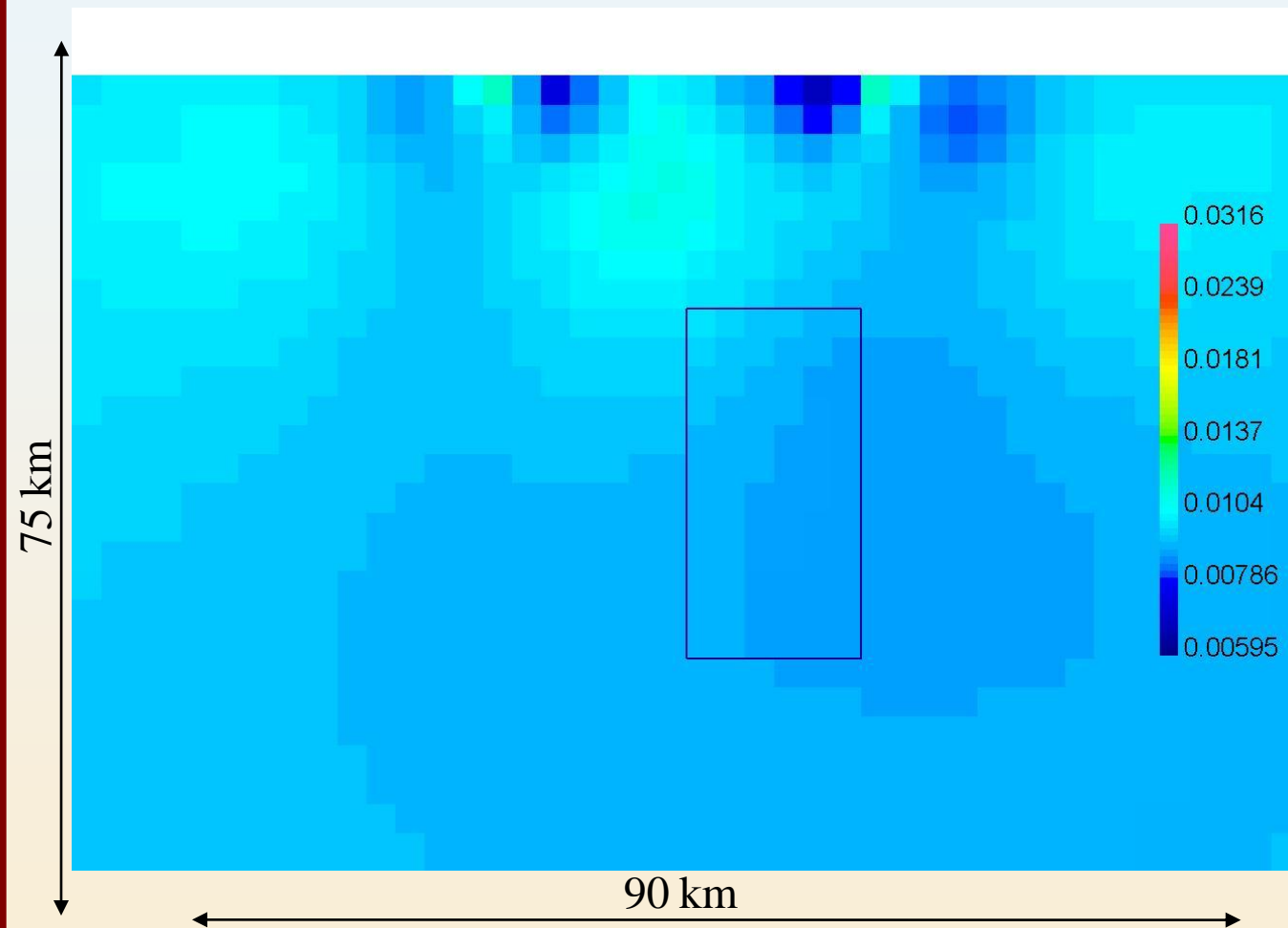
Inversion of 10000s, 1000s, 100s period data

$y = -20000\text{m}$



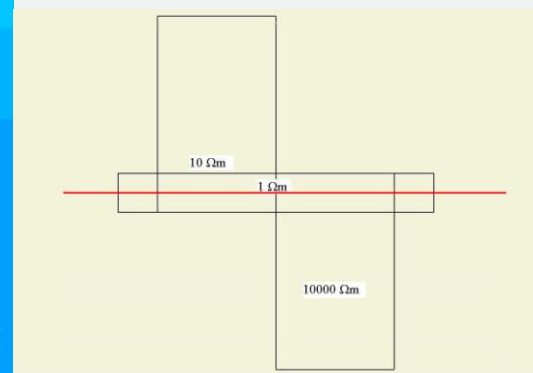
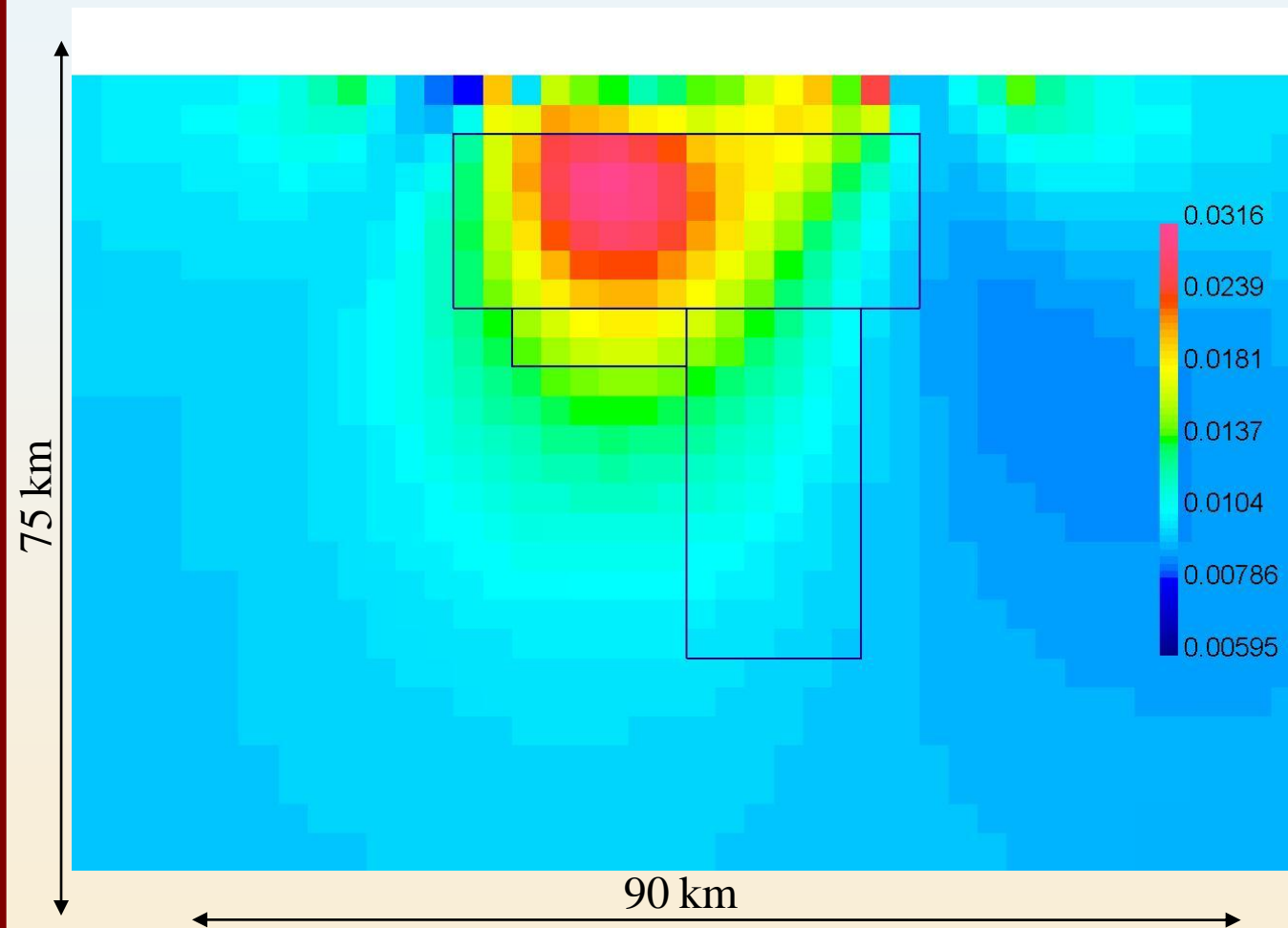
Inversion of 10000s,1000s,100s period data

$y = -10000\text{m}$



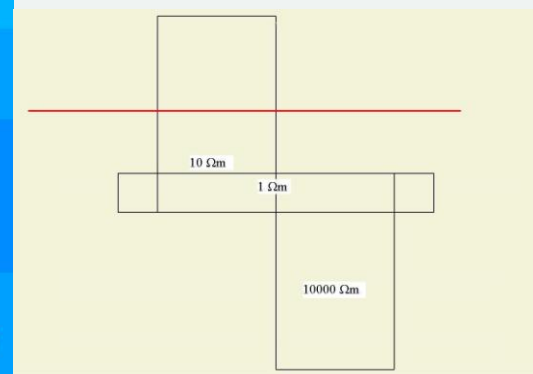
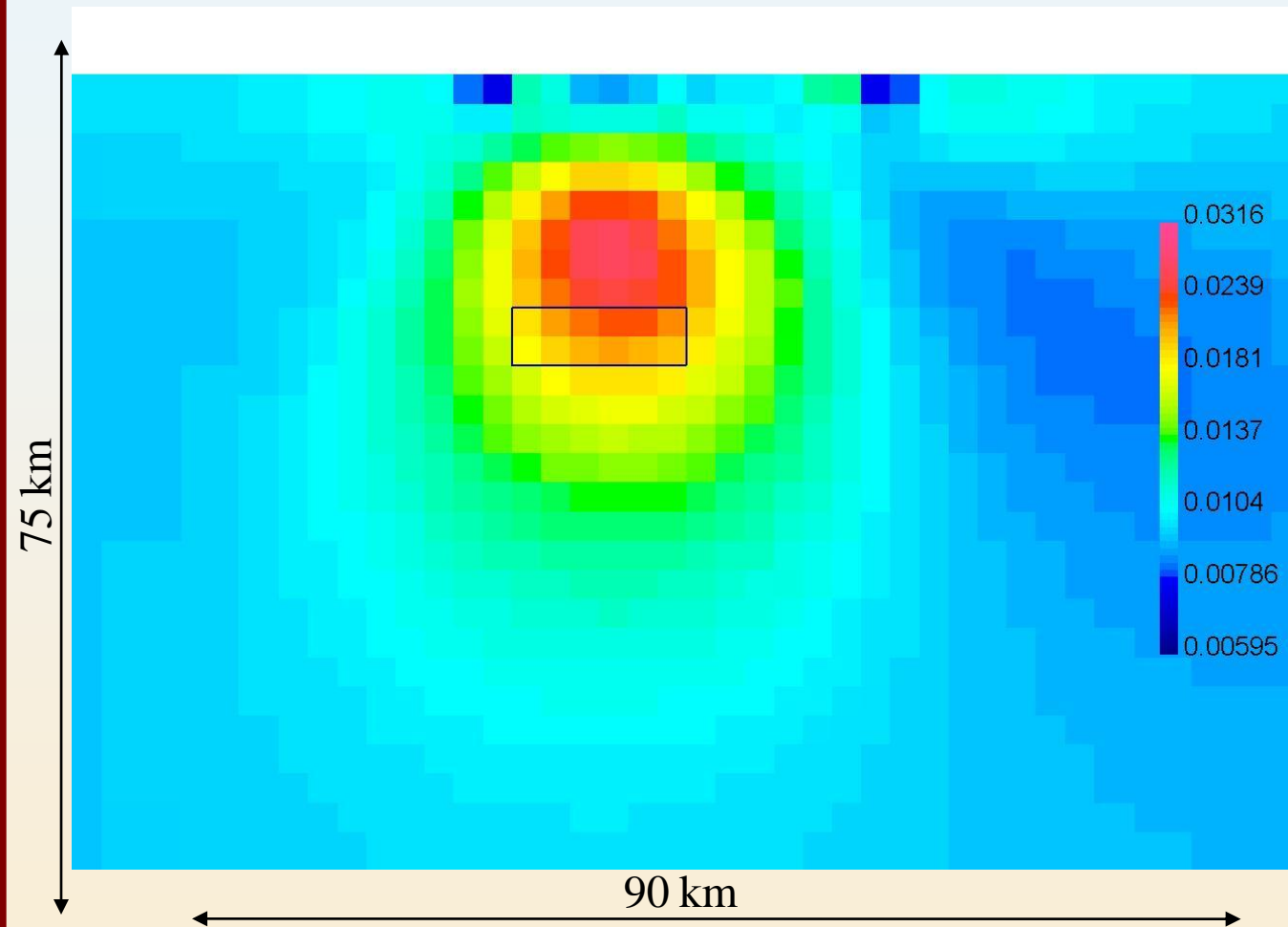
Inversion of 10000s, 1000s, 100s period data

$y=0\text{m}$



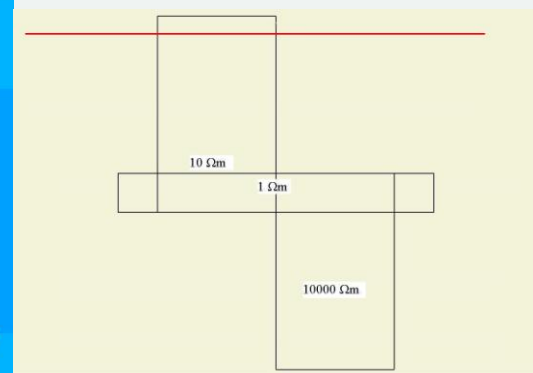
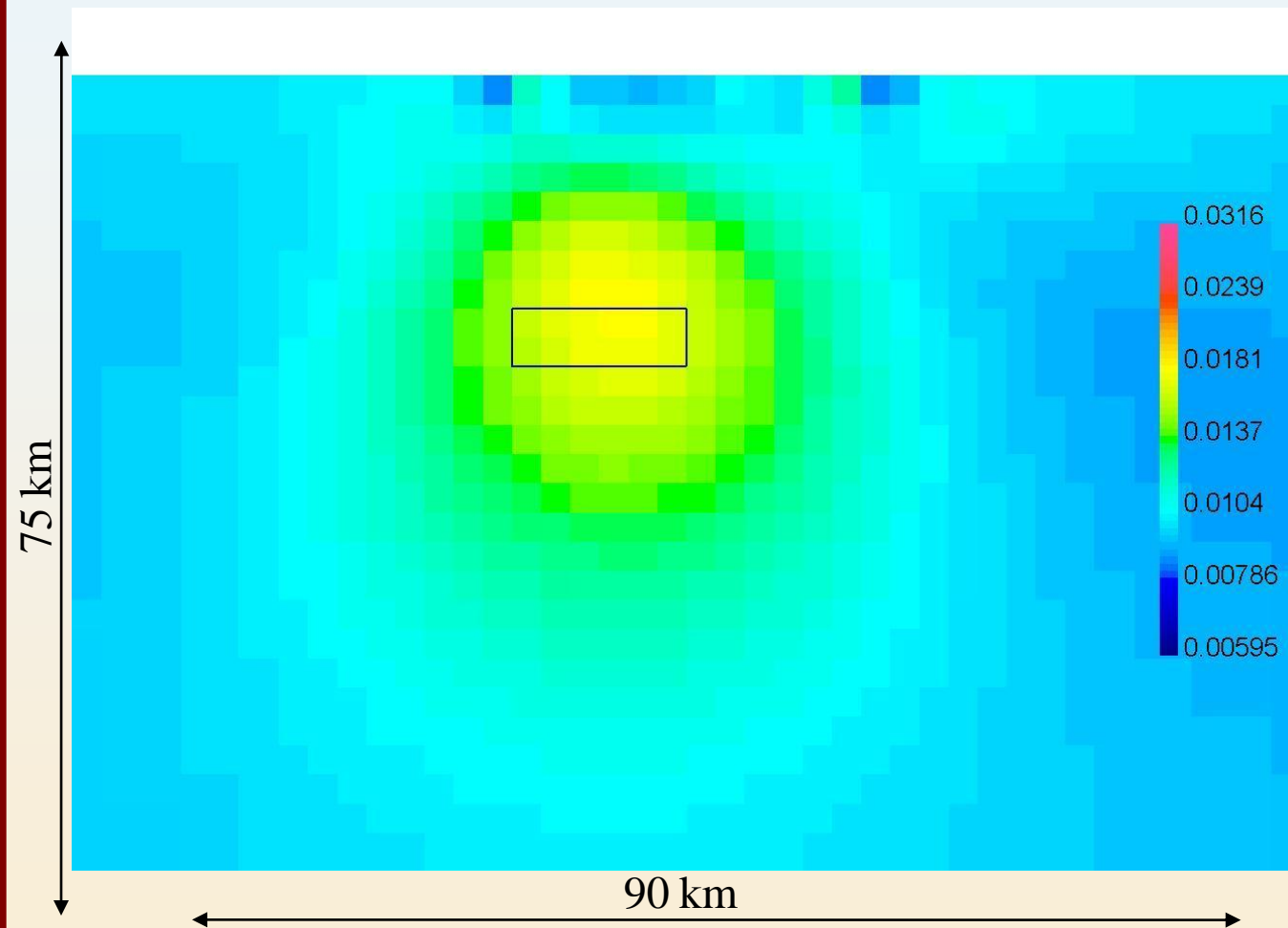
Inversion of 10000s, 1000s, 100s period data

$y=10000\text{m}$



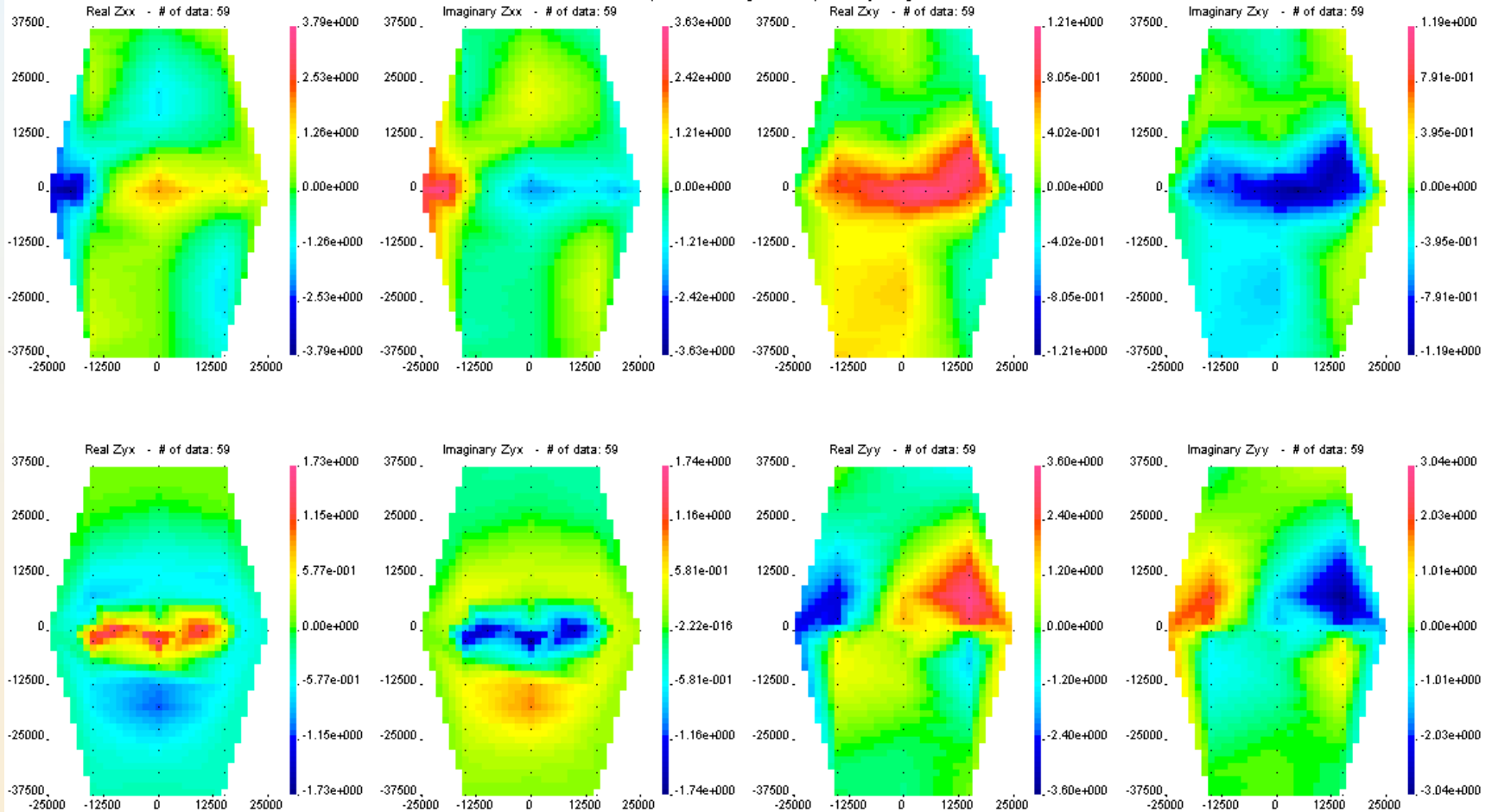
Inversion of 10000s, 1000s, 100s period data

$y=20000\text{m}$



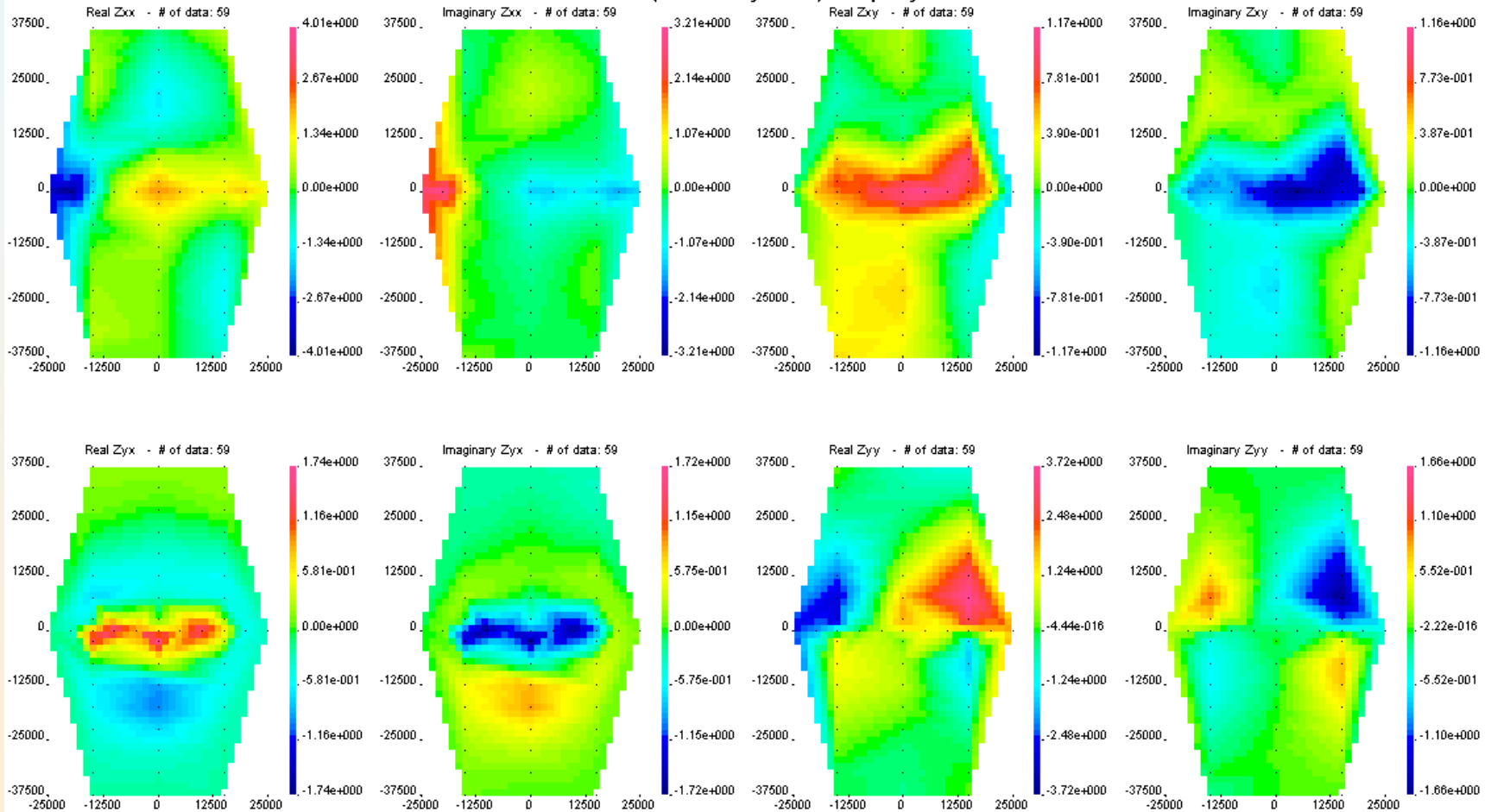
Data Misfit of 10000s period data

Observed - Predicted (Normalized by Stn Dev) Frequency: 0.0001 Hz

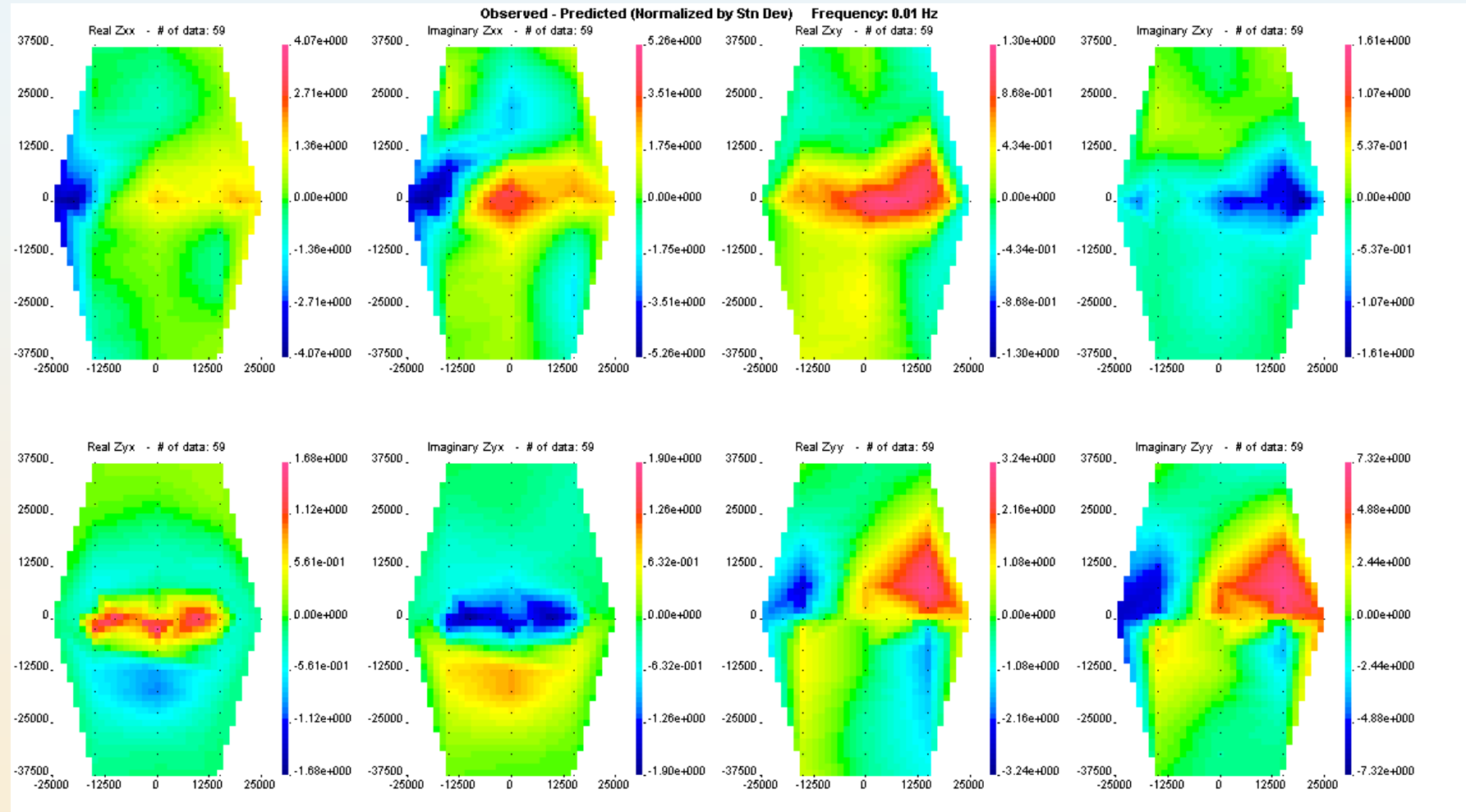


Data Misfit of 1000s period data

Observed - Predicted (Normalized by Stn Dev) Frequency: 0.001 Hz



Data Misfit of 100s period data



Convergence of 10000s 1000s 100s inversion

target misfit: 1.42E+03

final misfit: 1.83E+03

TOTAL cpu time: 124:24:04

