

Q1: Why different inversions give different answers?

Q2: Why should I run an inversion?

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MINERAL RESOURCES FLAGSHIP
www.csiro.au

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Different EM Inversion algorithms (codes):

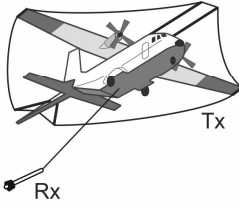
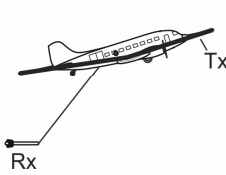
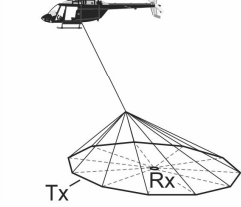
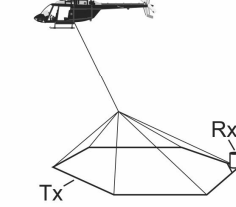
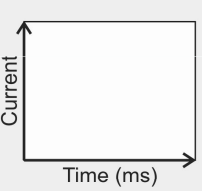
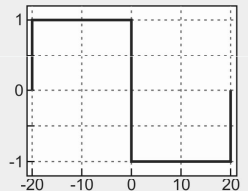
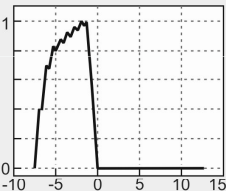
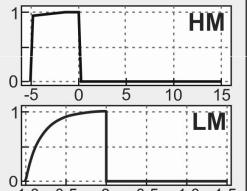
Autor	Forward Modeling	Inversion
Ellis (1995) (1998)	Hybrid (FE-IE) Finite Element Born Aproximation 1D Aproximation	Gauss-Newton Quasi-Newton Conjugate Gradients
Sengpiel y Siemon (2000)		Marquardt method
Sattel (2005)		Zohdy method
Cox y Zhdanov	Integral equation	Localized quasi-linear approximation
Brodie (2010)	Integral equation	Joint inversion (AEM-DC-Interface depth data)
Yang y Oldenburg (2012)	Volume finite in space Backward Euler in time	Gauss-Newton
Commer (2003)	Lanczos decomposition	Marquardt-Levenberg
Oldenburg, Haber y Shekthman (2013)	Volume finite in space Backward Euler in time	Gauss-Newton
Reich etal.		Damped eigenparameter (Jupp-Vozoff)
Sasaki (2001)	Finite Difference	Incomplete Cholesky biconjugate gradient
Auken etal (2014)	Schelkunoff Potential formulation (Ward and Hohmann)	Least-squares
Constable et al., 1987		Occam (Smoothest Possible Model)

Examples just from the CSIRO EM codes

Program	version number	Version date	Model description	Inversion?	Topography
Airbeo	4.7.0	2007-03-16	layered earth	yes	Flat earth
Beowulf	1.0.3	2007-11-07	layered earth	yes	Flat earth
LeroiAir	5.5.5	2008-02-03	Thin plates in layered host	yes	Flat earth
Leroi	8.0.0	2008-01-16	Thin plates in layered host	yes	Flat earth
ArjunAir	7.0.5	2007-09-26	2D mesh 3D source	yes	Full domain
Arjuna	2.1.0	2004-01-29	2D mesh 3D source	no	Full domain
SamAir	2.2.5	2007-09-22	Compact 3D in uniform host	yes	Limited
Samaya	2.0.0	2007-10-30	Compact 3D in uniform host	virtual	Limited
LokiAir	4.0.4	2007-09-24	3D full domain	yes	Full domain
Loki	3.0.0	2007-10-30	3D full domain	virtual	Full domain
MarcoAir	2.8.4	2007-09-24	prisms in layered host	no	Flat earth
Marco	4.4.0	2003-06-10	prisms in layered host	no	Flat earth

Several Systems



	TEMPEST	SPECTREM ₂₀₀₀	VTEM	SKYTEM ⁵⁰⁸
				
<i>Survey Year flown</i>	1998	2012	2011	2012
<i>Platform</i>	Fixed wing	Fixed wing	Helicopter	Helicopter
<i>System geometrical configuration</i>	Transmitter (Tx): Loop on aircraft Receiver (Rx): Towed bird	Tx: Loop on aircraft Rx: Towed bird	Concentric loop Tx/Rx Suspended weight	Rx: Offset 17(m) behind Tx centre Suspended weight
<i>Nominal heights Tx</i>	Tx: 120(m)	Tx: 90(m)	Tx: 49(m)	Tx: 30(m)
<i>Rx</i>	Rx: 65(m)	Rx: 50(m)	Rx: 49(m)	Rx: 32(m)
<i>Transmitter coil axis</i>	Vertical	Vertical	Vertical	Vertical
<i>Tx loop area</i>	186(m ²)	420(m ²)	531(m ²)	508(m ²)
<i>Tx base frequency</i>	25(Hz)	25(Hz)	25(Hz)	LM 200(Hz) HM 25(Hz)
<i>Tx number of loop turns</i>	1	1	4	LM 1 HM 8
<i>Peak current</i>	300 (A)	960 (A)	200 (A)	LM 10 HM 120 (A)
<i>Peak moment</i>	55,800 (Am ²)	403,200 (Am ²)	424,740 (Am ²)	LM 4,900 HM 492,000 (Am ²)
<i>Nominal waveform shape</i>	Quasi-Square	Quasi-Square	Half Sine-Trapezoid	Half Sine-Trapezoid
				
<i>Duty cycle</i>	50%	100%	37%	LM 40% HM 25%
<i>Tx height measured</i>	Measured	Measured	Not measured (derived from helicopter)	Measured 2 laser altimeters on rigid frame
<i>Tx orientation</i>	Measured (from aircraft)	Measured (from aircraft)	Measured Indirectly (GPS)	Measured inclinometers on frame
<i>Tx-Rx separations</i>	Not measured Nominal horizontal 100 vertical 53(m)	Not measured Nominal horizontal 121 vertical 41(m)	Not measured (flexible frame)	Measured (rigid frame)
<i>Receiver orientation</i>	Not measured	Not measured	Not measured	Measured (2 inclinometers on frame)
<i>Receiver coils</i>	X ,Z & Y not delivered)	X, Z (Y not delivered)	X & Z	X & Z
<i>EM Sensor</i>	dB/dt	dB/dt	dB/dt	dB/dt
<i># of receiver windows</i>	15	9	35	LM 18 HM 18
<i>EM channels start times (ms)</i>	0.007 to 12.4	0.013 to 13.3	0.078 to 8.6	0.028 to 11.84

YL009-13

data, \mathbf{d} =(observations)

things that are measured ...

model parameters, \mathbf{m} = (meaningful)

capture the essence of the process that is being studied

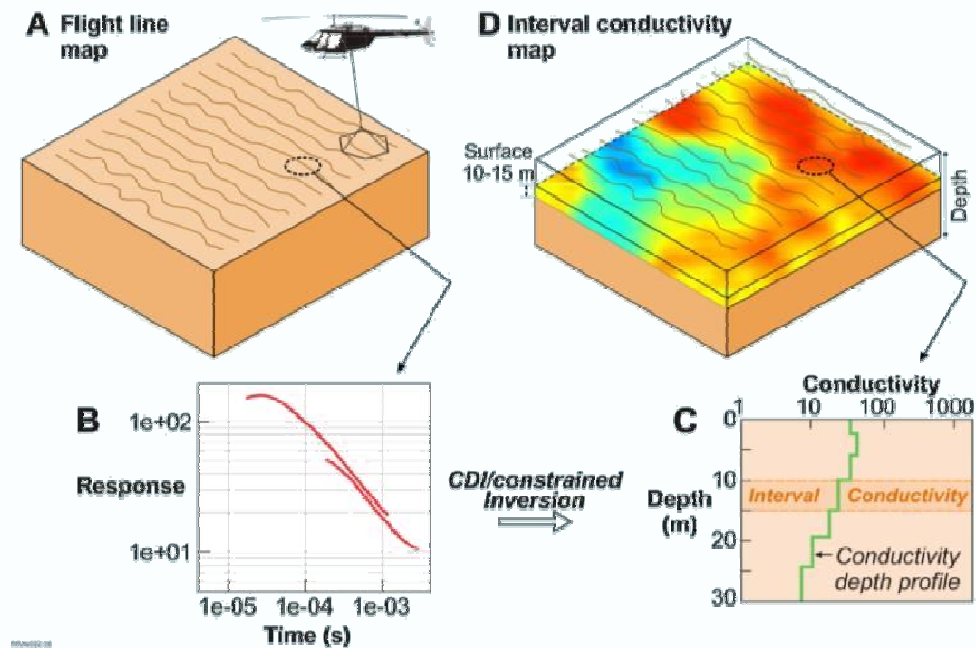
quantitative model (or *theory*)

relationship between data and
model parameters

$$\mathbf{d} = \mathbf{Gm}$$

“data kernel”

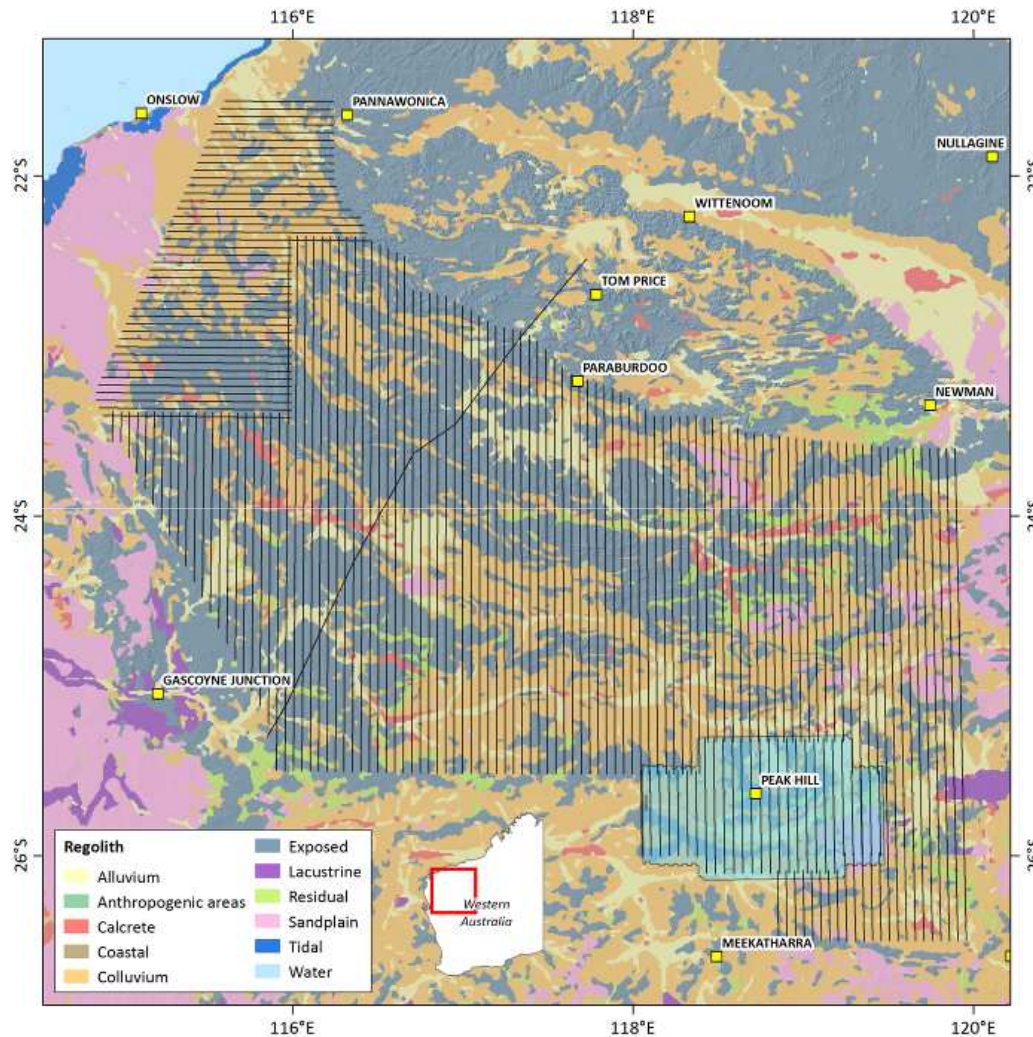
Inversion Theory



The Capricorn 2014 AEM survey

Line km: more than 30,000
Survey Completed:
January 2014

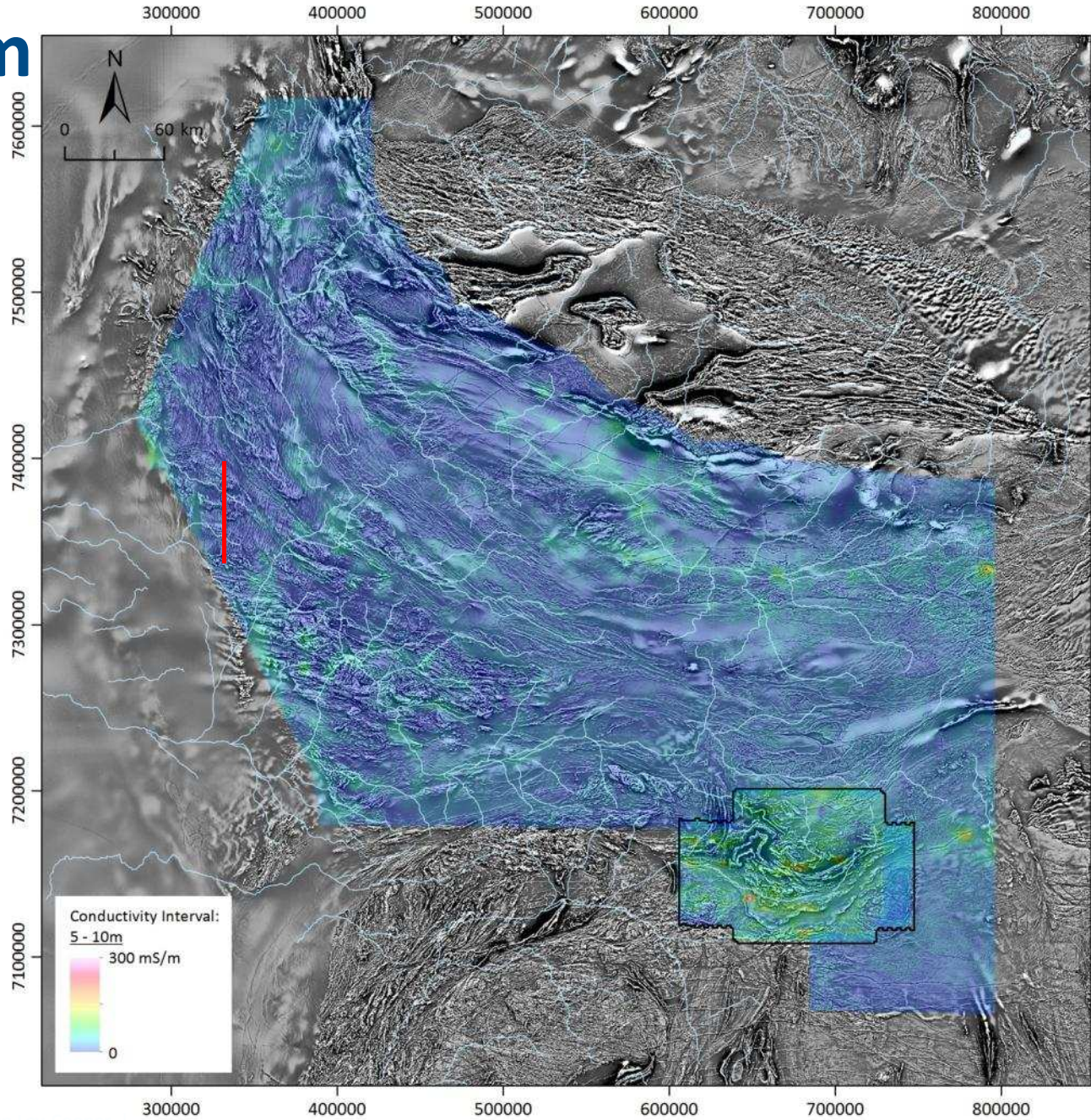
It is the largest AEM survey
by area flown in Australia to
date over 145 000 km²



5-10m

The Capricorn 2014 AEM survey

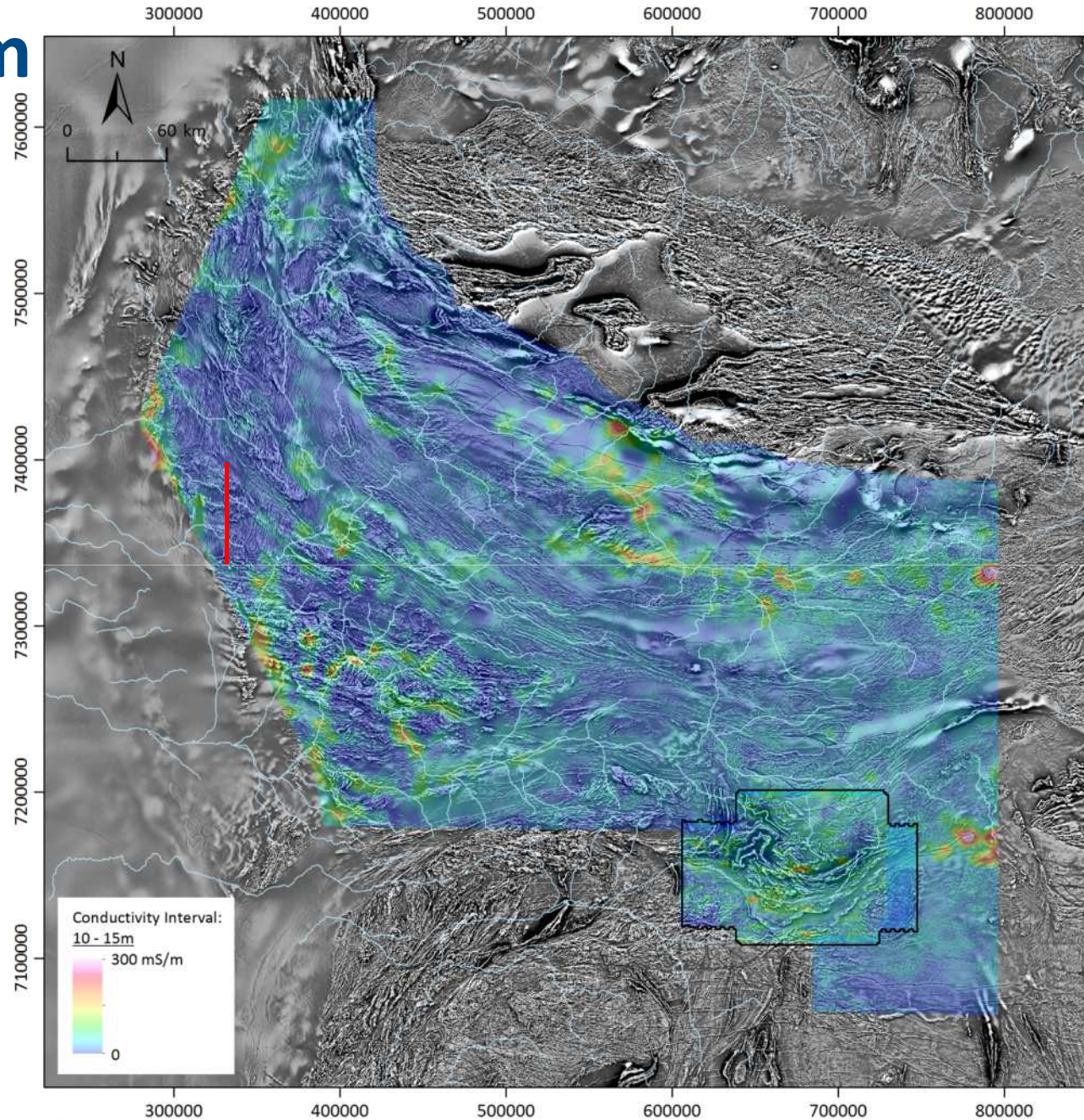
Line km: over 30,000
Survey Completed: January 2014



10-15m

The Capricorn 2014 AEM survey

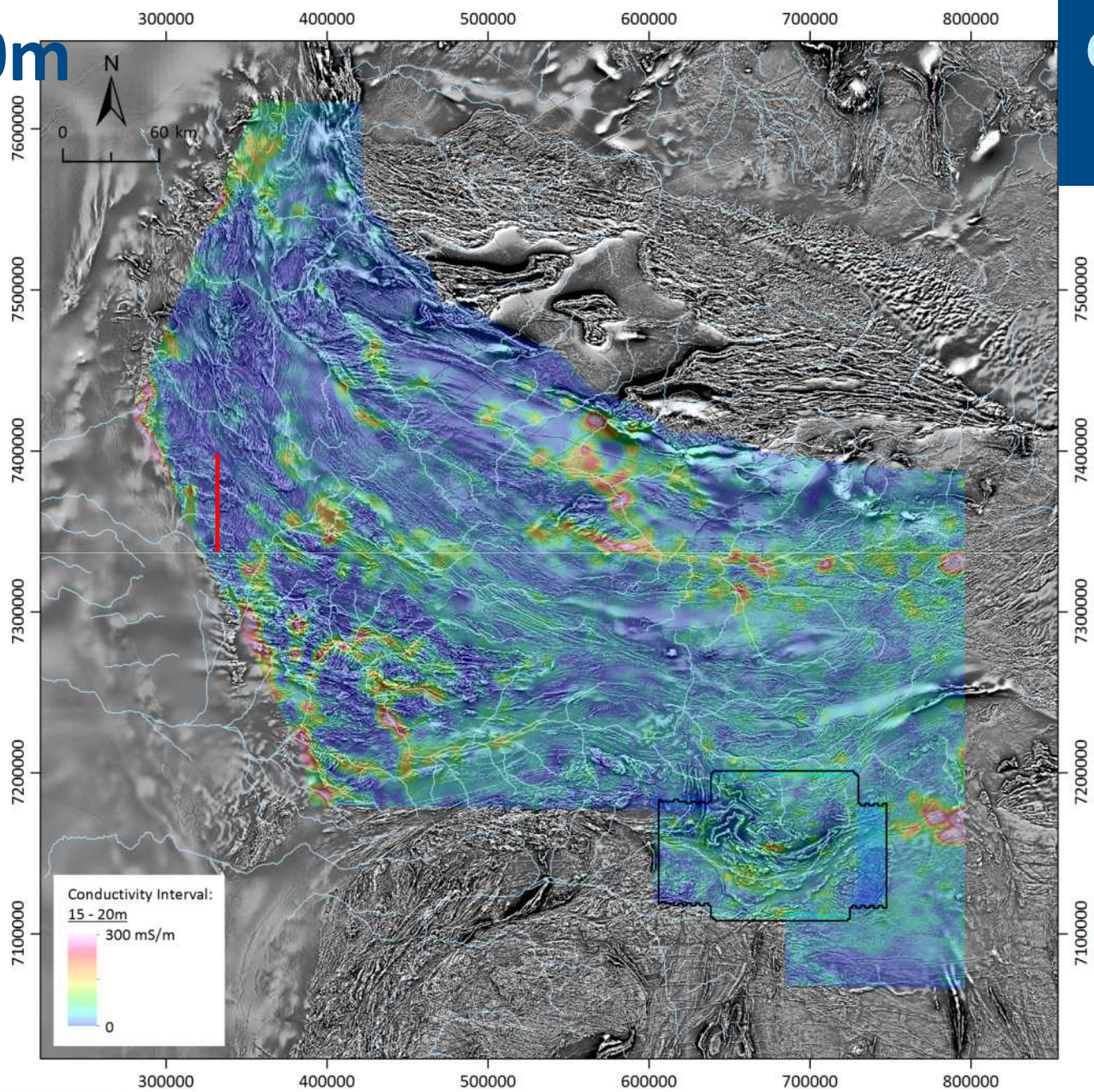
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Survey Completed: January 2014



15-20m

The Capricorn 2014 AEM survey

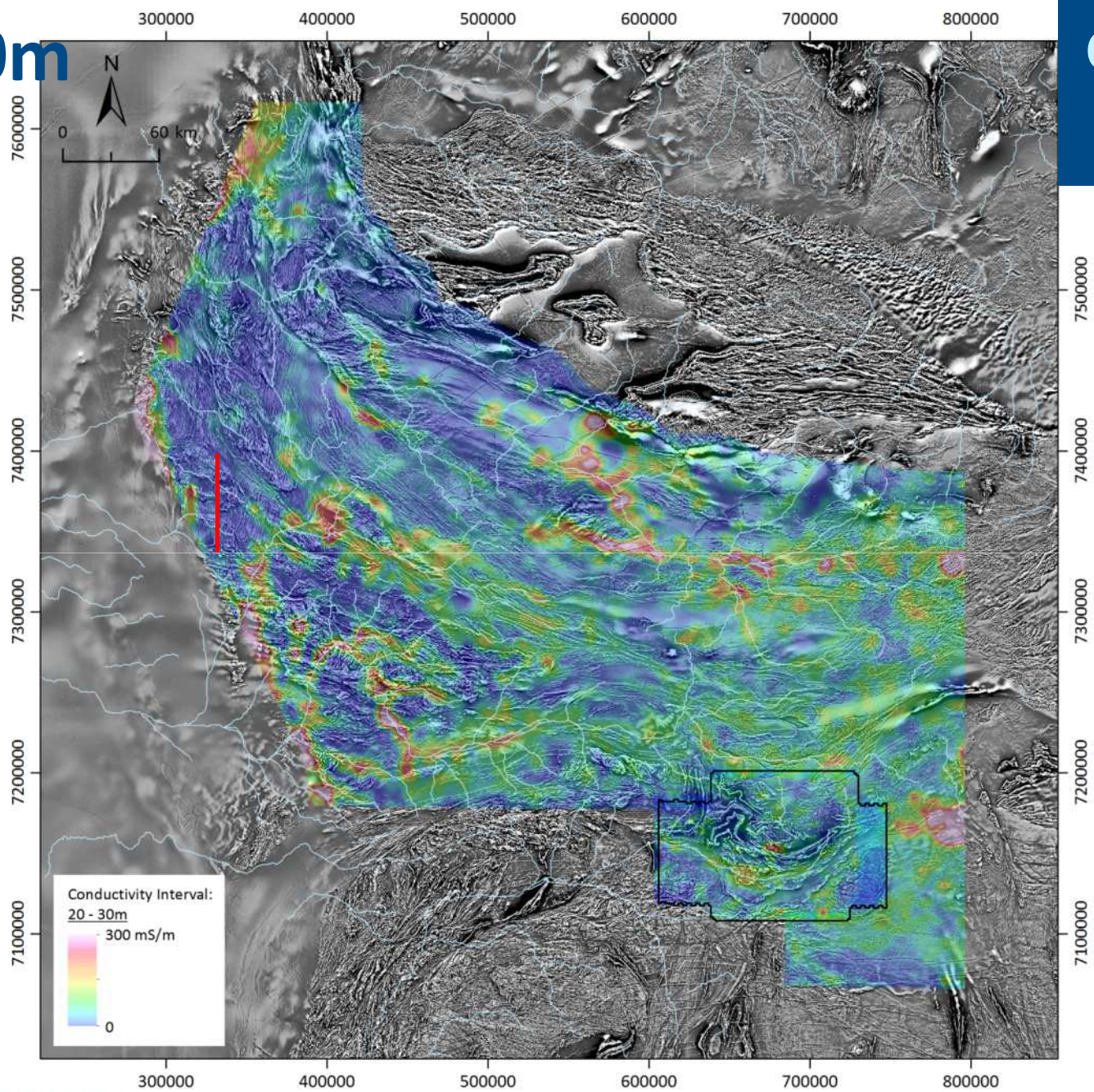
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20-30m

The Capricorn 2014 AEM survey

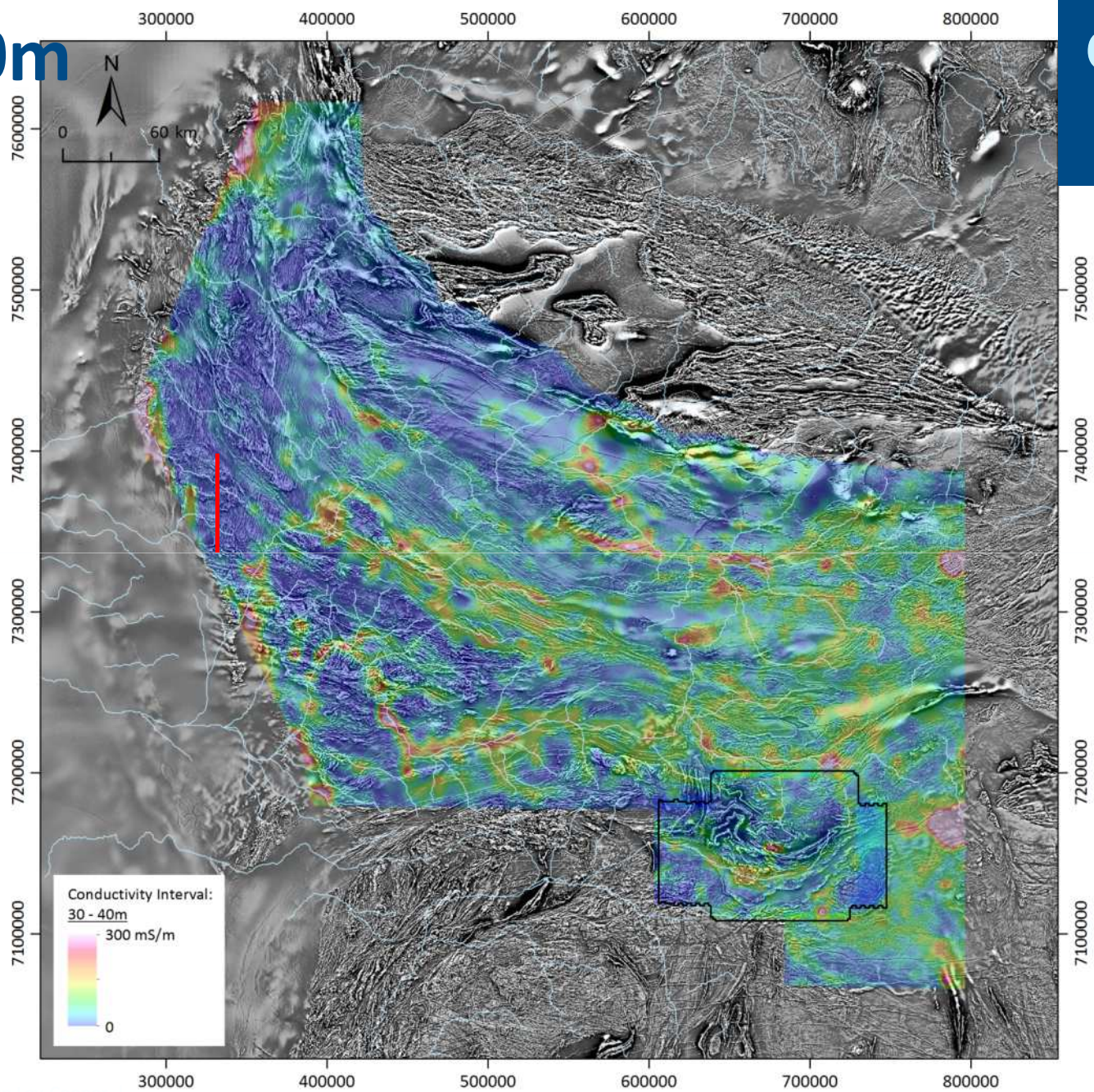
Line km: over 30,000
Survey Completed: January 2014



30-40m

The Capricorn 2014 AEM survey

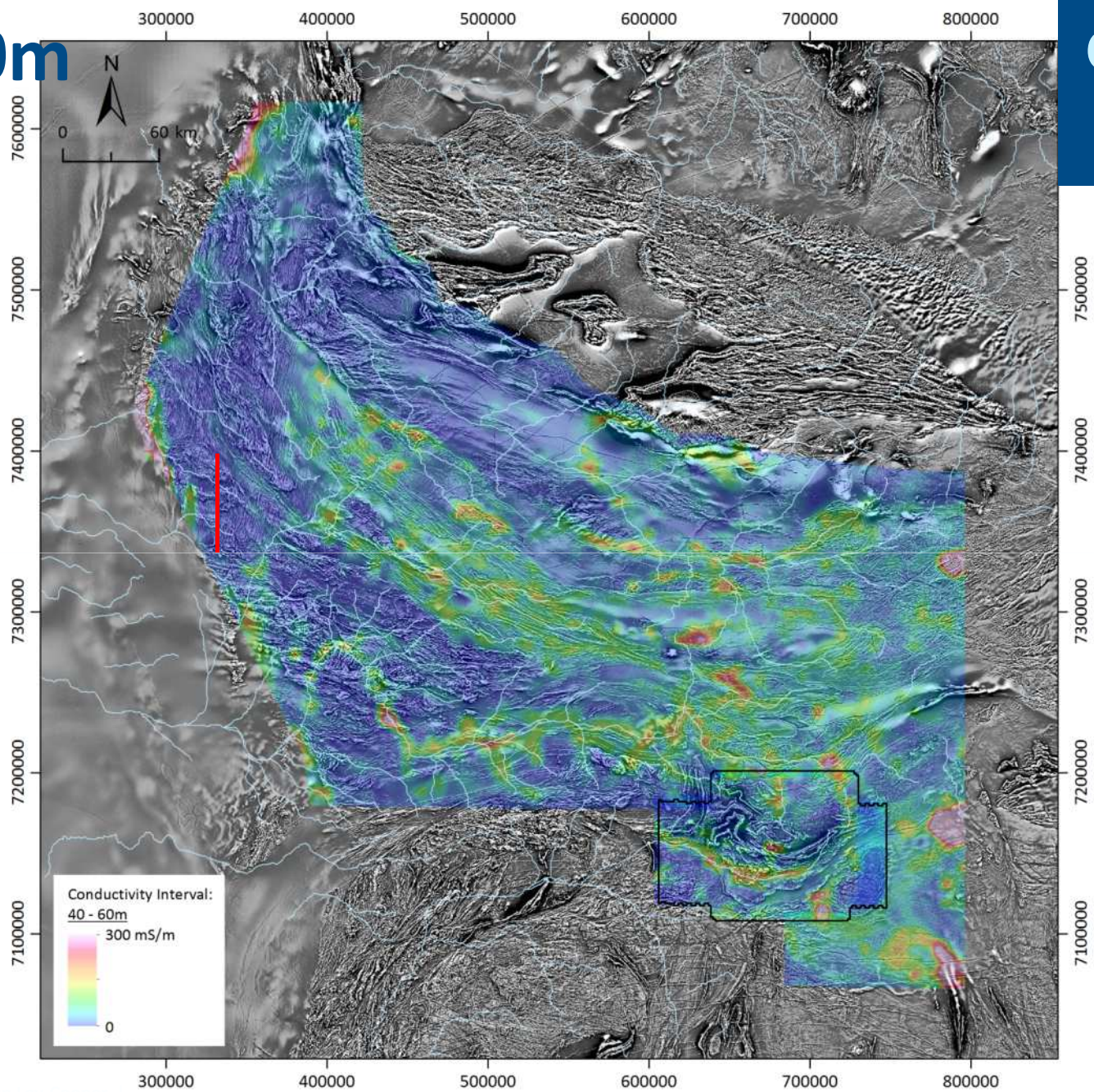
Line km: over 30,000
Survey Completed: January 2014



40-60m

The Capricorn 2014 AEM survey

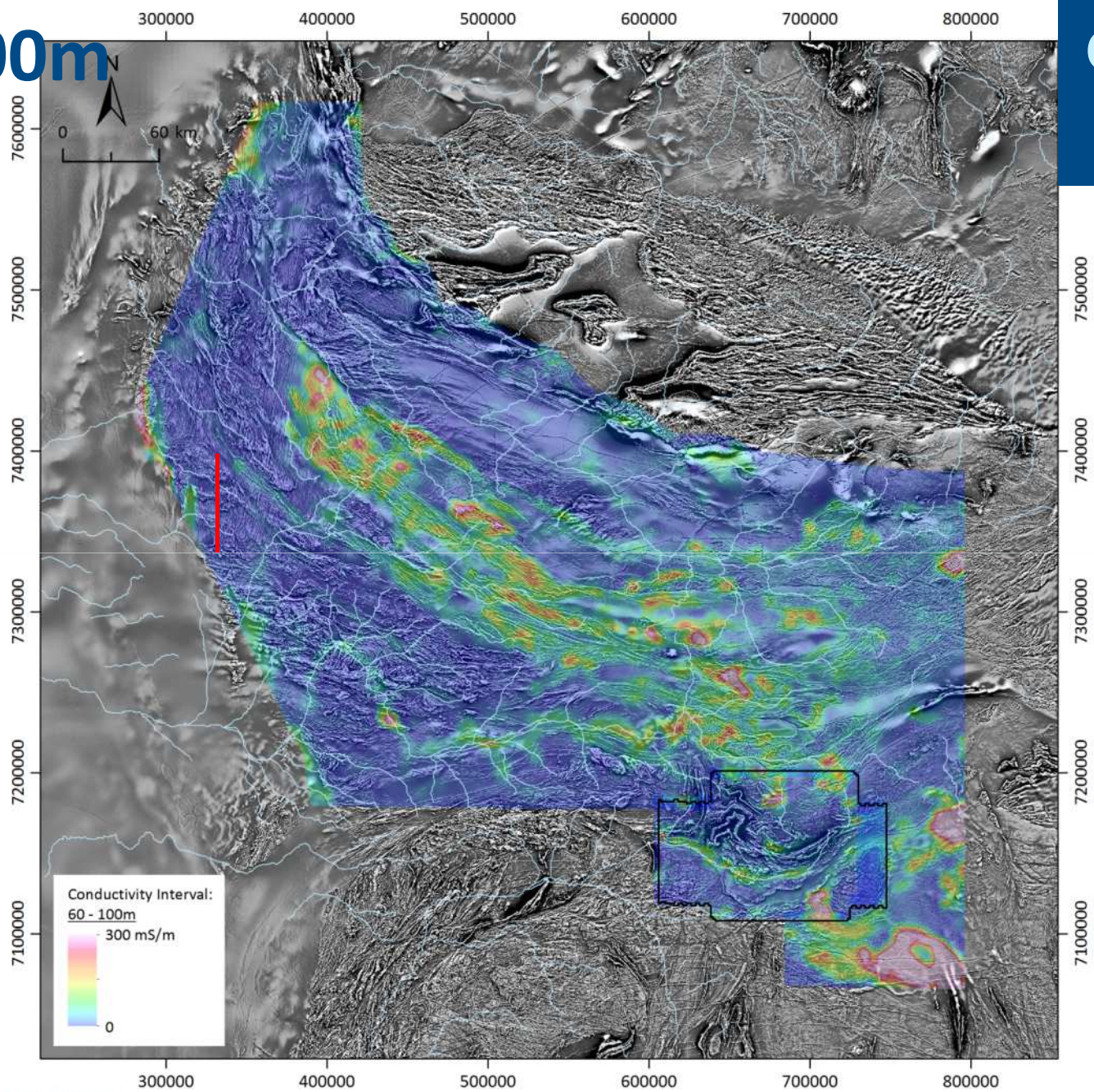
Line km: over 30,000
Survey Completed: January 2014

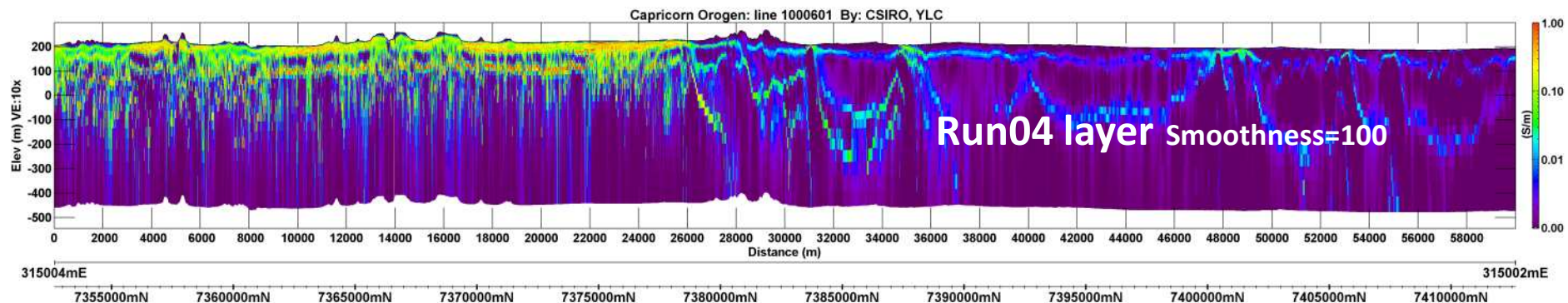
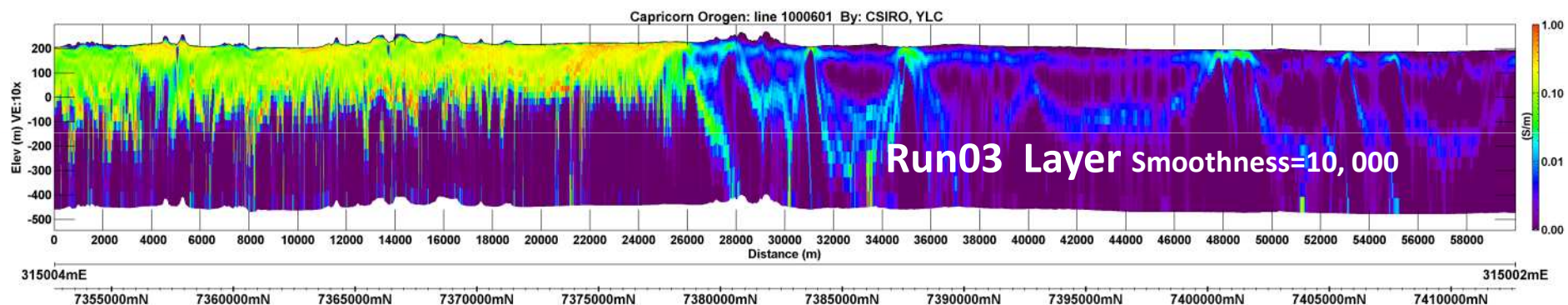
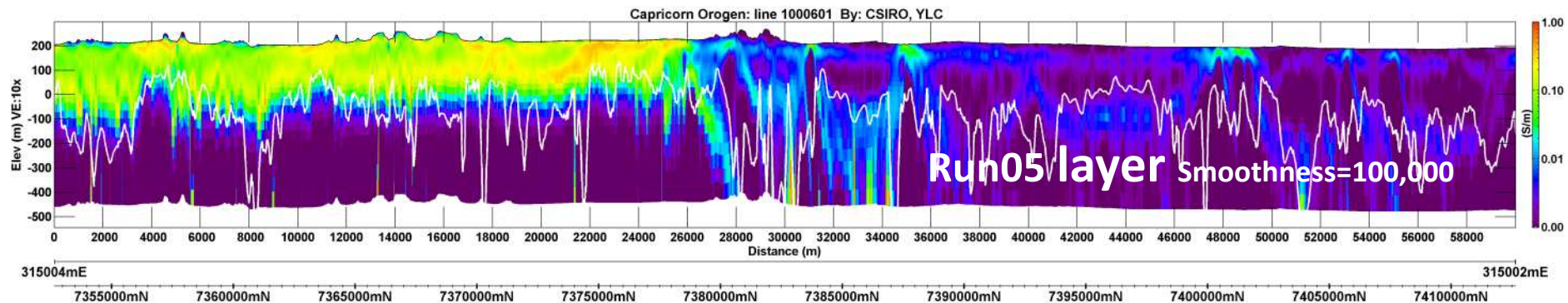


60-100m

The Capricorn 2014 AEM survey

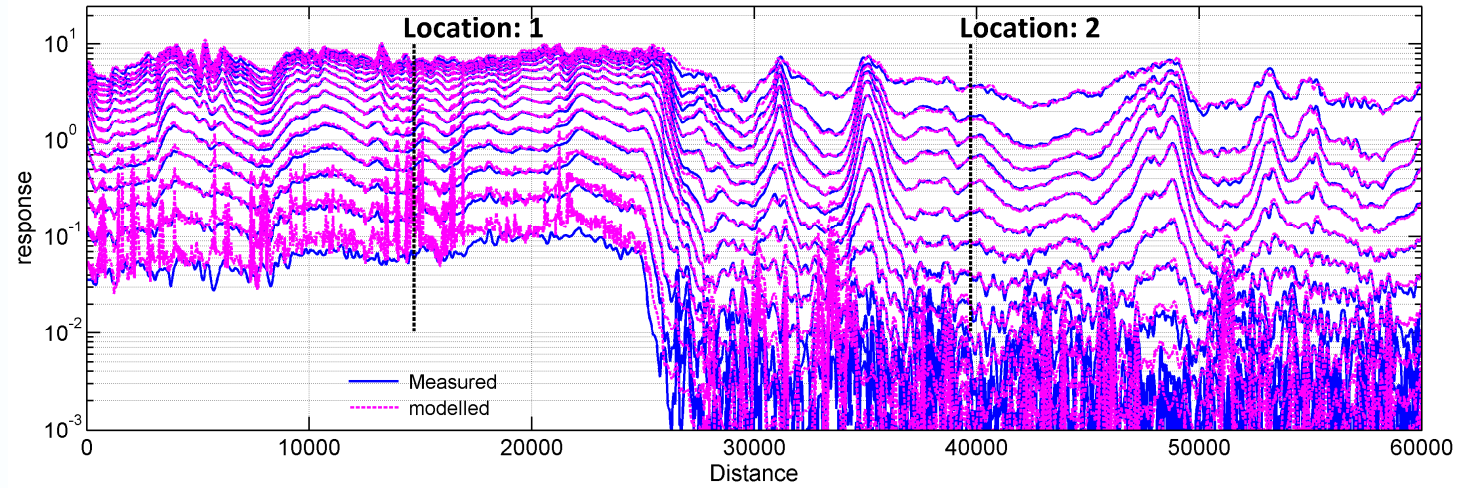
Line km: over 30,000
Survey Completed: January 2014



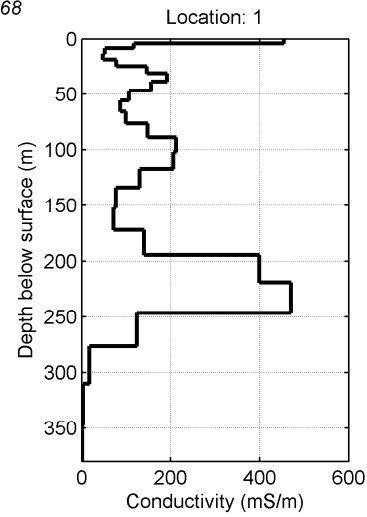
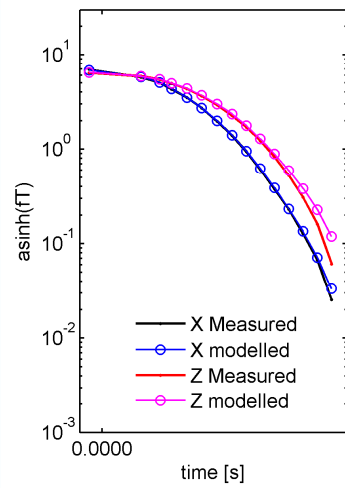


Run03 Layer Smoothness=10, 000

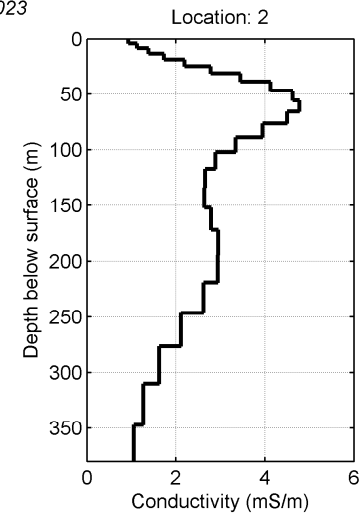
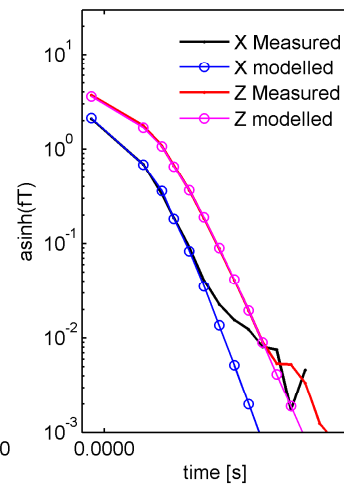
Z component Line: 1000601



E: 315007 N: 7367362.4 ϕ_d 1.0068

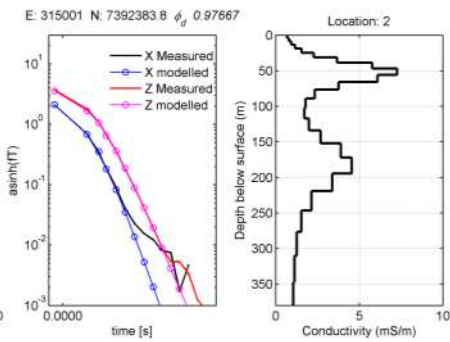
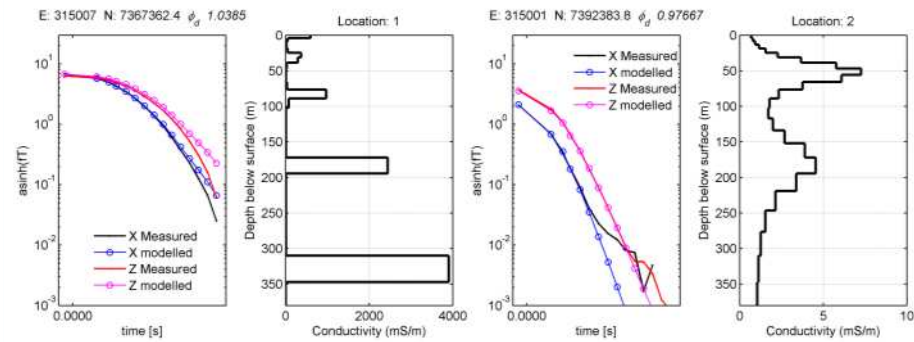
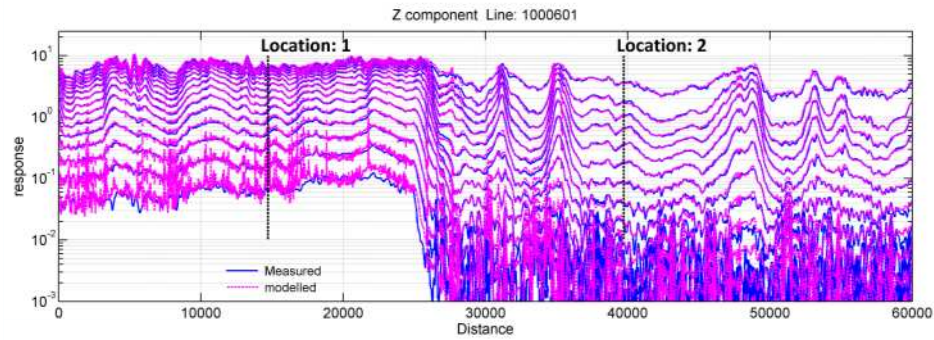


E: 315001 N: 7392383.8 ϕ_d 1.0023



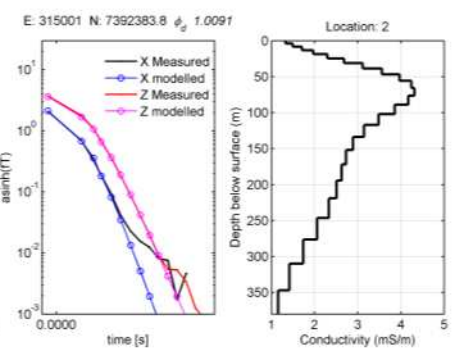
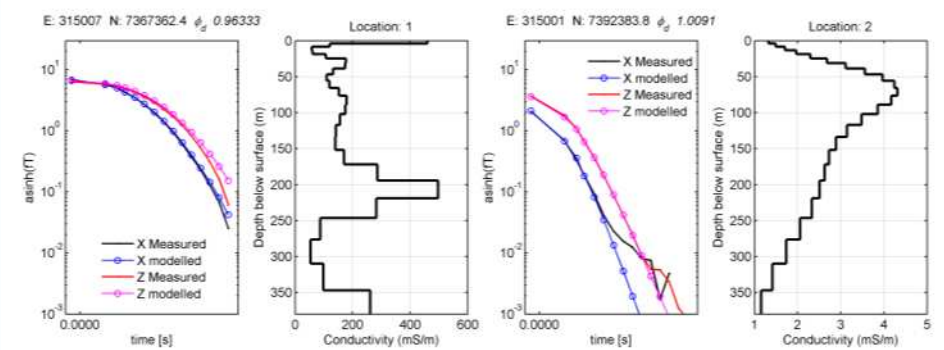
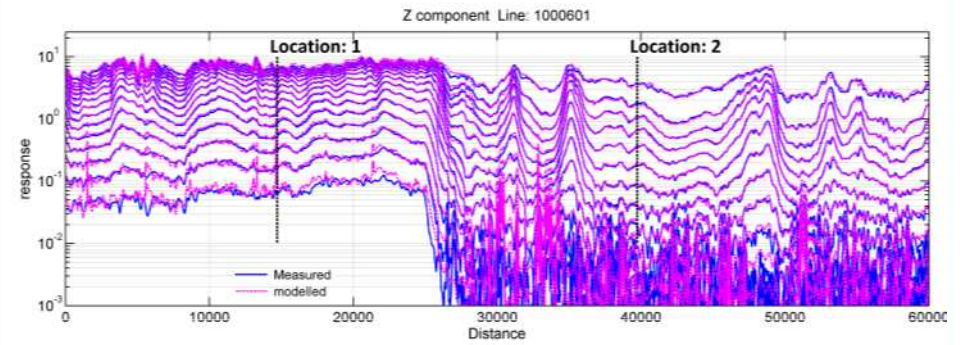
Run04 layer

Smoothness=100



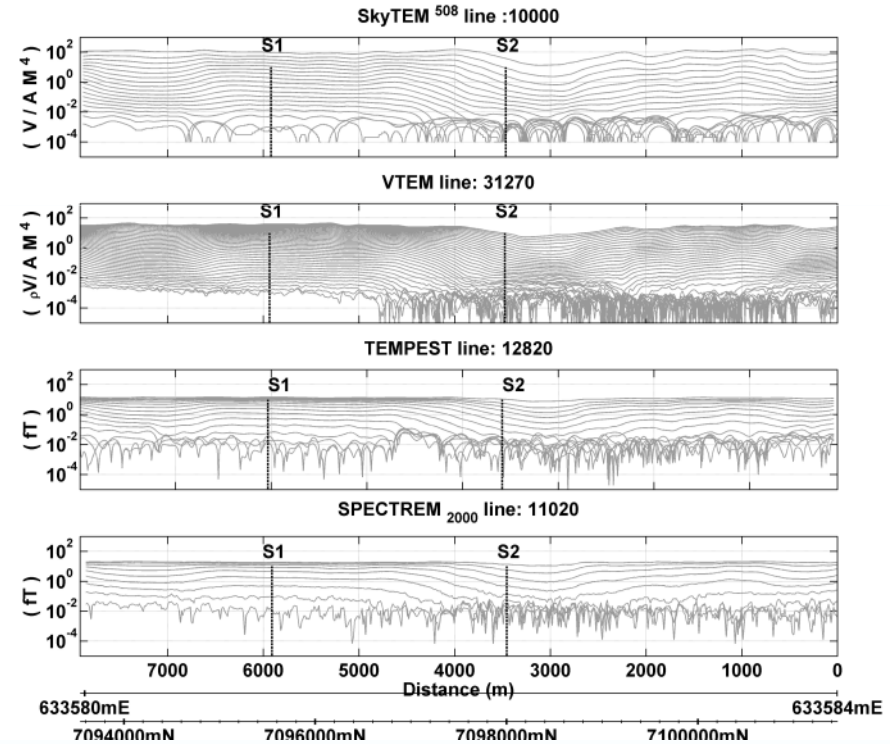
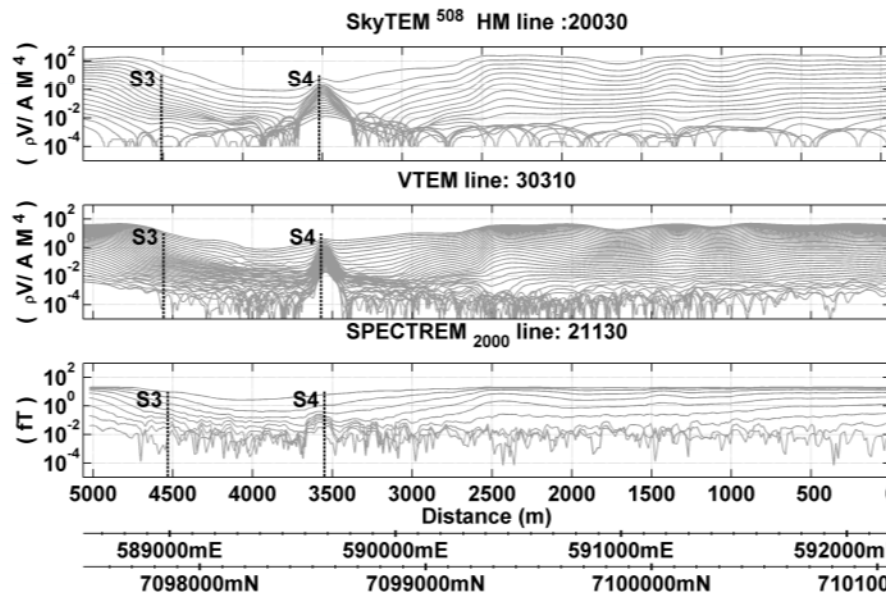
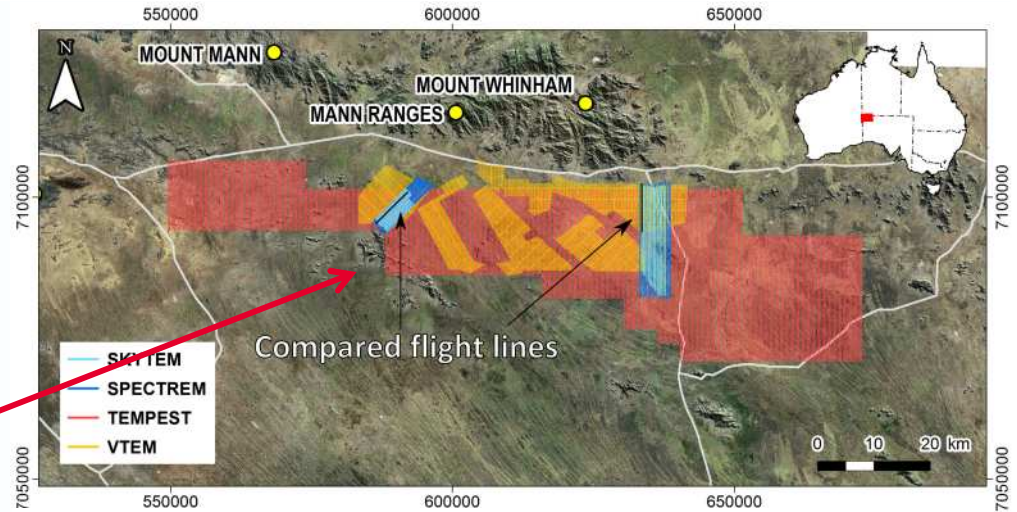
Run05 layer

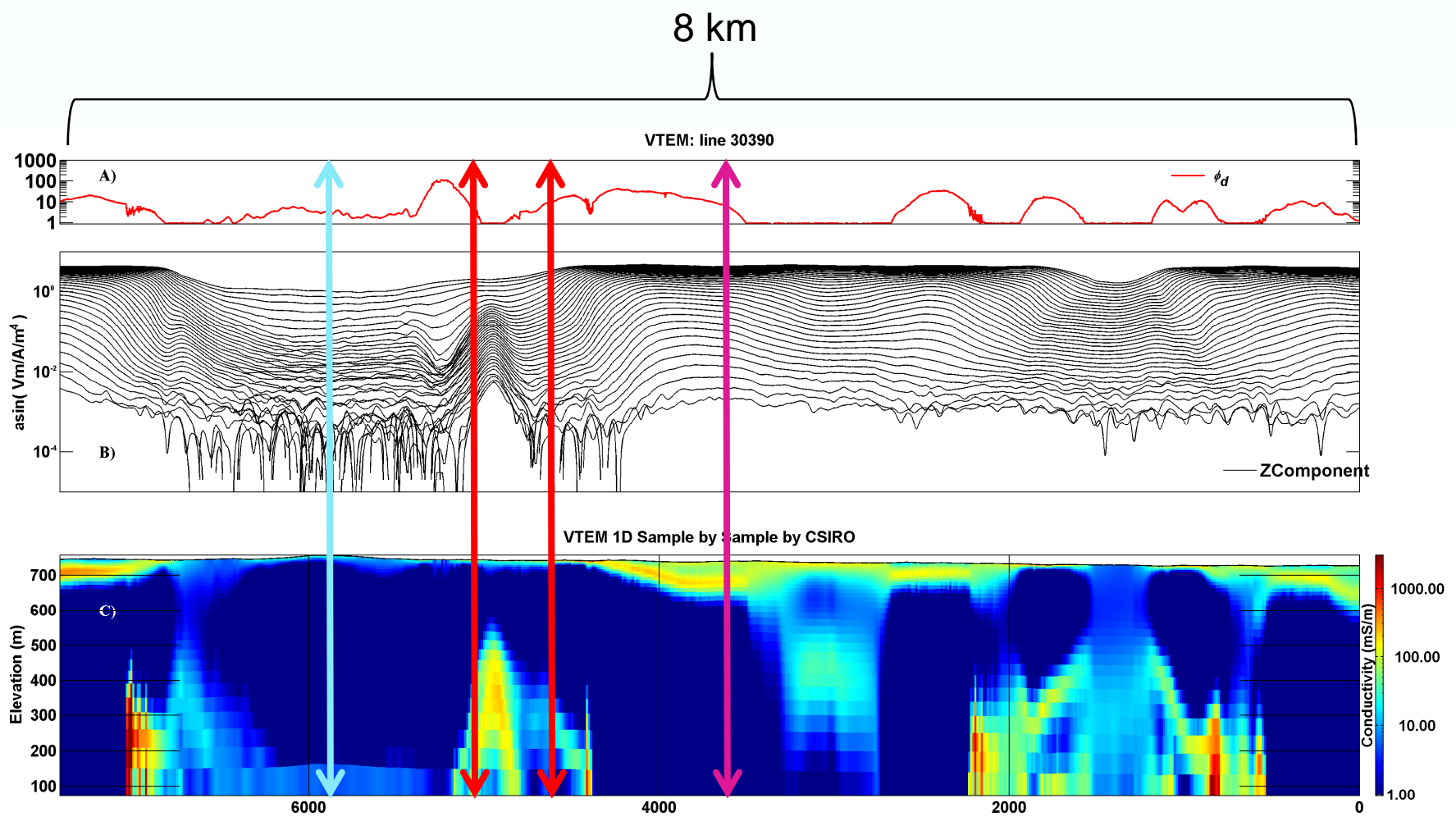
Smoothness=100,000



Musgrave Province coincident flight path

Deep conductive target





Deep

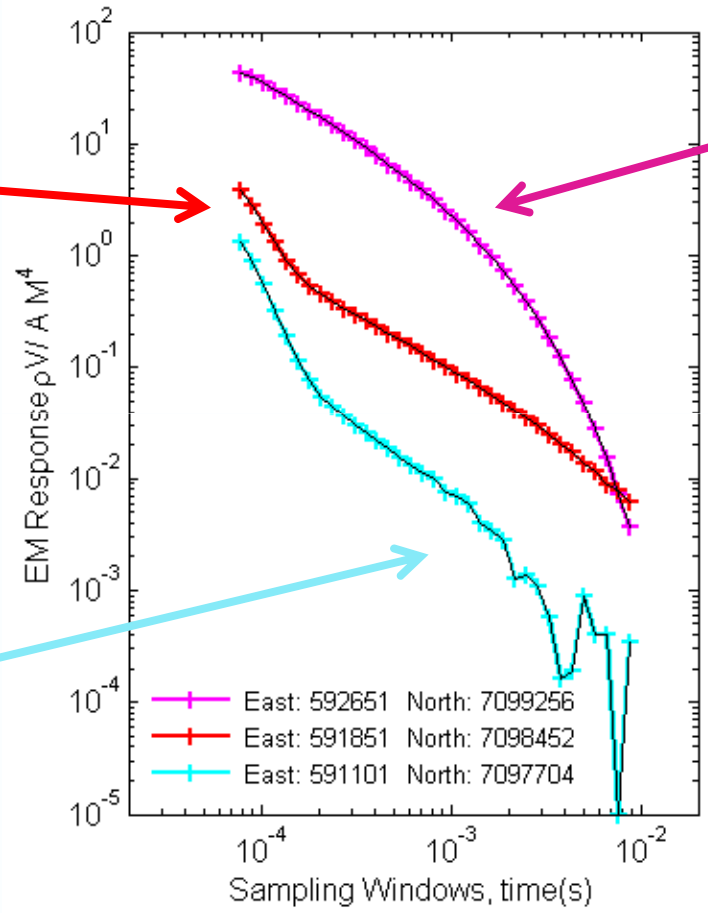
Interesting shape

Shallow

Interesting shape

Shallow

Deep

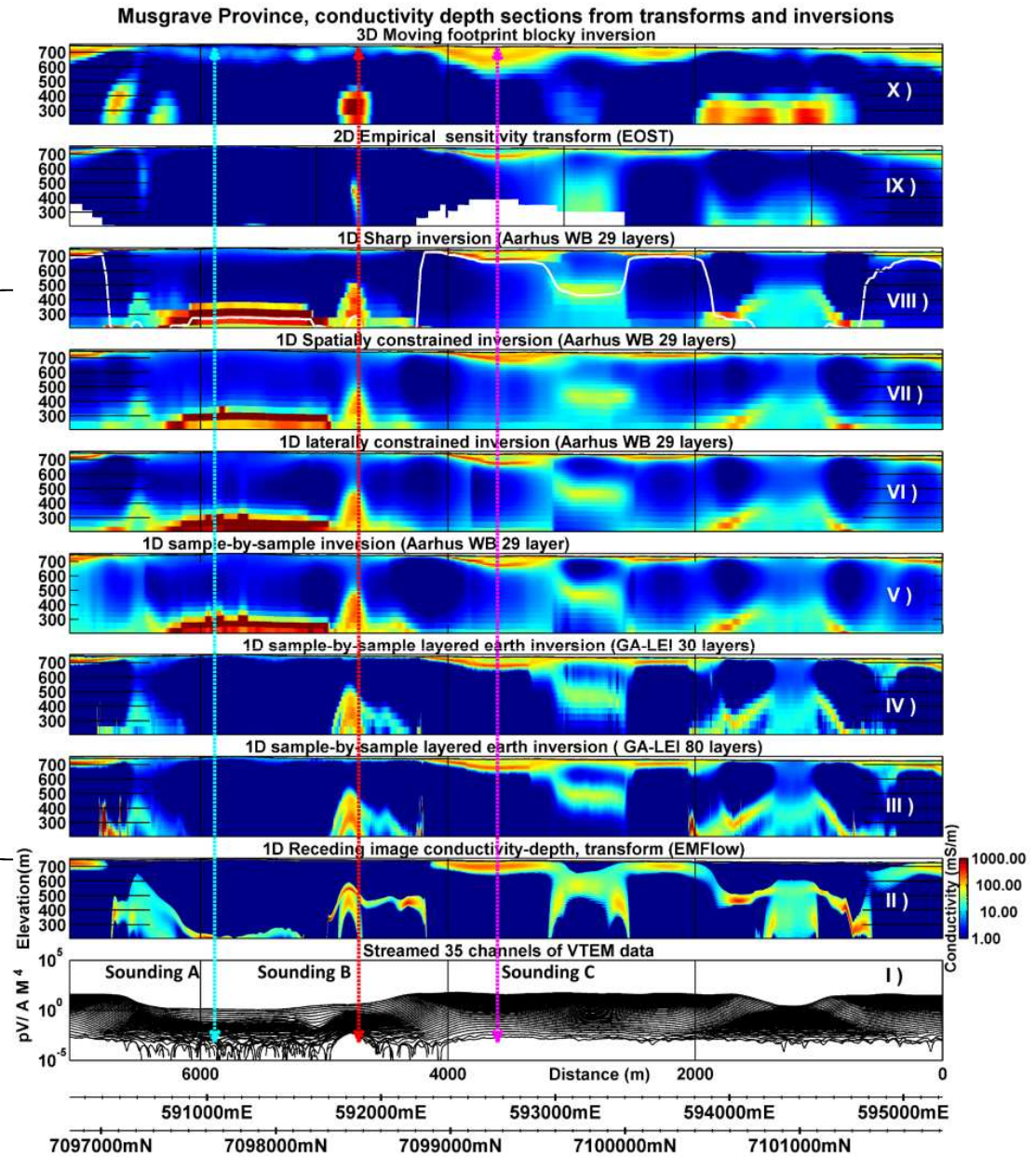


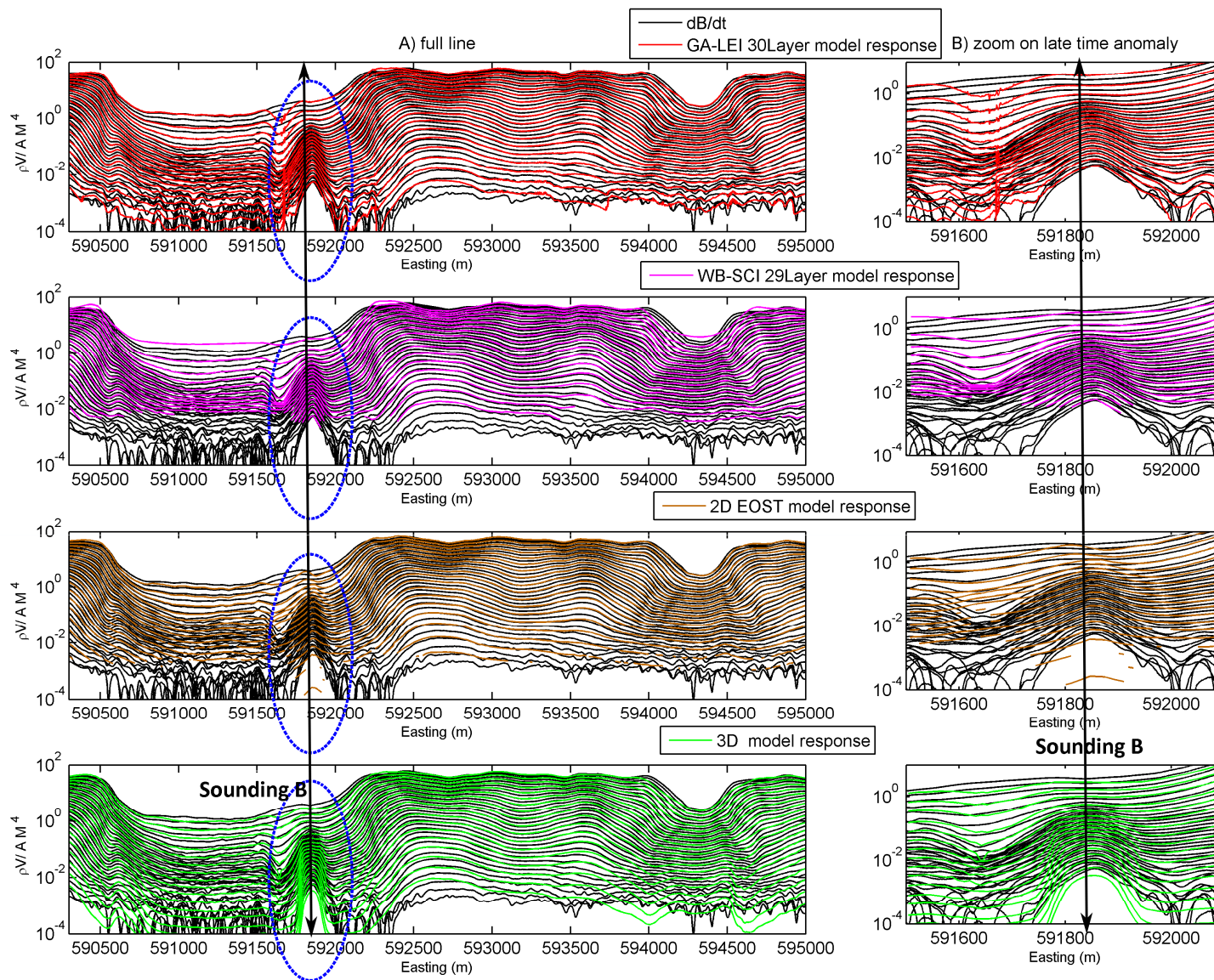
3D moving footprint

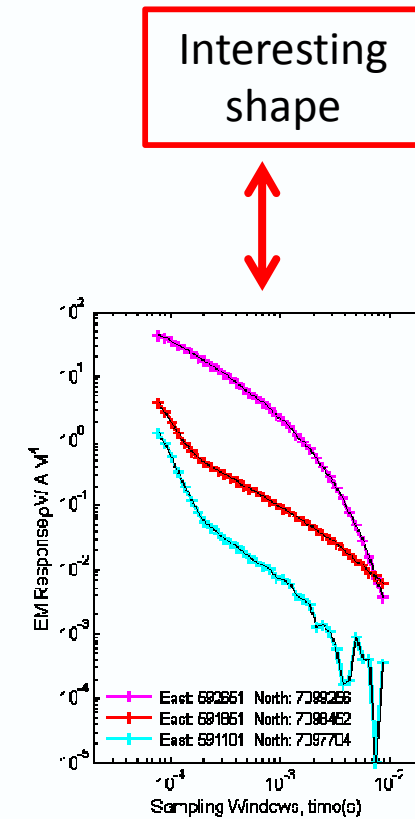
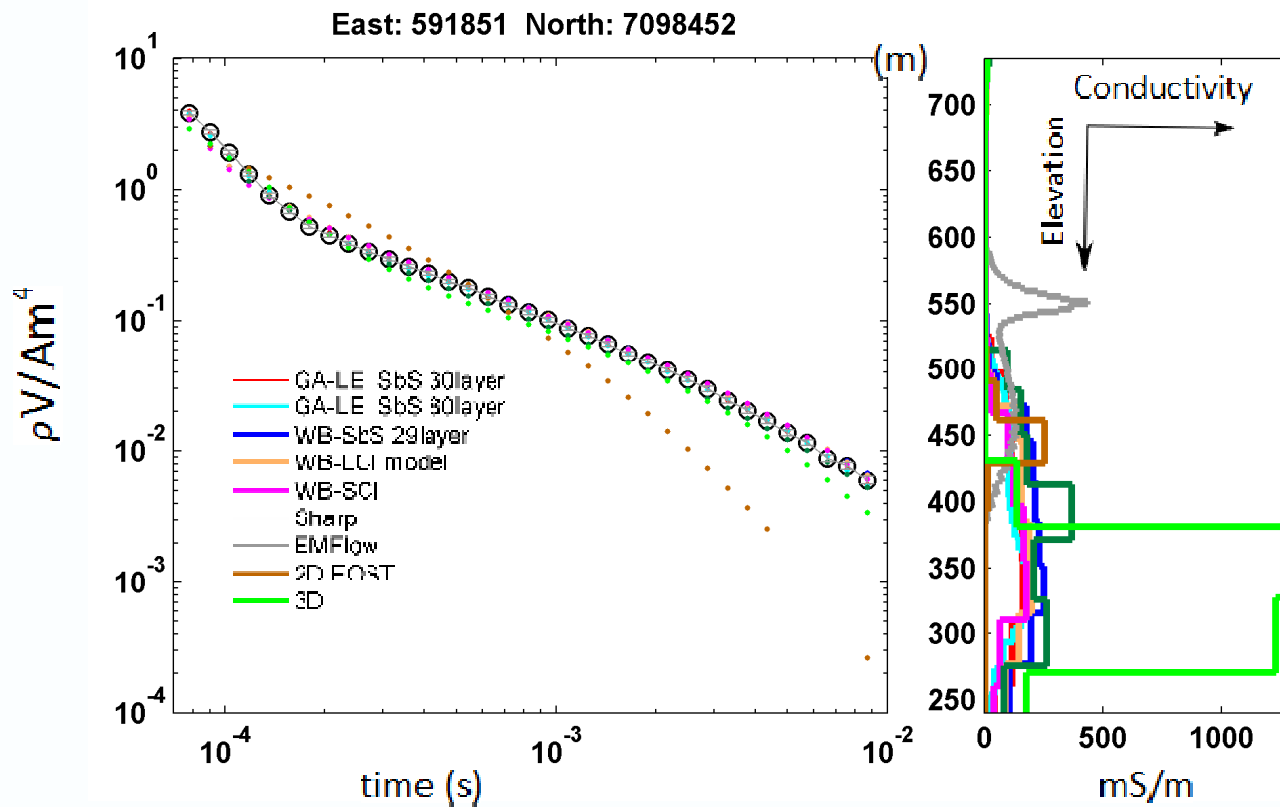
2D empirical sensitivity

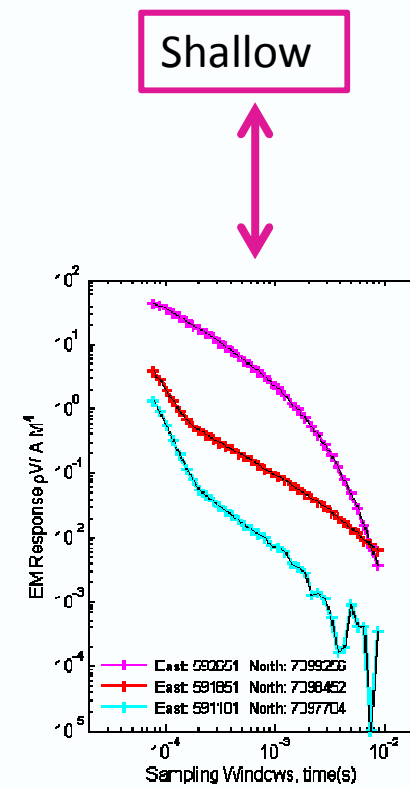
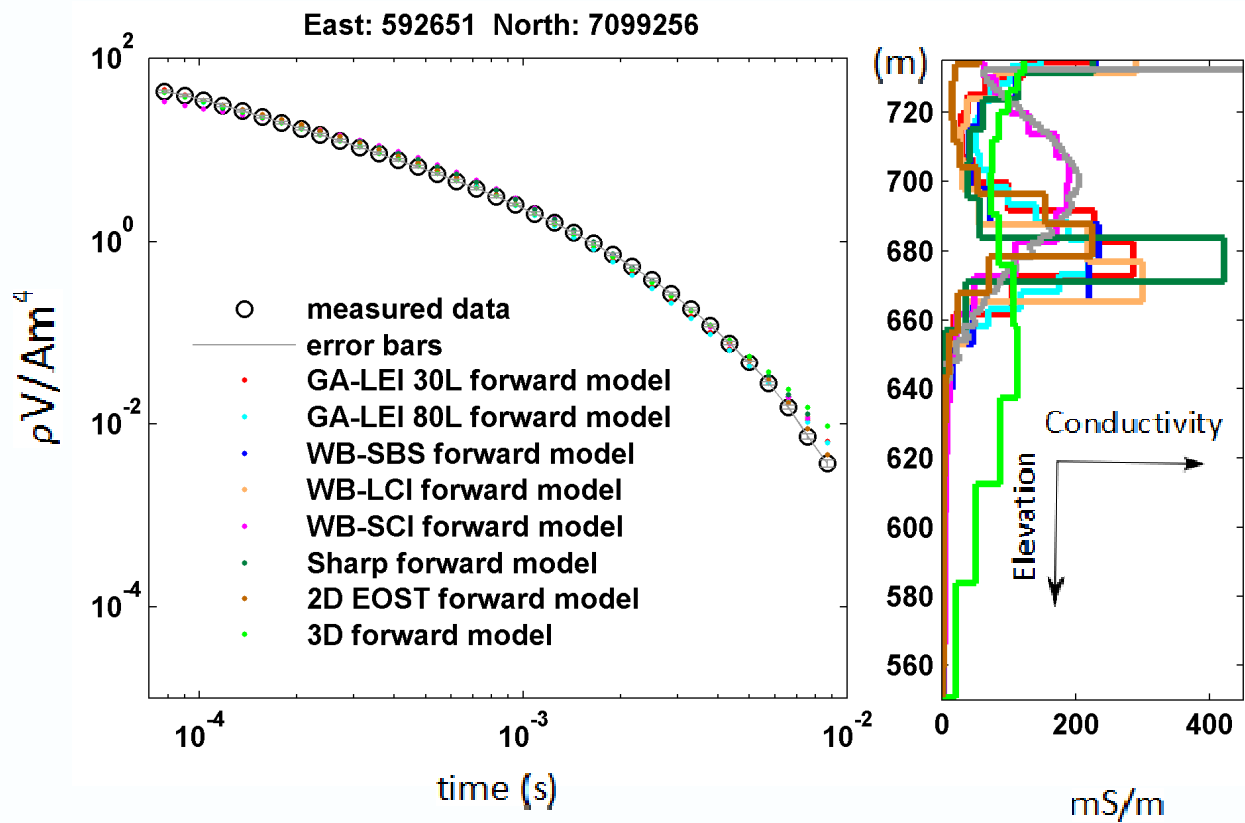
1D different inversion engines

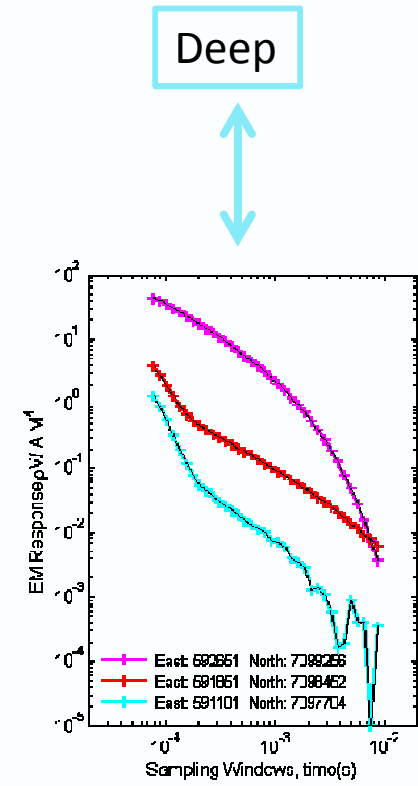
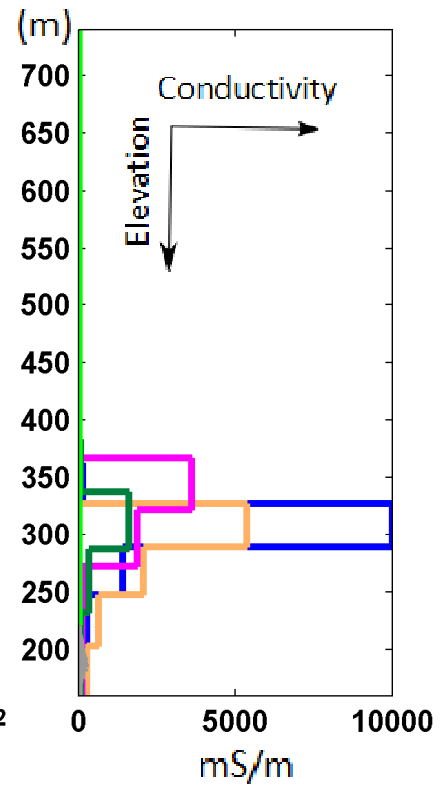
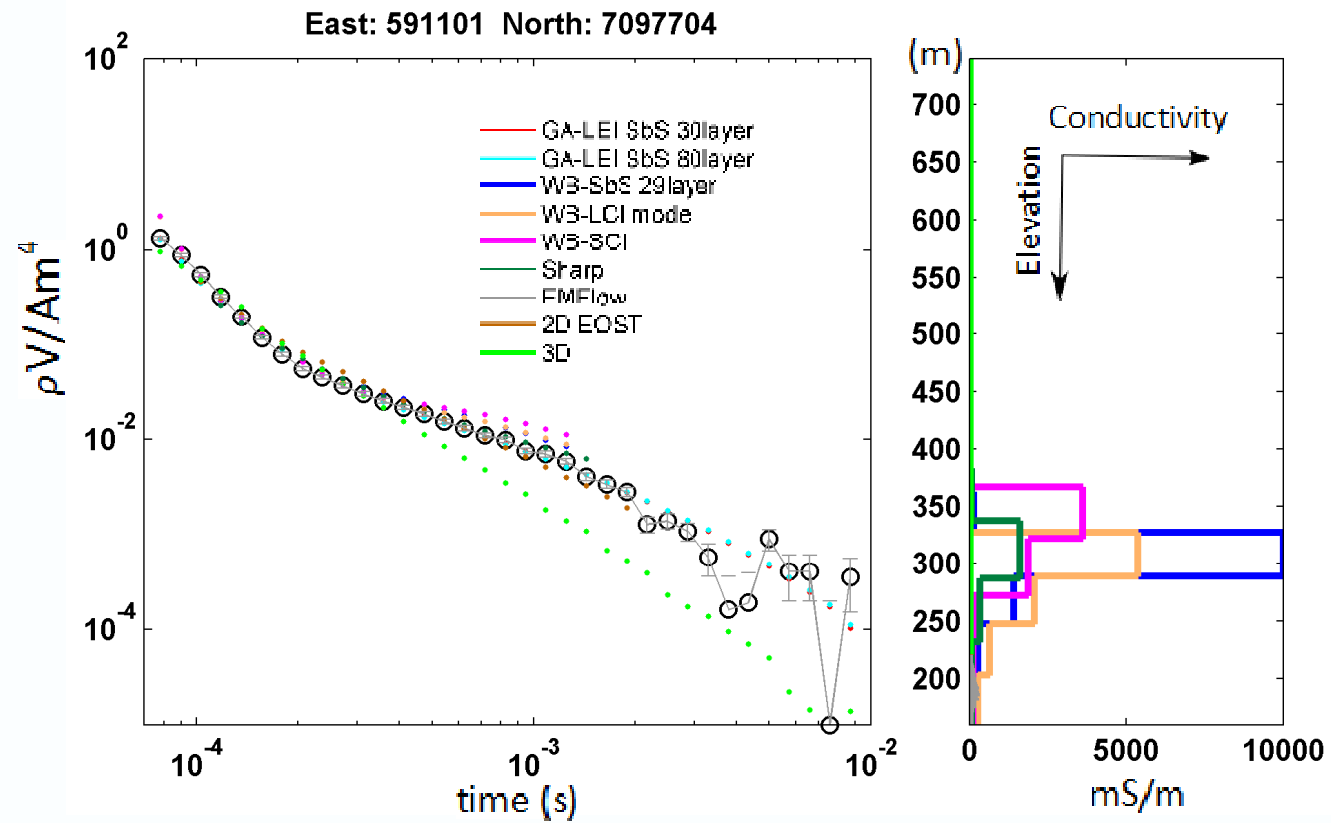
CDI fast transform



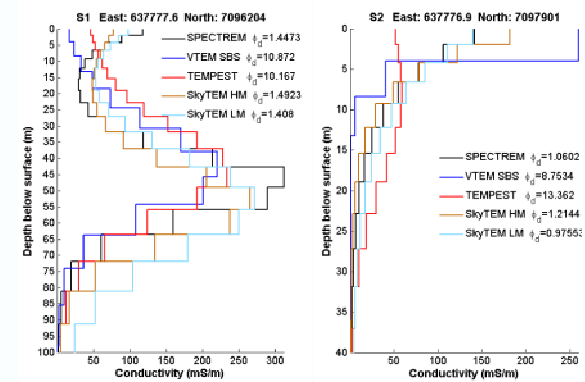
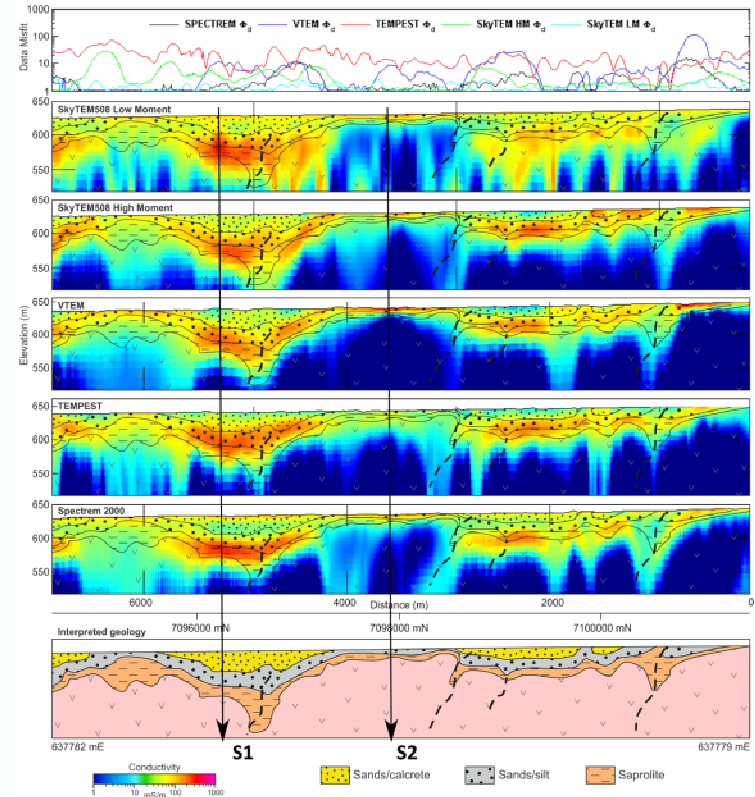
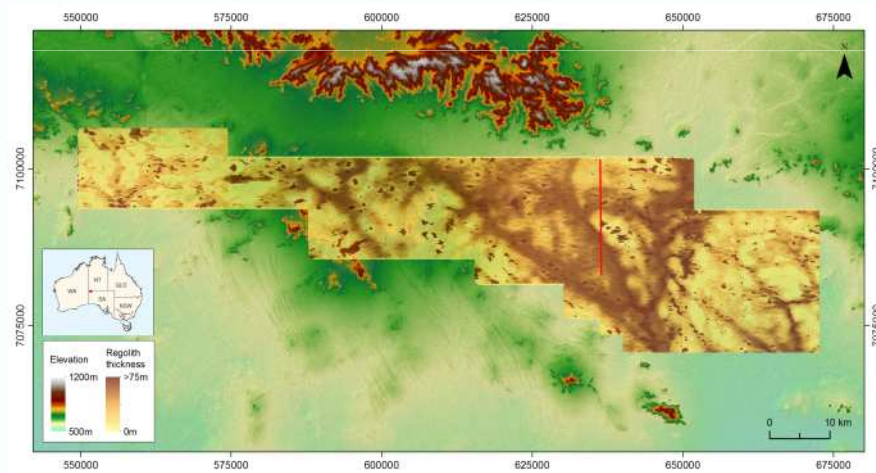
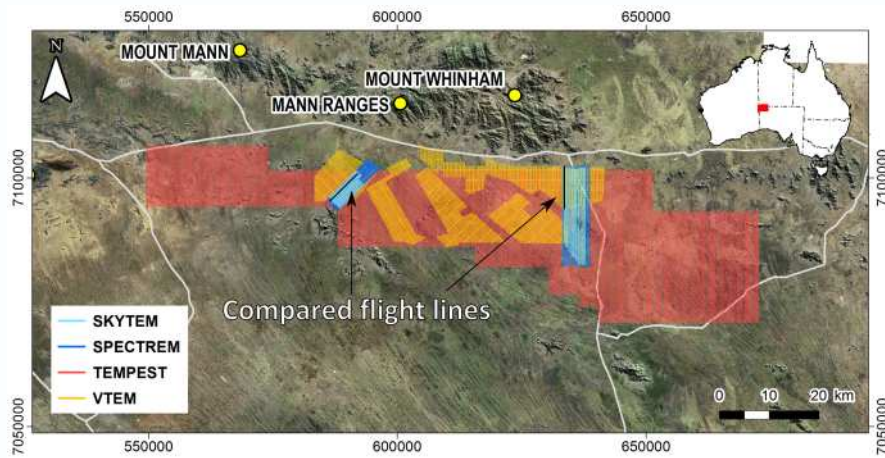




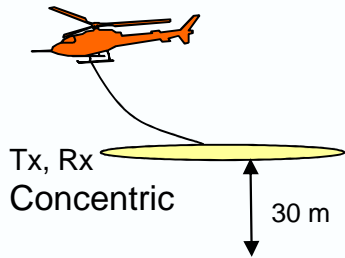




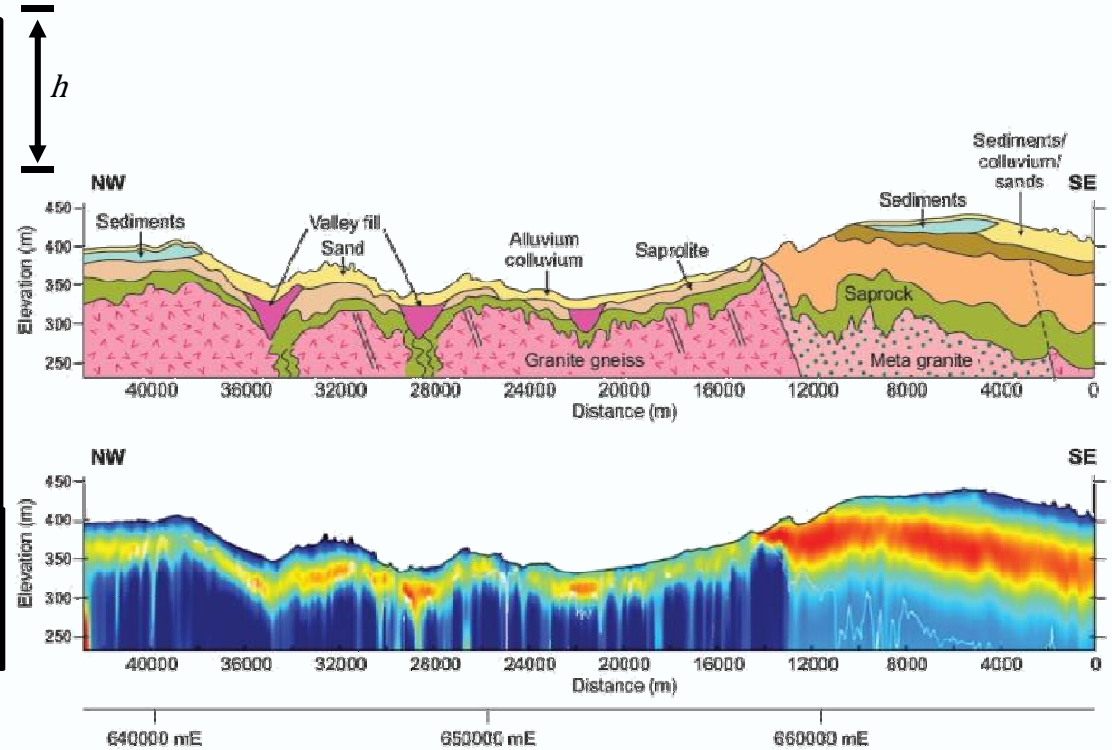
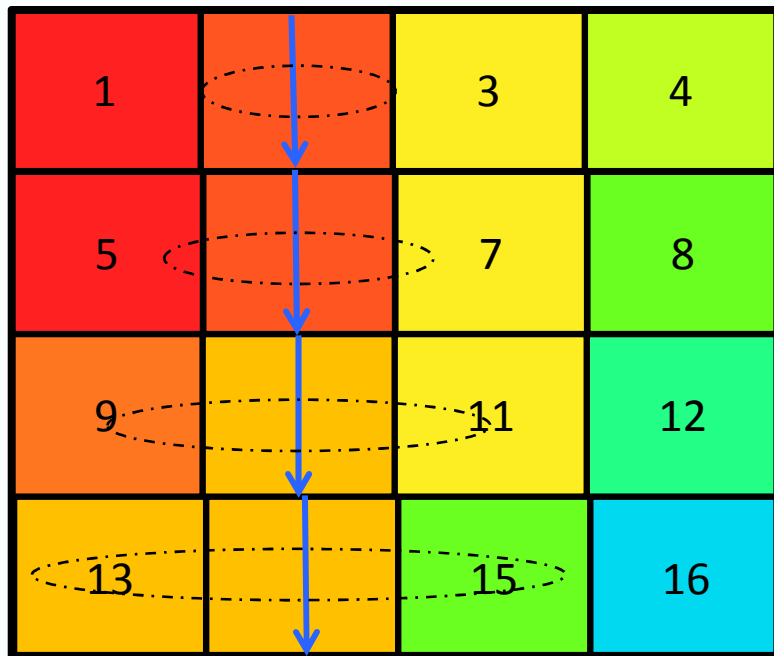
Model assessment



Making an image using observations



No. stations
↔



Inversion queries the data

Think of:

1. Noise levels Instrument and geology dependent
2. Incorporate prior knowledge
3. Assess your models numerical & geologically

Keep intimate with your data