

IL METODO AIRBORNE EM COME STRUMENTO PER LO STUDIO DI PROBLEMATICHE IDROGEOLOGICHE, GEOTECNICHE ED AMBIENTALI

Dott. Geol. Antonio Menghini

- Descrizione del metodo EM
- Implementazione su un sistema airborne
- Processing dei dati
- Inversione
- Interpretazione
- Case-studies
- Potenziali applicazioni sul territorio Italiano

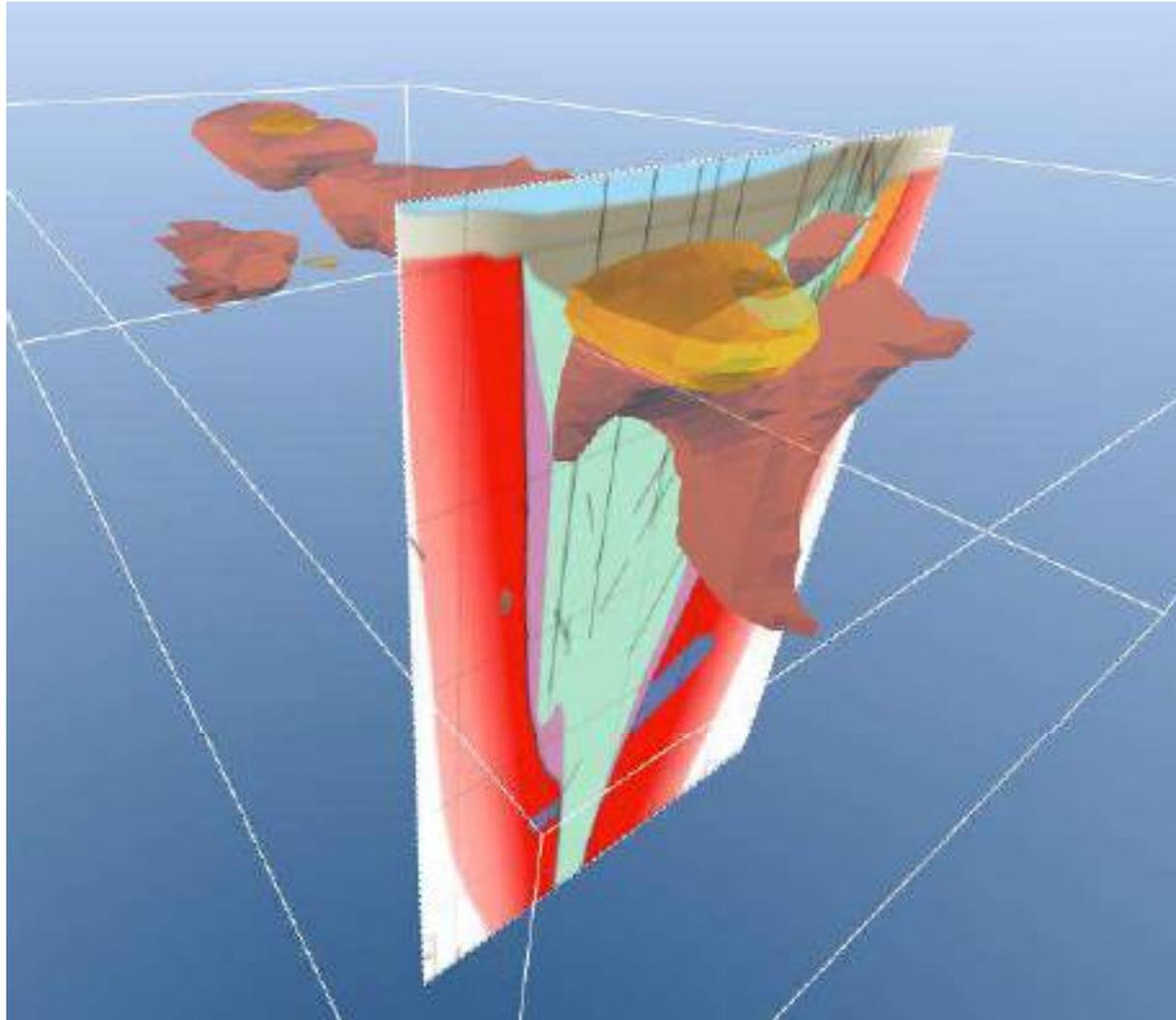


Perché l'EM ?



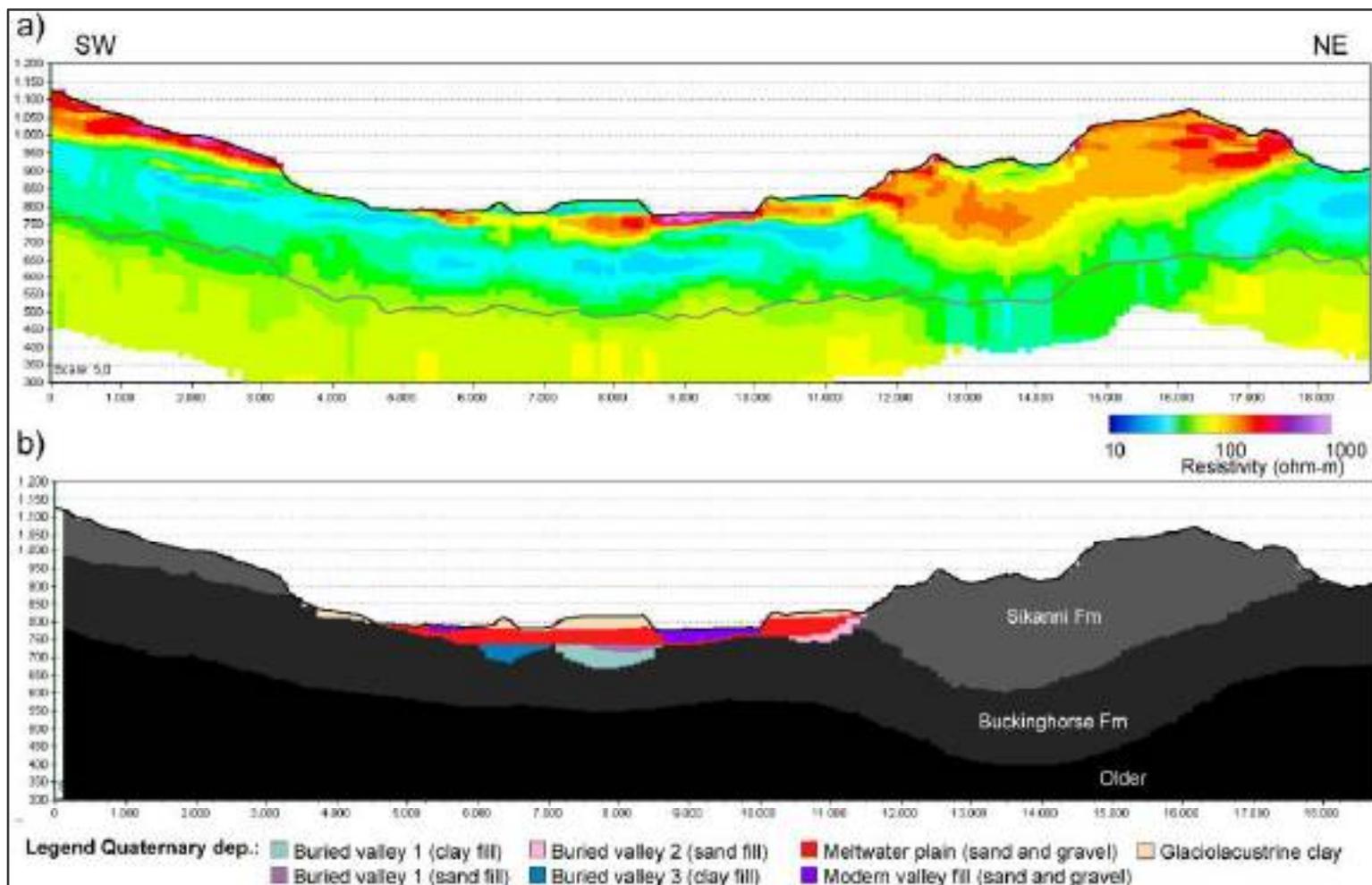
Ricerca mineraria

Target
conduttivi nella
maggioranza
dei casi
(eccetto
carbone,
kimberliti,
alcuni minerali
disseminati....)



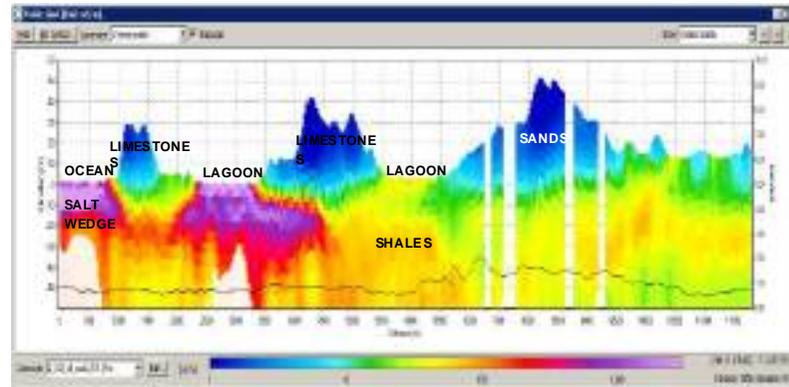
I drogeologia

Target resistivi per la ricerca di acque dolci (acquiferi granulari) Eccetto acquiferi fratturati in roccia

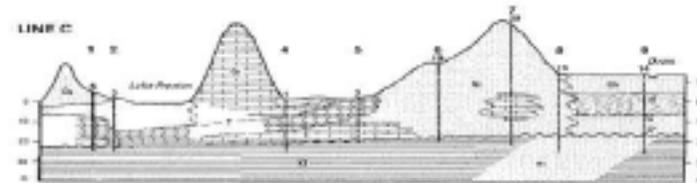


I drogeologia

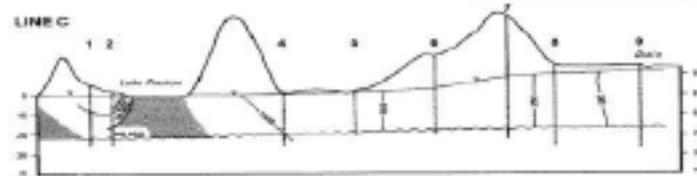
Target conduttivi per mappare l'intrusione marina o falde contaminate (eccatto da idrocarburi)



GEOLOGICAL CROSS SECTION

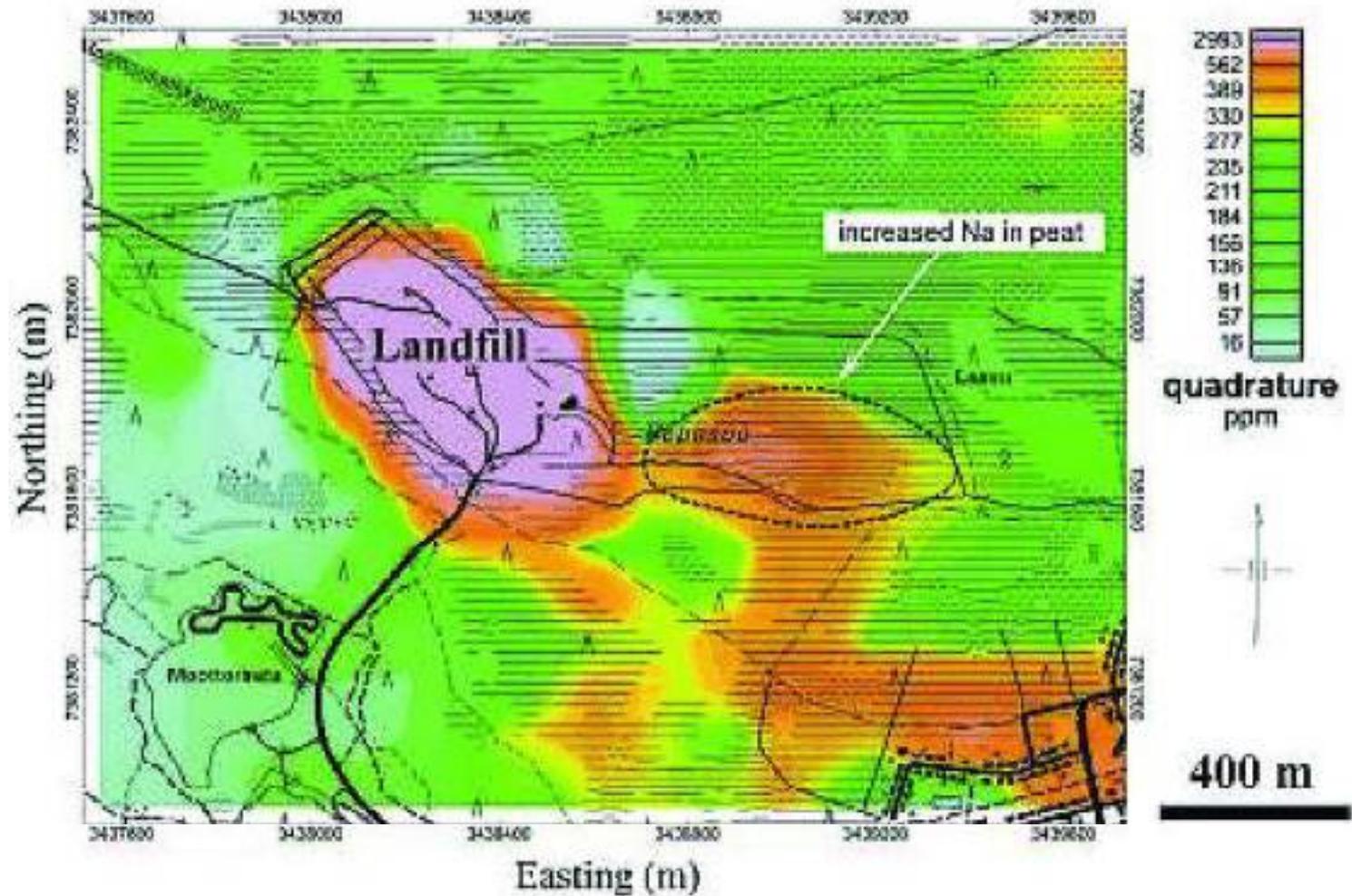


HYDROCHEMICAL CROSS SECTION



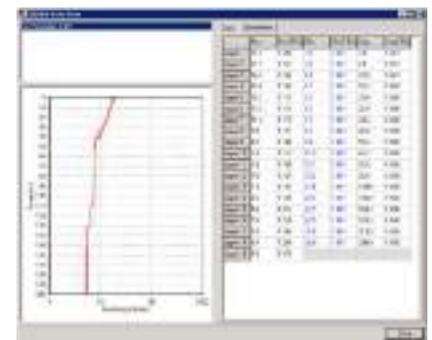
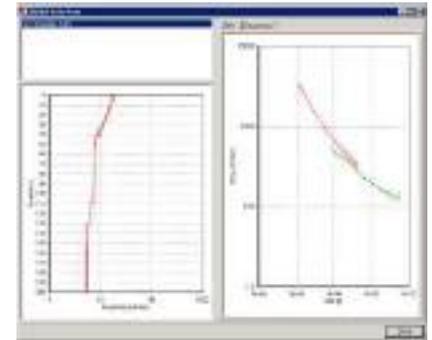
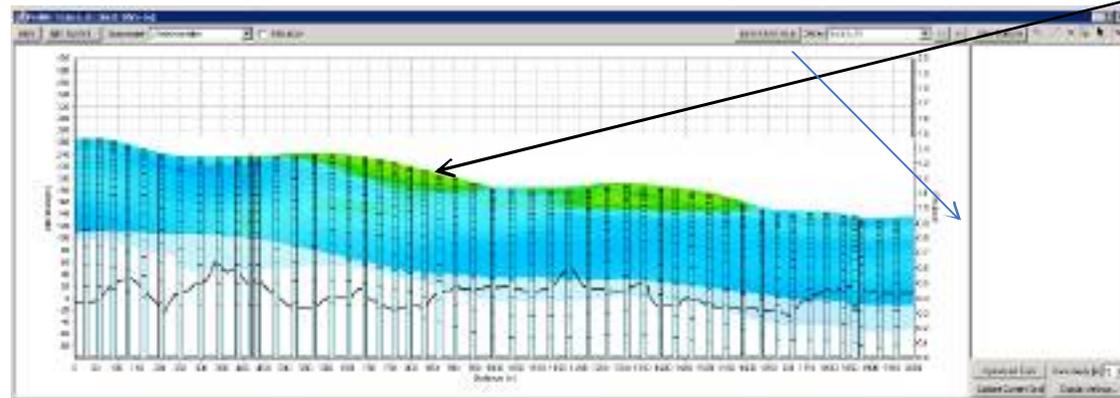
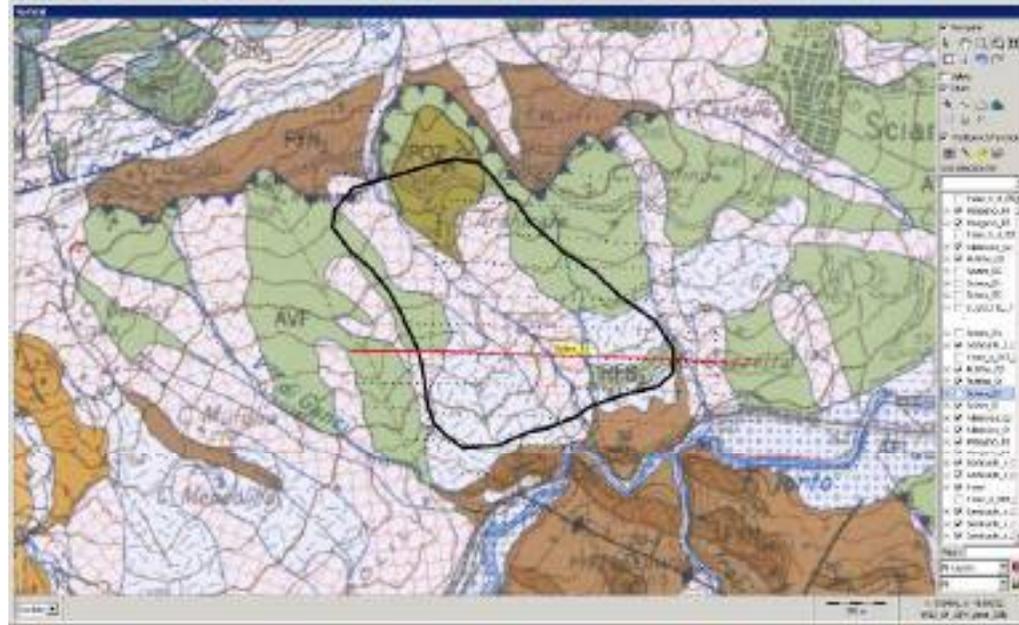
Ambiente

Target
conduttivi
(rifiuti,
percolato e
inquinanti in
genere)



Geotecnica

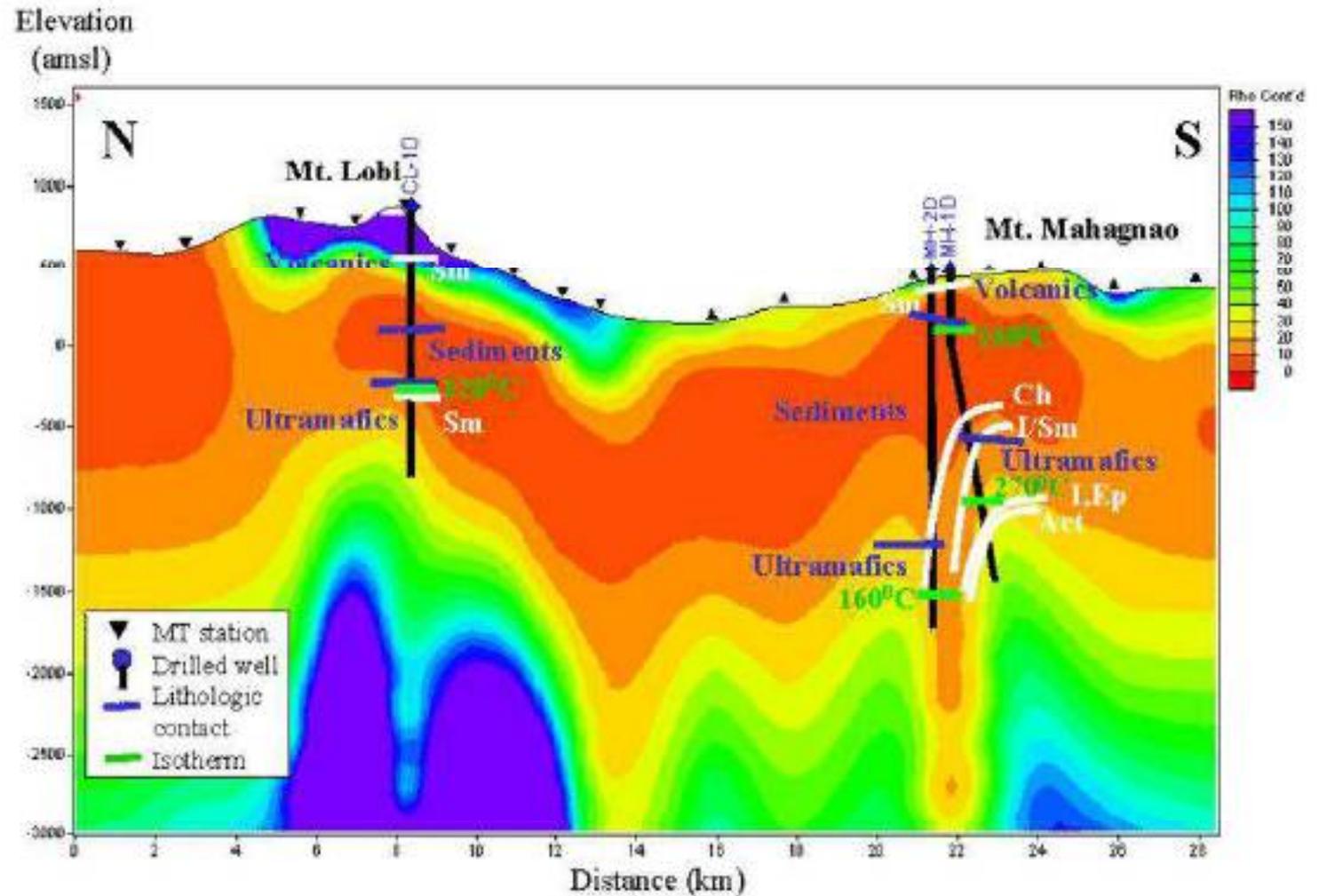
Target
conduttivi o
resistivi a
seconda del
grado di
imbibizione
del corpo
frana



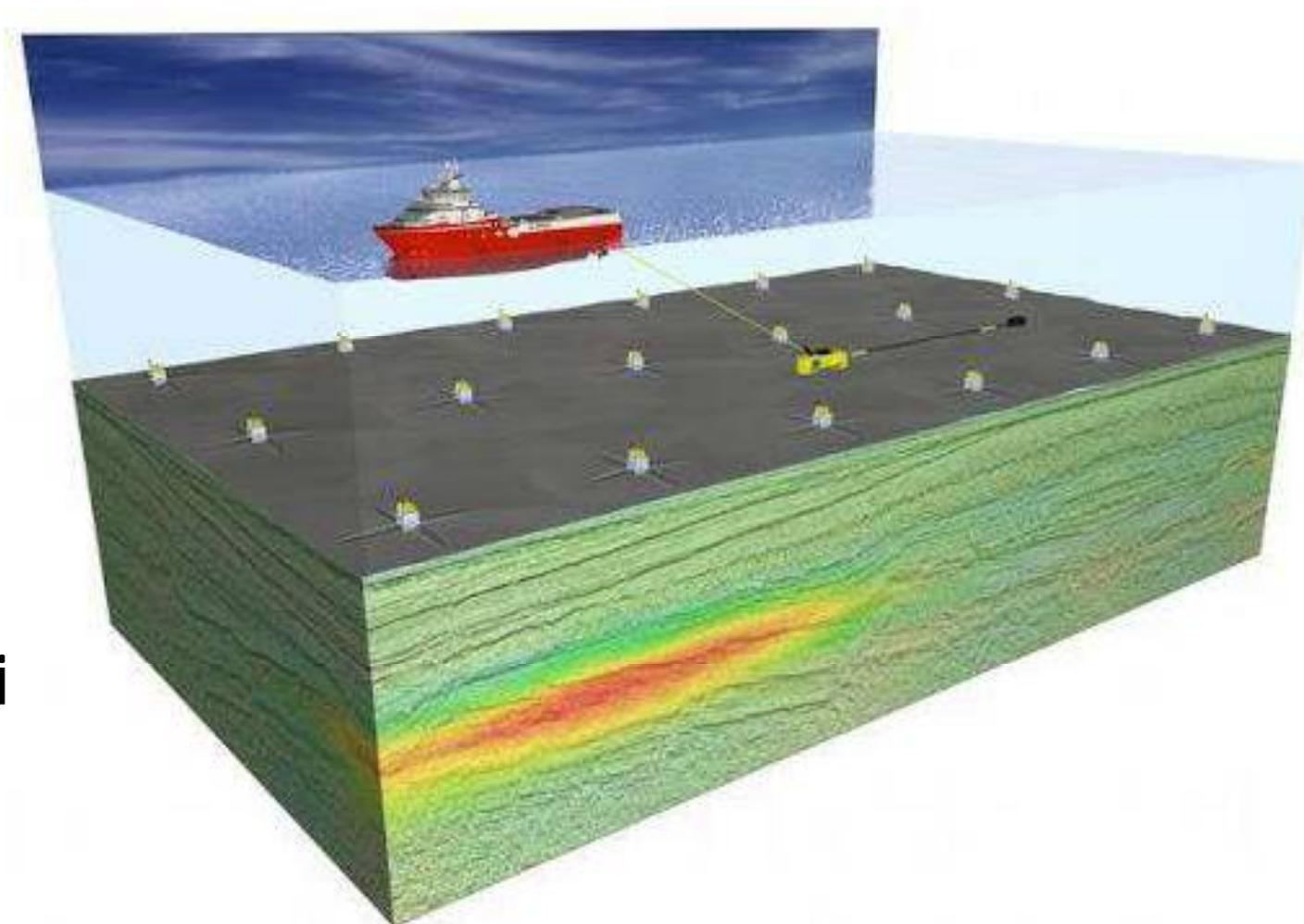
Il Metodo Airborne EM - Corso APC - OGL 30/03/21

Geotermia

Target
conduttivi nel
caso di
mappatura
faglie o resistivi
nel caso di
ricerca di
reservoir



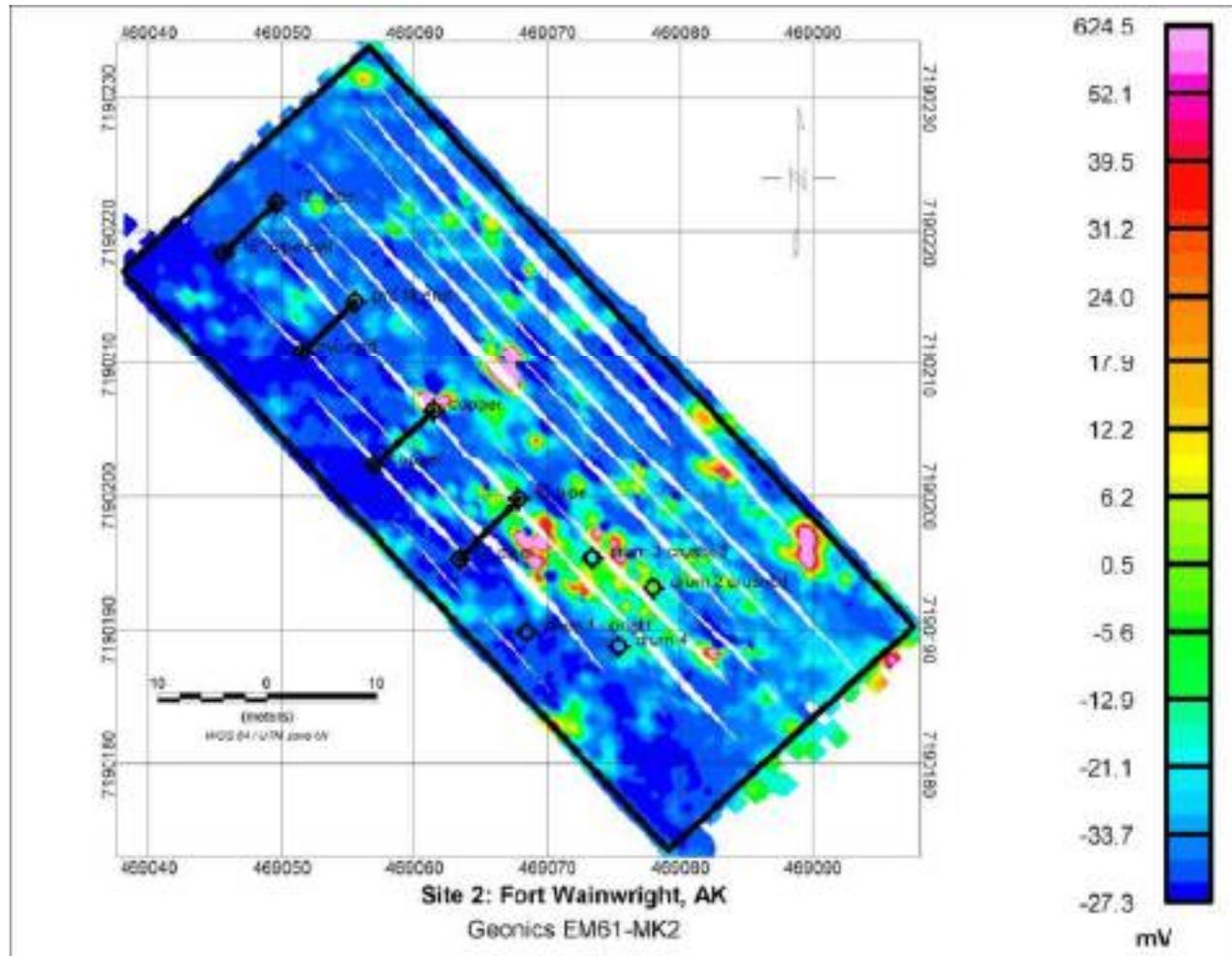
Ricerca petrolifera



Target resistivi

Ricerca ordigni bellici

Target
conduttivi



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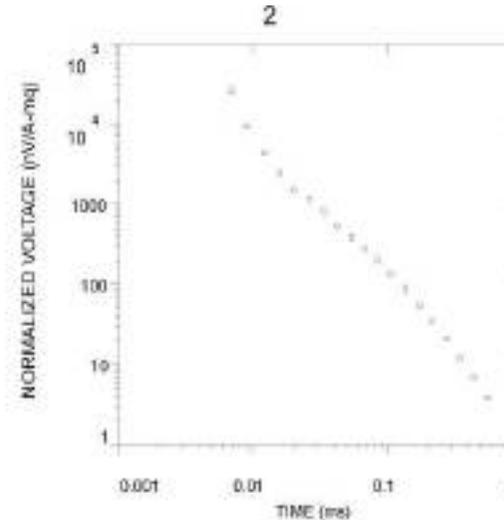
- **Descrizione del metodo EM**
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Classificazione dei metodi EM

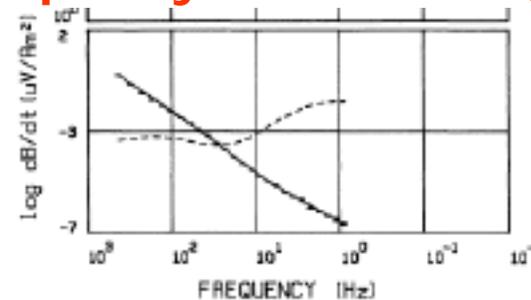
Dominio del tempo (Time Domain EM, TDEM)

La misura del campo EM viene effettuata in funzione del tempo, attraverso canali di ricezione posizionati a tempi via via crescenti



Dominio della frequenza (Frequency Domain EM, FDEM)

La misura del campo EM viene effettuata variando la frequenza del campo primario



Classificazione dei metodi EM

	Ricevitore	
Trasmittitore	<i>Dipolo elettrico</i>	<i>Coil</i>
<i>Contatto galvanico (grounded wire)</i>	RESISTIVITY (E) IP (E) LOTEM (E) CSAMT (E)	LOTEM (B) SHOTEM (B) CSAMT (B)
<i>Induzione (insulated loop)</i>		SHOTEM (B)
<i>Induzione (coil)</i>		METAL DETECTOR (B) SLINGRAM (B)
<i>Radio trasmettitori militari</i>		VLF (B)
<i>Naturale (correnti telluriche)</i>	MAGNETOTELLURICA (E) AMT (E)	MAGNETOTELLURICA (B) AMT (B)

E = dispositivo Tx-Rx utilizzato per la misura del campo elettrico

B = dispositivo Tx-Rx utilizzato per la misura del campo magnetico

Nero = Dominio del tempo - Rosso = Dominio della frequenza

SHOTEM (Acquisizione dati)



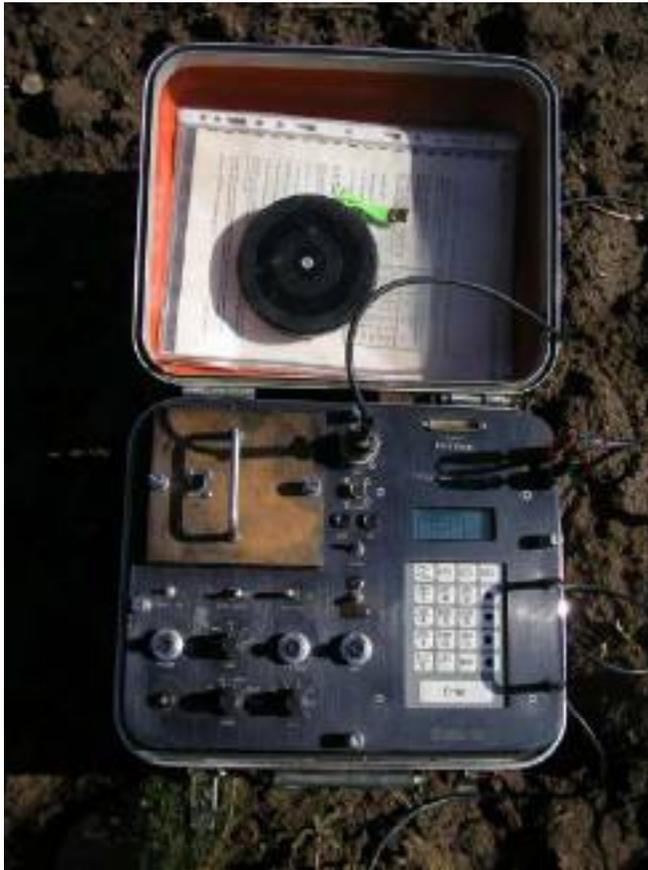
**Il Trasmettitore EM57 Geonics, alimentato da gruppo elettrogeno.
Max corrente = 20 A**

SHOTEM (Acquisizione dati)



**Il Trasmettitore EM57 Geonics che immette corrente in un
Tx loop 5 x 5 m, 8 spire. Corrente = 12.5 A**

SHOTEM (Acquisizione dati)



Il Ricevitore Protem Geonics.

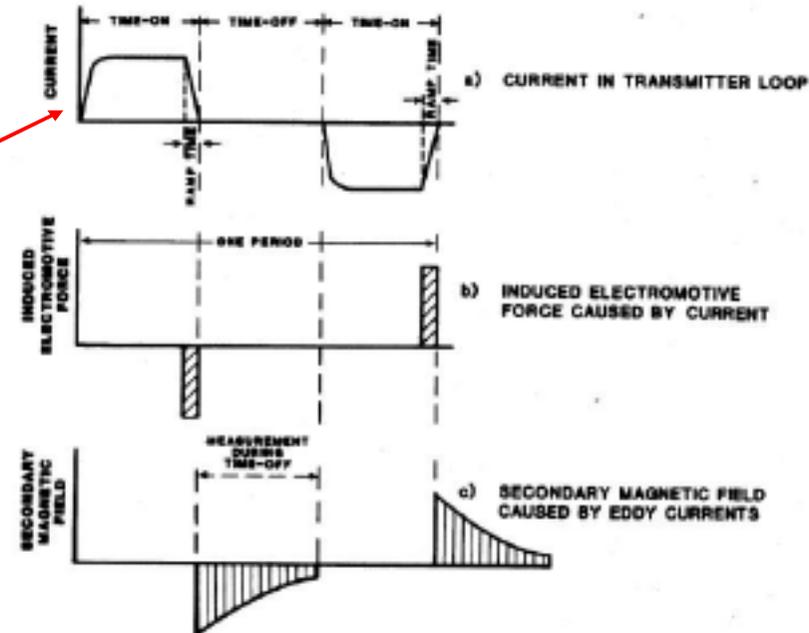


Il coil ricevente mentre misura la componente verticale del campo magnetico secondario.

SHOTEM

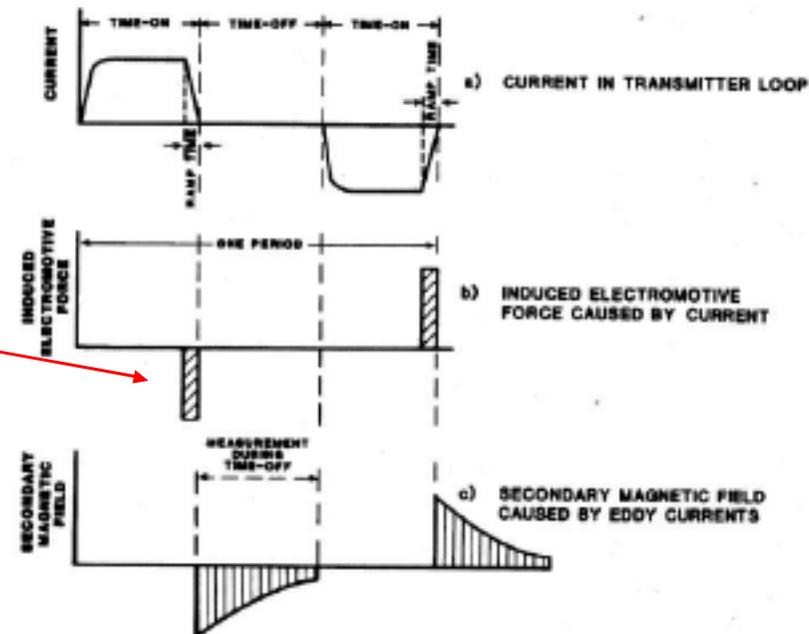
(SHort Offset Transient Electro Magnetic)

Il Trasmettitore è di norma costituito da un loop di forma quadrata o rettangolare, disteso sul terreno (si può anche far uso di un dipolo in contatto galvanico). Entro il loop viene fatta circolare una **corrente alternata**, con frequenze di ripetizione variabili da circa 250 a 2,5 Hz. Ad ogni impulso positivo (Time-on) segue un equal periodo durante il quale la corrente viene azzerata (Time-off). Segue un periodo di energizzazione, con inversione della polarità della corrente, e un nuovo intervallo di Time-off.



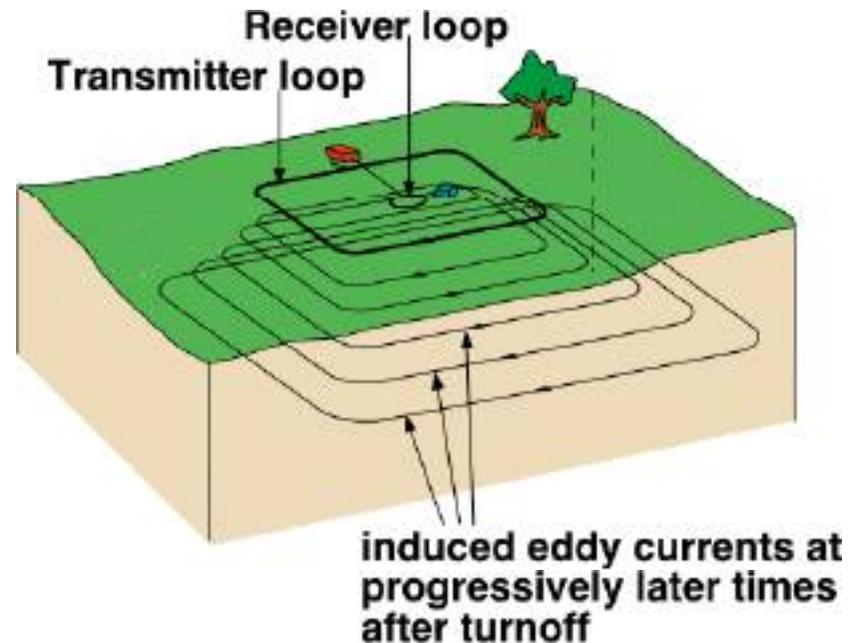
SHOTEM (Acquisizione dati)

Nel momento in cui si azzera bruscamente la corrente ("turn-off"), secondo quanto previsto dalla legge di Faraday, si produce un **campo elettromagnetico primario**, di brevissima durata, che tende ad annullarsi in tempi rapidissimi (nell'ordine dei millisecondi).



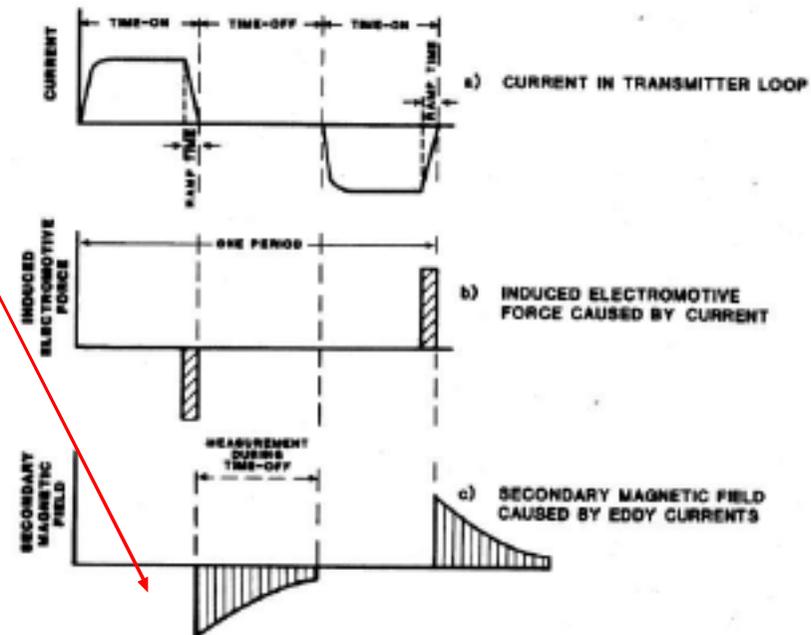
SHOTEM (Acquisizione dati)

Questo induce poi delle correnti
vacanti nel sottosuolo, che si
propagano, col passare del
tempo, sempre più in profondità
e con un allargamento
progressivo, secondo una
modalità che ricorda degli anelli
di fumo



SHOTEM (Acquisizione dati)

Queste correnti indotte si dissipano in tempi rapidissimi, producendo a loro volta, un **campo elettromagnetico secondario** che contiene le informazioni che ci interessano, ovvero le variazioni di resistività del sottosuolo. In realtà quello che viene misurato è un voltaggio (in mV) che si annulla nel giro di pochi millisecondi (chiamato "transiente") e che viene campionato dall'unità ricevente, collegata ad una bobina ricevente (coil), durante il "time-off", onde evitare interferenze con il campo primario. La sincronizzazione tra trasmettitore e ricevitore viene realizzata tramite un cavo di collegamento (reference cable) o tramite orologio al cristallo (crystal clock).



Tutto il ciclo delle misure viene ripetuto moltissime volte (ad es. nel Protem Geonics come minimo si fa uno stacking di 256 transienti)

Relazione tra frequenza e profondità di investigazione

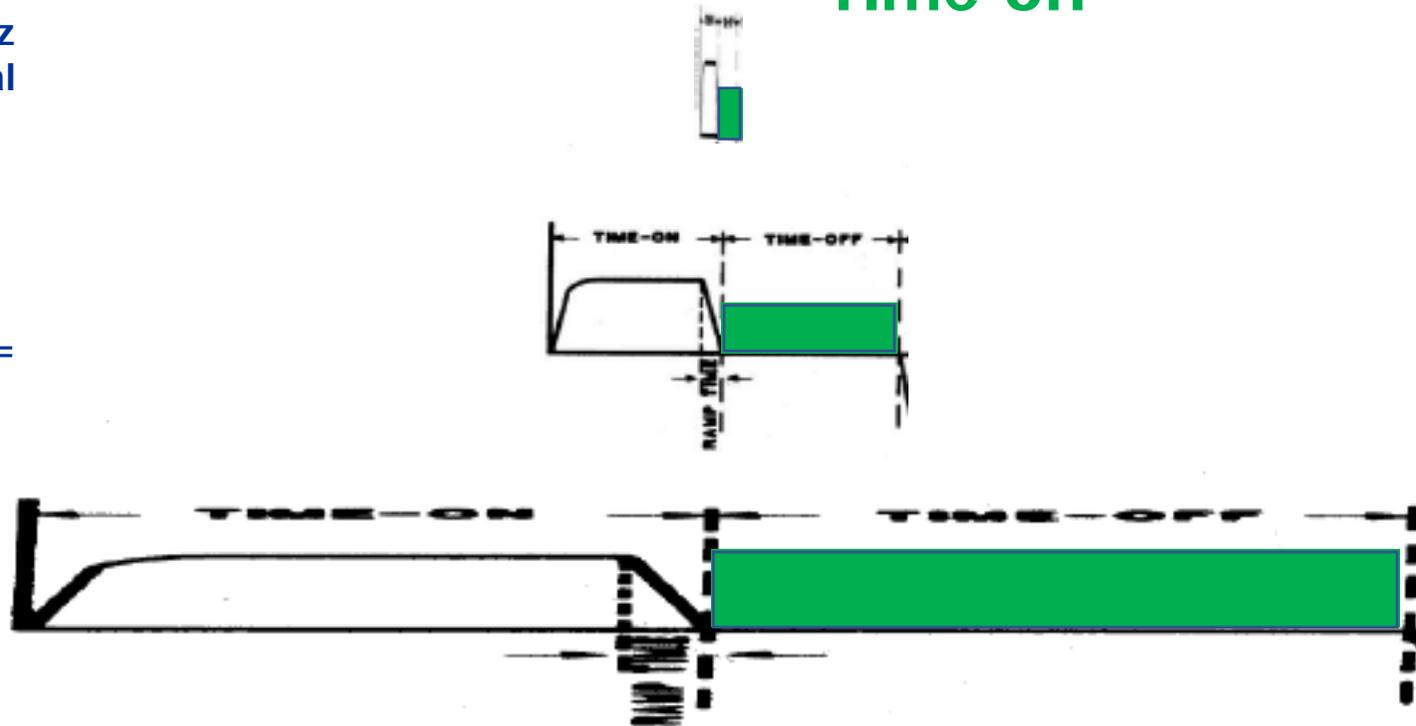
Usando una frequenza di 250 Hz possiamo contare su 250 cicli al secondo

Time-off = $1/250/4 = 1$ msec

Con 25 Hz il Time-off sarà = $1/25/4 = 10$ msec

Con 6.25 Hz → 40 msec

Time-off



Basics Physics of TEM

How does it work?

A stationary current flows in the transmitter loop

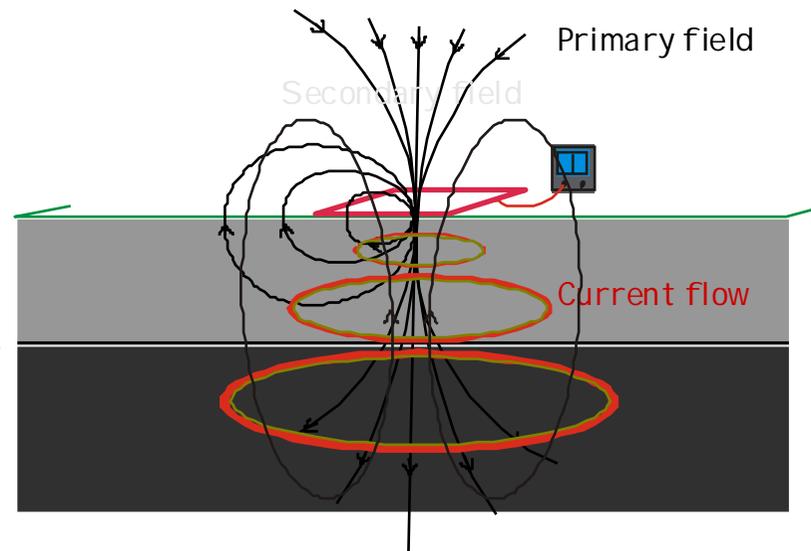
- *which sets up a primary magnetic field*

The current is shut off abruptly

- *which induces currents in the subsurface.*

This generates a secondary magnetic field

- *which is measured in the receiver coil at the surface*



Penetration depth

- Diffusion depth

$$z_d = \sqrt{\frac{2t}{\mu\sigma}} \approx 1.26 \times \sqrt{\rho t}$$

- Diffusion time

$$t_d = \frac{\mu\sigma z_d^2}{2} \approx 0.628 \times \frac{z_d^2}{\rho}$$

Penetration depth

- Diffusion depth – from late time db/dt

$$t_L = \mu \left(\frac{M}{20V_{noise}} \right)^{2/5} \left(\frac{\sigma}{\pi} \right)^{3/5} = t_d = \frac{\mu \sigma z_d^2}{2} \Rightarrow$$

$$z_d = \left(\frac{2}{25\pi^3} \right)^{1/10} \left(\frac{M}{\sigma V_{noise}} \right)^{1/5} = 0.551 \left(\frac{M}{\sigma V_{noise}} \right)^{1/5}$$

M momento energizzante

$$M = n I A$$

N= n di spire del loop Tx

I = intensità corrente

A = area del loop Tx

SHOTEM

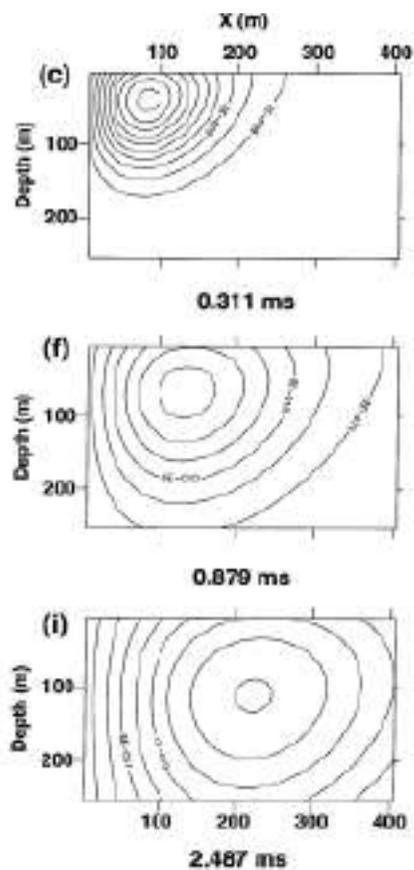
(Acquisizione dati)

Il ricevitore è in grado di campionare il transiente tramite 20 canali di acquisizione, che si aprono a tempi via via maggiori, indagando così zone sempre più profonde, visto che col passare del tempo le correnti indotte penetrano sempre più. Infatti la velocità di propagazione è direttamente proporzionale alla resistività elettrica (ovvero inversamente proporzionale alla conducibilità elettrica) del terreno. La profondità di penetrazione nel punto di massima intensità è regolata dalla formula:

$$d = 2\pi\sqrt{2t/\mu\sigma}$$

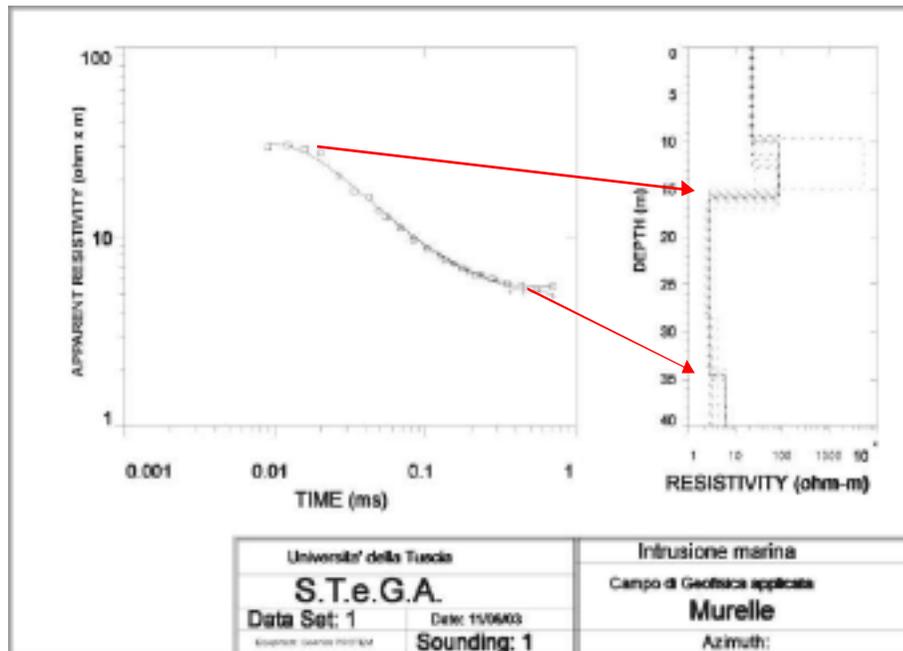
dove t = tempo, μ = permeabilità magnetica nel vuoto e σ = conducibilità elettrica.

SHOTEM (Acquisizione dati)



Il punto di massima intensità delle correnti indotte si propaga in profondità ed allontanandosi dalla sorgente trasmittente

SHOTEM (Acquisizione dati)



Animazioni EM su
<http://www.geofysiksamarbejdet.au.dk>

Differente velocità di propagazione delle correnti indotte:

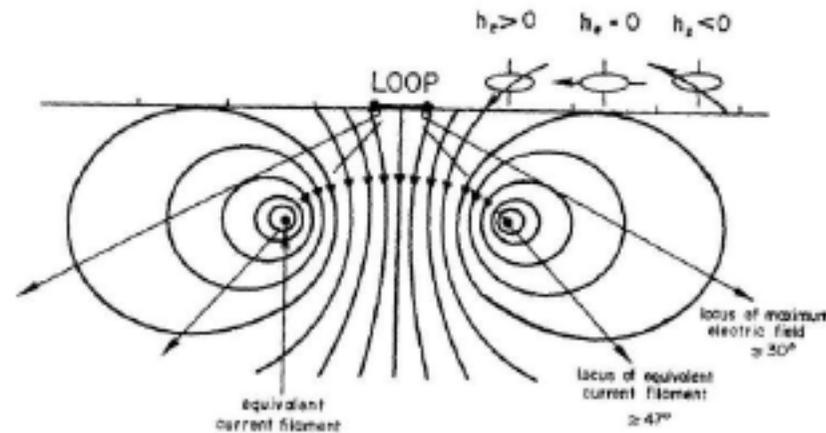
I primi due strati più resistivi vengo attraversati in pochi millisecondi (15 metri vengono percorsi in poco più di 20 μ sec).

Lo strato conduttivo determina un forte rallentamento delle correnti indotte, tanto che la maggior parte del transiente viaggia **all'interno** di esso (per percorrere 20 m, il transiente impiega più di 400 μ sec). Questo spiega perché i metodi EM sono più adatti per rilevare corpi conduttivi.

Il substrato più resistivo viene raggiunto dopo parecchi microsecondi.

SHOTEM

(Acquisizione dati)

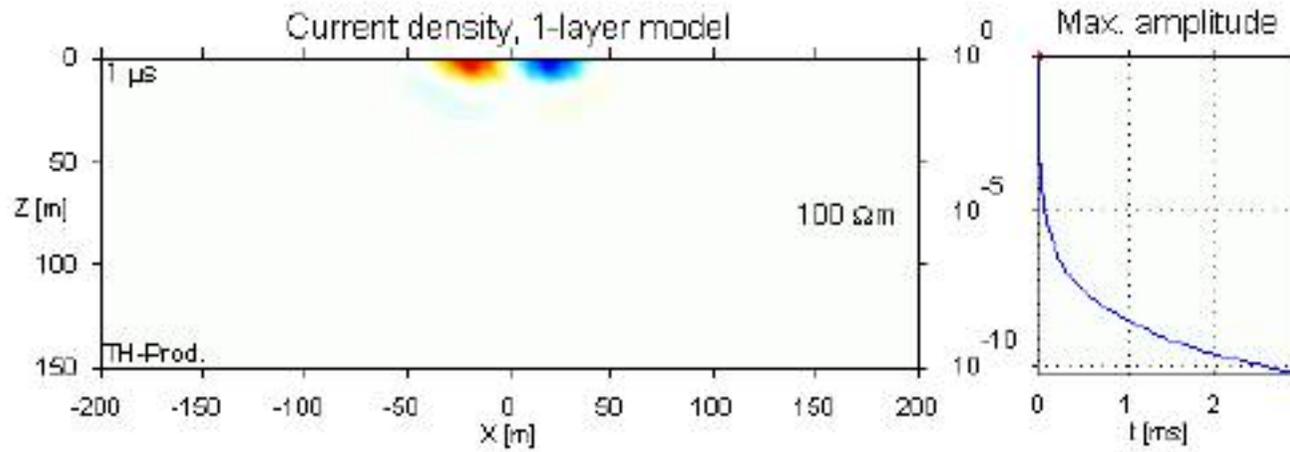


Il campo magnetico secondario che viene rilevato dal coil ricevente è orientato in maniera differente a seconda che mi allontani dal loop trasmittente e a seconda del tempo di acquisizione:

Al centro del loop (central mode sounding) il vettore è positivo ed è perfettamente verticale. Ad una certa distanza dal loop (offset-mode sounding) rileverò un valore nullo della componente verticale, in quanto il c.m. secondario è perfettamente orizzontale. Qui si verifica l'**inversione** di segno (crossover)

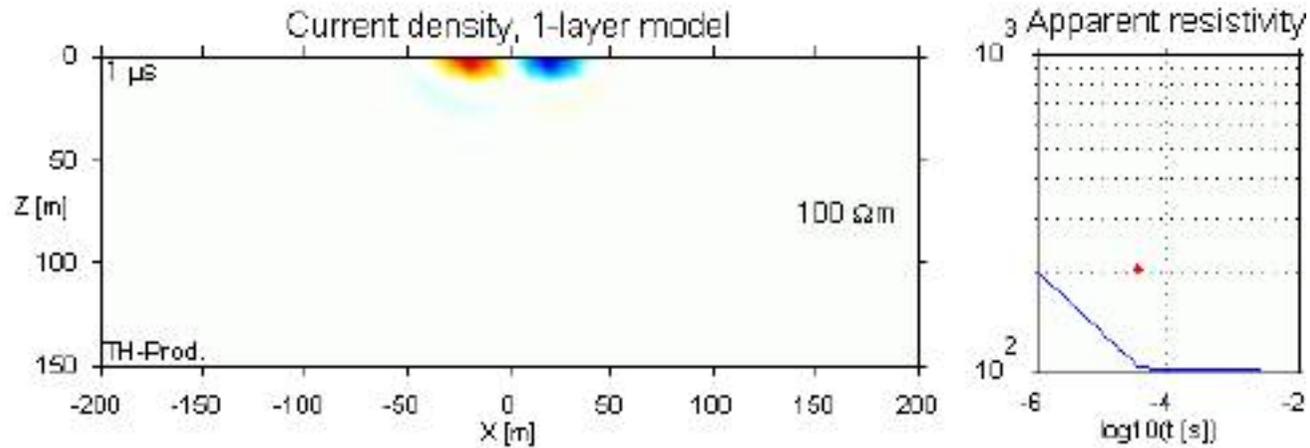
A distanza ancora maggiore il c.m. secondario assumerà valori negativi. Poiché il punto di massima intensità delle correnti indotte migra sempre più in profondità col passare del tempo, il transiente mostrerà un'**inversione** di segno, per cui tornerà ad essere positivo.

Current Diffusion in a Halfspace



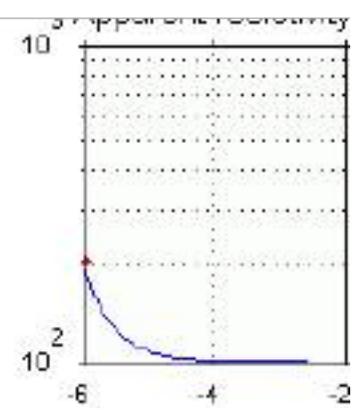
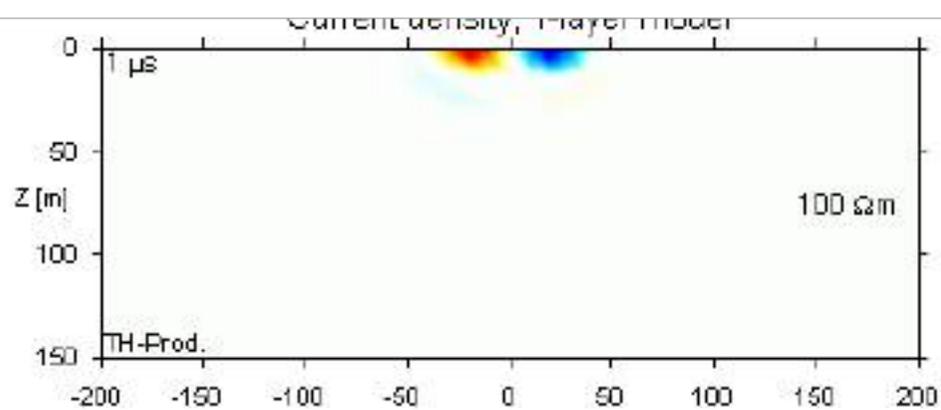
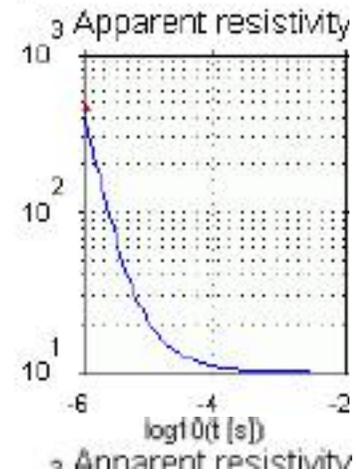
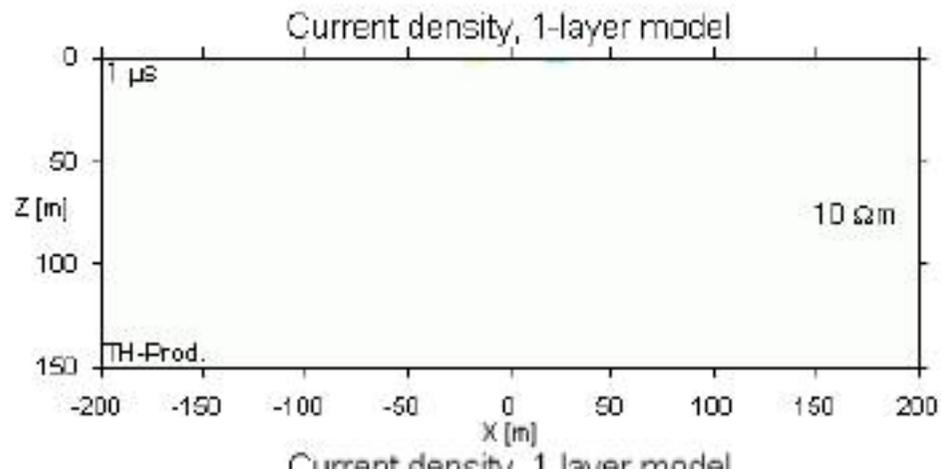
Log time sampled

Current Diffusion in a Halfspace

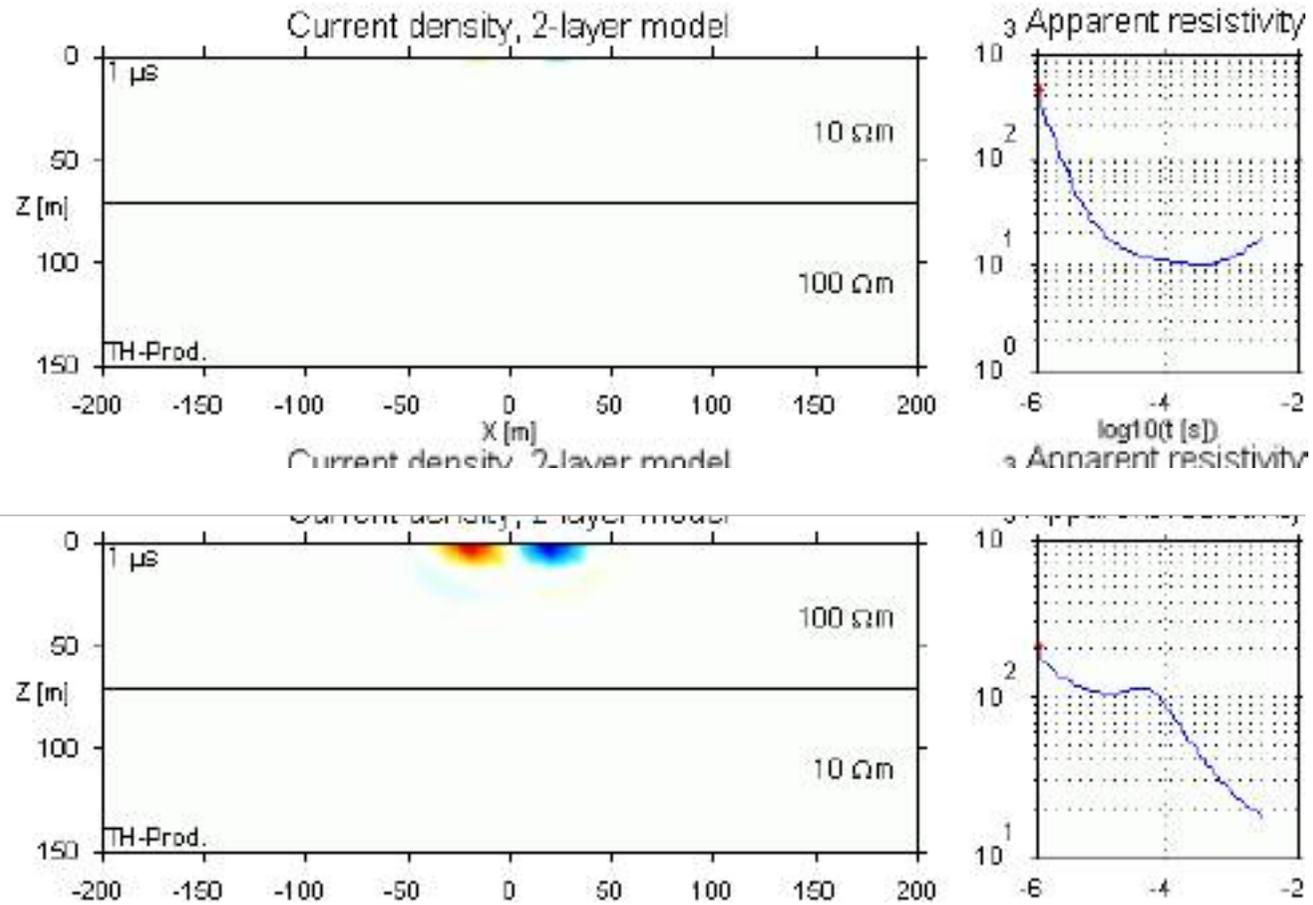


Linear time sampled

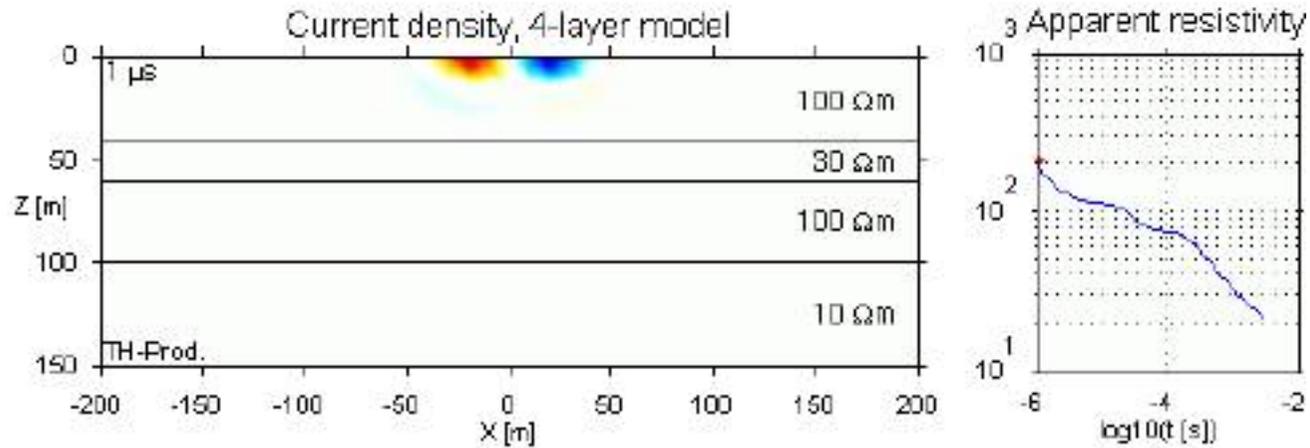
Current Diffusion in a Halfspace



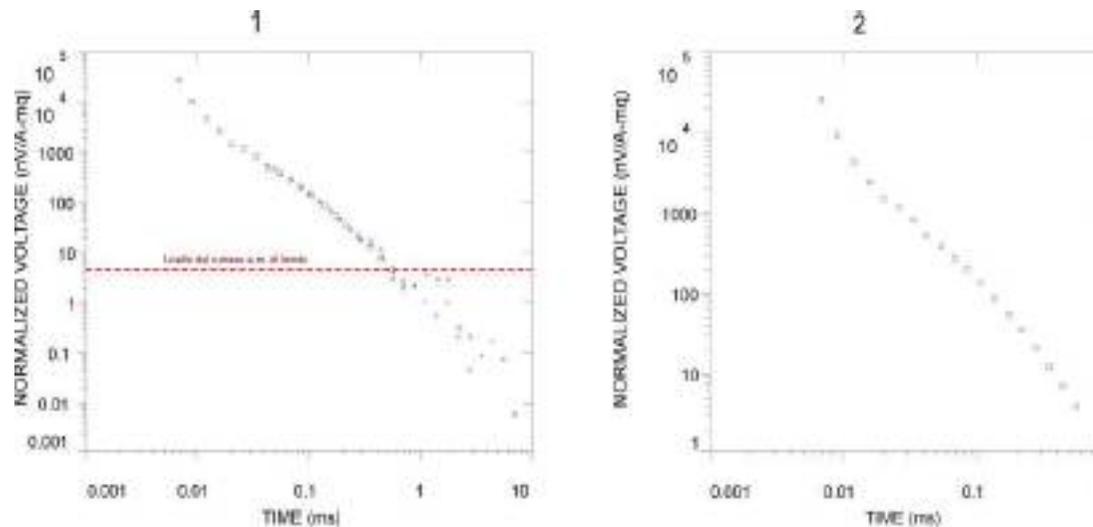
Current Diffusion - Two Layers



Current Diffusion – Four Layers



SHOTEM (Acquisizione dati)



Per aumentare il rapporto S/N si esegue uno stacking su un gran numero di transienti (minimo 256), variando anche il guadagno di ricezione.

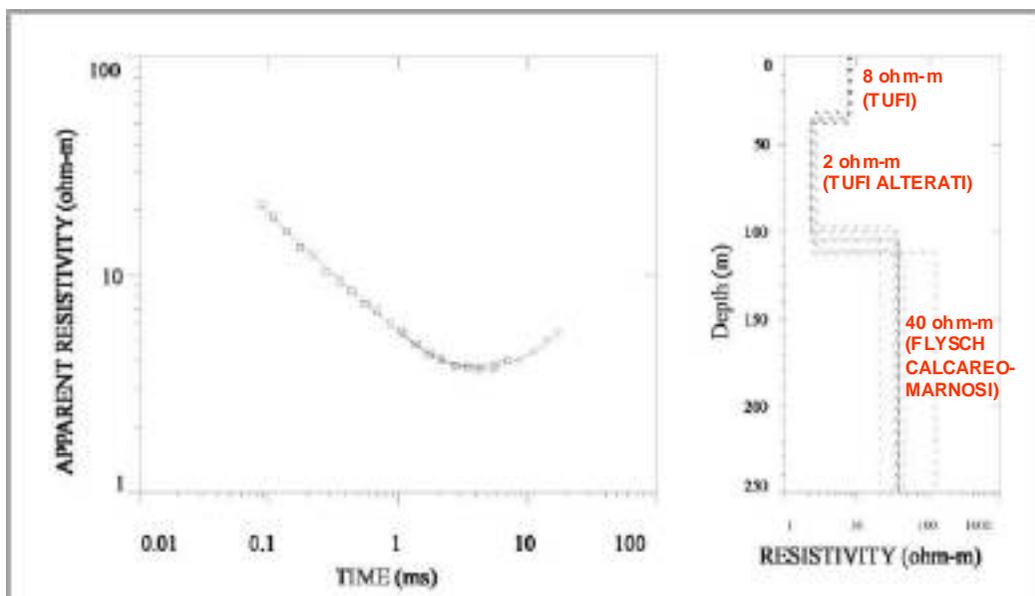
La curva a sinistra mostra il livello del rumore e.m. di fondo.

Il ricevitore ha 20 canali che vengono traslati su tempi di acquisizione via via più lunghi, man mano che diminuiamo la frequenza di ripetizione:

Quadrati = 236 Hz - Rombi = 62.5 Hz - Croci = 25 Hz

I 3 transienti che si ricavano si sovrappongono parzialmente.

SHOTEM (Inversione dati)



I valori di voltaggio vengono poi convertiti in valori di resistività apparente, in modo da ricavare una curva di campagna sulla quale si può procedere con le classiche modalità di interpretazione.

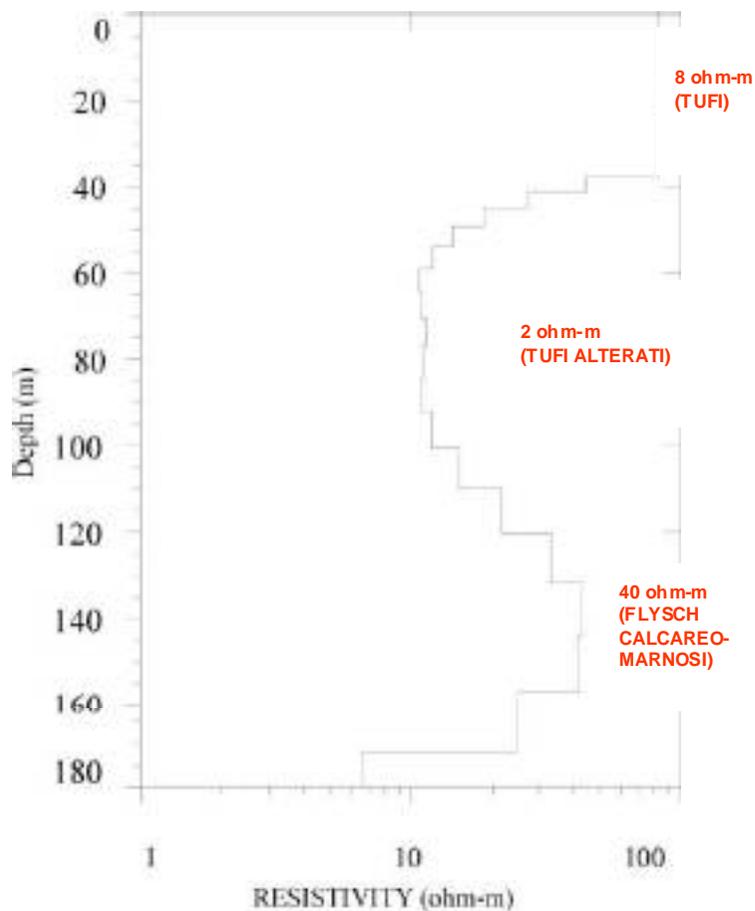
A sinistra curva "resistività apparente-tempi", a destra il modello 1D ricavato utilizzando l' algoritmo di Inman.

I singoli elettrostrati presentano spessore e resistività definiti.

Il modello finale (tratto continuo) è quello di "best fitting", essendo quello che più si avvicina ai dati di campagna (minimo scarto quadratico medio tra la curva sperimentale e quella del modello).

I modelli equivalenti (in tratteggio), seppur contraddistinti da un maggior discrepanza rispetto ai dati sperimentali, potrebbero essere comunque validi.

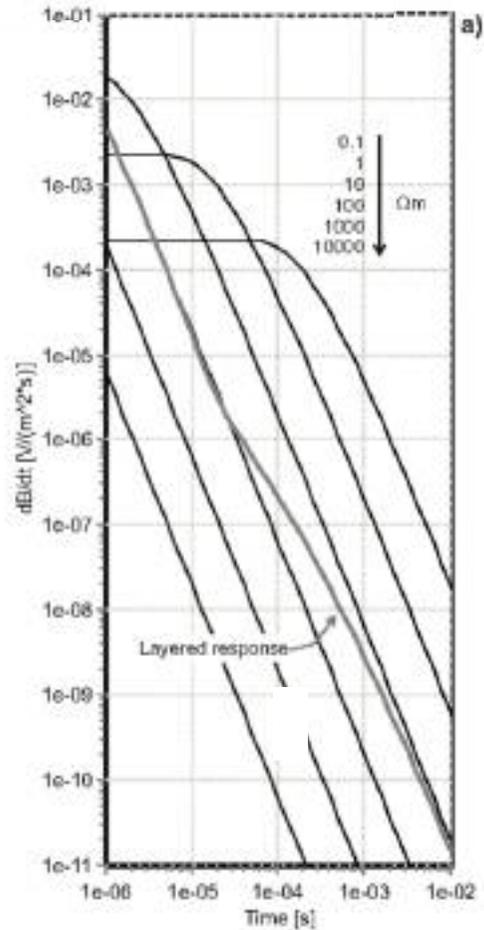
SHOTEM (Inversione dati)



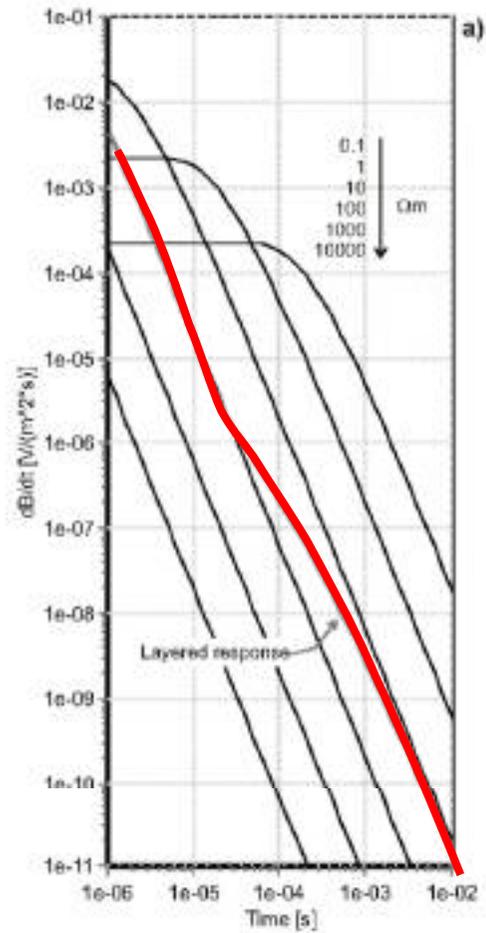
Una seconda modalità di inversione (completamente automatica) è quella che utilizza l'algoritmo di Occam (SMOOTHED INVERSION)

Grazie ad essa si può stimare la resistività di un numero elevato di elettrostrati (sino ad un massimo di 19), sino ad una profondità che viene calcolata direttamente dal programma.

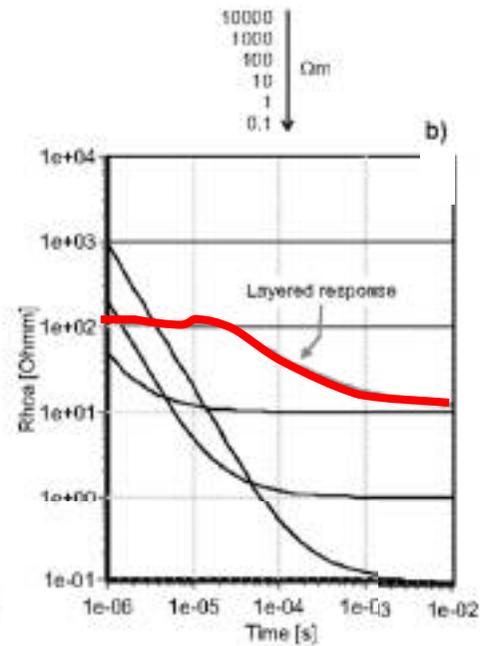
Half space curves



- Proportional to $t^{-2.5}$
 - 1 dec. in time is 2.5 dec. in field
 - or a factor of 320!



- 2-layer model
- 1st= 100 ohmm, 50 m
- 2nd= 10 ohmm



Noise Sources

"Natural" electromagnetic noise (random)

- Sferics
- Lightning
- Fluctuation in Earth magnetic field

Man-made electromagnetic noise (coherent)

- Electrical installations, 50 Hz Power Supply
- Electromagnetic fields from communication

Couplings (coherent)

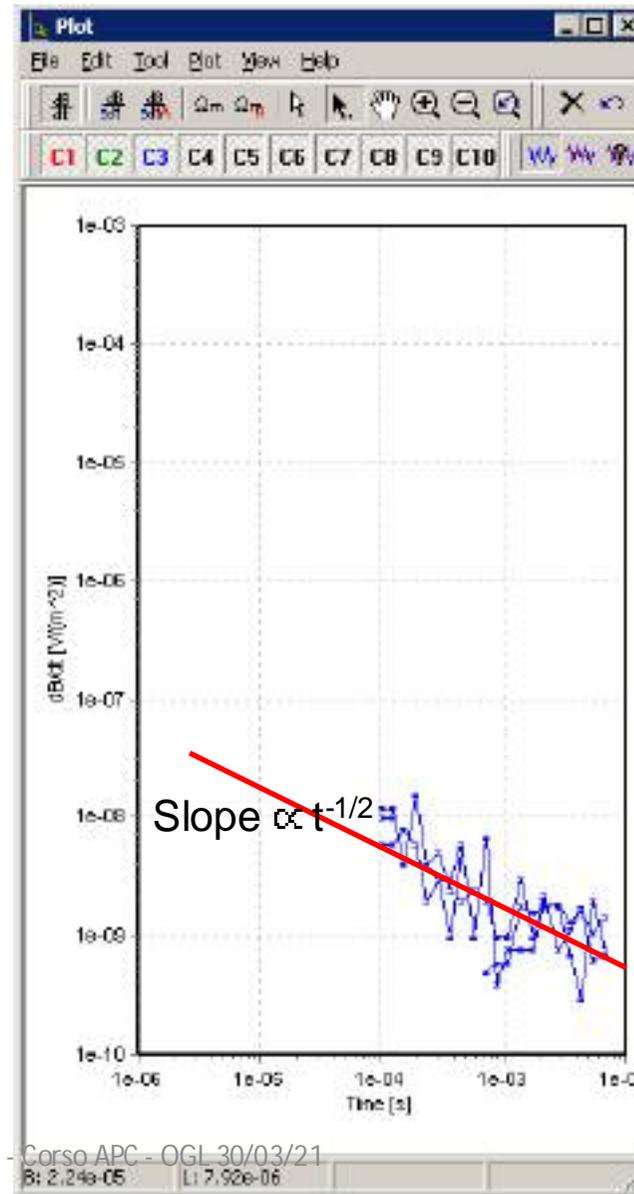
- Couplings to man-made conducting installations

"Geological Noise"

- Deviation from 1 D models

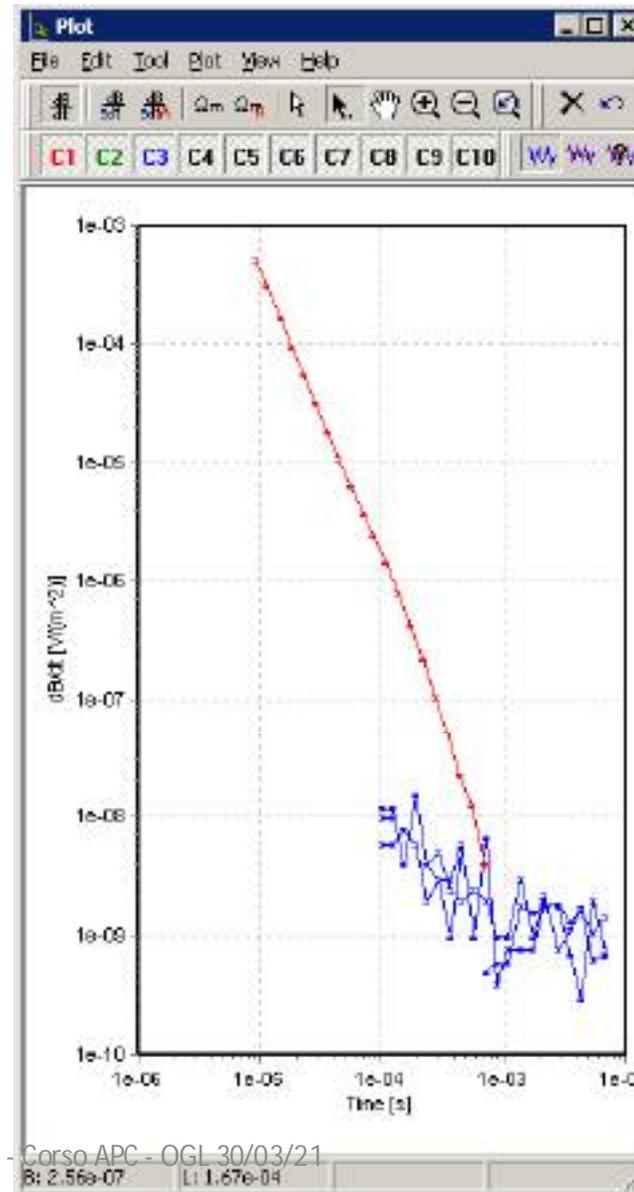
Instrumental noise & bias (random & coherent)

Measurement Noise



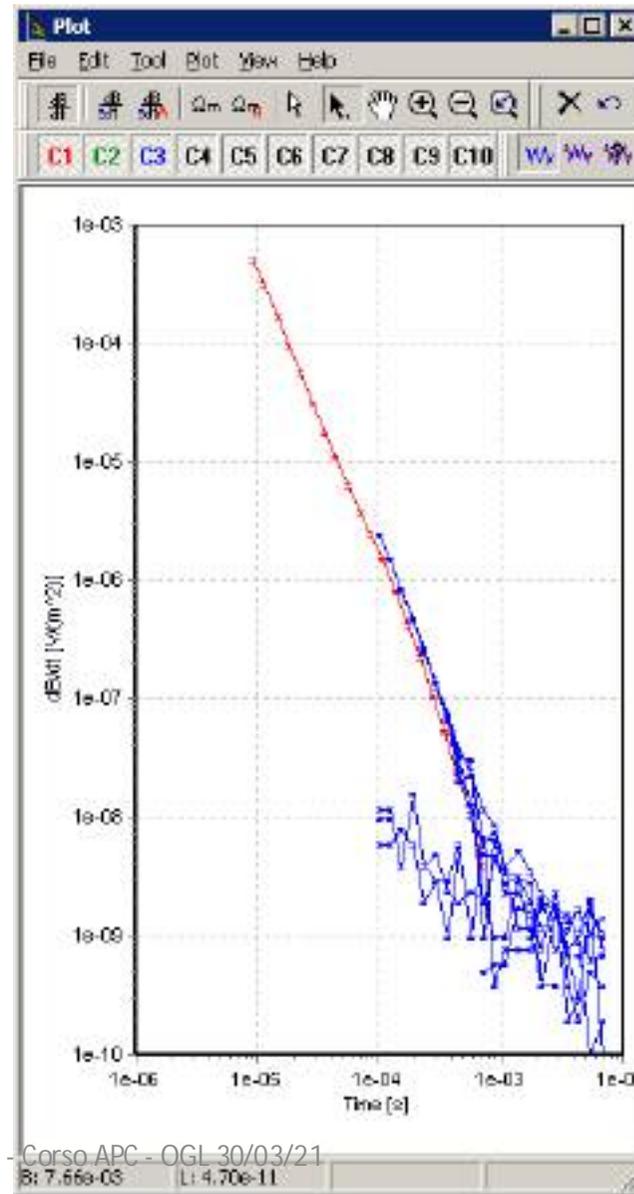
Measurement Noise

- Low Moment signal



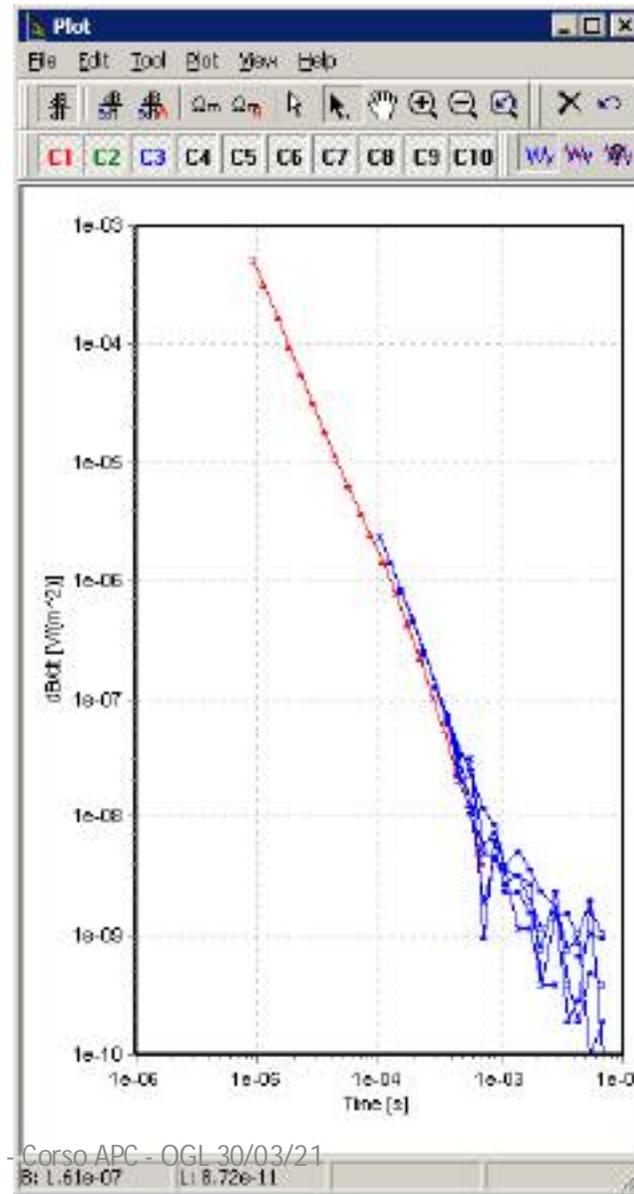
Measurement Noise

- Low Moment signal
- High Moment signal



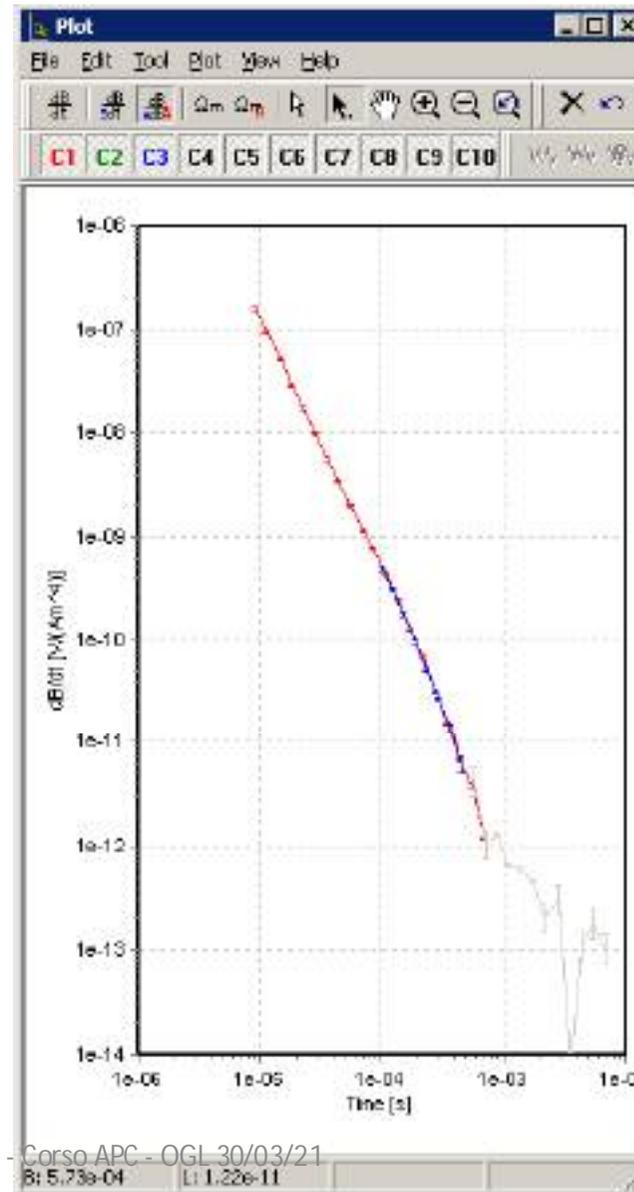
Measurement Noise

- Low Moment signal
- High Moment signal



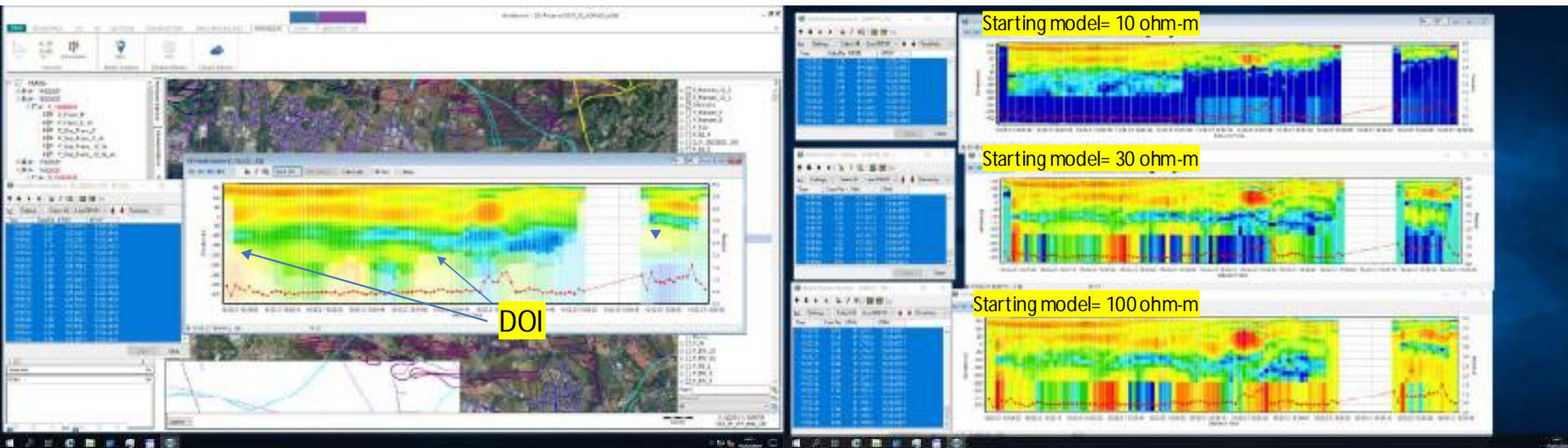
Measurement Noise

- Low Moment signal
- High Moment signal
- Processed



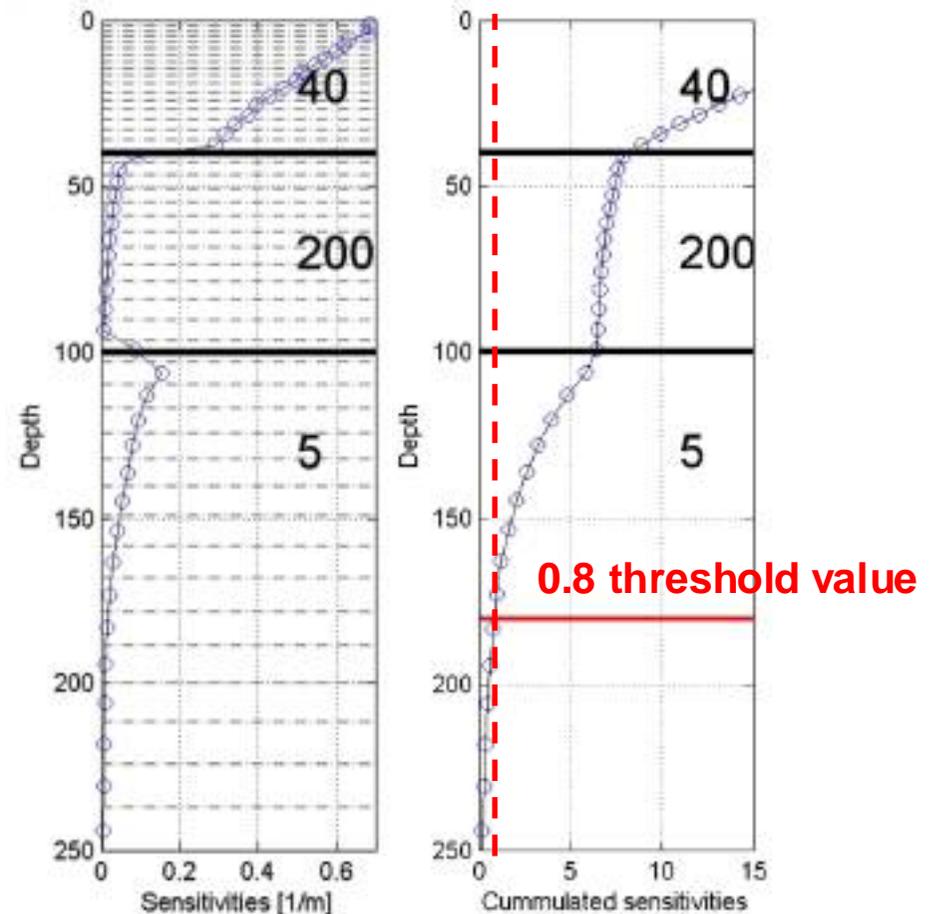
The Depth of Investigation

- Massima profondità di indagine, dove il modello geofisico è effettivamente supportato dai dati e non dallo starting model
- The actual model
 - DOI dipende dal modello
- Data and system characteristics
 - Pochi dati \Rightarrow bassa DOI
- Noise
 - Più noise \Rightarrow bassa DOI



Global DOI - calculation

- 3-layer model
 1. Sub-discretize
 2. Calculate sensitivities
 3. Compute cumulated sensitivities
 4. Interpolate for global threshold \Rightarrow DOI !

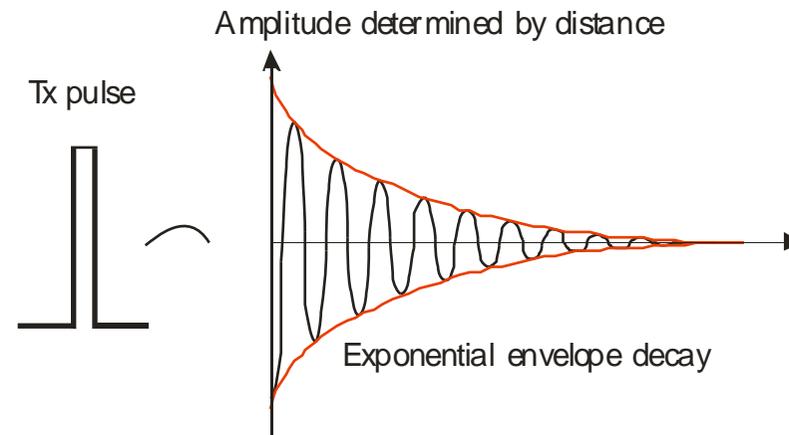
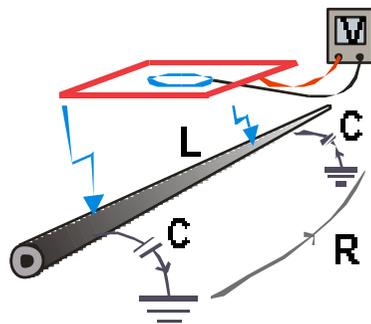


Coupling in TEM Data

- Distortion response due to transmitter-induced currents in manmade conductors
- Cannot be removed by stacking
- Two types of coupling
 - capacitive - LCR circuit
 - galvanic - LR circuit

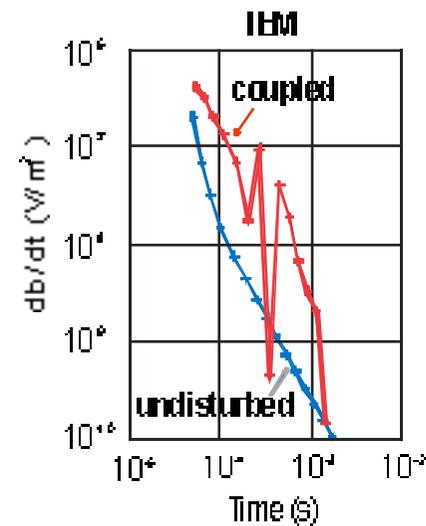
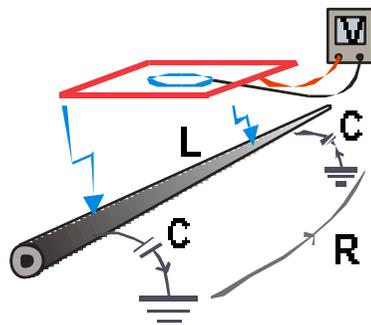
Capacitive Coupling

- Capacitive return path
- Where?
 - long isolated wires, telephones cables, buried cables
- LCR - oscillating, decaying circuit



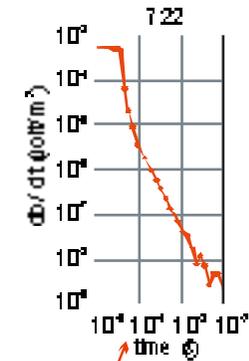
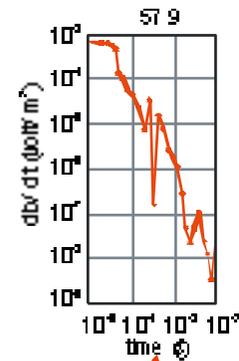
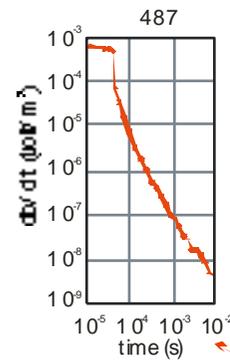
Capacitive Coupling

- Capacitive return path
- Where?
 - long isolated wires, telephones cables, buried cables
- LCR - oscillating, decaying circuit

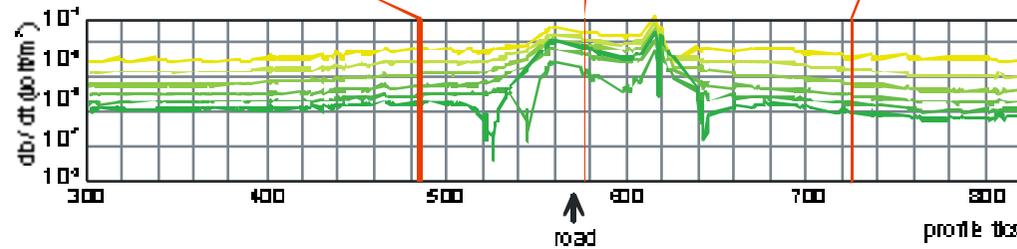


Capacitive coupling - PATEM field example

Site map

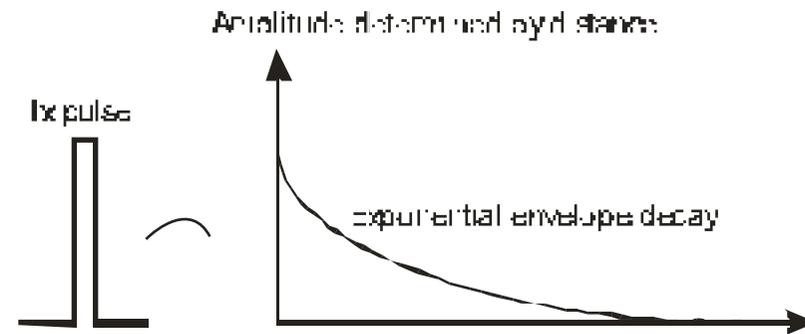
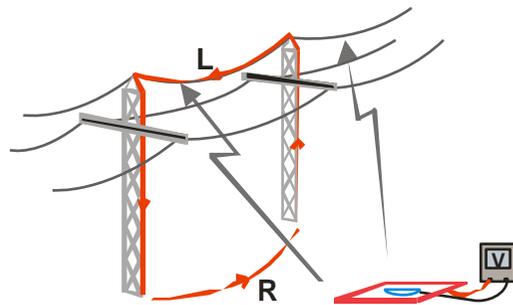


profile



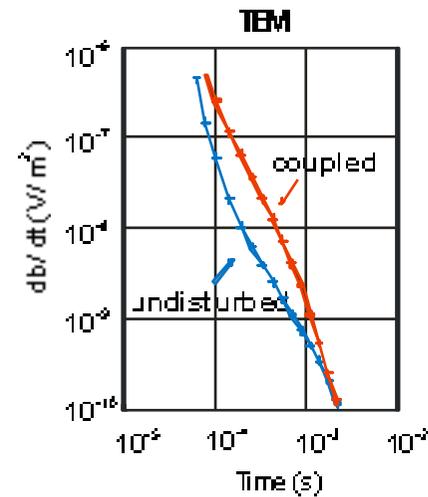
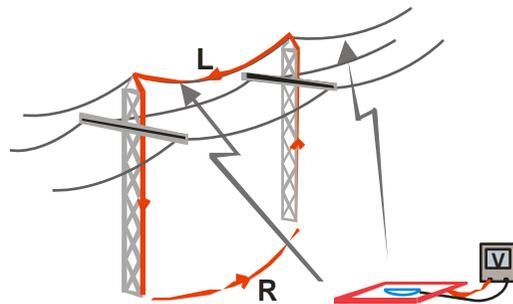
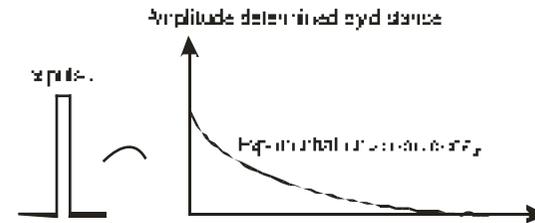
Galvanic Coupling

- Galvanic return path
- Where?
 - high voltage wires, metal road guards and fences
- LR - decaying circuit



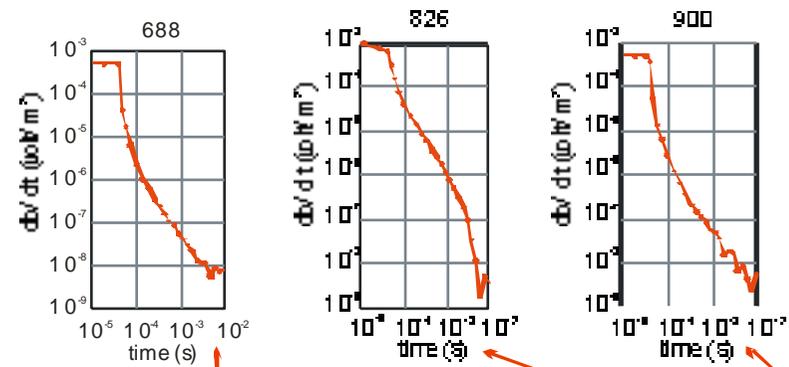
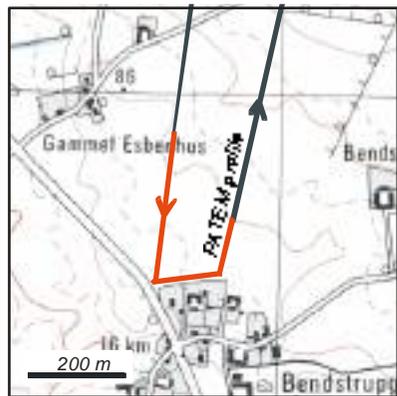
Galvanic Coupling

- Galvanic return path
- LR - decaying circuit
- Where?
 - high voltage wires, metal road guards and fences

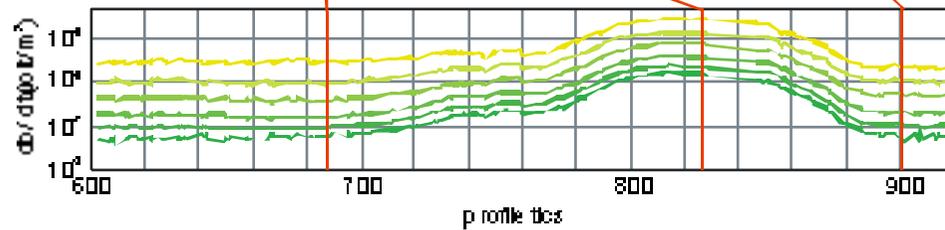


Galvanic coupling - PATEM field example

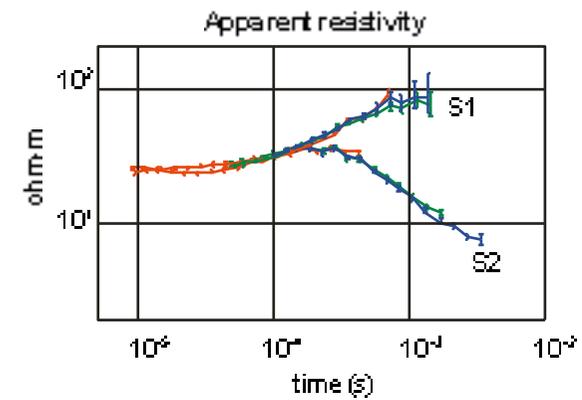
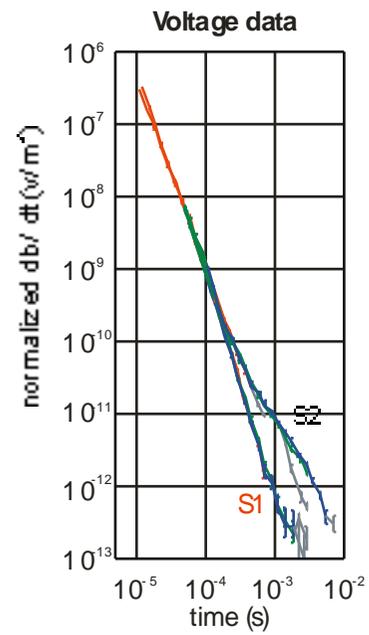
site map



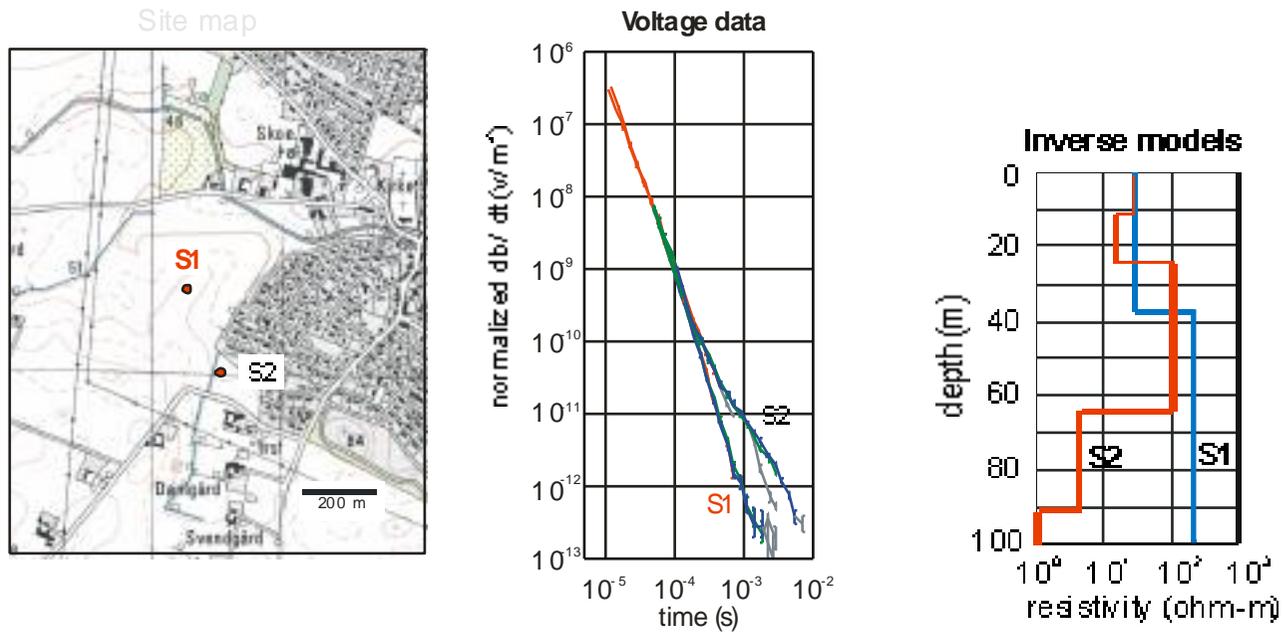
profile



Galvanic coupling

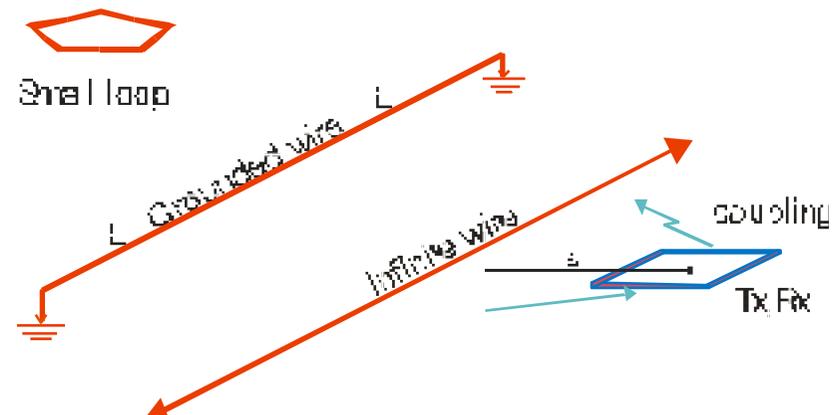


Galvanic coupling - inverse modelling



Coupling Amplitude Distance Dependency

- Infinite wire
 - $1/a$ (Tx to wire) * $1/a$ (wire to Rx) = $1/a^2$
- Finite length wire (grounded dipole)
 - $1/a^2$ (Tx to wire) * $1/a^2$ (wire to Rx) = $1/a^4$
- Small loop
 - $1/a^3$ (Tx to wire) * $1/a^3$ (wire to Rx) = $1/a^6$



IL METODO AIRBORNE EM COME STRUMENTO PER LO STUDIO DI PROBLEMATICHE IDROGEOLOGICHE, GEOTECNICHE ED AMBIENTALI

Dott. Geol. Antonio Menghini

- Descrizione del metodo EM
- **Implementazione su un sistema airborne**
- Processing dei dati
- Inversione
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SkyTEM



VTEM by Geotech



Xcite by NRG



Tempest by CGG



Spectrem



Helitem by CGG



Equator by Geotechnologies

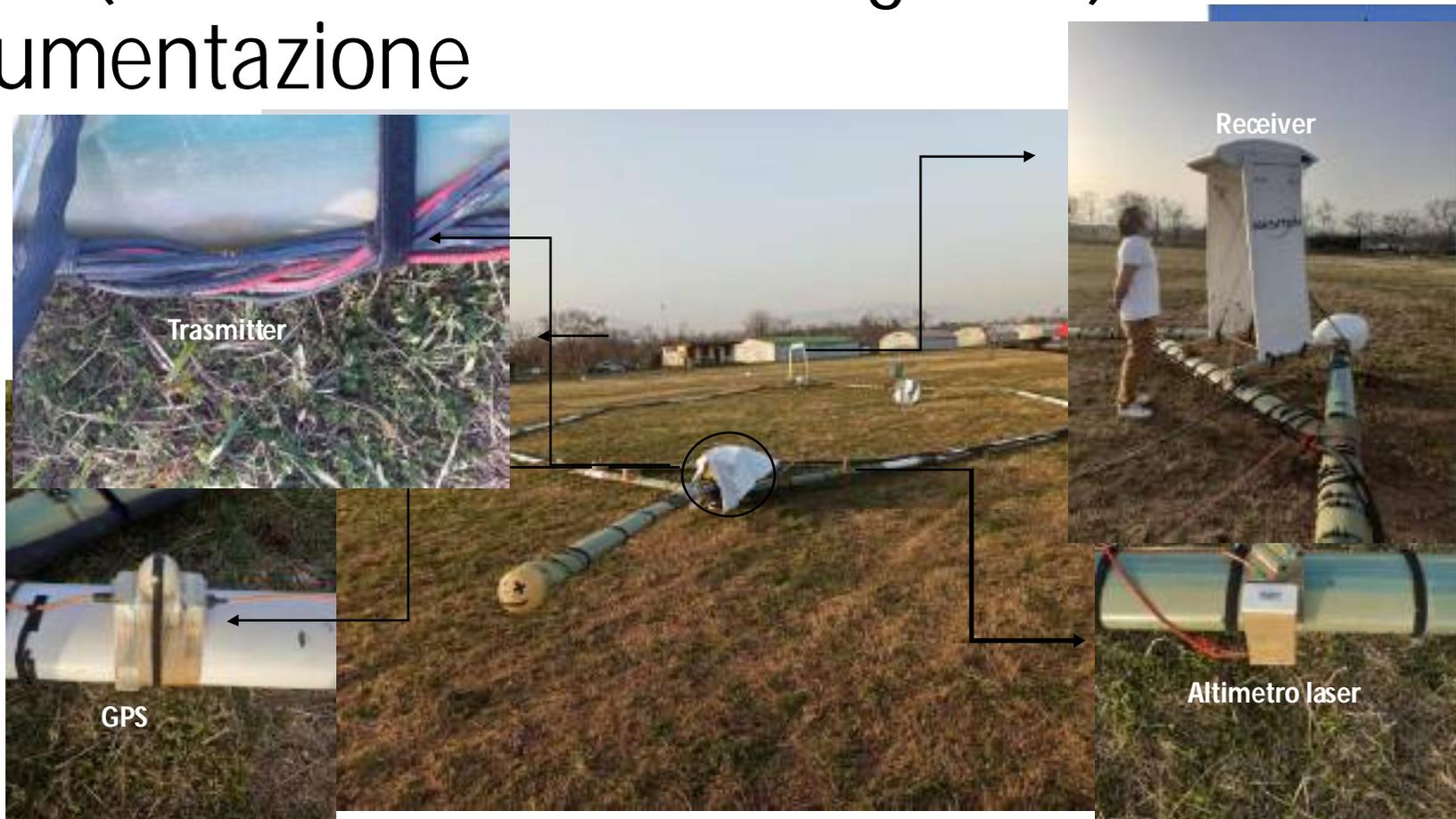


Resolve by CGG

30703721

- Video Skytem e Xcite

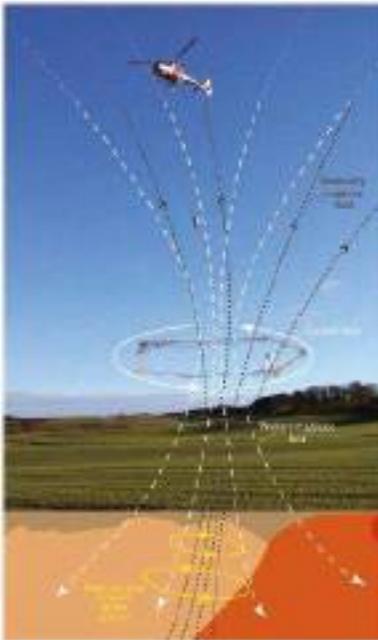
AEM (Airborne Electro-Magnetic): strumentazione



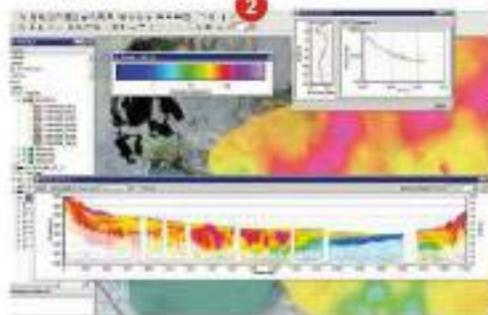
AEM (Airborne Electro-Magnetic): strumentazione



II Workflow

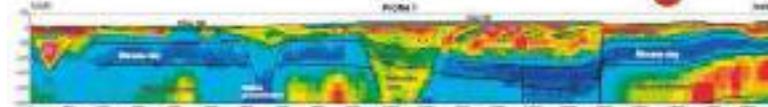


Step 1 The SkyTEM drone survey system has proved to be an invaluable aid in the large-scale mapping of groundwater resources in Denmark, and elsewhere, through the detailed mapping of the subsurface resistivity. The system transmits an electromagnetic signal towards the ground, and translates the signal it receives back into a resistivity model. (Courtesy: Aarhus University, HydroGeophysics Group/ GEUS)



Step 2 The Aarhus Workbench software allows geophysicists to turn the SkyTEM raw data into accurate, transparent and well-documented 3D resistivity models of the subsurface, which are the geophysical basis for the groundwater mapping programme. The software is unique, as it was developed specifically for the hydrogeological application of airborne geophysical data. It incorporates tools for applying data necessary and modelling protocols to ensure the results meet the quality required in groundwater mapping. (Courtesy: Aarhus Geophysics)

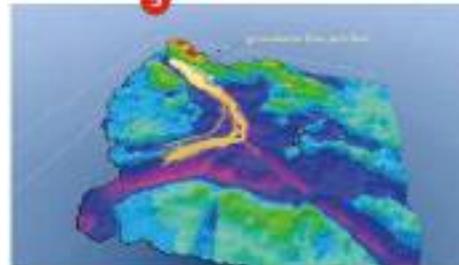
Step 3 When the geophysical datasets have been processed, and interpreted, specific structures in the subsurface can be identified. The task is to identify different layers and structure locations, if possible, in electrical conductivity. Knowledge about the electrical properties of different sediments is crucial for distinguishing the various geological structures. This operation usually can be performed from data collected in the field. Once the structures have been identified, geological modelling can be carried out, using the GeoScience3D tool. (Courtesy: GEUS)



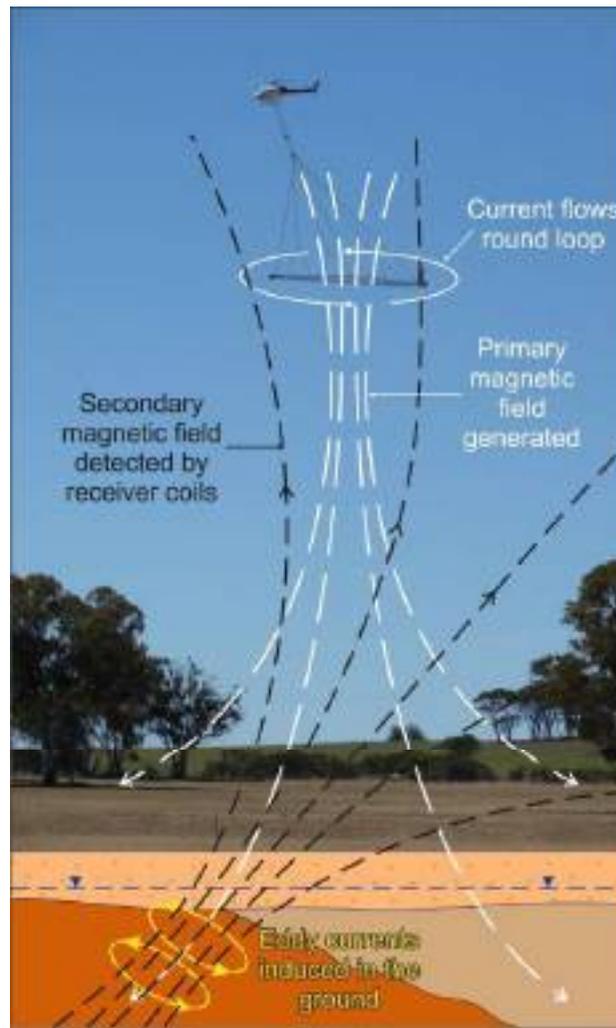
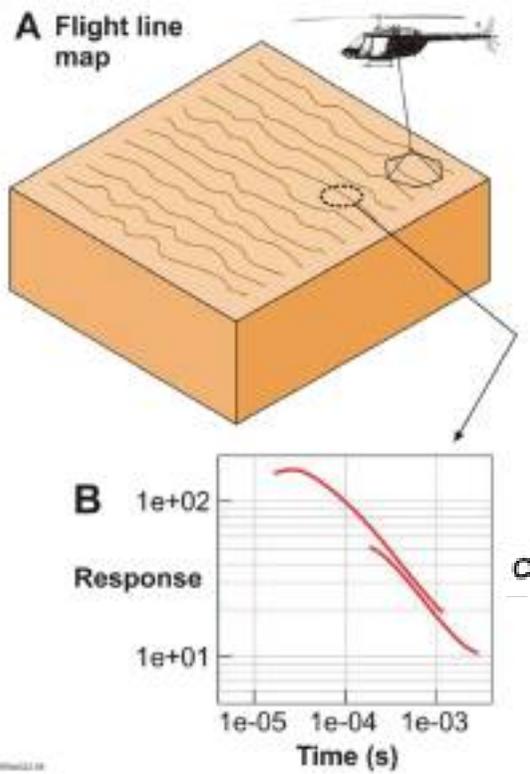
Source: Jørgensen et al., 2013. Three-dimensional geological modelling of subsurface resistivity data for the evaluation of subsurface resources in the North Sea. *Journal of Applied Earth System Science*, 247-262.



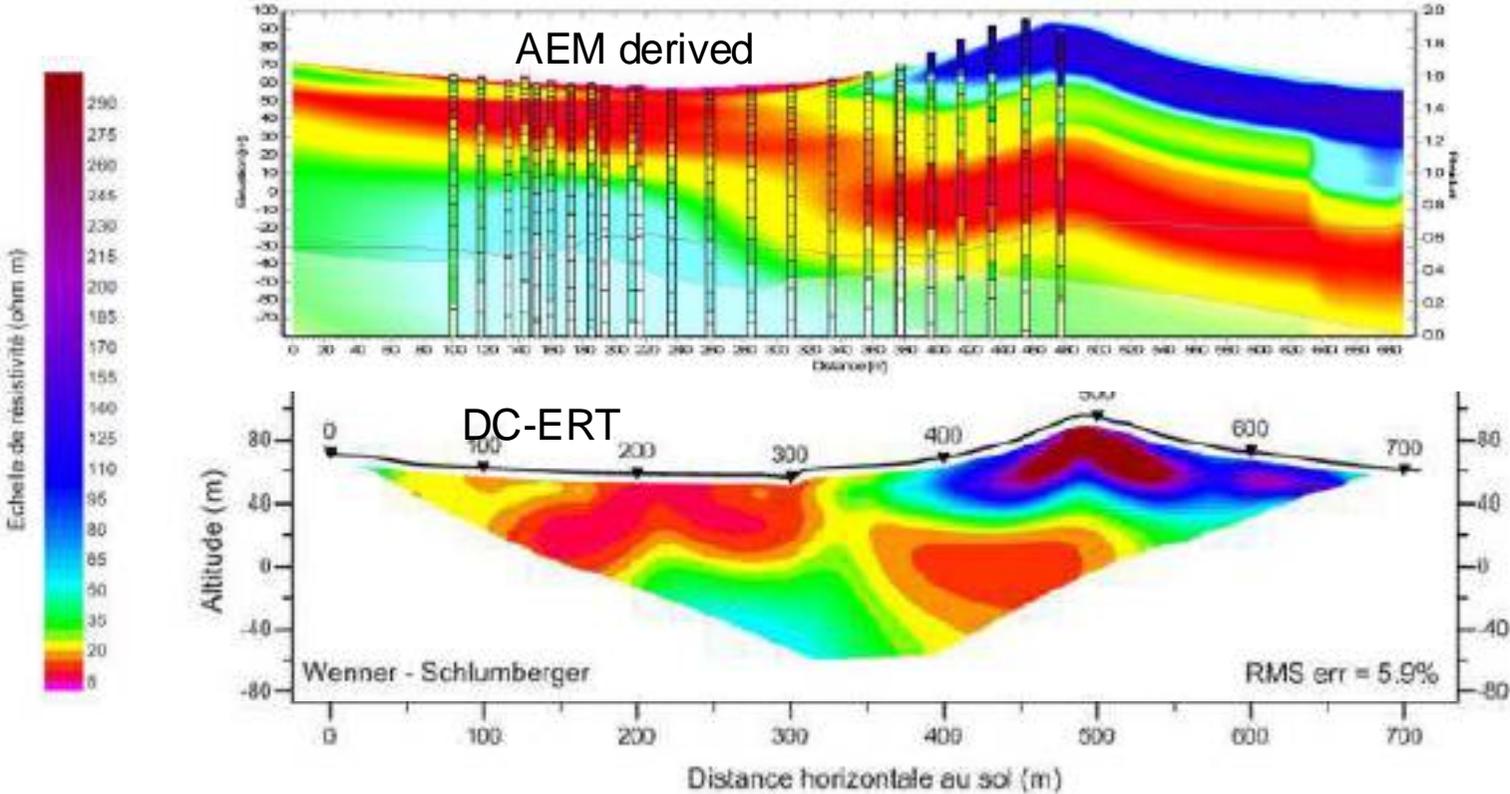
Step 4 In GeoScience3D both airborne and borehole data is collected in a 3D environment. The geologist, in collaboration with the hydrogeologist and hydrochemist, can now develop a geological model for the area being studied. The result is a model that can be used in groundwater flow calculations by applying hydrological modelling software, such as Modflow, Modflow or Feflow. (Courtesy: GEUS)



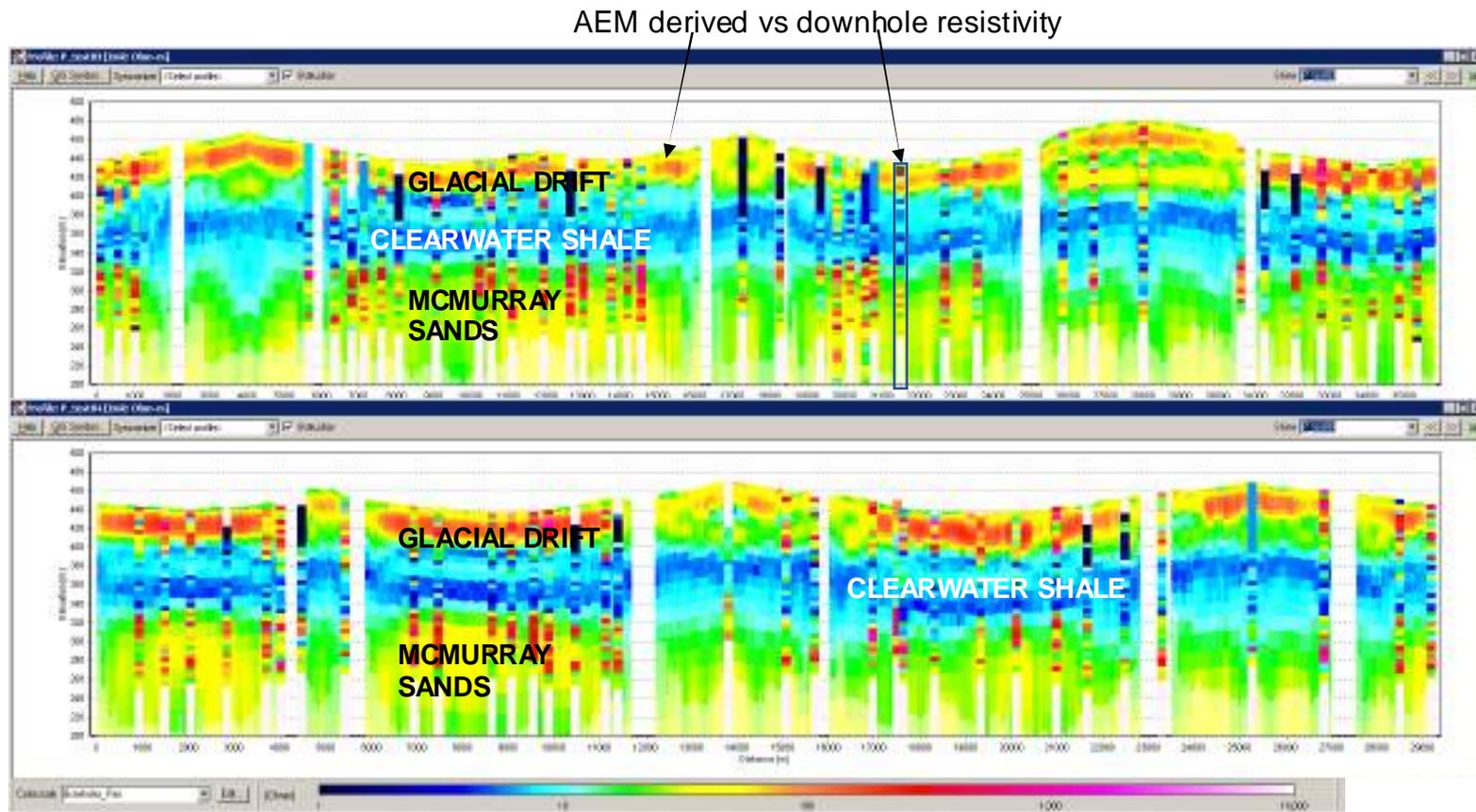
Step 5 A groundwater model reveals how groundwater flow is determined by geological structures. All the necessary data for the groundwater model are exported directly from GeoScience3D into the hydrological modelling software. Calculations of groundwater flow paths (see, for example, the example from the geological model) especially when it comes to more complex subsurface geological structures. An example would be the located water flow in the example here. (Courtesy: GEUS)



AEM a confronto con l'ERT

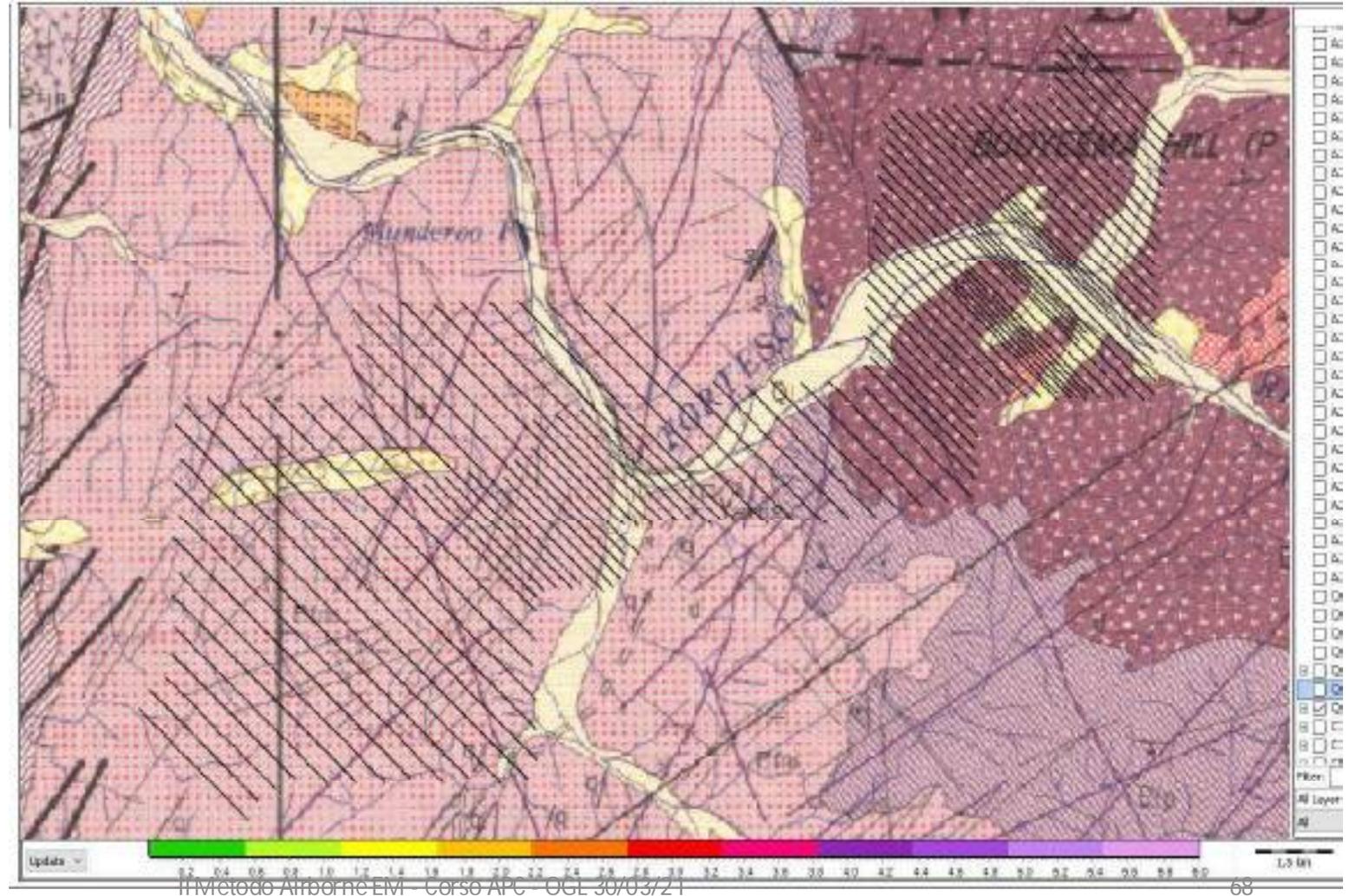


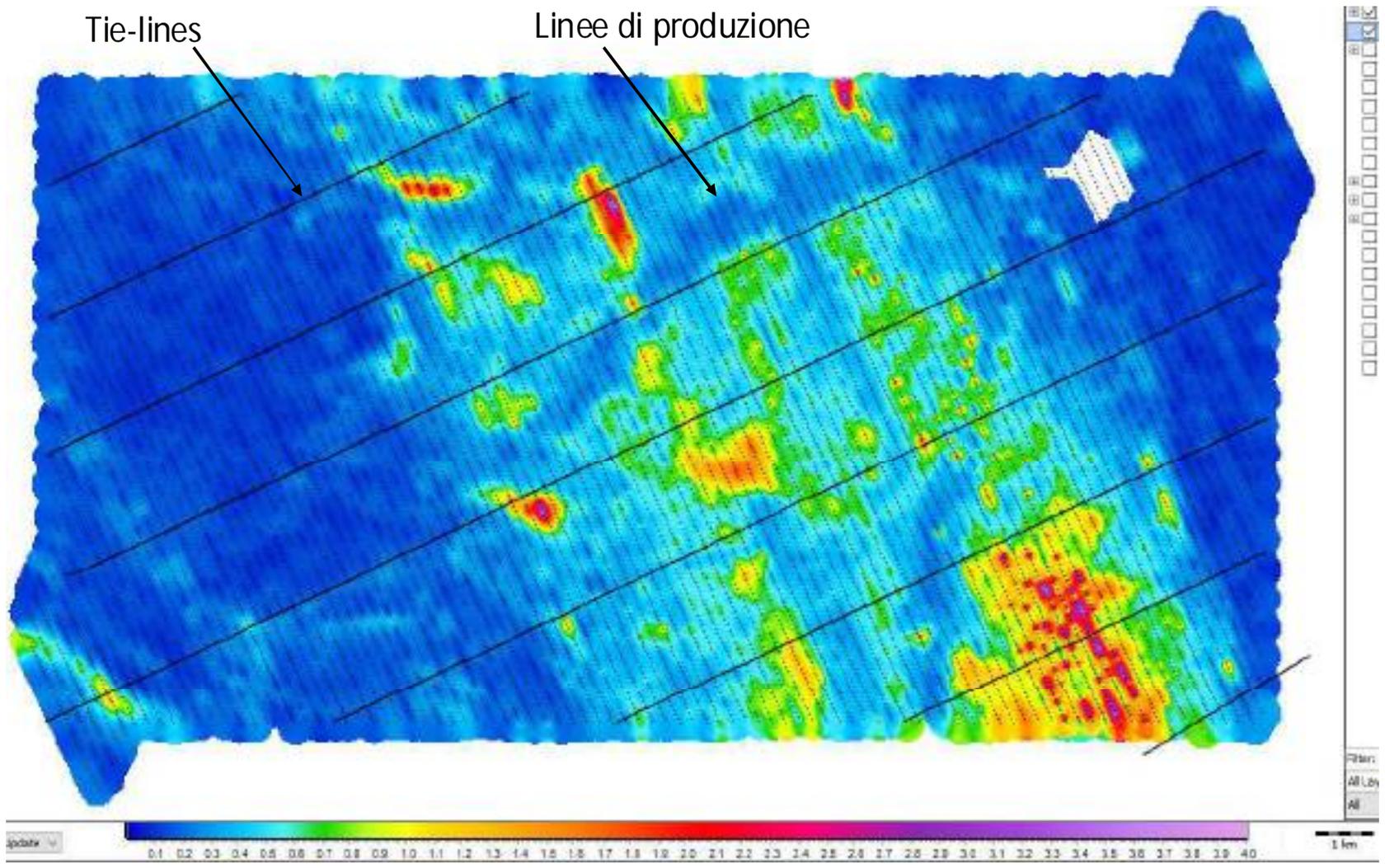
AEMI a confronto con logs elettrici



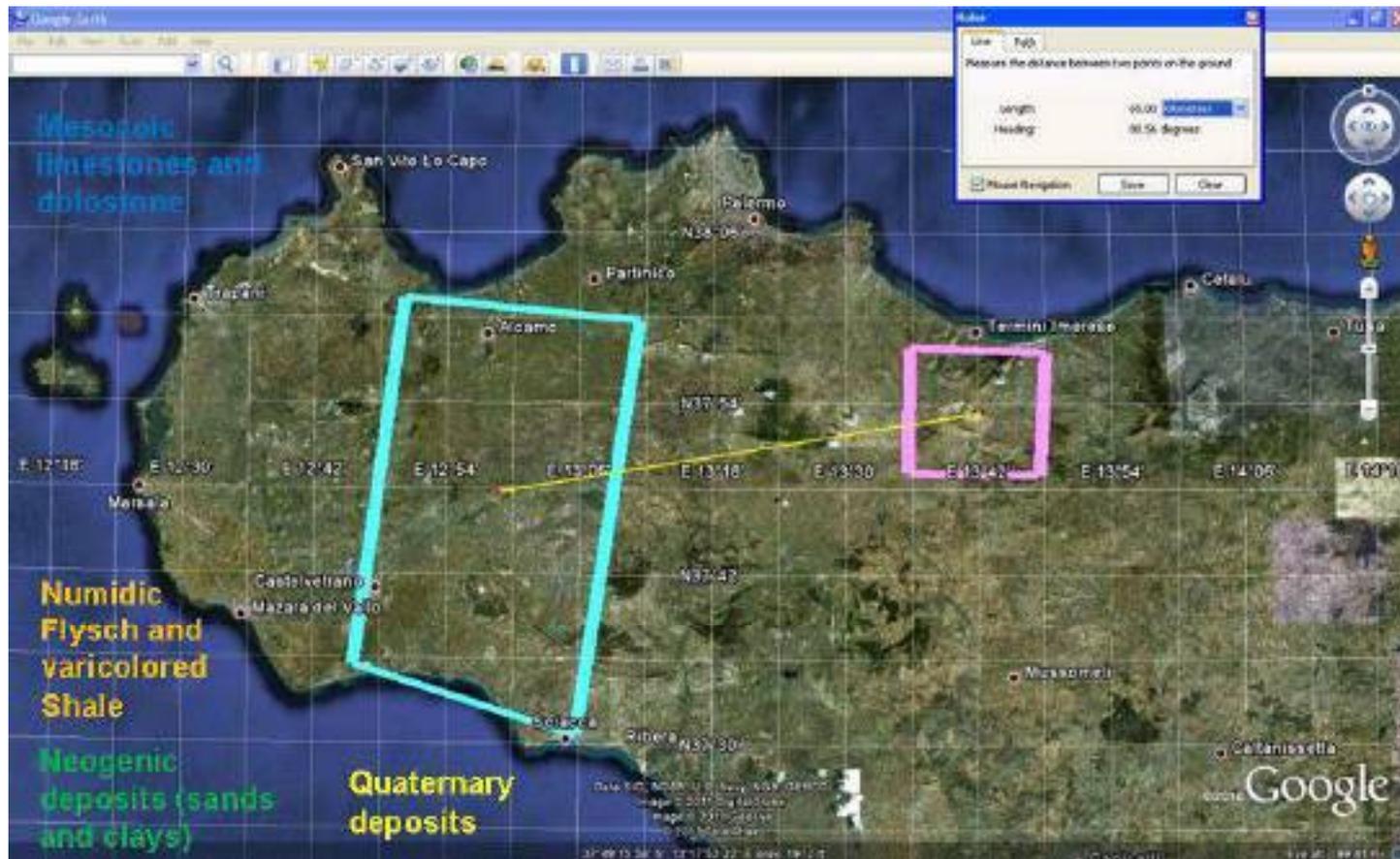
Programmazione del survey

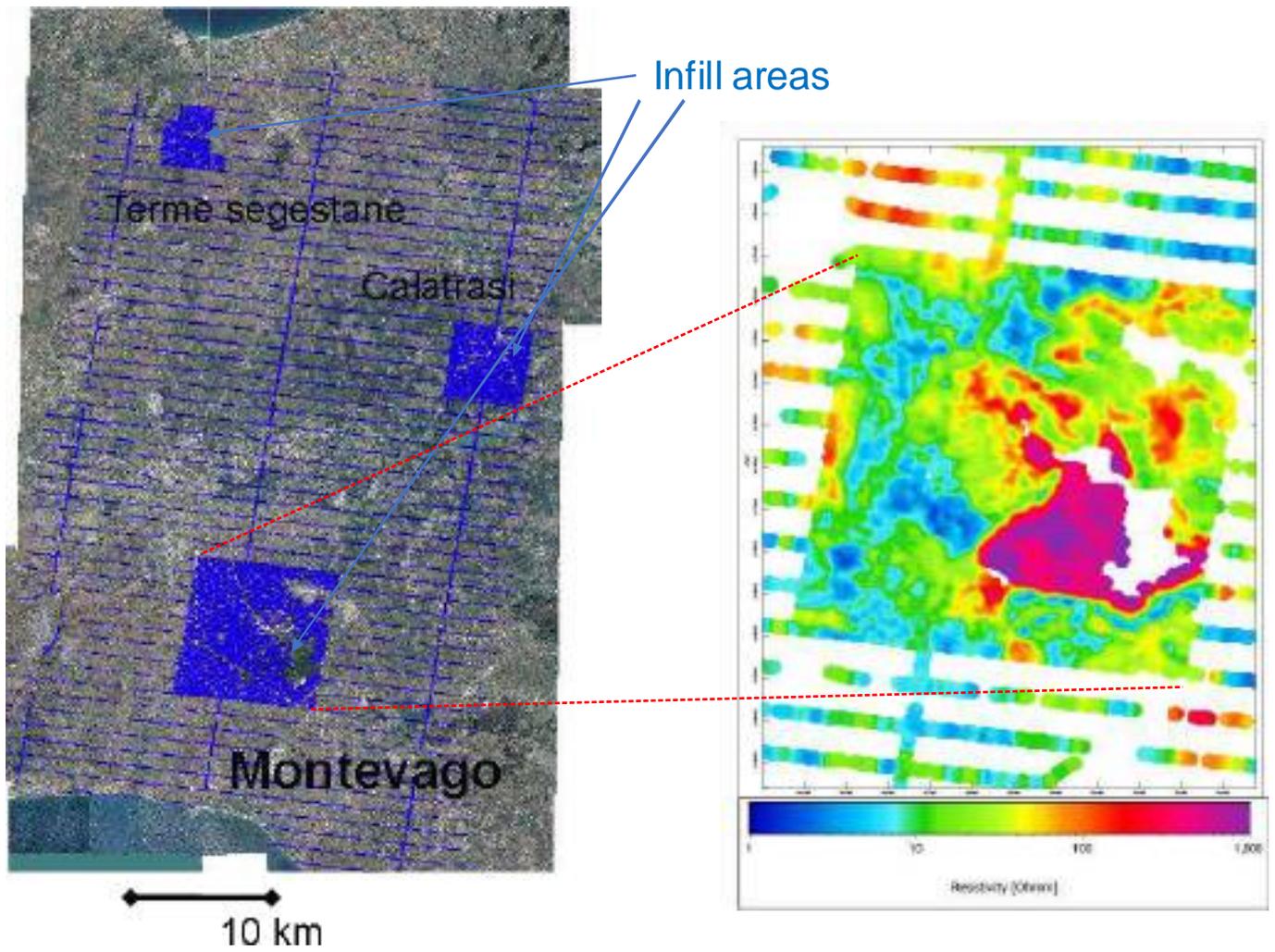
- Linee di volo spaziate da 100 a 200 m (per indagini di dettaglio)



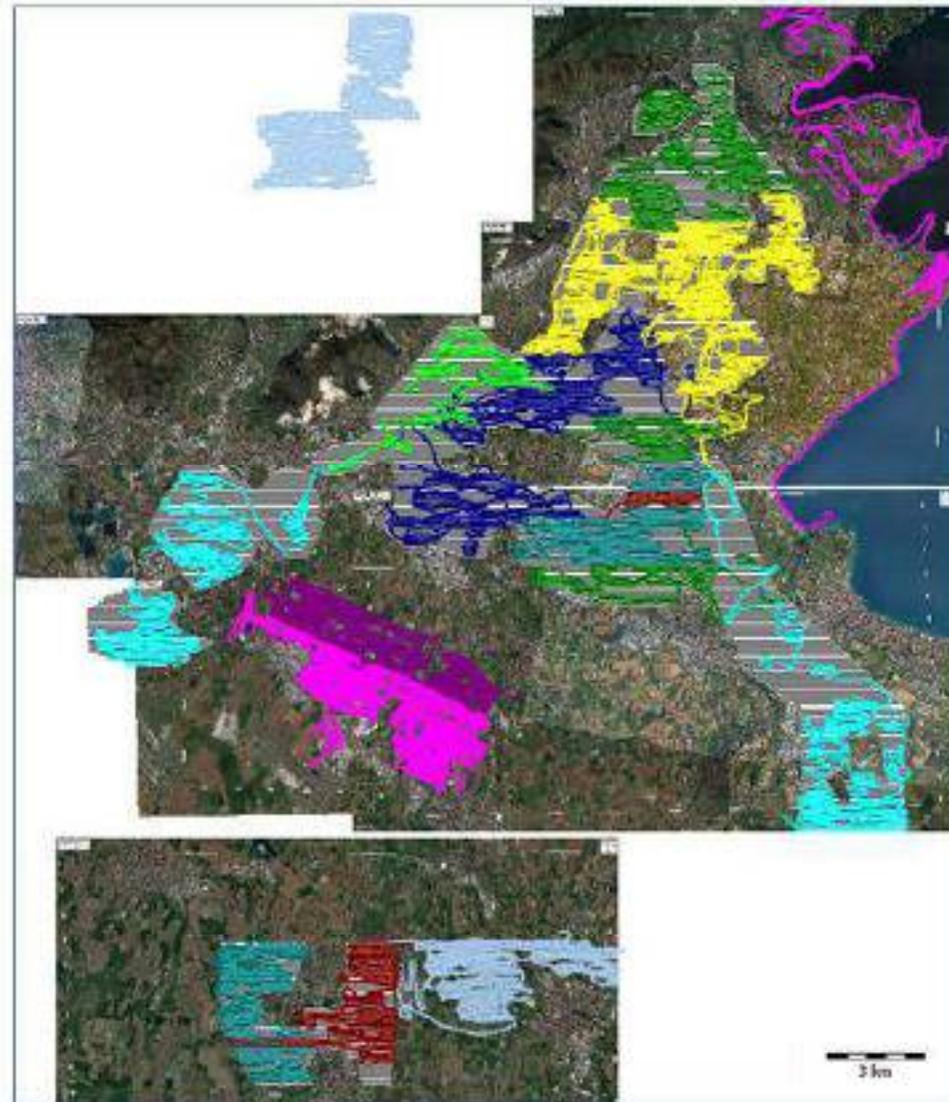


Ottimizzazione dei costi:
voli a bassa risoluzione (2 Km spacing) seguiti da infill (100 m spacing)





Adattamento del survey in aree antropizzate



Time	Seg	Type	Dur	TxAlt	RxAlt
23-02-2021 10:52:05	1	Raw	6.06	71.99	74.70
23-02-2021 10:52:05	2	Raw	100.44	72.00	72.72
23-02-2021 10:52:06	1	Average	6.06	70.94	72.62
23-02-2021 10:52:06	2	Average	100.44	71.46	74.22
23-02-2021 10:52:06	2	Raw	100.44	69.92	72.70
23-02-2021 10:52:07	1	Average	6.06	70.28	72.73
23-02-2021 10:52:07	1	Raw	6.06	69.78	72.55
23-02-2021 10:52:07	2	Average	100.44	70.04	72.62
23-02-2021 10:52:08	1	Raw	6.06	70.72	72.90
23-02-2021 10:52:08	2	Raw	100.45	70.16	72.52
23-02-2021 10:52:09	1	Average	6.06	72.74	74.79
23-02-2021 10:52:09	2	Average	100.44	71.89	74.02
23-02-2021 10:52:10	1	Average	6.06	77.31	79.22
23-02-2021 10:52:10	1	Raw	6.06	74.79	76.66
23-02-2021 10:52:10	2	Average	100.43	76.19	78.08
23-02-2021 10:52:10	2	Raw	100.43	73.62	75.50
23-02-2021 10:52:11	2	Raw	100.44	78.76	80.66
23-02-2021 10:52:12	1	Average	6.06	81.38	83.30
23-02-2021 10:52:12	1	Raw	6.06	79.02	81.74
23-02-2021 10:52:12	2	Average	100.44	80.74	82.68
23-02-2021 10:52:13	1	Raw	6.06	82.88	84.84
23-02-2021 10:52:13	2	Raw	100.44	82.72	84.63
23-02-2021 10:52:14	1	Average	6.06	82.87	84.87
23-02-2021 10:52:14	2	Average	100.43	82.64	84.62
23-02-2021 10:52:14	2	Raw	100.43	82.56	84.55
23-02-2021 10:52:15	1	Average	6.06	85.11	87.22
23-02-2021 10:52:15	1	Raw	6.06	82.84	84.89
23-02-2021 10:52:15	2	Average	100.43	84.16	86.26
23-02-2021 10:52:16	1	Raw	6.06	87.35	89.67
23-02-2021 10:52:16	2	Raw	100.43	85.76	87.97
23-02-2021 10:52:17	1	Average	6.06	91.77	94.08
23-02-2021 10:52:17	2	Average	100.42	95.80	92.05
23-02-2021 10:52:18	1	Average	6.06	101.26	103.86
23-02-2021 10:52:18	1	Raw	6.06	96.13	98.58
23-02-2021 10:52:18	2	Average	100.43	99.05	101.87
23-02-2021 10:52:18	2	Raw	100.43	93.85	96.14
23-02-2021 10:52:19	2	Raw	100.42	104.24	106.99
23-02-2021 10:52:20	1	Average	6.06	109.80	112.67
23-02-2021 10:52:20	1	Raw	6.06	108.30	109.13
23-02-2021 10:52:20	2	Average	100.42	109.16	110.99
23-02-2021 10:52:21	1	Raw	6.06	112.30	114.21
23-02-2021 10:52:21	2	Raw	100.42	112.07	114.98
23-02-2021 10:52:22	1	Average	6.06	114.41	117.93
23-02-2021 10:52:22	2	Average	100.43	113.78	116.67
23-02-2021 10:52:22	2	Raw	100.42	113.43	116.35
23-02-2021 10:52:23	1	Average	6.06	115.04	118.04
23-02-2021 10:52:23	1	Raw	6.06	115.51	118.46
23-02-2021 10:52:23	2	Average	100.42	115.10	118.08
23-02-2021 10:52:24	1	Raw	6.06	114.57	117.62
23-02-2021 10:52:24	2	Raw	100.42	114.77	117.80
23-02-2021 10:52:25	1	Average	6.06	114.62	117.68
23-02-2021 10:52:25	2	Average	100.42	114.63	117.63
23-02-2021 10:52:26	1	Average	6.06	118.61	119.61
23-02-2021 10:52:26	1	Raw	6.06	114.67	117.72
23-02-2021 10:52:26	2	Average	100.41	115.21	118.22
23-02-2021 10:52:26	2	Raw	100.41	114.49	117.50
23-02-2021 10:52:27	2	Raw	100.41	115.60	118.89
23-02-2021 10:52:28	1	Average	6.06	119.72	121.62
23-02-2021 10:52:28	1	Raw	6.06	116.55	119.49

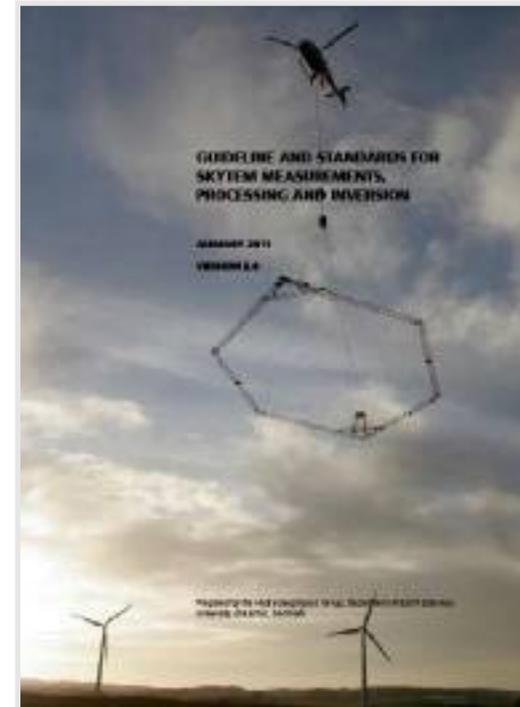
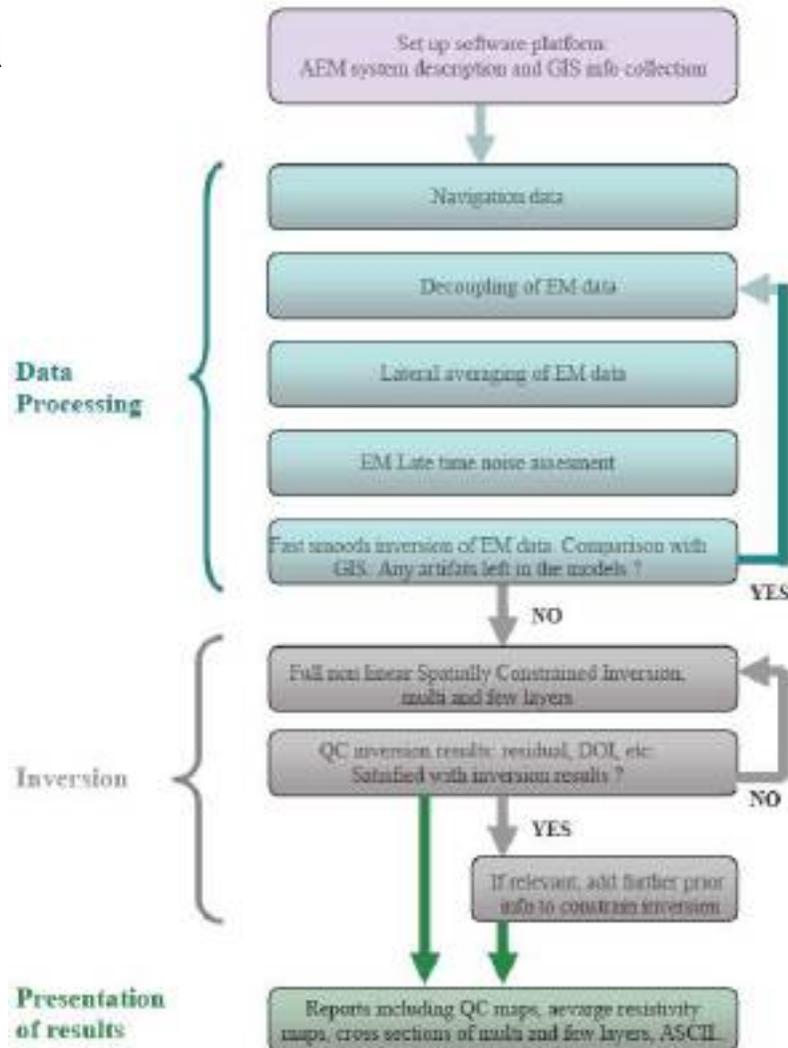
IL METODO AIRBORNE EM COME STRUMENTO PER LO STUDIO DI PROBLEMATICHE IDROGEOLOGICHE, GEOTECNICHE ED AMBIENTALI

Dott. Geol. Antonio Menghini

- Descrizione del metodo EM
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- Inversione
- Interpretazione
- Case-studies
- Potenziali applicazioni sul territorio Italiano

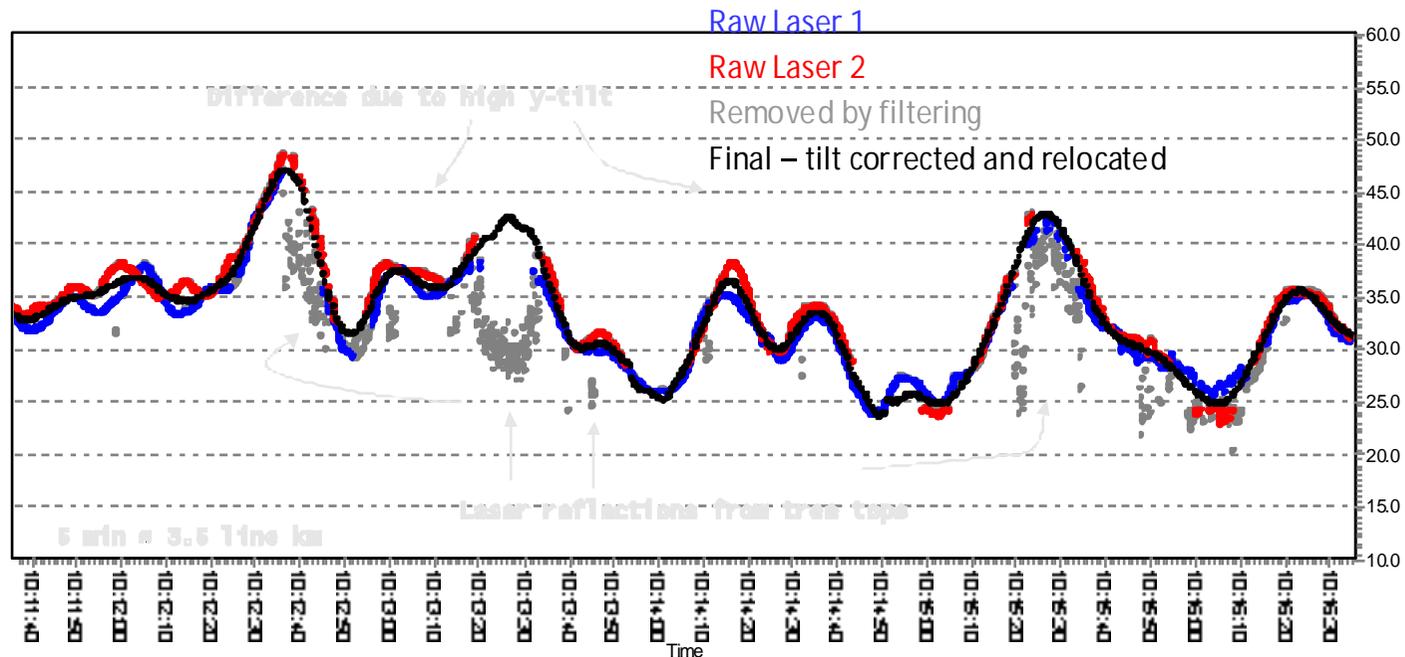


Data

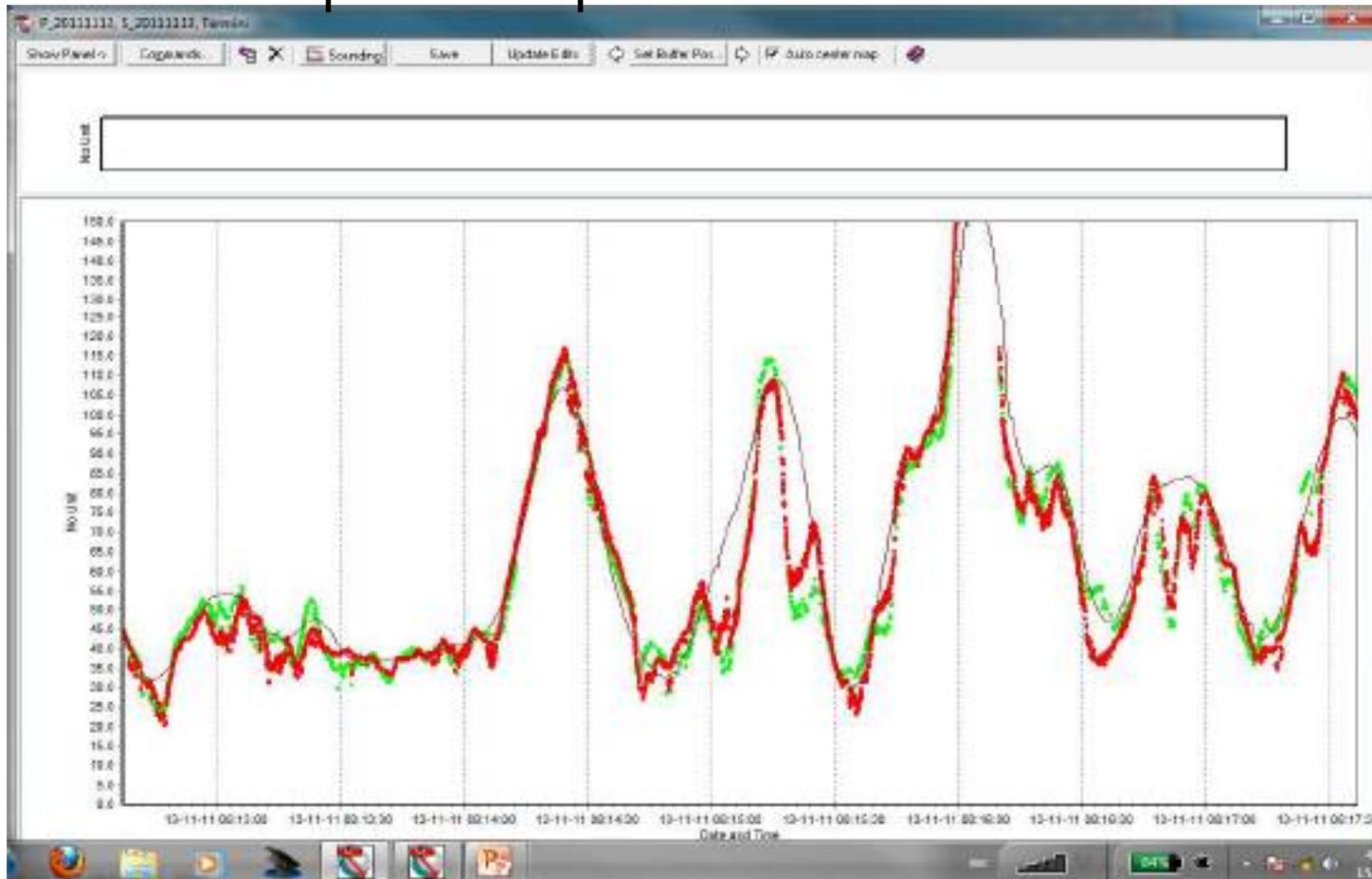


Navigation Processing

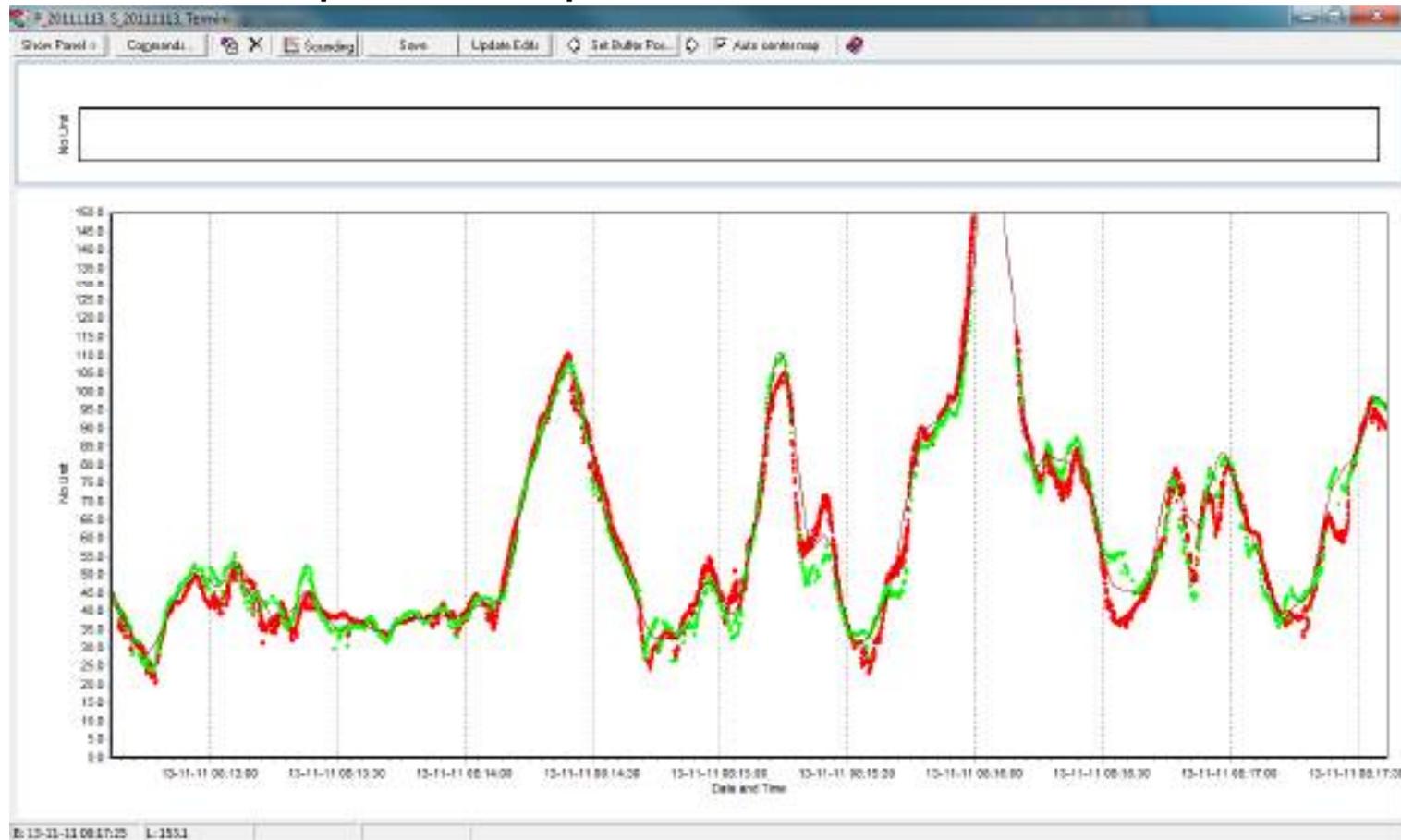
- Removal of laser reflection from tree tops
- Correction of altitudes for tilt



- First attempt to interpolate altitude data

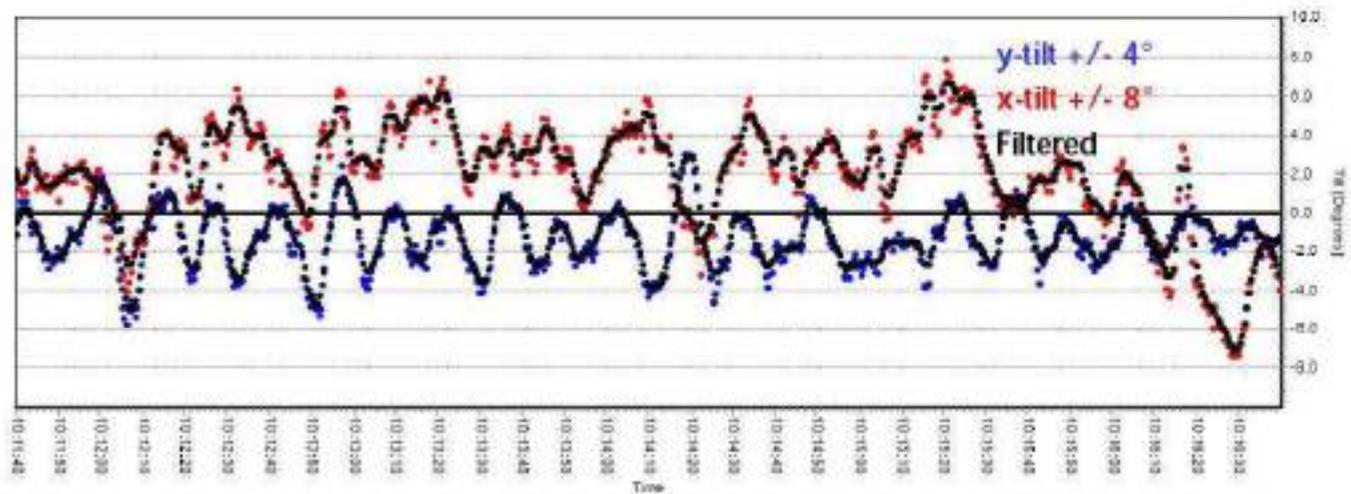


- Final attempt to interpolate altitude data



Data processing: Navigation Data

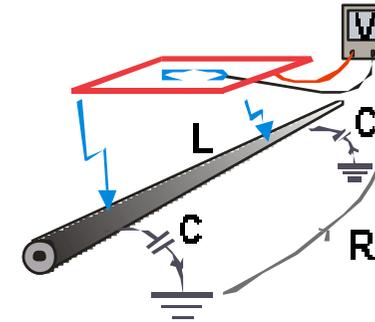
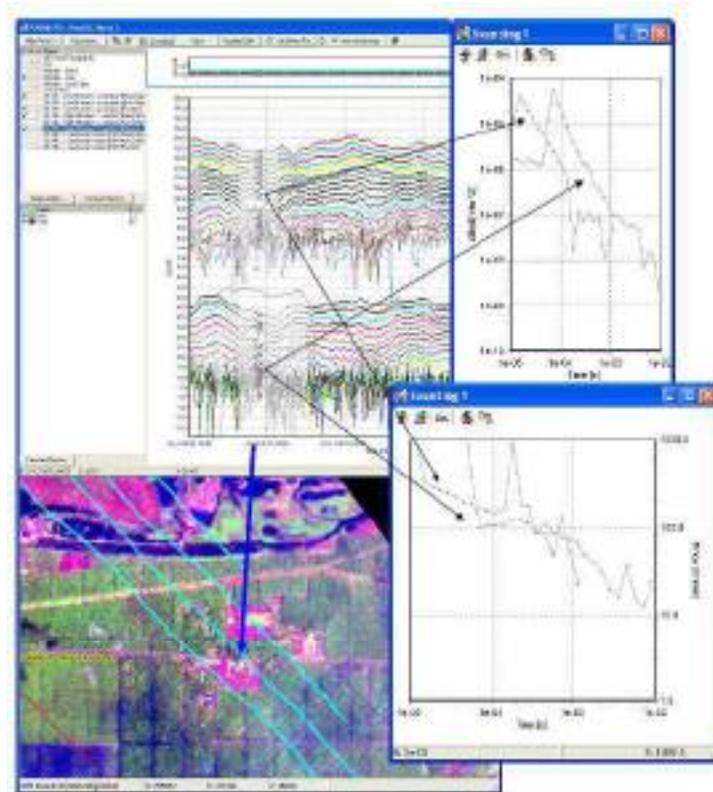
- Tilt corrections



Tilt variations of 10° can cause a voltage variation of 3 %

Decoupling

Capacitive coupling



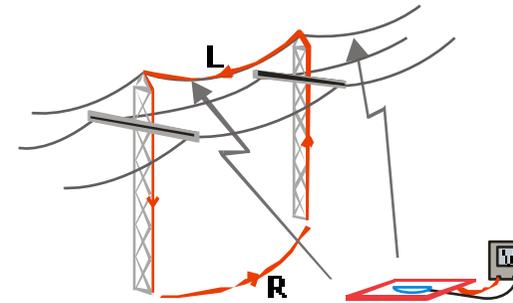
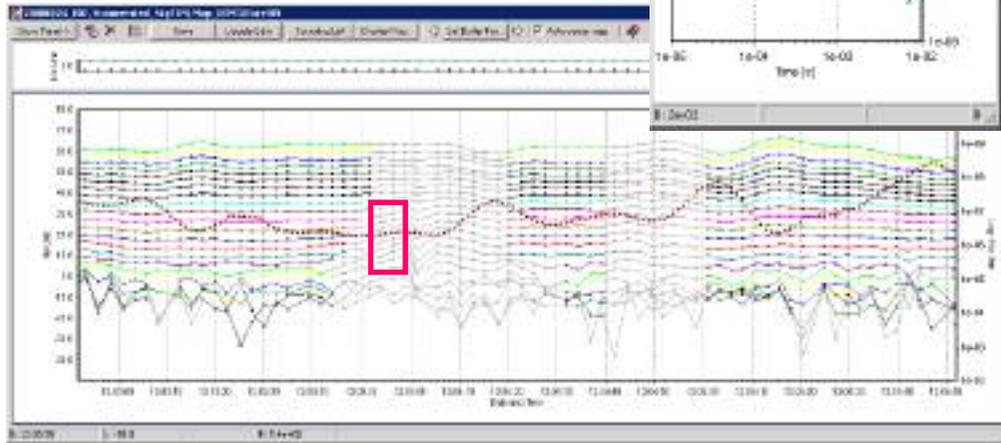
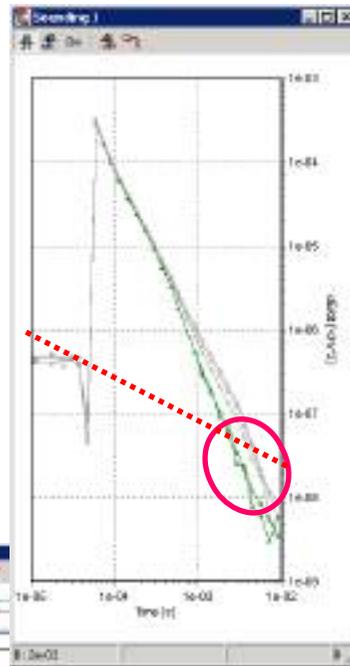
CHANGE OF TRANSIENT SIGN

ANOMALOUS DECAY RATE

EASILY RECOGNIZABLE

Decoupling

Galvanic coupling



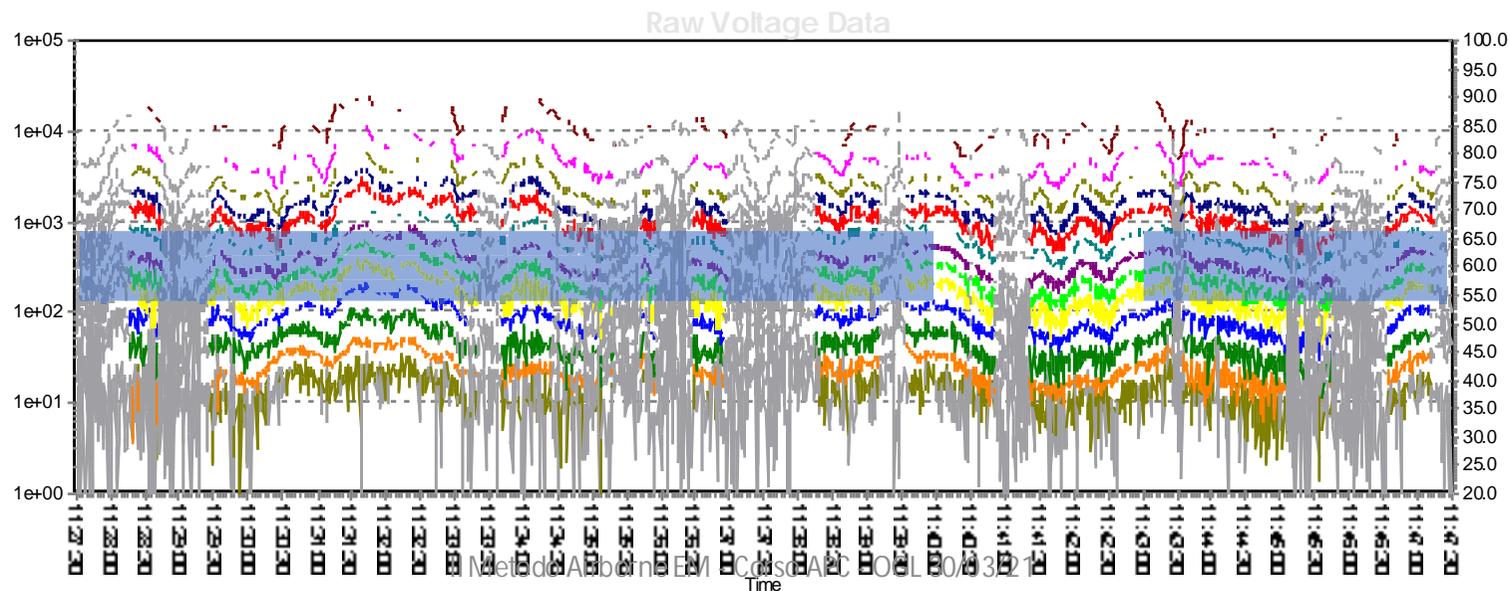
APPARENTLY GOOD TRANSIENT

SIGNAL INCREASE

**HARDLY RECOGNIZABLE:
IT CAN BE EXCHANGED WITH
A DEEP CONDUCTOR**

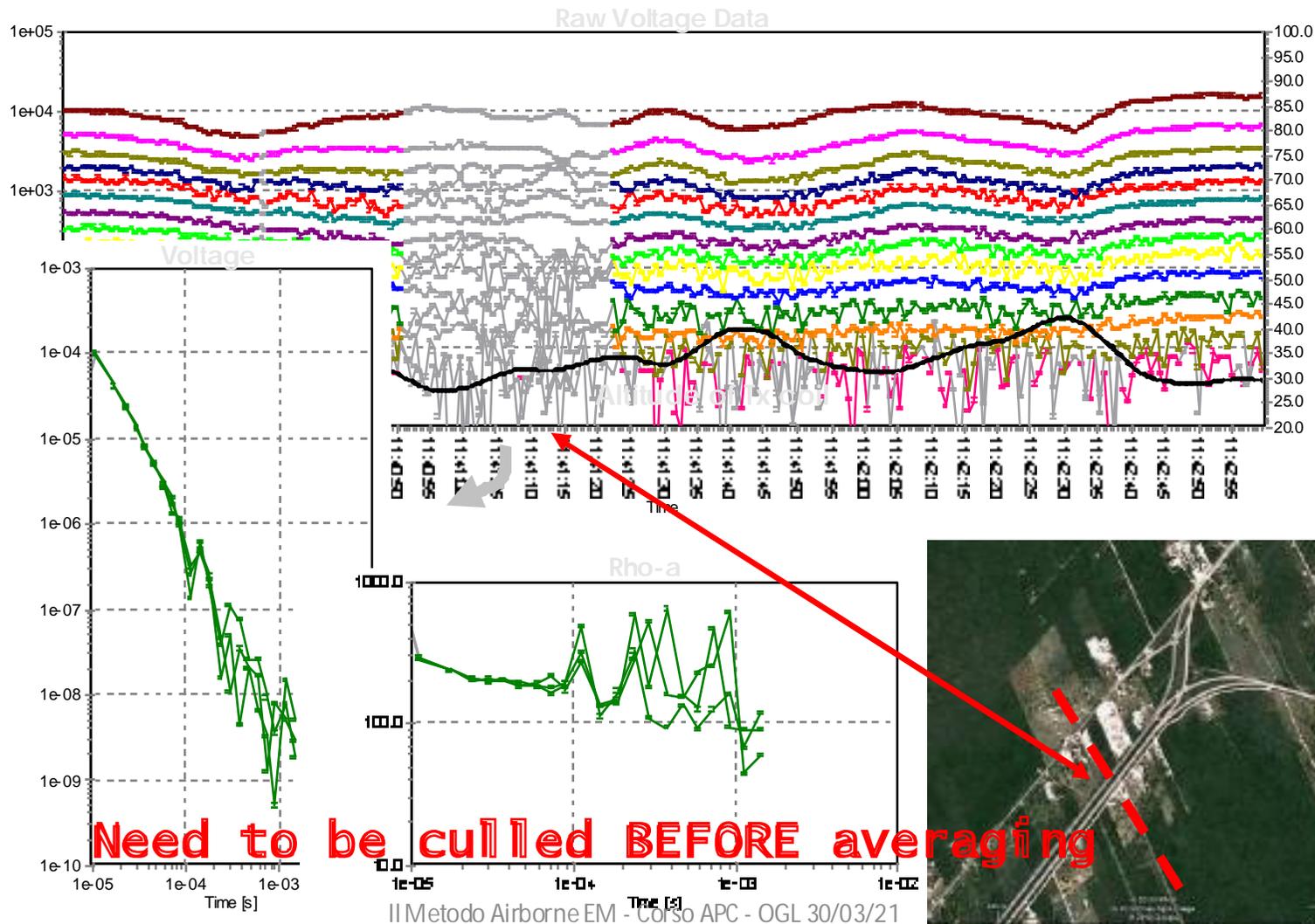
Data coupled to infrastructures

- 10 min \approx 7 line km
- Capacitive – rapid sign reversals
- Inductive – increase signal – easily mistaken for low resistivity layer

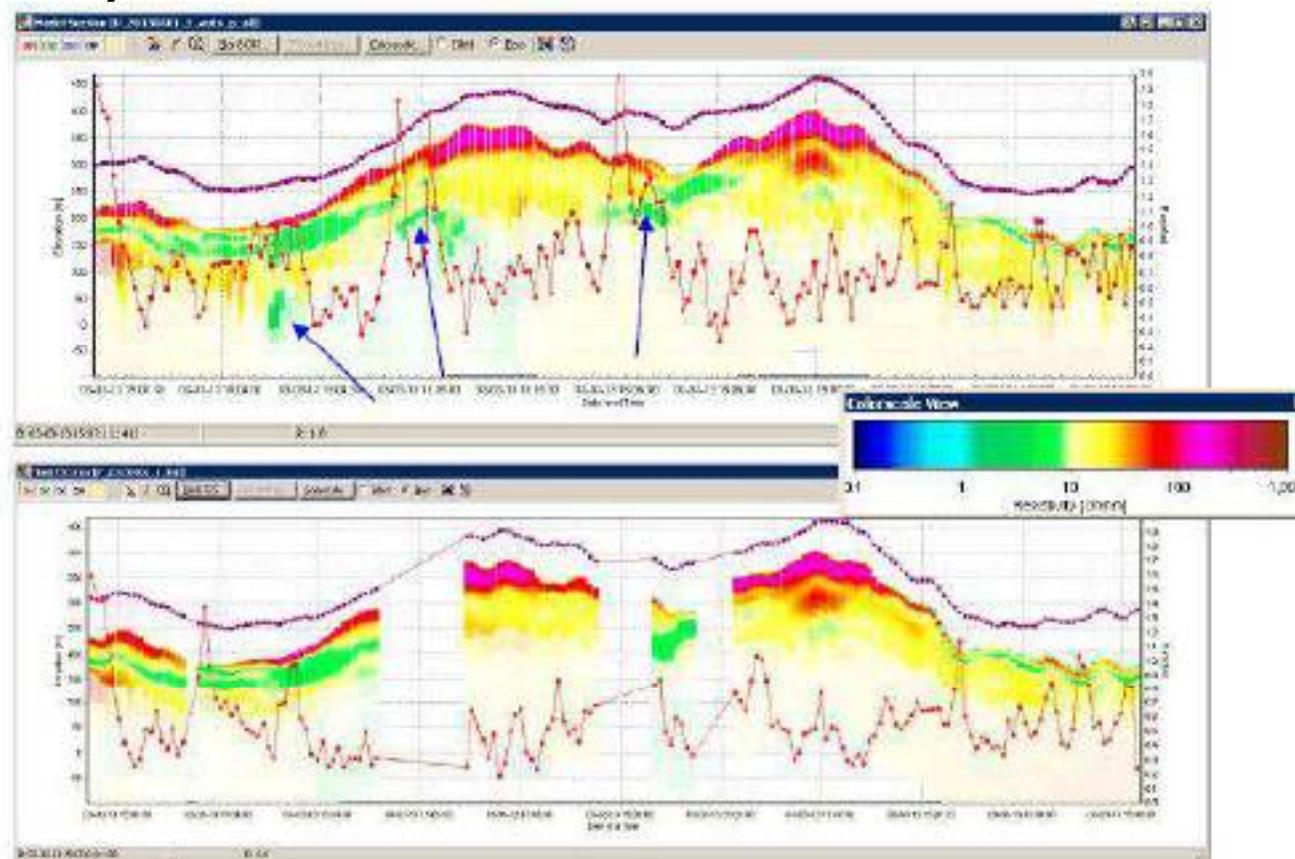


Data coupled to infrastructures

3 min \approx 2 line km



Fictitious conductive deep layers



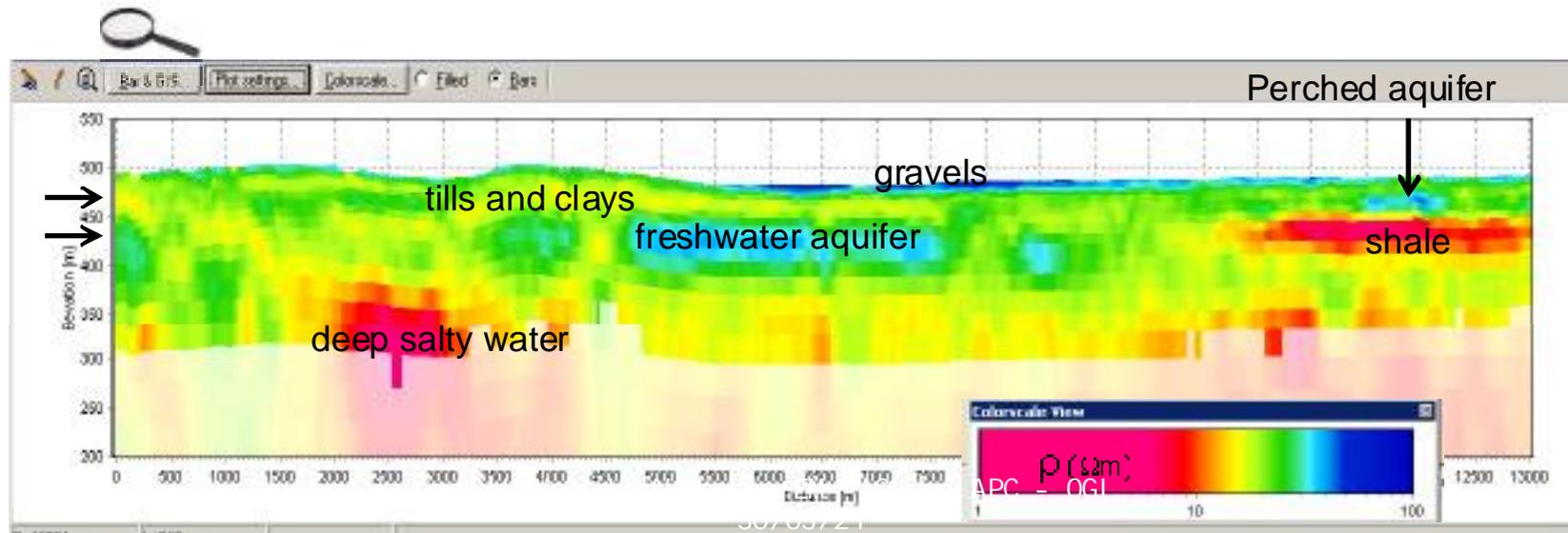
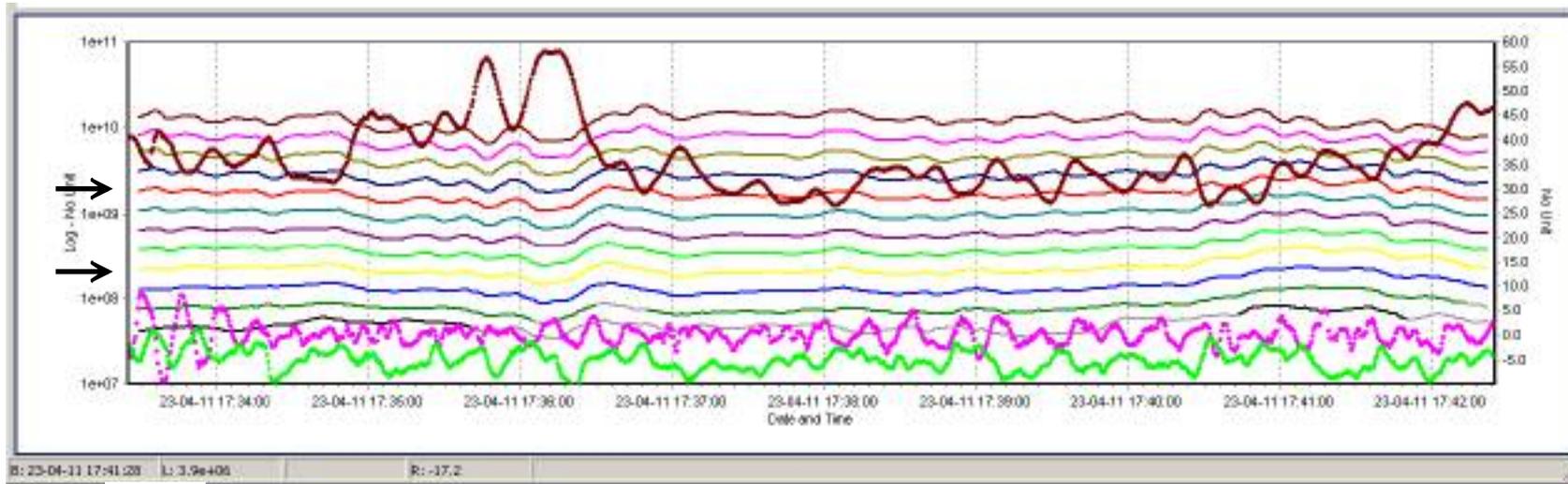
IL METODO AIRBORNE EM COME STRUMENTO PER LO STUDIO DI PROBLEMATICHE IDROGEOLOGICHE, GEOTECNICHE ED AMBIENTALI

Dott. Geol. Antonio Menghini

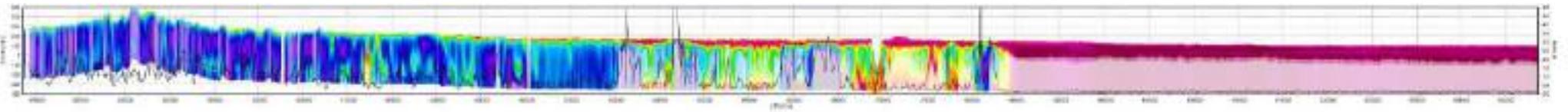
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Inversion of AEM data



170 Km di dati !!!



Da Roma A Napoli

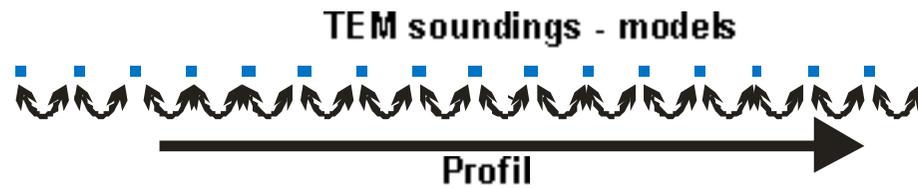
- 8000 sondaggi da invertire =
- circa 1 settimana di calcoli (con pc standard)

- LCI – soundings

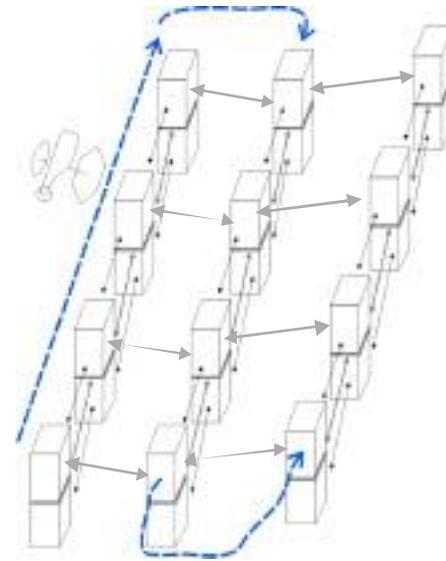
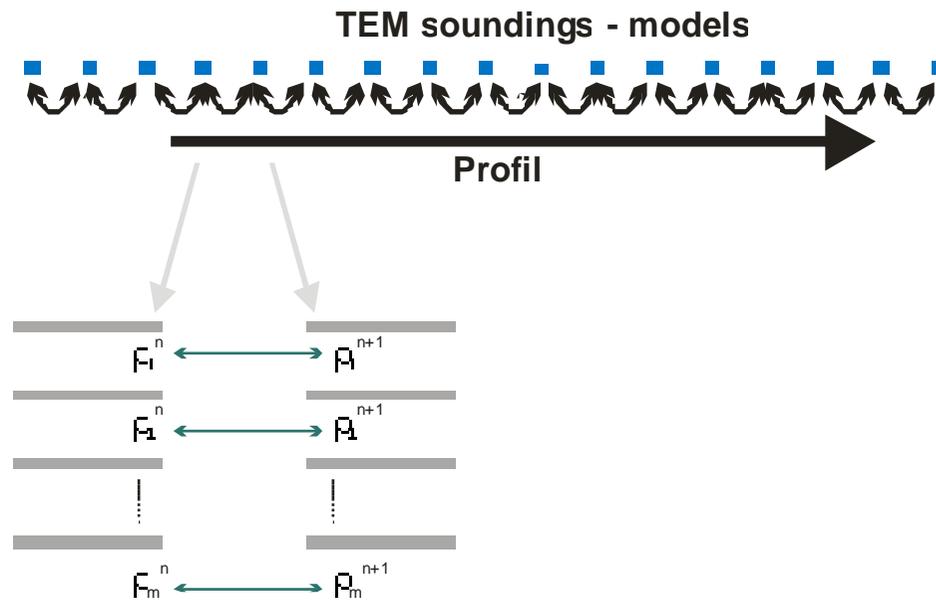


Inversion Methodology

- LCI – soundings
- Add constraints – a variance between the model parameters

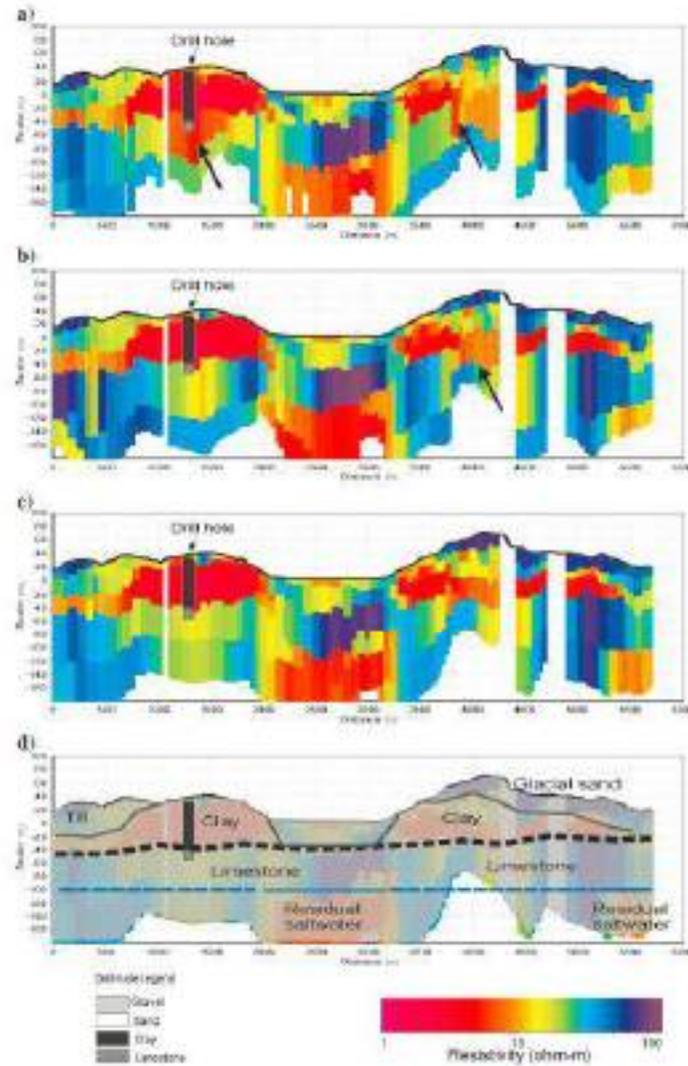
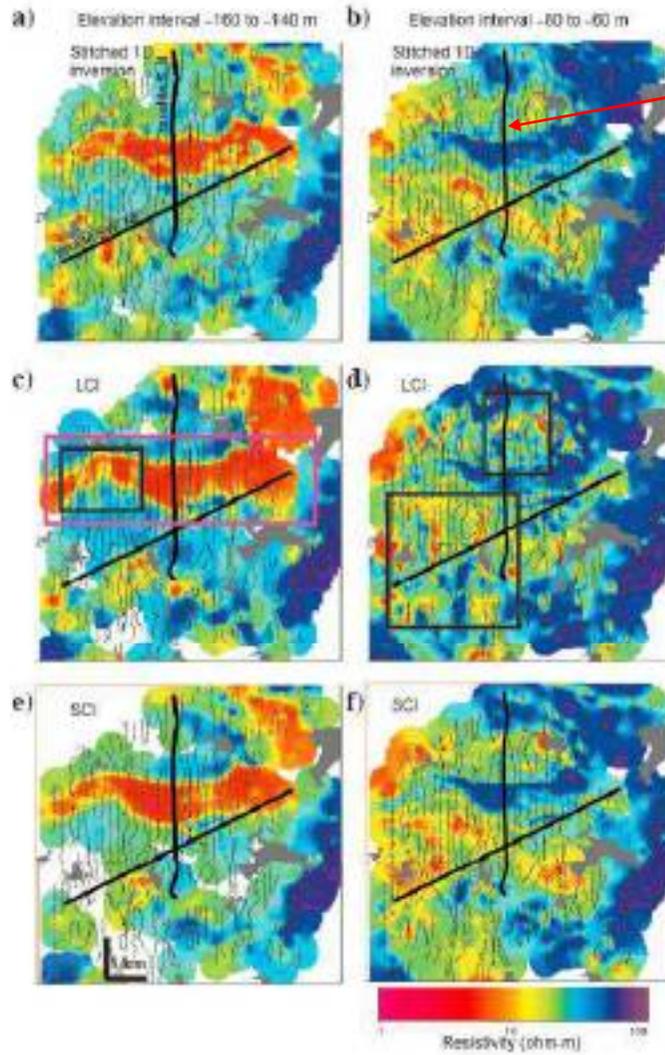


SCI



Spatial constraints imposed in the inversion problem carry information reflecting expected geological variability of the area

LCI

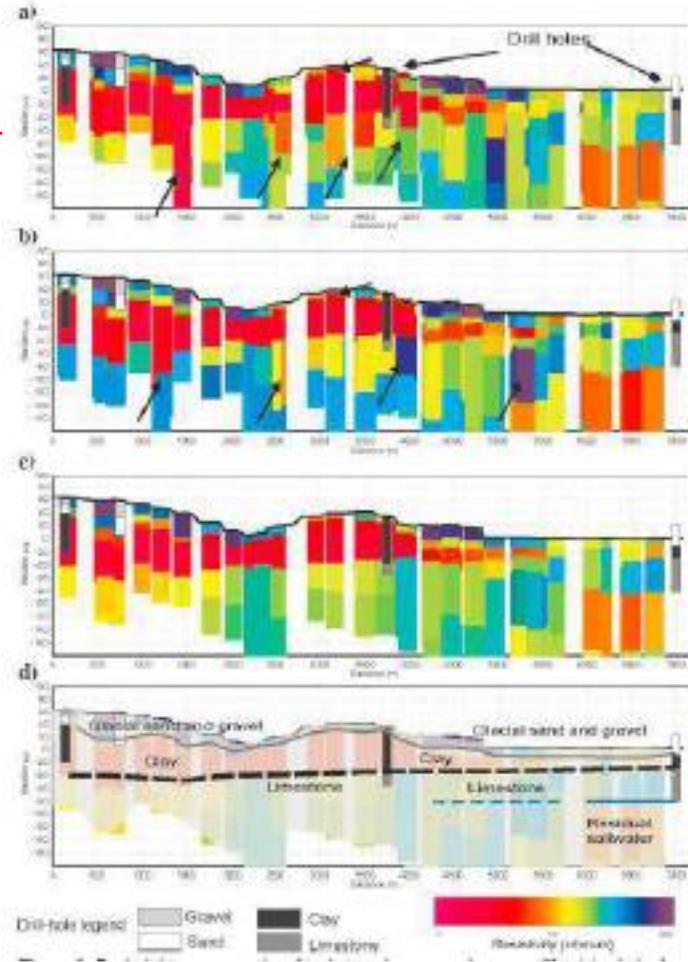
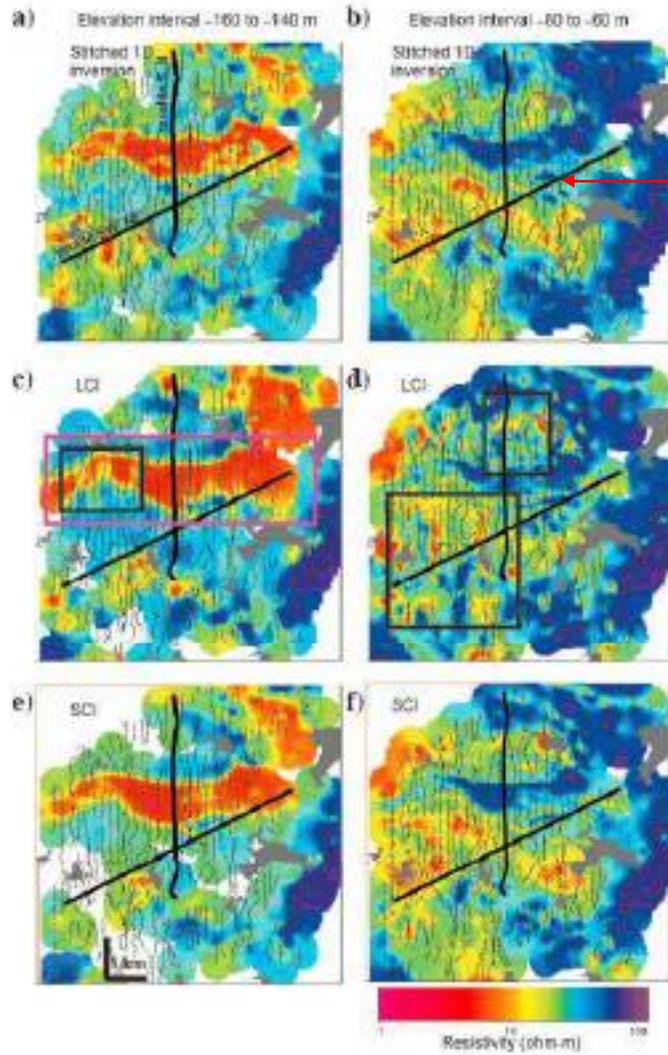


Stitched

LCI

SCI

LCI



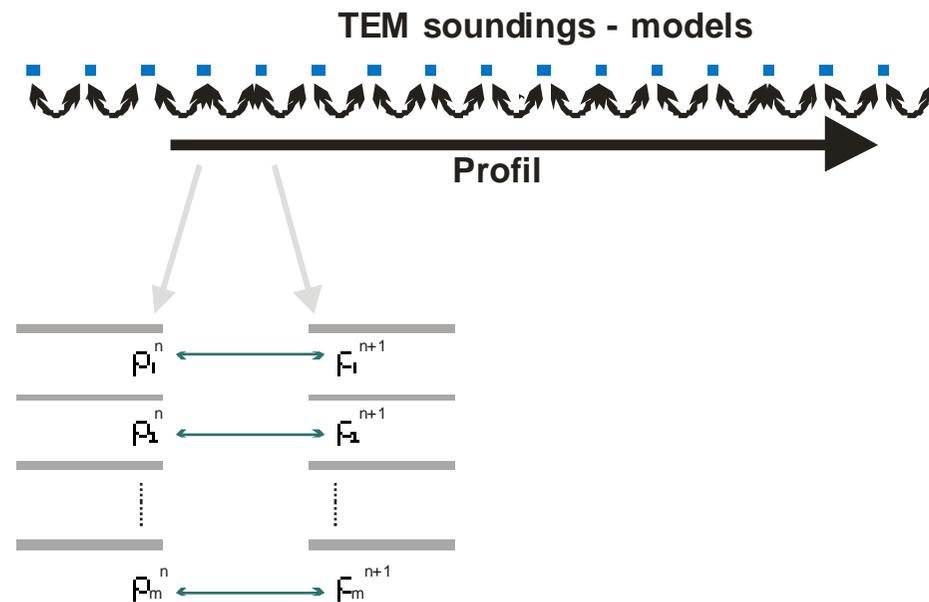
Stitched

LCI

SCI

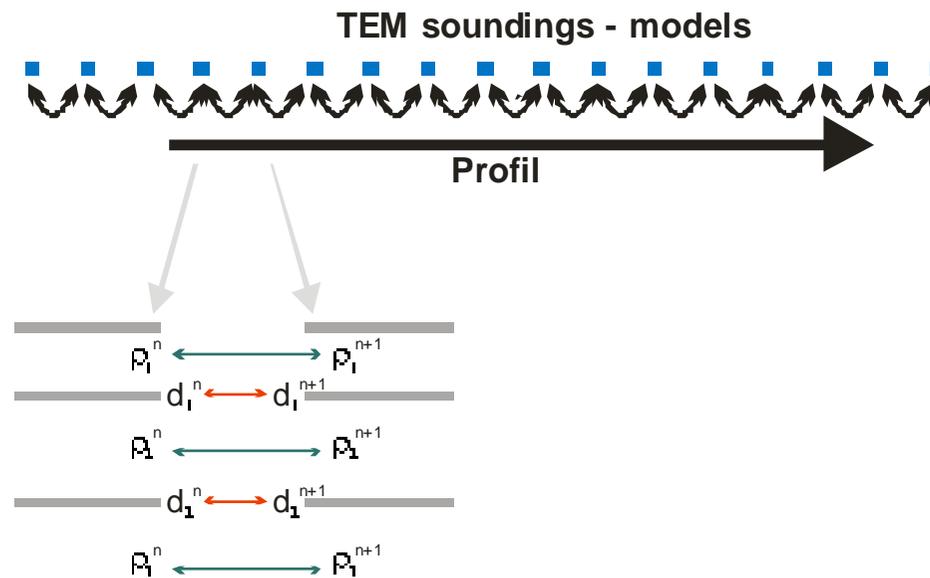
Inversion Methodology

- LCI – soundings
- Add constraints – a variance between the model parameters
- Smooth model parameterization – fixed layer boundaries

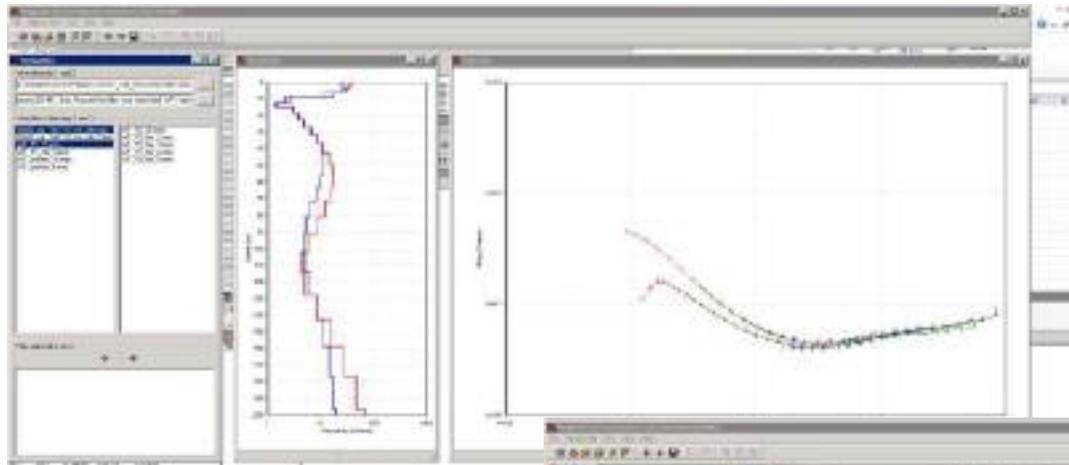


Inversion Methodology

- LCI – soundings
- Add constraints – a variance between the model parameters
- Few layer parameterization – all parameters floating

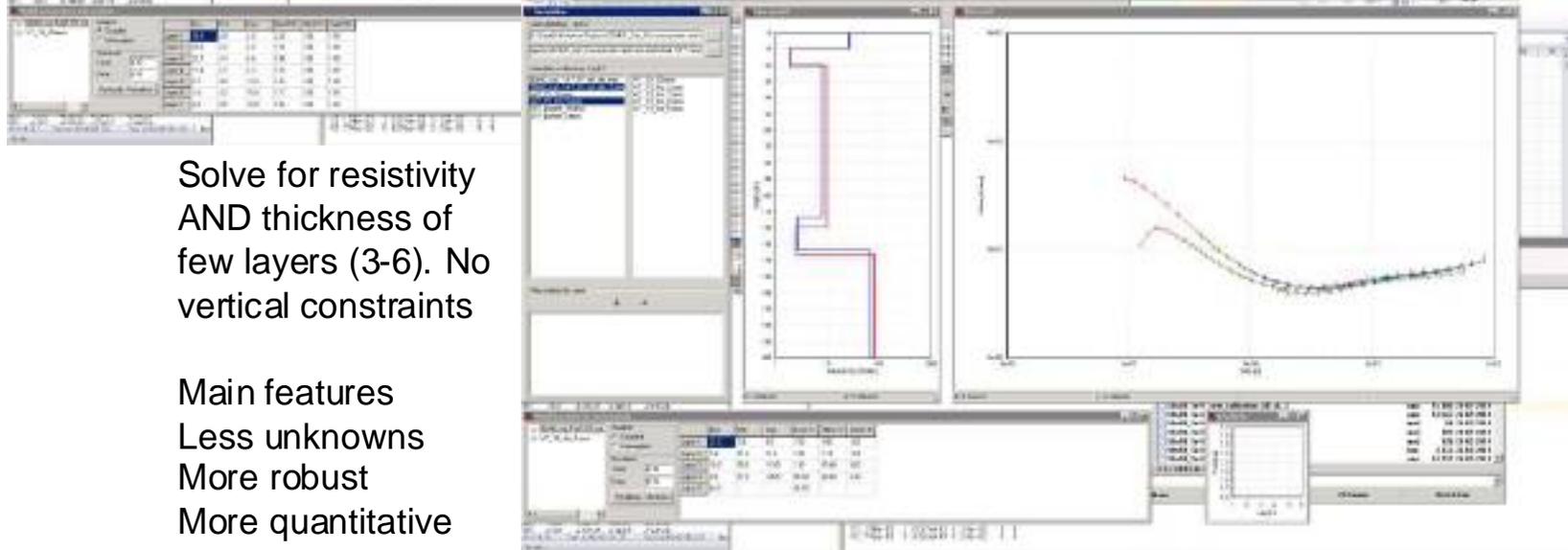


Few vs multilayer inversion: complementary approaches



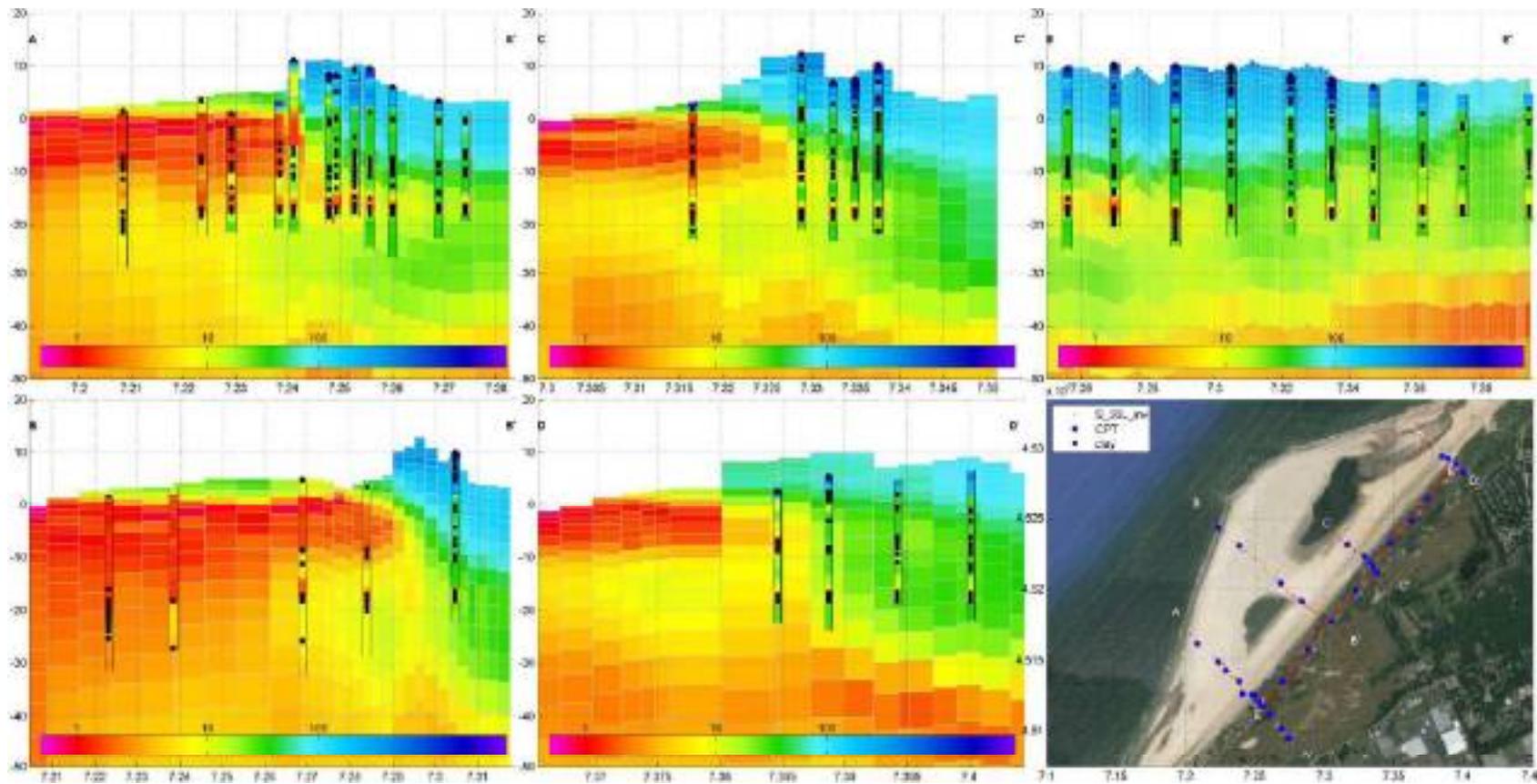
Solve for resistivity of many
(e.g., 20) layers
Impose vertical constraints

Subtle features
More unknowns
Less robust
More qualitative

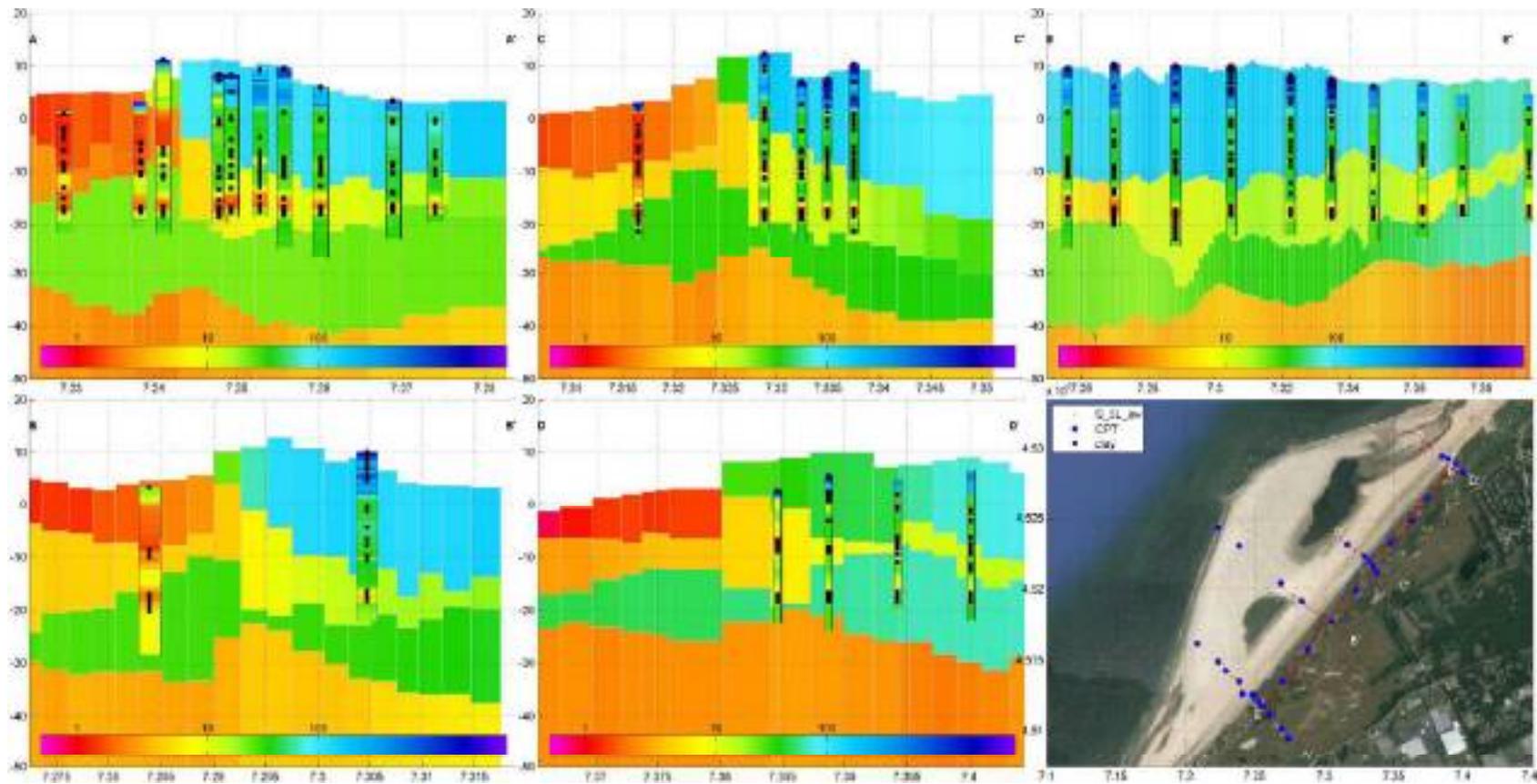


Solve for resistivity
AND thickness of
few layers (3-6). No
vertical constraints

Main features
Less unknowns
More robust
More quantitative

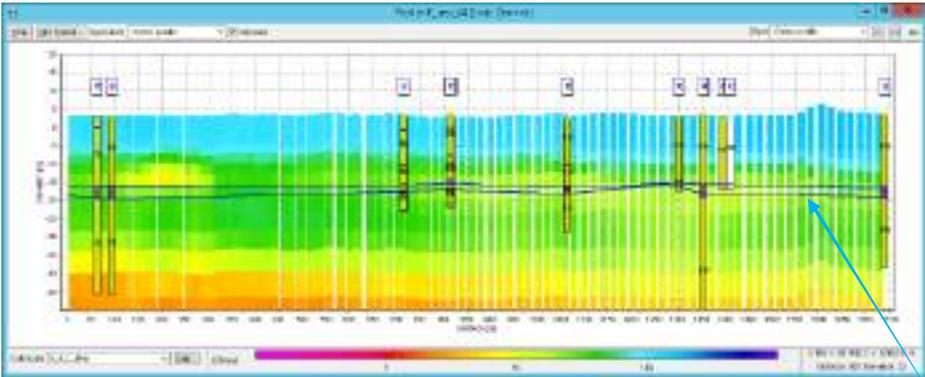


Comparison with electric logs

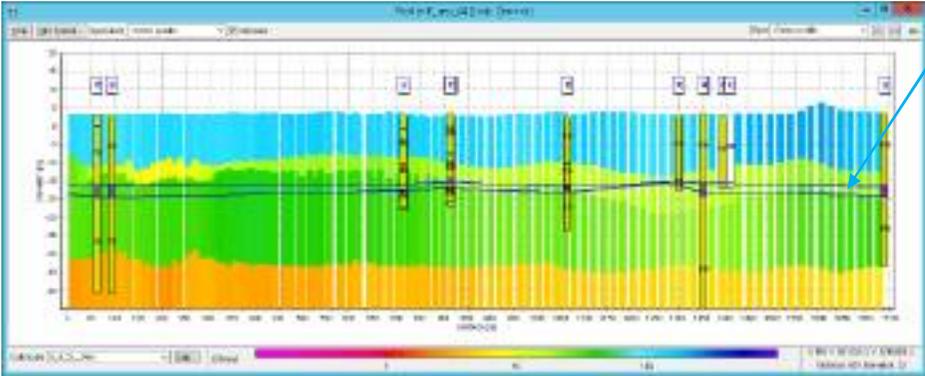


Comparison with electric logs

Multilayer

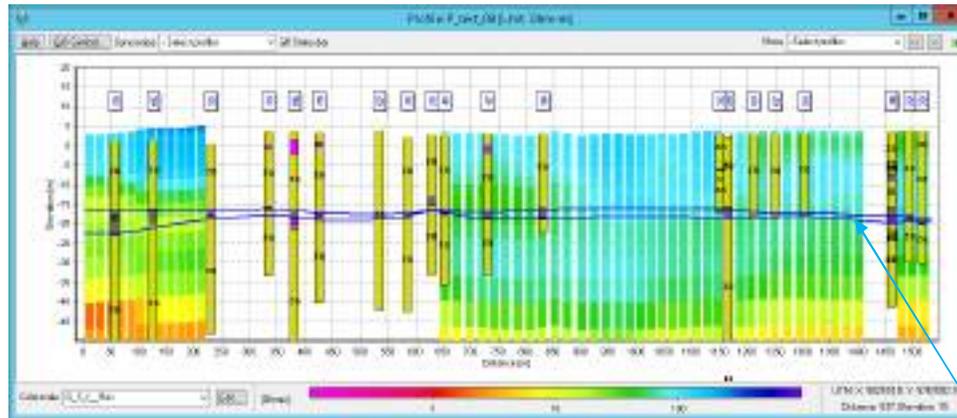


5 layers

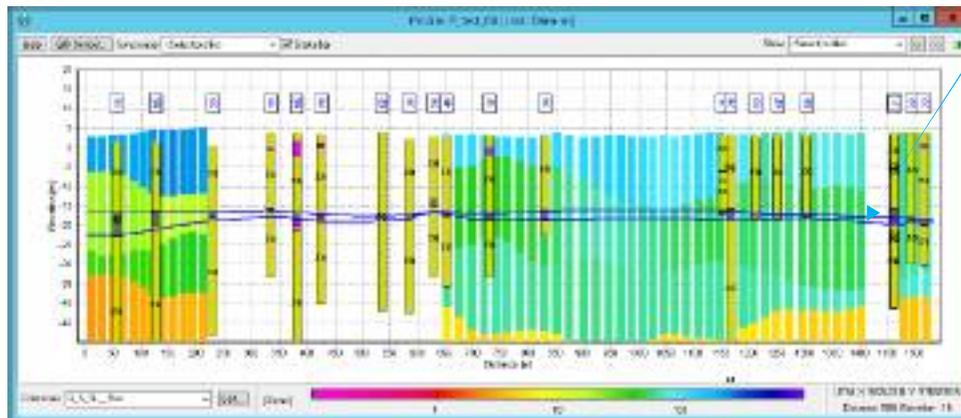


Thin clay layer

Multilayer

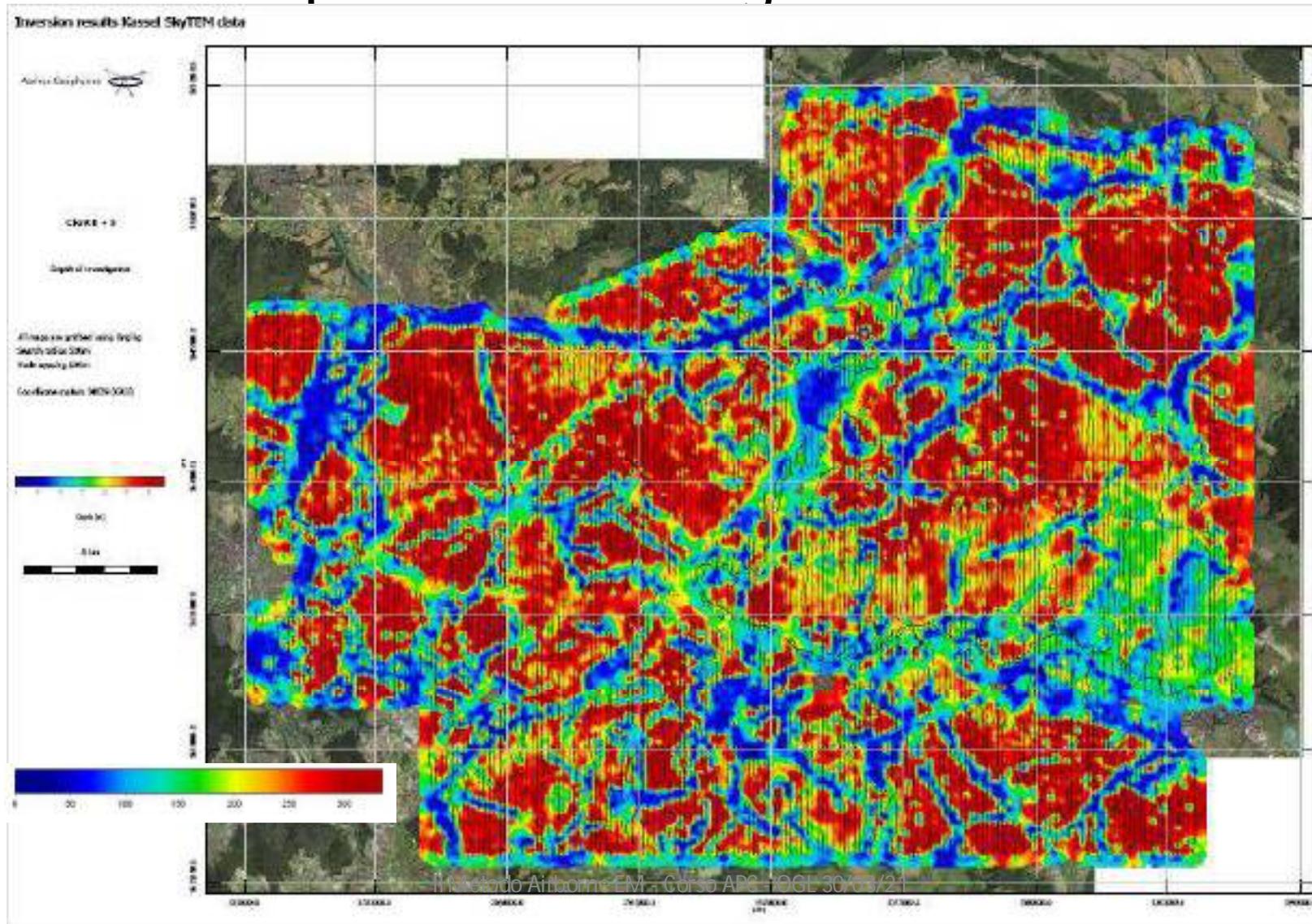


5 layers

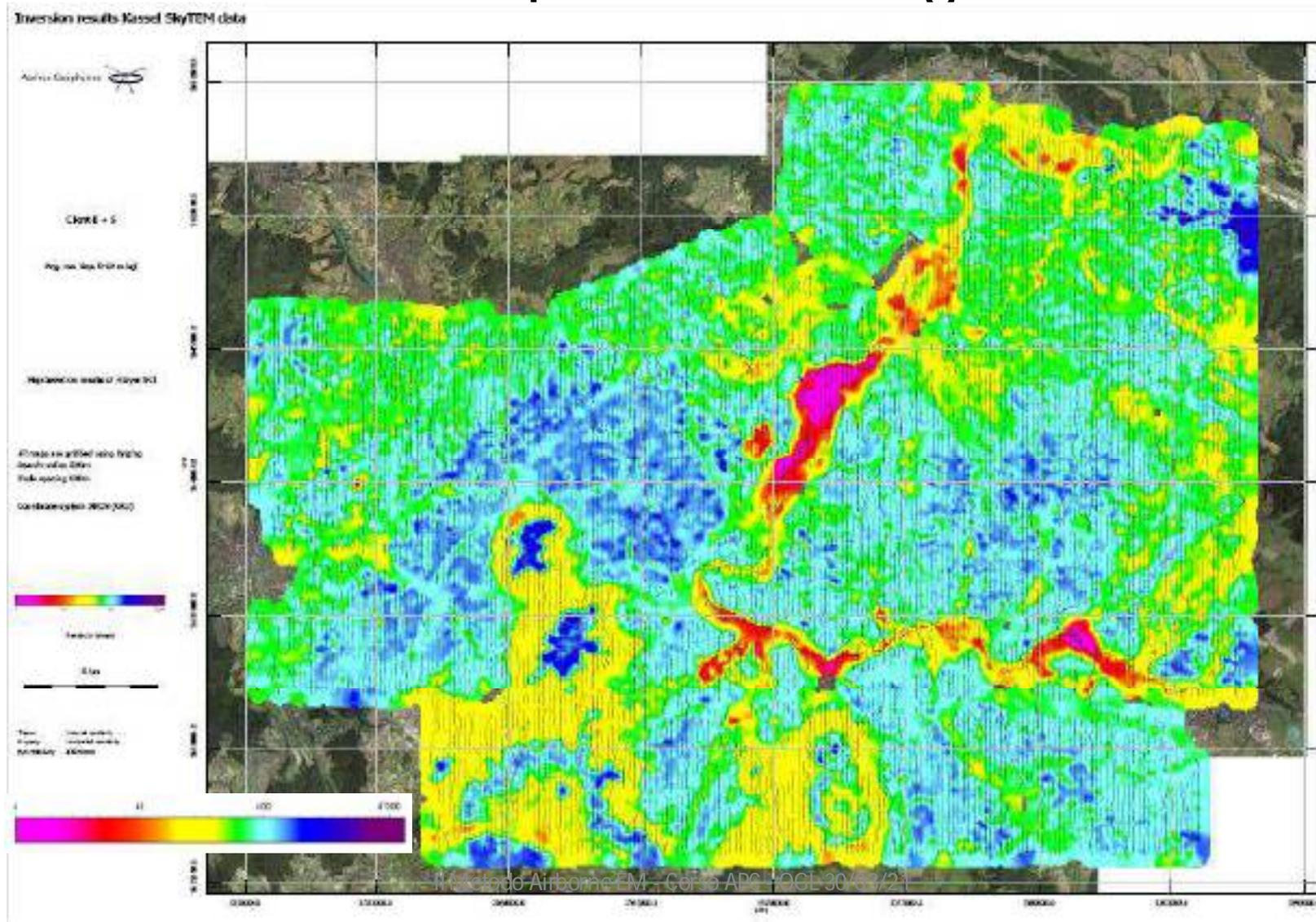


Thin clay layer

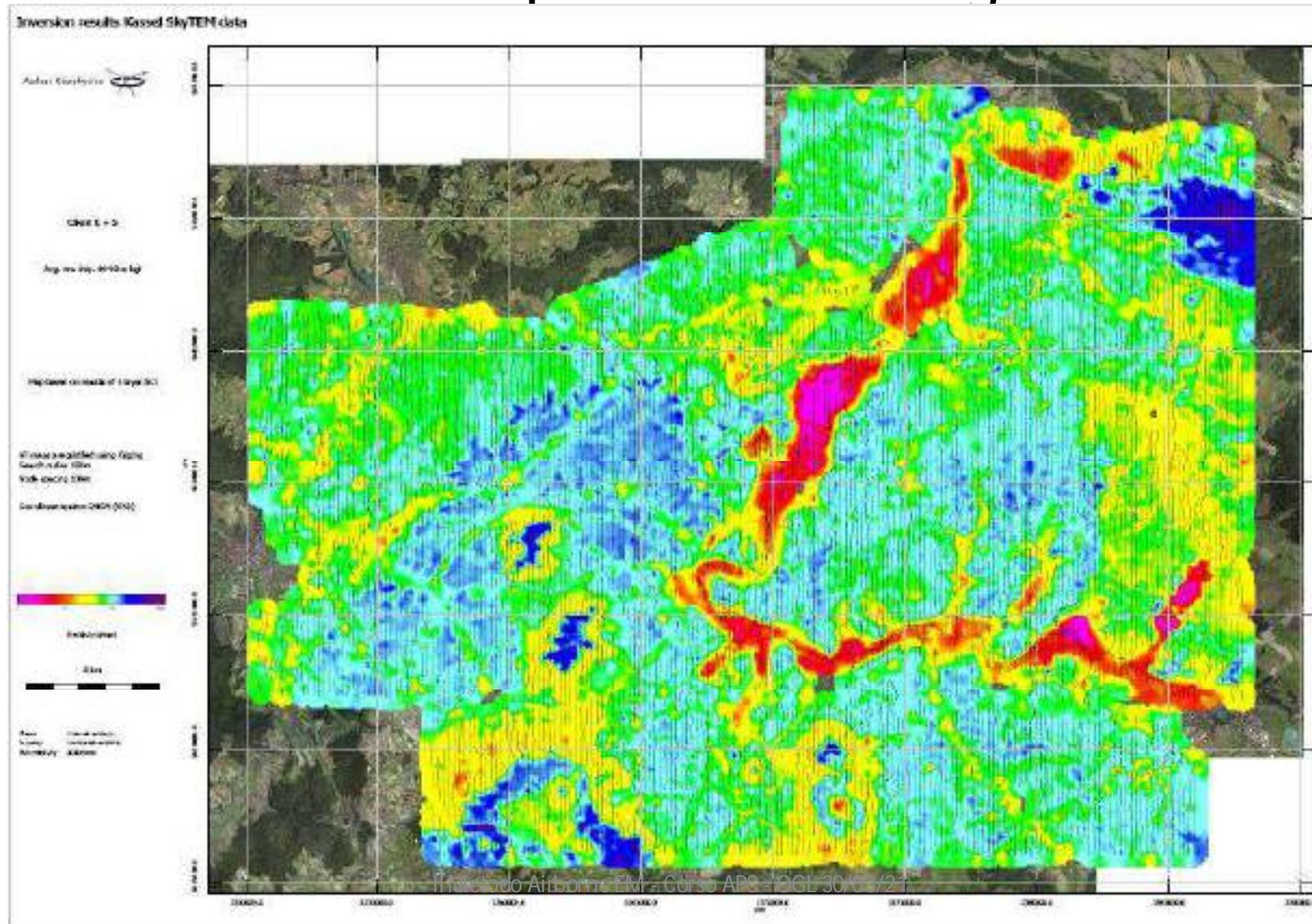
QC: Depth of investigation



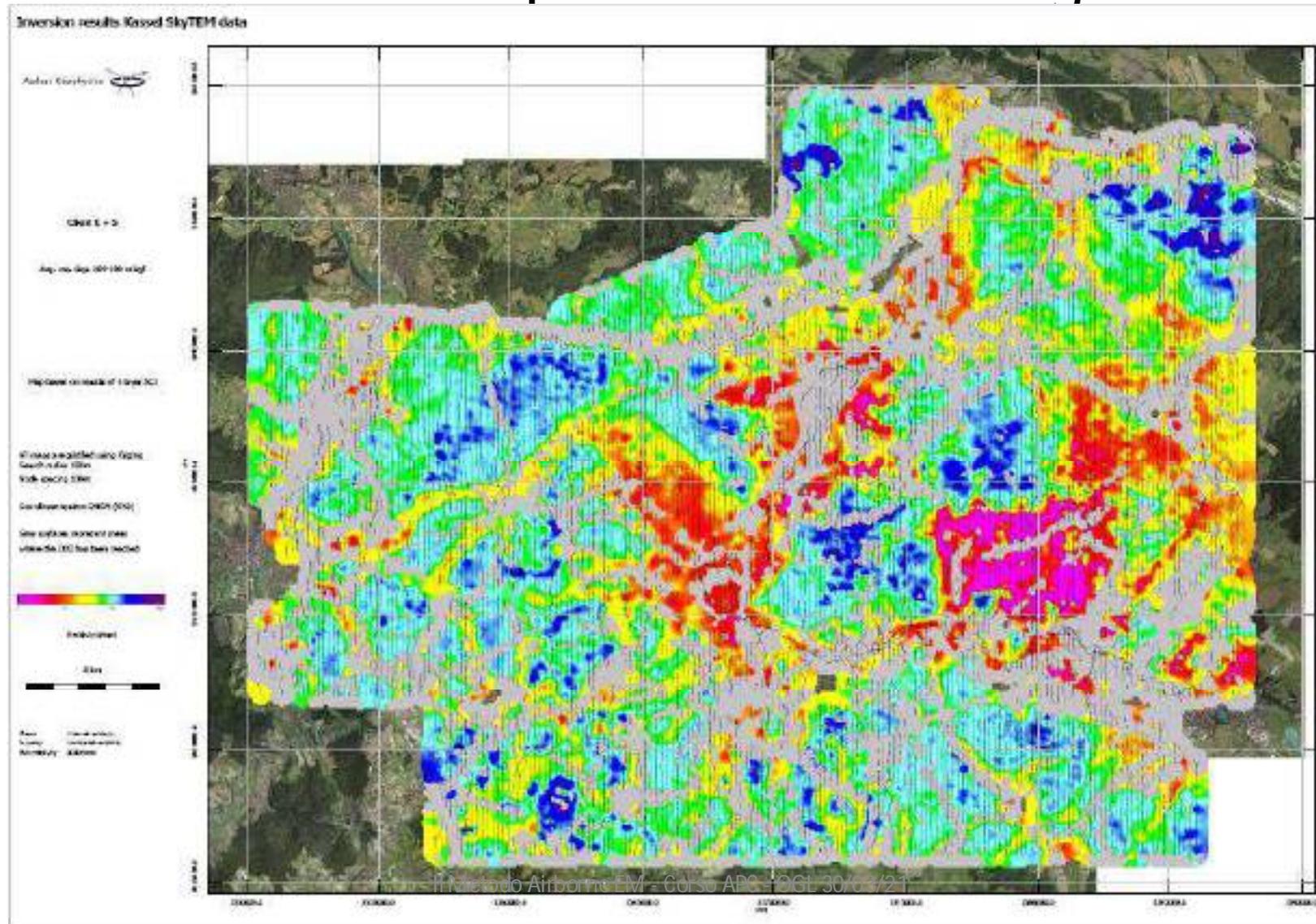
Ave. resist. maps: 0-10 mbgl



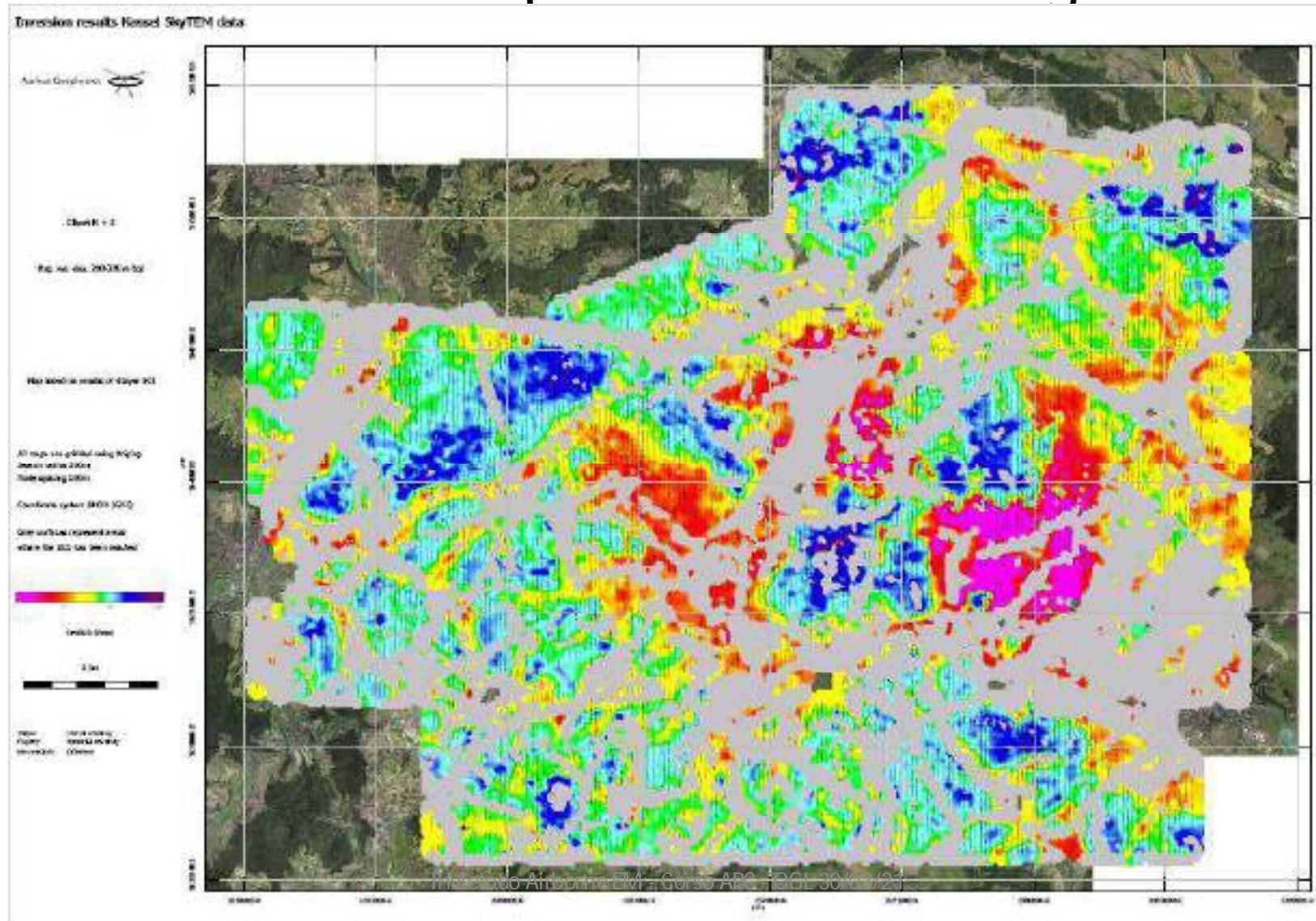
Ave. resit. maps: 40-60 mbq/l



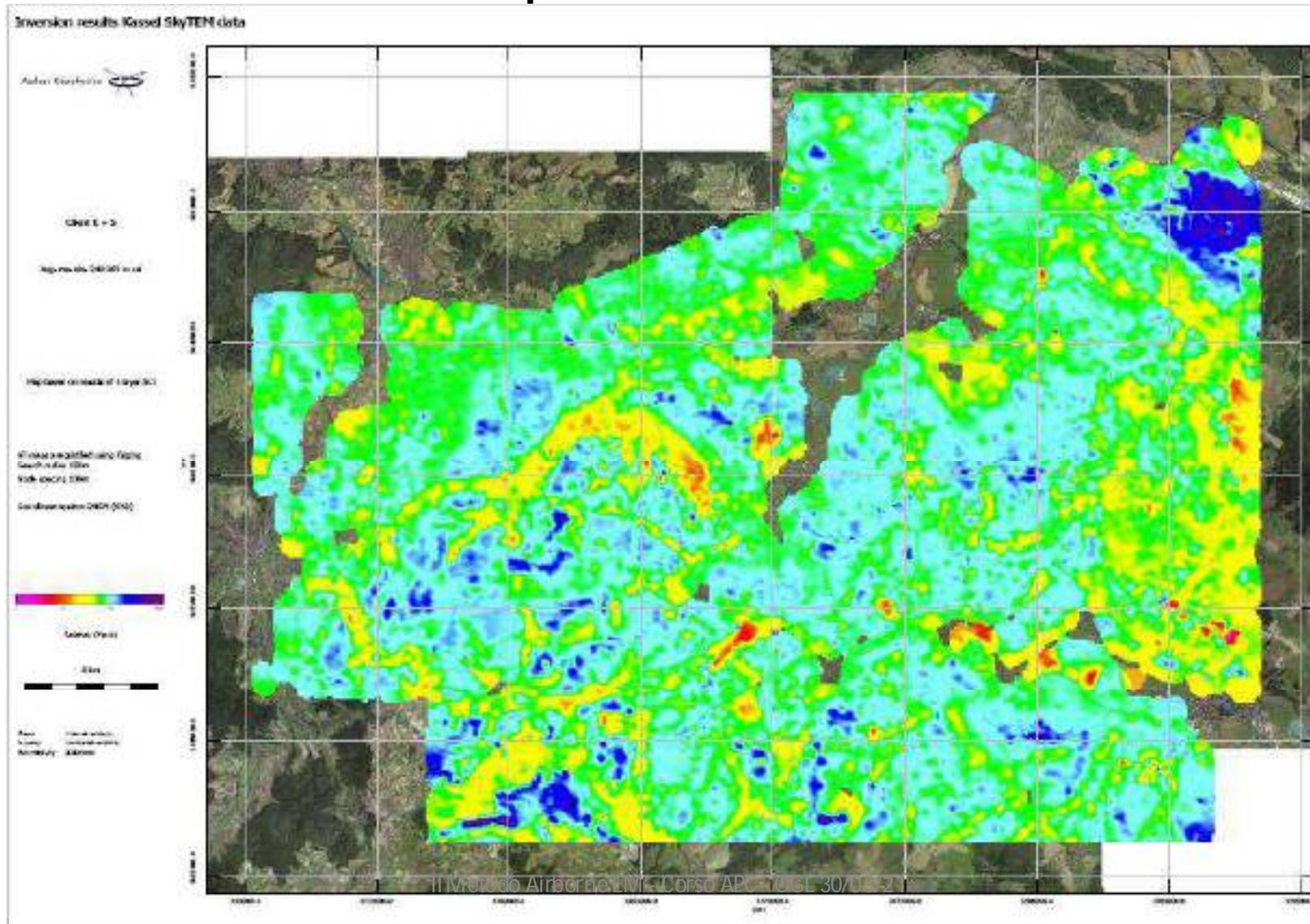
Ave. resit. maps: 160-180 mbql



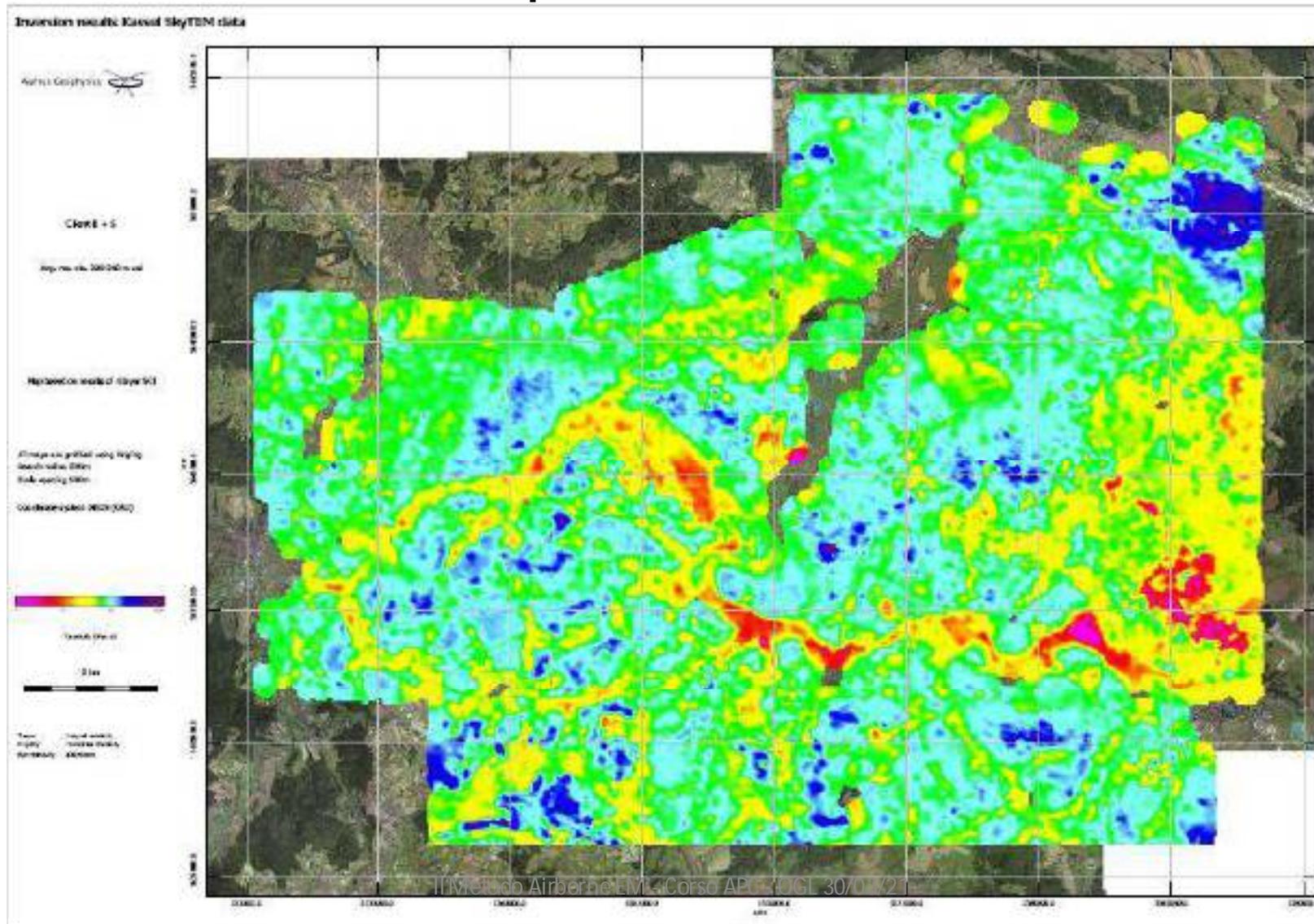
Ave. resit. maps: 200-220 mbql



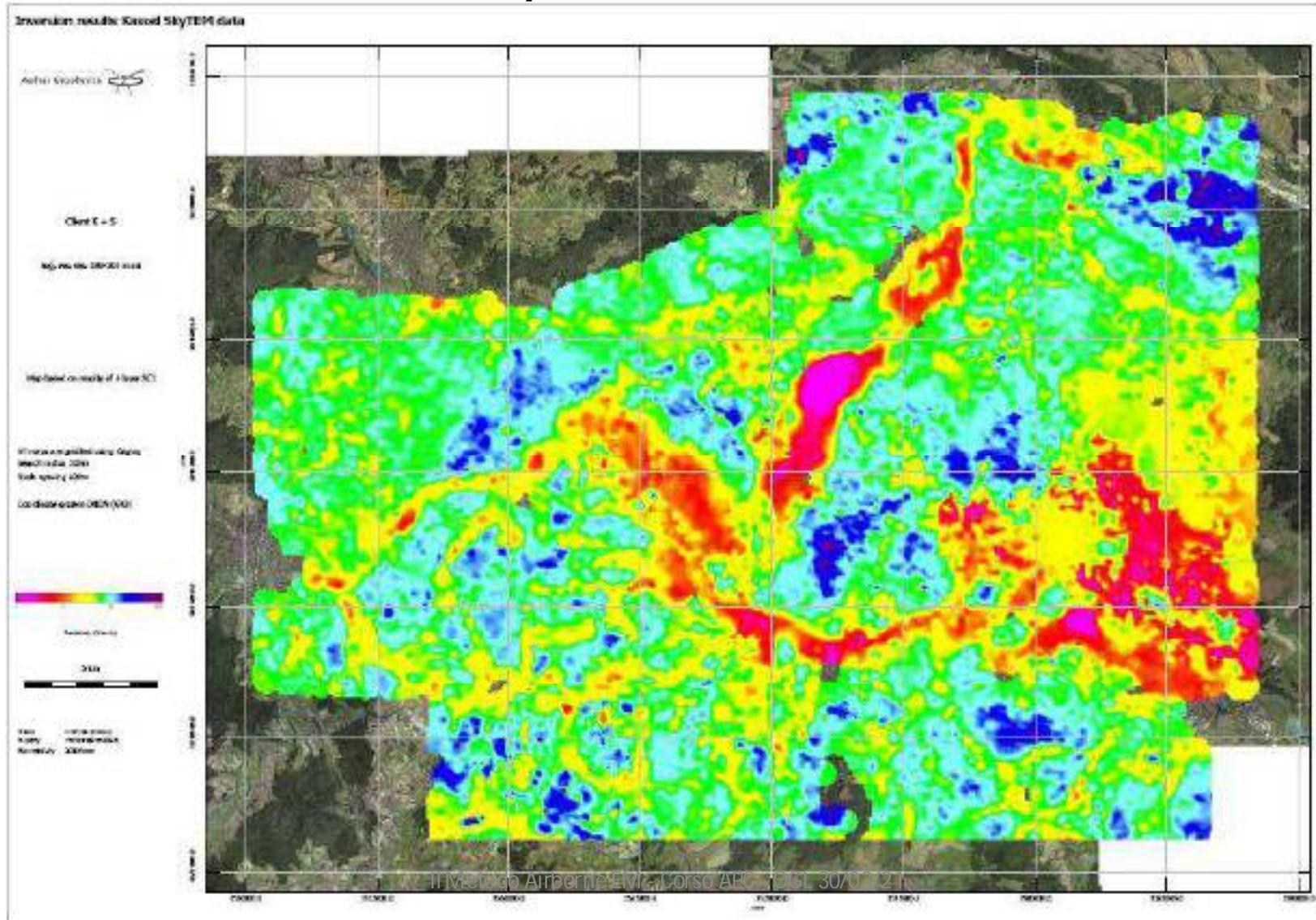
Ave. resit. maps: 240-260 masl



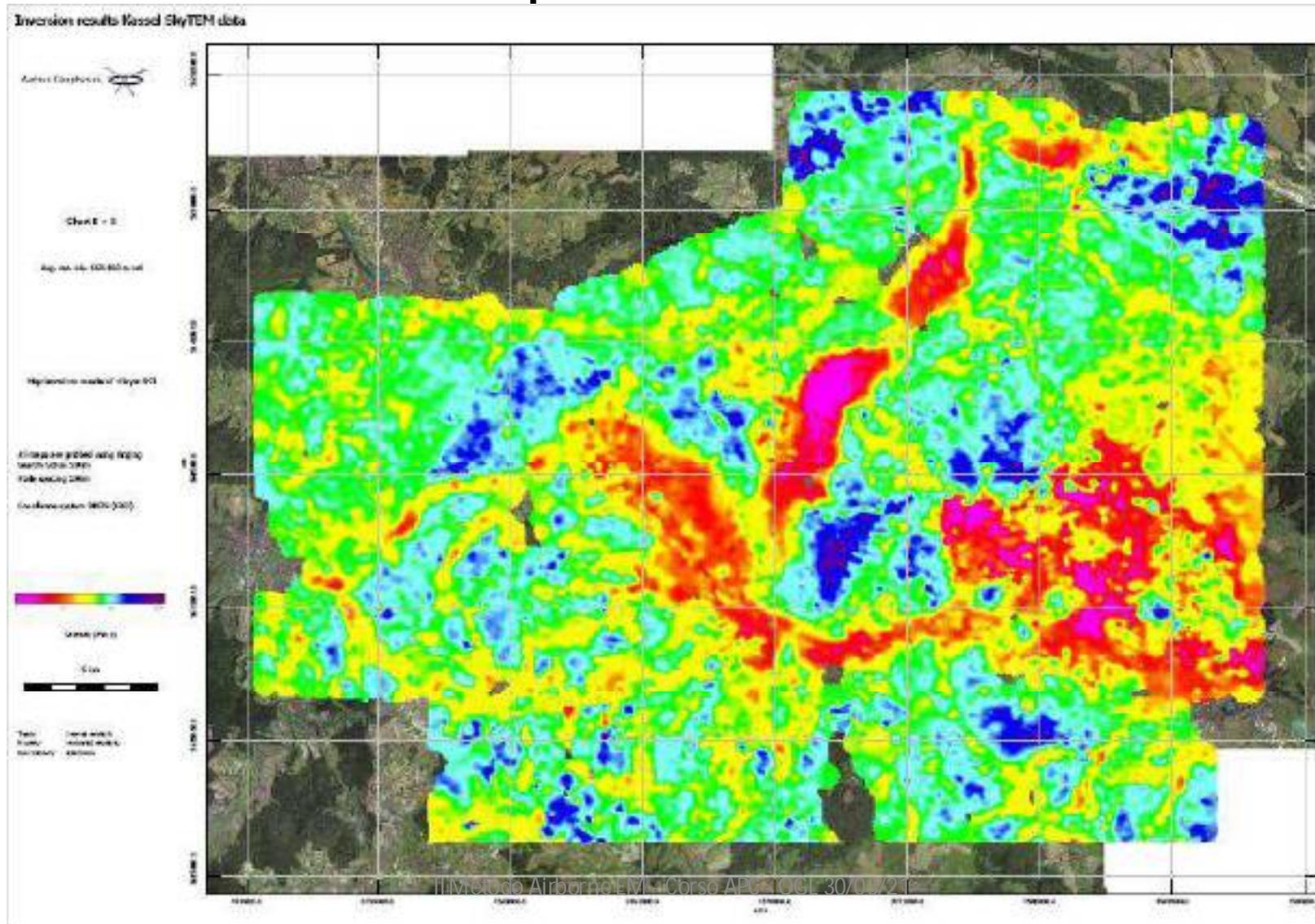
Ave. resist. maps: 220-240 masl



Ave. resit. maps: 180-200 masl



Ave. resit. maps: 160-180 masl



Ave. resit. maps: 120-140 masl

