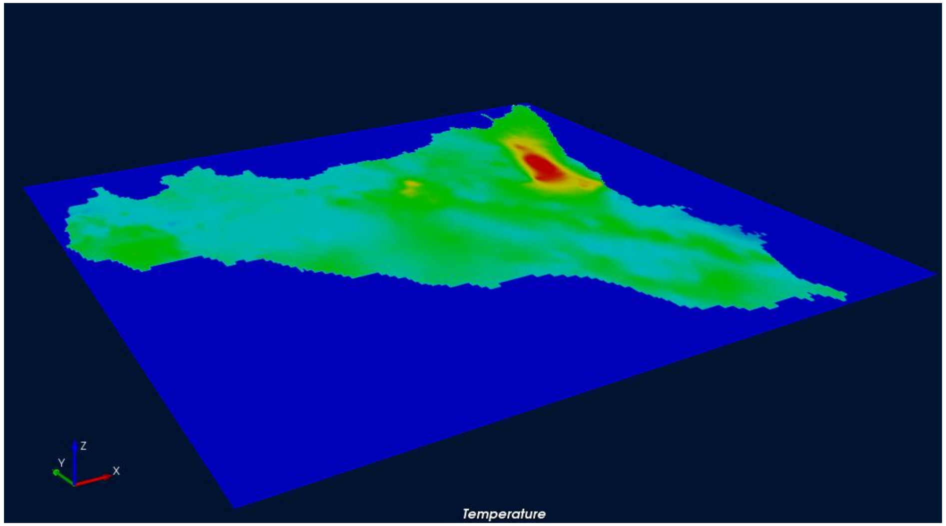
The VigorThermoGIS code:

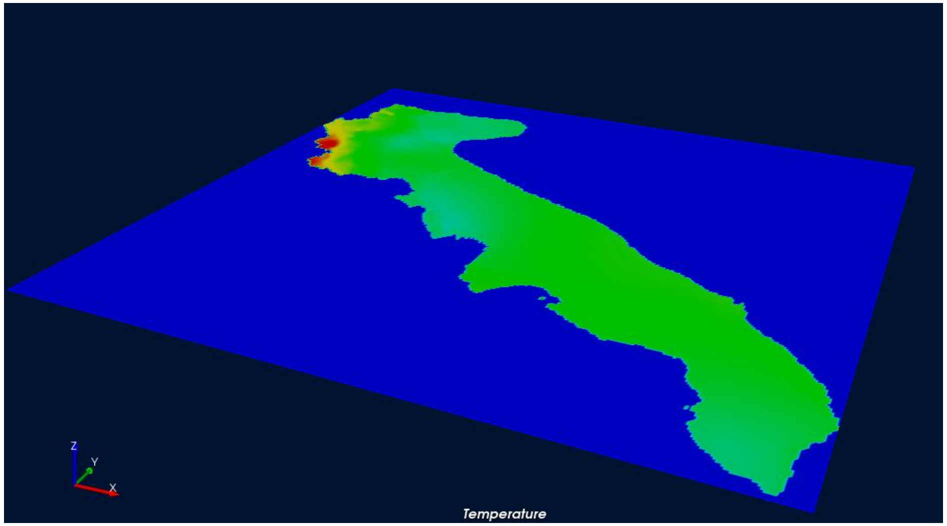
A new tool for geothermal resources assessment

Gianluca Gola[1], A. Manzella[1], D. Montanari[1], E. Trumpy[1] and J.D. Van Vees[2]

[1] Institute of Geosciences and Earth Resources (IGG) – National Research Council (CNR), Italy
[2] Netherlands Institute of Applied Geoscience – National Geological Survey, Netherlands

g.gola@igg.cnr.it - Via Moruzzi 1, 56124 Pisa, Italy





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Mezzogiorno
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ENERGIA DALLA TERRA
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Una scelta illuminata
UNIONE EUROPEA
Fondo Europeo di Sviluppo Regionale
QSN 2007-2013
REPUBBLICA ITALIANA

Where can we find geothermal resources in Southern Italy? Are suitable for economical exploitation?

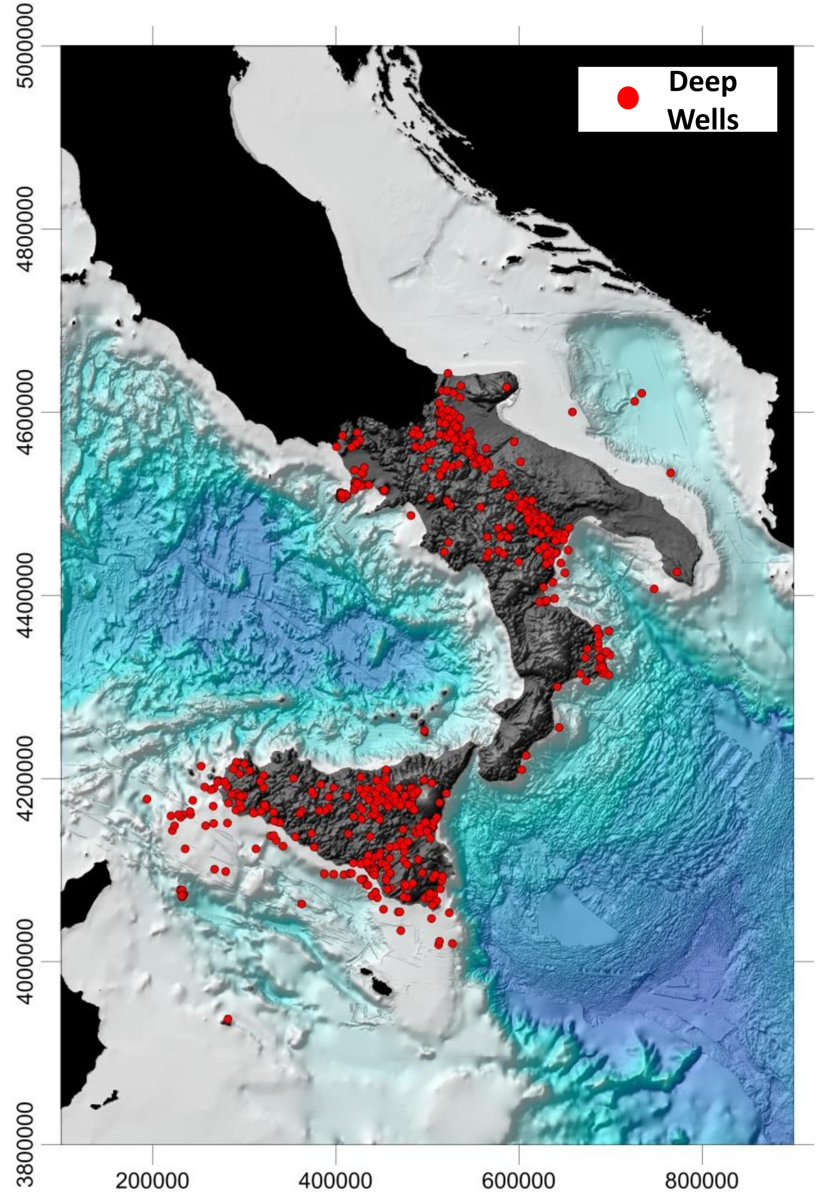
Enel, Eni-Agip, CNR, ENEA (1988)
National Geothermal Resources Inventory

ViDEPI Project
(Hydrocarbon exploratory wells database)

Geothopica Project
(update National Geothermal Resources Inventory)

VIGOR Project
New industrial drilling temperature data are used to:

- Update the National Geothermal Database
- Review thermal models down to 5 km depth
- Assess ***where*** and ***how*** the deep geothermal resources can be exploited



Temperature Data Base

Due to the different conditions under which the temperatures are measured and to the purposes for which they are used, these data constitute an heterogeneous database with different degree of accuracy and spatial distribution.

Temperature Log

- Continuous log
- Accuracy of ± 0.05°C
- Static conditions
- Few logged wells
- Shallow depth

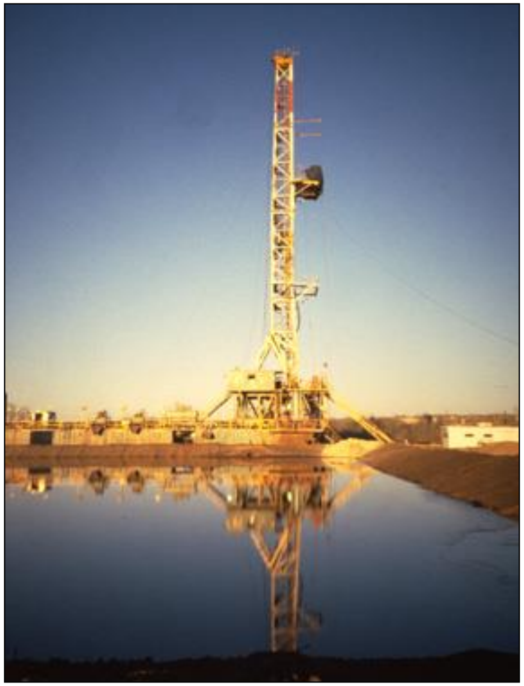
Drill Stem Test Temperature

- Referred to the productive interval
- Accuracy of ± 2°C
- Flowing fluid temperature
- Industrial confidential data
- High depth

Bottom Hole Temperature

- Punctual measurements
- Accuracy of ± 2°C
- Dynamic conditions
- Many available wells
- High depth

BHT Correction to Static Conditions
Time temperature series



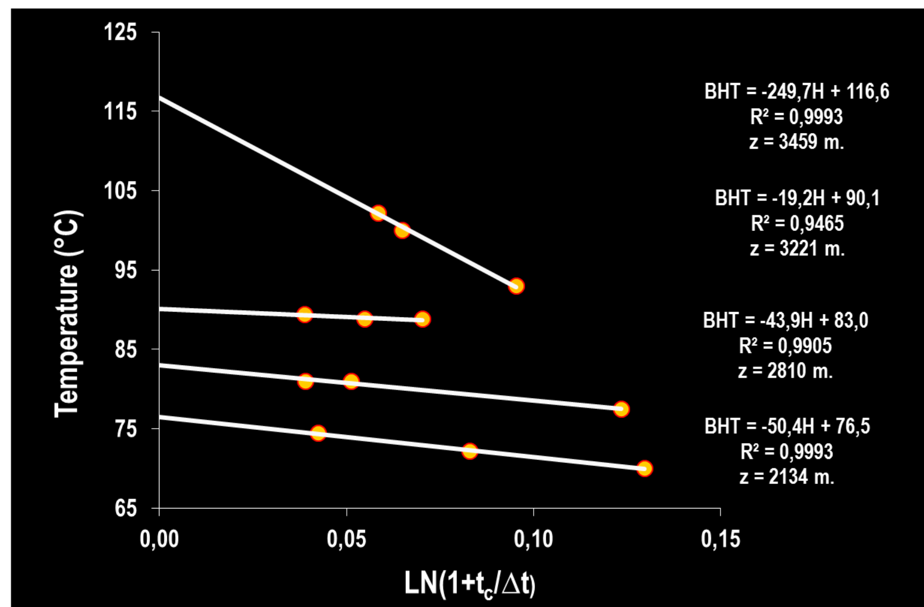
Bottom Hole Temperatures (**BHT**) reflect the thermal conditions of the drilling mud, not those of the undisturbed rock.

Most correction techniques treat temperatures as a transient function, i.e. they involve progressive measurements after drilling operation, to extrapolate the temperature to <u>static</u> conditions (**SBHT**).

The line source model assumes that the mud circulation acts as a heat sink

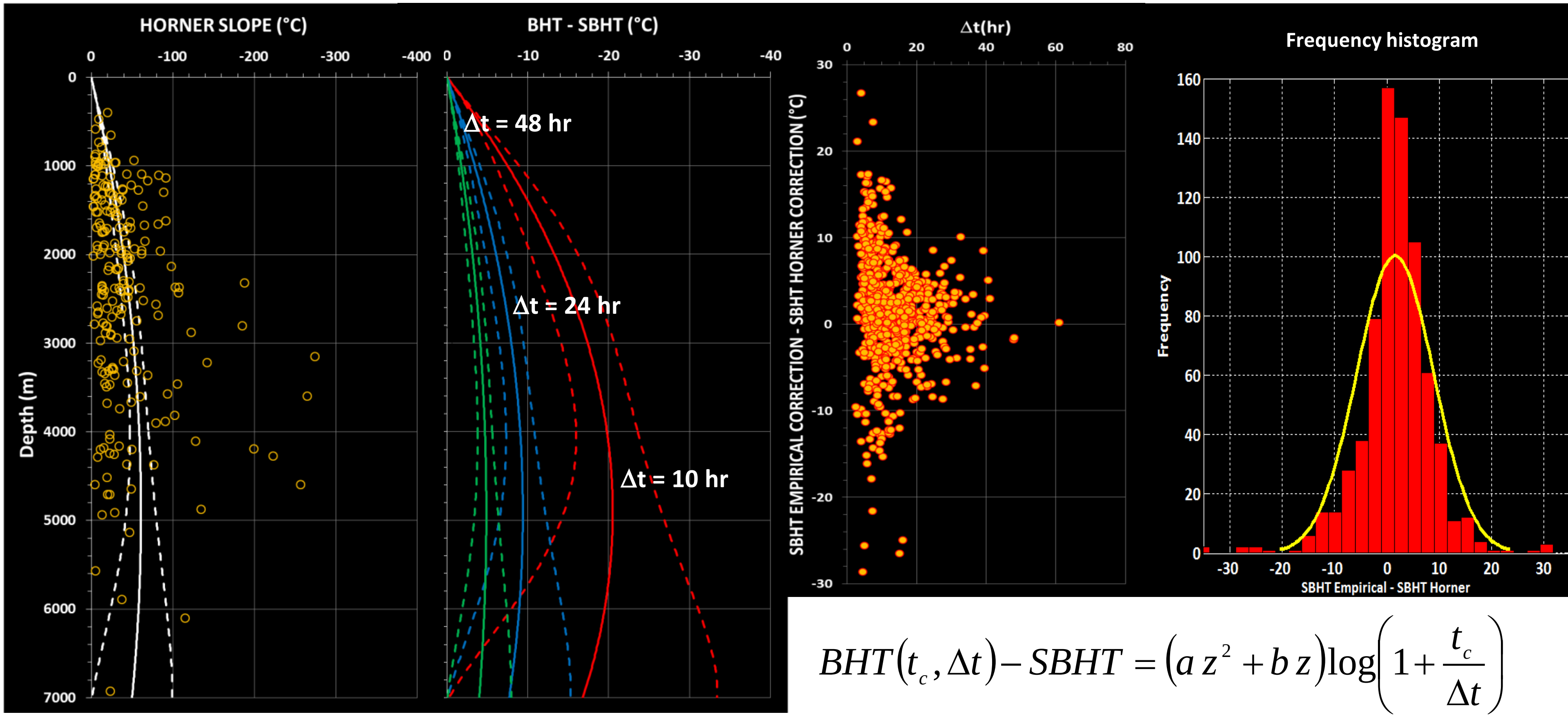
$$BHT(t_c, \Delta t) = SBHT + \frac{Q}{4\pi\kappa_r}\log\left(1 + \frac{t_c}{\Delta t}\right)$$

HORNER PLOT METHOD



BHT Correction to Static Conditions

Single temperature measurements

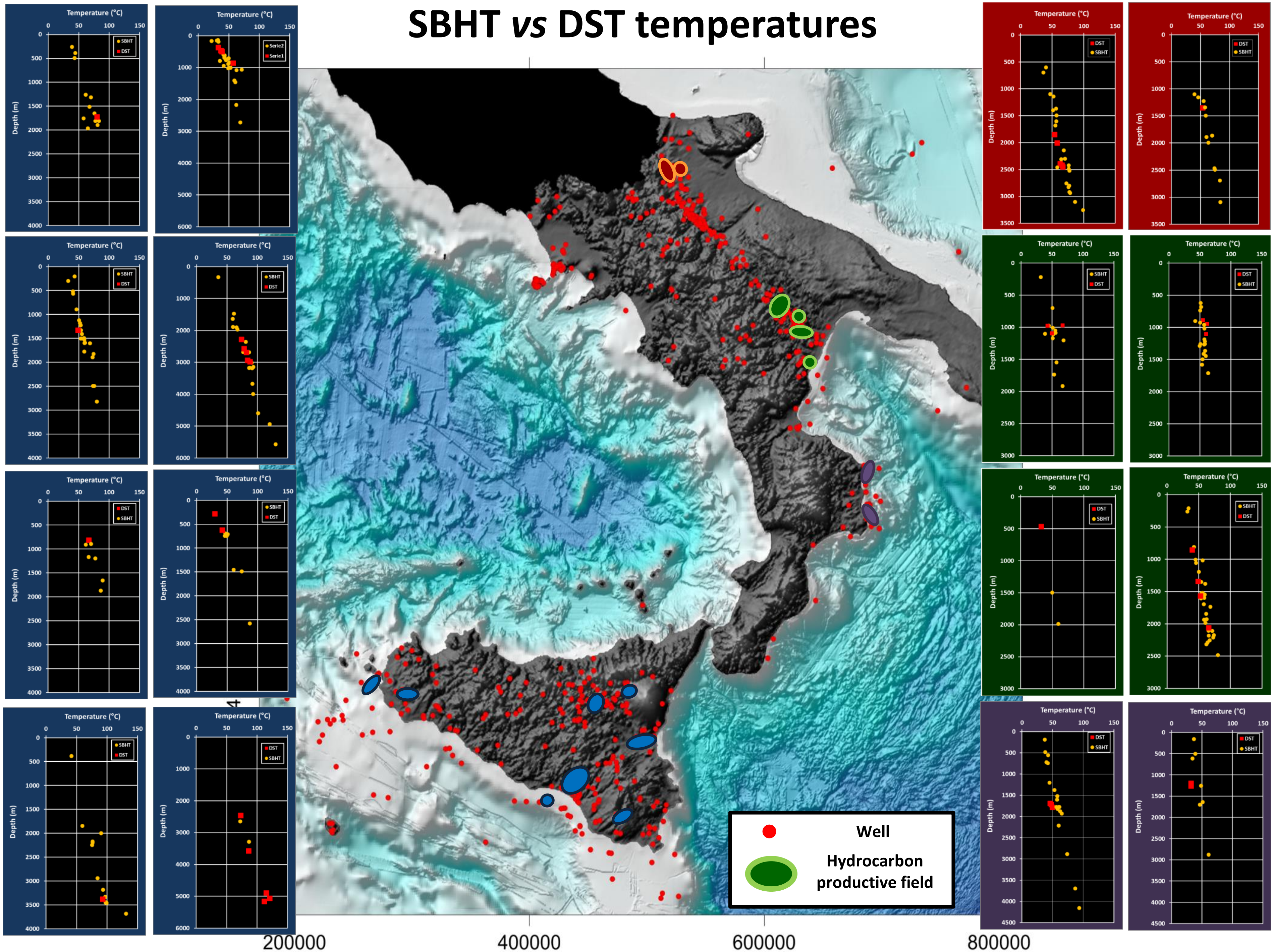


$$BHT(t_c, \Delta t) - SBHT = (a\,z^2 + b\,z)\log\left(1 + \frac{t_c}{\Delta t}\right)$$

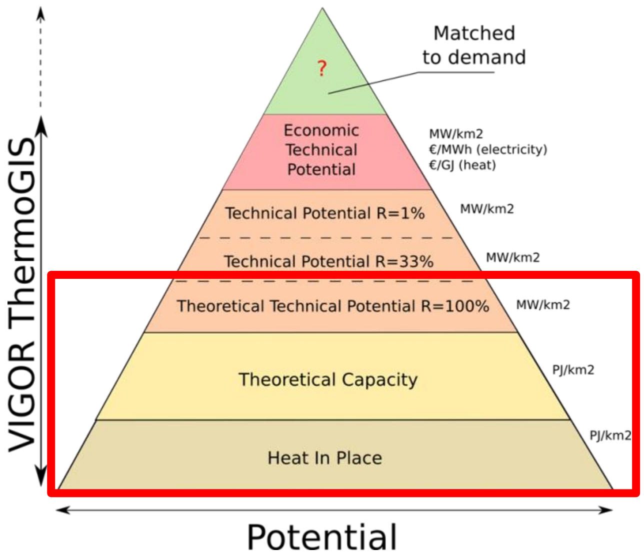
A technique that enables to correct **single BHTs** is calibrated in the study area. The depth-time correction method is based on the correlation between the Horner slope and depth.

A comparison of the corrected temperatures (**SBHT**) from the same dataset obtained by means of: 1) the depth-time function, 2) the Horner method, shows a decrease of the differences with the increase of the shut-in time.

SBHT *vs* DST temperatures



Geothermal Resources Assessment
VIGOR ThermoGIS code



- Progressive filtering approach starting from the total heat stored in the deep-seated reservoirs to the evaluation of the heat which can be extracted from the aquifers
- Volumetric Method
- Energy is extracted by a doublet (production and injection well)
- The subsurface is represented by a 3D voxet with horizontal resolution of 1000 m and vertical resolution of 100 m
- MonteCarlo simulation to incorporate the effects of uncertainty on permeability (P90, P50 and P10 values of transmissivity)

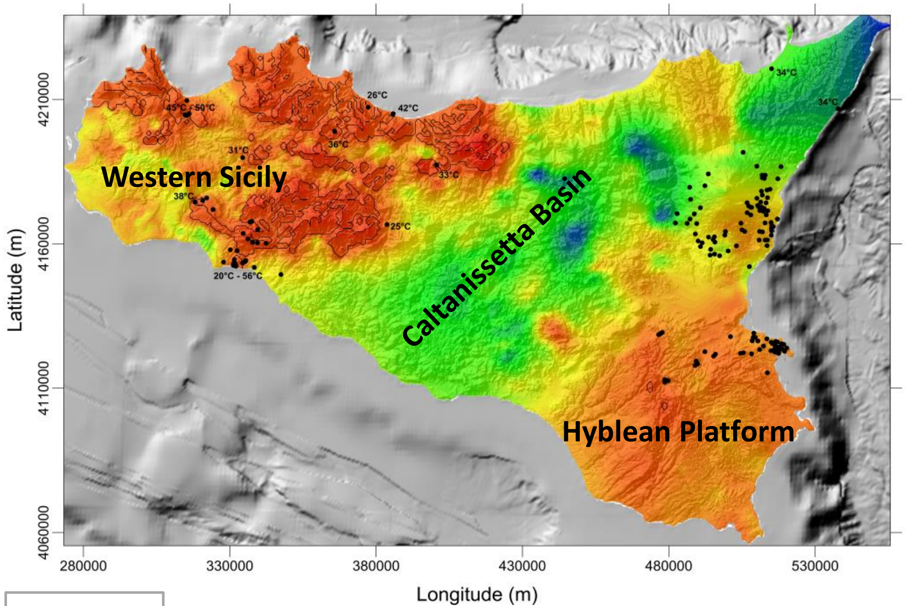
<u>Data input:</u>

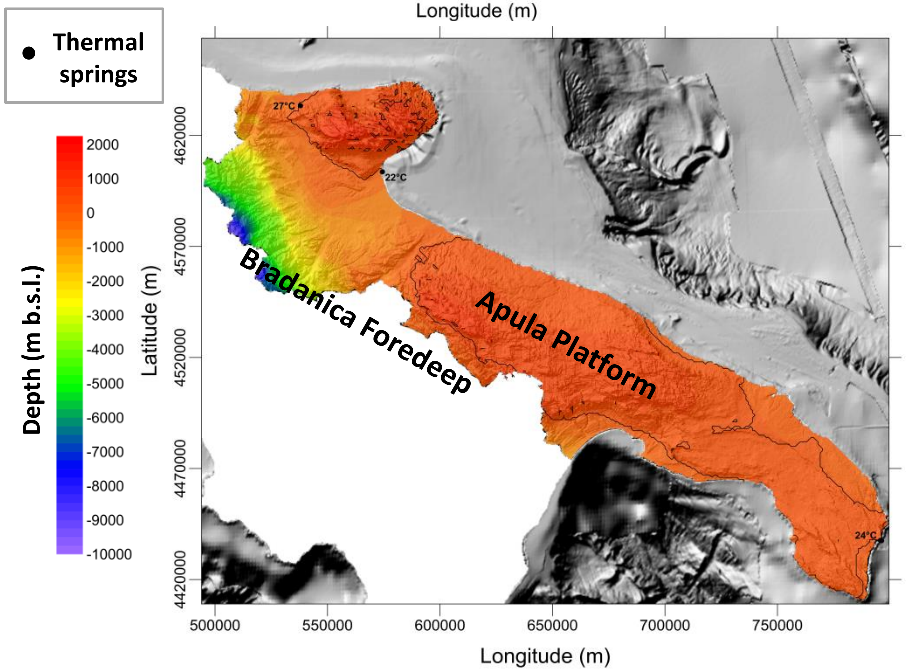
- **Geometric** characteristic of the reservoir
- **Temperature** model distribution

<u>Parameters:</u>

- Fluid and Rock-fluid system physical properties
- Technical constraints (e.g. minimum inlet temperature and outlet temperature as a function of application)

Geothermal Resources Assessment
Top of the reservoir



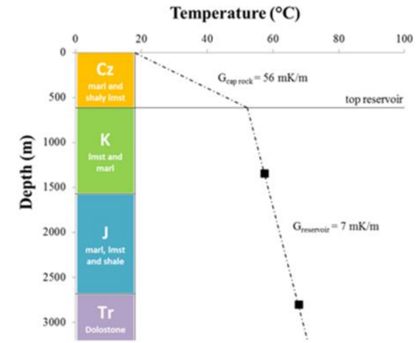


- Two case studies are here presented: Sicily and Apulia Regions
- We focused on the evaluation of the deep-seated geothermal resources (hydrothermal systems) **down to 5 km depth**
- Mesozoic Carbonate Units host the main regional aquifer
- Well data and interpreted seismic profiles allowed to define at regional scale the top of the reservoir

Geothermal Resources Assessment

Geothermal Gradients inferred by well data

Temperature data, analysed well-by-well together with lithostratigraphic information, allowed to describe the temperature increase with depth both in the impermeable cap-rock units and in the potential reservoir units



Example: Segesta 1 well (Sicily)

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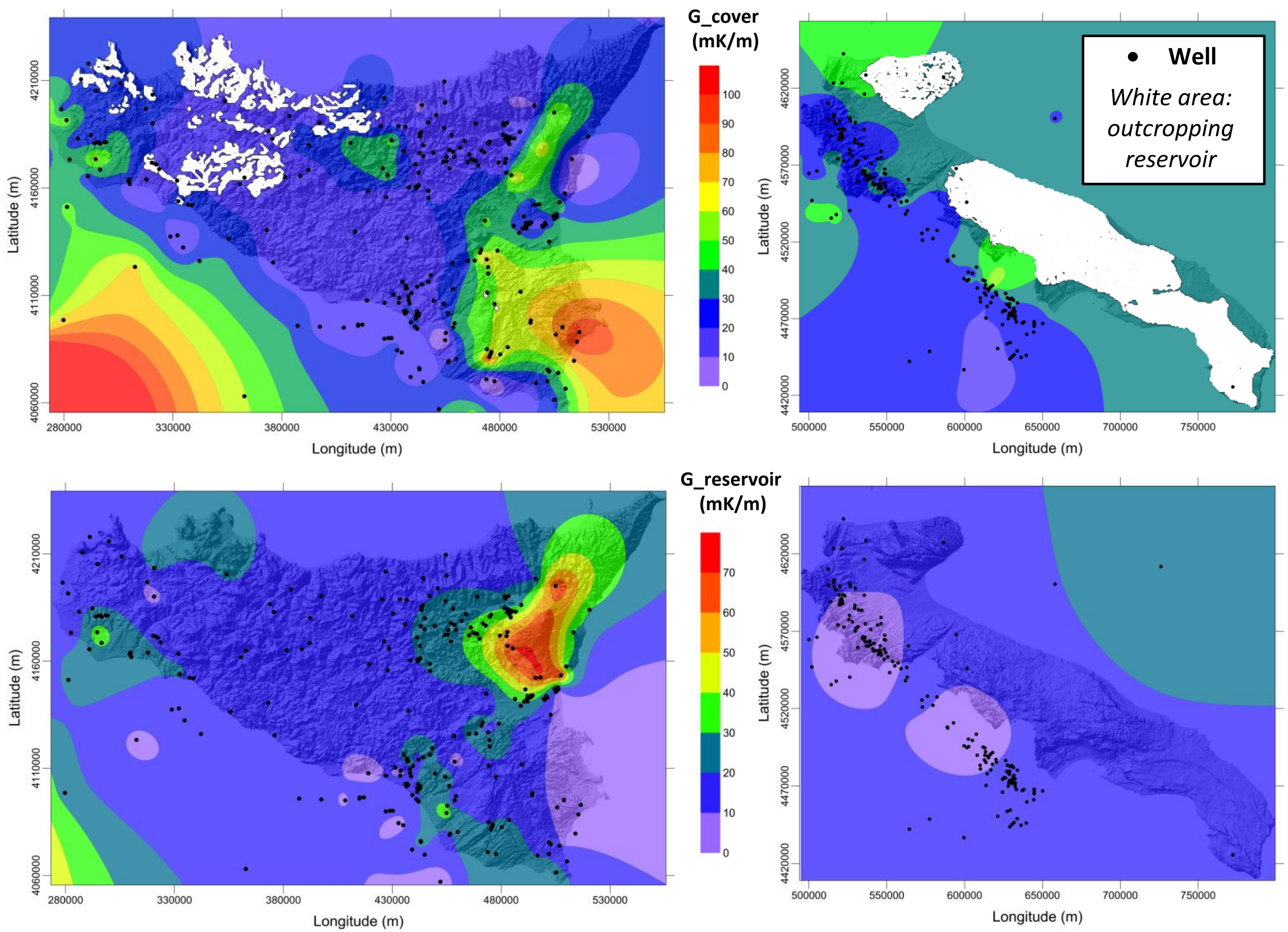
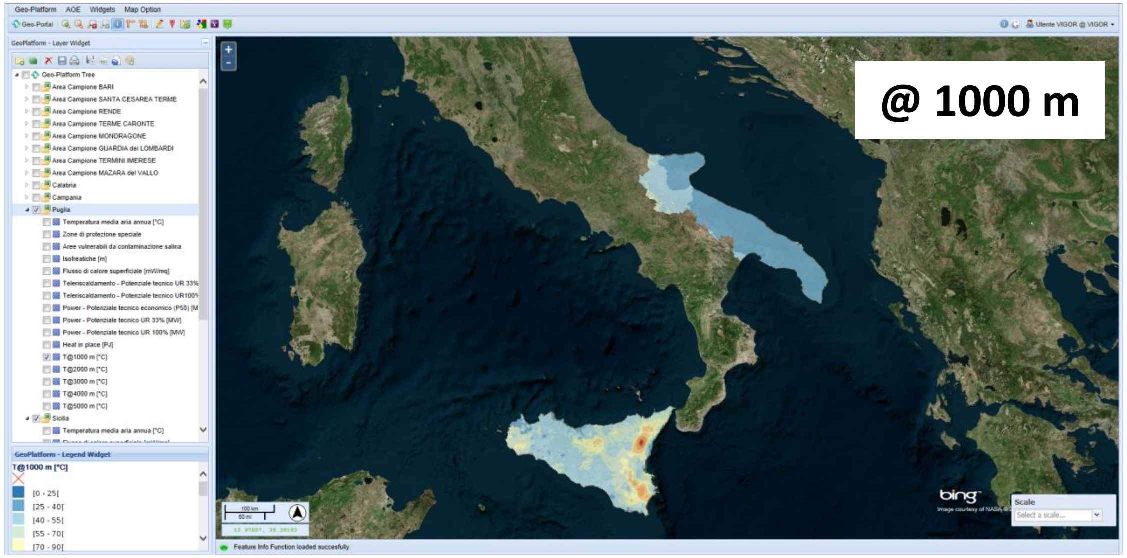


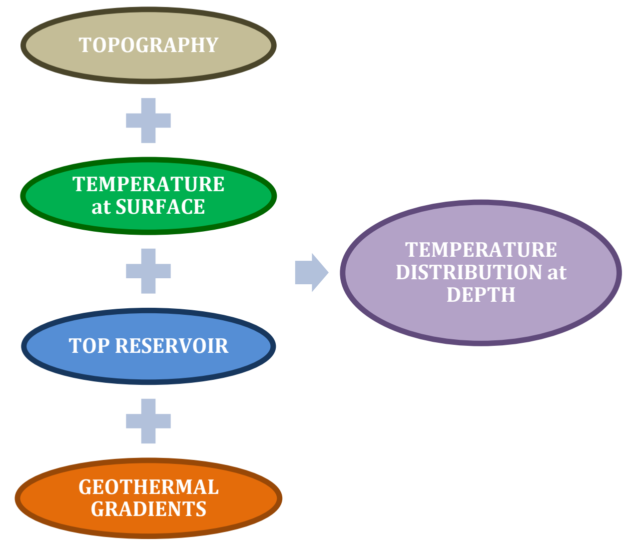
Focusing on conventional hydrothermal systems:

- In the <u>**cap rock**</u> the **high** temperature **gradients** imply a predominance of conductive heat transfer. Sedimentary cover geothermal gradients mimic the underlying geometries of the potential reservoir
- The temperatures in the carbonatic <u>**reservoir**</u> reveal very **low** geothermal **gradients** where the component of convective heat transfer is not negligible



Temperature distribution

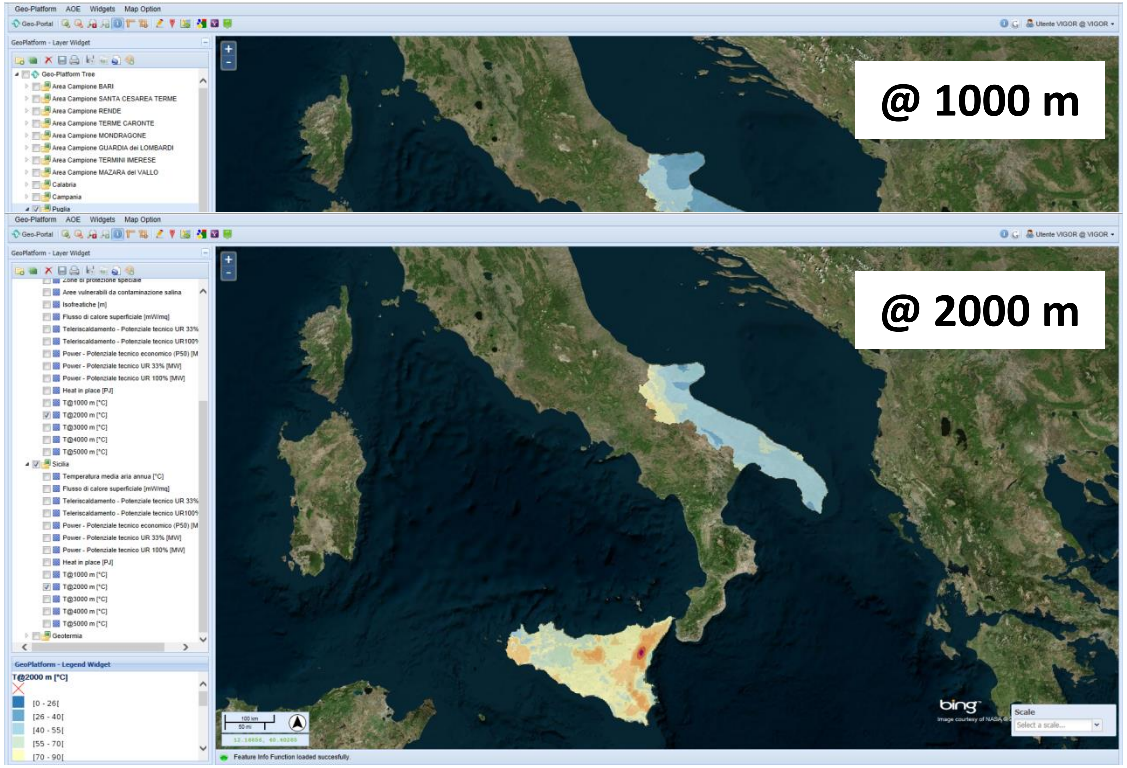
www.vigor-geotermia.it/geo-portal/



The potential calculations take as input this newly constructed model of subsurface temperatures up to 5 km depth

T (°C)

- < 25
- 25-40
- 40-55
- 55-70
- 70-90
- 90-120
- 120-180
- 180-250
- > 250



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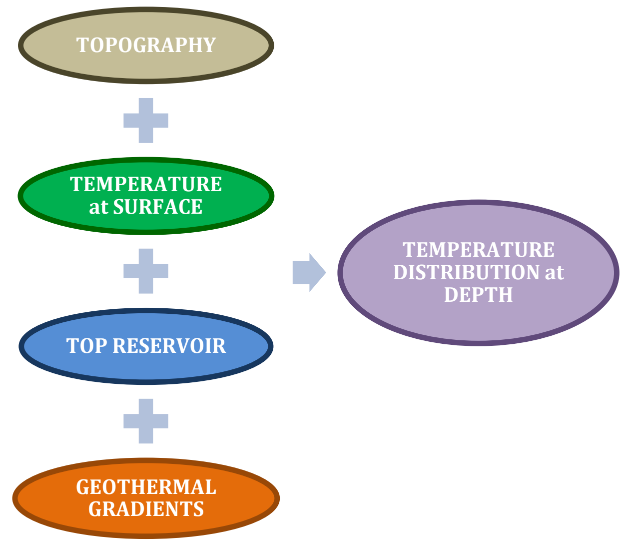

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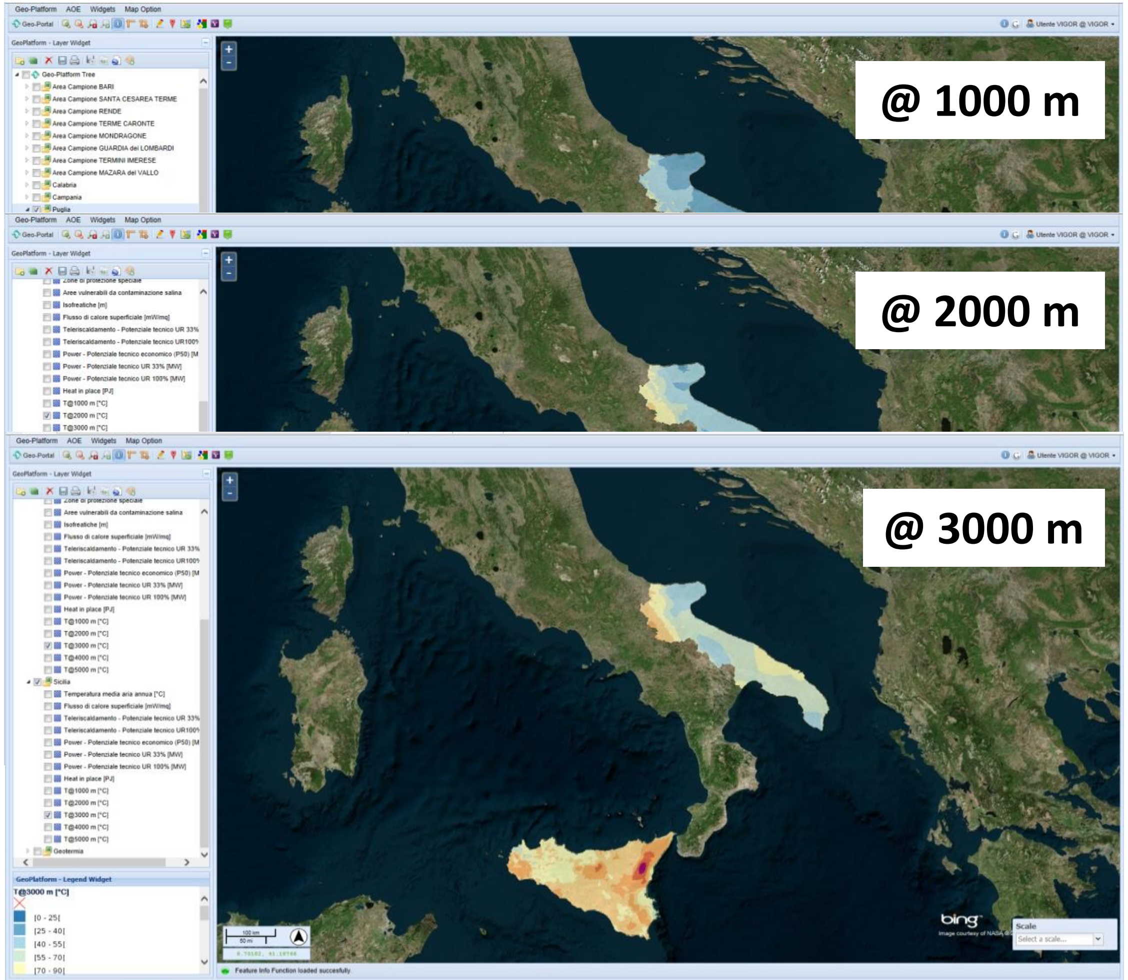

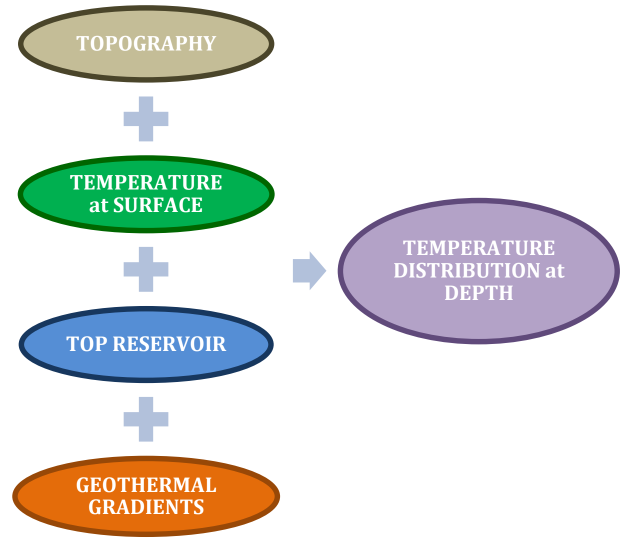

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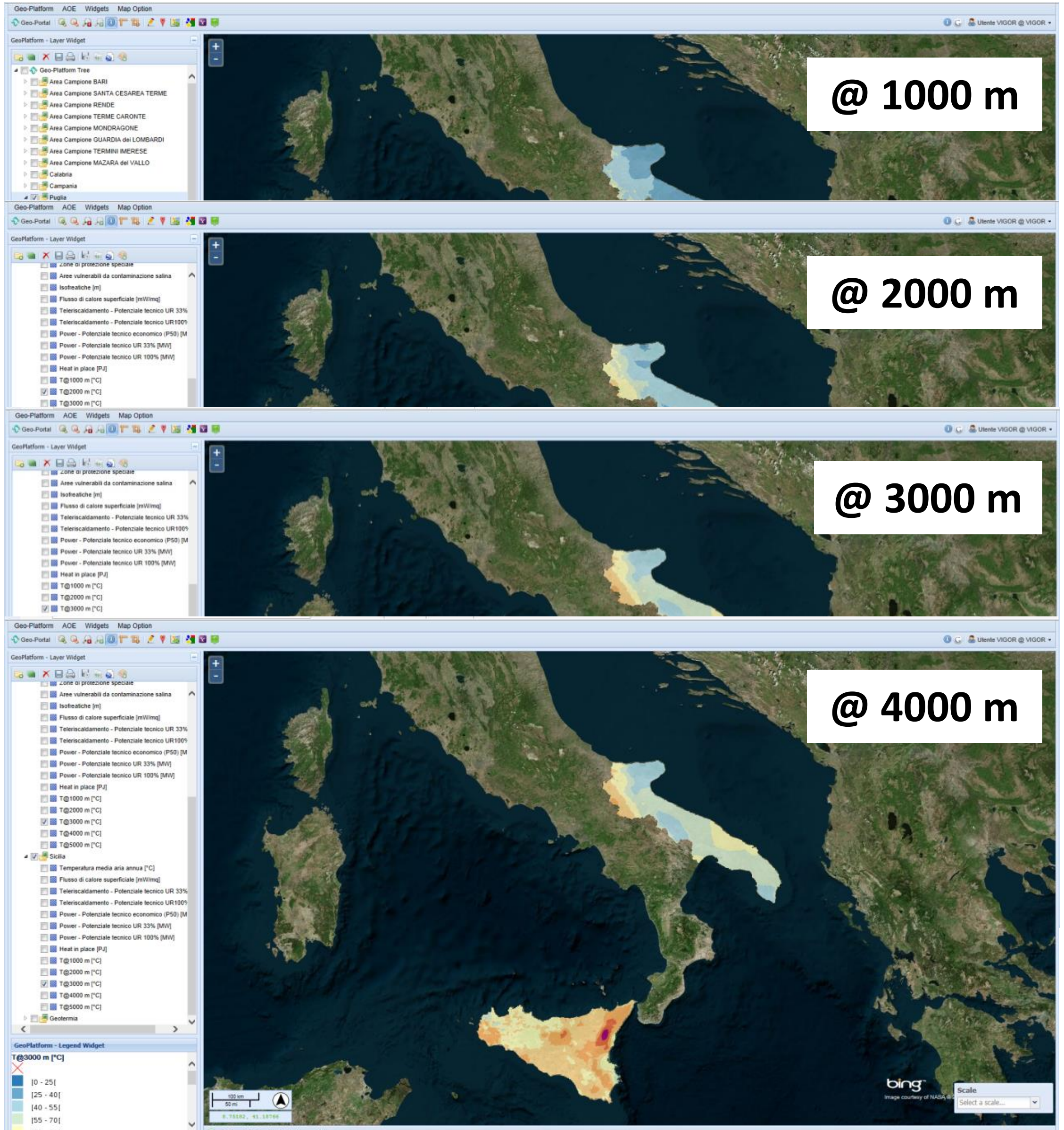

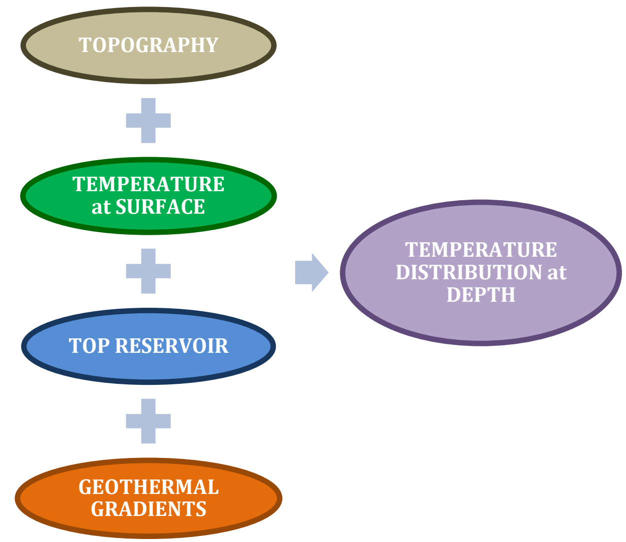

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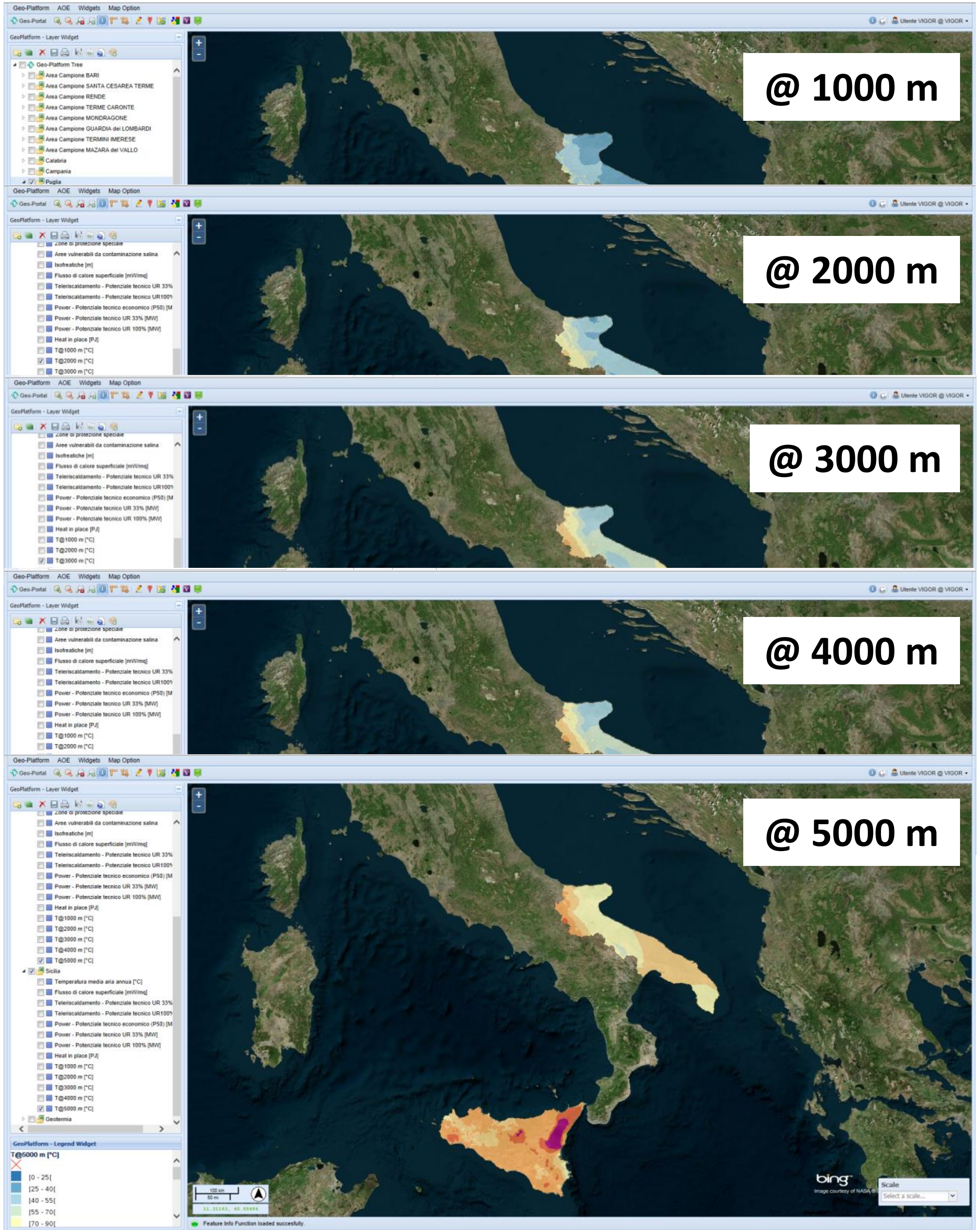

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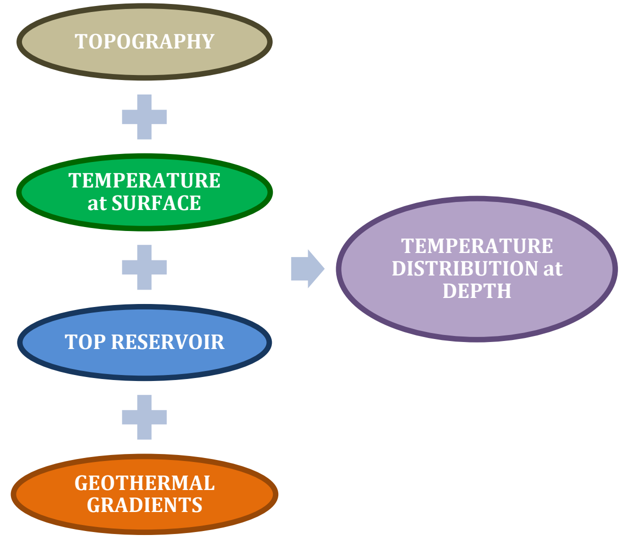

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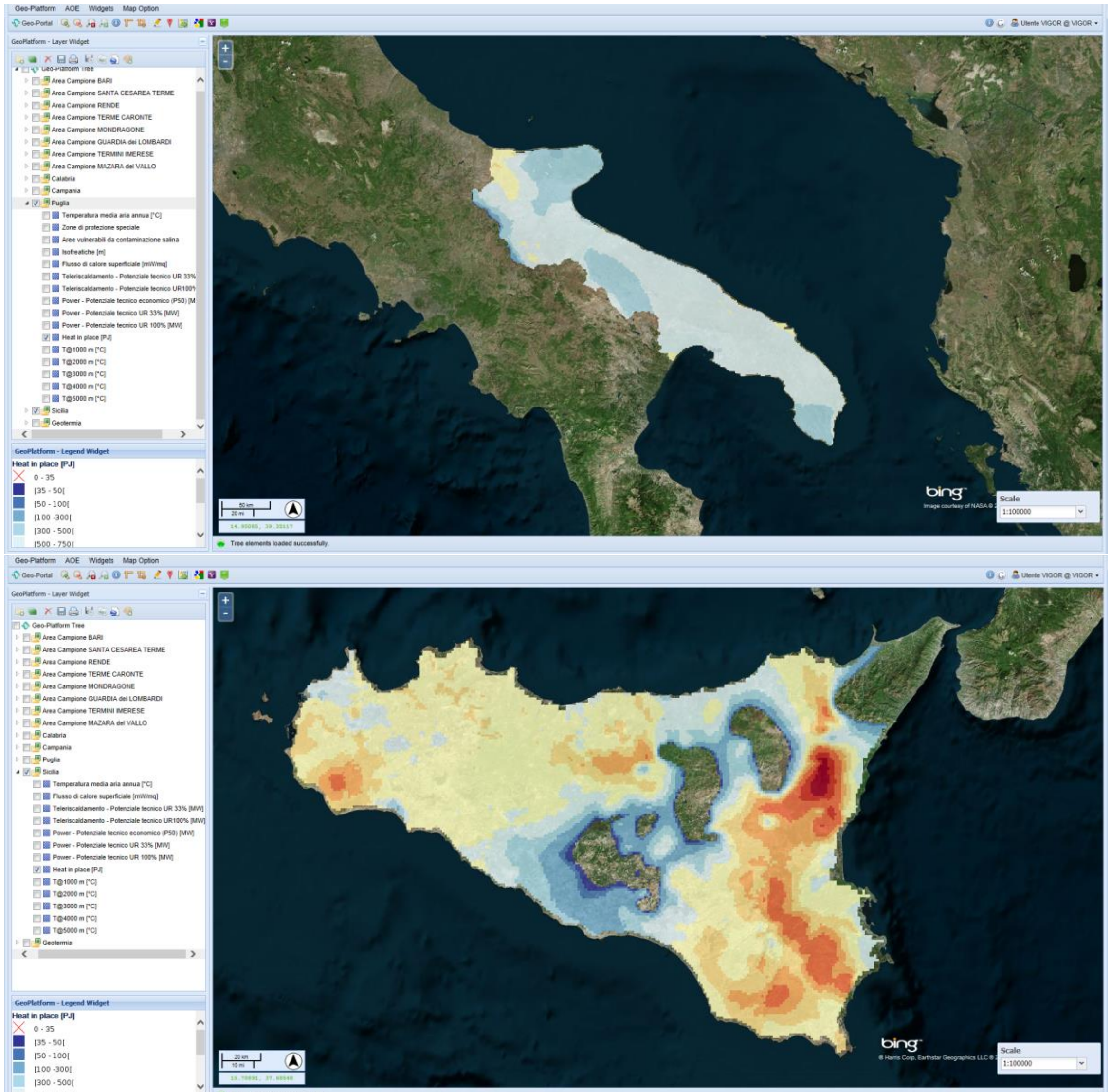
Heat in Place

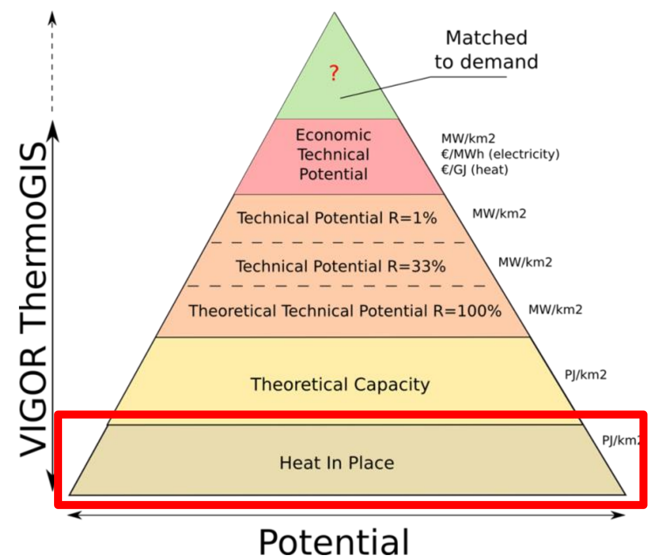
The *Heat in Place* (HIP) is calculated as the heat energy available in the subsurface. The calculation for a subvolume V of the grid is:



$$HIP\ [PJ] = V \times (\rho c)_{rock} \times (T - T_o) 10^{-15}$$

HIP (PJ)

- **< 50**
- **50-300**
- **300-500**
- **500-750**
- **750-1000**
- **1000-1250**
- **1250-1500**
- **1500-2000**
- **> 2000**

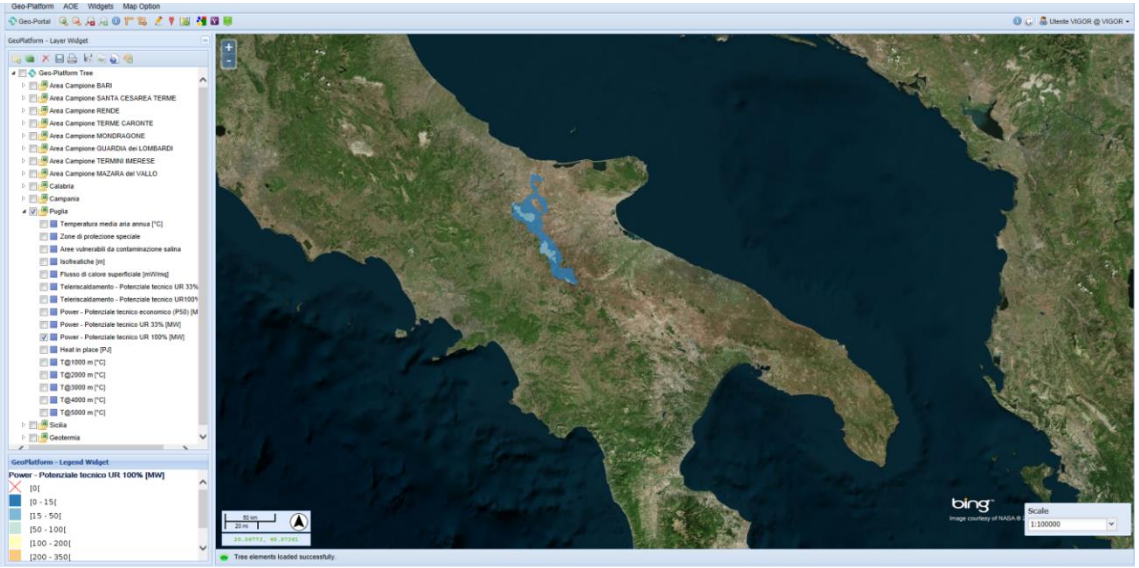


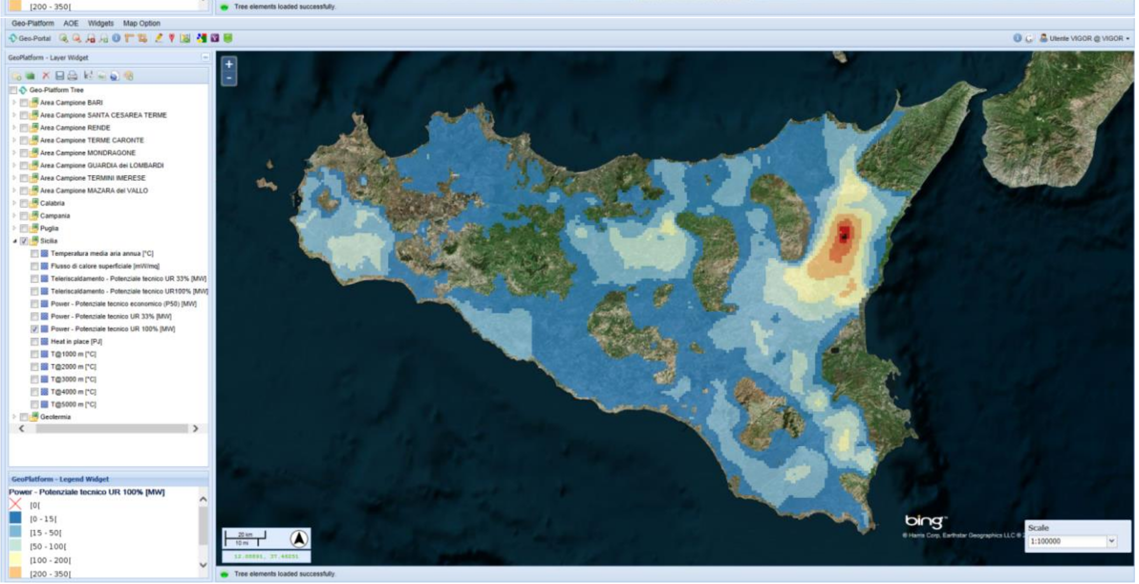
From Theoretical Capacity to Theoretical Technical Potential

The *theoretical capacity* (TC) is the heat in place utilized by the application and depends on the efficiency (η) and on the outlet temperature.

The *Technical Potential* (TP) denotes the expected recoverable geothermal energy [MW] and assumes that the resource will be developed in a period of thirty years.

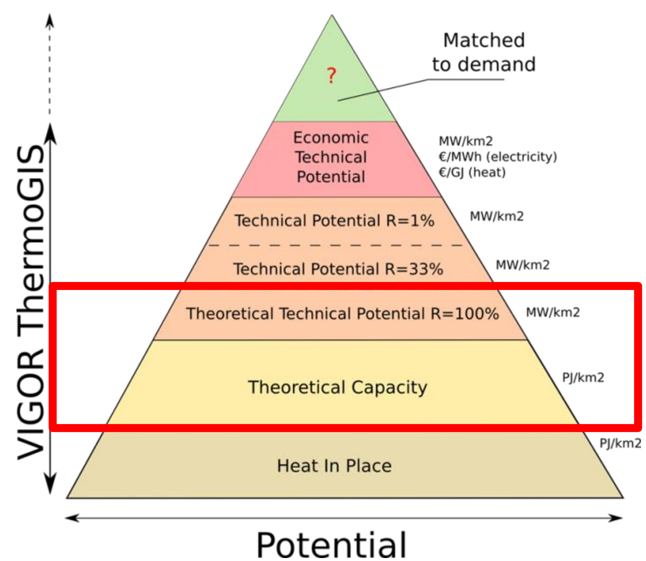
	Power (binary plant)
Minimum temperature	120 °C
Outlet temperature	97 °C





TP (MW)

- < 15
- 15-50
- 50-100
- 100-200
- 200-350
- 350-500
- > 500



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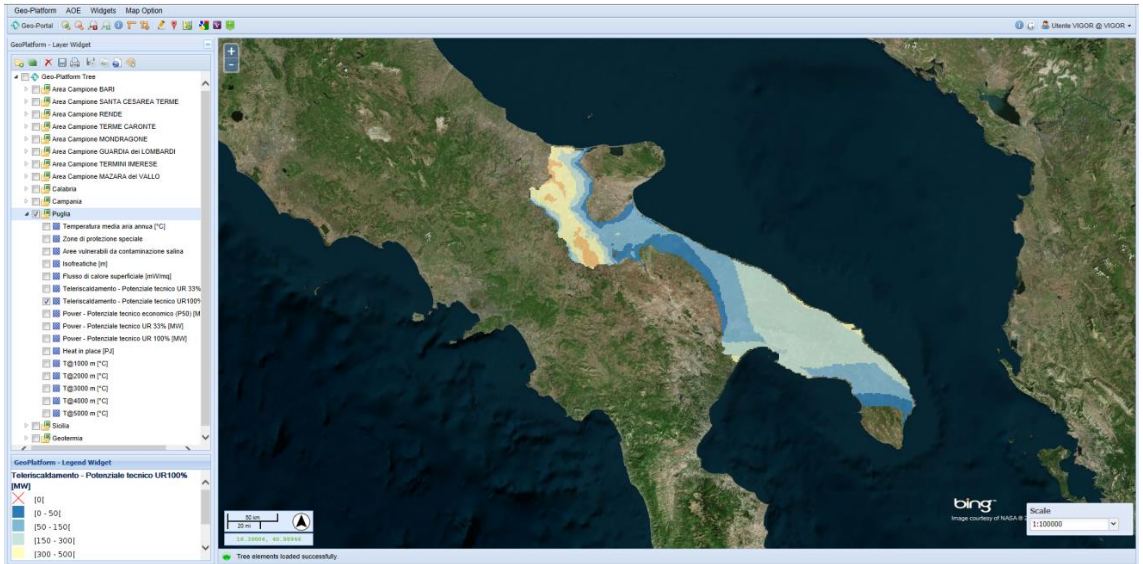
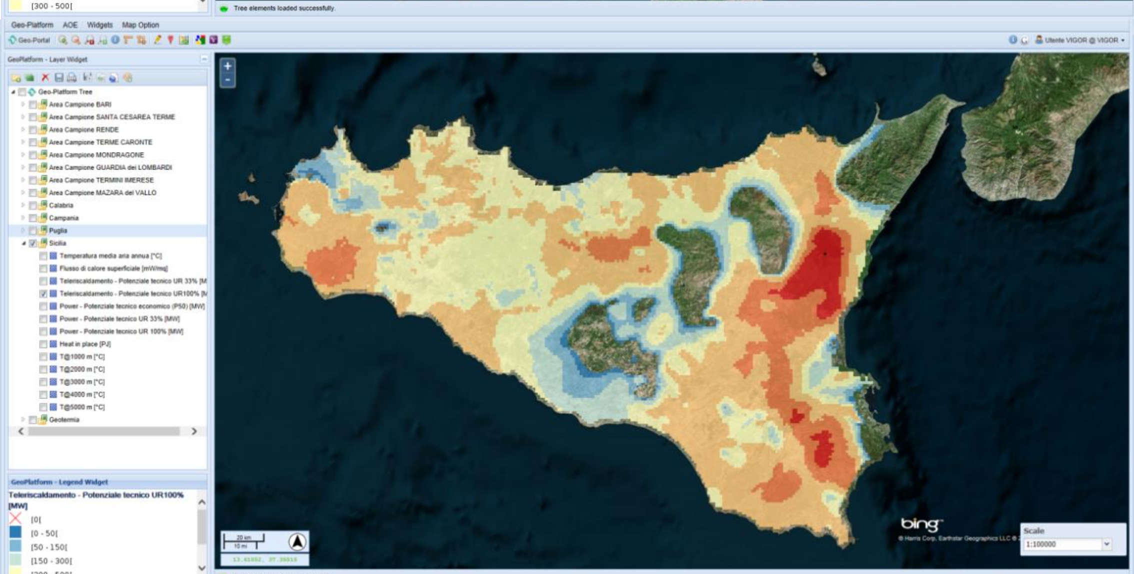
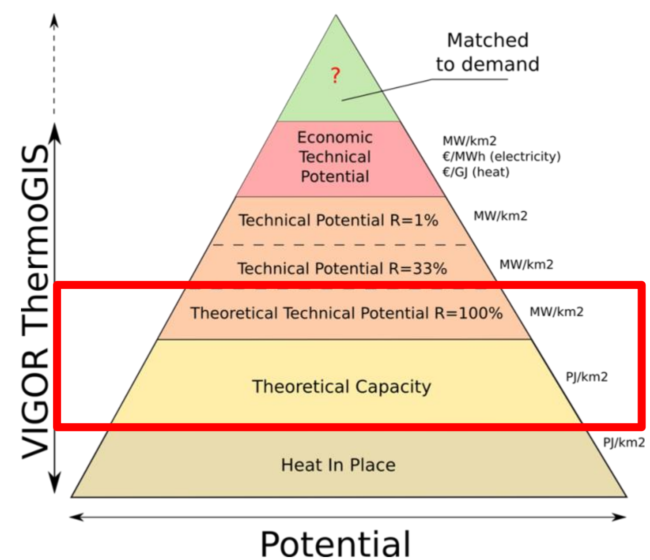




	Heating-Cooling
Minimum temperature	80 °C
Outlet temperature	40 °C

TP (MW)

- < 15
- 15-50
- 50-100
- 100-200
- 200-350
- 350-500
- > 500



Conclusions

Regional Temperature model

- **With the exception of volcanic areas, deep carbonate reservoirs can host important geothermal resources**
- **Far from recharge areas, the geothermal gradient of the cap rock varies laterally and reflects the trend of the underlying Mesozoic carbonate formations, with higher values where the fluid convection inside the carbonates is more efficient**
- **Regions of near-isothermal temperatures imply significant convective heat transfer and high permeability within the geothermal reservoir**

Resource assessment

- **The obtained results will be useful for the planning and development of geothermal applications on regional and national scale**
- **VIGOR ThermoGIS can be used to focus geothermal exploration**
  - ➢ **Apulia: Bradanica Foredeep**
  - ➢ **Sicily: Western sector, Caltanissetta Basin, Hyblean Platform, Mt.Etna**

THANKS
FOR
THE ATTENTION