Integrated Geoscience Research Group

7th EUropean Congress on REgional GEOscientific Cartography and Information Systems
Sustainable Geo-Management
Bologna | Italy
june 12th - 15th 2012

EVALUATION OF THE GEOTHERMAL POTENTIAL OF THE COASTAL AQUIFER NEAR RAVENNA (ITALY).

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OBJECTIVES

- Characterize the thermal properties of the Ravenna coastal aquifer by identifying:

  - The relationships of temperature with:
    - land use
    - surface water
    - proximity to sea

  - The stabilization temperature

  - The temperature stabilization depth (surficial zone)

- Evaluation of the geothermal potential (low enthalpy) by studying the potential performance of an heat pump.

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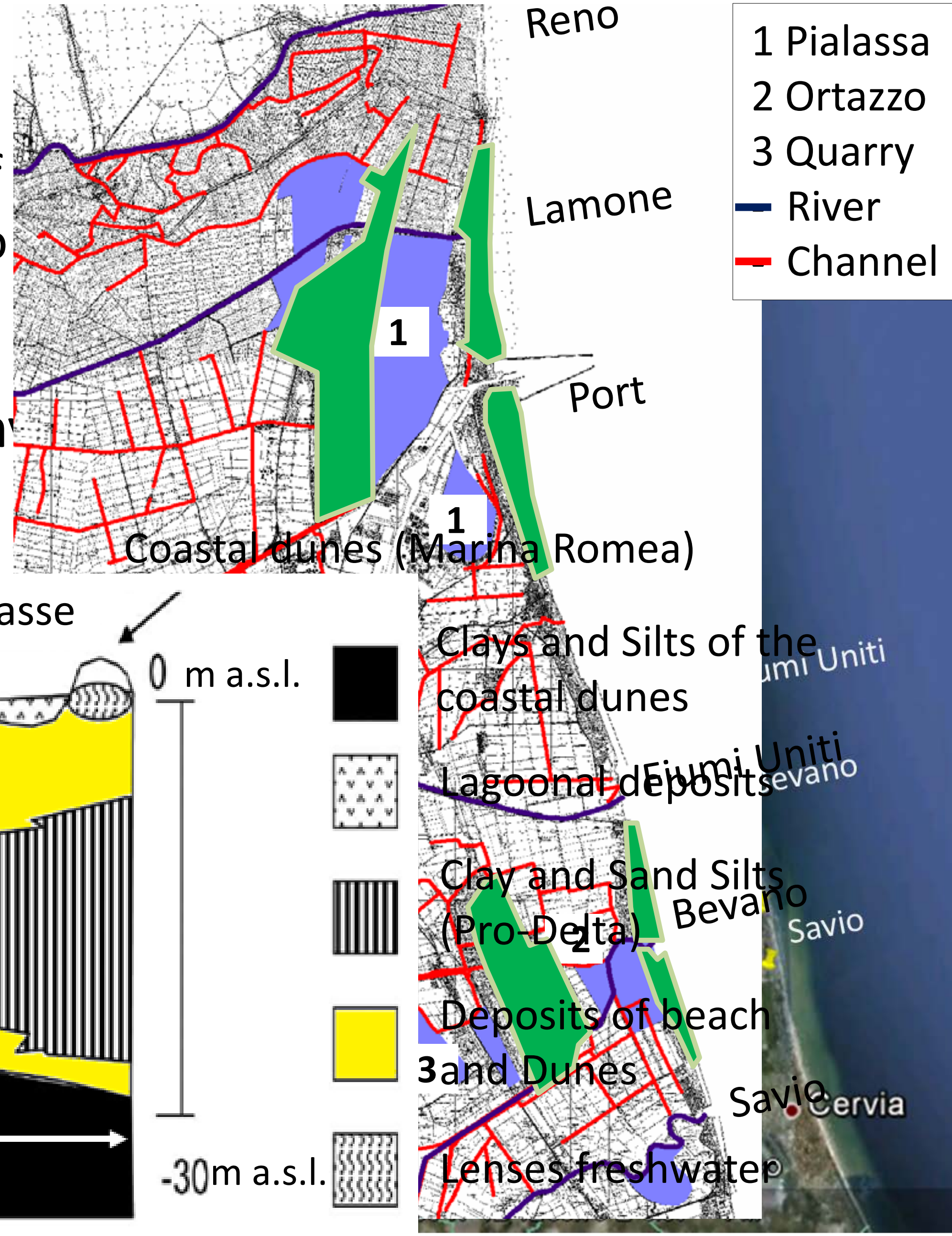
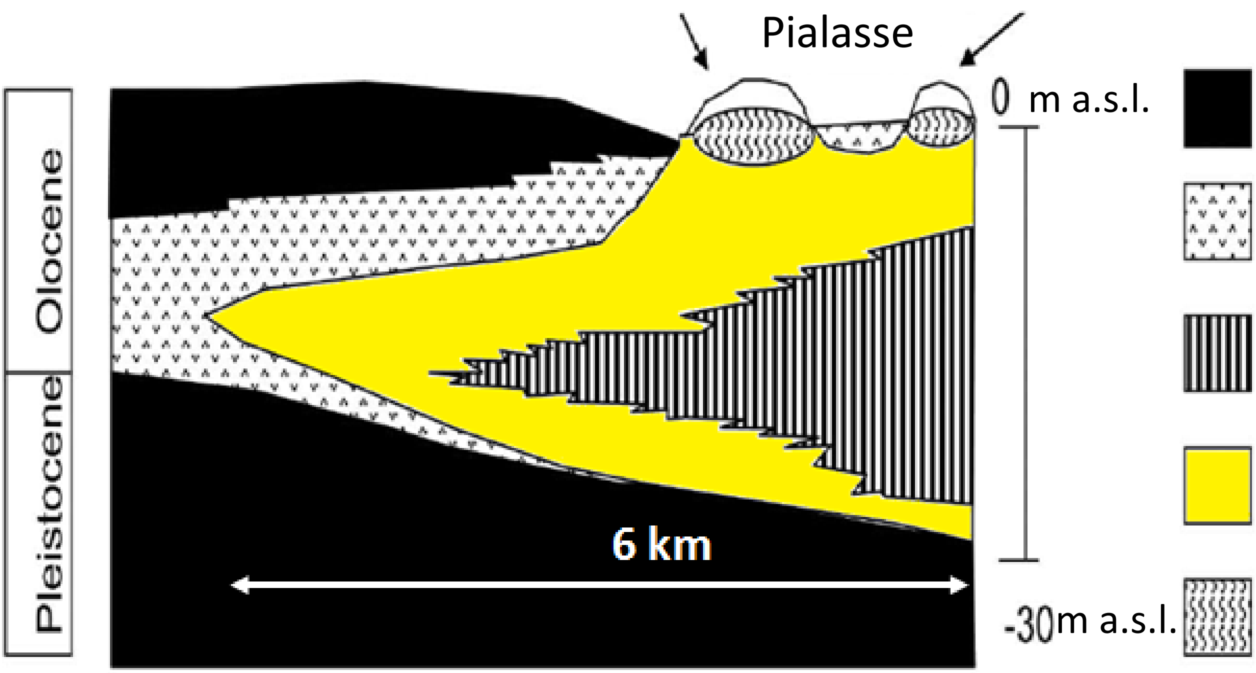
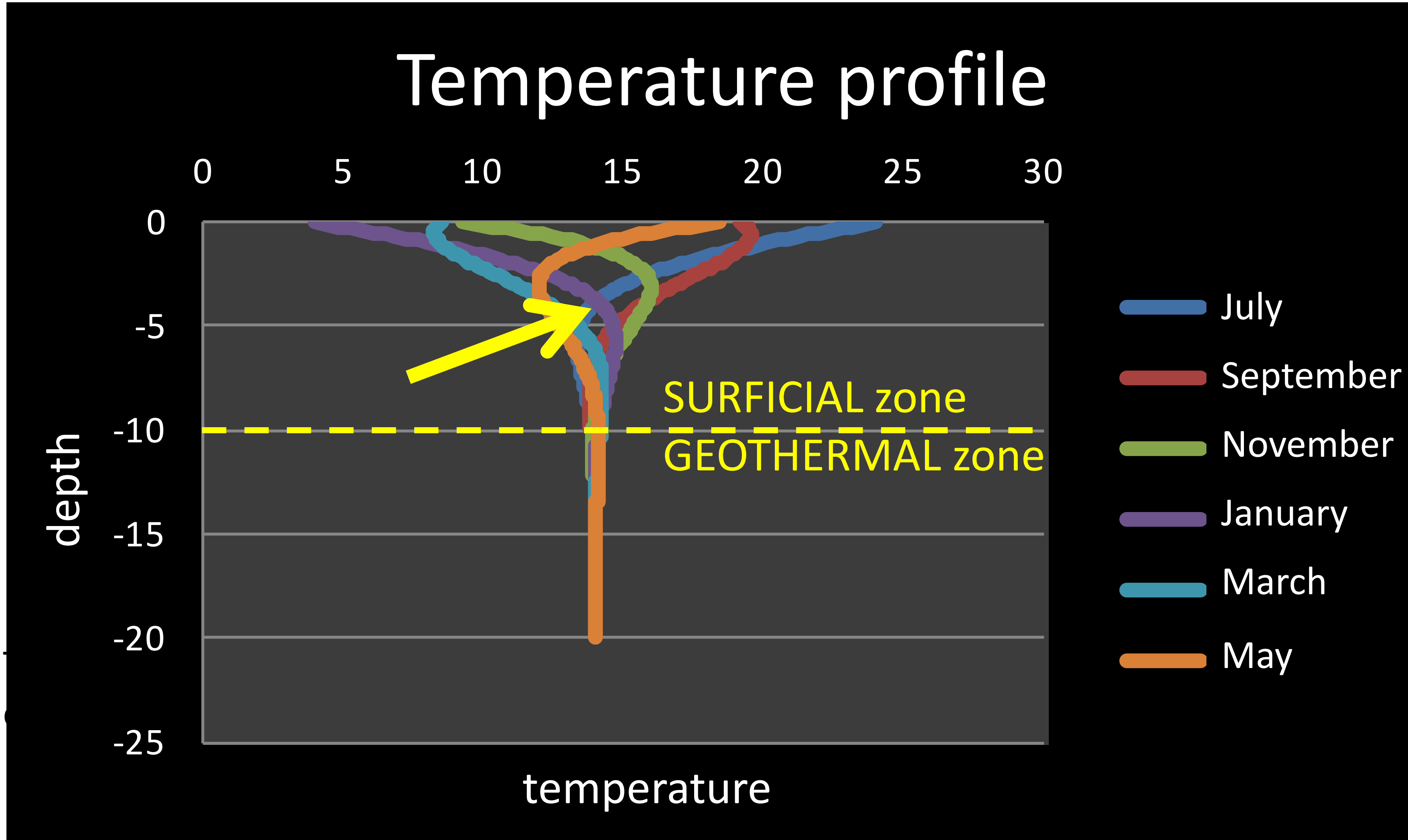
DESCRIPTION OF THE STUDY SITE

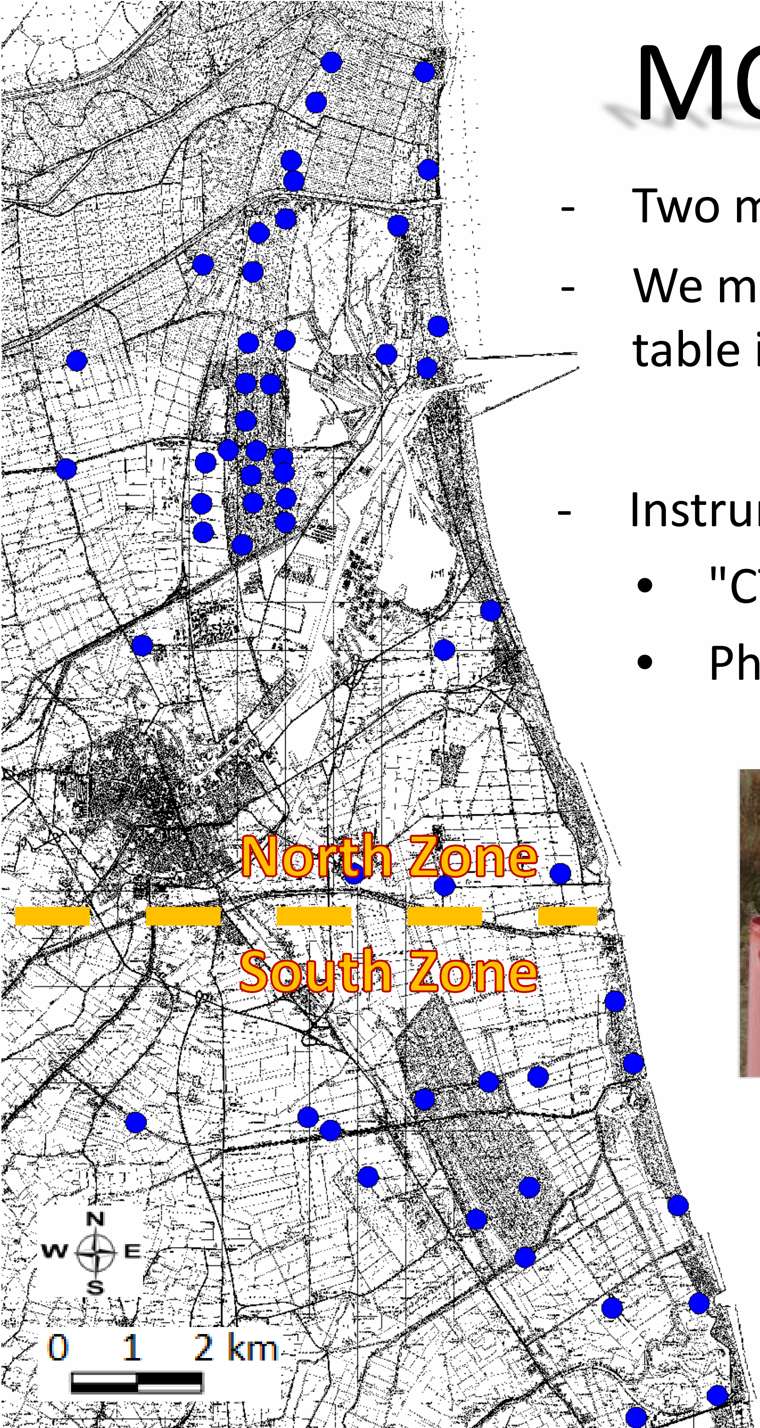
- Geographical context of the study eastern portion of the province of (from the mouth of the river Reno mouth of the river Savio).
- Surface geology and stratigraph
- Hydrological structure: Pialasse
-





THEORETICAL TRENDS OF GROUNDWATER TEMPERATURE IN A SHALLOW AQUIFER





MONITORING

- Two monitoring campaigns in June and December 2010.
- We measured temperatures and the height of the water table in 56 piezometers (in blue on the map).

- Instruments used:
  - "CTD probe Diver" and "Aquatroll" for temperatures;
  - Phreatimeter for water table levels.

DATABASE

METHODS

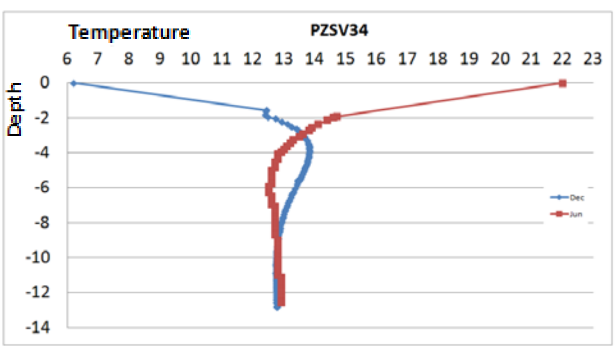
Database

							Measure of the Water Table (from the T.W)(m)	Elevation T.S. (m a.s.l.).	Elevation T.W (m a.s.l.)	Elevation Water Table (m a.s.l.)	Vadose Zone (m)
							1,26	0,83	1,00	-0,26	1,09
Well	East	North	Date and Time	Temperature (C)	Pressure (mBar)	Depth (m)					
PMSV8	757484,00	4929151,00				10,38	Real Depth (m	Depth T.W.	Elevation m a.s.l.		
			10/06/2010 16:57	19,9	1034,75	10,55	0,17	1,43	-0,43		
			10/06/2010 16:57	19,8	1035,71	10,56	0,18	1,44	-0,44		
			10/06/2010 16:57	19,2	1060,55	10,80	0,42	1,68	-0,68		
			10/06/2010 16:57	18,6	1085,38	11,05	0,67	1,93	-0,93		
			10/06/2010 16:57	18	1116,02	11,36	0,98	2,24	-1,24		
			10/06/2010 16:57	17,7	1128,16	11,49	1,11	2,37	-1,37		
			10/06/2010 16:57	17,3	1151,69	11,72	1,34	2,60	-1,60		
			10/06/2010 16:57	17	1175,62	11,97	1,59	2,85	-1,85		
			10/06/2010 16:57	16,8	1196,61	12,18	1,80	3,06	-2,06		
			10/06/2010 16:57	16,5	1215,91	12,37	1,99	3,25	-2,25		
			10/06/2010 16:57	16,3	1242,03	12,64	2,26	3,52	-2,52		
			10/06/2010 16:58	16,2	1248,30	12,70	2,32	3,58	-2,58		
			10/06/2010 16:58	15,9	1267,94	12,90	2,52	3,78	-2,78		
			10/06/2010 16:58	15,8	1286,45	13,09	2,71	3,97	-2,97		
			10/06/2010 16:58	15,8	1293,19	13,16	2,78	4,04	-3,04		
			10/06/2010 16:58	15,7	1303,21	13,26	2,88	4,14	-3,14		

Input *EnviroInsite*

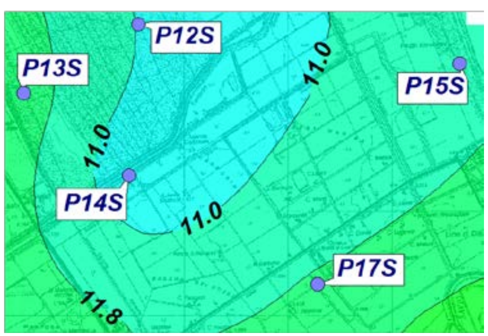
Well	Screen	Date	Value	Constituent
P1S	A	15/12/2010	12,4	Temperature
P1S	B	15/12/2010	12,5	Temperature
P1S	C	15/12/2010	12,8	Temperature
P1S	D	15/12/2010	13,1	Temperature
P1S	E	15/12/2010	13,2	Temperature
P1S	F	15/12/2010	13,4	Temperature
P1S	G	15/12/2010	13,4	Temperature
P1S	H	15/12/2010	13,5	Temperature
P1S	I	15/12/2010	13,5	Temperature
P1S	L	15/12/2010	13,6	Temperature

Temperature profile

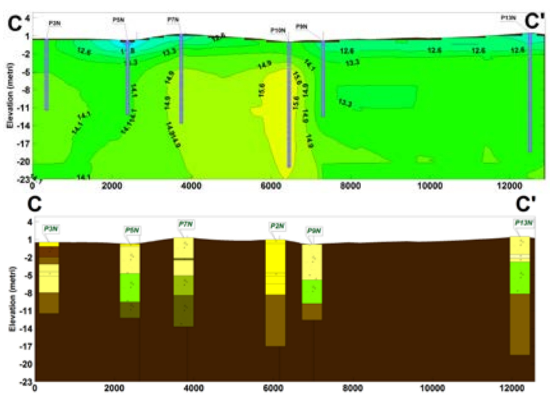


Output *EnviroInsite* :

Temperature maps



Sections



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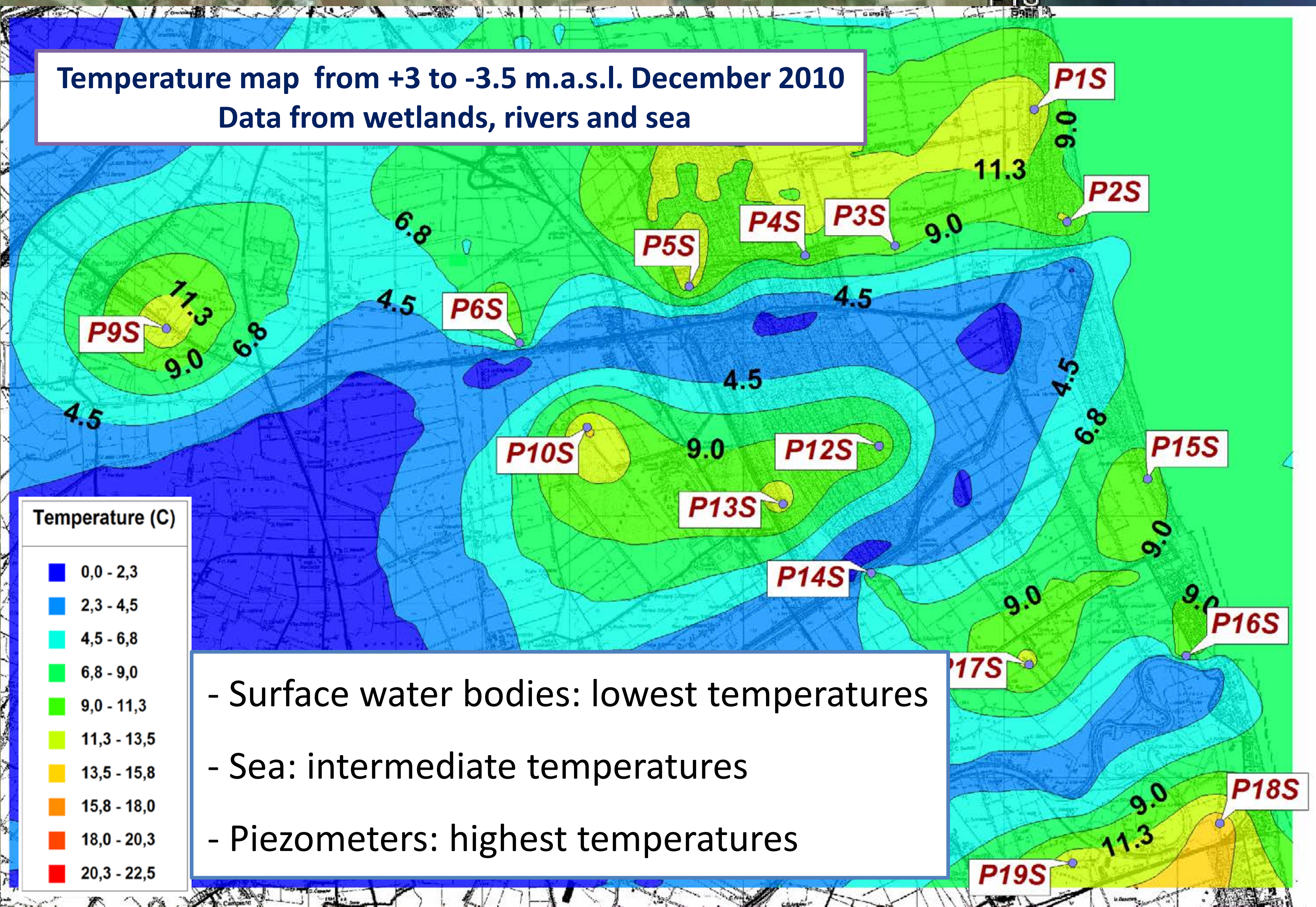
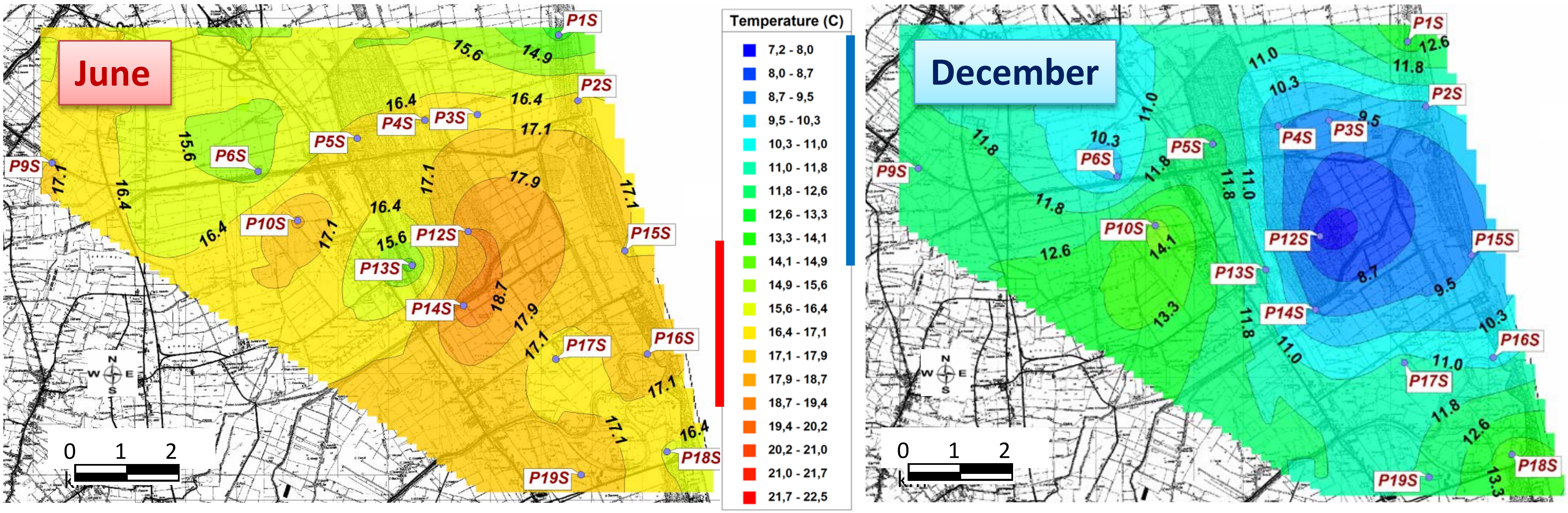
TEMPERATURE MAPS – SOUTH ZONE



- Surface water bodies: lowest temperatures
- Sea: intermediate temperatures
- Piezometers: highest temperatures

TEMPERATURE MAPS – SOUTH ZONE

Temperature maps from 0 to -1 m below the water table



Temperatures

between **14** °C (P1S) and **19,4** °C (P14S)

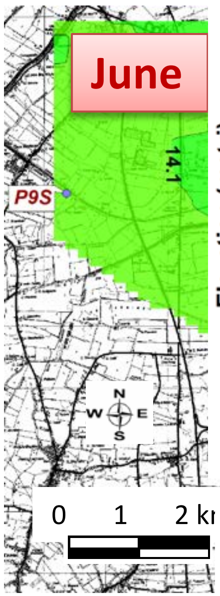
Temperatures

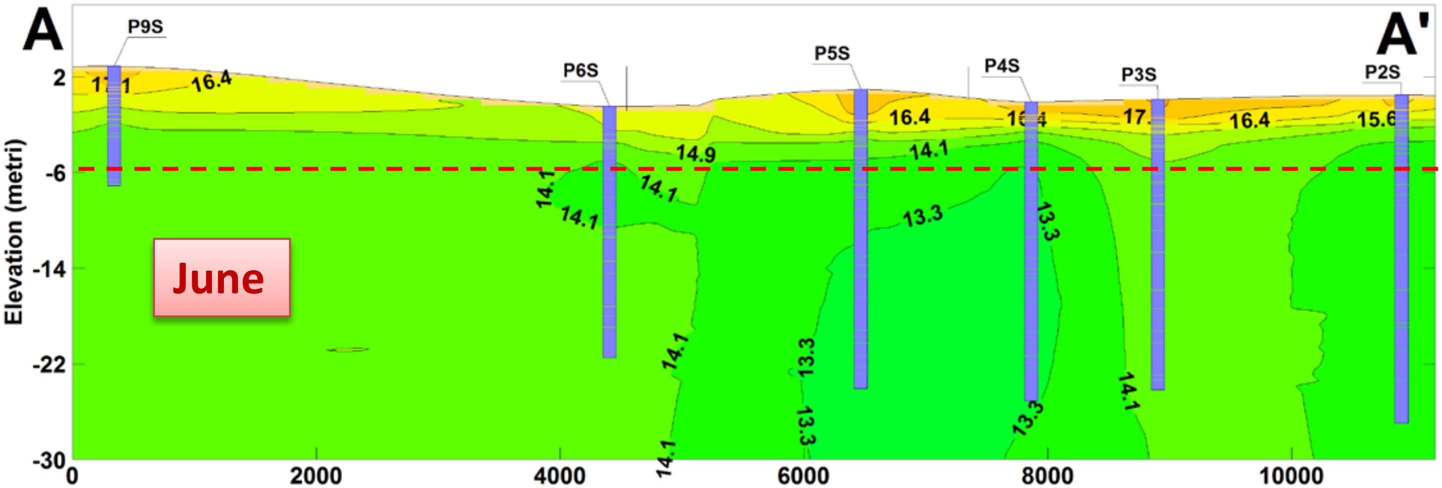
between **7,5** °C (P12S) and **14,4** °C (P10S)

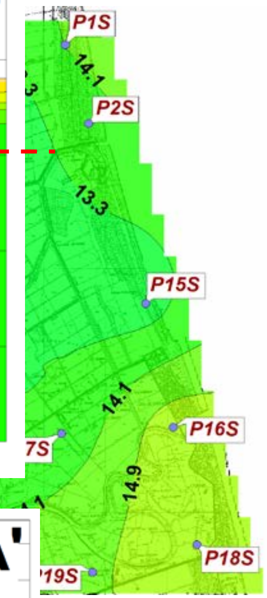
- Large difference in temperature between June and December. Largest difference in P12S and P14S, and smallest in P1S and P18S

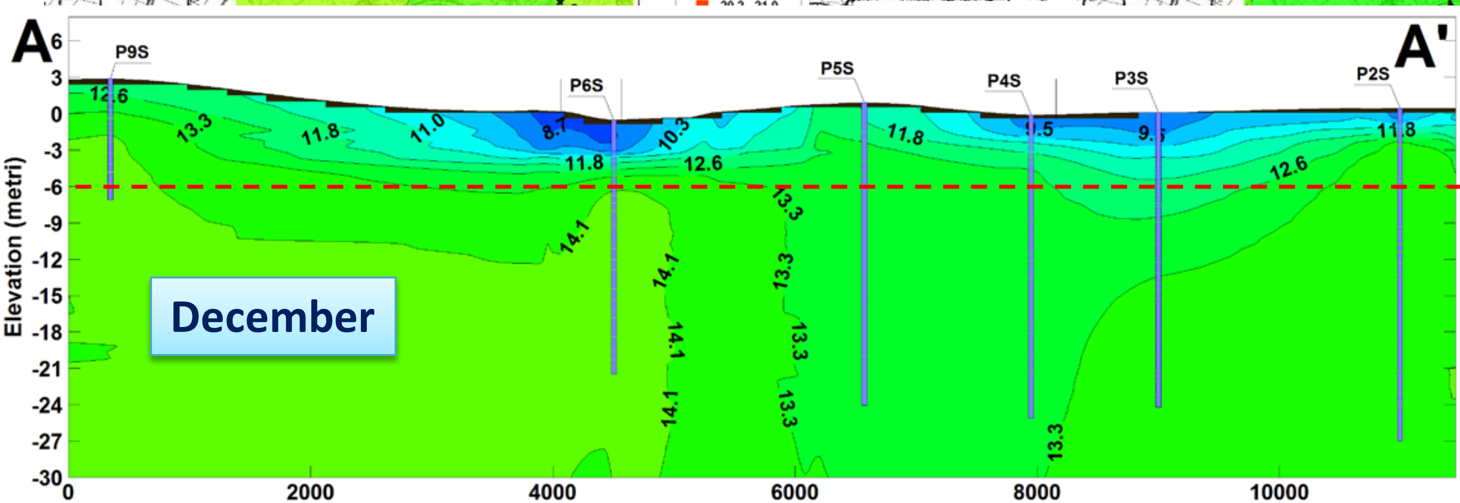
TEMPERATURE MAPS – SOUTH ZONE

Temperature ma| Sections of temperature |e water table









Temperatu

between 1 … (P18S)

- Simila

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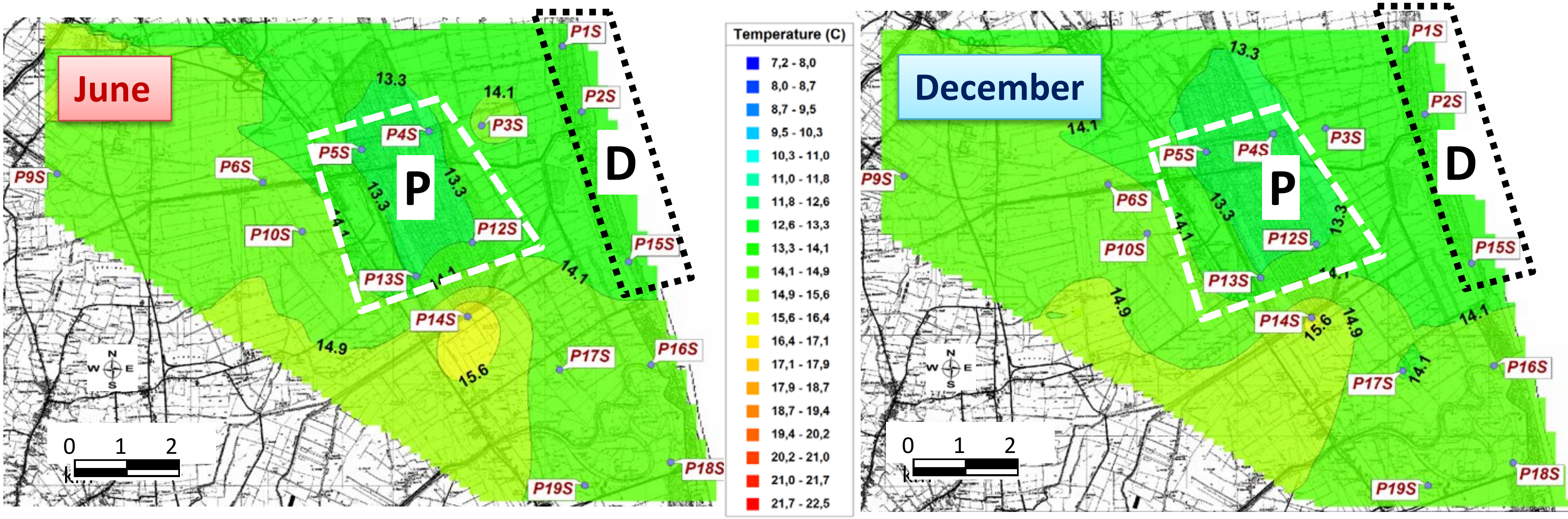
TEMPERATURE MAPS – SOUTH ZONE

Temperature maps from -17 to -18 m below the water table



- the piezometers of Paleodune (P) have the lowest temperature (about 13° C)

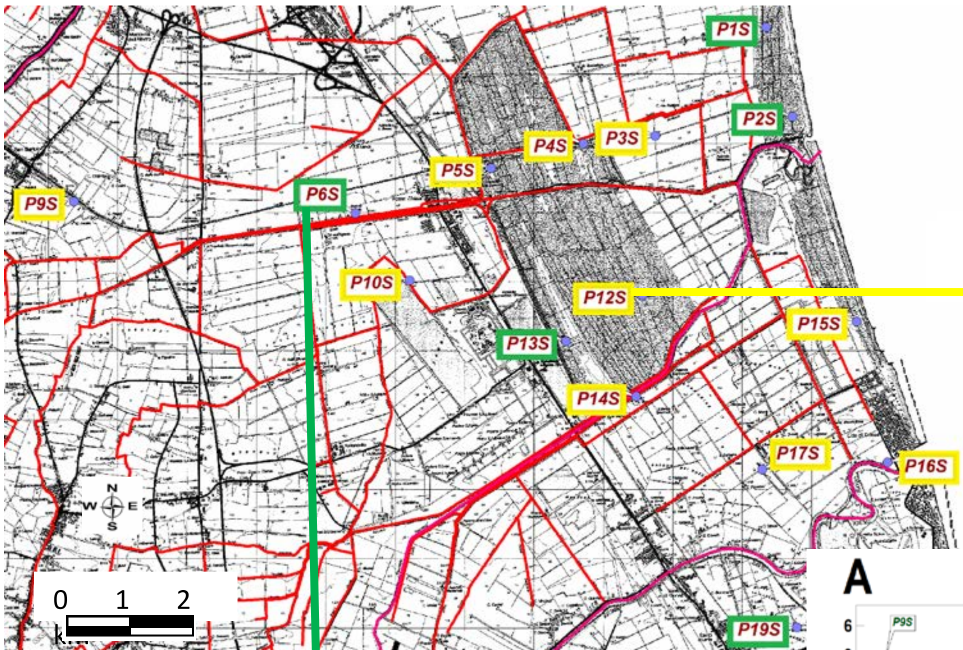
- the piezometers of the Dune (D) have intermediate temperatures (around 13.7 ° C)

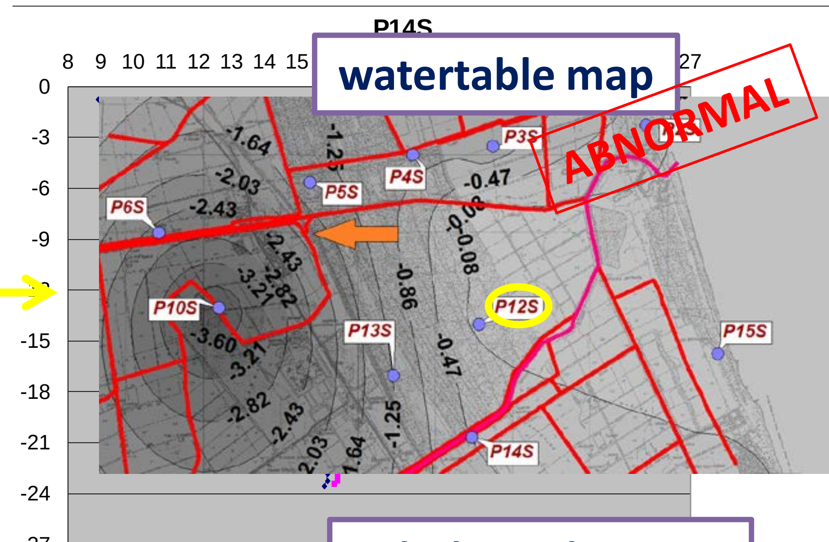
- the piezometers of the agricultural areas are the highest (about 14.5 ° C)

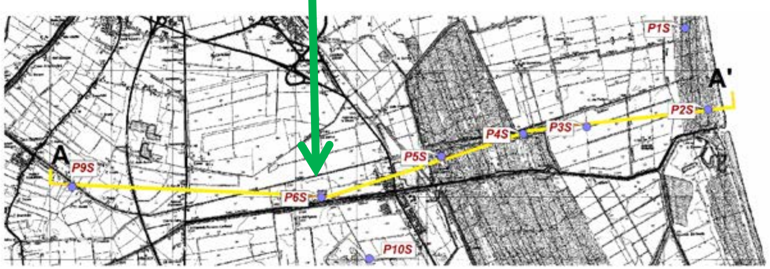
TEMPERATURE PROFILES - SOUTH ZONE

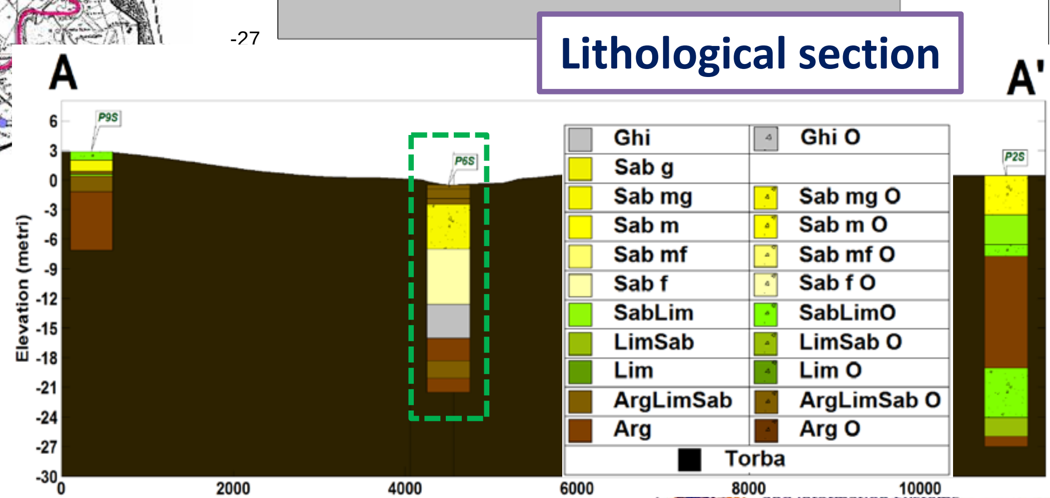
- 11 out of 17 wells have temperature profiles with abnormal behavior.
- There is a correlation between abnormal temperature profiles (in yellow) and the proximity to drainage channels and rivers.

EXCEPTIONS

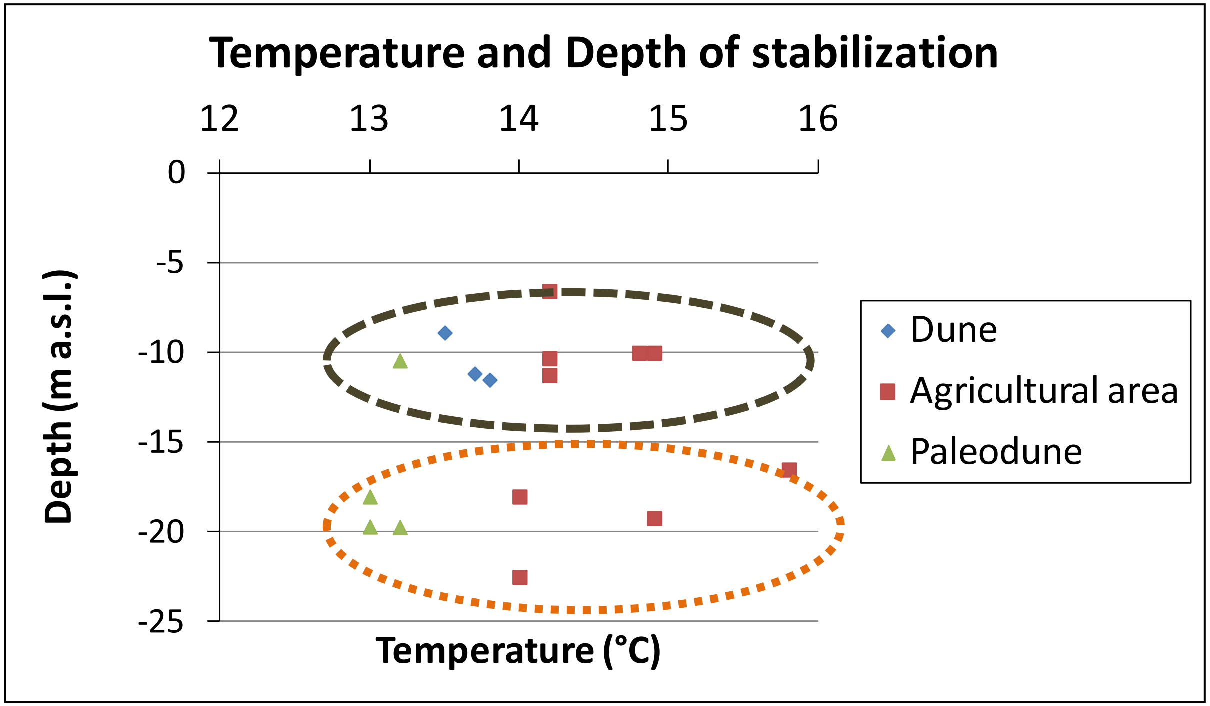








TEMPERATURE PROFILES - SOUTH ZONE

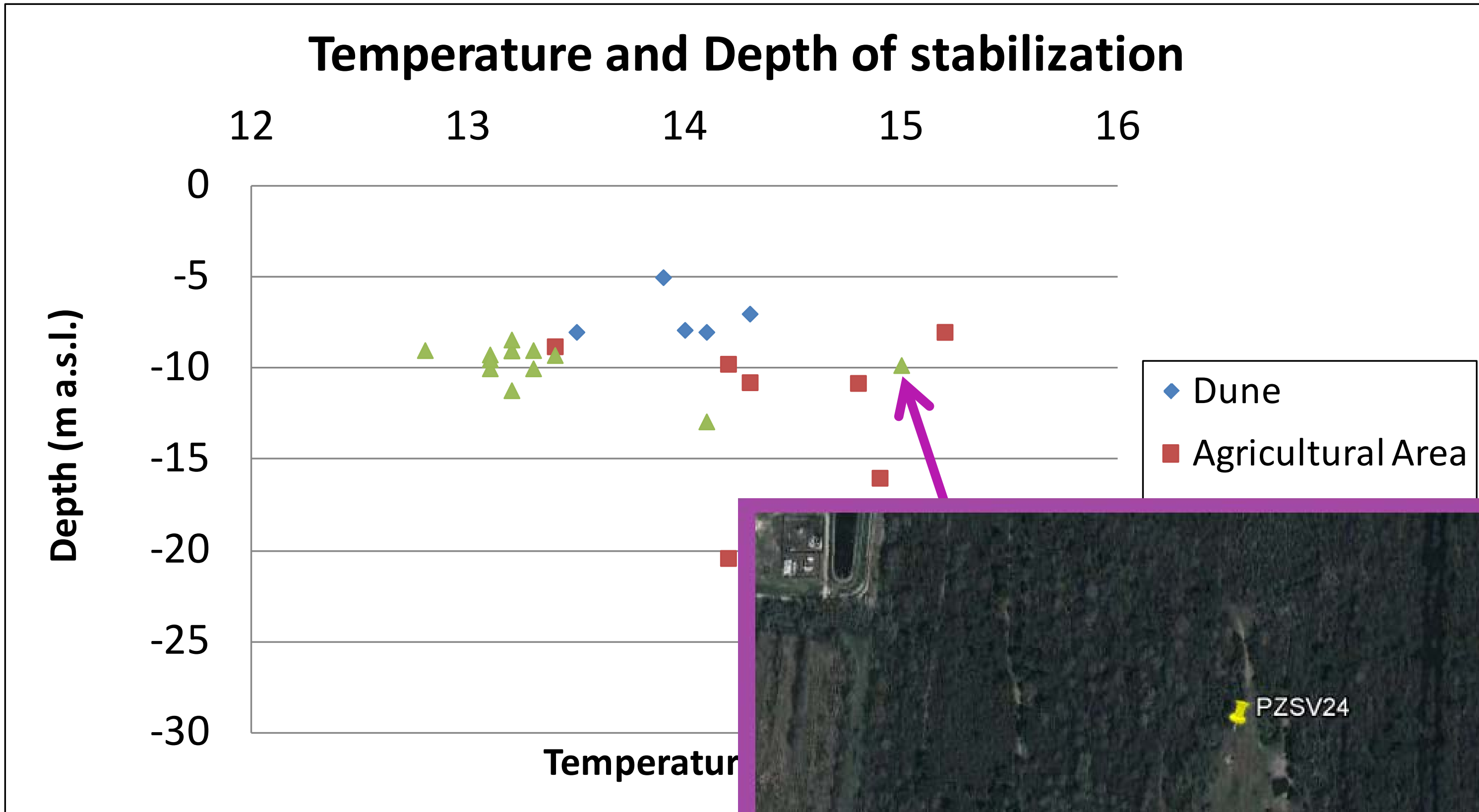


• The different "groups" of piezometers (dune, agricultural areas, paleodune) are divided according to the stabilization temperature:

- the piezometers of the Paleodune have the lowest temperature (about 13 ° C)
- the piezometers of the Dune have intermediate temperatures (about 13.7 ° C)
- the piezometers of the agricultural areas have the highest temperatures (about 14.5 ° C)

• Two groups of wells according to stabilization depth: -10 m a.s.l. and -20 m a.s.l.

TEMPERATURE PROFILES - NORTH ZONE



The different "groups" of piezometers (dune, a
according to the stabilization temperature.

CONCLUSIONS ON GROUNDWATER TEMPERATURES

- Groundwater temperature fluctuations in response to seasonal variations in air temperature decrease with depth.
- The time lag between air- and groundwater temperature increases with depth.
- There is a correlation between the stabilization temperature (ST) and the geographical location of the piezometer:

  - Present dunes: have an average ST of 13.9 ° C;

  - Paleodunes: have an average ST of 13.3 ° C (the lowest);

  - The remaining wells have an average ST of 14.5 ° C.

  The mean annual air temperature is 13.7 ° C (central city of Ravenna from 1999 to 2010).

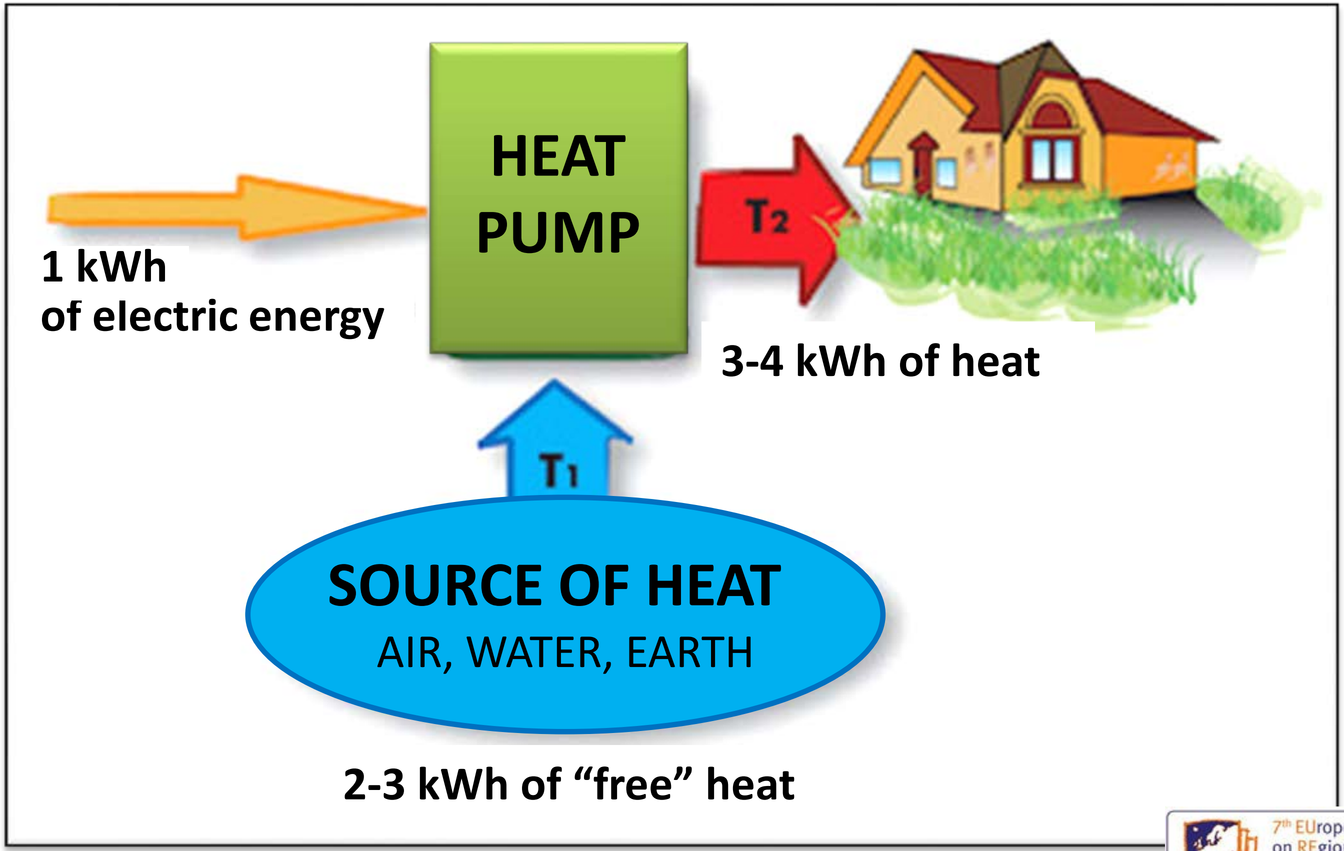
- The environmental factors that mostly influence the stabilization temperature are: vegetation cover (pine forest or agricultural crops), geographic location relative the sea and recharge with surface water bodies.
- The depth of the surficial zone is influenced by the drainage system and by surface water infiltration.

EVALUATION OF THE GEOTHERMAL POTENTIAL

The geothermal interest of the Ravenna coastal aquifer is for the so-called "low enthalpy" conditions.

The technology used in these conditions is based on the geothermal heat pump.

This technology allows to heat, cool and provide hot water using heat stored in the subsoil.



EVALUATION OF THE GEOTHERMAL POTENTIAL

Calculation of the potential performance of a heat pump.

$$r = \frac{Q_2}{L} = \frac{Q_2}{(Q_2 - Q_1)} = \frac{T_c}{(T_c - T_e)}$$

Q1: absorption of heat from the source in the evaporator
Q2: transfer of heat for the users in the condenser
L: electric energy consumption in the compressor
Te: temperature refrigerant when It evaporates (corresponds to that of the source)
Tc: temperature refrigerant when It is compressed (the same as that required by the domestic housing)

A typical good performance for a geothermal heat pump is a yield (r) of 2,5.

The calculation of performance has been performed for the two wells that have the most extreme stabilizing temperatures: the P14S (about 16 ° C) and the PZSV34 (12.9 ° C).

The performance has been calculated for two distinct depths: at - 5 m from ground level and at the bottom of the well.

In addition, the calculation was done both for the winter and the summer periods assuming that the thermal power plant specifications of the house require a temperature of 30 ° C for heating and 19 ° C for cooling.

EVALUATION OF GEOTHERMAL POTENTIAL

$$r = \frac{T_c}{(T_c - T_e)} = COP \qquad r = \frac{T_e}{(T_c - T_e)} = EER$$

P14S

	210 days			10 days			
	winter			**summer**			
		home	source		home	source	

P2N

	210 gg			10 gg			
	winter			**summer**			
		home	source		home	source	
5 m from ground level	**r**	**Tc**	**Te**	**r**	**Tc**	**Te**	**total performance**
	1,90	30	14,2	2,96	19,0	14,2	**1,95**
		home	source		home	source	
Downhole	**r**	**Tc**	**Te**	**r**	**Tc**	**Te**	**total performance**
17,50 m (from ground level)	1,89	30	14,1	2,88	19,0	14,1	**1,93**

5 m from ground level	**r**	**Tc**	**Te**	**r**	**Tc**	**Te**	**total performance**
	1,72	30,0	12,6	**2,58**	19,0	13,7	**1,76**
		home	sorgente		home	source	
Downhole	**r**	**Tc**	**Te**	**r**	**Tc**	**Te**	**total performance**
12,79 m (from ground level)	**1,75**	30,0	12,9	**2,11**	19,0	12,9	**1,77**

CONCLUSIONS HEAT PUMPS

Geothermal heat pumps would be more effective in:

- The areas where the aquifer has the highest temperatures (agricultural lands or areas with no vegetation cover);
- The areas in which there is a high hydraulic gradient. In this way the heat level of the subsurface surrounding the probe is constantly regenerated (near drainage channels and rivers);
- The areas where the soil and the saturated sediments have a high thermal conductivity allowing the exchange of heat with a larger volume of aquifer (i.e. where there is sand).


Thank
you for
your attention