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The BSI indicator: preventing thermal interferences between groundwater heat pump systems

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1. INTRODUCTION

The steady increase of geothermal systems using groundwater is compromising the renewability of the geothermal resources in shallow urban aquifers. The increase in the number of GWHP systems and the increase of thermal interferences between these systems enforces the need for new criteria to develop subsurface energy policies that allow planning their spatial distribution and limiting their operation regimes. To ensure sustainability, scientifically-based criteria are required to prevent potential thermal interferences between geothermal systems. In this context, the BSI management indicator (García-Gil et al., 2019) has been applied to groundwater heat pump systems to assign a quantitative value of sustainability to each system, based on their intrinsic potential to produce thermal interference. The BSI indicator relies on the net heat balance transferred to the terrain throughout the year as well as on the maximum seasonal thermal load associated.

The BSI of a GWHP system represents the thermal impact of a given operational scenario in a standard model considered as a reference framework. The objective of the BSI index is not to predict the real thermal impact of such scenario but to provide a quantitative value proportional to a potential thermal impact produced in a theoretical standardized model. This approach allows comparing any GWHP system in a simple way.

The BSI indicator could provide authorities and technicians with scientifically-based criteria to establish geothermal monitoring programs, which are critical to maintain the implementation rates and the renewability of these systems in the cities. The BSI indicator contributes to the fulfilment of the MUSE project objectives (*https://geoera.eu/projects/muse3/*). The MUSE project investigates the resources and the possible conflicts of use associated with shallow geothermal energy (SGE) in European urban areas and delivers key geoscientific subsurface data to stakeholders via a user-friendly web based platform within GeoERA. MUSE will lead to the development of management strategies considering both efficient planning and monitoring of environmental impacts to feed into general framework strategies of cities like SEAP's.

2. METHODOLOGY

To calculate the BSI indicator, first, the Heating-cooling ratio of the considered GWHP system was calculated. GWHP systems operating within the 0.00 to 0.10 Heating-Cooling ratio range were considered in a first polynomial regression model (Figure A), while those operating in a HC ratio larger than 0.10 were considered in a second polynomial regression model (Figure B). To use polynomial regression models, the maximum seasonal energy load [MWh] is required in addition to the HC ratio. Once the polynomial regression model is chosen, these two variables allow obtaining the BSI indicator automatically in a simple way (see table below). A sample spreadsheet is available as Supplementary Data in García-Gil et al., 2019. The BSI index calculated for every GWHP system considered in the city of Zaragoza is shown in Figure C.

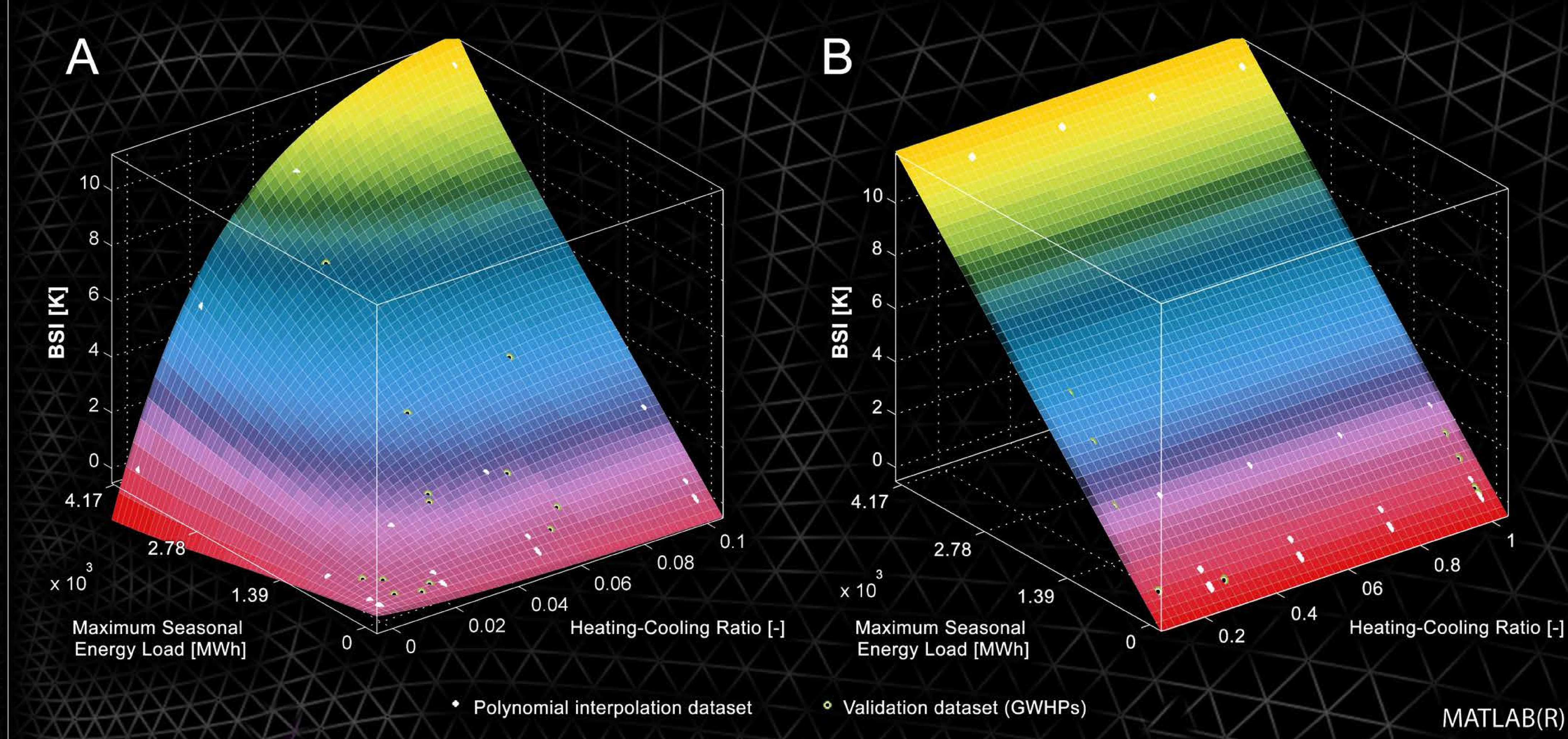
Polynomial regression model 1

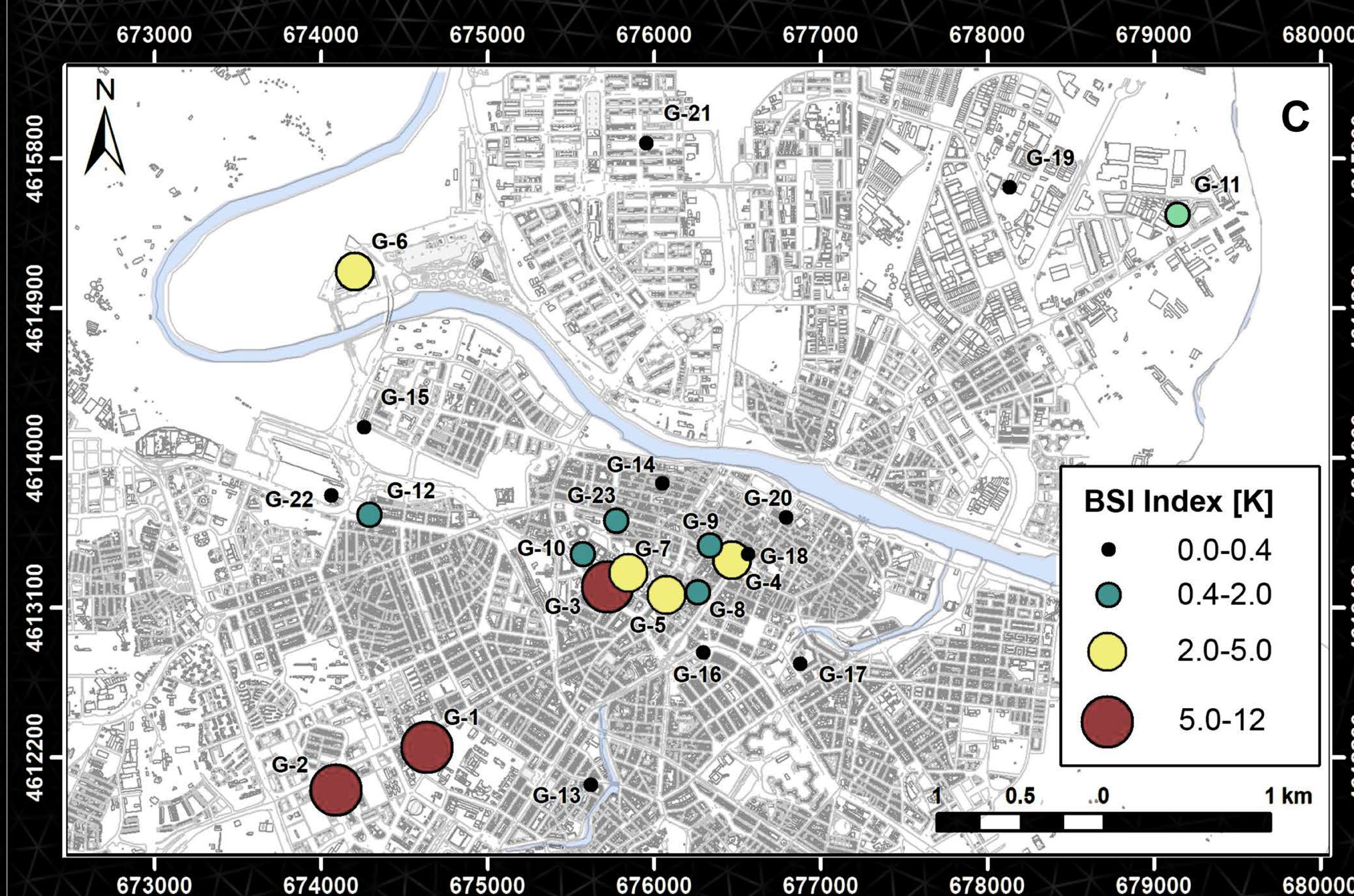
$$f(x,y) = p00 + p10x + p01y + p20x^2 + p11xy + p02y^2 + p30x^3 + p21x^2y + p12xy^2 + p03y^3 + p40x^4 + p31x^3y + p22x^2y^2 + p13xy^3 + p04y^4 + p50x^5 + p41x^4y + p32x^3y^2 + p23x^2y^3 + p14xy^4 + p05y^5$$

Coefficients	
p00	2.814E-04
p10	-3.698E-01
p01	-9.965E-16
p20	1.917E+01
p11	2.126E-11
p02	9.720E-28
p30	-2.790E+02
p21	-2.888E-10
p12	2.652E-25
p03	-1.733E-40
p40	1.254E+02
p31	2.229E-09
p22	-3.606E-24
p13	-1.318E-38
p04	-5.020E-54
p50	1.108E+04
p41	-7.408E-09
p32	1.078E-23
p23	8.558E-38
p14	3.186E-52
p05	8.852E-67

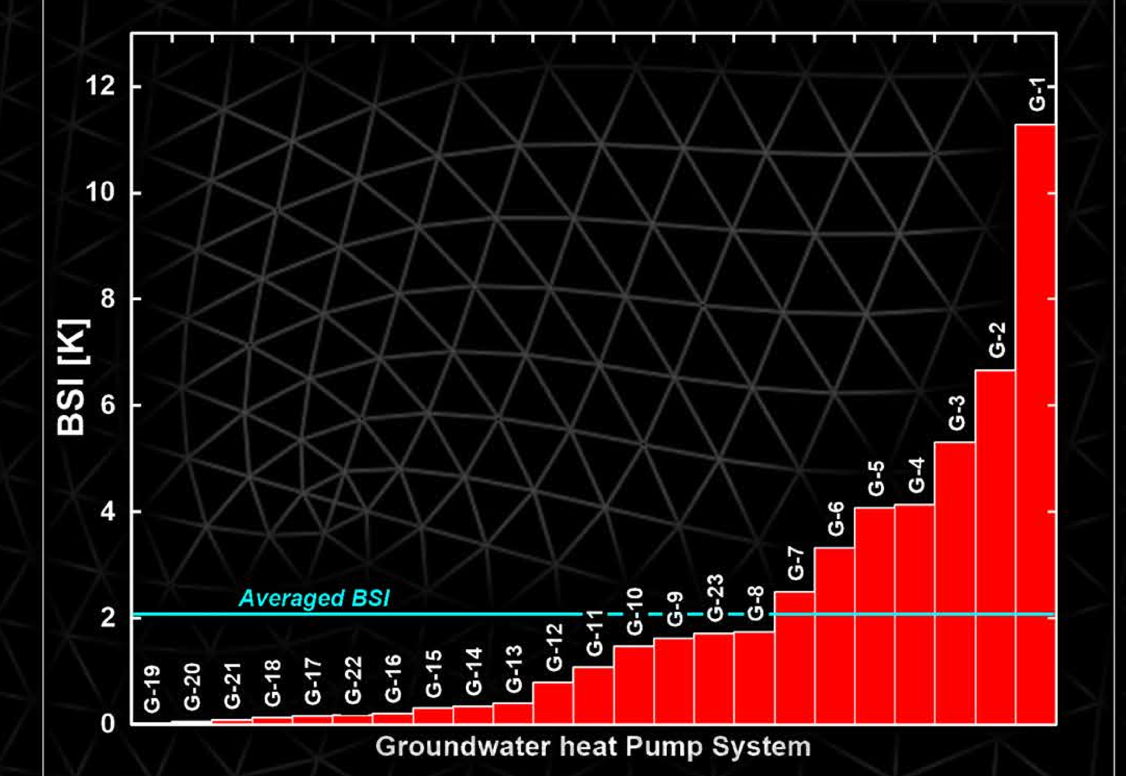
**x = heating-cooling ratio [-]*
**y = Maximum seasonal energy loads [J]*

3. RESULTS





4. BSI INDICATOR IN ZARAGOZA CITY



6. CONCLUSIONS

- The BSI indicator provides a first general view of the potential sustainability of the operating systems from a quantitative perspective by making use of simple installation operational parameters.
- The indicator provides a reference framework for hydrogeologists and technicians in order to harmonize thermal impacts of GWHP systems. This allows comparing the intrinsic potential sustainability of these systems independently of the hydrogeological conditions worldwide, thus providing the standardized thermal impact under normalized conditions without performing any numerical modelling.
- The BSI indicator applied to 23 real GWHP systems evidences its usefulness in the identification of different groups of installations that need different management policies to prevent plausible thermal interferences.

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