Geostatistical and Spatial Correlation Analysis of Planetary Data

Gianluca Chiarolanza[1], Giuseppe Mitri[1], and Antonio Genova[2]

[1]International Research School of Planetary Sciences
[2]Sapienza University of Rome

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Abstract

Data collected by space probes and Earth-based observations allow to investigate multiple aspects of planetary bodies in the Solar System. Typical spatial data utilized for geological and geophysical global scale investigations include imagery basemaps, digital elevation models, feature density maps, geochemical, magnetic and gravity anomaly maps. Different datasets often present local correlations, and their simultaneous use can help unveil the wide diversity of geological and geophysical processes that contribute to the planetary evolution. A geostatistical approach can be applied to quantify the level of correlation and anticorrelation between the different datasets. We developed a method based on a linear regression analysis of multiple planetary data, producing georeferenced maps that can be imported into a Geographic Information System (GIS) environment. We show how this geostatistical method can be used to quantify the level of correlation between different spatial data, and to investigate the geological and geophysical processes of planetary bodies. We present the results of the geostatistical method for the Mercury science case, using datasets returned by the MESSENGER mission.

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Gianluca Chiarolanza [1, 2*], Giuseppe Mitri [1, 2], Antonio Genova [3]

1 International Research School of Planetary Sciences, Pescara, Italy

2 Dipartimento di Ingegneria e Geologia, Università d'Annunzio, Pescara, Italy

3 Sapienza University of Rome, Department of Mechanical and Aerospace Engineering, Rome, Italy

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Introduction

Data collected by space probes and Earth-based observations allow to investigate multiple aspects of planetary bodies in the Solar System. Typical spatial data utilized for geological and geophysical globalscale investigations include imagery basemaps, feature density maps, geochemical, magnetic and gravity anomaly maps, and topographic models (Fig. 1).

Different datasets often present local correlations, and their simultaneous use can help unveil the wide diversity of geological and geophysical processes that contribute to the planetary evolution. A geostatistical approach can be applied to quantify the level of correlation and anticorrelation between the different datasets.

We developed a method to highlight regions of marked anticorrelation between pairs of selected datasets, producing georeferenced maps that can be imported into a Geographic Information System (GIS) environment. We show how this method can be used to quantify the level of correlation or anticorrelation between different spatial data, and to investigate the geological and geophysical processes of planetary bodies. We present an example of results of the geostatistical method for the Mercury science case, using datasets returned by the MESSENGER mission (Figs. 2, 3).

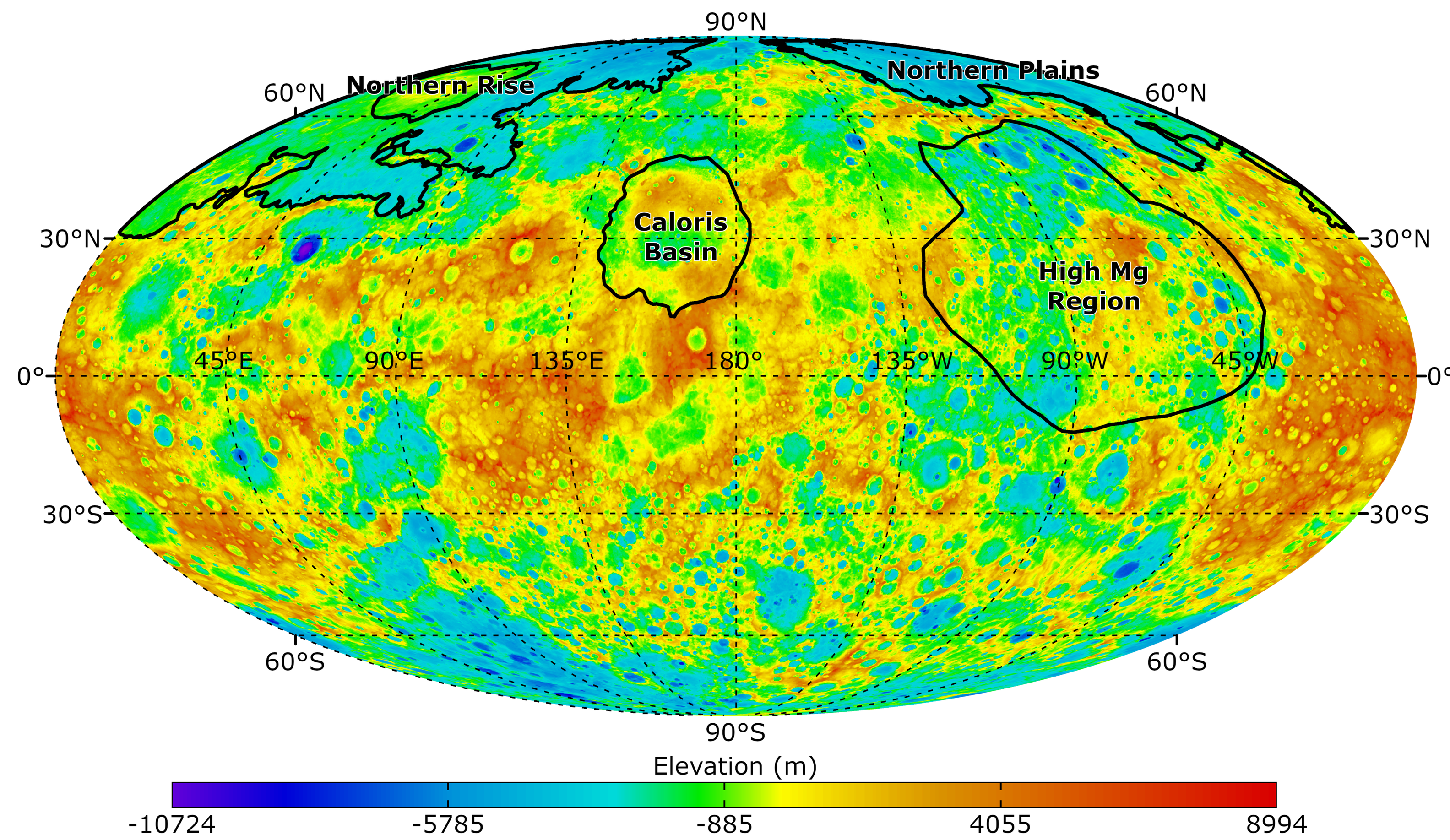

Fig. 1 Topographic map of Mercury, based on the global DEM developed by the USGS Astrogeology Science Center [*1*]

Methods

To produce planetary maps that enhance areas of anticorrelation, the acquired global datasets of Mercury must be uniformed in terms of extension, horizontal resolution and longitude domain. Then, for each matrix, values are normalized from 0 to 1 and substracted in correspondence of equal geographic coordinates. The larger their difference, the more they tend to approximate a linear anticorrelation. Vice versa, values close to zero indicate a linear correlation. The obtained matrices are finally georeferenced and imported into a GIS environment for further scientific investigations.

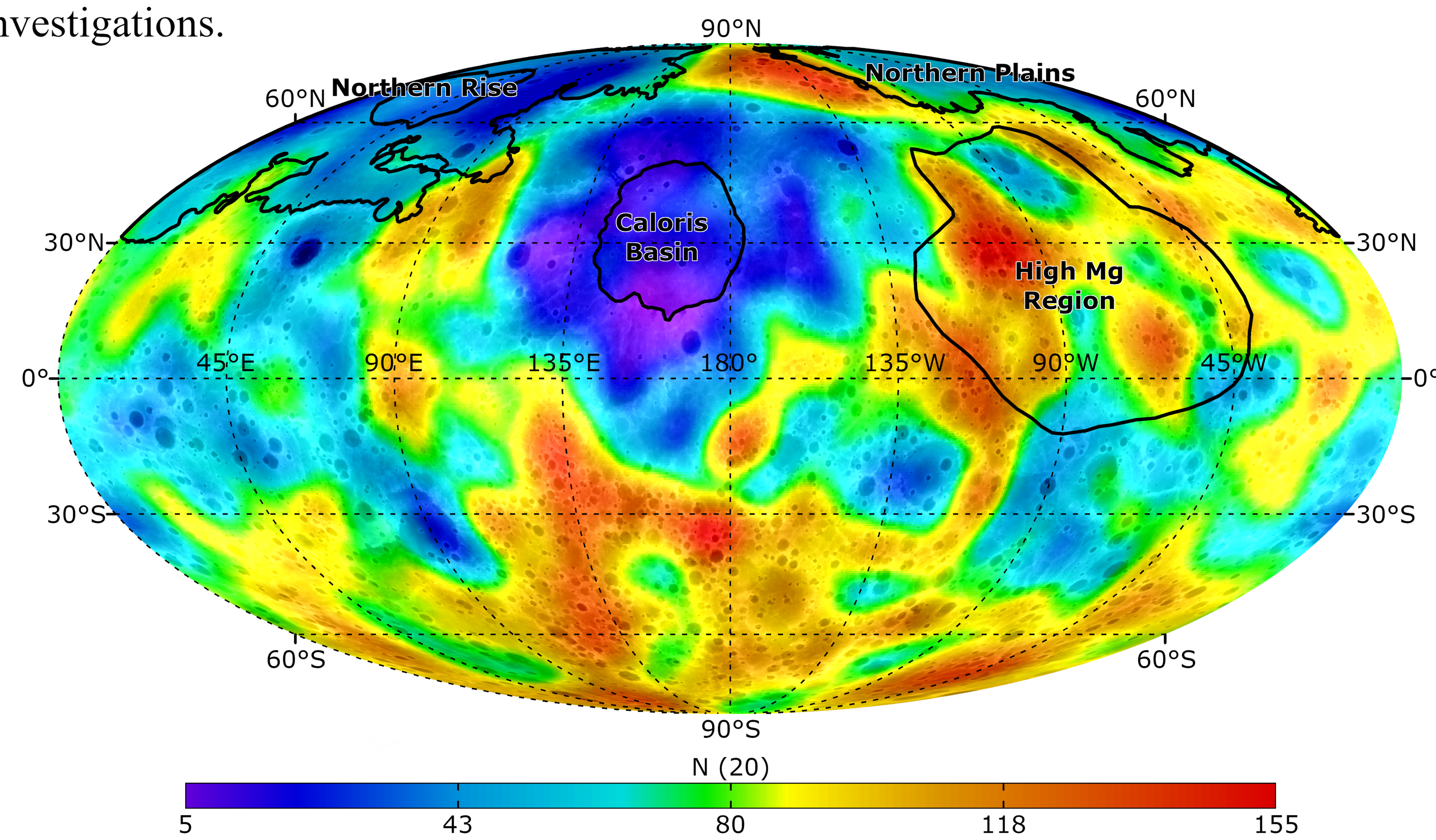

Fig. 2 Crater density map, expressed as the number of craters larger than 20 km in diameter, comprised within a circular neighborhood of radius 500 km. The map is based on an existing global dataset of Mercurian craters [*2*]

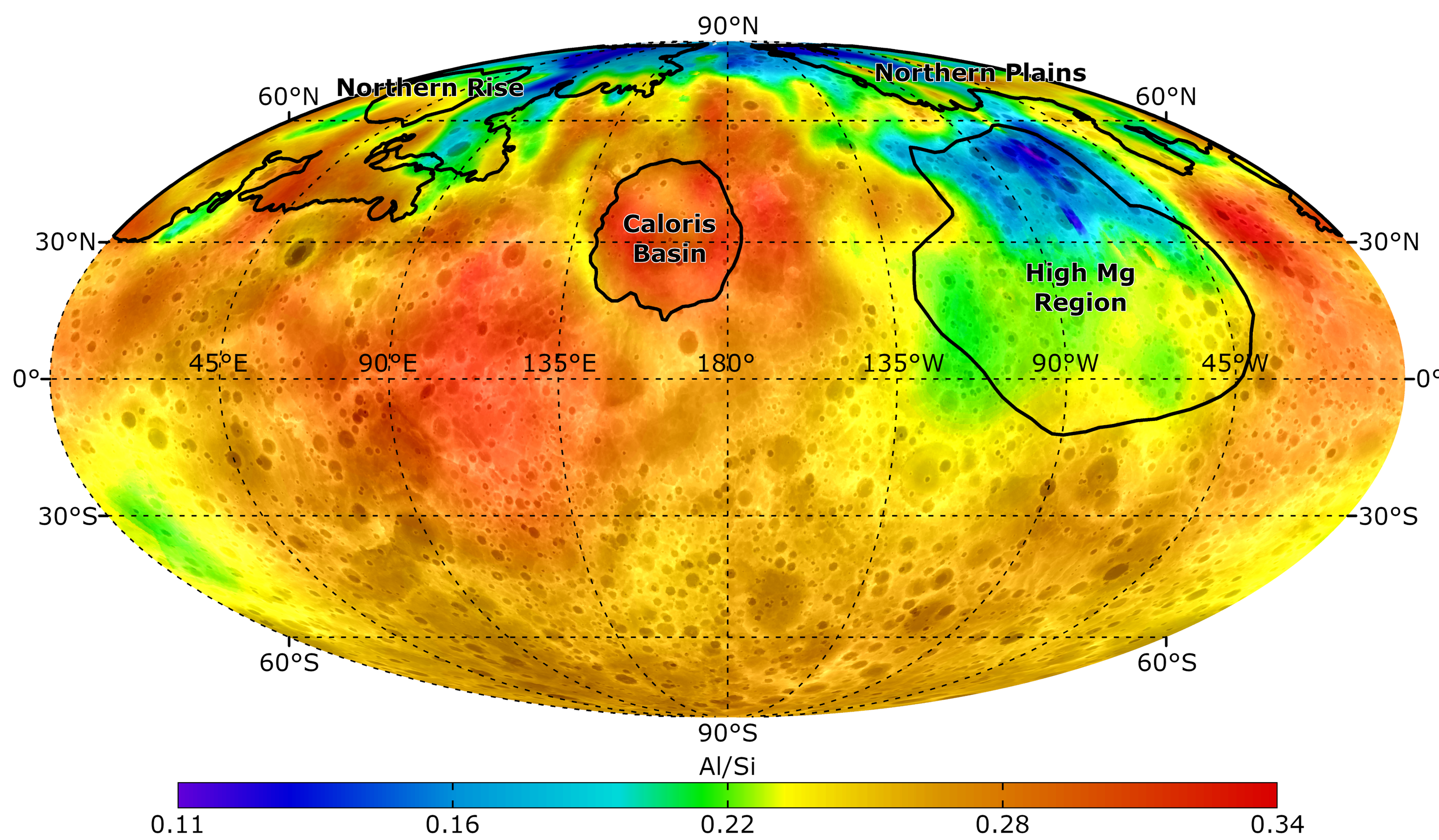

Fig. 3 Map showing the Al/Si elemental ratio on Mercury, as measured by the MESSENGER XRS [*3*]

Results and Discussion

Crater density shows how old a surface is and expresses the possible occurrence of resurfacing processes. Al/Si is the elemental ratio between aluminium and silicon, derived from X-Ray spectrometer measurements. At a global scale, these two datasets do not show any significant correlation, as confirmed by the low value of Pearson's coefficient (-0.08). In spite of this, the resulting correlation map (Fig. 4) shows the presence of a large region characterized by a lower crater density and a higher Al/Si ratio. Such region falls within and around the rim of Caloris Basin, a large impact structure infilled and surrounded by smooth

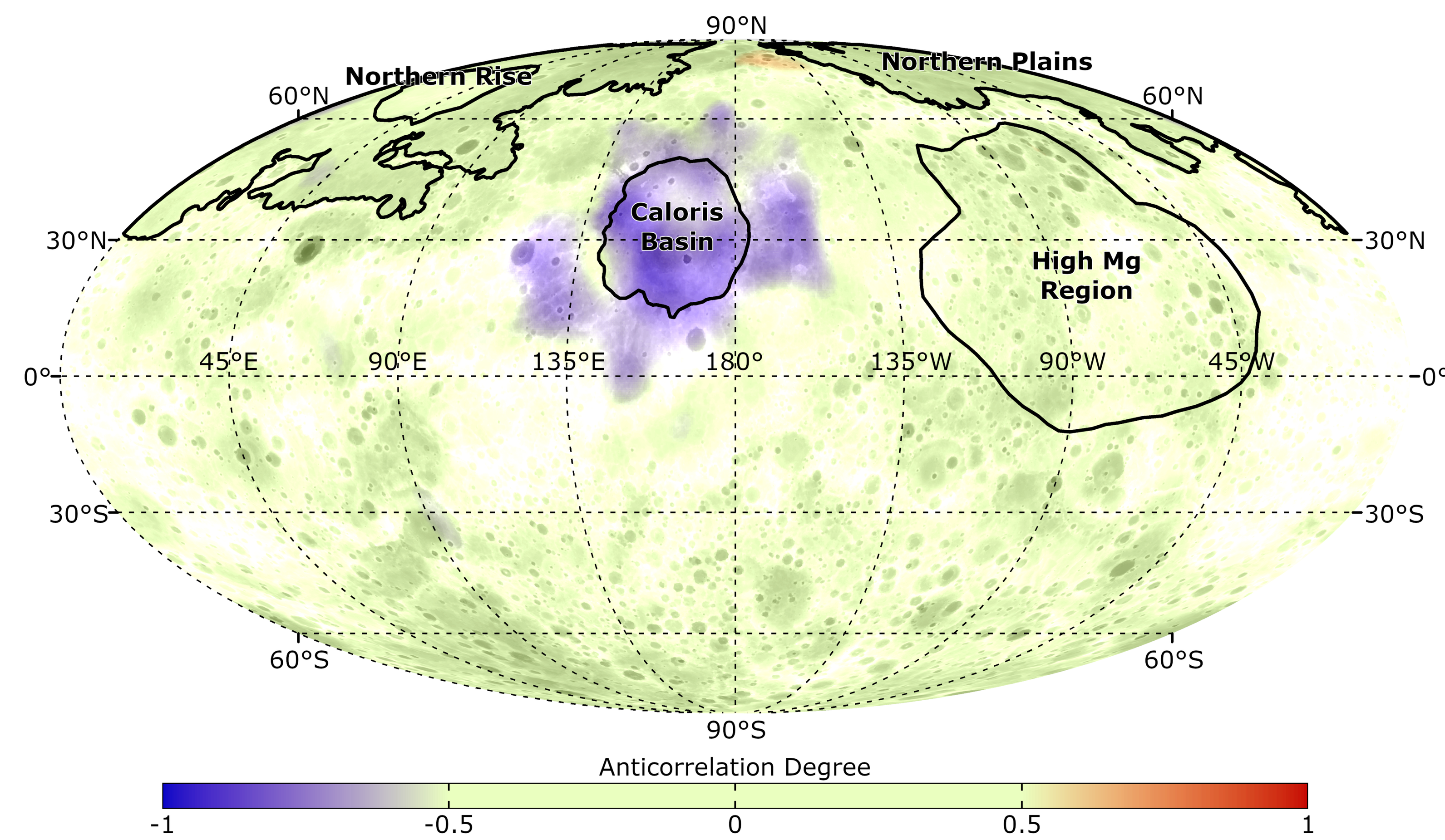

Fig. 4 Correlation map showing in blue regions of increasing Al/Si ratio and decreasing crater density. The most prominent of these regions falls within and surrounding Caloris Basin. In red are areas of increasing crater density and decreasing Al/Si ratio. Light yellow identifies terrains in which the two normalized datasets differ for less than 50% compared to the maximum difference allowed.

plains volcanically emplaced [*4-5*] and rich in plagioclase [*6*]. Further data correlations can be tested to identify large-scale surface features to be further investigated in order to understand their origin, ultimately leading to a better comprehension of the geological evolution of the planet.

Acknowledgements and References

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*e-mail: gianluca.chiarolanza@unich.it