Monitoring and Automatic Change Detection of Cultural Heritage Sites using Sentinels and Copernicus Contributing Missions

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Introduction

Currently available very high resolution space borne imagery can be used for mapping and 3D modeling of archaeologic sites and monuments from all over the world. This allows also the continuous monitoring, protection from natural and human threatening and may also be the base for virtual or real reconstruction of monuments. As an example it is shown how a mostly automatic approach for operationally monitoring from space may work on the example of the world heritage site of Palmyra, Syria.

Available satellite imagery

Sentinel-2, GSD 10 m, free, every 5 days

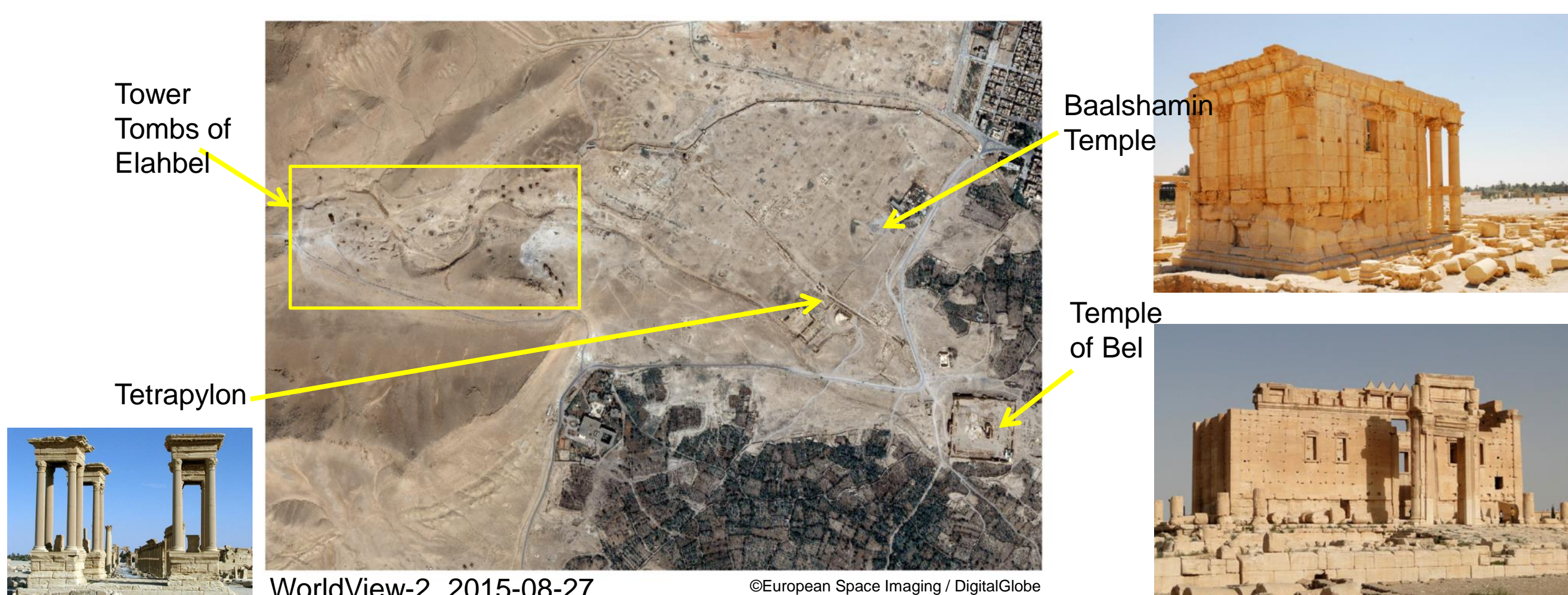**WorldView-2,** GSD 0.5 m, 100 €/km², min 100 km² tasked acquisition

Study site Palmyra

Listed as one of the 54 most endangered cultural heritage sites of UNESCO.

United Nations Educational, Scientific and Cultural Organization

Site of Palmyra

Site overview:

Tower Tombs of Elahbel

Baalshamin Temple

Tetrapylon

Temple of Bel

WorldView-2, 2015-08-27 ©European Space Imaging / DigitalGlobe

Method

A series of satellite images has been acquired over the city of Palmyra, Syria, which suffered huge losses related to its cultural heritage in a time span of two years. Damage detection was carried out
- visually by analyzing pre- and post-disaster satellite data and
- using automatic image processing algorithms.

The latter could speed up analysis over larger areas e.g. by highlighting potential undetected damages, which then can be investigated visually in more detail.
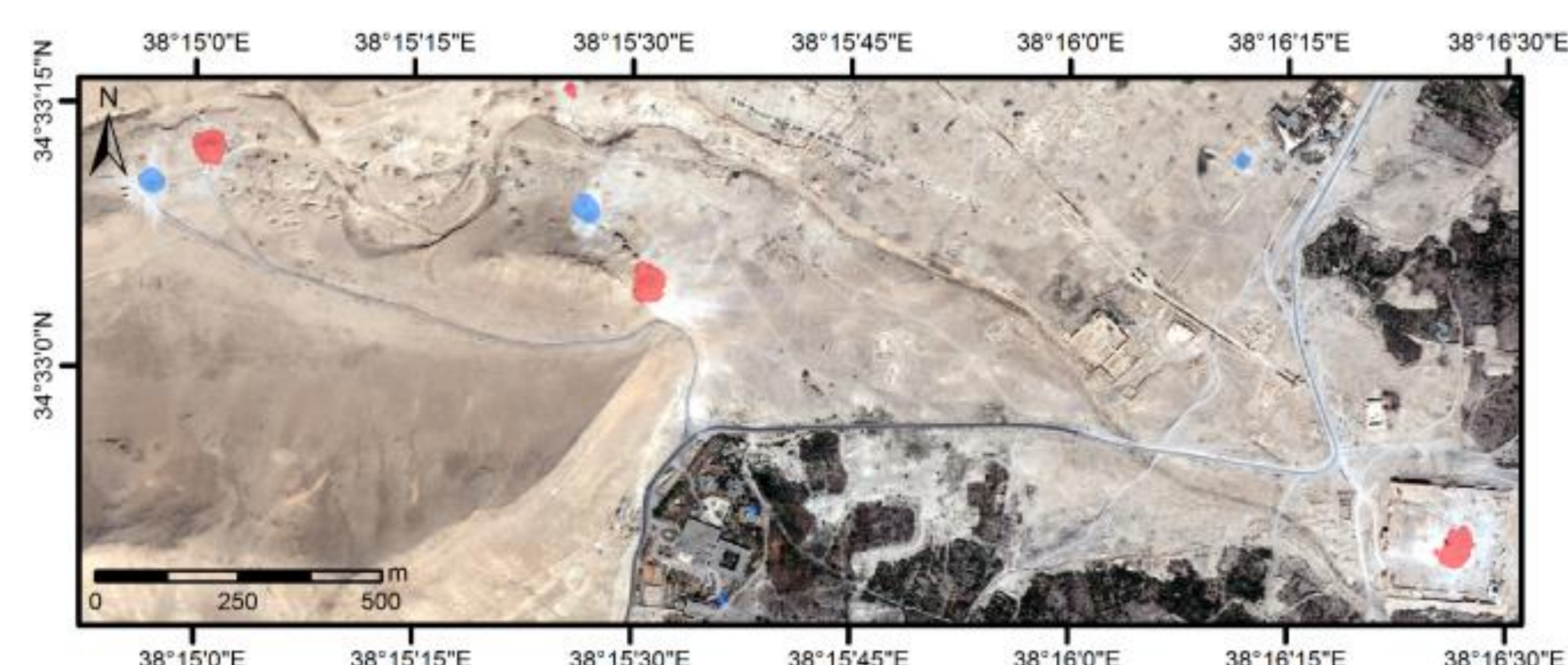

Automatically detected changed objects

Results

Automatic detection of differences in texture reveal consecutive damages, carried out until the 27th of August and the 2nd of September 2015 (highlighted in blue and red respectively). The texture of a target is defined by distribution of pixel values in its surroundings, which changes abruptly from smooth to rough whenever a structure is damaged or collapses, and when the shadows projected by a building disappear. Textural differences are robust to local variations in brightness values, and also to co-registration errors between the images due by misalignments and distortions.

The damages are related to the temple of Bel, the temple of Balshamin and several 2000 years old tower tombs scattered in the ancient necropolis.
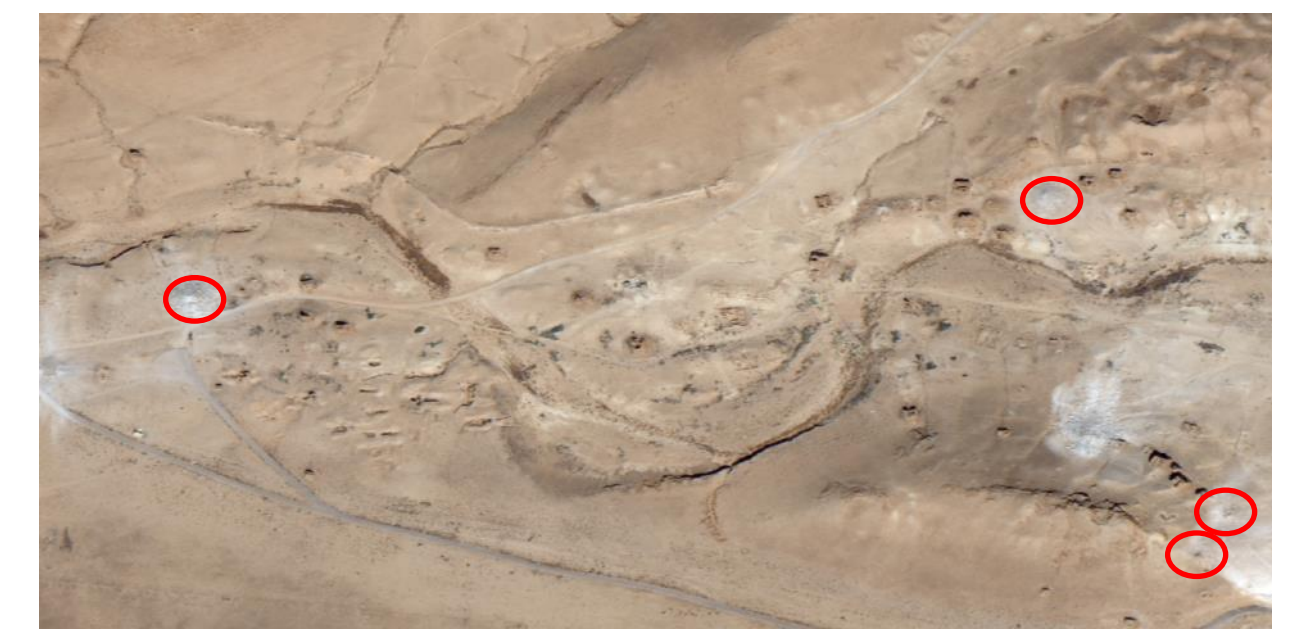
WorldView-2, 2015-08-27 © European Space Imaging / DigitalGlobe   WorldView-2, 2015-09-02 © European Space Imaging / DigitalGlobe

Palmyra, Tower Tombs of Elahbel

2014-02-20 © Google Maps   WorldView-2, 2015-09-02 © European Space Imaging/DigitalGlobe   WorldView-2, 2015-08-27 © European Space Imaging/ DigitalGlobe   WorldView-2, 2015-09-02 © European Space Imaging/ DigitalGlobe

Palmyra, Baalshamin Temple destroyed by IS (24.08.2015)   **Palmyra, Temple of Bel** destroyed by IS (~30.08.2015)

The Tetrapylon was destroyed later between 2016-12-26 and 2017-01-10 as shown in the images below. From the satellite imagery the height can be automatically derived just by marking the end of the shadow (red) and the corresponding top of an object (green) using the sensor model of the imagery.

13.34m   14.38m   14.35m   12.98m   11.01m   12.17m   11.51m   12.07m   9.30m   12.39m

WorldView-3, 2016-12-26 © European Space Imaging/DigitalGlobe   WorldView-2, 2017-01-10 © European Space Imaging/DigitalGlobe

Palmyra, Tetrapylon destroyed between 26.12.2016 and 10.01.2017

Conclusion

In this work we presented an automatic approach for monitoring cultural heritage sites to detect changes to the structures caused by natural hazards, touristic or population pressure or even intentional damage by armed forces or terrorists. The revisit time of Sentinel-2 would be great for this task but to get a reliable texture change detection and a detailed verification a ground sampling distance of less than one meter is required, so third party imagery from the WorldView satellites (DigitalGlobe) or also Pléiades is needed with all problems of tasking and buying the imagery.

Knowledge for Tomorrow

EARTH OBSERVATION CENTER

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

See more on: Cerra, D.; Plank, S.; Lysandrou, V.; Tian, J. Cultural Heritage Sites in Danger—Towards Automatic Damage Detection from Space. *Remote Sens.* 2016, 8, 781.