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Article *in* Space Policy · March 2018

DOI: 10.1016/j.spacepol.2018.03.002

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Higher resolution satellite imagery of Israel and Palestine: re-assessing the Kyl-Bingaman Amendment

Andrea Zerbini and Michael Fradley

ABSTRACT

Since 1997, the Kyl-Bingaman Amendment (KBA) to the 1997 U.S. National Defense Authorization Act, has limited the availability of high-resolution satellite imagery over Israel and Palestine. Although this law only applies to the United States of America, as this country dominates the commercial market for satellite imagery, its impact is global. Since 2012, the KBA has become increasingly anachronistic, as non-U.S. satellite firms, utilizing increasingly sophisticated satellite technologies, have begun retailing high-resolution imagery of Israel and Palestine. This major shift has, however, largely gone unrecognized, because the application of the KBA has become institutionalized in the commercial satellite imagery market. Nevertheless, the removal of these practical restrictions offers a major opportunity for all forms of remote-sensing analysis, whether for archaeologists, geographers, humanitarian organisations or others interested in landscape change across Israel and Palestine.

1. Introduction

Remote-sensing applications across Israel and the State of Palestine (hereafter abbreviated to Palestine; we follow the ISO 3166 naming conventions) have been traditionally limited by the Kyl-Bingaman Amendment (KBA), a piece of U.S. legislation that limits the ability of satellite operators and retailers in the U.S. from selling or disseminating satellite imagery of these countries at a resolution higher than what is available on the non-U.S. market, arguably a form of censorship [1]. Given the U.S. dominance of the satellite imagery market, this legislation has had an impact on researchers worldwide who use remote-sensing techniques over the Levant region. Since 2012, however, the rise of non-U.S. based satellite companies, producing very high-resolution (VHR) imagery of Israel and Palestine, means that a comprehensive reassessment of the set of regulations underpinning the application of the KBA is required. Through a detailed review of the background and application of regulations stemming from the KBA, as well as the development of satellite technologies outside the U.S., we propose that U.S. regulations are revised to allow for U.S.-based companies and public entities to declassify, retail and disseminate imagery at a resolution equal to 0.5m. We suggest that this is in accordance to the terms of the KBA, and will have clear scientific benefits to research in creating a balanced and open field for researchers using remote-sensing techniques in the Middle East. This includes potentially lifting restrictions on archival satellite imagery dating back to the 1960s, as well as reducing the current regulatory burden and commercial limitations on the innovative U.S. satellite industry.

2. Background

The research presented in this paper stems from the work of the Endangered Archaeology in the Middle East and North Africa (EAMENA) project. The EAMENA project is a major survey of archaeological sites across the MENA region, primarily

interpreting satellite imagery and historical aerial photography to study landscape change and record the condition of archaeological sites [2].

Fig. 1. The sites of Tell al-Sultan (Jericho, Palestine; imagery: DigitalGlobe 2 April 2011) and Tell Hesban (Madaba region, Jordan; imagery: CNES/Airbus 20 February 2010) as viewed in Google Earth. Although the two sites are only 35 km apart as the crow flies, the Tell al-Sultan imagery in Palestine was probably captured at 0.5 m and down-sampled to ca. 2 m. Map data ©2017 Google.

The project relies primarily on the analysis of freely available imagery, provided via platforms such as Google Earth and Bing Maps. Large parts of the MENA region are now covered by VHR imagery with an average resolution of around 0.5 m. This means

that any object with a greater horizontal surface than 0.5 m, including a large proportion of archaeological monuments, should be visible in some form on these satellite images. Consequently, one issue that hinders the systematic assessment of our study area is the variability in both the quality and coverage of the available imagery. In areas where the imagery resolution is 2m+, an accurate assessment of the archaeological landscapes and their changing conditions becomes particularly challenging. This is particularly notable in areas where there is evidence of rapid landscape change, as demonstrated, for example, in our work on the ancient gold mining sites of Egypt's Eastern Desert [3]. In that case, a massive increase in the destruction of archaeological sites since 2012 was detected that can be linked to modern gold extraction, as ancient mines are re-worked using modern techniques.

Across the MENA region as a whole, the lack of high-resolution satellite imagery with a ground sampling distance (GSD) of less than 2 m is most noticeable in Israel and Palestine. This difference stems from the impact of the so-called 'Kyl-Bingaman Amendment' (KBA), promoted by U.S. Senators Jon Kyl, Jeff Bingaman, and Kay Bailey Hutchison, and passed on 23 September 1996 as an amendment to the 1997 National Defense Authorization Act. When commercial satellite imagery first became available to the general public, around 2001 via the open platform Earth Viewer 3D, imagery resolution over Israel and Palestine was relatively poor at around 10–20 m, although this was enhanced on its successor Google Earth, who acquired Earth Viewer 3D in 2004 and instigated an imagery upgrade in October 2007 to ca. 2 m resolution [4]. Since then, this 2 m standard has remained the perceived baseline of what can be sold on the commercial imagery market according to the limitations set by U.S. regulators. However, technological improvements and a growing number of suppliers have made higher resolution imagery of 0.5 m GSD the norm in the regions surrounding Israel and Palestine (see Fig. 1).

For the work of the EAMENA project, the continued application of the KBA, with its enforcement of a 2 m resolution threshold over Israel and Palestine has proved to be a severe hindrance to applying the same methodology used elsewhere in the MENA region to this area. While it has so far been possible to record significant changes in land use, such as building developments or the expansion of cultivation, more subtle changes are not observable on the lower-resolution imagery. Features such as looting pits or the encroachment of small-scale developments can only be detected with sub-metre resolution imagery. Equally, while the systematic analysis of areas of land elsewhere in the MENA region has led to the recording of large numbers of sites not previously identified by archaeologists [2], the opportunity to achieve comparable results across Israel and Palestine has been limited by the KBA restrictions on imagery quality.

3. The KBA in theory and practice

Arriving during a period of commercialization of satellite technology, and less than two years after the declassification of the CORONA spy satellite imagery [5, 6, 7], the KBA was widely regarded as "the first step away from the open-skies policy that the U.S. and other countries have agreed to for more than three decades" [8]. The approval of the KBA marked the pinnacle of nearly four years of U.S.-Israeli tensions and negotiations arising from the Clinton administration's strong support for the so-called

'open-skies' policy and, more specifically, for the expansion of the commercial remote sensing sector.

The first tensions surfaced in 1992 when, following the issuing of the Land Remote Sensing Policy Act, the United Arab Emirates submitted an application to purchase an imaging satellite from the U.S. firm Litton/Itek. The application was ultimately rejected by the U.S. Department of State, and Israeli pressure reportedly played an important role in the decision-making process [9]. Two years later, in March 1994, Presidential Decision Directive 23 (PDD-23) further eased the licensing process for commercial satellite companies. Later that year, the U.S. satellite company Eyeglass (later renamed Orbimage and GeoEye, the latter now part of the DigitalGlobe consortium) announced its intention to build a ground station in Riyadh (Saudi Arabia), which would have allowed Saudi authorities access to high-resolution imagery for the whole Middle East, including Israel [10]. Months of Israeli lobbying prompted U.S. senators, championed by Senator Bingaman, and members of the House of Representatives, led by then Representative Kyl, to address letters of concern to the Secretary of Commerce, highlighting the threat that satellite imagery sales to Saudi Arabia might pose to Israeli security [11]. Eventually, in May 1995, Eyeglass pledged that its satellites would not cover Israel [10].

The next major development came with President Clinton's Executive Order 12951 (22 Feb 1995), which declassified more than 860,000 images taken by spy satellites between 1960 and 1972 [12]. From March to September 1996, images were gradually made available for purchase via the U.S. Geological Survey (USGS) National Satellite Land Remote Sensing Data Archive and the National Archives Record Administration (NARA) [13]. The mainstream reaction to this in Israel was not positive: on 25 June 1996, an image of Israel's Dimona nuclear reactor, taken by the Corona spy satellite in 1971, appeared on the front page of *Yediot Aharonot*, Israel's most-read newspaper [9]. Simultaneously, Israeli officials had been reportedly asking the Clinton administration to impose a 3 m-resolution threshold to commercial imagery providers covering Israel (14; 9].

Introducing what would be later known as the 'Kyl-Bingaman Amendment' on the Senate floor a day after the publication of the *Yediot Aharonot* article (26 June 1996), Senator Kyl presented it as a reaction to Clinton's declassification of the spy satellite photographs. In Kyl's words, Clinton's executive order "could unintentionally have a deleterious impact on the national security of the state of Israel" [15]. The wording of the KBA, is notably brief:

> *House Report 104-724 – NATIONAL DEFENSE AUTHORIZATION*
>
> *SEC. 1064. PROHIBITION ON COLLECTION AND RELEASE OF DETAILED SATELLITE IMAGERY RELATING TO ISRAEL.*
>
> *(a) COLLECTION AND DISSEMINATION – A department or agency of the United States may issue a license for the collection or dissemination by a non-Federal entity of satellite imagery with respect to Israel only if such imagery is no more detailed or precise than satellite imagery of Israel that is available from commercial sources.*

> *(b) DECLASSIFICATION AND RELEASE – A department or agency of the United States may declassify or otherwise release satellite imagery with respect to Israel only if such imagery is no more detailed or precise than satellite imagery of Israel that is available from commercial sources.*
>
> [16]

While point (a) of the law was aimed at creating licensing restrictions to commercial providers of satellite imagery, point (b) took direct aim at Clinton's declassification campaign, resulting most notably in the interdiction to declassify reconnaissance imagery taken over Israel and Palestine by the KH-7 Gambit (operational between 1963–1967) and KH-9 Hexagon (operational between 1973–1980) missions, both of which had captured films with a GSD at nadir of 2–4 feet (0.6–1.2m). A declassified memorandum of the Department of State (dated 14 Jun 2000) bears this out explicitly with respect to KH-7 imagery of Israel:

> The KH-7 film's best quality is 0.6 meters resolution, slightly better than the best current commercial system, IKONOS, that sells global coverage (except Israel) at 0.82 meters resolution. The statutory prohibition on selling or declassifying imagery of Israel at a quality better than that available from foreign commercial sources (currently calibrated at 2.0 meter resolution) applies to the historical KH-7 photography [17].

The vaguely formulated text of the KBA has been, since its approval, the subject of multiple and often contradicting interpretations by U.S. regulators, particularly with regards to the extent of its geographical remit and the maximum resolution allowed [18]. Regulations on matters of commercial remote sensing are the prerogative of the National Atmospheric and Oceanic Administration (NOAA). The regulator's website makes clear how compliance with the terms of the KBA is crucial for obtaining a commercial license:

> As part of its licensing process, NOAA requires an applicant to submit a plan explaining how its proposed system will be able to restrict the collection and/or dissemination of imagery of Israeli territory at a level of resolution determined by the Commerce Department. NOAA will review this plan to ensure compliance [19].

Concerning the issue of maximum resolution, an initial NOAA assessment released in November 1996 had declared a 1m threshold acceptable, on the grounds that "Russia's two-meter film-based imagery was deemed by U.S. government officials to be the qualitative equivalent of one-meter digital imagery" (18). However, in an unexpected ruling that contradicted earlier statements, the U.S. Departments of State and Commerce concluded in July 1998 that there was no "readily and reliably available commercial imagery" with 1 m resolution and barred U.S. commercial satellite companies from collecting and disseminating it [20, 15]. Final regulations for licensing released by the NOAA in 2006 stipulated that:

> The Department of Commerce will monitor the level of imagery resolution readily and consistently available in sufficient quantities from non-U.S.

> sources, to determine what imaging or data dissemination restrictions, if any, shall apply to licensees. A review of non-U.S. commercial availability will be conducted on an annual basis or more frequently if warranted […]. Findings of this review will be published in the Federal Register and will constitute the data collection and/or dissemination restrictions with respect to imagery of Israel [21].

However, findings from these annual assessments or any other mention of the KBA have never been published in the U.S. Federal Register, with only a brief mention of a review that resulted in no change to the standing regulation in 2007 [22]. There is no evidence to suggest that a different imagery resolution limit has ever replaced the 2 m threshold, enforced by the July 1998 ruling mentioned above.

The geographical remit of the law is also controversial; having been issued after the Oslo Accords and the formal creation of the Palestinian National Authority (PA), the KBA's reference to only Israel in its wording would, in theory, leave space for commercial satellite companies to collect and disseminate imagery of Palestine, that is, the so-called 'Gaza Strip' and 'West Bank'. Yet, in practice, this is not the case. As noted in an article posted on Mother Jones in the aftermath of the Gaza War of 2011 [23], Human Rights Watch's inability to use high-resolution satellite imagery of Gaza for its reports most likely stemmed from the application of the KBA to the occupied territories. Although Palestine has been recognized as a negotiating partner by all U.S. administrations since the Clinton presidency, no U.S. government has yet officially recognized its claim to statehood: the application of the KBA's imaging restrictions to Palestine is a consequence of this impasse.

The scale and diversity of global creation and consumption of satellite imagery has changed significantly since the last clear statement on the KBA in 2007. The re-launch of the Earth Viewer platform as Google Earth in 2005, alongside other open-access systems such as Bing Maps, has increased access to satellite imagery to anybody with an internet connection, providing they do not reside in a state where access is officially restricted. This growth of satellite imagery has had major implications for regulating organizations such as the NOAA, as will be discussed further below. However, in spite of satellite images becoming ubiquitous in western media, popular or academic discussion on the KBA has been relatively limited, with the details of this legislation in some cases unintentionally over-simplified to a universal restriction on high-resolution satellite imagery over Israel [24, 4]. By removing the context of the KBA in U.S. law and its inextricable link to the mechanisms of the commercial market, the perception that these restrictions are internationally accepted and enforced has been reinforced. However, this is clearly not the case.

4. The rise of non-U.S. high-resolution satellite imagery

In 2011, a number of newspaper articles and blog posts reported possible changes to the landscape of VHR imaging over Israel and Palestine. This stemmed from the imminent launch of non-U.S. Earth Observation commercial satellites with sensors capable of capturing imagery at sub-metre resolution. Particular coverage focused on the launch of Turkey's Göktürk-2 satellite, scheduled for 2012. This satellite was expected to deliver sub-2-metre resolution imagery of the whole world, including

Israel. A Reuters news agency covering the potential implications of this launch [25] was reprised by both Saudi and Israeli newspapers [26, 1]. Commenting on this news, the blog 'Ogle Earth', which had already come out critically against the KBA [27, 28] suggested that the commercial availability of Göktürk imagery would effectively free American companies to provide imagery at an equal GSD [29]. However, this suggestion ignored a basic fact concerning the Göktürk fleet, namely its military, rather than commercial nature: regardless of whether these satellites could be capable of capturing imagery below a 2 m resolution, such imagery would never be released into the international market, thus proving inconsequential for the application of the KBA.

The launch of the first Göktürk satellite was eventually delayed until the end of 2012 and its actual capabilities did not match expectations. Göktürk-1, capable of capturing imagery at 0.7 m GSD, was announced shortly afterwards and was finally launched in December 2016 [30, 31, 32], although it has not garnered comparable media interest. This second satellite is a joint Turkish-French-Italian venture, and issues surrounding the export of remote-sensing technology caused delays, before the unit was finally launched on a European Space Agency rocket [33]. Initial reports suggest that Göktürk-1 imagery collection will have both civilian and military applications [32], though this does not necessarily mean that the Turkish government intends to release it on the commercial market.

In spite of the delays to the Göktürk constellation, the supply market for VHR commercial imagery has vastly expanded over the last four years. For Israel and Palestine the most momentous change has been brought about by the introduction of Pléiades, a constellation of two VHR Earth Observation satellites developed and operated by Airbus Defense and Space under contract with the French Centre National d'Études Spatiales (CNES). Launched in December 2011 and December 2012, these satellites capture a panchromatic (PAN) band at 0.7 m and multispectral (MS) bands at 2.8 m. Imagery is pre-processed using a resampling algorithm to yield a GSD of 0.5 m for the panchromatic band, and 2 m for the multispectral [34]. Over the course of five years, the Pléiades satellites have covered the entire globe on thousands of runs. Unsurprisingly, therefore, the Pléiades tile coverage of Israel and Palestine is extensive, covering 100% of the territories of both states (see Fig. 2). VHR Pléiades imagery has already been used successfully by analysts working in the region, as in the case of a UNOSAT study of post-conflict damage in the Gaza Strip in 2014 [35].

Airbus is not the only commercial provider of VHR imagery of Israel and Palestine, although they appear to have been the first. Since 2013, six other companies and space agencies have launched VHR Earth Observation satellites capable of capturing imagery with a metre or sub-metre resolution. Four of these companies are members of the PanGeo Alliance, a consortium bringing together eight Earth Observation sensor operators (36). This includes Deimos Imaging, a Spanish operator owned by the Canadian Urthecast [37]. In June 2014, Deimos launched their VHR satellite Deimos-2, equipped with a push-broom camera with five spectral channels, including a 1 m GSD PAN band (up-sampled to 0.75 m) and 4 m MS bands [38; 39]. As Fig. 2 shows, Deimos-2 imagery captured between 2014 and 2017 covers ca. 43.54% of the West Bank territory and 26.22% of Israel.

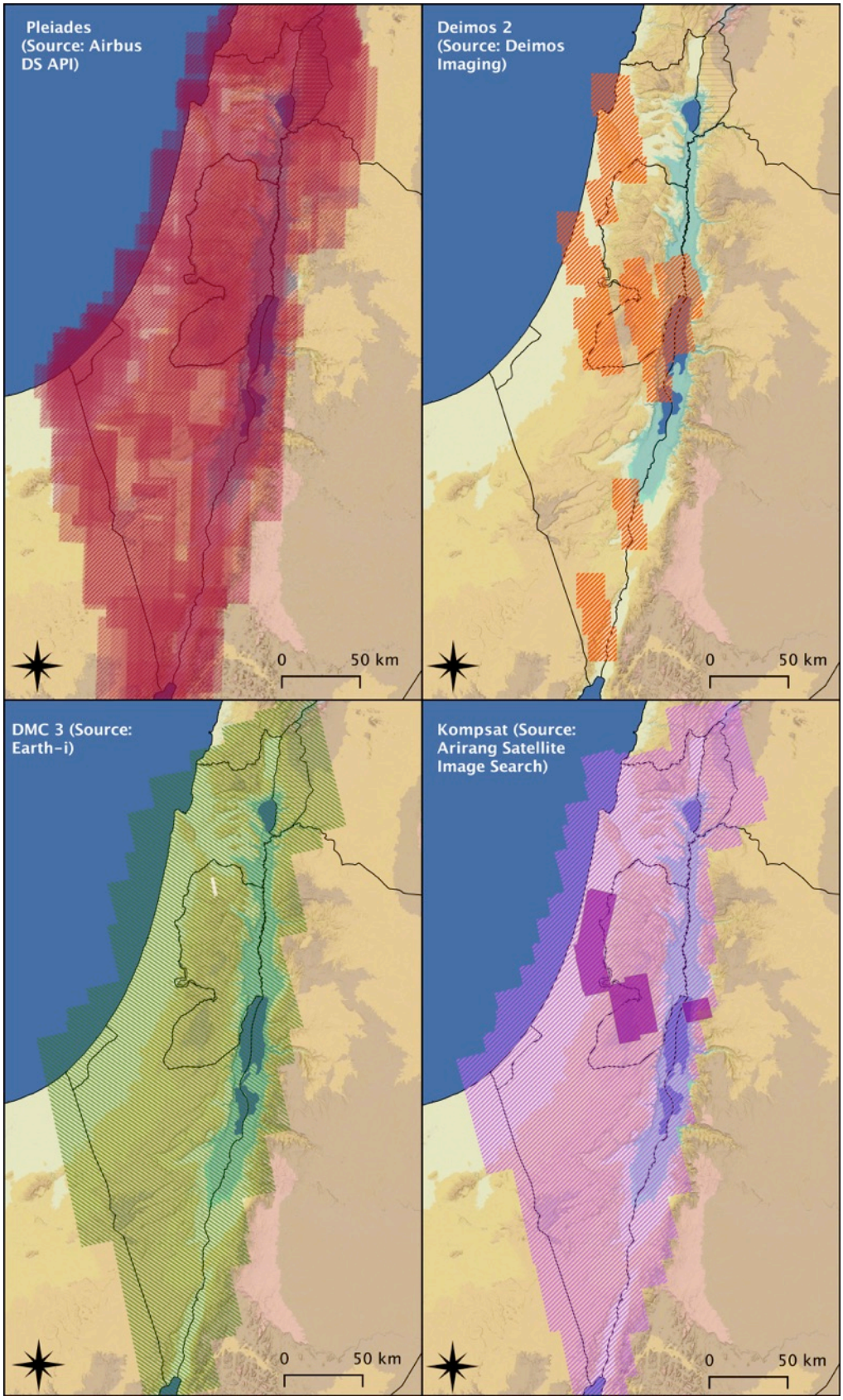

Fig.2. Composite of maps showing the current coverage of sub-2m resolution commercial satellite imagery over Israel and Palestine as of 1 May 2017. The darker shade visible in the Kompsat coverage (bottom right) indicates the extent of K3A cover, while the lighter extent indicates the broader imagery available from the K3 satellite.

More comprehensive coverage of Israel and Palestine has been achieved by the Anglo-Chinese DMC3/TripleSat fleet [40]. This constellation of three satellites with identical optics spaced 120 degrees in their global orbit on an orbital altitude of 651 km, launched in July 2015. The DMC3 sensors capture a PAN band at 1 m (up-sampled to 0.8m) and MS bands at 4 m [41]. As shown in Fig. 2, DMC3 imagery covers nearly the whole Israel, Palestine and the Golan, the latter term following the United Nations Disengagement Observance Force (UNDOF) naming convention for the area (only a strip of 0.05% of the West Bank territory is not covered).

Finally, the coverage achieved by the South Korean Kompsat 3/3A constellation (Fig. 2) is also noteworthy, particularly in view of its higher GSD. Kompsat comprises two satellites, both of which were developed by the Korea Aerospace Research Institute (KARI) in collaboration with Satrec-Initiative Co. Ltd. (SI Imaging Services). Kompsat-3 was launched in 2012; located at an orbital height of 675 km, it captures PAN imagery at 0.7 m (up-sampled to 0.5 m) and MS bands at 2.8 m. Kompsat-3A, on the other hand, was launched in March 2015 [42] and although it is equipped with the same sensor as the Kompsat-3 satellite, it orbits at a lower altitude (528 km), which allows it to capture a 0.55 m PAN band (up-sampled to 0.4 m) and 2.2 m MS bands (up-sampled to 1.6 m). This resolution is, at present, the best available on the market for Palestine and Israel. In its six years of operation, Kompsat-3 has achieved complete coverage of both countries. Archival Kompsat-3A imagery, however, is so far only available for 6.02% of Israel and 16.44% of Palestine.

A current constraint with the data provided by non-U.S. organisations providing VHR over Israel and Palestine is the lack of time-depth in available imagery, with the Pléiades imagery archive only dating back as far as 2012. However, as will be discussed further below, this challenge to the orthodox interpretation of the KBA, with the current commercial baseline resolution standing at 0.4 m up-sampled as provided by the Kompsat-3A satellite, could have wider implications. It could potentially enable the dissemination of earlier commercial imagery that had been down-sampled (particularly the DigitalGlobe archival data), as well as the release of further sets of declassified U.S. spy satellite imagery, chief among them the imagery collected by the KH-7 Gambit mission. This would be a significant contribution for archaeologists wanting to understand the change in land-use in the past decades.

5. Discussion

The restrictions set by the KBA have now clearly been challenged by the new imagery produced by numerous non-U.S.-based satellite companies, which offer a resolution of 0.4-0.7 m on imagery across Israel and Palestine, in line with the market average covering other parts of the globe. Since the Pléiades imagery came to the market in 2012, an update of NOAA regulations, which the text of the KBA implicitly requires, should have been enacted in order to conform to the newly-set international threshold of 0.5m. However, no such review appears to have taken place and the U.S. market continues to adhere to the 2m threshold enforced in 1998 and endorsed by the 2006 NOAA regulations discussed above. As demonstrated above, the Pléiades output has now been joined by several additional fleets offering imagery at resolution of 1 m or below; the trickle of VHR imagery that began coming on to the market in 2012 has now

become a flood. Yet, although the collection of satellite VHR imagery for retail has been the norm for several years, there is a general unawareness of its availability, suggesting that the concept that imagery of Palestine and Israel is restricted has, to an extent, become institutionalised. However, it is important to consider the extent to which the implications of the KBA have been disregarded, and how the wider U.S. political climate vis-à-vis Israel has discouraged any challenge to the standing of this legislation.

The problem of interpreting the current situation is exacerbated by the lack of official public discussion concerning the KBA and it application in the U.S., even though the Pléiades output set a new commercial precedent from as early as 2012 that should have triggered a review. As highlighted above, the NOAA has made no date-stamped statement on the KBA since 2007 [22], despite assurances in that statement that the market situation would be regularly reviewed and findings published in the Federal Register. The published minutes and reports of the Advisory Committee on Commercial Remote Sensing (ACCRES) make clear that U.S. satellite operators and regulators carefully monitor the development of non-U.S. companies and legal frameworks. The only passing reference to the KBA in the online output from ACCRES is to be found in the only recorded review of the imagery market by the NOAA [22]. Even there the KBA is only mentioned in relation to the international 'shutter control', where, by virtue of PDD-23, the executive branch of government may force companies to desist in capturing imagery of a specific geographical area over a specified time period, if this imagery is believed to harm U.S. security [43, 44]. It is possible that the issue is raised indirectly in their critical summary of current U.S. regulation, in which they note outdated laws, the ineffective nature of limiting U.S. companies when imagery can be acquired internationally, and the struggle for regulators to cope with the massive increase in satellite operators [45]. This overburdening of regulatory bodies is also arguably due to the default U.S. position that views all remote sensing technology as munitions, and as a technology that must be protected [43]. In defense of the NOAA, the organization has never been given the funding or infrastructure to effectively regulate the market, particularly in light of the massive growth in the number of commercial satellites in operation [46], and are likely to face extensive cuts in the future [47, 48].

It seems highly improbable that U.S. regulators and satellite operators are unaware of at least some of the developments discussed above that have undermined the feasibility of the KBA. The failure to review and act on these changes through the publication of clear guidance notes to U.S. satellite operators and imagery retailers has created a confused, ambiguous situation on the ground. At an anecdotal level, when we began our investigation into the availability of VHR imagery of Palestine in February 2017, we first approached a U.S.-based retailer, who initially responded negatively to our purchase enquiry for Pléiades imagery, but later agreed following further unspecified checks. A second U.S. retailer insisted that they could not sell us Pléiades imagery over Palestine or Israel at any resolution below 2 m, but were able to offer us the Korean Kompsat-3A imagery, which at 0.55 m (0.4 m after up-sampling) affords a higher GSD than Pléiades, across the same area. It would appear that the lack of transparency and updated guidance toward VHR imagery by U.S. regulators has been facilitated by the institutionalized assumption within the commercial market that this

region is subject to narrower restrictions in terms of imagery retail than is actually the case.

This situation takes on an added dimension when we consider the presentation of satellite imagery via open-access systems. Platforms such as Bing Maps and Google Earth have helped foster a global audience of satellite-imagery consumers, creating a heightened awareness, including a full range of positive and negative perspectives, on issues of privacy, security, and censorship. For the majority of users, including the EAMENA project, satellite imagery is consumed via platforms such as Bing Maps and Google Earth. The latter, as the larger of the two, has been the target of a range of criticisms, including investigations into its economic model [49]. In terms of the legality of the imagery used by Google Earth, Blitz has conducted a detailed assessment in relation to the First Amendment in the U.S., highlighting the complexity of the issue but ultimately viewing the current platform as benign [50]. Other legal perspectives, however, focus on perceived threats to privacy and security, and the need for greater international monitoring and regulation of data access [51].

When the original EarthViewer 3D was launched in 2001, and subsequently acquired by Google in 2004, the KBA was an established piece of legislation, but any U.S.-led strengthening of restrictions on data access would stand in contrast to the proposed ethos of an organization such as Google. Restrictions on satellite imagery via a platform such as Google Earth is in clear opposition to the openness and freedom supported at the top of Google as an organization, and it would seem to fall under what they would term as the work of a censor [52], and goes against the mantra of the virtual globe model from which Google Earth derives [53]. Returning to the idea of a more widespread ban on higher-resolution imagery among U.S. consumers described above, Schmidt and Cohen themselves even highlight the use of proxy servers to bypass digital restrictions imposed by regimes less comfortable with open sharing of information, a situation likely to be replicated in the U.S. if it engaged in a comparable exercise within its own borders [52].

The case of the display of high-resolution imagery west of the town of Qiryat Shemona in Israel offers an interesting point of reference. That the limitation on higher-resolution imagery over Israel and Palestine was not watertight was already demonstrable via online platforms such as Google Earth. For instance, a strip of CNES/Airbus imagery (formerly CNES/Astrium) captured on the 11 January 2014 and available on Google Earth overlaps the border of northern Israel and Lebanon (Fig. 3). While much of the imagery covering the interior of the territory has been processed and blurred, there remains a strip ca. 1.5 km wide between the Israeli town of Qiryat Shemona and the Lebanese border that is unaffected. This imagery was most likely collected by the Airbus Pléiades fleet, and has a resolution of below 1 m, probably ca. 0.5 m. Importantly, unlike imagery derived from U.S. satellite companies such as DigitalGlobe who are required to down-sample imagery tiles covering any part of Israel ahead of retail, non-U.S. companies such as Airbus are free to sell imagery of this area without any such restriction on imagery resolution. The responsibility to restrict access to these images, if any such requirement exists, would therefore fall to Google Earth or any third-party retailer from whom they purchased the imagery tiles.

Figure 3. Satellite imagery dating to 11 January 2014, showing a strip of land in Israel between the Lebanese border, as recorded by Google Earth to the right as a yellow line, and the town of Qiryat Shemona. The lower images are detailed extracts, with the lower right image illustrating the 'blurring' censor applied to the image (Image courtesy of CNES/Airbus via Google Earth). Map data ©2017 Google.

Bearing in mind Google's clear commitment to open and accessible data, a positive take on their making this portion of high-resolution imagery of Israeli territory available would be to see it as a statement about the institutionalized, incorrect understanding of what the KBA means in practice. While avoiding the controversy of the full exposure of the CNES/Airbus imagery tile, the imperfect application of a distorting layer offers a quiet act of resistance to these restrictions by finally opening up higher-resolution satellite imagery of Israel to a global, interactive audience, even if only a small area. This interpretation would seem feasible alongside Google's levelheaded response to the '*Nakba* layer' controversy that began in 2006 concerning the same territory [4]. What is more, VHR imagery, specifically Pléiades imagery from 2013 and 2014, is available through Google Earth for much of the adjoining northern and western sections of the Golan (occupied by Israel in the 1967 war and later annexed unilaterally in 1981), along with the majority of the UNDOF area. Finally, a tile of Pléiades imagery dating to 15 November 2013 is also available via Google Earth along the northwestern boundary of the West Bank area of Palestine, where it meets with Jordan and Israel (Fig. 4). In this case, while much of the Israeli territory covered by the imagery tile is blurred, with the exception of a strip ca. 800 m wide on its border with Palestine, no comparable distortion has been applied to any part of the West Bank area covered by this tile, an area of c. 175 km^2 (Fig. 5). The value of this quality of imagery to archaeologists is made clear where new sites can be identified that have not been previously recorded, in some cases where they have been illegally looted (Fig. 6).

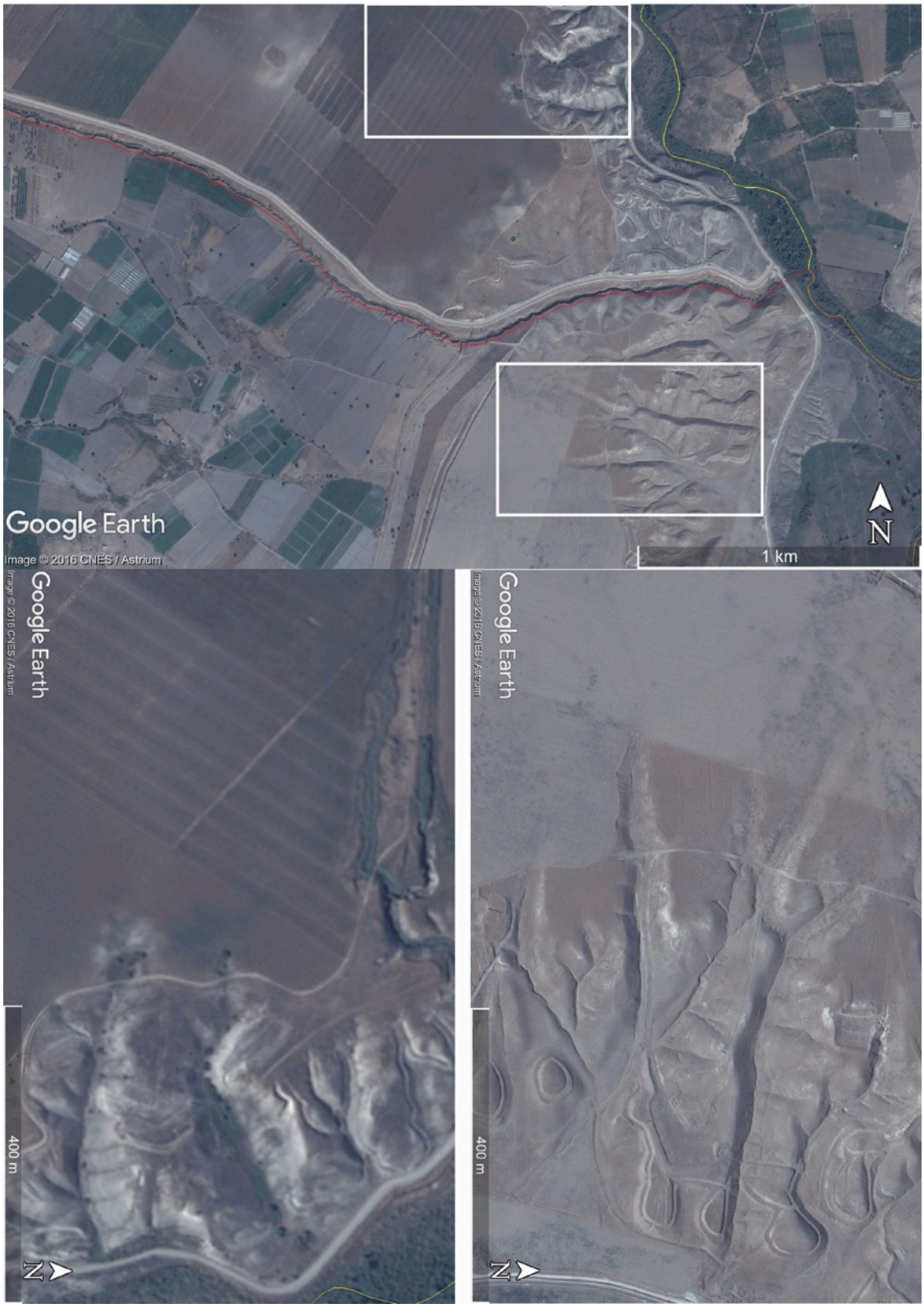

Figure 4. Satellite images dated 22 August 2013 showing the northern confluence of the West Bank area of Palestine with Jordan and Israel. The lower right image shows a detail of undistorted territory in Palestine, with that on the left showing the blurred effect on the image of Israeli territory. This is the earliest example identified by the authors of a higher resolution image for the territories of Israel or Palestine being disseminated globally by Google Earth (Images courtesy of CNES Airbus via Google Earth). Map data ©2017 Google.

Considering the blurred area as a whole, it could be argued that the exposure of the undistorted imagery simply reflects poor data control. The edge of the blurred area roughly mirrors this portion of the Lebanon-Israel border, just over 1 km to the east. This explanation seems redundant, however, when one considers that when Pléiades imagery along the Israeli border with Jordan and Egypt was added in 2016, blurring of the Israeli side of the border followed the marked boundary precisely (Fig. 7). As Google Earth is the holder of their 'borders' data layer, it would have been a simple process for such a technologically-sophisticated organization to replicate these lines while applying a blurring filter.

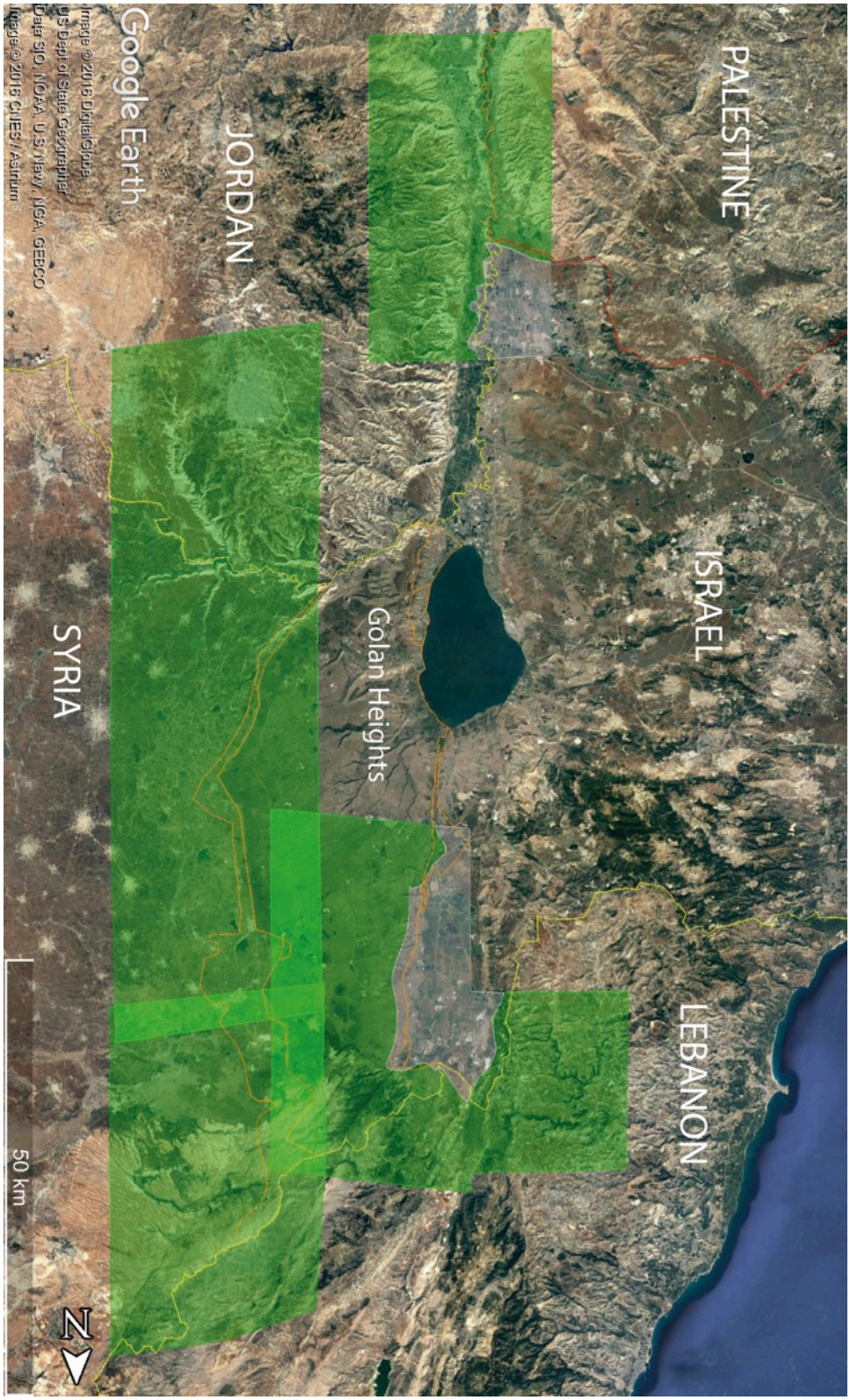

Figure 5. A Google Earth image indicating areas currently covered by CNES/Airbus imagery tiles over Israel and Palestine. The green areas are those depicted at high resolution, while the smaller opaque areas have been blurred. The yellow lines indicate accepted national borders and the red/orange contested boundaries, as depicted by Google Earth (imagery courtesy of DigitalGlobe, CNES/Airbus and the U.S. Dept. of State Geographer Data via Google Earth). Map data ©2017 Google.

Figure 6. A comparison of two satellite images of the same archaeological site in Palestine. The top DigitalGlobe image was captured on August 22, 2013 and has been blurred, while the bottom CNES/Airbus was acquired on November 15, 2013. The circular pits on the lower image are probably illegal looting pits to steal goods for the antiquities market, which could not have been identified via the lower-resolution imagery (Images courtesy of DigitalGlobe and CNES/Airbus via Google Earth). Map data ©2017 Google.

The implications of these additions to the imagery tiles and the use of an imagery blur filter on Google Earth are potentially of some significance. The careful application of the imagery filter over border areas uploaded in 2016 could be explained by the short-lived acquisition of Skybox/Terra Bella by Google [54, 55], necessitating the placation of NOAA regulators, although such an explanation would fail to provide an answer as to why no action was taken to improve the partially blurred coverage on Israel's

northwestern border outlined above. Most significant, however, is the addition to Google Earth of VHR satellite imagery tiles of the West Bank area of Palestine and the Golan, with no attempt to down-sample the resolution of this imagery. The statement in this case is arguably more explicit; that regardless of the present standing of the KBA, these areas are not internationally recognized as being part of Israel, and do not therefore fall within a literal reading of Section 1064 of the 1997 U.S. Defense Authorization Act.

Figure 7. Two satellite images showing a section of the Israeli border with Jordan (above, dating to 26 February 2016) and Egypt (below, dating to 18 April 2016). In these cases the application of a blurring effect on the Israeli side of the border closely follows the yellow boundary line (Images courtesy of CNES/Airbus via Google Earth). Map data ©2017 Google.

In making these images available, Google Earth disseminated satellite imagery at a resolution higher than the current 2 m baseline advocated by the NOAA. However, in purchasing high-resolution imagery produced by the European Pléiades constellation, available on the international market, Google has arguably not infringed upon the KBA. The lack of clarity stems from the failure of U.S. regulators to update their guidance notes with what has, since 2012, become the recognized baseline resolution for VHR imagery on the non-U.S. based market, namely 0.5m GSD.

Taking this argument forward, if the NOAA were to adopt the current international standard of 0.5 m GSD, an interesting advance would be if archival VHR imagery of Israel and Palestine collected by companies such as DigitalGlobe that was down-sampled for retail, as required by the KBA, could be re-released at, or very close to, its original resolution. On this front, the KBA lacks the specific wording to make a clear judgment of how the market can respond. There is no reference in the wording of the law to any conditions placed upon archival data. A positive outcome for archaeological applications on this front would be the declassification of KH-7 and KH-9 imagery of Israel and Palestine. The value of declassified imagery, particularly KH-4 Corona, for the investigation of Middle Eastern archaeological landscapes has been amply demonstrated [56, 57, 58]. So far, the highest-resolution spy satellite imagery to have been declassified is the KH-7 Gambit and KH-9 Hexagon missions. Imagery captured by an even higher-resolution spy satellite, KH-8 Gambit (capable of imaging at 0.15 m), remains classified. Overall, ca. 19,000 KH-7 Gambit and over 1.2 million KH-9 Hexagon frames were produced during the lifespan of the two satellite programs [59]. The vast majority of these images have been declassified as part of the second and third rounds of imagery declassification, which took place in 2002 and 2013, respectively [60, 61]. At least a hundred KH-7 photographs covering Israel [62] remain classified in accordance with the terms of the KBA. The number of KH-9 photographs of Israel and Palestine is unknown, but likely to be far higher considering the far larger output of the KH-9 program and the fact that coverage of the Middle East was among the program's priorities [63].

There are many gaps in this narrative that will only be resolved as more information is released by the U.S. government and its agencies, particularly the NOAA, but also by Google and the various satellite operators affected by the KBA. It has been conjectured above that the complex workload and lack of resources at the NOAA may have restricted their ability to deal with the KBA review. It should be highlighted that the KBA did not originate with the NOAA, but its implementation came to the organization as part of their wider role in regulating the commercial satellite sector. Nevertheless, the NOAA were able to respond, albeit with significant delay, to calls from DigitalGlobe to lower the broader threshold on imagery resolution across the globe from 0.5 m GSD down to 0.25 m GSD in the face of growing non-U.S. competition [64]. The NOAA's final rule on the licensing of private land remote sensing space systems, published in the U.S. Federal Register, even suggests that input from the general public will be taken into consideration in their review of market standards [21]. For the NOAA there is no clear solution that will not expose them to the difficult geopolitics of the issue, and there is only a limited commercial benefit for the heavily-regulated U.S. satellite operators to stand up and raise this issue, which would expose them to a potential reaction from the U.S. administration.

The fact that it is now possible to purchase VHR imagery over areas previously covered by the KBA should be of significant interest to archaeologists active in Israel and Palestine. It would suggest that we are entering a new era in the potential for satellite imagery to be used in the identification and monitoring of sites across these countries. For archaeologists, access to VHR imagery will allow preliminary remote sensing survey of areas such as the 'extensive army firing zone' in the Judean Desert to the south-east of Hebron/al-Khalīl, which has never been investigated archaeologically (Greenberg and Keinan 2009, 11). A growing awareness of the availability of higher-resolution imagery among researchers interested in land-use change in this region will, it is hoped, lead to it also being acquired for public platforms such as Google Earth and support a paradigm shift away from the current restrictions that are holding back scientific research.

6. Conclusion

The issues raised in this paper are, arguably, five years overdue. The higher-resolution satellite imagery that the Airbus Pléiades fleet brought to the commercial market in 2012 and its implications for the KBA should have initiated a review at that time. It is even more surprising that there has been no published comment following the publication of satellite imagery by Google Earth from 2013 and UNOSAT in 2014 that went beyond the KBA baseline set by the NOAA. Nevertheless, despite this late contribution to the discussion, the evidence is unquestionable. Imagery of Israel and Palestine with a resolution of 0.5 m (0.7 m prior to up-sampling) has been available on the international commercial market (i.e. from a non-U.S. source) since 2012, when the first Pléiades and Kompsat satellites were launched. Although this should have instigated a change by the NOAA to regulatory guidelines, we have demonstrated that this has not been the case. We have set out a clear case for the current resolution restrictions stipulated by the KBA to be reviewed and amended swiftly and in accordance with the wording of that very legislation.

Our research into, and interest in, this topic has been driven by our strong commitment as archaeologists to an open-skies policy, and open access to as much information as possible. The benefits of having an international standard of VHR imagery on the commercial market are clear. Leveling the playing field of the commercial market in satellite imagery following the revision of the NOAA regulations relevant to the KBA, which this paper calls for, would be of major benefit to humanitarian and environmental groups, archaeologists, geographers and other scientists with an interest in the use of geo-spatial data pertaining to Israel and Palestine.

Funding

The EAMENA project and this research is generously supported by the Arcadia Fund (https://www.arcadiafund.org.uk/).

Acknowledgments

The authors wish to thank all of the members of the EAMENA team (http://eamena.arch.ox.ac.uk/meet-the-team/) for their work and contributions. We would like to especially thank Morag Kersel for her help in locating the more obscure background material, and Nichole Sheldrick for help in editing. We are grateful to all those who commented on drafts of this paper. Any errors remain our own.

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