The Quest to Save Honey:
Tracking Bee Pests Using Mobile Technology

Diana Sammataro* and Sandra L. Arlinghaus**

Download the associated .kmz files to open in Google Earth: VarroaGlobal, Hawaii, Kenya
Use a high-speed internet connection.

Varroa (Acari: Varroidae) is a parasitic mite that threatens the extinction of the world's honey bee (*Apis mellifera*) population. This mite not only feeds on bees and bee larvae, but carries viral diseases and promotes stress to these hard-working insects (Sammataro et al., 2000). We have been mapping the spread of this blight for quite awhile (Figure 1) focusing on the importance of animation as a tool to draw together space and time. Understanding spatial pattern helps to tighten focus on intervention. There are obvious consequences associated with the possible extinction of honey bees: honey has long been an important agricultural crop (Ellis and Munn, 2005; Matheson, 1996). In addition, honey bees are important pollinators of one third of our crops, including fruits and vegetables and used in seed production (Free 1993; McGregor, 1976; http://www.sciencedaily.com/releases/2007/05/070510114621.htm). There are substantial economic implications to the possible demise of bee pollinators as well as to the production of honey, long used as a natural sweetener (a healthy alternative to processed sweeteners) and for medicinal purposes. The production of beeswax from the honeycomb is even more valuable, a primary foundation for cosmetics, as well as for making candles. All of these hive products have been important since beekeeping was first recorded; wax and propolis (bee-collected plant resins) were vital to preserving Egyptian mummies. Beyond the obvious, when an established species is removed from an ecosystem it is simple logic that the impact of such removal will have long-range, and perhaps unforeseen, consequences.

The Varroa problem began in Asia in the early twentieth century (Goncalves et al. 1985; Rosenkranz et al. 2010). Today, Varroa is found worldwide, with some exceptions (Bradbear 1988; Matheson 1996) such as Australia. Erroneous classification of the mite has clouded some of the reporting of information. First identified as *Varroa jacobsoni* on the Asian honey bee *Apis cerana*, molecular analysis has now separated out four different Varroa species. We refer here, for purposes of mapping, to the mite simply as "Varroa", and in general terms it represents the new *Varroa destructor* (Anderson and Trueman 2000) that jumped from the Asian honey bee onto the European honey bee (*Apis mellifera*). Careful analysis of the problem as a whole, beyond the tracking aspects, must consider the taxonomic problems as well (see Rosenkranz, et al., 2010; Navajas et al., 2010).

As late as 2000, Varroa was discovered in New Zealand (Matheson 2000), in Panama (Calderon et al. 2000) and in St. Kitts & Nevis in the Caribbean. It has also been found in the Caribbean islands of Grenada in 1994, Trinidad in 1996 (Hallim, M.K.I. 2000), Cuba in 1996, Dominica in 1998, St. Lucia in 1999, Tobago and Nevis in 2000. It apparently has also been reported in Haiti (dates forthcoming). On July 6, 2000, Varroa was first detected in Panama.

The recent discovery of Varroa mites in the Eastern Rift Valley in eastern Kenya (2009), the homeland of the honey bee species as well as a diverse population of wild (often unusual) animals, is particularly alarming because bees and honey are an integral part of subsistance-level farmers where honey is an important source of income. The discovery of mites somewhat earlier (2007) in the tropical paradise of the remote Hawaiian Islands, will have a huge impact since many breeders raise queen honey bees there. The spread of these mites can be directly attributed to the movement of bee colonies by beekeepers and as well as from some hitchhiking bee swarms on ships. Other mites are on the horizon which are equally devastating to bee pollinators.

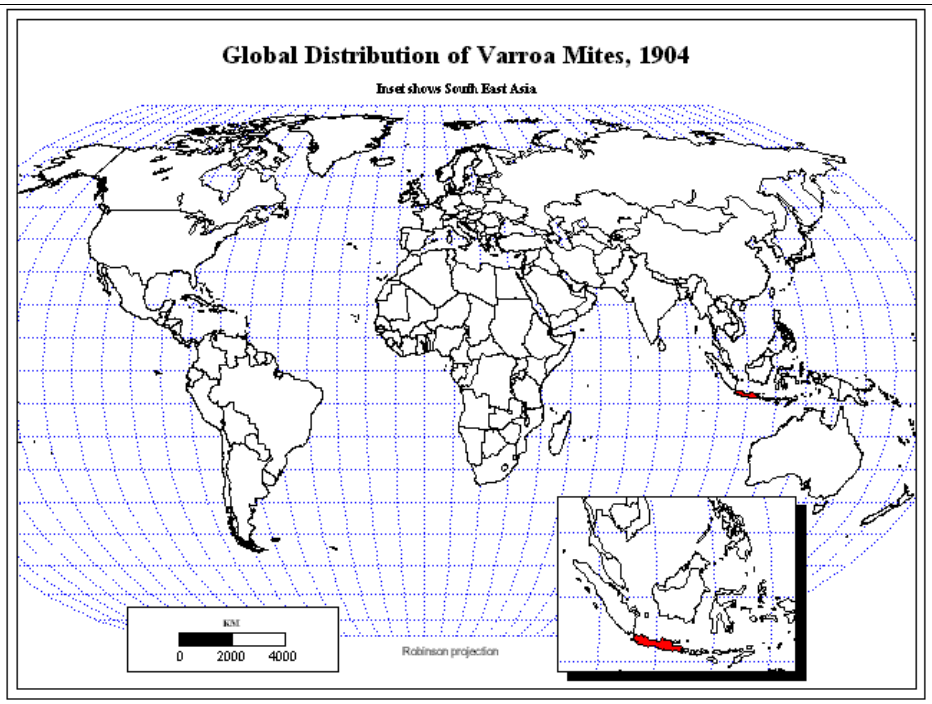

Figure 1. **Animated map.** Map by Sandra L. Arlinghaus and John D. Nystuen. *Solstice: An Electronic Journal of Geography and Mathematics*, Volume XVIII, Number 1, June 2007. http://www.imagenet.org/

Current technology permits far more than the basic mapping, by country, of Figure 1 which is really not well-suited to showing small islands. Improvement in technology to detect local locations in remote places, using GPS or other mobile technology, requires mapping capability beyond the traditional flat map. Adding local to global information about pattern yields fuller insight into spatial pattern and therefore into possible interventional strategy.

The Case of Hawaii

Detailed maps, showing sightings (or no sightings) of the mites in Hawaii can be fairly accurately superimposed in Google Earth to take advantage of layering of scientific maps, Google Earth aerials, and Google Earth Terrain. Figures 2, 3, 4, and 5 all show how to achieve such layering for each of four existing maps [Kunimoto]. The animations in these figures begin and proceed as follows through to an end product that shows superimposed Placemarks (yellow or red "balloons") representing an inventory of selected locations and whether or not varroa was present. As mapping has become more mobile, via laptops, smart phones, and GPSs, the possibility of field-checking computer results in the real world has become increasingly simplified. The mapping steps are:

- Find the general locale in Google Earth.
- Add the existing map as an image overlay (it will not be correctly aligned) (Kunimoto).
- Set the level of opacity of the added map to about 50% so that the map can be moved and stretched to fit, fairly well, the underlying landmass in Google Earth.
- While the opacity is still set at 50% add Placemarks (yellow or red balloons, in this case) at the locations (yellow dots) indicated on the maps.
- Hide the added map so that only the native Google Earth layer and the Placemarks show up.

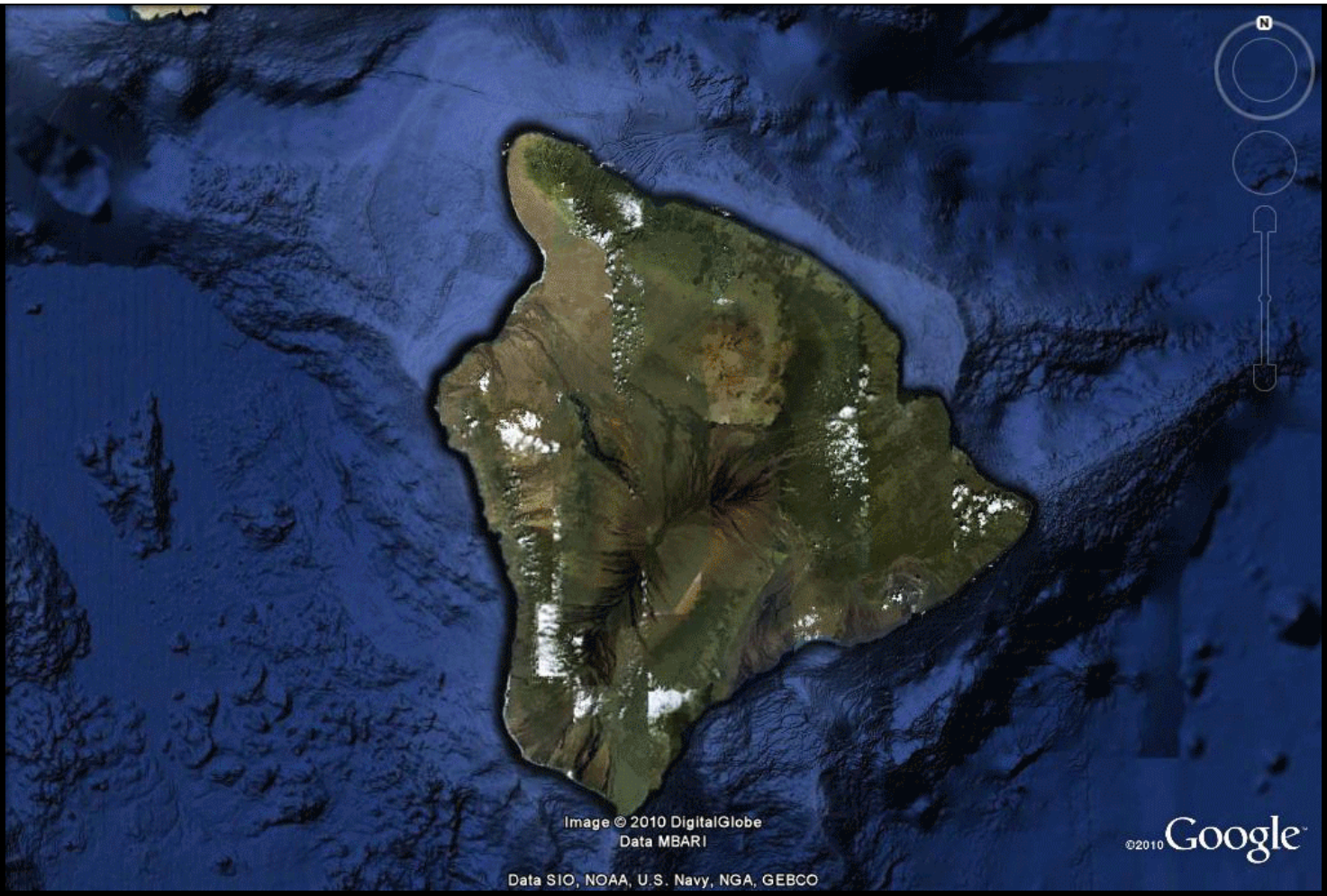

Figure 2. Hawaii (Big Island). Balloons indicate sites that are part of the mite inventory. Yellow means "no mites sighted" and red means "mites sighted."

Figure 3. Kauai. Balloons indicate sites that are part of the mite inventory. Yellow means "no mites sighted" and red means "mites sighted."

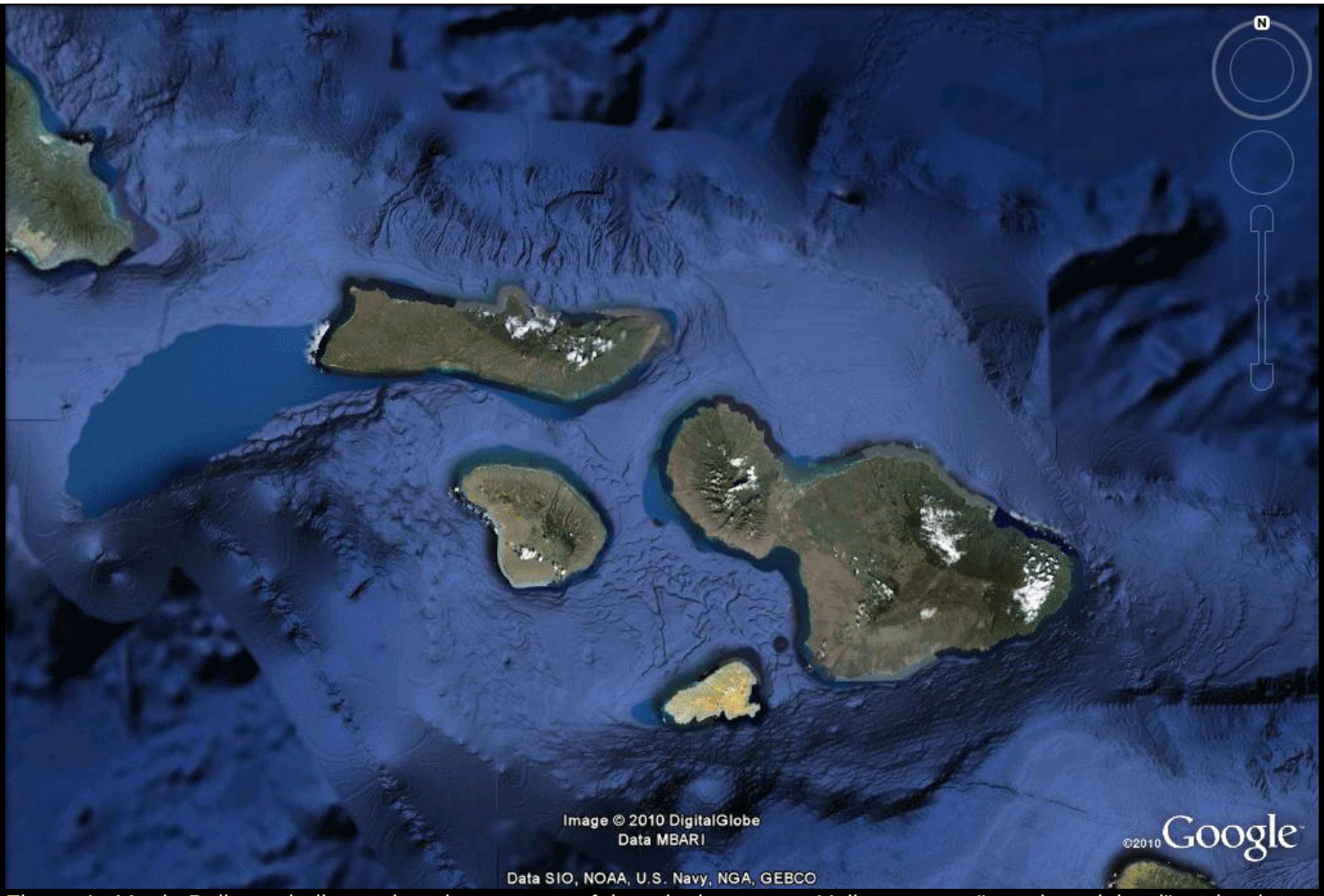

Figure 4. Maui. Balloons indicate sites that are part of the mite inventory. Yellow means "no mites sighted" and red means "mites sighted."

Figure 5. Oahu. Balloons indicate sites that are part of the mite inventory. Yellow means "no mites sighted" and red means "mites sighted."

Once the locations are tied to the Google Earth base, then one can zoom in and take a closer look, add other layers already present in Google Earth, and generally take full advantage of the software capability (download the Hawaii .kmz file and open it in Google Earth to look around). Such enhanced 3D visualization permits one to see the broad context of an actual environment. The major difficulty with taking a very close look, in the case of the Hawaii data, is imperfect alignment of sightings, recorded on beautiful flat maps, with the Google Earth coordinate system. The circles on the added maps really only suggest rough location and do not pinpoint location using latitude and longitude. Further, there are small misalignments because flat maps are stretched over the Google Globe (these are most evident in Figure 3, where the map is stretched in an attempt to fit a number of islands). Employing GPS technology solves both problems.

The Case of Kenya

In Kenya, the results of inventorying selected sites were recorded using GPS coordinates (Figure 6). Thus, the precision in locating them in Google Earth is greater than the precision used with the Hawaiian data. However, the images available in Google Earth, and related features, while helpful, are not as rich as those available for Hawaii.

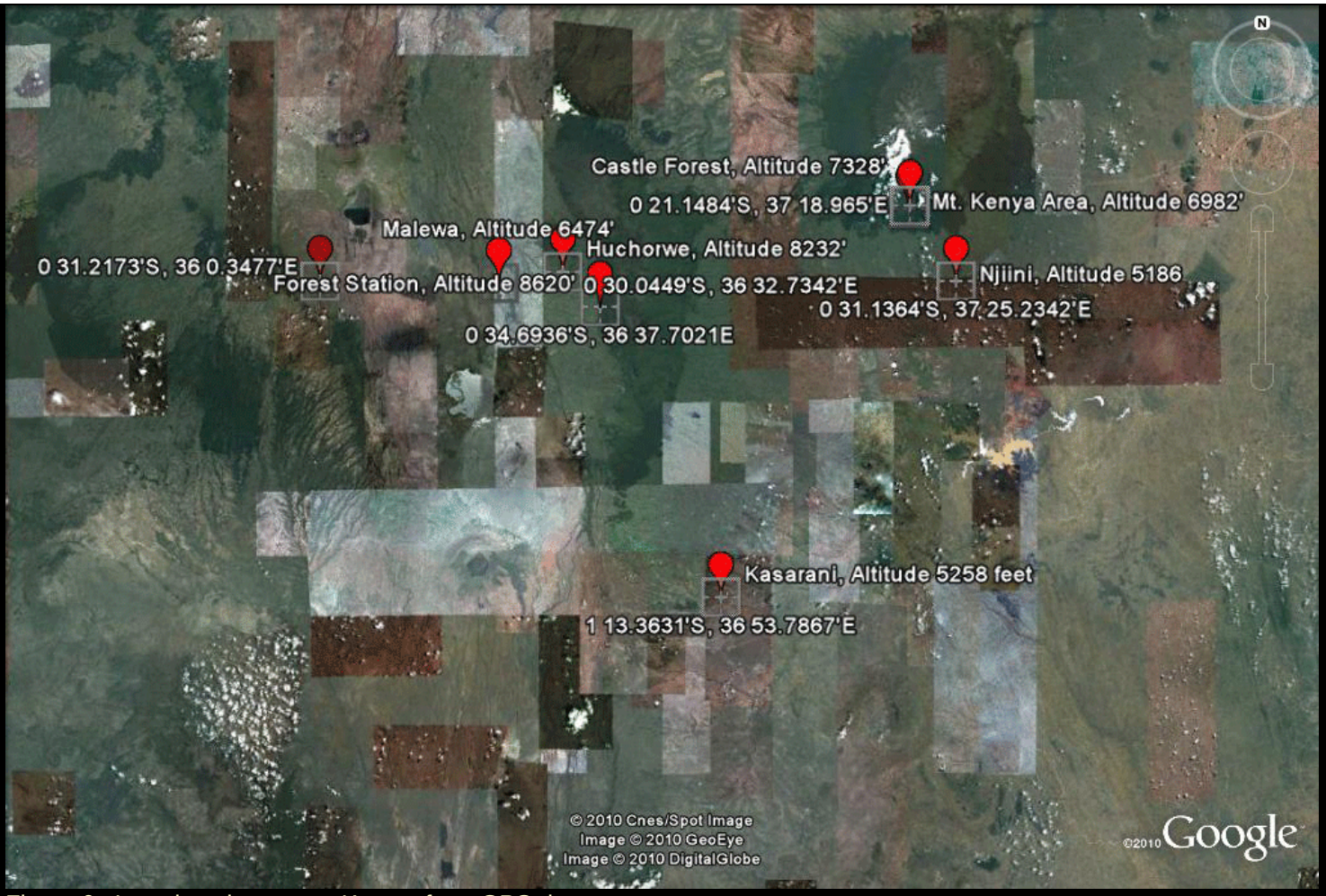

Figure 6. Locations in eastern Kenya, from GPS data.

The available imagery, whatever it might be, is nontheless vastly superior to what one might have found only a few years ago: it is in color and it is easily available and free. It is most useful, however, when other switches for other data already present in Google Earth are used to supplement it. Figure 7 shows the UNEP inventory with a sample from the Mount Kenya area of resolution higher than that of the native imagery, coupled with roads and a page from Wikipedia. Readers wishing to get the full effect should download the Kenya.kmz file and view it in Google Earth.

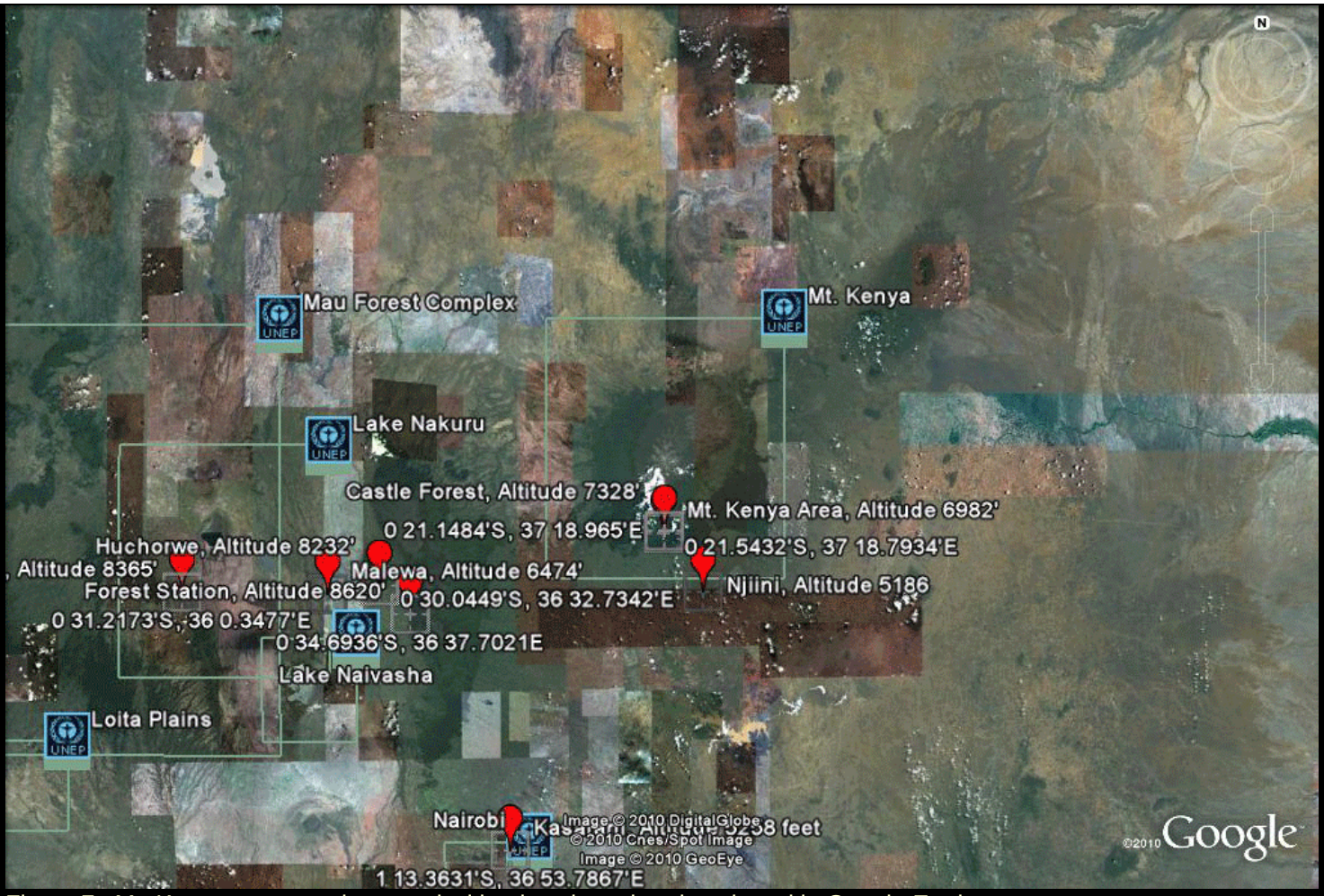

Figure 7. Mt. Kenya area supplemented with other data already onboard in Google Earth.

Similarly, Figures 8 and 9 illustrate other directions available to supplement field evidence acquired using GPS technology and subsequently embedded in Google Earth. Figure 8 delineates areas of change (three areas) surrounding Mt. Kenya. Figure 9 gives the reader an idea of the ruggedness of the terrain in the region.

Figure 8. Three areas of change (boxes outlined in yellow) in the region surrounding Mt. Kenya.

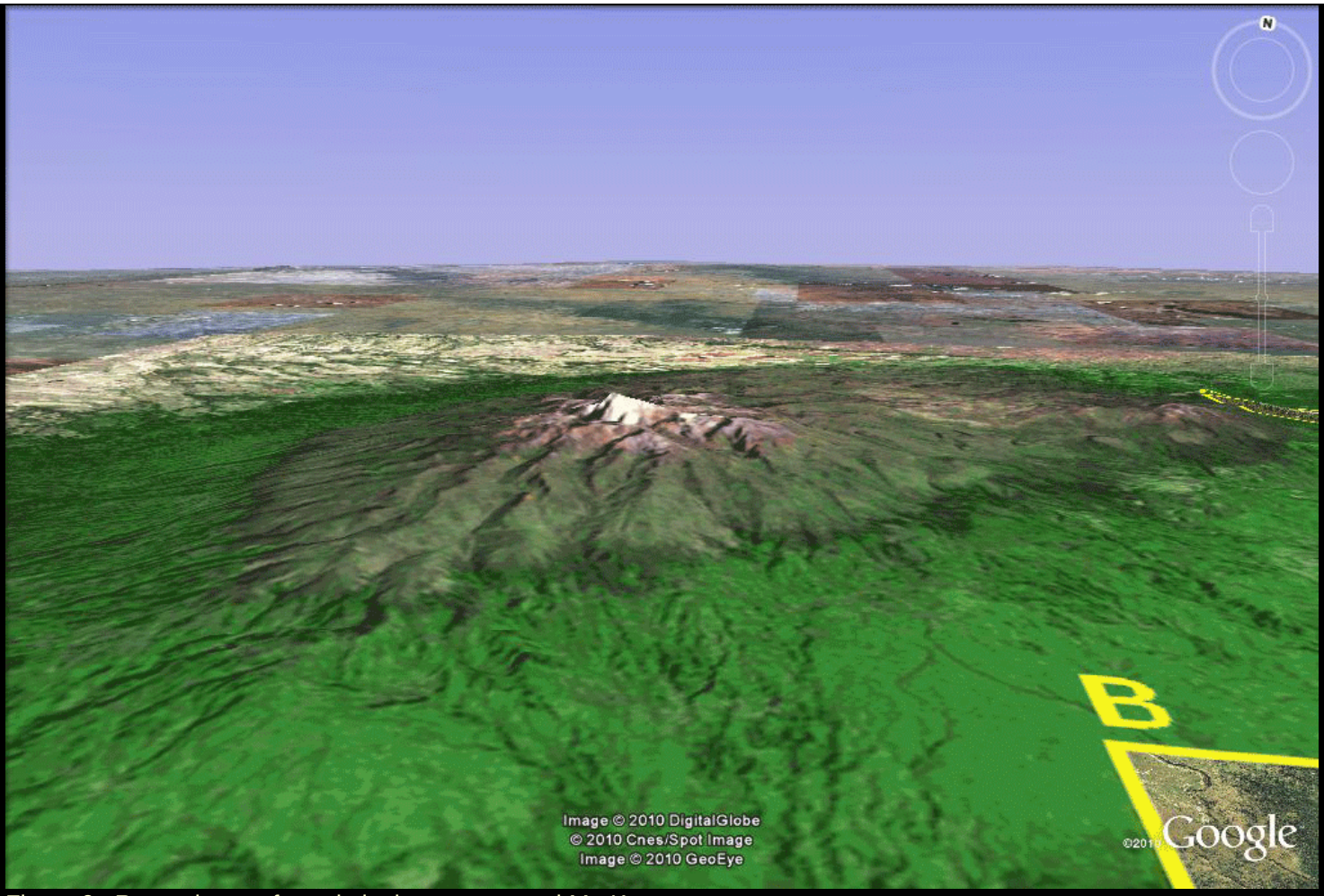

Figure 9. Ruggedness of terrain in the area around Mt. Kenya.

In a further similar survey (April-May, 2009) of 125 additional colonies located in the eastern, western and coastal regions of Kenya (69 colonies in 18 locations), coastal Tanzania (18 colonies in 4 locations) including Ugunja and Pemba Islands, collectively referred to as Zanzibar (likely A.m. litorea), and Western Uganda (14 colonies in 4 locations), 87% of the colonies tested positive for Varroa. Figure 10 is based on a map in Apidologie (Frazier, et al., 2010), subsequently translated to Google Earth using that map as an image overlay. Locations read from that map are coded as white balloons as it is not known precisely which of them has colonies with varroa. In the animation of Figure 10, the white balloons are displayed, as well, with the red ones from the GPS survey of selected locations. Among the white balloons, only the colonies surveyed in western Uganda and two of the Zanzibar colonies tested negative for mites. A limited survey of colonies in eastern Ghana (4 locations) found low numbers of Varroa in 2 out of 12 colonies sampled, suggesting that the mite has also spread to certain parts of West Africa.

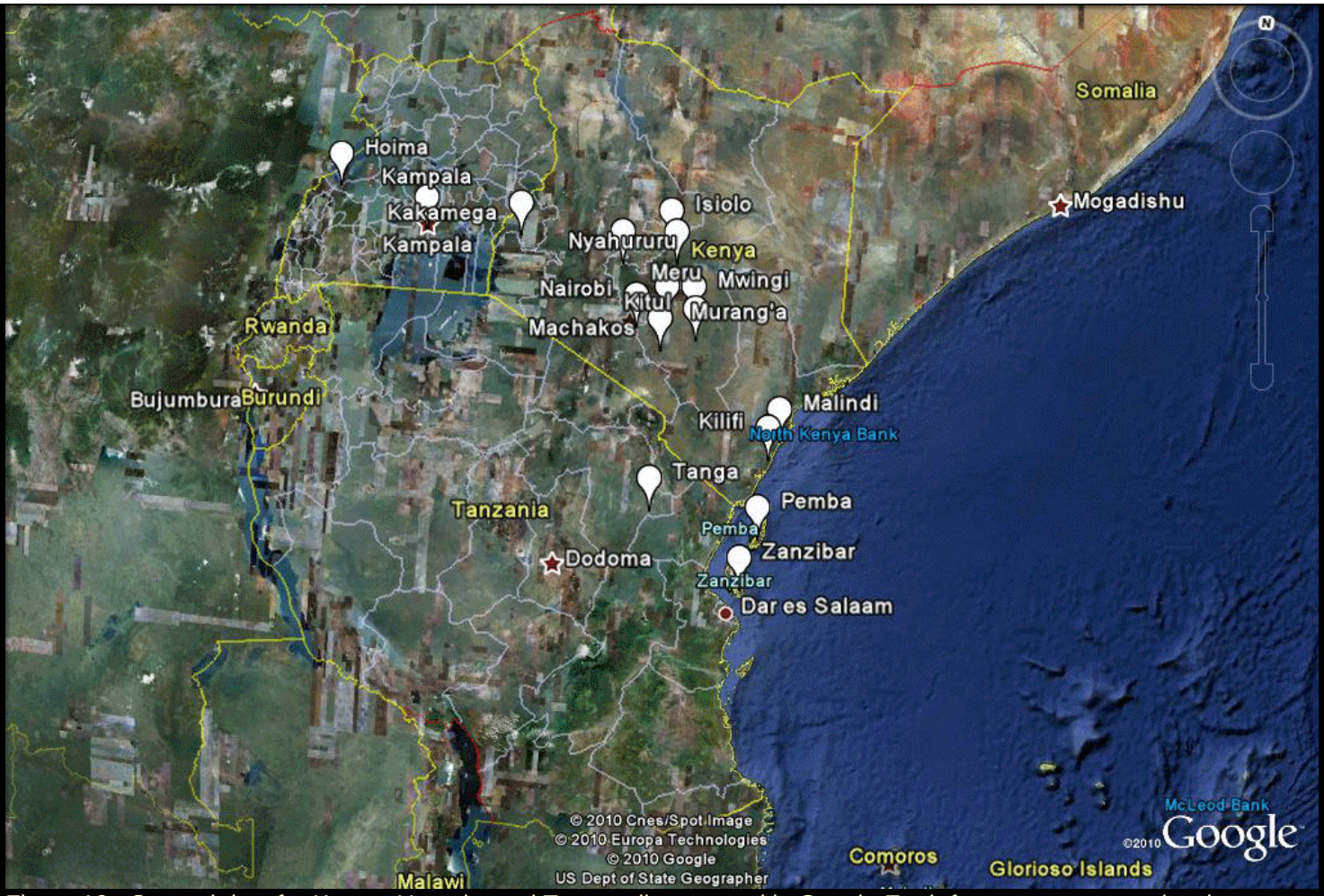

Figure 10. General data for Kenya, Uganda, and Tanganyika mapped in Google Earth from a paper map showing approximate locations of tested sites (Frazier et al., 2010).

The Global View, Revisited!

Animation of maps is a powerful tool for displaying spatial change over time. The simple layering of flat maps, adjusting successive animation frame spacing to correspond to real-world temporal spacing, can portray change effectively in a single view (as in Figure 1). More recent technology, however, permits the reader to do more than merely view the animation. The embedded "tour" of Google Earth lets the reader interact with a 3D display of Varroa distribution and experience directly the feeling of movement of that spread. One can dive into the display and see local imagery--stop the animation and extra navigation equipment appears; try your mouse buttons in various ways. Continue the animation after exploring a region; it will continue where it left off. One can also portray both global data, as in Figure 1, along with local data (as for Hawaii and Kenya in the other figures above) in a single display. The capability to adjust the image permits the simultaneous mapping of data at different scales. Further, the "tour" aspect of the display in Figure 11 emphasizes the global character of the distribution and helps to overcome the fact that less than half the Google globe can be in view at any one time. Test the interactive character of the imagery in Figure 11; travel with Varroa!

Tour with Varroa.

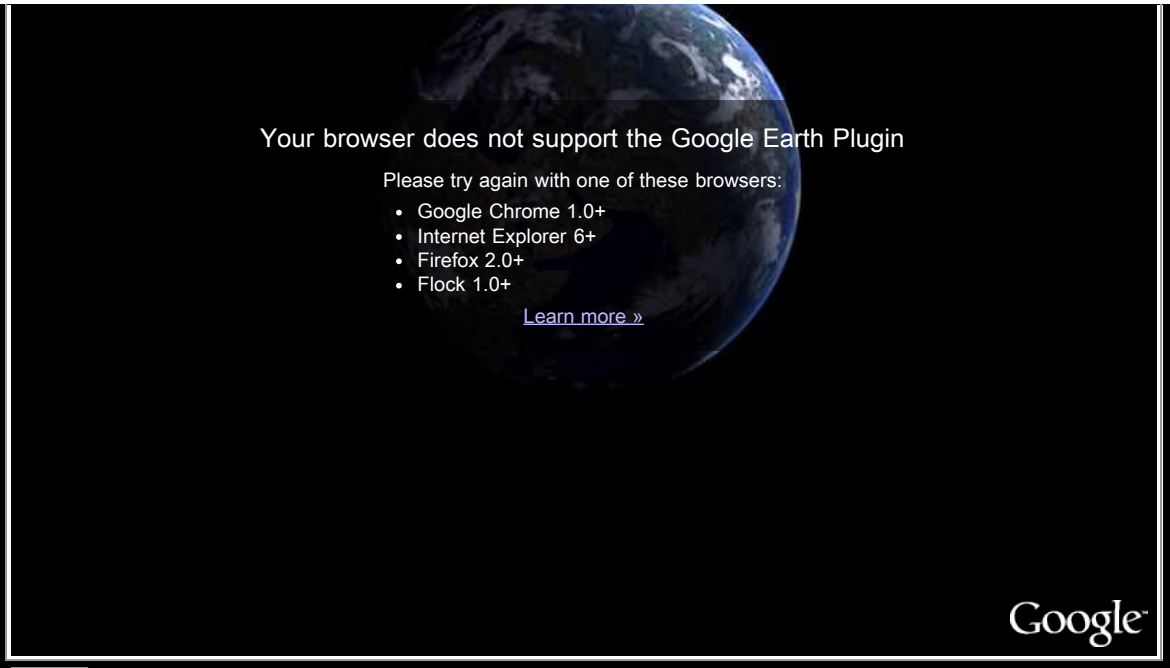

Figure 11. Travel with Varroa; maps at different scales legibly displayed together.

The mapping strategy employed for Varroa, now well-established, might work equally well elsewhere. The small hive beetle is a new player. Initial mapping efforts offer promising views of the distribution of this pest (Neumann and Elzen, 2004; Neumann and Ellis, 2008). Perhaps the day will come when the onboard data set of fine tools, such as Google Earth has, will carry areas of change associated not only with vegetation and development issues, but also with changing wild life and agricultural populations including even the humble, but important, status of the honey bee!

References and Software:

Anderson, D.L. and Trueman, J.W.H. 2000. *Varroa jacobsoni* (Acari: Varroidae) is more than one speices. Exp. Appl. Acarol. 24: 165-189.

Calderon, Rafael A.; Ortiz, Alberto; Aparisio, Bolivar; and, Ruiz, Maria Teresa. Varroa in Panama: detection, spread and prospects. DOI, Vo. 81 (3), 126-128.

Ellis, J. D. and Munn, P. A. 2005. The worldwide health status of honey bees. Bee World 86(4): 88–101 http://www.ibra.org.uk

Fakhimzadeh, K. Detection of major mite pests of *Apis mellifera* and development of non-chemical control of Varroasis. Helsinki, 2001. Dissertation, Univ. of Helsinki.

Frazier, M.; Muli, E.; Conklin, T.; Schmehl, D.; Torto, B.; Frazier, .J.; Tumlinson, J.; Evans, J.D.; and Raina, S. 2010. A scientific note on Varroa destructor found in East Africa; threat or opportunity? Apidologie 41 : 463-465. Online: RA/DIB-AGIB/EDP Sciences, 2009 http://www.apidologie.org DOI: 10.1051/apido/2009073

Free, J. D. 1993. Insect Pollination of Crops, 2nd edition. Academic Press: London. 684ppg.

Google Earth. http://www.google.com/earth/index.html

Hallim, M. K. I. 2000. Pests and diseases of honeybees in Trinidad and Tobago in the year 2000 and recommendations to reduce their spread in the Caribbean. Paper presented to the Second Caribbean Beekeeping Congress, Nevis, August 14-18, 2000. Ministry of Agriculture Fisheries and Food, U.K.(1996) Varroosis - a parasitic infestation of honeybees.

Kunimoto, S. L. Varroa Mite Survey, State of Hawaii, link.

Matheson, A. 1996. World bee health update 1996. Bee World 77: 45-51.

McGregor, 1976. Insect Pollination of Cultivated Crop Plants. Agriculture Handbook No. 496. ARS-USDA, Washington, DC. On line at: http://www.ars.usda.gov/SP2UserFiles/Place/53420300/OnlinePollinationHandbook.pdf

Navajas, M., Anderson, D.L., De Guzman, L.I., Huang, Z.Y., Clement, J., Zhou, T., Le Conte, Y. 2010. New Asian types of Varroa destructor: A potential new threat for world apiculture. Apidologie, 41 (2): 181-193.

Neumann, P., and J. D. Ellis. 2008. The small hive beetle (*Aethina tumida* Murray, Coleoptera: Nitidulidae): distribution, biology and control of an invasive species. J. Apic. Res. 47: 181-183.

Rosenkranz, P., Aumeier, P., Ziegelmann, B. 2010. Biology and control of *Varroa destructor*. Journal of Invertebrate Pathology, 103 (SUPPL. 1): S96-S119.

Sammataro, D., Gerson, U., Needham, G. 2000. Parasitic mite so honey bees: life history, implications and impact. Ann. Rev. Entomol. 45:519-548.

Author Affiliations

* D. Sammataro, Ph.D., Research Entomologist, USDA-ARS Carl Hayden Bee Research Lab, 2000 East Allen Road, Tucson, AZ 85719. diana.sammataro@ars.usda.gov

**S. Arlinghaus, Ph.D., Adjunct Professor of Mathematical Geography and Population-Environment Dynamics; The University of Michigan; School of Natural Resources and Environment; 440 Church St.; Ann Arbor, MI 48195; sarhaus@umich.edu

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***Solstice: An Electronic Journal of Geography and Mathematics*,**
Volume XXI, Number 1
Institute of Mathematical Geography (IMaGe).
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Remembering those who are gone now but who contributed in various ways to *Solstice* or to IMaGe projects, directly or indirectly, during the first 25 years of IMaGe:

Allen K. Philbrick | Donald F. Lach | Frank Harary | William D. Drake | H. S. M. Coxeter | Saunders Mac Lane | Chauncy D. Harris | Norton S. Ginsburg | Sylvia L. Thrupp | Arthur L. Loeb | George Kish |