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Towards establishment of GeoHealth, an open-data portal for health mapping and modelling based on Earth observations by remote sensing

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The International Society for Photogrammetry and Remote Sensing (ISPRS) Working Group on Health of Commission VIII (ISPRS WG VIII/2) held its 2nd Symposium on Advances in Geospatial Technologies for Health as a joint meeting with the 5th International Conference on Medical Geology (MEDGEO 2013) on August 24-30, 2013 in Arlington, Virginia, USA. Manuscripts published in this special issue of *Geospatial Health* are based on oral papers reported at this symposium by ISPRS members. Two additional reports are included: Capolupo et al. (2014) on the use of drones to monitor illegal spills and De Roeck et al. (2014) on fine-scale mapping of snail vector habitats in an agricultural setting.

The International Society for Geospatial Health (GnosisGIS) found many areas of joint interest, in particular the health impact of ground level airborne particulate matter with diameters of 2.5 microns or less ($PM_{2.5}$). This special issue of *Geospatial Health* came about because the use of remote sensing in conjunction with terrestrial meteorological data products was felt to be a novel area of spatio-temporal investigation where GnosisGIS could play a part.

The growing availability of digital data for geospatial studies made possible by remote sensing and resources from influential national space agencies, such as the National Aeronautics Space Administration (NASA) in USA (http://www.nasa.gov/), the French national centre for space studies (Centre national d'études spatiales (CNES) (Marechal et al., 2008), the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) (Igarashi et al., (2014) has led to the establishment of a number of multi-disciplinary scientific teams interested in geospatial health applications. This has also resulted in a greatly expanded number of publications in the geospatial health arena aimed at advancement of new knowledge on epidemiology, tele-epidemiology and control of disease (Tourre et al., 2009; Utzinger et al., 2011, Vanessa et al., 2014). Several new journals have emerged, e.g. *Geospatial Health* (http://www.geospatialhealth.unina.it) (Utzinger at al., 2011), the *International Journal of Health Geographics* (http://www.ij-healthgeographics.com), *Spatial and Spatio-Temporal Epidemiology* (http://www.journals. elsevier.com/spatial-and-spatio-temporal-epidemiology/) and others. The net result is that geospatial mapping and multidisciplinary modelling are becoming mainstream science in the health community at large. Amid this growth in interest, however, there is a clear need to increase new lines of collaboration and communication between research groups that are developing health applications based on the geospatial sciences. This is especially true of groups whose members come from different orientations and training and whose work are on very diverse health issues.

A key aim of this special issue is to establish communication and collaboration linkages between ISPRS WG VIII/2 and GnosisGIS, so that the mutual interests of both scientific bodies can be further developed. Six papers in this special issue emanate from ISPRS. The lead paper by Lary et al. (2014) describes the development of a unique global air quality surveillance system based on satellite data generated by the moderate resolution imaging spectroradiometer (MODIS) (http://modis.gsfc.nasa.gov/), while Liss et al., (2014) propose an updated global climate classification system made possible by advances in remote sensing technology. Both of these papers offer striking new ways

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to view the Earth system in relation to public health. The review by Igarashi et al., (2014) reports on Japan's efforts to promote global health using advanced satellite remote sensing data from JAXA for the prediction of infectious diseases in Kenya (malaria and cholera) as well as global air quality. Faruque et al. (2014) explain the development and implementation of GeoMedStat, a state-wide disease reporting and surveillance system used in Mississippi to track asthma emergency room admissions, and Murad et al. (2014) report their assessment on the distribution of health centres in Jeddah City, Saudi Arabia. Sarfraz et al. (2014) describe the results of a multi-national effort on mapping urban and peri-urban breeding habitats of the *Aedes* mosquito vectors of dengue in Thailand based on climatic and physical parameters and a fuzzy analytical hierarchical process. Finally, two publications in the special issue are by GnosisGIS members, both from Europe. Capolupo et al. (2014) illustrate how remote sensing technology can be applied for the detection of areas of illegal spills harmful to human health by applying drones, photogrammetry and hydrological models, and De Roeck et al. (2014) report on a pioneering study on fine-scale mapping of snail vector habitats of cattle liver flukes based on the sub-meter resolution imagery from the Worldview-2 satellite.

The formation of GnosisGIS took place during a Team Residency at the Bellagio Study and Conference Center sponsored by the Rockefeller Foundation on April 10-14, 2000. The aim of the Team Residency was to develop a network of collaborating health workers and Earth scientists dedicated to development of global computer-based models that can be used for improved control programs for schistosomiasis and other snail-borne diseases of medical and veterinary importance. The scope of this organization, now in its 14th year, has since been expanded to encompass other infectious diseases of medical and veterinary importance, publication of the journal *Geospatial Health*, annual international symposia on Geospatial Health and short course offerings.

The International Society for Photogrammetry (ISP) was founded in 1910 and was developed under the leadership of its first President, Eduard Dolezal, from Austria. After 70 years of functioning under its original name, it changed its name in 1980 to the International Society for Photogrammetry and Remote Sensing (ISPRS) recognizing the certainty of the future importance of surveillance and environmental imaging and interpretative studies from aircraft and Earth observing satellites. Using sensors for the various parts of the electromagnetic spectrum - ultraviolet, visible, infrared, thermal and microwave - products of these technological advances have come to be called "remote sensing". Except for interruptions during World Wars I and II, the Society has carried on its activities continuously since its founding. ISPRS activities culminate every four years at the International Congress on Photogrammetry and Remote Sensing, initially taking place in the great cities of Europe or North America, such as Vienna (1913), Rome (1938), Washington (1952) and London (1960). More recent global venues have been in Rio de Janeiro (1984), Kyoto (1988) Istanbul (2004) and Beijing (2008). Throughout this time, ISPRS has been at the forefront in the evolution of remote sensing, geographical information systems (GIS) and digital modelling in what is now known as the geospatial sciences, and its history has mirrored the growth of the national space programmes of the US, Japan, Europe and other nations. The ISPRS WG VIII/2 is charged with addressing health issues within the broad scope of the ISPRS organization and the particular objectives of the Group on Earth Observations (GEO) (https://www.earthobservations.org/geoss.php), an international agency with support from over 100 governmental, non-governmental and scientific organizations. These goals, coincidentally, are similar to the goals and objectives of the International Society of Geospatial Health - GnosisGIS (http://www.GnosisGIS.org). Yet another group, the International Medical Geology Association (MEDGEO) (http://rock.geosociety.org/GeoHealth/MEDGEO_2013/index.asp) has similar goals in its stated mission in medical geology, the science dealing with the relationships between geological factors and health. In light of this apparent convergence of interests, it is of great potential value to cross-fertilize and reinforce linkages of diverse interest groups on health applications of the geospatial sciences. One idea proposed during the recent GnosisGIS symposium is the creation of a "Global Health Observation System of Systems" (Malone et al., 2014; Luvall JC, 2014). In consequence, a proposal is put forward on how the authors and organizations that produced and shaped the research published in this special issue on seemingly very different health issues could work in a collaboration to further public health using a standardized, interoperable, open source global resource data portal within the concept of a "GeoHealth" network (see box).

Is it possible to develop a dynamical 3-dimensional (3-D) or even 4-D (adding the temporal dimension) models of disease, such as a bi-weekly global leishmaniasis or schistosomiasis report? We are on the cusp

of succeeding in this endeavour, facilitated by global Earth observation satellite systems, big data, climatology advances, new sensors such as a soil moisture active-passive (SMAP) device (http://smap.jpl.nasa.gov/mission/), 40 years of Landsat legacy data, vividly presented as a slide show available at http://www.oosa.unvienna.org/pdf/pres/copuos2012/panel-01.pdf and, perhaps most crucially, the sub-meter resolution environmental data now available from Worldview-2 and Worldview-3 (De Roeck et al., 2014). Add to this the elective value-added potential of low-altitude sensors on drone airborne vehicles as a source of very high resolution data collection within a user-set agenda (Capolupo et al., 2014).

Future NASA satellite and international space station missions such as HyspIRI (http://hyspiri.jpl.nasa.gov/) will provide further enhanced capability to map vector-borne and other environmentally sensitive diseases based on global hyperspectral visible and multispectral thermal data products (60 m^2, 5-day thermal and 19-day hyperspectral repeat intervals) that will enable structural and functional classification of ecosystems and the measurement of key environmental parameters (temperature, soil moisture). The planned ECOSTRESS instrument on the international space station (http://www.nasa.gov/jpl/nasas-ecostress) will monitor plant health using surface temperature measurements (and derived evapotranspiration values) with minimum daily repeat coverage at varying times during the day and at least one measurement at night at approximately 38 x 57 m spatial resolution (Luvall, 2014). Will these advances finally allow seamless mapping and modelling of diseases, not only at continental scales (1 km^2) and local community-agricultural field scales (30 m^2), but for the first time also at the habitat-household scale (<1 m^2) within individual communities? If so, this is a technology whose time has come.

What is now needed is an open source, inter-operable platform that is freely accessible by the global health community to link public health workers with the most current potential earth observation resources from the geospatial sciences community. We propose that NASA, JAXA, ESA, The United States Geological Survey (USGS), the Centers for Disease Control in China and USA, the Indian Space Research Organization (ISRO) the European Centre for Disease Prevention and Control (ECDC) and other important national agencies work together to make this possible. We anticipate that other organizations with an interest in geospatial health issues will join us in this commitment. GnosisGIS and ISPRS can play an important role working with members at leading academic institutions and global health organizations such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the American Society of Tropical Medicine and Hygiene (ASTMH), the Federation of European Societies for Tropical Medicine and International Health (FESTMIH) and philanthropic foundations, such as Carter, Gates, Rockefeller, Kellogg, Wallenberg and others. The following statement (box) describing the potential aims, organization and structure of the GeoHealth network is offered as a framework for initial effort at development in collaboration with GEO. We propose that GnosisGIS join and fully commit to the global vision of GEO.

Mandate of the Group on Earth Observations Health Network (GeoHealth)

The proposed Group on Earth Observations Health Network (GeoHealth) will collaborate on activities relating to the GEO societal benefit area (SBA) on Health of the Global Earth Observation System of Systems (GEOSS). GeoHealth will enable collaboration of governmental, inter-governmental and non-governmental organizations to organize and improve mapping and predictive modelling of the distribution of infectious, vector-borne and non-contagious diseases globally and make this data, information and forecasts more readily accessible to policy and decision makers, managers, experts and other users. The GeoHealth network aims to be both a Community of Practice and a Task in the GEO Work Plan. It is a voluntary partnership that is guided by a steering committee comprising the key stakeholders, initially the ISPRS VIII/2 Working Group, and the International Society of Geospatial Health-GnosisGIS that would actively recruit other organizations to join. GeoHealth draws on GEO's work on data-sharing principles to promote full and open exchange of data, and on the GEOSS common infrastructure to enable interoperability through adoption of consistent standards. To assist both holders and users of health information to engage with GeoHealth, an active website should contain links to information resources, activities, GeoHealth documents, meetings and other resources relevant to the GeoHealth mandate.

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