APOGEO SPATIAL

APOGEO SPATIAL 30 CELEBRATING EARTH IMAGERY 1985-2015

ELEVATING GLOBAL AW

Weather Data Commercialization

Q&A with Alan Hall, CEO Tempus Global Data p. 26

The Certainty of Sea Level Rise

by Hans-Peter Plag, PhD Old Dominion University p. 13

Earthquakes: Identifying Collapsed Buildings

by Valerio Baiocchi, PhD Sapienza University of Roma, Italy p. 22

GEOGLAM

GEO's Global Ag Monitoring Initiative

p. 16

"We need to realize that the coastal zone is borrowed from the world's oceans and they are about to take it back."

– Hans-Peter Plag, PhD, Mitigation & Adaptation Research Institute, Old Dominion University p. 13

"We'll see weather before it becomes weather... Our efforts are about saving lives (by providing better severe weather forecasting)."

– Alan Hall, CEO, Tempus Global Data p. 26

FORMERLY Imaging NOTES

[Winter 2015 / Vol. 30 / No. 1]

Satellite view of North America, courtesy of NASA

APOGEO SPATIAL

Apogeo Spatial communicates the power of geospatial tools and technologies in managing the world's environment and scarce resources, so that the global population has the security of water, food and energy.

APOGEO SPATIAL PROVIDES VISUAL INTELLIGENCE elevating global awareness for the long-term sustainability of the planet and people. Business, government and academic professionals find here the information—and inspiration—for using geospatial tools to build a more sustainable world. With the fresh, relevant insights from expert contributors, stunning visuals and clear examples of the technologies, those who make critical business and policy decisions about the world's resources will understand the visual power of remotely sensed data.

Apogeo Spatial is an important link to the education and academic communities to show young people the impact of geospatial technologies in helping to solve challenging problems facing humankind and to know more about the unknowns.

Mark Brender
Director / DigitalGlobe Foundation

The *Apogeo Spatial* launch is very exciting for those of us working in the geospatial field. *Apogeo* will be the leading source for understanding how global-scale issues can be addressed using geospatial information and tools. Combined with its partners in the Location Media Alliance, it becomes a primary means to keep up with the revolution in spatial information.

Bill Gail, PhD
CTO / Global Weather Corporation

It is exciting to see the launch of *Apogeo Spatial* and its focus on ecosystem health. Our ecological and social challenges are intertwined and global. Utilizing the view from space will assist us in addressing large-scale ecosystems health and in determining the actions that will be generative and effective in healing the planet. *Apogeo Spatial* is bringing critical ideas and tactics for utilizing geospatial tools to solve global issues.

Anita M. Burke
Founder / The Catalyst Institute

Apogeo *is providing game-changing insights for a game-changing sector.*

Nancy Colleton
President / Institute for Global Environmental Strategies
Executive Director / Alliance for Earth Observations

This global mosaic was compiled in 2002 using cloud-free imagery acquired by Landsat 7 over three consecutive years (2000, 2001 and 2002). These mosaics provide a snapshot of the world's land surface during that year.


TOPCON
MASTER THE SKIES
WITHOUT LEAVING THE GROUND
TOPCON
Mobilize the Sirius UAS with a simple hand launch and fly in any weather condition. In the air, Sirius can operate in full autopilot or auto-assisted flight mode. Save time by eliminating the need to set GCPs (Ground Control Points) with the Sirius Pro — taking advantage of GNSS RTK.
YOUR PRODUCTIVITY.
TECHNOLOGY.
topconpositioning.com/sirius

[Winter 2015 / Vol. 30 / No. 1]

Columns

Features

COVER IMAGE

North America from Space

THIS IMAGE OF NORTH AMERICA from NASA is reminiscent of the 1968 Apollo 8 Mission photo of the Earth from space, called Earth Rise, though this one is not the entire Earth. The further out the view, the more profound is the fact of seeing no boundaries and political borders.

Earth imagery has come a long way, with many people using both commercial and government imagery. Landsat 8 is a great victory for the academic and scientific communities with their precedent-setting free data (see Secure World Foundation Forum on page 10), and WorldView-3 is pushing the envelope for companies and government customers.

The Group on Earth Observations' Global Agricultural Monitoring initiative (GEOGLAM) is an excellent example of an organization using both free and commercial imagery for their important and far-reaching work, on page 16. ΛΟ

APOGEO SPATIAL

Formerly Imaging Notes

[Winter 2015 / Vol. 30 / No. 1]

MISSION

Apogeo Spatial communicates the power of geospatial tools and technologies in managing the world's environment and scarce resources, so that the global population has the security of water, food, and energy.

PARTNERSHIPS

Apogeo Spatial has a partnership with Secure World Foundation (www.swfound.org).

Apogeo is affiliated with the Alliance for Earth Observations, a program of The Institute for Global Environmental Strategies (www.strategies.org).

STAFF

Publisher/Managing Editor	**MYRNA JAMES YOO** myrna@apogeospatial.com
Editor	**RAY A. WILLIAMSON, PhD**
Contributing Writers	**LEONARD DAVID** **MATTEO LUCCIO**
Creative Director	**ANDREW STERNARD** www.andrewsternard.com

EDITORIAL CONTRIBUTIONS

Apogeo welcomes contributions for feature articles. We publish articles on the remote sensing industry, including applications, technology, and business. Please see Editorial Guidelines on www.apogeospatial.com, and email proposals to editor@apogeospatial.com.

SUBSCRIPTIONS

To subscribe, please go to www.locationalliance.net/subscribe.
If you cannot go online, you may write to the address below.

Apogeo (ISSN 0896-7091) Copyright © 2015

Blueline Publishing LLC, P.O. Box 11519, Denver, CO 80211

Inspiration Comes in Many Forms

WITH THIS ISSUE, BLUELINE PUBLISHING marks the beginning of the eleventh year of publishing *Apogeo Spatial* (formerly *Imaging Notes*). The past 10 years have been an exciting ride as the magazine continues to document the amazing steps forward that have been made in the world of Earth observations. We also celebrate 30 years of the publication's existence, in a few different incarnations.

This issue offers some reasons to be inspired. As the Secure World Foundation column notes, Landsat 8 is making history with the best Landsat data ever, the use of agile new unmanned aerial systems (UAS) is thriving, and new commercial space systems promise to revolutionize the industry of capturing Earth observations (EO) data and turning them into useful, actionable information. What an exciting time to be publishing the achievements of the industry!

Professor Chris Justice and other staff members of the University of Maryland's Department of Geographical Sciences demonstrate important international cooperation with their description of the Group on Earth Observations (GEO) Global Agricultural Monitoring (GLAM) initiative, which they have led. GEO is a major multilateral effort to provide global-scale information on different constituents of Earth's environment to organizations and individuals around the world, using both satellite and ground-based information. GEOGLAM is focused on improving agricultural forecasting and planning through international cooperation and is made possible in large part by the improved flow of high-quality data from Landsat 8.

The article by Dr. Valerio Baiocchi of Sapienza University of Roma summarizes the use of a new software-based technique to improve safety and reduce the loss of lives in earthquake-prone urban areas. It illustrates the use of Trimble's eCognition Developer 8.0 image analysis software with remotely sensed data and position, navigation and timing (PNT) data to identify collapsed buildings soon after an earthquake and improve chances that rescue teams can locate survivors quickly and efficiently.

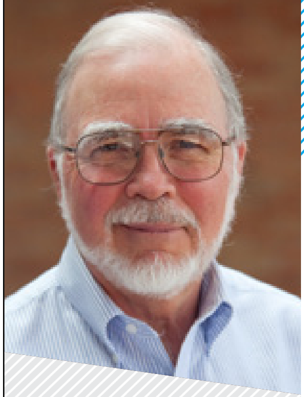
Finally, enjoy the Q&A with Alan Hall, CEO of Tempus Global Data, a firm that specializes in combining space-based weather observations with a "big data approach" to analysis to improve weather forecasting, particularly for severe weather. The Q&A should prove enlightening about what is on the horizon for commercial satellite weather data – ideally, better severe weather forecasts, lower costs, and bridging the pending weather data gap. This article follows our interview with PlanetiQ's CEO, Anne Hale Miglarese, in our Fall 2014 issue.

One of the most inspiring scientists of today is Dr. Neil deGrasse Tyson, well-known astrophysicist who spoke recently about the "Cosmic Perspective" of seeing the Earth from space, which is similar to the "Overview Effect," (included in our Fall 2014 Publisher's Letter). That view of our fragile planet from space changes our perceptions, and inspires a sense of unity, as we cannot see any political borders from space. We see only the captivating beauty, the land masses and oceans as one, and the smallness of our home. We hope that these articles similarly inspire us to work together for the benefit of all.

We look forward to another year of publishing timely, informative, and accessible articles on the many uses of Earth observations in support of elevating global awareness for the long-term sustainability of the planet and people. Send your suggestions for future articles and any comments to myrna@apogeospatial.com. We value your input to the magazine.

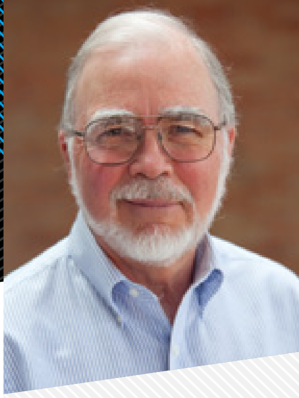
Sincerely,

Ray Williamson, PhD, Editor
Myrna James Yoo, Publisher



Ray Williamson, PhD
Editor
Apogeo Spatial

Myrna James Yoo
Publisher and Managing Editor
Apogeo Spatial and *LBx Journal*
Owner
Blueline Publishing LLC



Ray A. Williamson, PhD
Editor
Apogeo Spatial
Denver, Colo.
www.apogeospatial.com

Landsat & Google Earth Engine Prove Valuable to Scientific Community

ASPRS PECORA SYMPOSIUM REPORT

HOW THINGS HAVE CHANGED SINCE LANDSATS 4 & 5 were launched in the early 1980s, about the time I began working on analyzing space policy issues for the U.S. Congress. In those days the community that depended on data collected by satellite sensors was small, the data were very expensive and the United States was the only entity in the business of supplying digital data collected from the vantage point of Earth orbit.

The United States was then tied up in what turned out to be a fruitless search for a way to "commercialize" the Landsat system, turning first to NOAA and then to the private firm, EOSAT, to market the data commercially. Data sales remained depressingly small, in large part because prices were so high and the best resolution was medium sharpness (30 meters multispectral). U.S. policy drastically limited the allowable resolution of the data, "to protect national security," it was said.

Only in 1986 when the United States began to face competition from the French SPOT system, which offered 10-meter resolution data at competitive prices, did U.S. policy begin to change. By 1992, policymakers finally saw that the moderate resolution data provided by Landsat and other similar systems had relatively little commercial value but great worth for public good applications like monitoring environmental change, and passed the Land Remote Sensing Act of 1992 (Public Law 102-555). This far-reaching law brought back the Landsat system fully under government development and operation and allowed the private sector to operate its own high resolution commercial systems, subject to a licensing system managed by NOAA. The rest, as they say, is history.

Editor's Note:
This publication was originally created by EOSAT 30 years ago, to promote the use of commercial imagery, which is still part of our mission. Also, see related article on the need for UAS training in *LBx Journal* http://bit.ly/1u4uRxy.

Musings such as these were front and center in my mind during the 19th Pecora Symposium, an American Society for Photogrammetry and Remote Sensing meeting held in Denver November 2014 (http://pecora.asprs.org/). *Apogeo Spatial* publisher, Myrna James Yoo, and I both attended the conference, entitled *Sustaining Land Imaging: UAS to Satellites* and feasted on the smorgasbord of exciting news and research results from a wide variety of researchers, government representatives, and commercial data firms.

Customers can now purchase quarter-meter resolution data from commercial firms, and since 2008 most data from the Landsat archive, and from Landsat 8 are free for download to nearly anyone in the world simply by registering on the USGS Landsat Web service (http://landsat.usgs.gov/). This change of policy has proved especially important for the community of researchers that studies environmental change. To carry out a global-scale research project on, say, the extent of forest cover, or growth of urbanization, you need lots of data at a scale that allows for sufficient granularity to be useful to policymakers. See ***Figure 1***.

Fortunately for researchers and for operational applications, the data from Landsat 8 are well suited to such research and operational tasks. The bird has been operating well and delivering large amounts of high quality data to the archive. Speaker after speaker at the conference raved about the substantial number of scenes acquired since Landsat 8 began operations in May 2013. They were also pleased with the radiometric quality of the data, which exceeds design specifications, and with the additional spectral bands on the imager.

To underscore these gains and justify the speakers' enthusiasm for Landsat 8, in January 2015, USGS posted the results of a study touting the enormous economic impact of data from the Landsat program. This study, carried out by the Landsat Advisory Group of the National Geospatial Advisory Committee, a team of commercial, state/local government, and non-governmental organization (NGO) geospatial information experts, claims a value of between $350-436 million per year of savings in estimated productivity for the many applications of Federal and State governments, NGO's, and private sector firms compared with using alternative means of data. The Landsat program has thus shown a value much greater than the cost of building and operating the system. See http://www.usgs.gov/blogs/features/usgs_top_story/business-experts-see-landsat-as-stunning-return-on-public-investment/.

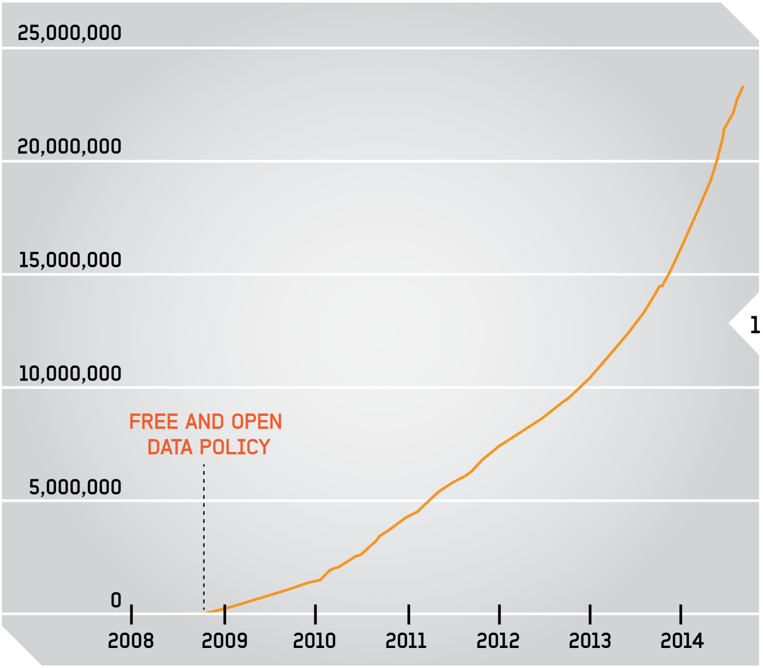
Although the news about the performance of Landsat 8 is very good, several speakers expressed their concerns about the future of the Landsat series. Those of us who witnessed the torturous process of reaching the design of what became Landsat 8 and the commitment to continuing the provision of data continuity are justifiably concerned about that future. Will we go through a similar interagency conflict for future systems? There were many questions raised about what comes after Landsat 8.

Several speakers who are involved in the current process of planning for data continuity of moderate-scale data took pains to assure conference attendees that substantial progress is being made to define the platform and processing system. At the time, they were unable to give details because the budget process was in full swing. We can look to President Obama's 2015 budget plans to provide some guidance.

VALUE AND POTENTIAL OF UAS

While the news about the field of moderate-resolution remote sensing proved very exciting, aerial remote sensing is not taking a back seat, especially in unmanned aerial systems (UAS), which are proving to be extremely advantageous in the monitoring and analysis of agricultural fields and other applications where high resolution is important, such as archaeology and pipeline monitoring.

Landsat Scenes Downloaded from USGS EROS Center (Cumulative)



▲ FIGURE 1. The number of Landsat scenes downloaded from USGS skyrocketed to about 20 million in about 5 years after free access was announced.

As we learned during the three day conference, the uses of UAS to collect extremely high-resolution data have really taken off (no pun intended). It is now possible to obtain multispectral imagery of ground cover such as crops, bushes and trees with resolutions at the level of a few centimeters quite cheaply compared to other methods. The information gained can be used to fine-tune the delivery of fertilizer and herbicide to crops. When the field data are paired with GPS-guided tractors, applications of chemicals can be calibrated precisely to the specific needs of each section of the field under cultivation.

Speaker after speaker on this topic argued that the use of UAS to monitor the health of fields and the growth of crops is revolutionizing agricultural management. Compared to standard aircraft, the much smaller UAVs (vehicles) tend to be cheap and easy to launch and recover. Equipment needed for data collection, processing and analysis can be carried into the field and used during and immediately after the flight, thus further reducing the costs of data gathering and analysis.

Nevertheless, there are some significant challenges ahead, and not just for improving agricultural practices. Perhaps the largest hurdle is regulatory. The FAA is still developing its proposed rules for operating UAS. While four companies have been approved for commercial use (Trimble, Woolpert, Clayco, and VDOS Global), other commercial operators have complained that they cannot develop their businesses beyond the experimental stage because they cannot yet obtain operators' licenses. Once again, the technology is running way ahead of regulations and other legal instruments.

> "This study claims a value of between $350-436 million per year of savings in estimated productivity."

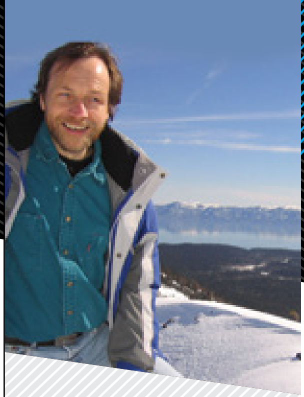
Beyond the regulatory barriers is a host of issues attendant on the development of new technologies. Various lightweight cameras are readily available and the needed electronics can be purchased or created from off-the-self components. Batteries, though, are a major challenge to UAS builders and operators. They need to be lightweight and capable of high energy density. Unfortunately, improvements in battery technology have not yet yielded the power density and low weight needed to power smaller devices for sufficient flight times. The wide popularity of the small UAS favored by hobbyists and the development of other battery-powered technologies are likely to provide strong economic incentive for battery makers to step up their game.

GOOGLE EARTH ENGINE INCREDIBLY IMPACTFUL

Finally, in what for me was one of the most hopeful and exciting developments discussed at the conference, Rebecca Moore, Engineering Manager at Google, gave us an exciting overview of Google Earth Engine (https://earthengine.google.org/), a service for which she led the development. Google has acquired vast amounts of Landsat data, and now collects and stores all the data Landsats 7 & 8 deliver. It is also hoping to have a similar arrangement with the European Union for data from its Sentinal series of satellites, and others.

The website calls this new service a "planetary platform for environmental data and analysis." Among other things, Earth Engine allows scientists and academics to access and apply a range of analytic tools to large amounts of satellite data, using Google's parallel processing platform.

Earth Engine provides a powerful set of tools to support another Google effort conceived and developed by Ms. Moore: Google Earth Outreach, a program to assist nonprofits, communities and indigenous peoples in their efforts to solve some of the world's pressing environmental and cultural preservation problems and human rights challenges. Google has also purchased Skybox Imaging, a new commercial high-resolution data company. Some percentage of those data will be made available for Earth Engine and Google Earth Outreach. A future article in this magazine will discuss these Google efforts in more detail.



The Slowly Developing Disaster of Sea Level Rise

OUR RESPONSIBILITY: PREPARING THE COASTS FOR LARGE-SCALE INUNDATION

Prof. Hans-Peter Plag, PhD
Mitigation and Adaptation Research Institute (MARI)
Old Dominion University
Norfolk, Va.
www.mari.odu.edu

IN 2013, JAMES BALOG'S PRESENTATION AT THE SCIENCE POLICY CONFERENCE of the American Geophysical Union (AGU) in Washington, D.C., motivated me to think about humanity as a planetary accident, causing the sixth major mass extinction event in Earth's long history.[1] Again, a presentation at an AGU meeting, this time the Fall meeting in San Francisco, set things right: James White, the Chair of the Working Group on Abrupt Climate Change Impacts of the National Research Council (NRC) attracted a huge crowd for his talk[2] about exactly that: how abruptly can things change and how big can the impacts be? In 2013, the NRC Working Group published a report,[3] which was rather moderate. James White, in his presentation, was not.

Even I, in all my presentations, which some find terrifying, have hesitated to present the full extent of what I think is likely going to happen. James White went to the full length, and rightly so. The time has come when science no longer can rule out many "worst case" scenarios that might be worse than the scenario described by Naomi Oreskes and Conway in their "Collapse of the Western Culture."[4] Tim Lenton used the analogy of being with a group of strangers in a small boat drifting down an unknown river and hearing a slowly growing rumbling in the far distance to picture the difficulty of communicating the threat we are facing.[5] James White used the same picture of a small boat in the middle of the Niagara River approaching the Niagara Falls to illustrated the fact that the threshold is not when the boat goes down the fall, but much further up the river, when the group in the boat loses the option to get safely to the shore. Thresholds are normally not visible and dramatic as Niagara Falls; they are hidden, silent… but crossing them determines destiny.

The most worrisome threshold we may have already crossed is the one for sea level. Sea level will rise, and it will rise much more than we want to acknowledge, and far more than the current numerical models predict. The sea level rise humanity has to face will be a disaster and this disaster is being nurtured today – so much that minor impacts are being felt already, and bigger ones are around the corner. It is time then for us to focus our efforts on minimizing the impacts and reducing the scope of the disaster, instead of discussing the questions of "why, when, and how much." It is an emergency humanity is about to face and we are past the stage of counting years and calculating inches.

Consider that over the last million years, atmospheric carbon dioxide (CO_2) varied between roughly 170 ppm (parts per million) during ice ages and 300 ppm during warm periods like ours. During ice ages, global sea level was 130 m (meters) lower than today. Thus, a range of 130 ppm in CO_2 correlates with roughly 130 m in global sea level.

Very simply put, we have 1 m sea level per 1 ppm in CO_2. Of course, during times of global warming, sea level was lagging in time behind the CO_2 and temperature increases, but eventually sea level caught up to match this simple relationship. The main contribution to these changes in sea level comes from changes in the water stored in land-based ice sheets. Of course, this correlation cannot hold to much higher CO_2 values because at one point, all land-based ice will be gone. This point will be reached when global sea level is roughly 75 m higher than today.

Today, atmospheric CO_2 has already reached 400 ppm, and there is no reason to believe that this is the maximum - in fact, the current rate of

▲ FIGURE 1. In Norfolk, VA, homeowners raise their houses by up to 8 feet to be protected against the nuisance flooding.

increase in CO_2 is higher than ever.[6] 400 ppm, that is 100 ppm higher than the previous maximum during the last 1 million years. This looks terribly like a threshold we have crossed and there is no return.

If the CO_2-sea level correlation holds, this would mean an increase in sea level of 100 m. Of course, that is not possible since we only have ice left for 75 m. But that is bad enough and going down Niagara Falls could be the easier thing to do than facing this sea level rise. If the current trend in atmospheric CO_2 and other GHGs continues, and the planet warms by 4 degrees Celsius or more, it may take a few hundred to thousand years to melt the land-based ice, but eventually this will happen.

▶ FIGURE 2. Some people damage their cars by driving through salt water inundating the roads.

▲ FIGURE 3. Raising the house may avoid flooding of the house, but the properties are frequently cut off (like islands) because roads are flooded and no services can get to the properties. In the face of a potentially large sea level rise, this is not adaptation but rather ignorance in the face of the knowledge we have about the likely future.

What is almost unbelievable is that most of us want to believe that we can get away with roughly one meter by 2100 and a little more in the following centuries. This is what our scientific knowledge seems to indicate, at least if you don't read the last report of the Intergovernmental Panel on Climate Change (IPCC) very carefully. The sea level projections discussed in this report do not include accelerated contributions from the ice sheets, and the only reason for that is that we do not know how the ice sheets are going to respond to the unprecedented speed of global warming that is taking place. We think, we can get away with a global sea level rise two orders of magnitude smaller than what seems to be the rule for the last 1 million years. It reminds me of kids who set the house on fire and then believe that by some magic the fire will not burn down the house.

Yet, we are not kids. The 20th century events alone should have been enough to awaken us to the consequences of such failure in judgment, especially by leaders of the nations who knew better.

Another serious situation, where the leaders of several countries chose not to see an emerging threat, was the time before the second world war (WW2). Adolf Hitler was very clear about his intentions; he even published them in books. Nevertheless, in September 1938, leaders of France and Great Britain met with Hitler to discuss his demands, ultimately granting the German leader control over the Sudetenland region of Czechoslovakia. In return, Hitler promised to leave the rest of Czechoslovakia alone, and to abandon all further ambitions of territorial expansion. The French and British leaders made the choice to ignore the evidence and instead hoped for the unlikely.

Our leaders of today are negotiating an enemy as powerful and as determined as Hitler was, and it is clear where this is heading. But we are not ready to accept the obvious and come to the right conclusions – to reduce the risk associated with a rapid sea level rise and to increase our resilience by preparing to move out of the coastal zone when it will be necessary. This has the potential for a disaster as big as WW2.

Most coastal zones are no longer pristine environments where only some ecosystems would be submerged during the massive inundations we will without a doubt see in the future. Many coastal zones are industrialized and have been engineered, they are polluted, misused for landfills with all types of waste, and in many locations we have areas with highly toxic contaminations. In the U.S., some of the "Superfund Sites" are in locations increasingly exposed to inundation.[7] Flooding these areas will lead to massive pollution, threatening the marine environment, degrading and poisoning crucial food resources, and throwing those who depend on coastal ecosystems for their food into long-lasting health problems and famine.

Instead of protecting coastal settlements and keeping them growing, we need to slowly migrate them to higher and safer grounds. Refocusing our economy on this task would create a huge amount of jobs and at the same time increase resilience and reduce disaster risk. Jim White indicated that the national flood insurance soon could cost the country more than social welfare. Instead of spending all this money on insuring flood-exposed infrastructure, it would be better to provide the funds to reduce exposure to flooding.

The action of the day is to clean up and to prepare the coasts for inundation of water. We need a major effort to map all critical infrastructure that could lead to pollution or other problems, and we need to remove these from the coastal zone. Eventually, they need to be moved high enough to be safe from inundation. A global sea level rise of 75 m means that local sea level can change much more, which is due to the gravitational effect of the ice masses and the elastic response of the solid earth to the shifting loads. Simply put, sea level rise is much smaller than the global average close to a melting ice mass and much larger further away from it. Since most of the melt water will come from Antarctica (almost 90%), local sea level rise on the northern hemisphere will be more like 100 m, while large parts of the southern hemisphere will see much less than 75 m.

We need to realize that the coastal zone is borrowed from the world's oceans and they are about to take it back.

Meanwhile, the immediate challenge we have is the increasing "nuisance flooding," as some call it, which are floods that are on the order of half a meter above the local high tide and in many locations are enough to cause problems but not pose severe threats to human life. Living in Hampton Roads, Virginia, I hear about that almost every day, and much of the science of the day is focused on quantifying and predicting the trajectories of this "nuisance flooding."[8]

Many coastal cities experience more frequent inundation because even the very slow rate of current sea level rise puts them closer to the tidal range. As a consequence, the combination of high tides with minor meteorological surges leads to increasing inundation of the built environment. The tides gain more influence of peoples' daily life, and the economic impacts are growing. They try to adapt by mitigating the impacts of the rising sea levels on the rapidly growing coastal settlements. However, the more we learn to cope with this slow sea level rise and continue to extend coastal infrastructure and settlements, the less we are prepared for the rapid sea level rise we are committed to.

In fact, protecting the coast through massive engineering of dikes and levies, as is standard, for example, for The Netherlands and is planned for places like New York City, attracting more population and more infrastructure into areas that one day in the not-too-distant future will be inundated and permanently under water is not the solution. The more we build in these areas, the more we leave for future generations to remove - or to accept that the ruins will be in the ocean, potentially polluting the waters. True adaptation to the large sea level rise we have committed to because of the wasteful use of energy and resources of modern society would entail a fundamental change in how we use and settle in the coastal zone.

We would have to accept the basic truth that the built environment that is less than 75 m above sea level has to be transient, built in a way that it can easily be moved to higher grounds when sea levels start to rise swiftly. The current use of the coastal zone is irresponsible, increasing disaster risk rapidly. It is putting an unacceptable load on the shoulders of our children and their children. It makes me deeply sad to see that we seem to sacrifice their future for our own short-term advantage. ∧♂

Endnotes:

1 Plag, H.-P., 2013. Uncontrolled Experiment or Planetary Accident? The Global High-Energy, Growth-Addicted Civilization is an "Extinction-Class Event." "On The Edge" column, *Apogeo Spatial*, 28(4), Fall 2013, 14-15.

2 White, J., 2014. Abrupt climate change: The view from the past, the present and the future. See https://agu.confex.com/agu/fm14/meetingapp.cgi#Paper/25728.

3 Abrupt Impacts of Climate Change: Anticipating Surprises. National Research Council, Washington, D.C., 2013. Committee on Understanding and Monitoring Abrupt Climate Change and Its Impacts; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies.

4 Oreskes, N. and Conway, E. M., 2014. *The Collapse of the Western Civilization: A View From the Future.* Columbia University Press.

5 Lenton, T. M., 2014. Game Theory: Tipping Climate Cooperation. *Nature Climate Change*, 4, 14-15, DOI: 10.1038/nclimate2078.

6 WMO Greenhouse Gas Bulletin, *WMO Bulletin 10*, 6 November 2014, available at http://www.wmo.int/pages/prog/arep/gaw/ghg/GHGbulletin.html.

7 See the information available at http://www.epa.gov/superfund/sites/.

8 Sweet, W. V., Park, J., 2014. From the Extreme to the Mean: Acceleration and Tipping Points of Coastal Inundation from Sea Level Rise. Earth Future, DOI: 10.1002/2014EF000272.

The GEOGLAM

Enhancing Agricultural Monitoring with EO-based Information

DR. CHRISTOPHER JUSTICE / PROFESSOR AND DEPARTMENT CHAIR
DR. INBAL BECKER-RESHEF / RESEARCH ASSISTANT PROFESSOR
KATIE MCGAUGHEY / FACULTY RESEARCH ASSISTANT
DR. MATTHEW HANSEN / PROFESSOR
DR. ALYSSA WHITCRAFT / RESEARCH ASSISTANT PROFESSOR
BRIAN BARKER / FACULTY RESEARCH ASSISTANT
MICHAEL HUMBER / FACULTY RESEARCH ASSISTANT / UNIVERSITY OF MARYLAND

DR. MICHEL DESHAYES / SCIENTIFIC AND TECHNICAL OFFICER
GEOGLAM INITIATIVE / GROUP ON EARTH OBSERVATIONS

WWW.EARTHOBSERVATIONS.ORG/GEOGLAM.PHP / CEOS.ORG / GEOGLAM-CROP-MONITOR.ORG / GLOBAL-AG.UMD.EDU
GENEVA, SWITZERLAND

▶ FIGURE 2.
The combined use of currently available, high quality observations from coarse, moderate and fine resolution satellite systems allow for multi-scale temporal and spatial sampling of global croplands. This image is a 24-km x 20-km zoom centered on 95 35 24W, 44 19 38N in southwest Minnesota during August, which is the peak of the growing season. The light green color is soybean and the dark green color is corn. On the left column is a 30-m Landsat image and on the right column is a 5-m RapidEye image. The lower rows are zoomed in images of the top row, with the zoom footprint shown over the Landsat image.

The Group on Earth Observations, GEO, (a partnership of governments and international organizations) developed the Global Agricultural Monitoring (GEOGLAM) initiative in response to the growing calls for improved agricultural information. The goal of GEOGLAM is to strengthen the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales through the use of current Earth Observations (EO), which include satellite and ground-based observations.

Recent developments in both satellite and information technology provide a significant opportunity to enhance current operational agricultural monitoring systems. This initiative is designed to build on existing agricultural monitoring programs and strengthen them through international networking, operationally focused research and development and data/method sharing.

A number of activities (two of which are described here) have been developed under the GEOGLAM initiative, within the GEOGLAM's framework of three core thematic components and three cross-cutting components. The three core components are the monitoring of global crop production, building national capacity around the world for crop monitoring, and the development of early warning systems for countries at risk.

The three cross-cutting activities include:

i. the coordination of satellite data for monitoring, executed in close collaboration with the Committee on Earth Observation Satellites (CEOS);

ii. operational research and development of best practices and methodologies across diverse agricultural landscapes (carried out through the Joint Experiment on Crop Assessment and Monitoring (JECAM) and the Stimulating Innovation for the Global Monitoring of Agriculture (SIGMA) Initiative); and

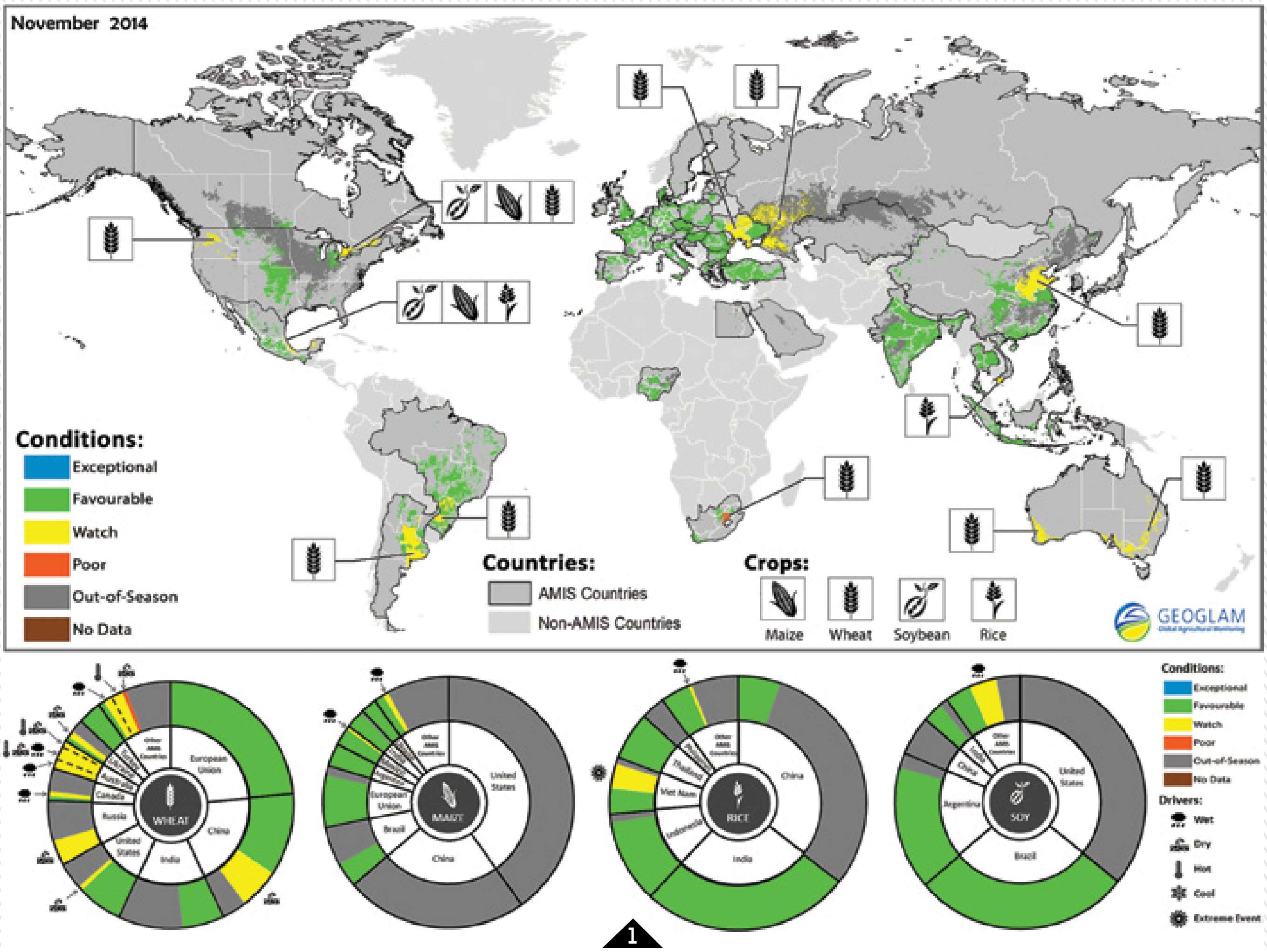
iii. the dissemination of data and information about regional-to-global scale croplands and crop condition.

Initiative

30-m Landsat Images

5-m RapidEye Images

> The three core components are the monitoring of global crop production, building national capacity around the world for crop monitoring, and the development of early warning systems for countries at risk.



▲ FIGURE 1. The output of the GEOGLAM Crop Monitor to the AMIS Market Monitor is a combination of one synthesis map, highlighting the crops that are other than favorable, and four pie charts representing a country's share of total AMIS production in a 5-year average per crop. Source: http://glam.umd.edu/content/geoglam-crop-monitor

THE GEOGLAM CROP MONITOR: *OPERATIONAL REPORTING ON GLOBAL CROP CONDITIONS*

GEOGLAM and AMIS (Agricultural Market Information System) were endorsed by the G20 Agricultural Minister's Declaration (Cannes, November, 2011) as part of their Action Plan on Food Price Volatility and Agriculture. GEOGLAM was tasked to "coordinate satellite monitoring observation systems in different regions of the world in order to enhance crop production projections and weather forecasting data." In response, GEOGLAM developed the Crop Monitor system, which provides monthly reporting using Earth observations (EO), global crop condition assessments and reports, in support of the AMIS market monitoring activities. The first report from the Crop Monitor appeared in the September 2013 issue of the AMIS Market Monitor and enhancements are being made based on feedback from AMIS.

The objective of the GEOGLAM Crop Monitor is to provide an international and transparent multi-source, consensus assessment of crop growing conditions, crop status, and agro-climatic conditions likely to impact global production. This activity covers the four primary crop types – wheat, maize, rice, and soy – within the main agricultural producing regions of the AMIS countries. These assessments are produced operationally and published in the AMIS Market Monitor Bulletin. The Crop Monitor reports provide cartographic and written summaries of crop conditions as of the 28th of each month, according to crop type. See ***Figure 1***.

The Crop Monitor initiative brings together international experts from national, regional, and global monitoring systems, agriculture organizations, universities, and members of industry who share and discuss information from a variety of independent yet complementary sources, enabling them to reach a consensus on global crop conditions. Information types used by GEOGLAM in its production of the Crop Monitor include EO data and products, agro-meteorological data, crop model output, and field reports. Representatives from over 30 different agencies and organizations are currently participating in the assessments and that number is continuing to grow. The assessments are coordinated and managed by the Center for Global Agricultural Monitoring Research in the Department of Geographical Sciences at the University of Maryland (UMD) with regional coordination of the rice assessment by the Asia-RiCE (Rice Crop Estimation and Monitoring) team along with the AFSIS (ASEAN+3 Food Security Information System project) using the Japanese Space Agency's (JAXA) outlook system (JASMIN).

In order to facilitate the monthly crop assessments, an online Crop Assessment Portal was developed by UMD. The interface includes a publicly available visualization interface that enables comparison between relevant datasets (national, regional, and global) according to crop type and accounting for crop calendars. The main data layers used in the interface include global Normalized Difference Vegetation Index (NDVI) anomalies (UMD/NASA), Global Rainfall Anomalies (European Commission Joint Research Centre (EC JRC)) and NOAA Earth System Research Laboratory (ESRL), Global Temperature Anomalies (EC JRC), crop type maps of major growing regions (International Food Policy Research Institute (IFPRI)/International Institute for Applied Systems Analysis (IIASA) Spatial Production Allocation Model (SPAM) 2005 [beta version; released 2013]), United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) 2013 Cropland Data Layer, 2013 Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory Map, Global Agriculture Monitoring (GLAM)/UMD, Advancing Methods for Global Crop Area Estimation (GLAD)/UMD (See ***Figure 2***), Australian Land Use and Management Classification (Version 7), Mexico's Agricultural and Fisheries Information Service (SIAP), Agricultural Research Council of South Africa (ARC), the EU JRC Monitoring Agricultural Resources (MARS), and crop calendars (based on GEOGLAM partner crop calendars and the Food and Agriculture Organization of the United Nations (FAO) and United States Department of Agriculture (USDA) crop calendars).

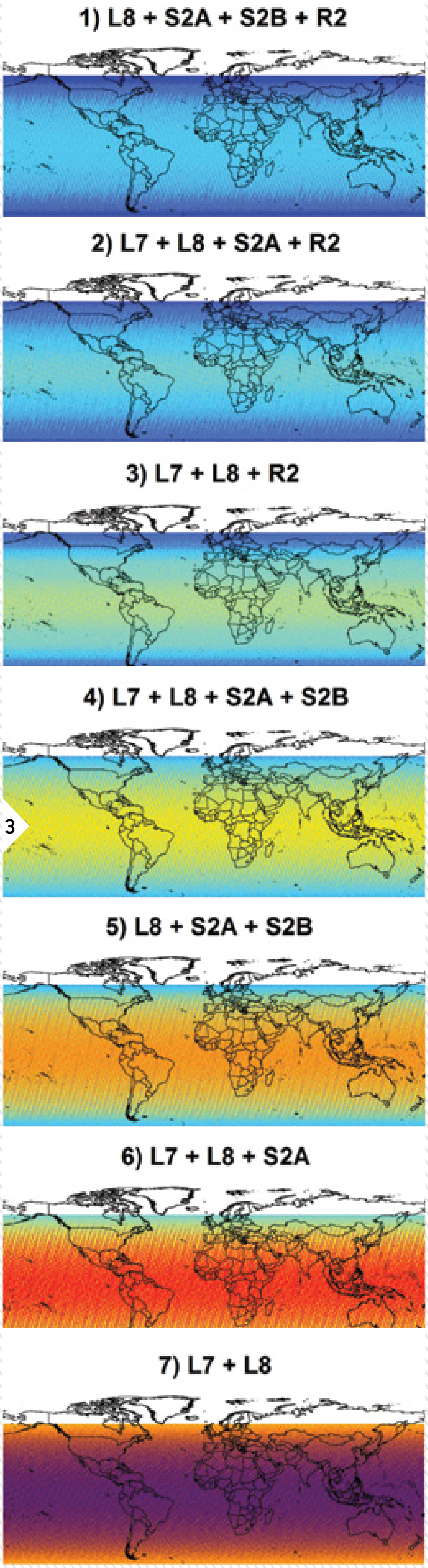
The crop type masks and crop calendars serve as base layers that provide vital, spatially explicit information on the general growth stage for major growing regions for each of the AMIS crops. This information enables crop-specific interpretation of the remote sensing-based crop condition indicators and provides context for the crop analysts' assessments. As part of the Crop Monitor activity, new datasets that reflect the 'best available' crop type masks and crop calendars are being developed through the compilation of high quality national products developed by the GEOGLAM partners. These will also capture information in cases where multiple crops are grown in the same year (e.g. 1st and 2nd corn crops). These crop type masks and crop calendar products are planned for release in 2015 alongside other next-generation global products being developed in the context of GEOGLAM Crop Monitor.

The GEOGLAM Crop Monitor has generated much international interest, including being highlighted in a feature article in the FAO Food Outlook in April 2014 and receiving the Esri Special Achievement in GIS Award at the Esri User Conference in July 2014.

EARTH OBSERVATIONS FOR AGRICULTURAL MONITORING: *SPACE-BASED DATA ACQUISITIONS AND ACCESS THROUGH CEOS*

Agriculture is a highly dynamic process both in space and in time, and as such, effective monitoring requires data that are both frequent as well as sufficiently fine spatial resolution in order to detect the significant changes in crop condition that can happen very quickly and at fine levels. Despite the history of space-based remote sensing of the Earth's surface having its roots in agricultural monitoring, the adoption of satellite data for the operational monitoring of croplands has been heterogeneous throughout the world. This is partly because data acquisitions have been inconsistent geographically and temporally, with some areas and time periods more frequently and regularly imaged than others, leaving crucial information gaps. Additionally, space-based data can be very costly, and in some cases may be inaccessible to certain users, due to licensing issues or computational or internet speed limitations.

A crucial step in the improvement of global agricultural monitoring is the coordination of space-based Earth observations (EO), which will ensure the acquisition of and access to EO over global croplands. This activity is being carried out in the context of GEOGLAM through close collaboration with the Committee on Earth Observation Satellites (CEOS), a consortium of space agencies tasked with the harmonization of satellite imaging assets for societal benefit.



In 2012, the CEOS Ad Hoc Working Group of GEOGLAM – comprised of GEOGLAM scientists and space agency representatives – was established to:

a. define the data requirements for agricultural monitoring at multiple levels and scales;

b. evaluate how the workload of satellite data acquisitions for agricultural monitoring could be shared between multiple missions and multiple space agencies; and

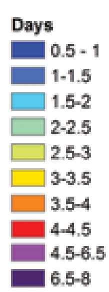
c. confront challenges in access to satellite data.

As of early 2015, two data acquisition strategies have been developed by the CEOS Ad Hoc Working Group, which identify where, when, and how frequently different classes of remotely sensed data should be acquired to provide timely information on a variety of agricultural variables, including crop condition, type, area, calendar, and yield, among others. Both of these strategies have been endorsed by the CEOS Plenary (November 2013 and October 2014), and are resulting in the acquisitions of data in the context of GEOGLAM. These data are being used in operational research as well as in the development of baseline datasets by the JECAM (Joint Experiment of Crop Assessment and Monitoring), SIGMA, and Asia-RiCE projects, as well as by agricultural monitoring experts around the world.

Additionally, analyses have been conducted to see whether and where currently available missions – individually or together, in an imaging constellation – can meet requirements (see ***Figure 3***). Initial results show that some areas and time periods are insufficiently covered, providing further evidence that operational agricultural monitoring requires a multi-mission constellation approach.

Similarly, to meet the challenge presented by slow internet connections and low-powered computer processors coupled with very high data volumes, the Ad Hoc Working Group is in the process of prototyping a variety of data dissemination systems. In addition to facilitating access to satellite EO from a variety of space agencies and missions, data services systems are being evaluated for utility in remote, cloud-based processing so as to decrease the need for local download of data and to maximize the timeliness of data analyses and information generation.

GEOGLAM continues to make the case for space-based monitoring of agriculture, identifying the utility of this method through its Crop Monitor and the value it adds to policymakers everywhere.



◀ FIGURE 3
Here are the combined revisit capabilities of a few proposed constellations, comprised of missions which fall under the purview of CEOS. These individual missions are independently capable of revisits between 5-16 days. However, together, they are capable of much more frequent revisits, which is very valuable for agricultural monitoring. The missions referenced here are: L8 = NASA/USGS Landsat 7 ETM+; L7 = NASA/USGS Landsat 8 OLI/TIRS; R2 = Indian Space Research Organization (ISRO) ResourceSat-2 AWiFS; S2A = European Space Agency Sentinel-2a MSI; S2B = ESA Sentinel-2b MSI. (Source: Whitcraft, Becker-Reshef, Killough, and Justice et al., in press).

EARTHQUAKES

Identifying Collapsed Buildings

DR. VALERIO BAIOCCHI / DOCTOR OF PHILOSOPHY / GEODESY AND SURVEY SCIENCES AND PROFESSOR AT SAPIENZA / UNIVERSITY OF ROMA
DR. WALDEMAR KREBS / ECOGNITION ACCOUNT MANAGER AT TRIMBLE / MUNICH, GERMANY
WWW.ECOGNITION.COM

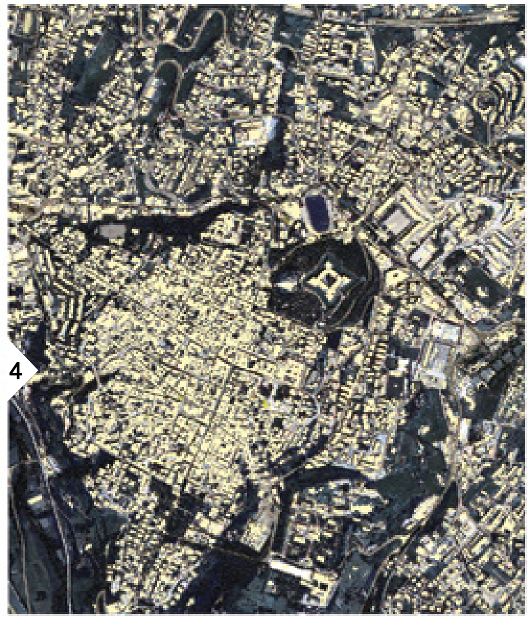
THE WORK TO RECOVER AND REBUILD FOLLOWING an earthquake requires reliable information on the condition of structures in the affected areas. In developed areas, efforts to gather this information can be time-consuming and prone to errors, often resulting in incomplete or inaccurate information.

A new, software-based methodology to recognize collapsed buildings utilizes classification of satellite images combined with height variation information. The methodology was demonstrated in a full-scale, real-life scenario by a team led by Prof. Valerio Baiocchi of the University of Rome. According to Baiocchi, the team's work was intended to demonstrate the methodology on actual data available for the entire city of L'Aquila in the Abruzzo region of central Italy, in an actual and complete simulation of quick damage assessment in a real emergency. The team utilized satellite imagery of the city of L'Aquila, which experienced a magnitude 6.3 earthquake on April 6, 2009. The work demonstrated a robust classification of collapsed structures that was completed quickly and with good confidence.

◀ **FIGURE 1.**
Classification of vegetated areas through NDVI.

▶ **FIGURE 2.**
Classification results (object-oriented approach) on some subsets (red for buildings, gray for streets, green for vegetated areas, and black for shadows).


2



◀ FIGURE 3.
The vector file of buildings obtained after the image classification.

◀ FIGURE 4.
The same file overlapping to a satellite image.

COMPARING PIXEL-BASED AND OBJECT-ORIENTED CLASSIFICATIONS

The first part of the process entails classification of remotely-sensed objects. Data were obtained from monoscopic, very high-resolution imagery taken by the WorldView-2 satellite in August 2010. Height information came from a digital surface model developed from imagery acquired by the EROS-B satellite in April 2009, just a few days after the main earthquake. The pansharpened images were orthorectified using 22 ground control points established by GNSS and a digital elevation model from existing Abruzzo regional cartography (CartaTecnicaRegionale, or CTR). The study region was then broken into nine 2.3 km x 2.3 km subsets.

Classification was performed using two approaches: traditional pixel-based analyses and an object-based approach using Trimble eCognition Developer 8.0 image analysis software. The approaches used identical class hierarchies comprised of buildings, green areas, roads and shadows.

The data were first processed using the object-based solution, which is based on the idea that the important information necessary to interpret an image is not represented only in a single pixel, but in meaningful image objects and their mutual relationships. Rather than classifying single pixels, the object approach uses a bottom-up, region-growing technique to create groups of pixels (known as segments) that possess a certain level of homogeneity in scale, shape and color.

Initial processing used NDVI (Normalized Difference Vegetation Index) to assign objects to the vegetation class. A similar process was used to reduce risk that shadowed parts of buildings might be eliminated from processing. See ***Figure 1***.

Other hierarchal classes were handled using nearest-neighbor classification techniques. The classification required 30 to 60 minutes per subset, which can be scaled by parallel processing. The produced vector files of building polygons were overlaid on the rectified satellite images.

A second round of classification utilized pixel-based approaches in NDVI and nearest-neighbor

As it is well known, during the Haiti event it was not possible to detect quickly all the collapsed buildings from aerial and satellite images. Local authorities needed to ask for the help of volunteers for a manual identification of collapsed buildings. For this reason, our automated methodology was utilized exactly as in a real emergency situation.

processing. Both sets of results were compared to the CTR cartography provided by the Abruzzo regional administration. The comparison was done using the visible surface area of building roofs. See ***Figure 2***.

The eCognition process recognized 93 percent of the known building areas, while the pixel-based process could recognize 64 percent. This result demonstrated that the object-oriented technique provided information that is more accurate and robust than the pixel-based approach.

When the vector file produced by eCognition was overlaid onto the satellite images, it was possible to quickly identify areas where buildings had collapsed in the quake. Because of this result, only the object-based classifications were used in the subsequent steps of the process.

Next, digital surface models were developed using pre- and post-quake imagery from EROS-B. Comparing these models exposed height differences of buildings before and after the earthquake, and a color-coded model was developed to highlight significant differences. These data could then be combined with the existing cartography.

Using building polygons identified by eCognition, locations where the height differences might be the result of a building collapse (as opposed to changes in height in areas where no buildings existed) could be identified. The data enabled users to readily identify all buildings in the study area that had collapsed as a result of the earthquake. See ***Figures 3 and 4***.

CONCLUSIONS

The project demonstrated that the use of a high-resolution, object-oriented classification image combined with digital surface models can produce accurate, robust information on changes in buildings in post-seismic scenarios. The object-oriented approach produced results superior to pixel-based methods. The process may be further improved through optimization and improved specialization of the classification rule sets.

To be effective, organizations must maintain accurate pre-event data. Similarly, the methods require the availability of high-performance hardware and software to quickly execute classification and DSM extraction in immediate post-quake events. The methodology could allow a first damage assessment to be performed quickly in a completely automated way through the use of remotely sensed data, thereby offering ready support for the emergency response activities carried out by humanitarian agencies with little or no error.

Baiocchi summarized the importance of the team's work: "Quick assessment of damage, particularly in earthquakes like the one that occurred in Haiti in 2010, can help to save potential victims buried under debris. Rescue operations need to know the location of collapsed buildings within hours to aid in rescue of trapped persons. As it is well known, during the Haiti event it was not possible to detect quickly all the collapsed buildings from aerial and satellite images. Local authorities needed to ask for the help of volunteers all over the world for a manual identification of collapsed buildings on the images. For this reason, our automated methodology (obviously faster than manual recognition) was utilized exactly as in a real emergency situation. By assessing the performance using real data, it has been confirmed that it can be used for future emergency situation." ∧♂

Acknowledgements:
This paper is taken from work produced by Valerio Baiocchi, "Sapienza" University of Rome; Raffaella Brigante, University of Perugia; Donatella Dominici, University of L'Aquila; Maria Vittoria Milone and Martina Mormile, "Sapienza" University of Rome; and Fabio Radicioni, University of Perugia. The full research is published in *European Journal of Remote Sensing* – 2014, 47: 413-435. The paper may be freely viewed at http://server-geolab.agr.unifi.it/public/completed/2014_EuJRS_47_413_435_Baiocchi.pdf

Commercializin

Financial and Societal Benefits

‹‹‹ ALAN HALL
CEO / TEMPUS GLOBAL DATA

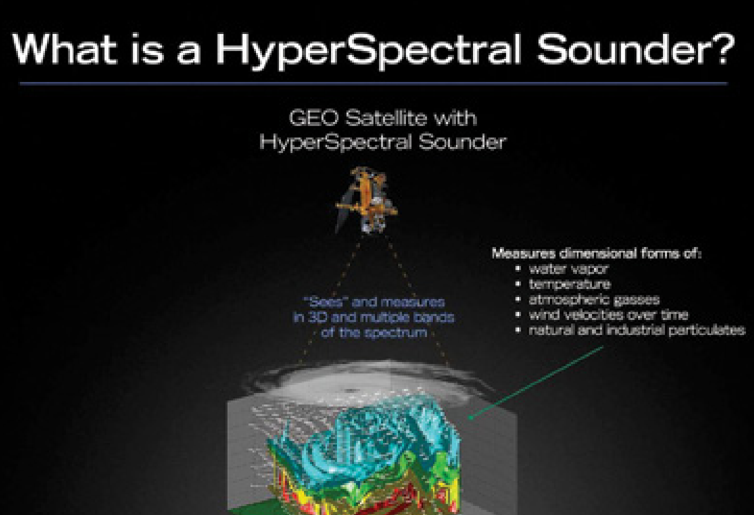
MYRNA JAMES YOO ›››
PUBLISHER / *APOGEO SPATIAL*

The commercialization of weather sensors and data will be the next in an important trend of the United States Federal Government using commercial companies for innovation and solutions. We have seen this in recent years, in transportation to the International Space Station, beginning 15 years ago in the Earth imagery market, and orginally, years ago, in satellite communications. Benefits generally include lower cost to the government and taxpayers, less risk of budget cuts, and on-time delivery. Specifically for the weather industry, benefits of better severe weather forecasting include the ability to save significant amounts of money for businesses whose operations are at risk due to weather, and to save lives.

In late January, forecasters predicted a "potentially historic blizzard" in New York, which caused the closure of transportation systems and other costly preparations. When the blizzard was not as severe, Director Louis Uccellini of NOAA's National Weather Service found himself apologizing for not communicating better that there is always uncertainty in forecasts. The public has an expectation of accuracy, and does not appreciate the complexities of forecasting.

Several new satellite weather companies intend to bring new technologies and datasets for forecast modeling. They claim that this will increase accuracy and mitigate damage and loss from severe weather. Also, due to U.S. government budget cuts and cancellations, a gap in weather data may occur about 2018. Commercial

1



Editor's Note:
The Fall 2014 issue included an interview with another commercial weather satellite company CEO, Anne Hale Miglarese, of PlanetiQ.

◀ **FIGURE 1.**
Hyperspectral sounding of the atmosphere gives a 3D, cat-scan-like view of the atmosphere refreshed within minutes.

g Weather Data

weather companies intend to fill that gap. Tempus Global Data is one of those companies.

MYRNA JAMES YOO *Tempus is planning to use hyperspectral atmospheric sounding sensors. What does that mean, and how do they work?*

ALAN HALL Hyperspectral atmospheric sounders use a highly sophisticated instrument that sees more than 1,800 visible and infrared bands in the atmosphere. Dubbed STORM, the sensors fly at geostationary (GEO) orbit providing data slices that meet requirements from 10 seconds to a global high-res scan of 30 minutes.

YOO *What are strengths and weaknesses of these sensors?*

HALL There are three distinct advantages. First: persistence. Flying in GEO orbit, we can persistently monitor the atmosphere, enabling timely detection of small variances or fast moving severe weather events. Only GEO orbiters can provide this "always on" approach.

Secondly, there is a dramatic improvement in clarity because we produce 3D soundings of the atmosphere encompassing the infrared and the visible spectrums of light. By continuously sensing the uncondensed water vapor in the atmosphere, the STORM sensor sees weather forming before it is recognized by today's technology. Essentially, we'll see weather before it becomes weather.

Finally, our data will provide meteorologists with a higher degree of accuracy to assist with their forecasts. Our big datasets provide unprecedented accuracy with algorithms that combine in-depth views of uncondensed water vapor, temperature and velocity. The atmospheric sounding will produce data that can predict landfall of tornadoes and hurricanes and other severe events with greater precision than ever before. By providing this data, atmospheric science researchers will be enabled to make greater advancements to benefit society.

A weakness is that the sounders cannot "see" through clouds. We may partner with a company providing radio occultation data to accomplish this.

YOO *Other private companies are planning to address the need for weather data using Global Positioning System/Radio Occultation (GPS/RO), such as PlanetiQ and GeoOptics. How is that technology different?*

HALL The two technologies are different but compatible. GPS/RO looks horizontally at the upper atmosphere; we provide a vertical look. These two combined give a more thorough dataset than anything else that is available.

Across the board, what is needed is better

"Essentially, we'll see weather before it becomes weather."

and more timely data, and better ways to visualize and leverage data insights to deliver more advanced weather risk insight. Radio occultation has proven to be an important part of reaching new goals in weather observation. We believe that hyperspectral atmospheric sounding, from geostationary orbit, represents a significant leap forward in observing and forecasting severe convective events. Our data, combined with other advanced measuring approaches, helps the entire forecasting community achieve a clearer and more accurate look at severe events, and will help provide a new level of confidence in longer-term forecasting.

YOO *What is the brief history of the STORM sensor and how did it end up as a private-sector enterprise?*

HALL The technology, developed by Utah State University and the Space Dynamics Lab, revolves around a complex interferometer that sees hyperspectral bands of the atmosphere in ways no other technology does. The STORM sensors were scheduled to fly aboard GOES-R satellites but during budget cuts in Washington, the program was suspended. Subsequently, USU commercialized the technology and later licensed it to Tempus Global Data, a private company headquartered in Ogden, Utah. There isn't another technology like this anywhere in the world.

YOO *Ball Aerospace is your prime contractor to build the hyperspectral sounders. What can you share about that?*

HALL Ball is one of the world's leading aerospace companies and we are so pleased they have agreed to work with us. Their reputation for quality construction, and their sophisticated approach to managing the process of development through deployment made them the perfect partner for us. Our technology was developed by Utah State University and the Advanced Weather Systems Foundation on that campus, at Ball. There is a long history of trust and cooperation and we chose to build on that lengthy relationship with Ball supervising and overseeing the build and further development of USU's GIFTS sensor (Geosynchronous Imaging Fourier Transform Spectrometer, the NASA prototype instrument). Ball has not only set in motion the myriad details of building our sensors but they are also lending their impressive business development credentials to us as we jointly seek customers for our advanced datasets.

YOO *You have a new partnership with Science and Technology Company (STC) and will be working with them and NOAA on data modeling. How will this work? Will it be possible to provide information to end users without going through NOAA for modeling?*

HALL STC brings an expertise to the table that helps any customer get information directly from Tempus while providing help for government modeling experts. We understand that governments have the obligation to get people out of the way of storms. Key to our success will be working with NOAA, FEMA, the National Weather Service and other agencies to develop datasets that meet their specific requirements. We cooperate with everyone to help to make everyone successful in their current roles as they make life and death decisions for the public good.

YOO *What types of data will you provide?*

HALL Tempus envisions delivering a wide variety of weather intelligence ranging from level 1b, which is calibrated and geo-located atmospheric radiance raw data, to government customers, all the way to completely processed forecast data, to governments of the world and to commercial entities around the globe that have less advanced weather processing systems and expertise to work with raw data.

Tempus will have the ability to process data for those who prefer to see data visualized in a form that provides them actionable intelligence for their particular needs. We'll offer the sophisticated user calibrated raw data from which they can do their own processing and algorithm development. We'll couple those datasets with other advanced technologies like GPS/RO and visible imaging from the government to create value added datasets for the world. In short, we see hundreds of value added products being offered.

YOO *How will you deliver the data to your customers?*

HALL The most common data platform today accepted by users is XML. We will provide the data in this form for every user to ingest and process. Our partnership with Utah State University and their vast experience with end users gives us the expertise to solve the big data issues. The hyperspectral atmospheric sounding technology was developed and proven decades ago, and from the very beginning USU's focus has been taking big datasets and delivering it to customers. It's an easy jump from that legacy expertise for Tempus to bring new complex data from satellites through transponders and fiber optics to a data center at USU. The data then gets calibrated and geo-located and put in a form that sophisticated customers can use.

YOO *What is your deployment timeline?*

HALL Our plans call for a launch of the first sensor early in 2018. We will announce, very shortly, a partnership with a major telecommunications satellite company. We have been in negotiations with this part of our business for many months and our efforts will culminate with a strategic partnership to host our payload aboard their geostationary flier. We'll work with them on the entire space-to-ground information continuum. Following the first launch, we will have a schedule set for deployment of a total of 6 sensors flying at geostationary orbit.

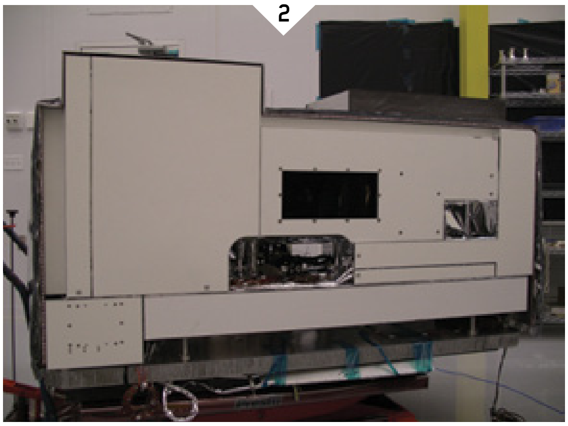
YOO *To what extent will you be able to fill the pending "weather data gap"?*

HALL Our technology will help fill the impending weather gap in several critical ways: More timely data (earlier advanced warnings), fewer false alarms, and more precise landfall prediction. This is the result of our granular datasets created by 1800 visible and infrared bands being measured frequently and persistently in a constellation of 6 sensors covering the globe. Additionally, Tempus will cooperate with government agencies so that all consumers will be able to take advantage of this newer, life saving technology sooner, and at a cost two-thirds less.

YOO *What is your business model?*

HALL Naturally, an undertaking of this magnitude takes time and a degree of evolution to find the right approach. We know this much: we have a proven technology, many years in the making. It has a $400 million investment from NOAA, NASA and the U.S. Navy, who have acknowledged that is has the power to change, by orders of magnitude, the way we can see "weather" before it is weather. First we are a technology company. We build and deploy weather sensors. Second, we are a big data company. Much of our planning revolves around big datasets and how to integrate them into a wide range of data options. Third, we are a weather intelligence company. We fully anticipate working with partners, like STC and others, who will prepare data for ingest by forecasters and scientists.

2



◀ FIGURE 2. GIFTS instrument prototype built and tested by Ball Aerospace, for NASA, as part of the New Millennium program.

YOO *Approximately how much will you charge for data and various information products?*

HALL We want to be fully open and transparent about our business and our technology because it is so transformational. We are working with partners, resellers, data companies, and we are developing a wide range of products and pricing options. We know what the governments of the world have spent to collect current weather data. We will be able to significantly reduce costs while providing advanced data over what it costs the taxpayer today.

YOO *Who will be your target customers?*

HALL We have spent the last 12 months carefully examining the weather data industry and believe that all forecasters will benefit from our clear, accurate, persistent looks at the atmosphere with our advanced sounding technology. Certainly, national meteorological agencies from governments around the globe will look to this data to enhance their forecast accuracy. The media, and those who give us all our daily forecasting, will appreciate our capability to provide enhanced accuracy. But at the top of our pyramid are commercial interests, particularly insurance companies and anyone who deals with weather risk management in commercial sectors like aviation, energy, agriculture, transportation, shipping and a variety of other sectors that see constant complications from weather events and that, increasingly, have their own meteorologists on board to help mitigate weather-related losses.

YOO *When will you actually begin to deliver data to customers?*

HALL We will likely have our first sensor on orbit in 3 years. Then, after a period of time to calibrate and bring weather observation data online, we would have this powerful and transformational approach to forecasting in place, transmitting game-changing data. Our current plans have us delivering data by mid-year 2018. Currently we are on schedule to meet our commitments.

YOO *Do you plan to have a Foundation? If so, what will be the primary purpose?*

HALL Let me just say this. I have been a venture capitalist and a strategic investor for many, many years. My wife and I decided long ago that as we create wealth, it is never our money. Rather we are stewards of that wealth and the only thing we can do in this life is to bless the lives of others. For some 20 years we have operated a family fund that supports some 30 charities.

But let me add this: my interest in founding and operating Tempus Global Data was the result of three important things. First, the technology is disruptive and badly needed. We believe that forecasting will get better and better by quantum leaps forward. Second, it is an extraordinary business opportunity that will return tremendous value to our shareholders.

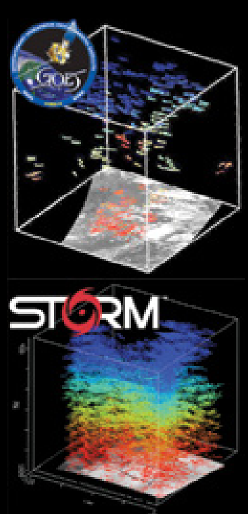
Third, this is about saving lives. It will be our intent to help all nations of the world achieve greater safety for their citizens with improved forecast accuracy. We are creating the Tempus Global Data Foundation with a portion of profits being used to help victims of violent storms – charities on the ground that help displaced families and groups that help re-build homes, communities and infrastructure.

More than anything else, our efforts are about saving lives. We can't stop weather, we can't prevent the damage it causes, but we can get people out of the way of severe weather events. There are many countries, like the Philippines, that have no advanced warning systems. We weep when we see 7,000 lives lost in Tocloban in 2013. We believe something must be done, and we are doing it. ∧♂

▼ FIGURE 3. Details of Tempus' STORM instrument, with graphic of current derived wind vector sounding products from GOES.

3

THE STORM™ SOUNDER



FOCAL PLANES

Two 128 x 128 Infrared focal plane detector arrays (8.8 – 14.6 μm and 4.4 – 6.1 μm)

4 km per pixel = 512 x 512 km nadir field of view

512 x 512 visible focal plane detector arrays with 1 km footprint size per pixel

FIELD OF VIEW

Pointing mirror provides Earth disk viewing capability

Ten second full spectral resolution integration time per field of view

DELIVERY

~ 80,000 atmospheric soundings every minute

~ 1 Terabyte a day of compressed data from each STORM sensor

Size: 1m x 1m x 2m; Mass: 300-350 kg; Power: 500-600 W

Our weekly email news service Location SmartBrief is now

LBxLITE

Business Game Changer

A weekly snapshot of location-based services with news from leading sources around the web:

* It's still free
* It's still delivered on Wednesdays
* It's still the smart way to stay up to date on location information, technology and economics.

Don't miss an issue. Sign up today.

http://promo.lbxjournal.com/LBxLITE.html

LBx JOURNAL