EARTH
OBSERVATORY
OF SINGAPORE

ANNUAL REPORT
2014

Contents

Professor Kerry Sieh
Director

The Earth Observatory came into even sharper focus throughout 2014, its sixth full year. We are a bit like a youngster growing through our late teens, realising more and more who we are and what we are becoming.

Our efforts to create the Asian School of the Environment leapt forward this year with the matriculation of our first cohort of undergraduate Environmental Earth System Science majors. These enthusiastic and hard-working students are a manifestation of our dedication to preparing future generations to understand and tackle humanity's environmental, ecological and geohazard challenges.

The occurrence of the destructive Nepal earthquake in April 2015, just after the end of the fiscal year, drew attention to the importance of being a research institution that investigates geohazards before they strike. Professor Judith Hubbard's group had been focusing attention on the earthquake geology of the Himalaya since her arrival at the Observatory in 2012, and Isaac Kerlow had nearly finished an educational film about that research and the Himalayan earthquake threat. The earthquake struck just as Paramesh Banerjee and his Technical Office team were on the Kathmandu airport runway, preparing to fly an airborne LiDAR mission that would enable Professor Paul Tapponnier's group to expand their investigation of the great fault that causes most Himalayan earthquakes and threatens a large fraction of Earth's human population. After the event, Professors Sylvain Barbot, Emma Hill and Shengji Wei joined in to help understand the source and nature of the earthquake and how it fits into the sequence of past and future great Himalayan earthquakes.

I've highlighted just two aspects of the Earth Observatory's important work through FY2014. Without further ado, I invite you to explore more of our progress and accomplishments in this year's Annual Report.

Professor Kerry Sieh
Director

Research

Our researchers were busy this past year! Southeast Asia is one of the most complex and active regions on Earth, and a natural disaster could affect hundreds of millions of people. Yet there are still so many questions about geohazards and how they may happen.

Our scientists are working across several countries to fill the gap in knowledge in tectonics, volcanoes, and climate. Their work takes them from mountains in Nepal to coastlines in Vietnam. Some project highlights include monitoring tectonic activity in Sumatra, studying volcanoes in Philippines, and collecting haze samples in Singapore.

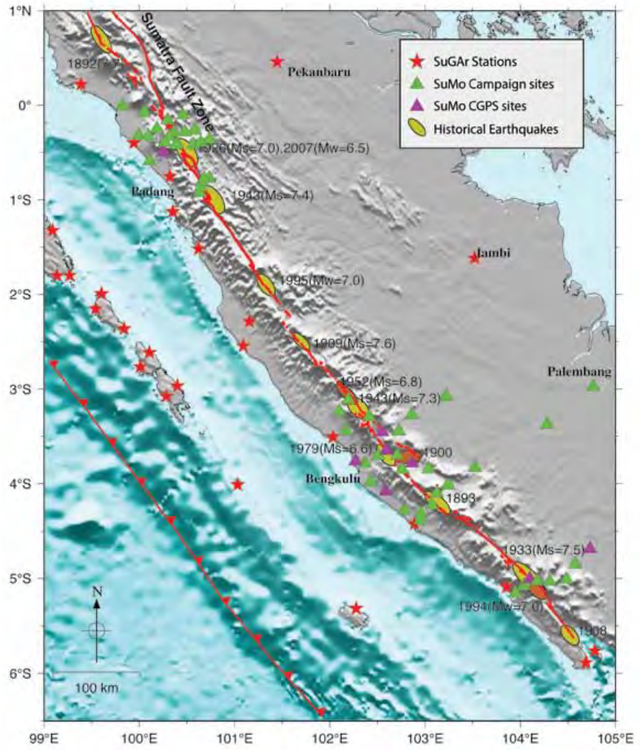
We've included a small sampling of the research happening at the Observatory, but there's much more to explore!

Tectonics

Home to 600 million people, Southeast Asia is one of the most active and complex tectonic regions on Earth. EOS geoscientists are working their way toward a clearer understanding of tectonic movement across Southeast Asia, with the aim to better prepare its residents for the earthquake and tsunami risk they face. In 2014, much of the tectonic group's research focused on Indonesia, which sits along the Pacific Ring of Fire, a hotbed of tectonic activity, but research also spanned the region including Nepal and Taiwan. Here are a few of the projects that our researchers focused on this past year.

Sumatran Fault Monitoring

Through the Sumatran Fault Monitoring Campaign GPS Project, Emma Hill and her collaborators are installing and monitoring a dense GPS network to track movement along the Sumatran Fault. This fault spans the ~1700-km length of Sumatra and passes close to many population centres, but so far is relatively poorly understood. This study may help to understand the potential size of earthquakes that can be generated by different segments of the fault.



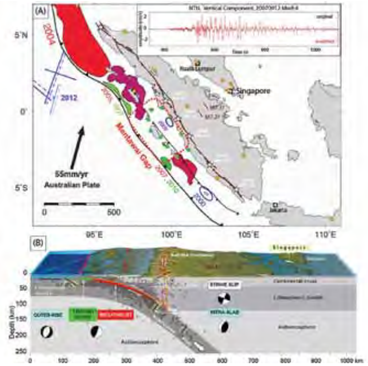
Monitoring activities in Sumatra.

Mentawai Gap

Many major earthquakes, including the 2004 Indian Ocean tsunami, have occurred along the Sunda megathrust, where the Indian Ocean crust is diving under the Sunda trench. A large section of the Sunda megathrust called the Mentawai Gap hasn't had an earthquake in 200 years. Scientists expect that the accumulated stress in this gap will soon cause a giant earthquake as destructive as the 2004 earthquake. Paul Tapponnier and Visiting Professor Satish Singh plan to set out on a deep-sea mapping expedition to assess tsunami risks along the Mentawai Gap.

Meanwhile, Wei Shengji and team built 11 seismic sites around the gap to investigate how seismic waves travel through the fault. The Sumatran GPS Array measures deformation of the Earth's crust in the region, and we can use this to measure how the fault slips, before, during and after earthquakes.

On the aft of R/V Falkor, crew, scientists, and the Sea and Land Technology team deploy seismic reflection gear, which helps with data acquisition.



Summary of the tectonic setting and earthquakes in Sumatra, in particular, the Mentawai seismic gap.

Aceh Cave

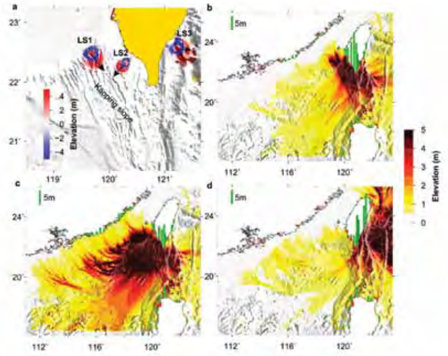
The 2004 tsunami was so devastating in part because the region hadn't experienced one in more than 500 years. Charles Rubin and his collaborators are investigating a treasure trove of sediments from a cave in Aceh, northern Sumatra. The cave will provide the team with an 8,000-year history of tsunamis and earthquakes. And by combining archaeology with geology, Kerry Sieh and his team are gaining insight into how trade and settlement changed after a tsunami struck northern Sumatra in the 1300s.

Nepal Earthquakes

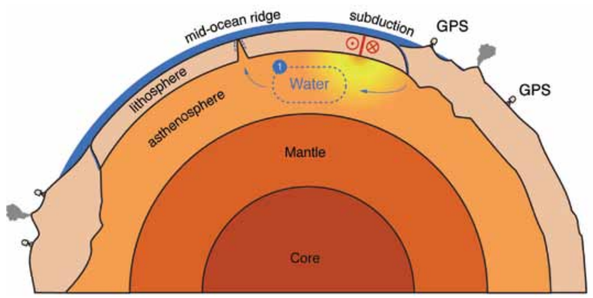
The April 2015 earthquake in Nepal killed more than 9,000 people and left hundreds of thousands of people homeless. An earthquake of 8.3 magnitude or greater could kill more than half a million people. Using a high-tech seismic wave producer called the Envirovibe Minibuggy, Judith Hubbard and her researchers study how waves travel through rocks underneath the surface. Their goal is to create more accurate 3D models of faults to better understand and forecast the sizes and recurrence intervals of Himalayan earthquakes.

Research Fellow Anna Foster marks the exact location of the path that the minibuggy will take.

The Envirovibe minibuggy sends vibrations into the rock layers beneath the ground, gathering data that allows them to better visualise subsurface faults. The Ratu River Expedition*, a documentary film produced by Isaac Kerlow, features the research of Hubbard and the tectonics group.*



Numerical models of the 18th century tsunami in southwestern Taiwan showed that an underwater landslide was most likely the cause.



Estimating trapped water will help scientists understand the role of water in plate movement.

South China Sea Tsunami

Southern China is one of the most densely populated and economically important regions in the world. It's also a prime location for coastal hazards. In the early 1780s, a disastrous tsunami hit the southwestern Taiwan coast, killing more than 40,000 people. Through numerical modeling, Adam Switzer and his team analysed plausible causes of the 18th century tsunami, concluding that the most likely explanation was an underwater landslide.

Earthquake and Tsunami Physics

Besides studying specific regions in Asia, research projects are investigating general tectonic processes. Sylvain Barbot's group is researching the role of water in the movement of Earth's tectonic plates. By studying the deformation of the mantle after the great Wharton Basin earthquake in 2012, the team is able to estimate how much water is trapped in the oceanic upper mantle, an indication of how much water can be recycled in subduction zones.

Besides studying earthquake physics, the Observatory is also researching tsunami dynamics. Huang Zhenhua and his PhD student built a model coastline and observed how cliff angles affect tsunami flow. The outcome of this research will aid early warning systems and help scientists predict how a tsunami will come ashore.

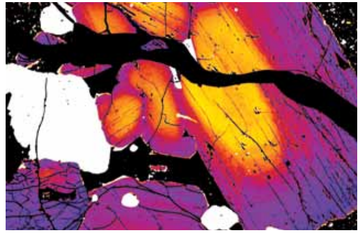
RESEARCH Tectonics

Volcano

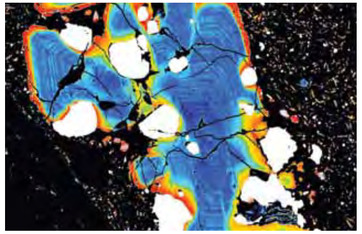
Southeast Asia has some of the most active volcanoes on Earth. Using a multidisciplinary approach, the volcano group advances knowledge about the processes behind volcanic eruptions. Working in close collaboration with the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the Indonesian Center for Volcanology and Geologic Hazard Mitigation (CVGHM), and the Rabaul Volcano Observatory (RVO), our volcanologists' research is producing tools that will better estimate hazards. These highlighted projects show how the group is mitigating impact of volcanoes on residents living in close proximity and the far-reaching effects of volcanic ash.

One of Fidel Costa's projects focuses on the EOS laboratory volcanoes: Mayon, in Philippines, and Gede, Indonesia. By closely studying the magma reservoirs and the conditions below these two active volcanoes, Costa and his team are learning what drives an eruption and improving volcano forecasts.

Benoit Taisne uses geophysical techniques such as seismicity and infrasound to understand the laboratory volcanoes and better anticipate their eruptions. He also works closely with various Singapore government agencies to improve the country's resilience to volcanic ash. In 2014, Kelud erupted in Indonesia, creating a huge blast that destroyed most of the monitoring equipment nearby. But with remote seismic and infrasound sensors thousands of kilometers away, Benoit Taisne and his collaborators could monitor the Kelud eruption from a safe distance. Remote instruments may be a key element in early warning systems, especially when local monitoring equipment is destroyed.

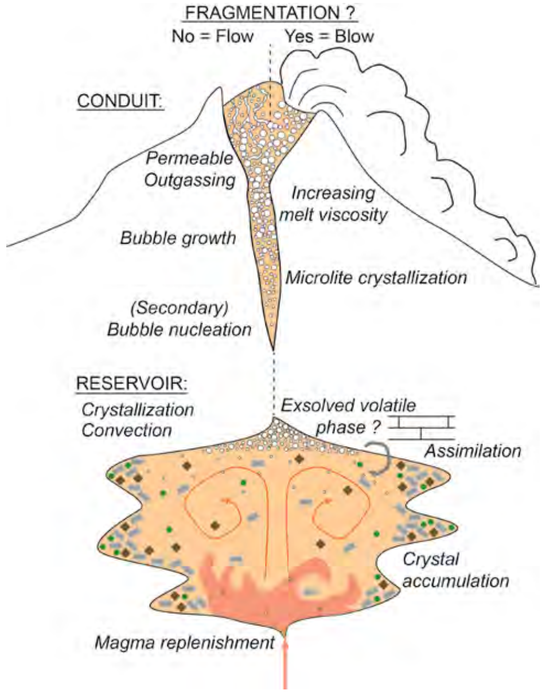


A cluster of orthopyroxene crystal with normal zoning, suggesting rapid growth and limited diffusion before eruption.



False colour images of volcanic crystals show different phases and portions of these crystals, giving clues as to what may happen in a volcano's magma reservoir.

Using remote seismic and infrasound sensors, scientists can monitor volcano eruptions from thousands of kilometres away.



A schematic representation of magmatic processes that take place in a volcano's conduit and reservoir.

Caroline Bouvet de Maisonneuve studies different volcanic eruptions to determine what conditions lead to the formation of a caldera. Trapped gas bubbles in magma can be the difference between an effusive volcano and a dangerously explosive caldera. She looks at the dynamics underneath volcanoes using a combination of methods such as petrology, geochemistry, textural analysis, and numerical modeling.

WOVOdat

The volcano community needs a comprehensive database on world volcanic unrest that aims to improve eruption forecasts. WOVOdat is a database hosted and maintained by EOS that provides free access to critical volcanic information for the public, especially volcanologists and policy-makers.

RESEARCH Volcano

Climate

Over the next century, global temperatures are expected to rise between 1 and 5 degrees Celsius. The important questions are: how will global climate change affect Southeast Asia, and how is human activity in Southeast Asia influencing climate change? Some highlights of our climate researchers' projects shed light on these questions.

Peat found at Riau Province, Sumatra.

Indonesian Haze

Haze in Southeast Asia affects radiative balance and hydrological cycle at least in regional scale. In addition, outdoor haze killed one million people living in Southeast Asia and affected millions more in 2012. One of the biggest contributors of haze in Southeast Asia is peatland fire, which dominantly occurs in Indonesia. Despite its detrimental consequences to climate and human health, haze in this area has not been well studied. Mikinori Kuwata is filling that gap in knowledge. He burns Indonesian peat in his lab to analyse its atmospheric chemistry and how it interacts with water. Next, he'll conduct observations in the field to study haze at its source in Indonesia. With the combination of experimental and observational data, Kuwata's work will help us to understand how haze develops from peat fires and how it contributes to climate change and air pollution.

Dangerous levels of thick haze from Indonesia forest fires envelop Singapore's Marina Bay area.

Scientists extracting coral cores with a drill.

Past Climate Unlocks the Future

In addition to studying current atmospheric science, our researchers are investigating past climate patterns in Southeast Asia. The monsoon season is a dominant player in Southeast Asia's climate. Too much or too little rain can spell disaster for the billions of people who depend on the monsoon for their livelihoods. Nathalie Goodkin's team focuses on the 450-year-old monsoon record that can be discerned from corals in Vietnam. By investigating the coral's chemistry, Goodkin can estimate the changing sea surface temperatures and rainfall in Asia.

Koh Tieh Yong and his team are modeling present tropical climates and carrying out studies on tropical atmospheric dynamics, striving to address some of the important issues surrounding the effect of global warming on Southeast Asia's climate. Wang Xianfeng analyses the chemistry of cave rocks in the Indo-Pacific to learn about what has driven rainfall for the past 100,000 years. Learning about climate variations in the past can help us answer questions about future climate change and better prepare ourselves for a warming world.

Society

Research on the intersection of science and society plays an important role in achieving sustainable societies in Southeast Asia and beyond. The Art + Media Group explores new ways to raise awareness of natural hazards and communicate Earth science topics to the public through documentary films, art projects and interactive games. It also develops and produces a number of original and exploratory artworks and media projects inspired by Earth science, blurring the line between science and art. The Aftermath of Aid project seeks answers to questions about the impact of reconstruction offers practical solutions to improve policy, and makes research accessible to the public.

Assistant Professor Judith Hubbard (standing) and two members of her team, Agathe Schmid and Peter Polivka, overseeing the collection of data.

Art + Media Group

This year, Isaac Kerlow produced The Ratu River Expedition, a documentary film about earthquakes in Nepal. The 25-minute film features the research of scientist Judith Hubbard and the tectonics group on the Ratu River in southeast Nepal. The river spans a section of the Himalayan fault where a magnitude-8.3 earthquake endangers the lives of over half a million people living in the region. In the documentary film, Kerlow presents how Hubbard and her team conduct scientific research to predict which sections of the fault might break and when, all to protect lives and to create a more sustainable Nepal.

Among many other projects, Kerlow also produced and directed the animated short SHADOWS: Saving the Rain Forest, a contemporary tale about preserving the world's forests. The film, which addresses the destruction of the Southeast Asia's forests using the language of wayang kulit performance, has won several awards and continues to show at dozens of international festivals.

The Ratu River Expedition, *a documentary film about earthquakes in Nepal.*

Survivors of the tsunami examine the extent of the destruction in the aftermath of the 2004 Indian Ocean tsunami in Banyak Islands, off the western coast of Aceh, Sumatra.

Aftermath of Aid Project

After the 2004 tsunami struck Aceh, Indonesia, billions of dollars were raised for relief and reconstruction efforts. Aceh has become an important case study for better understanding long-term processes of reconstruction and recovery and the sustainability of humanitarian aid. The Aftermath of Aid project, a collaboration between EOS and the International Center for Aceh and Indian Ocean Studies asked the following questions: What kind of lasting impacts did the relief have? Is Aceh now safer than it was before the tsunami in 2004? What lessons can we learn for future disaster relief?

Patrick Daly and his team have closely followed reconstruction and recovery efforts in Aceh in the decade following the tsunami, collecting a large and definitive dataset on post-tsunami reconstruction in both urban and rural areas. Daly and his colleagues are in the process of publishing their data for academic and policy audiences.

Since EOS scientists have recently shown that tsunamis have hit Aceh in the past and another one is likely to occur again, it's vital to understand how to better protect Aceh's 4.7 million residents. The results of this research project will improve the effectiveness of humanitarian aid not just in Indonesia, but also in Southeast Asia and around the world. It will also provide governments with practical solutions to provide better aid after a natural disaster.

Publications List

This list contains publications authored in 2014 by principal investigators, research fellows, staff members and PhD students at the Earth Observatory—by research area.

Tectonics

- **Chan, C-H,** and **Y-M Wu. "Seismic behavior in central Taiwan: Response to stress evolution following the 1999 M-w 7.6 Chi-Chi earthquake."** *Journal Of Asian Earth Sciences* 90, no. SI (2014): 101-106.
- **Coudurier-Curveur, Aurélie, Robin Lacassin,** and **Rolando Armijo. "Andean growth and monsoon winds drive landscape evolution at SW margin of South America."** *Earth and Planetary Science Letters* 14 (2015): 87-99.
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- **Hubbard, J, J.H Shaw, J Dolan, T.L Pratt, L McAuliffe,** and **T.K Rockwell. "Structure and Seismic Hazard of the Ventura Avenue Anticline and Ventura Fault, California: Prospect for Large, Multisegment Ruptures in the Western Transverse Ranges."** *Bulletin Of The Seismological Society Of America* 104, no. 3 (2014): 1070-1087.
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- **Lindsey, E.O, V.J Sahakian, Y Fialko, Y Bock, S Barbot,** and **T.K Rockwell. "Interseismic Strain Localization in the San Jacinto Fault Zone."** *Pure and Applied Geophysics* 171, no. 11 (2014): 2937-2954.
- **Martin, Stacey,** and **S.E. Hough. "The 21 May 2014 M-W5.9 Bay of Bengal earthquake: Macroseismic data reveals a high-stress drop event."** *Seismological Research Letters* 86, no. 2A (2015): 369-377.
- **Moulin, A, L Benedetti, A Gosar, P.J Rupnik, M Rizza, D Bourles,** and **J.F Ritz. "Determining the present-day kinematics of the Idrija fault (Slovenia) from airborne LiDAR topography."** *Tectonophysics* 628 (2014): 188-205.
- **Obrebski, M, G.A Abers,** and **A Foster. "Magmatic arc structure around Mount Rainier, WA, from the joint inversion of receiver functions and surface wave dispersion."** *Geochemistry Geophysics Geosystems* 16, no. 1 (2015): 178-194.
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Volcano

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RESEARCH Publications List

Publications List, continued

Climate

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Society

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- **Kerlow, I. "Life After the Tsunami: A motivation to Learn about Earth Hazards."** In *American Geophysical Union*. San Francisco, USA, 2014.
- **Kerlow, I. "The Prototype of Earth Girl 2: Preparing for the Tsunami."** In *FMX Conference/Games for Change Europe 2014*. Stuttgart, Germany, 2014.

RESEARCH Publications List

Tectonics

1. Active Faults in the Chittagong-Tripura Fold Belt
2. Developing a Robust Seamless Probabilistic Tsunami Hazard Assessment (PTHA) Framework for EOS using a Pilot Study in the South China Sea
3. Discrete Element Modelling of Fault Nucleation and Propagation in Collision Zones
4. Earthquake and Velocity Structure Study in Mentawai
5. Earthquake Geology in Myanmar
6. Earthquake Ruptures in China: Testing Seismic Faults Behaviour Models
7. Geological Records of Coastal Hazards in Southeast Asia
8. Geometry and Kinematics of the Main Frontal Thrust, Himalaya
9. Holocene Sea-level History on the Sunda Shelf from Coral Microatolls
10. Interaction of Geohazards and Settlements through the Past Millennium, Banda Aceh, Indonesia
11. Kinematics of the Bengal-Assam Syntaxis
12. Mentawai Gap—Tsunami Earthquake Risk Assessment (MEGA-TERA)
13. MIRAGE (Marine Investigation of the Rupture Anatomy of the 2012 Great Earthquake)
14. Neotectonics of the Sumatran Fault
15. Morphology and Paleoseismology of the Main Frontal Thrust in Nepal
16. Novel Approaches to Ground Penetrating Radar: Applications in Border Security
17. Physics of the Earthquake Cycle: from Tremors to Giant Earthquakes
18. Physics-Based and Data-Driven Predictive Modelling of the Earthquake Cycle in Sumatra
19. Predecessors of the 2004 Indian Ocean Tsunnami: A 8,000-Year Sediment Record of Tsunami Recurrence from a Coastal Cave in Northwest Sumatra
20. Probabilistic Seismic Hazard Assessment for Myanmar: Initiative of the Southeast Asia Earthquake Model
21. Seismic Behavior of Sinistral Strike-Slip Faults of the Shan Plateau
22. Sumatran Fault Monitoring (SuMo) Campaign GPS project
23. Sumatran Paleoseismic Study
24. Sumatran Tectonic Geodesy (SuGAr)
25. Testing the Potential of Wave Gliders for Ocean Exploration and Seafloor Geodesy in Southeast Asia
26. The Dauki Thrust System
27. Towards a Better Understanding of Climate Change and Natural Hazards In and Around Southeast Asia through Geodetic Data Combination
28. Understanding Tsunami Sources from Surveyed Tsunami Heights and Sediment Deposits

Volcano

1. Assessing the Hazard from Sumatran Volcanoes
2. Causes, Processes, and Forecasts of Eruptions of Open Vent Volcanoes in Southeast Asia
3. Dynamics of Dyke Propagation
4. Gede-Salak Lab Volcano
5. Magma Degassing and Controls on Eruption Style
6. Mayon Lab Volcano
7. MUON Tomography at Mayon Volcano, Philippines Toward a Better Understanding of Open-Vent Systems
8. Pattern Recognition of Crystal Zoning as a Means to Quantify Volcanic Processes
9. Reconstructing the Plumbing Systems and Dynamics of Magmatic Processes Below Active Volcanoes
10. Using an Infrasonic Array in Singapore to Monitor Volcanoes

Climate

1. Atmospheric Organic Aerosol in the Changing Environment of Southeast Asia
2. Continuous Haze Monitoring in Sumatra
3. Elevation, Facies and Timing of Coral Terraces in Sumba Island: a Revisit
4. Geological Records of Coastal Hazards in Southeast Asia
5. Holocene Sea-level History on the Sunda Shelf from Coral Microatolls
6. Malaysia's Palm Oil Crops
7. Mercury Isotopes for Source Apportionment Study of Atmospheric Particle Bound Mercury in an Urban Setting
8. Monsoon Dynamics, Predictability and Tropical Paleoclimate
9. Reconstructing Seasonal Climate Variations in the Indo-Pacific Using Coral Geochemical Records
10. Records of Early Holocene Post Glacial Sea Level Rise from the Singapore Kallang Basin-Stepped or Continuous
11. Records of Indonesian Throughflow, Regional Neotectonics, Holocene Paleoenvironments and Sea Level from the Southern Outflow of the Makassar Strait
12. Regional Downscale of Southeast Asian Climate
13. Spatial and Temporal Variations in Stable Isotopic Compositions of Precipitation in Southeast Asia
14. Tracking Hydro-Climate Variation in the Tropical Indo-Pacific with Highly Resolved Cave Records

Society

1. Aftermath of Aid
2. Earth Girl 2
3. Earth Systems Science and Society Series: Photographic Narrative of Bali's Sacred Traditional Agricultural Ecosystem
4. Knowledge Capsules
5. Living with Disaster
6. Malaysia's Palm Oil Crops
7. Merapi Interactive
8. Perpetual Motion
9. SHADOWS: Saving the Rainforest
10. The Tsunami of New Dreams

RESEARCH Research Map

Outreach

The Earth Observatory of Singapore has many initiatives to cultivate relationships and share our groundbreaking research with the community.

Our programmes target a range of audiences, from local educators and communities to research institutions and government agencies. Highlights of this year include a partnership with the Singapore Art Museum and a visit from Prime Minister Lee Hsien Loong to learn more about research at the Observatory.

This past year, we've continued to expand relationships beyond the scientific community throughout Southeast Asia and the world. Whether it's working with businesses in Indonesia to grow sustainable palm crops, or collaborating with government agencies to monitor geohazards, the Observatory is sharing its expertise and providing practical solutions to difficult problems.

Applied Projects Group

Collaborating with both government agencies and private sector companies to provide geo-hazards knowledge and solutions, the Applied Projects Group led by Andreas Schaffer aims to work towards safer and sustainable societies in Southeast Asia and beyond.

One of their projects focuses on the vulnerability of palm oil crops to climate change. The thriving agricultural economy in Southeast Asia sustains the food security and livelihoods of millions living in the region. The export of palm oil, crucial component in numerous food products globally, contributes significantly to the economies of Malaysia and Indonesia. Like other crops in the region, it too is sensitive to short-term climate variation in the El Nino and La Nina cycles, as well as long-term climate change. Using OPRODSIM, an oil palm crop model developed by the Malaysian Palm Oil Board, researchers in the Applied Projects Group are able to synthesise plant and plantation attributes, soil types, and high-resolution outputs from downscaled climate models to project oil palm crop yields for up to 30 years. This information provides the industry with the potential for a more holistic appreciation of the issues it faces, even as it responds to calls for more ethical and environmentally sustainable business practices.

The fruit of the oil palm from which the oil is extracted.

By using an oil palm crop model, researchers in the Applied Projects Group are able to project three decades' worth of crop yield.

Assistant Professor Caroline Bouvet de Maisonneuve gives a talk about Southeast Asian volcanoes at the Volcanic Ash Press Conference.

Community Engagement Office

Communication is part of the scientific process. The Observatory has several initiatives to effectively share our scientific research with various audiences. This makes for better collaboration with colleagues, government and corporate leaders, local educators, and regional communities that need help understanding natural hazards.

This past year, the Education & Outreach Office changed its name to Community Engagement Office and appointed Sabrina Smith as its new director. The change reflects the Observatory's commitment to expand relationships with the non-scientific community in and around Southeast Asia, and across the globe.

Outreach efforts have included informal education, field seminars, and museum exhibitions. Some highlights of last year include supporting the development of the 5th International Conference on Aceh and Indian Ocean Studies, a science and art programme in partnership with the Singapore Art Museum, and a visit from Prime Minister Lee Hsien Loong to learn more about our research.

Patra Rena Dewi, co-founder of Kogami, a local NGO committed to mitigating risk and raising awareness of earthquake and tsunami hazards.

Collecting grass to feed the family cow, an organic source of fertiliser for the Balinese rice terraces.

In collaboration with the Community Engagement Office, photographer Joanne Petrina travels with scientists in Southeast Asia and documents the intersection of Earth science, culture and history. Her humanistic photo-narratives have covered subjects relevant to the Earth Observatory and the Asian School of the Environment such as climate science in sacred caves of Myanmar, earthquake preparedness in West Sumatra, as well as ancient models of sustainability in Bali. Her compelling photographs show why the Observatory's work is so vital as our scientists address challenges for Southeast Asia.

The Observatory's researchers and staff collaborate with national and regional agencies and work with local and international media to build public awareness of Earth science research. The ultimate goal of relaying scientific information about natural hazards is to encourage knowledge, attitudes, and actions that make Southeast Asia a safer and more sustainable place for its people.

The Technical Office manages monitoring equipment used by the Observatory's scientists.

Technical Office

The Technical Office is responsible for setting up and managing the Earth Observatory's geophysical and other field instrumentation networks in South and Southeast Asian countries. It supports the Observatory in acquiring, computing, and archiving geophysical data. Under the direction of Paramesh Banerjee, the Technical Office manages the global navigation satellite system (GNSS), seismic, infrasound, and other permanent monitoring EOS networks spread over seven different countries. The Technical Office also provides complete service in modern geospatial techniques such as terrestrial and airborne Lidar surveys.

The Technical Office maintains the Observatory's vast network of nearly 100 permanent global positioning systems in Indonesia, Myanmar, Bangladesh, Bhutan and Philippines. The data received from these systems are telemetered to EOS' data centre, archived, and processed. The seismic networks managed by the Office include broadband, short period and strong-motion accelerograph stations, which aid in volcanic and tectonic studies in Nepal, Indonesia and the Philippines. The Technical Office works closely with both local and foreign government agencies, as well as research and educational institutions in these countries.

Near-future projects include expanding the GNSS network in Myanmar and carrying out a high-resolution airborne Lidar mapping survey in Nepal.

Education

The Asian School of the Environment (ASE) is an interdisciplinary school in the NTU College of Science that trains students and future leaders on some of the biggest environmental challenges that face Asia. The school, led by Charles Rubin, aims to fill a significant gap in our understanding of the world's landscapes and ecosystems by focusing on understudied tropical and urban environments throughout Southeast Asia. The school offers a PhD in Earth Sciences and a four-year (honours) Bachelor of Science in Environmental Earth Systems Science with specialisations in Geosciences, Ecology and Ecosystems, Environmental Systems Science, and Society and the Earth System. In addition it offers a minor in Environmental Sustainability and provides general education courses in sustainability.

Last year, ASE welcomed its first cohort of 28 undergraduate students. In addition to building a strong Earth systems science foundation, the highly selective programme focuses on understanding Earth processes using quantitative skills and modern computing techniques, with a strong emphasis on integrating field observations within the curriculum.

The Asian School of the Environment has a robust PhD program and has accepted almost 30 candidates to date. Whether they're modeling tsunami dynamics or reconstructing past climates, students have research opportunities in a broad range of areas. To perform their research, they have access to brand-new, cutting-edge laboratories.

Field experiences comprise a large part of students' education. During the school year, the undergraduates visited the JOIDES Resolution, a research vessel that studies the Earth's oceans and climate through ocean drilling. On board the students learned about the work, equipment, daily operations, and how scientists are chosen for expeditions. In the undergraduate core class, Earth Systems Science: Solid Earth, the undergraduates visited Sentosa Island and learned how to describe sedimentary rocks in the field. After their first year, all undergraduate students take a two-week environmental Earth systems field course in Bali to connect classroom learning to the field.

At their Open House in March, students and professors gave guided tours and answered questions from prospective students about the new Environmental Earth Systems Science programme.

The Asian School of the Environment has made great strides since its launch in 2011. It currently has 16 professors and lecturers from diverse academic fields and different parts of the world to address key issues of the environment, sustainability, and resilience. The wide range of personal backgrounds and perspectives that people bring to the school and the Observatory make it a welcoming and exciting community. The entire school is open, dynamic, and collaborative, which makes it a vibrant and fun place to study and work.

Supporters

The Development Office is dedicated to supporting the Observatory's ongoing commitment to scientific discovery and innovation by identifying and pursuing opportunities for financial support. Sustainable funding is crucial to our success in understanding the dynamics of earth processes in the region, which will ultimately result in making a difference to the many lives that are affected by them.

Investment income from endowment funds is particularly critical to the deployment and maintenance of our laboratories, geodetic, seismic, and other monitoring infrastructure in the region. The uninterrupted operation of these instruments is pivotal to our investigations as a source of valuable data and insights on geohazards plaguing these parts of the world.

The Development Office is also working with artist Joanne Petrina on a photography series titled "Earth System Science and Society." The series supports the Observatory by providing an artistic perspective on the human elements of scientific research and serves as a visual record of EOS scientists doing work to build safer and more sustainable societies. Petrina has traveled to Indonesia and Myanmar for her series and will work in Bali next year. The fine art photographs will be installed in institutions and museums around the world after a gallery debut at the Observatory.

As of December 2014, the Observatory has received S$10.3 million in endowment capital, primarily from the AXA Research Fund with dollar-to-dollar matching by the Singapore government. These gifts play a vital role in boosting our research capabilities by way of funding leading-edge scientific investigations with an aim to ensure greater resilience and safety for the region's people, cultures and economies.

Management Team

Kerry Sieh, Director
Paramesh Banerjee, Technical Director
Amir Reza Emami, Development Director
Isaac Kerlow, Principal Investigator
Charles Rubin, Head of the Asian School of the Environment
Andreas Schaffer, Sustainability Director
Paul Tapponnier, Tectonics Group Leader
Woo Kien Young, Corporate Services Director

Governing Board

Teo Ming Kian, Chairman, MediaCorp Pte Ltd, Governing Board Chairman
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Boey Yin Chiang, Freddy, Provost, Nanyang Technological University
John Lim, Director, Higher Education, Ministry of Education

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Ministry of Education SINGAPORE

AXA Research Fund

NATIONAL RESEARCH FOUNDATION

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Asian School of the Environment, Nanyang Technological University, Singapore
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AXA Research Fund
Badan Geologi, Indonesia
California Institute of Technology, USA
Center for Environmental Sensing and Modelling Singapore-MIT Alliance for Research and Technology
Center for Southeast Asian Studies Kyoto University, Japan
Centre for Volcanology and Geological Hazard Mitigation, Indonesia
Centre for Geography & Environmental Science, Monash University
Chulalongkorn University, Thailand
Commissariat à l'énergie atomique et aux énergies alternatives/Département analyse, surveillance, environment, DASE, France
Complexity Institute, Nanyang Technological University, Singapore
Department of Atmospheric Sciences, University of Washington, USA
Department of Chemistry, National University of Singapore
Department of Civil Engineering and Architecture, University of Udine, Italy
Department of Geography, University of California, Berkeley, USA
Department of Geological Sciences, Oregon
Department of Geology, Anna University, India
Department of Geology, National Museum of Natural Science, Taiwan
Department of Geology/Geography, Eastern Illinois University, USA
Department of Geophysics, Kyoto University
Department of Geophysics, Syiah Kuala University
Department of Geoscience, Virginia Tech, Blacksburg, USA
Department of Geosciences, National Taiwan University
Department of Mathematics, Syiah Kuala University
Department of Meteorology and Hydrology, Myanmar
Department of Mines and Geology, Kathmandu, Nepal
Department of Physics, University of Toronto, Canada
DIE, Nanyang Technological University, Singapore
Division of Geological and Planetary Sciences, California Institute of Technology
Earth and Environmental Sciences, University of Michigan, USA
Ecole et Observatoire des Sciences de la Terre, France
Engineering Society, Yangon, Myanmar
ETH Zurich, Switzerland
Faculty of Engineering, Computing & Science, Swinburne University of Technology, Australia
Faculty of Resource Science & Technology, University Malaysia Sarawak
Geological Survey of Bangladesh
Global Earthquake Model Foundation
Global Volcanism Program, Smithsonian Institute
Global Volcano Model Network
Graduate Institute of Geophysics, National Central Taiwan University
Graduate School of Agriculture, Kyoto University, Japan
Graduate School of Science, Kyoto University, Japan
HISPEC Lab, National Taiwan University
Institute of Earth Science, Academia Sinica, Taiwan
Institute of Geology, China Earthquake Administration
Institute of Geosciences, Vietnamese Academy of Science and Technology
Institute of Marine and Coastal Science, Rutgers, The State University of New Jersey, USA
Institute of Technology, Bandung, Indonesia
International Center for Aceh and Indian Ocean Studies, Indonesia
Komunitas Siaga Tsunami, Indonesia
Laboratoire Magmas et Volcans, France
Laboratory Forecast Research Department, Meteorological Research Institute, Japan
Lamont Doherty Earth Observatory, Columbia University, USA
Indonesian Institute of Sciences
Institut de Physique du Globe de Paris, France
Institut de Physique du Globe de Strasbourg, France
Institut Physique Nucléaire de Lyon
Marine Science Institute, University of the Philippines, Diliman
Meteorological Research Institute, Japan
Ministry of Marine Affairs and Fisheries, Indonesia
Myanmar Earthquake Committee
Nanyang Polytechnic, Singapore
National Museum of Marine Biology and Aquarium, Taiwan
National Central University, Taiwan
National Family Planning Department, Indonesia
National University of Singapore
Nha Trang Institute of Oceanography, Vietnam
North East Institute of Science and Technology, Jorhat, India
Northwestern University, Evanston, USA
Oxford Centre for Islamic Studies, University of Oxford, England
Philippine Institute of Volcanology and Seismology
Physics Department, Hasanuddin University, Indonesia
Royal Netherlands Institute of Southeast Asian and Caribbean Studies
Schlumberger Norge, Stavanger, Norway
School of Civil and Environmental Engineering, Nanyang Technological University, Singapore
School of Earth and Atmospheric Sciences, Georgia Institute of Technology
School of Earth and Environmental Sciences, James Cook University, Australia
School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore
School of Marine and Environmental Sciences, Universiti Malaysia Terengganu
School of Material Science and Engineering, Nanyang Technological University, Singapore
School of Ocean and Earth Science and Technology, Hawai'i Institute of Geophysics and Planetology, University of Hawaii
School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore
Singapore Centre for Environmental Life Sciences Engineering, Nanyang Technological University, Singapore
Singapore Police Coast Guard
Smithsonian Institution
Smithsonian Tropical Research Institute
SuMo Earthquake Geodesy Lab, Bengkulu University, Indonesia
Sun Yat Sen University, China
Swinburne Unviersity of Technology, Malaysia
Swire Institute of Marine Science, University of Malaysia, Trengganu and Sarawak
Syiah Kuala University
Tectonics Observatory, California Institute of Technology
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UME
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Universitas Islam Negeri Ar-Raniry, Indonesia
Université Joseph Fourier, France
University of Bengkulu, Indonesia
University of Hawaii at Manoa
University of Hong Kong
University of Toronto
Volcano Investigation and Technology Development Institution, Indonesia
Volcanology and Geological Disaster Mitigation Center, Indonesia
Wadia Institute, Dehradun, India
Xiamen University, China

SUPPORTERS

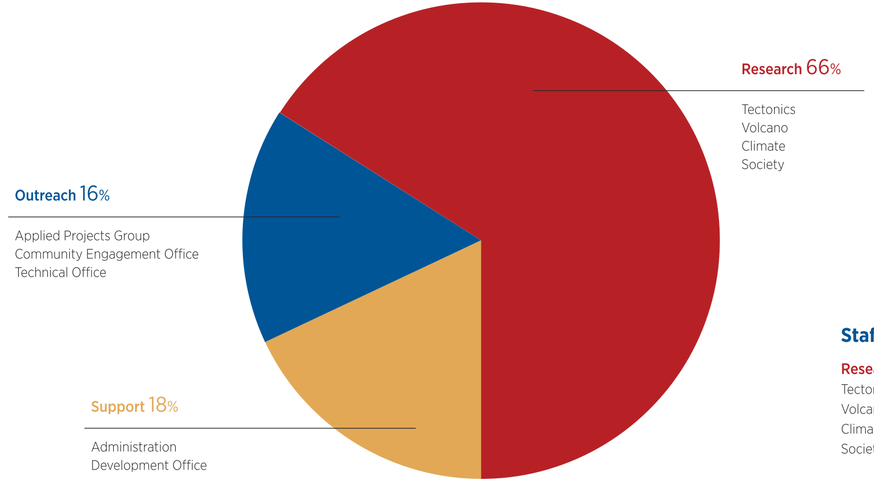
1 April 2014 – 31 March 2015

Assets

Cash on hand	10,000
Grants and other receivables	13,809,472
Net funds owed from NTU	5,111,702
Total current assets	**18,931,174**
Funds held on behalf by NTU	12,561,084
Plant and equipment	4,472,342
Total non-current assets	**17,033,426**
Total Assets (SGD)	**35,964,600**

Liabilities

Accrued expenses and other payables	3,023,926
Grants received in advance from NTU	8,714,771
Total current liabilities	**11,738,697**
Deferred capital grants	**4,472,342**
Endowment funds	12,561,084
Accumulated surplus	7,192,477
Total funds and reserves	**19,753,561**
Total liabilities, funds and reserves	**35,964,600**



Staffing

Research

Tectonics	29
Volcano	16
Climate	20
Society	15

Outreach

Applied Projects Group	5
Community Engagement Office	7
Technical Office	7

Support

Administration	19
Development Office	2
Total staff count	**120**

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Project Director Sabrina Smith

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Production Yvonne Soon

Writer Kathryn Free

Design Director Amy Ray

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