



2018 ANNUAL REPORT



EOS conducts fundamental research on
earthquakes, volcanic eruptions,
tsunamis and **climate change** in
and around Southeast Asia, toward
safer and **more sustainable societies.**

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Professor Kerry Sieh in Aceh, Indonesia

Director's Message

In just over a decade, the Earth Observatory of Singapore has become a strong and preeminent institution for geohazards research, education, and engagement in Southeast Asia. I feel enormous satisfaction and pride as I take stock of what we've built here in such a short time.

Nearly twelve years ago I presented to Singapore the initial proposal to create the EOS. In the interim, the dream articulated in that proposal has come to be — as has quite a bit more that we didn't anticipate.

Lest we forget, the terrible 2004 Indian Ocean tsunami was a total surprise both to the coastal communities it devastated and to our scientific communities. That surprise nurtured Singapore's interest in creating the EOS. We have done as we promised the leaders of this tiny but forward-looking island nation: Their Earth Observatory has taken a running start in filling the yawning gap in understanding this region's geohazards. To our neighbours, we have become a hub of multinational research and education. To our Western colleagues, we are an international outpost, welcoming them to be part of our nascent Southeast Asian geohazards community.

My version of an ancient Chinese proverb that I first saw attributed to Ho Chi Minh goes like this: *If you wish to do something important for the coming year, plant rice — so you'll*

have food on the table at harvest time. If you wish to do something that will be important even ten years on, plant a tree — so you'll have a reliable source of fruit for the table. If you want to do something that'll be important for a hundred years, create an institution that nurtures people. Our “rice” has been the annual funding of research, technical, and engagement projects from our core funding. Our “trees” have been the individuals we’ve hired as faculty and office directors and their devoted and talented students and staff. Our “institution” is the Observatory itself and the Asian School of the Environment that it has nurtured.

We took in our first cohorts of PhD students in 2010 and undergraduates in 2014. By mid-2019, we’d graduated 18 PhDs and our first two undergrad classes had finished their programmes. They are now off with degrees in hand, with a good leg up into the professional worlds of their choice. They have the knowledge, imagination, and drive that will enable them to have impact in building humanity’s resilience to geohazards.

Those challenges from our untamed Earth — sea-level rise, volcanic eruptions, earthquakes, tsunamis, floods, and climate change — did not end with the 2004 tsunami. Our vision is that knowledge of these perils will lead to a reduction of their baleful impacts. Through the remainder of what will undoubtedly be a very challenging 21st century, our success or failure will be measured in the near term by the impact of our own, ongoing research. Through the remainder of the century, though, it will be measured increasingly more by the impact and influence of our academic children.

With the accomplishments, impact, and promise of the EOS well in mind, I can see that the time has come for me to step aside as its Director. I do hope that the new leadership will strive to and have the support to develop an even stronger and more valuable nexus for Southeast Asian geohazards research, education, and community engagement.

My very best wishes to you all.

A handwritten signature in black ink, appearing to read 'Kerry Sieh', written in a cursive style.

Professor Kerry Sieh, Director



Durbar Square, Nepal, in the aftermath of the magnitude-7.8 earthquake that occurred in April 2015

Hazards, Risk, and Society

Investigating the impact of geohazards on the communities of Asia

Every year, natural disasters exact a massive toll on the rapidly growing populations of South and Southeast Asia. At the Earth Observatory of Singapore, the Hazards, Risk, and Society group is focused on helping communities react to and recover from geological hazards. The group brings local leaders and scientists together to share information, inform policy, and create new ways to mitigate the risks posed by the challenges of the environment.

Quantifying impact and getting aid to shaken communities

Funded in part by the Earth Observatory and by an award granted through the World Bank's Innovations Fund and the Global Partnership for Sustainable Development Data, a project led by Assistant Professor David Lallemand focuses on developing new and more equitable ways to assess post-disaster impacts and identify recovery needs. The study found that in the wake of an earthquake, early impact evaluations are aggregated at very coarse spatial resolution and are often inaccurate. In addition, by focusing entirely on physical losses — number of buildings destroyed, roads damaged, or bridges collapsed — such assessments do not account for differential impacts arising from factors other than damage (for example, poverty, and remoteness). The project is developing new ways to rapidly assess post-disaster damage by leveraging and integrating numerous remote-sensing and ground-based data at high spatial resolution, and developing new metrics for post-disaster assessment incorporating social vulnerability.

The study is therefore motivated by the central idea that disasters are not exogenous to social context — rather, their impacts often reflect and magnify the inequalities and vulnerabilities that were already there. In this study, the researchers analyse data sources readily available after an earthquake — such as satellite imagery, demographic data, and rapid field surveys — to give a more accurate and nuanced map of post-disaster need that can be useful to local authorities and aid organisations.

The project is an exciting transdisciplinary collaboration with Stanford University, ETH Zurich, Kathmandu Living Labs, the Humanitarian OpenStreetMap Team, and NASA's Jet Propulsion Laboratory. The activities have included the development of geostatistical analysis methods to combine multiple types of remote-sensing and field-based data, and the collection of an extensive field survey of over 800 earthquake-affected households across rural Nepal to collect firsthand information on the realities of impacts and recovery needs

following the earthquake. This information, along with associated data and the expertise of local collaborators, has formed the basis for a decision-support tool now under development. The tool, designed to facilitate data integration and needs assessments, will ultimately help guide recovery planning and aid allocation in the wake of future emergencies.

Balancing top-down and bottom-up responses

A team led by Senior Research Fellow Patrick Daly is examining how issues of aid governance are shaping community efforts to rebuild in the Kathmandu Valley following the 2015 earthquake. In this three-year project, Dr Daly's team is studying five historic urban settlements that were heavily damaged by the earthquake. The team's goal is to analyse the comparative effectiveness of both top-down (formal governance) and bottom-up (local) response efforts.

The project uses applied anthropological and ethnographic methods to collect intimate and real-time data on how different groups of stakeholders think about rebuilding, what strategies they have employed, and what have been the major obstacles slowing down reconstruction. To date, the team has conducted more than 6,000 surveys, gathering comprehensive information about individual households, the obstacles faced, and the strategies used during rebuilding efforts. The researchers also subsampled 30 households from each of the five settlements, charting the reconstruction progress of individuals and families over the course of four years.

In addition, the team has begun mapping the extent of the earthquake's damage by using high-resolution imagery from satellites and drones, enabling researchers to track progress through time. Maps created monthly show reconstruction progress in all five case study areas.

Their research provides a valuable window into how families and communities affected by disasters in urban environments struggle to rebuild in the face of a complex web of administrative, financial, and bureaucratic procedures. They hope that their research will provide new theoretical insights into how urban communities mobilise in the face of environmental stress, and also practical insights into how governments and non-governmental organisations can build more resilient and sustainable communities following major urban disasters.

The team has presented their recommendations to the National Reconstruction Agency of Nepal, and has published a number of academic and policy papers.



Dr Patrick Daly (foreground) interviews a Nepali man during a field trip.



*Vegetation damaged by the Manaro Voui eruption
in August 2018 in Ambae Island, Vanuatu*

Revisiting the past to predict impacts of future eruptions

The volcanoes of Southeast Asia are among the most active, destructive, and heavily populated on Earth. Volcanic eruptions can impact nearby populations in a variety of ways, from damage to the built environment to (positive or negative) changes in agricultural productivity.

To date, our understanding of these impacts has been shaped by a relatively small number of field observations and qualitative reports following an eruption. In this study, Assistant Professor Susanna Jenkins, Dr Sébastien Biais, and Mr Imantha Gunasekera are taking advantage of new technology to expand our dataset on past eruption impacts with the aim of improving our forecasting of future potential impacts. Google Earth Engine provides a new and exciting opportunity to access multiple geo-spatial and dynamic datasets, such as multi-spectral remote-sensing images, meteorological information, land use, and population data.

This enables the team to map, quantify, and evaluate the effects of volcanic eruptions over large areas, multiple exposed assets, and across long spans of time. These technologies allow researchers to “go back in time” — retrieving information on conditions before, during, and after a past eruption.

The project’s goal in the long term is to apply this method to as many eruptions as possible, developing a unique database that includes observations of hazards and impacts across time, and at several spatial scales. This new resource will provide valuable solutions for managing volcanic hazards and impacts in the future.

Protecting food security in Southeast Asia

Rice is a staple food in Asia, with almost 90 per cent of the global supply being produced and consumed within the region. Southeast Asian countries such as Indonesia, Thailand, Vietnam, and Myanmar are among the world's top exporters of rice. Nonetheless, food security in the region is threatened by the critical challenges posed by climate change and extreme weather conditions, from sea-level rise to tropical cyclones.

A team of researchers led by Assistant Professor Janice Lee is quantifying and modelling the impact of natural disasters on rice harvests in Southeast Asia's important rice-growing regions. The goal of their study is to evaluate the effects of cyclone damage on rice crops, and to develop tools to help promote resilience.

The team began by surveying reports of rice damage in Vietnam, and then added to the study three more cyclone-prone countries: Bangladesh, Myanmar, and the Philippines. They collected information from a variety of resources, including open-source databases, newspaper articles, research papers, weather and land-use information, humanitarian-relief reports, and the knowledge of experts in the field.

Asst. Prof Lee's team found that anthropogenic land-uses interact with natural hazard factors to produce key impacts on rice production. The team created a diagram to show these interconnected factors — from rates of precipitation to irrigation design — and have begun preparing a manuscript to share their findings. In addition, they're in the process of creating a comprehensive database of the extent of rice damage caused by tropical cyclones, which may be helpful for future researchers in modelling the agricultural damage caused by tropical cyclones in Southeast Asia.



The rice industry in Asia faces challenges from climate change and extreme weather conditions.



The film 'Haze, It's Complicated' focuses on the science behind haze caused by peat-burning, and presents perspectives from local and regional stakeholders.

Art and media make critical connections

The work being done by the Observatory's Hazards, Risk, and Society Group has stories to tell beyond data and analysis. That's where the Art+Media Group, led by Executive Creative Director Isaac Kerlow, comes in. Mr Kerlow's team uses filmmaking to connect science and society.

The group's documentary feature film, 'Haze, It's Complicated', explores the issue of haze pollution caused largely by the burning of peatland to clear soil for oil palm farming in Southeast Asia. This man-made hazard has displaced minorities and posed significant health risks. The documentary won Best Feature at the Kuala Lumpur Eco Film Festival, the oldest eco-film festival in Asia.

Another documentary, 'People of the Forest: Orang Rimba', received accolades at two international film festivals, and continues to be one of the most decorated films the team has produced. It presents the plight of the Orang Rimba of Sumatra, an ethnic minority being displaced by deforestation and palm-oil plantations.

The animated short, 'Change', which looks at climate-change issues from a child's point of view, was also well received. It won Best Short at the prestigious SXSW Films for the Forest, 2019.

Most recently, the team launched 'Earth Girl Volcano', the third instalment in the 'Earth Girl' game series. This interactive strategy game offers players tools to prepare for volcanic hazard scenarios based on real-life examples, while also communicating the science behind the events depicted. The game has received praise for its design and social science focus.

By understanding the environment's impact on the communities of South and Southeast Asia, the Observatory's scientists continue to devise new strategies and novel approaches to reducing vulnerability and increasing resilience throughout the region.

Research projects, publications, and our research map can be found at earthobservatory.sg/annualreport/research.



Prof. Sieh and his team in Laos searching for the impact crater of a meteorite that struck Southeast Asia 800,000 years ago.

Profile: Kerry Sieh

Earth scientists know Kerry Sieh as a pioneer in earthquake geology, deciphering the long histories of earthquake faults via the sediments and landforms they disturb and the mountains they incrementally build. Through the last decade, Sieh has largely put these studies aside to serve as Founding Director of the Earth Observatory of Singapore.

Why did Sieh become an Earth scientist? What ignited the creative spark within him? One of the primary reasons, he says, was the delight, excitement, and challenges he experienced as a child exploring the landscapes of his home state, Iowa, which nurtured his attraction to the natural world. "Dad said I should become a lawyer because I liked to argue and didn't have the disposition to become either a scientist or an engineer", he smiles. "But long before he made that judgement, he and Mom set the stage by dropping us off on our grandparents' farms each summer. Those were places where we had to invent our own play in the gardens, the haylofts, the fields, and the pigpens." Sieh says he didn't realise when he first went off to university that this had geared him up to do something that enlisted both brain and brawn.

While Sieh was on sabbatical from Caltech in 2007, the leadership at Nanyang Technological University (NTU) interrupted his plans to write a book for a television series with a request. They asked that he write a proposal as part of Singapore's plan for five new Research Centres of Excellence, an initiative designed to organise extraordinary research activities aligned with the country's long-term goals of economic growth and security.

With the shock of Sumatra's 2004 tsunami still fresh in mind, Sieh's proposal to create a centre for geohazards research struck a chord. "The great tsunami had just happened", Sieh says. "I made a case that, in fact, Singapore had significant exposure to geohazards in Southeast Asia because of its reliance on regional trade and need for regional security." Sieh also made the case that there were no academic institutions in the region that were working across national boundaries to promote resilience to geohazards such as earthquakes, tsunamis, volcanic eruptions, and climate change. Both NTU and Sieh considered his idea for an Earth Observatory a dark horse, but to their surprise, Singapore's leadership decided to fund it. The Observatory officially opened its doors less than a year later, in February 2009.

A month before its official launch, the first scientific paper under the EOS' imprimatur was published, with Sieh as first author. Based upon work he and his students had completed just prior to his departing for Singapore, it revealed that a 700-kilometre-long section of the Sunda megathrust in the Indonesian island of Sumatra had produced clusters of great earthquakes and tsunamis about every 200 years for the past 700 years.



Taking notes on tsunami deposits in a cave in Aceh, Indonesia.

Their discovery of the cyclical nature of such destructive events would prove to be important for alerting at-risk communities.

Scientists and outreach specialists at the Observatory subsequently built upon that research through additional paleoseismic work and the use of the Sumatran GPS Array (SuGAR), a network of GPS stations above the fault that records the buildup and release of strains that produce great earthquakes and tsunamis. EOS and its collaborators subsequently extended their geological work and GPS and seismic instrumentation into Myanmar.

Under Sieh's direction, the EOS has become a nexus for geohazards research. During its inaugural decade, the Observatory built teams in volcanology and climate research. Recently, the EOS has begun building a Hazards, Risk, and Society group, which conducts research at the boundary between geohazards science and its application. Today, EOS research teams are working together to acquire scientific knowledge on complex natural phenomena, and passing it on to at-risk communities throughout Southeast Asia.

Although he has had little time for research in the past 10 years, Sieh has managed to dabble here and there. He and his colleagues have explored the tsunami history of Aceh, a province at the northwestern tip of Sumatra. They found archeological evidence of the destruction of 10 communities along the Aceh coast about 600 years ago, and from sands in a cave along the west coast they discovered a record of tsunamis that extends back nearly 8,000 years.

In 2011, Sieh stumbled on a geological mystery while on a weekend vacation in Ho Chi Minh City, Vietnam. In the back of a small jewellery store, on a shelf behind the rubies and sapphires were odd black rocks. The proprietress told Sieh that they were tektites, and a short writeup she gave him explained that they were now-solidified blobs of sandstone melted by the impact of an ancient meteorite. “I couldn’t believe that the huge hole in the ground from which they came had never been found”, Sieh says, “so I set off to find it in my spare time.” He is proud to say that in diverting from earthquake science, his principal field of expertise, he has engaged in “scientific trespass” to pursue a question he knew nothing about but had the tools necessary to solve. As it turns out, the crater was hard to find because it lay buried beneath a large, mostly unstudied volcanic field in southern Laos. Now that Sieh and his colleagues have found the crater’s location, they’ve become intrigued by the volcanic field above it.

In August 2019 Sieh stepped down from his position as Director of the EOS. When asked about his hopes for the Observatory’s future, he put it simply: “Over the next century, I hope the government redoubles its efforts to nurture the Observatory so that, decades from now, it will have become the strongest regional beacon for geohazards research, education, and engagement aimed ultimately at making Southeast Asian communities more secure, more productive, and more sustainable in the face of their geohazards.”



Prof Sieh holding up a tektite he brought back from one of his field trips to Laos



The CGO team trekking through Shan State, Myanmar, to get to seismic stations

Centre for Geohazard Observations

In May 2018, the Technical Office — recently renamed the Centre for Geohazard Observations (CGO) — welcomed its new director, Mr Leong Choong Yew. The team is responsible for managing the geophysical instrumentation that enables the Observatory to carry out its cutting-edge research in the field.

During 2018, the CGO focused on a series of installation projects that will enable researchers to better locate and understand seismic activity in Myanmar. The knowledge gained will also help mitigate the impact of future earthquakes throughout the region.

In other areas, the CGO continues to maintain stations of the Sumatran GPS Array (SuGAR) in Indonesia, as well as at several volcano observation stations in Indonesia and the Philippines. The office has also successfully migrated data to new servers, providing a safer, more reliable network.

On the local front, the CGO participated in the EOS seismic survey of Singapore to assess its potential for seismic hazards. Working with EOS researchers, the team helped deploy 88 seismometers at 87 sites across Singapore.

Read more at earthobservatory.sg/annualreport2018/outreach.



Community Engagement Office

The Community Engagement Office, led by Mrs Sabrina Smith, shares the research and expertise of Observatory scientists through a variety of channels. The team highlights the Observatory's global impact by focusing on education, communication, and outreach.

This year, the Community Engagement Office launched the Dynamic Earth Games, a series

of board and card games for secondary school students exploring the science behind volcanoes and typhoons. The games are held in conjunction with tours of 'Earth: Our Untamed Planet', the Observatory's current exhibition at the Science Centre. In addition, the team mentored a group of Masters students from the University of Melbourne on a project focused on communicating sea-level rise to the Singapore public.

Reaching out to a wider audience, the Community Engagement Office participated in key conferences and events worldwide, including GeoConnect 2019, GreenFest, and the Singapore EcoFilm Fest. The Office also worked with the media to provide expert commentary on Earth science and geohazard topics, resulting in more than 500 press mentions across print and digital platforms.

Read more at earthobservatory.sg/annualreport2018/outreach.



Students from a school in West Sumatra, where Observatory scientists visited for fieldwork

Philanthropy Office

The Office of Philanthropy supports the Earth Observatory of Singapore through advancement initiatives that provide financial investment, strengthen strategic alliances, and promote institutional priorities.

Under the direction of Mr Andrew Krupa, the Office has created a campaign to help ensure the Observatory's financial security in perpetuity. To achieve funding goals,

the Office has implemented an infrastructure designed to incorporate best practices for institutional advancement, and created a grants administration unit to allow for the integration of additional investment streams.

In 2018, the Office of Philanthropy expanded its reach by collaborating with corporate, governmental, and non-governmental organisations, and community partners throughout Southeast Asia. The impact of these collaborations will ultimately benefit a broad spectrum of initiatives by the Observatory.

This year, the Philanthropy Office was honoured to participate in a number of conferences and workshops, including the United Nations Our Oceans Conference, World Economic Forum, and the Asian Venture Philanthropy Network. These connections provide a global platform for expanding visibility and developing partnerships to support the Earth Observatory's growth.

Read more at earthobservatory.sg/annualreport2018/outreach.



Students from ASE hiking up Panum Crater during their field trip to California

Asian School of the Environment

In July 2018, the Asian School of the Environment (ASE) was proud to present the first graduating class of its Environmental Earth Systems Science programme, noting that almost all have found employment in associated fields. The programme currently has 130 undergraduate and 42 PhD students enrolled, several of whom have already won prestigious honours and awards.

This year, ASE installed Professor Benjamin Horton as new Chair, and Associate Professors Fidel Costa and Emma Hill were awarded Provost Chairs in Earth Sciences. Prof Horton, who was awarded the President's Chair in Earth Sciences, was also elected a Fellow of the American Geophysical Union.

Early 2019 also brought a variety of media attention, from coverage of a study by Assistant Professor Janice Lee and her co-authors on the consumption of horn from the critically endangered saiga antelope in traditional Chinese medicine to NTU's 'Hey!' magazine, which included two environmental science jobs as hot careers of the future.

Read more at earthobservatory.sg/annualreport2018/outreach.

Impact

Accomplishments and Honours

Fidel Costa and Emma Hill, Principal Investigators

Provost's Chair in Earth Sciences

Benjamin Horton, Principal Investigator

President's Chair in Earth Sciences

AGU Fellow

Benoit Taisne, Principal Investigator

Accelerating Creativity and Excellence Award

Kerry Sieh, Director

Honorary Membership, Association of Environmental and Engineering Geologists

Li Weiran, PhD Student

Sixteenth International Symposium on Experimental Mineralogy, Petrology and Geochemistry Student Award

Paul Tapponnier

Asia Oceania Geosciences Society Axford Medal

Deepa Mele Veedu and Sri Budhi Utami, PhD Students

Dr Stephen Riady Geoscience Scholars Fund 2018

'CHANGE'

Best Short Film, Films for the Forest

'Orang Rimba'

Best Documentary, WILLiFEST

Best International Documentary EcoFilm, Rural Filmfest

'Haze, It's Complicated'

Best Feature, 11th Kuala Lumpur Eco Film Festival 2018

Full accolades are listed at earthobservatory.sg/impact.

Supporters

Sharing our commitment to creating safer and more sustainable societies



Read more at earthobservatory.sg/philanthropy.

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