



EARTH
OBSERVATORY
OF SINGAPORE

2016 ANNUAL REPORT



EARTH
OBSERVATORY
OF SINGAPORE

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



Table of Contents

5

Overview

•

6

Focus on Nepal

•

11

Paul Tapponnier

•

12

Caroline Bouvet de Maisonneuve

•

14

Nathalie Goodkin

•

16

Other Research Projects

Publications

Research Map

17

Applied Projects

•

18

Community Engagement Office

•

19

Technical Office

•

20

Asian School of the Environment

•

22

Impact

•

23

Supporters



“Through intensive research, our scientists are acquiring more insight into these events and passing on this knowledge to help communities at-risk be more resilient to earthquakes.”

Overview

Nepal is the home to stunning landscapes and the tallest mountain range in the world. It is also the site of the largest active continental thrust fault called the Main Frontal Thrust. This system of faults stretches 2,000 kilometres along the boundary where the Indian subcontinent is smashing into the Eurasian plate. This collision, which began about 50 million years ago, has produced many large, catastrophic earthquakes.

While the complex nature and vastness of the fault make it difficult to quantify earthquake hazard for the tens of millions of people living nearby in Nepal and India, these factors are precisely why it is important to learn about this fault. Through intensive research, our scientists are acquiring more insight into these events and passing on this knowledge to help communities at-risk be more resilient to earthquakes.

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Focus on Nepal

Searching for the Trace of Great Earthquakes

The Main Frontal Thrust has produced some of the most catastrophic earthquakes in history, including the 8.4-magnitude 1934 Bihar-Nepal event that killed more than 15,000 people. Yet, no one had found where these quakes had ruptured the surface, leading many geologists to conclude that these faults were “blind”—that the earthquake’s fault had not reached the surface of the earth.

Without surface evidence, it is difficult to answer important questions about how often earthquakes occur and how large they may be. That was what Principal Investigator Paul Tapponnier and his team set out to do: to find the undiscovered surface ruptures of four historic earthquakes and eventually decipher the history of 5,000 years of earthquakes along the Main Frontal Thrust in eastern Nepal.

In 2016, Tapponnier and his team found seven large earthquakes dating back 4,500 years and, with this information, they were able to estimate an average recurrence interval of 600 to 800 years between them. In recent years, the team demonstrated that great Himalayan earthquakes in past centuries were not “blind” as previously thought.



“That was what Paul Tapponnier and his team set out to do: to find the undiscovered surface ruptures of four historic earthquakes...”

“Judith Hubbard used the EOS Vibroseis Minibuggy to image faults and related deformation underground.”



They also investigated the earthquake that killed the king in Kathmandu in 1334. The team believes that the 1334 quake occurred in sequence, just west of the 1255 AD event, postdating it by only 89 years. This short lag time raises the question of whether another great earthquake similar to the 1934 event could occur fairly soon, perhaps in the next few decades. This makes it even more critical for Tapponnier and his team to search for the ruptures of other great historical earthquakes along the Himalayan Front in order to better prepare for the next one.

Below the Surface

Because of the challenges in locating and characterising surface faults along the Main Frontal Thrust, subsurface data is important to fill gaps in knowledge about Nepal’s active tectonics and geology. Principal Investigator Judith Hubbard used the EOS Vibroseis Minibuggy to image faults and related deformation underground. The truck works by shaking the ground, creating seismic waves that travel through the rocks. The waves reflect off stratigraphic layers and can be processed to produce detailed images of underground faults and folds. Thus far, Hubbard’s team has collected 135 kilometres of high-resolution profiles. This dataset is the first of its kind in the Himalayas. With this technology, Hubbard has successfully imaged various segments of the Main Frontal Thrust and produced a more precise model of the faults and folds at work, paving the way towards better hazard estimates.

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“Prof Tapponnier’s affinity with mountains brought him to study the highest peaks on the planet: the Himalayas and Tibet.”

Profile: Paul Tapponnier

Born and raised in the French Alps south of Geneva, Professor Paul Tapponnier’s affinity with mountains brought him to study the highest peaks on the planet: the Himalayas and Tibet. It was fitting then, that he moved to Singapore in 2009 to lead the tectonics group at the Earth Observatory of Singapore, closer to the mountains that he had spent much of his life studying.

One of the most distinguished scientists of his generation in the field of tectonics, Prof Tapponnier’s innovative research led to a renaissance in neotectonics, the study of Earth’s crust’s animated history. Much of our understanding of tectonics in Asia comes from Prof Tapponnier’s lead research since 1975. One of his major research project aims to reconstruct earthquake history and assess the potential return times of future events. He set out to Nepal to find surface slips, and discovered a record of seven surface-rupturing earthquakes in the past four millennia.

Besides his trailblazing work in Nepal, Prof Tapponnier has been an active partner of other tectonic studies in Asia. Some of the research projects he is involved in includes the study of the Altyn Tagh Fault in China, the Mentawai Gap—Tsunami Earthquake Risk Assessment (MEGA-TERA), and the Marine Investigation of the Rupture Anatomy of the 2012 Great Earthquake (MIRAGE) off the shores of Sumatra.

Throughout his career, Prof Tapponnier has contributed tremendously to the understanding of large-scale continental tectonics and earthquakes. There is such a sparkle in his eyes whenever he talks about the Earth, one can’t help but feel that even at 70, nothing will slow him down.

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Profile: Caroline Bouvet de Maisonneuve

Assistant Professor Caroline Bouvet de Maisonneuve was seven years old when she saw ash falling into her garden in Manila, Philippines, where she lived. She vividly remembers the June 15, 1991 eruption of Mount Pinatubo, one of the most violent of the 20th century.

Now a volcanologist at the Earth Observatory of Singapore, Asst. Prof Bouvet de Maisonneuve is studying volcanoes in the Philippines and across Southeast Asia. Currently, Asst. Prof Bouvet de Maisonneuve and her team are focusing on Singapore's volcanic hazard as they work to reconstruct eruption histories of Southeast Asia's volcanoes.

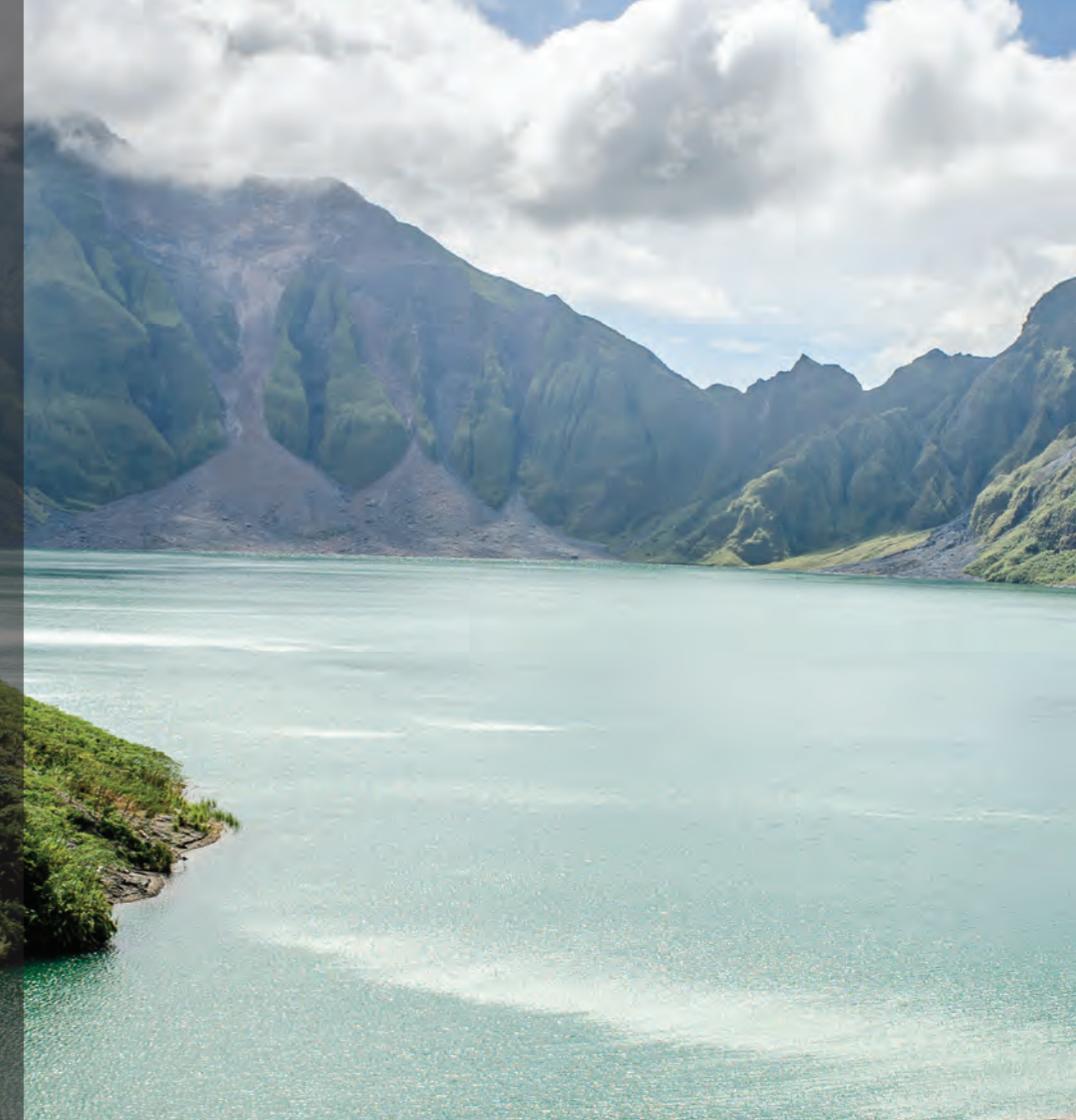
Coming full circle, another of the volcanoes that Asst. Prof Bouvet de Maisonneuve is interested in researching is Mount Pinatubo, the very volcano that inspired her career. She says, "It was quite special for me, knowing that I had witnessed that eruption." There was, however, something baffling about Mount Pinatubo's eruption: it released nearly 20 million tonnes of toxic sulfur dioxide into the atmosphere and this sulfur gas cooled the planet by 0.5 degrees Celsius for the next three years.

But where exactly did the sulfur come from? Asst. Prof Bouvet de Maisonneuve is hoping to solve this puzzle by tracing the isotopic signature of sulfur in the volcano's deposits. Because sulfur dioxide has a negative impact on our atmosphere, it is important to understand how it is transferred, released, and whether large sulfur-producing eruptions like that of Mount Pinatubo are typical or not.

[read more](http://earthobservatory.sg/annualreport2016/research) earthobservatory.sg/annualreport2016/research



"There are so many possibilities for volcano research in this region, because many of them haven't been intensely studied."





"I realised there was so much we didn't know about how the oceans impacted climate."

Profile: Nathalie Goodkin

In 2002, Associate Professor Nathalie Goodkin was working as an investment banker in the United States when Larson B, part of the Larson ice shelf in Antarctica, collapsed. The ice sheet, roughly four and a half times the size of Singapore, melted in the span of just 35 days. Right then and there, she decided to leave her promising career for climate science. "I realised there was so much we didn't know about how the oceans impacted climate," Assoc Prof Goodkin says of her decision to switch careers. "I wanted to see how these systems worked at a fundamental level."

One of the big questions she wants to answer revolves around the Southeast Asian monsoons. The summer and winter monsoons are the major drivers of climate in Southeast Asia, where too much or too little rain can threaten agriculture and damage infrastructure. Understanding how the monsoons have varied in the past will be critical to forecasting regional climate.

One project that stands out involves a massive coral dubbed "Tho Nhat," Vietnamese for "The Big One." Assoc Prof Goodkin and her team drilled a four-metre long core sample from the coral. By studying the sample, her team is able to gain insight into climate signatures recorded by the coral, such as ocean salinity, temperature, and circulation.

Next year, Assoc Prof Goodkin will continue to investigate how corals record ocean-atmospheric exchanges, reconstruct past climate histories, and model data to gain insight to future oceanic changes. In the face of a warming climate, her work is critical to understanding how regional climate may change.

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Other Research Projects

Our research extends across our dynamic planet, from climate studies in Taiwan to magma analyses in Papua New Guinea.

Publications

The online list contains all publications authored by researchers at the Earth Observatory between April 2016 and March 2017.

Research Map

Our scientists travel the world to conduct fundamental research on geohazards. Find out where our researchers have been in the past year.

To read more about our projects, and to view the full report, visit earthobservatory.sg/annualreport2016/research



Applied Projects

The Applied Projects Group, led by Andreas Schaffer, integrates scientific research into policies that aim to protect people living in the region, working with business and government leaders to address issues on geohazards.

In 2016, members of the Group visited Uttarakhand, in northern India, to study large historical Himalayan earthquakes and provide input into the state's earthquake risk model. The group also set up the Phuket Disaster Resilience Foundation to strengthen local hazard and risk research and disaster preparedness following the 2004 Indian Ocean earthquake and tsunami. To better understand seismic risks in and around Singapore, the Applied Projects Group is working with the Building and Construction Authority of Singapore as they compile a seismic hazard report.

In the following year, the group will continue to conduct rigorous research on these projects as they help to realise the Earth Observatory's mission of building safer and more sustainable societies.

read more earthobservatory.sg/annualreport2016/outreach

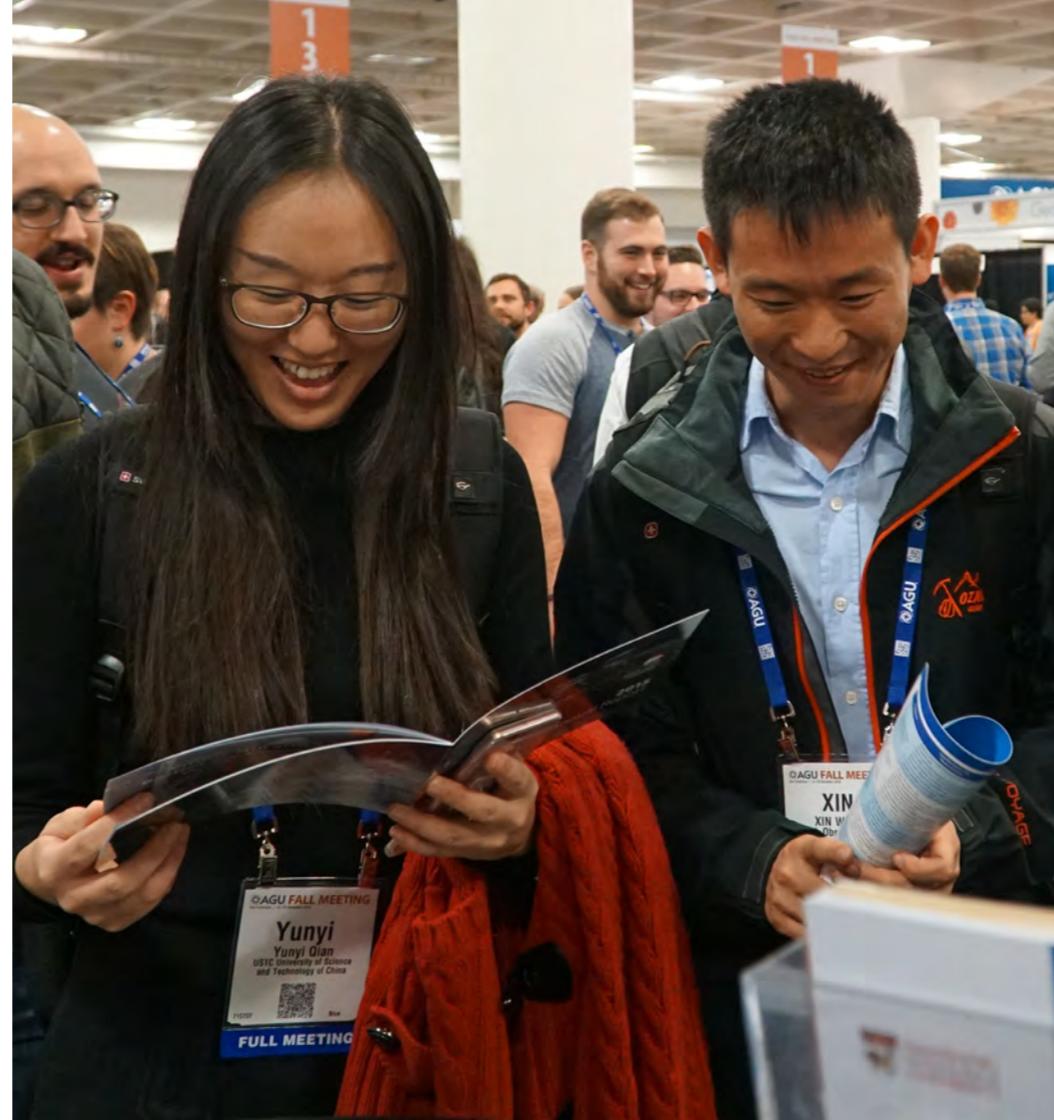
Community Engagement Office

The Community Engagement Office pursues a multi-tiered agenda to reach and engage key audiences in order to elevate awareness, inform communities, and grow the Earth Observatory of Singapore as a resource for Southeast Asia and the world.

Under the direction of Sabrina Smith, the Community Engagement Office created new channels of communication and developed more connections throughout Singapore and the world to share the Observatory's story and breadth of work. Last year, the Observatory received more media coverage, both local and international, that included commentaries on regional geohazards and new research findings.

The Community Engagement Office provides group support to the Observatory, hosting and participating in a number of on-site workshops, visits, outreach events and conferences. Next year, the Community Engagement Office will continue to increase its outreach, deepening engagement as the office works to forge new partnerships, while continuing to grow the Observatory's reach and relevance locally and globally.

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Technical Office

The Technical Office manages all major field geophysical, geodetic, geochemical, and geospatial instruments and networks conducted by the Earth Observatory. These include Global Positioning System (GPS) networks and seismological observatories, which are equipped with monitoring and survey instruments.

By working closely with foreign governments and research agencies, the Technical Office facilitates the installation and maintenance of instruments. To date, there are more than 100 continuously operating GPS stations and more than 50 seismological stations operating in nine countries across the region including Bhutan, India, and the Philippines.

This year was a fruitful year for the Technical Office. The team carried out surface gravity measurements in Laos, prepared for airborne LiDAR surveys in Nepal and Myanmar, and installed five new broadband seismic stations at Sumatra's Marapi volcano. The Technical Office will continue to support the Observatory's efforts to survey and monitor the region's geohazards.

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Asian School of the Environment

The Asian School of the Environment (ASE) is an interdisciplinary school, addressing key issues in sustainability and the environment in Asia. Launched in 2014, the school hosts one of Asia's premier geoscience programmes, training the next generation of earth scientists for the region.

The Environmental Earth Systems Science undergraduate programme offered by the ASE is highly selective, allowing students to specialise in geosciences, society and earth systems, or ecology. Teaching is placed in an outcome-based context, and field trips organised by the School afford students the opportunity to transform classroom knowledge into skills.

ASE is also home to a rigorous PhD programme, through which the School ensures that students work closely with their supervisors on projects and scientific papers. Many of them present at conferences. In May last year, four outstanding postgraduate students were awarded the Dr Stephen Riady Geoscience Scholarship.

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“Launched in 2014, the school hosts one of Asia's premier geoscience programmes, training the next generation of earth scientists for the region.”

Impact

We were honoured.

Linlin Li AXA Fellowship

Emma Hill AGU 2016 Geodesy Section Award

Társilo Girona AGU 2016 Natural Hazards Focus Group Award for Graduate Research

Priyamvada Nanjundiah AGU Fall Meeting 2016 Outstanding Student Paper Award

Mikinori Kuwata Japan Society of Atmospheric Chemistry Young Researcher Award

Daniel Krimer Springer Thesis Award

CHANGE Award of Merit, IndieFEST Film Awards

We expanded our reach.

483K hits on earthobservatory.sg

47 media mentions

Almost 1M of you engaged with us via our social channels

5X increase in Facebook page likes

9X increase in Twitter followers

We were involved in 100 workshops, seminars, and events



Supporters

Sharing our commitment to creating safer and more sustainable societies.



Project Director

Sabrina Smith

Project Manager/Editor

Cheryl Han

Production

Yvonne Soon

Writer

Kathryn Free

Design Director

Amy Ray

•

Image Credits

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Carl Rognstad

Cheryl Han

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