



# Thailand Training Program in Seismology and Tsunami Warnings



## Sponsored by:

**National Disaster Warning Center (NDWC) Thailand**  
**UNESCO Intergovernmental Oceanographic Commission (IOC)**  
**U.S. Geological Survey (USGS)**  
**U.S. Agency for International Development (USAID)**

**Seismology: May 15-18**  
**Tsunami Warnings and Tsunami Warning Center Operations: May 19-20**  
**Roundtable Discussion: May 22**

## Table of Contents

<b>Acknowledgements .....</b>	<b><i>iii</i></b>
<b>Sponsoring Agencies .....</b>	<b><i>iv</i></b>
<b>Introduction .....</b>	<b><i>v</i></b>
<b>Training Course Agenda .....</b>	<b><i>vi</i></b>
<b>Supplemental Training Material .....</b>	<b>1</b>
SECTION I: Seismology .....	2
I.1 Seismic Waves .....	2
I.1.a Elastic Waves & Travel Time Curves .....	2
I.1.b What Produces Seismic Waves .....	15
I.2 Earthquake Seismology .....	20
I.2.a Characteristics of Earthquakes, Plate Tectonics, & Probing the Earth's Interior .....	20
I.2.b Earthquake Statistics .....	54
I.2.c Earthquake Frequency & Distribution .....	55
I.3 Source Parameter Calculations .....	68
I.3.a Magnitude & Moment .....	68
I.3.b Earthquake Intensity .....	72
I.3.c Fault Plane Solutions from First Motions .....	74
SECTION II: Tsunamis .....	77
II.1 Physics of Tsunamis .....	77
II.2 Tsunami Distribution & Frequency .....	80
II.3 Case Study: 2004 Indian Ocean Tsunami .....	83
II.3.a Historical Account .....	83
II.3.b Seismological Aspects of the 2004 Tsunami Generation .....	89
SECTION III: Hazard Mitigation .....	95
III.1 How to Prepare for an Earthquake .....	95
III.2 How to Respond to an Earthquake or Tsunami .....	106
REFERENCES .....	111
<b>Additional Resources .....</b>	<b>112</b>
<b>Contact Information .....</b>	<b>113</b>

## **Acknowledgements**

### **Venues**

Department of Mineral Resources' Computer Laboratory : 15-19 May  
National Disaster Warning Center (NDWC), Nanthaburi : 20, 22 May

### **Responsible Organizers:**

Dr. Cherdsak Virapat  
*Assistant Executive Director, Thailand National Disaster Warning Center*

Dr. Laura Kong  
*Director, IOC International Tsunami Information Center, Hawaii*

Dr. Walter Mooney  
*U.S. Geological Survey, Menlo Park, California*

### **Assistant Training Program Organizer:**

Ms. Susan T. McDonald  
*Research Assistant, U.S. Geological Survey*

### **Lecturers:**

Dr. Annabel Kelly, *Coordinating Lecturer; Seismologist*  
*U.S. Geological Survey, Menlo Park, California*

Dr. George Choy, *Research Seismologist*  
*U.S. Geological Survey, Denver, Colorado*

Dr. Laura Kong, *Seismologist*  
*Director, IOC International Tsunami Information Center, Hawaii*

Dr. Chip McCreery, *Seismologist*  
*Director, Pacific Tsunami Warning Center*

Dr. Robert Mereu, *Research Seismologist*  
*Professor Emeritus, University of Western Ontario, Canada*

Dr. Walter Mooney, *Research Seismologist*  
*U.S. Geological Survey, Menlo Park, California*

Mr. Koichiro Nagasaka, *Former Director-General*  
*Japan Meteorological Agency, Tokyo, Japan*

Mr. Yuji Nishimae, *Senior Scientific Officer*  
*Japan Meteorological Agency, Tokyo, Japan*

Mr. Masahiro Yamamoto, *Senior Tsunami Advisor*  
*IOC United Nations Educational, Scientific, & Cultural Organization, Paris*

## Sponsoring Agencies



*The European Commission and the Governments of Finland, Germany, Japan, Netherlands, Norway and Sweden have contributed generously – through the UN Flash Appeal for Indian Ocean Earthquake – Tsunami 2005 – to support the UN/ISDR coordinated initiative: “Evaluation and Strengthening of Early Warning Systems in countries affected by the 26 December 2004 Tsunami”.*



The United Nations Educational, Scientific, and Cultural Organization (UNESCO) functions as a laboratory of ideas and a standard-setter to forge universal agreements on emerging issues. The Organization also serves as a clearinghouse- for the dissemination and sharing of information and knowledge- while helping Member States to build their human and institutional capacities in diverse fields. In short, UNESCO promotes international co-operation among its 191 Member States and six Associate Members in the fields of education, science, culture, and communication.



The Intergovernmental Oceanographic Commission (IOC) is a branch of UNESCO that provides Member States of the United Nations with an essential mechanism for global cooperation in the study of the ocean. The IOC assists governments to address their individual and collective ocean and coastal problems through the sharing of knowledge, information, and technology, and through the coordination of national programs.



The IOC International Tsunami Information Centre (ITIC), hosted by the USA and Chile, works to mitigate tsunami effects in the Pacific and globally. The ITIC is also supporting the IOC's establishment of a global International Tsunami Warning and Mitigation System. ITIC enables tsunami technology transfer among countries interested in establishing regional and national tsunami warning systems, acts as a clearinghouse for risk assessment and mitigation activities, and serves as a resource for the development, publication, and distribution of tsunami education and preparedness materials.



The U.S. Agency for International Development (USAID) provides overall management, coordination, and administrative support for the integrated U.S. program from its Regional Development Mission for Asia, located in Bangkok, Thailand. USAID coordinates directly with appropriate USAID Mission personnel and programs in India, Indonesia, and Sri Lanka, with the USAID Office of Foreign Disaster Assistance (OFDA) offices in Bangkok and Kathmandu, and with USAID/Washington. USAID manages the Program Integrator for the US IOTWS program, and works and coordinates directly with each of its U.S. agency partners.



The U.S. Geological Survey provides support for seismic and tide station technology transfer, regional and global interoperability through the IOC framework, and capacity building at both the detection/warning formulation and local preparedness levels. This is done at the data analysis and prediction stage, as well as in hazard/vulnerability/risk mapping and modeling standards, protocols, and methods. Training is one of the primary mandates of the USGS effort.



The National Disaster Warning Center, Thailand is responsible for planning, coordinating, controlling, operating, and preparing the disaster warning facilities and system, along with researching and updating technology. This educates the public and involved agencies to diminish the severity of damage from natural disasters, and supports disaster mitigation effectively and efficiently.

## **Introduction**

The December, 2004, Tsunami highlighted the need to increase capacity building in the countries most severely affected by the international disaster. In response to this need, the Indian Ocean Tsunami Warning and Mitigation System (IOTWS) Program, under the framework of the IOC, was developed in order to create “tsunami resilient” communities in the Indian Ocean region. An Intergovernmental Coordination Group for the IOTWS was established in June 2005 under the governance of the IOC of UNESCO coordinate activities to support the regional aspects of tsunami warning and mitigation. This IOTWS Program has several components including technical assistance, regional hazard detection, prediction, and warning formulation, national dissemination and communication of warnings, local knowledge and preparedness to act, and regional or sub-regional exchange of lessons learned and best practices.

This training program in Seismology and Tsunami Warning is an integral part of the IOTWS effort to provide technical assistance to Thailand using an “end-to-end” approach. This approach involves providing assistance in all stages of hazard mitigation, from identifying earthquakes and tsunamis to disseminating a warning to the public. The particular focus of this course will be to provide a solid background in seismology, relevant for developing a tsunami warning system. With this information, participants will, in turn, be expected to educate other members of the Thai community, or be actively engaged in tsunami warning system efforts.

The learning format of this course will be through a series of lectures and hands-on learning during practical sessions. All lectures will either be copied to CD’s available for distribution at the end of the course, or available on the Web one week after the completion of the Program. In addition, this Handbook contains information on the key aspects of the course, and is designed to provide supplemental material to the lectures.

# **TRAINING COURSE AGENDA**

- Monday, 15 May: Introduction to the Tectonic Situation in Thailand  
Introduction to Earthquakes**
- Tuesday, 16 May: Seismic Theory & Applications**
- Wednesday, 17 May: Pacific Tsunami Early Warning Exercise  
Global & Local Seismic Networks  
Instrumentation & Seismic Data Analysis**
- Thursday, 18 May: Earthquake Hazard Assessment**
- Friday, 19 May: Tsunami Warnings and Tsunami Warning Center Operations**
- Saturday, 20 May: Tsunami Warnings and Tsunami Warning Center Operations**
- Monday, 22 May: Roundtable Discussion – Tsunami Warnings for Thailand**

## **Training Program Course Objectives**

Increase capacity building in Thailand through instruction in the following areas:

- Global distribution and frequency of earthquakes, and relationship to plate tectonics
- Elastic Rebound Theory
- Paths taken by major body and surface wave phases (e.g., P, S, pP, sS, SKS, Love, Rayleigh)
- Identifying P, S and surface waves in seismograms
- Hypocentral location, intensity, and magnitude calculations
- Identifying different focal mechanisms
- Seismometer/recording station operations
- Physics of tsunamis and how they differ from wind-generated waves
- Steps involved in an end-to-end tsunami warning system
- What action to take in the event of an earthquake/tsunami warning, and how to increase public preparedness

**Day One: Monday, May 15**

**SEISMOLOGY**  
**Introduction and the Tectonic Situation of Thailand**  
**Introduction to Earthquakes**

**Pre-Training Event, May 14:**

*1-4pm - Table Top Exercise at NDWC*

*Facilitator: Pacific Disaster Center*

**9am- Session I.1: Introductions**

Welcome by Thailand

Welcome by IOC and USGS: Walter Mooney (also on behalf of IOC)

Welcome by US Embassy and USAID: Timothy Beans, Mission Director, USAID  
Regional Development Mission for Asia

Welcome on behalf of US IOTWS Program: Orestes Anastasia, USAID

Outline of Training Course: Annabel Kelly

Logistical Information (maps, rooms, meals, etc): Cherdsak Virapat

**10:15am- Session I.2**

Topic: Introduction to Earthquake Science: A Historical Perspective

Lecturer: Bob Mereu

**11:15am- Coffee Break**

**11:30am- Session I.3**

Topic: The Earth's Structure and Seismicity

Lecturer: Walter Mooney

**12:30pm- Lunch Break**

**1:45pm- Session I.4**

Topic: *Practical Session*

Lecturer: Bob Mereu

**2:45pm- Coffee Break**

**3pm- Session I.5**

Topic: Theoretical Seismology 1: Sources

Lecturer: George Choy

**4:15pm- Discussions**

**6pm- Dinner**

**8pm- TV Documentary: Nature Tech Earthquakes (*Optional*)**

**Day Two: Tuesday, May 16**

**SEISMOLOGY  
Seismic Theory & Applications**

**9am-** Session II.1

Topic: Theoretical Seismology 2: Wave Propagation

Lecturer: George Choy

**10am-** Session II.2

Topic: Structure & Interpretation of Seismograms 1: Waveforms and Hypocentral  
Locations

Lecturer: Walter Mooney

**11:00am-** Coffee Break

**11:15am-** Session II.3

Topic: Structure & Interpretation of Seismograms 2: Magnitude and Source Mechanisms

Lecturer: Walter Mooney

**12:15pm-** Lunch Break

**1:30pm-** Session II.4

Topic: *Practical Session*

Lecturer: Bob Mereu

**4pm-** Coffee Break

**4:15pm-** Session II.5

Topic: Damaging Effects of Earthquakes

Lecturer: Annabel Kelly

**5pm-** Discussions

**6pm-** Dinner

**8pm-** TV Documentary: Nature Tech Tsunamis (*Optional*)



**Day Three: Wednesday, May 17**

**SEISMOLOGY  
Pacific Tsunami Early Warning Center Exercise  
Global and Local Seismic Networks  
Instrumentation & Seismic Data Analysis**

**8am-** *Special Session:* Exercise Pacific Wave 06  
Location: National Disaster Warning Center

**12:30pm-** Lunch Break

*Training resumes at Department of Mineral Resources at 3 pm*

**3pm** - Session III.1  
Topic: Global & Local Arrays  
Lecturer: Bob Mereu

**4pm** –Session III.2  
Topic: Instrumentation, Recording systems, Data Transmission & Archiving  
Lecturer: Bob Mereu

**5pm-** Discussions

**6pm-** Dinner

**Day Four: Thursday, May 18**

**Earthquake Hazard Assessment**

**9am-** Session IV.1

Topic: Earthquake Forecasting

Lecturer: George Choy

**10am-** Session IV.2

Topic: Challenges in Observational Seismology in the Indian Ocean with special reference to the 2004 Sumatra-Andaman earthquake

Lecturer: Annabel Kelly

**11am-** Coffee Break

**11:15am-** Session IV.3

Topic: Web Resources for Earthquake Information (Hands-On Computer Lab Exercise)

Lecturer: Annabel Kelly

**12:15pm-** Lunch Break

**1:45pm-** Session IV.4

Topic: *Practical Session*

Lecturer: Bob Mereu

**3:15pm-** Coffee Break

**3:30pm-** Session IV.4

Topic: *Practical Session*

Lecturer: Bob Mereu

**4:30pm-** Session IV.5

Topic: Summary of seismology component of training course

Lecturer: Annabel Kelly

**5pm-** Discussions

**6pm-** Dinner

**Day Five: Friday, May 19**

**Tsunami Science, Warnings and Tsunami Warning Center Operations**

Pacific Tsunami Warning Center (Dr. Charles McCreery, Director)  
Japan Meteorological Agency (Koichi Nagasaka, Former Director-General; Yuji Nishimae,  
Senior Scientific Officer)  
IOC (Masahiro Yamamoto, Paris; Dr. Laura Kong, Director, ITIC)

**9am- Session V.1**

Topic: Tsunami Science – Generation, Propagation, Shoreline Impact

- a. Mechanisms (earthquakes, landslides, volcanoes, meteor impacts)
- b. Source Zones (Pacific Basin, Pacific Marginal Seas, Indian Ocean)
- c. Source Characteristics (wave period, directionality, size, complexity)
- d. Amplitude and Shoreline Impact (deep ocean, islands, spreading, reflections, attenuation, currents, number of waves, seiches, bores)
- e. Wave Observations, long wave theory)
- f. Tsunami travel-times, tides and their effects

Lecturer: PTWC (C. McCreery)

**9:45am- Session V.2**

Topic: Tsunami Warning and Mitigation Systems

- a. History & Mission – PTWS and globally
- b. System Components (communication, research, outreach, and education)
- c. Organizational structure – ICG
- d. TWS Partners (WMO, ISDR, Met. Services, Emergency management, FDSN/IRIS, GEOSS, etc)

Lecturer: IOC (M. Yamamoto)

**10:30am- Coffee Break**

**10:45am - Session V.2**

Topic: Component: Warning Guidance - Tsunami Warning Center Operations

- a. Objectives and Activities of Warning Centers - PTWC
- b. Guidance on developing and staffing new National Warning Centers - PTWC
- c. Data Networks required for earthquake monitoring and tsunami warning - IOC

Lecturer: PTWC, IOC

**12pm- Lunch Break**

**1:30pm- Session V.3**

Topic: Tsunami Warning Center Operations

- a. Reliability and Robustness
- b. Information Technology architecture
- c. Data and Message Communications

Lecturer: PTWC

**2:15pm** – Coffee Break

**2:30pm** – Session V.4

Topic: Tsunami Warning Center Data Processing (global / regional systems) - PTWC

Seismic Analysis

- a. TWC data processing history & background
- b. Signal acquisition and transmission format
- c. Disk writing format
- d. Earthquake locations and associations
- e. Magnitudes and mechanisms
- f. Alarm types and notifications

Tsunami / Sea Level Analysis

- a. Geographical Information system
- b. Tsunami travel-times
- c. Tsunami modeling and wave forecasting

Lecturer: PTWC

**4:30pm** – General Discussions

**6pm**- Dinner Break

**Day Six: Saturday, May 20**

**Tsunami Warnings and Tsunami Warning Center Operations**

**9:00am-** Session VI.1

Topic: Tsunami Warning Center Data Processing (national / local systems) - JMA

Seismic Analysis

- a. TWC data processing history & background
- b. Signal acquisition and transmission format
- c. Disk writing format
- d. Earthquake locations and associations
- e. Magnitudes and mechanisms
- f. Alarm types and notifications

Tsunami / Sea Level Analysis

- a. Geographical Information system
- b. Tsunami travel-times
- c. Tsunami modeling and wave forecasting

Lecturer: JMA

**10:45am-** Coffee Break

**11am -** Session VI.2

Topic: Component: Warning Guidance - Tsunami Emergency Response after Tsunami Warnings Issued (included hazards, shelters, etc)

- a. Objectives and Activities involved in Emergency Response - IOC
- b. Guidance on developing tsunami response - IOC
- c. Thailand Tsunami Emergency Response – Present and Future - NDWC

Lecturer: L. Kong, Thailand NDWC

**12pm -** Lunch Break

**1:30pm-** Session VI.3

Topic: Component: Tsunami Hazard Risk Assessment and Preparedness

- a. Hazard and Risk Identification of Vulnerable Communities
- b. Tsunami numerical modeling
- c. Inundation and Evacuation Maps

Lecturer: IOC or PTWC

**2:30pm-** Coffee Break

**2:45pm-** Session VI.4

Topic: Component: Tsunami Hazard Mitigation - Preparedness, Education, and Outreach (Earthquake Hazard Mitigation building codes and design guidance here)

- a. Preparedness - risk assessment, exercises and drills, structural mitigation
- b. Education and Outreach - reasons for, examples, and how carried out
- c. IOC Tsunami Teacher Resource Toolkit
- d. Thailand Preparedness Program and other initiatives – NDWC or other Agency

*Thailand Training Program in Seismology & Tsunami Warnings*  
*15 – 22 May 2006*

Lecturer: L. Kong, Thailand NDWC or appropriate Agency

**4:15pm-** Session VI.5

Topic: Discussion, Conclusions, and Recommendations

Lecturer: IOC (Kong, Yamamoto), PTWC, JMA

**5:15pm-** Closing

**Day Seven: Monday, May 22**

**Roundtable Discussion – Tsunami Warnings for Thailand**

**Participants:**

Thailand Government Representatives and other invited responsible organizations  
Pacific Tsunami Warning Center (Dr. Charles McCreery, Director)  
Japan Meteorological Agency (Koichi Nagasaka, Former Director-General; Yuji Nishimae, Senior Scientific Officer)  
IOC (International Tsunami Information Centre, Dr. Laura Kong, Director)  
Training Participants

**9am**            Opening  
                 Welcome by Thailand  
                 Welcome by IOC

**9:15am**        JMA's Tsunami Warning and Earthquake Information Service  
                 Koichi Nagasaka, Former Director-General, JMA

**10:15am**      Coffee Break

*The Morning Session will cover how the PTWC and JMA respond to earthquake and tsunami alarms, and include timelines for alarms, data receipt and evaluation, decision making for determining message content, and alert dissemination. Each Presentation is followed by 10-min Question-and-Answer and Discussion.*

**10:30am**      Tsunami Warning Center Operations - Scenarios  
                 Procedures of the Northwest Pacific Tsunami Advisory Center for the  
                 South China Sea Region – JMA  
                 Case Study: Exercise Pacific Wave 06 source – JMA  
                 Case Study: Other sources of concern – PTWC

**11:45am**      Tsunami Warning Center Operations - Scenarios  
                 Procedures of the IOTWS Interim System – PTWC  
                 Case Study: Northern and Southern Sumatra source – PTWC  
                 Case Study: Andaman-Nicobar Islands sources - JMA

**12:30pm**      Lunch Break

**2pm**            Recent developments and future plans of Thailand organizations –  
                 Thailand Agencies

**3pm**            Coffee Break

**3:15pm**        Panel Discussion – Opportunities and Challenges for Thailand

*Thailand Training Program in Seismology & Tsunami Warnings*  
*15 – 22 May 2006*

IOC (L. Kong), PTWC (C. McCreery), JMA (K. Nagasaka, Y. Nishimae)  
PDC (S. Goosby), Thailand (NDWC, TMD, others)  
5 min statements, followed by moderated discussion

***4:45pm***      Recommendations and Conclusions

***5pm***          Closing

***5:30 – 8 pm***      Farewell Dinner