ESCAP/WMO Typhoon Committee and WMO/ESCAP Panel on Tropical Cyclones
Training Workshop on Synergised Standard Operating Procedures for Coastal Multihazard Early Warning System
Nanjing, China, 9-11June 2014

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Organisation des Nations Unies pour l'éducation la science et la culture

Commission océanographique intergouvernementale

Organización de las Naciones Unidas para la Educación la Ciencia y la Cultura

Comisión Oceanográfica Intergubernamental

Организация Объединенных Наций по вопросам образования науки и культуры

Межправительственная океанографическая комиссия

Standard Operating Procedures for Tsunami Warning Systems

Tony Elliott
Head of ICG/IOTWS Secretariat
Intergovernmental Oceanographic Commission of *UNESCO*

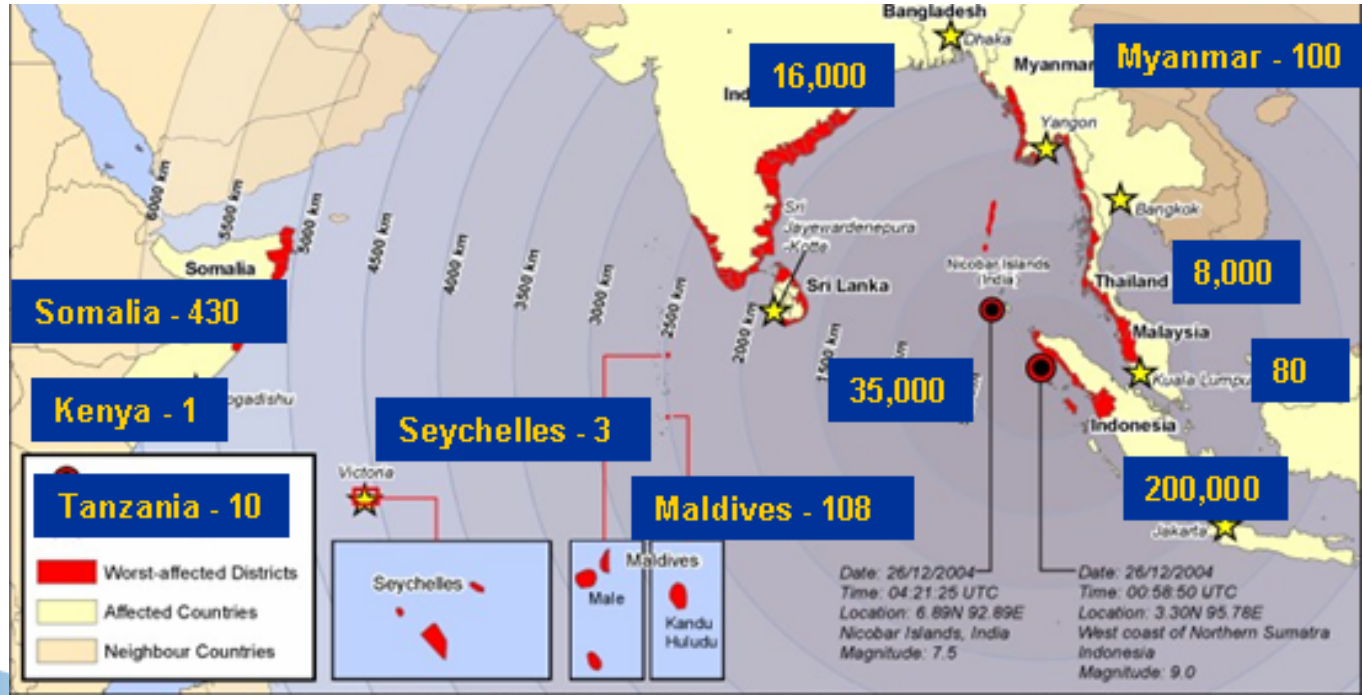
Outline

- Introduction to Regional Tsunami Warning Systems
- Tsunami hazard – description and some science
- Components and stakeholders in end to end tsunami warning systems
- Roles and Responsibilities at national level, Tsunami Warning Centre SOPs
- Information flow for coherent, integrated SOPs
- Discussion

26 December 2004

- c.230,000 Dead – Nations of the region react
- 2 international coordination meetings in early 2005
- IOC invited to lead TWS establishment
- ICG/IOTWS established by IOC Assembly, July 2005

11 countries
~230,000 deaths
1 million displaced



Countries that lost citizens while abroad (Indian Ocean Tsunami 26 Dec 2004)

Name of country	Deaths (Missing)	Deaths and Missing combined	Deaths per million inhabitants
Sweden	554 (17)	571	58.10
Germany	539 (13)	552	6.75
Finland	179	179	33.40
United Kingdom	143 (6)	149	2.40
Switzerland	106 (6)	112	14.40
France	95	95	1.45
Austria	86	86	10.30
Norway	84	84	17.30
Denmark	45 (1)	46	8.32
Italy	40	40	0.66

(Wikipedia 22/5/2014)

++ casualties from an additional 31 countries

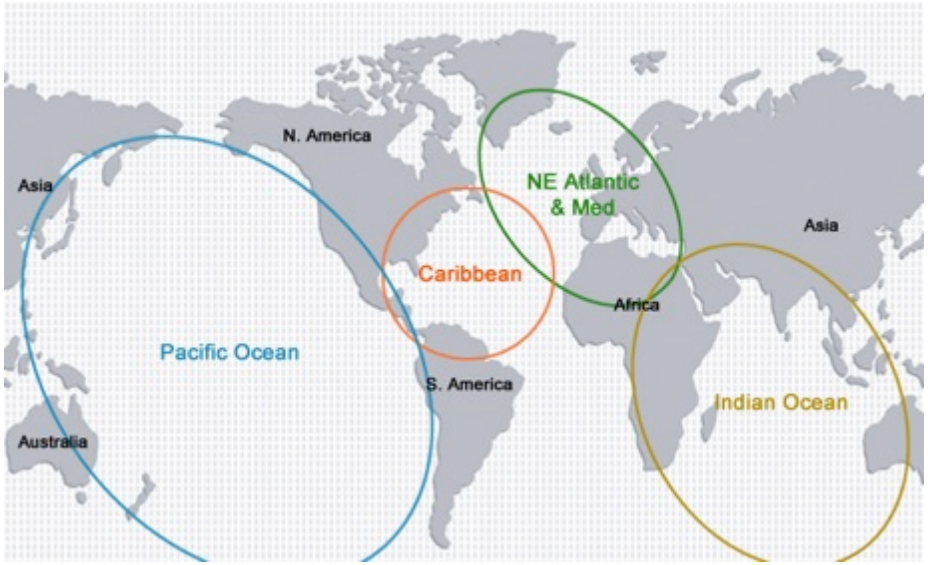
11 Deadly Tsunamis Since 2004

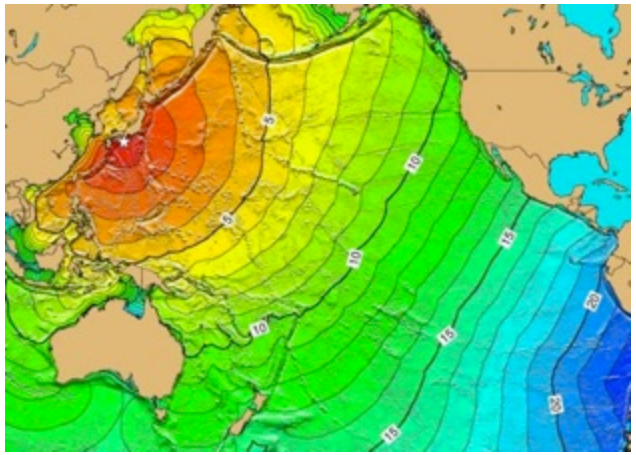
- Pacific Ocean: 6 Tsunamis killing over 17,000 people
  - 2007 (2), 2009, 2010, 2011, 2013
  - [Note 2014 Chile Tsunami - no direct deaths due to tsunami but due to earthquake]

- Indian Ocean: 5 Tsunamis killing over 230,000 people
  - 2004, 2005, 2006 (2), 2010

Tsunami Warning Systems

- Pacific since 1965
- 2004 tsunami in Indian Ocean illustrated need for more
- IOC mandated to establish three more TWS
    - ICG IOTWS
    - ICG CARIBE EWS and
    - ICG NEAMTWS



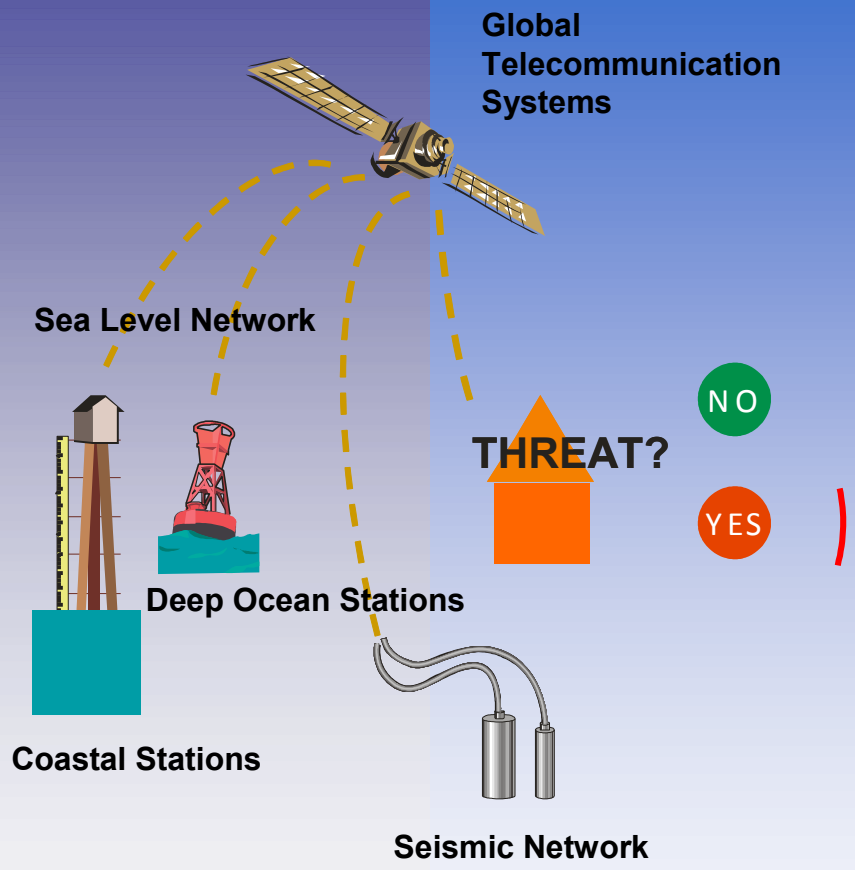


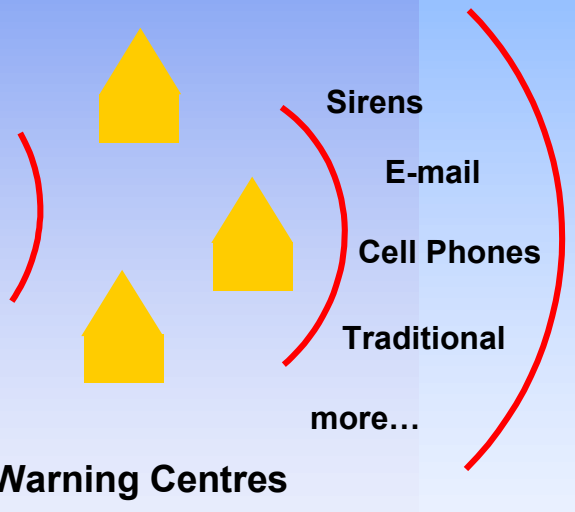
Regional Tsunami Warning System

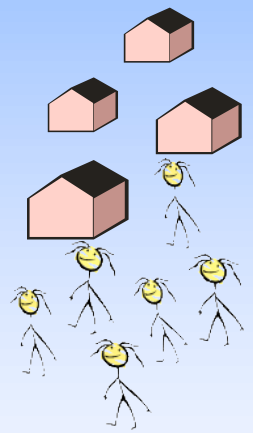
- Fully owned by the countries
- Based on international and multilateral cooperation, with governance provided by IOC
- Based on open and free data exchange
- Protects all countries in the region
- Transparent and accountable to all countries

How does it function?

- Based on joint operation of international networks of detection and monitoring connected with RTSPs/NTWCs
- Each nation is responsible for issuing warnings in their territory and for protecting its own population.
- National warning centres must have strong links with emergency preparedness authorities (national, provincial and local)





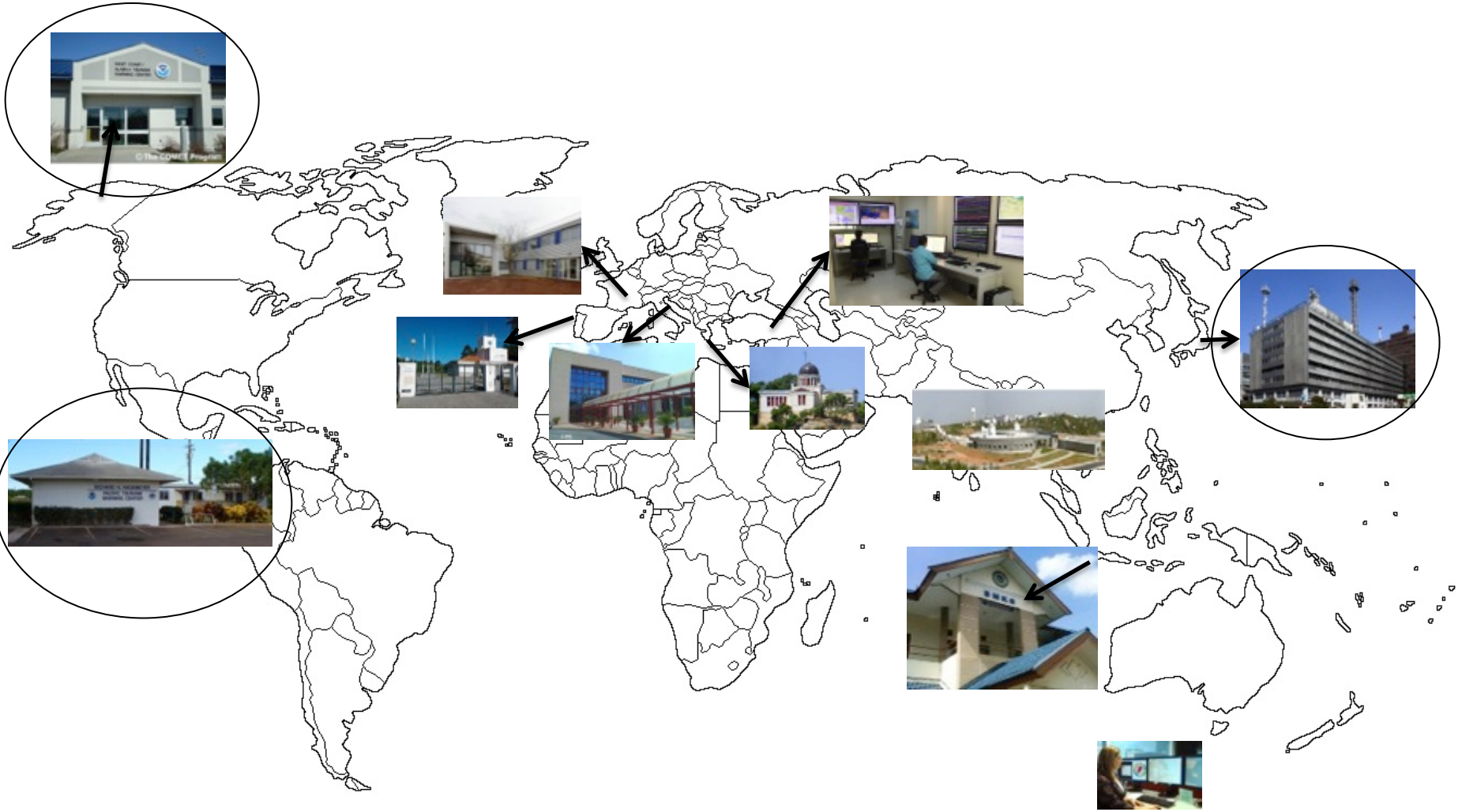


LIVES SAVED

Hazard Detection & Forecast ⟺ **Threat Evaluation Alert Formulation** ⟺ **Alert Dissemination Public Safety Msg** ⟺ **Preparedness & Response**

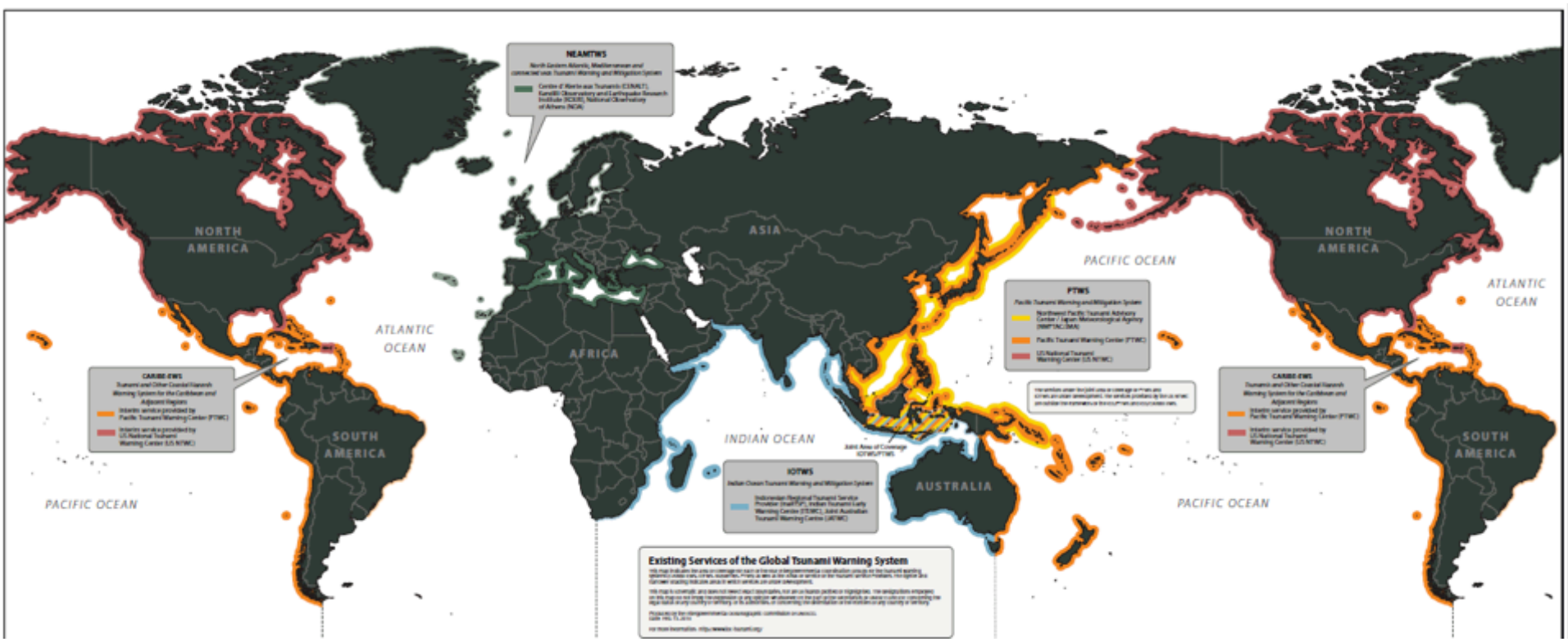
Regional **National** **Local**

Regional Tsunami Service Providers



8 RTSPs established since 2004 IO Tsunami

Existing Services of the Global Tsunami Warning System



IOC

Questions?

Tsunami: Japanese word meaning ‘harbour wave’

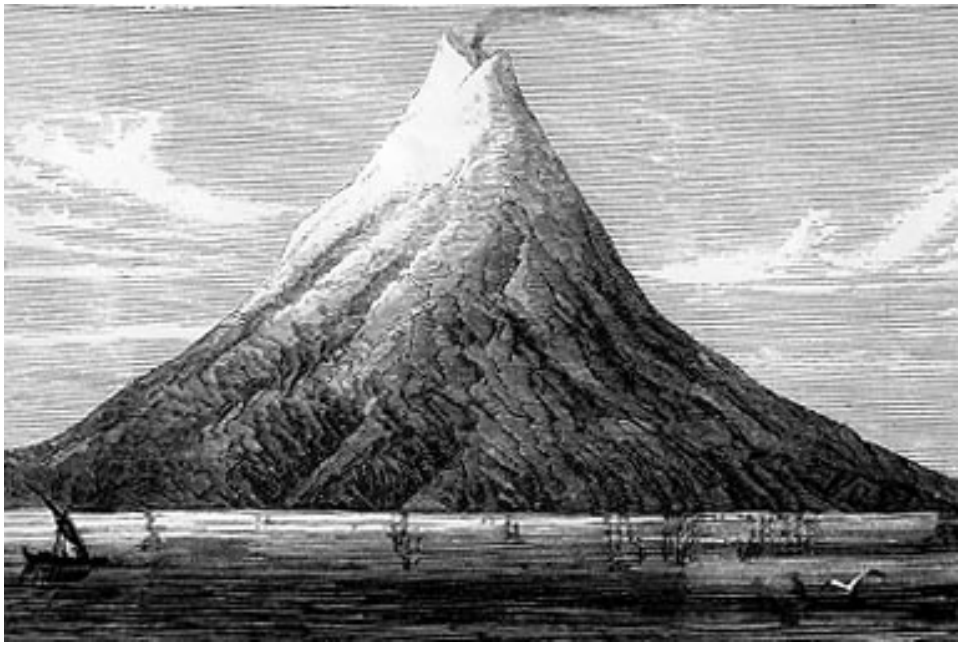
津波

Term coined by fishermen returning to port to find the harbour area devastated, although they had not been aware of any wave in the open water.

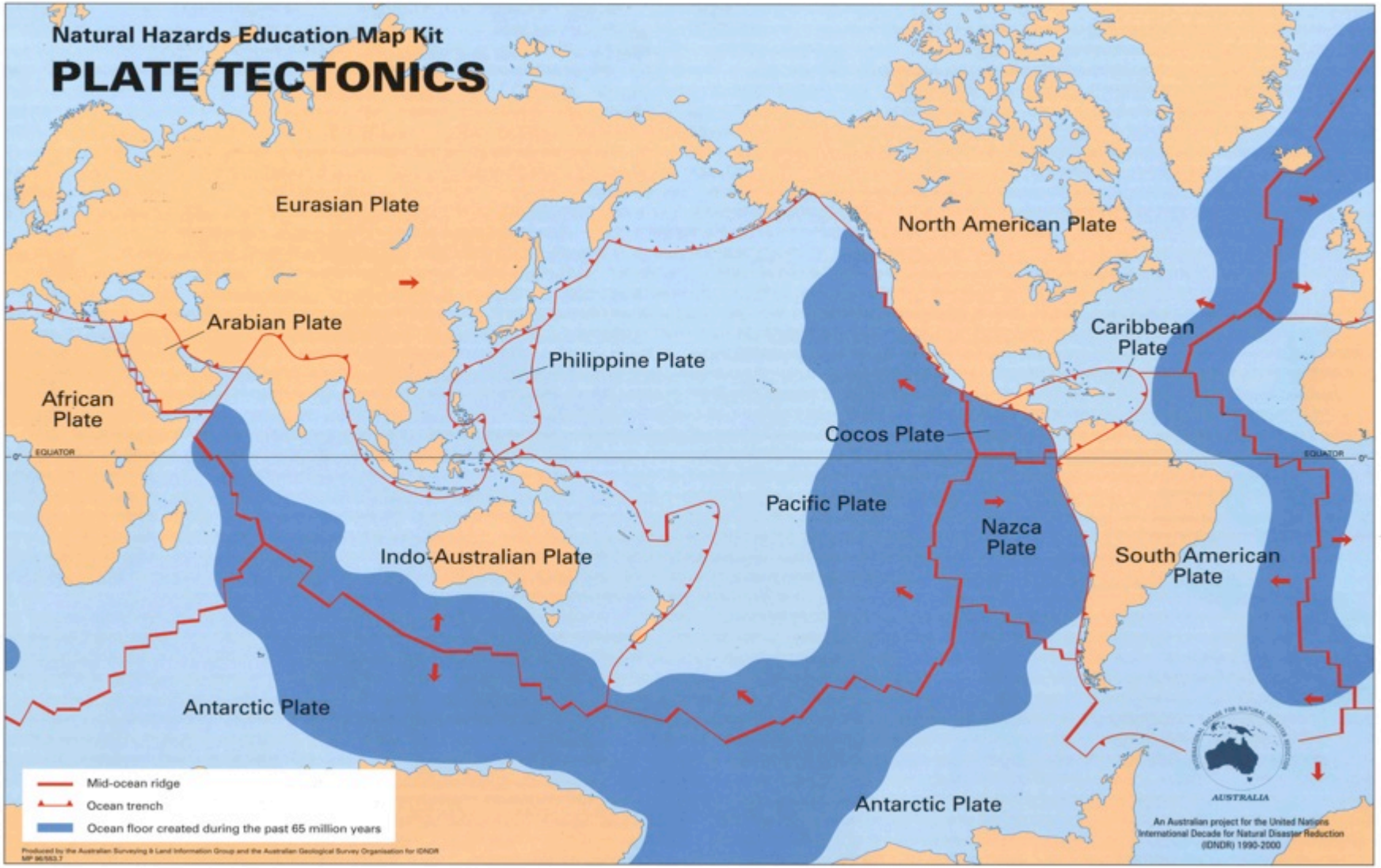
Recorded Causes of Tsunami

Cause	Events	%	Death toll
Landslide	65	4.6	14661
Earthquake	1171	82.3	390929
Volcano	65	4.6	51643
Unknown	121	8.5	5364
Total	1422	100	462597

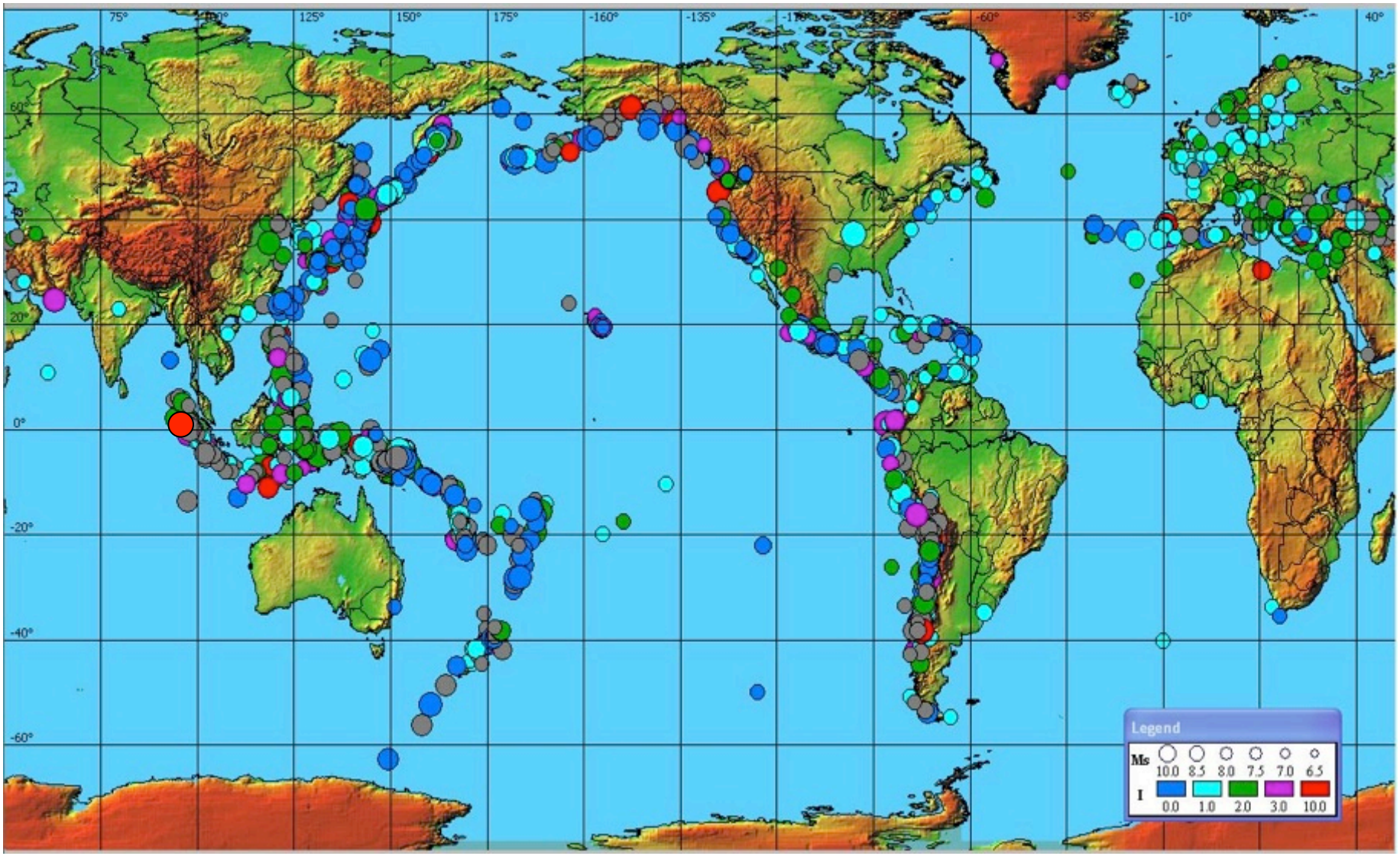
Causes of tsunami in the Pacific over last 2,000 years (IOC, 1999)



An early 19th century illustration of Krakatoa


Natural Hazards Education Map Kit
PLATE TECTONICS
Eurasian Plate
North American Plate
Arabian Plate
Philippine Plate
Caribbean Plate
African Plate
Cocos Plate
EQUATOR
EQUATOR
Pacific Plate
Nazca Plate
Indo-Australian Plate
South American Plate
Antarctic Plate
Antarctic Plate
Mid-ocean ridge
Ocean trench
Ocean floor created during the past 65 million years
AUSTRALIA
An Australian project for the United Nations International Decade for Natural Disaster Reduction (IDNDR) 1990-2000

IOC



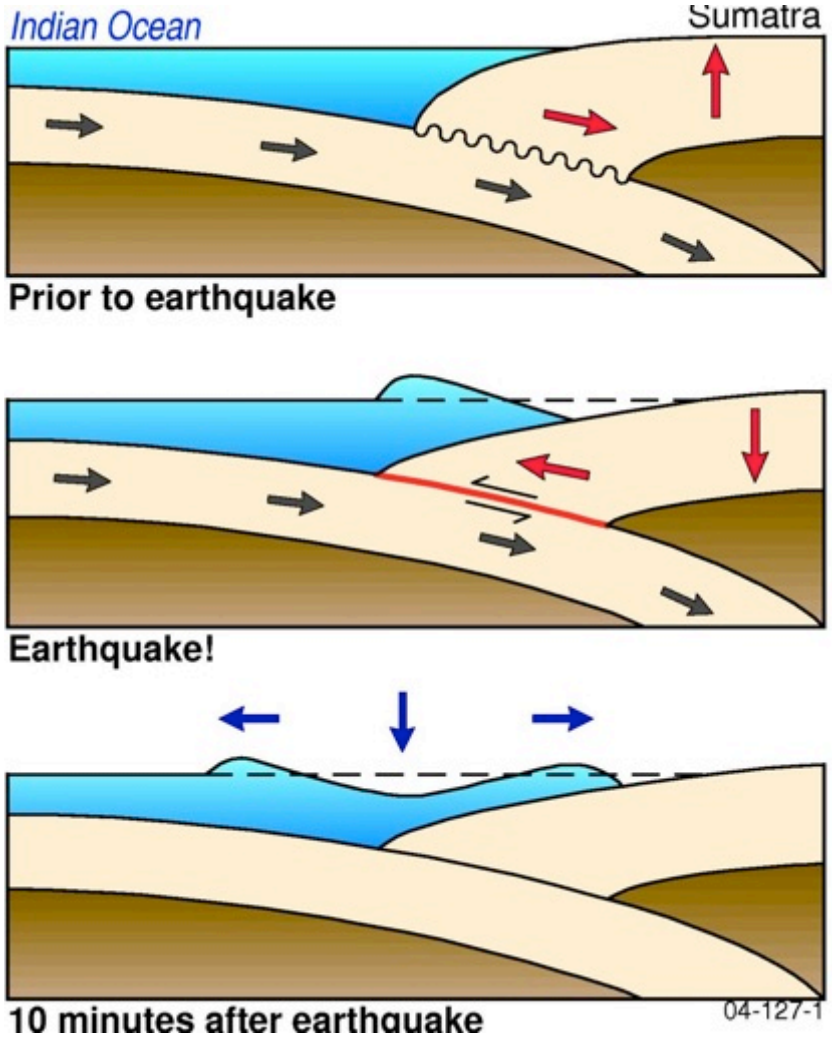
Tsunami Sources in the world

80 events from 1628 BC to 2005)

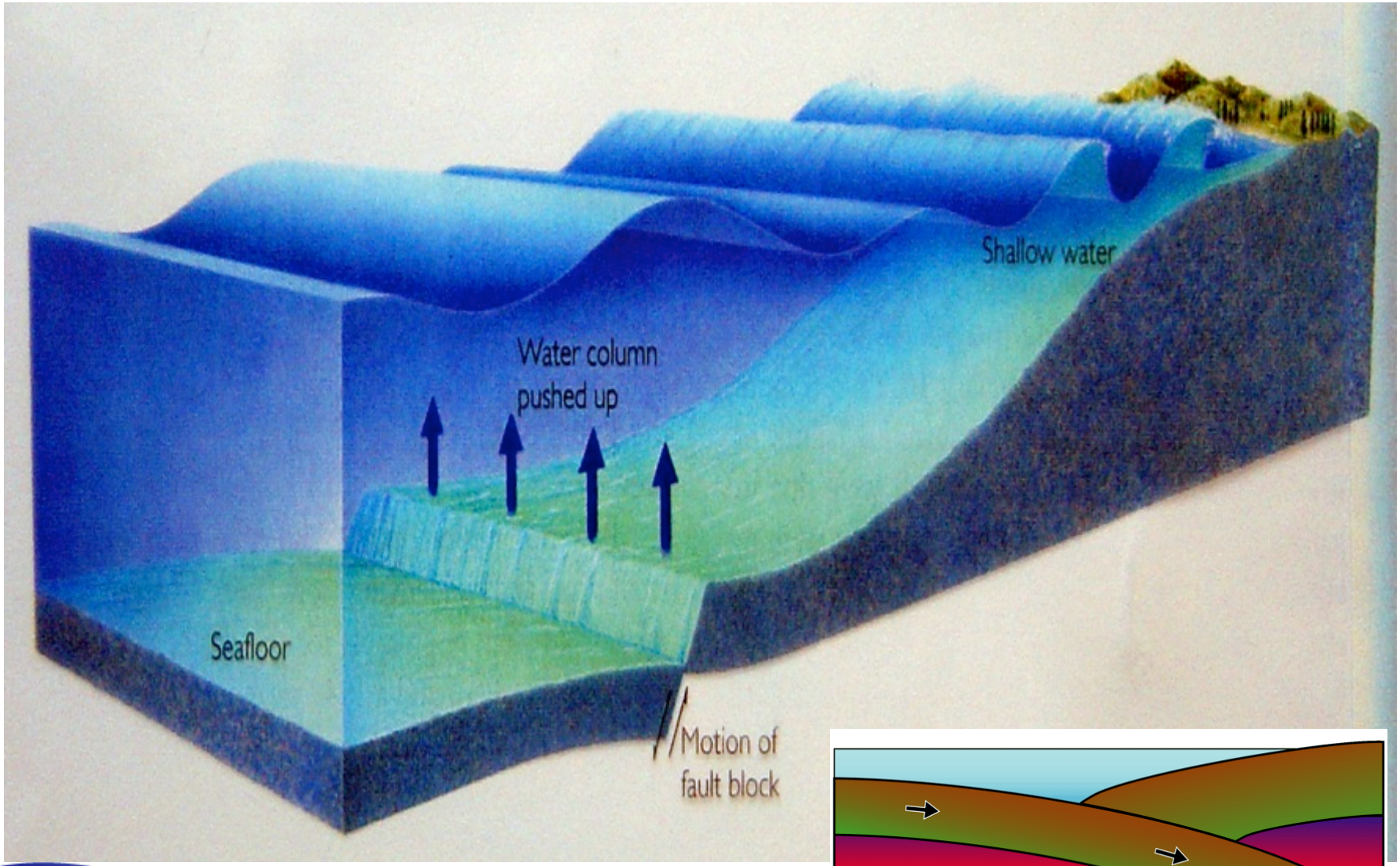
IOC

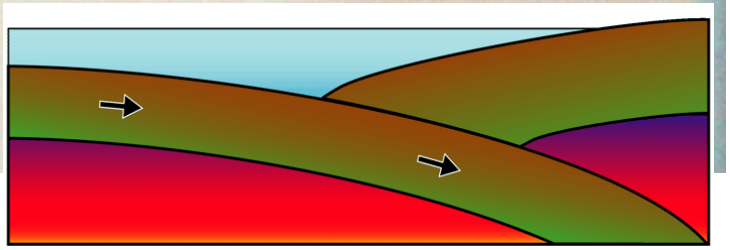
Source, ITDB, 2005

How do Earthquakes Cause Tsunami?

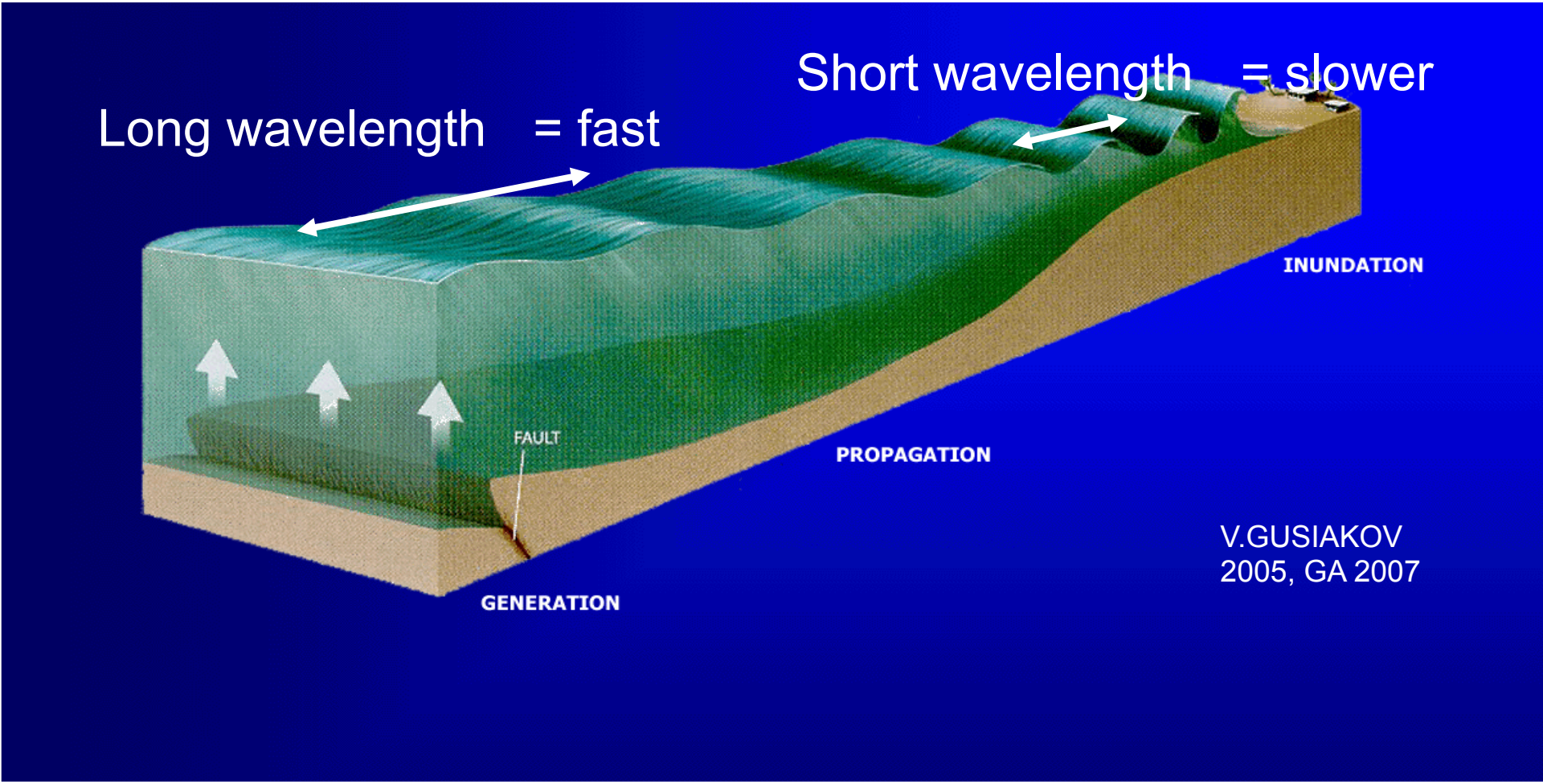


- Interplate friction causes Indian Ocean Plate to pull Sunda Plate down as it subducts, storing elastic strain energy as the Sunda Plate is deformed
- Strain energy is released when stress on the interplate contact exceeds frictional strength, causing it to rupture in an earthquake.
- The seafloor is deformed, vertically displacing a huge mass of water, which then propagates outward as a tsunami


Shallow water
Water column
pushed up
Seafloor
Motion of
fault block

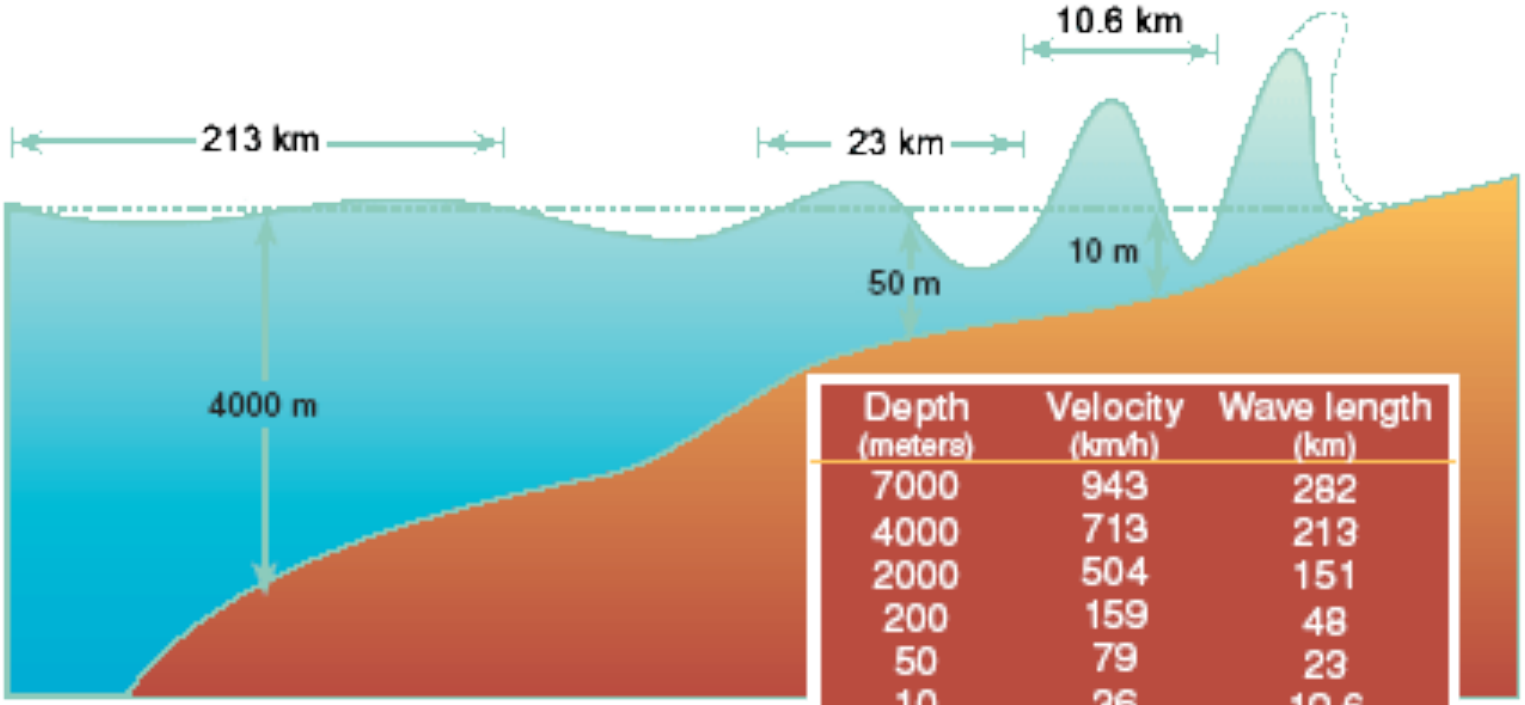


Shoaling


Long wavelength = fast
Short wavelength = slower
INUNDATION
FAULT
PROPAGATION
GENERATION
V.GUSIAKOV
2005, GA 2007

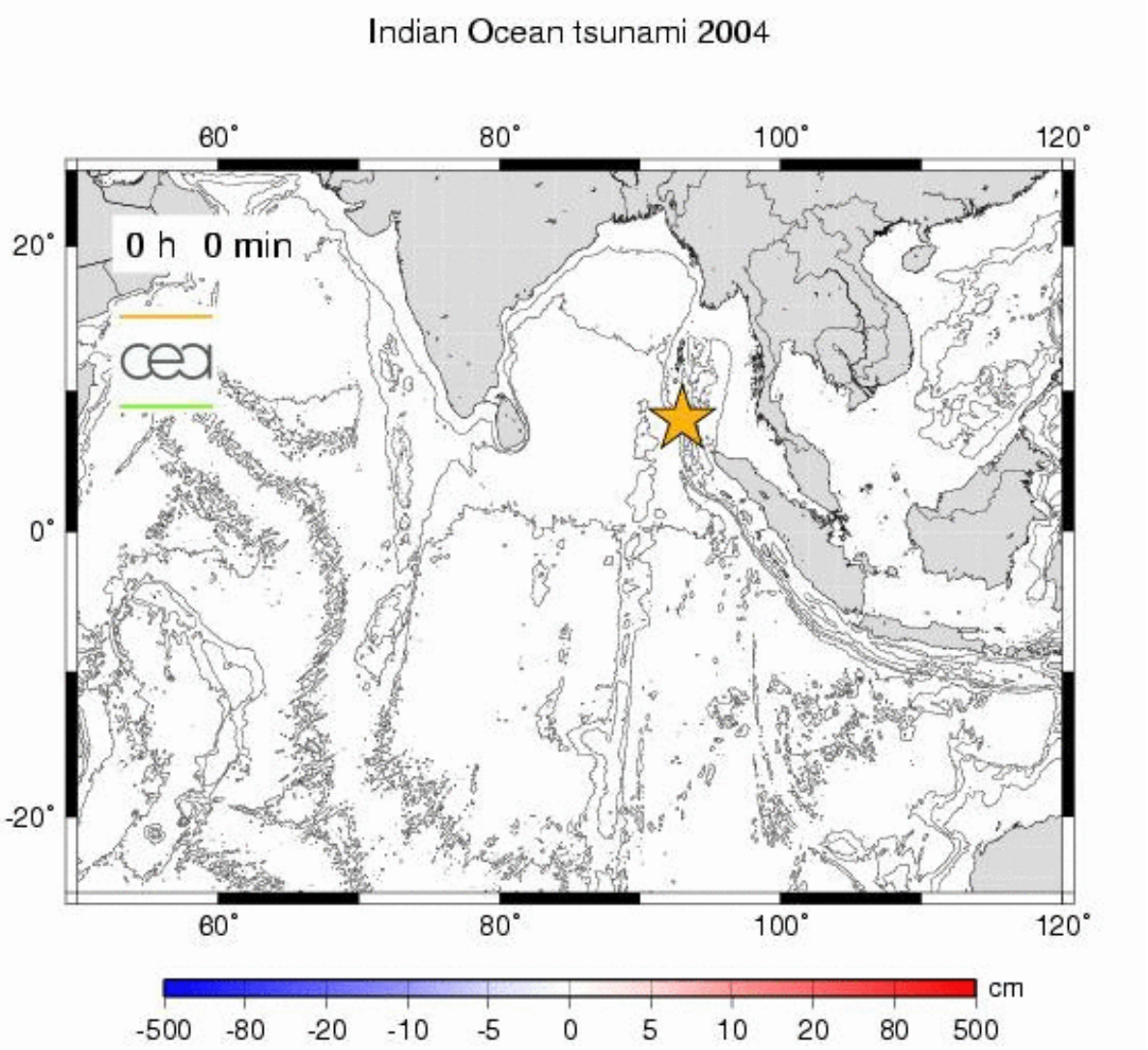
Tsunami Physics

- Tsunamis behave as “shallow water” waves, ie. Ratio between water depth and wave length is very small ($d/L < 0.05$)
- Speed of tsunami wave is = $(gd)^{1/2}$
- Amplitude in deep water small, < 1m
- Wavelength very long, 100 – 500km
- Energy loss ~ 1/wavelength
- Energy travels through water column
- In deep water, tsunami wave travels large distance at great speed with little energy loss

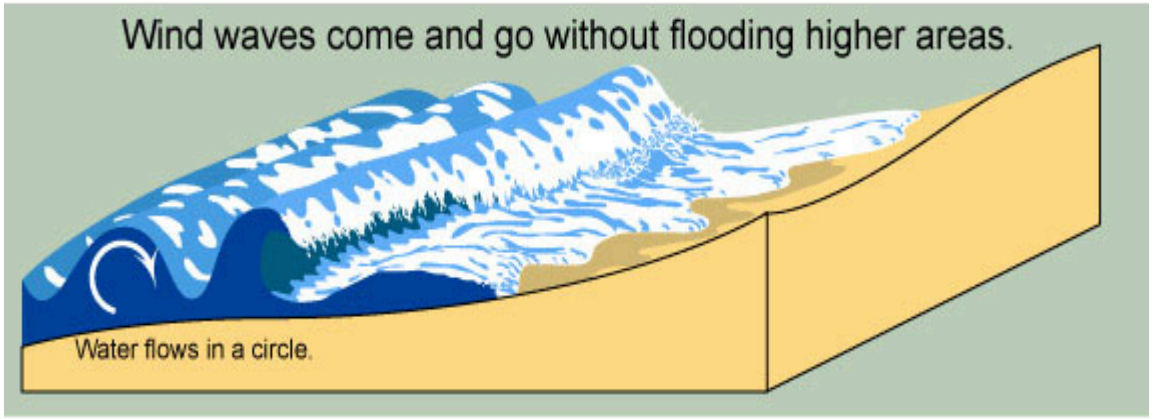


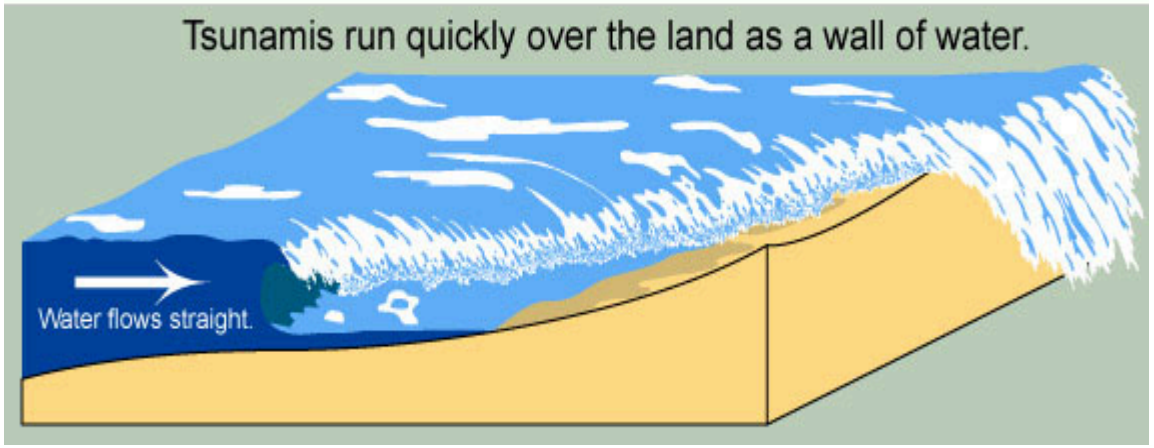
Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	213
2000	504	151
200	159	48
50	79	23
10	36	10.6

Model Simulation



Tsunami versus wind generated waves





Courtesy: University of Washington

Questions?

End-to-End Tsunami Warning Systems

Upstream

- Detection, verification, threat evaluation, tsunami forecast, warning dissemination

Downstream

- Delivery of public safety message.
- Initiate national counter-measures
- Prepare and implement standardised reaction

Goal – same quality every time

IOC

CONOPS and SOPs

Concept of Operations (CONOPS)

- High level document
- Describes system components
- Assigns responsibilities

Standard Operating Procedures

- Each system component and responsibility requires an SOP
- Each SOP separate but synchronised

Without CONOPS, SOPs may be unaligned or uncoordinated activities and actions

Concept of Operations – Typical contents

- Purpose of the concept of operations
- Roles and Responsibilities for
  - Tsunami risk assessment
  - Receipt and assessment of RTSP bulletins
  - Dissemination of warnings to NDMO and other response agencies
  - Alerting of local communities and mariners
  - Evacuations
  - Media management
  - Public Education
- Warning Concept (thresholds, threat levels etc)
- Types of warnings (including when each will be used)
- Glossary

What are SOPs?

Based on US Environmental Protection Agency Manual

- Set of written instructions for routine/repetitive organization activities. Procedure followed in an emergency.
- Detail work processes conducted/followed within organization.
- Document way activities performed for consistent conformance to system requirements and organisation's mission.

Why are SOPs important?

- Foundation of effective, reliable warning systems
- All warning systems require SOPs, but for tsunami, rapid evaluation, warning and response is essential to save lives
- In an end-to-end system, communications links between stakeholders must be robust or warning chain will be broken
- SOPs should be developed, practiced and modified as necessary – a “living document”

SOP Working Definition

"A description and procedure on agreed steps by institutions used in coordinating who, what, when, where and how for tsunami early warning and response"

From Indonesia Local SOP Workshops: Capacity Building for Development of Local SOPs for Tsunami Early Warning and Response. 2006-2007

End-to-End Tsunami Warning

Stakeholders

- Regional Warning Centres (RTWC, RTSPs etc)
- National Tsunami Warning Centres (NTWC)
- Disaster Management Offices (DMO)/ Local Authorities
- Emergency Services
- Media
- Public

Regional Warning Centres

(PTWC, US NTWC (formerly WC/ATWC), RTSPs etc)

- Regional Monitoring & Detection (24/7)
- International collation/sharing of data
- Issue Regional Threat Advice to National Tsunami Warning Centres
- Cancel Regional Threat

National Tsunami Warning Centres (NTWC)

- Local (Country-specific) Monitoring & Detection (24/7) using regional or national data streams
- Receive RTSP Alerts
- Assess information to determine local threat
- Issue Warnings to DMO's, media & agencies
- Cancel National Warnings
- Research & Public Education (with stakeholders)

Disaster Management Offices

(National and Local Authorities)

- Receive Warnings from NTWC
- Activate local public alert systems as needed
- Decide on & Manage Evacuations
- Communicate ‘All Clear’ (safe to return)
- Signage
- Public Education (with other stakeholders)

IOC

Emergency Services

- Support DMO/Local Authorities with
  - Public alerting
  - Evacuation
  - Law & Order
  - Response after tsunami has struck
    (Search and Rescue, etc)

Media (radio, television)

- Convey Official Warnings (National & Local)

  But also:

- Convey Unofficial Warnings

  Therefore:

- Can cause or counter public response

International media can mis-report warning regions/ countries causing public confusion

Public

- End Receiver of Warnings
- Convey Official and Unofficial Warnings
- To minimize their confusion, they must be educated to understand:
  - Official Warnings (how will they be warned)
  - Natural Warnings (what to look out for)
  - Where and What to do
    - Evacuation zones
    - Routes & Safe zones
  - How to respond if evacuation zones are not defined

Source:

giz | PROTECTS

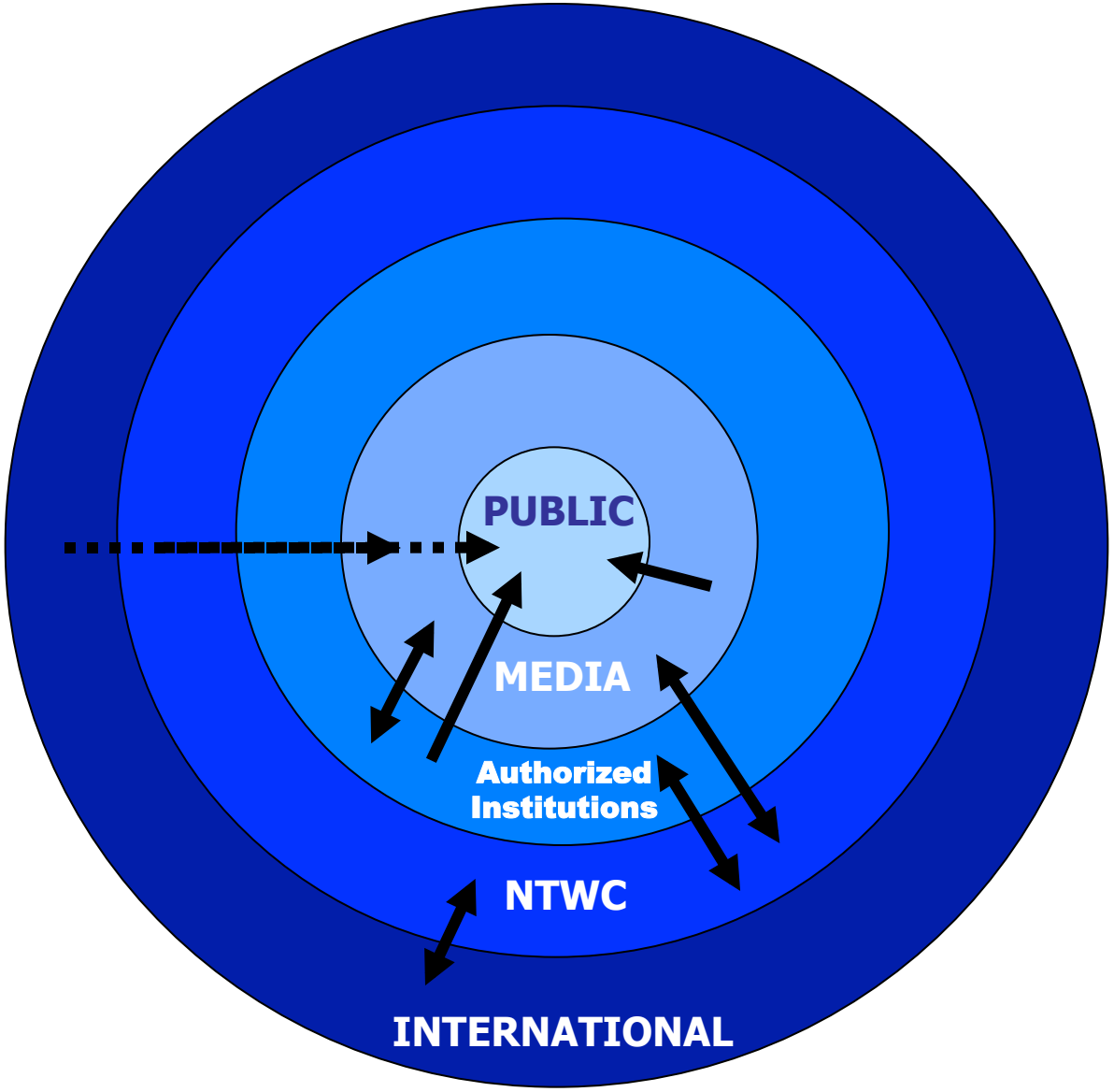
"Surviving a tsunami is a matter of getting out of the reach of tsunami waves and inundating waters in time"

UNESCO IOC

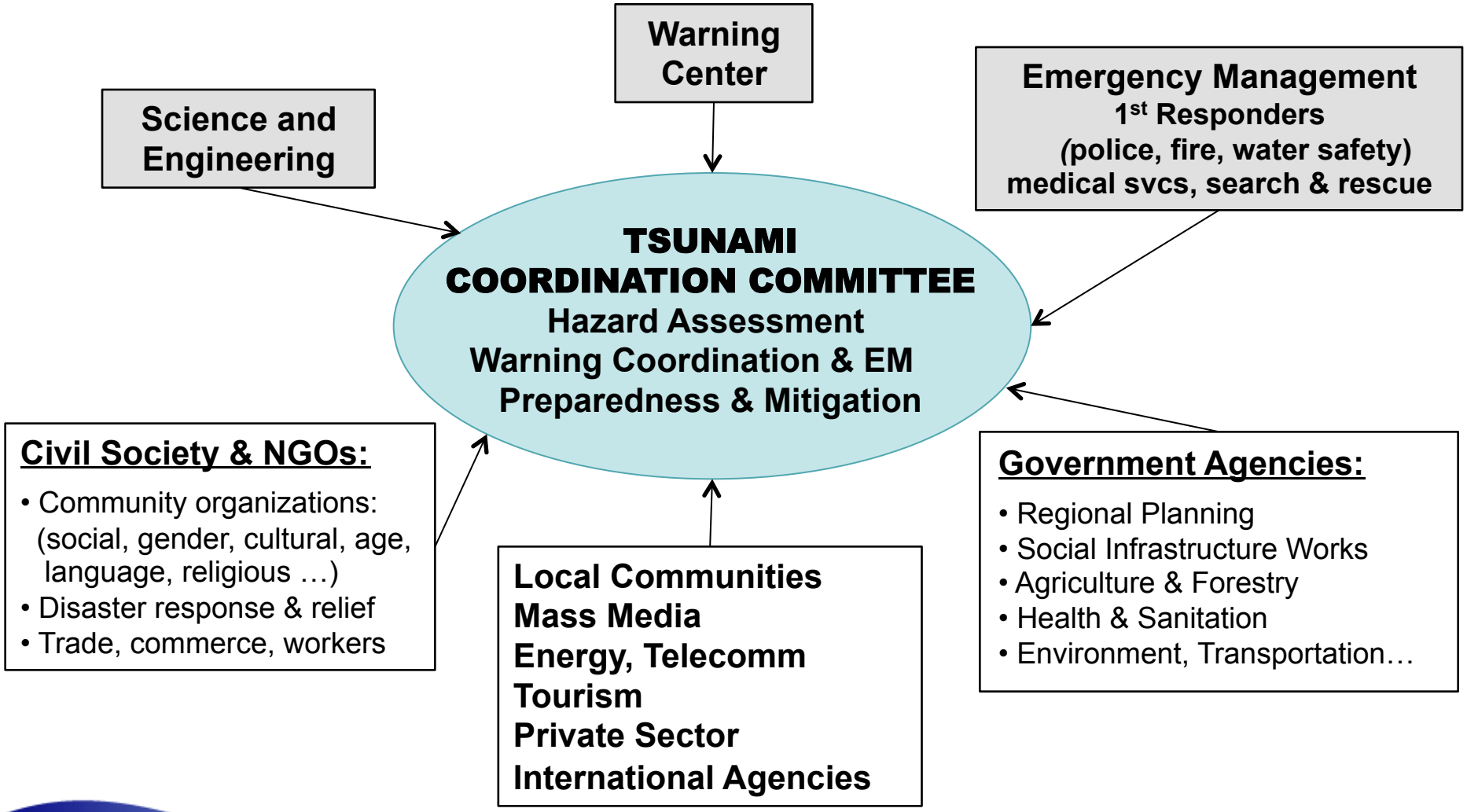
Official Warning to the Public

Public must understand:

- **How will they be warned**
- **How to react and respond**
- **Where to go (evacuation zones, routes & Safe zones)**



Stakeholder Coordination is Essential!



Stakeholders Roles & Responsibility Matrix

Roles & Responsibility Matrix

AGENCY	CONTACT INFO	LAW ENFORCEMENT	FIRE SUPPRESSION	EMERGENCY MANAGEMENT SERVICES	MEDICAL SERVICES	PUBLIC WORKS COMMUNICATIONS	SEARCH & RESCUE	SOCIAL SERVICES	HUMANE/ RELIEF	TRANSPORTATION	WARNING COORDINATION	INFORMATION PUBLIC	INFORMATION PUBLIC	RE SUPPRESSION FINANCE/ ADMIN

Questions?

Roles and Responsibilities of NTWCs

- Responsible for making decisions and issuing tsunami warnings to its communities
- Establish threat levels and develop SOPs for the corresponding jurisdictions. Utilize RTSP products for initializing inundation model output/selecting inundation scenarios
- Conduct hazard mapping and risk assessments using source hazard information (e.g. historic/potential earthquakes, volcanoes) inundation models/maps and vulnerability assessment
- Provide information/warnings and work with emergency management authorities to determine threat zones and develop/select appropriate evacuation maps

SOPs for Emergency Response

- The success of any tsunami early warning system will be measured by its ability to rapidly move people out of harms way.
- Disaster Managers are responsible for developing Standard Operating Procedures (SOP) for receipt of different types of tsunami messages.
- Standard Operating Procedures (SOP) will help communicate warning messages quickly to the public.
- Understanding of the various types of tsunami messages and implementation of action steps are linked via SOPs.

What to Consider

- National Tsunami Warning Centre:
  - Coordination and information flow (type, content, timeline) with NDMO
  - Iterative process (warning, update, cancellation)

- Tsunami Emergency Response:
  - DMO/EOC receipt, interpret, decide, notify
  - Notify Responders, Decision-makers, Public
  - Recommend Public Safety Action
  - Implement / coordinate Action
  - Inform on ‘All-Clear’ for safe return
  - Initiate Search-and-Rescue, etc.

Different Types of SOP Documents

1. Official SOP documents for management purposes

2. Comprehensive TW operations SOP documents with many details for study and reference during non-crisis

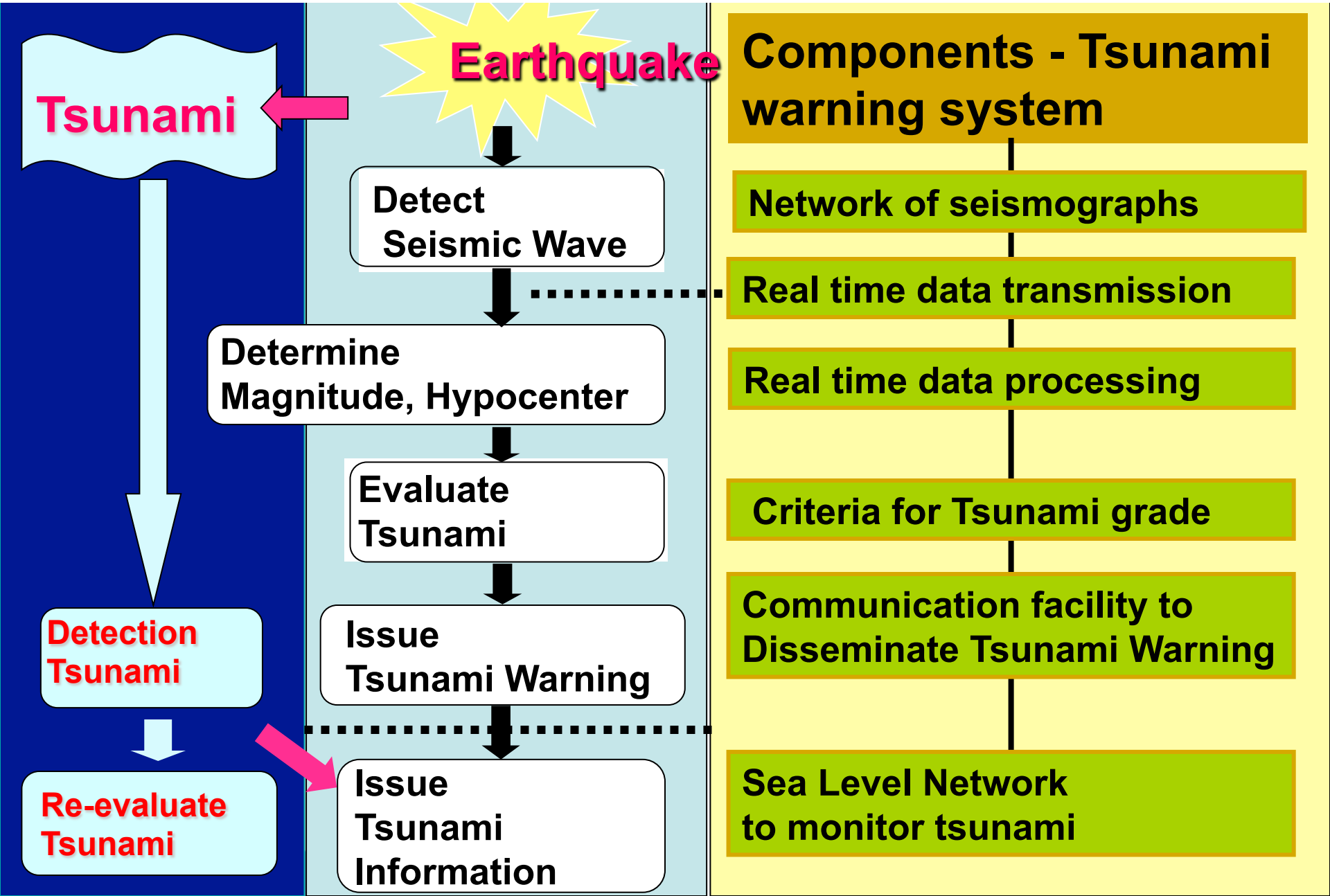
3. Quick-Reference SOP documents for reference during crisis

4. Systems SOP documents so recipients understand TWC/TER SOP and what to expect (Users Guide)

Official SOPs for Management

- Directives
  - **TWC Performance Expectations**
  - **Roles & Responsibilities / Concept of Operations**
  - **Maintained by Parent Organization**
  - **Formal Review / Change Process with Organizational Stakeholders**
- Station Duty Manual
  - **Duty Staff Performance Expectations**
  - **Maintained by TWC Management**
  - **Includes Tasks outside Crisis Operations**
  - **Formal Review / Change Process with Staff**

Tsunami Warning Centre Operations



TWC Operations - What SOPs should cover

- SOPs are Living Documents
- Main NTWC Characteristics
  - Fast
  - Accurate
  - Reliable
  - Effective
- Main NTWC Activities
  - Seismic Data Collection and Analysis
  - Sea Level Data Collection and Analysis
  - Decision-Making Tools and Procedures
  - Message Creation and Dissemination

For Warning Centres, SOPs are not just about what to do in an Earthquake.

They should also be geared to maintaining:

100% Operational Reliability

1. Data availability monitoring
2. Data quality monitoring
3. Maintenance and repair priorities
4. System Alteration Procedures
5. System Failure Procedures

Long Term Readiness:

1. Communication Tests
2. Table-top Exercises

TWC Operations Manual - Reference during non-crisis

- Most Detailed
- Steps to Carry Out
  - How ? Why ?
- Logical Flow
  - Flow Charts, Timelines
- Background Information
  - Scientific Basis
  - Organizational Basis
  - Definitions
- Format
  - Paper, Electronic (Web Based)

Different Types of SOP Documents

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Quick Reference SOPs - Crisis mode

- Timeline-driven activities
  - Need to act rapidly (minutes)
    >> there is no time to read detailed manual !
  - e.g., How much time do you have?
    What information is wanted?
  - Flow Charts describe overall flow, but Checklists allow faster response

- Criteria Tables & Checklists
  - What to use / What to look at
  - What is the action required?
  - When is the action needed by?
  - What are the steps/procedures not to forget?
  - Who to notify (with phone numbers, etc)?

General TWC SOP during an Event

0. EQ!!! - Digital Alarm - Duty Staff alerted

1. Detect and Analyze Large Earthquake
2. Determine Tsunami Hazard based on Pre-Determined Criteria
3. Issue Initial Message
4. Further Seismic Analyses
5. Detect and Analyze Tsunami Signals
6. Re-evaluate Tsunami Hazard
7. Issue Additional Message
8. Repeat Steps 4-7 until Threat Passed
9. Cancellation or Final Message

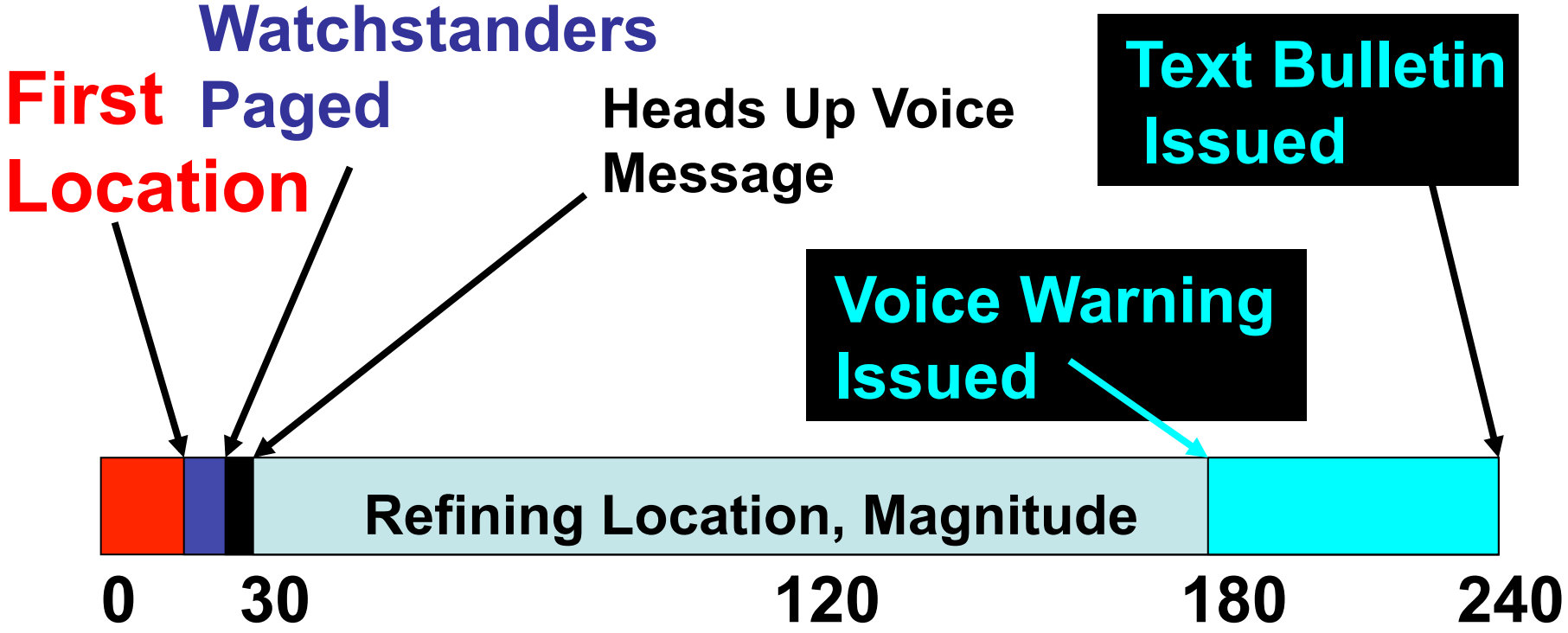
Event Operations - Timeline-driven

CASE 1. Center with Real Time Seismic Processing, Local Earthquake/Tsunami

STEP	TIME since EQ*	ACTIVITY	ACTION AND PROCEDURES
1	1 min	Seismic Alarm Trigger	• Feel earthquake and respond, receive phone call or other • Alarm sounds from automated seismic processing system • For a strongly felt earthquake (greater than Modified Mercalli Intensity Scale VI), alert should be issued immediately to the public and national disaster management or emergency operations centers advising to clear the beach.
2	2 min	Earthquake Review	• Review/update automatic phase picks and solution • Perform Interactive analysis if required • Highest priority for review is earthquake magnitude and focal depth
3	3 min	Tsunami Threat Decision Making	• Calculate tsunami travel times to nearest coasts. • If tsunami simulation database is operational, expected tsunami threat area and heights are determined. If no tsunami simulation database, earthquake magnitude and depth criteria are used as proxy for tsunami threat height and area. • Tsunami Threat threshold criteria should be pre-decided using historical and other science data.
4	5 min	Issuance of warning and related tsunami information	• If warning thresholds (for earthquake magnitude or expected tsunami height) are exceeded, issue warning to tsunami-threatened areas immediately. For warning, issue expected tsunami arrival times at forecast points.
5	7 min	Re-analysis	• Monitor sea level data (coastal run-up, coastal sea-level, deep-ocean gauges) • Re-evaluation of focal parameter obtained Step 2 using additional data.

Earthquake in Hawaii Region

Timeline to Issue Initial Warning Bulletin



Time in Seconds

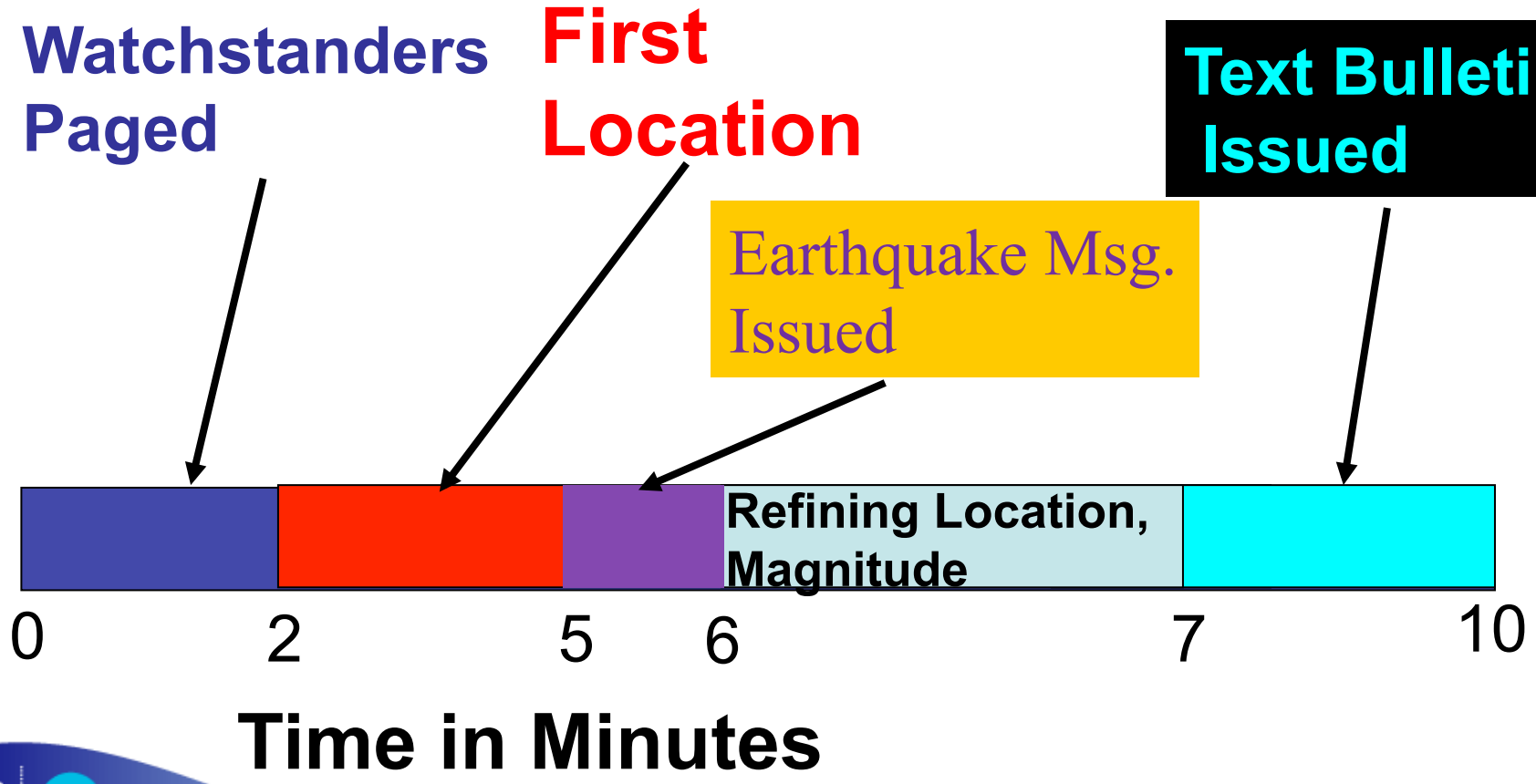
Event Operations - Timeline-driven

CASE 2: Center with Real Time Seismic Processing, Distant Earthquake/Tsunami

STEP	TIME since EQ*	ACTIVITY	ACTION AND PROCEDURES
1	3 min	Seismic Alarm Trigger	• Alarm sound from an automatic seismic processing system • Information provided by international centers; PTWC, WC/ATWC, JMA, WDC-Seismology-NEIC, GFZ??
2	10 min	Earthquake Review and Sea Level monitoring for tsunami generation	• Review/update automatic phase picks and solution, including addition of other international seismic stations • Calculate tsunami travel times to nearest international sea level stations and national territory • If tsunami travel time to the national territory is within the predefined time, GO to STEP 3. • Continue to monitor sea level data located near the epicenter. • If there is enough time, NTWC shall issue Information that event is under evaluation for the tsunami threat to the national territory. • (If no tsunami is observed in the near source region, Information is issued that there is no tsunami threat.)
3	13 min	Tsunami Threat Decision Making	• Decide on tsunami threat (height and area) based on pre-decided criteria, depending on whether tsunami simulation database exists or not; estimated tsunami • If tsunami is observed at nearby sea level stations, evaluate a tsunami magnitude based on the distance and observed tsunami height.
4	15 min to hours	Issue warning and related information	• If warning thresholds (for earthquake magnitude or expected tsunami height) are exceeded, issue warning to tsunami-threatened areas immediately. For warning, issue expected arrival times at forecast points. • If very distant, advise and wait until threat closer for warning.

Earthquake Outside Hawaii Region

Timeline to Issue Initial Bulletin



Different Types of SOP Documents

1. Official SOP documents for management purposes

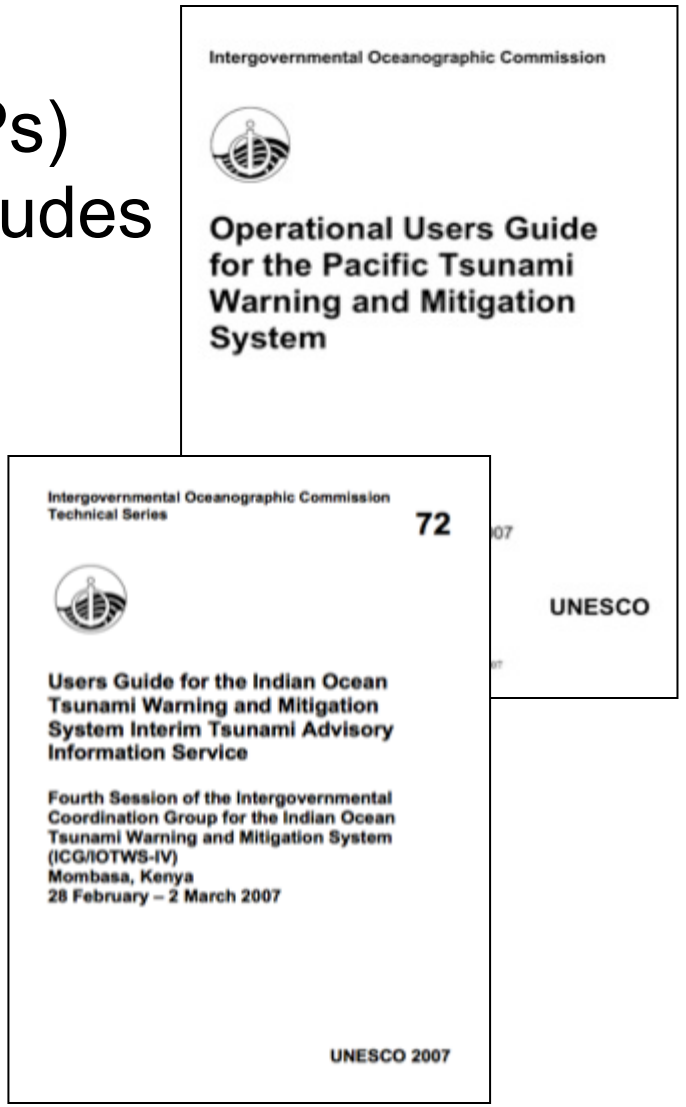
2. Comprehensive TW operations SOP documents with many details for study and reference during non-crisis

3. Quick-Reference SOP documents for reference during crisis

4. Systems SOP documents so recipients understand TWC/TER SOP and what to expect (Users Guide)

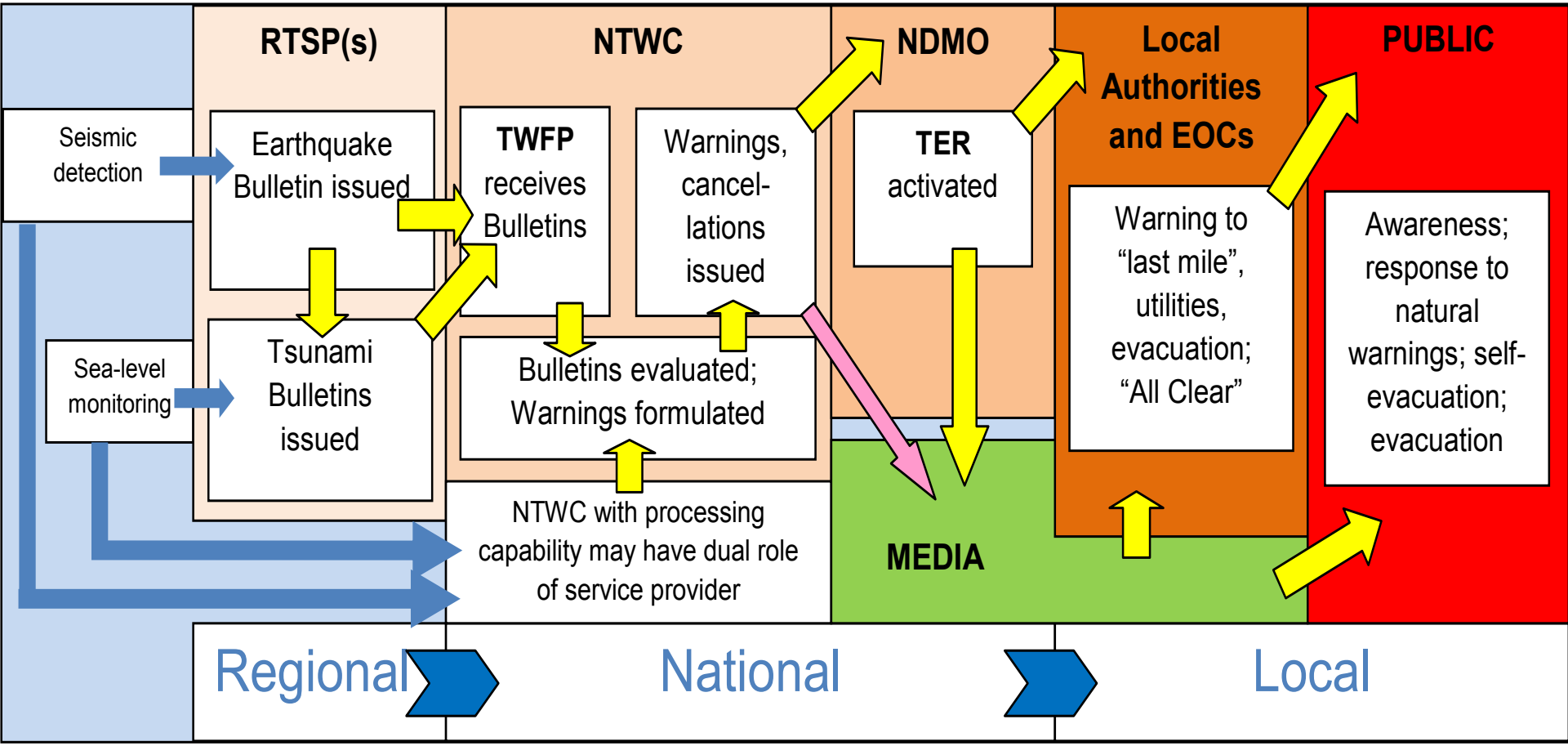
For NTWC Customers – Users Guide

- System overview / history
- Arrangements / Organizations
- TWC Procedures / Criteria (SOPs)
- Products and their Meaning, includes Example Products
- Technical Background and Interpretation Guidance
  - *Tsunami science and hazard*
  - *EQ source characterization*
  - *Message interpretation for emergency response*
  - *Sea level measurement*
  - *Travel time calculation*
  - *Wave forecasting*
  - *Glossary*

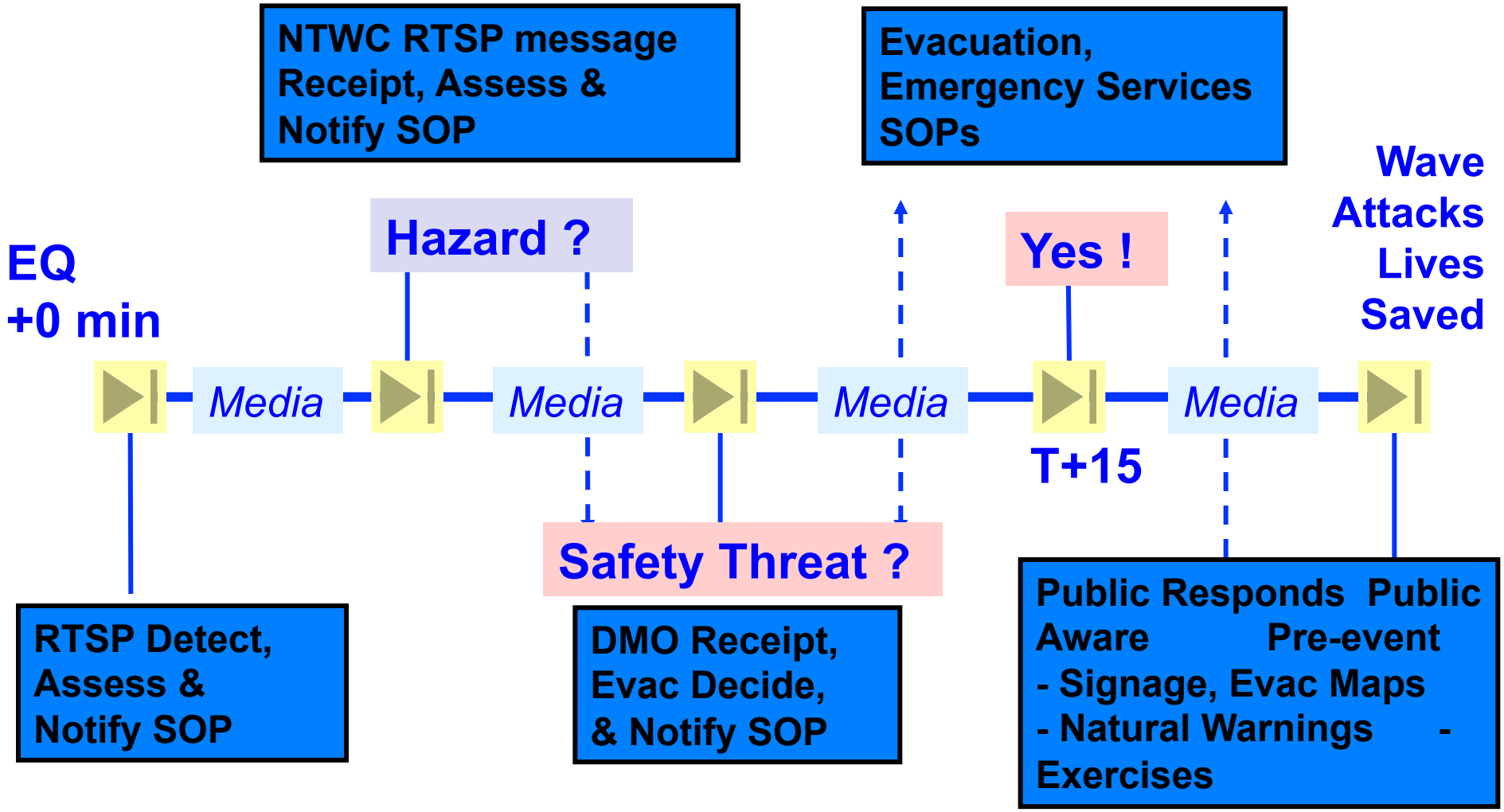


Questions?

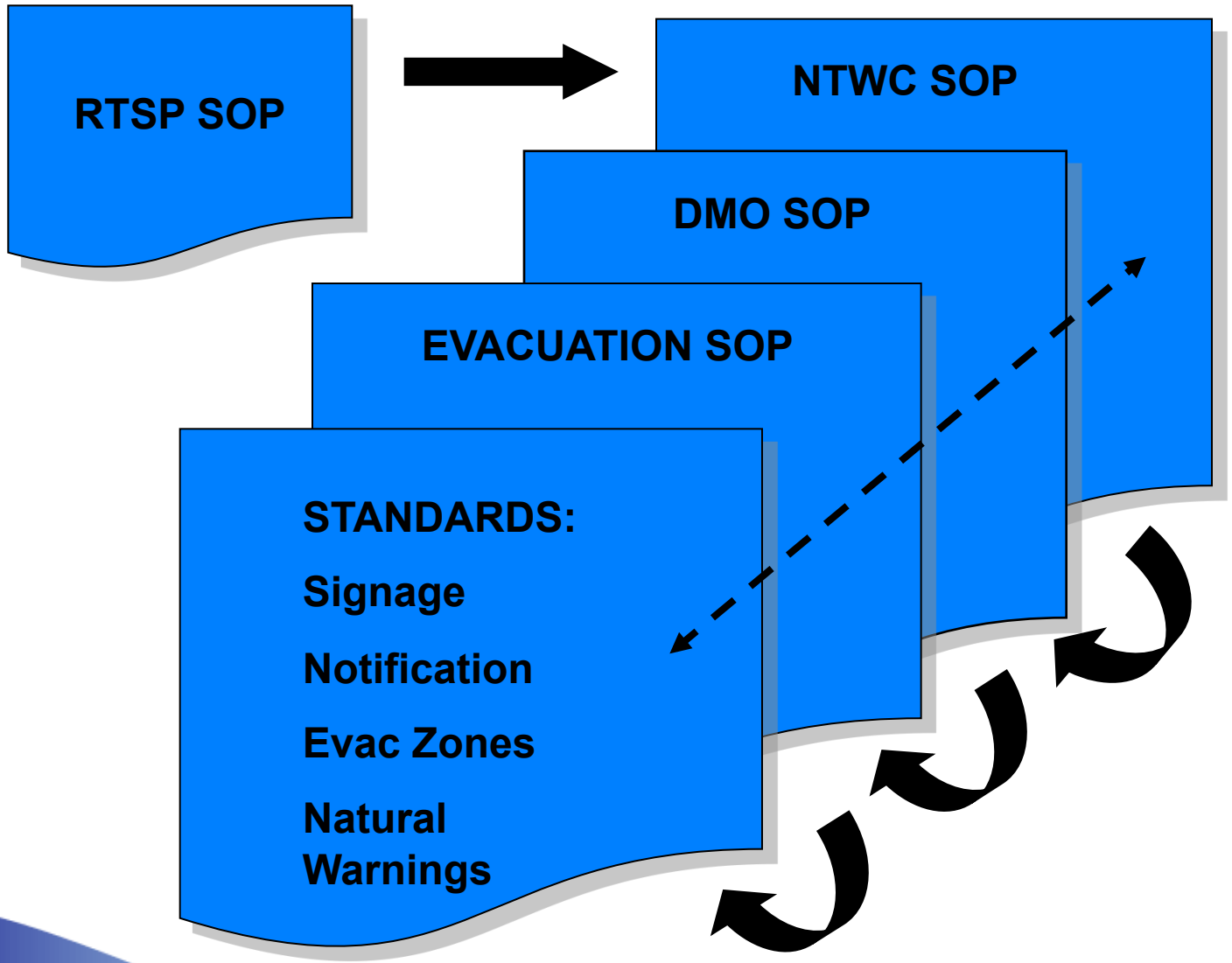
Tsunami Warning: Information Flow



End-to-End Warning SOP – Activities



Tsunami Warning SOPs are coherent



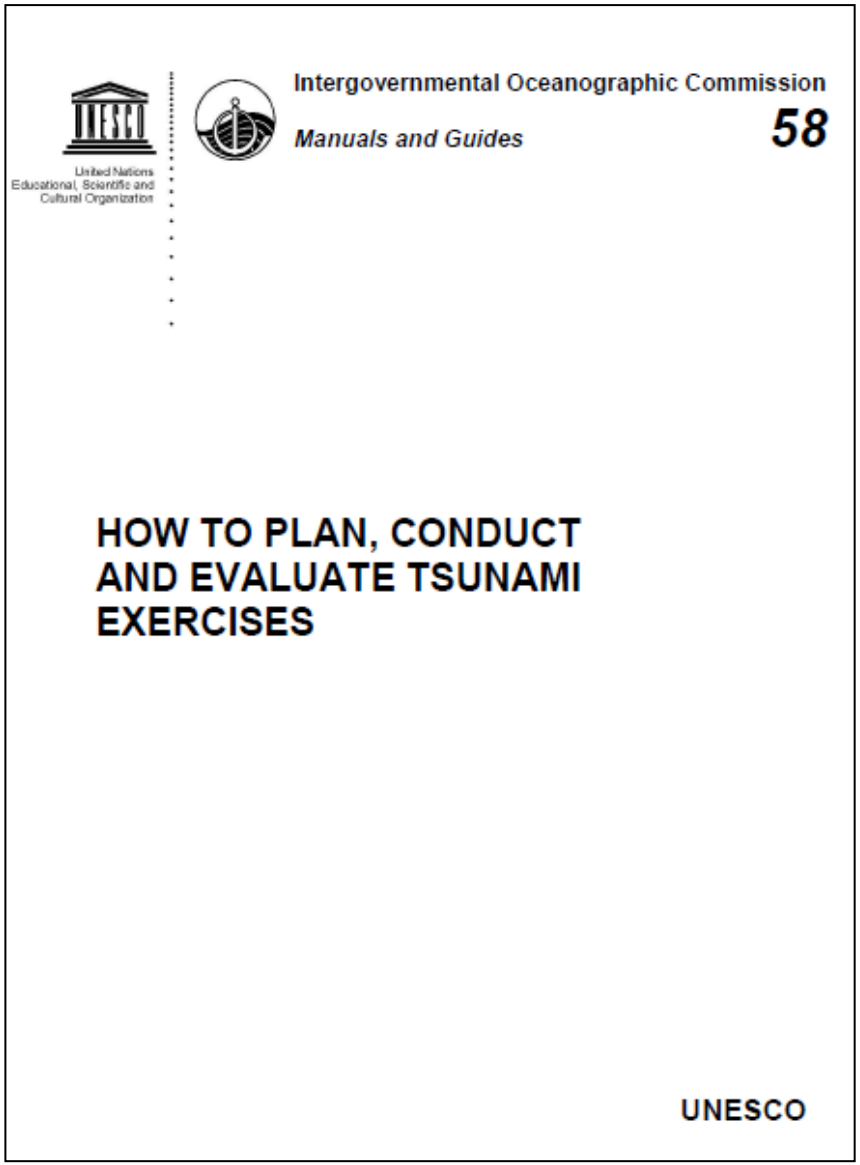
Tsunami Exercises

- Goals
  - Improve overall readiness
  - Identify, evaluate, improve organizational weaknesses / gaps in Plans, Policies, Standard Operating Procedures (SOPs), Communications, Interagency Coordination
- Purpose
  - Evaluate ability of agency or system to respond to local, regional, ocean-wide tsunami.
  - Test communications, review SOPs, promote Emergency Preparedness.
  - Exercises carried out in agency, amongst several agencies, or by all stakeholders.

What to Exercise?

- TWC:
  - “Upstream” process
  - Coordination and information flow (type, content, timeline) with DMO
  - Iterative process (warning, update, cancellation)
- TER:
  - NDMO/EOC receipt, interpret, decide, notify
  - Notify Responders, Decision-makers, Public
  - Recommend Public Safety Action
  - Implement / coordinate Action
  - Inform on ‘All-Clear’ for safe return
  - Initiate Search-and-Rescue, etc.

IOC Manual



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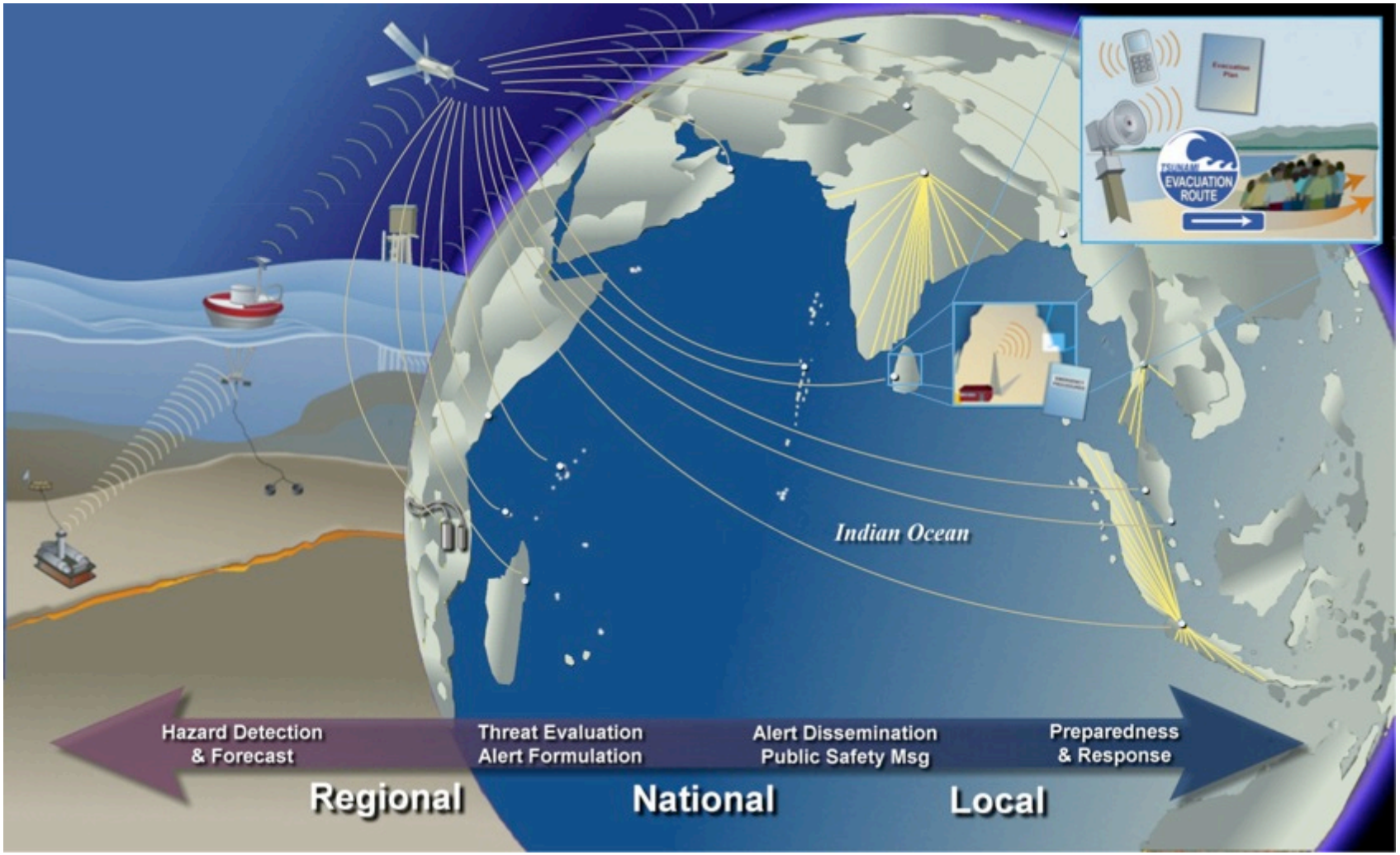
Single Hazard vs Multi Hazards Approach

- Uniqueness of the Hazard
- Early Warning System
- Disaster Management Investment
- Disaster Management Policy
- Standard Operating Procedures
- Exercises
- Awareness, Education and Preparedness

Discussion

- What are the unique features of tsunami hazard?
  - Hazard, exposures, potential loss (Risk)
  - Early Warning System
  - Policy
  - SOP on warning dissemination and response
  - Awareness and Preparedness
  - Exercise
- What are the advantages and disadvantages of choosing an approach for tsunami as single hazard?
- What are the consequences of choosing an approach for tsunami as part of multi-hazard approach?



Thank you!

www.ioc-tsunami.org

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