The Global Tsunami Model (GTM)

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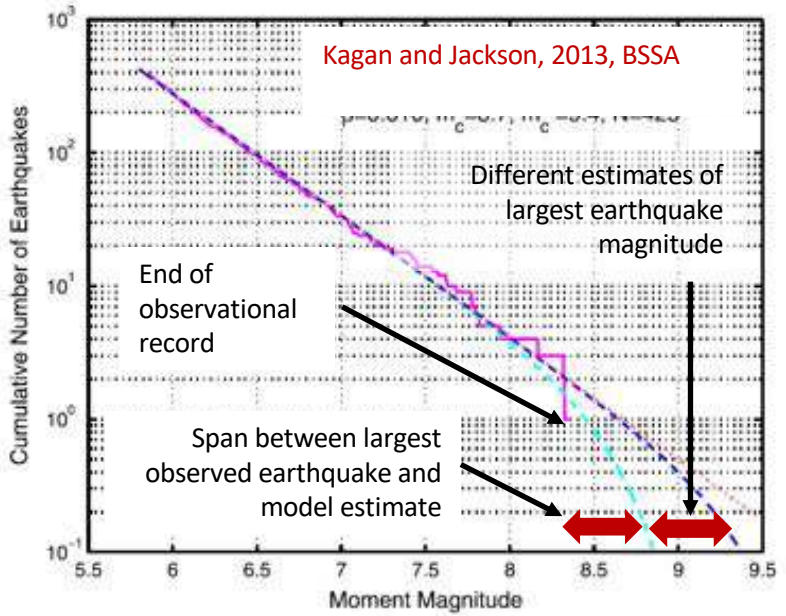
AGU fall meeting, San Francisco, 15.12.2016

Infrequent tsunamis and uncertainty dominate losses and challenge risk modellers

- ✓The tsunamis in 2004 and 2011 account for a majority of the monetary and mortality losses in the last 100 years
- ✓Infrequent tsunamis dominate risk – return periods of hundreds to thousands of years
- ✓The source statistics is poorly constrained at these return periods
  - Does not saturate at high return periods
  - Increasing uncertainty with higher return periods
- ✓The understanding of the hazard from several tsunami sources are poorly understood, including
  - Tsunami earthquakes
  - Non-subduction earthquakes
  - Non-seismic sources (landslides and volcanoes)
- ✓Standards non-existing, while consequences related to high return period tsunami hazards and their related uncertainties are formidable



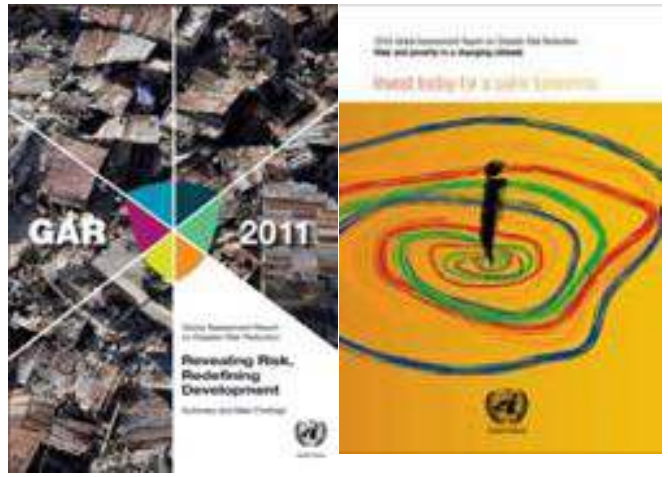
Background – why GTM?

- ✓Multi-institutional work on hazard and risk for the UN-ISDR (Global Assessment Report, GAR)
- ✓**Idea:** Need to gather scientific community for
  - *Collective effort for improved understanding of global tsunami hazard and risk*
  - Provide reference maps
  - Improve methods, develop guidelines and standards
  - Non-exclusive initiative ↔ open for the community
- ✓*Initiative from the tsunami community itself*
- ✓Ensure relevance towards stakeholders

GAR

Global Assessment Report on Disaster Risk Reduction

2015



GTM's added values and vision

The GTM overall vision and goals are to collaboratively achieve a thorough understanding of tsunami hazard and risk, together with the processes that drive them.

- ✓Facilitate compatibility and improve ***probabilistic tsunami hazard and risk analysis methods*** through the development of ***standards, guidelines, methods, tools,*** and identification of key research questions
- ✓The development of regional and global ***reference probabilistic tsunami hazard and risk maps***, as well as ***standardized processes for developing local hazard and risk analyses***
- ✓Establish ***reference pools of experts*** for completing and reviewing tsunami hazard and risk assessments from stakeholders
- ✓The provision of a ***consistent input and contribution to multi-hazard risk assessment*** through high-level harmonization with organizations covering other natural hazards
- ✓The interaction with stakeholders to ensure relevance and proper dissemination of results and ***uncertainty communication to non-scientists***
- ✓To develop the above products while ***being mindful of their benefits for society***

GTM will contribute to the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030

✓**SFDRR Four priorities:**

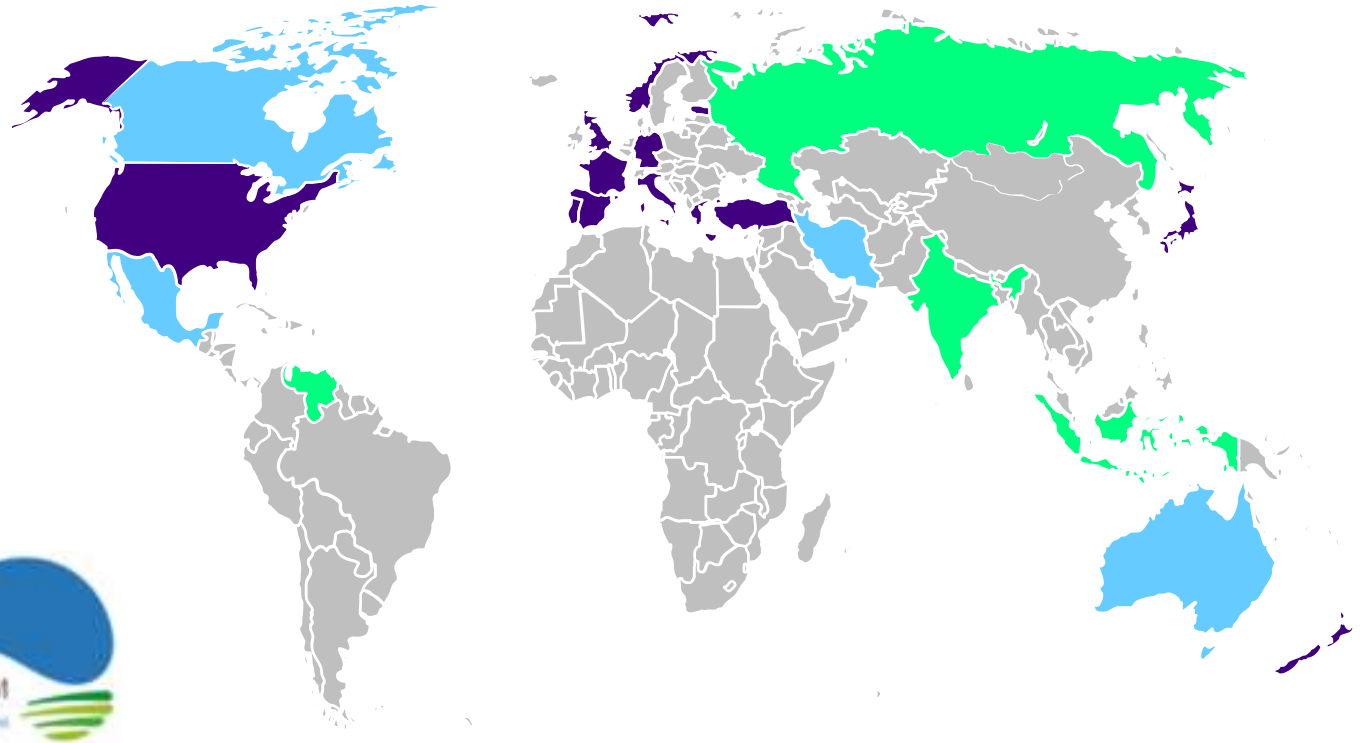
- **Priority 1. Understanding disaster risk**
- Priority 2. Strengthening disaster risk governance to manage disaster risk
- Priority 3. Investing in disaster risk reduction for resilience
- Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

✓**SFDRR Seven Global Targets in brief**

- Substantially reduce global disaster **mortality**
- Substantially reduce the **number of affected people** globally
- Reduce direct **disaster economic loss** in relation to global gross domestic product (GDP)
- Substantially reduce disaster **damage to critical infrastructure and disruption of basic services**, among them health and educational facilities, including through developing their resilience
- Substantially increase the number of countries with national and local disaster risk reduction strategies
- Substantially enhance **international cooperation to developing countries**
- Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people

Current GTM structure

- ✓ proposed to the tsunami community at IUGG June 2015, discussed among partners in several meetings since (AGU, EGU…)
- ✓ **Loose structure committing partners** to the GTM through signing of Letter of Interest (LoI's)
- ✓ **20 partners have signed LoI's, more than 30 partners interested (involved in meetings etc)**
- ✓ INGV and NGI receives LoI's on behalf of GTM and perform majority of secretary work



GTM global tsunami model

Main GTM drivers / stakeholders

- ✓The tsunami hazard and risk discipline is young and needs to adapt, in order to address recent unanticipated consequences of tsunamis
- ✓We are currently lacking well established procedures, methods and standards
- ✓The majority of the tsunami hazard and risk community contributes to GTM over a broad technical range
- ✓Relevant knowledge on dealing with a low frequency / high consequence hazard that differs from most other natural hazards
- ✓Societal relevance and endorsement from UNISDR and GFDRR

GTM global tsunami model

UNISDR United Nations Office for Disaster Risk Reduction

GFDRR Global Facility for Disaster Reduction and Recovery

Suggested short term priority items for GTM

Priority items below proposed by GTM to be discussed further with our stakeholders

✓General topics

- Framework for uncertainty treatment
- Develop standards and guidelines based on present good practices
- Produce, reviewed, well documented, reproducible, and standardized global reference maps
- Perform Hazard and Risk communication from the above products

✓Some specific scientific topics will be priorities

- Submarine fault characterization
- Homogenized global tsunami data handling

✓In the first phase, we suggest to focus on the tsunami hazard, and develop risk products at a later phase

Long term goals

- ✓Seismic source (probability and modeling)
  - Interface Global Earthquake Model (GEM)
- ✓Non Seismic source (probability and modeling)
  - interface with other global models covering sources such as Global Volcano Model (GVM)
- ✓Tsunami (probability and modelling)
- ✓Probabilistic Tsunami Hazard Assessment, PTHA
  - Non-earthquake sources
- ✓Vulnerability and fragility
- ✓Probabilistic Tsunami Risk Assessment
- ✓Development of standards and guidelines for tsunami hazard and risk quantification
- ✓Dissemination and geoethics (transparency – uncertainty communication)

Common grounds and first GTM products

Related project results contributing to GTM:

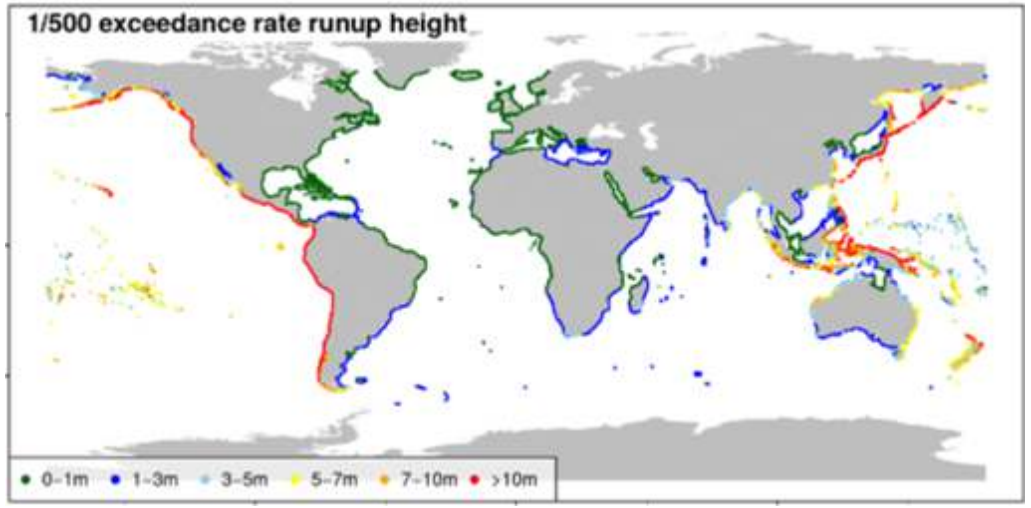
✓GAR15 global tsunami risk maps
- Full tsunami risk analysis, but not disaggregation of hazard
- Focused on losses estimation for nations

✓TSUMAPS-NEAM
- Tsunami hazard maps for DG-ECHO (European Civil Protection)
- Makes use of GTM pool of experts: elicitation on critical, subjective choices (developing and weighting alternative models)

✓New global tsunami hazard assessment finalized
- Deeper analysis on earthquake model epistemic uncertainties

GAR Global Assessment Report on Disaster Risk Reduction 2015

TSUMAPS NEAM Probabilistic TSUnami Hazard MAPS for the NEAM Region

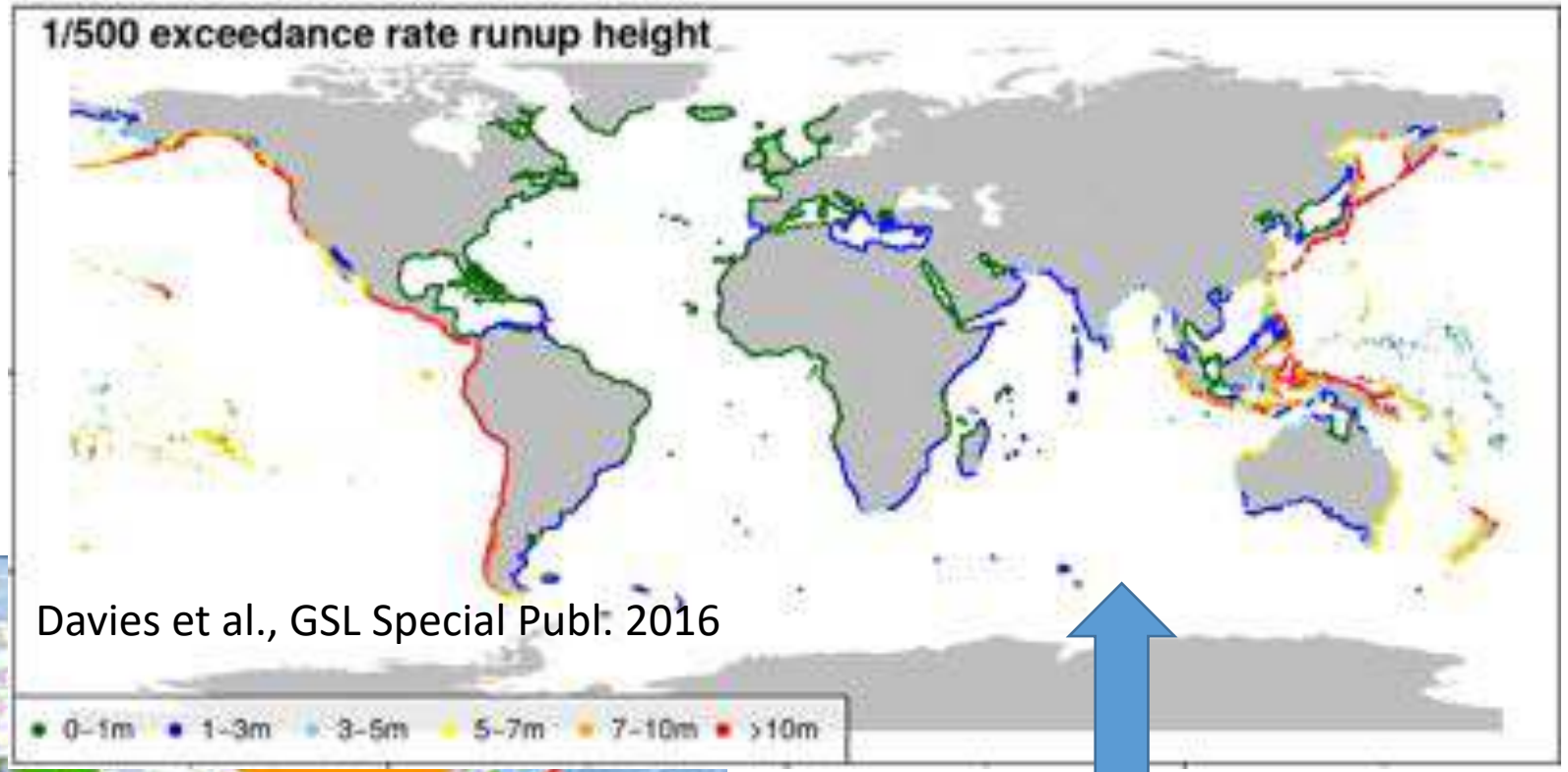


Davies et al., GSL Special Publ. 2016

GAR 15

Full tsunami risk analysis, but not disaggregation of hazard

Focused on losses estimation for nations



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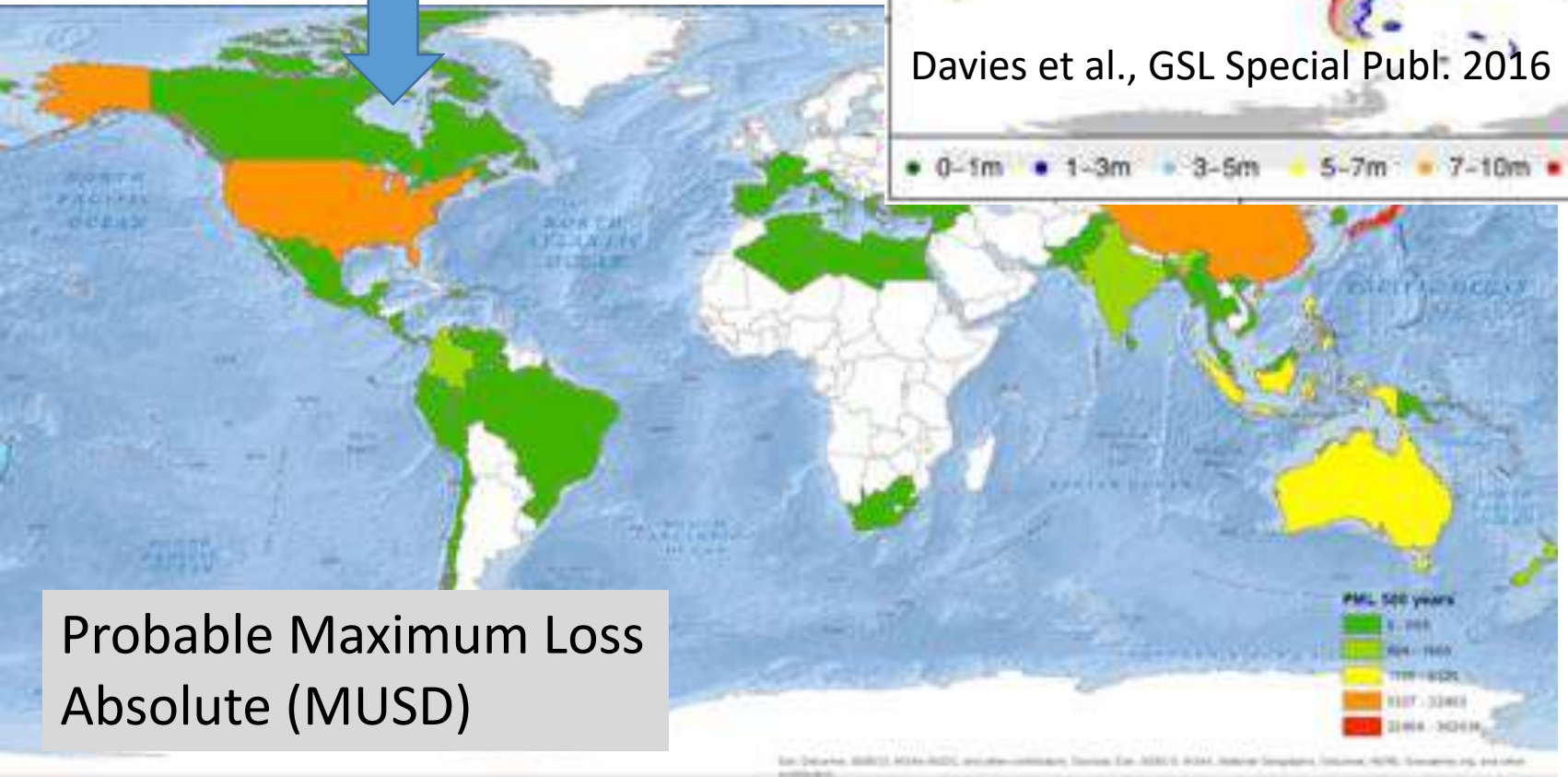


Probable Maximum Loss Absolute (MUSD)

GTM related work based on the GAR

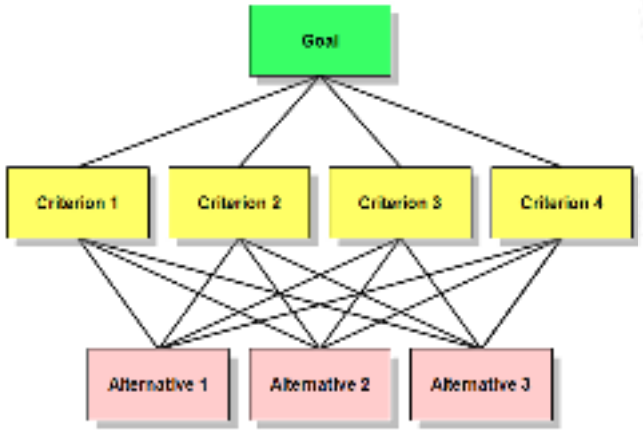
New global tsunami hazard maps finalized

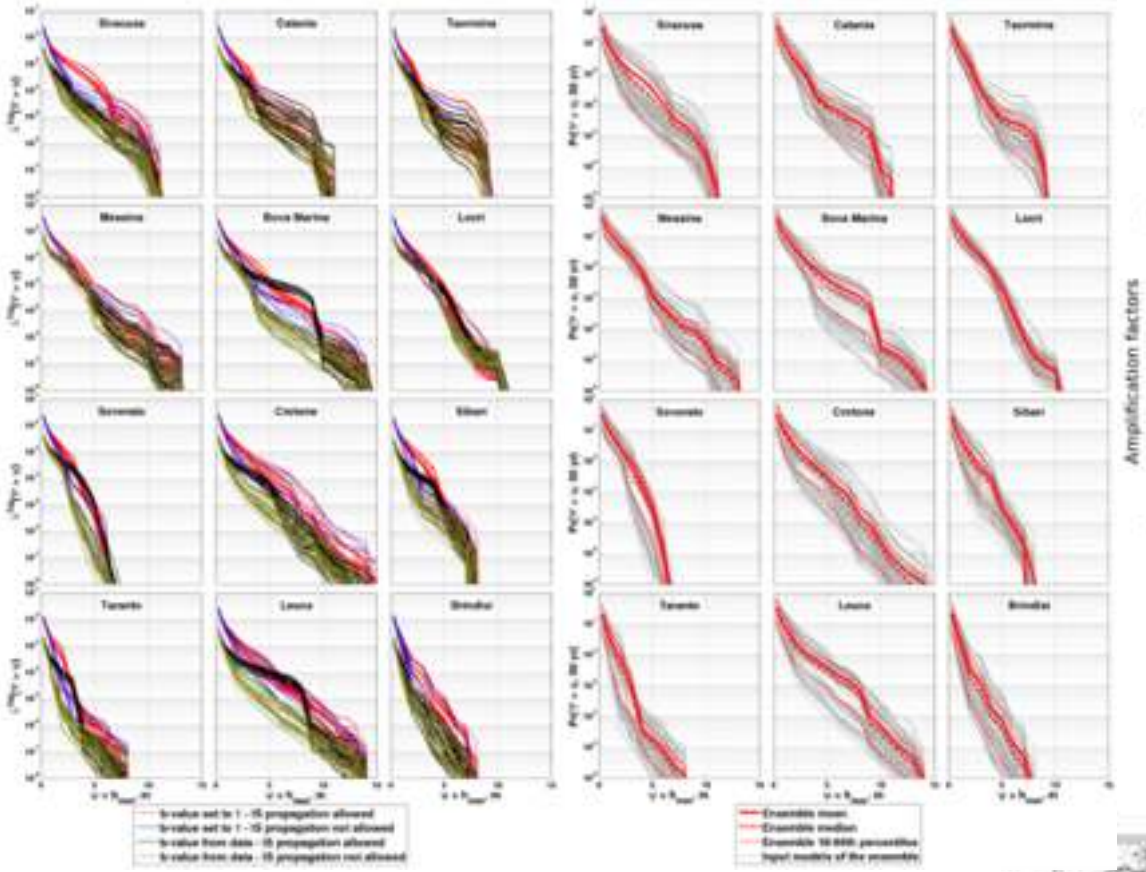
Deeper analysis on earthquake model epistemic uncertainties

GTM and the TSUMAPS-NEAM project

Multi-expert elicitation through Analytic Hierarchy Process (AHP)

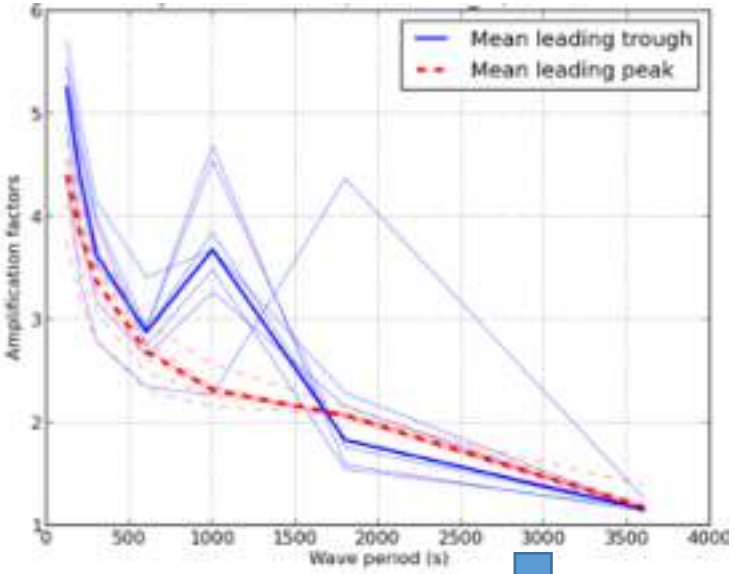
GTM provides pool of experts to TSUMAPS-NEAM

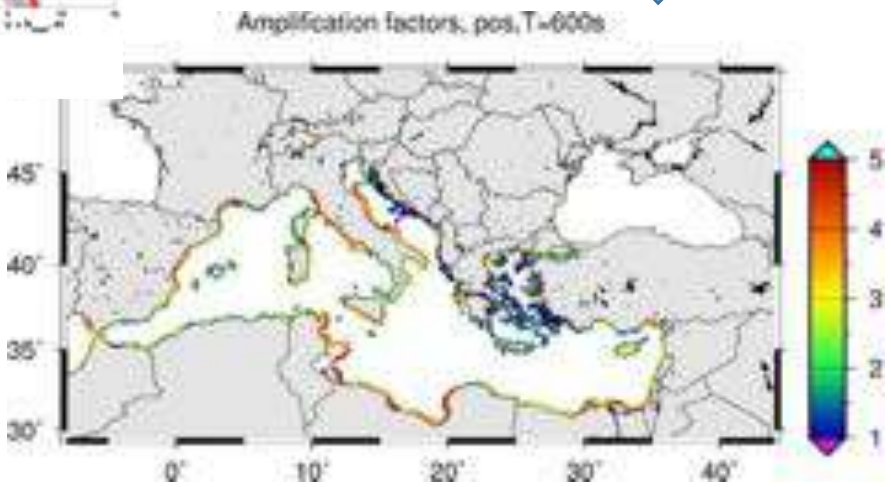




Examples of hazard curves from alternative models (left); ensemble modeling and ensemble statistics

Local amplification factors for the NEAM region





Common grounds and first products for GTM: First dissemination and outreach activities

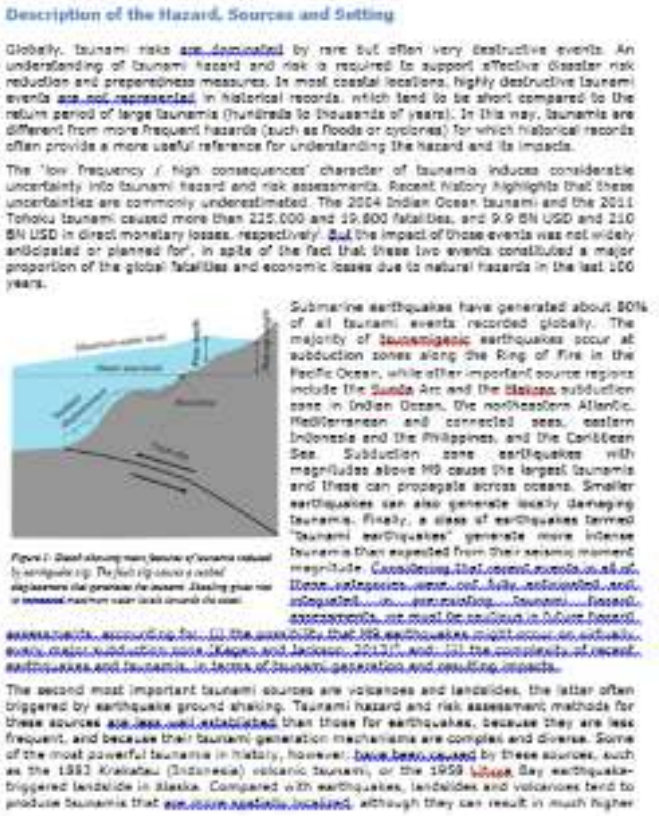
Towards the fulfilling implementation of the Sendai Framework for Disaster Risk Reduction (SFDRR):

✓UNISDR

- Words Into Action – the tsunami hazard section
- Tsunami awareness day blog http://www.unisdr.org/2016/tsunamiday/

✓Disaster Risk Mitigation Knowledge Centre (EC)

- JRC reference document of natural hazards


Description of the Hazard, Sources and Setting

Globally, tsunami risks are dominated by rare but often very destructive events. An understanding of tsunami hazard and risk is required to support effective disaster risk reduction and preparedness measures. In most coastal locations, highly destructive tsunami events are not represented in historical records, which tend to be short compared to the return period of large tsunamis (hundreds to thousands of years). In this way, tsunamis are different from more frequent hazards (such as floods or cyclones) for which historical records often provide a more useful reference for understanding the hazard and its impacts.

The 'low frequency / high consequences' character of tsunamis induces considerable uncertainty into tsunami hazard and risk assessments. Recent history highlights that these uncertainties are commonly underestimated. The 2004 Indian Ocean tsunami and the 2011 Tohoku tsunami caused more than 225,000 and 19,800 fatalities, and 9.9 BN USD and 210 BN USD in direct monetary losses, respectively. But the impact of those events was not widely anticipated or planned for', in spite of the fact that these two events constituted a major proportion of the global fatalities and economic losses due to natural hazards in the last 100 years.

Submarine earthquakes have generated about 80% of all tsunami events recorded globally. The majority of tsunamigenic earthquakes occur at subduction zones along the Ring of Fire in the Pacific Ocean, while other important source regions include the Sunda Arc and the Makran subduction zone in Indian Ocean, the northeastern Atlantic, Mediterranean and connected seas, eastern Indonesia and the Philippines, and the Caribbean Sea. Subduction zone earthquakes with magnitudes above M9 cause the largest tsunamis and these can propagate across oceans. Smaller earthquakes can also generate locally damaging tsunamis. Finally, a class of earthquakes termed "tsunami earthquakes" generate more intense tsunamis than expected from their seismic moment magnitude. Considering that recent events as of the...

The second most important tsunami sources are volcanoes and landslides, the latter often triggered by earthquake ground shaking. Tsunami hazard and risk assessment methods for these sources are less well established than those for earthquakes, because they are less frequent, and because their tsunami generation mechanisms are complex and diverse. Some of the most powerful tsunamis in history, however, have been caused by these sources, such as the 1883 Krakatau (Indonesia) volcanic tsunami, or the 1958 Lituya Bay earthquake-triggered landslide in Alaska. Compared with earthquakes, landslides and volcanoes tend to produce tsunamis that are more spatially localized, although they can result in much higher

Interested in GTM?

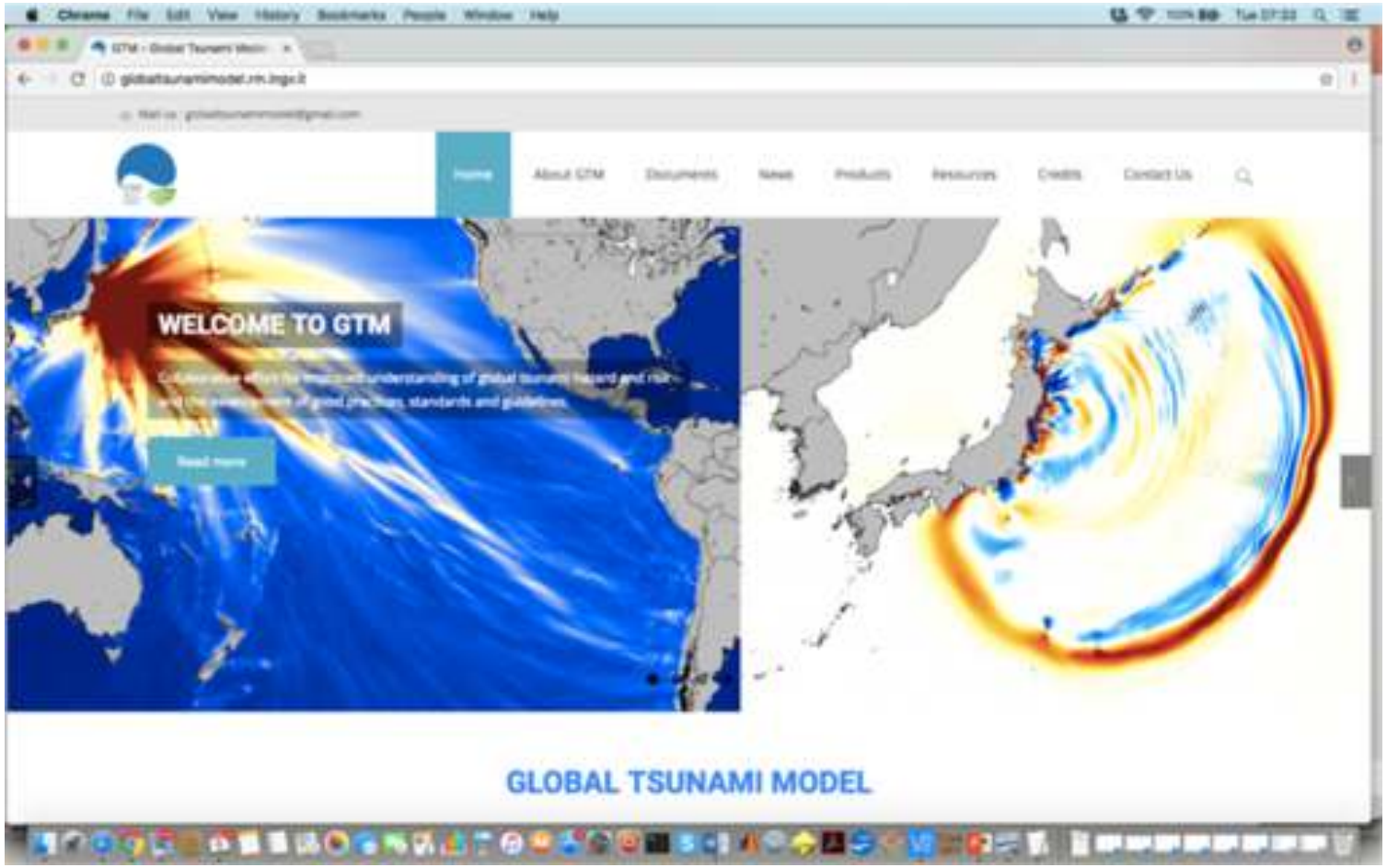
Web page:

http://www.globaltsunamimodel.org

Mailing list (google groups):

https://groups.google.com/forum/#!forum/globaltsunamimodel

Next meeting at EGU 2017



GFDRR

UNISDR
United Nations Office for Disaster Risk Reduction

Extra

Key stakeholders

- ✓Present endorsers having signed endorsement letters
  - ✓UNISDR
  - ✓GFDRR (World Bank)
- ✓Possible other stakeholders
  - ✓IOC UNESCO
  - ✓Industry stakeholders such as the re-insurance (some contact have been held with OASIS)
  - ✓National stakeholders
  - ✓Regional stakeholders (EU, NTHMP US)
- ✓Additional contact will be taken when the key challenges related to tsunami hazard and risk assessment is formulated

GTM knowhow includes at least:

- ✓Tsunami probability
- ✓Tsunami modeling
- ✓Source modeling (seismic and non-seismic)
- ✓Tsunami hazard and uncertainty treatment
- ✓PTHA
- ✓Building fragility and vulnerability
- ✓Risk assessment, multihazard, and multirisk assessment
- ✓Geoethics
- ✓Tsunami data and historical catalogues
- ✓Public dissemination and outreach

Global coverage (interested organisations)

Interested but not drawn on the maps:

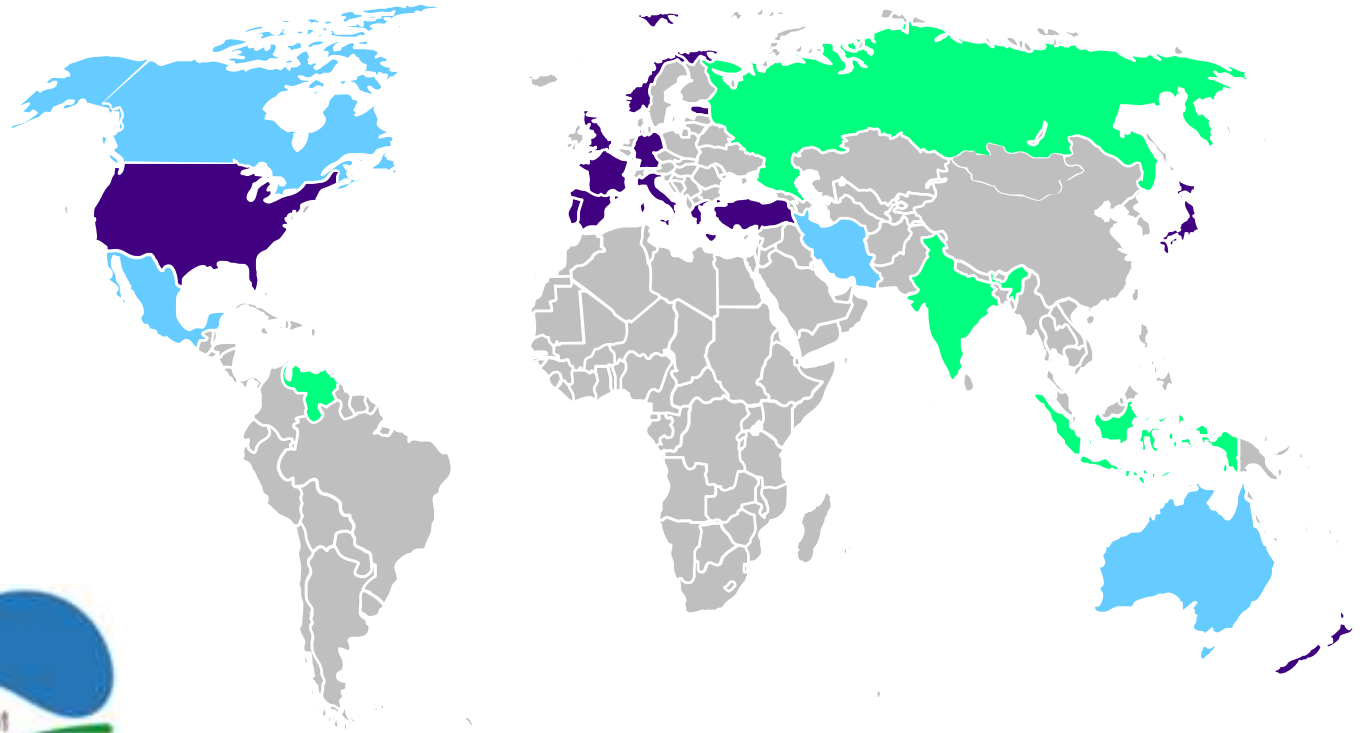
- ✓ Mexico
- ✓ Canada
- ✓ Indonesia
- ✓ Puerto Rico

Others?

GTM strategy I roundtable

Status per 9.12.2016
List of partners (signed LoI's): 19

Organziations interested in GTM (received LoI's): 15



Name	Organisation
Mohammad Mokhtari	IIEES (Iran)
Serge Guillas	UCL (UK)
Anawat Suppasri	IRIDES Tohoku Univ (Japan)
Ira Didenkulova	TTU (Estonia)
Maria Ana Viana-Baptista	IPMA (Portugal)
Íñigo Aniel-Quiroga	Cantabria Univ (Spain)
Robert Weiss	VT (USA)
Miquel Canals Artigas	UB (Spain)
Jorge Macías Sánchez	UMA (Spain)
Christa Von Hillebrandt-Andrade	NOAA (USA)
Öcal Necmioğlu	BOUN (Turkey)
Trevor Allen	NRCAN (Canada)
Raphaël Paris	LVM (France)
Alberto Armigliato	UNIBO (Italy)
Marlen Rodríguez	ERN (Mexico)
G. A. Papadopoulos	NOA (Greece)
Andrey Babeyko	GFZ (Germany)
Tom Parsons, Stephanie Ross	USGS (USA)
Jörn Behrens	Hamburg Univ (Germany)
Hong Kie Thio	AECOM (USA)
Frank Gonzalez, Randy Leveque	Washington Univ (USA)
Gareth Davies	GA (Australia)
Mario Salgado	CIMNE (Spain)
Andreas Schäfer	KIT (Germany) - GPI/KIT
Ahmet Yalciner, Utku Kanoglu	METU (Turkey)
Stefano Lorito	INGV (Italy)
Finn Løvholt, Carl Harbitz	NGI (Norway)
William Power	GNS (New Zealand)
Jascha Polet	Cal Poly Pomona (USA)
Stuart Fraser	Fraser Disaster Risk Consulting Ltd (USA)
Yong Wei	NOAA (USA)
Mathilde B. Sørensen	UiB (NO)
Helene Hebert	CEA (France)

GTM's added values and vision

The GTM overall vision and goals are to collaboratively achieve a thorough understanding of tsunami hazard and risk, together with the processes that drive them.

- ✓Facilitate compatibility and improve ***probabilistic tsunami hazard and risk analysis methods*** through the development of ***standards, guidelines, methods, tools,*** and identification of key research questions
- ✓The development of regional and global ***reference probabilistic tsunami hazard and risk maps***, as well as ***standardized processes for developing local hazard and risk analyses***
- ✓**Establish *reference pools of experts*** for completing and reviewing tsunami hazard and risk assessments **from stakeholders**
- ✓The provision of a ***consistent input and contribution to multi-hazard risk assessment*** through high-level harmonization with organizations covering other natural hazards
- ✓The interaction with stakeholders to ensure relevance and proper dissemination of results and ***uncertainty communication to non-scientists***
- ✓To develop the above products while ***being mindful of their benefits for society***

Present GTM structure

- ✓GTM proposed to the tsunami community June 2015, discussed among partners in several meetings since
- ✓**Loose structure committing partners** to the GTM through signing of Letter of Interest (LoI's)
- ✓**19 partners have signed LoI's, more than 30 partners interested (involved in meetings etc)**
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GTM evolution

- ✓**IUGG Prague June 2015 (public presentation, work meeting, discussion with IOC UNESCO) – GTM was suggested**
- ✓**AGU December 2015 – OAKLAND (AECOM)**
- ✓UNISDR S&T conference January 2016 – GTM poster (NGI)
- ✓**EGU 2016**
- ✓SSA 2016 (AECOM)
- ✓UR forum in Venice, Multirisk session May 2016 (INGV)
- ✓**INGV 4-6 July 2016 – work meeting**
- ✓Pavia Nov. 2016 – Global Partnership meeting (INGV, NGI)
- ✓**AGU Fall meeting 11 December 2016**

GTM strategy II roundtable

Suggested priority items for GTM – proposed next steps

- ✓ Framework for uncertainty treatment
  - → Hazard
  - → Risk?
- ✓ Standards and guidelines based on present good practices
- ✓ **Reviewed, well documented, reproducible,** and standardized global reference maps
- ✓ **Hazard and risk communication from products**

- ✓ Develop probabilistic hazard analysis methods for non-seismic sources
- ✓ **Submarine fault characterization**
- ✓ **Homogenized global tsunami data handling**

- ✓ **Tsunami vulnerability suggested for a later stage**
  - → **Structural**
  - → **Mortality and other possible non-structural components**

GTM strategy III roundtable

GTM organization round table background

✓Some key points discussed in Oakland (December 2015)

→Designation of working groups (not functioning) and timeline

- "All interested in the scientific aspects"

→Future board structure (advisory, management), etc.

→Ways of organizing the secretariat, tasks for the secretariat

→What can be obtained realistically with the amount of resources available

GTM strategy III roundtable

✓What are the resources needed to materialize GTM (feasibility)? (and for sustainability)

✓ What are the possible options for a GTM structure?

✓Identify stakeholders and funders

✓Plan a next meeting with GTM partners

→Establish a ToR
→Possible fee for partners
→GTM secretariat
→GTM governance (working groups and boards)

GTM actions - roundtable

GTM Actions – interim products and requests

- ✓Need for interim (at least hazard) products, in addition to the above publications; and how to make them happen
  - →Integration of results from external projects
    - Tsumaps
    - Updated hazard maps from GAR
    - **Other results available?**
  - →Start providing preliminary guidelines
  - →Where to publish interim products guidelines etc – active use of webpage etc.
  - →Other products?
  - →Ownership issues related interim products
- ✓How to handle interim external requests?
  - →We need rules to be accepted by GTM partners (LoI subscribers)

GTM webpage (and logo) available

- ✓http://www.globaltsunamimodel.org/
- ✓First version – contains a minimum to go online
- ✓High degree of volunteer efforts (INGV, METU, UW, NGI)
- ✓Visit the website
  - →***We need to agree on the main message we are delivering (Vision, Goals, Products, etc.)***
  - →Suggest improvements
  - →But…
  - →Contribute with material – we need to involve all partners actively!

White paper draft

- ✓First draft provided by NGI 27.6 as basis for discussion
  - →Comments received by a handful of contributors
- ✓Based on ideas for GEM Nature Geoscience paper
- ✓New revision based on first set of values / vision available
- ✓Needs further iteration
- **✓Now as the webpage is launched, and official endorsements are in place, we would like to contact a high profile journal or similar to enquire about their possible interest**
  - **→Nature Geoscience suggested in last meeting (Rome)**
  - **→Other suggestions / better candidates?**

Actions towards funding

- ✓Contact made with Lloyds Foundation
  - →Outline proposal (300 words) – for consideration of interest for a full proposal
  - →Expecting answer relatively soon
- ✓Planned
  - →**EC cost action 2017**
- ✓Other possibilities
  - →Joint / coordinated contact with industry and re-insurance
  - →Proper business model important for attracting long term funding
  - →Licenses versus open source must be carefully considered

Plan for first partner meeting

- ✓Location?
- ✓Time?
- ✓Can have joint meetings for partners non-partners, with exclusive sessions
- ✓Feasible amount of meetings – GTM still a volunteer effort