Advances in Coastal Disasters Risk Management

Lessons from the March 2011 Tsunami and preparedness to the climate change impact

Seminar report, Thursday June 7 and Friday June 8, 2012
Venue: JAL city hotel, Sendai, Japan

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Photo on the front cover: Rikuzentakata after the March 11 tsunami disaster

1 Background and seminar objectives

The earthquake and tsunami of March 2011 led to death and destruction in coastal areas in Japan. After the several tsunami investigations have focused on the effects of the earthquake and the tsunami, the performance of coastal defences and the preferred strategies and measures for rebuilding the coastal areas and managing the risk has been discussed. In addition to tsunami hazards, many of the densely populated coastal areas in Japan (e.g. the Tokyo Bay area) are prone to flooding due to coastal storms and typhoons.

The threat of various coastal hazards (storms, floods) is also very prominent in the Netherlands as large parts of the country are below sea level. Past disasters in the Netherlands (e.g. the 1953 storm surge disaster) and abroad (e.g. hurricane Katrina in New Orleans and the Tohoku tsunami in Japan) provide important opportunities to learn more about the devastating effects of disasters and possible strategies to minimize these coastal risks. In recent decades, new scientific concepts for assessing and managing risks have been developed.

On June 7 and 8, 2012 a seminar has been organized in Sendai, Japan to exchange information between Dutch and Japanese researchers to improve the methods for assessing, managing and mitigating coastal risks. In the days before the seminar, field visits have been organized to the coastal and river flood protection in Tokyo (June 4) and coastal areas affected by the March 2011 tsunami (June 5 and 6).

The following key questions have been addressed:

- What were the causes and effects of the March 2011 tsunami?
- What was the performance of the coastal protection system and which lessons can be learned for design and coastal management?
- Which strategies will be and can be used for reducing and managing the risks in coastal areas of Japan and the Netherlands?

The seminar has not only focused on engineering measures to prevent such disasters by means of coastal defences (e.g. dikes, levees, breakwaters and seawalls), but also on land use planning and emergency management. It has also been addressed how future developments, such as climate change and economic and population growth in coastal areas can be taken into consideration in the risk management strategy for coastal areas.

Organization and support

The seminar has been organized by the Disaster Prevention Research Institute (DPRI) of Kyoto University and Delft University (the Netherlands). The seminar has been supported by JSPS (the Japan Society for the Promotion of Science) and NWO (Netherlands Organisation for Scientific Research) and these organizations are gratefully acknowledged for this support.

Structure of this report

The remainder of this report is organized as follows. The next section includes the workshop program. After that a more detailed overview of observations from the field visits is included. The final part of the report summarizes the main findings from the seminar and includes the list of participants.

2 Field trip and seminar program

2.1 General overview

Monday June 4	Tokyo *Visit to the coastal protection system at the Tatsumi floodgate* *Visit to the Hirai super levee along the Arakawa river*
Tuesday June 5	Field visit to areas affected by the March 2011 tsunami in Iwate prefecture *Rikuzentataka* *Ofunato* *Yoshihama* *Kamaishi* *Otsuchi* *Ryoishi*
Wednesday June 6	Field visit to areas affected by the March 2011 tsunami in Miyagi prefecture *Onawaga* *Ishinomaki* *Higashi-matsushima* *Yamamoto* *(Nakahama elementary school)* *Sendai Airport* *Yuriage* *Arakawa elementary school*
Thursday June 7	Seminar day 1 *Morning: introduction session* *Afternoon: Design and performance of coastal protection systems*
Friday June 8	Seminar day 2 *Morning: Climate change and coastal protection* *Afternoon: Emergency and risk management strategies* *Seminar conclusions*

2.2 Seminar program

Title: Advances in Coastal Disasters Risk Management, Lessons from the March 2011 Tsunami and preparedness to the climate change impact

Thursday June 7		
Introduction session		
9:30	Opening remarks	S.N. Jonkman *TU Delft* *& Royal Haskoning* T. Yasuda *Kyoto University*
9:40	Overview of the 2011 Tohoku earthquake tsunami survey results	N. Mori *Kyoto University*
10:10	Developments in coastal flood risk management in the Netherlands	S.N. Jonkman *TU Delft* *& Royal Haskoning*
10:40	Coffee Break	
11:00	A multi-layer safety perspective on the 2011 Tohoku earthquake tsunami disaster	V. Tsimopoulou *TU Delft* *& HKV Consultants*
11:30	Discussion	
12:00	Lunch break	
Session 1: Design and performance of coastal protection systems		
13:30	From forces of nature to design loads	J.K. Vrijling *TU Delft*
14:00	Improvement in Coastal Dike Design based on the lessons learned from the Great East Japan Earthquake Tsunami	F. Kato *NILIM, JPN*
14:30	Stability of armour units in the Tohoku 2011 tsunami: design implications	M. Esteban *Waseda University*
15:00	Coffee Break	
15:30	The impact of the 2011 Tohoku earthquake tsunami disaster - Lessons towards tsunami-resilient communities	S. Koshimura *Tohoku University* H.Gokon *Tohoku University*
16:00	Discussion	

Friday June 8		
Session 2: Climate change and coastal protection		
9:00	Projections of future risks related to climate change and flooding in The Netherlands	L.M. Bouwer *VU University Amsterdam*
9:30	Projection of climate change impact on storm surge and its uncertainty	T. Yasuda *Kyoto University*
10:00	Coffee Break	
10:20	Relationship between wave climate variability and teleconnection patterns	T. Shimura *Kyoto University*
10:50	Technical issues of coastal defense design criteria for future climate change	H. Kawai *PARI, JPN*
11:20	Discussion	
12:00	Lunch break	
Session 3: Emergency and Risk management strategies		
13:30	What strategy is needed for catastrophic tsunami disasters? after the 2011 Tsunami Disaster	Y. Okumura *Kyoto University*
14:00	Tsunami resilient community development from discussions with affected people	S. Suzuki *Kyoto University*
14:30	Coffee Break	
14:50	Evacuation and flood risk management	B. Kolen *HKV Consultants & Radboud University Nijmegen*
15:20	Discussion on emergency management	
15:40	Seminar Conclusions	S.N. Jonkman *TU Delft*
16:00	Seminar closure	

3 Summary of field visit findings

The team visited the affected areas by the March 2011 tsunami (June 5 and 6) and the main findings are summarized below.

Areas affected by the tsunami

The scale of the disaster was immense. Almost 600km of coastline has been affected by the tsunami, 15,850 people were killed and more than 3,200 people are still missing. The economic losses were between 16 and 25 trillion Yen (between 160 and 250 billion Euro). In an extensive effort Japanese scientists have recorded tsunami inundation and runup heights, see figure below. In the limited time available no complete assessment of the impacts was possible. Yet, some observations that are relevant for the Netherlands and further exchange between the Netherlands and Japan are summarized below.

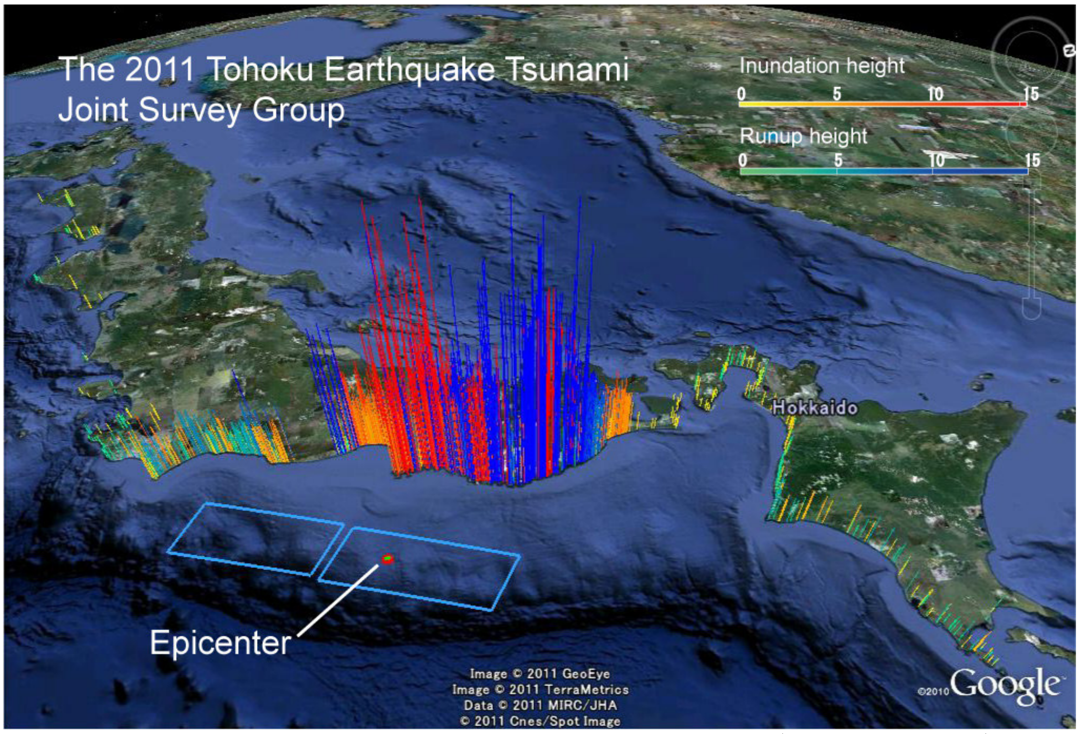

Figure: Measurements of the tsunami inundation and run-up (Mori et al., 2011)[1].

Findings

The event has proven that extreme and rare events can happen and that their magnitude can exceed historical records. In many affected locations tsunami heights were higher than ever recorded in history.

The consequences for such extreme events are very large (see numbers presented earlier). The disaster also gives insight in the composition of the damage. Firstly, there is the extensive loss of life and direct damage to houses, infrastructure, vehicles and other objects. A very significant component that is not addressed in most existing flood and disaster loss models is the indirect losses from business and damages to the national and even global economy. Finally, there are the high costs of rehabilitation and reconstruction.

[1] Mori N., Takahashi T., Yasuda T., Yanagisawa H. (2011) Survey of the Tohoku earthquake tsunami inundation and run-up. *Geophysical Research Letters* Vol. 38, L00G14, 6p, doi:10.1029/2011GL0492102011.

The event gave empirical support for possible tsunami heights and for on-land propagation of the tsunami wave. By using video observations, flood simulation models for such tsunami and flood events can be calibrated and improved. These models can be utilized to evaluate several protection measures

The field observations give empirical support for the tsunami loading on structures such as breakwaters, coastal dikes and tsunami walls, and the resistance and failure modes of these structures in extreme conditions. More specifically, phenomena such as scouring, wave reflection and impulsive loads as a function of time can be better understood by analyzing the observations. Even 10 m high solid concrete walls failed due to the enormous impact. As part of the protection system floodgates were in place at locations where rivers flowed into the ocean. Not all floodgates could be closed during the disaster, due to the earthquake and the limited time available before arrival of the tsunami wave. Some of the floodgates were also structurally damaged due to the event.

Figure: Damaged floodgate at Minamisanriku

A through analysis of flood and impact patterns with some support of numerical simulation can also reveal in which conditions the coastal defences have contributed to the reduction of the hazard and / or consequences. For example, for the town of Kamaishi it is expected that the presence of the breakwater in the bay mouth has reduced tsunami flood levels in the town by 30% to 40%.

Positive and negative experiences with evacuation were reported. Many people were saved, but also many people did not survive. A careful evaluation of the events can give more insight in effective emergency management strategies. The outcomes should influence future emergency planning in Japan, but also other parts of the world.

In the coastal areas of Japan a risk reduction is in place that relies on various "layers" of protection (protection, land use planning and emergency management). This tragic event is also an opportunity to learn how such a multiple layered system performs under extreme conditions. From the field visits and information from experts, it appeared that the level of damage was dependent on the (combined) performance of coastal protection, previous land use planning policies and possibilities to take shelter in safe structure or high ground.

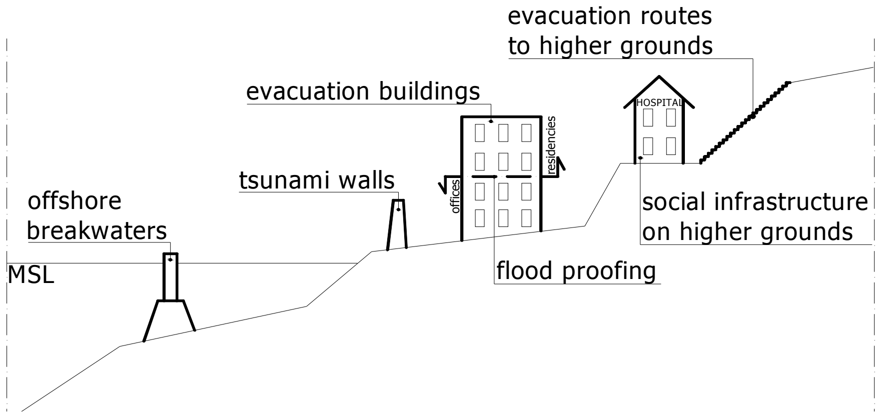

Figure: Typical measures for tsunami risk reduction along the Rias type coast (bays) (Presentation V. Tsimopoulou, this seminar).

4 Seminar findings

4.1 Background

There are similarities and differences between the coastal systems and threats in the Netherlands and Japan. The coastline of the Netherlands is about 450 km long and coastal defences consist of sand dunes, coastal dikes and barriers. These protect densely populated and valuable in the west of the country. The main threats are storm surges from extratropical storms and coastal erosion.

The Japanese coastline is much longer, almost 35,000 km, and about 25% of the coastline is protected by means of hard structures such breakwaters, dikes and gates. These provide coastal protection against tsunamis and typhoons. Most of the densely populated areas, such as Tokyo and Osaka, are located along the coast.

Despite the differences in the size of the country and coastal protection and threats there are various similarities. In both countries, the coastal (protection) system is essential for reducing and managing the risks in densely populated urban areas along the coasts. Despite the current economic stagnation in both Japan and the Netherlands, the values and populations in coastal areas are still growing, leading to an increase of potential impacts and risks if no measures are taken. Both countries have to cope with aging coastal infrastructure, as many of these systems have been constructed in the 1960's and 1970's and are not sufficient for the current standards. For the future, sea level rise and climate change could lead to increases of loads on coastal defences. It is therefore essential to exchange and develop the state-of-the-art approaches for assessing and managing coastal risks and systems. The above topics have been discussed during the seminar and the main findings are summarized below.

4.2 The performance and design of coastal protection systems

The March 2011 resulted in a severe overloading of the coastal defences (dikes, seawalls) and failure in various locations. The behaviour of the coastal protection under such conditions is not yet well-understood and field observations from the disaster and follow-up experiments are important sources of new knowledge.

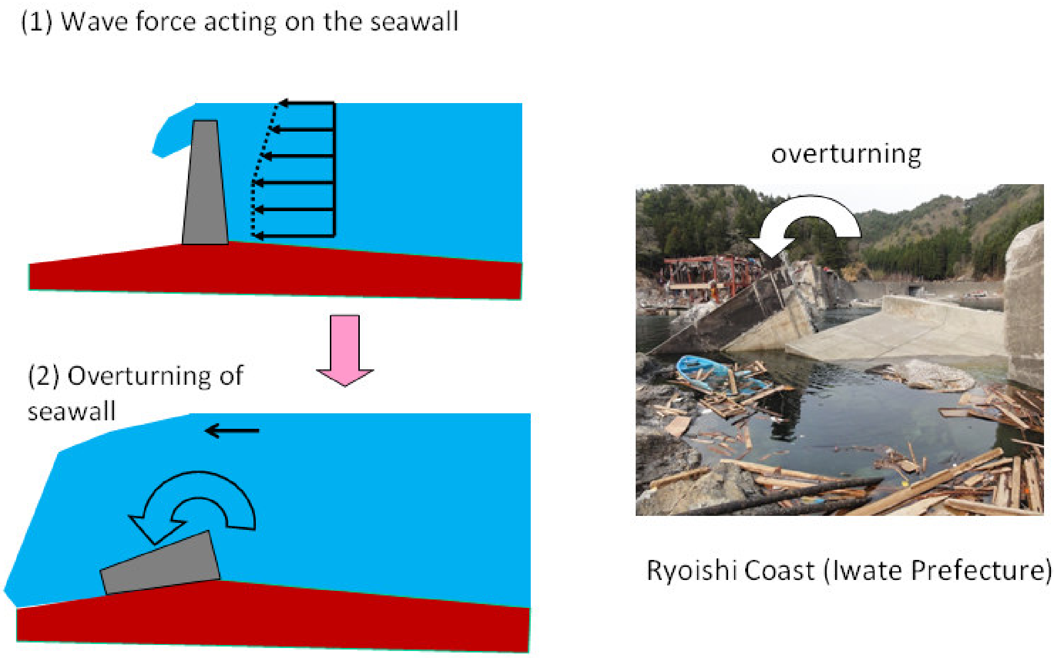

Figure: Overturning of seawalls during the March 2011 tsunami event (Presentation F. Kato, this seminar).

Both in the Netherlands and Japan, it has been discussed how coastal protection should perform if load is exceeded the design level. Related concepts such as resilience (also applied in New Orleans after hurricane Katrina), resilient structures (Japan) and overflow and overtopping resistant deltadikes (the Netherlands) are under discussion. An important research question is how such systems can be safely designed.

In the current Japanese guidelines a concept is proposed in which a structure is designed to perform safely until the design load (level 1) and a higher (potential maximum) level of loading (level 2) for which some damage to the structure is allowed. From a risk management perspective (also see the next section) it is important to define the rationale for designing for certain structure behaviour during overloading. It should be defined and investigated if the behaviour of the overloaded structure contributes to the reduction of damage, life loss, improvement of evacuation or other purposes.

In the Netherlands and Japan, challenges exist with respect to managing and investing in the aging coastal infrastructure, also given possible future changes, such as sea level rise. A rational approach is to come to an effective asset management and investment program given the limitations in budget. Research can contribute to the development of new and better approaches for optimizing and prioritizing for management of coastal infrastructure.

4.3 Multiple layers of safety and risk management

Both in the Netherlands and Japan, it is under discussion how multiple levels or layers of protection (coastal defences, land use planning and emergency management) can contribute to a reduction of risks from storm surges and tsunamis. Related concepts have been developed in other parts of the world, e.g. "multiple lines of defence" in New Orleans.

Information and experiences from the March 2011 tsunami can be used to a) evaluate the performance of such a multilayered risk reduction system; b) to develop effective strategies to reduce future risks. At this moment, discussions are ongoing on appropriate redevelopment and risk reduction strategies for the areas affected by the tsunami. The figure below gives an example of a proposed strategy for the Sendai area.

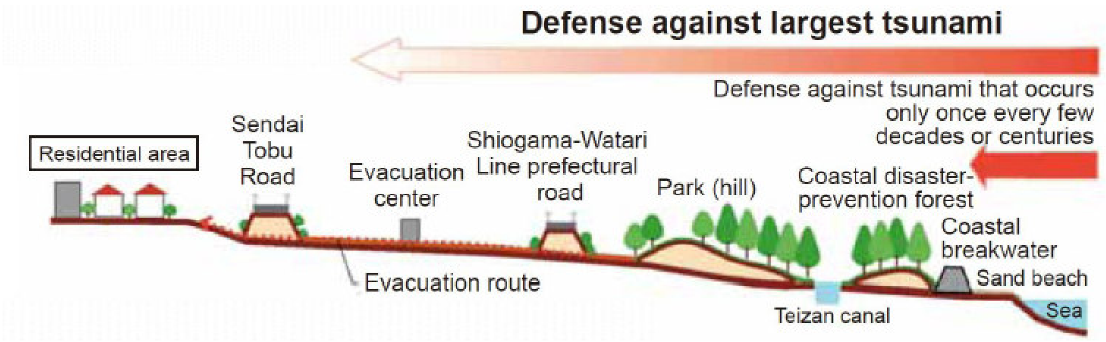

Figure: One of the proposed strategies for the future protection on the Sendai coastal area (Presentation S. Koshimura, this seminar).

The bases for deciding on investments in coastal protection and other layers of protection differ between the Netherlands and Japan. Decision making in Japan on investments in the system is largely based on local political decision-making and consensus. In the Netherlands "rationalized" approaches such as Cost Benefit Analysis, and criteria for acceptable risk to life are used to support decision making. As a scientific case study it is recommended to elaborate a case study for an area in Japan in which Dutch concepts are applied.

4.4 Emergency management

One of the main questions that was discussed is how emergency managers can plan for extreme events. Historical events do not cover the full spectrum of possible circumstances. As one of the solutions in the Netherlands a scenario-based planning was proposed.

The evidence from the disaster in Japan highlighted the relationship between emergency management, land use planning and coastal protection. In some of the presented examples, the ability for people to escape was heavily dependent on the level of development in tsunami prone areas and the preparation in advance. About 60% people evacuated directly after the earthquake and did not wait for another early warning. This relatively high percentage can be associated with the high level of preparedness (by means of drills and exercises) and the high frequency of earthquakes in Japan.

The field evidence from the Sendai plain and analyses for deep polders in the Netherlands, shows that for these areas without natural high grounds nearby vertical evacuation should be the preferred strategy. However the question remains how high and strong these buildings have to be, and if people can reach this destination. Despite planning assumes people to evacuate by walking, it is shown that many (about 60%) people uses cars which decreases effectiveness of evacuation because of traffic jams.

The events and lessons from the 2011 tsunami provide an important basis for better understanding warning, response and evacuation effectiveness in extreme conditions. Criteria have to be developed that can be used to answer the question when emergency planning is successful. Emergency planners should take into consideration the fact that unforeseen events happen and that some people will not evacuate. Further joint study of the available data by Dutch and Japanese scientists is recommended, and the links with other extreme events (e.g. the 2010 tsunami in Chile) and the factors that can influence evacuation effectiveness.

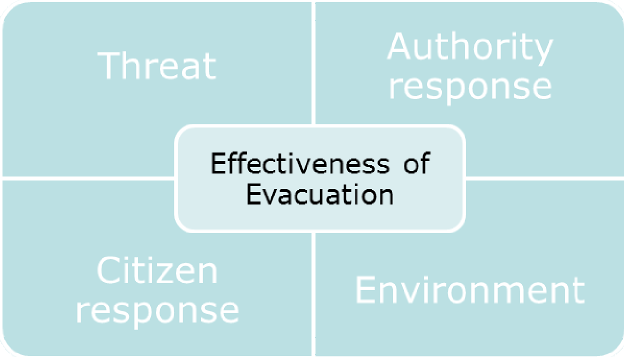

Figure: Factors affecting evacuation effectiveness (Presentation B. Kolen, this seminar).

4.5 Climate change and coastal protection

Both Japan and the Netherlands face the possible effects of anthropogenic climate change and increasing sea level rise. Also, the possible increase of tropic and extra-tropical cyclone intensities can give rise to higher storm surges and storm-generated waves, against which coastal areas need to be protected.

The sea level rise scenarios that have been developed in both countries were discussed during the seminar. It is also being investigated whether changes in storm patterns can occur. In Japan, very high resolution modelling of atmosphere is being applied, and model results showed a possible decrease of minimum pressure is projected especially for intense typhoons (see figure below), and thus possible strengthening of the storm surges.

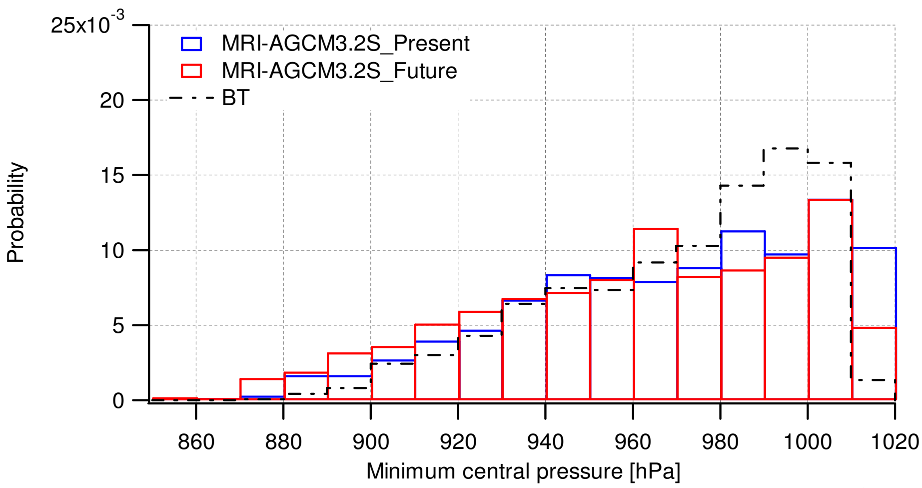

Figure: increase in the probability of intense tropical cyclones (low minimum pressure, left side of the graph) by the end of the 21st century, according to the state-of-the-art GCM (Presentation of T. Yassuda, this seminar).

Also, teleconnections between waves and large-scale climatology can provide insight in the variations and drivers behind extreme waves. Different approaches are being employed, including empirical relations on the basis of observations, as well as wave modelling based on output from GCM and RCM models.

The relationship between sea level rise projections and existing design criteria for coastal defences has been discussed. In The Netherlands, design criteria for coastal defence for events with a 1000 to 10,000 year return period have to be derived from a limited recorded data basis (e.g. 100 years) and uncertain future model predictions. This requires extrapolation, with considerable uncertainties. These uncertainties increase further given the likely non-stationarity created by anthropogenic climate change.

Apart from the changes in water levels and waves, future changes in the economy and population are also important drivers of risk increase. These latter factors also have to be considered in future assessments. Participants of the Dutch and Japanese delegations are both involved in the reporting of the Working Groups 1 and 2 of the Intergovernmental Panel on Climate Change (IPCC) or the Fifth Assessment Report, and this will be a basis for further exchange of ideas.

4.6 Future work and cooperation

The seminar has highlighted important practical and theoretical issues in coastal protection, risk and emergency management, and climate change and sea level rise research that are of importance for the Netherlands and Japan and other coastal regions. A number of follow-up activities has been identified and discussed.

- The results of the seminar will be presented at the Coastal Engineering Conferece (ICCE) in July 2012 in Santander, Spain.
- A PhD researcher from TU Delft will apply Dutch concepts for design and risk evaluation to a coastal area in Japan and will cooperate with Japanese researchers in this case study.
- Information and case studies from Japan will be used in another ongoing Dutch research project on "multifunctional flood defences", funded by STW.
- Apart from this report, the findings of the workshop will be published in national journals and forums (Waterforum, H2O) in the Netherlands and international publications (e.g. the ICCE 2012 proceedings).

For the longer term a number of other opportunities have been defined, such as the preparation of a joint discussion paper on challenges in "coastal disasters risk management", further application for NWO-JSPS scholarships for researchers, cooperation in an existing research project on coastal and tsunami risks in Chile (SATREPS) and cooperation in an upcoming EU KP7 call in the field of coastal threats. Based on these plans we are confident that the seminar has contributed to strengthening and expanding partnerships between Dutch and Japanese researchers.

5 Overview of the participants

Dutch participants

Name	Title	Organization	Signature / other
Han Vrijling	Prof. drs. ir.	Delft University	
Sebastiaan (Bas) Jonkman	Dr. ir.	Delft University & Royal Haskoning	
Vana Tsimopoulou	Ir.	Delft University & HKV Consultants	
Laurens Bouwer	Dr.	Free University Amsterdam IVM	
Bas Kolen	Ir.	HKV Consultants & Radboud University Nijmegen	

Japanese participants

Name	Title	Organization	Signature / other
T. Yasuda	Dr.	Kyoto University, Disaster Prevention Research Institute	安田誠宏
N. Mori	Prof.	Kyoto University, Disaster Prevention Research Institute	森信人
F. Kato	Msc	National Institute for Land and Infrastructure Management (NILIM)	加藤史訓
M. Esteban	Dr.	Waseda University	
S. Koshimura	Prof.	Tohoku University, Disaster Control Research Center	International Research Institute of Disaster Science (IRIDeS)
T. Shimura	Msc	Kyoto University	志村智也
H. Kawai	Dr.	Port and Airport Research Institute	河合弘泰
Y. Okumura	Dr.	Kyoto University	奥村与志弘
S. Suzuki	Dr.	Kyoto University, Disaster Prevention Research Institute	鈴木進吾
H. Kiri	Dr.	National Agriculture and Food Research Organization	桐博英
H. Shibaki	Dr.	Ecoh Corporation	柴木秀之
J. Ninomiya	Msc	Kyoto University	二宮順一
Y. Chida		Kyoto University	千田優
N. Katahira		Kyoto University	片平成明
Y. Mizobata		Kansai University	溝端 [illegible]
H. Gokon		Tohoku University	郷右近英臣