Japan Earthquake - Tsunami Reconnaissance April 29 – May 10, 2011

Blog posts by Lori Dengler
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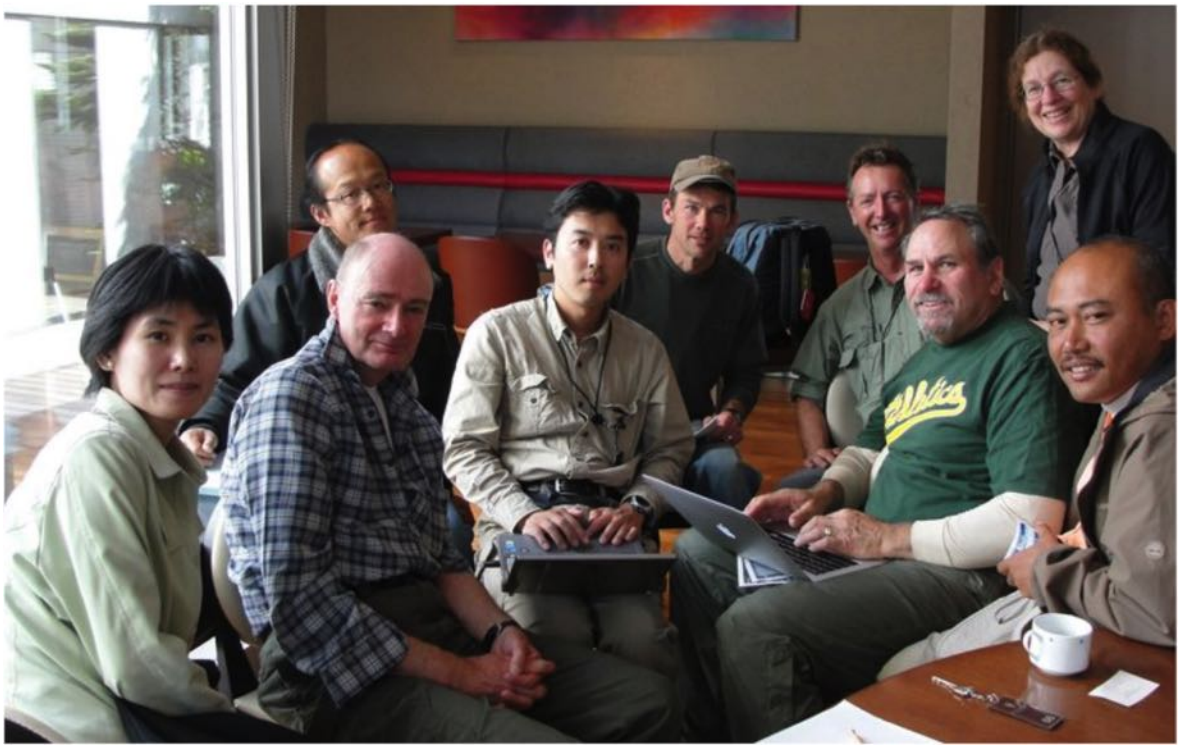

The Japan Post Tsunami Survey team members from the USGS and HSU. This blog reports the activities of Megumi Sugimoto (left) and Lori Dengler (upper right).

Day 1: April 29 - 30

A long day in transit but flights were on time, the San Francisco – Narita flight half empty (the flight attendants say a relatively common after effect of 3-11) and an easy train trip to Ueno where I'm staying tonight. In the first few weeks after the earthquake, there were major power disruptions and train schedules were chaotic. That seems to be over for the time being. I saw almost no signs of an earthquake en route from Narita to Tokyo. In Ueno, the main sign is numerous tables soliciting donations for relief efforts and lots of anti-nuclear paraphernalia (T-shirts, signs, buttons, satchels, etc.). Tomorrow I take the Shinkansen to Sendai to begin field work in earnest. Normally I would have flown, but the tsunami caused major damage to Sendai's airport and access is still limited.

Day 2: May 1

Slept 10 hours and spent much of morning downloading as many reports I could find on the Tohoku-oki earthquake (or Great East Japan earthquake in its English translation). One report summarizes the demographics of the victims. 92% are attributed to the tsunami, 4.5% to falling objects and structural failures, and the remainder due to fire. This is based only on bodies recovered – assuming all the missing are attributed to the tsunami, the tsunami victims increase to 97%. If there had been no tsunami, the casualties would have been less than 700. Of the victims, nearly two-thirds were over age 60, and more than half over 70. This really brings up issues about mobility and the ability to self-evacuate in a near-source event when time is very short.

Took the Shinkansen (bullet train) to Sendai. The train was unusually crowded. This is "Golden Week" in Japan – a week the encompasses a number of National holidays including the Emperor's Birthday (until 1988), Constitution Memorial Day, Greenery Day, and Children's Day. Many people get the whole week off and many have chosen to spend their vacations volunteering in the tsunami hit areas. Yomiuri Shimbun estimates as many as 8000 volunteers a day to invade the area, more than three times the typical average before this week. Volunteerism has plusses and minuses. There is much to be done – assisting in shelters, distributing aid, working on cleanup – but coordinating large numbers of untrained people puts additional stress on the situation. My real work begins tomorrow.

Day 3: May 2

I met up with my Japanese host and colleague Megumi Sugimoto – a postdoctoral scholar at Tokyo University. She was working in Indonesia in 2004 and joined one of the first teams to visit Aceh. She has been working on a tsunami mitigation project in Padang for the last several years and was with the first group to visit the Mentawai Islands after last October's tsunami. That was a so-called "tsunami earthquake" – where the ground shaking doesn't feel very strong but the tsunami is large. Her work convinced me to emphasize how long the earthquake lasts rather than how strong it feels. Tsunami earthquakes may not shake very strongly but they still last a long time.

Megumi has been working in the tsunami-hit area for several weeks now and it's been very informative to see it through her eyes. There is more earthquake damage than I first thought. Most of it is non-structural – cracks in walls and at the corners of doors and windows, heavy tile roofs that are now covered with tarps, building facades neatly covered with enormous mesh sheets to hide the construction work being done behind. The cleanup of the earthquake damage has proceeded so quickly that it is hard to recognize. She tells me that there is much more earthquake damage in Fukishima Prefecture, but we won't be working there because of the nuclear plant.

Today we rent a car – a brand new Mazda that we are told not to get sandy – and head towards the Sendai coast near the airport. The airport, located slightly more than half a mile from the coast, suffered major damage in the tsunami estimated to have reached 32 feet (see http://www.youtube.com/watch?v=-DSSssHxm4Y , and the before and after pictures at http://www.nytimes.com/interactive/2011/03/13/world/asia/satellite-photos-japan-before-and-after-tsunami.html) . 1300 people were trapped at the airport for two days. The airport reopened on April 13 in large part due to the assistance of the US military. It was rather bizarre to see an island of well-dressed passengers headed to and from the airport in the midst of total devastation. We wanted to check out the fate of a grove of pine trees that had been planted about 15 years ago as a "tsunami forest". Some scientists have argued that a sufficiently large grove of trees can dissipate tsunami energy. Unfortunately this grove didn't have a chance. Most of the trees had been neatly snapped about a foot above the ground and now were mere indicators of the flow direction.

Trees bent by the tsunami near Sendai Airport. These trees were part of a tsunami forest planted in 1996 to reduce tsunami impacts.

Next stop Matsushima, considered one of the three most beautiful ocean views in all Japan (the other two are Miyajima off of Hiroshima and Amanohashidate near Kyoto). This picturesque vacation town inside Matsushima Bay was nearly untouched by the tsunami. Waters surged over a five foot wall and several hundred feet into the town but not sufficient to cause much damage. The shape of the bay protected the town from brunt of the tsunami. The town has well-signed evacuation routes leading people to the most beautiful evacuation shelter I've ever seen – the Zen Meditation Center within the 13th century Zuiganji Temple grounds. For five days many tourists were sheltered at the temple. Because the town had so little damage, it served as a staging area to launch relief efforts in the much harder hit areas to the north and south. Matsushima was very busy today – with a large film crew, a beauty queen, and several large mascot-sized creatures - all celebrating the reopening of the Matsushima ferry service.

Tsunami evacuation route sign painted on sidewalk in Matsushima.

Last stop was East Matsushima just north of Matsushima Bay and unfortunately exposed to the triple whammy of the Pacific Ocean, River, and a canal system. After the beauty of Matsushima, it was a blow to be plunged again into devastation.

Just felt a light aftershock, a 4.8, 65 miles east of here – my first since being in Japan.

Day 4: May 3
The day began nearly as it ended – with a low rumble followed 9 seconds later by slightly sharper swaying. Another aftershock. The day was focused on the people caught up in the tsunami and the decisions they made that contributed to their surviving. We started back at the Sendai Airport, this time going inside to talk with the people who had been there on March 11. Although in a mapped tsunami inundation zone, the water height was never expected to flood into the main part of the terminal. On March 11 there were about 600 employees at the airport and about a similar number of passengers. The earthquake caused the power to go out but the generators (located underground) immediately came on. There was a lot of confusion – some people rushed outside during and after the ground shaking, some people were told to go up to the second or third floor and others told to go downstairs. The airport is not a designated tsunami evacuation shelter but many people from the community sought it out because of its modern design and high profile.

Security personnel and some of the passengers and staff received the tsunami forecasts by JMA, the Japanese Meteorological Agency that warned of significant wave heights. Nearly 1300 people ended up squeezing onto the second and third floors (with broken glass and other earthquake damage) when the tsunami advanced on the airport (see the link day 2). The generators died at 4 PM, about 1 hour 15 minutes after the earthquake and marks the likely time of complete inundation. Many people outside and on the ground floor were caught in the waves and perished. Those high enough endured 2 difficult days of cold, inadequate food, water and sanitation. On the third day, only passengers and elderly neighborhood evacuees were provided helicopter airlifts and staff had to walk across the inundated area to get out of the zone.

Tsunami display in the Sendai Airport.

Next stop the Natori City Cultural Hall, which serves as the shelter for the survivors who have lost their homes in an area northeast of the airport called Yuri Age. We spent the afternoon interviewing willing evacuees to get a sense of the factors that triggered them to evacuate, how they evacuated and what made them think an area was safe. Several themes emerged from their responses. There was more time between feeling the earthquake and the tsunami flooding than I had been led to believe. A series of timed photographs made from the roof on an elementary school that served as an evacuation site clear shows the first flooding just before 4 PM, the same time the airport was hit. Almost no one said they began to evacuate after feeling the earthquake.

Many headed from safe areas back into the hazard area to contact relatives. The decision to evacuate in most cases came after hearing the JMA tsunami warning of significant waves. And almost everyone evacuated by car. Of course we didn't get to interview those who failed to successfully evacuate.

Tonight we are staying at a mountain hotel in the hills behind Iwanuma. It only just reopened because of earthquake damage and persistent power outages. It does have a hot springs, which I am about to partake of.

Our room in the mountain hotel inland of Iwanuma.

Day 5: May 4

Best night so far – a futon on a tatami mat. Good preparation for the day. We visited the elementary school in Yuriage where several of the evacuees we talked to yesterday had waited out the tsunami. It looked almost as if it had been designed with tsunami evacuation in mind – a sturdy three-story reinforced concrete structure with multiple exterior staircases and a large accessible roof. The gymnasium of the school has now been turned into a "memory hall", where photographs and other belongings retrieved from the demolished Yuri Age homes have been posted on walls, stashed in boxes, and hung on lines. Then out to the hardest hit area of Yuri Age – the extremely flat land within a half-mile of the coast. It also provided our first (and so far only) contact with police attempting to control access. The scale of the event is so large, there are so many ways to access the area, and personnel are stretched so thin that it would be very difficult to establish effective roadblocks. This was the most devastated area we've seen yet. Water heights in this region exceeded 30 feet and more than 1000 people died. Whole blocks were leveled with an occasional structure partially standing. The highest points were two mountains fo removed debris.

Elementary school at Yuriage. Note exterior stairways that provided the community with access to upper floors.

Photo from the Yurige tsunami memorial exhibit showing people on roof and third floor during the tsunami.

A mix of activities were going on – body searches still in progress, debris removal, people looking for belongings, and other people just looking on. One woman commented while picking through the debris at her home site – isn't this interesting, but it isn't ours so we shouldn't take it.

In the midst of the devastation was an artificial hill with monuments on the top. It was about 20 feet high with one large stone marker and several other flat stone bases. People were using the hill as a viewing point and had established an informal memorial to the victims. From gouges in the bark of a pine tree growing on the top, it looked like the tsunami reached at least eight feet above the top of the hill. We were trying to figure out the purpose of the hill. The riddle was solved when we went down to the back where the three other stone monuments had ended up after being overtopped by the tsunami. The largest was a tsunami stone – noting the 1933 Showa tsunami that had killed a number of people in Yuriage. It was written in old calligraphy with characters not used today and Megumi wasn't sure of all of the details but it described the tsunami and explained that this was a safe place. Well it may have been safe in 1933, but it certainly wasn't safe in 2011.

Yuriage tsunami memorial mound – the stone monuments were originally n top of the mound and inscribed that this was a safe place from tsunami.

Day 6: May 5

Today is Children's Day – the final National Holiday that closes Golden Week. The day is marked by flying large gaily painted koi representing family members from poles or wires. The koi on First stop today was the evacuation shelter in Iwanuma City– the next city south of Yuriage in Natori City. Iwanuma had made much more progress in establishing temporary shelters. Neat rows of three room mobile housing filled the open spaces around the evacuation shelter. We talked to people both still in the main evacuation shelter and to people who had moved into the new temporary spaces. The difference in morale was night and day – no surprise that having one's own space beats a cardboard cubicle.

Completed temporary housing, Iwanuma

Next we headed north to East Matsushima. Over 1700 people died in the East Matsushima – Higashi area where tsunami surges attacked from three directions – the coast, the Naruse River, and a canal that cuts across the city and joins Matsushima Bay to the Naruse River. We looked at the designated evacuation place in a school auditorium that was located only 2/3s of a mile from the coast and less than 800 feet from the canal. The building had no upper floors and was filled

with tsunami debris. It seemed and odd choice for vertical evacuation when it was located right next to the three-story reinforced concrete elementary school. Megumi thought that the reason the school wasn't the choice was that, unlike the school in Yuriage, the stairs were within the building and Japan has been very nervous about allowing outsiders to enter the interior of schools ever since the Osaka school massacre in 2001.

We met a group of volunteers wearing Animal Rescue T-shirts. The group included two women - from Ireland and British Columbia. These are the first Caucasians I've run into in the disaster area. They said their group was sponsored by FEMA, which has become very active in animals in disasters since Hurricane Katrina. The situation for pets is very difficult in Japan. The women told me that many shelters won't accept animals and some tsunami survivors have had to give up their animals to city shelters and near-certain euthanasia. There are several animal rights groups working to develop alternatives.

We finished the day with a quick tour out to the tip of the peninsula that separates Mastushima Bay from the Pacific Ocean. We chose a bad time of day to do the drive – 4 PM when all of the dump trucks and other heavy equipment were heading home for the end of the day. Some places were a very tight squeeze. The contrast between the impacts on the Pacific side and the Bay were remarkable. On the Pacific, communities were obliterated. On the Bay, the main impacts were from liquefaction and the tsunami was relatively negligible.

Koi strung to celebrate Children's Day, Matsushima Bay.

Day 7: May 6

Disclaimer and Acknowledgements – I should have mentioned this earlier, but better late than never. All the comments in this blog are preliminary and the opinions my own. The purpose of reconnaissance trips is to get a quick overview of the issues in an event and the process begins with small slices of what happened based on what we see, read, and who we talk to. Gradually a picture emerges that (I hope) comes close to the truth. But some of the early hypotheses may turn out to be in error or downright wrong. Numerous Japanese researchers are working on many aspects of the event and other international teams are hear or will be headed to Japan soon. We share our ideas, debate issues, publish results and by a year from now, I expect there will be pretty clear consensus on the most important lessons from this event. But right now, data is still being gathered, and the situation is still fluid. It's one of the aspects of reconnaissance efforts that I find

most stimulating – the scientific process in action and in overdrive. Much of the information I'm passing on here has been gathered by others - in particular, casualty statistics (National Police Agency), and water heights (numerous teams, data compiles by IOC/UNESCO).

So far we've spent most of our time on the broad, flat coastal plain south and east of Sendai. The tsunami water heights in this area were in the 30 – 35 foot range. This was a big tsunami – the damages impressive and the losses significant. But most concrete buildings in this area appeared to have survived – especially the structures designated as evacuation places. Today we headed further north – first to Ishinomaki and then to Minami Sanriku.

The water heights were greater in Ishinomaki, a city of over 160,000 people and a major port. Some areas were hit by surges reaching more than 45 feet high. Much of the city was exposed to the tsunami and over 5600 died or went missing, the highest overall total of any city in the tsunami area. We started in the port area where cleanup had removed almost all traces of major damage in the harbor. The other side of the city was in much worse shape, but the rate at which debris is being removed is remarkable. This occurs at both a large and small scale – with massive machines and an army of individual volunteers.

Ishinomaki

Last stop of the day was Minami Sanriku, a city noted for its tsunami preparedness efforts including sea walls, tsunami gates to cut off surges at the river mouth, designated evacuation buildings, and a well-exercised disaster prevention organization. In the harbor area are a series of commemorative plaques for the past tsunamis to hit the area – 1896 Meiji, 1933 Showa, 1960 Chile. The height of the Chile tsunami – 2.6 meters – was indicated on a marker. It would have all worked fine had the tsunami been similar to what happened in those previous events and what the community had planned for. But 2011 easily overtopped and broke the sea walls, and reached fourth floor elevations in much of the city. A particularly tragic story played out at the City's Disaster Prevention Center, and a designated evacuation place. A woman official kept at the microphone announcing to the public that a tsunami was coming. Until she was finally overwhelmed. Of the thirty people on the fourth floor of the building, only 10 survived. Her body was found only a few days ago. Perhaps the saddest part of the story is that the building is only a five minutes walk from high ground and if everyone had headed to the hill instead of the building, they all would have survived.

Disaster Services building, Minami Sanriku.

Day 8: May 7

How does one describe scenes of devastation day after day in a way that is not numbing? Today was Kessenuma near the northern edge of Miyagi Prefecture and Rikuzen-Takata in southern Iwate. Both of these cities were hit very hard with water heights over 5 stories high. As one approaches Kessenuma from inland, it looks very normal. The higher land in the outskirts is filled with shops and cars and people going about their business. The steady stream of military vehicles going in and out is an indication that things are not normal. The western end of the port area wasn't so badly hit – although boats keep appearing in odd places and many of them are partially blackened by fires. As we head east, the situation quickly deteriorates and the alien landscape of debris, bombed out shells of buildings, and really bad smells come over us. Driving is a challenge.

Boats in Kessenuma.

The roadways were the first things to be cleared in the response and they have done a remarkably good job. But the combination of differential settling and subsidence, loss of pavement, piles of debris on either side of the roadways and large vehicles coming the opposite way make it a nail biting experience. And sometimes the road just ends – requiring a long backtrack to get back to

firm footing. Megumi has been doing all the driving - thank goodness – and she has done an admirable job. Kessenuma is a major port and the impact to port structures will have economic reverberations for some time. The sunken boats created an oily sheen on the water. This area was knows for fisheries – one fisherman told us he thought it would be ten years before the area returned to normal.

Rikuzentakata is the southernmost city in Iwate Prefecture. It sits on a flat plane at end of an elongate bay that appeared to funnel the tsunami three to four miles inland up narrowing river valleys. It made me think of Orick and the mouth of Redwood Creek with about 23,000 more people. The sea walls were obliterated. Wood frame buildings were obliterated. Steel frame buildings were obliterated. The only structures left standing were reinforced concrete, and if you were lucky enough to be in one of those, you needed to be on the fifth floor or higher to survive. The big question now in cities like Kessenuma and Rikuzentakata is how to rebuild. It's clear from Japanese television that there is pressure from some experts to rebuild the sea walls – just higher and larger. There will certainly be discussions about zoning and land-use planning. There is no easy answer – land is at a premium in Japan and figuring out how to co-exist with the tsunami hazard will be difficult.

Rikuzentakata, like many coastal cities in the Tohoku region, had planted a forest of pine trees along the coast to dissipate tsunami energy. Of the thousands of trees in the tsunami forest, only one survived.

Damaged floodgate control system at Rikuzentakata. A number of firemen perished while attempting to close the gates. The lone surviving pine tree is to the left.

Day 9: May 8

A 5.7 to start the day and a 4.6 to go to bed by. They get one's attention and remind you that this event isn't over yet. A few final tasks today in Iwate Prefecture before heading back to Sendai. We needed to track down the location of the shelters for people from Kessenuma and Minami Sanriku so we could get a comparison to the stories and experiences of the Sendai area. We are lucky today. It's Sunday and we were concerned that city offices would be closed. But the man who ran the shelter last night was just clocking out to go home and is willing to guide us to the Ichinoseki temporary housing. After a long day and night's work, this was really going out of his way for us. No matter what country I've been in, I'm always impressed and gratified by the kindness of strangers – especially the closer one gets to the disaster area. I've had some unpleasant hurdles set by a few bureaucrats far from the scene, but very few doors shut in my face in the midst of the destruction.

The Ichinoseki temporary housing facility makes use of partially occupied four-story public apartment buildings. We don't feel comfortable knocking on doors so wait in the parking area hoping to intercept someone willing to talk to us as they enter or leave. It's not a statistically accurate sampling technique, but at this point we are trying to be as unobtrusive as possible and still get an idea of the principal issues.

We talk to two older men who were both outside of the inundation area when the earthquake struck and both headed back into the zone on feeling the earthquake. The first was from Kessenuma. He was at work away from the coast, and the earthquake was the trigger for him to get in his car and drive to his home. His wife was there and had mobility issues. He knew his house was at risk – it was in a low area near the river and frequently flooded. But he was stopped by the first tsunami surges before he was able to get home and he was able to turn around and drive to a safe area. Fortunately another relative had picked up his wife so they both survived. He spent 40 days in an evacuation shelter before moving into the temporary housing. Every day he goes back to Kessenuma to get information about the cleanup and recovery efforts because he gets no information where he now lives.

The second man was from Minami Sanriku and he was working in his fields far from the coast when the earthquake struck. He had a different reason for wanting to go back to his house. He wanted to get his wallet and other personal belongings. His wife and daughter begged him not to go, but he went anyway. He was also stopped by the first tsunami surges before he arrived, and by driving very fast, was able to escape. We have heard this story now too many times – the earthquake was a trigger. Not the trigger to head to higher ground, but to go from a safe area and drive back into a hazard zone to get a loved one or to rescue possessions. We've only talked to the ones who escaped. My guess is that many of the victims did the same thing – they just weren't as lucky.

On the drive back to Sendai, we pass close to Hiraizumi, and a good excuse to visit Chuson-ji, a famous Buddhist temple founded around 1100 by the Fujiwara clan. The first Fujiwara lord lost most of his family in the vicious civil wars of the era and established the temple to foster peace and reconciliation. It is a beautiful site – tall trees, a complex of beautifully restored temples and an opportunity to decompress and reflect on what we are learning. The site is one of two in Japan currently under consideration for World Heritage designation by UNESCO.

Chuson-ji, a reminder of the beauty of Japan.

Day 10: May 9

We start out today with a short meeting with members of the International Tsunami Survey Team (ITST). This group is focused on tsunami deposits and tsunami geology. The challenge has been to find good transects that have been undisturbed by cleanup activity. We also meet with Masahiro Yamamoto, the Senior Advisor to the Intergovernmental Oceanographic Commission of UNESCO. I'm currently on the advisory team that Masahiro heads to revise the ITST post event survey guide. The first ITST guide was completed in 1998 and focused primarily and getting water height measurements. A lot has changed in the tsunami field since 1998 – technology and tools, scope, and involvement of many more disciplines. The revisions was supposed to be completed and ready for review by the end of March – one more thing the Japan tsunami postponed.

Then it's back to Tokyo on the Shinkansen. It's a clear day and everything looks normal from the window of the train. We discuss report strategies and next steps. One of the biggest challenges I have found in post event reconnaissance is distilling the information and getting reports written in a timely way. As soon as I returned, I'll be inundated by all the work that has piled up over the past ten days, plus the items that were overdue before I left. I want to get a draft report done today while everything is still fresh in my mind and I still understand what my field notes refer to.

Day 11: May 10

This will be my last post for this reconnaissance trip. I had a smooth return trip – all flights on time! On my last day in Tokyo, I met with Professor Tsuji of the University of Tokyo. Tsuji-sensei is well-known in tsunami science – having participated in or lead post-tsunami field investigations all over the world. His keen eye, breadth of background, and infectious humor have helped to create the International Tsunami Survey Team (ITST) format that we use today. He is also known for having found the highest inundation in the 1993 Okushiri tsunami (over 90 feet), and the second highest point in the current tsunami (over 120 feet). He is a very busy man, the phone constantly ringing with inquiries from the media, government officials, and other scientists. I was lucky to have an hour appointment. He's seen much more of the inundation area than I have. I was particularly interested in the story of the town of Taro in Iwate Prefecture. Taro was famous for the Japanese "Great Wall of China " a towering 33-foot edifice that was completed in 1958 to protect the town from tsunamis. When new development began outside the limits of the older walls, a new was extended in the 1990s to cover this area also. Unfortunately, the construction company who built the new wall failed to put in steel or other reinforcement to hold sections of the wall together and the tsunami toppled them as easily as child's blocks. The tsunami was high enough to overtop the old walls as well, but they didn't topple and the level of damage in the older area was a little less. The standing walls did reduce the amount of flooding and gave residents an extra few minutes to get to higher ground. More on Taro at http://www.youtube.com/watch?v=xBKtw9JMba4.

I asked him about how Japan should be approaching tsunami hazard mitigation issues in the future. He suggested a two-tier approach. Tsunamis are much more frequent in Japan than on the West Coast of the United States. Major tsunamis occurred in 1896, 1933 and 1960. Sea walls and engineered tsunami abatement structures should still be the primary line of defense for these relatively common tsunamis. But there needs to be a second tier – a life safety plan to protect people from much larger tsunamis such as the March 11 event. This is what needs to worked on and applied to other tsunami prone areas as well as the NE coast of Honshu.

I'm still sorting through my notes and photographs to summarize our findings from the trip. I took more than 1200 photos and Megumi has a similar number. A small sampling is posted at https://picasaweb.google.com/lh/sredir?uname=105862892016189181305&target=ALBUM&id=5604574501661513313&authkey=Gv1sRgCLvZ4fr9otPZJw&feat=email

We conducted more than 30 detailed interviews. I am also pouring through the reports from other scientific teams and the flood of government and other reports that have been released. Here are my preliminary thoughts on the themes that are emerging. My disclaimer is that "preliminary" is the operative word here. Additional information may change some of these findings.

The most important lesson is that underestimating the hazard has tragic consequences. Japan spends more of their GDP on earthquake and tsunami hazard mitigation than any other country in the world. This includes more instruments, more tsunami scientists and engineers, more numerical modeling, and more engineering works. These mitigation efforts were built on an assessment of the size of the likely maximum earthquake and maximum tsunami that turned out to be wrong. The majority of sea walls in the affected area (like those in Taro) built to restrain the tsunami and many of the designated vertical evacuation places were overtopped or failed in the event. Because it was expected that the mitigation efforts would be effective, there was no catastrophic response plan in place. This affected the ability to effectively respond, to coordinate both national and international offers of assistance, and prolonged the amount of time some people were on their own in isolated evacuation places.

There had been a few studies by geologists that suggested a much greater hazard than had been adopted in planning efforts and it is easy now to point back at those studies and say they should have been used. Hazard assessment is a difficult process, the historic record (even in Japan) is short and interpreting paleoseismic data is not always straightforward. Megathrust earthquakes (earthquakes with magnitudes of 8.5 and greater) are particularly tricky because they are so rare. Sixteen magnitude 8.5 or larger earthquakes have been recorded on seismographs (post 1900), and only five of these were magnitude 9 or larger. Both 9+ earthquakes that have occurred since modern broadband instruments have been in existence have changed the conventional wisdom. The 2004 Andaman Sumatra earthquake changed our ideas about the relationship among earthquake size, age of crustal material, and convergence rate, and the Japan earthquake is challenging the accepted scientific ideas about the relationship among magnitude, fault area, and slip.

I have been privileged to work with and learn from many of Japan's earthquake/tsunami professionals for years and as a group they are an extremely hard working and conscientious and this earthquake showed that much of their effort was successful. On first look, it appears that the built environment performed very well even when subjected to some of the strongest ground shaking levels ever recorded. The early warning system that analyzes an earthquake during the initial seconds of the rupture appears to have worked in shutting down trains and other facilities before the strongest shaking. While power went out at 2:46 PM when the earthquake struck, sirens, cell phones and radios continued to work in all of the areas we visited. In Chile, after the February 2010 M 8.8 earthquake, only one radio station continued to work in the Bio Bio region and cell phone coverage was down. In recent much smaller California earthquakes (2008 M 5.5 Chino Hills, 2010 M 7.2 Baja) both cell and landline telephone communications were jammed by overuse. But all of the successes in reducing earthquake impacts are overwhelmed by the enormity of the tsunami losses.

What I am taking away from Japan is the importance of allowing for uncertainty in hazard estimation and making sure we are conservative when it comes to life-safety decisions. We'll be taking a long second look at what we have been doing in California – and I know that other folks working in the Cascadia region will be doing the same.

Here's a quick take on other lessons (in no priority order)

• People not aware of risk. Few of the people we talked to thought they were at risk where they lived or worked. We don't know the reasons for this – whether they believed the sea walls would protect them, or education efforts weren't effective, or there were other reasons. I hope other groups study this issue in more detail.
• Vulnerability was a function of the unique geography of a location and the characteristics of the tsunami (height, flow velocities, duration, and arrival time). The situation on the broad coastal plain near Sendai was very different than the population centers like Minami Sanriku and Kesennuma that were built on alluvial flood planes and valleys near the mouths of large rivers. At East Matsushima, the situation was complicated by exposure from the ocean, a large river, a canal, and Matsushima Bay.
• Elderly appear to have been more vulnerable.
• Evacuation issues
People relied on cars
Planning centered on vertical evacuation in designated structures, rather than getting to high ground outside of the hazard area.
The earthquake often triggered behavior – but not to evacuate to a safe area. A number of people who were in safe areas, drove back to into hazardous areas after feeling the earthquake. Most often the reason was to check on/rescue loved ones at home, but in some cases it was to retrieve property.
• Response/Recovery
Evacuation places were unprepared to hold people for days in winter conditions
Enormous shelter needs and inadequate shelter facilities – frustration of people in shelters with lack of privacy, bathing facilities, and lack of information about what is happening in their home towns.
Enormous temporary housing needs
Long duration loss of utilities and services in the affected area requiring resources – such as an army of traffic control officers at major intersections now without traffic signals
Coordinating volunteers
Relentless reminders of the event Aftershocks News/media coverage – daily revised body/missing counts, radiation levels
Reconstruction debates – how to rebuild and mitigate hazards from future tsunamis
• Loss of confidence in technical community
• The patience and perseverance and kindness of the people affected – lack of looting, cooperation, and general willingness to talk to us!