

Chile Earthquake - Tsunami Reconnaissance March 24 – April 2, 2010

Blog posts by Lori Dengler

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The HSU Chile Post Tsunami Survey team from left to right: Troy Nicolini, Lori Dengler, Pancho Luna, Nick Graehl, Sepastian Araya.

Day 1: Wednesday March 24

Made it as far as Petaluma on the first leg of our trip to Chile. In addition to me, the group includes Troy Nicolini, the Warning Coordination Meteorologist of the Eureka NWS office – an engineer by background, and the coordinator of today’s Live code tsunami warning communications test, and Nick Graehl, geology grad student whose thesis project is studying the tsunami hazard in Yaquina Bay near Newport, Oregon.

The first lesson I’ve learned is not to schedule a tsunami test at the same time as a post-tsunami survey expedition. Troy has been up to his ears with all of the details of a three county live Emergency Alert System (EAS) test, siren activations, civil air patrol flyovers and we’ve both been busy with a massive educational campaign. The big danger with a Live Code test is that someone might be confused and think a real tsunami is on its way. For the test, I was stationed in Crescent City and had to be at a briefing at 8 AM. We won’t know how successful the test was until all of the information comes in over the next few days, but I was impressed with what I saw of Del Norte County’s full scale evacuation drill. Definitely very noisy at 10:15 when the sirens went off. The best moment for me was when all of the students and staff from St. Josephs school showed up. Tsunami aware children can be real heroes in tsunami events. Tillie Smith, aged 10, saved 100 people in Thailand in 2004 when she recognized the unusual wave activity as a possible tsunami and alerted people to get off the beach, and in the Chile earthquake, 12 year old Martina Maturana,

rang the village bell alerting most of the inhabitants of Robinson Crusoe Island. This is a story we hope to learn more about.

After the test, Troy was contacted by a number of reporters. The furthest was a woman from Chile who had heard about our test on the internet. So now we have a Chilean media person to meet with in Santiago.

Day 2: Thursday March 25

Petaluma to San Francisco to Dallas to Santiago. Flights on time but we almost weren't. After all the years and miles of flying, I pulled a real beginner's error – confusing the departure and boarding times. We were casually enjoying our dinner in an airport pub and we pulled out tickets to compare seats and discovered that boarding had begun 40 minutes ago and the gates were closing in 10. I think we were the last group on the plane. Because we made it, it's a good story.

Sebastian Araya joined us in Dallas. Sebastian took my Natural Disasters Class at HSU in Fall 2000. He was a geography major at Humboldt and a terrific cartographer, a native of Chile and very interested in hazards. He was the top student in my class that term, and one of the top 2 or 3 who have ever taken that class from me. After the class, I continued to rely on Sebastian's map-making skills for other projects and in the summer of 2001 when a magnitude 8.4 earthquake occurred in southern Peru, it took me about 10 seconds to decide I wanted Sebastian to accompany me on the International Tsunami Survey Team that Emile Okal of Northwestern was putting together. Sebastian was the hero of that trip, doing most of the surveys with survivors and managing to get our four-wheel drive out of a very precarious situation in the sand that another driver had gotten us into. After leaving Humboldt, Sebastian went on to get a Masters at the University of Colorado studying urban runoff problems in Santiago. After the Peru survey in 2001, he assisted a Japanese tsunami team in Chile in 2002, and went to Aysen in southern Chile in 2007 to study a landslide-generated tsunami.

Day 3: Friday March 26

No time to log on until Friday evening. We arrived in Santiago this morning after an 11 hour red eye. Earthquake signs all over the airport – missing ceiling tiles and cracks in the walls and ceilings and almost all the vendors (restaurants, rental cars, gift shops) have been moved to tents in the parking lot. But other than the airport, signs of a magnitude 8.8 earthquake are surprisingly rare in the city. A number of the pedestrian bridges were damaged and there is tape blocking certain areas but you'd never notice that anything is out of the ordinary.

We spent most of the day in a briefing organized by UNESCO and Laura Kong of the International Tsunami Information Center. It was very useful. We got reports from 4 teams who have recently finished their reconnaissance work – gave us a good foundation to build on. Three themes seem to be emerging:

- 1) Most deaths were caused by the tsunami (note: this turned out not to be true – only about 1/3 of the ~550 casualties were caused by the tsunami and 2/3s were shaking related), and the most vulnerable populations to the tsunami were the people camping on an island in the Constitución area followed by several other low-lying camp grounds. At least 50% of the tsunami victims appear to have been campers – we'll try to pin this down. The earthquake struck on a very special day – a weekend celebration just before fall with local parties, camping trips and fireworks. If the same earthquake had occurred a few weeks later, or even during the week, the casualties numbers may have been cut in half. This really points out a problem for us on the North Coast – think Gold Bluffs Beach. We need to work much harder at educating the out of town camping populations.

2) There was a long time between successive surges, and in some locations, the largest surges may have been as much as four hours after the earthquake. There were a number of examples of people returning to the coast thinking it was over only to run to high ground as another surge rolled in. We've been preaching the long duration of a tsunami for many years, but now Troy and I are thinking of adding "Tsunamis are tricky – just when you think the danger may be over, more waves may come surging in".

3) The peak water heights along the south central Chile coast are apparently very variable. In the 2004 Sumatra earthquake, one of the things that really struck me was the uniformity of the inundation zone. The 40 to 60 foot zone of stripped vegetation and exposed bedrock made it look like a ring around the bathtub that extended nearly 100 miles. In some places it was higher, but the general uniformity was very impressive. This tsunami seems to have been much patchier – high splash areas and then just around the corner much lower values. The tsunami scientists and modelers will have much to work with to explain the detail and complexity.

Tomorrow we head to the coast.

Day 4: Saturday March 27

Drove from Santiago to Concepción today – a distance of about 300 miles and a latitude change equivalent to going from the Salton Sea to Santa Cruz. Our fellowship is now complete. We met the final member of our survey team, Francisco (Pancho) Luna. Pancho is a Childhood friend of Sebastian's and an investigative journalist.

It was my first chance to see the Chilean country side. The first part of the drive reminded me a lot of the Beaumont – Banning area and Concepción area seems very like the San Mateo coast. Chile turns your head around both in terms of directions and in seasons. It is a very linear country – the populated corridor bounded by the Andes and the coastal range. Sebastian says that people give directions according to North, South, Up, and Down. It's just past the autumn equinox, days are getting short and one of the consequences of the earthquake is that the switch from Daylight Savings time to Standard time was postponed a few weeks to help the reconstruction effort.

As we drove south, earthquake damage became more prevalent. At first we only noticed some cracks along the road margins and soil slips on bridge overpass abutments. Then the road damage became more severe, some bridges completely down, and noticeable damage to adobe buildings. In Curicó, all of the adobe buildings appeared to be damaged, many tiles were off roofs, and piles of debris still sat on sidewalks. But it is still impressive how many structures are undamaged.

The reason for our detour into Curicó was in pursuit of an interview with the policeman Moisés Molina who helped to save Iloca. Iloca is a small coastal village about 50 miles away from Curicó. We had read in the newspapers how this policeman had helped to save the people of Iloca by using his bullhorn to urge people to go to high ground. I've been interested in local tsunami heroes for some time and I really wanted to see if we could find this person and learn what had motivated him to take the actions he did. The problem – he was no longer stationed in Iloca. Much of the year only a few hundred people live there but during the summer, vacationers swell the ranks to over a thousand. Rather than maintain year-round police force large to handle the summer visitors, police from neighboring municipalities are rotated in to help coastal towns like Iloca in the peak periods. Our policeman was one of these extra summer officials. It took Pancho about ten phone calls and 45 minutes to track down his whereabouts and lead us into the heart of Curicó.



Sebastian interviewing Moisés Molina, the policeman who alerted many tourists in Iloca.

What ensued was an extraordinary interview. We spent over a half hour listening to his story and it will take us some time to complete a transcript and pull out all of the details, but there are several points that emerged right away. First, he had no particular training in tsunamis or earthquakes. He was from an inland community and had no cultural history or oral tradition about tsunamis. But he had been stationed in Valparaiso for 5 years during the time that tsunami hazard signs had been posted there. He had also participated in a number of drills and training exercises for other types of emergencies. Tsunami signs had also recently been posted in Iloca. In the early morning hours of February 27, he was able to see the ocean quite clearly because of the full moon. He didn't immediately associate the strong ground shaking with a tsunami (the Valparaiso signs didn't mention earthquakes), but he noticed the water becoming agitated and that reminded him of the signs so he organized the other police and they notified the town. He also had the instinct to keep people in the evacuation area until he got official notification that the danger period had passed. As a result of his actions, no one died and no one got hurt even though the town was destroyed.

Day 5: Sunday March 28

Felt three earthquakes today, the first two while interviewing Mauro Mosciatti, the Director of Radio Bio Bio (see below) and the third during a rest stop in Lota. They were gentle vibrations but a reminder that we are still in the midst of a vigorous aftershock sequence. I'm glad we are staying in a new Holiday Inn Express that doesn't seem to have a single crack from the main shock. Not my normal style – but here I'll take a well-engineered structure over quaint or rustic any day.

We spent the morning in downtown Concepción on the track of Radio Bio Bio. This is another one of those wonderful stories of an organization filling a vital need when almost all forms of communications were down. Pancho came through once again by arranging for us to talk to the director. Radio Bio Bio is an institution in Chile – around 40 radio stations throughout the country and currently celebrating its 40th anniversary. These are commercial stations that have a long tradition of community service and involvement. The director of the Concepción station is a civil engineer by training with a long interest in preparedness. About 5 years ago, he began to feel that Concepción was overdue for another strong earthquake. Concepción has a long earthquake history

– hit by at least 5 major earthquakes between 1570 and 1750, and in 1751 so badly damaged that the entire city was moved further inland to its present site.

Concerned that another major earthquake might come soon spurred the radio station to secure all of the equipment in the studio, purchase a generator and even stock food and water. The preparedness actions paid off – the studio suffered no damage in the 8.8 mainshock and was back on the air within 20 minutes. For at least two days, it was the only station on the air throughout the region of strongest shaking. The station dropped all of its normal programming and went to information sharing 24-7 – no ads and no music. When a listener called in to see if someone could locate a needed prescription, the station became an informal connector of the medically needy to the needed supplies. When people couldn't find a loved one, the station broadcast the information widely. When a large aftershock occurred a week later, even the Navy realized that the quickest way to get their tsunami message out to the public was via Radio Bio Bio. The station is filled with banners, flowers, and testimonials from the public with thanks for the critical role it has played. Even their return to normal programming was carefully planned – no ads or music for the first 8 days, then a gradual insertion of carefully chosen music.



Sebastian interviewing Mauro Mosciatti, Director of Radio Bio Bio whose preparedness actions allowed the radio station to provide the only information for coastal residents the first four days after the earthquake.

Afterwards, we spent an hour on a quick tour of downtown Concepción. At first glance, it survived the February earthquake remarkably well. The overwhelming majority of buildings are still standing and many with no apparent damage. But a closer look reveals that almost every brick/adobe building is seriously compromised. I've never seen such a clear example of the selectivity of an earthquake to pluck all the weak structures. There were a few spectacular examples of newer buildings that failed, but the overwhelming majority looked fine. Infrastructure – roads, bridges and pipes – did not fare as well and no question that construction crews will be

busy for some time. Spread failures and differential settling was particularly hard on the structures near the Bio Bio river.



One of the few newer buildings in Concepción with major structural damage. The 11th floor collapsed. Fortunately the building was unoccupied at the time.

Day 6: Monday March 29

Another aftershock just as I was going to bed but nothing today so far. It was a very busy day of interviews. We are so fortunate to have Sebastian and Pancho in the group. Sebastian knows the kind of information I am looking for and Pancho can track just about anything down. The first interview was with a coastal ecology professor from Valdivia. He has been studying the ecosystems of Chilean coasts for decades and had just finished surveying his lines in February. We were lucky that he had just made it to Concepción in the process of resurveying all of the lines post earthquake. He hasn't completed the surveys or analyzed the data yet, but his perception is that the land level changes are very irregular with some areas uplifted a couple of meters and others nearby showing little or no change. He was surprised that there were no ecologists on the international survey teams he has met. There's a real need for this discipline – the changes to ecosystems caused by uplift or subsidence, high velocity water, sand deposition and scour, and the influx of marine waters into estuaries needs to be documented and long term adjustment to the altered circumstances tracked.

Interview two was with two urban planners from Concepción whose responsibility was urban design. They reported that of 996 buildings four stories or higher, seven were damaged so severely as to require demolition and only one had collapsed to the point where people couldn't walk out of it. Note – this contradicts a report by Peter Yanev who is quoted in the media as saying 20% of Concepción's tall buildings were severely damaged. I don't know where he got his data from but it doesn't agree with what we've seen or heard so far. This is a good time to emphasize the preliminary nature of our observations. Our emphasis isn't engineering and a number of earthquake engineers have been here – I'm interested in what they have to say. The planners also told us that, like California, designing and planning for earthquakes has long included regulations and well-defined best practices. But tsunamis, in spite of Chile's relatively high frequency of tsunami events compare to most other countries, have not received similar treatment. There are no prohibitions or regulations on building within inundation zones. The planning dilemma now is how to treat reconstruction of the inundated areas. The coastal land is valuable and there will be pressure to rebuild. There are discussions about permanent relocations of some communities. There is historic precedent – they told us that the relocation of all of Concepción after the 1751 earthquake was in part due to the tsunami damage.

Interview three was with a geospatial analyst responsible for the city housing and other building stock. I have been impressed with the scientific, engineering, and technical capacity of the country. This includes GIS. But while the capability is top notch, not all agencies have embraced its benefits. The earthquake and tsunami may have helped to overcome this resistance as the benefits of tracking the status of structures and reconstruction have become obvious. They are also using geospatial techniques to map the inundation zone using wetness and sand/mud signatures. The analyst was very interested in Nick's Fairhaven evacuation time GIS modeling project and wanted to explore trying a similar approach in Concepción.

Our last interview was with a Geography professor at the Universidad de Concepción. After the earthquake there was a complete breakdown in communication and civil authority. He described the chaos of the first two days before the military arrived. The military took over most governmental functions including geospatial support for response crews. A problem was that the military wasn't equipped to map at scales larger than 1:25,000. Our professor had geospatial expertise and past military experience and when he volunteered to help, was quickly put to work assembling an ad hoc team of GIS experts (including our interviewee #3) to provide the needed products. What I found most interesting was his final comment – the need for better education of the decision makers on how to respond to an event that knocks out all of the structural layers they normally depend on. For two days there was no government presence and no decisions made. It was a very hard time to be in Concepción

Tomorrow we leave Concepción and head to Pelluhue. I'm not expecting any internet service for a few days.

Day 7: Tuesday March 30

Left Concepción and headed north. We wanted to spend a day in Talcahuano but our time is too short and I figure that many other teams will work there. Talcahuano is Chile's largest port and I know the COPRI team that should arrive next week will probably spend most of their time in that area. Still it would have been interesting to see the impacts on a major port. Driving north around the Bahía de Concepción we first went to Tome, a fishing/tourist town on the south facing part of the bay. The tsunami had very little impact – reaching only a few meters in height and causing almost no damage to structures. Tome did have tsunami evacuation route signs. The signs were jointly funded by the town and the local school and school children helped to install the signs. Some signs even have the name of the school sponsor written on them.

Then up and over the hill to the town of Dichato on a north facing bay only a few miles away from Tome. The picture was entirely different. Over 80% of the town was demolished, and only the buildings on the higher hills were spared. In one area, the tsunami had swept inland about 2 miles depositing a boat in a large field. Up till now, we've seen little tsunami damage. We've spent most of our time talking with officials and eyewitnesses outside of the tsunami zone. Dichato was walking into ground zero – and for Troy, Nick and Pancho, their first experience of major tsunami devastation. I never get used to it – seeing marks of impact or debris in trees 15 or 20 feet high and the strewn remnants of peoples lives on the ground, in trees, and in the water. The tsunami in Dichata did not level all structures like the 2004 tsunami in Aceh – a number of stronger structures were still standing but had you been even on the second floor, you wouldn't have survived because the water was too high. We don't know the official death toll in Dichato – the Chilean government is still sorting through the numbers and won't release the data until all possibilities of double counting and trying to locate the missing is completed. We talked to a number of survivors and their perception was that most residents knew to go to high ground. Some people had experienced the 1960 earthquake as children. It was centered further south but they remembered the ground shaking very clearly. The 1960 tsunami was fairly small in Dichato, and one person refused to evacuate this time on the basis that the 1960 tsunami wasn't very big. Bad decision – he didn't survive. Past experience can be a hindrance if you expect the next event to be exactly like the last. We talked to the owner of a small hotel who told us that the magnitude of the earthquake was really 9.2 and the government was saying it was an 8.8 in order to avoid paying more damage costs. It was his contention that if the magnitude were over 9, the Chilean government would be required to pay for all of the damages to both public and private property. I heard very similar stories back in 1994 when I was doing an intensity study of the Northridge earthquake and people told us that the US government made sure the magnitude was below 7 because over 7 meant FEMA would be required to pay out more.



Personal belongings swept into the street by the tsunami in Dichato.

After Dichato we left the coast, driving on narrow, winding roads very reminiscent of the Sonoma or Mendocino coast. The towns were small and had many badly damaged adobe structures. At Buchupureo the volunteer fire department pulled their two fire engines out after the earthquake,

sounded the sirens and drove around the town picking people up and taking them to high ground. Further north, Curanipe was a camp ground tragedy. According to a surfer we talked to, there were nearly 500 people camping and many were swept away. He saw at least 30 bodies laid out in the church afterwards. The campgrounds was located at the edge of town close to the coast and, unlike Iloca, no one tried to notify the campers. An added complication – the campground was located in a grove of trees and the earthquake knocked limbs down. Some of the campers went to the beach to get away from the hazard of tree fall.



Campground at Curanipe where many campers ran to the beach when tree limbs began falling in the earthquake.

We ended the day at Pelluhue – a gorgeous beach town that was very hard hit. Our hotel is on a bluff about 60 feet high overlooking the ocean and the devastation. It's a surreal view – calm ocean, lovely sunset, smashed houses and front end loaders picking up debris.



Memorial to family lost in the tsunami at Pelluhue.

Day 8: Wednesday March 31

Best night's sleep so far – slept right through two aftershocks that everyone else was talking about this morning. Started the day out talking to a woman who lived in Pelluhue and lost her home and her parent's home to the tsunami. She and her brother became more concerned about tsunamis after the Indian Ocean tsunami. Her brother had made an informal inundation map of the town based on elevation that showed their parents home at risk. The parents didn't want to leave the area so she moved to a house nearby just to be able to help them if/when a tsunami came. They were a well-prepared family, knew how to evacuate and had plans and where to meet afterwards. The plans worked well on February 27 and all of them survived. Their neighbors didn't fare as well, refused to evacuate and an older woman and child died. The woman felt a little guilty about surviving and was now trying to organize to community events to improve morale.

Most of the casualties in Pelluhue, like Curanipe, were campers. There was an informal camping area in the lowest area in the center of town. The radio station manager told us about 100 people died, mainly out-of-town visitors. The problem of educating tourists is common to all tsunami-prone areas and may be compounded by business concerns that pointing out the tsunami risk will deter vacationers. Pelluhue had posted tsunami evacuation signs and began holding tsunami evacuation drills after the 2004 Indian Ocean tsunami. Two summers ago, the drill coincided with the peak of the tourist season and many tourists were reportedly upset by the drill and left the town. They hadn't had another drill since then.

We crossed paths with a survey team from the architecture department of the Universidad Catolica de Valparaiso. They were constructing a detailed map of the inundation zone, topography, and noting location and construction type of all the damaged structures. The plan is to develop a velocity model to explain the pattern and type of damage. We arranged to stay in touch electronically.

Next stop Constitución, heavily hit by both the earthquake and the tsunami. In many ways, the city was a remarkable success story. Constitución is a city of about 50,000 with many older brick and adobe buildings did not do very well in the earthquake. Driving through the city one month later was still a challenge because the bricks and debris piled on the roadway. Thanks to Pancho's skills at contacting people were able to meet with the mayor and the head of education programs in the city.



La Isla Orrego where people were camping on February 27. The only access to and from the island was by boat. Normally uninhabited, the island was crowded with people to view fireworks.

Almost everyone in Constitución managed to evacuate. The one notable exception was where people were camping on La Isla Orrego, an island in the Rio Maule, enjoying the last weekend of summer and wanting a good location for the fireworks. The island, tantalizingly close to the main part of the city, was overrun by the third or fourth surge and swept away over 100 people. The people camping on the island had no high ground, no way to get off, and the eucalyptus trees on the island couldn't be climbed. The mayor told us that although the city had a high level of tsunami awareness – their planning hadn't identified all of the vulnerable areas in their evacuation planning and it hadn't occurred to anyone how vulnerable the island was. We showed him Nick's evacuation model as an example of an approach to identify problem zones and he was interested. More on what happened on the island at <https://www.latimes.com/archives/la-xpm-2010-mar-21-la-fg-chile-survivor22-2010mar22-story.html>

The island tragedy shouldn't take away from the remarkable success evacuating the main part of town. About 40,000 people managed to successfully evacuate in the dark in a city filled with rubble and damaged structures. Off of the island, only 4 other people died, and according to the mayor, it was because they refused to leave. The city had a variety of tsunami education programs including evacuation signs, programs in schools, workshops, and drills. But even with successful evacuation, the mayor emphasized two important lessons to incorporate into their future planning. First – many people on feeling the earthquake just ran. They didn't think to put on shoes or grab jackets. Taking a minute to put on shoes would have saved them time and reduced injuries because the broken glass and rubble was very hard on bare feet. Second, very few people had any plans on how to contact other family members after they had evacuated. In some cases it took 3-4 days for people to re-unite. The mayor also noted the difficulties of engaging the business community. For the last several years, he had been trying to do a drill for the private sector. They had nearly set a date, but then the earthquake happened.

After Constitución, we drove inland and spent the night at a beautiful spot on Lake Vichuquén. Sebastian is a master at finding wonderful places at off season rates.

Day 9: Thursday April 1

Last full field day. Started out by talking to the staff at the hotel what happened during the earthquake. They were full and there was a mixed response to what to do during the shaking. Some people moved to doorways but many went outside. No one had heard of "Drop, Cover, Hold-on". But they were somewhat prepared – had a generator and the guests were fairly calm. The power was out for weeks and their credit card reader was still not up. This presented a problem as we didn't have enough cash. Fortunately they were very easy going and just gave us their bank info in Santiago and told us to deposit the money when we got there. Can't imagine that happening in many other places. The guests were stuck there until Tuesday (the earthquake was early Saturday) because landslides had closed the roads. We were told this happened in many places and some hotels didn't charge their stuck clients. Fortunately they had plenty of food on hand and minimal damage – though I noticed it was nearly impossible to open/close the door to my room and the snooker table had a distinct undulation that wasn't there before.

Off to Iloca, the town where the policeman we talked to on Day 4 had been stationed during the earthquake/tsunami. It was a crazy drive – off on a dirt road without the help of Susie, our GPS navigator. Troy had programmed her with a sweet female voice and Sebastian christened her sassy Susie. She helped us a lot in getting to Concepción, but was balky and difficult to use when we didn't have a specific address and many of the roads weren't in her data base. No help at all on the dirt roads between Vichuquén and Iloca – attempt 1 ended up fording a river to a dead end, attempt 2 went a couple miles past our turn and attempt 3 worked, but on the last turn a logging truck had turned too fast, the load had shifted and over they went. Fortunately the driver was ok.

The towns of Duao and Iloca were both heavily hit by the tsunami. We started out at the police station hoping to talk to some of the people who had worked with the policeman we had talked to earlier and have them show us their evacuation route. The station had been destroyed by the tsunami and the police were currently occupying a temporary modular building. Unfortunately for us, all of the staff who had been stationed in Iloca on February 27 had been re-stationed in inland communities because of their stress levels. It was considered too difficult for them to continue to be surrounded by the devastation of the tsunami. The man at the station explained what the route was so we decided to walk it and time it.

The official evacuation route that the police pointed out took over twenty minutes. Most of it was parallel to the beach. It made no sense to us. So we began to interview as many people as we could both about how they figured out it was important to evacuate and where they went. Turned out there had been many more preparedness efforts in Iloca than what we had heard from the policeman. This shouldn't have been a surprise – he was a temporary visitor from inland and only stationed there during peak tourist times. A team from the University at Talca had been holding workshops in the town for several years. They sounded similar to Judy Warren's Red Class course "Living on the Faultline and along the Coast" complete with preparing a grab-and-go bag to keep by the door. People were urged to figure out the best route to get to high ground within ten minutes from where they lived and everyone further from the official evacuation route just headed to the nearest inland site. The police actions did play a very important role – they notified the people in the campground and other people who hadn't evacuated. We had lunch at, and talked to, the staff at the Hotel Iloca who were all from inland towns. They went outside after the earthquake and just stood around not knowing what to do. The police came by and told them to evacuate. If the police had not been pro-active, I think the locals would have all survived. But their action clearly kept Iloca from becoming a Curanipe or Pelluhue where so many campers died. We need to find out more about the Talca program, who ran it, and what it included.

Talking to the staff at the hotel gave us a different perspective on the event. The Hotel Iloca was virtually untouched by either the earthquake or tsunami. It was right on the beach and only about 4 meters above mean sea level. Areas both to the north and south were devastated. Other research teams have commented on the fingers of devastation this tsunami produced. In some areas it seems fairly easy to understand the pattern – south of the epicentral region north facing beaches and bays were nailed and south facing ones spared. But the Iloca pattern seems more complex. Troy talked to a retired scientific photographer who spoke good English and spent his summers in Iloca. He observed the Humboldt current reverse during the earthquake. The moon was full, and he was very familiar with observing the predominant offshore current here and saw a distinct change from the normal northern flow to heading south after the earthquake. Another story to further pursue as this could also affect the direction the tsunami surges came in from.

In addition to the staff at Hotel Iloca, Sebastian and Pancho talked to several other business owners who were very concerned about their future. There were a number of intact businesses – hotels, restaurants, shops – that although open for business, had very few customers. They were concerned that the media coverage of the Iloca damage had created the perception that the town was essentially closed. We certainly had that perception and probably would not have stayed in Vichuquén if we had realized what nice lodgings were available right in Iloca.

Our last stop was the brand new school in Duao. Before the earthquake/tsunami, there were three elementary through junior high schools in the Lincantén municipality that includes Iloca and Duao. All were damaged by the earthquake and the two coastal schools by the tsunami as well. For years the district had hoped to build a new combined school but lacked the funds to do so. The

earthquake created the opportunity to make it happen. As a result of the help of businesses, the Canadian government and the volunteer efforts of the community and construction crews, they built a new modular school (on high ground) in one week. It was cheerful and well-organized and included a new computer lab that had not existed in any of the old schools. We talked to the principal and she was concerned that some families might not allow their children to return to school because of worries about aftershocks. Regionally, there has been a sharp decrease in attendance in most schools within the earthquake area. The Duao school staff went door-to-door explaining to families how well-equipped and safe the school was and when the school opened a little over a week ago, we were told that attendance was nearly normal. Many of the parents said they thought going back to school would be good for their students as so many were displaced and the parents stressed by the earthquake/tsunami impacts. Staff were also having difficulty dealing with the aftermath and we were told the Red Cross was providing counseling services.



Pancho and Sebastian with teacher at Duao elementary school where all classes practice evacuation drills once a month.

We asked what they taught about earthquakes and tsunamis in the schools. There isn't much in text books but many teacher voluntarily enrich the curriculum (sounds similar to California). What is different is a national program called Operation Daisy that teaches hazards preparedness throughout the country. What hazards are covered are chosen by the individual municipalities. For example Andean schools might choose to teach landslides and volcanic hazards. We heard about Operation Daisy in several other communities and it was our sense that most coastal districts teach earthquake and tsunami safety in the program. This includes many drills and we heard a number of stories of school children urging their parents to evacuate and showing them where to go during the February 27 event.

One big difference between Chile and California is what students and the public are told to do during an earthquake. At the Duao school, students are taught to gather in the center of the classroom (no Drop, Cover, Hold-on) and in the shaking lasts more than 20 seconds or so to

evacuate the building while the ground is still shaking. A number of adults mentioned moving to doorways, suggesting that was what they had been taught, but the principal told us schools no longer make that suggestion.

Off to Pichilemu, a surfer's mecca, for our last night on the coast. We are staying at the Waitara (a Maori name) no more than 10 feet above high tide. I asked the hotel manager where the tsunami evacuation route was and she said don't worry, there won't be a tsunami. I'm not so sure – put my shoes and computer backpack by the door and hung my headlamp on the bed post.

Day 10: Friday April 2

Fortunately no strong earthquakes in the night so I didn't have to try out my evacuation strategy. First access to internet in three days – but only if I sit out in the driveway near the manager's building where the router is located. Amazing how quickly an inbox fills up in three days. We had a late morning – breakfast served on the porch in front of our rooms. The sky is clear and the community expectant of a large crowd of visitors for the three day weekend. It's Good Friday, a national holiday, and many people from Santiago and other inland cities head to coastal towns. The towns from Pichelemu and north were not hard hit from the tsunami and are only a couple of hours drive from Santiago. The mood here is much different than in the towns further south, no one seems much interested in the earthquake or tsunami and there is an insistence that everything is normal. There's an interesting video posted on Youtube from this area of a young man joking about the tsunami as it comes in. You can see how modest the waves are, but still enough to pull him under the water and struggle with the surges. Afterwards, he is still hamming for the camera. You can see it at <https://www.youtube.com/watch?v=UI15TcydrD4>.

We arrive back in Santiago early afternoon and spend the rest of the day pouring through our notes. We have an exit briefing scheduled with UNESCO tomorrow afternoon. It's good to have the deadline and get a preliminary report pulled together before we leave. I'm already thinking of the stack of work in my office I'll face on Monday and know that the time to write up a summary report. Sebastian wanted us to experience the "gran lomito tomate palta completo" sandwich, a Santiago classic consisting of a bun the size of a plate stuffed with avocado, pork, sauerkraut, and about a ¼ cup of mayonnaise. His favorite restaurant was closed because of Good Friday, but we found a reasonable substitute. I can't think of the right words to describe them. We made it through about half and boxed the rest for dinner.

Days 11 and 12: Saturday and Sunday April 3/4

Troy, Nick, and I spent the morning working very hard to pull our report together. Pancho and Sebastian joined us after lunch to prepare for the exit briefing with ITIC and UNESCO staff. We identified factors that effected impacts and made a number of recommendations. In a nutshell, the factors that reduced impacts were:

- Public Awareness (drills, education programs, previous experience, signs, culture)
- Time of day, day of the week (earthquake)
- An educated public
- Engineered structures
- Availability of high ground (with a few exceptions)
- Altruism/heroism
- Resilient organizations like Radio Bio Bio.
- A developed country with technical, scientific, and engineering capacity.
- Availability of tsunami inundation maps for a number of areas.

Factors that exacerbated impacts

A very large earthquake, damaged infrastructure (particularly roads and communication) and large near-source tsunami.

Time of day, day of week, and time of year – this reduced earthquake impacts (people at home sleeping) but increased the tsunami exposure (people camping) and difficulties in evacuating (night).

Inability of the normal response personnel (police, fire) to respond in urbanized areas like Concepción.

Vulnerable campgrounds with no tsunami information.

Lack of security delayed response for several days in some areas.

Planning for tsunamis was lower priority than planning for earthquakes in urban areas.

Variable education/outreach/signage/drills efforts. Extensive programs in some communities, few in others.

Signage doesn't connect the earthquake and the tsunami. Signs point out tsunami hazard zones, or tsunami evacuation routes but don't mention that the ground shaking is the natural warning.

Barriers to evacuation – no way to get off the island in Constitución.

Worries about impacting tourism caused some resistance among business owners to tsunami education efforts.

Ignorance or false expectations: Some expected to see the water drawdown first, or expected to hear a siren or receive an official notification.

Largest surges in some areas came very late (as much as 4 hours), people re-entered hazard zone, and in some cases, had to re-evacuate one or two more times.

Few people had personal plans – people left without shoes, and had no pre-arranged meeting places.

Based on what we saw and learned, we've made a preliminary list of important lessons for the United States, and the Cascadia region in particular.

- School curriculum. No question that Chilean coastal communities have gone much farther than California in school programs teaching tsunami safety. Institutionalizing earthquake/tsunami education programs in schools would go a long way towards producing an aware population. Seminars/Workshops. Classes and workshops were frequently identified as the source of preparedness information. Even if only a small percentage of the population attended, the information was spread informally.
- Physical barriers to evacuation. All regions of the U.S. Should be carefully reviewed for cases where coastal residents or visitors cannot reach high ground soon enough to avoid tsunami inundation. See the blog description Day 8.
- NOAA Weather Radio (NWR). The lessons learned from Radio Bio Bio have some relevance to the role that NWR can play after an event has occurred. The two screaming messages from Radio Bio Bio's experience are that silence should be avoided at all costs, and that the silence should be filled with meaningful information. While the NWS already recognizes the importance of keeping NWR functioning, some thought needs to be given to what would be broadcast in the hours and days following an event. Without advanced planning, NWR may simply default to providing the weather forecast when there is more urgent information that could be provided. Examples of information that could be provided by NWR includes: which radio stations are providing information, where to find medications, which roads are impassable, where meeting places have been designated, information about the recent event, and where food and water is being disturbed.
- Coastal Campgrounds. The message from the event in Chile is tragically clear: Special care must be given to the education of visitors to tsunami hazard areas in the U.S. This education must be

aggressive and must use active methods whenever possible. An example of an aggressive method would be to place tsunami signs above urinals and on stall doors in bathrooms – making them difficult to ignore. An example of a active method, where applicable, would be to train park staff to provide verbal and written education information to campers when they check in. Additional recommendations will be developed in the coming weeks.

- Connecting earthquakes and tsunamis, and the natural warning. The majority of locals we talked to knew that the strong earthquake indicated a tsunami would occur, and to therefore evacuate immediately. Evidence indicates that visitors to the coast did not make this connection. In the case where they were warned, by the police, for example, they survived. In the cases where there was no opportunity to warn visitors, there were significant fatalities. The message for the U.S. Is clear: for regions where a significant near-field tsunami threat exists, education that focuses on people responding based on a felt earthquake is of the highest importance.
- Set nature of tsunamis. The Chilean event, as well as historic North Coast tsunamis (2006, 1964), continue to suggest that people are not understanding that tsunamis last for a long time. Our messaging is not working, and our group concludes that the problem is that we are not addressing the temporal non-homogeneous nature of tsunami wave arrival times. People are lulled into a false sense of security when an hour or two passes with no additional waves. We must address this in our educational messaging and in the wording of our warning products. Interestingly, this is aspect of tsunamis is very similar to that of sneaker waves that claim many lives on the West Coast each year. There may be an opportunity, and benefits, to cross utilization of phrases and wording.
- Drills. In coastal communities where drills had taken place before this event, many interviewees mentioned that the drills enabled them to remain calm during the earthquake and to evacuate effectively. In contrast, some community members in Constitución evacuated so hastily that they didn't even put shoes on. This actually slowed their evacuation because they had to walk through debris and broken glass. Giving people calmness and the resultant clarity of mind needed to make decisions in a stressful situation is a recognized benefit of drills. While drills are already a best practice for Tsunami Ready communities in the U.S., their actual use is limited. Drills should be conducted more aggressively, especially for schools and other public facilities in the tsunami hazard zone.

After the briefing it was time to pack up and leave. We were advised that the concessions in the airport had not reopened because of the earthquake damage, and the only place open to eat was possibly the worst Chinese restaurant I've ever eaten at. But no harm done, The food, accommodations, and company on this trip has been outstanding. In the airport I ran into Bret Luzinda who I had worked with on a reconnaissance study of the January 9 offshore Eureka earthquake. He was returning with a group of engineers from the Applied Technology Council who were looking at design, code and tagging issues. It's a fairly small group of people who do post event assessment and I often run into people I know coming and going. We faced the usual trials on the homeward trip – delays and missed connections – that set us back a few hours. A rude shock to go from warm, dry, early fall conditions to a full blown winter storm complete with snow in Laytonville. We heard about the Baja earthquake near Healdsburg. No – the number of earthquakes is not increasing, but exposure and vulnerability is and this year we had the bad luck of a magnitude 7 (Haiti) located in nearly the worst possible place. But I've had enough to last me quite awhile.