1. Local Tsunami Procedures

   Very rare occurrence of local tsunami generated by cliff failure or submarine landslide. No procedures for local tsunami are implemented.

2. Distant Tsunami Procedures

   The distant tsunami procedure is written in the “PSS-tsunami” procedure (Plan de Secours Spécialisé, i.e. Specific Tsunami Emergency Plan), this procedure is under the responsibility of High-Commissioner, representative of the French Government.

2.1. What organization becomes aware of tsunamigenic events from a distant source?

   The Centre Polynésien de Prévention des Tsunamis (CPPT) implemented by the CEA/LDG/Pamatai.

2.2. What actions does this organization take with regard to tsunamigenic events from a distant source?

   An alert message with recommendations on the actions to be taken is sent to the Direction de la Protection Civile that informs the general public and the media, in accordance with the Specific Emergency Plan.

2.3. What are the criteria for initiating tsunami mitigation procedures?

   The tsunami warning plan defines 5 levels of procedures as follow:

   - **Level 1**: High-Authorities are informed. This level gives the warning to high authorities, with the main purpose to prepare the next stages.
   
   - **Level 2**: majors and municipalities are informed. The majors will prepare the warning to population.
   
   - **Level 3**: tsunami watch or marine threat. This is a tsunami watch corresponding to a marine threat, with potential strong currents in bays and harbors, without significant inundation of the shore. This stage can occur in 2 situations:
     - for a tsunami with small amplitudes expected (less than 1m)
     - during the hours after the passage a big tsunami.
   
   - **Level 4**: general warning. This is a general warning involving the evacuation of populations from the shore, at the predefined levels of evacuation given by Communal Plan of Safety (CPS), and applied in each Municipality.
   
   - **Level 0**: return to normal status. The tsunami risk is null: the social life returns to the normal status, after a warning.

   Different chronologies of level are possible: in function of the seriousness of the warning.

   The predefined levels of evacuation given by Communal Plan of Safety (CPS) are the following:

   - **Altitude of evacuation of 20 m:**
     For all Marquesas islands:

   - **Altitude of 10m, or 200 m from the shore**
     * Shores without protection of the corral reef ()
     * Bays and pass opened to the sea.
• **Altitude of 3 m, or 300 m from the shore**  
  Coasts protected by the corral barrier (Society, Austral, and Gambier Archipelago)

There is no specific level of evacuation for the Tuamotu archipelago: the tsunami threat is minor for these atolls.

**The different levels of warning and actions**

The major evolution concerning the levels of warning is that the old criteria that were based on the magnitude of the earthquake will be no longer used; the new criteria of warning and action are now based on the estimated tsunami height, $H$ in meter. These criteria are in a stage of validation by Civil Defense, and a new tsunami warning plan is in preparation. Nevertheless, the future criteria will be probably as follow:

- $H < 0.30$ m: no action, no danger
- $0.30$ m $< H < 1.0$ m: tsunami vigilance
- $1.0$ m $< H < 3.0$ m: minor inundation
- $H > 3$ m: major inundation

An other important evolution is that the level of warning will be regionalized by archipelago, or even for different coasts of Tahiti that are protected/exposed or not by the corral barrier.

**2.4. What actions are taken in response to warnings issued by PTWC during intersessional period?**

PTWC warning messages are received at the CPPT; in addition the Direction of Civil Defense, and at headquarters of the Army in French Polynesia receive also the messages of PTWC; they must verify that the CPPT is well informed of the current warning or bulletin. Furthermore, the CPPT has its own seismic warning that call the agent on duty.

Just the level 1 of warning was issued for the Queen Charlotte 2012 (M 7.8) , and the Santa Cruz 2013 (M 8.1) events.

**3. National Sea Level Network**

Currently there are 8 sea gauges installed in harbors in French Polynesia, maintained by University of Polynésie Française UPF), SHOM (Service Hydrographique et Océanographique de la marine), CPPT, PTWC and/or the University of Hawaii:
- two in Tahiti, one in Papeete (Tahiti harbor) and one in Vairao
- one in Rikitea harbour (Gambiers Islands)
- two in Marquesas Archipelago, one in Taiohae (Nuku-Hiva) and one in the Tahauku bay (Hiva-Oa)
- one in Tubuai (Austral island) installed in 2010.
- one in Rangiroa atoll (Tuamotu Archipelago), installed in 2010.
- Makemo (Tuamotu) will be installed in 2014.
4. Information on tsunami occurrences

The Queen Charlotte Mw = 7.8, 28 oct. 2012

For this event, we got a luxury of different estimations of the seismic sources, converging globally through a common focal geometry and a seismic moment given in the [5-7] E20 N.m range., as shown below.

Queen-Charlotte 28 oct. 2012

<table>
<thead>
<tr>
<th>Method</th>
<th>Mw</th>
<th>M0</th>
<th>NP1</th>
<th>NP2</th>
<th>15 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS_AL Inversion</td>
<td>7.8</td>
<td>6.5e+20</td>
<td>296</td>
<td>17</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>136</td>
<td>74</td>
<td>96</td>
</tr>
<tr>
<td>GCMT</td>
<td>7.7</td>
<td>5.2e+20</td>
<td>320</td>
<td>29</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>116</td>
<td>63</td>
<td>79</td>
</tr>
<tr>
<td>USGS WMT</td>
<td>7.78</td>
<td>7.4e+20</td>
<td>320,17,110</td>
<td>119, 74, 84</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>119</td>
<td>74</td>
<td>84</td>
</tr>
<tr>
<td>USGS CMT</td>
<td>7.7</td>
<td>4.8e+20</td>
<td>328 37 123</td>
<td>109 60 68</td>
<td></td>
</tr>
</tbody>
</table>

As the tsunami height estimated with both MERIT and COASTER methods, were less than 0.30 m in French Polynesia, Civil defense was just informed, and no further actions were required.
Queen Charlotte 29/10/2013: map of the maximum tsunami height estimated in deep ocean computed by MERIT software. The values indicated in the map are the estimated height for the DART stations, and for some virtual gages in deep ocean.

Queen Charlotte 29/10/2013: Example of predicted tsunami height for Hiva Oa (Marquesas Island), bay of Atuona: the values of the scale are in meter. No actions were required for this event.
Queen Charlotte 29/10/2013: same as the previous picture, predicted tsunami height for Tahiti harbor and the international airport.
The Santa Cruz Mw=8.1, 6 Feb. 2013

The moment tensor of this event of a classical thrust faulting mechanism was rather well constrained with coherent results given on by the SYS_AL inversion, and on the other side by the available published focal mechanisms:

<table>
<thead>
<tr>
<th>Source</th>
<th>NP1 (deg)</th>
<th>M0 (N.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SYS_AL inversion:</strong></td>
<td>313 8 74</td>
<td>1.6E21 N.m</td>
</tr>
<tr>
<td><strong>USGS Wphase MT:</strong></td>
<td>309 17 61</td>
<td>1.2E21 N.m</td>
</tr>
<tr>
<td><strong>USGS centroid MT:</strong></td>
<td>311 28 68</td>
<td>7.8 E20 N.m</td>
</tr>
<tr>
<td><strong>Global CMT project:</strong></td>
<td>320 20 89</td>
<td>9.4E20 N.m</td>
</tr>
</tbody>
</table>

Despite of its magnitude, the radiation pattern of the tsunami into the Pacific was rather weak. Consequently the tsunami in French Polynesia had weak amplitudes. For this event again, no actions and no warning to the population were required by Civil Defence.
Santa Cruz 2 Feb; 2013:

Santa Cruz 2 Feb 2013: predicted tsunami height for Hiva Oa (Marquesas Island), bay of Atuona: the values of the scale are in meter. Again no actions were required for this event.
5. Web site
CEA and CEA-DASE has implemented 2 web sites in France
http://www.cea.fr/fr/sciences

PART 2: NATIONAL PROGRAMMES AND ACTIVITIES INFORMATION

6. EXECUTIVE SUMMARY
Brief statement of no more than one page addressing all items discussed in the Narrative section of the National Report

The seismic warning is executed via the SEISCOMP system, on the base of the P wave magnitude, with a threshold at 7.3.

The Moment Tensor (MT) is estimated by SYS_AL via an automatic inversion of the surface waves; SYS_AL is a process running in parallel to SEISCOMP, and uses the data provided by SEISCOMP.

Independently to SYS_AL, the MT is also performed independently by the inversion of Wphase developed by L; Kanamori & Rivera, (2008).

The tsunami amplitude is estimated with the MERIT process that uses the Green law for the computation of tsunami amplitude near the shore. This process is run in less than 5 minutes.

In addition a precise numerical modeling of the tsunami is obtained with the COASTER software, that performs the tsunami propagation until the shore, via nested grids of increasing resolution. As far as the source estimation is precise, the tsunami estimation can be very accurate. The time of computation on super-computer (212 processors) is less than 45 minutes.
The installation of the tide gauge stations in French Polynesia is achieved with 8 stations. These stations are available via the Sea Level data facility web site (http://www.ioc-sealevelmonitoring.org).

The PACWAVE2013 exercise, for testing the new PTWC products and bulletins, was played with the North Chile scenario.

7. NARRATIVE

7.1. Assessment of tsunami events
CPPT responded to the PACWAVE2013 questionnaire.

7.2. Siren implementation for Tsunami Warning in French Polynesia
More than 93 fully operational sirens have been installed in French Polynesia. The total number of sirens will be 131. These sirens are local transmission independent, equipped with Inmarsat mini-C Satellite detector. These sirens are electronic equipment, 136 dB (A), with possibility of solar panel power supply. They will be operated by High-Commissariat Departments, located in Tahiti.

7.3. New sea-level stations
The installation of the sea-level stations have been achieved in French Polynesia, resulting from a conjugate effort of the University of French Polynesia (UPF) and the French Government. Installation and maintenance is assumed by the SHOM (Service hydrographique et océanographique de la Marine). The total number of sea-stations at this time is 8, from which 3 are belonging to NOAA/PTWC and UH-Sea level. The stations can be processed either by TideTool (S. Weinstein, PTWC), or http://www.ioc-sealevelmonitoring.org.

7.4. SEISCOMP, SYS_AL, WPHASE

Estimation of the seismic source
CPPT is equipped by its own seismic warning based on SEISCOMP system, that gives a first rapid location, and a warning using the P wave magnitude.

In addition, an automatic computation of the Seismic Moment Tensor (SMT) have been implemented in the SYS_AL system, that is a kind of software plug-in developed for running in parallel to SEISCOMP. The SMT is calculated from a joint inversion of the surface waves, and P-wave first motions.

At least the SMT is also computed independently and automatically with the Wphase-inversion method developed by Luis Rivera, Hiroo Kanamori and Zaccarie Duputel.

The SEISCOMP tools has been installed in CPPT, receiving about 230 stations from different networks (mainly IU, GE, and G, C), through the SEEDLINK protocol.

For each earthquake of magnitude greater than \( \approx 5.5 \) SEISCOMP automatically detects, localize and computes a magnitude using the P waves.
In parallel to SEISCOMP, the SYS_AL process computes automatically the Mm magnitude, the slowness (\( E/M_o, \) Newman* & Okal*, 1998), the scalar moment and the seismic moment tensor (via a joint inversion of surface waves and P waves first-motions).
Practically the results and the source estimation becomes reliable for events of magnitude greater than 6.0

In addition to the SYS_AL process, the Wphase inversion method (Duputel & al. 2012) has been implemented to the CPPT since February 2013.
The events of magnitude greater than 6.0 are processed automatically 30 minutes after the origin time of the earthquake, using the data received via SEEDLINK/SEISCOMP.
This method that uses ultra-long periods of mantle waves, is known to be very robust for estimating the Centroid Moment Tensor (CMT) of big earthquakes, including tsunami-earthquakes and mega-sources (like Sumatra 2004 and Tohoku 2011).

Either the source solution provided by SYS_AL and/or Wphase can be injected into the numerical modeling made by MERIT and COASTER; the worst scenario will be retained.

References:

The networks and stations used by SEISCOMP, received via the SEEDLINK protocol

7.5. **Numerical tsunamis simulations: estimation of the tsunami height**

The tsunami height is computed by 2 methods

1) **The MERIT method (Modélisation et Estimation Rapide des Inondations de Tsunami)**

**MERIT** is a method that computes rapidly the tsunami height in deep sea; then the maximum tsunami height near the coasts is estimated via the Green law that has been modified with a coefficient depending on the slope of the shore. The estimations of the tsunami height with this method are obtained in less than 5 minutes.

2) **The COASTER method (COAStal Tsunami Evaluatin Risk)**

This method is a full computation of the tsunami amplitude near the shore that uses nested grids of increasing resolution, until a 5 m x 5 m high resolution near the shore. Like other methods that use the Navier-Stokes equations approximated with finite differences, it gives the most accurate estimations of tsunami height, as it able to take into account resonance, focalization and refraction effects of the waves.

The time of computation on a super-computer (216 processors) is less than 45 minutes for 15 hours of tsunami propagation in the Pacific.

The Civil Defense is informed of new estimations/observations made on the tsunami amplitude along its propagation. The tsunami warning can be cancelled/confirm in function of the tsunami amplitudes observed.
Notice that the tsunami warning procedure can be applied for the whole territory of French Polynesia, or only for a given archipelago, in function of the expected tsunami amplitude.

**PACWAVE2013**, North Chile Mw 9.1 scenario: Example of maximum estimated tsunami amplitude given by COASTER in Atuona bay (Hiva Oa, Marquesas); the synthetic tsunami waveform given at the point (1), is plotted at the bottom; notice the tremendous height forecasted (9 m).
**PACWAVE2013**, North Chile Mw 9.1 scenario: Example of maximum estimated tsunami amplitude given by COASTER for Papeete harbour (Tahiti); the synthetic tsunami waveform given at the different points are plotted at the bottom; notice the tremendous height forecasted (9 m).

**7.6. Tsunami Public Education**

Brochures and a short clip is displayed regularly on TV for tsunami education, giving general information, delay of warning and evacuation procedure. This work has been made by the initiative of Civil Defence and French Government.

**7.7. Publications**

