The UWI Seismic Research Centre is the official source of information for earthquakes and volcanoes in the English-speaking Eastern Caribbean.
World Heritage Site, Pitons Management Area

Cover Image:
Rising to 770 m above sea level, Gros Piton (left) and Petit Piton (right-foreground) are part of the Piton Management Area which was recognized as a World Heritage Site in 2004. This designation was due largely to the visual impact and aesthetic qualities of the Pitons, two adjacent forest-clad volcanic lava domes rising abruptly from the sea.

The Pitons are part of the Soufriere Volcanic Centre that comprises a series of volcanic vents and a vigorous high-temperature geothermal field. This Centre is currently considered to be the only live volcanic centre in Saint Lucia. The most likely type of activity expected from this volcanic centre in the future is a phreatic or hydrothermal eruption.
Welcome to our year...

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UWI Seismic Research Centre
2009-10 Annual Report
Our vision

To be the leading agency in the Eastern Caribbean for earthquake, volcano and tsunami monitoring and for the dissemination of information to reduce risk, deaths, injuries, property damage and economic loss.
The UWI Seismic Research Centre (SRC) is the regional agency responsible for monitoring earthquakes and volcanoes in the English-speaking islands of the Eastern Caribbean. The Centre has been providing governments in the Caribbean with expert advice on geologic events and associated hazards affecting these islands for over fifty years. It is one of the few specialised research institutions of the University and its work directly impacts vulnerable island communities throughout the Eastern Caribbean. In addition to the day-to-day monitoring of 19 live volcanoes and a seismically active region, the Centre collaborates with local, regional and international agencies on research projects relevant to its core areas of operation (seismology, volcanology and education & outreach).

During the reporting period, the seismograph network recorded a minimum of 757 earthquakes in the area of responsibility. There were 30 significant felt events for the period, the strongest of which was a magnitude 5.3 event for an earthquake located east of Guadeloupe on 7 May, 2010. The densest concentration of epicentres for the year was seen in the vicinity of the Paria Peninsula, with 223 of the 757 located events (more than 29%) occurring within the Centre’s area of responsibility south of 11.5°N and west of 61.7°W.
Volcanic activity in the Eastern Caribbean for the reporting period was relatively quiet with most of the volcanoes, with the exception of Morne aux Diables in northern Dominica, exhibiting background levels of activity. Seismic activity in northern Dominica showed elevated levels from June 2009, with the largest earthquake in the series occurring on 18 November, 2010 with a magnitude of 3.6. This was felt strongly in northern Dominica. Towards the end of the reporting period, output levels had declined.

The SRC continued to manage the operations of theMontserrat Volcano Observatory (MVO), under a contract with the Government of Montserrat. With the exception of the Volcano-Seismologist post, all scientific posts have been filled. Several of our Trinidad-based staff also undertook tours of duty at the MVO to provide relief to the full-time staff.

The Centre embarked on several new projects during the year including:

- A UWI Disaster Risk Reduction Centre (DRRC) project funded by the World Bank to produce a Caribbean Risk Atlas for floods, hurricanes and earthquakes for a select number of CARICOM countries. The SRC will be involved in the seismic risk component of the project.
- Radon monitoring in south-west Tobago for seismic surveillance. This project aims to detect changes in radon concentrations as a precursory indicator of seismic activity.
- Research continues to be focused on the core areas of volcanology (numerical modeling, geochemical studies and hazard communications) and seismology (strong motion studies, and radon monitoring). During the review period work was completed on the Tsunami and other Coastal Hazards Warning System (TCHWS) project which was funded by the United States Agency for International Development - Office of Foreign Disaster Assistance (USAID-OFDA), in collaboration with the Caribbean Disaster Emergency Management Agency (CDEMA).

All activities regarding a project funded by the International Development Research Centre (IDRC) of Canada and administered by CDERA1 re: ICT Applications in Disaster Management were also completed. The project provided funding for a 2-year MPhil Studentship in Seismology at the SRC.

Work on the joint research project entitled Assessment and Mitigation of Seismic Risk in the Eastern Caribbean undertaken in collaboration with the European Centre for Training and Research in Earthquake Engineering (EUCENTRE) and co-funded by the Municipality of Milan in the year 2009, was also completed. This research involved the preparation of updated and IBC2-compliant Probabilistic Seismic Hazard Maps for the Eastern Caribbean Islands, especially the islands of Dominica, Barbados and Trinidad. The results of the investigation will be useful to local engineers and authorities for the purposes of structural design and construction practices.

Planned activities of note for the 2010-2011 academic year include the installation of several VSAT seismic stations, in collaboration with the Institut de Physique du Globe de Paris (IPGP), to improve the seismograph network covering the Lesser Antilles region, the implementation of various research projects and most importantly continued lobbying for a new building to house the Centre. Work will also continue on formalising arrangements for postgraduate research at the Centre.

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1 Caribbean Disaster Emergency Response Agency, now CDEMA
2 International Building Code
Operations

Seismograph Network

The Eastern Caribbean Seismograph Network (ECSN) operated by the SRC consists of over 52 instruments (see Figure 1) that comprise a mixture of three-component broadband stations, Kinematic K2 accelerographs, three-component short-period seismometers and single vertical component stations. Data is transmitted in real or near real-time to the Centre headquarters in Trinidad. When activity increases at any node of the system data can be processed locally in real time.

In addition to data from the seismograph network, volcanic systems in the region are monitored by ground deformation and gas monitoring networks.

Figure 1: Eastern Caribbean seismic monitoring network.
GPS monitoring of ground deformation is an excellent medium-near real-time monitoring tool.

**Ground Deformation Network**

The seven continuous GPS (cGPS) stations operated in Dominica, Grenada, Antigua, St. Kitts, St. Vincent and Tobago were fully operational throughout the period under review. Data from these stations along with three other stations from other international institutes are contributing to determining the tectonic velocity of this region and aid in increasing the accuracy of our volcano monitoring GPS networks (see Figure 2). Our GPS data repository is available online through request. Additionally, two cGPS stations were installed in northern Dominica: one at Ross University on the roof of the Information Technology Department; and the second site is on a ridge near Penville village on the eastern flanks of Morne Aux Diables volcano, very close to a Cable & Wireless installation. These stations were installed to augment the Centre’s volcano monitoring capabilities on Dominica and to strengthen the Eastern Caribbean cGPS network.

The SRC has fully adopted and implemented the GAMIT/GLOBK tool to produce high precision GPS solutions and velocities. The GPS acquisition and processing with this tool has been automated which allows for the production of daily reports and a many fold increase in precision for volcano GPS networks. The precision of the Montserrat Volcano Observatory’s local cGPS network has significantly improved with the implementation of GAMIT/GLOBK. Along with the increase in Eastern Caribbean stations, this highlights that GPS monitoring of ground deformation is an excellent medium to near real-time monitoring tool.
**Geothermal Monitoring**

The SRC initiated geothermal monitoring (measurement of temperature, pH, and chemical composition) of hot springs and fumaroles associated with Lesser Antilles volcanoes in 2001. Routine sampling in islands including Dominica, Saint Lucia, Grenada, St. Vincent, St. Kitts, and Nevis have taken place on an almost annual basis. Geothermal field investigations were conducted in Dominica during the reporting period (December 2009 and January 2010). These trips were undertaken as part of the programme of regular geothermal monitoring in Dominica, as well as in response to increased seismic activity in northern Dominica. Sampling of the hot springs and bubbling pools associated with volcanic systems were carried out across the island (see Figure 3). No major anomalies in temperature, pH or geothermal activity were observed at the sites sampled, as compared with previous data. The results of the chemical analyses, when complete, will provide more details of the chemical composition of the geothermal fluids sampled and reveal any changes that may have occurred since the last visit to these sites.

**Seismic Activity 2009 - 2010**

During the period, the TRN network stations recorded a minimum of 757 earthquakes in the area of responsibility, of which a total of 513 events were located (68%), using our own data and the data contributions from Martinique, Guadeloupe, Puerto Rico and Venezuela. The pattern of seismicity seen in the Eastern Caribbean has been changing in recent years from the distribution of previous decades. While activity in the Paria Peninsula area (north of Venezuela) was maintained at its usual high level, there continues to be a marked absence of a similar concentration of events in the Antigua-Barbuda area. The elevated output level in the vicinity of Dominica-Martinique, apparent since the 29 November, 2007 magnitude 7.3 earthquake in the area, persists. The daily generation of earthquakes is shown in Figure 4. The elevated activity seen in mid-September through mid-December arose from an increase in background seismicity along with earthquakes recorded in the northern Dominica area (see section on volcanic earthquakes for further details). The largest event for the period occurred on 7 May, 2010 east of Guadeloupe with magnitude 5.3. There were 9 earthquakes with magnitude higher than 4.5, 24 events in the 4.0-4.5 magnitude range and 88 in the 3.6-3.9 magnitude range. The magnitude distribution of located events with magnitude >2.0 is shown in Figure 5. There were 30 events reported felt for the period.

![SRC scientists, Erouscilla Joseph and Richard Robertson, prepare water samples during a geothermal monitoring trip to Dominica.](image)
Figure 4: Daily and cumulative number of earthquakes generated in the Eastern Caribbean during 2009/08/01 – 2010/07/31.

Figure 5: Monthly magnitude distribution of earthquakes with magnitude >2.0 during 2009/08/01 – 2010/07/31.
Epicentral locations of the events for the period are shown in Figure 6. The densest concentration of epicentres for the year is seen in the vicinity of the Paria Peninsula, with 223 of the 757 located events (more than 29%) occurring within our area of responsibility south of 11.5°N and west of 61.7°W. There were 48 earthquakes in the area east of Trinidad and 43 on land Trinidad. There were two events of magnitude 4.8 near the east coast of Trinidad. They were the largest earthquakes in that general area for the period. Activity in the area within 16°N-19°N and east of 62.5°W, which from past patterns would be on par with that seen in the Paria Peninsula area continues at a reduced level and contributed approximately 0.03% to the total number, while about 12% of the located events occurred in the area between 14°-16°N. Figure 7 is a map of the earthquake locations presented in 3-D. The plot allows an appreciation of the depth distribution of seismicity along the subducting slab.

Figure 6: Epicentral map of earthquakes occurring during the period 2009/08/01 – 2010/07/31.

Figure 7: 3-D plot of earthquakes during the period within boundaries shown.
Trinidad seismicity for the period

There were 98 earthquakes located in the area bounded by 9.5°N-11°N and 60°W-62°W during the period 2009/08/01 – 2010/07/31. Figure 8 is an epicentral map for the period. The largest events in the area for the year were of magnitude 4.8 and occurred on 22 November, 2009 and were located on land Trinidad, near the east coast. Both earthquakes were reported felt and MMI - III (see footnote) was associated with the observations (Table 1). The overall pattern of seismicity revealed in Figure 8 is consistent with that usually seen. However, the number of earthquakes located on land Trinidad during the period continues to be somewhat elevated over the long term average and may be a consequence of the earthquakes of magnitude > 5.0 that occurred on land Trinidad in 2004 and 2006. There were no events in the immediate vicinity of Point Fortin.

Figure 8: 98 Epicentres within the area bounded by 9.5°N - 11°N and 60°W - 62°W for the period 2009/08/– 2009/07

*MM = Modified Mercalli
## Table 1: List of felt events for the reporting period.

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME (UTC*)</th>
<th>LAT. (°N)</th>
<th>LONG. (°W)</th>
<th>DEP. (km)</th>
<th>MAG. (Mt)</th>
<th>FELT REPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/08/16</td>
<td>11:33:54.77</td>
<td>14.959</td>
<td>60.725</td>
<td>57</td>
<td>3.9</td>
<td>North-east of Martinique. Felt in Saint Lucia MM INT: II-III – Gros Islet, Corinth, Gran Riviere, Marchand</td>
</tr>
<tr>
<td>2009/10/05</td>
<td>16:28:07.53</td>
<td>17.956</td>
<td>62.542</td>
<td>3</td>
<td>4.1</td>
<td>East of St. Maarten. Felt in St. Kitts and Nevis MM IN II-III. Felt strongly in St. Maarten; also reported felt in Anguilla and St. Bartholomew.</td>
</tr>
<tr>
<td>2009/12/13</td>
<td>05:11:37.94</td>
<td>10.558</td>
<td>61.532</td>
<td>44</td>
<td>2.0</td>
<td>Trinidad. Felt in Trinidad MM INT II Curepe</td>
</tr>
<tr>
<td>2010/01/05</td>
<td>03:36:16.84</td>
<td>10.886</td>
<td>62.213</td>
<td>120</td>
<td>4.3</td>
<td>North of Paria Peninsula. Felt in Trinidad MM INT: III – Westmoorings, Glencoe, Cascade, St. Augustine Also felt in Maracas Valley, Diego Martin and Santa Cruz</td>
</tr>
<tr>
<td>2010/01/13</td>
<td>07:46:42.01</td>
<td>10.944</td>
<td>62.118</td>
<td>69</td>
<td>3.5</td>
<td>North of Paria Peninsula. Felt MM INT: III – Glencoe, Trinidad</td>
</tr>
<tr>
<td>2010/01/15</td>
<td>18:00:52.94</td>
<td>10.817</td>
<td>63.288</td>
<td>28</td>
<td>4.8</td>
<td>North of Venezuela. Felt in Trinidad MM INT: III – Port of Spain, Invaders Bay, Newtown, Guayaguayare</td>
</tr>
<tr>
<td>2010/01/23</td>
<td>09:56:30.83</td>
<td>15.299</td>
<td>61.357</td>
<td>3</td>
<td>2.1</td>
<td>Near south-east coast of Dominica. Felt MM INT: III – Trafalgar, Savanne Paille, Castle Bruce, Laudat Village, Mt. Carnot, Cochrane Dominica III – Bolans, Jolly Harbour, Antigua</td>
</tr>
<tr>
<td>2010/02/03</td>
<td>23:26:29.48</td>
<td>13.91</td>
<td>61.029</td>
<td>26</td>
<td>3.3</td>
<td>Northern Saint Lucia. Felt MM INT: III – Castries, Dennery, Cap Estate, Gros Isle, Saint Lucia</td>
</tr>
<tr>
<td>2010/02/19</td>
<td>12:59:41.97</td>
<td>14.033</td>
<td>60.604</td>
<td>65</td>
<td>3.9</td>
<td>East of Saint Lucia. Felt MM INT: III – Castries, Monier, Corinth, Rodney Bay, Saint Lucia</td>
</tr>
<tr>
<td>2010/03/10</td>
<td>08:00:42.34</td>
<td>10.544</td>
<td>62.53</td>
<td>5.17</td>
<td>3.9</td>
<td>Gulf of Paria. Reported felt in Trinidad.</td>
</tr>
</tbody>
</table>
Seismicity associated with volcanic centres

Generally, the volcanic centres have manifested background activity, except for the area in northern Dominica. In June of 2009, small earthquakes were recorded in the area and some were reported felt. Since that time, the activity has persisted punctuated by periods of elevated output. For example, there were 54 earthquakes recorded during the period 16-26 October, 2009. The largest of these, which was felt in northern Dominica, was, at magnitude 3.1. The largest earthquake of the series so far had a magnitude of 3.6 and occurred on 18 November, 2009 at 08:49 a.m. This was strongly felt in northern Dominica. Towards the end of the reporting period, the output level was relatively low. Fig. 9 shows the daily count for the current period along with the cumulative count since the episode began. The generating mechanism for this activity is still being investigated. Thus far, seismicity is the sole indicator of unusual activity with ground deformation and geochemical measurements maintaining their usual pattern.

Volcanic activity

With the exception of the Soufrière Hills Volcano (SHV) in Montserrat, the volcanic centres of the Eastern Caribbean exhibited low levels of activity throughout the review period.

After a 10 month period in which the SHV showed little or no signs of visible and seismic activity, activity resumed on 4 October, 2009 with an episode of ash venting lasting two hours. Thirteen more ash venting events occurred in the next four days, sending ash up to 20,000 ft. The onset of activity was preceded by a swarm of twenty four volcano-tectonic earthquakes about one hour before activity started. A drop in sulphur dioxide output occurred for 3 days prior to the onset of activity. The fifth phase of lava dome extrusion began on 9 October and displayed pronounced cyclicity, with periods ranging from 3 to 13 hours. Activity continued at an elevated rate, with rapid extrusion and regular venting near the lava
dome summit. The height and volume of the large, pre-existing lava dome were consequently increased up to about 235 million cubic metres - a record for this eruption.

Pyroclastic flows occurred in all directions during the four months of activity and several of the major drainages on the volcano’s flanks were filled with associated deposits. In January and February 2010 there were five vulcanian explosions, one of which on 8 January sent pyroclastic flows further down the Belham Valley than ever before.

On 11 February 2010 there was a major partial dome collapse, involving around 50 million cubic metres of lava dome and sending pyroclastic flows mainly to the northeast. The pyroclastic flows impacted previously unaffected areas and the deposits extended the pre-existing coastline more than 650 m and added around 1 km². Magmatic explosions also occurred associated with the dome collapse generating pumiceous flow and fallout deposits. Ash columns associated with the partial dome collapse event rose to 15 km and spread east and south-eastwards across large parts of the Eastern Caribbean, closing airports for several days.

Since the partial dome collapse there has been very little surface activity and seismicity has been low. Occasional short pyroclastic flows are formed from degradation of the lava dome and these are likely to continue for some time. On 25 June, 2010 and 2 July, 2010 there were two minor ‘ash-venting’ episodes both of which were preceded by a few volcanic tectonic earthquakes. Audible venting could be heard from areas close to the volcano for several weeks afterwards.

As of December 2010 volcanic activity has been very low as the volcano remains in a pause in lava extrusion.

This dome collapse involved around 50 million cubic metres of lava dome...
The research effort of the Centre is focused primarily on seismology, volcanology and outreach with a view towards an improvement in our ability to provide accurate and up-to-date information about earthquake and volcanic activity in the Eastern Caribbean.

- **Seismic Hazard Assessment:**
  The Centre concluded a major collaborative project with the European Centre for Training and Research in Earthquake Engineering (EUCENTRE), IUSS, and the University of Pavia of Italy. This project involved probabilistic seismic hazard assessment of the Eastern Caribbean. SRC Earthquake Engineer, Dr. Walter Salazar, was a visiting faculty researcher at the European Centre for Training and Research in Earthquake Engineering (EUCENTRE) – Italy during September to December 2009. During his visit he focused primarily on the seismicity evaluation and the strong ground motion estimation for the Eastern Caribbean. A new earthquake catalogue for magnitudes above 5.0 for the period 1530-2009 establishing fifteen seismogenic sources in the region was compiled. The available strong motion data cited above was compared with some attenuation relationships proposed for subduction and
presents a framework for future seismic hazard assessment initiatives

upper-crustal earthquakes for the peak ground acceleration and spectral ordinates. Seismic hazard analysis and related maps (see Figure 10) were implemented through the use of approaches that can account for the uncertainties of the estimates employing the logic tree approach through updated computer codes with a validation procedure using a seismic hazard programme developed at the SRC by Dr. Salazar. The results of the investigation will be useful to local engineers and authorities for the purposes of structural design and construction practices. It has direct linkages to the global effort to determine seismic hazard and risk models and tools and presents a framework for future seismic hazard assessment initiatives sponsored by the World Bank and the CARICOM Regional Organization for Standards and Quality (CROSQ). PI: Dr. Walter Salazar.

Figure 10: Seismic hazard maps for Peak Ground Acceleration (PGA in “g”) (a) setting 2% of probability of exceedance in 50 years life time (return period of 2,475 years); (b) for the period of 0.2s setting 2% of probability of exceedance in 50 years life (return period of 2,475 years); (c) for the period of 1.0s setting 2% of probability of exceedance in 50 years life (return period of 2,475 years).
• **Tsunami and Other Coastal Hazards Warning System Project:**

SRC was involved in a collaborative project with the Caribbean Disaster Emergency Management Agency (CDEMA formerly CDERA) to develop the public education component of the *Tsunami and Other Coastal Hazards Warning System* (TCHWS) project, aimed at preparing CDEMA States to respond to tsunamis and other coastal threats. The project was funded by USAID OFDA. SRC executed the public education component of the project which included preparation of a suite of multimedia products for use among the general populations, teaching modules for the 12-15 year group, and the implementation of public awareness campaigns and product review workshops. The project was completed in February 2010. PI: Stacey Edwards.

• **Caribbean Disaster Emergency Management Agency (CDEMA)/ International Development Research Centre (IDRC) Project:**

The main objective of this project was to test and analyze the role of Information and Communication Technologies (ICT’s) to strengthen community knowledge and support in the collection of post information for earthquakes in the Eastern Caribbean. One of the final outputs for the project was a system to automatically collect, analyze and illustrate the results using GIS technology. PI: J. Latchman

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**Ongoing Projects and Research in Progress**

• **Radon monitoring:**

This research seeks to investigate the utility of radon monitoring as an additional technique that may reveal observable changes indicative of the imminence of an expected earthquake. Such monitoring, in the earthquake context, would be novel in the region. Monitoring for $^{222}$Rn in earthquake precursor research could be potentially effective in the Tobago setting because of the experience of the significant impact on groundwater flow occasioned by the 1997 magnitude 6.1 event. Groundwater in Tobago is principally held in a fracture network (Lennox Petroleum – Earthwater Technology International 2000) apparently dominated by the lithological boundaries in south-west Tobago (Latchman 2009). In 1997, the fracture network is considered to have narrowed or closed in response to the earthquake, thus driving water out of the system (Latchman 2009). Changes in strain on the fault system projected to carry the next significant earthquake near Tobago may, therefore, result in precursory changes in the local groundwater fracture network that might produce anomalies in radon output. Radon monitoring is scheduled to begin in early 2010 to establish a baseline of radon output for each well. Once baseline character is established, then monitoring for anomalous changes before the anticipated 2011 earthquake will continue. PI: Drs. J. Latchman and E. Joseph.

• **Geophysical survey of submarine debris avalanche deposits offshore from Montserrat:**

The objective of the project was to identify and map the distribution of large submarine debris avalanche deposits on the seafloor between Montserrat and Guadaloupe. In May 2010, the RRS James Cook, a UK Research vessel was used to conduct detailed 2D and 3D seismic surveys and sidescan sonar imaging of the sea floor deposits. The project was a major collaboration between researchers at the National Oceanography Centre/University of Southampton in the UK; IPGP, Paris and from the University of Kiel, Germany and was funded by the Natural Environment Research Council in the UK. The project is expected to further our understanding on the generation of large submarine landslides and their relationship with volcanic activity in the Lesser Antilles, in particular that on Montserrat. This also includes identifying links with tsunamis. The results of this research are of great interest to the many coastal communities in the Caribbean, as well as the scientific community at large. Dr. A. Stinton (MVO) participated in the cruise as an observer and consultant on the recent volcanic activity on Montserrat. The cruise/project is being led by
Dr. Pete Talling from the National Oceanographic Centre, Southampton, UK. PI: Dr. A. Stinton.

- **Study of the hazards and impact, on human health, of persistently degassing volcanoes; and the use of geothermal sites for recreational purposes:**

Geothermal sites in Dominica and Saint Lucia are used for recreational purposes including sight-seeing, bathing and drinking. Geothermal waters used for recreation were found to have concentrations of lead, cadmium, nitrite, iron and aluminium greater than was safely recommended for consumption by the United States Environmental Protection Agency USEPA. The concentration of sulphur dioxide emissions at these sites may also prove hazardous to health with long term exposure. These concerns must be examined in greater detail for proper safety guidelines to be created and implemented for safe use of these sites for recreational activity. PI: E. Joseph

- **Fluids geochemistry in the Lesser Antilles: the study of volcanic gases and hot springs chemistry and temperature as a tool for volcano monitoring:**

Mineral equilibria studies of hydrothermal minerals were used to investigate the evolution of geothermal systems in the region. This research will continue to build on the previous work carried out (2001 - present) to establish long-term patterns in behaviour of volcanic emissions associated with hydrothermal systems and how they respond to changes in magmatic input. This information will be used along with other tools (ground deformation and seismicity) to monitor volcanic activity in the region, thus providing information to island governments and the general public. PI: E. Joseph

- **Dynamics of Geothermal Systems in the Eastern Caribbean:**

A collaborative PhD research project commenced in January 2009 between the SRC and the Department of Earth Sciences at the University of Bristol UK (Dr. F. Witham). The rationale for this project is to gain a better understanding of the factors which significantly influence the behaviour of geothermal systems in the region. To that end, times series data, weather information and seismic activity surrounding the Boiling Lake in Dominica have been collected. The project focuses on the dynamics of regional geothermal systems on three scales. The first of which is well underway and the second phase commenced. The study will be helpful to Government and monitoring agencies such as the SRC both in terms of hazards mitigation and monitoring and in terms of potential use of geothermal systems for energy production in the Caribbean. PI: D. Robertson

- **Montserrat Volcano Observatory Management Contract:**

The SRC/IPGP contract with the Government of Montserrat for management of the Montserrat Volcano Observatory (MVO) for the period 2008 – 2013, is ongoing. During the period in review the full staff complement to manage the Observatory was achieved and the programme of work proposed by SRC/IPGP in their Technical Proposal was well underway. In addition to managing the routine operations of the volcano the SRC team, based at the MVO, has effectively managed a significant period of elevated activity which occurred during the reporting period. PI: R. Robertson

- **New SRC building project**

The preliminary design and estimates for the new building to house the Centre were completed. A completely new, purposefully designed building is urgently required to house the SRC, to address the present congestion and to halt deterioration of valuable equipment, books, records, journals and other materials that currently are not properly stored. The new building should allow for adequate accommodation of present activities and should also make provision for the planned developments in terms of geosciences at the Centre.

...to address present congestion and to halt deterioration of valuable equipment...
Earth Science Week promotes understanding and appreciation of the value of Earth Science Research and its application and relevance to our daily lives. In October 2009, the SRC chose Understanding Tsunamis as the main theme to mark Earth Science Week and targeted two schools for raising awareness on tsunamis. During Earth Science Week, the SRC in collaboration with the Office of Disaster Preparedness and Management (ODPM) in Trinidad & Tobago sponsored a group of geography students from Mayaro Secondary School - a small village on Trinidad’s east coast – to attend a student workshop at the SRC in St. Augustine. During the workshop, the students learned about the causes of tsunamis and they learned how to recognize a tsunami’s natural warning signs. Students were also encouraged to share the information with family and friends.
Students of Cedros Secondary School benefited from a similar educational activity when a team from the SRC visited Bonasse Village - a fishing village along Trinidad’s southwestern peninsula - during Earth Science Week. In addition to learning about tsunamis, Cedros Secondary students planted trees along the beach as part of the SRC’s Tsunami Ready Environment & Education (TREE) event. According to the Food & Agriculture Organization of the United Nations (FAO) coastal forests can reduce the depth, force and velocity of a tsunami and other large wave events.

The SRC partnered with the Department of Forestry in the Ministry of Agriculture, Land & Marine Resources and the Trinidad & Tobago Meteorological Service and received generous sponsorship from First Citizens, ODPM, Neal & Massy Foundation, Scrip-J and Cool Connections Ltd. for the TREE project.

Haiti Earthquake

Demand for information was so high following the devastating earthquake in Haiti on 12 January, 2010, that the SRC held its first ever press conference at its premises on 14 January, 2010. This event was well attended by local media and provided an efficient means of disseminating the information that was being sought. A live video stream of the press conference was also made available via the Internet. The demand for information was reinforced when the magnitude 8.8 earthquake on 27 February, 2010 occurred off the coast of Chile. Following these events, the SRC sought to capitalize on the heightened interest in tsunamis and earthquake safety by facilitating countless interviews for local, regional and international media and by providing relevant tsunami and earthquake preparedness information on the SRC’s web media (web site and Facebook).

Tsunami and Other Coastal Hazards Warning System Project

For the majority of the reporting period the E&O team was heavily involved in implementing the Public Awareness and Education (PAE) component of the Tsunami and Other Coastal Hazards Warning System Project (TCHWS). Funded by the USAID Office of US Foreign Disaster Assistance (USAID/OFDA) and executed by the Caribbean Disaster Emergency Management Agency (CDEMA), the PAE component of the TCHWS Project sought to increase public awareness about tsunamis and other coastal hazards within communities in the CDEMA Participating States through the production and dissemination of public awareness and teacher materials, as well as the execution of public awareness campaigns. A key component of the project Strategy was the development of a brand, Tsunami Smart, for promoting tsunami awareness across the region. The Strategy focused on promoting awareness of a tsunami’s natural warning signs (strong earthquake, withdrawal of the sea, unusual roar from the ocean) and appropriate responses to these signs, since the most likely scenario for a tsunami in the Caribbean is one that is locally generated with little or no time for official warning.

A suite of region-specific multi-media public awareness material...
was produced under the Tsunami Smart brand together with a teacher resource kit which included four lesson plans and accompanying teaching charts. The material was launched during on-island public awareness and education campaigns at several Tsunami Smart Sessions, which were essentially stakeholder meetings in three (3) pilot states — Antigua, Barbados, Trinidad & Tobago. During these campaigns comments and suggestions for improvement of the material were provided. Feedback received from the Workshop participants, the Public Awareness and Education Sub-Committee and the Tsunami Smart Sessions was incorporated in the final material, electronic versions of which will be made available from the CDEMA and SRC web sites.

At the end of the Project a Final Report was submitted to CDEMA which included Project activities implemented, challenges faced and recommendations for follow up activities such as mass production and dissemination of the information material to non-pilot countries, development of a strategy and communication tools for the boating community and creation of a model end-to-end system with all elements completed (i.e. inundation maps, protocols, PAE materials etc.). The SRC hopes to begin implementation of some of these follow up activities in the last quarter of 2010.

Members of the Head Table at the launch of the TCHWS Project in Trinidad.
Left to Right: Dike Noel (Public Information Specialist, ODPM), Col. (Ret’d) George Robinson (Former CEO, ODPM), Dr. Richard Robertson (Director, SRC), Stacey Edwards (Education Officer, SRC), Lloyd Lynch (Research Fellow, SRC).
Earth Day 2010

The SRC celebrated Earth Day for the first time this year with an Art & Illustration competition for lower secondary school students in Trinidad & Tobago. Co-ordinated by the Earth Day Network, Earth Day is celebrated each year on April 22 across the globe and it is intended to broaden the base of support for environmental programmes, rekindle public commitment and build community activism around the world through a broad range of events and activities.

The theme for the SRC Earth Day Art & Illustration competition was Understanding Earth Systems. The objective was to raise awareness of geo-hazards (earthquakes, volcanoes, tsunamis) that affect the Caribbean and students were judged on their ability to use the visual arts to communicate the connections between the different systems, the effects of their impact on populations and how to mitigate against these hazards. Over seventy (70) entries were received from students across Trinidad. Prizes were awarded to the top three winners from each form (Forms 1, 2, and 3) as well as the top twelve entries were selected for publication in the SRC’s 2011 Earth Day calendar. Partial funding was provided by First Citizens Ltd.

CORE Internship Programme

Following the success of the first CORE (Creating Opportunity from Research Experience) Internship Programme in 2009, the SRC offered two internship placements for summer 2010. The CORE Internship Programme seeks to identify future geoscientists and communications practitioners by providing undergraduate and post-graduate students with the opportunity to gain hands-on work experience during an 8-week internship at the SRC. Two internship placements were offered for this year’s Programme which ran from May 17th – July 9th. Ramon McVorran and Jenalee Samaroo, both 2010 graduates of the University of the West Indies, Mona and St. Augustine campuses respectively, secured these positions. The CORE 2010 projects were:

- **Magnitude Derivation and Regression Analysis**
  Supervisor: Dr. Joan Latchman, Seismologist
  This project sought to derive duration magnitude formulae using regression analysis. Three software packages were used - Matlab, NLREG and Microsoft Excel.

- **Modeling of Geothermal Systems**
  Supervisor: Deborah Robertson, Geophysicist
  This project involved comparison studies of three geothermal models using state-of-the-art Finite Element Method (FEM). The intern was given the opportunity to assist in the development of a numerical model using TOUGH2 multiphase-flow code.
The CORE programme is designed to give successful candidates a full understanding of how the SRC attains its objectives through collaboration within the department. Four days per week, interns worked directly with supervisors on research projects with one day each week being reserved for information sessions. These one-day sessions gave the interns an opportunity to interact with other sections within the SRC, which included electronics, seismology, volcanology and education/outreach.

Public Awareness Seminars
During the reporting period, at least fourteen (14) seminars, involving all members of the scientific staff, were given to various groups requesting them. This included schools and offices based in Trinidad as well as an earthquake presentation in Barbados to Mission Disaster Response Officers from the USAID Office of US Foreign Disaster Assistance (USAID/OFDA). This year also marked the launch of a series of earthquake safety seminars with staff on the UWI St. Augustine campus, Trinidad. This initiative was spearheaded by the Human Resources Department and eight sessions were completed.

Caribbean Youth Science Forum (CYSF)
The National Institute of Higher Education, Research, Science and Technology (NIHERST) hosted sixth form science students from across the region for the 8th Session of the Caribbean Youth Science Forum (CYSF) 2009. The SRC facilitated one CYSF interactive student visit to the SRC and Dr. Erouscilla Joseph represented the SRC at the CYSF “Meet a Scientist” event.

National Consultation on Earthquake Safety in Trinidad & Tobago
The SRC and the Office of Disaster Preparedness and Management of Trinidad & Tobago partnered to host a national consultation relevant to the broad topic Earthquake Safety in Trinidad and Tobago – A call for action! The objective of this consultation was to identify the measures necessary to improve earthquake safety in Trinidad and Tobago.
Media

In the aftermath of the Haiti Earthquake (12 January) and Chile Earthquake (27 February), the SRC continued to receive numerous requests for interviews from local, regional and international media.

In addition to news features, four staff members also participated in two documentaries. The first documentary required information on earthquakes and volcanoes in the Caribbean and was produced by a Barbadian production company, Digiscapes. The programme will be broadcast throughout the English-speaking Caribbean and it seeks to provide regional viewers with pertinent information on the various natural hazards to which the Caribbean is vulnerable. The second documentary focused on tsunami preparedness in the Caribbean. The programme was produced by the United States Geological Survey (USGS) and will be made available on DVD and via the Internet.

STUDENTS

The SRC continued to develop its small postgraduate degree programme with a new student enrolled in the PhD programme in Volcanology. Additionally, several MPhil and MSc postgraduate research students are based at SRC working on collaborative projects with other UWI departments including Civil and Environmental Engineering, Lands and Surveys, and Geography.
The single most important activity for the SRC for the next three years is the construction of a new building. The SRC currently occupies a building which is long past its expected lifespan (>50 years old) and has a multitude of major structural problems such that it is now deemed most urgent that the existing building be condemned and a new facility constructed within the next 2-3 years.

The SRC will continue to manage its monitoring operations, seek external funding and undertake research and other projects and continue to develop its outreach programmes as can best be done given current limitations. However, the focus for the SRC over the next biennium will be to secure the construction of a new building.

Some of the other specific projects planned or already underway are summarized below.

• **Global Facility for Disaster Reduction and Recovery (GFDRR) Disaster Vulnerability and Risk Assessment Modeling Jamaica and the Greater Caribbean Basin Project:** A project managed by the Disaster Risk Reduction Centre and funded by the World Bank to produce a regional scale Risk Atlas for Flood, Hurricane and Earthquake with high resolution maps for similar hazards for four islands. The SRC involvement in this project amounts to US$80K and will result in the development of an Earthquake Loss Estimation method for use in the Caribbean. SRC will be involved in the seismic risk component of the project. PI: Drs W. Salazar and R. Robertson.

• **CDEMA/IDRC project:** Extending from the ICT project, an opportunity to collaborate with the Instituto Nazionale di Geofisica (INGV) in Rome, Italy to adopt and modify their “Did you feel it?” online macroseismic survey system presented itself. An experimental website was quickly put together for demonstration...
A simulation was completed, using volunteers who were involved in the CDEMA project, to demonstrate how the information from the felt report questionnaires could be used to calculate intensities and produce intensity maps for Trinidad and Tobago. A presentation was made to SRC staff and the benefits of implementing the system for the Eastern Caribbean were highlighted. A proposal, discussing the full implementation process and expenses that would be incurred, has to be drafted and submitted for approval.

- **Installation of five (5) strong motion instruments:** In Trinidad and Tobago as part of a project funded by the Trinidad and Tobago government entitled Strong Ground Motion Studies in Trinidad and Tobago.
- **Installation of new continuous GPS (cGPS) stations:** New stations are going to be deployed in Nevis and Saint Lucia, and additional stations in Dominica. All stations were funded from the SRC Departmental Consultancy Fund.
- **GPS Survey:** Field trip to Dominica to undertake another GPS survey and installation of a tiltmeter, along with field studies of the deposits around Morne Aux Diables volcanic complex. This work will be achieved in collaboration with Dr. Paul Cole (Director of Montserrat Volcano Observatory).

The budget we receive from our contributing territories provides sufficient funds for basic, routine monitoring only and all other work, including most research, major developments in the network and outreach, has to be undertaken through grant funding mainly from external sources or from applications to the SRC Departmental Consultancy Fund. Since 2008 such funds have enabled the recruitment of new technical and professional staff and the purchase of equipment. The proposals that have been submitted and which may come on-stream during the 2011-2013 period are summarized as follows:

1. **Seismic Microzonation Studies in Trinidad and Tobago:** a proposal submitted to the Ministry of Planning, Government of Trinidad and Tobago to undertake microzonation of major cities and population SRCs in Trinidad and Tobago over the next 10 years.

2. **GEM Caribbean Regional Programme:** a proposal submitted to the Secretariat of the Global Earthquake Model (GEM) to implement a Caribbean Regional Programme. GEM is a global collaborative effort that brings together state-of-the-art science, national, regional and international organisations and individuals aimed at the establishment of uniform and open standards for calculating and communicating earthquake risk worldwide. Funding has been approved by GEM for recruitment of one Research Fellow post at SRC for 2 years in order to execute this programme.

3. **A new accelerometric network to evaluate and mitigate seismic risk in the Caribbean:** a proposal submitted to the Caribbean Catastrophic Risk Insurance Facility (CCRIF) that seeks to reinforce (in the case of Jamaica) and establish (in the case of the English-speaking Eastern Caribbean), a network of sensors to record strong ground movements in the Caribbean, to be used in technical studies for the benefit of the region. The project will be done in collaboration with the Earthquake Unit at the UWI Mona Campus in Jamaica.

4. **VUELCO (Volcanic Unrest in Europe and Latin America: Phenomenology, eruption precursors, hazard forecast, and risk mitigation):** a collaborative project (with 22 other participating organisations) submitted to the European Commission under its 7th Framework Programme. The proposal falls under the small/medium-scale focused research project category designed for specific cooperation actions (SICA) dedicated for international cooperation partner countries (focus on Latin American).

5. **REAKT (for Real Time Earthquake Risk Reduction):** a collaborative project (with 9 other participating organisations) submitted to the European Commission under its 7th Framework Programme. The proposal falls under the large-scale integrating research project category.

6. **High-resolution marine geophysical investigation of pyroclastic density current dynamics at the land-ocean transition: Soufrière Hills Volcano, Montserrat:** an application for a NERC Small Grant has been submitted to fund this project, which is a collaborative effort between Dr. A. Stinton (MVO), Drs. Mark Vardy and Tim Henstock (University of Southampton, UK) and Drs. Pete Talling and Veit Hühnerbach (National Oceanographic Centre, Southampton, UK). The purpose of the project is to carry out high-resolution geophysical surveying of recent pyroclastic flow deposits in the shallow waters along the east coast of Montserrat, including the area affected by the large partial dome collapse at the Soufrière Hills volcano in February 2010. Should the application be successful, the survey will be carried out in early 2011.
PARTNERSHIPS & COLLABORATIONS

The Seismic Research Centre strengthened its capacity through collaborations with the following institutions:

- Aspinall & Associates, United Kingdom
- The University of South Florida, USA
- The University of Southern California, USA
- The University of South Hampton, United Kingdom
- National Oceanography Centre, Southampton, United Kingdom
- The University of Trieste, Trieste, Italy
- California State University, Department of Geological Sciences, USA
- Coventry University, School of Science and the Environment, United Kingdom
- European Centre for Training and Research in Earthquake Engineering (EUCENTRE)
- Geological Survey of Canada, Pacific Division, Canada
- Indiana University, Department of Geological Sciences, USA
- International Institute of Earthquake Prediction Theory and Mathematical Geophysics
- Instituto Nazionale di Geofisica e Vulcanologia, Italy
- Institut de Physique du Globe de Paris, France
- Laboratoire de Physique des Géomatériaux, IPGP, France
- Massachusetts Institute of Technology, USA
- Montserrat Volcano Observatory, Montserrat
- National Oceanic and Atmospheric Agency, USA
- Naval Research Laboratory, USA
- Observatoire de Physique du Globe de Clermont-Ferrand, France
- Rowan University, Computer Science Department, USA
- The University of Bristol, Department of Earth Sciences, United Kingdom
- The University of the West Indies, Department of Chemical Engineering, St. Augustine
- The University of the West Indies, Department of Surveying and Land Information, St. Augustine
- University of East Anglia, School of Environmental Sciences, United Kingdom
- University of New Mexico, USA
- University of Miami, USA
- University of Washington, Department of Geophysics, USA
<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Richard Robertson</td>
<td>Director</td>
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<tr>
<td>Joan Latchman</td>
<td>Seismologist</td>
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<tr>
<td>Walter Salazar</td>
<td>Earthquake Engineer</td>
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<tr>
<td>Lloyd Lynch</td>
<td>Instrumentation Engineer</td>
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<tr>
<td>Roderick Stewart</td>
<td>Volcano-Seismologist</td>
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<tr>
<td>Erouscilla Joseph</td>
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<td>Robert Watts</td>
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<tr>
<td>Paul Cole</td>
<td>Director – MVO</td>
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<td>Adam Stinton</td>
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<td>Thomas Christopher</td>
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<td>Henry Odbert</td>
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<tr>
<td>Caroline Murrell</td>
<td>Environmental Officer - MVO</td>
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<tr>
<td>Machel Higgins</td>
<td>Software Engineer</td>
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<tr>
<td>Chandradath Ramsingh</td>
<td>IT Officer II</td>
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<tr>
<td>Stacey Edwards</td>
<td>Education Officer</td>
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<tr>
<td>Deborah Robertson</td>
<td>Research Assistant – Volcanology</td>
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<tr>
<td>Cassandra LaBarrie</td>
<td>Research Assistant – Seismology</td>
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<tr>
<td>Omari Graham</td>
<td>Research Assistant – Seismology</td>
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<td>Monique Johnson</td>
<td>Research Assistant – Outreach</td>
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<tr>
<td>Clevon Ash</td>
<td>Research Assistant – Outreach</td>
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<tr>
<td>Ian Juman</td>
<td>Electronics Technician</td>
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<td>Garth Mannette</td>
<td>Engineering Technician</td>
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<tr>
<td>Nisha Nath</td>
<td>Chief Research Technician</td>
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<td>Amit Balchan</td>
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<td>Farrah Madoo</td>
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<td>Kafele Reddock</td>
<td>Research Technician</td>
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<tr>
<td>Yvonne Joseph</td>
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<tr>
<td>Carol Liverpool</td>
<td>Clerical Assistant</td>
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<tr>
<td>Shaun Bhodoo</td>
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<tr>
<td>Susan Neverson</td>
<td>Librarian</td>
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<tr>
<td>Nolan Ali</td>
<td>Senior Maintenance Assistant</td>
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<tr>
<td>Margaret Nero</td>
<td>Custodian</td>
</tr>
<tr>
<td>Joenel Alexander</td>
<td>Groundsman</td>
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MEETINGS, WORKSHOPS & CONFERENCE ATTENDANCE

Staff attended the following national and international meetings, workshops and conferences:

<table>
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<tr>
<th>Date</th>
<th>Conference/Meeting</th>
<th>Organized by</th>
<th>Location</th>
<th>Staff member</th>
<th>Paper(s)</th>
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<tr>
<td>3rd - 25th June 2009</td>
<td>Mount Katmai &amp; Novarupta Dome, Field workshop</td>
<td>organized by University of Alaska, Fairbanks</td>
<td>Alaska, USA</td>
<td>R. Watts</td>
<td>No</td>
</tr>
<tr>
<td>August 2009</td>
<td>The National Emergency Management Organization of Belize (NEMO) workshop</td>
<td>NEMO</td>
<td>Belmopan, Belize</td>
<td>W. Salazar S. Edwards</td>
<td>Yes</td>
</tr>
<tr>
<td>10th – 19th March 2010</td>
<td>Workshop of the Commission of Volcanic Lakes (CVL Commission)</td>
<td>IAVCEI</td>
<td>Costa Rica</td>
<td>D. Robertson E. Joseph</td>
<td>Yes</td>
</tr>
<tr>
<td>21st – 24th April 2010</td>
<td>Seismological Society of America (SSA)</td>
<td>SSA</td>
<td>Portland, Oregon</td>
<td>Joan Latchman</td>
<td>Yes</td>
</tr>
<tr>
<td>31st May – 4th June 2010</td>
<td>Cities on Volcanoes 6 (CoV6)</td>
<td>IAVCEI</td>
<td>Tenerife, Spain</td>
<td>P. Cole J. Stone</td>
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<tr>
<td>10th – 14th May 2010</td>
<td>TsunamiReady Summit</td>
<td>PRSN</td>
<td>Mayaguez, Puerto Rico</td>
<td>S. Edwards</td>
<td>Yes</td>
</tr>
<tr>
<td>July 2010</td>
<td>National Earthquake Consultation Workshop</td>
<td>SRC</td>
<td>Lok Jack Institute, UWI, St. Augustine</td>
<td>W. Salazar</td>
<td>Yes</td>
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SRC authors in bold text

**Refeereed Journals**


BOOK CHAPTERS


TECHNICAL REPORTS


ABSTRACTS AND POSTERS


