

Ting Wang Postdoctoral Fellowship

Stochastic Modelling of Geophysical Hazard

June 2010 – December 2011

Funding by Earthquake Commission and Massey University

The Postdoctoral Fellowship of Dr Ting Wang focused on research in the area of stochastic models for volcanic hazard and earthquake occurrence. One aspect of the fellowship looked to develop robust estimation procedures for models of volcanic hazard (with Mark Bebbington and Shane Cronin, Massey University, and Mark Stirling, GNS Science). The second aspect focused on building collaborative research initiatives with geoscience researchers and geological hazards groups from other organisations.

During her Postdoctoral Fellowship, Dr Wang had great success with both the above areas of focus. Her work on robust estimation procedures for volcanic hazard models saw her developing new methods to identify, and compensate for, gaps in volcanic records. Using a combination of statistical techniques, Dr Wang's research proved that the completeness level of a volcanic eruption record can be estimated, and determinations can be made as to where in the record the missing observations (if any) can be found. These procedures were tested on the Holocene eruption record of Mt Taranaki. The preliminary estimates are that the record 6ka to present are 85-87% complete and 76-78% complete beyond that. The estimated present hazard is approximately 20% higher than previously estimated. This work has been submitted for publication to the *Journal of Volcanology and Geothermal Research*, and is currently under review (see Outputs list and attachments for details).

A further paper, looking at a method of reconciling multiple differing catalogues and producing a robust hazard forecast, is currently being revised. In addition, Dr Wang presented these results at the 2011 IUGG General Assembly in Melbourne, to attend which she was awarded a grant by the Organising Committee.

During the Postdoctoral Fellowship, Dr Wang met with staff at GNS Science in Avalon (Dr David Rhoades, Dr Rob Langridge, Dr Graham Leonard, Dr Mark Stirling) and Victoria University at Wellington (A/Prof John Townend, Prof Marta Savage).

The contact with Dr Rhoades and Dr Leonard has been leveraged into the PhD work of Emily Kawabata (partly supported by the EQC), with Dr Wang (now a Lecturer at the University of Otago) as a co-supervisor. Dr Rhoades has generously assisted in the research on estimation of completeness of the volcanic record at distal locations by providing his expertise on statistical modelling of tephra deposits, and with the complete data files and programmes from his seminal 2002 paper. Dr Stirling was a collaborator on the robust estimation work, lending his expertise to assess the completeness of the volcanic records.

Further into her Fellowship, Dr Wang had the opportunity to visit GNS Science's site in Wairakei, where she met with Dr Gill Jolly, Dr Art Jolly, Mr Brad Scott, Dr Steve Sherburn and Dr Nico Fournier and learnt more about GeoNet. Dr Wang also presented her research to the group during her visit.

A link that will prove very useful for the future of statistical hazards research in New Zealand is that with Professor Steve Sparks, at the University of Bristol, UK. Prof Sparks offered Dr Wang the opportunity to visit his group in Bristol in October 2010 to initiate contacts, and work with the VORGRIPA database the group have compiled of large eruptions from volcanoes worldwide. This will feed into the upcoming Global Volcanic Model (GVM) exercise. This trip was funded by Massey University.

Time at Bristol and through interactions with staff of the volcanology group at Massey University and staff at GNS Science have given Dr Wang good training in volcanology and allowed her to develop knowledge of new statistical techniques. Dr Wang also had the opportunity during her Fellowship to extend her work on statistical analysis of earthquake data (the subject of her PhD). Three papers on this topic were revised and accepted during the Fellowship (see Outputs list and attachments for details). In addition, through links made during her time at Massey, Dr Wang has been able to secure a 5 month Visiting Fellowship at the University of Tokyo's Earthquake Research Institute, which has been funded by the Japan Society for the Promotion of Science. This Fellowship will be taken up in July 2012.

Finally, Dr Wang's successful Postdoctoral Fellowship has had a very fitting conclusion with her securing a Lectureship at the University of Otago's Department of Mathematics and Statistics. The position started in January 2012. Dr Wang's continued involvement in the supervisory panel of Massey University statistics PhD student Emily Kawabata will ensure that Dr Wang is kept involved in volcanic statistics research at Massey and will help build new links between Massey University and the University of Otago. In her new appointment, Dr Wang is seeking to establish her own research profile, and is looking to expand on her work in statistical seismology. The contacts developed under the EQC Fellowship with GNS and VUW scientists are proving to be of great value in this respect.

Outputs during Postdoctoral Fellowship

Journal Articles

Papers revised and accepted during fellowship:

Wang, T., Bebbington, M., in press: Identifying anomalous signals in GPS data using HMMs: An increased likelihood of earthquakes? Computational Statistics and Data Analysis.

Wang, T., Bebbington, M., Harte, D., 2012: Markov-modulated Hawkes process with stepwise decay. The Annals of the Institute of Statistical Mathematics 64: 521-544.

Wang, T., Bebbington, M., Harte, D., 2011: Extracting coseismic signals from groundwater data. Mathematical Geosciences 43: 799-817.

Paper submitted during fellowship:

Wang, T., Bebbington, M. Estimating the likelihood of an eruption from a volcano with missing onsets in its record. Submitted to Journal of Volcanology and Geothermal Research.

Paper in preparation:

Wang, T., Bebbington, M. Robust estimation for the Weibull process applied to eruption records.

Presentations and Conference Contributions

Wang, T. (08/10/2010) The use of hidden Markov models in modelling earthquake data. Hotstuff Seminar series at University of Bristol, UK.

Wang, T. (15/12/2010) Statistical analysis of earthquake data and volcanic eruptions. GNS Wairakei

Wang, T., Bebbington, M., 2011: Robust Estimation for the Weibull Process Applied to Eruption Records. Poster presentation in: XXV IUGG General Assembly "Earth on the Edge: Science for a Sustainable Planet" 28 June - 7 July 2011, Melbourne Convention & Exhibition Centre, Melbourne, Australia. Abstract USB #920.

Wang, T., Bebbington, M., Harte, D., 2011: Investigation of Seismicity Rate Using Markov-modulated Hawkes Process with Stepwise Decay. Oral presentation in: XXV IUGG General Assembly "Earth on the Edge: Science for a Sustainable Planet" 28 June - 7 July 2011, Melbourne Convention & Exhibition Centre, Melbourne, Australia. Abstract USB #919.

The following copies of journal articles and conference abstracts are included in attachments:

Attachment 1: Wang, T., Bebbington, M., Harte, D., 2011: Extracting coseismic signals from groundwater data. *Mathematical Geosciences* 43: 799-817.

Attachment 2: Wang, T., Bebbington, M., Harte, D., 2012: Markov-modulated Hawkes process with stepwise decay. *The Annals of the Institute of Statistical Mathematics* **64**: 521-544.

Attachment 3: Wang, T., Bebbington, M., in press: Identifying anomalous signals in GPS data using HMMs: An increased likelihood of earthquakes? *Computational Statistics and Data Analysis*.

Attachment 4: Wang, T., Bebbington, M. in review: Estimating the likelihood of an eruption from a volcano with missing onsets in its record. Submitted to *Journal of Volcanology and Geothermal Research*.

Attachment 5: Wang, T., Bebbington, M., 2011: Robust Estimation for the Weibull Process Applied to Eruption Records. Poster presentation in: XXV IUGG General Assembly "Earth on the Edge: Science for a Sustainable Planet" 28 June - 7 July 2011, Melbourne Convention & Exhibition Centre, Melbourne, Australia. Abstract USB #920.

Attachment 6: Wang, T., Bebbington, M., Harte, D., 2011: Investigation of Seismicity Rate Using Markov-modulated Hawkes Process with Stepwise Decay. Oral presentation in: XXV IUGG General Assembly "Earth on the Edge: Science for a Sustainable Planet" 28 June - 7 July 2011, Melbourne Convention & Exhibition Centre, Melbourne, Australia. Abstract USB #919.