IAPETUS
doctoral training partnership

NERC SCIENCE OF THE ENVIRONMENT

Active Tectonics of the Apennines, Central Italy (Ref IAP-17-109)

Department of Earth Sciences, Durham University
In partnership with School of Engineering, Newcastle University

Supervisory Team	• **Professor Ken McCaffrey, Durham University** • **Professor Zhenhong Li, Newcastle University** • **Dr Richard Walters, Durham University**
Key Words	**Geohazards; Earthquakes; Active Tectonics; Geodesy; Geoinformatics**

Overview

Central Italy has the highest levels of seismic hazard in Western Europe, and has experienced a long history of damaging earthquakes, including the 2009 L'Aquila event and the recent 2016/7 Central Italy seismic sequence (Figure 1).

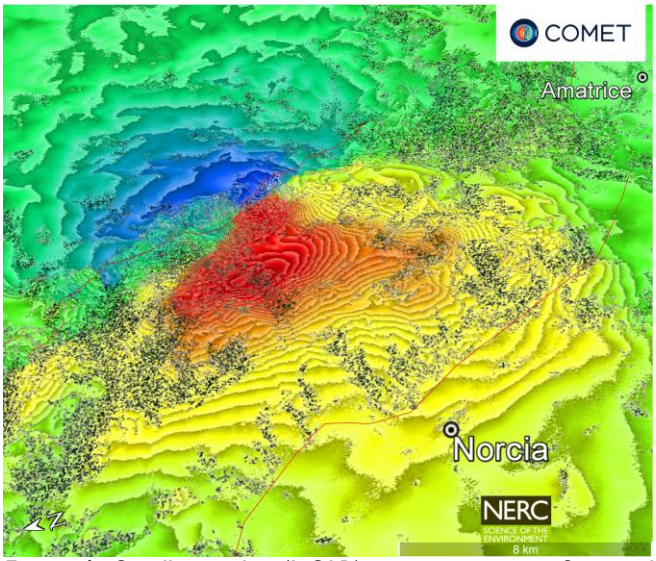

Figure 1: Satellite radar (InSAR) measurements of ground deformation from the 30th October 2016 M_W 6.6 earthquake in Central Italy. Colour shows total ground displacement towards (blue) or away from (red) satellite, with bands corresponding to 2.8 cm contours. Red lines show mapped faults.

These earthquakes result from active NE-SW extension in the Apennine mountain belt in previously shortened continental crust located within the zone of convergence between the Eurasian and African Plates. Geodetic observations from GNSS capture the broad-scale pattern of interseismic deformation (D'Agostino, 2014, Figure 2) and reflect the viscous flow that mainly occurs in the lower crust and/or upper mantle.

In the brittle upper crust, deformation is distributed across a complex inter-linked network of active normal faults. Individual fault slip-histories revealed by cosmogenic dating of bedrock faults indicate that patterns of fault activity (and thus upper crustal seismicity) are extremely varied in time and space compared to the decadal smooth deformation fields derived from GNSS.

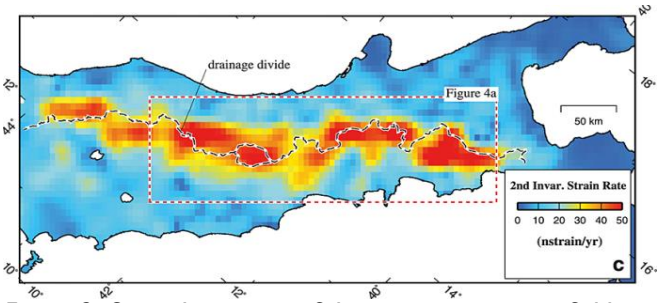

Figure 2: Second invariant of the strain-rate tensor field derived from GPS velocities. Adapted from D'Agostino (2014)

The recently-launched European Space Agency radar satellites Sentinel-1A and 1B together provide high precision measurements of crustal movements for all of Italy every 3 days at least. These datasets offer a new opportunity to investigate the entire earthquake cycle in the Apennines, a region in which the active tectonic framework is exceptionally well constrained by previous work.

This project will use high resolution field, survey and space geodetic datasets to provide new insights into the earthquake cycle in the central Apennines. These data will be used to address the general question of

how apparently smooth and stable interseismic deformation relates to the temporally- and spatially-varying slip on complex arrays of faults in the upper crust that gives rise to damaging earthquakes.

The main aims of this project are:

- to collect and analyse field survey data (GNSS, LiDAR and Structure from Motion photogrammetry - SfM) on known active fault systems in the central Apennines
- to use satellite radar to measure and model interseismic, coseismic and postseismic deformation across active normal faults in Italy
- to combine both approaches to understand how active tectonic processes operate on a range of spatial and temporal scales within the Central Apennines.
- to determine to what extent surface complexity is reflected by fault structure at depth

Methodology

The student will use (SfM), terrestrial LiDAR scanning (TLS) and short-baseline GNSS to capture postseismic and interseismic deformation at multiple scales in time and space across individual faults. Data will be processed using a combination of in-house scripts and specific geospatial data packages. Interferometric SAR (InSAR) will be used to measure crustal interseismic velocity across target faults by processing and analysing long time-series of SAR observations. InSAR will also be used to study the postseismic signal from the 2016 Central Italy earthquake sequence and to investigate any shallow earthquakes that occur in Italy during the course of the PhD. The GACOS online service developed at Newcastle will be employed to mitigate atmospheric effects on InSAR measurements (Yu et al., 2017a, 2017b). Newcastle and Durham Universities are members of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) and can access unique supercomputer facilities for processing large volumes of Sentinel-1 SAR data at the UK Facility for Climate and Environmental Monitoring from Space (CEMS).

This project also involves collaborations with Dr Max Wilkinson, GRL Ltd and Dr Laura Gregory, Leeds University.

Timeline

Year 1: Training in space geodesy techniques, in particular the processing and analysis of satellite radar data. Processing of InSAR interseismic/postseismic deformation time-series. In parallel, training will be provided on programming skills, processing data and modelling of tectonic deformation. A field excursion to Central Italy to survey active faults and deploy GNSS instruments.

Year 2: Analysis of field survey measurements. Modelling of geodetic results from Year 1. The work from Years 1 and 2 should lead to at least one publication in an international journal.

Year 3: Processing and modelling of additional radar data and comparison of earthquake cycle deformation to long-term deformation patterns. This work should lead to an additional publication that reconciles the shallow short base line deformation patterns with deeper long term records.

Year 4 (six months only): Focus on combining the published outputs and associated material into a PhD thesis.

Training & Skills

The student will receive specialist training in space geodesy (InSAR, GNSS) and field surveying (Terrestrial LiDAR & SfM) techniques, as well as training in the analysis and computer modelling of these datasets. Training in a wide range of essential skills (e.g. presentation skills, programming skills, paper/thesis writing, and enterprise skills) important both for life as a PhD student and afterwards is provided by the Department of Earth Sciences at Durham University, and the student will also benefit from cross-disciplinary training provided as part of IAPETUS.
The student will become a member of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) and she/he will attend regular meetings where the research of this UK-wide research group is presented and discussed.
There will be opportunities to work with other partners in the UK and internationally and students are encouraged to travel to national and international scientific meetings to present results. We aim to see all students publish at least two papers in leading scientific journals during their PhD. Upon completion, the student will be well equipped for a career in academia or in a range of industries.

References & Further Reading

D'Agostino, N. 2014. Complete seismic release of tectonic strain and earthquake recurrence in the Apennines (Italy). *Geophysical Research Letters,* **41 (4), 115-1162**.
Walters et al., 2009. The 2009 L'Aquila earthquake (Central Italy): a source mechanism and implication for seismic

hazard. Geophysics Research Letters, L17212. doi:10.1029/2009GL039337
Wilkinson, M.W., McCaffrey, K., .., Gregory, L., Walters, R.J. … (2017). Near-field fault slip of the 2016 Vettore Mw 6.6 earthquake (Central Italy) measured using low-cost GNSS. Scientific Reports 7: 4612.
Yu, C., N. T. Penna, and Z. Li (2017a), Generation of real-time mode high-resolution water vapor fields from GPS observations, J. Geophys. Res. Atmos., 122, 2008–2025.

Further Information

Prof Ken McCaffrey: k.j.w.mccaffrey@durham.ac.uk
Tel: 0191 334 2322
https://www.dur.ac.uk/earth.sciences/staff/academic/?id=375