G61B-0998 0830h POSTER

Realistic Error Modelling for InSAR: Determination of Uncertainties in Earthquake Slip Distributions.

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The major source of error in InSAR measurements results from changes in tropospheric water vapour concentrations, creating phase delays that are unrelated to ground motion. These can be distributed over distances of tens of kilometres and, if interpreted as surface deformation, can cause errors in measurement as large as 10 cm. Here we present a simple modified Monte Carlo (MC) method for determining the impact of these errors on the accuracy of model parameters derived from InSAR data. In particular, we examine the reliability of InSAR-derived earthquake slip distributions.

Conventional MC bootstrap methods are often used for determining errors in model parameters derived from InSAR data. An ensemble of best-fit parameter estimates is found using different input data sets. Each of these data sets is derived from the original, but has its individual phase measurements randomly perturbed in a normal distribution about their original value using an a priori standard deviation. Errors in model parameter estimates are found from the distribution of best-fit solutions to each perturbed data set. For InSAR data, however, conventional MC fails to account for the spatial correlation of atmospheric errors between multiple sampled phase measurements. When the interferogram is sampled densely compared to the wavelength of atmospheric errors, conventional MC can grossly underestimate the errors of model parameter estimates.

To produce realistic error bars for parameter estimates, the interferograms variance-covariance matrix (VCM) must first be determined. A practical approach for this is to determine the mean covariance vs distance function (autocorrelation function), either spatially or from the interferograms power spectrum using the Wiener-Khinchine theorem (e.g. Hanssen, 2001). This must be done using a part of the interferogram away from the deformation, or, where this is not possible, after a first-pass model has been removed. Using the covariance vs distance function, an approximate VCM can be generated for the sampled points of the interferogram. It is then possible to synthesise an ensemble of perturbed data sets that will have this VCM. These perturbed data sets can be used to produce realistic errors for model parameter estimates.

We use this technique to examine the reliability of earthquake slip distributions derived from InSAR. Plots of the distribution of slip error on the fault plane are powerful tools for distinguishing those areas of the fault plane where slip patterns should be believed and those where they are spurious.

URL: http://www.earth.ox.ac.uk/~timw

G61B-0999 0830h POSTER

Application of Spaceborne Differential Radar Interferometry to Rockbursts, Mining Subsidence and Shallow Moderate Earthquakes

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We have processed ERS SAR scenes for several sites of rockbursts and mining subsidence, including South Africa (gold), Colorado (coal), the state of New York (salt), Germany (potash), and Poland (copper). We are also looking at JERS-1 scenes from a potash mine in the Ural mountains (Russia) for which no suitable ERS data exist. Sizeable mining-induced events have occurred at most of these sites: mb5.1 in April 1999, S. Africa; ML3.6 in March 1994, New York; ML4.8 in September 1996, Germany; mb4.9 in April 2000, Poland; and mb4.7 in January 1995, Urals. It is reasonable to expect detectable surface displacements from rockbursts, as they are rather shallow compared with tectonic earthquakes of similar size. Indeed, in the case of the 1999 S. African event differential InSAR detects up to 9-cm displacement away from the satellite, while the 1995 collapse in the Urals has resulted in up to 4.5-m surface subsidence. Some of the study rockbursts have occurred on the background of ongoing mining subsidence (e. g., Poland, Urals, New York), adding a detectable boost to the existing subsidence rate. In other cases, mining subsidence is planned and intermittent, without unexpected collapse (e.g., long-wall coal mining in Colorado).

We have applied deformation modeling using a 3D finite-difference code, focusing on the April 1999 event that was associated with a normal slip along the Dagbreek fault. Seismic events in this area (Welkom, S. Africa) are commonly associated with collapse of mined out volumes around west-dipping normal faults, but it is not clear how these faults contribute to the seismic and static displacements. The 1999 event provides an opportunity to address this ambiguity, as our InSAR measurements of surface displacements are complemented by local, regional, and teleseismic waveform records, as well as by measurements of displacements in the mine tunnels intersecting the Dagbreek fault. We are using these data to constrain the source and are investigating the use of 3D modeling methods in resolving discrepancies between seismically and geodetically based models.

Other than contributing to the mining practice, our InSAR results are relevant to the identification of ground truth to be compared with seismically determined epicenters. The 1999 S. African event is our best example in this respect, with an interferogram showing a clear fringe pattern that is easy to compare with existing seismic locations. For the purpose of ground truth, we have also examined ERS SAR scenes over sites of moderate tectonic earthquakes in Algeria (northern Africa). Due to the configuration of the existing seismic networks, these events are commonly located much too to the north. So far we have identified a possible signal (2 cm LOS) in the differential interferograms from descending and ascending interferometric pairs over the site of a December 1999 Mw5.6 earthquake, and are in the process of looking at additional SAR scenes over a site of a November 2000 Mw5.7 event.

Our results show that differential InSAR can be effective in providing detailed spatial coverage of surface changes associated with mining activities, as well as in establishing ground truth for the seismic locations of moderate tectonic earthquakes. The main limitation of the technique for such purposes is the insufficient temporal coverage of sites of interest by the ERS satellites, resulting in extensive decorrelation in some of the study cases. ENVISAT data are likely to be more effective in the future, especially if regular data collection is supplemented with ordering of data acquisitions on as-needed basis.

G61B-1000 0830h POSTER

Crustal Deformation Mapping with Satellite SAR Interferometry: Applied to 1999 Chi-Chi, Taiwan Earthquake

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The 1999 Mw=7.6 Chi-Chi earthquake was the largest inland earthquake of Taiwan in the twentieth century. We study with synthetic aperture radar interferometry (InSAR) the pre- and co-seismic surface deformations in an epicentral area of about 1500 km2. Five radar images acquired by C-band SARs onboard the ERS-1/2 satellite are combined to create interferograms to map the sensor-to-ground displacements.

The co-seismic interferograms (1998-1999) have revealed significant crustal deformations. The arc-shaped fringe patterns (about 10 fringes) reflect uneven ground displacements produced by the major slip along the Chelungpu fault, a low-angle reverse fault. The interferometric results agree well with GPS measurements at 19 sites. Combining the co-seismic interferogram with the GPS data, it is found that the most significant deformations in the study area were around the Taichung city area where the subsidence ranged from 10 to 30 cm, and the southeastward horizontal motions ranged from 70 to 140 cm. The measurements are compared with the latest fault model derived for the earthquake. The results showed good agreement in general between the measurements and the model. Some disagreement at localized areas may indicate some minor geological structures.

The pre-seismic interferograms (1996-1999) have shown up to more than 1 fringe of crustal deformations. The measured deformations are considered having been governed by the general tectonic settings in Taiwan, i.e., east-west tectonic compression. The results also support the recent findings that the southwestern coastal region belongs to the active deformation front, rather than to the stable foreland.

G62A MCC: 133 Saturday 1330h

Geophysical Modeling Using Spaceborne InSAR Measurements II
(joint with S, T)

Presiding: H Zebker, Stanford University; B Minster, Scripps Institution of Oceanography

G62A-01 1330h INVITED

Co-seismic and post-seismic slip from multiple earthquakes in the northern Chilean subduction zone: Joint study using InSAR, GPS, and seismology

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Several large subduction zone earthquakes (Mw > 7) occurred in the region near Antofagasta, Chile between 1987-1998. Here, we investigate the spatial and temporal relationship between these events and any associated post-seismic slip. We use InSAR, GPS, and seismic data to constrain the distribution of slip on the subduction zone interface for the July 30, 1995, Mw 8.1 earthquake. Only InSAR and seismic observations are available for the Mw 7.1 earthquake on January 30, 1998. We find that the seismic data is particularly useful in providing spatial resolution of co-seismic slip for the 1998 earthquake. For earlier earthquakes in 1987 and 1988, only seismic data is available. Our current inversion, as well as previous results from others, suggest that there is little slip during the 1995 earthquake near a 1987 Mw 7.5 event. Our analysis further suggests that little moment from the 1995 slip distribution released near a 1988 Mw 7.2 event. According to our model for the 1995 event, the 1998 event occurred down-dip of the 1995 rupture. In other words, preliminary models indicate that these events do not overlap significantly and appear to be tilling up the slab interface.

Compared with other recent large subduction zone earthquakes (e.g., Jalisco, Mexico, 1995), post-seismic slip from the Mw 8.1 Antofagasta earthquake is small. The satellite line of sight displacements are of order a few cm, comparable to the noise. This signal strongly correlates with topography in most of our interferograms, suggesting a possible atmospheric origin. However, when the InSAR data from several tracks is combined with horizontal GPS displacements (Klotz et al., 2001), we are able to bound the magnitude and distribution of after-slip on the fault.

G62A-02 1345h INVITED

Melt Beneath the Siple Coast Ice Streams

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The Siple Coast ice streams flow over a well lubricated bed. With virtually no surface melt, basal melt is required to sustain a well lubricated bed. We used a recently derived InSAR map of the velocity of Siple Coast ice streams to estimate basal melting/freezing. Melt is determined, in part, by the basal temperature gradient. To obtain this gradient, we modeled ice temperature using the standard advection-diffusion equation for heat transport with the InSAR data used to determine the horizontal advection. Basal melt is also affected by the basal shear stress. We used both force-balance and control-method inversions of the InSAR velocity data to determine basal shear stress.

We find a wide range of melt conditions. Most of the melt occurs beneath the tributaries where larger basal shear stresses and thicker ice favors greater melt (e.g., 10-20 mm/yr). Basal freezing is predicted beneath much of the ice plains of Ice Stream C and Whillans Ice Stream. With a significantly higher basal shear stress, little or no freezing occurs beneath Ice Stream E. These findings are consistent with indications of variable flow over the last millennium in the section of the Ross Ice Shelf fed by Whillans Ice Stream and Ice Streams A and C and with relatively steady flow inferred for the region fed by Ice Streams D and E.

G62A-03 1400h INVITED

Postseismic Poro-elastic Deformation in South Iceland Observed with Radar Interferometry: Implications for Aftershock Decay

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Postseismic pore-pressure changes caused the deformation observed during the first two months following two M_w 6.5 earthquakes in South Iceland. The earthquakes occurred in the South Iceland Seismic Zone (SISZ) on June 17 and 21, 2000. The right-lateral ruptures are parallel, separated by 17 km, and trend N-S within the E-W striking transform zone. Satellite radar interferograms spanning the first two months after the quakes exhibit a fringe pattern consistent with models of poro-elastic relaxation within the crust surrounding the faults. Interferograms from subsequent periods show no significant signal.

Afterslip is not a plausible explanation of the fringe pattern, as it would demand left-lateral back-slip as well as vertical slip, neither favored by Coulomb stress changes on the faults. Visco-elastic relaxation is also not plausible for two reasons: (1) the two month duration of the transient deformation would require very low viscosity ($\sim 10^{17}$ Pa-s), (2) the observed deformation is too localized near the faults to be explained by lower crustal or mantle processes.

Our poro-elastic interpretation is further supported by water level changes observed in numerous boreholes throughout the epicentral region. The sign of the coseismic water level changes exhibits a quadrantal pattern consistent with the predicted undrained response. The postseismic water level recoveries have a spatial distribution consistent with the InSAR observations. While the postseismic behavior varies from well to well, the duration of the water level recovery of most wells is 1-3 months, consistent with the two month long deformation signal observed in the interferograms.

We test whether the aftershock decay follows the predicted changes in effective stress, induced by poro-elastic effects. Off-fault aftershocks preferentially occur in the two quadrants that experienced coseismic unclamping on N-S oriented faults and post-seismic pore-pressure increase. However, the duration of the aftershock sequence is much longer than the duration of the pore-pressure transients. Extrapolation of the ongoing Omori-like decay predicts an aftershock duration of 3-4 years. Therefore, the aftershock decay does not seem to be controlled by pore-pressure changes near the faults, although interpretation is complicated due to the shallow depth of the wells in south Iceland. All wells are shallower than 2 km and most are shallower than 1 km. The bulk of the aftershock activity is deeper, between 3 km and 10 km depth. If the permeability decreases significantly below 2-3 km then the deeper pore-pressure recovery would last longer, possibly 3-4 years like the aftershocks. We show that the InSAR data alone cannot constrain whether the poro-elastic rebound occurs only in the uppermost 2-3 km or down to the bottom of the seismogenic crust.

We conclude that poro-elastic rebound is responsible for the observed postseismic deformation and that the different time scales of the pore-pressure changes (2 months) and the aftershock decay (3-4 years) may indicate that these processes are unrelated, although at present we can not rule out slower poroelastic relaxation at depth.

G62A-04 1415h INVITED

Inversion of InSAR Data for the Aseismic Slip-Rate on the Hayward Fault

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The Hayward fault is a major strand of the San Andreas fault system, and has received considerable attention because of the seismic hazard it poses to the San Francisco Bay Area. We perform a least-squares inversion of multiple geodetic and seismic data sets to determine the strike-slip distribution of the aseismic slip-rate on the fault. The analysis focuses on the northern 60 km of the fault where surface creep rates appear to be constant over the past several decades. InSAR data from 24 independent ERS interferograms are stacked to obtain range-change rates from 1992 to 2000. Surface displacement rates at 43 sites are observed using GPS from 1994 to 2002. Surface creep observations and estimates of deep slip rates determined from characteristic repeating earthquake sequences are also incorporated in the inversion. The densely spaced InSAR data require a non-planar fault surface to adequately model the near-fault data. The fault is discretized into 283 triangular dislocation elements that approximate the non-planar attributes of the fault surface. South of Hayward, a steeply, east-dipping fault geometry accommodates the divergence of the surface trace and the micro-seismicity at depth. Laplacian smoothing and a positivity constraint are included in the inversion. The InSAR data provide the greatest resolution on the shallow portion of the fault. The additional data sets help to complement the InSAR data and improve the model resolution. The inversion result suggests a heterogeneous distribution of aseismic slip-rate that is characterized by both locked and freely slipping patches. A seismic cluster beneath San Leandro coincides with a creeping patch as resolved by the geodetic data. A locked region at depth coincides with the source region of the 1868 earthquake (M 6.8) on the southern Hayward fault.

G62A-05 1450h INVITED

Styles of Volcano Deformation in Iceland Mapped by InSAR

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InSAR observations cover a large part of the divergent plate boundary in Iceland. In combination with other geodetic, seismological, and field observations, they are important for identifying the style of deformation, the first step in understanding the underlying dynamics relevant for geophysical modeling. To date InSAR studies have covered over 15 central volcanoes that are focus of volcanic production along the plate boundary. At a number of these volcanos, local uplift or subsidence can be attributed to either expanding or contracting sources in the crust. The expanding sources reflect inflow of magma in different quantities. Contracting sources are the result of magma outflow, solidification and cooling, or pressure reduction in shallow magma chambers.

The observed deformation usually falls into one of the following categories: (i) No deformation: In this case, the usual interpretation is that the volcano receives no flow of magma during the observation interval. We suggest that such absence of deformation can also be taken as indication of no residing magma at shallow depth, as it would give off its heat to the surroundings and solidify, causing contraction. Absence of deformation is characteristic of volcanoes that have not erupted for a long time. (ii) Continuous subsidence: In this case, there is also no flow of magma to shallow depths. The interpretation infers that molten magma still resides at shallow depths from earlier events. Krafla and Askja volcanoes are examples, with subsidence up to 5 cm/yr over decades. Continuous subsidence can also result from industrial pumping for geothermal power that can be difficult to discriminate from subsidence from magmatic processes, such as at Svartsengi in southwest Iceland. (iii) Gradual uplift: Magma flows slowly from depth through a conduit open over several of years. At , Hengill volcano, for example, InSAR measurements indicate inflow of magma at the rate of 4 million cubic meters per year over a period of four years. (iv) Episodic intrusions: Magma moves suddenly from depth to shallow levels as at Eyjafjallajkull in 1994 and 1998. (v) Co-eruptive deformation: Co-eruptive deflation and dike injection during an eruption as observed at Hekla volcano in 2000. (vi) Faulting on volcanoes without magma involvement. Example is faulting in 2000 at Lake Kleifarvatn on the Reykjanes Peninsula volcanic area, that was triggered by earthquakes 85 km away.

InSAR has been a critical complementary technique in identifying magma budget and volcano dynamics in Iceland. Volcanoes where deformation styles (i) and (ii) dominate have a low alert level, whereas volcanoes with a recent history of inflow of magma are more likely to erupt.

G62A-06 1505h INVITED

Parameter estimation in PS-InSAR deformation studies using integer least-squares techniques

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Interferometric synthetic aperture radar (InSAR) methods are increasingly used for measuring deformations of the earth's surface. Unfortunately, in many cases the problem of temporal decorrelation hampers successful measurements over longer time intervals. The permanent scatterers approach (PS-InSAR) for processing time series of SAR interferograms proves to be a good alternative by recognizing and analyzing single scatterers with a reliable phase behavior in time.

Ambiguity resolution or phase unwrapping is the process of resolving the unknown cycle ambiguities in the radar data, and is one of the main problems in InSAR data analysis. In a single interferogram, the problem of phase unwrapping and parameter estimation is usually solved for in separate consecutive computations. It is often assumed that the final result of the phase unwrapping is a deterministic signal, used as input for the parameter estimation, e.g. elevation and deformation. As a result, errors in the ambiguity resolution are usually not propagated into the final results, which can lead to a serious underestimation of errors in the parameters and consequently in the geophysical models which use these parameters. In fact, however, the resolved phase ambiguities are stochastic as well, even though they are described with a probability mass function in stead of a probability density function.

In this paper, the integer least-squares technique for integrated ambiguity resolution and parameter estimation is applied to PS-InSAR data analysis, using a three-step procedure. First, a standard least-squares adjustment is performed, assuming the ambiguities are float parameters, leading to the real-valued 'float'-solution. Second, the ambiguities are resolved using the float ambiguity estimates. Third, if the second step was successful, the integer estimates are used to correct the float solution estimate. It has been proved that the integer least-squares estimator is an optimal method in the sense that it maximizes the probability of correct integer estimation, and it has been efficiently implemented in the LAMBDA method. The success-rate is the probability of correct integer estimation, and depends on the various assumptions underlying the mathematical model used. It will be discussed how a priori estimates on the success rates of this method can be given based on the satellite acquisition characteristics and how testing methodology can be applied to compare the likelihood of different models.

G62A-07 1520h

Aseismic slip on a shallow thrust imaged by SAR interferometry: the Shahdad thrust, SE Iran

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Some of the convergence between the Arabian plate and the Eurasian plate is accomodated by shear in eastern Iran. The strain manifests itself primarily in a series of large strike-slip faults combined with narrow thrust belts, separated by less deformed blocks. One of the strike-slip fault systems, the Gowk Fault, runs between the Central Iranian Plateau and the Lut block. The central Gowk fault orientation is slightly oblique to the plate motion direction and a fold-thrust belt has formed beside this section near the town of Shahdad in southeast Iran.

Shallow and gently dipping thrust faults are believed to be present beneath many fold-thrust belts. Movement on these faults is difficult to observe, but a Synthetic Aperture Radar interferogram has imaged slip on a 800 km^2 portion of the Shahdad thrust. The approximately 80 mm of thrust motion on the roughly

6 degrees dipping Shahdad thrust occurred 8 to 30 km to the east of the 14 March 1998 Fandoqa earthquake ($M_w = 6.6$) that involved about 2 m of oblique slip on a steeply dipping fault. That earthquake transferred stress to the Shahdad fault, probably triggering slip on it either immediately or in the following six months. We use nonlinear inversion of the interferograms with the Okada elastic half-space approximation to determine the slip geometry and magnitude of both the Fandoqa and Shahdad ruptures. Further elastic calculations show Coulomb stress change due to the Fandoqa rupture was positive in exactly the area of the Shahdad thrust that slipped. The material above the Shahdad thrust is likely to have a very low strength, and there are hints of plastic behavior. The anomalous slip-to-length ratio for the slip on the Shahdad thrust suggests a mechanism unlike most earthquakes, likely aseismic.

* Work partially performed under contract with the National Aeronautics and Space Administration.

\# Centre for Observation and Modelling of Earthquakes and Tectonics

G62A-08 1535h

Ross Tide Modeling Using INSAR and Radar Altimetry

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Ocean tides play a significant role in the complex interactions between the atmosphere, ocean, sea ice and floating glacial ice shelves. Tidal currents create turbulent mixing at the bottom of the ice shelf contributing to the creation of rifts for the possible detachment of part of the ice bergs and can influence heat transport between the ice shelf and sea water. Tides near and under floating ice shelves and sea ice, and depending on surface and basal slopes, grounding line migrates with time within a grounding zone. Improved knowledge of the grounding line is inherently necessary to study ice mass balance and its contribution to the global sea level change. Even with the availability of most recent suite of global tide models based primarily on TOPEX/POSEIDON data, e.g., GOT00, NAO99, Delft, FES00, extreme southern ocean tides (-60 deg. latitude South pole-ward) are limited both in accuracy and resolutions, especially in regions near Antarctica, seasonally or permanently sea-ice-covered oceans. InSAR tidal deformation analysis using ERS-1/-2 tandem missions over Ross Sea and in a test region over the Sulzberger Ice Shelf, Ross Sea (-77.50 latitude, 1500 East Longitude) will be presented. In our initial study with the objectives to improve tides in Antarctica oceans for accurate prediction of ground-line locations to enhance ice mass balance studies, we provide an assessment of accuracy of tide models in the region. In addition to global models, finer resolution regional models in the Antarctica Ocean such as the Padman model are available. Coarse resolution tide models using (-50 deg latitude South pole-ward) using available over-ocean and over sea ice and ice-shelf data from ERS-1 and ERS-2, and GFO, will be presented. A fine-resolution test ocean tide model using combined radar altimeter and ERS tandem mission InSAR data over the Sulzberger Ice Shelf is described.

G62B MCC: 133 Saturday 1600h

Bowie Lecture (joint with S, T)

Presiding: J T Freymueller, University of Alaska, Fairbanks; V M Dehant, Royal Observatory of Belgium

G62B-01 1615h INVITED

Towards Imaging the Earth's Surface in 4 Dimensions

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In the seventies, the first generation of Landsat images allowed scientists to map active faults over continents and in some cases to determine direction of motion. In the eighties, 10m-resolution SPOT satellite images provided the means to measure lateral offsets of geomorphic features along faults, helping to determine long-term rates of slip on faults. In the nineties, spaceborne synthetic aperture radar (SAR) systems and advances in the technique of radar interferometry (InSAR) brought spatially continuous observations of the Earth's surface displacement field at the sub-cm level over broad areas, opening a new era in geodesy from space. Totally new insights into earthquakes, volcanic activity, ice flow, and human-induced ground subsidence are resulting. For seismology and tectonics, InSAR data have been invaluable to characterize specific sub-surface processes including poroelastic rebound, after-slip, and visco-elastic relaxation after large earthquakes, characterization of the depth distribution of fault creep along the Hayward fault and the southern section of the San Andreas fault, nonlinear elasticity of the crust from the surface displacement field of the M7.6, Tibet, 1997 earthquake, triggered creep on adjacent faults after the 1999 Hector Mine, California earthquake, and 8 years of transient creep along the Blackwater fault in the Eastern California Shear Zone. In the Los Angeles area, joint analysis of spatially continuous InSAR data and temporally continuous GPS data allows characterization of processes occurring at various temporal and spatial scales. In particular allowing discrimination between seasonal subsidence above acquifers, oil field subsidence, and long-term tectonic strain accumulation along faults and folds. These major advances in Earth science have been demonstrated only in a few areas using the data from the European ERS satellites and the Japanese JERS satellite, both of which were designed for purposes other than InSAR. A dedicated mission, designed specifically for interferometry, would greatly expand applications of InSAR with improved coherence over vegetated areas, better orbit control and determination, frequent revisit time, and multi-look direction. Such a system is an integral part of Earthscope and will open space geodesy to the continuous surveillance of the Earth's surface, globally, and in 3 dimensions.

G71A MCC: Hall C Sunday 0830h

Crustal Deformation I Posters (joint with S, T)

Presiding: J N Kellogg, University of South Carolina; S Hreinsdóttir, University of Alaska, Fairbanks

G71A-0939 0830h POSTER

The Central Apennine Geodetic Network (CAGeoNet): Description and Preliminary Results

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During the time span 1999-2001 we set up and surveyed the CA-GeoNet (Central Apennine Geodetic Network), a dense sub-regional GPS network located in one of the highest seismic areas of the Apennines (Italy), with the aim to detect the active strain rate of this sector of the chain, during inter-seismic and co-seismic epochs. The network extends across southern Umbria (Norcia area), Abrutii and southern Latium (Sora area) regions and from the Tyrrhenian to the Adriatic sea, in an area of about 130 km x 180 km. It consists of 129 vertices distributed with an average grid of 5 km over the main seismogenetic and geological structures of the area. The non permanent network is linked with the ASI and INGV permanent GPS stations. Among them, INGR, VVLO, ROSE and AQU are deployed E-W in this area, allowing a high precision estimation of the current strain rate component normal to the chain,

from Tyrrhenian to Adriatic. Site selection and monumentation were performed after an accurate geological study of the area, with the aim to set up group of stations across the typical basin and ranges seismogenetic structures of the central Apennines, to estimate the strain rate in the near field. To obtain the best accuracy during surveys, the monuments were located on significant outcrops using steel markers screwed in the rock (3D monument) or concrete pillars with deep foundations. Data analysis performed by means of Bernese 4.2 and Gamit software, show accuracy within 1?2 mm in the planar and 1?5 mm in the vertical components, respectively. A preliminary comparison between 1999 and 2001 data for the Rieti and Leonessa sub-network shows horizontal displacements ranging from 5 to 15 mm.

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The GIS of the Central Apennines Geodetic Network (CA-GeoNet): Database Description and Application for Crustal Deformation Analysis

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During the last few years we set up and surveyed a GPS geodetic network to investigate the active tectonic areas of the Central Apennine, using a combination of permanent and not-permanent geodetic stations. The final goal is to evaluate the geodetic strain rate and the coseismic deformations of this seismically active area. For an optimal management and mapping of the CA-GeoNet (Central Apennine Geodetic Network) a Geographical Information System (GIS) has been developed. The GIS is used to analyze geodetic sources and improve the analysis of crustal deformations and has been realized on PC platform using MapInfo 6.0 and ArcGIS8.1 software. The GIS manages an SQL database consisting of different classes (Geodesy, Topography, Geography, Seismicity and Geology) administrated according to Thematic Layers. A GIS is required for the multidisciplinary approach and management of large multi-scaled data set, geographically referenced and with continuos or discrete coverage; it is particularly designed to analyze GPS sources and to improve crustal deformation analysis related with tectonic structures and seismicity. Through GIS we can display site displacements, strain rate maps and create new layers gained by numerical and spatial analysis. A tailor-made application to support co-seismic deformation scenarios related with historical and instrumental earthquakes and seismic sources, has been created. Our procedures can be successfully applied to design new geodetic networks in seismically active areas with respect to the known seismotectonic features. This dynamic approach in planning and managing GPS networks for geodynamic applications provides a useful tool for geophysical research, earthquake impact and civil protection management.

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New Constraints Into the Present day Kinematics of the African/Eurasian Plate Boundary System From the Analysis of Permanent and Non-Permanent GPS Data

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The Mediterranean area is presently characterized by a relatively high number of crustal wedges behaving independently or partially independently with respect to one another, as consequences of a complex space and time evolution of the African/Eurasian plate boundary system. This work concerns the analysis of continuous and non-continuous GPS data collected in the