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.

URL: http://www.ingv.it

G71A-0940 0830h POSTER

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.

URL: http://www.ingv.it

G71A-0941 0830h POSTER

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

Mediterranean region, and in particular in the Adriatic/Tyrrhenian domain, in order to tentatively constrain the kinematics of crustal blocks and the distribution of geodetic strain rates. The structural complexity of the Mediterranean and its relatively low deformation rates ask for a high number of GPS stations with very high precision and long observation time spans. In this work we improve the space and time resolutions of the available GPS data combining both permanent and geophysical dedicated non-permanent networks, providing significant information to better constrain the complex deformation pattern of this high tectonically fragmented zone. Continuous GPS data for the time span 1998-2002, collected on stations managed by different Italian and European institutions, have been processed and combined with survey mode GPS data, collected on different geodetic networks in the time span 1991-2001. The whole data set has been analyzed following a uniform processing strategy, by means of the distributed session approach, and using each individual daily solution in terms of quasi-observations for a position time series analysis and the evaluation of crustal motions. The final velocity field has been used to evaluate a stable European frame, which significantly differs from the NNR-NUVEL-1A. An analysis in terms of rigid-block motions has been performed and a kinematic interpretation has been carried out, delineating some first order crustal wedges. The long wavelength geodetic strain rate field has been computed in order to obtain a smoothed picture of the higher strain concentrations zones, which seems to be the Aegean area, the Calabrian arc and the central-southern Apennines.

G71A-0942 0830h POSTER

Geodetics in a Sandbox: Implications for Measuring Strain at Convergent Margins

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Analogue modeling can be a very useful complement to theoretical analyses of convergent margin mechanics. They are robust and inherently 3-dimensional, with the potential for a broad range of model boundary conditions. A critical limitation of analogue models has been their lack of suitability for comparison to other, inherently more quantitative, techniques (e.g., numerical models and earthquake and GPS data). To address this we have quantified our experiments by applying techniques common in both remote sensing and geodesy to track the displacements of surface markers at small intervals in a series of digital images. We measure the surface velocities, and calculate the resulting strain fields and no-length-change directions to a very high accuracy and precision allowing for comparison with other types of data. We employ an automated algorithm to re-grid, allowing both the velocity and strain field to be measured continuously to any stage of the model run, and to add additional markers as needed during an experiment. In addition to measuring larger strains, our experiments differ from actual surveys in that they are carried out in a controlled environment where the tectonic style is known. This allows us to devise a network of markers that will optimally sample the tectonics, which is often not possible in actual field surveys. Thus, we can evaluate the effects of various non-optimal network geometries on the determination of strain. Our results show that the interpretation of a strain field is ultimately affected by the choice of stations used to determine it. When active accommodating structures intersect a grid at non-ideal orientations the resulting variability in strain in adjacent triangular elements along strike may not accurately represent the true style of deformation. This misrepresentation can appear as a spurious alternating pattern in the calculated strain, a problem that can typically be alleviated by averaging strain using triangle pairs to yield quadrilaterals that do a much better job of representing the strain patterns. The validity of the strain representation is also affected by the orientation of the chosen triangle pair and how that pair samples the deforming region. Our results indicate that a sparse well-located array of stations is often preferable to a dense but poorly connected grid.

G71A-0943 0830h POSTER

Interseismic Deformation across the Himalaya of Central Nepal from GPS measurements, 1997-2001

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We report results from monitoring current shortening rate across a transect across the Himalaya of central Nepal a the latitude of Kathmandu between 1997 and 2001. Three permanent Global Positionning System stations were settled and have been operated continuously since 1997. Continuous GPS stations are equipped with dual-frequency receivers. Raw GPS data are transmitted by radio links via a relay at Phulchoki every 30 s to the NSC of Katmandu where they are demultiplexed. The data were processed with the Bernese software in ITRF 97 using a set of Eurasian and Indian IGS stations. The 3 permanent stations come in addition to a network of 10 campaign points that were settled along the section by the NSC and the LDG in 1995 and surveyed in 1995, 1998 and 2000. All available GPS data coming from the LDG, CIRES and IDYL-HIM network, were expressed in the same ITRF97 reference frame. The data were modeled using a simple 2-D creeping dislocation embedded in an elastic half space, taken to approximate ductile flow at depth. The data imply that the MHT is fully locked at the front if the Himalaya to beneath the high range over a distance of about 103 10km. The depth of the edge of the creeping dislocation is constrained between 20km and 12km. The slip 18.51 mm/yr, a value that is comparable to the 211.5mm/yr long term slip rate on the MHT. The model is compared to vertical displacements derived from repeated leveling campaigns over the period 1977-1990 The two sets of data show slight discrepancies either due to underestimated errors or bias, or to a possible variation of the position of the edge of the creeping zone a depth. The time series between 1997 and 2001 show seasonal variations but no clear tectonic transient deformation was detected over this period however.

G71A-0944 0830h POSTER

Three-dimensional Crustal Velocity Field of the Nankai Forearc, Southwest Japan: Oblique Subduction and Forearc Slip

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Oblique subduction of the Philippine Sea plate (PH) is the dominant factor controlling crustal deformation field of southwest Japan. Interseismic crustal shortening in the direction of plate convergence has been clearly illustrated by the nationwide continuous GPS array measurements. On the other hand, oblique subduction should generate small but permanent lateral slip of the Nankai forearc along the arc-parallel strike-slip fault system (the Median Tectonic Line: MTL) that separates the forearc from the main part of southwest Japan. Since station spacing of the continuous array is still too sparse to investigate this possibility, we use velocities obtained from GPS campaign measurements along a 200km-long margin-normal traverse across the MTL. By combining 23 campaign velocities with the velocities at 60 continuous stations, we obtain a dense three-dimensional velocity map. Crustal shortening observed is well reproduced by the elastic deformation due to the PH subduction, using multi-rectangular plate interface segments, depth-dependent plate coupling, and newly determined PH velocity relative to southwest Japan. Vertical velocity field observed also shows good accordance with the PH subduction. The subsidence-uplift pattern is consistent with the leveling results but space coverage and time resolution have been greatly improved. After subtracting the elastic deformation from the observed velocity field, the residual velocity field shows right-lateral strike-slip block motion of about 5mm/yr across the MTL, consistent with long-term slip rate estimated from geological observation. New finding is that the block boundary (narrow zone of a high velocity gradient) does not coincide with the surface trace of the MTL, being displaced 20-30km to the north. The residual velocity field is reproduced by a model with a 35-45deg northward-dipping fault plane, full locking of the upper portion to a depth of 15km, and steady slip of 5mm/yr below. These results are supported by imaging of an inclined fault plane revealed by recent seismic profiling and currently low activity of shallow earthquakes.

G71A-0945 0830h POSTER

Spatial Variation in Present Day Deformation, Southcentral Alaska, Revealed by GPS Measurements

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Southcentral Alaska is a region of complex tectonics. The plate boundary between the Pacific and North-American plates changes from being convergent to transform with the additional complication of the Yakutat block colliding into and accreting onto the North-American plate. In 1964 an M_W 9.2 earthquake occurred on the very shallow dipping plate interface between the subducting Pacific plate and the overriding North-American plate. Recent studies of deformation have revealed postseismic deformation continuing to the present, in addition to variation in coupling along the plate interface. Here we present a spatially and temporally improved dataset that allows for more detailed study of deformation processes affecting the region.

GPS velocities from more than 150 sites reveal considerable spatial variation in deformation, caused by multiple deformation processes. In general points on the eastern part of the Kenai Peninsula and Prince William Sound show rapid NNW movement, as expected from the plate convergence direction. On the western Kenai Peninsula, however, sites move in opposite direction, trenchward, resultng from postseismic deformation. East of the Kenai Peninsula, velocity vectors are more westerly, showing the effect of the colliding Yakutat block. We use three dimensional models to estimate the contributions of these deformation sources, as well as permanent deformation, translation and rotation of the overriding North American plate.

G71A-0946 0830h POSTER

Effects of the Earthquake Cycle on Crustal Deformation in the Northern Andes

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Along the coast of Ecuador and Colombia, recent results from Global Positioning System (GPS) measurements show considerable variability by latitude that can be linked to the rupture zones of recent earthquakes in 1979 and 1991. We use a boundary element model to simulate crustal deformation observed with GPS measurements taken in 1991, 1994, 1996, and 1998. Deformation is consistent with 50% seismic locking along the subduction interface in Ecuador including the area south of the 1906 earthquake rupture zone and crossing the Carnegie Ridge. A significant reduction in apparent seismic locking along the subduction interface

occurs in Colombia, where 30% apparent seismic locking in the 1979 earthquake rupture zone (Mw 8.2) is sufficient to explain the GPS-measured deformation in southern Colombia, and no apparent seismic locking is required to explain the GPS measurements immediately north of the 1979 rupture zone, near the epicenter of an Mw 7.2 earthquake in 1991. These two earthquakes, respectively, took place 12 years before and the same year as the beginning of the GPS campaign. We attribute the reduction of apparent elastic locking at the plate interface in the same areas as the 1979 and 1991 earthquakes to two potential causes: either ongoing slip along the fault rupture plane (ie. postseismic backslip or afterslip), or viscoelastic relaxation of the ductile parts of the lower crust/upper mantle. These results are the first indication that post-seismic deformation from even moderately large earthquakes continues for years or decades.

G71A-0947 0830h POSTER

Gravity Changes Caused by Subducting the Philippine Sea Plate

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Great interplate earthquakes have frequently occurred at plate boundaries such as the Nankai Trough subducting the Philippine Sea Plate beneath the Eurasian Plate. At interseismic periods, the land area of island arc begins subsidence. At the Cape Muroto in the Shikoku Island, Japan after the occurrence of Nankai earthquake (Magnitude 8.0: 1946), is subsiding recently at about 1 cm/year as a result the repeated leveling survey by the Geographical Survey Institute of Japan. In this area, we have attempted to detect secular gravity changes caused by elevation changes since the 1970s. Although the subsidence is continuing, we could not detect the gravity increase using the relative gravimetry. It may be due to the gravity change of the reference station by the relative gravity measurements. In order to avoid these uncertainties, we performed the absolute gravity measurement. In February 2001 we carried out the first absolute gravity measurements using the absolute gravimeter FG5 (SN210) at the Muroto Geophysical Observatory of the University of Tokyo (33.244N, 134.181E, 10mH) where located at the tip of a promontory of the Cape Muroto. The relative gravity measurements are also carried out around the Cape Muroto by employing LaCoste and Romberg gravimeters on benchmarks of the leveling routes as well as on the GPS continuous observation stations by the Geographical Survey Institute of Japan. In order to confirm the absolute gravity changes at a subducting plate margin, we will repeatedly carry out the absolute gravity measurement. The latest results of the absolute gravity measurements in September 2002 will be presented.

G71A-0948 0830h POSTER

An FEM modeling for the tsunami source area of the 1993 Hokkaido Nansei-oki Earthquake, Japan

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We propose a modeling method of tsunami source area to evaluate tsunami run-up height on the safe side. This method should be applied to the design of important coastal structures, which combines safety and economical efficiency against tsunami. We choose the 1993 Hokkaido Nansei-oki earthquake tsunami as a case study, because large tsunami run-up heights were measured at the coasts of the Okushiri Island close to the source area and further we can acquire good geophysical datasets for model parameters. First, to decide the fault dimension, we relocated the first 1-day aftershock hypocenters determined by JMA (Japan Meteorological Agency), by referring to the hypocenters determined by an OBS-network later installed at the source area. The relocated hypocenters are concentrated onto some clusters correlating well with the en-echolen oceanic ridges with N-S strike over 100km long. We classified them to six fault segments. Secondly, we constructed a 3-D FEM crustal model including the shape of the faults and displaced those hanging wall sides upward as reverse faults in order of the source process for about 70 seconds. The amount of displacement on each fault was estimated from fault area, seismic moment and rigidity. The calculated vertical deformation of seafloor finally shows subsidence in northwest, uplift in northeast, very large uplift in southwest and subtle subsidence in southeast of the source area. As a result of following numerical simulation based on shallow water theory using the dynamic tsunami source model, the calculated tsunami run-up heights became equal or more than observed ones all around the Okushiri Island. Since we didn't revise the source model with trial and error to fit the observed tsunami run-up heights, the method can be an advantage to evaluate tsunami run-up height on the safe side.

G71A-0949 0830h POSTER

High-Quality Long-Base Strain Measurements in a Thrust Zone, Los Angeles, California

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As part of the Southern California Integrated GPS Network (SCIGN), we have constructed, with backing from the Keck Foundation, Caltrans, and the City of Glendale, a long-base laser strainmeter in the Los Angeles urban area. The purpose of this installation is to complement the GPS part of SCIGN by providing much greater sensitivity to deformation at relatively short periods (hours to months). This instrument, GVS (Glendale-Verdugo Strain), is located in Verdugo Canyon by the side of the Glendale freeway, about 5 km south of the outcrop of the Sierra Madre thrust zone: a region of posited NS compression. The strainmeter is 558 m long, with an azimuth of N 14 deg E, and uses Michelson interferometers to measure the distance between the two endpoints, as well as any displacements of the two end-monuments using optical anchors that go to 20 m depth. The operation of the strainmeter has been significantly automated over previous systems, using commercially-available laboratory-control software; the instrument also includes improved temperature control at both ends. The first data from the instrument began on August 29, 2002, and shows large (0.05 mm) diurnal displacements of the one monument that is based on shallow fill (a few meters) and close to the freeway embankment; correcting for this effect provides reasonable secular and tidal results.

G71A-0950 0830h POSTER

Modeling GPS Data Across a Four Fault Transect in Southern California, USA

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The southern San Andreas and San Jacinto faults (Anza and Coachella segments) are generally interpreted to have rates of 25 (+5, -5) mm/yr and 12 (+7, -5) mm/yr respectively (e.g., Working Group on California Earthquakes, 1995). New geologic data suggest that the slip rate of the San Jacinto Anza fault may be somewhat faster, perhaps as high as 20 mm/yr, and the southern San Andreas fault correspondingly slower.

GPS data can also constrain the present day slip rates of these faults, provided that we apply an appropriate rheological model to convert short term geodetic velocities to longer term fault slip rates. We used SCEC GPS velocity data and a simple viscoelastic coupling model to investigate this problem. We find that the data support a faster rate interpretation for the San Jacinto fault, but results are sensitive to the assumed rheology and also to the earthquake history (recurrence interval and date of last earthquake) for the two faults, which are imperfectly known.

G71A-0951 0830h POSTER

Interseismic Strain and Rotation Rates in the Northeast Mojave Domain, Eastern California

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The Northeast Mojave Domain is a region of east-striking, left-lateral faults in the northeast corner of the Mojave block, a block otherwise dominated by N40°W striking, right-lateral faults. Paleomagnetic evidence suggests that the Northeast Mojave Domain has rotated 63.5°±7.6° clockwise about a vertical axis since 12.8 Ma [*Schermer et al.*, 1996]. The U. S. Geological Survey surveyed in 1994 and 2001 an array of 14 geodetic monuments distributed cross the Northeast Mojave Domain. The 2001 survey results were adjusted to remove the coseismic offsets imposed by the nearby Hector Mine earthquake (October 16, 1999, M_w=7.1). Strain accumulation across the corrected array appears to be uniform and can be approximated by the principal strain rates (in nanostrain yr^{-1}) ϵ_1=28.9±9.1 N77.2°E and ϵ_2=-48.2±8.9 N12.8°W, extension reckoned positive. The areal dilatation rate ($\epsilon_1+\epsilon_2$) is -19.3±12.7 nanostrain yr^{-1}, and the vertical-axis rotation rate is 71.0±6.4 nanoradians yr^{-1} (4.07±0.37° Myr^{-1}) clockwise as seen from above. In a coordinate system with the 1 axis directed N50.5°E and the 2 axis N39.5°W (perpendicular and parallel, respectively, to the principal right-lateral faults in the Mojave block) the strain rates are ϵ_{11}=-19.3±6.9, ϵ_{12}=-37.3±6.4, and ϵ_{22}=0.0±10.7 nanostrain yr^{-1} (i.e., right-lateral shear and contraction across the trend of the principal faults in the Mojave block and no extension parallel to the trend). Thus, we find that the current strain rates in the Northeast Mojave Domain are consistent with the right-lateral deformation on N40°W striking faults elsewhere in the Mojave block. Moreover, the geodetically observed rotation rate acting over the entire 12.8 Myr would produce a clockwise rotation of 52.1°±4.7°, in rough agreement with the observed 63.5°±7.6° paleomagnetic rotation since 12.8 Ma. However, the geodetic estimate of rotation does not include coseismic rotations, nor does the paleomagnetic estimate require that the rotation occurred at a steady rate over the entire 12.8 Myr.

G71A-0952 0830h POSTER

Crustal Deformation Across the Basin and Range Province, Western United States, Measured with the Global Positioning System, 1992-2002

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The Basin and Range province of the western United States lies east of the Sierra Nevada mountains and accommodates roughly 25% of the motion between the North American and Pacific Plates in this region. It is experiencing both active extension and dextral shear, whose orientation is consistent with relative plate motion, suggesting that the province is an important part of the overall plate boundary system.

We present results from recent measurement of Basin and Range crustal motion using the Global Positioning System (GPS). As of September 2002, ten years of deformation will have been observed with GPS measurements in 1992,1996, 1998 and 2002. The 800 km long east-to-west line of campaign-style geodetic benchmarks extends from east of the Wasatch fault zone in Utah to west of the Genoa fault zone and Lake Tahoe in Californias Northern Sierra Nevada mountains, primarily along Interstate Highway 50. In all there are velocities at 91 GPS sites, nearly double the number previously presented (Thatcher et al. [1999]), all of which will be measured in September 2002. Incorporating this new data is expected to reduce the uncertainty in earlier measurements that show the motion of the Sierra Nevada block with respect to non-deforming North America to be accommodated by right lateral shear and extensional deformation in Nevada and Utah. Velocity variation of about 9 mm/yr is concentrated in the western one-third of the network, with a lesser amount (roughly 3 mm/yr) localized to the easternmost edge of the network, in the vicinity of the Wasatch fault zone. Recent densification of the GPS network across these two zones will also improve the spatial resolution of the deformation in these regions. The greatest rate of present-day deformation occurs near the ruptures of the Fairview Peak and Rainbow Mountain earthquakes in the Central Nevada Seismic Zone, extending west past the Genoa fault into the Sierra Nevada.

This strain rate pattern is correlated with the concentration of historic faulting and seismicity in the western half of Nevada and eastern California, but is less well correlated with the relatively broad distribution of faults with Holocene and late Quaternary age. To process the data we use the GIPSY/OASIS II and Quasi-Observation Combination Analysis (Dong et al. [1998]) software packages and incorporate data from continuously recording GPS stations in California and Nevada.

G71A-0953 0830h POSTER

Time-Varying Deformation Observed by a GPS Traverse Campaign Across the Yamasaki Fault, SW Japan

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We have been conducting GPS campaign surveys along traverses across active faults and other tectonic zones in western Japan over the last several years. These surveys are useful, if the scale of deformation along strike of the tectonic zones is much larger than the width of the deformation zone. Here we report our recent work on the Yamasaki fault, which has a length of about 80 km along the Chugoku Expressway, between Hyogo and Okayama prefectures in southwest Japan. This structure has left-lateral strike-slip faulting on a NW-SE trending vertical fault plane.

We established a traverse line crossing the Yamasaki fault in October 1995. It spans about 30 km in the N-S direction and consists of 6 sites. In August 1996 one more site was established. Over the last 7 years, we have conducted campaign surveys once or twice per year. Phase data were sampled every 30 seconds and the elevation mask was 15 degree. We calculate coordinates in the ITRF for all campaigns using data from several IGS sites. For each campaign, we first calculate the coordinates of the GEONET station Mitsu with the IGS sites fixed. Mitsu is located 20 km south of the Yamasaki fault. Then the coordinates of our sites and 4 nearby GEONET sites are determined relative to Mitsu. In the ITRF all sites move southeastward at about 2 cm/yr. In order to observe the local velocity field, we subtract the velocity of Mitsu from those of other sites. Several sites near the Yamasaki fault move northwest to westward with a velocity of 3 mm/yr.

Our results show that there is a northward trending gradient of velocities that covers the entire network. Two sites near Mitsu have small velocities. The whole network seems to be under left lateral deformation. Since there are no clear offsets near the surface trace of the Yamasaki fault, we suggest that the shallow part of the fault is locked. We suspect that the width of the locked zone might be large. The velocity gradient seems to be different on the different sides of the fault, which implies a gently dip of the fault plane.

G71A-0954 0830h POSTER

Dense GPS Array observations across the Atotsugawa fault, central Japan

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Recent deployment of GEONT by GSI, Japan, has revealed a concentrated deformation zone, NKTZ, in central Japan. The Atotsugawa fault is located in the NKTZ. Only on this fault in Japan, a surface creep with a rate of 1.5 mm/y has been detected by repeated EDM measurements in the central portion of the fault. To investigate the details of strain accumulation around this fault, we established a dense cross-fault GPS array and have observed since May in 1997. With a GPS software Bernese ver 4.2, we determine the daily positions for our 7 GPS sites and 5 GEONET ones, referred to that of our site, KMTK. Referred to the site (950279) on the fault, the sites, which are located on the southern and the northern sides of the fault, move eastwards and westwards, respectively. As approaching the fault from the most southern site to the one on the fault, the rate gradually decreases and the direction changes to parallel to the strike of the fault. In the zone sandwiched by the Atotsugawa and the northern Ushikubi faults, the rates are small, and the rate vectors have the fault-normal components. Then from the outside of this zone toward the north sites, the rate grows. Moreover the sites, on this zone, have high shear strain rates, which are 4.7×10^{-7}/yr and 6.4×10^{-7}/yr, respectively. These two rates are remarkably high values in the high strain zone NKTZ. We assume that the crust is an elastic body with the thickness of 30 km. The model is composed of three materials, which are the water-weakened lower crust, the low rigidity upper crust sandwiched by these two faults and the crust other than these two materials. We assign the displacement rate and the directions at the bottom of the crust, which are estimated from the rate vectors observed on sites far from the faults. The computed displacement rate profile well simulates the rigid motion and high strain zone. However in the zone sandwiched by the two faults, we cannot explain the observed fault-parallel components. This disagreement suggests the possibility that there is surface fault creep on both the Atotsugawa and the Ushikubi faults.

G71A-0955 0830h POSTER

New Estimates of Crustal Velocity in the Solomon Islands

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We present crustal velocity estimates derived from a dense GPS network in the western Solomon Islands. Initial crustal motion estimates reported by Tregoning et al. (1998) showed convergence between the Australian Plate and the Solomon Arc at the San Cristobal Trench. Active deformation between the Pacific Plate and the Solomon Arc block was also detected. In 1997, we established a continuous GPS (CGPS) site on Guadalcanal and five rover GPS sites in the New Georgia Group. The Guadalcanal site was short-lived due to vandalism so we established a new CGPS site in the New Georgia Group in 1999. The original rover sites were re-occupied in 1999 and 2001. We have analyzed this four-year time series using GAMIT/GLOBK software. Our measurements show convergence with the Australian Plate as well as motion between the Solomon Arc and the Pacific Plate. Possible intra-arc deformation is also observed. Regional tectonic interpretations based upon our GPS measurements and other data will be discussed.

G71A-0956 0830h POSTER

Ability of Detecting Significant Strains From the North China GPS Network

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GPS networks have been widely used in monitoring crustal deformations. The deformation strength has been considered as an optimum design indicator in deformation monitoring. The deformation strength is described by functions of strains. The geometric design, choice of observation types and numbers of and even data processing method would eventually affect the maximum detectable ability of strains. Thus it is desirable to detect strains that are lager than the deformation strength. Besides the traditional accuracy detectable ability, we can also optimize the monitoring network to realize the specific deformation strength. In this paper, the dilation strain and shear strain are chosen as the deformation strength measurements. We calculated deformation strengths of each stations of the North China GPS network, which reflect the ability of detecting significant strains in each station. Then stations with significant dilation and shear strains are chosen for spatial analysis and some geological and geophysical implications are concluded.

G71A-0957 0830h POSTER

Absolute Gravity and GPS Measurements of Uplift in the James Bay Region, Quebec, Canada

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The Nouveau Quebec-Labrador region was the site of one of the major ice domes of the Laurentide Ice Sheet and is currently experiencing postglacial rebound. Geodetic data provide a useful and accurate method of measuring the pattern and rates of contemporary uplift in this region. In order to monitor the temporal variations in gravitational potential resulting from regional glacial isostatic adjustment, a line of absolute gravity sites has been established in the area near James Bay in northern Quebec. These absolute-gravity field stations are co-located with sites of the Canadian Base Network (CBN). Initiated in 1994, the CBN is a network of pillar monuments with forced-centering plates for Global Positioning System (GPS) receiver antennae. Accurately positioned three-dimensionally with GPS, the CBN can serve as a monitoring network for deformation studies of the Canadian landmass.

Recent velocity estimates based on both the multiple-epoch GPS network surveys as well as preliminary results from absolute-gravity trends indicate regional uplift. Issues such as mass redistribution or changes in density contrasts within the Earth may be better addressed by monitoring positional changes (*e.g.*, primarily height changes) and integrating these observations with gravitational variations. The comparison of the temporal rate of change of gravity with the GPS height rate is thus highly desirable. Additionally, the observations will be compared to vertical crustal motions and gravity trends predicted by postglacial rebound models. Finally, as part of a densification plan for the study area, one additional CBN point and two new absolute gravity sites were established of during the Summer of 2002.

G71A-0958 0830h POSTER

Intraplate Deformations Measured with an Absolute Gravimeter Across the Ardenne and the Roer Graben (North-western Europe)

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In the Roer Graben and the Belgian Ardenne, there is a difference of an order of magnitude in the inferred vertical crustal movements deduced from the difference of levelling (1 mm/yr) and geological information (0.1 mm/yr). Moreover, within such intraplate areas, the tectonic deformation signal is usually smaller than the error of geodetic data.
To better constrain the present-day deformation, absolute gravity measurements using the FG5-202 gravimeter have been conducted along a profile twice a year since September 1999. This 140 km long profile includes 8 stations across the Belgian Ardenne and the Roer Graben. A description of the network is given, and specific difficulties met in some stations are presented. We also discuss the possible causes of gravity variations in this region. The precision, less than 2.0 μGal integrated over more than 24 hours of observations, is quite satisfactory in all stations but Jülich (Germany). The mining activities around Jülich cause an increase in the noise up to 7 Gal integrated over more than 72 hours. However, we observe there a gravity change of 6.4±2.6 μGal/yr related to a subsidence of more than 1 cm/yr caused by water pumping.
At this present time, it is still not possible yet to detect any tectonic deformation in the available data. However, after 5 years of observations, we should be able to detect or to constrain any possible long-term trend with an accuracy of 2.5 mm/yr, assuming a height change of 1 mm causes a change in gravity of 0.2 μGal. To ensure that the absolute gravimeter is giving accurate results it has been regularly compared with the superconducting gravimeter installed at the Membach reference station, which belongs to the profile.

G71A-0959 0830h POSTER

The IVS Observing Program

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Starting in 2002 the IVS (International VLBI Service for Geodesy and Astrometry) is coordinating a unified geodetic and astrometric observing program to provide data for EOP and for the terrestrial and celestial reference frames. Following from the recommendations of the IVS Working Group 2 for Product Specification and Observing Programs, the unified observing program augments the previously existing weekly 24-hr EOP measurements with a second weekly, rapid-turnaround series called R1. The R1 sessions are observed with a fourfold increase in data rate using Mark IV compared to the 1993-2001 NEOS sessions, which are now designated R4. Baseline repeatability tests indicate that the R1 measurements are better than the R4 measurements. However, the R1 EOP measurements do not show a comparable improvement.

The future enhancements of the IVS observing program described in the IVS WG2 report should permit detection of time variations in harmonic signals with relevance to studies of internal and external global geophysical fluids. Inclusion of other VLBI systems (e.g., the Japanese K4 and Canadian S2) with the standard Mark III/IV and introduction of new technologies such as the disk-based Mark V recorders (data rate increase up to a factor of 4 beyond the current R1 series) will increase the density of geodetic measurements and the reliability of the program.

G71A-0960 0830h POSTER

Secular Sea Level Change in the Russian Sector of the Arctic Ocean

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Sea level change in the Arctic Ocean is investigated based upon approximately 50 years of the monthly mean data from 57 tide gauges. Analyses of the raw data show that at the majority of stations the sea level rises at a rate of aproximately 1.4 mm/year. When the secular rates of change are corrected for the influence of glacial isostatic adjustment, the average rate of secular sea level rise is determined to be 2.3 mm/year which is very close to the rate of 2.0 mm/year that has been determined on the basis of analysis of US East coast data. The time series from the individual gauges are sufficiently short, however, that no significant reduction in the RMS of the secular rates is achieved by the GIA correction procedure.

Investigation of decadal variability of sea level change using observational data and model results shows that the cumulative action of the wind-driven and thermohaline circulation may account for about 80% of sea level variance in the Arctic Ocean during 1950-1990. The most intriguing results were observed in the decade 1990-2000 during which time the rate of sea level rise was close to zero or became negative, contrary to the common expectation that the rate of sea level rise should increase uniformly as a consequence of global warming. This clearly warrants more detailed investigation.

G72A MCC: Hall C Sunday 1330h

New Results From GRACE and Other Gravity Missions Posters *(joint with H, OS)*

Presiding: **M M Watkins,** Jet Propulsion Laboratory**; B D Tapley,** University of Texas**; J M Wahr,** University of Colorado

G72A-0962 1330h POSTER

Geoid Anomalies due to Low-Viscosity Crustal Zones in Glacial Adjustment Models and Their Detectability by GOCE

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Glacial Isostatic Adjustment (GIA) due to late-Pleistocene Ice Age cycles has left clear imprints in various global and regional geodetic signatures. In GIA models these signatures are often modeled with an elastic crust/lithosphere as top layer in the earth model.

Seismic observations indicate the presence of low-viscosity ($10^{17} - 10^{18}$ $Pa \cdot s$) layers at various regions in the Earth's continental crust. In a recent study (Vermeersen, *Space Sci. Rev., in press*) it has been shown that such shallow low-viscosity layers can create high-harmonic patchlike geoid anomalies that should become observable by the Gravity field and steady-state Ocean Circulation Explorer (GOCE) satellite mission, scheduled to be launched in 2006: anomalies of 1 cm - 1 m for length scales of 100 - 1000 km.

In the present study, thickness, depth and viscosity of a low-viscosity crustal layer are varied and the variations in the resulting geoid anomalies are compared with the expected sensitivity of GOCE geoid data. A spherically symmetric analytical viscoelastic earth model is used, in combination with the pseudospectral method developed by Mitrovica and Peltier (1991) for self-consistently solving the sea-level equation up to high harmonics, to determine GIA-induced geoid anomalies due to Ice Age cycles based on the ICE-3G model of Tushingham and Peltier (1991). These modeling results on the discriminative power may help in identifying GIA-induced contributions in geoid anomaly maps.

G72A-0963 1330h POSTER

Gravity Fields from CHAMP Mission Data

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The CHAMP mission, launched in July 2000, is the first in a series of missions that will revolutionize our ability to model the Earth's geopotential. The CHAMP spacecraft is equipped for precision tracking by the Global Positioning System (GPS) and Satellite Laser Ranging (SLR) along with a precision accelerometer to provide measurements of the surface forces. Preliminary satellite-only geopotential solutions with only 30 days of CHAMP data are, by some criteria, as strong as solutions made from tracking data collected over the previous 30 years of the space age. Compared to EGM96, CHAMP makes notable contributions in regions where the terrestrial data (surface gravimetry and altimetry) were weak, for example in the polar regions, in the Amazon and the Himalayas. The CHAMP data allow us to separate the geoid from the dynamic ocean topography (DOT) up to at least degree 25 rather than just under degree 20 as in EGM96. We report on satellite-only and combination models that incorporate up to 100 days of CHAMP data as well as other satellite data. We report on our updated processing of the CHAMP tracking and accelerometer data and evaluate the performance of the geopotential models using a variety of tests.

G72A-0964 1330h POSTER

A Parana State Gravimetric Geoid, Brazil

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In geodesy, a geoid model is required to transform satellite-derived heights to physically meaningful heights based on the Earths gravity field, but it also has applications in geophysics and oceanography. Geoids models have been developed in many parts of the world, in particularly in North America an Europe. Recently, a project to determine the geoid in South America has been carried out. The purpose of this project was the determination of a regional gravimetric geoid in Parana State, Brazil. Gravity data were collected in Parana State and surroundings by different organizations since 1985 allowing the computation of a geoid. This study comprises: the preparation of terrestrial gravity and terrain data; the use of appropriate geodetic datum during gravity data reduction; the selection of the best fitting global geopotential model; the application of the gravimetric terrain corrections; the gridding of the gravity anomalies prior to geoid computation; and comparisons of a preliminary Parana State gravimetric geoid solution with geometrical control, provided by Global Positioning System (GPS) measurements in conjunction with leveling data.

G72A-0965 1330h POSTER

First Recoveries of Water Storage Changes From GRACE

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Upon completion of the current commissioning phase, GRACE will begin delivering global estimates of the Earth's gravity field approximately every 30 days. After removing the atmospheric contribution, these gravity solutions can be inverted to determine changes in continental water storage, spatially averaged over regions of arbitrary shape and size. Recovering hydrologic signals with the exact averaging function for some region results in the inclusion of large satellite measurement errors. Approximate averaging kernels can be created which improve accuracy by reducing measurement errors. For example, with *a priori* estimates of measurement error and signal covariance matrices, one can construct an averaging kernel which minimizes the sum of the variances of the measurement and leakage errors. We construct optimal averaging kernels for continental regions, and examine the accuracy and resolution with which regionally averaged changes in water storage can be recovered from GRACE data.

G72A-0966 1330h POSTER

Multi-Resolution Representation and Estimation of the Gravity Field Using Spherical Wavelets

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In this paper, we explore the feasibility of the use of radially symmetric spherical wavelet functions (1) for the multi-resolution representation of the geopotential and (2) for the estimation of the wavelet-represented gravity field model using data from advanced gravity missions such as CHAMP, GRACE, and GOCE. The representation approach can be split into an expansion in terms of spherical harmonics for the long-wavelength components and a spherical wavelet expansion for the medium- and high-frequency components. This multi-resolution representation consists of a sum of detail signals and each detail signal is related to a certain frequency band and resolution step. Developed data compression methods can reduce the number of wavelet coefficients drastically. To satisfy several properties many eligible wavelet functions like the Abel-Poisson and the de la Vallee-Poussin wavelet have to be taken