Guerrero subduction zone, the thermal stress due to nonuniform temperature distribution in the subducting slab is calculated using finite element method. The calculation results revealed that the first shallow part of the subducting slab is characterized by low deviatoric compressional thermal stresses in its central part (0.25 Kbars); then the stress field changes to a extensional behavior for the core of the slab with maximum values of 0.4 Kbars for the flat region and 0.75 Kbars deeper. An important feature for the central Mexican subduction zone is its shallow subhorizontal plate contact; significant thermal compressional stresses (0.65 kbars) arisen in the upper and lower part of the slab are not consistent with the normal fault intraplate earthquake focal mechanism. Since the Cocos plate dips into the asthenosphere at angle of 20°, pressure forces due to the induced flow in the mantle wedge are partially balanced by the gravitational body forces. A net clockwise torque might exist at the hinge point and its value is set in such way that the compressional stresses for the flat part of the plate vanishes. For the lower part of the slab, ductile behavior is assumed, the compressional stresses decreasing exponentially with depth. According with the thermal models for Guerrero, the temperature range of 700°C-800°C is in good agreement with the maximum depth extent of the intraplate earthquakes and with the maximum extent of the tensional stresses in the subhorisontal part of the slab, being considered as cutoff temperature range.

G21A-08 0830h POSTER

Structural studies beneath Honshu and Hokkaido Japan using receiver function analysis.

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Combining land seismic, offshore seismic, and receiver function structure, allows delineation of the main structural discontinuities beneath the Japanese Islands. The location of the subducting Pacific and Philippine Sea Plates can also be discerned. The focus areas of study are beneath Hokkaido, Northern Japan and the Tokai Region, Southwest/Central Japan. Both regions have detailed offshore/onshore seismic reflection and refraction studies that have been carried out by JAMSTEC (Japanese Marine Science and Technology Center). In this study the seismic crustal study is supplemented with analysis of teleseismic events. Teleseismic data is obtained from NIED (Natural Research Institute for Earth Science and Disaster Prevention) F-net broadband network. Combining the receiver function study with velocity structure from the seismic experiments allows determination of Moho depths and depth to the subducting plate more accurately. The non-uniqueness of the receiver function study is removed by using wide-angle information to constrain upper crustal structure. For the Hokkaido region, the focus is to determine possible velocity variations within the double seismic zone that may be caused by dehydration reactions. For the Tokai region, where intraslab seismicity terminates at about 60 km depth, we hope to map out the subducting plate to greater depth and try to delineate possible subducted ridge structures. Finally we hope to include analysis of data from the denser HINET network. This is a first step in construction of a more accurate 3D structural velocity model for future modeling of geologic processes and earthquake relocation for the Japanese Islands region.

G21B CC: 220 C-E Tuesday 0830h

New Advances in Global Plate Kinematics and Dynamics From Space Geodesy I Posters *(joint with S, T, SEDI)*

Presiding: **T Dixon,** University of Miami; **C Kreemer,** Collge de France; **W Holt,** State University of New York at Stony Brook

G21B-01 0830h POSTER

Estimates of Continental Plate Motions Derived From Continuous GPS Measurements of Station Coordinates and Velocities, 1996-2004

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Analysis Centres of the International GPS Service (IGS) currently compute daily Earth Rotation Parameters (ERPs) and weekly precise coordinates for over 200 globally distributed tracking stations. These estimates are made available to the scientific community in the Solution Independent Exchange (SINEX) format, developed for exchange and analysis of position estimates from techniques such as SLR, LLR, VLBI, DORIS and GPS. On behalf of the IGS, National Resources Canada (NRCan) has been combining, officially since 1999, all weekly SINEX files from the ACs to form weekly and cumulative solutions. The weekly solution (named igsyyPwwww, yy = 2-digit year, wwww = 4-digit GPS week) contains estimates of station coordinates, ERPs and geocentre pertaining to the GPS week, and the cumulative solution (named IGSyyPWW, WW = 2-digit week number, 01 to 52, within the year) comprises station coordinates and velocities in a common reference epoch, Jan. 1, 1998. For example, two solutions produced for week 1253 (2nd week of year 2004) were igs04P1253 (weekly) and IGS04P02 (cumulative). Since week 1253, all IGS solutions have been aligned to IGb00, a realization of IGS's most recent International Terrestrial Reference Frame, ITRF2000. IGb00 was obtained from coordinates and velocities of 99 globally distributed reference stations by alignment to ITRF2000 at GPS week 1231 of cumulative solution IGS03P33. Before week 1143, a realization of IGS's previous reference frame, ITRF97, was used instead. Using the cumulative solution from any given week, the rotation components of any continental plate with at least two stations are estimated and compared with published results. These include three known plate models: NNR NUVEL 1, NNR NUVEL 1A and the most recent REVEL 2000 aligned to ITRF97. The findings can be summarized as follows: Continental rotations derived from IGS04P02 are shown to be significantly different at 99% confidence level from NNR NUVEL 1A's estimates for North American, Eurasian, Australian, Pacific, Antarctic, Indian, Nazca and Nubian (the latter compared to NNR NUVEL 1A African) plates. In addition, certain plates previously regarded as belonging to an adjacent, larger continent in NNR NUVEL 1 or 1A are now seen to move significantly differently; e.g., Amurian distinct from Eurasian, Adriatic and Sinai distinct from NNR NUVEL 1A African. North American, Eurasian, Australian and Pacific plates show significantly different rotations in IGS04P02 than predicted by REVEL 2000, yet not from the alignment of REVEL 2000 to IGb00. Certain pairs of adjacent plates show relative Euler poles near their plate boundaries; e.g., Eurasian and North American, Amurian and Eurasian, Amurian and South-China, Adriatic and Eurasian, Arabian and Nubian, Sinai and Nubian, Sinai and Arabian, Nubian and Somali. This phenomenon can be expected when bordering plates show no subduction or obduction. RMS difference between velocities of stations used in Euler pole calculation in IGS04P02 and those expected from NNR NUVEL 1A rise to 4.3 mm/yr in the horizontal component and 8.7 mm/yr in the vertical. The horizontal RMS velocity difference decreases significantly to 2.4 mm/yr when IGS04P02 is compared with REVEL 2000.

G21B-02 0830h POSTER

Interactive Web Interface to the Global Strain Rate Map Project

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An interactive web interface allows users to explore the results of a global strain rate and velocity model and to compare them to other geophysical observations. The most recent model, an updated version of Kreemer et al., 2003, has 25 independent rigid plate-like regions separated by deformable boundaries covered by about 25,000 grid areas. A least-squares fit was made to 4900 geodetic velocities from 79 different geodetic studies. In addition, Quaternary fault slip rate data are used to infer geologic strain rate estimates (currently only for central Asia). Information about the style and direction of expected strain rate is inferred from the principal axes of the seismic strain rate field. The current model, as well as source data, references and an interactive map tool, are located at the International Lithosphere Program (ILP) "A Global Strain Rate Map (ILP II-8)" project website: http://www-world-strain-map.org. The purpose of the ILP GSRM project is to provide new information from this, and other investigations, that will contribute to a better understanding of continental dynamics and to the quantification of seismic hazards. A unique aspect of the GSRM interactive Java map tool is that the user can zoom in and make custom views of the model grid and results for any area of the globe selecting strain rate and style contour plots and principal axes, observed and model velocity fields in specified frames of reference, and geologic fault data. The results can be displayed with other data sets such Harvard CMT earthquake focal mechanisms, stress directions from the ILP World Stress Map Project, and topography. With the GSRM Java map tool, the user views custom maps generated by a Generic Mapping Tool (GMT) server. These interactive capabilities greatly extend what is possible to present in a published paper. A JavaScript version, using pre-constructed maps, as well as a related information site have also been created for broader education and outreach access. The GSRM map tool will be demonstrated and latest model GSRM 1.1 results, containing important new data for Asia, Iran, western Pacific, and Southern California, will be presented.

G21B-03 0830h POSTER

Terrestrial Reference Frames for Current Plate Motion

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We examine recent estimates of plate motions relative to the hotspots with a view to better understanding both the hotspot and no-net-rotation frames. In recent years, two independent studies of present plate motion relative to the hotspots reached very different conclusions. On the one hand, Gripp & Gordon [2002] used trends and rates from volcanic edifices formed during the past 6 Myr to estimate the HS3-NUVEL1A set of angular velocities relative to the hotspots. Their angular velocities are constrained to consistency with the relative plate angular velocities of NUVEL-1A. They found that only eleven hotspot trends and two volcanic propagation rates met their minimum reliability criteria. They combined these and found that the rates and trends were mutually consistent. They find that the lithosphere has a relatively rapid net rotation of 0.44 ± 0.11 degs/Myr (95% confidence limits), which is much faster than the net rotation of the lithosphere over the past 47 Myr of about 0.15 degs/Myr. One the other hand, Wang & Wang [2001] use twice as many (22) trend data and no rate data to estimate the T22A set of current angular velocities of plates relative to hotspots, which is also constrained to consistency with NUVEL-1A. They find that their angular velocities are inconsistent with volcanic propagation rate data and hypothesize that this is due to motion of hotspots relative to the mantle in a direction opposite to that of plate motion at a rate about one-fourth of the plate velocity. They hypothesize, for example, that Pacific hotspots move about 20 mm/yr to the east-southeast. This hypothesis, if correct, has several profound implications, one of which is that the net rotation of the lithosphere implied by their angular velocities is about half the size of that implied by HS3-NUVEL1A. Key to their result is the acceptance of trends that can only be estimated by averaging over the locations of volcanic edifices spanning several tens of millions of years in age. They assert that hotspot tracks with volcanic propagation rates pertinent to the last 10 Myr exhibit no significant change in trend in at least the past 30 Myr. In this talk we will take a fresh look at the trend data used by both groups to evaluate their applicability to motion during the past 6 Myr. Moreover, we will use plate reconstructions over longer intervals of time to more rigorously test both the fixed-hotspot and 25%-of-plate-speed moving-hotspot hypotheses. We will furthermore examine whether either frame of reference can be reconciled with the no-net-rotation frame of reference.

G21B-04 0830h POSTER

Seafloor Geodetic Measurements of Nazca-South America Plate Stick-Slip Behavior

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A combination of GPS and acoustic travel time measurements were taken from the R/V Roger Revelle in

2001 and 2003 from two seafloor precision transponder arrays at 12S off the coast of Peru. The geodetic positioning technique uses two reference points located 20 km and 50 km upslope from the Peru-Chile trench to characterize the updip limit of locking between the downgoing Nazca plate and the South America plate. Stick slip behavior is thought to cause the majority of interseismic activity between the convergent plates. Absolute and relative horizontal deformation was determined with 1-cm uncertainty and may help in understanding the cause and location of stick slip behavior between the plates. Combined with land based geodetic stations, this study presents the first observations of convergent plate motion above the entire subduction thrust zone. We will report preliminary results and their implications for models of thrust fault behavior.

G21C CC: 220 C-E Tuesday 0830h

Toward a Stable North America-Fixed Reference Frame II Posters *(joint with S, T)*

Presiding: **G Blewitt,** University of Nevada, Reno**; M Craymer,** Natural Resources Canada**; W E Holt,** State University of New York at Stony Brook

G21C-01 0830h POSTER

First Report of the Stable North America Reference Frame (SNARF) Working Group

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We report on the first SNARF Workshop funded by NSF EarthScope, held on Jan 27, 2004. The initial SNARF Working Group membership was approved by the UNAVCO Board and is charged with producing a standard reference frame (for studies in North America) and specifying standard procedures to realize such a frame to meet the needs of EarthScope and the UNAVCO community. SNARF is an official IAG working group under the North America Reference Frame (NAREF) sub-commission. There is also a public service element to these activities in that one objective is for SNARF to become part of the definition of the legal reference frame used in the USA and Canada (NAD83), a natural spin-off demanded by society's increasingly sophisticated needs following on the heels of scientific progress. Through the first workshop, the SNARF WG has already begun to address the pressing needs for a North America-fixed reference frame that is stable at the sub-millimeter level, and what is involved in defining a frame with such stability. Velocity solutions from GPS networks covering the North America-Pacific plate boundary (including the Plate Boundary Observatory under construction) are most naturally expressed with respect to the stable interiors of either the North America or Pacific plates. As well as providing a common frame by which to compare results from different analysis groups, such a system makes it easier to interpret the data in terms of where the total budget of relative plate motion is accomodated, and how deep plate boundary dynamics penetrate into the plate interior. Defining a stable frame at the sub-millimeter level requires adequate characterization of kinematics at that level across a sufficiently broad expanse of what may be termed the "plate interior," which deforms due to GIA and other mantle processes, coupled with lithospheric heterogeneity. A dynamically defined velocity datum (as opposed to a purely kinematic choice) is preferable to add interpretive value to site velocities. We summarize initial findings of the workshop that begin to address these issues, and present a roadmap of what is required to realize a reference frame for stable North America.

G21C-02 0830h POSTER

The NAREF Perspective on a New Plate-Fixed Reference Frame for North America

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In collaboration with the IAG community, its service organizations and the national geodetic organizations of North America, the IAG's Sub-Commission 1.3a on Regional Reference Frames for North America (NAREF) provides international focus, cooperation and coordination for issues involving the geodetic reference frames and control networks of North America. Some of these issues include the maintenance and future evolution of reference frames for North America and the setting of standards and guidelines. To this end, NAREF has coordinated the densification of the ITRF reference frame in North America and has been providing regular weekly coordinate solutions for most of the permanent GPS receivers on the continent since 2001. Work is now progressing on providing regular cumulative solutions with velocities estimates for all stations. More recently, a new initiative has begun, underwritten by UNAVCO, Inc. in support of the Earthscope project, to establish a stable, plate-fixed reference frame for North America that would serve the broad scientific and geomatics communities. The goal is to provide a consistent reference system, including velocity models, procedures and transformations, tied to a "stable" North America in which scientific and geomatics results (e.g., positions in tectonically active areas) can be produced and compared. This paper focuses on the requirements that such a reference frame would need to satisfy from the perspective of NAREF. We also make some suggestions for how such a new reference frame could be implemented for the benefit of the general public and discuss some pitfalls learned from the ITRF densification work.

URL: http://www.naref.org

G21C-03 0830h POSTER

Test of a Center of Lateral Figure (CL) reference frame for a global GPS network

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Seasonal degree-one deformation related to loading effects are a source of significant misfit between observed site coordinates and assumed positions that are based on a linear center of surface figure (CF) reference frame. This discrepancy is partly absorbed by apparent annual variations in the GPS "scale" parameter which, in turn, spreads annual deformation artifacts to sites elsewhere on the Earth's surface. In the presence of degree-one deformation, a suitable reference frame model should allow for non-linear site motion. The Center of Lateral Figure (CL) reference frame is one possible solution. With the CL model, station motions are constrained to move with constant horizontal velocities, and the vertical velocities are unconstrained. This confines degree-one deformation to the unconstrained vertical component. A CL reference frame model is demonstrated here using the results of a GIPSY/OASIS II fiducial-free analysis of over 100 globally distributed GPS sites. The reference frame model utilizes only the horizontal component of site positions and the GPS "scale" parameter is neglected in the initial solution. Preliminary results show that seasonal deformation is placed in the vertical component, as expected, and that the geographical distribution of seasonal signals is consistent with degree-one loading models. An additional finding from this test is that the WRMS scatter in daily horizontal site positions is reduced. This is likely due to reliance on the precise horizontal component, and omission of the noisier vertical component. The result is that the horizontal scatter for stations in a global solution approaches the quality of a regionally-filtered solution. For analysis on a plate-wide to global scale, as is the case for SNARF, use of a CL frame with the vertical component unconstrained may be useful. With the vertical component unconstrained, horizontal positions are not biased by seasonal vertical motion and noisy vertical motion at sites located 90 degrees around the side of the earth. In turn, a precise datum for the local vertical component is realized using horizontal data from the same sites a quarter turn around the Earth.

G21C-04 0830h POSTER

New Constraints on Crustal Deformation in the New Madrid Seismic Zone From Continuous GPS Geodesy.

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Preliminary results from the first determination of crustal velocities in the area of the New Madrid seismic zone based on two years of continuous GPS geodetic measurements indicate that velocities with respect to stable North America are small (less than 3mm/yr) and not significantly different than zero. Our results are significantly stronger than previous campaign results, which while also not statistically different from zero, yielded velocities with respect to stable North America from near zero to several cm/yr. They also rule out velocities determined by campaign measurements that are "statistically significant" with magnitudes larger than a few mm/yr. The continuous GPS results are also the first to suggest tectonically reasonable deformations, in terms of both rates and geologically and seismologically defined structures in the New Madrid seismic zone. The relatively unindurated pile of Mississippi Embayment sediments, may also act as a filter to displacements at its base, which may be significantly larger that those observed at the surface. Our results strengthen the argument against models based on conventional, plate boundary style dynamics for the generation of large earthquakes in the New Madrid seismic zone. With respect to the development of new models for New Madrid tectonics, we stress both the preliminary nature of our results and the sparse sampling provided by the continuous network. Our results can clearly be used to reject models that do not produce small or no surface deformation but are currently less useful to additionally constrain or distinguish among competing tectonic models that meet the stringent limitations placed on surface deformation. The upper bound, of a few mm/yr, on the velocity of our stations with respect to a stable North America shows the importance, timeliness and necessity of improving the definition of stable North America to further our understanding of intraplate earthquakes.

G21D CC: 516 B Tuesday 0830h

Toward a Stable North America-Fixed Reference Frame I *(joint with S, T)*

Presiding: **G Blewitt,** University of Nevada, Reno**; M Craymer,** Natural Resources Canada**; W Holt,** State University of New York at Stony Brook

G21D-01 0830h INVITED

Evolving from NAD 83

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