El Nino Tectonic Modulation in the Pacific Basin (Revisited)

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ABSTRACT

The Easter and Juan Fernandez microplates, two counterclockwise-rotating microplates along the East Pacific Rise, are driven by downwelling tectonic vortices, as explained by a more recent geophysical theory known as the surge tectonic hypothesis. These twin microplates underlie the high-pressure cell of the Southern Oscillation associated with El Nino. The Central Pacific Megatrend connects planetary-scale tectonic vortices underlying the El Nino Southern Oscillation (ENSO) pressure cells. It connects the East Pacific Rise across basin to the Banda Sea tectonic vortex. The Banda Sea is a triple-plate junction (between the Australian, Pacific, and Southeast Asian plates) just north of Darwin and is considered an upwelling mantle vortex underlying the low-pressure cell of ENSO. Active surge channels, or geostreams, defined by the newer surge model link these planetary-scale tectonic vortices. The original lead for a trans-Pacific megatrend was from the works of the late A.A. Meyerhoff. He brought attention to this region with the publication *of Surge Tectonics: A New Hypothesis of Earth Dynamics* [1, 2]. His insight was based on many years of field study for oil exploration in Southeast Asia, the former USSR, and China, as well as on his background in fluid dynamics. In addition, high-pass-filtered satellite altimetry data from the Geodetic Earth-Orbiting Satellite (GEOSAT) reveal across-basin trends in the gravity geoid.

Keywords: ENSO, Surge tectonic, vortex modulation, gravitational teleconnection

1. INTRODUCTION: SURGE INTERPRETATION

A new geodynamic model in the Pacific Basin (Fig. 1), constructed with circulation principles common to ocean/atmosphere models, links tectonic dynamics to the El Nino phenomena with several lines of evidence as outlined below.

1.) Foremost in the new model is a dynamic link across the Central Pacific Megatrend (CPM, Fig. 1). This megatrend is considered a tectonic vortex street [3] between tectonic vortices modulating the Southern Oscillation (SO) by microgravity processes. Atmospheric pressure is directly modified by internal density changes in planetary-scale (350-1200 km diameter) tectonic vortices [4 ,5 ,6, 7, 8]. The low-pressure side of the SO is underlain by the Banda Sea [9], an upwelling upper-mantle vortex (Figs. 2a and 2b). The high-pressure side of the SO is underlain by Easter Island and Juan Fernandez rotating microplates, a set of twin downwelling upper-mantle vortices along the East Pacific Rise (EPR, Figs. 3a and 3b).

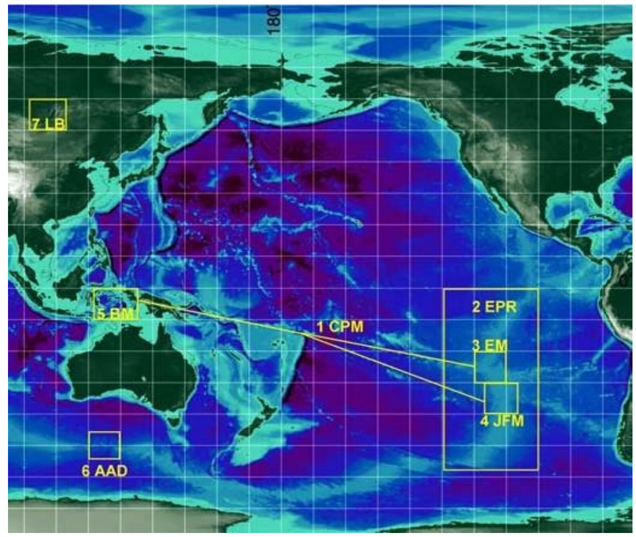

Fig. 1. Location Map: 1. Central Pacific Megatrend (CPM); 2. East Pacific Rise (EPR); 3. Easter Microplate (EM); 4. Juan Fernandez Microplate (JFM); 5. Banda Microplate (BM); 6. Australian- Antarctic Discordance (AAD); 7. Lake Baikal (LB). (NAVOCEANO).

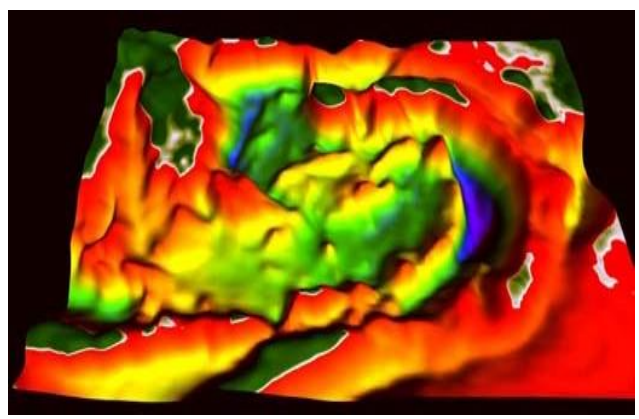

Fig. 2a. South View Close-up 3-D Bathymetry (NAVOCEANO) of Banda Sea Tectonic Vortex: Note Indonesian Volcanic Arc Outflow and Wings of the Vortex are Much Like the Hurricane Symbol.

Another solid line of evidence was uncovered by Daniel Walker in his article *Seismic Predictors of El Nino Revisited* [10]. Walker correlates increased T- phase seismicity along the EPR near the Easter and Juan Fernandez microplates as a precursor to El Nino events. Associated phenomena include episodic seafloor spreading and reduced pressure in the high- pressure cell of the SO. These observations have occurred seven times since 1964 in a pattern unexplained by current geophysical theory.

Anomalous gravity trends in the mid-Pacific [11] delineate a physical tectonic link between the Banda Sea and Easter

Island/Juan Fernandez regions. The CPM is a trans-basinal feature that may provide a conduit for microgravity oscillation transfers between these regions. Gravity lineaments on high-pass-filtered GEOSAT data highlight the CPM (Fig. 4) and further delineate upper-mantle flow dynamics [1, 2, 12] throughout the Pacific Basin as will be shown in the new model.

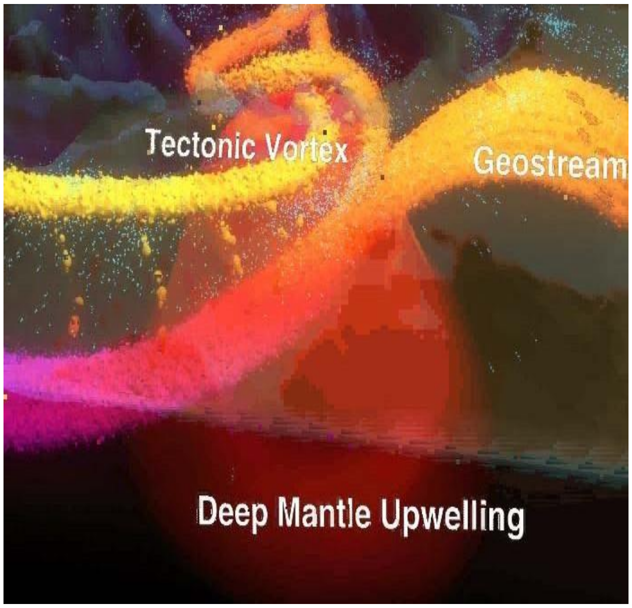

Fig. 2b. Artist Conceptualization Under Seafloor of Deep Mantle Upwelling and Stream Flow Hypothesized to form Banda Vortex Geomorphology. Viewing Direction North, Same as Fig. 2a. (MSRC).

Although inconclusive, Bouguer gravity anomalies on the EPR found during the Mantle Electro- magnetic and Tomography (MELT) experiment [13] may indicate colder/denser mantle sinking beneath overlapping spreading centers on the ridge. This evidence is in direct conflict with the plate concept of upwelling mantle under the ridges.

Microgravity increases of approximately 17 *u*gals over about a 6-month interval in early 1996 were measured in Belgium and were attributed mostly to geophysical origins [14]. A tectonic surge of this magnitude could possibly migrate from Europe to the Pacific Basin, especially if it moves preferentially eastward like weather fronts. In this case the timing of the migration event may coincide with the 1997/98 El Nino.

Additional lines of evidence indicate wavelengths filtered from the geoid data [15] not only correspond to mantle discontinuities at approximately 410, 660, and 1050 km but also correspond to some planetary-scale tectonic vortex diameters.

The new geodynamic model links these lines of evidence in the theoretical framework of surge tectonics, which incorporates mantle stream flow and vortex formation processes like ocean/atmospheric models. The circulation pattern known as Walker circulation, which is the dominant atmospheric circulation pattern in the Pacific, can be applied directly to a Pacific Basin mantle model. The new model also explains: (1) the western bulge on the EPR (Figs. 3a and 3b) as the result of a mantle intertropical convergence zone, (2) the Hawaiian hot-spot trace as the result of counterflow to a North Pacific downwelling mantle gyre (Fig. 4), and (3) the orthogonal patterns which pervade the Pacific Ocean Basin [16].

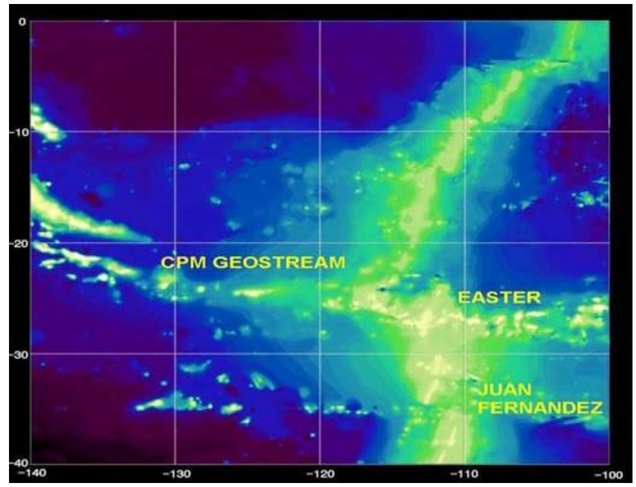

Fig. 3a. Bathymetry of EPR near Easter and Juan Fernandez Microplates. Note Off Ridge Island Chains Indicating Geostreams from the CPM (NAVOCEANO).

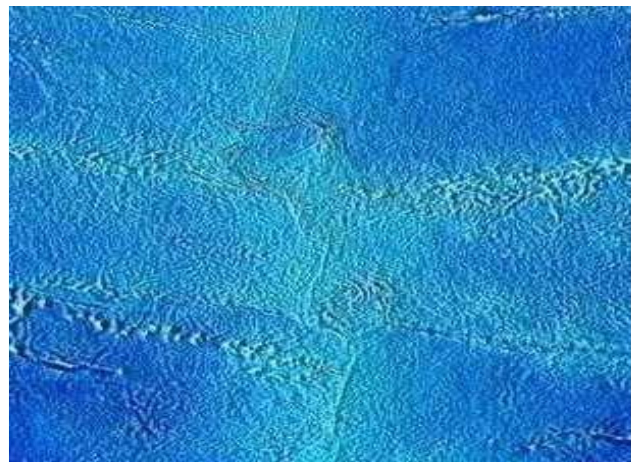

Fig. 3b. Two-min. Color Relief Image of the EPR [17]. Ring-Shaped Structures are the Easter (north) and Juan Fernandez (south) Tectonic Vortex Signatures (NOAA).

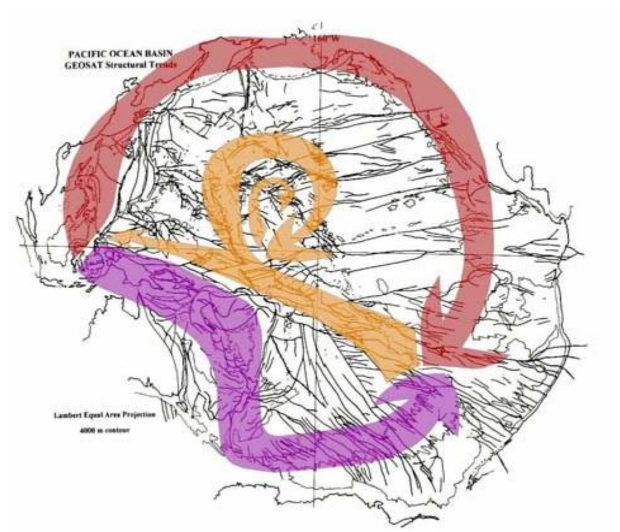

Fig. 4. Pacific Ocean Basin Structural Trends Based on High-Pass Filtered GEOSAT data in Lambert Equal Area Projection. Overlain Arrows Depict Pacific Basin Tectonic Gyres and the CPM from the Banda to EPR Vortices. Compiled by Smoot [3], Modified for this Paper by Adams.

2. EVIDENCE FOR TECTONIC LINK TO CLIMATE

Since 1964, almost four decades of extensive work [10, 18, 19, 20] on T-phase seismicity in the Pacific documents earthquakes along spreading ridges occurring in swarms along hundreds of kilometers, specifically, along the EPR near Easter and Juan Fernandez microplates (Figs. 3a and 3b). T-phase seismic are tele seismic signals detected by hydrophone arrays placed in the ocean's acoustic waveguides. These earthquakes are associated with hydrothermal venting, magma outpourings, and atmospheric high-index pressure phases of the Southern Oscillation Index (SOI, Fig. 5) and indicate a swelling of the entire ridge along the plate boundary. Walker found that earthquakes associated with these intense episodes of seafloor spreading are precursors to the reduced atmospheric pressure in the El Nino Southern Oscillation (ENSO) high-pressure cell over Easter Island. These observations occurred seven times since 1964 in a pattern unexplained by current geophysical theory. Walker's 1999 article [10] considers the energy transfer mechanism for the correlation between earthquake activity and the atmospheric pressure drop to possibly be microgravity, as suggested by Leybourne in 1996 [4].

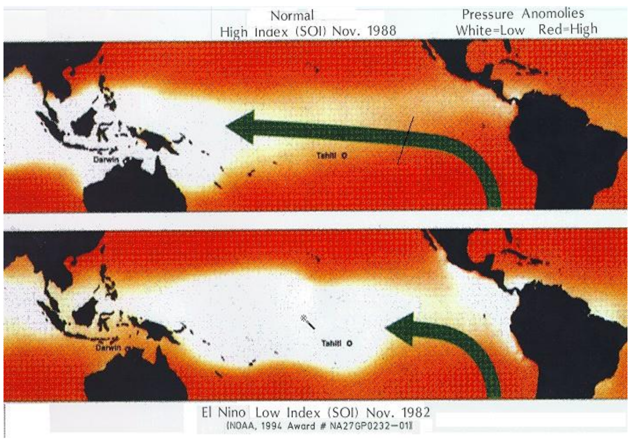

Fig 5. Normal vs. El Nino Sea-Level Pressure Distribution (NOAA).

These two counterclockwise-rotating microplates along the EPR, the Easter and Juan Fernandez microplates, are driven by downwelling tectonic vortices, as explained by the surge tectonic hypothesis. These twin microplates underlie the high-pressure cell of the SO associated with El Nino. The tectonic vortices may be responsible for the pressure changes as they shape- shift from global-scale geoid undulations. Shape-shifts create density oscillations within a vortex and may account for local microgravity change. This mechanism is analogous to pressure changes in atmospheric vortices like tornadoes and hurricanes, which are known to affect local microgravity. Approximately 0.33 *u*gal/mbar (gravity field to atmospheric pressure change) has been demonstrated and quantified as early as 1977 by Warburton and Goodkind [21] using super-conducting gravity meters. The "missing link" [19] between seismicity and El Nino may well be tectonic microgravity-induced atmospheric pressure change or gravitational teleconnection. This mechanism for tectonic coupling to atmospheric pressure oscillations through tectonic vortices may explain ENSO, a known teleconnection of other parameters such as sea surface temperature and sea- level pressure. The CPM connects these planetary- scale tectonic vortices underlying the ENSO pressure cells. It connects the microplates on the EPR across basin to the Banda Sea tectonic vortex.

3. PACIFIC BASIN TECTONIC CIRCULATION

The upwelling mantle under the Banda Sea (Figs.2a and 2b) has dynamics like a hurricane. Deep mantle inflows wrap into the Banda tectonic vortex upwelling and diverge along outflow boundaries in the upper mantle and asthenosphere. These outflow boundaries are delineated by the regional tectonic trends of the Indonesian Island Arc to the west, Papua New Guinea mountain belts to the east, and Island Arc and trench systems of the Philippines to the north.

In the Northern Hemisphere, the mantle-flow regime extends through Japan, the Kurils, and Alaskan Island Arcs into the western mountain belts of the Rockies around the Pacific "Rim of Fire." The mantle-flow regime trend continues through the San Andreas fault zone and western Mexico, where it merges with the EPR. Mantle stream convergence occurs in the region of the Easter Island and Juan Fernandez microplates and down wells within these tectonic vortices. Convergence occurs with the southern Pacific tectonic gyre flowing north from the Southeast Indian Ridge (SEIR) to the EPR ridge system. This circulation system is like the intertropical convergence zone in ocean basin circulation models, where basin-scale gyres meet near the Equator and return flow westward. This dynamic occurrence is also like Walker Circulation in atmospheric models, where jet streams flow eastward in the upper atmosphere and are countered by westward-flowing trade winds. The counterflows are interconnected by the large vertical convection cells of the SO that drives El Nino. The similarity of the new geodynamic model to ocean/ atmospheric circulation models is not a coincidence; it is the natural consequence of slow fluid motion within the mantle.

The direct across-basin path connecting the Banda to the EPR comprises the CPM. It begins in the Banda Sea region and passes through structural features of Irian-Jaya and the Van Rees and Maoke mountains of New Guinea. It then continues along the north edge of the western Pacific trenches through the southern portion of the Ontong-Java Plateau. The Vityaz Trench System then extends the CPM over 2500 km in the form of the Kilinailau, the North Solomon, the Ulawan, and the Cape Johnson trenches. The megatrend appears to splay eastward along a flowing magma regime, then south-southeast at the Tuamotu Ridge, and finally diverts eastward as a massive ridge merging with the north fork of the Easter Fracture Zone. This trend continues to the Easter "microplate," or vortex structures on the EPR.

4. EAST PACIFIC RISE

Mantle geostreams converge from the north and south along the EPR axis and combine with across basin convergence along the CPM, making the EPR highly pressurized. This pressure induces mantle downwelling within overlapping spreading centers of the microplates. Mantle streamlines are defined by the ridge axis trend. Mantle sinks along these trends into the Endeavor Deep of Juan Fernandez microplate and the Pito Deep of Easter microplate. Asthenosphere counterflow generated in the upper-level low flows opposite the mantle and supplies magmas to the volcanoes and ridge system (Figs. 6a and 6b).

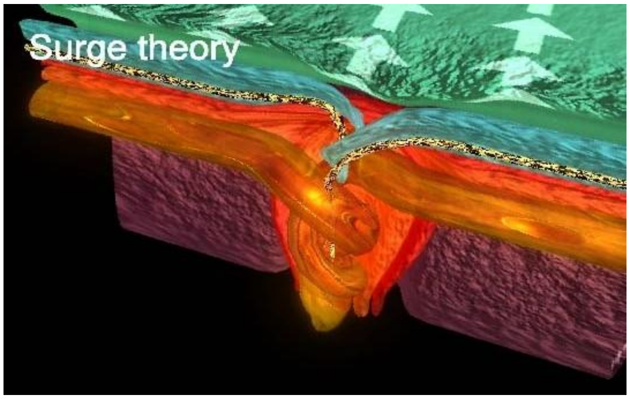

Fig. 6a. Generic Downwelling Vortex of Easter and Juan Fernandez Microplates. Arrows Represent Spreading Direction from Geostream Contraction/Expansion or Surges (MSRC).

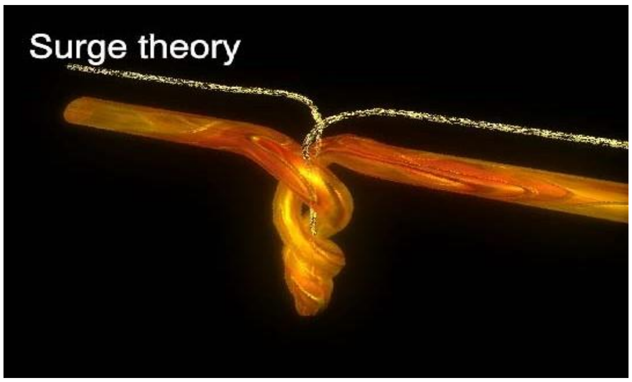

Fig 6b. Thin Upper Line Represents Asthenosphere Axial Counterflow and Explains Why the MELT experiment did not Find Evidence for a Narrow-Focused Zone of Upwelling along the Ridge from the Deep Mantle (MSRC).

This geodynamic interpretation is based on atmospheric dynamics or basic fluid dynamics and explains the rotation of the microplates and underlying geomorphology. If this model proves correct, it points out the basic flaw in the plate tectonic concept. The flaw is that the mantle flow dynamic of plate tectonics along ridges is 180 degrees out of phase. There is no linear upwelling of mantle at the ridge along a crack in the plates, but instead there is horizontal mantle flow along the ridge axis with discrete downwelling within vortices along over-pressurized zones of the ridge. Counterflow to the mantle feeds magmas to interconnected magma chambers in the asthenosphere. Surges within these interconnected magma chambers, also called surge channels, produce extrusions of volcanic rocks. This principle not only applies to ridge systems, but also to continental rifts and island arcs. It may be applied globally without ad hoc interjections. Pressure magnitude variations and flow orientation (up vs. down) within different systems (continental vs. ocean basin) may explain differing geomorphology.

Within the plate tectonic interpretation, the Easter Island and Juan Fernandez microplate rotations are driven by shear along the edges from relative motion of the surrounding major plates (Pacific, Nazca, and Antarctic plates) like "roller bearing" [22, 23, 24]. Larson et al. state "Enclosing the core of the microplate, the inner pseudo faults form a pattern resembling the meteorological symbol for a hurricane." While Bird states "The result is a feature that appears much like a geological "hurricane" embedded in the crust of the earth." These references to the Juan Fernandez microplate belie the significance of the surge tectonic interpretation of these features as tectonic vortices (Figs. 6a and 6b).

Basic fluid dynamics can be applied based on surge theory. Within a surge interpretation the Easter and Juan Fernandez structures represent high-pressure or downwelling tectonic vortices, as opposed to the low- pressure upwelling of a hurricane mentioned above. The reasoning is based on atmospheric dynamics, where high pressure is counterclockwise in the Southern Hemisphere, and a well-defined high has a characteristic upper-level low with an opposite spin, or clockwise rotation, like the microplates exhibit. In an atmospheric low-pressure system, it is well known that an upper-level high is necessary for development of the low pressures in hurricane formation. If the upper- level high is sheared, hurricanes weaken.

5. EVIDENCE OF DOWNWELLING ON RIDGE

Gravity studies undertaken in conjunction with a wide-angle seismic refraction survey during the Mantle Electromagnetic and Tomography (MELT) experiment find evidence for denser, colder mantle near a small Overlapping Spreading Center (OSC) on the EPR at approximately 15º 55' S [13]. The direct quote from page 1217 is "Wide-angle seismic refraction data recorded on secondary Ocean Bottom Seismic (OBS) array show that crustal thickness and structure near this small OSC is normal. Therefore, the gravity anomaly probably is caused by denser and perhaps colder mantle near the OSC. P and S wave arrivals from tele seismic earthquakes are earlier along the secondary array than at comparable distances from the axis in the primary array, consistent with lower temperatures or lower melt fractions near the OSC. Finally, Rayleigh wave phase velocities show a pronounced, along-axis increase beginning in the vicinity of the OSC, suggesting that melt concentrations are lower beneath the OSC and northward." This evidence is contrary to the plate tectonic concept of upwelling mantle under a ridge, which should be hotter and less dense, characteristics of a buoyant mantle. How could the mantle possibly down well under the ridge, especially in the vicinity of an OSC, where all plate tectonic models predict mantle upwelling? The answer is found with a surge tectonic interpretation of converging mantle flow along-axis under a pressurized ridge. The ridge pressure forces denser mantle down- ward and volatile magmas upward in a counterflow pattern very similar to atmospheric dynamics.

6. GRAVITATIONAL TELECONNECTION

Studies carried out with superconducting gravity meters in 1977 [21] at the University of California Department of Physics indicate strong correlations between the gravity residual (what is left after filtering out earth tidal effects) and barometric pressure changes at frequencies associated with weather patterns. Six *u*gal changes in the gravitational field are typical with barometric fluctuations in sea-level pressure. Maximum fluxes are up to 45 *u*gals. The gravity response is essentially in phase with the pressure variations throughout the frequency range considered. The gravimeter signal noise is correlated with the random fluctuations of the atmospheric pressure. For the purposes of gravimetric measurements, the results show that gravity can be corrected for pressure effects within 10% by assuming the two are in phase and have admittance of 0.30 *u*gal/mbar below 1 cycle/day, and 0.33 *u*gal/mbar between 4 and 7 cycles/day.

In 1997 researchers [14] stated conclusively that they had found microgravity variations "mainly of geophysical origin." This study shows an expansion/contraction phase of a microgravity wave or surge moving through Europe in the vicinity of Membach, Belgium in 1996. Microgravity increases approximately 17 *u*gals over six months during a contraction phase. These data are corrected for ocean and atmospheric loading and earth tides. This study shows the first conclusive proof of surges and how they may be quantified and modeled.

The 1996 surge moving through Europe may correlate to the 1997/98 El Nino in the Pacific, since surges are predicted to migrate eastward much like weather patterns. Since a surge may induce microgravity oscillations, an amplification effect may occur upon reaching the Banda Sea vortex enhancing the coupling effect on the atmospheric pressure flux of ENSO.

Assuming the validity of the geophysical origins of changes in microgravity discussed above, Earth surges or slight geoid undulations may provide the mechanism for large climate oscillations. This natural frequency of earth oscillation would be modified continually by atmosphere/ocean loading or tides, orbital torques, planetary alignments, and/or other astrophysical means, most of which can be filtered out, assuming the periods are known. Planetary alignments produce gravity fluctuations in the *u*gal range, as shown by simple calculations. This should perturb the natural oscillation enough to modify the "normal" flux and create larger variations in surge activity. These perturbations are amplified within the larger tectonic flow regimes and tectonic vortices and may be responsible for weather teleconnections around the globe. These teleconnections have been documented by many scientists using pressure and temperature data sets but are not yet resolved in a comprehensive theoretical framework.

7. CORRELATING GEOID WAVELENGTHS

Conventional spectral analysis of altimetry data defining the Pacific geoid reveals a broad range of dominant wavelengths at approximately 280, 400, 660, 850, 1050, and 1400 km [15]. An intriguing correlation of these wavelengths to several well-documented seismic discontinuities is significant, especially at 410 km (olivine-spinel phase change) [25] and 660 km (spinel-perovskite phase change) [26]; the latter discontinuity separates the upper and lower mantle. Seismic models of Earth's structure have also suggested more tenuous discontinuities at 220, 520, 840, 700, and 900 km depth. Another interesting association is the diameter of planetary-scale tectonic vortices in the region. The Juan Fernandez and Easter Island vortices are 350-400 km across, whereas the AAD is 600 km, and the Banda is 1100-1200 km in diameter. The relationships between the geoid wavelengths, mantle discontinuities, and planetary- scale tectonic vortices may become apparent, if ever explored.

8. CONCLUSIONS

As discussed, the newer surge tectonic interpretation of geodynamics within the Pacific Basin sheds light on several lines of evidence that remain unresolved within the plate model. The major argument against the new surge interpretation is that mantle viscosity is much too high for fluid motions such as vortex formation and stream flow processes. The arguments are based on seismic velocities of Rayleigh waves, laboratory studies of rock deformations, ideas based on incompressible fluids, and theoretical assumptions of temperatures and pressures within the earth based on plate tectonic models. Although these are all valid arguments, there may be flaws in some of the assumptions made in these arguments. For instance, pressures and temperatures could be much higher within vortex structures than originally assumed in conveyor-type convection models. Seismic tomographic images actually infer stream-flow structures with eddy characteristics along the ridges, whereas many previous velocity analyses of seismic wave forms were more of an average velocity of the upper mantle than an accurate depiction of velocities within more localized flow structures. In addition, one would not expect laboratory studies of rock deformation to be applicable to real mantle conditions. The idea of incompressible fluids may not consider lattice changes of minerals at phase change boundaries, which may play an important role in density oscillations within tectonic vortices and the link to microgravity variations and atmospheric pressure oscillations.

The mantle intertropical convergence zone of geostreams on the EPR (Fig. 4) creates a western bulge (Figs. 3a and 3b) as the result of westward return flow from sinking mantle along the ridge. This effect probably extends at least down to the 410-km mantle discontinuity, considering the diameters of the Easter and Juan Fernandez microplates. This return flow may be traced westward along gravity lineation of the CPM [27] in the central Pacific, where they encounter eastward flow from the Banda region. Here, westward mantle flow diverts north, while eastward flow moves south, consistent with Rossby theory. The mantle gyre in the north Pacific most likely creates a mantle shear zone associated with the Hawaiian hot-spot trace and other volcanic trends. Asthenosphere counterflows feed these volcanoes. Finally, the orthogonal fracture patterns that dominate the Pacific Ocean Basin are due to the orthogonal stress fields set up by upper geostream Walker-type circulation and deeper-mantle gyre-type circulation. This working model begins to explain interrelationships between the parameters of geomorphology, tectonics, and climate. It sets forth a comprehensive framework for new discussion and further investigation of the powerful evidence suggesting a link between tectonic dynamics and climate.

B.A. Leybourne is an employee of the Naval Oceanographic Office. However, this paper was prepared in his personal time. As such, the opinions and assertions contained herein are those of the authors and are not to be considered as official statements of the U.S. Department of the Navy.

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