Surge Theory vs. Plate Theory: El Nino has the Last Word - A Theoretical Discussion of the Driving Force Behind El Nino

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ABSTRACT

Based on surge tectonic concepts, the coupling of tectonic dynamics with ocean/atmosphere dynamics is explained. Gravitational teleconnection of tectonic mass with atmospheric mass provides the coupling mechanism. The proposal may be confirmed experimentally and uses the following assumptions: (1) Oscillations or expansion/contraction of the Earth generates tectonic fronts that migrate slowly eastward across oceanic basins. Earth rotation is conducive to eastward migration of tectonic frontal boundaries which reconfigure tectonic pressure cells or vortices. (2) This tectonic reconfiguration alters existing atmospheric pressure patterns, thus altering jet stream configurations controlling climate trends. (3) In addition, the geodynamo has an intertropical convergence zone. The upper-level flow structure of this intertropical convergence zone is reflected in the tectonic trends across basins along the equator. Tectonic pressure fluctuations are transferred across the oceanic basin via major geostreams of the tectonic intertropical convergence zone, thus explaining the El Nino Southern Oscillation (ENSO) teleconnection. (4) Tectonic fronts produce changes in tectonic flow rates and direction along tectonic trends with enough mass to produce fluctuations in the gravitational field. (5) These regional fluctuations in the gravitational field affect local atmospheric pressure through density or phase changes of mineral suites within tectonic eddy or vortex structures. These structures are associated with island arcs and offsets along mid-ocean ridges, rift zones, and mountain fold belts.

The best experiment to test this hypothesis would be a global array of instrument packages containing superconducting relative gravity meters and seismic and environmental monitoring stations within the most intense tectonic vortex structures. Continuing precisely made gravity measurements should prove that changes in the gravity field generated within a tectonic vortex modulate atmospheric pressure changes and form the basis of a new climatic model which accounts for tectonic frontal surges. The tectonic force of gravitational teleconnection is the sought-after trigger of El Nino. Surge tectonics explains the Gravitational Earth Teleconnected Global Oscillation System (GETGOS) which has affected fundamental global weather patterns and climate throughout Earth's history.

SURGE THEORY EXPLAINS FUNDAMENTAL WEATHER PATTERNS

The three major global Sea Level Pressure (SLP) oscillation systems or teleconnections (Diaz, H. F. and M. Vera, 1992) are coincidentally underlain by major tectonic vortex structures portrayed by surge tectonics (Meyerhoff et al., 1992). These are the Southern Oscillation (SO), associated with El Nino (ENSO), the North Pacific Oscillation (NPO), controlling fronts moving toward North America, and the North Atlantic Oscillation

(NAO), exerting control over European weather patterns. The SO is controlled by the largest upwelling tectonic vortex structure on Earth, the Indonesian Island Arc. The Weber Deep in the Banda Sea region north of Darwin, Australia is the eye of the tectonic vortex. Across the Pacific Basin, the SO is controlled by strong downwelling vortices along offsets on the East Pacific Rise near Easter Island. The NPO is considered an oscillation of SLP between a belt at high latitudes extending from eastern Siberia (the Siberian High pressure system coincidentally hovers over the region near Lake Baikal, the deepest lake on Earth along a continental rift zone) to western Canada and a broad region at lower latitudes including the subtropics. The NPO is controlled by island arcs and deep trench systems in the north and northwest Pacific, which include the Japan, Kuril, and Aleutian island arcs and trench systems. To the south, the NPO pressure is controlled by the Mid-Pacific and Hawaiian volcanic systems. The NAO is controlled by an upwelling tectonic vortex beneath Iceland and a downwelling tectonic vortex along an offset of the Mid-Atlantic Ridge near the Azores (Leybourne, 1997). The controlling effects of tectonic fronts on weather patterns are exerted globally along the world-encircling vortex street (Smoot and Leybourne, 1997) and is implied from the principles of surge tectonic theory (Meyerhoff et al., 1992, 1996).

The AY structure of surge channel divergence portrayed in eastern Asia on the inset of Fig. 1 (Meyerhoff et al., 1996) begins along the North-South Zone trend which terminates in the continental rift lake, Lake Baikal. This north-south divergence continues along a southeast trend toward the Banda Sea region north of Darwin, Australia, as evident from the tectonic trends of Southeast Asia. The extreme pressures created at the divergence zone are transferred gravitationally north along the North-South Zone to the continental rift and southeastward along tectonic trends, which control the teleconnection between the Siberian atmospheric high-pressure cell and the Indonesian atmospheric low-pressure cell of the Banda Sea region.

Two assumptions must be made about the scale and direction of tectonic flow dynamics which oppose the currently accepted theory of plate tectonics. First, to modulate the SLP at observed frequencies of teleconnections, tectonic flow rates within the mantle should be greater than the measured lithospheric plate movement which is on the order of cm/year. El Nino frequencies of three to seven years should correlate with surges. The surges propagate tectonic fronts across the Pacific Basin. The tectonic stream flow coupled to these fronts may possibly be orders of magnitude greater than crustal motion of the lithosphere; thus cm/day magnitudes may be expected, as evidenced by near-continuous microseismicity within these areas. The second assumption follows directly from surge tectonic theory. The major component of tectonic flow is parallel to tectonic surface trend strikes. A secondary component is perpendicular Aconveyor belt flow dynamics as proposed in plate tectonics, comparable to Hadely cell circulation in the atmosphere. This assumption is extremely important because it allows comparison of flow structures in the tectonic domain with analogous features in oceans and atmosphere, such as fronts, eddies, and stream flow. We define geostream to represent high-tectonic flow regimes within the crust and mantle such as those occurring along the Pacific Rim, which has previously been termed surge channel by Meyerhoff et al. (1992). The current understanding of the driving forces behind El Nino based on natural variability of sea surface temperature, solar insolation, and ocean currents does not consider tectonic coupling influences. Encouraging circumstantial evidence which lends support to this hypothesis includes the following. Seismic activity (T-phase episodes) along the East Pacific Rise increases during an El Nino (Walker, 1988, and

1995; Walker and Hammond, 1990; Hammond and Walker, 1991). Sea level changes across the Pacific Basin during an El Nino as shown by altimetry studies. This indicates a shift in the regional gravity field referred to as surges, tectonic fronts, planetary scale waves, Kelvin waves, or geoid undulations. And finally, there is an anomalous temperature increase near the Indonesian upwelling vortex which is a known precursor to El Nino. The question which begs an answer is: Does El Nino cause this tectonic coupling, or does tectonic activity cause the El Nino phenomena? In other words, does the natural variability of ocean/atmospheric climate events such as El Nino drive tectonic change, or does Earth oscillation/geoid undulation trigger a climatic response? It would be invaluable to determine which of these events occur first.

QUATERNARY CLIMATOLOGY

The Quaternary is characterized by two climatic signatures: the Upper Pleistocene Climatic Signature (UPCS) within approximately the last 800,000 years, and the Middle Pleistocene Climate Signature (MPCS) from approximately 900,000 to 2,000,000 years ago. This change is best documented with $^{18}O/^{16}O$ ratio data (Prell, 1982; Pisias and Moore, 1981). The UPCS is correlated with eccentricity of the Earth=s orbit and contains high amplitudes and long periodicities (100,000 y.) in the oxygen isotope data, which represents a single major glacial cycle (Fairbridge, 1972). The MPCS data contain low amplitude and short periodicities with cycles roughly 20,000 and 40,000 years duration. The MPCS, with its shorter cycles, is a period during which the climate is correlated to precession and obliquity of the Earth=s orbit. The MPCS is characterized as and inter-glacial epoch (Prell, 1982). These two sequences (UPCS and MPCS) of unconformities were climatic/glacially formed by sea-level oscillations as revealed by sedimentology, paleontology, geophysics (seismic reflection and well-hole electric log data), and isotopic dating.

Leading researchers at the National Oceanic and Atmospheric Administration (NOAA), International Research Institute (IRI), Scripps, and other groups involved with research on the El Nino phenomena disagree about the causes of global warming. Some argue that manmade gases are linked to global warming through the greenhouse effect (which traps solar heat in the troposphere) and the increased frequency of El Ninos (during the past 15 years El Ninos have occurred in the winters of 1982-83, 1986-87, 1991-92, 1994, and 1997). Others argue that the Earth may be naturally warming regardless of manmade effects, as historical climate records indicate happened periodically in the past. Still others believe this may be a temporary warming during a longer cooling trend. Modeling efforts have met with some success in simulating past results using various climate indicators, and precursors to El Nino events are fairly well understood. However, without concrete evidence and sound theory, predictions for long-range climate change will be ambiguous at best.

GRAVITATIONAL VARIATION

Gravity variations are commonplace and are caused by many factors. Measured gravity values near the equator approximate 980 gals (g = 9.8 m/sec^2) and increase toward the poles because the Earth's shape flattens and centripetal acceleration is reduced. Changes are also due to variation in topography, lateral variations in internal mass, changing internal mass distributions, and to a much lesser extent by variable rotation rates. Observed variations of gravity due to mass inhomogeneity are of the order of 10^{-6} to 10^{-4} of the average value of gravity in gals, which put these variations in the sub-*m*gal range (NASA, 1987). Short-period tidal variations in gravity are also caused by the attraction of the sun, moon, and planets, and on longer time scales by galactic and universal periodicites. Gravity values associated with density oscillations within tectonic geostreams and vortices are on the order of less than 10^{-6} gals, which is in the *u*gal range.

The scale and structure of mantle flow is a subject of current debate. Geochemical isotopic studies have been interpreted as suggesting the existence of a multilayer structure (Jacobsen and Wasserburg, 1981). However, geophysical arguments indicate that a single-layer convective regime is more likely (Spohn and Schubert, 1982). If multilayer convection exists, it is hypothesized that the 670-km seismic discontinuity will be the boundary between separate flow systems in the upper and lower mantle. Due to upwelling and downwelling associated with mantle flows, undulations or vertical displacements at this boundary will occur with a wide range of wavelengths (Christensen and Yuen, 1984). Due to the attenuating effects of distance, the ones with the most signal will be in the range of several thousand kilometers (Busse, 1981). The gravitational characteristics of a stratified mantle are quite different from those of a mantle with uniform composition. Consequently, high-resolution gravity data can be used to delineate the competing hypotheses better (NASA, 1987).

PHASE CHANGES OF MINERAL SUITES WITHIN A VORTEX: MECHANISM FOR GRAVITATIONAL TELECONNECTION

Earthquake data along convergent margin geostreams portray the lithosphere as uncoupled below the 40-km depth, whereas approximately 80% of all earthquakes appear in the upper 100 km (Smoot, 1997). Between the depths of 80-150 km, the upper mantle composition may be up to 50% eclogite, a metamorphic high-pressure equivalent of basalt which contains pyroxene and garnet (Ehlers and Blatt, 1982). Eclogite can migrate to the surface in a rapid-transport setting. Wysession (1995) layers earthquake regimes at phase change discontinuities: one at 450 km, where olivine (a major constituent of basalt) changes to spinel (a denser phase of olivine), and another at 650 km, where spinel undergoes a phase change. It is important to recognize that the phase change depths are theoretical. Less than 1% of earthquakes occurring at convergent margins occur along the 450-km boundary, and at the 650-km boundary there is less than 2% occurrence. The lithosphere is largely uncoupled below the 40-km depth within the asthenosphere, where the first phase change is from basalt to eclogite (Smoot, 1997). Convergent margins or trenches form from deep, denser mantle geostreams flowing counter to lighter upper asthenosphere geostreams. This process is similar to the organized flows of cooler, more-saline countercurrents running beneath the Kuroshio and Gulf Stream in ocean dynamics. Vortices transfer minerals to and from asthenosphere and mantle geostreams by heat- and density-driven convection and generally occur along areas with large momentum changes such as divergence/convergence zones and island arcs. The analogous structure in weather patterns is super-cell formation and tornado development which occur along arcing weather fronts.

From laboratory creep studies of minerals under mantle conditions (i.e., high temperature and pressure), it is inferred that mantle rock should deform according to a power law non-Newtonian rheology (Kohlstedt and Hornack, 1981). Some studies find that the viscosity of both the upper and lower mantle is about 10^{21} Pa-sec (Wu and Peltier, 1983), while other studies indicate that the viscosity of the lower mantle is approximately one order of magnitude higher, accompanied by an asthenosphere viscosity of 10^{19} Pa-sec (Hager and Clayton, 1989). However, a Newtonian model for the mantle has been utilized to delineate mantle viscosity; such a model can approximately fit the isostatic glacial rebound data and the gravity data around Hudson Bay in Canada (Peltier and Wu, 1982). Studies utilizing non-Newtonian rheology indicate that the viscosity of the lower mantle is probably not constant but changes with a two to three order-of- magnitude variation across the lower mantle (Karato, 1981). One possibility is that due to the probable existence of volatiles and inhomogenities within the mantle, its deformation mechanism may be modeled as a Newtonian fluid (NASA, 1987).

With high variation of viscosity and large inhomogenities within the mantle and asthenosphere, it is more likely that density oscillations due to phase shifts within mineral suites are occurring within tectonic vortices. These density oscillations will induce gravitation coupling to the atmosphere. A vector surge analysis ANewtonian model of rotation and subduction was created for the Adriatic Basin downwelling vortex using 3.5-kHz seismic data to delineate tectonic trends and earthquake epicenter data to portray a 5-year surge throughout the region (Leybourne et al., 1995). The principles of this modeling effort can be applied globally (Smoot and Leybourne, 1997).

TECTONIC FABRIC: AN ANALYTICAL TOOL FOR CLIMATOLOGISTS

Trend maps compiled from high-pass filtered Geosat data (Figs. 2, 3, and 4) of the Indian, Pacific, and Atlantic Ocean basins show the regional trends of sea surface topography with wavelengths less than 125 miles. These sea surface trends reflect gravitational variations in the Earth=s crust and mantle caused by density variations and tectonic dynamics. A high-pass filter was applied to the 5-minute gridded Geosat data set which incorporated approximately 8,000 revolutions collected between March 1985 through October 1986. This yields an averaged data set within each 5-minute grid cell for the approximately 20 months of data collection (Cheney et al., 1989; Sramek, 1992). This technique tends to smooth tides, storm surges, and seasonal variations, leaving features produced by gravitational variations, although semiconstant ocean dynamics such as major ocean currents may also produce these topological features. By limiting interpretations of the filtered altimetry data to regional first-order trends in open-ocean basins, it also limits the effects of ocean dynamics on the trends. The residual trends approximate the changes of the sea surface caused by gravitational variations due to depth variations of bathymetry. Thus the first-order trends of sea surface topography and bathymetry should and do generally agree when overlaid.

The map of seafloor trends interpreted from the bathymetric superchart of the North Atlantic compiled in the 1980s at the Naval Oceanographic Office with almost total coverage of predominantly high-resolution bathymetry data shows major fracture valleys and seamount locations (Smoot, 1989). This map was compared to the Seasat data, a less-detailed data set than Geosat by Smoot and Meyerhoff (1995). The Geosat trends (Fig. 4) drawn from the high-pass filter data set in 1995 show matching trends with a slight offset of less than 1.7 km, which is the footprint of the satellite. Comparing the Geosat structural trends to the bathymetric structural trends allows several observations: (1) The trends agree; (2) The trends pass under the sediment layers on the Geosat diagram where they stop on the bathymetry; (3) The Romanche and St. Paul's Fracture Zones appear as a swarm on Geosat and are connected where they are not on the bathymetry chart; (4) The Barracuda/Vema/Guinea Fracture Zones all merge on the east for both sets of data. They do continue to the east by Geosat; (5) The Kane Fracture Zone is definitely a double trace; (6) The Atlantis/Hayes/Oceanographer Fracture Zone swarm merges on the east bathymetrically. It continues to the northeast by Geosat. The appearance on the west is the same; and (7) No continuous fractures exist between 38°N and 52°N at the Charlie-Gibbs Fracture Zone, a distance of some 1,400 km. The Charlie-Gibbs Fracture Zone continues to the east to a vortex structure at Iceland. The Faraday and Maxwell Fracture Zones have been speculated to appear in that region, and this is possibly shown by Geosat. Bathymetrically, they are unseen. An advantage of using the structural trend maps based on Geosat instead of bathymetry is that sediment covers many of the bathymetry trends, whereas structural trends along gravitational variation are easily followed under sediment cover with Geosat data. This advantage becomes apparent when analyzing the regional tectonic fabric of a basin for interpretation of tectonic dynamics within the basin (Leybourne and Smoot, 1997).

Using observations such as these, a tectonic forcing function for biasing climate oscillations can be illustrated with trend maps of filtered Geosat data (Figs. 2, 3 and 4), which should enhance the capacity of global climate models to monitor and predict long-range climatic trends. The phenomena can best be illustrated in the Pacific Basin. Tectonic dynamics can be inferred from the tectonic fabric (Fig. 3) between the Indonesian Island Arc and the vortices along the East Pacific Rise near Easter Island (Fig. 5), which shows an elliptical ring in sea surface topography directly over the Easter Island Vortex from filtered Geosat data. This gravitationally teleconnected relationship between tectonic structures has been measured and defined since 1924 as the Southern Oscillation Index (SOI).

EL NINO'S OTHER LINK TO SEISMICITY: GRAVITATIONAL TELECONNECTION

Expansion episodes of geostreams related to El Nino have already been well documented. The irregular periodicity of El Ninos defined by a low index phase of the SOI, makes the matching irregularities of seismicity very difficult to dismiss as merely coincidence (Walker, 1995; Forsyth et al., 1995). Extreme lows have been correlated in the SOI between 1964 and 1987 with episodes of intense seismicity along the East Pacific Rise (EPR) (Walker, 1988). Swarms of T-phase seismicity are often accompanied by unusually high levels of seismic activity along ridge systems and have been found to coincide with hydrothermal activity and volcanic activity along the Juan de Fuca Ridge (Baker et al., 1993; Dziak and Fox, 1993; Embley et al., 1993). Walker states in his rebuttal to Forsyth et al. (1995), "Epicenters and T-phase source locations during intense (El Nino related seismic) episodes have been found to be distributed lengthwise along hundreds of kilometers of ridge systems and laterally displaced from ridge crests by tens of kilometers" (Walker, 1988; Walker and Hammond, 1990; Hammond and Walker, 1991). The causative link of direct and indirect thermal effects associated with increases of submarine volcanic and hydrothermal activity accompanying these seismic swarms, as Walker speculates, is not the only link of El Ninos and seismicity.

References to gravitational teleconnection with atmospheric pressure (Warburton and Goodkind, 1977) in studies with superconducting gravity meters provide conclusive evidence of a direct relationship between barometric pressure change and the force of gravity with values of 0.30 *u*gal/*m*bar with typical fluctuations in the 6-45 *u*gal range. Therefore, surges or tectonic fronts (geoid undulations/planetary waves) are coupled to ocean/atmosphere dynamics not only through tectonic thermal effects but also through gravitational teleconnections controlling the SOI. The regional gravity field change of a tectonic front associated with an El Nino event across the Pacific Basin is amplified through tectonic vortices and geostreams (Leybourne, 1996; 1997), especially at the divergence of the Indonesian Geostream and convergence of geostreams along the East Pacific Rise. Before the theory of surge tectonics was developed, there was no framework or nomenclature existing within tectonic theory to verbalize this possibility. Plate tectonic theory does not consider the existence of tectonic vortex structures, ridge parallel stream flow or geostreams, and tectonic fronts. Surge tectonic theory does not cover these issues completely either. Tectonic fronts must be implied. Meyerhoff uses the term _surge channel_ instead of _geostream_; but once theory recognizes tectonic geodynamics to be analogous to ocean/atmospheric dynamics, coupling through gravitational teleconnection inevitably becomes understandable.

GRAVITATIONAL TELECONNECTION: BREATH OF EL NINO

Studies at the University of California Department of Physics using superconducting gravity meters (Warburton and Goodkind, 1977) indicate strong correlations between the gravity residual (results obtained by removing the effects of tides) 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 of up to 45 *u*gals can occur. Warburton and Goodkind (1977) report:

> They measure specifically the influence of barometric pressure on gravity in the frequency range between 0.1 and 10 cycles/day. The power spectrum of the gravimeter and barometric pressure signals measured suggest that the background noise continuum on the gravity signal at all frequencies is produced by pressure fluctuations. Cross-spectral analysis was used to compute that portion of the gravimeter signal which was specifically a response to pressure variations, which yields meaningful results only if there are no other influences on gravity which vary coherently with the pressure. The most important characteristic of atmospheric-pressure variations is the size of the region over which the variation takes place coherently. The atmospheric tides, for example, are coherent on a world-wide scale whereas the periodic variations resulting from the motion of weather systems are coherent on a scale of hundreds of kilometers. Random fluctuations in the frequency range of a few cycles/day are coherent over distances of tens of kilometers. The gravity variation which results from a given pressure variation depends on this

coherence distance. The gravity response is essentially in phase with the pressure variations throughout the frequency range considered. The noise on our gravimeter signal is correlated with the random fluctuations of the atmospheric pressure. For the purposes of gravimetric measurements, the results show that (except at 1 and 2 cycles/day) 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. For precise corrections of gravity, the pressure, the phase, and amplitude of the 1- and 2-cycles/day atmospheric tides will have to be determined and their effects on gravity computed separately.

The SO varies well within the pressure ranges which could cause or, as this new tectonic theory would have it, be an effect of a change in the gravitational field between 6-45 *u*gals. Density changes within a tectonic vortex may alter >*g*= by many *u*gals when viscosity variations of up to three orders of magnitude are proposed for the lower mantle (Karato, 1981). This is especially plausible when the vortex structure is considered a conduit between the mantle-asthenosphere. Sudden phase changes at critical tectonic temperature and pressure between specific mineral suites should be considered as a possible mechanism for these viscosity changes (Wysession, 1995; Ehlers and Blatt, 1982), and density oscillations translate to atmospheric pressure changes near the vortices of the global oscillation system that modulates the global weather patterns through gravitational teleconnection. Generally, atmospheric pressure changes are caused by tropospheric convection which is modulated by solar insolation, but within the domain of a tectonic vortex, sea-level pressure may provide a tectonically modulated atmospheric pressure component.

Density oscillations of a mineral slurry associated with up to three phase changes of mineral suites within a vortex seem highly probable, especially in conjunction with up to three orders of magnitude possible variation of viscosity of the lower mantle. These phase changes should be expected during tectonic fronts, especially within a vortex structure. During magma outpourings along the East Pacific Rise, an increased seismic event occurs associated with El Ninos. As pressure is released by extrusion through the asthenosphere and lithosphere, a phase transition of magmas occurs within the vortex. This expansion decreases density as mineral lattice structures shift phase, which reduces the gravitational attraction by *u*gals within the region of the vortices and geostreams. The slight weakening of the gravity field is translated to the atmosphere as a pressure drop from expansion or decreasing density. Thus, it is teleconnected from tectonic vortex not only to the surface, but also through geostreams to other vortices across the basin near Indonesia. This explains the mechanism of the SO controlling El Nino. The SO is the largest oscillation of the GETGOS, influencing large climate fluctuation. Millions of dollars in climate research could have been redirected if we had known this from the GETGOS!

WAVES OF EL NINO

To date, models coupling only ocean/atmosphere interaction have not adequately accounted for changes in climatic trends. The World Climate Research Program’s initiative on Stratospheric Processes and their Role in Climate (SPARC) currently indicates the importance of parameterizing gravity wave effects in numerical climate simulation models. Using radiosonde data, prominent eastward-propagating stratospheric gravity waves around the equator were first identified byYanai et al. (1968) during atomic bomb testing in the Pacific. The dominant source of these stratospheric gravity waves is thought to originate in the upper troposphere from convection processes due to the high heat budgets near the equator. A potentially overlooked source for fluctuations of gravity waves could be attributed to coupling influences of the Earth=s interior controlled through tectonic trends (Leybourne, 1996).

Planetary scale waves associated with El Nino seem to emanate initially within the Indian Ocean Basin during a phenomena known as Madden-Julian waves, a 40- to 60-day weather oscillation also called the Madden-Julian Oscillation (MJO). Nicholas Graham of the International Research Institute (IRI) for Climate Prediction in San Diego suggests that one trigger for El Nino might have been unusually strong AMadden-Julian waves. These are knots of wind and rain that travel eastward from the Indian Ocean every month or two. In early 1997, there were two particularly powerful ones which could have weakened the trade winds sooner than expected and given the system a nudge in the direction of an El Nino. In June, with temperatures already up 4 °C or more, the trade winds reversed direction all across the Pacific for the first time since 1982.

Can MJO be caused by small-scale convection in the mantle? Theoretical calculations suggest that longitudinal rolls can exist only if the upper mantle viscosity is extremely low (Yuen et al., 1981) and that they may have a typical horizontal wavelength of about 150 km with an amplitude of 5 *m*gals (Buck, 1985). One of the major discoveries of the Seasat altimeter mission is gravity undulations with the predicted wavelength, amplitude, and orientation in the Central Pacific (Haxby and Weissel, 1986). However, in the Indian Ocean, cross-grain features (Fig. 2) with the same wavelength but even larger amplitude variation (20-60 *m*gal) are thought to be due to buckling of the lithosphere in response to north-south compression of the Indian plate as it collides with Asia (Weissel et al., 1980; McAdoo and Sandwell, 1985). Do these features contain information concerning asthenosphere viscosity, or are they indicative of lithospheric stress and rheology (NASA, 1987)? Gravitational teleconnection of the MJO to longitudinal rolls (geostream) within the upper mantle seems a likely source of the triggering mechanism of El Nino as planetary waves (tectonic fronts) migrate eastward.

In a series of papers published between 1923-37, Sir Gilbert Walker pioneered statistical methods revealing the nature of climatic teleconnections (Brown and Katz, 1991). Before the exceptionally anomalous oceanographic and atmospheric conditions of 1957-58, no theoretical evidence for linking worldwide climate anomalies existed until Jacob Bjerknes proposed they were not unique and occurred interannually. He named the physical mechanism that links El Nino with the Southern Oscillation the Walker Circulation (Rasmusson and Wallace, 1983; Ramage, 1994). He noted that the sea surface temperature gradients are a necessary condition for the atmospheric gradients to drive this circulation. In the 1970s Klaus Wyrtki proposed the Kelvin Wave Hypothesis, based on analysis of tide gauge data, which interprets fundamental ocean dynamics associated with the onset of the warm episodes as a consequence of changes in the circulation of the tropical Pacific Ocean in response to changes in the winds that drive the circulation (Wyrtki, 1975a and 1975b).

Kelvin Waves bring warm equatorial waters eastward and are considered the pulse of El Nino in what is considered a gravity-driven process. They originate with the western equatorial Pacific warm pool that normally lies near Indonesia and New Guinea. These waves migrate eastward on interannual time scales in phase with the SOI and takes 2 to 3 months to cross the Pacific. Convergence of this less-saline warm pool of water with more-saline cold water from the eastern Pacific creates a well-defined salinity front. The zonal displacement of this front, a Kelvin Wave, is associated with El Nino-La Nina wind-driven (often cyclonic, i.e., typhoon) surface current variations (Picaut et al., 1996). Based on surge theory (Meyerhoff et al., 1992) the Indonesian Island Arc is the largest upwelling tectonic vortex on Earth. The geostream beneath Indonesia diverges into a northern component through the Philippines and the Japan Island Arcs, creating a North Pacific gyre around the Arim of fire. A southern component goes through New Guinea and turns south to New Zealand. An east-west-trending geostream (Fig. 3) flows in phase with the intertropical convergence zone between Indonesia and the East Pacific Rise, depending on El Nino/La Nina conditions. The east-west component converges near Easter Island with the northern and southern geostream components after they complete a circuitous route around their corresponding basins. The Weber Deep in a remote region north of Darwin, Australia within the Banda Sea appears to be the central vortex (the eye of the tectonic tornado/hurricane) and will likely rival the East Pacific Rise for the strongest gravitational teleconnection with the opposite sign occurring on the planet, as well as the largest thermal output via tectonic sources. The Kelvin Waves would be thermally and gravitationally teleconnected to the tectonic trends and longitudinal rolls in the Central Pacific all the way to the East Pacific Rise. Thus the tectonic fabric of the ocean basins is an excellent tool for understanding the processes involved in climate dynamics.

Another wave with influence on climate is the Rossby Wave, which in the case of El Nino, is actually a reflection of the Kelvin Wave off the American continents. The effects of El Ninos can linger for years as discovered by Navy research scientists at Stennis Space Center (Jacobs et al., 1996). From satellite altimetry studies of sea surface height variations, it became apparent that small (5- to 10-cm) anomalies in the sea surface from Japan to the Gulf of Alaska could be traced back in time, and were found to originate during the 1982-83 El Nino. These slow-moving masses of warm water originate as Kelvin Waves that bounce off South America, split in two, and travel north and south along the coasts. They become smaller with latitude and eventually reflect back across the Pacific as waves roughly consistent with linear Rossby Wave theory. Finally they slowly dissipate after merging with the Kuroshio Current.

CONCLUSIONS

The creation of a global array of relative gravity stations monitoring *u*gal changes of gravity within the GETGOS would supply researchers with the concrete information needed to ground-truth satellite altimetry data and determine coefficients of surge which may have the units of *u*gals/day, to be incorporated into Earth-ocean-atmosphere-coupled models and form sound predictions. This information would map geoid undulations and predict their global trends for climate modeling. This data set may be useful for earthquake prediction, in explaining climate correlations such as lake levels proxies to magnetosphere and sunspot activity, and discernment of the expansion/contraction phase of the planet (Smirnoff, 1992; Wezel, 1992). Planetary alignments which have recently occurred affect Earth's gravity in the *u*gal range. This alignment possibly is teleconnected with recent climate trends, coinciding with increase frequencies of El Nino and current warming trends. The strength, magnitude, and duration of these expansion/contraction phases hold the answers to questions which climate researchers have been recently asking. To calculate tectonic forcing functions, coefficients of surge must be developed from precise measurement of small-scale gravity fluctuations within the GETGOS. Satellite information will be ground-truthed by these products, whereby true predictive powers of Earth-ocean-atmosphere-coupled models will be realized. The eastward migration of tectonic fronts may be the reason increased vorticity of the phenomena moved to the Atlantic in 1995 after it peaked at the end of 1994 in the east Pacific (Leybourne, 1996). In the 1995 hurricane season many hurricanes formed within the Tropical Atlantic. Within the Atlantic, one could expect an even more severe hurricane spawning event in 1998/99, depending on when the tectonic front or surge peaks in the Pacific.

Other factors may be involved in climate processes, such as atomic bomb testing. The effect of atomic tests on tectonic surges may be an important area of future research. These and a myriad of other questions left to be answered by understanding the coupling influences of tectonics should be addressed by scientists.

The resolution of the gravity field needed for vortex analysis requires *u*gal measurements of the gravity field. This will require the use of superconducting gravity meters on stable land- based platforms in addition to altimetric techniques. A pilot study should be conducted near Darwin, Australia. If results are promising, establishment of stations within Easter Island vortex to develop coefficients for the SOI would be justified. Assuming success, stations within other vortices of the GETGOS with the most predictive power such as the NOA between Iceland and the Azores would seem appropriate.

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