Himalayan Geology, Vol. 22 (1), 2001, pp. 139-151, Printed in India

Surge hypothesis implies gravitational teleconnection of tectonics to climate : El Nino and the Central Pacific Geostream/Jetstream

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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 taphrogenesis/tectogenesis (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 jetstream 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 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.

INTRODUCTION

The Earth scientist has many different, and seemingly mutually exclusive, hypotheses/paradigms/theories from which to draw his or her conclusions as to the driving forces of all of the actions and interactions taking place on Earth. Some have reached scientific dead ends. Some have made an impact, some are just roadblocks to the furtherance of any scientific knowledge. That seems to be the case of the plate-tectonic hypothesis. The majority of Earth scientists have adopted that hypothesis in toto, so much so as to preclude any original thought or input into the inner workings of that hypothesis since it's inception in the mid-1960s. The same probably holds true for the climatic sciences because little or no meaningful work has been forwarded to explain the occurrences of the physical oceanographic problem known as "El Nino" (Diaz and Markgraf, 1992). In this paper we will try to incorporate what is known, using climatic, physical oceanographic, geophysical, and the newer global dynamic hypothesis, called surge tectonics, to derive a more meaningful explanation as to the causes and possible prediction mechanism to explain El Nino in a more robust manner (Fig.1).

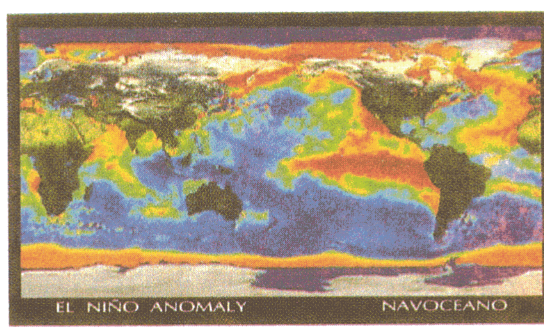

Fig. 1. Typical EI Nino Temperature Anomaly.

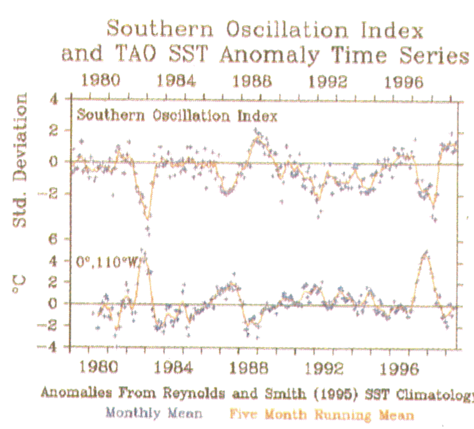

Fig. 2. Southern Oscillation Index (NOAA).

Gravitational teleconnection of tectonics to atmospheric pressure oscillations (Fig. 2) is implied by the inclusion of vortex structures within the surge tectonic hypothesis

(Leybourne, 1998a). Gravitational teleconnection can be visualized as a spring in the atmosphere, which contracts and expands in relation to micro-gravity oscillations within the earth. Just north of Darwin, Australia, the Banda Sea region may play an important role in modulating the El Nino Southern Oscillation (ENSO Fig. 3) through mantle dynamics.

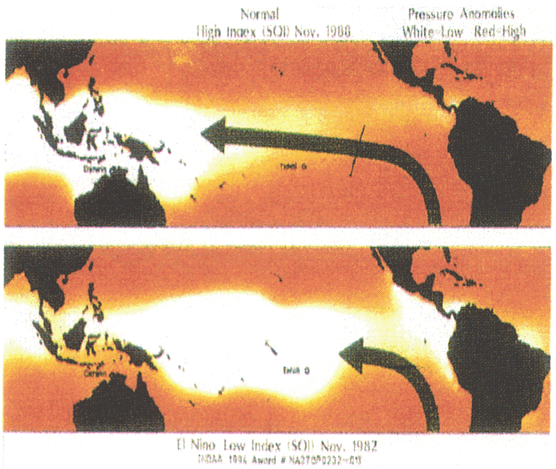

Fig. 3. Normal vs. El Nino SLP Distribution (NOAA).

Based on the surge tectonic hypothesis (Meyerhoff *et al.*, 1992; Meyerhoff *et al.*, 1996) the Indonesian Island Arc is the largest upwelling tectonic vortex on earth. The Weber Deep in a remote region north of Darwin, Australia within the Banda Sea appears to be the central vortex (Fig. 4 Eye of the tectonic tornado/hurricane). It 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 (Smoot and Leybourne, 1998; in review). Within the Banda Sea vortex mantle upwelling and divergence occurs. The geostream beneath Indonesia diverges into a northern component through the Philippines and the Japan Island Arcs. A southern component goes through New Guinea and turns south to New Zealand. An E--W-trending geostream flows

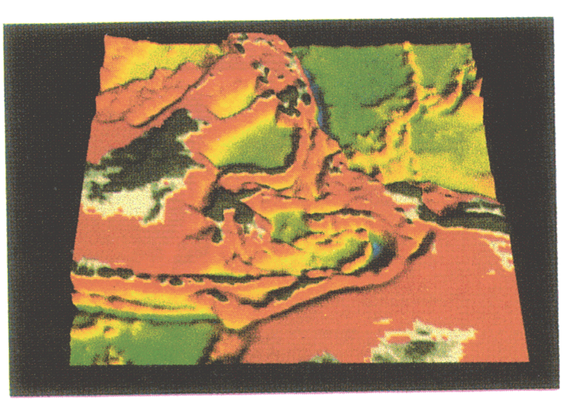

Fig. 4. Banda Sea Tectonic Vortex, South View 3-D Bathymetry (NAVOCEANO). Note Indonesian Volcanic Arc outflow and wings of the vortex much like the hurricane symbol.

in phase with the inter-tropical 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 and induces mantle downwelling at the East Pacific Rise. Thus a surface and deep mantle connection transmit micro-gravity oscillations of tectonic surges across the Pacific Basin.

Once a simple shift to a surge tectonic perspective is made it is fairly easy to understand how large downwelling tectonic pressure cells along offsets on the East Pacific Rise are dynamically linked to mantle upwelling in the Banda Sea tectonic vortex. Upper mantle stream flow processes around the Pacific "ring of fire" diverging in the Banda Sea (Fig. 5) and converging on the East Pacific Rise along with a deep connection near the outer core complete a simple Walker Circulation model for the tectonics of the Pacific basin (Leybourne and Adams, 1999). The plate tectonic hypothesis seems to be the limiting factor on explaining the link between seismicity and El Nino.

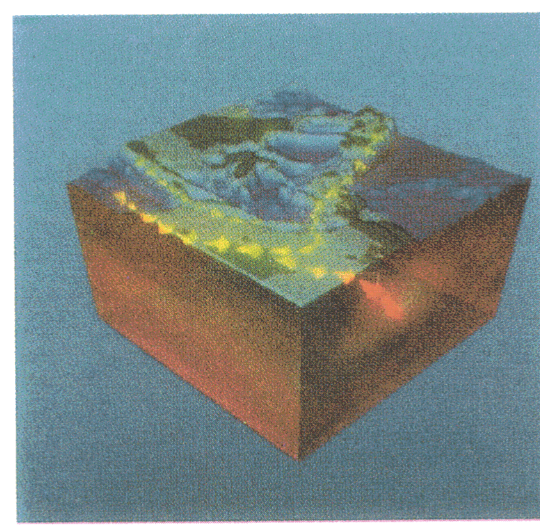

Fig. 5. Early Model Development Portraying Incoming Geostream Under Indonesia, Counterflow within the Volcanic Arc and Divergence of Geostreams around the Pacific Rim (MSRC Visualization Lab).

Teleconnection of the gravitational field to atmospheric pressure was demonstrated (Warburton and Goodkind, 1977) with super-conducting gravimeters. Barometric pressure fluctuations were shown to correlate with micro-gravity variations. The inverse is suspected in the Banda Sea vortex, where micro-gravity fluctuations due to tectonic surges may modulate pressure oscillations of the El Nino/La Nina climatic flux.

The Banda Sea near the tip of the Indonesian Island Arc and offsets of transform faults along the East Pacfic Rise near Easter Island are good examples of tectonic vortexes which affect the ENSO. These two areas are gravitationally teleconnected through stream flow processes in the mantle. A deep connection between these two areas and the outer core have been numerically modeled by scientists at Los Alomos Laboratories.

METHODS AND MATERIALS

We must cross many boundaries in the Earth sciences to reach our final conclusions. Gravity, and its derivative, satellite altimetry data, is the primary focus of this study. The earthquakes are used to outline the time sequence of events leading to an El Nino. Together with the gravity measurements, these are used to outline geostream activity. Climatology of recent times is used to explain periodicities and oscillations in jetstream activity. The wave theories are used to tie it all together into a somewhat reasonable explanation.

A. Gravity

Studies at the University of California Department of Physics with superconducting absolute gravity meters indicate strong correlations between the gravity residual (what is left after filtering out tidal affects) and barometric pressure changes at frequencies associated with weather patterns (Warburton and Goodkind, 1977). Six ugal changes in the gravitational field are typical with barometric fluctuations in sea level pressure with maximum fluxes of up to 45 microgals. 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 ugal/mbar below 1 cycle/day, and 0.33 ugal/mbar between 4 and 7 cycles/day.

Researchers stated conclusively that they had found micro-gravity variations "mainly of geophysical origin". (Francis *et al.*, 1997). This study shows an taphrogenesis/ tectogenesis phase of a gravity wave or surge moving through Europe in the vicinity of Memback, Belgium in 1996. Micro-gravity increases approximately 17 ugals over six months during a contraction phase. These data are corrected for ocean and atmospheric attraction and loading and earth tides. This study shows the first conclusive proof of surges and how they can be quantified and mapped.

Gravity variations are commonplace and are caused by many factors. Gravity values near the equator approximate 980 gals ($g = 9.8$ m/sec^2) and weaken toward the poles because the Earth's shape flattens and centripetal acceleration is reduced toward the poles. 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 in-homogeneity 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-mgal 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 ugal 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 multi-layer structure (Jacobsen and Wasserburg, 1981). However, geophysical arguments indicate that a single-layer convective regime is more likely (Spohn and Schubert, 1982). If multi-layer 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 down-going currents 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).

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 by Yanai and others (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).

B. Satellite Altimetry/Bathymetry

Trend maps compiled from high-pass filtered Global Earth Orbiting Satellite (GEOSAT) data 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 semi-constant 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 generally agree when overlaid.

In a preliminary exercise, the map of seafloor trends interpreted from the bathymetric super-chart of the North Atlantic compiled in the 1980s at the Naval Oceanographic Office (NAVOCEANO) with almost total coverage of predominantly high-resolution bathymetry data shows major fracture valleys and seamount locations (Smoot, 1989). This map, when compared to the Seasat data (Smoot and Meyerhoff, 1995), proved conclusively the relation of the sea surface topography collected by the satellite altimeter to be more than favorable with the multibeam Sonar Array Survey System (SASS) bathymetry.

Because the North Atlantic Ocean basin is the only one currently available with sufficient bathymetric coverage to allow a comparison, the same SASS data (Smoot, 1989) was compared to the GEOSAT (Leybourne and Smoot, 1997). Comparing the GEOSAT structural trends to the bathymetric structural trends allows the observations that the trends agree and that the trends pass under the sediment layers on the GEOSAT diagram where they stop on the bathymetry. 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). With the introduction of the later GEOSAT high-pass filtered data set, the world's ocean floor structural trends are now known from 70°N latitude to 70°S latitude. The GEOSAT trends 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.

Using observations such as these, a tectonic forcing function for biasing climate oscillations can be illustrated with trend maps of filtered GEOSAT data, 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 between the Indonesian Island Arc and the vortices along the East Pacific Rise near Easter Island, 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).

C. Earthquake Seismicity

Earthquake data (Fig. 6) along active margin geostreams (Fig 7; Fig. 8) portray the lithosphere as uncoupled below the 40 km depth where 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 active margins occur along the 450 km boundary and at the 650 km boundary there is less than 2% occurrence.

Above geostreams 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, which flow counter to lighter upper asthenosphere geostreams within the volcanic arcs. 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

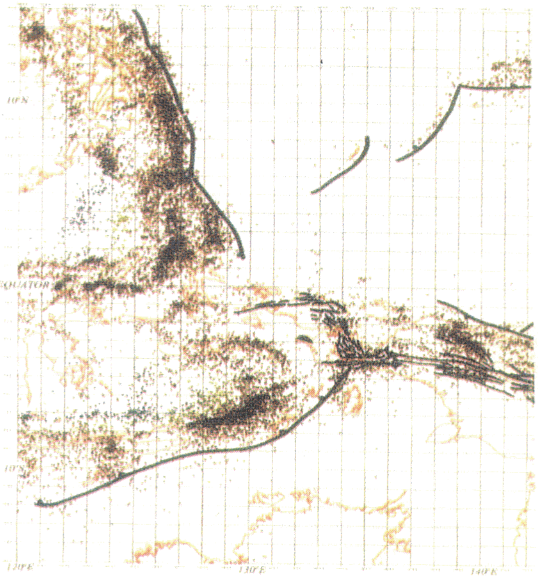

Fig. 6. Banda Sea Earthquake Epicenter Data (from NGDC Seismicity Catalogs). Dark lines mark trench systems and fault zones.

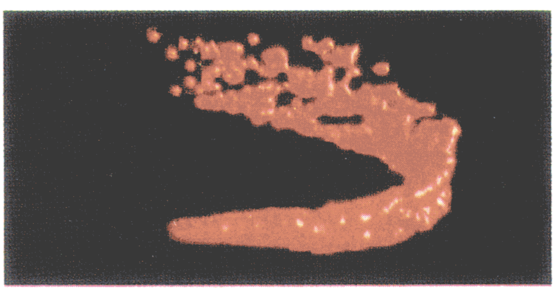

Fig. 7. Mantle Geostream in the Banda Sea under Indonesian Island Arc. (Michael Adams - Logicon Inc.)

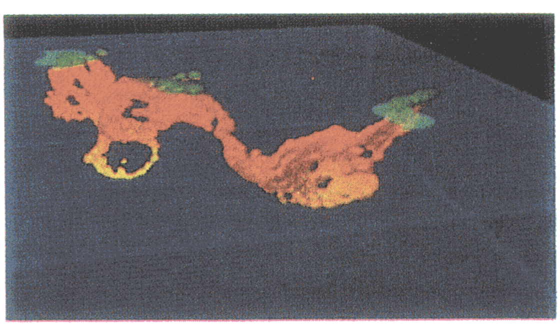

Fig. 8. Volcanic Arc Geostream, Counter Flow to Mantle in the Asthenosphere. A true Surge Channel within the Surge Tectonic Concept (Micael Adams-Logicon Inc.)

with large momentum changes such as divergence/ convergence zones and island arcs. The analogous structure in weather patterns is super-cell formation and tornadic 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 1021 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 1019 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. And these density oscillations will induce gravitation coupling to the atmosphere. A vector surge analysis "Newtonian" 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).

After a decade of extensive work (Walker, 1988; 1995; Walker and Hammond, 1990) at the University of Hawaii on T-phase (tele-seismic signals detected by hydrophone arrays placed in the oceans acoustic wave-guides) seismicity in the Pacific portrayed earthquakes along midocean ridges occurring in swarms along hundreds of kilometers. These earthquakes are associated with hydrothermal venting, magma outpourings, and atmospheric high-index pressure phases of the ENSO. This indicates a swelling of the entire ridge and slippage of the lithosphere. Walker associated these intense episodes of seafloor spreading with reduced atmospheric pressure in the ENSO high-pressure cell over Easter Island (Walker, 1988; 1995; 1999). His latest work considers gravity as a possible mechanism.

D. 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 18O/16O ratio data (Pisias and Moore, 1981; Prell, 1982). The UPCS is correlated with eccentricity of the earths' 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 earths' 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 Institution of Oceanography (SIO), and other groups involved with research on the El Nino phenomena disagree about the causes of global warming. Some argue that man made 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 man made 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. Precursors to El Nino events are fairly well understood. But without concrete evidence and sound theory, predictions for long-range climate change will be ambiguous at best.

Milankovitch series correlations (1941) were the computation of orbital changes, which were then related to climatic variations, assuming that changes in mean temperature are based on simple radiative equilibrium with respect to changing insolation. In other words, orbital parameters control the amount of incoming solar energy, thus controlling some long-term climate trends. Three principal orbital parameters affect low-frequency oscillations of the Earth's size, shape, and distance from the sun. Eccentricity (100,000 year cycles) is the deviation of the orbit from a perfect circle; obliquity (40,000 year cycles) is the angle of tilt of the Earth's axis with respect to the plane of its orbit; and precession (26,000 year cycles) is the direction in which the rotation axis points. The interaction between these orbital parameters apparently controls much of long-term climate change. The dominance of eccentricity has been linked to glacial cycles. The similarity between the duration of major glacial cycles, such as those of the past 800,000 years, and the duration of eccentricity cycles imply a causal relationship (Berger, 1980; Berger *et al.*, 1984). Such orbital periodicities have been found in deep-sea cores (Hays *et al.*, 1976; Berger *et al.*, 1984). Investigations of the long-term climate of the Late Pleistocene (van der Hammen *et al.*, 1971; Kellogg, 1976; Ruddiman and McIntyre, 1976; Koming *et al.*, 1979; Clark *et al.*, 1980; Prell, 1982; Hooghiemstra, 1984 and Williams, 1984) yielded a synchroneity of these global changes (Lowrie, 1986).

Earth scientists generally accept that global eustatic sealevel changes of various magnitudes and durations have various origins within the constraints of the plate-tectonic hypothesis. Supercontinental Gondwanaland-type plate collisions or and rifting have tectonic cycles on the order of 10^8 years (Fairbridge, 1972). Seafloor spreading rate changes and mid-ocean ridge volumetric expansion and contraction have tectonic cycles on the order of 10^7 years (Koming, 1984; Pitman, 1978). Sedimentary depositional cyclicities are recorded throughout the Phanerozoic in seismic sequences at periods of 10^5 and 10^6 years. Planetary orbital motions, controlling the amount of incoming solar radiation of 20,000-, 40,000- and 100,000-year duration, are the apparent cause of these depositional cycles via climate/sealevel fluctuations as opposed to tectonic fluctuation.

Arguments that solar insolation variations with sunspot activity have higher magnitudes than those induced by orbital parameters make the point that the issue is more complex than allowed by plate tectonics. Variations in height of lake levels in the Middle East, such as the Caspian, have been linked to sunspot activity, (Rodionov, 1994). Recent paleoclimate records recovered in the Baikal Drilling Project (BDP-96) are continuous for the last five million years (Williams *et al.*, 1998). Lake Baikal is the world's deepest and oldest extant lake which occupies the deepest potion of the Baikal Rift Zone (BRZ), one of the most active continental rift zones. The climate in the region is dominated by the large atmospheric system known as the Siberian high, known as such for it's extreme and prolonged high pressures. This pressure system is also teleconnected to the Southern Oscillation (SO), the North Pacific Oscillation (NPO), and the North Atlantic Oscillation (NAO) via tectonic trends. From detailed studies of piston and drill cores (Williams *et al.*, 1998) evidence exists that the Lake Baikal region acted like a "cryogenic pump" during transitional periods of climate change. The region cooled to such an extent that moisture was "pulled" from the high latitude North Atlantic when it was still relatively warm and stored in the western Siberian region of the Kara Peninsula. The westerly transport of moisture from the North Atlantic during late glacial times acted as a primary source of water which coincided with the extreme insolation minimum in the interior of Siberia.

E Wave Theories

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). These are knots of wind and rain that travel eastward from the Indian Ocean every one to two months.

Kelvin Waves bring warm equatorial waters eastward and are 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 with interannual time scales in phase with the SO Index (SOI). They take 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 surface current variations (Picaut *et al.*, 1996).

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 increasing latitudes and eventually reflect across the Pacific as waves roughly consistent with linear Rossby Wave theory.

TELECONNECTIONS

Sir Gilbert Walker pioneered statistical methods revealing the nature of climatic teleconnections, primarily sea level pressure oscillations between Darwin and Tahiti, later known as the SO associated with El Nino. These cross-correlations over great distances between time series of meteorological variables, such as Sea Level Pressure (SLP), were realized in the early 1900s (Walker, 1924; Walker and Bliss, 1932; Wise, 1927). These linkages between weather anomalies were later called teleconnections. Extensive analysis of SLP and Surface Air Temperature (SAT) has resulted in the discovery of three major oscillation systems or teleconnections around the globe. The most familiar are the SO associated with El Nino (ENSO), the NPO controlling fronts moving toward North America, and the NAO exerting control over European weather patterns. An intriguing pattern of tectonic vortexes underlies all of these global oscillation systems (Smoot and Leybourne, 1997).

The mysterious climate link can be explained by variations in the magnitude of gravitational teleconnection, which alters storm tracks dependent on tectonic vortex teleconnection strength. When the effect of tectonic gravitational teleconnection on atmospheric flow dynamics is additionally considered, a much more powerful concept for the drastic changes observed in climatic proxies emerges, linking all eustatic sealevel change to tectonic dynamics. Shifting wind patterns, especially the jet streams meridional to zonal perturbations controlled by the Global Oscillation System (GOS), dominate the modern climatic swings of El Nino (Leybourne, 1998b). Logic implies larger changes recorded in climate proxies are a result of more dramatic changes in these modern processes, which can be quantified and modeled using accurate time-series micro-gravity data collected within the tectonic vortices of GOS.

This hypothesis goes a long way in explaining why gravitational teleconnection of tectonic vortex structures in addition to solar insolation extremes are related to Milankovitch's series correlation with climatic shifts. Orbital changes of the earth probably do not by themselves invoke enough change in temperature correlated to distance from the sun to explain the degree of climatic change observed in the geologic record. But local changes in "g" could invoke a weakening or strengthening of gravitational teleconnection between tectonic vortices, thus extremely altering global weather patterns and moisture transport from present-day circulation patterns. In addition, gravitational teleconnection may explain lake level climate proxy correlations to magnetosphere and sunspot activity. And finally, simple calculations show that recent planetary alignments affect Earths' gravity in the ugal range. This alignment is probably teleconnected to recent climate trends coinciding with increase frequencies of El Nino and current warming trends.

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 ugals. Density changes within a tectonic vortex may alter 'g' by many ugals 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).

Density oscillations translate to atmospheric pressure changes near the vortices of the global oscillation system that modulate 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, sealevel 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 change, which reduces the gravitational attraction by ugals 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.

EL NINO'S 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 (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. 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.

WAVES OF EL NINO

To date, models coupling only ocean/atmosphere interaction have not adequately accounted for changes in climatic trends. 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 identified (Yanai *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 MJO. Nicholas Graham of the IRI suggests that one trigger for El Nino might have been unusually strong "Madden-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 the trade winds reversed direction all across the Pacific for the first time since 1982, with temperatures already up 4+°C.

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 mgals (Buck, 1985). One of the major discoveries of the Seasat altimeter mission was 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 with the same wavelength but even larger amplitude variation (20-60 mgal) are thought to be due to buckling of the lithosphere in response to N--S compression in the Himalayas (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 SO 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. This is 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 take 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).

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.

GRAVITATIONAL EARTH TELECONNECTED GLOBAL OSCILLATION SYSTEM (GETGOS)

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.

The creation of a global array of relative gravity stations monitoring ugal changes of gravity within the GETGOS would supply researchers with the concrete information needed to ground-truth satellite altimetry data. From this data coefficients of surge may be determined, which could have the units of ugals/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 taphrogensis/tectogenesis phase of the planet. Planetary alignments, which have recently occurred affect earths' gravity in the ugal 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.

A 1996 surge moving through Europe is likely related to the 1997/98 El Nino in the Pacific since surges migrate eastward much like weather patterns. As this surge induces micro-gravity oscillations, they are amplified upon reaching the Banda Sea vortex and produce a coupling effect on the atmospheric pressure flux of the southern oscillation of El Nino.

Assuming the validity of the geophysical origins of changes in "g", the Earth would have periodic surges or geoid undulations. This natural frequency of earth oscillation would be modified continually by atmosphere/ocean loading or tides, orbital torque's, 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 ugal range, as shown by simple calculations. This should perturb the natural oscillation enough to modify the "normal" flux or create larger variations in surge activity. These perturbations are amplified within the larger tectonic flow regimes or tectonic vortices 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 framework. 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.

Concerns that atomic bomb testing in the Pacific and elsewhere may be adversely affecting not only the environment through radiation but also climate processes such as El Nino may be valid. The coupling of atomic tests with 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 ugal 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 the 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.

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!

CONCLUSIONS

The influence of gravitational teleconnection on atmospheric pressure may be factored into current global General Circulation Models (GCM) by coupling geodynamic tectonic flow to ocean/atmosphere models based on the principles of surge tectonics. The surge hypothesis provides a framework for modeling mantle dynamics that incorporates more geophysical data into the model than were previously used. The surge hypothesis also uncovers the relationship between tectonics and climate patterns. The amplification of small global gravity changes within tectonic vortices has the potential to store and release enormous amounts of energy. The possibility that tectonic phenomena may modulate weather patterns when gravitational potential energy is released at the surface as pressure/temperature changes in the ocean/atmosphere coupled dynamics should be investigated. Micro-gravity studies undertaken on the most dominant vortices may provide the data to calculate a regional surge index for modeling longer-range climate patterns such as the ENSO. ENSO is controlled by the largest upwelling tectonic vortex structure on earth, in the Indonesian Island Arc. Across the Pacific Basin the ENSO is controlled by strong downwelling vortices along offsets on the East Pacific Rise near Easter Island.

Application of these concepts in other areas such as the North Pacific and the North Atlantic may provide the answers to questions such as (1) What creates the large-scale changes in pressure (SLP) that cause a vacillation of meteorological patterns between zonal and meridional flow in the northern hemisphere? Or (2) Why is zonal flow predominant in the southern- hemisphere? E-W vs. N-S orientation of dominant vortices answers these questions.

The NPO is considered a seesaw of SLP between a belt at high latitudes extending from eastern Siberia, in the Lake Baikal region, 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 includes the Japan, Kuril, and Aleutian Island arc 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. These teleconnected pressure systems affect weather patterns around the globe.

By comparing geodynamic tectonic flow as analogous to ocean and atmosphere flow, which is inferred in surge tectonic theory, we can make the following conclusions. Atmospheric jetstream flow is analogous to the Gulf Stream or Kuroshio Current flow structures in the ocean, or aquastreams. These in turn are analogous to tectonic flow or geostreams, which create surface trends in the crust. The high/low pressure cells in the atmosphere are analogous to cold/warm core eddies in the oceans and downwelling/upwelling vortex structures in the earth's crust and mantle. Weather fronts are analogous to Kelvin/Rossby waves in the oceans, or oceanic fronts. These fronts are pressure/temperature waves moving through their corresponding medium and in the earth are called surges, gravity waves, or tectonic fronts (Leybourne, 1997).

Earth oscillations of various periods generate these surges, and affect the vortex structures and geostreams in ways that may be predictable, provided micro-gravity studies of tectonic vortices are undertaken. A strategically placed global array of super-conducting gravimeters, networked with seismic and other environmental monitoring stations, may increase the ocean/atmospheric modelers' ability for climate prediction. Satellite geoid data may be ground-truthed for micro-gravity oscillations. A pilot study in the Banda Sea is recommended to test the validity of these proposals.

The "missing link" between seismicity and El Nino (Walker, 1988, 1995, 1999) may well be tectonic micro-gravity induced atmospheric pressure changes. Walker's observations of increased T-phase seismicity along the East Pacific Rise correlated to episodic seafloor spreading and reduced pressure in the high pressure cell of the SO should be explainable with the plate tectonic hypothesis. It is not. If geophysicists fail to explain this, there is little chance that the debate on the human contribution to climate change will ever be clearly resolved. However, the surge tectonic hypothesis allows atmospheric circulation patterns such as Walker Circulation to be considered as a model for tectonic dynamics in the Pacific Basin instead of simple Hadley Cell convection, which is considered as a driving force in plate tectonics.

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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 author, and are not to be considered as official statements of the U.S. Department of the Navy.

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