Research Article

Earth & Environmental Science Research & Reviews

Phase-Adjustment Mechanism during Enso Cycles under Sun-Moon Gravitation

ZhirenWang

Institute of Marine and Coastal Sciences, Rutgers, The State University of New Jersey

*Corresponding author
Zhiren Wang, Institute of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, 71 Dudley Road, New Brunswick, NJ 08901; Email: joewwh77@gmail.com

Climate predictions often fail when climate starts to adjust, with uncertainties increasing with the length of prediction windows where observations are no longer available to contain the missed dynamics and correct climate models. I introduced the missed dynamic astronomy factor (Sun-Moon gravitation) into climate studies and found it producing phase adjustments during ENSO cycles through seasonally changing the atmospheric and oceanic circulations, besides producing structural atmospheric-oceanic currents, climate-paleoclimate variations, and initiating and maintaining planetary rotations that play key roles in weather-climate systems, as reported here in series after concerned miscellaneous equations and their derivations were published in [1,2].

Climate presents abundant variations during which phase-adjustment mechanism is the key for accurate climate predictions. As a prominent climate signal among climatic variations, inter annual variability during ENSO cycles has been explained using theories, e.g., on westerly wind bursts, Kelvin and Ross by waves, oscillations, self-sustaining internal dynamics, and stochastic forcing [3-18]. Processes within the atmosphere and oceans alone seem not to have actively brought the phase adjustment with abundant variations and a clear seasonality. The Kelvin and Ross by waves need to be triggered before their occurrence. Stochastic forcing does not necessarily have the seasonality. Noise-like westerly wind bursts are more concomitants than El Niño triggers during atmospheric circulations [19]. During ENSO cycles, the zonal Walker circulation and the meridional Hadley circulation are negatively correlated to one another. A warm ENSO phase (El Niño) often accompanies with a weakened and eastward retreated Walker circulation with an eastward zonal wind anomaly, while a cold ENSO phase (La Niña) often accompanies with an intensified and westward extending Walker circulation with a westward zonal wind anomaly [19]. During El Niño/La Niña phase, the weakened/intensified Walker circulation or the intensified/weakened Hadley circulation changes heat exchanges and therefore temperatures spatially, with wind-transporting latent energy up to 10,000 times the kinetic energy of wind itself, depending on air humidity and wind speed. Wind anomalies in both speeds and directions result from wind accelerations. Where are the accelerations from? Internal energy from thermodynamic processes can be stored in a baroclinic atmosphere in the form of potential energy and can be partially transferred into kinetic energy during instabilities to produce accelerations, but the accelerations are often established and released for the quick weather processes (e.g., 20).

In fact, the accelerations could be produced in the atmosphere and oceans under the Sun-Moon gravitation (SMG), as shown below.

Atmospheric-oceanic circulations and ENSO cycles:
Atmospheric and oceanic circulations highly correlated with ENSO cycles. The observed monthly sea-surface temperature anomaly (SSTA) averaged within Niño3.4 region (i.e., 180−240°E, 5°S−5°N) and the observed and the SMG-induced atmospheric and oceanic circulations averaged at surface and within equatorial Pacific Ocean (i.e., at a 1000hPa-elevation for winds, at a 5m depth for currents, and within a domain of 148−272°E, 10°S−10°N) were employed to express the ENSO cycles and circulations during the period of 1980−2007, as depicted in Fig. 1 and 2.

During El Niño/La Niña, the SSTA was above/below 0.5/-0.5°C continuously for at least five months, and the zonal wind had a positive/negative anomaly with amplitude of a couple m/s. Zonal wind/current highly correlated to the SSTA with a correlation of 0.85/0.57 (above a 95% confidence level using a t-test, same for all the correlations mentioned below), with the zonal current leading approximately eight months and with an amplitude of a couple cm/s. The observed acceleration for zonal wind was several mm/s/day and highly correlated to the SSTA with a correlation of 0.8, leading approximately 11 months during the period of which 0.5−1.0 m/s speed anomaly can be produced from the acceleration; the observed acceleration for zonal current was several mm/s/month and correlated to the SSTA with a correlation of 0.35, leading approximately 19 months during the period of which, 0.1−0.2 cm/s speed anomaly can be produced from the acceleration. For the entire thickness of the atmosphere and Pacific Ocean, the SMG-induced accelerations for zonal wind/current were a couple mm/s/week and highly correlated to the SSTA with correlation coefficients of 0.52/0.61, leading approximately 14/23 months (Fig. 1).

Averaged within latitudes of 10°S − 0° where meridional wind/current was northward/southward, the acceleration of meridional wind/current correlated to the acceleration of zonal wind/current with a correlation of 0.54/0.57, leading 9/0 month; averaged within latitudes of 0°−10°N where meridional wind/current was southward/northward, the acceleration of meridional wind/current correlated to the acceleration of zonal wind/current with a correlation of 0.60/0.79, leading approximately 15/8 months (Figure: 2)
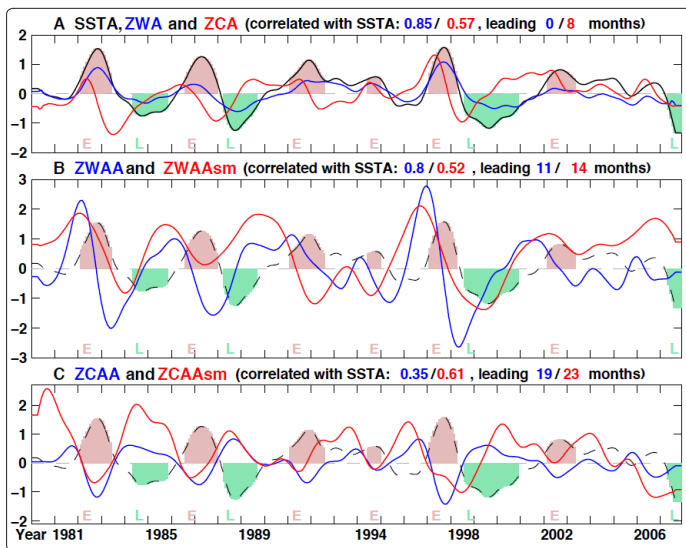
Figure 1: Tropical surface circulations and Niño3.4 sea-surface temperature anomaly (SSTA, °C). A. Observed zonal wind and current anomalies (ZWA in m/s and ZCA in cm/s). B/C. Observed acceleration anomalies of zonal wind/current (ZWAA in mm/s/day / ZCAA in mm/s/month) and the SMG-induced acceleration anomalies of zonal wind/current (ZWAAsm/ZCAAsm in mm/s/week). E/L: starting time for El Niño/La Niña phase. Winds and currents were obtained from the Physical Sciences Division, Earth System Research Laboratory, NOAA (www.esrl.noaa.gov/psd)
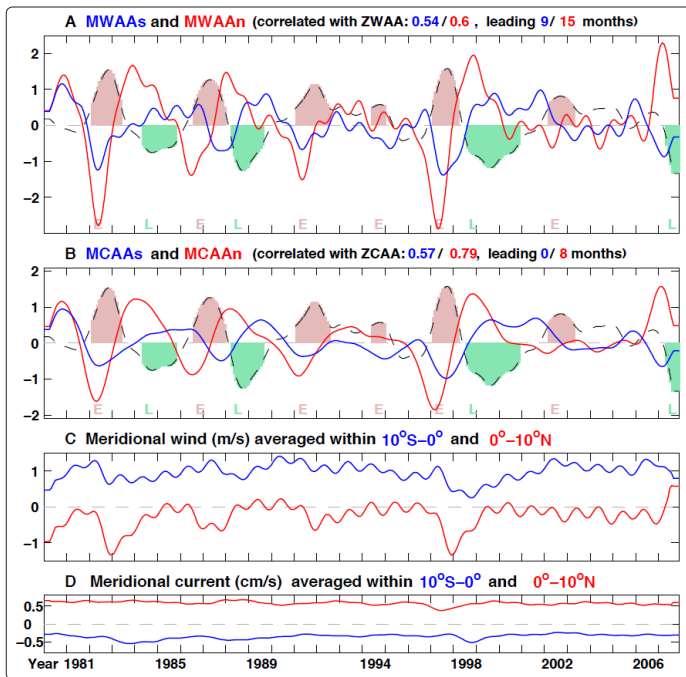
Figure 2: A/B. Accelerations (mm/s/day) of meridional wind/current averaged within 10°S − 0° (MWAAs/MCAAs) and 0°−10°N (MWAAn/MCAAn). C/D. Meridional wind and current speed (m/s and cm/s) averaged within 10°S−0° and 0°−10°N. Winds and currents were obtained from the same data source as Fig. 1

During/prior to an El Niño, there were positive anomalies for observed zonal flow speed and observed and SMG-induced speed acceleration in both atmospheric and oceanic circulations, with larger positive anomalies for the stronger El Niño in 1982/1983 and 1997/1998. A positive/negative anomaly of the zonal wind and current helps establish a convergent/divergent upper-layer ocean near Niño3.4 region to increase/decrease the SSTA there and must be produced from accelerations for winds and currents [19]. The above changes were approximately opposite during/prior to a La Niña phase.

The accelerations of winds highly correlated to the accelerations of currents in both zonal and meridional directions. Leading approximately 8 months, the acceleration of zonal wind correlated to the acceleration of zonal current with a correlation of 0.72. The meridional current speed and acceleration correlated to the meridional wind speed and acceleration with correlations of 0.93 and 0.95 if averaged within latitudes of 10°S−0°, or 0.92 and 0.96 if averaged within latitudes of 0°−10°N, respectively. During air-sea interaction, winds partially produce currents and heat fluxes change wind fields, which complicate the acceleration-correlation between winds and currents with a correlation of 0.69 [20].

However, on climate scales, atmospheric and oceanic circulations were highly correlated with ENSO cycles in their flow speeds and accelerations, the highly consistent accelerations of winds and currents with correlations above 0.9 dynamically testified one thing, that is, the winds and currents shared the same external dynamic forcing, here, the SMG, especially in meridional direction where the equator-ward SMG applied on the atmosphere and oceans and the SMG-induced meridional accelerations were less influenced by horizontal boundaries than the SMG-induced zonal accelerations were.

Characteristics of the SMG-induced feedback tendencies in circulations:

In the atmospheric and oceanic circulations, a negative/positive feedback weakens/enhances the present flow speeds through negative/positive accelerations. Different feedback tendencies (or acceleration patterns) exited in the SMG-driven circulations that may cause phase-adjustment in ENSO cycles. The SMG-driven accelerations were functions of orbital parameters and flow speeds, as defined in Eq. 35 and 36 in [1].

The feedback tendencies for the SMG-driven circulations were quantified using the westward-flow tendency (WFT) that had negative acceleration, eastward-flow tendency (EFT) that had positive acceleration, negative zonal feedback tendency (NZFT) that had positive/negative acceleration to the present westward/eastward flow, and positive zonal feedback tendency (PZFT) that had negative/positive acceleration to the present westward/eastward flow. Examination conditions for checking the feedback tendencies were set as follows:
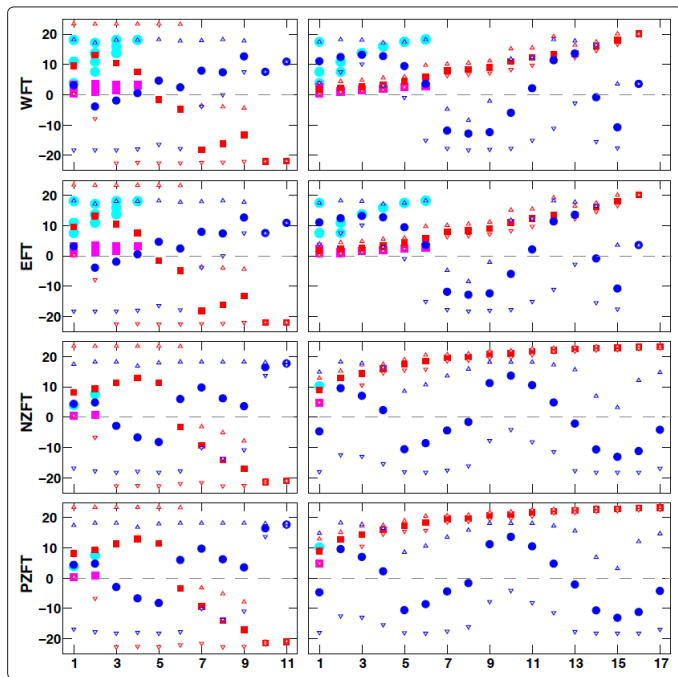
Figure 3: Latitudes (degree) of the Sun (red squares) and Moon (blue dots) during different feedback tendencies as shown in rows 1−4 for the SMG-driven winds (left column) and currents (right column) averaged within the examination conditions as defined in text. X-axis represents the number of times for the feedback tendencies to occur during the four-year period. Magenta squares/cyan dots represent the latitudes of the Sun/Moon when their phase difference between atmospheric and oceanic circulations is no larger than 7/46 days (or ~1°/6° in latitude). Red/blue triangles provide the maximum and minimum values due to different initial relative longitudes and phases of the Sun and Moon

1. A four-year period was examined and within each of the days, different zonal and meridional flow speeds (m/s) were examined with u Є [-30, 30] ∪ v Є [-20, 20] for the atmosphere, and u Є [-1.5, 1.5] ∪ v Є [-1.0, 1.0] for oceans in order to provide parameters for the SMG-induced accelerations and to serve as the present flow speeds.

2. Multiple initial relative longitudes (0−315 degrees) between fluids and the Sun or Moon and different phases of the Sun and the Moon (with the Moon lagging the Sun by 0−14 days) were examined.

3. Feedback tendencies were under the attractions of both the Sun and Moon and were averaged within latitudes of 10°S to 10°N.

The SMG-driven circulations produced acceleration of several mm/s/day, comparable to the observations. For oceanic circulations, the significant feedback tendencies occurred in April to May (ranging from March to July), with the Sun only locating over the Northern Hemisphere; for atmospheric circulations, the significant feedback tendencies occurred in May to June (ranging from January to October). An overlap in feedback timing for the atmospheric and oceanic circulations will facilitate the phase adjustment during ENSO cycles.

During a four-year period, the timing-overlap in WFT/EFT occurred more than a dozen times in March to create westward/

eastward accelerations, with the Sun's phase difference between atmospheric and oceanic circulations no more than one week (or ~1° in latitude), the Sun's latitudes of 0.4−3.6°N (near the Equator), and the Moon's latitudes of 3.9−18.2°N. A timing-overlap in PZFT/NZFT that enhances/weakens a westward or eastward flow in both atmospheric and oceanic circulations, however, rarely occurred during the four-year period, for only a couple times in March to April, with the Sun's phase difference between atmospheric and oceanic circulations no more than one and half months (or ~6° in latitude), the Sun's latitudes of 0.4−4.8°N (near the Equator), and the Moon's latitudes of 3.8−10.1°N. All feedback tendencies occurred when the Sun and Moon were located over the Northern Hemisphere, displaying seasonality and temporal asymmetry of the short-range climate system (Fig.3).

Different feedback tendencies played conditionally different phase-adjustment roles during ENSO cycles through enhancing or weakening zonal and meridional flows, adjusting to or maintaining an El Niña or a La Niña phase, hindering the further enhancement of the present tendencies, and transferring between different feedback tendencies, characterized as (Figure :4 & 5):

1. WFT produced negative zonal acceleration to enhance/weaken present westward/eastward flow, and accordingly produced positive feedback to meridional wind component to enhance the present equator-ward wind components, enhancing Walker circulation and conducing to adjusting to or maintaining a La Niña phase. When the present zonal wind was strong westward (<-20m/s), negative feedback occurred to symmetrically weaken the present meridional wind component, and hindered the further enhancement of the present westward wind.
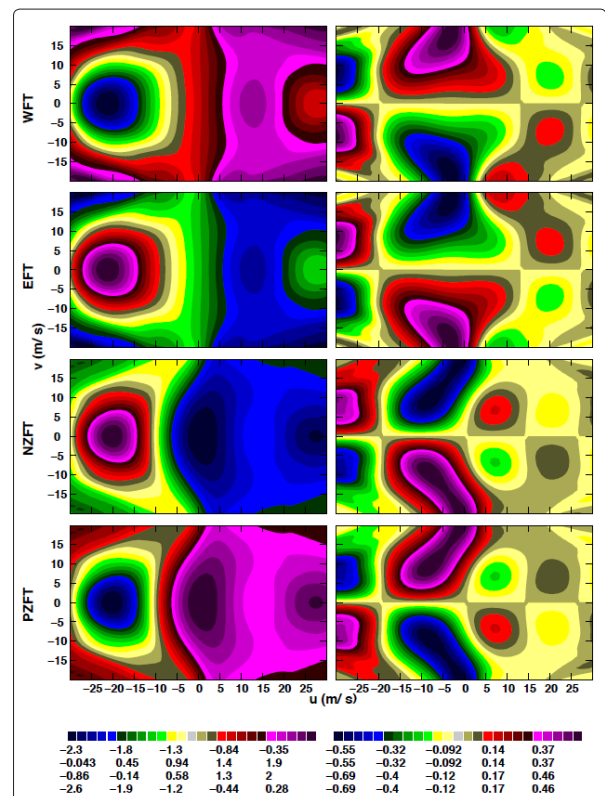
Figure 4: Mean feedback tendencies (shown in rows 1−4) for the SMG-driven winds averaged within the examination conditions

as defined in text for zonal (left column) and meridional wind (right column). X-axis and y-axis represent the present zonal and meridional flow speeds, respectively. Same color bar was shared but with different scales (in unit of mm/s/day) for rows 1−4.
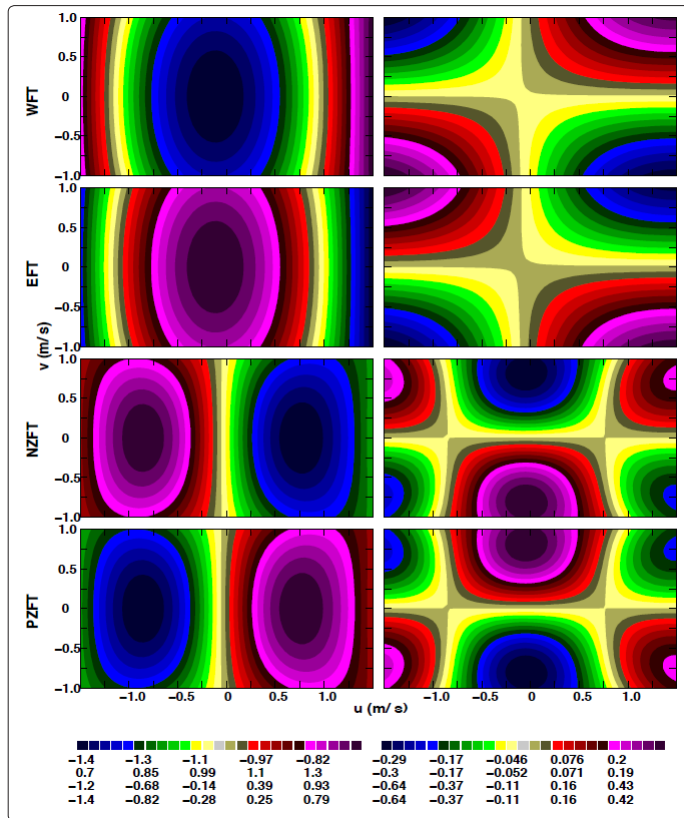
Figure 5: Mean feedback tendencies (shown in rows 1−4) for the SMG-driven currents averaged within the examination conditions as defined in text for zonal (left column) and meridional current (right column). X-axis and y-axis represent the present zonal and meridional flow speeds, respectively. Same color bar was shared but with different scales (in unit of mm/s/day) for rows 1−4.

2. The EFT produced positive zonal acceleration to enhance/ weaken the present eastward/westward flow, and the present equator-ward wind components within approximately - 15 to 10m/s was accordingly weakened, conducing to adjusting to or maintaining an El Niña phase during weakening Walker circulation. When the present zonal wind was strongly westward (<-20m/s), positive feedback occurred to enhance the present equator-ward wind component, and hindered the adjustment toward an El Niño phase. With the enhanced/weakened the present eastward/westward current, the present equator-ward currents were accordingly weakened (enhanced) if the present zonal current was eastward (westward). The enhanced present eastward current plus the weakened present equator-ward currents should conduce to adjusting to an El Niño phase. The present westward current was weakened, but the enhanced present equator-ward currents hindered the further weakening of the present westward current.

3. The NZFT/PZFT weakened/enhanced the present zonal flow and accordingly weakened/enhanced the present equator-ward flows when the present zonal flow was within approximately -20 to 5m/s for atmospheric circulations and -0.9 to 0.6m/s for oceanic circulations, conducing to adjusting to or maintaining an El Niña/a La Niña phase if the present flow was westward, but conducing to adjusting to or maintaining a La Niña/an El Niña phase if the present flow was eastward. The NZFT/PZFT could be transferred to a PZFT/NZFT if the present zonal flow was strongly westward (<-20m/s for the atmosphere, <-0.9m/s for oceans) or strongly eastward (>0.6m/s) for oceans, which accordingly enhanced/weakened the present equator-ward flow.

The WFT and EFT were symmetrical for the present meridional flows with peak values occurring when the present meridional flow was zero, were unsymmetrical for the present zonal flows with peak values occurring for some present zonal flow (e.g., of -5m/s, -20m/s, 0, and 25m/s for atmospheric circulations, and -0.125m/s, and 0.9m/s for oceanic circulations), and produced symmetrical/unsymmetrical meridional feedback tendencies for the present meridional/zonal flows. If the present winds were pure zonal and around -20m/s or 15m/s, the feedback became weak and uncertain, presenting an unstable state. Similarly, if the present oceanic currents were weak (around zero) during the WFT and EFT, or if the present currents were pure zonal and around ± 1.0 m/s, the feedback became weak and uncertain, presenting an unstable state.

Discussion
The real climate system is complicated and influenced by the interactions among factors of dynamics, thermodynamics, astronomy, and so on. Circulation adjustment under accelerations induced by the SMG is only one key link for ENSO cycles during locally and temporally controlled by weather systems in that circulations were highly correlated to ENSO cycles and a small fraction kinetic energy can transport huge amount of energy (e.g., a latent energy of up to 10,000 times the kinetic energy of wind itself can be transported by the wind, depending on air humidity and the wind speed) and a small change in circulations may cause large weather climate adjustment.

Tropical meridional/zonal wind can be an abnormally enhanced/ weakened and cause abnormal precipitations and temperatures during an abnormal phase (e.g., El Niño). It may take time for the abnormal circulations to be adjusted back to a regular phase (e.g., La Niña) with quasi-zonal circulations. On average, 0.2−1.0m/s of zonal wind anomaly and 0.2−2.0cm/s of zonal current anomaly could be induced during El Niño phases, and the SMG can produce $1.5−2$mm/s/week of acceleration for zonal wind and 0.5−1.5mm/s/ week of acceleration for zonal current, accordingly, the adjusting time to cancel the zonal wind and current anomalies is estimated as approximately 2−10 years within the atmosphere and 2−40 weeks within oceans, respectively, implying that oceanic circulations can be adjusted with the SMG much faster than atmospheric circulations, which further suggests that the SMG may serve as a trigger in adjusting circulation directions. Accumulative factors on global scales may not be omitted for the reduced adjustment time within the atmosphere.

References
1. Wang Z, D Wu, X Song, X Chen, and S Nicholls (2012) Sun-Moon gravitation-induced wave characteristics and climate variation, J. Geophys. Res., 117, D07102, doi: 10.1029/2011JD016967.
2. Z Wang, X Lin (2015) Astronomy and Climate-Earth System: Can Magma Motion under Sun-Moon Gravitation Contribute to

Paleoclimatic Variations and Earth's Heat? Adv. in Astronomy, Article ID 536829 doi: 10.1155/2015/536829.

3. Angell J K and J Korshover (1964) Quasi-biennial variation in temperature, total ozone, tropopause height, J. Atmos. Sci 21: 479-492.

4. N. Nicholls (1984) The Southern Oscillation, sea-surface-temperature, and interannual fluctuations in Australian tropical cyclone activity, International Journal of Climatology 4: 661-670.

5. Lau K M, and P H Chan (1986) The 40-50 day oscillation and the El Ni\~{no-Southern Oscillation: A new perspective. Bull. Amer. Meteor. Soc 67: 533-534.

6. Meehl G A, (1987) The Annual Cycle and Interannual Variability in the Tropical Pacific and Indian Ocean Regions. Mon. Wea. Rev 115: 27-50.

7. Kushnir Y, (1994) Interdecadal variations in North Atlantic Sea surface temperature and associated atmospheric conditions. J. Clim 7: 141-157.

8. E Tziperman, S E Zebiak, and M A Cane (1997) Mechanisms of seasonal: Enso interaction. Journal of the Atmospheric Sciences 54: 61-71.

9. Wyrtki K, (1975) The dynamic response of the equatorial Pacific Ocean to atmospheric forcing. J. Phys. Oceanogr 5: 572-584.

10. T Barnett (1984) Wea. Rev 10: 2380-2400.

11. Y Hayashi (1970) J. Meteor. Soc. Japan 48: 140-179.

12. Masaaki Takahashi (1987) A Theory of the Slow Phase Speed of the Intraseasonal Oscillation using the Wave-CISK, Journal of the Meteorological Society of Japan 65:43-49.

13. FF Jin (1997) An equatorial ocean recharge paradigm for ENSO. Part I: conceptual model, J. Atmos. Sci 54: 811-829.

14. Weisberg R H, and C Wang (1997) A Western Pacific Oscillator Paradigm for the El Nino-Southern Oscillation, Geophys, Res Lett 24: 779-782.

15. C Wang (2001) A Unified Oscillator Model for the El Ni??o???Southern Oscillation, Journal of Climate 14: 98-115.

16. Cane M A, M Munnich and S E Zebiak (1990) A study of self-excited oscillations of the tropical ocean atmosphere system. Part I: Linear analysis. J. Atmos. Sci 47:1562-1577.

17. Dake Chen, Mark A Cane, Alexey Kaplan, Stephen E Zebiak, Daji Huang (2004) Predictability of El Niño over the past 148 years, Nature 428:733-736.

18. Moore A M, R Kleeman (1999) Stochastic forcing of ENSO by the intraseasonal oscillation. J. Climate 12: 1199-1220.

19. WANG Zhiren, WU Dexing, CHEN Xue'en, QIAO Ran (2012) Adv. in Atmos. Sci., 30:1491-1506.

20. J M Wallace, P V Hobbs (2006) Atmospheric Science - An Introductory Survey 92: