PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

LINEARIZAÇÃO DAS TEMPERATURAS DO AR NO OCEANO PACÍFICO NA LINHA EQUATORIAL

LINEARIZATION OF AIR TEMPERATURES ON THE PACIFIC OCEAN ON THE EQUATORIAL LINE

DÍEZ, César Manuel[1*]; SOLANO, Carlos Javier

[1] Universidad Nacional de ingeniería. Facultad de Ciencias, Unidad de Postgrado

* Av. Túpac Amaru, 210, código postal 31, Lima – Perú
e-mail: cdiezch@uni.pe

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RESUMO

Radiações de ondas curtas sobre a atmosfera do Oceano Pacífico influenciam diretamente sua temperatura. Assim, deve-se esperar que as temperaturas do ar variem de acordo com as latitudes (por causa da radiação), por um lado; e, também, variam de acordo com a profundidade do oceano, ou seja, longitudinalmente, pelo outro lado. O Projeto TAO do Laboratório Ambiental Marinho do Pacífico (PMEL) da Administração Nacional Oceânica e Atmosférica (NOAA) dos Estados Unidos possui dados de temperaturas do ar no Oceano Pacífico de 10º Norte a 10º Sul de latitude ao longo da linha equatorial, organizada por meridianos de 95º Oeste para 135º leste. O presente projeto processa dados de temperatura meteorológica e matematicamente, para considerar sua evolução longitudinal ao longo do tempo e como os pontos da grade interagem entre si e como essas interações variam gradualmente do lado leste deste oceano para o oeste significa correlações de defasagem. No entanto, existe uma característica peculiar na temperatura do ar em uma grande região da parte oeste do oceano, onde as variações mudam acentuadamente, o que pode ser observado, novamente, pelas funções de correlação lag. O código usado para processar matematicamente e traçar esses dados foi desenvolvido através do meio da versão de estudante Matlab da MathWorks Inc.

Palavras-chave: *Correlação por atraso, linearização, temperaturas do ar, processo de dados, análise de dados, flutuaçõess*.

ABSTRACT

Shortwave radiation over the atmosphere of the Pacific Ocean influence directly on the temperature. So, it should be expected that air temperatures vary according to latitudes (because of the radiation), by one side; and, also, they vary according to the depth of the ocean, it means, longitudinally, by the other side. TAO Project of Pacific Marine Environmental Laboratory (PMEL) of National Oceanic and Atmospheric Administration (NOAA) of United States has data of air temperatures in the Pacific Ocean from 10º North to 10º South of latitude along the equatorial line, organized by meridians from 95º West to 135º East. The present project processes temperature data meteorological and mathematically, to regard their longitudinal evolution along the time and how points of the grid interact between themselves and how these interactions vary gradually from the east side of this ocean to the west means lag correlations. Nevertheless, there is a peculiar characteristic in air temperature on a great region of the West part of the Ocean, where variations change sharply, the fact that could be observed, again, by dint of lag correlation functions. The code used to process mathematically and plot these data was developed through the medium of Matlab student version from MathWorks Inc.

***Keywords**: Lag correlation, linearization, air temperatures, data process, data analysis, fluctuations.*

1. INTRODUCTION

Temperature influences considerably over many systems in the environment (Blonder & Michaletz, 2018), evaporation (Wu, Zhu, Ye, Zhou, Tang, 2019), speed of gases (Anderson, Penn, 1955; Singh, 2013), the surface of the seas.

Nevertheless, it could be affected by many parameters such as radiation balance (Ding, Zhou, Zhang, Liu, & Cao, 2018), soil moisture (Fan *et al.,* 2019). For this reason, when it is necessary to study any system, it is relevant to analyze temperature, i.e., urban analysis (Yoo, Im, Park, Quackenbush, 2018), forecasting (Curceac, Temynck, Ouarda, Chebana, Niang, 2018), model prediction (Sanikhani, *et al*., 2018), extreme weather events (Gong, Hu, 2019), research in changes in weather (Livada, *et al*., 2019), detecting changes in data and operational environment (Zvara, Szabó, Balázs, Benczúr, 2018).

This work seeks to find a physical apprehension of the temperature upon the air in the Pacific Ocean means real data process. Any variable measurement "yield different values that seemingly fluctuate and adopt a random pattern, which, at best, cluster near the actual value of the observable of interest" (Pruneau, 2017). Then, it will be necessary to develop an algorithm to process these data (Zhang, 2018), be it an interpolation means covariations (Alidoost, Stein, Su, 2018), or a statistical model such correlation model (Yang, Bai, Liu, 2019).

Interpretation of correlations is very wide, between two variables or itself. With this parameter, it can be indicated mixture fraction space that occurs in an evaporation process (Wu, Zhu, Ye, Zhou, Tang, 2019); also, it will be possible to characterize behavioral patterns (Liu *et al*., 2018), even, it will handle with the activation of fire detection in an aircraft cargo compartment (Wang *et al*., 2018). For the present work, the lag correlation will allow us to understand linear demeanor of air temperatures between more than fifty positions over the Pacific Ocean.

In general, data of air temperature in the boundary of the equatorial line in the Pacific Ocean around the equatorial line fluctuate randomly, presenting warmer and colder periodical trends. Perceive if these fluctuations synchronize between these buoys, is very difficult, basically, because the amplitude of the time series in the east of this ocean is very tiny. For this reason, to appreciate these eventualities, the lag correlation function will be used.

2. MATERIALS AND METHODS

2.1. Data

Daily observations of an air temperature of the atmosphere at 3.00 m of altitude are obtained from the grid of the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON) project of the Pacific Marine Environmental Laboratory of the National Oceanic and Atmospheric Administration project (PMEL-NOAA, 2015) grid, shown in Figure 1.

The quality control of the daily temperature dataset over the Pacific Ocean was done by the PMEL-NOAA. These data were used to analyze warm anomalies (Bond, Cronin, Freeland, 2015), in an ocean heat balance (Cronin, McPhaden, 1997), to analyze circulations (Cronin, Kessler, 2008).

Air temperature data set is used in this study from 1980 to 2016; also, the lack of data is omitted in the present process, especially in the calculation of lag correlations processes.

2.2. Anomalies in air temperature

Fluctuations of an air temperature of the atmosphere at 3.00 m of altitude of the Pacific Ocean, may be related to phenomena such ENSO, particular currents, or may influence over winds, relative humidity. It will be comprehended observing variations on time series of air temperatures (Pickard & Emery, 2007) for the grid analyzed in this project, their ranges, the amplitude of fluctuations, and trends will be understood; a process that will be presented in the Characteristics in air temperature in the Pacific Ocean section.

Also, average data sets along the time are presented in every time series plot. Its tendency might be a sign if temperatures were increasing or decreasing in time, (Zhu, Li, Jiang, 2017).

2.3. Statistical model

To analyze behaviors of air temperature related between the several buoys of the present grid, time correlation (DeWalle, Boyer Buda, 2016) processes might be applied, of each buoy respect the others, pair by pair; see Comparison to a lag correlation model section.

If the lag correlation is relatively high (values bigger than 0.75 points), it can be ensured that there is an astounding linear relationship within them (Chenchua, 2015); i.e., buoys with a huge influence on two different points. And if the lag correlation is smaller than the half point, there would be no linear relationship among the observed pair which may have a lofty possibility of being a complex or chaotic system.

Calculation of lag correlation coefficients τ, could be done by means of the relationship between covariance of two positions of buoys that measure the air temperature (i.e., x and y) with their respective standard deviation, see Eq. 1 (Emery & Thomson, 2006):

$$\tau(x,y) = \frac{\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2}=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(y_i-\bar{y})^2}} \quad \text{Eq 1}$$

where:
$\bar{x}$: mean value of an x dataset (x buoy).
$\bar{y}$: mean value of an y dataset (y buoy).
N: length of data set.
x_i: any value of x dataset.
y_i: any value of y dataset.

It can be appreciative certainly that numerator represents covariance between two data sets, and each root in the denominator represents the standard deviation of each dataset (Wilks, 2006).

3. RESULTS AND DISCUSSION:

3.1 Characteristics in air temperature in the Pacific Ocean.

Range of occurrences of air temperature, from 1990 to 2015, around the expected value, in the third part of the big ocean (east), is very dwarf. Although, due to the number of occurrences, it is troublesome to appreciate if temperatures increase in summer or decrease in winter; or how this parameter, in this part of the ocean, is affected by any phenomenon.

Average values along the time in the east side of the Pacific Ocean are straight lines; while in the west, it could be appreciated small oscillations. Perhaps, it is due because of the different size of the fluctuations in these two sides of the Pacific Ocean.

Figure 4: Area where oscillations are bigger along the Pacific Ocean.

Adapted from "Centro de Previsión de Estudios Climáticos" by http://satelite.cptec.inpe.br/repositoriogoes/goes16/goes16_web/gl_sat_rgb_baixa/2018/12/S11635397_201812141445.jpg

In this section, it could be ensuring that, in the east side of the Pacific Ocean, there is a trend that the time series oscillates with small amplitudes, mainly in the northeast, see Figure 2. This fact makes it impossible to comprehend the harmony of fluctuations.

By the other side, while displacing from the east of the Pacific Ocean to the west, it could be detected that the range of occurrences of air temperatures around the expected values, increase little by little, achieving the major fluctuations near the American Continent, especially in the 95º W meridian, as can be seen in Figure 3.

It is clearly appreciated that the size of fluctuations in the east Pacific Ocean is much smaller than the west. There appears a triangle in the west of the Pacific Ocean, Figure 4, where amplitudes of oscillations are greater than other buoys. One vertex is located in 0º N 170º W, and the other two vertices at 95º meridian at 8º N and at 8º S, respectively.

Maxima amplitudes of oscillations are remarked along the equatorial line (0º N). In this latitude, fluctuations are notoriously not harmonic; during years, some buoys seesaw upon the time average line of air temperature, Figure 5, top; while others seesaw below the time average line, Figure 5, bottom.

3.2 Comparison to a lag correlation model

It has been already seen that range of air temperature is small, notably on the eastern Pacific Ocean, and that, it does not mean that they have homogeneous behavior, or that higher values are expected in summer and lower in winter. To ascertain the behavior of fluctuations, there will be analyzed correlation functions (Emery & Thomson, 2006) between each pair of buoys in the Pacific Ocean.

Time correlations of eastern buoys respect all meridians shows that until 165E meridian, all the results have almost null values. This sight that, time series of air temperature in the East side of the Pacific Ocean are not periodical, even oscillations ranges are very small, they do not oscillate harmonically. So, it could be assured that behavior of variations of air temperatures in the east side on the Pacific Ocean respect each buoy off the grid might be chaotic, even when no phenomenon is happening, see Figure 6; because lag correlation keeps constant with an expected value of 0.

If it is delved into time correlations for buoys from East to West, there might be found that from buoys based at the meridian 165º E against buoys on the West, their ranges begin to increase, mainly with respect to neighboring buoys and just after the year 2000 but with values oscillating no bigger than 0.5 units. What it means is that the previous mentioned nonlinear system starts to break, because lag correlation indexes approaching to null values for these buoys start to increase, little by a little while moving to west ordinates. What it means is that the interaction of buoys appears while moving towards the west of the ocean.

At the buoys occupying the 180W meridian, it is descried a considerable change in the time correlation functions, the null time correlation values of the eastern buoys become to increase from the buoys in this Meridian regarding to western buoys; so there appears a grand linear trend between many western buoys cognate to 180º W during many years and with values of correlations having small anomalies over time, as shown in Figure 7. Even that, these values start to decrease from buoys in the longitude of 125º W; but on 2º S 95º W, where the lag correlation is very high again around 0.75 points (lag correlation has no units).

Observing time correlation of the buoy located at 0ºN 170º W reference to the rest of the buoys of the Pacific Ocean, there could be found higher values of correlation coefficients over time but with markedly variable fluctuations in their values for western buoys. Perchance this correlation values compared to buoys positioned at 180º W, are very similar. Again, decreasing values begin when contrast to buoys positioned from 125º W to buoys near the American continent (95º W). So far, time correlation with buoys above 5º N in the North Hemisphere and below 5º S in the South Hemisphere has very small oscillating values, but from 125º W, these values will increase slightly without a sizable factor. It means, the values achieved are still small, so they cannot be considered a linear relationship.

Analyzing time correlation of the buoys at 0º N, 140º W and 125º W respect to the others, it is seen that their correlating values begin to increase progressively in regard to buoys based on the east side (i.e. 0º N 155º W) in reference to the buoys at its west lateral, (i.e. 0º N 95º W), although the others locations present low values of lag correlations respect to the 0º N 95º W, as it may be seen in figure 8. This zone has the maxima lag correlations indices raised in the Pacific Ocean, bordering the 0.75 units.

If east side buoys of 0º N 125º W preserve high correlation values up to the buoys located at the West from the Meridian 180º W, the correlation of few buoys at 0º N 110º W with reference to the neighbor buoys settled on their east meridian are very big. They have bigger values of all the Pacific Ocean respect to interactions; mainly when comparing lag correlations with reference to the same Meridian (110º W) and related to buoys located at 95º W, they have vast values for Air Temperature on the Tao Project. This is a tremendous anomaly because if it is evaluated the correlation of 95º W, the highest values start again between the meridian of 125º W and 110º W, but their inconstancy values noticeably. It can be observed in figure 9, that they have not uniform shapes like other cases.

Based on lag correlations for air temperature between all the buoys of the Tao/Triton project, even the size of the Pacific Ocean, it is possible to find a big area where linear relationship hold sway, it means, time correlations achieve values around 0.75 units. Oscillations of time correlation values of air temperatures for the western buoys maybe constant or have very small anomalies; the fact that may imply that there is a constant flux of heat on their atmosphere.

It has seen the peculiar behavior in the temporal occurrences of air temperature in the west Pacific Ocean. This fact is corroborated in the lag correlation processes, where a considerable progressive increase is regarded to buoys of 155º W, in reference to buoys located in this particular area, especially to 95º W; while other buoys present small values of lag correlation in reference to buoys located at 95º W, see Figure 10.

4. FUTURE PREDICTIONS:

It Is known that temperatures influence over many systems, so, the study of interactions between air temperatures with relative humidity, sea surface temperatures, wind speeds, and other parameters will be relevant.

Chaotic behavior of air temperatures in the east of the Pacific Ocean has tremendous importance in front of phenomena.

There could be possible to predict air temperatures in the west of the Pacific Ocean, manly in the area shown in Figure 4.

5. CONCLUSIONS:

Time series of air temperature on the East side of the Pacific Ocean are not harmonic. No one lag correlation for air temperatures on the eastern side of the Pacific Ocean has non zero value. Lag correlations initiate to increase from 180º W, achieving higher values at 125º W. The Pacific Ocean could be seen as two oceans into a big one. One on the East Pacific Ocean (uncorrelated) and the other on the West Pacific Ocean (correlated).

Anomalies in the west Pacific Ocean have clearly pronounced while the east; especially close to the 0ºN 95º W.

Fluctuations of lag correlations of air temperatures in the Pacific Ocean are very small, presenting constant trends.

There is a triangular region in the west Pacific Ocean, where oscillations are bigger, the thing that is corroborated with the appearance of fluctuations of lag correlation functions respect to this area.

Higher lag correlation functions are found in the mentioned particular area of the west Pacific Ocean; this implies that these buoys oscillate synchronized.

6. ACKNOWLEDGMENTS:

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7. REFERENCES:

1. Alidoost, F., Stein, A., & Su, Z. Copula-based interpolation methods for air temperature data using collocated covariates. *Spatial Statistics*, **2018**, 28.
2. Blonder, B., & Michaletz, S. T. A model for leaf temperature decoupling from air temperature. *Agricultural and Forest Meteorology*, **2018**, 7.
3. Bond, N., Cronin, M., Freeland, H. & Mantua, N. Causes and Impacts of the 2014 Warm Anomaly in the NE Pacific. American Geophysical Union, **2015**, 16.
4. Chenchua, S. Analysis of detrended time-lagged cross-correlation between two nonstationary time series. *Physics Letters A*, **2015**, 8.
5. Cronin, M & McPhaden, M. The upper ocean heat balance in the western equatorial Pacific warm pool during SeptemberDecember 1992. Journal of Physical Research, **1997**, 21.
6. Cronin, M & Kessler, W. Near-Surface Shear Flow in the Tropical Pacific Cold Tiongue Front. Journal of Physical oceanography, **2008**, 16.
7. Curceac, S.; Temynck, C.; Ouarda, T. B.; Chebana, F.; Niang, S. D. Short-term air temperature forecasting using Nonparametric Functional Data Analysis and SARMA models. *Environmental Modelling and Software*, **2018**, 44.
8. DeWalle, D. R., Boyer, E. W., & Buda, A. R. Exploring lag time between monthly atmospheric deposition and stream chemistry in Appalachian using cros-correlation. *Atmospheric Environment*, **2016**, 9.
9. Ding, I., Zhou, J., Zhang, X., Liu, S., & Cao, R. Downscaling of surface air temperature over the Tibetan Plateau based on DEM. *Int J Appli Earth Obs Geoinformation*, **2018**, 12.
10. Emery, W. J., & Thomson, R. E. *Data Analysis Methods in Physical Oceanography.* COLORADO, USA: ELSEVIER. **2006**.
11. Fan, K.; Zhang, Q.; Singh, V. P.; Sun, P.; Song, C.; Zhu, X.; Shen, Z.

Spationtemporal impact of soil moisture on air temperature across the Tibet Plateau. *Science and the Total Environment*, **2019**, 11

12. Gong, J., & Hu, X. Framework for prioritizing geospatial data processing tasks during extreme weather events. *Advanced Engineering Informaics*, **2019**, 13.
13. Liu, W., Li, R., Zimmerman, M. A., Walton, M. A., Cunningham, R. M., & Buu, A. Statistical methods for evaluating the correlation between timeline follow-back data and daily process data with applications to research on alcohol and marijuana use. *Addictive behaviors*, **2018**, 36.
14. Livada, I., Synnefa, A., Haddad, S., Paolini, R., Garshashbi, S., ulpiani, G., Santamouris, M. Time series analysis of ambient air-temperature during the period 1970-2016 over Sydney, Australia. *Science of the Total Environment*, **2019**, 12.
15. Miller R. C. & Kusch P. Velocity Distribution in Potassium and Thalium Atomic Beams. Physical Review, **1955**, 8.
16. Pickard, G. L., & Emery, W. J. *Descriptive Physical Oceanography. An Introduction.* Burlington, USA: BUTTERWORTH HEINEMANN, **2007**.
17. PMEL-NOAA, N. O. *Global Marine Moored Buoy Array*. Retrieved from https://www.pmel.noaa.gov/tao/drupal/disdel/. **2015**.
18. Pruneau, C. A. *Data Analysis Techniques for Physical Scientists.* New York: Cambridge University Press, **2017**.
19. Sanikhani, H.; Deo, C. R.; Samui, P.; Kisi, O.; Mert, C.; Mirabbasi, R.; Yaseen, Z. M. Survey of differen data-intelligent modeling strategies for forecasting air temperature using geographic information as model predictors. *Computers and Electronics in Agriculture*, **2018**, 19.
20. Singh, Ashmeet. A simplistic pedagogical formulation of a thermal speed distribution using a relativistic framework. Journal of Physics, **2013**, 14.
21. Wang, L., Pan, Y.-y., Jiang, X.-p., Chen, W.-s., Lu, K.-h., & Zhang, H. j. Lag time of fire Plume in Aircraft Cargo Compartment Fires at Reduced Pressures. *Procedia Engineering*, **2018**, 7.
22. Wilks, D. S. *Statistical Methods in the Atmospheric Sciences.* USA. **2006**.
23. Wu, Y., Zhu, M., Ye, T., Zhou, T., & Tang, P. Numerical simulation of the effects of evaporation on the n-heptane/ air auto-ignition process under different initial air temperatures. *Fuel*, **2019**, 8.
24. Yang, Y., Bai, Q., & liu, Q. A probabilistic model for truth discovery with object correlations. *Knowledge-Based Systems*, **2019**, 14.
25. Yoo, C., Im, J., Park, S., & Quackenbush, I. J. Estimation of daily maximum and minimum air temperatures in urban lanscapes using MODIS time series satellite data. *ISPRS Journal of Photogrammetry and Remote Sensing*, **2018**, 14.
26. Zhang, J. J. A new greedy Kaczmarz algorithm for the solution of very large linear systems. *Applied Mathematics Letters*, **2018**, 7.
27. Zhu L., Li, Y. & Jiang, Z. Statistical Modeling of CMIP5 Projected Changes in Extreme West Spells over China in the Late 21st Century. Jurnal of Meteorological research, **2017**, 18.
28. Zvara, Z.; Szabó, P. G.; Balázs, B.; Benczúr, A. Optimizing distributed data stream processing by tracing. *Future Generation Computer Systems*, **2018**, 21.

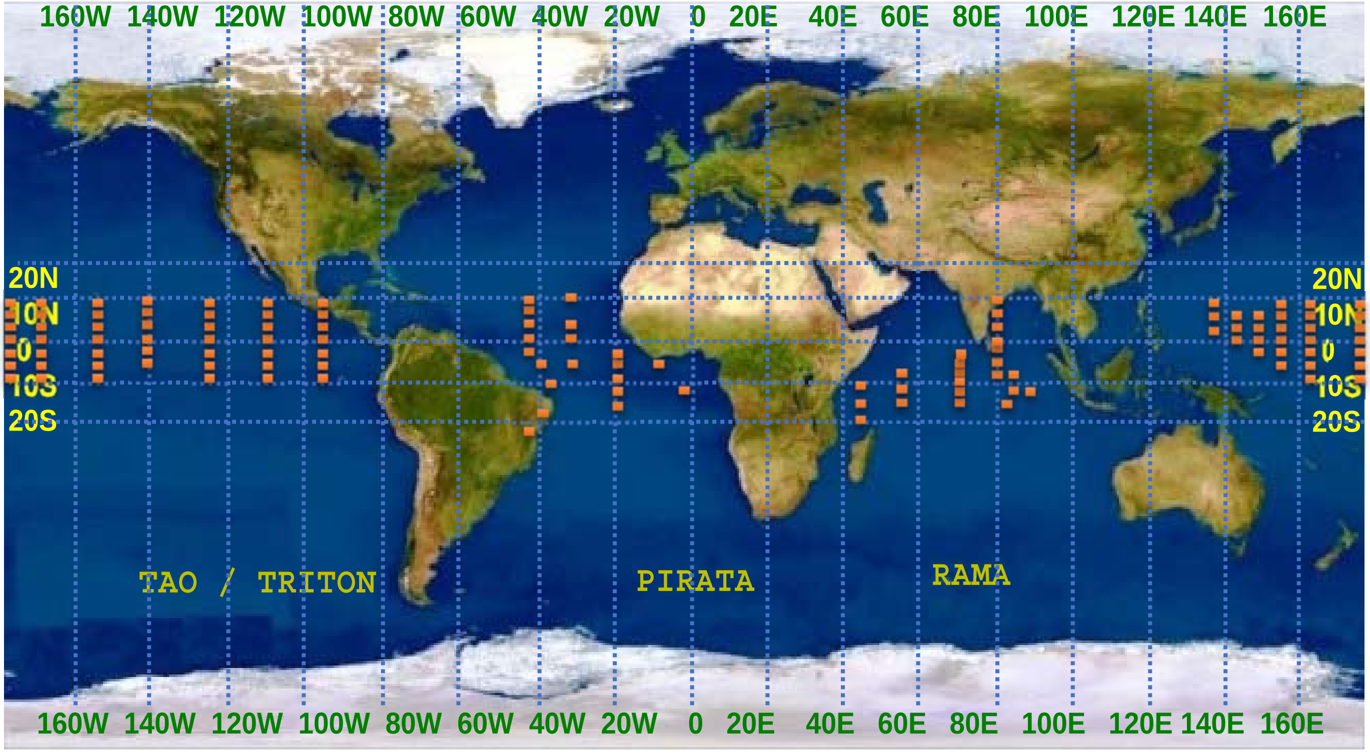

Figure 1: Location of the buoys for TAO project along the Pacific Ocean

Adapted from "Transpacific project" by http://www.transpacificproject.com/

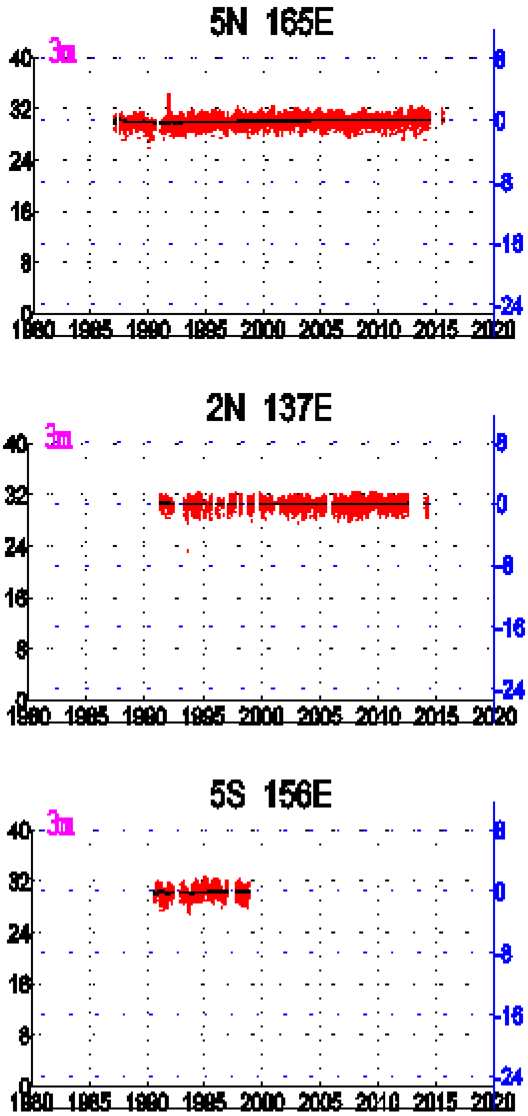

Figure 2: Time Series of air temperature for buoys in the east side of the Pacific Ocean, at the top at 5N 165E; in the middle 2N 137E; and, at the bottom 5S 156E.

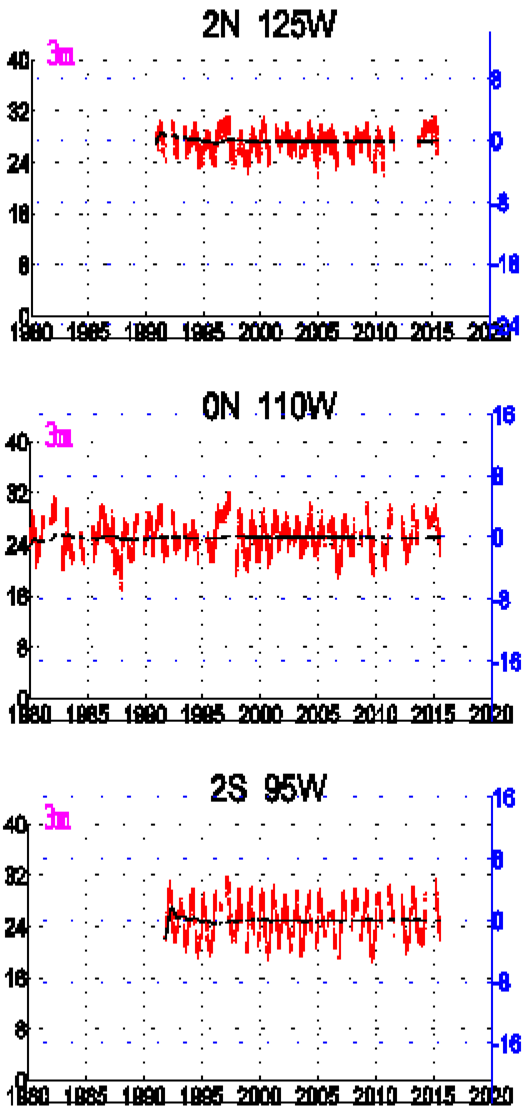

Figure 3: Time Series of air temperature for buoys in the west side of the Pacific Ocean, in the top 2N 125W; in the middle 0N 110 W; and in the bottom 2S 95W.

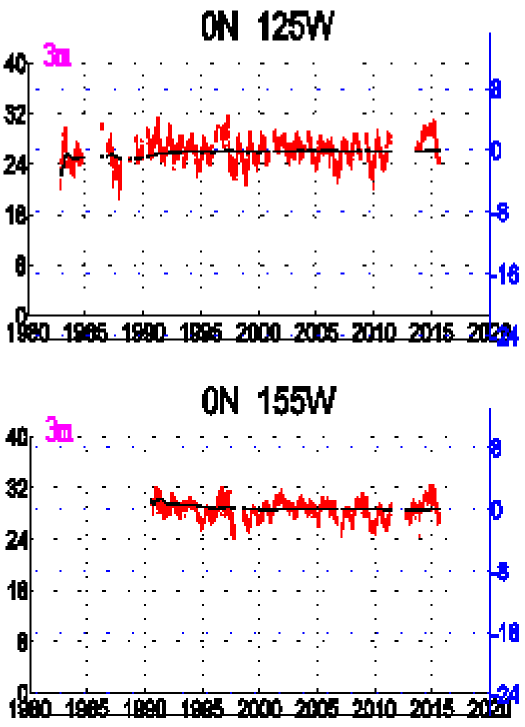

Figure 5: Time Series of air temperature with major oscillations for buoys in the west side of the Pacific Ocean, at the top at 0N 125W; and, at the bottom 0N 155W.

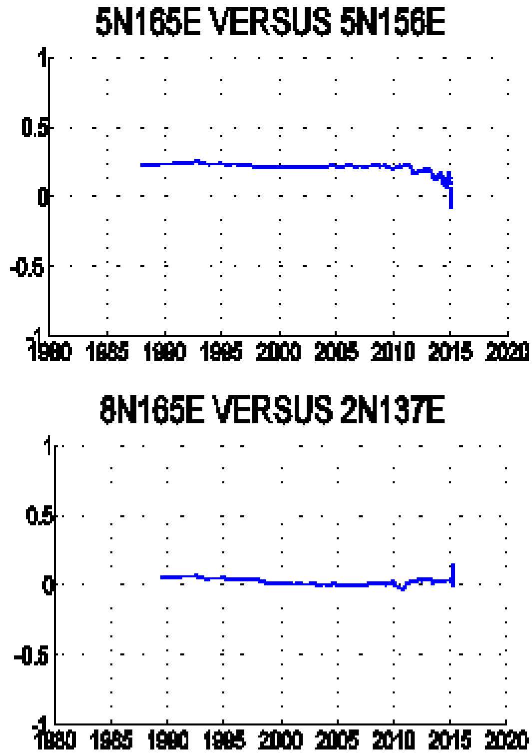

Figure 6: Lag correlation of buoys located at the northeastern side in the Pacific Ocean eastern buoys. At the top 5N 165E respect to 5N 156E, at the bottom 8N 165E respect to 2N 137E.

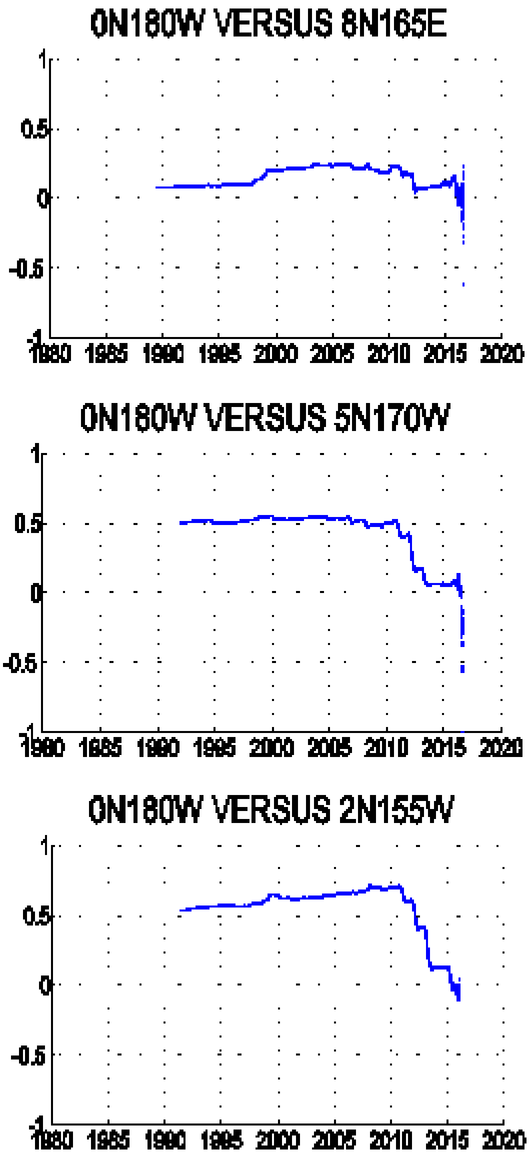

Figure 7: Lag correlation of buoys at 0N 180W respect to buoys located in the Pacific Ocean from East to West. From top to bottom: 8N 165E, 5N 170W, and 2N 155W.

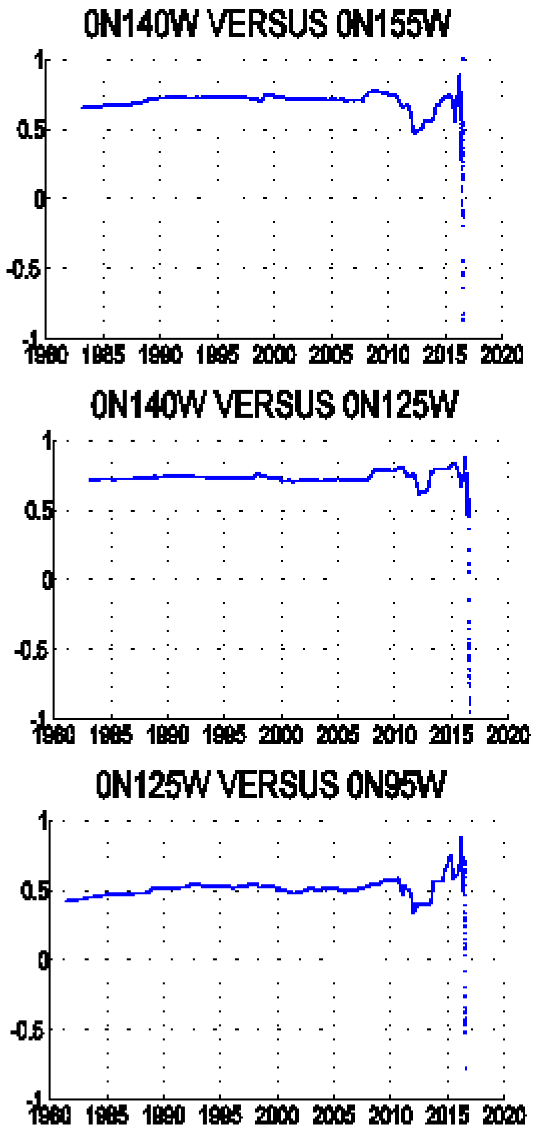

Figure 8: Lag correlation of buoys located at the major indexed region buoys in the west side in the Pacific Ocean. At the top 0N 155W respect to 0N 140W; in the middle, 0N 140W in reference to 0N 125W; and at the bottom 0N 125W respect to 0N 95W.

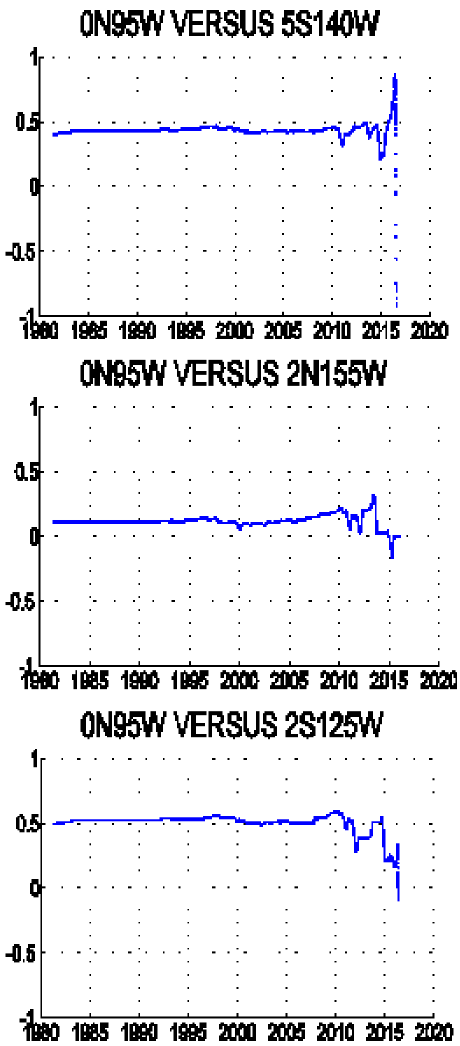

Figure 10: Decrease of lag correlation of buoys located in the west side in the Pacific Ocean. At the top 0N 155W respect to 5S 140W; in the middle, 0N 95W in reference to 2N 155W; and at the bottom 0N 95W respect to 2S 125W.