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An El Niño That "Failed to Appear", an El Niño That Was "Hiding" and a Prediction of the Next El Niño

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Abstract

This paper discusses why model predictions of El Niño events fail. We begin by commenting on a recent retrospective about the failed prediction of an El Niño during 1975 McPhaden *et al.* state that "*for all the advances in seasonal forecasting over the past 40 years, the fundamental problem of skillfully predicting the development of ENSO events and their consequences still challenges the scientific community.*" In a second paper McPhaden, this time alone, discusses the case of a "monster" El Niño "that failed to materialize in 2014". Unbeknown to McPhaden, these two climate "nonevents" have already been discussed and "explained" in some details in papers that report that the climate system consists of a series of finite time segments bounded by abrupt climate shifts. These finite time segments are phase-locked to the 2nd or 3rd subharmonic of an annual forcing. This paper will be an updated review of these "explanations". Additionally, we note that the climate system is presently (August 2017) in a phase-locked state of period 3 years that began in 2009 to make a qualified prediction: *The next El Niño will occur during boreal winter of 2018 unless this phase-locked state terminates before then.*

Keywords

El Niño, ENSO, Climate, Phase-Locked States, Climate Shifts

1. Introduction

In a retrospective paper McPhaden *et al.* [1] (hence forth Mc1) with a Sherlock Holmes-like title: "THE CURIOUS CASE OF THE El NIÑO THAT NEVER HAPPENED". These authors commented on why the climate modelers predicted in 1974 that an El Niño would occur in 1975 but it was not observed. In a second paper McPhaden [2] (hence forth Mc2), this time alone, with another cute title: "Playing hide and seek with El Niño". In this paper McPhaden points out that a "monster" El Niño that was forecasted to occur in 2014 but was also not observed.

The failure to observe these two "nonevents" is explained below.

2. Background

The central tropical Pacific Sea Surface Temperature (SST) climate index *SST3.4,* that was introduced and defined by Barnston *et al.* [3], is commonly used as a proxy to study the El Niño/La Niña phenomena. For a recent example, Douglass, Knox, *Curtis, Giese and Ray* [4] (hence forth DKCGR) have used this index to define, seek and then to find many El Niño episodes. They repotted 40 since 1872. Their list included all previously reported El Niño episodes plus new episodes. This list included those from the classic paper bY Quinn, Neal and Mayolo [5]. The Quinn *et al.* list was compiled from various historical reports of major climate anomalies in wind, ocean currents, physical changes, rain fall, flooding etc.

In order to explain the failure to observe the El Niños that modelers had forecasted as described in Mc1 and Mc2 it is necessary to review the results of prior studies on climate shifts and phase-locked states.

2.1. Climate Shifts

Tren beth [6] was among the first to comment on the Pacific mid-1970s climate shift. Ebesmeyer *et al.* [7] documented that this climate shift was seen in 40 different environmental time series.

Tsonis, Swanson and Krastow [8] considered correlation among two or more climate indices. They introduced a synchronization parameter S in which a maximum in S corresponded to known climate shifts. They applied their method to a set of 4 northern hemisphere climate indices that included index SST3.4 and reported 5 climate shifts since 1900. One of these shifts was listed as occurring during 1976-1981.

In a later paper, Douglass [9] introduced a different metric that measured also coherence or "closeness" among many climate indices that was more sensitive.

This new metric comes from the field of Topology and is called the topological diameter D. Large D means low correlation and low D means high correlation.

A more "global" set of indices was achieved by inducing a climate index from the southern hemisphere. Eighteen minima in D were found since 1873 that were identified with known climate shifts. This list included the 5 from Tsonis *et al.* One of the strongest minima occurred during 1976-1977.

Thus, climate shifts are "global" and are not confined to a particular geographic region, such as that of SST3.4. Indeed, index SST3.4 is the proxy that it purports to be.

A question arises: From what to what does the global climate shift refer to? The answer is: from one discreet climate phase-locked state to a different discreet phase-locked climate state. See next section.

2.2. Phase-Locked Climate States

What happens between climate shifts? The answer can be found by studying the index SST3.4 that in the above section was one of the "global" indices.

An exhaustive study on index SST3.4 was carried out by Douglass [10] (henceforth D2011). The annual term was removed by applying a 12-month (1 year) digital filter *r F* to SST3.4. The filtered signal is *FSST3.4.* An anomaly index free of any annual effect was defined

aSST3.4 = FSST3.4-average (FSST3.4),

where the average is from 1980 to 2010. Note. This index is different from the nino3.4 anomaly index derived from SST3.4 by the "climatology" method. Nino3.4 was not used because it is contaminated with features from the annual effect [11].

The SST3.4 and nino3.4 indices can be found at the NOAA web site [12].

Douglass showed by a novel analysis named the "autocorrelation method" that the *aSSt3.4*data series consisted of a sequence of distinct finite time segments that were phase locked to either the 2nd or 3rd subharmonic (period 2 or 3 years) of an annual forcing. The autocorrelation method also determines the end dates of each segment which are the climate shifts are determined with an uncertainty of several months. The aSST3.4 signal was sinusoidal-like where the maxima are identified with El Niños and the minima with LaNiñas. There are one or more cycles in each phase-locked segment.

Both the annual component and aSST3.4 are phase locked to an annual forcing that derives from the annual component of the solar irradiance which arises from the eccentricity of the Earth in its orbit around the Sun. Its magnitude is 11.2 w/m^2 with maximum in early January. Thus, the Sun is the "climate pacemaker" through the annual component of the solar irradiance (Note. This annual effect, that is seen everywhere, should not be confused with the much larger annual summer/winter seasonal effect that is observed in the extratropical latitudes with northern and southern hemispheres having opposite signs). See Douglass and Knox [13].

The phase-locked states are characterized be 3 discrete indices:

1) *n*: The number of annual oscillations in one oscillation of a SST3.4 (2 or 3);

2) Parity: Ortho (maximum of aSST3.4 during boreal winter; Para (maximum during boreal summer). There is only one example of *para* parity.

3) Sub index *s*: There are *n* equivalent states for each *n*. For example, *If n = 3* the equivalent sub index states are labeled 0, 1 and 2.

It is noted that these 3 indices do not completely describe the phase-locked segment. Missing is information on amplitudes and when the phase-locked state will begin or and.

An important inference

Information (the three discrete climate indices) in a particular phase-locked state is of no value in forecasting the termination date of that state nor the future beyond that unknown date.

3. Theories and Models

Are there theories or models that produce solutions that have both subharmonics and abrupt beginnings and endings as has been observed in index aSST3.4? We discuss two such examples that are instructive although they do not explain the observed aSST3.4 data.

Douglass [14] has discussed the 1-D nonlinear harmonic oscillator. Stoker (13) has shown that when this oscillator is subjected to a forcing at frequency *f* that this system is chaotic and that there are solutions at subharmonics of *f*. These solutions are stable only between a lower and upper bound of a parameter *p* that characterizes the nonlinearity. Thus, there will be abrupt beginnings and endings for certain values of *p*.

This same phenomenon was found in physical models that were based upon the Cane and Zebiak coupled atmosphere/ocean model [15] of ENSO. For example, in the model of Chang *et al.* [16], there is an annual forcing and a nonlinear heat flux term comprising a chaotic system. As the heat flux is varied solutions appear at subharmonics of 1.0 cy les/year. These solutions appear only when the heat flux is between lower and upper values.

The aSST3.4 data have the phase-locked segments and abrupt beginnings and endings in common with these two examples. In addition, Douglass [11] has shown that aSST3.4 is chaotic.

We next consider the two cases of "misbehaving" El Niños.

4. The El Niño "That Did Not Happen"

This climate "nonevent" is well documented and is usually referred toas *"The 'aborted' event of 1975*". A review of the history of reports on this unusual climate event is given in D2011a. An explanation of the failure to observe the predicted El Niño was also given in D2011a. A summary of that explanation is now given.

Figure 1 is an update of a figure from D2011a. The plot shows a SST3.4 from 1967 to 1985 that includes the time interval around the "aborted" event. The climate index *aSST3.4* is shown in red. There are two phase-locked segments in this plot. The date range is determined by the autocorrelation method and is indicated by shaded rectangles. Phase-locked state 6 begins at about May 1969 and ends at about January 1975. It is described by indices: n = 3; parity = *ortho* and sub index *s* = 2. The aSST3.4 index is seen as sinusoidal—like with two maxima during boreal winters of 1969 and 1972. These maxima are El Niño episodes labeled #26 and #27 from the DKCGR list.

Phase-locked state 7 begins at about January 1975 and ends at about June

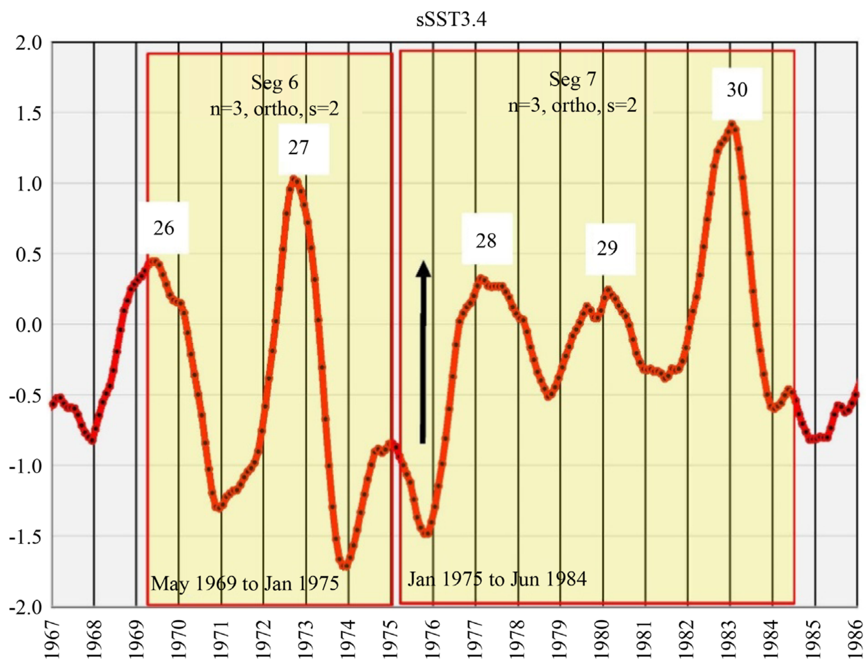

Figure 1. The El Nino/La Nina anomaly index aSST3.4 is shown in red. The date range of phase-locked segments 6 and 7 are shown as shaded rectangles. The various maxima (El Nino episodes) are indicated by the numerical sequence in the list of DKCGS. There are two El Nino episodes in segment 6 and three in segment 7. The black arrow indicates when the "aborted" El Nino was supposed to occur.

1984. The indices are the same as for segment 6 except that sub index$s$ = 0. The aSST3.4 signal shows maxima during boreal winters of 1075, 1978 and 1981. These maxima are El Niño episodes #28, #29 and #30 from the list of DKCGR.

The 3-year oscillation in segment 6 with maxima in boreal winters of 1969 and 1972n indicates that a 3rd maximum will occur during 1975. Unfortunately for the climate modelers of 1974 a climate shift occurred at about January 1975 and the El Nino of 1975 "never happened". Bad luck for the modelers! A black arrow show when the predicted El Nino would have occurred.

5. Does Nature "Play Hide and Seek"?

McPhaden (2) published another paper: "Playing hide and seek with El Niño". Here McPhaden is commenting on the fact that the forecasting models being used by climate scientists predicted that a "monster" El Niño would occur in 2014 but was not observed. To quote McPhaden:

"So, it was doubly perplexing when, first, an Incipient El Niño of major proportions loomed large on the horizon in early 2014, only to disappear suddenly from the radar screen …"

The explanation is below.

Douglass and Knox [13] (hence forth DK2015) carefully studied index aSST3.4 over this time period. They determined as of the date of submission

(August 2014) that the climate system was in a phase-locked state of period 3 years that began at about March 2009.This new phase-locked state was labeled #11.

Figure 2 shows an updated plot of a figure from DK 2015. The plot goes from 2000 to the present (July 2017). Two phase-locked segments (#10 and #11) are indicated by shaded rectangles. Segment 10 is an n = 2, parity = ortho state. One sees a sinusoidal-like oscillation with three maxima at boreal winters of 2002, 2004 and 2006, spaced 2 years apart. These 3 maxima are El Niño episodes #35, #36 and #37 from the DKCGS list. This phase-locked state ends abruptly at about March 2008. Our interest, however, is in phase-locked state #11.

Using the data after March 2008 to the end at the date of submission DK2015 determined that the climate system entered a new period 3-year phase-locked state (#11) that began at about March 2009. This state showed maxima in aSST3.4 during boreal winters of 2009 and 2012. These are El Niño episodes #38 and #39 from the DKCGS list.

Based upon the 3-year periodicity Douglass and Knox stated in August 2014:

"If the climate system remains in this phase-locked state the next maximum [El Niño] *will not occur until about 2016* [boreal winter of 2015]."

This statement <u>excludes</u> an El Niño occurring during 2014. An El Niño (#40) did occur during boreal winter of 2015 as was predicted.

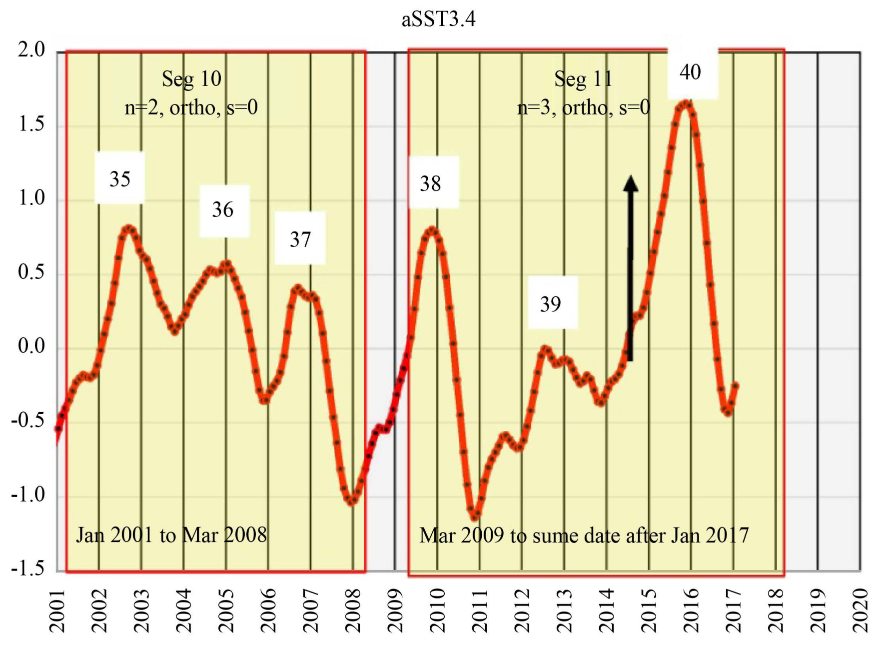

Figure 2. The El Nino/La Nina anomaly index aSST3.4 is shown in red. The date range of phase-locked segments 10 and 11 are shown as shaded rectangles. The various maxima (El Nino episodes) are indicated by the numerical sequence in the list of DKCGS. There are three El Nino episodes in segment 10 spaced two years apart and three in segment 11 spaced three years apart. The black arrow indicates when the "hiding" El Nino was supposed to occur. The qualified prediction of a 4th El Nino occurring during boreal winter of 2018 is discussed in the text.

A black arrow in Figure 2 indicates when the predicted El Niño would have occurred.

6. Discussion

Although climate scientists were "seeking" El Niños, it is clear that nature was not "hiding" them. They were, in fact, "hiding in plain sight "but not where the modelers expected. The reason for not finding them was that the modelers had not understood the climate system well enough to predict what will happen. This was true 40 years ago and according to McPhaden (2) was also true in 2014.

In retrospect, the modelers in 1974 were unlucky in that the phase-locked state ended right after *their* prediction. The modelers of 2014 do not have this "excuse".

7. Prediction of an El Niño from the Data

Qualified prediction of future El Niños can be made from the aSST3.4 index without the use of any model. Here are the steps. Use theaSST3.4 index that was successfully used to seek and find 40 El Niños. Then:

Determine the end date *D* of the last complete phase-locked state.

If the data after *D* is less than 24 months in length you cannot know what state the system is in. It may be chaotic or contain the beginning of a new phase-locked state.

When the end of the data is about *D*+ 36 months do an autocorrelation analysis. The state of the climate system may be revealed. If not, you must wait for more data to accumulate-perhaps 12 months.

Application of the above procedure to forecast the future

The date of the last phase-locked state (segment 10) was about March 2008. Analysis of the data after that date using the autocorrelation method shows that a new phase-locked state (#11) of period 3 years began at about March 2009 and continues to end of the aSST3.4 data (SST3.4 ended in July 2017; aSST3.4 ended in January 2017). Three maxima (El Niño Episodes) have been observed during boreal winters of 2009, 2012 and 2015.

At this date (August 2017) one can make a qualified forecast.

The next El Niño episode will occur during boreal winter of 2018 unless the present phase-locked state terminates before then.

This forecast is only about dates and states nothing about the magnitude. Here is where models could really be useful if they could predict the magnitude of an *El Niño episode* and also the termination (climate shift) of a phase-locked state.

If the 4th *El Niño* is observed in boreal winter of 2018 t and if the climate system remains in the *period* 3-year state then a 5th *El Niño* could occur during boreal winter of 2021.

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