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Influence of the 2015-2016 ENSO event on length-of-day variations.

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❶ Objective

To regionally characterize the contributions of the relative angular momentum to the AAMz during a significant event such as ENSO. The disturbances, mostly generated by the motion terms, cause variabilities with periods between 2-7 years and amplitudes up to 1 millisecond in LOD .
ENSO is the trigger of atmospheric teleconnections affecting the global atmospheric circulation. A study of the regional variability will allow us to analyze the relative impact of the different atmospheric events on a large scale in a changing scenario due to anthropogenic forcing in the 21st century.

❷ Introduction

De Viron and Dickey (2014) studied the different types of El Niño Southern Oscillation (ENSO: EP, eastern Pacific and CP, central Pacific) and their influence on LOD variations. They conclude that the EP kind of ENSO is more than twice as large as CP and that explains the different impact of the ENSO events on Earth rotation. Lambert et al, (2017) asseverated that although the three extreme ENSO events (1982-83, 1997-98 and 2015-16) produced comparable answers in LOD excitations (near 1 ms.), the ENSO 2015-16 is a mix kind EP-CP.

El Niño Southern Oscillation

(sources:https://ggweather.com/enso/oni.htm; https://www.esrl.noaa.gov/psd/enso/dashboard.html; http://www.cpc.noaa.gov/products/analysismonitoring/ensostuff/ensoyears.shtml)

The Oceanic Niño Index (ONI) is used to identify and distinguish El Niño (warm) and La Niña (cool) events in the tropical Pacific. It is the running 3-month mean Sea Surface Temperature (SST) anomaly for the Niño 3.4 region.

- El Niño: characterized by a positive ONI greater than or equal to +0.5°C.
- La Niña: characterized by a negative ONI less than or equal to -0.5°C.

These thresholds must be exceeded for a period of at least 5 consecutive overlapping 3-month seasons.

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2007	0.7	0.3	0.0	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.4	-1.5	-1.6
2008	-1.6	-1.4	-1.2	-0.9	-0.8	-0.5	-0.4	-0.3	-0.3	-0.4	-0.6	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.1	0.4	0.5	0.5	0.7	1.0	1.3	1.6
2010	1.5	1.3	0.9	0.4	-0.1	-0.6	-1.0	-1.4	-1.6	-1.7	-1.7	-1.6
2011	-1.4	-1.1	-0.8	-0.6	-0.5	-0.4	-0.5	-0.7	-0.9	-1.1	-1.1	-1.0
2012	-0.8	-0.6	-0.5	-0.4	-0.2	0.1	0.3	0.3	0.3	0.2	0.0	-0.2
2013	-0.4	-0.3	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3
2014	-0.4	-0.4	-0.2	0.1	0.3	0.2	0.1	0.0	0.2	0.4	0.6	0.7
2015	0.6	0.6	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.5	2.6
2016	2.5	2.2	1.7	1.0	0.5	0.0	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6
2017	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.1	-0.4	-0.7	-0.9	-1.0
2018	-0.9	-0.8	-0.6	-0.4	-0.1	0.1	0.1	0.2	0.4	0.7	0.9	0.8
2019	0.8	0.8	0.8	0.8	0.6	0.5	0.3					

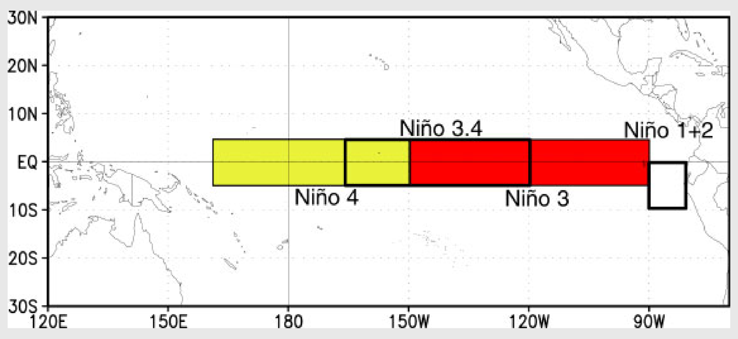


Figure 1: (Left) Historical table of El Niño (EN, red) and La Niña (LN, blue) episodes based on the ONI (source: https://origin.cpc.ncep.noaa.gov/products/analysismonitoring/ensostuff/ONIv5.php). (Right) El Niño regions.

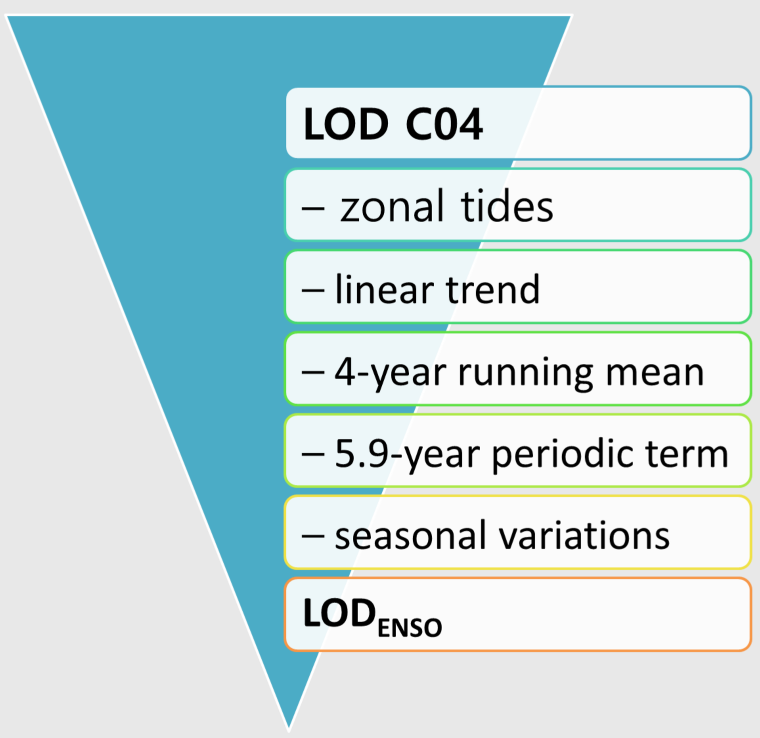
Two types of El Niño can be classified according to the interaction of the Tropical Pacific Ocean.

- Eastern Pacific (EP) type: interaction with the Walker circulation which is caused by the pressure gradient (high pressure system over the eastern Pacific Ocean and a low pressure system over Indonesia.). Traditional EN. The temperature anomaly is in El Niño areas 1 & 2.
- Central Pacific (CP) type: interaction with the Hadley circulation (air rising near the Equator, flowing poleward at a height of 10-15 kilometers, descending in near 30°latitude, and then returning equatorward near the surface). Non-traditional EN or EN "Modoki". The temperature anomaly is in El Niño area 3.4.

❸ Data

We used the Atmospheric Angular Momentum (AAM) approach: considering that the angular momentum of the system Earth is conserved, we estimated the Earth rotation change. In this case: the change in the angular velocity of the Earth with respect to an inertial frame (the variation to the length-of-day, LOD).
LOD series were taken from the International Earth Rotation and Reference System Service (IERS) Earth Orientation Parameters (EOP) 14 C04 series. This multi-technique combined series is publicly available at the IERS Earth Orientation Center web site (https://datacenter.iers.org/eop.php).

The AAM employed for this study were determined from the operational analysis of the European Centre for Medium-Range Weather Forecasts (ECMWF). Mass and motion terms were calculated as volume integrals over pressure increments as described in Schindelegger et al. (2011).



The LOD time series (2010-2018) was processed to remove the effects of zonal tides, secular tidal breaking, post-glacial rebound and variations in the fluid core angular momentum (Lambert et al., 2017), as well as seasonal variations (annual and semi-annual). These reduction steps are summarized schematically in Figure 2. The 5.9-year periodic function was estimated from a longer LOD time series (1962-2019).

Figure 2: Scheme of process on LOD data.

El Niño 3 (N3) and El Niño 4 (N4) indexes are provided by the Earth System Research Laboratory of the NOAA Climate Prediction Center.

❹ Method

$$AAM_z^{motion} = \int_0^{P^{surf}} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \int_0^{2\pi} \frac{r(\theta,\lambda)^3}{g} u(P,\theta,\lambda) \cos^2(\theta)\, d\lambda\, d\theta\, dP;$$

$$AAM_z^{mass} = \int_0^{P^{surf}} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \int_0^{2\pi} \frac{r(\theta,\lambda)^4}{g} \cos^3(\theta)\, d\lambda\, d\theta\, dP$$

Let's call $Z(i,j,t)$ to the elements of AAM $_z^{motion}$ after performing the vertical integration from surface till ∞. Then, $\overline{Z(i,j)}^A = \sum_{t_A} \frac{Z(i,j)}{N_A}$

where A = EN, LN or N (Neutral); t_A and N_A refer to time and number of values, respectively.

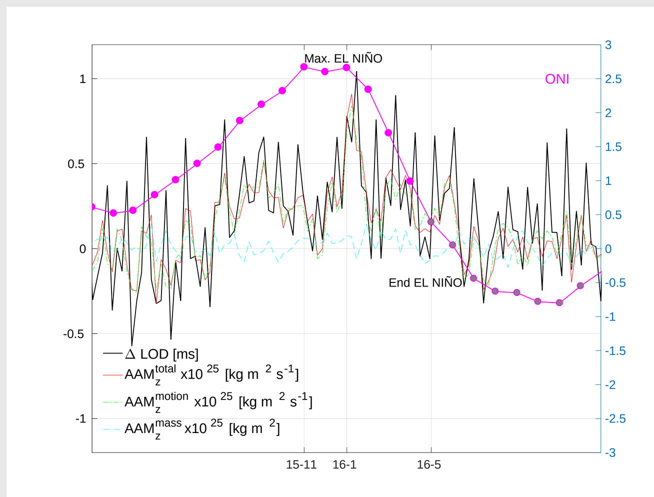
The elements of the mean AAM $_z^{motion}$ anomalies are

$$\Delta Z^{EN}(i,j) = \overline{Z}^{EN}(i,j) - \overline{Z}^{N}(i,j)$$
$$\Delta Z^{LN}(i,j) = \overline{Z}^{LN}(i,j) - \overline{Z}^{N}(i,j)$$

g = mean gravity acceleration
θ, λ = latitude and longitude
P = atmosph. pressure
u = zonal winds

$$NEP = N3 - \alpha N4 \qquad \alpha = \begin{cases} 2/5 & \\ 0 & \text{if } N3.N4 < 0 \end{cases}$$
$$NCP = N4 - \alpha N3$$

❺ Results



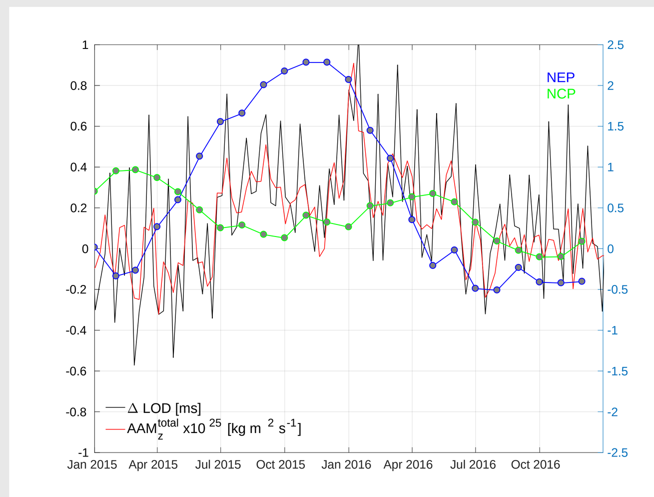
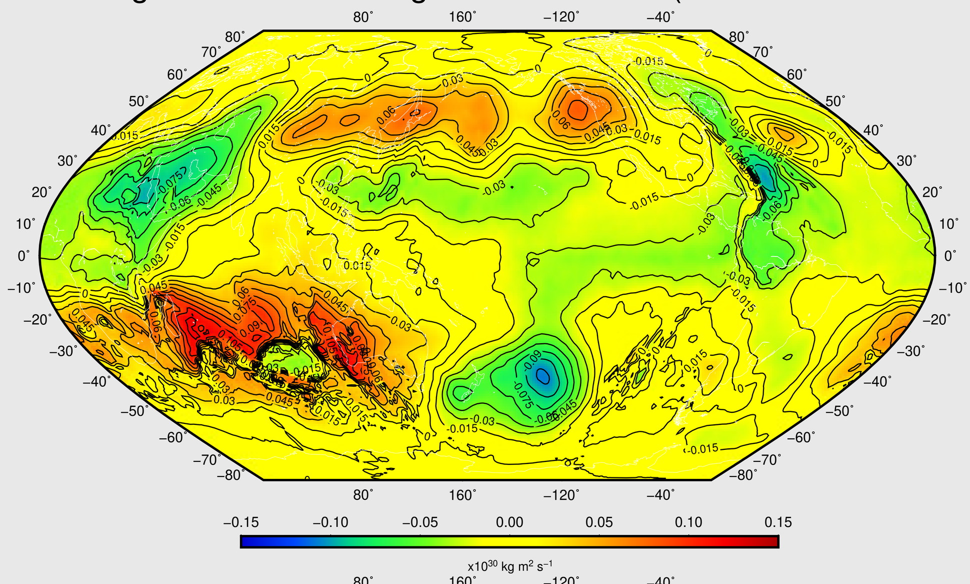


Figure 3: (Left) LOD ENSO, AAMz and ONI. As expected the mass term of AAM$_z$ is 2 orders of magnitude smaller than the motion term. (Right) The detrended length-of-day time series (LOD ENSO) along with AAMz , and the EP and CP anomalies as defined by Ren and Jin (2011) for the period 2015-2016. Notice that a value of NEP is almost 5 times larger than NCP during austral summer (maximum of ENSO 2015-16).

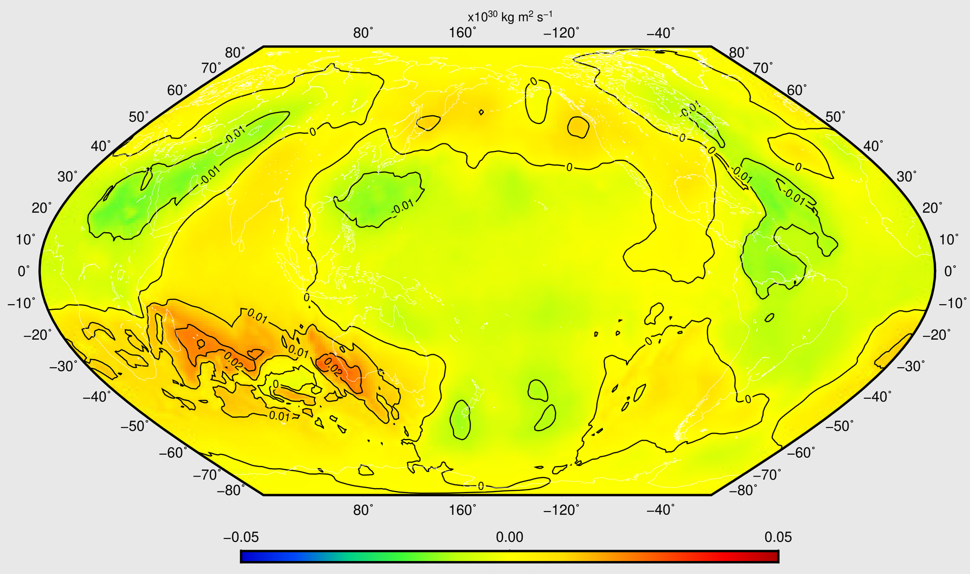


El Niño

Mean AAM $_z^{motion}$ anomalies for the period t_{EN} = Jan 1, 2015- May 1, 2016

Neutral

t_N = May 2, 2016- Aug 1, 2016



La Niña

Mean AAM $_z^{motion}$ anomalies for the period t_{LN} = Aug 2, 2016- Dec 31, 2016.

❻ Discussion

We present preliminary results of the regional analysis of AAM$_z$ variations due to ENSO 15-16. From Figure 3, we can see that NEP is the biggest and NCP values are less than 0.5 during the austral summer 15-16. (from Ren and Jin (2011) NEP < 0.5 during a CP event). Moreover, the maximum anomalies of the AAM$_z^{motion}$are in the South Indian Ocean as expected for a traditional ENSO. Nevertheless, from Lambert et al. (2017) the absence of mountain torque exerted by the solid Earth over the atmosphere reveals a mix event.

Future work

ENSO has been shown to have a strong impact on different parts of the planet through atmospheric teleconnections. Such teleconnections are sensitive to the longitudes and different according whether an EP or CP event is (Yeh et al., 2018). In order to continue and advance with this work our next steps will be:

- To analyze the differences between the teleconnections for EP and CP events from global meteorological parameters, understanding their impact on the conservation of the Earth's total angular momentum.
- To apply space-time spectral analysis techniques (PCA or 2D-FFT).

❼ References

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