Institut für Meteorologie

Freie Universität Berlin

Ocean-Atmosphere Effects on Intraseasonal & Interannual Length-of-Day (LOD) Variations

E. Lehmann, G.C. Leckebusch, U. Ulbrich and P. Névir

Contact: elfrun.lehmann@met.fu-berlin.de, Institut für Meteorologie, Carl-Heinrich-Becker-Weg 6-10, 12165 Berlin, www.met.fu-berlin.de, Phone: +45 30-838-71154

Introduction

Intraseasonal and interannual variations in the Length of Day (LOD) are caused by various phenomena of the coupled ocean-atmosphere system that yet need to be clearly identified and quantified. This study assesses variations in the wind-driven axial atmospheric angular momentum (AAM) that are proportional to LOD variability on intraseasonal and interannual time scales. For this purpose we examine the frequency behavior of the LOD (IERS' EOP C04) excited by large scale atmospheric circulation patterns using ERA40 reanalysis data (1962-2001). ENSO is a prominent coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales.

Several studies relate changes in the interannual LOD variability to the El Nino/Southern Oscillation phenomenon due to strong wind anomalies associated with ENSO events. For that reason, this study performs a detailed investigation of LOD cycles by using filters to determine the relation of dominant modes for intraseasonal and interannual periods of LOD variations and corresponding ENSO events. Changes in the LOD signal are explored by relating ENSO sensitive parameters, such as NINO3.4 sea surface temperatures (SST) to semi-annual, annual and interannual variations in the relative AAM and the LOD for selected ENSO events.

Correlations between annual and interannual amplitudes of the LOD and selected parameters of the ocean-atmosphere system (SST, AAM) demonstrate their significant but highly varying effect on the LOD variability. A cross wavelet analysis confirms these results. However, the highly variable influence of ocean and atmosphere on the variability of LOD in relation to atmospheric background processes needs to be further investigated.

Webpage Earth Rotation Portal: ***http://www.erdrotation.de (Project P10)***

Data & Methods

Times Series & Fields

- **Length-of-Day (LOD):** IERS EOP C04
- **Atmospheric angular momentum (AAM),** computed using wind data from ERA-40 reanalysis, ECMWF.

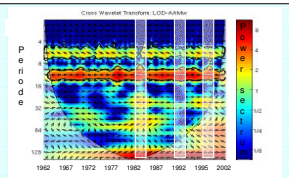
$$M_{rel} = \frac{R^3}{g} \int_{1}^{1000} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \int_{0}^{2\pi} u \cos^2 \varphi \, d\lambda \, d\varphi \, dp$$

(Barnes et al., 1983, Proc.Roy.Soc., London, A, 387, 31-73)

ENSO Index:

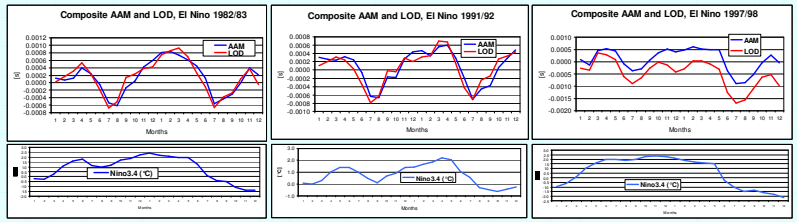
NINO3.4 SST (tropical sea surface temperatures and associated anomalies observed in the particlar ENSO region of NINO3.4)

Semi-annual & annual relation AAM - LOD

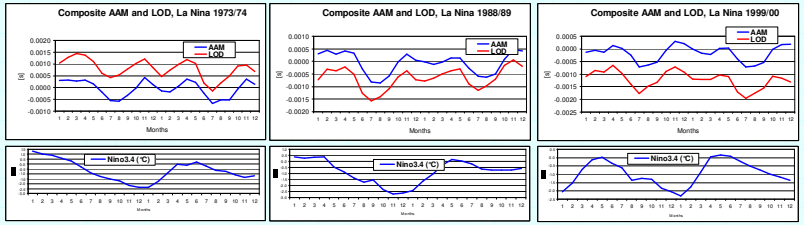


Cross wavelet transform of LOD and AAM times series (1962-2001). Thick black contour indicates 5% sign. level against red noise. Lighter shades designate edge effects. Arrows indicate relative phase relationship: in-phase: pointing right; anti-phase pointing left. AAM leading LOD by 90° pointing straight down.
The annual cycle (12 months period) displays prominent regions of high common power spectra for LOD and AAM variability. LOD oscillations are manifested in AAM variability within the annual band in particular during dominant El Nino events (1982/83, 1991/92, 1997/98).

Dominant ENSO events compared to NINO3.4 SST



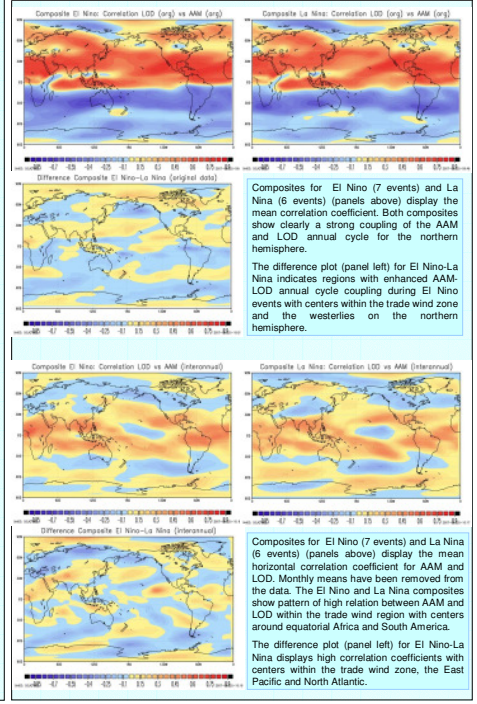
The 2-year cycle of selected strong El Nino events is compared to amplitudes of tropical NINO3.4 sea surfce temperatures (SST). The AAM and the LOD cycle clearly show that their amplitudes are forced by variations in the SST. AAM and LOD display highly correlated amplitudes with maxima from late winter to spring (December-March). Following an increase in SST a second maxima can be observed in both data around fall (September-October).



Selected dominant La Nina events are presented indicating a semi-annual cycle in their amplitudes. However, AAM and LOD annual variations does not seem to be closely related to the annual cycle of tropical NINO3.4 sea surface temperatures (SST). The first maxima in the AAM and LOD data appear around late winter (February-March) following an increase in SST amplitude. A second maximum can be observed for fall /early winter (October-December) when SST decreases to a minimum.

ENSO events are classified into weak (0.5-0.9°) moderate (1.0-1.4°) and strong (>1.4°) events based on observed SST anomalies in the tropical NINO3.4 region (NOAA, 2003).

Correlation Composites for ENSO Events



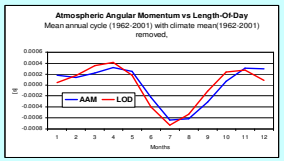
Composites for El Nino (7 events) and La Nina (6 events) (panels above) display the mean correlation coefficient. Both composites show clearly a strong coupling of the AAM and LOD annual cycle for the northern hemisphere.

The difference plot (panel left) for El Nino-La Nina indicates regions with enhanced AAM-LOD annual cycle coupling during El Nino events with centers within the trade wind zone and the westerlies on the northern hemisphere.

Composites for El Nino (7 events) and La Nina (6 events) (panels above) display the mean horizontal correlation coefficient for AAM and LOD. Monthly means have been removed from the data. The El Nino and La Nina composites show pattern of high relation between AAM and LOD within the trade wind region with centers around equatorial Africa and South America.

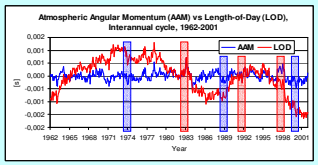
The difference plot (panel left) for El Nino-La Nina displays high correlation coefficients with centers within the trade wind zone, the East Pacific and North Atlantic.

Mean annual cycle of AAM & LOD



Comparing different cycles of LOD and AAM: For the mean annual cycle monthly averages were taken for a time period of 1962-2001. From the interannual cycle monthly mean averages have been removed from the original time series. Amplitudes of AAM and LOD show a close relation in their mean annual cycle. When horizontal westerly winds increase in strength AAM amplitudes are largest for spring and fall. At those times Earth's rotation slows down due to conservation of the total angular momentum. As a result LOD increases following closely variations in AAM. The mean annual cycle shows AAM lagging behind LOD variations by about 1 month.

Interannual time series of AAM & LOD



(AAM in [s]; Rosen & Salstein, JGR,88,1983)

The LOD time series (monthly means removed) still contains decadal contributions from core-mantle and ocean angular momentum variations. However, both time series show similar amplitudes during El Nino events. Color bars mark strong El Nino (red) and La Nina (blue) events.

		Correlation coefficient
Mean annual cycle	LOD-AAM	0.93
Interannual	LOD-AAM	0.34

Findings & Outlook

- AAM and LOD variability display regions of high common power spectra in the annual and semi-annual band.
- Amplitudes of the mean annual cyle of AAM and LOD are closely related; AAM lagging variations in LOD by about 1 month. The physical background processes causing this lag yet have to be investigated.
- Due to decadal variations in LOD the correlation coefficient for the AAM and LOD (monthly means removed) is low (r=0.34) compared to the correlation coefficient for the mean annual cylce (r=0.93).
- During strong El Nino periods SST forces the annual cycle of AAM and LOD while during strong La Nina years the semi-annual cycle of AAM and LOD is enhanced.
- Correlation composites of AAM and LOD for El Nino and La Nina events were used to identify typical patterns of AAM during ENSO events. The global correlation of AAM and LOD is dominated by high correlation coefficients on the northern hemisphere.
- Further analysis focus on underlying processes and mechanisms (e.g. meridional momentum transport) to investigate
  - causes of this inter-ENSO variability,
  - relate patterns of AAM meridional transport to variations in large-scale northern hemispheric circulation patterns.
- Analyse ocean-atmosphere model simulations
  - to validate model simulations with observed AAM and LOD data,
  - assessing future ocean-atmosphere simulations to investige LOD-AAM relation under climate change.