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GFZ Helmholtz Centre Potsdam

Long-term ERP time series as indicators for global climate variability and climate change (ERP-CLIVAR)

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Introduction

This study assesses whether variations in observed Earth rotation parameters (ERPs) such as length-of day (LOD IERS EOP C04) and polar motion (PM IERS EOP C04) can be used as indicators for climate change and climate variability. On interannual time scales the El Niño-Southern Oscillation (ENSO) dominates climate variability. ENSO is a coupled ocean-atmosphere phenomenon originating in the equatorial Pacific. Our analysis suggests a varying effect of atmosphere and ocean on observed ERPs on interannual time scales. Anomalies of observed parameters associated with the atmosphere and ocean are correlated with LOD and PM variability and related to possible physical background processes. Analyses on present data (ERA40 reanalysis, 1962-2000) suggest variations in location and strength of jet streams as the main source of the varying ENSO signal on observed LOD. While strong El Niños affect the relation between observed LOD-AAM (relative atmospheric angular momentum) differently strong, corresponding results for the relation AAM-SSTs (ocean sea surface temperatures) are also obtained by coupled ocean-atmosphere model scenarios (ECHAM5-OM1) for present times (20C) and for climate warming (A1B) and climate variability (PICTRL). While changes in atmospheric patterns dominate variations in observed LOD, the ocean mainly influences changes in polar motion. We apply an ocean model (OMCT) to assess excitations of LOD and polar motion by the ocean. On interannual time scales observed ERPs (effects of atmosphere and hydrology removed) compare well to OMCT simulated OAMmass (IB) with 82% w.r.t. polar motion.

Project web page: **www.erdrotation.de,** Project P10

Ocean and atmosphere excitation of ERPs for present times (OMCT model, ERA40 reanalyses)

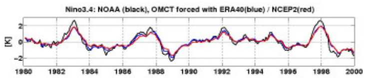


Fig. 1: Nino3.4 SST: Observations (NOAA black) and OMCT simulations, ERA40 forcing blue, NCEP2 red.

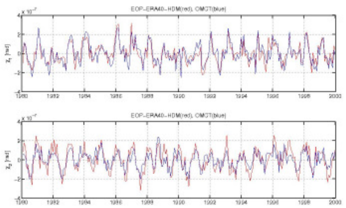


Fig 2: Polar Motion: Diff. ERP-AAM-HAM (red), OMCT simulated OAM (blue).

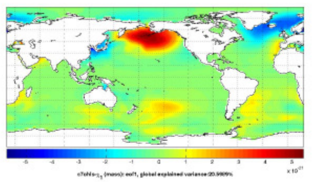


Fig 3: Empirical Orthogonal Function of OMCT-simulated OAM (mass term of $X1$ component) for 1980 – 2006. Most dominant impact of OAMmass on $X1$ in extratropics.

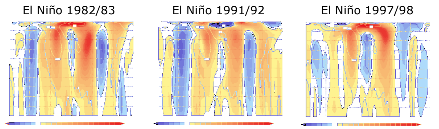


Fig. 4: Zonal means (90°S–90°N) of zonal wind for 3 strong El Niños. Jet stream regions (30°; 60°): strong zonal wind maxima in upper troposphere (>200 hPa).
Data: Peak El Niño months, monthly means removed, ERA40 reanalyses, (ECMWF, UK, Reading).

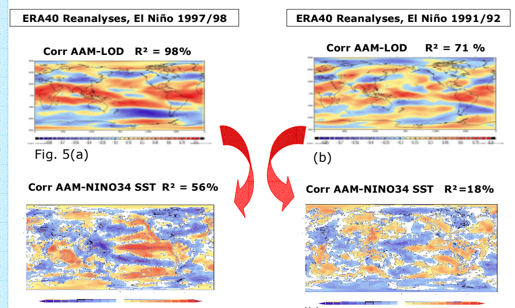


Fig. 6(a) (b)

Fig 5: (a,b) Regional distribution of correlation coefficient for obs. LOD vs AAM for 2 strong El Niños. (Fig. 6) Corresponding correlation patterns AAM vs NINO3.4 SST indicating El Niño warm tongue for 1997/98 El Niño (a).
Data: LOD (IERS EOP C04), AAM (ERA40 reanalyses), monthly means removed, all signals concerning core-mantle interactions removed.

Excitation of ERPs in coupled ocean-atmosphere (ECHAM5-OM1) simulations

Explained variances between AAM and NINO3.4 SST for observations (ERA40) and ECHAM5-OM1 coupled model projections

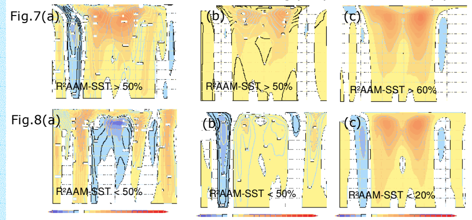
ERA40: Reanalyses, 1962-2000 (40 years)
20C: 20th century projection, 1961-2000 (40 years)
A1B: Climate warming projection, 2001-2100 (101 years)
PICTRL: Pre-industrial climate variability simulation (506 years)

Class / Years	ERA40 40	20C 40	A1B 101	PICTRL 506	Total episodes/class 687
90 < r² <= 100					
80 < r² <= 90			1		1
70 < r² <= 80		1	7	1	9
60 < r² <= 70	1		5	9	15
50 < r² <= 60	1	1	2	11	15
40 < r² <= 50		1	4	12	17
30 < r² <= 40				6	6
20 < r² <= 30				4	4
10 < r² <= 20	1			4	5
0 <= r² <= 10			1	4	5
Total episodes/ data set	3	3	20	51	77

Panel top right (Fig. 7,8): Zonal means of zonal winds for ECHAM5-OM1 simulations for the 20th century (20C), climate warming (A1B) and climate variability (PICTRL) when explained variances between AAMwind and ocean surface temperatures (SST) vary above 50% (Fig.7 a,b) and below 50% (Fig.8a,b), and above 60% (Fig.7c) and below 20% (Fig.8c), respectively.

Panel bottom right (Fig. 9,10): Geographical distribution of correlation coefficients for AAM and SSTs for ECHAM5-OM1 simulations for the 20th century (20C), climate warming (A1B) and climate variability (PICTRL) when explained variances between AAM and ocean surface temperatures (SST) vary above 50% (Fig.7 a,b) and below 50% (Fig.8a,b), and above 60% (Fig.7c) and below 20% (Fig.8c), respectively.

El Niño events associated with anomalies in zonal winds for ECHAM5-OM1 simulations



Contours: climate mean (20C: 1971-2000, A1B: 2071-2100, CTRL: 2150-2655) zonal wind (m/s).
Colors: Zonal wind anomalies (m/s) for peak El Niño months.
Data: **ECHAM5-OM1,** monthly means removed.

Geographical distribution of correlation coefficients AAM – SST for ECHAM5-OM1 simulations

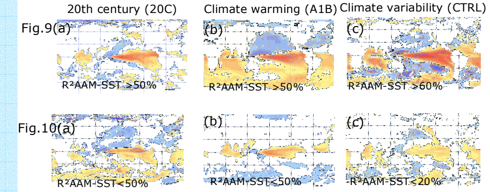


Fig.9-10: AAM and SST (sea surface temperature): ECHAM5-OM1, monthly means removed, correlations based on 24 months.

Excitation of ERPs by atmosphere and ocean

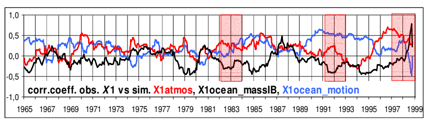


Fig. 11(a): Running 2-year correlation coefficents between observed polar motion ($X1$) and ERA40 atmospheric (motion+massIB, red) and OMCT simulated oceanic motion (blue) and mass (IB) (black) excitation functions.

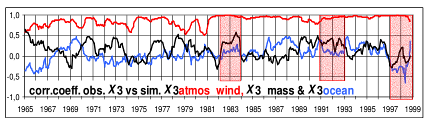


Fig. 11(b): Running 2-year correlation coefficents between observed LOD ($X3$) and ERA40 atmospheric motion (relative AAM, red), atmospheric mass (IB) (black) and OMCT simulated oceanic (motion+massIB, blue) excitation functions.
Data: Monthly means removed from all data. For observed ERPs all signals related to core-mantle interactions and Earth tides are removed.

Summary & Conclusions

- Data analyses on interannual time scales (monthly means removed) for present times (ERA40) and coupled model simulations (ECHAM5-OM1) indicate that main source of varying El Niño signal on observed LOD is associated with different relative AAM anomalies related to location and strength of jet streams.
  - High positive correlation of observed LOD and relative AAM
  - Corresponding high correlation of AAM and NINO3.4 SST
- OMCT model forced with atmospheric reanalyses (ERA40, NCEP2) capable of reproducing observed climate variability in NINO3.4 SST.
- Correlation of OMCT simulated OAM and observed ERPs (atmospheric and hydrological effects removed) >82% w.r.t. mass term of polar motion ($X1$).
- On interannual time scales 2-year running correlations between observed LOD and polar motion component $X1$ (all signals related to core-mantle interactions removed) suggest that
  - El Niño has strong signal in observed LOD to be almost entirely accounted for by variations in wind component of AAM (El Niño events marked red).
  - El Niño effects on mass term of observed polar motion component $X1$ much weaker. Strong excitation of observed $X1$ mass by ocean mass (IB) term during first part of 90s.