Progress Report

DFG Research Group FOR 584
Earth Rotation and Global Dynamic Processes

Project 10

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

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1 General Information

1.1 DFG reference number

UL 167/5-2 as sub-project P10 of the research unit FOR584.

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1.3 Topic

Long-term ERP time series as indicators for global climate variability and climate change (Project 10).

1.4 Period covered by the report

Work related to the atmosphere: 01.09.2006 to 30.06.2008 (22 months), three years funded by DFG.

Work related to the ocean: 01.07.2006 to 30.06.2008 (24 months), 39 months funded by DFG. First two year expenses covered by regular funds of sub-project P2, further 15 months from remaining funds initially allowed for the applicant M.T. within sub-project P2.

1.5 List of publications related to this project

Oral presentations and posters

DOBSLAW, H., THOMAS, M., GRÖTZSCH, A., 2007: Numerical models of transient atmospheric and hydrospheric dynamics: Benefits for the interpretation of geodetic observations. *IUGG XXIV 2007, General Assembly,* July, Perugia, Italy.

ENDLER, C., LECKEBUSCH, G.C., ULBRICH, U., NEVIR, P., LEHMANN, E., 2006: Relationship between interannual variations in the length-of-day (LOD) and ENSO (Poster). *Geodetic Week*, October, Munich.

GRÖTZSCH, A., 2007: Analyse von Signaturen in simulierten Verteilungen regionaler Beiträge zu den effektiven Drehimpulsfunktionen bei ENSO-Ereignissen. *Geodetic Week,* Leipzig.

GRÖTZSCH, A., THOMAS, M., DOBSLAW, H., 2007: Operational estimates of transient hydrospheric effects on Earth rotation parameters (Poster), *EGU General Assembly*, April, Vienna, Austria.

LEHMANN, E., LECKEBUSCH, G.C., ULBRICH, U., NEVIR, P., 2008: The influence of zonal winds on the ENSO-LOD relation on interannual time scales, *Geodetic Week*, Sept./Oct., Bremen.

LEHMANN, E.; LECKEBUSCH, G.C.; ULBRICH, U.; NEVIR, P., 2008: Effects of ENSO on sub-seasonal to interannual length-of-day (LOD) variability. *EGU General Assembly,* April, Vienna, Austria.

LEHMANN, E., LECKEBUSCH, G.C., ULBRICH, U., NEVIR, P., 2007: Ocean-Atmosphere Effects on Interannual Length-of-Day (LOD) Variations (Poster), *Geodetic Week*, September, Leipzig.

LEHMANN, E., ENDLER, C., LECKEBUSCH, G.C., ULBRICH, U., NEVIR, P., 2007: LOD - An independent indicator for climate variability & change? (Poster) *EGU General Assembly*, April, Vienna, Austria.

THOMAS, M., Grötzsch, A., Dobslaw, H., 2008: Operational simulations of transient atmosphere-ocean dynamics: Benefits for the interpretation of Earth rotation variability (solicited), EGU General Assembly, April, Vienna, Austria.

Progress report

2.1 Goals of the project

The main goal of this project is to determine whether variations in Earth orientation parameters (EOPs) such as length-of day (LOD) and polar motion (PM) can be used as climate indicators independently of observations in the atmosphere and ocean. Combined effects of atmospheric and oceanic variability patterns on LOD and PM will be examined taking into account that they are interdependent. To obtain this objective, anomalies of atmospheric and ocean patterns will be identified associated with the coupled atmosphere-ocean phenomenon of the El Niño-Southern Oscillation (ENSO). Considering the different effects of atmosphere and ocean on LOD and PM, analyses will focus on relations between LOD - atmosphere and PM – ocean. Corresponding analyses on EOPs will be performed using reanalysis data and the ocean model OMCT to obtain atmosphere and ocean related parameters related to rotational variations of the Earth. Concerted results from these analyses can lead to a classification of ENSO-LOD and ENSO-PM relations characterized by specific anomalies in the atmosphere (climate indices, mean sea level pressure) and parameters effecting the ocean surface (ocean sea surface temperatures). Obtainend results will be joint by further analyses exploring the relevance of variations in EOPs as indicator for specific variations in the coupled ocean-atmosphere system. Analyses will shift from effects of subtropical atmospheric anomalies prominently related to LOD variations to extratropical effects. Consequently, the more prominent influence of the ocean will be assessed in terms of combined variations in LOD and PM to identify joint modes of EOPs.

If suitable the small data base of observational EOP time series is extended by model results obtained from the coupled atmosphere-ocean model ECHAM5-OM5. Model results will be examined evaluating in how far the model is able to reproduce observed patterns and their combination/sequence related to variations in atmosphere and ocean. A multi-century climate warming experiment will also provide information on transient changes in atmosphere/ocean angular momentum in a warming climate.

2.2 Status and results

LOD EOP C04 - Time series of the LOD **(**IERS, www.iers.org, EOP C04 (Bulletin B, IAU2000A) is used to assess high- and low-frequency behavior of changes in the length of day. We performed a detailed investigation of the LOD EOP C04 time series removing individual signals using Fourier analysis to determine the relation of dominant modes for sub-seasonal, annual and interannual periods of LOD variations to corresponding ENSO events. Effects of zonal earth tides and interdecadal variations have been removed from the geodetic LOD EOPC04 time series (IERS Analysis Tools) to eliminate any influence of celestial gravitation and core-mantle interactions on the LOD – ENSO relation. This resulting time series is referred to as '*LOD*'. For further data analysis anomalies from the LOD time series have been computed (base period 1962-2001). The resulting time series is referred to as '*LOD anomalies*'. A better assessment of ENSO effects on the LOD time series can be achieved by removing effects from sub-seasonal variations in the monthly cycle of LOD. This LOD time series are referred to as '*interannual variations in LOD*'.

ERA40 versus NCEP1 evaluation – For corresponding analyses on the variability of zonal winds the relative atmospheric angular momentum (AAM) was computed using data provided by the ERA40 reanalysis project (ECMWF, Reading, UK). The computation follows the derivation of the dynamic relation between atmosphere and solid earth as described by Barnes et al. (1983).

For this study and on request of the research unit FOR 584 the ERA40 reanalyses have been compared to another commonly used reanalysis data product, the NCEP1 reanalyses (NCEP/NCAR, U.S). The comparison was done to assess possible uncertainties related to the computation of AAM. The data evaluation obtained conclusive results in terms of data quality and uncertainties. Maximum differences in zonal winds of more than 7 m/s are observed for the equatorial Pacific region of ENSO. Consequently, differences in zonal wind speed are reflected in AAM contributions calculated from each of the reanalysis products. Most of AAM contributions are generated in the middle tropophere where NCEP1 AAM contributions compare to ERA40 AAM (being 100%) with 60%. For the upper troposphere NCEP1 AAM overestimates ERA40 AAM contributions by +113%. No estimates can be done for zonal wind contributions to AAM for the lower troposphere due to unaccounted torque effects between solid earth and atmosphere on net contributions on the angular momentum.

This project gives preference to the ERA40 reanalysis data for following reasons: (1) consistency with model simulations that are forced with ERA40 reanalysis, such as IPCC model experiments, (2) for El Niño events ERA40 computed AAM results in smaller differences compared to the geodetic LOD time series than NCEP1 reanalyses. Thus, atmosphere-ocean effects on LOD can be assessed with greater certainty, (3) data availability for stratospheric pressure levels (>10hPa) for further investigation of stratospheric effects on the LOD - AAM relation.

The <u>O</u>cean <u>M</u>odel for <u>C</u>irculation and <u>T</u>ides (*OMCT*; Thomas, 2002) - Simulation results from the OMCT model have been used to analyse ocean related characteristic signals of EOPs due to dynamical processes in the atmosphere-ocean system. The OMCT model was forced with ERA40, NCEP1 and NCEP2 reanalyses. Thus, simulation results can be used to identify oceanic signals in geodetic angular momentum functions that have to be reduced by atmospheric angular momentum contributions calculated from atmospheric fields used to force the OMCT model.

An evaluation of the OMCT model has been performed concerning simulating ocean contributions on PM variations. For this purpose, geodetic angular momentum functions derived from the total observed excitation in the EOP C04 time series for polar motion are reduced by decadal variations, contributions of the atmosphere (AAM) and the continental hydrology (HAM). Data sets from the atmospheric reanalysis project ERA40 have been used to calculate the AAM correction. The additionally HAM corrections have been derived from the hydrological discharge model (HDM, Hagemann and Dümenil, 1998) from the Max-Planck-Institute for Meteorology (MPI-M), Hamburg. For reasons of consistency, output from HDM runs forced with ERA40 reanalysis data sets have been used for the HAM calculations.

To compare resulting polar motion residuals with oceanic contributions, OAM functions were derived from output data sets of OMCT model simulations forced with ERA40 reanalysis data and continental runoff simulated by the HDM. Finally the reduced geodetic angular momentum functions have been compared with OAM simulations (Fig. 1). The OAM simulations and the corrected geodetic angular momentum functions agree very well in phase and amplitude with correlations of more than 82% and explained variances of more than 42%. Especially the results for χ_2 improved significantly when considering the excitation of HAM and corresponding runoff caused by the higher impact of the continental regions to χ_2. In summary, results point out strong oceanic signals that can be identified in polar motion residuals. These findings reason further studies concerning the origin of OAM variations by means of modelled regional OAM patterns.

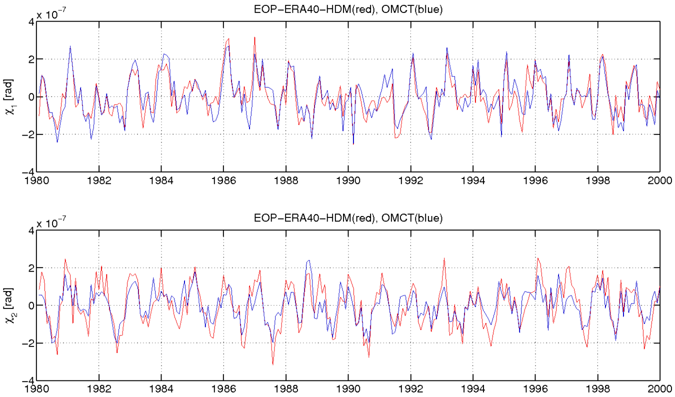

Figure 1: EOP-AAM-HAM (red), OAM (blue)

Temporal atmospheric contributions on LOD variations – For a more comprehensive understanding of LOD variations in relation to variability of large scale atmospheric patterns the relation LOD - AAM has been initially studied on sub-seasonal to interannual time scales**.** Results from a continuous wavelet transform analysis indicate that for the time period 1962 to 2001 changes in AAM and LOD display an overall strong in-phase relationship in the semi-annual and annual band due to sub-seasonal and annual variations in zonal winds. In the annual band the strength of the atmospheric effect on LOD clearly varies for different El Niño episodes. In particular, the effect of atmospheric contributions is investigated for two prominent El Niño events. While the El Niño of 1982/83 caused a strong signal in LOD varaitions the event of 1991/92 effected LOD variations less.

The varying effect of the atmosphere on changes in LOD anomalies is investigated by comparing amplitudes of the mean annual cycles of LOD for strong El Niños (1982/83, 1991/92, 1997/98) and La Niñas (1973/74, 1988/89, 1999/00) to the time mean (1962-2001). Results suggest that during El Niño the mean annual amplitude of LOD anomalies is larger compared to strong La Niñas and the time mean. While during El Niño the annual amplitude of LOD increases in average by +16% compared to the time mean, changes are neglectable for La Niña events.

Temporal oceanic contributions on LOD variations – A small difference between the mean annual cycles for LOD and AAM is observed shortly before spring maximum and around summer minimum. This residual represents the part of the combined geodetic LOD solution that is not excitated by the atmosphere. In order to assess the non-atmospheric excitation on LOD variations the geodetic LOD time series is reduced by AAM contributions computed with ERA40 reanalyses.

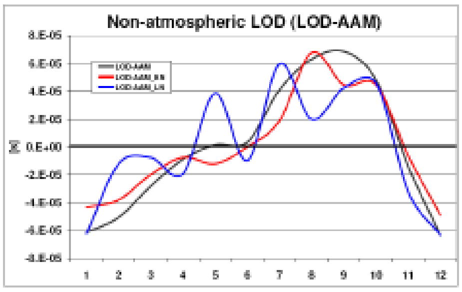

Figure 2a: Mean annual cycle of non-atmospheric LOD residual. Time period 1962-2001 in black, El Niño (1982/83, ‘91/92, ‘97/98) in red, La Niña (1973/74, ‘88/89, ‘99/00) in blue.

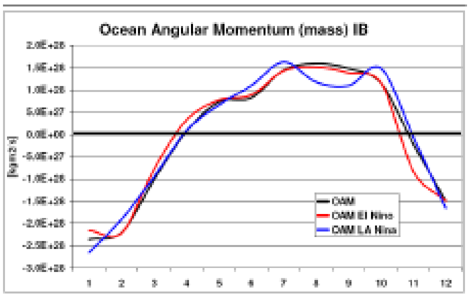

Figure 2b: Mean annual cycle of OAMmass (IB). Time period 1962-2001 in black, El Niño (1982/83, ‘91/92, ‘97/98) in red, La Niña (1973/74, ‘88/89, ‘99/00) in blue. (OAMmass 1961-2001, ERA40-OMCT, Courtesy P2 Project M.Thomas, A. Grötzsch).

Non-atmospheric contributions to the LOD residual have been accessed by comparing the mean annual cycles of the residual (Fig.2a) and the ocean angular momentum associated with mass and with inverted barometric correction (OAMmass IB) (Fig.2b). The mean annual amplitude of the LOD residual varies less during strong La Niñas (-7%) than during El Niño episodes (-12%) compared to the time mean (1962-2001). While the LOD residual (Fig.2a) and OAMmass (IB) (Fig2b) display a maximum in August/September a late summer minimum from July to August is observed in both data during La Niña. Similarity in phase and amplitude of the mean annual cycle of the non-atmospheric LOD residual and the OAMmass IB implies that the LOD residual represents a significant non-tidal oceanic signal. The non-atmospheric LOD residual also correlates well with OAMmass (IB) at r=0.5.

Since analyses of atmospheric and ocean effects on LOD variations include only a small data base (72 months each for El Niño and La Niña analyses) additional data from a coupled model simulation (ECHAM5-OM1) will be included in further analyses to examine if these findings can be confirmed in the control run and climate warming simulation.

Spatial patterns of extratropical ocean contributions to polar motion variations - In addition to time series analyses a spatial analysis of extratropical contributions of OAM to polar motion has been conducted to identify underlying oceanic processes responsible for rotational variations. The Principal Component Analysis (PCA) was applied to OMCT simulated regional OAM contributions to reveal the most dominant excitation regions. Due to the strong impact of the ocean on χ_1 and the dominating mass term considering OAM simulations with atmospheric surface pressure forcing, an example for the mass term of the OAM-χ_1 component is given in Fig. 3 and 4. For the analysis monthly regional contributions to the mass term of OAM-χ_1 have been used for the period from 1980 until the end of 2006.

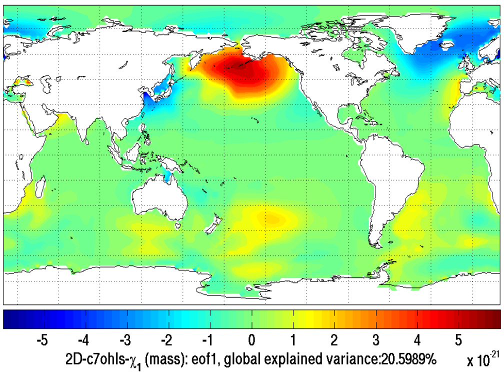

Figure 3: EOF1 of OAM-χ_1 (mass)

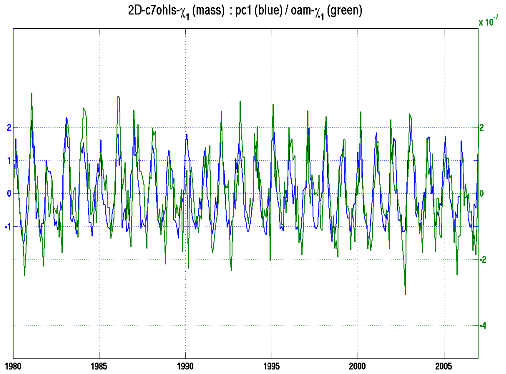

Figure 4: PC1 (blue) of OAM-χ_1 (mass) (green)

Fig. 3 represents the first Empirical Orthogonal Function (EOF) and Fig. 4 the corresponding Principal Component time series (PC). The most dominant impact on χ_1 can be found in regions close to longitudes 0° and 180° in the mid-latitudes. The obtained EOF patterns reflect these geographical effects especially for the North Pacific and North Atlantic Ocean which are the most prominent excitation regions. Since OMCT is additionally forced by atmospheric surface pressure, the variability pattern in Fig. 3 is strongly associated with the pattern of atmospheric pressure anomalies. The first EOF shown in Fig. 3 explains about 20% of the variance of the regional contributions to χ_1, mainly consisting of an annual signal (see Fig. 4).

Spatial patterns of atmospheric contributions to LOD variations - In concert with the above study an analysis has been conducted to assess spatial patterns of atmospheric forcing in LOD excitation signals. For this reason, the impact of interannual variability in zonal wind patterns on the spatial distribution of AAM contributions is investigated. Specific patterns of AAM anomalies during ENSO are identified in terms of their effect on the observed geodetic LOD. Changes in AAM are associated with specific atmospheric circulation patterns to identify atmospheric or oceanic forces on LOD variations.

During ENSO events the tropics and subtropics observe a modification in zonal winds. During El Niño and La Niña episodes north-easterly winds on the Northern hemisphere and south-easterly winds on the Southern hemisphere (trade winds), weaken or strenghten, respectively. The modified patterns of these surface winds are reflected in AAM contributions. Figures 5a and 5b display mean anomalies of interannual AAM contributions for selected El Niño (1982/83, 1986/87, 1991/92, 1997/98) and La Niña (1973/73, 1988/89, 1999/00) episodes. During an El Niño (La Niña) period north- and south-easterly trade winds weaken (strengthen) in the lower troposphere (1000-600hPa) while at upper troposheric levels westerly (easterly) winds of the subtropical jet stream strengthened (weakenend) (Fig. 6a, 6b respectively). As a result strong positive (negative) interannual variations in AAM contributions can be observed along 30°North and South. During El Niño (La Niña) areas of negative (positive) AAM contributions are observed along the equatorial Pacific and Indian Ocean as a result of easterly (westerly) winds of the quasi-biennial oscillation (QBO) in the stratosphere (100 and 10 hPa).

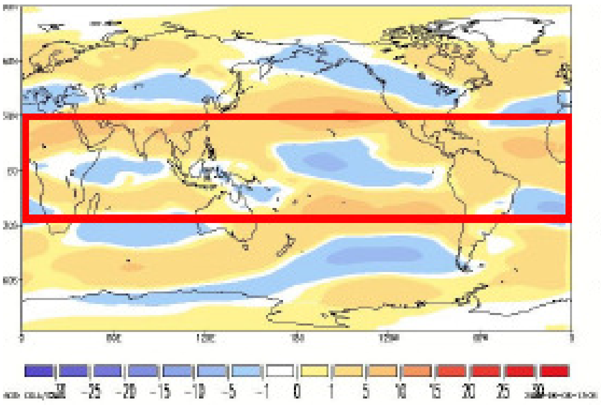

Figure 5a: El Niño – Enhanced positive interannual variations in AAM contributions $[kgm^2/s]$ are shown along the jet stream regions (30° N and S) while negative AAM contributions along the equator are a result of stratospheric winds during the easterly phase of the QBO.

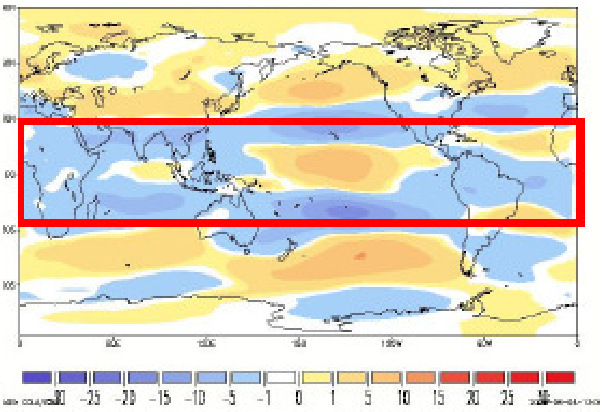

Figure 5b: La Niña - Enhanced negative interannual variations in AAM contributions $[kgm^2/s]$ are shown along the jet stream regions (30° N and S) while positive AAM contributions along the equator are a result of stratospheric winds during the westerly phase of the QBO.

Further investigation of effects of interannual variations in zonal wind patterns on the spatial distribution of AAM contributions indicates that spatial patterns of AAM vary differently during strong El Niño periods. We selected two strong El Niño episodes following the definition of NOAA (2003) that effected LOD variability with different strength. Typical spatial patterns of positive interannual variations in AAM anomalies are observed during El Niño 1982/83 (Fig. 6a) with largest AAM contributions within the West wind belt (40°-60° North and South) and jet stream regions (30° South and North) on both hemispheres. During El Niño 1991/92 (Fig. 6b) large negative interannual variations in AAM anomalies are observed for the southern jet stream region (30°S) and AAM contributions for the northern hemisphere appear smaller. The 1982/83 El Niño had a strong atmospheric impact on LOD variability with mean LOD variations differing by +22% compared to mean AAM contributions. During El Niño 1991/92 a smaller atmospheric signal has been observed in the LOD. Interannual LOD variations compared negatively (-132%) to AAM contributions.

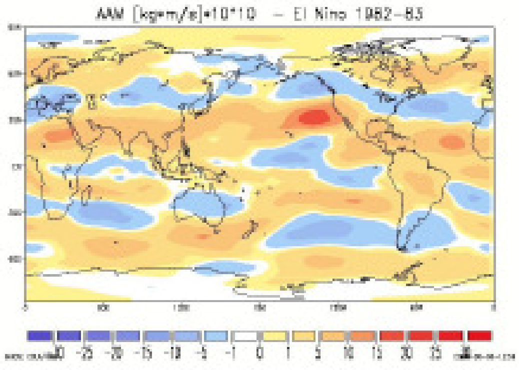

Figure 6a: Spatial distribution of mean interannual variations in AAM contributions for El Niño 1982/83.

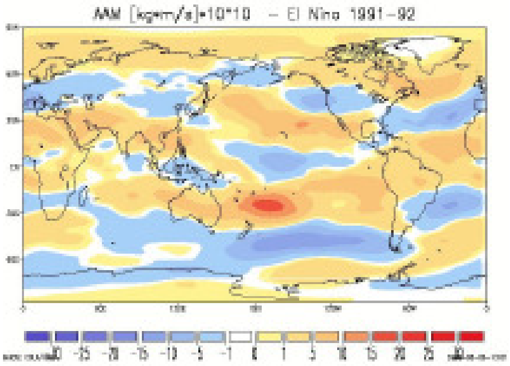

Figure 6b: Spatial distribution of mean interannual variations in AAM contributions for El Niño 1991/92.

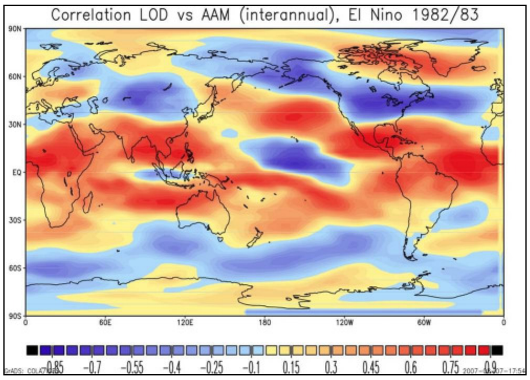

Figure 7a: Spatial distribution of correlation coefficients between fields of interannual AAM and LOD time series for El Niño 1982/83.

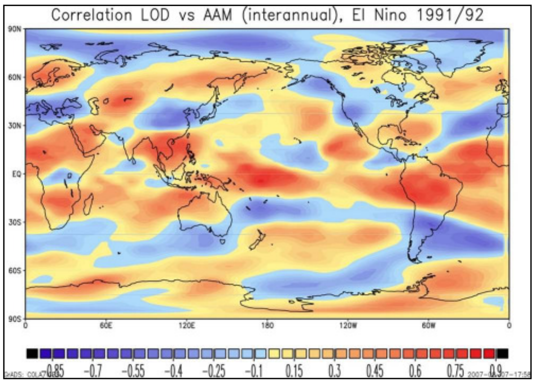

Figure 7b: Spatial distribution of correlation coefficients between fields of interannual AAM and LOD time series for El Niño 1991/92.

Correlation results between fields of interannual variations in AAM and LOD time series for both strong El Niño episodes (1982/83, 1991/92) indicate large differences in spatial distribution of correlation coefficients. For the El Niño 1982/83 spatial correlation coefficients (Fig. 7b) follow similar patterns as spatial interannual variations in AAM with highest correlations between LOD and AAM reflecting the subtropical jet stream regions (30° North and South) on both hemispheres. For the El Niño 1991/92 correlation patterns are not conclusive in terms of spatial patterns of AAM contributions.

Atmosphere / ocean excitation of interannual LOD variations during El Niño 1982/1983 and La Niña 1989/1990 - For this analysis, mass and motion terms of atmospheric and oceanic angular momentum excitation function (AAM/OAM) were derived from data of the ERA40 reanalyses and the ocean model OMCT forced with ERA40 (Fig. 8). For the interpretation of Fig. 8 it is important to consider that axial OAM variations are about one order of magnitude less than those of the AAM. Apparently, the observed positive LOD anomaly during the El Niño event 1982/1983 was caused by zonal wind anomalies affecting the motion term of the AAM. Thus OMCT model analysis confirms previous results shown in Fig. 6a&b and Fig. 7a&b.

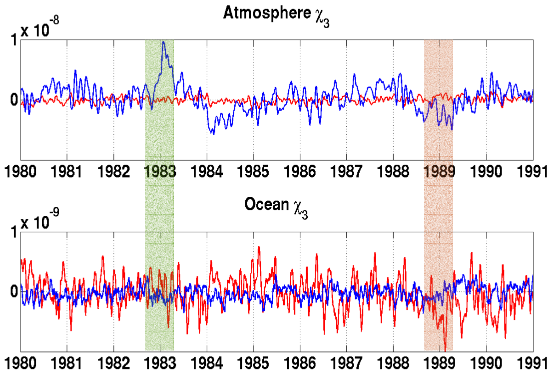

Figure 8: AAM / OAM, mass (red) and motion terms (blue).

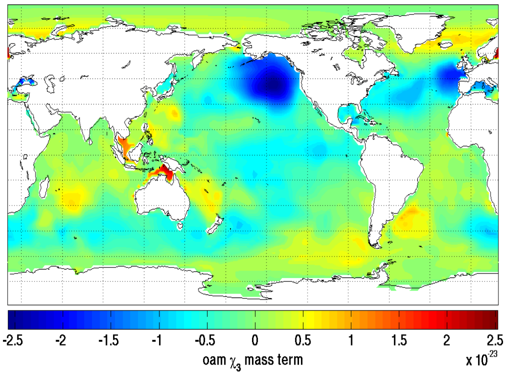

Figure 9: Regional contributions to OAM χ_3 during La Niña 88/89 (mass term).

These findings suggest that the distribution of spatial patterns of AAM indicate that the main source of the varying strength of the ENSO signal on interannual variations in LOD can be seen in the difference of spatially distributed AAM anomalies. Results are confirmed by spatial patterns of correlation coefficients between interannual variations in AAM and LOD. Spatial patterns of strong correlations reflect areas of the northern and southern hemisphere jet streams. Both, oceanic and atmospheric analyses conclude that the strong excitation of interannual LOD variations during El Niño 1982/83 was caused by the atmosphere.

Considering the OAM anomalies in Fig. 8 a negative peak in the OAM mass term is visible during the La Niña event 1988/1989. Although the impact of the OAM anomaly on LOD (Fig.8) was rather weak, the interrelation to the La Niña event was studied by means of modelled regional OAM contributions. In this context it has been investigated whether the ocean could be a possible source of excitation in the LOD during this La Niña event of 1988/89. A strong OAM anomaly has been localized by generating the mean OAM field for the OAM mass term with the OMCT model (Fig. 9). Since the OMCT model was forced with atmospheric surface pressure, anomalies in the OAM patterns are mostly caused by surface pressure anomalies of the atmosphere. The intense negative anomaly patterns in Fig. 9 correspond with the negative peak in the OAM mass term. However, the regions of these patterns (mainly in the Northeast Pacific Ocean) are not consistent with the typical ENSO region in the Southern Pacific Ocean. Thus, an interrelation between the negative peak in the OAM mass term and the La Niña event 1988/1989 could not be detected. Because of the rather weak impact of the ocean on LOD variations compared to the atmosphere, further studies using the OMCT model focus on the oceanic excitation of polar motion.

Interrelation of climate indices and OAM – A preliminary study extends previous analyses on the effect of ocean excitation on EOPs by assessing the impact of climate variability on the relation of PM variations and ocean excitation. For this purpose, the OMCT model has been evaluated in terms how well it simulates various well known climate indices (e.g., for Southern Oscillation, North Atlantic Oscillation and ocean Sea Surface Temperature (SST)). The computed climate indices have been simulated by means of data sets from atmospheric reanalyses (ERA40, NCEP2) and ocean models (OMCT, LSG) to study their coherence to corresponding OAM simulations.

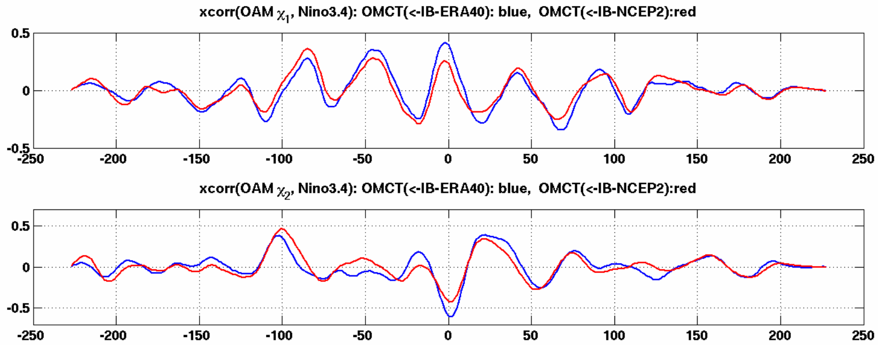

Figure 10: Cross correlation of OAM excitation functions (polar motion) and simulated Niño3.4 SSTs (the unit of the x-axis is [months]).

For this purpose, cross-correlation time series have been calculated to analyse the coherence between the simulated indices and the OAM functions for polar motion on interannual time scales, both derived from OMCT forced with ERA40 as well as with NCEP2 reanalysis data. The cross-correlations were used to identify the changes of the correlation coefficients by shifting the time series for evaluation. Fig. 10 reflects significant correlations between OAM (polar motion) and simulated Niño3.4 SSTs. Considering χ_2 and the OMCT simulations with ERA40 forcing, the correlation even exceeds 50% clearly and results with NCEP2 forcing are very similar. However, these results only indicate an interrelation between OAMs and climate indices, whose potential causes still have to be studied by means of modelled regional OAM patterns.

Quasi-biennial oscillation (QBO) and LOD variations – A preliminary analysis has been conducted to better understand feedback mechanisms between stratosphere-troposphere and ocean and how they effect variations in LOD during ENSO periods. In this context the time-frequeny behaviour of the QBO has been assessed in relation to ocean sea surface temperatures. For this purpose, AAM contributions have been separated into QBO dominated stratospheric (200-1hPa) and tropospheric AAM (>200-1000hPa) contributions to take into account the impact of different atmospheric wind systems on interannual variations in LOD. Results of a continuous wavelet transform analysis indicate that a dominant El Niño signal can be observed in interannual variations in LOD when high power spectra are shown for ocean sea surface temperatures in the 2- and 4-year band and for stratospheric (QBO) and tropospheric AAM contributions in the 2-year band.

Outlook: Analyses of atmosphere-ocean model simulations

Data for the discussed analyses for the atmospheric study part is limited to only a few strong ENSO events in the available 40-year time period. Further investigations will take advantage of data made available through the coupled atmosphere-ocean IPCC model experiments (ECHAM5-OM1). Additional data will involve simulation results from the control run (20C1) and the SRESA1B experiment. Preliminary data analyses suggest good agreement on phase between control experiment and observations for NIÑO3.4 SSTs and SOI (southern oscillation index) while amplitudes differ. Results from the SRES A1B experiment suggest increasing SSTs for the NIÑO3.4 region between 2000 and 2100, while the SOI indicates decreasing variability for the same time period.

Results from the oceanic study part reflect that contrary to LOD, the atmospheric and the oceanic excitation of polar motion are of the same order of magnitude. Thus, ongoing analyses in the third year will further focus on dynamical processes in the atmosphere-ocean system that cause polar motion excitations, using data sets of coupled model runs with ECOCTH.

2.3 Contributions to the results

2.3.1 Cooperation with partners of the research unit ‘Earth rotation and global dynamic processes.’

- *B. Richter, P1*
  Data, results and software, scripts have been provided.
- *J. Schröder, M. Thomas, P2*
  Complementary model data (LSG, OMCT) and results of OAM and AAM excitations obtained.
- *H. Greiner-Mai, P4*
  Complementary data have been obtained for further analysis.
- *H. Schuh, R. Weber et al., P8*
  Results on LOD have been provided for further analysis.

2.3.2 Cooperation with partners outside the research unit

C. Walter and R. Dill (Helmholtz-Zentrum Potsdam – GFZ)
We obtained HAM and runoff data sets from the HDM that we used to force the ocean models and to correct the EOPs for HAM.

- *A. Korbacz and A. Brzezinski* (Space Research Centre at the Polish Academy of Science, Warsaw, Poland)
  We provided a consistent set of AAM and OAM derived from data of the ERA-40 reanalysis project and also output of the OMCT forced with ERA-40 data to study atmospheric and oceanic excitation of polar motion and length of day [Korbacz et al., 2008].
- *D. Salstein* (IERS Special Bureau of the Atmosphere, Lexington, MA) and *J. Boehm* (Vienna University of Technology)
  Cooperating work related to the validation of results of the AAM calculations [Boehm et al. 2008]).
- *Prof. Dr. J. Sündermann* and Dr. M. Müller (Institute for Oceanography, University of Hamburg, Germany)
  Within the upcoming months a close cooperation is anticipated with the scientists

concerned with the coupled ECOCTH experiments.

2.4 Qualifiation of researchers

In connection with this project following theses have been prepared or are ongoing. Ph.D theses by E. Lehmann and A. Grötzsch are expected to be completed during the second funding period.

- **Diplom** (2007): Endler C., *Untersuchung zu Variationen der Tageslänge (LOD) und ihrer Beziehung zu ENSO auf der interannualen Skala*, Fachbereich Geowissenschaften, Freie Universität Berlin, Berlin.
- **Dissertation** (9/2006-ongoing): Lehmann, E., *Long-term ERP time series as indicators for global climate variability and climate change,* Fachbereich Geowissenschaften, Freie Universität Berlin, Berlin.
- **Dissertation** (11/2007-ongoing): Grötzsch A., "*Statistische Analyse des Zusammenhangs von numerisch modellierten Massenumverteilungen im Ozean, Erdrotationsparametern und Klimaindikatoren*", Fachbereich Geowissenschaften, Freie Universität Berlin, Berlin.
- **Bachelor** (in preparation): Felicitas Hansen, *El Niño Telekonnextionen und Klimaänderung unter Berücksichtigung des atmosphärischen Drehimpulses*, Fachbereich Geowissenschaften, Freie Universität Berlin, Berlin.

3. Summary

Results obtained during this project period are summarized in the following.

- During El Niño episodes atmospheric effects lead to an enhanced variability in the mean annual cycle of the combined geodetic LOD product while for the same time period the non-atmospheric LOD residual varies less than during La Niña. Corresponding results obtained with the OMCT model indicate that atmospheric and oceanic excitations of polar motion are of the same order of magnitude. A correlation between OMCT simulated time series of OAM and observed polar motion variations reduced for atmospheric and hydrological effects is generally higher than 82% with respect to polar motion and is not satisfying with respect LOD.
- The main source of variability of the El Niño signal in LOD can be seen in different AAM anomalies. Results from a continuous wavelet transform analysis suggest that El Niño effects LOD on interannual timescales when high power spectra are observed for ocean sea surface temperatures in the 2 and 4 year band and for the stratospheric (QBO) and tropospheric AAM in the 2 year band. Complementary OMCT simulation results report on a relation between variations in ocean sea surface temperatures and oceanic excitation of polar motion on interannual timescales.
- The OMCT model forced with atmospheric reanalyses (ERA-40, NCEP2) is able to reproduce significant observed climate indices (SOI, NAO, Niño3.4 SST) important for further analyses on the relation between variations in LOD and polar motion and climate variability.

References

[Boehm et al., 2008] BOEHM, J., P. J. M. CERVEIRA, S. ENGLICH, and H. SCHUH, 2008: The 5th IVS general meeting proceedings. *Technical Report.*

[Endler 2007] ENDLER C., 2007: Untersuchung zu Variationen der Tageslänge (LOD) und ihrer Beziehung zu ENSO auf der interannualen Skala, *Diploma Thesis*, Fachbereich Geowissenschaften, Freie Universität Berlin, Berlin.

[Hagemann and Dümenil, 1998] HAGEMANN, S., and L. DÜMENIL, 1998: Documentation for the Hydrological Discharge Model. *Technical Report* 17.

[IERS] IERS, *International Earth Rotation & Reference Systems Service*, www.iers.org.

[IERS Analysis Tools] IERS Analysis Tools, *http://hpiers.obspm.fr/eop-pc/products/combined/C04.html*

[Korbacz et al., 2008] KORBACZ, A., A. BRZEZINSKI, and M. THOMAS, 2008. Atmospheric and nontidal oceanic excitation of Earth rotation estimated from the output of the models ERA-40 and OMCT, *J. Geodesy*, submitted).

[NOAA] NOAA, 2003: *http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml*

[Thomas, 2002] Thomas, M., 2002: Ozeanisch induzierte Erdrotationsschwankungen – Ergebnisse eines Simultanmodells für Zirkulation und Gezeiten im Weltozean, 129 S., *Dissertation* am Fachbereich Geowissenschaften der Universität Hamburg.