Geophysical Research Abstracts
Vol. 13, EGU2011-7385, 2011
EGU General Assembly 2011

Influence of the North Atlantic Oscillation and the Quasi-Biannual Oscillation on Earth Orientation Parameters

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Variations in the earth rotation parameters are strongly influenced by atmospheric and oceanic variability patterns. In order to develop a climate index from Earth rotation parameters, the influence of known large-scale climate variability features on Earth rotation must be assessed. This can be done using Atmosphere-Ocean General Circulation Models (CGCMs), simulating the climate system in a physically consistent way.

The analysis performed is based on the computation of effective angular momentum functions derived from: a) an ocean model (OMCT) driven with ECMWF (ERA Interim/ERA40) atmospheric reanalysis data, and with a 500 year run of the ECHAM5/OM1 model, developing its climate without an observational forcing. Results obtained from re-analysis and the simulated ocean can be directly a compared with the observational IERS geodetic earth orientation data (C04 excitation functions). Data from the free model run shall demonstrate in how far the fully coupled model is able to reproduce the same features for the geodetic variations.

One of the variability features investigated is the North Atlantic Oscillation (NAO), the dominant atmospheric winter teleconnection pattern for the Northern Hemisphere. Its influence on polar motion(e.g. Chao and Zhou, 1998) was thought to be caused largely by mass redistribution. This assumption is, however, inconsistent with the inverted barometer assumption, telling that atmospheric pressure anomalies over the ocean (where the larger part of the NAO anomalies lies) should be outweighed by an elastic response of the ocean surface.

Our results suggest that, instead of atmospheric mass redistribution, the influence of the NAO on polar motion is exerted through changes in wind speed and resulting oceanic transport, mainly via the χ_1 motion components of the atmospheric (AAM) and oceanic (OAM) effective angular momentum (EAM) functions.

As a second variability feature, the possible influence of the Quasi-Biannual Oscillation (QBO) on polar motion is examined. Because of the link between NAO and QBO (significantly correlated with r=0.22 in the ERA Interim dataset), an indirect influence of the QBO on earth orientation would be expected. However, no significant correlation between the EAM functions and the QBO index is found.

To investigate this connection further, Granger causality is used, a statistical tool to determine whether the knowledge of past values of one timeseries (y) is useful in predicting future values of a second timeseries (x) over and above the knowledge of past values of x alone. It is shown that, for the ERA Interim period, the QBO "granger-causes" the winter AAM χ-1 mass component as well as the OAM χ-1 motion component at 99% significance level, meaning that previous QBO index values may influence the earth orientation.

The comparison with data from the ECHAM5/OM1 model - which does not include a well resolved stratosphere and fails to reproduce correctly the QBO - is used to determine whether the influence of the NAO on earth rotation is modified by the existence of the QBO.