11B.8 ANALYSIS OF ANGULAR MOMENTUM LOSS IN WEATHER PREDICTION MODELS

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1. INTRODUCTION

The angular momentum (AM) with respect to the earth's axis of rotation is one of the fundamental parameters used to characterize the general circulation of the atmosphere and the climate (Peioxoto and Oort 1992) Although AM in the earth atmosphere system is nearly conserved, AM is constantly exchanged between the atmosphere and the solid earth, and variations in atmospheric AM (AAM) are often associated with particular types of atmospheric circulation patterns. Huang and Sardeshmukh (1999) found that medium-range forecast runs of the National Centers for Environmental Prediction (NCEP) reanalysis model systematically loses AAM with time. They speculated that most of the loss was due to the parameterization of gravity wave drag (GWD) in the model. However, impacts of corrected drag were often opposite expectations in regions of the drag, suggesting other sources of error. This project applies budget analysis to investigate other contributing factors.

In order to facilitate tracking variations in AAM, Weickmann and Berry (2009, hereafter WB09) generated a two-dimensional phase space by plotting the time tendency of AAM against anomalous AAM. They termed the variations represented in their index the global wind oscillation (GWO), and related many signals therein to the MJO and to the El Niño/Southern Oscillation (ENSO). They divided this diagram into 8 convenient phases. One issue with this index is that it only diagnoses global changes in the AAM budget, and there may be an infinite set of pathways whereby the atmosphere could attain a given mean state, even if select types of patterns might occur more frequently than others. Meteorologists in the private sector have used this index to make subseasonal to seasonal forecasts for specific regions without taking into account that it is a global quantity.

2. METHODS

This work follows the methods of WB09 in tracking variation of AAM. The NCEP/NCAR reanalysis-1 (Kalnay et al., 1996) is the primary dataset used. The total global AAM and its time tendency are computed as described by Weickmann and Sardeshmukh (1994) using daily averages of 4x daily average of zonal wind. However this study averages AAM only in the vertical, to diagnose the spatial patterns and features that may contribute to a specific GWO phase. The global tendency is estimated from the global AAM time series using a forward finite difference scheme. The anomalies are relative to a 1979-2010 climatology and are standardized by dividing by the standard deviation of the entire time-series. Composites of both standardized anomalies and time tendency of the AAM will be constructed for each phase of the GWO.

3. CLIMATOLOGY

In both northern summer and winter the highest values of total angular momentum occur at the equator, because the Earth spins fastest there (Fig.1). Subtropical jet regions show the largest variance in AM, as a result of the shift of the jets with the seasonal temperature gradient. Jets are stronger in the winter hemisphere due to the stronger temperature gradients.

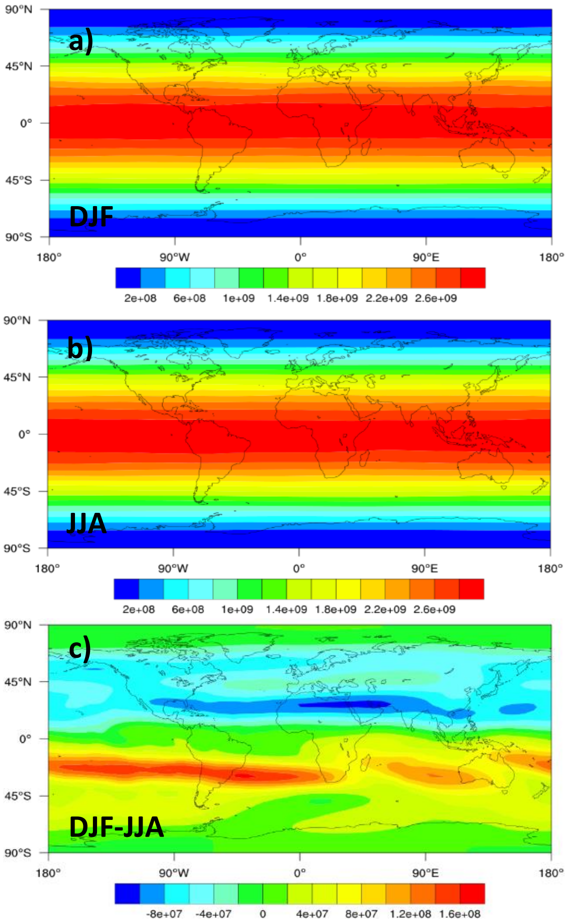

*Figure 1. Seasonal composites of atmospheric angular momentum from 1979 to 2010 (kg*m^2/s). a) December-February, b) June-August, c) difference between a and b.*

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4. COMPOSITES

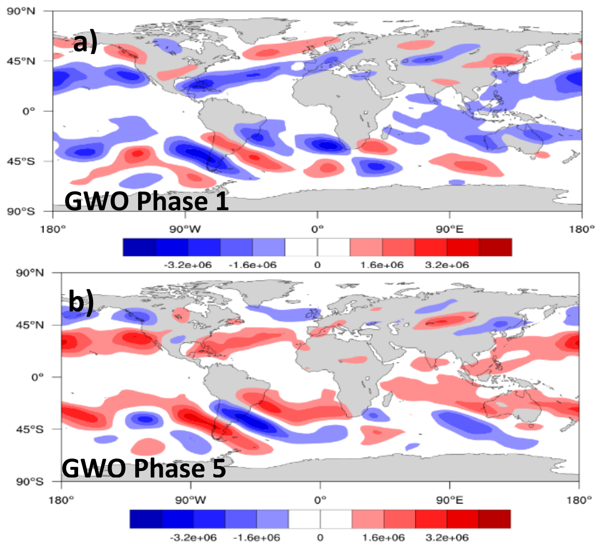

*Figure 2. Composite from 1979-2010 of time tendency of atmospheric angular momentum (kg*m^2). a) Global Wind Oscillation phase 1, b) Global Wind Oscillation phase 5.*

AAM tends to vary between GWO phases (Fig.2). The time tendency term tends to dominate in phases 1 and 5, where AM transport between the mid-latitudes and lower latitudes occurs. This transport tends to dominate around South America. Anomalies in global AAM reach a minimum in phases 3 and a maximum 7, resulting from previous phases where transport into or away from the equator lead to fluctuations in local AM at the equator. (Fig.3)

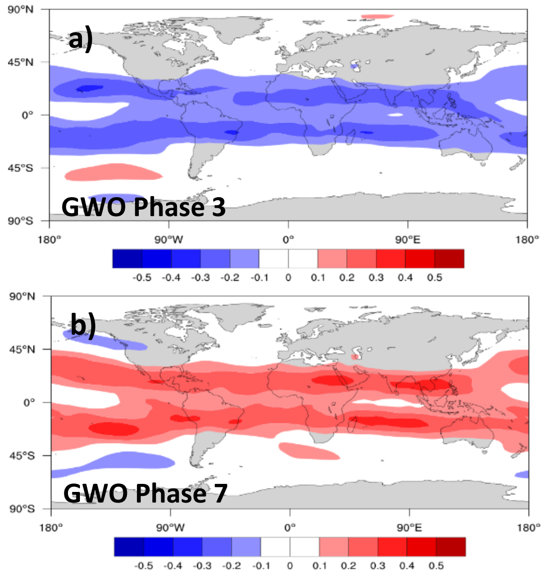

Figure 3. Composite from 1979-2010 of normalized atmospheric angular momentum anomalies. a) Global Oscillation phase 3, b) Global Wind Oscillation phase 7.

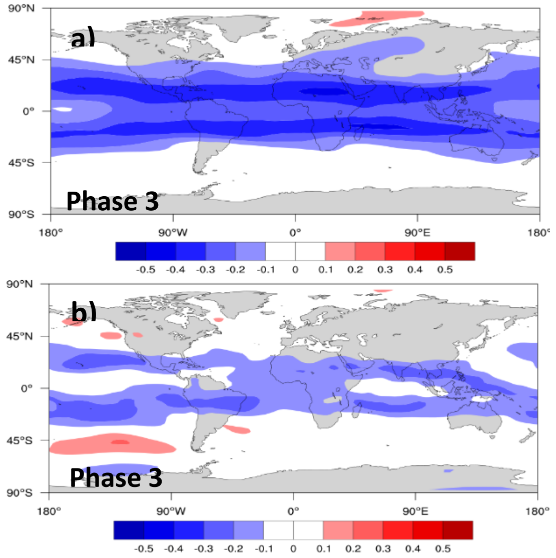

Figure 4. Same as 3 but Phase 3 of the Global wind Oscillation. a) stratosphere, b) troposphere.

To assess the locations of the largest anomalies around the equator, a composite of AM in the stratosphere and troposphere was created (Fig.4). As noted, the stratosphere contributes the largest anomalies around the equator, while the troposphere appears to contribute most over the middle latitudes. Low variance (Fig.5) over the tropics in phase 3 suggests that this signal is consistent in time, and it may suggest that the Quasi Biennial Oscillation (QBO) may be responsible for the anomalies in this phase.

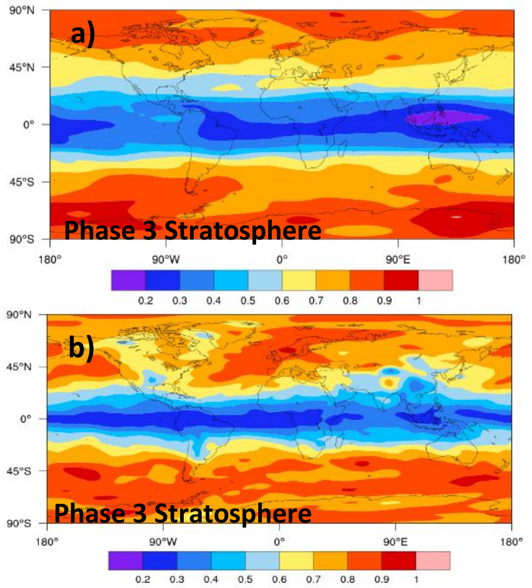

Figure 5. Same as fig. 4 but variance of atmospheric angular momentum anomalies. a) Stratosphere, b) troposphere.

5. FUTURE WORK.

These results raise the following questions: What terms in an AM budget lead to the patterns that appear in these composites? Do medium range forecast models display skill forecasting GWO? If not, what terms in the AM budget lead to errors and what is the geographical distribution of these errors? Are there models that display better skill or less bias than others in predicting GWO phase and local AM outcomes?

The first question will be addressed by conducting an AM budget analysis at each grid point. This budget will allow for an assessment of the geographical distribution of AM, treating seasons separately. Since reanalysis budgets do not close, results will be compared with the residual. The second question will be addressed by performing a similar diagnosis but utilizing GEFS reforecast data this analysis will also be stratified by GWO phase. Finally, the last question will be addressed by using different reanalysis and reforecast datasets. Analysis will be extended to the NCEP Climate Forecast System (CFS) reanalysis and reforecast and the European Centre for Medium-Range Weather Forecast (ECMWF) as obtained by direct request to ECMWF.

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