11B.7 DETERMINING PERIODIC BEHAVIOR OF GLOBALLY AVERAGED TROPICAL JET AVAILABLE POTENTIAL ENERGY

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1. INTRODUCTION

The integrated outflow mass from tropical convection and storms causes APE to accumulate in the Upper Troposphere – Lower Stratosphere (UTLS) (Lorenz 1955). Lorenz later defines specific Available Potential Energy, with respect to a fully mixed atmosphere, as:

$$APE = \frac{\rho - \rho_{mixed\ atmos.}}{\rho} gz \ \left(\frac{J}{kg}\right) \quad (1)$$

When one takes the difference of APE across the subtropical jet, with respect to a standard atmospheric sounding, they find what Tripoli and Madsen (2014) call the Jet Available Potential Energy (JAPE), defined as:

$$JAPE = \frac{\rho - \rho_{std.\ atmos.}}{\rho} gz \ \left(\frac{J}{kg}\right) \quad (2)$$

The JAPE bubble, which is also "fed" by mass outflow from tropical convection, is bounded by the subtropical jet and the elevated tropical tropopause. The bubble is restricted by angular momentum, which prevents lateral movement, and the lack of net radiation, which inhibits vertical motion. The JAPE bubble is seen clearly over the tropics in Fig. 1.

APE must therefore be released via extratropical interactions with the lower troposphere or the surface. A mixture of APE from tropical convection and angular momentum transport are found to be responsible for the creation of subtropical jets. (Krishnamurti 1961). Subtropical jets form along the poleward boundary of a UTLS JAPE plume.

Integrated JAPE is the total potential energy stored in the tropical JAPE bubble, which must eventually be fluxed to the extratropics. Over time, JAPE builds up and bleeds off to the extratropics in response to tropical plumes transporting JAPE out of the bubble, which is seen in Fig. 2. This appears to occur frequently over time, leading to this investigation of the periodicity of the rises and falls of energy within the bubble.

The JAPE plume carries both potential and kinetic energy from the jet poleward, transporting APE out of the tropics and into the extratropical Rossby Wave Train. Regional-scale JAPE plume surges like this overcome restrictions to mean global scale meridional overturning caused by angular momentum, thus allowing APE to flow towards the poles where it can radiate out of the atmosphere and angular moment can be dissipated into the ground via surface friction.

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2. DATA & ANALYSIS

This analysis utilizes European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis – Interim (ERA-I) four-times daily data from 1979 January 1 through 2014 December 31. Data is processed using the University of Wisconsin Nonhydrostatic Modeling System (UW-NMS) (Tripoli 1992), which calculates layer-averaged JAPE values as:

$$\{JAPE\} = \iint_{x,y} \int_z \ JAPE\ \rho\ dV \ \ (J) \quad (3)$$

As this analysis will focus on isentropic layers, the vertical plane becomes

$$\int_z = \int_{z_{\theta_1}}^{z_{\theta_2}} dz \ \ (J) \quad (4)$$

where $dz = z_{\theta_2} - z_{\theta_1}$.

Of particular interest in this analysis is the latitudinal region 30˚N-30˚S (hereafter referred to as the "tropics") and the isentropic layer 370-380 K. This highlighted area is thought to be representative of the core of the JAPE bubble.

Spectral analysis in the single year and 36-year analyses is performed through the use of a Fast Fourier Transform (FFT) and a Hamming window. Statistical significance is computed at the 95% confidence level through chi-squared testing.

2.1 *Single Year Analysis*

The time series seen in Fig. 3 shows clear cyclic behavior, revealing at first glance daily and 20-60-day cycles. The maximum value of layer-averaged JAPE is seen in early March, while the minimum is seen in late August.

Spectral analysis performed using 95% confidence levels, as seen in Fig. 4, reveals prevalent periods lasting 0.5, 1, 40-50, and 365 days. As the upper half of the plot has low resolution between points, the data set was then tripled as an effort to increase resolution.

2.2 *36-Year Analysis*

Fig. 5 shows the expanded data set, which encompasses 36 years. In this time series, it is easy to see the annual cycle hinted at in Fig. 4, although it is now more difficult to see smaller periods.

Spectral analysis using 95% confidence levels, as in Fig. 6, reveal prevalent periods lasting 0.5, 1, 45, 122, 182, and 365 days. Longer significant periods are seen, but are currently deemed "uninteresting" due to low resolution with lack of a longer range of data.

The following section aims to provide insight to select results noted in this analysis.

3. DISCUSSION

3.1 *Annual Cycle*

One cycle of particular interest, the annual cycle, is very well defined in both the single- and multi-year spectral analyses. By averaging four-times-daily data across 36 years, a general trend is seen (Fig. 7). It becomes evident that the highest JAPE values are found in late January and early February, while the lowest values are found in late September through October.

Although this further confirms the presence of the annual cycle, it also poses the question of why an annual cycle is present, especially if the Northern and Southern Hemispheres receive approximately equal radiation annually. One possible answer that merits further investigation is that the Southern Hemisphere is more “efficient” at releasing energy throughout the year, while the Northern Hemisphere better releases energy during the boreal late summer and early fall. This hypothesis is supported by the high values of layer-averaged JAPE in boreal winter, and low values in boreal summer.

3.2 *45-Day Cycle*

Another cycle of interest, the 45-day cycle, aligns with the 30-60 day cycle seen with the Madden Julian Oscillation (MJO), suggesting a possible connection between these two phenomena. High levels of tropical convection associated with the oscillation could serve as a source of a large amount of energy to the tropical JAPE bubble. This causes one to question why a localized phenomenon would affect a global energy reservoir. One hypothesis is that high levels of convection constantly fuel the JAPE bubble, while eruptions from the bubble can occur where there is a connection to the subtropics via a subtropical jet.

4. CONCLUSIONS

Thus far, there are several conclusions that can be noted. Interesting prevailing peaks in frequency are seen at periods equal to 0.5, 1, 45, and 365 days per cycle. On average, the highest JAPE values occur January through March, while the lowest JAPE values occur September through November. This, in conjunction with the annual cycle, suggests unbalanced efficiency in energy release between the Northern and Southern Hemispheres. Finally, the 45-day cycle could indicate high influence by the MJO, emphasizing that local events could have globally-experienced effects.

There is still much to be studied within this topic. Currently, effort is being made to further confirm the significance of the 45-day and annual cycle, as well as to determine the cause of other statistically significant periods discovered within spectral analysis. Future research will entail relating high-impact meteorological observations to high and low values found within single-year time series in order to learn more about the physical processes that affect the build-up and release of JAPE.

5. REFERENCES

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Tripoli, G., and M. Madsen, 2014: Examining the Relationship Between Tropical Jet Available Potential Energy (JAPE) and the Level of Extratropical Storm Activity During the Winter Season. *31st Conf. on Hurricanes and Trop. Meteor.*, San Diego, CA, Amer. Meteor. Soc., 11D.8.

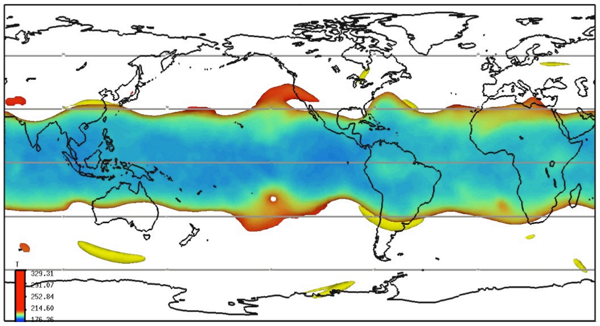

Figure 1: Multicolored surface representing JAPE bubble and 42 m/s positive wind speed (yellow surface) indicative of subtropical jets as seen 0000 UTC 27 October 2012.

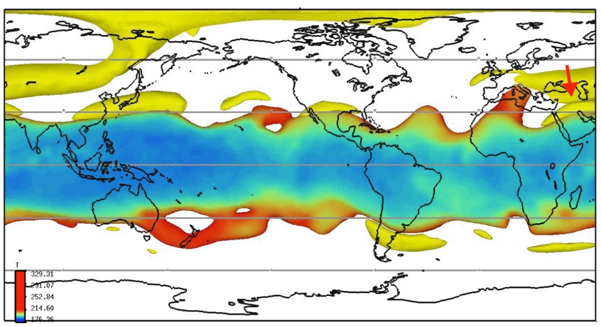

Figure 2: Multicolored surface representing JAPE bubble and 42 m/s positive wind speed (yellow surface) indicative of subtropical and polar jets as seen 1200 UTC 23 December 2012. Red arrow denotes area of energy transfer via jets.

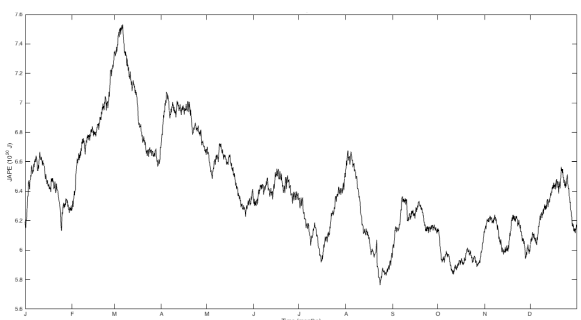

Figure 3: Time series of layer-averaged JAPE measured in units of 10^{20} J from 1 January 2005 through 31 December 2005.

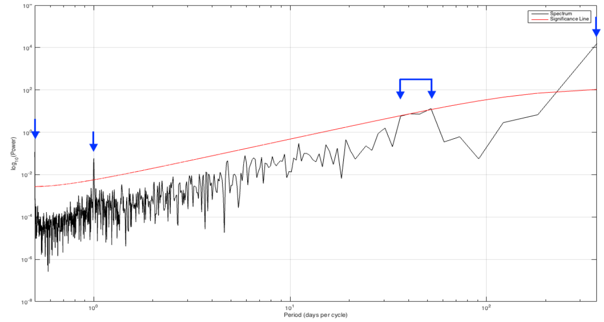

Figure 4: In black, spectrum of layer-averaged JAPE ($\log_{10}$(Power)) from 1 January 2005 through 31 December 2005, with period shown in days per cycle. In red, significance at 95% confidence. Significant points indicated with blue arrows.

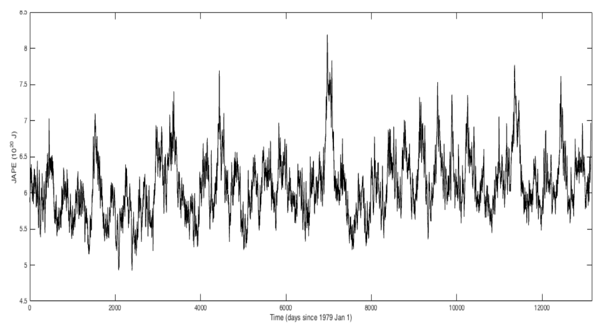

Figure 5: Time series of layer-averaged JAPE measured in units of 10^{20} J from 1 January 1979 through 31 December 2014.

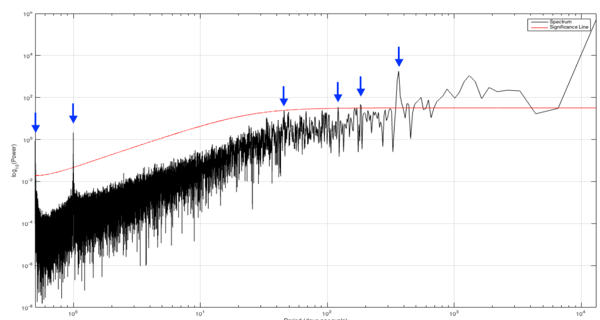

Figure 6: In black, spectrum of layer-averaged JAPE ($\log_{10}$(Power)) from 1 January 2005 through 31 December 2005, with period shown in days per cycle. In red, significance at 95% confidence. Significant points indicated with blue arrows.

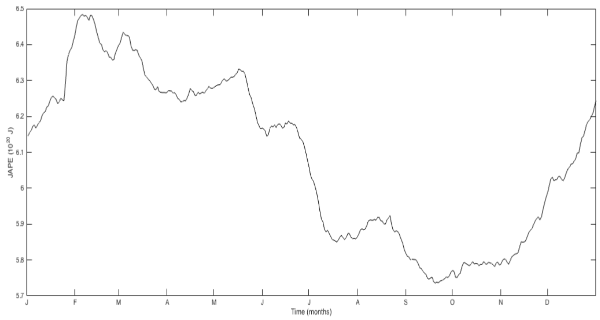

Figure 7: Composite time series of daily-averaged layer-averaged JAPE from 1 January 1979 through 31 December 2014 measured in units of 10^{20} J.