An Exploration of Tropical Jet Available Potential Energy

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1. Background and Data

Available Potential Energy (APE), with respect to a fully mixed atmosphere, is defined as:

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

Similarly, the difference of APE across the subtropical jet, with respect to a standard atmospheric sounding, is the Jet Available Potential Energy (JAPE), defined as:

$$JAPE = \frac{\rho - \rho_{std.atmos.}}{\rho} gz \quad (\mathrm{J\ kg^{-1}})$$

This analysis utilizes ECMWF Re-Analysis - Interim (ERA-I) four-times-daily data from 1979 January 1 through 2015 December 31, with layer-averaged JAPE calculated via the University of Wisconsin Nonhydrostatic Modelling System (UW-NMS) as:

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

Since this analysis uses isentropic layers as a vertical coordinate,

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

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

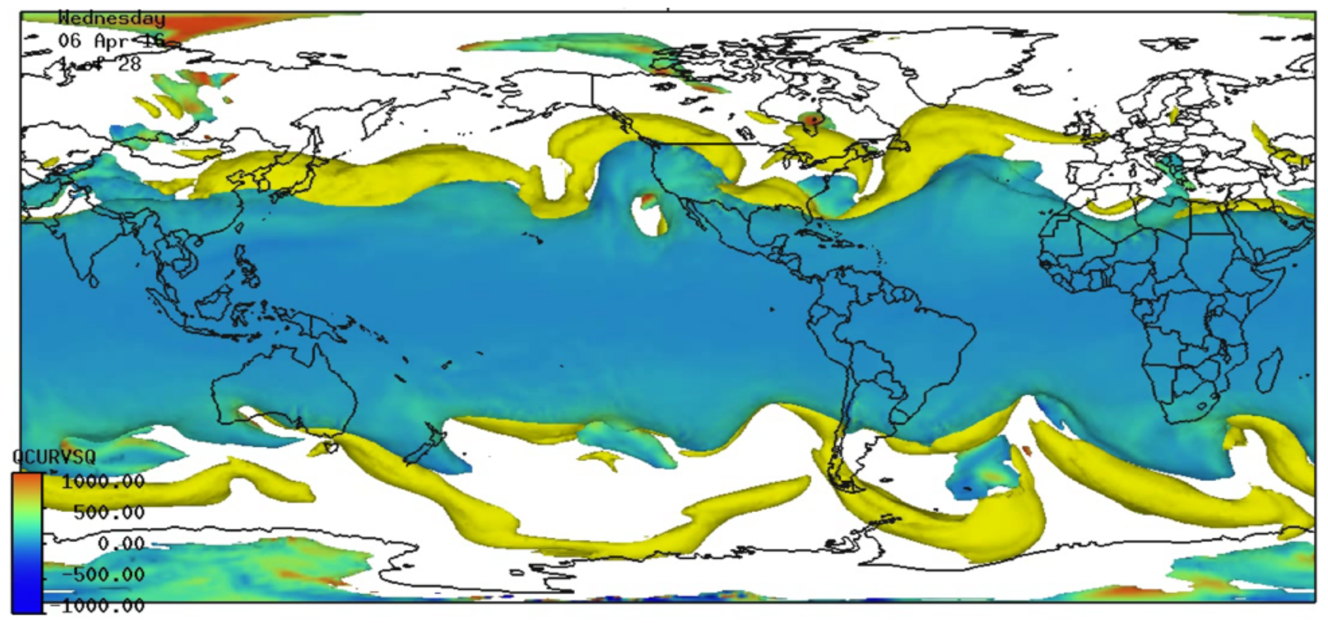


Figure 1 – JAPE bubble (multicolored surface) and subtropical jets (yellow surfaces) as seen 0000 Z 06 April 2016

- The integrated outflow mass from tropical convection and storms causes JAPE to accumulate in the Upper Troposphere - Lower Stratosphere (UTLS)
- JAPE is stored in the UTLS in a bubble bounded by subtropical jets, which form through APE from tropical convection and angular momentum transport
- The bubble's movement is restricted by inertial and radiative forces; angular momentum prevents lateral movement while lack of net radiation inhibits vertical motion
- Over time, JAPE builds up and is released to the extratropics in response to tropical plumes transporting both potential and kinetic energy from the jet towards the poles
  - Plumes form most regularly in the presence of a polar jet, forming a connection with the subtropical jet and transferring JAPE via the jet connection.
  - This occurs frequently over time, leading to an investigation of the periodicity of the energy fluctuations within the bubble.
  - In the absence of these jet connections, the bubble continues to accumulate energy until the inertial wall restraining it is weakened by the energy it contains, leading to anomalous, strong surges

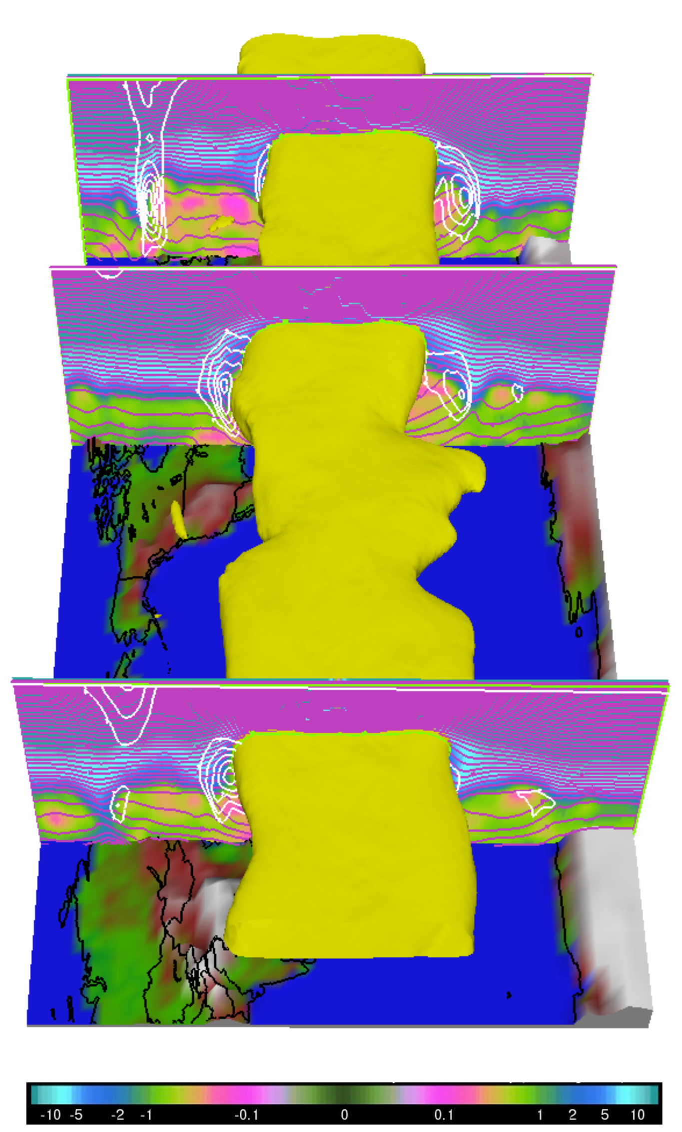


Figure 2 – as seen 1200 Z 30 December 2016. 2500 J/kg JAPE, isotherms (contoured in pink every 10 K), westerly winds greater than 32 m s⁻¹ (contoured in white every 10 m s⁻¹), and potential vorticity (PVU, log-scale seen at left).

2. Time Series and Spectral Analysis

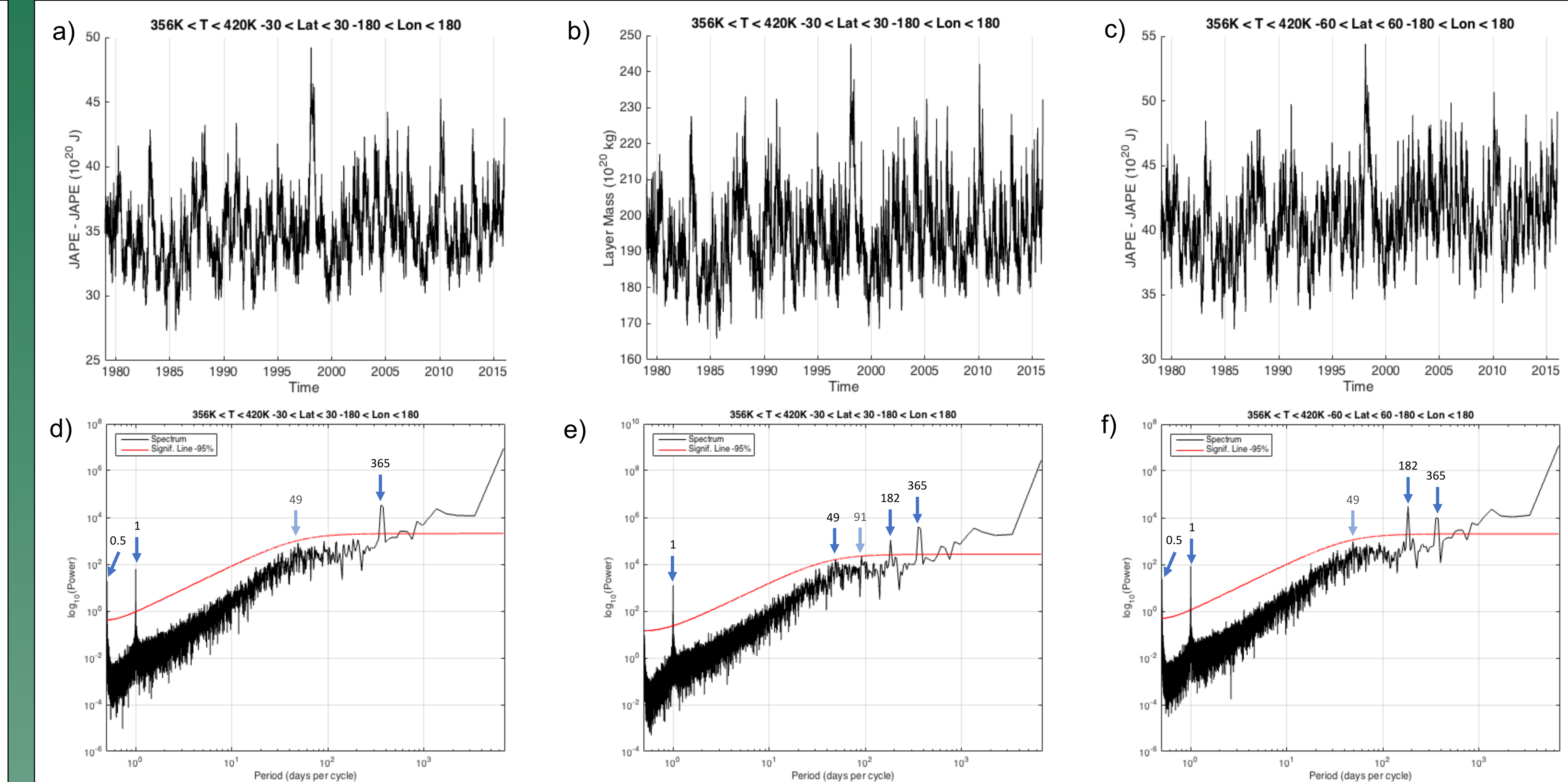


Figure 3 – a. Time series of JAPE from 1 January 1979 through 31 December 2015 (30˚S-30˚N), 356-420K; b. Time series of Layer Mass from 1 January 1979 through 31 December 2015 (30˚S-30˚N), 356-420K; c. Time series of JAPE from 1 January 1979 through 31 December 2015 in (60˚S-60˚N), 356-420K; d. Spectrum of JAPE (30˚S-30˚N), 356-420K; e. Spectrum of Layer Mass (30˚S-30˚N), 356-420K; f. Spectrum of JAPE (60˚S-60˚N), 356-420K

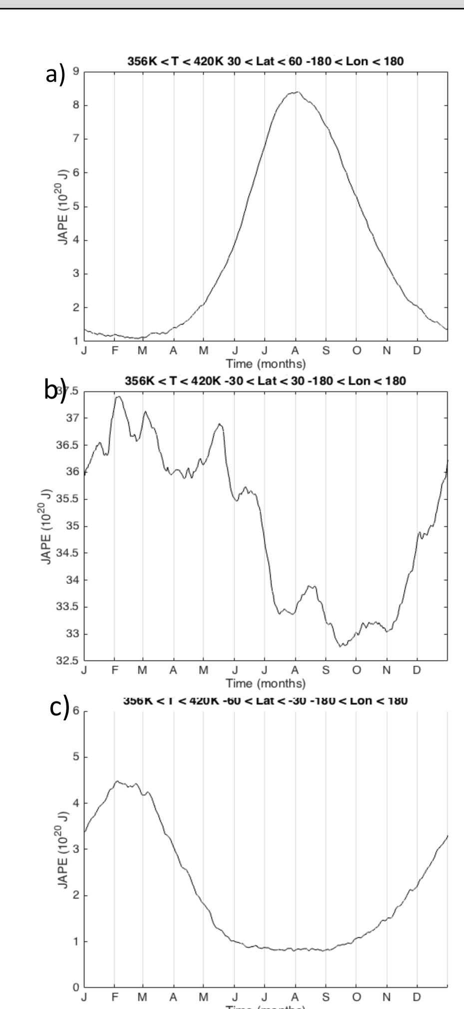
a, d) Tropical JAPE (30˚S-30˚N) – Significant values at 0.5, 1, 365; near significance with 49

b, e) Tropical Layer Mass (30˚S-30˚N) – Significant values at 1, 49, 182, 365; near significance with 91

c, f) Nonpolar JAPE (60˚S-60˚N) – Significant values at 0.5, 1, 182, 365; near significance with 49

- Similarity in peaks, in addition to near identical time series, suggests a strong relationship between JAPE and Layer Mass near and above the tropical UTLS
- Similarity in peaks between tropics and nonpolar regions, with the addition of the 182-day period, suggests the tropics largely controls variability in periodicity in nonpolar regions
- 49-day cycle appears to align with 30- to 60-day cycle characteristic of the Madden Julian Oscillation (MJO) – increased convection associated with the MJO may serve as a high-impact source of energy to the JAPE bubble

3. Composites



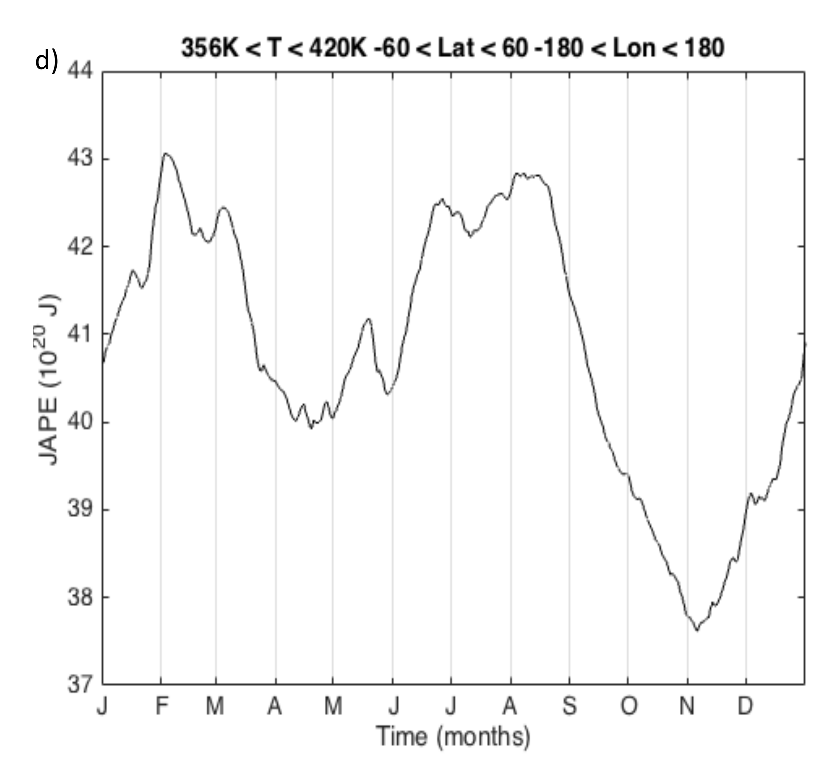


Figure 5 - a. Composite of JAPE in the north midlatitudes over 37 years 356-420K; b. Composite of JAPE in the tropics over 37 years 356-420K; c. Composite of JAPE in the south midlatitudes over 37 years 356-420K; d. Composite of JAPE in the nonpolar region over 37 years 356-420K

a) North Midlatitudes (30˚N-60˚N) – Maximum in August, minimum in February; smooth composite shows little short-term variability; high contrast between maximum and minimum suggests inefficient energy release

b) Tropics (30˚S-30˚N) – Maximum in February, minimum in September, with relative maxima every month or two; jagged composite indicates much short-term variability

c) South Midlatitudes (60˚S-30˚S) – Maximum in February, minimum in JJA; smooth composite shows little short-term variability. Lower contrast between maximum and minimum suggests more efficient energy release

d) Nonpolar Regions (60˚S-60˚N) – Pattern appears most like that of the tropic, indicating the tropics contribute most short-term variability, while midlatitudes influence magnitude of peaks

4. Conclusions

- Prevailing peaks in frequency are seen at periods equal to 0.5, 1, 49, 182, and 365 days per cycle
- The tropics contribute towards much of the "short-term" variability of JAPE in the nonpolar region, while midlatitudes affect the magnitude of peaks
  - ➢ A 49-day cycle could indicate high input of convective energy by the MJO
- The annual and semiannual cycle, as well as composites, suggest asymmetric efficiency in energy release between the Northern and Southern Hemispheres
  - ➢ Could be explained by frequency and strength of the polar jet; the southern polar jet is typically stronger, lasts longer than the northern polar jet
- The summer maximum of JAPE in the Northern Hemisphere creates the secondary maximum of JAPE in nonpolar regions

5. Ongoing Work

- Investigation of individual anomalies seen in time series (i.e. large maximum seen in 1998 in time series)
- Continuing efforts in determining cycle correlations (i.e. confirmation of MJO involvement using the RMM index)
- Implementation of PV parameter in plume identification
- Scan the QR code or go to http://mapmaker2.aos.wisc.edu/jape/ for maps of JAPE and other parameters initialized from recent GFS model output

6. Acknowledgements

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7. References

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