Study of Short-term Migrating (DW1) Tidal Variability in eCMAM30 and SABER Using Information Theory

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ABSTRACT

Wavelet analysis on DW1 migrating tide using extended Canadian Middle Atmospheric Model (eCMAM30) run (1979-2010) and the sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on NASA's TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite temperature data in the mesosphere-lower thermosphere revealed strong short term tidal variability on time scales from few days to 1-2 months. In this research we investigate the statistical properties (Autocorrelation and time dependent probability density functions) of the short-term tidal variability of DW1 with periods less than 30 days. The response of short term tidal variability to different scales of periodicity (QBO, seasonal harmonics, etc.) will be discussed using time dependent probability density functions (TDPDFs) and wavelet coherence analysis.

MOTIVATION

- The wavelet analysis revealed strong short-term tidal modulation of the tidal variability on scales from several days to 1-2 months.
- Atmospheric tides have been regularly observed to fluctuate on planetary wave time scales and interpreted as a nonlinear interaction between the migrating tide and planetary waves.

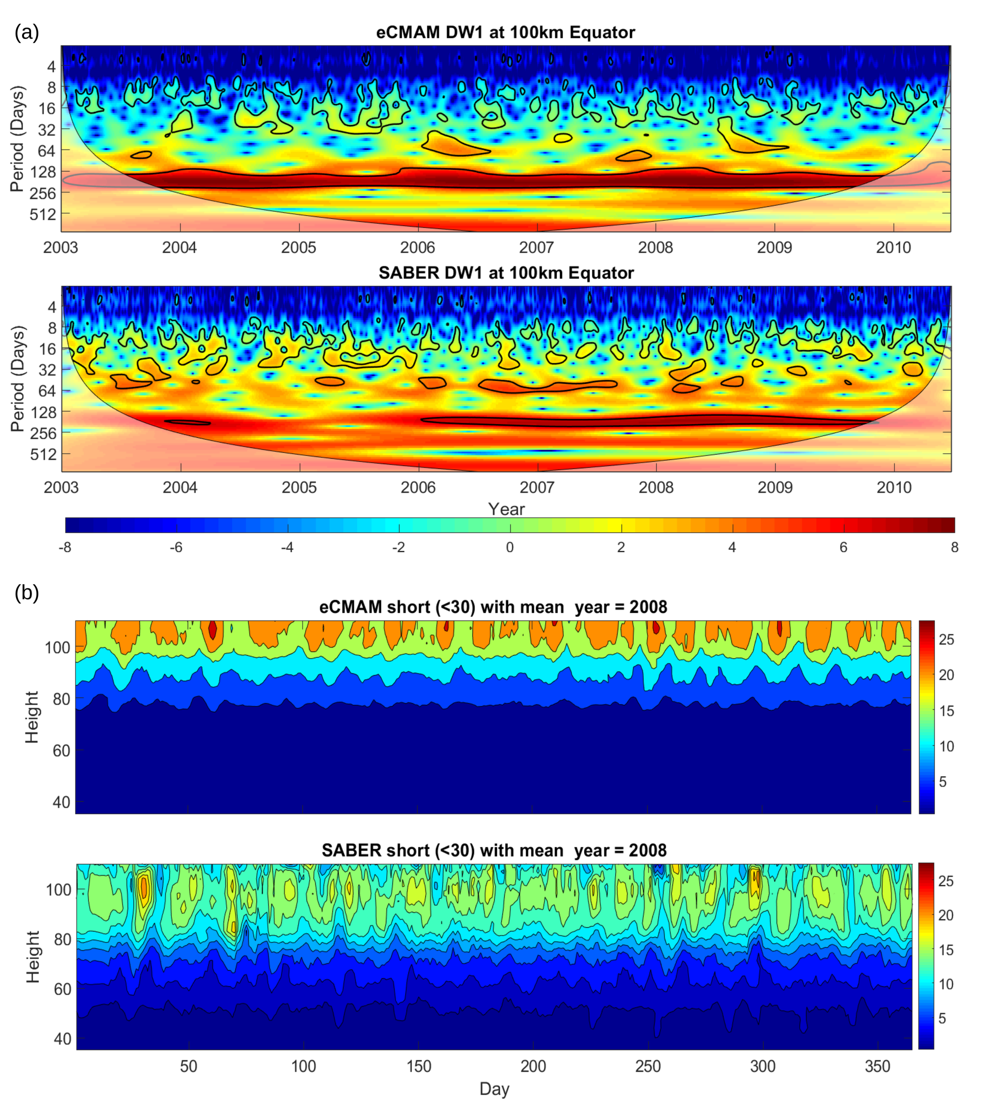
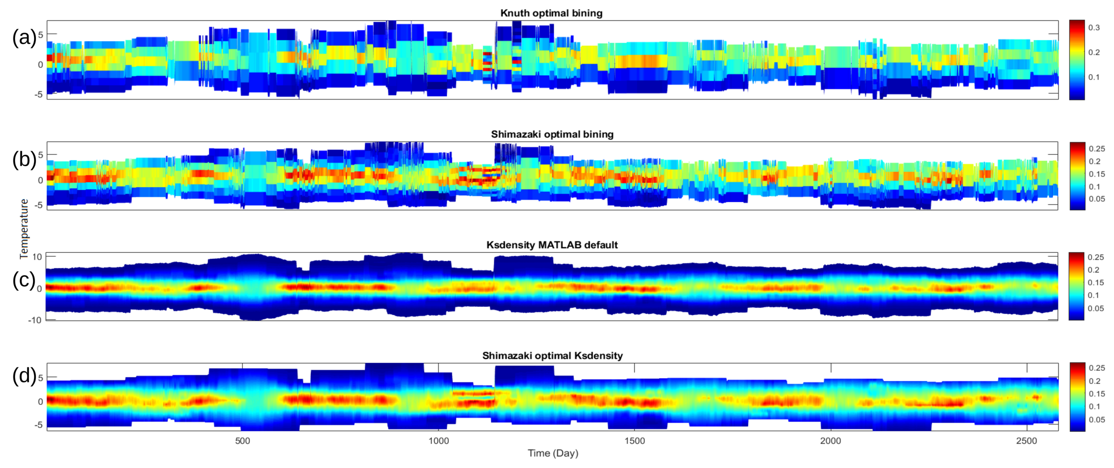


Figure 1: a) The wavelet analysis of DW1 temporal variability at 100km equator for both eCMAM and SABER reveals periodicities on several scales
b) eCMAM and SABER DW1 short-term tidal variability after bandpass at equator as a function of latitude and time in year 2008

RESULTS

Section A: Time Dependent Probability Density Function (TDPDF)

Histogram and kernel method based probability density models depend on the choice of the number of bins or bandwidth. The optimal bin number or bandwidth critically determines the information content of the PDF vs noise.



Here we test several methods based on Bayes' theorem [1,2] and minimizing Mean Integrated Squared Error (MISE) [3,4].

Figure 2: a) TDPDF obtained using a) Knuth optimal binning b) Shimazaki optimal binning c) MATLAB default kernel method d) Shimazaki optimal Bandwidth

PDF created using a 30 day window and advancing the window by one day until the end of the time series provides the complete TDPDF. Each PDF reveals the average short-term tidal variability within the window. TDPDFs reflect how the average short-term tidal variability evolve with time and respond to the seasonal, QBO, ENSO etc.

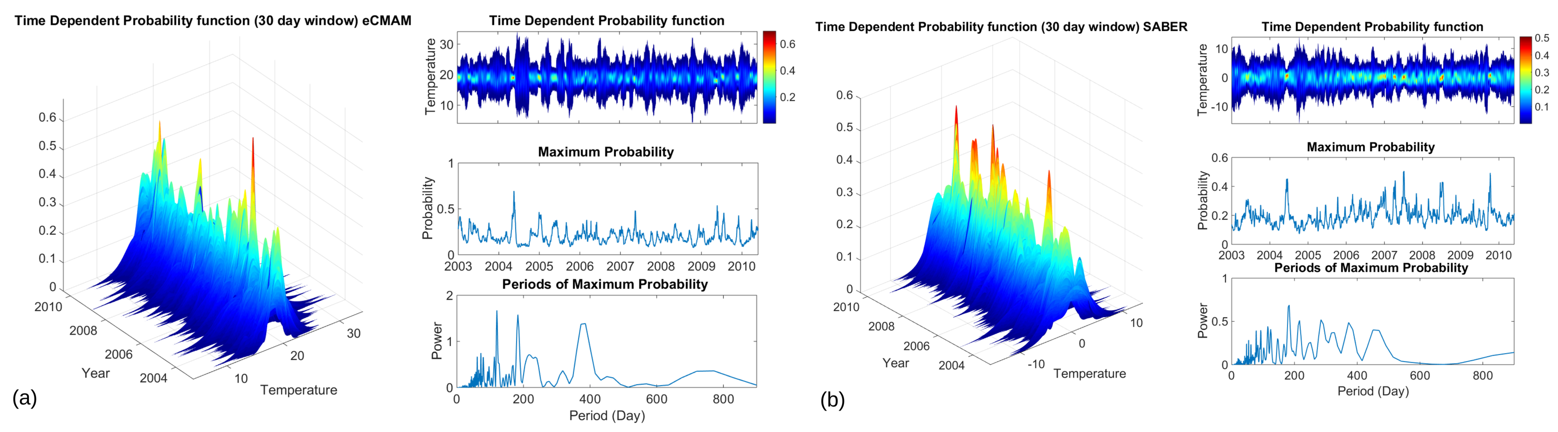


Figure 3:eCMAM (a) and SABER (b) TDPDF, change of the Peak probability over time and the period of the peak probability

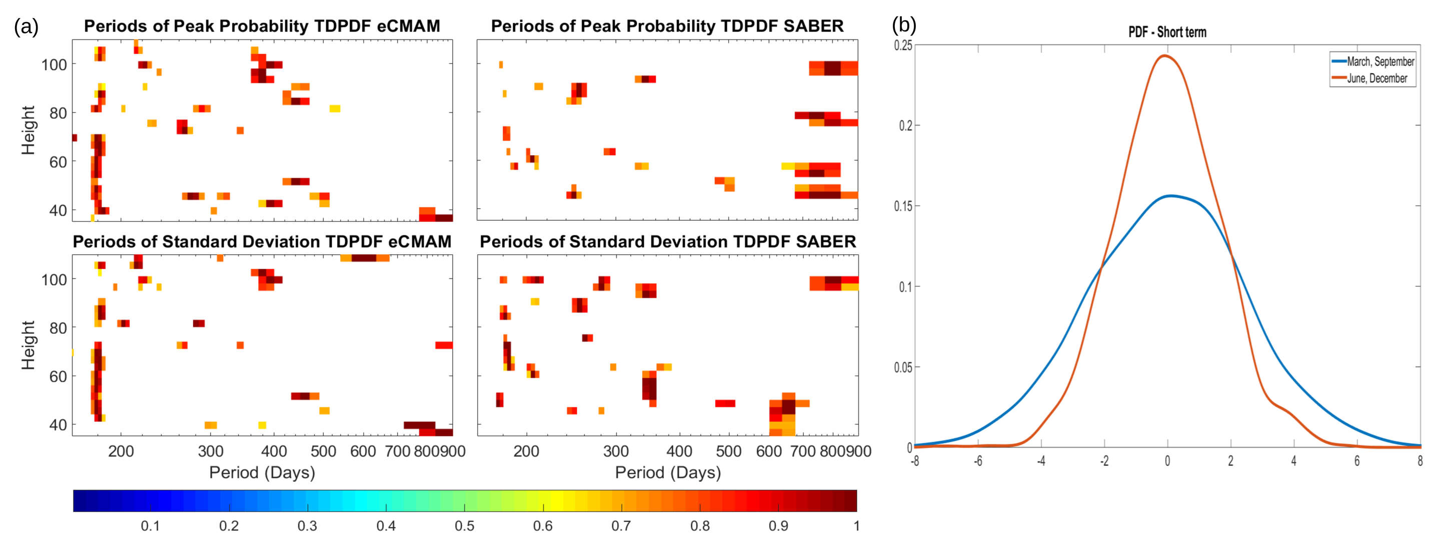


Figure 4: a) Periodicity of amplitude and standard deviation of TDPDF for eCMAM and SABER.
b) Change of short-term tidal variability PDF in March, September equinoxes and June, December solstices

Section B: Physical Mechanism

Our objective is to understand how the short term tidal variability responds to other forcing factors in the atmosphere. Time series were filtered into quasi 10-day, quasi 16-day and quasi 23-day to mimic the Planetary wave signatures in DW1.

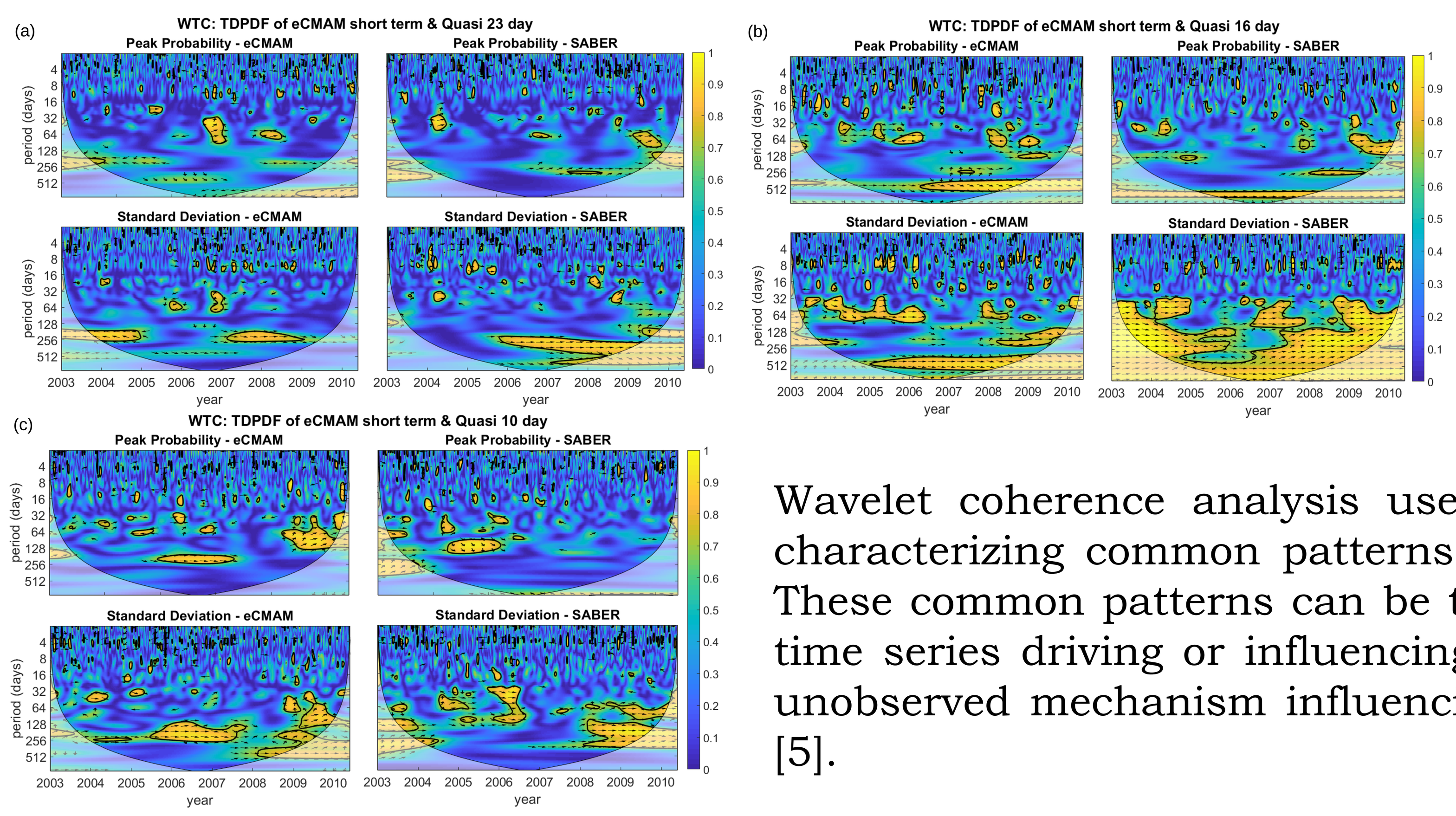


Figure 5: a) Wavelet coherence analysis between TDPDFs of short-term tidal variability and quasi 23-day wave. b) Quasi 16-day c) Quasi 10-day

Wavelet coherence analysis use in identifying and characterizing common patterns in two time series. These common patterns can be the results from one time series driving or influencing the other or some unobserved mechanism influencing both time series [5].

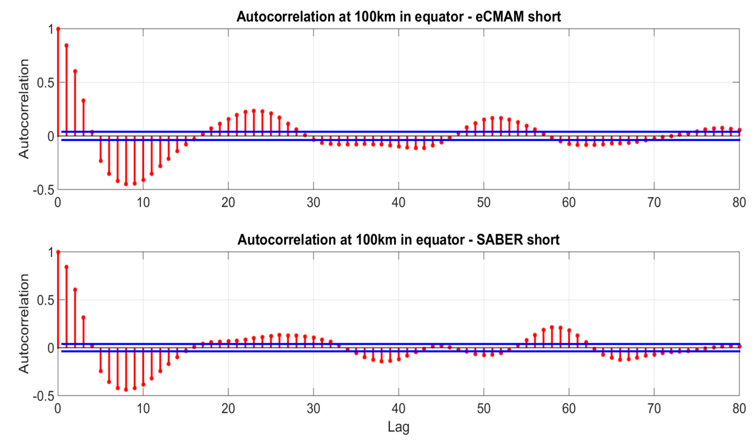


Figure 6: The autocorrelation function (ACF) plot for the eCMAM and SABER short-term tidal variability

Autocorrelation function plots for different heights and latitudes from both eCMAM and SABER short-term tidal variability reveal a common pattern with approximately 23 days of periodicity. I.e. the time series strongly correlated with itself after a lag of 23 days

CONCLUSIONS

- Preliminary studies show seasonal and inter-annual periodicity involved in TDPDF of short term tidal variability in DW1 for both eCMAM and SABER in equator .
- Wavelet coherence analysis reveals influence from quasi 10,16 and 23-day waves to the TDPDFs of short-term tidal variability.
- We intend to further investigate the influence from planetary waves on the short term tidal variability, the causes behind 23 day lag, and apply the thermodynamic budget equation to study physical mechanism.

REFERENCES

1. J. Walter Larson, "Visualizing Climate Variability with Time-Dependent Probability Density Functions, detecting It Using Information Theory", Procia Computer Science 9 (2012) 917-926.
2. K. H. Knuth, "Optimal data-based binning for histograms, https://arxiv.org/pdf/physics/0605197.
3. Shimazaki H. and Shinomoto S., Kernel Bandwidth Optimization in Spike Rate Estimation. *Journal of Computational Neuroscience* (2009) doi:10.1007/s10827-009-0180-4.
4. Shimazaki H. and Shinomoto S., A method for selecting the bin size of a time histogram *Neural Computation* (2007) Vol. 19(6), 1503-1527.
5. A. Grinsted, J. C. Moore, S. Jevrejeva. Application of the cross wavelet transform and wavelet coherence to geophysical time series. Nonlinear Processes in Geophysics, European Geosciences Union (EGU), 2004, 11 (5/6), pp.561-566.

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