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Evaluation of Temperature and Ocean Currents within Hybrid Coordinate Ocean Model (HYCOM) Using Rama Mooring Buoys Data in Indian Ocean

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Abstract

Variance-preserving Power Spectra (VPS) from Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) observational and HYbrid.Coordinate Ocean Model (HYCOM) output data of sub surface temperature and current for the couple of year at mooring locations in the Indian Ocean was used to understand the variability of ocean parameters. The VPS of 20º isothermal depth (d20) reveals fact that it has intra-seasonal, seasonal and semiannual oscillation trends. Zonal current's VPS show the intra-seasonal, biweekly and weekly characteristics. Meridional current's VPS gives biweekly and weekly oscillation. The HYCOM model output data does not capture the exact same signals amplitude and frequency produced by RAMA VPS. These scientific findings are consistent with the results obtained from similar analysis of Triangle Trans Ocean Buoys Network (TRITON) data by other investigations. We suggest an assimilation of the HYCOM product and then it should be used for analysis purpose.

INTRODUCTION:

The movement of heat around any ocean and its exchange with the atmosphere is highly variable in time. The Indian Ocean has a unique system of three-dimensional currents and interactions with the atmosphere that redistribute heat to keep the ocean approximately in a long-term thermal equilibrium (International Clivar Project Office, 2006). The unusual anomalies in the atmosphere are mainly affected by various oceanic parameters such as ocean temperature, upper ocean currents, heat flux, atmospheric pressure, etc. These parameters exhibit large spacio-temporal variability at different time scales which is driven by a wide variety of factors occupying the periodic band of a few days to years.

The Indian Ocean Sea surface temperature (SST) shows strong signals at diurnal (within 24 hour) and synoptic scales (5 to 10 days). The persistent anomalies in SST and wind on a seasonal cycle (Meehl,1994) influence the air-sea interaction. The SST in the Indian Ocean is determined by the net heat flux at the surface and the wind stress forcing (Murtugudde and Busalacchi, 1999).While SST has a strong control on the annual evolution of the Tropical Convergence Zone (TCZ), the precipitation in the TCZ has a strong control on the evolution of the SST(Pandey.,2011). The seasonal cycles of SST are more pronounced with distance from equator. The annual variations are strong in surface variables. Various studies(Masumoto and Meyers, 1998; Perigaud and Delecluse, 1993; Webster and Yang,1992) have shown that propagating oceanic waves, exhibiting intra-seasonal variation, play a crucial role in energy transport. Madden and Julian, 1972; Lau and Shen, 1988 have observed 30-60 days variability in these waves controlling the dynamics of Tropical Indian Ocean(TIO). Sengupta et al.,(2001) have shown that the 30-60 day variability of off-equatorial zonal current is wind forced and they reported a dominant 90 day peak in observed sea level in the eastern Equatorial Indian Ocean(EqIO). Wind forced intra-seasonal currents make a significant contribution to ocean heat transport and upper ocean heat balance (Loschnigg and Webster (2000) and Waliser et al. ,2004). Duing and Schott (1978) reported 50 day oscillations in the south equatorial current of Indian Ocean. Indian Ocean variability with 100 days of periodicity is mostly associated with eddies(Traon and Morrow, 1999), Monsoonal and seasonal signals are also apparent in the upper ocean. Another important mechanism governing the variability of TIO is the phenomenon of EI-Nino (Cadet and Diehl, 1984; Webster and Yang, 1992) which determines the inter-annual climate variability in the Indian Ocean. Cadet and Diehl (1984)demonstrated the existence of SO signal of 40-60 months over Indian Ocean using power spectral estimates. They speculated that the observed variability is consistent with a 20 year cycle. Recently discovered Indian Ocean Dipole mode event is believed to be a responsible mechanism for climate change in a wide area from the Indian Ocean to the Pacific Ocean (Saji et al., 1999; Yu and Rienecker, 1999; Webster et al., 1999; Murtugudde et al., 2000). It is identified as a pattern of inter-annual variability with anomalously low sea surface temperatures off Sumatra and high sea surface temperatures in the Western Indian Ocean, with accompanying wind and precipitation anomalies. Yet another interesting phenomenon associated with the variability of monsoon reported in literature is the sunspot cycle having a periodicity of 11 year. During this event an amplitude variation of 1.5 Wm^{-2} in incoming shortwave radiation flux is reported (Nimmi R Nair, 2004).

The measures of in situ oceanic parameters are necessarily needed for the study of oceanic response to these seasonal variables which are helpful in the determination of forced oceanic oscillations and consequently these Indian Ocean observations become essential for predictability studies. The accurate estimates of high resolution, research-quality estimates of surface wind, current and temperature can be obtained from the scatterometer on QuikSCAT over the Ocean surface for the required period of time to study their variability in the particular region. The present study is an attempt to analyze the seasonal variability of 20° isothermal depth (D20) and zonal-meridional ocean currents at different locations of TIO using Hybrid Coordinate Ocean Model(HYCOM). The Hybrid Coordinate Ocean Model (HYCOM) will be validated against available RAMA observational data to point out the variability of the above mentioned parameters in the upper 200 m of the Equatorial Indian Ocean (EqIO). The variability of the parameters will be studied using the Variance Preserving Power Spectral(VPS) technique. Furthermore, the consistency of HYCOM model outputs will be observed by comparing the same VPS obtained from RAMA.

METHODOLOGY AND DATA SET:

The following methodology used for the Model Run: Hybrid Coordinate Ocean Model(HYCOM), simulation output data for the region 10˚ E to 124˚ E and 43˚ S to 30˚ N using Generalized Digital Environment Equatorial Model (GDEM) climatology and it is forced by 3 hourly Global Forecast System (GFS) data, with the topographical data General *Bathymetric* Chart of the Oceans (CEBCO) for bathymetry of 1΄, was analyzed for the Indian Ocean and Indonesian throughflow region i.e. for the Indo-Pacific region of the ocean. The model resolution for the simulation was very fine i.e. of the 1/12˚ which made the output resolution very useful for every passage, existing in the Indonesian archipelagoes region.

In order to check the variability of intensity of signals, we use a technique of Variance Preserving Power Spectral (VPS) analysis which analyses the ratio of log of squared magnitude of the continuous Fourier transform of the signal to that of log of frequency, hence known as the power spectral analysis. Through the VPS technique, we can identify the strength of a signal and their respective frequencies on different time bands (Weekly, biweekly, intra-seasonal, seasonal, etc).

RESULT AND DISCUSSION:

In the VPS spectra of the parameters, the X – axis represents logarithmic of frequency and Y – axis represents the intensity of the signal. VPS are presented and observation of intensity of signals and their particular frequency band are described.

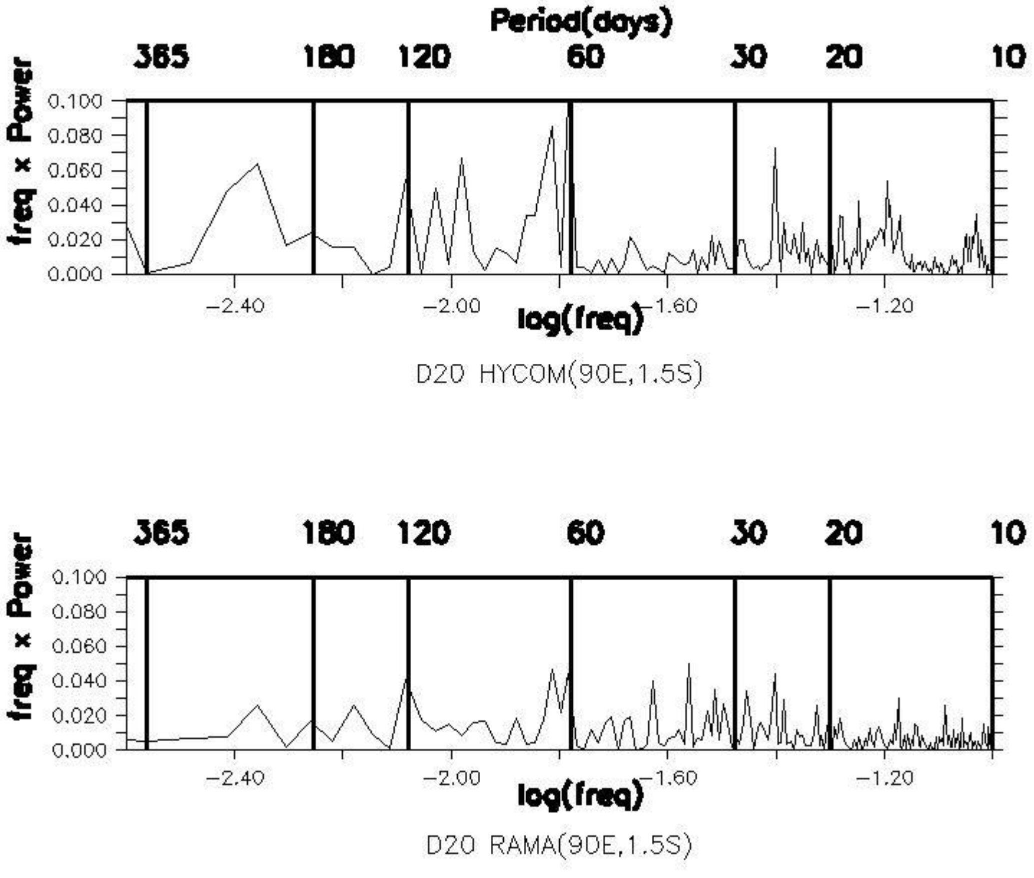

Figure 1(2009-10)

In figure 1, the upper panel represents the VPS of 20° isothermal depth(D20) of HYCOM data which shows several significant peaks within the time band 10-20 days, 20-30 days and at the time band 60-120 days, there are several low intensity spikes at 30-60 days which shows that the D20 signal obtained from HYCOM data is intra-seasonal and seasonal in nature.

Similarly, the lower panel in the above figure 1 represents the VPS obtained by RAMA data which consists of various significant peaks at the time band 10-20,20-30, 30-60and 60-120days. This implies that the D20 signal is biweekly, intra-seasonal and seasonal in nature.

From the above two panels of figure 1, we conclude that the D20 obtained from HYCOM data provides significant peaks of greater intensity in comparison with that of RAMA data within the time span of 1-120 days.

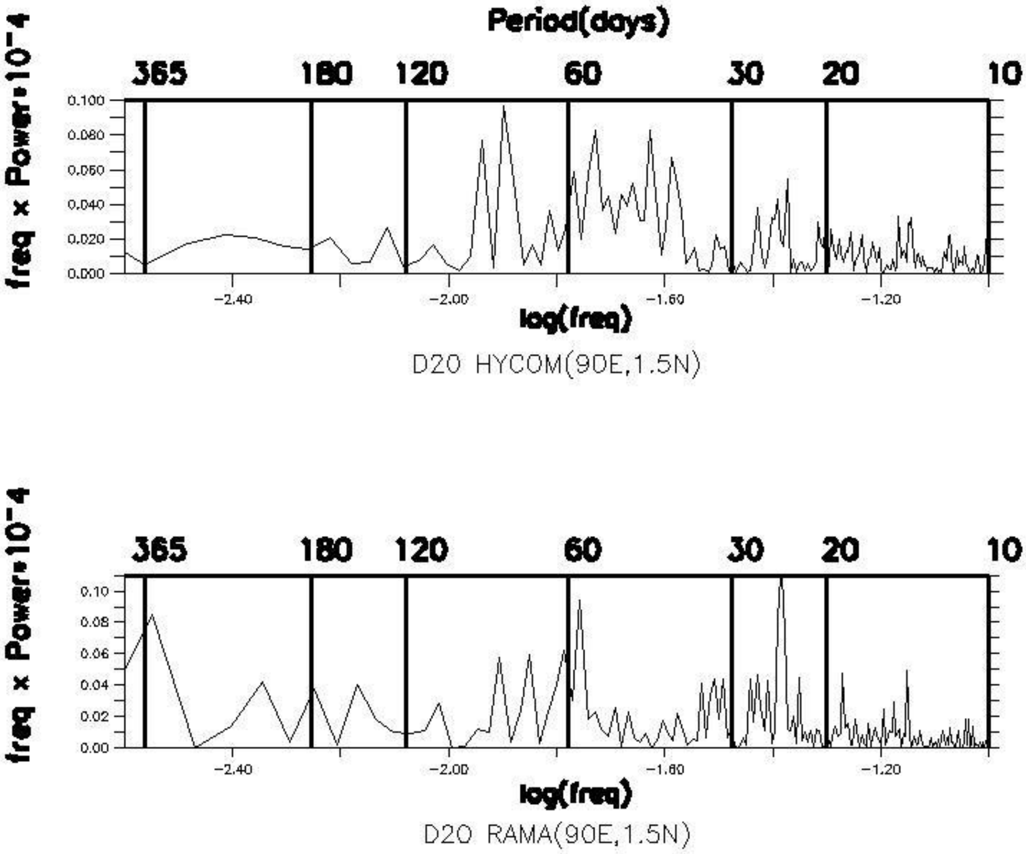

Figure 2

In figure 2, the upper panel represents the VPS of D20 of HYCOM data which shows several significant peaks within the time band 20-30,30-60 and 60-120 days. There are several low intensity spikes at 20-30days which shows that the D20 signal obtained from HYCOM data is biweekly, intra-seasonal and seasonal in nature.

Similarly, the lower panel in the above figure 2 represents the VPS obtained by RAMA data which consists of various significant peaks at the time band 30-60, 60-120 and at 180-365 days. There are several low intensity spikes at 10-20, 20-30 days This implies that the D20 signal is biweekly, intra-seasonal, seasonal and semi-annual in nature.

From the above two panels of figure 2, we conclude that the D20 signal obtained from HYCOM data provides significant peaks of greater intensity in comparison with that of RAMA data throughout the year.

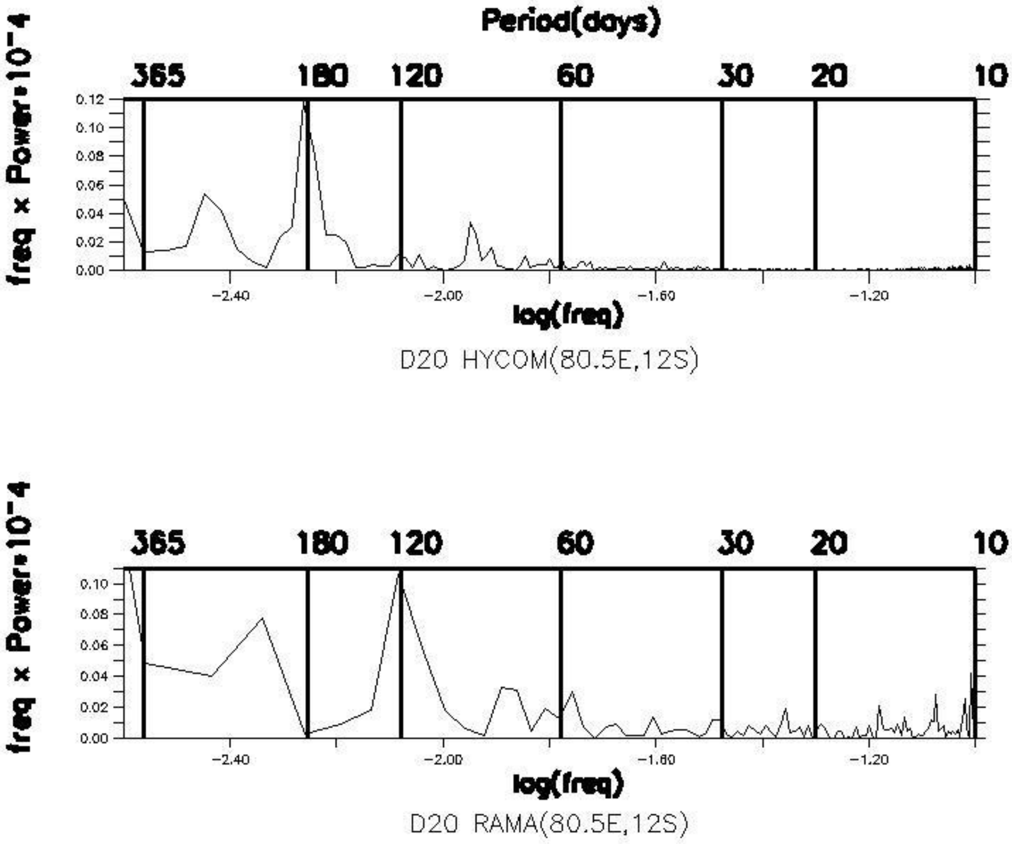

Figure 3

In figure 3, the upper panel represents the VPS of D20 of HYCOM data which shows very low intensity peaks during the time band of 10-60 days. Thereafter, after 90 days several high intensity peaks are observed which shows that D20 signal obtained form HYCOM at 80.5°E, 12°S is seasonal and interannual in nature.

Similarly, the lower panel in the above figure 3 represents the VPS obtained by RAMA data which shows the similar pattern as that of obtained by HYCOM. In the VPS obtained by RAMA data, we obtain several low intensity peaks at the time band of 10-60 days. The intensity of these peaks is higher than that of HYCOM and after 90 days, several high intensity peaks are recorded which shows that the D20 signal obtained from RAMA is seasonal and interannual in nature.

From the above two panels of figure 3, we conclude that the D20 signal obtained from HYCOM data provides similar VPS pattern as that obtained by RAMA. This figure also verifies that the D20 signal becomes seasonal in nature when it's distant from the equator as stated by RN Nimmi(2004).

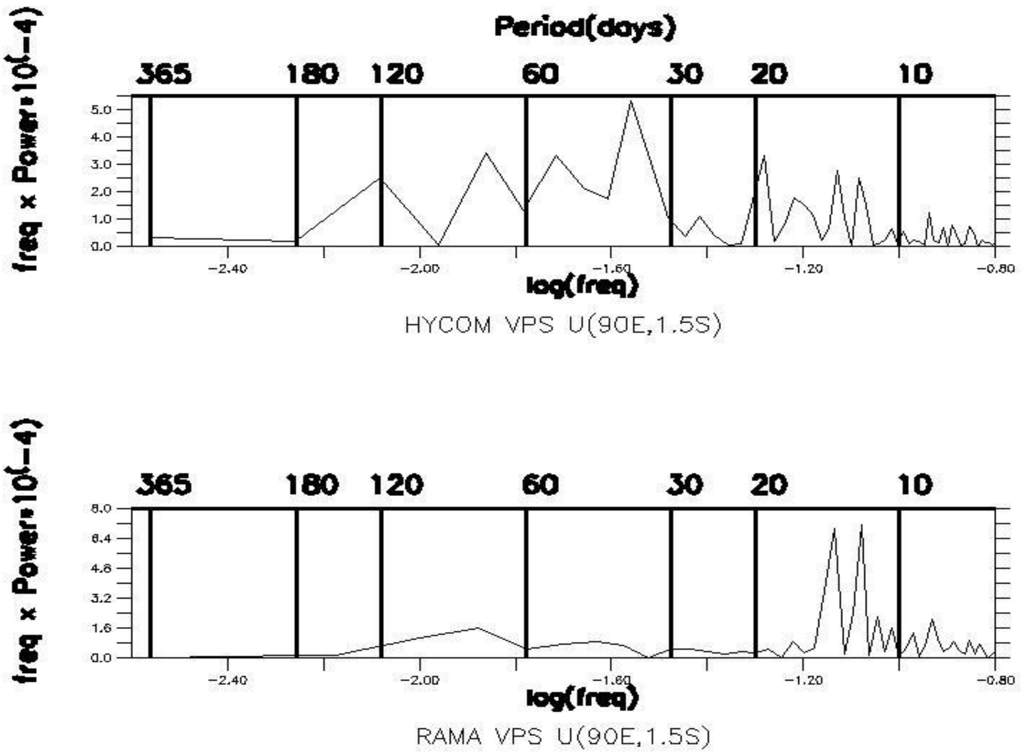

Figure 4 (2009-10)

In figure 4, the VPS of zonal current obtained through HYCOM for the year 2009-10 represents significant peaks at time bands of 10-20 days and 30-60 days which shows that signal of zonal current is biweekly and seasonal in nature.

On the other hand VPS of zonal current obtained through RAMA data has the only significant peaks within the time band 10-20 days, thus zonal current signals are biweekly in this case. From the above figure, it is clear that VPS of zonal current obtained through HYCOM provides more high frequency spikes in comparison with RAMA data.

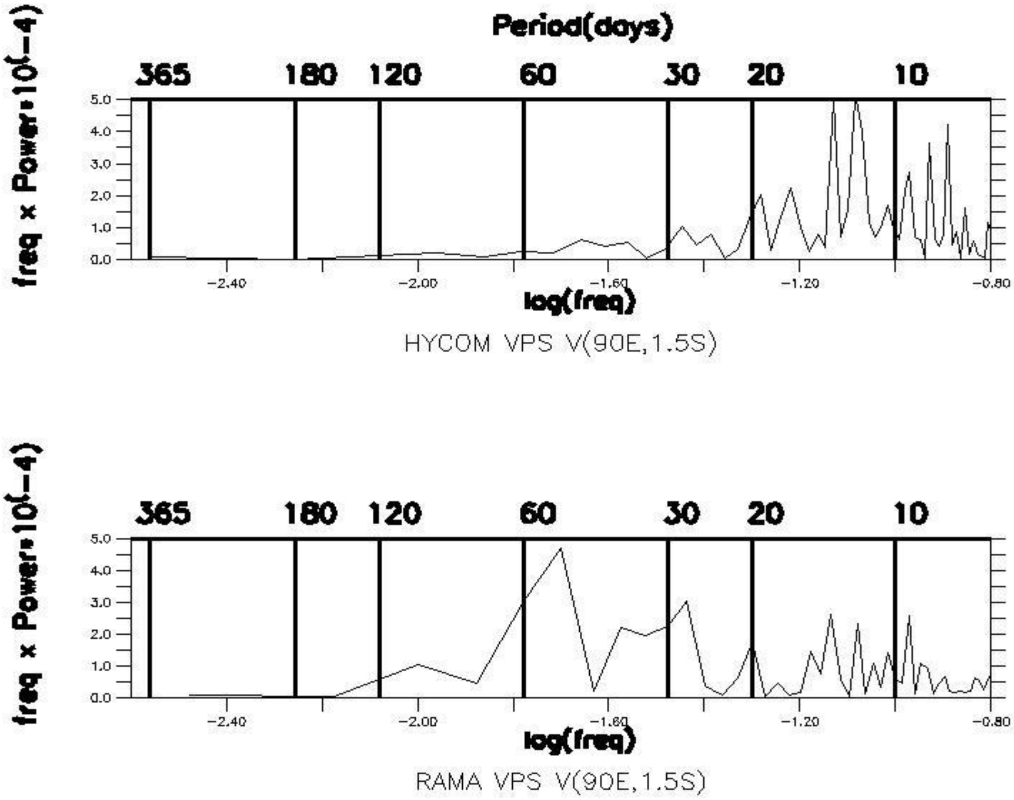

Figure 5 (2009-10)

From figure 5 it is clear that the VPS of meridional current obtained from HYCOM data has significant peaks within the time band 0-10 and 10-15 days which shows that the current signal is weekly and biweekly in nature.

VPS of RAMA data shows relatively low intensity peaks at the time band 0-10 days,10-15 days, 20-30 days and 30-60 days which shows that the current signal is weekly,biweely and strongly intra-seasonal in nature.

On comparing the two given VPS of HYCOM and RAMA data, we see that HYCOM data VPS has strongly weekly and biweekly variations whereas RAMA VPS has strongly seasonal variations. Also the intensity of signals of HYCOM data is greater than that of RAMA data.

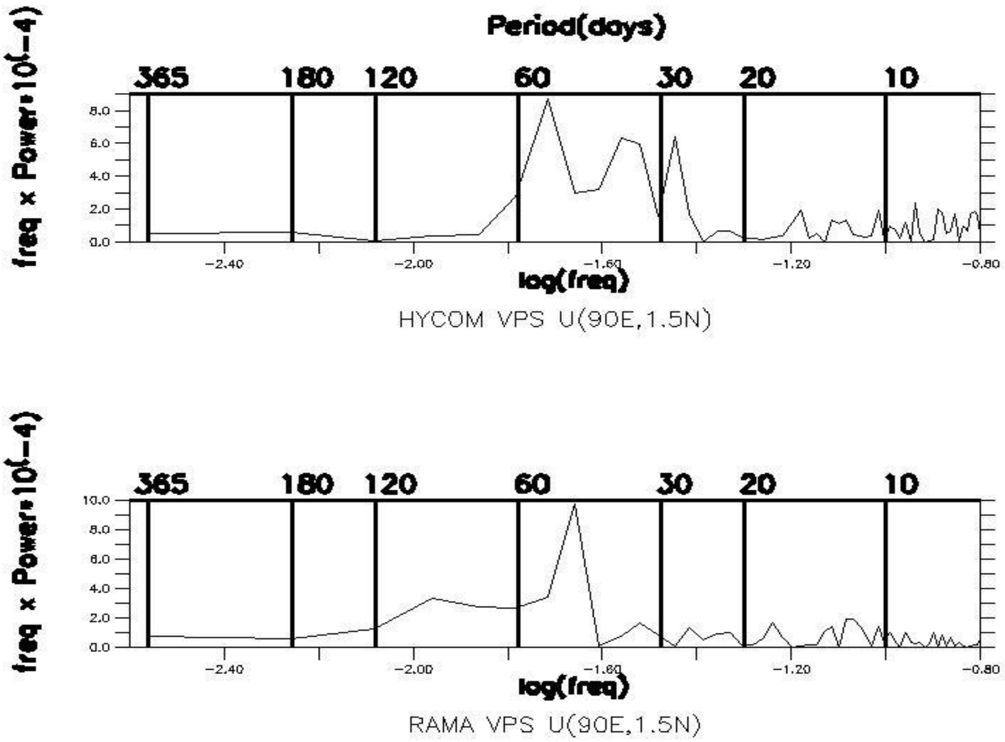

Figure 6 (2009-10)

In Figure 6 we see that the VPS of zonal current obtained by HYCOM shows high intensity peaks within the time band 20-30 days and 30-60 days. There are several other high frequency spikes are present which suggests that signal of zonal current is intra-seasonal and may be weekly and biweekly in nature.

Similarly if we study the signal of zonal current obtained through RAMA, we observe a significant high intensity peak within the time band 30-60 days and several spikes between 10-20 days which shows that the signal of zonal current are biweekly and intra-seasonal in nature.

From figure 6 it is clear that VPS of zonal current obtained through HYCOM has relatively high intensity spikes within the time bands 0-10 days, 20-30 days and relatively high frequency spikes at the time band within 30-60 days in comparison with RAMA.

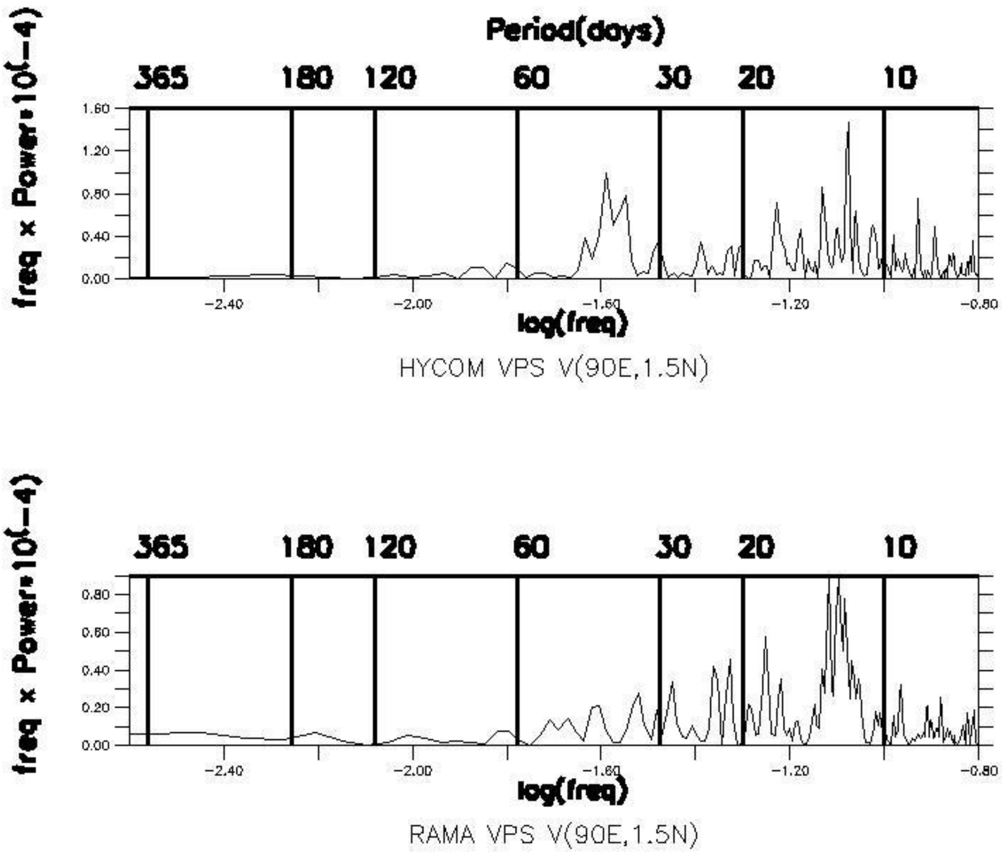

Figure 7 (2009-10)

From Figure 7 we see that the VPS of meridional current obtained by HYCOM data shows several significant peaks at the time band 0-10 days, 20-30 days and 30-60 days, which shows that the current signal is weekly, biweekly and intra-seasonal in nature.

Similarly if we observe the VPS of current obtained by RAMA data, it shows several high frequency high intensity spikes at the time band 10-15 days and relatively low intensity peaks within the time band 20-30 and 30-60 days. This shows that this current signal obtained by RAMA data is weekly, strongly biweekly and may be intra-seasonal in nature.

If we compare the two VPS shown above in Figure 7, we observe that the current signal obtained from HYCOM data shows high intensity peaks in comparison with that of RAMA data during weekly, biweekly and intra-seasonal time span.

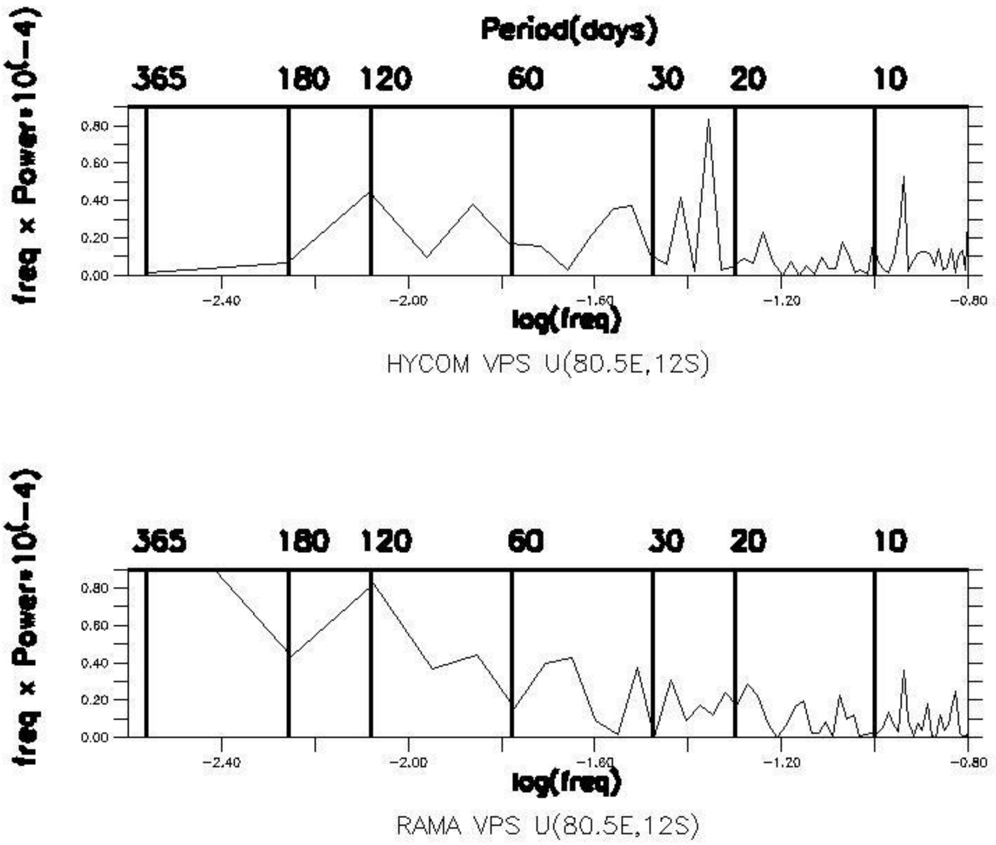

Figure 8 (2010)

The VPS of zonal current obtained from HYCOM data shows high intensity peaks at the time band 0-10 days, 20-30 days, 30-60 days and 60-120 days, which shows that current signals are weekliy, biweekly, intra-seasonal and seasonal in nature.

Similarly, VPS of zonal current obtained from RAMA data shows a low intensity peak within the time band 0-30 days. It occupies several other high intensity peaks after 30-60 days, 60-120 days and even after 120 days which is not visible in the VPS of HYCOM. This shows that the RAMA current signal is biweekly, intraseasonal and seasonal in nature

On comparing the two VPS obtained from HYCOM and RAMA data we conclude that current signal obtained from HYCOM data has more variability in comparison with RAMA data.

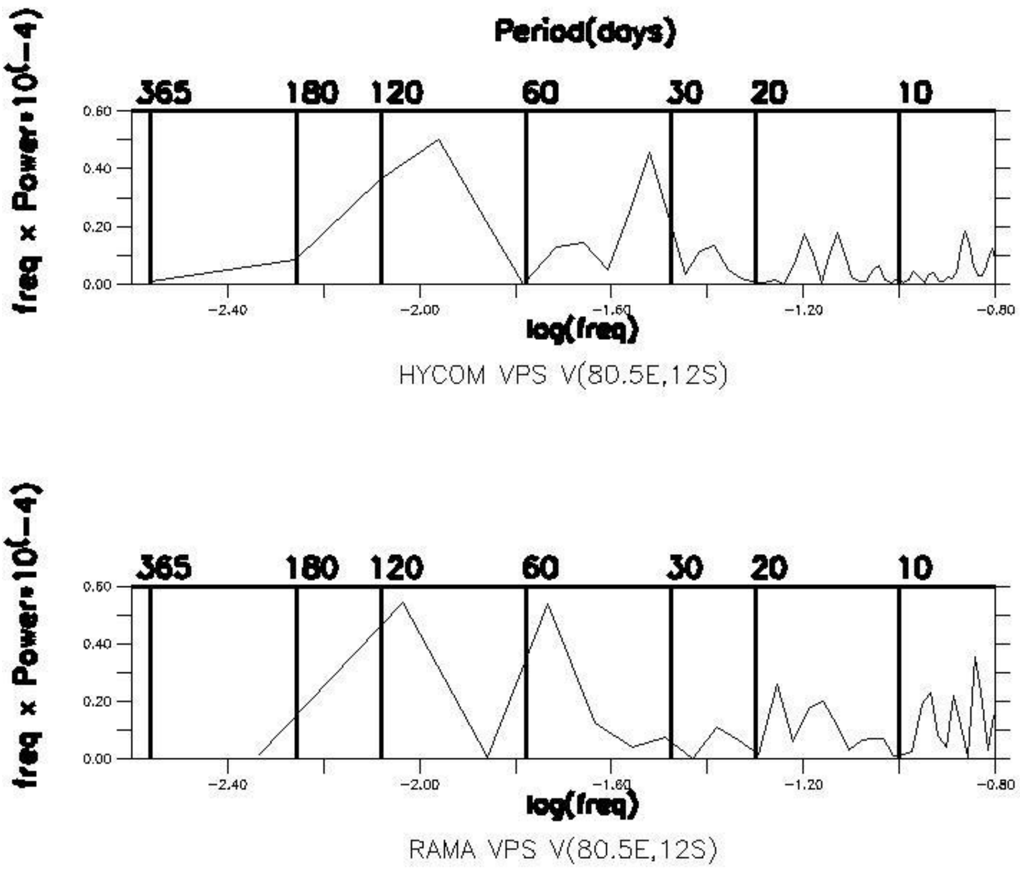

Figure 9 (2010)

The VPS of meridional current obtained by HYCOM data shows the significant peaks within the time band 0-10 days, 10-20 days, 30-60 days and 60-120days which reveals that the signal currents are weekly, biweekly, intra-seasonal and seasonal in nature.

Similarly, VPS obtained by RAMA data shows high variation of signal during 0-10 days, 10-20 day ,30-60 days and 60-120 days revealing that the signal is weekly, biweekly, intra-seasonal and seasonal in nature.

If we compare the two VPS shown above in Figure 9, we observe that the current signal obtained from RAMA data shows high intensity peaks in comparison with that of HYCOM data during weekly, biweekly, intra-seasonal and seasonally time span.

CONCLUSION:

Analysis of HYCOM daily output data of the subsurface temperature and current for the year 2009-2010 has been analyzed using variance preserving power spectra in form of D20 analysis and surface currents. It is found that at 90°E,1.5°N; 90°E, 1.5°S the D20 have intra-seasonal and sometimes seasonal oscillations with intense amplitude and zonal-meridional ocean current signals at the same locations are weekly, biweekly oscillation with intense signal strength in the data provided by HYCOM. The signals of D20 and ocean currents of HYCOM strongly seasonal in nature at 80.5°E, 12°S and the performed VPS analysis reveals a fact that the D20 signal of HYCOM exhibits more variation than that of RAMA while at the other location it is low. Moreover, the zonal and meridional currents signals obtained by HYCOM are consistent with the RAMA output during the weekly and biweekly phase, yet they show significant bias in intra-seasonal and seasonal time span. Therefore, we suggest an assimilation of the HYCOM product and then it should be used for analysis purpose.

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