COASTAL CURRENTS ON THE NORTHERN OMANI SHELF

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1. Introduction

Coastal currents affect morphology, ecology and economy of the coastal zone. The main controlling factors for coastal currents are shelf topography, terrestrial discharges, tides, wind and motions imposed from the open ocean [1]. Since all these factors depend on specific local conditions, coastal currents must be studied locally. Currently, the hydrodynamics along Oman's northern coasts are not well understood. Concepts about currents on the shelf are mainly derived from studies on open ocean processes within the Sea of Oman. The relative importance of tides, wind and mesoscale dynamics on the coastal circulation has not been studied. Nearshore currents remain unclear, largely owing to missing high resolution models and local field data. Here we study coastal flow in the vicinity of Muscat, based on ADCP measurements. Our principal research question was: what are the general patterns and the main drivers of the local circulation?

2. Site description

The Sea of Oman connects the Arabian/Persian Gulf with the north western Indian Ocean. Several studies on regional ocean circulation describe the slope current of the Persian Gulf Water (PGW) , propagating southwards at 150 - 350 m depth [2] and a system of energetic mesoscale eddies occasionally impinging on the Omani shelf [3, 4]. In this study we focus on the coastal region around Muscat. Tide gauge records at Muscat show a mixed, mainly semidiurnal tide with an average (maximum) tidal range of 1.5 m (3.3 m). Local winds are variable and seldom exceed 10 knots at 10 m height. Local coastal upwelling appears as short irregular events [5].

3. Methods

We measured flow between Ras Al Hamra and Jazirat Al Fahal (Figure 1). A 600 kHz RDI Workhorse Sentinel ADCP was deployed upwards looking at a depth of 20 m. Data was recorded every minute for 76 days during Sep.-Dec. 2017 at a vertical resolution of 1 m. Here we present hourly filtered horizontal current velocities. Records from the tide gauge at Port Sultan Qaboos and wind data measured at Muscat Airport, both in vicinity of the ADCP location, are included in the study. Tidal analysis was performed with the UTide Matlab routines [6]. Rotary spectra using Slepian tapers and wavelet analysis using Morse wavelets were computed following the methods described in [7]. Principal axes and the ratio of the variances along them are determined by principal component analysis.

4. Results

Figure 1 shows the scatter (east vs. north) of all hourly current components. The depth and time averaged flow goes to the east (84°) at 15 cm/s (white arrow Fig.1). The first principal component axis of the scatter, indicating the direction of the highest variance, is also directed to the east (88°). The major and minor axes (black lines in Figure 1) are scaled by 5 times the standard deviation and have an eccentricity of about 4.

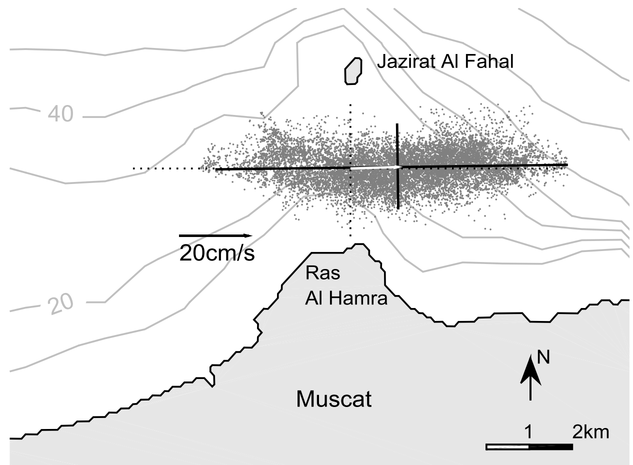

Figure 1. Scatter of east vs. northward current velocity components; residual flow vector (white) and principal component axes (black).

Figure 2 shows the rotary spectra for the surface and bottom layers and for the wind data. All three spectra show distinct diurnal (d) and semidiurnal (sd) peaks. The diurnal band is dominant in the wind and the upper water column. In the upper water layer a second peak appears for clockwise rotation at inertial frequency (f, ~29 h). Inertial and diurnal components decrease towards the sea floor. A weaker peak shows in the rotary spectra over the entire water column at periods between 5 and 30 days.

Figure 3 shows the time series of the current vectors and their wavelet transform. In the time series of the dominant eastward current the diurnal and semidiurnal fluctuations are superimposed by larger low frequency variations. The wavelet transform shows a series of events at periods around 5 days. A longer event around periods of 20 days shifts energy to periods around 5 days on 15. Nov.

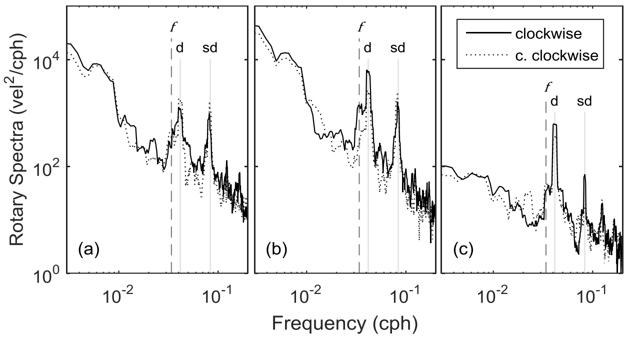

Figure 2. Rotary spectra of currents in cm/s, 2 m above the sea floor (a) and 3 m below the sea surface (b); wind in m/s at 10 m above the sea surface (c).

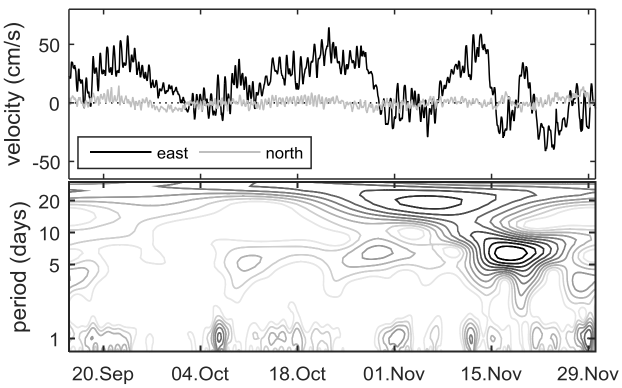

Figure 3. Top: time series of east and northward depth averaged current components. Bottom: wavelet transform of the currents using Morse wavelets.

The wind record mainly correlates to currents in the upper water column. Near the sea surface a maximal correlation of r = 0.48 was found for a time lag of 1 h (wind leading) and an angle of 18° between wind and current vectors. Below the sea surface, wind influence decreases with depth at increasing time lags and changing angles to a correlation of r ~ 0.1 at 3 m depth. Tidal analysis of the flow below the wind influenced layers gives 35 significant harmonics of which K1, M2, OO1 and S2 are the most important ones. MSF and MM were excluded as not realistic (see discussion). The K1/M2 energy % ratio is 50/10 3 m below the surface and 30/16 close to the sea floor. Predicted tidal currents, using the 33 components, correlate to the high pass filtered (period < 1.15d) measurements at r = 0.9. Tidal flow is oriented in east-west direction with an average eccentricity of major/minor axes of 3 and average magnitudes of 10 cm/s.

5. Discussion

The observed currents show high energy in semidiurnal, diurnal and longer period bands. Tides account for about 80% (r^2) of the variation in the semidiurnal and diurnal bands below the wind influenced layers. The local wind also peaks at these two frequencies giving evidence to a pronounced sea breeze. The vertical influence of the wind is however restricted to near surface layers reducing the potential smearing of tidal analysis for lower layers. Possible reasons for the shallow influence of the wind are its strong diurnal and semidiurnal variations and generally low wind speeds. The influence of the diurnal and inertial bands decreases with water depth as has been observed by others [1]. The most energetic currents of up to 60 cm/s are linked to easterly low frequency pulses. When including fortnightly and monthly constituents (MSF + MM) in the tidal analysis some of the low frequency variation can be resolved but this results in an over dominance of these harmonics (combined > 70%). Also, monthly harmonics are insignificant for the local sea level tides and therefore not considered realistic. The isolated pulses identified in the wavelet transform furthermore suggest nonstationary processes. Low pass filtered wind correlates to surface currents but no to the depth averaged low frequency flow and can therefore also not account for this variability.

6. Conclusions

Based on the analysis of ADCP data and local wind and tide gauge records we could determine general patterns of the local circulation on the Muscat shelf. Wind influence is mostly restricted to the upper water column while tidal flow accounts for most of the super inertial variation within the lower water column. Tidal currents are oriented in east-west direction with magnitudes ranging up to 15 cm/s. Sub inertial variations appear as irregular easterly pulses of up to 60 cm/s. Possible drivers for these energetic low frequency pulses are oceanic processes such as PGW flow, mesoscale eddies or alongshore barotropic gradients and coastal trapped waves. Ongoing research aims at understanding the low frequency dynamics and their general impact on the local shelf currents.

7. Acknowledgments

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8. References

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