Chapter 7

Summary & Conclusions

7 SUMMARY AND CONCLUSIONS

In recent times, one of the biggest challenges for the existence of life on earth is the unequivocal rate of changing climatic conditions. The effects of global warming are not just limited to the land surfaces but are being felt across the oceans as well. However, for a holistic understanding of the impacts of climate change, regional assessments are required. It is in this regard that the present work was carried out to analyze the effect of the climate change on the physical parameters like SST and Wind speed over the Arabian Sea and also to assess its impact on the biological productivity of the basin.

The salient findings of the present research work are as follows:

1. Impact of Climate Change on SST of the Arabian Sea

There has been a rapid warming of the Arabian Sea since 1950, with the annual SST increasing by 0.78 °C in past 65 years. This warming has occurred across all the four seasons with the highest rise in SST during the SWM season, with the normalized SST anomalies increasing at the rate of +0.43/ decade, followed by those during the AIM (+0.41/decade). However, the warming of the Arabian Sea on annual as well as seasonal scale has speeded in the last 20 years, i.e. from 1995 to 2015, with all the almost all the years showing positive deviation from the climatological mean.

On a decadal basis, there has been a rise in SST of the Arabian Sea across all the decades from 1950 to 2015. Though only 5 years data was included in the decade from 2010, yet the increase

in SST during the period from 2010 to 2015 was highest for all the decades since 1950. This provides significant evidence that the warming in last 5 years have been most substantial.

The satellite images of SST provided evidence for different warming pattern in different domains of the Arabian Sea. There has been an expansion of the warm waters of the Arabian Sea in the range of 30-32°C, from the southeast domain to the central domain of the Arabian Sea since 2005.

Domain wise analysis revealed that there has been an upward trend of annual SST in all the domains of the Arabian Sea, except for the Gulf of Aden, and these trends were statistically significant for the Arabian Sea basin, its northern, southern, eastern and western domains along with the Persian Gulf. As compared to the northern and western domains, the warming in the eastern and southern domains were higher, with their normalized SST anomalies increasing at the rates of +0.56 units /decade and +0.51/decade, respectively. Significant warming has occurred during the months from June to December in eastern and southern domains. In the northern domain, significant warming has happened during the months of March, August, September and December; whereas the western domain showed significant warming during September, October and November.

In the western gulfs of the Arabian Sea, the warming in the Persian Gulf and the Red Sea has been more than those of the Gulf of Oman and Gulf of Aden whereas amongst the eastern gulfs of the basin, the rise in SST was more prominent in the Gulf of Kutch than in Gulf of Khambat.

2. The changing pattern of Wind Speed over the Arabian Sea

In the last 23 years from 1988 to 2010, there has been a gradual decrease in annual speed of the wind over the Arabian Sea basin. Though it was found that the wind speed during the months of April, July and December followed an upward trend, yet for the rest of the months a decreasing trend was found. The rate of decrease of wind speed was highest during August, which was -1.5 cm/sec/year, followed by those of May, with -0.8cm/sec/year. The decrease in the wind speed during the months of August and September, which are the favourable months for the growth of phytoplankton is an issue of concern, as it would hamper the productivity which is maximum during these two months.

3. Spatio –Temporal variability of Phytoplankton biomass and their productivity over the Arabian Sea

The phytoplankton biomass (indexed from chl. - a conc.) in the Arabian Sea was observed to follow a typical bimodal pattern, with peaks during the NEM and SWM seasons. For the period from 1998 to 2009, it was observed that September was the month with peak chl.-a conc. However, for the period from 2010 to 2015, a deviation was observed with February turning out to be the month with the maximum productivity instead of September. This shift in the peak can be considered as a change in the phenology of the phytoplankton of the Arabian Sea, occurring either due to a change in its species composition or due to a change in the lifecycle of the phytoplankton. Moreover, this shift was not an episodic one, instead it continued for all the successive years from 2010 to 2015, making it evident that it was a phenological change of the phytoplankton of the Arabian Sea. This shift in the peak was noticed in the Northern and Eastern domains as well, but not in the Southern domain.

The Western domain did exhibit a similarity, with its higher productivity during February, which was comparable to that of July, but a distinct shift cannot be said.

The decadal analysis of chl.-a conc. revealed a substantial decrease in the extent of the productive areas of the Arabian Sea basin especially the Northern, Western and Eastern domains from 1998 to 2008 and from 2005 to 2015.

It was also found that the decrease in the phytoplankton biomass of the Arabian Sea basin has been occurring at a statistically significant rate annually as well as seasonally. From 2007 to 2015, only one year (2014) showed positive deviation in the biomass from the climatological mean, while in all the years it was negative. However, the most notable observation was the decrease in the phytoplankton biomass of the Arabian Sea, during the SWM season, which considered as the season with highest productivity. It was found that amongst all the four seasons the highest decrease in phytoplankton biomass was during the SWM season, with its normalized anomalies decreasing at the rate of -1.5 units/ decade. This poses a serious issue of concern, as rate at which the phytoplankton are dwindling during SWM, it will affect the overall productivity of the Arabian Sea basin.

Amongst the Northern, Southern, Eastern and Western domains, there has been a decreasing trend in the phytoplankton biomass annually since 2003. The seasonal trend analysis for these four domains revealed that during the SWM season, there has been a decrease in the phytoplankton biomass in the Northern, Southern and Eastern domains, while there was no trend for the Western domain.

The monthly trend analysis of chl.-a conc. for the different domains of the Arabian Sea, revealed that it was only in the Western domain in which a significant increase in phytoplankton biomass has happened, but limited to the month of January, from 1998 to 2009 and this trend did not continue for the period from 2003 to 2015. For all the rest of the months either a decreasing trend was observed or even if the increase was there, it was not significant. It was also observed that in all the four domains, there has been a significant decrease in the phytoplankton biomass in the months of September, October and November from 2003 to 2015. This can be interpreted as a threat to the overall productivity of the Arabian Sea, as September being peak season for biological productivity; a decrease in the phytoplankton biomass will affect the other organisms of the trophic level, disrupting the entire food chain.

4. Correlation of the changing climate on the biological productivity of the Arabian Sea

The Intra annual variability of SST, and phytoplankton biomass in Northern, Southern, Eastern and Western domains of the Arabian Sea followed the typical bimodal pattern which is the characteristic of the Arabian Sea basin for the period from 1999 to 2009. However, for the period from 2003 to 2015, a marked variation in the bimodal pattern of the phytoplankton biomass was observed. It was noticed that in the Arabian Sea basin, as well as the Northern and Eastern domains, the peak productive season shifted from SWM season to NEM season with February being the most productive month instead of July. However, wind speed, and SST did not exhibit any marked deviation.

The inter annual variability of SST, Wind Speed and phytoplankton biomass in Northern, Southern, Eastern and Western domains of the Arabian Sea showed a similar pattern of

increasing SST, decreasing wind speed and diminishing phytoplankton biomass. In none of the domains any increase in productivity was noticed.

The warming of the Arabian Sea and its domains was found to be more during the decade from 1999 to 2009 than the period from 2003 to 2015. However, post 2010, there has been a sharp increase in the SST in all the domains. The wind speed decreased substantially over all the domains of the Arabian Sea during the decade 1999 to 2009. On the other hand, the phytoplankton biomass and the resulting productivity decreased substantially from 1999 to 2015, though the decrease was sharper during the period from 2003 to 2015. While the basin wide decrease in the normalized anomalies of chlorophyll-a was at the rate of -1.22 /decade, the rate of decrease was higher for the western (-1.4/ decade) and southern domains (-1.56 /decade) and even for the Gulfs especially in the Persian Gulf, Gulf of Oman and the Red Sea.

The statistical analysis of the correlation of SST, Wind Speed and phytoplankton biomass was done to conclude that the decrease in productivity as observed was because of the rise in SST and the decrease in wind speed. Very strong negative correlation was found between SST and phytoplankton biomass for all the domains, implying that the rise in SST was indeed hampering the growth of the phytoplankton in the Arabian Sea. On the other hand, positive correlation was found between wind speed and phytoplankton biomass, for all the domains, asserting that the winds play an important role in promoting the growth of the phytoplankton. However, as the wind speed have decreased across the years in all the domains, the growth and the productivity of the phytoplankton have been hampered resulting in a substantial decrease in the biomass of the phytoplankton and their productivity.