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DUST STORMS ADD IN BLOOMING OF PHYTOPLANKTON, TINY WANDERER PLANTS AS FOOD-CHAIN, OVER ARABIAN SEA: A RESEARCH STUDY BASED ON TEMPORAL SATELLITE IMAGES

NAYYER ALAM ZAIGHAM[1*], TANVEER ALAM[2], GOHAR ALI MAHAR[3] AND ZEESHAN ALAM NAYYAR[4]

[1]*GETS, A Research Group of Geoscientists & Environmentatists, A-40, Block-15, Gulistan-e-Jauhar, Karachi*
[2]*Chair of Oman's Medical Plants & Marine Natural Products, University of Nizwa, Nizwa, Sultanate of Oman*
[3]*Department of Geography, Federal Urdu University, Karachi, Pakistan*
[4]*Department of Applied Physics, University of Karachi, Karachi, Pakistan*
[*]*Corresponding author's email: nazaigham@gmail.com*

Abstract

Geologically, climatologically and biodiversity-wise, Arabian Sea and Oman Gulf are unique from many other marine basins, where tiny-floating or drifting marine plants, phytoplankton, distinctly grow. Phytoplanktons are important because they serve as foundation of food chain sustaining the marine life. It was generally considered that the available incoming sunlight and the periodic phenomena of seawater upwelling from deeper depths provide essential nutrients for survival of phytoplanktons. An integrated research study is conducted to evaluate controlling factors for typical phytoplankton blooming based on analyses of satellite images of different periods related to dust-sandstorms, geotectonic-setup & submarine configuration, atmospheric-aerosol, sun-glittering and phytoplankton-bloom. It was observed that satellite images consistently reflected varying-pattern of phytoplankton-growth indicating dependence on number of multiple-factors. Results revealed that tropical cycles, dust-sandstorms, atmospheric-aerosol and prevailing-monsoons in Arabian Sea affect the levels of incoming sunlight and available nutrients impacting on phytoplankton growth within surface seawaters. It was also deduced that the dust-sandstorms carry iron, phosphorite and other minerals rich-particles from surrounding unique geological land regions, e.g., Afghanistan, Pakistan, Iran, and Arabian Peninsula serving as source of essential nutrients; and also control light-levels affecting photosynthesis processes in addition to monsoon-clouds, which collectively effect the phytoplankton-growth. Moreover, it was observed that submarine tectonic exotic features, e.g., Owen Fracture-Zone Ridge, Murray-Ridge, abyssal plains, Indus submarine fan, dynamic eddy-currents as well as cyclones affect growth and dispersal-trends of phytoplankton in Arabian Sea too.

Key words: Biodiversity, Dispersal-trends of Phytoplankton, Arabian Sea, land-food Source.

Introduction

Phytoplanktons, the very tiny organism (marine algae) in the ocean, are important because they are the basic marine food chain and a good indicator of environmental change as well. Small fishes and several other species eat them as food; larger fishes then eat the smaller ones; and human catch many of these fishes on commercial scale. There are many species of phytoplankton, each of which has own specific characteristics. It was experienced that different shades of ocean colour reveal the presence of varying concentrations of sediments, organic materials, or even phytoplankton, which cannot be observed by human eye, but differentiated on the satellite images.

It was observed that the aerosol and cloud blankets increase onset of monsoon season in June and July, which lowers the amount of light available at a minimum in summer for photosynthesis over the Arabian Sea-surface. Literature survey revealed that the 'light' scenario was different from other northern latitude ocean basins. Usually, in the North Atlantic Ocean, for example, phytoplanktons bloom in April, but in the Arabian Sea they bloom during winter. Comparative analyses of the relevant multi-disciplinary data and the Coastal Zone Color Scanner (CZCS) composite images of the Arabian Sea for April-June 1979 show low productivity preceding the southwest monsoon, whereas for July-September 1979, the high productivity was observed under the monsoon influence (Arnone *et al*., 1998; Fig. 1).

A Joint Global Ocean Flux Experiment was conducted in Arabian Sea to study ocean biological and physical processes and their links to the global carbon cycle during 1994-1996 (Nelson, 2000). It was also identified that Arabian Sea was unique from many other ocean basins, where monsoons over the Arabian Sea affect light levels, yielding significant biological growth in its surface waters. It was assumed that phytoplankton-growth and other biological activities increase in direct proportion to the amount of incoming sunlight and available nutrients, including dissolved nitrate and phosphate (Arnone *et al*., 1998). Nutrient fields reflect horizontal and vertical ocean circulation under the advection and upwelling processes.

In view to assess the impact of dust-sandstorms on the phytoplankton growth, a preliminary study was also conducted based on satellite-images, captured during 2003-2005 (Zaigham & Nayyar, 2005), which depicted the phytoplankton and dust-sandstorm trends and revealed the interactive dependency between them (Zaigham & Nayyar, 2008).

Present paper describes a review study with particular reference to geological characterization of dust particles, impact of the dust-sandstorms and other relevant environmental variability scenarios associated with phytoplankton-growth in Arabian Sea based on the analyses of the satellite images captured during 2005-2017, the general submarine configuration of Arabian Sea and Gulf of Oman, sunglittering process, and other relevant data/information.

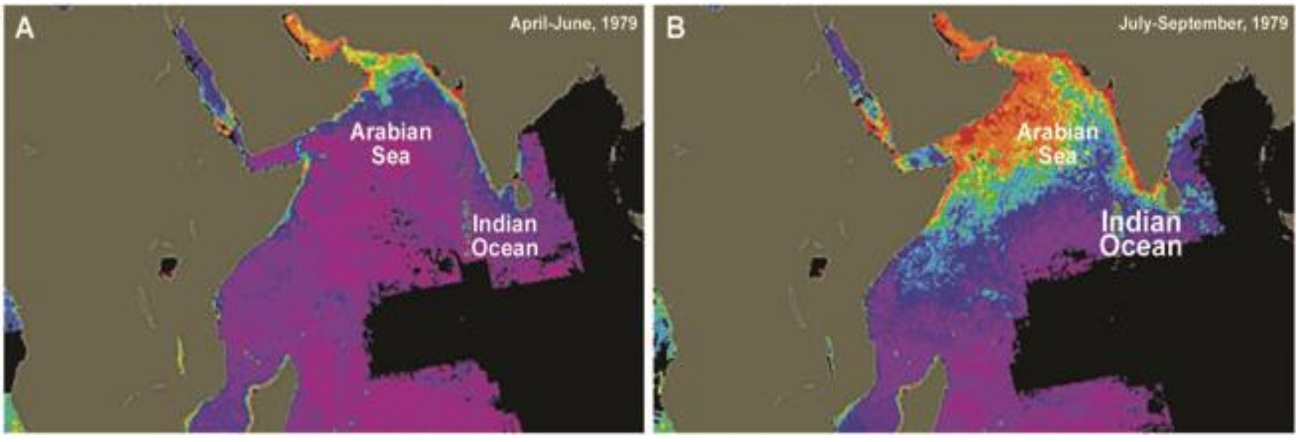

Fig. 1. Archive images show strong control of pre- and after monsoon conditions on phytoplankton growth in Arabian Sea region. A: Coastal Zone Color Scanner (CZCS) image for April-June 1979 shows pre-monsoon low productivity. B: CZCS-image for July-September 1979 shows after monsoon high productivity. Modified after Arnone *et al*., (1998).

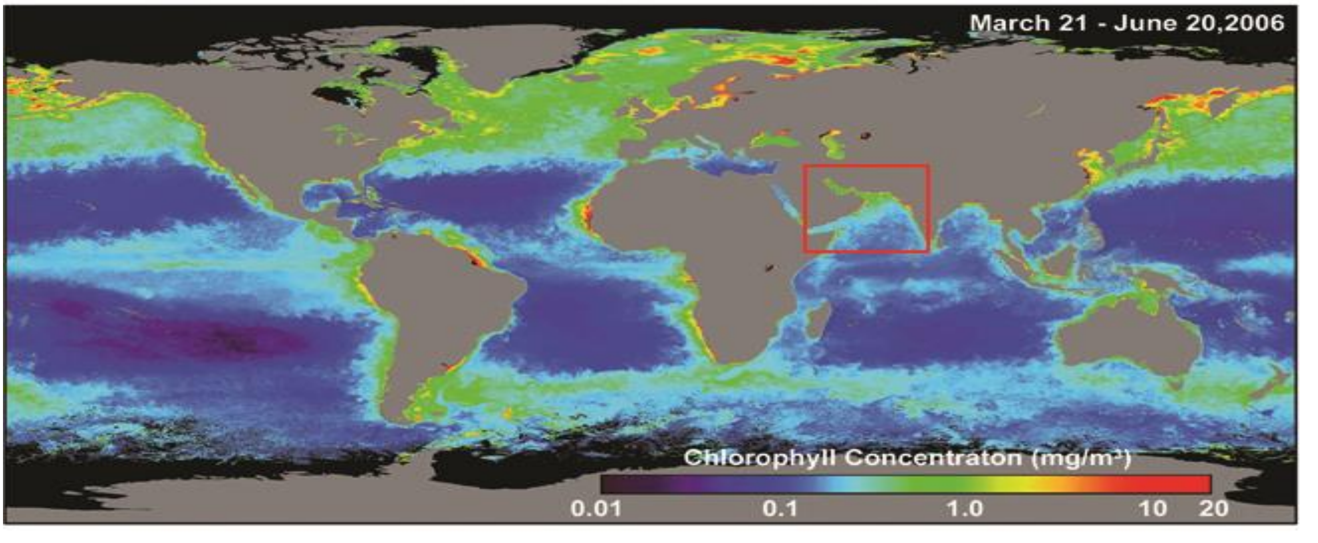

Fig. 2. Map shows panoramic view of global trends of chlorophyll concentration. Red square shows study area, where phytoplankton blooming occurs during winter season. Modified after Allen (2006).

Global chlorophyll distribution: Integrated MODIS-images, captured between March 21 and June 20, 2006 showed global chlorophyll concentrations patterns (bright green, yellow, and red colour tones), where the ocean-surface plants, mainly the phytoplankton, were growing (Fig. 2). Distinct-growth of the plant life was identified in the northern oceans as compared to southern oceans of the globe during the spring season. The global chlorophyll distribution map also gave an idea of how much carbon the tiny plants are soaking up, which is important in understanding the global carbon budget (Allen, 2006). In contrast, the blue tones represent ocean areas with lowest or negligible chlorophyll concentrations. It is deduced that lack of the circulation of upwelling, blowing sandstorms, and/or run-off land waters curtailed the supply of nutrients and prevented life from thriving in certain parts of these ocean regions. However, the higher blooming of the phytoplankton occurs in Arabian Sea and Gulf, marked with red rectangle, during winter season after monsoon period.

Growth pattern of phytoplankton in Arabian Sea: The salient satellite images, time to time released by NASA, greatly helped in providing the regional panoramic bird's eye-views, which revealed multi-disciplinary interrelationships among the "earth's systems", i.e., the biosphere, atmosphere, hydrosphere, lithosphere under the influence of energy provided from the solar and other celestial bodies.

MODIS-image, taken on February 22, 2005 (Kuring, 2005), shows ribbons and swirls of white-yellowish to light turquoise traces over the region of high chlorophyll concentration within whole of the Arabian Sea (Fig. 3A), which corresponded to distinct blooming of phytoplankton thriving at the surface of Arabian Sea.

The image helped in monitoring the detailed interactive relationship of chlorophyll concentration/ plankton in association with features in and around the Arabian Sea and Gulf of Oman. However, the higher concentrations were seen along the coastal areas. The whirling or twisting trends were also seen where potential problems exist as resulted due to dynamic eddy-currents under complex wind as well as submarine features. Regions where no data exist because of cloud cover and/or other technical reasons are light gray while land terrains are dark grey.

The natural-color MODIS-image, captured on February 18, 2010, revealed swirled phytoplankton zones across the Arabian Sea in the form of thin green ribbons due to turbulent eddies (Fig. 3B). The bloom stretches along the shores of Pakistan and away the off-coast of Oman central sea-part extending towards eastern region. The washed-out appearance in the Gulf of Oman and eastern region of Oman coast was considered due to sunglint, which is the mirror-like reflection of sunlight off the water (Lindsey & Kuring, 2010). Some of the brightness may also be caused by blowing dust in western part. Pakistan's coastal waters are tinged blue as well as green. The color may result from numerous influences, including phytoplankton and/or sediment.

MODIS-satellite image, captured on February 14, 2015, portrays the magnificent strings of the phytoplankton twist and curl over the vast region of the Arabian Sea (Fig. 3C). In general, the winter is the prime season for such blooming. It has been identified that the winter monsoon brings a reversal of wind direction from southwesterly to northeasterly, which used to stir up nutrients helping the phytoplankton boom (Kuring, & Hansen, 2015). However, the details of phytoplankton growth trends were partly over shadowed due to the thin dust-cover blown from eastern Thar Desert that exists beyond the image.

The satellite image, acquired on February 03, 2016, shows the plankton blooms as green whorls in the Arabian Sea (Fig. 3D). In recent years, an algae-filled plankton species, Noctiluca Scintillans, were found changing the ecology of the sea-waters (Schwartz, 2016). Similar conditions were also identified associated with Arabian Sea. Masses of plankton add swirls of green to the blue waters of the Arabian Sea in February 3 snapshot from NASA's Aqua satellite (Iran, Pakistan and India). Most of the vibrant colour probably comes from algae living in the single-celled bodies of the Noctiluca Scintillans. It was further deduced that Noctiluca Scintillans started appearing in the Arabian Sea in large numbers in the early 2000s, blooming in the winter months.

It was deduced based on comparative assessment of the images discussed above that the growth pattern of phytoplankton varies year to year though all images were captured in the month of February in each year. The varying decadal trends indicate the dynamic weather conditions in and around the Arabian Sea. On the other hand, Noushaba & Zaighan (2005) described the nature of the exotic submarine geomorphic features, which may also play key role in controlling the hydrodynamics of the Arabian Sea affecting the phytoplankton distribution patterns. The submarine geomorphic features of Arabian Sea are distinct as well as puzzling and show altogether different geo-tectonic conditions from each other. Owen Fracture Zone Ridge (OFZR), Murray Ridge Complex (MRC), submarine Indus River Fan IRF), deep-Abyssal plain with steep scarped slopes along Pakistan and Oman coasts are the most significant submarine features in the Arabian Sea. The highly diversified bottom of Arabian Sea is considered to influence the distribution of tiny plants in the sea-basin. MODIS natural-color image, captured on April 11, 2017, displayed a unique dark feature that looked like something mysterious is happening in the waters of Arabian Sea along the off-coasts of Oman extending towards Pakistan coast (Fig. 4A), but this was explained simply as the water reflection phenomena of sunlight recoded from satellite (Hansen & Schmaltz, 2017).

The areas, where that light is reflected by the water, appear brighter than surrounding areas. The image showing sunglint over the Arabian Sea and Gulf of Oman was correlated with submarine geomorphic features (Fig. 4B). It was revealed the OFZR, eastern edge of Oman Gulf and southern part of Pakistan off-coastline areas represent the sunglint (bright area). Green reflection of the chlorophyll (sea tiny plants) is also well visible in shallow-seawater between Oman coast and Masarat Island (Fig. 4C). Similar, green reflections can also be seen along Pakistani coastline too (Fig. 4A).

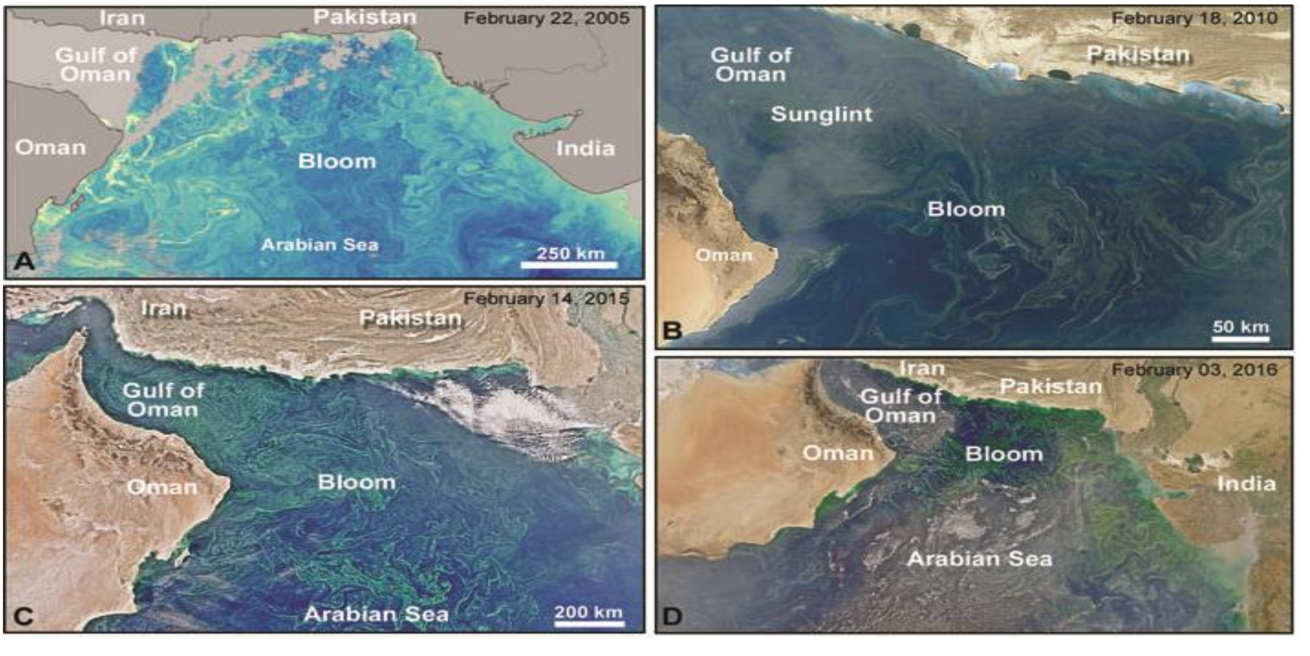

Fig. 3. Collage of MODIS-images shows annual varying growth distribution patterns of Phytoplanktons. A: February 22, 2005, B: February 18, 2010, C: February 20015, D: February 03, 2016.

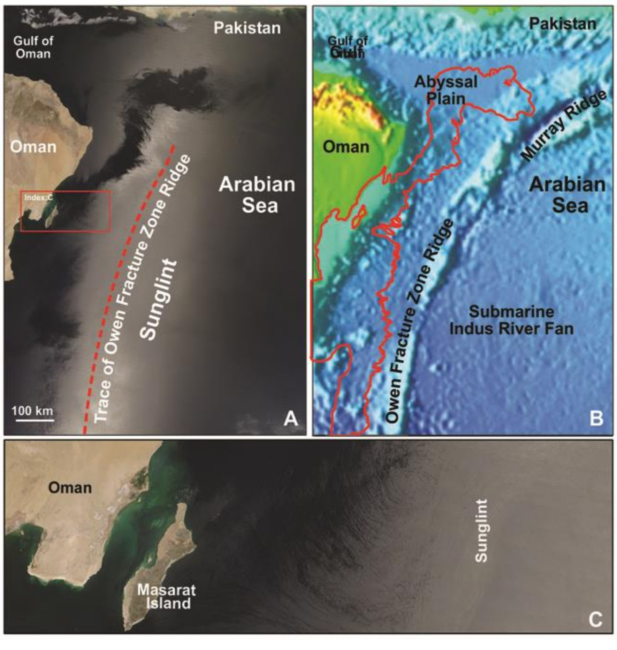

Fig. 4. Collage of images shows the sunglint (A), the bathymetry with overlay of dark-shaped feature of image (A), and the enlarged view showing distinct chlorophyll along Oman coast (C).

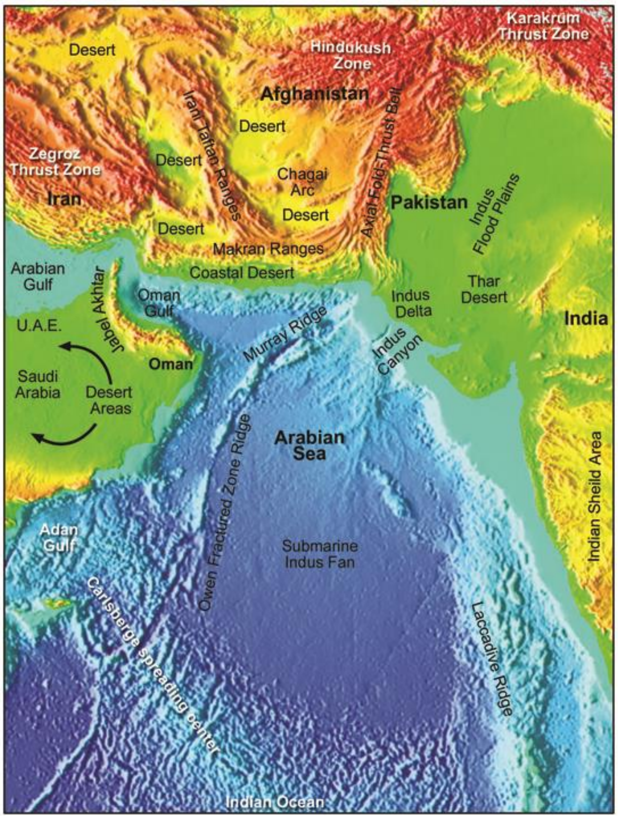

Fig. 5. General geo-tectonic setup.

Geological setting in and around Arabian Sea: Arabian Sea and Gulf of Oman are encircled by the highly complex geotectonic setups of Arabian Peninsula's countries (particularly Oman, Saudi Arab, UAE), Iran, Afghanistan, Pakistan and India (Fig. 5). Geologically, the exposed land rock-masses surrounding these marine bodies are unique from many other ocean basins in relevance to the nutrient sources for biological growth. Intensely deformed mountain ranges host a variety of rocks, like intrusive, extrusive, metamorphic, sedimentary, ophiolites and many types of mineralization. Even, the submarine geo-features of the Arabian Sea and Oman Gulf have their own key importance in this connection. The rocks range from Proterozoic to late Tertiary periods and are well exposed for the weathering and ultimate disintegration into particles of varying sizes. Thus, all sorts of weathered terrains, like various volcanic products, flood-plains & sabkhas alluvial unconsolidated sediments, desert sand-seas, exist within the region. These rock terrains contain different types of mineral particles, which are considered imperative for these marine bodies. Dust-sandstorms carry iron, phosphorite and other minerals rich particles directly from the weathered terrains developed in Afghanistan, Pakistan, Iran, India, Arabian Peninsula and even Eastern Africa. The dumping of mineral-rich particles provides essential nutrients. On the other end, these dust storms also control the light levels affecting the photosynthesis process for the effective growth of phytoplankton.

Impact of atmospheric setup on phytoplankton growth: With reference to the arid regions of Africa and Eurasia, the satellite map shows distribution trends of the estimated aerosols, the fine particles, near ground-level throughout the world (Simmon *et al*., 2010). The map was customized and re-compiled from satellite measurements, acquired during 2001-2006 and from other model data (Fig. 6A). Correlation of arid regions of the high concentrations over northern Africa and the Middle East revealed that the fine dust particle anomalies belong to the prevailing deserts in surrounding of the Arabian Sea. Though, the aerosols are tiny particles, but their impact is big. The satellite-measured aerosol pollution, poses environmental threat to human health on one end (Jimoda, 2012). On the other end, these fine particles, composed of different mineral constituents, are the rich nutrition sources for the phytoplankton at sea-surface. The dust and sea-salt are two of the most abundant aerosols, as sandstorms whip small pieces of mineral dust from deserts into atmosphere and wind-driven sea-salt spray from ocean waves throw into air.

It is observed that most dust particles are hygroscopic, i.e., water-loving. In fact, small mineralized particles usually form the nucleus of precipitation drops. Because of this affinity to moisture, any precipitation will very effectively remove nutrient-rich dust from the troposphere ultimately into the sea or the land. Majority of the world's dust-sandstorms arise from Africa, Middle East, Southwest Asia and Mongolia (Fig. 6B). Take the case of dust from Afghanistan, Pakistan, Iran, Arabian Peninsula, and north part of Africa, the winds are anticipated to carry hundreds of millions of tons of dust from the dry lakes and mountainous valleys every year. The dust transports various minerals, chemicals and micro-organisms that hitchhike on the small particles. The average soil particle size within a dust cloud decreases as the cloud travels and the larger particles settle. Eventually, the remaining particles become so small that our lungs cannot readily expel them.

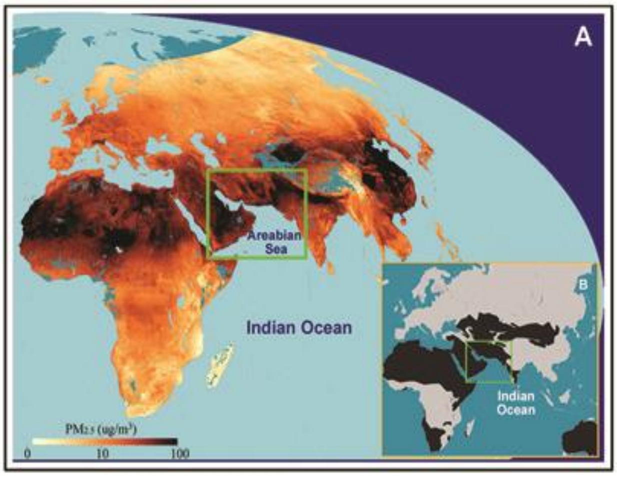

Fig. 6. Map shows fine aerosol distribution over Africa and Eurasia (A) in correlation to arid zones (B).

Trends of dust-sandstorms over Arabian Sea: Dust-sandstorms can happen any time of the year in the areas under study. For example, on average, Afghanistan experiences blowing dust-sand one or two days/month in winter and six-days/month in summer. Zabon, an Iranian city located near border with Afghanistan in the Hamun wetlands, reported 81 dust-sandstorms/year (Schmaltz & Riebeek, 2011).

On 23rd September 2007, the dust plumes from two regions were recorded by MODIS; the large one blowing from Afghanistan southward through Pakistan and over the Arabian Sea and the other smaller one from Iran over the Gulf of Oman (NASA, 2007). These dust storms were quite different from each other (Fig. 7A). The western storm, off the coast of Iran, consists of a series of plumes' channels pattern, whereas eastern storm, originating in Afghanistan, consists of one large, undulating plume with an amorphous outline.

The eye-catching MODIS-image of dust-storms, acquired on March 3, 2008, displayed complex dust-sandstorms setups in the Middle East (NASA MODIS Web, 2008), which blew out in the form of channels over the waters of the Red Sea, Aden Gulf, Arabian/Persian Gulf, Arabian Sea and Indian Ocean (Fig. 7B). Uniquely, sheets of dust can be seen blowing over the waters at the same time from different countries of Arabian Peninsula, like Saudi Arabia, Yemen, and Oman, as well as also blowing off Iran and Pakistan coasts.

The satellite image of 20th December 2011 (Schmaltz & Riebeek, 2011) showed dense cloud of dust-sandstorm blown from the northwestern bordering part of Afghanistan with Iran Hamun Wetlands, passing across the southern Afghanistan desertic region and Pakistan's desertic mountainous Chagai, Raskoh and Makran ranges (Fig. 7C). The pointed origin of dust-sandstorm was well defined, which kept widening, largely edged by NW-trending Raskoh ranges along Pakistan-Iran border areas in the west and along eastern edge of the N-S trending Pakistan Axial Fold-Thrust Belt. The broaden dust-storm converted into narrow channels when passing coastal areas over the Arabian Sea and eastern part of the Oman Gulf.

On 20th March 2012, a giant dust-sand plume stretched across the Arabian Sea from the coastal areas of Oman to southeastern Pakistan and Kutch and surrounding areas of India (Fig. 7D). This extensive plume followed days of dust-storm activity over the Arabian Peninsula and Southwest Asia (Schmaltz and Scott, 2012). The super sandstorm was resulted from the convergence of two different storms; the first front carried dust from Iraq and Kuwait; and the second dust front diverted towards southeastern Iran (Kazmi, 2012).

The satellite image, acquired on January 13, 2013 (Schmaltz & Scott, 2013), displayed a blanket of dust extended from eastern coastal regions Oman and Iran eastward to the coastal areas of Pakistan and India (Fig. 7E). Thickness of flying swirly dust varies from thin causing translucent effects to the thick enough to completely hide the water surface. Dust plumes initially arose from discrete source points in northern Iran, and the storm likely picked up additional particles from mid-Oman desertic area as it spread. It was estimated that over the course of three days, the dust-storm traveled roughly 1,900 kilometers to south-southwest.

The NASA's Terra satellite MODIS image, acquired on October 14, 2014 (Schmaltz & Voiland, 2014), typically shows dominant northeasterly winds blowing several dust-plumes off the coast of Iran, Pakistan, and India (Fig. 7F). The reason of such drastic change in blowing of the duststorms is the climatic fact that the October is a month of transition for weather patterns over the Arabian Sea. In the summer, winds blow from sea toward land, whereas in the winter, the winds reverse and push out over the Arabian Sea from northeast. During October, between the summer and winter monsoons, the prevailing wind direction varies. Practically, there are other dust-sources, like the Thar, Thal and Cholistan deserts of Pakistan, the Arabian Sea coastline areas stretching from Pakistan to Iran, and the alluvial plains of the Indus River of Pakistan; and Runn of Kutch and Registan desertic areas of India.

The satellite image, acquired on October 26, 2016 (Fig. 7G), was recorded by visible infrared imaging radiometer suite (VIIRS). The image shows that the northeasterly winds were dominant and blew several dust plumes off the coast of Iran and Pakistan under the set weather reversal mechanism (Schmaltz, & Voiland, 2016). The wind-blow trend is similar to the dust-storm blowing condition as was discussed in case of satellite image acquired on October 14, 2014.

River flooding: Some of the high chlorophyll concentrations seen along the shelf region may be related to the floods along the coastal areas of Pakistan, Iran and other neighboring countries. An image of Makran coast of Pakistan and Iran, captured on February 11, 2005, (Allen, 2005), revealed the effects of the devastating flooding along the coast of the Arabian Sea as well as eastern part of Oman Gulf (Fig. 8A). The most noticeable change is the rivers' discharging of huge plume of the sediment-loaded rainwater off the coastal areas reflecting with dark blue tones. As an example, the NASA image of Pasni, acquired on 16th February 2005 (Anderson, & Allen, 2005), revealed in more details that the mouth of the river has reshaped by flooding of the huge volume of sediment-loaded heavy rainwater. Moreover, the flood plums were also seen for the distance of more than 10km off the coastline of Pasni (Fig. 8B). It may be noted that this region consists thick flysch sediments and mud volcanoes rich in mineral constituents.

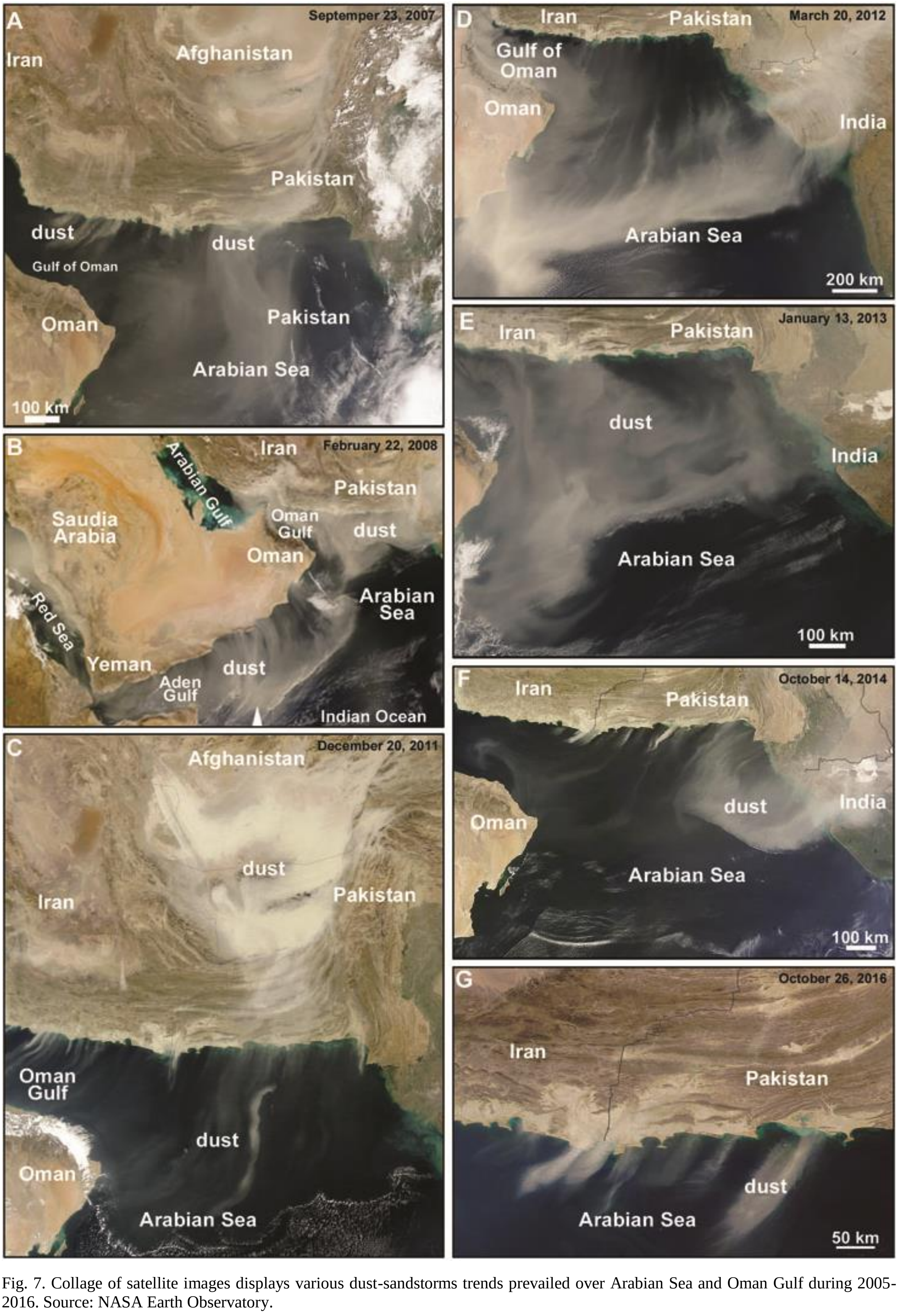

Fig. 7. Collage of satellite images displays various dust-sandstorms trends prevailed over Arabian Sea and Oman Gulf during 2005-2016. Source: NASA Earth Observatory.

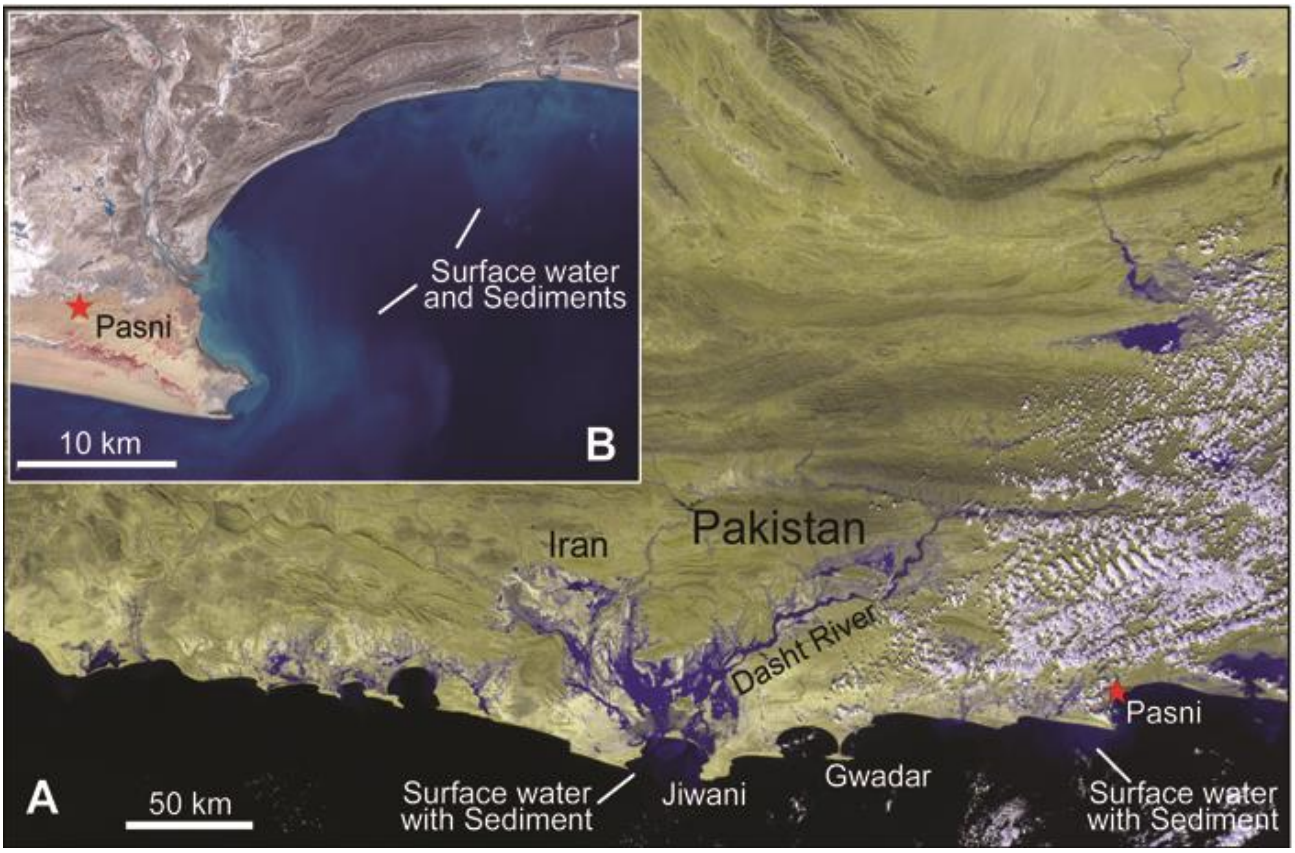

Fig. 8. Satellite images of February 11, 2005 (A) and February 16, 2005 (B) show the flooding of rainwater and sediment discharge during the heavy rains along the Pakistani Makran coastal areas.

In general, the northern and eastern regions (Iran, Pakistan and India) and western region (Oman) directly supply the waters loaded with mineralized sediments through the ephemeral and/or perennial wadis/rivers into the Arabian Sea as well as Oman Gulf. During the heavy rains, particularly in monsoon periods, the flooding causes more discharges into the Sea.

Interpretation and Discussion

Based on the detailed assessments of numerous dust-sandstorm images and the field observations while working in the dust-sandstorm prone areas of Saudi Arabia, some of the basic characteristics were identified associated with the dust-sandstorms. The initial dust-sand plume extends in a narrow swath immediately downwind from a relatively smaller source region. As the wind continues to blow, the plume expands laterally and also continues to move downwind. Sometime later, the winds start to diminish, particularly on the detachment of dust-sand plume, eventually falling below the threshold required to continue raising dust/sand particles. First the sand, then dust settles when winds drop below the speed necessary to carry the particles, but some level of dust haze may persist for longer periods of time. Moreover, it was also realized that the dust reflects more sunlight than the dark surface of the seawater. When the dust-sand plume detaches from the source region, the lateral dispersion diminishes the penetration of full sunlight spectrum improves for phytoplankton growth in the Arabian Sea. From the phytoplankton's growth point of view, the intensity and density of dust-sandstorms are important, because the incoming sunlight required for the growth of phytoplankton is being controlled by the prevailing aerosols in the atmosphere over the Arabian Sea.

Moreover, it was found that during June and July, monsoons increase cloud cover and aerosols, that lower the amount of light available at the ocean surface for photosynthesis affecting the growth of the phytoplankton (Arnone *et al*., 1998). The amount of light actually reaching the sea surface is thus sometimes at a minimum in summer, which is different from other northern latitude ocean basins. For example, phytoplankton blooming occurs during April, in North Atlantic Ocean but in Arabian Sea it occurs in August. Though, the major dust-sandstorms were identified during 1911 in southern Alaska, but only during the past decade it was found that high-latitude dust-sandstorms play a role in fueling phytoplankton blooms (Voiland & Stevens, 2017). Crusius *et al*., (2011) published their first study to describe how dust-sandstorms play a role in supplying nutrients, particularly iron, to the Gulf of Alaska. Similarly, Zaigham & Nayyar (2008) assessed impact of the dust-sandstorms on the phytoplankton growth in 2005. They deduced that the dust-sandstorms are one of the major sources to carry necessary nutrients for the phytoplankton blooming in Arabian Sea and other nearby marine bodies.

The detailed assessments of numerous NASA periodic images of phytoplankton blooming in Arabian Sea as well as other worldwide marine bodies have also helped in identifying some of the basic characteristics related to phytoplankton growth. Basically, phytoplankton contains the chlorophyll pigment, which gives them their greenish color, like terrestrial plants. Chlorophyll is used for photosynthesis depending on the available sunlight as an energy source to fuse water molecules and carbon dioxide into carbohydrates, the plant food. It was inferred that the phytoplankton produce food for themselves and consequently also serve as big sink for absorbing atmospheric CO_2. Thus, phytoplankton blooming is a good indicator of the environmental change in the Arabian Sea region.

In every spring the Arabian Sea waters begin swarming with the phytoplankton after the monsoon & autumn seasons for a narrow window of time. It is in late August-to-October window, when nutrients are plentiful and sunlight is strong, which provide phytoplankton-start to grow most readily in the Arabian Sea. The distribution pattern of the phytoplanktons appears to follow the general trends of the submarine complex geomorphic features, summer and winter wind directions and the cyclone induction in the Arabian Sea.

These microscopic plants can both nourish and destroy a marine ecosystem. Phytoplanktons are a major source of food for many marine animals. Regions that produce large amounts of phytoplankton also tend to support a thriving fish population. The location of phytoplankton usually tells us where we can find zooplankton, fishes for commercial catch, and higher marine animals that consume them. This primary productivity also plays a key role in producing oxygen and absorbing carbon dioxide from the atmosphere. Larger the phytoplankton population, the more carbon dioxide gets pulled from the atmosphere lowering volumes of this greenhouse gas and improving natural environment in Arabian sea region. On the other hand, when phytoplankton concentrations get to be too great, they can create dead zones in the ocean-oxygen-poor regions where few, if any, fish can survive. Dead zones occur when phytoplankton die and begin to sink to sea floor. Bacteria break down the plants by consuming oxygen in the region. In ideal conditions an individual phytoplankton only lives for about a day or two. When it dies, it sinks to the bottom. Consequently, over geological time, the ocean becomes the primary storage sink for atmospheric carbon dioxide.

Conclusions

Arabian Sea is an unusual member of the world's oceans because of its geological and climatic setups. It is surrounded by the unique geological landmasses from three sides and the bizarre submarine bottom configuration; and the light levels are strongly influenced by cloud covers generated by the monsoons and the terrestrial dust-sandstorms. Interactive processes used to provide nutrients from various sources like the wind-blown mineral-rich dust-sand particles derived from vivid weathered-desertic geological terrains, the mineral and nitrate rich run-off of the rivers, and/or from the ocean floor by process of currents upwelling from deeper depths to the surface for the growth of phytoplankton in Arabian Sea. During June and July, monsoons cloud-cover and aerosols increase, that lower the amount of light available at the ocean surface for photosynthesis affecting the growth of the phytoplankton. In every spring the waters of the Arabian Sea begin swarming with the phytoplankton after the monsoon & autumn seasons. The distribution pattern of the phytoplankton appears to follow general trends of the submarine complex geomorphic features, summer and winter wind directions and usual cyclone occurrences in Arabian Sea. Locations of healthy phytoplankton zones usually indicate the prospective targets for the zooplankton, fishes for commercial catch, and higher marine animals those consume them. Moreover, larger the primary productivity of the phytoplankton, the more carbon dioxide is expected to get pulled from the atmosphere lowering volumes of this greenhouse gas, which improves natural environment in Arabian Sea region. Oxygen depleted toxic marine zones may also destroy the marine ecosystem due to the bacterial consumption of oxygen in breaking down massively dead phytoplankton and consequently depositing the carbon dioxide at the sea bottom.

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