# Effects of Rising Temperature on Microwave Communications in Ducting Environment over the Northern Arabian Sea

Sartaj Khan[1], Imran Ullah Khan[1*], Sumrin Mehak Kabir[2], M. Waheed-uz-Zaman[2], Ahthasham Sajid[3], Muhammad Yousaf Ali Khan[4]

[1]College of Underwater Acoustics Engineering, Harbin Engineering University, Harbin, 150001, China

[2]Department of Electrical Engineering, Muslim Youth University, Islamabad, Pakistan

[3]Department of Computer Sciences, Faculty of ICT, BUITEMS, Quetta, Baluchistan, Pakistan

[4]Department of Electrical Engineering, Gomal University, Dera Ismail Khan

[*]Corresponding Author: Imran Ullah Khan (khan@hrbeu.edu.cn)

***Abstract*:** The propagation of microwave (MW) of frequencies above 300 MHz is affected by the existence and properties of the atmospheric duct. Atmospheric ducts exist in many areas of the world ocean, including the Arabian Sea. Located in the Hadley Cell and monsoon region, different seasons bring air masses of different properties into the area under investigation, which has a significant impact on the formation and strength of the atmospheric duct. In this paper, we have done the modeling to analyze the patterns of electromagnetic ducting, which is significant in the southern region of Pakistan in the northern Arabian Sea. To analyze the real-time scenario, data were collected from three different areas off the southern coast of Pakistan in the northern Arabian Sea to observe the electromagnetic wave's effect on the evaporation ducts. Our analysis results reveal that rising temperature plays a significant role where ducts occur above 30% in the summer months and less than 7% in the spring, autumn, and winter months. It is due to an increase in temperature, especially in summer and autumn months, where humidity gradients play an essential role in creating a higher frequency of duct. The same observations were simulated to view the time analysis of pressure, humidity, and potential temperature in this region, depending upon the refractive index.

***Keywords:*** Microwave communication, surface duct, refractive index, coastal region

## 1. Introduction

The ducts are usually formed when the air interacts with the ocean surface, which is a water vapor saturated surface (i.e., the relative humidity is 100%). It is natural phenomena water vapor pressure decreases with the increase of height until and unless ambient value achieved to the state where no change takes place even the height increases. The most important factors to be kept under consideration are the variations in the concentration and temperatures of water vapours as the pressure of water vapours are quickly settled to equilibrium. As it is clear from the statement that temperature is playing a vital role in ducts formation and with the increase in temperature, this process will also increase. Wireless communications show unreliable performance due to unpredictability and variable atmosphere conditions, especially when temperature increases. Depending on their location and the widespread climate, the heights of the evaporation duct may vary from a few meters to few tens of meters. Duct depth and roughness are changed due to variations in temperature. If the duct depth is small compared to the wavelength, energy will not be trapped. The ducts will scatter out the energy if the unevenness is more than the wavelength.

It is essential to understand the effect of temperature on atmospheric refractive variability to determine how the temperature pattern can affect electromagnetic propagation in the atmosphere. During the warm season, the atmospheric refractivity is more affected by moisture than temperature [1]. Radar and communication equipment which operate in an electromagnetic wave may not perform as well as would be expected in some areas because of environmental phenomena, particularly atmospheric ducting [2]. Atmospheric ducting is the trapping of electromagnetic propagation in the lower layers (surface to 500 hPa) of the atmosphere in a horizontal layer [3]. It may occur due to an increase in temperature, a decrease in air moisture with height, or a combination of both [2]. Communication systems such as Radar operating with a frequency above 100 MHz could be influenced by such atmospheric ducting [4]; frequencies below this limit have wavelengths too large to be trapped in the duct. However, higher frequencies are more likely to be trapped.

### 1.1 Thermal Structure of the Atmosphere

The condition of the earth is apportioned into three primary different layers or regions. As shown in Figure 1, the first layer is the troposphere, which leads up to 6 miles (10 km) upwards the sea level in every way that matters, all atmosphere wonders that is assortment in temperature, thickness, cloud advancement, and pneumatic anxiety occurs in the troposphere. There is a brilliant impact on the change vanishing channel due to these conditions, which is likewise impacts the augmentation of radio waves. The next layer is the stratosphere that leads from 6 miles (10 km) and ends up to 30 miles (48 km) situated in the troposphere and ionosphere. The stratosphere technically has little water vapor appearance as the temperature of this layer is thought to be in every way that matters predictable. Hence, it has formally little impact on the radio waves. Next, from 30 to 250 miles (48 to 400 km), the ionosphere is heightened. The troposphere is the inferior some fragment of the world's condition and most uncommon affected by the climate parameters such as temperature, weight, and sponginess.

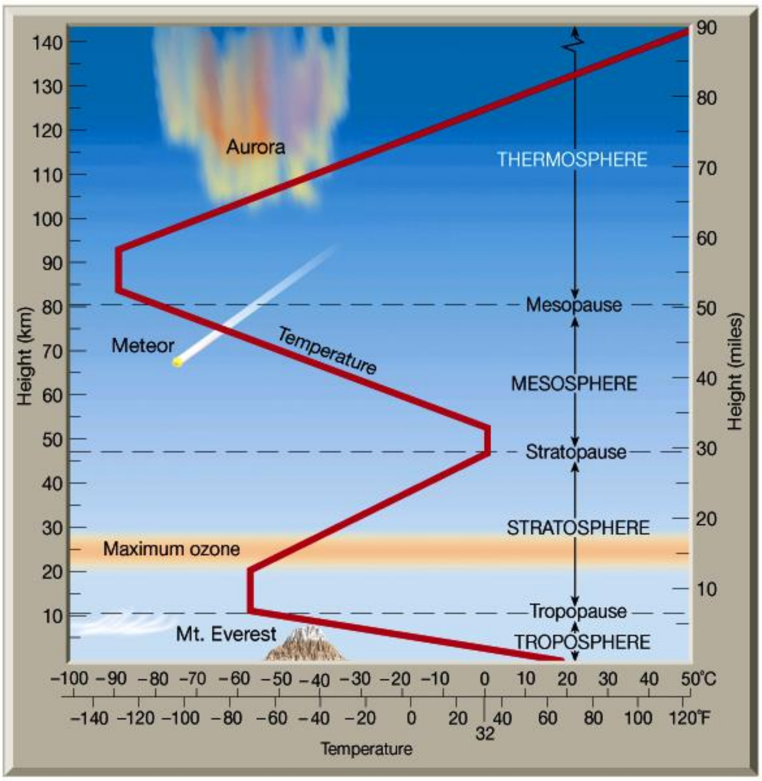



**Figure 1.** Thermal Structure of the atmosphere (Adopted from: Lutgens et al. [5])

With an observation, it is seen that in the troposphere area, there is a decrease in temperature to a height at the rate of around 7ºC for every km [6—7]. Correspondence secured these rehash ranges in the troposphere very high frequency (30—300 MHz), ultra-high frequency (300—3000 MHz), and extremely high frequency (30—300 GHz). In this audit, the Microwave Communications performance in a Metrological Ducting Environment both the spatial and standard scale in the troposphere. A general tried, and the stringent rule is that lower the repeat, the more far off the banner will travel.

### 1.2 Study Area

In this study, we have chosen the northern Arabian Sea (the southern coast of Pakistan) to investigate the influence of rising temperatures on microwave communication. Geographic extents of the northern Arabian Sea are shown in Figure 2. As shown in the figure, the Arabian Sea is a north-western extension of the Indian Ocean bounded by India (to the east), Pakistan and Iran (to the north), and the Arabian Peninsula in the west. In the northeast, the sea connects the Persian Gulf through the Gulf of Oman. The area under investigation is split into three different zones with latitude/longitude measurements 24.5N˚/63.5˚E (Zone A), 24.5˚N/64˚E (Zone B), and 24˚N/64.5˚E (Zone C).

The past studies revealed that electromagnetic wave propagation is significantly affected by the presence and properties of the atmospheric duct in the Arabian Sea [8]. The Arabian Sea is a region with one of the highest probabilities of atmospheric ducting around the world [9]. Assessment of climate models indicates that a 1.5˚C increase represents a trapping point. Over the years, climatologists have worked with warning temperatures nearer to 2˚C. The running models forecast the influence of rising temperatures on sea levels, biodiversity, weather events, and many other factors. Among them, the major part of the ocean climate depends upon the sea surface and air temperature interaction. Other aspects of the environment that are affected by temperature are increased humidity, rise in ocean temperatures, and the sea level often directly relevant to the performance of Radio Waves Propagation above the sea surface. The maximum thermal structure variation occurs in the lower atmosphere surface up to 1000 m (Figure 3). The water vapor density also varies significantly in this region.

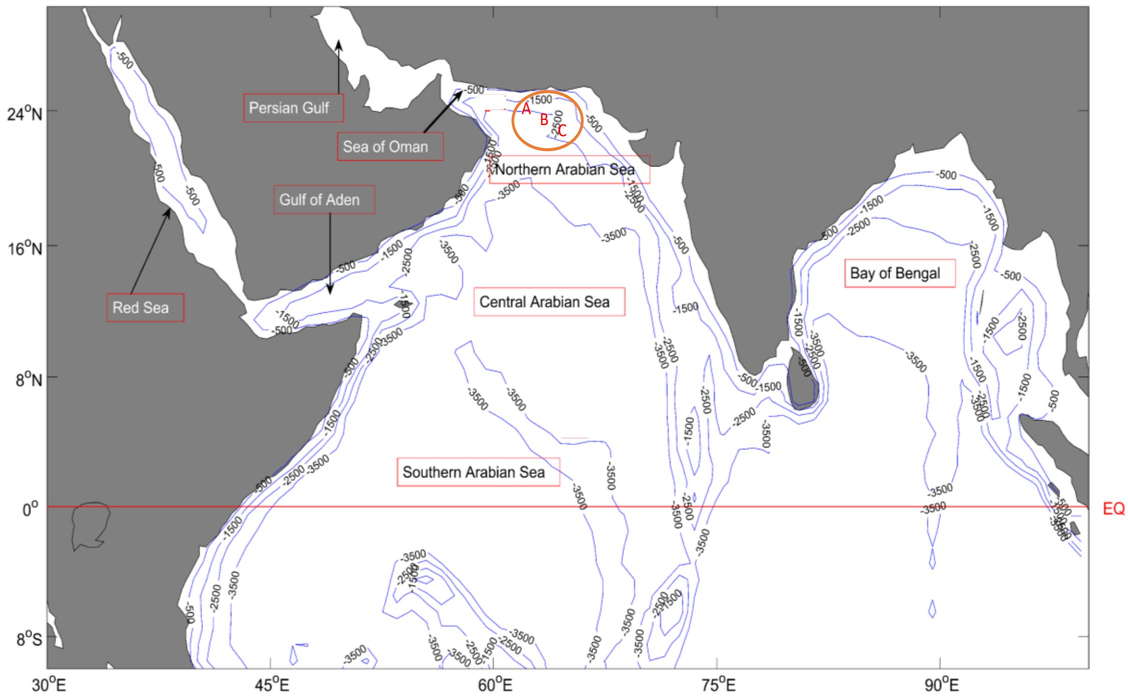



**Figure 2.** Bathymetry and geographical extents of the northern Arabian Sea. The area under study is highlighted by Zone A (24.5N˚/63.5˚E), Zone B (24.5˚N/ 64˚E), and Zone C (24˚N/64.5˚E). The map is generated in Matlab using the m_map tool.

Located in the monsoon region, different seasons bring air masses of different properties into the area under investigation, which has a significant impact on the formation and strength of the atmospheric duct. In this study, we have done the modeling to analyze the patterns of electromagnetic ducting, which is significant in the southern region of Pakistan in the northern Arabian Sea [10]. Further, the region has a global economic, strategic, and military importance. This paper is structured as follows. The materials and methods are presented in Section 2. Results and discussion are described in Section 3 followed by conclusion in Section 4.

## 2. Materials and Methods

In this paper, the model and analysis of the evaporation structure inside a duct are examined in Pakistan coastal waters at three different positions, as shown in Figure 2. The graphical examination visibly elucidates and gives the basic appreciation to the reader to survey the difference between the atmospheric conditions of Pakistan shoreline front waters and diverse areas of the oceans. The information utilized as a bit of the under-review zones is gathered by the assistance of the device given by the

National Institute of Oceanography (NIO) Karachi and Pakistan Naval Authority (PNA) Karachi. Outline Echo Sounder (Hydro Star 4900) and Echo Sounder (NJA-193S) were used to do remote ocean and low hugeness information independently. Current modeling meters, 108,308 MKIII, were utilized to hoard data of weight, conductivity, and temperature parameters [11—14].

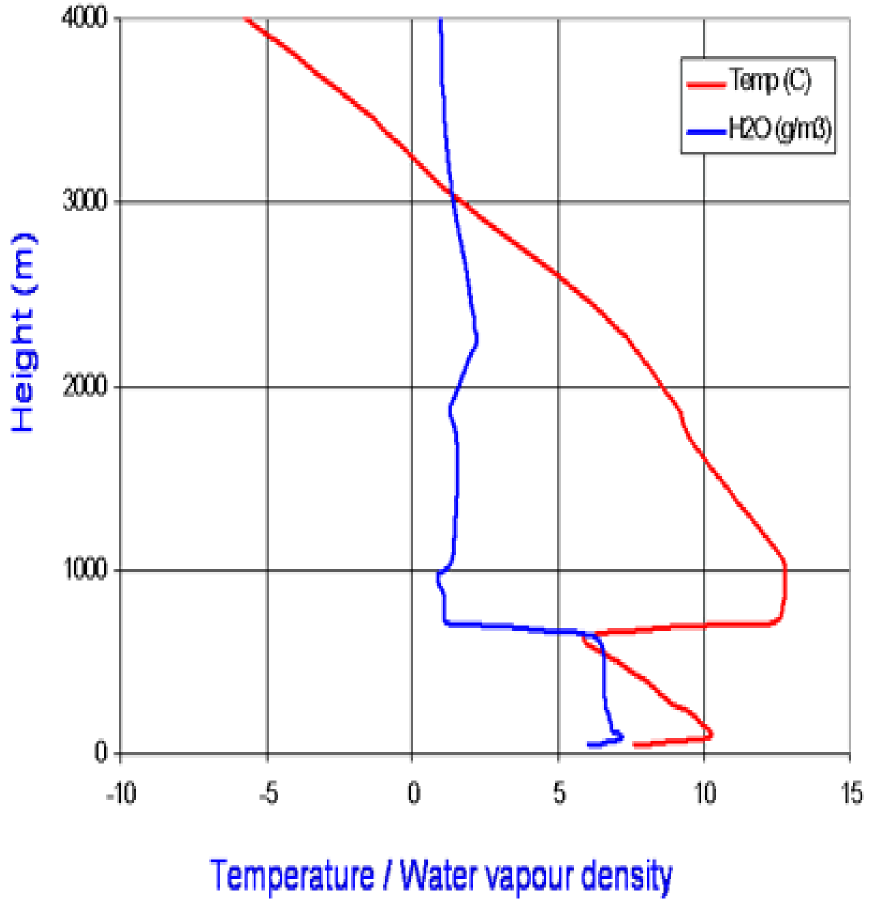



**Figure 3.** Schematic of temperature and water vapor density variation from the sea level.

### 2.1 Atmosphere Refractivity

As shown in Figure 4, the atmospheric refraction is split into four types: sub-refraction, normal, super refraction, and trapping. The four types of electromagnetic wave paths occurred because of variability in atmospheric density [15]. The sub- refraction path occurs when decreases in atmospheric density with height are smaller than normal. The super refraction path occurs when decreases in atmospheric density with height are more than normal. Atmospheric refraction can be calculated by the modified refractivity (M) formula [15—16],

$$M=\frac{77.6}{T}\left(p+4810\frac{e}{T}\right)+\frac{z}{R}\mathrm{x}10^{6} \quad (1)$$

Where, *T* represents the air temperature (K), *p* represents the air pressure (hPa), *e* denotes the water vapor pressure (hPa), *z* denotes the height above sea level (m), and *R* represents the mean radius of the earth (km) [17].

Unmodified refractivity, N, which does not take the earth's curvature or height into account and therefore has some limitations, can also be used:

$$N=\frac{77.6}{T}(\mathrm{P}+4810\frac{e}{T}) \quad (2)$$

Saleem [18] investigate a modified refractivity gradient using remote sensing data over Pakistan. He mapped the modified refractivity gradient by averaging the years 2008 to 2012, where the propagation conditions occurring over the 700 hPa pressure level. It was shown that permanent super-refractive conditions existed over Baluchistan from February to September.

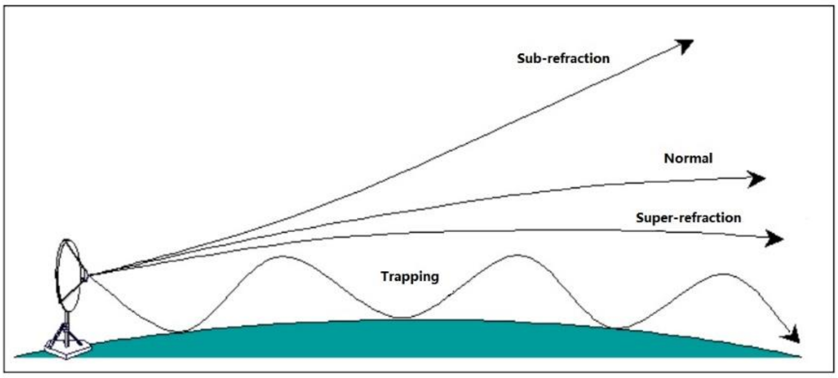



**Figure 4.** Four types of electromagnetic wave paths due to variability in atmospheric density. Refractivity is measured using modified refractivity.

If the super-refraction bends equal to or more than the earth's curvature, then trapping occurs, and that is called atmospheric duct [15]. To define which meteorological refraction category applies, one must plot the quantity of modified refractivity (M) with height. A decrease in the quantity of modified refractivity with height forms an atmospheric duct; while, an increase in the quantity of modified refractivity with height leads to super-refraction or standard refraction or sub refraction depending on the modified refractivity gradient [19].

Analysts are ending up being more aware of the relationship between physical techniques and figuring, and many now surmise that it's supportive of seeing the world in computational terms [20]. In this way, PC re-enactment is now and again observed as a third kind of science, somewhere close to speculation and examination. Also, appreciation can be updated utilizing impelled PC portrayal to change over large volumes of data into clear and possible cases. Some current instructive lists are limited in ease of access because of national security concerns. Though the temperature is the basis for any physical depiction of the ocean, it is appropriately the most generally perceived kind of oceanographic estimation made.

## 3. Results and Discussion

In this study, we carried out essential considerations, the first to take a gander at ocean side properties and other is the applications on the execution of microwave correspondence of temperature climbing in a particular locale of Pakistan. The graphical point of view of the data accumulated from three exceptional territories of Pakistan coastline locale. Minitab was used for the examination of the oceanographic data obtained from different resources. Minitab is a serious, finish, and easy to use condition for specific figuring. It gives pros, scientists, and other specific specialists with a single, smart structure that consolidates numeric estimation, portrayal, and programming.

After a survey, it is speculated that the inducing of radio waves through the pipe and the distinctive results are procured in the Pakistan Coastal Sea from an examination test being driven by the differing Radio Systems. Variations of the refractive index with height for three distinct zones A, B, and C are shown in Figures 5a—b, respectively. These different scatter plots are obtained to elucidate the association between redesigned hail quality occasions and the meteorological environment in the shoreline sea of Pakistan through ultra-high-frequency radio association.

The air-sea monthly temperature variations over the southern coast of Pakistan in the northern Arabian Sea in three different Zones A to C are shown in Figures 6a—c, respectively. Matlab code was used for simulation and analysis of datasets. As shown in the figures, drastic variations are observed in the three regions during the summer months (July to September). In this part, it is every way that matters asserted that climbing in the temperature will change the climatic condition of the ocean. And hence, it can be deduced that the steady barometrical state is accessible in the Pakistan shoreline atmosphere because colder air (unusual relation with Cold Ocean) resides underneath the more smoking upward air. The outlines underneath exhibit the banner qualities that were found in the domain under audit if the temperature rises from 1.5˚C to 2˚C.

From our results, it can be summarized that rising temperatures play a vital role where ducts are pronounced and above 30% in the summer months and less pronounced in the spring, autumn and winter months with less than 7%. It is due to an increase in temperature, especially in summer and autumn months, where humidity gradients play an essential role in creating a higher frequency of duct.

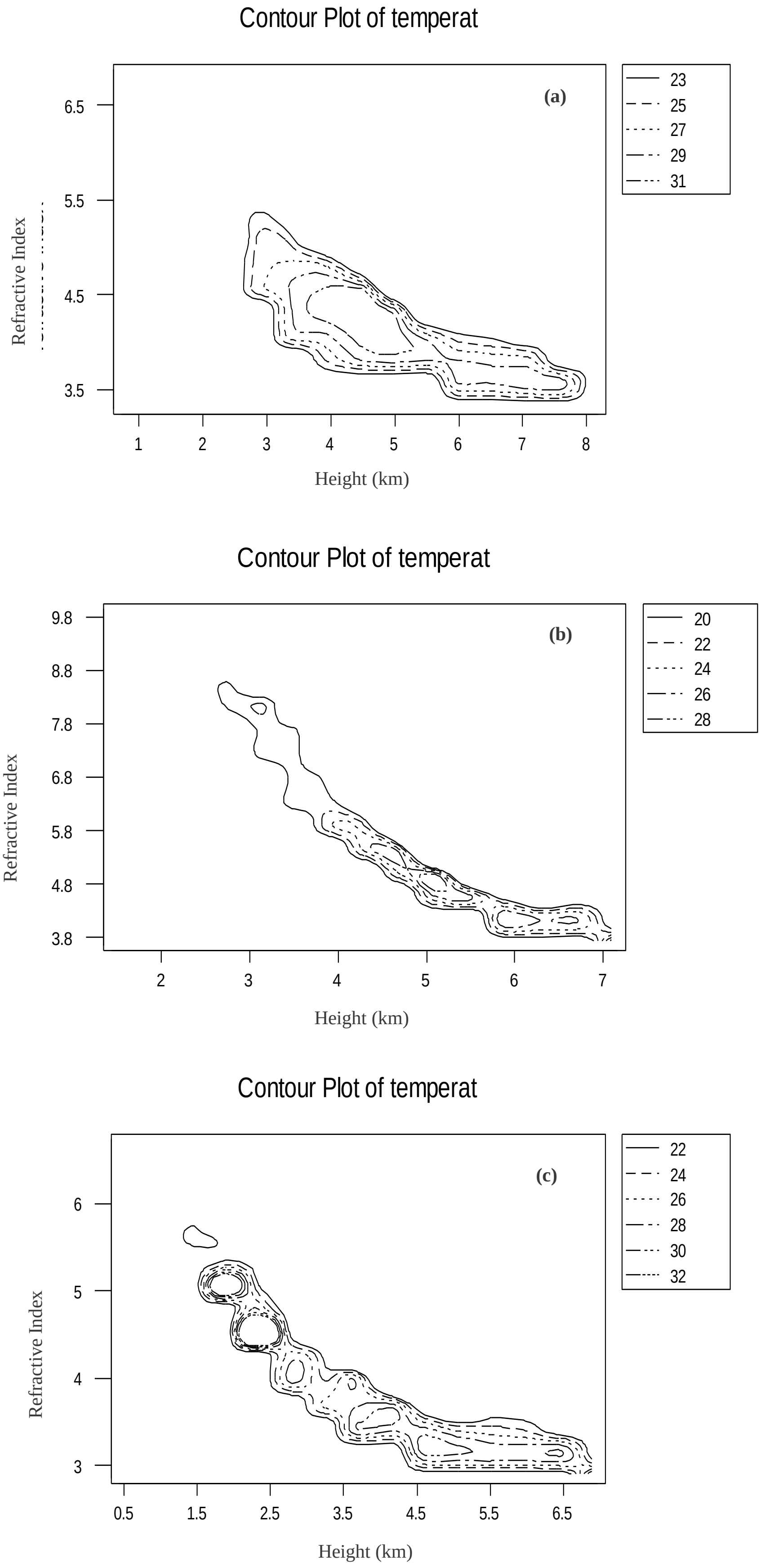
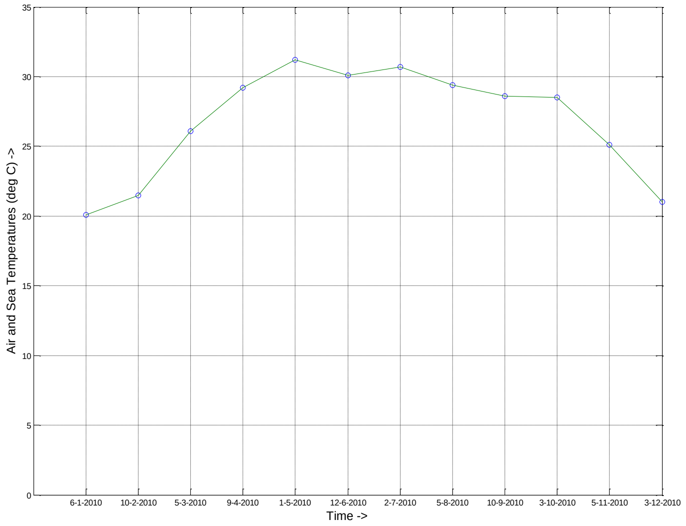
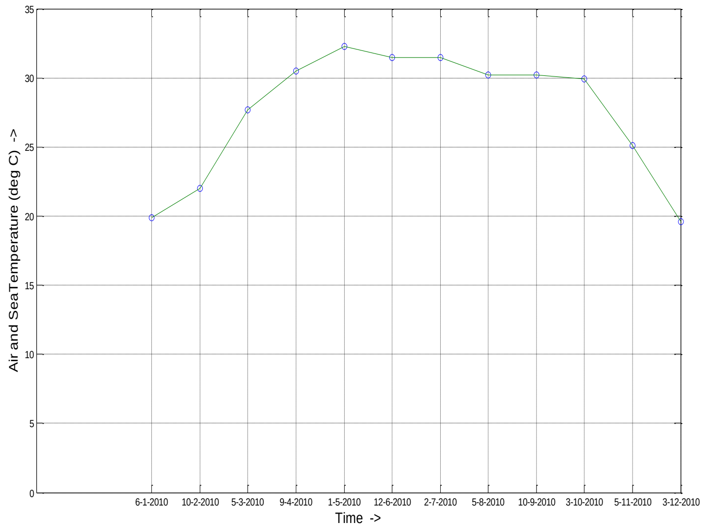



**Figure 5.** Variations of the evaporation duct with temperature, **(a)** to **(b)** represent Zone A, Zone B, and Zone C, respectively.

**(a)**




**(b)**




**(c)**

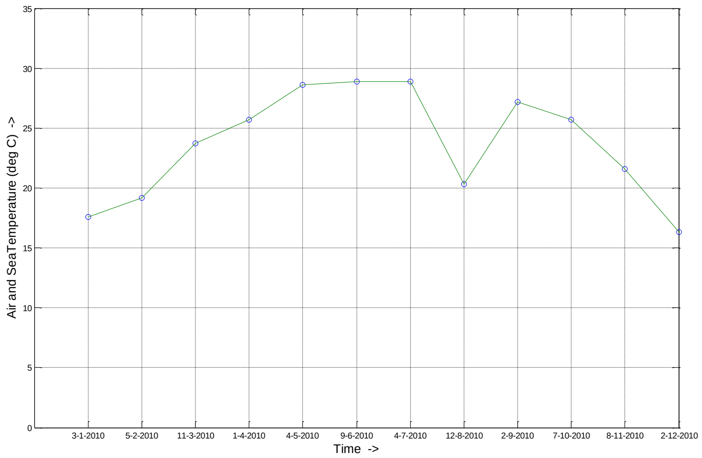



**Figure 5.** One-year cycle of air-sea temperature variations, **(a)** to **(c)** represent Zone A, B, and C respectively**.**

## 4. Conclusion

In this study, the patterns of electromagnetic ducting have been analyzed in the southern region of Pakistan in the Arabian Sea. Located in the Hadley Cell and monsoon region, the area of study has a significant impact on the formation and strength of the atmospheric duct. Our analysis results indicate that rising temperature plays a key role where ducts occur above 30% in the summer months and less than 7% in the spring, autumn, and winter months. It is mainly due to an increase in temperature, especially in summer and autumn months, where humidity gradients play an essential role in creating a higher frequency of duct. The same observations were simulated to view the time analysis of pressure, humidity, and potential temperature in this region, depending upon the refractive index. Our analysis by viewing the examination outcomes of the zone being surveyed shows that front shoreline circumstances scattering channel statures depend continually hinting at change atmospheric environments in the sea has a somewhat essential perspective in marine and waterfront circumstances. Temperatures expect a crucial part in this circumstance and rising of temperature and pipe statures can exceedingly figure over a 24-hour cycle. Because of this exceptional troposphere ponders, radio waves to travel longer parcels than anticipated and to have higher pennant qualities. Consequently, the impact of scattering channels on over-ocean radio wave spread should be all around explored. Good knowledge of atmospheric duct characteristics enables the practical assessment of the range of MW propagation, which is essential for several practical applications, such as coastline telephone systems, business transportation, ocean radar operations, and ocean save.

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