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Fast algorithm for infrared transmittance in marine environment

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Fast algorithm for infrared transmittance in marine environment

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Abstract. Because Modtran software is not convenient to connect with other software programs, a fast algorithm for infrared transmittance in marine environment was established. The relevant meteorological parameters were obtained by actually measuring the marine environment of a certain sea area. The suitable parameters of Modtran to calculate the infrared transmittance of 3~5 μm and 8~12 μm at different distances were selected. Using the exponential function relationship, this paper constructed a fast algorithm in 3~5 μm and 8~12 μm infrared transmittance of marine environment. The comparison between the fast algorithm and the Modtran calculation shows that the maximum error of the 3~5 μm infrared transmittance calculation method is only 2.16%, and the maximum error of 8~12 μm is 0.16%. The formula of the fast algorithm has high precision and can meet the requirements of fast calculation of infrared radiation transmittance.

1. Introduction

Infrared transmittance is one of the parameters often required for the calculation of target infrared radiation. In the infrared radiation engineering, the test method can be used to measure the black body radiation state at different distances, and indirectly obtain the transmittance of the corresponding infrared radiation band at a certain distance. The transmittance of the infrared radiation band can also be calculated by numerical calculation[1]. At present, there are many calculation formulas[2-3] and methods[4-5] for infrared transmittance, and some calculation methods[6] have fast and accurate calculation effects in a specific field. Among them, Modtran software is widely used by relevant researchers for its consideration of many parameters and its accurate calculation[7]. In fact, after many years of revision and experimental verification, the infrared transmittance calculation results of Modtran software itself have been approved by infrared researchers. To some extent, its calculation results are even considered as infrared transmittance standard values. But precisely because there are too many parameters to consider, Modtran software is cumbersome to use, and it is card-based data management, which is not convenient to use in conjunction with other programs. On the other hand, the results of Modtran calculations are also quite abundant. The infrared transmittance is only one of the outputs of the large number results. If Modtran is called to calculate the transmittance during every calculation of the target infrared radiation, the calculation efficiency is relatively low. In addition, in other relatively simple and fast calculation methods, a fast infrared transmittance algorithm suitable for the marine environment is not common.

To this end, this paper obtains the relevant meteorological environment parameters by actually measuring the marine environment of a certain sea area, and selects the suitable parameters of Modtran to calculate the infrared transmittance of 3~5 μm and 8~12 μm at different distances. On this basis, an exponential function relationship is used to obtain a fast algorithm for infrared transmittance



of marine environment with infrared transmittance of 3~5 μm and 8~12 μm as a function of observation distance, thereby solving the problem of rapid calculation of infrared transmittance in the marine environment.

2. Marine environment measurement

This article uses the Kestrel 4500 portable weather station (as shown in Table 1, Figure 1) to measure the temperature, humidity, wind and other parameters of a certain sea area.

Table 1. Kestrel 4500 weather station parameters

Parameter	Performance
Wind speed	0.4~40m/s accuracy $\pm 3\%$
Temperature	-29°C~ 70°C accuracy 1°C
Relative humidity	0~100% accuracy 3%
Air pressure	300~1100hpa/mb accuracy 1.5hpa/mb
Elevation	-2000~9000m accuracy 15m
Wind direction	0~360° accuracy 5°

Table 2 shows the measurement and analysis results of meteorological parameters in a certain sea area. Modtran uses the corresponding ocean environment parameters to calculate infrared atmospheric attenuation of 3~5 μm and 8~12 μm . The results are shown in Figure 2.

Table 2. Statistical analysis results of meteorological parameters in a certain sea area

No.	Parameter	Value
1	Temperature	31.8°C
2	Relative humidity	71.2%
3	Wind speed	0.68m/s
4	VIS	23km



Figure 1. Kestrel 4500 weather station working status

3. Fast algorithm for infrared transmittance in marine environment

In general, infrared atmospheric transmittance is a function of many parameters such as temperature, humidity, wind speed, visual angle, and viewing distance.

$$\tau = f(\text{temperature, humidity, wind speed, VIS, visual angle, } R, \text{ etc.})$$

When the atmospheric conditions change little and the observed height angle is a horizontal angle, the infrared atmospheric transmittance can be considered as a function of the observation distance:

$$\tau = f(R) \quad (1)$$

Where: τ is the atmospheric transmittance; R is the observation distance.

From the calculation results, it can be judged that the formula (1) should satisfy the exponential change relationship. To this end, this paper uses the exponential form relation (2) to fit the results of Modtran calculations:

$$T = T_0 + A \times e^{B \times R} \quad (2)$$

Table 3. Fitting coefficients of fast algorithm for infrared transmittance of marine environment

	3~5 μm transmittance	8~12 μm transmittance
T_0	0.01763	0.00976
A	0.86539	0.98841
B	-2.00713E-4	-1.35085E-4

Substituting the coefficients of Table 3 into (2) yields a fast algorithm formula.

3~5 μm transmittance in the sea environment:

$$T_{\text{trans},3\sim5} = 0.01763 + 0.86539e^{-2.00713E-4 \times R} \quad (3)$$

8~12 μm transmittance in the sea environment:

$$T_{\text{trans},8\sim12} = 0.00976 + 0.98841e^{-1.35085E-4 \times R} \quad (4)$$

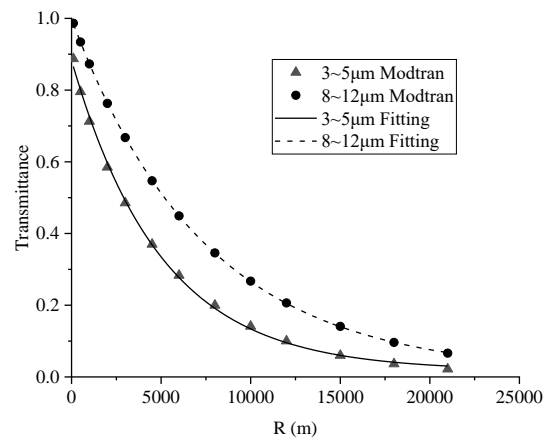


Figure 2. Comparison of 3~5 μm and 8~12 μm atmospheric attenuation calculation results

4. Error Analysis

The infrared transmittance of 3~5 μm and 8~12 μm at 13 different distances were calculated by Modtran, and the infrared transmittance of the corresponding bands with distance was obtained. The fitting was performed using an exponential function relationship. Through the comparison analysis of 13 numerical sampling points, the maximum error of the fast calculation method of 3~5 μm infrared transmittance is only 2.16%, and the maximum error of 8~12 μm is 0.16%. The calculation error is within the allowable range of engineering applications.

Table 4. 3~5 μm and 8~12 μm band fitting relative error

No.	Distance km	3~5 μm Relative error %	8~12 μm Relative error %
1.	0.1	2.168	0.149
2.	0.5	-0.509	0.048663
3.	1	-1.284	-0.03746
4.	2	-1.189	-0.126
5.	3	-0.625	-0.134
6.	4.5	0.146	-0.08503
7.	6	0.613	-0.01364
8.	8	0.834	0.071019
9.	10	0.728	0.122
10.	12	0.473	0.124
11.	15	-0.01588	0.074401
12.	18	-0.478	-0.03416
13.	21	-0.862	-0.159

5. Conclusion

Based on the results of a marine environment test, this paper uses Modtran to calculate the infrared transmittance of 3~5 μm and 8~12 μm of the sea area. On this basis, the infrared transmittance of the above two bands in the sea area is fitted by the exponential function relationship. The calculation of results shows that the maximum error of the fast calculation method of 3~5 μm infrared transmittance is only 2.16%, and the maximum error of 8~12 μm is 0.16%. It is feasible to use the exponential function to fit the infrared atmospheric transmittance. The fitted formula can meet the requirements of fast calculation of infrared radiation transmittance.

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