CHAPTER V

MODEL AND REFERENCE VERIFICATION

This chapter presents the results of climatic temperature change calculation using the developed simulation. The comparison of the results obtained from the developed program with those of the program based on the original model and observation data from reliable references was carried out.

5.1 Developed Program Characteristics

The simulation program developed by using the modified atmospheric-oceanic model is useful for the estimation of average climatic temperature change at sea surface level. The knowledge of this temperature tendency can be utilised as an indicator to warn people to protect and to control the increasing of global temperature before the damage is out of control.

The program for calculating the climatic temperature change at sea surface level (herein called the program based on the original model) provides results of the temperature for comparison to those obtained from the simulation program developed in this work. Though objective of both programs is to estimate sea-surface temperature change of the globe, they have some different characteristics. The developed program is written in Visual Basic language on Windows system. The main principle of calculation is the same concept but the effect of other greenhouse gases including methane, nitrous oxide, and chlorofluorocarbon are also considered in the developed simulation program. The simulation can be used to predict the increasing sea-surface temperature in two patterns. One is prediction of average global temperature at any time. The other is prediction of global temperature change subject to any greenhouse gas concentration. Therefore, some variables and parameters used for calculation in both programs are different. These differences are due to an awareness of more factors in climatic temperature change. Calculation equations in the developed program contain more parameters which are considered to make the estimation more reliable. The developed simulation program also provides more flexibility in parameters and variables selection. It contains a reliable database for selection, which can be changed in wide range. It also provide the default values such as model's parameters to guide and help the estimation. Besides, the developed simulation program has provided database feature, which users can save the calculation results and all selection in order to retrieve data easily for correcting estimating results.

In this work, the sea-surface temperature in each kind of simulation variables (time or greenhouse gas concentration) was calculated from the developed program in order to compare with the calculated value of the program based on the original model and the observed data. The acquired simulated temperatures from these programs are expressed as the possible interval temperature change or the temperature varying by the overall heat transfer coefficient value of sea water. As mention above, the heat flux into the lower ocean layer in the oceanic model, $F_o(t)$, is expressed as

$$F_o(t) = \Delta F(t) - B\theta_o(t) + \frac{\upsilon}{f_o}[\theta_{LS} - \theta_o(t)] - R_m\left(\frac{d\theta_o(t)}{dt}\right) \quad (5\text{-}1)$$

If we know the land-surface temperature change relates to the 1860's, θ_{LS}, the heat flux into the lower ocean layer can be estimated. Therefore, in this work, it will sufficient to consider only the extreme cases of complete land-ocean heat transfer or infinite overall heat transfer and no land-ocean heat transfer or zero overall heat transfer.

For infinite overall heat transfer, $\theta_{LS}(t) = \theta_o(t)$

$$F_o(t) = \frac{\Delta F(t)}{f_o} - \frac{B\theta_o(t)}{f_o} - R_m\left(\frac{d\theta_o(t)}{dt}\right) \tag{5-2}$$

For zero overall heat transfer, $\theta_{LS}(t) = \Delta F(t)/B$

$$F_o(t) = \Delta F(t) - B\theta_o(t) - R_m\left(\frac{d\theta_o(t)}{dt}\right) \tag{5-3}$$

After necessary data such as time, type of greenhouse gas, growth rate of greenhouse gas, and their physical properties (concentration, heat capacity, specific heat, and density) as well as thermal diffusivity of sea water are inputted, the developed program will calculate sea-surface temperature. Some representative results are shown in Table 5.1, and Table 5.2 for time simulation factor, and greenhouse gas simulation factor, respectively.

Table 5.1 Sea-Surface Temperature Change with respect to Time

Year	Calculation from the developed program	Calculation from the program based on the original model
1860	0	0
1870	0.0048-0.0056	0.0039-0.0045
1880	0.0113-0.0132	0.0091-0.0106
1890	0.0203-0.0237	0.0162-0.0189
1900	0.0326-0.0380	0.0257-0.0301
1910	0.0493-0.0576	0.0387-0.0452
1920	0.0723-0.0844	0.0563-0.0657
1930	0.1036-0.1210	0.0800-0.0935
1940	0.1465-0.1711	0.1122-0.1311
1950	0.2051-0.2395	0.1558-0.1820
1960	0.2853-0.3332	0.2148-0.2509
1970	0.3951-0.4615	0.2947-0.3442
1980	0.5457-0.6374	0.4028-0.4705
1990	0.7486-0.8744	0.5493-0.6415
2000	1.0195-1.1908	0.7475-0.8731
2010	1.3900-1.6235	1.0160-1.1867
2020	1.9007-2.2201	1.3795-1.6112
2025	2.2270-2.6012	1.6069-1.8769

Table 5.2 Sea-Surface Temperature Change with respect to Concentration of Greenhouse Gases

Carbon dioxide equivalent concentration (ppm)	Sea-surface temperature change from the developed program
353	0
360	0.0048-0.0056
368	0.0106-0.0124
376	0.0203-0.0237
385	0.0312-0.0364
394	0.0493-0.0576
403	0.0749-0.0875
412	0.1001-0.1169
422	0.1464-0.1710
432	0.2050-0.2395
442	0.2852-0.3331
453	0.3950-0.4613
465	0.5456-0.6373
485	0.7484-0.8741
517	1.0194-1.1907
554	1.3894-1.6229
596	1.9010-2.2203
621	2.2273-2.6015

Graphical comparison of the climatic temperature change estimated by both programs and the observed data are shown in Figure 5.1 to 5.4.

5.2 The Analysis of Climatic Temperature Change with respect to each Simulation Factor

Calculation results in Table 5.1 show time dependency of the sea-surface temperature varying from preindustrial period until the present when atmospheric concentration of carbon dioxide becomes double. For the modified atmospheric-oceanic model, not only the effect of carbon dioxide but also the influence of methane, nitrous oxide, and chlorofluorocarbon was considered in time simulation factor.

With respect to these greenhouse gases, the developed program reports higher the sea-surface temperature change than those of the program based on the original model about 36 percent. As mentioned in section 5.1, the program developed in this work takes more consideration on other greenhouse gases including methane, nitrous oxide, and chlorofluorocarbon, which the greenhouse impact due to their concentration are one third, one twelfth, and one fourth of carbon dioxide, respectively. Although carbon dioxide is considered to provide the greenhouse effect most, but the combined effect of other greenhouse gases could equal or exceed the potential warming of carbon dioxide alone. The addition of an incremental molecule of methane, for example, will result in the trapping of 20-30 times as much heat as the addition of an incremental carbon dioxide molecule. An incremental chlorofluorocarbon molecule will result in the trapping of 20,000 times as much as would a carbon dioxide molecule.

Table 5.2 shows results of the sea-surface temperature change from preindustrial period (1860). As a result of increasing levels of carbon dioxide, combined with rising concentrations of other greenhouse gases, the global temperatures may increase 0.7-0.8 ^{o}C by the year of 1988. The amount of each greenhouse gas added to the atmosphere will be calculated as an carbon dioxide (CO_2) equivalent concentration.

5.2.1 Temperature change with respect to time

To compare the temperature change more clearly, the graphical results of the increasing sea-surface temperature calculated by the developed program and the program based on the original model from 1860 to 2025, is displayed in Figure 5.1.

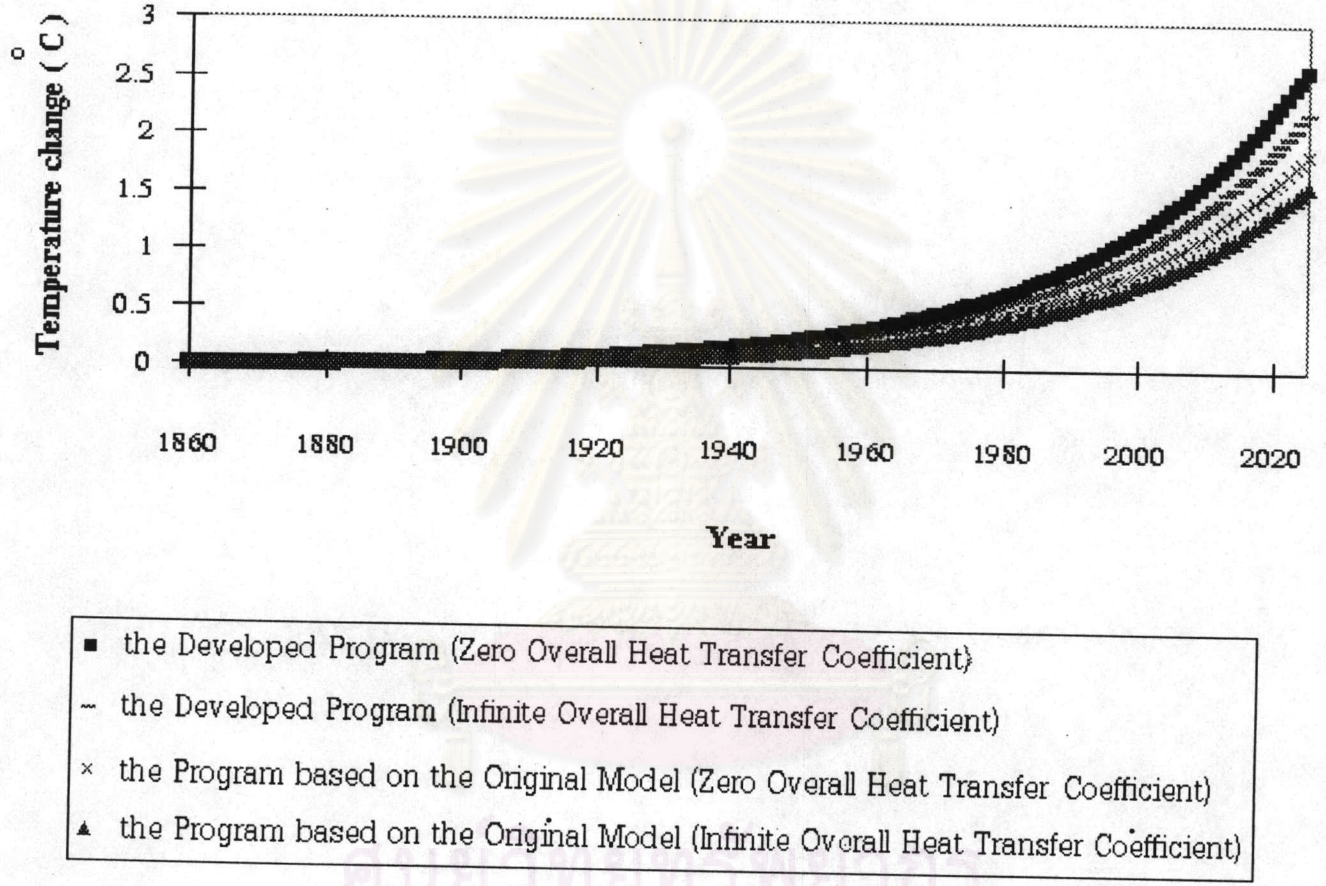

Figure 5.1 Sea-Surface Temperature Change with respect to Time from the Developed Program and the Program based on the Original Model

5.2.2 Temperature change with respect to concentration of greenhouse gases

The relationship between the average global temperature and carbon dioxide equivalent concentration are shown in Table 5.2. These temperatures were calculated from the developed program of which the global temperature change are regarded as the greenhouse gases effect. In Figure 5.2, the significant increase of the predicted global temperatures is clearly seen.

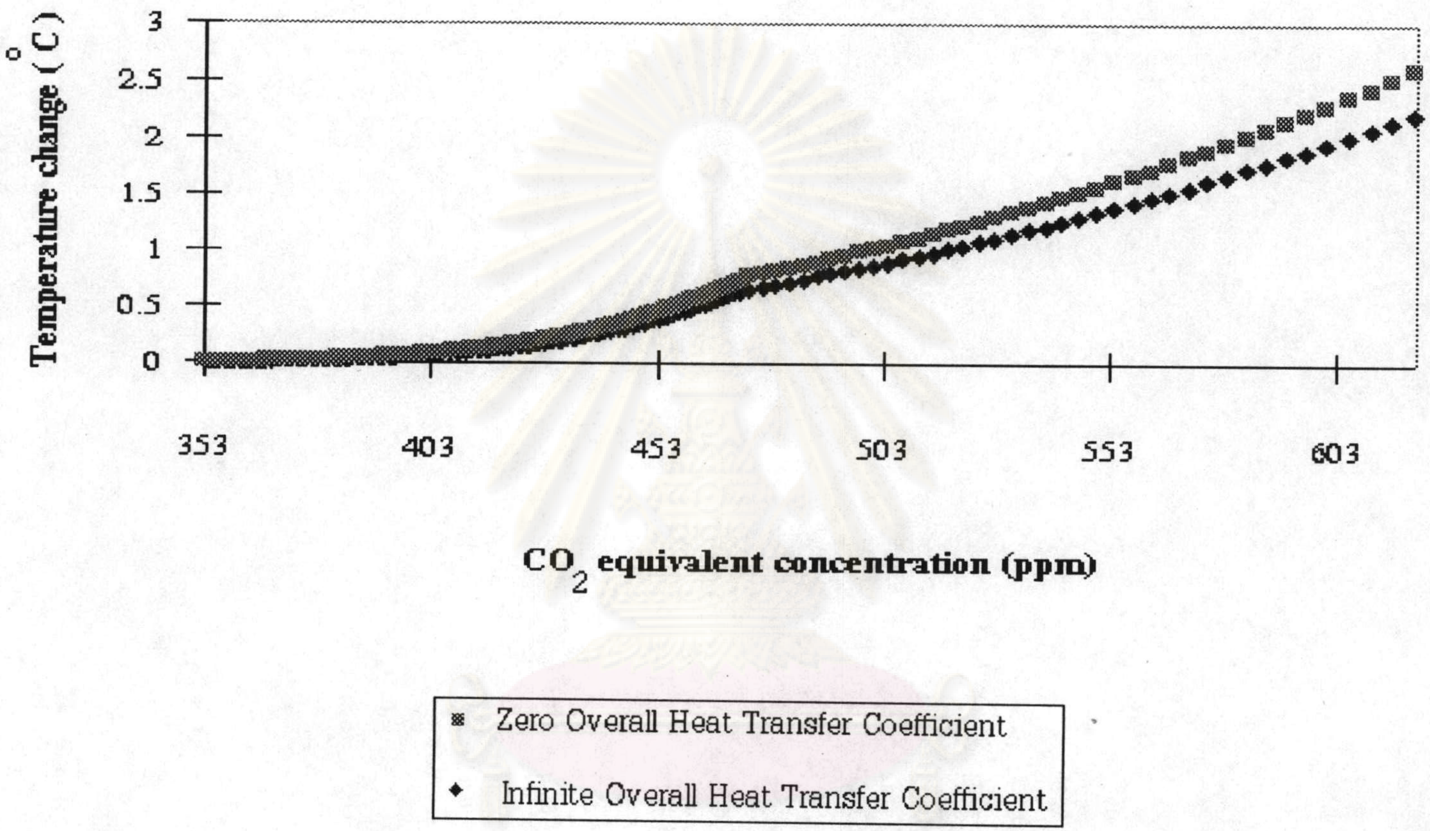

Figure 5.2 Sea-Surface Temperature Change with respect to Concentration of Greenhouse Gases from the Developed Program

5.3 Comparison of Climatic Temperature Change to Reference Data

The comparison of the average sea-surface temperatures estimated by the developed program with respect to time and that of the program based on the original model and the observed data can be carried out by the developed program if the user choose an option in the simulation result form and display menu.

The accuracy of calculation of the climatic temperature at any concentration of atmospheric greenhouse gases can be proved with reference temperature data (Jone, P. D. Wigley, M. L., and Wright, P. B., 1989) by using the concentration of greenhouse gas at any time (in this case the carbon dioxide is taken into account).

5.3.1 Temperature change with respect to time

The elevation of the sea-surface temperature from the 1860 to 1988, predicted from both programs and observed data, are shown graphically in Figure 5.3. In this figure, the reference data and the measured one are compared.

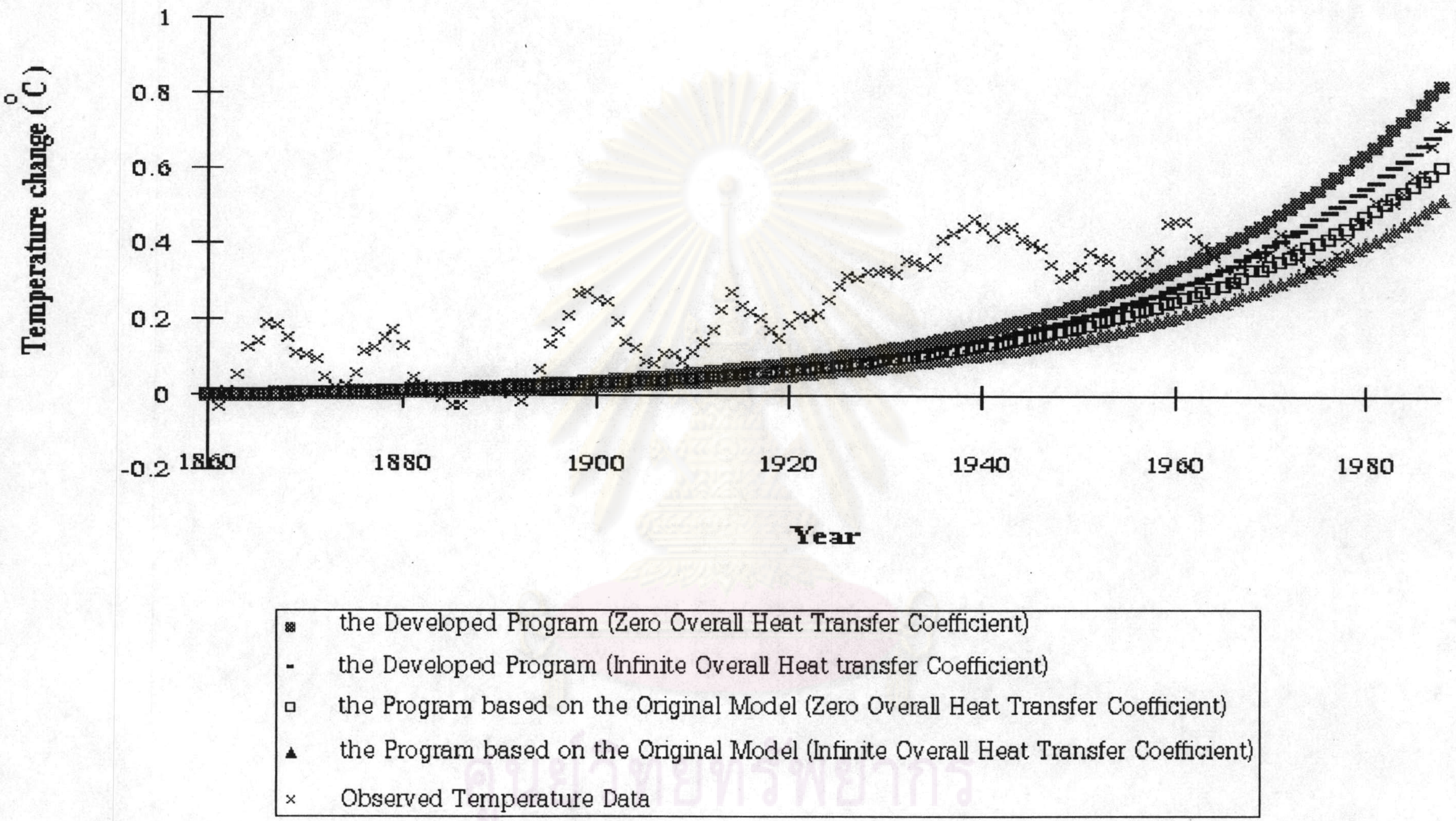

Figure 5.3 Sea-Surface Temperature Change with respect to Time compared with the Observed Temperature Data

From Figure 5.3, the sea-surface temperature predicted from the program based on the original model is lower than the measured one. For the developed program, the predicted value is higher than that of the program based on the original model and more closed to the measured value. Because of the consideration of the increasing of methane, nitrous oxide, and chlorofluorocarbon gases, not only carbon dioxide, the more accuracy of the developed program is obtained. These gases exhibit greater effect on the elevation of global temperature than that of the carbon dioxide per unit mass. There is the tendency that they would increase by the industrial development in the future.

5.3.2 Temperature change with respect to concentration of greenhouse gases

To consider the increasing of the average temperature due to the atmospheric concentration of greenhouse gas in the developed program, the user can compare the simulation results with the reference temperature data, utilising the relationship between the amounts of carbon dioxide at any time.

As be known, the global warming phenomena take place by an increase in the concentration of atmospheric greenhouse gases that can absorb and reemit the longer-wavelength radiation. Consequently, heat is trapping in the lower part of the Earth's atmosphere. This work, therefore, will focus on the influence of four kinds of gases hence in Figure 5.4 we indicate the significance of all greenhouse gases in the developed program compared with the case that only carbon dioxide is considered. The estimation results is also taken to compare with the reference data.

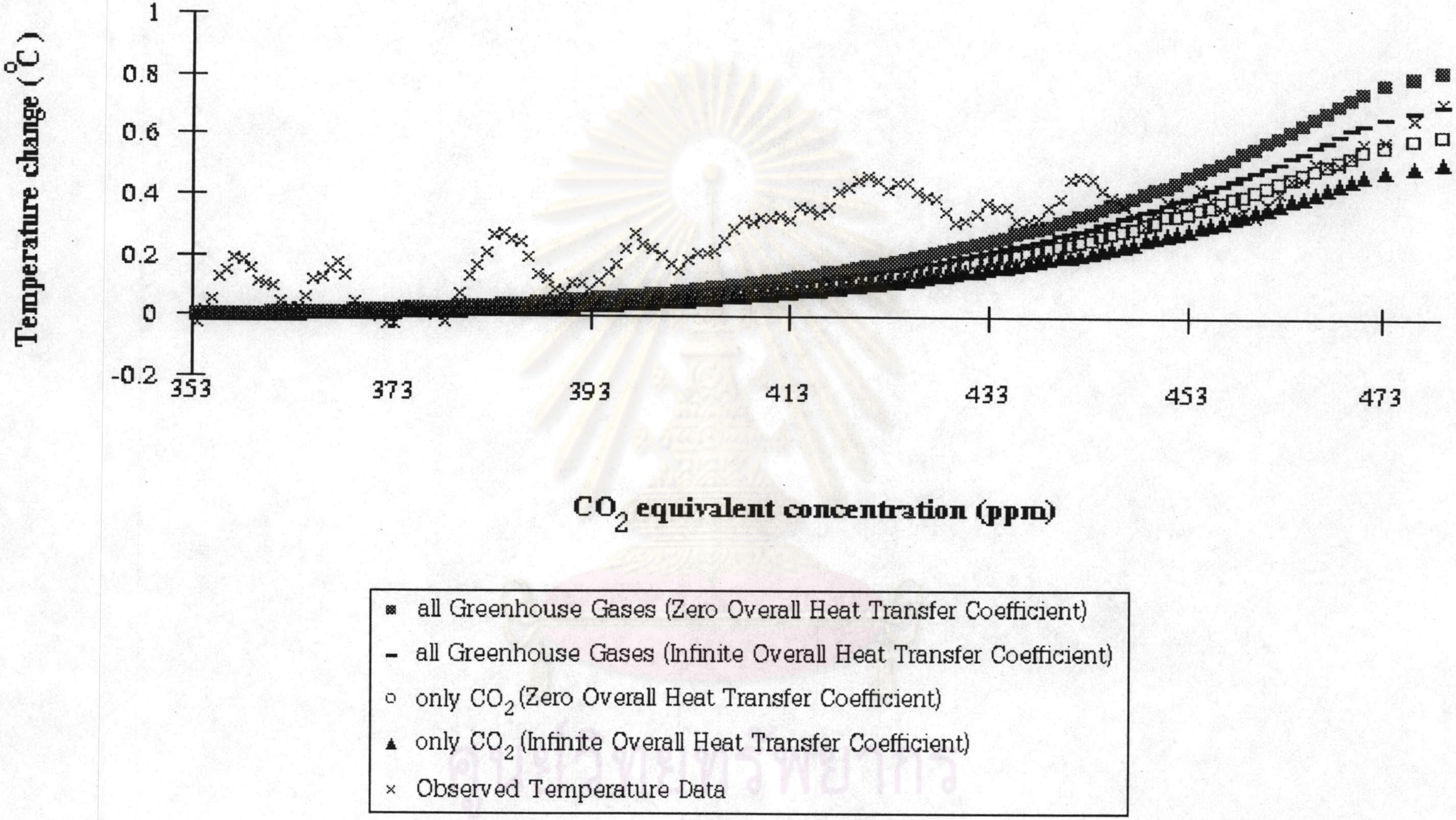

Figure 5.4 Sea-Surface Temperature change with respect to Concentration of Greenhouse Gases compared with the Observed Temperature Data

The graphical results in Figure 5.4 indicate that the developed program with considering all four kinds of greenhouse gases predicts higher the sea-surface temperature than the case of considering carbon dioxide only. However, the simulated sea-surface temperatures from the developed program agree well with the observed temperature data. Therefore it can be concluded that the developed program using the modified atmospheric-oceanic model can provide more precise results of the climatic temperature change.