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POSSIBILITY TO SOUND THE ATMOSPHERIC OZONE BY A RADIOSONDE EQUIPPED WITH TWO TEMPERATURE SENSORS, SENSITIVE AND NON-SENSITIVE TO THE LONG WAVE RADIATION

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ABSTRACT

The sensitiveness of the white coated thermistor sensor and non-sensitiveness of the gold coated over white thermistor sensor, which was manufactured by vacuum evaporation process, to the long wave radiation were ascertained by some simple experiments in room and also by analyses on some results of experimental soundings.

From results of analyses on the temperature discrepancies caused by long wave radiation, the possibility to sound the atmospheric ozone partial pressure by a radiosonde equipped with two kinds of sensors, sensitive and non-sensitive to the long wave radiation was suggested again, and the test result of the newly developed software for the deduction of ozone partial pressure in upper layers was also shown.

However, it was found that the following is the necessary condition to realize the purpose. The sounding should be made by a radiosonde equipped with three sensors, instead of two, one being non-sensitive to the long wave radiation perfectly, and the other two also non-sensitive only to the upward radiation but sensitive partially to the downward one, with two different angles of exposure upward.

Because it is essential for the realization of the purpose to get two different values of temperature discrepancies simultaneously observed by the three sensors mentioned above and to avoid the troublesome effects of the upward long wave radiation.

1. INTRODUCTION

From some statistical investigations on data observed by Japanese radiosonde, T. Kitaoka took notice to the sensitiveness of the white coated thermistor sensor used in normal upper air soundings to the long wave radiation and suggested the possibility to sound the atmospheric ozone by a radiosonde equipped with two temperature sensors, sensitive and non-sensitive to the long wave radiation.

The sensitiveness of the sensor to the radiation was ascertained by some simple experiments in room and also by some analyses on results of some experimental flights. Here results of these experiments are described and the possibility to sound the atmospheric ozone by a radiosonde equipped with three temperature sensors, one non-sensitive and two sensitive only to the downward radiation, is suggested.

In this connection, the results of testing the software, which was newly developed to deduce the atmospheric ozone partial pressures at every standard pressure levels from data observed by the radiosonde mentioned above, are shown.

2. EXPERIMENTS IN ROOM FOR CHECKING THE SENSITIVENESS OF WHITE COATED THERMISTOR SENSOR AND NON-SENSITIVENESS OF A GOLD COATED OVER WHITE THERMISTOR SENSOR PRODUCED BY VACUUM EVAPORATION PROCESS.

The experiments were made by covering a heated aluminum black painted pipe over the sensors to be checked and by changing the ventilation speed as of 1,2,3 and 5m/sec. The simple arrangements used are shown in Fig 1. Though the gold coated over white thermistor showed some small risings of temperature, they were due to those of air temperature themselves. On the other hand, it was clearly observed that the temperature of the white coated sensor rose up with the temperature of heated pipe. These show that the former sensor is perfectly nonsensitive and the latter is very sensitive to the long wave radiation.

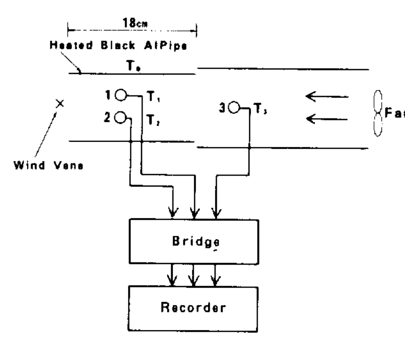

Fig.1

By analyzing results of a series of experiments, it was found that the emissivity or absorption rate of long wave radiation of the sensor changes linearly with temperature from 1.0 at about 27.5 ℃ to 0.85 at 40.5 ℃. This means that the emissivity of the sensor changes with wave length of the radiation and the sensor acts as a black body in wave lengths longer than about 9.8 μ .

3. TWO EXAMPLES SHOWING CONSPICUOUS DISCREPANCIES OF THE WHITE COATED TEMPERATURE SENSOR FROM THE TRUE AIR TEMPERATURE, WHICH ARE CONSIDERED AS CAUSED BY THE EFFECT OF LONG WAVE RADIATION.

3-1. Comparative sounding of two radiosondes, which was carried out at 20 h 30 m, on June 23, 1981.

Two kinds of radiosondes were lifted up with one balloon, one equipped with the bimetal sensor of temperature and the other with the white coated thermistor sensor, at 20 h 30 m, on June 23, 1981, as one of serial ascents of the comparison between two sensors.

Significant discrepancies between two temperatures simultaneously sounded by the two radiosondes were observed as shown in Fig 2. 7 minutes after the release of balloon, the temperature of thermistor sensor showed 8.3℃ lower than that of bimetal one, 9 minutes after about 1℃ lower and 11 minutes after 0.7℃ higher.

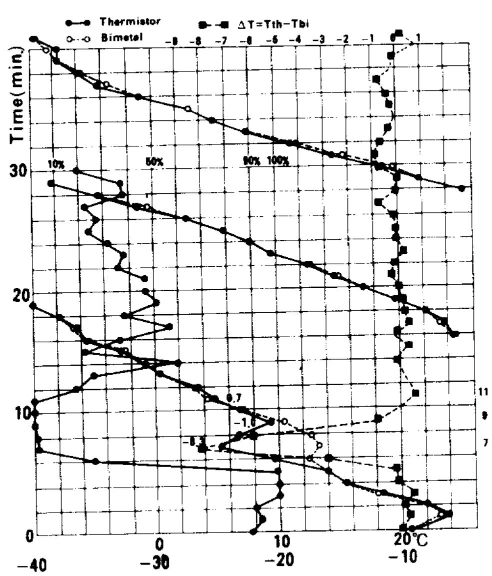

Fig.2 1981, June 23, 20 30

The amount of cooling can not be explained by the cooling effect of wet-bulb temperature of cloud droplets which might attach to the thermistor sensor during the ascent of balloon through clouds. In the case of wet-bulb cooling, the humidity calculated by temperature observed 7 minutes after the release of balloon should be 31% instead of the value observed 1% and the other two discrepancies, especially the warmer value observed 11 minutes after, can never be explained by the wet-bulb effect.

On the other hand, the series of the temperature discrepancies could be explained by the long wave radiation effect of the white coated thermistor sensor.

The results of calculation on the radiation balance between the thermistor sensor, which are sensitive to the long wave radiation as ascertained by experiments in room above mentioned, and clouds, which were extending in lower layer during the period concerned and abruptly appeared in upper

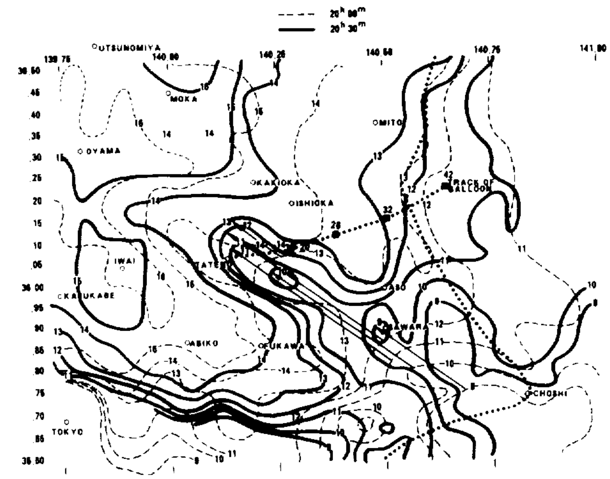

Fig.3 Temperatures observed by Satellite GMS-1

layers over the area near by the observation site as shown in Fig 3, showed that the amount of long wave radiation from these clouds alone could not support such small amount of cooling as 8.3℃ observed, being too scarce, and some more amount of radiation from the other sources were needed.

The long wave radiation from the strong absorption bands of O_3, CO_2, and H_2O in wave length longer than 9 μ, were recognized as sufficient to supplement the shortage of radiation balance.

After some complicated calculations, analyses and discussions, it was concluded that the temperature discrepancies were caused by the effect of long wave radiation coming on the sensor from upper and lower clouds and the absorbing gases existed in lower and upper layers at that time.

3-2. Experimental Sounding by a Radiosonde equipped with Two Sensors, the White coated Thermistor and the Gold coated over White Thermistor and the Ozone Sonde Observation, which were made at Moriya and at Tateno, respectively, on the Same Day, Feb. 19. 1992.

Results of soundings are shown in Fig 4. This figure shows three records of temperatures. The thick full lines T_1 indicate the temperatures of the gold coated over white thermistor sensor and the thin broken lines T_2 show those of the usual white coated thermistor sensor. Both sensors were equipped on the same radiosonde and two temperatures were sounded alternately by a switching measure. The balloon hanging this radiosonde was released at Meisei Electric Moriya Factory, at 13 h 37 m on Feb. 19, 1992.

The thin full lines T_3 indicate the temperatures sounded by the usual white coated thermistor sensor equipped on the ozone sonde, which was lifted up at Tateno Aerological Observatory, JMA, at 14 h 30 m, on the same day as above. Tateno is apart about 20km east to Moriya.

The following features in this figure are to be noticed.

1) In layers from 125mb to 65mb, the thin full temperatures over Tateno were higher about 2 to 3 degrees than the thick

full ones over Moriya, against showing that the thin broken ones were lower by less than 1℃ than the thick full ones.

2) In layers above 33mb, both the thin full and thin broken lines showed the cooler temperatures than the thick full ones, giving about 6 and 2 degrees discrepancies for the former and the latter lines, respectively.

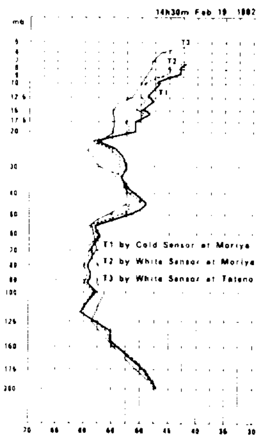

Fig.4 P-T CHART

Long Wave Radiation Coming up from Lower Clouds. $\theta e_i'$

P	$\theta e_i'$ Moriya	Tateno	T'	t℃
20	22.79× 10^4	22.79× 10^4	24.36× 10^4	− 51.0
25	23.74	22.94	23.03	− 54.0
30	24.89	24.38	23.67	− 52.6
35	25.42	25.00	23.37	− 53.3
40	25.76	26.16	24.14	− 51.5
45	25.82	26.04	25.25	− 49.0
50	26.36	26.66	23.84	− 52.2
55	26.35	26.57	21.79	− 57.1
60	26.42	27.34	21.59	− 57.6
70	27.30	28.70	21.15	− 58.7
80	27.37	28.98	20.84	− 59.5
90	27.32	29.17	21.07	− 58.9
100	27.70	28.97	21.51	− 57.8
125	28.38	29.17	21.51	− 57.8
150	28.81	28.81	23.03	− 54.1

Table 1

The two different features as mentioned above mean that the white thermistor sensors cooled in higher levels over Tateno with larger amount than over Moriya and the sensors grew warmer in lower levels over Tateno against the cooling of small amount over Moriya. These features correspond to the changes of amounts of the upward radiation as shown in Table 1. The amounts of upward radiation were calculated on base of temperatures of the top of clouds over the area of about 1000km in diameter, which were observed by the radiometer on board the Meteorological Satellite, GMS-4.

In layer from 125mb to 65mb, the amount of upward radiation was about 5% larger over Tateno than that over Moriya. On the other hand, in layers above 33mb it became smaller about 3% over Tateno than over Moriya.

The air temperatures measured by the gold coated sensor were higher about 7℃ in higher levels than those in lower levels. This means that the amount of long wave radiation emitted from the sensor itself was larger about 12% in the higher levels than those in the lower levels.

The upward radiation normally decreases with height. In this case, the decrease was about 22%. The increase of cooling in higher levels as observed was caused by two effects with promotive sense, and the difference of cooling amount between over two stations was caused mainly by the difference of upward radiation, if the downward radiation were kept as almost constant during the short time period of about one hour and in small horizontal range of about 20km between two stations. This assumption might be accepted as proper.

The larger differences of cooling in higher levels, in spite of the smaller percent changes of upward radiation, might be supported by the changes of effective net flux of radiation caused by the sensor.

The results described above give one more evidence to show the sensitiveness of the white coated thermistor sensor to the long wave radiation and the close relationship between the temperature discrepancy of the sensor and the amount of long wave radiation.

It was clearly observed here that the amount of temperature discrepancy varies mainly with the change of upward radiation, because the variation of the upward radiation with time and space is most remarkable. This suggests us something on the way of sounding system by the long wave radiation, how can we get the best information on the amount of the radiation due to the absorbing gases.

In the following section, the results of a test on a newly developed software for the deduction of the atmospheric ozone partial pressure is described and one of the best observation systems to make possible the sounding of ozone by the long wave radiation is suggested.

4. TEST RESULTS OF SOFTWARES NEWLY DEVELOPED FOR THE ABSORPTION COEFFICIENTS AND THE PARTIAL PRESSURE OF OZONE.

A software to deduce the atmospheric ozone partial pressure at every standard pressure level was newly developed to see if it would be available or not. Test of the software were made according with the following procedure. The amount of the downward radiation at every standard pressure levels were calculated by the radiation equation developed, taking the provisional values for the unknown absorption coefficients of O_3,CO_2 and H_2O, and giving the following values for the partial pressure of the same three gases.

O_3 : The values observed on Sept. 4, 1991 at Tateno Aerological Observatory.

CO_2: The values estimated for the means in September, 1991, considering the normal trends of seasonal and vertical variation of CO_2.

H_2O: The values estimated under the assumption of constant mixing ratio over 100mb level.

Though the initial value of the coefficients necessary for the calculation by the software might be given by anyone, values of 1 percent of the assumed ones in the radiation equation were given in this testing. For the initial values of CO_2 and H_2O partial pressures, the values given for the calculation of radiation themselves were taken again. For the initial values of O_3, the 20 years normal of the same month and over the same observation site, Tateno, in this time, were taken. Results of the calculation are summarized as follows.

The absorption coefficients deduced quite coincided with the real ones, excepting values calculated from three levels, 12.5, 50, and 175mb. The vertical change of ozone partial pressure at 175mb was very small. It seems to be essential for getting good results by software that data of pressure level, at which the vertical change of O_3 partial pressure is less than some small definite value, are excluded.

The partial pressure of O_3 deduced perfectly coincided with the real ones.

5. PROPOSAL OF ONE OF THE BEST OBSERVATION SYSTEMS TO MAKE THE SOUNDING OF ATMOSPHERIC OZONE POSSIBLE BY THE LONG WAVE RADIATION.

In order to know problems on deduction of the amounts of downward radiation, some investigations on the data observed on Feb. 19, 1992 were made as follows.

If one could assume that the amount of downward radiation $\sigma \theta_{e1}^4$ and the coefficient of heat conductivity K were equal at the same pressure level over two stations, in spite of differences of time and space of observation, the amount of downward radiation can be deduced from values of temperature differences, $\delta \theta_{00}$, observed between two sensors, white coated and gold coated sensors. The results of calculation have some errors, which might be caused by the above assumption. Therefore, some running means of θ_{e1}^4, taken by three levels, are plotted in Fig.5, together with values of ozone partial pressure observed. The results of this investigations shown in Fig.5 give us some imaginations on possibility to get the information on the amount of downward radiation.

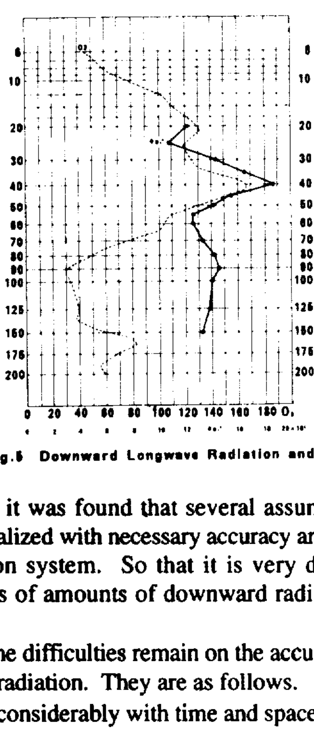

Fig.5 Downward Longwave Radiation and O_3

However, it was found that several assumptions which could not be realized with necessary accuracy are included in this observation system. So that it is very difficult to get accurate values of amounts of downward radiation by those soundings.

Further some difficulties remain on the accurate estimation of the upward radiation. They are as follows.

(1) K varies considerably with time and space. It can not be assumed that K is equal at the same pressure level. It must be determined at every instant of every sounding level as accurately as possible.

(2) The amount of upward radiation is very changeable with time and space, so that it is very difficult to estimate without error. Further it is necessary for its accurate estimation to know the accurate values of absorption coefficients of absorbing gases. It needs some complicated calculation processes for the purpose and some amounts of error must occur from this calculation processes.

Considering these conditions mentioned above, the following sounding system is proposed as the best one. This is the conclusion of this report.

6. CONCLUSION AND DISCUSSIONS.

It is possible to sound the atmospheric ozone by a radiosonde, equipped with three kinds of temperature sensors, of which lag coefficients are equal or nearly equal each other, and a switching measure, by which the three temperatures can be sounded alternately with very short time interval. One of the sensors is perfectly non-sensitive to the longwave radiation and the other two are non-sensitive to the upward longwave radiation but sensitive to the downward radiation with different angles of exposure upward.

The amount of downward radiation θ_{e1}^4 can be connected with the temperature discrepancy $\delta \theta$ of the sensor, which is nonsensitive to the upward radiation but sensitive to the downward one, by the following equation,

$$K \times \delta \theta = \sigma (\beta \theta_{e1}^4 - \theta^4) \quad (1)$$

where β is the coefficient referring on the exposing ratio to the downward radiation and proper for the sensor.

K in this equation varies considerably with the condition of air flow around the sensor. Therefore, it is essential for the good determination of θ_{e1}^4 that the value of K could be determined as accurately as possible at every instant. Two values of temperature discrepancies observed are necessary and sufficient number of data for the calculation of K, and θ_{e1}^4.

However, the sounding system suggested have many critical factors which may influence the quantitative determination of ozone content.

One of them is the accuracy of sounding of temperature discrepancies. It may be expected from the results of experimental soundings as described in Sec. 3.2, to obtain rather large temperature discrepancies more than 10 degrees and to make possible to minimize random errors of sounding by some adjusting techniques, considering that the discrepancies shown by sensors, which have different angles of exposure, should have definite relations with each other. The relative error of sounding may be kept as less than 1 or 0.1 percent. The error of estimation of ozone content coming from the assumed values of CO_2 and H_2O should be checked and readjusted by adopting some checking system, like as by making comparison flights with ozone sondes once or twice every month or every season, for example.

Anyhow, it is most desirous to make further developments on the sounding techniques of both software and hardware, by making several numbers of experimental flights of radiosondes equipped with several sensors and ozone sondes hanged in the same trains of balloons.

REFERENCES

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