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A Time-Dependent Oceanic Aerosol Profile Model

STUART G. GATHMAN

Atmospheric Physics Branch
Environmental Sciences Division

February 10, 1982

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A model is presented which will describe the time evolution of oceanic aerosol. The model is designed to operate on a desk top computer (Tektronix 4052) and is written in the easy to understand BASIC language. The model is based on the physical processes operating on a column of air as it travels with the wind over the ocean. Inputs to the model are the time history (or forecasts) of six surface observable parameters: air temperature, cloud cover, dewpoint, windspeed, sea surface temperature, and the inversion height. The output of the model is a series of aerosol

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20 **ABSTRACT** *(Continued)*

concentration profiles every 10 minutes of one particular dry size of aerosol. Provisions are made for tandem runs for different dry sized particles so that size distributions of aerosols can be plotted as they evolve over time.

The model takes into account the production of oceanic aerosol at the sea surface by white caps and spray and the changes in droplet sizes as a function of the relative humidity profile as well as the mixing processes as it changes with both time and altitude.

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A TIME-DEPENDENT OCEANIC AEROSOL PROFILE MODEL

INTRODUCTION

Marine aerosols have always been of concern to man. In the early days of seafaring by man, optical visibility was of major concern for navigation in commerce and warfare. Visual observations are important to make navigational fixes on shoreline landmarks as well as for sighting the stars. The effects of visibility during wartime played an important role in the outcome of many naval engagements. The advent of radar in World War II, however, did away with this strong dependence on visual observations because radar band wavelengths are not affected by the existence of micron sized aerosol. With the use of radar the navigator can scan the distant shoreline for known land marks. Radio navigation can provide fixes to unheard of precision even in the open ocean. Communication with other ships and with land bases became routine with radio waves. All of these twentieth century advances using radio waves are essentially independent of the aerosol content of the marine atmosphere.

The sophistication of the modern age, however, has come full circle. There is now more dependence on the aerosol content of the atmosphere because different wavelengths of electromagnetic radiation are being exploited by the current weapons designers due in part to the technological explosion of ideas that has occurred during the last several decades. Thus when infrared and optical radiation are involved, a whole area of its interaction with atmospheric aerosol again becomes important. This is particularly interesting because transmission of energy through an aerosol cloud is a function of wavelength.

The Navy has a need to predict what the effect of meteorology will be on electro-optical transmission characteristics of the marine atmosphere and shoreline atmospheres anywhere throughout the world and at any time. Obviously this problem can be solved only if a suitable maritime aerosol model is developed which can utilize for inputs the synoptic scale weather information that is gathered routinely and synthesized by various large-scale numerical weather predictive systems and by direct satellite observations of the globe with sensors of various wavelength emissions and the appropriate processing of these data.

It is an observation of seafarers that conditions do not stay constant for long periods of time. There are periods of calm, and then come the storms. In addition the environmental history of an air parcel which is observed on a ship at any point in the world's ocean, most probably is vastly different from the environmental history of the observing platform itself.

Observational data of aerosols at sea [1] show that at intermediate and large aerosol sizes, the aerosol concentrations increase markedly during high wind, high sea state periods and lower during calm periods. It is during these high sea state periods that the oceanic component of the aerosol size spectrum is most noticeable.

The purpose of this report is to describe a time-dependent aerosol model which will predict the behavior of aerosol throughout the planetary boundary layer in both calm and white water conditions and in the transitions between them. This model will respond to changes in the marine inversion height, stability, sea state, relative humidity profile, and wind speed.

Manuscript submitted October 16, 1981.

PHYSICAL BASIS OF THE MODEL

These processes are the result of whitecaps and spray produced by the action of wind on the sea. Figure 1(a) shows a cumulative probability curve of wind speed for both summer and winter in the North Atlantic. These curves indicate that 90% of the time the minimum wind speed required to produce whitecaps is exceeded in the ocean. Thus droplets from white water could be a very important part of the marine aerosol in this part of the world.

Central to the ultimate aims of this effort is the desired ability to be able to predict the future characteristics of the aerosol size distribution as it will be affected by generation rates, fallout, and diffusion. A time-dependent model of the evolution in concentration at all levels of the boundary layer of a single dry size class of aerosol is the means by which this need will be met. The model will describe the marine aerosol produced by processes at the air-sea interface. The droplets are composed of water and sea salt and are therefore very hygroscopic and will change sizes as the ambient relative humidity changes. It is also well known that in the typical marine atmosphere the relative humidity is about 80%. There are certainly many times when the relative humidity is about 80% and even above 90%. Consider for example the plot shown in Fig. 1(b). Here is plotted the cumulative probability curve of the measured relative humidity for areas such as the North Atlantic. The model must also take these changes in size into account.

The simplest case of the partial differential equations which will adequately describe our processes on particles of dry size class i is shown in Eq. (1).

$$\frac{dN_i}{dt} = \frac{\partial}{\partial z} K(z) \frac{\partial N_i}{\partial z} + V_i \frac{\partial N_i}{\partial z}. \tag{1}$$

This equation describes the processes acting on a column of air moving with a constant velocity in the direction of the wind. This equation describes the time history of the concentration of particles of the size class i at an altitude z above the sea surface. There are three physical processes assumed acting on the particles and they are:

(1) generation rate at the sea surface
(2) eddy diffusion
(3) gravitational fall.

The generation rate will be reflected by the lower boundary condition. The mean micrometeorological state of the atmosphere is described by an altitude-dependent eddy diffusion coefficient represented by $K(z)$. The fall rate of the particles in class i is represented by V_i and will be a function of the ambient relative humidity which will in general be different for each altitude.

To adequately represent the time-dependent solution of this differential equation, certain boundary conditions must be defined. At time equals zero, the initial concentrations of particles throughout the column must be specified. If we are interested in only observing that portion of the total aerosol spectrum which is being locally generated by wave action, then we may specify the initial conditions such that there is a negligible amount of aerosol throughout the column at the start of the calculation time. This is equivalent to looking at the cases where the continental component of the atmospheric aerosol is always equal to zero. In addition, surface boundary conditions must be specified. In this simple one-dimensional case, only the conditions at the top and the bottom of our column of air must be specified. The upper boundary condition is easily taken care of if the height of our air column is substantially greater than the height of the inversion layer specified in the $K(z)$ function. Since we are only looking at sources of aerosol at the sea surface and the capping inversion specifies no diffusion of particles through the inversion, then there is no problem in arbitrarily keeping the upper boundary constant in value as time progresses. On the other hand, the white water processes at the sea's surface will

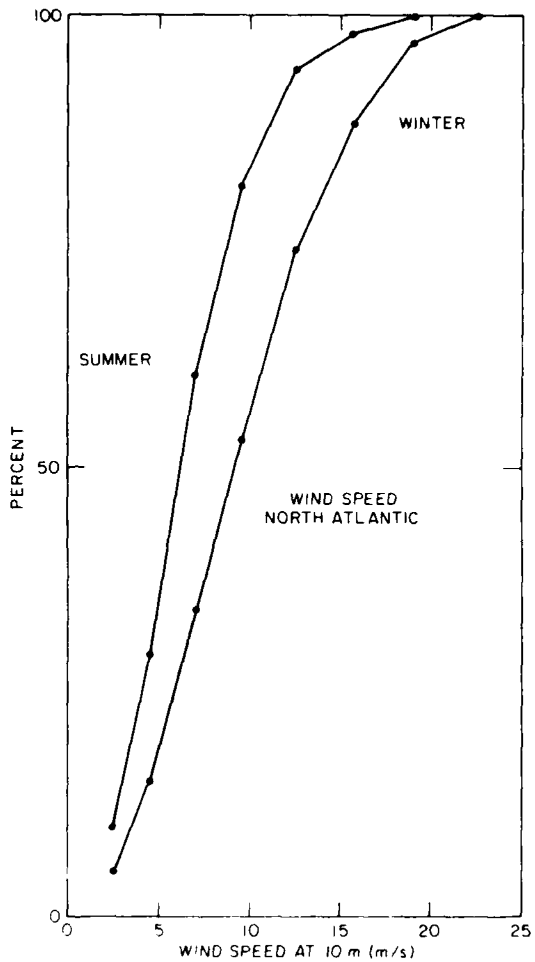

Fig. 1(a) — The cumulative probabilities of wind speed at 10 m (climatological scale) for the North Atlantic Ocean for the summer and winter seasons

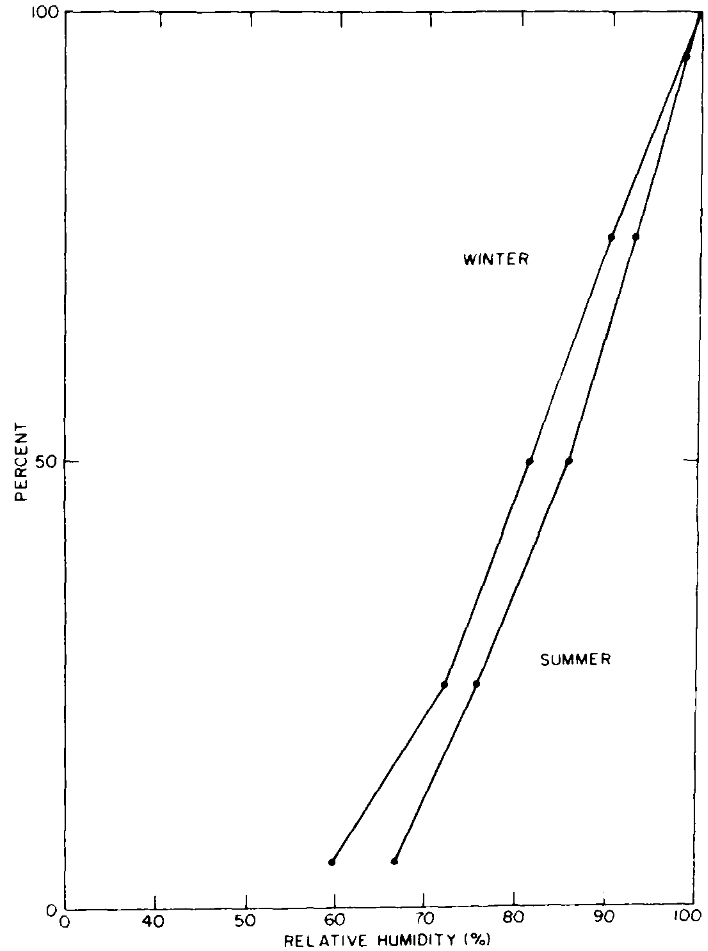

Fig. 1(b) — The cumulative probability of relative humidity over the North Atlantic Ocean on a climatic scale for the summer and winter seasons greatly affect the concentrations at the lowest levels of the column and in addition may even vary as a function of time. To simulate this process, a flux boundary condition is maintained at the sea surface which will be varied as a function of the meteorological input parameters.

EDDY DIFFUSION

The problem of defining the eddy diffusion coefficient as a function of altitude is taken care of in this model by using the work of O'Brien [2], where he has constructed a functional form for $K(z)$ which is continuous in both its value and its derivative. The general characteristics of this function can be matched to the atmospheric conditions by parameter setting. Of particular importance in this regards is the parameter describing the height of the inversion over a typical open oceanic area. This altitude will correspond to the top of the marine layer. This is the altitude at which we wish to make the eddy diffusion function to become small or zero under neutral and unstable conditions.

The process this model goes through to determine the profile parameters necessary to define the functional form of the eddy diffusion coefficient starts with the calculation of various micrometeorological scalar parameters based on the six bulk meteorological input parameters. These parameters are stored in a storage array for future reference. This process commences in task 2 of the program with the calculation of the drag coefficient, C10. This parameter (stored in P(6) of the scalar storage array) is linearly related to the measured wind velocity in the functional form suggested by Deacon [3,4].

$$C_{10} = 0.0011 + 4 \times 10^{-5} \times U_{10}, \tag{2}$$

where U_{10} is the wind speed at 10 m measured in meters per second.

The friction velocity, U^* is next calculated from the input wind speed at 10 m and the previously calculated drag coefficient. This parameter is stored in P(8) with the units of meters per second.

$$U_* = \sqrt{C_{10}} \times U_{10}. \tag{3}$$

The dynamic roughness of the sea surface, Z_0, is next calculated from the friction velocity in the manner of Charnock [5].

$$Z_0 = C_{10} \times U_{10}^2. \tag{4}$$

This parameter is stored in P(9) with the units of meters.

Next the bulk derived Richardson's number is calculated from the gradient in virtual potential temperature and wind speed at the associated 10-m level [6] by:

$$Riv_{10b} = 3.55(\theta v_{10} - \theta v_0)/U_{10}^2 \tag{5}$$

where the influence of the water vapor gradient on stability is accounted for by the gradients in the virtual potential temperature calculated from the sea surface temperature, the air temperature, and the dewpoint in the standard manner. Once the bulk Richardson's number is calculated, it is stored in the location P(10). This number will be used in later determinations to describe the eddy diffusion coefficient profile.

The actual stability of the atmospheric boundary layer will be determined by the ratio of the reference altitude z_{10} to the Monin-Obukhov length, L. Negative values of this ratio z_{10}/L indicate instability whereas positive values indicate stability. The dimensionless stability parameter z_{10}/L is calculated by the method of Barker and Baxter [7] from the bulk Richardson's number and is stored for later reference in P(7).

The calculation of the O'Brien [2] polynomial form of the eddy diffusion coefficient, $K(z)$, requires values of the eddy diffusion at 1 m, $K(1)$ and its derivative, $K'(1)$ at the 1-m level. $K(1)$ and $K'(1)$ are computed from the formula:

$$K(z) = 0.35 U_{*} z/\phi(z/L), \tag{6}$$

were $\phi(z/L)$ is the semiempirical stability function for heat transport [8].

For unstable conditions the depth of the planetary boundary layer is taken as the height of the capping inversion stored as one of the input time parameters. During stable conditions, Clarke [9] empirically determined that turbulent mixing approaches zero at a level:

$$H = 0.23 \times U_{*}/\ [\text{Corioles parameter}]. \tag{7}$$

For very stable conditions (Rib $\geqslant 1/4.7$), no turbulent mixing is predicted by the model and $K(z)$ is everywhere negligible.

RELATIVE HUMIDITY EFFECTS

The dynamic aerosol model is able to determine the effect of droplet growth in near saturation conditions. Information on the relative humidity profile of the atmosphere is obtained from model predictions based on surface shipboard observations [10]. The dynamic aerosol model assumes a profile based on the previously declared inversion height and surface meteorological measurements.

In the model the hygroscopic particles produced at the sea surface are always in size equilibrium with the relative humidity of their surroundings. When the computer first asks what size particle is desired to follow, it also asks at what "reference" relative humidity is to be used. Thus with the formulations of Fitzgerald [11] it determines the dry size of the particle and thus can predict to what size it would grow in any other subsaturated relative humidity environment in which they would be placed. Since these particles are all of the same dry size no matter how large they grow, we can at any altitude talk about the number of particles which have the same dry size. That is the particles are always identifiable by their dry size. Therefore even though the relative humidity changes we can always keep track of the particular dry sized particles. Thus given any size distribution of dry sized particles we can easily determine the size distribution which this population would have if it were immersed in other relative humidity environments.

The fall velocity of the droplets is the only quantity in which the defining partial differential equation is affected by the droplet size and therefore most strongly by the relative humidity profile. Thus this is accounted for in the model by adjusting the fall velocity for each different level to that which a particle of the initial dry size would have if it were grown to the size indicated by formula for the relative humidity at that level.

To implement this feature, the profile of relative humidity must be known. Such information is not ordinarily known unless a sounding has been done. Gathman [10], however, has devised an empirical model for predicting the relative humidity profile given only the sea surface meteorological measurements. The main features of this model are incorporated into this time-dependent oceanic aerosol model, and its structure is based on the hourly surface meteorological inputs.

The sedimentation rate for water droplets in air is determined by the Stokes-Cunningham relationship where the settling velocity expressed in meters per second is given by:

$$V = 3004 \times D^2 \times (1 + 1.6 \times 10^{-5}/D), \tag{8}$$

where D is the diameter of the particle in centimeters at the ambient relative humidity [12].

LOWER BOUNDARY CONDITION

The model uses as the lower boundary condition, the upward flux of particles which occur over salt water for that particular sea state. This approach essentially uses an empirical wind-dependent relationship to define the aerosol flux which is necessary for the profile calculation of the oceanic component of the atmospheric aerosol.

The works of Woodcock [13] who obtained salt particle distributions as a function of wind speed and of Eriksson [14], who computed the fall velocities for salt particles in equilibrium with a 91.4% relative humidity are the basis by which Blanchard [15] obtained a set of curves that give (under the assumption of steady state) the spectra of the number of ocean produced drops leaving the sea surface per unit area per second per $0.2 \times \text{Log}(D)$ interval (where D is the droplet diameter). Blanchard produced different spectra for different wind speeds. This family of curves can be fitted by a set of log-normal distributions, the three coefficients of which are wind dependent and can be themselves represented by simple functions of the wind speed. The fitted spectra, shown in Fig. 2, closely resemble Blanchard's figure and will be the basis of this model.

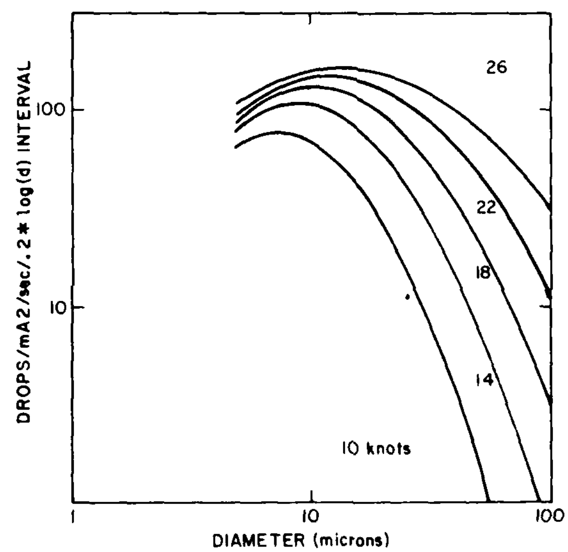

Fig. 2 — The aerosol flux size distribution plotted as a log normal, wind-dependent function fitted to Blanchard's data

Thus by knowing the wind speed, we can compute the three coefficients which describe the particular log-normal size distribution of the droplet flux. By knowing the size our particular dry sized particles have at the relative humidity of 91.4% we can then easily obtain the surface flux boundary condition.

The extrapolation of these curves to low wind speeds shows that at wind speeds below 4.5 knots, the amplitude parameter of the log-normal distribution drops to zero. This result is to be expected because of the lack of whitecaps at these speeds. The curves also show a general broadening of the distribution with increasing wind speed as well as the shifting of the maximum concentration size to larger values at the higher wind speeds.

The droplets in this distribution in the diameter range of from 6 to 60 microns are presumably the results of the bursting of bubbles and the spray from waves and do not include the very small droplets which result from the fragmentation of the bubble film in the bubble bursting process.

MODEL IMPLEMENTATION

This model deals with the expected concentrations of oceanic aerosol of a particular dry size of particle. As the relative humidity cannot generally be expected to be invariant with altitude we are then talking about the concentrations of different real size droplets at each of the levels of our model grid because the relative humidity can be expected to be different at each of these levels. The fact remains, however, that any of our droplets if dried out would approach a common size.

To tag each of the droplets so that the computer can always keep track of the particular droplet we are studying, both a diameter and the relative humidity must be known. Thus as a computer input, a diameter and a relative humidity at which this diameter is referenced must be given. Once this is known, a dry size is calculated and all processes affecting this set of constant dry sized particles are computed.

The model is designed to predict the concentration of only one dry size of particle at any particular run. This is a limitation on the size and speed of the computer being used. Size distributions can be obtained by running the model several times with the same set of input parameters except that different dry sizes of particles will be given to the computer to be considered. As the concentrations at all levels of these various dry sized particles are predicted by the model as well as their ambient relative humidities, the size distribution at any time and at any altitude can be calculated by tandem computer runs.

If a log normal distribution is adequate to represent the size distribution, then only three runs need be done as these type of distributions can be completely defined by the concentrations of three sizes of particles (any three sizes of particles).

A rerun provision is included in this program which will remember all of the meteorological history vectors in order to provide identical runs for different sized droplets. A range of droplet sizes which this models' input data is matched is from a 2 to 90 microns diameter, at relative humidities of approximately 90%. Sources of droplets from the ocean surface such as film droplets, jet droplets, and spray fall with in this range. Thus asking the computer to look at droplets outside of this range is prohibited by the software.

The model results depend on certain meteorological measurements as inputs and boundary conditions which are required information in order for the model to operate. Hourly meteorological measurements are assumed. When used to look backwards at the atmospheric aerosol history actual hourly meteorological records can be given to the computer. The computer assumes the "current" meteorological environment is a good approximation until told of future changes during the input process. Standard weather forecasts or the use of more sophisticated model forecasts may also be used to provide the meteorological history parameters for forward-looking predictive runs.

Various calculations based on the measured meteorological parameters are used to provide those specifically needed by the model and are included as subroutines which can be changed as necessary. For instance the micrometeorological estimates used in the calculation $K(z)$ based on O'Brien [2] can be easily updated as research in that field progresses.

The inversion height is considered a meteorological parameter and entered by hand. These may come from several sources such as an acoustic sounder, a lidar, a radiosonde, a model, or from a climatology.

The model is implemented in the BASIC language on the Tektronix 4052 desk top graphic computer equipped with disc storage. The model has certain characteristics of the machine, but these features are not absolutely necessary to the basic structure and flow of the model. The program, without the added special features, should be runable with few modifications on any BASIC language computing machine with adequate memory.

The speed of computations will of course vary from machine to machine and could make many small-scale computer systems require an excessive amount of time for computation. On the other hand if speed of computation is of utmost importance, the program could be converted to a compiler-like language and run with small modifications on a fast large-scale computer.

The method used in the solution of this initial value problem with one spatial dimension is described in Young and Gregory [16] as the forward difference method. To increase the grid spacing close to the sea's surface where the largest spatial variations in the various quantities takes place, a variable grid is introduced for 24 levels used to describe this model.

The computational stability of this method of solution depends on the mesh ratio r which is defined as the ratio of the time step to the square of spatial grid spacing. It can be shown that $K(z) \times r$ must be less than or equal to 1/2 in order to assume satisfactory results in the computation. In the variable grid scheme used here, the lowest grid spacing is usually the critical one which limits the speed of computation. The program is set up so that the Tektronics 4052 will normally process 24 hours of computational time in 1 hour of wall clock time. Given a particular machine the processing speed can be improved only by degrading the grid spacing such that the stability conditions in the mesh ratio remains valid. However to maximize the speed of computation, a new maximum time step interval is calculated after each new $K(z)$ is determined.

MODEL INPUTS

The interacting capabilities of the 4052 computer are utilized to allow the computer to ask questions of the operator so that all of the required input parameters are satisfied. The program's meteorological input data are stored in the form of time lists, with estimated or measured values for each of these meteorological quantities required for each "model time" hour that the calculations are made. In inputting this data, the concept of persistence is used in that an initial value is required for the first model time hour of each parameter and these initial values are assumed for the remaining 23 hours unless they are specifically changed for some later times. If they are changed, the new values are used until the twenty-fourth hour unless it is again changed. There are six meteorological time lists used in the model, and they are listed below together with their required units for the input process.

(1) $A1$ = Air temperature history (°C)
(2) $C1$ = Cloud cover history (tenths)
(3) $D1$ = Dew point history (°C)
(4) $H9$ = Inversion base height history (m)
(5) $U9$ = Wind speed history (m/s)
(6) $S0$ = Sea surface temperature history (°C)

In addition to the time lists, certain parameters concerning the calculation are required before the program can begin. The general geographical latitude is required (in degrees) as well as the droplet size of interest (expressed as a diameter in microns) together with a reference relative humidity at which the desired droplet size is associated. This latter information is used to determine the actual dry size of the particle so that its changes in size with respect to the various relative humidities encountered in the model can be accurately determined.

The model makes a number of calculations based on the meteorological input data. Profiles of the eddy diffusion coefficient and the relative humidity as well as the value of the surface flux are based entirely on the time list data and are calculated initially and are updated each "model time" hour thereafter to provide the dynamic framework on which the physical processes of *fallout and eddy diffusion* operate.

The determination of these three quantities contains much of the physics on which the model depends and in turn affects the size of the droplets and thus the falling velocities, the ability of the boundary layer to redistribute the droplets which are in it, and the oceanic source of these droplets from white water phenomenon. The methods for determining these quantities from the surface meteorological inputs are based on other works. Presumably as research in these areas continues, an improvement in this model can be obtained by simply upgrading the various subroutines used in the model. These data are stored as elements of parameter vector *P*, and the definitions of these elements are shown in Table 1.

Table 1 — Definition of the Storage Array P

P(1)	-----	DROPLET DIAMETER (MICRONS)
P(2)	-----	REFERENCE RELATIVE HUMIDITY OF SIZE MEAS. ( )
P(3)	-----	DROPLET DRY DIAMETER (MICRONS)
P(5)	-----	LATITUDE
P(6)	-----	DRAG COEFFICIENT, C10
P(7)	-----	Z/L
P(8)	-----	FRICTION VELOCITY, U*
P(9)	-----	SURFACE ROUGHNESS, Z0
P(10)	-----	BULK RICHARDSON'S NUMBER
P(11)	-----	FRICTION POTENTIAL TEMPERATURE THETA*
P(12)	-----	FRICTION MIXING RATIO, R* OR Q*
P(13)	-----	HEIGHT OF SUPERADIABATIC LAYER, ZSA
P(14)	-----	HEIGHT OF CONDENSATION LAYER, ZCON
P(15)	-----	FLUX OF DROPLETS FROM THE SURFACE
P(16)	-----	HOUR COUNTER
P(17)	-----	PARAMETER UPDATE TRIGGER (NORMALLY =0)
P(18)	-----	DATA STORAGE BLOCK LOCATOR
P(19)	-----	DELTA TIME STEP
P(20)	-----	TRIGGER VALUE FOR DISPLAY AND OPERATOR DIRECTION
P(21)	-----	TRIGGER FOR AUTOMATIC DATA STORAGE
P(22)	-----	TIME HOURS
P(23)	-----	TIME # OF 10 MINUTE INTERVALS
P(24)	-----	TIME SEC

FLOW CHART

The flow of the program is illustrated in Fig. 3 where the main features of the model steps are shown as blocks. Because certain of the steps are lengthy and require much memory space, the program is broken down into tasks for convenience. The programs for these tasks and their required subroutines are stored on disc and are copied into an overlay section of the main program when they are needed. The portions of the program flow chart which are identified with the various tasks are outlined in the figure. Most of the program calculation time is spent in task 5 so that the overlaying does not take up too much time.

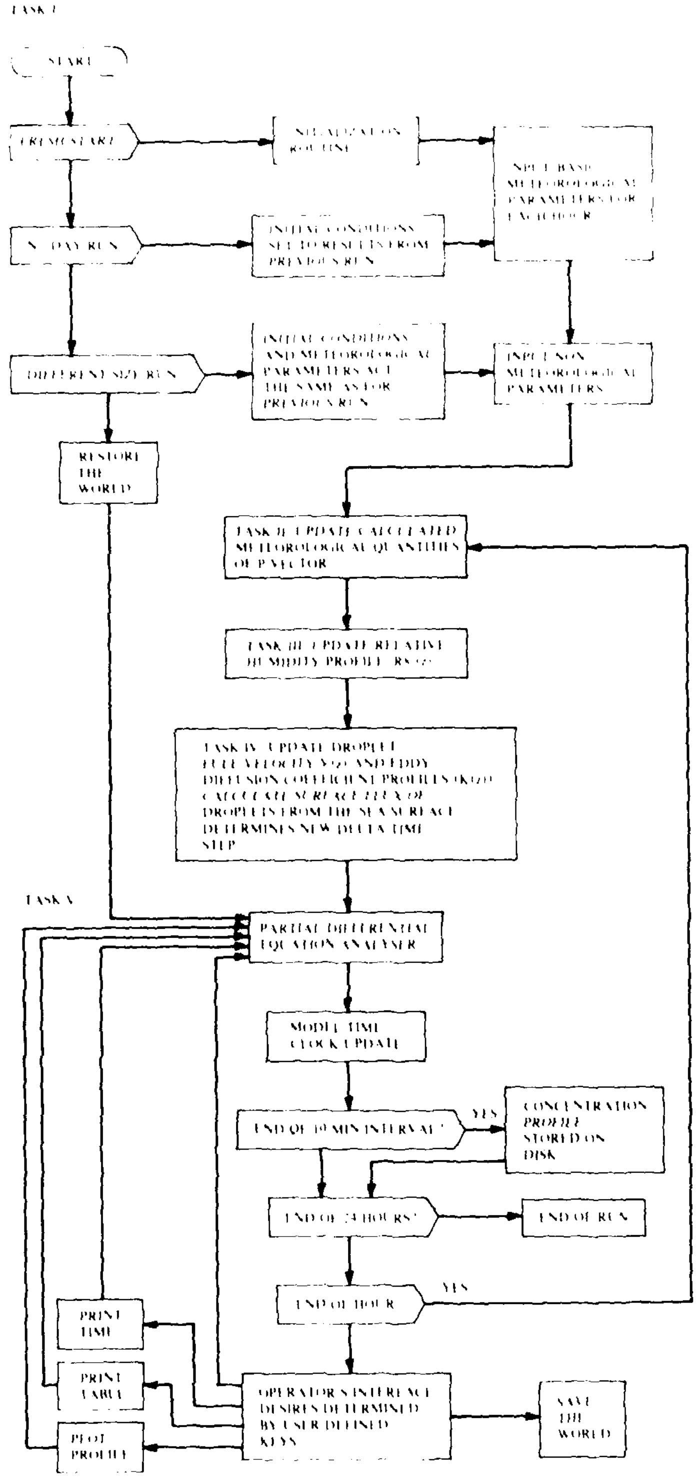

Fig. 3 — Flow chart for the time-dependent aerosol profile model

The main product of the program is a disk file written as a random access file which stores the complete aerosol profile every 10 minutes of "model time." The information in this file can be easily accessed by other analysis programs to describe the evolution of the aerosol concentration of the particular dry sizes asked for at the beginning of the calculation.

The basic model describing mixing by eddy diffusion and the gravitational fall of droplets is affected by the meteorological measurements used in the functional form of the profile of the eddy diffusion coefficient $K(z)$ and the fall velocity $V(z)$ of the droplets themselves, which depends on the size of the droplets, which in turn depends on the ambient relative humidity of the atmosphere. The lower boundary condition in the model presented here $N1(1)$ is also related empirically to wind speed.

Because the predictions of the model do not in any way affect the meteorological values of the air column being modeled, there is no feedback process occurring. Hourly observations are usually adequate to describe the meteorological features of mesoscale processes, and this frequency of updating is assumed adequate for the time-dependent oceanic aerosol profile model.

Every model hour the meteorologically sensitive profiles $K(z)$, $V(z)$, and $N1(z)$ are updated from the best estimates of the basic meteorological input parameters while the calculation continues. In this way the lengthy calculations of these values are not repeated more often than necessary.

MODEL PERFORMANCE

The complete testing of a comprehensive numerical geophysical model is an extremly difficult process because of the large number of combinations of parameters which are allowed as inputs. A given field test may be a basis for testing the model for a finite set of input conditions, but there is always a chance that one certain set of parameters will cause completely erroneous results. Also, the numerical solution of a problem causes further uncertainties when finite grid spacings and time steps are employed.

One approach of checking for the errors introduced into the numerical solution is to find a case that can be solved by analytical means and then to check the numerical solution with the analytical solution to see how valid the numerical approximation is.

Other tests that can be done to strengthen the plausibility of the model's results are to run very specific cases where the outcome is generally known. All inputs in these cases can be simplified and made to remain constant except the particular parameter for which the model's sensitivity is desired to be known.

The defining partial differential equation (Eq. (1)) may be solved analytically for steady state cases. The numerical solution of the time-dependent oceanic aerosol model approaches the steady state solution (if the boundary conditions remain constant) as time approaches very large numbers. Thus a check of the digital technique can be obtained by comparisons with a steady state analytic solution.

For this purpose the subroutines defining the profiles of eddie diffusion coefficient and the relative humidity were changed in the numerical model to correspond with integratable functions for the analytic solution. To this end the relative humidity profile is also held constant at the reference value so that the fall velocity would not be a function of altitude but only of the droplet dry size.

The altitude dependence of the proposed eddie diffusion coefficient for the comparison between the digital computer solution and the analytical model was chosen to be:

$$K(z) = K \times z + g, \tag{9}$$

where K and g are arbitrary constants.

In the steady state case $dN/dt=0$ and therefore Eq. (1) becomes:

$$K(z) \times dN/dz + v \times N = \text{constant}. \tag{10}$$

If $K(z)$ is defined as in Eq. (9) and v is held constant, the equation integrates to:

$$N(z) = C1 \times (K' \times z + g)^{(v/K')} - C2 \tag{11}$$

where $C1$ and $C2$ are constants of the integration.

In the comparison between the analytical and the numerical solution, we defined $K' = 2$ and $g = 0.01$, and solved the problem for a 40 micron droplet in an ambient 80% relative humidity. This droplet has a fall velocity of 0.0482 m/s.

When a computer run of five and a half model hours was done, the digital solution had reached a steady state condition and the integration constants $C1$ and $C2$ were evaluated from the numerical model levels of 11 and 594 m. Figure 4 is a plot of the error in percent between the analytical solution and the numerical solution plotted as a function of altitude. This curve shows the effects of large grid spacings at the higher altitudes on the accuracy of the solutions. Likewise the larger errors at the lowest levels probably reflect the matching of boundary conditions at the boundary itself.

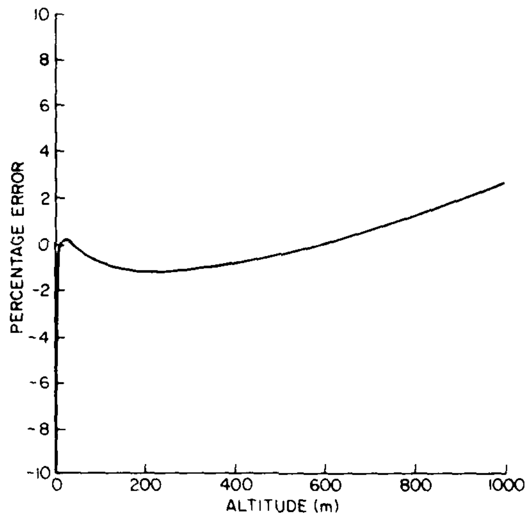

Fig. 4 — Error between an analytical solution and a steady state digital solution for a simplified profile of relative humidity and eddy diffusion

A second example in which the performance and importance of the time dependent oceanic aerosol model can be seen is the response of the atmosphere to a sudden increase in wind speed for a short duration. In the carrying out of this test the subroutines of the model are all restored to their normal form. The meteorological parameters are set to be thermally stable, and the relative humidity was forced to be very high so as to simulate an encounter in a slightly subsaturated condition. The wind speed input was set to zero for the first hour, 15 m/s during the second hour, and again zero for the remainder of the calculation. In this case of course, there is no input flux unless the wind speed is high. Likewise the eddie diffusion parameter is very low except for the mechanical mixing produced during the period of high wind speed. Four runs were made of this case for the sizes of 20, 10, 5, and 2.5 microns diameter with a relative humidity of 90%.

The results of the first 500 min of this run are plotted in Fig.5. These three dimensional plots show the surface defined by the altitude, concentration, and time of a certain dry sized aerosol computed by these runs. The vertical axis is altitude plotted linearly. The horizontal axis is the linear measure of aerosol concentration. The time axis goes back into the page at an angle. The altitude-time plane is a background concentration profile of $N(z) = 10^{5}$ per cubic meter which is represented by the vertical lines describing constant $N(z)$ profiles every 10 min and the slanted lines depicting levels of constant altitude which show the variable grid levels used in the model. For comparison purposes, the scale of the concentration is not constant but is adjusted so that the maximum concentration distance of the whole surface is the same for each of the aerosol size classes. The absolute values of these concentrations vary by a considerable amount.

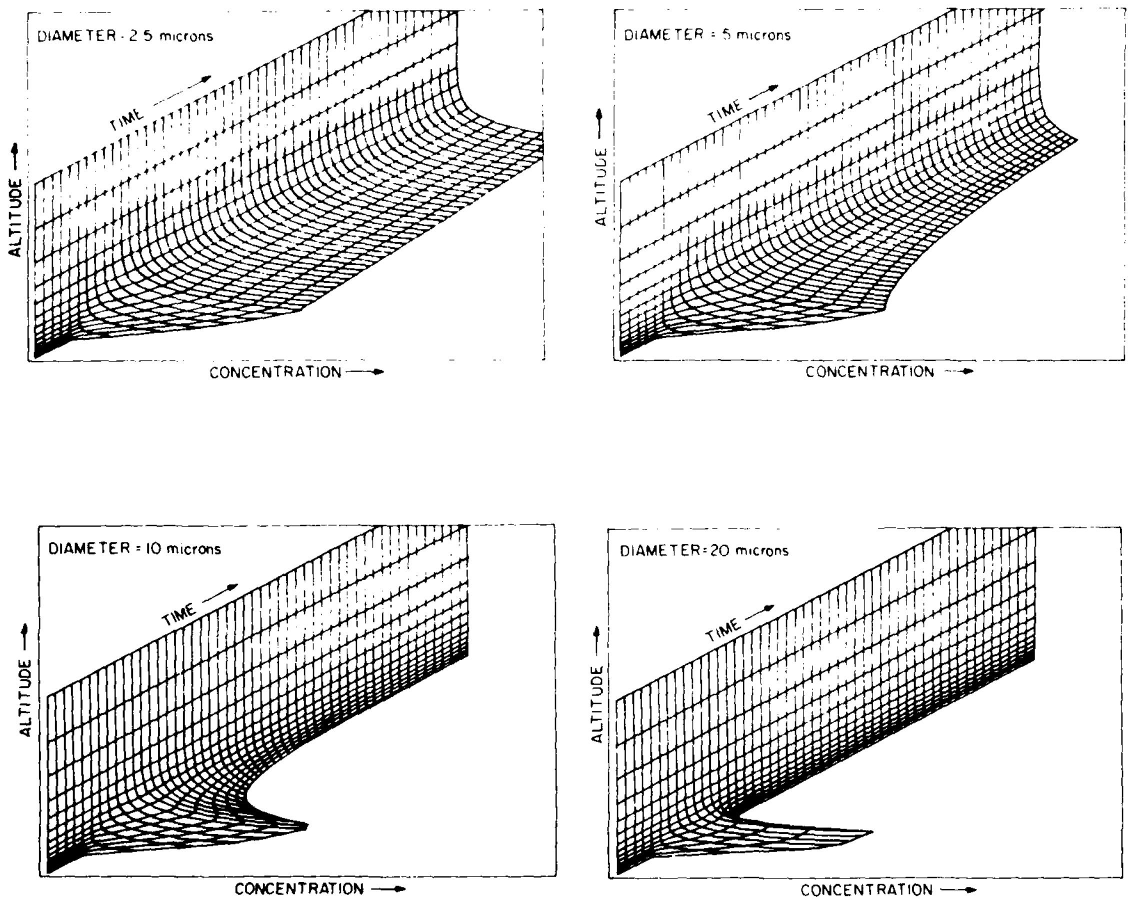

Fig. 5 — Three-dimensional surfaces describing the time and space evolution of various size droplets

The interesting feature of these surfaces is the time responses of the atmosphere to each of the aerosol sizes. The largest aerosol size class mirrors the wind speed function and does not affect the atmosphere above 50 m while the smallest size class appears to just stay in the atmosphere once introduced into it. It of course eventually falls out but at a much slower rate than the largest aerosol. This of course will be exhibited in a changing size distribution which will narrow and shift to smaller sizes as time goes on in the event there are no generation processes.

This shifting of the size distribution can be seen in Fig. 6 where the atmosphere was filled initially everywhere with the same log-normal distribution of aerosol shown by the solid line in the figure. The model was allowed to operate for 11 hours of model time under idealized conditions. These conditions included a constant relative humidity profile, and a wind speed such that no flux was introduced from the surface but yet there was enough eddy diffusion to keep the boundary layer stirred. The resulting size distribution is shown by the crosses in the figure. This calculation shows that indeed the size distribution does change with time as expected.

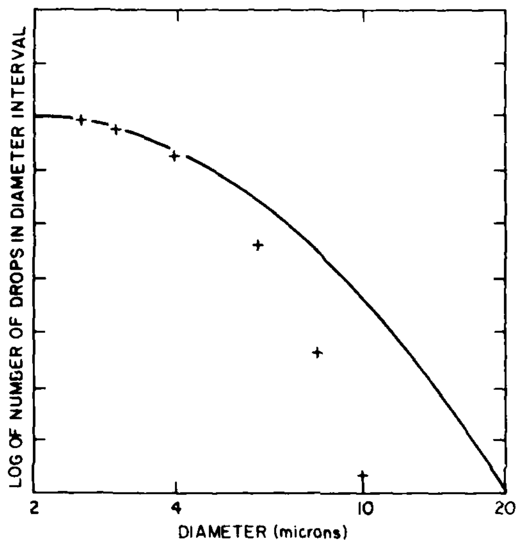

Fig. 6 — The modification of an aerosol size distribution in a nonequilibrium state. The curve is the initial size distribution throughout an atmospheric column. The crosses are the model calculations at an altitude of 8 m of the modified size distribution after a period of 11 h of mixing produced at a level just below the white cap threshold

CONCLUSIONS

The performance of the model gives plausible results when certain "setup" cases are introduced to it. There are several sets of field data available which provide enough of both the aerosol size distributions and the necessary meteorology input data so that it can be tested on a case study basis. These lengthy case studies are beyond the scope of this report but are presently being processed and prepared in the form of a companion report.

The convenience of operating the model on a small desk top computer is very great. Numerical experiments can be carried out easily and inexpensively and the results plotted with ease. As the original desire was expressed, the most productive use of the model is expected to be the ability to use forecasted meteorological data as well as historical meteorological data to determine the future of an evolving vertical profile of the oceanically produced aerosol size distribution.

ACKNOWLEDGMENT

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```
1 GO TO 10000
8 REM PRINT MODEL TIME
9 P(20)=2
10 RETURN
12 REM PLOT N1
13 P(20)=3
14 RETURN
16 REM PRINT N1
17 P(20)=4
18 RETURN
20 REM SAVE WORLD ROUTINE
21 P(20)=5
22 RETURN
10000 GO TO 30090
20000 REM-------------------- OVL -- AREA
20010 REM
30000 REM
30010 REM  !------------------------------------------------------------!
30020 REM  !  M A I N    P R O G R A M                                  !
30030 REM  !  MAIN                                                       !
30040 REM  !------------------------------------------------------------!
30050 REM
30055 REM-------------------- LOAD OVL ---AREA
30060 GOSUB 30220
30070 GO TO 20060
30080 REM-------------------- MAIN PROGRAM
30090 INIT
30100 Z$=""
30110 U=1
30120 REM         ---
30130 REM          !
30140 REM          !
30150 REM-------------Typical Overlay Request
30160 F$="@AEROSOL/PROGRAM/TASK1"
30170 GO TO 30060
30180 REM          !
30190 REM          !
30200 REM         ---
30210 REM---------------------------LOAD OVL AREA
30220 IF F$=Z$ THEN 30280
30230 DELETE 20020,29990
30240 Q=MEMORY
30250 CALL "UNIT",U
30260 APPEND F$;20010,10
30270 Z$=F$
30280 RETURN

20000 REM
20010 REM  !------------------------------------------------------------!
20020 REM  ! @AEROSOL/PROGRAM/TASK1                                      !
20030 REM  ! STUART GATHMAN NRL CODE 4327                                !
20040 REM  !------------------------------------------------------------!
20050 REM
20060 UNIT 1
20070 DIM A$(300)
20080 PRINT "IS THIS A FRESH START (Y OR N)?";
20090 INPUT B$
20100 IF B$="N" THEN 20310
20110 REM SET UP NEW PARAMETER STORAGE FILE
```

```
20120 GOSUB 22330
20130 IF B$="N" THEN 20080
20140 REM SET UP NEW OUTPUT FILE
20150 GOSUB 22490
20160 IF B$="N" THEN 20080
20170 REM INITIATE OUTPUT FILE
20180 GOSUB 22630
20190 REM DIMENSION VARIABLES
20200 GOSUB 20930
20210 P=0
20220 REM INPUT NON MET PARAMETERS
20230 GOSUB 22750
20240 REM INPUT Z GRID AND MET PARAMETERS WITH N1&O1 =1E-5
20250 E$="Y"
20260 GOSUB 22960
20270 F$="@AEROSOL/PROGRAM/TASK2"
20280 GO TO 30060
20290 REM
20300 REM
20310 PRINT "IS THIS A DUPLICATE RUN WITH DIFFERENT DRY SIZE"
20320 PRINT "(Y OR N ) ?";
20330 INPUT B$
20340 IF B$="N" THEN 20560
20350 REM REOPEN OLD PARAMETER STORAGE
20360 GOSUB 22420
20370 REM OPEN NEW OUTPUT FILE
20380 GOSUB 22490
20390 REM INITIATE OUTPUT FILE
20400 GOSUB 22630
20410 IF B$="N" THEN 20080
20420 REM DIMENSION VARIABLES
20430 GOSUB 20930
20440 READ #2:P,N1,K,H9,U9,Z,A1,C1,D1,SO,R8,V
20450 REM INPUT NON MET PARAMETERS
20460 GOSUB 22750
20470 N1=1.0E-5
20480 O1=N1
20485 P(18)=0
20490 P(16)=0
20500 P(23)=1
20510 P(24)=0
20520 F$="@AEROSOL/PROGRAM/TASK2"
20530 GO TO 30060
20540 REM
20550 REM
20560 PRINT "IS THIS A SAVE THE WORLD RECOVERY (Y OR N)?";
20570 INPUT B$
20580 IF B$="Y" THEN 20820
20590 PRINT "AT WHAT FILE NAME IS THE INITIAL CONCENTRATION DATA"
20600 INPUT B$
20610 OPEN B$;3,"R",A$
20620 PAGE
20630 PRINT A$
20640 REM OPEN NEW OUTPUT DATA FILE
20650 GOSUB 22490
20660 REM INITIATE NEW OUTPUT FILE
20670 GOSUB 22630
20680 REM OPEN NEW PARAMETER STORAGE FILE
```

```
20690 GOSUB 22320
20700 E$="N"
20710 REM DIMENSION VARIABLES
20720 GOSUB 20930
20730 REM INPUT NON MET PARAMETERS
20740 GOSUB 22750
20750 REM INPUT Z GRID AND MET MARAMETERS
20760 GOSUB 22950
20770 F$="@AEROSOL/PROGRAM/TASK2"
20780 GO TO 30060
20790 REM
20800 REM
20810 REM RECOVER FROM A SAVE THE WORLD
20820 GOSUB 20930
20830 OPEN "@AEROSOL4/PARAMETER/STORAGE";2,"F",A$
20840 OPEN "@AEROSOL4/OUTPUT";1,"F",A$
20850 READ #2:P,N1,K,H9,U9,Z,A1,C1,D1,SO,R8,V
20860 O1=N1
20870 F$="@AEROSOL/PROGRAM/TASK5"
20880 GO TO 30060
20890 REM
20900 REM ############## SUBROUTINES ########################
20910 REM
20920 REM==========SUBROUTINE DIMENSION===============================
20930 DIM U9(24),H9(24),SO(24)
20940 DIM K(24),Z(24),O1(24),R8(24),V(24)
20950 DIM N1(24),P(24),A1(24),D1(24),C1(24)
20960 RETURN
20970 REM
20980 REM============VERTICAL SPACING SUBROUTINE=====================
20990 REM
21000 Z(1)=1
21010 O1=1.0E-5
21020 FOR I=1 TO 23
21030 Z(I+1)=Z(I)+1.4^I+3.5
21040 O1(I+1)=1.0E-5
21050 NEXT I
21060 N1=O1
21070 IF E$<>"N" THEN 21100
21080 READ #3,144:N1
21090 O1=N1
21100 RETURN
21110 PRINT Z
21120 REM=====ROUTINE TO FILL THE INVERSION HEIGHT LIST===============
21130 REM
21140 PRINT "INPUT EXISTING INVERSION HEIGHT (METERS)";
21150 INPUT H8
21160 I9=1
21170 GOSUB 21270
21180 PRINT "ARE THERE FUTURE ESTIMATES OF INVERSION HEIGHTS (Y OR N)?";
21190 INPUT B$
21200 IF B$="Y" THEN 21220
21210 RETURN
21220 PRINT "INPUT RELATIVE HOUR AND INVERSION HEIGHT"
21230 INPUT I9,H8
21240 I9=INT(I9)
21250 GOSUB 21270
21260 GO TO 21180
21270 FOR I=I9 TO 24
```

```
21280 H9(I)=H8
21290 NEXT I
21300 RETURN
21310 REM
21320 REM=====SUBROUTINE TO FILL THE WIND SPEED LIST=================
21330 REM
21340 PRINT "INPUT EXISTING 10 METER WIND SPEED (M/S)"
21350 INPUT H8
21351 IF H8>0 THEN 21360
21352 H8=0.1
21360 I9=1
21370 GOSUB 21460
21380 PRINT "ARE THERE FUTURE ESTIMATES OF THE WIND SPEED (Y OR N)?"
21390 INPUT B$
21400 IF B$="N" THEN 21490
21410 PRINT "INPUT NEXT RELATIVE HOUR AND WIND SPEED"
21420 INPUT I9,H8
21421 IF H8>0 THEN 21430
21422 H8=0.1
21430 I9=INT(I9)
21440 GOSUB 21460
21450 GO TO 21380
21460 FOR I=I9 TO 24
21470 U9(I)=H8
21480 NEXT I
21490 RETURN
21500 REM
21510 REM================== SST INPUT SUBROUTINE======================
21520 REM
21530 PRINT
21540 PRINT "INPUT EXISTING SEA SURFACE TEMPERATURE VALUE (CENT)"
21550 INPUT X
21560 I9=1
21570 GOSUB 21660
21580 PRINT "ARE THERE FUTURE ESTIMATES OF THIS VALUE? (Y OR N)";
21590 INPUT B$
21600 IF B$="N" THEN 21650
21610 PRINT "INPUT RELATIVE HOUR AND DATA VALUE";
21620 INPUT I9,X
21630 GOSUB 21660
21640 GO TO 21580
21650 RETURN
21660 FOR I=I9 TO 24
21670 S0(I)=X
21680 NEXT I
21690 RETURN
21700 REM
21710 REM==============AIR TEMPERATURE INPUT SUBROUTINE================
21720 REM
21730 PRINT
21740 PRINT "INPUT EXISTING AIR TEMPERATURE VALUE (CENT)"
21750 INPUT X
21760 I9=1
21770 GOSUB 21860
21780 PRINT "ARE THERE FUTURE ESTIMATES OF THIS DATA? (Y OR N)",
21790 INPUT B$
21800 IF B$="N" THEN 21850
21810 PRINT "INPUT RELATIVE HOUR AND DATA VALUE";
21820 INPUT I9,X
```

```
21830 GOSUB 21860
21840 GO TO 21780
21850 RETURN
21860 FOR I=I9 TO 24
21870 A1(I)=X
21880 NEXT I
21890 RETURN
21900 REM
21910 REM============= DEWPOINT INPUT SUBROUTINE======================
21920 REM
21930 PRINT
21940 PRINT "INPUT EXISTING DEWPOINT TEMPERATURE VALUE (CENT)"
21950 INPUT X
21960 I9=1
21970 GOSUB 22060
21980 PRINT "ARE THERE FUTURE ESTIMATES OF THIS DATA? (Y OR N)";
21990 INPUT B$
22000 IF B$="N" THEN 22050
22010 PRINT "INPUT RELATIVE HOUR AND DATA VALUE";
22020 INPUT I9,X
22030 GOSUB 22060
22040 GO TO 21980
22050 RETURN
22060 FOR I=I9 TO 24
22070 D1(I)=X
22080 NEXT I
22090 RETURN
22100 REM
22110 REM ============== CLOUD COVER INPUT SUBROUTINE ==============
22120 REM
22130 PRINT
22140 PRINT "INPUT EXISTING CLOUDCOVER IN TENTHS"
22150 INPUT X
22160 I9=1
22170 GOSUB 22260
22180 PRINT "ARE THERE FUTURE ESTIMATES OF CLOUD COVER?"
22190 INPUT B$
22200 IF B$="N" THEN 22250
22210 PRINT "INPUT RELATIVE HOUR AND CLOUDCOVER VALUE"
22220 INPUT I9,X
22230 GOSUB 22260
22240 GO TO 22180
22250 RETURN
22260 FOR I=I9 TO 24
22270 C1(I)=X
22280 NEXT I
22290 RETURN
22300 REM
22310 REM ===SUBROUTINE TO SET UP NEW PARAMETER STORAGE ======
22320 REM
22330 CALL "FILE",1,"@AEROSOL4/PARAMETER/STORAGE",A$
22340 IF LEN(A$)=0 THEN 22420
22350 PRINT "OK TO DESTROY DATA ON @AEROSOL4/PARAMETER/STORAGE "
22360 PRINT "TYPE IN 'Y' OR 'N'";
22370 INPUT B$
22380 IF B$="N" THEN 22450
22390 KILL "@AEROSOL4/PARAMETER/STORAGE"
22400 CREATE "@AEROSOL4/PARAMETER/STORAGE";700,0
22410 REM REOPEN PARAMETER STORAGE
```

```
22420 OPEN "@AEROSOL4/PARAMETER/STORAGE";2,"F",A$
22430 PAGE
22440 PRINT A$
22450 RETURN
22460 REM
22470 REM ======SUBROUTINE TO SET UP NEW OUTPUT FILE ========
22480 REM
22490 CALL "FILE",1,"@AEROSOL4/OUTPUT",A$
22500 IF LEN(A$)=0 THEN 22550
22510 PRINT "OK TO DESTROY DATA ON @AEROSOL4/OUTPUT (Y OR N)?";
22520 INPUT B$
22530 IF B$="N" THEN 22590
22540 KILL "@AEROSOL4/OUTPUT"
22550 CREATE "@AEROSOL4/OUTPUT","U";240,250
22560 OPEN "@AEROSOL4/OUTPUT";1,"F",A$
22570 PAGE
22580 PRINT A$
22590 RETURN
22600 REM
22610 REM == SUBROUTINE TO INITIATE RANDOM DISC FILE #1 ======
22620 REM
22630 DIM D$(657)
22640 D$=""
22650 FOR I=1 TO 245
22660 D$=D$&" "
22670 NEXT I
22680 FOR I=1 TO 240
22690 WRITE #1,I:D$
22700 NEXT I
22710 RETURN
22720 REM
22730 REM =====SUBROUTINE TO INPUT NON MET PARAMETERS=========
22740 REM
22750 P(22)=1
22760 P(19)=0.1
22770 P(20)=1
22780 PRINT "AT WHAT LATITUDE IS THIS TAKING PLACE?"
22790 INPUT P(5)
22800 PRINT "ENTER THE DIAMETER OF THE DROPLETS IN MICRONS"
22810 INPUT P(1)
22820 PRINT "ENTER THE REFERENCE HUMIDITY OF DROPLET SIZE"
22830 INPUT P(2)
22840 IF P(2)<99.9 THEN 22860
22850 P(2)=99.9
22860 P(3)=P(1)*(1+0.9/(1-P(2)/100))^(-1/3)
22870 IF P(3)>90 THEN 22900
22880 IF P(3)<0.07 THEN 22900
22890 RETURN
22900 PRINT "DROPLET SIZE IS OUTSIDE OF MODEL LIMIT: TRY AGAIN"
22910 GO TO 22800
22920 REM
22930 REM ===== SUBROUTINE TO INPUT Z GRID AND MET PARAMETERS =====
22940 REM
22950 REM WORK OUT VERTICAL SPACING
22960 GOSUB 21000
22970 H9=0
22980 REM INPUT INVERSION HEIGHT
22990 GOSUB 21140
23000 REM
```

```
23010 REM INPUT WIND SPEED
23020 GOSUB 21340
23030 REM
23040 REM INPUT SEA SURFACE TEMPERATURE VALUES
23050 GOSUB 21530
23060 REM
23070 REM INPUT AIR TEMPERATURE VALUES
23080 GOSUB 21730
23090 REM
23100 REM INPUT DEWPOINT TEMPERATURE VALUES
23110 GOSUB 21930
23120 REM
23130 REM INPUT CLOUD COVER DATA
23140 GOSUB 22130
23150 RETURN
20000 REM
20010 REM  :------------------------------------------------------:
20020 REM  :   @AEROSOL/PROGRAM/TASK2                             :
20030 REM  :   S. GATHMAN   NRL CODE 4327                         :
20040 REM  :------------------------------------------------------:
20050 REM
20060 REM
20070 REM==ROUTINE TO UPDATE  THE METEOROLOGICAL TERMS OF P VECTOR==
20080 REM CALCULATE DRAG COEFFICIENT,C10 (ROLL FIG 41 P160)
20090 P(6)=0.0011+4.0E-5*U9(P(22))
20100 REM CALCULATE THE FRICTION VELOCITY,U* (M/SEC)(ROLL EQN 4.51)
20110 P(8)=U9(P(22))*SQR(P(6))
20120 REM CALCULATE ZZERO(M) [ROLL EQN 4.18]
20130 P(9)=0.00125*P(8)^2
20140 REM ROLL EQN 4.14
20150 REM CALCULATE BULK RICHARDSON'S NUMBER,RBI
20160 T=S0(P(22))
20170 GOSUB 21260
20180 V0=E
20190 T=D1(P(22))
20200 GOSUB 21260
20210 V1=E
20220 R0=V0*0.622*0.98/1013.25
20230 R=V1*0.622/1013.25
20240 T=(A1(P(22))+273)*(1+R/0.622)/(1+R)
20250 T0=(S0(P(22))+273)*(1+R0/0.622)/(1+R0)
20260 T=T*1.0098
20270 P(10)=(T-T0)*3.55/U9(P(22))^2
20280 REM
20290 REM CALCULATE THE Z/L PARAMETER AT 10 METERS BARKER&BAXTER(75)
20300 REM
20310 P(4)=LOG(10/P(9))/0.4
20320 IF P(4)=>10 THEN 20390
20330 RESTORE 20340
20340 DATA 0.07872,0.05532,0.006197,4.7,0.35
20350 READ C0,C2,C3,C4,C5
20360 P(7)=C5*P(4)*(P(10)-C0+SQR(C2*P(10)+C3))/(1+C4*P(10))
20370 P(7)=P(7)/10
20380 GO TO 20450
20390 P(7)=P(10)*(0.471*P(4)-1.045)
20400 IF P(7)>-0.05 THEN 20330
20410 REM
20420 REM UPDATE THE FRICTION MIXING RATIO,Q*
```

```
20430 REM REQUIRES P(6),P(22),S0,D1
20440 REM RESETS P(12)
20450 Z1=10
20460 T=D1(P(22))
20470 GOSUB 21360
20480 Q1=R5
20490 Z1=0
20500 T=S0(P(22))
20510 GOSUB 21360
20520 Q0=0.98*R5
20530 P(12)=SQR(P(6))*(Q1-Q0)/0.38
20540 REM
20550 REM UPDATE THE FRICTION POTENTIAL TEMPERATURE,THETA*
20560 REM
20570 REM REQUIRES P(6),P(22),S0,A1
20580 REM RESETS P(11)
20590 Z1=10
20600 T=A1(P(22))
20610 GOSUB 21430
20620 T1=T9
20630 Z1=0
20640 T=S0(P(22))
20650 GOSUB 21430
20660 P(11)=SQR(P(6))*(T1-T0)/0.38
20670 REM
20680 REM UPDATE THE HEIGHT OF SUPERADIOBATIC ZONE,ZSA
20690 REM REQUIRES P(22),S0,A1
20700 REM RESETS P(13)
20710 D=ABS(A1(P(22))-S0(P(22)))
20720 IF D>0.5 THEN 20750
20730 P(13)=10*D
20740 GO TO 20810
20750 P(13)=11.92+9.69*LOG(D)
20760 REM
20770 REM UPDATE THE HEIGHT OF THE CONDENSATION LAYER
20780 REM REQUIRES ZSA(P(13)),AND POTENTIAL TEMP
20790 REM AND MIXING RATIO AT TOP OF SUPERADIOBATIC ZONE
20800 REM RESETS P(14)
20810 Z1=P(13)
20820 GOSUB 21650
20830 Z1=P(13)
20840 GOSUB 21760
20850 T=T7
20860 R=Q7
20870 Z1=P(13)
20880 GOSUB 21500
20885 T6=T6+273.15
20890 GOSUB 21580
20900 X=EXP(LOG(T6)/0.286)
20910 X1=732.02-150.41*(LGT(X)-LGT(V6))
20920 X1=X1+7.21*(LGT(X)-LGT(V6))^2
20930 X1=X1+273.15
20935 T7=T7+273.15
20940 P1=1000*EXP(-LOG(T7/X1)/0.286)
20950 GOSUB 21050
20960 P(14)=A
20961 IF A>0.3*H9(P(22)) THEN 20970
20962 P(14)=H9(P(22))
20970 F$="@AEROSOL/PROGRAM/TASK3"
```

```
20980 GO TO 30060
20990 REM################### SUBROUTINES ##########################
21000 REM
21010 REM
21020 REM ****************  ALT(P1)=A  *****************************
21030 REM
21040 REM INPUT P(MB) : OUTPUT A(METERS)
21050 IF P1<=1013 THEN 21080
21060 A=0
21070 RETURN
21080 IF P1<=958 THEN 21110
21090 A=9.09*(1013-P1)
21100 RETURN
21110 A=7850*LOG(1021.38/P1)
21120 RETURN
21130 REM
21140 REM  ***************  PRESSURE @(Z=A)  ***************************
21150 REM
21160 REM INPUT A(METERS) : OUTPUT P1(MB)
21170 IF A<500 THEN 21200
21180 P1=1021.38*EXP(-1.2739E-4*A)
21190 RETURN
21200 P1=1013-55*A/500
21210 RETURN
21220 REM
21230 REM  **************  E=VAPPR(T)  *************************
21240 REM
21250 REM INPUT T(DEGREES C) : OUTPUT E(MB)
21260 T1=1-373.25/(T+273.25)
21270 RESTORE 21280
21280 DATA 1013.25,13.3185,1.976,0.6445,0.1299
21290 READ R0,R1,R2,R3,R4
21300 E=R0*EXP(R1*T1-R2*T1^2-R3*T1^3-R4*T1^4)
21310 RETURN
21320 REM
21330 REM  **********  R5=SMIXR(Z1,T)  *************************
21340 REM
21350 REM INPUT Z1 (METERS) ,T(DEGREES C) : OUTPUT R5 (GM/KG)
21360 GOSUB 21260
21365 A=Z1
21370 GOSUB 21170
21380 R5=0.622*E/(P1-E)
21390 RETURN
21400 REM
21410 REM  *** CONVERTS TEMP TO POTENTIAL TEMP @ ALT Z1  **********
21420 REM INPUT T(DEGREES C),Z1(METERS) :OUTPUT POTENTIAL TEMP T(DEG C)
21430 GOSUB 21170
21440 T9=(T+273.15)*EXP(0.286*LOG(1000/P1))
21450 RETURN
21460 REM
21470 REM  *** CONVERTS POTENTIAL TEMP @ ALT Z1 TO TEMPERATURE ****
21480 REM
21490 REM INPUT T(DEG C) & Z1(METERS): OUTPUT T6(DEG C)
21500 GOSUB 21170
21510 T6=(T+273.15)/EXP(0.286*LOG(1000/P1))
21520 T6=T6-273.15
21530 RETURN
21540 REM
21550 REM  ******CONVERTS MIXING RATIO @ ALT Z1 TO VAPOR PRESSURE
```

```
21560 REM
21570 REM INPUT R(G/KG) &Z1(METERS) :OUTPUT V6(MB)
21580 GOSUB 21170
21590 V6=P1*R/(0.622+R)
21600 RETURN
21610 REM
21620 REM ****** CALCULATION OF MIXING RATIO IN SUPERADIOBATIC ZONE **
21630 REM
21640 REM INPUT Z1,S0,P(22),P(12),P(9),P(7): OUTPUTS Q7
21650 X=(Z1+P(9))/P(9)
21660 Z1=0
21670 T=S0(P(22))
21680 GOSUB 21360
21690 Q0=0.98*R5
21700 Q7=Q0+P(12)*(LOG(X)+4.8*P(7))
21710 RETURN
21720 REM
21730 REM SUBROUTINE TO CALCULATE POT. TEMP IN SUPERADIOBATIC ZONE
21740 REM
21750 REM INPUT Z1,A1,P(9),P(22),P(11),P(7): OUTPUT T7
21760 X=(Z1+P(9))/P(9)
21770 Z1=0
21780 T=A1(P(22))
21790 GOSUB 21500
21800 T7=T6+P(11)*(LOG(X)+4.8*P(7))
21810 RETURN

20000 REM
20010 REM  |---------------------------------------------------------|
20020 REM  |  @AEROSOL/PROGRAM/TASK3                                 |
20030 REM  |  AFTER NRL REPORT 8279 : S.GATHMAN                      |
20040 REM  |---------------------------------------------------------|
20050 REM
20060 REM == ROUTINE TO CALCULATE REL HUM PROFILE FROM P VALUES ==
20070 REM
20080 IF P(7)>0.1 THEN 20120
20090 IF P(7)<-0.1 THEN 20140
20100 IF C1(P(22))>2.5 THEN 21390
20110 GO TO 21690
20120 IF C1(P(22))>1 THEN 20200
20130 GO TO 20790
20140 IF C1(P(22))>2.5 THEN 22370
20150 GO TO 22630
20160 REM
20170 REM-----------------------------------------------------------
20180 REM
20190 REM CASE 1 (STABLE WITH C/C > 10%)
20200 FOR I=1 TO 24
20210 IF Z(I)>20 THEN 20490
20220 REM FOR ALTITUDES BELOW 20 METERS
20230 Z1=0
20240 T=S0(P(22))
20250 GOSUB 23600
20260 T0=T9
20270 Z1=20
20280 T=A1(P(22))
20290 GOSUB 23600
20300 T1=T9
20310 T7=T0+Z(I)*(T1-T0)/20
```

```
20320 T=D1(P(22))
20330 GOSUB 23420
20340 A=20
20350 GOSUB 23330
20360 R6=622*E/(P1-E)
20380 T=S0(P(22))
20390 GOSUB 23420
20400 E=0.98*E
20410 A=0
20420 GOSUB 23330
20430 R0=622*E/(P1-E)
20440 Q7=R0+Z(I)*(R6-R0)/20
20450 Z1=Z(I)
20470 GOSUB 24100
20480 GO TO 20730
20490 IF Z(I)>H9(P(22)) THEN 20720
20500 REM BELOW STRATUS CLOUD
20510 Z1=20
20520 T=A1(P(22))
20530 GOSUB 23600
20540 T7=T9+2*(Z(I)-20)/(H9(P(22))-20)
20550 T=D1(P(22))
20560 Z1=20
20570 GOSUB 23520
20590 Q0=R5*1000
20600 T=T9+2
20610 Z1=H9(P(22))
20620 GOSUB 23690
20630 T=T6
20640 Z1=H9(P(22))
20650 GOSUB 23520
20660 Q1=R5*1000
20670 Q7=Q0+(Z(I)-20)*(Q1-Q0)/(H9(P(22))-20)
20680 Z1=Z(I)
20700 GOSUB 24100
20710 GO TO 20730
20720 R8(I)=100
20730 NEXT I
20740 GO TO 23140
20750 REM
20760 REM---------------------------------------------------------
20770 REM
20780 REM CASE 2 (STABLE WITH C/C < 10%)
20790 FOR I=1 TO 24
20800 IF Z(I)>20 THEN 21060
20810 REM FOR ALTITUDES BELOW 20 M
20820 Z1=0
20830 T=S0(P(22))
20840 GOSUB 23600
20850 T0=T9
20860 Z1=20
20870 T=A1(P(22))
20880 GOSUB 23600
20890 T1=T9
20900 T7=T0+Z(I)*(T1-T0)/20
20910 T=D1(P(22))
20920 GOSUB 23420
20930 A=20
20940 GOSUB 23330
```

```
20950 R6=622*E/(P1-E)
20960 T=S0(P(22))
20970 GOSUB 23420
20980 E=0.98*E
20990 A=0
21000 GOSUB 23330
21010 R0=622*E/(P1-E)
21020 Q7=R0+Z(I)*(R6-R0)/20
21030 Z1=Z(I)
21040 GOSUB 24100
21050 GO TO 21330
21060 IF Z(I)>H9(P(22)) THEN 21190
21070 REM FOR ALTITUDES BELOW INVERSION LEVEL
21080 Z1=20
21090 T=A1(P(22))
21100 GOSUB 23600
21110 T7=T9+2*(Z(I)-20)/(H9(P(22))-20)
21120 T=D1(P(22))
21130 Z1=20
21140 GOSUB 23520
21150 Q7=R5*1000
21160 Z1=Z(I)
21170 GOSUB 24100
21180 GO TO 21330
21190 IF Z(I)>H9(P(22))+500 THEN 21320
21200 REM ALTITUDES IN 500 M LAYER ABOVE INVERSION.BASE
21210 Z1=20
21220 T=A1(P(22))
21230 GOSUB 23600
21240 T7=T9+2+3*(Z(I)-H9(P(22)))/500
21250 T=D1(P(22))
21260 Z1=20
21270 GOSUB 23520
21280 Q7=R5*1000
21290 Z1=Z(I)
21300 GOSUB 24100
21310 GO TO 21330
21320 R8(I)=78
21330 NEXT I
21340 GO TO 23140
21350 REM
21360 REM------------------------------------------------------------
21370 REM
21380 REM CASE 3  (NEUTRAL WITH C/C > 25%)
21390 FOR I=1 TO 24
21400 IF Z(I)>20 THEN 21500
21410 REM FOR ALTITUDES BELOW 20 METERS
21420 T=D1(P(22))
21430 GOSUB 23420
21440 E1=E
21450 T=A1(P(22))
21460 GOSUB 23420
21470 R1=100*E1/E
21480 R8(I)=98+(R1-98)*Z(I)/20
21490 GO TO 21660
21500 IF Z(I)>P(14) THEN 21650
21510 REM FOR ALTITUDES BELOW ZCON
21520 T=D1(P(22))
21530 GOSUB 23420
```

```
21540 Z1=20
21550 GOSUB 23330
21560 Q7=0.622*E/(P1-E)
21570 T=SO(P(22))
21580 Z1=0
21590 GOSUB 23600
21600 T7=SO(P(22))
21610 Z1=Z(I)
21620 Q7=1000*Q7
21630 GOSUB 24100
21640 GO TO 21660
21650 R8(I)=100
21660 NEXT I
21670 GO TO 23140
21680 REM CASE 4 (NEUTRAL WITH C/C<25%)
21690 FOR I=1 TO 24
21700 IF Z(I)>20 THEN 21800
21710 REM FOR ALTITUDES BELOW 20 METERS
21720 T=D1(P(22))
21730 GOSUB 23420
21740 E1=E
21750 T=A1(P(22))
21760 GOSUB 23420
21770 R1=100*E1/E
21780 R8(I)=98+(R1-98)*Z(I)/20
21790 GO TO 22310
21800 IF Z(I)>0.8*P(14) THEN 21960
21810 REM FOR ALTITUDES IN HOMOGENEOUS LAYER
21820 T=D1(P(22))
21830 GOSUB 23420
21840 Z1=20
21850 GOSUB 23330
21860 Q7=0.622*E/(P1-E)
21870 T=SO(P(22))
21880 Z1=0
21890 GOSUB 23600
21900 T7=T9
21910 T7=SO(P(22))
21920 Z1=Z(I)
21930 Q7=Q7*1000
21940 GOSUB 24090
21950 GO TO 22310
21960 IF Z(I)>P(14) THEN 22300
21970 REM FOR ALTITUDES IN THE TRANSITION ZONE
21980 Z5=Z(I)-P(14)*0.8
21990 Z1=0
22000 T=SO(P(22))
22010 GOSUB 23600
22020 Z1=0.8*P(14)
22030 T=T9
22040 GOSUB 23690
22050 T=T6+0.006*Z5
22060 Z1=Z(I)
22070 GOSUB 23600
22080 T7=T9
22090 REM FIND MIXING RATIO AT ZCON
22100 Z1=P(14)
22110 T=T6+0.006*0.2*P(14)
22120 GOSUB 23600
```

```
22130 T=T9
22140 GOSUB 23420
22150 V1=0.78*E
22160 Z1=P(14)
22170 GOSUB 23330
22180 M9=0.622*V1/(P1-V1)
22190 REM FIND MIXING RATIO AT  8*ZCON
22200 T=D1(P(22))
22210 GOSUB 23420
22220 Z1=20
22230 GOSUB 23330
22240 M8=0.622*E/(P1-E)
22250 X=M8+(M9-M8)*(Z(I)-0.8*P(14))/(0.2*P(14))
22260 Q7=X*1000
22270 Z1=Z(I)
22280 GOSUB 24100
22290 GO TO 22310
22300 R8(I)=78
22310 NEXT I
22320 GO TO 23140
22330 REM
22340 REM------------------------------------------------------------
22350 REM
22360 REM CASE 5   (UNSTABLE WITH C/C > 25%)
22370 FOR I=1 TO 24
22380 IF Z(I)>P(13) THEN 22470
22390 REM FOR SUPERADIOBADIC LAYER
22400 Z1=Z(I)
22410 GOSUB 23850
22420 Z1=Z(I)
22430 GOSUB 23960
22440 Z1=Z(I)
22450 GOSUB 24100
22460 GO TO 22570
22470 IF Z(I)>P(14) THEN 22560
22480 REM FOR ALTITUDES BETWEEN ZSA AND ZCON
22490 Z1=P(13)
22500 GOSUB 23850
22510 Z1=P(13)
22520 GOSUB 23960
22530 Z1=Z(I)
22540 GOSUB 24100
22550 GO TO 22570
22560 R8(I)=100
22570 NEXT I
22580 GO TO 23140
22590 REM
22600 REM------------------------------------------------------------
22610 REM
22620 REM ** CASE 6 (UNSTABLE ATMOSPHERE WITH C/C < 25%)
22630 FOR I=1 TO 24
22640 IF Z(I)>P(13) THEN 22730
22650 REM FOR ALTITUDES < ZSA
22660 Z1=Z(I)
22670 GOSUB 23850
22680 Z1=Z(I)
22690 GOSUB 23960
22700 Z1=Z(I)
22710 GOSUB 24100
```

```
22720 GO TO 23130
22730 IF Z(I)>0.8*P(14) THEN 22820
22740 REM FOR ALTITUDES IN HOMOGENEOUS ZONE
22750 Z1=P(13)
22760 GOSUB 23850
22770 Z1=P(13)
22780 GOSUB 23960
22790 Z1=Z(I)
22800 GOSUB 24100
22810 GO TO 23130
22820 IF Z(I)>P(14) THEN 23120
22830 REM FOR ALTITUDES IN TRANSITION ZONE
22840 Z5=Z(I)-P(14)*0.8
22850 Z1=P(13)
22860 GOSUB 23960
22870 Z1=P(14)*0.8
22880 T=T7
22890 GOSUB 23690
22900 T=T6+0.006*Z5
22910 Z1=Z(I)
22920 GOSUB 23600
22930 T7=T9
22940 REM FIND MIXING RATIO AT Z(I)
22950 Z1=P(14)
22960 T=T6+0.006*0.2*P(14)
22970 GOSUB 23600
22980 T=T9
22990 GOSUB 23420
23000 V1=0.78*E
23010 A=P(14)
23020 GOSUB 23330
23030 R9=622*V1/(P1-V1)
23040 Z1=P(13)
23050 GOSUB 23850
23060 X=Q7+(R9-Q7)*(Z(I)-0.8*P(14))/(0.2*P(14))
23070 Q7=X
23080 Z1=Z(I)
23090 GOSUB 24100
23100 GO TO 23130
23110 REM CLOUDLESS CLOUD LAYER
23120 R8(I)=78
23130 NEXT I
23140 F$="@AEROSOL/PROGRAM/TASK4"
23150 GO TO 30060
23160 REM ################## SUBROUTINES ################################
23170 REM
23180 REM ****************  ALT(P1)=A  ****************************
23190 REM
23200 REM INPUT P(MB) : OUTPUT A(METERS)
23210 IF P1<=1013 THEN 23240
23220 A=0
23230 RETURN
23240 IF P1<=958 THEN 23270
23250 A=9.09*(1013-P1)
23260 RETURN
23270 A=7850*LOG(1021.38/P1)
23280 RETURN
23290 REM
23300 REM  ***************  PRESSURE @(Z=A)  ***************************
```

```
23310 REM
23320 REM INPUT A(METERS) : OUTPUT P1(MB)
23330 IF A<500 THEN 23360
23340 P1=1021.38*EXP(-1.2739E-4*A)
23350 RETURN
23360 P1=1013-55*A/500
23370 RETURN
23380 REM
23390 REM  **************  E=VAPPR(T)  ************************
23400 REM
23410 REM INPUT T(DEGREES C) :OUTPUT E(MB)
23420 T1=1-373.25/(T+273.15)
23430 RESTORE 23440
23440 DATA 1013.25,13.3185,1.976,0.6445,0.1299
23450 READ R0,R1,R2,R3,R4
23460 E=R0*EXP(R1*T1-R2*T1^2-R3*T1^3-R4*T1^4)
23470 RETURN
23480 REM
23490 REM  **********  R5=SMIXR(Z1,T)  ************************
23500 REM
23510 REM INPUT Z1 (METERS) ,T(DEGREES C) :OUTPUT R5 (GM/GM)
23520 GOSUB 23420
23530 A=Z1
23540 GOSUB 23330
23550 R5=0.622*E/(P1-E)
23560 RETURN
23570 REM
23580 REM  *** CONVERTS TEMP TO POTENTIAL TEMP @ ALT Z1  **********
23590 REM INPUT T(DEGREES C),Z1(METERS) :OUTPUT POTENTIAL TEMP T(DEG C)
23600 A=Z1
23610 GOSUB 23330
23620 T9=(T+273.15)*EXP(0.286*LOG(1000/P1))
23630 T9=T9-273.15
23640 RETURN
23650 REM
23660 REM  *** CONVERTS POTENTIAL TEMP @ ALT Z1 TO TEMPERATURE ****
23670 REM
23680 REM INPUT T(DEG C) & Z1(METERS): OUTPUT T6(DEG C)
23690 A=Z1
23700 GOSUB 23330
23710 T6=(T+273.15)/EXP(0.286*LOG(1000/P1))
23720 T6=T6-273.15
23730 RETURN
23740 REM
23750 REM  ******CONVERTS MIXING RATIO @ ALT Z1 TO VAPOR PRESSURE
23760 REM
23770 REM INPUT R(G/KG) &Z1(METERS) :OUTPUT V6(MB)
23780 GOSUB 23330
23790 V6=P1*R/(622+R)
23800 RETURN
23810 REM
23820 REM SUBROUTINE TO CALCULATE MIXING RATIO IN SUPERADIOBATIC ZONE
23830 REM
23840 REM INPUT Z1,S0,P(22),P(12),P(9),P(7): OUTPUTS Q7
23850 X=(Z1+P(9))/P(9)
23860 Z1=0
23870 T=S0(P(22))
23880 GOSUB 23520
```

```
23890 Q0=980*R5
23900 Q7=Q0+P(12)*1000*(LOG(X)+4.8*P(7))
23910 RETURN
23920 REM
23930 REM SUBROUTINE TO CALCULATE POT. TEMP IN SUPERADIOBATIC ZONE
23940 REM
23950 REM INPUT Z1,A1,P(9),P(22),P(11),P(7): OUTPUT T7
23960 X=(Z1+P(9))/P(9)
23970 Z1=0
23980 T=A1(P(22))
23990 GOSUB 23690
24000 T7=T6+P(11)*(LOG(X)+4.8*P(7))
24010 RETURN
24020 REM
24030 REM SUBROUTINE TO CALCULATE RELATIVE HUMIDITY FROM
24040 REM INPUTS OF POTENTIAL TEMPERATURE (DEG C), ALT (METERS)
24050 REM AND MIXING RATIO (G/KG) AND TO OUTPUT THIS
24060 REM INFORMATION IN PERCENT IN VARIABLE R8(I)
24070 REM
24080 REM INPUTS I,T7,Q7,Z1
24090 REM OUTPUTS R8(I)
24100 T=T7
24110 GOSUB 23690
24120 R=Q7
24130 GOSUB 23780
24140 T=T6
24150 GOSUB 23420
24160 R8(I)=100*V6/E
24170 IF R8(I)<=100 THEN 24190
24180 R8(I)=100
24190 RETURN

20000 REM
20010 REM  |---------------------------------------------------|
20020 REM  |   @AEROSOL/PROGRAM/TASK4                          |
20030 REM  |   S. GATHMAN NRL CODE 4327                        |
20040 REM  |---------------------------------------------------|
20050 REM
20060 REM CALCULATE K PROFILE FROM SURFACE METEOROLOGY DATA
20070 REM K1=K(1) & K3=K'(1)
20071 P7=0.1*P(7)
20072 IF P(10)<1/4.7 THEN 20080
20073 K=0
20074 GO TO 20450
20080 IF P(7)<=0 THEN 20180
20090 REM
20100 REM----------------------STABLE CASE-------------
20110 REM
20120 K1=0.35*P(8)/(0.74+4.7*P7)
20130 K3=0.43*P(8)*P7/(0.74+4.7*P7)^2
20140 GO TO 20210
20150 REM
20160 REM--------------------- UNSTABLE CASE -----------------
20170 REM
20180 K1=0.47*P(8)*SQR(1-9*P7)
20190 K3=K1-2.13*P(8)*P7/SQR(1-9*P7)
20200 REM CALCULATE THE K PROFILE
20210 H8=H9(P(22))
20220 IF P7<=0 THEN 20250
```

```
20230 SET DEGREES
20240 H8=0.23*P(8)/(2*7.29211E-5*SIN(P(5)))
20250 K9=0
20260 F=K3+2*K1/(H8-Z(1))
20270 F=F/(H8-Z(1))^2
20280 G=K1/(H8-Z(1))^2
20290 D=0
20300 K=0
20310 A=G-F*(2*H8+Z(1))
20320 B=F*H8^2-2*H8*(G-F*Z(1))
20330 FOR I=1 TO 24
20340 IF Z(I)<=H8 THEN 20370
20350 K(I)=0
20360 GO TO 20380
20370 K(I)=F*Z(I)^3+A*Z(I)^2+B*Z(I)+H8^2*(G-F*Z(1))
20380 NEXT I
20390 REM-----------------------------------------------
20400 REM CALCULATE THE FALL VELOCITY PROFILE VECTOR
20410 REM
20420 REM INPUT R8, THE RELATIVE HUMIDITY PROFILE VECTOR
20430 REM INPUT P(3), THE DRY DROPLET DIAMETER
20440 REM OUTPUT V9, THE FALL VELOCITY PROFILE VECTOR
20450 FOR I=1 TO 24
20460 IF R8(I)<99.9 THEN 20480
20470 R8(I)=99.9
20480 D9=P(3)*(1+0.9/(1-R8(I)/100))^(1/3)
20490 V(I)=3.0E-5*(1+0.166/D9)*D9^2
20500 NEXT I
20510 REM
20520 REM ROUTINE TO CALCULATE THE FLUX OF AEROSOL FROM THE SURFACE INTO
20530 REM THE ATMOSPHERE AFTER BLANCHARD (1963)
20540 REM
20550 REM FIND THE DROPLET DIAMETER AT 91.4% RH
20560 D9=P(3)*(1+0.9/(1-0.914))^(1/3)
20570 W=U9(P(22))*1.9438
20580 IF W<4.5 THEN 20700
20590 C2=-13.3+8.966*LOG(W)
20610 C2=C2/1000
20620 C3=14.301-0.386*W
20630 C3=-C3/10
20640 C4=1.764+0.191*W
20650 F=C2*EXP(C3*LOG(C4/(0.5*D9))^2)
20660 F=1737.178*F/D9
20680 P(15)=F
20690 GO TO 20705
20700 P(15)=0
20705 GOSUB 20740
20710 F$="@AEROSOL/PROGRAM/TASK5"
20720 GO TO 30060
20730 REM ROUTINE TO FIND THE MAX TIME STEP ALLOWED
20740 P(19)=60 MIN 1/(1.0E-5+K(1))
20750 FOR I=1 TO 23
20760 Z1=Z(I+1)-Z(I)
20770 Z2=Z1^2
20780 K1=(K(I)+K(I+1))/2+1.0E-3
20790 T9=Z2/(2*K1)
20800 P(19)=P(19) MIN T9
20810 NEXT I
```

```
20820 P(19)=P(19)-0.1
20830 RETURN
20000 REM
20010 REM  |-----------------------------------------------------|
20020 REM  :  @AEROSOL/PROGRAM/TASK5                             :
20030 REM  :  S. GATHMAN NRL CODE 4327                           :
20040 REM  |-----------------------------------------------------|
20050 REM
20060 SET KEY
20070 REM
20080 REM GO TO PARTIAL DIFFERENTIAL ANALYSER
20090 GOSUB 20660
20100 REM
20110 REM
20120 REM GO TO CLOCK UPDATE SUBROUTINE
20130 GOSUB 20940
20140 REM
20150 REM GO TO STORAGE ROUTINE
20160 GOSUB 21170
20170 REM
20180 REM PARAMETER UP DATE ROUTINE
20190 IF P(17)=0 THEN 20240
20200 P(17)=0
20210 F$="@AEROSOL/PROGRAM/TASK2"
20220 SET NOKEY
20230 GO TO 30060
20240 GO TO P(20) OF 20090,20310,20360,20490,20580
20250 END
20260 REM
20270 REM*************************************************************
20280 REM *****************KEYBOARD SERVICE ROUTINES*****************
20290 REM ***********************************************************
20300 REM PRINT MODEL TIME (SEC)
20310 PRINT P(24)
20320 P(20)=1
20330 GO TO 20090
20340 REM
20350 REM PLOT N1
20360 PAGE
20370 N9=-1.0E+24
20380 FOR I=1 TO 24
20390 N9=N9 MAX N1(I)
20400 NEXT I
20410 WINDOW 0,N9,0,Z(20)
20420 AXIS
20430 MOVE N1(1),Z(1)
20440 DRAW N1,Z
20450 P(20)=1
20460 GO TO 20090
20470 REM
20480 REM PRINT N1
20490 PAGE
20500 PRINT "ALT(M)","#/M^3","K(Z)"
20510 FOR I=24 TO 1 STEP -1
20520 PRINT Z(I),N1(I),K(I)
20530 NEXT I
20540 P(20)=1
```

```
20550 GO TO 20090
20560 REM
20570 REM SAVE THE WORLD ROUTINE
20580 CALL "REWIND",2
20590 P(20)=1
20600 WRITE #2:P,N1,K,H9,U9,Z,A1,C1,D1,S0,R8,V
20610 INIT
20620 END
20660 REM
20670 REM========PARTIAL DIFFERENTIAL EQUATION ANALYSER================
20680 REM
20690 T1=P(19)
20700 H=P(22)
20710 S6=Z(2)-Z(1)
20720 S7=(Z(3)-Z(1))/2
20730 S1=-(O1(2)-O1(1))/S7
20740 N1(1)=O1(1)+T1*(P(15)-K(2)*S1)/S6
20750 N1(1)=N1(1)+V(1)*T1*(O1(2)-O1(1))/S6
20760 FOR I=2 TO 22
20770 S7=Z(I+1)-Z(I)
20780 S8=(Z(I+2)-Z(I))/2
20790 S9=(Z(I+1)-Z(I-1))/2
20800 S1=-(O1(I+1)-O1(I))
20810 R1=-(O1(I)-O1(I-1))
20820 N1(I)=O1(I)+T1*(K(I)*R1/S9-K(I+1)*S1/S8)/S7
20830 N1(I)=N1(I)-V(I)*T1*S1/S7
20840 NEXT I
20850 FOR I=1 TO 24
20860 IF N1(I)=>0 THEN 20880
20870 N1(I)=0
20880 NEXT I
20890 O1=N1
20900 RETURN
20910 REM
20920 REM===============CLOCK UPDATE SUBROUTINE=======================
20930 REM
20940 P(24)=P(24)+P(19)
20950 P(23)=P(23)+P(19)
20960 IF P(23)<600 THEN 21010
20970 P(23)=0
20980 P(21)=1
20990 P(18)=P(18)+1
21010 P(16)=P(16)+P(19)
21020 IF P(16)<3600 THEN 21110
21025 P(22)=P(22)+1
21030 P(16)=0
21040 P(17)=1
21110 IF P(18)<144 THEN 21130
21120 P(20)=5
21130 RETURN
21140 REM
21150 REM==============STORAGE SUBROUTINE==============================
21160 REM
21170 IF P(21)=0 THEN 21200
21180 P(21)=0
21190 WRITE #1,P(18),N1
21200 RETURN
```

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