THE ROSCOE MANUAL
Volume 8—Flow Fields Around Rising Fireballs

Mission Research Corporation
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A model is presented here to give the detailed position-time history of a parcel of fluid flowing around a rising spherical fireball vortex. The model is based on the assumption of steady incompressible, irrotational flow around the spherical vortex. The model has been coded for use in large systems type codes. The technique used is based on interpolation from a solution table. Included is the Fortran coding and typical output.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>I</th>
<th>Introduction</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Mathematical Method</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>(A) Flow Field Calculation</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>(B) Shock Displacement Calculations</td>
<td>15</td>
</tr>
<tr>
<td>III</td>
<td>Coding Consideration for Flow Field Calculation</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>(A) Control of Calculation by Subprogram HYDRO</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>(B) Criteria for Editing Fireballs</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>(C) Single Burst Case</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>(D) Multiple Burst Case</td>
<td>19</td>
</tr>
<tr>
<td>IV</td>
<td>Description of Subprograms</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>(A) Description of Code HYDRO</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Inputs</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Outputs</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Glossary</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Flow Chart of HYDRO</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>(B) Description of Code EDITX</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Inputs</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Outputs</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Glossary</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>(C) Description of Code SYZYGY</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Inputs</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Outputs</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Glossary</td>
<td>32</td>
</tr>
</tbody>
</table>
(D) Description of Code CIPHER 33
   Inputs 33
   Outputs 33
   Glossary 35

(E) Description of Code SCHCK 36
   Inputs 36
   Outputs 36
   Glossary 37

(F) Variables Generated by Model, Used by HYDRO 38

V  Listing of Subprograms 40
VI Typical Output 59
VII Bibliography 71
SECTION 1

INTRODUCTION

Hydrodynamics has in recent years given impressive results in the solution of flow field problems by making simplified assumptions of steady flow relative to a moving body. This aspect has appeared in many physics codes attempting to solve the problem of the rising fireball. However, because of computing considerations, flow fields have generally been ignored in large system codes such as RANC and others. This has meant errors in energy deposition and a resulting ghost fireball problem.

A solution to these problems for system codes is presented here. By modeling the hydrodynamic flow using the simplified assumption of steady flow, the detailed particle motion can be specified in the flow field.

This model is a result of advances that have been made in the understanding of fluid particle movement by studying the deformation of "drift" of material surfaces. Sir Charles Darwin (1953) has drawn important conclusions about the movements of individual particles in irrotational flow of fluid around hard objects. Darwin considered an infinitely thin plane of fluid at right angles to the motion of the sphere and asked what the final displacement of the plane was after the passage of the sphere. This final displacement is the total drift function.

Darwin's method has been used to calculate the position-time history of the particles of fluid as they move around a rising fireball.
To solve the rising fireball problem, it is assumed that the fluid is incompressible and the flow is irrotational, that the fireball at any instant is a perfect sphere with no entrainment. This reduces the problem of finding the velocities anywhere in the field outside the fireball to one of taking the gradient of a velocity-potential for an incompressible fluid, the motion is steady; thus the fluid does not cross streamlines.

The velocity-potential $\phi$ can be found from Laplace's equation with the boundary condition of no radial velocities at the surface of the sphere and zero velocity at infinity for a fluid moving around the sphere. The velocities and positions are found for a coordinate system fixed with the sphere. A Galilean transformation then gives the position in a frame fixed with the fluid.
SECTION 2
MATHEMATICAL METHOD

FLOW FIELD CALCULATION

Consider an infinite thin plane of fluid at right angles to the motion of the fireball vortex. It can be asked, what is the final shape of the marked fluid plane after the fireball has passed through it. It is to be expected that the part of the plane nearest the spheroidal fireball is moved the greatest distance. The fluid contained between the initial plane position and its final position equals the "hydrodynamic mass" or "virtual" mass associated with the body's motion.

To solve the problem of what happens to the displaced fluid particles requires that the streamlines be determined and also the time at which each fluid particle reaches a given point measured from some fixed reference time for the particles—in this case when it passes the plane at right angles to the center of the spheroid had it been an undisturbed region.

In a coordinate system fixed with the fireball, with \( z \) parallel to the direction of the flow and the reference point defined as \( z = 0 \), then we require solution of the equations

\[
\frac{dt}{v_x} = \frac{dy}{v_y} = \frac{dz}{v_z} \quad (1)
\]
with
\[ t - z/u \to 0 \quad \text{as} \quad z \to -\infty \]
where \( v_z \) is the \( z \) velocity and an undisturbed stream flow has the value
\[ v_z = u, \quad v_x = v_y = 0. \]
The velocities \( v_x, v_y, \) and \( v_z \) are found from
\[ v_x = -\frac{\partial \phi}{\partial x}, \quad v_y = -\frac{\partial \phi}{\partial y}, \quad v_z = -\frac{\partial \phi}{\partial z} \]
where \( \phi \) is the velocity-potential solution of Laplace's equation.

This definition implies that far upstream material planes at right angles to the stream are planes of \( t = \text{constant} \). This is the classical "drift function" discussed by Darwin (1953).

Consider flow past a spherical fireball vortex in which the velocity field far upstream from the obstacle is defined as
\[ v_z = V(x, y) \quad v_y = v_x = 0. \quad (2) \]
The stream lines of the flow can be represented by equations of the form
\[ x = x(x_0, y_0, z) \quad y = y(x_0, y_0, z) \quad (3) \]
where
\[ x_0 = \lim_{z \to -\infty} (x), \quad y_0 = \lim_{z \to -\infty} (y). \quad (4) \]
These are solutions of Equation 1. The solution for the variable \( t \) is

\[
t = t(x_0, y_0, z) = \frac{z}{u} + \int_{-\infty}^{z} \left\{ \frac{1}{v_z(x_0, y_0, z)} - \frac{1}{u} \right\} \, dz \quad (5)
\]

where \( v_z \) is the \( z \) component of the velocity on the stream line given by Equation 3, and \( u \) is the undisturbed fluid velocity.

Given a point in the flow field outside of a sphere, the drift function can now be determined.

The drift function \( t' \) at a burst time \( T' \) can be found by subtracting the actual time difference \( \Delta T \) between the calculation time \( T \) and the burst time \( T' \). Once the new drift function \( t' \) is known, a new position can be found from it.

Using polar spherical coordinates \( r, \theta, \phi \) fixed at the center of the sphere, the Stokes stream function, LAMB (1932), is given for unit upward velocity as

\[
\rho_0^2 = r^2 \sin^2 \theta (1 - a^3/r^3) \quad (5a)
\]

where \( a \) is the radius of the sphere, \( \psi \) is equal to zero. It should be noted that \( \rho_0 \to x \) as \( x \to \infty \).

The solution for the drift function \( t \) can be obtained from either of the coupled ordinary differential equations

\[
dt = \frac{dr}{v} = \frac{dr}{u \left(1 - \frac{a^3}{r^3}\right) \cos \theta} \quad (6)
\]
and

$$\frac{dt}{v_\theta} = \frac{rd\theta}{u(1 + \frac{a^3}{r^3})\sin\theta}$$  \hspace{1cm} (7)

and on any given streamline

$$t + \frac{r}{u} \to 0 \quad \text{as} \quad \theta \to \pi.$$  \hspace{1cm} (8)

Although Equations (6) and (7) are hyper-elliptic, useful expressions can be obtained for large and small values of \( \rho_0/a \).

For large \( \rho_0/a \), Stokes stream function can be expanded in powers of \( a^3/r^3 \) as

$$r = \frac{\rho_0}{\sin\theta}\left(1 + \frac{1}{2} \frac{a^3}{r^3} \sin^3\theta - \frac{3}{8} \frac{a^6}{\rho_0^3} \sin^6\theta + \ldots\right).$$  \hspace{1cm} (9)

Using this expansion, Equation (7) can be expanded to give

$$udt = -\frac{\rho_0 d\theta}{\sin^2\theta} \left(1 + \frac{3}{8} \frac{a^6}{\rho_0^3} \sin^6\theta - \frac{a^9}{\rho_0^9} \sin^9\theta + \frac{315}{128} \frac{a^{12}}{\rho_0^{12}} \sin^{12}\theta + \ldots\right)$$  \hspace{1cm} (10)

Integrating, yields

$$ut = \rho_0 \cot\theta + \frac{3}{8} \frac{a^6}{\rho_0^3} \int_0^\pi \sin^4\theta d\theta - \frac{a^9}{\rho_0^9} \int_0^\pi \sin^7\theta d\theta + \frac{315}{128} \frac{a^{12}}{\rho_0^{12}} \int_0^\pi \sin^{10}\theta d\theta - \ldots$$  \hspace{1cm} (11)

The limits for the integral satisfy Equation (8). This series evaluation converges for all \( \theta \) with the value \( \rho_0/a > 1.375 \).
The total drift function \( z(\rho_0) \) from Darwin (1953) is given as:

\[
z(\rho_0) = \lim_{z \to \infty} (ut-z) = \frac{3}{8} \frac{a^6}{\rho_0^2} \left( \frac{3n}{8} \right) - \frac{a^9}{\rho_0^3} \left( \frac{32}{35} \right) + \frac{315}{128} \frac{a^{12}}{\rho_0^{11}} \left( \frac{63\pi}{256} \right)
\] (12)

It should be noted that for any streamline

\[
t(\theta) = 2t(\pi/2) - t(\pi - \theta)
\]

and

\[
z(\rho_0) = \lim_{\theta \to 0} (ut-z) = 2(ut)_{\theta=\pi/2} - \lim_{\theta \to \pi} (ut-z) = 2(ut)_{\theta=\pi/2}
\] (13)

For small values of \( \rho_0/a \) each streamline is divided into two parts. Part one for \( \theta \) near 0 or \( \pi \), and second one on which \( (r/a - 1) \) is small.

When \( \theta \) is near \( \pi \), then \( -\sec \theta = 1 + \frac{1}{2} \sin^2 \theta \) in Equation (6) and using Equation (5) gives the value of

\[
vt = -r + \frac{1}{6} \frac{\rho_0^2}{(r/a)^3 - 1} r^2/a^3 - \frac{1}{3} a \left( 1 + \frac{1}{3} \frac{\rho_0^2}{a^2} \right)
\]

\[
\ln \frac{r/a - 1}{\sqrt{(r/a)^2 + r/a + 1}} - \frac{a}{\sqrt{3}} \left( 1 - \frac{\rho_0^2}{3a} \right) \tan^{-1} \left[ \frac{\sqrt{3}}{(1 + 2 r/a)} \right].
\] (14)

For the case when \( \theta \) departs from \( \pi \) (or 0), \( (r/a - 1) \) is small and the following approximation can be used.

\[
\frac{r}{1 + \frac{a^3}{2r^3}} \approx \frac{2}{3} a + \frac{4}{9} \frac{\rho_0^2}{a} \cos \theta.
\] (15)
This then gives the result

\[ ut = \frac{1}{2} Z(\rho_0) + \frac{2}{3} a \left( 1 + \frac{\rho_0^2}{3a^2} \right) \ln \tan \left( \frac{1}{2} \theta \right) - \frac{2\rho_0^2}{9a} \cot \theta \csc \theta . \]  

(16)

The value of the total drift function is then found from Equation (16) and (14) to be for small \((r/a - 1)\) to be

\[ z(\rho_0) = \frac{4}{3} a \left( 1 + \frac{\rho_0^2}{3a^2} \right) \ln \frac{3^{3/4}}{\rho_0} (2a) - \left( 2 + \frac{\pi}{3\sqrt{3}} \right) a \]

\[ + \left( \frac{\pi}{\sqrt{3}} - 1 \right) \frac{\rho_0^2}{9a} . \]  

(17)

Equations (12), (13), (14), (16), and (17) can be used to calculate the drift function \(t\) for any given value of \(\rho_0\), \(r\) and \(\theta\). For \(\theta > 5/6\pi\) Equation (14) is used. For \(1/2 \pi < \theta < 5/6 \pi\) and \(r/a < 1.5\), Equation (16) is a good approximation. When \(r/a > 1.75\) Equation (11) is valid. The gap between \(1.5 < r/a < 1.75\) can be filled by interpolating Equations (16) and (11).

Lines of \(t = \text{constant}\) drift function values are plotted in Figure 1. The horizontal lines were initially at right angles to the motion of the sphere. They are distorted around the sphere as it moves through the fluid. The plot was made in a coordinate system fixed with the rising sphere.

The lines of constant drift function show in detail where every particle is and when it is there. For example, if in polar spherical coordinates, a point is given as \(r = 1.6\) and \(\theta = -\pi/4\), the corresponding drift function can be found, which is say \(+2.0\), scaled to a unit fireball with unit rising velocity. It is requested to know where the point was \(3.5\) seconds before. This would put it on a drift function plane of \(-1.5\) seconds, with the same stream function.
Figure 1. Plot of drift functions $t$ and stream functions $\psi$ for a unit sphere in a unit flow field. Coordinates of the intersection of $t$ and $\psi$ are stored in the table XX in Subroutine CIPHER, where $\psi = \frac{1}{2} \rho_0^2$. 
The corresponding new position at a time of -1.5 seconds can be found by inverting Equations (11) to (17), or more conveniently, a table of solutions of Equations (6) and (7) can be made for different stream functions and drift functions. Since both the stream function and drift function values are known, the solution can be found by interpolating from the table. Only one of the solution-variables \( r \) or \( \theta \) need be stored since the other can be calculated from the constant Stokes stream function Equation (5a).

To generate the table that inverts Equations (11) to (17), the coupled Equations (6) and (7) are solved numerically in the form:

\[
\begin{align*}
\frac{dr}{dt} &= + \left(1 - \frac{a}{r^3}\right) \cos \theta \\
\frac{d\theta}{dt} &= - \left(1 + \frac{a}{2r^2}\right) \frac{\sin \theta}{r}
\end{align*}
\]

where the rise velocity and radius \( a \) are both taken as unity.

Numerical integration of Equations (18a) and (18b) gives the position of the particle in the flow field for discrete times. The numerical method used was that of Gear (1971). The Gear algorithm is useful for solving stiff equations. It uses an Adams Predictor-Corrector method with the initial values generated by a Runge-Kutta method.

The polar spherical radial coordinate \( r \) was saved in a data table for each discrete time \( t \) and stream function \( \psi \), where

\[
\psi = \frac{1}{2} r^2 \sin^2 \theta \left(1 - \frac{1}{r^3}\right).
\]
Thus for a given $\psi$ and $t$, $r$ can be found by a table look-up. Then $\theta$ can be found from the inversion of Equation (19) using $r$ and $\psi$

$$\theta = \sin^{-1} \frac{2\psi}{\sqrt{r^2 - \left(1 - \frac{1}{r^2}\right)}}$$

Thus, the position is specified. The table look-up and interpolation is done in subroutine CIPHER and the outputs converted to fireball centered Cartesian coordinates.

Once the positions $(z_q, x_q)$ in fireball coordinates is known, a simple Galilean transformation gives the position $({z}_f, {x}_f, {y}_f)$ in a coordinate system fixed at the position of the initial burst,

$$z_f = S_{r1} - V_R z_q$$

where $S_{r1}$ is the slant range between the initial burst position and the present fireball position, $V_R$ is the fireball rise velocity, and $z_q$ is the $z$ coordinate fixed at the initial burst position. Coordinates $y_f$ and $x_f$ remain constant under the Galilean transformation in the $z$ direction. The point defined by $x_f$, $y_f$, and $z_f$, in the initial burst position coordinates, is then rotated to the earth centered Cartesian coordinates. The vector position in this new frame is then added to the vector position of the initial burst giving the new vector position of the point in earth centered Cartesian coordinates.

The trajectory of the particles in a frame fixed with the stationary fluid are plotted in Figure 2 for some typical values of $\rho_0(= .5, 1.0, 1.5, 1.8)$. From the figure, it can be seen that as the fireball passes the point, it is at its maximum lateral displacement. It should also be noted that as the fireball passes the point, the point takes on a retrograde motion.
Figure 2. Plot of fluid particle displacements as seen in a coordinate system fixed with the fluid. The dotted line represents the total drift displacement after the passage of the unit sphere.
SHOCK DISPLACEMENT CALCULATIONS

The shock displacement is calculated after the point has been moved back in time to a burst time. It is assumed that the shock arrives instantaneously at the point of interest. This is a zeroth order approximation and will be changed to include the shock arrival time and shock duration. For calculation times long enough after burst time for shock traversal of the point, this assumption causes only a small error because of two facts: 1) if the fireball is very far away from the point, the shock displacement time is greatly in error, but the actual displacement is very small, 2) if the burst is close to the point, the timing error is small and the shock displacement is large.

The distance from the initial burst position to the point is scaled to dimensionless coordinates using a modified Sach's scaling

\[ a = 0.345 \left( \frac{W_{KT}}{P_0} \right)^{1/3} e^{\frac{S_1}{3H_s}} \]

where \( W_{KT} \) is the yield in kilotons, \( P \) is the pressure at the point of interest, \( P_0 \) is the sea level pressure, \( S_1 \) is the height of the point above (+) or below (-) the fireball, \( H_s \) is the scale height. This expression reduces down to

\[ a = 13.6 \frac{S_1}{3H_s} R_{H_0} e \]

where \( R_{H_0} \) is the initial fireball radius at the end of the radiation phase.

Based on a fit to a RADFLO run (5KT at 9.15 km), a shock displacement \( \Delta \lambda \) in scaled distance is given by

\[ \Delta \lambda = 0.096 (\lambda' (2+\lambda'))^{-1} \]

where \( \lambda' = \lambda + \Delta \lambda \) is the final position in scaled units.
SECTION III
CODING CONSIDERATION FOR FLOW FIELD CALCULATIONS

CONTROL OF CALCULATIONS BY SUBPROGRAM HYDRO

The above mathematical method of calculating particle movements in the flow field around a rising fireball has been coded into eight subprograms for use in ROSCOE. The controlling routine is HYDRO, which is called with a given time and position.

Previous to a call to HYDRO, a call has been made to the burst environment module (PMDS) which sets up the vortex radii at the initial times and at the calling time. Also saved are all the fireball vortex positions at that time of call.

Given the position of a point, the time and pertinent fireball positions, HYDRO makes a call to subprogram EDITX to determine which bursts affect the given point.

EDITX begins the loop over all existing fireballs including those created by a hydromerge. If the burst was created by a hydromerge, it creates the initial vortex information for the merged fireball. It then calculates the distance of closest approach to the line connecting the initial fireball center and present center. If this radius scaled distance is greater than 1.8, it rejects this fireball for consideration. If the time it takes for the fireball to get to the point is very large, the event is rejected. If the point is more than a radius on front of the fireball, the burst is rejected. For all bursts accepted as influencing the given point, a count is kept (≡NAI) and the fireball index is stored in the NCAG array.
HYDRO then begins to loop over all the bursts including bursts created during a hydromerge. It starts with the most recent burst time first and does the calculation back to this time. It then does the shock displacement calculation. It saves this new calculated position and puts it into the output array if the time was a burst time and not merely a merge time. The saved new position is now used to regress the calculation back to the second to the last occurring burst. This new position is saved and used to continue the calculation back to where the parcel was for the first burst before the arrival of any shock waves.

For each regression back to a burst time, an inner loop is made over all the fireballs that will influence the point during this time increment. After the time regression goes back beyond the burst time of an event affecting the point, this event is removed from the NCAG array, and the calculation continues with the remaining influencing fireballs.

When multiple events influence the point, the individual displacements from each burst are saved. After the inner loop over all influencing events is completed, a vector sum is made of all the individual displacements.

A check is made of the influencing fireball type flag KINDF to determine if the fireball is active at this time. If it is not active, i.e., has been radiation or hydromerged, then it is not used to calculate the change in position of the point PXYZ. After the calculation regresses back to the time of the merge for this fireball, the burst is used to determine the position.
CRITERIA FOR EDITING FIREBALLS

Before a flow field calculation is performed, a call is made to an editing routine. This routine loops over all the existing fireballs, active and inactive, and determines which fireballs will affect the given point. All fireballs that will ever have an affect on the point are stored in array NCAG.

If the distance of closest approach to the line of centers between the initial burst and present fireball position (scaled to the fireball radius at the calculation time) is greater than 1.8, the fireball is rejected as not affecting the point.

If the point of interest is more than 1.5 radii above the fireball position at calculation time or 1.5 radii below the initial burst position, the burst is rejected.

SINGLE BURST CASE

For the single burst case, when EDITX returns NAI equal to 1 and NCAG(1) equal to 1, subprogram HYDRO begins the calculation of the effect of burst 1 on PXYZ. The burst will always be active since there is only one burst. Also the calculation can proceed back to the initial burst time in one pass through the routine.

Hydro calculates the distance of closest approach, DIST. It calculates the slant range $S_{r1}$ along the line of centers between the initial burst position and the position at calling time, the slant range, $S_{l}$, from burst point to point of closest approach; slant range, $R_{ad}$, from present burst position to point $P_{xyz}$. If the point is more than a fireball radius below the initial burst point, the effect of burst N on the point is considered negligible.
The radius of the fireball where most of the influence is occurring on point $P_{xyz}$ is found by interpolating linearly between the initial and final radii:

$$ R = \frac{R_{in} S_{rd} + R_v S_1}{S_{rd}} $$

where $S_{rd}$ is the slant range from the present position of the fireball to the point of closest approach, $R_{in}$ is the initial vortex radius, $R_v$ is the present vortex radius.

MULTIPLE BURST CASE

The mathematical method for the case where two or more fireballs are affecting a point is handled similarly to the single burst case. The displacement calculation is done separately for each fireball. The final displacement is the vector sum displacement over all fireballs.

No attempt is made to account for the change in a fireball flow field due to another fireball flow field. It is expected that the effect is small except in cases where the fireballs are closer than .5 fireball radii.
SECTION IV

DESCRIPTION OF SUBPROGRAMS

Subroutine HYDRO is the main ROSCOE subprogram for calculating the particle time history in the flow field around a rising fireball.

Fireballs are edited as to their effect on the given point by EDITX.

Subprogram SYZYGY calculates the drift function \( t (=\text{TOUT}) \) for the initial given point.

Subprogram CIPHER calculates the position of the particle at a given drift function and stream function.

Subprogram SCHCK calculates the shock displacement of a given point by a given burst.
Description of Code HYDRO

Purpose

Subroutine HYDRO calculates the position of a given point at a given time at all burst times previous to the given time. This requires that the code run backwards in time.

Inputs to Subroutine HYDRO

Formal Argument

\[ PXYZ(I) = 3 \text{ word array of coordinates } x, y, z \text{ in cm.} \]

Earth centered Cartesian with \( x \) through Greenwich

Inputs from Labeled Common

<table>
<thead>
<tr>
<th>Block</th>
<th>Variable</th>
<th>Description</th>
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<td>/RADDAT/</td>
<td>XIN(3,I)</td>
<td>Initial vector position of event I (cm)</td>
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<tr>
<td></td>
<td>XEV(3,I)</td>
<td>Vector position of event I at time = TSIM (cm)</td>
</tr>
<tr>
<td></td>
<td>REIN(I)</td>
<td>Initial vortex radius = 4* RHZERO</td>
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<td></td>
<td>REV(I)</td>
<td>Vortex radius of event I at time = TSIM (cm)</td>
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<td>VRZ(I)</td>
<td>Event rise velocity magnitude (cm/sec)</td>
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<td>/EVXDAT/</td>
<td>NUMX</td>
<td>Number of real events</td>
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<tr>
<td></td>
<td>TSIM</td>
<td>Time of calculation (sec)</td>
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<td>/EVENTX/</td>
<td>NF</td>
<td>Total number of events at time = TSIM includes hydromerges</td>
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<td>TB(I)</td>
<td>Burst time of event I</td>
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<td>KINDF(I)</td>
<td>Flag to indicate type of event</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>= 2 spheroidal, pressure equilibrium</td>
</tr>
</tbody>
</table>
\[3\] torus
\[4\] merged during radiation phase
\[5\] merged during hydrodynamic phase

\(\text{MRGID}(I)\) Flag to indicate index of merged events
\(\text{TCHAR}(I)\) Characteristic time for merged events

\text{/SAVEVX/} \(\text{BUFFR}(15, I)\) Initial event radius for the 1th event to which all parameters are scaled (=RHZERO(I)) in common block/EVENTX/

Output from Subroutine HYDRO

Formal Arguments

\(\text{XARAY}(3, N)\) Vector position array for point PXYZ at all previous events \((N=1, NMX) \text{ (cm)}\)
\(\text{MODE}\) Flag to indicate significant fluid movement
\[=1\] fluid has moved
\[=0\] fluid has not moved significantly

External Subprograms Used in HYDRO

Name Information requested/description

\(\text{EDITX}\) Loops over all bursts and selects those that will affect point PXYZ
\(\text{SYZYGY}\) Gives the time since the point passed the center of the burst (+) or the time it will take to pass the center of the burst (-), scaled to radius of fireball
\(\text{CIPHER}\) Calculates the position of the point for a given time in a coordinate system attached to the burst center and in the x-z plane. It does the calculation for a unit vortex radius and unit velocity.
\(\text{EVENAD}\) Performs the vector addition of point displacement resulting from the multiple burst interactions.
SCHCK  Calculates the shock displacement from each burst on the point at the burst time.
ROOTT  Calculates the time at which a given stream function crosses the zero axis.
DISCAP  Calculates the distance of closest approach of the point to the line connecting centers. Calculates the needed slant ranges.

External Utility Subprograms Required

Name  Vector package
LOCLAX  Generates transformation matrix
XMIT  Copies vector A to B
XMAG  Gives magnitude of vector
SUBVEC  Subtracts two vectors
VECLIN  Adds two vectors
MATMULT  Does matrix multiple
DOT  Does Dot product
UNITV  Finds unit vector
CROSS  Finds cross product AxB
CROSS1  Find cross product and normalizes to 1
PROJ  Finds projection of A on B
LOC1  Find SCM address
FDIV  Prevents division error abort
VECSUM  Vector sum
EFCGEO  Transforms from xyz to geographic coordinant
GEOEFC  Inverse of EFCGEO
## Glossary of Variables

Roscoe Routine HYDRO

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PXYZ(3)</td>
<td>Input vector position</td>
</tr>
<tr>
<td>XARAY(3,I)</td>
<td>Output vector position at each burst time of Index I</td>
</tr>
<tr>
<td>MODE</td>
<td>Flag to indicate significant flow field movement</td>
</tr>
<tr>
<td>TIM</td>
<td>Calculation time local variable</td>
</tr>
<tr>
<td>TSIM</td>
<td>Global calculation time</td>
</tr>
<tr>
<td>XSAV(3)</td>
<td>Local Var., vector position array</td>
</tr>
<tr>
<td>MI</td>
<td>Flag to indicate data is saved for fireball vortex</td>
</tr>
<tr>
<td>L</td>
<td>Running index for burst index contained in NCAG</td>
</tr>
<tr>
<td>NAI</td>
<td>Return from EDITX, Number of burst affecting PXYZ</td>
</tr>
<tr>
<td>M1A(I)</td>
<td>Array of flags indicating data saved for burst I</td>
</tr>
<tr>
<td>NRUN</td>
<td>Dummy running variable for DO 1000</td>
</tr>
<tr>
<td>NX</td>
<td>Number of bursts up to time TIM</td>
</tr>
<tr>
<td>K</td>
<td>Index of burst starting with last burst first</td>
</tr>
<tr>
<td>XOOU(3)</td>
<td>Local variable, array of vector position</td>
</tr>
<tr>
<td>KFF</td>
<td>Flag whether index K is for real burst or merged burst</td>
</tr>
<tr>
<td>TOBIO</td>
<td>Local variable set to the burst time or merge time</td>
</tr>
<tr>
<td>TB(K)</td>
<td>Burst time from/GEOTD/</td>
</tr>
<tr>
<td>DTEL</td>
<td>Time difference between present time and burst time</td>
</tr>
<tr>
<td>NCAG(10)</td>
<td>Array of burst indexes affecting PXYZ</td>
</tr>
<tr>
<td>NN</td>
<td>Running index of burst affecting point PXYZ</td>
</tr>
<tr>
<td>KINDF(10)</td>
<td>Array of flags describing fireball type/GEOTD/</td>
</tr>
<tr>
<td>TCHAR(10)</td>
<td>Characteristic burst or merge time for each fireball</td>
</tr>
<tr>
<td>PSI</td>
<td>Stream function</td>
</tr>
<tr>
<td>VNORM</td>
<td>Speed of fireball in effective vortex radii/sec</td>
</tr>
</tbody>
</table>
TZ  Relative time since passage of point past fireball (normalized by R)
SR1  Slant range of initial position to present position
S1  Slant range from initial position to PXYZ on line connecting centers
DIST  Distance of closest approach of PXYZ to line of centers
R  Radius of vortex near PXYZ used to scale distances
XIN(3,I)  Initial position of fireball vortex
XEV(3,I)  Final position of fireball vortex
RAD  Slant range from fireball position to PXYZ
REV(I)  Radius of vortex at calculation time
SRD  Slant range from fireball to point of closest approach
RH  Normalized distance of closest approach
RR  Radius normalized RAD
PSI  Stream function in unit velocity field
VRZ(I)  Speed of fireball unnormalized (cm/sec)
TRELX  Time difference scaled to fireball with unit rise
XF  X position in fireball centered coordinates of point PXYZ
YF  Y position in fireball centered coordinates of point PXYZ
ZF  Z position in fireball centered coordinates of point PXYZ
XQ  X positions of point at new time TIM
ZQ  Z positions of point at new time TIM
D(3)  Vector position of point PXYZ in initial fireball coordinates multiply used
CVEC(3,N)  Array of vectors from initial fireball N to final fireball N.
UVEC  Transformation matrix from XYZ to user frame
NRA  Row size of matrix
NCARB  Column size of matrix
NCB  Vector column size
POF(3)  Vector position in burst centered coordinates at time = TOB10
NUMX  Number of actual bursts
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOU(3,N)</td>
<td>Local array to store positions</td>
</tr>
<tr>
<td>TMBU(10)</td>
<td>Burst times in descending order</td>
</tr>
<tr>
<td>NCOT</td>
<td>Total number of print times</td>
</tr>
<tr>
<td>ALPHA</td>
<td>Shock scaling parameter</td>
</tr>
</tbody>
</table>
Flow Diagram for Subprogram HYDRO
Description of Code EDITX

Purpose

This subroutine loops over all existing fireballs at calling time and determines which fireball will affect the given point.

Inputs

PXYZ(3) Vector position of point

Inputs from Common

XIN(3,L) Initial position of fireball L
XEV(3,L) Final position of fireball L
TB(L) Burst time for event L

Outputs to Common

NAI Number of bursts interacting with point
NCAG(I) Array of burst indexes interacting I=1, NAI

Externals used

DISCAP Calculates distance of closest approach

Method

EDITX is a simple routine which is called every time HYDRO is called.

It loops over all fireballs and calculates the distance of closest approach of the line connecting centers with the given point. The calculation is done in DISCAP.
Criteria

A point is rejected if it is greater than 1.8 final fireball radii from the line connecting centers.

It is rejected if it is 1.5 fireball radii above the final position or 1.5 radii below the initial position. The radius at call time is used.

Glossary of Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PXYZ(3)</td>
<td>Input-vector position</td>
</tr>
<tr>
<td>NAI</td>
<td>Output-number of burst affecting point</td>
</tr>
<tr>
<td>NCAG(L)</td>
<td>Output - array of burst indexes</td>
</tr>
<tr>
<td>L</td>
<td>Running variable over all bursts</td>
</tr>
<tr>
<td>NX</td>
<td>Total number of bursts</td>
</tr>
<tr>
<td>SR12</td>
<td>Slant range from final fireball position to initial</td>
</tr>
<tr>
<td>CVEC(3,L)</td>
<td>Vector from initial fireball position to final position</td>
</tr>
<tr>
<td>XIN(3,L)</td>
<td>Initial position vector</td>
</tr>
<tr>
<td>XEV(3,L)</td>
<td>Final position vector</td>
</tr>
<tr>
<td>DIST</td>
<td>Distance of closest approach to line of centers</td>
</tr>
<tr>
<td>S1</td>
<td>Distance from initial position to point of closest approach</td>
</tr>
<tr>
<td>TDIS</td>
<td>Time for fireball to travel from point of closest approach to intial position</td>
</tr>
<tr>
<td>REV(L)</td>
<td>Final vortex radius (event L) (cm)</td>
</tr>
<tr>
<td>VRZ(L)</td>
<td>Speed of rise for event L (cm/sec)</td>
</tr>
<tr>
<td>TTEST</td>
<td>Time to go from point to 1.5 fireball radii below initial fireball position</td>
</tr>
<tr>
<td>NCO</td>
<td>Running variable</td>
</tr>
</tbody>
</table>
Description of Code SYZYGY

Purpose

This subroutine calculates the drift function TZ scaled to a unit fireball radius rising at unit speed, given a position.

Inputs

R  Radius of fireball
VR  Rise speed
PSI  Stream function (= \(1/2 \rho \dot{z}\))

Outputs

TOUT  Drift function

Outputs to Common

THETA  Angle to point measured from rise line
RR  Distance in radii R from fireball to point
RH  Distance of closest approach in R
VNORM  Speed scaled by R
XROZ  Total drift displacement
TZ  Drift function time (sec)

Method

See Section II
### Glossary of Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSEC</td>
<td>Cosec of THETA</td>
</tr>
<tr>
<td>COTAN</td>
<td>Cotan of THETA</td>
</tr>
<tr>
<td>ROA</td>
<td>Equivalent to RO</td>
</tr>
<tr>
<td>RO</td>
<td>$= \rho_0$</td>
</tr>
<tr>
<td>XROZ</td>
<td>Total drift function</td>
</tr>
<tr>
<td>UTZ</td>
<td>Distance from reference $(z=0)$</td>
</tr>
</tbody>
</table>

All other variables are defined previously.
Description of Code CIPHER

Purpose

This subroutine calculates the position of a point in fireball coordinates for a given stream function and drift function.

Inputs

T Drift function
PP Stream function

Inputs from Common

THETA Angle to point measured from line of rise
VNORM Rise speed in radii
RH Distance of closest approach in R
RR Slant range from fireball to point

Outputs

X Cartesian coordinate perpendicular to rise in R
Y Cartesian coordinate parallel to rise in R

Method

The coupled equations (6) and (7) in Section II were solved and the r coordinate solution was stored in a table for 35 times and 15 stream functions.

Then for a given time (drift function) T and stream function PP, a value of r can be picked from the table.
The X and Y coordinates are now determined from the equation

\[ X = \sqrt{\frac{2 \cdot PP \cdot r^3}{r^9 - 1}} \]

and

\[ Y = \pm \sqrt{r^2 - X^2}. \]

The sign of Y is positive above the fireball center and negative below. Close to fireball the sign of Y is determined by finding the slope of the stream function dy/dx. For values of X far from the sphere function subprogram ROOTT is used to find the time at which the given stream function crosses the zero Z axis.
**Glossary of Variables**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Drift function</td>
</tr>
<tr>
<td>PP</td>
<td>Stream function ( = \frac{1}{2} \rho )</td>
</tr>
<tr>
<td>X</td>
<td>Output - Cartesian coordinates perpendicular</td>
</tr>
<tr>
<td>Y</td>
<td>Output - Cartesian coordinate parallel to rise</td>
</tr>
<tr>
<td>NFLAG</td>
<td>Flag to indicate if point has moved</td>
</tr>
<tr>
<td>TI(35)</td>
<td>Array of drift functions</td>
</tr>
<tr>
<td>PS(15)</td>
<td>Stream functions ( = \frac{1}{2} \rho )</td>
</tr>
<tr>
<td>XX(35,15)</td>
<td>Array of solutions for TI and PS((=r))</td>
</tr>
<tr>
<td>P</td>
<td>Local variable - stream function</td>
</tr>
<tr>
<td>NOFF</td>
<td>Flag indicates whether ( P ) is off table</td>
</tr>
<tr>
<td>ITOFF</td>
<td>Flag indicates whether ( T ) is off table</td>
</tr>
<tr>
<td>FT</td>
<td>Interpolation weight for ( T )</td>
</tr>
<tr>
<td>FP</td>
<td>Interpolation weight for ( P )</td>
</tr>
<tr>
<td>XN</td>
<td>Nth point to interpolate from</td>
</tr>
<tr>
<td>RQ</td>
<td>Interpolated solution ( r )</td>
</tr>
<tr>
<td>XTEM2</td>
<td>( x^2 )</td>
</tr>
<tr>
<td>YTEM2</td>
<td>( r^2 - x^2 )</td>
</tr>
<tr>
<td>INFLG</td>
<td>Flag indicates whether this is first or second pass through calculation</td>
</tr>
<tr>
<td>XS</td>
<td>Temporary x coordinate</td>
</tr>
<tr>
<td>DELX</td>
<td>Change in ( X ) from pass 1 to 2</td>
</tr>
<tr>
<td>DTEL</td>
<td>Time difference (sec)</td>
</tr>
<tr>
<td>TDIF</td>
<td>Time difference since it made it to edge of table</td>
</tr>
</tbody>
</table>
| DNOM | \( x^2 - 2 \cdot P \)  

\[
(\gamma = \left( \frac{x^2}{x^2 - 2 \cdot P} \right)^{2/3} - x^2 \right)^{1/2})
\]
Description of Code SCHCK

Purpose

This subroutine calculates the shock displacement of a given point from a given fireball.

Inputs

- XOU(3) Initial position vector
- K Fireball index
- ALPHA Scaling parameter

Inputs from Common

- XIN(3,L) Initial position for fireball L
- XEV(3,L) Final position for fireball L

Output

- XSAV Vector position after displacement

Method

See Section II. It does not take into account the change in the fireball position resulting from the interaction of one fireball with another.

A more sophisticated shock routine should take into account the change in position of all other fireballs from the shock passage of the fireball under consideration. This however would slow down the calculations considerably by necessitating a NxN calculation of shock interactions and by causing a re-evaluation of flow field parameters for every burst.

The next order approximation will take into account the shock arrival time and duration.
Glossary of Variables

Name

C(3) Vector from fireball to point
SR Magnitude of C
SRLAM Scaled slant range
DLAM Scaled shock displacement
SRNEW Final slant range
XSAV Final position after shock passage.

All other variables are defined previously.
Variables Generated by MODEL and used by ROSCOE model HYDRO

Common Block Array Used

<table>
<thead>
<tr>
<th>Block</th>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOTD</td>
<td>TCHAR(I)</td>
<td>Array of characteristic times for event I</td>
</tr>
<tr>
<td></td>
<td>KINDF(I)</td>
<td>Type of event I, i.e.,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 1 spheroidal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 2 spheroidal pressured equilibrium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 3 torus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 4 merged during radiation phase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= 5 merged during hydrodynamic phase</td>
</tr>
<tr>
<td></td>
<td>MRGID(I)</td>
<td>Flag to indicate merging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For non-merged events (MRGID(I)=KINDF(I))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For merged events, MRGID(I) units digit contains</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the event index from which the merge took place;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the tens digit the event index of the second event.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The MRGID of the events from which the merged event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>occurred contains in the unit digit, the other event,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in the tens digit the new event formed.</td>
</tr>
<tr>
<td>RADDAT</td>
<td>XIN(3,I)</td>
<td>Initial geocentric Cartesian coordinates with X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>through Greenwich for the event I, with ordering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X,Y,Z, (cm).</td>
</tr>
<tr>
<td></td>
<td>XEV(3,I)</td>
<td>Geocentric Cartesian coordinates of event I at the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>calling time</td>
</tr>
<tr>
<td></td>
<td>REIN(I)</td>
<td>Initial vortex radius (cm)</td>
</tr>
<tr>
<td></td>
<td>REV(I)</td>
<td>Vortex radius at calculation time (cm)</td>
</tr>
</tbody>
</table>

SAVEVX | BUFFR(15,I) | Initial event radius for the 1\textsuperscript{th} event (cm) to which all parameters are scaled (\(=\text{RHZERO}(I)\)) in common block/EVENTX/ |
The output array XARAY is filled in time ascending order.

Running times for multi-event scenarios at relatively high altitude and high energies promise to be long. A five burst scenario with a hydromerge and radiation merge for example will run greater than 77 ms per call with multiple events affecting the point. (Run on a CDC 7600).
SECTION V
SUBPROGRAM LISTINGS

MYDRO

SUBROUTINE MYDRO(PXYZ,XRAY,MODE)

THIS SUBPROGRAM CALCULATES THE TIME HISTORY OF THE GIVEN POINT
PXYZ AND RETURMS ITS POSITION AT EACH EVENT TIME.

INPUT
PXYZ ARRAY OF GEOCENTRIC CARTESIAN COORDINATES

OUTPUT
XRAY(I) VECTOR POSITION OF EVENT I AT EVENT TIME.

COMMON/EVDAT,NUMX,NAI,XAR(3,10),NCAU(10),TSIM,MCOT,THBU(10)

COMMON/EVENT/ N;1, TTH(50), W4H(50), GLW(50),

10 TLH(50), THU(50), MCH(50), TFG(50), WRIE(50), EVNTX,2

COMMON/EVENT/ N;1, TTH(50), W4H(50), GLW(50),

10 TLH(50), THU(50), MCH(50), TFG(50), WRIE(50), EVNTX,3

COMMON/EVENT/ N;1, TTH(50), W4H(50), GLW(50),

10 TLH(50), THU(50), MCH(50), TFG(50), WRIE(50), EVNTX,4

COMMON/EVENT/ N;1, TTH(50), W4H(50), GLW(50),

10 TLH(50), THU(50), MCH(50), TFG(50), WRIE(50), EVNTX,5

EQUIVALENCE(THE(1),TH(1))

TIME DEPENDENT MODEL PARAMETERS

COMMON/GEOTD/ ND, IDNDF(50), RTF(50), ALF(50), HF(50), GCF(50),

10 GLF(50), WHAXF(50), WHITH(50), KLDF(50), TILTF(50), GLET0,3

COMMON/GEOTD/ ND, IDNDF(50), RTF(50), ALF(50), HF(50), GCF(50),

10 GLF(50), WHAXF(50), WHITH(50), KLDF(50), TILTF(50), GLET0,4

COMMON/GEOTD/ ND, IDNDF(50), RTF(50), ALF(50), HF(50), GCF(50),

10 GLF(50), WHAXF(50), WHITH(50), KLDF(50), TILTF(50), GLET0,5

COMMON/GEOTD/ ND, IDNDF(50), RTF(50), ALF(50), HF(50), GCF(50),

10 GLF(50), WHAXF(50), WHITH(50), KLDF(50), TILTF(50), GLET0,6

DIMENSION TOR(21)

COMMON/RANDAT/IH(3,10),XEV(3,10),RELX(10),XYYZ(3,10),

VRZ(3,10),XEV(3,10)

COMMON/GEOM/THETA,RR,WH,NORM,DELX,KHOX,TZ

COMMON/GEOM/THETA,RR,WH,NORM,DELX,KHOX,TZ

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

COMMON/FIXST/ BE, BREAK, RADIUS, DEPHD, DRE2

DATA TRAVL/1,E05/

CALL UP THE EXIT ROUTINE TO ELIMINATE THE NON ESSENTIAL EVENTS
FROM BEING CONSIDERED IN THE FLOW FIELD CALCULATIONS FOR THE POINT MYDRO

MODN,4

CALL XRTI (5,PXYZ,XSAV)

CALL EDII (XSAV)

MODN,15

MODN,16

MODN,17

MODN,18

MODN,19

MODN,20

MODN,21

MODN,22

MODN,23

MODN,24

MODN,25

MODN,26

MODN,27

MODN,28

MODN,29

MODN,30

MODN,31

MODN,32

MODN,33

MODN,34

MODN,35

MODN,36

MODN,37

MODN,38

MODN,39

MODN,40

MODN,41

MODN,42

40
HYDRO

27 DO 1000 NRUN=1,NX
30 KX=NRUN=1
C LOOP OVER ALL EVENTS INCLUDING HYDROMETHYLO EVENTS.
C
C BEGIN
C DO MOST RECENT EVENT FIRST
C
32 CALL XK(X=XSAV.XOU)
35 C IF (KINDF(I),GT,3) GO TO 60
36 C IF (MNGD(I),EQ,2) GO TO 60
34 40 C IF (TOPI=TCHAR(K)) GO TO 60
50 C GO TO 60
52 60 C TOPI=TRB(I)
54 C IF (TOPI) CONTINUE
55 80 C DTFL =TIME-TB10
57 C IF (NAI,LE,0) GO TO 700
58 C IF (AC1(1),EQ,0) GO TO 700
60 C CONTINUE
65 100 C IF (MANGA(I),LT,0.5) GO TO 700
65 100 C CONTINUE
65 100 C ISNN=AC1(I)
C IS NN ACTIVE AT THIS TIME

67 C IF (KINDF(NN),LT,4) GO TO 105
68 C IF ((TIN=CHAR(1),LT,1,LH=5) GO TO 105
70 C GO TO 865
75 104 C CONTINUE
76 104 C W1=IA(1)
100 C IF (M1,EQ,0) GO TO 110
C RESTORE ALL VARIABLES FOR EVENT NN PREVIOUSLY SAVED
C THESE VARIABLES ARE REGENERATED FOR EACH CALL TO HYDRO
C AND NEED NOT BE SAVED IN THE MAIN OVERLAY.
C
102 C PST=PSIA(NN)
103 C VNRM=VNRMA(NN)
106 C TTE=TTA(NN)
107 C TXT=TXA(NN)
111 C DIST=DISTA(NN)
112 C RN=RAA(NN)
114 C M=MAA(NN)
116 110 C GO TO 200
116 110 C CONTINUE
C GET DISTANCES FROM EVENT AND LINE OF CENTERS
C
C CALCULATE THE DISTANCES FROM THE LINE OF CENTERS TO THE POINT
C AND THE DISTANCE FROM THE FINAL EVENT POSITION TO THE POINT.
C
116 C CALL DSCAP(XIN(I),NN),AXY(1,NN),PXY,0,S1,DIST,S1
130 C CALL SUBVEC(AXY(1,NN),PXY/C)
MYORD

134       C RADXMAG(C)
140       C CALCULATE RADIUS OF EVENT AT TIME OF PASSAGE

150       C IF(S1<LT.1,5*REV(K)) GO TO 700
155       C
151       C SRI=SRI+SR
154       C R=(REIN(NN)*SRO+REV(NN)*SRI)/SR
155       C
156       C RM=DIST/R
157       C
158       C PSIS IS CALCULATED FOR UNIT RADIUS AND VELOCITY
162       C IF(PSI,GT,1.0) GO TO 650
172       C
175       C NORMALIZE THE TIME DIFFERENCE TO AN EVENT WITH UNIT RISE
203       C CALL SYV0CVR(VRZ(NN),PSI,DIST,SRO,TI)
205       C
206       C 00 GALILEAN TRANSFORMATION
210       C CONTINUE
213       C XF=0.0
215       C XMDIST/R
217       C IF(PSI)
223       C IF(NFLAG,EQ,1) GO TO 650
227       C 2F=SRI-VRZ(NN)*DT*ZQ*SR
233       C YF=XR
235       C CALL SUBVF(EVY,NXIN(1,NN),C)
240       C IF(EXAG(D)+LT,1,0) D(1)=100.
246       C CALL LOCAX(CVEC1,NN),0,1,2,UVFC)
260       C XFR=X
261       C NCARBE1
265       C PCE(1)*XK
266       C PDF(2)*FX
266       C PDF(3)*FK
267       C A=1
270       C A=1
271       C CALL MATHNLTT(UVEC,PDF,D,XR1,NCARBE1,NCARBE2)
273       C CALL VECLIN(A,XIN(1,NN),B,0,XOU)
306       C CONTINUE
312       C IF(NUX,EQ,1) GO TO 700
314       C SAVE THE FLOW FIELD PARAMETERS FOR EVENT NN
**HYDR0**

312  **H1A(NN) = M1**  HYDR0, 157
313  **PS1A(NN) = PSI**  HYDR0, 158
314  **VMDMA(NN) = VMDM**  HYDR0, 159
316  **DISTA(NN) = DIST**  HYDR0, 161
317  **RPA(NN) = RPA**  HYDR0, 156
318  **H1A(NN) = M1**  HYDR0, 157
319  **PS1A(NN) = PSI**  HYDR0, 158
320  **SAVE THE VECTOR DISPLACEMENT CALCULATED FOR EVENT M4ASPOU**  HYDR0, 168
321  **CALL XMIT(3, XOU, SPOU(1, L))**  HYDR0, 170
322  **GO TO 686**  HYDR0, 171
323  **CONTINUE**  HYDR0, 172
324  **CALL XMIT(3, XOU, SPOU(1, L))**  HYDR0, 173
325  **GO TO 686**  HYDR0, 174
326  **CONTINUE**  HYDR0, 175
327  **LXM = 1**  HYDR0, 176
328  **LXM = 1**  HYDR0, 177
329  **FIND THE VECTOR ADDITION OF THE DISPLACEMENTS FOR PXYZ FROM MULTIPLE EVENTS**  HYDR0, 178
330  **CALL EVENAD(SPOU, NAI, PXYZ, XOU)**  HYDR0, 179
331  **CONTINUE**  HYDR0, 180
332  **CALL XMIT(3, XOU, X5AV)**  HYDR0, 181
333  **CONTINUE**  HYDR0, 182
334  **CONTINUE**  HYDR0, 183
335  **TIMATBIO**  HYDR0, 184
336  **IS THE EVENT TIME**  HYDR0, 185
337  **IF (KFF, EQ, 1) GO TO 400**  HYDR0, 186
338  **TIMATBIO**  HYDR0, 187
339  **NCHRE = NCHRE + 1**  HYDR0, 188
340  **TIMATBIO**  HYDR0, 189
341  **NCHRE = NCHRE + 1**  HYDR0, 190
342  **CALL SCWCK(XRUX, XALPHA, X5AV)**  HYDR0, 191
343  **CALL XMIT(3, XOU, X5AV)**  HYDR0, 192
344  **CALL XMIT(3, XOU, XARAY(1, K))**  HYDR0, 193
345  **CALL XMIT(3, XOU, XARAY(1, K))**  HYDR0, 194
346  **CONTINUE**  HYDR0, 195
347  **IF (NCSKIT(NAI, EQ, 1) ) NA1 = 1**  HYDR0, 196
348  **CONTINUE**  HYDR0, 197
349  **IF (MCX1 = 0, 0)**  HYDR0, 198
350  **MODE = 0**  HYDR0, 199
351  **GO TO 1200**  HYDR0, 200
352  **CONTINUE**  HYDR0, 201
353  **CALL SUBVEC(XRAY(1, 1), PXYZ, C)**  HYDR0, 202

43
HYDRO

428  XM1=MAG(C)+XM1  HYDRO,213
452  CONTINUE  HYDRO,214
454  IF(XM1,GT,TRAVL) MODE=1  HYDRO,215
460  RETURN  HYDRO,216
461  END  HYDRO,217

SUBPROGRAM LENGTH

00652

FUNCTION ASSIGNMENTS
EDITX

SUBROUTINE EDITX(PXY2)

THIS SUBPROGRAM LOOPS THROUGH THE EVENTS IN STORAGE UP TO THE SIMULATION TIME.
The array of pertinent events is stored in NCAG.

INPUTS:
- TOTAL NUMBER OF EVENTS UP TO TSIM
- SIMULATION TIME

OUTPUTS:
- NCAG ARRAY OF PERTINENT EVENT INDEXES
- NUMBER OF IMPORTANT EVENTS

THIS ROUTINE IS A FIRST CUT AT EDITING THE EVENTS.
The criteria used are simple and can reject events that should not be rejected and accept events that should be rejected.

IF AN EVENT IS ACCEPTED AS INFLUENCING THE POINT HISTORY, IT SHOULD BE CHECKED AFTER THE DETAILED CALCULATIONS HAVE BEGUN.

TIME DEPENDENT MODEL PARAMETERS

COMMON /GEOIN/ NF, INDEX(50), RTF(50), RF(50), GCF(50), GEOTX.
1 GEL(50), WILAF(50), WIMAF(50), WILCF(50), WIMCF(50), TILTF(50), WITF(50).
2 AGE(50), NTA, INDXD(100), DLADL(100), XNW(100), WEDO.
3 XH(100), RTF(100), RF(100), RFSE(100), NR(100), NRS(100), NMEP.
4 GCTA(100), GLBTA(100), TF(100), TCH(100), TCGD(50), TCHG(50), XERGO(50), XFR(100), XUT(50), GENTX.
5 XFR(50), YFR(100), ZFR(50), AUT(50), GENTX.
6 COMMON/EVXDAT/NX,NAX,XAX(100),XAGC(100), S1M, NGDT, TSHU(100).
7 EVXDAT.
8 COMMON/ADDAT/NX, XAX(100), XEVY(3,10), XEV(10), XEVX(3,10),
1 XAZ(100), XCEC(3,10)
2 COMMON/GEOMD/THETA, RR, RR, VNORM, OTEL, XROX, T2
3 COMMON/GEOMD/THETA, RR, RR, VNORM, OTEL, XROX, T2
4 COMMON/GEOMD/THETA, RR, RR, VNORM, OTEL, XROX, T2

EVENT PARAMETERS

COMMON /EVENTY/ NX, IDY, THF(50), RF(50), GCF(50), GLB(50),
1 GEL(50), WILAF(50), WIMAF(50), WILCF(50), WIMCF(50), TILTF(50), WITF(50).
2 AGE(50), NTA, INDXD(100), DLADL(100), XNW(100), WEDO.
3 XH(100), RTF(100), RF(100), RFSE(100), NR(100), NRS(100), NMEP.
4 GCTA(100), GLBTA(100), TF(100), TCH(100), TCGD(50), TCHG(50), XERGO(50), XFR(100), XUT(50), GENTX.
5 XFR(50), YFR(100), ZFR(50), AUT(50), GENTX.
6 COMMON/GEOMD/THETA, RR, RR, VNORM, OTEL, XROX, T2
7 DIMVCH/IDY(3), C(3), X(3), Y(3), M(3)
8 NNEWLIST/EDITX/PXY2+CAL, SRI2
9 BEGIN EVENT LOOP

NCMT = 0
1 COMMON/EVENTY/ NX, IDY, THF(50), RF(50), GCF(50), GLB(50),
2 AGE(50), NTA, INDXD(100), DLADL(100), XNW(100), WEDO.
3 XH(100), RTF(100), RF(100), RFSE(100), NR(100), NRS(100), NMEP.
4 GCTA(100), GLBTA(100), TF(100), TCH(100), TCGD(50), TCHG(50), XERGO(50), XFR(100), XUT(50), GENTX.
5 XFR(50), YFR(100), ZFR(50), AUT(50), GENTX.
6 COMMON/GEOMD/THETA, RR, RR, VNORM, OTEL, XROX, T2
7 BEGIN EVENT LOOP
8 NCMT = 0
9 COMMON/EVENTY/ NX, IDY, THF(50), RF(50), GCF(50), GLB(50),
10 AGE(50), NTA, INDXD(100), DLADL(100), XNW(100), WEDO.
11 XH(100), RTF(100), RF(100), RFSE(100), NR(100), NRS(100), NMEP.
12 GCTA(100), GLBTA(100), TF(100), TCH(100), TCGD(50), TCHG(50), XERGO(50), XFR(100), XUT(50), GENTX.
13 XFR(50), YFR(100), ZFR(50), AUT(50), GENTX.
IS THIS EVENT ACTIVE?  

16 READ CONTINUE
LOAD EVENT PARAMETERS FOR THE EVENT L

BEGIN CALCULATION
CALCULATE DISTANCE OF CLOSEST APPROACH

CALL DISCAP(YIN(1),XLEN(1),PXZ(1),M,S1,DIST,SRZ1)

16 PTS = DIST

31 IF(S1,L,T,-1.5*REV(L))TOIS=000000

43 IF(SRZ1-S1),(T,-1.5*REV(L))TOIS=85555

THE RADIUS RPY(L) SHOULD NOT BE USED HERE, R THE RADIUS OF THE EVENT NER THE POINT OF INTEREST SHOULD BE USED. HOWEVER, THIS RADIUS R REQUIRES EXTENSIVE CALCULATION NOT DESIGNED JUSTIFIED AT THIS POINT IN THE HISTORY PROCESS.

52 RHDIS/REV(L)

50 IF(RM,GT,1.8) GO TO 1000

40 IF(TOTIS,GT,7777,) GO TO 1000

67 IF(TOTIS,GT,TEST) GO TO 1000

73 NO=NOC

74 NCAGMCCYL

77 CONTINUE

102 NAFFCTN

103 RETURN

104 END
EDIT}

SUBROUTINE EDITX(PXZ)

THIS SUBPROGRAM LOOPS THROUGH THE EVENTS IN STORAGE UP TO THE SIMULATION TIME.

THE ARRAY OF PERTINENT EVENTS IS STORED IN NCAG.

INPUTS:

- THROUGH COMM EVTOUT
- NUMTOTAL NUMBER OF EVENTS UP TO TSIM
- TSIM SIMULATION TIME

OUTPUTS:

- NCAG array of NAI PERTINENT EVENT INDEXES
- NAINFO number of important events

THIS ROUTINE IS A FIRST CUT AT EDITING THE EVENTS.

THE CRITERIA USED ARE SIMPLE AND CAN REJECT EVENTS THAT SHOULD NOT BE REJECTED AND ACCEPT EVENTS THAT SHOULD BE REJECTED.

IF AN EVENT IS ACCEPTED AS INFLUENCING THE PAST HISTORY, IT SHOULD BE CHECKED AFTER THE DETAILED CALCULATIONS HAVE BEEN PERFORMED.

SUBROUTINE MVPP.

TIME DEPENDENT MODEL PARAMETERS

COMMON/GEOMETRY/XX, YY, ZZ, XX0, YY0, ZZ0, XX00, YY00, ZZ00, XX000, YY000, ZZ000, XX0000, YY0000, ZZ0000

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  

EVENT PARAMETERS

COMMON/EVENTS/X0, Y0, Z0, TH0, W0, M0, G0, GL0, GL1, GL2, GL3, GL4, GL5, GL6

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  

BEGIN EVENT LOOP

NCINFO

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  

RETURN

ENDX

SUBROUTINE SYZGY(R,VR,PSI,DIST,SRD,TOUT)
C THIS SUBPROGRAM CALCULATES THE DRIFT FUNCTION = TOUT FOR A GIVEN POINT RELATIVE TO A SPHERE.
C
INPUTS
C R=RAIDUS OF CURRENT EVENT AT TIME OF PASSAGE OF TP
C VR= VELOCITY
C PSI=STREAM FUNCTION VALUE
C
OUTPUTS
C T=TIME CONSTANT contour RELATED TO EVENT CENTER OF ZERO SYZYGY.
C
COMMON/CONST,RE,PI,THD,PZLRG,AZLRG,UZERO,TZERO,PIO2
C
COMMON/GEOM,THETA,RA,KM,VNORM,NT,AX,EQ,IU
C
COMMON/DATA,PIO2,15707963/
C
DIST IS A POSITIVE DEFINITE QUANTITY BY THE DEFINITION C OF THE COORDINATE FRAME
C
PSI=MAXX(PSI,5,57)
DIST=MAXX(DIST,1,6)
THETA=ATAN2(DIST,SRD)
23 IFLAG=0
24 VRMAX=VR/0
25 RESYN=(2.0*PSI)
31 COSC=1./SIN(THETA)
40 TAN=SRD/DIST
41 RC=0
42 RHIDIST
44 R2=DIST*COS/R
46 PHINT=1060*PI*RCA*SRD*PSI
1000 FGNMAT(1,16,+RCA,+1*PE12,5,16=1*PE12,5,1*PE12,5) RGA,SHD,PSI= +1*PE12,5)
72 IF(ULT,1,6)
117 IF(ULT,1,7) GO TO 50
146 UZ=AXDZ(1,16,+RCA,1*PE12,5) UZ=AXDZ(1,16) GO TO 50
164 T2=UZ/VNORM
165 TV=T2
166 IFLAG=1
167 IF(ULT,1,5) GO TO 100
176 IFLAG=0
176 GO TO 300
177 50 CONTINUE
177 100 CONTINUE
177 100 U2=RCA*COTAN*AXDZ
202 T2=U2/VNORM
203 IF(ULT,1,13) GO TO 500
206 200 CONTINUE
SYZYGY

206  \( B = R R \)

207  \( R = R B (R + 1) \)

212  UTZ=RR*P(R+R)2/(RR*3=R+1)=.111111*(1,0+0.2)...

1  ALG(RA/B/S0HT(RR=RR+R+1))=.19245*(1.0+RQ)*ATAN(1,73205)

2  (1+2*RR)

252  RR=RR

253  UTZ=UTZ+WZ

254  T=CUTZ/VNORM

255  IF(THEETA,LT,PICP) T=CUTZ

261  T=CUTF ETA,LT,PICP) T=CUTZ/VNORM+TZ

266  CONTINUE

266  T=CUTZ/VNORM

270  CONTINUE

271  CCUTZ

271  CONTINUE

277  T=CUTZ/VNORM

300  CONTINUE

301  RETURN

302  END

SUBPROGRAM LENGTH

0012
SUBROUTINE CIPHERT(PA, P, X, Y, Z, T, FLAG)

THIS SUBROUTINE CALCULATES THE POSITION OF A POINT IN
COORDINATES FIXED WITH THE SPHERE FOR A GIVEN STREAM
FUNCTION PP AND A GIVEN UNIT FUNCTION T (SEC)

INPUTS
TRANSFUNCTION IN SEC SCALLED TO A UNIT RISE VELOCITY,
PRESSURE FUNCTION FOR UNIT EVENT RADIUS AND UNIT VELOCITY

OUTPUTS
X=COORDINATE RELATIVE TO EVENT CENTER AND PERPENDICULAR TO
RISING VELOCITY
Y=COORDINATE AT TIME T IN UNITS RELATIVE TO
UNIT RADIUS AND RISE VELOCITY,
NFLAG=FLAG TO INDICATE WHETHER ANY CHANGE IN POSITION HAS OCCURRED.

COMMON/CONST, PI, PI3, PI4, ZERO, ZERO, ZERO, PI02

COMMON/GEOM, THETA, R, R, V, N, VM, T3, AND 0, Z

M=LENGTH OF PP, PS, PS(15), XX(15, 15)
DATA TI/10., 25., 35., 45., 55., 65., 75., 85., 95., 105.1/
A =*.3,.6,.9, 1.2, 1.5, 1.8, 2.1, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.2, 4.5, 4.8, 5.1, 5.4, 5.7, 6.0, 6.3, 6.6, 6.9, 7.2, 7.5, 7.8, 8.1, 8.4, 8.7, 9.0, 9.3, 9.6, 9.9, 10.2, 10.5, 10.8, 11.1, 11.4, 11.7, 12.0, 12.3, 12.6, 12.9, 13.2, 13.5, 13.8, 14.1, 14.4, 14.7, 15.0, 15.3, 15.6, 15.9, 16.2, 16.5, 16.8, 17.1, 17.4, 17.7, 18.0, 18.3, 18.6, 18.9, 19.2, 19.5, 19.8, 20.1, 20.4, 20.7, 21.0, 21.3, 21.6, 21.9, 22.2, 22.5, 22.8, 23.1, 23.4, 23.7, 24.0, 24.3, 24.6, 24.9, 25.2, 25.5, 25.8, 26.1, 26.4, 26.7, 27.0, 27.3, 27.6, 27.9, 28.2, 28.5, 28.8, 29.1, 29.4, 29.7, 30.0, 30.3, 30.6, 30.9, 31.2, 31.5, 31.8, 32.1, 32.4, 32.7, 33.0, 33.3, 33.6, 33.9, 34.2, 34.5, 34.8, 35.1, 35.4, 35.7, 36.0, 36.3, 36.6, 36.9, 37.2, 37.5, 37.8, 38.1, 38.4, 38.7, 39.0, 39.3, 39.6, 39.9, 40.2, 40.5, 40.8, 41.1, 41.4, 41.7, 42.0, 42.3, 42.6, 42.9, 43.2, 43.5, 43.8, 44.1, 44.4, 44.7, 45.0, 45.3, 45.6, 45.9, 46.2, 46.5, 46.8, 47.1, 47.4, 47.7, 48.0, 48.3, 48.6, 48.9, 49.2, 49.5, 49.8, 50.1, 50.4, 50.7, 51.0, 51.3, 51.6, 51.9, 52.2, 52.5, 52.8, 53.1, 53.4, 53.7, 54.0, 54.3, 54.6, 54.9, 55.2, 55.5, 55.8, 56.1, 56.4, 56.7, 57.0, 57.3, 57.6, 57.9, 58.2, 58.5, 58.8, 59.1, 59.4, 59.7, 60.0, 60.3, 60.6, 60.9, 61.2, 61.5, 61.8, 62.1, 62.4, 62.7, 63.0, 63.3, 63.6, 63.9, 64.2, 64.5, 64.8, 65.1, 65.4, 65.7, 66.0, 66.3, 66.6, 66.9, 67.2, 67.5, 67.8, 68.1, 68.4, 68.7, 69.0, 69.3, 69.6, 69.9, 70.2, 70.5, 70.8, 71.1, 71.4, 71.7, 72.0, 72.3, 72.6, 72.9, 73.2, 73.5, 73.8, 74.1, 74.4, 74.7, 75.0, 75.3, 75.6, 75.9, 76.2, 76.5, 76.8, 77.1, 77.4, 77.7, 78.0, 78.3, 78.6, 78.9, 79.2, 79.5, 79.8, 80.1, 80.4, 80.7, 81.0, 81.3, 81.6, 81.9, 82.2, 82.5, 82.8, 83.1, 83.4, 83.7, 84.0, 84.3, 84.6, 84.9, 85.2, 85.5, 85.8, 86.1, 86.4, 86.7, 87.0, 87.3, 87.6, 87.9, 88.2, 88.5, 88.8, 89.1, 89.4, 89.7, 90.0, 90.3, 90.6, 90.9, 91.2, 91.5, 91.8, 92.1, 92.4, 92.7, 93.0, 93.3, 93.6, 93.9, 94.2, 94.5, 94.8, 95.1, 95.4, 95.7, 96.0, 96.3, 96.6, 96.9, 97.2, 97.5, 97.8, 98.1, 98.4, 98.7, 99.0, 99.3, 99.6, 99.9
BEGIN INTERPOLATION OF X IN TABLE AT TIME T AND STREAM PSI.

C

CONTINUE

IF (T < T1(N1)) GO TO 210

CONTINUE

IF (T1(N1) - T1(NM - 1))
CIPHER

107  X=A*X(N1,N2)

111  X=GINTABS(A1*X1**2+A2*X2**2+A3*X3**2+A4*X4**2))

117  X=INTABS(X1*X2)

123  X=INTABS(X1*X2)

204  X=INTABS(X1*X2)

210  X=INTABS(X1*X2)

215  X=INTABS(X1*X2)

220  X=INTABS(X1*X2)

225  X=INTABS(X1*X2)

230  X=INTABS(X1*X2)

235  X=INTABS(X1*X2)

240  X=INTABS(X1*X2)

245  X=INTABS(X1*X2)

250  X=INTABS(X1*X2)

255  X=INTABS(X1*X2)

260  X=INTABS(X1*X2)

265  X=INTABS(X1*X2)

270  X=INTABS(X1*X2)

275  X=INTABS(X1*X2)

280  X=INTABS(X1*X2)

285  X=INTABS(X1*X2)

290  X=INTABS(X1*X2)

295  X=INTABS(X1*X2)

300  X=INTABS(X1*X2)

305  X=INTABS(X1*X2)

310  X=INTABS(X1*X2)

315  X=INTABS(X1*X2)

320  X=INTABS(X1*X2)

325  X=INTABS(X1*X2)

330  X=INTABS(X1*X2)

335  X=INTABS(X1*X2)

340  X=INTABS(X1*X2)

345  X=INTABS(X1*X2)

350  X=INTABS(X1*X2)

355  X=INTABS(X1*X2)

360  X=INTABS(X1*X2)

365  X=INTABS(X1*X2)

370  X=INTABS(X1*X2)

375  X=INTABS(X1*X2)

380  X=INTABS(X1*X2)

385  X=INTABS(X1*X2)

390  X=INTABS(X1*X2)

395  X=INTABS(X1*X2)

400  X=INTABS(X1*X2)

405  X=INTABS(X1*X2)

410  X=INTABS(X1*X2)

415  X=INTABS(X1*X2)

420  X=INTABS(X1*X2)

425  X=INTABS(X1*X2)

430  X=INTABS(X1*X2)

435  X=INTABS(X1*X2)

440  X=INTABS(X1*X2)

445  X=INTABS(X1*X2)

450  X=INTABS(X1*X2)

455  X=INTABS(X1*X2)

460  X=INTABS(X1*X2)

465  X=INTABS(X1*X2)

470  X=INTABS(X1*X2)

475  X=INTABS(X1*X2)

480  X=INTABS(X1*X2)

485  X=INTABS(X1*X2)

490  X=INTABS(X1*X2)

495  X=INTABS(X1*X2)

500  X=INTABS(X1*X2)

505  X=INTABS(X1*X2)

510  X=INTABS(X1*X2)

515  X=INTABS(X1*X2)

520  X=INTABS(X1*X2)

525  X=INTABS(X1*X2)

530  X=INTABS(X1*X2)

535  X=INTABS(X1*X2)

540  X=INTABS(X1*X2)

545  X=INTABS(X1*X2)

550  X=INTABS(X1*X2)

555  X=INTABS(X1*X2)

560  X=INTABS(X1*X2)

565  X=INTABS(X1*X2)

570  X=INTABS(X1*X2)

575  X=INTABS(X1*X2)

580  X=INTABS(X1*X2)

585  X=INTABS(X1*X2)

590  X=INTABS(X1*X2)

595  X=INTABS(X1*X2)

600  X=INTABS(X1*X2)

605  X=INTABS(X1*X2)

610  X=INTABS(X1*X2)

615  X=INTABS(X1*X2)

620  X=INTABS(X1*X2)

625  X=INTABS(X1*X2)

630  X=INTABS(X1*X2)

635  X=INTABS(X1*X2)

640  X=INTABS(X1*X2)

645  X=INTABS(X1*X2)

650  X=INTABS(X1*X2)

655  X=INTABS(X1*X2)

660  X=INTABS(X1*X2)

665  X=INTABS(X1*X2)

670  X=INTABS(X1*X2)

675  X=INTABS(X1*X2)

680  X=INTABS(X1*X2)

685  X=INTABS(X1*X2)

690  X=INTABS(X1*X2)

695  X=INTABS(X1*X2)

700  X=INTABS(X1*X2)

705  X=INTABS(X1*X2)

710  X=INTABS(X1*X2)

715  X=INTABS(X1*X2)

720  X=INTABS(X1*X2)

725  X=INTABS(X1*X2)

730  X=INTABS(X1*X2)

735  X=INTABS(X1*X2)

740  X=INTABS(X1*X2)

745  X=INTABS(X1*X2)

750  X=INTABS(X1*X2)

755  X=INTABS(X1*X2)

760  X=INTABS(X1*X2)

765  X=INTABS(X1*X2)

770  X=INTABS(X1*X2)

775  X=INTABS(X1*X2)

780  X=INTABS(X1*X2)

785  X=INTABS(X1*X2)

790  X=INTABS(X1*X2)

795  X=INTABS(X1*X2)

800  X=INTABS(X1*X2)

805  X=INTABS(X1*X2)

810  X=INTABS(X1*X2)

815  X=INTABS(X1*X2)

820  X=INTABS(X1*X2)

825  X=INTABS(X1*X2)

830  X=INTABS(X1*X2)

835  X=INTABS(X1*X2)

840  X=INTABS(X1*X2)

845  X=INTABS(X1*X2)

850  X=INTABS(X1*X2)

855  X=INTABS(X1*X2)

860  X=INTABS(X1*X2)

865  X=INTABS(X1*X2)

870  X=INTABS(X1*X2)

875  X=INTABS(X1*X2)

880  X=INTABS(X1*X2)

885  X=INTABS(X1*X2)

890  X=INTABS(X1*X2)

895  X=INTABS(X1*X2)

900  X=INTABS(X1*X2)

905  X=INTABS(X1*X2)

910  X=INTABS(X1*X2)

915  X=INTABS(X1*X2)

920  X=INTABS(X1*X2)

925  X=INTABS(X1*X2)

930  X=INTABS(X1*X2)

935  X=INTABS(X1*X2)

940  X=INTABS(X1*X2)

945  X=INTABS(X1*X2)

950  X=INTABS(X1*X2)

955  X=INTABS(X1*X2)

960  X=INTABS(X1*X2)

965  X=INTABS(X1*X2)

970  X=INTABS(X1*X2)

975  X=INTABS(X1*X2)

980  X=INTABS(X1*X2)

985  X=INTABS(X1*X2)

990  X=INTABS(X1*X2)

995  X=INTABS(X1*X2)

1000 X=INTABS(X1*X2)
<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>353</td>
<td>66n</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>354</td>
<td>X=X*X</td>
<td>CIPHEF, 224</td>
</tr>
<tr>
<td>355</td>
<td>XNOR=ABS(X-2.*P)+.000001</td>
<td>CIPHEF, 225</td>
</tr>
<tr>
<td>361</td>
<td>Y=LN(S(X/ONCH)**.66666=2)</td>
<td>CIPHEF, 226</td>
</tr>
<tr>
<td>365</td>
<td>Y=F.SURF(V)</td>
<td>CIPHEF, 227</td>
</tr>
<tr>
<td>373</td>
<td>IF(TLT.RANDT(FP,PS,N2)) Y=Y</td>
<td>CIPHEF, 228</td>
</tr>
<tr>
<td>404</td>
<td>800</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>408</td>
<td>RETURN</td>
<td>CIPHEF, 230</td>
</tr>
<tr>
<td>405</td>
<td>END</td>
<td>CIPHEF, 231</td>
</tr>
</tbody>
</table>

**SUBPROGRAM I.FNGTH**
SCCK

SUBROUTINE SCCK(YOU,K,ALPHA,XSAV)

THIS SUBROUTINE CALCULATES THE SHOCK DISPLACEMENT OF POINT YOU FROM EVENT K, GIVING THE NEW POSITION XSAV.

INPUTS
XOU: INITIAL POSITION
K: EVENT NUMBER
ALPHA: SHOCK SCALING PARAMETER

OUTPUT
XSAV: FINAL POSITION AFTER DISPLACEMENT.

TIME DEPENDENT MODEL PARAMETERS
COMMON /GEOM/ NF, INDEX(50), NT(50), RL(50), KF(50), GCF(50), GFNTDK.
1
GLF(50), M+X(50), M+NX(50), KINF(50), TILTF(50), GFNTDK.
2
AGE(50), NOTA, INDEX(100), GLADL(100), NOT(100), GFNTDK.
3
HNS(100), KNS(100), HNSL(100), HNS(100), HNSL(100), GFNTDK.
4
GCTAY(100), GLRATA(100), IF(50), TCMAR(50), VNLG(50), GFNTDK.
5
XIR(50), YIR(50), ZIR(50), PUT(50), GFNTDK.
6
COMM/SHADAT/XIN(10), XELV(10), YELV(10), ZELV(10), RADAT(10), WADAT(10).
7
VIRZ(10), CVLC(10), WADAT(10), RADAT(10), RADAT(10).

EVENT PARAMETERS
COMMON /EVENTS/ XU, IXO, IX(50), HA(50), GCR(50), GLU(50),
1
IDUR(50), PNO(50), HR(50), TEH(50), VRSL(50), EVENT.
2
RZERO(50), HZERHC(50), HZERAC(50), HZEB(50), EVENT.
3
BYB(50), RZB(50), LRVB(50), XALPHA(50), KALC
EVENT.

FINAL POSITION OF EVENT K, FIRST FIND DISTANCE BETWEEN EVENT AND POINT.

DIMENSION XOU(3), XSAV(3), C(1,3), D(3)

CALL SURVEC(XU(1),XIN(1,K),C)

S=XMAG(C)

CALL SURVEC(XU(1),XSAV(1,1),D)

RETURN

END

SUBPROGRAM LENGTH
00101

FUNCTION ASSIGNMENTS
FUNCTION ROOTT(FP, PS, N2)

THIS FUNCTION SUBPROGRAM CALCULATES THE TIME CONTOUR THAT
CROSSES ZERO AT A GIVEN STREAM FUNCTION VALUE

INPUT
INPUT DEFINED IN CIPHER

OUTPUT
TIME OF CONTOUR CROSSING ZERO AXIS FOR GIVEN X

DIMENSION PS(15), TCRS(15)
DATA TCPS/4.396, 3.41, 2.77, 1.71, 1.69, 1.67, 1.65, 1.63, 1.61, 1.59, 1.55, 1.52, 1.47, 1.42, 1.37, 1.32, 1.27, 1.22, 1.18, 1.15, 1.12, 1.08, 1.05/1
1
.221, .1727, .104, .0156, .0013/
A1=FP
A2=1.+FP
A3=TCRS(N2)**2*TCRS(N2-1)**A1
RETURN
END

SUBPROGRAM LENGTH

00056
SUBROUTINE DISCAP(P,Q,D,M,S1,DIST,BZ1)

THIS ROUTINE FINDS THE CLOSEST DISTANCE TO THE LINE OF CENTERS
OF INITIAL EVENT POSITION AND FINAL EVENT POSITION.
USES VECTOR ANALYSIS AND ROSEE LIBRARY.

DIMENSION P(3),Q(3),D(3),F(3),H(3),M(3)
DIMENSION D(3)

CALL SUBVEC(Q,P,C)
CALL SUBVEC(D,P,F)
CALL P Vec(F,C,R)
CALL SUBVEC(G,F,R)

DIST(REHAG(R))

CALL VECLINE(AP,D,AP,RH)

BIRXMAG(G)

Determine the sense of G with respect to C

AMCOT(C,G)
SIGN(S),AM

RETURN
END

SUBPROGRAM LENGTH
00125
SUBROUTINE EVNAD(SPOU,NAI,PIXZ,XOU)

C

C THIS SUBPROGRAM DOES THE VECTOR ADDITION OF THE POSITION PIXZ
C TO GIVE A FINAL DISPLACEMENT.

C INPUTS

SPCU(L,L)=POSITION ARRAY OF POINT AFTER AFFECT FROM EVENT L

C OUTPUT

XOU(L)=FINAL VECTOR POSITION

C

DIMENSION SPOU(L,4),PIXZ(L),XOU(L),C(L)

CALL XINIT(0,0,0)

DO 10 L=1,NN1

10 LLM=L

CALL VECSUM(A,SPCU(L,L),B,SPOU(LL,L),C)

B=A

CALL VECADD(A,L,SPCU(1,L),B,SPOU(1,L),C)

RETURN

END

SUBPROGRAM LENGTH
00027
SECTION VI

TYPICAL OUTPUT

Three test problems were run to give some typical output from the flow field models. Each test problem consisted of finding a position at burst times of a given particle at the calculation times. The first two problems consisted of a single event at 43 km and a spherical Vortex radius of 8.68 km. The last test problem consisted of a five burst scenario at relatively small yields and altitudes.

The output gives the number of actual events that have occurred as distinguished from hydromerged events. The values of the parameters are given for both the initial and the calculation time. The initial parameters are labeled with the "Type" - INITIAL; the calculation time parameters have a "Type" - ACTUAL. The height, colatitude and longitude are given along with the indexes of the fireballs affecting the point. The position of the point at the burst time is then given.

For example, the first test problem has a point at 48 km at 2.7 sec; at 0.0 sec the point is at 41 km. The drastic change is altitude for such a short time span is a result in assuming that the shock arrives instantaneously at burst time. A correction of this error has been made and will appear in the next version. The shock error is even more apparent for the given point at 70 km at 2.78 sec which was at 53 km at 0.0 sec.
## OUTPUT FOR FLCH FIELD TEST — PROBLEM NUMBER 1

**NUMBER OF ACTUAL EVENTS = 1**

**COORDINATES AT BURST TIME FOR 1 EVENTS**

<table>
<thead>
<tr>
<th>EVENT NO.</th>
<th>TIME (GMT)</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>43.0000</td>
<td>41.2988</td>
<td>238.9807</td>
<td></td>
<td>0.0000</td>
<td>INITI</td>
</tr>
</tbody>
</table>

**COORDINATES OF 1 EVENTS AT CALCULATION TIME = 2.780**

<table>
<thead>
<tr>
<th>EVENT NO.</th>
<th>TIME (GMT)</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.78</td>
<td>45.1565</td>
<td>41.2988</td>
<td>238.9807</td>
<td>6.34633</td>
<td>0.0562637</td>
<td>ACTU</td>
</tr>
</tbody>
</table>

**POSITION OF POINT AT CALCULATION TIME = 2.78SEC**

- HEIGHT(Km): 45.0000
- COLATITUDE: 41.2449
- LONGITUDE: 238.9807

**POINT APPEARS INSIDE BURST NUMBER 1**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>44.3261</td>
<td>41.2761</td>
<td>238.9807</td>
<td></td>
<td>0.0000</td>
<td>INITI</td>
</tr>
</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>44.0000</td>
<td>41.2449</td>
<td>238.9807</td>
<td></td>
<td>0.0000</td>
<td>INITI</td>
</tr>
</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>44.0000</td>
<td>41.2449</td>
<td>238.9807</td>
<td></td>
<td>0.0000</td>
<td>INITI</td>
</tr>
</tbody>
</table>

**POINT APPEARS INSIDE BURST NUMBER 1**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>53.3256</td>
<td>41.2781</td>
<td>238.9807</td>
<td></td>
<td>0.0000</td>
<td>INITI</td>
</tr>
</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 0 INDEXES ARE 0**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGH (Km)</th>
<th>COLATITUDE (deg)</th>
<th>LONGITUDE (deg)</th>
<th>RADIUS (km)</th>
<th>VELOCITY (km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>53.3256</td>
<td>41.2781</td>
<td>238.9807</td>
<td></td>
<td>0.0000</td>
<td>INITI</td>
</tr>
<tr>
<td>EVENT NO.</td>
<td>TIME (H)</td>
<td>HEIGHT (K)</td>
<td>COLATITUDE (D)</td>
<td>LONGITUDE (D)</td>
<td>RADIUS (K)</td>
<td>VELOCITY (K/S)</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>------------</td>
<td>----------------</td>
<td>---------------</td>
<td>------------</td>
<td>----------------</td>
</tr>
<tr>
<td>1</td>
<td>25.00</td>
<td>56.9528</td>
<td>41.2988</td>
<td>238.9807</td>
<td>11.8921</td>
<td>5581114</td>
</tr>
</tbody>
</table>

**POSITION OF POINT AT CALCULATION TIME = 25.00SEC**

<table>
<thead>
<tr>
<th>HEIGHT (K)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.0000</td>
<td>41.2449</td>
<td>238.9807</td>
</tr>
</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 1**

**INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (K)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0.00</td>
<td>44.2030</td>
<td>41.2489</td>
<td>238.9807</td>
</tr>
</tbody>
</table>

**HEIGHT (K) | COLATITUDE | LONGITUDE**

| 51.0000    | 41.2449    | 238.9807  |

**POINT APPEARS INSIDE BURST NUMBER 1**

**HEIGHT (K) | COLATITUDE | LONGITUDE**

| 48.0000    | 41.2449    | 238.9807  |

**POINT APPEARS INSIDE BURST NUMBER 1**

**HEIGHT (K) | COLATITUDE | LONGITUDE**

| 44.0000    | 41.2449    | 238.9807  |

**NUMBER OF EVENTS AFFECTING POINT = 1**

**INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (K)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0.00</td>
<td>43.3918</td>
<td>41.2489</td>
<td>238.9807</td>
</tr>
</tbody>
</table>

**HEIGHT (K) | COLATITUDE | LONGITUDE**

| 70.0000    | 41.2449    | 238.9807  |

**NUMBER OF EVENTS AFFECTING POINT = 1**

**INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (K)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0.00</td>
<td>42.7415</td>
<td>41.2943</td>
<td>238.9807</td>
</tr>
</tbody>
</table>

**HEIGHT (K) | COLATITUDE | LONGITUDE**

<p>| 74.0000    | 41.2449    | 238.9807  |</p>
<table>
<thead>
<tr>
<th>EVENT NO.</th>
<th>TIME (SEC)</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE (DEG)</th>
<th>LONGITUDE (DEG)</th>
<th>RADIUS (KM)</th>
<th>VELOCITY (KMS)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50,000</td>
<td>71.577</td>
<td>41.2486</td>
<td>238.9807</td>
<td>17.34179</td>
<td>5715537</td>
<td>ACTUAL</td>
</tr>
</tbody>
</table>

**COORDINATES OF EVENTS AT CALCULATION TIME = 50,000 SEC**

**HEIGHT (KM) COORDINATE LONGITUDE RADIUS (KM) VELOCITY (KMS) TYPE**

**ACTUAL**

**POSITION OF POINT AT CALCULATION TIME = 50,000 SEC**

**HEIGHT (KM) COORDINATE LONGITUDE**

**45,0000 41.2440 238.9807**

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE**

**1 POSITIONS OF POINT AT EVENT TIMES**

**EVENT TIME HEIGHT (KM) COORDINATE LONGITUDE**

**1 0.00 44.7787 41.2426 238.9807**

**HEIGHT (KM) COORDINATE LONGITUDE**

**51.000 41.2440 238.9807**

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE**

**1 POSITIONS OF POINT AT EVENT TIMES**

**EVENT TIME HEIGHT (KM) COORDINATE LONGITUDE**

**1 0.00 48.8496 41.2555 238.9807**

**HEIGHT (KM) COORDINATE LONGITUDE**

**48.0000 41.2440 238.9807**

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE**

**1 POSITIONS OF POINT AT EVENT TIMES**

**EVENT TIME HEIGHT (KM) COORDINATE LONGITUDE**

**1 0.00 44.8942 41.2430 238.9807**

**HEIGHT (KM) COORDINATE LONGITUDE**

**44.0000 41.2440 238.9807**

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE**

**1 POSITIONS OF POINT AT EVENT TIMES**

**EVENT TIME HEIGHT (KM) COORDINATE LONGITUDE**

**1 0.00 44.1808 41.2410 238.9807**

**HEIGHT (KM) COORDINATE LONGITUDE**

**70.0000 41.2440 238.9807**

**POINT APPEARS INSIDE BURST NUMBER = 1**
### Coordinates of 1 Events at Calculation Time = 75,000

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Time</th>
<th>Height (km)</th>
<th>Co-latitude</th>
<th>Longitude</th>
<th>Ecliptic (km/s)</th>
<th>Velocity (km/s)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>75,000</td>
<td></td>
<td>85,959</td>
<td>41,2988</td>
<td>238,9807</td>
<td>22,09456</td>
<td>54,20841</td>
<td>Actual</td>
</tr>
</tbody>
</table>

**Position of Point at Calculation Time = 75,000 Sec**

<table>
<thead>
<tr>
<th>Height (km)</th>
<th>Co-latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>41,2449</td>
<td>238,9807</td>
<td></td>
</tr>
</tbody>
</table>

**Number of Events Affecting Point = 1** Indexes Are 1

**Positions of Point at Event Times**

<table>
<thead>
<tr>
<th>Event Time</th>
<th>Height (km)</th>
<th>Co-latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00</td>
<td>44,9750</td>
<td>41,2413</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Height (km) | Co-latitude | Longitude |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>51,0000</td>
<td>41,2449</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Number of Events Affecting Point = 1** Indexes Are 1

**Positions of Point at Event Times**

<table>
<thead>
<tr>
<th>Event Time</th>
<th>Height (km)</th>
<th>Co-latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00</td>
<td>49,4530</td>
<td>41,2511</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Height (km) | Co-latitude | Longitude |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>48,0600</td>
<td>41,2449</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Number of Events Affecting Point = 1** Indexes Are 1

**Positions of Point at Event Times**

<table>
<thead>
<tr>
<th>Event Time</th>
<th>Height (km)</th>
<th>Co-latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00</td>
<td>47,0339</td>
<td>41,2453</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Height (km) | Co-latitude | Longitude |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>44,0600</td>
<td>41,2449</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Number of Events Affecting Point = 1** Indexes Are 1

**Positions of Point at Event Times**

<table>
<thead>
<tr>
<th>Event Time</th>
<th>Height (km)</th>
<th>Co-latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00</td>
<td>44,0580</td>
<td>41,2410</td>
<td>238,9807</td>
</tr>
</tbody>
</table>

**Height (km) | Co-latitude | Longitude |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>70,0000</td>
<td>41,2449</td>
<td>238,9807</td>
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</tbody>
</table>

**Point Appears Inside Burst Number 1**
**OUTPUT FOR FLOW FIELD TEST**

**PROBLEM NUMBER** 2

**NUMBER OF ACTUAL EVENTS** 1

**COORDINATES AT BURST TIME FOR 1 EVENTS**

<table>
<thead>
<tr>
<th>EVENT NO.</th>
<th>TIME (M)</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
<th>RADIUS (Km)</th>
<th>VELOCITY (Km/s)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
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<td>41.2988</td>
<td>236.9807</td>
<td>6.68008</td>
<td>0.00000000 Initial</td>
<td></td>
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**COORDINATES OF 1 EVENTS AT CALCULATION TIME = 25,000**

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<thead>
<tr>
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<th>TIME (M)</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
<th>RADIUS (Km)</th>
<th>VELOCITY (Km/s)</th>
<th>TYPE</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>25.00</td>
<td>56.9528</td>
<td>41.2988</td>
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**POSITION OF POINT AT CALCULATION TIME = 25,000 SEC**

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<tr>
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<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
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</thead>
<tbody>
<tr>
<td>43.0000</td>
<td>41.2988</td>
<td>236.9807</td>
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</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1 POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
<th>RADIUS (Km)</th>
<th>VELOCITY (Km/s)</th>
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<tbody>
<tr>
<td>0.00</td>
<td>38.3511</td>
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**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1 POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
<th>RADIUS (Km)</th>
<th>VELOCITY (Km/s)</th>
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</thead>
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<tr>
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**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1 POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
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<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
<th>RADIUS (Km)</th>
<th>VELOCITY (Km/s)</th>
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**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1 POSITIONS OF POINT AT EVENT TIMES**

<table>
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<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (M)</th>
<th>LONGITUDE (M)</th>
<th>RADIUS (Km)</th>
<th>VELOCITY (Km/s)</th>
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<tr>
<td>0.00</td>
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64
<table>
<thead>
<tr>
<th>EVENT NO.</th>
<th>TIME (SEC)</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
<th>RADIUS (KM)</th>
<th>VELOCITY (KM/S)</th>
<th>TYPE</th>
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**COORDINATES OF EVENTS AT CALCULATION TIME = 50.000**

**POSITION OF POINT AT CALCULATION TIME = 50.000 SEC**

<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
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</thead>
<tbody>
<tr>
<td>43.0000</td>
<td>41.2988</td>
<td>238.9807</td>
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</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>30,000</td>
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<td>41,000</td>
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<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.0000</td>
<td>41.2444</td>
<td>238.9807</td>
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</table>

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
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<td>41,000</td>
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<table>
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<tr>
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<th>LONGITUDE</th>
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</thead>
<tbody>
<tr>
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<td>238.9807</td>
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**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>30,000</td>
<td>35,000</td>
<td>41,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.0000</td>
<td>41.2444</td>
<td>238.9807</td>
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**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 1**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>30,000</td>
<td>35,000</td>
<td>41,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
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</thead>
<tbody>
<tr>
<td>25.0000</td>
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**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 0**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
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<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
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<td>41,000</td>
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</tbody>
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<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
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</thead>
<tbody>
<tr>
<td>25.0000</td>
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<td>238.9807</td>
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</tbody>
</table>

**NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 0**

**POSITIONS OF POINT AT EVENT TIMES**

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
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<td>41,000</td>
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<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
<th>LONGITUDE</th>
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</thead>
<tbody>
<tr>
<td>25.0000</td>
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</table>
COORDINATES OF EVENTS AT CALCULATION TIME = 75,000 SEC

<table>
<thead>
<tr>
<th>EVENT NO.</th>
<th>TIME (SEC)</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
<th>VELOCITY (Km/S)</th>
<th>TYPE</th>
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<tbody>
<tr>
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<td>42,69450</td>
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POSITION OF POINT AT CALCULATION TIME = 75,00SEC

<table>
<thead>
<tr>
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<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.0000</td>
<td>41.2988</td>
<td>238.9807</td>
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</tbody>
</table>

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE
POSITIONS OF POINT AT EVENT TIMES

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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</thead>
<tbody>
<tr>
<td>1 0.00</td>
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<table>
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<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.0000</td>
<td>41.2444</td>
<td>239.9807</td>
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</table>

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE
POSITIONS OF POINT AT EVENT TIMES

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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</thead>
<tbody>
<tr>
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<table>
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<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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</thead>
<tbody>
<tr>
<td>39.0000</td>
<td>41.2444</td>
<td>238.9807</td>
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</table>

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE
POSITIONS OF POINT AT EVENT TIMES

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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</thead>
<tbody>
<tr>
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<td>41.2358</td>
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<thead>
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<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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</thead>
<tbody>
<tr>
<td>35.0000</td>
<td>41.2444</td>
<td>239.9807</td>
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NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE
POSITIONS OF POINT AT EVENT TIMES

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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<table>
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<th>LONGITUDE (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0000</td>
<td>41.2444</td>
<td>239.9807</td>
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</table>

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE
POSITIONS OF POINT AT EVENT TIMES

<table>
<thead>
<tr>
<th>EVENT TIME</th>
<th>HEIGHT (Km)</th>
<th>COLATITUDE (D)</th>
<th>LONGITUDE (D)</th>
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</thead>
<tbody>
<tr>
<td>1 0.00</td>
<td>25.2216</td>
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### Output for Flow Field Test 3

**Problem Number:** 3

**Number of Actual Events:** 5

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Time (Sec)</th>
<th>Height (KM)</th>
<th>CLATITUDE</th>
<th>Longitude</th>
<th>Radius (KM)</th>
<th>Velocity (Km/S)</th>
<th>Type</th>
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<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>5.0000</td>
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<td>239.0093</td>
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<tr>
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<tr>
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<tr>
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**Coordinates of 5 Events at Calculation Time:** 22,000

<table>
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<th>Time (Sec)</th>
<th>Height (KM)</th>
<th>CLATITUDE</th>
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<th>Radius (KM)</th>
<th>Velocity (Km/S)</th>
<th>Type</th>
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<td>0.053219 ACTUAL</td>
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<td>239.0093</td>
<td>0.00</td>
<td>0.056068 ACTUAL</td>
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<td>0.004160 ACTUAL</td>
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**Position of Point at Calculation Time:** 22,000SEC

<table>
<thead>
<tr>
<th>HEIGHT (KM)</th>
<th>CLATITUDE</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
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<td>9.0000</td>
<td>41.2958</td>
<td>238.9864</td>
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</table>

**Number of Events Affecting Point:** 1 Indexes Are 2

**Positions of Point at Event Times**

<table>
<thead>
<tr>
<th>Event Time</th>
<th>Height (KM)</th>
<th>CLATITUDE</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
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<td>8.9539</td>
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**Number of Events Affecting Point:** 2 Indexes Are 2

**Positions of Point at Event Times**

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**Number of Events Affecting Point:** 2 Indexes Are 2

**Positions of Point at Event Times**

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<td>1.00</td>
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**Number of events affecting point = 1**

**Positions of point at event times**

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**Coordinates of 5 events at calculation time = 30,000**

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<th>Height (km)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Radius (km)</th>
<th>Velocity (km/s)</th>
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**Position of point at calculation time = 30,000sec**

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<th>Latitude</th>
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<th>Velocity (km/s)</th>
<th>Type</th>
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**Number of events affecting point = 1**

**Positions of point at event times**

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**Height (km) | Latitude | Longitude**
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**Number of events affecting point = 2**

**Positions of point at event times**

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<td>Colatitude</td>
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Point appears inside burst number 2

Point appears inside burst number 3
## COORDINATES OF 6 EVENTS AT CALCULATION TIME = 40,000

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<th>TIME</th>
<th>HEIGHT (KM)</th>
<th>COLATITUDE</th>
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<th>RADIUS (KM)</th>
<th>VELOCITY (KM/S)</th>
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## POSITION OF POINT AT CALCULATION TIME = 40,000 SEC

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### NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 2

### POSITIONS OF POINT AT EVENT TIMES

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### NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2

### POSITIONS OF POINT AT EVENT TIMES

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### NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2

### POSITIONS OF POINT AT EVENT TIMES

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