The program Cones calculates asymptotic directions of particles for fixed geographical point and date. From a given height, antiprotons of various rigidity are lunched, their trajectories traced and asymptotic coordinates of the arrival of particles are determined. The program can calculate trajectories in one of the magnetosphere model: dipole, IGRF, Tsyganenko-89, 96, 02. Particles are lunched under given vertical and azimuth angles.

All input parameters are written in the file Cones.ini.

```
Input parameters for the program CONES:
01.07.2015 Date
00:00:00   Time
   1.37    Solar wind dynamic pressure (nP)     0.1 -     4
 -23.0     Dst-index (nT)                  +50   -  -500
  -2.20    IMF By    (nT)                  +30   -   -30
  -4.40    IMF Bz    (nT)                  +30   -   -30
   6.49    G1
  11.51     G2
  10.0     G3
   3       Kp-index
  10        Model 00-dipole, 10-IGRF, 89-T89_Kp, 96-T96_01, 01-T01_01, 03-T01S
  20.00    Height    (km)
 0         Output in GEO [0], GSE [1] or GSM [2]
-180. 180. Longitudinal limits for grafics
#          Geogr.latitude and longitude, vertical and azimuthally angles
c 35.00 -106.00  0   0 Albuquerque
c 43.10   76.60  0   0 AlmaataB
 67.57   33.39  0   0 Apatity
c 37.58   23.47  0   0 Athens
c -41.00  174.00  0   0 Arneb
c 43.28   42.69  0   0 Baksan
c 78.08   14.15  0   0 Barentsburg
#            Set of rigidities
999.00
500.00
200.00
170.00
160.00
150.00
140.00
130.00
120.00
110.00
100.00
90.00
80.00
70.00
64.00
63.00
61.00
60.00
59.00
58.00
57.00
56.00
53.00
50.00
30.00
```

20.00
15.00
12.00
11.00
10.50
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.90

where
• Date and Time UT.
• Further 8 parameters for different models of magnetosphere are following.
Dipol and IGRF need not the input parameters.
T-89 – uses only Kp-index.
T-96 – uses the first 4parameters, and
T-01 – uses the first 6 parameters

| Model | Setting Parameters | Range of the measured Parameter changes |
|---|---|---|
| Диполь | No | нет |
| IGRF | Epoch | 1900–2050 (extrapolation 2020–2050) |
| IGRF+T89 | Date and Time (UT)<br>Kp | 1900–2050 (extrapolation 2020–2050)<br>0÷9 |
| IGRF+T96 | Date and Time (UT)<br>Dynamical pressure of the Solar wind (nPa)<br>$D_{st}$–index (nT)<br>IMF $B_y$ (nT)<br>IMF $B_z$ (nT) | 1900–2050<br>0.1÷4<br>+50÷-500<br>±30<br>±20 |
| IGRF+T01 | Date and Time (UT)<br>Dynamical pressure of the Solar wind (nPa)<br>$D_{st}$–index (nT)<br>IMF $B_y$ (nT)<br>IMF $B_z$ (nT)<br>$G_1$<br>$G_2$<br>$G_3$ | 1900–2050<br>0.1÷4<br>+50÷-500<br>±30<br>±20<br>0÷20<br>0÷20<br>0÷20 |

• Next parameter is the height with which antiprotons are launched, (20 km).
• Further – the kind of the coordinate system is going: GEO, GSE or GSM in which the asymptotic directions are calculated.
Further – thye range of longitudes for graphics plotting.
Next - there is a comment list of detectors preceded by coordinates (latitude and longitude) and angle of particles start (zenith and azimuth angle). Calculations are carried out only for uncommented detectors.
• Next –there is the list of rigidities for which the asymptotic directions are calculated.

**ВЫХОДНЫЕ ДАННЫЕ**

In the end the file Cones.dat is output: one line for each rigidity (Rigidity, latitude and longitude).

| Rig_GV | ApaLa | ApaLo |
|---|---|---|
| 999.00 | 67.5 | 35.2 |
| 500.00 | 67.5 | 36.9 |
| 200.00 | 67.1 | 42.0 |
| 170.00 | 66.9 | 43.4 |
| 160.00 | 66.8 | 44.0 |
| 150.00 | 66.7 | 44.6 |
| 140.00 | 66.6 | 45.4 |
| 130.00 | 66.5 | 46.2 |
| 120.00 | 66.3 | 47.2 |
| 110.00 | 66.1 | 48.3 |
| 100.00 | 65.8 | 49.5 |
| 90.00 | 65.4 | 51.0 |
| 80.00 | 64.9 | 52.8 |
| 70.00 | 64.2 | 54.8 |
| 64.00 | 63.6 | 56.3 |
| 63.00 | 63.5 | 56.5 |
| 61.00 | 63.2 | 57.0 |
| 60.00 | 63.1 | 57.3 |
| 59.00 | 63.0 | 57.5 |
| 58.00 | 62.8 | 57.8 |
| 57.00 | 62.7 | 58.1 |
| 56.00 | 62.5 | 58.4 |
| 53.00 | 62.1 | 59.2 |
| 50.00 | 61.5 | 60.1 |
| 30.00 | 54.5 | 66.2 |
| 20.00 | 46.6 | 67.0 |
| 15.00 | 41.2 | 65.0 |
| 12.00 | 38.5 | 63.2 |
| 11.00 | 38.0 | 62.9 |
| 10.50 | 37.8 | 62.9 |
| 10.00 | 37.6 | 63.1 |
| 9.00 | 37.2 | 64.1 |
| 8.00 | 36.2 | 66.2 |
| 7.00 | 33.4 | 69.1 |
| 6.00 | 28.5 | 70.8 |
| 5.00 | 24.2 | 70.1 |
| 4.00 | 22.2 | 73.0 |
| 3.00 | 14.0 | 76.2 |
| 2.00 | 4.7 | 85.4 |
| 1.00 | -12.2 | 120.1 |
| 0.90 | -12.2 | 130.3 |

# CALCULATING PARAMETERS.

•**Calculation** of the solar wind dynamic pressure**.**

The pressure of the solar wind is the magnitude of the derivative of the velocity and density of the solar wind plasma and is calculated from the formula: $\boldsymbol{P}$=1.673 $10^{-6}\times\boldsymbol{n}\times\boldsymbol{V}^2$ , where $\boldsymbol{P}$ – is a pressure [nPa], $\boldsymbol{n}$ – density of the particles [$cm^{-3}$], $\boldsymbol{V}$ – particle velocity [km/s].

**•Calculation of $G_1$ , $G_2$ and $G_3$.**

On the page by Tsyganenko http://geo.phys.spbu.ru/~tsyganenko/modeling.html there is the information on the model T02. There are also references on two papers (Paper I и Paper II), where this model is described. In the second paper there are the formulas for G1 and G2.

• **The contribution of the current in the tail of the magnetosphere,** which has a great influence on the inner and near magnetosphere, is taken into account in the linear approximation by introducing the parameter G1.

$$G_1 = V \cdot h(B_\perp) Sin^3 \frac{\theta}{2} . \qquad (1)$$

Here are hourly mean parameters obtained by any way.

*V* – Solar wind velocity,

$B_\perp$ -Transverse component IMF, i.e. $B_\perp^2 = B_y^2 + B_z^2$ and is always positive. Coordinate system is GSM. Function $h(B_\perp) = B_{\perp/40}^2 /(1 + B_{\perp/40})$, $B_{\perp/40} = B_\perp / B_0$ for >$B_0$=40 nT.

θ – Angle between $B_\perp$ and Z axis (Tsyganenko calls it "clock angle of the IMF transverse component", and Akasofy - "polar angle of the IMF"). This angle ranges from 0 to 180 grad.

If take *V*=400 km/s, $B_\perp$=5 nT, θ=180 grad, then for $G_1$ it will be $G_1$=400×0.014×$Sin^3$(180/2) ≈6

• **Shift of the current in the magnetosphere tail** is accounted in linear approach with introducing of the parameter $G_2$, determined as [http://geo.phys.spbu.ru/~tsyganenko/T01b.pdf]:

$$G_2 = aVB_S , \qquad (1)$$

where V and $B_S$ are velocity of the solar wind and south component of the interplanetary magnetic field IMF ($B_S$=| $B_z$ | for $B_z$<0 and $B_S$=0 at $B_z$>0) averaged by 1- hourly interval. Constanta a=0.005 was introduced only as convenience for to keep parameter $G_2$ within the region 0 ≤ $G_2$ ≤ 10, for usually observed values V and $B_S$. For example, for normal interplanetary conditions (V=400 km/s, $B_y$=0 and $B_z$=5 nT) parameter $G_2$ is equal 10. Indeed, $G_2$=*a*400×5=10. Equation (1) is only one possible way to realize the hypothesis that variations of the convective electric field associated with the southern component of the IMF should lead to a proportional shift of the current sheet in the tail of the magnetosphere.

• **Modification T02 for the Storm conditions. Model T02s.**
[https://pdfs.semanticscholar.org/665a/f74079ff64c532e836746fe4fe22995d2fc0.pdf]

Instead of a linear dependence of the ring current on the Dst index in model T02, a nonlinear term with the control variable G3 is introduced, based on a dependence on the solar wind energy.

$$G_3 = anVB_S , \qquad (3)$$

Like G2, parameter G3 was defined as the average over the previous 1-hour interval geoeffective characteristic of the solar wind. It differs from G2 in that in addition to the solar wind speed V and the southern IMF component BS, G3 also includes the density of the solar wind particles n. The constant factor a = 0.0005 is introduced for convenience in order to store the parameter G3 within the range 0 ≤ G3 ≤ 10, for the normally observed values of n, V and BS. For example, for normal interplanetary conditions (n = 10 cm-3, V = 400 km / s, By = 0 and Bz = 5 nT), the parameter G3 is 10. Actually, $G_3$=*a*×*10*×400×5=10.

The idea of replacing Dst by the function G3 follows from the fact that the rapid buildup of the ring current is the result of a strong amplified, directly convection from the tail, and it must also fall off quickly during the recovery phase. This type of behavior is easily reproduced by the leading variable G3, while the Dst index can remain fairly low for many hours after the main phase of the storm, due to the much more slowly decaying symmetrical current ring