水珠迁移沉降拉格朗日计算中出现的问题及解决办法

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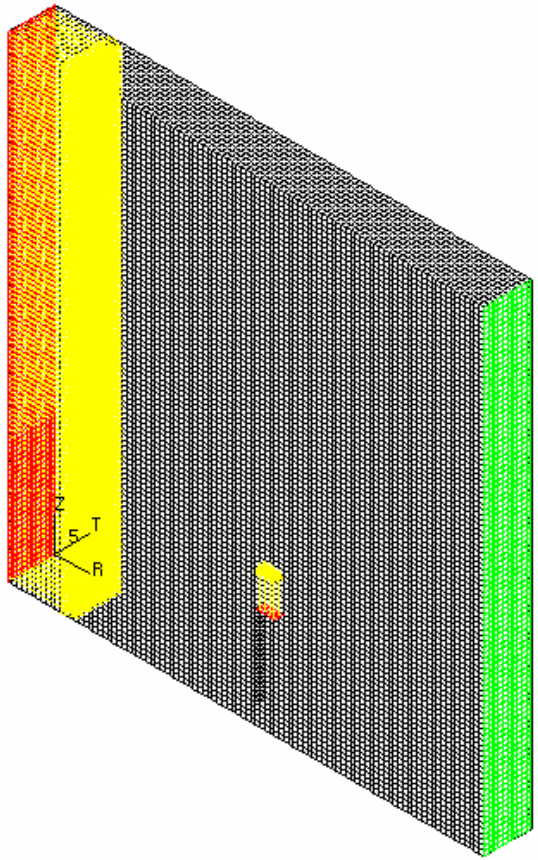
CDAJ for digital solution

计算模型

- 计算区域：1000m*1000m*100m
- 网格分配：100*100*10
- Inlet 速度：7m/s，300K
- 采用拉格朗日两相流计算底部喷出的水珠（T=293K）的迁移和沉降过程;
- 拉格朗日传热传质开启;
- 重力模型开启.



问题-1

- 1. 水珠在迁移过程中温度异常偏低，低于环境大气温度；

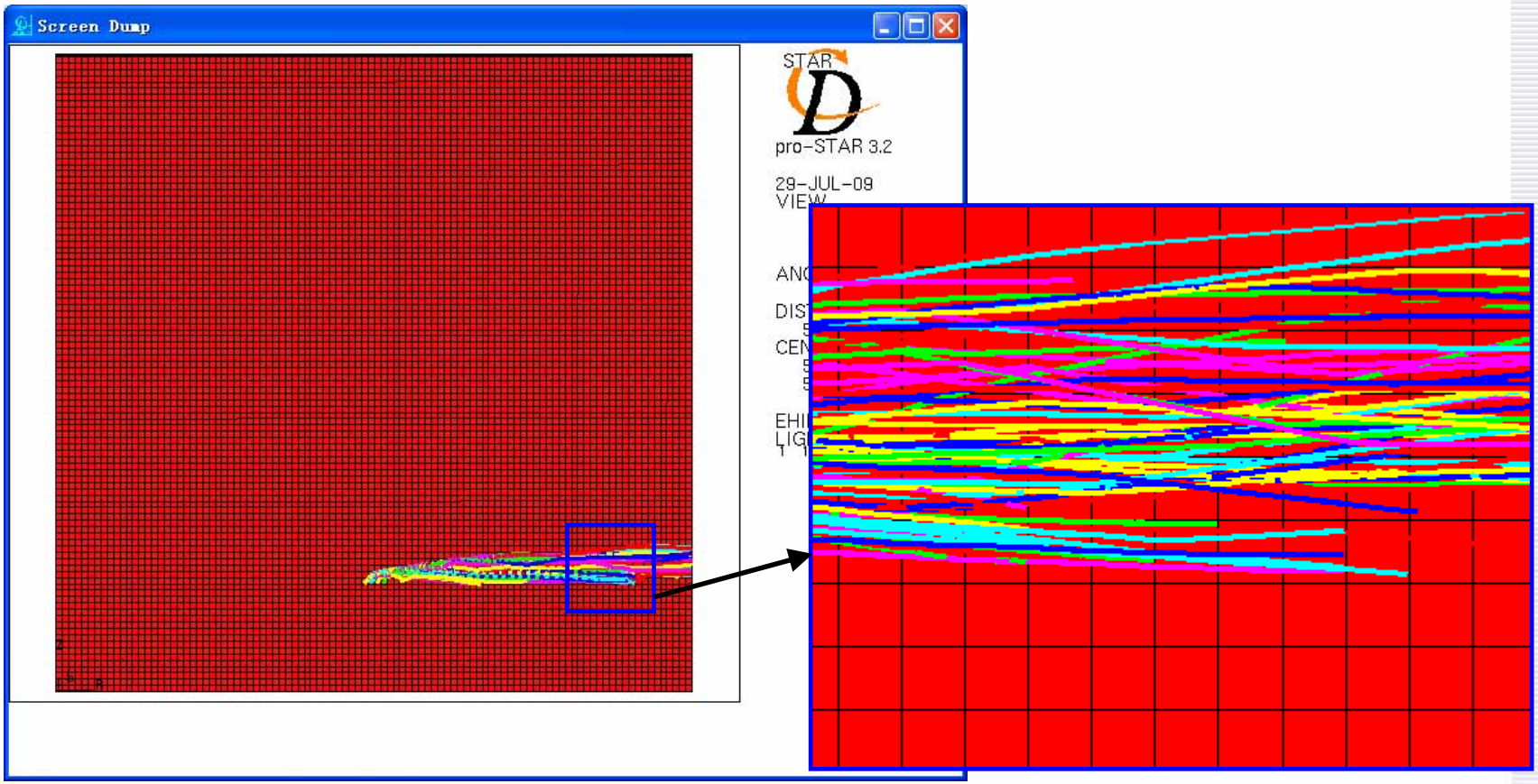
Particle/Droplet Track Data

Track	Time	X	Y	Z	Cell	U	V	W	Temp	Diam	Mass	Count
15	0	495	170	55	54918	0	4	7.78828e-07	293	0.000210235	1.15351e-06	237.668
16	2.60884	500	177.757	57.3177	54918	2.98093	2.7844	1.15907	294.703	0.000210233	1.15351e-06	237.668
17	3.4763	502.469	180	58.2765	55018	3.01229	2.49018	1.15282	293.967	0.000210232	1.15351e-06	237.668
18	5.02014	508.129	183.333	60	55019	3.91628	2.02011	1.13246	295.517	0.000210231	1.15351e-06	237.668
19	5.37496	510	183.715	60.4683	65019	5.96148	0.471214	1.39373	296.993	0.000210231	1.15351e-06	237.668
20	7.07277	520	184.059	62.5087	65119	5.93576	0.0855282	1.10408	297.321	0.00021023	1.15351e-06	237.668
21	8.79071	530	183.652	63.9717	65219	5.80601	-0.345788	0.719016	297.206	0.000210228	1.15351e-06	237.668
22	10.5751	540	182.673	64.9605	65319	5.60378	-0.606849	0.312137	297.218	0.000210227	1.15351e-06	237.668
23	12.4318	550	181.383	65.3555	65419	5.2884	-0.729817	0.16791	297.217	0.000210226	1.15351e-06	237.668
24	14.2426	559.315	180	65.5465	65519	5.06145	-0.775176	0.0819781	297.309	0.000210225	1.15351e-06	237.668
25	14.3834	560	179.911	65.549	65518	4.53247	-0.432246	-0.0913267	297.257	0.000210224	1.15351e-06	237.668
26	16.6327	570	179.091	65.0516	65618	4.52965	-0.27388	-0.293424	297.449	0.000210223	1.15351e-06	237.668
27	18.8259	580	178.505	64.3221	65718	4.5682	-0.250562	-0.356986	297.668	0.000210221	1.15351e-06	237.668
28	20.9936	590	177.986	63.498	65818	4.62359	-0.222261	-0.396399	297.864	0.00021022	1.15351e-06	237.668
29	23.2173	600	176.74	62.4623	65918	4.45398	-0.66519	-0.506797	298.099	0.000210218	1.15351e-06	237.668
30	25.422	610	175.312	61.2977	66018	4.56704	-0.62337	-0.547709	298.356	0.000210216	1.15351e-06	237.668
31	27.5739	620	174	60.092	66118	4.67437	-0.586568	-0.575175	298.6	0.000210215	1.15351e-06	237.668
32	27.7802	620.99	173.887	60	66218	5.08	-0.489285	-0.123399	298.64	0.000210214	1.15351e-06	237.668
33	29.7069	630	173.344	59.907	56218	4.71569	-0.268722	-0.0406146	296.991	0.000208308	1.12243e-06	237.668
34	31.7882	640	172.76	59.8653	56318	4.88266	-0.269748	-0.0168997	292.742	0.000202391	1.02951e-06	237.668
35	33.8042	650	172.212	59.867	56418	5.03014	-0.252011	0.00338437	288.79	0.000193006	8.92849e-07	237.668
36	35.8926	660	172.283	59.2004	56518	4.69602	0.163838	-0.448518	284.997	0.000180613	7.31688e-07	237.668
37	38.0138	670	172.659	58.2819	56618	4.72591	0.215075	-0.429289	281.522	0.00016487	5.56559e-07	237.668
38	40.1249	680	173.162	57.4044	56718	4.74289	0.285026	-0.412489	278.263	0.000145242	3.80523e-07	237.668
39	42.23	690	173.84	56.5591	56818	4.75034	0.380024	-0.398416	275.185	0.000120737	2.18596e-07	237.668
40	44.1436	700	173.957	56.0673	56918	5.37074	0.0343023	-0.21882	272.663	8.68219e-05	8.12907e-08	237.668
41	45.9968	710	174.154	55.6777	57018	5.41086	0.194932	-0.207965	269.729	2.55003e-05	2.05993e-09	237.668
42												
43												

Load Data | Track File Name: star.trk | Close

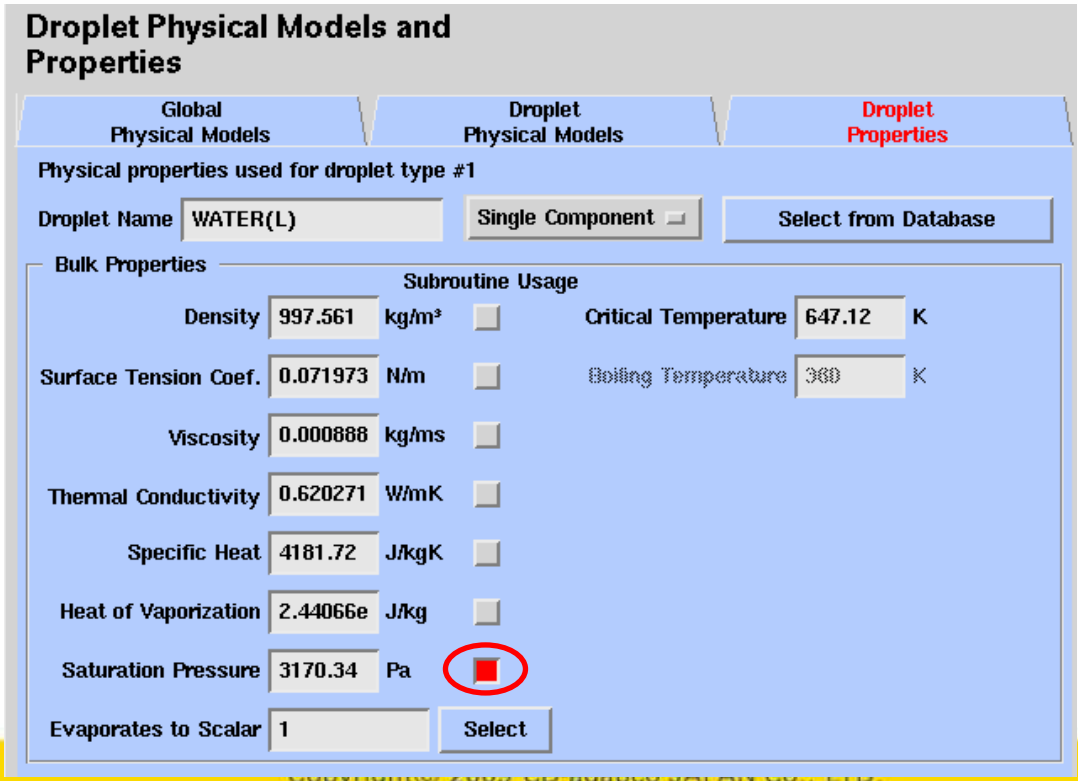
问题-2

- 水珠轨迹并没有在预期的出口停止，而是在计算区域中途停止；



原因及解决办法

- 原因：水采用常物性设置时，与物理真实不符合，因而出现不真实的计算结果。
- 本计算开启了传热传质，此时水的饱和压力起着非常关键的作用,需要给出准确的值，而该值是随温度而变化的，因此需要同过用户子程序dropro.f给出水的真实饱和压力函数。

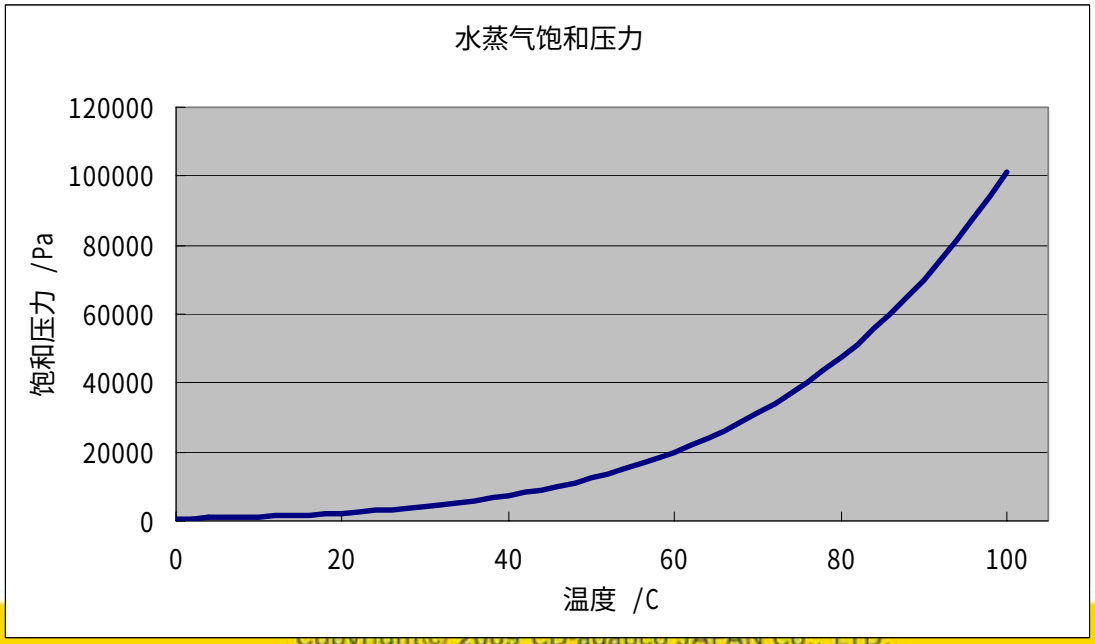


水蒸气饱和压力公式

- 以下是使用最广泛的水蒸气饱和压力公式是Goff–Gratch 公式**[1]:**

$$\log_{10}(p) = -7.90298\left(\frac{373.16}{T} - 1\right) + 5.02808\log_{10}\frac{373.16}{T}$$
$$-1.3816.10^{-7}\left(10^{11.344\left(1-\frac{T}{373.16}\right)} - 1\right)$$
$$+8.1328.10^{-3}\left(10^{-3.49149\left(\frac{373.16}{T}-1\right)} - 1\right)$$
$$+\log_{10}(1013.246)$$

式中：T为温度，单位K; P为饱和压力，单位为1e2Pa;适用范围：-50～120℃



dropro.f代码


```
C---Water Saturation Pressure----------------
      real A(4),E(2)
      real log10PS
      TREF=373.16
      PSREF=1013.246
      data A/-7.90298,5.02808,-1.3816e-7,8.1328e-3/
      data E/11.344,-3.49149/
      log10PS=A(1)*(TREF/T-1)+A(2)*log10(TREF/T)
     &  +A(3)*(exp(E(1)*(1-T/TREF)*log(10.))-1.)
     &  +A(4)*(exp(E(2)*(TREF/T-1)*log(10.))-1.)
     &  +log10(PSREF)
      PS=exp(log10PS*log(10.))*100.
```

结果

- 水珠温度计算正常，喷入的293K的粒子在环境气温（300K）作用下缓慢升温。

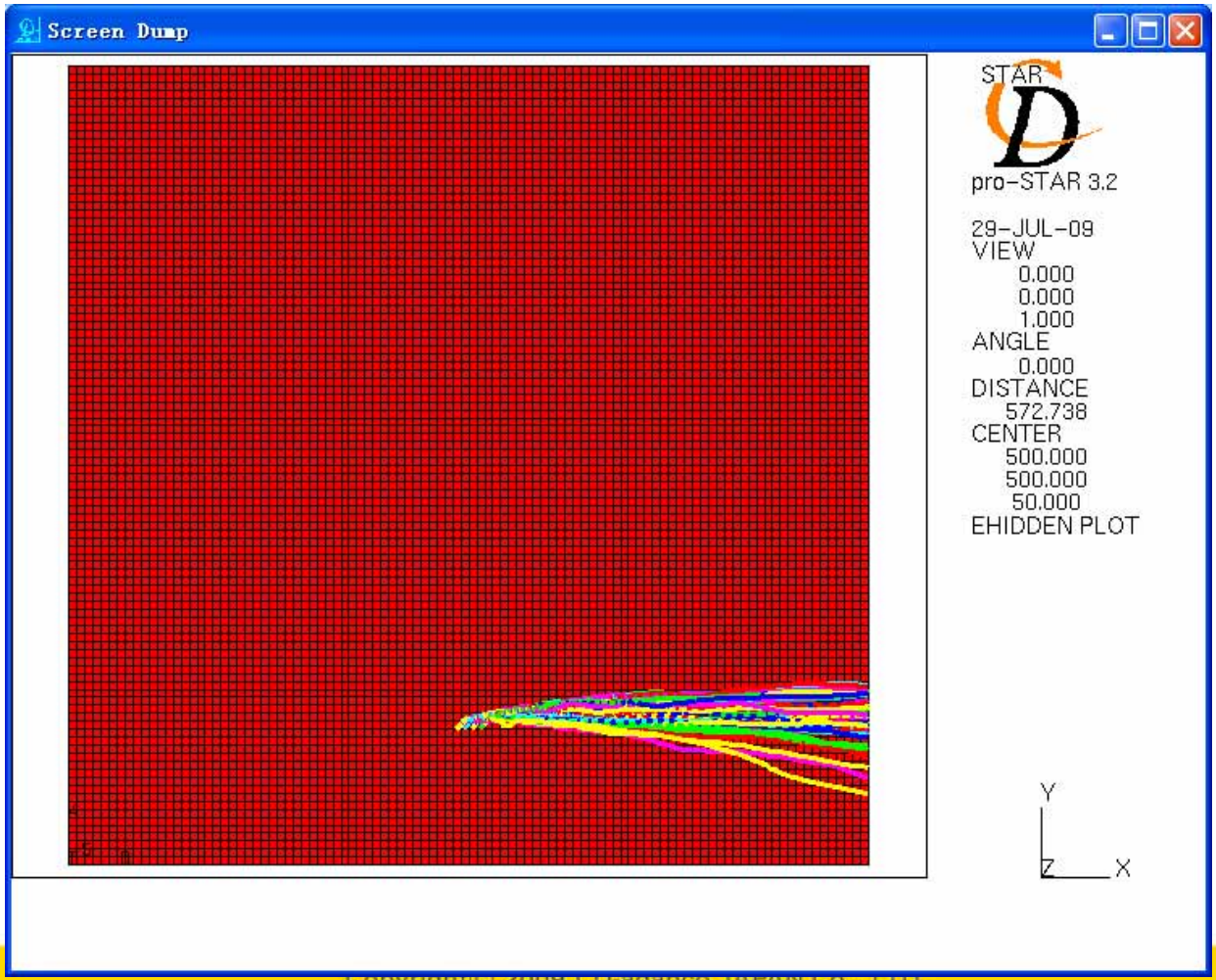
Particle/Droplet Track Data

Track	Time	X	Y	Z	Cell	U	V	W	Temp	Diam	Mass	Count
1	0	485	170	45	44818	0	4	7.78828e-07	293	9.23364e-05	5.172e-08	125.777
2	1.96337	490	176.355	42.7065	44818	3.26771	3.08821	-1.40411	296.239	9.2334e-05	5.172e-08	125.777
3	3.1275	494.329	180	41.0018	44918	4.20172	3.06591	-1.60164	296.019	9.23326e-05	5.172e-08	125.777
4	3.88059	497.585	181.976	40	44919	4.42455	2.54737	-1.32731	296.728	9.23317e-05	5.172e-08	125.777
5	4.27564	500	182.442	39.3633	34919	6.28577	1.02883	-1.63589	298.648	9.23312e-05	5.172e-08	125.777
6	5.88872	510	183.938	37.0624	35019	6.29976	0.864013	-1.33494	298.034	9.23292e-05	5.172e-08	125.777
7	7.50416	520	184.995	35.2214	35119	6.24961	0.557402	-1.05022	297.694	9.23273e-05	5.172e-08	125.777
8	9.12464	530	185.418	33.9002	35219	6.18056	0.171988	-0.699544	297.633	9.23255e-05	5.172e-08	125.777
9	10.7985	540	185.421	33.0348	35319	5.89592	-0.0380109	-0.396827	297.662	9.23235e-05	5.172e-08	125.777
10	12.5477	550	185.195	32.4947	35419	5.67158	-0.16196	-0.276401	297.629	9.23214e-05	5.172e-08	125.777
11	14.3499	560	184.823	32.1459	35519	5.50734	-0.220206	-0.176922	297.393	9.23193e-05	5.172e-08	125.777
12	16.1796	570	184.413	31.938	35619	5.49742	-0.210205	-0.0992401	297.353	9.23172e-05	5.172e-08	125.777
13	18.0325	580	184.01	31.8279	35719	5.3522	-0.217202	-0.0470811	297.375	9.2315e-05	5.172e-08	125.777
14	19.9285	590	183.609	31.792	35819	5.23494	-0.207776	-0.00930088	297.409	9.23128e-05	5.172e-08	125.777
15	21.8523	600	183.25	31.8379	35919	5.16884	-0.178351	0.0347191	297.457	9.23106e-05	5.172e-08	125.777
16	23.8082	610	182.936	31.9426	36019	5.08622	-0.15236	0.0609675	297.509	9.23083e-05	5.172e-08	125.777
17	25.7974	620	182.671	32.0973	36119	4.99762	-0.143433	0.0290471	297.564	9.23059e-05	5.172e-08	125.777
18	27.82	630	182.196	31.6506	36219	4.96888	-0.233847	-0.221246	297.631	9.23035e-05	5.172e-08	125.777
19	29.831	640	181.748	31.2333	36319	5.00006	-0.219355	-0.201988	297.704	9.23011e-05	5.172e-08	125.777
20	31.827	650	181.329	30.857	36419	5.2243	0.0198709	-0.103281	297.782	9.22986e-05	5.172e-08	125.777
21	33.6875	660	181.663	30.804	36519	5.3882	0.186522	-0.0247199	297.858	9.22963e-05	5.172e-08	125.777
22	35.5415	670	182.023	30.7753	36619	5.40411	0.197831	-0.0131666	297.935	9.22939e-05	5.172e-08	125.777
23	37.3876	680	182.4	30.7668	36719	5.42759	0.208152	-0.00244566	298.013	9.22916e-05	5.172e-08	125.777
24	39.3323	690	182.564	30.5922	36819	4.62909	-0.143723	-0.253616	298.093	9.22891e-05	5.172e-08	125.777
25	41.4684	700	182.257	30.0717	36919	4.71874	-0.145664	-0.239163	298.175	9.22863e-05	5.172e-08	125.777
26	41.7746	701.452	182.213	30	37019	4.74958	-0.144209	-0.232811	298.243	9.22858e-05	5.172e-08	125.777
27	43.3239	710	181.629	29.587	27019	5.54839	-0.383331	-0.264566	298.689	9.22837e-05	5.172e-08	125.777
28	45.122	720	180.953	29.1284	27119	5.57499	-0.376386	-0.25147	298.74	9.22813e-05	5.172e-08	125.777
29	46.8686	730	180.369	28.6479	27219	6.13613	-0.23961	-0.36544	298.786	9.2279e-05	5.172e-08	125.777

Load Data | Track File Name | star.trk | Close

结果

- 水珠运动轨迹完整，终止于出口。



参考文献

- [1]. http://en.wikipedia.org/wiki/Water_vapor