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Bundesanstalt für Gewässerkunde
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Global Runoff Data Centre
Federal Institute of Hydrology
Koblenz, Germany

Report No. 19

**Evaluation of Statistical Properties of
Discharge Data of
Stations Discharging Into the Oceans
- Europe and Selected World-Wide Stations -**

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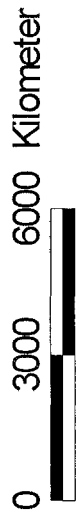
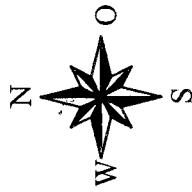
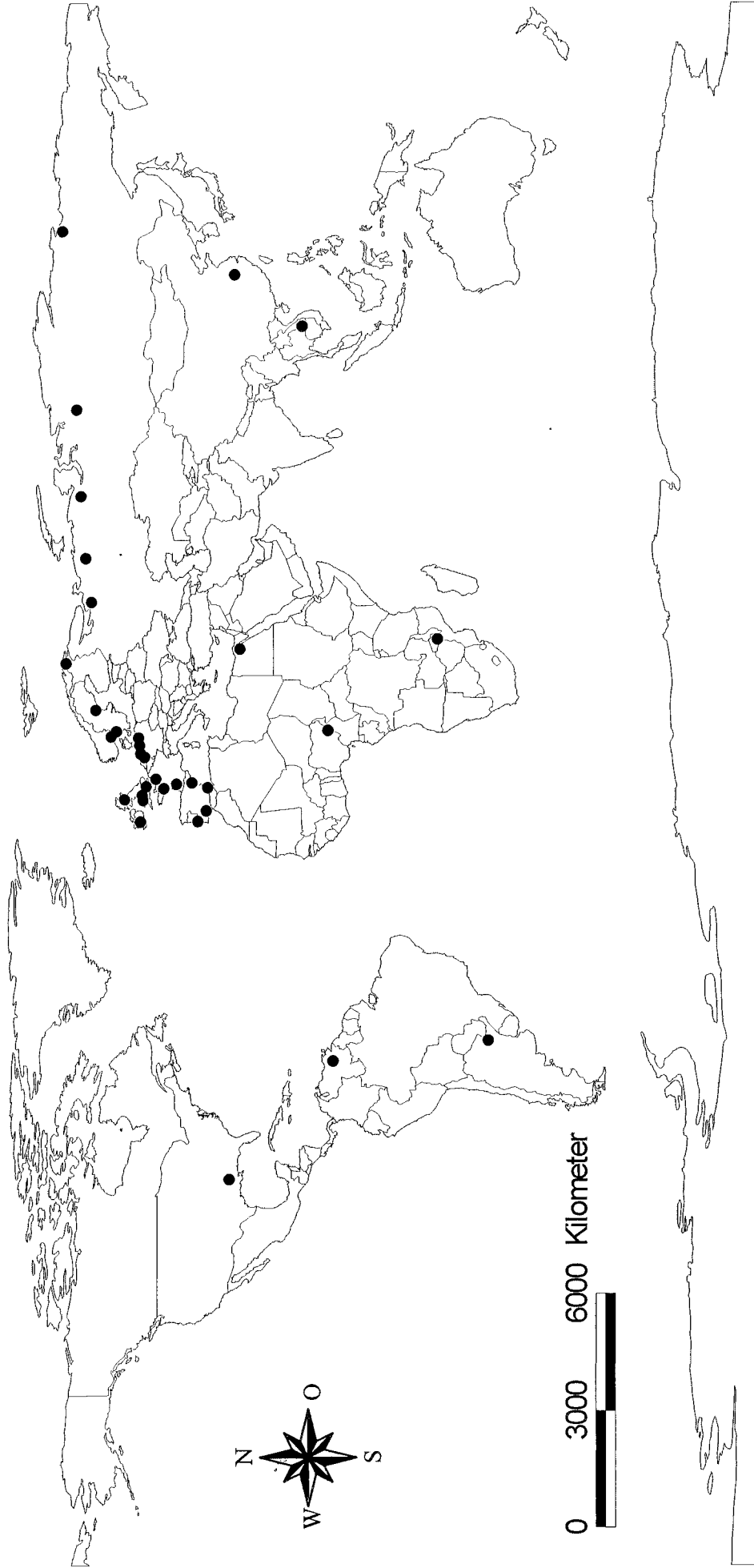
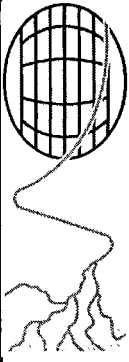
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Distribution of gauging stations used for statistical analysis



Against right-sided alternative - elements of different kinds tend to alternate regularly:

$$u \geq |u(\alpha)|$$

Respective critical values of the standard normal distribution for $u(\alpha/2)$ and $|u(\alpha)|$ are given in the following table (CMHI 1996, SACHS 1984):

Critical parameter	Error probability α		
	0.10	0.05	0.01
$u(\alpha/2)$ (two-sided)	1.645	1.960	2.576
$ u(\alpha) $ (one-sided)	1.282	1.645	2.326

That is, given an error probability α of 5 % and a sampled u of -1.05:

- the H_0 is not rejected against the two-sided alternative ($|u| < u(\alpha/2)$, i.e. $1.05 < 1.96$)
- the H_0 is not rejected against the left-sided alternative ($u > -|u(\alpha)|$, i.e. $-1.05 > -1.96$)
- the H_0 is not rejected against the right-sided alternative ($u < |u(\alpha)|$, i.e. $-1.05 < 1.96$).

(13) Periodogram and Fisher's Test of Periodicity (cf. YEVJEVICH 1972b; CMHI 1996)

A hydrological series may be looked at as one out of several possible realisations of a continuous random hydrological process $\{x_t\}$ creating hydrological series.

The finite series of length T may be fitted by a number of trigonometric functions of the following type:

$$x_t = \mu_x + C_1 \cos(2\pi f_1 t + \Theta_1) + C_2 \cos(2\pi f_2 t + \Theta_2) + \dots + C_j \cos(2\pi f_j t + \Theta_j) + \dots + C_n \cos(2\pi f_n t + \Theta_n)$$

They have an infinite number of noncommensurate ordinary frequencies, f_j , or their corresponding angular frequencies, λ_j . They will fit every point of the series when frequencies are sufficiently dense on the line of the ordinary frequencies f_j , or on the line of their corresponding angular frequencies λ_j , while their parameters C_j and Θ_j may be estimated for each f_j and λ_j by adequate estimation method.

If only a limited number of f -values or λ -values is used in approximating the sampled series, each particular discrete value f_j or λ_j with its respective estimates of amplitude C_j and phase Θ_j has the variance $C_j^2/2$.

A plot of the variance $C_j^2/2$ (sometimes also C_j , C_j^2 , or $\sum C_j^2/2$) with $i = 1, 2, \dots, j$ versus the frequencies f_j or λ_j represents the line-spectrum, the discrete spectrum, or the periodogram.

Using angular frequencies λ_j , the **variance line-spectrum** or **discrete spectrum** of the series x_t is given by:

$$C_j^2/2 = \Psi(\lambda_j)$$

where

$$j = 1, 2, \dots$$

$$\sum C_j^2/2 = \text{variance}(x_t) = \sigma^2.$$

When the frequency intervals $\Delta\lambda$ of the λ -line is used, and for each interval $\Delta\lambda$ at λ , the variance of all fitted trigonometric functions is defined as ΔD , then for $\Delta\lambda \rightarrow 0$ the following term

$$\lim \Delta D/\Delta\lambda = v_\lambda$$

represents the variance density at any point for λ of the λ -line. Analogous to the variance line-spectrum, the **variance density spectrum**, or **continuous spectrum** is given by:

$$v_\lambda = \Psi(\lambda)$$

For the first four most significant linear trends of the annual series, the coefficients of the trend equation are listed in the following table, together with the mean and standard deviation of the respective period and the ratio of the slope with the total mean of the series, a measure of the intensity of the trend:

Statistical Significant Partial Trends (1st - 4th) of Annual Series (Programme TREND1)							
River	Begin year	End year	Mean	StdDev	Slope	Intercept	Slope/ Total mean
GARONNE	1952	1979	615.5	146.7	10.54	-20095.8	1.7
GARONNE	1953	1979	616.1	149.4	11.61	-22214.6	1.9
GARONNE	1955	1979	631.4	141.6	10.59	-20197.8	1.7
GARONNE	1956	1979	634.3	143.9	11.21	-21428.1	1.8
GLOMA	1969	1984	614.7	58.1	7.28	-13773.3	1.1
GLOMA	1973	1984	623.4	60.7	10.3	-19762.3	1.5
GLOMA	1975	1984	627.2	66.2	14.95	-28962.3	2.2
GLOMA	1976	1984	629.0	70.0	19.18	-37354.0	2.9
GUADALQ	1984	1993	53.7	27.3	-6.39	12760.0	-5.3
GUADALQ	1985	1993	54.0	28.9	-9.02	17999.9	-7.5
GUADALQ	1986	1993	51.1	29.5	-10.38	20708.8	-8.6
JUCAR	1965	1981	42.8	11.6	-1.60	3201.7	-3.3
JUCAR	1966	1981	42.4	11.8	-1.76	3514.3	-3.6
JUCAR	1969	1981	40.2	10.8	-1.92	3824.7	-3.9
JUCAR	1970	1981	39.4	10.9	-1.99	3978.1	-4.1
LOIRE	1945	1979	816.3	276.0	13.26	-25195.0	1.6
LOIRE	1946	1979	822.0	278.0	13.42	-25519.1	1.6
LOIRE	1953	1979	863.3	248.9	13.11	-24917.1	1.6
LOIRE	1971	1979	902.3	310.2	92.86	-182490.2	11.1
ORINOCO	1979	1989	3226.2	3054.7	-587.23	1197336.1	-1.9
ORINOCO	1980	1989	3229.1	3218.3	-802.51	1624871.8	-2.6
ORINOCO	1981	1989	3207.7	3336.7	-942.44	1902812.6	-3.1
ORINOCO	1982	1989	3144.8	2941.9	-807.18	1634108.9	-2.6
PARANA	1967	1982	1658.2	3776.9	623.24	-1213998.0	3.8
PARANA	1968	1982	1675.9	3840.3	681.01	-1328239.0	4.2
PARANA	1969	1982	1721.4	3540.6	628.10	-1223594.0	3.8
PARANA	1970	1982	1757.4	3408.8	605.36	-1178623.0	3.7
TANA2	1969	1987	165.4	28.9	2.75	-5268.3	1.6
TANA2	1970	1987	166.8	29.1	2.74	-5263.5	1.6
THAMES	1977	1984	79.6	20.3	-6.89	13717.1	-8.4
VAENERN	1970	1992	498.8	129.3	8.43	-16210.2	1.6
YENISEI	1966	1994	1817.2	1493.4	69.90	-120232.6	0.4

6 Significant Periodicities

Statistically significant periods have been detected for annual series only in exceptional cases listed in the following table. For the River Zambeze, because of the extremely short length of the series, the monthly sequence of values was taken instead of the derived annual series.

Statistical Significant Periods (Programme CHPP)							
River	Begin year	End year	Type of series	Transformation	Period of annual series	Period of monthly sequence	Remarks
					Years	Months	
GUADALQ	1952	1993	annual	no	-	nil	periodicity of length of series
GUADALQ	1952	1993	annual	log-normal, 2 parameter	8.2	nil	1/5 of length of series; other periodicity: length of series
PARANA	1905	1982	annual	no	8.6	nil	1/9 of length of series
ZAMBEZE	1976	1979	monthly sequence	no	nil	-	no periodicity
ZAMBEZE	1976	1979	monthly sequence	log-normal, 2 parameter	nil	7.8	1/6 of length of series

The following autocorrelation coefficients for lags $i = 13, \dots, 24$ of the monthly series were calculated by the TS-programme:

River	AC (13)	AC (14)	AC (15)	AC (16)	AC (17)	AC (18)	AC (19)	AC (20)	AC (21)	AC (22)	AC (23)	AC (24)
ANGERMAN	0.105	-0.050	-0.019	-0.009	0.055	0.120	0.071	0.042	0.019	0.036	0.133	0.297
BENUE	0.388	0.120	-0.126	-0.250	-0.307	-0.319	-0.303	-0.237	-0.102	0.170	0.420	0.638
CHANGJIA	0.659	0.375	-0.008	-0.387	-0.652	-0.745	-0.630	-0.352	0.016	0.385	0.648	0.741
EBRO	0.357	0.204	0.032	-0.117	-0.262	-0.336	-0.286	-0.141	-0.010	0.133	0.287	0.362
EMS												
GARONNE	0.331	0.195	0.001	-0.157	-0.286	-0.323	-0.279	-0.131	0.030	0.140	0.268	0.341
GLOMA	0.514	0.140	-0.128	-0.299	-0.388	-0.429	-0.382	-0.282	-0.123	0.142	0.501	0.726
GUADALQ	0.305	0.226	0.100	-0.012	-0.078	-0.108	-0.090	-0.038	0.060	0.141	0.277	0.289
JUCAR	0.394	0.316	0.246	0.181	0.127	0.104	0.105	0.145	0.192	0.222	0.227	0.229
LABE	0.372	0.241	0.072	-0.091	-0.199	-0.204	-0.152	-0.070	0.015	0.118	0.194	0.239
LENA	0.387	0.092	-0.075	-0.271	-0.400	-0.408	-0.392	-0.263	-0.068	0.095	0.385	0.909
LOIRE	0.345	0.205	0.009	-0.184	-0.328	-0.386	-0.338	-0.199	-0.003	0.189	0.325	0.405
MEKONG	0.658	0.273	-0.124	-0.392	-0.519	-0.552	-0.504					
MISSISSIPPI	0.404	0.207	0.050	-0.149	-0.311	-0.370	-0.364	-0.286	-0.106	0.036	0.199	0.270
NILE	0.486	0.045	-0.233	-0.319	-0.198	-0.107	-0.170	-0.280	-0.226	0.013	0.397	
N_DVINA	0.278	-0.107	-0.196	-0.174	-0.119	-0.101	-0.131	-0.180	-0.207	-0.116	0.284	0.814
OB	0.656	0.223	-0.154	-0.377	-0.489	-0.520	-0.483	-0.363	-0.134	0.226	0.637	0.841
ORINOCO	0.784	0.422	-0.034	-0.450	-0.732	-0.831	-0.731	-0.451	-0.037	0.414	0.769	0.906
PARANA	0.286	0.150	0.023	-0.092	-0.198	-0.242	-0.193	-0.112	-0.024	0.066	0.164	0.217
PECHORA	0.381	-0.078	-0.162	-0.162	-0.225	-0.279	-0.228	-0.153	-0.157	-0.079	0.376	0.767
RHEIN	0.159	0.086	0.030	-0.029	-0.064	-0.084	-0.124	-0.116	-0.066	0.013	0.085	0.126
SEINE	0.261											
SEVERN1	0.358	0.174	0.035									
SEVERN2	0.479	0.236	-0.003	-0.286	-0.486							
SHANNON	0.562											
TANA1	0.279	-0.049	-0.116	-0.146	-0.195	-0.222	-0.195	-0.151	-0.116	-0.053	0.317	0.632
TANA2	0.324	-0.048	-0.133	-0.167	-0.232	-0.274	-0.224	-0.149	-0.114	-0.046	0.336	0.609
TAY												
TEJO	0.318	0.245	0.119	0.041	-0.059							
THAMES	0.320	0.172	-0.017	-0.257	-0.415	-0.472	-0.415	-0.303	-0.087	0.148	0.364	0.481
VAENERN_	0.335	0.234	0.128	0.051	-0.002	-0.037	-0.042	-0.009	0.037	0.095	0.142	0.158
WESER	0.298	0.177	0.021	-0.139	-0.253	-0.275	-0.256	-0.179	-0.064	0.119	0.240	0.271
WYE	0.344	0.204	0.018	-0.232	-0.414	-0.427	-0.336	-0.243	0.014	0.277	0.371	0.469
YENISEI	0.329	-0.029	-0.109	-0.186	-0.300	-0.341	-0.292	-0.178	-0.101	-0.027	0.330	0.901
ZAMBEZE												

Explanation of abbreviations:

River: River / Time Series

AC(i): Autocorrelation coefficient of monthly series with lag $i = 13, \dots, 24$

Trends of Annual and Monthly Series (Programme TREND1)					
River:	MEKONG				
Total period:	1982-1991				
Time interval	Mean	StdDev	Slope	Intercept	R
JAN	2814.30	361.21	-52.73	107569.15	-0.467
FEB	1972.30	206.00	-33.28	68080.70	-0.516
MAR	1939.10	244.47	-16.32	34361.27	-0.216
APR	1841.60	217.77	-26.10	53683.24	-0.385
MAY	2478.40	397.71	-57.03	115769.11	-0.459
JUN	6900.20	1856.58	225.70	-441446.81	0.391
JUL	14566.30	3596.29	472.22	-923507.13	0.421
AUG	25830.90	4200.69	561.41	-1089414.00	0.429
SEP	23888.10	2435.08	-15.99	55660.09	-0.021
OCT	16816.70	2074.35	-167.41	349380.91	-0.261
NOV	8290.70	1199.57	-41.93	91591.28	-0.113
DEC	4403.90	525.63	-49.51	102753.72	-0.304
ANNL	9311.88	1025.25	66.59	-122959.90	0.210

Trends of Annual and Monthly Series (Programme TREND1)					
River:	MISSISSIPPI				
Total period:	1969-1982				
Time interval	Mean	StdDev	Slope	Intercept	R
JAN	19677.43	7996.21	-556.48	1119010.63	-0.303
FEB	21690.14	9697.95	-791.03	1584375.75	-0.355
MAR	23833.07	9281.33	633.53	-1227709.00	0.297
APR	29037.07	11159.91	213.19	-392117.81	0.084
MAY	25472.57	10734.95	-800.33	1606515.13	-0.325
JUN	19476.86	8087.50	268.85	-511633.00	0.145
JUL	14412.07	3384.89	-27.04	67828.73	-0.035
AUG	11229.21	2368.12	150.92	-286906.31	0.278
SEP	10089.64	2791.78	279.59	-542238.38	0.435
OCT	10335.64	2767.69	-244.31	492961.13	-0.384
NOV	12344.00	4426.64	-365.42	734239.44	-0.359
DEC	18436.21	8402.87	186.55	-350096.59	0.097
ANNL	18002.83	4644.6	-87.67	191185.86	-0.083

Trends of Annual and Monthly Series (Programme TREND1)					
River:	NILE				
Total period:	1973-1984				
Time interval	Mean	StdDev	Slope	Intercept	R
JAN	1238.75	231.69	49.73	-97153.58	0.791
FEB	1035.25	105.71	14.60	-27860.54	0.519
MAR	1125.75	98.44	7.23	-13187.25	0.279
APR	1110.17	131.29	11.31	-21262.10	0.326
MAY	1169.75	94.23	2.19	-3167.73	0.089
JUN	1542.17	56.75	0.84	-118.11	0.056
JUL	1742.08	82.33	13.47	-24898.49	0.611
AUG	1559.50	53.78	5.36	-9052.45	0.377
SEP	1190.58	77.06	15.31	-29102.60	0.736
OCT	1102.58	100.07	18.59	-35679.53	0.690
NOV	1075.42	89.09	13.96	-26547.49	0.586
DEC	1123.92	128.83	21.44	-41289.31	0.621
ANNL	1251.33	81.61	14.50	-27443.26	0.662

Trends of Annual and Monthly Series (Programme TREND1)					
River:	SEINE				
Total period:	1971-1977				
Time interval	Mean	StdDev	Slope	Intercept	R
JAN	390.14	152.07	26.32	-51568.36	0.414
FEB	591.00	191.45	64.21	-126168.00	0.768
MAR	433.00	111.72	34.86	-68375.00	0.720
APR	380.57	133.29	22.71	-44457.43	0.408
MAY	307.43	85.39	14.64	-28597.57	0.410
JUN	244.43	67.46	-0.54	1301.93	-0.019
JUL	207.86	53.38	2.79	-5291.14	0.127
AUG	203.14	72.08	-2.57	5279.14	-0.087
SEP	202.29	41.12	2.32	-4380.21	0.137
OCT	242.29	91.55	5.14	-9909.71	0.136
NOV	346.57	146.26	10.54	-20450.93	0.175
DEC	454.43	155.05	31.11	-60951.07	0.477
ANNL	333.60	74.88	17.63	-34464.03	0.556

Trends of Annual and Monthly Series (Programme TREND1)					
River:	SEVERN (sub-series #1)				
Total period:	1965-1972				
Time interval	Mean	StdDev	Slope	Intercept	R
JAN	120.75	36.49	-3.83	7666.67	-0.281
FEB	98.38	42.96	2.99	-5783.69	0.187
MAR	81.50	15.03	-1.81	3643.55	-0.322
APR	64.25	27.74	0.64	-1201.21	0.062
MAY	61.50	35.93	-3.86	7654.29	-0.287
JUN	34.38	11.04	0.54	-1020.18	0.131
JUL	29.00	26.76	-0.76	1528.81	-0.077
AUG	27.88	5.77	1.35	-2620.23	0.610
SEP	35.88	22.43	-6.25	12339.00	-0.719
OCT	53.63	45.58	-8.85	17465.48	-0.512
NOV	78.63	13.63	-3.46	6898.07	-0.661
DEC	132.13	79.52	-21.80	43040.74	-0.708
ANNL	68.16	10.75	-3.76	7467.61	-0.880

Trends of Annual and Monthly Series (Programme TREND1)					
River:	SEVERN (sub-series #2)				
Total period:	1976-1984				
Time interval	Mean	StdDev	Slope	Intercept	R
JAN	121.44	33.47	6.70	-13144.56	0.580
FEB	107.78	51.31	-4.07	8159.78	-0.234
MAR	99.11	51.04	-0.23	561.11	-0.014
APR	50.44	25.36	0.27	-477.56	0.031
MAY	39.44	26.77	0.77	-1478.56	0.085
JUN	27.00	10.5	1.05	-2052.00	0.295
JUL	14.33	5.29	0.33	-645.67	0.186
AUG	17.67	9.58	-0.13	281.67	-0.041
SEP	25.78	8.09	0.97	-1888.22	0.352
OCT	63.22	33.13	0.53	-992.78	0.048
NOV	92.78	38.64	2.68	-5220.22	0.205
DEC	118.11	31.71	0.65	-1168.89	0.061
ANNL	64.76	10.24	0.79	-1505.49	0.229

