A climatology of runoff for the global ocean-ice model ORCA025

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1 Introduction

This note documents the runoff forcing for the DRAKKAR version of ORCA025 as well as the new (2006) version of the MERCATOR ORCA025 ”POG” prototype. It is based on the report written by R. Bourdallé-Badie (2005) which describes the global 1/4° version as well as the global 1/12° version. The basic assumption (usual in global ocean models) is that the runoff enters the ocean at the surface, as rain.

2 Input data

The runoffs data file comes from the Dai and Trenberth study[1]. It is documented in a publication (Dai and Trenberth, 2002, hereafter DT02). The spatial resolution of this file is $1^\circ \times 1^\circ$ with monthly data. This data are available on the web : http ://www.cgd.ucar.edu/cas/catalog/dai/

In the past (in the case of the CLIPPER model for example, Treguier et al, 2001), runoff inputs in ocean models were based on UNESCO data for the major rivers. The 50 to 100 largest rivers contribute only about half the total runoff ; to reach a reasonable total of about 1.2 Sv it is necessary to take into account the contribution of small (and often ungauged) rivers, that we call here the ”coastal runoff”. As an example, a first runoff file was calculated by Edmée Durand (2003) at MERCATOR based on 67 rivers plus the Antarctic coastal runoff. The total runoff in this file was 0.65 Sv, which is not enough. The Dai and Trenberth dataset has the advantage to provide monthly values of runoff that take into account both the major rivers the coastal runoff. A similar dataset is provided by Large and Yeager (2004) as part of the CORE forcing but it does not include an annual cycle and the repartition of coastal runoff is more arbitrary (less well localized).

One drawback of the Dai and Trenberth dataset is that the reference to specific rivers is lost. There are 3556 grid points different from zero in that file (DT02 have considered 921 rivers plus the coastal runoff), and the total (excluding the Antarctic runoff) is 1.25 Sv. We have found that this file was not adequate to specify the discharge of large rivers like the Amazon, or rivers that have narrow mouths like the Ob. In those cases, nothing is better than positioning directly each river mouth on the model grid

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[1]New Estimate of Continental Discharge and Oceanic Freshwater Transport ; Dai & Trenberth ; Feb 2003 ; AMS symposium on Observing and Understanding the Variability of Water in Weather and Climate

and spreading the runoff onto an adequate number of grid points. The method we describe here uses the DT02 dataset as a basis but a special treatment is performed for the major rivers.

Note that the Dai and Trenberth dataset does not include the Antarctic coastal runoff due to the discharge of continental ice. We prescribe the value of Jacobs et al (1992), 2613 kg/year, or 0.0829 Sv. (units transformation : 1 Sv = 10^6m^3.s^{-1} = 10^9 kg.m^2.s^{-1} ; 1 kg.m^2.s^{-1}= $3600x24x365x10^{-12}$ km^3/year).

3 Identification of major rivers

We have ordered the annual mean runoff values in the DT02 dataset, and the first 99 values have been selected to be applied as ”major rivers” (Table 1 at the end of this report). This makes sense because we want be able to spread large runoff values on many grid points : a 1/4° grid does not resolve the turbulence that disperses the river outflows in the real ocean. A few problems arise :

- Some runoffs are not referenced the table of the 200 greater rivers of DT02. These runoffs are indicated in Table 1 with a “XXX” in place of the DT02 river number, and a river name has been chosen from an Atlas[2].
- Some data from the Dai and Trenberth file fall in the land or away from the coast. The Jacui (50) and the Chidwin (87) have been left in land and have no impact on the global runoff discharge in the resulting files. The runoff 90 was in the sea and has been replaced like the “Huang” river in the mask file.
- Some runoff data can be just a branch of another river. In these cases, according to DT02 we take as the final value the sum of the main river and its tributaries :
  Amazon(1) = Amazon(1) + Tapajos(12) + Xingu(19)
  Tocantins(11) = Tocantins(11) + Para(21)
  St Laurence(16) = St Laurence(16) + Ottawa(92) + Saguenay(99)

The spread of each river over a few grid points has been constructed manually on the ORCA025 grid with the software developed by Edmée Durand (IDL graphic software). All rivers are given a large extension, even in the land, so that the rivermask is to a large extent independent of the coast line and can be used for higher resolution ORCA grid (like the global 1/12° MERCATOR model).

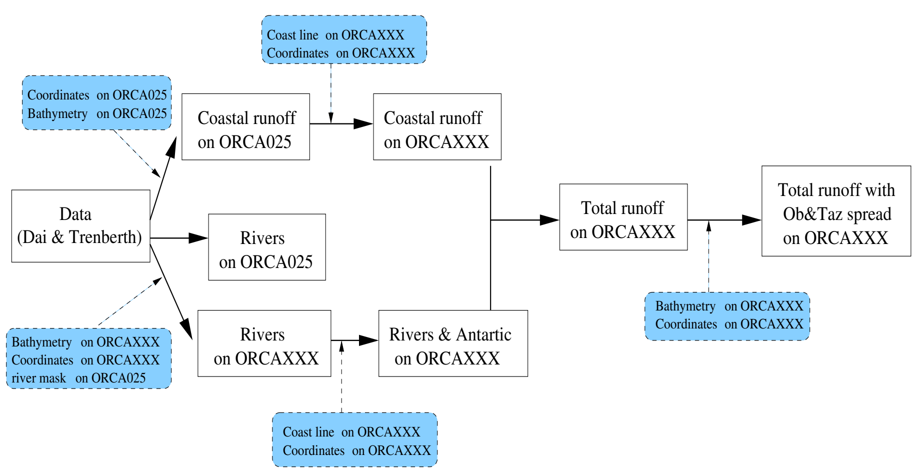

FIG. 1 – The steps to construct the runoff file. The input files are in blue

[2]The new internationnal Atlas 1982 ; Rand McNally & Compagny

4 Construction process

Several routines have been developed for the construction of the new runoff file. At each step an output file in NetCDF form is saved. The runoffs file can be created for any ORCA grid global configuration (ORCAXXX). The input file are : bathymetry, coordinates on the target grid (here ORCA025), and the river mask file on the ORCA025 grid. We use the coordinates_ORCA_R025_lombok+ombai.nc file, with modified scale factors in some Indonesian straits. The choice of the bathymetry file (ORCA025_combined_etopo_gebco_coast_corrected_oct05_G44.nc, to be precise) is not important because the coastline has not been modified often DRAKKAR or MERCATOR (this is not true of the deep bathymetry, which is not used here). The different steps are described below and on the figure 1 :

1. *compute_coast2.f90* : routine which allows the user to create a "mask file" that will be used to distribute the coastal runoff on the model grid. The first ocean point along the coast is saved in the present case (there is an option wich allows the creation of a mask with the 3 first points, *nbcoastpt* parameter). With another option the user can suppress the very little islands, where no significant amount of coastal runoff is expected. The minimum number of point for an island can be specified (*sizeisl_min* parameter).
   Input file : Bathymetry on ORCAXXX grid
   Output file : coastal mask on ORCAXXX grid
2. *compute_river.f90 :* this routine computes the N major rivers (*nbriver* parameter) from the Dai & Trenberth data base and creates two output files on the ORCA025 grid :
   One with the N major rivers placed at the nearest point of the global ORCA025 grid. For the next steps this runoff will be called "major river runoff".
   One with all the other runoff placed at the nearest point of the global ORCA025 grid. For the next steps this runoff will be called "coastal runoff".
   Input file : Bathymetry on ORCA025 grid ; Coordinates on ORCA025 ; Dai& Trenberth data file
   Output file : N major runoff on ORCA025 grid ; Other runoff on ORCA025 grid
3. *compute_costalrunoff.f90 :* the aim of this routine is to spread the coastal runoff along the coast. Each coastal runoff point of the Dai and Trenberth data base is spread over all coastal points within a $1^\circ \times 1^\circ$ box. If no coastal point of ORCA025 is found in a the box, the search is widened to a $2^\circ \times 2^\circ$ box. Even in that case, more than 200 points are found to be too far from any model coastline. Because they represent less than 0.1 Sv they are left out. Input file : Coast mask on ORCAXXX grid ; Coordinates on ORCA025 ; coastal runoff on ORCA025 grid
   Output file : Coastal runoff spread along the coast on ORCAXXX grid
4. *Construction of the river mask.* This is the only manual step of the process. A program with IDL graphic software has been developed by Edmée Durand (2003) that allows the user to attribute a number to some grid points near a river mouth, based on a high resolution map of the coastline. These numbers correspond to the numbers of the major rivers in table 1.
   Input file : surface mask on ORCA025 grid
   Output file : river mask on ORCA025 grid
5. *apply_river_ORCAgrid.f90.* With this routine, the user applies the N major rivers on the model grid with the river mask constructed manually. The process takes into account the area of the grid cells to preserve the total water input of each river (in Sv).
   Input file : Bathymetry on ORCAXXX grid ; Coordinates on ORCAXXX ; Dai& Trenberth data file, mask river on ORCA025 grid
   Output file : N major rivers on ORCAXXX grid

6. *compute_antartic.f90.* This routine adds the Antractic coastal runoff based on Jacobs et al (1992), with a pseudo annual cycle applied (fig 2, parameter *coefmois*). This value can be spread on 1 or 3 points, depending of the coast mask chosen (here 3 points). Input file : N major rivers on ORCAXXX grid ; Coordinates on ORCAXXX ; mask coast on ORCAXXX grid
   Output file : N major rivers and Antartic coastal runoffs on ORCAXXX grid
7. *compute_totalrunoff.f90 :* This routine simply adds the N major rivers and the coastal runoff.
   Input file : N major rivers on ORCAXXX grid ; Coastal runoff on ORCAXXX grid ;
   Output file : Total runoff on ORCAXXX grid
8. *compute_obtaz.f90 :* This routine allows to spread further the runoff in the Ob river estuary. It computes the total (rivers+coastal) runoff in the Ob area and spreads it in all the bay. This is to limit the risk of numerical instabilities during the month of june. We assume that those instabilities arise from the fact that the estuary is long and narrow, so that the 1/4° model is not able to generate strong enough currents to carry out the freshwater. This estuary should probably have been closed off in the 1/4° model.
   Input file : Bathymetry on ORCAXXX grid ; Coordinates on ORCAXXX ; Total runoff on ORCAXXX grid
   Output file : Total runoff (with Ob and Taz spread) on ORCAXXX grid
9. *verif_runofftot.f90 :* a simple programme to print the total annual value of the runoff file.
   Input file : Bathymetry on ORCAXXX ; Coordinates on ORCAXXX ; Total runoff on ORCAXXX grid
   Output file : None

Note that the runoff data is positive in the netcdf file but counted negative in the NEMO code.

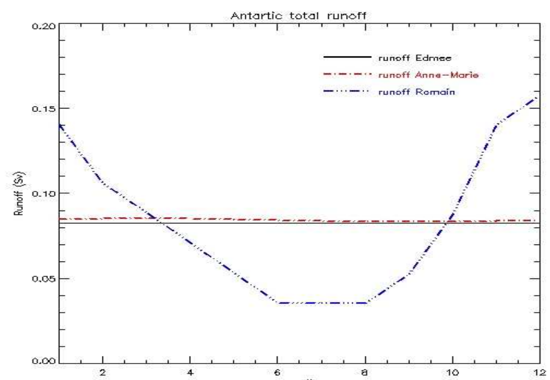

FIG. 2 – Monthly antartic discharge, in blue. The black and red lines are from previous runoff files (where the Antarctic coastal runoff did not have a seasonal cycle).

5 Results

The global annual discharge is 1.31 Sv, larger than the DT02 dataset, mainly due to the addition of the Antarctic coastal runoff. The latitudinal repartition is shown in fig 3. 84 runoff values in the data file have not been taken into account in the in the coastal runoff part : runoff located on a small island (smaller than 20 grid points) and runoff located more than 3 degrees away from the coast. The global annual discharge of these rejected runoffs is 1.5 $1O^{-2}$ Sv

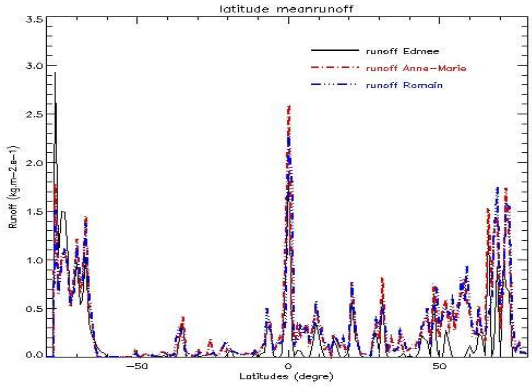

FIG. 3 – Zonal mean of the annual runoff (in blue). It is compared with a previous version (red) used for run ORCA025-G42, and to the runoff of Edmee Durand (2003), in black.

Regional maps are shown in Fig. 4. In the Amazon region (upper left), the Amazon and the Tocantins have a larger extension relative to previous runoff files (motivated by an unsufficient spreading of low salinity water in early ORCA025 experiments). Rivers near 50°W-5°N are represented with greater extension (Oyapock, Corentyne). The Alabama river (88°W-29°N) is represented. In the North of Russia (upper right), the Ob and the Taz have been spread over all the estuary. The Yenissei (110°E-74°N) is much more diffused as well. On the East coast of the North America (lower left), the St Laurence river has been spread out and more rivers appear in the north of Canada : George, Arnaud, Naskaupi. The south Asian region (lower right) shows similar features.

6 References

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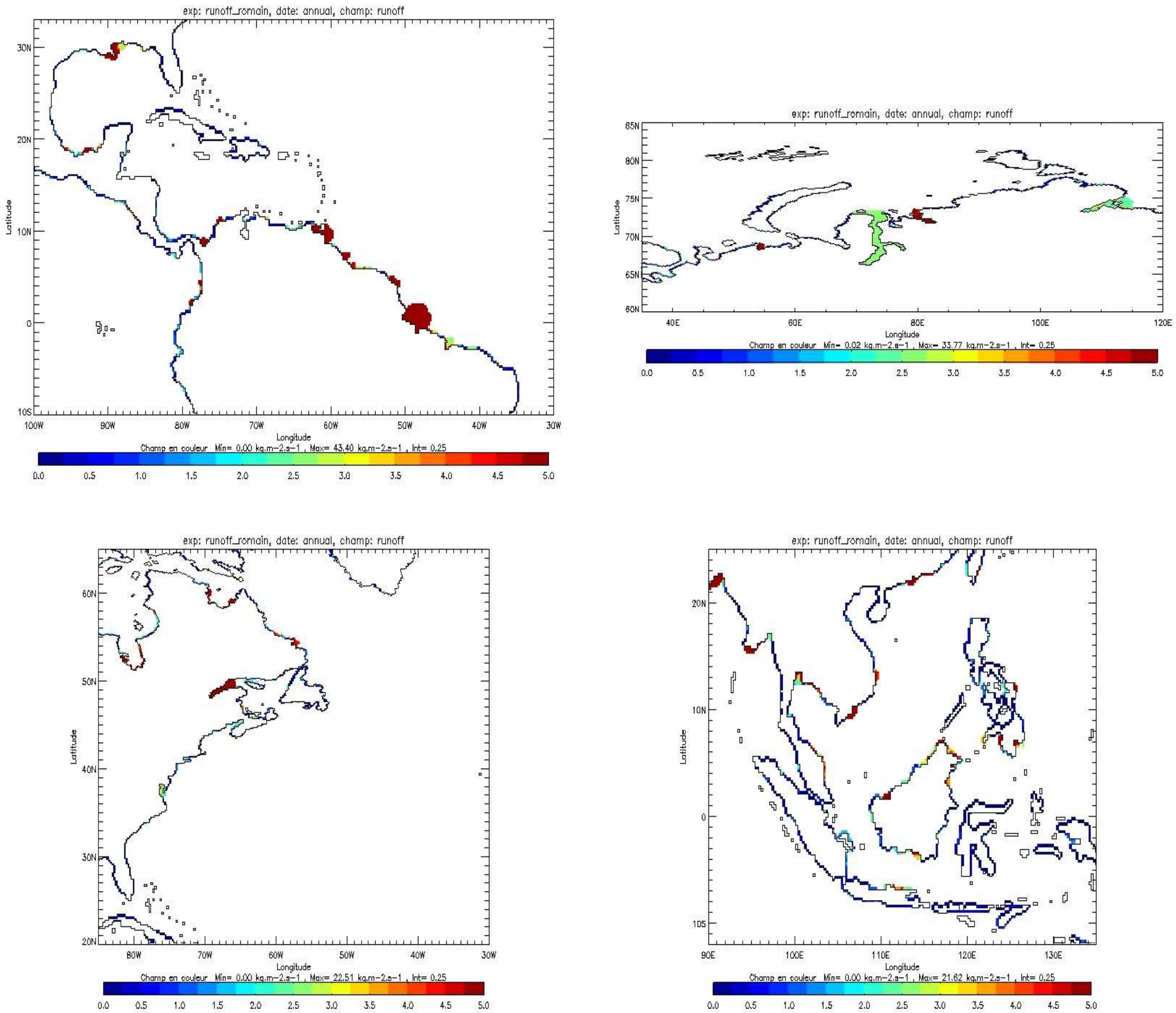

FIG. 4 – Annual runoff in four regions : Amazon, North Russia, North-East America, south Asia.

Table 1 (following pages) : list of the 99 major rivers.

river numer	Dai & Trenbeth number	River name	Annual volume (km3.yr-1)	lon D&T	lat D&T	i for ORCA025	j for ORCA025
1	1	amazon	6674.3129882812500	-51.00	0.00	946	499
2	2	congo	1306.5723876953130	13.00	-5.00	1202	479
3	3	orinoco	1126.1466064453130	-61.00	10.00	906	539
1	1	amazon	6674.3129882812500	-51.00	0.00	946	499
2	2	congo	1306.5723876953130	13.00	-5.00	1202	479
3	3	orinoco	1126.1466064453130	-61.00	10.00	906	539
4	4	changjiang	951.0073242187500	121.00	33.00	194	641
5	5	brahmaputra	624.4034423828125	90.00	25.00	70	602
6	6	mississipi	610.1058959960938	-91.00	31.00	786	630
7	7	yenissey	599.2224121093750	84.00	71.00	216	985
8	8	parana	567.9719848632813	-57.00	-34.00	922	354
9	9	lena	530.6795043945313	127.00	73.00	294	906
10	10	mekong	522.1766357421875	106.00	13.00	134	551
11	11	tocantins	517.8544921875000	-49.00	-1.00	954	495
12	12	tapajos	416.1152648925781	-55.00	-2.00	930	491
13	13	ob	413.2666320800781	70.00	67.00	1267	1007
14	14	ganges	401.1645507812500	89.00	25.00	66	602
15	15	irrawaddy	390.6878662109375	96.00	18.00	94	572
16	16	st lawrence	362.5499572753906	-67.00	49.00	886	731
17	17	amur	359.3233032226563	141.00	52.00	281	748
18	20	xijiang	357.762291015625	114.00	23.00	166	594
19	18	xingu	306.2500305175781	-52.00	-2.00	942	491
20	19	mackenzie	289.6512756347656	-134.00	69.00	551	906
21	XXX	para	268.4865112304688	-50.00	-2.00	950	491
22	36	zambeze1	266.6909790039063	36.00	-19.00	1294	422
23	21	columbia	255.1826171875000	-123.00	47.00	656	726
24	22	magdalena	235.2661895751953	-74.00	11.00	854	543
25	23	uruguay	227.9460449218750	-58.00	-33.00	918	359
26	24	yukon	215.1253509521484	-164.00	63.00	479	817
27	25	atrato	203.9931640625000	-77.00	7.00	842	527
28	26	danube	202.2315063476563	29.00	46.00	1262	724
29	28	ogooué	201.2275695800781	10.00	0.00	1190	499
30	27	niger	195.7747802734375	7.00	5.00	1178	519
31	29	essequibo	165.5147094726563	-58.00	7.00	918	527
32	XXX	bukuan	162.6399841308594	124.00	7.00	206	527
33	30	fraser	146.0812988281250	-122.00	49.00	660	742
34	31	pechora	140.2949676513672	54.00	68.00	1245	952
35	33	khatanga	128.5770568847656	107.00	74.00	265	942
36	32	nelson	126.1325759887695	-92.00	58.00	794	830
37	48	mahanadi	123.4809188842773	87.00	21.00	58	585
38	34	sepik	122.5293045043945	144.00	-3.00	286	487
39	36	zambeze2	119.6366806030273	36.00	-18.00	1294	426
40	35	kolyma	117.4317474365234	161.00	69.00	367	852
41	XXX	barka	115.8996505737305	38.00	18.00	1302	572
42	XXX	ulut	115.1665878295898	125.00	12.00	210	547
43	39	sanaga	112.9029922485352	11.00	4.00	1194	515
44	43	usumacinta	110.9588088989258	-92.00	19.00	782	576
45	XXX	nyong	106.8598785400391	10.00	4.00	1190	515
46	41	rajang	102.6780242919922	112.00	3.00	158	511
47	80	oyapock	101.2432785034180	-51.00	4.00	946	515
48	44	maroni	101.0052337646484	-54.00	6.00	934	523
49	134	senegal	99.8810424804688	-16.00	19.00	1086	576
50	XXX	turiacu	98.4281387329102	-45.00	-2.00	970	491

river numer	Dai & Trenbeth number	River name	Annual volume (km3.yr-1)	lon D&T	lat D&T	i for ORCA025	j for ORCA025
51	40	godavari	96.6239852905273	82.00	17.00	38	568
52	174	Grande de San	94.5379867553711	-106.00	23.00	726	594
53	XXX	davao	92.9742279052734	125.00	7.00	210	527
54	42	sao fransisco	91.9746551513672	-36.00	-10.00	1006	459
55	38	indus	88.5257339477539	69.00	25.00	1426	602
56	51	san juan	85.9970092773438	-77.00	5.00	842	519
57	61	taz	83.4067001342773	79.00	68.00	187	996
58	46	purari	77.9644470214844	145.00	-7.00	290	471
59	45	rhine	77.4084854125977	6.00	53.00	1166	755
60	57	tigris	76.9235153198242	47.00	32.00	1338	636
61	XXX	arnaud	72.5932998657227	-68.00	59.00	894	805
62	XXX	uda	72.5395431518555	135.00	55.00	262	773
63	50	jacui	71.7191543579102	-51.00	-29.00	946	378
64	49	sacramento	69.1390914916992	-122.00	38.00	662	667
65	92	chao praya	69.0412216186523	100.00	12.00	110	547
66	XXX	ba	69.0412216186523	109.00	12.00	146	547
67	XXX	gambia	68.2213363647461	-16.00	14.00	1086	556
68	63	courantyne	66.2140274047852	-57.00	6.00	922	523
69	77	susitna	66.1370086669922	-150.00	62.00	529	823
70	82	rufiji	66.1315231323242	40.00	-11.00	1310	455
71	XXX	sesayap	64.9734344482422	118.00	3.00	182	511
72	87	skeena	64.9120254516602	-130.00	55.00	621	789
73	150	cross	63.6736831665039	8.00	8.00	1182	531
74	189	orange	62.7484817504883	17.00	-29.00	1218	378
75	XXX	naskaupi	62.7029953002930	-60.00	53.00	916	754
76	62	po	61.8996849060059	12.00	46.00	1195	713
77	67	alabama	60.3524131774902	-88.00	31.00	798	630
78	XXX	mamberamo	59.7507133483887	138.00	-2.00	262	491
79	102	esmeraldas	59.1020812988281	-78.00	2.00	838	507
80	81	george	59.0025749206543	-68.00	58.00	892	797
81	XXX	digul	58.8638496398926	139.00	-7.00	266	471
82	XXX	cacipore	58.7281494140625	-52.00	4.00	942	515
83	131	nyanga	58.4193611145020	9.00	-2.00	1186	491
84	164	narva	57.6874122619629	29.00	60.00	1232	836
85	53	kuskokwim	57.0187950134277	-162.00	61.00	489	805
86	54	albany	56.8876037597656	-81.00	53.00	833	769
87	60	chidwin	56.6758766174316	96.00	22.00	94	589
88	129	kinabatangan	56.4265480041504	118.00	6.00	182	523
89	74	susquehanna	56.4206466674805	-76.00	40.00	847	677
90	XXX	huang	56.3485527038574	121.00	35.00	194	651
91	64	indigirka	55.8909683227539	150.00	72.00	342	878
92	59	ottawa	55.2164001464844	-74.00	46.00	856	713
93	58	krishna	54.8718070983887	81.00	17.00	34	568
94	177	juba	54.7996520996094	48.00	4.00	1342	515
95	83	nile	54.5960731506348	10.00	34.00	1190	645
96	88	garonne	53.8341102600098	5.00	44.00	1168	699
97	XXX	barito	53.6225967407227	115.00	-3.00	170	487
98	199	fortescu	53.2418670654297	116.00	-21.00	174	413
99	XXX	saguenay	52.4743309020996	-70.00	49.00	874	732