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Supporting Information for

Development of a World-Wide Database of Atoll Morphometrics

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Introduction

- Text S1 – detailed description of method for calculating complex morphometrics for each object on the atoll
- Figure S1 – example image of calculated per-point widths and other morphometrics on Faaite Atoll, French Polynesia
- Table S1 – summary table of all 154 atolls analyzed in dataset including total calculated areas for each landcover class

Detailed Methods of Atoll Morphometric Calculations.

Once the temporal composite is classified, the number and size of lagoons present on the atoll is given by user input. An automatic lagoon finder uses morphometric opening and closing to connect adjacent reef flats. If the automatic (unsupervised) lagoon finder is unable to find the correct number of lagoons, the user clicks pairs of points to close gaps between reef flats. These points are saved in a text file to ensure reproducibility. Morphometrics of the lagoons are calculated including area, perimeter, all the perimeter points (on a per-pixel basis), and the centroid. Atoll level morphometrics are also calculated including outside atoll perimeter (ocean perimeter), the atoll centroid, and shape factors used by Stoddart (1965). Area, perimeter, and centroid of each object (i.e. reef flat or motu) are calculated and stored in pandas dataframe where each row is the perimeter point per object (motu or reef flat) basis.

To determine if a perimeter point is an ocean or a lagoon side point, the closest distance to an atoll ocean or lagoon point is calculated. For each object (motu or reef flat), the perimeter points closest to the ocean and to the lagoon are determined and subtracted from the ocean and the lagoon distances respectively, creating relative distances, allowing for proper classification of points for motu positioned close to the edge of the reef flat (on the ocean or lagoon side). Each point is then classified as an ocean or lagoon point based on the relative distance. Points classified as ocean are checked to ensure that a line from that point to the closest atoll ocean point does not cross the object. If it does, that point is reclassified as a lagoon point. The points for each motu object are filtered to have a continuous ocean and a continuous lagoon side with the

points in spatial order. This filtering is not performed on the reef flat objects because there may be multiple lagoon and ocean segments based on the number of lagoons.

Several angles are calculated for each perimeter point. The shoreline exposure angle is the angle normal to the shoreline of the object that is pointing away from the lagoon towards the ocean. The positioning angle is the angle from the centroid of the atoll to the point in question. This positioning angle is used to create four bins (north, east, south, and west) used when analyzing atoll level morphometrics.

The widths calculated for each motu are motu width, ocean reef width (reef flat width in front of the motu), and lagoon reef width (reef flat width behind the motu). The widths calculated for the reef flat are reef flat width and effective reef flat width (width from the ocean to the closer of either the motu or lagoon) (Figure S1). The width code takes a list of points that the width will be calculated from, the exposure angle associated with those points and a list of points the width will be calculated to. The code finds the nearest point within a certain degree of normal (default 15°). The near normal width is used unless it is more than x times longer than the closest distance (default x is twice the distance). Motu width is measured from the ocean side to lagoon side motu points with an x of four times the distance (Figure S1). Ocean reef flat width is measured from ocean side motu points to ocean side reef flat points and the lagoon reef flat width is measured from lagoon side motu points to lagoon side reef flat points (Figure S1). For the ocean reef flat width and lagoon reef flat width, any width measurement that crossed another motu or itself is replaced with not a number (nan). Reef flat width is measured from ocean side to lagoon side reef flat points. Effective reef flat width is measured from ocean side reef flat points to the lagoon side of the reef flat unless a motu is in the way in which case it is measured to the ocean side of the motu in question. The closest point ±7° of normal is used unless that distance is more than 10 times the closest point. If the effective reef flat width is found to cross any motu, the closest width is used instead.

The length of each motu is calculated using the center points of motu width measurements. The center points are rounded to the nearest two pixels and connected into a line. A code steps through the points removing any loops. The motu length is calculated as the cumulative distance along that line. The length is also calculated along the ocean side and the lagoon side points. For the reef length, the ocean side length is used as proxy for the length. Since the reef flat ocean side points may not be in order, any points that are more than 3 pixels apart are skipped in the length sum. This skips points between adjoining reef flat pieces and any jumps between sections of the reef. After processing the motu, reef flat, and lagoons, all data frames are saved to CSV and excel spreadsheets. An example of the final summarized per atoll level output is shown in Table S1, detailing the total landcover area for every atoll analyzed (154).

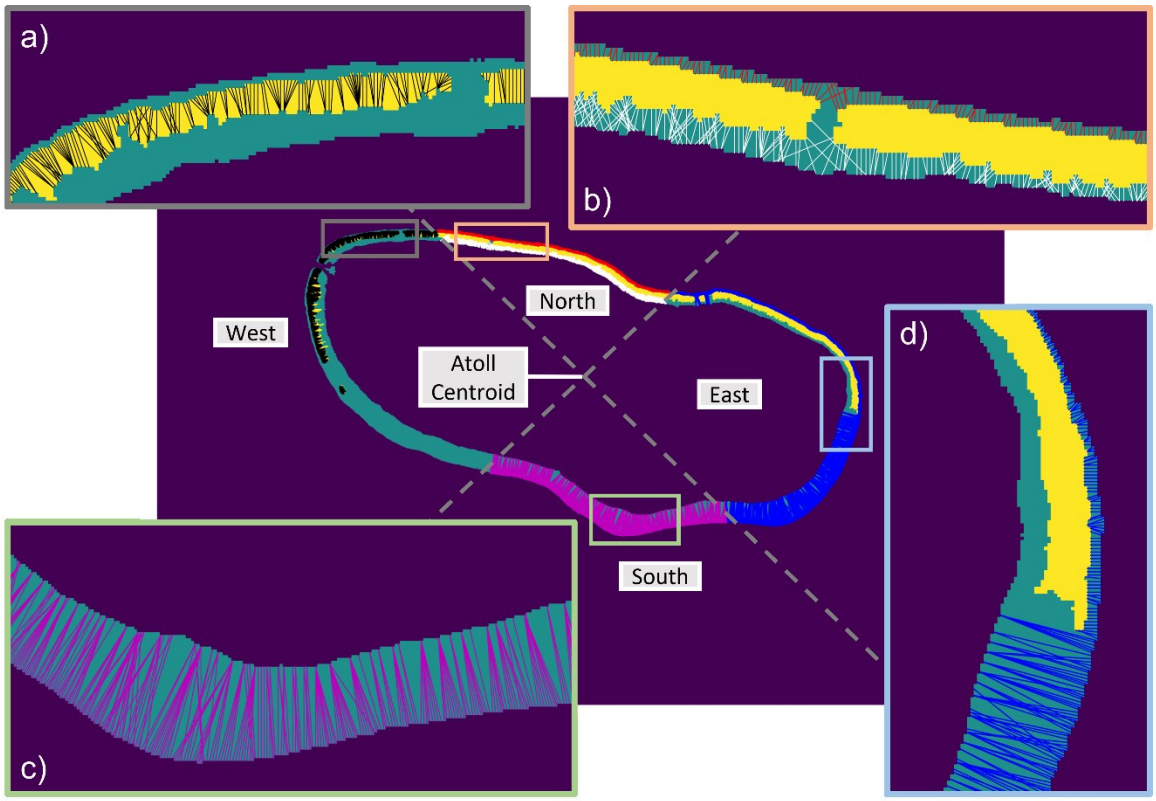

Figure S1. **Example of per-perimeter point morphometrics of width on Faaite Atoll, French Polynesia for a) motu width (black lines), b) ocean side reef width (red lines), lagoon side reef width (white lines), c) total reef flat width (purple lines), and d) effective reef flat width (blue lines). The motu are yellow, reef flat are teal, and water is purple. The atoll centroid and crossed dashed grey lines show how points are binned by cardinal position on the atoll (North, East, South and West).**

Table S1: Summary of all 154 Atolls analyzed with total area for each landcover class listed

Ocean Basin	Country	Name	Location	# Motu	# Reef Flat	Land Area (km^2)	Lagoon Area (km^2)	Reef Flat Area (km^2)	% Reef Flat Length Blocked
Indian	India	Bangaram	10.94°N, 72.29°E	2/4	2	1.23	5.84	23.43	8.5
		Kalpeni	10.1°N, 73.64°E	2/7	3	3.2	4.48	21.36	38.7
		Minicoy	8.28°N, 73.03°E	1/3	2	4.98	12.78	16	46.7
	Republic of Maldives	Goidhoo	4.86°N, 72.9°E	4/6	3	2.28	69.48	29.89	10.3
		Kaashidhoo	4.96°N, 73.46°E	1/3	2	2.84	1.58	6.21	38.7
		Kolhumadulu	2.55°N, 73.07°E	27/53	23	10.11	1533.24	124.21	20.8
		Rasdhoo	4.3°N, 72.96°E	3/5	5	0.65	41.29	15.22	13.2
	Seychelles	Aldabra	9.42°S, 46.35°E	10/44	8	153.9	13.64	338.54	38
	United Kingdom	Diego Garcia	7.23°S, 72.42°E	2/5	4	30.9	112.25	63.37	85.5
		Peros Banhos	5.24°S, 71.83°E	20/27	12	8.75	438.27	38.44	48.9
		Saloman	5.34°S, 72.24°E	5/10	1	3.22	21.69	13.84	48.3
Pacific	Caroline Islands	Ant	6.79°N, 157.95°E	7/12	1	3.04	70.61	25.46	34.3
		Ifalik	7.25°N, 144.45°E	2/2	1	1.42	2.06	4.46	44.2
		Murilo	8.75°N, 152.3°E	5/12	10	1.47	368.86	30.92	7.6
		Namoluk	5.92°N, 153.14°E	3/7	1	1.7	7.3	7.42	41.7
		Nomwin	8.6°N, 151.79°E	4/10	11	1.6	290.93	38.94	9.3
		Pakin	7.06°N, 157.8°E	8/15	1	2.68	11.14	13.79	46.9
		Ulithi	10.07°N, 139.73°E	15/33	23	4.24	310.2	46.04	19.2
		Woleai	7.37°N, 143.91°E	9/16	5	4.26	27.57	15.46	53.8
	Fiji	Fulqana	19.14°S, 178.57°W	8/20	1	18.29	15.33	48.48	57.4
		Nggelelevu	16.09°S, 179.25°W	2/3	5	1.67	123.49	61.54	6.3
		Wailangilala	16.77°S, 179.1°W	2/2	1	0.48	11.57	10.68	10.1
	France	Beautemps Beaupre	20.33°S, 166.18°E	1/2	4	0.55	53	62.04	5.4
		Nokanhui	22.73°S, 167.57°E	2/2	3	0.63	2.77	16.34	6.8
		Ouvea	20.55°S, 166.55°E	22/35	33	156.88	683.37	364.52	60.8
	French Polynesia	Ahe	14.49°S, 146.32°W	21/26	1	18.16	147.85	32.28	97.6
		Amanu	17.81°S, 140.76°W	24/62	2	17.51	219.59	39.14	82
		Apataki	15.46°S, 146.29°W	25/70	2	28.99	706.65	72.02	69.4
		Aratika	15.48°S, 145.51°W	17/48	2	13.15	154.66	32.65	73
		Arutua	15.32°S, 146.76°W	26/54	1	19.51	535.7	71.5	55.2
		Faaite	16.76°S, 145.24°W	7/27	2	11.48	233.37	52.27	52.6
		Fakahina	15.99°S, 140.13°W	1/1	1	11.88	18.31	18.04	100
		Fakarava	16.29°S, 145.51°W	22/71	2	27.22	1157.47	149.2	53.6
		Fangatau	15.82°S, 140.87°W	3/5	1	9.53	8.06	14.86	96.4
		Fangataufa	22.24°S, 138.75°W	9/25	1	5.62	39.03	15.68	80.2

Ocean Basin	Country	Name	Location	# Motu	# Reef Flat	Land Area (km^2)	Lagoon Area (km^2)	Reef Flat Area (km^2)	% Reef Flat Length Blocked
Pacific	French Polynesia	Hao	18.26°S, 140.88°W	73/183	1	33	520.38	84.48	83.6
		Haraiki	17.47°S, 143.45°W	4/12	1	5.12	10.77	15.14	61.4
		Hikueru	17.59°S, 142.61°W	4/13	1	6.4	81.45	30.96	47.7
		Hiti	16.73°S, 144.1°W	1/4	1	3.09	14.4	12.55	55.2
		Katiu	16.36°S, 144.42°W	11/44	2	12.03	238.59	39.52	61.1
		Kauehi	15.87°S, 145.14°W	14/44	1	18.54	319.31	36.66	78.5
		Kaukura	15.76°S, 146.71°W	33/72	3	17.55	431.01	138.62	37.7
		Manihi	14.4°S, 145.95°W	20/38	1	19.42	169.11	33.89	93.1
		Manuhangi	19.2°S, 141.25°W	1/2	1	3.92	8.62	6.72	95
		Maria Est	22.02°S, 136.19°W	2/2	1	4.19	6.81	7.7	98.1
		Marokau	18.06°S, 142.29°W	16/30	1	15.83	224.65	46.94	67.1
		Marutea Nord	17.07°S, 143.16°W	12/31	1	7.53	468.39	83.8	29.7
		Marutea Sud	21.52°S, 135.56°W	23/59	1	12.17	117.6	31.96	73.5
		Matureivavao	21.47°S, 136.4°W	1/4	1	4.38	18.29	9.8	84.7
		Maupihaa	16.82°S, 153.96°W	3/9	1	4.87	30	23.3	38.7
		Moruoa	21.85°S, 138.91°W	14/48	2	10.32	146.92	33.92	60.2
		Motu One	15.82°S, 154.53°W	4/4	1	3.84	2.74	10.05	78.5
		Motutunga	17.12°S, 144.37°W	20/43	2	4.87	127.3	34.91	50
		Nengonengo	18.76°S, 141.82°W	7/17	1	7.67	70.71	22.89	72.1
		Niau	16.16°S, 146.35°W	1/1	1	21.51	33.91	25.01	113.9
		Nihiru	16.7°S, 142.83°W	12/29	1	9.94	77.42	27.54	75.3
		Paraoa	19.14°S, 140.69°W	2/7	1	4.51	16.45	8.96	87.8
		Pukarua	18.32°S, 137.02°W	4/6	1	12.96	30.45	23.4	101.8
		Rangiroa	15.17°S, 147.59°W	69/184	4	73.38	1630.56	196.9	76.4
		Raraka	16.19°S, 144.9°W	28/70	1	18.42	369.85	47.4	81.4
		Raroia	16.09°S, 142.42°W	50/114	1	23.08	371.8	61.4	77.1
		Ravahere	18.24°S, 142.16°W	6/20	1	9.16	46.33	29.88	62.7
		Reao	18.52°S, 136.38°W	6/6	2	21.64	41.19	35.5	102
		Reitoru	17.86°S, 143.08°W	3/3	1	2.48	5.02	9.75	63
		Scilly	16.55°S, 154.69°W	5/10	1	5.77	84.92	35.08	43.4
		Taenga	16.36°S, 143.13°W	11/53	1	12.5	174.44	33.82	60.1
		Tahanea	16.9°S, 144.79°W	30/69	3	15.11	561.66	100.93	52
		Taiaro	15.74°S, 144.63°W	2/3	1	3.09	12.41	5.15	86
		Takapoto	14.63°S, 145.21°W	2/3	1	16.62	79.73	27.01	102
		Takaroa	14.45°S, 144.96°W	10/13	1	19.52	89.6	31.57	98.8
		Takume	15.79°S, 142.19°W	32/49	1	11.91	42.3	30.82	81.1
		Tatakoto	17.34°S, 138.39°W	14/20	1	12.31	18.29	23.88	83.1
		Tauere	17.38°S, 141.51°W	3/8	1	4.72	7.99	10.33	87.8

Ocean Basin	Country	Name	Location	# Motu	# Reef Flat	Land Area (km^2)	Lagoon Area (km^2)	Reef Flat Area (km^2)	% Reef Flat Length Blocked
Pacific	French Polynesia	Tematangi	21.68°S, 140.63°W	13/14	1	10.02	64.33	19.54	98.3
		Temoe	23.35°S, 134.48°W	9/16	1	3.8	14.46	8.78	87.4
		Tepoto Sud	16.82°S, 144.28°W	3/3	1	2.77	1.25	5.08	103.6
		Tetiaroa	17.01°S, 149.56°W	6/9	1	5.55	9.67	23.76	37.2
		Tikehau	15.02°S, 148.17°W	48/86	2	32.81	399.62	70.06	95.9
		Toau	15.93°S, 146.05°W	20/31	4	15.94	570.45	113.38	48.5
		Tuanake	16.66°S, 144.22°W	9/27	1	5.61	25.55	14.41	73.4
		Tupai	16.27°S, 151.82°W	4/4	1	11.25	6.91	23.75	57.7
		Tureia	20.83°S, 138.54°W	2/2	1	10.56	61.9	17.63	99.7
		Vahanga	21.33°S, 136.65°W	1/1	1	3.78	5.26	6.59	98.1
		Vahitahi	18.78°S, 138.83°W	9/13	1	5.21	8.3	12.02	76.3
		Vairaatea	19.35°S, 139.23°W	5/8	1	4.82	13.5	9.44	87.4
	Indonesia	Dauwi	1.27°S, 136.68°E	4/4	6	2.07	10.65	8.67	27.5
		Kakaban	2.14°N, 118.54°E	1/1	1	6.03	4.45	7.29	105.4
		Mapia	0.88°N, 134.31°E	3/4	1	3.21	23.63	35.51	25.1
		Maratua	2.19°N, 118.65°E	3/12	9	23.19	43.48	115.27	27.2
		Nggasuang	2.19°S, 123.44°E	3/5	3	1.02	31.2	38.14	6
		Noekori	0.9°S, 135.45°E	3/3	1	3.68	7.49	50.08	11.9
		Pulau Karompa Lompa	7.23°S, 121.61°E	2/3	17	13.79	139.31	108.28	6.2
		Pulau Kokota	0.62°S, 128.54°E	18/39	1	8.91	12.67	33.97	56.2
		Pulau Lentea	5.81°S, 123.89°E	2/2	11	8.5	32.33	44.03	15.4
		Pulau Panggang	5.74°S, 106.6°E	1/1	1	0.15	0.46	1.52	10.9
		Pulau Pei	1.24°S, 136.38°E	5/8	1	14.05	66.46	66.75	27.6
		Pulau Sapuka	7.07°S, 118.15°E	1/1	3	1.17	4.7	30.84	6.6
		Pulau Sukar	0.56°S, 128.39°E	9/21	1	15.35	7.08	35.94	74.4
		Pulau Urbabo	0.39°N, 130.99°E	2/4	3	5.89	22.08	87.55	10.1
		Sabalana	6.84°S, 119.12°E	10/26	15	9.83	54.26	82.97	8.2
		Tiger	5.86°S, 106.6°E	2/7	1	0.92	1.45	8.94	13.1
	Kiribati	Abaiang	1.88°N, 172.91°E	9/25	12	17.99	249.43	103.01	50.2
		Abemama	0.41°N, 173.88°E	5/7	4	31.89	151.29	108.47	71.4
		Aranuka	0.17°N, 173.6°E	4/12	2	16.07	17.35	49.38	68.5
		Beru	1.32°S, 175.98°E	1/9	1	18.37	0.78	51.01	52.8
		Butaritari	3.18°N, 172.83°E	16/69	6	23.23	290.74	114.32	45.6
		Maiana	0.94°N, 173°E	7/14	5	26.04	46.24	116.78	41.6
		Marakei	2.01°N, 173.28°E	1/10	1	13.61	17.02	27.91	96.4
		Onotoa	1.87°S, 175.57°E	2/5	10	13.85	29.32	79.28	55.7
		Orona	4.51°S, 172.18°W	3/4	1	8.02	24.69	15.96	93.1

Ocean Basin	Country	Name	Location	# Motu	# Reef Flat	Land Area (km^2)	Lagoon Area (km^2)	Reef Flat Area (km^2)	% Reef Flat Length Blocked
Pacific		Tarawa	1.48°N, 173.02°E	18/34	2	36.3	342.93	133.55	63
	Marshall Islands	Ailinginae	11.15°N, 166.41°E	18/34	2	5.71	105	48.56	34.5
		Ailinglapalap	7.57°N, 168.93°E	26/42	15	16.23	768.26	70.24	51.8
		Ailuk	10.35°N, 169.96°E	36/49	4	11.33	188.51	55.42	42.6
		Arno	7.11°N, 171.69°E	43/90	7	20.84	350.51	81.34	65.8
		Aur	8.25°N, 171.13°E	16/47	5	7.01	234.05	38.18	29
		Bikar	12.25°N, 170.11°E	3/6	1	0.57	40.05	22.06	7.2
		Bikini	11.65°N, 165.38°E	15/23	8	8.35	615.65	93.63	23.9
		Jaluit	6.13°N, 169.47°E	35/56	9	20.41	781.05	106.91	59.2
		Knox	5.91°N, 172.15°E	10/16	1	2.8	1.05	11.12	83.6
		Kwajalein	9.32°N, 167.52°E	57/97	41	22.04	2214.77	127.49	36.7
		Likiep	9.95°N, 169.16°E	39/75	8	13.39	411.88	58.81	44.9
	Marshall Islands	Majuro	7.13°N, 171.17°E	20/54	7	16.31	306.84	50.43	75.8
		Maloelap	8.76°N, 171.08°E	29/84	14	11.94	939.05	77.44	27.1
		Millie	6.25°N, 171.92°E	48/87	11	22.51	773.99	91.64	74.1
		Rongelap	11.45°N, 166.95°E	35/64	9	11.78	1006.62	115.38	31.6
		Taka	11.17°N, 169.63°E	4/6	4	0.85	99.6	37.49	6.3
		Ujelang	9.83°N, 160.9°E	15/39	4	3.84	68.82	30.33	26.6
		Utirik	11.27°N, 169.8°E	4/7	4	3.56	68.88	30.32	21.7
		Wotho	10.12°N, 165.99°E	9/19	8	6.03	90	31.97	27.9
		Wotje	9.5°N, 170.07°E	36/61	11	14.34	706.98	76.99	36.1
	New Zealand	Fakaofo	9.38°S, 171.22°W	10/32	2	4.03	47.39	20.1	41.2
		Nikunonu	9.16°S, 171.82°W	11/33	1	4.53	97.21	21.48	49.1
	Papua New Guinea	Awin	1.65°S, 144.02°E	2/2	1	0.84	3.43	5.58	29.9
		Budibudi	9.29°S, 153.67°E	4/7	2	3.23	9.15	12.38	52.6
		Conflict	10.73°S, 151.8°E	10/18	7	4.18	156.08	34.91	31
		Duperre	11.19°S, 151.94°E	4/5	5	0.85	116.01	50.36	5
		Heina	1.12°S, 144.5°E	7/7	2	2.87	5.9	7.54	61.9
		Liot	1.41°S, 144.51°E	1/1	1	1.23	1.26	4.27	42.6
		Ninigo	1.23°S, 144.34°E	12/15	9	7.57	324.78	82.58	18.6
		Palawat	1.95°S, 146.49°E	1/4	2	0.14	6.62	3.08	6.7
		Pelleluhu	1.13°S, 144.39°E	10/11	1	5.52	29.09	31.98	37.1
		Pinipel	4.4°S, 154.13°E	1/2	1	6.02	7.79	16.75	54.4
		Sama	1.4°S, 144.08°E	2/3	1	0.7	1.31	5.93	26.5
		Samasuma	1.47°S, 144.04°E	1/2	1	2.25	2.89	7.9	40.1
	Philippines	Sibutu Group	4.73°N, 119.37°E	10/15	11	27.79	107.65	396.41	10.6
	The Republic of Palau	Kayangel	8.07°N, 134.7°E	3/4	1	1.67	2.43	18.92	22.1

Ocean Basin	Country	Name	Location	# Motu	# Reef Flat	Land Area (km^2)	Lagoon Area (km^2)	Reef Flat Area (km^2)	% Reef Flat Length Blocked
Pacific	Tuvalu	Nanumea	5.67°S, 176.1°E	2/5	1	4.04	3.34	17.51	43.3
		Nui	7.22°S, 177.15°E	5/9	1	6.1	2.7	17.28	69.4
		Nukufetau	8°S, 178.37°E	8/35	2	5.48	93.01	26.1	51.7
		Nukulaelae	9.39°S, 179.84°E	8/19	1	3.53	16.73	23.19	54.1
		Vaitupu	7.48°S, 178.68°E	1/4	1	5.79	0.56	9.55	78.5
	United Kingdom	Nukapu	10.09°S, 166.04°E	1/1	1	0.35	0.26	5.87	15.7
		Nupani	10.07°S, 165.72°E	1/4	1	0.38	9.36	12.73	6.5
Total	**17**	**154**		**1,752/3,791**	**593**	**1,831.6**	**27,784**	**7,370.4**	