

Ship wakes: Kelvin or Mach angle? – Supplemental Material

We have selected a series of images from Google Earth (www.earth.google.com) taken close to harbors, in order to have both a large number of boats and a good image resolution. We had to discard many pictures because the boat had no constant heading or the wake was not clearly visible. The data for the 37 selected wakes are listed in Tab. 1. Images can be retrieved by copying the coordinates given in the table directly into Google Earth.

For each image, we give in Tab. 1 the latitude and longitude of the boat, the date of the picture (because various images at the same location are available in Google Earth). The local sea depth H at each location has also been determined from nautical charts (Navionics, <http://www.navionics.com/en/>). On each image we measure the boat length L using the calibration provided by Google Earth (we assume here that the total length as seen from above is close to the water length of the hull). We determine the wake angle α as the angle between the line going through the brightest points of the wake and the direction of the boat. Along this line we measure the wavelength λ of the waves as the perpendicular distance between two crests. We also measure the angle θ between the wavevector and the boat trajectory (Fig. 3a), and we compute the boat velocity using the stationary pattern condition (Eq. 1). From U and L we deduce the value of the hull Froude number $Fr = U/\sqrt{gL}$, with $g = 9.81 \text{ m s}^{-2}$ the gravitational acceleration. The depth Froude number, $Fr_H = U/\sqrt{gH}$, is also given in the table.

Uncertainty on the measurement of the angle α is of the order of $\pm 2^\circ$, and uncertainty for the Froude number is typically $\pm 20\%$.

label	location	Lat.	Long.	H (m)	Picture date	α (°)	λ (m)	θ (°)	U (m/s)	L (m)	Fr	Fr _H
1	Honfleur, FR	49.500	0.067	14	Mar-07	7.00	3.70	13.00	10.68	6.2	1.37	0.91
2	Baltimore, US	39.171	-76.494	5	Aug-10	7.50	3.20	10.50	12.27	5.50	1.67	1.75
3	Athens, GR	37.714	23.938	7	Aug-11	7.65	2.50	13.00	8.78	3.00	1.62	1.06
4	Palma2, ES	39.526	2.589	30	Sep-10	7.70	2.25	15.00	7.24	4.90	1.04	0.42
5	Napoli, IT	40.789	14.183	20	Sep-07	8.10	2.86	15.10	8.11	8.10	0.91	0.58
6	Corsica, FR	42.133	8.573	45	Aug-09	8.20	3.50	15.00	9.03	7.00	1.09	0.43
7	Toronto, CA	43.630	-79.364	2	Sep-09	9.00	2.10	14.20	7.38	5.2	1.03	1.67
8	Boston, US	42.294	-70.918	6	Jun-10	9.50	6.70	22.25	8.54	10.70	0.83	1.11
9	Palma, ES	39.497	2.738	9	Sep-10	9.75	5.10	17.50	9.38	8.90	1.0	1.00
10	Ventimiglia, IT	43.770	7.667	50	Jul-11	12.00	8.00	21.30	9.73	14	0.83	0.44
11	Marseille, FR	43.278	5.317	25	Aug-07	13.00	5.61	20.00	8.65	30.80	0.50	0.55
12	Geneva1, CH	46.263	6.169	5	Jun-11	13.55	4.70	23.60	6.77	50.00	0.31	0.97
13	Lausanne1, CH	46.505	6.563	37	Jul-09	13.83	2.00	16.40	6.26	7.20	0.74	0.33
14	Singapore2, SG	1.218	103.911	11	Nov-09	14.30	15.50	26.55	11.01	56.90	0.47	1.06
15	Istambul5, TR	41.108	29.074	60	Sep-11	16.40	4.80	33.45	4.97	20.30	0.35	0.20
16	Lorient, FR	47.688	-3.393	8	Nov-05	16.90	4.40	40.80	4.01	57.70	0.17	0.45
17	Ibiza, ES	38.901	1.456	30	Jul-07	17.00	3.80	35.70	4.17	19.60	0.30	0.24
18	Istambul2, TR	41.037	29.018	32	Sep-11	17.30	10.90	28.45	8.66	15.60	0.70	0.49
19	Istambul1, TR	41.028	28.996	38	Sep-11	17.40	8.40	34.20	6.44	59.00	0.27	0.33
20	Singapore3, SG	1.282	104.042	10	Feb-08	17.59	7.20	40.15	5.20	71.70	0.20	0.52
21	Lausanne2, CH	46.506	6.576	120	Jul-09	17.65	2.50	36.30	3.34	9.70	0.34	0.10
22	Geneve2, CH	46.296	6.187	45	Jun-11	17.67	10.50	30.80	7.91	73.00	0.30	0.38
23	Antwerpen, BE	51.350	3.794	20	Jan-05	18.50	8.45	45.50	5.09	95.80	0.17	0.36
24	Singapore1, SG	1.231	103.704	7	Sep-08	18.65	5.00	36.70	4.68	16.30	0.37	0.56
25	Canakkale, TR	40.166	26.393	80	Jul-11	18.80	15.70	42.35	7.35	137.50	0.20	0.26
26	Lorient2, FR	47.699	-3.371	10	Nov-05	19.00	7.10	46.70	4.57	17.70	0.35	0.46
27	Saint-Nazaire, FR	47.291	-2.159	10	Apr-11	19.15	14.00	46.45	6.45	142.00	0.17	0.65
28	Istambul8, TR	41.195	29.104	65	Aug-11	19.50	6.35	37.50	5.17	79.00	0.19	0.20
29	Lausanne3, CH	46.508	6.611	55	Jul-09	19.85	4.40	41.50	3.96	9.20	0.42	0.17
30	Istambul7, TR	41.178	29.084	55	Aug-11	19.95	8.60	43.30	5.34	146.00	0.14	0.23
31	Cadiz, ES	36.555	-6.299	10	Jun-10	20.00	6.20	50.00	4.06	21.40	0.28	0.41
32	Antwerpen2, BE	51.354	3.878	16	Jan-05	20.00	5.20	42.50	4.22	77.50	0.15	0.34
33	Amsterdam, NL	52.371	4.982	2	May-08	20.50	3.50	44.50	3.34	11.50	0.31	0.75
34	Singapore4, SG	1.322	104.073	7	Sep-11	20.60	20.00	53.00	7.00	56.60	0.30	0.84
35	Istambul3, TR	41.055	29.037	20	Sep-11	21.00	4.90	42.30	4.11	24.00	0.27	0.29
36	Istambul4, TR	41.075	29.050	60	Sep-11	21.00	5.10	53.00	3.53	11.80	0.33	0.15
37	Istambul6, TR	41.143	29.067	18	Jun-11	21.00	18.40	36.75	8.96	26.30	0.56	0.67

Tab. 1. Data corresponding to the set of images taken from Google Earth, giving in particular the measured wake angle α and the hull Froude number Fr plotted in Fig. 2.