

Upscaling CH₄ fluxes using high resolution imagery in arctic tundra ecosystems

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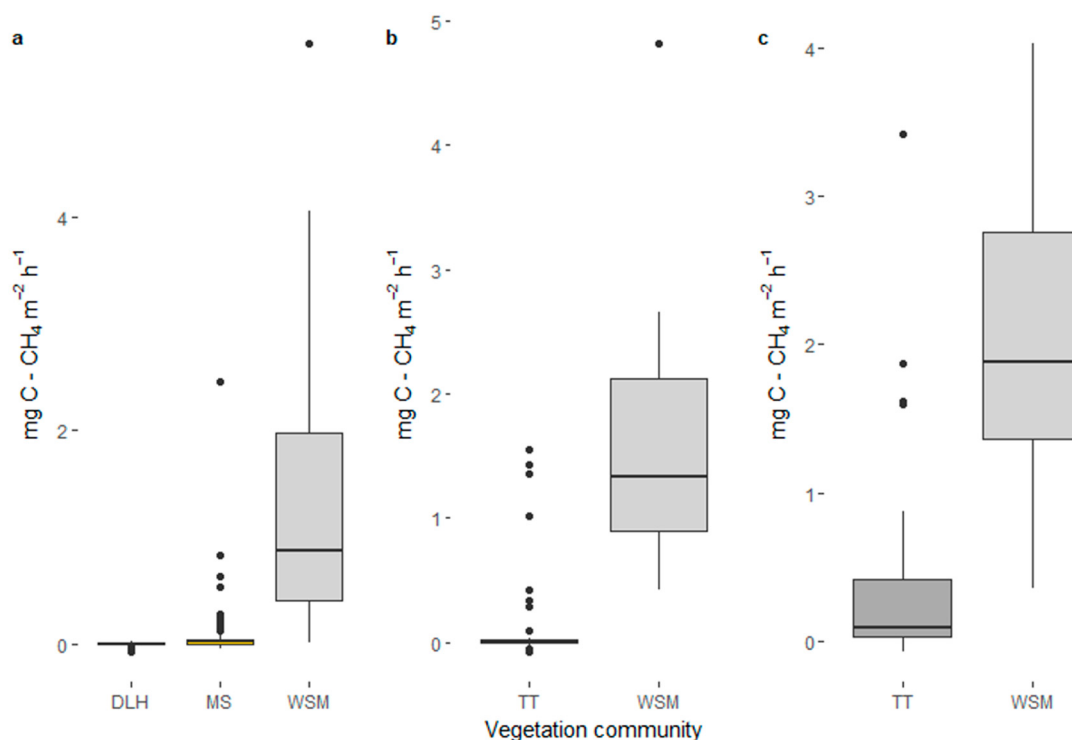


Figure S1. CH₄ flux (mg C-CH₄ m⁻² h⁻¹) for each vegetation community at a) Barrow-BEO/Barrow-BES (6 measurements between 29 June and 22 August 2014, b) Atqasuk (3 measurements between 3 July and 13 August 2014) and c) Iqotuk (3 measurements between 22 June and 20 August 2014). At Barrow-BEO/Barrow-BES; DLH is dry lichen heath (n=37), MS is mesic sedge-grass-herb meadow (n=65), WSM is wet sedge meadow (n=101). At Atqasuk; TT is tussock tundra (sandy substrates) (n=42), WSM is wet sedge meadow (n=20). At Iqotuk; TT is tussock tundra (non-sandy substrates) (n=46), WSM is wet sedge meadow (n=10). Boxplots represent median (midline), quartiles (box), maximum and minimum (whisker) with outliers represented as black points.

To establish whether there were any influential outliers within the data set, we used Cook's Distance (1977). This is a measure which computes the influence exerted by each data point on the predicted outcome. We used the following diagnostic plots to define which data points were influential.

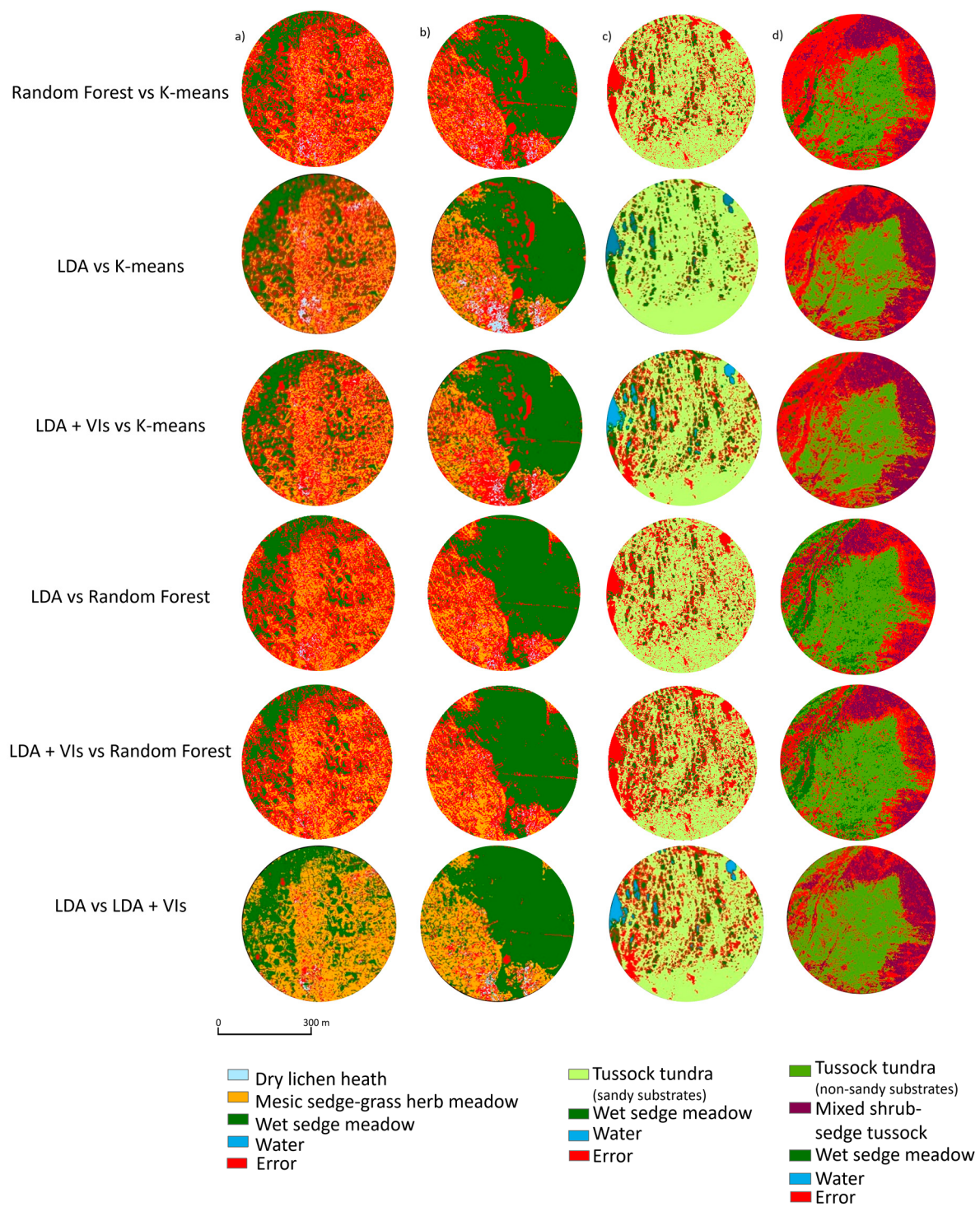


Figure S2. The error between mapping techniques (shown in red) a) Barrow-BEO b) Barrow-BES c) Atqasuk and d) Ivotuk.

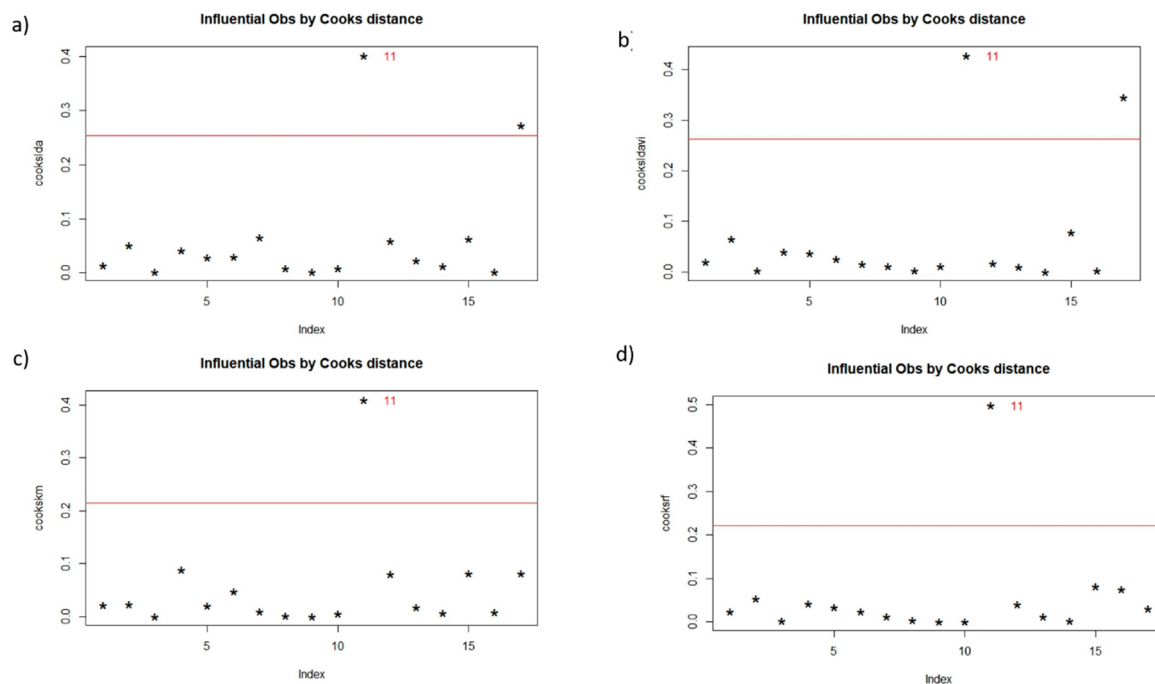


Figure S3. Diagnostic plots looking influential observations defined by Cook's Distance for a) Linear Discriminant Analysis (LDA) b) LDA including Vegetation Indices (VI) c) K-means (KM) and d) Random Forest (RF). Red line is the cut-off line, with values above this line being deemed influential.

After examining each influential row in the dataset, all observations of upscaled CH₄ estimates observed on the 22 August 2014 at Barrow-BES and 22nd June 2014 at Iivotuk were removed. 2 observations were removed from Barrow-BEO on the 22 August. 2 observations derived from the K-means and the Random Forest technique was removed at the same sites on the 22 August and 18 July 2014 respectively. The results of the Pearson's correlation coefficient between upscaling techniques and EC tower measurements excluding all outliers are shown in Figure 5 in the main manuscript. The results of the correlation coefficient when all outliers are included are shown in Figure S4.

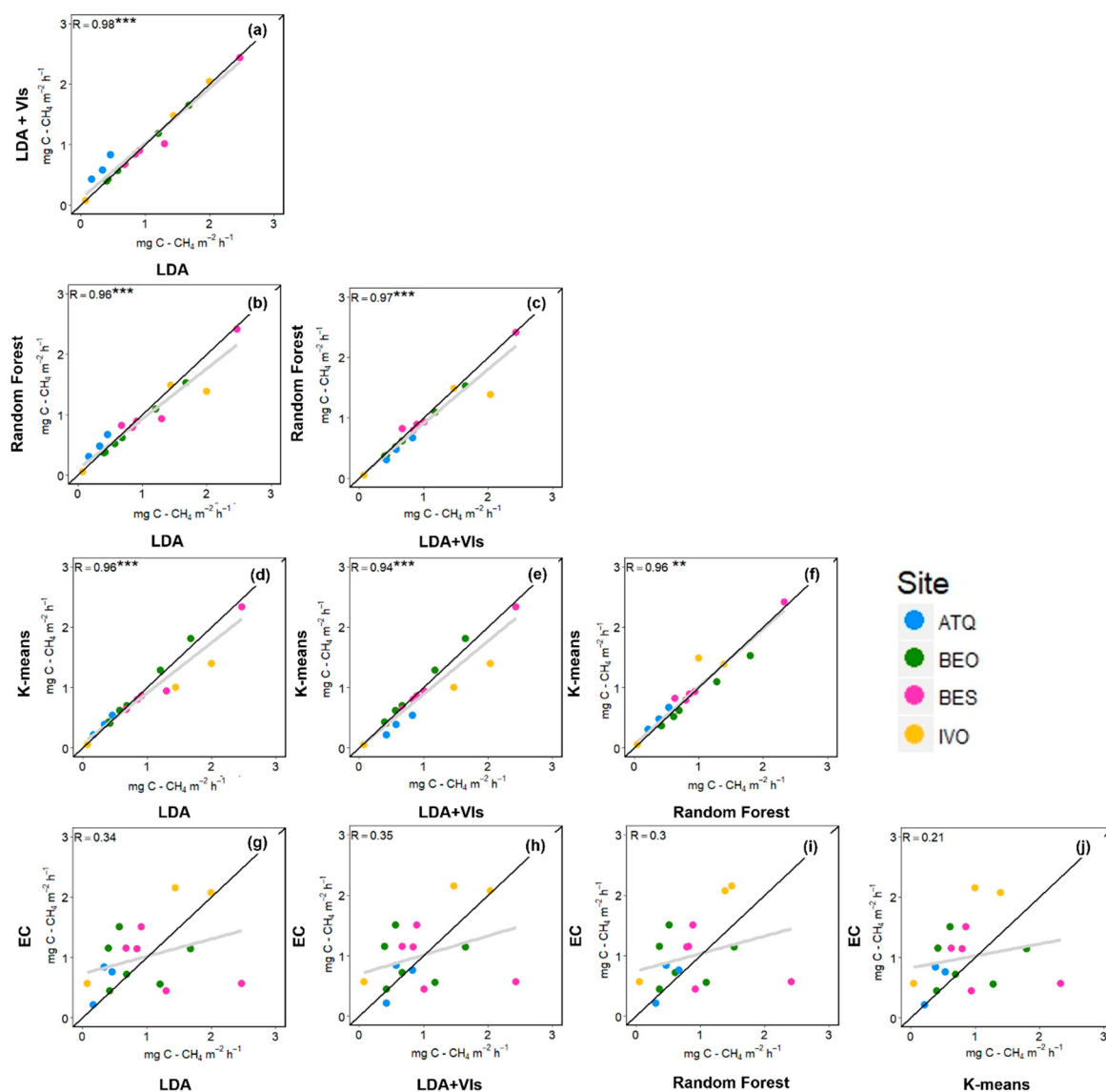


Figure S4. Comparisons between upscaled fluxes for the four mapping methods (a-f) and between the non-footprint-weighted upscaling and eddy covariance tower measurements (g-j). R is the correlation coefficient and *** denotes significance, $p < 0.001$, ** denotes significance, $p < 0.01$, * denotes significance, $p < 0.05$. Black line shows 1:1 relationship and grey line is the linear regression.

Table S1. Producer accuracy and user accuracy for each vegetation community and each mapping technique and each site.

Site	Vegetation community	Producer Accuracy (%)				User Accuracy (%)			
		LDA	LDA + VIs	KM	RF	LDA	LDA + VIs	KM	RF
Barrow-BEO/BES	Mesic sedge-grass-herb meadow	50	54	49	56	77	83	68	73
	Dry lichen heath	67	61	38	59	40	57	27	57
	Wet sedge meadow	84	82	79	77	66	54	66	62
Atqasuk	Tussock tundra (sandy substrates)	87	88	85	85	97	82	95	85
	Wet sedge meadow	91	68	87	70	70	77	67	70
Ivotuk	Tussock tundra (non-sandy substrates)	100	93	100	72	0.07	22	72	98
	Mixed shrub-sedge tussock	66	73	56	75	62	88	98	66
	Wet sedge meadow	67	71	96	90	98	90	80	33

Table S2. Vegetation community distribution in m² for each mapping technique. N/a denotes community was not present.

Site Vegetation community (m ²)	LDA	LDA + VIs	KM	RF
Barrow-BEO				
Mesic sedge-grass-herb meadow	149074.2	146967.1	110189.2	116127.2
Dry lichen heath	10927.64	15672.26	33549.98	54218.3
Wet sedge meadow	123846.2	121213.8	133512.3	123440.5
Water	n/a	n/a	6300.15	n/a
Total:	283848.0	283853.2	283851.6	282785.9
Barrow-BES				
Mesic sedge-grass-herb meadow	81561.71	83056.65	62433.11	62943.4
Dry lichen heath	14505.76	15581.08	33746.29	34582.3
Wet sedge meadow	187523	184937.6	177818.8	185273.1
Water	n/a	n/a	9546.38	n/a
Total:	283590.5	283575.3	283544.6	282798.8
Atqasuk				
Tussock tundra (sandy substrates)	237353.9	179841.9	226819.1	210954.1
Wet sedge meadow	35716.87	91949.56	46479.49	66823.8
Water	9785.24	11308.32	9923.98	5749.6
Total:	283128.0	283099.8	283222.6	283527.5
Ivotuk				
Tussock tundra (non-sandy substrates)	178733.52	182548.74	125923.72	68155.3
Mixed shrub-sedge tussock	99411.84	86936.92	131877.26	163393.2
Wet sedge meadow	2269.04	10925.96	21415.06	51970.0
Water	n/a	n/a	4318.33	n/a
Total:	280414.40	280411.62	283534.37	283518.4

Table S3. Agreement (A) and disagreement (D) of vegetation community distribution between mapping techniques.

Mapping technique	Barrow-BEO		Barrow-BES		Atqasuk		Ivotuk	
	A (%)	D (%)	A (%)	D (%)	A (%)	D (%)	A (%)	D (%)
LDA vs. RF	52.2	47.8	72.8	27.2	78.2	28.1	76.1	23.9
LDA + VIs vs. RF	52.1	47.9	73.2	26.8	67.7	32.3	76.4	23.6
KM vs. RF	21.9	78.1	66.3	33.7	78.2	21.8	60.4	39.6
LDA vs. KM	66.2	33.8	82.2	17.8	94.8	5.2	71.0	29.0
LDA + VIs vs. KM	62.5	37.5	77	23	83.1	16.9	72.2	27.8
LDA vs. LDA + VIs	92.8	7.2	92.9	7.1	79.0	21.0	81.0	19.0

Table S4. Upscaled methane (CH₄) fluxes assuming a constant vegetation and using the distribution of each vegetation community from the four mapping methods and associated eddy covariance tower flux measurement for each date. VIs indicate Vegetation Indices – Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Enhanced Vegetation Index (EVI). EC indicates Eddy Covariance. N/A denotes upscaled flux could not be calculated.

		LDA	LDA + VIs	KM	RF	EC
Site	Date	(mg CH ₄ -C m ⁻² h ⁻¹)				
Barrow-BEO	29 th June 2014	0.432	0.424	0.411	0.3730	0.446
	10 th July 2014	0.579	0.567	0.615	0.5219	1.506
	22 nd July 2014	0.690	0.676	0.697	0.6206	0.716
	7 th August 2014	1.684	1.648	1.805	1.5305	1.143
	15 th August 2014	0.407	0.399	0.426	0.3669	1.150
	22 nd August 2014	1.206	1.181	1.284	0.3730	0.559
Barrow-BES	29 th June 2014	1.303	1.015	0.943	1.0929	0.453
	10 th July 2014	0.915	0.902	0.861	0.9281	1.506
	22 nd July 2014	0.828	0.817	0.775	0.8921	1.395
	7 th August 2014	0.850	0.838	0.800	0.7937	1.143
	15 th August 2014	0.681	0.671	0.637	0.8247	1.150
	22 nd August 2014	N/A	N/A	N/A	N/A	0.573
Atqasuk	3 rd July 2014	0.173	0.424	0.221	0.3114	0.217
	30 th July 2014	0.345	0.580	0.390	0.4779	0.840
	13 th August 2014	0.467	0.831	0.537	0.6722	0.762
Ivotuk	22 nd June 2014	0.078	0.080	0.055	0.060	0.567
	18 th July 2014	1.441	1.471	1.004	1.890	2.155
	20 th August 2014	2.001	2.043	1.394	1.984	2.075

Table S5. Absolute difference between the EC tower flux measurements and the upscaled chamber flux measurements for each measurement date. Values are rounded to two decimal places. Negative values indicate the upscaled chamber flux was greater than those derived from the EC tower. Percentage difference is shown in parenthesis with values rounded to nearest whole number.

Site	Date	LDA		LDA + VIs		KM		RF	
Barrow-BEO	29 th June 2014	0.01	(3)	0.02	(5)	0.03	(8)	0.07	(16)
	10 th July 2014	0.93	(62)	0.94	(62)	0.89	(59)	0.98	(65)
	22 nd July 2014	0.03	(4)	0.04	(6)	-0.01	(2)	0.09	(13)
	7 th August 2014	-0.54	(47)	-0.51	(44)	-0.66	(58)	-0.39	(34)
	15 th August 2014	0.74	(65)	0.75	(65)	0.72	(63)	0.78	(68)
	22 nd August 2014	-0.65	(116)	-0.62	(111)	-0.72	(130)	0.19	(33)
Barrow-BES	29 th June 2014	-0.58	(127)	-0.56	(127)	-0.49	(108)	-0.64	(141)
	10 th July 2014	0.59	(39)	0.60	(40)	0.64	(43)	0.58	(38)
	22 nd July 2014	0.57	(41)	0.58	(42)	0.62	(45)	0.50	(36)
	7 th August 2014	0.29	(26)	0.30	(27)	0.34	(30)	0.35	(31)
	15 th August 2014	0.47	(41)	0.48	(42)	0.51	(45)	0.33	(28)
Atqasuk	3 rd July 2014	0.04	(20)	-0.21	(96)	0.00	(2)	-0.09	(44)
	30 th July 2014	0.50	(59)	0.26	(31)	0.45	(54)	0.36	(43)
	13 th August 2014	0.29	(39)	-0.07	(9)	0.22	(30)	0.09	(12)
Ivotuk	22 nd June 2014	0.49	(86)	0.49	(86)	0.51	(90)	0.51	(89)
	18 th July 2014	0.71	(33)	0.68	(32)	1.15	(53)	0.26	(12)
	20 th August 2014	0.07	(4)	0.03	(2)	0.68	(33)	0.09	(4)