Fennoscandian Land Uplift Gravity Lines Revisited

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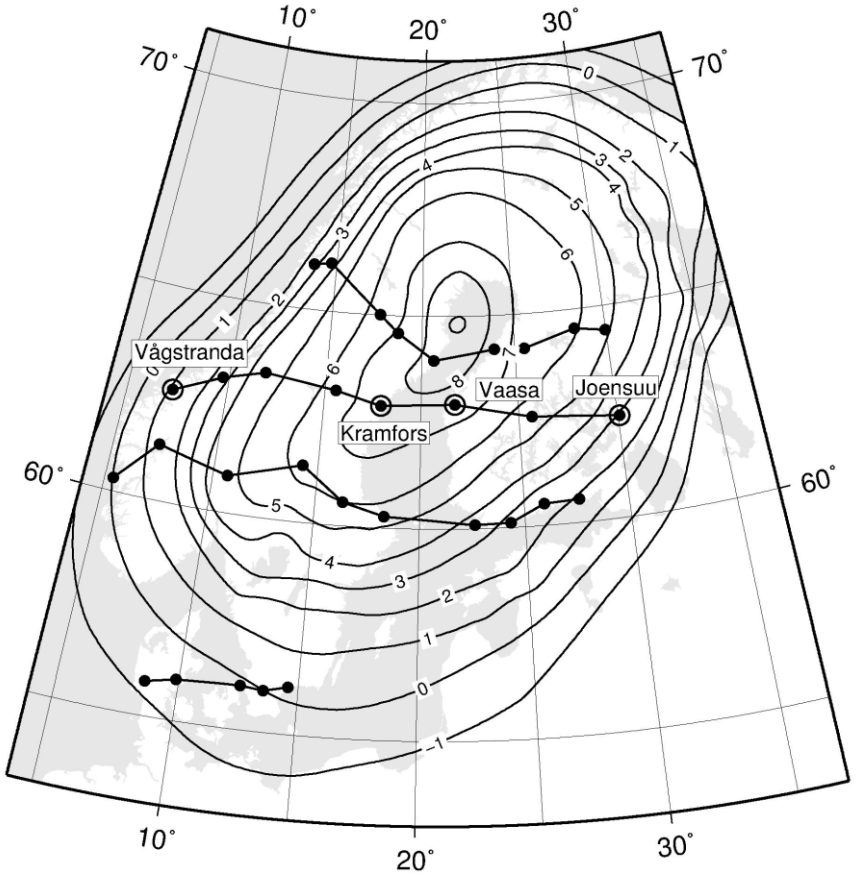
Some history



- Started 1966 in Finland along the latitude 63°N by A. Kiviniemi (FGI)
- Continued 1967 to Sweden and Norway by Lennart Pettersson (LMV)
- Norway (observers Bjørn Geirr Harsson and Åge Midtsundstad) joined 1972
- International (not only Nordic) participation, from 10 institutions
- Line along 65°N, first measurement in 1975
- Line along 61°N, first measurement in 1976
- Line along 56°N (Denmark- Sweden) first measured in 1977

Background: Land uplift isobases by Ekman (1996)

Research rationale

Kramfors, campaign of 2003

- To study the change in gravity (differences) associated with the Fennoscandian PGR
- In the absence (= non-existence) of accurate field-deployable absolute gravimeters, relative meters (LaCoste & Romberg G and D meters) were used
- Only quite small gravity differences could be accurately measured
- Stations had to be cleverly reconnoitered
- Line 63° had gravity differences of the order of 1 mGal, later lines some tenths of mGal
- Smoothed surfaces of bedrock with a marker for height reference

Results, publications, data compilations

85:4

THE FENNOSCANDIAN LAND UPLIFT GRAVITY LINES 1966–1984

by

Jaakko Mäkinen, Finnish Geodetic Insitute
Martin Ekman, National Land Survey of Sweden
Åge Midtsundstad, Geographical Survey of Norway
Ole Remmer, Danish Geodetic Institute

Martin EKMAN (Sweden)
Jaakko MÄKINEN (Finland)
Åge MIDTSUNDSTAD (Norway)
Ole REMMER (Denmark)

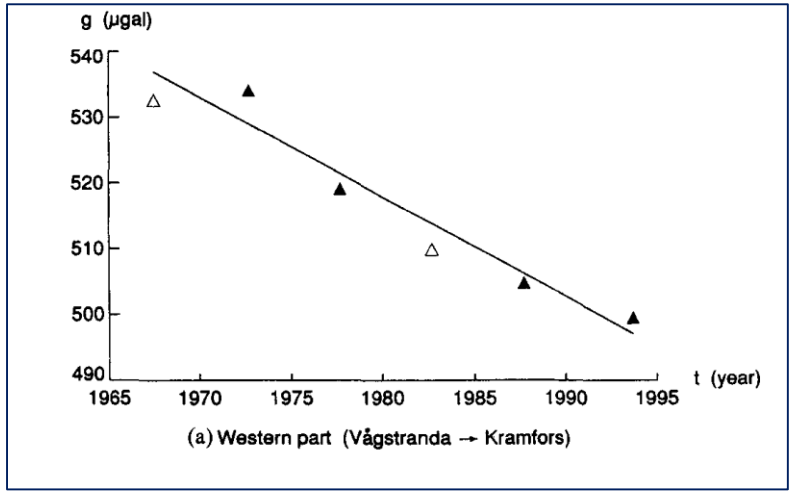
GRAVITY CHANGE AND LAND UPLIFT IN FENNOSCANDIA 1966 - 1984 (*)

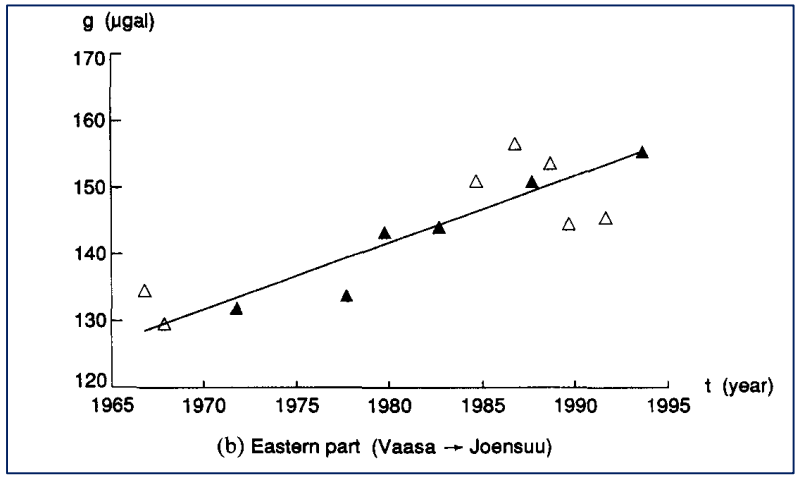
about $-0.22\,\mu\text{gal/mm}$.

Bull. Géod. 61 (1987) pp. 60–64.

- objective: estimate the ratio g_dot/h_dot
- was hampered by the fact that the h_dot was not so well known either
- publications by individual tems based on partial data
- until the NKG took measures to collect, recompute, and publish all data
- … up to 1984, published in Rep. FGI 85:4
- leading to the estimate at left

More publication history





Ekman and Mäkinen, GJI 1996

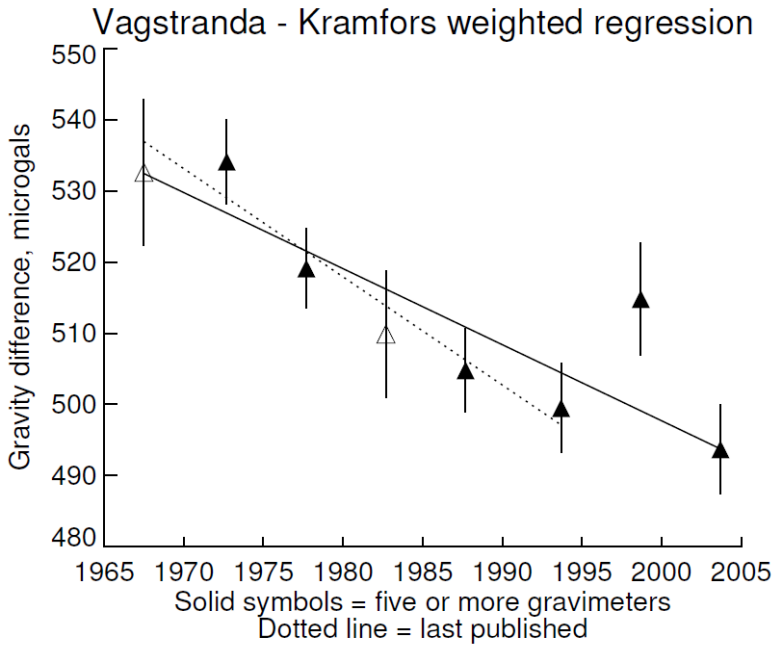
$$\dot{g} = -1.52 \pm 0.20 \ \mu\text{gal yr}^{-1}$$

$$\dot{g} = 1.00 \pm 0.14 \ \mu\text{gal yr}^{-1}.$$

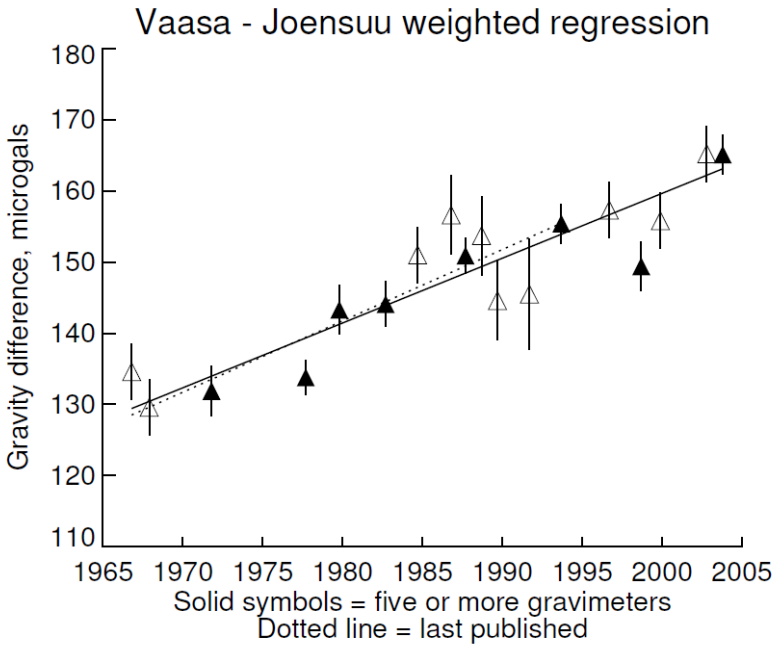
$$\dot{g}/\dot{h} = -0.204 \pm 0.058 \ \mu\text{gal mm}^{-1} \qquad \text{(95 per cent)}.$$

More publication history, bis

Mäkinen et al, GGSM2004 Proceedings (Springer IAG series)



$$\dot{g} = -1.07 \pm 0.24 \ \mu\text{gal/yr} \quad \text{(W)}$$



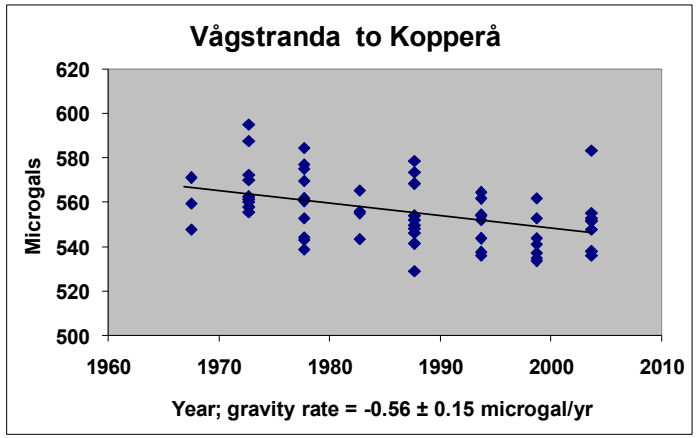
$$\dot{g} = +0.91 \pm 0.09 \ \mu\text{gal/yr} \quad \text{(E)}$$

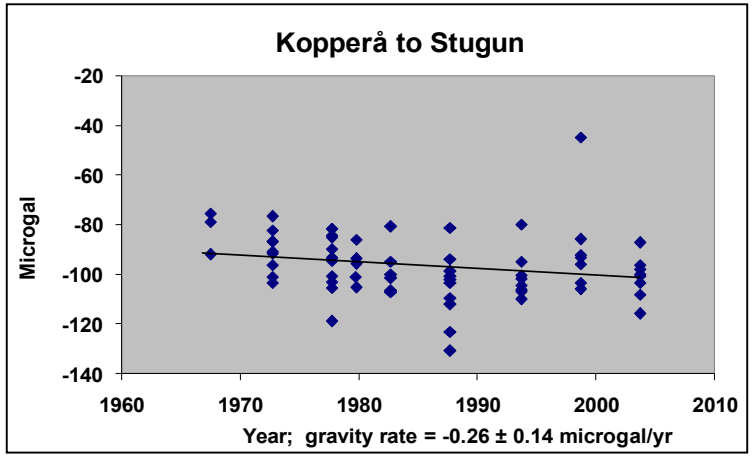
Much more h_dot results were available, including CGPS on the Eastern side
g_dot/h_dot estimates there were now -0.16 to -0.18 µGal/mm

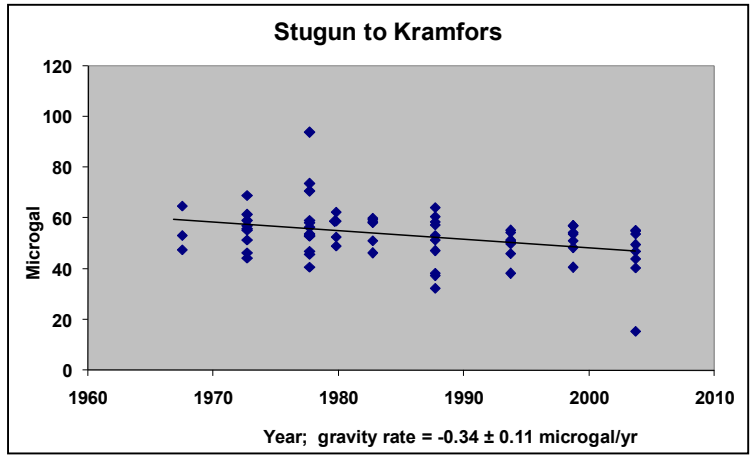
The aftermath

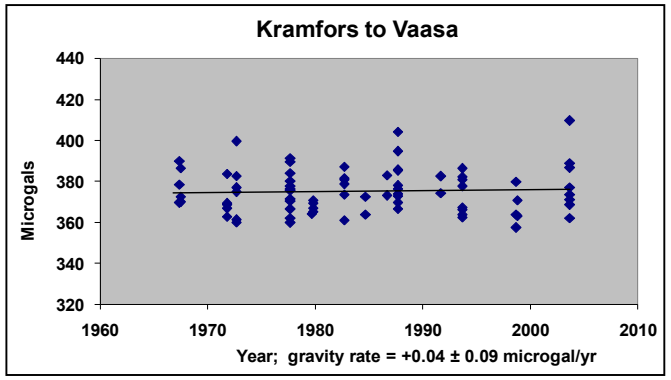
- 2003 was the last major campaign
- after that we were all scrambling to do FG5-measurements
- why was that?? – the g_dot uncertainties previously quoted were comparable with what is now being achieved with FG5 time series
- the answer is the much larger expenditure of work needed for the relative measurements
- AG gravity differences at AG stations close to the lines can be linked to the relative results

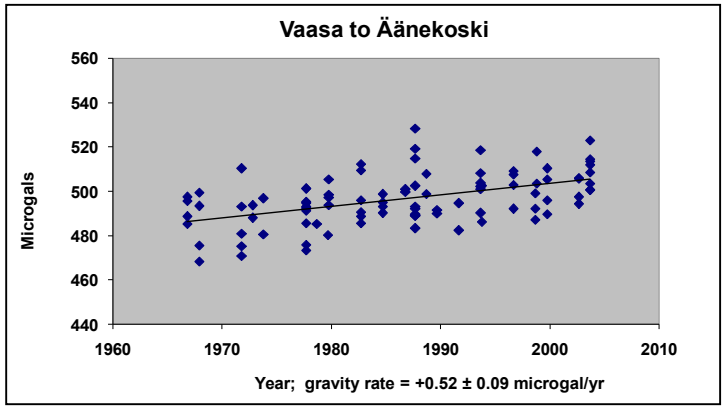
Each dot here is a result of a single gravimeter. Not from one to-and-fro measurement but from 3 to 4 to-and-fro measurements

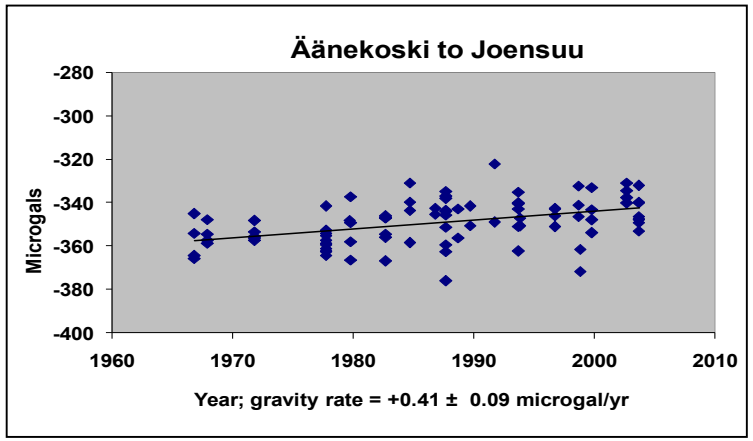








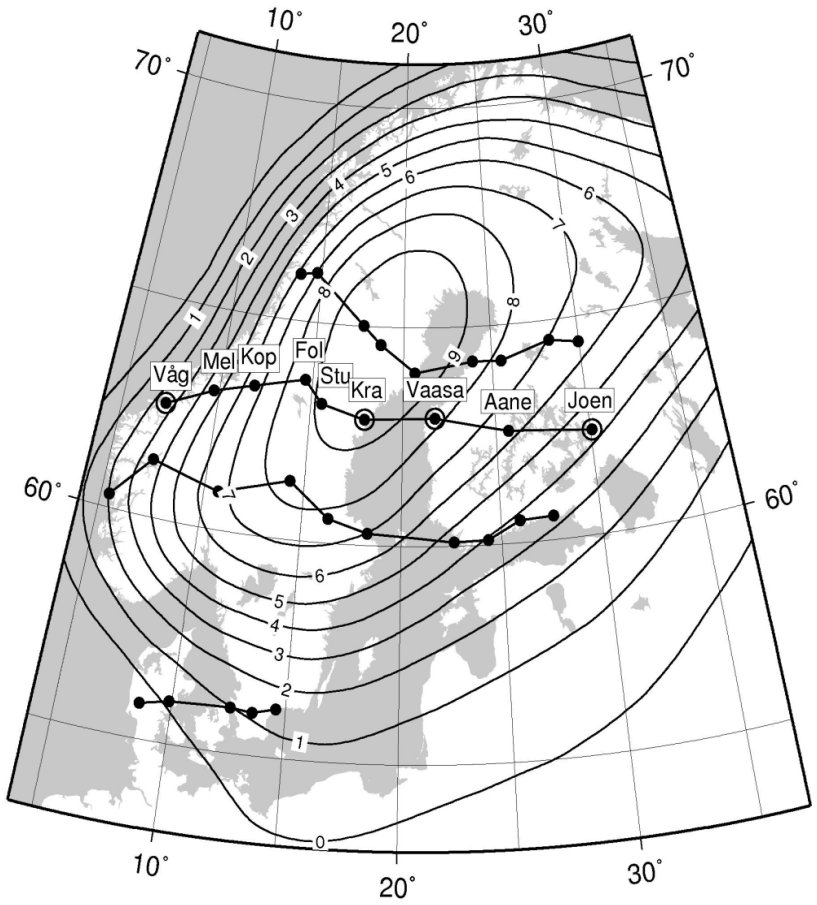




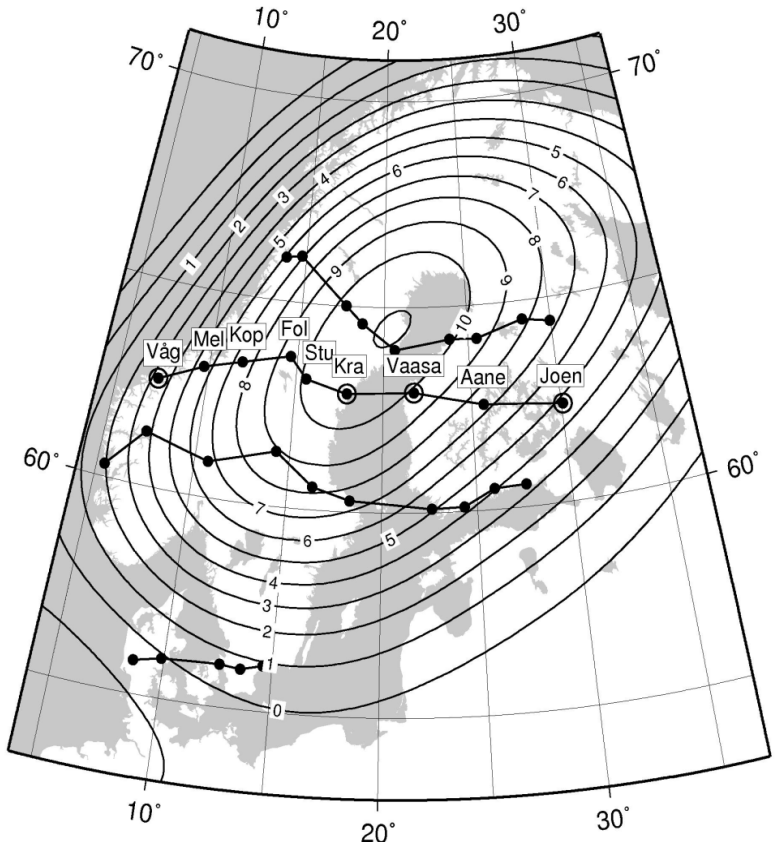
It takes 4 days to do one leg from Joensuu to Vågstranda, i.e. 24 days for 3+3 legs

Later assessments

- At some time we realized that doing δg_dot/δh_dot is not the only way of using the results or not even the best
- We can compare δg_dot results directly with models
- GIA modellers still do not routinely publish g_dot predictions
- but for a large class of GIA models it is adequate to do g_dot_predicted = k·h_dot_predicted
- where k depends on the size of the deglaciation
- in the following we use k = -0.163 µGal/mm

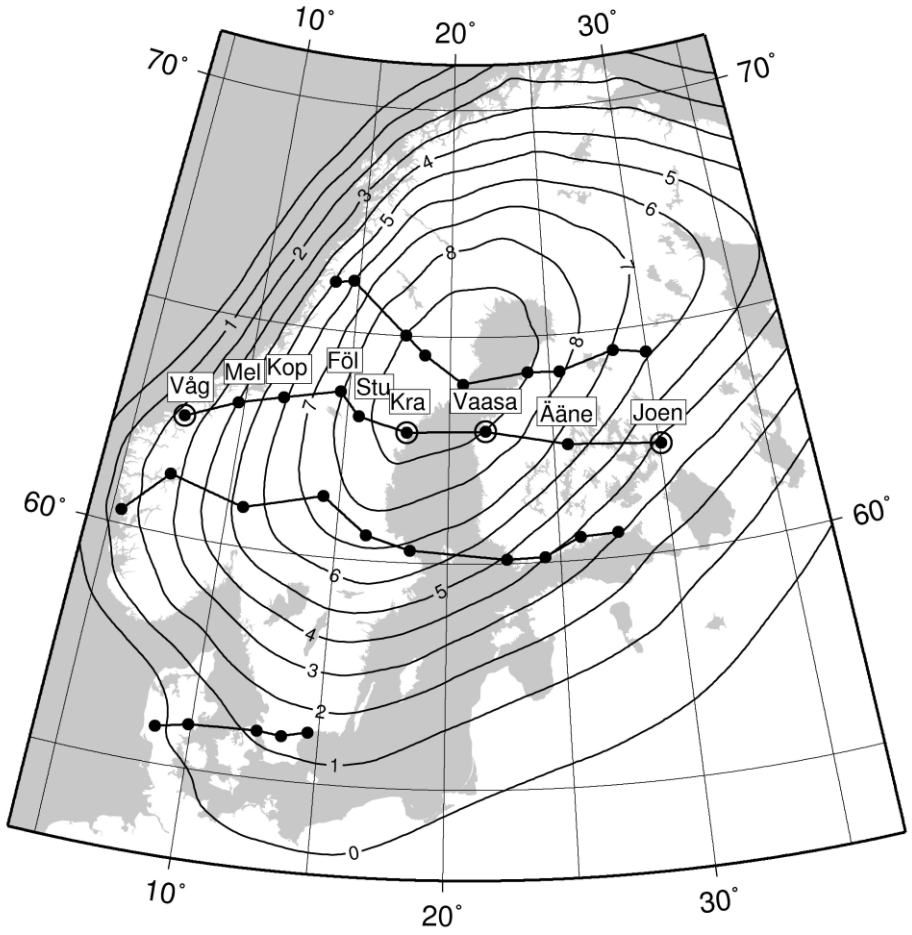


Lambeck et al. (1998)



Milne et al. (2004)

Old



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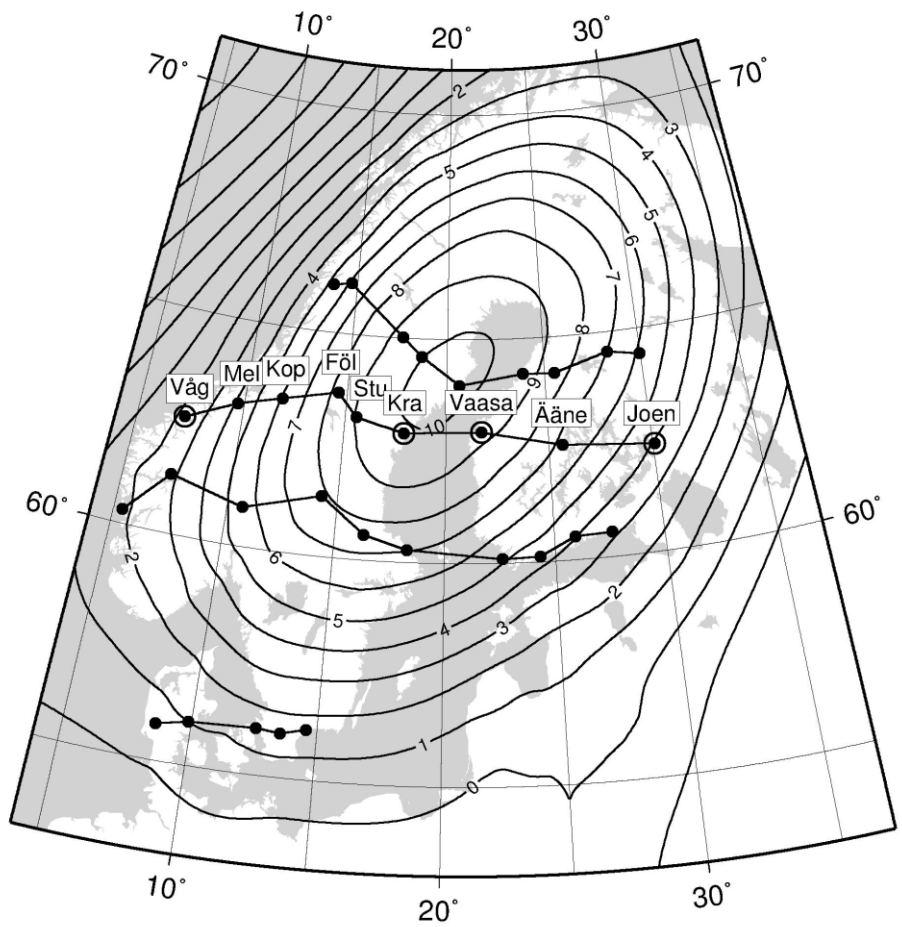
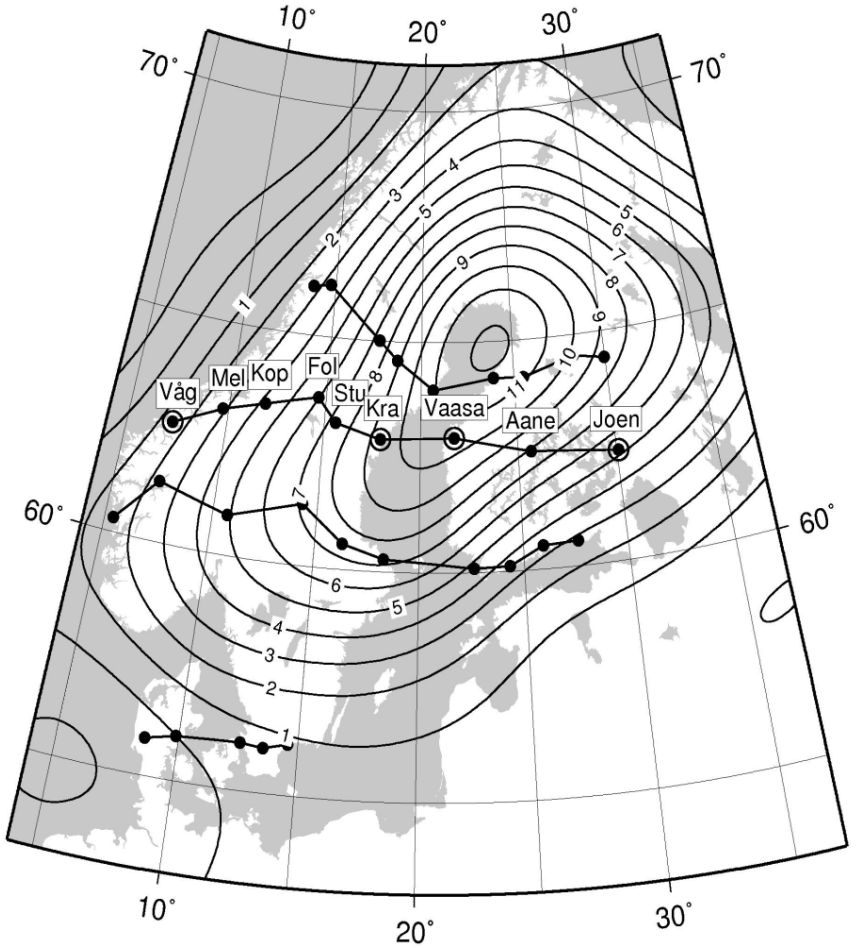


NKG2005LU_abs

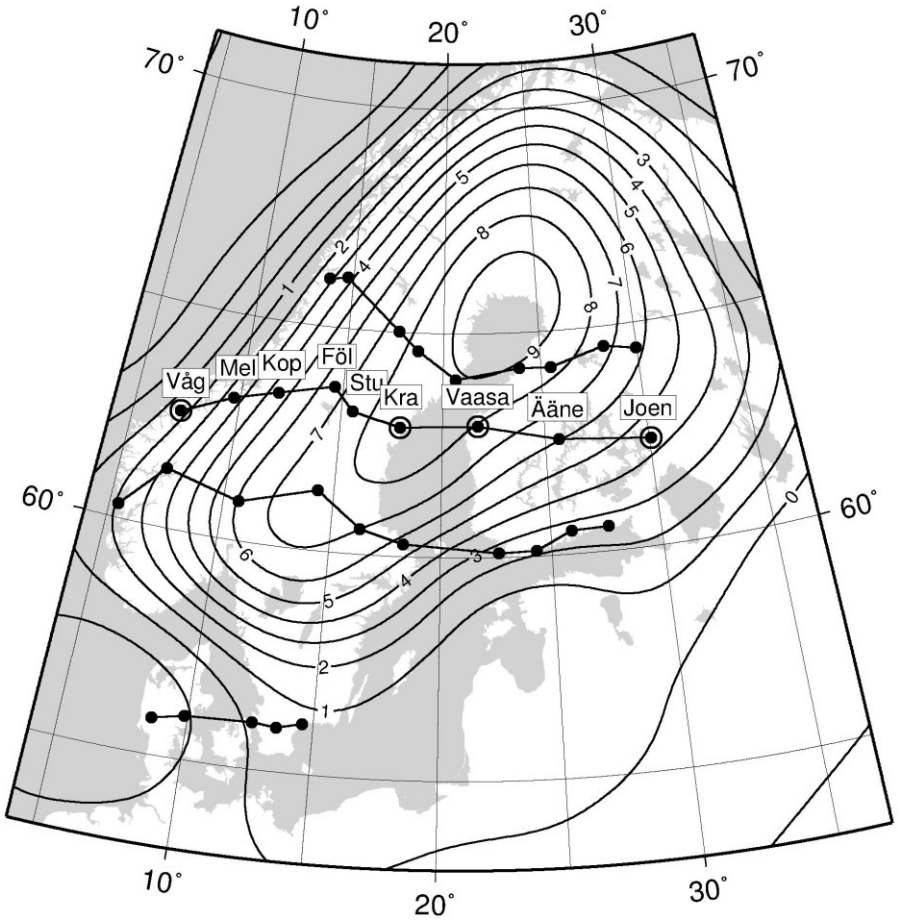
NKG2016LU_abs

Old



ICE-5G(VM2)

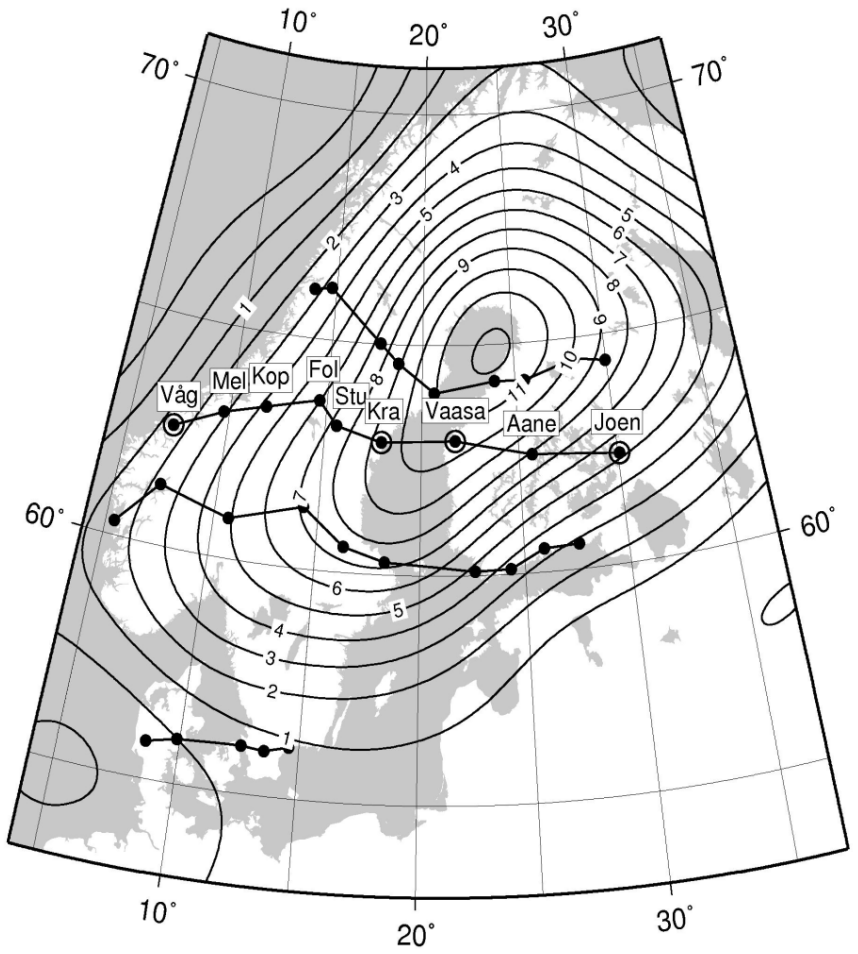
New



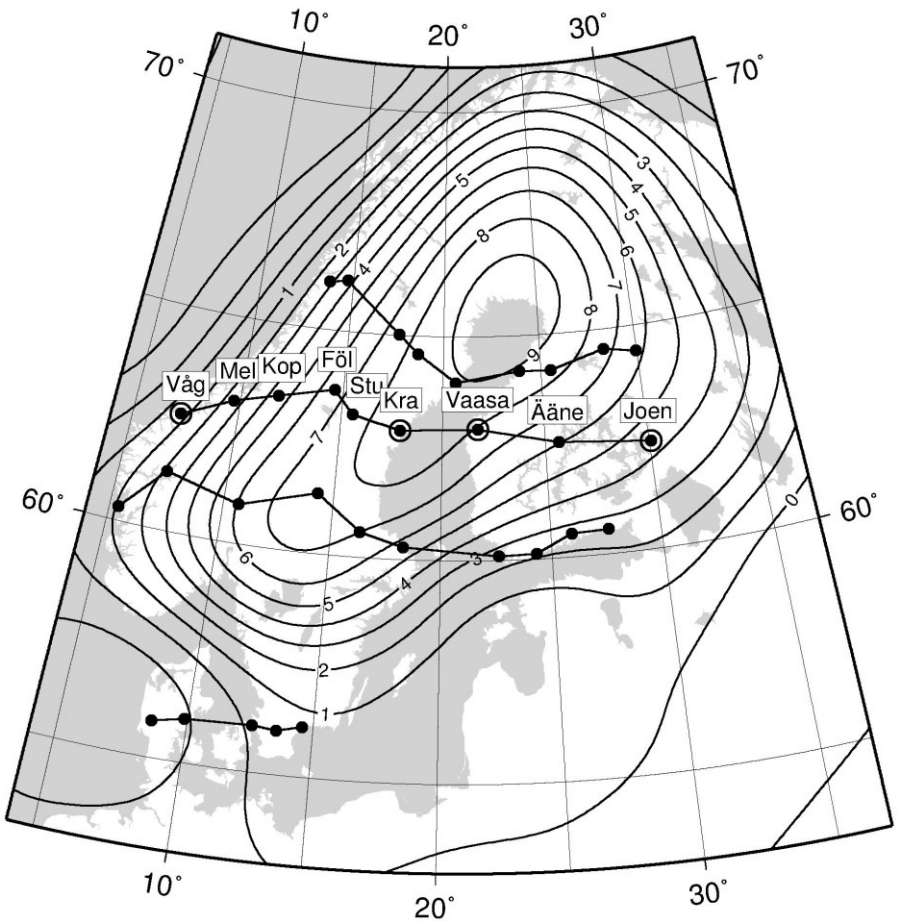
ICE-6G_C(VM5a)

As originally published in 2004, before the 2012 corrections

Old



New

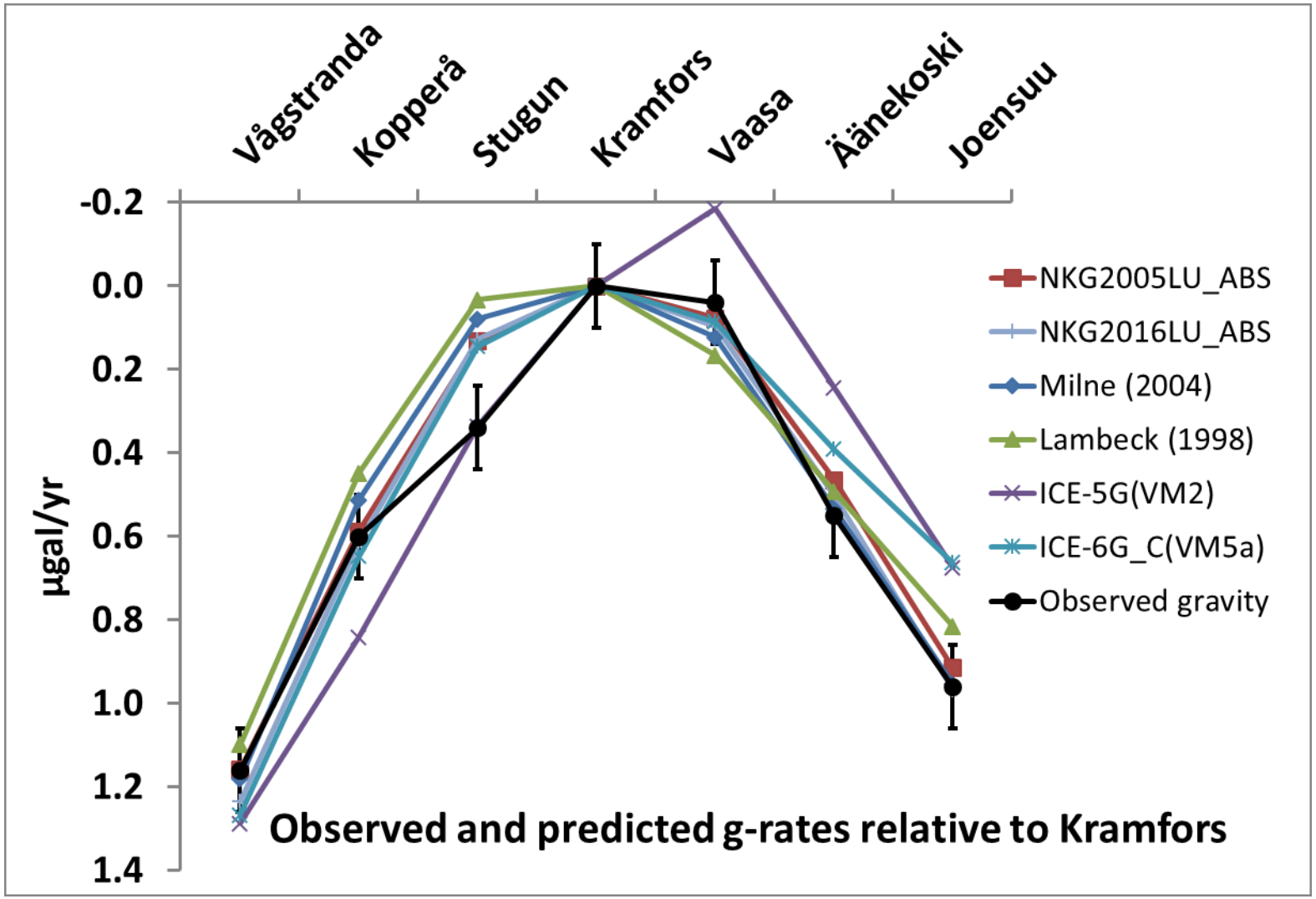


ICE-5G(VM2)

ICE-6G_C(VM5a)

As originally published in 2004, before the 2012 corrections

Vertical rates predicted from the different models were multiplied by –0.163 µGal/mm to obtain predicted gravity



Model	Std. dev. µgal/yr	Normed Chi-square
NKG2005LU_ABS	0.08	0.67
NKG2016LU_ABS	0.10	0.91
Milne (2004)	0.11	1.22
Lambeck (1998)	0.14	1.84
ICE-5G (VM2)	0.21	4.53
ICE-6G_C (VM5a)	0.15	2.31

- Discrepancy between observed and predicted gravity
- The model graphs that were presented relative to Kramfors in the previous slide were shifted vertically to obtain best fit to observed gravity
- Std. dev. is the RMS fitting error.
- The normed Chi-square was calculated using 0.14 µGal/yr as the standard uncertainty for observed gravity differences, and ignoring model uncertainty

What are we doing now?

Table 6.3 (continued). Line 63*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

OBSERVATION SERIES 63:53. GRAVIMETER G-258, GALVANOMETER, OBSERVER E.GROTEN, C=5430800, FACTOR=1.06634

65362	1979	9	18	6	16	202	982.1	10.2	2821.8	3010.7	-13.5	2.0	13.3	-6.0	0.0	0.0	0.0	0.0	3006.5	-6.2	3000.3
65367	1979	9	18	11	2	200	975.0	18.2	3135.8	3345.8	-19.8	1.6	12.7	-7.7	0.0	0.0	0.0	0.0	3333.5	5.4	3338.9
781001	1979	9	18	13	24	194	968.1	15.5	2671.2	2850.0	-59.2	1.4	10.8	-8.5	0.0	0.0	0.0	0.0	2794.5	0.5	2795.0
781002	1979	9	18	14	28	188	972.5	12.8	2777.5	2963.4	-73.1	1.3	8.9	-8.9	0.0	0.0	0.0	0.0	2891.8	-1.2	2890.6
65370	1979	9	18	16	8	195	978.7	11.8	2729.5	2912.2	-82.5	1.2	11.1	-9.6	0.0	0.0	0.0	0.0	2832.4	1.6	2834.0
65370	1979	9	19	5	43	198	981.3	9.2	2653.0	2830.6	-48.2	1.2	12.0	-8.8	0.0	0.0	0.0	0.0	2786.7	2.5	2789.2
KR4 A	1979	9	19	15	4	203	978.9	13.2	3119.3	3328.1	-73.8	0.8	13.6	-6.7	0.0	0.0	0.0	0.0	3262.0	-2.5	3259.5
KR4 A	1979	9	20	6	33	206	989.3	7.5	3042.0	3245.6	-54.7	0.8	14.5	-3.5	0.0	0.0	0.0	0.0	3202.7	-3.6	3199.1
STU B	1979	9	20	9	50	199	970.7	9.5	2140.8	2284.1	-18.1	0.5	12.3	-2.9	0.0	0.0	0.0	0.0	2276.0	-4.5	2271.5
FÖL A	1979	9	20	11	46	210	967.3	11.5	2171.5	2316.9	-25.3	0.4	15.7	-3.1	0.0	0.0	0.0	0.0	2304.6	-0.6	2304.0

Thank you!