Geodynamics with the NSWT tilt meter in Lohja, Finland

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Content

- Interferometric water level tiltmeters in geodynamics-historical review
- Old NSWT and EWWT observations in Lohja Finland
- A new water level tilt meter with modern technique
- Recordings at the Tytyri mine Lohja

Michelson&Gale WT 1914-1919

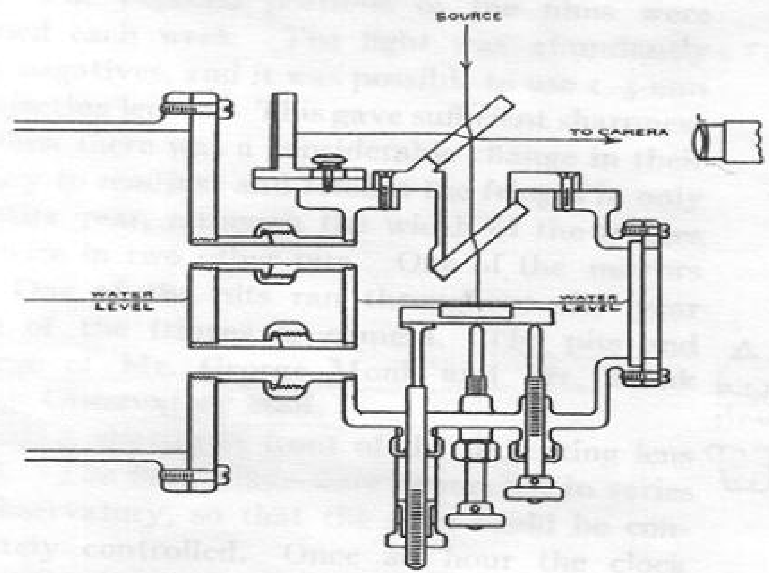
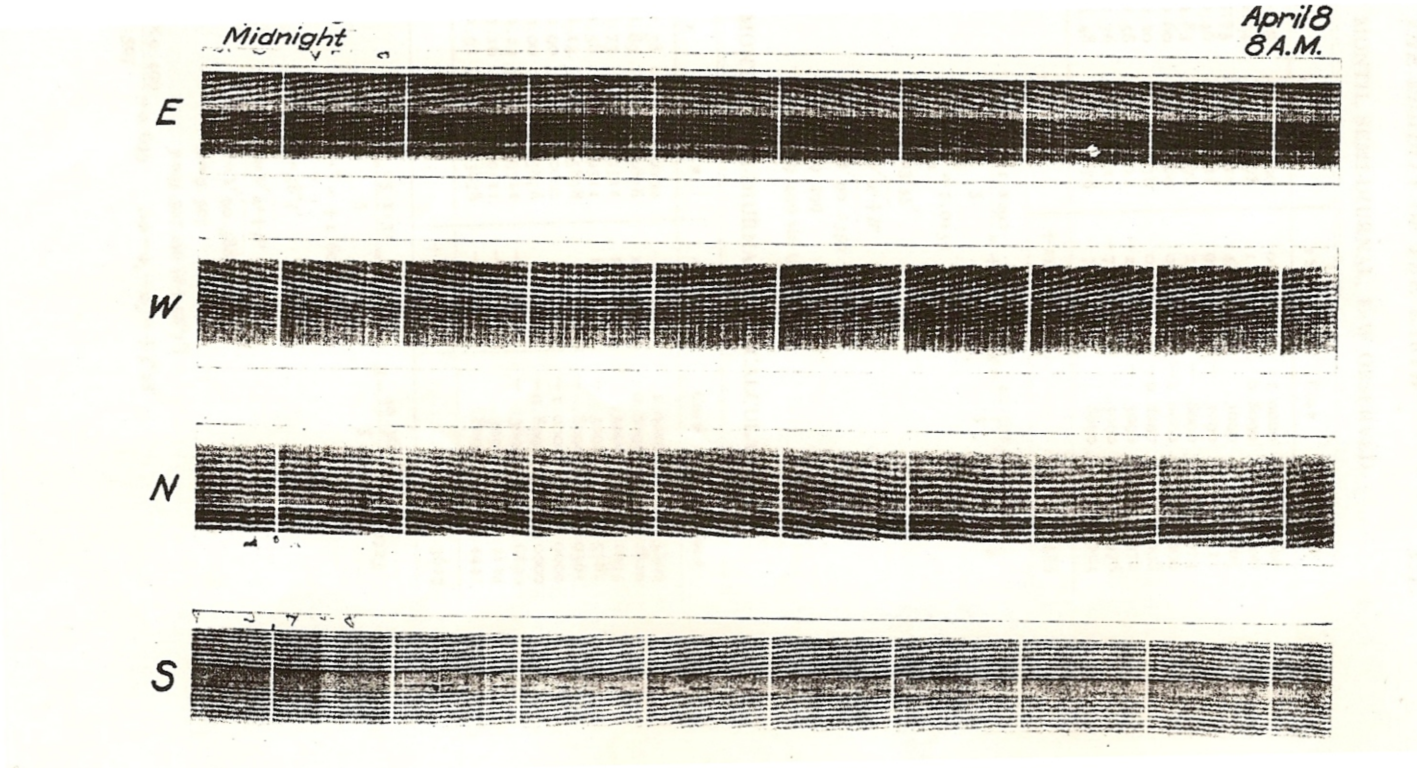


FIG. 1

Other interference arrangements are obvious which would give a displacement of a greater number of fringes, or permit the use of a shorter pipe; e.g., the fringes formed between the water surface and the lower mirror might be used, or the lower mirror might be dispensed with and use made of the fringes formed by the light reflected from the water surface and the vertical mirror. But the arrangement actually used was the most satisfactory, since the long pipes, 502 feet, were already installed.

Courtesy: Michelson & Gale, (1919)



Courtesy:Michelson& Gale, 1919

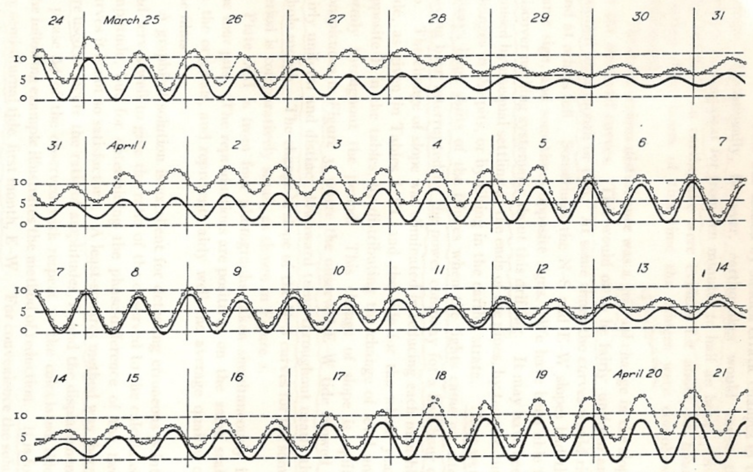


FIG. 2.—N-S tides, March 24 to April 21, 1917. Dotted curves, observed values. Full curves, 0.7 of calculated values

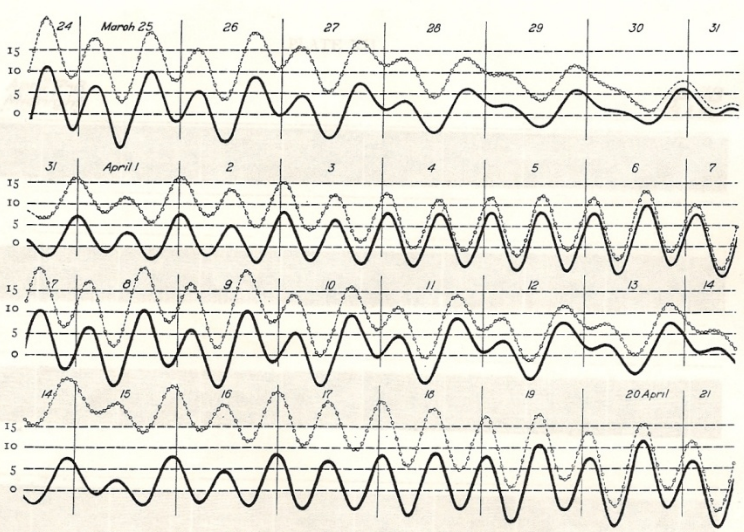


FIG. 3.—E-W tides, March 24 to April 21, 1917. Dotted curves, observed values. Full curves, 0.7 of calculated values

Courtesy:Michelson&Gale, 1919

Kukkamäki 1 km landuplift tiltmeter plan in1965

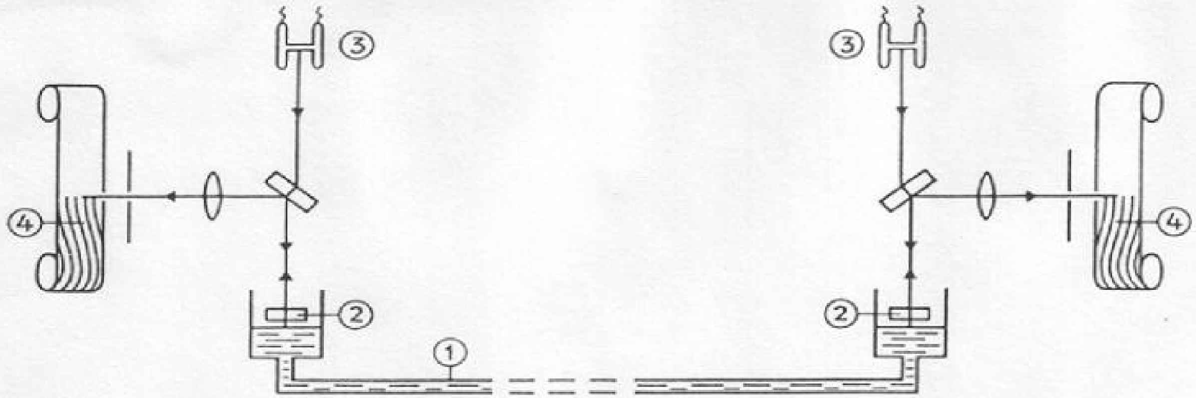


Fig. 1. Pipe level.

1. Pipe, 1000 m long
2. Fixed reference surface
3. Light source of the interferometer
4. Photographic record of interference fringes

A pipe about 1000 m long is planned to be placed in a horizontal drift situated perpendicularly to isobases. The pipe is filled with a suitable liquid, e.g. with mercury. The elevation of the liquid surface at each end is recorded with light interference by which an internal precision of one tenth of the interference fringe interval, i.e. $\pm 0.02\ \mu$ is to be obtained.

This precision, when compared with the yearly tilting of 15 μ per 1000 m would be satisfactorily high. This precision would be a real accuracy for

Courtesy: Kukkamäki, 1965

Kääriäinen NS & EW WT in Lohja 1977-1998

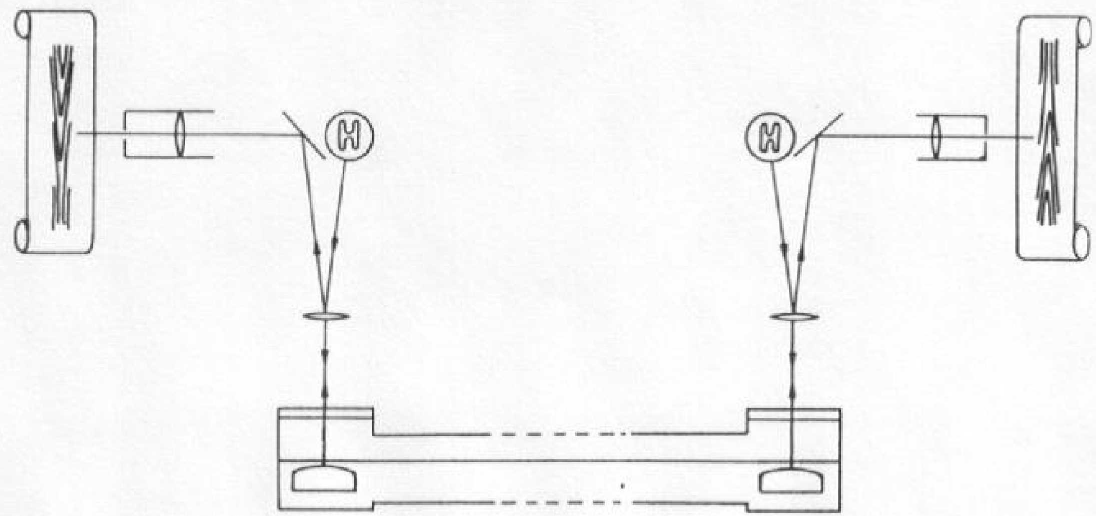


Fig. 2. The principle of the instrument .

would be satisfactorily high. This precision would be a real accuracy for

Courtesy:Kääriäinen, 1979


Photo:H. Ruotsalainen, FGI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EWWT recordings analysed with Eterna 3.3 (Wenzel, 1995)

adjusted tidal parameters :

from [cpd]	to [cpd]	wave	ampl. [mas]	ampl.fac.	stdv.	ph. lead [deg]	stdv. [deg]
0.721500	0.851182	138	0.0572	1.37066	0.54489	10.6357	22.7839
0.852096	0.857262	2Q1	0.0804	0.56144	0.18085	7.2778	18.4642
0.857571	0.870023	SIG1	0.0949	0.54918	0.15241	7.0314	15.9174
0.887327	0.894010	Q1	0.7606	0.70299	0.02398	1.1341	1.9557
0.895216	0.906315	RO1	0.1255	0.61070	0.12707	2.6861	11.9281
0.921941	0.932583	O1	3.9684	0.70227	0.00455	0.4411	0.3717
0.932583	0.940487	TAU1	0.0799	1.08348	0.34699	2.5312	18.3382
0.958086	0.968565	M1	0.3052	0.68672	0.05319	-0.2869	4.4423
0.968566	0.974188	CHI1	0.0532	0.62583	0.31049	-33.7735	28.4286
0.989049	0.994755	PI1	0.1279	0.83172	0.19968	3.9360	13.7475
0.995143	0.998028	P1	1.8668	0.70999	0.01254	-1.9379	1.0129
0.999853	1.000147	S1	0.0973	1.56456	0.76176	-126.5737	27.8548
1.001825	1.003651	K1	5.7740	0.72655	0.00414	-2.8628	0.3271
1.005329	1.005623	PSI1	0.0210	0.33704	0.52373	-28.3115	89.2665
1.007595	1.011099	FI1	0.0560	0.49472	0.27922	8.2502	32.3242
1.013689	1.034320	THE1	0.0472	0.55569	0.30626	28.3914	31.5835
1.034467	1.044800	J1	0.3013	0.67800	0.05826	-3.2356	4.9228
1.064841	1.073202	SO1	0.0579	0.78526	0.35450	-1.9257	25.8351
1.073349	1.080797	OO1	0.1645	0.67640	0.09048	0.7635	7.6679
1.080944	1.216397	V1	0.0362	0.77640	0.43654	5.3150	32.2846
1.719381	1.827343	3N2	0.0152	0.67881	0.31430	-22.3711	26.5291
1.827799	1.853920	EPS2	0.0412	0.71131	0.14223	1.5487	11.4596
1.854524	1.863634	2N2	0.1401	0.70608	0.04113	-0.0527	3.3362
1.864091	1.872142	MI2	0.1697	0.70851	0.03513	-1.5131	2.8420
1.888387	1.900529	N2	1.0417	0.69458	0.00550	-0.3031	0.4534
1.900545	1.906462	NI2	0.1919	0.67360	0.02942	1.3149	2.5020
1.923766	1.942753	M2	5.4571	0.69667	0.00105	-0.8168	0.0862
1.958233	1.966446	LMB2	0.0406	0.70281	0.14513	-7.6831	11.8283
1.966447	1.976926	L2	0.1650	0.74535	0.03069	0.4608	2.3574
1.991787	1.998287	T2	0.1260	0.59099	0.04271	3.2979	4.1411
1.999706	2.000766	S2	2.5470	0.69887	0.00260	-0.2271	0.2134
2.002591	2.002885	R2	0.0295	0.96518	0.25443	-41.4186	15.1120
2.003032	2.031288	K2	0.6810	0.68728	0.00893	-2.9251	0.7441
2.031435	2.044652	ETA2	0.0273	0.49240	0.13396	-3.0273	15.5802
2.047243	2.182843	2K2	0.0060	0.41278	0.36113	-13.3625	50.1153
2.753244	2.869714	493	0.0191	0.91138	0.17184	-9.8374	10.8073
2.892640	2.935615	M3	0.0629	0.82238	0.04983	-1.5685	3.4714
2.940178	3.081254	SO3	0.0078	0.78184	0.35594	9.4799	26.0795
3.791964	3.937897	M4	0.0021	3.07459	3.87061	-169.7102	72.1331

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Courtesy: Ruotsalainen, 2005 (C)

NSWT-recordings analysed with Eterna3.3 (Wenzel, 1995)

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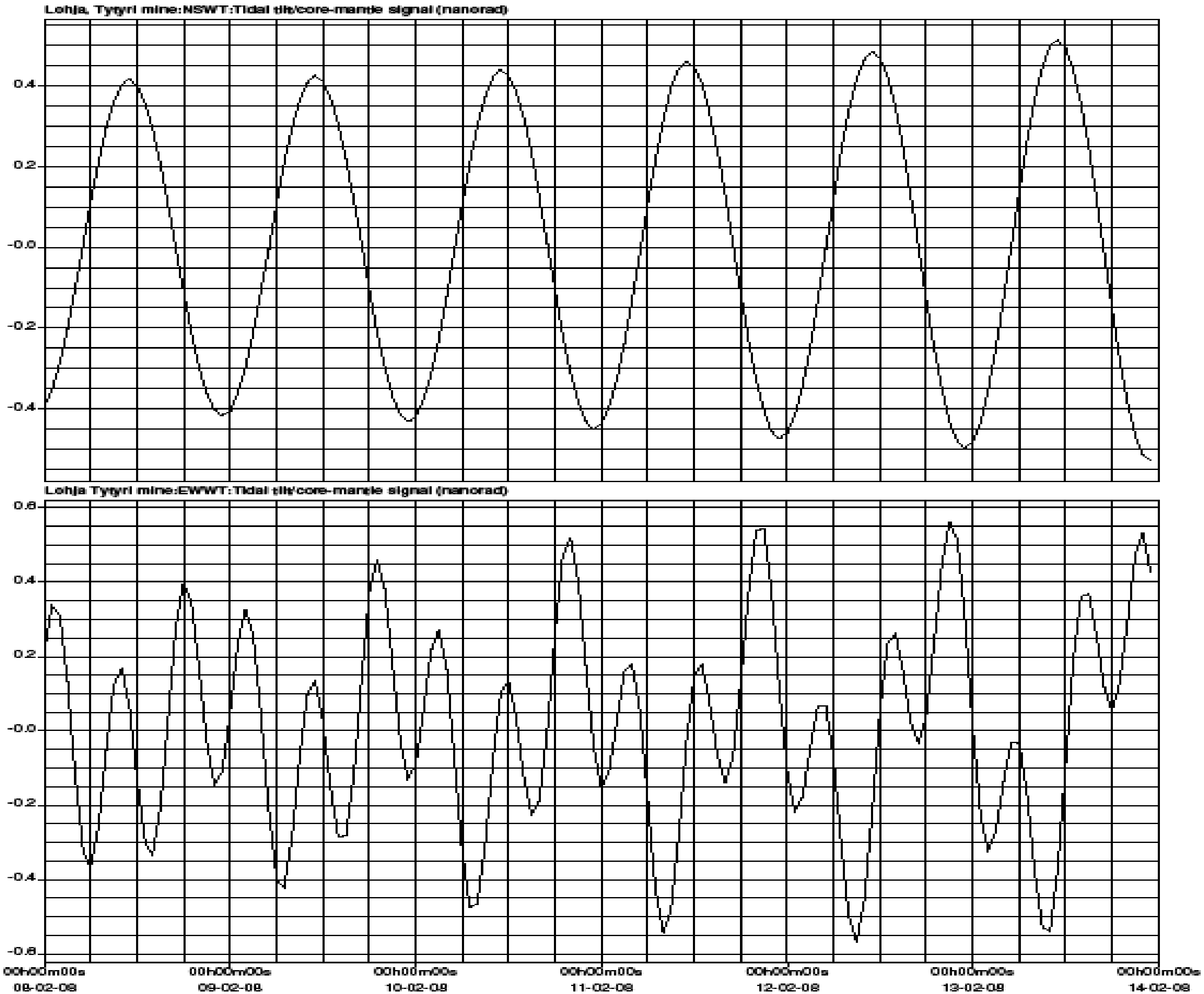
Adjusted tidal parameters :

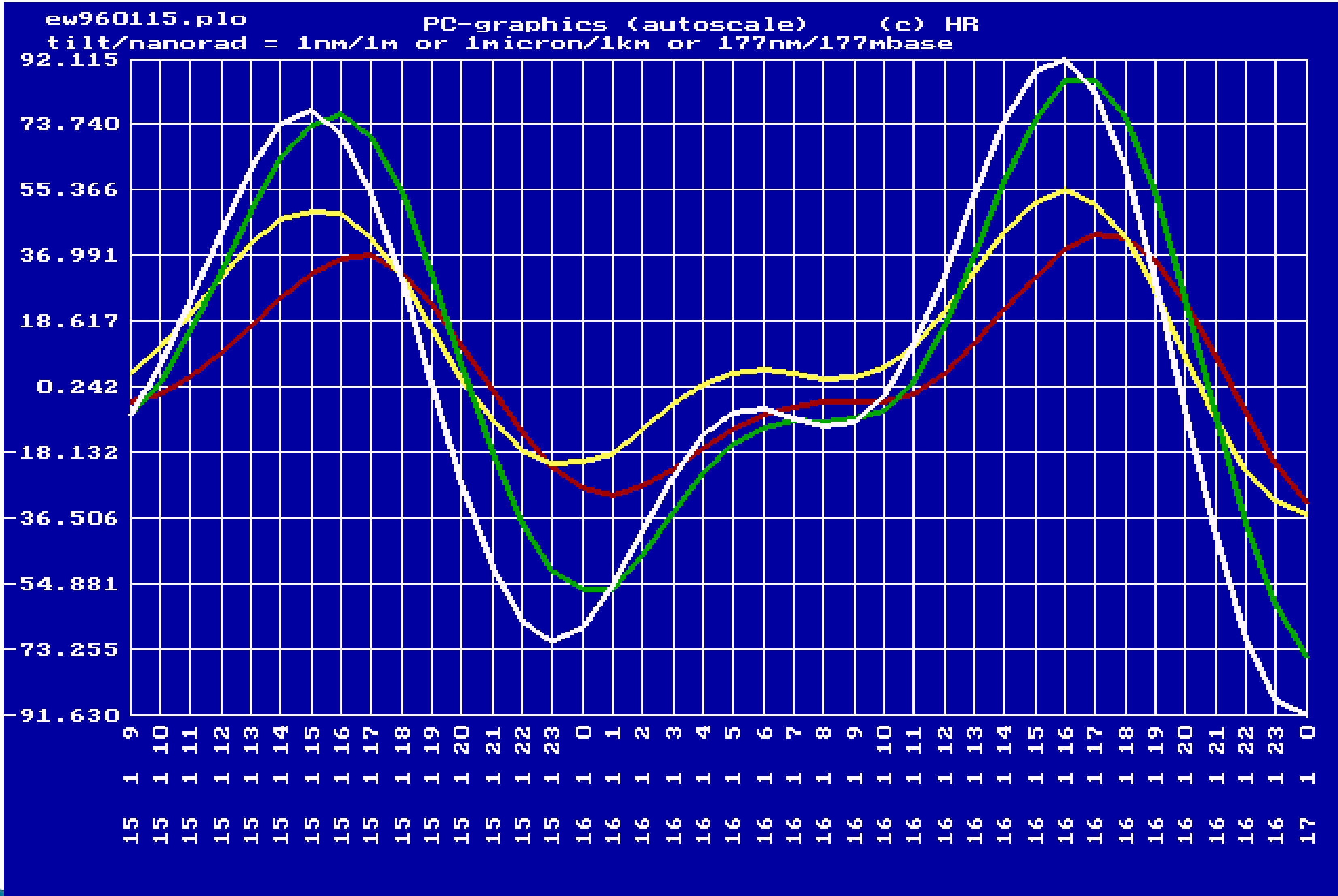
from [cpd]	to [cpd]	wave	ampl. [mas]	ampl.fac.	stdv.	ph. lead [deg]	stdv. [deg]
0.002428	0.003425	SA	2.7860	21.55820	0.75580	4.8689	1.8418
0.004710	0.010951	SSA	4.5598	5.60478	0.12162	51.5398	1.2575
0.025812	0.044652	MM	0.8659	0.93765	0.10133	8.7152	6.1477
0.060132	0.080797	MF	1.1464	0.65560	0.04199	2.8095	3.7034
0.096423	0.249951	MTM	0.0922	0.27538	0.21450	-80.1844	44.7297
0.721500	0.851182	138	0.0343	1.41036	3.25907	24.0543	132.2977
0.852096	0.857262	2Q1	0.0951	1.13901	1.01500	-4.9167	51.0428
0.857571	0.870023	SIG1	0.0548	0.54408	0.84477	13.5732	88.9585
0.887327	0.894010	Q1	0.4579	0.72561	0.13443	-1.9058	10.6178
0.895216	0.906315	RO1	0.0833	0.69542	0.70207	1.5820	57.9633
0.921941	0.932583	O1	2.5148	0.76295	0.02591	-1.4785	1.9463
0.932583	0.940487	TAU1	0.0307	0.71399	2.52335	59.1197	202.5765
0.958086	0.968565	M1	0.1768	0.68231	0.31800	2.8929	26.7250
0.968566	0.974188	CHI1	0.0561	1.13219	1.70969	-42.1682	86.3876
0.989049	0.994755	PI1	0.1312	1.46351	1.10599	-10.4809	43.2952
0.995143	0.998028	P1	1.2100	0.78906	0.06562	-7.2004	4.7656
0.999853	1.000147	S1	0.0289	0.79809	4.04260	84.9280	290.2278
1.001825	1.003651	K1	3.6823	0.79470	0.02026	-5.7299	1.4605
1.005329	1.005623	PSI1	0.0158	0.43636	2.68225	-145.4647	352.3107
1.007595	1.011099	FI1	0.0999	1.51310	1.55209	39.6401	58.7408
1.013689	1.034320	THE1	0.0380	0.76677	1.73124	-4.0525	129.3109
1.034467	1.044800	J1	0.1800	0.69451	0.32882	-3.5987	27.1182
1.064841	1.073202	SO1	0.0391	0.91002	1.95890	-25.1447	123.2810
1.073349	1.080797	OO1	0.1034	0.72898	0.45691	2.2679	35.9021
1.080944	1.216397	V1	0.0212	0.77909	2.24936	0.3968	165.4682
1.719381	1.827343	3N2	0.0122	0.62731	4.20675	28.4906	384.3158
1.827799	1.853920	EPS2	0.0396	0.78810	1.88617	-35.8638	137.1802
1.854524	1.863634	2N2	0.0746	0.43242	0.54204	-10.9248	71.8084
1.864091	1.872142	MI2	0.1389	0.66747	0.46639	-20.2920	40.0389
1.888387	1.900529	N2	0.7334	0.56285	0.07322	-6.9163	7.4590
1.900545	1.906462	NI2	0.1687	0.68164	0.39201	-9.2398	32.9550
1.923766	1.942753	M2	3.9361	0.57841	0.01415	-1.7387	1.4019
1.958233	1.966446	LMB2	0.0358	0.71342	1.92947	17.7563	154.9270
1.966447	1.976926	L2	0.1195	0.62105	0.44625	-9.0471	41.1837
1.991787	1.998287	T2	0.0959	0.51820	0.53139	-6.0360	58.7565
1.999706	2.000766	S2	1.9665	0.62117	0.03120	3.5951	2.8779
2.002591	2.002885	R2	0.0372	1.40775	3.02582	40.4057	123.1780
2.003032	2.031288	K2	0.5167	0.60060	0.09613	3.0589	9.1716
2.031435	2.044652	ETA2	0.0193	0.40182	1.48795	5.8089	212.1664
2.047243	2.182843	2K2	0.0081	0.64315	3.80547	26.9722	338.7919
2.753244	2.869714	493	0.0175	0.96148	5.09948	-48.6560	303.9119
2.892640	2.935615	M3	0.0540	0.81358	1.45512	-18.6712	102.4983
2.940178	3.081254	SO3	0.0112	1.29493	8.45729	-58.6584	374.0662
3.791964	3.937897	M4	0.0137	22.83434	149.00132	-113.3949	373.8013

Courtesy: Ruotsalainen, 2005, FGI (C)

Core resonance signals in small diurnal waves separated from tidal tilt recordings of the old EWWT and NSWT in Lohja



Courtesy: H.Ruotsalainen, FGI

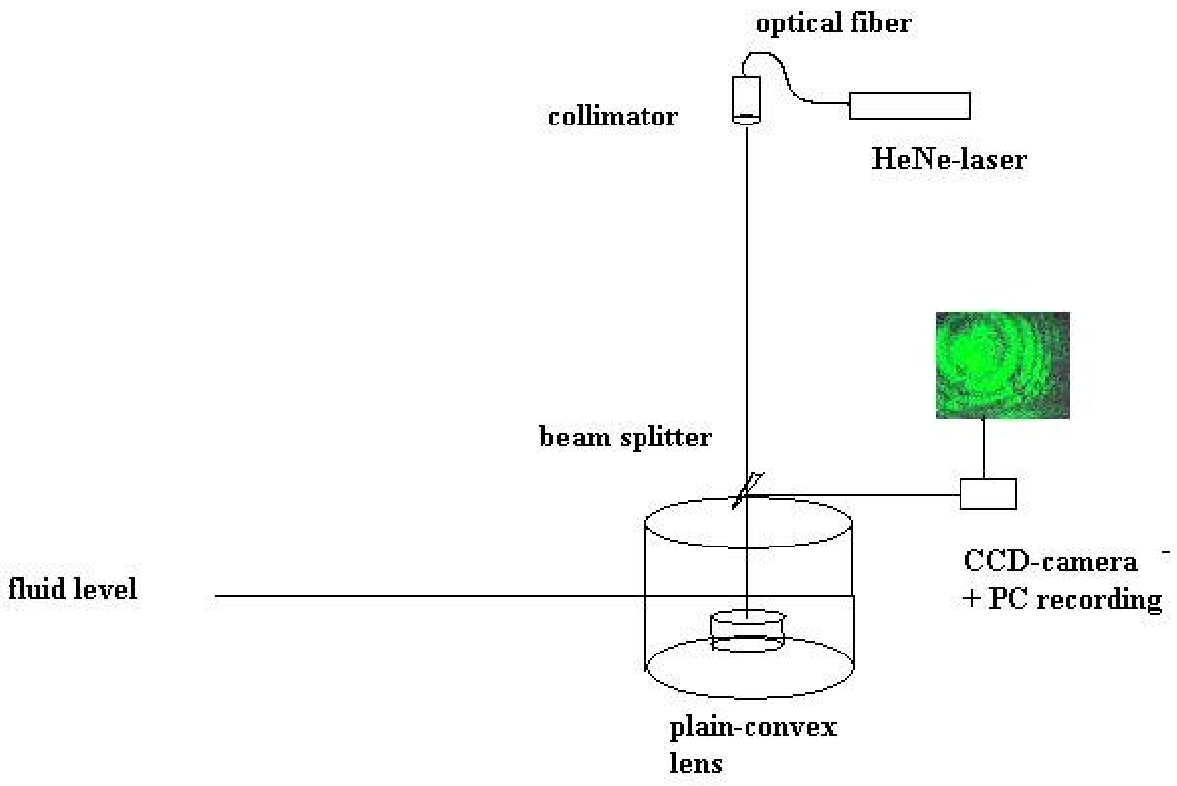


Courtesy: Hannu Ruotsalainen, FGI

Modernizing water level tilt meter

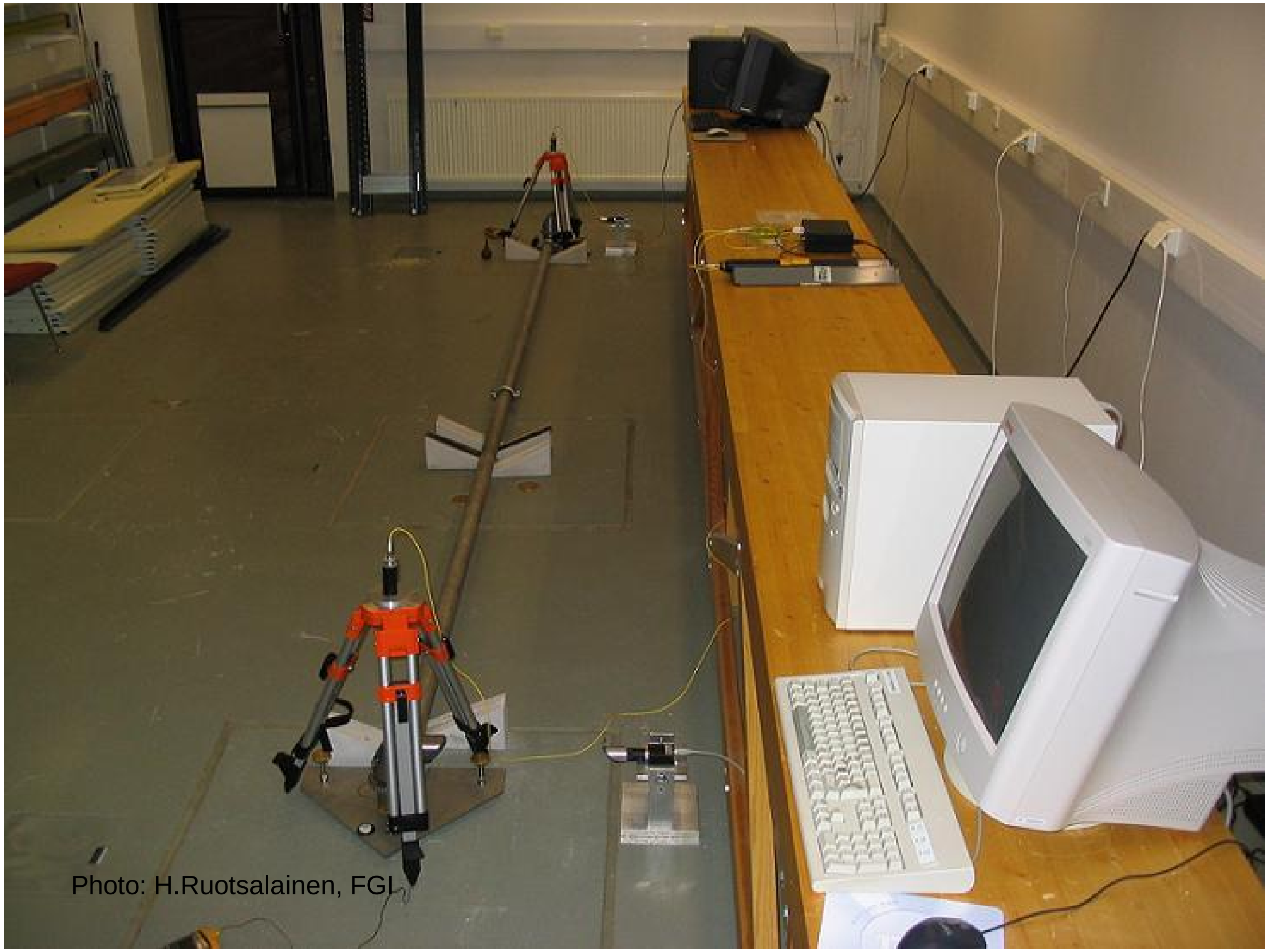
- Project started in year 2000
- Critical temperature modelling and tests
- New end pots were built at the Helsinki University of Technology
- Modular half-filled stainless steel tube and special junctions
- End pots installed on the adjustable tripods with special ball&socket type junctions
- End pots plated inside by teflon to avoid fluid friction against pot walls
- Single mode fibres used between 2 mW HeNe-lasers and collimators to avoid thermal influence of laser on the level interferometer
- Fringe image recordings are carried out using Basler digital firewire cameras
- Interference phase interpretation carried out by recording computer on-the-fly 15 hz sampling rate under Linux operating system
- Estimated tilt resolution 0.1 nanoradian with 50.4 m tube

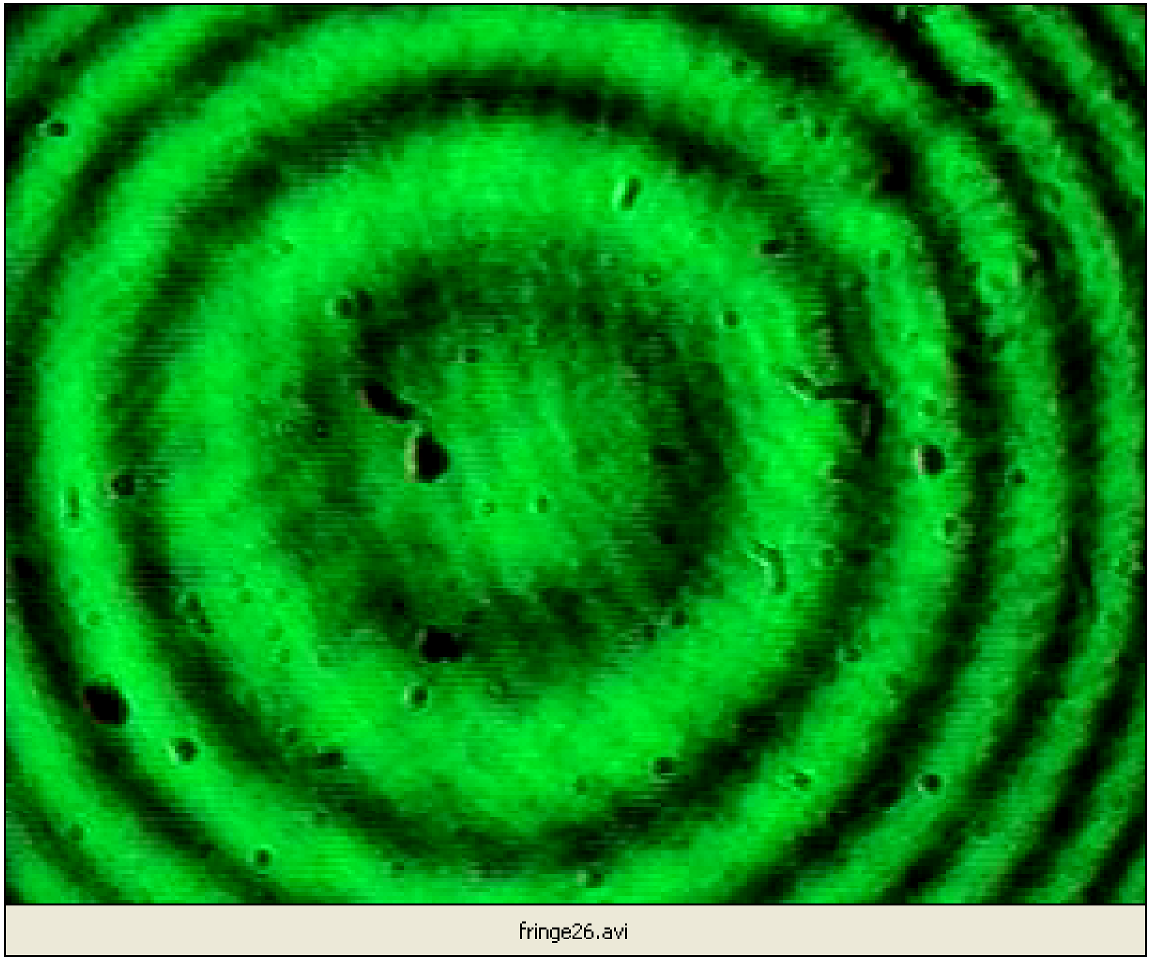
Fizeau-Kukkamäki level interferometer



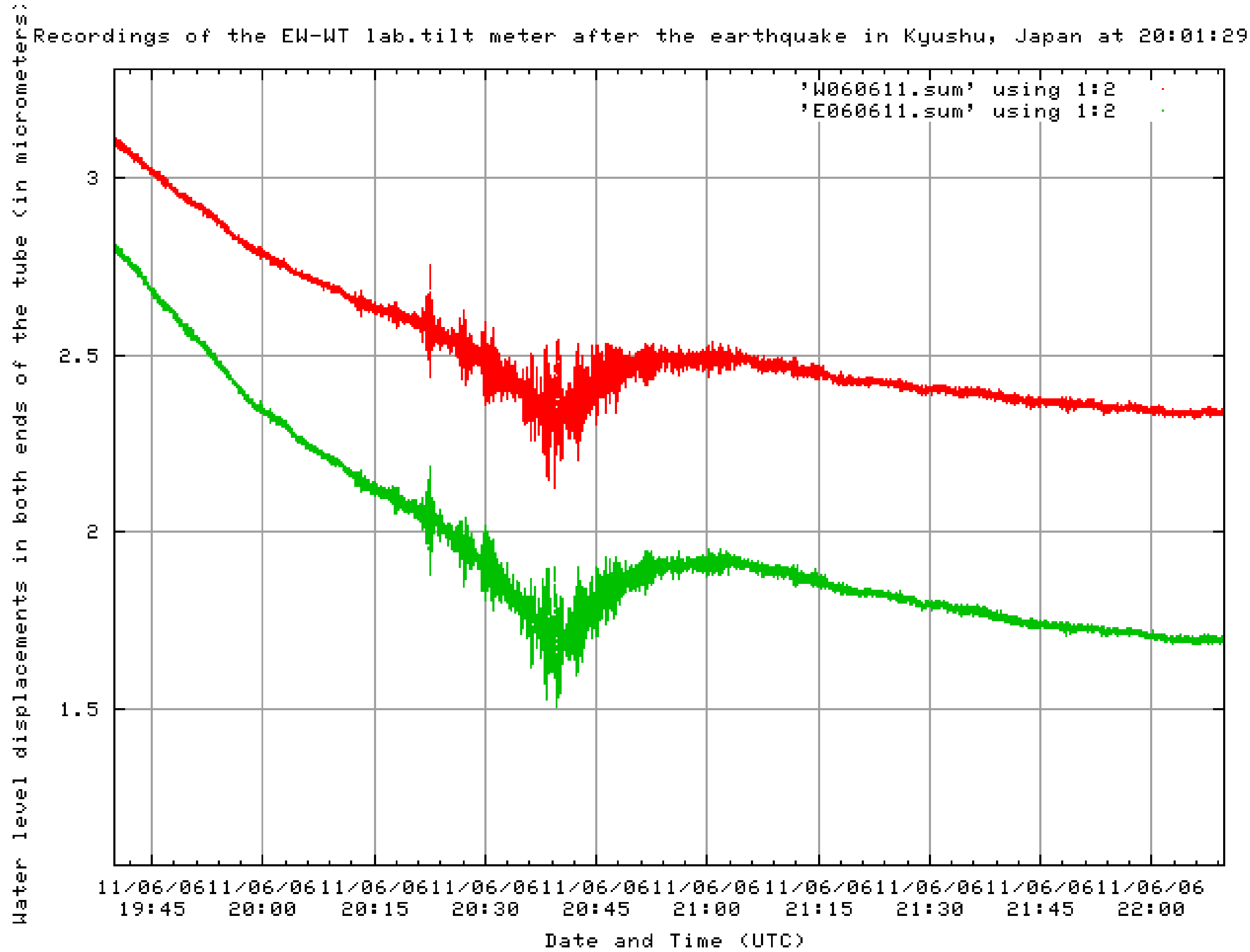
(C) Courtesy: Hannu Ruotsalainen, FGI

Prototype in FGI lab



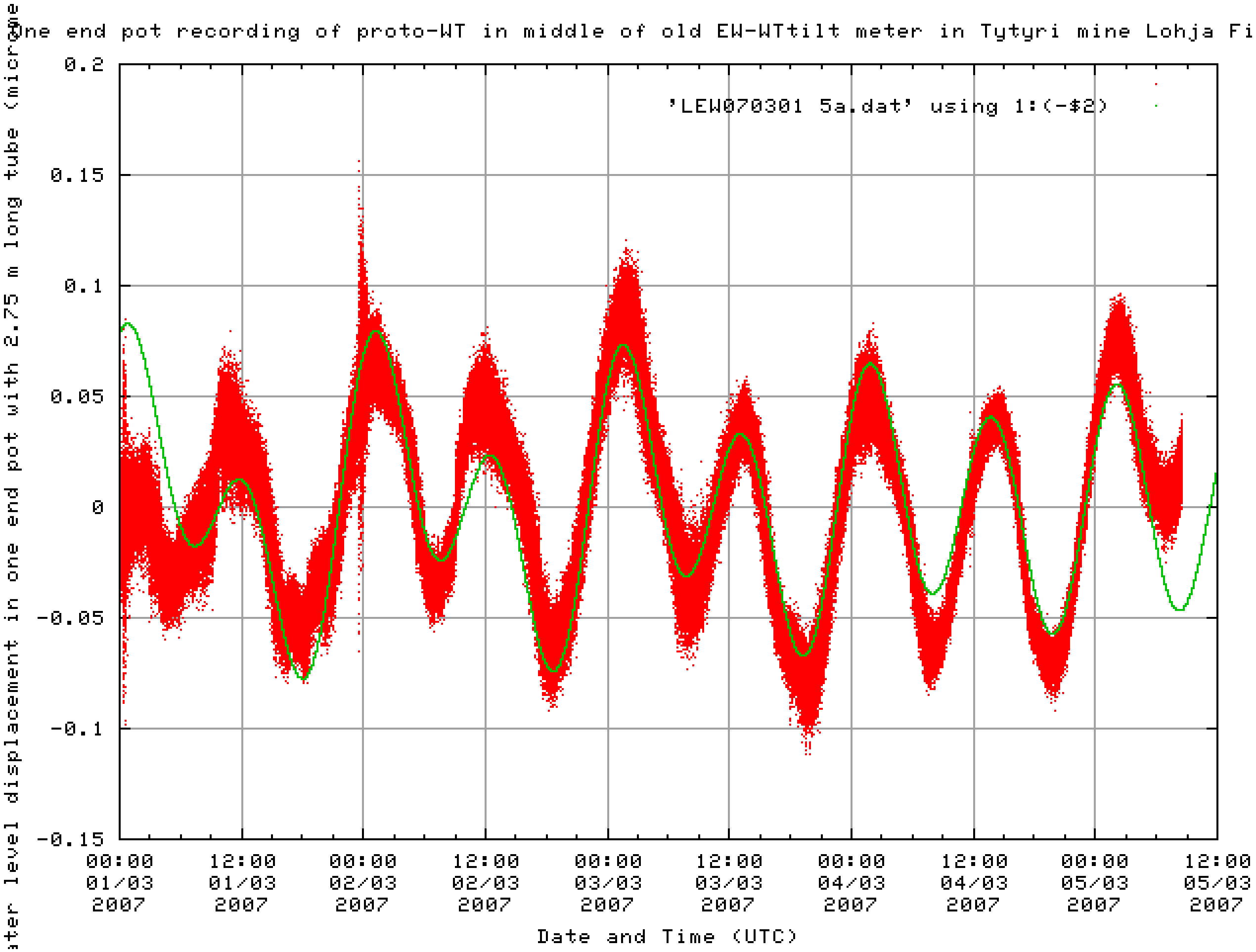


(C) Courtesy : Hannu Ruotsalainen, FGI



(C) Courtesy: Hannu Ruotsalainen, FGI

Proto WT (2.75m) in Tytyri mine
Lohja with one end recording test



Courtesy: Hannu Ruotsalainen, FGI

Northern end pot & firewire camera system

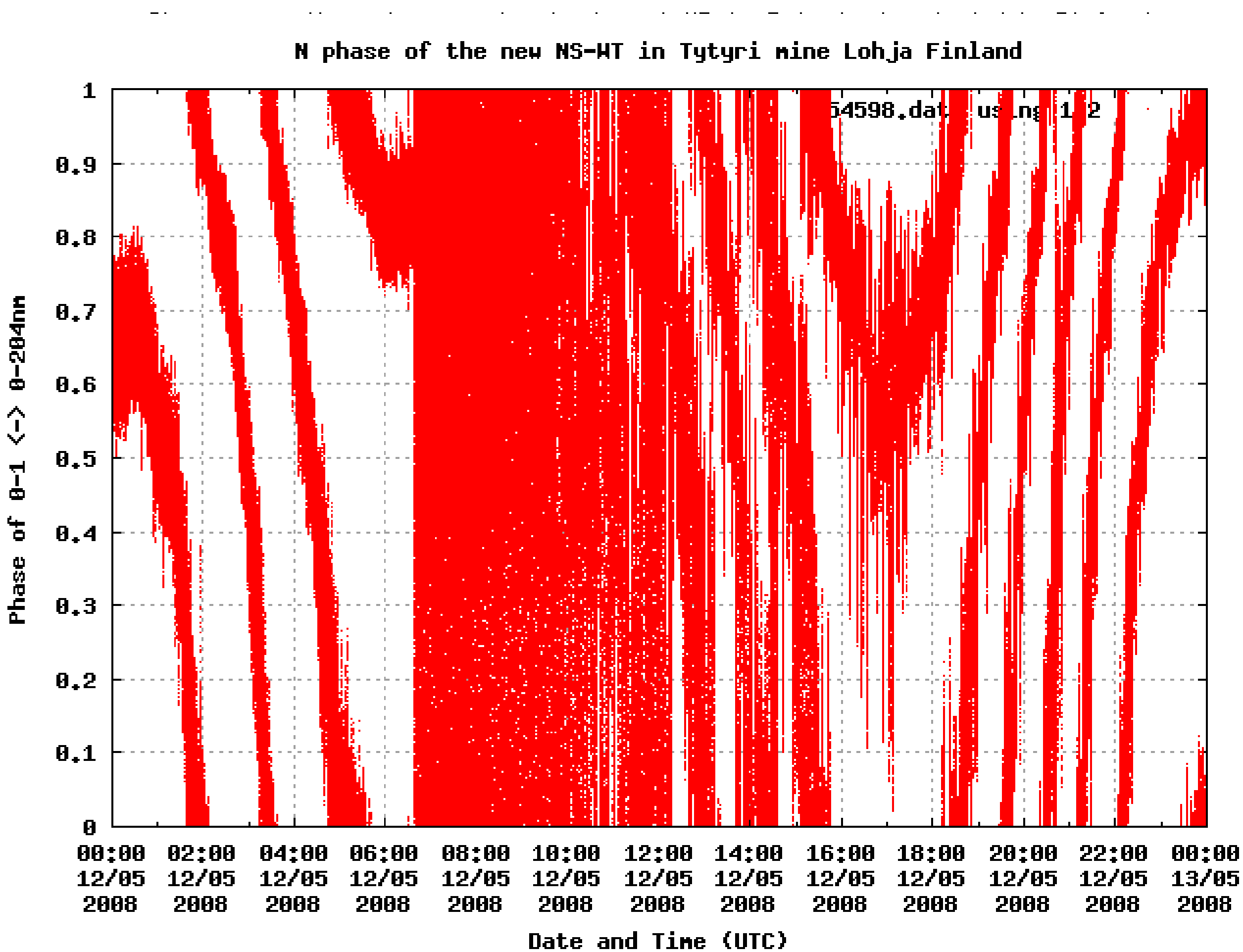
orange cable is a fiber-optic firewire extender cable (260 m) between camera and computer
yellow - single mode fibre from HeNe laser to collimator

Photo: Hannu Ruotsalainen, FGI

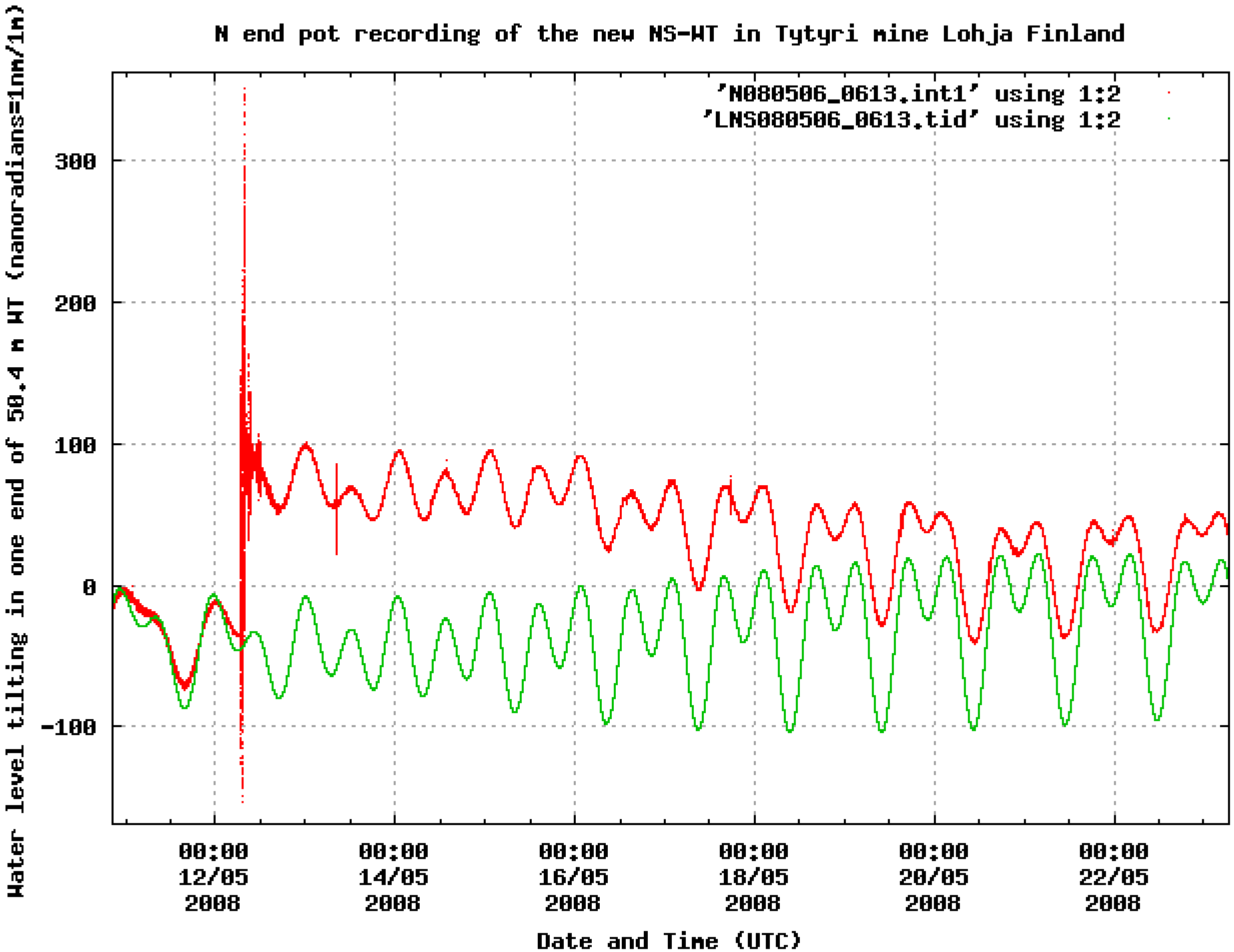
Computers in entrance room (200 and 260 m from interferometers) recording fringes and interpreting on the fly with 15Hz sampling rate. Data is downloaded from computers on hard disks and transported to FGI for analyse

Photo: H. Ruotsalainen, FGI

12.5.2008 earthquake in China and N end phase recording of tiltmeter in Lohja

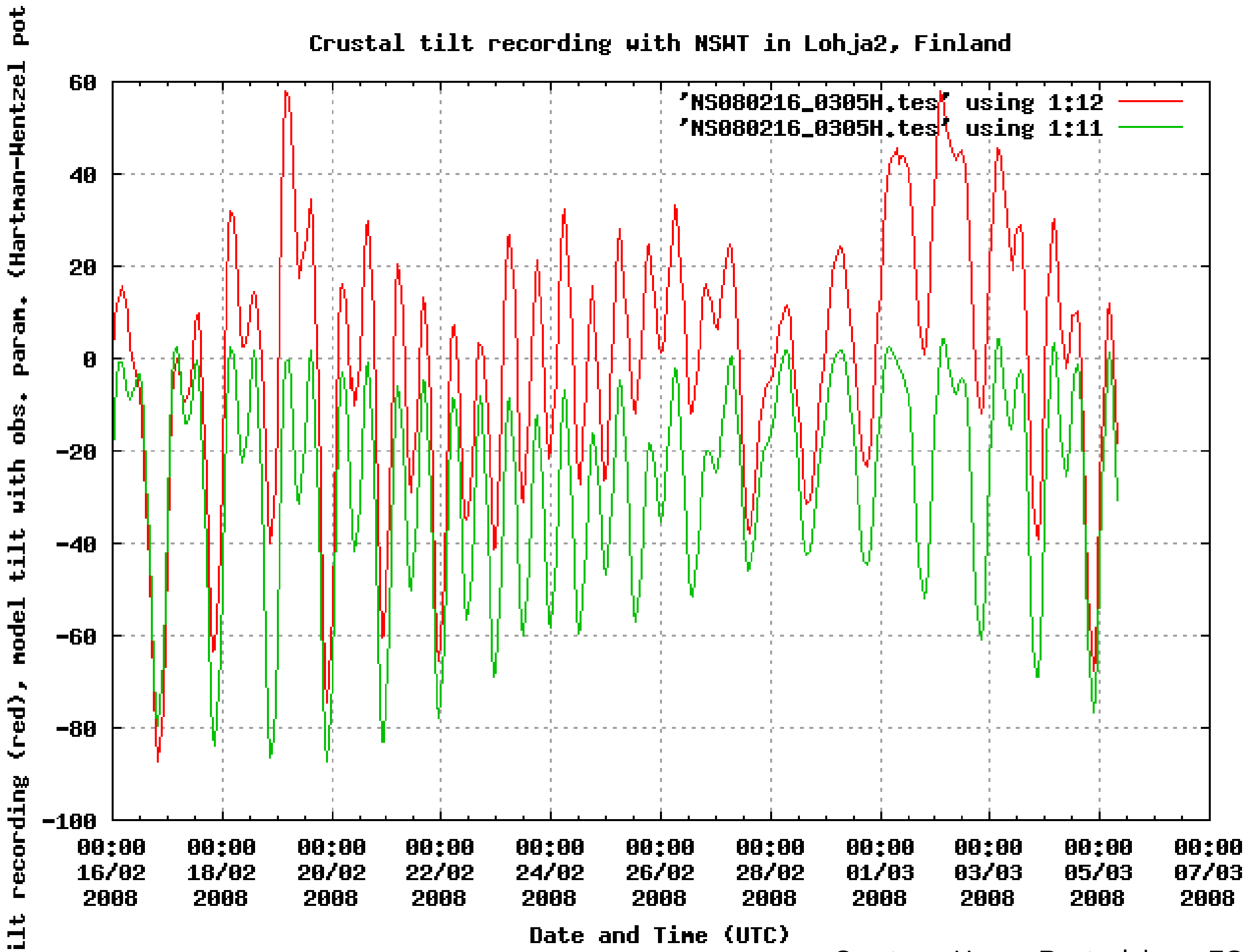


Courtesy: Hannu Ruotsalainen, FGI



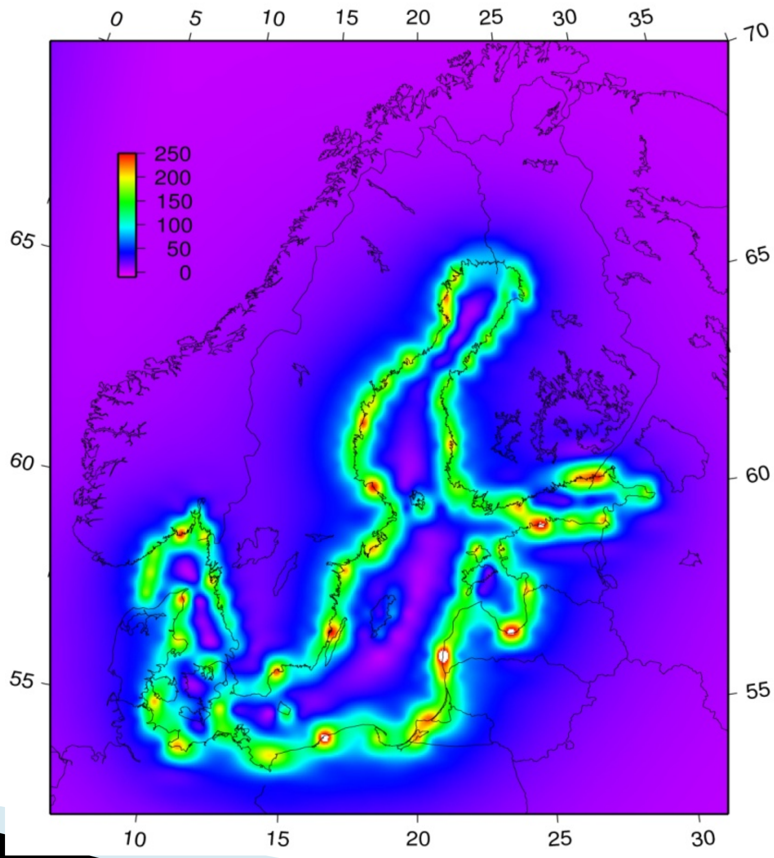
Courtesy: Hannu Ruotsalainen, FGI

NS-WT RECORDING IN LOHJA, 16.2. – 05.03. 2008
Green theoretical model tilt – red observed tilt



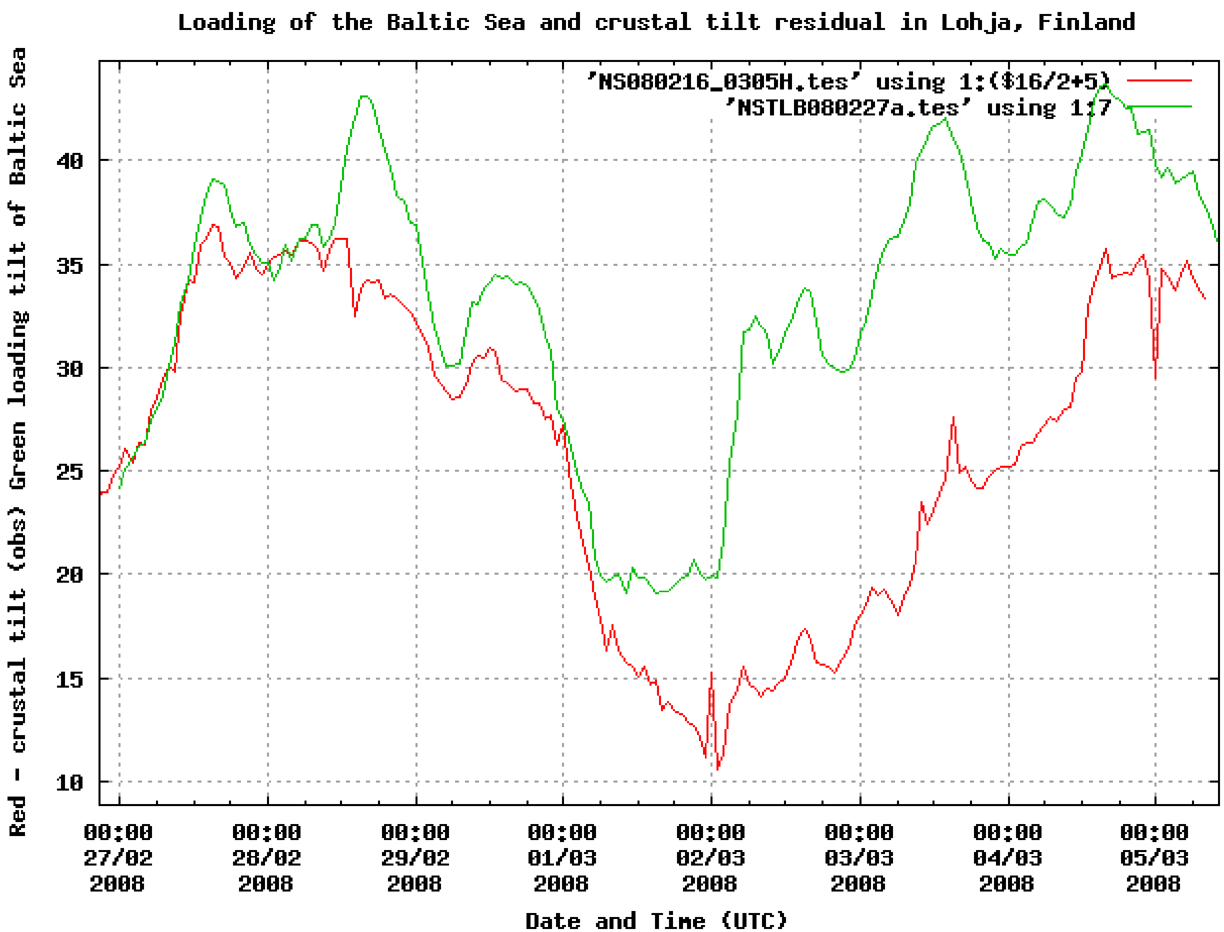
Courtesy: Hannu Ruotsalainen, FGI

Crustal loading model of the Baltic Sea with 1 m standard load (nanoradian) calculated by M. Nordman (FGI) using D.C.Agnew's program NLOADF

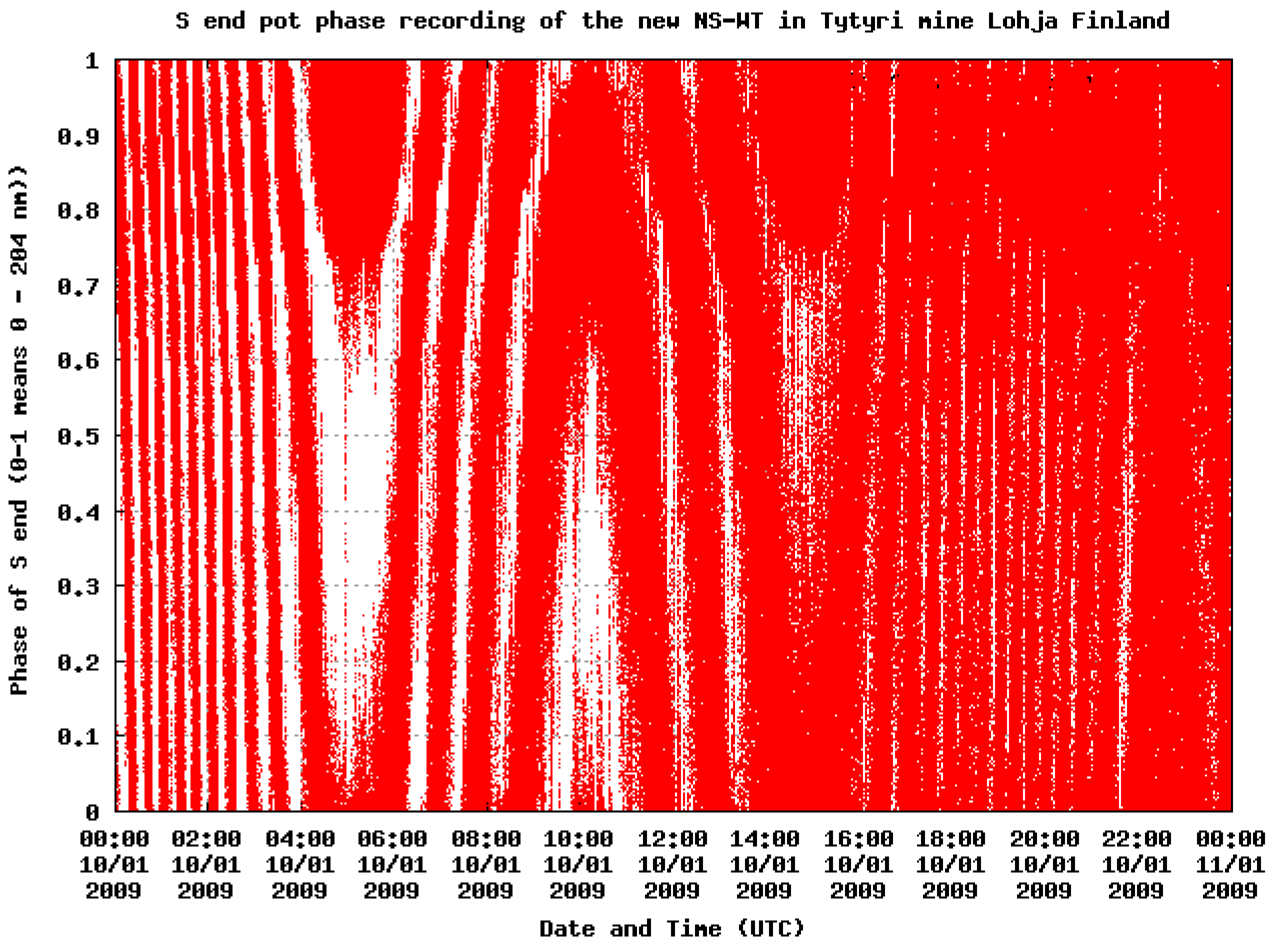


Courtesy of map: M. Nordman, FGi

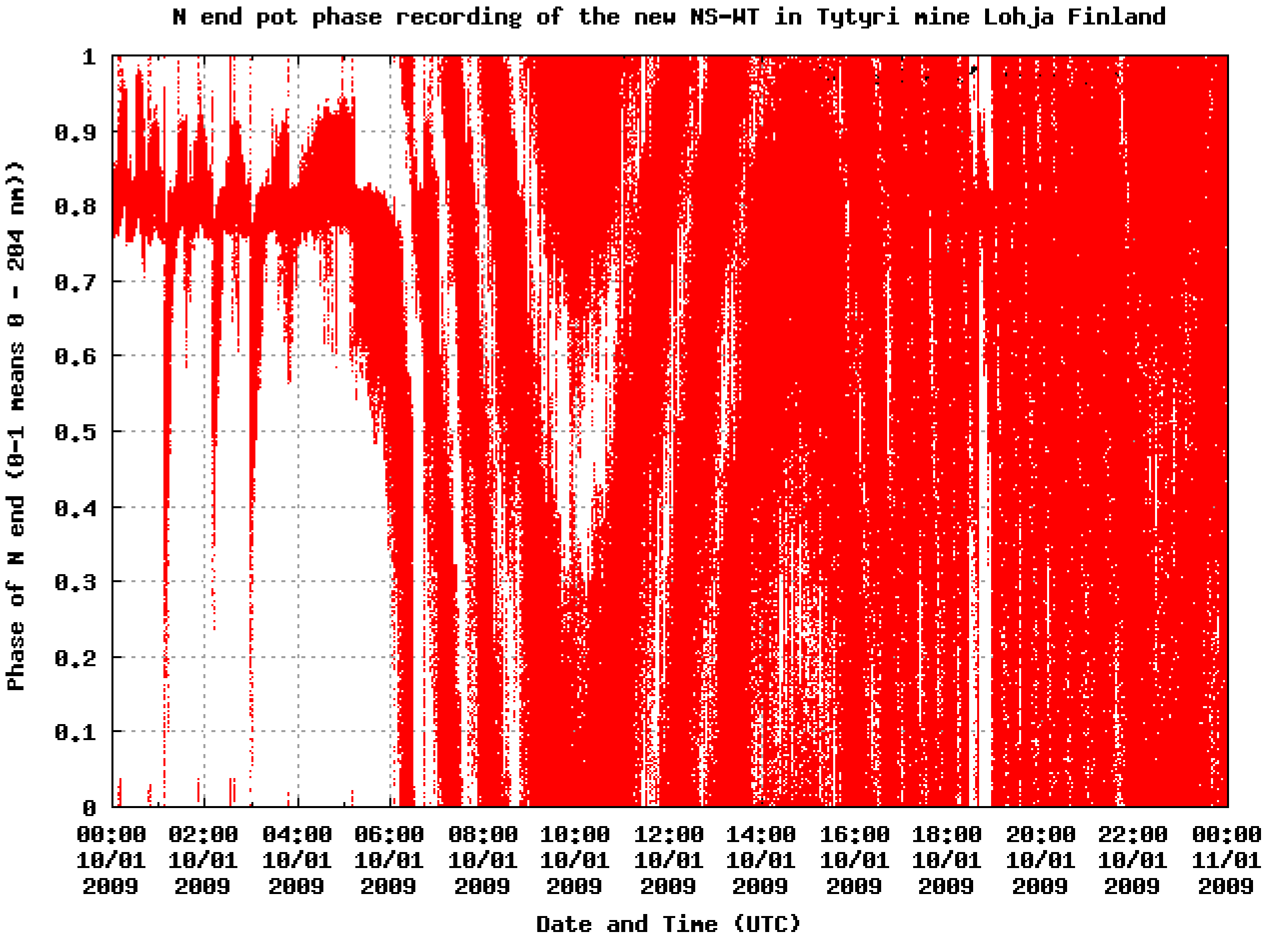
RED - NON-TIDAL RESIDUAL TILT of the NSWT
GREEN- CRUSTAL LOADING MODEL OF BALTIC SEA, Calculated using NLOADF, Agnew 1997, Nordman M. and Baltic Sea level data from the Finnish Institute of Marine Research, and BOOS



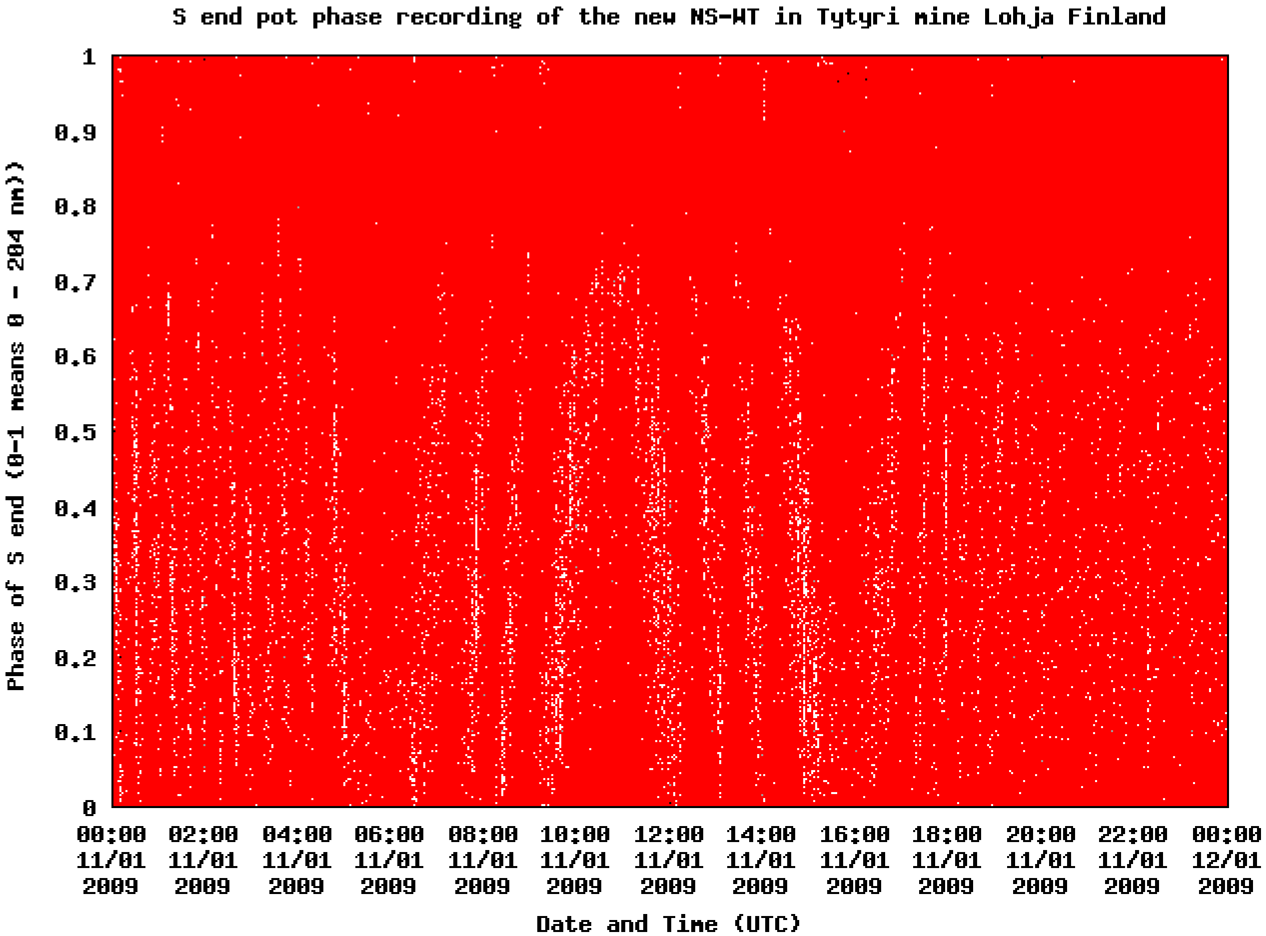
Courtesy: H. Ruotsalainen and M. Nordman FGI



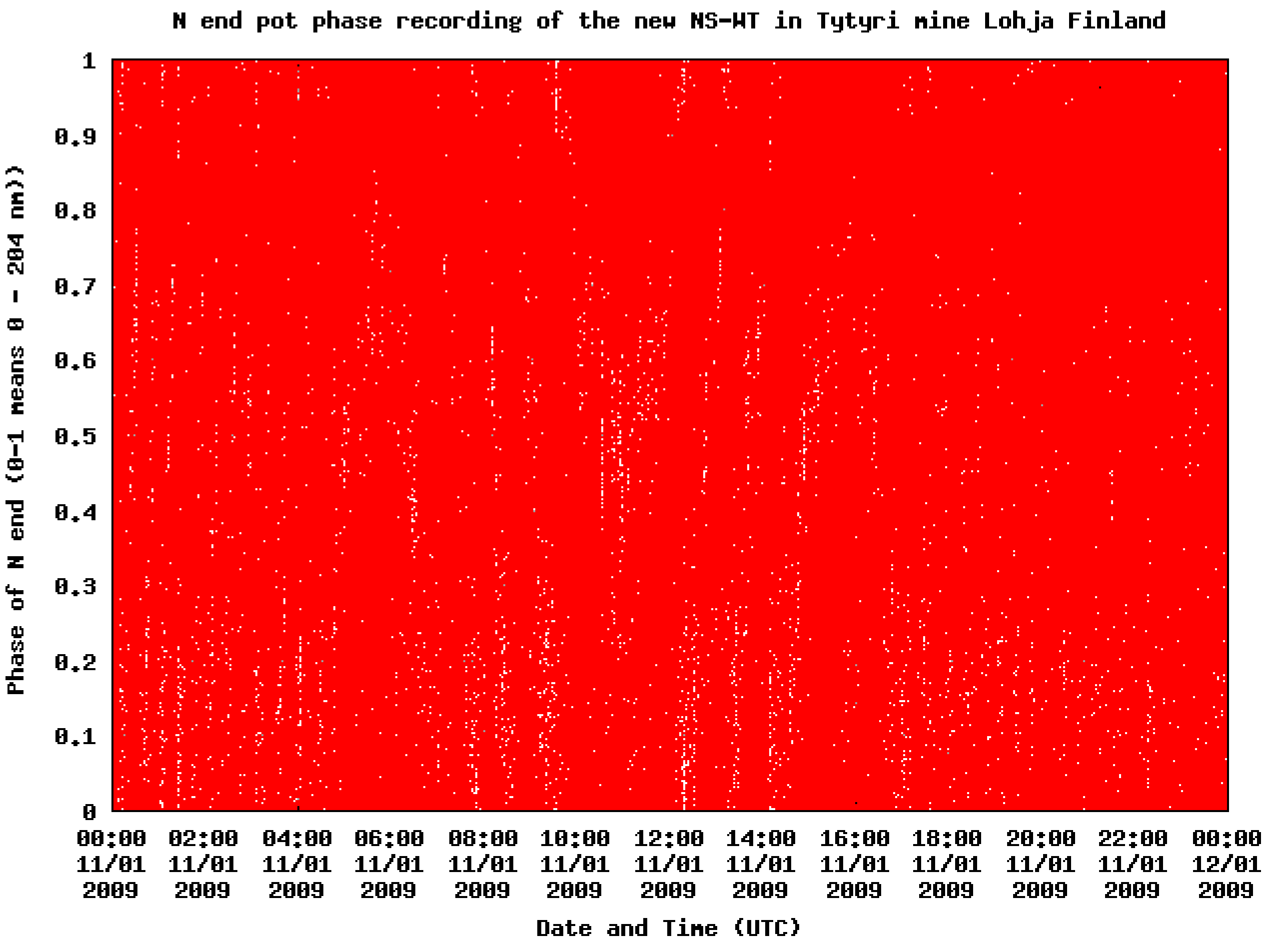
Courtesy: Hannu Ruotsalainen, FGI



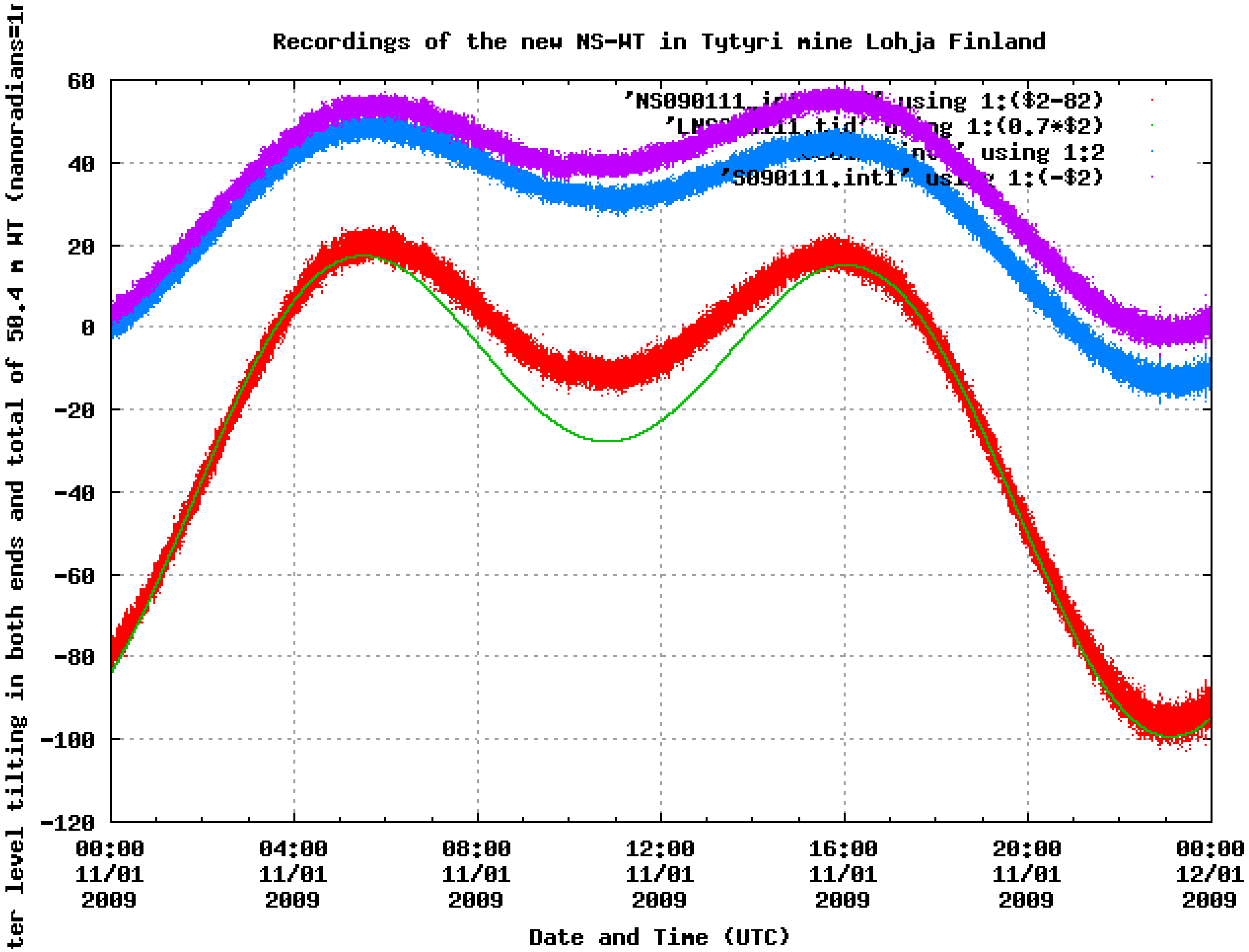
Courtesy: Hannu Ruotsalainen, FGI



Courtesy: Hannu Ruotsalainen, FGI



Courtesy: Hannu Ruotsalainen, FGI



Courtesy: Hannu Ruotsalainen, FGI

Conclusions

- A new interferometric water level tilt meter with absolute scale
- WT recording contain broad spectrum of geodynamical signals from microseism and free oscillations to tides
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- Loading tilt of Baltic Sea gives information on crustal dynamics under surface load
- Modular instrument can be used for different kind of crustal dynamic research
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- In north-south direction M2 tilt amplitude factor deviates – phase not - Why? Similar effect was observed by Gale in Yerkes observatory, Wisconsin USA 1914.

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