Concentrations and inventories of ^{137}Cs in dated sediments sampled in the Swedish Marine Environmental Monitoring Program

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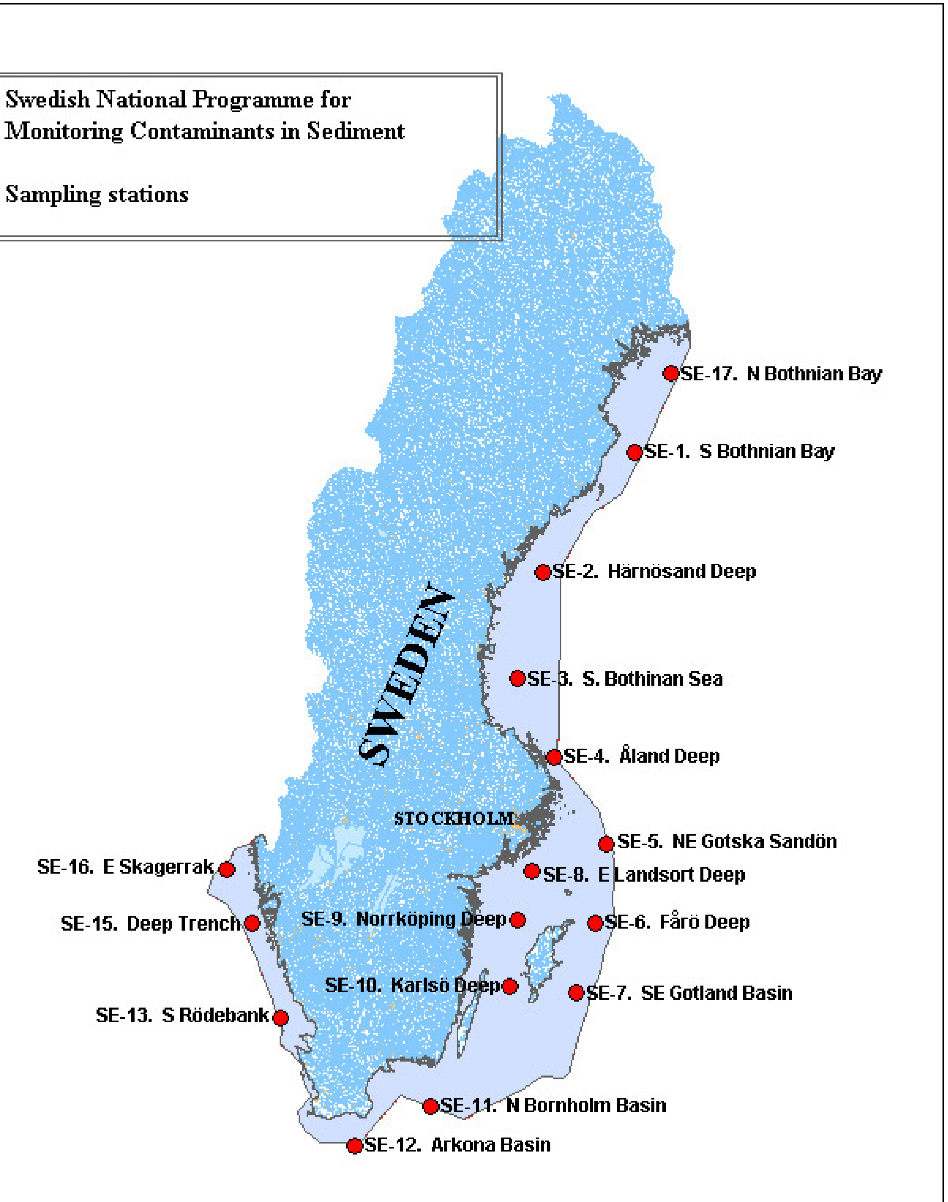
Swedish Radiation Safety Authority

Swedish Marine Environmental Monitoring Program
- aimed to study trends in pollutions



Sampling

- SGU ship, Ocean Surveyor
- Gemini sediment corer used
- 7 double cores at each station
- Cruises, 2003,2008,2014

Samples collected 2008

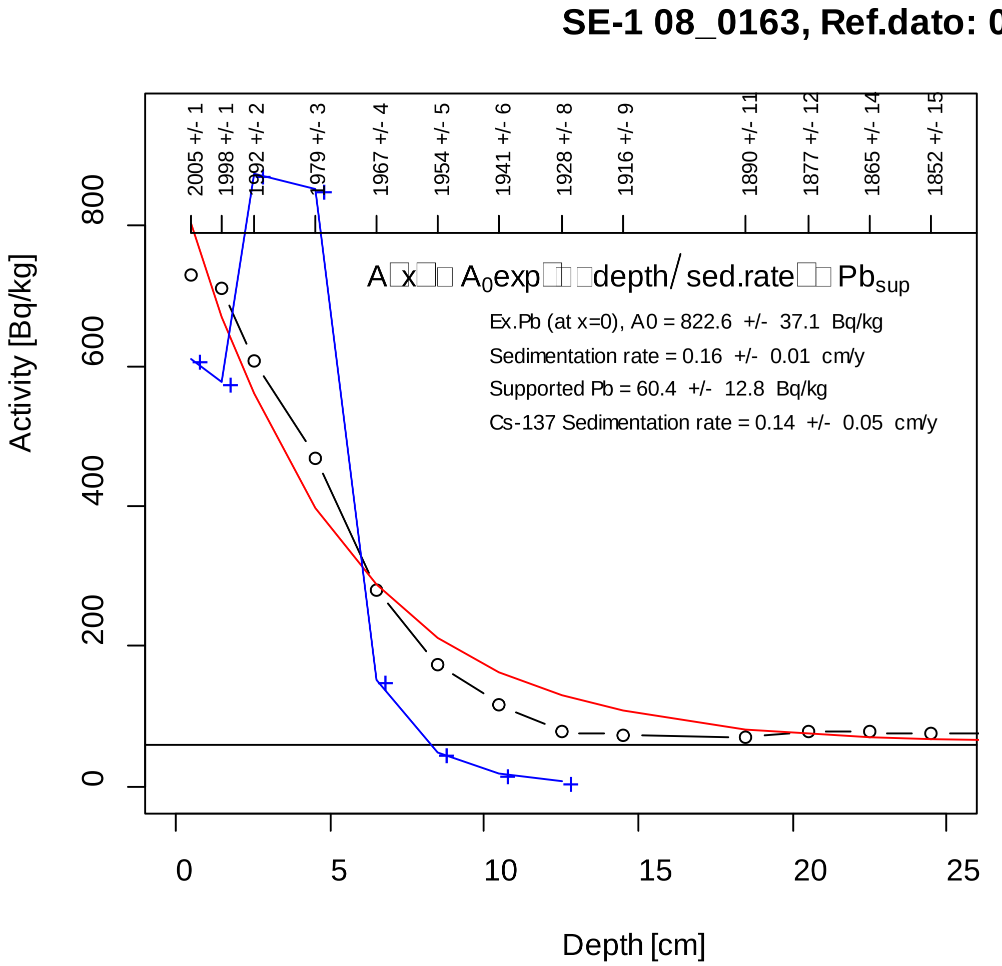
- SGU collected and freeze-dried the sediments
- SSM contracted DTU NUTECH in Denmark to measure selected sediment layers for their content of 137Cs, 210Pb and 208Tl
- SSM analyzed the results and performed the dating of the cores

Sediment dating

- Three independent models were used
- Cs-137 time marker in the sediment profile (Chernobyl peak assumed to represent the year 1986)
- Pb-210 sediment model (assuming constant flux and initial concentration of Pb-210)
- Th-228 sediment model (where sedimentation rate was high, assuming constant flux and initial concentration of Th-228)

Sediment model, Pb-210

(assuming constant flux and concentration of Pb-210)

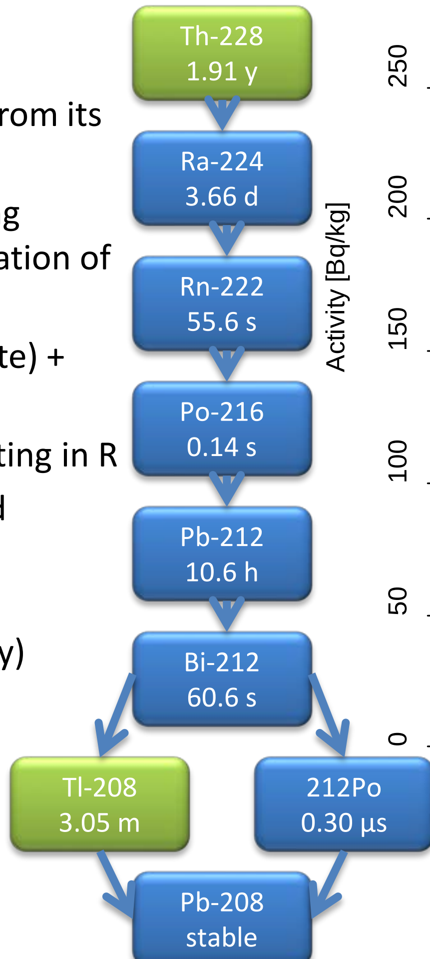


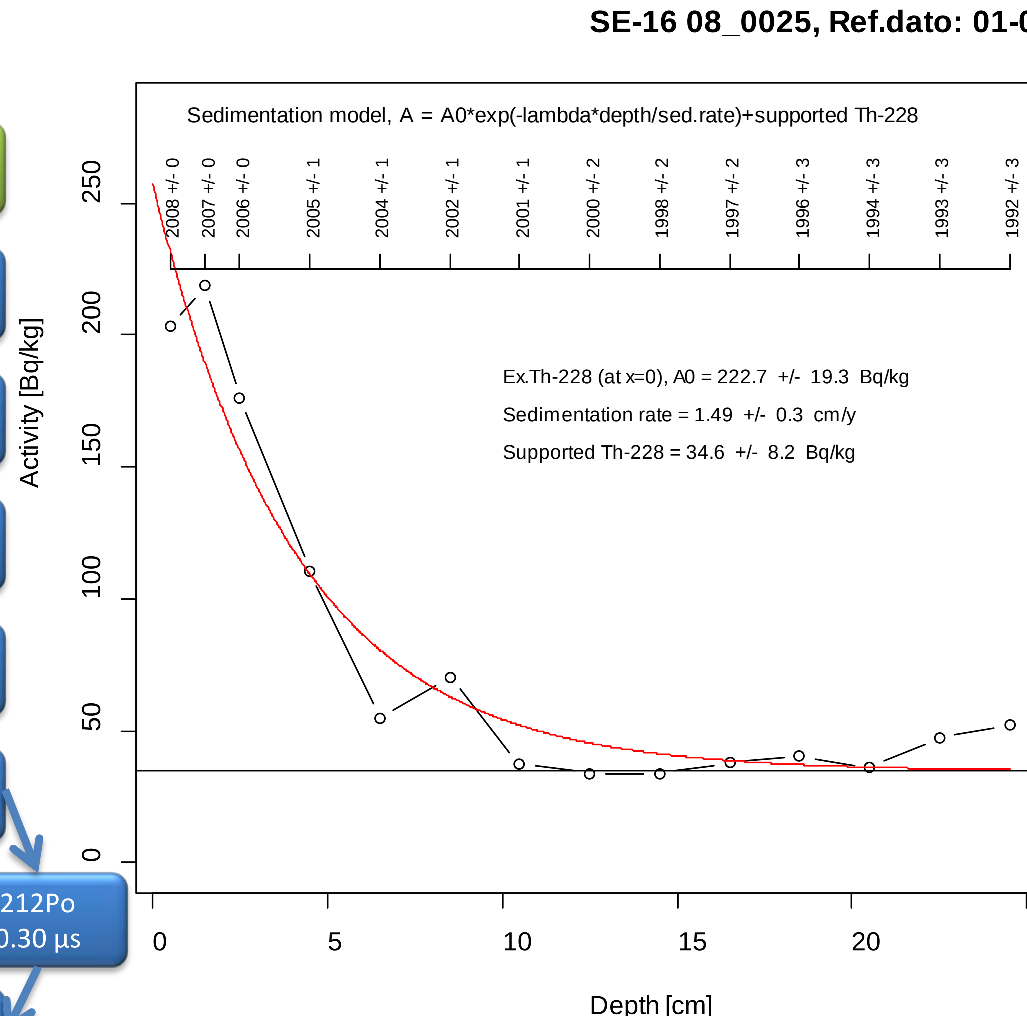
- Pb-210 sediment model (assuming constant flux and initial concentration of Pb-210):
  - $A(x)=A_{(0)} \exp(- \lambda * x / \text{sed.rate}) + Pb_{sup}$
- Using nonlinear least-squares fitting (nls) in the program R
- Fitted initial conc., A0, sedimentation rate and supported Pb-210
- Advantage: easy and fast method, nls fit provides statistic on the fitted parameters

Sediment model, Th-228

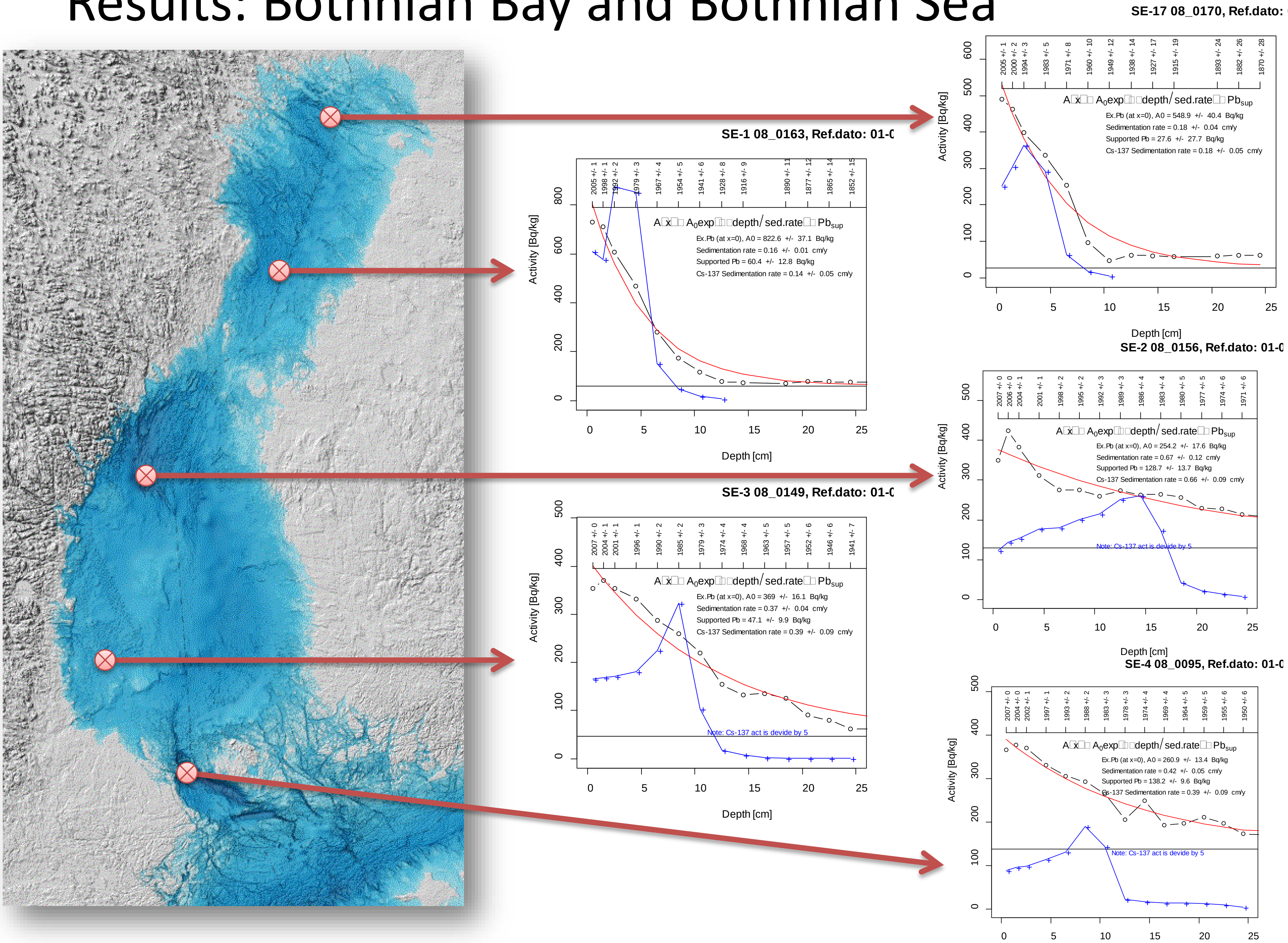
(assuming constant flux and initial concentration of Th-228)

- Th-228 ($t_{1/2}$ = 1.9 y) determined from its daughter Tl-208
- Th-228 sediment model (assuming constant flux and initial concentration of Th-228):
  - $A(x)=A_{(0)} \exp(-\lambda * x / \text{sed.rate}) + Th_{sup}$
- Using nonlinear least-squares fitting in R
- Fitted A0, sedimentation rate and supported Th-228
- Advantage: can be used where sedimentation is high (over 1cm/y)

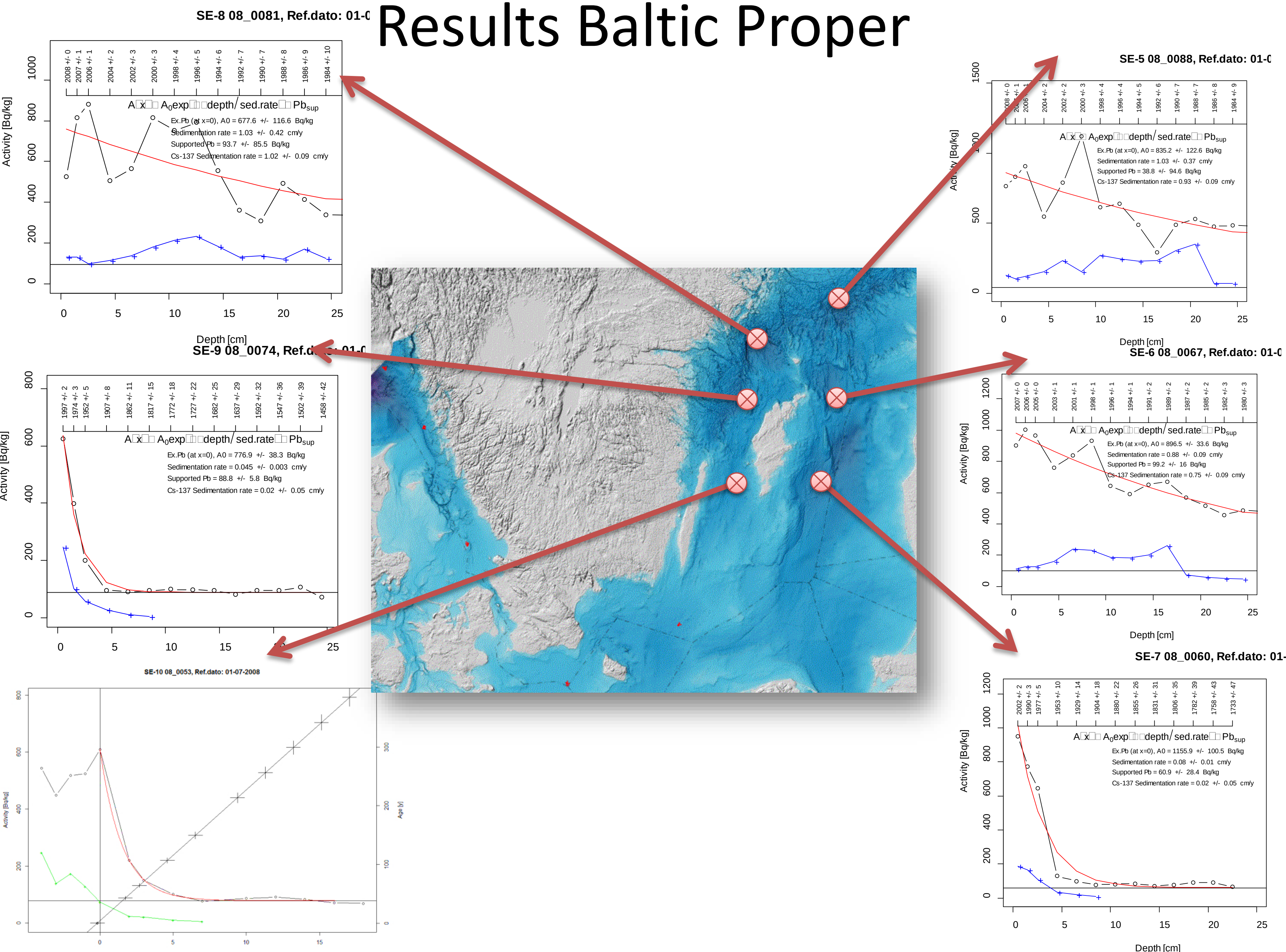




Results: Bothnian Bay and Bothnian Sea

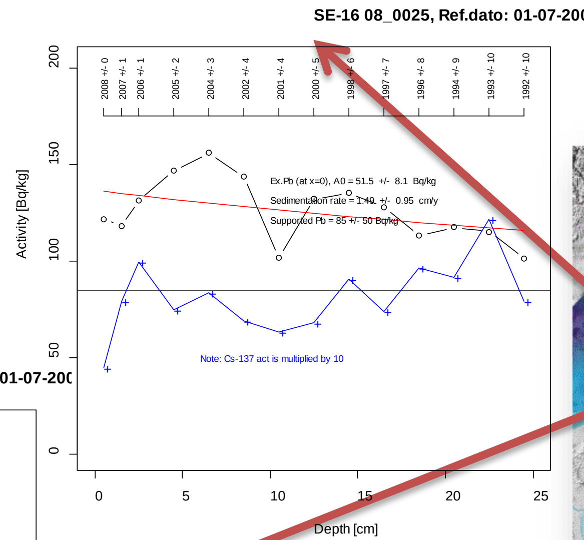


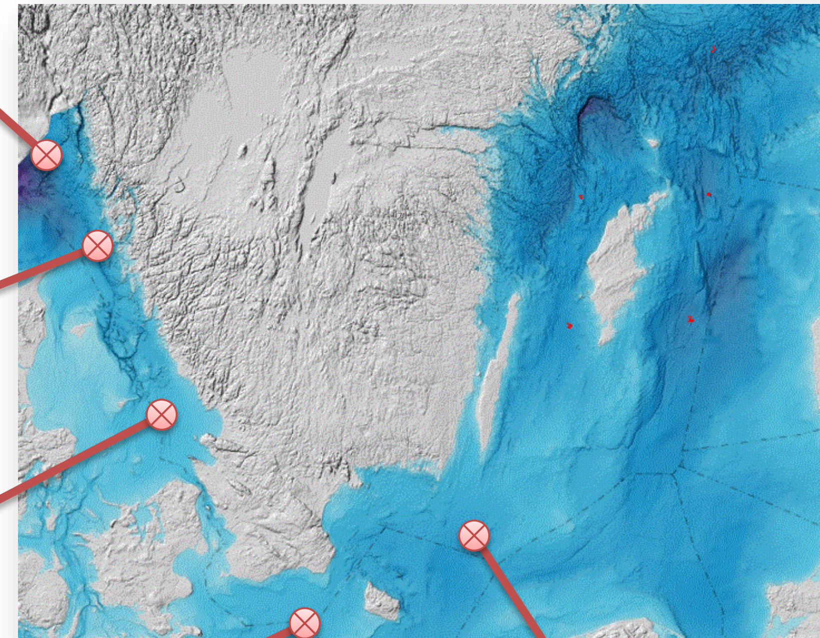
Results Baltic Proper

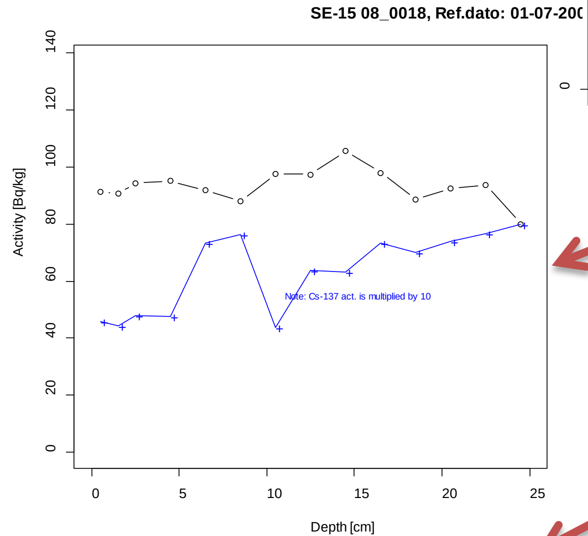


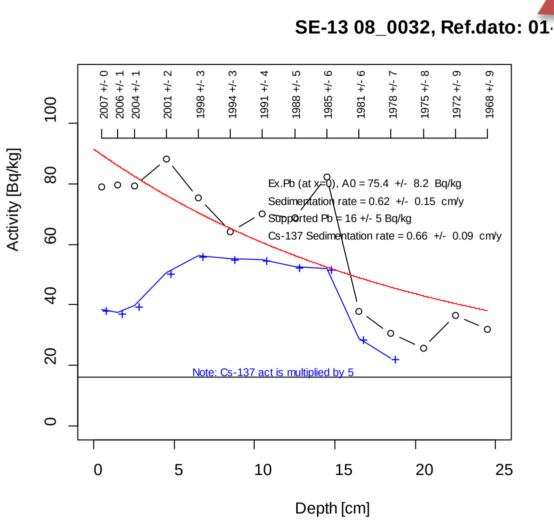
Results:

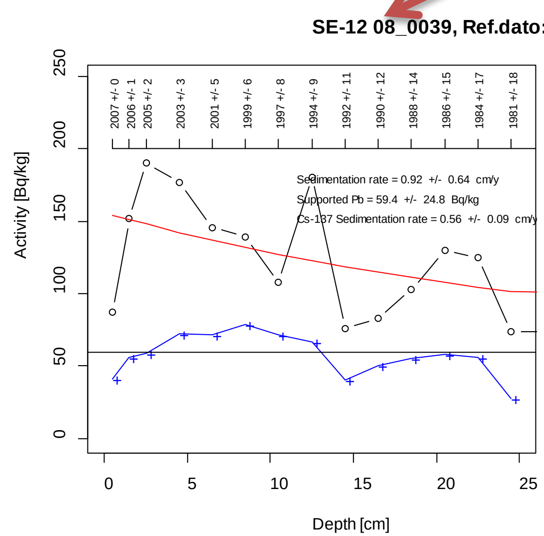
Southern Baltic Proper,
Kattegat and Skagerrak

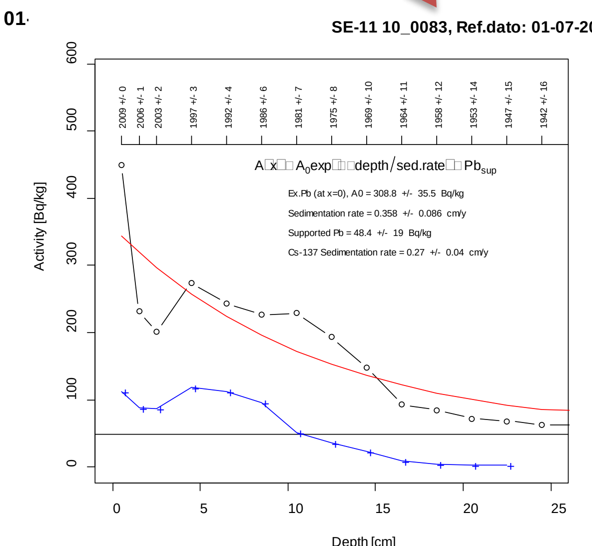












Sedimentation rates

	Pb-210 sed.rate		Th-228 sed.rate		Cs-137 sed.rate		Comment
Station	[cm/y]	± 1 SD	[cm/y]	± 1 SD	[cm/år]	± 1 SD	
SE-17	0.18	± 0.04			0.18	± 0.05	
SE-1	0.16	± 0.01			0.14	± 0.05	
SE-2	0.67	± 0.12	0.78	± 0.22	0.66	± 0.09	Used Ra-226 activity as support level
SE-3	0.37	± 0.04			0.39	± 0.09	
SE-4	0.42	± 0.05	0.83	± 0.34	0.39	± 0.09	Probably Cs-137 peak at 9.5 cm slice (NA)
SE-5	1.03	± 0.37	1.56	± 0.14	0.93	± 0.09	
SE-6	0.88	± 0.09	1.49	± 0.30	0.75	± 0.09	
SE-7	0.08	± 0.01			0.02	± 0.05	Difficult to determine Cs-137 sed.rate
SE-8	1.03	± 0.42	2.13	± 0.97	1.02	± 0.09	
SE-9	0.045	± 0.003			0.02	± 0.05	
SE-10	0.047	± 0.002					Pb-210 sed.rate determined under mixing zon
SE-11	0.36	± 0.09			0.27	± 0.04	
SE-12	0.57	± 0.25			0.56	± 0.09	
SE-13	0.62	± 0.15			0.66	± 0.09	
SE-15							Mixed to at least 25 cm or an very high sed.rate
SE-16	1.49	± 0.95	1.5	± 0.3	>1		Difficult to determine Cs-137 sed.rate

Inventories

Station	Cs-137 inventory 2008 kBq/m^2	Cs-137 inventory 2003 kBq/m^2	Cs-137 added between 2003-2008, derived from sed. rate Bq/m^2	net change over the 5 years Bq/m^2	Cs-137 added between 2003-2008 in percent %	Cs-137 decayed between 2003-2008 in percent %
SE-17	5.2	5.5	473	decreasing	10.0	10.9
SE-1	10.3	11.3	722	decreasing	7.5	10.9
SE-2	52.8	76.5	4550	decreasing	9.4	10.9
SE-3	44.4	55.8	3556	decreasing	8.7	10.9
SE-4	24.2	22.7	2261	decreasing	10.2	10.9
SE-5	3.6*	4.6	284	decreasing	8.6	10.9
SE-6	2.7	3.5	244	decreasing	9.7	10.9
SE-7	0.65*	1.0	40	decreasing	6.6	10.9
SE-8	2.6*	4.8	180	decreasing	7.5	10.9
SE-9	0.79	1.1	55	decreasing	7.5	10.9
SE-10	1.2	2.9	73	decreasing	6.4	10.9
SE-11**	3.0	1.3	328	increasing	12.2	10.9
SE-12	3.7	2.6	292	decreasing	8.6	10.9
SE-13	0.92	0.82	95	increasing	11.5	10.9
SE-15	1.2*	1.1	0			10.9
SE-16	0.98*	3.0	246	increasing	32.7	10.9

* some activity might be missing due to limited sample depth

** sample station has been moved approx 20km to the east

Conclusions

- Good agreement between independent sediment dating techniques
- Highest sedimentation rate at the western stations (> 1 cm/y) and lowest at the south-east, west and south-west of Gotland (< 1mm/y)
- Cs-137 concentrations in surface sediment (0-1 cm) has a decreasing time trend at all stations (4-7 Bq/kg West Coast, 40-100 Bq/kg South Coast, 110-250 Bq/kg Baltic Proper, 250-830 Bq/kg Bothnian Bay and Bothnian Sea
- Cs-137 inventory at 2008 has decreased about 1-3 % since 2003 at most of the stations