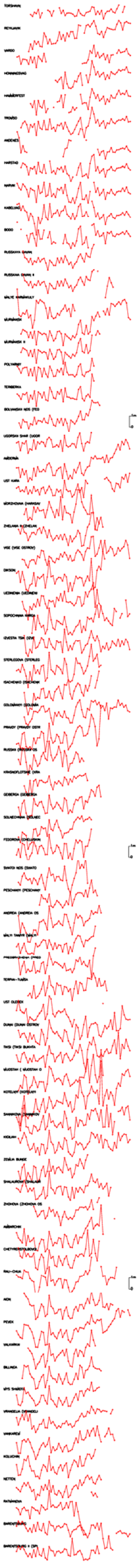
Arctic Sea Level – Analysis of PSMSL RLR Tide Gauge data.

Per Knudsen, DTU Space, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark. pk@space.dtu.dk.



Summary
Tide gauge data from the Arctic region (>65 deg) covering a period of time from 1950 to 2010 are evaluated. Only the 69 stations having RLR data for at least 30 years have been used. Each tide gauge data record was averaged to annual averages after the monthly average seasonal anomalies were removed.
During the period 1990 to 2000 the number of operational stations dropped from 60+ to less than 25. Hence, to compute representative sea level trends for the 1950-2010 period a procedure for filling in estimated sea level values in the voids, is needed.
To fill in voids in the tide gauge data records a reconstruction method was applied that utilizes EOF.s in an iterative manner. Subsequently the trends were computed. The average trend of the reconstructed time series is 2.1 mm/y. Without the fill-in values, i.e. using the measured values only, the average trend is 1.75 mm/y. Hence, increased sea level during 1990-2010 is reflected in the average computed using the reconstructed time series for 1950-2010 of 2.1 mm/y.

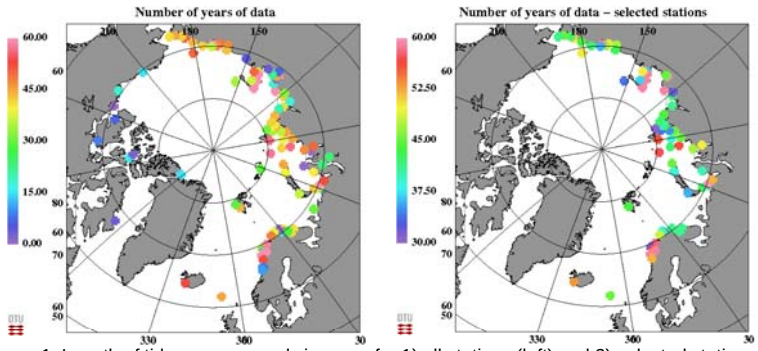


Figure 1. Length of tide gauge records in years for 1) all stations (left) and 2) selected stations (right).

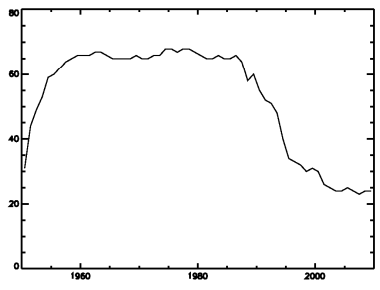


Figure 2. Histogram showing the number of stations per year providing data to the study.

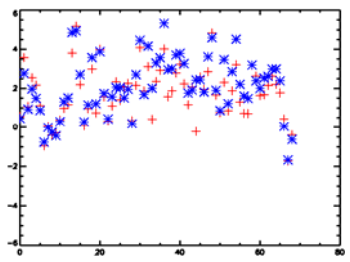


Figure 5..Trends of original time series (red) and of reconstructed time series (blue).

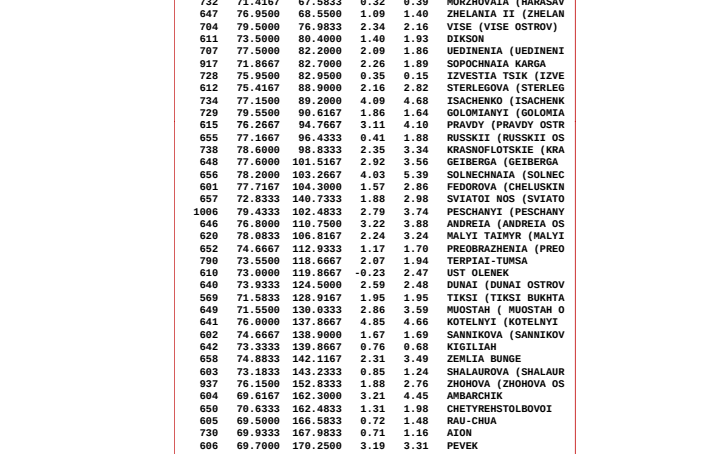


Figure 6. Trends of reconstructed time series.

Results
The tide gauge locations are shown in Figure 1 – both the complete set of gauges providing RLR data and the selected set of tide gauge stations. Note that, as shown in Figure 2, that the number of stations in operation decreased dramatically during the 90'ties.
The observed sea level data records from the selected stationer are shown in Figure 3. The reconstructed time series are shown in Figure 4 together with the regression lines computed using both the reconstructed time series and the observed values only. The trends are shown in Figure 5-6. The mean and std.dev. of the trends of the original data are 1.75 and 1,36 mm/y. The mean and std.dev. of the trends of the reconstructed data are 2.11 and 1,49 mm/y. The individual values are shown in the Table on the right.
Finally, the average sea level time series for the Arctic region was computed using the reconstructed time series. This is shown in Figure 7.

ID	Lat	Lon	Trend1	Trend2	(mm/y)
839	62.0167	353.2333	0.55	0.46	TORSHAVN
638	64.1506	338.0601	3.58	3.11	REYKJAVIK
524	70.3333	31.1000	1.07	1.06	VARDO
1267	70.9833	25.9833	2.55	2.07	HONNINGSVAG
758	70.6667	23.6667	2.17	1.59	HAMMERFEST
680	69.6500	18.9667	1.11	0.95	TROMSO
425	69.3167	16.1500	-0.95	-0.80	ANDENES
681	68.8000	16.5500	0.05	-0.04	HARSTAD
312	68.4333	17.4167	-0.39	-0.32	NARVIK
45	68.2167	14.4833	-0.28	-0.27	KABELVAG
562	67.2833	14.3833	0.37	0.18	BODO
711	76.2000	62.5833	0.97	1.28	RUSSKAYA GAVAN
710	76.1833	62.5833	1.16	1.49	RUSSKAIA GAVAN II
609	72.3667	52.7000	3.81	4.58	MALYE KARMAKULY
684	68.9667	33.0500	5.18	4.97	MURMANSK
687	68.9667	33.0500	2.19	2.75	MURMANSK II
2027	69.2000	33.4833	0.08	0.28	POLYARNIY
2028	69.2000	35.1167	0.97	1.31	TERIBERKA
651	70.4500	59.0833	3.00	3.69	BOLVANSKII NOS (FED
622	69.8167	60.7500	0.73	1.24	UGORSKII SHAR (UGOR
599	69.7500	61.7000	3.99	3.99	AMDERMA
600	69.2500	64.5167	1.58	1.67	UST KARA
732	71.4167	67.5833	0.32	0.39	MORZHOVAIA (HARASAV
647	76.9500	68.5500	1.09	1.40	ZHELANIA II (ZHELAN
704	79.5000	76.9833	2.34	2.16	VISE (VISE OSTROV)
611	73.5000	80.4000	1.40	1.93	DIKSON
707	77.5000	82.2000	2.09	1.86	UEDINENIA (UEDINENI
917	71.8667	82.7000	2.26	1.89	SOPOCHNAIA KARGA
728	75.9500	82.9500	0.35	0.15	IZVESTIA TSIK (IZVE
612	75.4167	88.9000	2.16	2.82	STERLEGOVA (STERLEG
734	77.1500	89.2000	4.09	4.68	ISACHENKO (ISACHENK
729	79.5500	90.6167	1.86	1.64	GOLOMIANYI (GOLOMIA
615	76.2667	94.7667	3.11	4.10	PRAVDY (PRAVDY OSTR
655	77.1667	96.4333	0.41	1.88	RUSSKII (RUSSKII OS
738	78.6000	98.8333	2.35	3.34	KRASNOFLOTSKIE (KRA
648	77.6000	101.5167	2.92	3.56	GEIBERGA (GEIBERGA
656	78.2000	103.2667	4.03	5.39	SOLNECHNAIA (SOLNEC
601	77.7167	104.3000	1.57	2.86	FEDOROVA (CHELUSKIN
657	72.8333	140.7333	1.88	2.98	SVIATOI NOS (SVIATO
1006	79.4333	102.4833	2.79	3.74	PESCHANYI (PESCHANY
646	76.8000	110.7500	3.22	3.88	ANDREIA (ANDREIA OS
620	78.0833	106.8167	2.24	3.24	MALYI TAIMYR (MALYI
652	74.6667	112.9333	1.17	1.70	PREOBRAZHENIA (PREO
790	73.5500	118.6667	2.07	1.94	TERPIAI-TUMSA
610	73.0000	119.8667	-0.23	2.47	UST OLENEK
640	73.9333	124.5000	2.59	2.48	DUNAI (DUNAI OSTROV
569	71.5833	128.9167	1.95	1.95	TIKSI (TIKSI BUKHTA
649	71.5500	130.0333	2.86	3.59	MUOSTAH (MUOSTAH O
641	76.0000	137.8667	4.85	4.66	KOTELNYI (KOTELNYI
602	74.6667	138.9000	1.67	1.69	SANNIKOVA (SANNIKOV
642	73.3333	139.8667	0.76	0.68	KIGILIAH
658	74.8833	142.1167	2.31	3.49	ZEMLIA BUNGE
603	73.1833	143.2333	0.85	1.24	SHALAUROVA (SHALAUR
937	76.1500	152.8333	1.88	2.76	ZHOHOVA (ZHOHOVA OS
604	69.6167	162.3000	3.21	4.45	AMBARCHIK
650	70.6333	162.4833	1.31	1.98	CHETYREHSTOLBOVOI
605	69.5000	166.5833	0.72	1.48	RAU-CHUA
730	69.9333	167.9833	0.71	1.16	AION
606	69.7000	170.2500	3.19	3.31	PEVEK
792	70.0833	170.9333	2.63	2.49	VALKARKAI
708	69.8833	175.7667	1.64	1.95	BILLINGA
616	68.9000	180.6333	1.67	2.41	MYS SHMIDTA
608	70.9833	181.5167	2.16	2.66	VRANGELIA (VRANGELI
607	67.8333	184.1667	2.64	3.17	VANKAREM
621	67.4833	185.3500	2.21	3.09	KOLUCHIN
613	66.9667	188.0667	1.77	2.35	NETTEN
617	66.8500	190.8667	0.43	0.30	RATMANOVA
541	78.0667	14.2500	-1.71	-1.72	BARENTSBURG
547	78.0667	14.2500	-0.39	-0.53	BARENTSBURG II (SPI

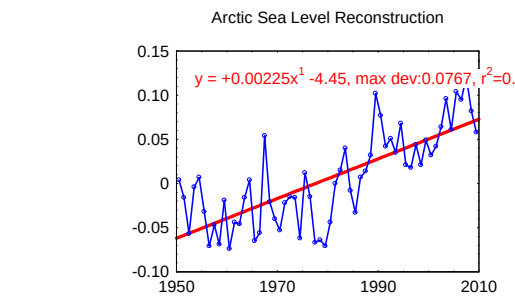


Figure 7. Arctic regional averaged sea level time series.

Details on the EOFs
A mentioned above the reconstruction was carried out using the first and second EOF. The first EOF picks the main signal associated with the general sea level in the region. The second EOF was included to describe regional to local phenomena that may influence sea level. The remaining EOFs are assumed to describe purely local signals and errors/off-sets/jumps.
The loading of the two EOFs are displayed in Figure 8. The values associated with EOF#1 vary in a very similar manner compared to the trends shown in Figure 6. This is quite natural as this EOF picks the main sea level variability. The loadings of EOF#2 show more variability. There are some local coherency but it is difficult to conclude on a general pattern.
Alternative sea level reconstructions were tested using the EOF#1 and EOF#2 alone. Here the mean loadings associated with EOF#1+2 were used af weights. In Figure 9 left graph the curves obtained using EOF#1 and EOF#1+2 are shown. In Figure 9 right graphs three curves are shown. They were obtained using EOF#1+2 with the load of EOF#2 varying with +- its st.dev.

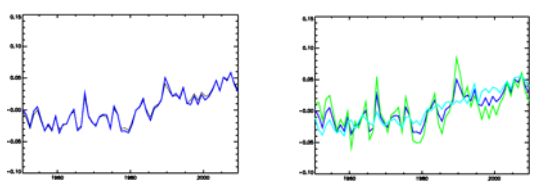


Figure 9. Alternative sea level reconstruction using the EOF#1 and EOF#2 and the mean loading associated with them.
Left graph shows the curves obtained using EOF#1 and EOF#1+2
Right graph shows three curves obtained using EOF#1+2 with the load of EOF#2 varying with +- its st.dev.

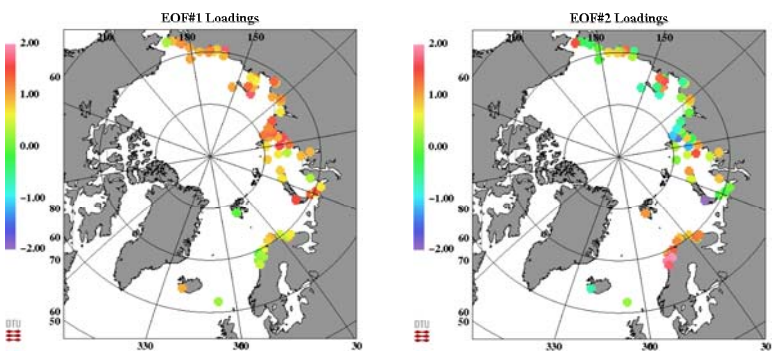


Figure 8. Loading associated with EOFs 1 (left) and 2 (right).

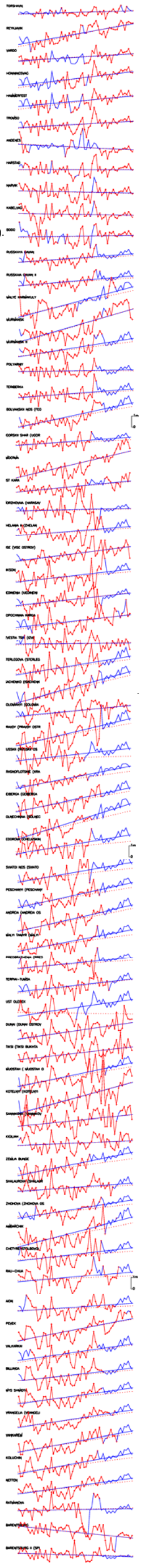


Figure 4. Reconstructed sea levels.

Figure 3. Observed sea levels.