

An Overview of Tides and Sea Level Variations in the Arctic: Their Characteristics and Measurement

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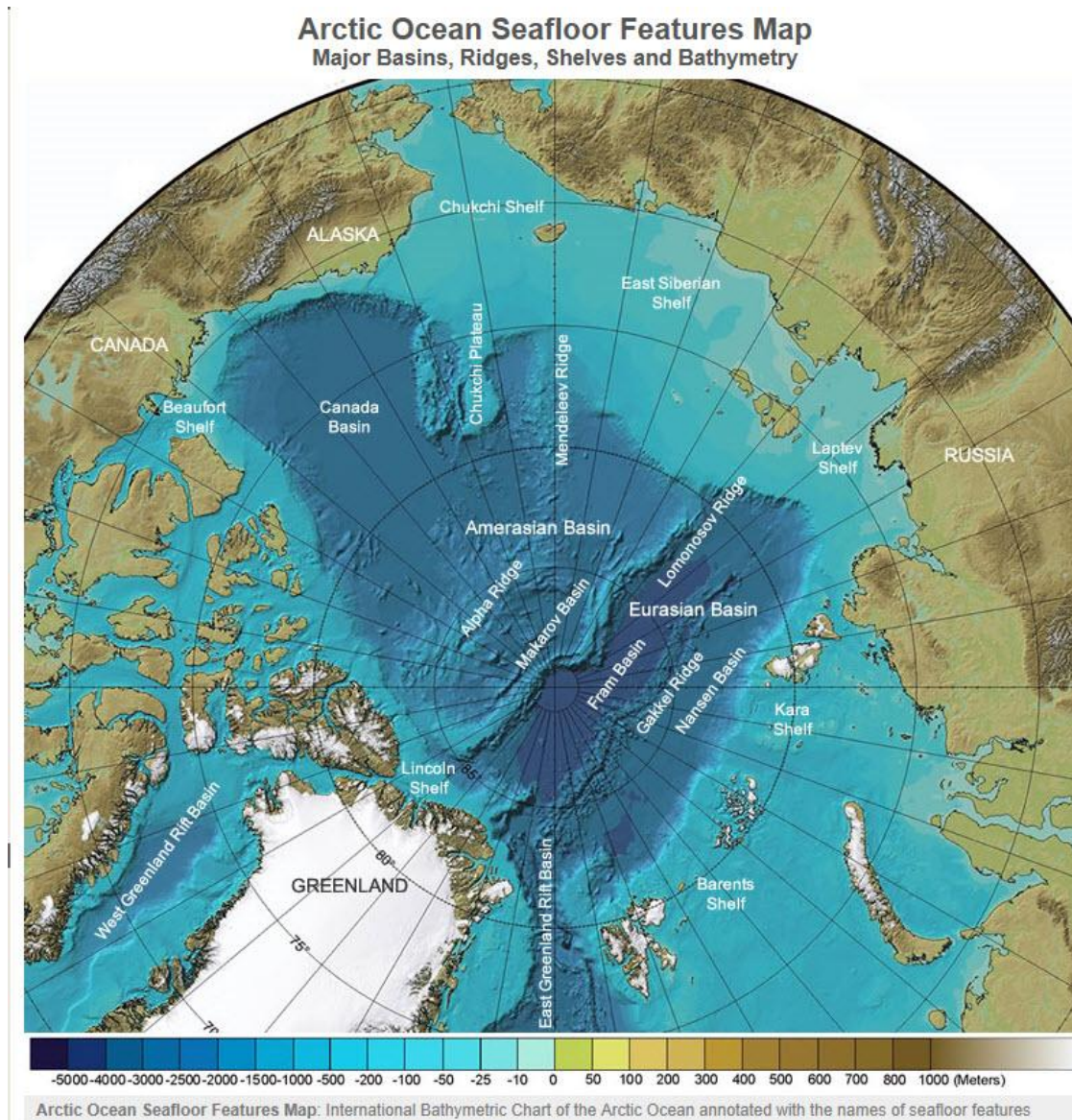


Arctic Science Forum: Science in Support of Hydrography in the Arctic

University of New Hampshire

January 28, 2014

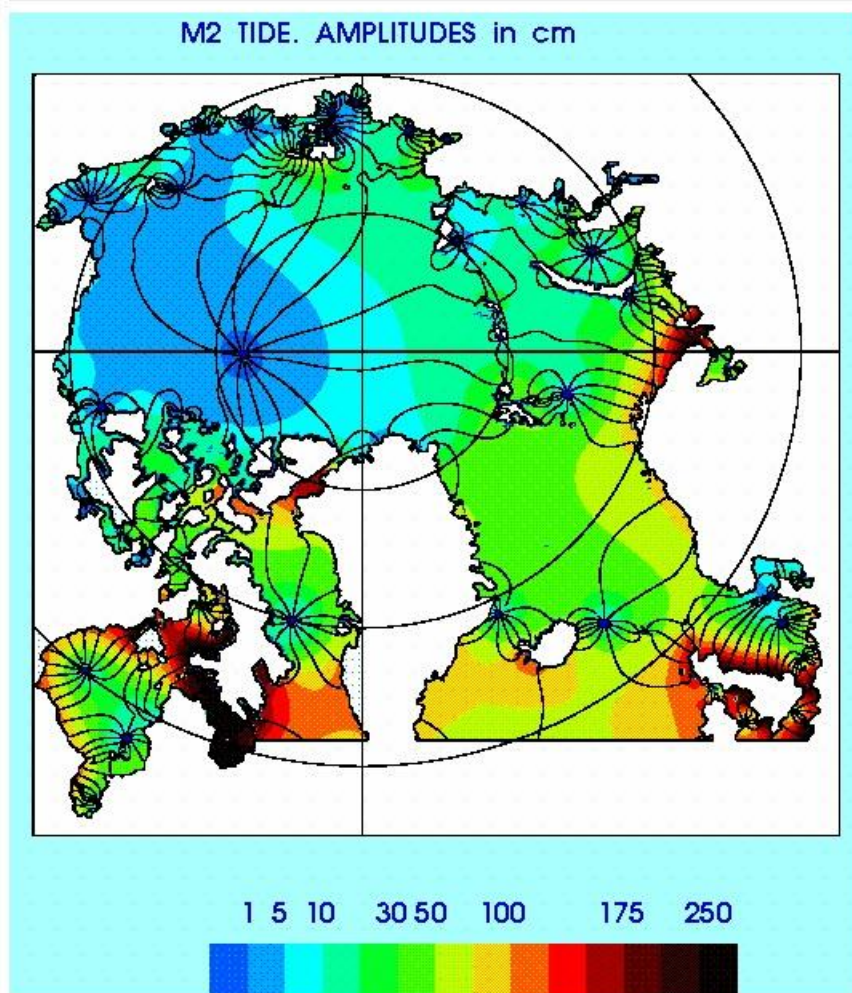
Bathymetric Character of Arctic Ocean Basin



<http://geology.com/articles/arctic-ocean-features/>

Investigation of the ice-tide interaction in the Arctic Ocean

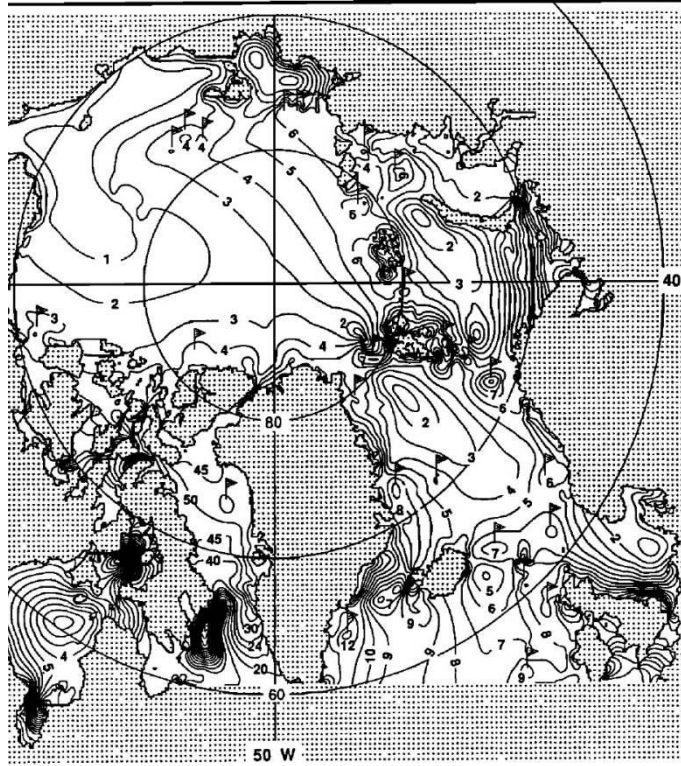
Z. Kowalik - PI, A. Proshutinsky - CoPI, R. H. Thomas - Manager, NASA Polar Research Program.



Semidiurnal component dominates

Amplitude (cm) and phase (degree) for the M2 constituent.

Arctic Ocean Diurnal Tidal Component



2a. Computed amplitude (in centimeters) of surface elevation for the diurnal constituent K_1 . Flags denote shelf wave regions.

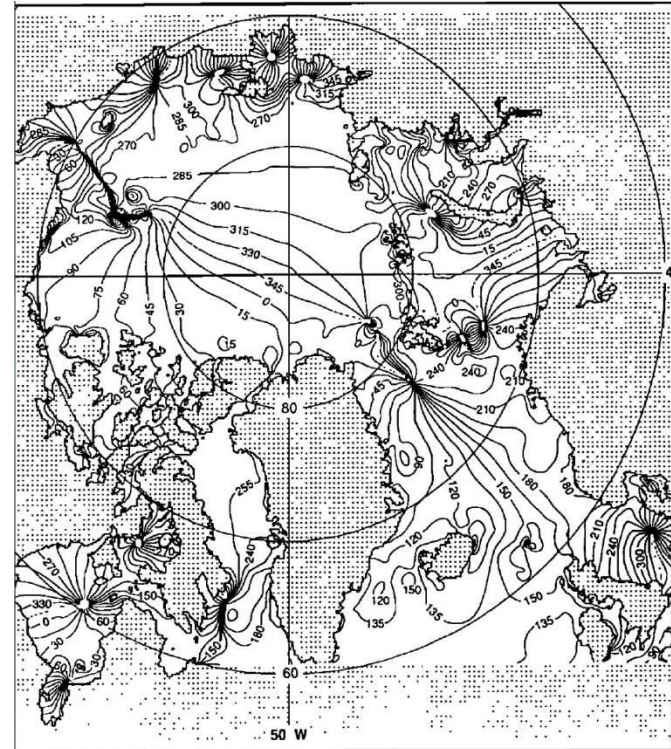
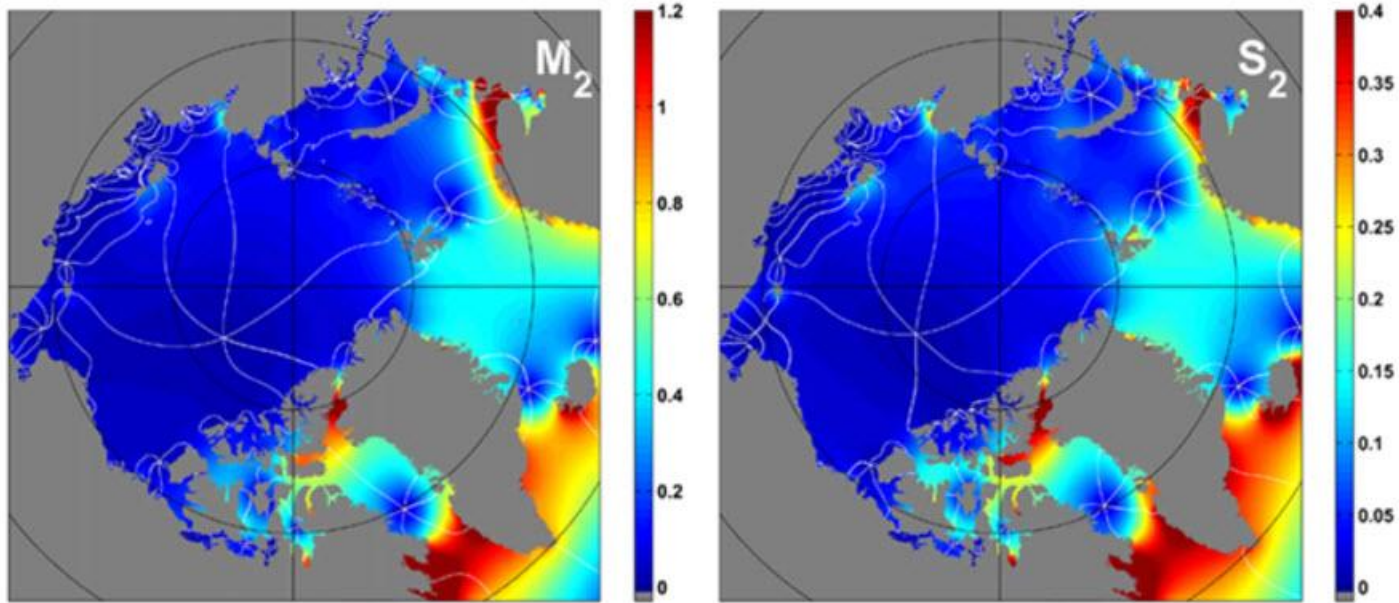
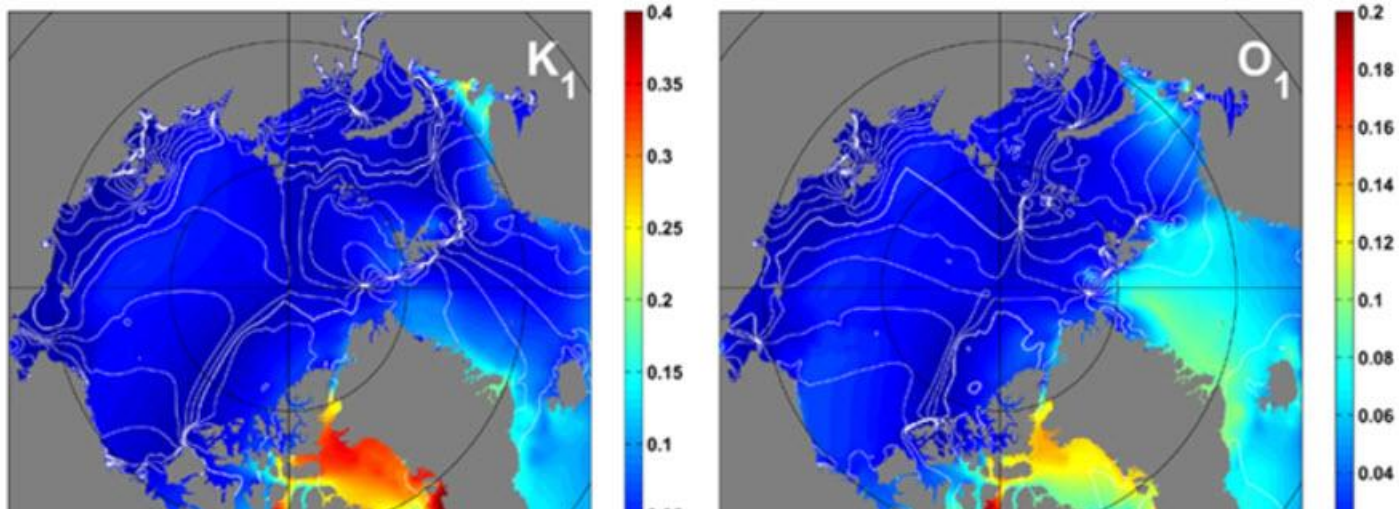


Fig. 2b. Computed phase (in degrees) of surface elevation for the diurnal constituent K_1 .

Arctic Ocean Tidal Co-Tidal Maps from a Tidal Model

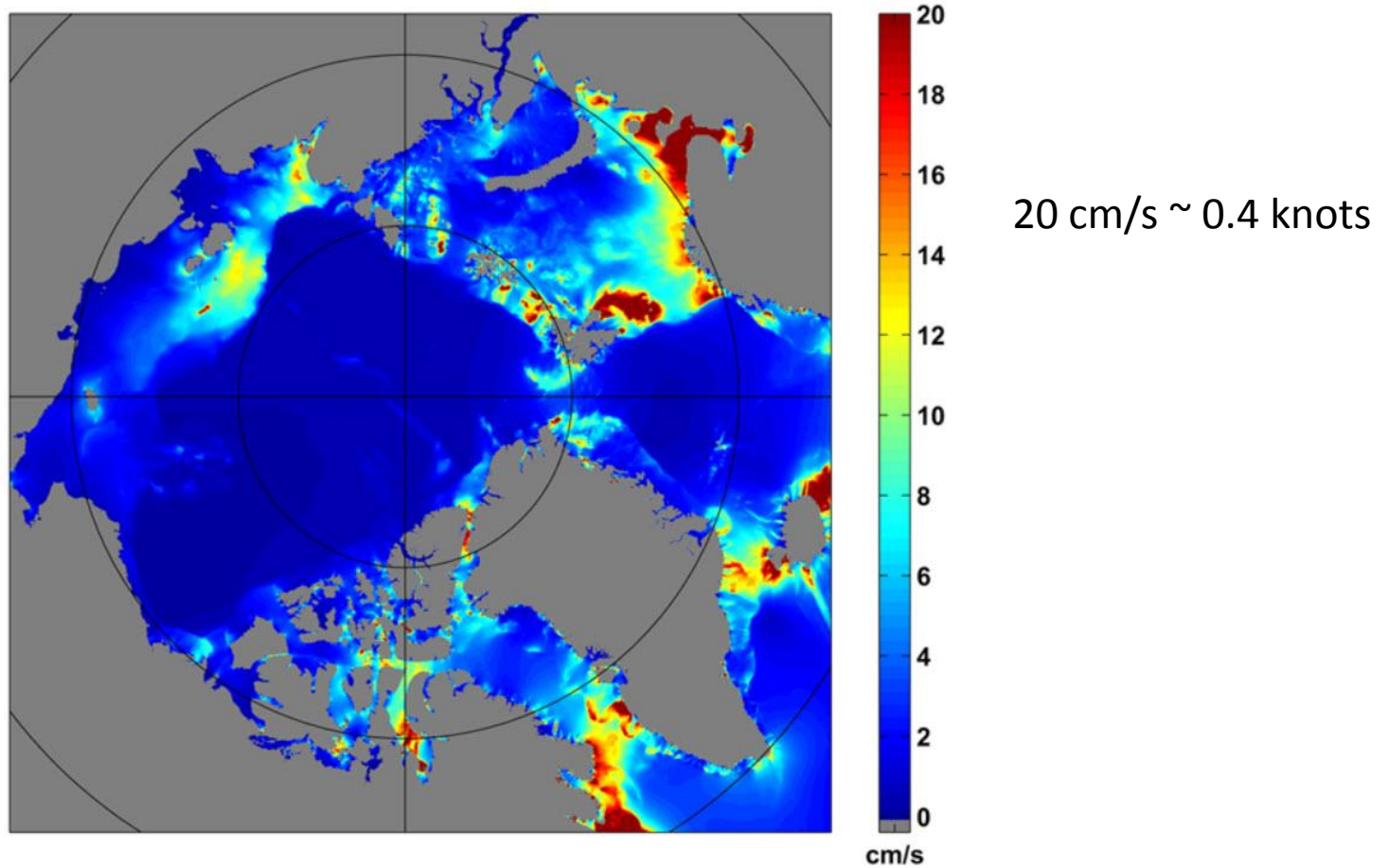


Phases depicted by white contours (in degrees), Amplitudes depicted by color scale (meters)



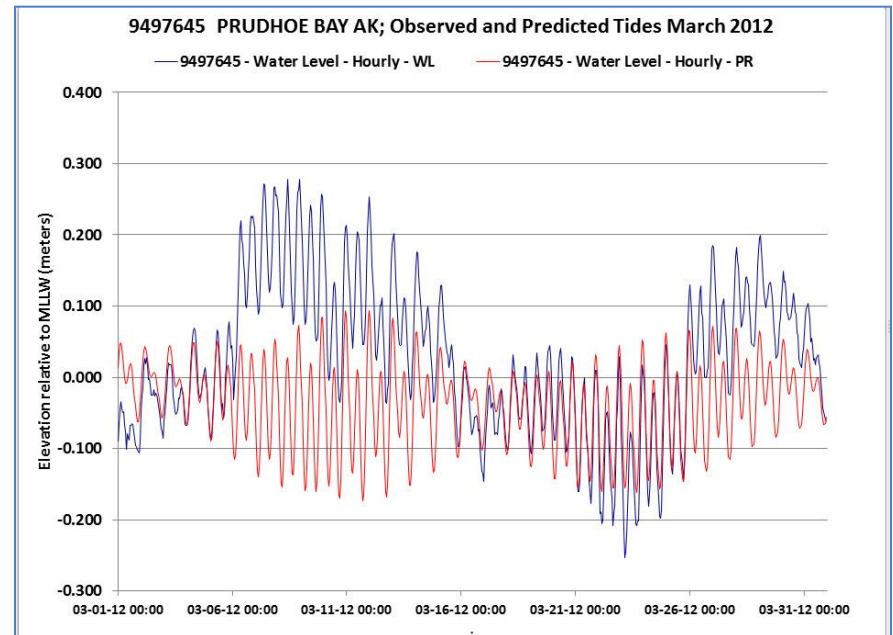
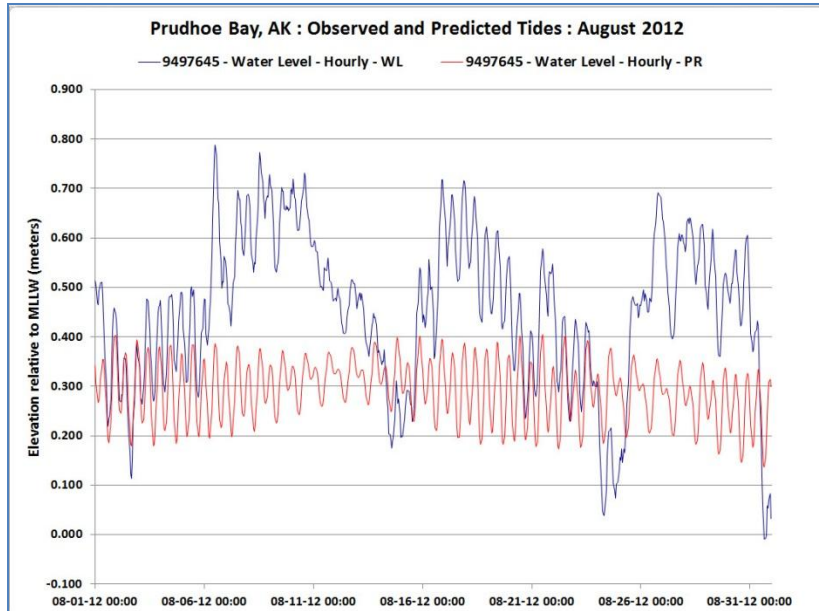
Source; L. Padman and S. Erofeeva, GRL, Vol. 31, 2004

Arctic Ocean Maximum Tidal Currents

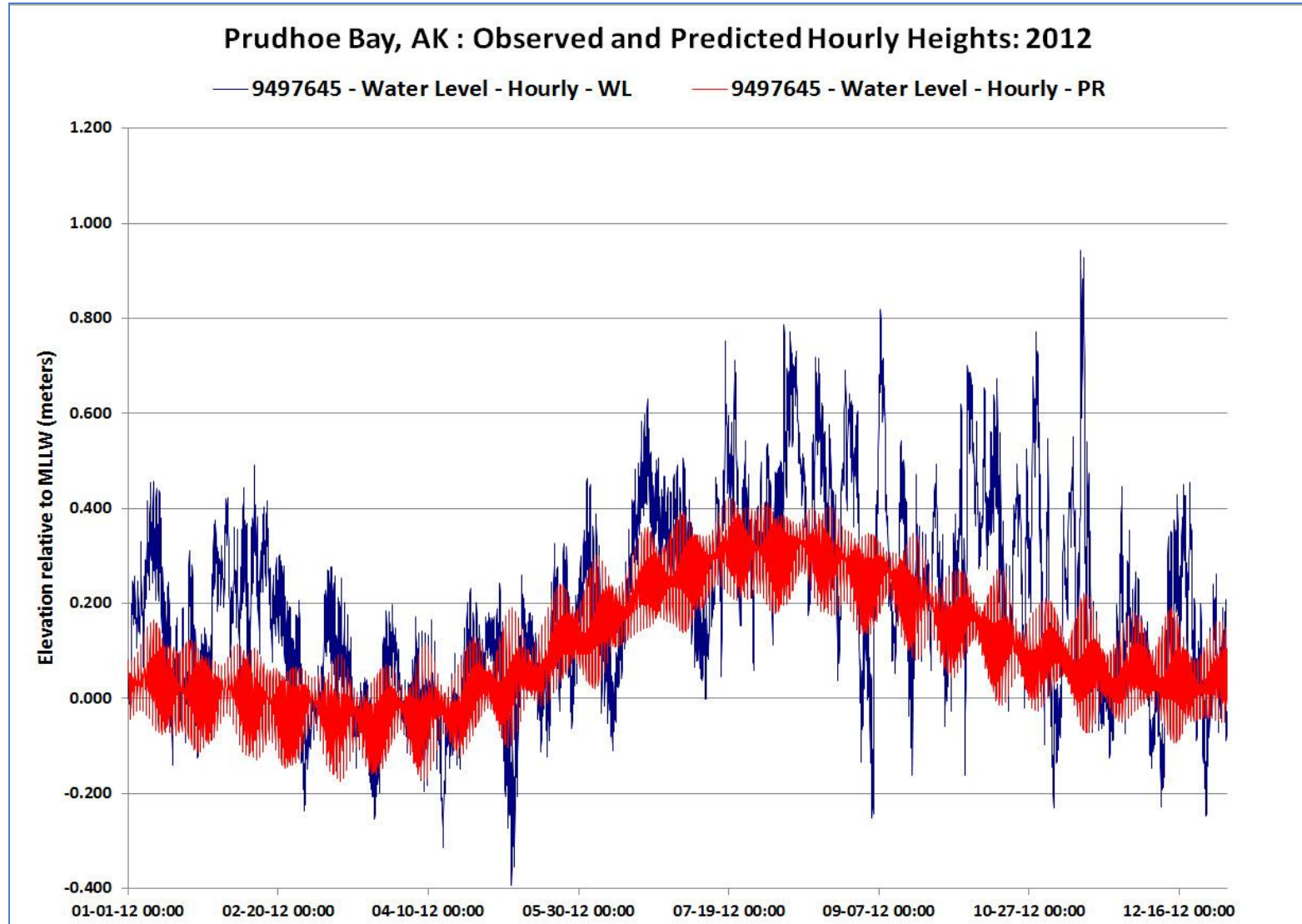


Source; L. Padman and S. Erofeeva, GRL, Vol. 31, 2004

Observed and Predicted Tide Comparisons

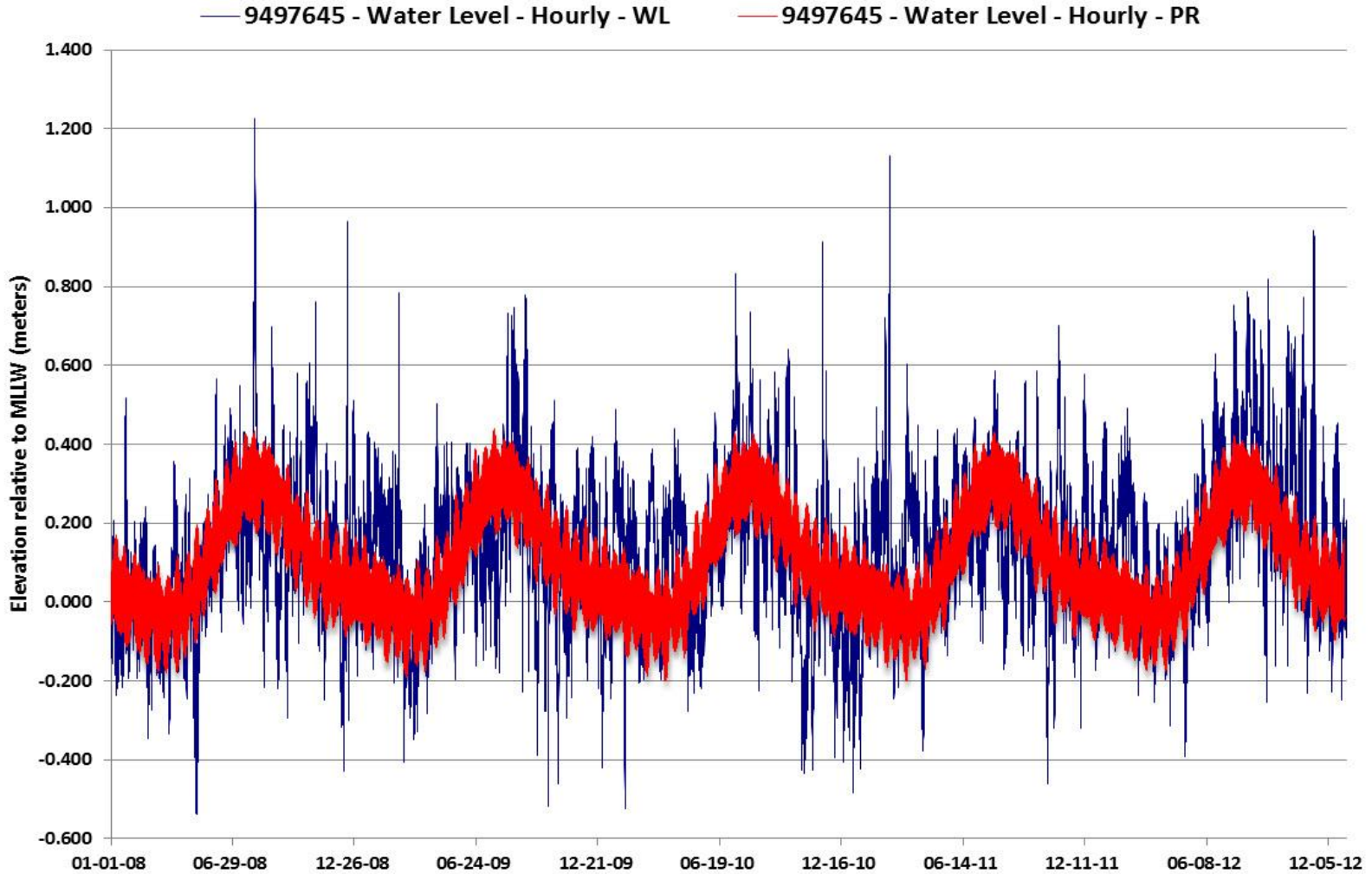


Observed and Predicted Tide Comparisons



Observed and Predicted Tide Comparisons

9497645 PRUDHOE BAY AK: Observed and Predicted Tides 2008-2012

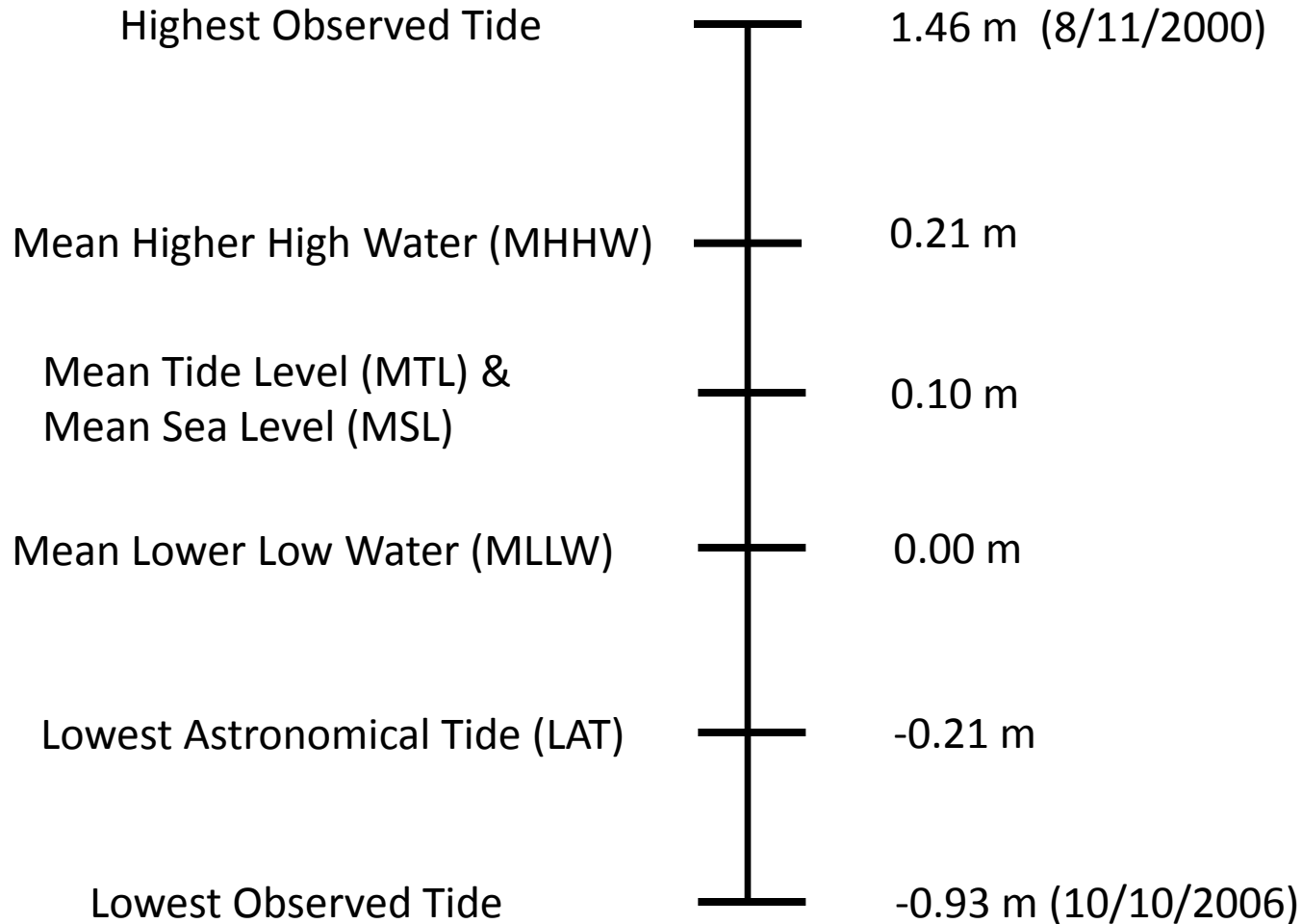


Arctic Tides in Context

For those areas with small tidal amplitudes, water level variations are dominated by meteorological forcing, illustrated by Prudhoe Bay tidal reduction of variance using harmonic analysis:

Tidal Constituent	Reduction of Variance	Name	Period
Sa	31%	Solar Annual	365 days
Ssa	7%	Solar Semiannual	183 days
M2	5%	Lunar Semidiurnal	12.42 hrs.
Mm	3%	Lunar Monthly	27.5 days
O1	1%	Lunar Diurnal	25.8 hrs.
S2	1%	Solar Semidiurnal	12.00 hrs.
K1	1%	Luni-Solar Diurnal	23.9 hrs
Msf	1%	Lunar Fortnightly	13.8 days
Total	50%		
Semidirunal and Diurnal	only 8%		

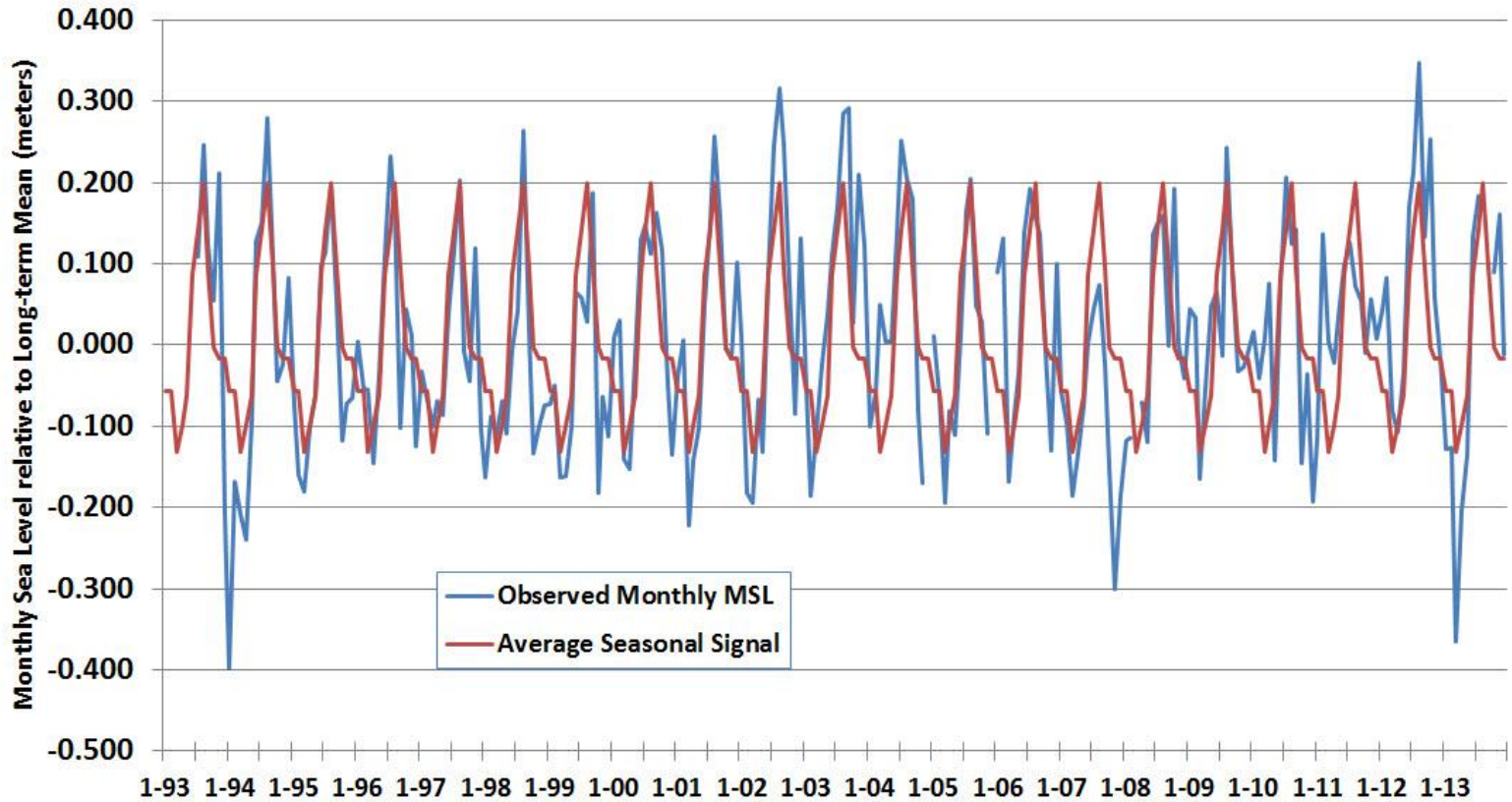
Tidal Datum Elevations – Prudhoe Bay, AK

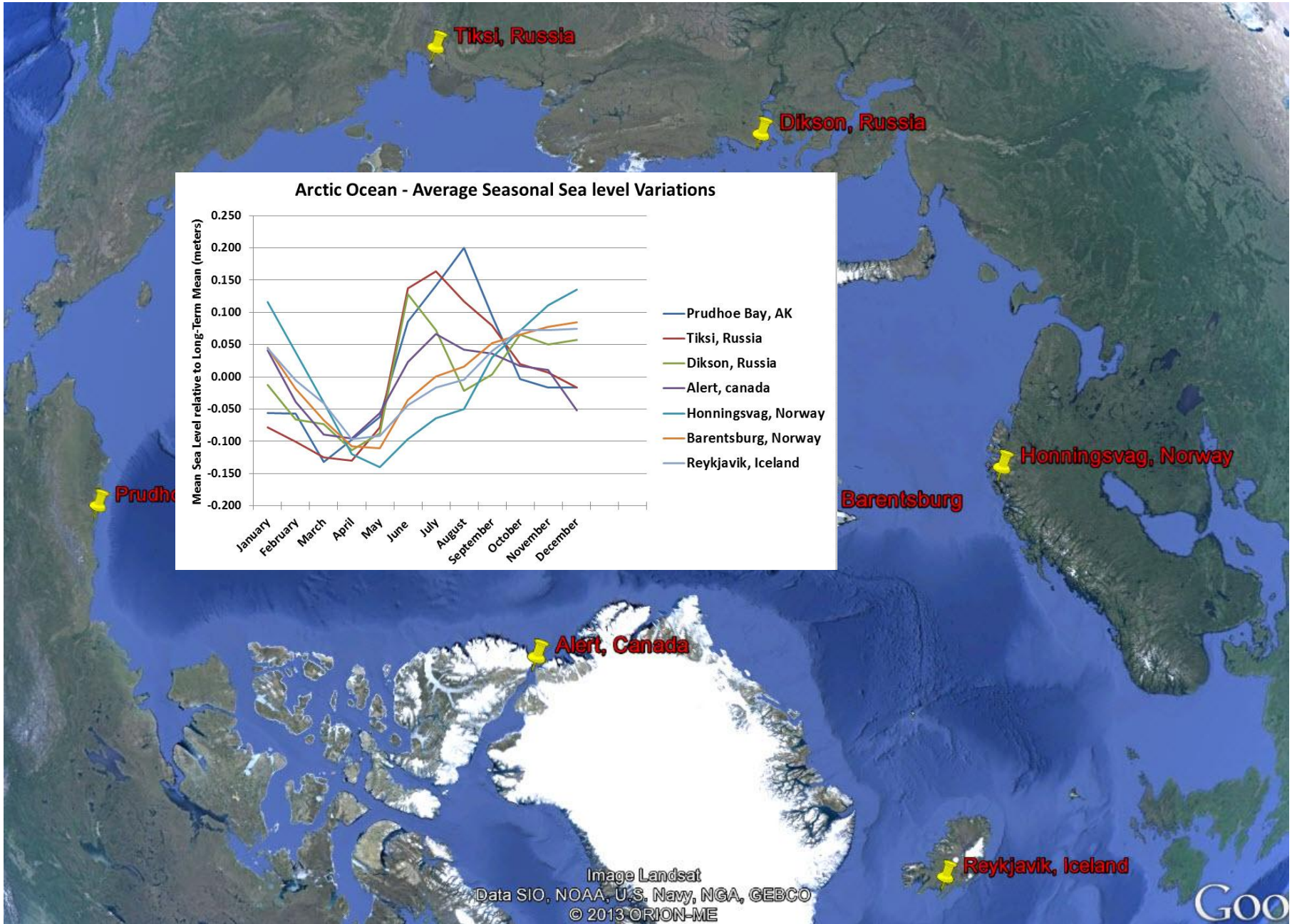


Note: Elevations in meters relative to MLLW (US Chart Datum)

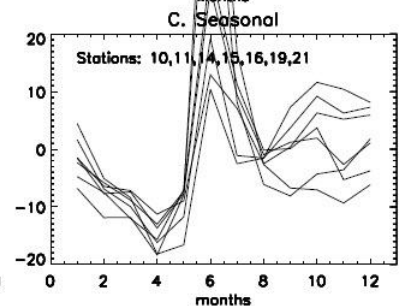
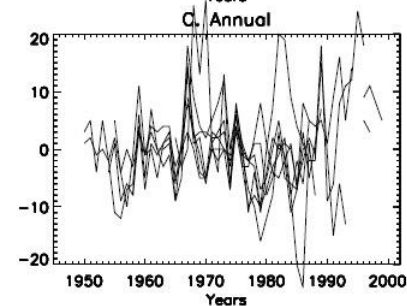
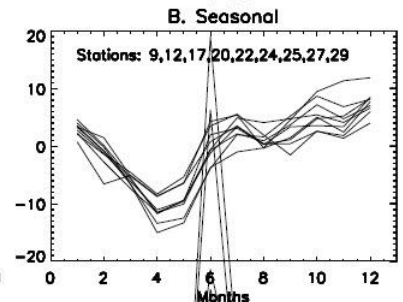
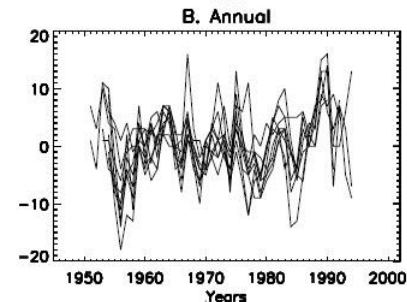
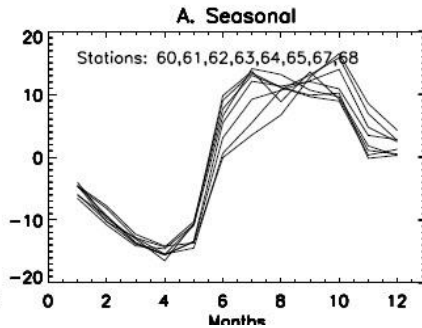
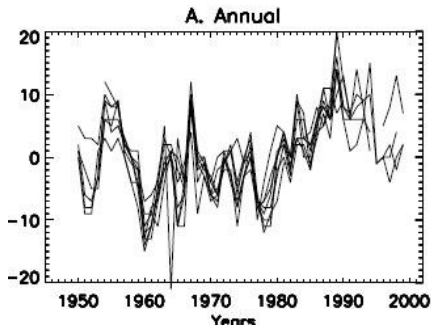
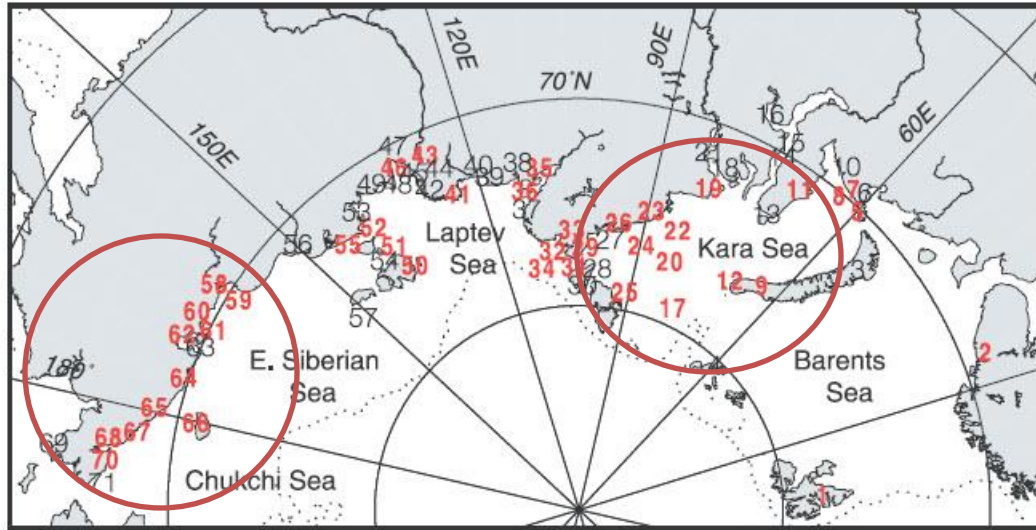
Variations in Monthly Mean Sea Level: 1993-2013

Prudhoe Bay, AK - Observed Monthly and Average Seasonal Mean Sea Level



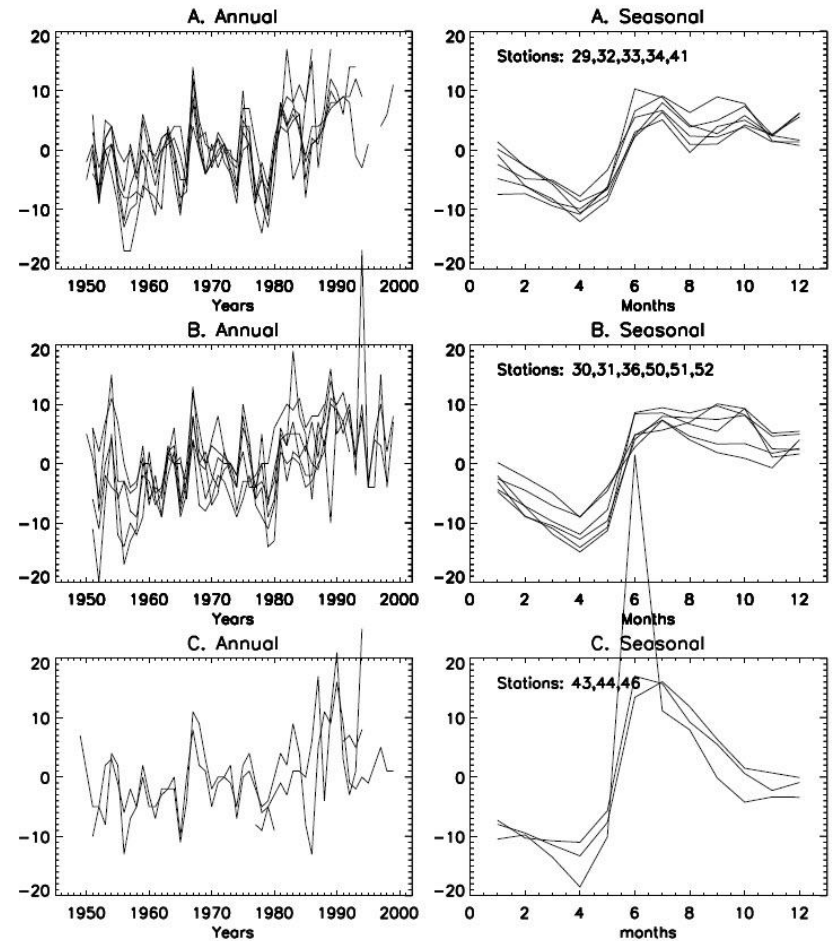
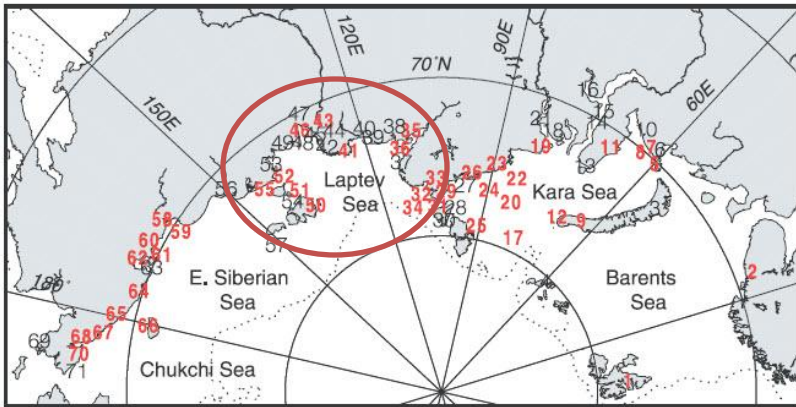


Sea Level Variations in Russian Sector of Arctic Ocean



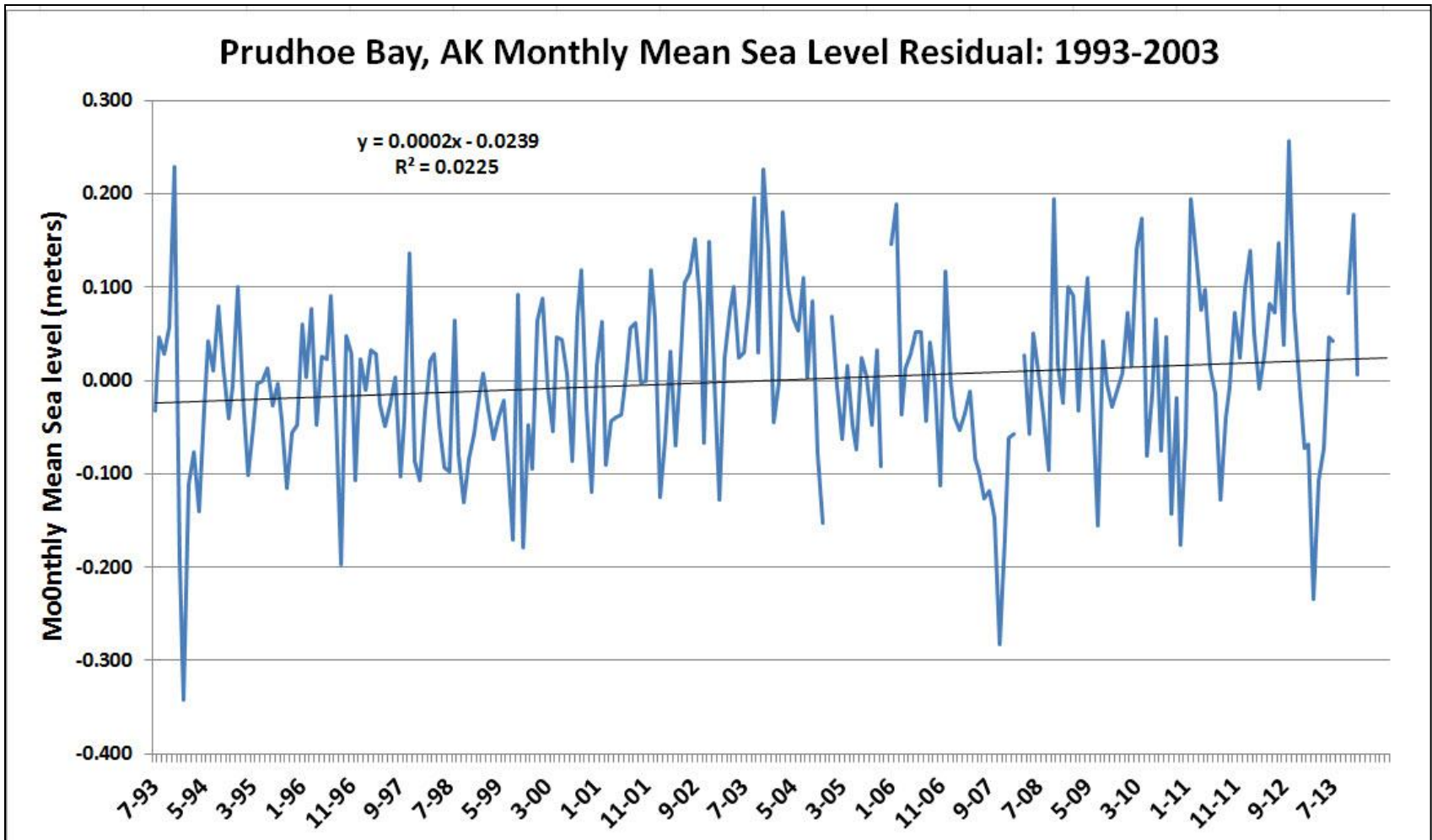
Source: A. Proshutinsky et al, JGR, Vol. 109, C03042, 2004

Sea Level Variations in Russian Sector of Arctic Ocean

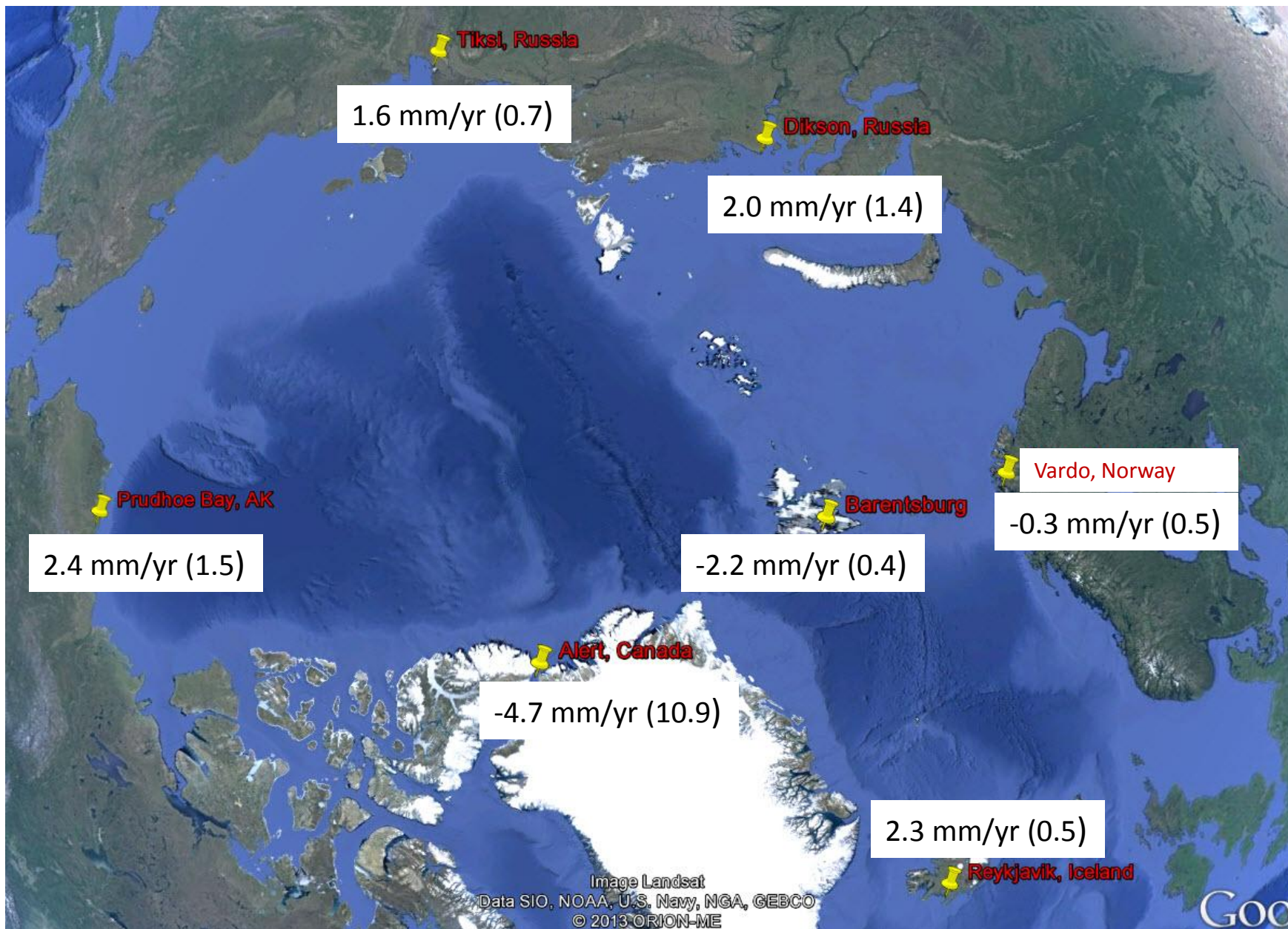


Source: A. Proshutinsky et al, JGR, Vol. 109, C03042, 2004

Mean Sea Level Trends

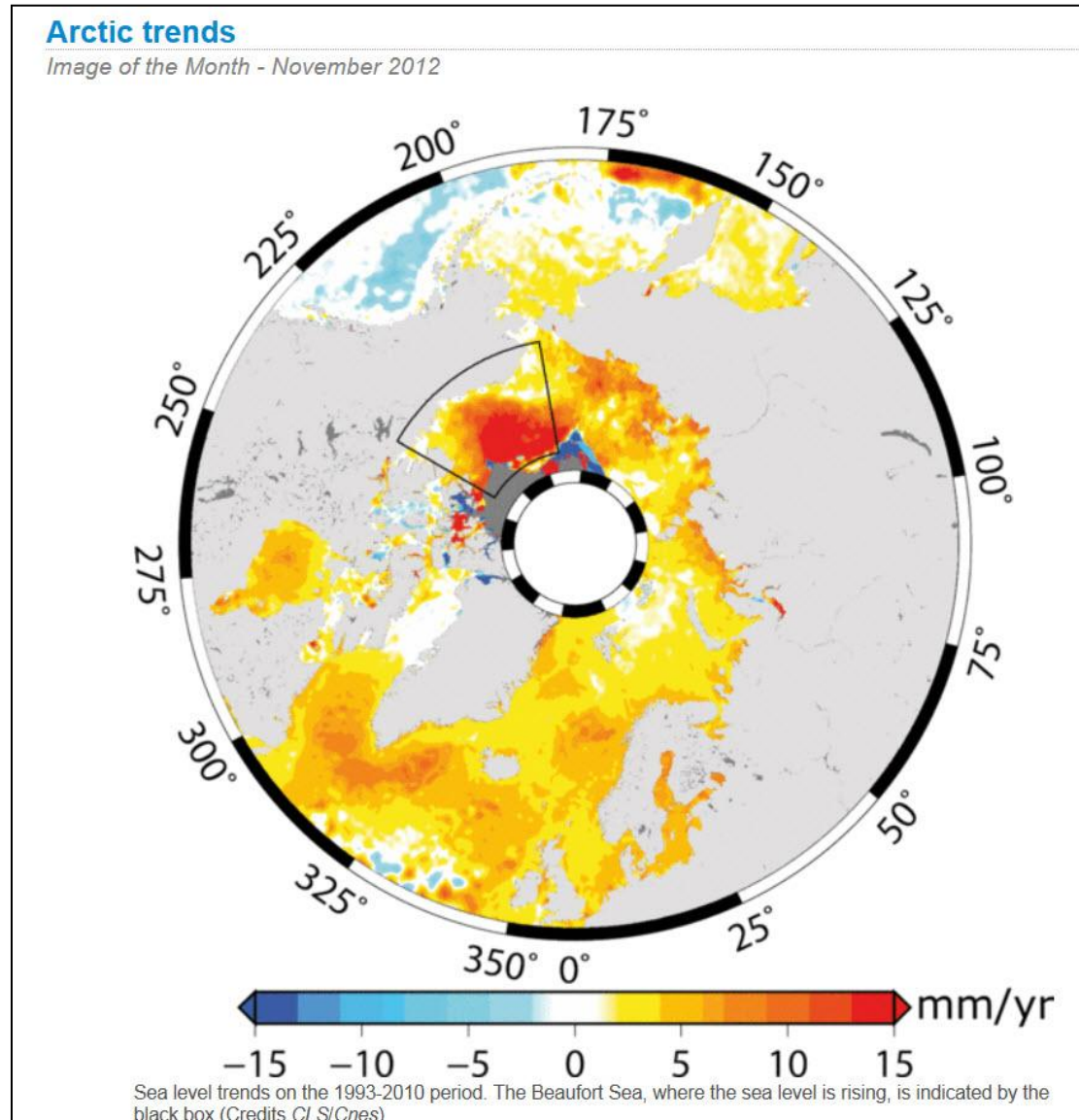


Arctic Ocean Relative Sea Level Trends



Trends in mm/yr with standard error of trend in parentheses

Arctic Sea Level Trends from Satellite Altimetry: 1993-2010



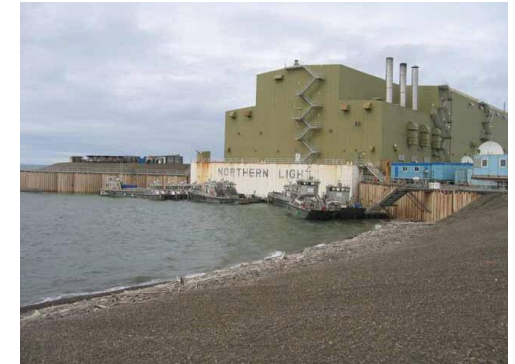
Measurement of Water Levels in the Arctic Ocean

Long-term Measurements require substantial infrastructure

Prudhoe Bay, AK example: using existing infrastructure

Oil industry man-made cause way

Salt-water treatment and pumping plant



Water level sensors housed in plant

Bench marks established using existing infrastructure

Continuous GPS at nearby infrastructure



Bench mark leveling and GPS connection

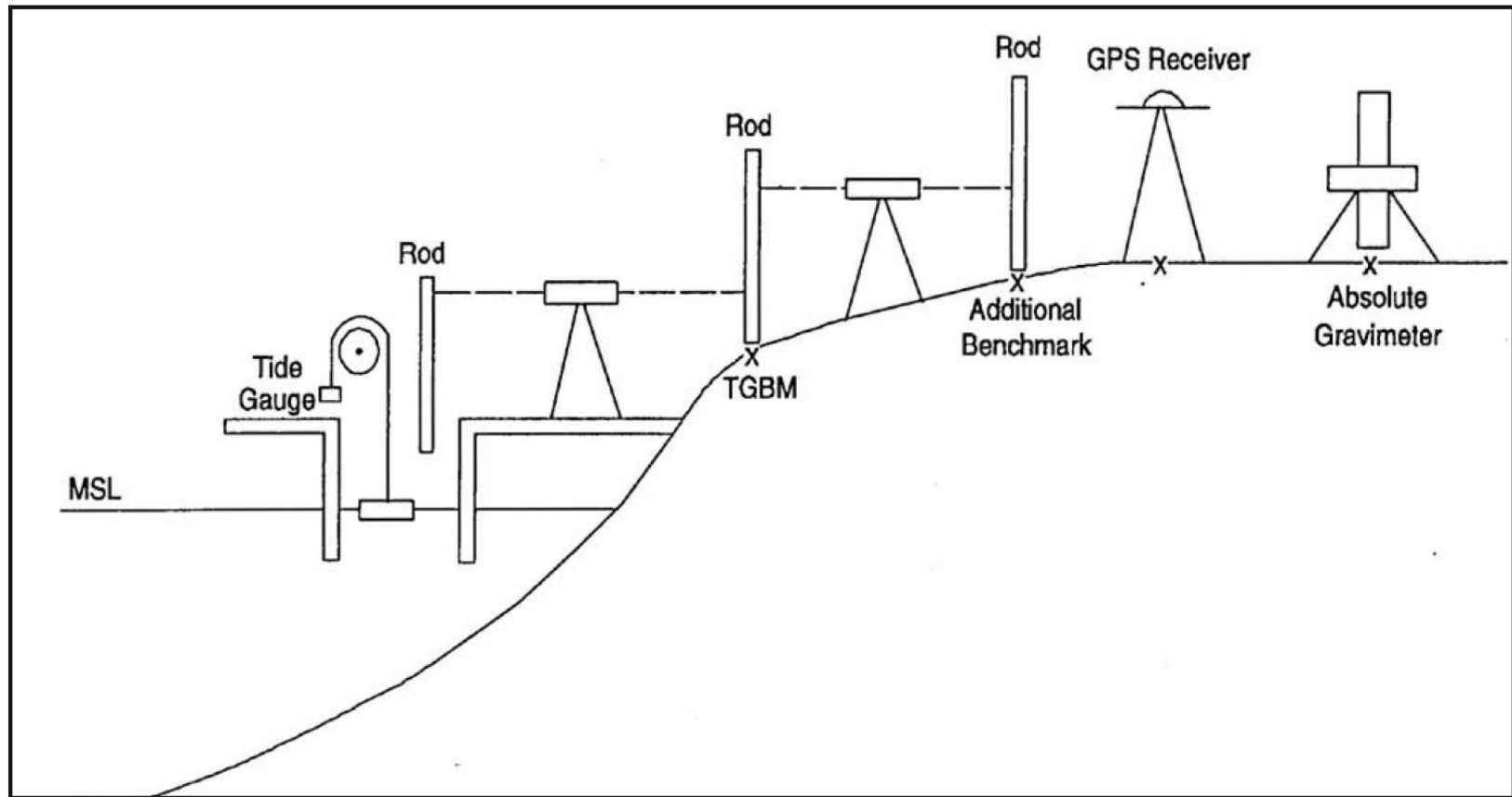


Figure 4.2 Schematic of levelling required between various benchmarks at a tide gauge station.

Source: http://www.psmsl.org/train_and_info/training/manuals/manual_14_final_21_09_06.pdf

Measurement of Water Levels in the Arctic Ocean

Water level Measurements should be integrated with GPS measurements;

- 1) To obtain relationship between ellipsoidal and tidal datum reference frames
- 2) To monitor for regional vertical land movement and vertical bench mark/sensor instability



Repeat Static GPS
on tidal bench marks



Continuous GPS Systems



Measurement of Water Levels in the Arctic Ocean

Long-term Measurements require substantial infrastructure

Qikiqtarjuaq, Canada



Continuous
GPS →

Tregde, Southern Norway



Continuous
GPS →

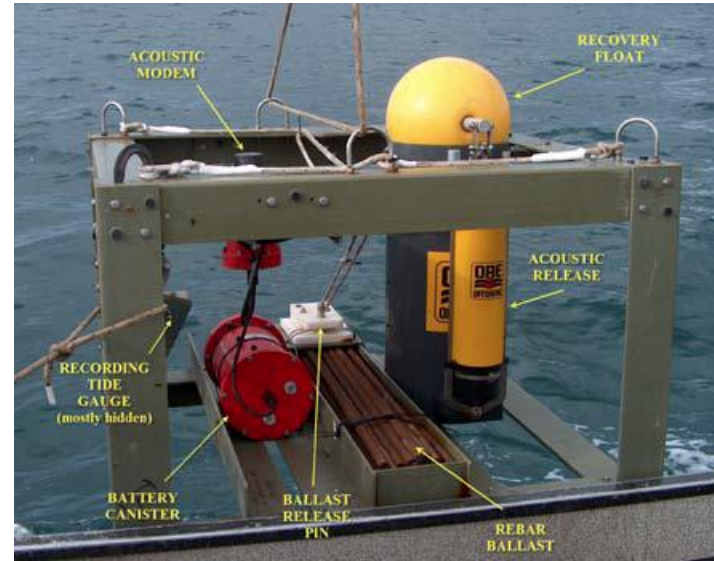
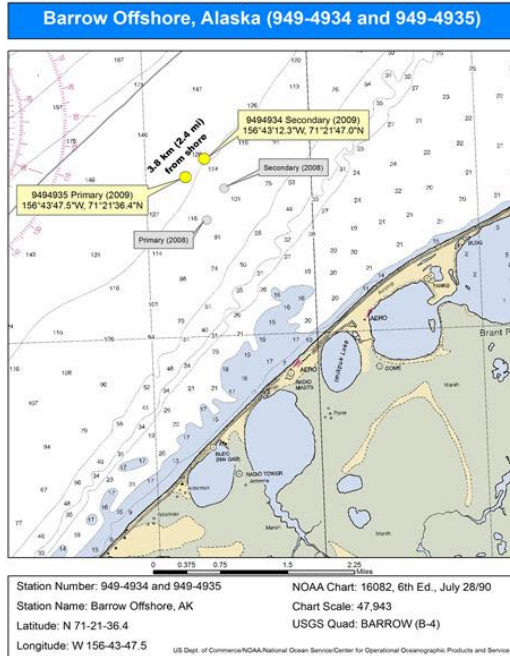
Andenes, Norway



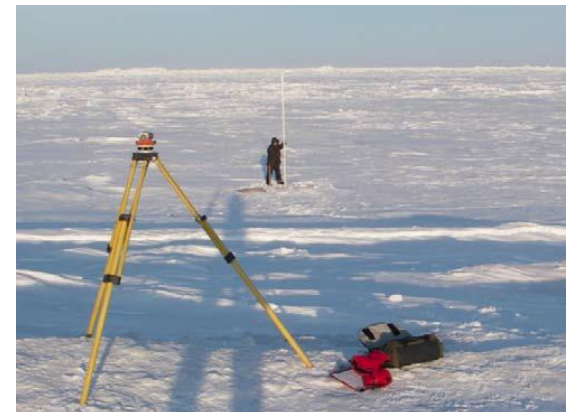
Continuous
GPS →

Measurement of Water Levels in the Arctic Ocean

Bottom-mounted Pressure Gauge Systems

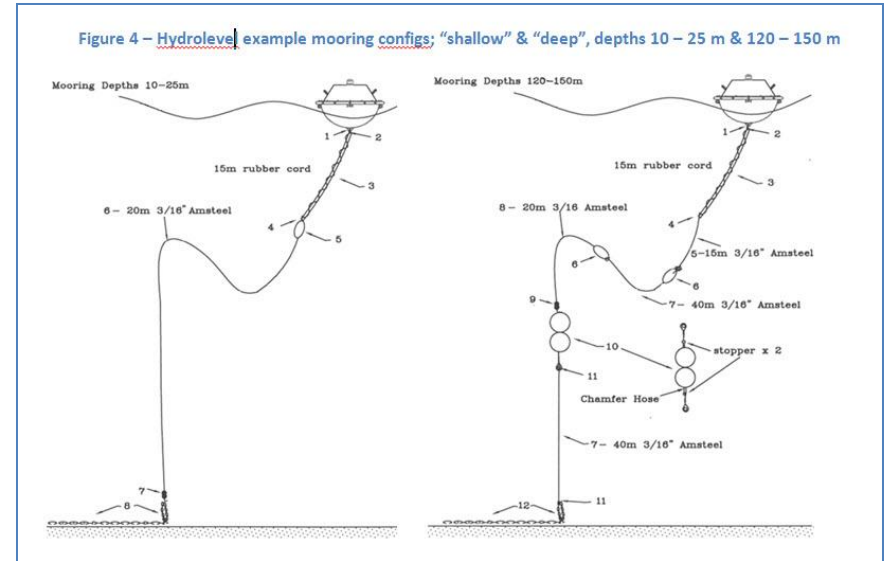
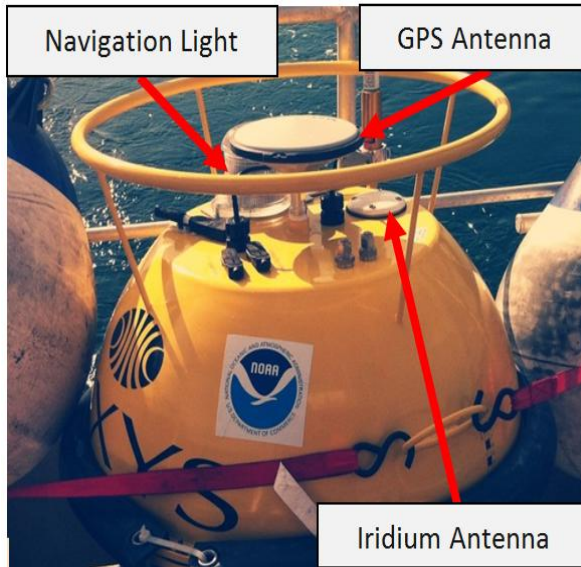


Independent Water Level Readings

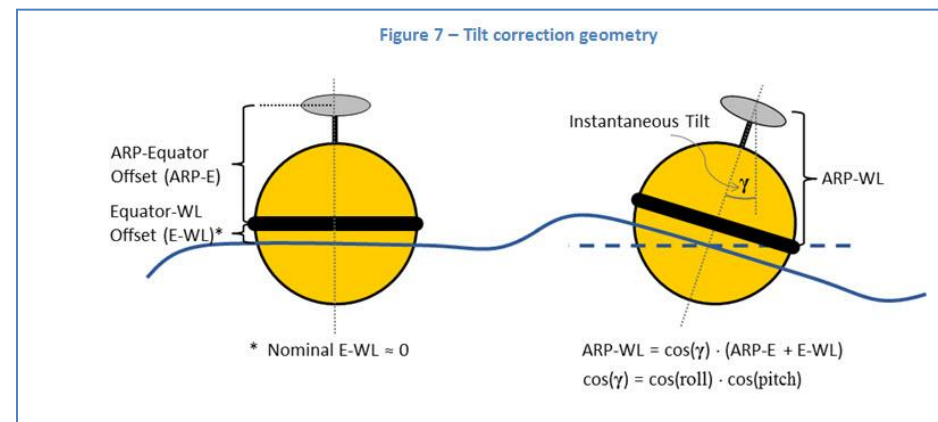
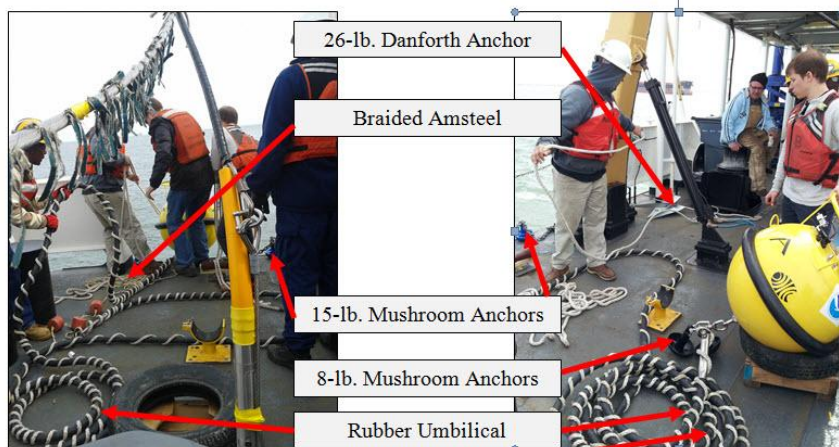


Measurement of Water Levels in the Arctic Ocean

GPS Buoy Systems



Correction for wave motion



Questions?



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