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Supplementary Information

The supplementary information is divided into three sections:
(1) *Tide model and datums*,
(2) *Vertical error calculation*, and
(3) Supplementary Figures and Tables.

The section, *Tide model and datums,* addresses how the tide model was implemented, tidal datum definitions, and comparison of tidal datums computed from the tide model data and from the method outlined in National Ocean Service (NOS) (2003).

The *Vertical error calculation* section details calculation of vertical error defined in equation 2 of the main text.

Data repository Figure 1 (Fig. DR1) contains 3 study maps: (1) a map of the regional location of Baffin Bay and tide gauges, (2) a map of the modern microbial mat survey, and (3) a map of core locations. Figure DR2 plots the observed tide data and tide model. Figures DR3 and DR4 plot the principal component analysis and correlation matrix of factors affecting upper Baffin Bay water levels respectively. Table DR1contains coordinate information for cores, core top elevations, basal microbial mat elevation data, vertical error tabulations, and microbial mat radiocarbon data. Table DR2 contains tidal datums computed from the 10-year tide model and tidal datums estimated by the method of NOS (2003).

Tide Model and Datums

Establishing the indicative range of microbial mats in upper Baffin Bay requires not only the elevation distribution of modern microbial mats (Fig. 3) but also the long-term (annual to decadal) in-situ water-level measurements capturing the yearly to decadal tidal fluctuations. In the absence of a permanent tide gauge in upper Baffin Bay we deployed a Valeport 740 tide gauge set to measure water levels every 5 minutes for 6 months (Fig. DR2A). The gauge was calibrated to the salinity and temperature of the bay water at the time of deployment on November 21, 2010. The tide gauge data were not calibrated for changes in temperature or salinity with time, as no salinity or water temperature time-series are available for upper Baffin Bay.

We implemented a model to predict upper bay water levels from a 10-year time-series of modeled astronomic tides, a tide gauge at the bay-mouth, and meteorological data. The astronomic tide was modeled for 10 years using a MATLAB® routine "Secrets of the Tide: Tide & Tidal Current Analysis" (Boon, 2004). Data from a permanent gauge at the bay-mouth of Baffin Bay provided a nearly continuous record of water level observations for the last 10 years (Fig. DR1A). Another permanent station, South Bird Island, located 20 km northeast of the bay-mouth (Fig. DR1A) recorded 10 years of meteorological data including: wind direction, wind speed, water temperature, atmospheric pressure, and air temperature.

Principal component analysis (Fig DR3) and a correlation matrix (Fig DR4) were utilized to determine which factors correlated with the upper bay tide data. Time-series that correlated most with the 6 months of upper bay tide gauge data are: the upper bay modeled astronomic tide data, lower Baffin Bay water level, water temperature, wind direction, and air pressure.

The tide model was created by a recursive technique by the following steps:

1. The initial residual was calculated between the observed upper bay tide data and predicted astronomic tide data.
2. The linear relationship between the upper bay residual calculated in step 1 and lower bay water levels was found thereby establishing Upper bay water levels as a function of lower bay water levels.
3. The linear coefficients calculated in step 2 were used to calculate an estimate of the remaining upper bay water level residuals.
4. The predictions calculated in step 3 were added to the initial astronomic model.
5. A second (and reduced) residual was calculated from subtracting the new model (now a function of astronomic tides and lower bay-water levels) from the observed upper bay tide data.
6. Steps 2 through 5 were then repeated with successive time-series (e.g. wind direction) reducing the residual between the "new" models and observed upper bay tide data.
7.

Using the above technique, upper bay water levels as a function of predicted astronomic tides, lower bay water levels, water temperature, wind direction, and air pressure were found and have an R^2 fit of 0.66 with the observed upper bay water-level data (Fig. DR2A). With the upper bay water level as a function of these time-series we modeled the upper bay-water level for 10 years (Fig. DR2B) and calculated yearly mean tidal datums.

NOS (2003) provides a method of estimating long-term tidal datums by tying short-term tidal records to nearby longer-term tide records. Tidal datums termed herein as NOS estimated tidal datums were computed from tying the 6-month upper bay tide gauge record to the 10-year lower bay tide gauge record. NOS estimated tidal datums and tidal datums computed from the 10-year tide model are within 0.00 m to 0.07 m (Table DR2). We interpret this close agreement between tidal datums to support the validity of tide model. For definition and calculation methods for tidal datums the reader is referred to NOS 2001 and 2003.

Vertical Error Calculation

The vertical range (VR) to paleo mean sea level for each buried microbial mat sample is calculated by:

$$VR = E_m \pm (\delta + VE) \quad (1)$$
$$VE = [e_1^2 + e_2^2 + e_n^2]^{0.5} \quad (2)$$

E_m is the elevation of a buried microbial mat derived from the core tope elevation minus the midpoint depth of the buried microbial mat sample thickness. E_m is taken as the midpoint of a buried microbial mat sample thickness because microbial mats found in upper Baffin Bay vary in thickness from 2 mm to ~ 5 cm and exhibit wavy lamination (Fig 2A). δ is the indicative range of the microbial mats and VE is vertical error from additional sources of e_i errors. The upper vertical range (VR+) and lower vertical range (VR-) are computed by:

$$VR+ = E_m + (\delta*0.5 + VE+) \quad (3)$$
$$VE+ = [(D^2 + (0.5*L)^2 + T^2 + Ac^2)]^{0.5} \quad (4)$$
$$VR- = E_m + (\delta*0.5 + VE-) \quad (5)$$
$$VE- = [(D^2 + (0.5*L)^2 + T^2)]^{0.5} \quad (6)$$

Where VE+ is the upper vertical error and VE- is the lower vertical error. D is the error from the differential GPS survey. L is the loss or compaction of sediment during coring. L is the difference between core penetration and core recovery. L may be from loss of sediment from the core barrel or additional compaction during core recovery. T is the buried microbial mat sample thickness. Ac is error from non-normal coring.

The differential GPS observations were collected using a Topcon Hiper® Lite GPS composed of a fixed GPS base station and GPS rover. D, error from the differential GPS survey, and the vertical precision of the modern microbial mat survey includes base station elevation error and error from the observation between the base station and rover (henceforth referred to as base to rover error). Each GPS base station was deployed between 4 and 8 hours. Base station elevations and elevation error were calculated from base station observations using the Online Positioning User Service (OPUS) provided by the National Geodetic Survey. Base to rover errors were computed using Topcon Tools® software.

The absolute depth of the microbial mat down-core will be underestimated if the core barrel is non-normal to the sea floor. An estimate of Ac is computed from:

$$Ac = \sin(\Theta)*SD \quad (7)$$

Where Θ is the angle of coring in degrees from normal (a maximum of 15° in this study) and SD is the down-core sample depth. Ac is only included in VE+ because these errors will only act to decrease sample elevation. All vertical error calculations may be found in Table DR1.

References

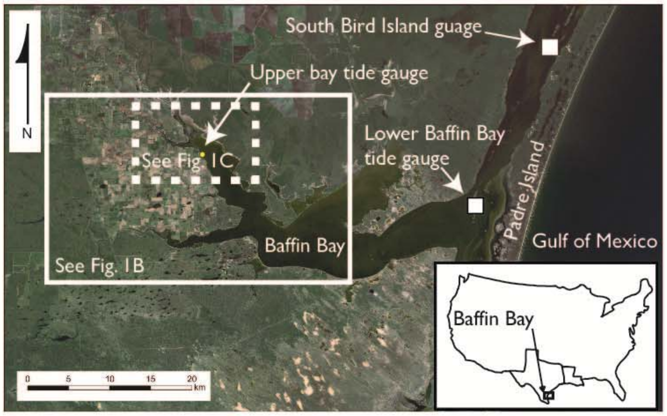
Boon, J.D., 2004, Secrets of the Tide: Tide and Tidal Current analysis and Predictions, Storm surges and Sea Level Trends: Horwood Publishing, Chichester, U.K. 212 pp.

NOS, National Ocean Service, 2003, Computational Techniques for tidal datums handbook: NOAA Technical Report NOS COOPS, no. 2

NOS, National Ocean Service, 2000, Tide and Current Glossary: Center For Operational Oceanographic Products and Services.

Trauth, M., 2010, Matlab recipes for the Earth sciences: New York, Springer-Verlag Berlin Heidelbeg, 336 p.

a



b c

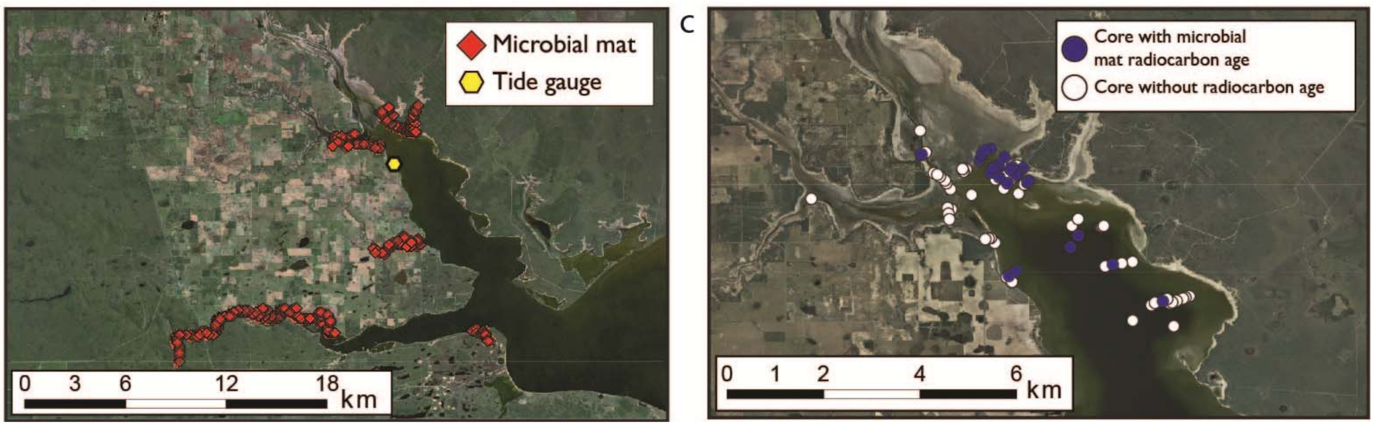


Figure DR1 | Study area maps. **a,** Regional location of Baffin Bay with locations of tide and meteorologic gauges from which time-series were derived for the tide model. **b,** Map of modern microbial mat survey with location of upper bay tide gauge and diagram of survey method. Microbial mats were surveyed during March 2008. **c,** Map of 101 shallow marine cores taken to sample buried microbial mats. Microbial mats were sampled from 23 of the 101 cores.

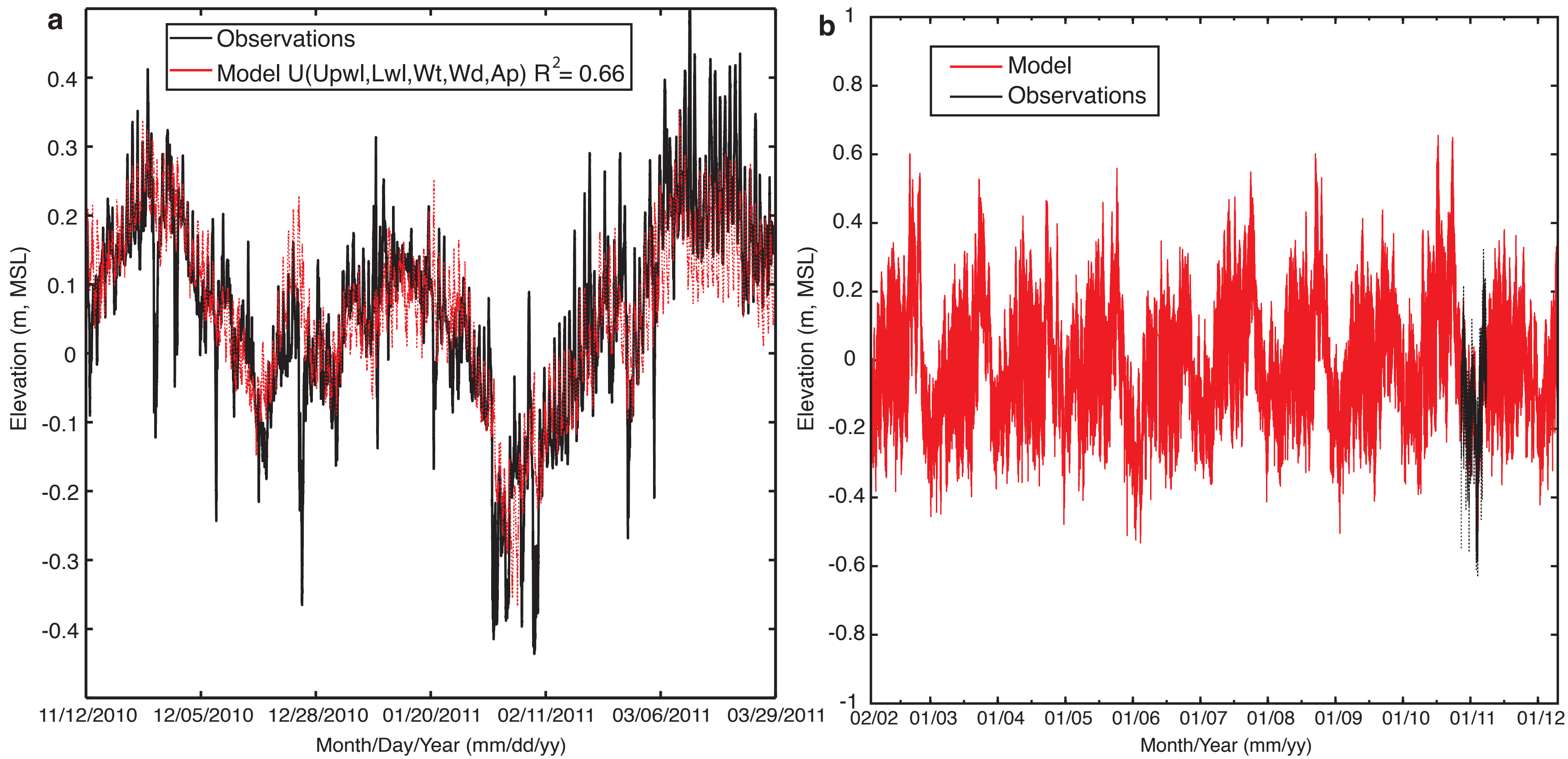


Figure DR2 | Tide data and model. a, Comparison of 6 months of upper bay tide gauge data and the tide model. The tide model is a function of modeled astronomic tide (Upwl), lower bay water level (Lwl), water temperature (Wt), wind direction (Wd), and barometric pressure (AP). Note model fit with R^2 of 0.66. **b,** 10 year projection of tide model from **a** and 6 months of upper bay tide gauge data.

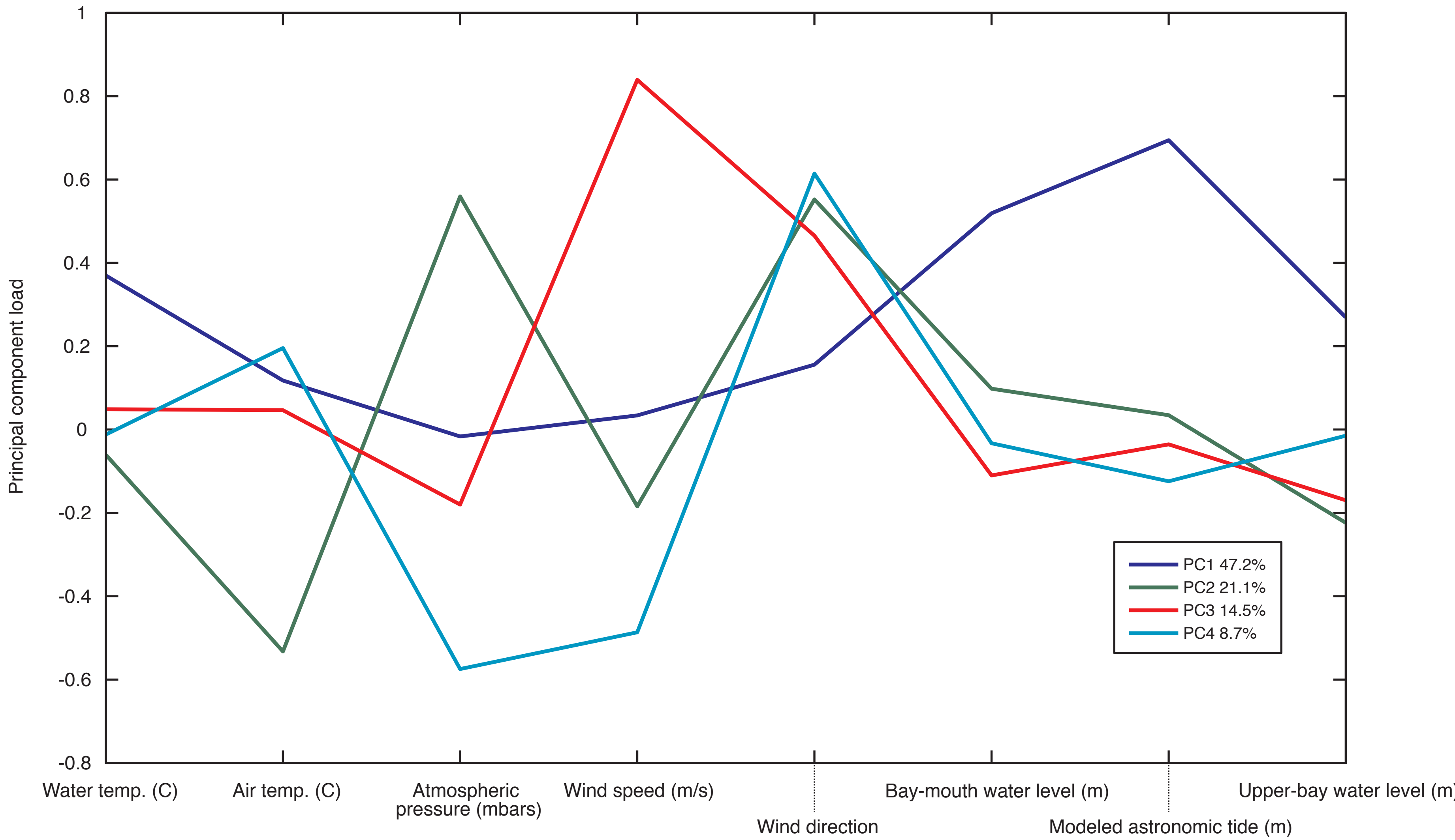


Figure DR3 | Factors affecting upper Baffin Bay water level. Principal component (PC) loadings of 6 months of meteorological and modeled astronomical time-series data that affect upper Baffin Bay water levels. Percentages of each nth PC indicates percent of data variance described by nth PC. First four PC plotted describe 91.5% of data variance Loadings indicate amount that given variable contributes to nth PC. Note predicted astronomic tides and bay-mouth water levels exhibit the greatest loadings in PC1 that explains 47% of data variance. Wind direction has the greatest loadings of PC2 that explains 21% of data variance. Wind speed only has the greatest loadings in PC3 that only explains 14.5% of data variance. Therefore astronomic tidal forcing is interpreted to have the strongest influence on upper-bay water levels followed by wind direction having moderate influence, and wind speed having the least influence upon upper-bay water levels. All time-series data, except for the upper-bay water levels and modeled astronomic tides, obtained from the Division of Nearshore Research, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi. See Trauth (2010) for further description of principal component analysis. Astronomic tides were modeled from the 6 months of upper bay tide gauge data using the MATLAB® routine` "Secrets of the Tide: Tide & Tidal Current Analysis" 2 available at http://www.mathworks.com/matlabcentral/fileexchange/

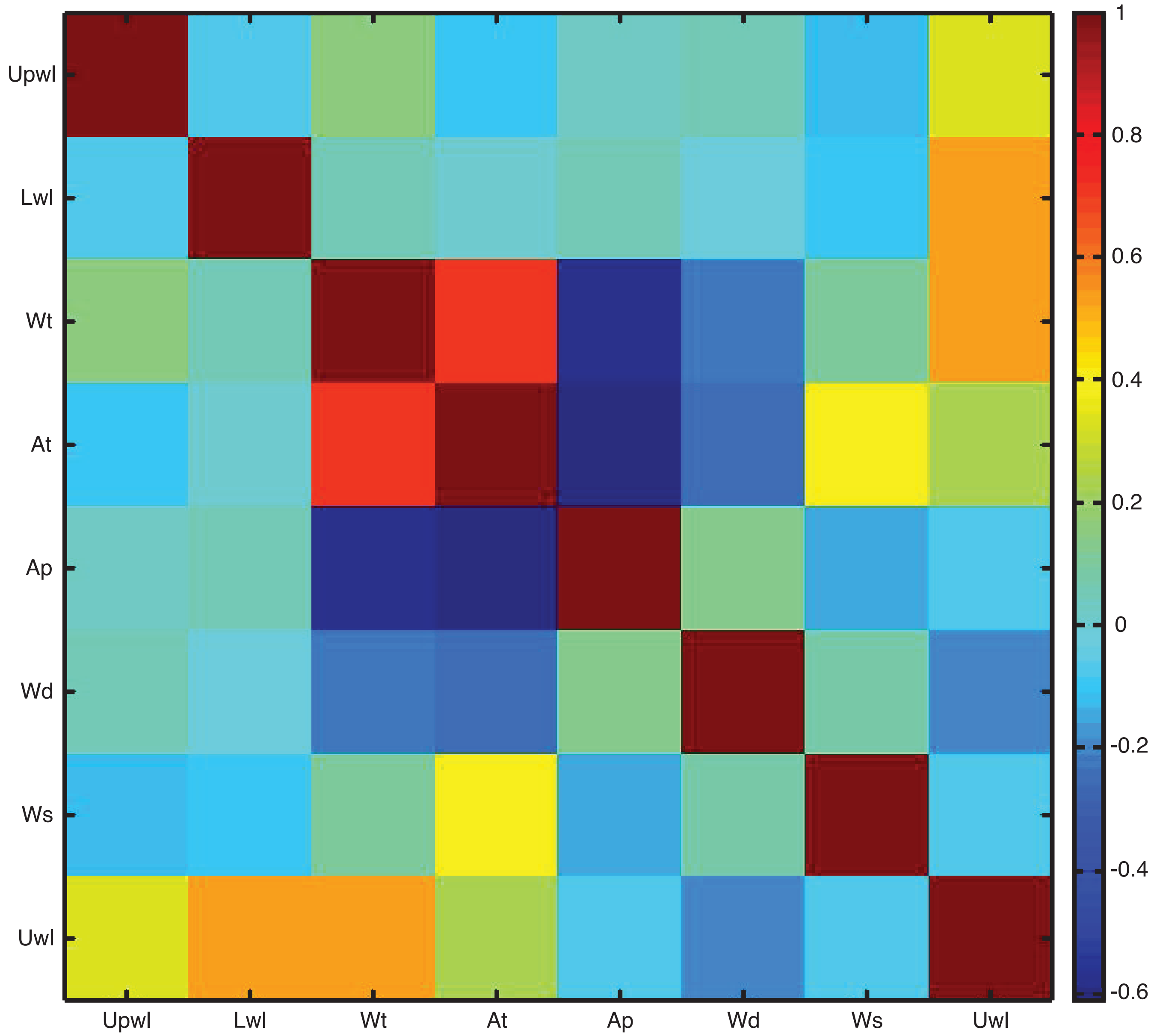


Figure DR4 | Correlation analysis. Correlation matrix of meteorologic and modeled astronomic tide time-series data that affect upper Baffin Bay water levels. Abbreviations are as follow: upper bay modeled astronomic tide (Upwl), lower bay water level (Lwl), water temperature (Wt), air temperature (At), barometric pressure (Ap), wind direction (Wd), wind speed (Ws), and 6 months upper bay water-level data (Uwl). A correlation coefficient of 1 indicates a given variable is positively correlated with another variable. Conversely a correlation coefficient of -1 indicates a given variable is inversely correlated with another variable. A correlation coefficient near 0 indicates that two variables are not related. Note that lower bay water level, water temperature, and upper bay modeled astronomic tide have the greatest positive correlation with upper bay water-level data while wind speed exhibits a correlation coefficient of ca. 0. Wind direction exhibits an inverse correlation with upper-bay water levels. This is expected as greater azimuths would indicate more northerly winds forcing water from Baffin Bay and decreasing upper-bay water levels. All time-series data, except for the observed upper-bay water levels and modeled astronomic tide, obtained from the Division of Nearshore Research, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi. See Trauth (2010) for further description of correlation coefficient calculations. Astronomic tides were modeled from the 6 months of upper bay tide gauge data using the MATLAB® routine` "Secrets of the Tide: Tide & Tidal Current Analysis"[2] available for free at http://www.mathworks.com/matlab-central/fileexchange/

Table DR1 | Buried microbial mat elevation, error, and age data

Sample ID	Latitude (WGS84)	Longitude (WGS84)	Sample elevation (m) (NAVD88)[a]	Sample elevation (m) (MSL)[b]	Positive range (VE+)[c] to mean sea level (m)	Negative range (VR-)[c] to mean sea level (m)	Error of DGPS survey (m) (D)[c]	Loss (m) (L)[c]	Non-normal coring (m) (Ac)[c]	Depth between sample and incompressible substrate[d] (m)	Sample type[e]	Total Holocene thickness (m)	14C age[f]	Age Error (+/-)[f]	d13C[f]	Radiocarbon reservoir[g]	Calibrated median age (yr BP)[h]	2 sigma calibrated younger age (yr BP)[h]	2 sigma calibrated older age (yr BP)[h]
AM 11_02 16 cm	27.38379662	-97.70358933	-0.32	-0.51	0.31	0.31	0.11	0.04	0.01	0.07	Basal	0.23	475	35	-12.09	200 +/- 100	183	-4	306
AM 10_08 19 cm	27.38368207	-97.70394876	-0.44	-0.64	0.32	0.32	0.13	0.00	0.01	0.54	Intercalated	0.73	535	45	-12.94	200 +/- 100	276	-2	452
AM10_07 24 cm	27.38341136	-97.704254	-0.54	-0.73	0.30	0.30	0.07	0.00	0.01	0.26	Intercalated	0.50	545	30	-12.64	200 +/- 100	294	-2	460
AM 11_13 34 cm	27.38140136	-97.70388363	-0.71	-0.90	0.31	0.31	0.10	0.09	0.01	0.97	Intercalated	1.31	1260	25	-10.84	200 +/- 100	880	740	989
AM10_18 53 cm	27.38005979	-97.69921733	-0.79	-0.99	0.40	0.40	0.09	0.51	0.02	1.13	Intercalated	1.66	1400	20	-11.38	200 +/- 100	1031	929	1167
AM 11_17 51 cm	27.38191057	-97.70077018	-0.77	-0.97	0.31	0.31	0.10	0.13	0.02	0.44	Intercalated	0.95	1470	30	-11.74	200 +/- 100	1111	973	1250
AM 11_09 34 cm	27.38280741	-97.70177771	-0.52	-0.71	0.38	0.38	0.11	0.43	0.01	0.11	Intercalated	0.85	1490	25	-12.42	200 +/- 100	1133	994	1263
AM 11_16 58 cm	27.38217779	-97.70051086	-0.81	-1.00	0.31	0.31	0.10	0.00	0.02	0.30	Intercalated	0.88	1540	30	-12.03	200 +/- 100	1187	1056	1291
AM 11_17 27 cm	27.38191057	-97.70077018	-0.53	-0.73	0.31	0.31	0.10	0.13	0.01	0.68	Intercalated	0.95	1540	65	-11.7	200 +/- 100	1178	984	1308
AM 11_18 57 cm	27.38166979	-97.70100939	-0.91	-1.10	0.31	0.31	0.10	0.08	0.02	0.56	Intercalated	1.13	1550	25	-11.45	200 +/- 100	1198	1066	1290
AM 11_15 47cm	27.38249194	-97.70032802	-0.67	-0.86	0.31	0.31	0.10	0.00	0.02	0.02	Basal of basal	0.60	1560	25	-9.67	200 +/- 100	1206	1071	1294
AM 10_19 47 cm	27.38057581	-97.69852154	-0.77	-0.96	0.31	0.30	0.09	0.00	0.02	0.88	Intercalated	1.35	1580	25	-11.32	200 +/- 100	1223	1081	1307
AM10_06 43 cm	27.38220864	-97.70545809	-0.82	-1.01	0.30	0.30	0.07	0.08	0.01	*	Intercalated	*	1600	40	-12.23	200 +/- 100	1238	1084	1344
AM 11_10 60 cm	27.3824268	-97.70228659	-0.87	-1.06	0.31	0.31	0.10	0.11	0.02	0.34	Basal	1.24	1760	25	-13.2	200 +/- 100	1379	1292	1510
AM10_16 58 cm	27.38073835	-97.69831212	-0.83	-1.03	0.30	0.30	0.07	0.05	0.02	* 0.82	Intercalated	1.40	1950	25	-11.27	200 +/- 100	1588	1421	1712
AM 10_18 141 cm	27.38166979	-97.70100939	-1.67	-1.87	0.40	0.40	0.09	0.51	0.05	0.07	Intercalated	1.66	2550	30	-14.13	200 +/- 100	2290	2139	2446
AM 11_20 118 cm	27.38090265	-97.70181003	-1.67	-1.87	0.32	0.31	0.11	0.10	0.04	0.09	Intercalated	1.29	2600	35	-12.58	200 +/- 100	2364	2155	2660
AM10_17 138 cm	27.38041998	-97.69867697	-1.72	-1.92	0.32	0.32	0.07	0.20	0.05	0.02	Basal of basal	1.47	2630	30	-11.72	200 +/- 100	2411	2210	2683
AM10_33 116 cm	27.36430937	-97.70095848	-2.16	-2.36	0.35	0.35	0.13	0.30	0.04	0.75	Intercalated	2.24	2730	40	-12.21	200 +/- 100	2542	2357	2708
AM10_52 267 cm	27.36554734	-97.68294962	-4.95	-5.14	0.38	0.37	0.21	0.15	0.09	0.26	Basal	2.93	4500	30	-13.55	200 +/- 100	4763	4573	4907
AM 09_05_16' 62 cm	27.36844908	-97.69060991	-4.55	-4.75	0.36	0.31	0.08	0.15	0.19	*	Intercalated	*	4540	30	-14.87	200 +/- 100	4836	4626	4976
AM10_20_20' 15 cm	27.37057193	-97.68915562	-5.35	-5.55	0.39	0.32	0.11	0.16	0.21	0.63	Intercalated	6.58	4700	30	-12.92	200 +/- 100	5037	4868	5259

a Reference datum: North American Vertical Datum 88 (NAVD88) calculated using the Geoid03 model

b Elevation plotted in figure 4 of paper; sample elevation below modern yearly mean sea level (MSL) calculated from 10 year tide model *

c See the "*Vertical error calculations*" section of supplemental information for further explanation of VR+,VR-, D, L, and Ac

d Thickness of sediment between sample and incompressible substrate below. Incompressible substrate is taken as either the compacted Pleistocene sediments or the relatively incompressible sands[g] overlying the Pleistocene sediments.

e See main text for explanation of sample type

f The 14C dates of buried microbial mat samples were measured by accelerator mass spectrometry (AMS) at the National Ocean Sciences AMS facility (NOSAMS), Woods Hole Oceanographic Institution, MA

g See the "*Sampling and radiocarbon dating*" section of supplemental information for details on radiocarbon reservoir

h Ages calibrated using the mixed marine/northern hemisphere terrestrial curve of CALIB 6.0 (Reimer et al., 2009)

* Pleistocene was not encountered in core; Holocene thickness is unknown

Table DR2 I Tidal datums derived from tieing 6-month upper bay tide gauge record to 10-year lower bay tide gauge record and tidal datums derived from 10-year upper bay tide model.

Tidal datum[a]	**Datums calculated after method of NOS[b] (UBT)**	**Datums calculated from 10 year upper bay tide model[b] (UBM)**	**Difference between tide datums (UBT - UBM)**
Highest astronomical tide (HAT)	*	0.66	*
Mean high water spring (MHWS)	*	0.28	*
Mean high water neap (MHWN)	*	0.08	*
Mean higher high water level (MHWL)	0.06	0.13	-0.07
Mean high water (MHW)	0.01	0.01	0.00
Diurnal tide level (DTL)	-0.04	-0.01	-0.03
Mean tide level (MTL)	-0.06	-0.02	-0.04
Mean sea level (MSL)	*	0.00	*
Mean low water (MLW)	-0.09	-0.05	-0.04
Mean lower low water (MLLW)	-0.14	-0.16	0.02
Mean low water neap (MLWN)	*	-0.10	*
Mean low water spring (MLWS)	*	-0.30	*
Lowest astronomical tide (LAT)	*	-0.54	*
Great diurnal range (GT) GT = MHHW - MLLW	0.20	0.29	-0.09
Mean tidal range (Mn) Mn = MHW - MLW	0.10	0.06	0.04
Mean spring tidal range (MSTR)	*	0.58	*

a See NOS (2000) for tidal datum definitions. All elevations reference to yearly MSL calculated from 10-year upper bay tide model. MSL is 0.195 m from NAVD88

b 10-year upper bay tidal datums estimated from extrapolating 6-month upper bay tide gauge record to 10 year lower bay tide gauge record. Method for estimating tidal datums from short-term tide gauges from NOS (2003).

c 10 year upper bay tidal datums calculated from upper bay tide model implemented in this study. Datums calculated from upper bay tide model reference herein as upper bay modeled (UBM) datums.

* Indicates where NOS (2003) did not provide method for extrapolating long-term tide datum from short-term tide gauge record.