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OBSERVATIONS OF SEDIMENT DYNAMICS AT DISKEN

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Physical oceanography measurements

Introduction

The sandbank Disken in the Sound, SE of Elsinore (for location see Figure 1), was investigated in 2017 in order to assess the importance of sand extraction for the biology of the sandbank (Rambøll, 2018). The investigations in 2017 included both the Danish and Swedish parts of the sandbank, and they were a follow-up on a biological assessment of the Danish part of the sandbank in 2014 (Orbicon, 2014).

As part of the investigations in 2017, the morphology and surface sediment characteristics of the sandbank was also investigated in order to assess the regeneration of the seabed morphology and surface sediment characteristics in the extraction area, based on multibeam surveys and seabed sampling campaigns conducted in 2014 and 2017 (Hansen and Ernstsen, 2018). A geomorphometric analysis of the Digital Elevation Models (DEMs) of the sandbank enabled an overall geomorphological map of the sandbank as well as the detection and delineation of stationary and trailing suction dredging marks and dynamic bedforms. Based on an analysis of the DEMs and the DEM of Difference (DoD) for the period 2014-2017, the net sediment transport related to bedform migration was estimated to ~2 m³/year (Hansen and Ernstsen, 2018, and also presented in Rambøll, 2018). However, the questions emerging from these investigations were how often is the seabed mobilised, and at which conditions is it mobilised?

Measurements of waves, currents, water temperature, salinity and suspended sediment concentration as well as bedforms and seabed dynamics were conducted at the sandbank Disken in the Sound (Øresund) SE of Elsinore during the period 10/9 – 18/10 2018 (Figure 1). The measurements were also used to estimate bed shear stress and hence the physical impact on the seabed in the test area. Specific research questions included the following:

- What are the wave and current conditions capable of mobilizing sediment (sand) from the seabed at Disken?
- What is the critical bed shear stress for mobilization of the bed sediment?
- Is bed mobility specifically associated with inflow (southerly currents) or outflow (northerly currents) situations?
- What is the annual frequency of bed mobilization?
- What is the magnitude of bed mobility/bedform dimensions at the field site?
Figure 1. a) Location of the sandbank Disken in the Sound, SE of Elsinore. The overall bathymetry is visualized with a grid cell size of 120 m (bathymetry data is from the EMODnet Bathymetry-portal, http://www.emodnet.eu/bathymetry). b) Location of the instrumental platform (star) on the sandbank Disken. The detailed bathymetry is visualized with a grid cell size of 1 m (the bathymetry data was collected in relation to the studies by Rambøll, 2018 / Hansen and Ernstsen, 2018). c) Zoom-in of the bathymetry in the vicinity of the instrument platform. The dotted line shows the border between Denmark and Sweden. The projection is ETRS89 / UTM zone 32N.
Methods

Instrumentation

An instrument platform was installed with a Sontek Ocean Hydra Acoustic Doppler Velocity Meter (ADVO, serial number B488) fitted with a pressure sensor for wave- and water depth measurements as well as two OBS-3+ sediment suspension sensors. Further sensors on the platform included an Imagenex 881A Imaging sonar (fanbeam) and an Imagenex 881A Profiling sonar (pencilbeam) for assessing bedform dimensions and seabed dynamics, an RDI Acoustic Doppler Current Profiler (ADCP) for measuring vertical profiles of flow velocity components and backscattered intensity, a TCM tilt-current meter and an Aanderaa current meter intended for measurement of salinity.

![Figure 2. Installation and deployment of the instrument platform.](image)

The platform was deployed at a mean depth of approximately 15 m on the northeastern flank of Disken (position I: UTM E727596 N6213500) where the median grain size of the bed sediment D50 = 0.22 mm. There was no admixture of silt- or clay-sized particles. The nominal elevation of the current meter sensor head was 62 cm above the seabed, corresponding to a measurement volume centered at 44 cm above the bed, but due to settling upon installation velocities were measured at 32 cm above the bed. The two OBS-sensors were mounted at nominal elevations of 10 and 20 cm above the bed. The settling caused the lower OBS to become located within the bed for much of the measurement campaign. All sensors returned good data for the deployment period, except for the Aanderaa, which unfortunately failed. The ADV recorded data at 8 Hz for periods of 15 minutes once per hour.
The ADCP was mounted on the platform at 2 m above the bed in upward-looking mode. Data were recorded in burst mode with data recording every full hour at 1 Hz for a duration of 5 minutes. The data were collected with a vertical resolution, i.e. bin size, of 0.25 m and a total range of 12 m, i.e. 2-14 m above the bed. Hence, 48 bins were recorded per ensemble and 14,400 bins per burst. The fanbeam was mounted on the SE leg of the platform at 0.5 m above the bed in sidescan mode. Scans were recorded in burst mode with recording of four full 360° scans every full hour. At every full hour, three scans were collected with a range of 5 m in 0.3° steps, i.e. slow step size mode for high spatial resolution, with an operating frequency of 675 kHz; in addition, one scan was recorded with almost similar settings, albeit with an operating frequency of 1 MHz in order to test the performance of a very high operating frequency. The 1 MHz scans were, however, omitted in the further processing. The pencilbeam sonar scanned a 2½ m transect along the platform axis and a seabed profile was constructed once per hour by averaging 6 individual sonar scans.

A second, smaller platform, holding a Sontek Hydra ADV (B489) was deployed at position II on the southeastern margin of Disken (UTM E727222 N6210160). This sensor failed, unfortunately, since the endcap on the communications plug was removed by persons unknown during the deployment. This resulted in drainage of the internal batteries and data loss.

Data processing

The velocity records from the ADVO were quality controlled and de-spiked in order to remove noise. Quality control followed the guidelines suggested by Elgar et al. (2005), using a threshold velocity signal-to-noise ratio of 20 and a signal correlation threshold given by:

\[ 0.3 + 0.4 \frac{sf}{25} \]

where \( sf \) is the sampling frequency. Record spikes were identified using the phase-space method (Mori et al., 2007; Ruessink, 2010) and subsequently replaced with filtered values using a 1 Hz low-pass box filter on the de-spiked time series. Orbital velocity (\( u_o \)) was calculated from \( u_o = 2\sigma_u \) where \( \sigma_u \) is the standard deviation of the vector-added horizontal velocity time series, and resultant mean current speeds (\( U \)) were determined from vector addition of N-S and E-W mean current speeds.

The bed shear stress due to waves was calculated as
\[ \tau_w = \frac{1}{2} \rho f_w u^2 \]

where \( \rho \) is the density of the water and the friction factor \( f_w \) is calculated from Nielsen (1992) using a bed roughness of 2.5D50. The bed shear stress due to mean currents was calculated as

\[ \tau_c = \rho c_D U^2 \]

where the drag coefficient \( c_D = 0.0026 \) was taken from tabulated values in Soulsby (1997). The total stress (waves plus current, \( \tau_{wc} \)) was determined using the approach in Soulsby (1997). In the absence of salinity measurements due to instrument failure, the salinity was calculated from the Mackenzie (1981) 9-term equation using measurements of speed of sound, temperature and pressure. The OBS-sensors were calibrated in a recirculating wave tank using sand from the field deployment site and sediment concentration in the water column was also determined from the acoustic backscatter measured by the ADVO using the approach of Moate & Thorne (2012) and Aagaard (2014).

The vertical distributions of horizontal flow velocity direction and magnitude were calculated from beams 1 and 3 of the ADCP. Hourly burst averages were calculated; and subsequently, a moving average of three burst averages was applied in order to optimize the signal to noise ratio, and at the same time retaining the tidal signal in the data. Depth-averaged flow velocity magnitude was calculated below 3 m, i.e. 2-5 m above the bed, in order to estimate the near bed flow velocities and for comparison with the flow velocities measured near the bed by the ADVs. The vertical distribution of backscattered intensity was calculated from beam 3 of the ADCP. Hourly burst averages were calculated; and subsequently, a moving average of three burst averages was applied as in case of flow velocity direction and magnitude. Likewise, depth-averaged backscattered intensity was calculated below 3 m, i.e. 2-5 m above the bed, in order to relate the depth-averaged backscattered intensity to the depth averaged flow velocity magnitude 2-5 m above the bed. The processing of the ADCP data was performed using the compiled MATLAB software mADCP (cf. Becker et al., 2013).

Bedform geometry was determined using the pencilbeam sonar scans of the seabed. Bedform heights \( (\eta_r) \) were estimated from \( \eta_r = 2\sqrt{2}\sigma_r \) where \( \sigma_r \) is the standard deviation of the bed elevation (Hay, 2011) and bedform wavelengths \( (\lambda_r) \) were estimated from peaks in the auto-correlation function of the individual bed profiles.
Seabed dynamics in the vicinity of the instrument platform, i.e. in a circular area with a radius of 5 m, was assessed using the fanbeam scans of the seabed. The single scans can be considered as more or less instantaneous “sound-images” of the seabed. The scans show the acoustic backscatter from the seabed. In general, a hard substrate has higher acoustic backscatter than a soft substrate, and a more exposed surface has higher acoustic backscatter than a more sheltered surface. Assuming that the bed material is relatively uniform in the vicinity of the instrument platform, spatial variations in acoustic backscatter indicate morphological features; and hence, any temporal variations in the spatial distribution of acoustic backscatter indicate morphological changes and thereby mobilization and transport of bed material, i.e. seabed dynamics.

For each full hour, an average scan was calculated from the three hourly single scans in order to increase the signal to noise ratio, producing the most robust scan for further analysis. Subsequently, an average scan was calculated for each day based on the 24 hourly average scans, yielding robust daily average scans for assessing temporal variations in the spatial distribution of acoustic backscatter. All processing of the fanbeam scans, including conversion of data formats, was carried out using MATLAB and the compiled MATLAB software IView (cf. Kopiske, 2014). Temporal variations in the spatial distribution of acoustic backscatter were determined by calculating daily difference-scans between two successive daily average scans, i.e. calculating the backscatter Rate of Change (ROC). Subsequently, the mean backscatter ROC was calculated for each daily difference-scan by calculating the mean value of the numerical differences. Hereby, the mean backscatter ROC can be visualized as a time series record.

**Results**

**Time series records**

Figure 3 shows the ADVO-measurements of near-bed currents and wave orbital velocities during the deployment period from September 10-October 18. The period was dominated by two intense events both leading to mean current speeds of the order of 70 cm/s near the seabed, and both were characterized by negative N-S flows, i.e. inflow situations where higher density water is pushed from the Kattegat into the Sound. The first event (A) occurred on September 21-22 (hours 280-305) when the storm ‘Knud’ passed through the area. Winds were westerly but not particularly strong in the Sound region (19-20 m/s). The second event (B) was associated with a severe NW gale occurring
on October 2-3 (hours 535-555) where wind speed was up to 22-23 m/s. Further significant events occurred near hours 400-420 (westerly winds, up to 19 m/s at Drogden on September 26) and a brief wave event during hours 643-647 with winds directly from the north. All these identified events were associated with near-bed orbital velocities (15-16 m mean water depth) in excess of 20 cm/s. Averaged over the record length the N-S current had a mean of −0.6 cm/s, indicating near-bed inflow.
Figure 3. Near-bed mean currents and wave orbital velocities during the deployment at Disken. The upper panel shows E-W directed current speeds (red line) and N-S directed currents (blue line). Positive current speeds are directed towards the east and north. The black line shows the resultant current magnitude. The middle panel shows the direction of the mean current and the lower panel plots wave orbital velocity. The event labelled A is the storm Knud on September 21-22, and event B is the NW gale on October 2-3.

Figure 4. Near-bed water temperature (T), salinity (S) and resultant current speed (U) over the period of measurement.

Temperature and salinity in the bed layer are shown in Figure 4. For the first 10-11 days of the deployment, temperature and salinity fluctuated in response to weak in/outflows but the Knud storm (near hour 300) brought in warmer water from the Kattegat. Conditions stabilized thereafter, indicating a more laterally mixed water mass. The mean temperature was 13.7°C over the deployment period and the mean salinity was 15 ppm.
Bed shear stresses were generally dominated by the mean current component (Figure 5), which would be expected because of significant wave attenuation at the water depths at which the measurements took place. However, the strong gale around hour 535-555 caused a considerable contribution from waves which were estimated to have reached a significant height of $H_s = 1.65$ m with periods of $T = 5.6$ s during this gale. Suspended sediment concentrations were mostly very small, or negligible, but increased dramatically during high-energy events. As is evident from the plots, suspension events were aligned precisely with periods of large bed shear stresses which indicates that sediment was suspended locally and advection of fine-grained sediment from distant sources was negligible.

Figure 6 illustrates a plot of the non-dimensional bed shear stress (the Shields parameter), calculated as

$$\theta = \frac{\tau_{wc}}{(p_s - \rho)gD50}$$

where $\rho_s$ is the sediment density and $g$ is the acceleration of gravity. Experimental evidence has shown that the critical threshold for sediment mobilization is $\theta_c = 0.045-0.05$ (e.g. Nielsen, 1992) and $\theta = 0.05$ has been plotted with the dotted blue line in the left plot. Following the definition of
ecological disturbance proposed by Pickett & White (1985) as ‘any discrete (natural) event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability, or the physical environment’, Harris & Hughes (2012) proposed a threshold for ecological disturbance of the seabed. They argued that since $\theta = 0.25$ is the threshold when the seabed becomes highly mobile and sedimentological conditions are met for formation of large-scale bedforms, stresses exceeding this threshold are likely to develop patches of disturbed benthic habitat. The $\theta = 0.25$ threshold has also been plotted in the left panel of Figure 5. The data indicate that the bottom habitat was disturbed during Events A and B and possibly briefly during the early part of the measurement campaign.

The right-hand panel in Figure 6 shows the relationship between bed shear stress and measured near-bed sediment concentration. Ignoring the few outliers displaying large concentrations at small (or zero) stress and typically related to current reversals when sediment had insufficient time to settle, there is strong correlation between the two. The second-order polynomial function plotted in the figure ($C=2.38 \tau^2 + 1.53 \tau +0.017$) has an $r^2 = 0.88$.

The vertical distributions of flow velocity direction and magnitude are shown in Figure 7a and b, respectively. In general, the water column was well-mixed throughout the survey period; and while the first 2/3 of the survey period was characterised by relatively short periods of in- and outflow, respectively, the last 1/3 of the survey period was characterised by a general outflow after the two storm events A and B. However, stratification was observed with inflow in the lower part of the water column and outflow in the upper part in the beginning of the survey period (September 12) and interchangeably in the last part of the survey period (September 10-17) during the period characterised by general outflow.

The depth-averaged flow velocity magnitude below 3 m, i.e. 2-5 m above the bed, is shown in Figure 7c. The depth-averaged flow velocity magnitude 2-5 m above the bed also displayed the highest magnitudes during the two storm events A and B (“Knud” on September 21-22 and NW gale on October 2-3) as in case of the flow velocity measured by the near-bed ADVs (Figure 3-Figure 5). In general, the depth-averaged flow velocity magnitude 2-5 m above the bed displayed similar trends as the near-bed flow velocity, albeit with higher magnitudes due to the larger distance to the bed.
The vertical distribution of backscattered intensity, which is a proxy for suspended matter in the water column, is shown in Figure 7d. The highest backscattered intensity occurred during the two storm events A and B. However, high backscattered intensity were also observed during the two minor events between the two storm events, as well as in the beginning of the survey period. All these events with high backscattered intensity in the water column were also observed in the near-bed OBS measurements (Figure 5). This supports the earlier conclusion that observations of high sediment concentration and backscattered intensity in the water column was due to local mobilisation and suspension of bed material as opposed to advection of fine material. In addition, it suggests that the high energy events may be capable of bringing bed material high up in the water column.

High backscattered intensity was observed interchangeably in the uppermost part of the water column above ~10 m, i.e. ~12 m above the bed or in the uppermost ~3 m, and with the intensity decreasing down through the water column. This indicated advection of fine material, most likely including organic matter, as well as settling in the water column. No water sampling was conducted during the survey period, so we were not able to quantify the suspended sediment concentration, the grain size distribution or the organic matter content in the water column.

The depth-averaged backscattered intensity below 3 m, i.e. 2-5 m above the bed, is shown in Figure 7e. It displayed similar trends as the near-bed OBS measurements (Figure 5) with the highest values during the two storm events A and B, and relatively high intensities were also observed during the two events between the two storm events as well as in the beginning of the survey period.
Two types of bedforms were observed in the profile scans from the pencilbeam-sonar: Small ripples with wavelengths in the order of 10 cm, and larger, low hummocky ripples with lengths in the order of 1.5 m. Both had heights in the order of 2-3 cm. These bedforms were also observed in the fanbeam scans. In general, four different seabed conditions were observed during the survey period, representing different seabed states before and after storms and high-energy events. Examples of these four seabed conditions are shown in Figure 8. The pre storm event A (“Knud”) seabed condition (Figure 8a) displayed irregular bedforms with lengths of ripple-to-dune size, i.e. lengths of 0.5-1 m. It is not possible to directly calculate bedform heights from the fanbeam scans, as these display acoustic backscatter only and not geometry, but the pencilbeam data show bedform heights of 3.0 cm on September 20 along the scanning transect. The post storm event A (“Knud”) seabed condition (and pre high-energy events between the two storms) (Figure 8b) displayed large local scour holes around the legs of the instrument platform along with remnants of the irregular bedforms of small-dune size with lengths around 1 m. In addition, the seabed was characterised by
more regular bedforms of ripple size with lengths of 0.1-0.2 m; the bedform height was 2.6 cm in the pencilbeam transect. The pre storm event B (NW gale) seabed condition (and post high-energy events between the two storms) (Figure 8c) displayed an overall similar morphology as before the high-energy events, albeit with some further development of the scour holes and the small dune-sized bedforms. The ripple-sized bedforms developed a more straight-crested morphology compared to the pre high-energy events; however, the ripple height had further reduced to 2.3 cm. The post storm event B (NW gale) seabed condition (Figure 8d) also displayed an overall similar morphology as after the high-energy events, however, with further development and migration of the scour holes and the small dune-sized bedforms. The ripple-sized bedforms developed an even more straight-crested morphology with individual crest widths extending as wide as 1-2 m. In general, the presence of local scour and bedform features of ripple as well as dune size are indicators of sediment erosion, transport and deposition, i.e. a dynamic seabed.
Seabed dynamics was assessed by determining the temporal variations in the spatial distribution of acoustic backscatter by calculating daily difference-scans between two successive daily average scans, i.e. calculating the backscatter Rate of Change (ROC) as described previously. It is not
possible to directly calculate volume changes related to erosion and deposition from the fanbeam scans, as these display acoustic backscatter only, and not geometry. Examples of daily difference-scans from successive daily average scans are shown in Figure 9. The impact of storm event A ("Knud") is shown in Figure 9a and b. Initially, the seabed dynamics driven by the storm were related to bedform migration and bedform development, e.g. of the ripple-sized bedforms south of the instrument platform (Figure 9a). Subsequently, the large scour around the legs of the instrument platform developed, and the ripple-sized bedforms south of the instrument platform developed a more regular morphological pattern (Figure 9b). The impact of the high-energy events between the two storm events is shown in Figure 9c. The difference scans revealed the further development and migration of the scour holes and the dune-sized bedforms. Likewise, more straight-crested ripple-sized bedforms started to emerge. The impact of storm event B (NW gale) is shown in Figure 9d. Here, the difference scans revealed the further development and migration of the scour holes and the small dune-sized bedforms. Specifically, the difference scans revealed the migration of the ripple-sized bedforms and the development of an even more straight-crested morphology. In general, the backscatter ROC showing the temporal variations in the spatial distribution of acoustic backscatter showed to be a robust indicator of seabed dynamics, and hence seabed disturbance.
Figure 9. Examples of daily difference-scans from successive daily average scans from a) September 21-22 of storm event A (“Knud”), b) September 22-23 of storm event A (“Knud”), c) September 26-27 of the high-energy events between the two large storm events A and B, and d) October 2-3 of storm event B (NV gale). The instrument platform is illustrated by a square with dots as the four legs provided a constant low backscatter difference; and the attached frame is illustrated by a triangle with dots as the instruments also produced a constant low backscatter difference.

The mean backscatter ROC, which was calculated for each daily difference-scan by calculating the mean value of the numerical differences, is shown in Figure 10 for the complete survey period. The three peaks are the mean backscatter ROC of the daily difference-scans showed in Figure 9. These
peaks, which are associated with the two storm events A and B and the high-energy events between the two storms, are the only periods during the survey period where significant seabed dynamics were observed. The mean backscatter ROC in the remaining part of the period is a combination of noise and potentially of very small variations in seabed morphology, e.g. minor variations in ripple morphology. These peaks in mean backscatter ROC coincide with the peaks in bed shear stress and suspended sediment concentration, where these peaks are of a longer duration. This shows the importance of the duration of a storm/high-energy event in relation to changing the seabed morphology, and hence for seabed dynamics and seabed disturbance.

**Storm events**

Given that Events A and B may have led to benthic disturbance, time series of hydrographic and sediment parameters during these events are explored in more detail. Event A (Sep.22-24; Figure 11) was current-dominated. Strong inflow and wave activity started in the early morning of the 22nd and near-bed water temperatures increased by about 2 degrees, brought about by the inflow of warmer waters from the Kattegat. Bed shear stresses increased above the threshold for sediment mobilisation and there was a 1:1 correspondence between excess shear stress and sediment concentration throughout the event. Shear stresses increased periodically above the threshold for ecological disturbance for a period of 16 hours.

Event B started in the early evening of October 2 with the mean current reversing from outflow to inflow and wave heights and near-bed orbital velocity increasing rapidly (Figure 12). In this case, wave activity was more significant than during Event A and again there is almost perfect correspondence between sediment suspension and the threshold for sediment mobility. The ecological disturbance criteria was exceeded for a period of only 1-2 hours, however.

![Figure 10. Mean backscatter rate of change (ROC) for each daily difference-scan calculated from the mean value of the numerical differences.](image-url)
Figure 11. Environmental conditions during Event A, Sep. 22-Sep. 24. The upper panel plots wave orbital velocity (blue line) and N-S mean current speed, corresponding to out/inflow conditions (red line; outflow positive, inflow negative). The second panel shows water temperature (solid line) and salinity (dashed line). The two lower panels illustrate near-bed sediment concentration and non-dimensional bed shear stress with the two threshold conditions ($\theta_c = 0.05; 0.25$) shown by the dotted blue and red lines.

Figure 12. Same as Figure 11, but for Event B on October 2-4.
Annual variability

It is important to ascertain whether or not the field measurements were representative for annual dynamic conditions at Disken. Model predictions of near-bed current speed and wave height for the year 2018 were acquired from the DHI for both positions I and II. These data are plotted in Figure 13.

Figure 13. Model-predicted wave heights (blue) and resultant current speeds at the seabed (red) for positions I and II during 2018. The dashed lines indicate the period of the field campaign.

While model-predicted resultant current speeds are clearly underestimated relative to measured speeds (see Figure 4), the predictions suggest that the field campaign (at position 1) comprised the most intense current event during 2018, and three of the 6 most significant events over the year. The largest wave heights occurring during the campaign are predicted to have been slightly exceeded on
three occasions. Therefore, the measurement conditions during the field campaign is deemed to have been representative for the most energetic wave/current conditions of the year.

Summary
The main points from the field measurements at position I can be summarized as follows:

- Sediment at 15 m water depth on the northern part of Disken is mobilized mainly during inflow conditions with current speeds $U > 40$ cm/s and/or waves generating orbital velocities $u_s > 30$ cm/s at the seabed.
- The threshold for sediment mobilisation was $\theta_c \approx 0.05$, as theoretically expected. Mean sediment concentrations close to the bed reached almost 6 kg/m$^3$ during the peak of storm events.
- Bed material was suspended throughout the water column during storms and high-energy events. Potentially, part of the material in the water column may be associated with advective processes of organic matter and fines.
- Seabed morphology was characterised by ripple- and dune-sized bedforms, and local scour holes developed around the legs of the instrument platform. These morphological features are indicators of sediment erosion, transport and deposition, i.e. a dynamic seabed.
- Bedform heights were small, in the order of 2-3 cm. Both ripples with wavelengths of about 10 cm and hummocky bedforms having wavelengths an order of magnitude larger were observed at the site.
- Seabed morphological changes were observed in relation to the development of local scour holes and ripple- and dune-sized bedforms and their migration. The seabed morphological changes, i.e. seabed dynamics and seabed disturbance, were observed at three storm/high-energy events during the total survey period. This demonstrated the importance of storm/high-energy event duration (in combination with intensity) for significant seabed dynamics, and hence seabed disturbance.
- The seabed was mobilized six times during the 5½ week experimental period and ecological disturbance is expected to have occurred only three times and only for brief periods at the time. Based on the measurements and model predictions, the benthic fauna is expected to be only rarely disturbed by physical processes at this position/depth at Disken.
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