The complexity of modeling a glaciated shelf using SEDFLUX

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Abstract

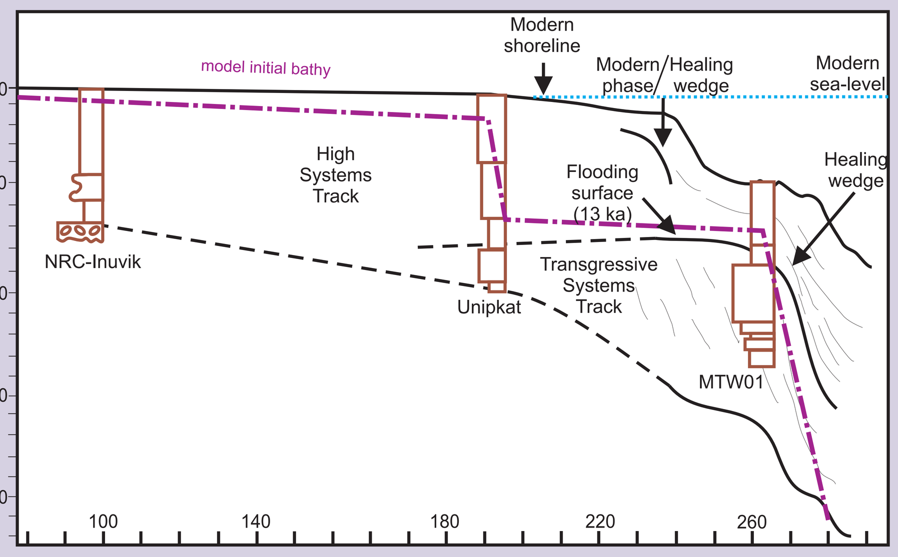
The present study uses the Sedflux stratigraphic model to simulate the Late Pleistocene evolution of the Eastern Beaufort Continental Shelf, Canadian Arctic. During this period, the proximity and the dynamics of the Laurentide Ice Sheet (LIS) created a complex glacial environment. Modeling such environments thus presents challenges. Modules and input parameters have to be able to simulate major fluctuations in sea-level and sediment supply, an ever evolving source of sediments, a large outwash plain, sudden outburst floods, permafrost aggradation, glacial isostasy, etc. In addition, detailed understanding of glacially-influenced environments in general and the glacial history of the local region specifically make it difficult to estimate parameters such as sediment supply. This poster thus presents the challenges and the potential solutions in using SEDFLUX to simulate the stratigraphy of a glaciated shelf such as the Beaufort Shelf.

Mackenzie Delta: Experiment on sediment supply; Last 4500 years; Decelerating sea-level rise

Model challenge: Estimate sediment supply over a long time period, for which measurements were not acquired.

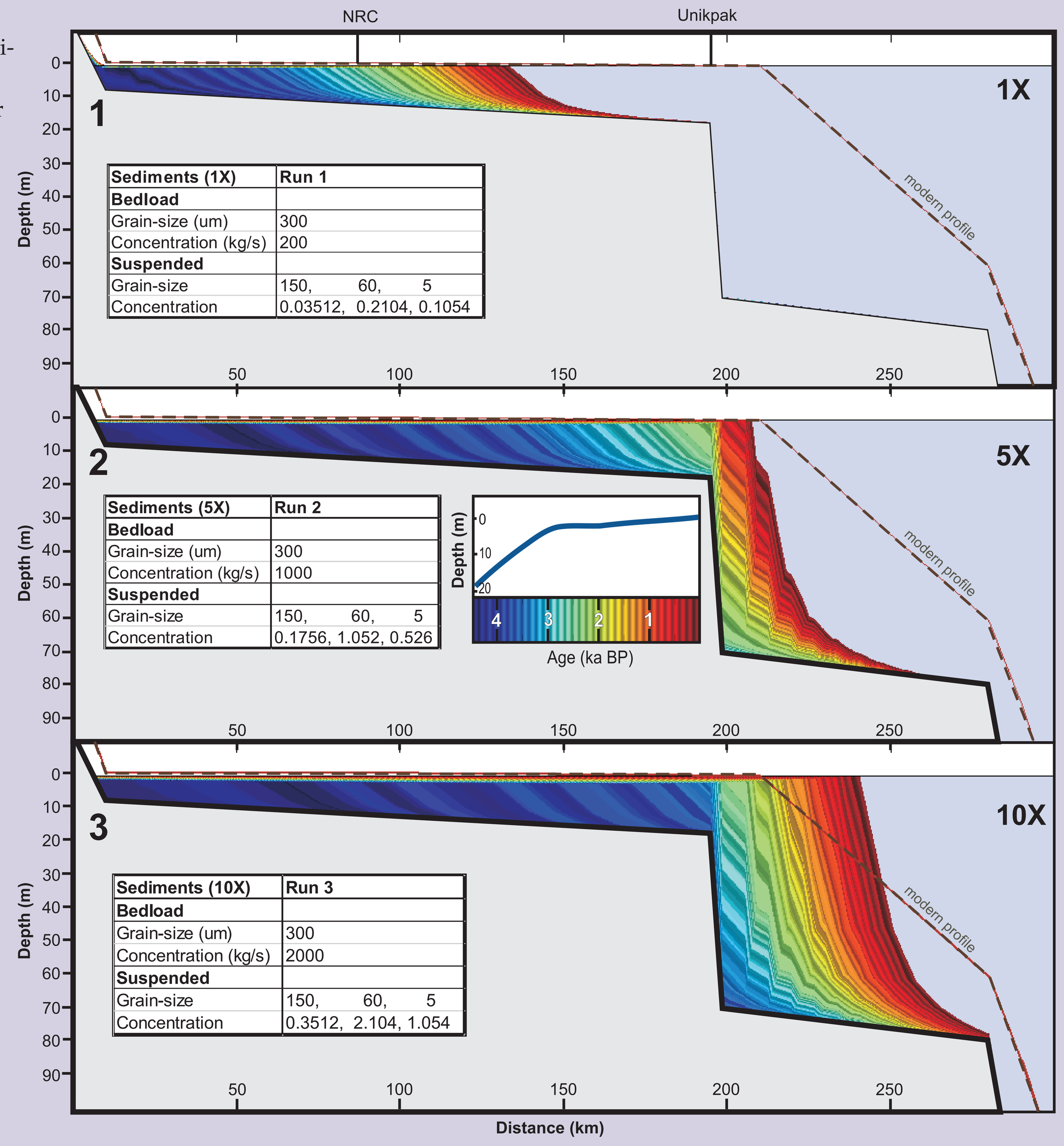
Solutions: Use analogs of similar modern environments

Runs 1, 2, & 3: Based on 1X, 5X and 10X (respectively) the sediment input for the modern Mackenzie Delta as estimated from hydrometric and sediment measurements collected over a 20 year period [7].



Objective: Verify, based on seismostratigraphic and borehole interpretation, if the modern sediment supply, used over a 4500 year period, is sufficient.

PARAMETERS	RUN 1-3
Sea-level curve	Hill 85/93
INITIATION	
Basin width (km)	60
X-shelf resolution (m)	25
Vertical resolution (m)	0.1
EPOCH	
Run time (ka)	120
Time step (yr)	1
RIVER	
Width (m)	1000
Depth (m)	8
Velocity (m/s)	1.4
PROCESSES	
Compaction	no
Isostasy	yes
Avulsion (max < 180°, std: 25, hinge pt: 50)	yes
Erosion	yes
Bedload dumping (distance to dump: 5 km)	yes
Hyperpycnal plume	yes
Hypopycnal plume (max width: 15, grid-nodes x-shore: 21, grid-nodes river	yes

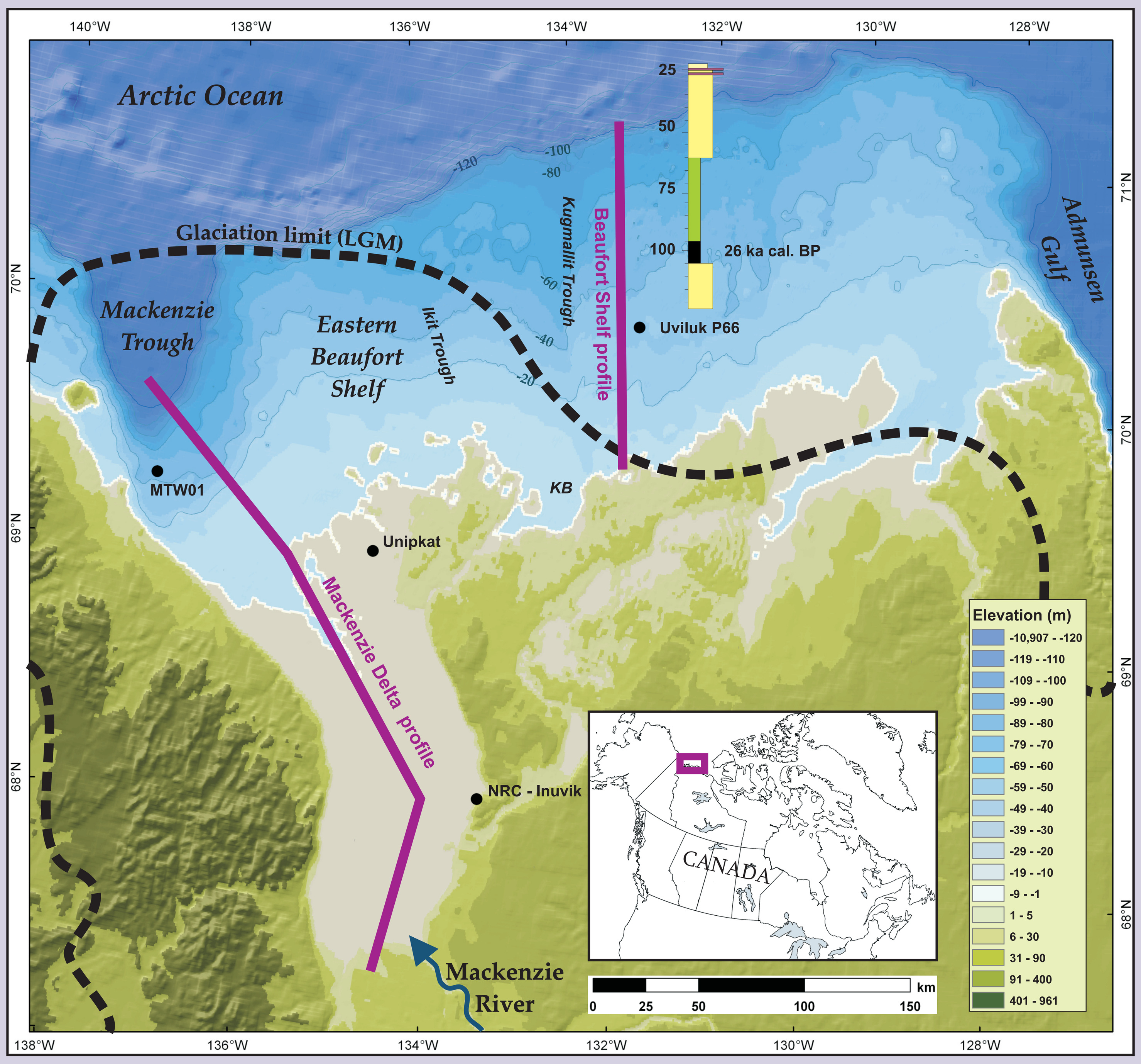


Results:

1) Up to 10 times the amount of the modern sediment supply estimate is necessary to approach the necessary volume to fill the trough.

2) The geometry of the delta is however not reproduced. Other processes, such as storm re-mobilisation and sea-ice dynamics, may be responsible.

Introduction



The Eastern Beaufort Shelf is bounded to the west by the glacially carved Mackenzie Trough. The trough and the shelf were occupied by the Mackenzie ice lobe between 22 and 16 ka cal. BP [1]. During this lowstand period, the Laurentide Ice Sheet (LIS) generated a glacial outwash [2], and the exposed shelf allowed permafrost aggradation [3]. Following deglaciation, the Mackenzie River Delta infilled the terrestrial portion of the trough and prograded offshore [4]. Between 13 and 11 ka cal. BP, outburst floods from glacial Lake Agassiz flooded the region, leaving some evidence in the form of a boulder lag along the shoreline and a regional unconformity identified in the offshore seismostratigraphy [5]. During the Holocene, the Mackenzie River became the principal source of sediment supply for the shelf; the supply mostly directed into the Mackenzie Trough, but with a small contribution flowing towards Kugmallit Bay (KB) and Trough. Today, sea ice covers the region year around with the exception of the four summer months. Thus, most sediment is supplied to the offshore during open water season and distributed according to the wind-driven currents and ocean storms [6].

Beaufort Shelf: Experiment on the effect of sea-level; Constant sediment supply

Model challenge: Characterize the impact of sea-level fluctuations in an environment where detailed stratigraphy is lacking.
- Thick permafrost masks shallow seismic data
- Radiocarbon dates are sparse
- Limited borehole information is available.

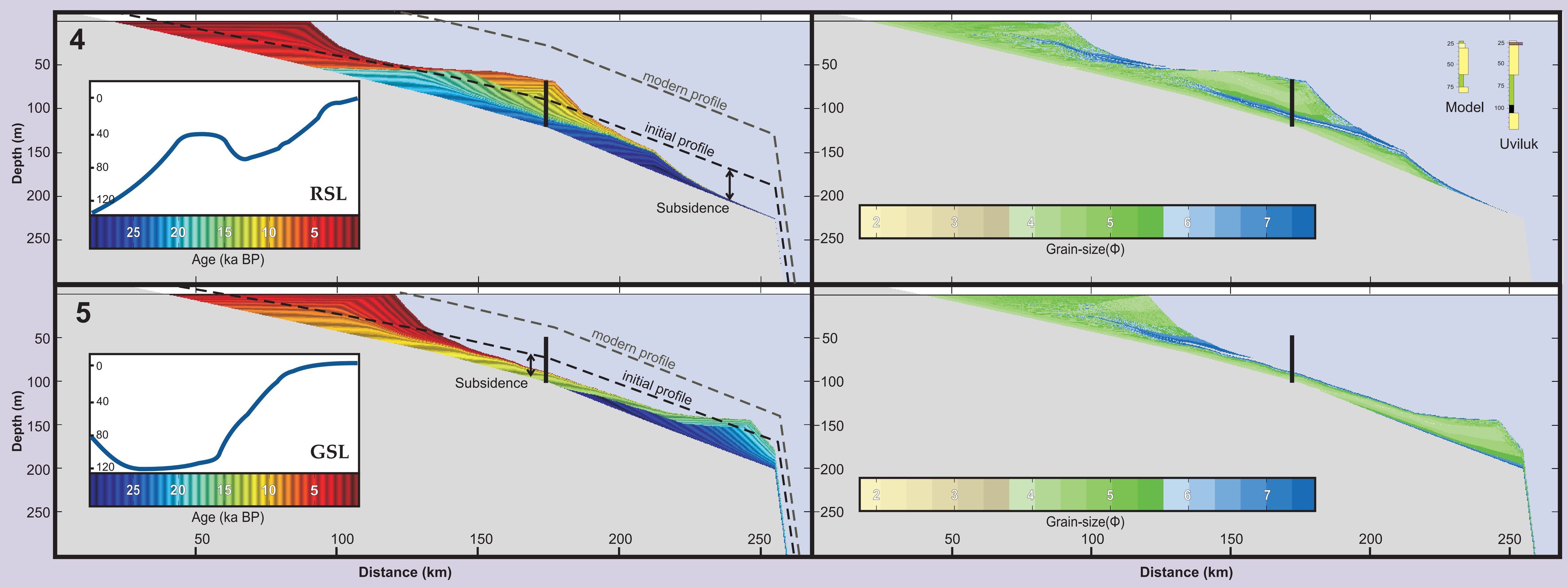
Initial bathymetry determined from:
Modern bathymetry, Uviluk borehole stratigraphy, the only trustworthy radiocarbon dates collected offshore, and water loading effect

Objective: Verify, based on seismostratigraphic and borehole interpretation, which sea-level curve best represent the modern stratigraphy.

PARAMETERS	RUN 4	RUN 5
Sea-level curve	Hill 85/93	Peltier 06
INITIATION		
Basin width (km)	50	50
X-shelf resolution (m)	50	50
Vertical resolution (m)	0.1	0.1
EPOCH		
Run time (ka)	30	30
Time step (yr)	1	1
RIVER		
Width (m)	1000	1000
Depth (m)	8	8
Velocity (m/s)	1.4	1.4
SEDIMENTS		
Bedload		
Grain-size (um)	300	300
Concentration (kg/s)	200	200
Suspended		
Grain-size	150, 60, 5	150, 60, 5
Concentration	0.03512, 0.2104, 0.1052	0.03512, 0.2104, 0.1053
PROCESSES		
Compaction	no	no
Isostasy	yes	yes
Avulsion (max < 180°, std: 25, hinge pt: 50)	yes	yes
Erosion	yes	yes
Bedload dumping (distance to dump: 5 km)	yes	yes
Hyperpycnal plume	yes	yes
Hypopycnal plume (max width: 15, grid-nodes x-shore: 21, grid-nodes river mouth: 3)	yes	yes

30 ka runs

Run 4 & 5: Use the "empirical" relative sea-level (RSL) containing a forebulge effect [8] and the eustatic sea-level (GSL) [9] curves under a constant sediment supply.



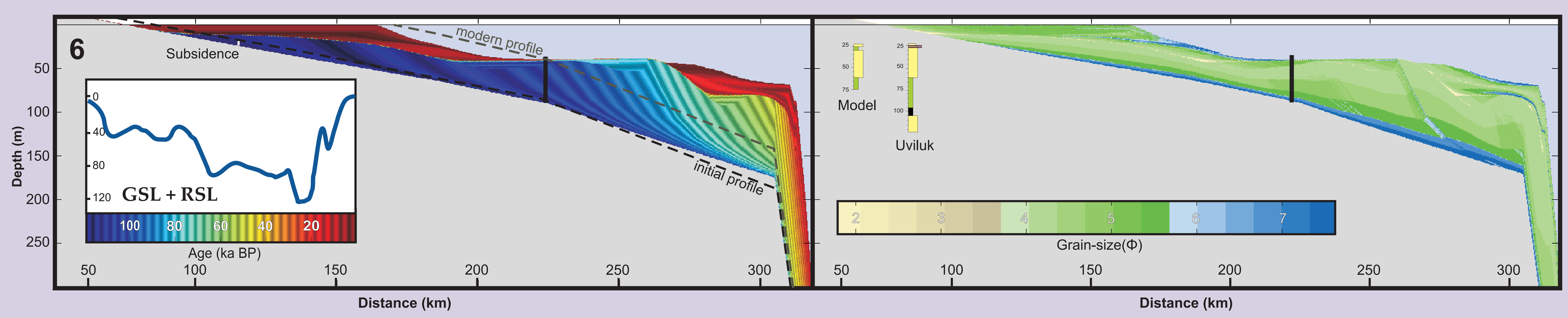
Results run 4 & 5:
1) The core section in Run 4 produces a stratigraphic pattern closer to the observed than the GSL curve.
2) A closer match could probably be achieved by using variable sediment supply more representative of the different epochs characterising the last 30 ka.

120 ka run

Run 6: Models the stratigraphy since the last interglacial using a GSL curve [7] combined with the RSL [8] characterising the last 30 ka.

PARAMETERS	RUN 6
Sea-level curve	Peltier & Hill
INITIATION	
Basin width (km)	50
X-shelf resolution (m)	50
Vertical resolution (m)	0.1
EPOCH	
Run time (ka)	120
Time step (yr)	100
RIVER	
Width (m)	1000
Depth (m)	8
Velocity (m/s)	1.4
SEDIMENTS	
Bedload	
Grain-size (um)	300
Concentration (kg/s)	200
Suspended	
Grain-size	150, 60, 5
Concentration	0.03512, 0.2104, 0.1054
PROCESSES	
Compaction	no
Isostasy	yes
Avulsion (max < 180°, std: 25, hinge pt: 50)	yes
Erosion	yes
Bedload dumping (distance to dump: 5 km)	yes
Hyperpycnal plume	yes
Hypopycnal plume (max width : 15, grid-nodes x-shore: 21, grid-nodes river mouth: 3)	yes

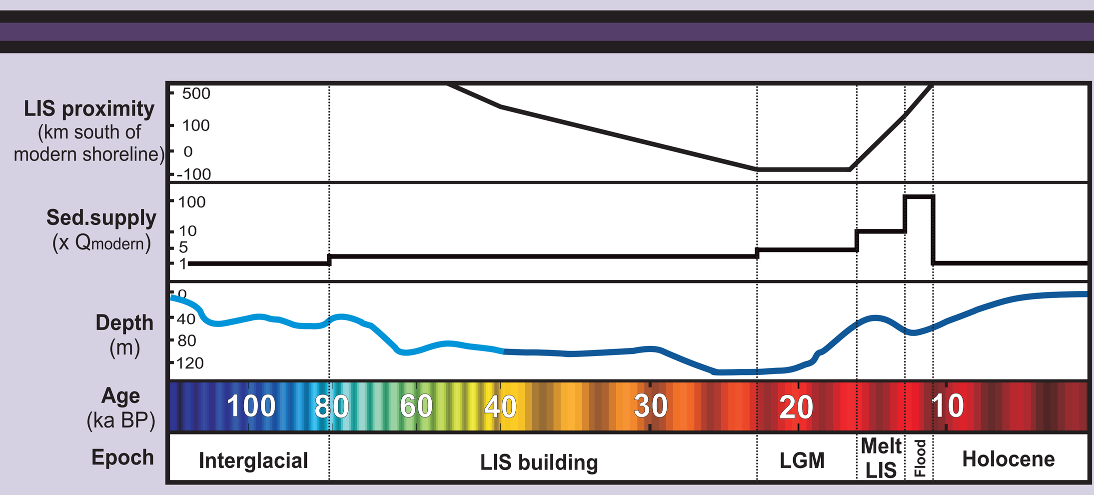
120 ka run



Results run 6:
1) Progradation (10 km) of the shelf.
2) Thick deposition towards the shelf edge (100 m).
3) The core section at Uviluk is as thick and similar in pattern as #4.
4) The sediments are, however, much older (120-100 ka BP) and thus, do not match the existing date.

Future experiments:

Considering the last Interglacial-glacial cycle, how would you define the epochs and quantify the different model parameters for this region?



References

1) Dyke, A.S., 2004. An outline of North American deglaciation with emphasis on central and northern Canada, In: J. Ehlers and P.L. Gibbard, Ed(s), Developments in Quaternary Science, Elsevier, 2004, Volume 2, Part 2, Quaternary Glaciations-Extent and Chronology - Part II: North America, p. 373-424
2) Blasco, personnal communication
3) Judge, A.S. et al., 1981. Permafrost - Canadian Geothermal Data Collection - Northern Wells, Geothermal Service Canada, Earth Physics Branch, Energy Mines and Resources Canada.
4) Hill, P. R. 1996. Late quaternary sequence stratigraphy of the Mackenzie Delta. Canadian Journal of Earth Sciences 33 (7): p. 1064-1074.
5) Murton, J. B., M. D. Bateman, S. R. Dallimore, J. T. Teller, and Z. Yang. 2010. Identification of Younger Dryas outburst flood path from Lake Agassiz to the Arctic Ocean. Nature 464: p. 740-743.
6) Hill, P. R., C. P. Lewis, S. Desmarais, V. Kauppaymuthoo, and H. Rais. 2001. The Mackenzie Delta: sedimentary processes and facies of a high-latitude, fine-grained delta. Sedimentology (5): p. 1047-1078.
7) Carson, M. A., J. N. Jasper, and F. M. Conly. 1998. Magnitude and Sources of Sediment Input to the Mackenzie Delta, Northwest Territories, 1974-94. Arctic 51 (2): p. 116-124.
8) Hill, P. R., A. Héquette, and M.-H. Ruz. 1993. Holocene sea-level history of the Canadian Beaufort shelf. Canadian Journal of Earth Sciences 30 (1): p. 103-108.
9) Peltier, W. R., and R. G. Fairbanks. 2006. Global glacial ice volume and Last Glacial Maximum duration from an extended Barbados sea level record. Quaternary Science Reviews 25 (23-24): p. 3322-3337.