J Paleolimnol (2022) 67:183–189
https://doi.org/10.1007/s10933-021-00203-y

NOTE

A portable extruder for accurate and precise high-resolution subsampling of unconsolidated sediment cores

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Received: 20 August 2020 / Accepted: 27 May 2021 / Published online: 5 June 2021

Abstract We developed a portable extruder for precise and accurate high-resolution subsampling of unconsolidated sediment cores. This extruder is capable of producing subsamples at a minimum 1-mm resolution and is designed for easy operation and maintenance in the field. Movement of the threaded extruder rod (½" 8 start acme thread) through the core barrel is driven by a crank wheel graduated in 1-mm increments. This extruder design is particularly useful for obtaining incremental subsamples for applications where high-resolution subsamples of identical size are required (e.g. time series analysis, climate variability, land use change, contamination), and for use in field settings where it is impractical to deploy a freeze corer.

Keywords Portable core extruder · Precision subsampler · Core samples · Paleolimnology · Lacustrine sediment

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Introduction

Lake sediments archive biological, sedimentological, and geochemical variables that can be used to reconstruct past environmental change through analysis of subsamples from sediment cores (Cohen 2003). Under optimal conditions, where bioturbation and sediment reworking are not an issue, very high-resolution subsampling (annual to sub-decadal) of sediment cores can be carried out to provide invaluable temporal records (Kulbe and Niederreiter 2003; Blass et al. 2007; Gammon et al. 2017). Such high-resolution subsampling is imperative for recognizing past environmental and climate changes that would otherwise not be detected if low subsampling resolutions were used. For example, recognition of high-resolution climate trends and cycles archived in sediment records (El Niño/Southern Oscillation, Pacific Decadal Oscillation, solar cycles; Patterson et al. 2013; Upiter et al. 2014; Dalton et al. 2018; Macumber, et al. 2018) and similar-temporal-scale environmental changes related to industrial contamination (Thienpont et al. 2016; Gavel et al. 2018; Patterson et al. 2019) and agricultural runoff (Patterson et al. 2013) all require sub-decadal sampling resolution.

In this note we describe a custom-designed core extruder for precision subsampling of unconsolidated lake sediments at a resolution of ≥ 1-mm for core barrels up to 60 cm long. The impetus for the construction of the extruder was the mm-scale resolution required to subsample sediment cores at annual and sub-decadal-resolution for the detection of the high-temporal-resolution environmental changes described above. In addition, there was a requirement for an extruder that could be easily deployed and maintained in the field, where it was impractical to deploy a freeze corer that can only be subsampled in the lab using a freeze-core microtome (Macumber et al. 2012). Previous gravity corer extruder designs, although effective for coarser subsampling resolution (Glew 1988; Glew et al. 2001), are not capable of sampling at the precision of the instrument described here. Although the metal work was custom designed and built, the gearing was sourced commercially. Total cost to produce the prototype unit illustrated here, including CAD design work was ~ 6000 Canadian dollars. The maximum core length that can be subsampled with this design is 60 cm, which is constrained by the length of the extruder rod assembly. Although this length is adequate for most gravity cores obtained in lacustrine environments, the design could be readily adapted to subsample longer cores, through inclusion of adjustable legs, and through construction of extruder rod assemblies of varying lengths.

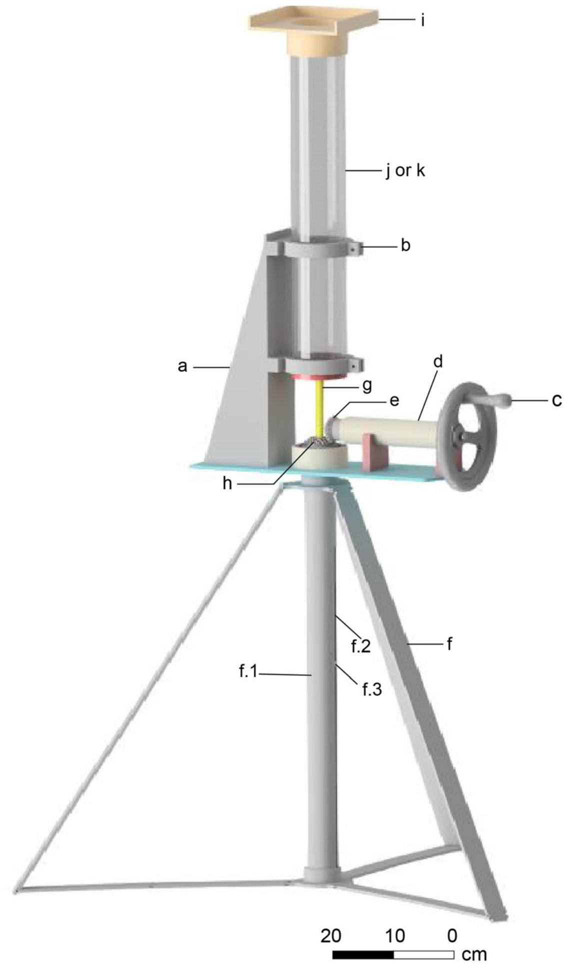


Fig. 1 CAD image of the extruder assembly. *Scale bar* = 20 cm. Parts of the extruder: (**a**) metal support structure; (**b**) core supports; (**c**) crank wheel; (**d**) crank shaft bevel gear guide; (**e**) bevel gear attached to crank wheel using a ½” 8 start acme thread; (**f**) tripod assembly; (**f.1**) threaded extruder rod housing; (**f.2**) threaded extruder rod guide; (**f.3**) pin positioned in extruder rod guide keeps extruder rod from ineffectually spinning during extrusion; (**g**) threaded extruder rod; (**h**) bevel gear attached to extruder, which drives extruder rod up and down; (**i**) section box where core intervals are subsampled at down to 1 mm precision; (**j**) UWITEC core barrels, which are compatible with extruder; (**k**) Glew Maxi-core barrels, which are compatible with extruder. Please note that to save space the lower parts of the tripod legs below the leg stabilizers are deleted from this schematic but are shown in the photograph in Fig. 5B

Description

The core extruder is constructed of light-weight aluminum with a stainless steel base, and is comprised of a tripod with a broad stable base that is designed for outdoor use on a level surface, with the core extruder mechanism mounted on top (Fig. 1). Cores are secured

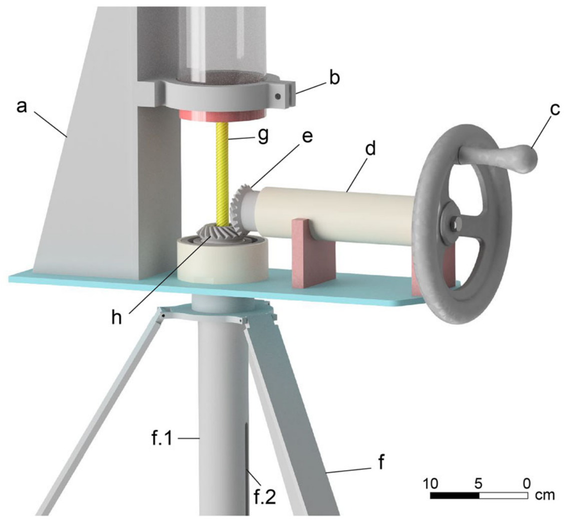


Fig. 2 Enlarged CAD image showing details of the geared portion of the extruder assembly. Scale bar = 10 cm. Parts listed: (**a**) metal support structure; (**b**) core supports; (**c**) crank wheel; (**d**) crank shaft bevel gear guide; (**e**) bevel gear attached to crank wheel using a ½” 8 start acme thread; (**f**) tripod assembly; (**f.1**) threaded extruder rod housing; (**f.2**) slot where pin attached to threaded extruder rod runs (**f.3**) pin positioned in extruder rod guide keeps extruder rod from ineffectually spinning during extrusion; (**g**) threaded extruder rod; (**h**) bevel gear attached to extruder, which drives extruder rod up and down

in a vertical position and core extrusion is carried out using a threaded extruder rod, for which the incremental motion is controlled by a crank wheel (Figs. 2, 3). The device is lightweight ($\sim$ 15 kg) and can be disassembled and reassembled in a few minutes and safely transported aboard commercial aircraft to the field as checked luggage in a pair of Pelican™-type cases, or even in hard-sided luggage (Fig. 4). When disassembled for transport, the extruder is comprised of three main components, as shown in Fig. 4: the tripod base; the bevel gear crank assembly with crank wheel and core guides; and the threaded extruder rod. The extruder is compact enough that disassembly is generally not required for transportation in a personal vehicle. The tripod of the prototype was built of stainless steel to increase stability. However, after field testing it was determined that a tripod built of lighter-weight aluminum would be equally stable.

Collars are used to secure core tubes to the extruder mechanism, and these can be custom built using Delrin® or other plastics to accommodate a wide variety of core diameters (Figs. 4j.1, 4 k.1). For example, the collars used for the extruder described here were designed to accommodate UWITEC gravity cores (outside diameter = 9 cm; UWITEC 2020; Fig. 3j) and Glew Maxi-cores (outside diameter = 8 cm; PEARL 2020; Fig. 4k). A lipped sectioning box is attached to the top of the core that was constructed following the designs of Glew (1988) and Fast and Wetzel (1974) (Figs. 1i, 4i). It was also custom designed to accommodate both Glew Maxi-core and UWITEC core barrels. The threaded extruder rod is driven by a ½” (8 start acme thread) bevel gear assembly, which provides a movement of 1″ per revolution (Fig. 2g, h). The bevel gear assembly is positioned on shafts that are 90° apart, and is comprised of 20° spiral miter gears that are controlled by a crank wheel that is calibrated to 1-mm stops (Figs. 2, 3AC, 4). The extruder rod (Figs. 2g, 4g) is kept in position and advances upward in a sleeve mounted to the support tripod (Figs. 1, 4, 5), which is secured to the extruder with a guide that extends from the base of the extruder assembly (Figs. 2, 3AB, 4). The extruder rod is kept from ineffectually spinning by means of a pin mounted at the base of the extruder rod (Figs. 3Af.3,Bf.3, 4 g.2) that moves up and down within a slot on the extruder guide (Figs. 1f.1,f.2, 2f.1,f.2). The bevel gears are protected from water drips as the core is being extruded, by a plastic housing shown in Fig. 4h.2, which is not illustrated in the schematic drawings (Figs. 1, 2 and 3), as it would have obscured the working of the bevel gears.

Operation of the core extruder

Following core recovery in the field, rubber stoppers are inserted into the bottom of cores. Insertion of these stoppers is critical as these will remain in place during the core subsampling process. The cores are then capped top and bottom to seal the cores and are kept vertical until subsampling takes place (Fig. 5A). To

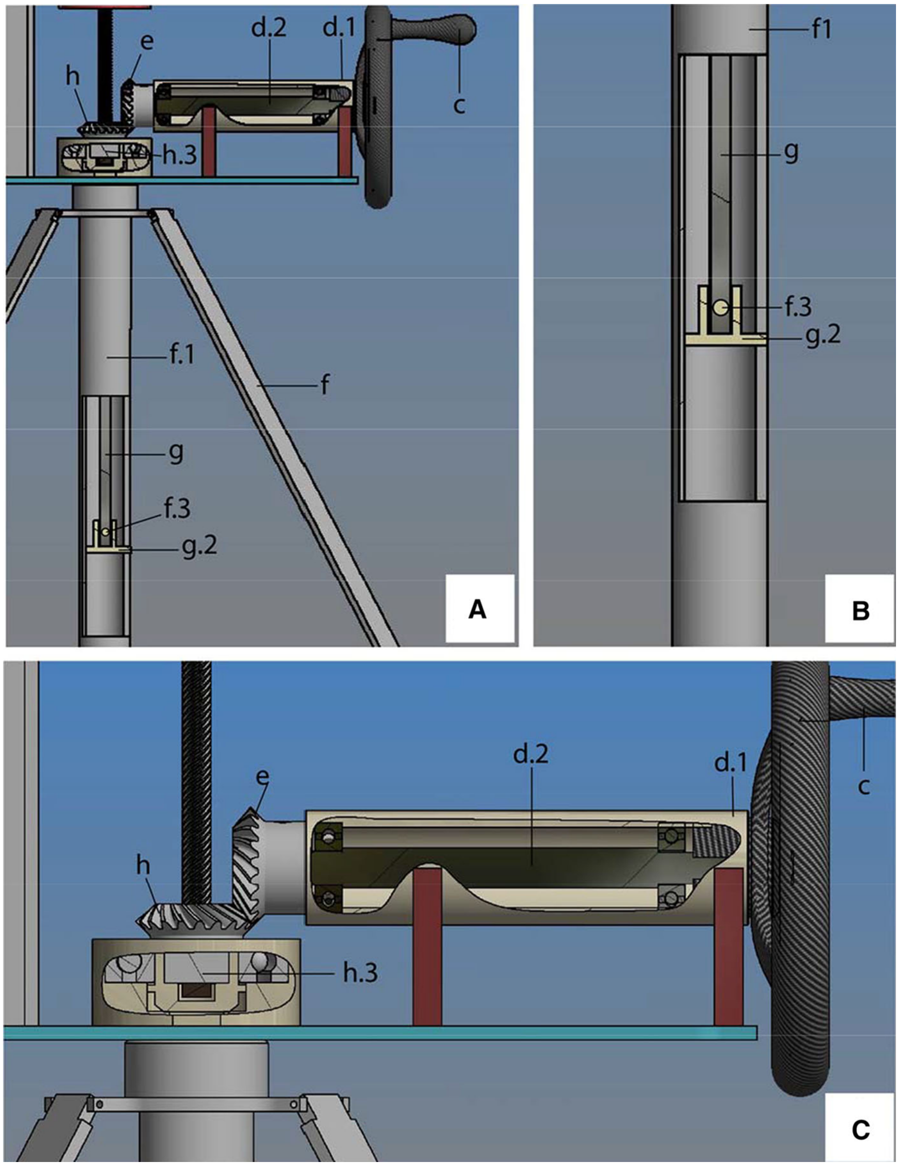
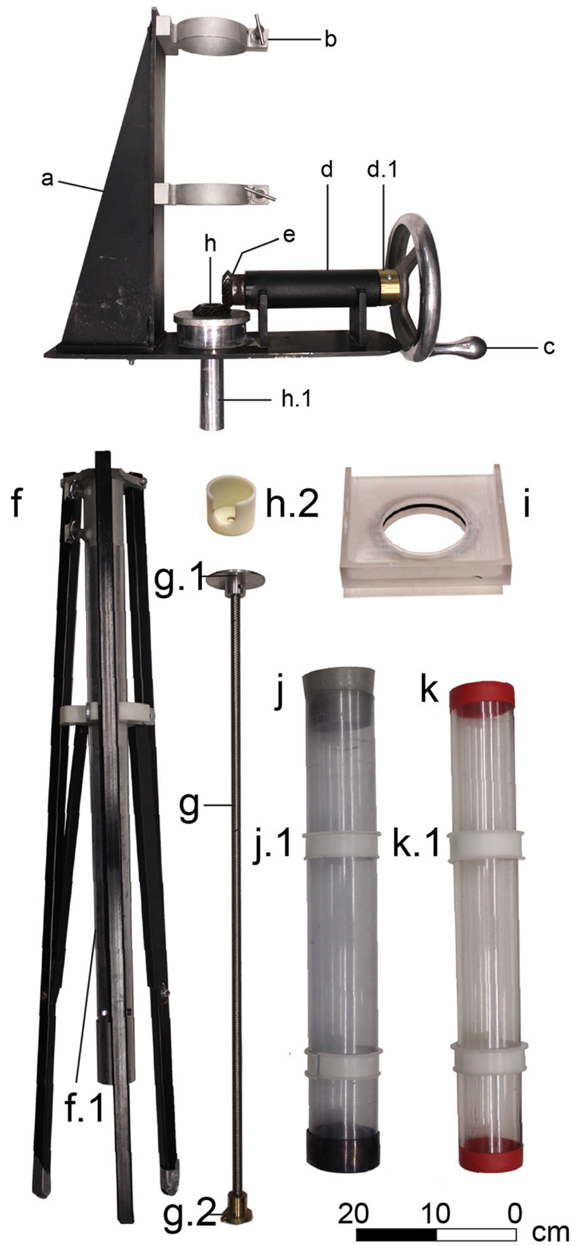


Fig. 3 Enlarged CAD image with cut-outs showing details of the geared portion of the extruder assembly. Not to scale. **A** Parts listed: (c) crank wheel; (d.1) crank shaft bevel gear guide housing; (d.2) crank shaft (e) bevel gear attached to crank wheel using a ½" 8 start acme thread; (f) tripod assembly; (f.1) threaded extruder rod housing; (f.3) pin positioned in extruder rod guide to keep extruder rod from ineffectually spinning during extrusion; (g) threaded extruder rod; (g.2) basal mount to threaded extruder rod where f.3 pin is attached; (h) bevel gear attached to extruder, which drives extruder rod up and down. **B** Enlarged details of extruder rod and housing. Parts listed: (f.1) threaded extruder rod housing; (f.3) pin positioned in extruder rod guide to keep extruder rod from ineffectually spinning during extrusion; (g) threaded extruder rod; (g.2) basal mount to threaded extruder rod where f.3 pin is attached. **C** Enlarged details of geared portion of extruder. Parts listed: (c) crank wheel; (d.1) crank shaft bevel gear guide housing; (d.2) crank shaft (e) bevel gear attached to crank wheel using a ½" 8 start acme thread; (f) tripod assembly; (f.1) threaded extruder rod housing; (f.3) pin positioned in extruder rod guide to keep extruder rod from ineffectually spinning during extrusion; (g) threaded extruder rod; (g.2) basal mount to threaded extruder rod where f.3 pin is attached; (h) bevel gear attached to extruder, which drives extruder rod up and down



◀**Fig. 4** Photograph of the extruder broken down for transport. *Scale bar* = 20 cm. Parts of the extruder: (a) metal support structure; (b) core supports; (c) crank wheel; (d) crank shaft bevel gear guide; (d.1) calibration gauge with mm stops, which is not illustrated in the schematic diagrams in Figs. 1, 2 and 3; (e) bevel gear attached to crank wheel using a ½" 8 start acme thread; (f) tripod assembly; (f.1) slot where pin attached to threaded extruder rod runs; (g) threaded extruder rod; (g.1) circular plate attached to top of extruder rod that pushes up against snug fitting plugs inserted into the base of the core during extrusion; (g.2) basal mount to threaded extruder rod where f.3 pin is attached; (h) bevel gear perpendicular to the crank wheel bevel gear, which drives extruder rod; (h.2) protective plastic sleave, which fits over the bevel gear assembly to protect it from water dripping from core during the extrusion process; not shown in Figs. 1, 2 and 3; (i) section box where core intervals are subsampled at down to 1 mm precision; (j) UWITEC core barrels, which are compatible with extruder; (j.1) custom manufactured plastic sleaves for UWITEC core barrels, which fit into metal core supports (b); (k) Glew Maxi-core barrels, which are compatible with extruder; (k.1) custom manufactured plastic sleaves for Glew Maxi-core barrels, which fit into metal core supports (b)

minimize potential homogenization related to core transportation we recommend sampling on site if possible.

For extrusion of subsamples, the core tube is securely clamped into the extruder frame using the appropriate collar and the lower cap is removed (Fig. 5B). The extruder rod, which has a broad flange attached to the top (Fig. 4g) is then moved upward using the crank wheel until it abuts against the rubber stoppers that were placed in the bottom of the core tube. The upper cap is then removed and a custom-built sectioning box is secured to the top of the core by friction fit (Fig. 1i; 5B). The interior width of section boxes is generally designed to not only fit properly over the core barrel, but to work with joint (taping) knives, either plastic or stainless steel, of an appropriate width, which are readily available at hardware stores. Any water in the core tube is then removed using a siphon tube, with care being taken to not disturb the top of the sediment column. The crank wheel is then turned clockwise to move the sediment column to the top of the core barrel where subsamples are taken sequentially, both accurately and precisely, at the selected sampling interval (Figs. 5B–D). The bed of the section box and joint knife should be cleaned following the collection of each subsample to avoid cross contamination (Fig. 5D, E).

Both before and after use, the entire assembly should be thoroughly cleaned and lubricated, to avoid corrosion, particularly if subsampling cores from saline environments. We recommend that the

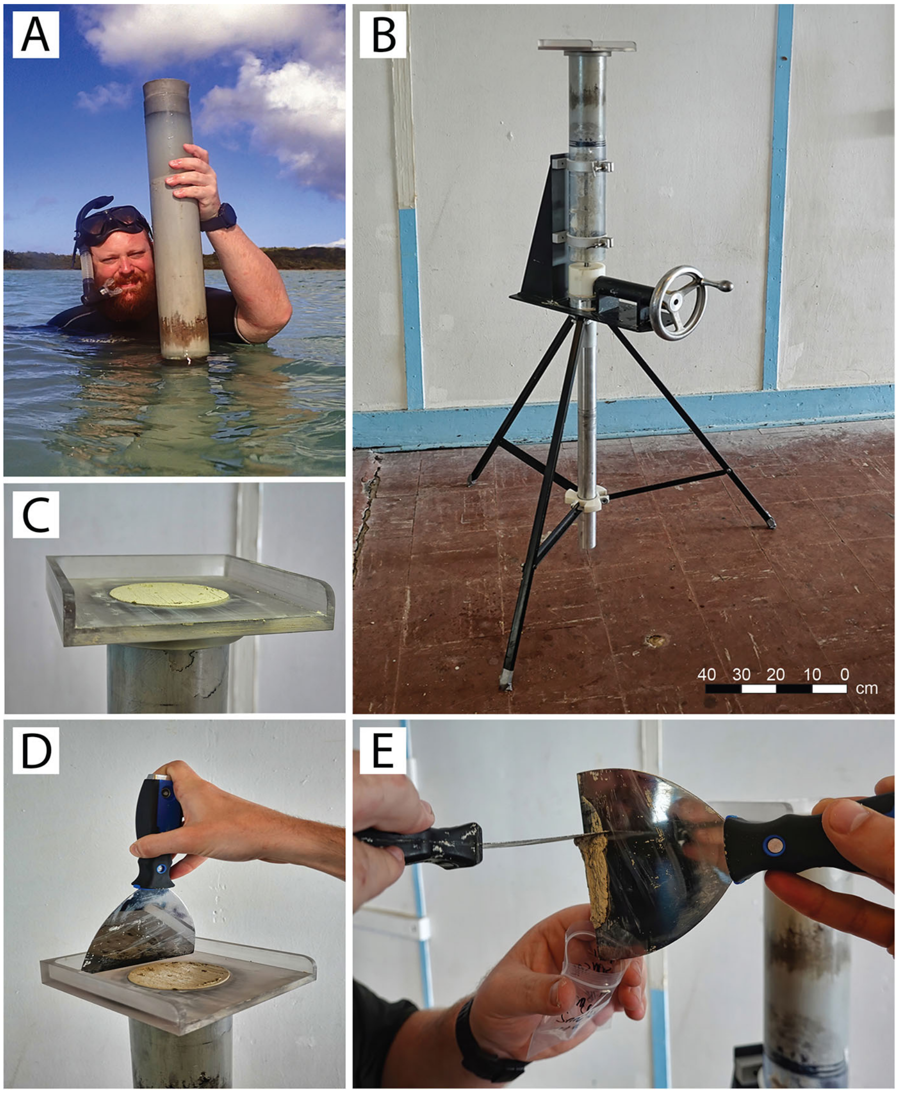


Fig. 5 Demonstration of core extruder being deployed to subsample cores on San Salvador Island, Bahamas in February 2020. **A** Core collected from Moon Rock Pond; **B** photograph of core extruder where core from **A** is being subsampled. *Scale bar* = 40 cm; **C** core has been extruded 1-mm and is ready for subsampling; **D** a joint knife the exact width of section box is used to subsample precisely 1-mm interval of core which is placed in sample bag for subsequent analysis (**E**)

lubrication process be carried out in two phases, first with a water displacement product to force water out of hard to clean areas, and second, and that after drying, the extruder be treated with a high-quality penetrating oil lubricant.

Acknowledgements This contribution is dedicated to the memory of John Glew, whose innovative sediment corer, extruder and other instrument designs are widely used by paleolimnologists worldwide, and whose corers and extruders inspired development of this new design. We thank the staff of the Science Technology Centre (STC) at Carleton University for assistance with the design and manufacture of the extruder. We acknowledge David Singer and Calder Patterson for demonstrating how the extruder works under field conditions in Fig. 5. We are appreciative of the input of two anonymous reviewers whose constructive comments greatly improved the contribution. Cost of design and fabrication of this core extruder was supported by NSERC Discovery (#RGPIN05329) and NRCan Clean Technology (#CGP-17-0704) Grants to RTP, and ArcticNet Grant P51 to JMG. This contribution represents NRCan Contribution Number 20200574.

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