Table 1:

Variable	Description	Units
$g = 9.81$	gravitational acceleration	$\mathrm{m\,s^{-2}}$
$a_s = 0.3$	surface mass balance	$\mathrm{m\,a^{-1}}$
$a_s = 0$	basal mass balance	$\mathrm{m\,a^{-1}}$
$\rho = 917$	ice density	$\mathrm{kg\,m^{-3}}$
$\rho_o = 1030$	ocean density	$\mathrm{kg\,m^{-3}}$
$A = 2.9377 \times 10^{-9}$	ice rate factor	$\mathrm{kPa^{-3}\,a^{-1}}$
$n = 3$	flow law stress exponent	
$C = 0.001$	basal slipperiness	$\mathrm{m\,a^{-1}\,kPa^{-3}}$
$m = 3$	sliding law stress exponent	
$\mathrm{d2a} = 365.2422$	days in a year	days

1 Thule

Thule is a synthetic geometry designed to be used as a test case for various ice-sheet modelling experiments. The Thule bedrock, B, is defined as a function of the polar coordinates r and θ, as

$$B = B_a \cos(3\pi r/l) + a$$

where

$$l = R\,(1 - \cos(2\theta)/2)$$
$$a = B_c - (B_c - B_l)\left(\frac{r - r_c}{R - r_c}\right)^2$$

and $R = 800\,\mathrm{km}$, $B_c = 900\,\mathrm{m}$, $B_l = -2000\,\mathrm{m}$, $B_a = 1100\,\mathrm{m}$, and $r_c = 0\mathrm{m}$.

In MATLAB, the bedrock B can be calculated as a function of (x, y) as:

```
B=function(x,y)
  % paramters
  R=800e3;
  Bc=900;
  Bl=-2000;
  Ba=1100;
  rc=0;
  % polar coordinates
  r=sqrt(x.*x+y.*y);
  theta=atan2(y,x);
  % B calculation
  l=R -   cos(2*theta).*R/2  ;
  a=Bc - (Bc-Bl)*(r-rc).^2./(R-rc).^2;
  B=Ba*cos(3*pi*r./l)+a  ;

end
```

The initial calving front is set at $r = r_c = 750\,\mathrm{km}$. The computational domain should obviously be large enough to for the calving front to be within the domain. In the runs done with Úa a circular computational domain with a radios of 1000 km was used.

The value for rate factor A corresponds to an ice temperature of $-20\,C^\circ$, assuming the Smith & Morland (1982) conversion:

$$A(T) = A_0\, f(T)$$

where

$$f(T) = 1.2478766 \times 10^{-39} \exp(0.32769\,T) + 1.9463011 \times 10^{-10} \exp(0.07205\,T) \quad (f \text{ has no units, } T \text{ in Kelvin})$$
$$A_0 = 5.3 \times 10^{-15} \times 365.25 \times 24 \times 60 \times 60 \quad (\text{units } \mathrm{kPa^{-3}\,a^{-1}})$$

We use Weertman sliding law, often simply written as

$$u_b = C\,\tau_b^m\ ,$$

where C is the basal slipperiness and m a stress exponent. Here u_b is the basal sliding velocity and τ_b the bed tangential component of the basal traction. This sliding can also be written more precisely as

$$\boldsymbol{T}\boldsymbol{\sigma}\hat{\boldsymbol{n}} + C^{-1/m}\,\|\boldsymbol{T}\boldsymbol{v}\|^{1/m-1}\,\boldsymbol{T}\boldsymbol{v} = 0 \qquad \text{for } z = B(x,y)$$

where

$$\boldsymbol{T} = \mathbf{1} - \hat{\boldsymbol{n}} \otimes \hat{\boldsymbol{n}},$$

where $\boldsymbol{T}$ is the tangential operator, and $\hat{\boldsymbol{n}}$ unit normal vector to the bed. The sliding law applied over the grounded sections of the ice sheet only. Other formulations for this same sliding law frequently found in the literature are

$$\boldsymbol{t}_b = \mathcal{G}\,C^{-1/m}\,\|\boldsymbol{v}_b\|^{1/m-1}\,\boldsymbol{v}_b, \tag{1}$$

$$= \mathcal{G}\,\beta^2\,\boldsymbol{v}_b, \tag{2}$$

where $\boldsymbol{t}_b$ is the bed-tangential basal traction, β^2 has been defined as,

$$\beta^2 = C^{-1/m}\,\|\boldsymbol{v}_b\|^{1/m-1}\ , \tag{3}$$

and where $\mathcal{G}$ is the grounding-floating mask, with $\mathcal{G} = 1$ where grounded, and $\mathcal{G} = 0$ otherwise.

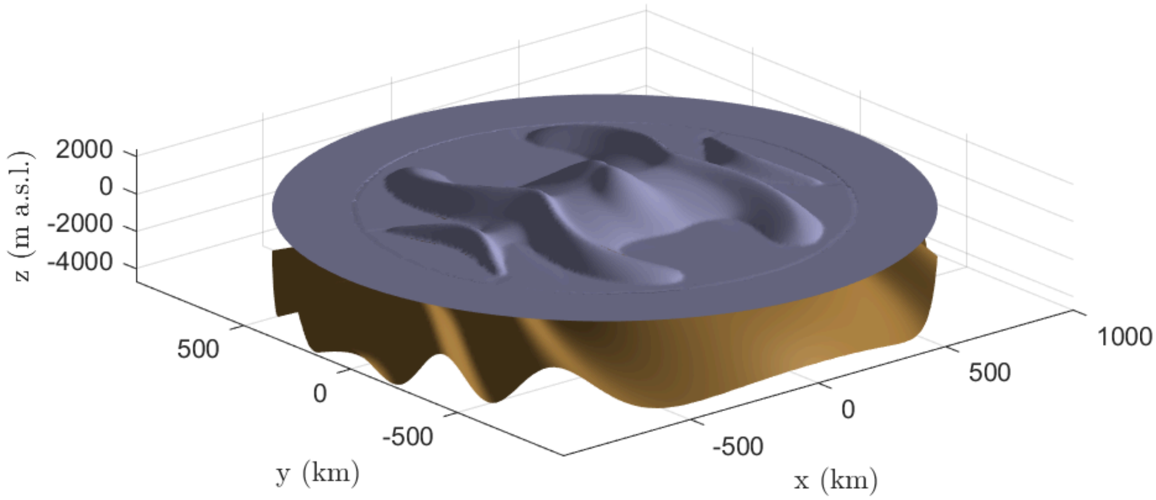

Figure 1: Surface and geometry of Thule. This surface geometry is the steady-state solution when starting with zero ice thickness everywhere.

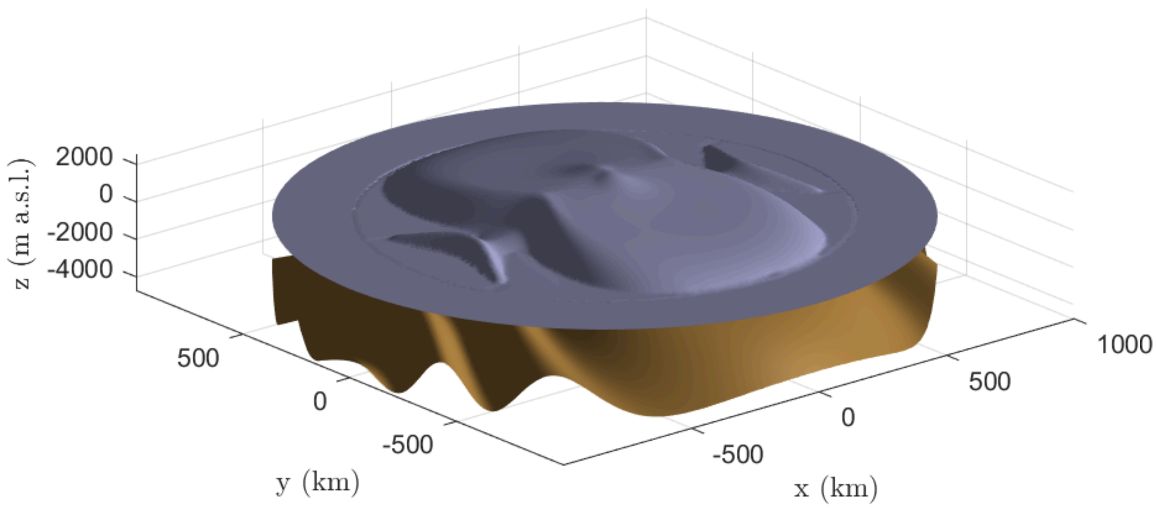

Figure 2: Surface and geometry of Thule. This surface geometry is the steady-state solution when starting with a large initial ice thickness where the initial surface geometry is $s = s_0\sqrt{(}1-r/R)$ where $R = 750\,\text{km}$ and $s_0 = 4000\text{m}$, and r is the radial distance from the centre.

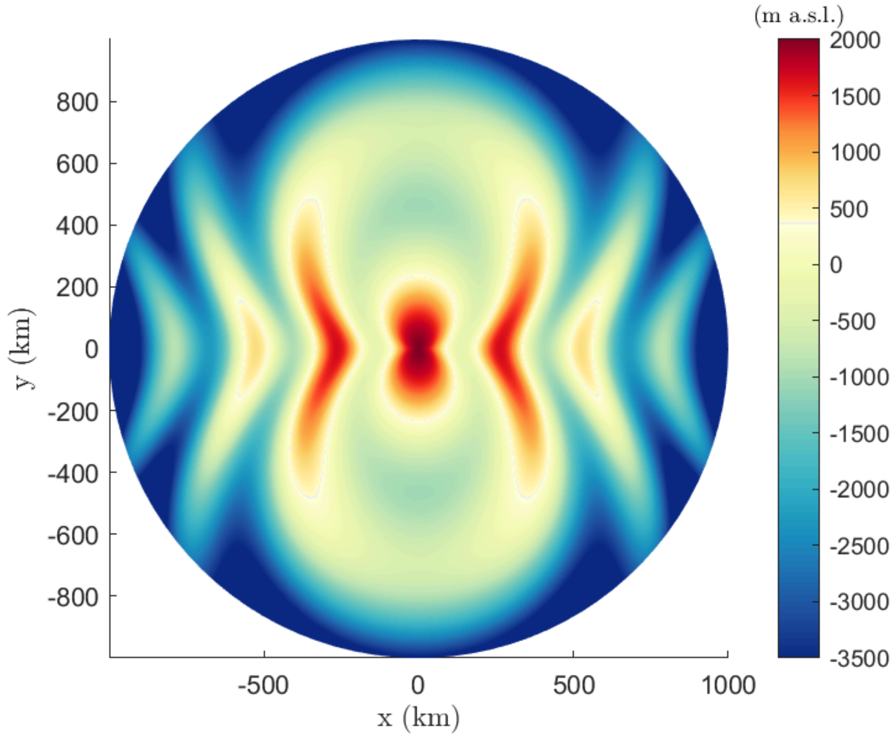

Figure 3: Bedrock geometry of Thule

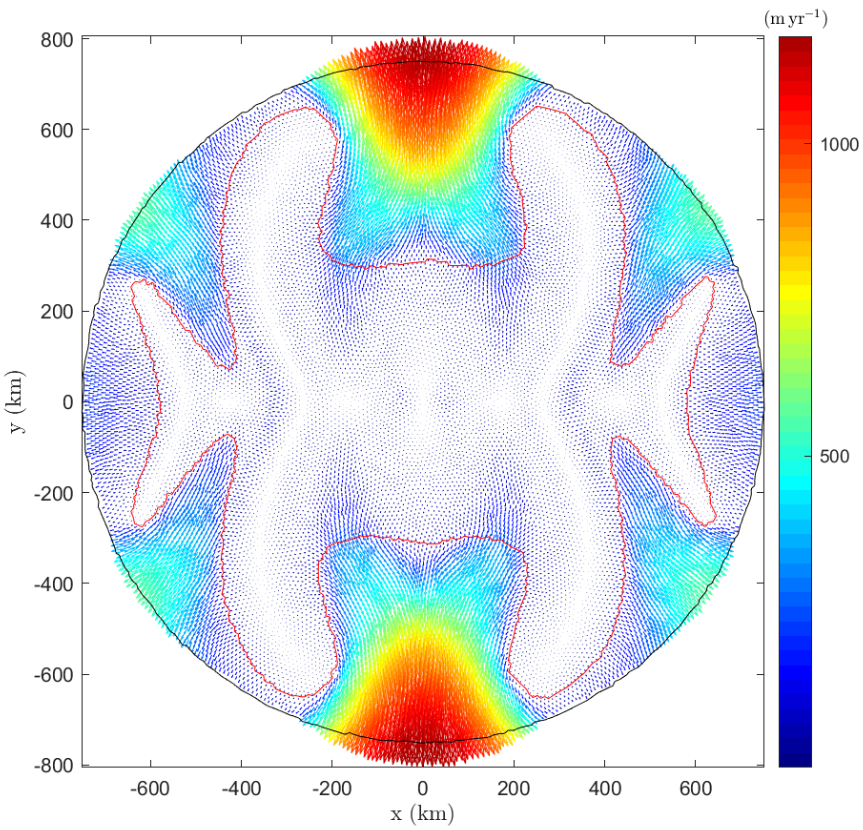

Figure 4: Velocities for steady state Thule Min