Supplementary information for: **<u>The impact of crystallographic orientation fabric on streaming ice kinematics</u>** by Hruby, Gerbi, Koons, Campbell, Martín, Hawley.

These supplementary data files contain the following information:
1. Examples of fabric parameters for AIFlow
2. .sif template for input files
3. A table (S1) listing the model parameters and flux results examined for this study, and tables S2 and S3 listing results of sensitivity analysis. [separate file]
4. Figures (S2-S3) showing velocity and strain-rate distributions for additional models than are shown in the main text.
5. Newly developed solvers for assigning temperature and fabric by node [separate files]

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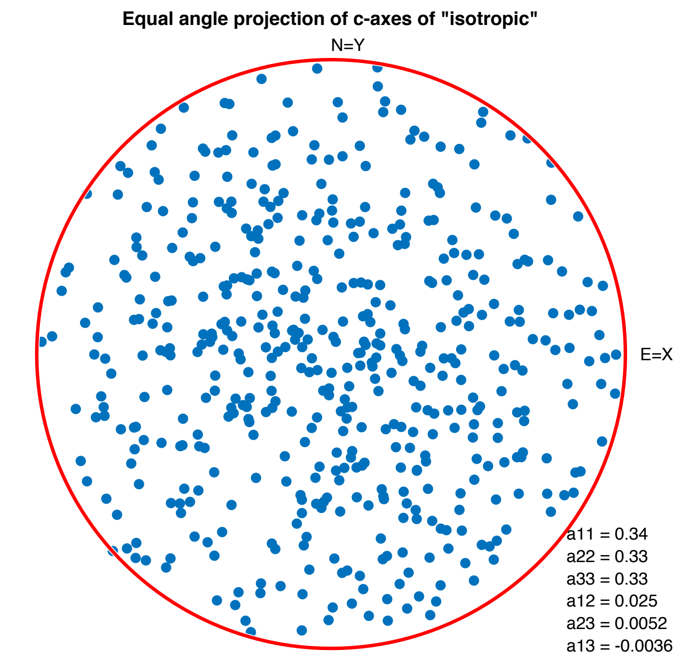
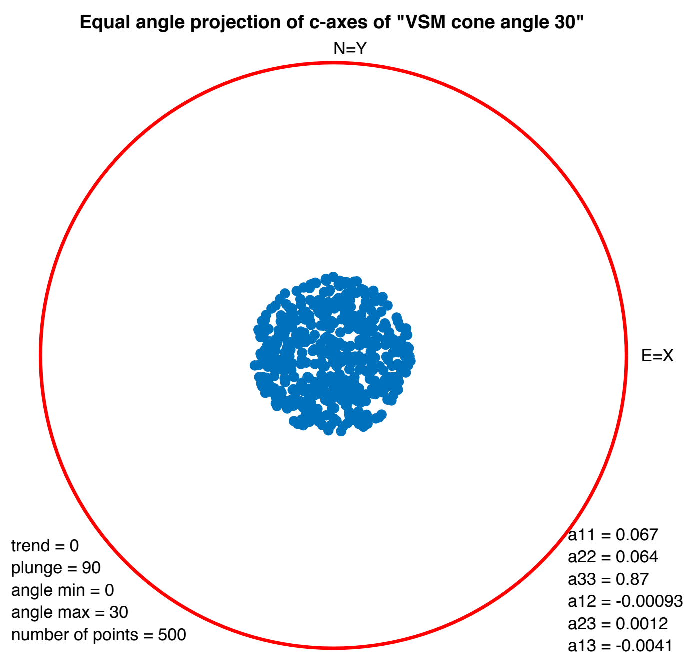
1. Example fabric parameters for AIFlow

AIFlow requires the components of the second order orientation tensor (**A**) as input, subject to the constraint that $\mathbf{A}_{11}+\mathbf{A}_{22}+\mathbf{A}_{33}=1$:

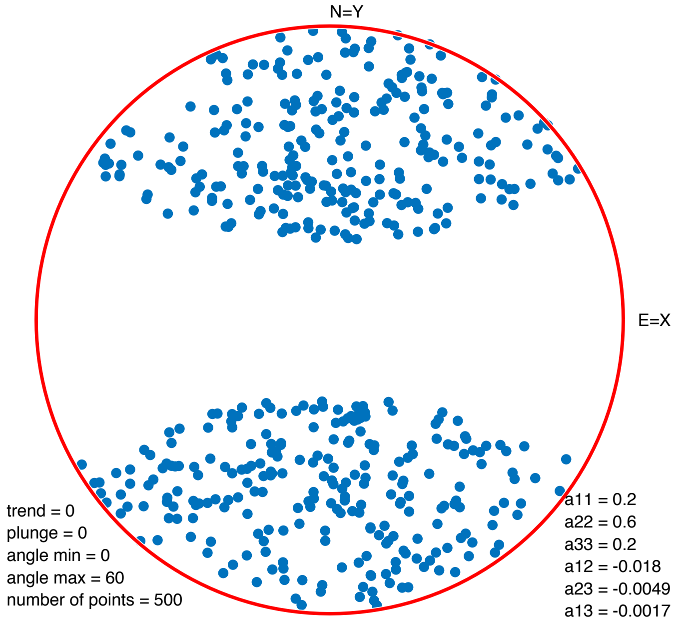
Fabric 1 = $\mathbf{A}_{11}$
Fabric 2 = $\mathbf{A}_{22}$
Fabric 3 = $\mathbf{A}_{12}$
Fabric 4 = $\mathbf{A}_{23}$
Fabric 5 = $\mathbf{A}_{13}$

Fig S1. Examples of synthetic crystallographic fabrics. In contrast to the similar plots in the main text, the view direction for these plots is vertically down; flow is to the right. Each plot includes 500 points. VSM=vertical single maximum, TSM=transverse single maximum.

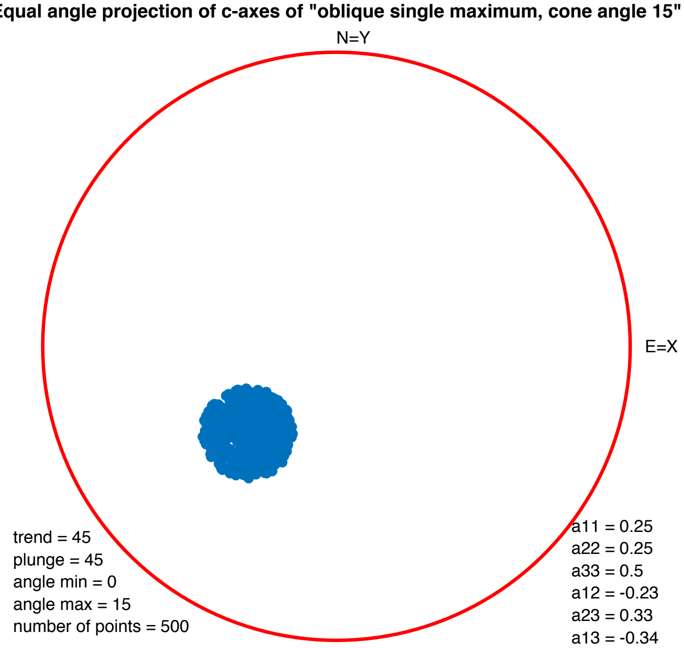

Equal angle projection of c-axes of "isotropic"
N=Y
E=X
a11 = 0.34
a22 = 0.33
a33 = 0.33
a12 = 0.025
a23 = 0.0052
a13 = -0.0036


Equal angle projection of c-axes of "VSM cone angle 30"
N=Y
E=X
trend = 0
plunge = 90
angle min = 0
angle max = 30
number of points = 500
a11 = 0.067
a22 = 0.064
a33 = 0.87
a12 = -0.00093
a23 = 0.0012
a13 = -0.0041

Equal angle projection of c-axes of "TSM cone angle 60"



Equal angle projection of c-axes of "oblique single maximum, cone angle 15"



2. .sif template for input files

The text below is an example .sif for implementation in Elmer/Ice.

```
!                              Necessary Items
! Mesh with: mesh.header, mesh.nodes, mesh.element, mesh.boundary,
! in a folder with your geometry name
! .sif file (this one) with whatever solvers you want referenced in it.
!     This .sif file has the two parameter-by-node solvers:
    !       InitializeFabricFromNumberOfNode
    !       InitializeTempFromNumberOfNode
! *** parts are important and/or fun to change

! You will get: a result file and a .vtu file in your mesh folder
! that can be opened and viewed in Paraview


!                                Glacier geometry

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
check keywords warn
echo on

!***************************************************************************!

$Step = "result_name"

!***************************************************************************!

!Defining MATC: MATC is another code that Elmer calls on to use
$function conductivity(T)  { _conductivity=9.828*exp(-5.7E-03*T)}
$function capacity(T) { _capacity=146.3+(7.253*T)}
       !UNITS

!Parameters: make sure units are correct
!       Mpa - a - m, meters,
$yearinsec = 365.25*24*60*60
$MPainPa = 1.0e6
$rhoi = 917.0/(MPainPa*yearinsec^2)   !Density of ice
$rhow = 1000.0/(MPainPa*yearinsec^2)  !Density of water
$gravity = -9.81*yearinsec^2   !m/s^2

!Prefactor from Cuffey and Paterson (2010) in MPa^{-3} a^{-1}
$A1 = 1.2e-25*1.0e18*yearinsec !In s^-1 Pa^-3 for n=3 and for -20 degC.
$A2 = 3.5e-25*1.0e18*yearinsec !In s^-1 Pa^-3 for n=3 and for -10 degC. This
matches with Q2.
$Q1 = 60.0e3 !kJ/mol, so e3 changes it to J/mol
$Q2 = 115.0e3 !kJ/mol, so e3 changes it to J/mol

Constants
  Water Density = Real $rhow
End

!*******************************************************************

Header       !Where to search for the mesh
```

```
  Mesh DB "." "simplejarvis"
End

!*******************************************************************

Simulation
  Coordinate System  =  Cartesian 3D
  Simulation Type = "Steady" !Transient
  Steady State Min Iterations = 1
  Steady State Max Iterations = 1
  Timestepping Method = "BDF"           ! All of these are for the
  BDF Order = 1                         ! "transient" Simulation
!  Timestep Sizes = 100.0               ! Type
!  Timestep Intervals =  5              !
!  Output Intervals = 1                 !
  Output File = "$Step".result"
  Post File = "$Step".vtu"       !File for paraview
  max output level = 4
  Initialize Dirichlet Conditions = Logical True
End


! Solvers

Solver 1
  Equation = InitializeFabric
  Variable = Fabric
  Variable DOFs = 5
  Procedure = "InitializeFabricFromNumberOfNode" "InitializeFabric"
!  Optimize Bandwidth = False
End

Solver 2
  Equation = InitializeTemp
  Variable = Temperature
  Variable DOFs = 1
  Procedure = "InitializeTempFromNumberOfNode" "InitializeTemp"
!  Optimize Bandwidth = False
End

Solver 3
  Equation = AIFlow
  Variable = AIFlow
  Variable DOFs = 4 !3 for 2D (u,v,p) -- 4 for 3D (u,v,w,p)
                    !This is the velocity
                    !AIFlow1 is u, 2 is v, 3 is w, 4 is pressure

  Exported Variable 1 = Temperature ! Define Temperature
  Exported Variable 1 DOFS = Integer 1

  Exported Variable 2 = Fabric ! Define Fabric Variable
  Exported Variable 2 DOFS = Integer 5 ! Mandatory if Isotropic=False

  Exported Variable 3 =  StrainRate ! Compute SR
  Exported Variable 3 DOFS = Integer 6 ! 4 in 2D 6 in 3D (11,22,33,12,23,31)

  Exported Variable 4 =  DeviatoricStress ! Compute Stresses
```

```
  Exported Variable 4 DOFS = Integer 6 ! 4 in 2D 6 in 3D (11,22,33,12,23,31)

  Exported Variable 5 = Spin ! Compute Spin
  Exported Variable 5 DOFS = Integer 3 !1 in 2D 3 in 3D (12,23,31)

  Procedure = "ElmerIceSolvers" "AIFlowSolver_nlD2"
End


!  The Body

!The Ice:
Body 1
  Equation = 1
  Body Force = 1
  Material = 1
  Initial Condition = 1
End


!  Equations

Equation 1
  Active Solvers(3) = 1 2 3
 ! Flow Solution Name = String "Flow Solution"
  Convection = String Computed
End


!  Body Forces

Body Force 1
  !Flow BodyForce 1 = Real 0.0
  !Flow BodyForce 2 = Real 0.0
  !Flow BodyForce 3 = Real $rhoi*gravity

  AIFlow Force 1 = Real 0.0
  AIFlow Force 2 = Real 0.0
  AIFlow Force 3 = Real $rhoi*gravity
End


!  Material

Material 1
  Density = Real $rhoi
  Viscosity = 1.0e8 ! Dummy but avoid warning output
  Viscosity Model = String "Glen"
!  Viscosity Exponent = Real MATC "1.0/3.0"
  Glen Enhancement Factor = Real 1.0
  Glen Exponent = Real 3.0
  Powerlaw Exponent = Real 3.0 ! Real $nGlen
  Viscosity File = FILE "040010010.Va"
           !Contains the tabulated relative viscosities

  Rate Factor 1 = Real $A1
  Rate Factor 2 = Real $A2
```

```
  Activation Energy 1 = Real $Q1 ! for T<TL in SI because R is in SI
  Activation Energy 2 = Real $Q2  ! for T>TL

  Critical Shear Rate = Real 1.0e-10
  Cauchy = Logical True
  Diffusion Parameter = Real 0.0
           !Diffusion term. By default set to 0 if not defined
  Isotropic = Logical False ! If True, no need of Fabric variable
  Min Second Invariant = Real 1.0e-10
           !Min value for the second invariant of strain-rates
  Fluidity Parameter = Real 240000 ! Bn(T0) MPa^-n yr^-1

  Reference Temperature = Real -10.0
  Limit Temperature = Real 0.0
!  Constant Temperature = Real -10.0

  !!!! For Fabric Solver
  Interaction Parameter = Real 0.
           !0 => Fabric Evolution function of Strain rates
           !1 => Fabric Evolution function of dev stresses
           !If not defined set to the default value given
           !in the viscosity file
End


!  Initial Conditions

Initial Condition 1
  Pressure = Real 0.0
  Velocity 1 = Real 0.0
  Velocity 2 = Real 0.0
  Velocity 3 = Real 0.0

!****************************************************************************
!! Comment these out if you are using the Initialize fabric or temp solvers

!  Temperature = Real -10.0

!  Fabric 1 = Real 0.333 !a2_11
!  Fabric 2 = Real 0.333 !a2_22
!  Fabric 3 = Real 0.0 !a2_12
!  Fabric 4 = Real 0.0 !a2_23
!  Fabric 5 = Real 0.0 !a2_13

!****************************************************************************
!
  AIFlow 1 = Real 0.0 ! u_1
  AIFlow 2 = Real 0.0 ! u_2
  AIFlow 3 = Real 0.0 ! p for 2D u_3 for 3D
  AIFlow 4 = Real 0.0 ! only for 3D = p
End


!  Boundary Conditions
    ! Change the numbers of these Target Boundaries
    ! based on what geometry you use
```

```
! lateral side of the glacier
Boundary Condition 1
  Target Boundaries(1) = 1
! Dirichlet condition for velocity
  AIFlow 1 = Real 0.0
!Normal-Tangential boundary condition (for Dirichlet and Neumann):
  Normal-Tangential AIFlow = Logical True

!*****************************************************************************
*! How to make it slip: 1.0 is no slip, 0.01 is temperate glacier
  AIFlow Slip Coeff 2 = Real 1.0 !0.01
  AIFlow Slip Coeff 3 = Real 1.0 !0.01
!*****************************************************************************
*
End

Boundary Condition 2
  Target Boundaries(1) = 3
  Velocity 1 = Real 0.0
  Velocity 2 = Real 0.0
  Velocity 3 = Real 0.0
! Dirichlet condition for velocity
  AIFlow 1 = Real 0.0
  AIFlow 2 = Real 0.0
  AIFlow 3 = Real 0.0
!  Neumann condition for AIFlow:
  Normal force = Real 0. ! a pressure along the normal of the surface
  Force 1 = Real 0. ! stress along x (Sxn, with n the surface normal)
  Force 2 = Real 0. ! stress along y (Syn)
  Force 3 = Real 0. ! stress along z (Szn)

  !Normal-Tangential boundary condition (for Dirichlet and Neumann):
  Normal-Tangential AIFlow = Logical True
  Normal-Tangential Velocity = True
End
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

!  The End
```

3. Table S1. Model parameters and flux results examined for this study. **See next page.**

4. Velocity and strain-rate distributions for additional models than are shown in the main text

Figure S5. Example parameter, velocity, and strain rate distributions within a cross-section of the glacier at the flux gate. (a) Varying temperature only. (b) Varying fabric only. (c) Varying both temperature and fabric. Flow is out of the page and the model is non-slipping.

Figure S2a.

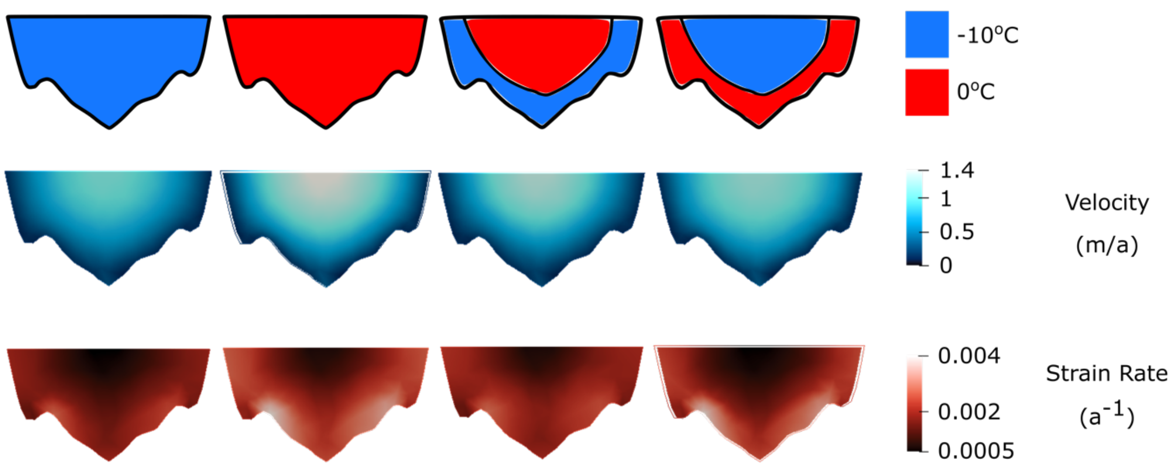
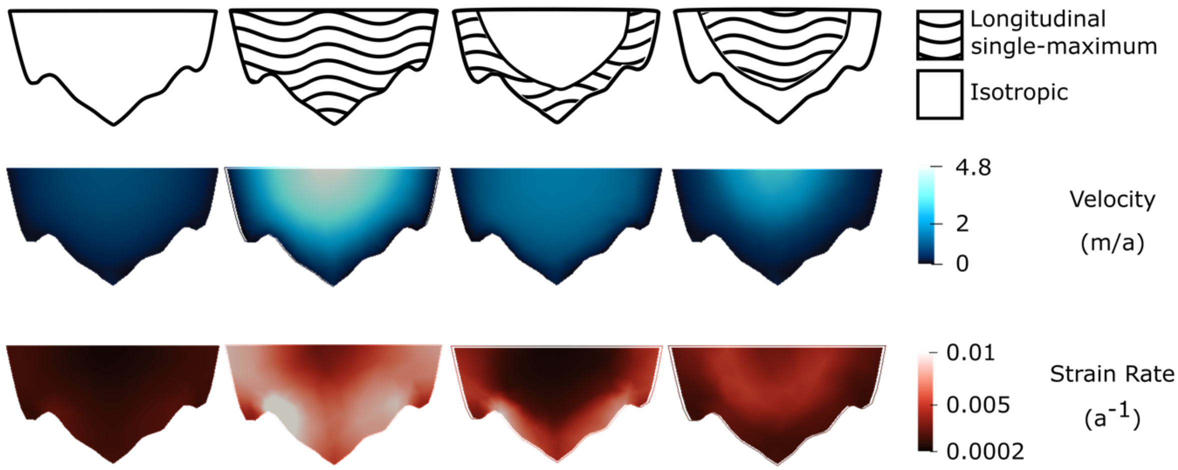
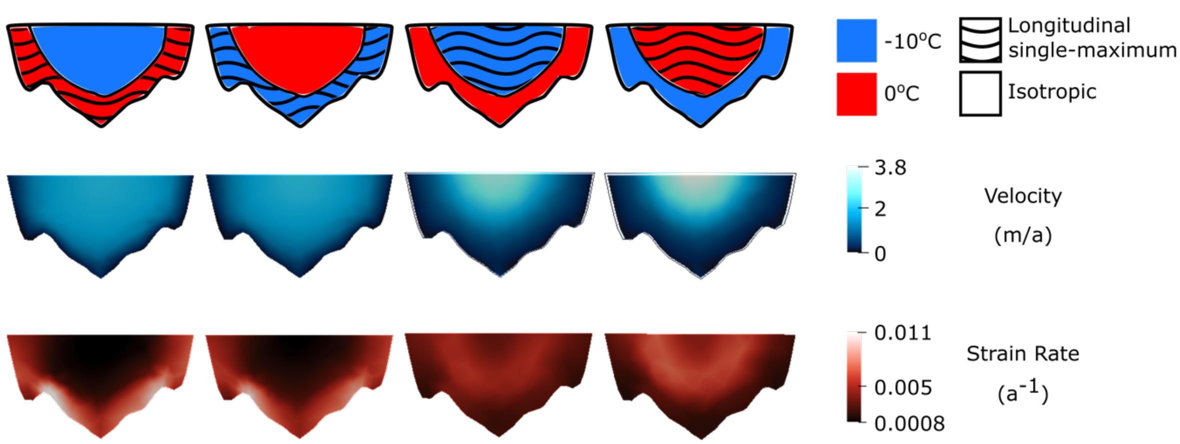


Figure S2b.



Longitudinal
single-maximum
Isotropic
4.8
2
0
Velocity
(m/a)
0.01
0.005
0.0002
Strain Rate
(a-1)

Figure S2c.



-10°C
0°C
Longitudinal
single-maximum
Isotropic
3.8
2
0
Velocity
(m/a)
0.011
0.005
0.0008
Strain Rate
(a-1)

Figure S3. Example parameter, velocity, and strain rate distributions within a cross-section of the ice stream at the flux gate. (a) Varying temperature only. (b) Varying fabric only. (c) Varying both temperature and fabric. Only half of the cross-section is shown; the other half is a mirror image. Flow is out of the page.

Figure S3a.

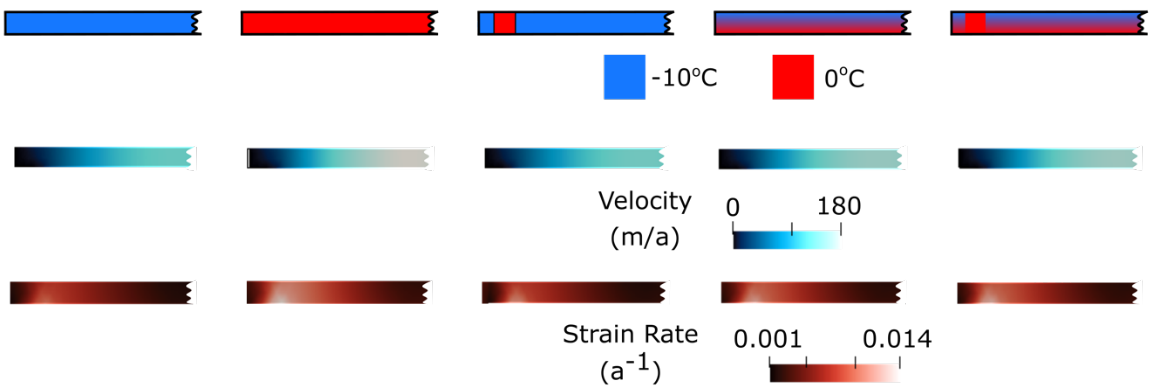


Figure S3b.

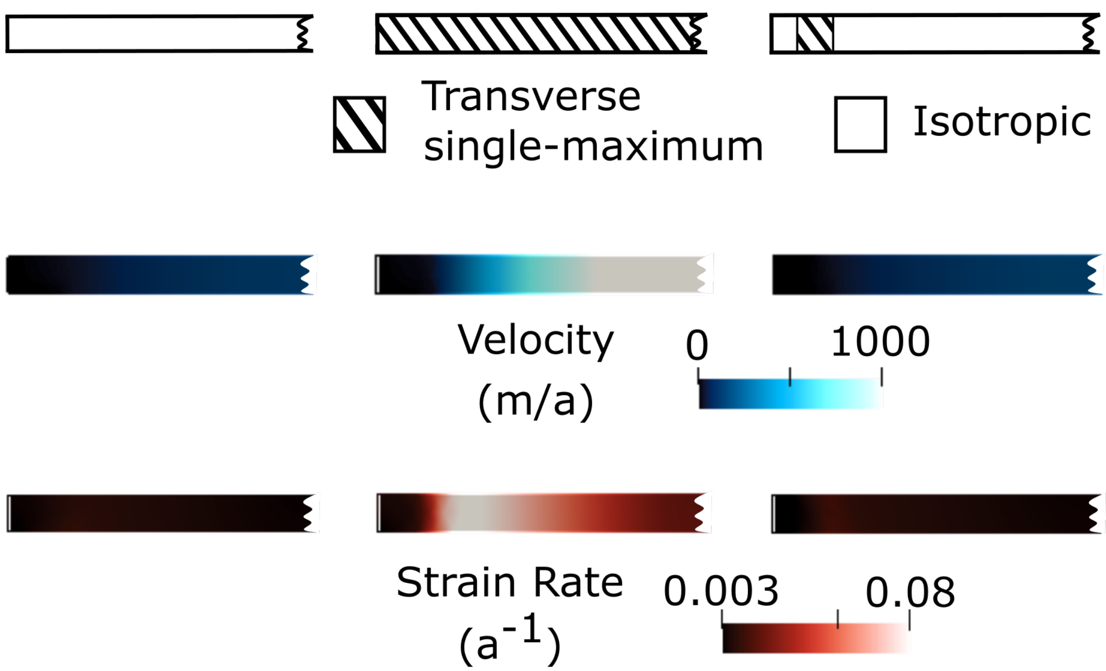
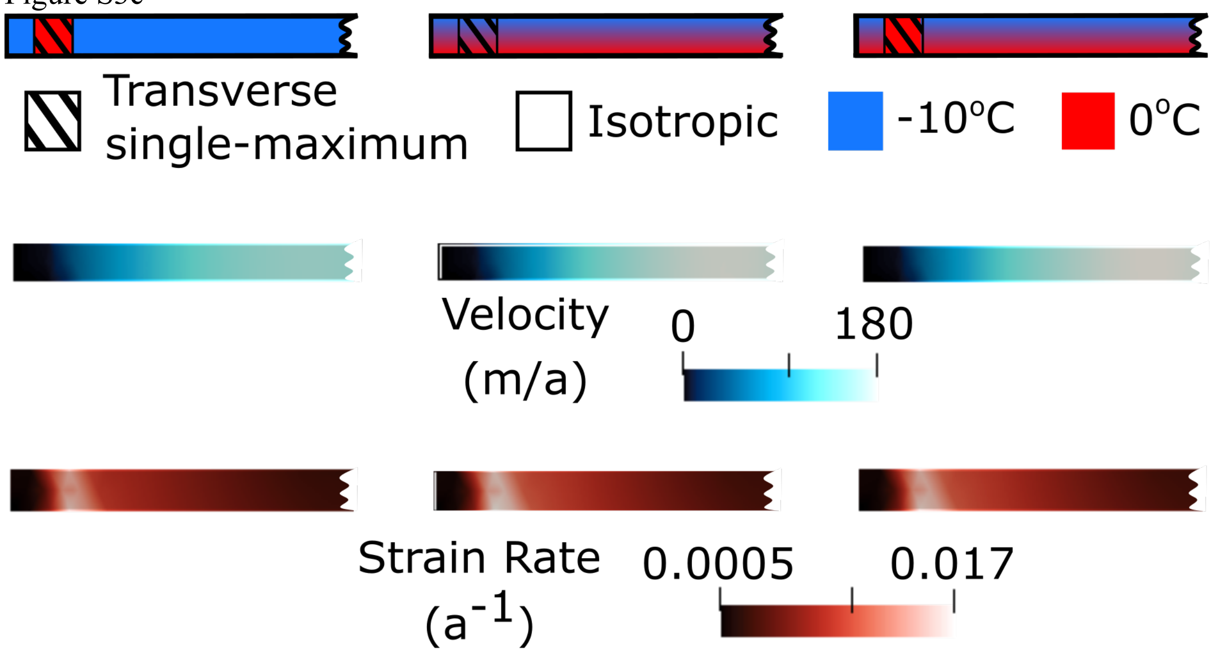


Figure S3c


Transverse single-maximum
Isotropic
-10°C
0°C
Velocity (m/a)
0
180
Strain Rate (a-1)
0.0005
0.017