**A simplified energy-balance model for ice melt below debris**

By Michael McCarthy

This model simulates ice melt below debris at the surfaces of debris-covered glaciers using a simplified energy-balance approach.

It solves heat conduction through the debris as such:

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|  |  | (1) |

where is debris density, is debris specific heat capacity, is debris thermal conductivity, is time, is depth within the debris, and is debris temperature.

The boundary condition at the debris surface is the simplified debris-surface energy balance:

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

where is incoming shortwave radiation, is outgoing shortwave radiation, is air temperature, and and are free parameters to be calibrated. This equation has a similar form to the simplified debris-free energy balance of Oerlemans (2001). Surface temperature is determined iteratively for each model timestep using Newton’s method, following Reid and Brock (2010).

The boundary condition at the ice surface is the temperature of melting ice, (273.15 K):

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| --- | --- | --- |
|  |  | (3) |

where is debris thickness.

Melt rate, , is computed as follows:

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| --- | --- | --- |
|  |  | (4) |

where is the model timestep, is ice density, and is the latent heat of fusion of water.

**References**

Oerlemans, J. (2001). Glaciers and climate change. CRC Press.

Reid, T. D., & Brock, B. W. (2010). An energy-balance model for debris-covered glaciers including heat conduction through the debris layer. Journal of Glaciology, 56(199), 903-916.