Remote sensing of Greenland Ice Sheet supraglacial stream discharge

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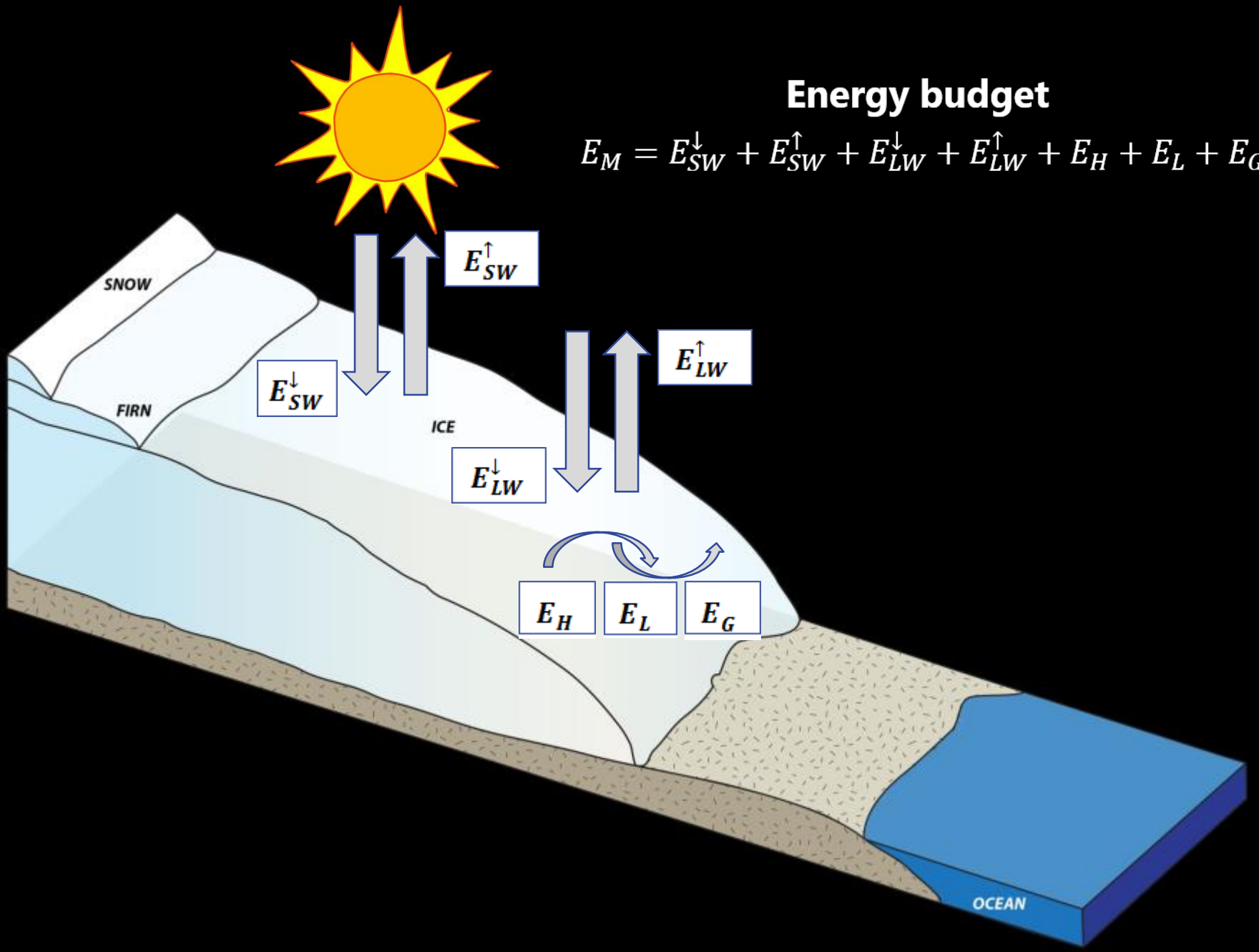
Energy budget

$$E_M = E_{SW}^{\downarrow} + E_{SW}^{\uparrow} + E_{LW}^{\downarrow} + E_{LW}^{\uparrow} + E_H + E_L + E_G$$



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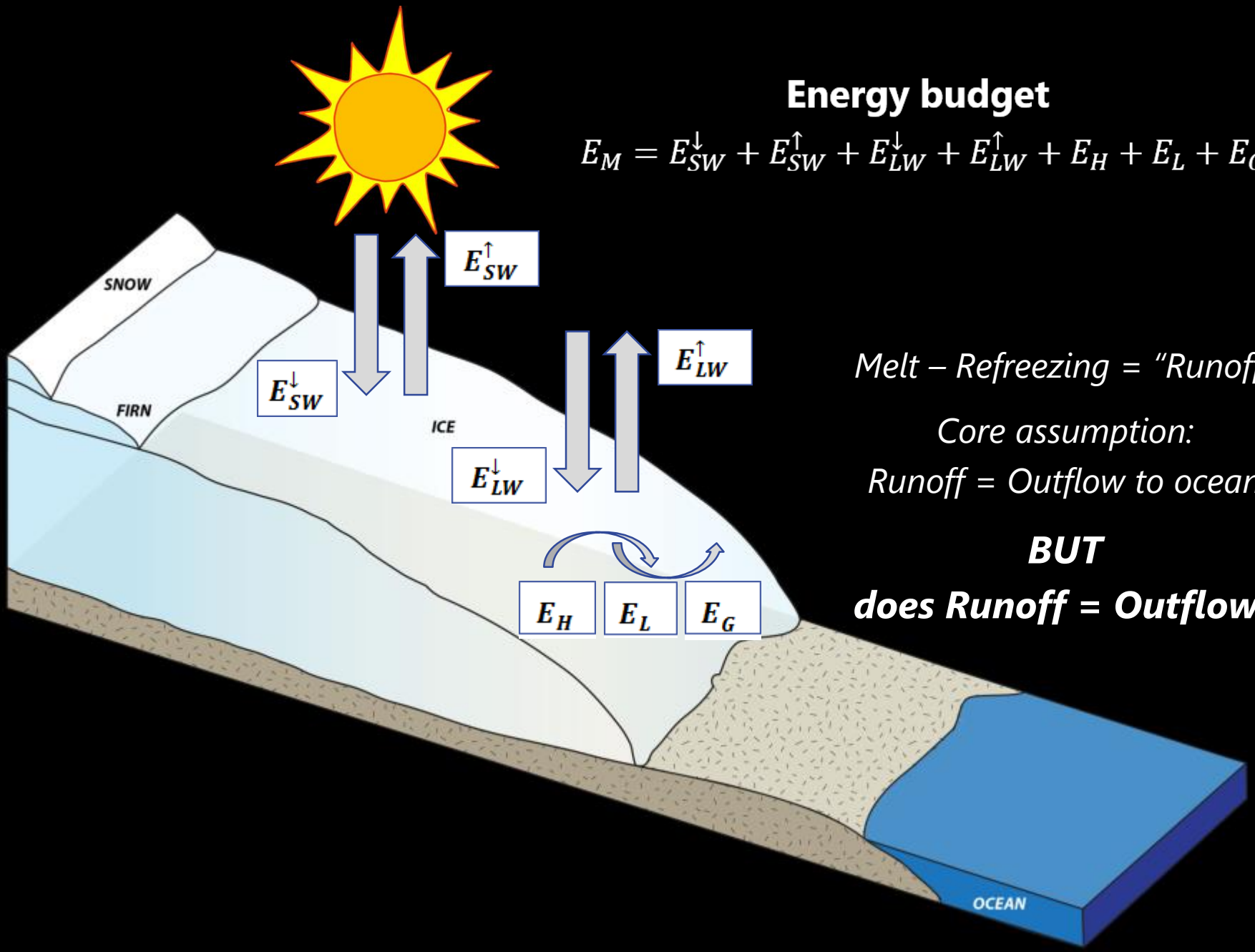


Melt – Refreezing = "Runoff"

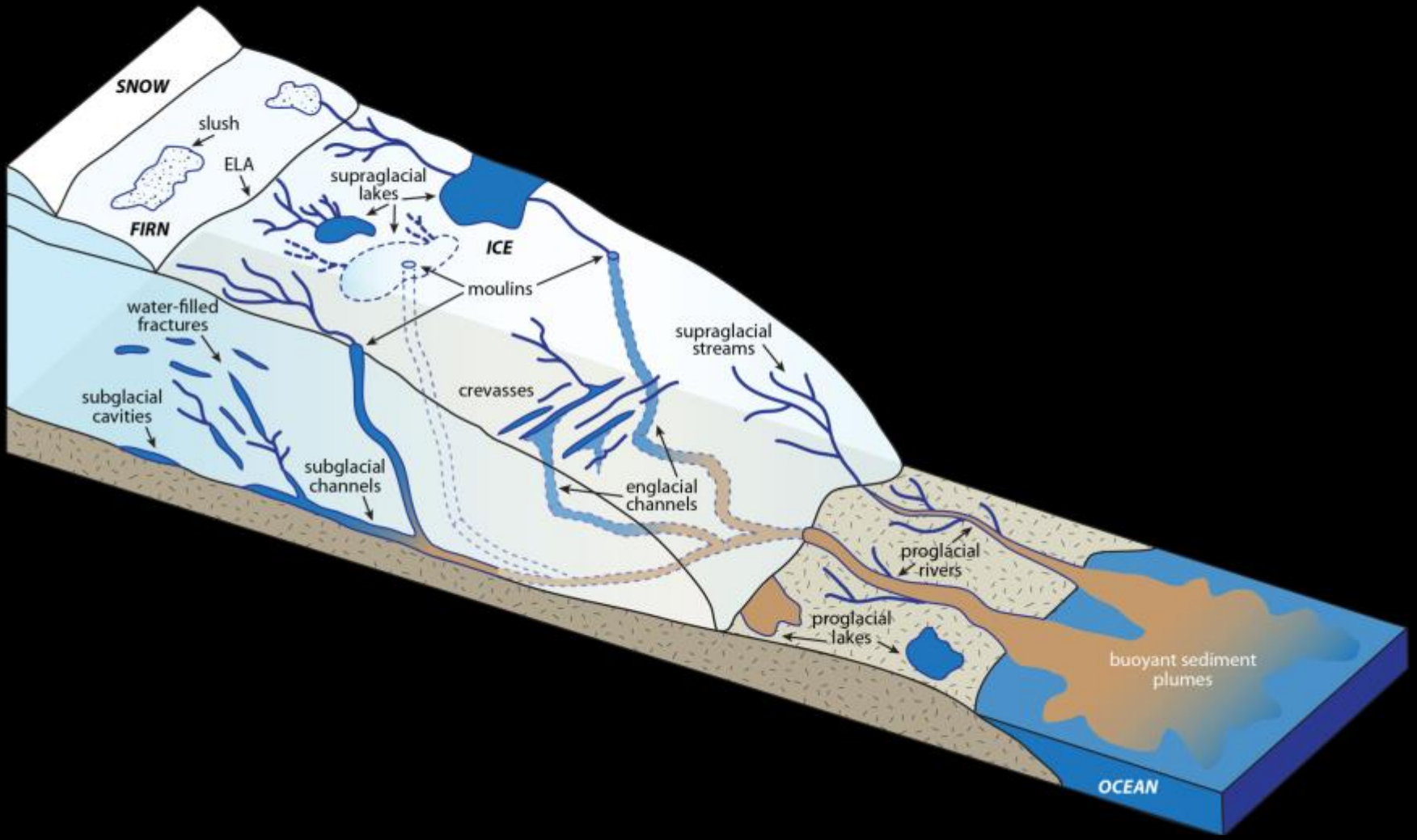
Core assumption:

Runoff = Outflow to ocean

BUT

does Runoff = Outflow?

Overarching goal: To understand Greenland ice sheet hydrology



Chu (2014) *Progress in Physical Geography*

Overview: Supraglacial discharge retrieval method

- ***Pre-processing***
  - WV2 imagery over western Greenland from 2010-2012 (~400 scenes)
  - Orthorectification using 30 m Greenland Ice Mapping Project (GIMP) dem
  - Atmospheric correction using ENVI's FLAASH module

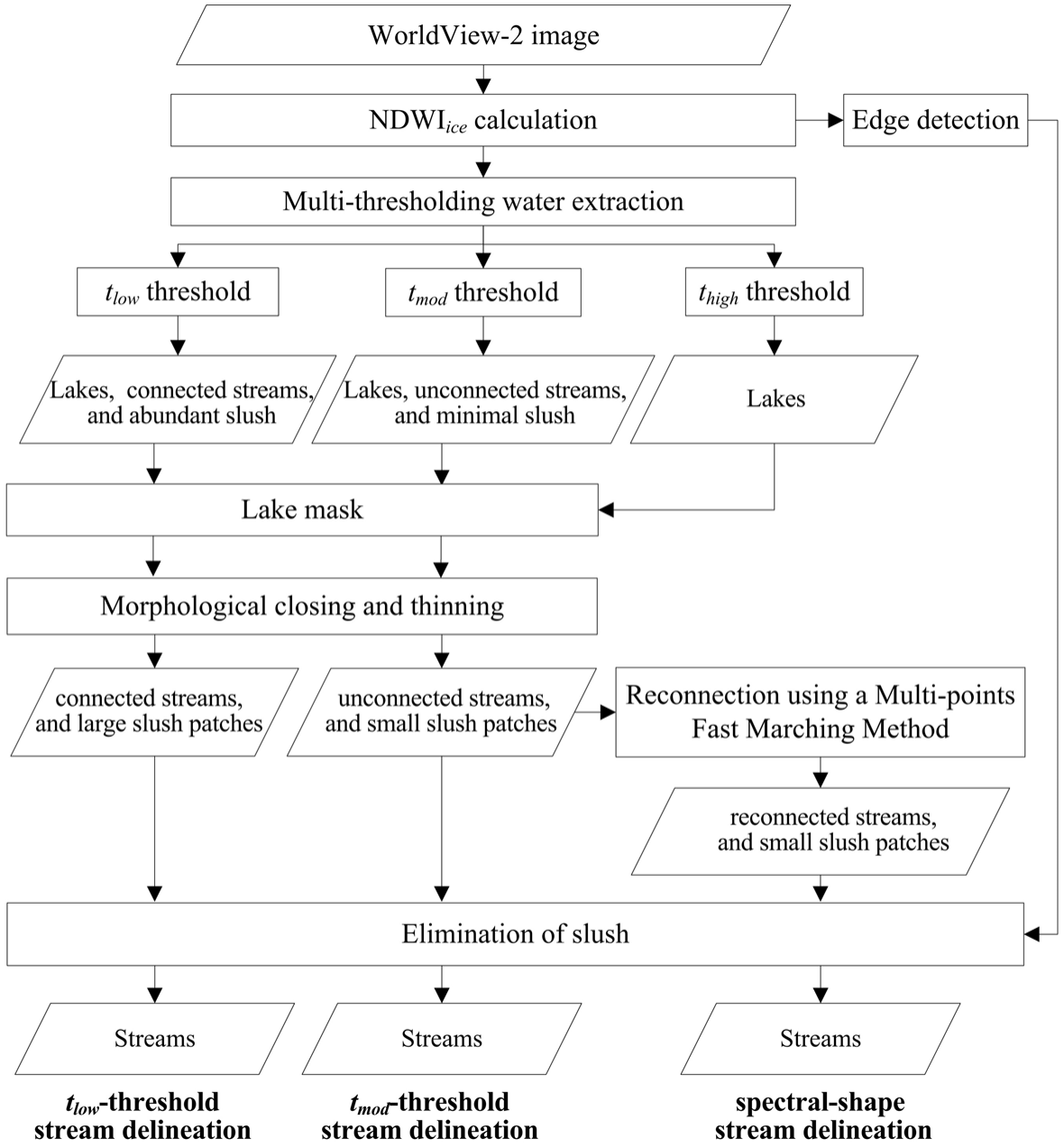
- ***Stream network delineation***
  - Delineate stream networks using a modified method of Yang and Smith (2012)
    - Water mask from modified normalized difference water index (NDWI) threshold

$$\mathrm{NDWI}_{\mathrm{ice}} = \frac{\mathrm{Blue} - \mathrm{Red}}{\mathrm{Blue} + \mathrm{Red}}$$

    - Minimum size threshold to remove groups of pixels too small to be streams/lakes
    - Delineate centerline vector product
  - Manually identify stream networks and moulins (stream termination points)

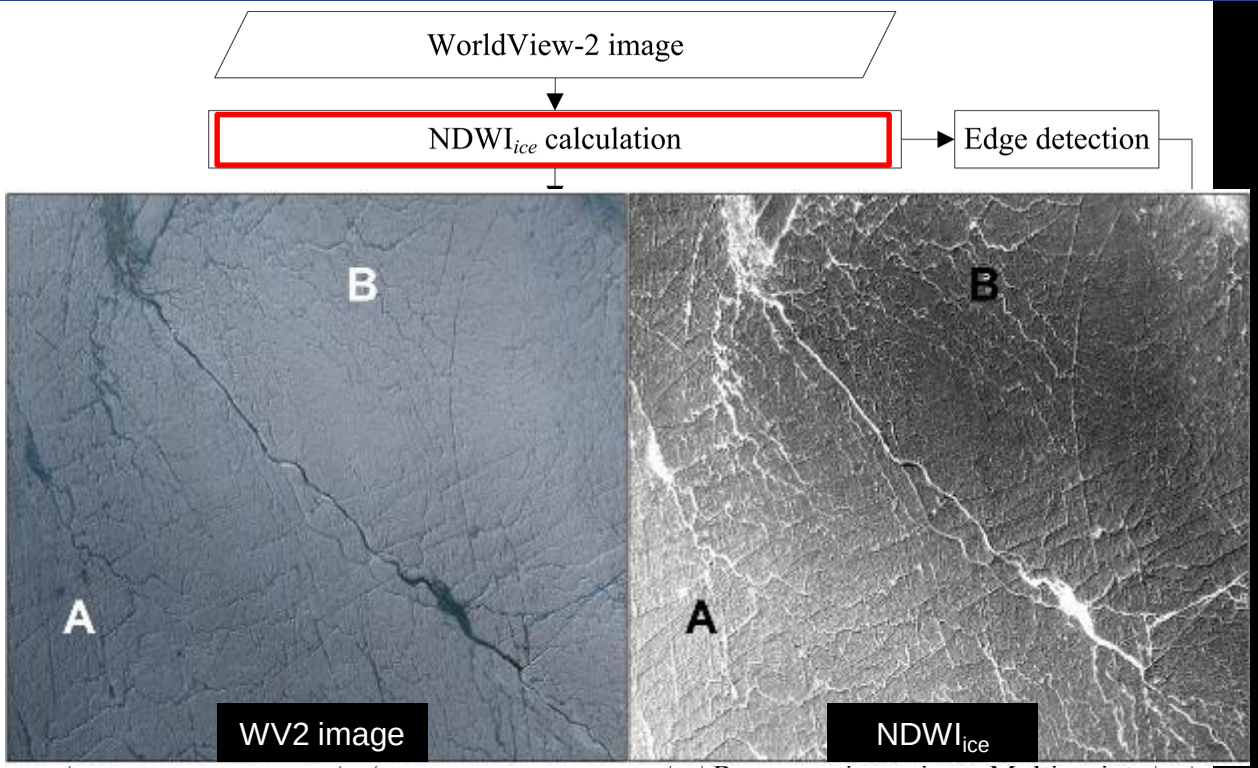
- ***Discharge retrieval (multiple methods)***
  - Width: calculated from water mask for each pixel along the centerline
  - Depth: empirical relationships between field measurements of depth and WV2 reflectance
    - Validate depth retrieval using field measurements of depth from drifter
  - Velocity: calculated from Manning's method based on field-measured Manning's n parameter

Stream delineation



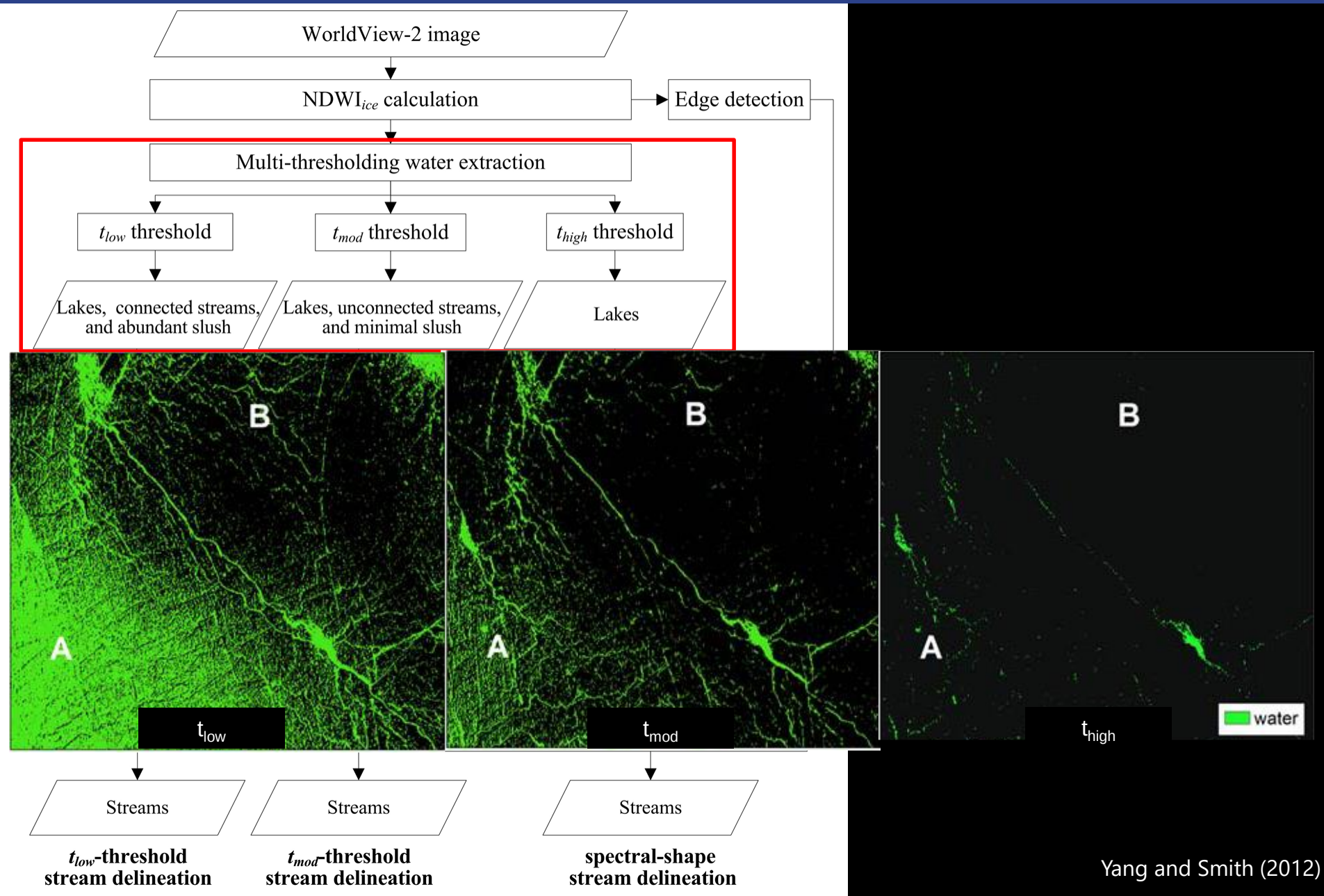
Yang and Smith (2012)

Stream delineation



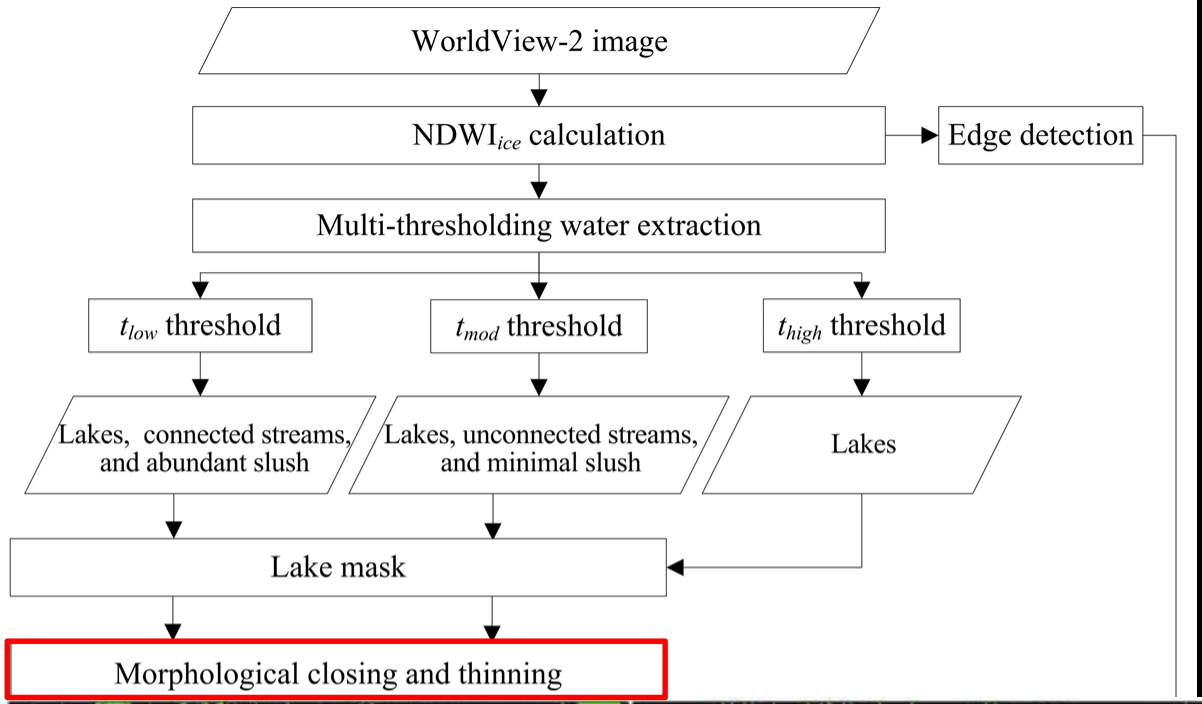
Yang and Smith (2012)

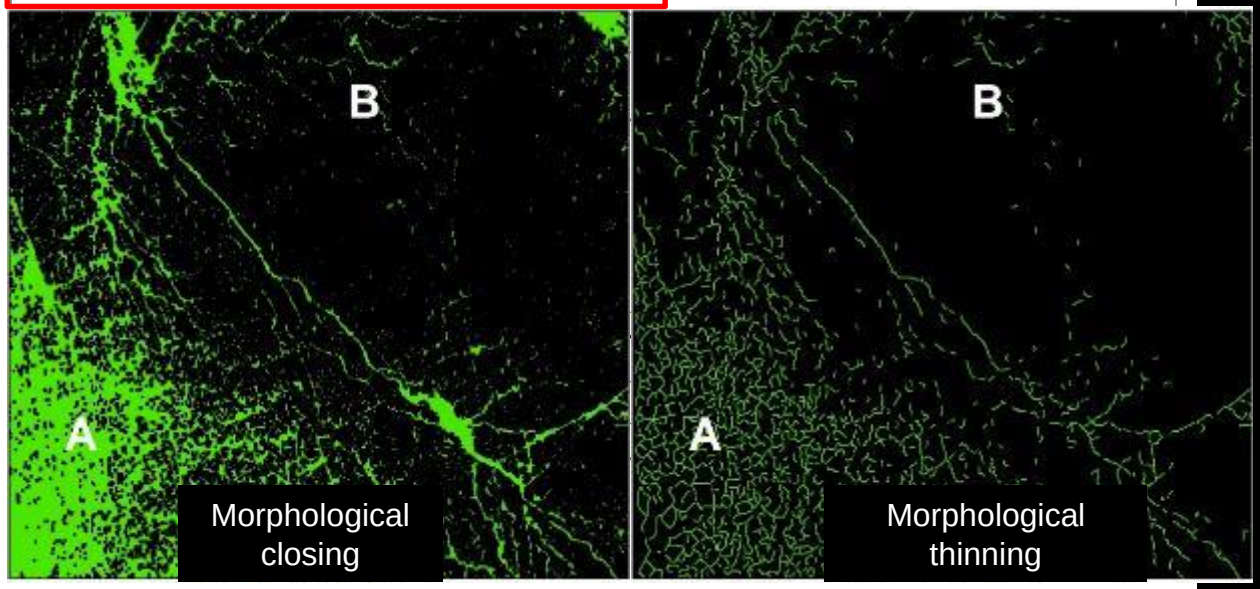
Stream delineation



Yang and Smith (2012)

Stream delineation

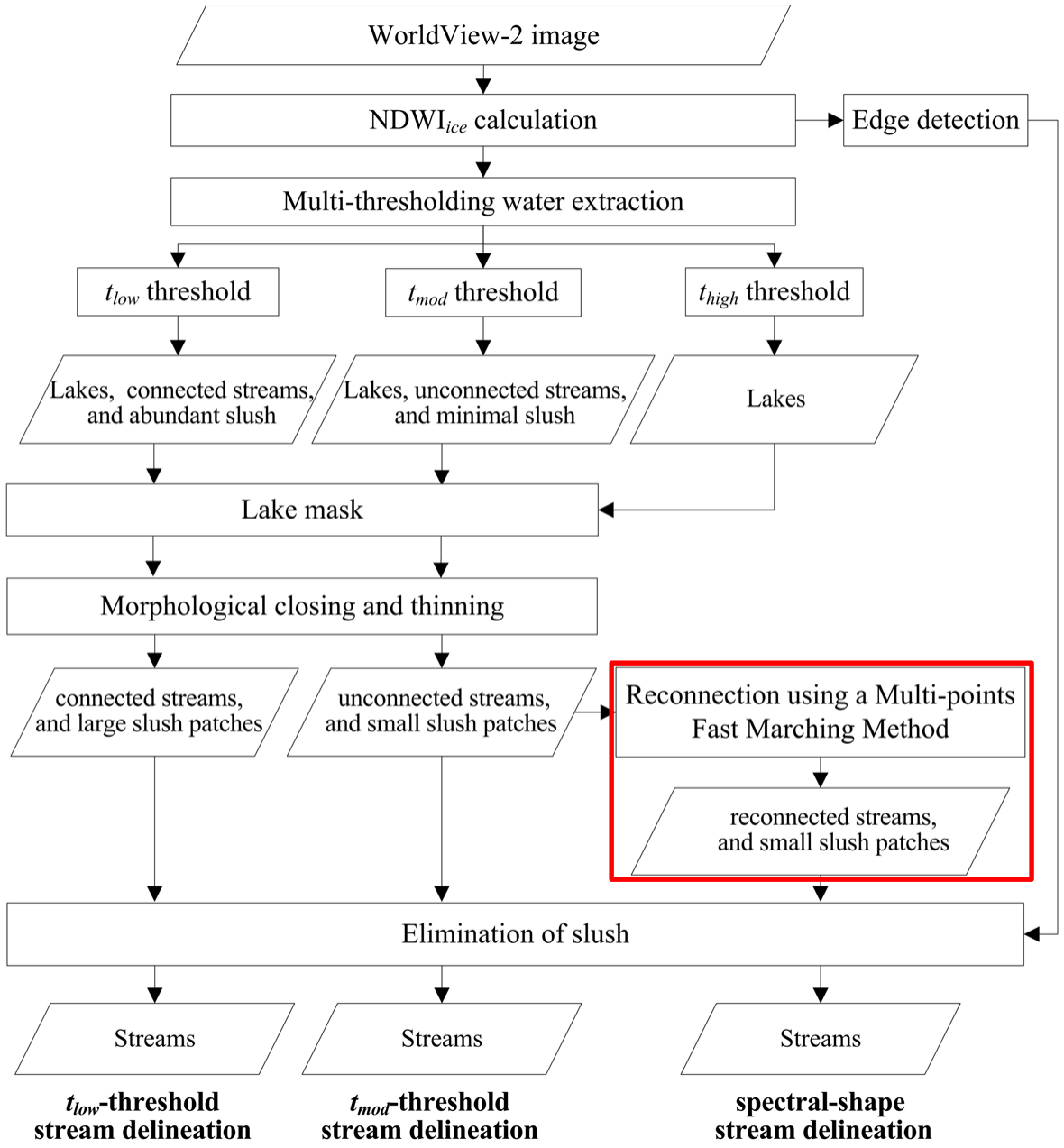


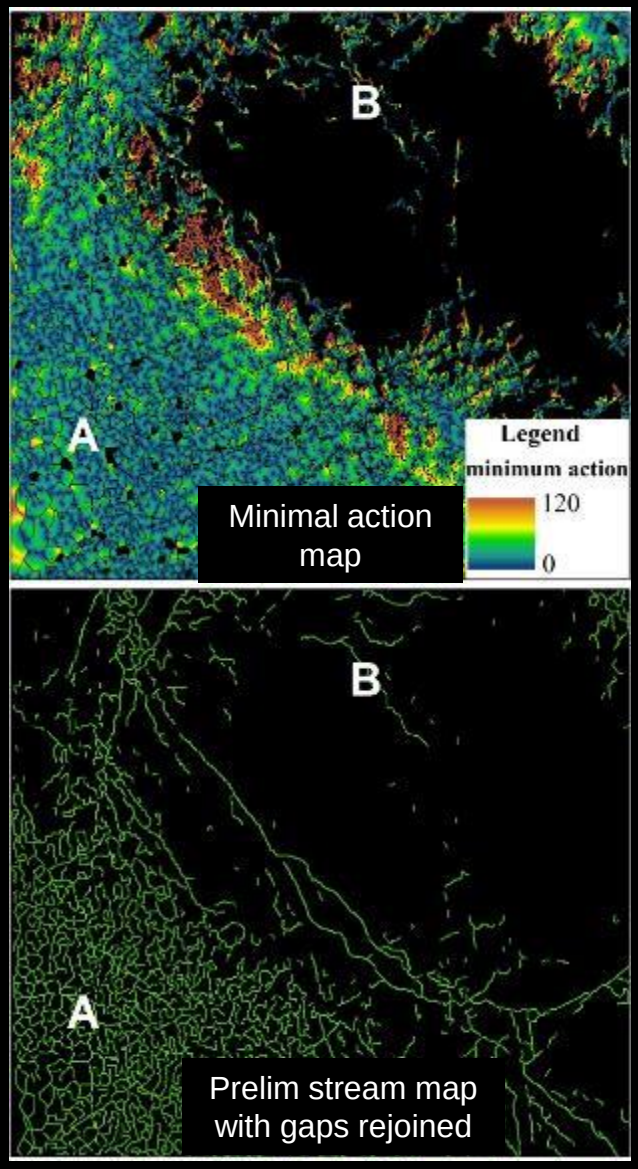


t_{high}

Yang and Smith (2012)

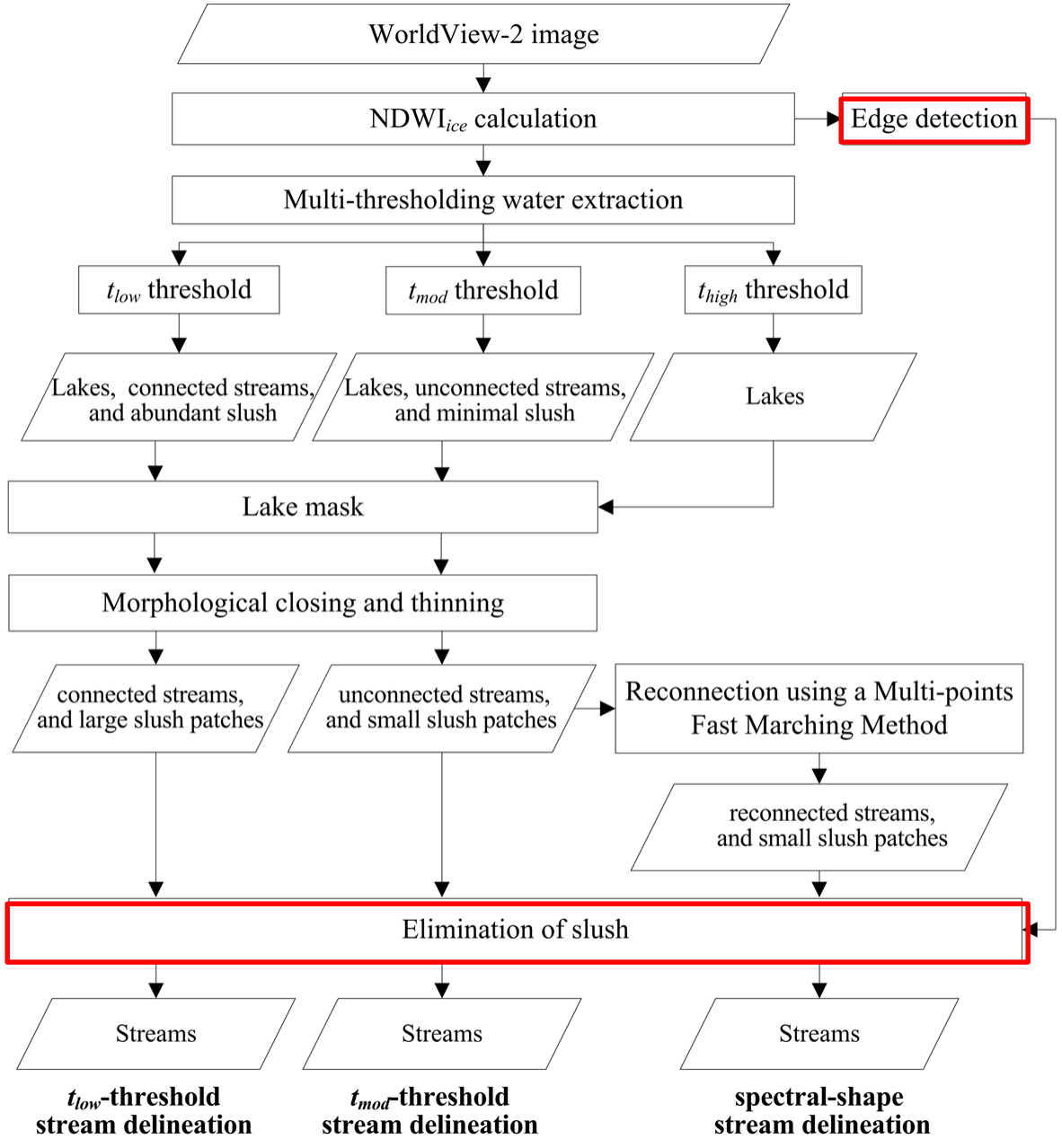
Stream delineation

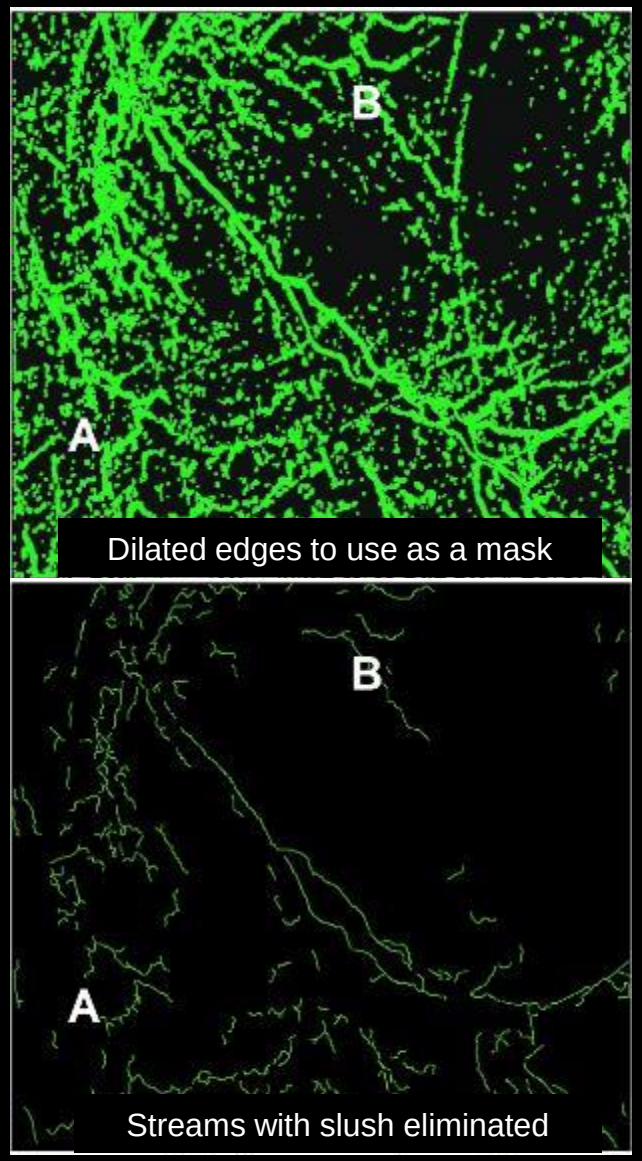




Yang and Smith (2012)

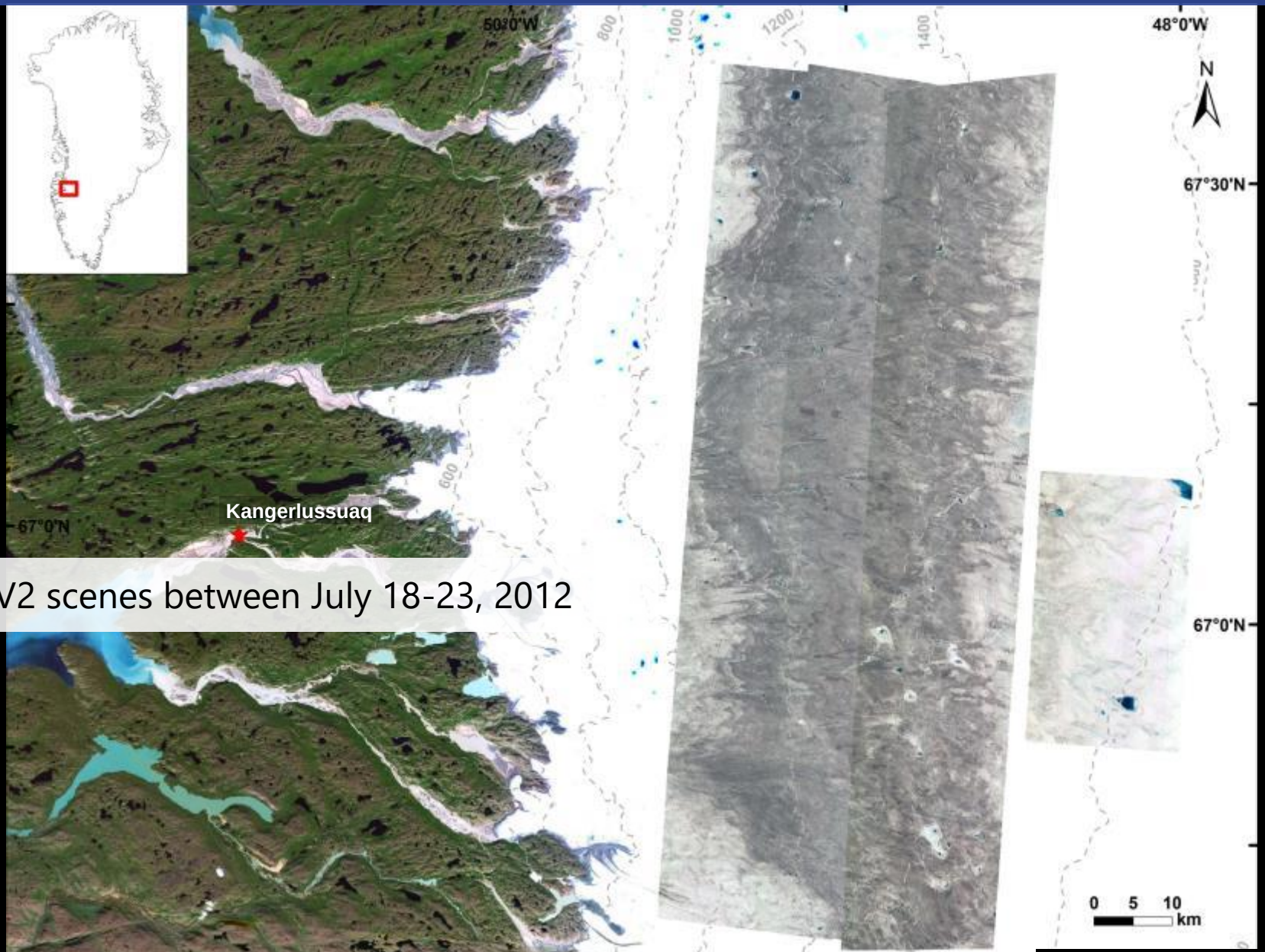
Stream delineation





Yang and Smith (2012)

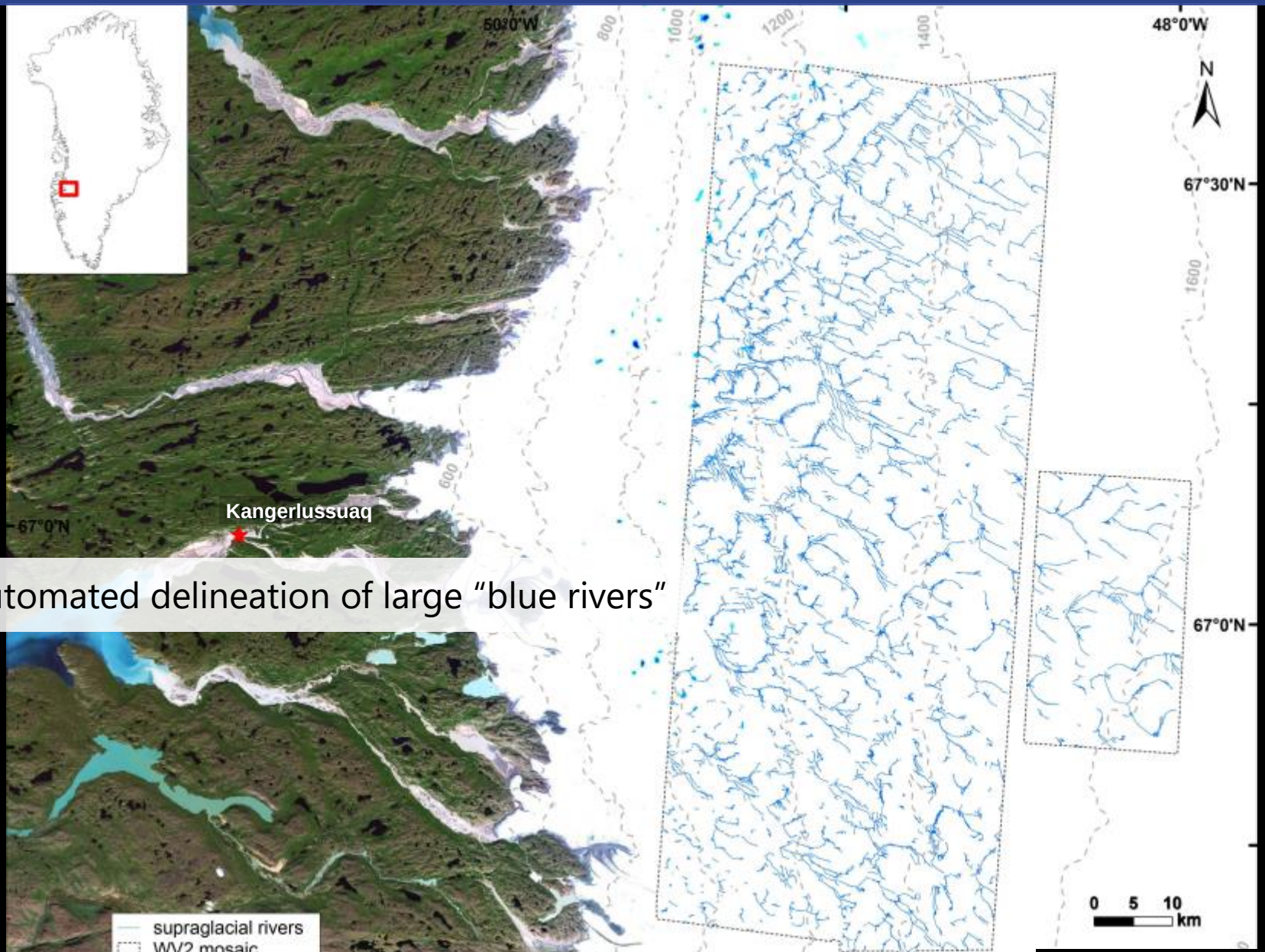
WorldView-2 satellite imagery



- WV2 scenes between July 18-23, 2012

Smith et al., 2015

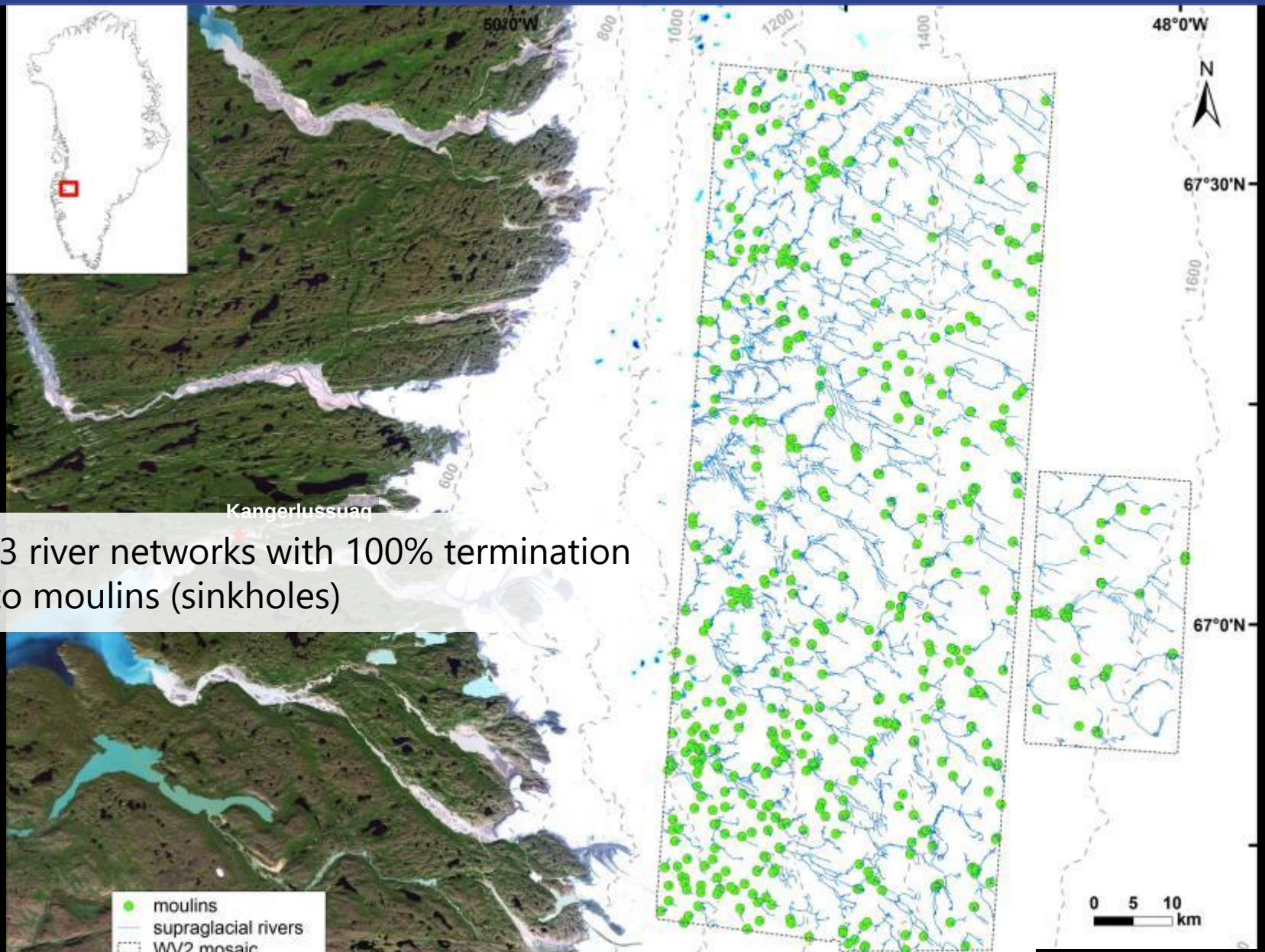
River network extraction



- Automated delineation of large “blue rivers”

Smith et al., 2015

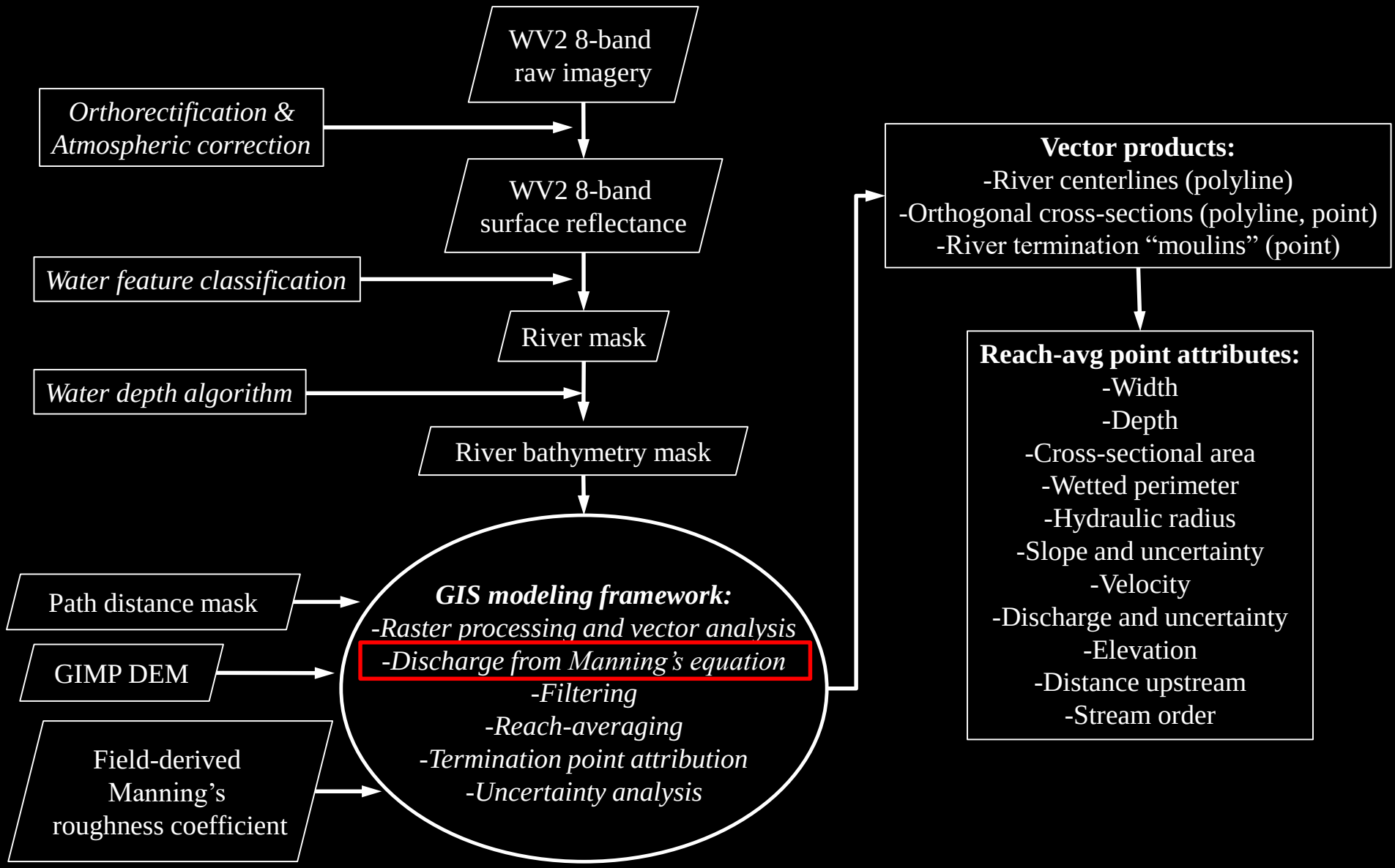
Moulin extraction



- 523 river networks with 100% termination into moulins (sinkholes)

Smith et al., 2015

Discharge retrieval model: Manning's method

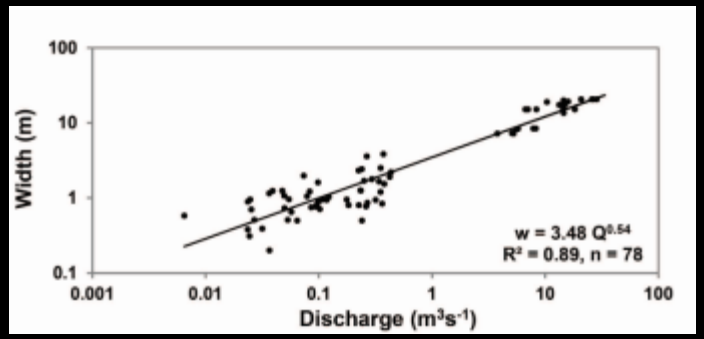


Chu et al. (In revision)

Discharge retrieval method

1. Empirical relationship between width and discharge

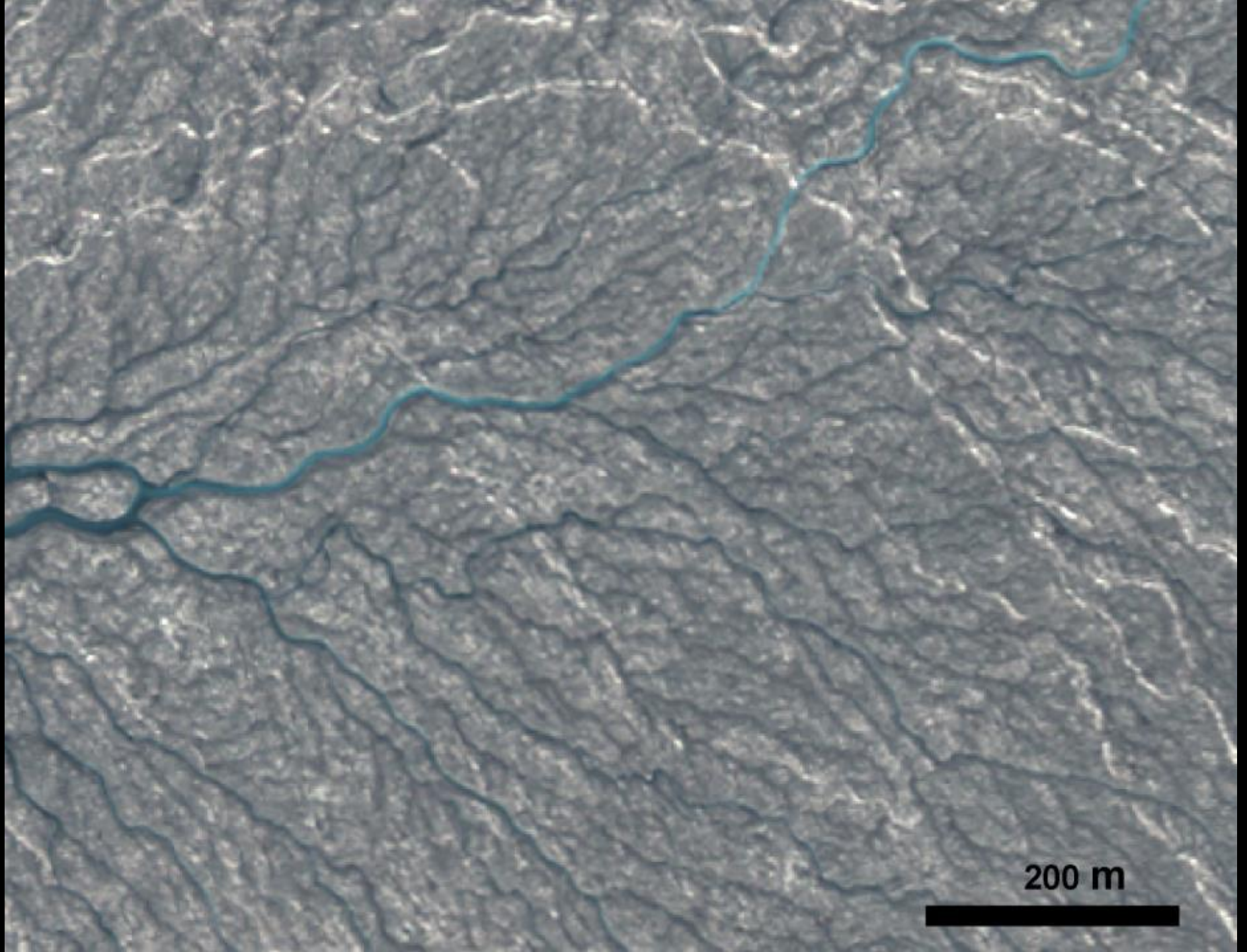
   - WorldView-2 multispectral satellite imagery
   - Field-derived width-discharge relationship

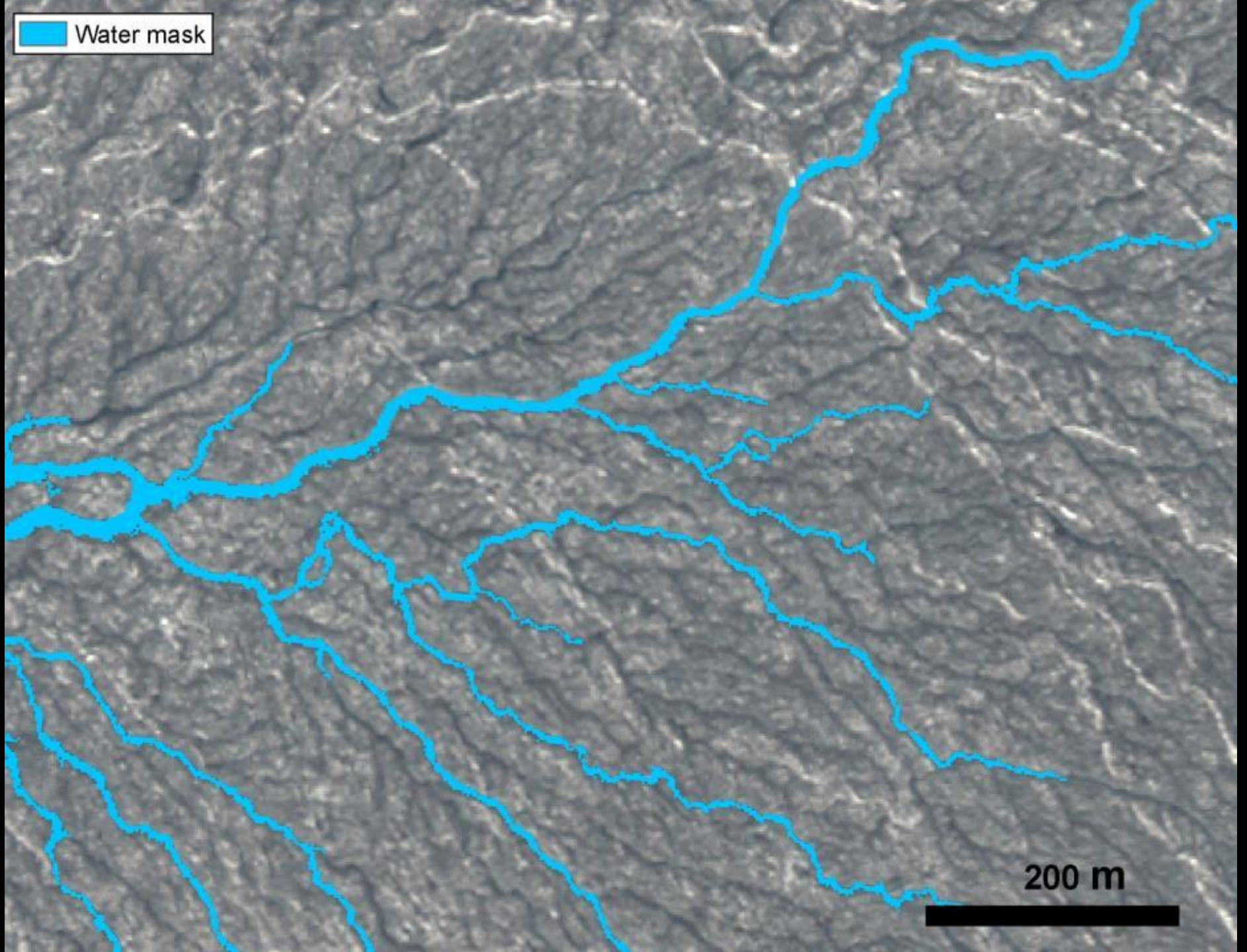


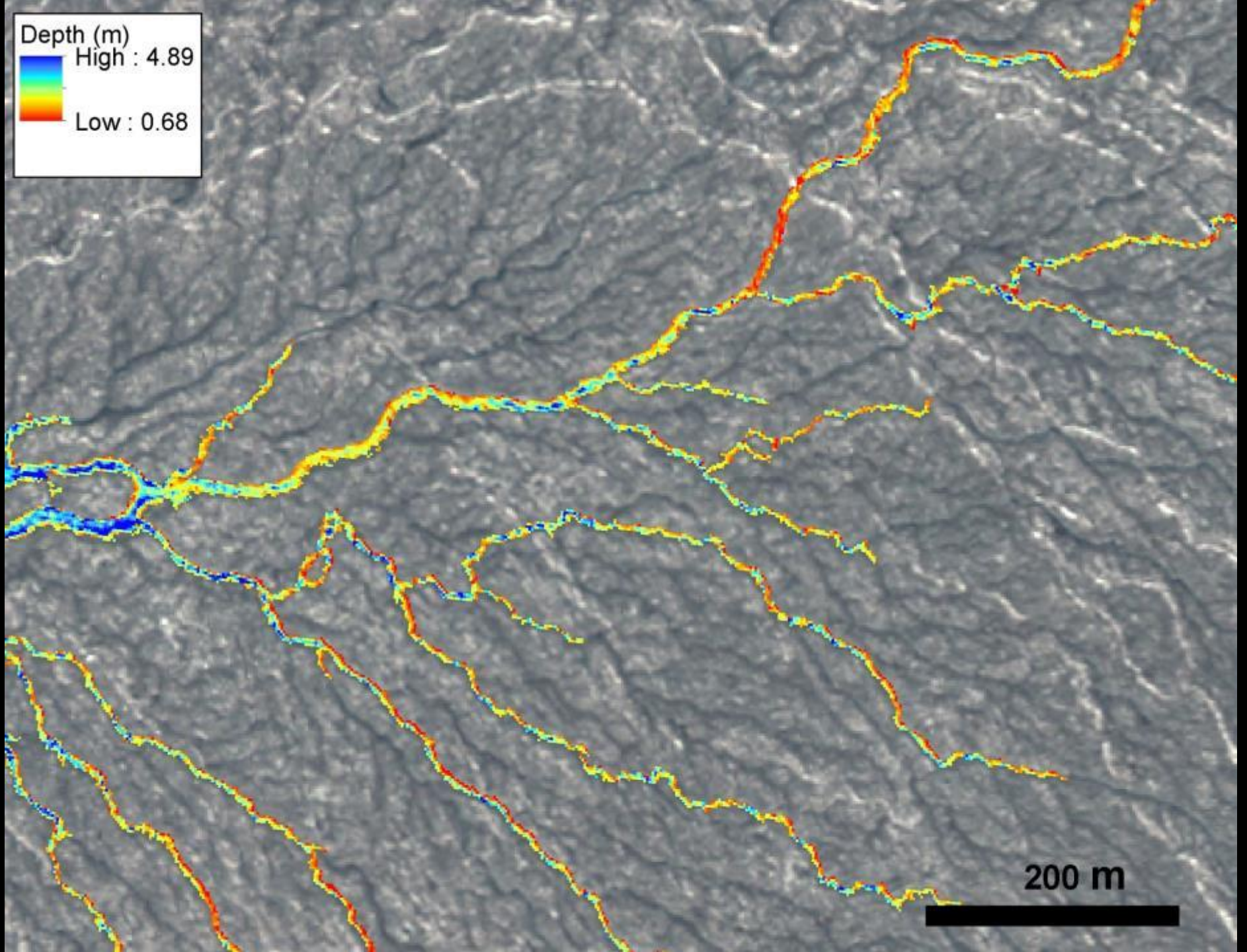
(Smith et al., 2015

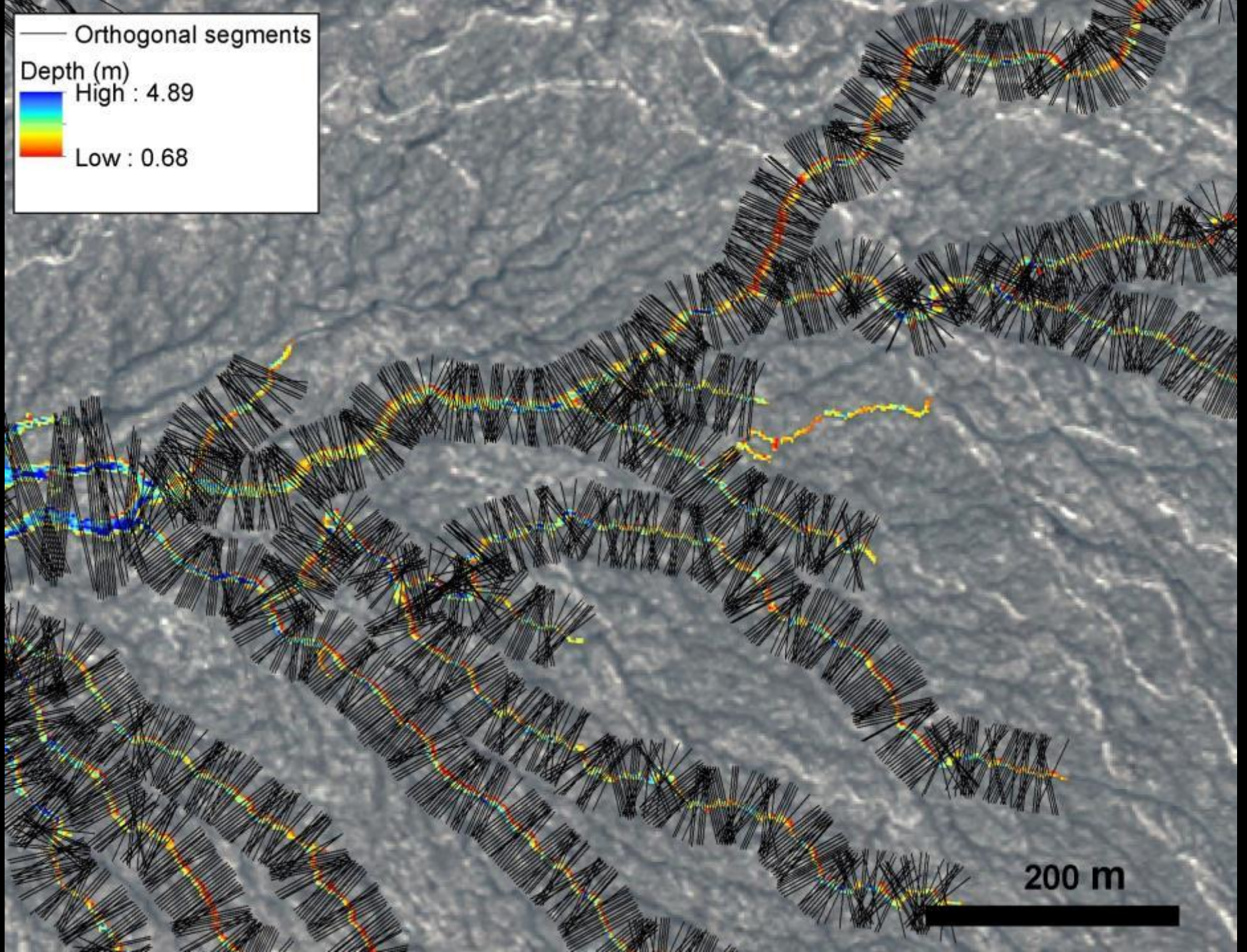
2. Spatially apply Manning's equation

   - WorldView-2 multispectral satellite imagery
   - Digital Elevation Model (DEM)
   - Field-derived Manning's roughness coefficient

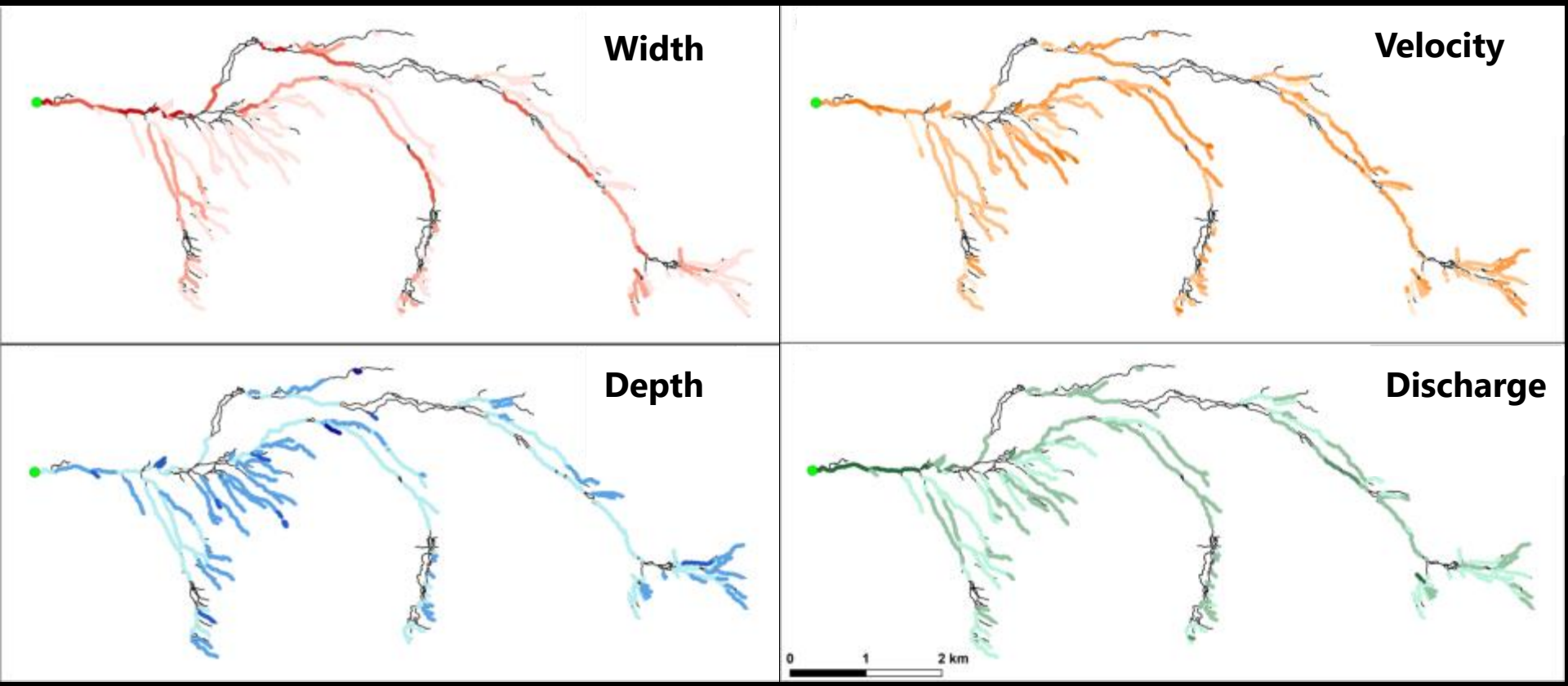

200 m


Water mask
200 m


Depth (m)
High : 4.89
Low : 0.68
200 m

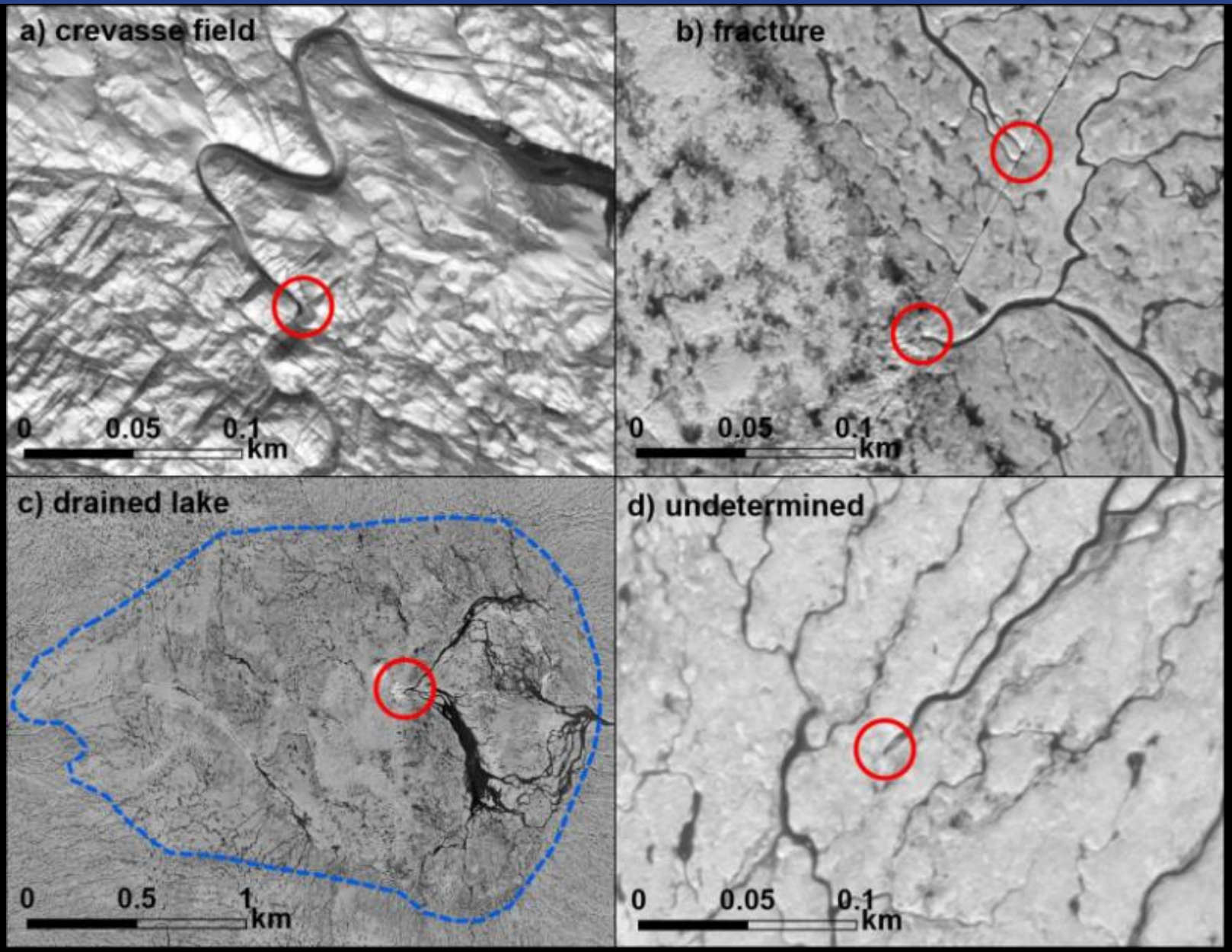

Orthogonal segments
Depth (m)
High : 4.89
Low : 0.68
200 m

Supraglacial river network discharge



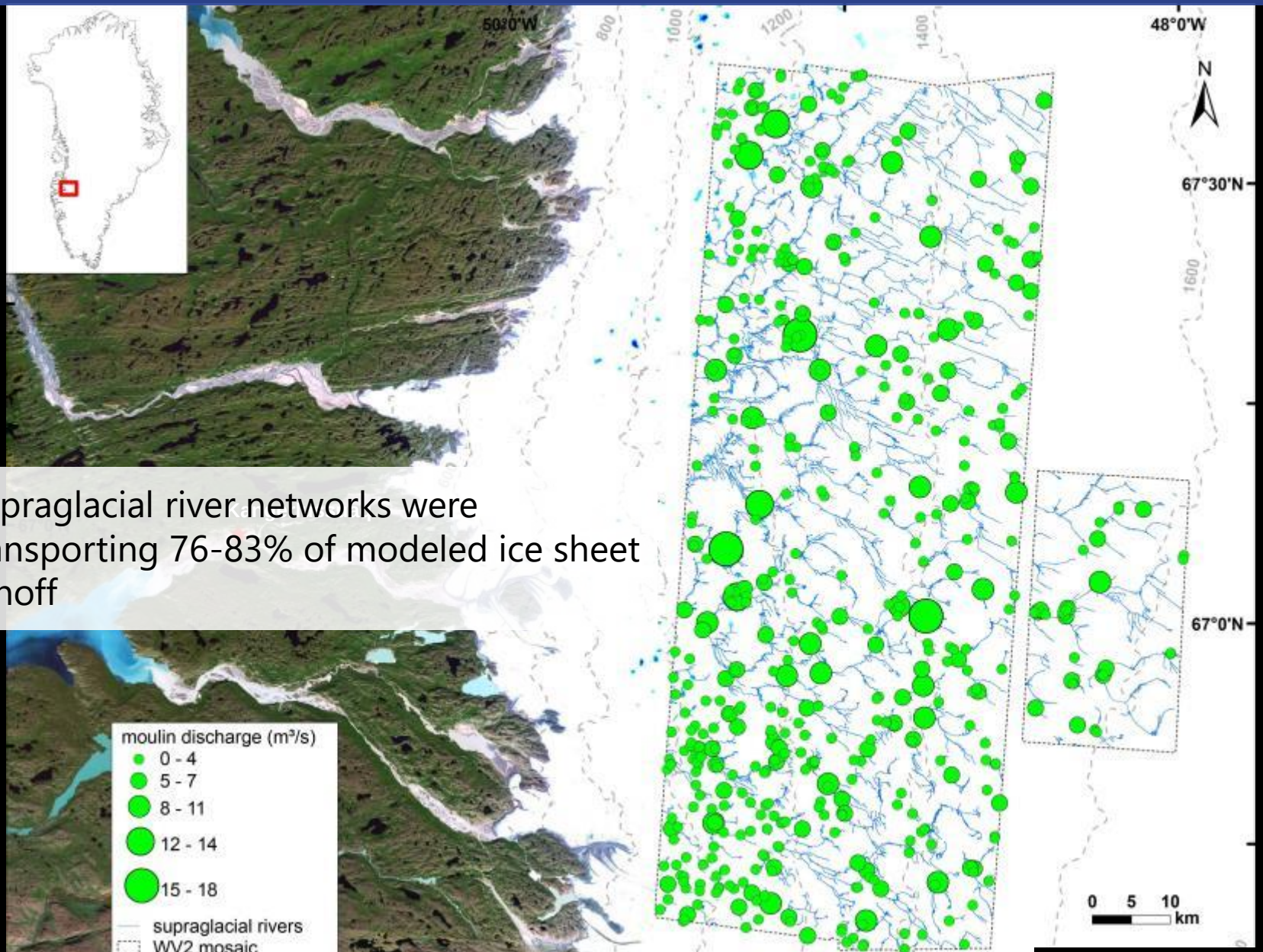
Chu et al. (In revision)

Moulin identification




WorldView-2, July 21, 2012

Moulin discharge



- Supraglacial river networks were transporting 76-83% of modeled ice sheet runoff

Smith et al., 2015

Current limitations and obstacles

- ***Stream delineation***
  - A lot of manual clean up for stream delineation (inactive river beds, shadows)
  - Therefore still need manual identification of moulins (river termination points)

- ***Discharge retrieval***
  - Depth retrieval based on site-specific empirical relationship
  - Manning's method discharge retrieval relies on field-measured parameter (Manning's n)