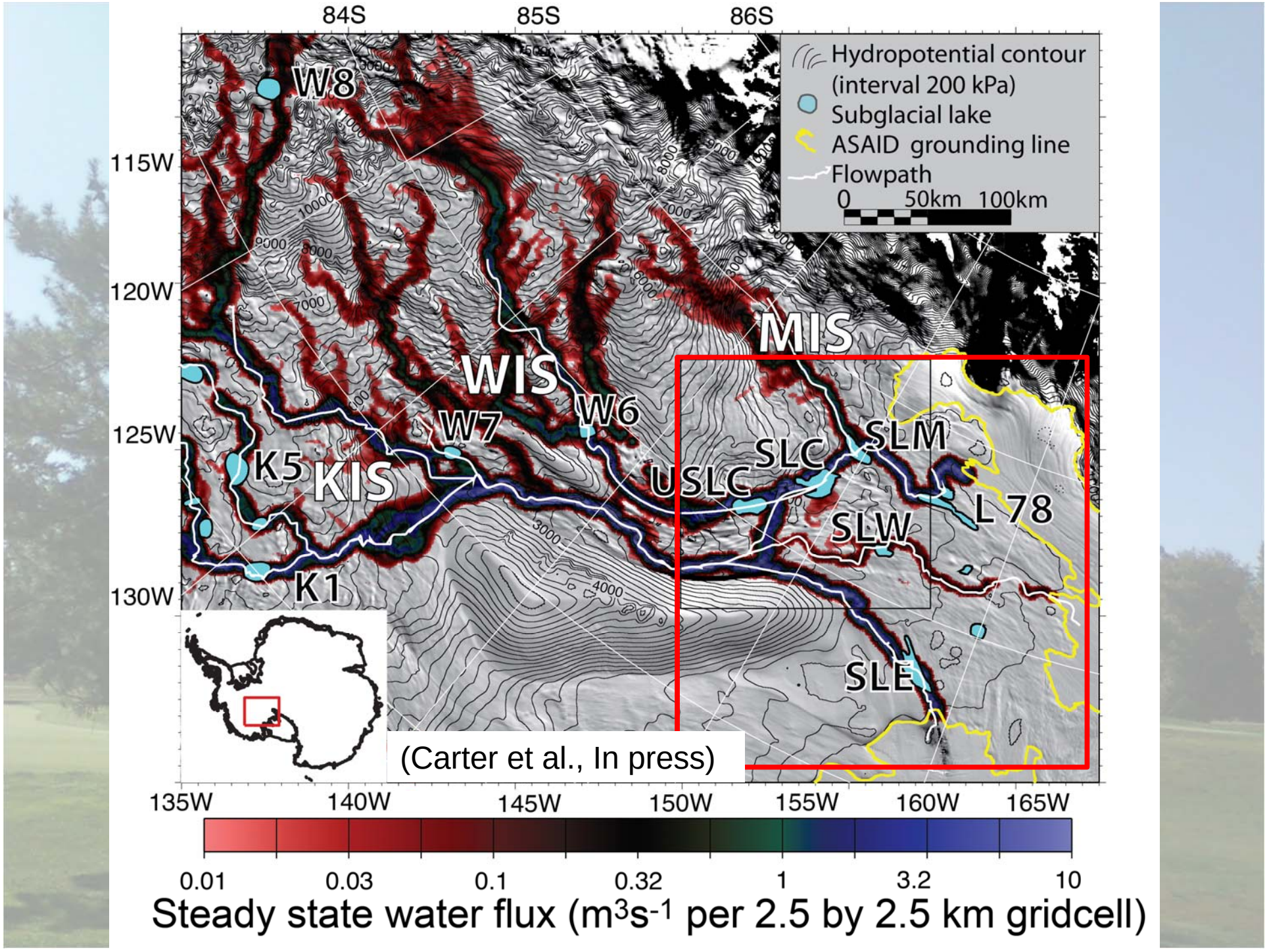
Evidence of rapid subglacial water piracy under Whillans Ice stream

S. P. Carter[1], H. A. Fricker[1], M. R. Siegfried[1]

Special thanks to:
NSF
Poul Christoffersen
Jason
NASA
SIO/IGPP Business office
WISSARD field team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Hydropotential contour
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Subglacial lake
ASAID grounding line
Flowpath
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(Carter et al., In press)
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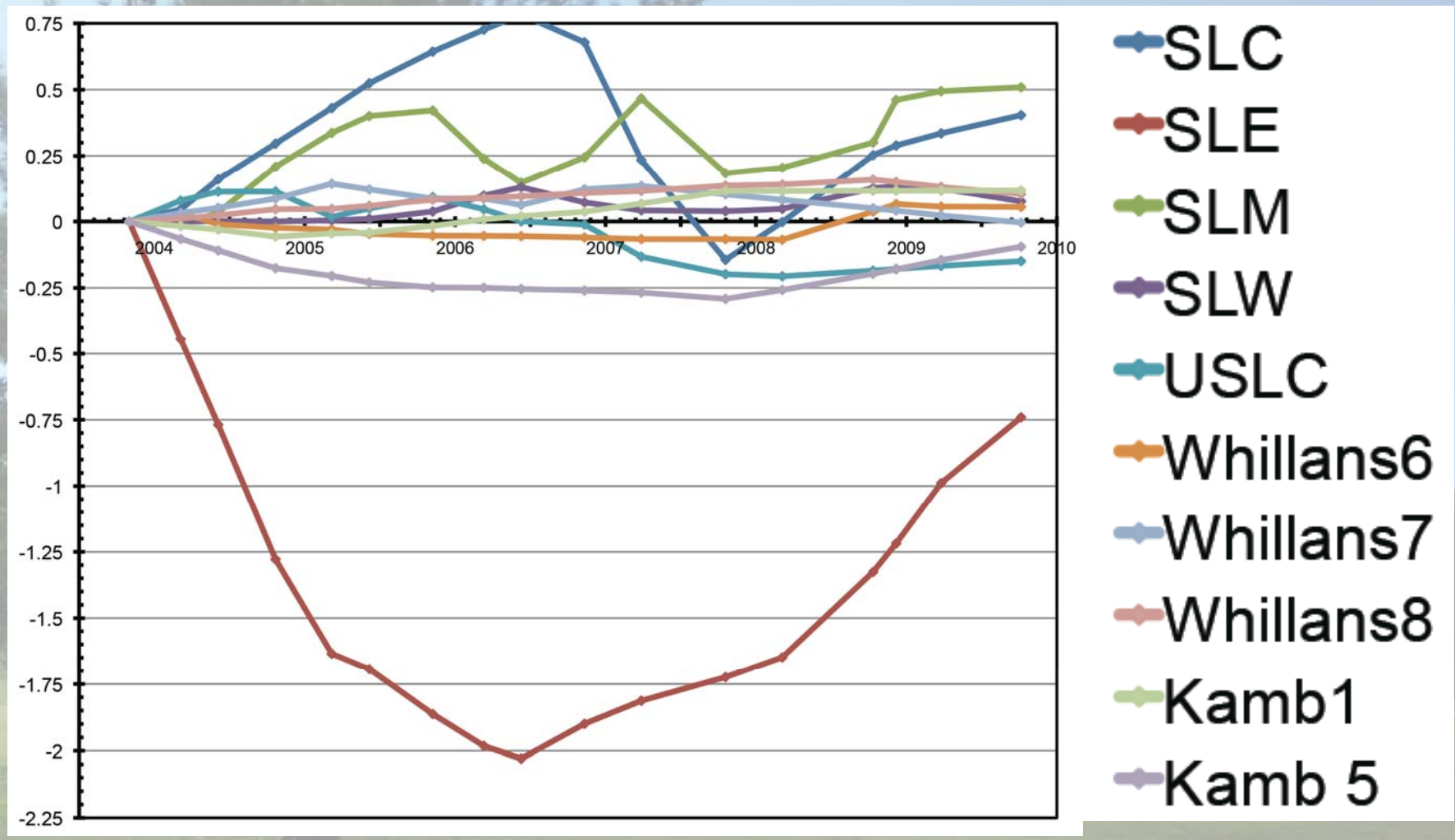
Steady state water flux (m3s-1 per 2.5 by 2.5 km gridcell)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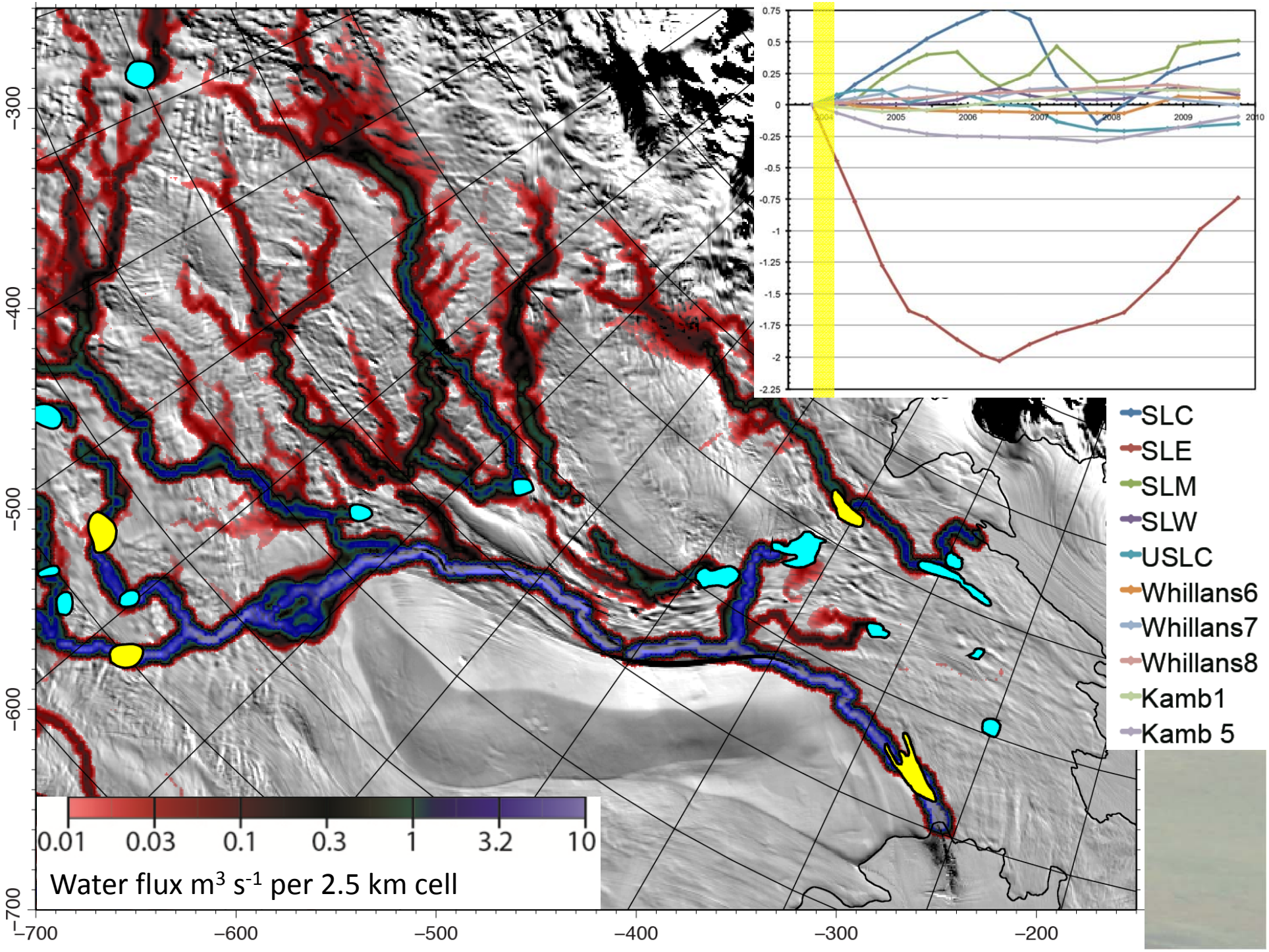
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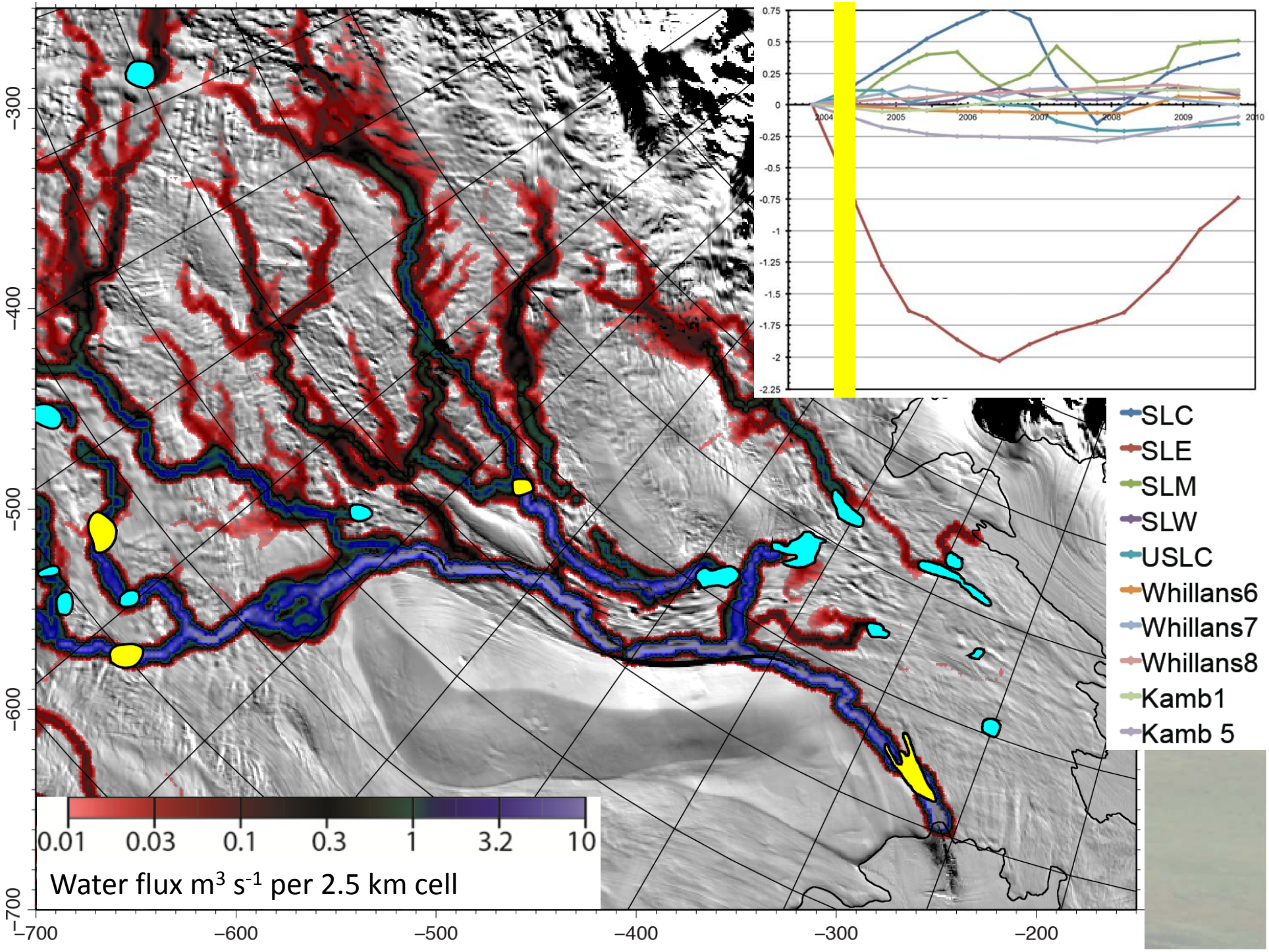
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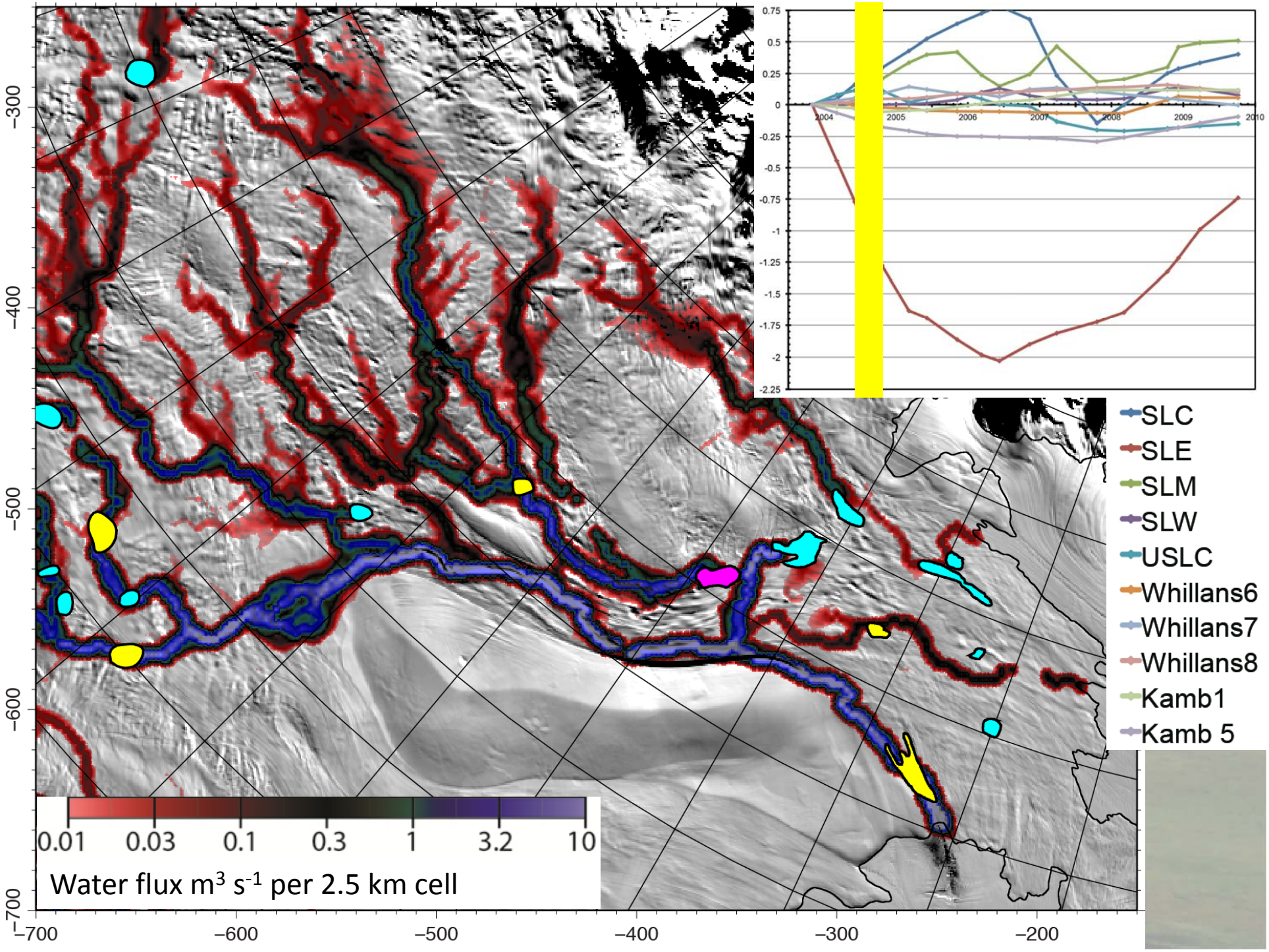
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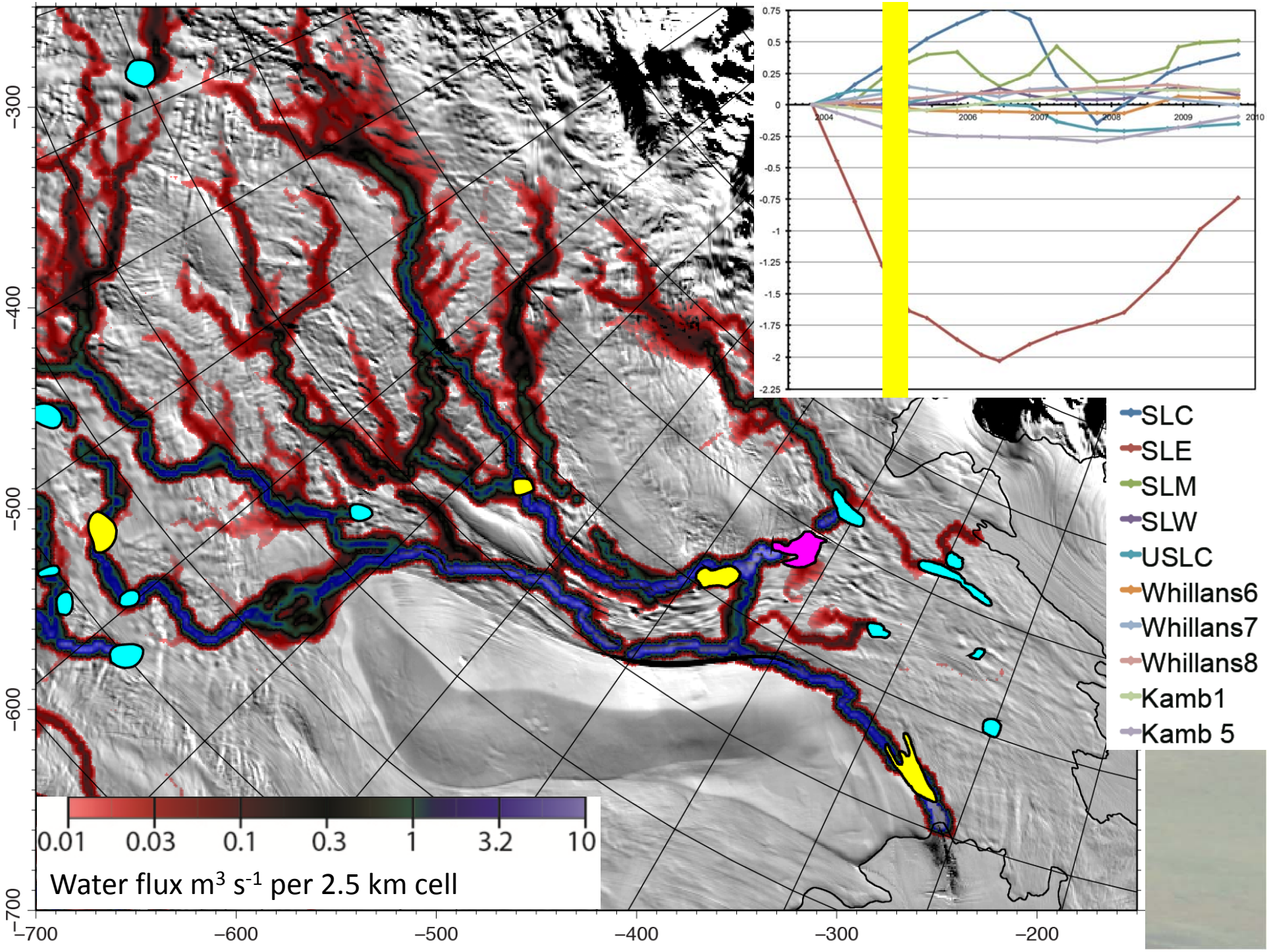
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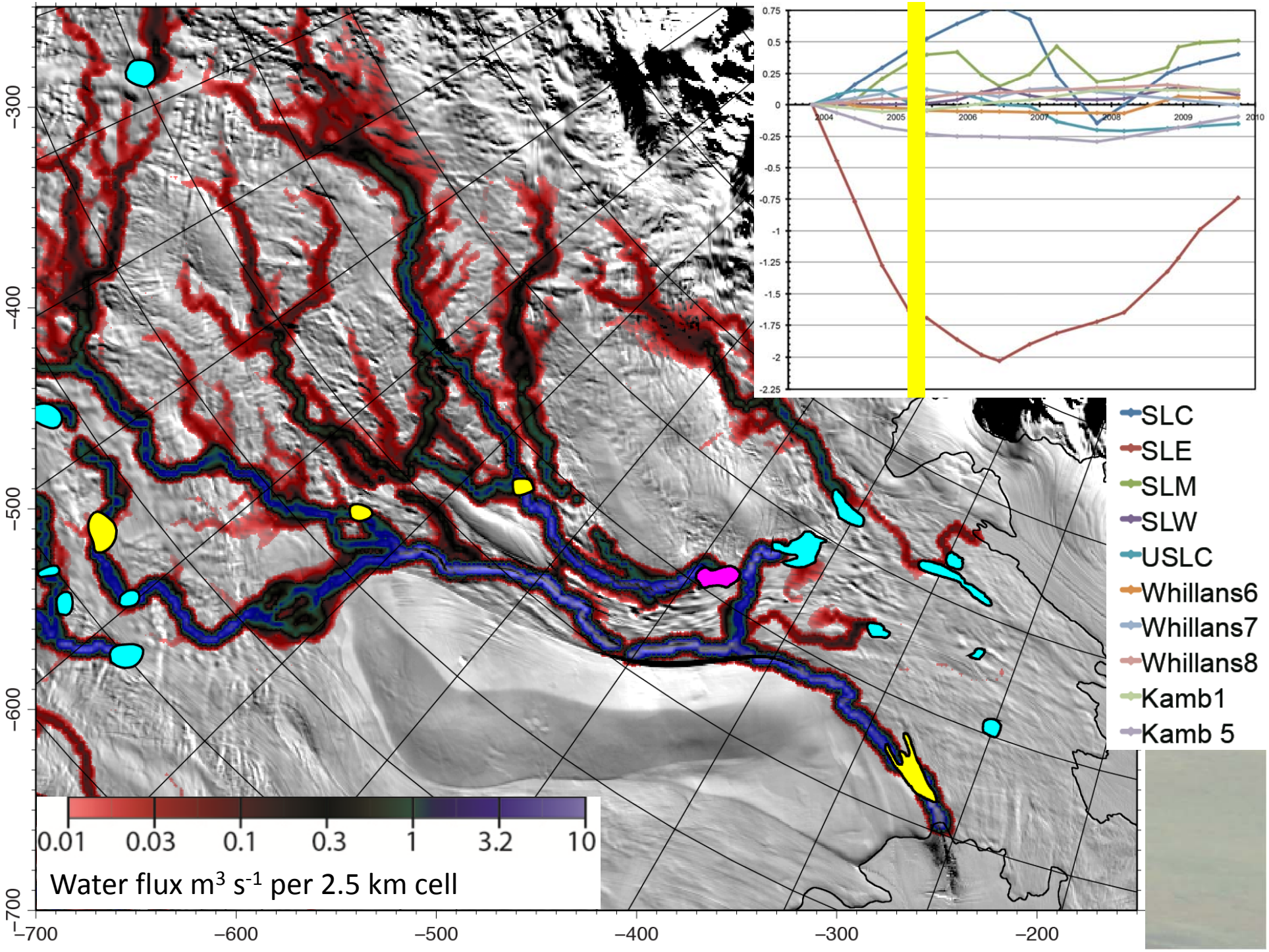
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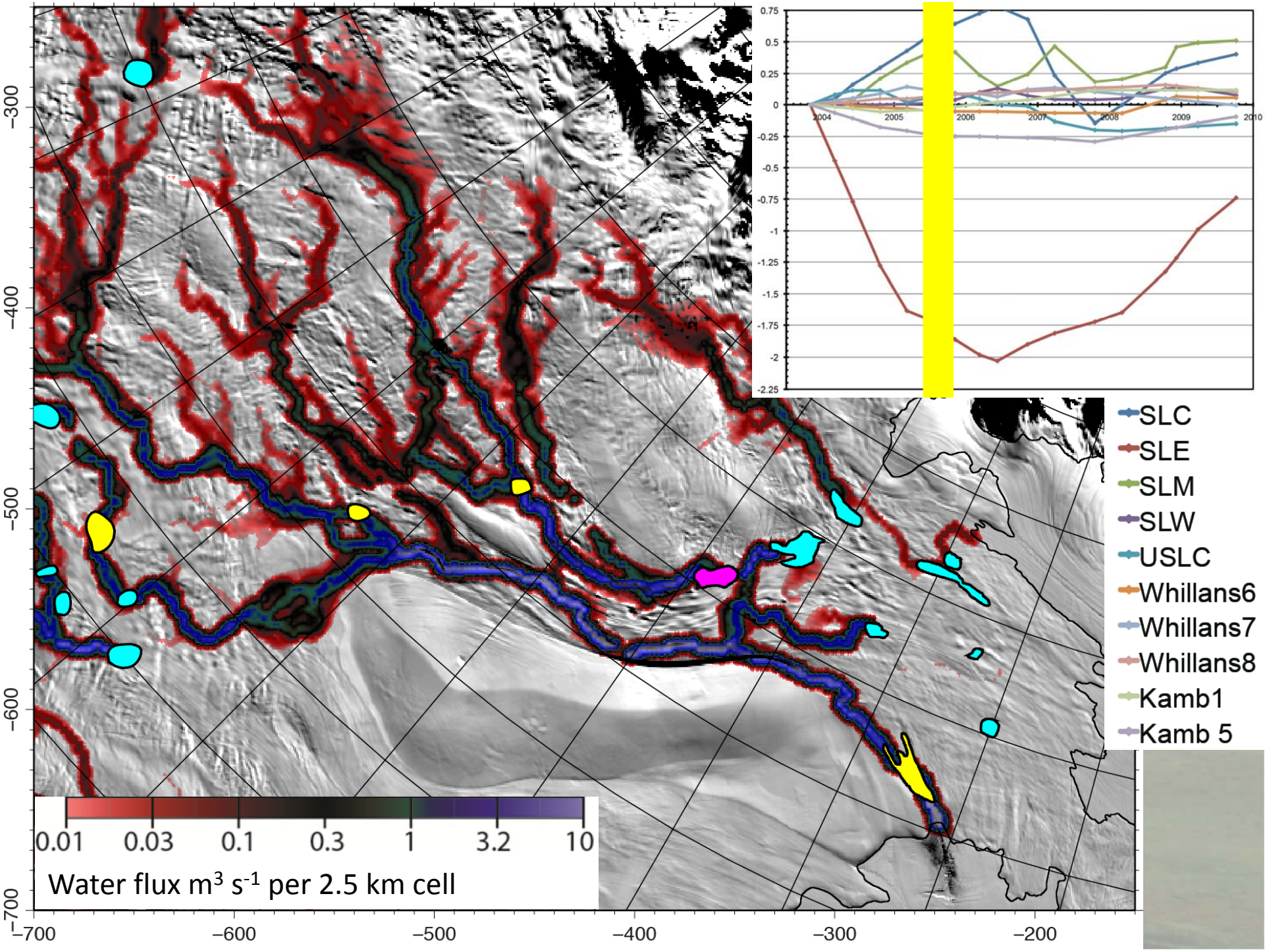
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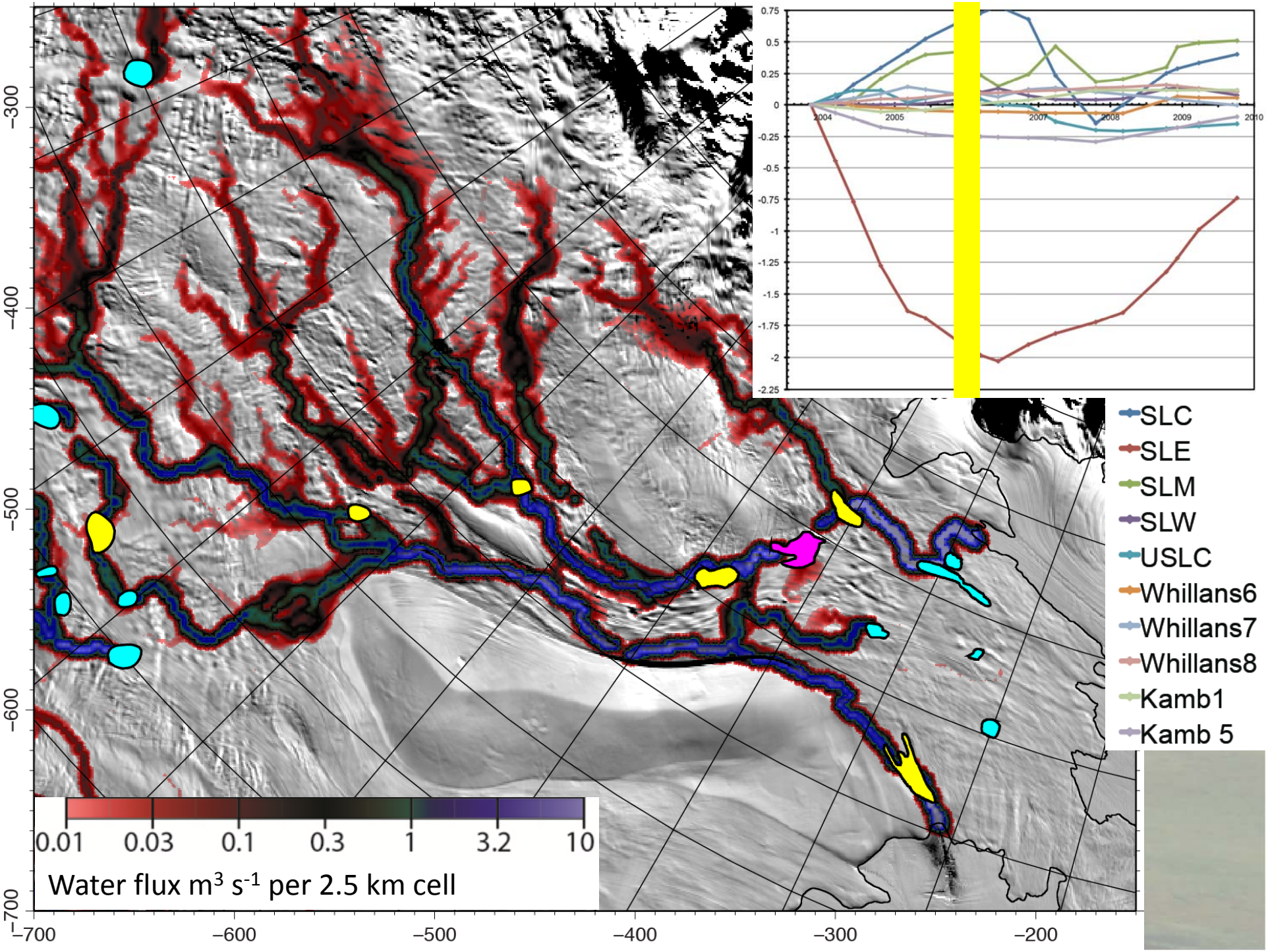
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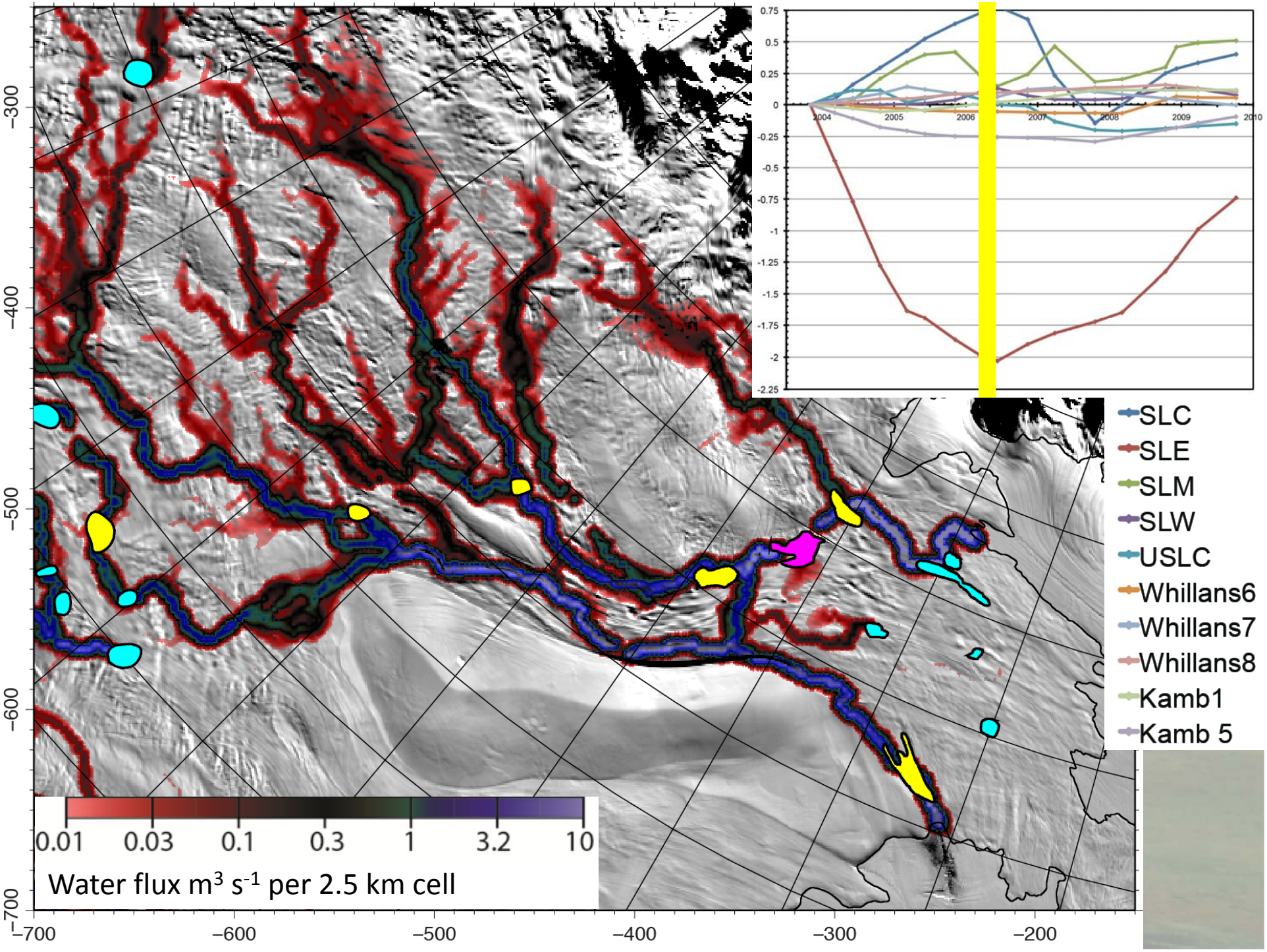
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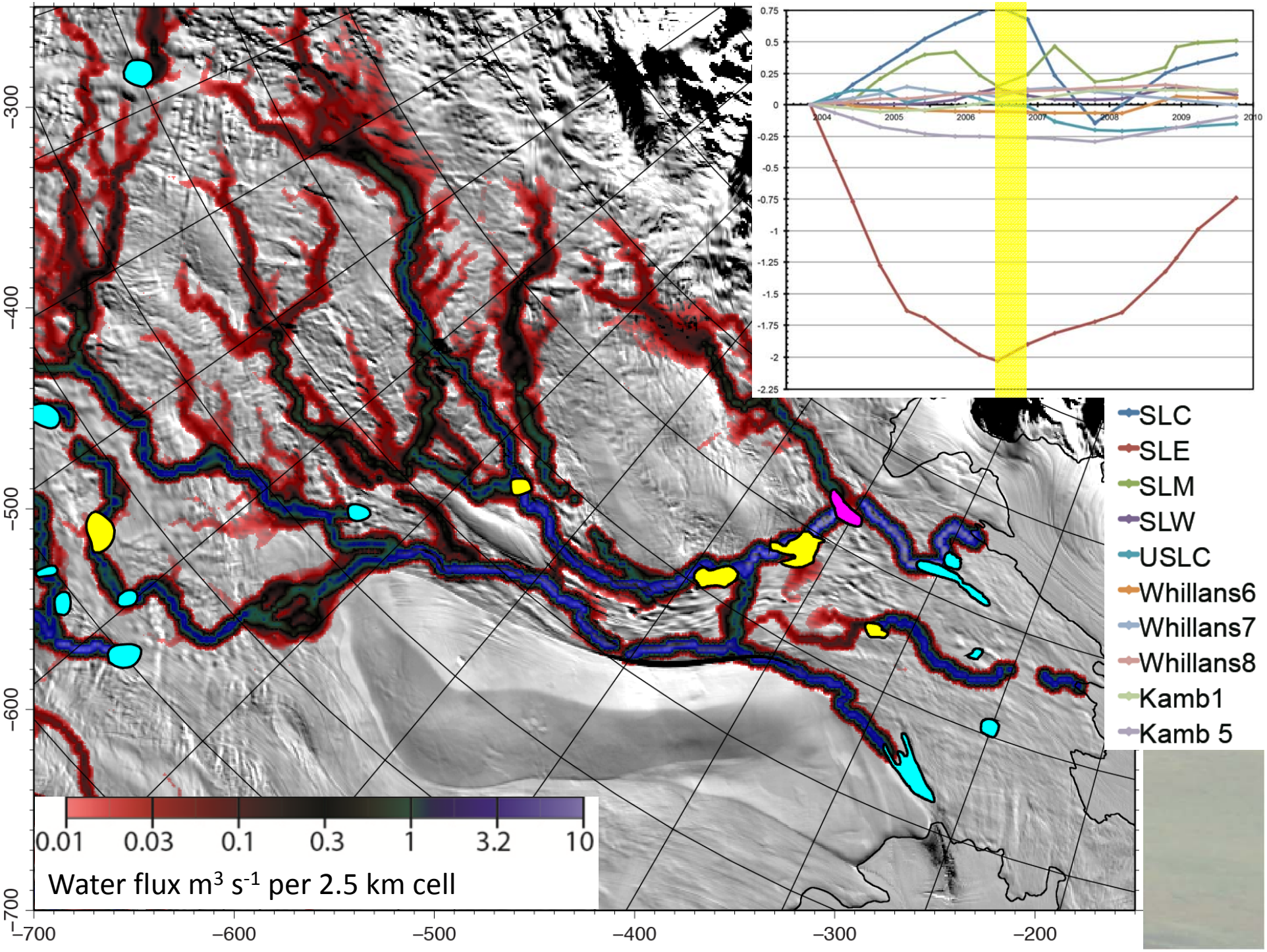
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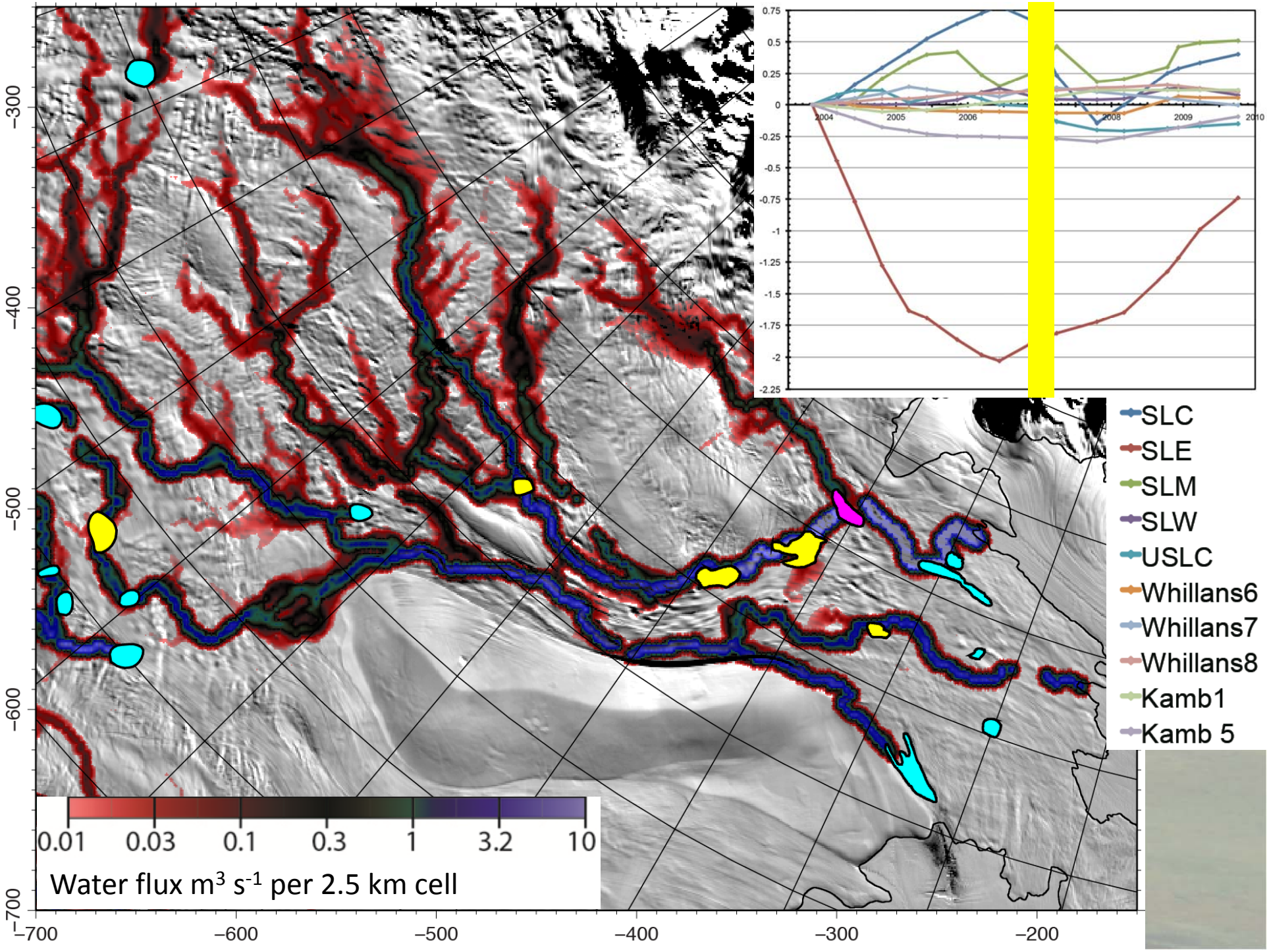
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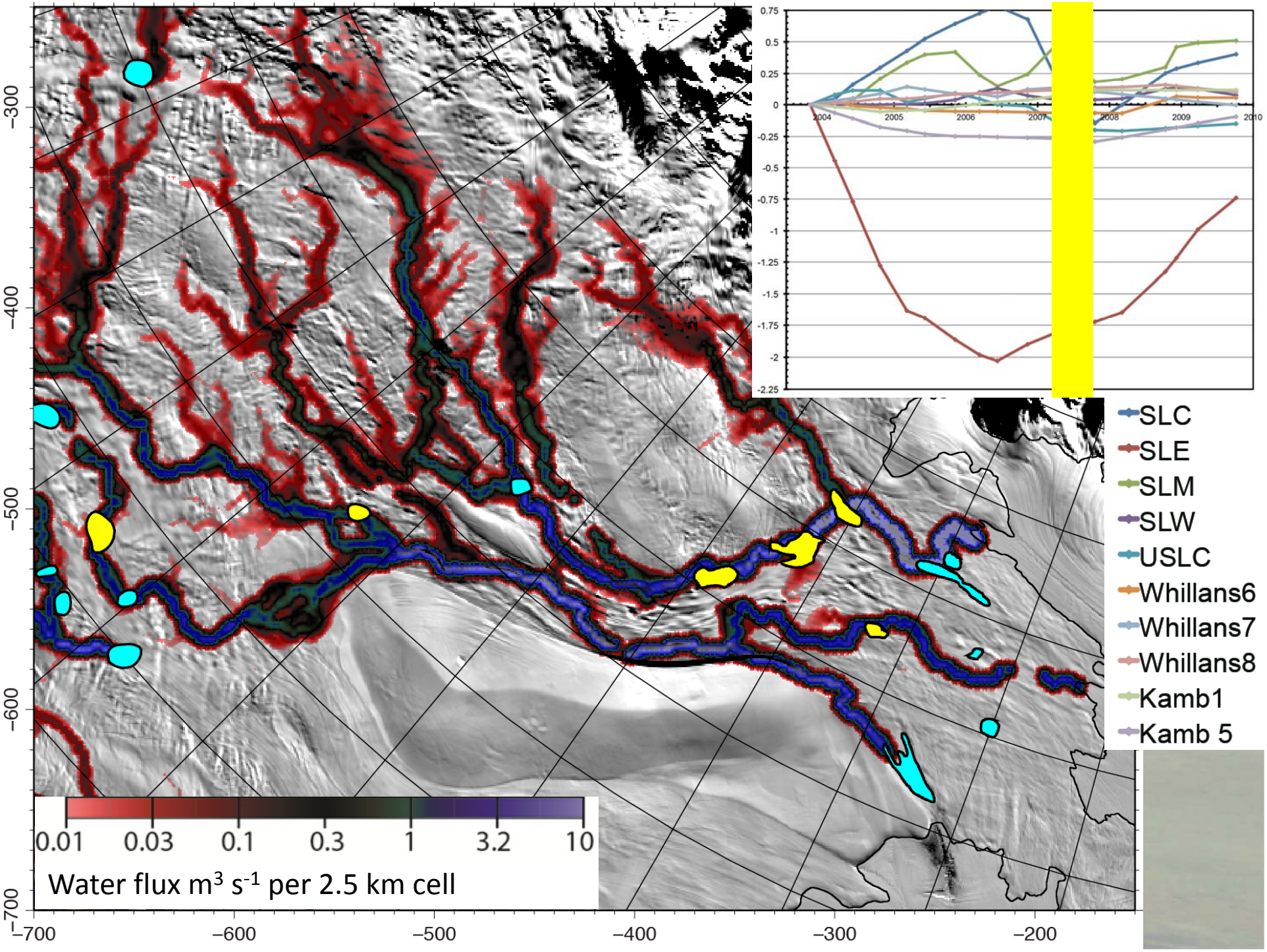
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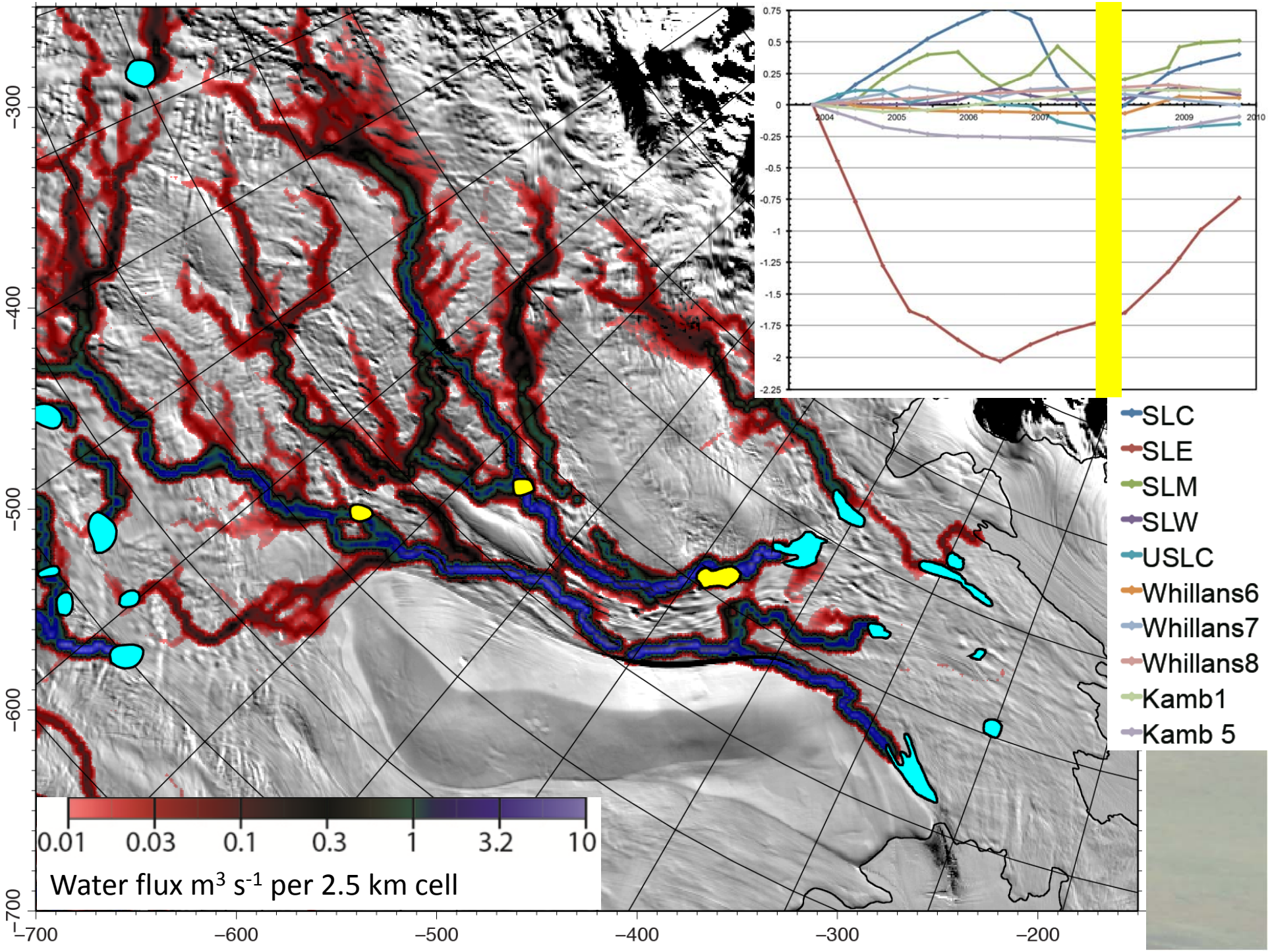
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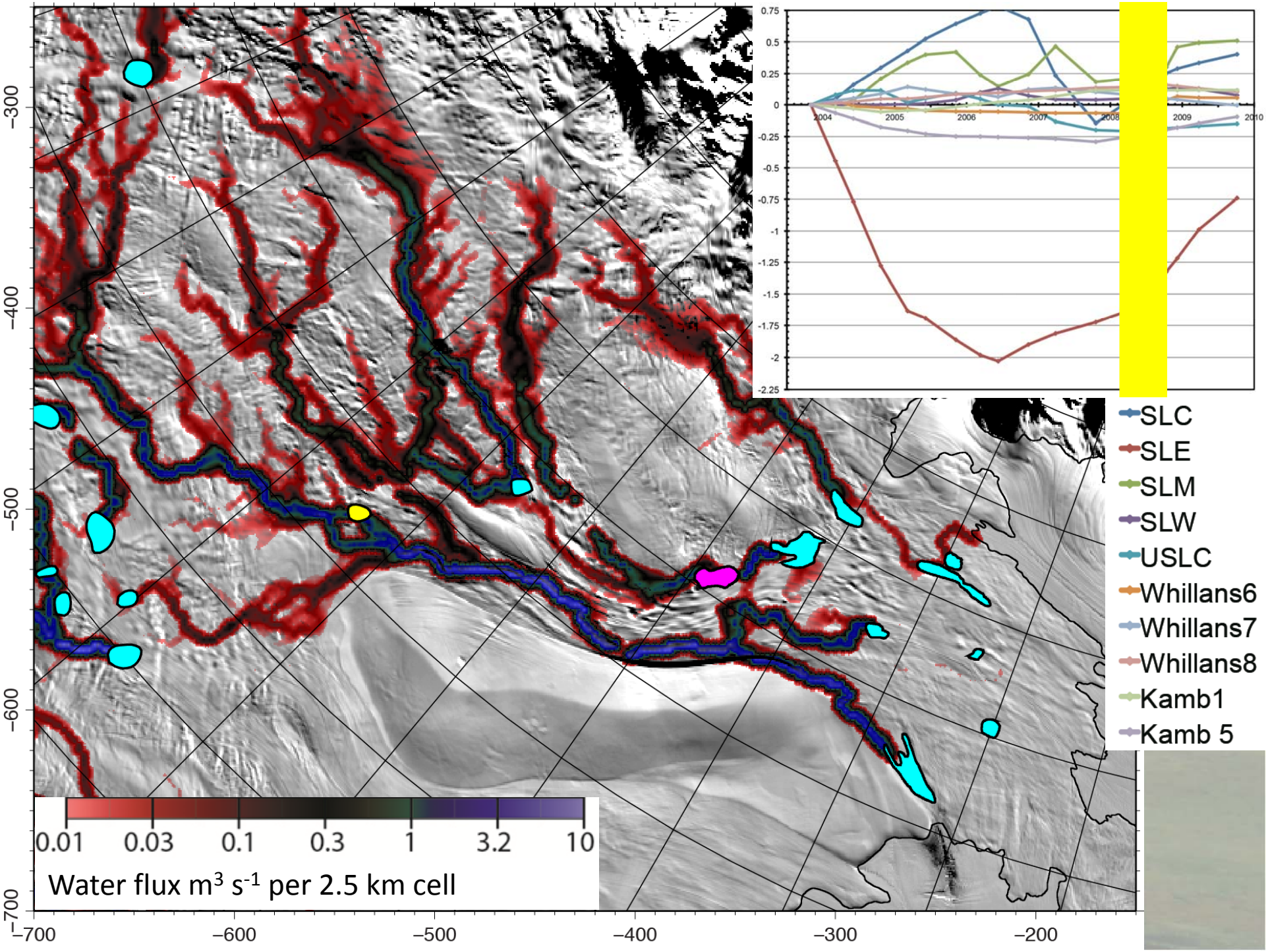
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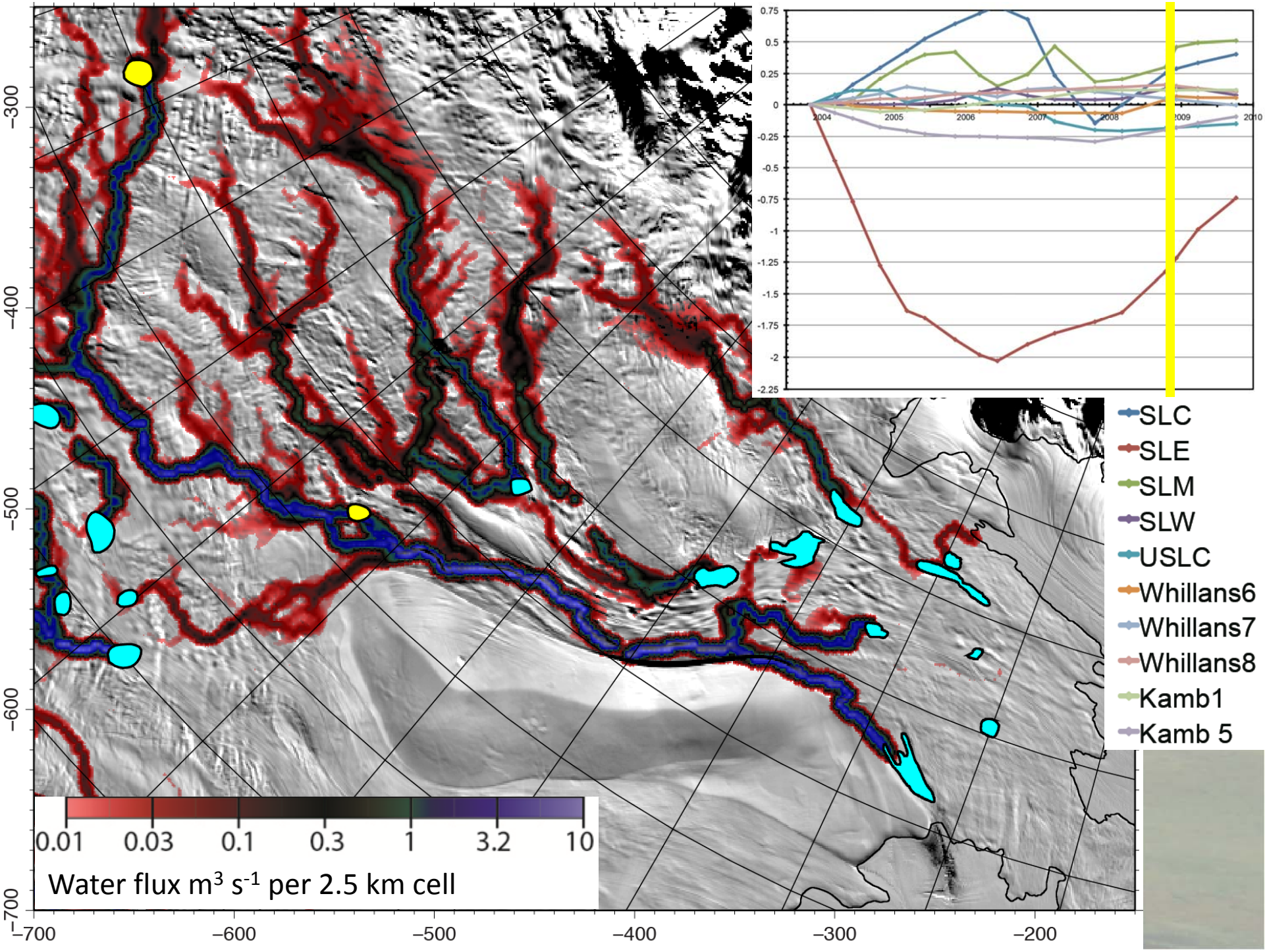
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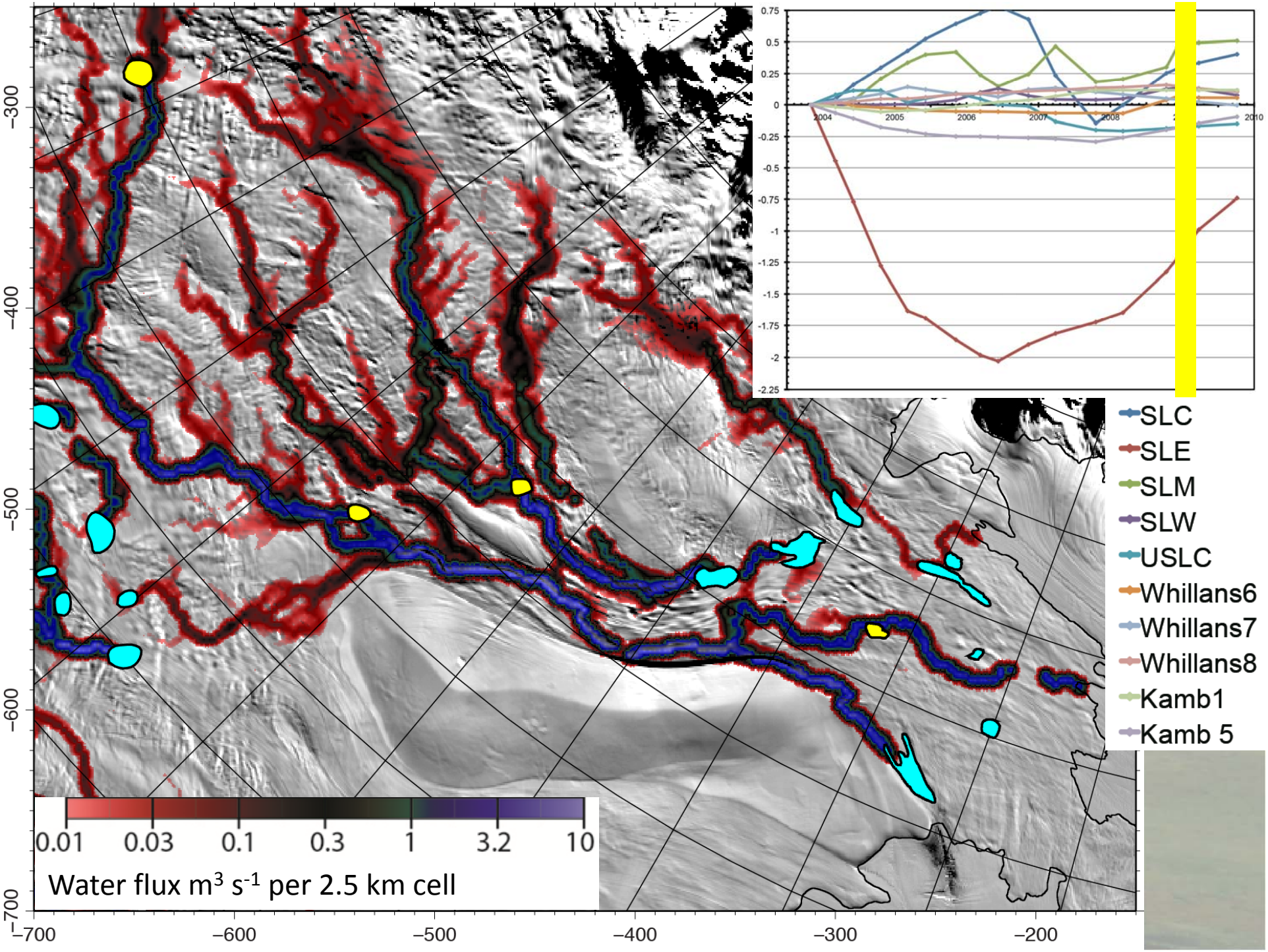
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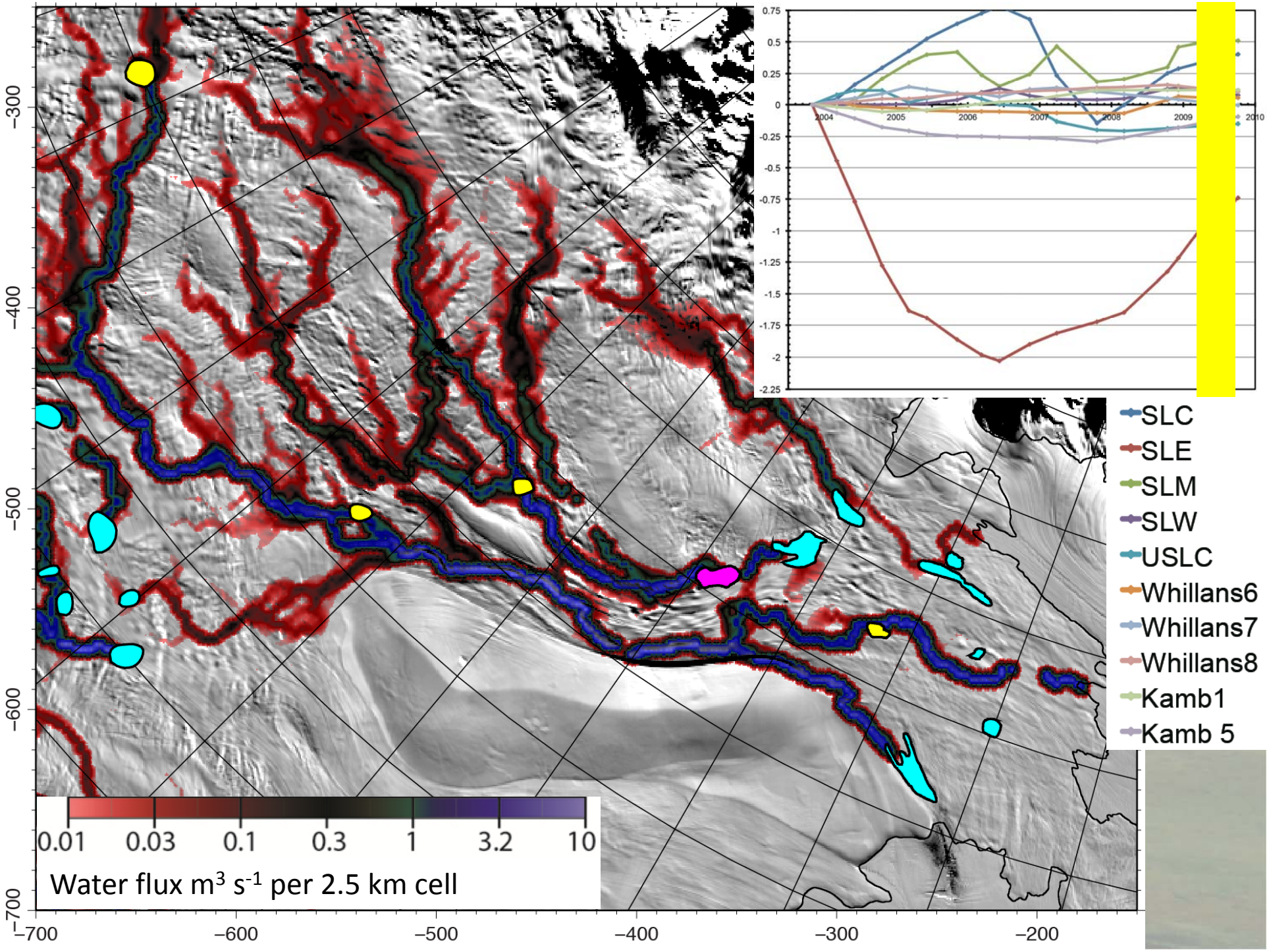
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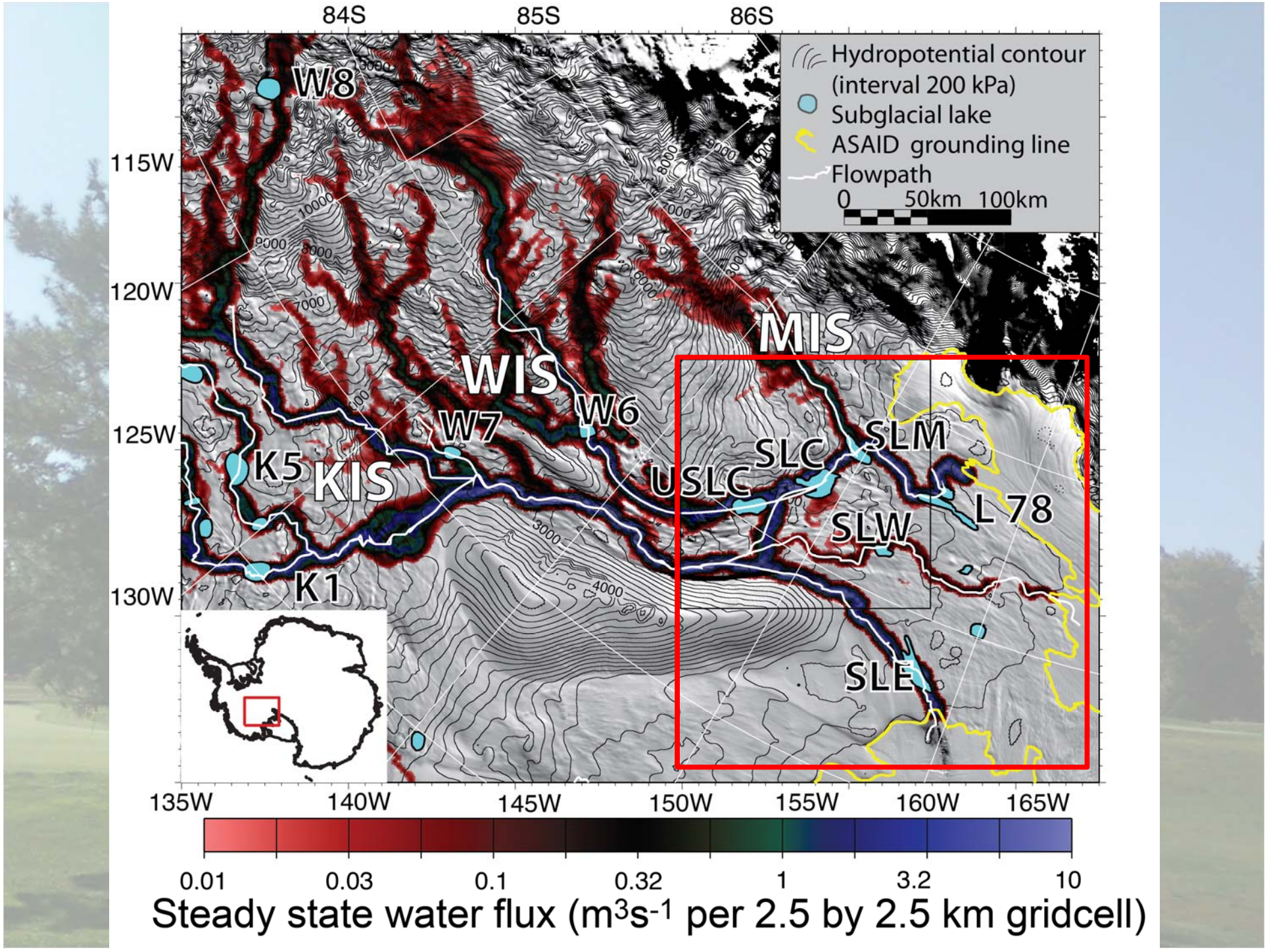
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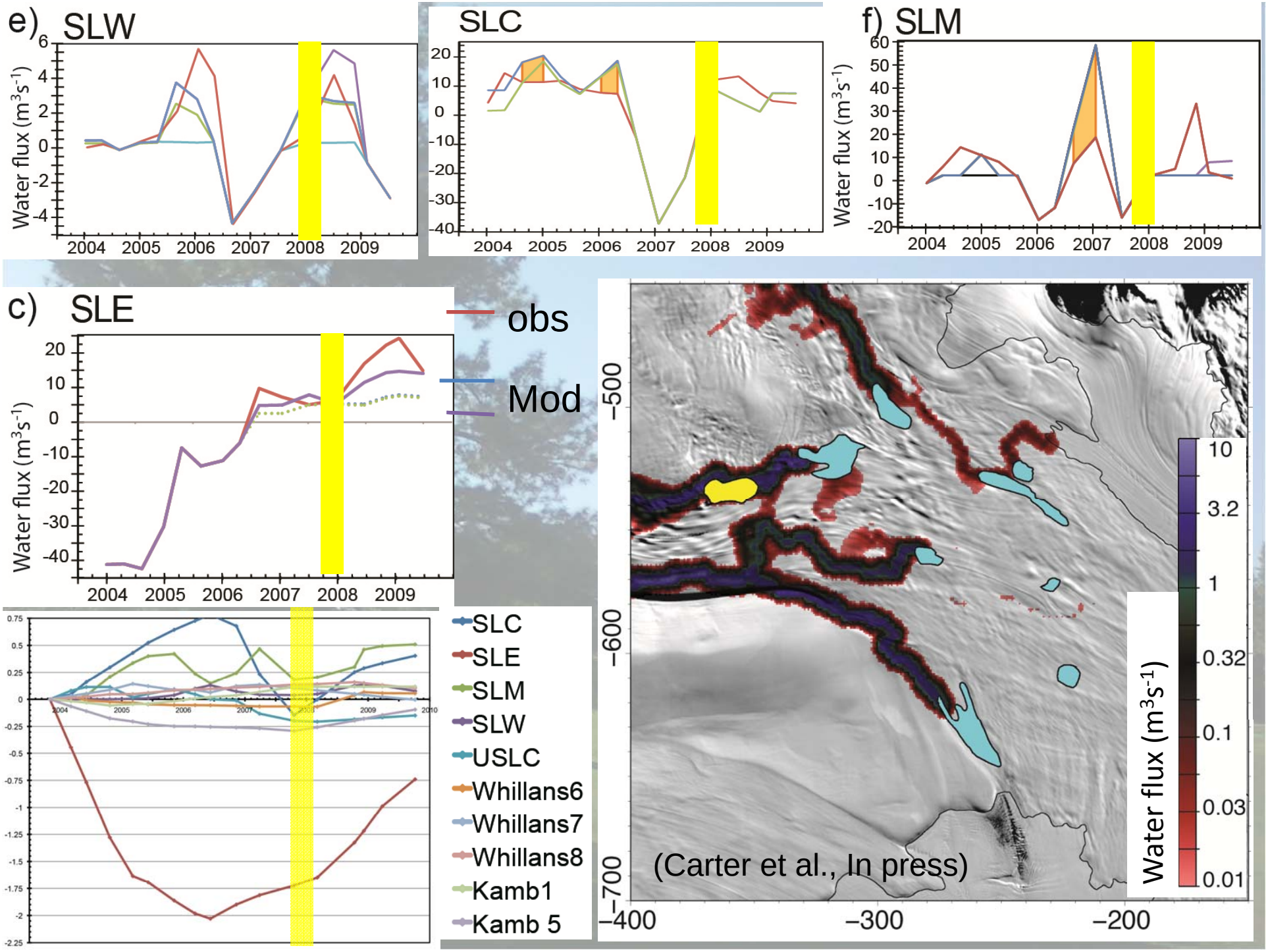
e) SLW
Water flux (m^3s^{-1})
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f) SLM
Water flux (m^3s^{-1})
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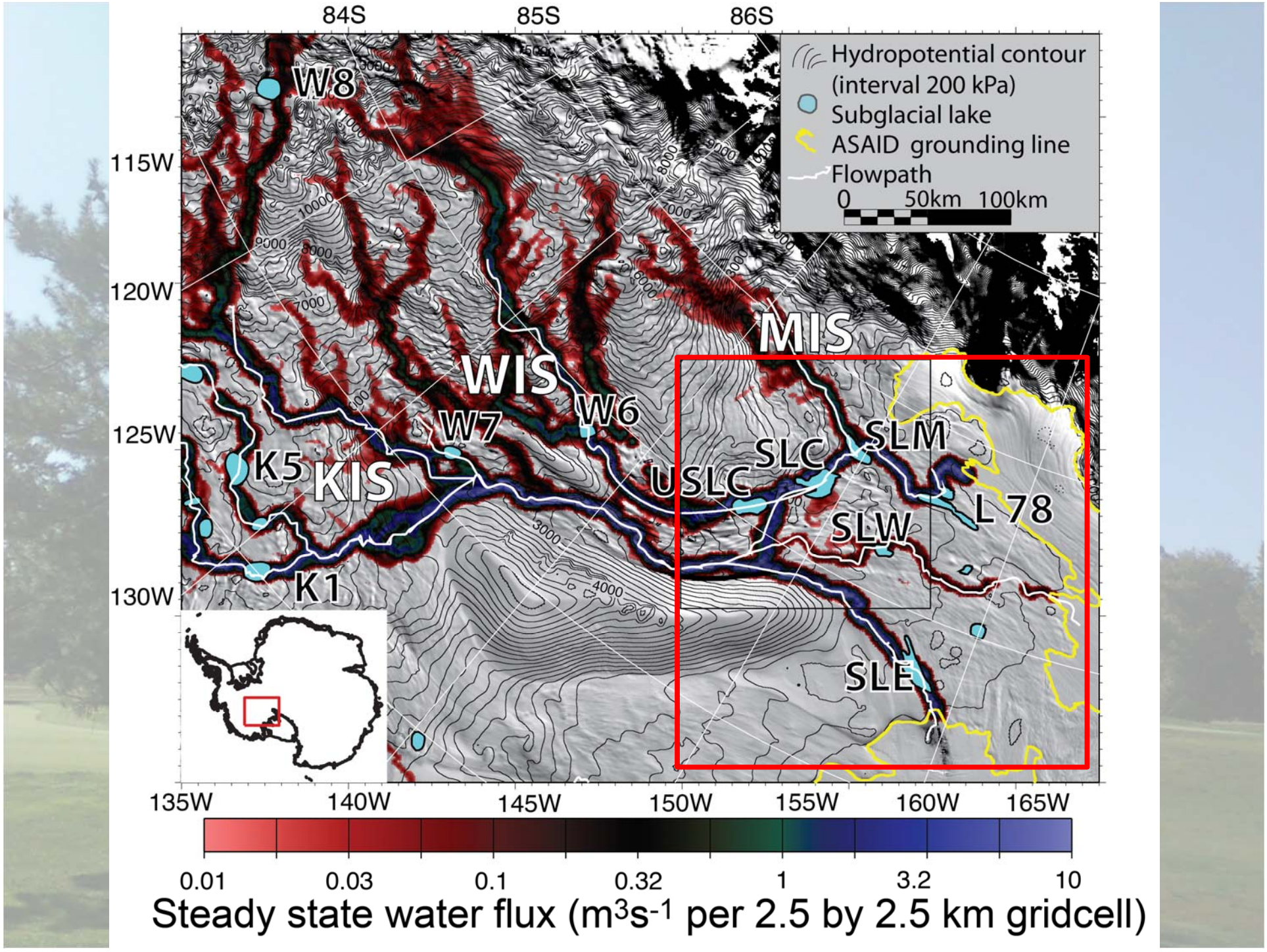
Water flux (m^3s^{-1})
(Carter et al., In press)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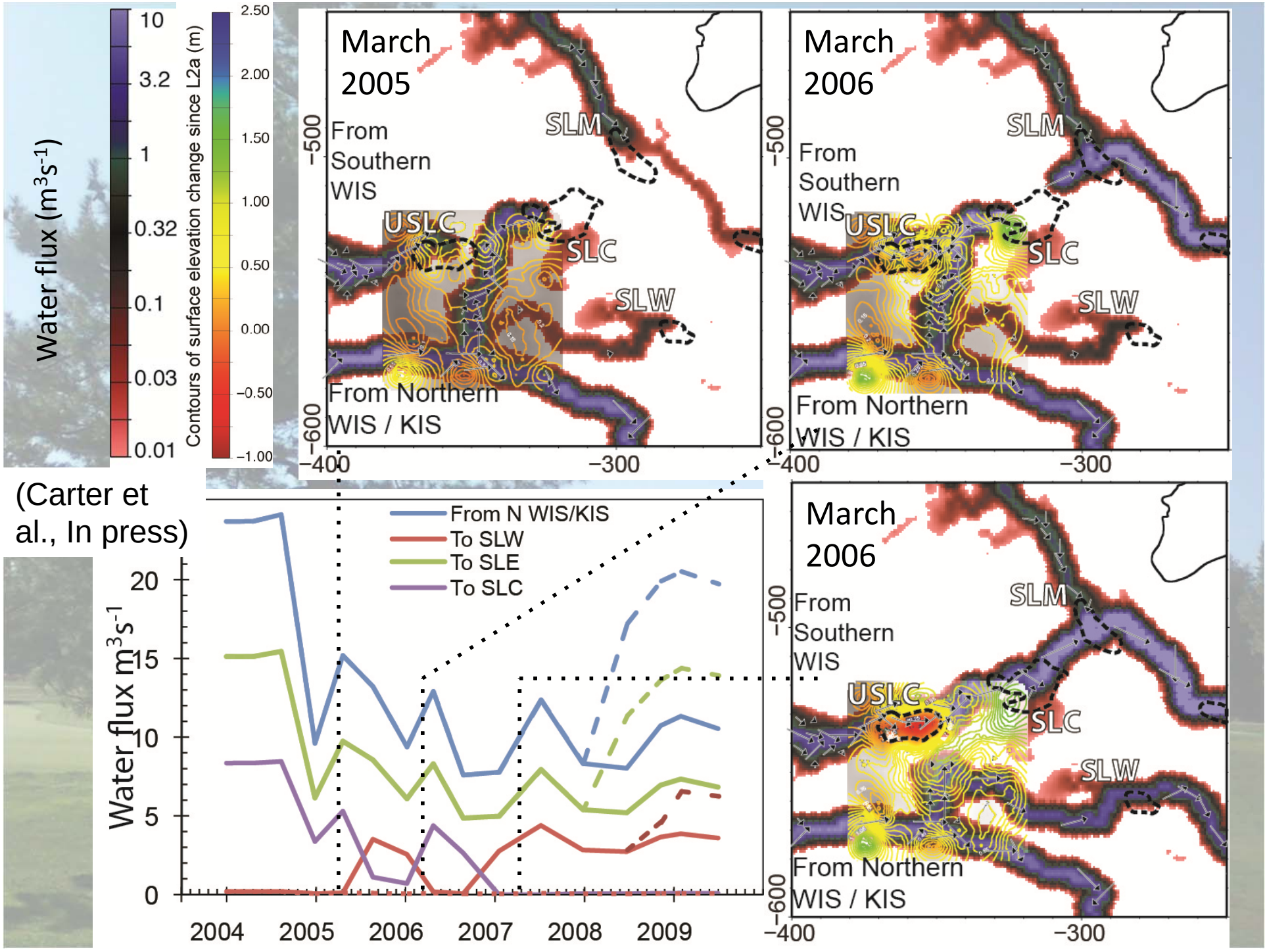
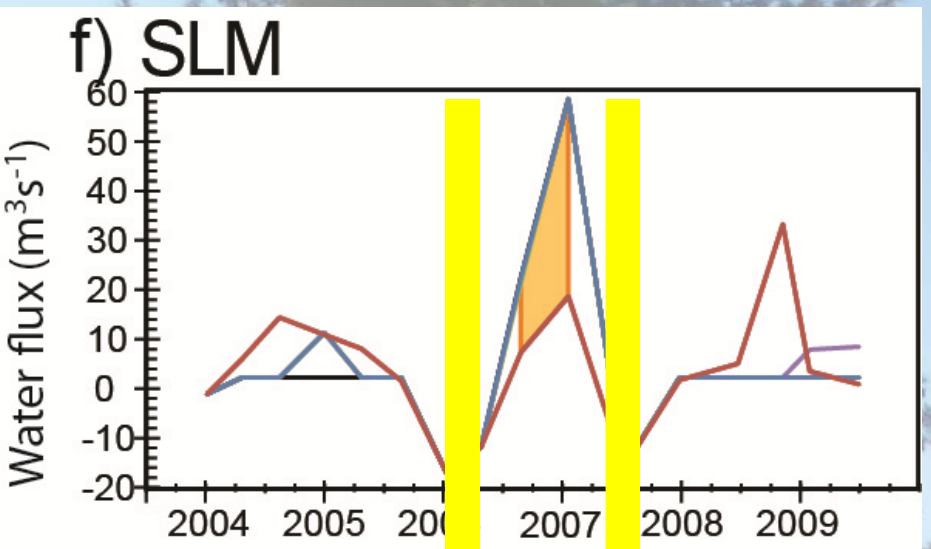
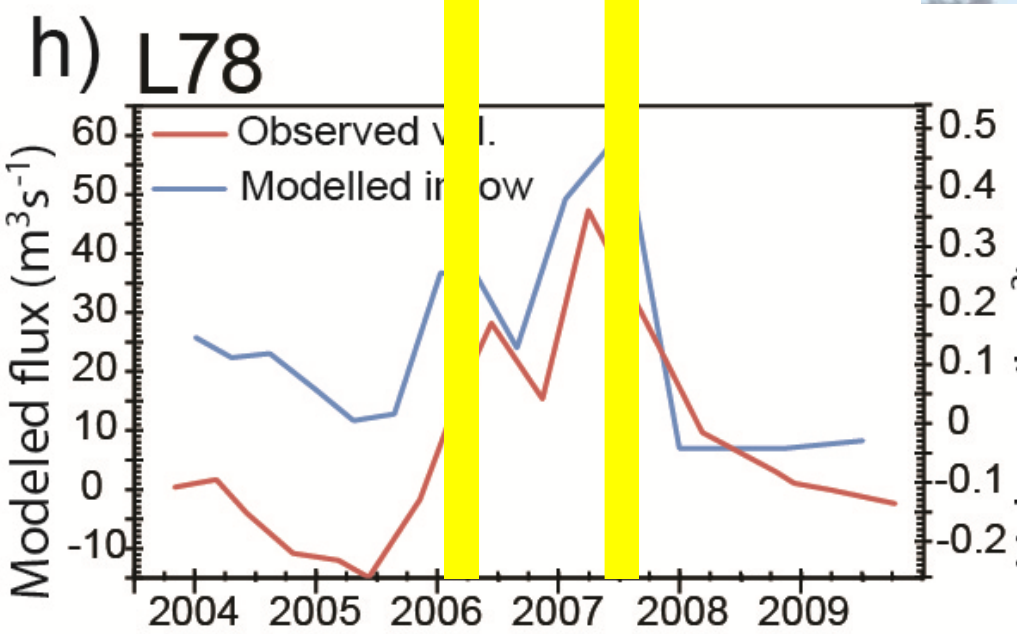
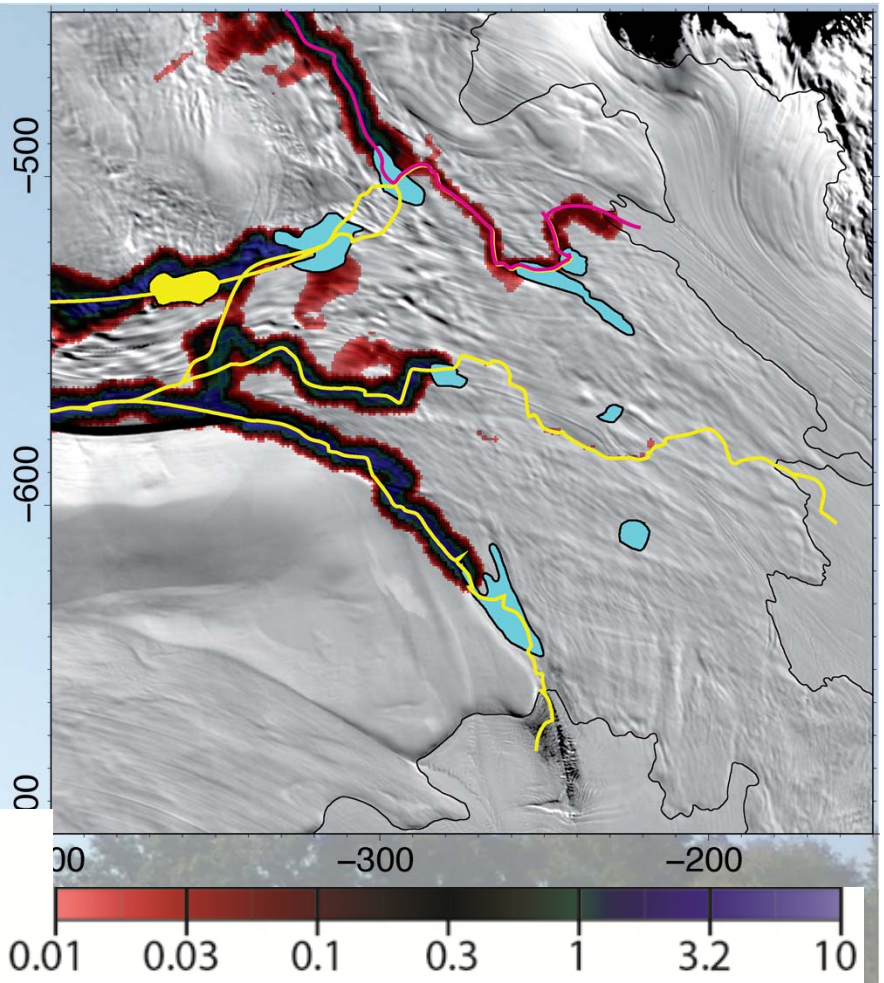


(Carter et al., In press)

L78: more like a natural pressure gauge than a lake

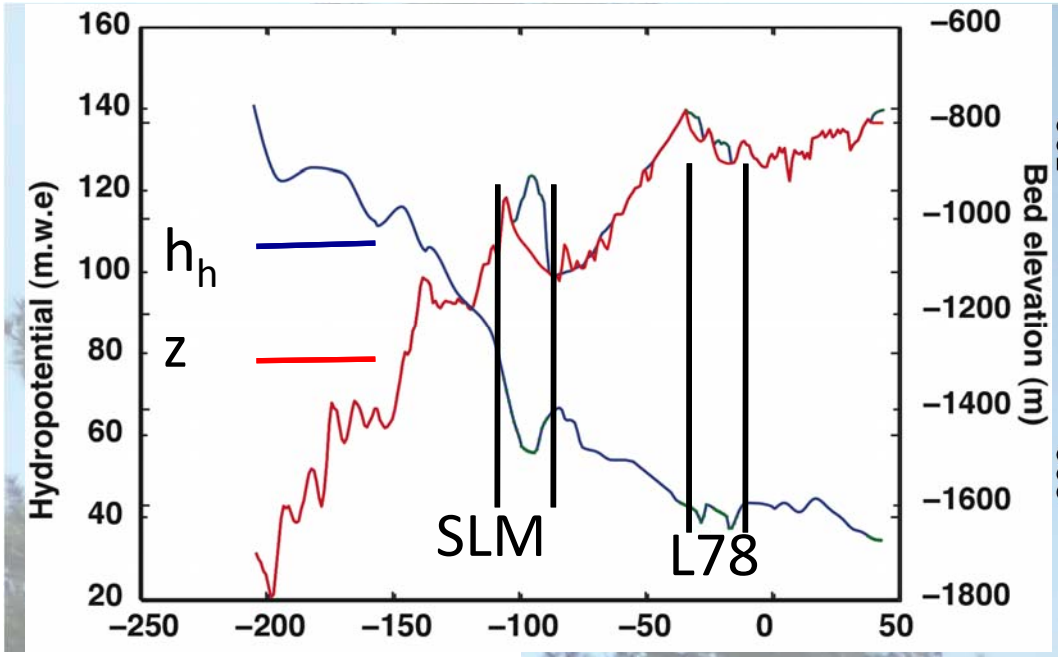






Water flux $m^3\ s^{-1}$ per 2.5 km cell

(Carter et al., In press)



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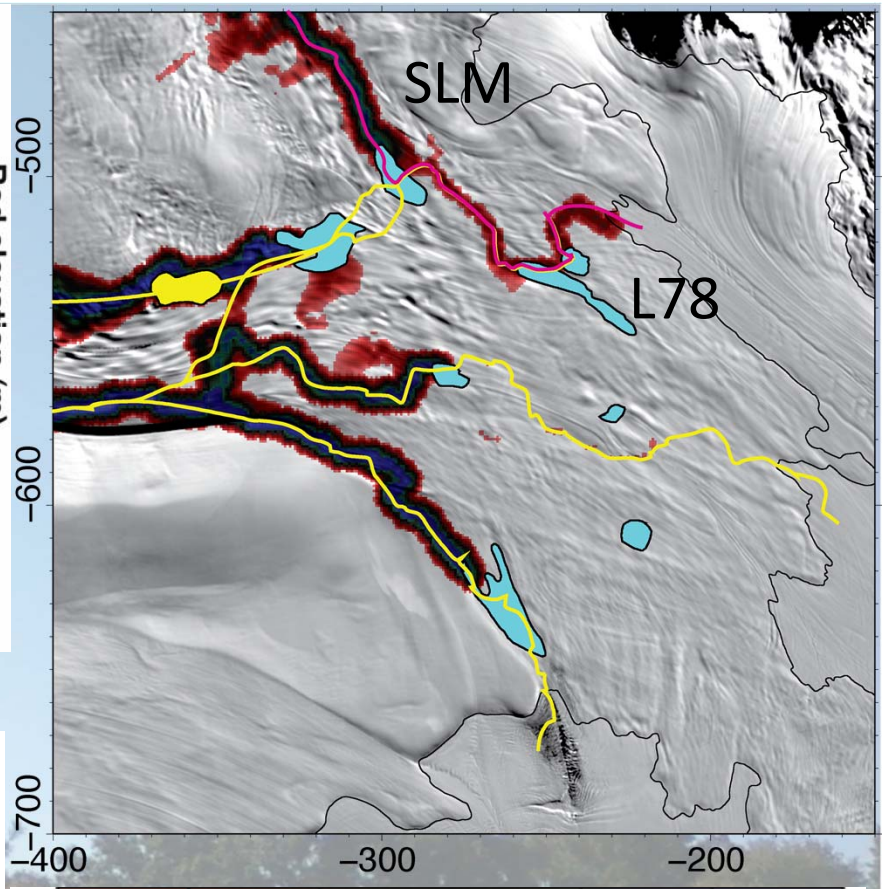
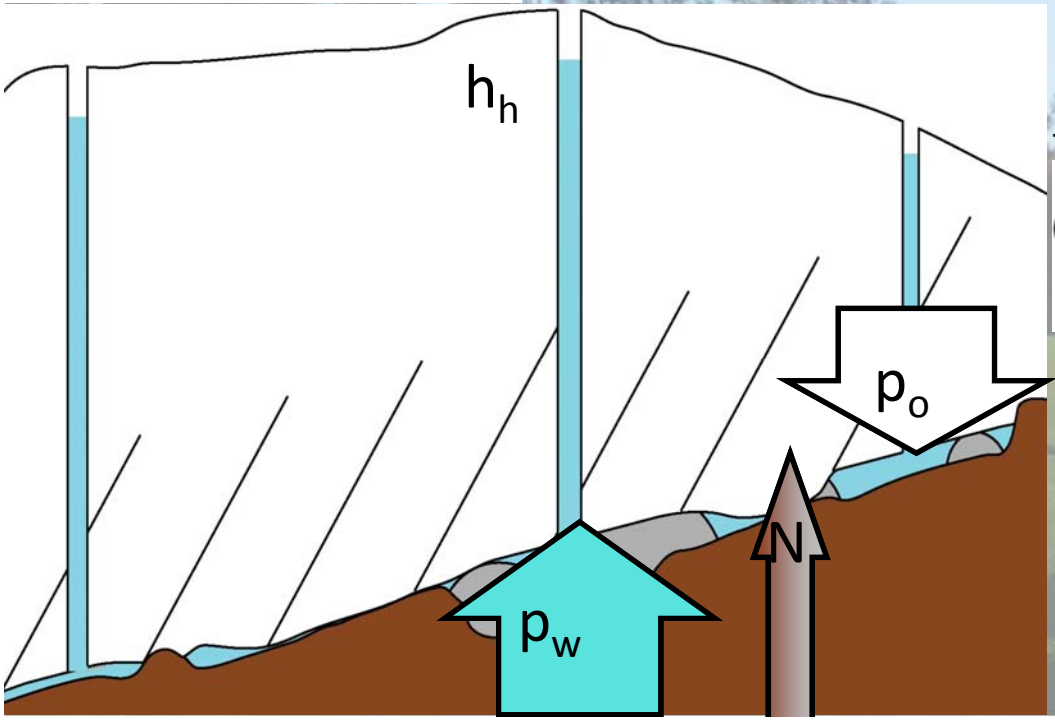
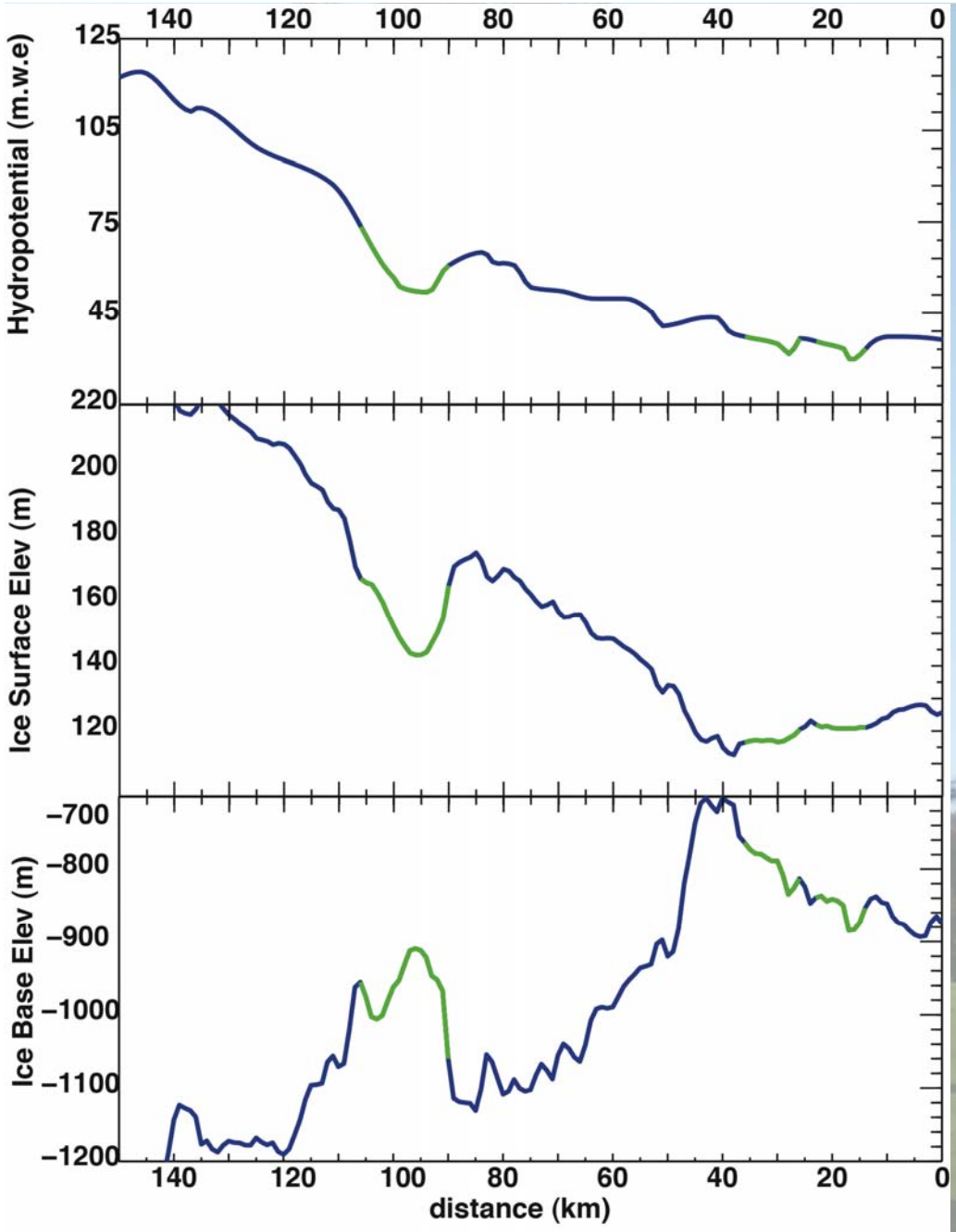
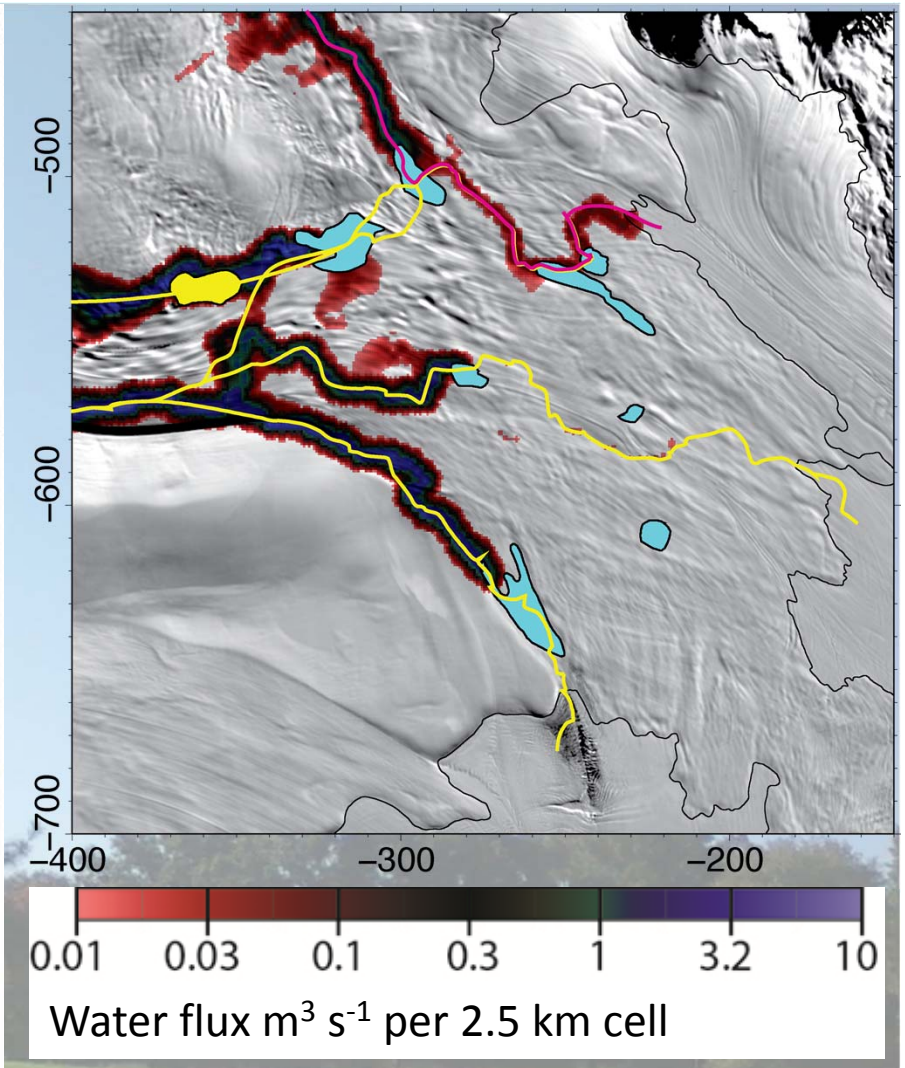


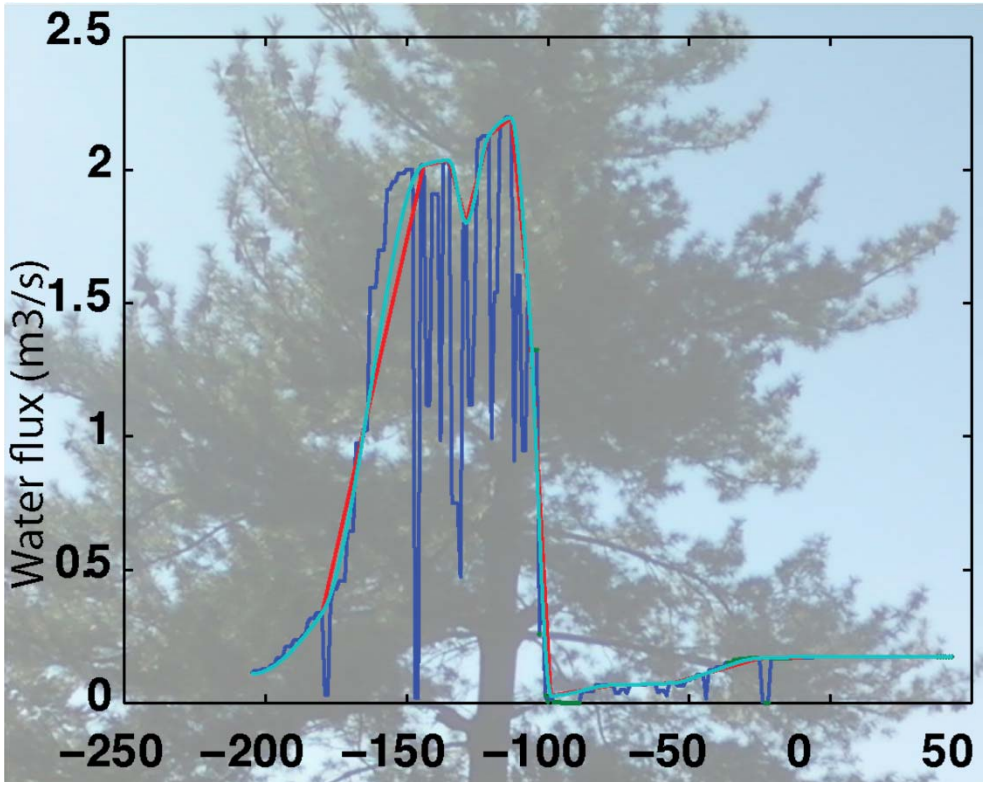


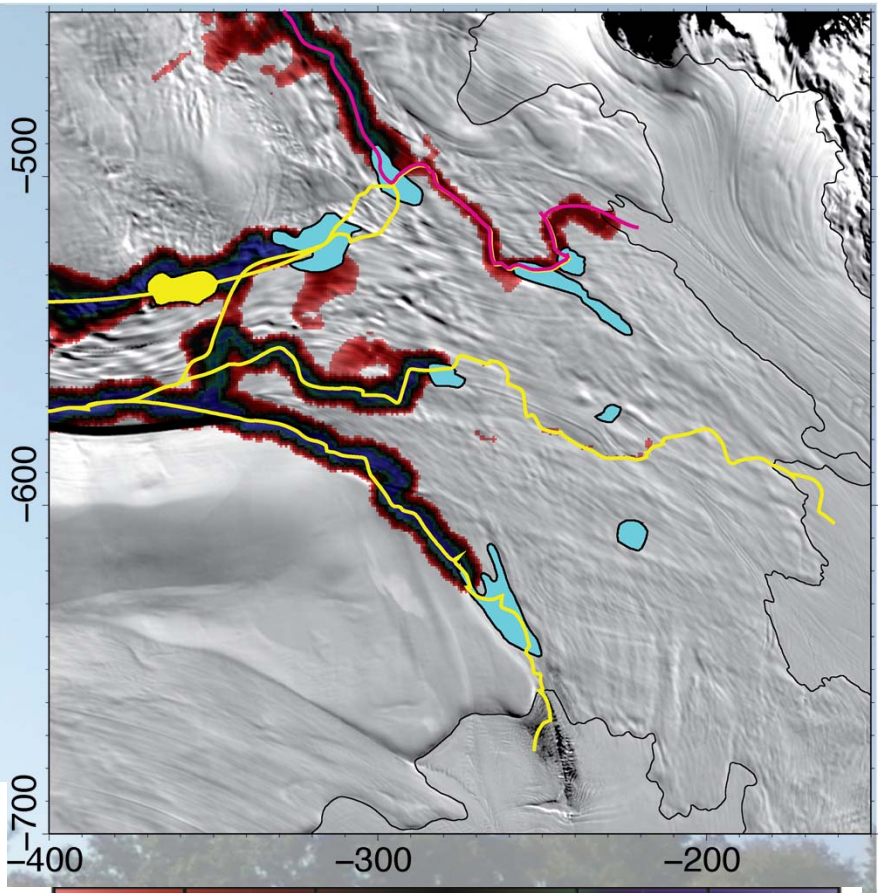
- Hydraulic potential (h_h) = Water pressure (P_w) + elevation (z)
- Water pressure (P_w) = Overburden (P_o) – effective pressure (N)

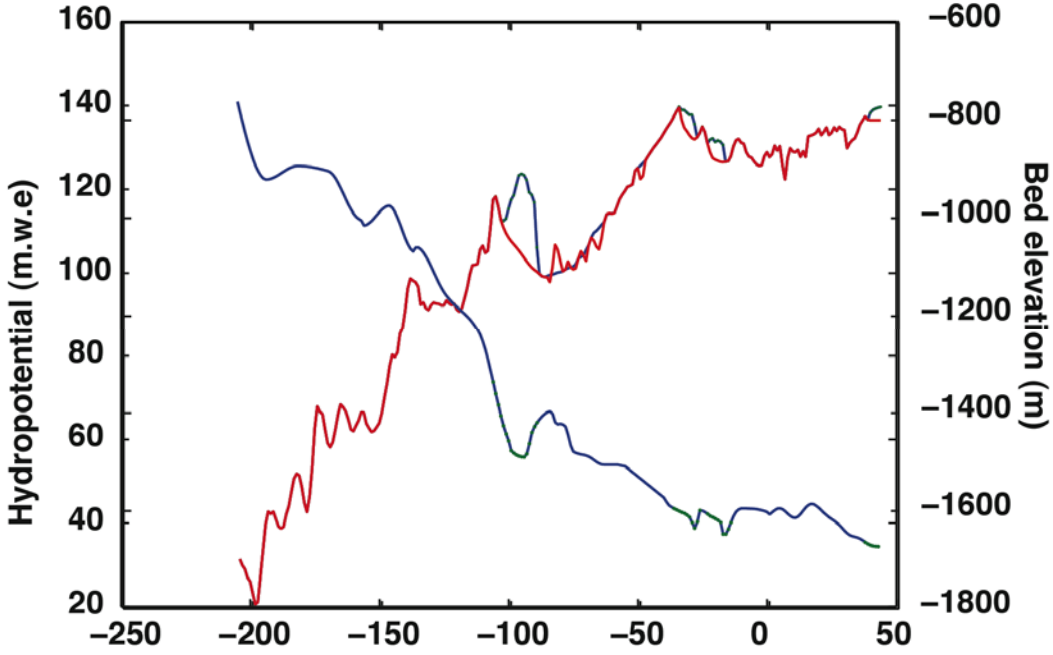


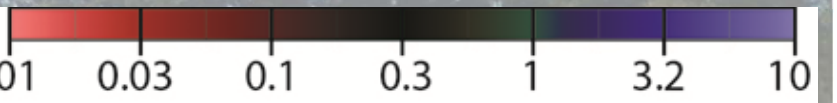


Surface slope generally directs water flow





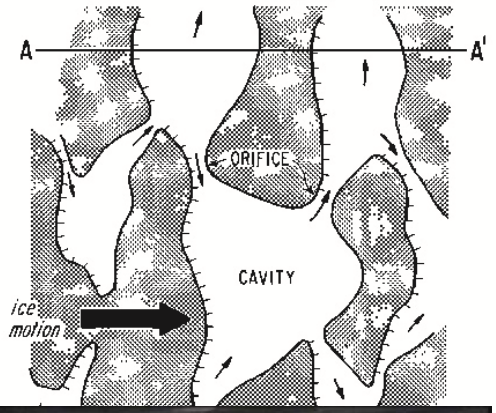


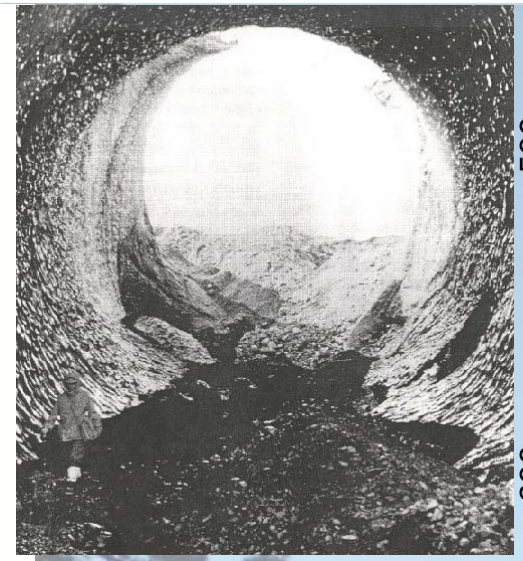


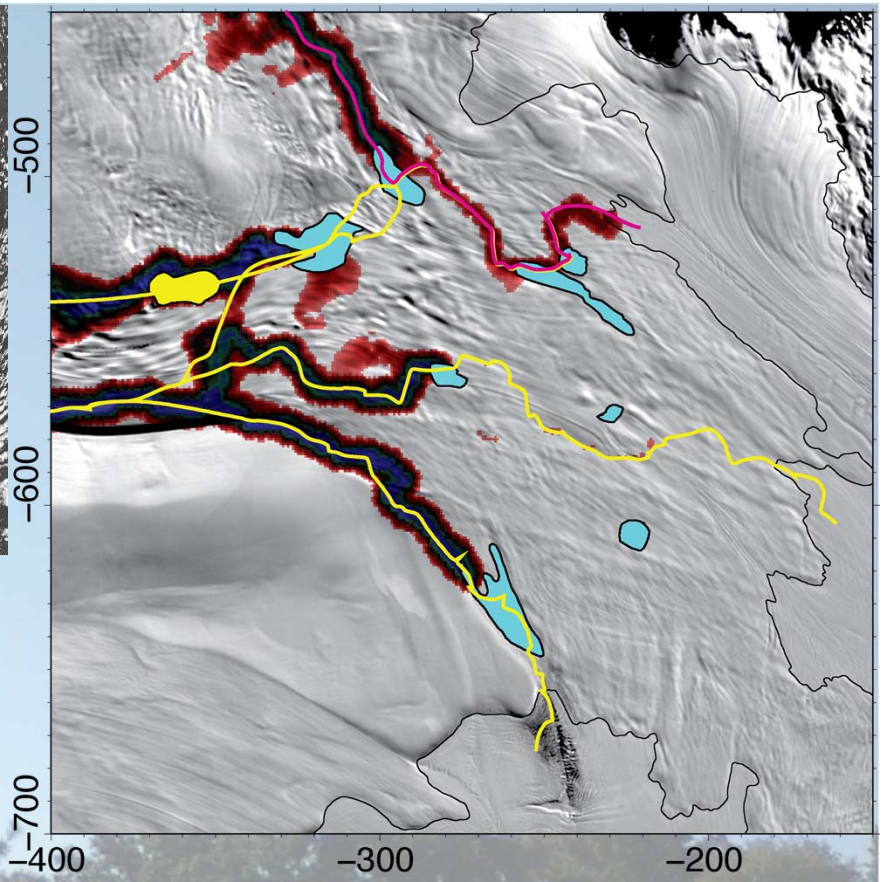
Water flux $m^3\ s^{-1}$ per 2.5 km cell

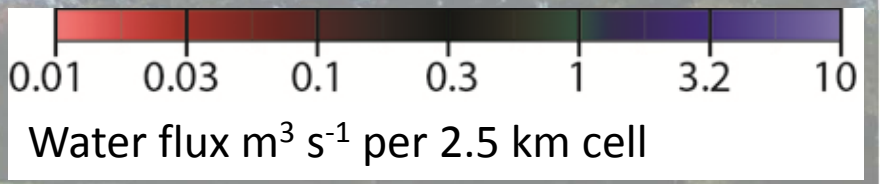
Water budget model + our flowpaths = inputs

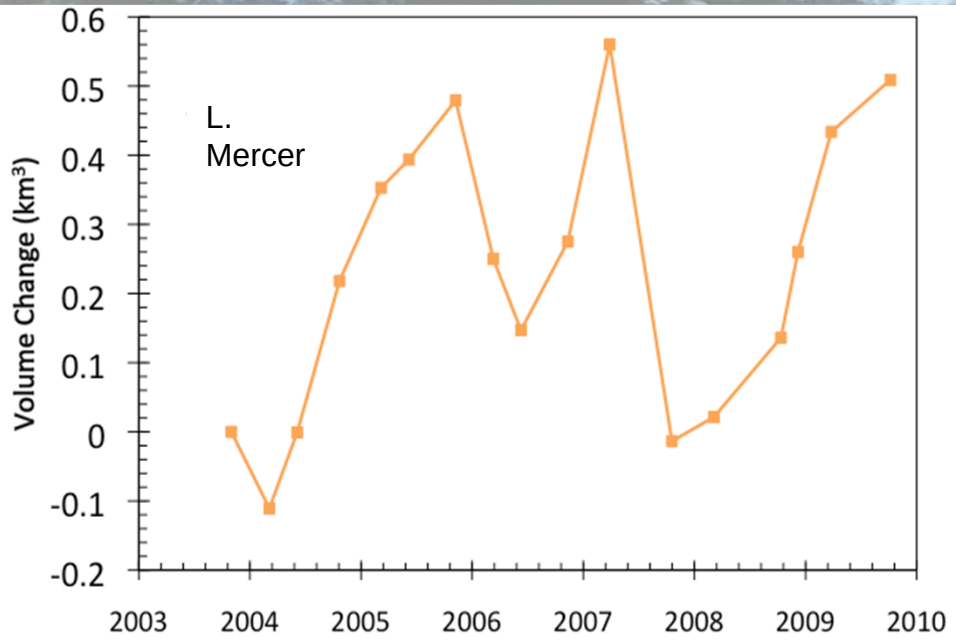
(Carter et al., In prep)











Conduits versus distributed sheetflow

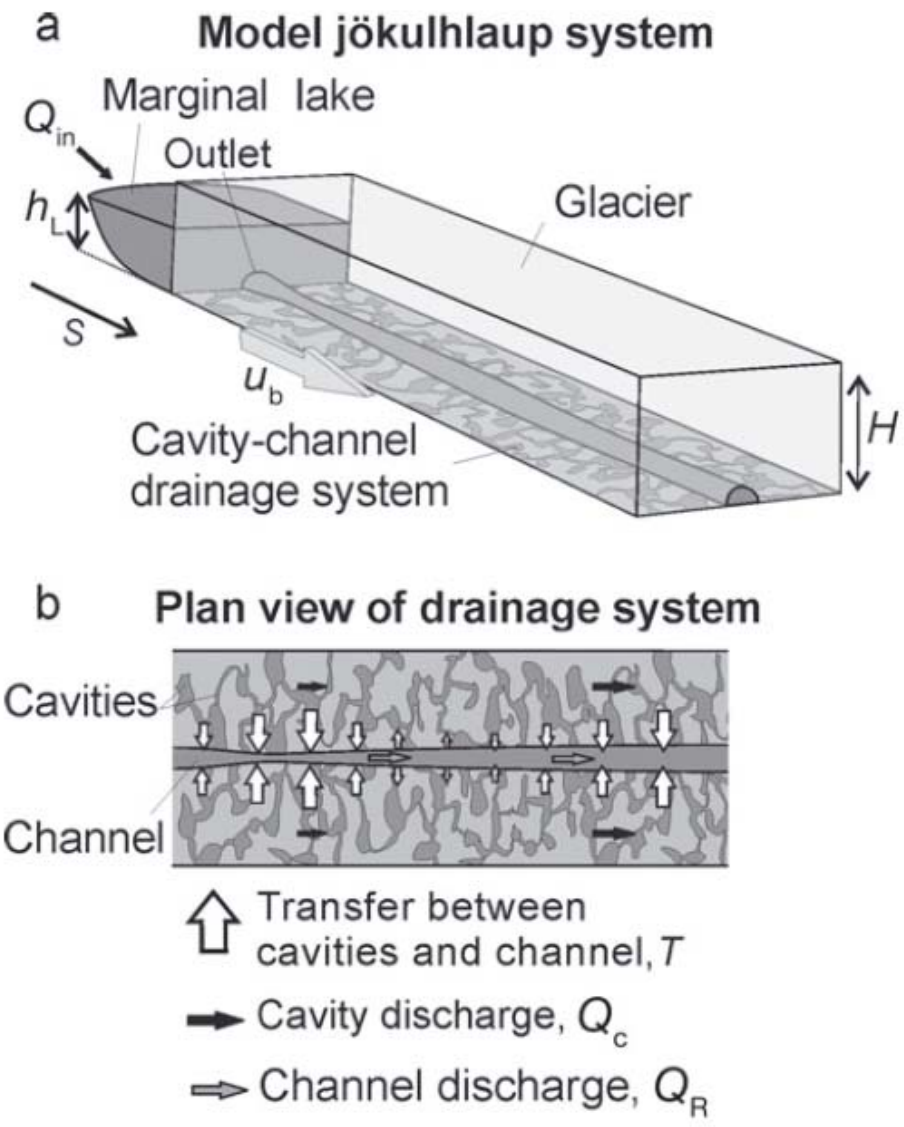
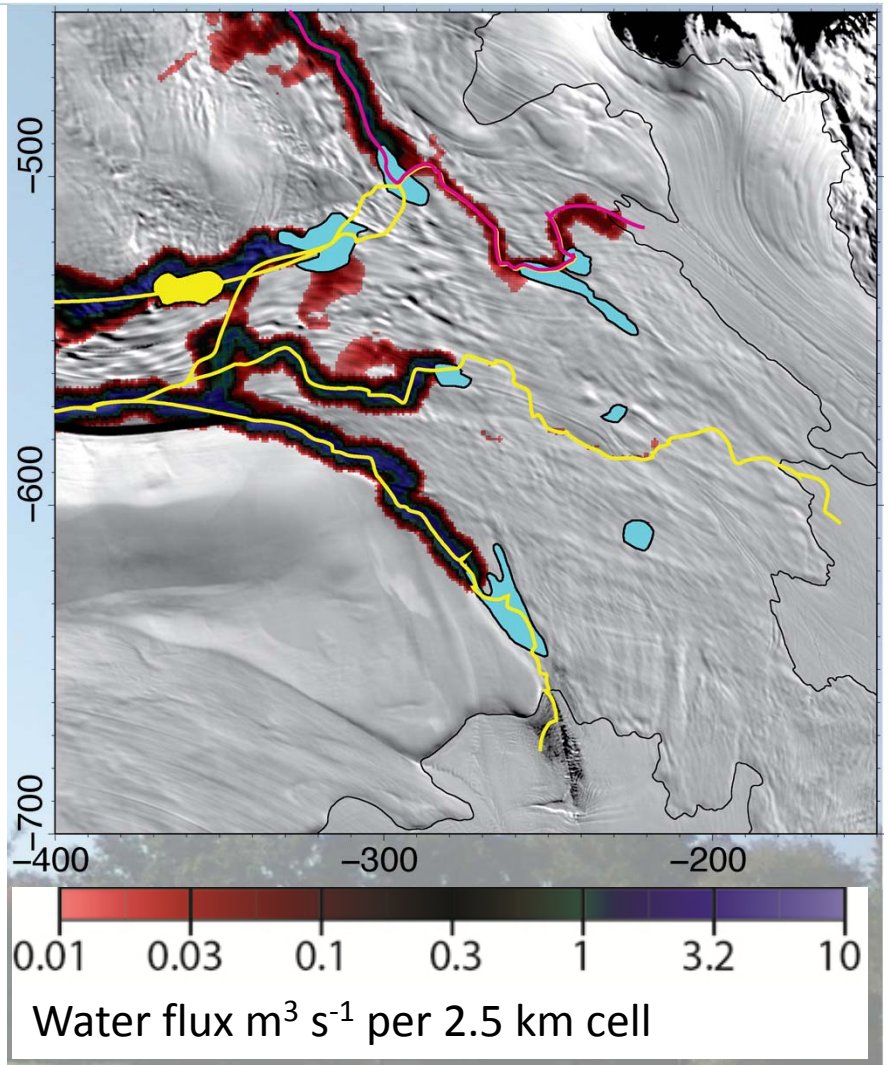


Fig. 1. Diagram of our model jökulhlaup system.

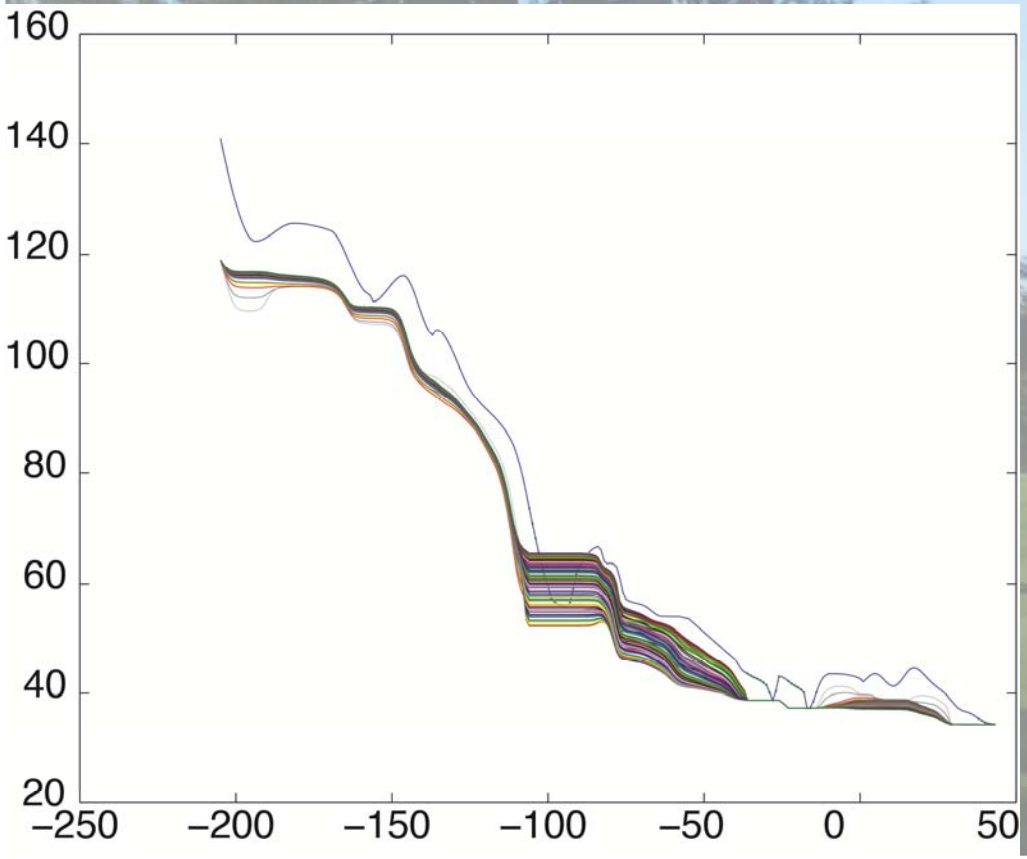


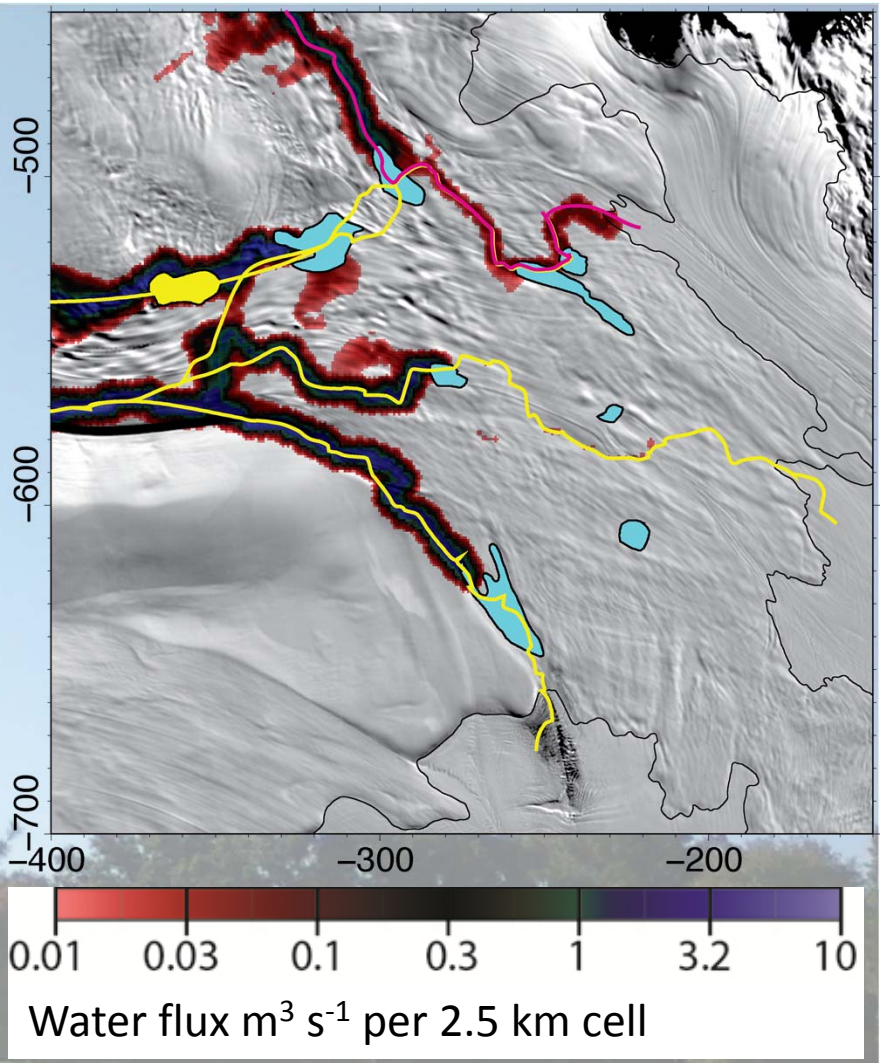
How about both?

Kingslake and Ng 2013

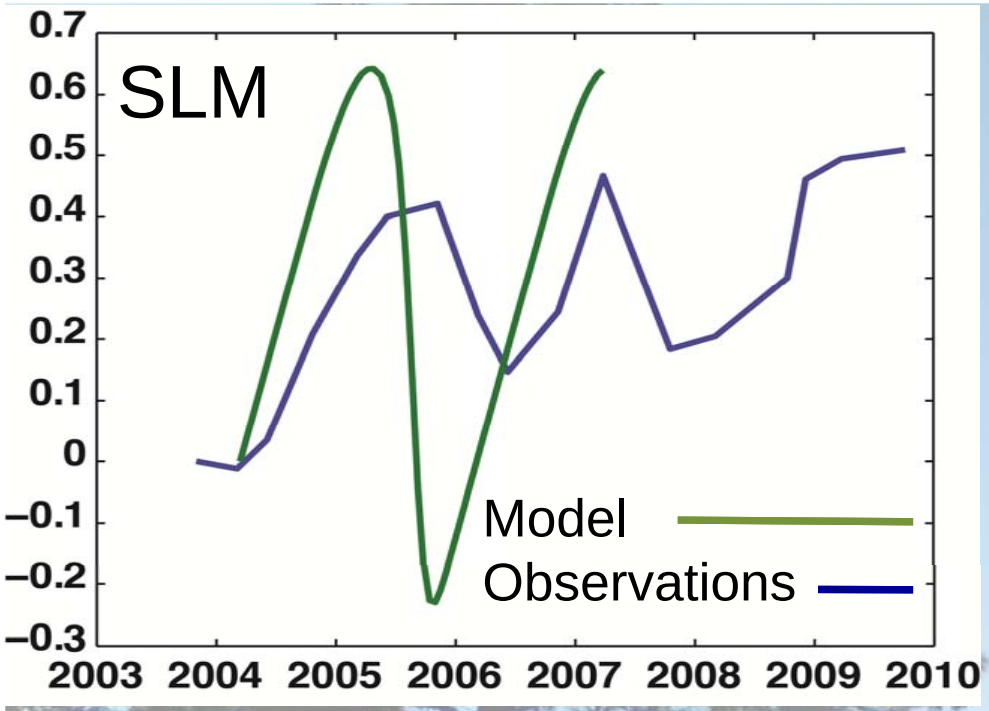
Model results

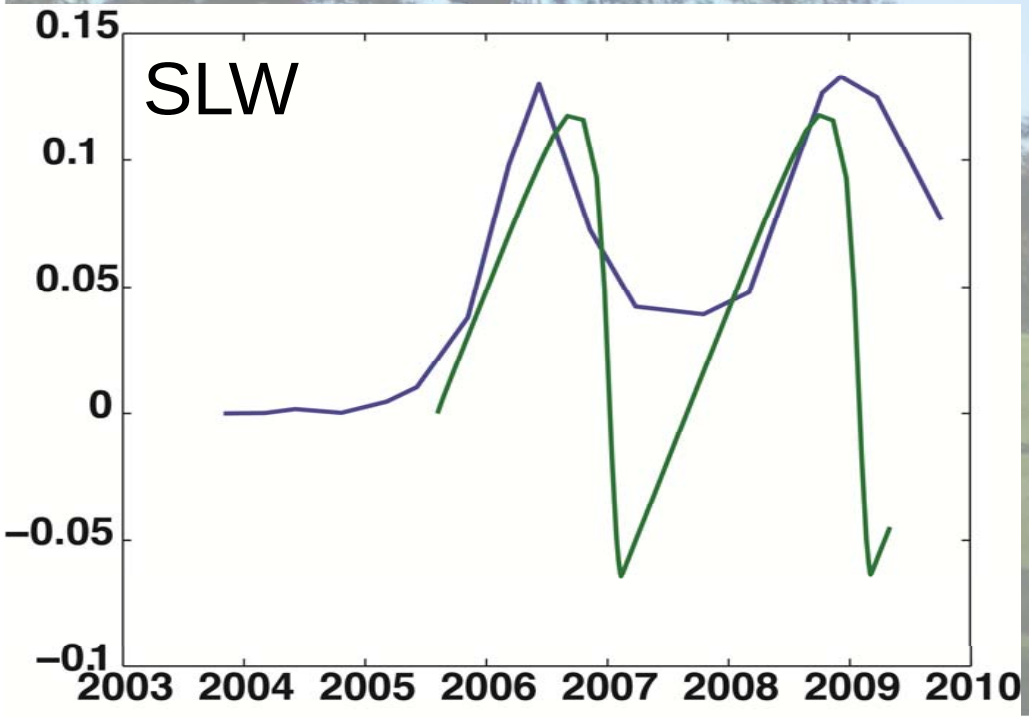
Changes to effective pressure smooth over small lows

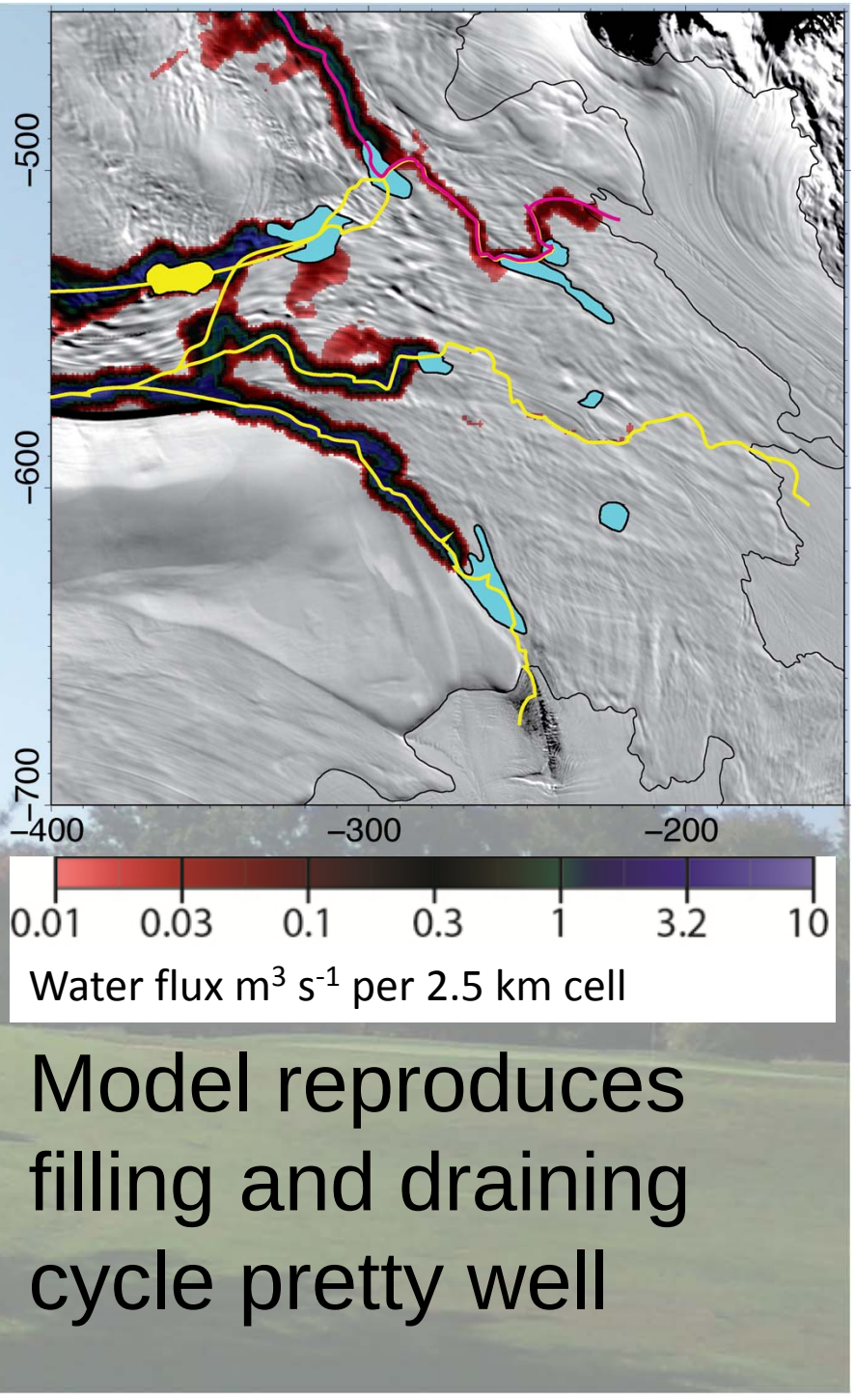




Hydropotential evolves over time

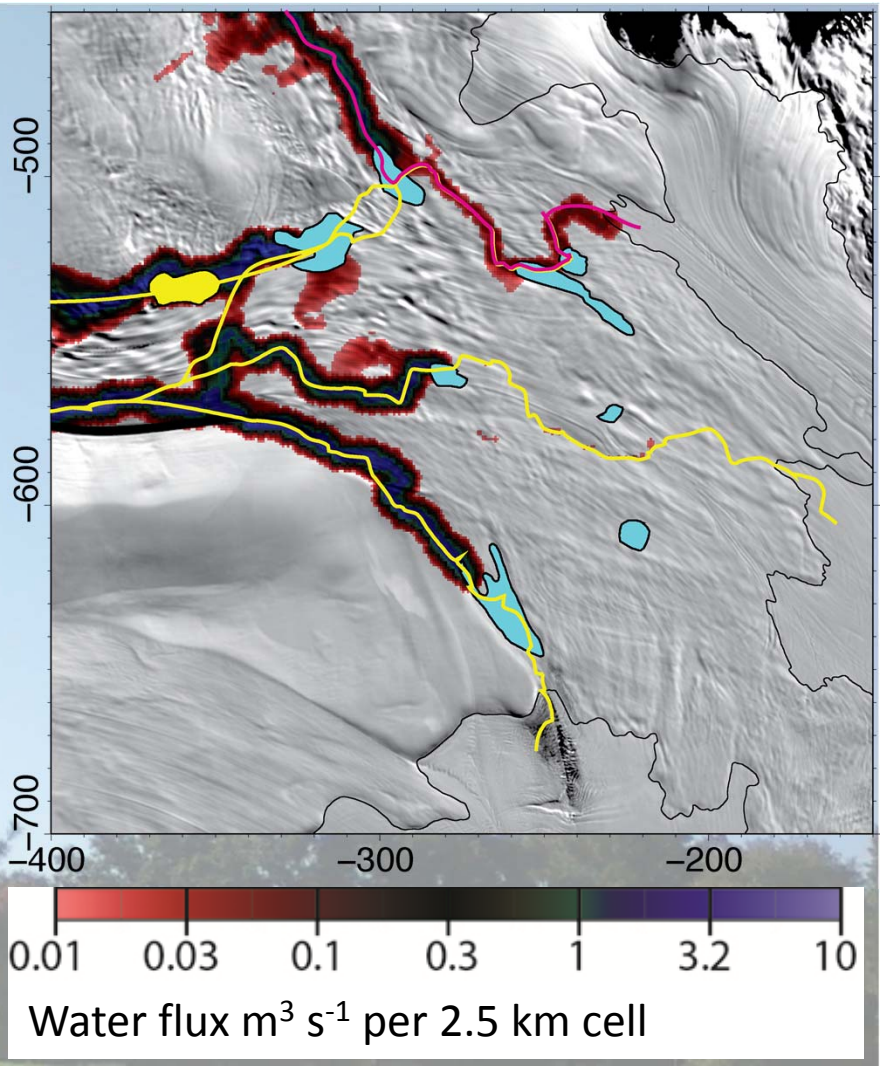






Model reproduces filling and draining cycle pretty well

Water

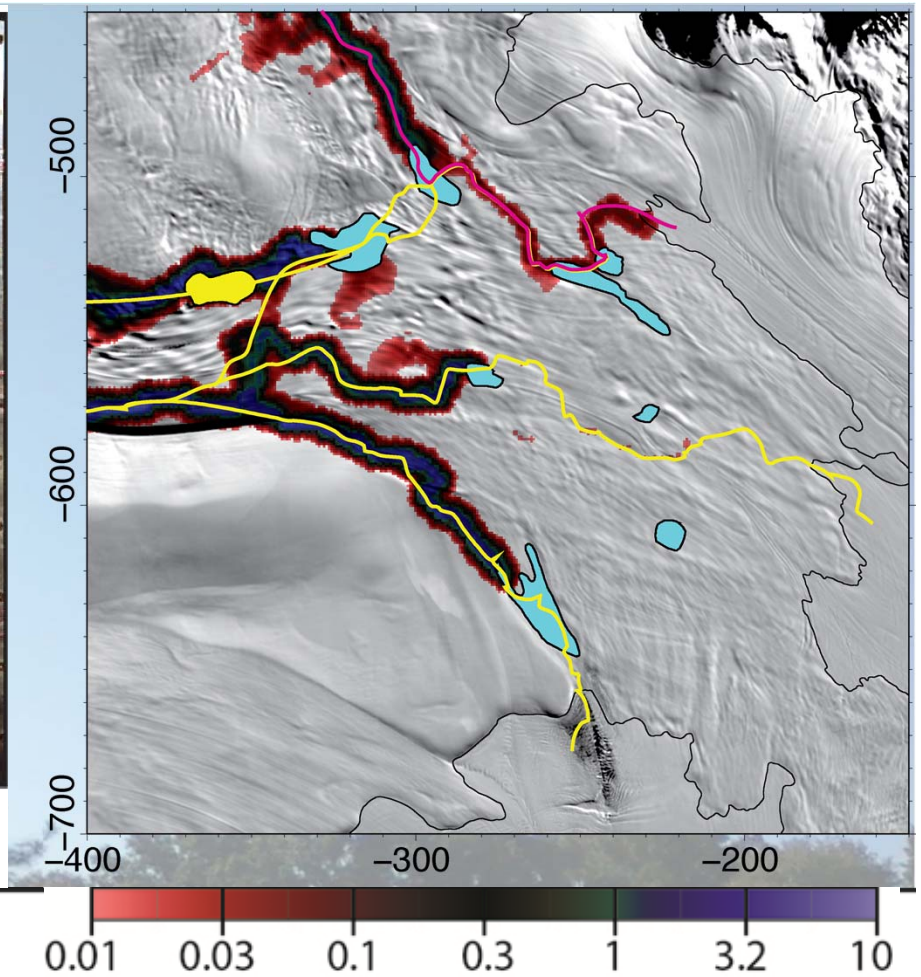


But at what cost?

(Catania and Paola, 2001)

Figure 2.15b: Experiment P.L 3, Q=131 cm^3 s^{-1}, t=27 hours

Figure 2.15c: Experiment P.L 3, Q=210 cm^3 s^{-1}, t=36.1 hours



Water flux m^3 s^{-1} per 2.5 km cell

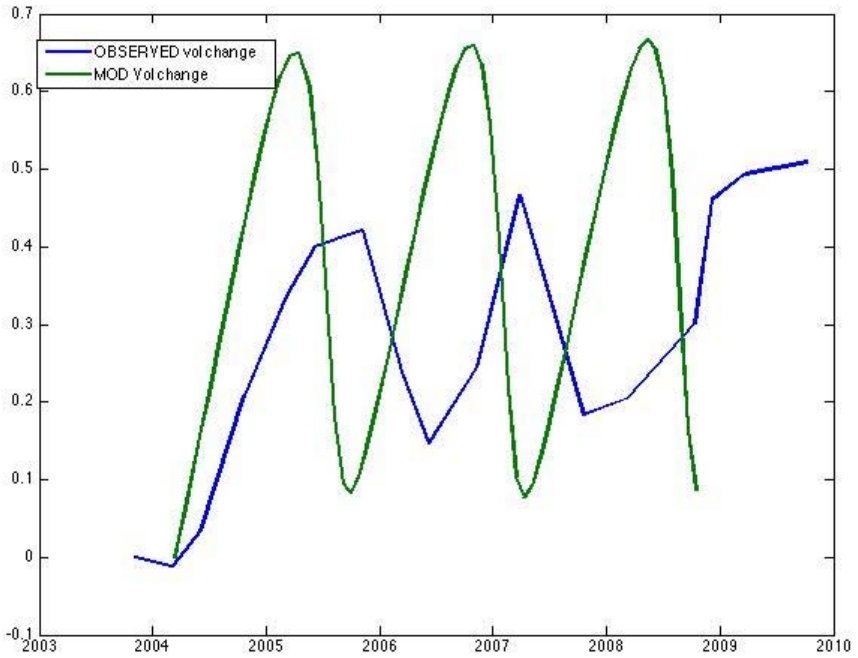
Annals of Glaciology 30 2000

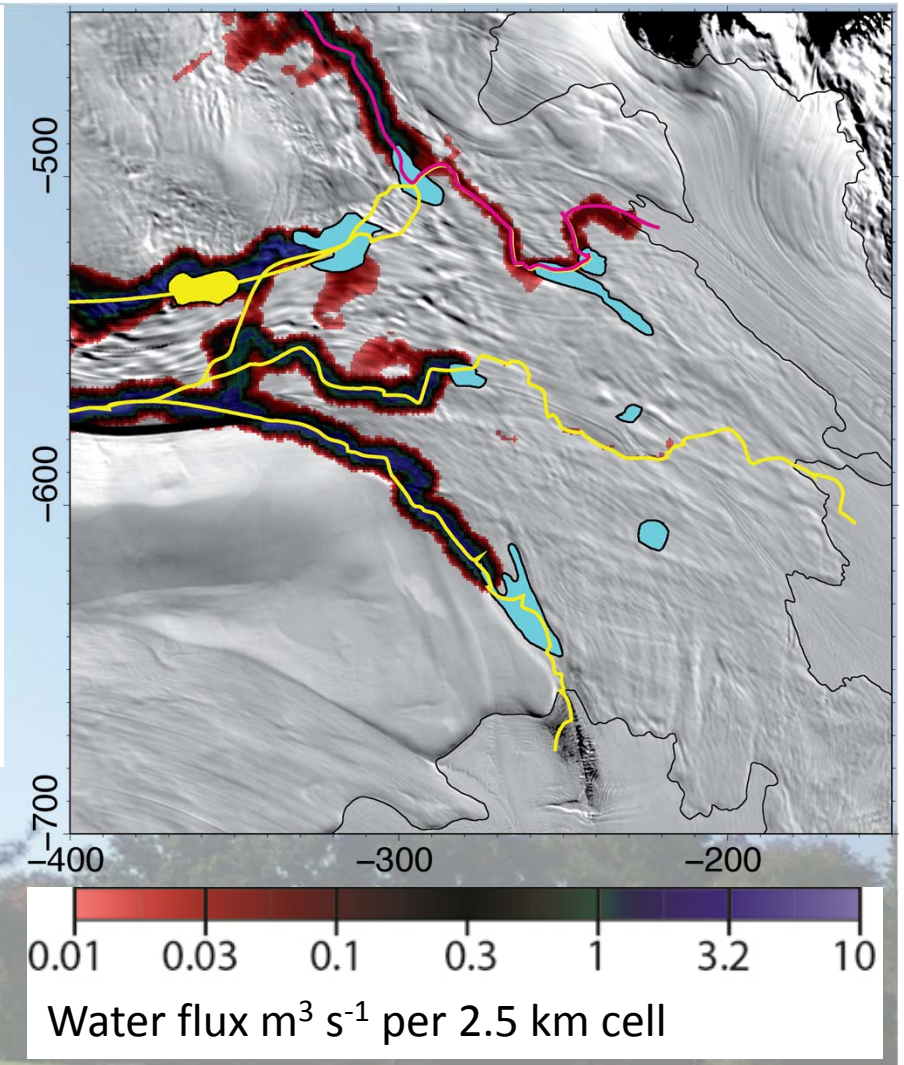
Ask for mud!

Canals under sediment-based ice sheets

FELIX S. L. NG
Mathematical Institute, University of Oxford, Oxford OX1 3LB, England

•Some muds / silts have about the right viscosity / erosivity to explain observations (Folwer 2009)

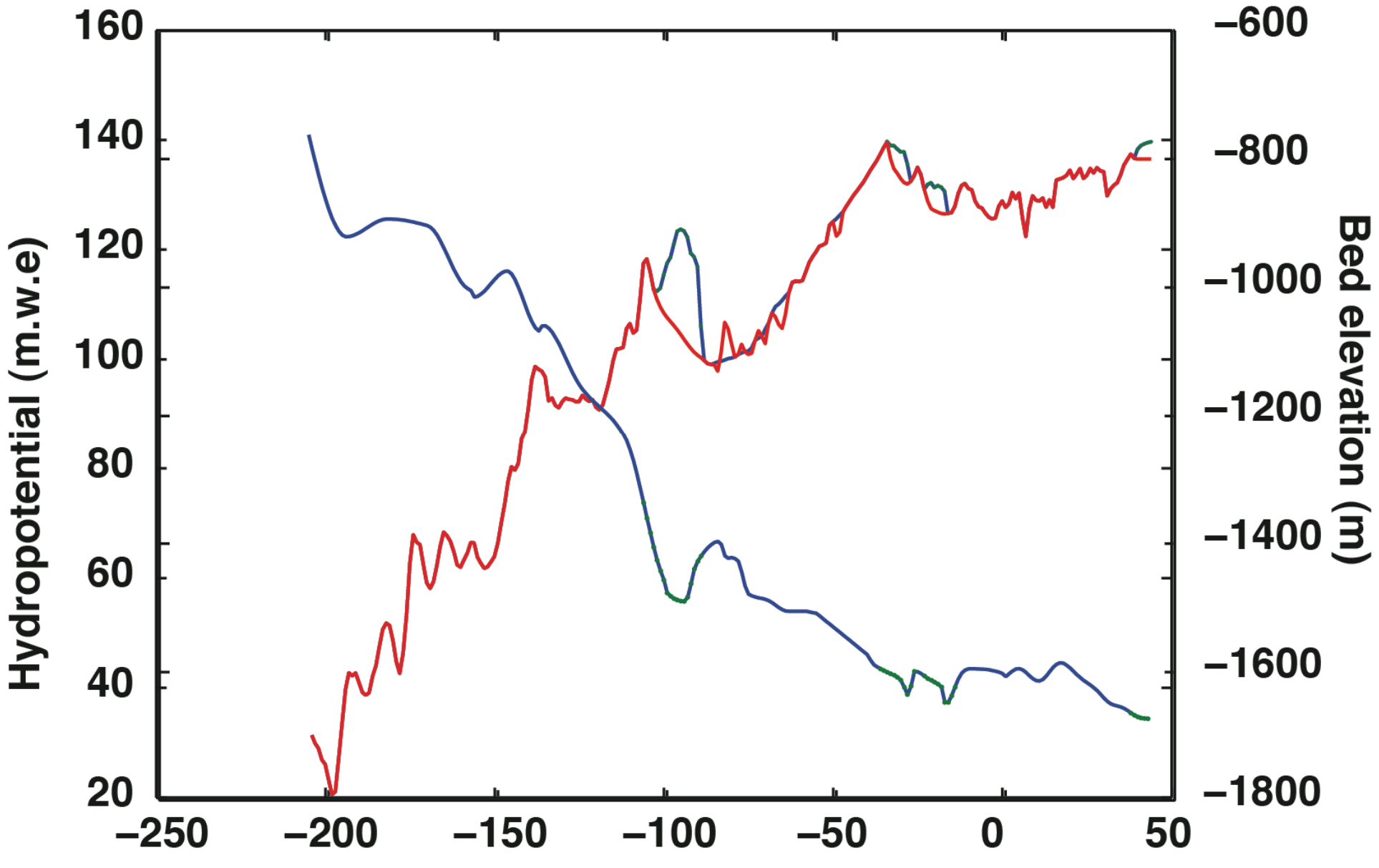




And as of 6 AM today it works

Conclusions

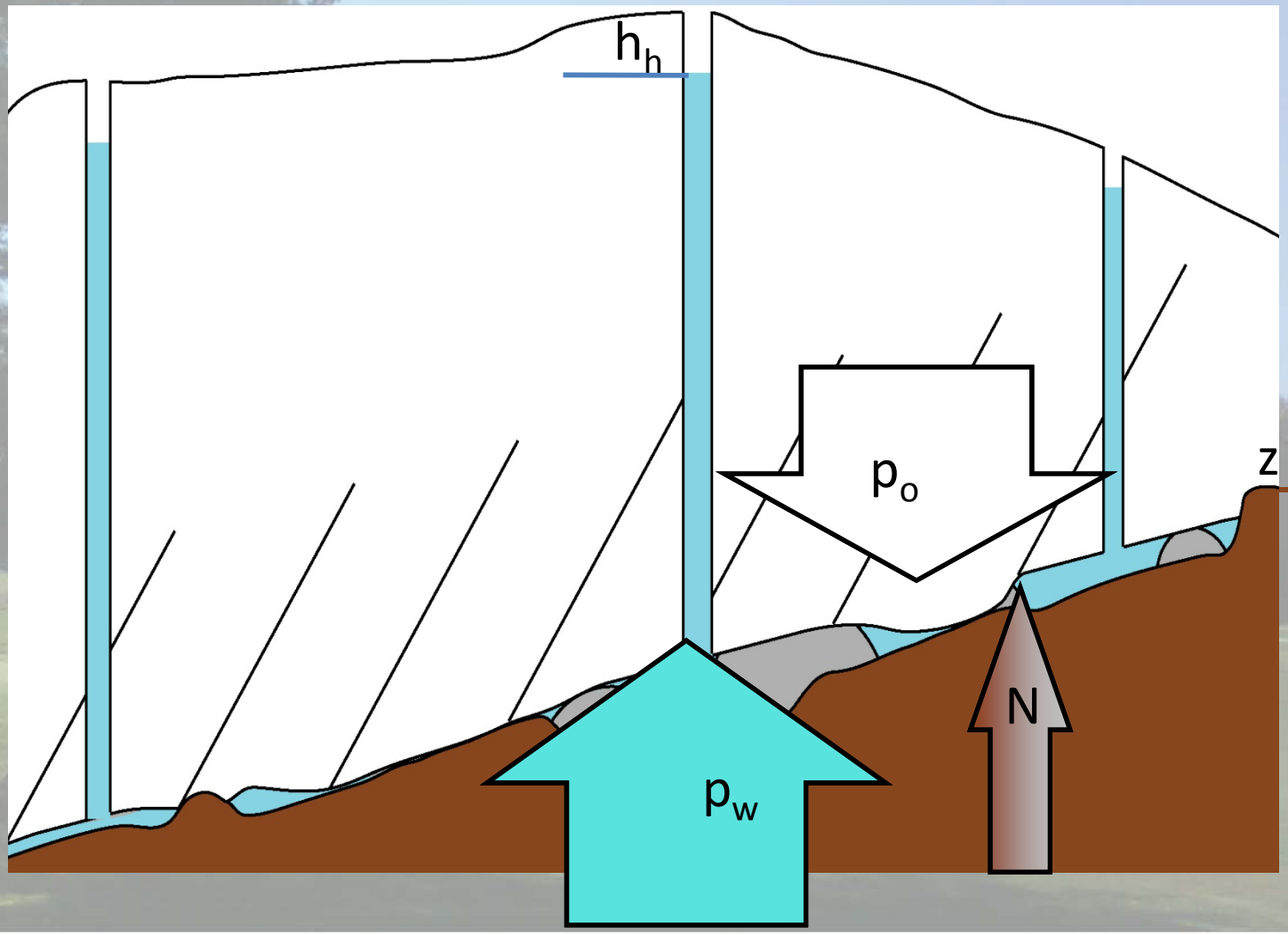
- Water flow in WIS very sensitive to small changes in ice thickness
- SLW might be quite young.
- SLW might now be around for very long
- SLW's water is sourced from upper Kamb Ice Stream
- Some lakes are better though of as pressure gauges / eddies
- Our flowpaths can greatly aide modelling of lake dynamics
- R-Channel theory explains onset of drainage before the lake reaches floatation height.
- However rates of channel growth and contraction suggest sediments
- This means glaciofluvial sediment load may be substantial
- Sediment properties matter

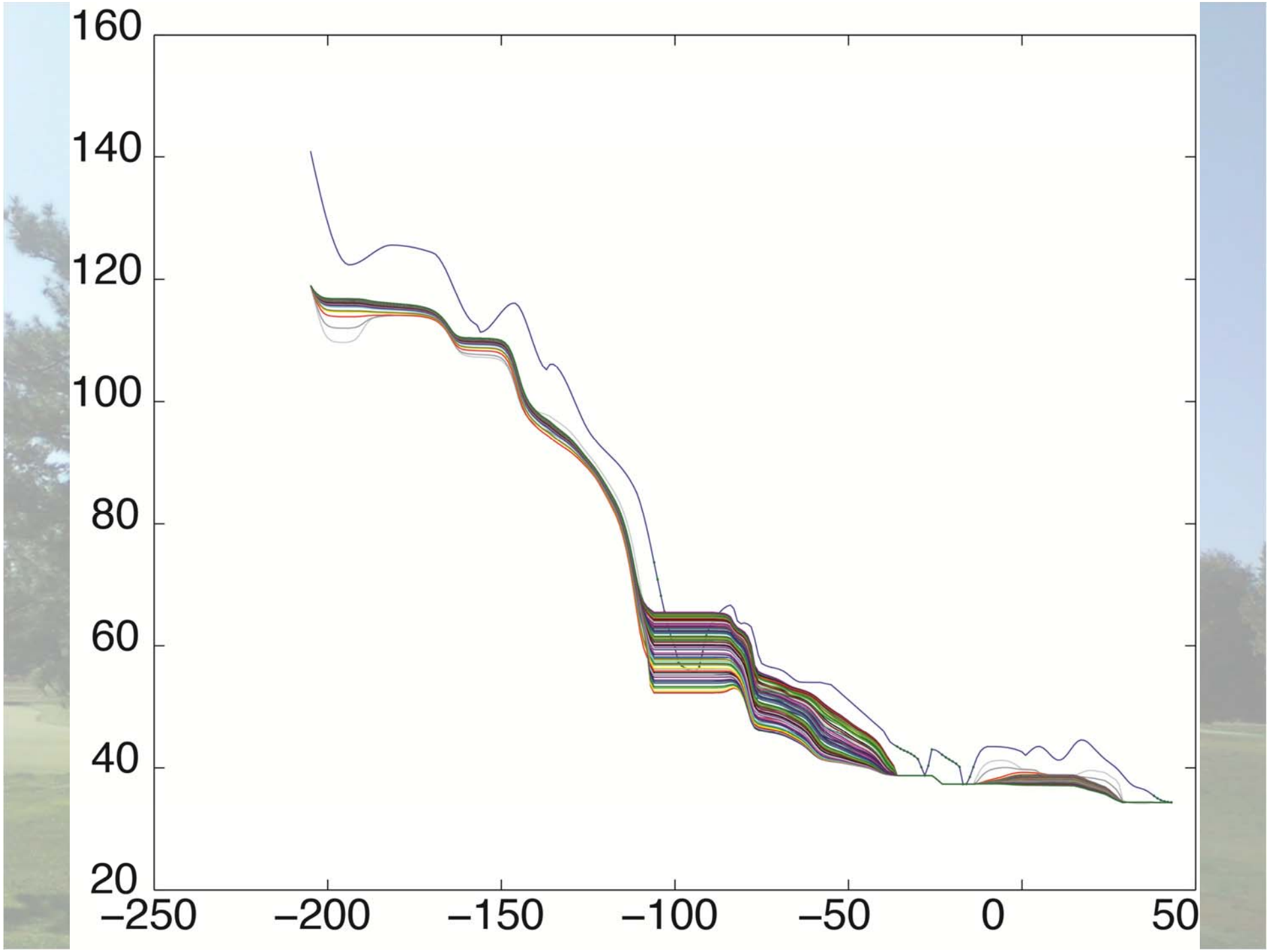

160
140
120
100
80
60
40
20
Hydropotential (m.w.e)
−600
−800
−1000
−1200
−1400
−1600
−1800
Bed elevation (m)
−250
−200
−150
−100
−50
0
50

Hydraulic potential explained

- Hydraulic potential (h_h) = Water pressure (P_w) + elevation (z)
- Water pressure (P_w) = Overburden (P_o) – effective pressure (N)
- Surface elevation 11 times more important than bedrock elevation*

N usually not considered ***(bedrock gradient can be <11 times surface gradient) **(N can also vary spatially)




160
140
120
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80
60
40
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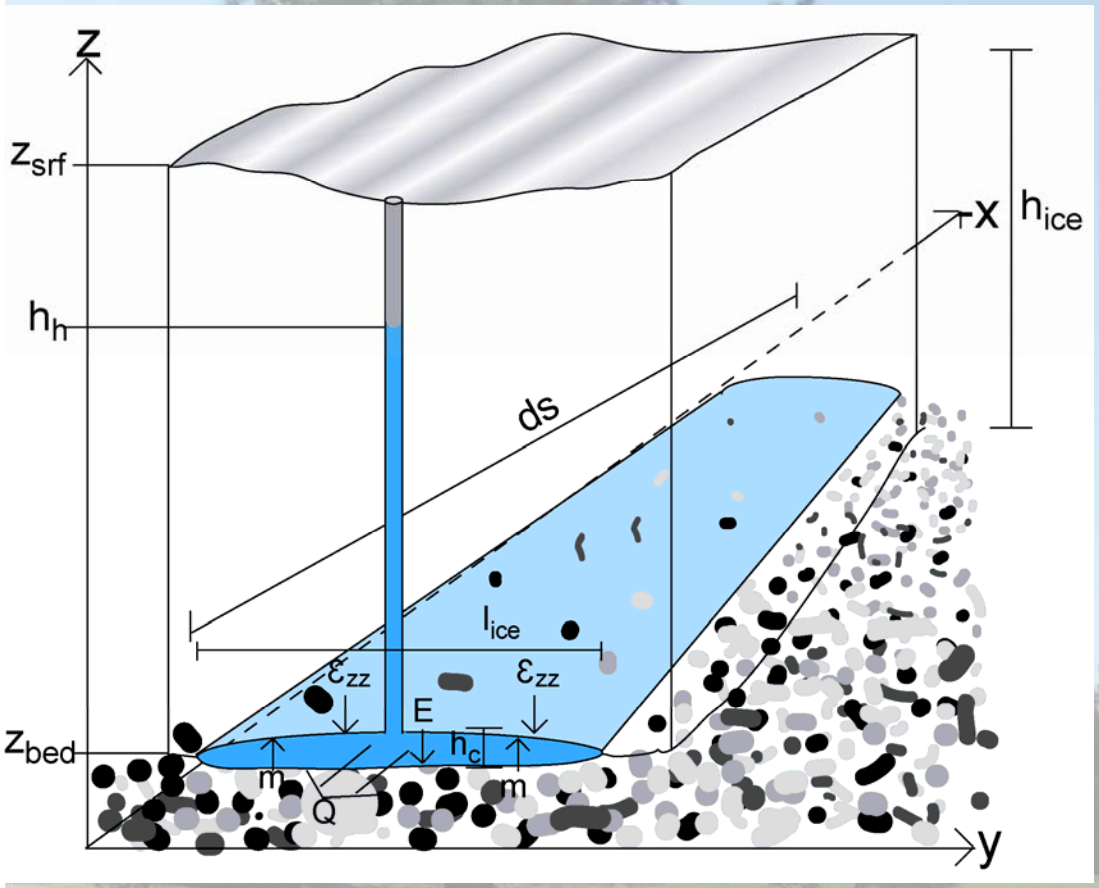
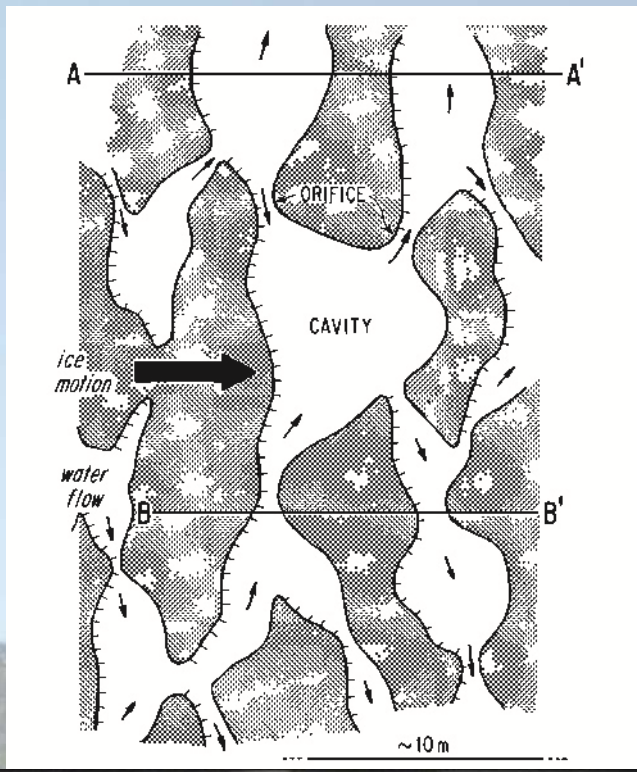
−250
−200
−150
−100
−50
0
50

How water flows: distributed system

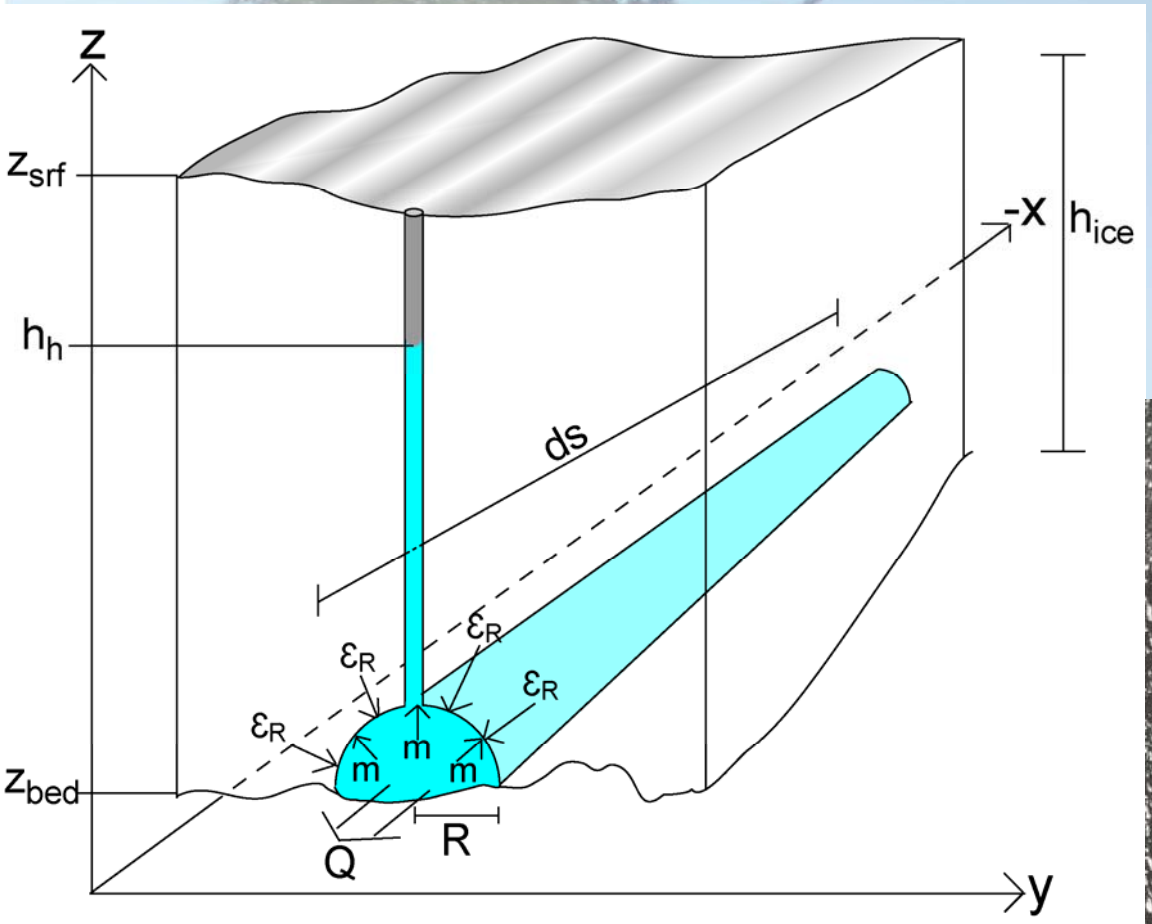




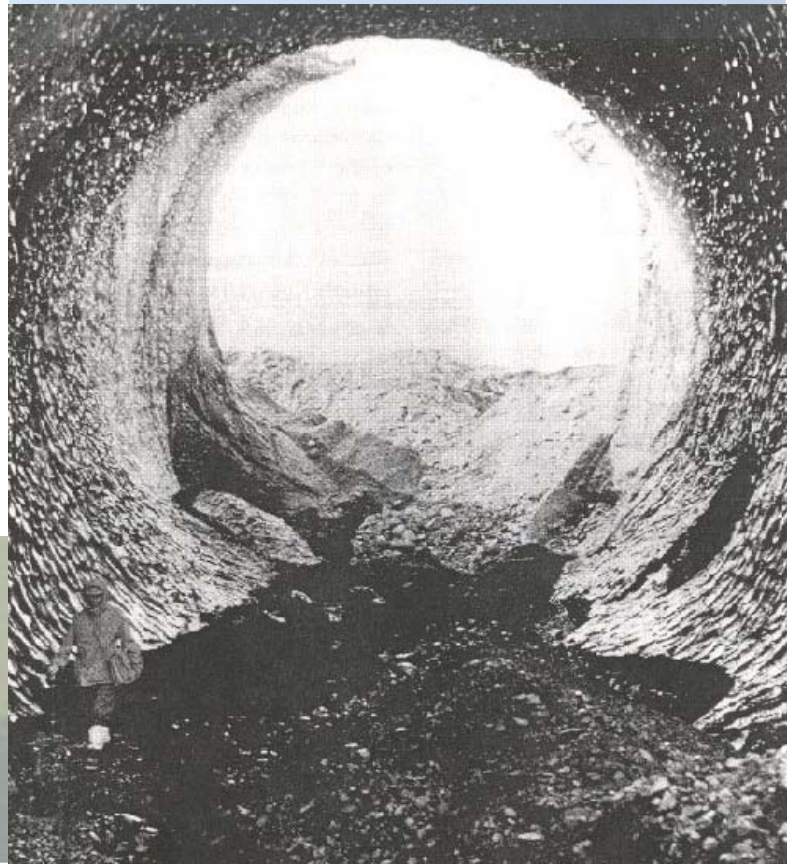
- Floored with deformable sediment
- Water pressures high enough to nearly support overburden.
- Slow drainage

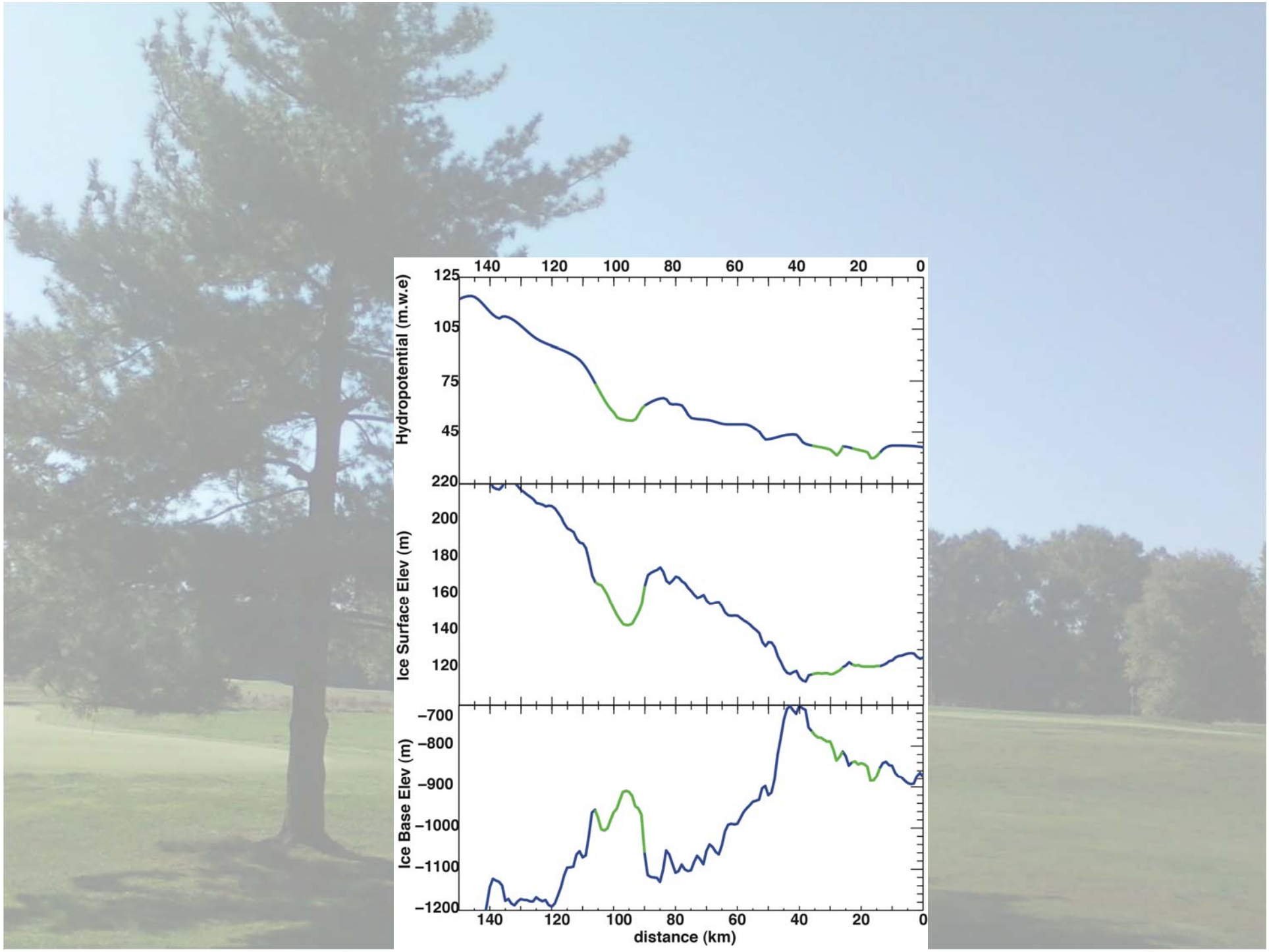
Photo credits (S Vogel)

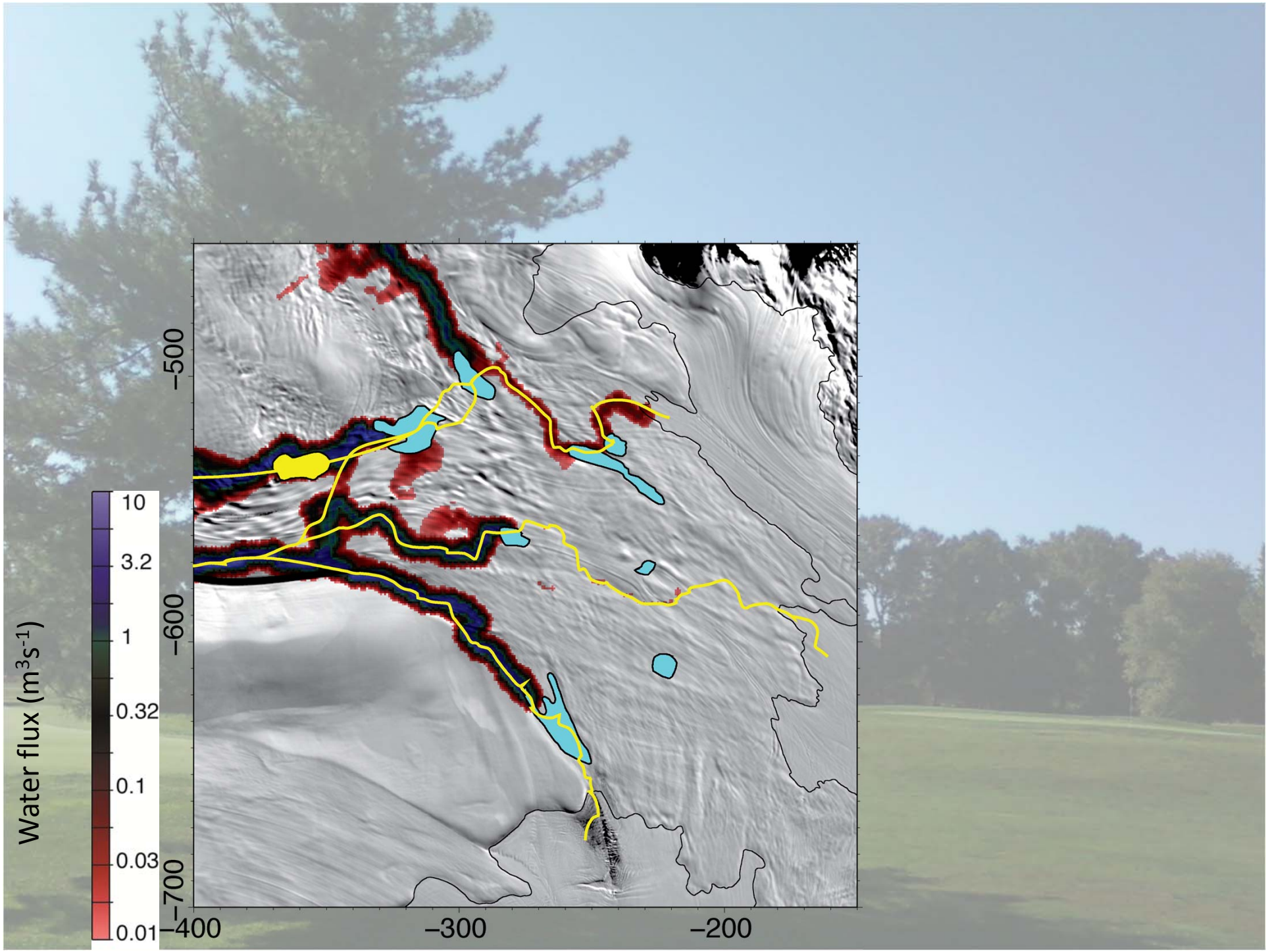
How water flows: distributed system

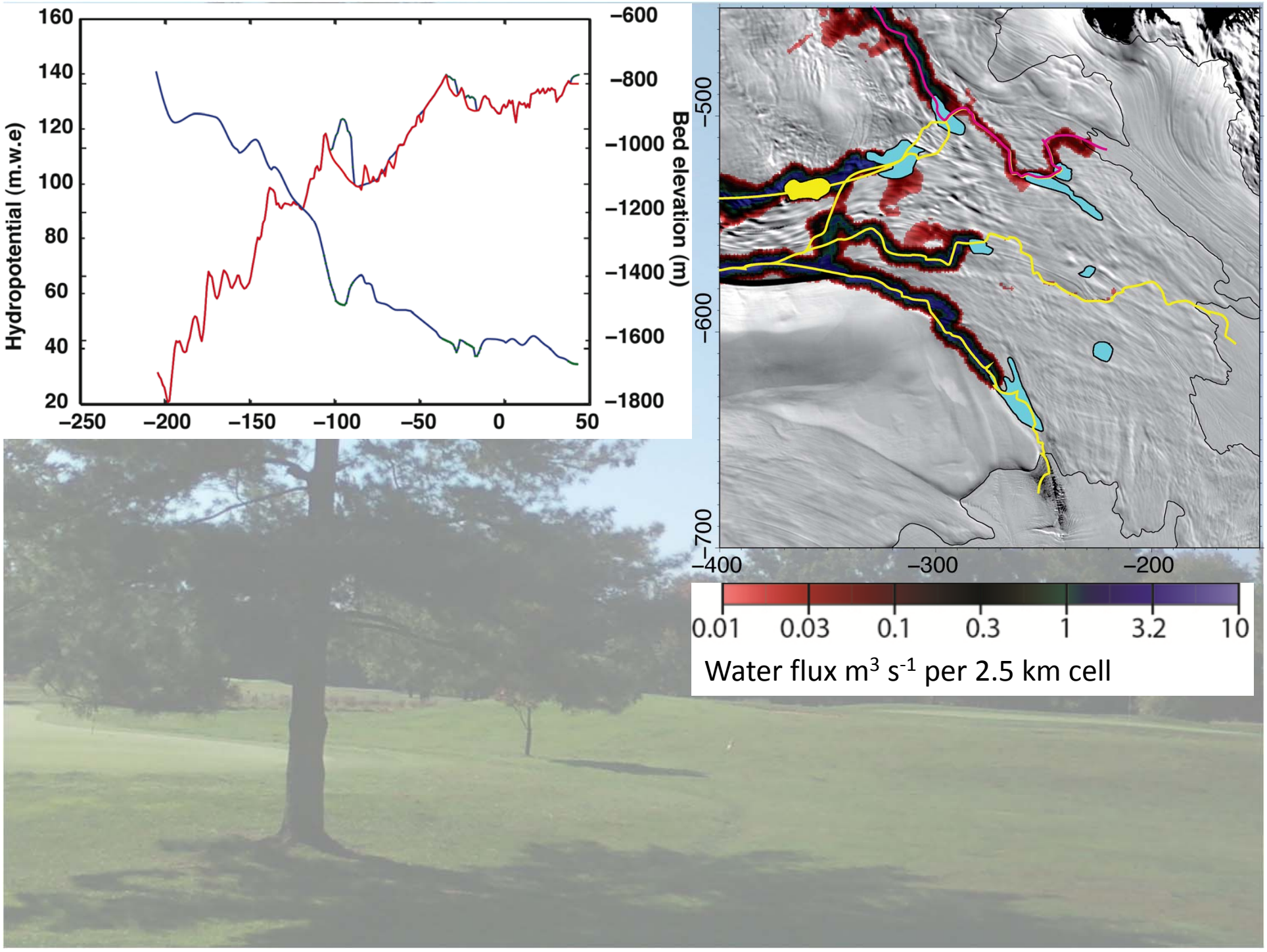


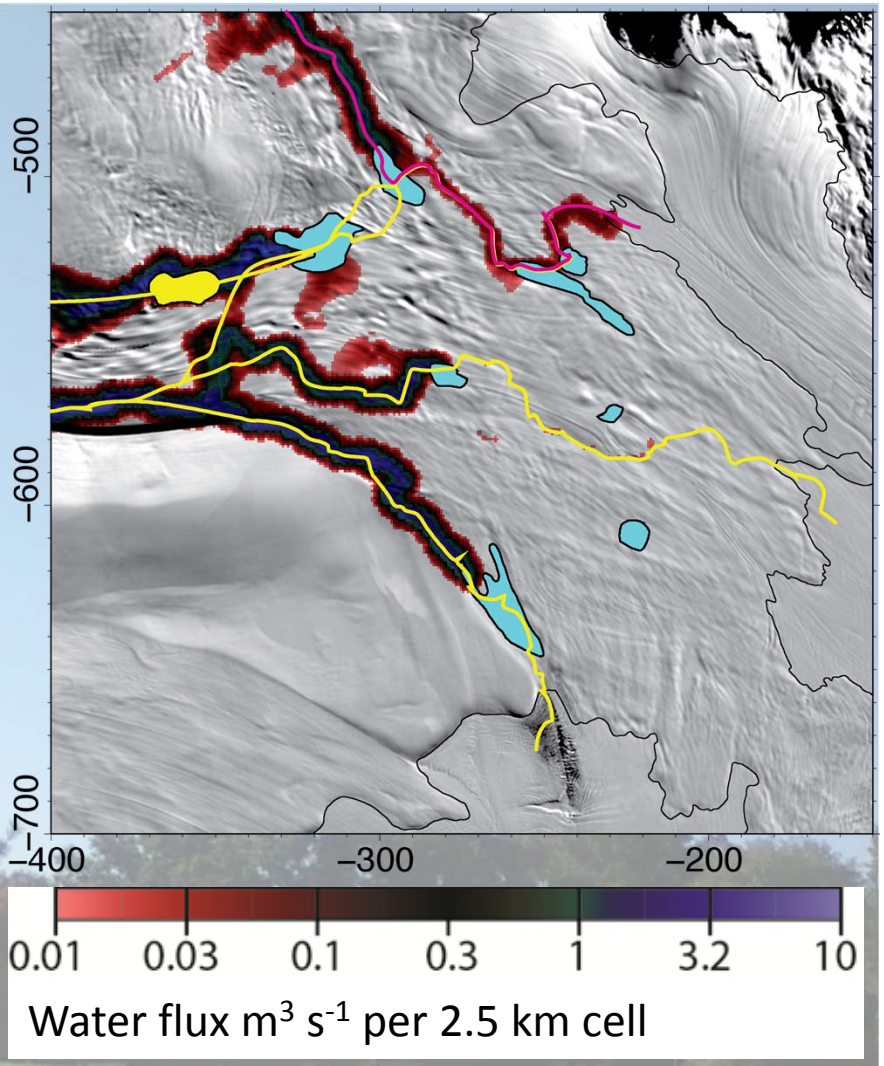
- Expands by melt
- Contracts through ice deformation
- Efficient
- Closure requires change in water pressure at “seal” region.




Hydropotential (m.w.e)
125
105
75
45
Ice Surface Elev (m)
220
200
180
160
140
120
Ice Base Elev (m)
−700
−800
−900
−1000
−1100
−1200
140
120
100
80
60
40
20
0
distance (km)


Water flux (m^3s^{-1})
10
3.2
1
0.32
0.1
0.03
0.01
−500
−600
−700
−400
−300
−200


Hydropotential (m.w.e)
160
140
120
100
80
60
40
20
−250
−200
−150
−100
−50
0
50
Bed elevation (m)
−600
−800
−1000
−1200
−1400
−1600
−1800
−500
−600
−700
−400
−300
−200
0.01
0.03
0.1
0.3
1
3.2
10
Water flux m3 s-1 per 2.5 km cell



Sorry no cool demos this time