Implementing and validating a model for basal water

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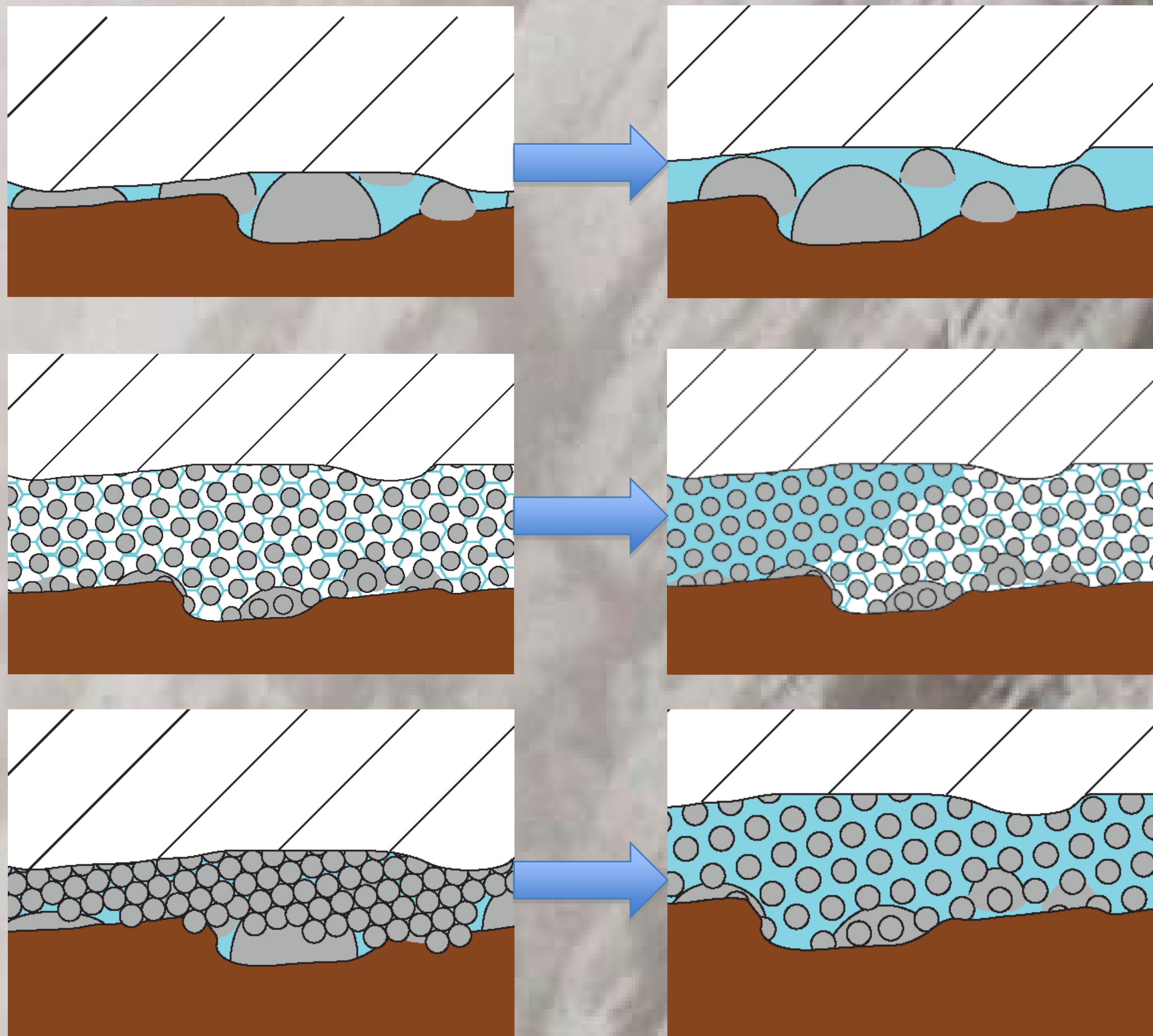
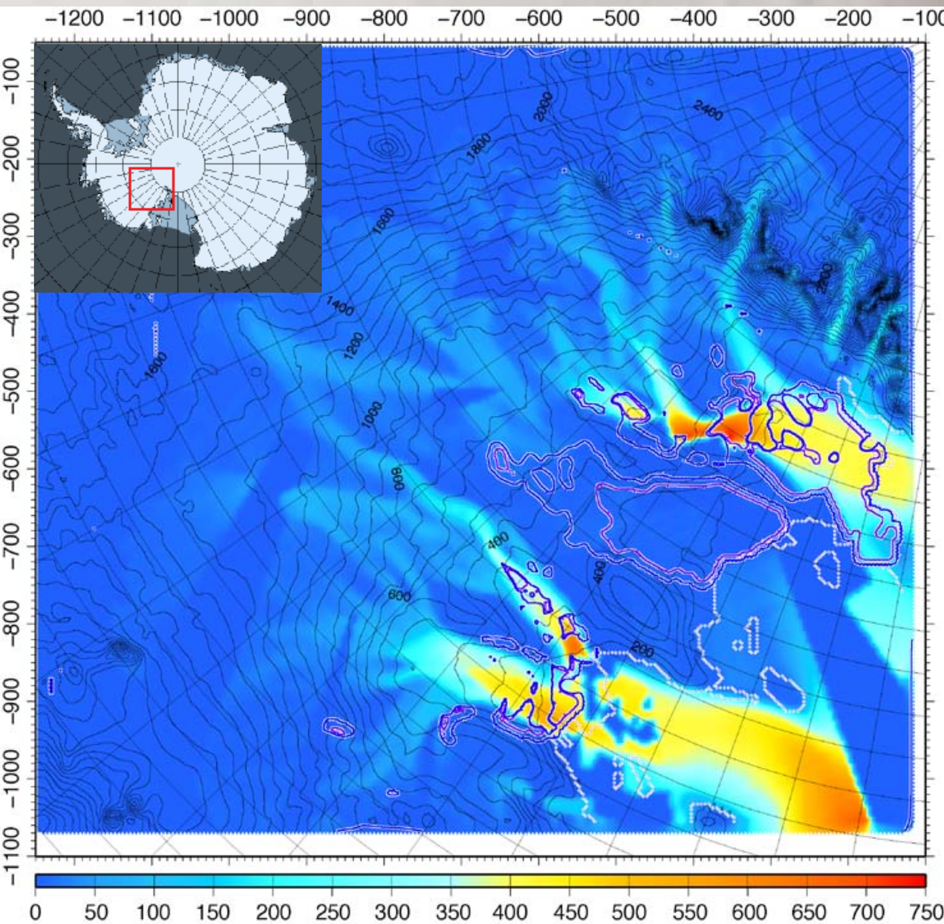
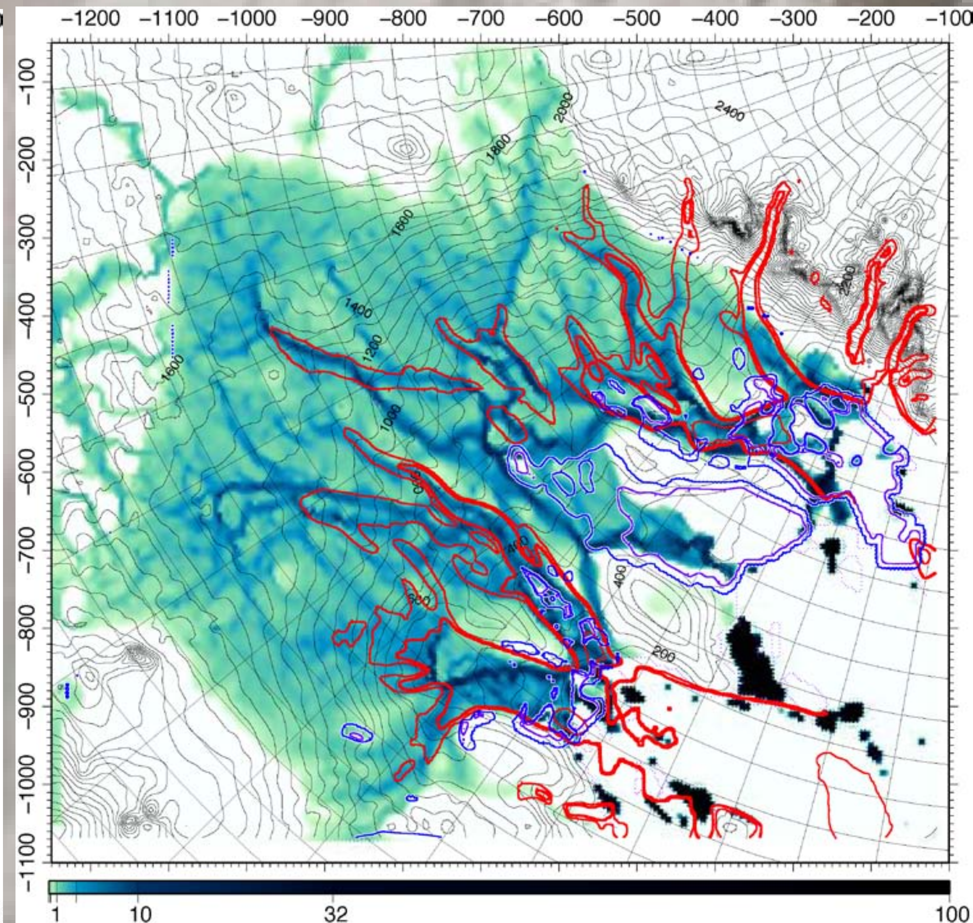
How water accelerates ice flow

1. Reduced obstacle density
2. Thawing frozen bed
3. Softening subglacial till



Water and fast ice flow correlate





Ice velocity (m/a)
(Joughin et al., 2004)

Estimated basal water thickness (mm)
(Carter et al., in prep)

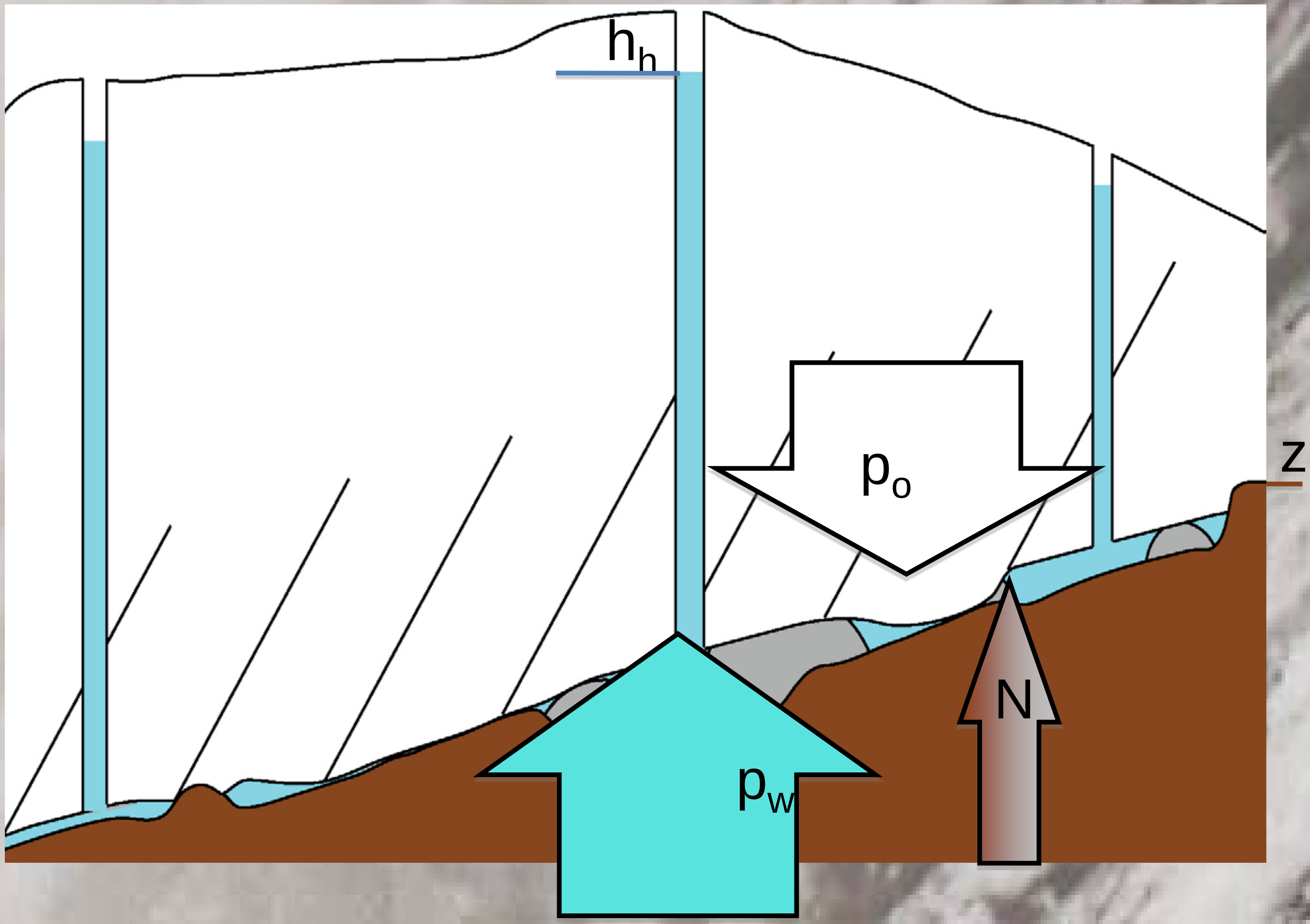
Denote regions of net basal accretion

Ice velocity contour

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*

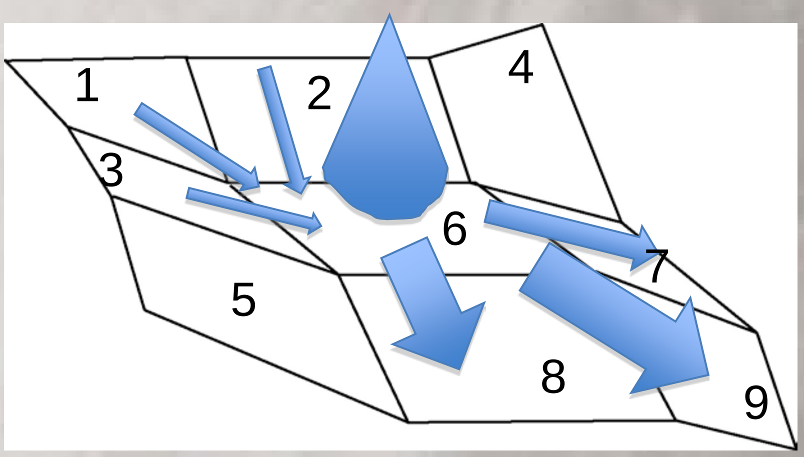
N usually not considered**
*(bedrock gradient can be <11 times surface gradient)
**(N can also vary spatially)

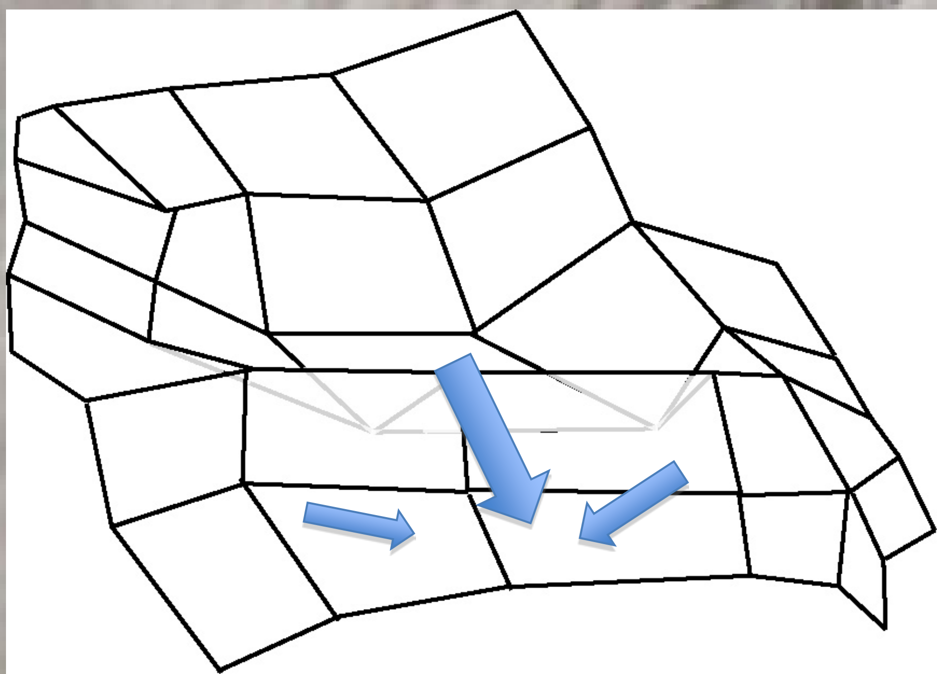


Current Glimmer-cism water model

- Steady state D8
- $Q_{out} = Q_{in}$+melt
- Cells sorted by h_h high to low
- Q_{out} distributed among all downslope neighbors
- Conservative
- Computationally simple

- Issues:
  - Steady state assumed
  - Water tends to fall into 1 grid cell channels (Le Brocq et al., 2009)
- Needed:
  - Effective pressure
  - A way for water to bypass enclosed basins





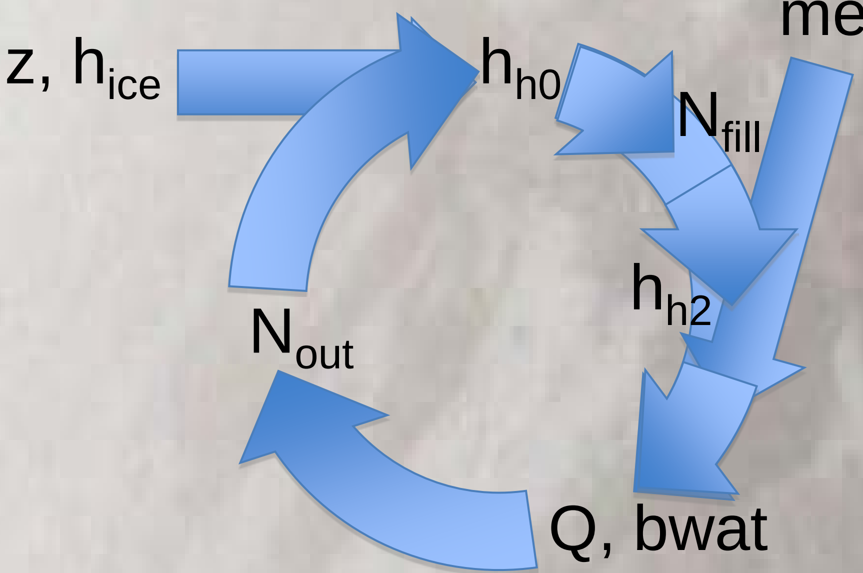
Effective pressure

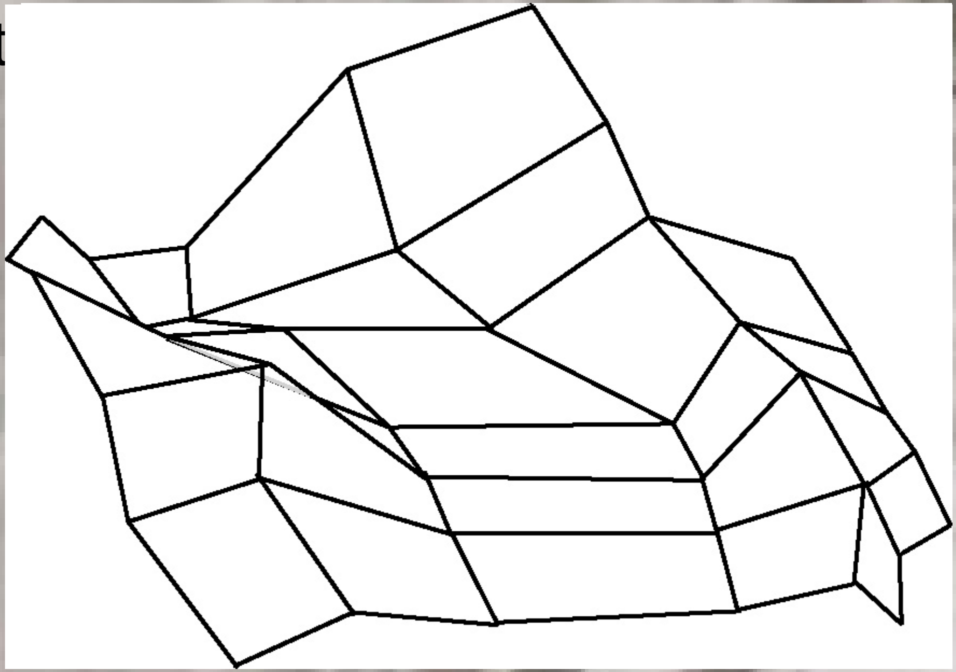
$$N = \frac{\tau_b * k_d}{bwat}$$

(Alley 1996)

τ_b = basal shear stress
k_d = roughness (~1 mm)
bwat= basal water depth

- N treated as function of water thickness
- Water thickness function of hydropotential
- Solving for both requires iterative process
- Enclosed basins complicate this process and become more common each iteration
- Adjusting N also a convenient way to fill holes without editing topography



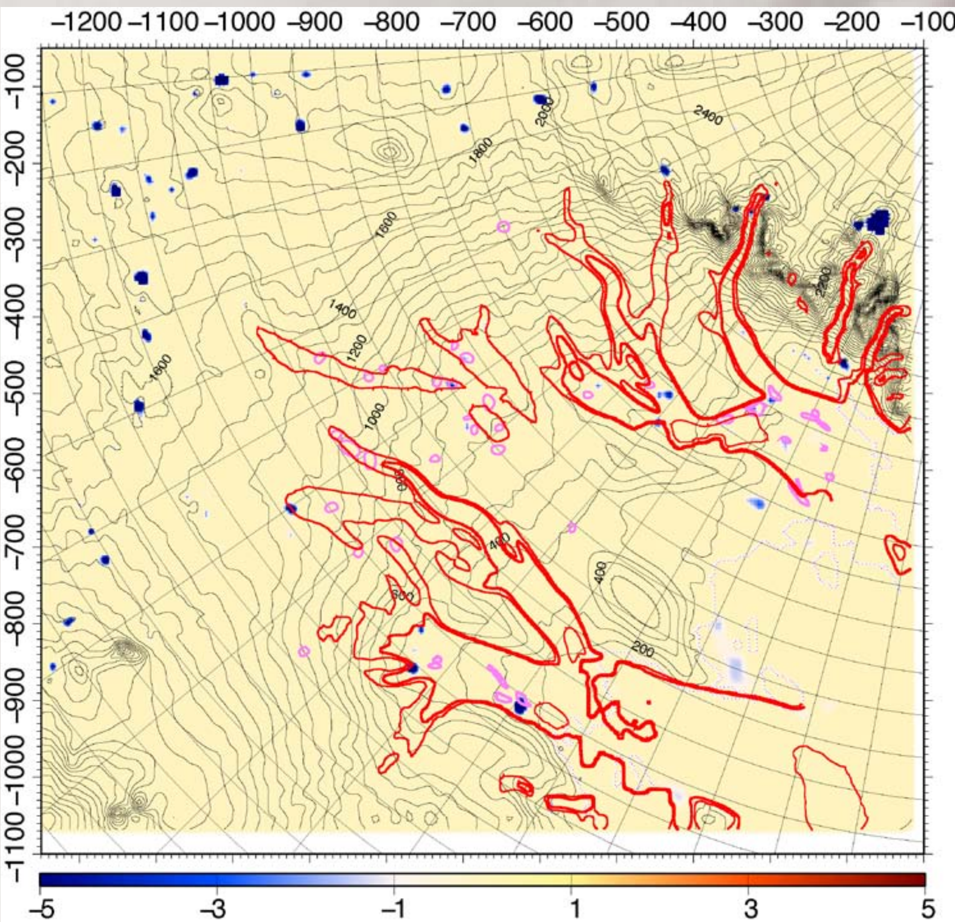


Routing through enclosed basins

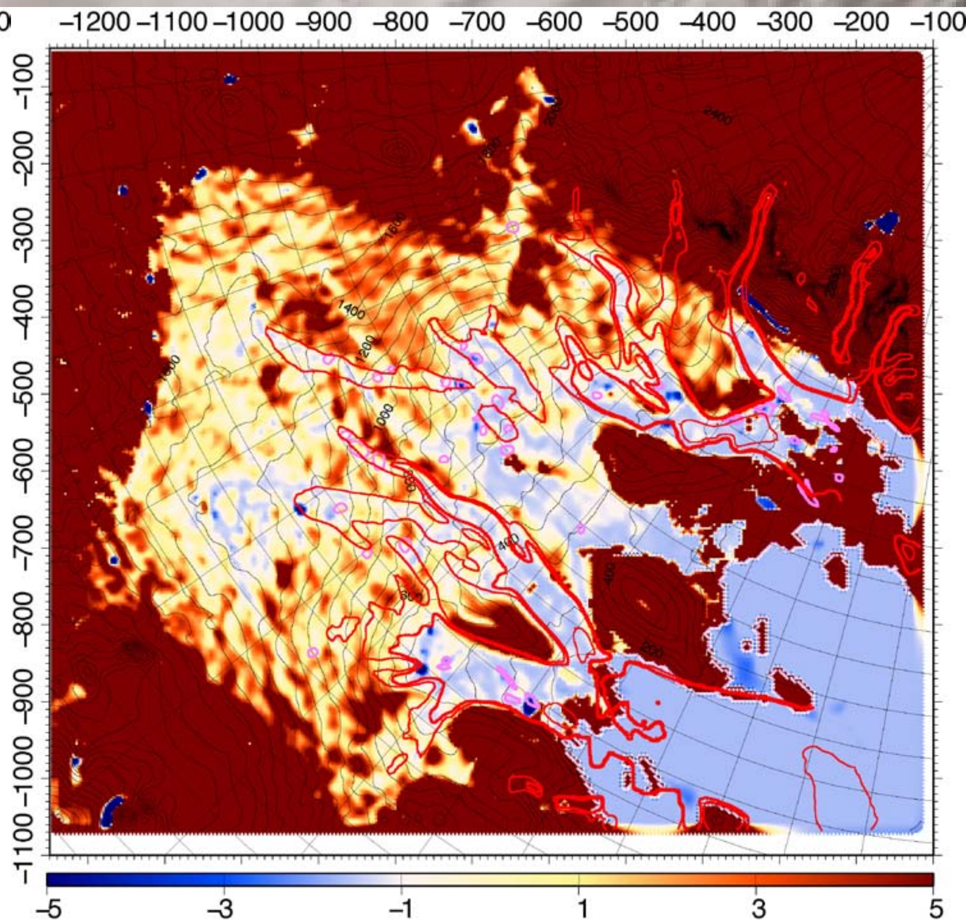
- Calculate h_{h0}
- Identify holes
- Raise to level of lowest outlet h_{h2}
- Identify (x,y) coordinate of outlet
- Sort by h_{h2} and then distance from outlet
- $N_{fill} = (z + p_o) - h_{h2}$

Results

$N_{in\_initial}$



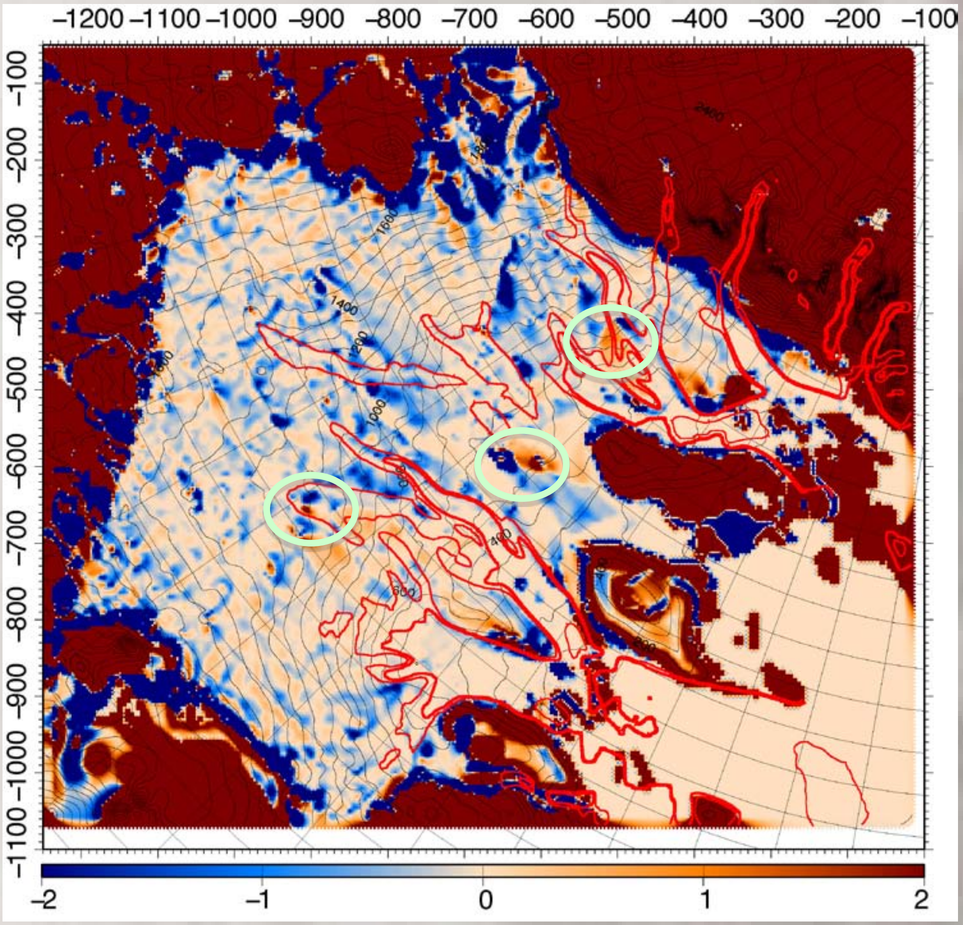
N_{out} after five iterations.



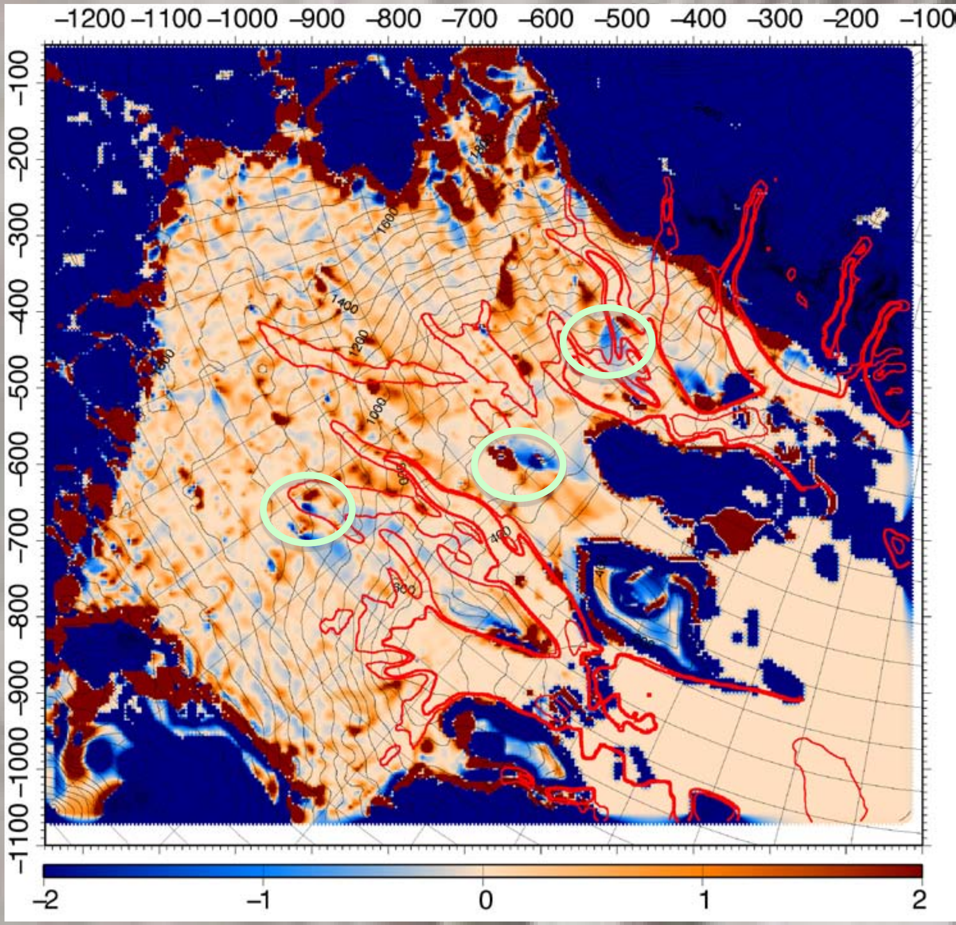
Meters of water equivalent

1^{st} iteration

N_{out}-$N_{out\_previous}$



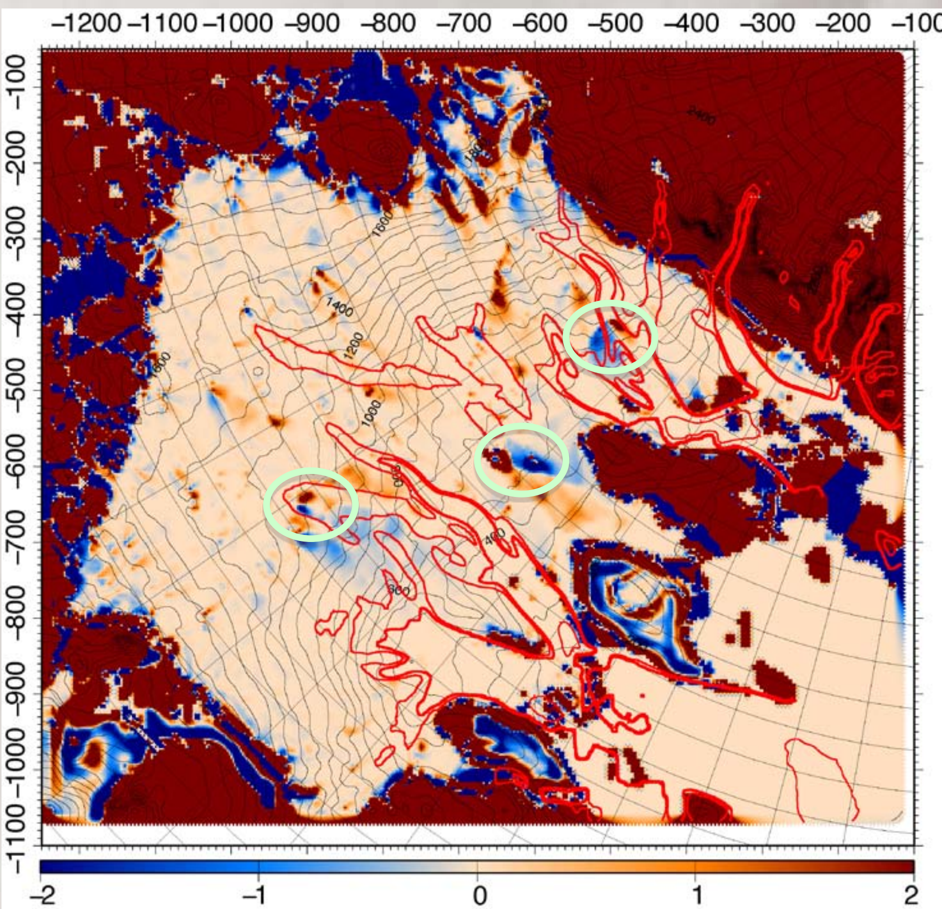
N_{out}-N_{in}



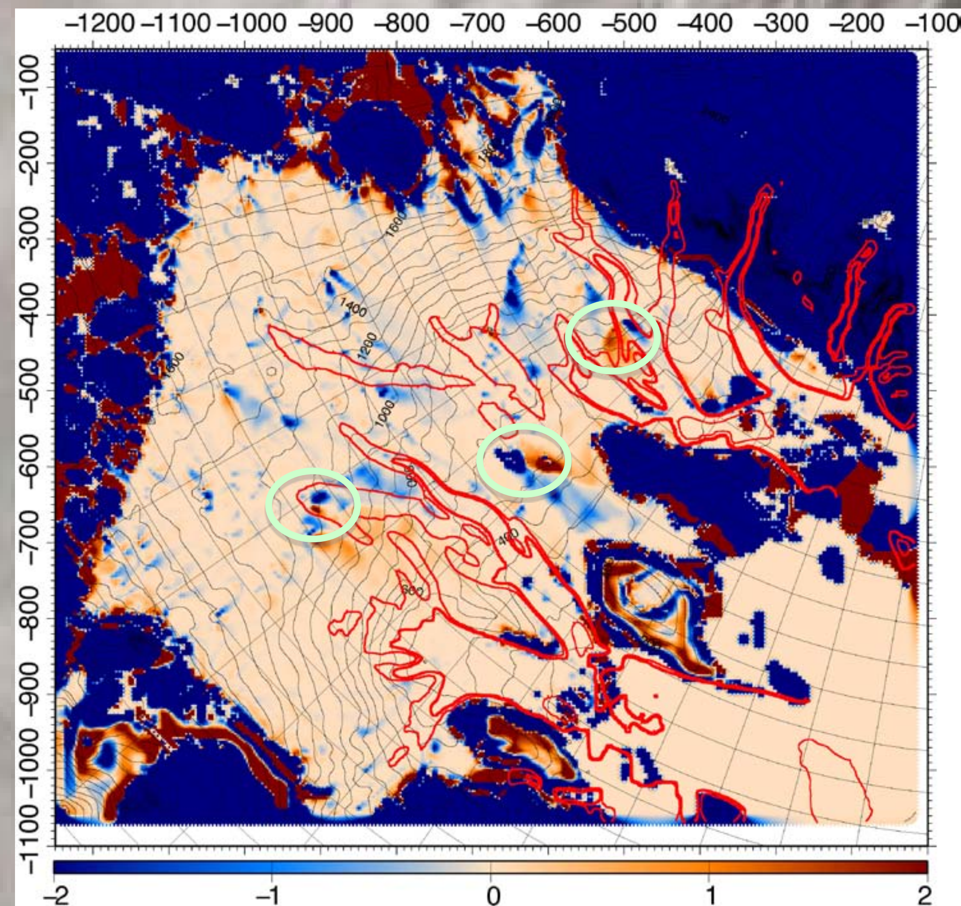
Meters of water equivalent

2^{nd} iteration

N_{out}-$N_{out\_previous}$



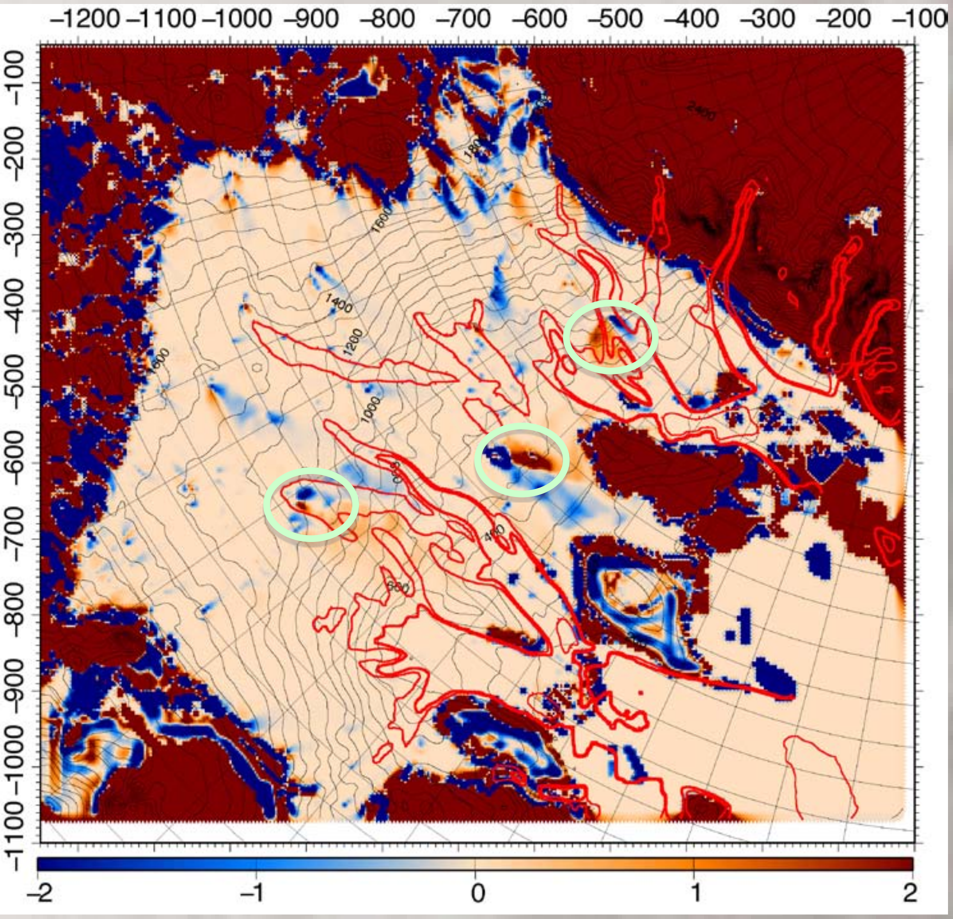
N_{out}-N_{in}



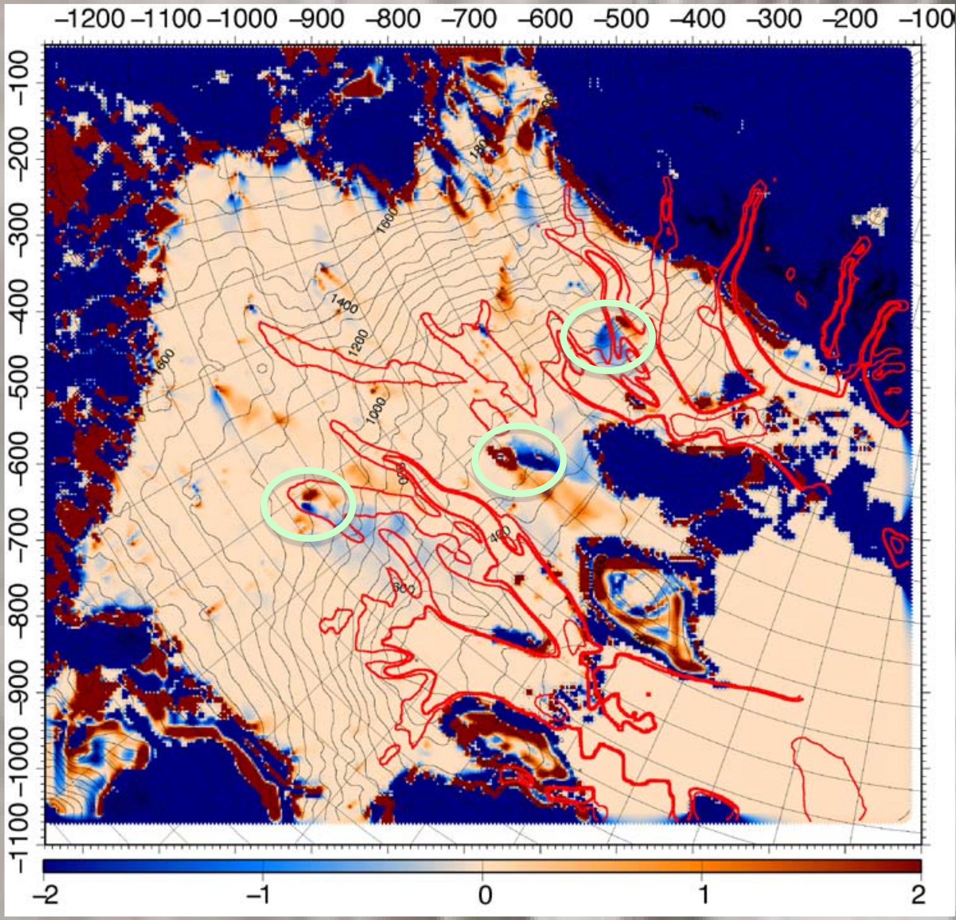
Meters of water equivalent

3^{rd} iteration

N_{out}-$N_{out\_previous}$



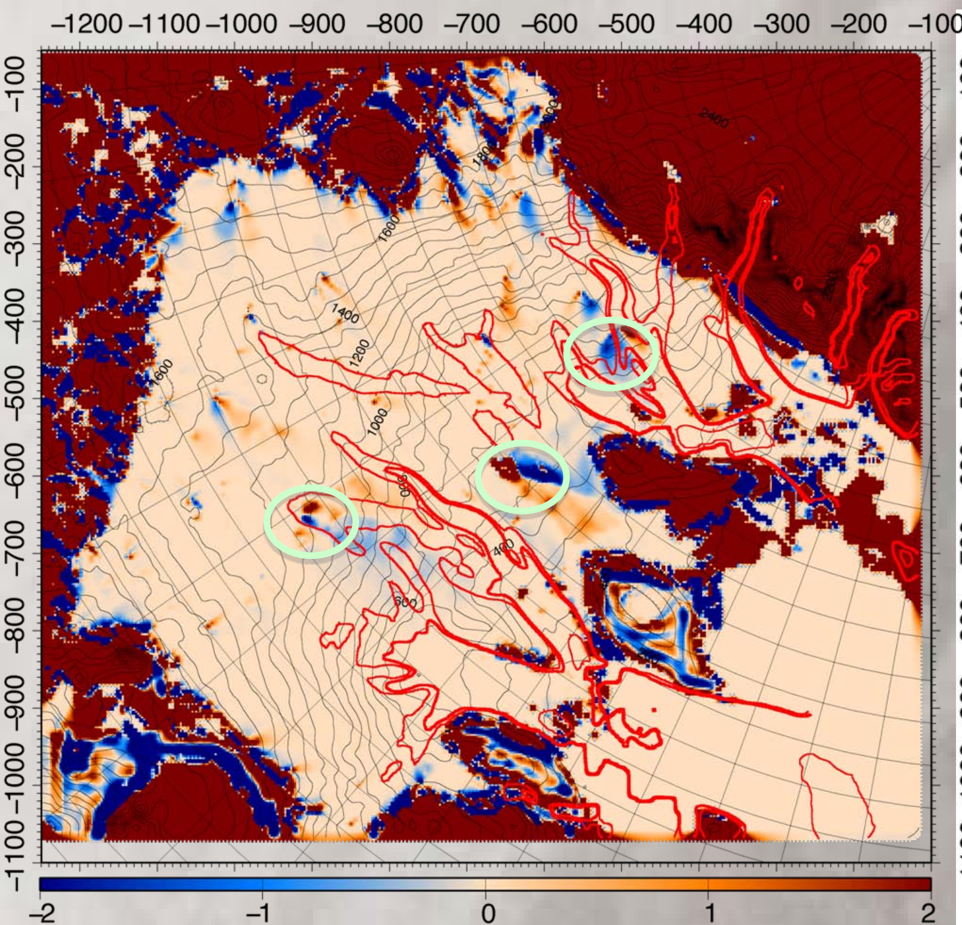
N_{out}-N_{in}



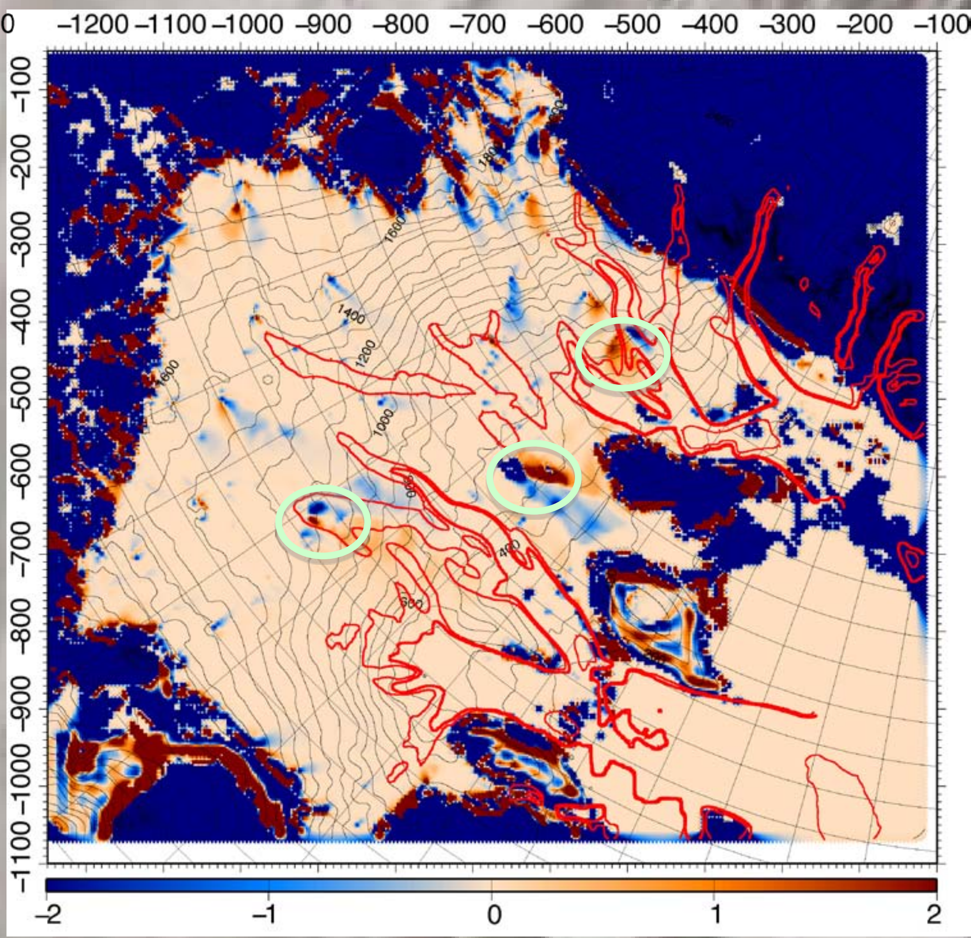
Meters of water equivalent

4^{th} iteration

N_{out}-$N_{out\_previous}$



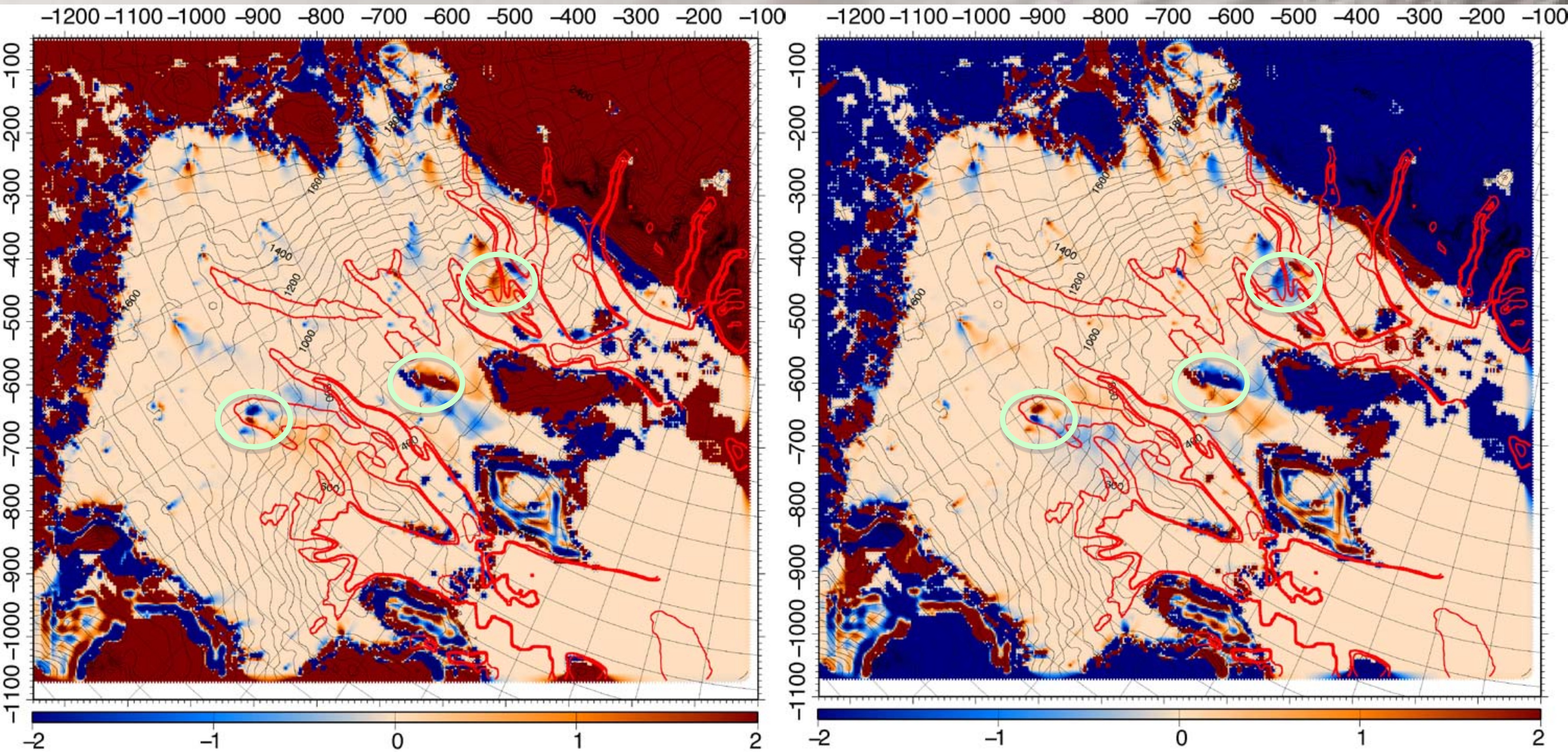
N_{out}-N_{in}



Meters of water equivalent

5^{th} iteration

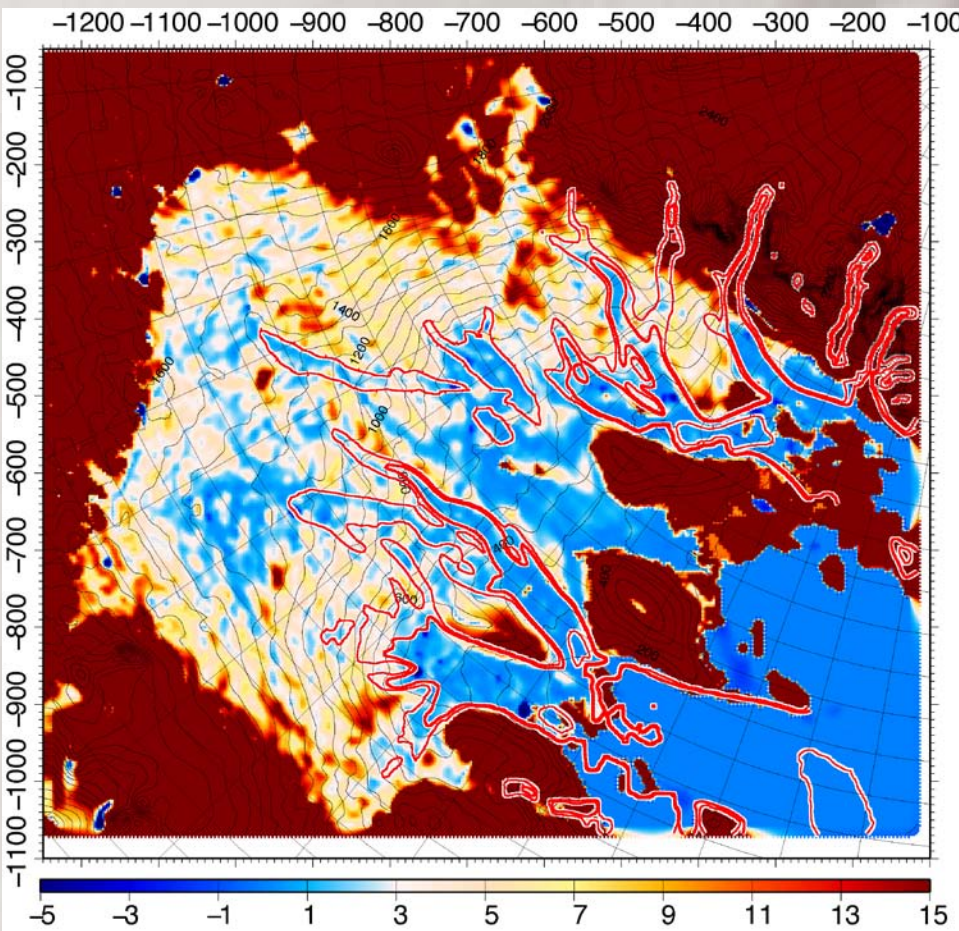
$N_{out}-N_{out\_previous}$ $N_{out}-N_{in}$



Meters of water equivalent

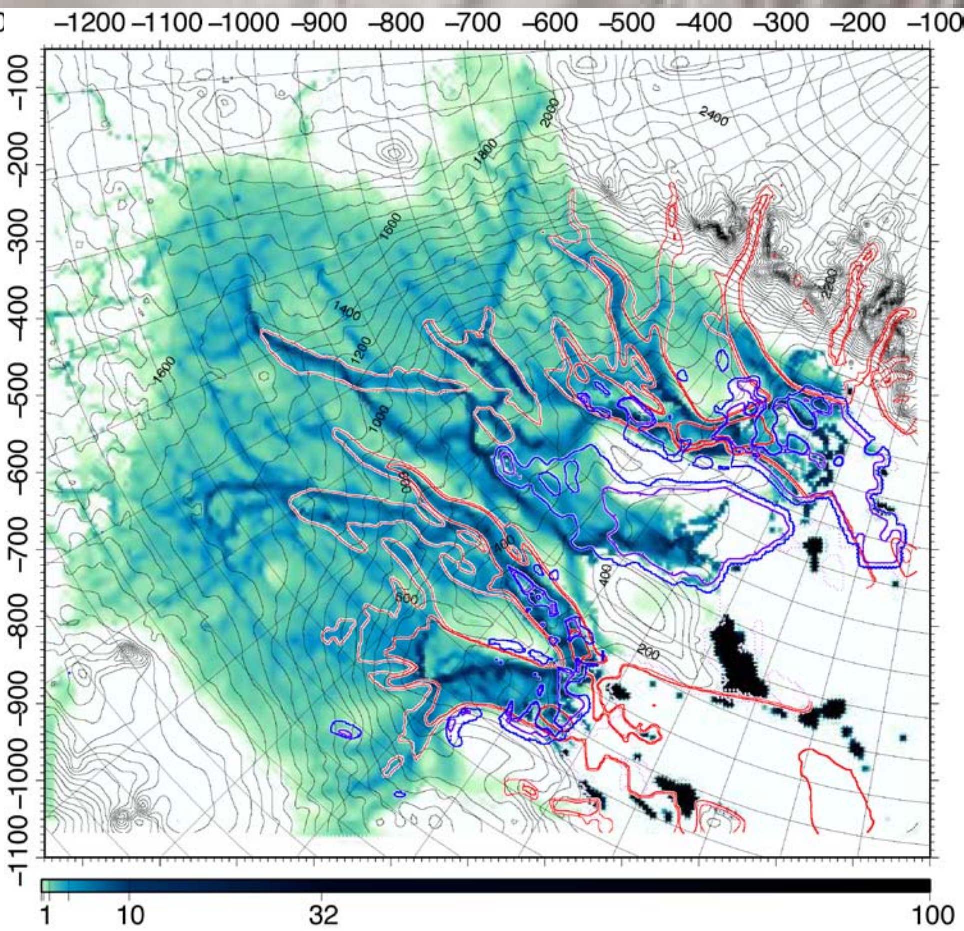
Average N of last 3 iterations

N



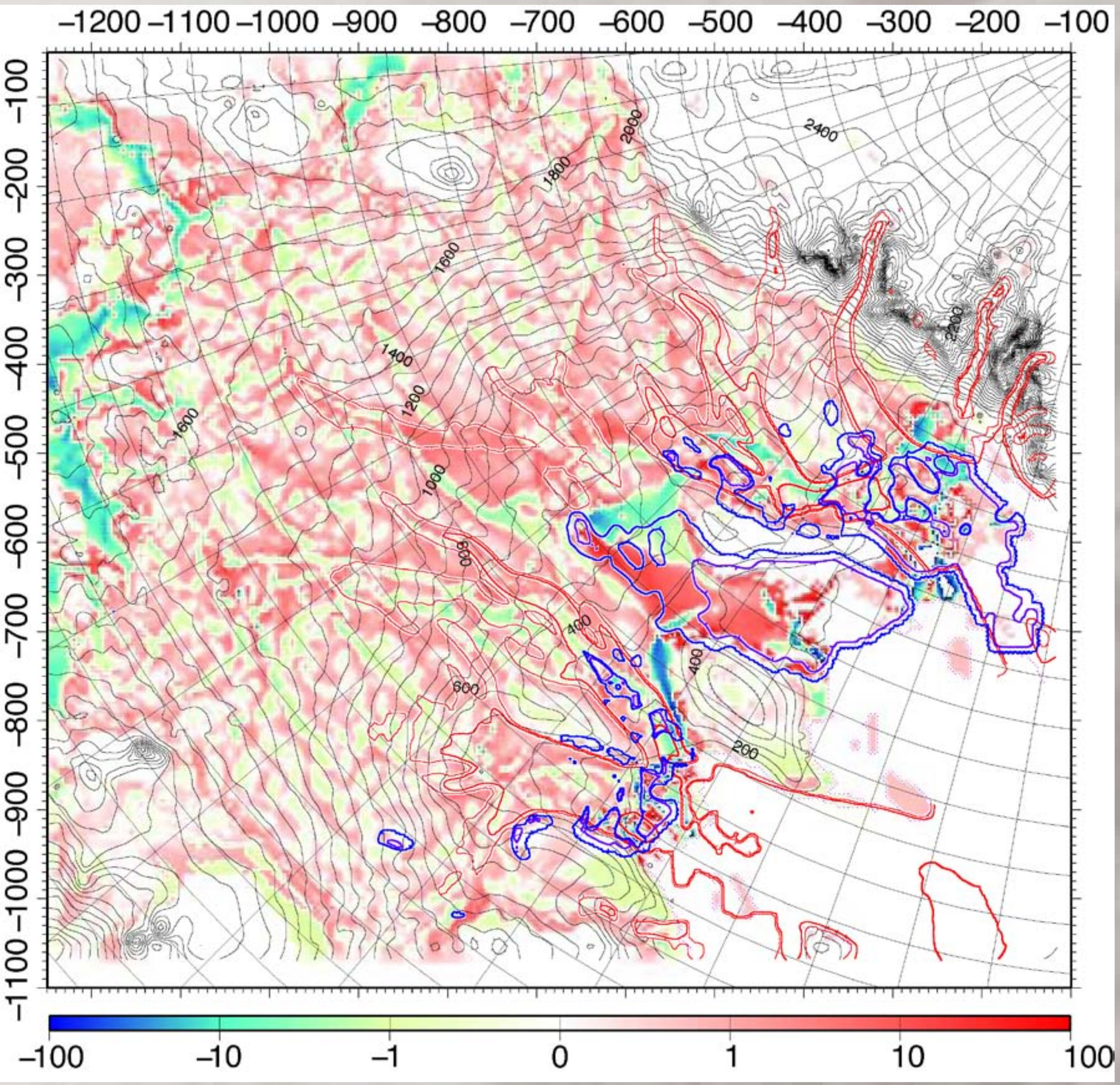
Meters of water equivalent

Water layer thickness



mm

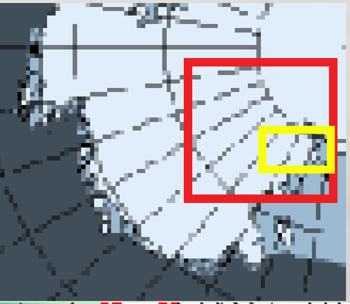
A different distribution of water

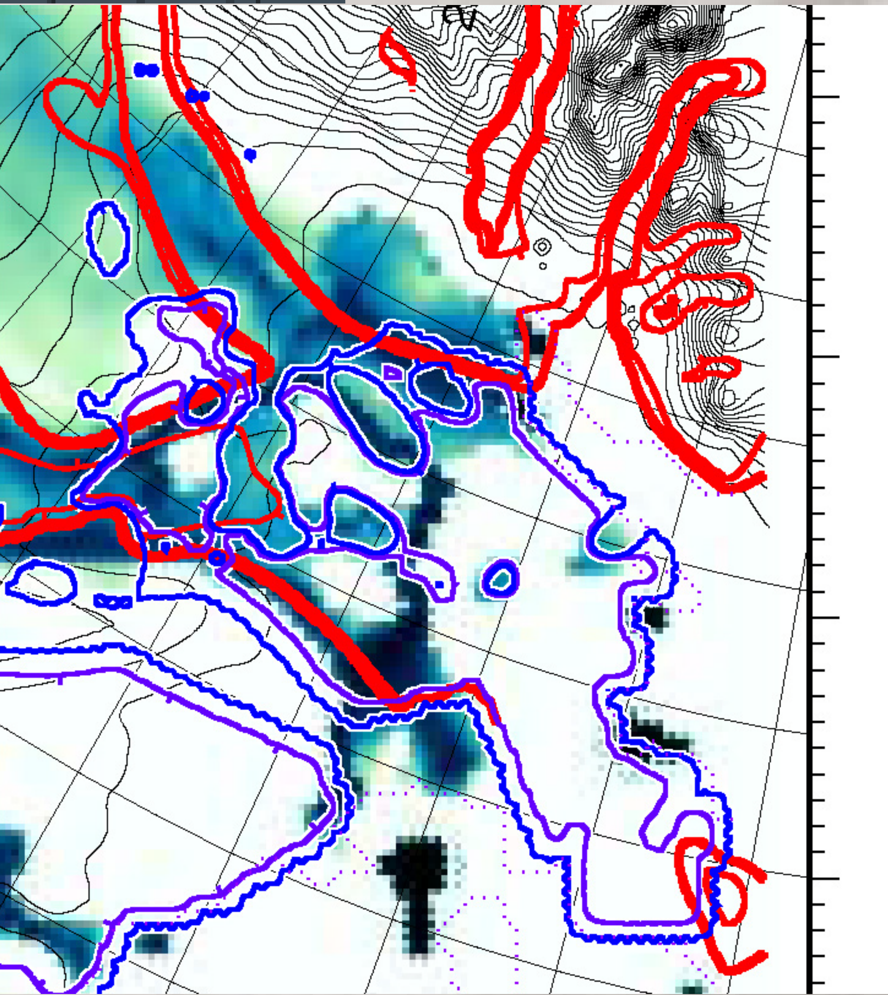


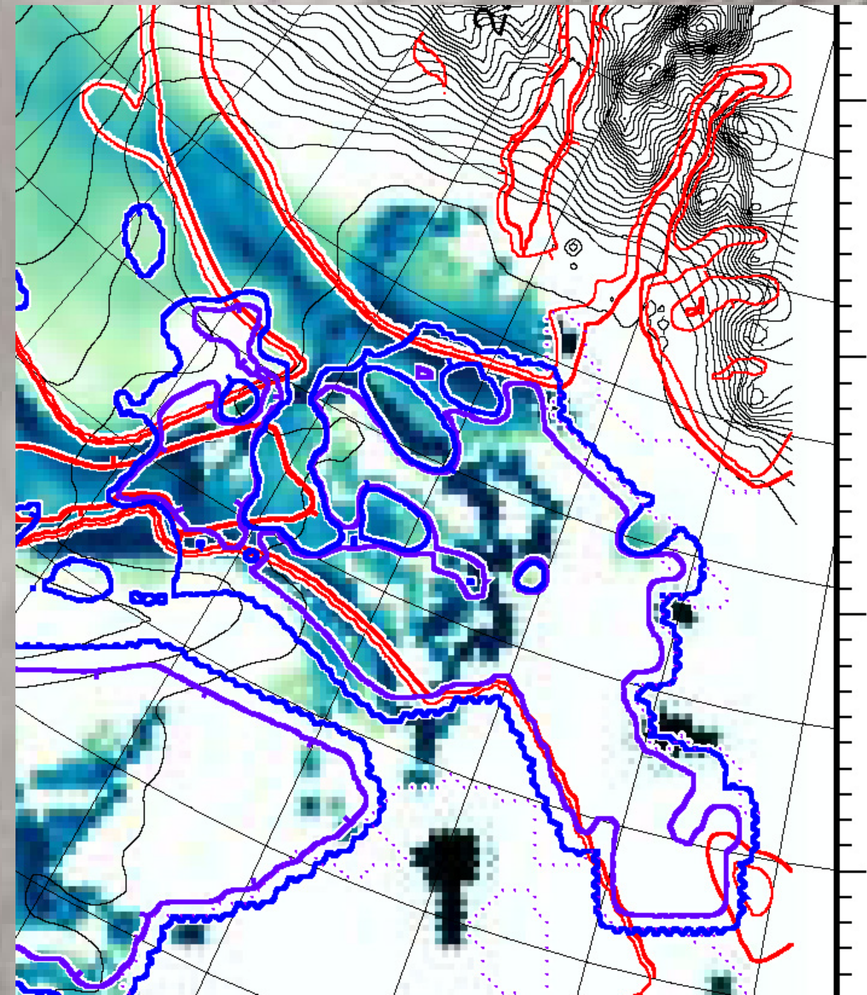
mm

- Shallower broader channels in tributary and ice streaming regions
- More water to areas of net basal freeze on
  - Whillans Ice Plain
  - MacAyeal Grouding line

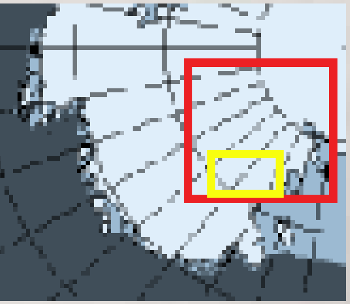
A closer look: Whillans ice plain

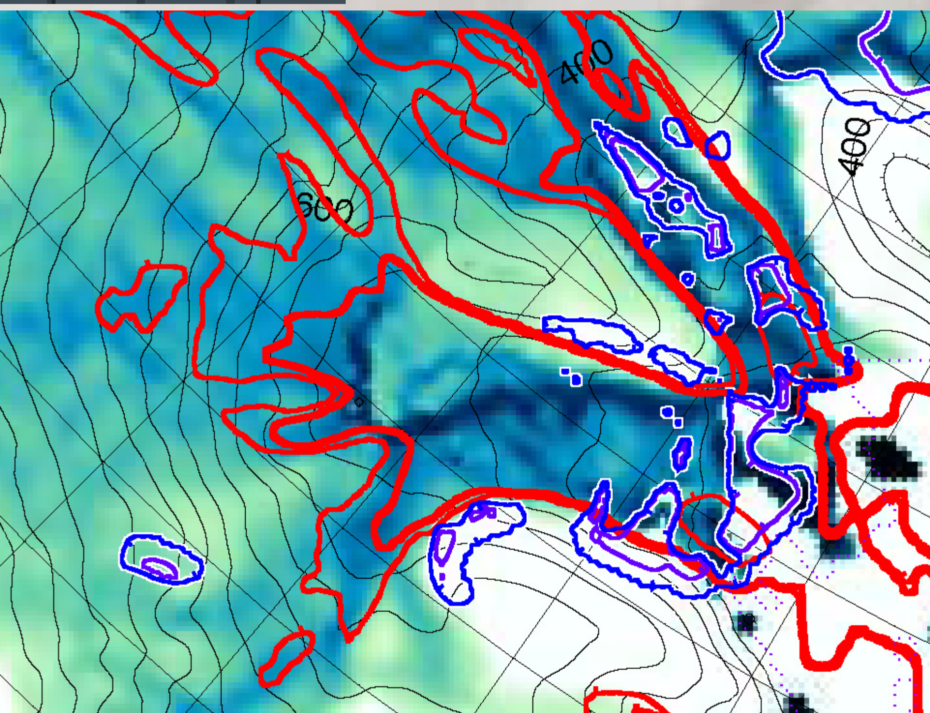


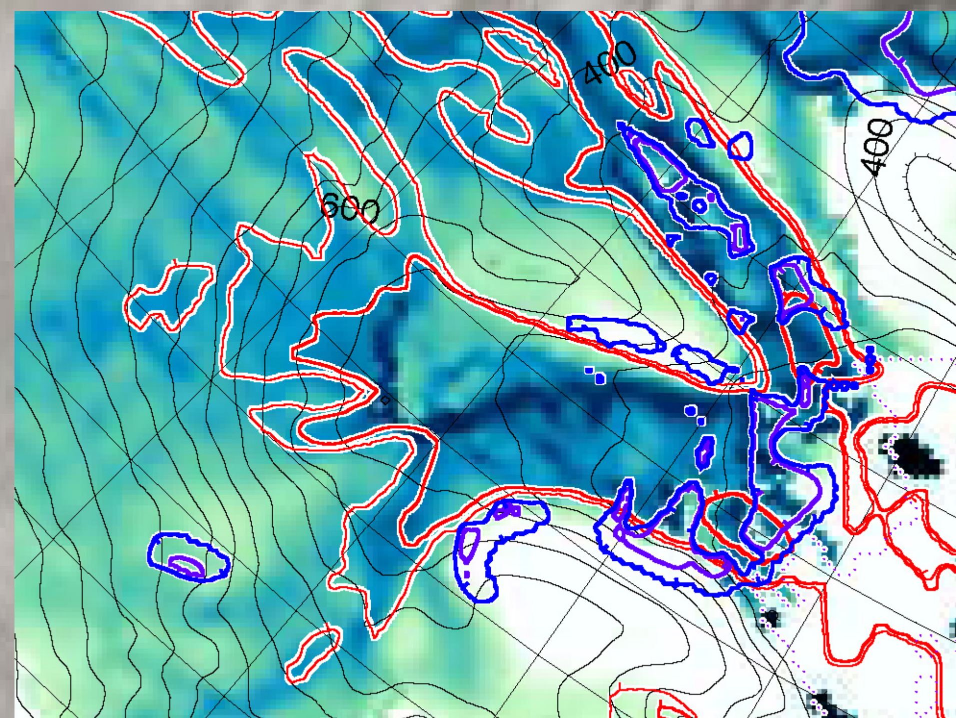




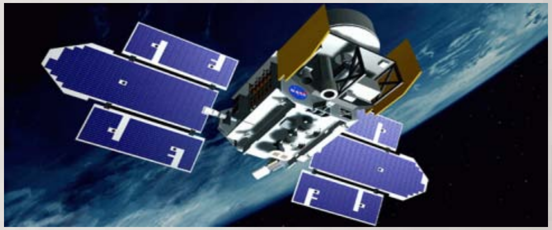
A closer look: Downstream MacAyeal IS



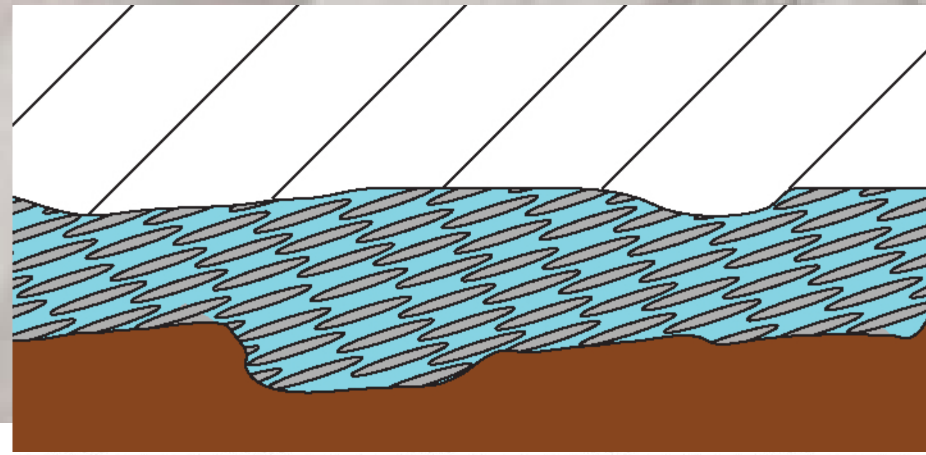


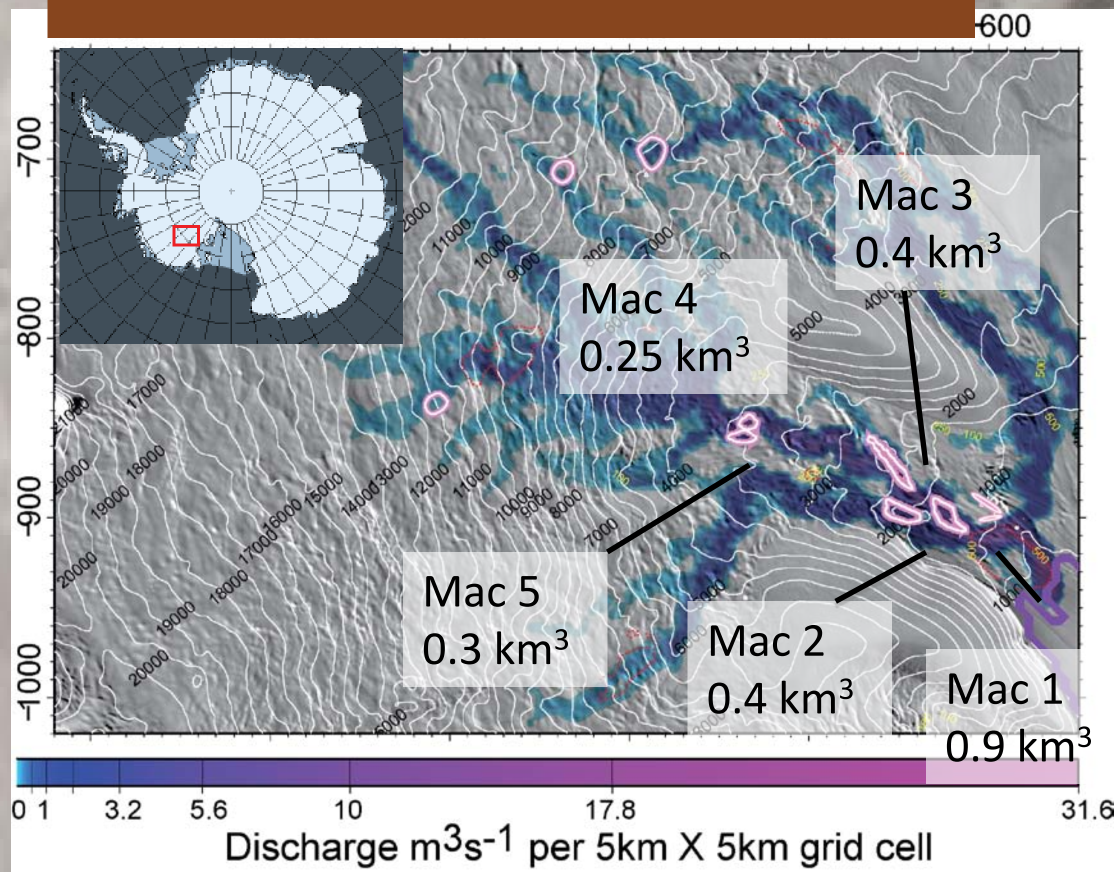


Validation



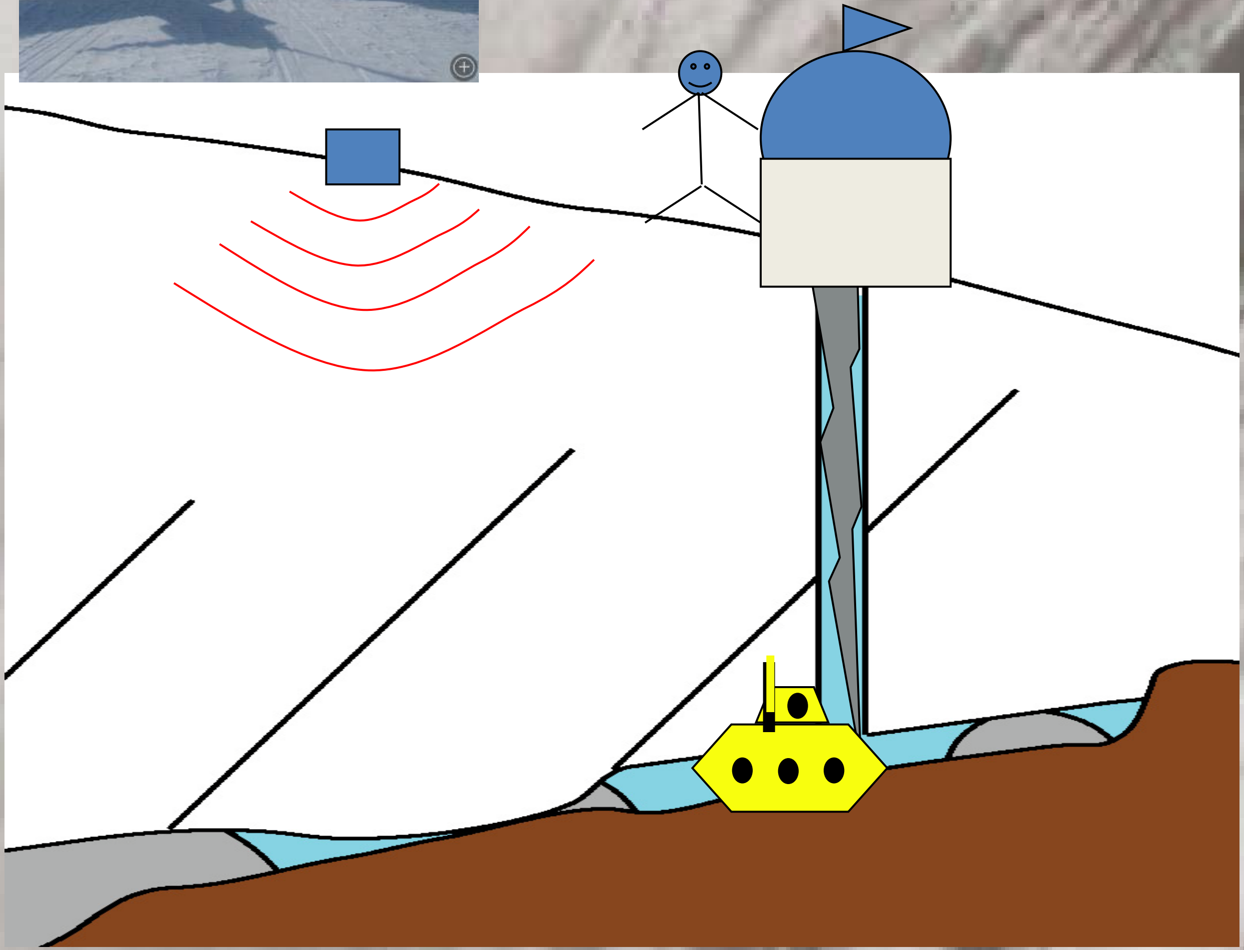
- $Q_{Sea} = \sum m$
- Btrc ≈ N
- Satellite observations of subglacial lake behavior (Carter et al., in prep; See also virtual poster)





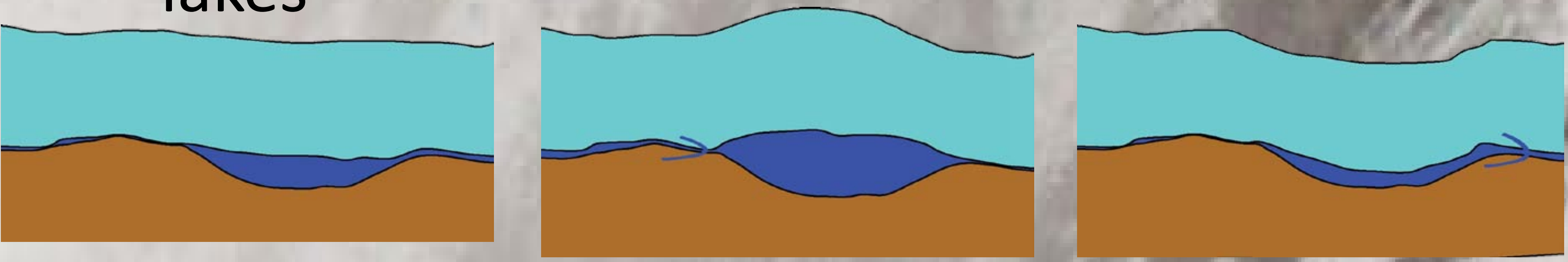
Validation

- Radar Sounding can infer presence of water and possible channels.
- Boreholes (Engelhardt et al., 1997) confirm N is on the order of a few m.
- Seismic work Blankenship et al., 1987; Winberry et al., 2009).
- The WISSARD project to send a probe to explore the subglacial water environment in situ providing a raft of new calibration data.



Wish list / Future directions

- A better, but still simple parameterization for N
- Distribution of subglacial sediments
- Grounding Lines
- Higher order 2- D model
- Simulation of outburst events for individual lakes



Conclusions

- Incorporating even the most basic parameterization for effective pressure produces a significantly better correlation between water distribution and sliding velocity
  - Wider shallower streams
  - More water to basal freeze on
- Although N is on the order of a few m water equivalent, in low sloping regions like Whillans Ice Plain, these changes are very significant to water distribution
- The convergence of h_h bwat, and N over most of Siple Coast is a promising result
- Areas in which convergence does not occur may require a higher order routing scheme. Other lines of research have also indicated that these are features of interest (LeBrocq et al., 2009; Creyts et al., personal Communication)

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