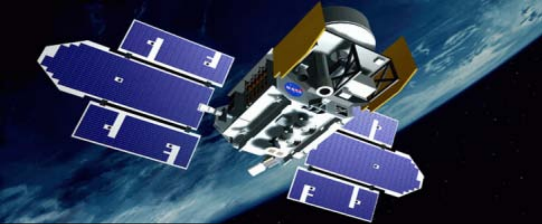

A simple parameterization for subglacial water storage, transport, and episodicity validated by independent geophysical observations

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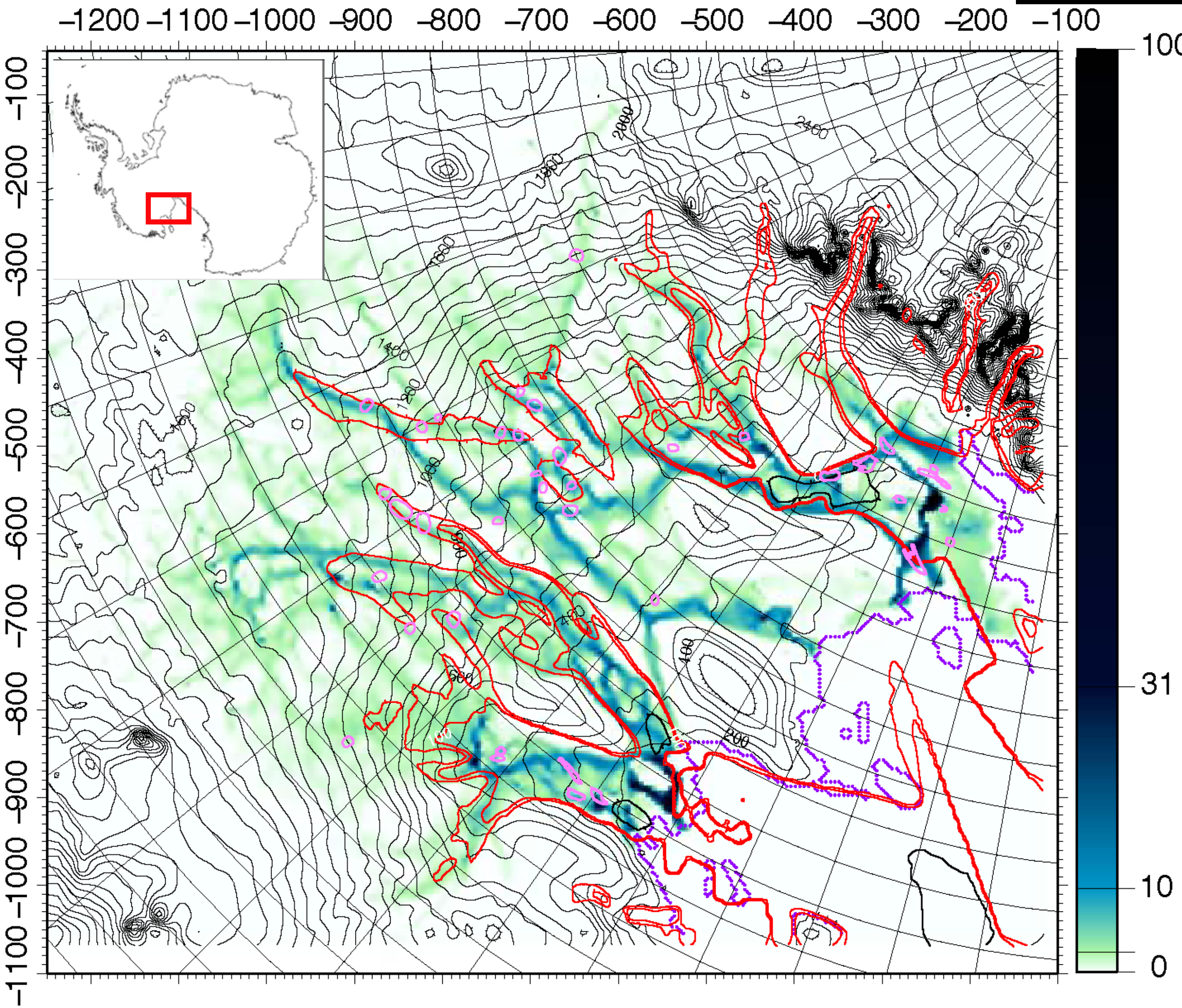
Water Matters

Steady state water sheet thickness(mm)



Any constant flux subgalcial water flow model shows a spatial correlation between predicted water sheet thickness and observed ice velocity (Johnson and Fastook 2002; Vogel et al., 05; Lebrocq et al., 2009)

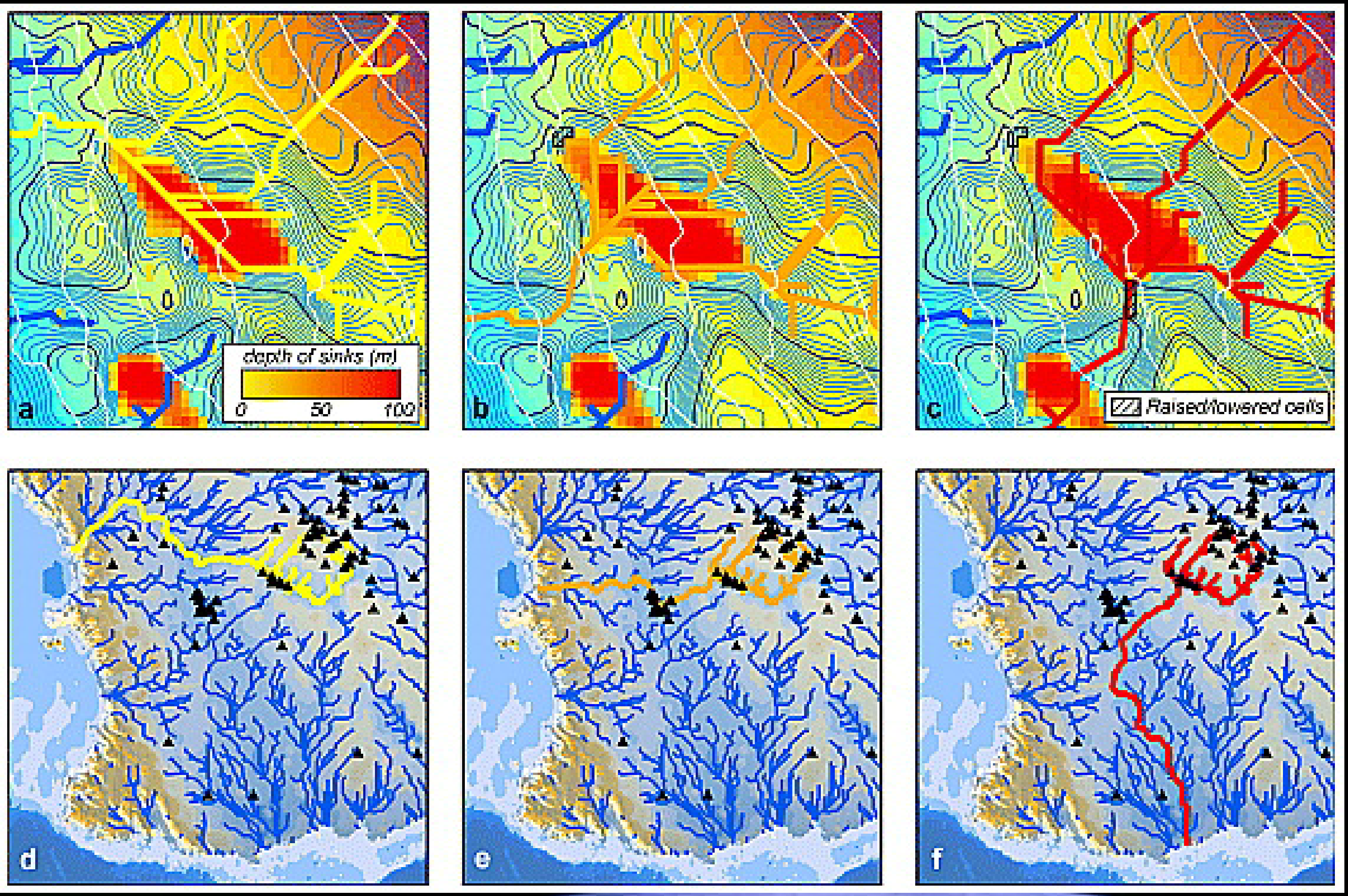
Hydraulic head (C.I. 100m)

Grounding line (Bohlander and Scambos 2007)

Subglacial lakes (Smith et al., 2009)

Boundary of fast flow (Joughin et al 2003)

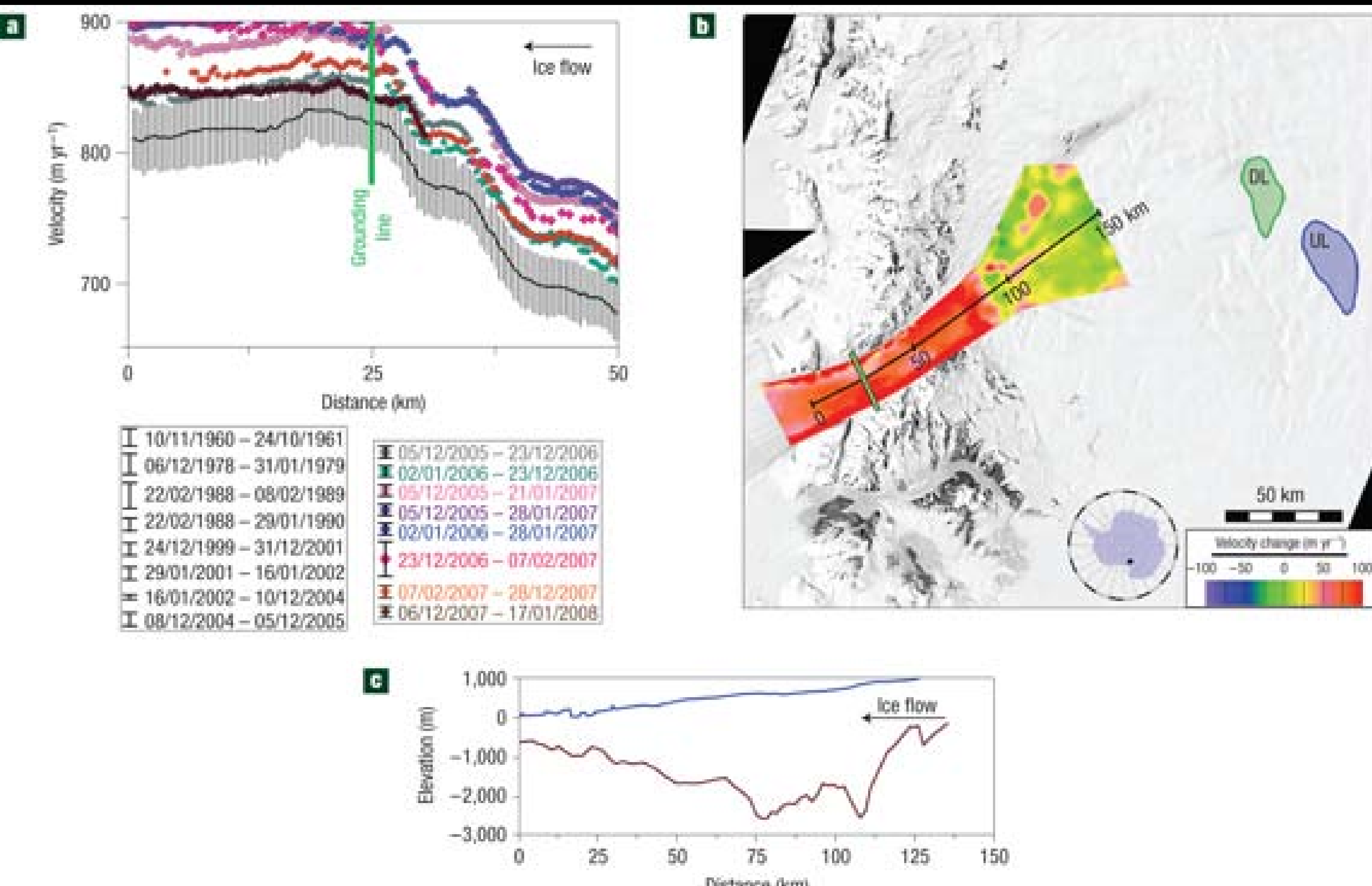
Water Matters: Where



Small changes in surface elevation and ice thickness can dramatically reroute large quantities subglacial water.

Wright, A. P., M. J. Siegert, A. M. Le Brocq, and D. B. Gore (2008), High sensitivity of subglacial hydrological pathways in Antarctica to small ice-sheet changes, Geophys. Res. Lett., 35, L17504, doi:10.1029/2008GL034937.

Water Matters: When

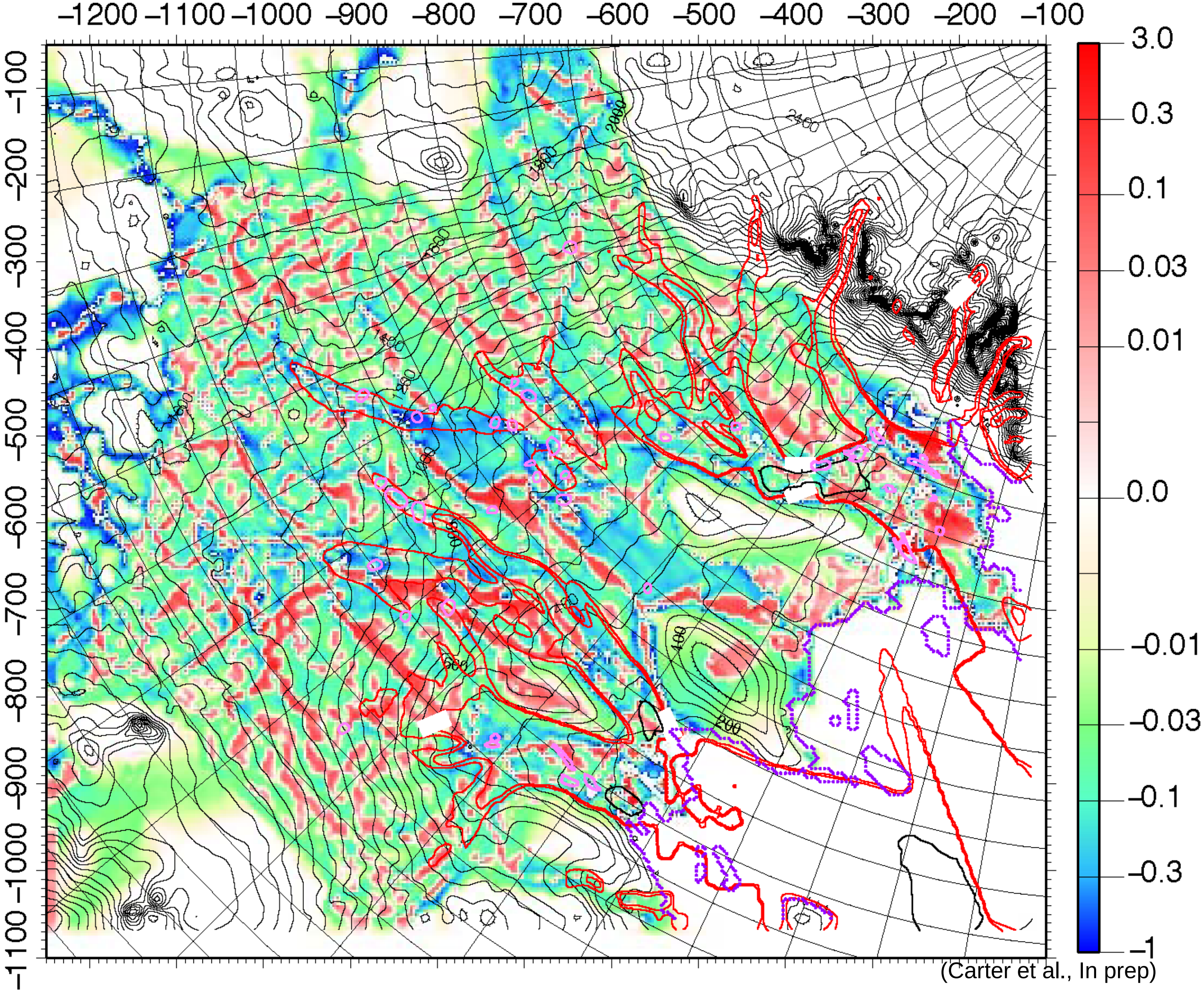


Ice velocity downstream of a subglacial lake accelerates following a subglacial flood

Stearns, L. A., B. E. Smith, and G. S. Hamilton (2008), Increased flow speed on a large East Antarctic outlet glacier caused by subglacial floods, Nature Geoscience, 1(12), 827-831.

Water Matters: How

Water thickness with effective pressure
– water thickness without effective pressure (mm)



(Carter et al., In prep)

Even a change in the effective pressure parameterization can substantially redistribute water, especially in fast flowing regions.

Hydraulic head (C.I. 100m)

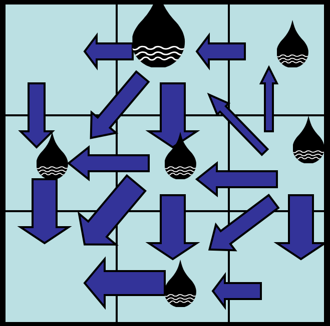
Grounding line (Bohlander and Scambos 2007)

Subglacial lakes (Smith et al., 2009)

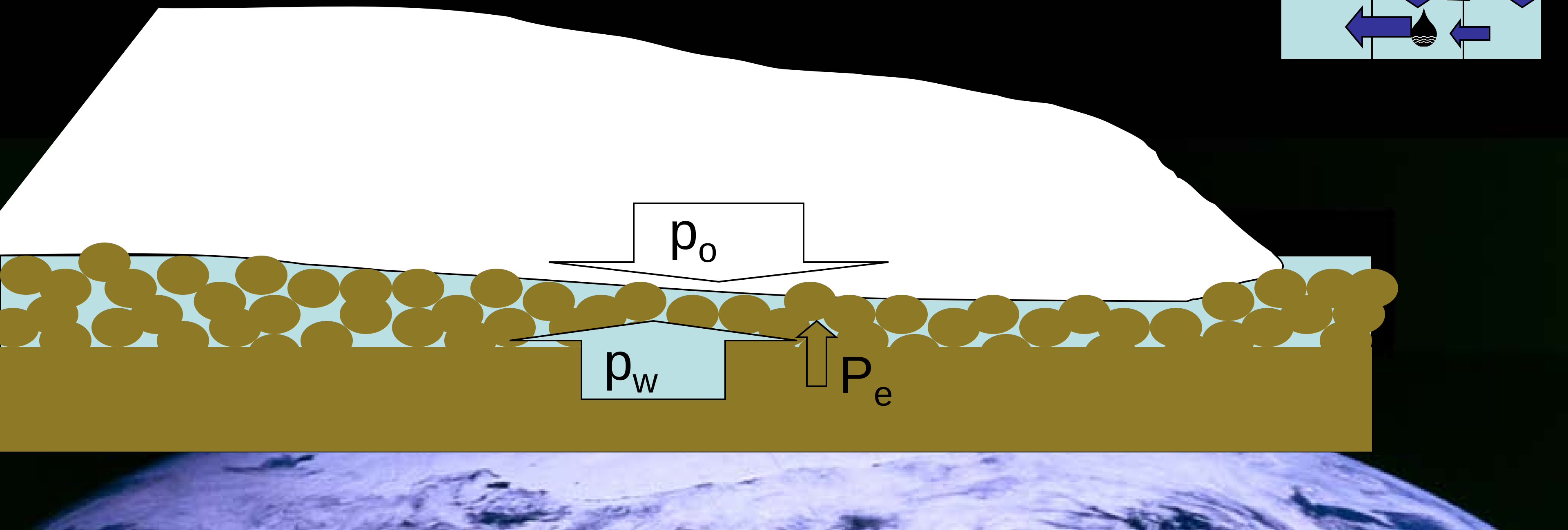
Boundary of fast flow (Joughin et al 2003)

Getting at better water models

- How can we use existing geophysical data, and the CISM data structures to get better parameterzations for the following:
  - Subglacial lakes
  - Episodic flow
- How can geophysical data validate these changes?
- *Got effective pressure?*

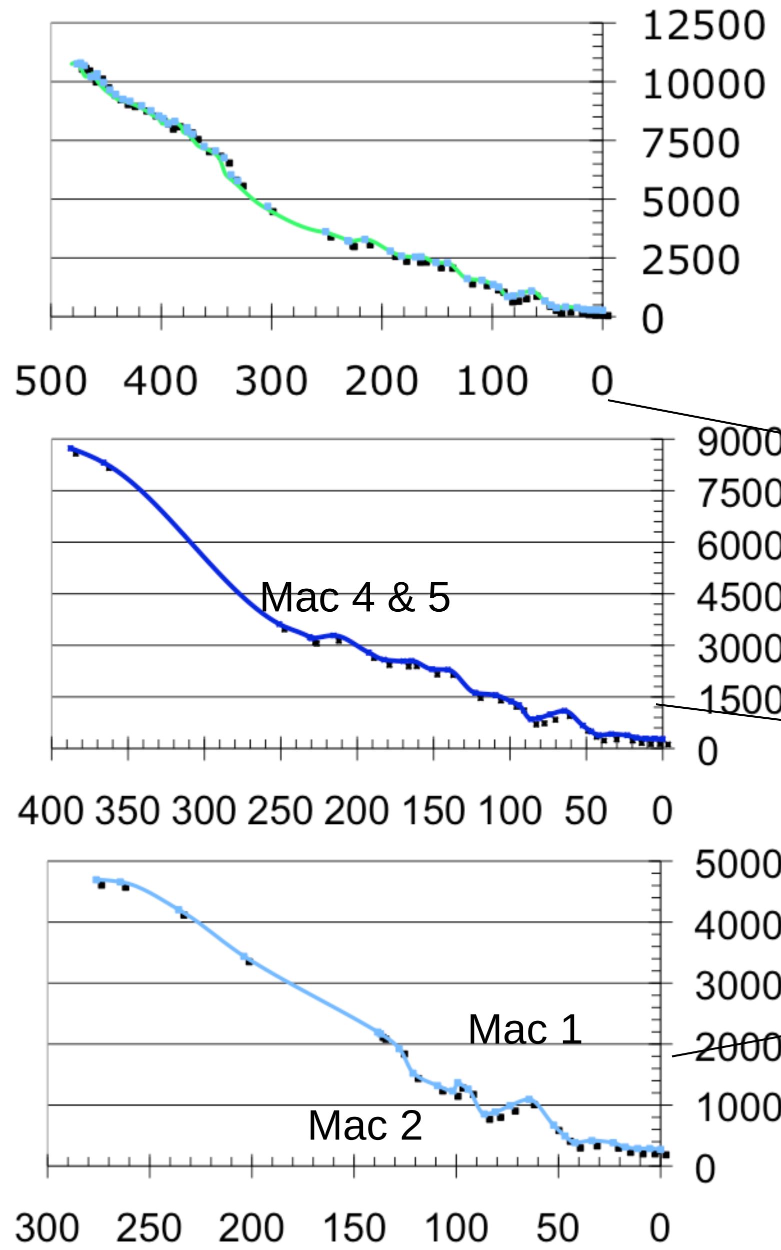


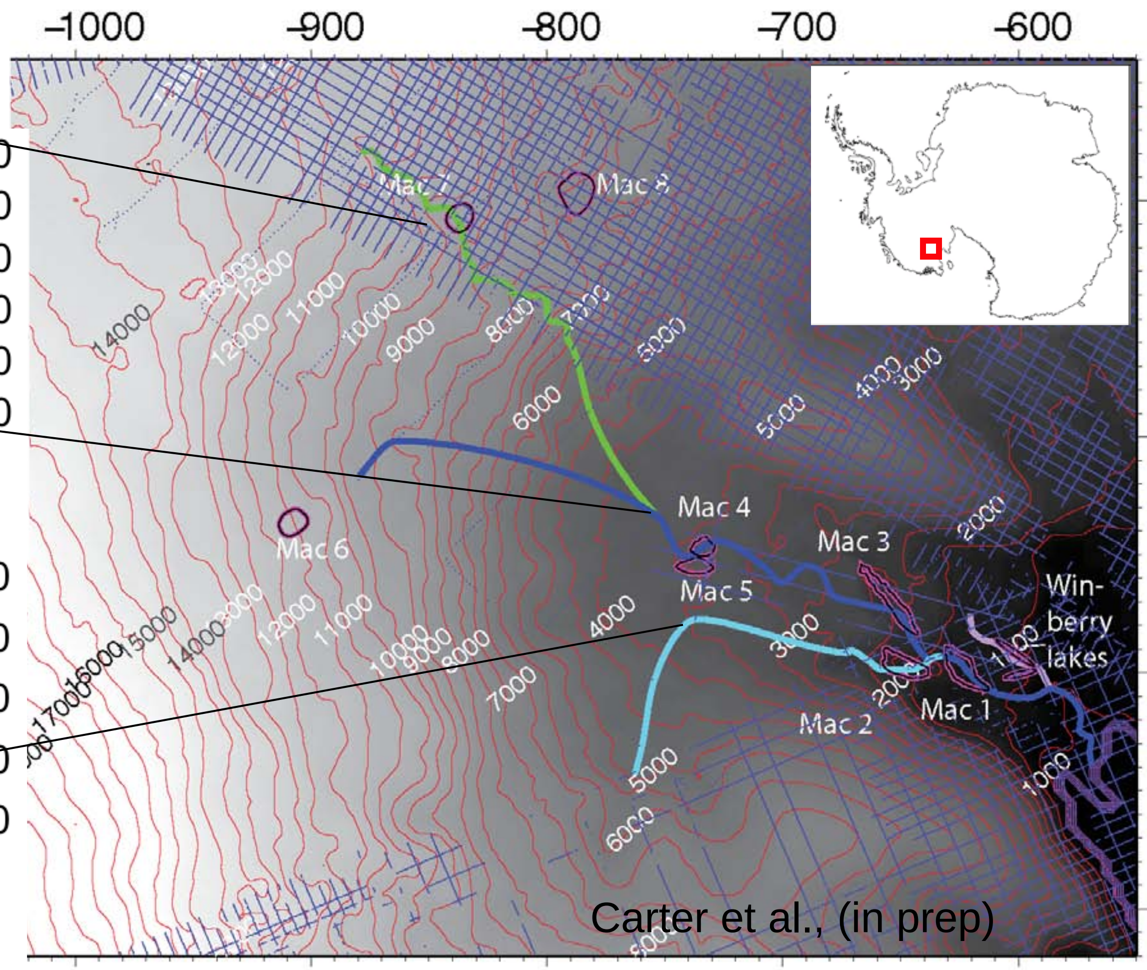
$$H_h=\rho_w g z_{bed}+p_o-p_e$$



Parameterizing subglacial lakes

Close examination of RES data shows that hydraulic head decreases monotonically along most flow paths except where flow paths intersect subglacial lakes

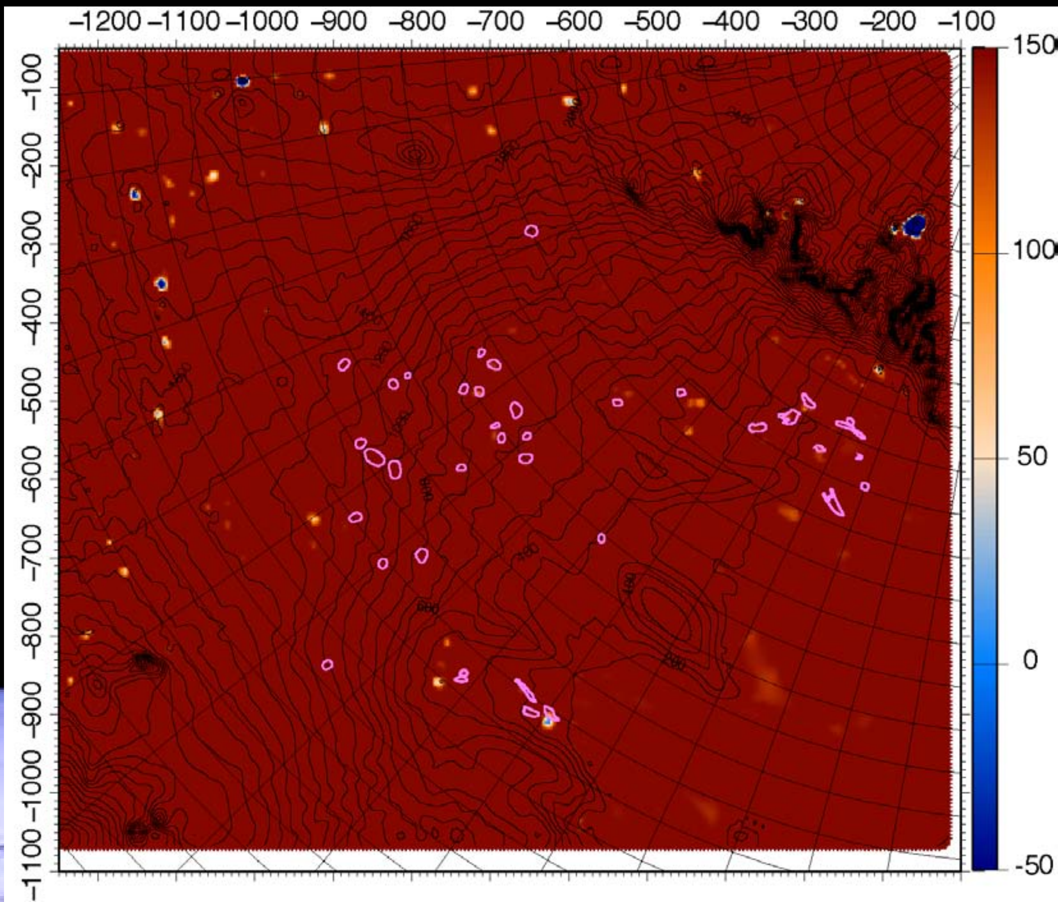




Effective pressure to fill holes

- Depth of most holes <15m equivalent to 150 Kpa.
- Subglacial lakes should have an effective pressure near 0 as overlying ice is in floatation.
- Observed effective pressure for non-lake areas ~ 50 Kpa – 150 Kpa (Engelhardt et al., 1990; Blankenship et al., 1987)

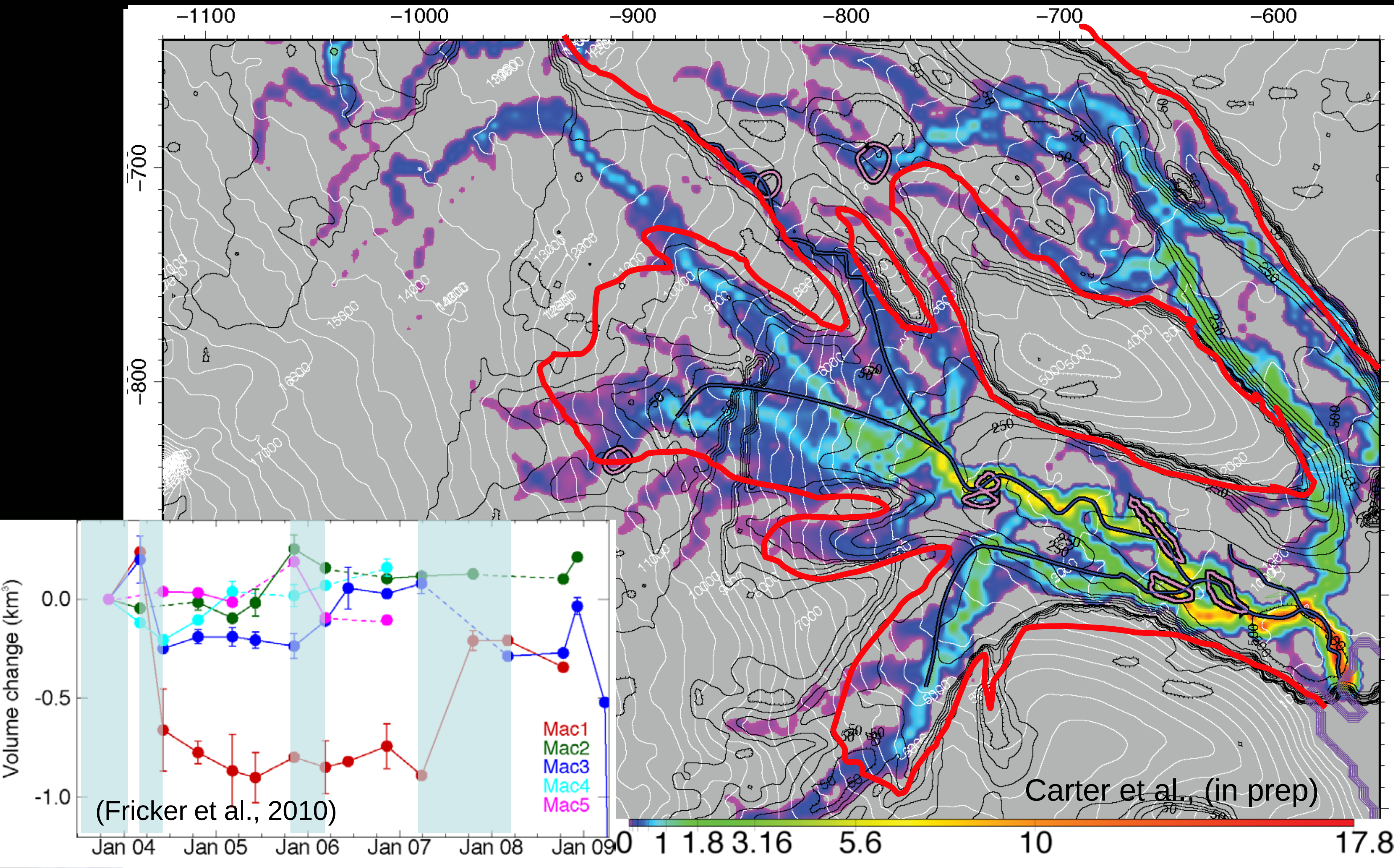
- Subglacial flood models generally require some modest effective pressure at lake outlet. (Nye, 1976)
- This also means you don’t have to edit the bed topography.
- Start with N=150 Kpa everywhere then edit until holes are filled
- “Holes” in areas of rugged basal topography, thin ice cover and no melt probably do not matter



Using RES and SrfAlt to improve CISM SIMPLY

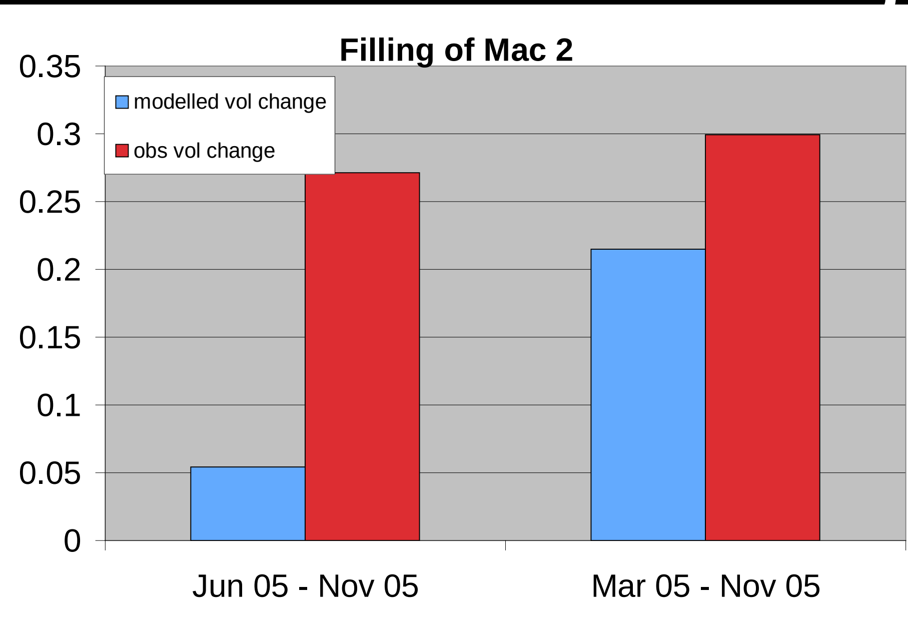
- Assume that only known active lakes matter
- There's 6 years of lake activity data for much of the Siple Coast from ICESAT
- Fill all holes or use routing algorithm to bypass them.
- Identify grid cells belonging to particular lake
- When lake is filling treat as sink
- When lake is draining, add lake's discharge to melt rate for cell immediately downstream
- Melt = f(t)
- Current netcdf input structure should allow for this.

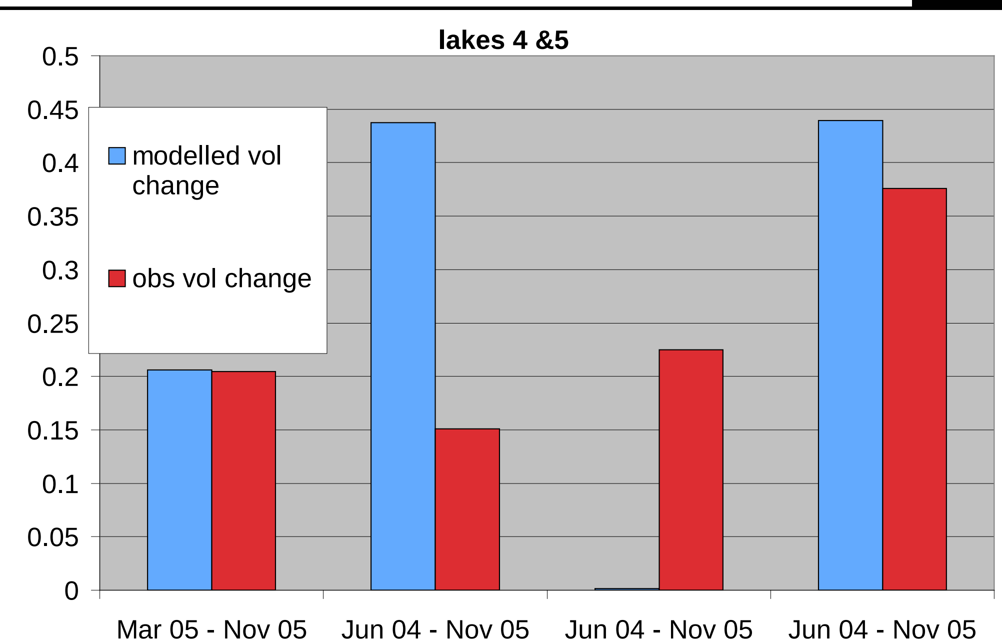
Results



−1100
−1000
−900
−800
−700
−600
−700
−800
0 1 1.8 3.16 5.6 10 17.8
Carter et al., (in prep)
Volume change (km³)
0.0
-0.5
-1.0
Jan 04
Jan 05
Jan 06
Jan 07
Jan 08
Jan 09
Mac1
Mac2
Mac3
Mac4
Mac5
(Fricker et al., 2010)

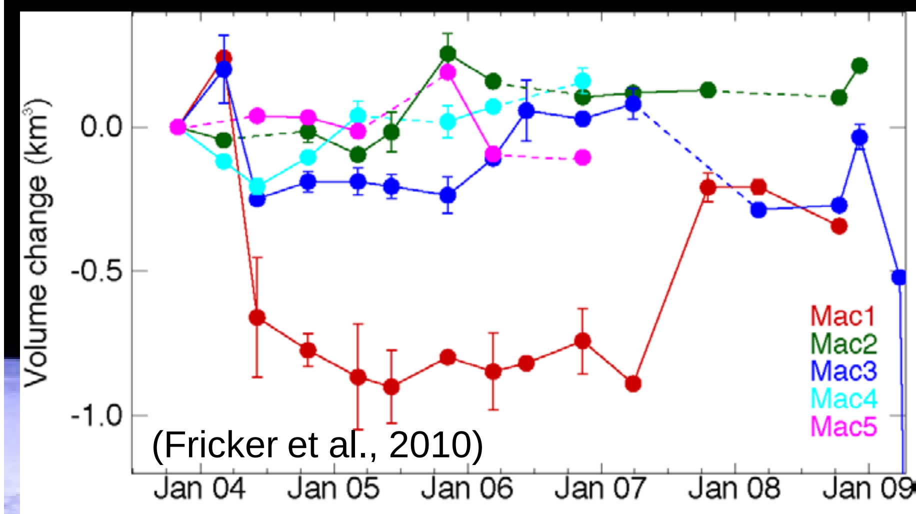
Validation using surface altimetry





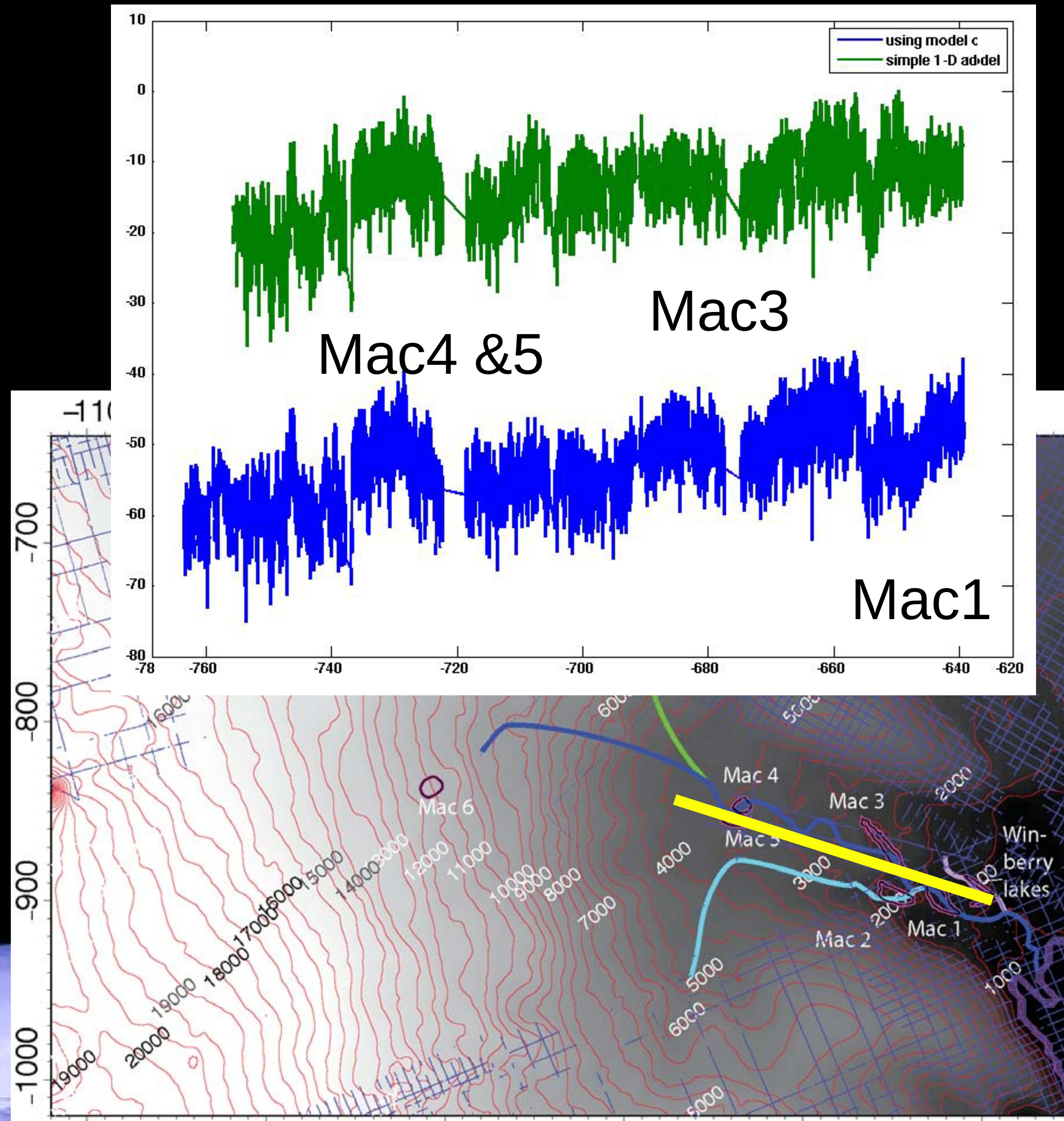
Carter et al., (in prep)

- Satellite altimetry observations are can be made consistent with modeled melt rate and routing
- Misfit may indicate presences of other undetected lakes



Validation using radar sounding data

- Radar reflectivity is a function of the nature of the basal interface., i.e. water distribution (Gudmundsen 1971)
- Obtaining accurate reflectivity requires a correction for temperature dependant dielectric attenuation
- Part of CISM's standard output is an englacial temperature distribution
- If the modeled englacial temperature distribution is correct, then the corrected basal reflectivity should match the modeled water distribution.
- Currently works on Siple Dome and Dome C



Future Work

- Still needs to be coupled to the ice sheet model
- Making water model time varying using upwind remapping or incremental remapping
- Looking at other subglacial catchments
- Exploring reflectivity with spun-up temperature distributions

Conclusions

- Highest resolution water budget to date
- Holes are often real and often correspond to subglacial lakes
- Episodic flow dominates the subglacial environment in many areas of fast glacier flow
- We may have a smoothly varying effective pressure field
- There may still yet be additional water storage in the MacAyel Ice Stream Catchment
- Existing geophysical data can provide us both with improved inputs and validation

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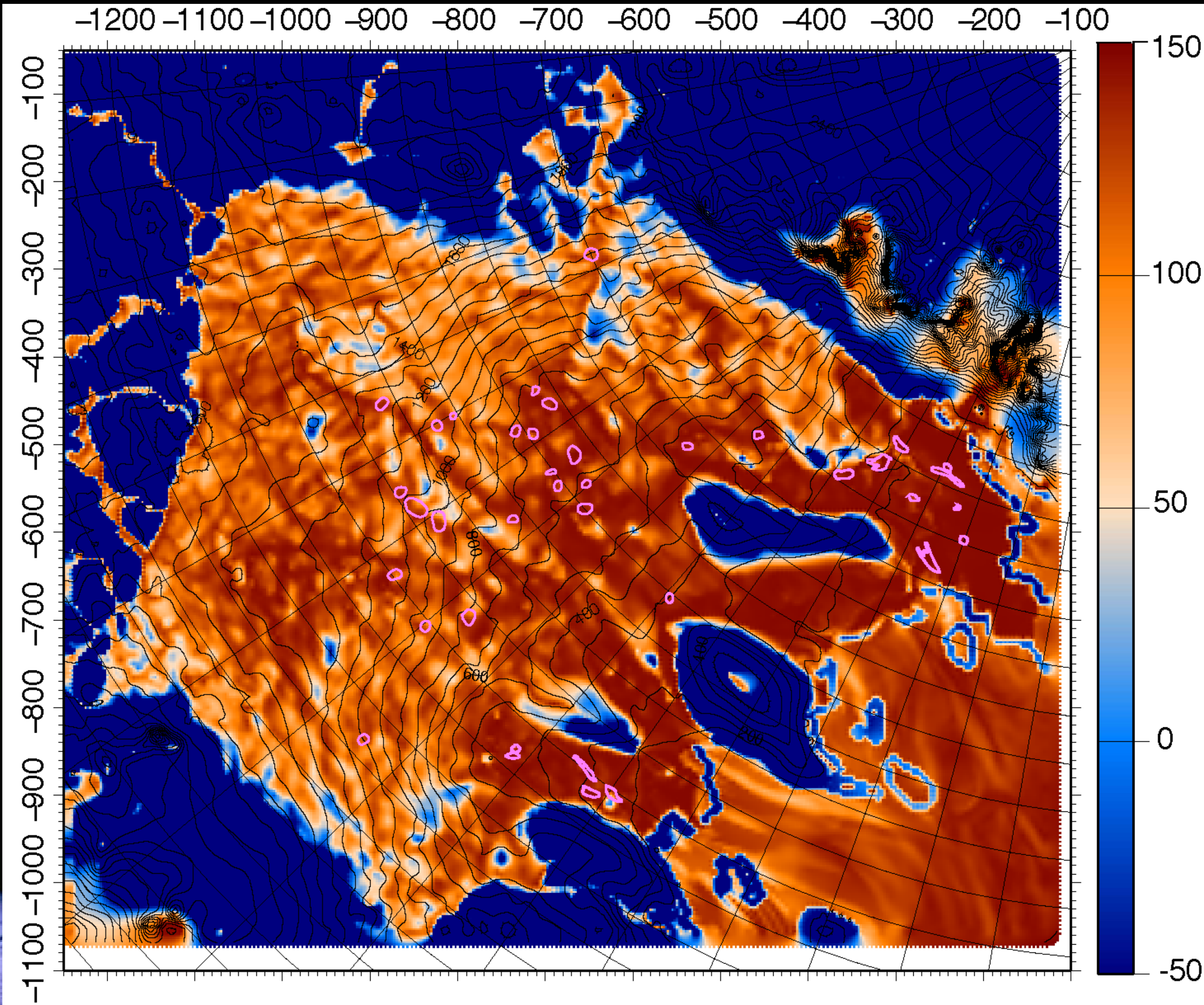
- Charles Jackson
- Ben Smith
- Tim Wiley
- Tim Bocek



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