Building a Next-Generation Community Ice Sheet Model
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Data Driven Model Development

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outline

- The problem of connecting models to data
- Solutions from stochastic inversion
- Interest in basal water systems, Thwaites glacier

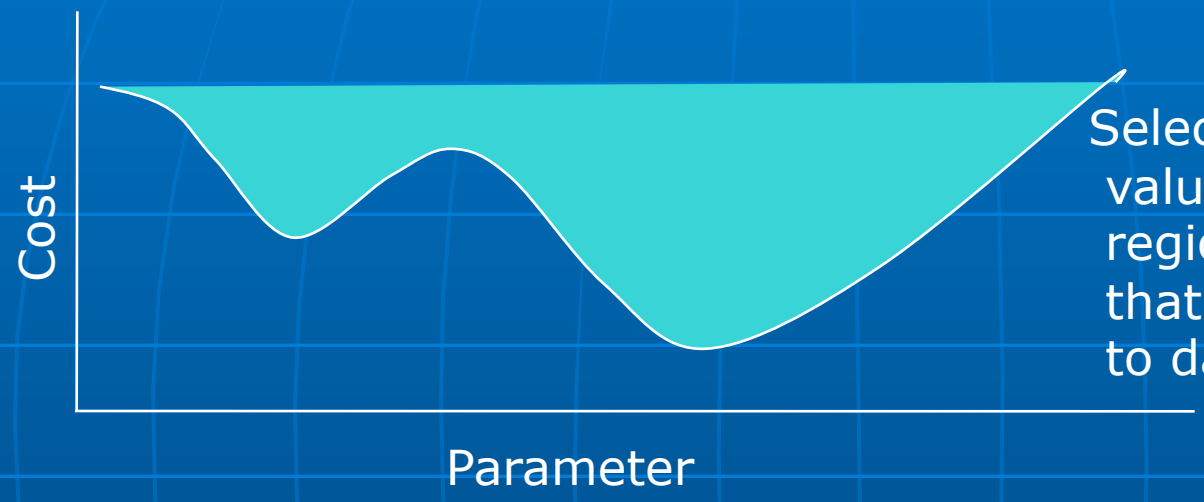
Problem: What is observed is (mostly) only indirectly related to what we need to know:

data	model
Thickness	Basal topography
Surface velocities	Basal friction
Internal Layers	Ice rheology
Crustal thicknesses	Geothermal heat
Basal reflectance	Temperature
Basal scatter	Sub-glacial water

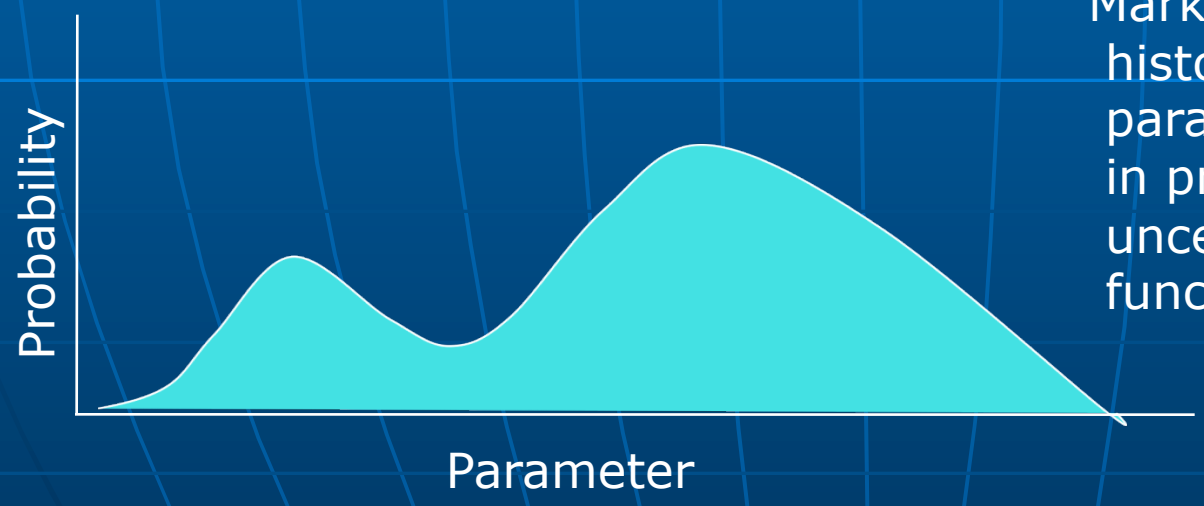
Solution: Stochastic inversion

- Completely general (appropriate for non-linear problems)
- Quantify process uncertainty in terms of observational uncertainties
- Easy to implement
- Better suited to problems with fewer (<20?) degrees of freedom

Idea of stochastic importance sampling

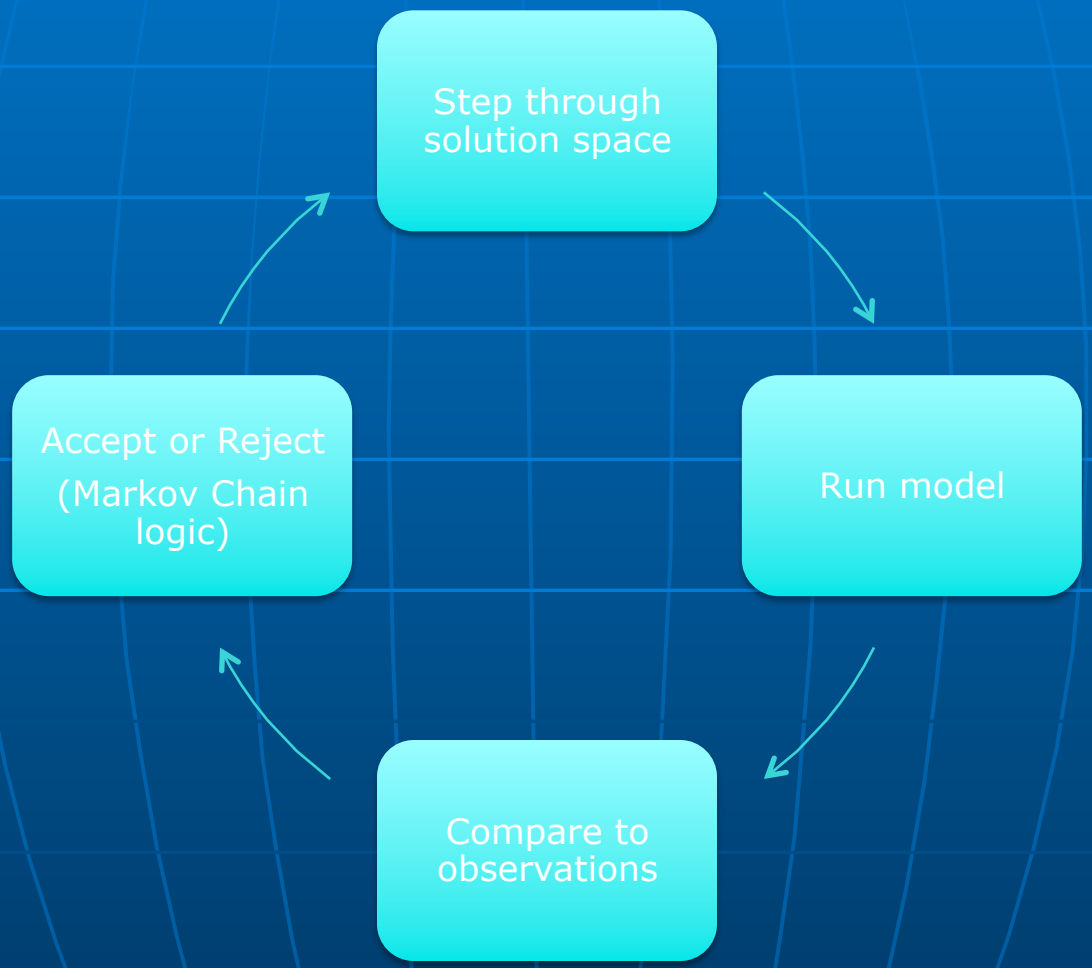


Select candidate parameter values more often from regions of parameter space that provide a better match to data.



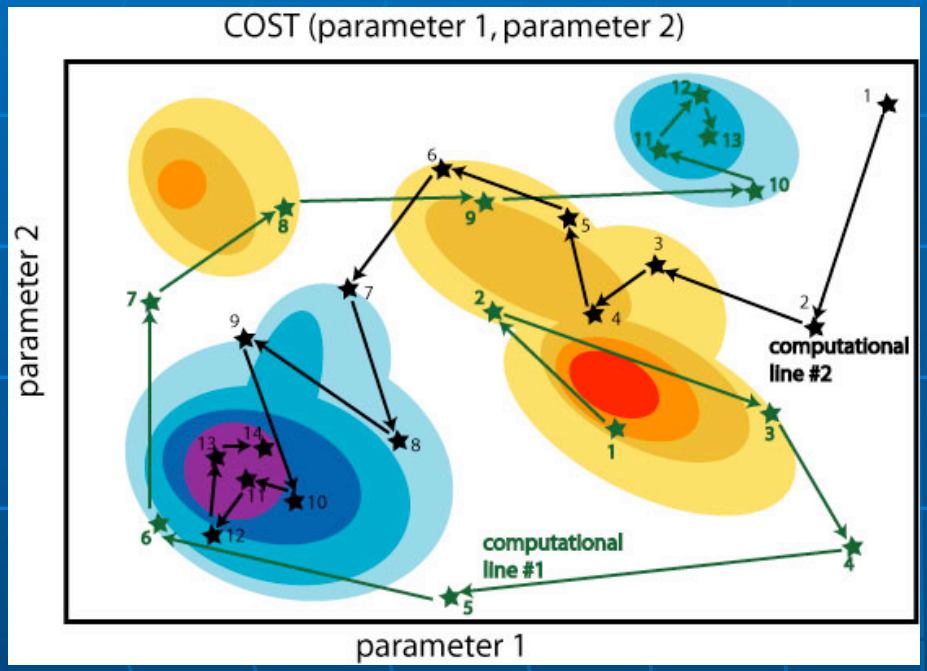
Markov Chains insure that the histogram of accepted parameter values is selected in proportion to the uncertainties in the cost function.

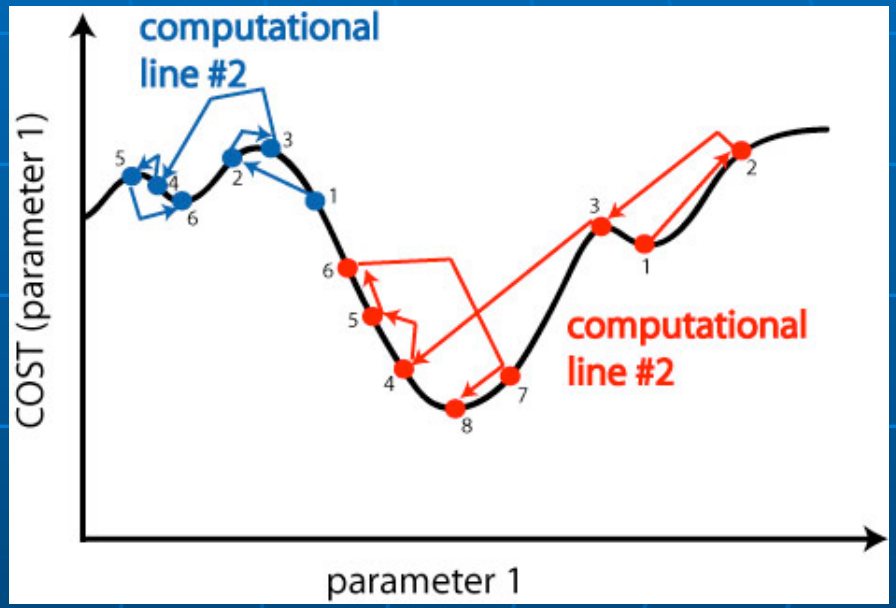
Importance Sampling



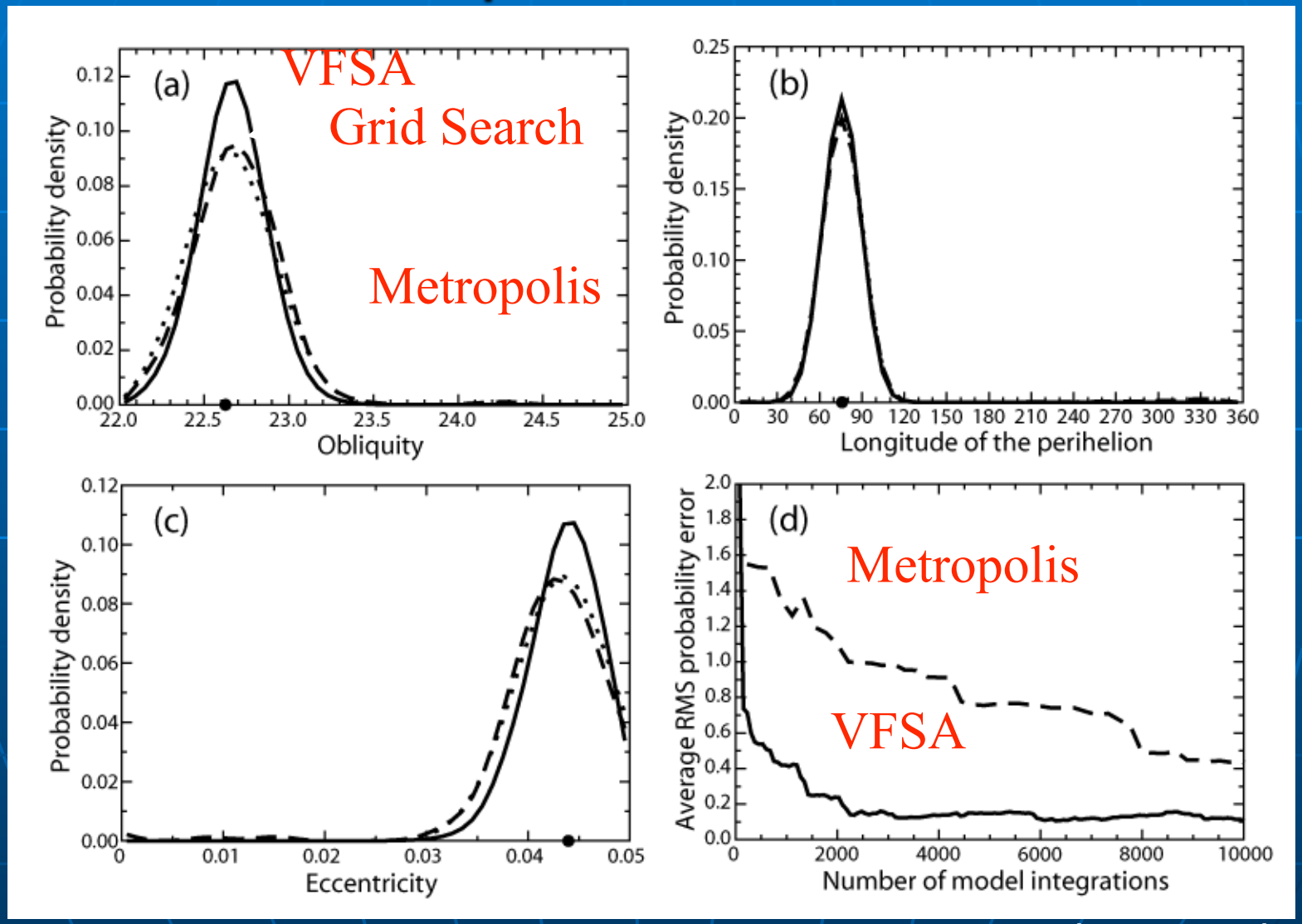
Methods to estimate multi -dimensional probability distributions

- Grid Search
- Monte Carlo (random sampling)
- Metropolis/Gibbs' Sampler (MCMC)
- Bayesian Stochastic Inversion using multiple Very Fast Simulated Annealing (Sen and Stoffa, 1996).


COST (parameter 1, parameter 2)
parameter 2
parameter 1
computational line #2
computational line #1


computational line #2
computational line #2
COST (parameter 1)
parameter 1

Probability density functions for 3 parameters:



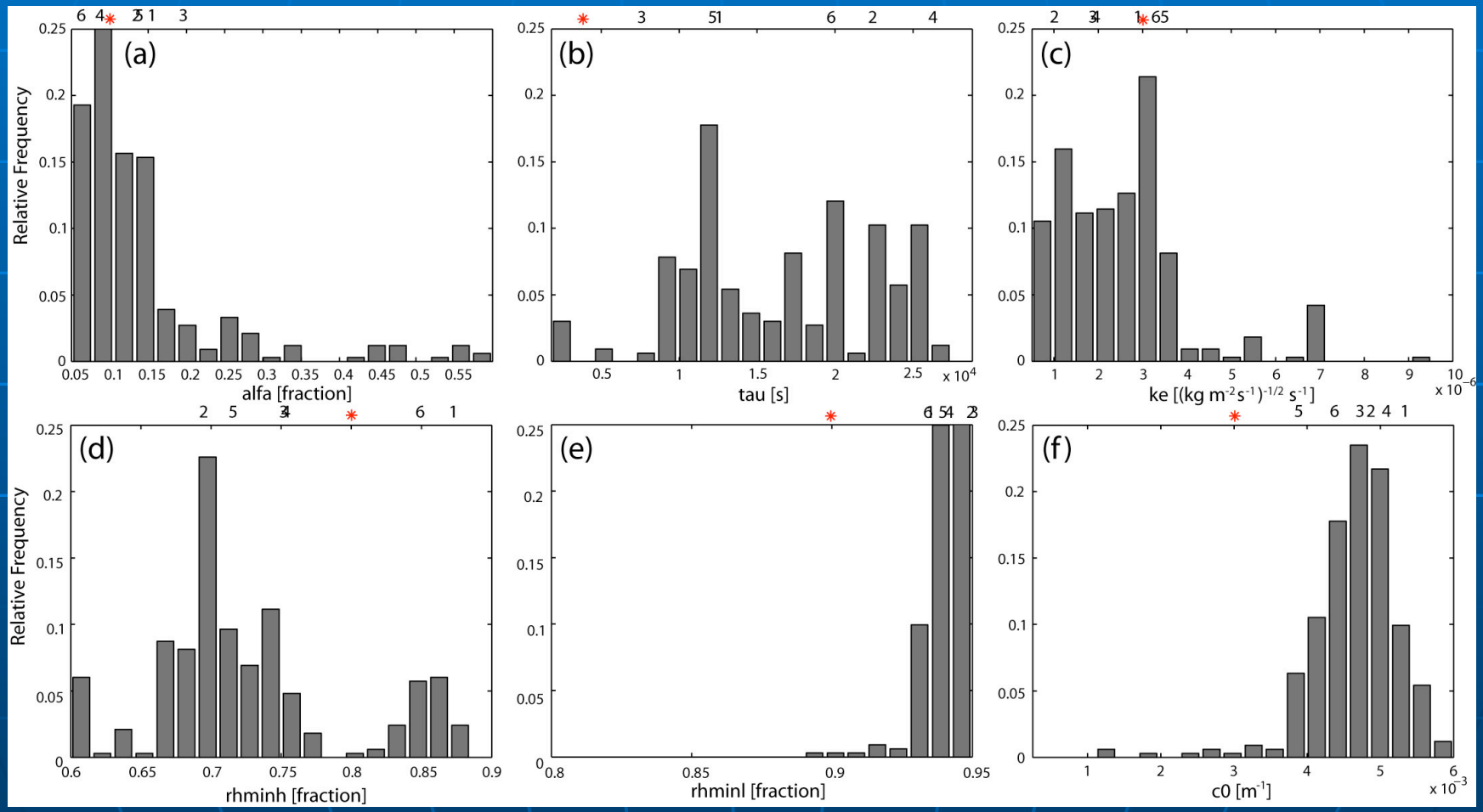
Jackson et al. (2004)

Example: Constrain uncertain cloud parameters of CAM3.1with observational-Data

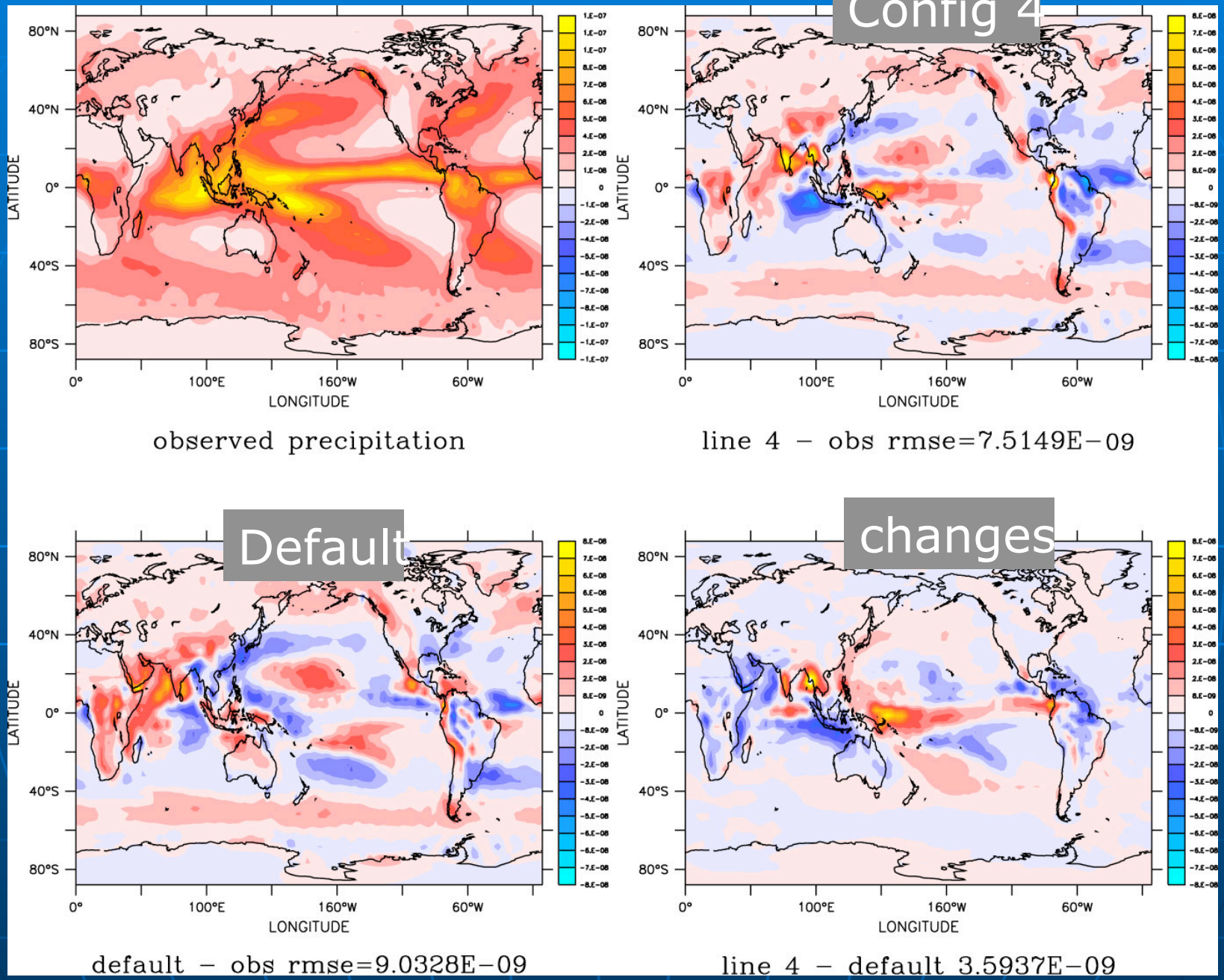
1. **Low-level clouds**, 1990-2001, ISCCP satellite observations (Rossow et al. 1991)
2. **Mid-level clouds**, 1990-2001, ISCCP satellite observations (Rossow et al. 1991)
3. **High-level clouds**, 1990-2001, ISCCP satellite observations (Rossow et al. 1991)
4. **Net shortwave top**, 1985-1989, ERBE satellite observations (Barkstrom et al. 1989)
5. **Net longwave top**, 1985-1989, ERBE satellite observations (Barkstrom et al. 1989)
6. **Global radiative balance top**, 0.3 Watts/m2, imposed.
7. **Shortwave radiation to surface**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al.2001)
8. **2m air temperature**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al. 2001)
9. **Surface sensible heat flux**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al. 2001)
10. **Surface latent heat flux**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al. 2001)
11. **Relative humidity (zonal mean)**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al.2001)
12. **Air temperature (zonal mean)**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al. 2001)
13. **Zonal winds (zonal mean)**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al. 2001)
14. **Sea level pressure**, 1990-2001, NCEP reanalysis data (Kalnay et al. 1991, Kistler et al. 2001)
15. **Precipitation**, 1990-2001, CMAP instrumental record (Xie and Arkin 1996, 1997)

Jackson et al (in press, J. Climate)

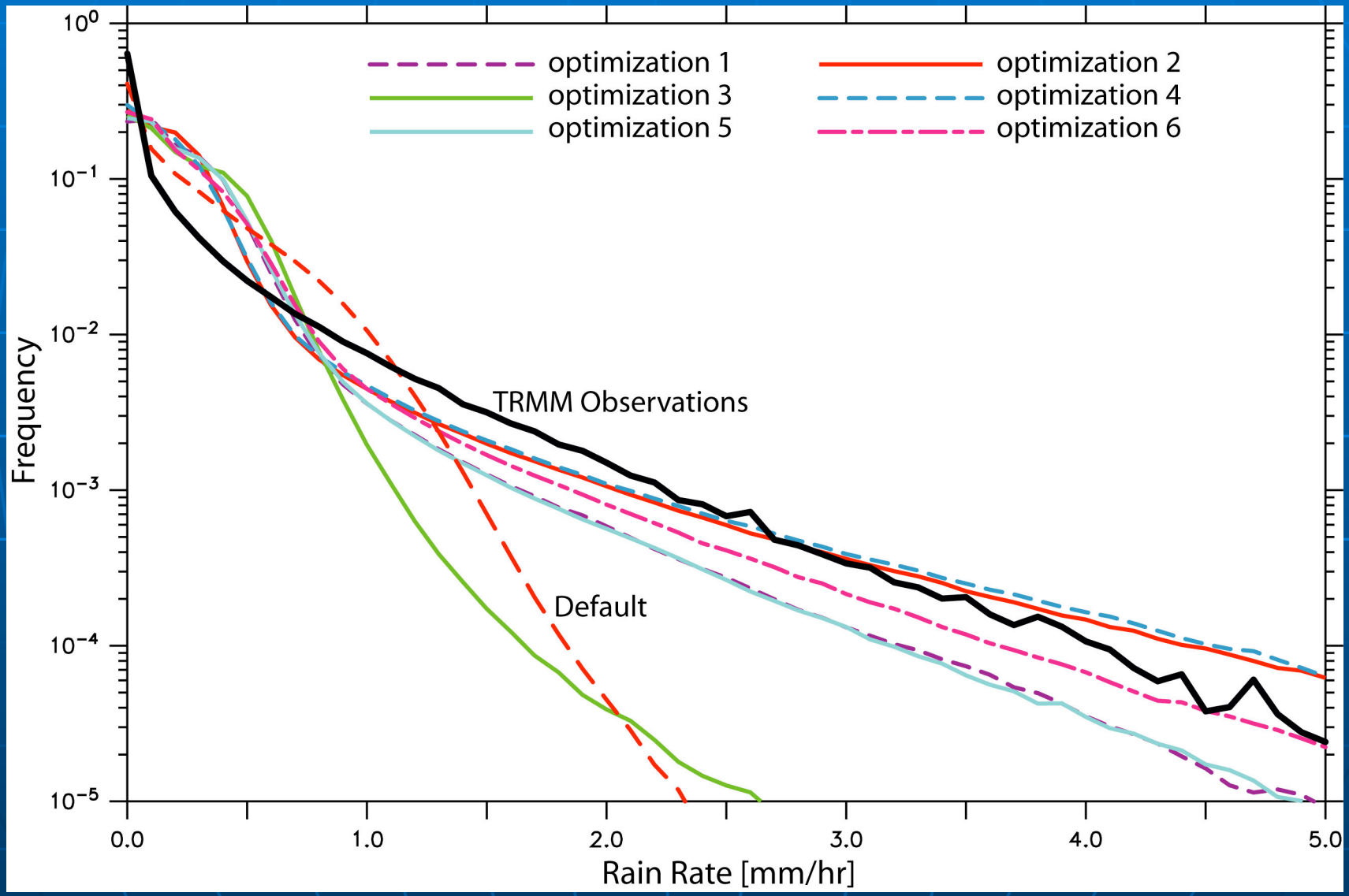
Distribution of parameter values that improve cam3.1 skill:



Jackson et al (in press, J. Climate)


Config 4
Default
changes
80°N
40°N
0°
40°S
80°S
LATITUDE
0°
100°E
160°W
60°W
LONGITUDE
observed precipitation
line 4 – obs rmse=7.5149E−09
default – obs rmse=9.0328E−09
line 4 – default 3.5937E−09

Much improved simulation of rain intensities over tropics.



Jackson et al (in press, J. Climate)

Development target: Thwaites sub-glacial water system

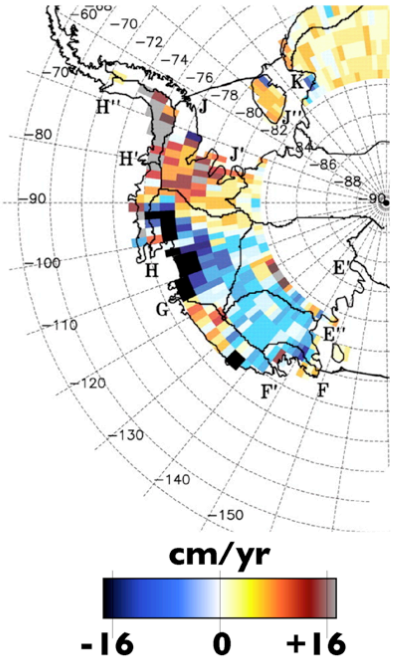
Starting questions:

- Where is excess water first produced?
- How does it affect ice flow?

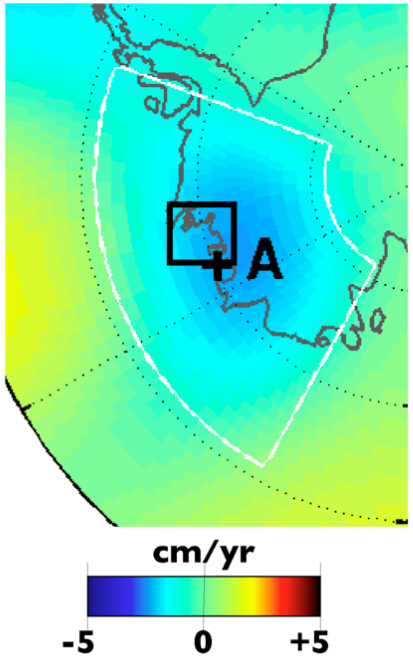
Goal #1 Forward model that connects basal heat generation to sub-glacial water system.

Goal #2 Inverse model that constrains subglacial water/heat transport uncertainties to surface velocities.

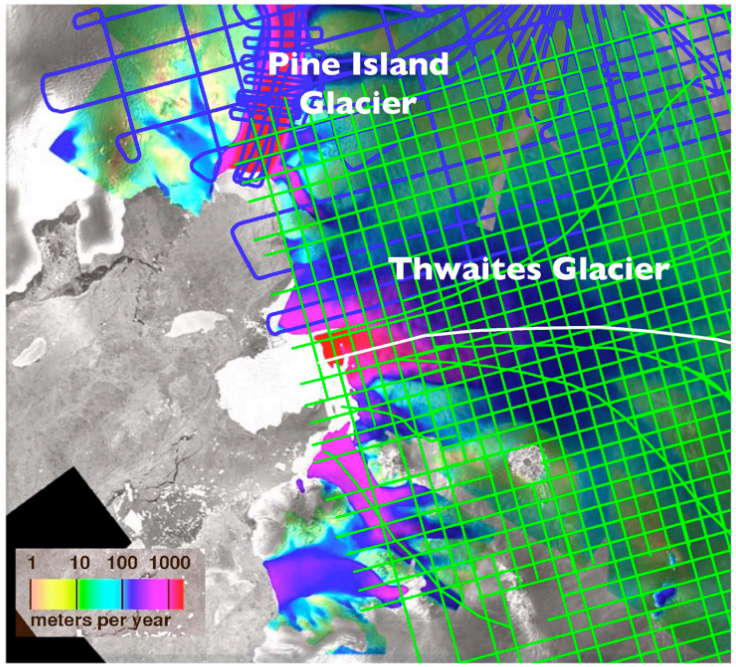
Surface Lowering in ERS altimetry (Davies et al., 2005)

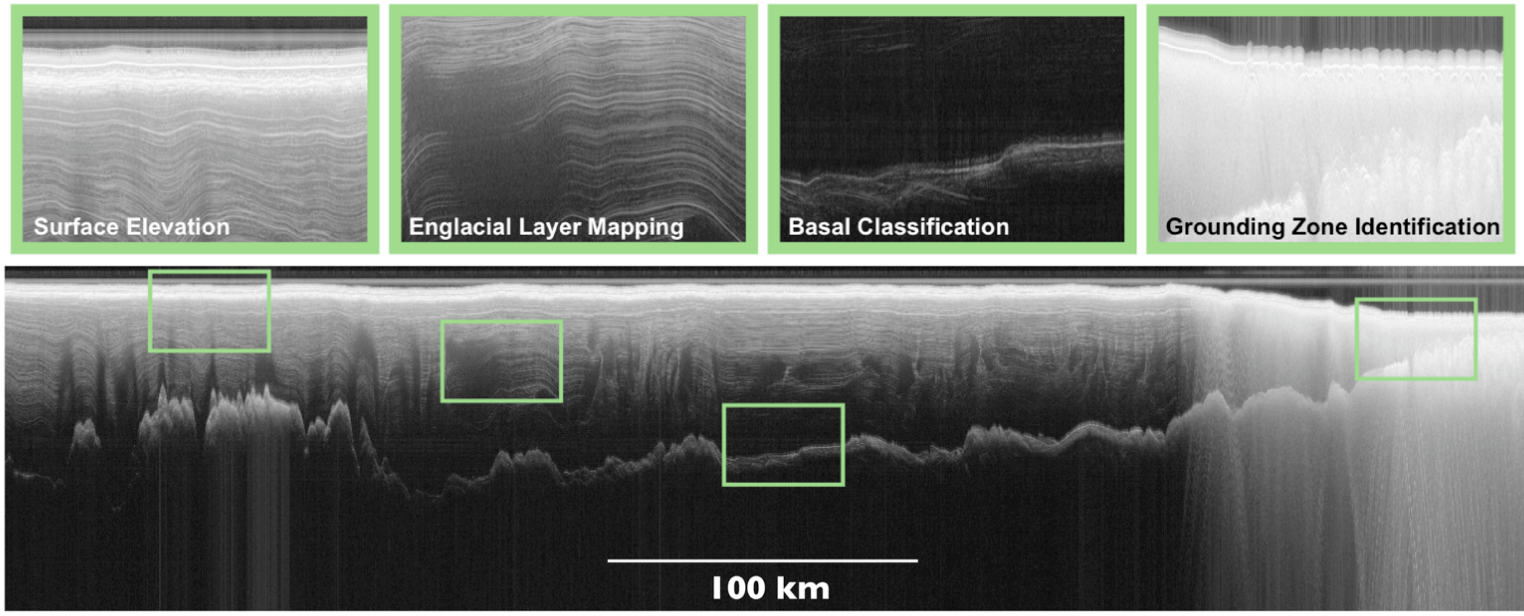


Mass deficits in GRACE Gravity (Chen et al., 2005)



InSAR surface velocities (Rignot et al., 2003) & new areogeophysical data (Holt et al., 2006)

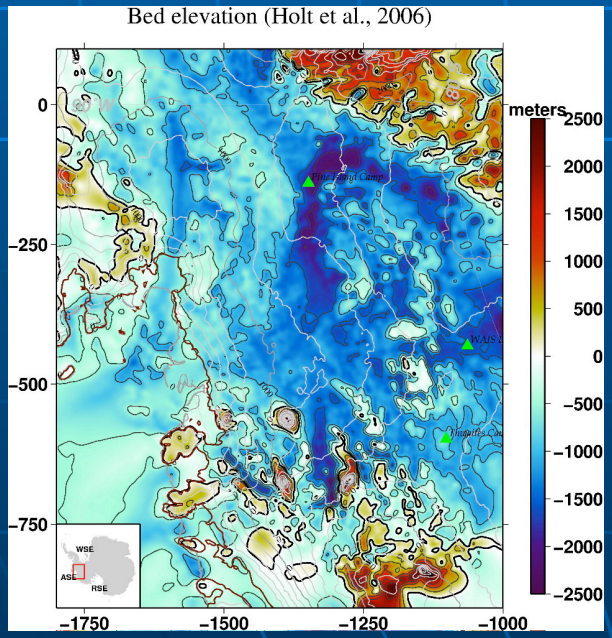




Key boundary conditions important to water system

- Geothermal heat flux
- Sediment distribution
- Basal/surface topography

Young/Blankenship (new result)



Ice sheet modeling assumptions important to water system (that could be tested later)

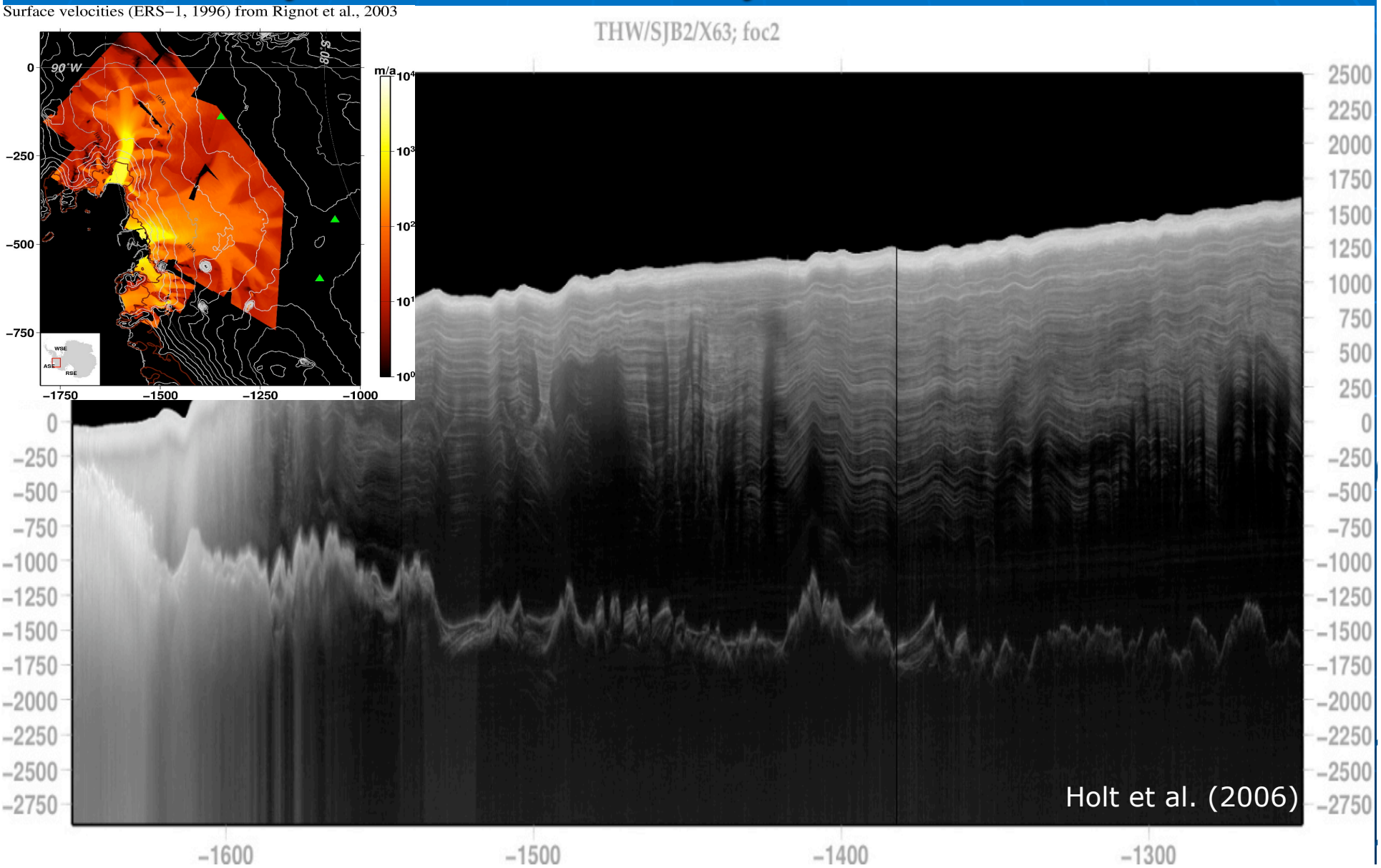
- Correct flows
- Correct thermal structure
- Correct rheology

Young/Blankenship (new result)

Exercise will predict

- Frictional heating
- Water/heat transport

Modeling assumptions can be tested with internal layers surface velocity measurements.



summary

- Rich data exists that may indirectly constrain key process uncertainties.
- Stochastic inversion will be an important tool for connecting data to model development.
- Interested in developing capacity to tie sub-glacial water to sub-glacial heat budget.