UAVSAR Greenland Data: Inferring Accumulation Rates and Comparing with ALOS Data

Albert Chen

Stanford University, Electrical Engineering Dept.

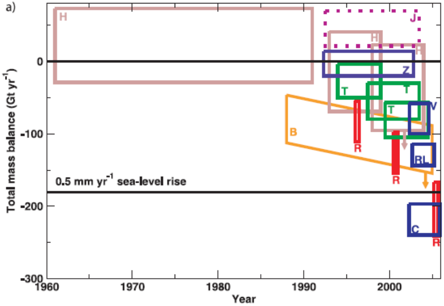
UAVSAR Workshop, Mar. 26-27, 2013

Outline

- Motivation and Problem Formulation
- Case Study 1: B-26 site
- Case Study 2: UAVSAR data
- Case Study 3: ALOS InSAR transect

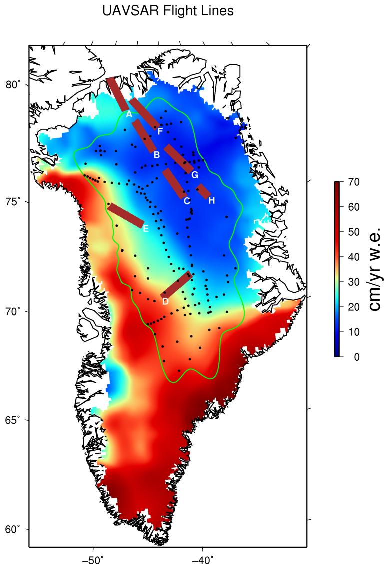
Greenland Ice Sheet Mass Balance

IPCC AR4 Greenland Total Mass Balance Estimates

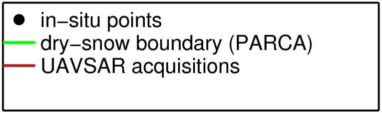


- Greenland Ice Sheet mass balance important for sea level and climate change awareness.
- Coastal ablation rates often easier to measure.
- Accumulation rates in interior also important!
  - Sparse in-situ measurements.
  - Field work challenging.

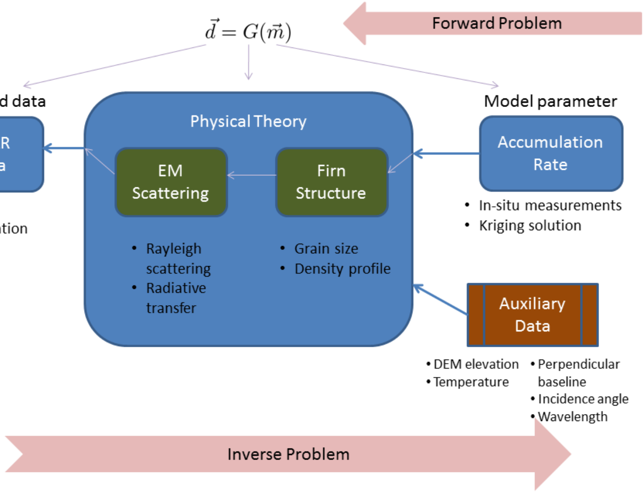
Greenland Ice Sheet Accumulation Rates



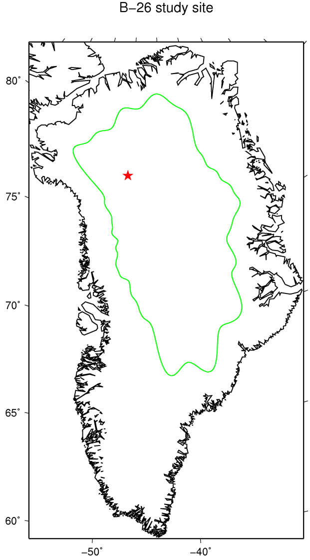
- In-situ accumulation rate measurements and kriging solution [Bales et.al., 2001]
- Gradient in NE direction
- 168 in-situ data points in dry-snow zone
- Dry-snow zone boundary (PARCA): no observed melt days, 1979-2007 [Abdalati, et.al.]
- Several UAVSAR flights in dry-snow zone



Model Formulation: Conceptual Diagram



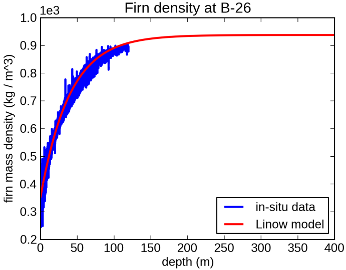
Case Study 1: B-26

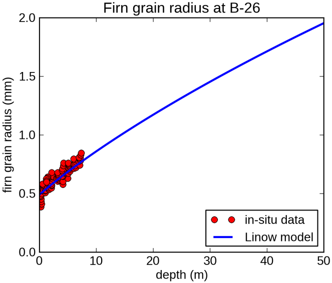


- In-situ firn profile available at this location.
- Forward model of firn profile fits in-situ data.
- Simulation shows that inversion recovers accumulation rate (ideal case).

Case Study 1: B-26

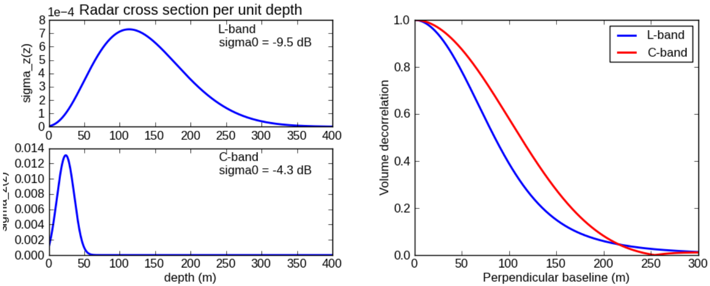
Density and grain radius match in-situ measurements.





Case Study 1: B-26

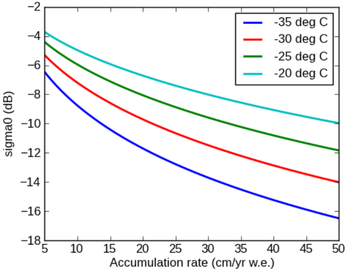
Electromagnetic scattering forward model calculations illustrate differences between C-band and L-band sensor responses.

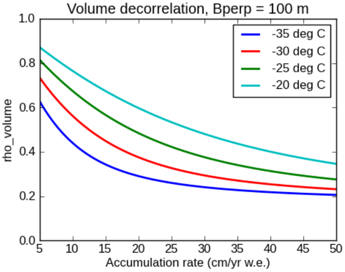


L-band return comes from deeper within firn, which causes greater volume decorrelation. However, longer wavelength improves correlation. Simulations show good correlation over a similar range of perpendicular baselines.

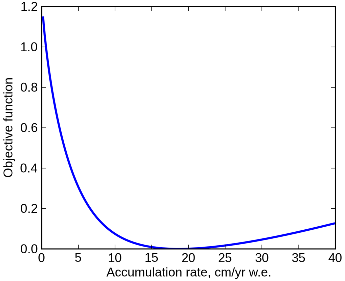
Case Study 1: B-26

It is illustrative to examine how the simulated data vary with accumulation rate.





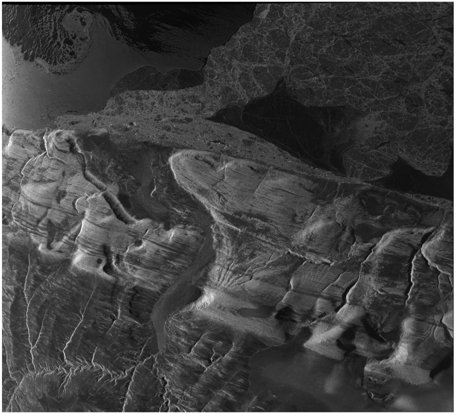
Case Study 1: B-26



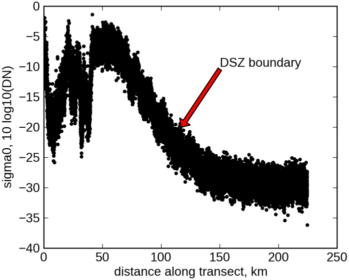
- Inversion performed on simulated data.
- Objective function shows good convexity (no local minima).
- We can recover the accumulation rate used to generate the simulated data.

Case Study 2: UAVSAR Flight A

Northern coast of Greenland...



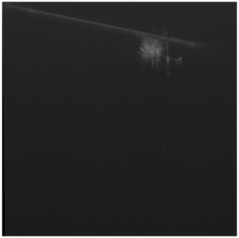
Case Study 2: UAVSAR Flight F



- Percolation region much brighter than dry-snow zone.
- Dry-snow zone boundary is same as inferred from PARCA.
- Verifies that UAVSAR identifies Greenland Ice Sheet facies (cf. ALOS mosaic).

Case Study 2: UAVSAR Flight D

Ice runway and research station visible in otherwise "featureless" image.

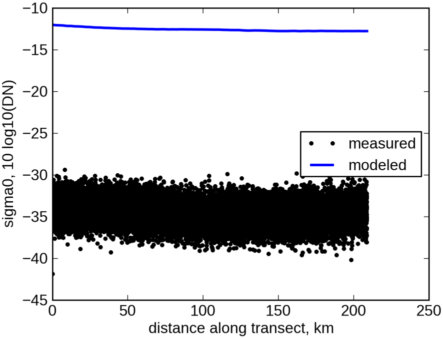


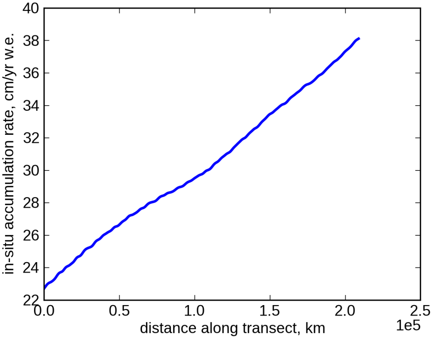
(a) UAVSAR image

(b) Photo

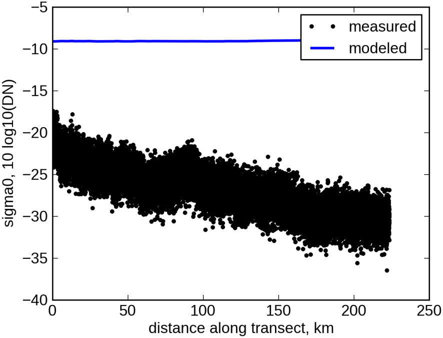
Photo from www.flickr.com/photos/coastaleddy/6961187802/sizes/c/in/photostream/

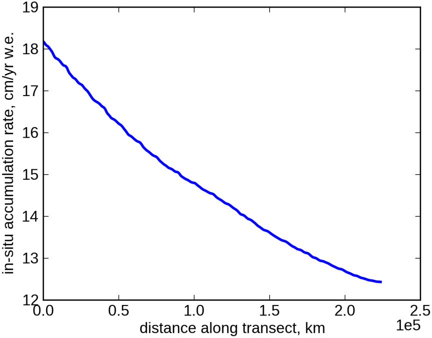
Case Study 2: UAVSAR Flight D



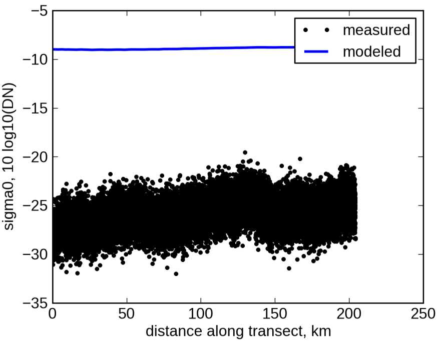


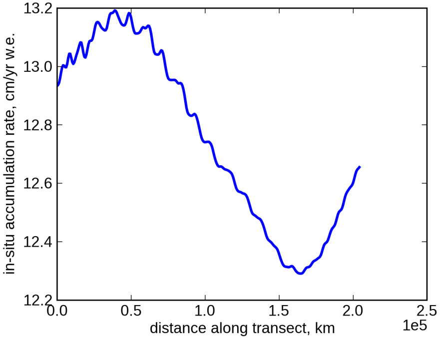
Case Study 2: UAVSAR Flight B



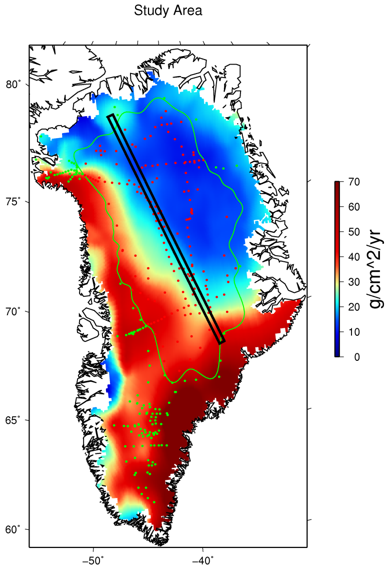


Case Study 2: UAVSAR Flight C

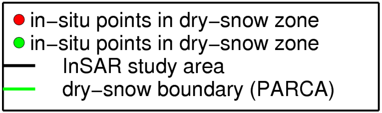




Case Study 3: ALOS InSAR Transect

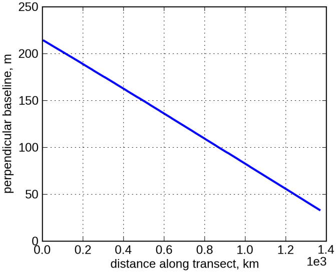


- Lies close to many in-situ points
- Traverses entire dry-snow zone
- Covers large range of accumulation rates
- Consists of 24 ALOS InSAR frames

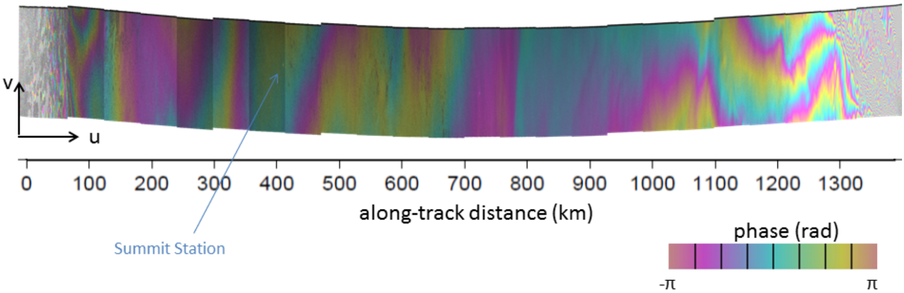


Case Study 3: ALOS InSAR Transect

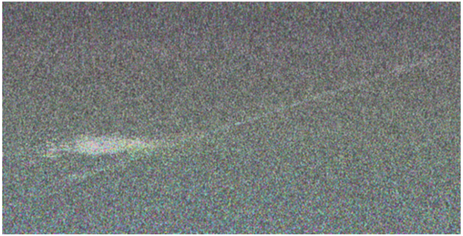
Parameter	Value
Incidence Angle	21.5^o
Wavelength	23.61 cm
Orbit	Ascending
Temporal baseline	46 days
Perpendicular baseline	40 - 210 meters
Mode	PLR



Case Study 3: ALOS InSAR Transect



http://www.flickr.com/photos/coastaleddy/6961187802/



ALOS Interferogram

Case Study 3: ALOS InSAR Transect

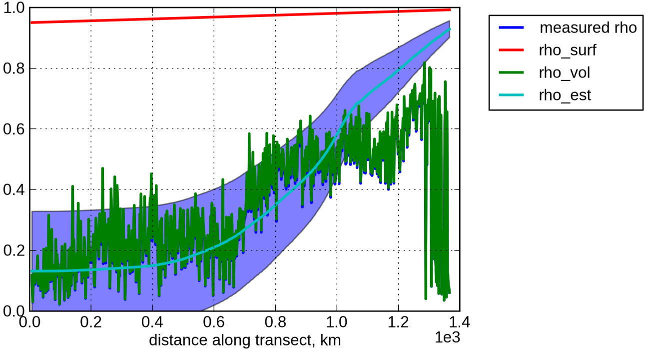


Figure: Simulated $\hat{\rho_{vol}}$ using in-situ accumulation rate (teal) compared to measured $\hat{\rho_{vol}}$ (green).

- Surface decorrelation is very small.
- Model correctly predicts the trends in the data.
- Purple interval shows simulated uncertainty in $\hat{\rho_{vol}}$ due to std. dev. of correlation estimator.

Case Study 3: ALOS InSAR Transect

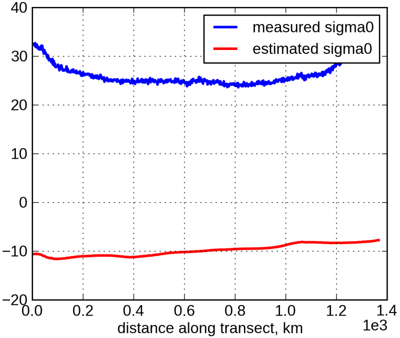
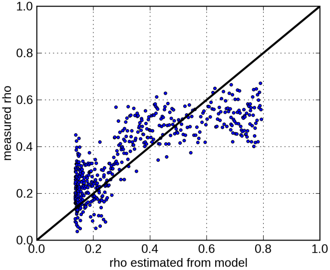


Figure: Simulated σ^0 using in-situ accumulation rate (red) and measured, uncalibrated $sigma^0$ (blue).

- Both measured and estimated σ^0 show litte variation over the dry-snow zone.
- Increase in measured σ^0 at ends of transect could be due to brighter radar returns in percolation zone.

Case Study 3: ALOS InSAR Transect



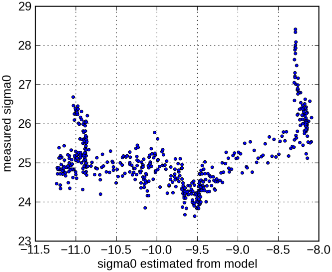


Figure: Scatter plots of measured $\rho \hat{vol}$ (left) and σ^0 (right) vs. simulated values from in-situ accumulation rate.

Case Study 3: ALOS InSAR Transect

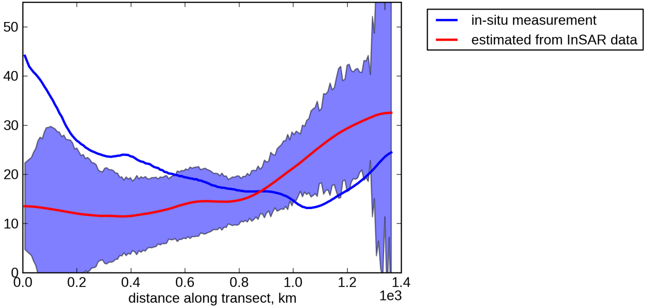
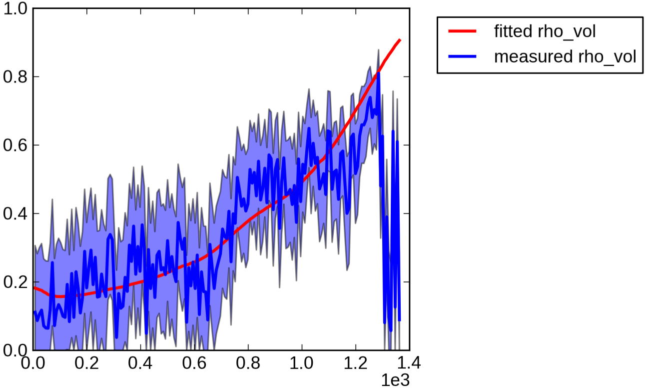


Figure: Accumulation rates: Inversion result (red) and in-situ accumulation rate (blue).

- Inversion based on $\hat{\rho_{vol}}$ only.
- Regularized solution, minimizes residual + first derivative.
- Purple interval gives estimated uncertainty resulting from std. dev. of data.

Case Study 3: ALOS InSAR Transect



- To verify that the inversion algorithm is working, we can plot the inversion result's simulated data (red) along with the actual data (blue).
- Purple interval shows estimated data standard deviation.

Conclusions

- Implemented a model relating SAR and InSAR data to Greenland ice sheet accumulation rate.
- L-band radar brightness seems to be less useful for estimating accumulation rate than C-band radar brightness.
- However, L-band InSAR correlation does seem to be related to accumulation rate.
- For small spatial baselines, L-band interferograms can be formed, and correlation depends much more on volume effects (including accumulation rate) than on scattering from ice sheet surface.
- UAVSAR data can help us understand temporal decorrelation!!
- Accurate UAVSAR correlation data would be useful even with motion artifacts!