

Zwally and Li and Li and Zwally Discussion

Big Thoughts:

Yes, seasonal densification occurs but Zwally and Li do not do a good job modeling it. The approach is questionable, and there is insufficient evidence presented to suggest that it matches observations well.

More Details:

New observations by Bob Hawley show that rate of firn densification is greater in the summer than winter as hypothesized by Zwally and Li.

Zwally and Li, 2002:

They use a modified Herron and Langway approach to model the change in surface elevation seasonally at Summit, Greenland. The firn compaction rate is temperature dependent and the accumulation rate can be transient.

We did not like the Zwally and Li approach:

- unclear why grain growth rates relate to densification rates. Oh beta, beta, beta
- why does the activation energy increase with temperature (logically it makes more sense that the activation energy would be lower because there is more energy in the system when the temperature is higher)
- the k_0 values appear to be what is required to cancel out in the temperature dependent activation energy. Rational for this approach is not well explained.
- The units for $K(T)$ do not appear to work in equation 4.
- The fit of the activation energy (Figure 3) is suspect. It looks like it should be fit in two sections, with the break at -10. The exponential fit may only indicate a good agreement with the 3 points for the highest temperatures
- There is confusion about whether the model is Lagrangian (moving with the layers) or Eulerian (fixed reference frame). The heat flow equations (7) suggests Eulerian (there's an advective term) while the dH/dt equation (10) looks more Lagrangian. Indexes are little screwy in this equation.

Almost all of the increased densification occurs in the first year, Figure 6a. The match in figure 6c is questionable: maybe because of density measurements and maybe because the match just isn't good.

The comparison of the models to observations in 7 and 8 are unsatisfying because it is difficult to determine how much of the observations are explained by the temperature-dependent firn compaction.

Li and Zwally, 2002:

Same model as above applied to Berkner Island, Antarctica but with constant accumulation. The emphasis was on the seasonal density variations of the firn layers. The model shows that layers deposited in summer have the highest density. This contrasts with the density record from a core, where the summer density is lower than the winter density. This may be because the Z&I model has constant accumulation and depositional processes are not accounted for. However, the model also does not predict the more rapid densification of the initially less dense (big grain) layers that become the more dense layers after the cross-over point at ~15m. The model predicts that the relative density of a layer is determined primarily in the first year and it keeps that relative density until becoming ice.