Reviewer 1 (RV1, RC C2543)

The vertical density profile in ice shelves is required by all the studies that need, for example, estimates of the ice thickness from hydrostatic equilibrium. However the densification of snow to ice depends on many factors that can be temporally and spatially variable. Accurate and efficient field data are then required to improve our understanding of this variability.

This paper presents a new algorithm to invert the vertical density profile from wide angle radar measurements. There is an application at 6 locations on the Roi Baudoin Ice shelf. The presentation of the method is clear and its performance validated against a model twin experiment. The method is further validated using 2 density profiles obtained by optical televiewing in 2 boreholes located in the area.

This study is an important and timely study and I have mainly minor comments.
Response: Thank you for your positive feedback, we have implemented many of your suggestion. Please find detailed answers to each point below.

Specific comments:

RV1-1: the paper conclude that the firn in the channel is "anomalously" (title) dense or "denser" (abstract, discussion, conclusion) . By this, we understand that the measurements in the channel are outside the spatial variability. However there is only 7 measurements (5 radar + 2 boreholes) and the derived air content at site 3 (in channel) is higher that site 2 (outside channel) and within the error bar of site 6 (outside channel). I think this is difficult to conclude from this that the measurements in the channel present an anomaly. It's maybe only that the spatial variability is underestimated? At least the authors should try to discuss processes that would make the firn denser in the channel than outside to support the idea that there is something special in the channel.
Response: Agreed, the data itself are not densely enough sampled to conclude that firn inside the channel is „anomalously" denser than outside the channel. Indeed, we could be seeing smaller-scale density variations which are not necessarily linked to the ice-shelf channels at all. In the revised version we address this point, by speculating about mechanisms which can lead to systematically denser firn in ice-shelf channels. We suggest that surface melt water (which is abundant near the grounding-zone of the Roi Baudouin Ice Shelf) collects in the channel's surface depressions and forms an increased number of (refrozen) ice layers, causing a systematically increased depth-averaged density inside ice-shelf channels. Given that densification also depends on other factors (which may also vary across ice-shelf channels, for example, the surface mass balance and the strain-regime), we emphasize that more work is required to pinpoint a mechanism which may cause higher firn densities in ice-shelf channels.

The changes are implemented in section 5.2 and the in the new title.

RV1-2: In the inversion, they suppose that the density at the surface is uniform in the study area (the parameter A in the model is constant). However from the OPTV measurements (Figure 7) we have the filling that the surface density could be higher in the channel. Maybe a sensitivity study to the value of A should be added.
Response: We conducted the sensitivity tests by letting the the surface density vary between 300 – 500 kg m^{-3} and found that the assumption of a unifom surface density does not affect the main result of this paper. We find the smallest data-model discrepancies for values around 400 kg m^{-3}. The differences in the firn-air content remain within the previously given error bars for all surface densities. This means that this uncertainty is corrected for by adapting the densification length/reflector depths.

The assumption of a constant surface density was mostly due to the algorithm, which becomes rather unstable if all parameters (surface density, reflector depths, and densification length) are inverted for simultaneously. In reality surface density likely varies. Similar as Brown et al., 2012, J. Geophys. Res., we have investigated the velocity of the surface waves (dashed green lines in Fig. 3) to get a better handle on the surface densities, but in this 10 MHz dataset the surface wave is hard to identify and it cannot be used as a good constraint for surface densities.

The changes are implemented in the revised Section 5.1.

RV1-3: It could be interesting to check if, with the derived density and thickness, there is hydrostatic equilibrium at each field site?
Response: Agreed, we added a column to Table 1. The maximum (minimum) deviation from hydrostatic equilibrium is 19 m (4 m). Other than the depth-averaged density, hydrostatic inversion also requires knowledge of the geoid height, the mean dynamic topography and the surface elevation. All of these parameters are not perfectly constrained in this area and may deviate within meters (Drews, T. Cryosph., 2015). Because hydrostatic inversion amplifies uncertainties roughly with a factor of 10, the deviations from hydrostatic equilibrium observed here are in an acceptable range (assuming that no marine ice is present).

RV1-4: Symbols: "c" is used 3 times: c for speed of light introduced in Eq. 3; Capital C introduced in Eq. 4, and covariance matrices Ct and Cm in Eq. 11. It could be better to use different letters.
Response: Agreed. We replaced the constant "C" in eq. 4 (and following) with "k".

RV1-5: Sec. 2.3 forward model: I find a bit strange to give approximations of the forward model (Eqs. 5 to 10) before the forward model itself. I think it could be more clear to put equations 5 to 10 in the section 2.4 (Inversion) and explain that computing the gradient of the first term of J (Eq. 11) requires to compute the adjoint of the forward model which is not possible. The partial derivatives of J, required to update efficiently the model parameters, are then estimated from simple approximations (Eqs. 5 to 10).
Response: No change. We feel that both ways are equally valid.

RV1-6: Eq. 11 : change "C_M" to "C_m" , in agreement to what is given below.
Response: Agreed, changed.

RV1-7: Eq. 11 : " C_t" and " C_m" should be "C_t^{-1}" and " C_m^{-1}"
Response: Agreed, changed.

RV1-8: page 5657 line 22: "fin-ice" => "firn-ice"
Response: Agreed, changed.