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Subglacial hydrology indicates a major shift in dynamics of the West Antarctic Ross Ice Streams within the next two centuries, S. Goeller, V. Helm, M. Thoma, and K. Grosfeld

Response to Anonymous Reviewer #2

Dear reviewer,

thank you for your review of the manuscript. We understand that thorough reviewing is a time consuming process, so we appreciate the effort you put into completing the reviews. We found your comments very helpful and modified our manuscript according to them.

Please find all of your comments elaborated in detail below.

Best regards,
Sebastian Goeller.

General comments

This manuscript presents results of a simple model which uses data constraining ice sheet geometry in the region draining theWest Antarctic ice sheet into Ross Ice Shelf to estimate subglacial water routing and subglacial drainage basins. The authors assume that the drainage area is a proxy of subglacial water flux by assuming that the basal melting rate is spatially uniform in the study area, in spite of prior modeling results inconsistent with such an assumption (Beem et al., 2010; Joughin et al., 2003).

We do NOT assume, that there is a spatially uniform basal melt rate at the Siple Coast. This seems to be a huge misunderstanding. In our study, we investigate basal water pathways and we express local water fluxes in terms of percentage of the entire catchment area which is locally draining. We simulate and discuss exclusively pathways, catchment areas and drainage in percentage of the total catchment area, but no melt rates. To calculate these pathways and fluxes, we make use of the water routing algorithm from Budd and Warner (1996). We feed this algorithm with a constant melt rate, which allows us to scale the calculated local fluxes with the known total area of the catchment und thus receive the draining percentages. This constant melt rate is solely a tool, used to normalize the local fluxes by the total catchment area.

We restructured two sections in the manuscript and completely revised the paragraph which is explaining our methodology: *In this study, we avoid the above discussed uncertainties associated with coupled ice–water flow modeling by choosing a different approach. We use the hydrology-module within the ice model* RIMBAY *(Goeller et al., 2013; Thoma et al., 2014) to simulate local basal water fluxes in terms of local draining in percent of a total area. Therefor, the above* *described water routing algorithm is applied with a constant melt rate. This does not mean, that we assume a prevailing spatially constant melt rate at the Siple Coast. Instead, it is only a tool to calculate fluxes in percent of an area in a second step. Once we obtained the balance flux for every grid cell in this manner, we use the area of the entire Ross Ice Stream catchment area and the used constant melt rate to calculate the local flux as a percentage of the latter catchment.*

Finally, they use the modern rates of ice surface elevation changes to estimate evolution of subglacial water routing and subglacial drainage basins 200 yeears into the future. The methodology used in this study is simplistic compared to the current state-oftheart in modeling ice stream evolution (van der Wel et al., 2013) to the point that it is hard to see that this manuscript is actually contributing much new to the scientific understanding of Antarctic ice stream evolution. For instance, within the next 200 years Kamb Ice Stream may restart (which would switch it from rapid thickening to rapid thinning) and Whillans Ice Stream may completely stop. The simplistic assumptions made by authors would not allow an ice stream to turn on and off because a stopped ice stream will thicken and permanently drive water away from its bed towards neighboring ice streams. What would restart an ice stream in the logic of their model? Similarly, an active ice stream should be drawing down its surface elevation and 'attracting' water towards its trunk from upstream and surrounding regions.

Our focus on observational data (like measured ice thicknesses, ice surface velocities and surface elevation change rates) in combination with well known hydrological water routing principles for large scales is the strength of this study. This straightforward approach bases on measurements and thus on observable data, representing a useful complementary strategy compared to complex coupled ice–water flow modeling. Applying recently observed surface change rates as an extrapolation for a limited time span is highly suitable to gain meaningful statements about the ice geometry of the close future and the associated basal hydraulic potential with all implications to basal water flow and the development of catchment areas. To investigate time scales beyond, this extrapolation becomes more and more error-prone and complex interactions between ice dynamic and basal hydraulic system should be considered instead. Our approach does not fully cover the complexity of (yet not completely understood) ice–water interactions, but instead avoids the large uncertainties of highly complex coupled ice & water flow models, resulting from free parameters, poorly known forcing parameters (e.g., geothermal heat flux) and uncheckable results (e.g., basal melt rates and water pressure).

We added this paragraph: *Our approach to assess future ice sheet geometries by the extrapolation of observed surface change rates allows robust statements for the next decades and could be used to validate and tune complex ice–water flow models. However, the uncertainties of this projection increase with extrapolation time. Beyond time spans, which typically describe the stagnation or development of an ice stream (e.g., ∼150 years for the stagnation of the Kamb Ice Stream; Rose, 1979; Retzlaff and Bentley, 1993), the complex interactions between ice dynamic and basal hydraulic system should be considered. This requires the application of state-of-the-art models, which are also capable* *to describe observed on-off behavior of ice streams (e.g., Carter et al., 2013; van der Wel et al., 2013).*

Beyond problems with methodology, the manuscript is burdened by problems with execution, particularly with citations. The citations are mostly outdated and often their use suggests that the authors either did not read them (beyond reading the abstract) or did not understand them. On a number of occasions the authors invoke data or interpretations that have been cited by somebody else instead of going to the original papers (e.g., citing Jacobel et al. (2009) as if they would drill to the bed of Kamb ice stream).

We thoroughly reviewed and edited all citations in the manuscript. We replaced outdated citations by more recent ones, corrected typos and errors and added a range of new up-to-date citations, following the reviewers suggestions. Please see the *Specific comments* below for details.

Specific comments

Lines 55 through 65 - Have the authors adjusted the numbers published by Retzlaff and Bentley (1993) for the fact that it has been a quarter of a century since these measurements were made?

In our manuscript, all numbers refered to the date of the cited publication. In order to make it more consistent for the reader, we followed the suggestions and adjusted all numbers for the current year: *The stagnation wave had its initiation at the grounding line of the ice stream 153±25 years ago, followed by the slowdown of the middle part 123±30 years ago and finally ended at the upstream part only ∼53 years ago (Retzlaff and Bentley, 1993; Anandakrishnan et al., 2013; Catania et al., 2006).*

Lines 75 through 85 - InSAR measurements made by Scheuchl et al. (2012) showing 25% of slowdown between 1997 and 2009 cannot 'confirm' the velocity loss of 23% between 1974 and 97 reported by Joughin et al. (2002). First of all, no temporal overlap between these two data sets means no 'confirmation' is possible. These are two independent and complementary data sets. Yes, the absolute magnitudes of deceleration for both time periods are similar (23% and 25%) but the lengths of the time periods are very different (25 years versus 12 years). So, in fact the deceleration rate has increased by a factor of two between the two periods. The long-term variability of ice flow rates on Whillans Ice Stream has been recently documented and extensively discussed by Beem et al. (2014) who should be cited here.

We reworded this section, to clarify that Scheuchl et al. (2012) found an increased deceleration for the Whillans Ice Stream and added the latest results from Beem et al. (2014) like suggested: *Over the period 1974–97 Joughin et al. (2002) estimated a velocity loss of about 23 % with a combination of conventional interferometry and speckle-tracking methods applied to* RADARSAT-*1 data. Full InSAR measurements made by Scheuchl et al. (2012) revealed an increased velocity change of –100 m a^{-1} (–25 %) for the Whillans Ice Stream and –40 m a^{-1} (–17 %) for the Mercer Ice Stream at their grounding lines between the years 1997 and 2009. Finally, Beem et al. (2014) showed a further deceleration of* *the Whillans Ice Stream of 6.1 to 10.9±2 m a^{-1} between 2009 and 2012, which is double the multidecadal average.*

Lines 89 through 94 - This sentence is not well written. Furthermore, there is a logical contradiction here. When one talks about dynamic behavior of ice streams, this implies discussion of temporal ice flow variability. However, the second part of this sentence talks about ice stream location, which pertains to spatial distribution of ice streams rather than to their temporal dynamics. This sentence needs to be fixed.

We added the word *spatial* to clarify that: *In order to understand or even predict their spatial dynamic behavior, we consider two of the most commonly controls on ice stream locations defined by literature (e.g., Winsborrow et al., 2010): subglacial geology and subglacial melt water routing.*

Line 96 - Use "develop" instead of "evolve" in this sentence.

Replaced like suggested: *The prime control which creates the precondition for ice streams to develop in this area of investigation is clearly given by the subglacial geology.*

Line 97 - I think that "numerous" is a bit of an exaggeration that is not needed to make the point that the authors are making. Either provide a number of citations to support this claim or re-phrase the sentence just to say that till has been found beneath these ice streams.

We replaced *numerous* by *several* to get rid of this unintentional exaggeration: *Several seismic campaigns detected a layer of till under the Ross Ice Streams (e.g, Rooney et al., 1987).*

Lines 100 through 102 - This makes it seem like the whole ice stream has been shown to be underlain by a till layer with these characteristics. In fact, its just in a limited area where the seismic survey used by Rooney et al. (1987) and Alley et al. (1986) has been conducted.

We reworded this sentence: *Beneath the surveyed parts of the Whillans Ice Stream this unconsolidated layer of sediment was estimated to be 5–6 m thick on average and presumed to be glacial till (e.g., Alley et al., 1986).*

Lines 100 through 115 - Much of this discussion is dated and supported by old references. The authors should read more recent papers, not just those published in 1980s and 1990s. This appears to be another unnecessary over interpretation that the authors do not need to include to support their line of argumentation.

Apart from supporting our line of argumentation, we want to give the reader a broad overview and thus consider this part of our introduction also as a kind of review about the research at the Siple Coast. Consequently, we give credit to the scientists who discovered or observed certain phenomenons first.

Lines 115 through 120 - The paper of Studinger et al. (2001) would be the best way to point out that there are widespread sedimentary basins in the region that provide a geologic template for these ice streams.

As suggested, we reworded this paragraph and cited Studinger et al. (2001): *Peters et al. (2006) also observed sedimentary basins in seismic reflections upstream of the Kamb and Bindschadler Ice Streams, which are considered to con-*

trol the onsets of these ice streams. The inland termination of these sediments suggests that a possible future migration of the last-named onsets is unlikely (Siegert et al., 2004). Studinger et al. (2001) support these findings by using aerogeophysical data to show that widespread sedimentary basins provide a geologic template for ice streams in the region.

Lines 120 through 127 - Again, the authors are failing to cite more relevant and more recent papers. The term "till delta" is not preferred anymore (use "grounding zone wedge" instead). Its surprising that the authors are citing Anandakrishnan et al. (2007) to talk about stabilization of the grounding line rather than Alley et al. (2007), which was the paper on this subject. Instead, they cite Alley et al. (1989), which basically is a less upto-date version of Alley et al. (2007). Im starting to get the sense that the authors may not be actually reading the papers that they are citing just either reading their abstracts or skipping through them. Why otherwise would they cite what they cite? In addition, they refer to Alley et al. (1989) discovering a till delta at the grounding line of Whillans Ice Stream whereas this paper was more of a theoretical consideration of what should be happening under a soft-bedded ice stream.

We replaced *till delta* by *grounding zone sedimentary wedge* as suggested. Both Anandakrishnan et al. (2007) and Alley et al. (2007) talk about stabilization of the grounding line by these wedges, so we added a citation of Alley et al. (2007). We agree, that Alley et al. (2007) is a more up-to-date version of Alley et al. (1989) and replaced this citation: *At the grounding line of the Whillans Ice Stream, Alley et al. (2007) discovered a grounding zone sedimentary wedge tens of meters thick and tens of kilometers long. These sediments originate from upstream locations and are transported downstream by the moving ice. Beyond, this sedimentary wedge at the grounding line is believed to stabilize the position of the grounding line even despite moderate changes in sea level (Alley et al., 2007; Anandakrishnan et al., 2007).*

Lines 129 through 132 - The relationship between subglacial water drainage and ice stream is a case of two-way coupling. Ice streams draw down ice surface and water flows then towards ice streams from upstream regions. The statement that the authors make implies that somehow there is only a one way coupling, so that water flows wherever it chooses and then ice streams form there.

We reworded and complemented this paragraph to elaborate this two-way coupling: *The existence of subglacial till gives the precondition for the development of ice streams at the Siple Coast. However, their exact locations correlate with the pathways of melt water flow: Basal water lubricates the substrate and enables higher ice sliding velocities. The resulting ice stream draws down the ice surface and thus attracts water from adjacent areas with a higher basal hydraulic potential.*

Line 135 - Actually, the paper of Alley et al. (1986) is not based on radar data. The only place where radar data are mentioned in this paper is in their abstract, where they refer to Robin (1970). This just serves to re-affirm my suspicion that the authors are actually not reading the papers they cite. The statements they make in the next two sentences after these 'radar' citations are not supported by any 'radar' data in Alley et al. (1986).

We removed this citation, which got there by accident.

Lines 143 through 146 - This statement has been made before already in this manuscript and represents a repetition.

Earlier in the manuscript, we discussed the general presence of a till layer and its observation by radar campaigns. Here, the focus is on the seismically detected saturation of this layer by water in correlation with the outlines of the Whillans Ice Stream.

Lines 169 through 172 - The authors missed a recent observational constraint on basal melt rate beneath the lower part of Whillans Ice Stream in Fisher et al. (2015).

Thanks, we added a citation.

Lines 172 through 175 - This citation of the results from Beem et al. (2010) is incorrect. Beem et al. (2010) reported that the basal melt rate is 20-50 mm/yr beneath shear margins and their range of 3-7 mm/yr is averaged across ice stream width. In fact, there is no "contrast" between their results and those of Joughin et al. (2003). The two models agree, except in shear margins where Beem et al. use a method that treats shear margin dynamics at a higher resolution.

We decided to reword and shorten this paragraph: *Observations of many (active) subglacial lakes at the Siple Coast reveal a widespread, dynamic subglacial water system (e.g., Gray et al., 2005; Fricker et al., 2007; Fricker and Scambos, 2009; Wright and Siegert, 2012; Carter and Fricker, 2012; Horgan et al., 2012). However, the precise local melt rates are barely known since they elude direct measurements. The calculation of melt rates in ice flow models is heavily dependent on the assumed geothermal heat flux at the ice base, which is still not very well known for Antarctica (discussed by Fisher et al., 2015). Analytical model results, e.g., for the Whillans Ice Stream, indicate melt rates between 3–50 mm a^{-1} (e.g., Beem et al., 2010; Joughin et al., 2003) but lack validation by observations. The ice stream tributaries and the inland ice could account for about 87 % of the total melting generated beneath the Ross Ice Streams including their catchments (Joughin et al., 2004). Following Parizek et al. (2003), this melt water transports latent heat from beneath inland ice to the base of the ice streams. The temperatures at the bottom of the ice streams itself and accordingly the melt rates are low, caused by the internal scarce ice deformation and the consequently lacking internal frictional heating.*

Lines 188 through 199 - The assumption of a spatially uniform basal melt rate is not justified by the data. This assumption arises from the authors flawed interpretation of the results of Beem et al. (2010). In reality, these past modeling results are very much inconsistent with this assumption. Calculated basal melt rates vary by at least an order of magnitude. The assumption made by authors basically pre-determines the later result they get.

Please see our answer in the *General comments* above.

Equation 1 makes no sense to me. I see no difference between the variable p and pw. I presume that this is a confused interpretation of Equation 4 from Shreve (1972).

The hydraulic potential p is a function of the elevation potential $\rho_w gh$ and the water pressure p_w (Shreve, 1972).

The discussion above equation 2 - It is not as obvious as the authors would like to make it appear that subglacial water pressure can be taken to be equal to the ice overburden pressure. Yes, effective stresses tend to be small but they are within the range of pressure differences that can significantly shift the direction of subglacial water flow (see Carter et al., 2013). Between the errors in ice surface slope, ice thickness, the average density of an ice column, and the assumption that effective stress is zero any routing of subglacial water can be quite uncertain.

It is a well known and accepted approximation to set the subglacial water pressure equal to the overburden ice pressure (e.g., Budd and Jenssen, 1987; Alley, 1996; Le Brocq et al., 2009; Livingstone et al., 2013). At the Siple Coast, the validity of this approach is additionally proved by measurements (e.g., Kamb, 2001). Furthermore, the observed till layer points out a prevailing distributed flow system, which has an effective pressure close to zero. We agree, that even an effective pressure very close to zero in combination with the above listed uncertainties regarding ice geometry and density could possibly change the hydraulic potential in such a way, that water pathways are redirected. But since we use a routing algorithm which takes into account the four nearest neighbors, this switching would be gradual and not abrupt. We simulate every scenario in three different model resolutions (5, 10, 20 km), whereby the consistency of the results and the resolution convergence reveal the robustness and validity of our approach.

The series of recent papers by Carter et al. should be cited here since they represent the state-of-the-art in hydrological routing models for this study region.

As suggested, we added a citation in the section *Ice sheet geometry*, where we added a paragraph to point out the limitations of our extrapolation approach (see our answer in the *General comments* above) and in section *Results and discussion* where we discuss the results.

Lines 257 through 259 - Again, one could argue as well that ice streams control where subglacial water flows because they draw down the ice thickness and ice surface elevation, thereby creating areas of low subglacial water pressure towards which water flows from upstream areas.

Please see above, where we added a short paragraph to the manuscript to point out this two-way coupling between fast ice flow and enhanced basal water flow.

Lines 265 through 268 - This is an artifact of their assumption that there is spatially uniform melt rate in the whole study area.

We do not assume, that there is a spatially uniform basal melt rate at the Siple Coast. Please see our answer in the *General comments* above.

Lines 278 through 280 - Jacobel et al. (2009) did not drill any boreholes to the bed of the sticky spot. (Engelhardt, 2004) did report on the boreholes drilled by him and colleagues. And Jacobel et al. (2009) cite this work. The authors should read Jacobel et al. (2009) carefully and refer to the original publication.

Citation corrected. We are aware of this original paper and apologize for the typo in our LaTeX document.

Lines 317 through 319 - This is, again, the artifact of the assumption that there is a uniform basal melt rate throughout the study region.

We do not assume, that there is a spatially uniform basal melt rate at the Siple Coast. Please see our answer in the *General comments* above.

Section 3.3 - The assumption of constant ice surface elevation changes into the future is a pretty significant one. The authors should at least discuss why this simplifying assumption may fail and what would be the consequences.

Please see our answer in the *General comments* above, where we added a paragraph to the manuscript, to point out the limitations of our extrapolation approach.

The complete lack of ice dynamics and ice-water flow coupling in their model really makes it difficult to have much trust in the results. The level of sophistication in numerical ice stream models is increasing and I am not sure that there is still scientific value in doing simple extrapolations from the modern state (compare this manuscript to van der Wel et al. (2013)).

Please see our answer in the *General comments* above, where we motivate our observation-based approach as complement to ice–water flow modeling approaches.

References

Alley, R.: Towards a hydrological model for computerized ice-sheet simulations, Hydrological Processes, 10, 649–660, doi:10.1002/(SICI)1099-1085(199604)10:4<649::AID-HYP397>3.0.CO;2-1, 1996.

Alley, R., Blankenship, D., Bentley, C., and Rooney, S.: Deformation of till beneath ice stream B, West Antarctica, Nature, 322, 57–59, doi:10.1038/322057a0, 1986.

Alley, R., Blankenship, D., Rooney, S., and Bentley, C.: Sedimentation beneath ice shelves – the view from ice stream B, Marine Geology, 85, 101–120, doi:10.1016/0025-3227(89)90150-3, 1989.

Alley, R. B., Anandakrishnan, S., Dupont, T. K., Parizek, B. R., and Pollard, D.: Effect of Sedimentation on Ice-Sheet Grounding-Line Stability, Science, 315, 1838–1841, doi:10.1126/science.1138396, 2007.

Anandakrishnan, S., Catania, G. A., Alley, R. B., and Horgan, H. J.: Discovery of till deposition at the grounding line of Whillans Ice Stream, Science, 315, 1835–1838, doi:10.1126/science.1138393, 2007.

Anandakrishnan, S., Alley, R. B., Jacobel, R. W., and Conway, H.: The Flow Regime of Ice Stream C and Hypotheses Concerning Its Recent Stagnation, pp. 283–296, American Geophysical Union, doi:10.1029/AR077p0283, 2013.

Beem, L. H., Jezek, K. C., and Van der Veen, C.: Basal melt rates beneath Whillans Ice Stream, West Antarctica, Journal of Glaciology, 56, 647–654, doi:10.3189/002214310793146241, 2010.

Beem, L. H., Tulaczyk, S. M., King, M. A., Bougamont, M., Fricker, H. A., and Christoffersen, P.: Variable deceleration of Whillans Ice Stream, West Antarctica, Journal of Geophysical Research: Earth Surface, 119, 212–224, doi:10.1002/2013JF002958, 2014.

Budd, W. and Jenssen, D.: Numerical Modelling of the Large-Scale Basal Water Flux under the West Antarctic Ice Sheet, in: Dynamics of the West Antarctic Ice Sheet, edited by Veen, C. and Oerlemans, J., vol. 4 of *Glaciology and Quaternary Geology*, pp. 293–320, Springer Netherlands, 1987.

Budd, W. and Warner, R. C.: A computer scheme for rapid calculations of balance-flux distributions, Annals of Glaciology, 23, 21–27, 1996.

Carter, S. and Fricker, H.: The supply of subglacial meltwater to the grounding line of the Siple Coast, West Antarctica, Annals of Glaciology, 53, 267–280, doi:10.3189/2012AoG60A119, 2012.

Carter, S., Fricker, H., and Siegfried, M.: Evidence of rapid subglacial water piracy under Whillans Ice Stream, West Antarctica, Journal of Glaciology, 59, 1147–1162, doi:doi:10.3189/2013JoG13J085, 2013.

Catania, G., Scambos, T., Conway, H., and Raymond, C.: Sequential stagnation of Kamb Ice Stream, West Antarctica, Geophysical Research Letters, 33, doi:10.1029/2006GL026430, 2006.

Engelhardt, H.: Ice temperature and high geothermal flux at Siple Dome, West Antarctica, from borehole measurements, Journal of Glaciology, 50, 251–256, doi:10.3189/172756504781830105, 2004.

Fisher, A. T., Mankoff, K. D., Tulaczyk, S. M., Tyler, S. W., Foley, N., and : High geothermal heat flux measured below the West Antarctic Ice Sheet, Science Advances, 1, doi:10.1126/sciadv.1500093, 2015.

Fricker, H. A. and Scambos, T.: Connected subglacial lake activity on lower Mercer and Whillans Ice Streams, West Antarctica, 2003–2008, Journal of Glaciology, 55, 303–315, doi:10.3189/002214309788608813, 2009.

Fricker, H. A., Scambos, T., Bindschadler, R., and Padman, L.: An active subglacial water system in West Antarctica mapped from space, Science, 315, 1544–1548, doi:10.1126/science.1136897, 2007.

Goeller, S., Thoma, M., Grosfeld, K., and Miller, H.: A balanced water layer concept for subglacial hydrology in large-scale ice sheet models, The Cryosphere, 7, 1095–1106, doi:10.5194/tc-7-1095-2013, 2013.

Gray, L., Joughin, I., Tulaczyk, S., Spikes, V. B., Bindschadler, R., and Jezek, K.: Evidence for subglacial water transport in the West Antarctic Ice Sheet through three-dimensional satellite radar interferometry, Geophysical Research Letters, 32, doi:10.1029/2004GL021387, 2005.

Horgan, H. J., Anandakrishnan, S., Jacobel, R. W., Christianson, K., Alley, R. B., Heeszel, D. S., Picotti, S., and Walter, J. I.: Subglacial Lake Whillans – Seismic observations of a shallow active reservoir beneath a West Antarctic ice stream, Earth and Planetary Science Letters, 331, 201–209, doi:10.1016/j.epsl.2012.02.023, 2012.

Jacobel, R. W., Welch, B. C., Osterhouse, D., Pettersson, R., and MacGregor, J. A.: Spatial variation of radar-derived basal conditions on Kamb Ice Stream, West Antarctica, Annals of Glaciology, 50, 10, doi:10.3189/172756409789097504, 2009.

Joughin, I., Tulaczyk, S., Bindschadler, R., and Price, S. F.: Changes in West Antarctic ice stream velocities: Observation and analysis, Journal of Geophysical Research: Solid Earth, 107, 1–22, doi:10.1029/2001JB001029, 2002.

Joughin, I., Tulaczyk, S., and Engelhardt, H. F.: Basal melt beneath Whillans Ice Stream and Ice Streams A and C, West Antarctica, Annals of Glaciology, 36, 257–262, doi:10.3189/172756403781816130, 2003.

Joughin, I., Tulaczyk, S., MacAyeal, D. R., and Engelhardt, H.: Melting and freezing beneath the Ross Ice Streams, Antarctica, Journal of Glaciology, 50, 96–108, doi:10.3189/172756504781830295, 2004.

Kamb, B.: Basal zone of the West Antarctic ice streams and its role in lubrication of their rapid motion, The West Antarctic Ice Sheet: Behavior and Environment, pp. 157–199, doi:10.1029/AR077p0157, 2001.

Le Brocq, A. M., Payne, A. J., Siegert, M. J., and Alley, R. B.: A subglacial water-flow model for West Antarctica, Journal of Glaciology, 55, 879–888, doi:10.3189/002214309790152564, 2009.

Livingstone, S. J., Clark, C. D., Woodward, J., and Kingslake, J.: Potential subglacial lake locations and meltwater drainage pathways beneath the Antarctic and Greenland ice sheets, The Cryosphere, 7, 1721–1740, doi:10.5194/tc-7-1721-2013, 2013.

Parizek, R., Alley, R. B., and Hulbe, C. L.: Subglacial thermal balance permits ongoing grounding-line retreat along the Siple Coast of West Antarctica, Annals of Glaciology, 36, 251–256, doi:10.3189/172756403781816167, 2003.

Peters, L. E., Anandakrishnan, S., Alley, R. B., Winberry, J. P., Voigt, D. E., Smith, A. M., and Morse, D. L.: Subglacial sediments as a control on the onset and location of two Siple Coast ice streams, West Antarctica, Journal of Geophysical Research: Solid Earth (1978–2012), 111, doi:10.1029/2005JB003766, 2006.

Retzlaff, R. and Bentley, C. R.: Timing of stagnation of Ice Stream C, West Antarctica, from short-pulse radar studies of buried surface crevasses, Journal of Glaciology, 39, 1993.

Rooney, S., Blankenship, D., Alley, R., and Bentley, C.: Till beneath ice stream B: 2. Structure and continuity, Journal of Geophysical Research: Solid Earth (1978–2012), 92, 8913–8920, doi:10.1029/JB092iB09p08913, 1987.

Rose, K.: Characteristics of ice flow in Marie Byrd Land, Antarctica, Journal of Glaciology, 24, 63–75, 1979.

Scheuchl, B., Mouginot, J., and Rignot, E.: Ice velocity changes in the Ross and Ronne sectors observed using satellite radar data from 1997 and 2009, The Cryosphere, 6, 1019–1030, doi:10.5194/tc-6-1019-2012, 2012.

Shreve, R. L.: Movement of water in glaciers, Journal of Glaciology, 11, 205–214, 1972.

Siegert, M. J., Taylor, J., Payne, A. J., and Hubbard, B.: Macro-scale bed roughness of the Siple Coast ice streams in West Antarctica, Earth Surface Processes and Landforms, 29, 1591–1596, doi:10.1002/esp.1100, 2004.

Studinger, M., Bell, R. E., Blankenship, D. D., Finn, C. A., Arko, R. A., Morse, D. L., and Joughin, I.: Subglacial sediments: A regional geological template for ice flow in West Antarctica, Geophysical Research Letters, 28, 3493–3496, doi:10.1029/2000GL011788, 2001.

Thoma, M., Grosfeld, K., Barbi, D., Determann, J., Goeller, S., Mayer, C., and Pattyn, F.: RIMBAY – a multi-approximation 3D ice-dynamics model for comprehensive applications: model description and examples, Geoscientific Model Development, 7, 1–21, doi:10.5194/gmd-7-1-2014, 2014.

van der Wel, N., Christoffersen, P., and Bougamont, M.: The influence of subglacial hydrology on the flow of Kamb Ice Stream, West Antarctica, Journal of Geophysical Research: Earth Surface, 118, 97–110, doi:10.1029/2012JF002570, 2013.

Winsborrow, M., Clark, C. D., and Stokes, C. R.: What controls the location of ice streams?, Earth-Science Reviews, 103, 45–59, doi:10.1016/j.earscirev.2010.07.003, 2010.

Wright, A. and Siegert, M. J.: A fourth inventory of Antarctic subglacial lakes, Antarctic Science, 24, 659–664, doi:10.1017/S095410201200048X, 2012.