Review of „Instantaneous sea ice drift speed from TanDEM-X interferometry"
by D. O. Dammann and 7 co-authors (original manuscript)

General assessment:
From a technological point of view, the paper is very interesting. The shown case studies represent different scenarios for which the results of single-pass along-track interferometry (S-ATI) can potentially contribute to extend our understanding of sea ice dynamics for specific conditions. However, I disagree strongly with the author's assessment concerning the benefit of instantaneous drift fields for different applications. The technique provides useful results only if the ice drift component (anti)parallel to the line-of-sight between radar and resolution cell is considerably larger than the drift component perpendicular to it. If the line-of-sight drift component is zero, along-track InSAR is blind to sea ice movements. Besides this limitation of information on direction it is not clear how representative a single snapshot of millisecond ice movement is for the temporal variations of an ice drift field over several minutes to hours.
Since I regard the topic of the paper and the scientific analysis (section 3) as important contribution to the use of InSAR for sea ice research, I recommend a major revision of the paper to sharpen its message and to provide the reader with a clear list of pros and cons of the technology and still existing gaps of knowledge.

Details

Abstract:
In the abstract, not a single word is related to the inherent limitations of the method. Why is the knowledge of the millisecond ice drift line-of-sight (LOS) velocity component of advantage for ice management and transportation if compared to standard SAR-based drift algorithms? I doubt this since (1) the field of instantaneous drift components for a given location can be obtained only with time gaps of hours to days between single data takes, (2) the standard SAR-based drift algorithms have the potential to retrieve 2D displacement information with higher temporal resolution if the time gaps between (non-tandem) SAR data acquisitions get shorter. This will be the case e.g. in satellite constellations, or by using images of different SAR systems - a combination of C- and L-band was already successfully tested. I could imagine that for engineering, instantaneous drift can be a valuable information to get statistics of extreme values, but sea ice modellers prefer to get magnitude and direction of drift vectors, and time steps used in simulations of sea ice dynamics are not on the order of milliseconds.

Introduction
p. 2, 15-23: It is of course true that complex drift patterns often cannot be resolved into sufficiently small time steps by traditional ice drift retrievals. However, using the Doppler-approach described by Kræmer et al. (2015, 2018) or S-ATI as described here is NOT the solution to this problem, since, as described above, one obtains milliseconds snapshots of ice movement only with large time gaps between single shots. One motivation for Kræmer et al. was to make use of a single SAR image for obtaining information on ice drift – with the same limitations as for S-ATI plus a relatively coarse spatial resolution. In lines 20-22 the authors list factors that influence the accuracy of the Doppler method, but in the following sections I did not find a similar list for the S-ATI method (see below). The Doppler method requires the identification of land areas, but so does S-ATI (which the authors describe on p. 5, 9-10 – here they use landfast ice as reference).
p. 2, 24-29: why is the method described here "consistent" but the other methods are not? Please explain what you mean by "consistent". Which requirements do Arctic stakeholders have with regards to spatial resolution of drift fields? Any reference? On regional scales of a few hundred kilometres, a spatial resolution of drift vector fields around 100 m (which is possible to achieve with traditional methods) is certainly sufficient for many applications. The only ice services, which started to consider results of automated drift retrievals in ice chart production, is to my knowledge CIS. Why and for what specific purpose do shipping and resource exploration need drift fields with a meter-resolution? How is drifting pack ice "locally used"? (For traffic on landfast ice, information on differential motion with resolutions of meters is of course beneficial). Is S-ATI really the full

answer when it comes to gather “high-resolution” data of ice hazard distributions, ice movement etc.? It must be taken into account that it often fails to deliver useful data, see above.
The last paragraph of the introduction should be moved to section 2.3, since it specifically addresses issues of InSAR processing.
p. 3 11-13 If the temporal baseline is too large (the limit dependent on ice speed and environmental conditions changing scattering properties), the interferometric coherence over sea ice is lost. Dependent on drift speed and SAR resolution, this can be minutes.
p.3 13-15 Inverse modelling to provide 2D motion from the line-of-sight drift can be used for landfast ice but not for drifting sea ice.

Section 2

p. 3 29: Radar images are archived every *5 m*…??
What are the uncertainties in velocity as determined from coastal radar and ADCP data?
p. 4, 1-3: Regarding the coastal radar - the motion product represents an average field over a time interval of 1.5 hours. How large is the noise contribution? Would it be possible to calculate motion for much smaller time intervals to judge short(er)-term variations of the drift field that could help to estimate a time interval for which millisecond ice movements derived from S-ATI can be representative?
Table 1: it would be useful to add the perpendicular baselines (for use in equation 3) and to mention the spatial resolution of the filtered interferogram used for calculating the LOS drift speed in the text.
p. 4: at the end of the sentence following equation 1, another hint to Table 1 (v_a) would be useful.
p. 4, after line 14: The expected magnitudes of phase noise and the resulting relative error of the retrieved values of v_ϕ should be discussed. See also “p. 8, 11” below.
p. 4, equation 4: Values of h_0 should also be listed in Table 1.
p. 4, 25-26 and p. 5, 1-2: important point! Here, the information on the spatial resolution of the derived drift field would again be useful. For a single resolution cell, we cannot distinguish the influence of height variations from the influence of motion. The inclusion of the amplitude images and the judgement of the neighbourhood of each pixel in the analysis of the drift field is required as the authors demonstrate in their case studies. This should be made clear, e. g. in the discussion.
p. 5: last paragraph of 2.4: good point! What about rotational motion of single ice floes that might have occurred in mixtures of smaller ice floes in open water that appear in your examples?

Section 3:

Here one should note that (naturally) optimal conditions were selected as examples: Except for Oct 30 it can be expected that the respective dominant ice speed component is the one parallel to the LOS.
p. 7 12-13 “…is consistent with….” I assume that the authors did not directly observe the amplitude increase of dm-scale wind waves with distance from the shore but merely speculate that this could be the case. Do you have a reference concerning observations of the increase of amplitudes with distance from the coast? Is it also possible that streaks of frazil and grease ice were present? With the given wind direction in Fig. 2c, it would have accumulated at the shore, thus reducing the retrieved LOS drift velocity.
p.7 19: Here one should start a new paragraph: “ We further compare…”
p. 7 23-24: It is misleading that in the first sentence v_{gr} is used for the drift vector derived from the coastal radar, and in the second sentence for the LOS-component “v_{gr}” derived from v_{gr}.
p. 7 26: Here the averaging time for the coastal radar is given as 2.5 hours, in section 2.1, 1.5 hours were mentioned.
p.8, 1-2: the drift speed error mentioned here is only related to the motion-height ambiguity. But phase noise also contributes to the drift speed error.
p. 8, 2-4: Why is a difference between landfast and adjacent drifting ice of 5 cm not possible? I interpret the SAR amplitude image in Fig. 3 such that there is a mixture of smaller dark appearing (hence thinner) ice floes in open water (bright) - in the middle interrupted by more consolidated thin

ice - next to the landfast ice. However, since the image is relatively small in the manuscript, it is difficult to interpret it.
p. 8, 11: the phase cannot be solved accurately, it includes an uncertainty due to phase noise (which depends on decorrelation effects) and the achievable accuracies in determination of baselines, incidence angles, co-registration in processing etc. These factors are not mentioned in section 2 or in the discussion.
p. 8, 15-17: "….sea ice and features a…" Isn't it "which features"?
p. 9, 16-19: This interpretation again raises the question about how representative milliseconds snapshots are on time-scales of minutes to hours. Convergence should be given in velocity per length unit. The identification of ridges and rubble fields is relatively difficult at higher frequencies such as X-band, unless the spatial resolution is high (another reason to mention it in the paper).
p. 9, 29-30: Since only one temporally isolated snapshot of milliseconds LOS velocity is available, *short-lived (or transient)* dynamics cannot directly be deduced from the data alone. This requires a careful additional analysis of the environmental context over a longer time period. Without such an analysis one does not know whether an event lasts for seconds, minutes or hours. It also needs to be clarified what "short-lived" means in terms of time units. Certainly not milliseconds.

Section 4

p. 10, 1-2: "high accuracy" – the plot Fig. 3 d does not support this statement, since 2.5 hours average velocities are compared with milliseconds ice movements. It looks like a "reasonable" agreement between both velocities, but with maximum deviations up to 0.3-0.4 m/s even when excluding the young ice values. It would be helpful to get examples of the relative error for different velocity ranges.
p. 10, first paragraph: the limitations of S-ATI have to be accounted for in this discussion!

- Examples: Opening and closing rates for leads can only be provided for certain orientations between lead and LOS, and information on those rates is only available for the past – for navigation such information may be useful - but as forecast.
- Is a millisecond snapshot well suited to separate landfast and temporally stationary ice – and would this really improve ice charting? The duration to classify stationary ice as landfast is often fixed at 20 days. What is then "temporally stationary"? How can a practical approach to distinguish landfast and temporally stationary ice by means of S-ATI look like?

p. 10, second paragraph: a reconstruction of the 2D instantaneous drift field from the 1D-LOS component will not be very reliable but the consideration of wind, current and general ice drift information will help to decide when conditions for the application of S-ATI are close to optimal.
p. 11, first paragraph: I regard this example of deriving absolute speed from a moving vessel and relative speed between vessel and surrounding ice as an interesting scientific exercise but not useful for ice navigation. The example of protecting offshore installations should be elaborated but I presume that it is more a question of collecting statistics of maximum pressure loads on planned installations instead of giving sporadic information to already existing installations.
p.11, third paragraph: No, the S-ATI approach cannot be more accurate than the traditional approaches because of the reasons mentioned above. They are two very different, complementary approaches. It would be worth to design experiments to study ice motion on temporal scales from sub-seconds (S-ATI) to minutes (coastal radar, buoys) to several hours (buoys, SAR constellations) to better relate both approaches to one another.

Conclusions:

Comments given above should be considered.
p. 12, 19-20: Given (1) the (yet) missing link between millisecond and hours timescales, (2) the difficult interpretation related to the missing information on drift direction, and (3) the lack of tandem-missions useful for operational ice charting it is NOT clear that S-ATI is relevant as a tactical tool for Arctic stakeholders.

Recommendations:

It is not up to the reviewer to demand changes of the paper contents. Nevertheless, I would like to recommend some items for consideration in the discussion:

- It would be useful to compare the approach of Kræmer et al. and the S-ATI technique in some detail since they have similar limitations concerning certain aspects but are also different in other aspects. Move lines 19-23 on p. 2 into the discussion.
- In the Dierking et al. paper the goal was to retrieve sea ice topography, and the influence of ice motion on the interferometric phase was a disturbing factor that needs to be minimized in this type of application. Here, it is vice versa: motion as wanted information and topography as disturbing factor. Which along- and across-track baselines would you recommend, considering the typical ranges of ice drift speed and height elevations?
- What is the highest temporal resolution that is required for investigating “short-lived” events? Examples of such events? I am sure that we can extrapolate the milliseconds measurements into the range of seconds, but what are the highest possible frequencies of motion changes, and to which events are they linked? This item is very tricky to answer, and it may be sufficient at this time just to raise these questions to make the reader aware of still existing problems.
- Since the interpretation of drift fields derived from S-ATI is not straightforward, it may be useful for the reader to get a “recipe” of important factors to be considered (e .g. uncertainty of the measurement which depends on phase noise and along-track baseline, LOS – where to get information of the main drift direction, millisecond snapshot – what has to be expected for the next minutes/hours etc).