This paper documents the matching of wind driven free drifting sea ice to observations of ice tethered buoy drift. A number of methodological scenarios are considered.
First a constant parameter set for the equations of freed drift are sought.
Secondly the ocean surface currents are considered with climatological maps of ocean currents retrieved along with the free drift parameters.
Finally the free drift parameters are replaced with sea ice thickness dependent parameters.
I suggest this paper for publication. The writing is technically accurate with few typos and grammatical errors. The results shown are compelling and make a useful contribution to sea ice science. In particular it is very interesting to see the wind driven and ice thickness dependent components of sea ice drift quantified. Also the retrieval of ice surface currents and their comparison to other ocean surface data and models is very interesting.

However, I found reviewing the paper quite frustrating and challenging. A few kept parts of the method are lacking, which makes the interpretation of the complex results rather difficult. In particular the description of the Pathfinder data used, and the description of the 'Polar Pathfinder' parameterisation makes many parts of the paper difficult to interpret. The Pathfinder data is described in the data section as pathfinder free drift data, that from the description seems to be a custom made free drift data set using a NCEP/NCAR reanalysis, whilst descriptions of the data in the paper appears to be the version 4 pathfinder dataset I am familiar with, that includes many floe tracking and ice buoy additions to the free drift equations. What data is used here? I suggest finding an alternate description of the base 'control' free drift parameterisation (using the same parameters used to create the Pathfinder dataset) within the paper in order to make it much easier to read.

The description of the methods used in section 3.2 requires more information. The paper appears to have three key scenarios where various parameters are retrieved and additional data is also retrieved (ocean currents, wind-ice transfer coefficient in figure 4(a)?). It will be much easier to understand these methods if each can have an equation (7) describing exactly how the values are retrieved. Also in this section more information is required on which data are collected for each case. It is confusing at times how many buoy observations, how many reanalysis based free drift equations and how many parameter values are considered in each scenario. For example are you seeking maps of \alpha and \theta or single values? The case of allowing for variable ocean surface currents is very difficult to understand. Do you actively search of ocean currents with each pixel a free parameter? Or is it simply the residual in the equation as mentioned later in the text.

I suggest the paper for publication after minor revisions. While the paper was difficult to interpret at times, the quality of the figures and results suggest that it will al work out if the points above are addressed.

H. Heorton.

Specific points.

L4-5 'has a structure as the spatial distribution of sea ice thickness'
Please reword this sentence as the above is very difficult to interpret
L 5 please include to what you have introduced this parameterisation. Which model are you using?
L 13 'minimize' - minimizes
L13 what cost function?

It is unclear from the abstract what exactly you have undertaken in this study.

L 25 I enjoyed this quotation. Thank you

Section 2.3

Here you describe a Pathfinder Data set I am unfamiliar with. The citation and DOI given point me towards the Polar Pathfinder version 4 data set. This data is the ice motion data set derived from

Floe tracking algorithms and the IABP buoy data set you mention above along with NCEP/NCAR reanalysis. Is the data you are using?
The free drift data you mention in this section appears to be a conversion from NCEP/NCAR surface winds through free drift ice drift equations only (using constant parameters). This data is then interpolated onto the 25km EASE grid. Is this correct?
Did you create this data yourself? If so can you title this section appropriately. For instance if this free drift data is NCEP/NCAR derived free drifting sea ice estimates, then please call it this.

Section 3.2

Equation (7). If I have interpreted the text from line 225 correctly, then U_i^{fd} in equation (7) is also a function of U_w. Is this correct? If so is it possible to show this within equation (7)? As in U_i^{fd}(\alpha,\theta,U_w)? If you use different equations at different times, then perhaps listing all the equations used will aid the reader.

Whilst this section technically well written I find it hard to follow the exact methodology. Evaluation of equation (7) at a single data point is under constrained, so I assume there is a high number of n data points. You mention that U_w is only varying spatially. What temporal and spatial resolution do you use for the IABP data, the ERA5 data and for the searched for \alpha and \theta? What is a typical value of n? How do you co-locate the temporarily varying IABP data with the static but spatially varying U_w, and how does this relate to the extracted parameterisations? The results and conclusions suggest that you create spatially varying maps of \alpha and \theta, and then the results suggest you only extract single values for each case, can you clarify? For discussion of the role of time averaging of drift and wind data in the free drift calculations see Heorton et al. 2019.

Section 4,

I’m struggling to understand what has been performed during each scenario. What data is used in which part of the equation and what is being solved for in each case?

L 240 So does fig 1 indicate the density of IABP buoy drift data?

Table 1, can you expand on what exactly is meant by the mean bias error metrics. Each case has two numbers, which is which? How is the value in brackets for ui and vi all equal to 0.0 for every case except for \sigma_p. What is this number? Is it the mean dimensional bias for this value? Does this show that the error for this value is evenly spaced around the mean?

L 252, Polar Pathfinder parameterisation. This line is difficult to interpret when the form of this data is unclear. If the data here is free drift ice equations applied to NCAR/NCEP are you extracting \alpha and \theta by comparing winds from ERA5 to free drifting sea ice created using NCAR/NCEP? Do you replace the IABP buoy data in equation (7) with the free drift sea ice data set? It is unclear in section 3 and equation (7) how you evaluate buoy data, free drifting sea ice gridded data, and the minimisation of two free parameters at each point, or for the full data set. Or do these cases just imply that you have applied some parameters to colocated IABP drift and ERA5 winds, and then compared this to the free drifting sea ice calculated from NCAR/NCEP winds (the Polar Pathfinder data)? If this is the case, then this is a strange comparison of two different surface wind reanalysis data sets. If this Polar Pathfinder dataset is the floe tracking derived ice drift data from the citation in section 2.3, and not a ‘free drift’ data set created for this study, then this comparison makes sense.

L 253, does constant wind-ice transfer coefficient mean single values of \alpha and \theta were calculated for all the data? Or do you produce static maps of \alpha, \theta?

L 260 Can you comment more of the differences for the \sigma_p case? Here you are comparing this difference between ‘Polar Pathfinder’ parameterisation, a new constant parameterisation and the IABP buoy drift vectors? Is this correct? Is this Pathfinder the v4 data set? If this is the case then the changes discussed in this section come from either the parameters in the free drifting ice used in the Pathfinder dataset, the correction to this from floe tracking and buoy drift performed as part of the creation of the Pathfinder v4 dataset, or the use of NCAR/NCEP compared to the ERA5 dataset used in this paper? If however this ‘Pathfinder free drift dataset’ is of your own creation, then what comes from using a different reanalysis and what comes from changing the parameters?

L 261 In this case (\sgima_0) is a single parameter extracted for \alpha \theta for all data?

L 265 Is this case not \sigma_w? See also figure 3.

L 280 this peak in zero-velocity ice drift suggests that this is the floe tracking Pathfinder drift data set. This confusion in what Pathfinder data you are comparing to is making this interpretation of your results very difficult.

L299 please describe how the value of wind-ice transfer coefficient is calculated here. Is this a map of extracted values of \alpha? Or the ratio |U_i|/|U_w|? Do you compare the directional velocity in this ratio, or simply the drift speed? An equation here may be helpful.

L 302 Also of comparison here is Heorton, H.D.B.S. et al. 2019.

L 323 bias-corrected parameterisation is \sigma_0? Please check all text descriptions of \sigma_w and \sigma_0. Are you including the consideration of ocean currents in figure 5?

L 326-328 Is this sentence referring to the Pathfinder drift data you are comparing to? If this is the case then this is the v4 data including the floe tracking and buoy data.

L 327 are you using time-dependant variables here, or is this a suggestion for future work?

L 425 ‘thegyre’

L 428 Please reword the last part of this sentence, it is difficult to interpret

L 430 What are the buoy data counts for these two cases as you give on line 402 for pre/post 2000?

L 451 Here you point out the limitations of your model in that it does not resolve sea ice rheology. I think it is also worthwhile to discuss the physical limitations in your representation of the ocean surface currents. You previously cite the Meneghello et al. (2018) paper where the inversion of sea ice to ocean stress is described. Do you think your method of resolving ocean currents using wind forced sea ice free drift may only resolve the wind driven (through the sea ice cover) component of ocean surface currents? Can you account for cases where the ocean currents drive ice drift during low wind speeds? What further information may be presented by including geostrophic currents and resolving Ekman currents?

L 459 I think it is important to point out that your ocean surface currents do not resolve the northern, eastward part of the Beaufort Gyre.

L 470 It is unclear from the methodology where and when and how you created the maps of wind-transfer coefficient that you compare to the sea ice thickness data.

L 488, how do they appear as a residual? Equation 7 and the associated text refer to them as a value to be solved for.

L 489 please correct the parentheses.

L 493 - ‘post-200s’ to ‘post-2000s’

L 496 It will be more accurate here to describe them as the ‘wind driven component of ocean surface currents’

Figure 3 caption. Here you list the columns as (pathfinder \sigma_p, free drift \sigma_0 and thickness dependant \sigma_h) but the figure labels show the middle column as \sigma_w for ocean currents. Please re-write accurately.

Figure 4, which case is this map of \alpha calculated for?

Figure 5, It is unclear which data is compared here. Is this the averaged drift only where there is co-located IABP and parameterised ice drift data? If not then this is an unfair comparison. How do you calculated the relative error? Is it part of the use of equation (7)? Also again I'm unsure what the Pathfinder drift data is. There are large differences in these plots between the parameterised ice drifts and the buoy data. Visually your new free drift parameterisations are much closer to the IABP drift data than the 'Pathfinder' parameterisation, whilst the relative error plots show only a slight reduction, can you explain this? What time periods do the data represent? The ERA5 winds used here are daily averages. Are the buoy drifts also daily averages?

Figure 7, which case does this figure relate to? Please indicate this in the caption.

Figure 9, can you clarify the definition of the difference plots? Is it (post 2000) - (pre 2000)?

References:

Heorton, H.D.B.S. et al. 2019. Retrieving Sea Ice Drag Coefficients and Turning Angles From In Situ and Satellite Observations Using an Inverse Modeling Framework. Journal of Geophysical Research: Oceans. 124, 8 (2019), 6388–6413. DOI:https://doi.org/10.1029/2018JC014881.