Following is my review of the revised manuscript entitled “Effects of including the adjoint sea ice rheology on estimating Arctic ocean–sea ice state” by Guokun Lyu, Armin Koehl, Xinrong Wu, Meng Zhou, and Detlef Stammer (egusphere-2022-1099).

General Comment

In this study, motivated by Toyoda *et al.* (2019), the adjoint sea-ice model with viscous–plastic rheology (adjoint-VP) is applied to a coupled ocean and sea-ice state estimation system for the Arctic Ocean, and compared with the previous version in which the simplified adjoint sea-ice model of free drift (adjoint-FD) is used to avoid numerical instability. One year of optimization experiment for 2012 shows that the adjoint-VP can produce better state of the ocean and sea-ice through more appropriate dynamic and thermodynamic processes than the adjoint-FD.

The revised manuscript became much understandable than the original one in many aspects, but still needs to explain or respond adequately to the following points to be accepted for the publication in *Ocean Science*.

Specific Comments

1. Introduction: Indeed, the adjoint method has a characteristic that optimized fields strictly obey the model governing equations, but the control variables are subject to bad influences in some cases as shown in this study (unrealistic adjustment of 2-m air temperature when using the adjoint-FD). In addition, statistical methods can estimate atmospheric forcing and model parameters as well as the initial conditions by augmenting the state vector. Therefore, the reviewer recommends not to exaggerate the advantages of the adjoint method over statistical methods.
2. Line 182: Clarify whether the diffusivity of 500 $m^2 s^{-1}$ is for the vertical or the horizontal.
3. Line 182: Is a harmonic viscosity used in the adjoint model in spite that a biharmonic viscosity is used in the forward model (line 101)?
4. Section 3.2.1: As the authors mention that “the normalized RMSEs in Figure 3d should be close to 1.0 if the optimization found a model simulation consistent with the observations and the prior uncertainties” (line 243), the normalized SIC errors of about 0.5 indicates that simulated SICs are overfitted to observations or the prior uncertainties are overestimated. The same can be said of the normalized RMSEs of SIT (Figure 4). Again, discuss this point.
5. Section 4: Briefly describe the differences between the ERA5 and NCEP-RA1 reanalyses, especially from the viewpoint of the treatment of sea-ice boundary conditions. The reviewer remembers that the NCEP-RA1 does not use a fractional sea-ice concentration but 0 or 1.
6. Section 4: Similar to the specific comment 4, the normalized RMS of adjustments of the atmospheric variables of around 0.1 indicates that their estimated prior uncertainties are too large, or equivalently, the relative contribution of the last term in Equation (1) is too small.

Discuss this point.

7. Figure 9: It is confusing to use the blue line for adjoint-FD and the black line for adjoint-VP, because they are opposite in other figures.
8. Figure 11, caption: Explicitly describe the contour intervals.

Technical Corrections

1. The reviewer pointed out the followings in the previous report, but they are not corrected in the revised manuscript.
   1.1 Lines 67: Dynamic should read dynamics.
   1.2 Line 142: 0.25% should read > 25%.
   1.3 Line 170: C^* should be 20.0 rather than –20.0.
   1.4 Line 187 and 192: Dynamic should read dynamics.
   1.5 Line 231: Visual should read visible.
   1.6 Line 470 and 473: Dynamic should read dynamics.
   1.7 Figures 1, 3, 4, 7, and 11: Paint the Great Britain Island gray.
2 Line 101: $m^{-2}\,s^{-1}$ should read $m^2\,s^{-1}$.
3 Line 114: Right hand should read right hand side.
4 Line 447: –6ºC should read 6ºC.
5 Line 449: Figure 10b should read Figure 11b.