Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., author comment AC1
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Reply on RC1

William K. Jones et al.

Author comment on "A semi-Lagrangian method for detecting and tracking deep convective clouds in geostationary satellite observations" by William K. Jones et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-31-AC1, 2022

We thank the reviewer for their careful and considered review and constructive feedback. Please see below our responses to the individual comments, with the original comments included in italics.

This paper proposes a new algorithm for the detection and tracking of DCC from geostationary observations. The data and method are very well presented, and the manuscript is well written and easy to read. This new method addresses some issues related to DDCs detection at any moment of their lifetime and their movement tracking, showing good performances. The method claims to improve the accuracy of the current detection algorithms; however, I believe it would benefit the paper to place this work in a broader context. It could be beneficial to the paper to mention the accuracy of some of the most common DCCs detection algorithms for missed and falsely detected DDCs. In general, the manuscript lacks some data to support and justify certain affirmations. In the minor comments I added some parts that could benefit from a better context, in my opinion.

Direct comparison with the accuracy of existing detection algorithms is difficult due to the lack of an agreed standard for how to validate the accuracy of different algorithms. We agree however that more context is required here, so we have further elaborated on the challenges faced by existing algorithms and how our new algorithm addresses these.

Minor comments:

- *In the introduction, please briefly introduce the concept of DDCs.*

We have included a new paragraph on DCCs, focusing on the properties of importance to detection and tracking, starting at L20 in the updated manuscript:

Line 20: "Deep convective clouds (DCCs) are dynamical atmospheric phenomena resulting from instability in the troposphere. DCCs consist of a vertically growing core with a diameter of ̃10 km and updraught velocities of around 10 ms-1 (Weisman, 2015), and a surrounding anvil cloud formed due to horizontal divergence of cloud droplets lifted to the level of neutral buoyancy (Houze, 2014). The lifecycle of DCCs can be separated into three sections: a growing phase, where the core develops vertically; a mature phase in which the anvil cloud develops horizontally while convection continues within the core, and a dissipating phase in which the anvil cloud dissipates after convective activity ceases within the core (Wall et al., 2018). For isolated DCCs, – consisting of a single core – the overall lifecycle typically spans 1-3 hours (Chen and Houze, 1997). However, DCCs may also form with multiple cores feeding a single anvil cloud (Roca et al., 2017), and in these cases may span areas several orders of magnitude larger (Houze, 2004), and exist for 10-20 hours or longer (Chen and Houze, 1997).

This has replaced the paragraph at L66, which has now been removed.

- *All the references to figures throughout the text should be if within the text or Figure if at the beginning of a sentence.*

We have edited the text to correct this.

- *L52-55 Maybe it would be useful to give some numbers here (e.g., the spatial resolution improved from ~5-7km to ~1km) to give an order of magnitude of the improvements with the newest generation.*

We have moved the discussion of ABI capabilities vs older sensors to the data section, and added a table comparing the properties of the ABI instrument aboard GOES-16 to previous instruments to show the improvements in resolution, channels and SNR.

- *Acronyms need to be introduced only once. Please double check your manuscript for this (e.g. L107). On the other hand, some acronyms were not introduced (e.g. L130 LW)*

We have checked and corrected the introduction of acronyms throughout the text.

- *L121-122 Please add again some numbers here for SNR to give an order of magnitude of the improvements.*

This has been included in the table referred to in response to point 3, with a comparison both SNR of the IR channels and an estimation of the SNR of the water vapour difference combination. We have added the following:

Line 131: "Compared to older geostationary instruments, ABI has higher spatial and temporal resolution, more channels in both the LW IR window spectrum and the LW IR water vapour (WV) spectrum, and low noise (table 1) (Iacovazzi and Wu, 2020)"

- *L140-141 This sentence is not clear, please reformulate*

The sentence was missing a word and has now been corrected to:

"However, in the presence of high, thick clouds the 6.2 μm channel has an additional contribution from stratospheric water vapour resulting in a warmer, and in extreme cases positive, WVD value (Schmetz et al., 1997)".

- *L176 What does sufficiently mean? Please give more data.*

In this case, "sufficiently" means in relation to the motion of observed DCCs between subsequent images in comparison to the spacing of those features. We have included an additional reference to show what the motion of detected DCCs is in relation to the spacing between DCCs to demonstrate how the improved frequency of imagery from GOES-16 ABI allows individual DCCs to be identified between time steps, as follows:

Line 210: "Optical flow algorithms have been previously shown to be accurate for the prediction of AMVs using geostationary satellite images (Wu et al., 2016), as long as the observations are sufficiently frequent such that the motion of unique features between images is less that the length scale at which neighbouring features can be resolved (Bresky and Daniels, 2006). Heikenfeld et al. (2019) found that at imaging frequencies of less than 5 minutes the motion of DCC cores was less than the spacing between neighbouring cores in the majority of cases, indicating that the frequency of the ABI CONUS scan region is suitable for calculating optical flow vectors of DCCs."

- *L187-189 Please add references, numbers or data to support your affirmation that the Farnebäck algorithm is robust for the complex morphology of cloud fields.*

We have included information on our selection of parameters for the Farnebäck algorithm which we found to provide the best balance between reliability and accuracy. We have also included data of our error estimates of the motion vectors calculated using the Farnebäck algorithm to demonstrate that the accuracy is sufficient for the use case presented in this paper. We find that the majority of optical flow vectors have a relative uncertainty of less than 0.1 for cold cloud scenes (BT <270K)

Changes regarding the use of the Farnebäck algorithm:

Line 233: "Although other optical flow algorithms may provide better accuracy in different circumstances (Baker et al., 2011), we have found that the ability of the Farnebäck algorithm to accept a range of parameters is important for detecting the motion of clouds across a wide range of scales. The choice of parameters used is a compromise between the ability to robustly detect flow vectors in areas of the image with low contrast between features (e.g. in the centre of anvil clouds), versus the fidelity of the motion vectors detected for small, high contrast features such as developing cores. The parameters we have chosen for the Farnebäck algorithm are shown in table 2. It should be noted that the values used for these parameters in the case of detecting the motion of DCCs is scale dependent. In particular, we find that the choice of window size is proportion to the time between subsequent images, and inversely proportional the spatial resolution. The parameters given are for ABI imagery in the CONUS scan region, which has a temporal resolution of 5 minutes and the spatial resolution of 2km."

Additional paragraph on the estimation of the uncertainty in the optical flow errors:

Line 246: “We estimate the uncertainty of the optical flow vectors by comparing the residual error in the location of features in subsequent images after the detected motion from optical flow is accounted for (see fig. 4d). We restrict the estimation of uncertainty to regions of clouds with brightness temperatures less than 270 K as these are the situations in which we see enough contrast with the background to detect optical flow motion vectors. We find that in the majority of cases that the relative uncertainty in the magnitude of the location offset versus the magnitude of the estimated optical flow vector is less than 10 %, with mean and median relative uncertainties of 15.0 % and 8.4 % respectively.”

- *In Fig. 9 the histograms are barely visible, please regenerate them with better choice of the axis limit*

After consideration, we have replaced figure 9 with a table containing the validation results as this presents the results in a clearer manner.

Small typos and notes:

L16 this framework to be applicable

L37 how satellites operating in the visible and IR

L40 large area

L43 the Geostationary Lightning Mapper

L45 Column mean radar reflectivity […] shows

L52-53 The newest generation […] offers

L156 GLM has the same field […]

L183 is used here for to

L183 […] tracking of DDCs .

L197 based of of

L200 its

L204 include the effects

L251 and edge-based

L269 the detected anvil cloud begins

L306 FAR of 0.27

Thank you for catching these errors, these have been corrected in the text.