

A review on 'Investigation of cirrus clouds properties in the Tropical Tropopause Layer using high-altitude limb scanning near-IR spectroscopy during the NASA-ATTREX Experiment'

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This study shows a new method to derive IWC from ice water absorption derived from NASA ATTREX MiniDOAS limb scanning near-IR observations. A case study is used to interpret the retrievals, validations, and uncertainties. Sensitivity tests were performed using a radiative transfer model, and a conceptual model was derived to understand observations.

This paper is well-organized and well-written. However, I still have some concerns.

1. This study uses one case to show the performance of IWC retrievals from MiniDOAS, validated with in-situ measurements from Hawkeye FCDP and NOAA water instruments. Validation shows good agreement at some times but not that good at another time. The authors discussed possible factors that contribute to the uncertainty. However, with only one case, it is not that convincing how good the method is to derive IWC. I would suggest adding other cases (as complementary materials).
2. Please check the equations 10 -13.
3. Throughout the entire paper, the authors may state the same concept in various places but use different terminology, which is confusing. These include concentration, number concentration, mass concentration, particle density, also IWC and IWP. Please keep the terms consistent, correct, and easy to understand for readers.
4. An important conclusion in this paper is the high sensitivity of the method to detect and derive information for thin cirrus clouds. However, there is no comparison or discussion with other methods to prove the method's sensitivity.

Specific comments:

Line 2: 'High altitude aircraft offer', aircraft → aircrafts

Fig 1. Please define optical density, and explain its usage in this study. Y titles of fig.1 'OD' is not expanded. Readers may be misled by optical depth. Please clarify it.

Line 160: 'IWP is defined as the vertical integral of ice mass concentration through a cloud'. Why not just use ice water content instead of ice mass concentration? It seems easy to confuse it with concentration, number concentration, and number density in this paper.

Line 163: 'Mice' why not just IWC? It will directly relate to the retrieval of IWC from SIWP later in the paper.

Line 187: add ',' between 'angle One'.

Line 190: what does 'SIWP tracks the O2 SCD' mean?

Line 192: 'This is somewhat counter-intuitive, considering ....' Why that happens?

Line 267: 'FCDP measurements yielded the number density of the particles', please define number density.

Line 272-274: 'using the ice volume related to the averaged particle number concentration n', are you sure you mean particle number concentration, not the mass concentration as mentioned above?

'This resulted in a nominal ice concentration of  $N_{ice} = 1.22 \times 10^{-3} \text{ g m}^{-3}$ ' Obviously, the unit here refers to mass not number concentration. I think it has the same meaning as  $M_{ice}$  in Equation (5). To get rid of confusion, please keep the symbol consistent. Again, I would suggest using IWC instead of mass concentration.

'n is referred to as the nominal case', do you mean  $n = N_{ice}$ ? Then n is mass concentration not mass concentration?

Equations 6 and 7: Could you explain more why it needs two wavelengths to retrieve  $\tau_{ice}$ , but only one wavelength to retrieve  $\tau_{O2}$ ?

Table 3: it is confusing to read.

Line 301-306: my understanding here ice concentration refers to ice mass concentration.  $n = 1.22 \times 10^{-3} \text{ g/m}^3$ .

Figure 3: for y titles, replace ice absorbance with SIWP, and oxygen absorbance with SCD, if I understand correctly. Please add units for both x and y axis. For x axis, what does ice nominal x n mean? I think n represents ice nominal case.

Equations (10) and (11): the radiation being reflected by surface or atmosphere below the aircraft may be transmitted through clouds. Why extinction of clouds is ignored? Which is to say, instead of  $I_s(\lambda)R(\lambda)$ , it may be more realistic using  $I_s(\lambda)R(\lambda)T(\lambda)$ , T is the transmissivity.

Line 379 ' $N_{ice}$  identifies the ice particle number density' I think it is called nominal ice concentration in Line 273, which should be mass concentration, not particle number density. Again, please keep the terms and symbols consistent if you are meaning the same thing.

Equation 13: I think  $\tau = \ln \left[ \frac{I_{obs}}{I_s} \right]$ , based on Equation 7. Then Equation 13 misses a negative sign.

Table 4: size distribution 'bimodal 3-5 um', change as 'bimodal peak 3-5 um' might be clearer.

Line 446: 'the average ice particle number' is it the ice particle mass concentration as mentioned in Line 273? Note that particle number and particle mass are two different terms.

Line 447- 448: 'SIWP and number concentration are proportional', be sure if you mean the number concentration or mass concentration.

Line 460: 'This difference is likely due to an actual IWP higher than the modeled IWP'. This is confusing. SIWP? Ice concentrations?

Line 463: ' the model favors an ice density', is it the observation favors an ice density of about half of the nominal value? I think the nominal values is used in the model.

Line 470-480: Please explain more specifically how to get IWC from SIWP? Is there any equations or references to point the readers to a better understanding of the methods?

Line 472: 'Four different cases were chosen...' please add details (date, location, flight altitude etc.) about these four cases.

Line 473: 'retrieved IWCs for these four cases range from  $5.4 \times 10^{-3} \text{ g/m}^3$ ...', how well is this limit compared to lidar?

Section 4.3: the whole section discusses IWC rather than IWP.

Figure 8, panel b, the unit of IWC 'gr m<sup>-3</sup>' → g m<sup>-3</sup> to keep it consistent in the paper.

Line 512: Fig. 8 shows SIWP not 'retrieved IWP'. Do you mean IWC?

Lines 521-525: It is confusing how to get IWPs and their uncertainties in this section. What is the best retrieval? How do you get the percentage uncertainty?

Line 538: 'as IWP is the IWC integrated over the vertical extent' move the definition of IWP before the discussion of IWP uncertainty, and explain a little bit on why discuss IWP not IWC.

Line 573: 'lower detection sensitivity for IWC in limb geometry'. Do you mean higher detection sensitivity? Compare to what other approaches to demonstrate a better sensitivity of your approach?