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Interactive comment on “The Atmospheric Infrared Sounder Version 6 cloud products” *by* B. H. Kahn et al.

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The authors of this paper faced the ambitious task of introducing a new release of the cloud property retrieval algorithm for the AIRS instrument. The AIRS sounder was the first of its kind, a hyperspectral infrared sounder, in space and has been operational in polar-orbit since 2002. This is the sixth version of the retrieval algorithm. Since 2002, three hyperspectral infrared sounders have been launched; IASI on Metop-A in 2006, CrIS on Suomi-NPP in 2011, and IASI on Metop-B in 2013. With four infrared sounders in operational polar-orbit, hyperspectral sounding retrievals offer an unprecedented characterization of the vertical atmospheric column in space and time. Of the 2374 available channels in AIRS, only half are still useful today and this number is continually decreasing due to what is commonly referred to as channel popping. This said however, the strong advantage AIRS has is its decadal data record. This could perhaps

be the dominant motivation for a new algorithm release and reprocessing of the full data record. The value in generating an accurate and long-term cloud retrieval set is recognized by the authors in the first few paragraphs of the introduction and again in the conclusion. They state that AIRS offers “unique decadal scale and global snap-shots of clouds within the diurnal and annual cycles at all latitudes” (line 14, p14510). This means that the (Version 6, reprocessed) AIRS cloud retrieval record has the potential to help characterize “long-term, global-scale cloud trends that has been uncertain and difficult to determine” thus far (line 18, p14480).

An algorithm release is a difficult type of paper to write; even more so when the algorithm is the sixth version in a series of algorithms for an instrument with a life cycle spanning a decade. Over and above communicating the scientific integrity of algorithm improvements, it is the type of paper that needs to reach a wide audience and make a case for one data set (V5) over another (V6). In essence, a paper like this needs to fulfill three requirements; provide (1) an overview and summary of the instrument, its retrieval algorithm, products, and usefulness thus far, (2) technical description of algorithm changes and additions, as well as (3) a thorough examination and justification of improvements by way of comparison with other relevant datasets.

In my opinion the paper in its current form almost succeeds in addressing this ambitious set of requirements. They give a thorough technical description of new algorithms and updates on old ones. They do a thorough evaluation of the quality flags and discuss the impact quality control can have on the final results. They spare no detail in describing how the quality flags, that are “neither absolute nor quantitative” (line 1, p14496), should be applied to derive at meaningful results. This is often overlooked in algorithm papers, but key in making the data products useful to the community. Then they present and analyze a rich set of results at different spatial and temporal scales; e.g., localized Tc patterns (V5 versus V6) at a single-granule scale over the Pacific Ocean (Fig. 1), global statistics of Tc and ECF (Table 1), global distributions of AIRS V6 Tc and ECF (Fig. 2), a comparison of global ocean and land cloud heights between

V5, V6, Caliop and Calipso (Fig. 3 & 4), global patterns of V6 cloud phase (Fig. 5), a global evaluation of the sensitivity of the cloud phase results to algorithm thresholds (Fig. 6), AIRS spectrum (in brightness temperature units) sensitivity to changes in the three ice cloud products, optical depth, effective diameter, and effective temperature. This gives insight into the challenges faced during algorithm design (Fig. 7), global distribution, statistical analysis, effect of quality flags, zonal averages and diurnal patterns of ice cloud properties (Fig. 8–13), and lastly a mid-latitude cyclone evaluation with the different V6 cloud products (Fig. 14–16). I want to commend the authors on their thorough evaluation and presentation.

However, I do have a couple of major concerns and questions. My overall impression is that the paper lacks a clear goal and seems haphazard in its collection of results presented. It does not form a coherent whole and instead comes across as a collection of parts. More specifically, given what I consider to be the requirements for a paper like this, it lacks a meaningful summary of the AIRS algorithm evolution and accompanied pivotal algorithm papers. In addition, there's a conspicuous dearth of citations on how AIRS data have been used till now. The reader is left with the conclusion that even though there's been a V5 cloud retrieval data set, it has not been used much in analysis. Why then do the authors envisage V6 retrieval products to be applied with more enthusiasm? Yes, compared to Cloudsat and CALIOP, there's now an improvement in cloud height and frequency estimates. This is encouraging and clearly demonstrated. But, given the fact that the authors make a case for using the decadal AIRS cloud record in long-term trend studies it remains unclear how the V6 AIRS record adds "unique" information to the suite of existing decadal datasets. How does a global day of cloud retrievals compare between V5 and V6? Or between V6 and other existing cloud products (notably from imagers such a MODIS)? Apart from improved cloud height, is there a significant improvement in depicting spatial patterns and their diurnal/seasonal variation? This is especially relevant since one of the primary improvements in V6 is that cloud retrievals are now performed at single-FOV scale. Given the objective of depicting cloud trends on a global-scale, do single-FOV

retrievals really matter?

The V6 products suite includes, for the first time, the capability of characterizing cloud thermodynamic phase and ice cloud properties with an infrared sounder. This is a major contribution and promises to serve the user and scientific community well. However, it remains unclear why a user should switch from using imager-retrieved to sounder-retrieved microphysical properties. The authors make a brief statement on how V6 AIRS phase retrievals compare with those from ISCCP and MODIS, but I find this statement to be a shallow and largely meaningless. Were the data scaled to a similar spatial resolution? Were any attempts made at neutralizing instrument (AIRS and MODIS) and product (ISCCP is a multi-instrument product) differences before comparison? In a time when multi-instrument analysis of the environment and climate becomes not only possible but also essential, it is more important than ever to be clear and specific so that results can be reproduced, tested and scrutinized. How do sounder microphysical retrievals improve on broad-band retrievals? Or stated differently, what specific types of information do the V6 AIRS cloud retrievals add that can compliment existing efforts at existing methods of cloud characterization?

Given the fact that the authors made the introductory statement that CrIS, and IASI (Metop-A and Metop-B) "will continue the AIRS legacy into the future" (lines1–5, p14483), I find it odd that no further mention is made of CrIS and IASI in the remainder of the paper. Do the authors have a comment on how data continuity among the four hyperspectral sounders in space can be established or promoted?

I am at issue with the list of factors (lines 14–19, p14482) the authors cite as reasons why sounder retrievals have not been used widely in atmospheric science. (i) Excessive computational expense. Perhaps this was an issue in 2002 but computational capabilities have improved significantly since then. Could you specify the system for which AIRS processing will be prohibitively expensive? Apart from computational capabilities, there are well-known statistical methods for compressing data that preserve the information content, most notably principal component analysis. This has been used with great success in hyperspectral sounding retrievals as well as radiative transfer modeling (Huang and Antonelli 2001, Antonelli et al. 2004, Xu et al. 2005). (ii) Complexity and variability of cloud geometry. This is a cloud remote sensing problem in general and not limited to infrared hyperspectral sounders. (iii) Uncertainties in underlying surface and atmospheric state. Again, this is an atmospheric remote sensing problem in general and not limited to infrared hyperspectral sounders. (iv) The necessity of using a large channel set. Almost every paper describing a hyperspectral retrieval algorithm has a section on channel selection that focuses on reducing the channel set and improve the signal-to-noise ratio. There are also numerous papers describing methods for quantifying the information content of soundings as a means to identify suitable channels for parameter retrieval, or compressing the relevant information into a small number of super channels (or principal components) (references are too numerous to list here). And lastly, according to my best knowledge, the full channel set of AIRS (2374 in total) has never been employed in retrievals (an optimal set of $\sim$1500 was used for a long time). Moreover, the number of functional channels continues to decrease due to channel popping. (v) The ongoing difficulty in developing an automated, rigorous, and fast retrieval that is applicable to 10+ years of data at single FOV. This is true, but the difficulties have been rigorously addressed and largely overcome with the development of a regression retrieval algorithm (Huang et al. 2004, Weisz et al. 2007, Smith et al. 2012)

A list of some minor issues:

(1) The term “pixel” is typically not used to refer to the field of view (FOV) of sounders. The authors use “pixel” and “FOV” interchangeably in this paper.

(2) What is the difference between “process based evaluation of climate models” and the study of “long-term global-scale cloud trends” (p14480)?

(3) What are “adverse scale-dependent behaviors in clouds” (line 28, p14481)?

(4) The language used is often too informal for a scientific paper, e.g., “Coarser res-

olution broadband type measurements”, (line 12 p14482), “native temporal and pixel scales” (line 8, p14482), “hyperspectral retrievals have proved elusive until now” (line 14, p14482), etc.

(5) Can the authors be more specific as to why the TES algorithm was adopted for ice cloud property retrievals? Perhaps a short discussion on the strength of the TES algorithm will suffice.

(6) If the ice cloud physical property retrievals are to be a legacy for the CrIS and IASI instruments, then a clear description of the channel selection process is required. Currently a PhD dissertation is cited as reference but this is not a widely accessibly source. Which channels (in wavenumber units) are currently being used for these retrievals? How will the authors deal with the challenge of channel popping in retrievals that relies on such a small set of core channels?

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