Ice cloud property retrievals from high spectral resolution measurements in the thermal infrared: Application to IASI and IASI-NG

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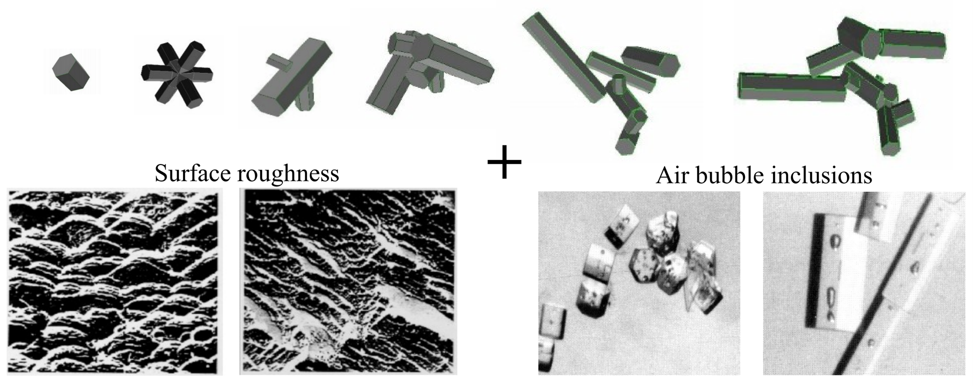
Abstract: The present study aims in quantifying the potential of retrieving ice cloud properties, and more specifically, the Ice Water Path (IWP) and layer altitude, from hyperspectral infrared sounders such as IASI and the future IASI-NG. The method is based on the variational approach of the optimal estimation (Rodgers (2000)). We applied an information content analysis and a test of the retrieval algorithm to different ice cloud profiles coming from a global database originate from analysis of the ECMWF. We have taken into account the Signal-to-Noise ratio of the instruments and the inherent non-retrieved atmospheric and surface parameters errors. The forward model used is the fast radiative transfer model RTTOV (Saunders *et al.* (1999), Matricardi *et al.* (2004)) with ice cloud microphysics from the ensemble model developed by Baran and Labonnote (2007) and size distribution parametrization by Baran *et al.* (2014).

ICE CLOUD MICROPHYSICS MODEL

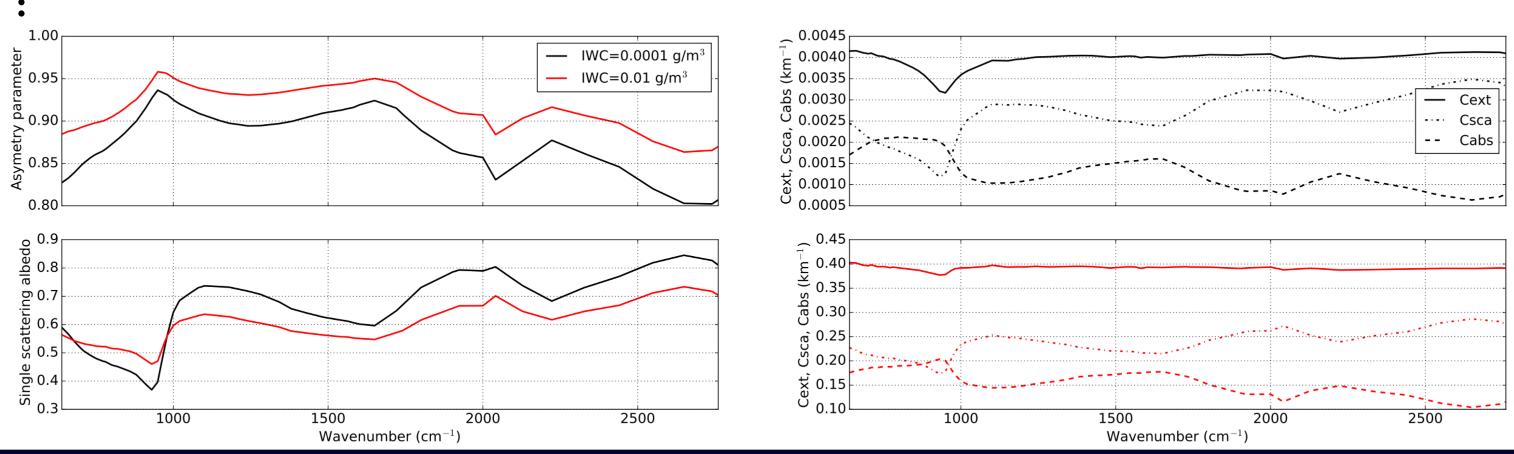
The ensemble model is composed of six individual ice particles with increasing complexity as a function of size. Concentration of each individual particle depends on their maximum dimensions.

This model also takes into account surface roughness as well as spherical air bubble inclusions (Baran and Labonnote (2007)).



The scattering phase matrix and optical properties are integrated over the PSD obtained from Field *et al.* (2006) and Field *et al.* (2007). Optical properties are parametrized, from integrating them over 20662 parametrized PSDs, as a function of IWC and in cloud temperature (Baran *et al.* (2014)).

Variation of the ensemble model optical properties for two different IWC on the IASI spectrum :



METHODS

Forward model: fast radiative transfer code RTTOV (Saunders *et al.* (1999), Matricardi (2004)) including the Baran parametrization (Vidot *et al.* (2015)) with Chou approximation (1999).

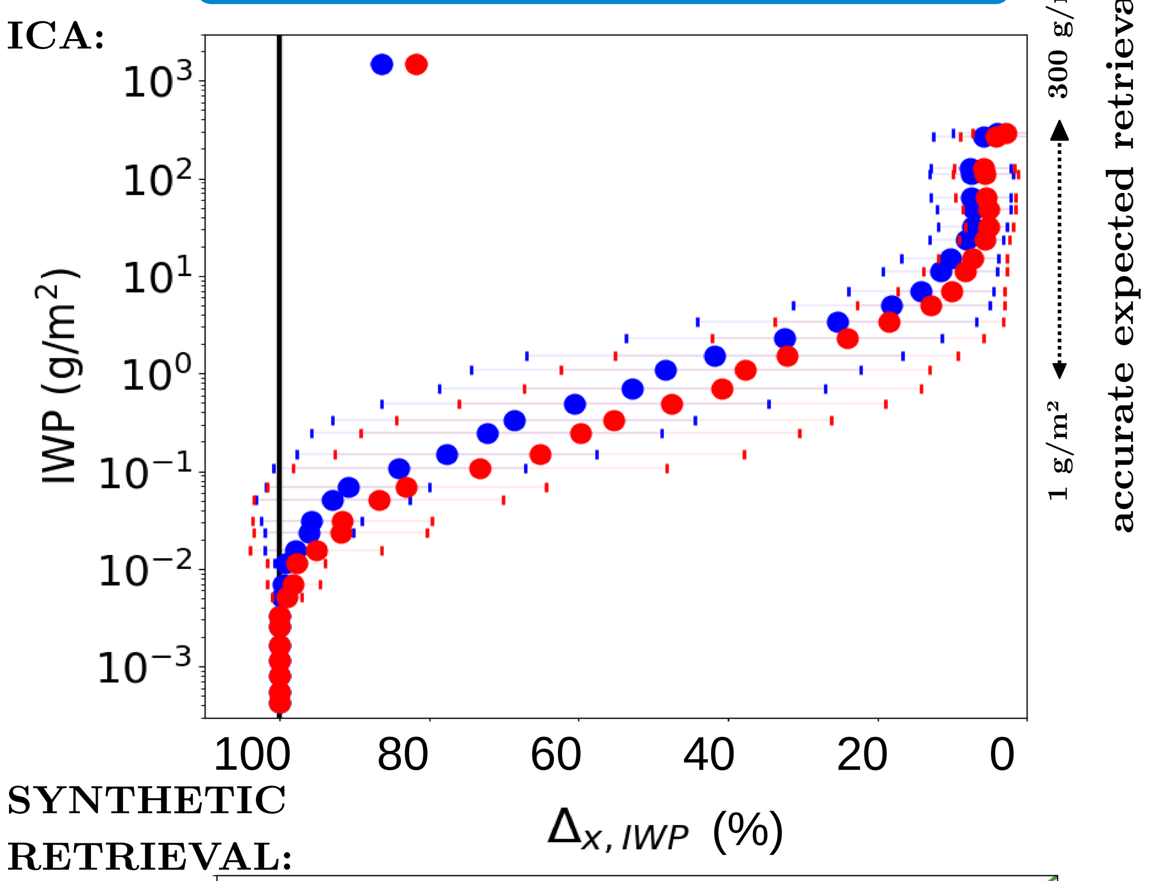
Inverse model: optimal estimation (Rodgers (2000)). The retrieved variables are the integrated ice water content (IWP), the cloud top height (CTH) and the cloud bottom height (CBH) constrained for the latter by the use of a climatology built from DARDAR retrievals (Delanoë and Hogan (2010)).

Information content analysis: the information brought by the observing system is assumed to be given by the posterior covariance (S_x) matrix as: $S_x^{-1}=K^T S_\epsilon^{-1} K+S_a^{-1}$ with K the jacobians, $S_\epsilon=S_y+K_b S_b K_b^T+S_{simpl.}$ the sum of covariances matrices of non-retrieved parameters, simplifications assumed in the forward model and the radiometric noise and S_a the a priori covariance matrix. The errors are the followings (with value when possible): o gas concentration profiles (H_2O, O_3) : 10 % o emissivity : 5 % o profile and surface temperature : 1K o liquid cloud parameters : 50% o homogeneous vertical representation assumption of ice clouds o use of a microphysical model

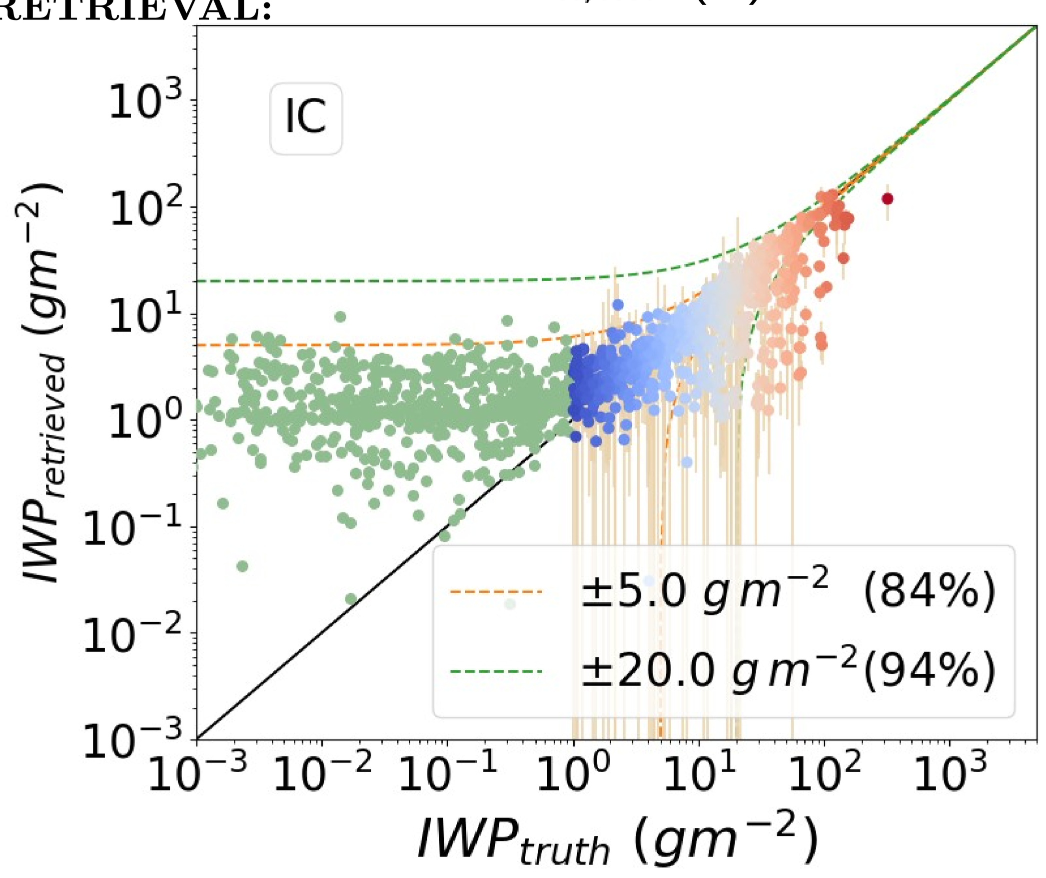
Set of profiles for ICA and synthetic retrievals: 4524 representative profiles of normal conditions, variability and extreme conditions (Eresmaa and McNally (2014)) containing an ice cloud in mono- and multi-layer configuration. Only the mono-layer cases are shown here but the tendency is the same for multi-layer, with poorer results expected when mixing liquid water is present in the ice cloud layer.

ICE WATER PATH (IWP)

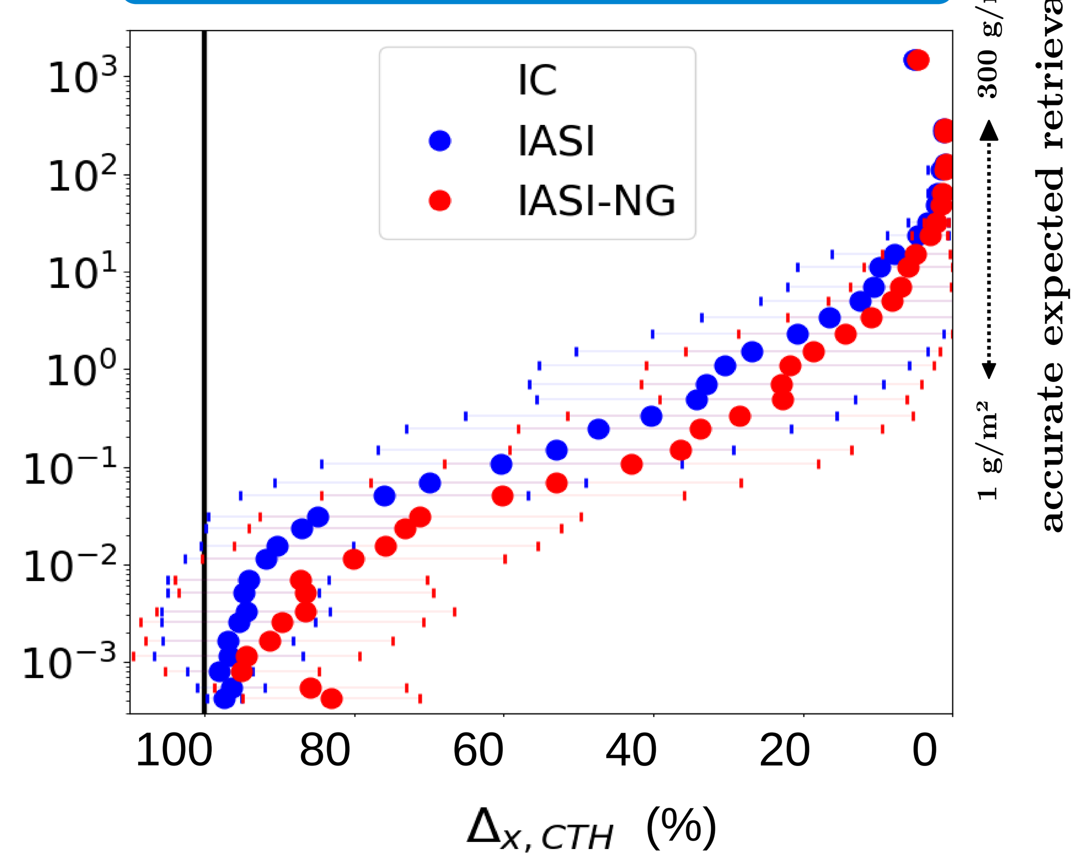
ICA:

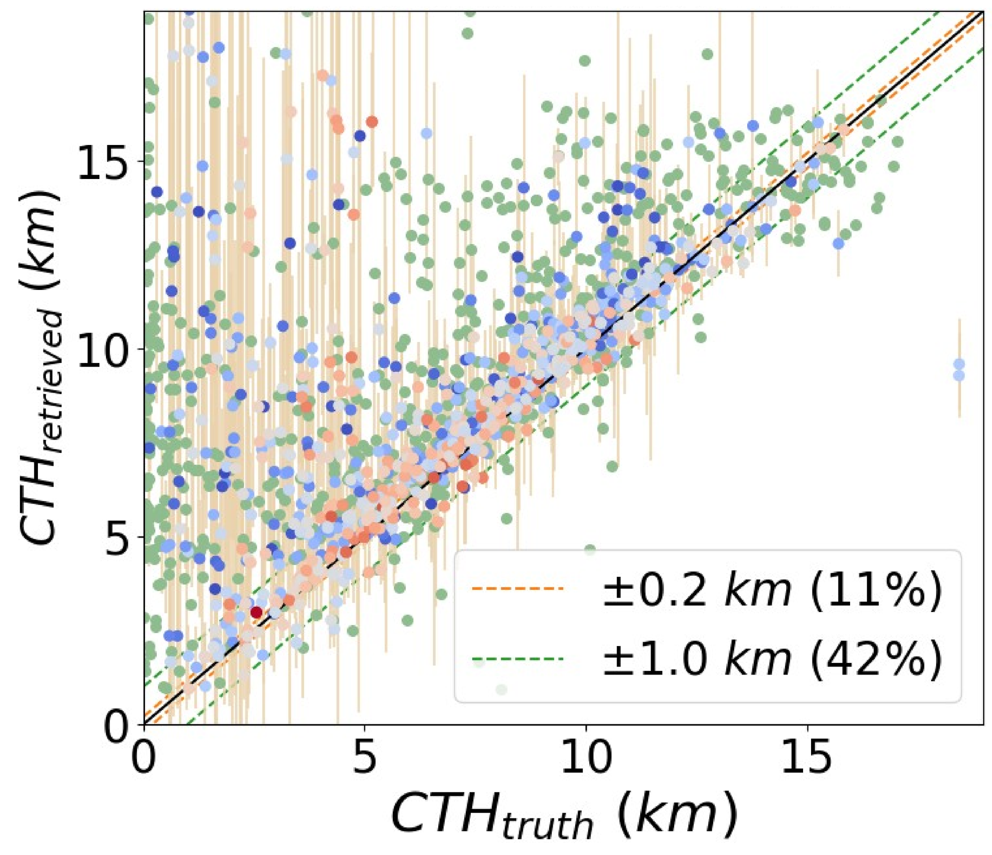


SYNTHETIC RETRIEVAL:

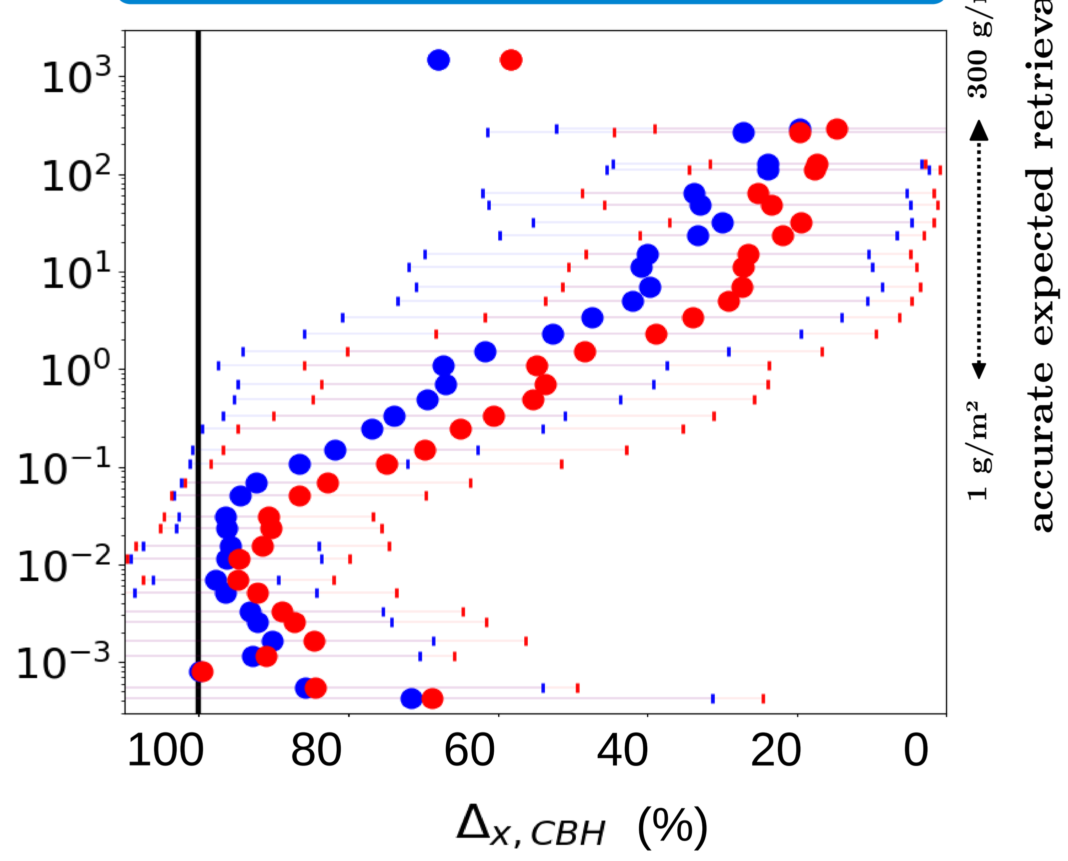


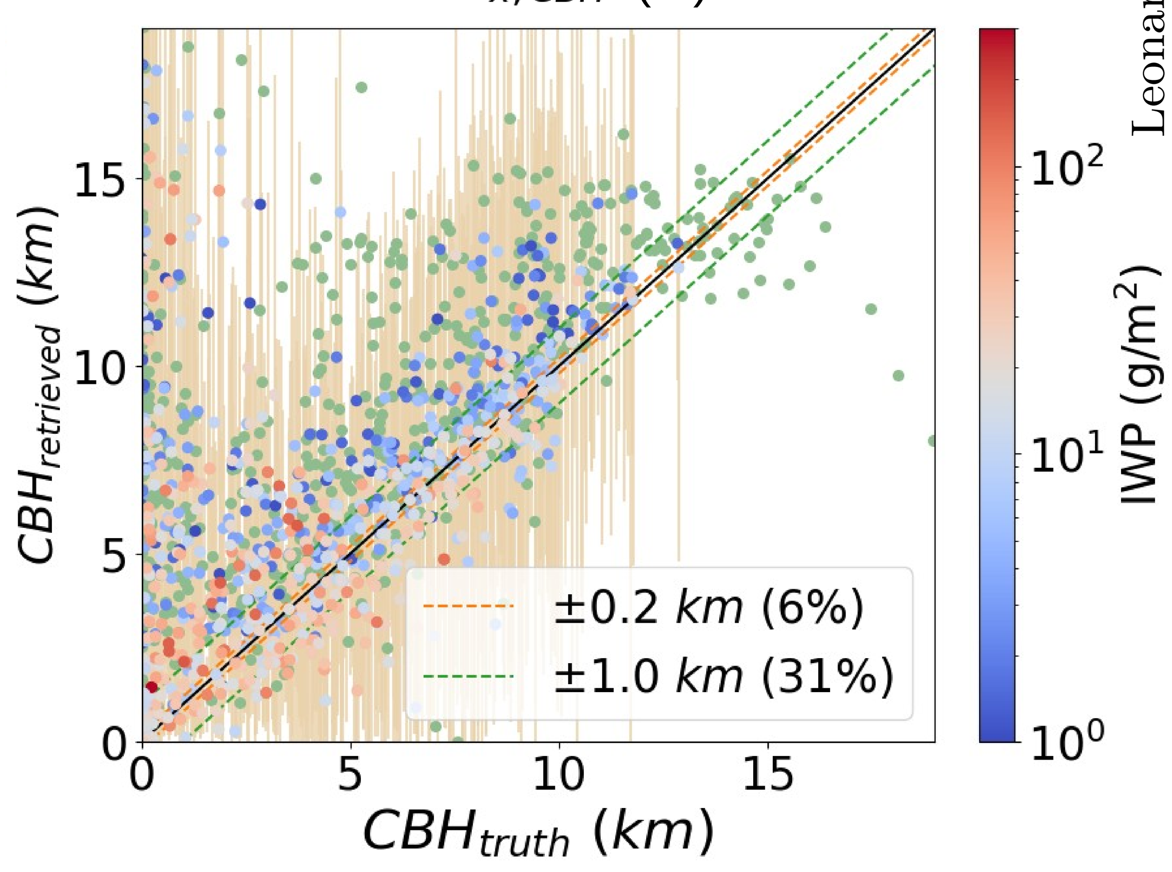
CLOUD TOP HEIGHT (CTH)





CLOUD BOTTOM HEIGHT (CBH)

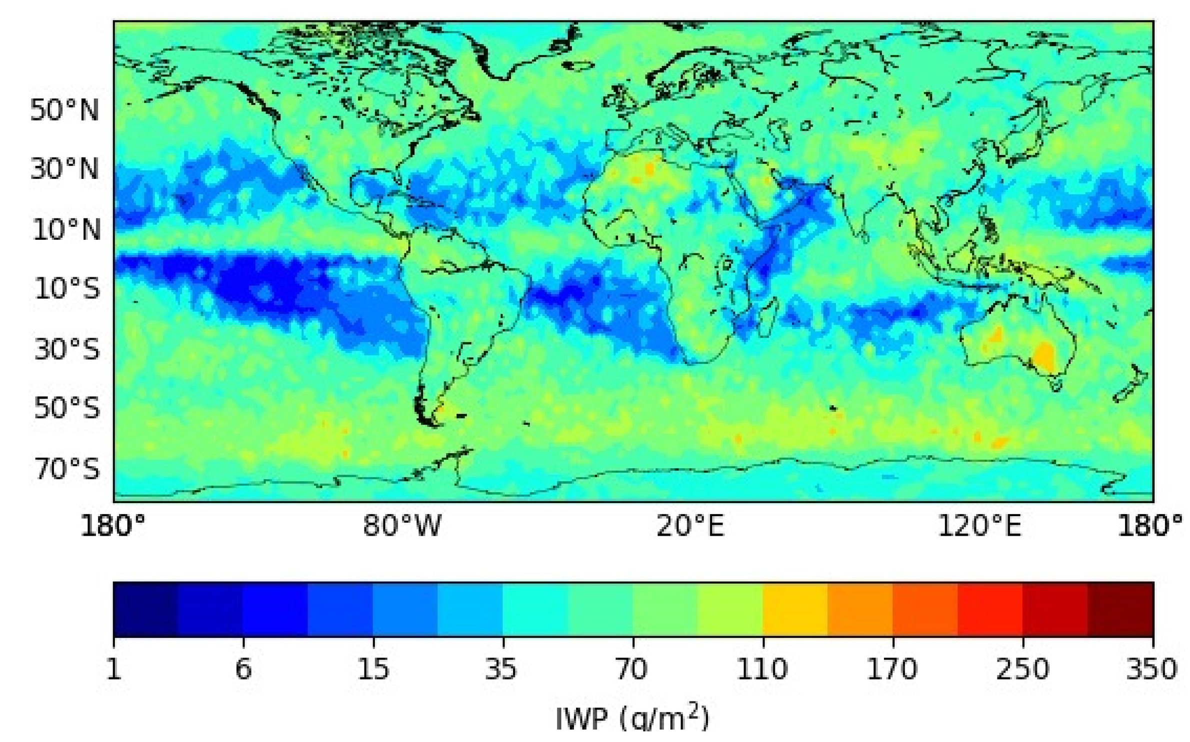




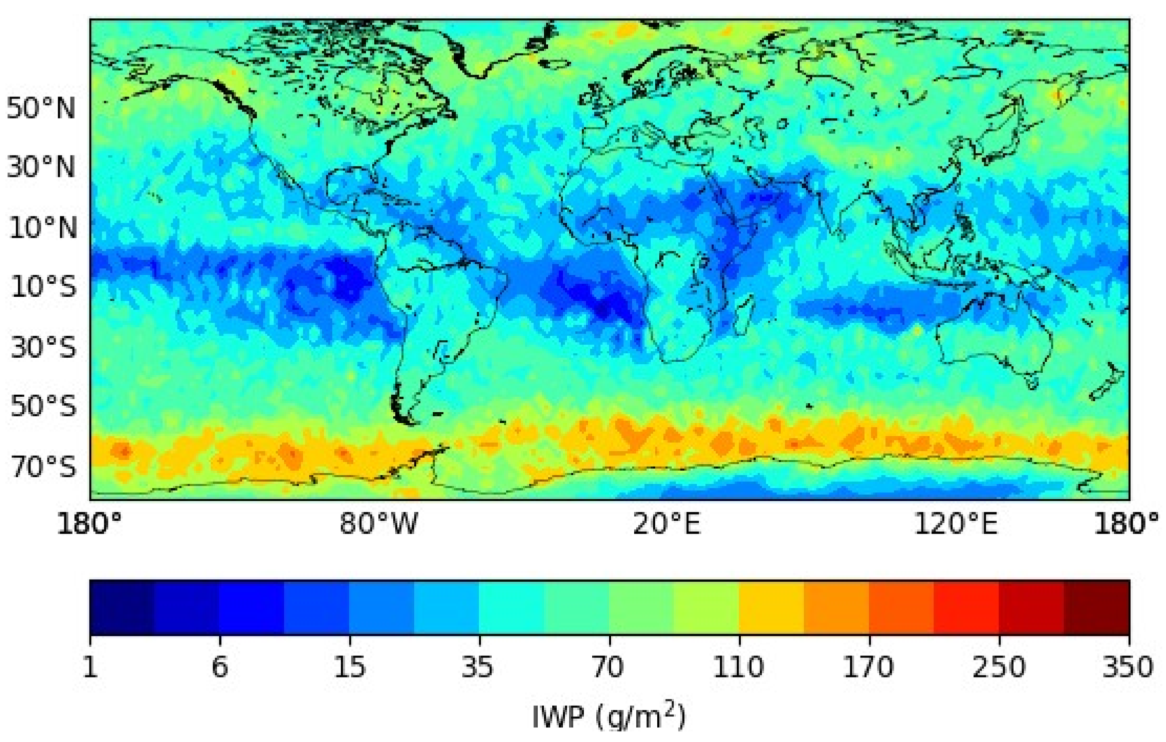
Leonarski *et al.* (2021)

EVALUATION (1 < IWP < 300 g/m²) OVER 2008

Our algorithm with IASI data



DARDAR



Conclusion and perspectives: Results show that IASI and IASI-NG can provide information on the IWP as well as the layer position of the ice clouds that should therefore be well retrieved with expected errors that decrease with cloud opacity until the signal saturation is reached. The retrieval algorithm tested on synthetic radiances show a good behaviour for clouds whose IWP is sufficent as well as the temperature contrast between the cloud and the surface. The range of IWP in which accurate retrievals are expected is between 1 and 300 g/m². We have compared a climatology built from retrievals obtained with real IASI measurements inside the latter range of IWP to the same type of climatology obtained from active measurements. This comparison shows that our algorithm is able to reproduce the large scale structures of the distribution of the IWP and cloud geometrical thickness (not shown). A validation based of direct comparison of co-located retrievals have to be performed.

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