Ice cloud properties, an information content analysis from high spectral resolution measurements in the thermal infrared (IASI-like)

L C-Labonnote (1), A J. Baran (2), J. Vidot (2) and H. Herbin

(1) Laboratoire d’Optique Atmosphérique (LOA), Université de Lille 1 Sciences et Technologies, France
(2) Met Office, Exeter, UK and the Department of Physics, Astronomy and Mathematics, the University of Hertfordshire, Hatfield, UK
(3) Centre de Météorologie Spatiale (CMS), Lannion, France

contact: Laurent.Labonnote@univ-lille1.fr

Abstract: The present study aims in quantifying the potential of retrieving ice cloud properties, and more specifically, the ice water content (IWC) profile, or column ice water path (IWP) together with layer position. This being retrieved from thermal infrared sounders such as IASI (and the future IASI-NG). The method used here is based on a Shannon information content analysis (ICA). We ran this ICA for different ice cloud opacities, by taking into account the Signal-to-Noise ratio of the instrument and the inherent non-retrieved atmospheric and surface parameters errors. The synthetic measurements have been simulated by a line-by-line model developed at the Laboratoire d’Optique Atmosphérique (LOA), and the multiple scattering by the open source radiative transfer code LIDORT (Spurr et al., 2008). The ice cloud microphysics has been simulated by the ensemble model developed by Baran and Labonnote (2007) and its size distribution parameterization as a function of IWC and ice in the cloud temperature by Baran et al. (2009). Results shows that the IWP as well as layer position (top and bottom layer altitude) should be well retrieved with expected errors that decrease with cloud opacity, until signal saturation is reached. Because of better SNR and spectral resolution, IASI-NG will also provide more accurate retrievals.

The ensemble model is composed of an individual ice particle with increasing complexity as a function of size. Concentration of such individual particle depend on their maximum dimensions. This model also takes into account surface roughness as well as spherical air bubble inclusions. The scattering phase matrix and total optical properties are integrated over the PSD obtained from Field et al. (2007) and Field and Gayet(2006).

Optical properties are parameterized, from integrating them over 2002 parameterized PSDs, as a function of IWC and Ti.

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

- Surface roughness
- Ice bubble
- Artifical inclusions

Effects of an Ice cloud layer on IASI like measurements

- Relative radiance code used for these comparison: LIDORT (108 retrievals with TMS correction).
- This code takes into account multiple scattering, polarization and pseudo-opalescence of the atmosphere, and is linearized about atmospheric properties such as gas concentration, IWC, temperature profile and surface emissivity.
- Ice cloud between 7.9 and 11.5 km divided in 12 layers of 180 m thickness. The cloud is assumed homogeneous (constant IWC profile)

Information content and expected improvement from IASI-NG

- Errors due to a missing knowledge of the non-retrievable parameters, which also need to be computed. We required their Jacobian as well.
- The non-retrievable parameters are as follows:
  - Surface and atmospheric temperature profile (TK)
  - Surface emissivity (TK)
  - Ice water content profile (IWC profile)
  - Gas profile concentrations (CO2, CO, CH4, and O2) (10%)

The averaging kernel defined as:

\[ A = \frac{\partial G}{\partial x} K \]

And the posterior covariance matrix \( S \) is defined as:

\[ S = \left( \frac{\partial G}{\partial x} S_{\text{model}} \frac{\partial G}{\partial x} \right)^{-1} \]

Where \( K \) is the Jacobian, defined as:

\[ K = \left( \frac{\partial G}{\partial x} \right) \]

and \( G \) is the gain matrix, defined as:

\[ G = 1 + S_{\text{model}} \frac{\partial G}{\partial x} \]

With \( K \) the Jacobian about the non-retrievable parameters and 10% error (%) matrix.

- The expected error (%) on the Water Path.
- The expected error (%) on the Carbon Dioxide.
- The expected error (%) on the Methane.

Conclusion and perspectives

- We have shown in this study the potential of high spectral resolution measurements in the infrared region (IASI-like) to obtain information on ice cloud layers.
- We have chosen to follow the parameterization developed by Baran et al. in order to represent the ice cloud microphysical properties, and top and bottom layer altitude to represent the layer position (altitude). In this study, we also took into account errors contributed to the non-retrieved parameters that are in the forward model computations e.g. temperature and gas profile, surface temperature and emissivity IWC profile shape. The measurement noise was randomly taken into account from the IASI SNR ratio and the expected one for IASI-NG.
- Results shows that despite the numerous error contributions the IWP should be well retrieved for IWP = 1 g/m² (COD=0.83±0.02) with an expected error = 10%.
- The top layer altitude is also expected to be well retrieved with an error = 10% for ice cloud with IWP = 10 g/m² (COD=0.83±0.02). Bottom layer altitude should be more difficult to retrieve with an expected error = 10% for IWP ranging between [10,200]g/m². As expected, and because of a higher resolution and better SNR, IASI-NG will improve these retrievals with much smaller posterior errors.