Sensitivity Analysis of a Novel Infrared Hyper-Spectral Optimal Estimation Cirrus Cloud Retrieval

Paolo Veglio and Robert Holz
Space Science and Engineering Center, University of Wisconsin - Madison

Introduction

The determination of cirrus cloud parameters from satellite measurements usually requires some assumptions on the ice scattering properties. Here we show how critical these assumptions are and how the retrieved quantities can be affected by changing them. For this purpose a collocated data set of hyper-spectral infrared measurements (Scanning HIS) and lidar data (CPL) has been created, and a novel infrared cloud retrieval (FEANOR) has been developed. FEANOR relies on an optimal estimation framework to derive optical depth, effective radius, cloud top height, and their associated uncertainties and offers the opportunity to easily change the scattering properties in order to perform sensitivity analysis.

The Retrieval

- The retrieval relies on the Levenberg-Marquardt formulation of the optimal estimation algorithm described by Rodgers (2000)
- **Forward calculations** are performed with LbLRTM (Clough et al., 1992) for the clear sky and LbLDIS (Turner, 2003; 2005) for the scattering layers
- FEANOR retrieves **optical depth**, **effective radius** and **cloud top height** simultaneously with their uncertainties
- Scattering models can be easily changed
- The flexibility of FEANOR allows to use either broadband or hyper-spectral measurements

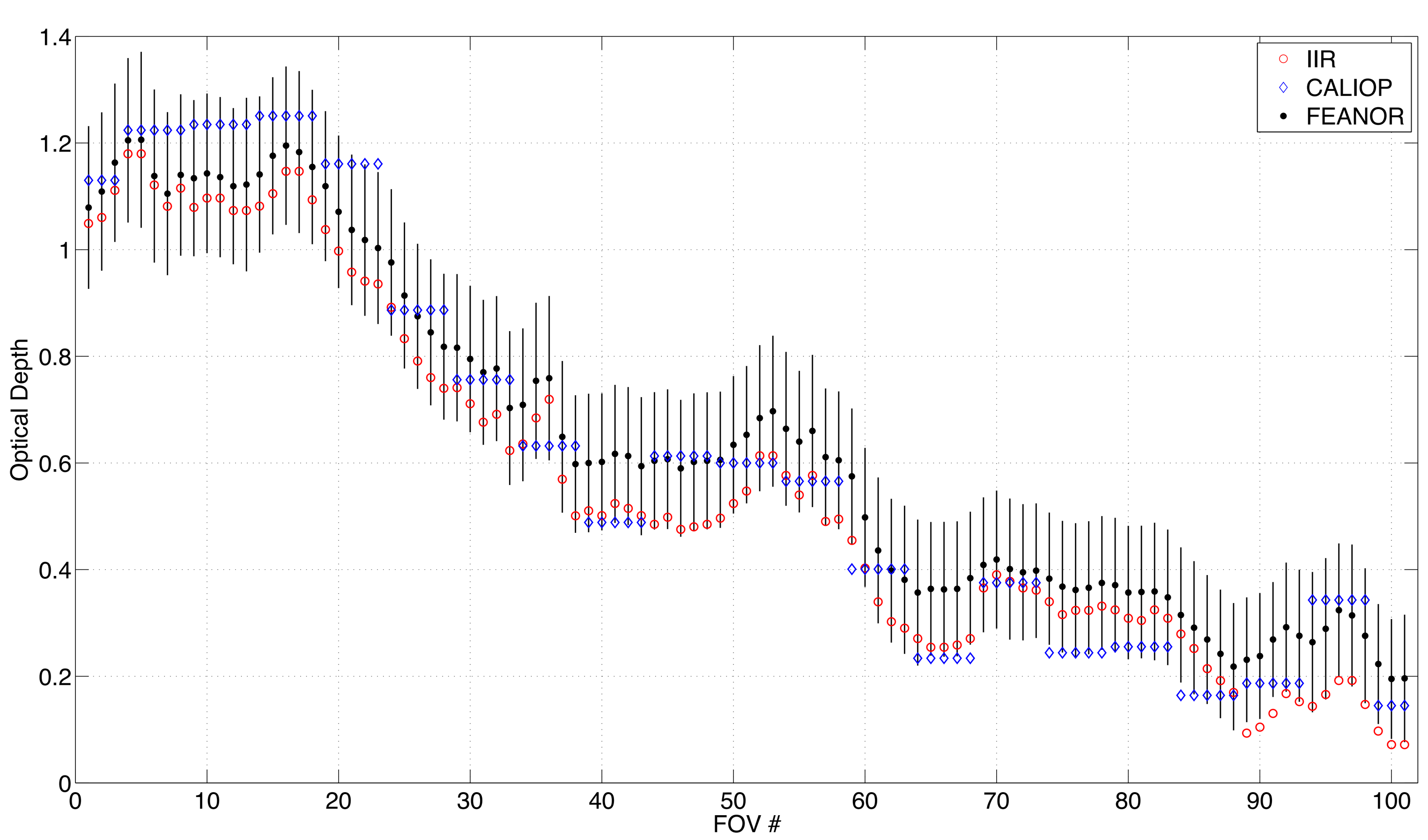
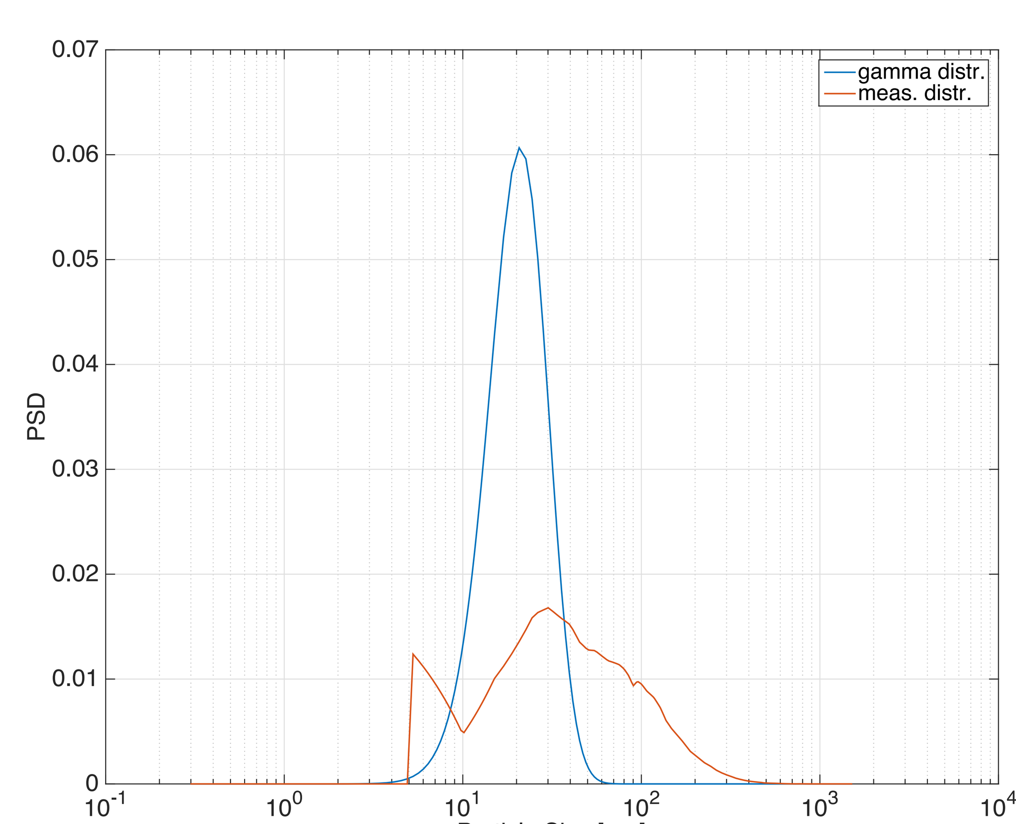


Figure 1 - left. *Sample of FEANOR output (optical depth in this case) using CALIPSO IIR compared with measurements and products of CALIOP (blue) and IIR (red). Vertical black bars represent the derived uncertainties on the retrieved OD.*

The Inputs

- S-HIS measurements: microwindows in the 800-1200cm^{-1} interval and full spectrum in the 650-750cm^{-1} region
- CPL collocated data to define the cloud boundaries
- Latest Ping Yang's ice crystal models (Yang et al., 2013)
- In situ measurements of ice particle size distributions from SEAC4RS campaign using the 2DS probe on board the NASA SPEC Learjet

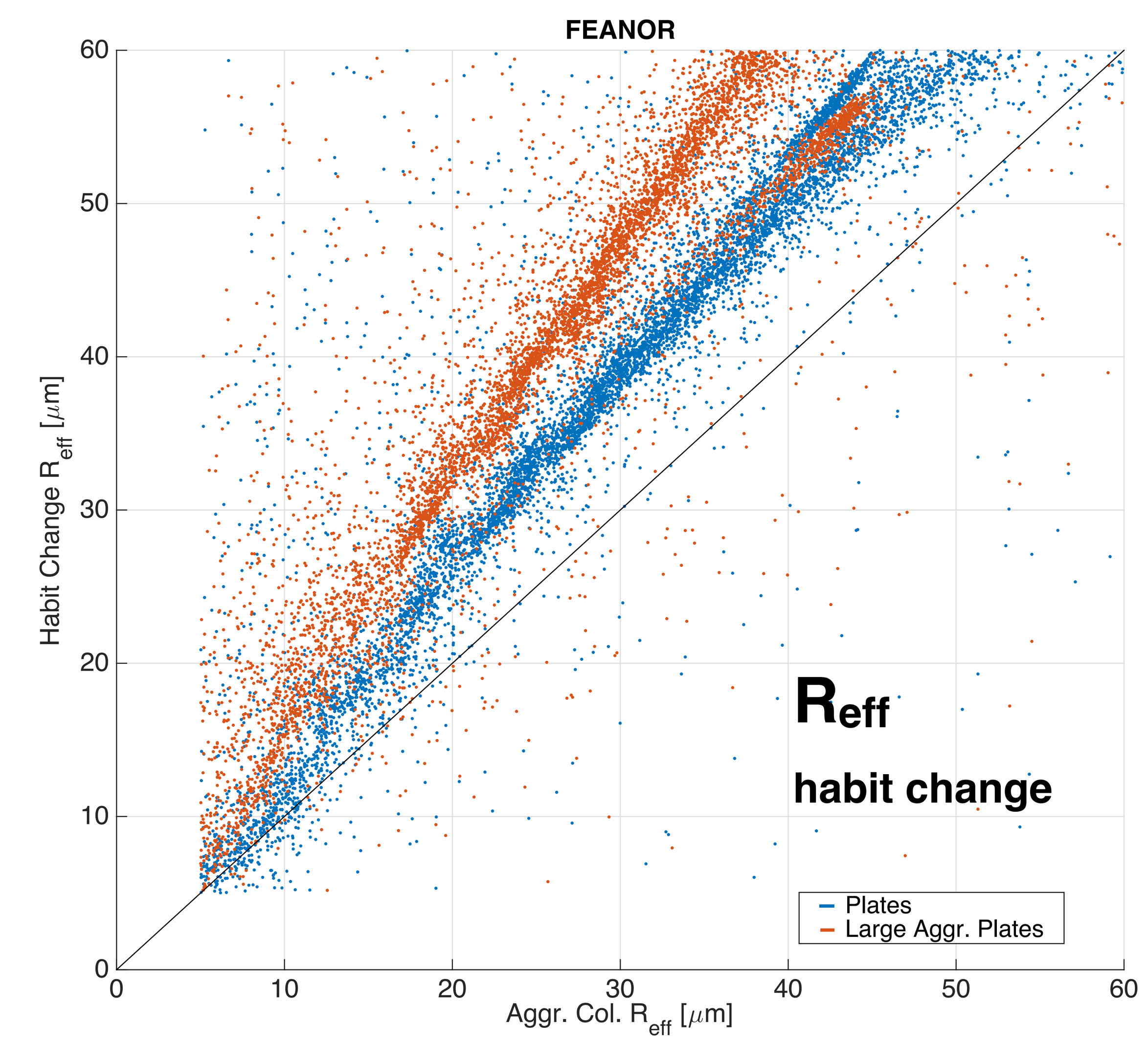
Figure 2 - below. *Particle size distributions used for the results shown in Figure 3-5. In blue is the modified gamma distribution, in red the measured one from SEAC4RS*



Contact:
paolo.veglio@ssec.wisc.edu

Results

- The habit change has important effects on the effective radius retrieval as shown in Figure 3
- Changes in habit have significant impact also on the Ice Water Path (Figure 4)
- The differences in derived Ice Water Path are even larger if the shape of the particle size distribution is changed instead of the habit (Figure 5)
- Some changes are observed also in the optical depth, especially when a different particle size distribution is used



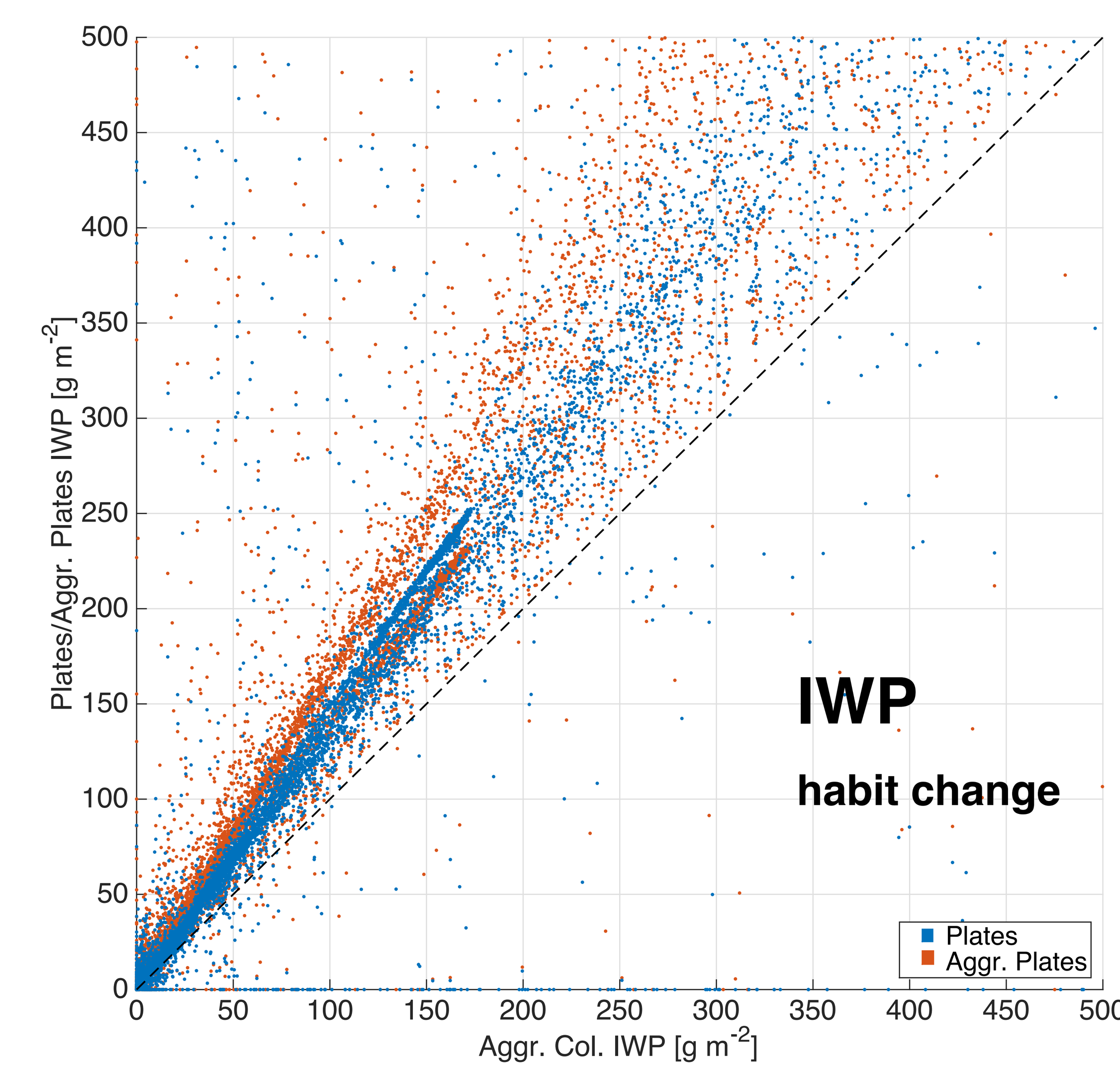
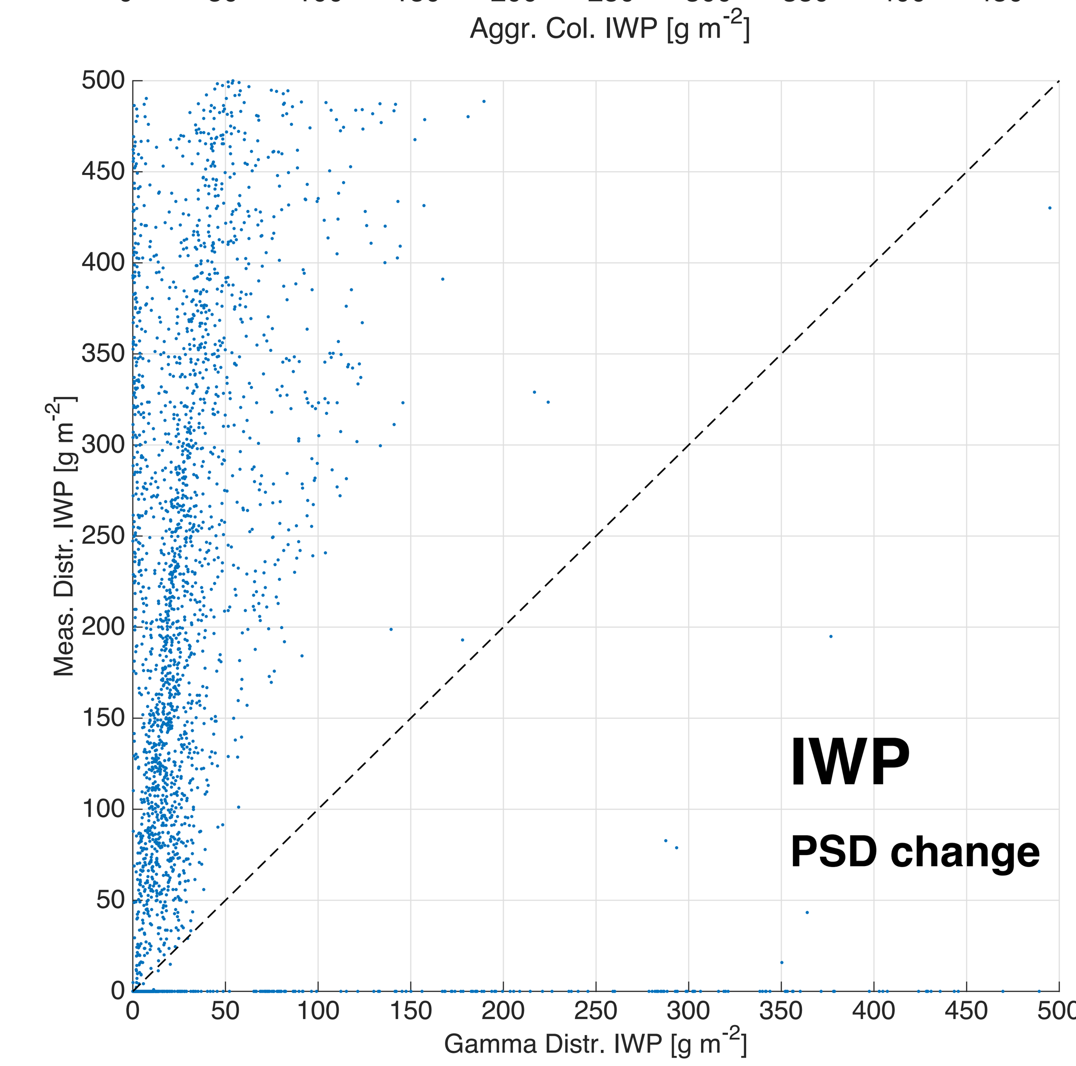


Figure 3 - above. *scatter plot of effective radius retrieved using aggregate columns (x-axis) versus plates (y-axis, blue) or aggregate of plates (y-axis, red)*

Figure 4 - above right. *Same as Figure 3, but for the Ice Water Path.*

Figure 5 - right. *Scatter plot of effective radius retrieved using a modified gamma PSD (x-axis) versus a measured PSD from SEAC4RS (y-axis)*



Future Work

- Implement the retrieval of temperature and water vapor profiles by using a fast forward radiative transfer model
- Compile a satellite collocated dataset AIRS-CALIOP-MODIS
- Extend FEANOR capabilities to work with satellite data
- Provide feedback for satellite products
- Compile accurate and extensive dataset of cirrus cloud parameters