

Submillimeter-wave Radiometric Measurements of Cirrus Clouds and Water Vapor

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Objective:

To explore retrievals of cirrus cloud parameters and water vapor profiles with millimeter-wave and sub-millimeter-wave radiometric measurements.

Approach:

- Ice water path (IWP), median mass equivalent sphere diameter (D_{me}), and water vapor retrievals are based on measurements made by the new Conical Scanning Submillimeter-wave Imaging Radiometer (CoSSIR), which has 12 channels covering the frequency range of 183-640 GHz (see Figure 1 below).

- Reflectivity measurements from the Cloud Radar System (CRS) are used to evaluate the CoSSIR cirrus retrievals. Rather than retrieve IWP and D_{me} from CRS data, we instead compare vertically integrated 94 GHz radar backscattering (units of sr^{-1}) between 4.5 and 17 km. IWP and D_{me} are retrieved with Bayesian algorithm (Evans et al., JGR, Feb. 2002). Retrieval data base contains 400,000 cases with random profiles/cirrus properties and associated simulated brightness temperatures. Scattering properties are calculated for 7-bullet rosettes, spherical "snow" with three density formulas, and spherical "graupel" with constant density ($0.46 g/m^3$).

- Drosondes and rawinsondes are used to validate the water vapor retrievals. The algorithm to retrieve water vapor profiles is physical based, iterative scheme previously applied to the MIR (Millimeter-wave Imaging Radiometer) measurements over the frequency range of 89-183 GHz (Wang et al., JAM, September 1997). For the present case, CoSSIR data from the 220 GHz, 640 GHz, and the three 183 GHz channels are used.

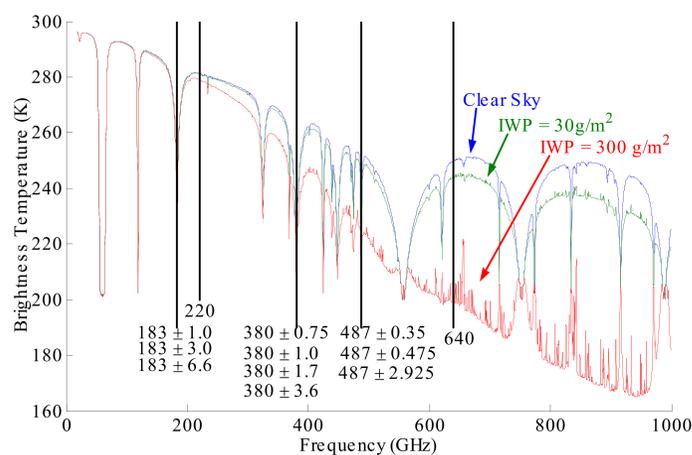


Fig. 1. Model calculations for the response of upwelling radiation to the presence of cirrus clouds for two different IWP and clear sky. The twelve CoSSIR measurement channels are indicated.

Sample Results:

- Retrievals of cirrus parameters and water vapor have been performed from selected segments of flights on July 1, 3, 7, 28, and 29.

- One sample each of the cirrus and water vapor retrievals from the flight on July 28 (flight segments are indicated in Figure 2) are chosen for illustration.

- Another sample of the cirrus retrievals was selected from the transit flight on July 1 when data from the 487 GHz channels were available.

- Retrieval results compare well with dropsonde data and CRS measurements.

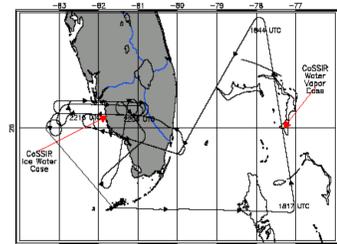


Fig. 2 ER-2 aircraft flight path on July 28, 2002. The flight segments selected for the cirrus and water vapor retrievals are highlighted.

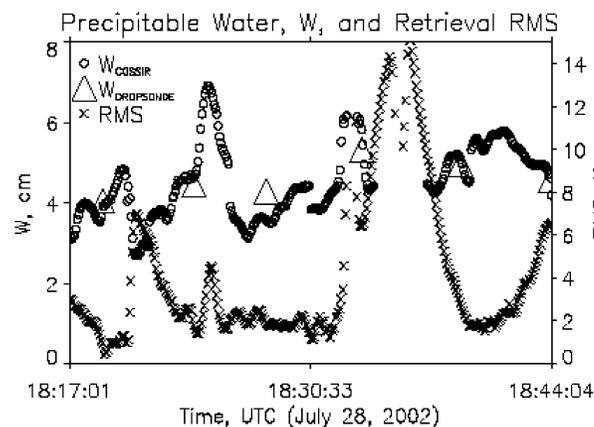
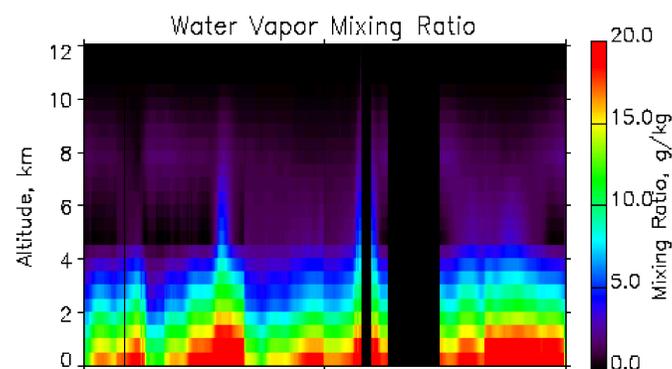


Fig. 3. Water vapor profile and precipitable water (W) retrieved from CoSSIR measurements. RMS is a measure of retrieval convergence; large RMS normally occurs in regions of dense clouds. There is a good agreement between retrieved and measured W when RMS is < 3 K.

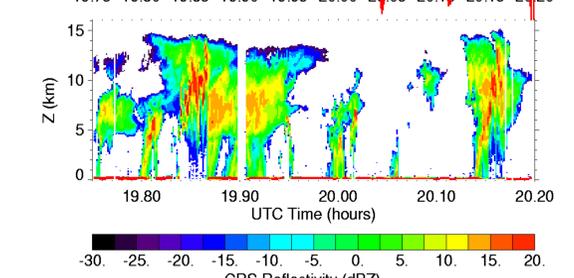
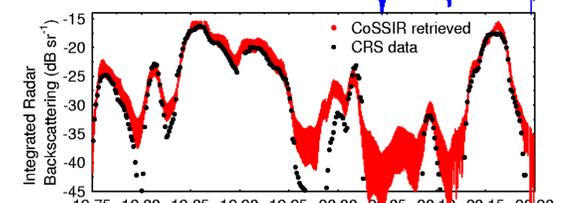
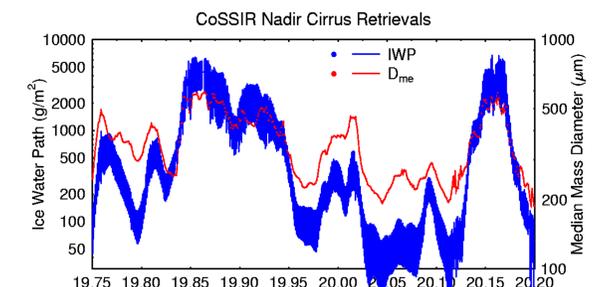
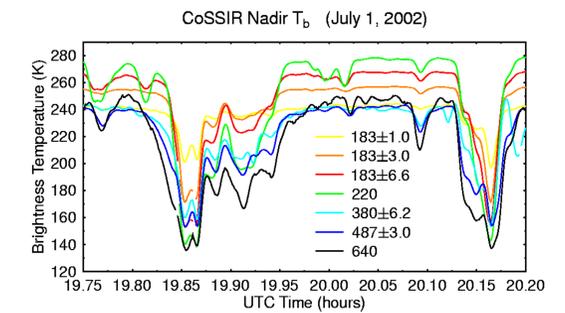
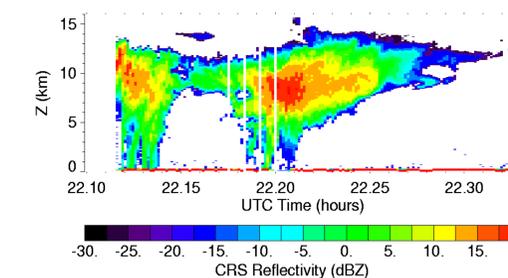
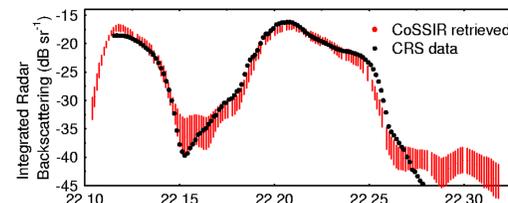
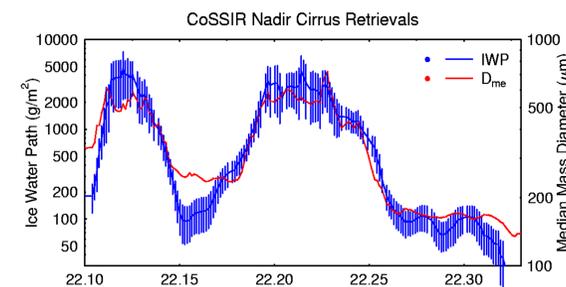
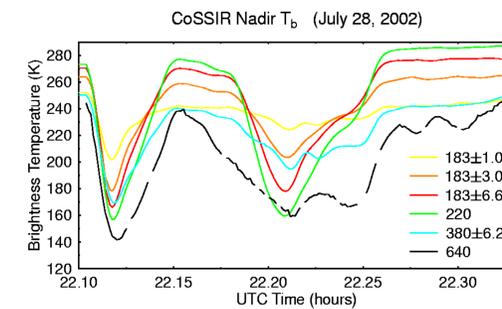


Fig. 4. The top and bottom panels are nadir measurements from CoSSIR and CRS from July 28. The retrieved IWP and D_{me} , and the comparison between the CoSSIR retrieved and CRS measured integrated radar backscattering are shown in the middle two panels. The agreement between the CoSSIR retrieved and CRS measured radar backscattering is very good.

Summary:

- The cirrus retrievals of anvil cloud ice water path and median mass particle diameter are performed with a Bayesian algorithm. The CoSSIR measurements show a better sensitivity to thin cirrus than previous measurements at frequencies < 350 GHz.

- The CoSSIR cirrus retrievals are validated with vertically integrated radar reflectivity from the CRS. The agreement is very good, usually within the error bars of 1 to 2 dB for the thick anvils.

- A reasonable agreement is obtained between the values of total precipitable water derived from the retrieved water vapor profiles and calculated from the dropsondes. Thick cirrus degrades the retrievals of water vapor profiles, because the current retrieval algorithm did not take into account wave scattering by cirrus particles.

- The cirrus retrievals used in this presentation are based upon statistics of cirrus top and bottom IWC and D_{me} obtained from 2DC cloud probe data in tropical anvils during CEPEX. Future studies will use statistics derived from the CRYSTAL-FACE data.