Cloud Properties from High Spectral Resolution Infra-Red Measurements Observed During CRYSTAL-FACE

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Overview

- NAST-I cloud property retrieval algorithm
- Current methods to derive cloud pressure from NAST-I data (MLEV and CO$_2$ slicing)
- A new algorithm to combine with MLEV and CO$_2$ slicing to improve cloud top pressure determination
Cloud mean effective diameter ($D_{\text{eff}}$) and Optical Depth Retrievals

Input parameters for retrieval:
I. Temperature and water vapor profile
II. Cloud top pressure
III. NAST-I observations between 8.5 - 12 microns

Output:
I. Cloud mean effective diameter
II. Cloud optical depth at 11 microns

• Focus: The retrievals are sensitive to errors in cloud top pressure
Cloud Pressure Determination

MLEV (Minimum Local Emissivity Variance)
Strength: Accurate for optically thick clouds
Problem: Low sensitivity to optically thin clouds

CO$_2$ Slicing
Strength: Insensitive to cloud fraction and capable of detecting thin clouds
Forward model required to simulate upwelling radiances
Problem: Optimal channels are a function of cloud top pressure
CO$_2$ Channel Selection Algorithm (CO$_2$ Sorting)

The selected clear sky CO$_2$ spectrum is sorted according to brightness temperature.
CO$_2$ Sorting: Sensitivity to Brightness Temperature

![Graph showing CO$_2$ sorting sensitivity to brightness temperature with different cloud thicknesses: High and Thick Cloud, Thinner Cloud, Low Cloud.](image)
CO₂ Sorting: CRYSTAL July 3rd 2002

MLEV vs. CO₂ Sorting

CPL Cloud Top Altitude
Cloud Altitude Frequency of Occurrence
3 July, 2002 1600 - 1810 UTC
Summary

• Accurate cloud top pressure is critical for accurate retrievals of $D_{\text{eff}}$ and optical depth (see Shaima Nasiri’s poster)

• Demonstrated a new algorithm which uses the sorted CO$_2$ spectrum. CO$_2$ sorting shows promise for cloud top pressure retrievals and for choosing optimal CO$_2$ slicing channel pairs.
Future Work

• Reduce cloud top altitude bias
• Apply to more data: AERI (ground-based) and AIRS (satellite-based)
• Use CO$_2$ sorting to choose CO$_2$ slicing channel pairs.
• Apply the sorting algorithm to the H$_2$O band.
• Combine CO$_2$ sorting, CO$_2$ slicing, and MLEV.
Particle Size and Optical Depth Retrieval Procedure

- The retrieval is based on the comparison between simulated and observed radiances
- Simulated radiances are computed for 18 micro-windows between 8.5 and 12 µm
- The cirrus scattering calculations are based on three-dimensional randomly oriented ice columns assuming 6 different particle size distributions
- Multiple scattering calculations are performed for 26 different optical thicknesses between 0 and 20
MLEV: Solving Equation

\[
\eta(\nu) = \frac{R^{ob}(\nu) - R^{cl}(\nu)}{R^{cd}(\nu, p_c) - R^{cl}(\nu)}
\]
Retrieval Uncertainties

- Particle shape
  - Retrieval assumes pristine columns in the simulated data. Plans underway to include other habits, e.g., bullet rosettes
- Particle size distribution
  - Plans are underway to include more expanded set of size distributions in the form gamma distributions (Heymsfield et al. 2002)
- The retrievals are sensitive to errors in cloud top pressure
Cloud Particle Size and Optical Depth Retrieval

Band 1 Particle Size

Band 2: Particle Size
Particle Size and Optical Depth July 3\textsuperscript{rd} 2002

Optical Depth Retrieval 1710 - 1735 UTC

Particle Size Retrieval 1710 - 1735 UTC
The PS and OD Retrieval Sensitivity to Cloud Height