Investigation of cloud properties using a Raman lidar

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NASA/GSFC Raman Group Presentations

- "Holographic Optical Element Raman Lidar" - Berkoff
- "A new Raman water vapor lidar calibration technique and measurements in the vicinity of Hurricane Bonnie" - Evans
- "Research efforts in the absolute calibration of a Raman water vapor lidar" – Whiteman
- "Simulated performance of an airborne Raman water vapor lidar" – Whiteman
- "Raman Lidar observations of lifting at a convergence line" - Demoz

Outline

- Introduction
- Raman Lidar cloud measurements
  - Warm clouds
    - Liquid water, droplet radius, number density
  - Cold (cirrus) clouds
    - Corrected optical depth, extinction/backscatter ratio, particle radius
- Influence of cirrus on satellite radiances and retrievals

Introduction

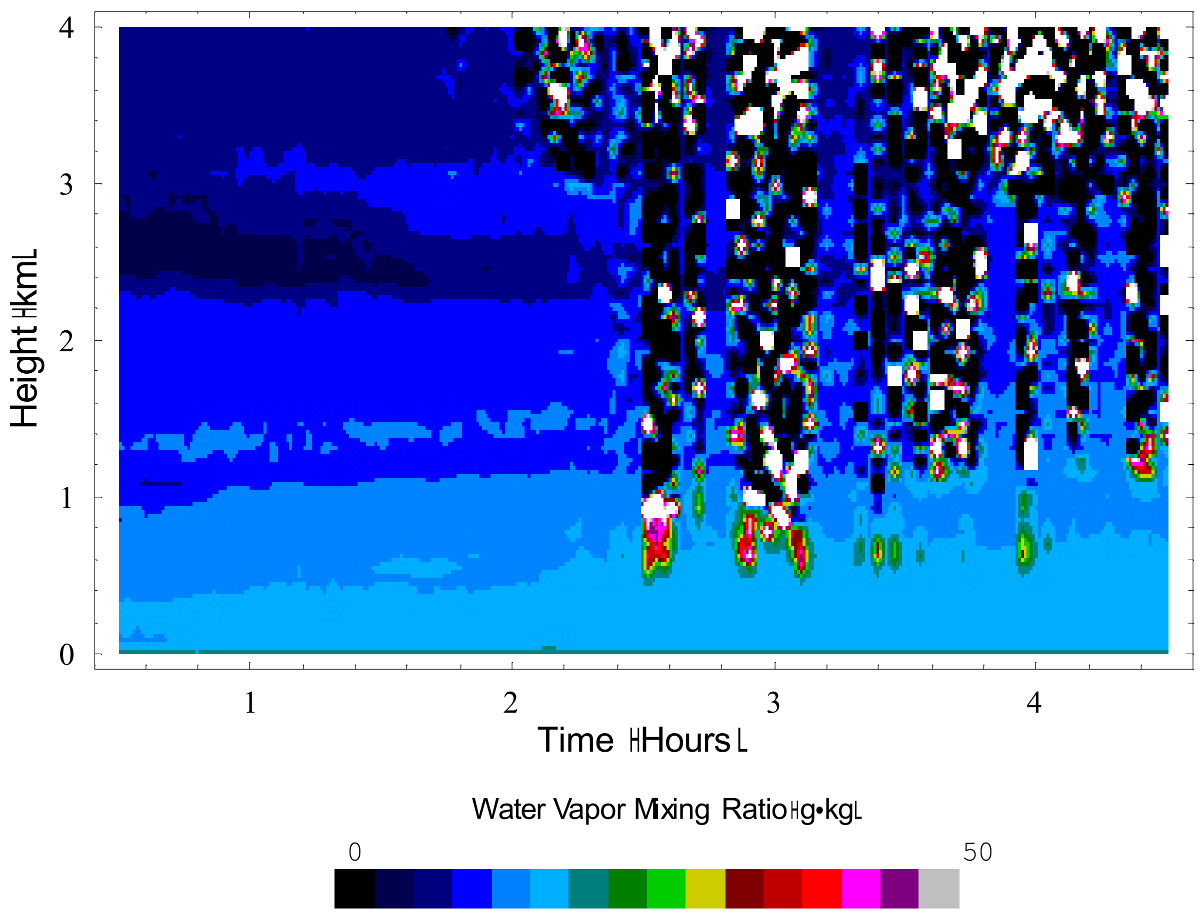
- Clouds play a major role in determining the balance between incoming shortwave radiation and outgoing longwave radiation.
- Inaccuracies in cloud measurements and modeling are currently the largest source of error in global climate modeling.
- Raman lidar offers a wide measurement capability that can be used to measure key cloud properties more accurately

NASA/GSFC Scanning Raman Lidar (SRL)

- Single trailer mobile system
- Two lasers: XeF excimer, Nd:YAG
- 0.76 meter telescope
- Full aperture scanning capability
- Day and night measurements of water vapor, aerosols, clouds
- All weather operations

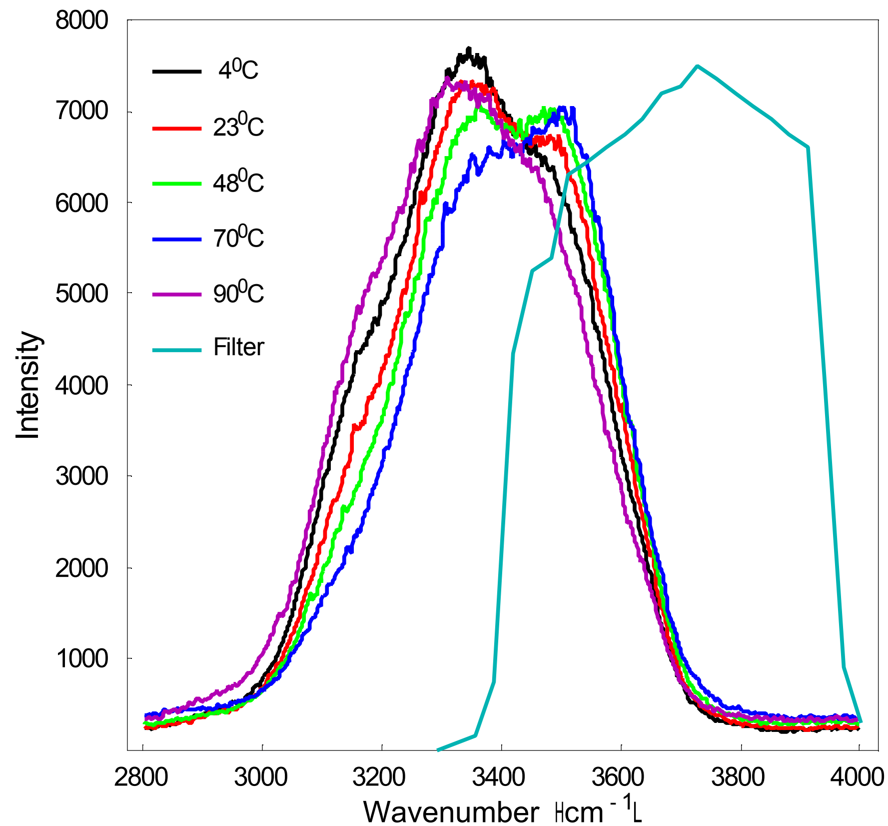
SRL on location at Andros Island, Bahamas for the third Convection and Moisture Experiment (CAMEX-3)

Cloud liquid water measurements at Wallops Island, VA September, 1995

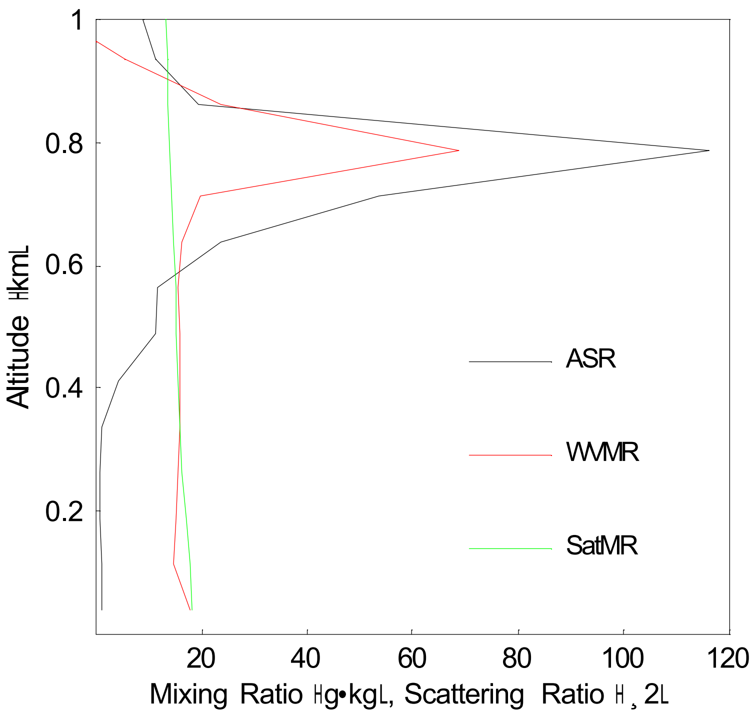


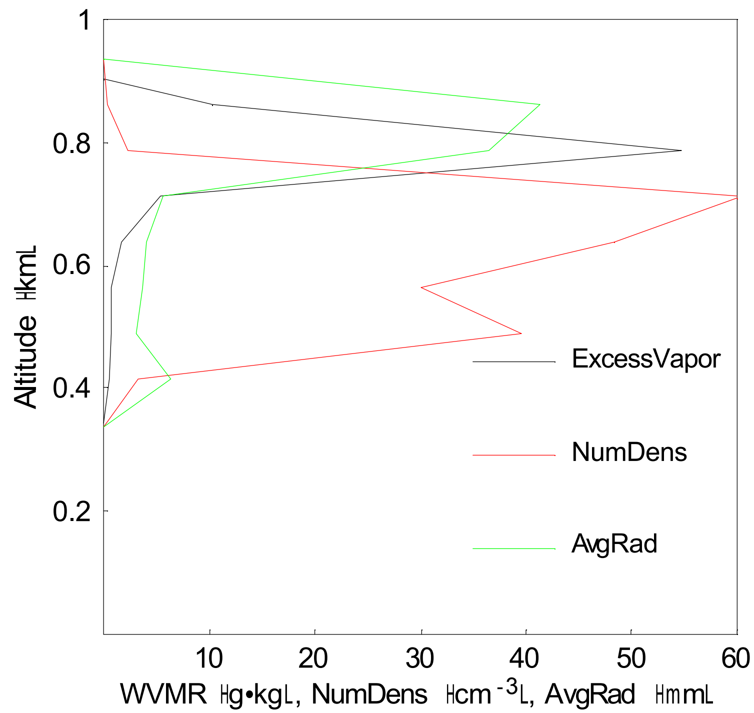
Raman Lidar measurements of cloud liquid water (*J. Geophys. Res., 1999:* 104, 31411- 31419)

- Raman scattering is proportional to the liquid water content
- Liquid spectrum overlaps the vapor spectrum
- Liquid component is that which exceeds the saturation mixing ratio
  - Separation of signals sensitive to local temperature
  - Need a calibration of the liquid component



Cloud droplet radius and number density retrievals

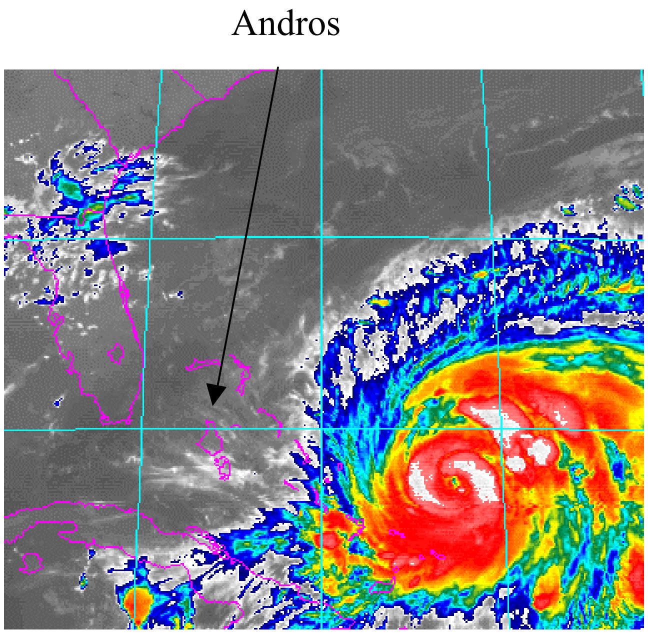




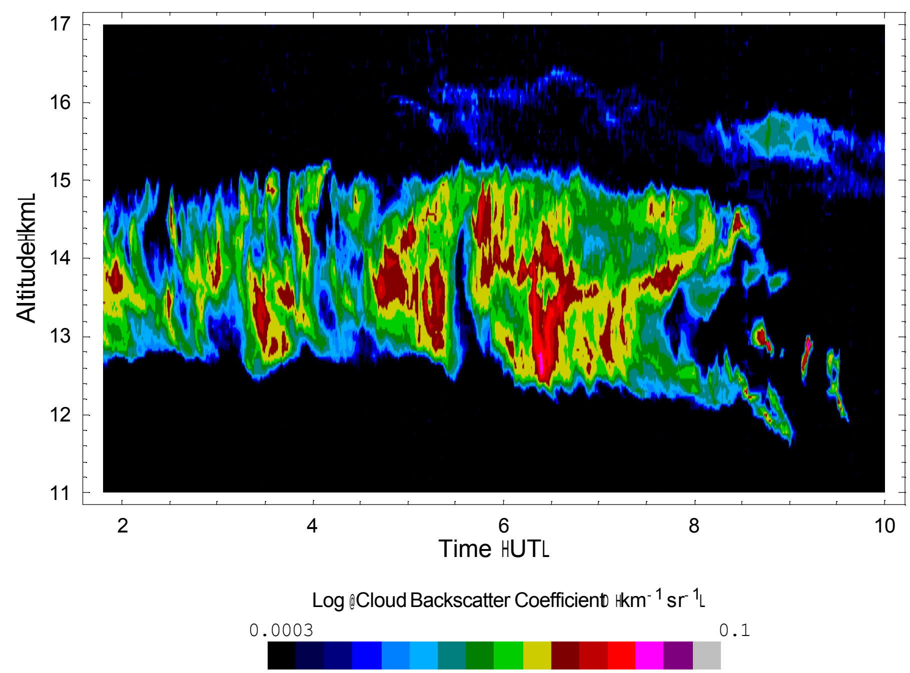
Raman Lidar characterization of liquid clouds

- Stable, single valued solution
- Not influenced by multiple scattering, temperature of cloud
- Retrievals limited to the bottoms/tops of clouds (300-500m)
- Improved technique is to measure the liquid and vapor components separately
- Simultaneous profile measurements of
  - cloud backscatter coefficient
  - cloud liquid water content
  - cloud droplet average radius
  - droplet number density
  - aerosol extinction and backscatter below cloud

Hurricane Bonnie Induced Cirrus Cloud August 23, 1998



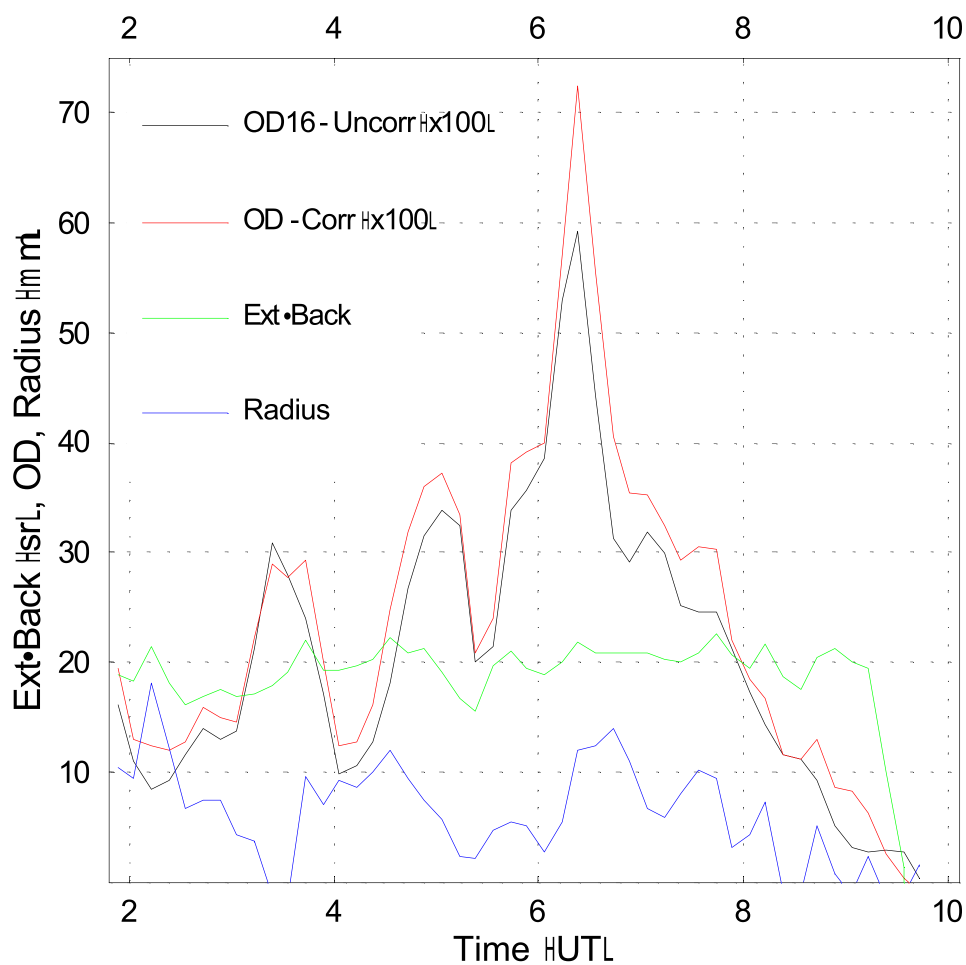
GOES infrared image



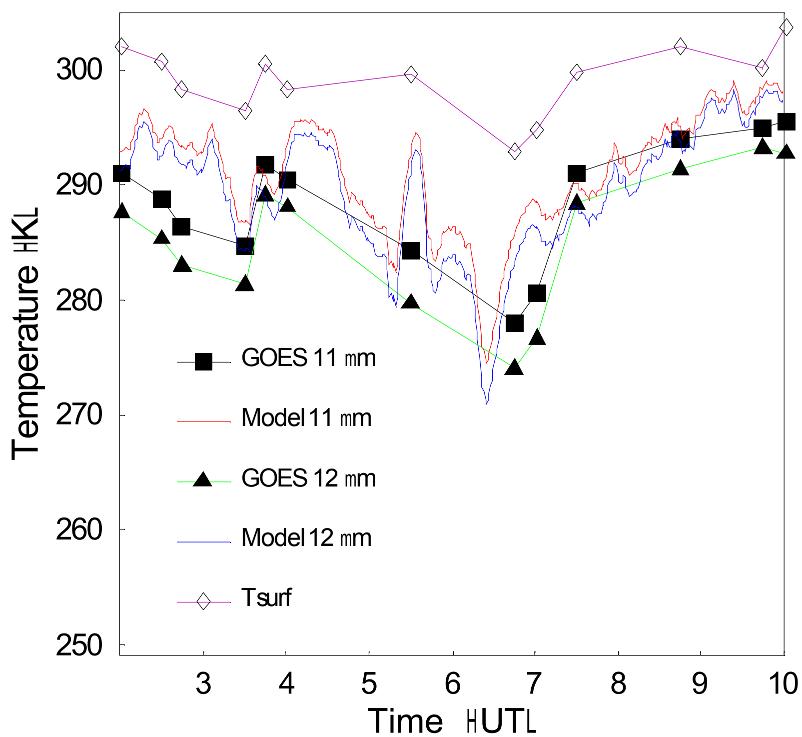
Cirrus cloud backscatter coefficient

Cirrus Retrieval Technique

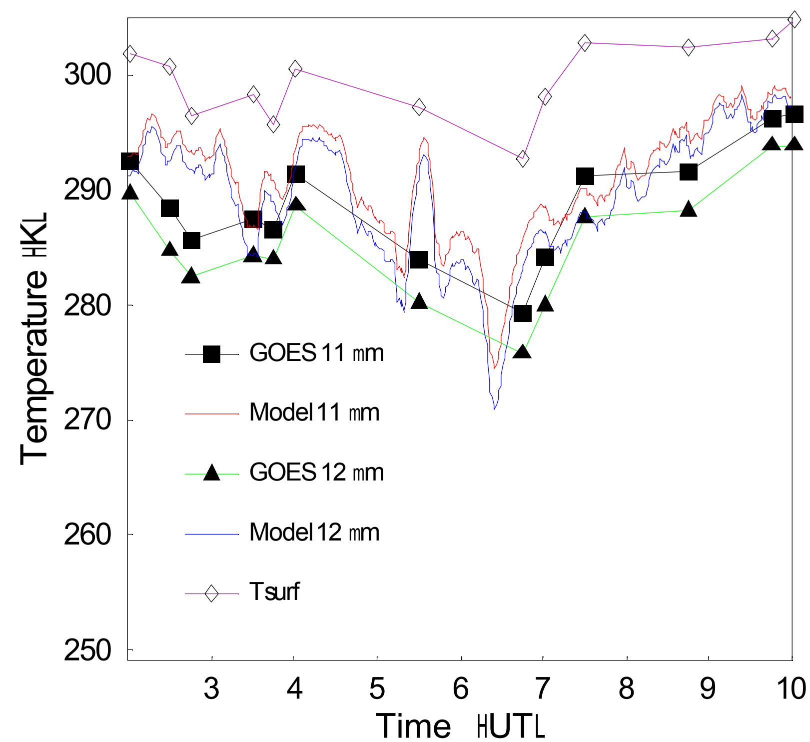
- An iterative solution was developed for the following:
  - multiple scattering in the cloud
  - layer average extinction/backscatter ratio
  - layer average diffraction equivalent particle radius
- Now the influence of cirrus clouds on satellite measurements can be studied.



Model and GOES Radiances
Retrieved T_{surf}

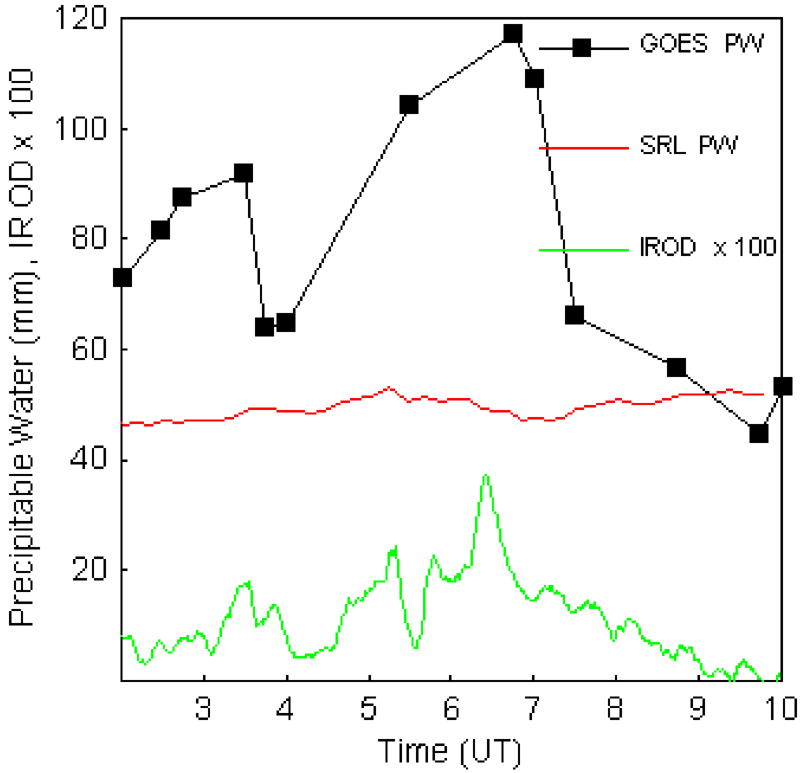


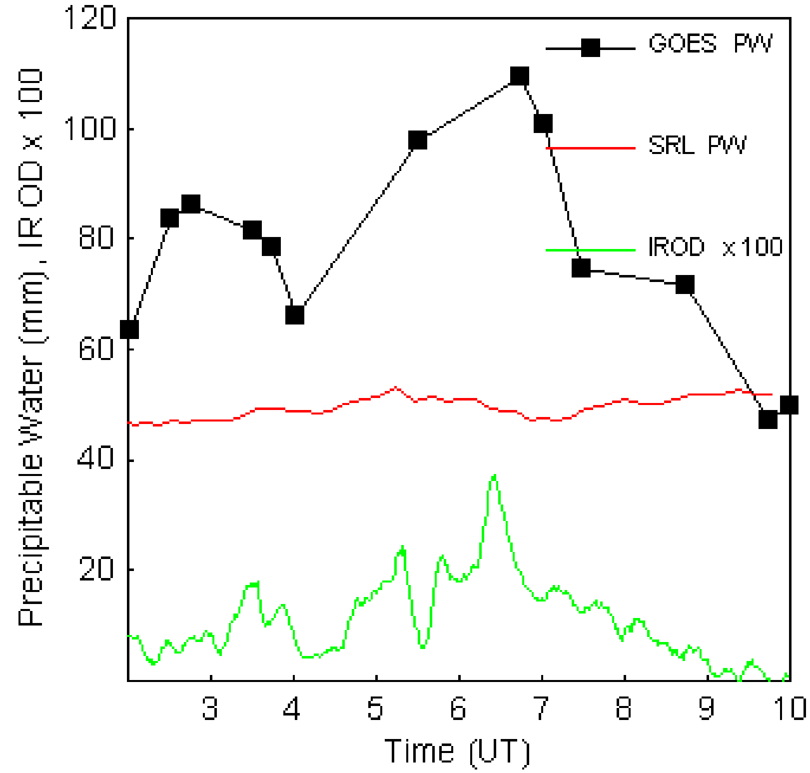
GOES pixel over the SRL site



GOES pixel over the ocean

SRL-Measured and GOES-Retrieved Total Precipitable Water





Cirrus influence on satellite radiances

- GOES is sensitive to cirrus at the > 0.005 optical level
- EOS Science plan (King et al, 1999) indicates that EOS sensors need to be able to detect cirrus down to the 0.05 level
  - if the EOS satellites discriminate clouds with this sensitivity there can be significant influence due to undetected cirrus
- ISCCP cirrus detection threshold implies errors in GOES TPW retrievals due to undetected cirrus
  - up to 20% over water (OD ~ 0.05)
  - up to 40% over land (OD ~ 0.1)

Summary

- A broad suite of Raman Lidar measurements in liquid clouds is possible
  - Studies of fundamental cloud processes
- MS influence on cirrus optical depth can be corrected
  - Extinction/backscatter
  - Diffraction equivalent particle radius
- GOES radiances and retrievals are influenced significantly at OD well below detectable level
  - high bias in retrieved TPW

Multiple Scattering in Cirrus Clouds

- Second and third order multiple scattering are simulated for 5 and 20 micron radius particles
- Notice that the influence of multiple scattering decreases with altitude above the most intense portion of the cloud.