Mesoscale Raman Water Vapor Lidar Network Concept

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Outline

- Review current state of Raman water vapor lidar technology
  - operational research systems (CARL)
  - research systems (SRL, HURL)
- Calibration
- Daytime and nighttime error characteristics
  - random error statistics
- Concept of a network of automated, eye-safe Raman water vapor lidars for mesoscale studies
  - cost
  - data assimilation activity

Raman Water Vapor Lidar Systems

- U. S. DOE CART Raman Lidar (CARL)
  - 0.6 m telescope (0.3 mrad FOV)
  - 3.5 A water vapor filter
  - UV (~10-12W) water vapor, aerosol, clouds
  - Eye-safe, automated
  - Operational since 1996
  - **Photon counting only requires signal attenuation during the daytime (currently being upgraded)**
- NASA/GSFC Scanning Raman Lidar (SRL)
  - 0.75 m telescope (0.25 mrad fov)
  - 2.5 A filter
  - UV (~8-10W) water vapor, aerosol, clouds
  - Being converted to eye-safe, automated (expected spring, 2005)
  - Operational since 1991
    - But consistently upgraded
  - **Photon counting and analog detection**
    - **No signal attenuation**
    - **~x10 increase in water vapor signal**

Southern Great Plains
Lamont Oklahoma

Deployed in western Oklahoma for IHOP

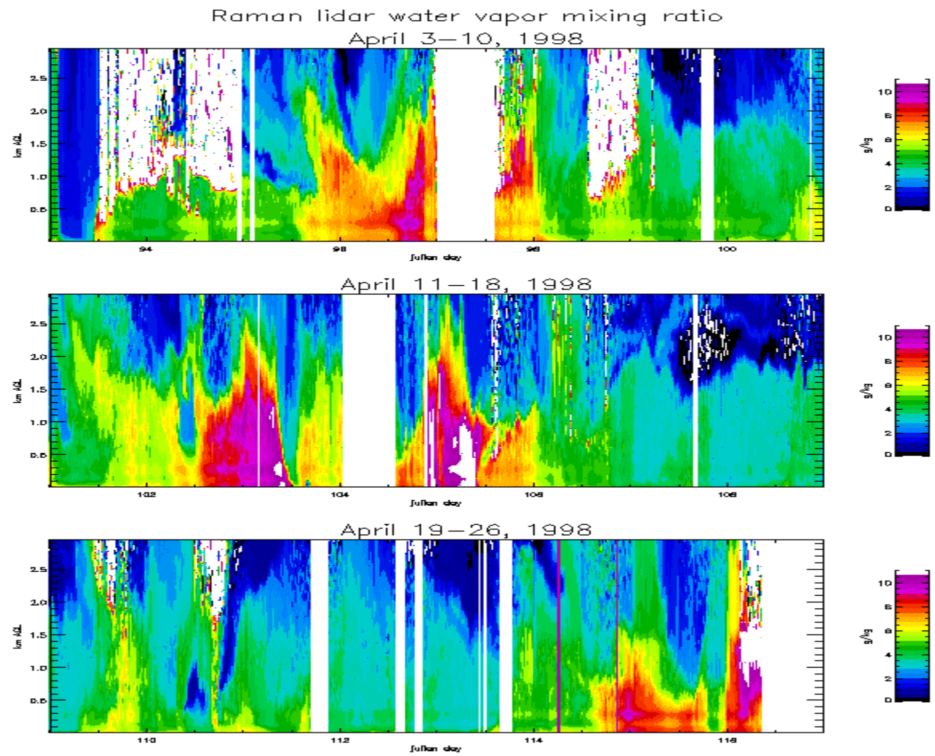
Data Examples

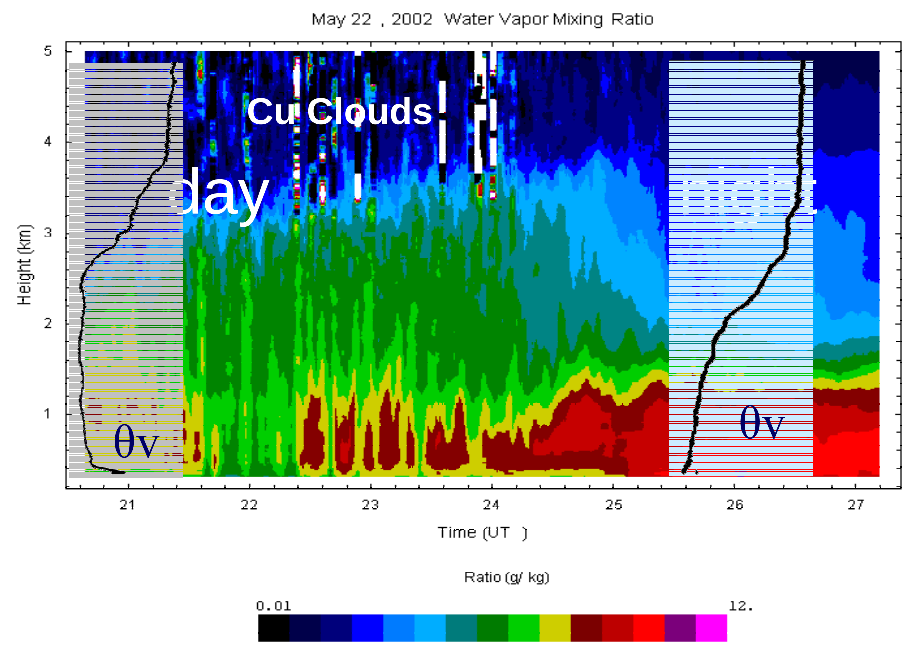
CARL

- Three weeks of 10 minute resolution water vapor mixing ratio measurements
- acquired with 1/10 full water vapor signal in the daytime!

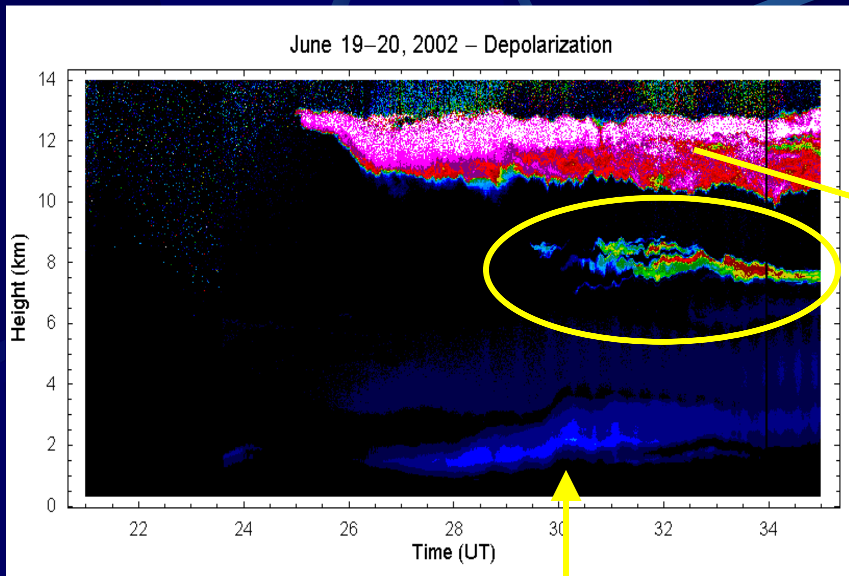
SRL

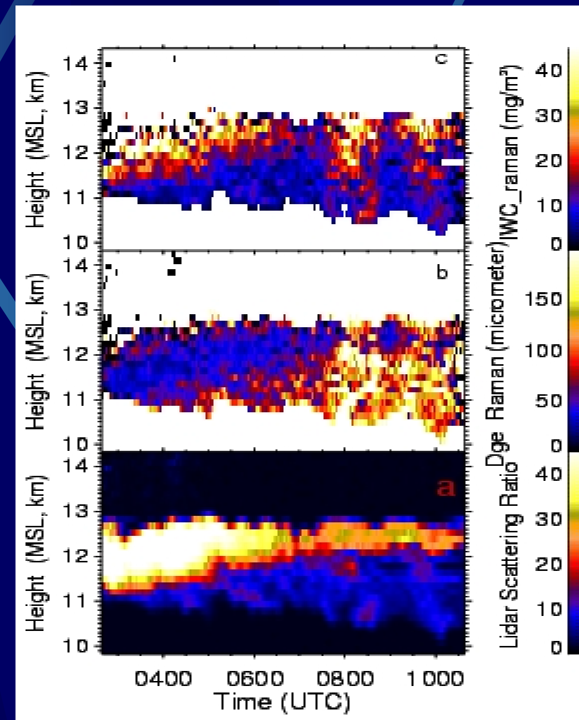
- Dryline passage on May 22, 2002 during IHOP
- ~2 minute temporal and 60 – 200 m spatial resolution
- Random Error
  - Daytime: less than 10 % in boundary layer
  - Nighttime: less than 10% to beyond 6 km

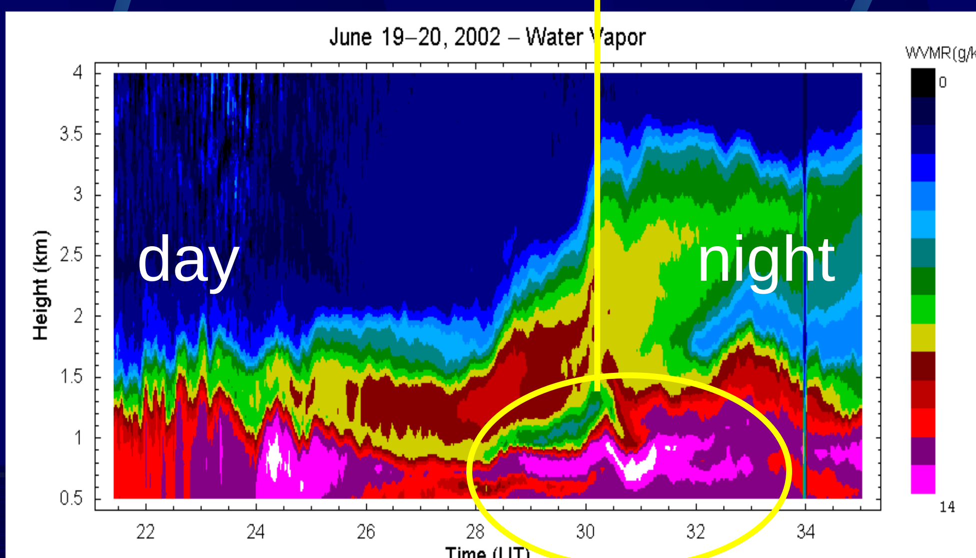




June 19-20, 2002





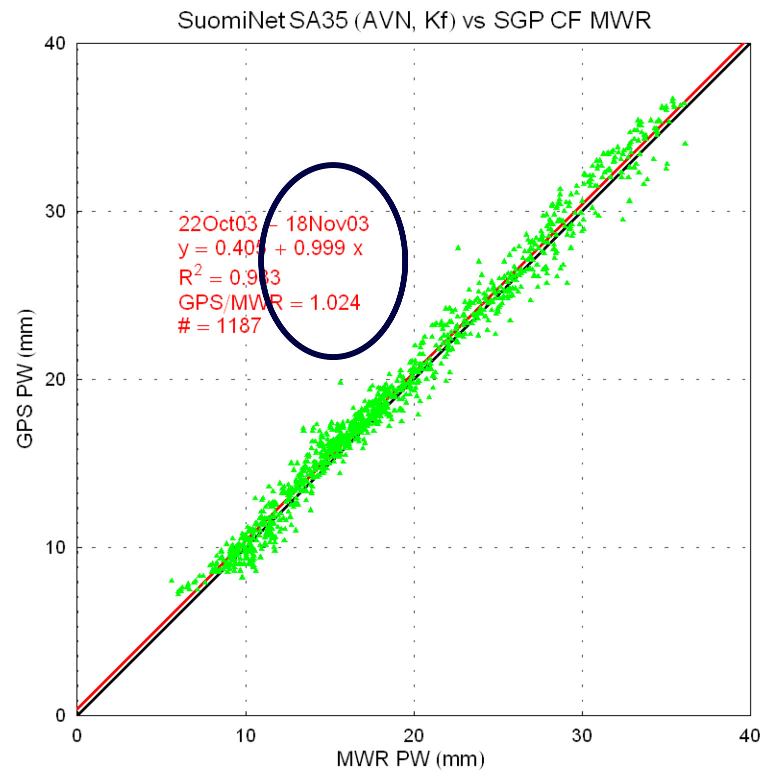


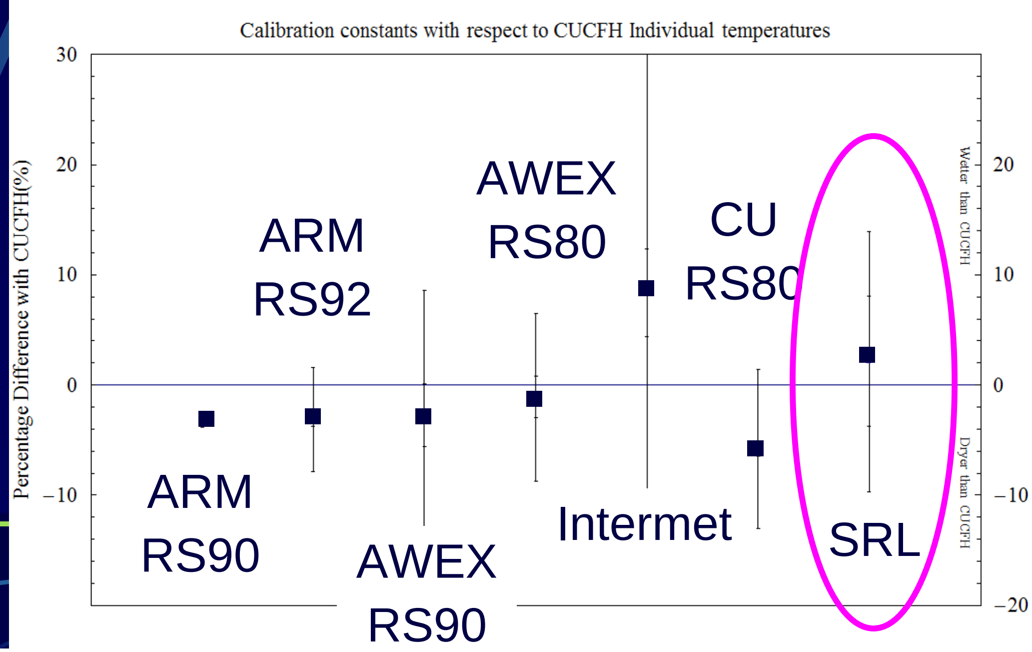
Cirrus Cloud Ice Water Content and Particle size Retrievals

Wang et. al., GRL, August, 2004

Calibration and Intercomparison Results

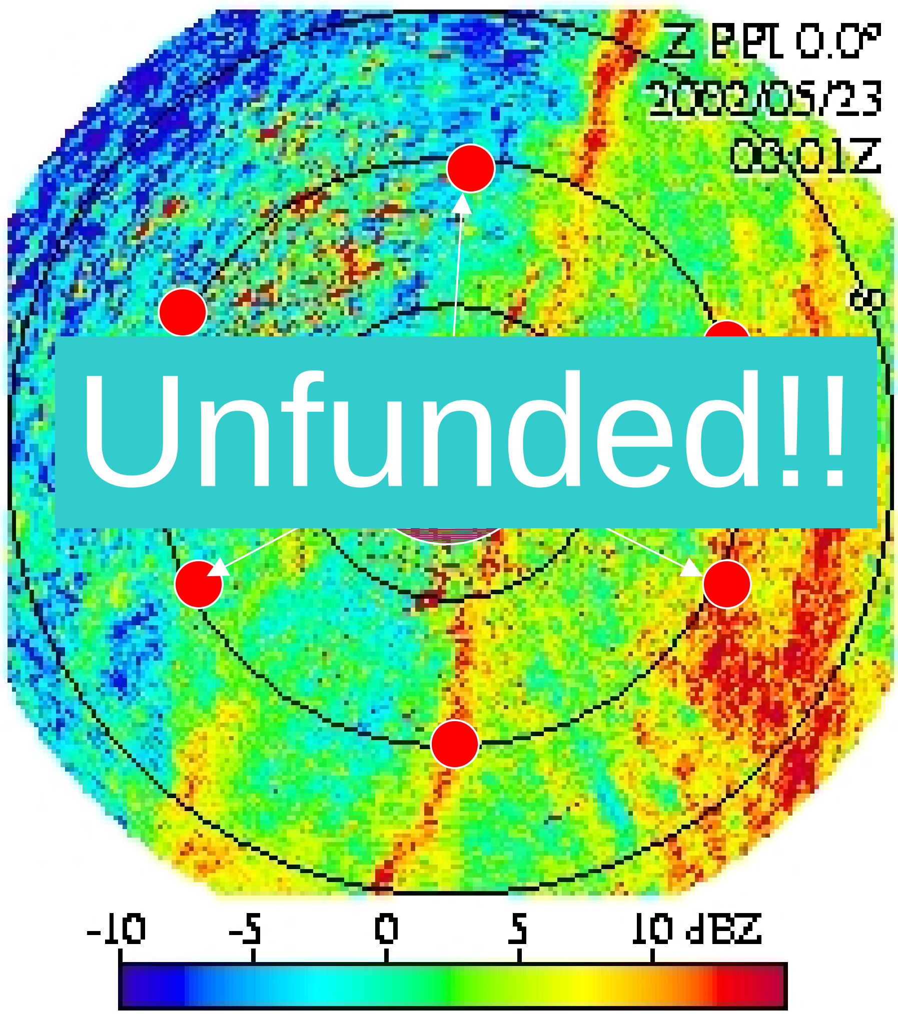
- Absolute calibration is straightforward
  - Limited by cross section uncertainty (10%)
- SRL mobile calibration source (SuomiNet GPS) agrees within 2% of DOE ARM water vapor standard
  - Day and night IHOP calibration agree within 1%
- IHOP (2002) tropospheric profile comparisons
  - <5% mean bias with respect to LASE in lowest 4 km
  - <5% mean bias with respect to Chilled Mirror Hygrometer (SnowWhite) in lowest 6 km
- AWEX (2003) upper tropospheric comparisons
  - Mean PW between 7km – troposphere agrees within 2% of CU-CFH cryogenic frostpoint hygrometer
- Long-term stability
  - CARL calibration +/-3% over more than 1 year





Data Assimiliation Study
Dryline May 22, 2002

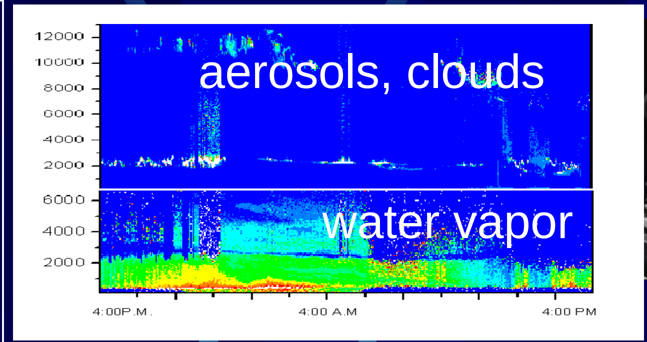
- Use data assimilation techniques to study the impact of different water vapor lidar systems on mesoscale modeling
- Use a high-resolution mesoscale model to “predict” the measurements of lidar systems
  - Scanning DIAL
    - Unprecedented precision, technology heading to space
  - Networked Raman
    - Much lower resolution, ground and airborne only
      - Automated, eye-safe, lower cost
- Nudge the initial conditions and re-run the model
  - Study how well different measurement systems constrain the model predictions

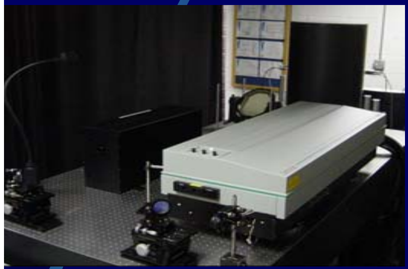


22 May IHOP2002 dryline: illustrating the scales of interest. Scanning water vapor lidar (30km diameter) is placed at the center surrounded by profiling continuous Raman lidars.

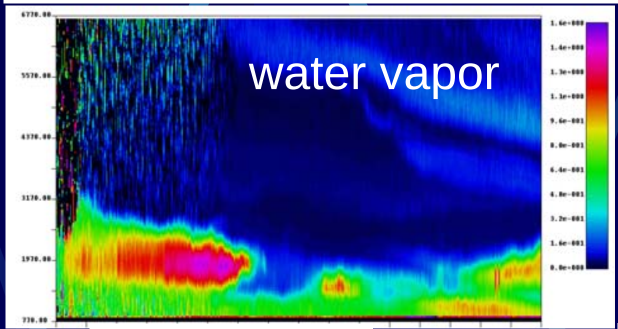
Smaller systems – what do they cost?

Howard University Raman lidar (Beltsville, MD)
- 0.5 m telescope, 10-12 W laser (355 nm)
- water vapor, aerosol, eye-safe
- ~ equivalent to the SRL for water vapor
- hardware cost: <$250,000

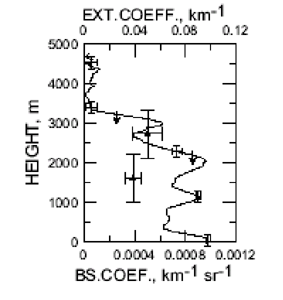




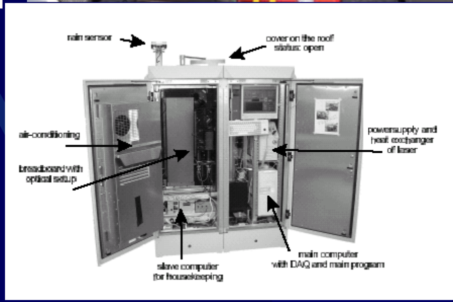
UNIBAS Raman lidar (Potenza,Italy)
- 0.4 m telescope, 5 W laser
- water vapor, aerosol
- hardware cost: ~$100,000



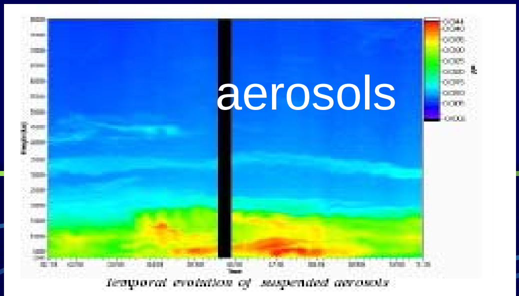
IfT "Polly"
- 0.2 m telescope, 2 W laser
- automated (internet!), weather-proof
- hardware cost: ~$100,000



aerosol extinction



Raymetrics (Athens, Greece)
- 0.4-0.5 m telescope, 1-3 W laser
- water vapor, aerosol
- "automated", weather-proof
- delivered cost – $200 – $400k



The next steps

- Develop water vapor performance specifications for the various small Raman lidar options
  - Include solar blind possibilities possibilities
    - Diode-pumped, micropulse laser available now
- Perform model assimilation study to determine “optimum value” network configuration
- Design “optimum value” Raman lidar system
- Try to get funded!

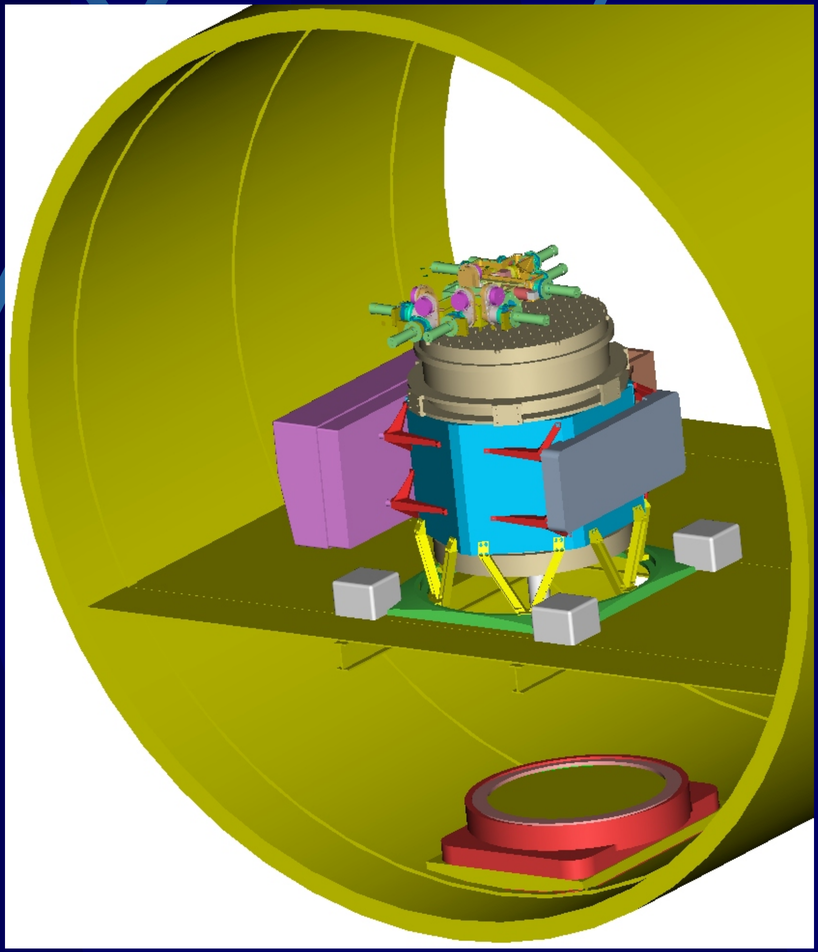
Summary

- Raman water vapor lidar is a mature technology with ability to quantify boundary layer convective variation
- Systems can be made automated and eye-safe for moderate cost
- Is the idea of a network of such systems a “good value” for mesoscale research?

Raman Airborne Spectroscopic Lidar (RASL)

- Water vapor mixing ratio
- Aerosol backscatter, extinction, depolarization
- Research mode
  - Cloud liquid, ice water
  - CO_2
- Eye-safe beyond 500m
- Compatible aircraft
  - P-3
  - DC-8
  - Dash-7
- Being configured for first flight
  - Spring 2005

RASL during lab testing

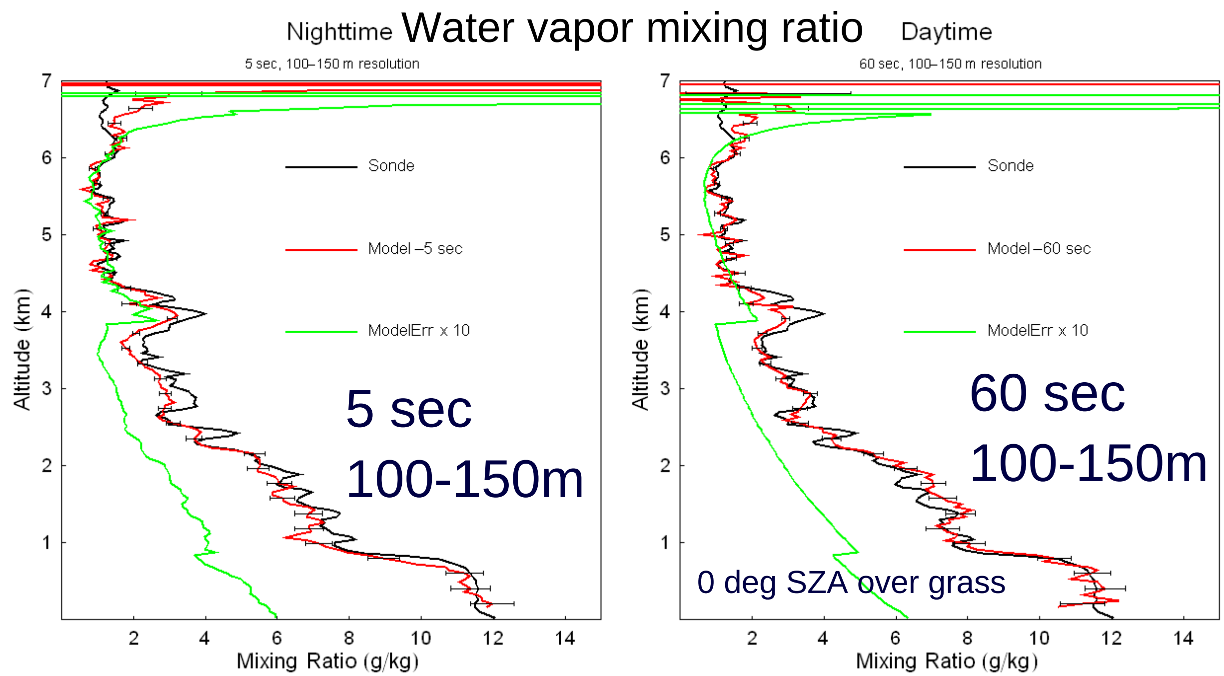


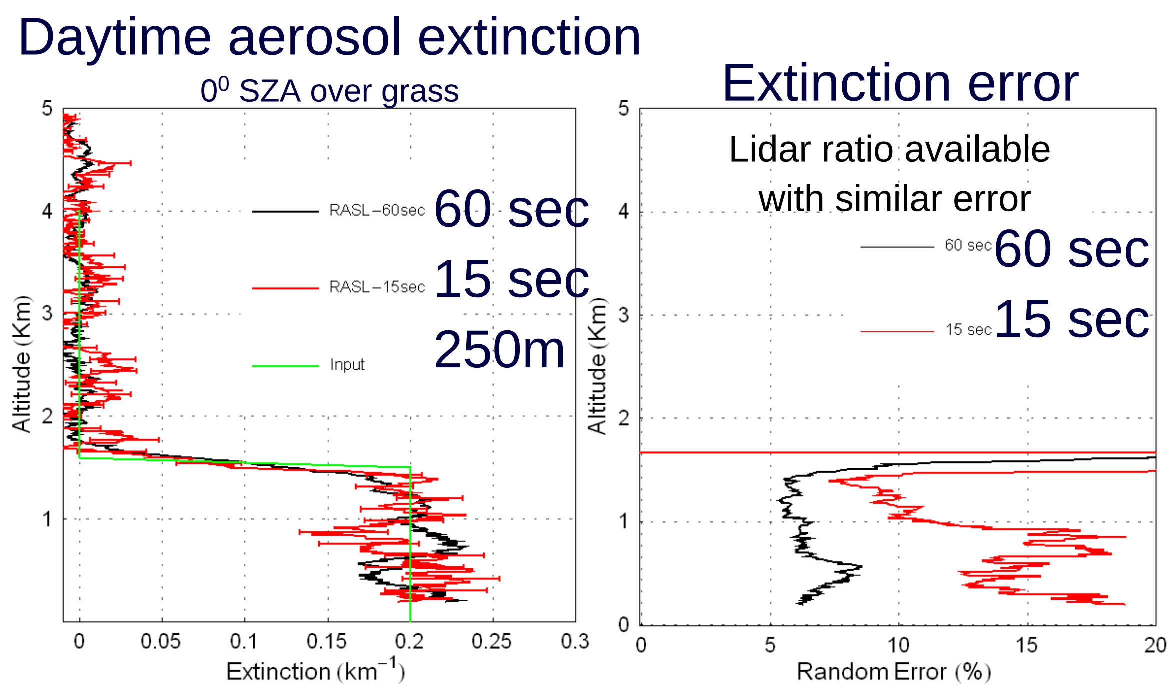
Concept of RASL in the P-3

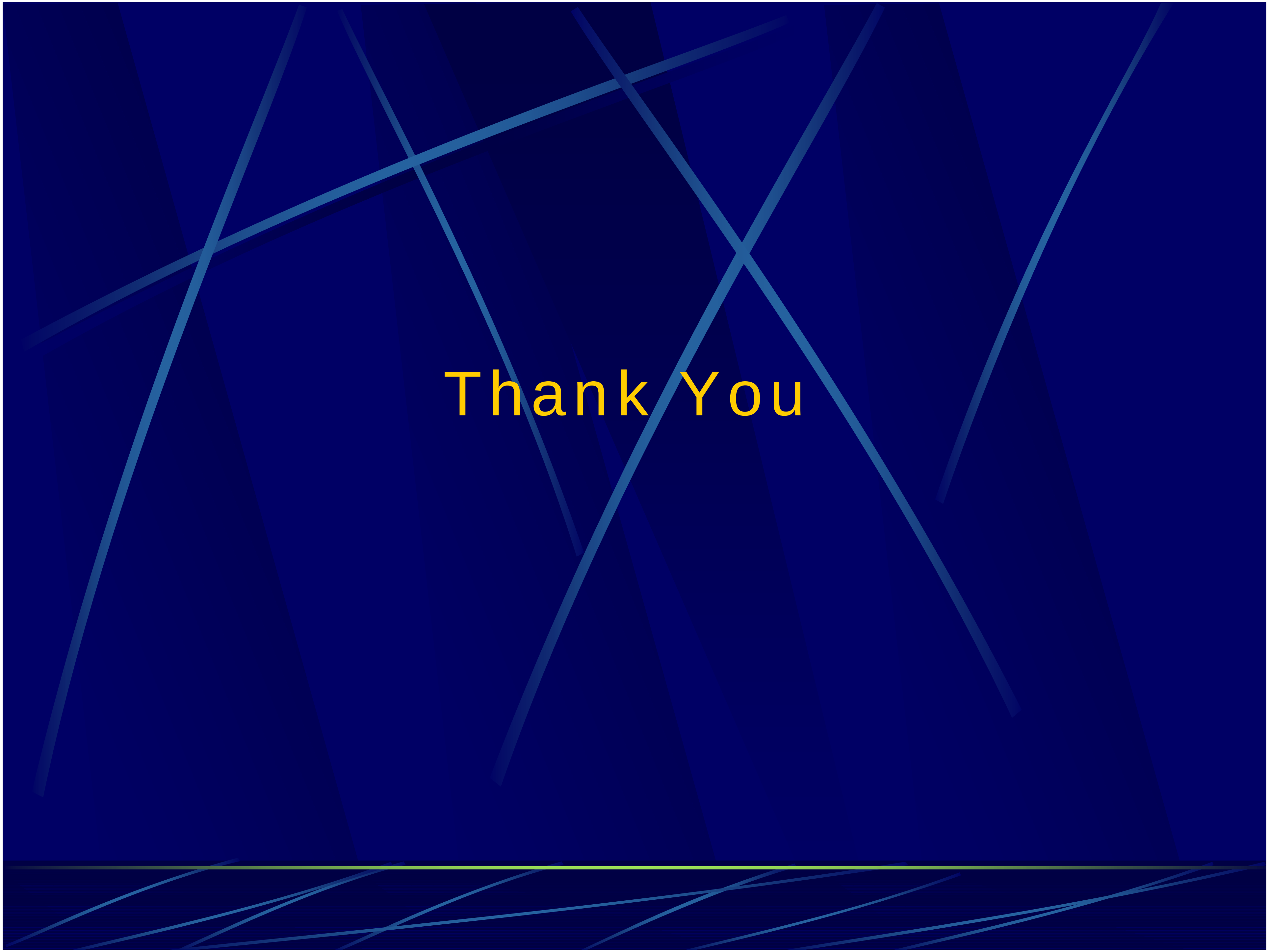
RASL Airborne Simulations

- Quantities
  - Water vapor mixing ratio
  - Aerosol extinction
    - A surrogate for cloud CCN?
- Simulated parameters
  - Flight altitude 7 km
  - Averaging time
    - Nighttime-5 sec
    - Daytime-15,60 sec
- Errors
  - 5-10% (20%) for both water vapor and aerosol extinction

Appl. Opt. 40 (3), 375-390 (2001)






Thank You