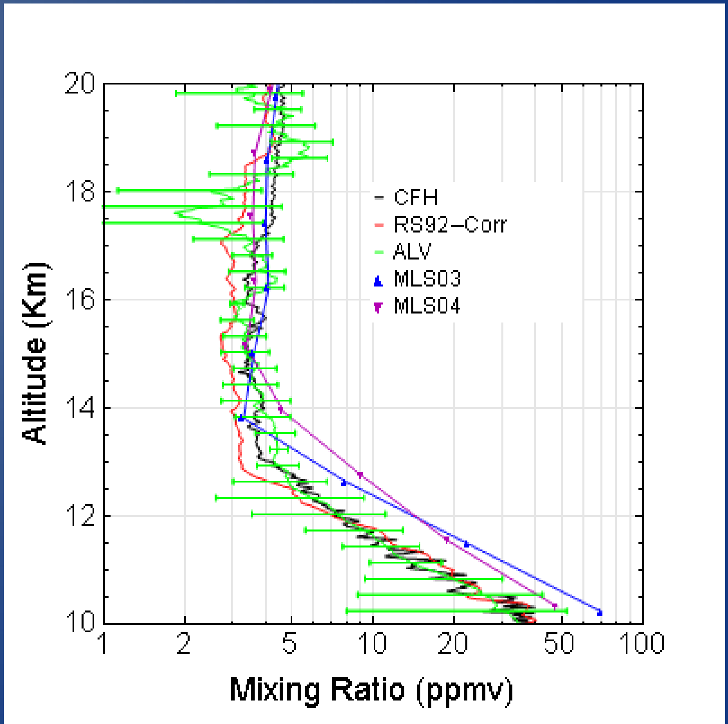
Anticipated climatic trends in atmospheric water vapor, the challenge of measuring them and possibilities for NDACC/GRUAN Collaboration

D. N. Whiteman, L Oman, NASA/GSFC
K. Vermeesch, SSAI

ALVICE on location at Table Mountain Facility for MOHAVE_2007



UT/LS Water Vapor measurements from N-WAVES_2009

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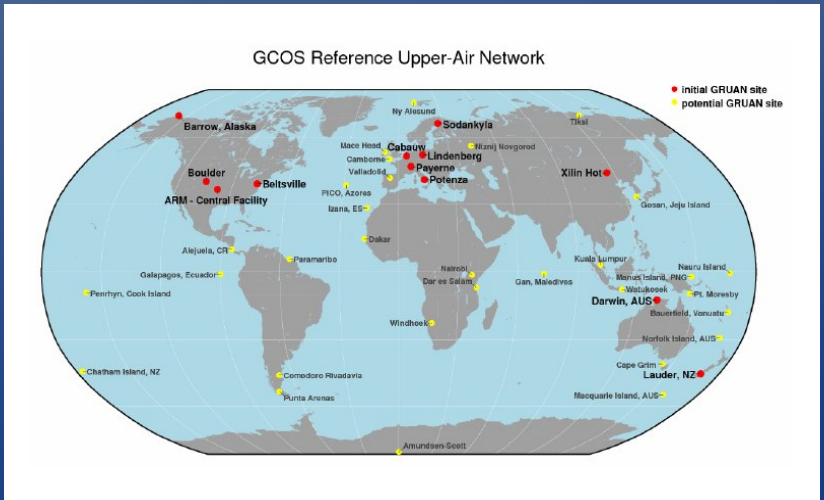
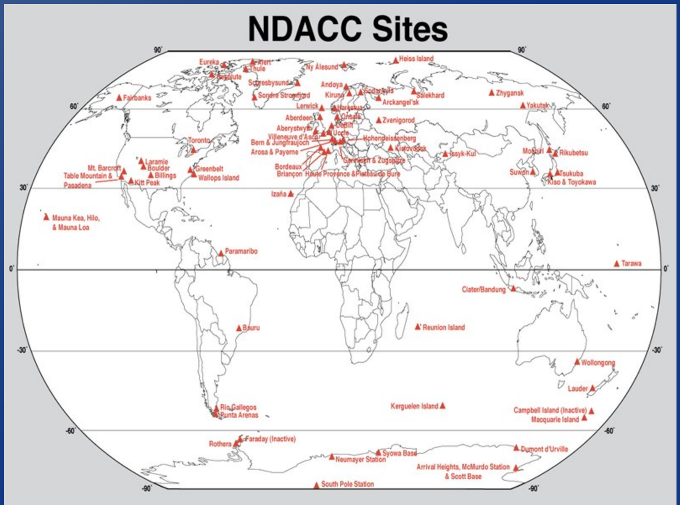
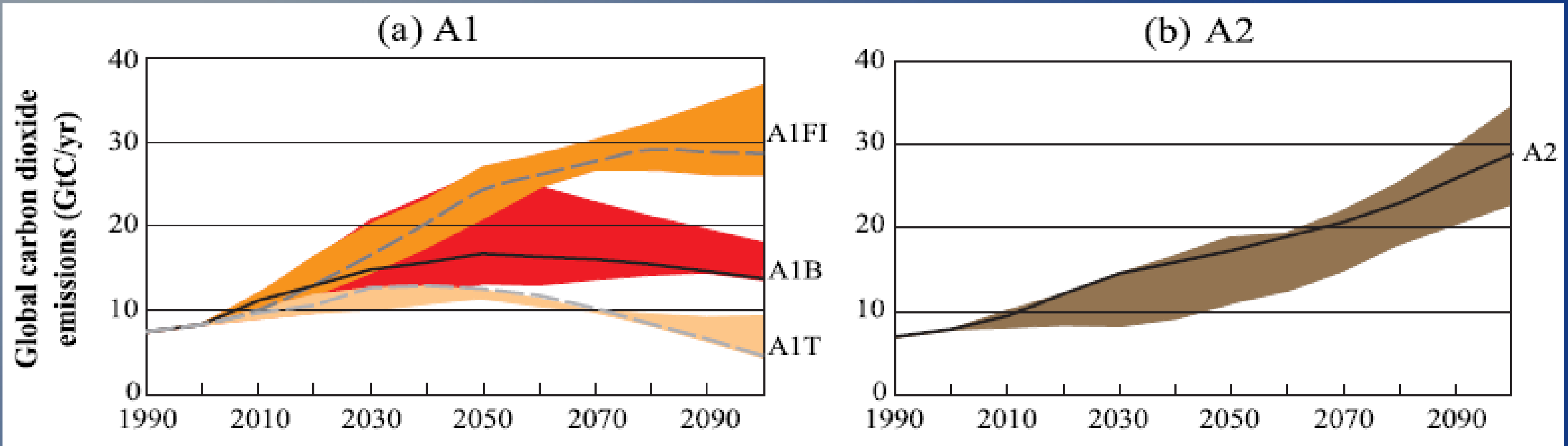
Overview

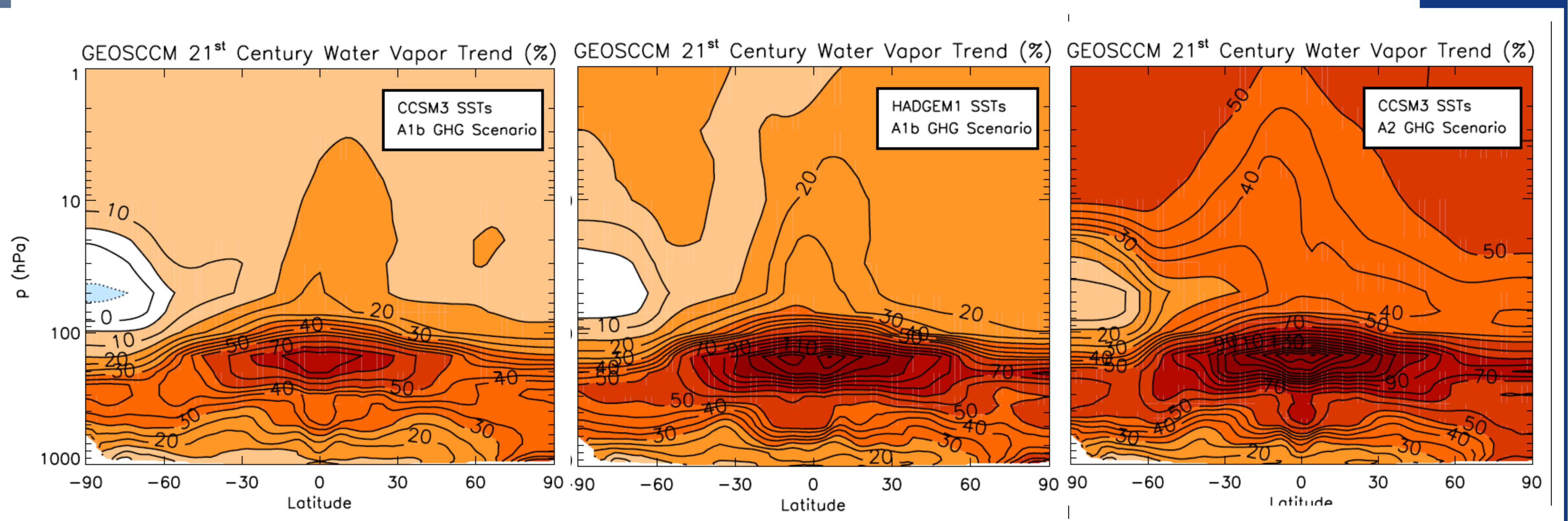
- Networks for monitoring water vapor
  - NDACC
    - lidar monitoring
  - GRUAN
    - Balloon-borne sensors
- What are the anticipated trends?
- What are the measurement requirements
  - How long will it take? (preliminary...)





Simulations of future water vapor concentrations





Can we validate these predictions?

- Long term climate monitoring with sufficient data quality needed to test the predictions of the model
- How long a time series is needed?
- What is the quality of the data required?

GRUAN Priority 1 Measurement Requirements

Variable	Temperature	Water Vapour	Pressure
Priority (1-4)	1	1	1
Measurement Range	170 – 350 K	0.1 – 90000 ppmv	1 –1100 hPa
Vertical Range	0 – 50 km	0 to ~30 km	0 – 50 km
Vertical Resolution	0.1 km (0 to ~30 km) 0.5 km (above ~30 km)	0.05 km (0 – 5 km) 0.1 km (5 to ~30 km)	0.1 hPa
Precision	0.2 K	2% (troposphere) * 5% (stratosphere)	0.01 hPa
Accuracy	0.1 K (troposphere) 0.2 K (stratosphere)	2% (troposphere) * 2% (stratosphere)	0.1 hPa
Long-Term Stability	0.05 K *	1% (0.3%/decade) *	0.1 hPa
Comments	*The signal of change over the satellite era is in the order of 0.1–0.2K/ decade (cf. section 3.1), therefore long-term stability needs to be an order of magnitude smaller to avoid ambiguity	*Precision, accuracy and stability are relative with respect to mixing ratio	

Source: GCOS - 112

“For some variables, such as upper-tropospheric and lower-stratospheric water vapour, this may not immediately be possible to the specified requirements, although some research instruments show considerable promise. Nevertheless, having active sites and commitment should motivate manufacturers to meet these requirements with new instrumentation that would be field-tested and validated before being used in an operational context.”

How long does it take to reveal a trend?

- Use the statistical aproach discussed in Weatherhead et. al., JGR, 1998

$$Y = \mu + \omega T + N$$

μ constant term

ω trend

T time (months)

N noise

$$n^* \approx \left[\frac{3.3\,\sigma_N}{|\omega_0|} \sqrt{\frac{1+\phi}{1-\phi}} \right]^{2/3}$$

n^* the number of years

ω_0 trend magnitude

σ_N standard deviation

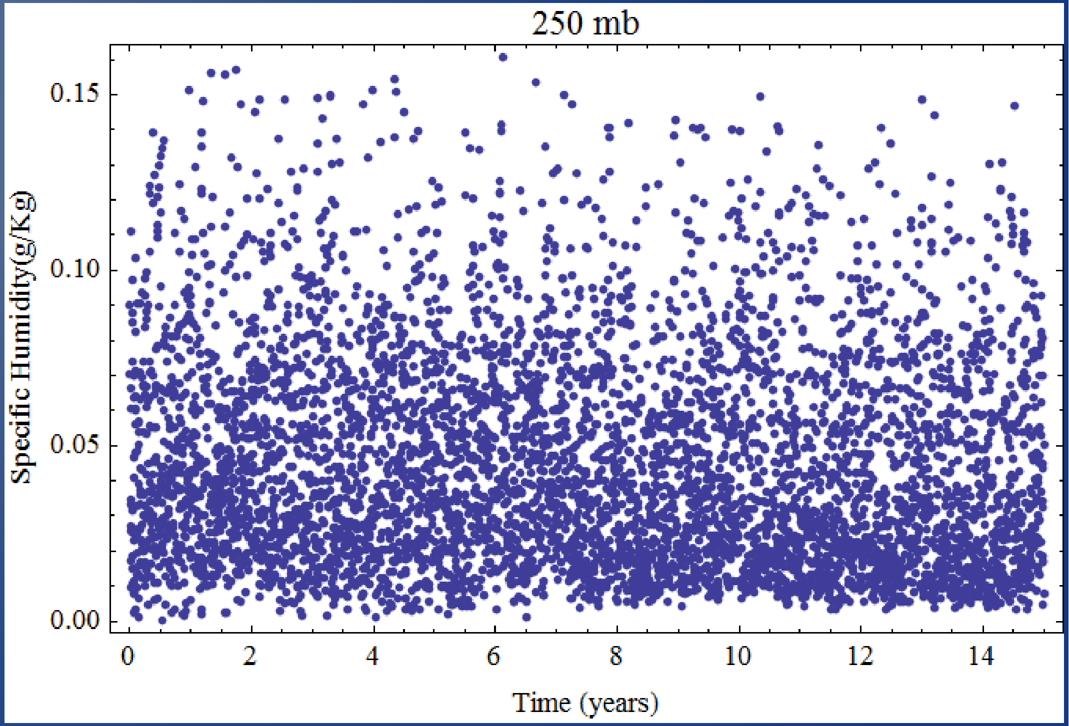
ϕ autocorrelation

"the number of years of data required to detect a real trend of specified magnitude with probability 0.90"

Radiosonde data analysis

- Use 15 year times series of Vaisala radiosonde noise data from the Southern Great Plains ARM site.
  - Standard deviation of daily noise data ~ 70%

Sampling Rate	SD of monthly mean	Autocorr of monthly mean
Daily	19.4%	0.25
Every 4 days	29%	0.19



What if you had a sensor that met GRUAN requirements?

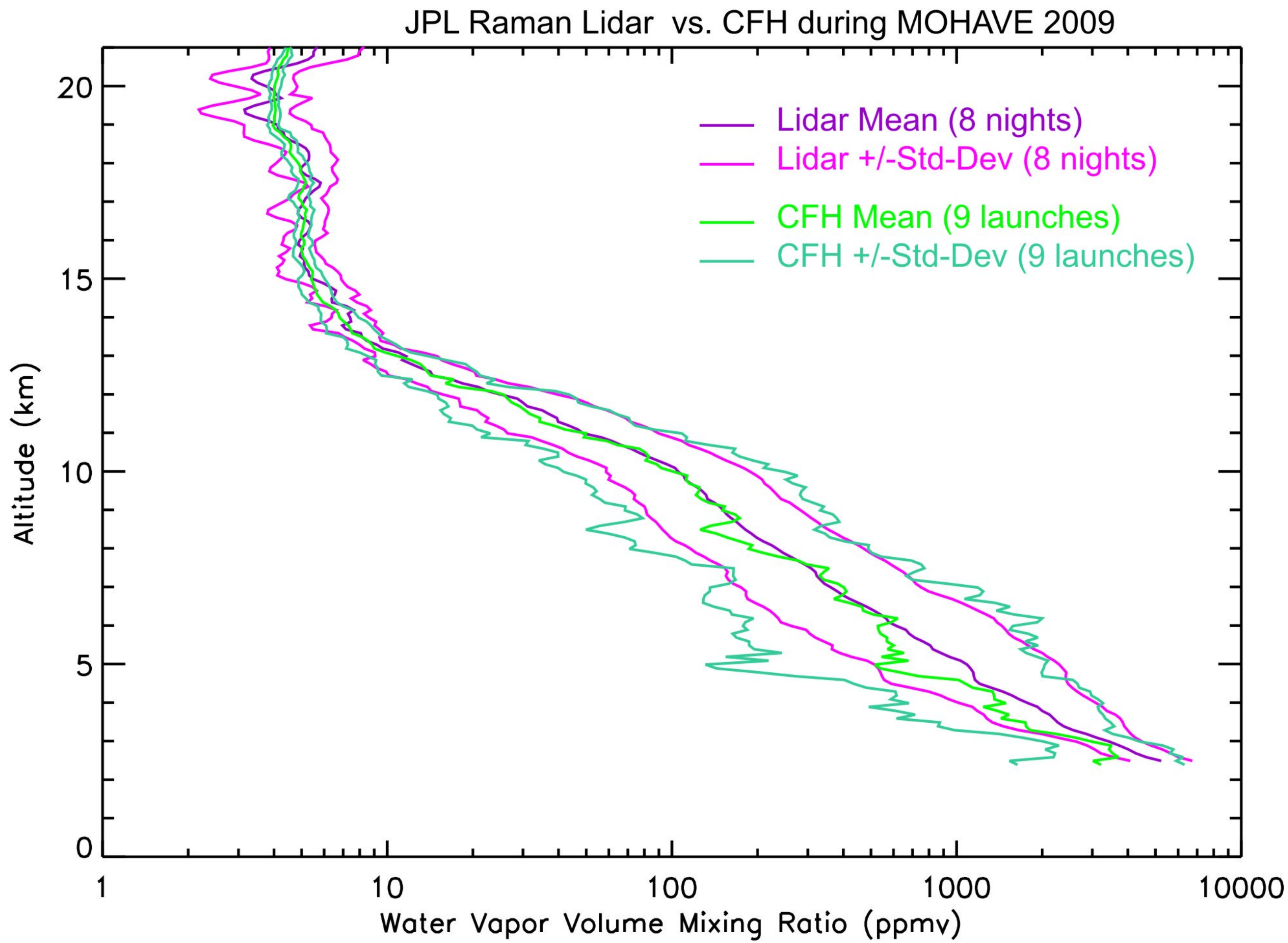
Number of Years to Detect Trends Using Different Sensors			
Measurement Frequency	GRUAN required sensor	10% sensor	15% sensor
Daily	18	18	19
Every 4 days	22	23	23
Monthly	36	38	39

- *The use of a sensor meeting GRUAN requirements yields a small decrease in the time required to detect trends versus a 10% - 15% sensor*
- *The expense of the sensor that can provide 10% accuracy in the UT currently limits its use to once per month at selected sites*

Potential Synergy Between NDACC Raman Lidar Effort and GRUAN

- Difficulty of RS92 to measure in the critical region ~ 200 mb
  - An optimized Raman lidar of relatively modest performance can reach these altitudes reliably through long-term averaging
- Hybrid product of Lidar + sonde can provide better water vapor profile than standard radiosonde
  - Alternate to balloon borne GRUAN reference measurement sufficient for UT trend detection
- NDACC uses roving standards for intercomparison activities such as MOHAVE_2009

Recent Results from Table Mountain, CA



Preliminary Conclusions

- Revealing trends in water vapor will take extended measurements
  - Tropical upper troposphere will show the largest change
  - High accuracy and precision not necessarily required. 10-15% seems “good enough”
    - Measurements every few days needed versus once per month
  - The acceptable error budget may need to be less in the LS than in the UT
- Synergy between GRUAN sondes and NDACC Raman lidars could provide more frequent climate quality measurements

What's Next

- Use lidar water vapor data (CARL) to characterize water vapor noise and autocorrelation
  - Error budget better understood than sonde
- Simulate effects of calibration jumps and drifts, data gaps
- Establish realistic measurement/calibration requirement for NDACC water vapor lidars
  - NDACC Calibration Workshop
    - NASA/GSFC: May, 2010

Thank You!