ARM Atmospheric Radiation Measurement Program

Raman Lidar Update

Rob Newsom

Aerosol Working Group Meeting
17-19 September 2007, Madison, WI

OUTLINE

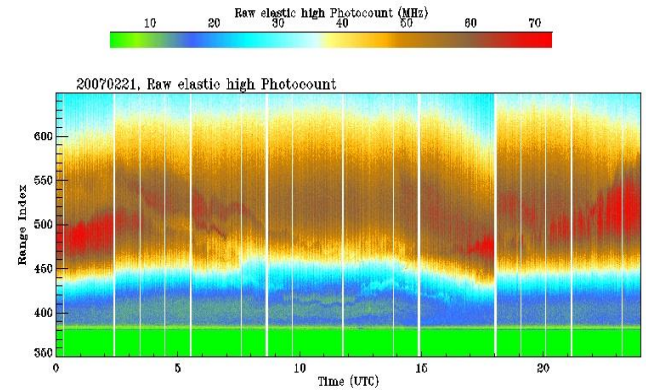
- Brief Intro
- Instrument status and recent upgrades
- VAP Status
  - Merge (raw signal processing)
  - Other VAPs (ASR, MR, EXT, DEP)
- Current efforts and issues

BRIEF INTRO

Raw Measurements

Height resolved photocounts at 3 primary wavelengths

- WFOV & NFOV Elastic channel @ λ = 355 nm
- NFOV Depol @ λ = 355 nm
- WFOV & NFOV H_2O Raman channel @ λ = 408 nm
- WFOV & NFOV N_2 Raman channel @ λ = 387 nm



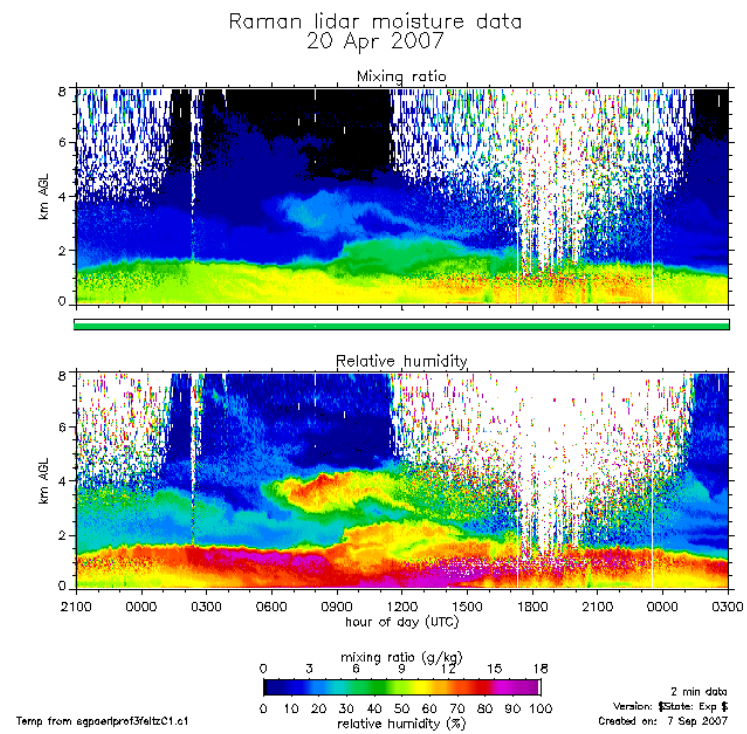
Derived Quantities

Current:

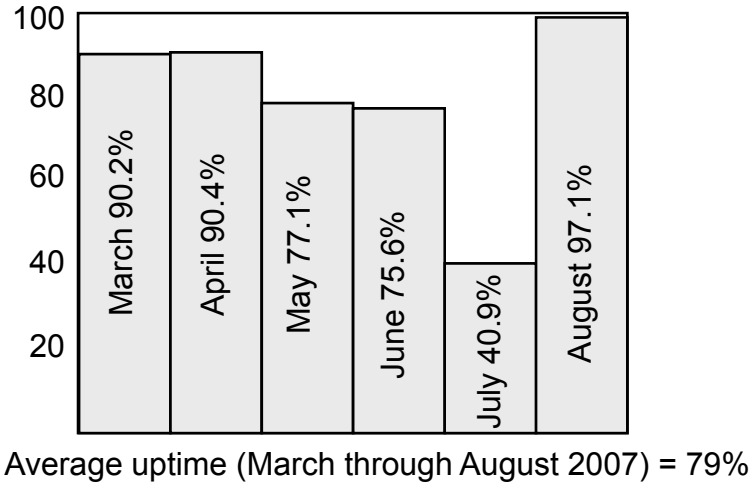
- Water vapor mixing ratio
- Relative humidity
- Aerosol Scattering Ratio
- Aerosol Extinction
- Aerosol backscatter coefficient
- Aerosol optical depth
- Aerosol extinction-to-backscatter ratio
- Depolarization ratio

Under development:

- Temperature profiles
- Cirrus extinction profiles
- Liquid water content profiles
- Ice water content profiles
- Liquid water cloud droplet number density



Instrument Status

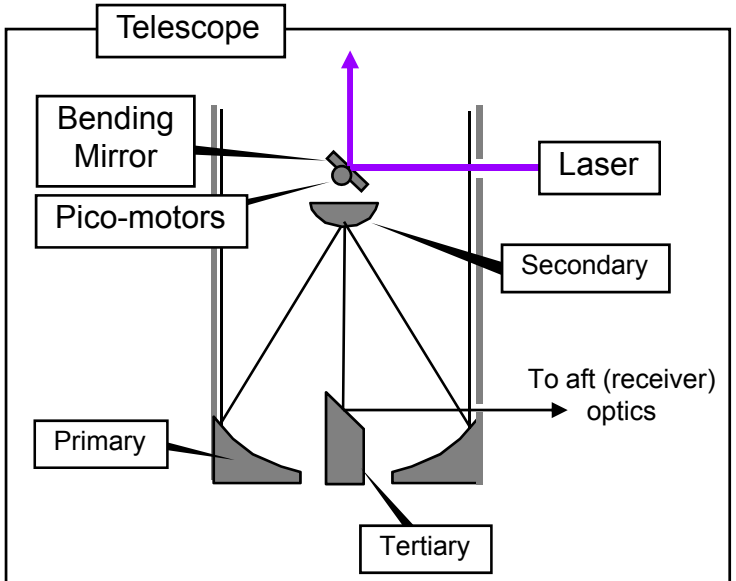


- The system is currently humming along
- Uptime since 3/01/2007 = 79%
- Experienced problems during CLASIC (of course), and lost a significant amount of uptime during June and July due to water chiller problems
- Licel unit failed on May 22, no significant loss of data because backup available. Unit was sent to Licel, repaired and returned to SGP
- Identified reason for sensitivity loss. Fixed the problem.

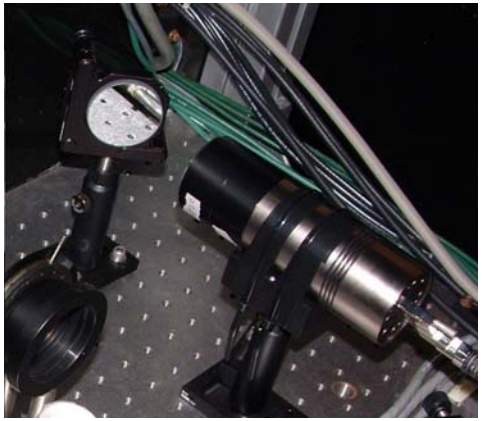
Recent Upgrades

- Three new channels added (NFOV T1, T2 and LW) in Oct 2005
  - 3 new Licel units (transient data recorders, Licel Corp., Berlin, Germany)
  - New photomultiplier tubes installed
- New boresight alignment module added in Apr 2007

Boresight alignment module added in APR 2007



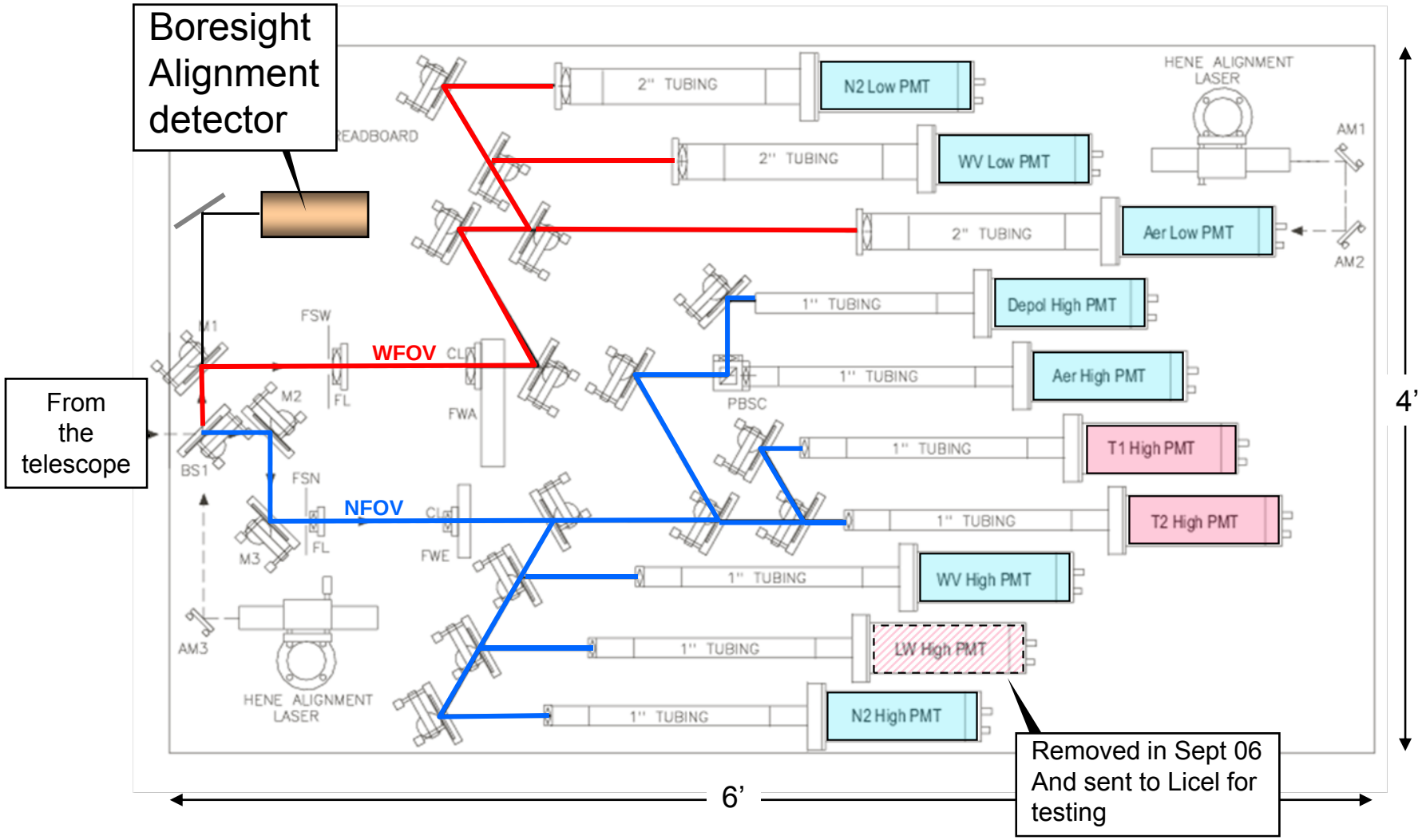
Alignment between the outgoing laser and the optical axis of the receiver telescope is key



- Uses quad detector to determine laser spot location
- Output used to actively control pico-motors on beam steering mirror

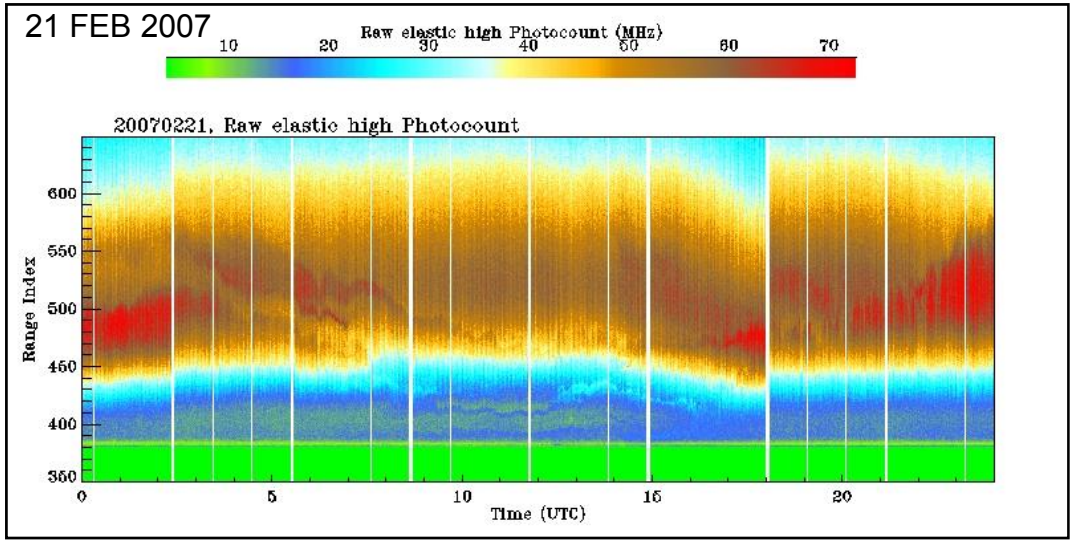
AFT OPTICS

Current configuration as of September 2007



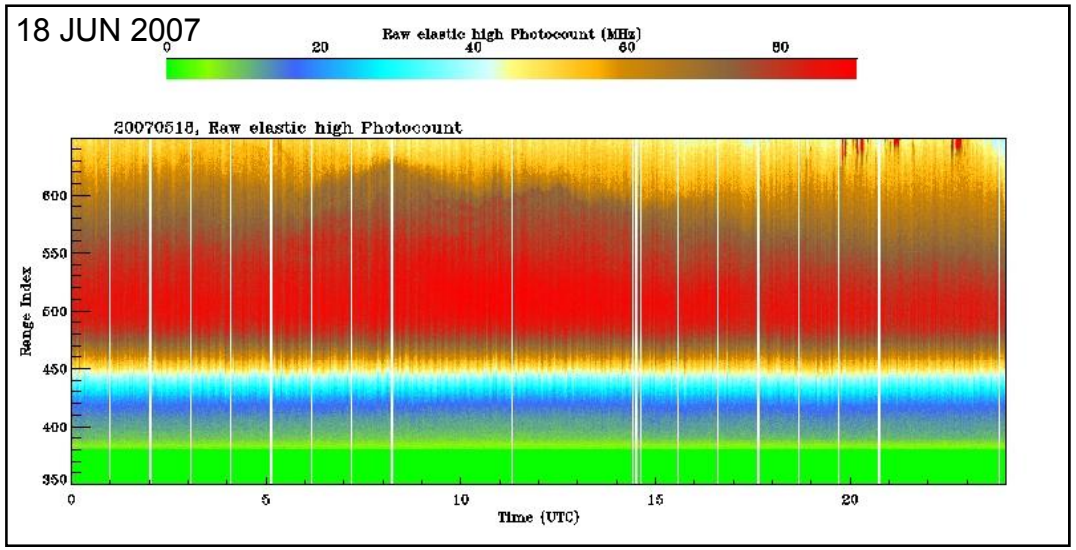
Boresight alignment module

Affect on NFOV signals



Before Install

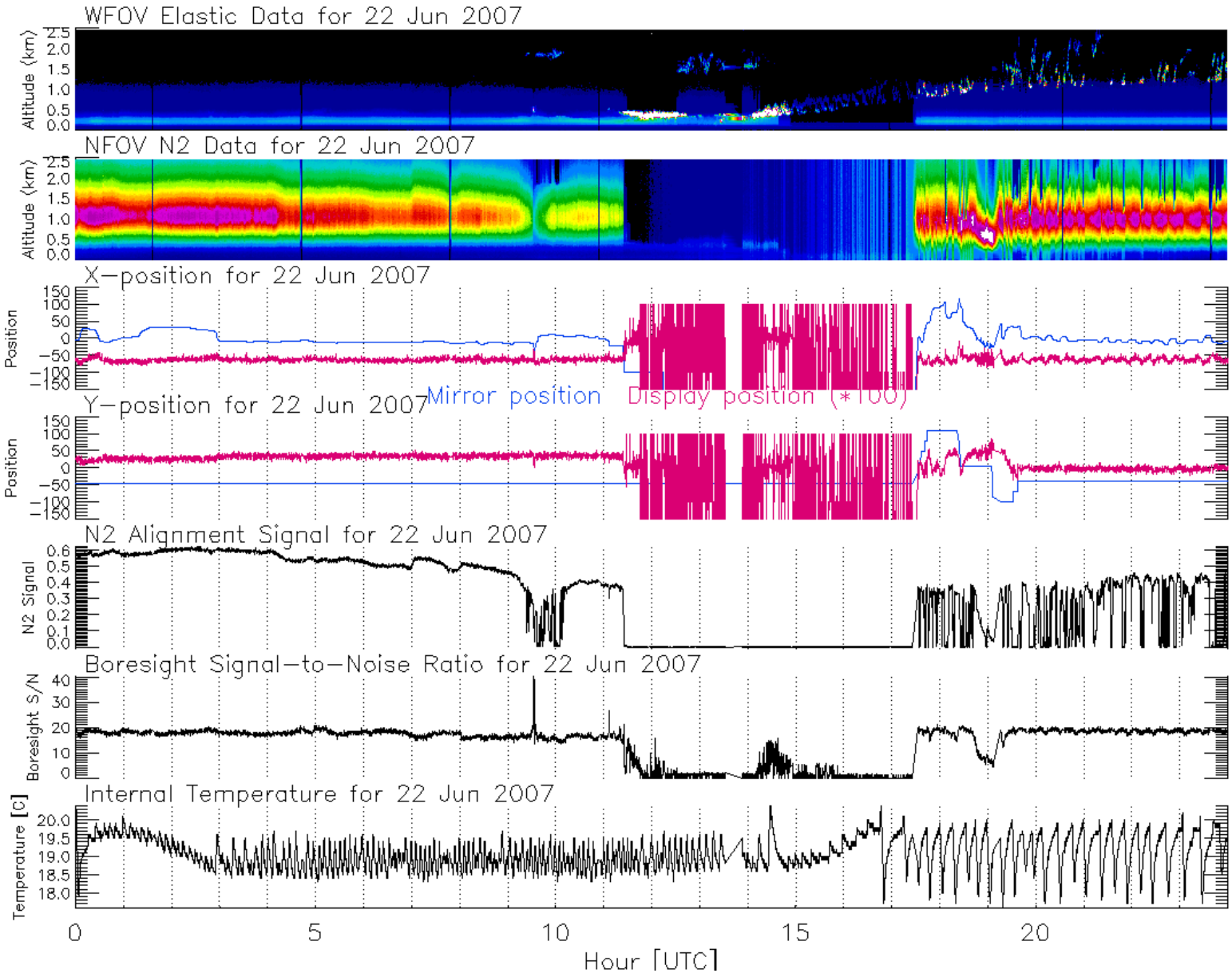
- Alignment tweaks were performed once every ~3 hours
- Discontinuities
- Problems when clouds present



After install

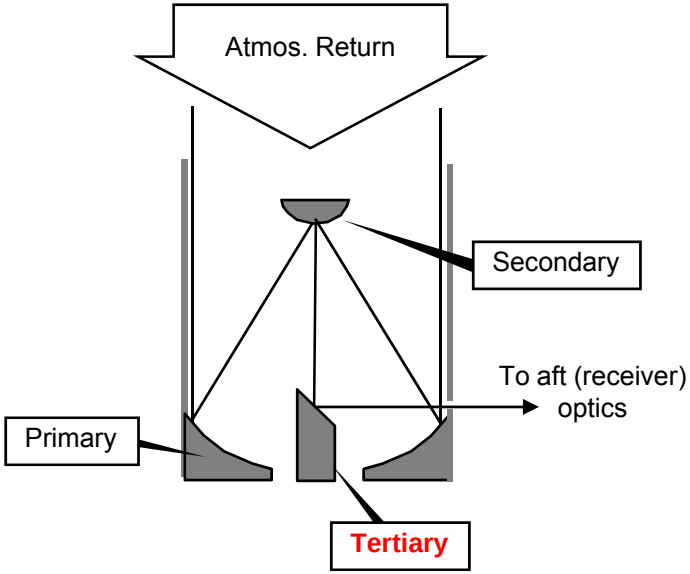
- Alignment is continually adjusted
- No more discontinuities, but …
- Small amplitude, high frequency "jitter"
- Logic added to disable when clouds are present
- Still tuning
- John Goldsmith has added logic to re-enable when sky conditions become favorable

Behavior of the boresight alignment module



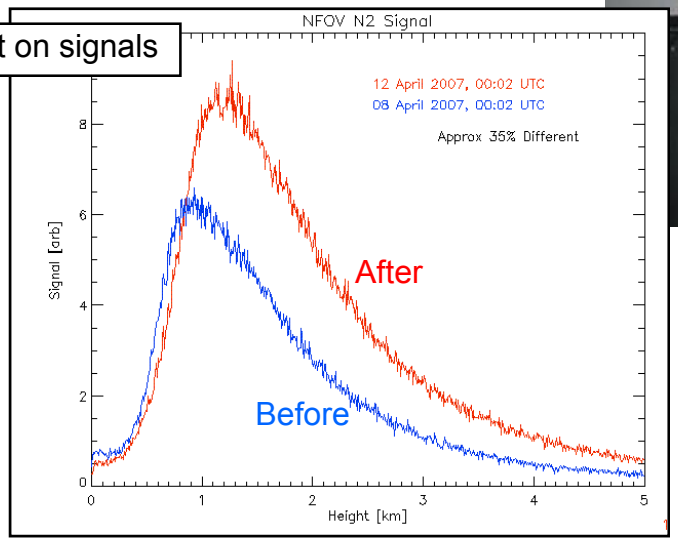
SENSITIVITY LOSS 2006-2007

Cause: Spider Webs on Tertiary Mirror

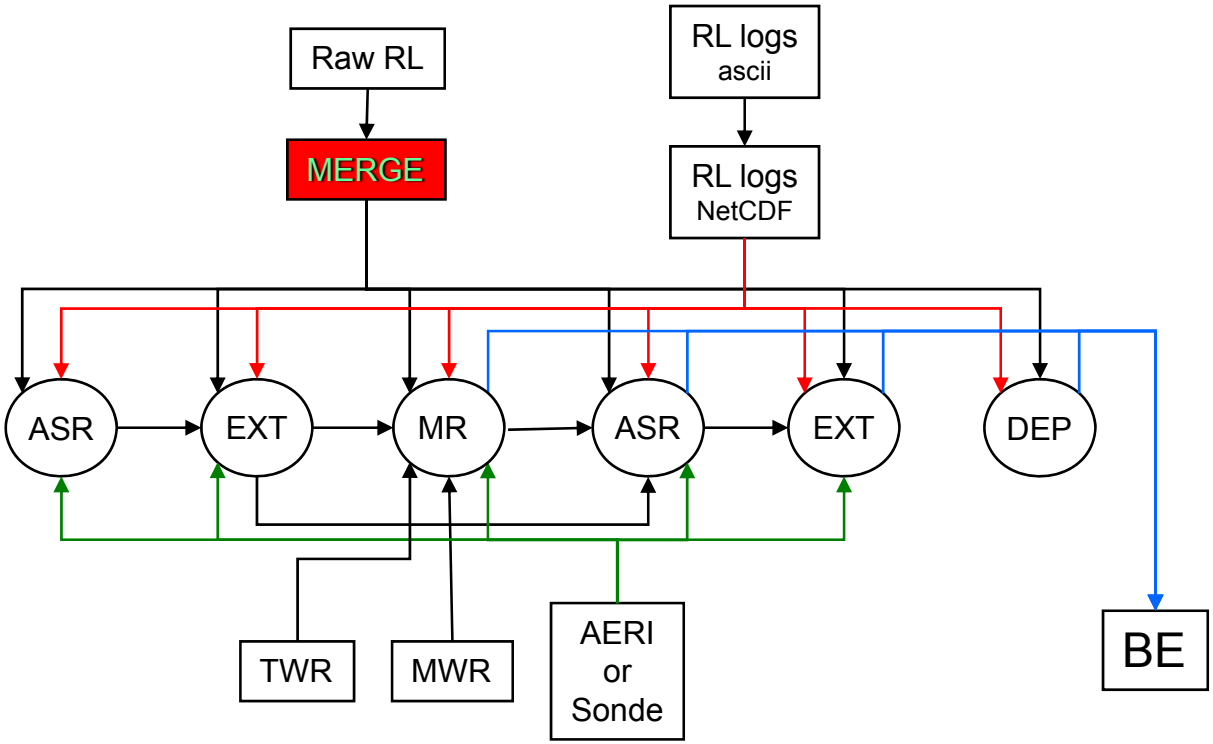


Cleaned off spider webs on 12 Apr 2007

Effect on signals



RL VAPs



ASR = Aerosol scattering ratio
EXT = Extinction
MR = (water vapor) Mixing Ratio
DEP = Depolarization ratio
BE = Best Estimate
TWR = Tower
MWR = Microwave Radiometer

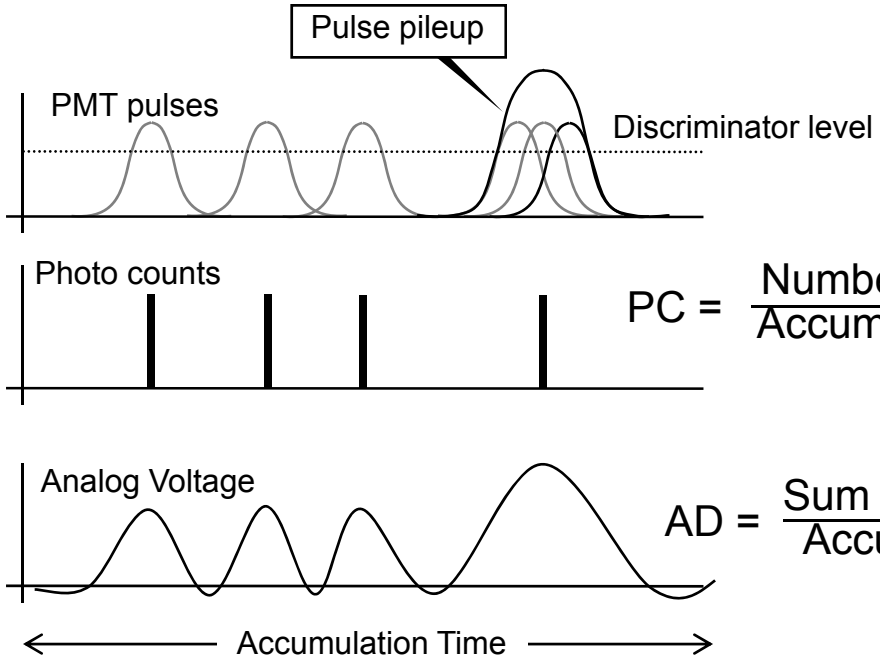
VAP Status

- RLPROF_MERGE has been released
  - In production this week
  - Will start processing most current raw data
- Currently working on release of RLPROF_ASR
  - when?
- Other VAPS (EXT, MR, and BE) will follow
  - when?
- Best Estimate (BE) code is being modified to output nighttime MR, ASR and EXT
  - What about DEP?

MERGE

Basic Signal Processing

- Converts raw signals from the Licel data acquisition units to photon count rates
- Feeds all other RL VAPs (ASR, EXT, MR, DEP)
- Introduced in 2004 with upgrade to Licel electronics.
- Raw measurements for each channel consist of:
    - Analog signal (AD)
    - Photocount signal (PC)



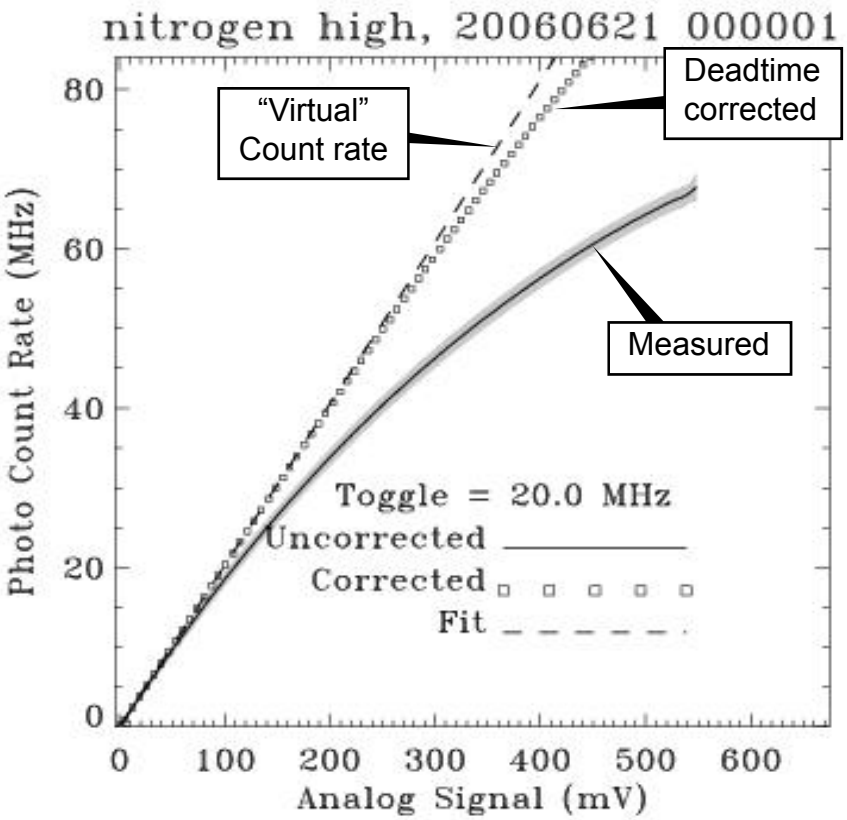
$$PC = \frac{\text{Number of counts}}{\text{Accumulation Time}}$$

$$AD = \frac{\text{Sum of analog signal}}{\text{Accumulation Time}}$$

Combing PC and AD signals

PC provides better sensitivity at low signal levels, but is very non-linear at higher signal levels due to pulse pileup. AD is better for higher signal levels. By combining the PC and AD signals it should be possible to extend the dynamic range of the measurement.

Gluing: The process of combining the PC and AD signals?



$$PC_{true} \approx \frac{PC_{measured}}{1 - \tau PC_{measured}}$$

Non-parallizable deadtime or pulse pileup correction

$$PC_{true} = aAD_{measured} + b$$

"Virtual" Count rate

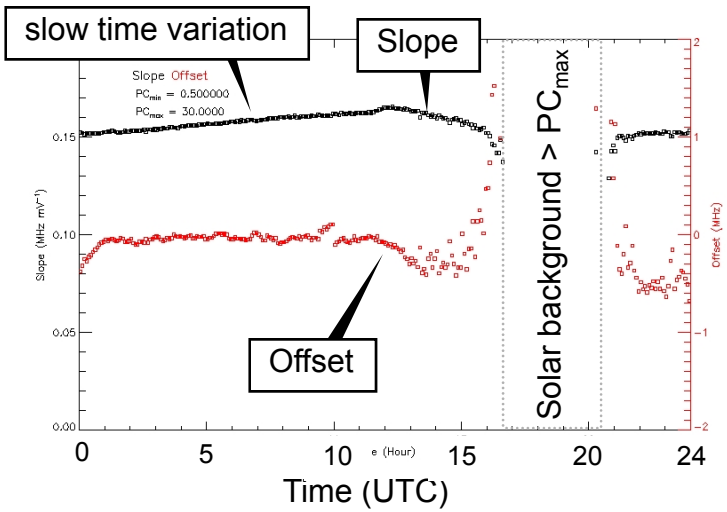
slope

offset

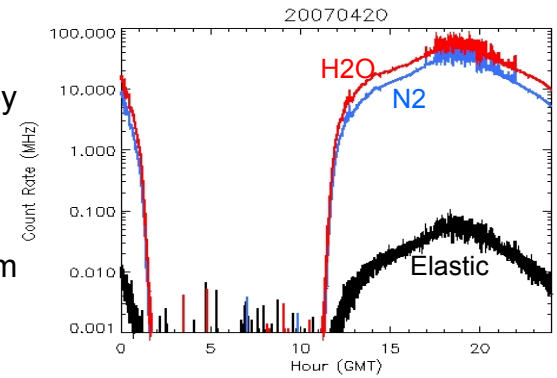
Apply linear regression to determine the slope and offset

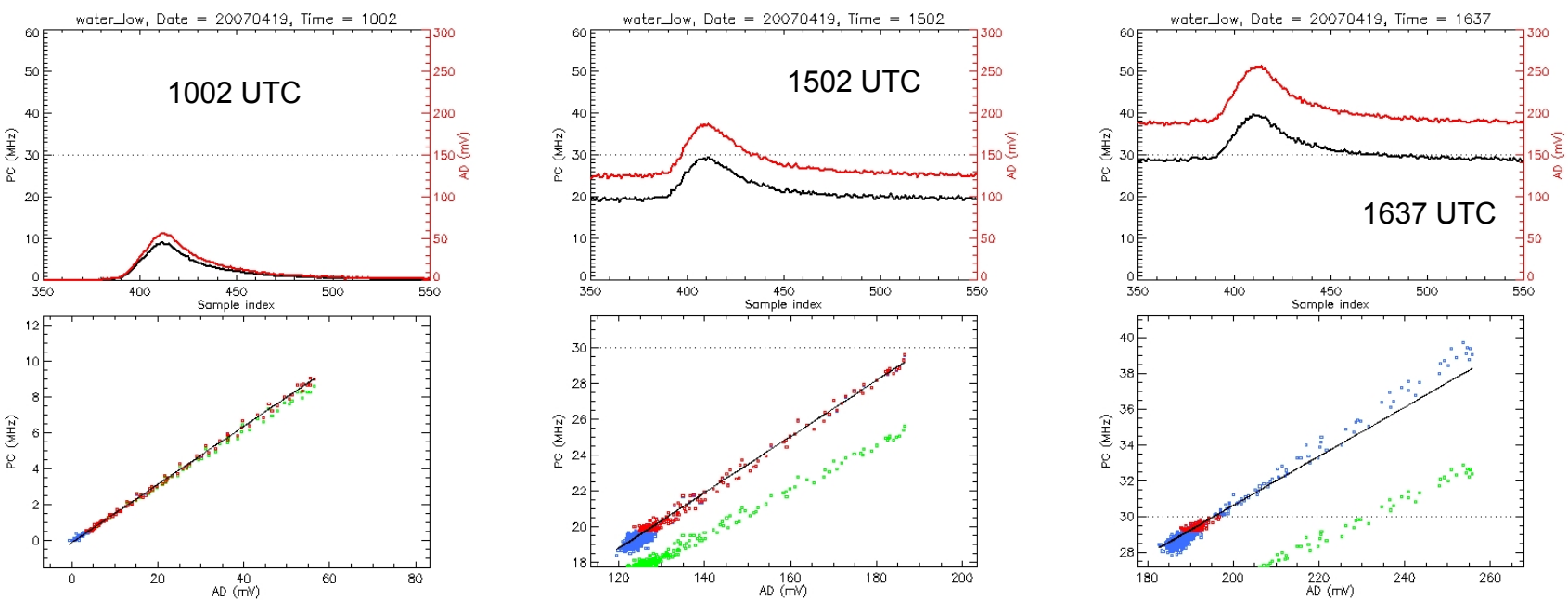
Time-dependence of glue coefficients

WFOV water vapor channel

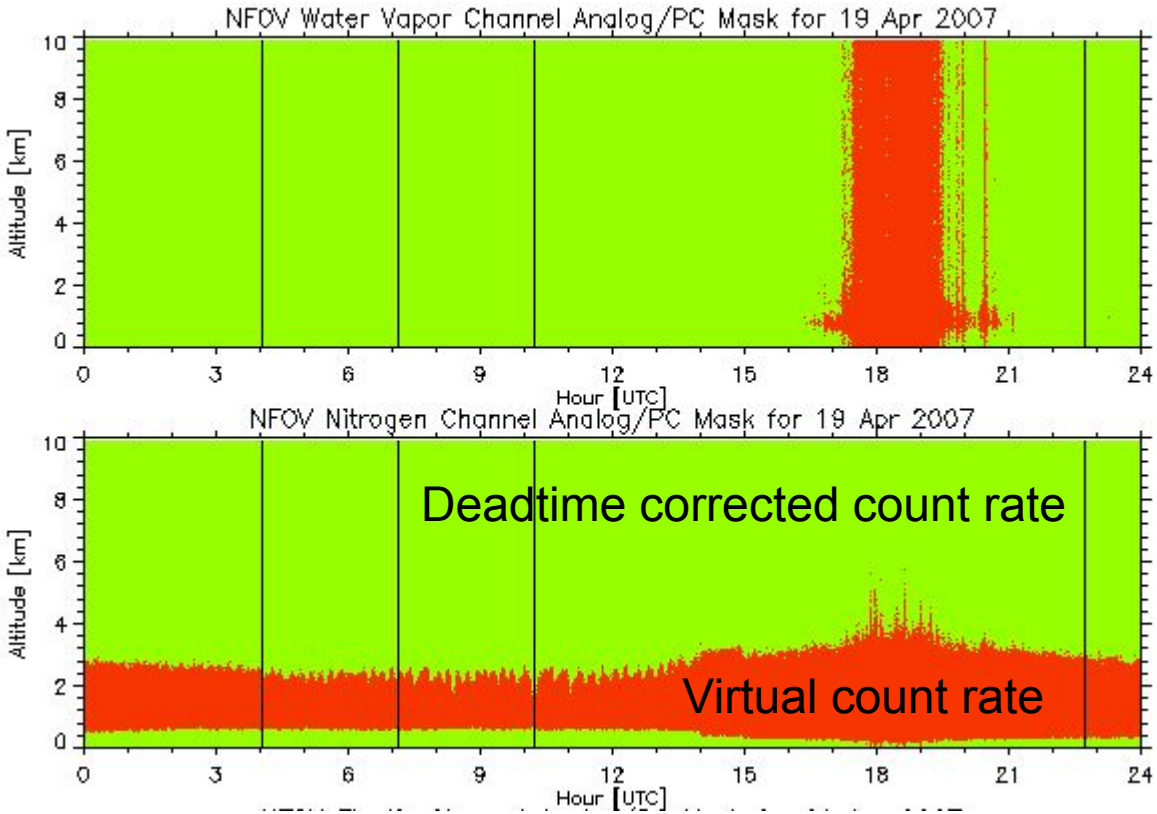


- Water vapor channels are most affected by changing solar bkg
- Elastic channels are least affected by changing solar bkg
- Slow time variation in slope during nighttime may be the result a slow relaxation (return to some equilibrium state)
- Slope decrease during daytime is initially due to the nonlinearity





The combined backscatter profile uses PC data below some threshold and scaled AD data above.

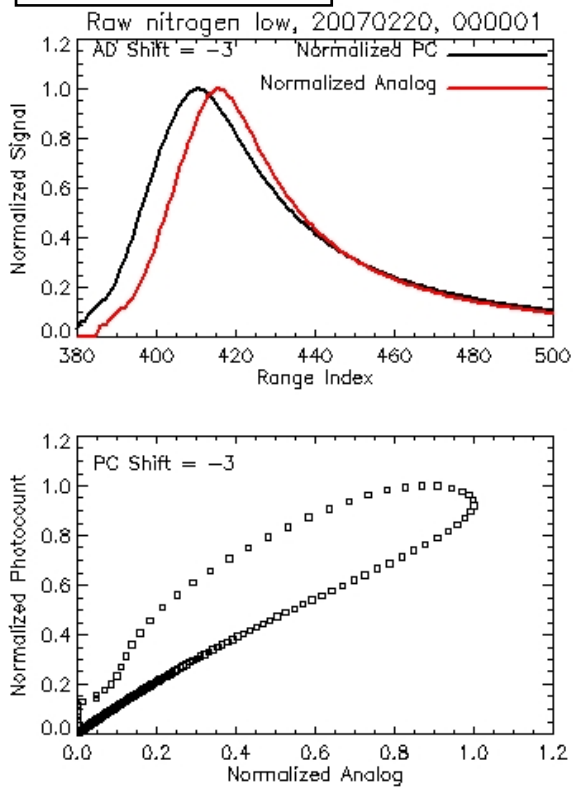


AD/PC Range Offset

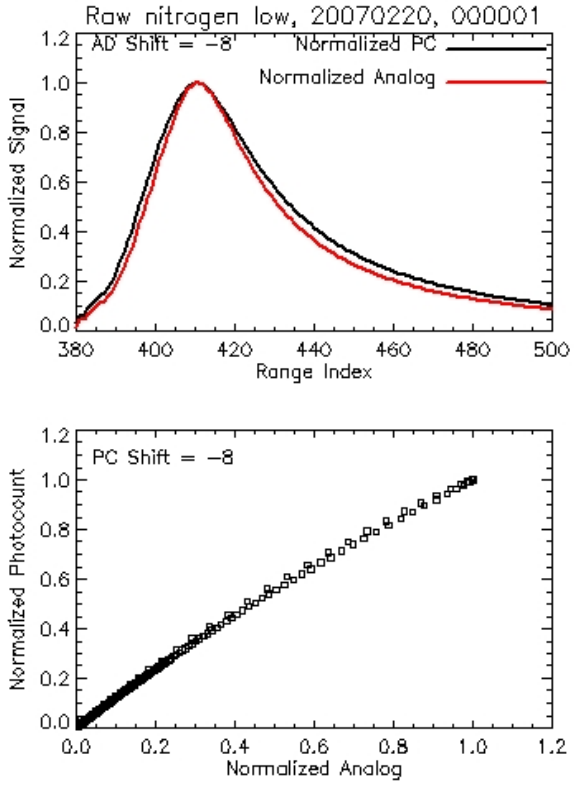
PC and AD signals from the Licel electronics exhibit a range offset.

- All original Licel units installed in 2004 produced the same offset (AD and PC were shifted by 3 range bins)
- Three Licel units installed in OCT 2005 produced a difference range offset (8 range bins)
- Change in the shift went undetected until MAR 2007
- All 3 WFOV channels were effected

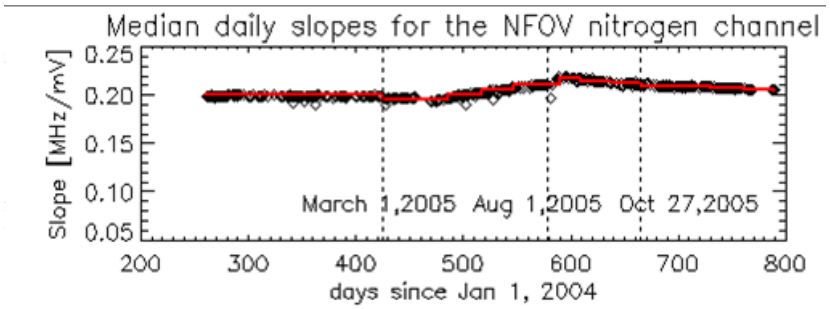
Assumed Shift

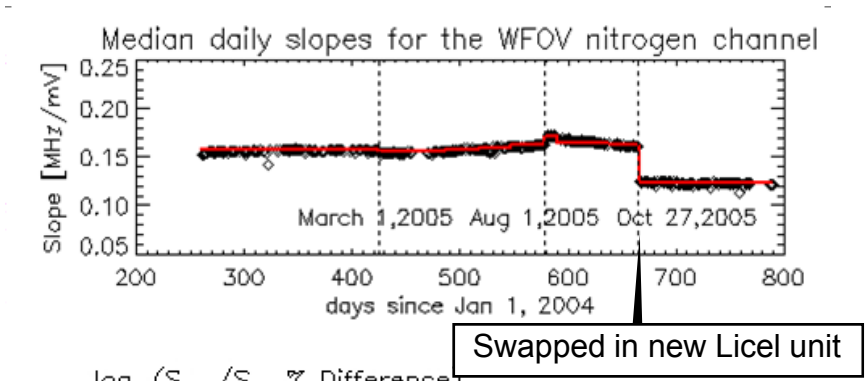


Correct Shift



Effect of AD/PC Range Offset





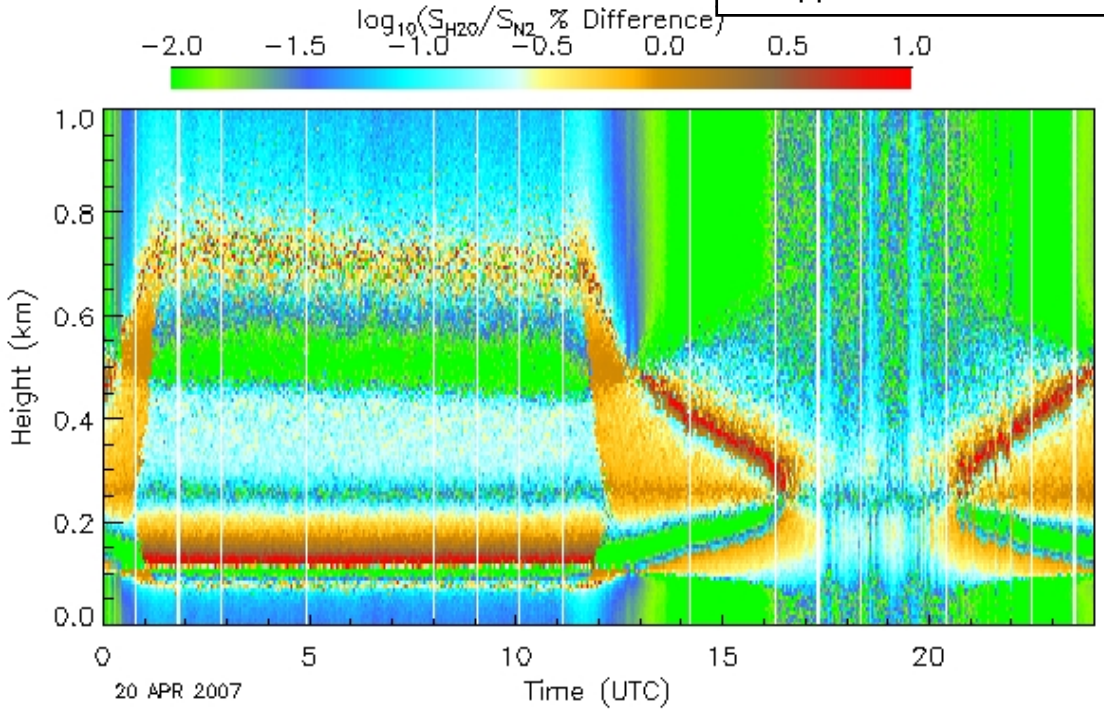
$$wv_8 = \left(\frac{S_{H2O}}{S_{N2}}\right)_8$$

Correct offset

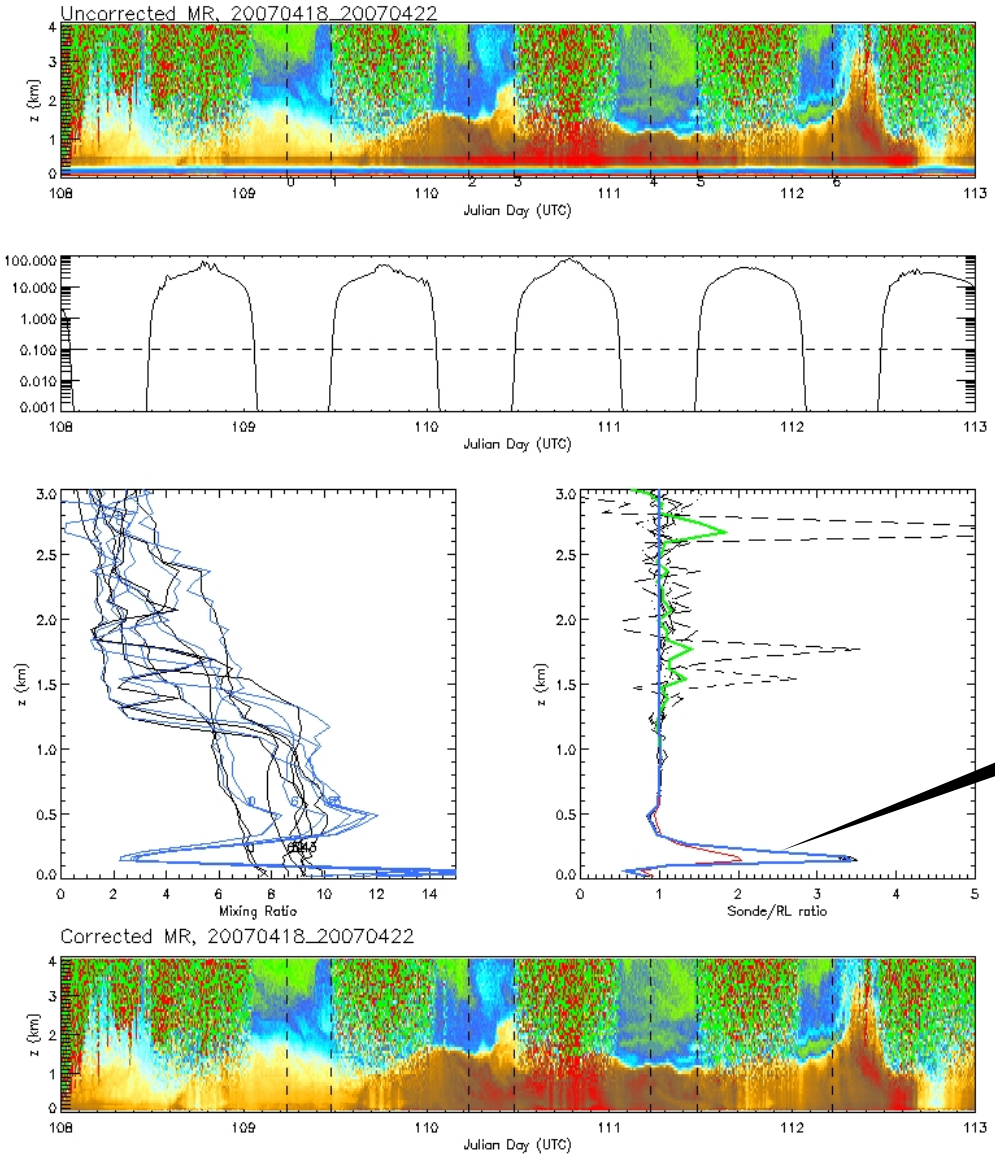
$$wv_3 = \left(\frac{S_{H2O}}{S_{N2}}\right)_3$$

Incorrect offset

$$\log\left(\left|\frac{wv_8 - wv_3}{wv_8}\right|\right)$$



Semi-Automated MR overlap determination



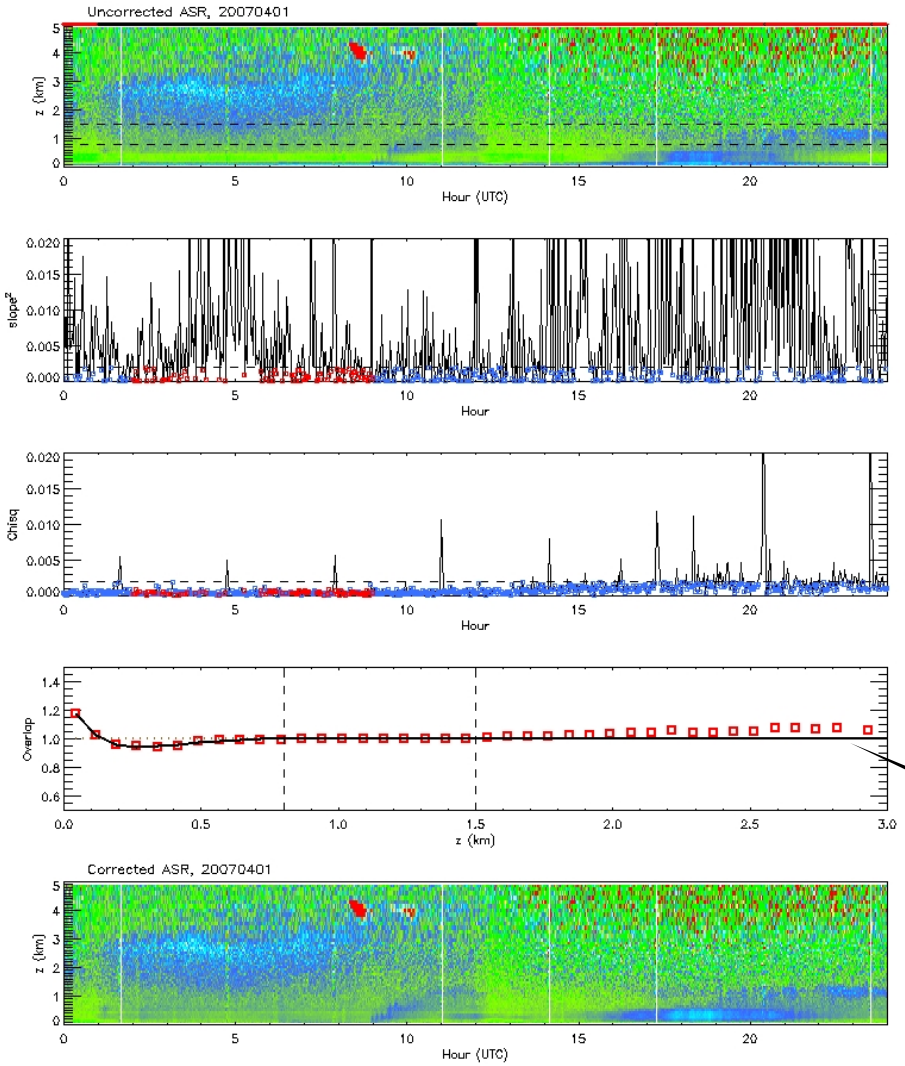
- Select a range of days
- Compute ratio of the RL MR profiles with coincident nighttime MR profiles from the sondes.
- Compute average ratio
- Fit polynomial to the average
- Test it on data set
- Keep or reject

Polynomial fit

$$x = e^{-\alpha z}$$

$$f(x) = 1 + \sum_{n=1}^{N-1} c_n x^n$$

Semi-Automated ASR overlap determination



- Find a “clean” day
- Find all profiles that are nearly constant between say 800m and 1500m
- Compute average of these profiles
- Fit polynomial to the average
- Test it on data set
- Keep or reject

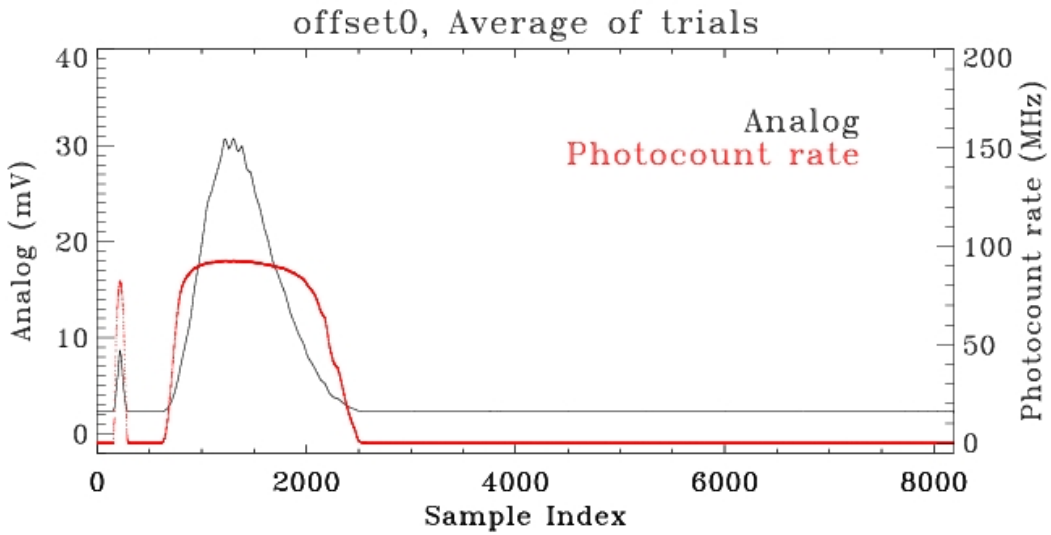
Polynomial fit

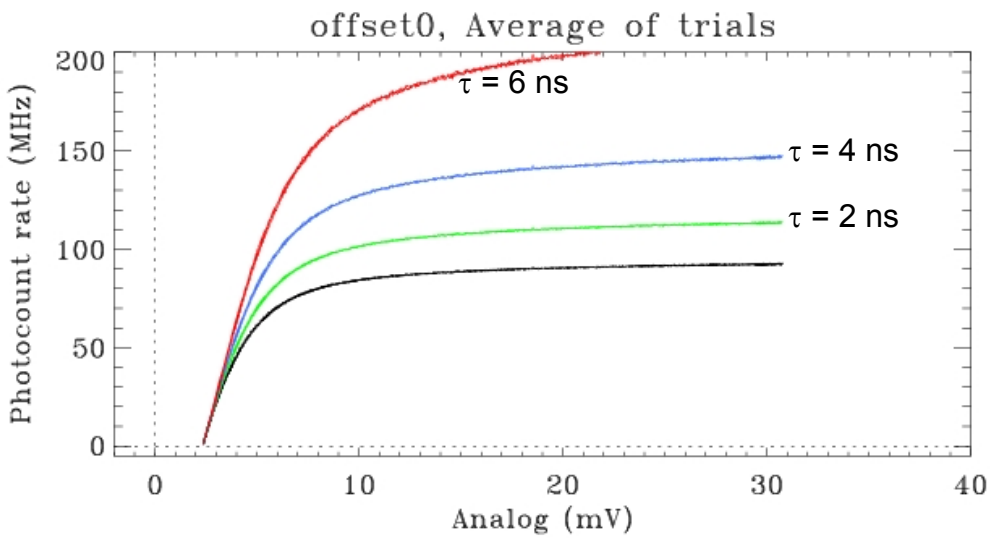
$$x = e^{-\alpha z}$$

$$f(x) = 1 + \sum_{n=1}^{N-1} c_n x^n$$

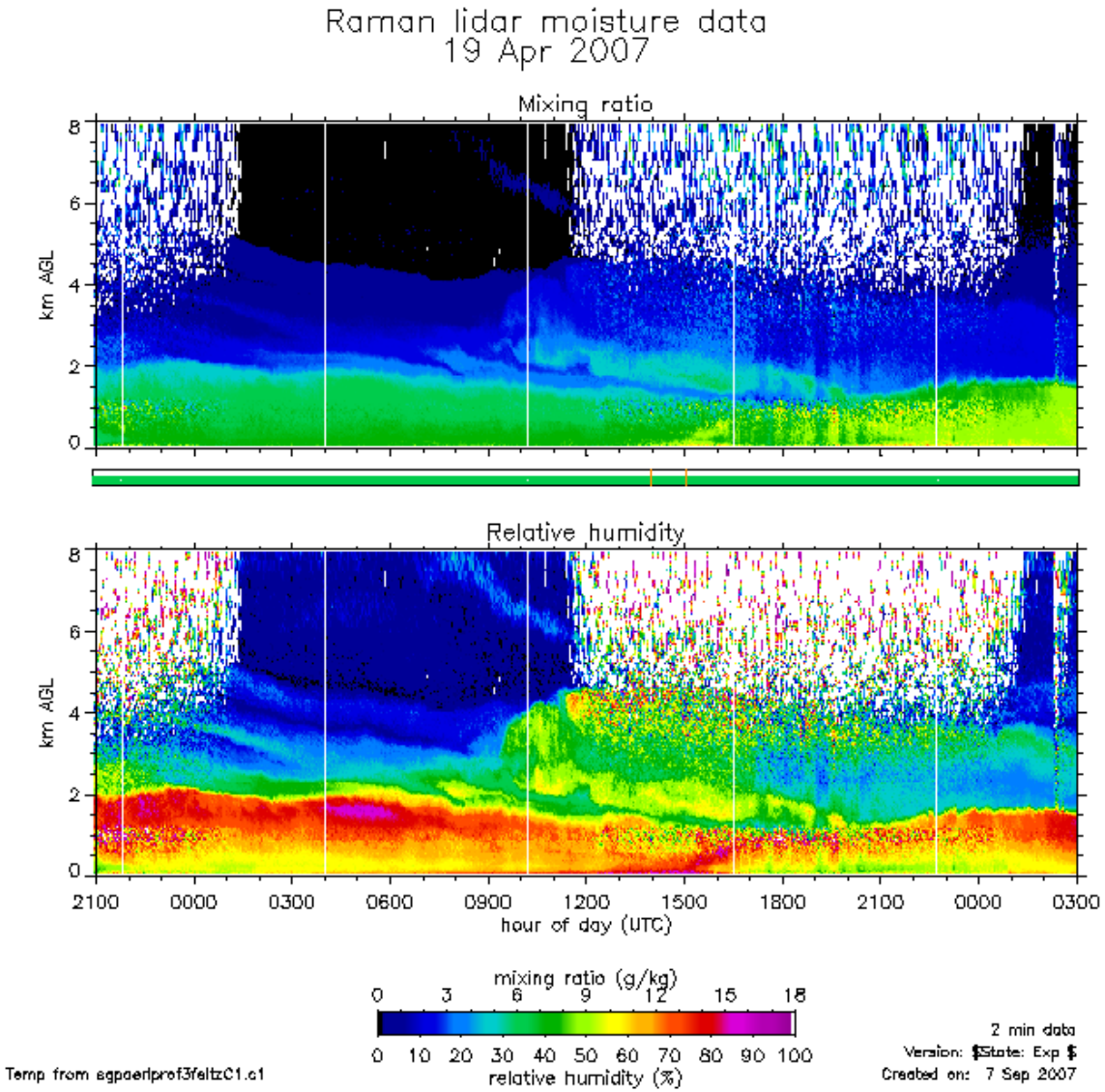
Licel Test Results

Lab tests conducted by Licel to simulate affects of changing (solar) background





Water Vapor Mixing Ratio



Current Efforts

- Currently working on release of ASR. EXT, MR and BE will follow.
- Modify BE to either flag or not include daytime MR, ASR, and EXT data. Daytime data will be identified based on solar background level.
- Begin operational processing
  - Routine monitoring of the data quality
  - Update configuration files as needed
- Refocus effort on resolving the daytime MR bias issue and best approach at combining (gluing) PC and AD signals.