

Raman Lidar Update

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**Aerosol Working Group Meeting
11-13 November 2008, Lansdowne, VA**

OUTLINE

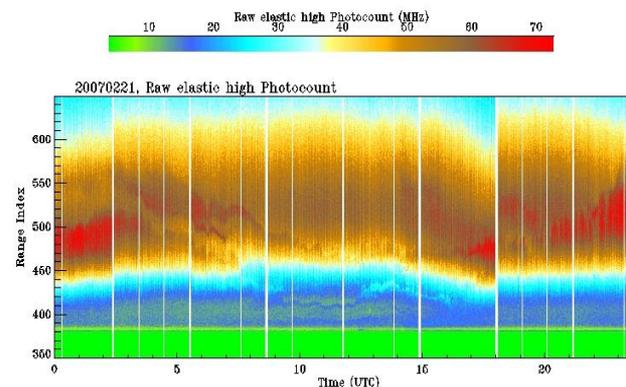
- Brief Intro
- Instrument status
 - Uptime
 - Issues
- Value Added Procedures
 - MERGE
 - Operational Status
- Current efforts and issues

BRIEF INTRO

Raw Measurements

Height resolved photocounts and analog voltages

- Wide & narrow FOV elastic @ $\lambda = 355$ nm
- Narrow FOV Depol @ $\lambda = 355$ nm
- Wide & Narrow FOV H₂O @ $\lambda = 408$ nm
- Wide and narrow FOV N₂ @ $\lambda = 387$ nm



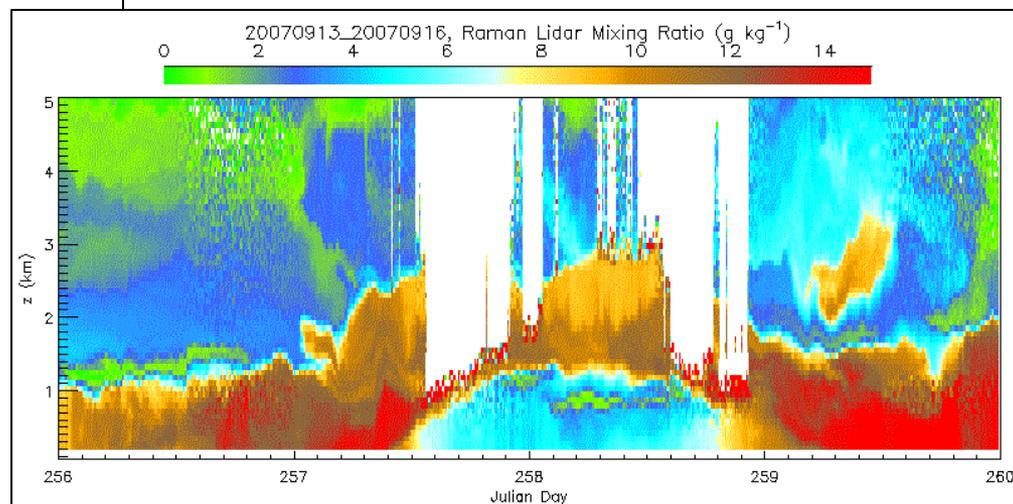
Derived Quantities

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

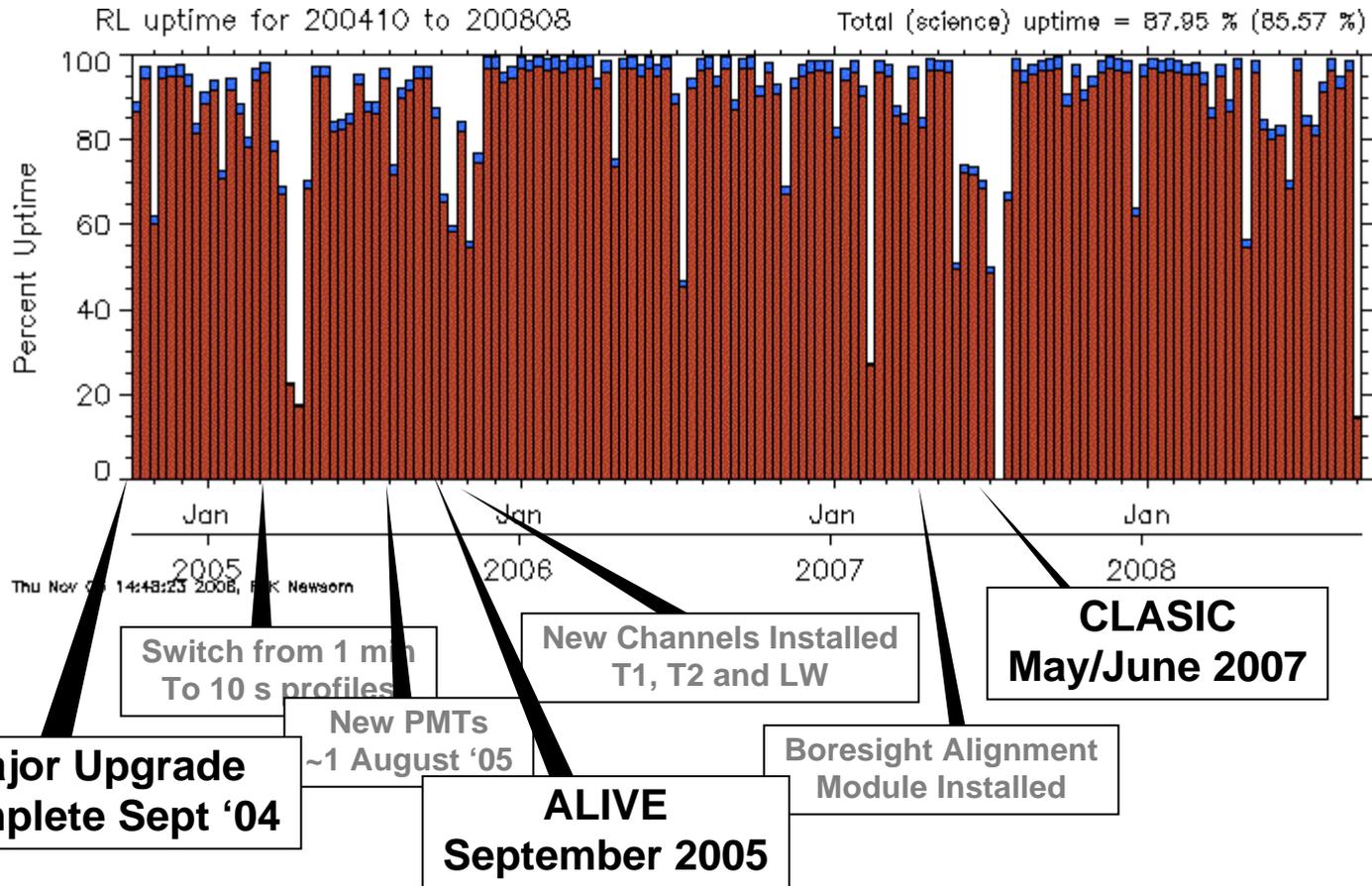
Under development:

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



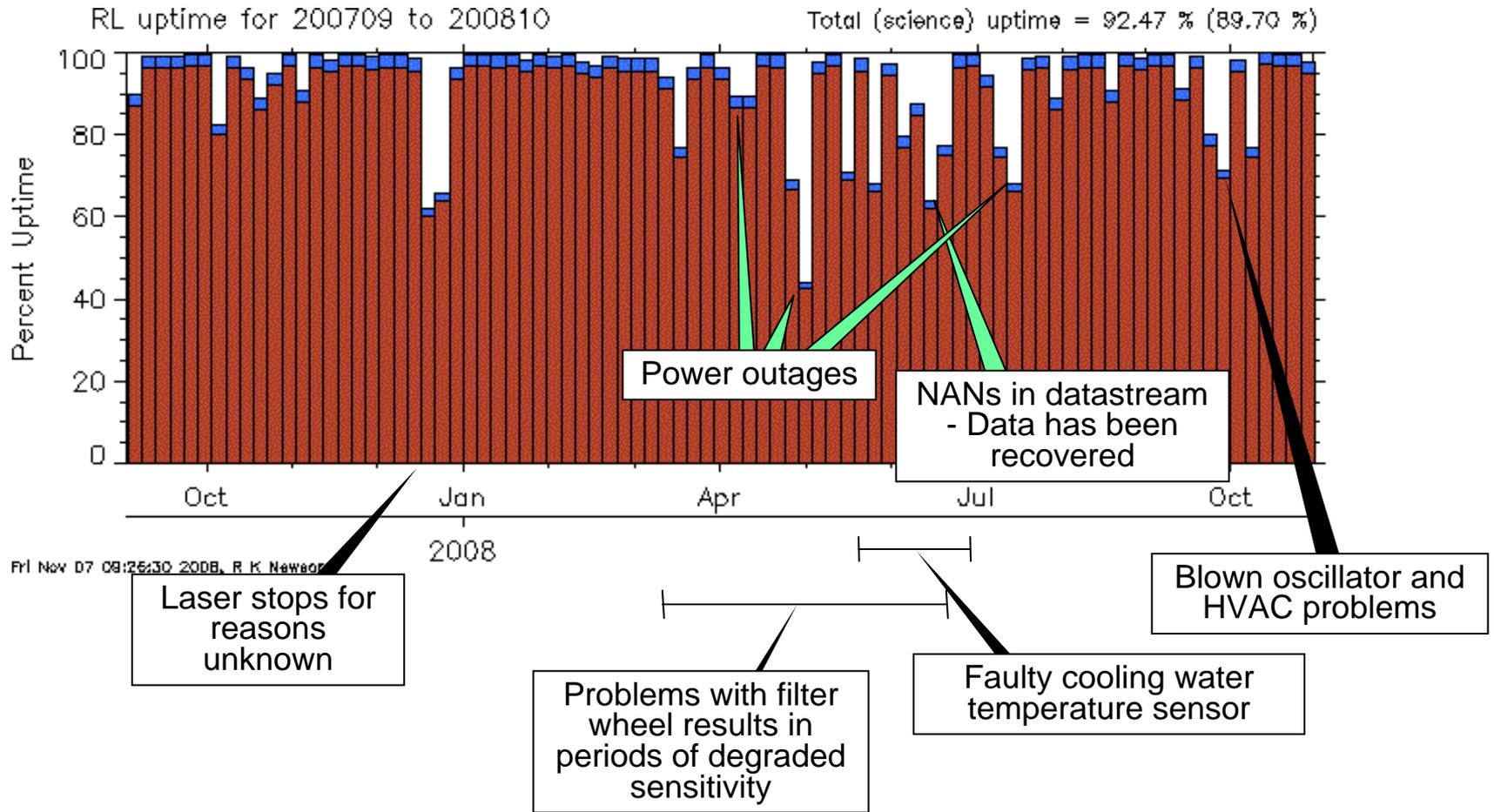
Instrument Uptime

since major upgrade in 2004



Instrument Uptime

Last year or so



Significant Hardware Related Issues

August 2007 to May 2008

AUG 07

- John Goldsmith installs new Labview software to add “auto re-enable” functionality to the boresight alignment module

FALL '07

- No major problems

DEC '07

- Laser stops firing on one occasion for unknown reasons. 45 hours of uptime lost.

JAN-FEB '08

- Noticed increased noise in pulse energy.
- Operational processing of merge data begins

MAR-APR 08

- Noise in pulse energy getting worse.
- Filter wheel controller begins giving us problems, resulting in a couple of periods of reduced sensitivity.
- LW PMT is reinstalled in system.

MAY '08

- NANs in datastream cause temporary suspension of data transfer.
 - Only some house keeping data is affected (T and RH)
 - The problem was fixed by inserting missing values.
- Noise in pulse energy getting worse but tests suggest the problem may be in the energy monitor.

Significant Hardware Related Issues

June 2008 to October 2008

JUN '08

- Noise in pulse energy getting worse but now convinced problem is in the energy monitor.
- Filter wheel causes problems again. This time problem is fixed by using a different port on the filter wheel controller.

JUL '08

- Energy monitor is replaced resulting in more stable energy measurements.
- Filter wheel behaves
- Missing temperature and RH data causes problems with ingest.
 - Only some house keeping data is effect (T and RH)
 - The problem is fixed by inserting zeros for the missing data.

AUG '08

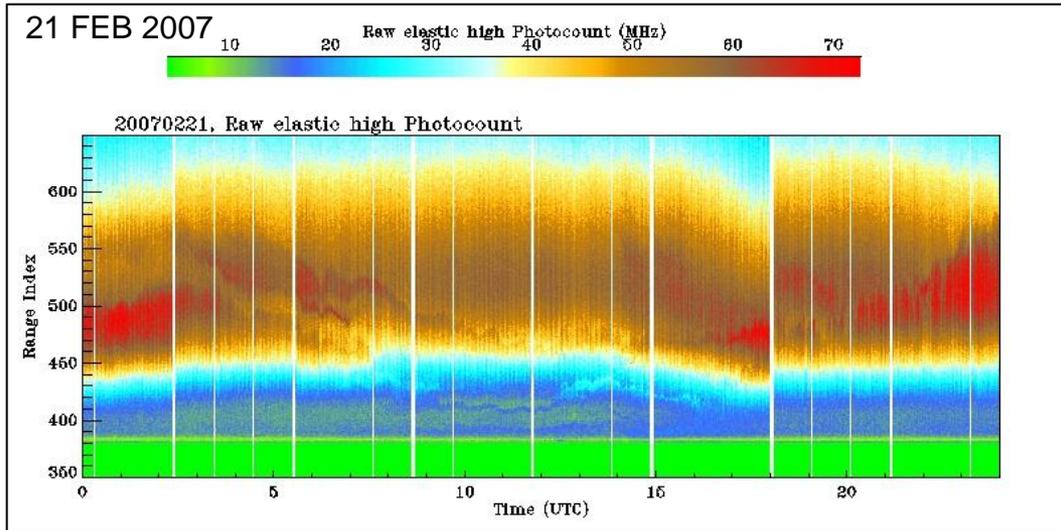
- AC is becoming increasingly problematic
 - large temperature cycling
 - Cyclical artifacts in the data
 - Maintenance doesn't really solve the problem.

SEP '08

- Continuing problems with AC. Partially wrapping the telescope with a tarp results in a dramatic improvement. What we really need is a better AC.

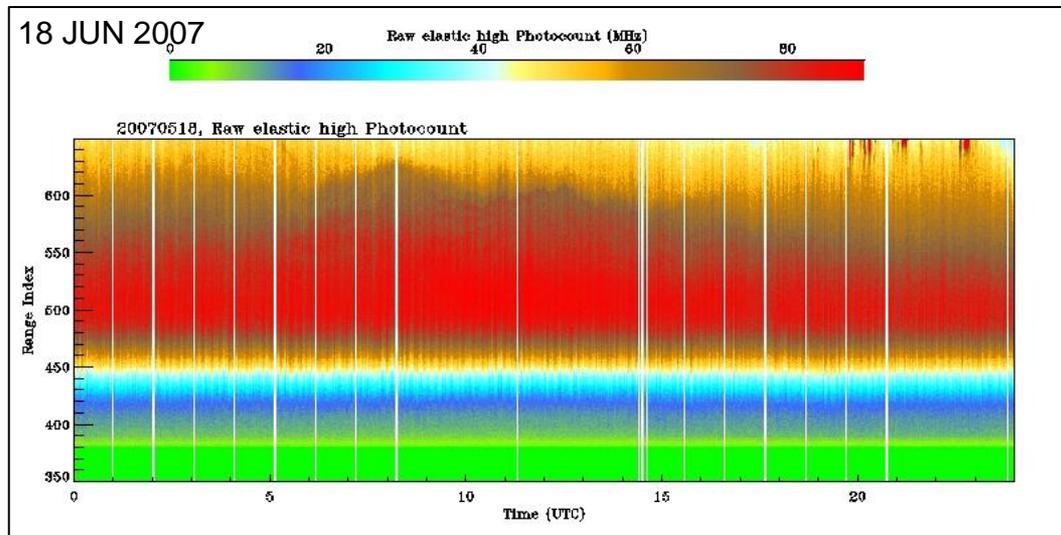
Boresight alignment module

Affect on NFOV signals



Before Install

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

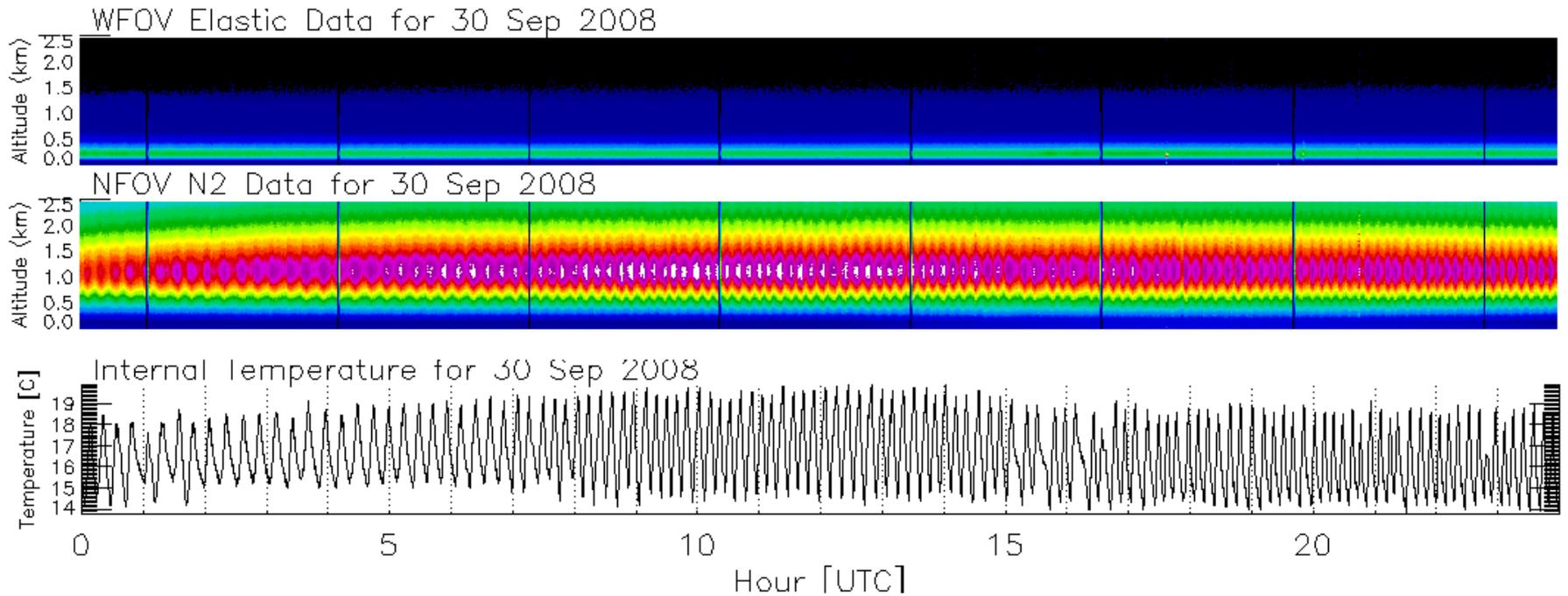


After install

- 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

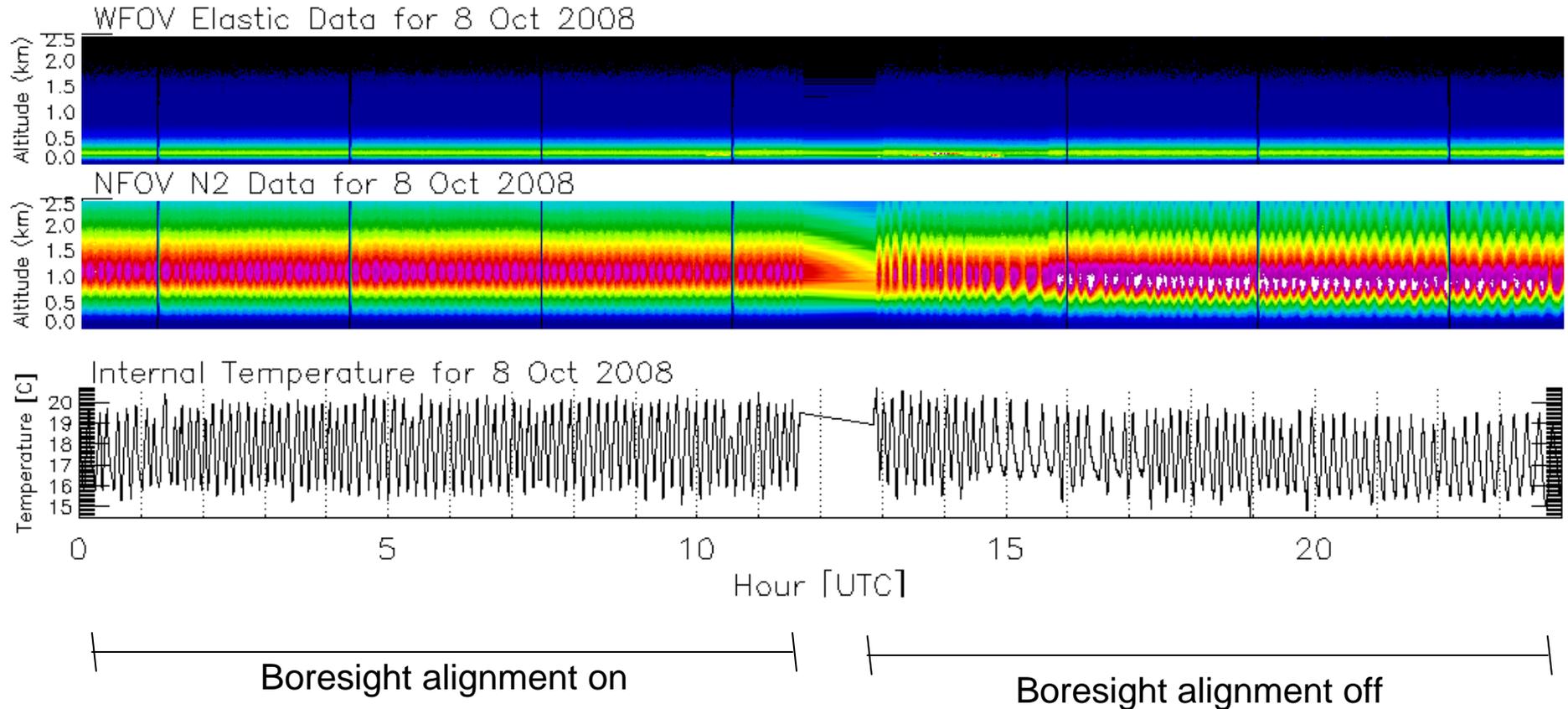
AC Effects

With active alignment

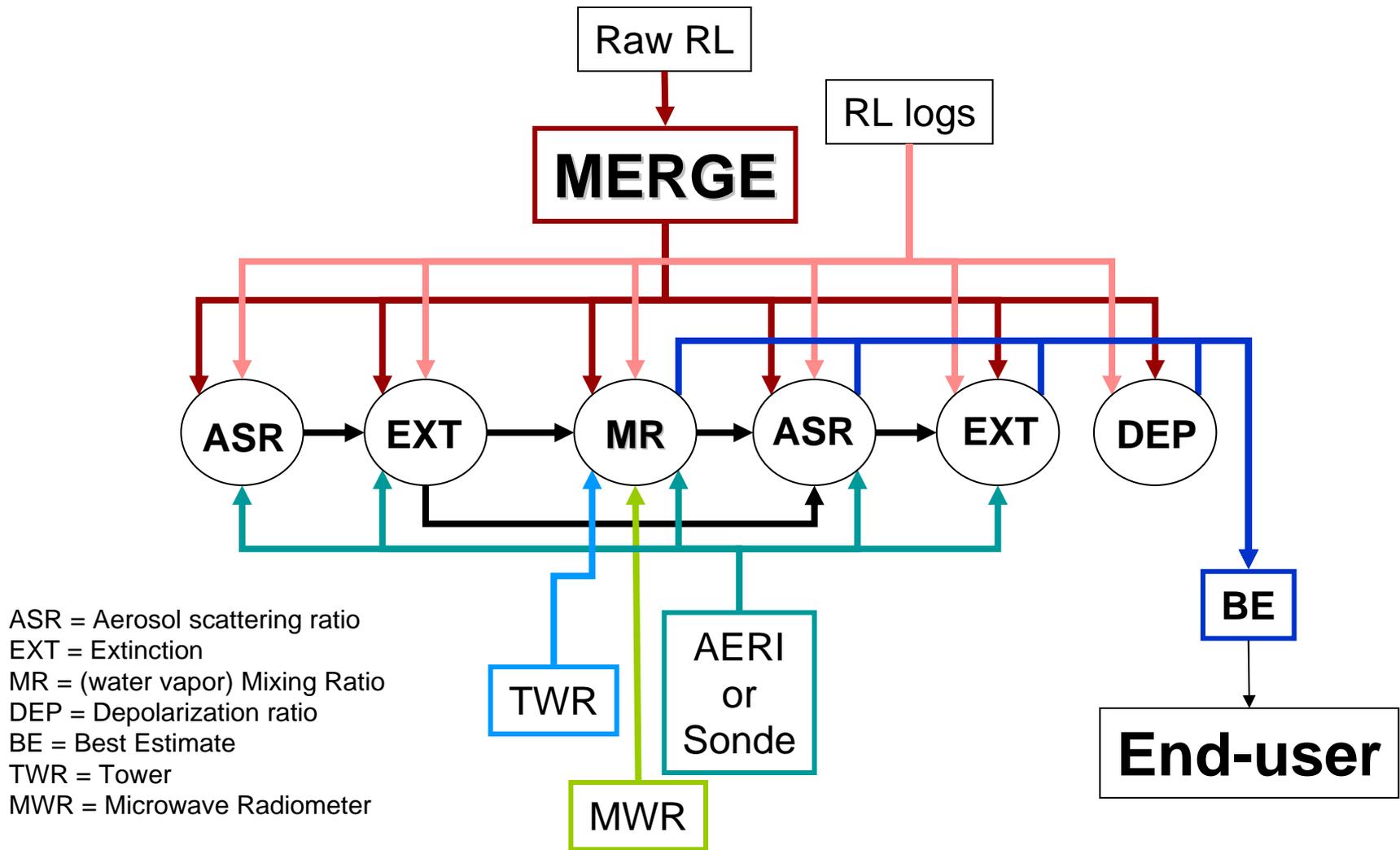


AC Effects With Tarp

With and without active alignment



Value Added Procedures (VAPs)



Cant run any of the “higher level” VAPs without the MERGE VAP

VAP Status

- Priority given to getting all the VAP results into the archive (September 2004 to present).
- A new “modified” MERGE VAP was released into production in February '08
 - Resolved long standing issues with daytime biases in water vapor mixing ratio
 - Have completed processing of all data going back to October 2004
 - Merge data is now available in the ARM archive
- The RLPROF_ASR and RLPROF_EXT VAPs were released into production during the spring and summer of '08
 - 1 Apr 2007 to present is done and (probably) ready for the archive.
 - 1 Oct 2004 to 31 Mar 2007 needs overlap corrections
- RLPROF_MR VAP will be released by 1 December '08
- RLPROF_DEP and RLPROF_BE be released soon

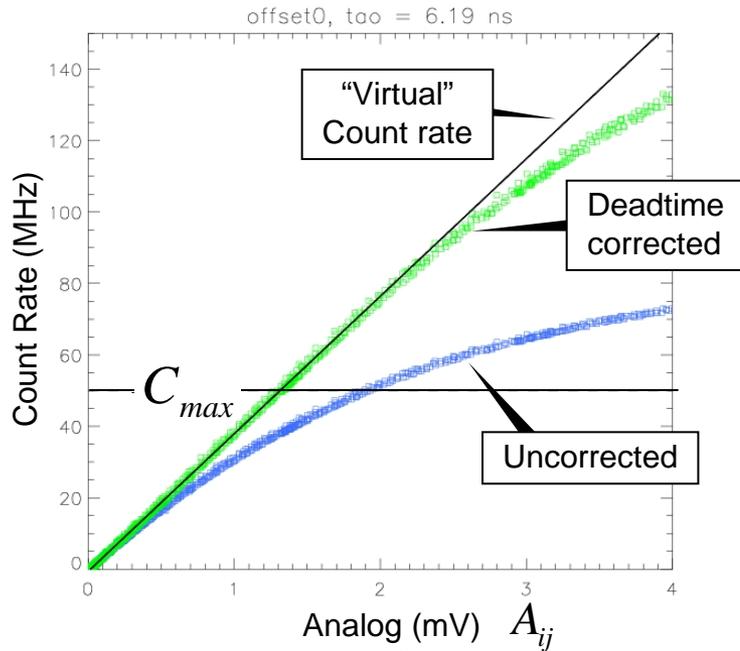
MERGE VAP

- The Raman lidar was upgraded in 2004 with new Licel data recorders
- Licel recorders provide simultaneous measurements of the photomultiplier analog output voltage and photon counts.
- The function of the **MERGE VAP** is to optimally combine the photon counting and analog signals in order to extend the dynamic range of the measurement.
 - Photon counting signal is very sensitive, but is very non-linear at higher signal levels.
 - The analog signal isn't as sensitive but has good linearity at higher signal levels.
- The original version of the MERGE VAP caused significant biases in the water vapor mixing ratio during the daytime.

Mods to MERGE

- Changes to MERGE were evaluated by comparing water vapor mixing from the lidar to sonde measurements
 - 1 April to 30 September 2007
 - Also discovered and fixed a bug in the water vapor calibration in the MR VAP.
- Specific Mods to MERGE include:
 - Changes to the regression method for determination of the glue coefficients
 - New method for determining the system deadtime, τ

MERGE Basics



- Deadtime Correction

$$C'_{ij} = \frac{C_{ij}}{1 - \tau C_{ij}}$$

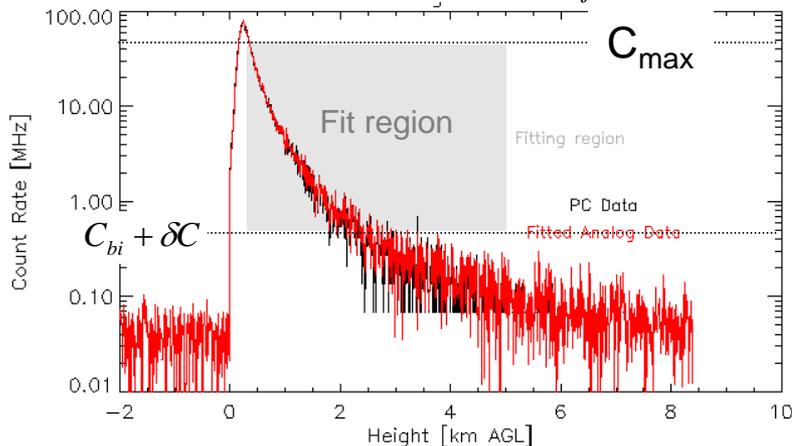
where $C_{ij} = C(t_i, z_j)$

Labels: C_{ij} (Uncorrected photon count rate), τ (Deadtime parameter)

- Virtual Count Rate (scaled analog)

$$\hat{C}_{ij} = s_i A_{ij} + o_i$$

Labels: A_{ij} (Analog Signal), s_i and o_i (Slope and offset: Glue coefficients)



- Perform linear regression to determine the slope and offset (glue coefficients)

- Merge the analog and count rate signals

$$C^{merge}_{ij} = \begin{cases} C'_{ij} & \text{for } C'_{ij} < C_{max} \\ \hat{C}_{ij} & \text{for } C'_{ij} \geq C_{max} \end{cases}$$

The merged signal contains the virtual count rate data above C_{max} , and the deadtime corrected count rate data below C_{max} .

MERGE Regression Methods

1. Baseline method.

$$\text{Minimize } J = \sum_j \frac{(C'_{ij} - \hat{C}_{ij})^2}{\sigma_{ij}^2}$$

subject to $C_{bi} + \delta C < C'_{ij} < C_{max}$

2. Modified method

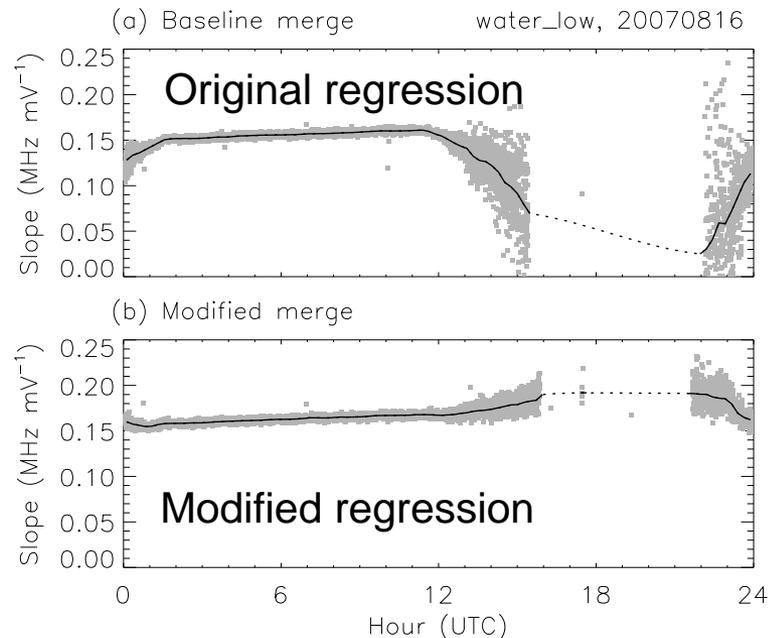
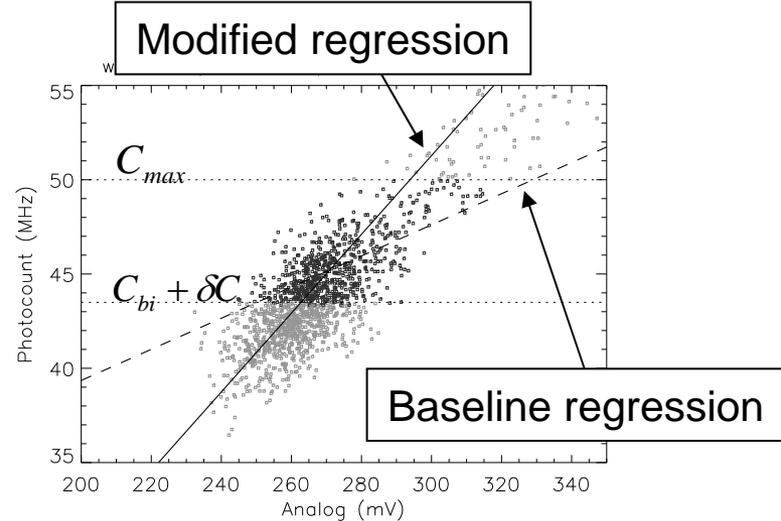
$$\text{Minimize } J_{\text{modified}} = \sum_j \frac{(A_{ij} - \hat{A}_{ij})^2}{\sigma_{ij}^2}$$

where $\hat{A}_{ij} = s'_i C'_{ij} + o'_i$

subject to $C_{bi} + \delta C < C'_{ij} < C_{max}$

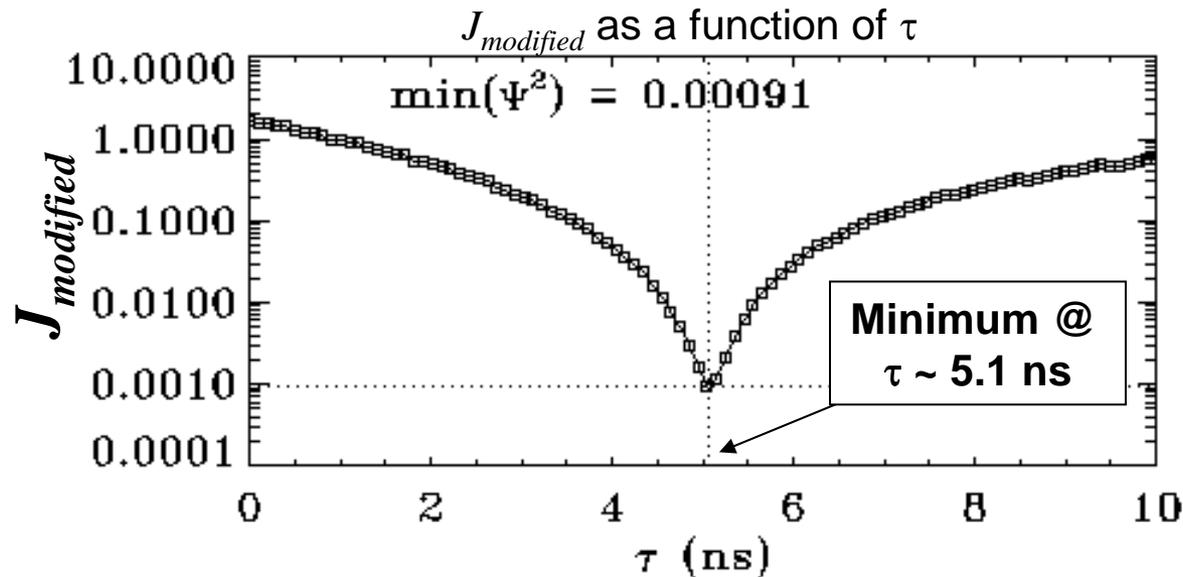
Invert to get glue coefficients:

$$s_i = 1 / s'_i \quad \text{and} \quad o_i = -o'_i s_i$$

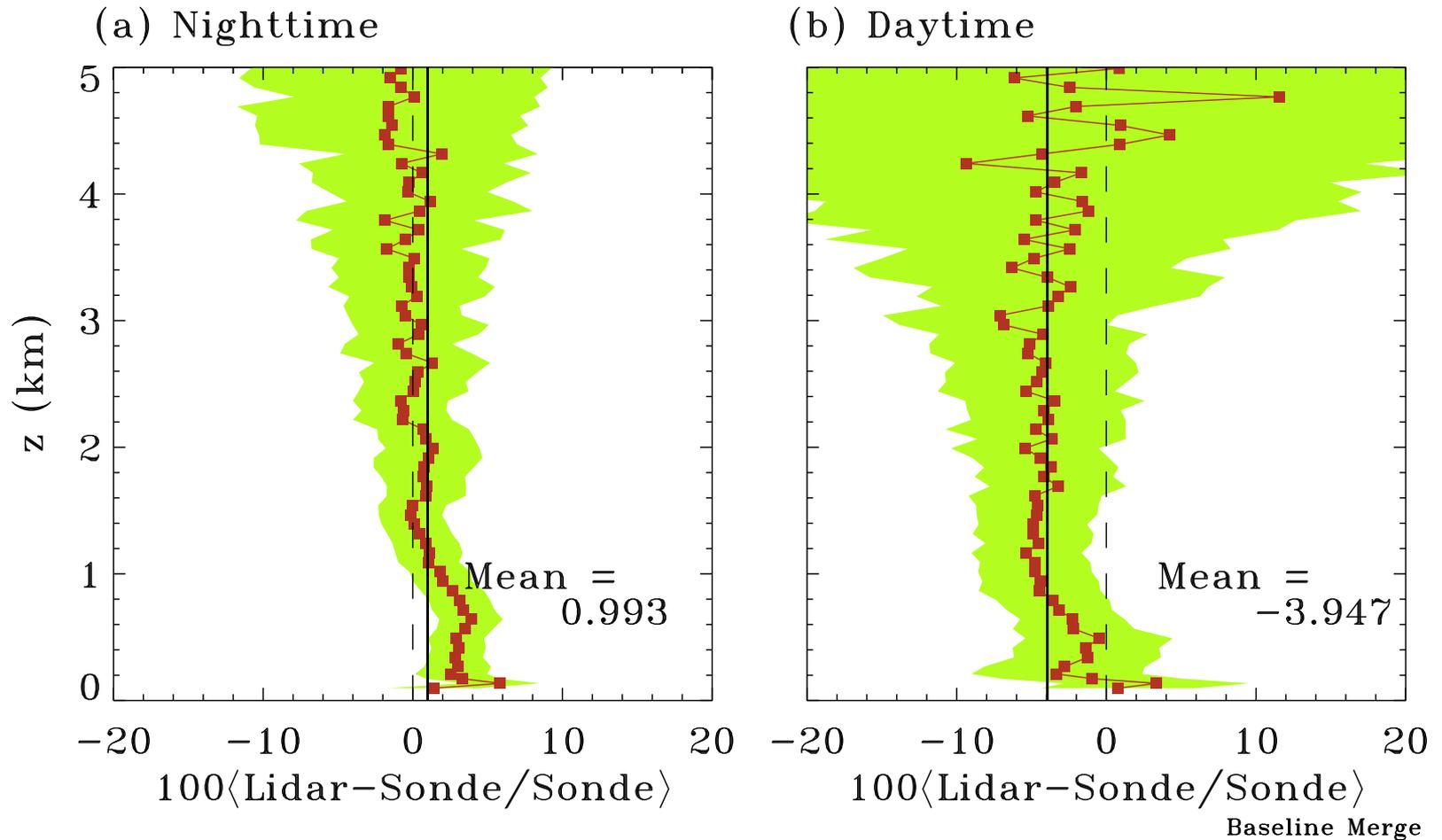


System Deadtime Estimation

1. In the baseline MERGE the deadtime parameter, τ , was obtained using the so-called full- and and reduced-strength signal method.
2. In the modified MERGE the dead-time correction parameter, τ , is obtained by minimizing $J_{modified}$ with s , o AND τ treated as adjustable parameters.



Baseline Merge Results

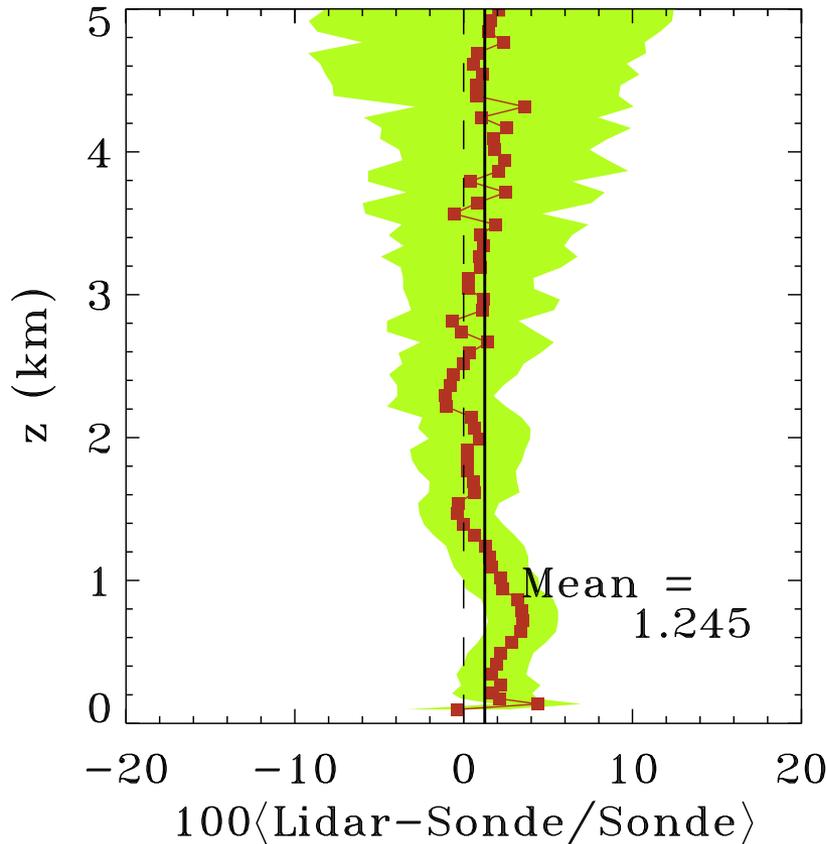


~ 4% dry bias during the day
~ 5% difference between night and day

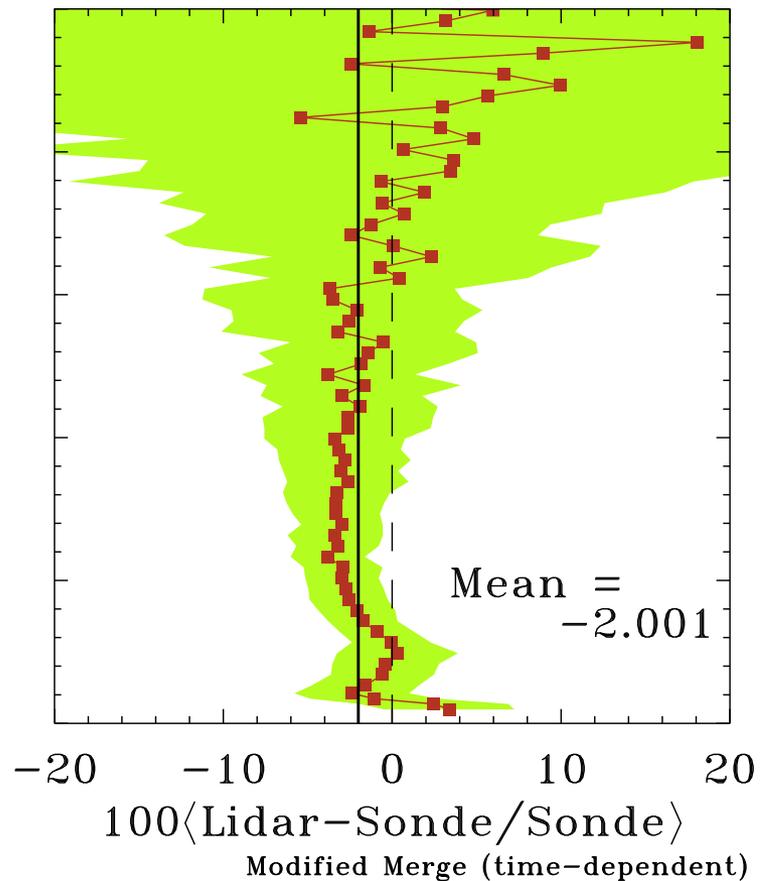
Modified MERGE Results

Time Dependent Glue Coefficients

(a) Nighttime



(b) Daytime

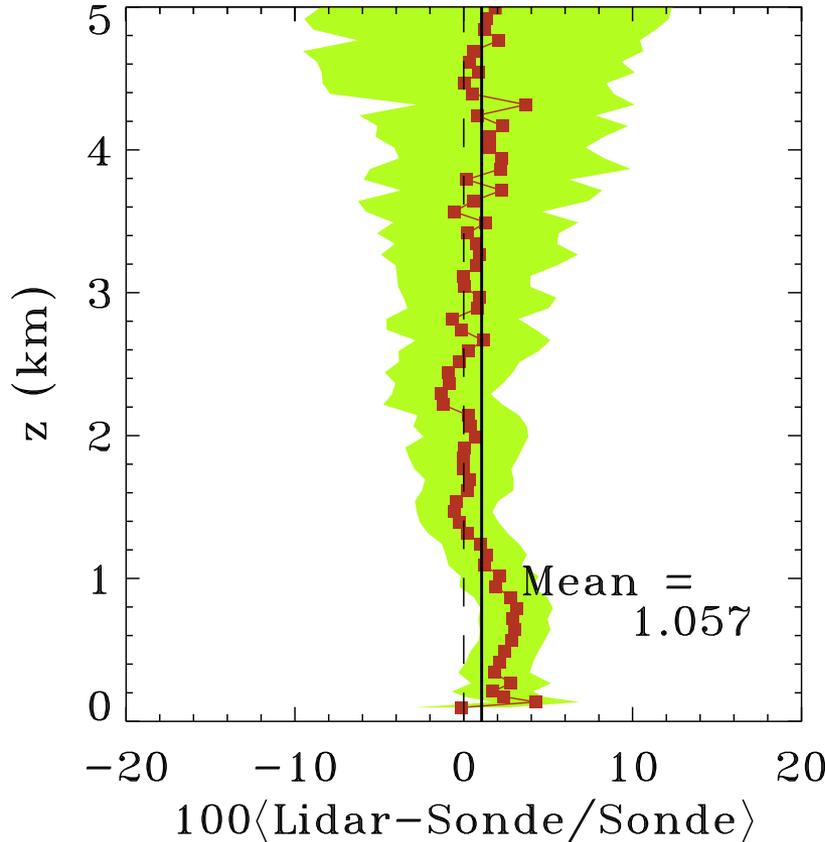


~ 2% dry bias during the day
~ 3.2% difference between night and day

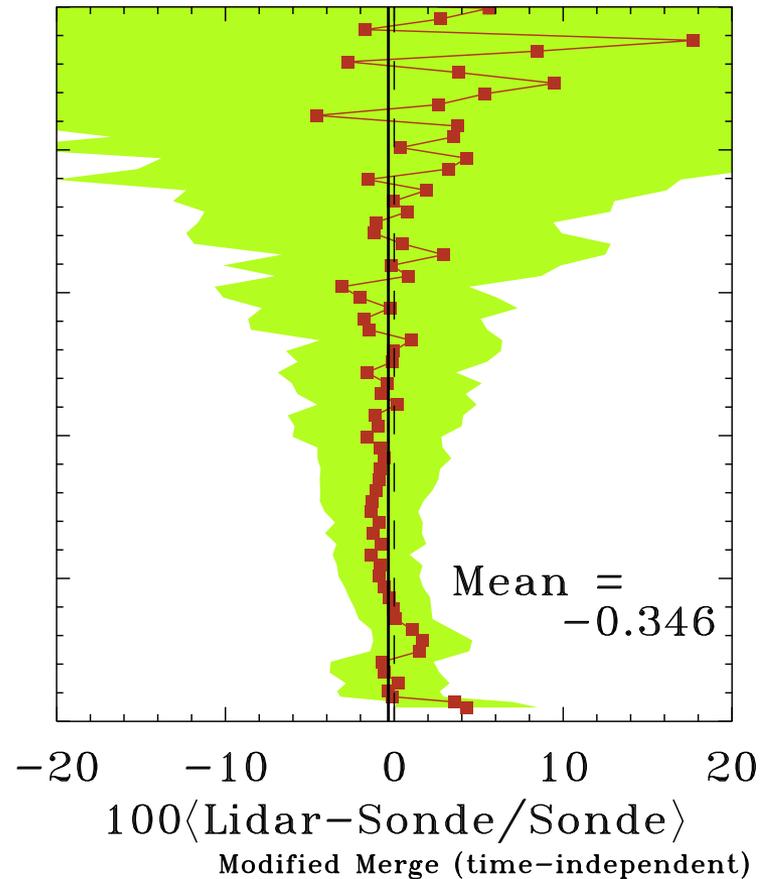
Modified MERGE Results

Time Independent Glue Coefficients

(a) Nighttime



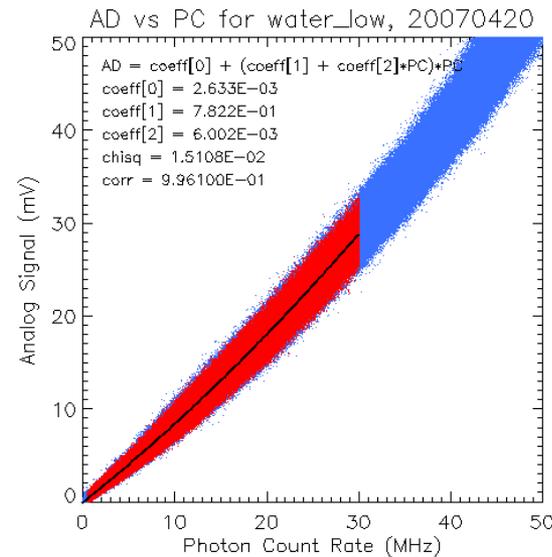
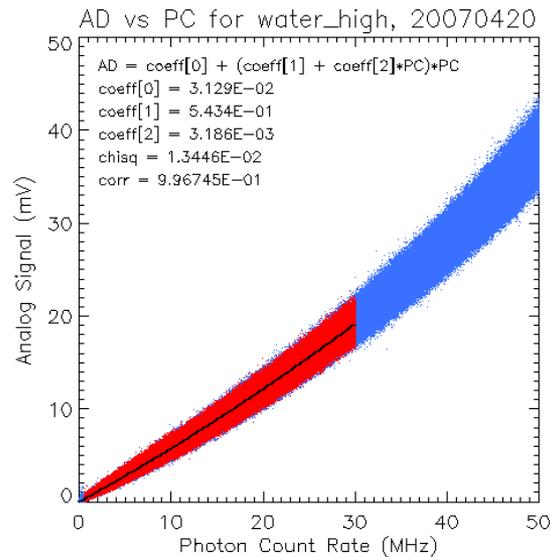
(b) Daytime



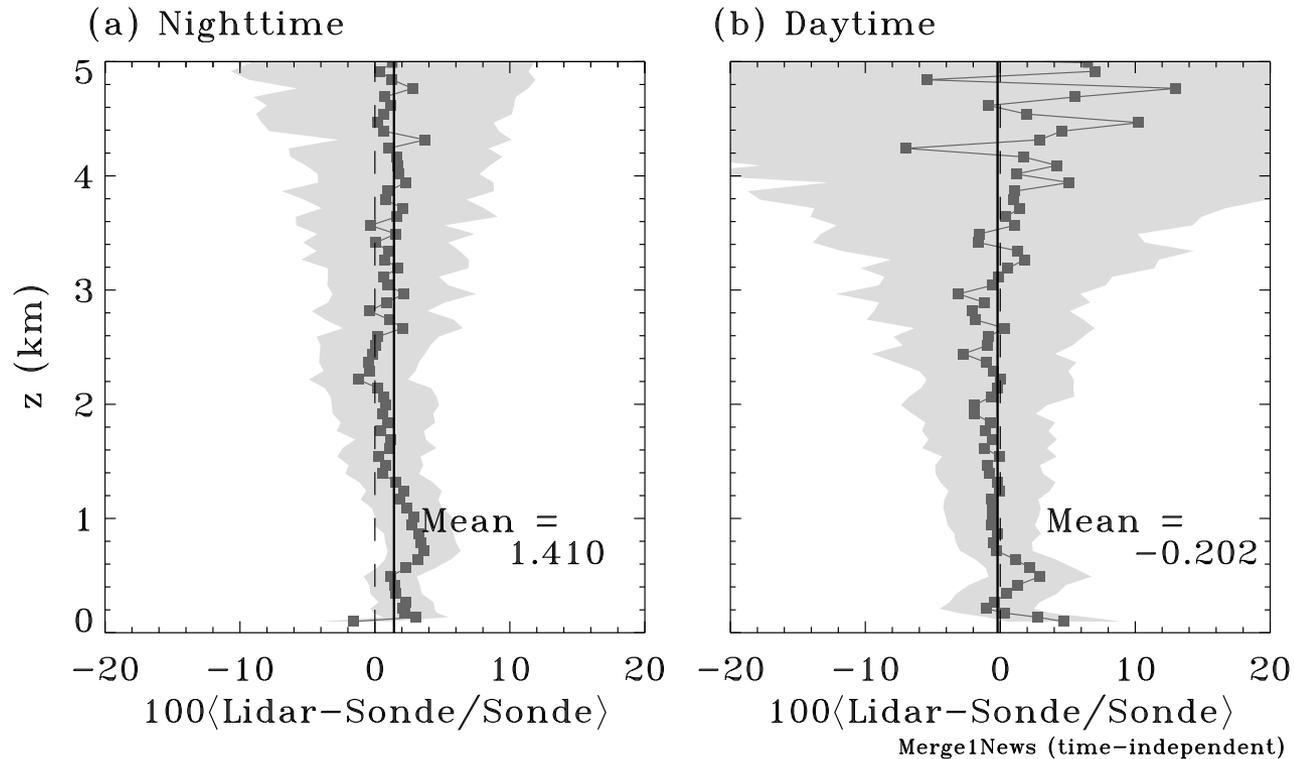
~ 0.3% dry bias during the day
~ 1.4% difference between night and day

Other ideas for the MERGE VAP

- Developed and tested a new MERGE algorithm called Merge1News.
- Uses an entire day of data to estimate the appropriate nonlinear correction for the photon count rate signal.
- Correction curve is obtained from the observed relationship between the analog and count rate data.
 - Simple polynomial fit
 - Linear least squares
- Count rates are converted to analog voltage (instead of vice versa) below Cmax
- Pure analog is used above Cmax



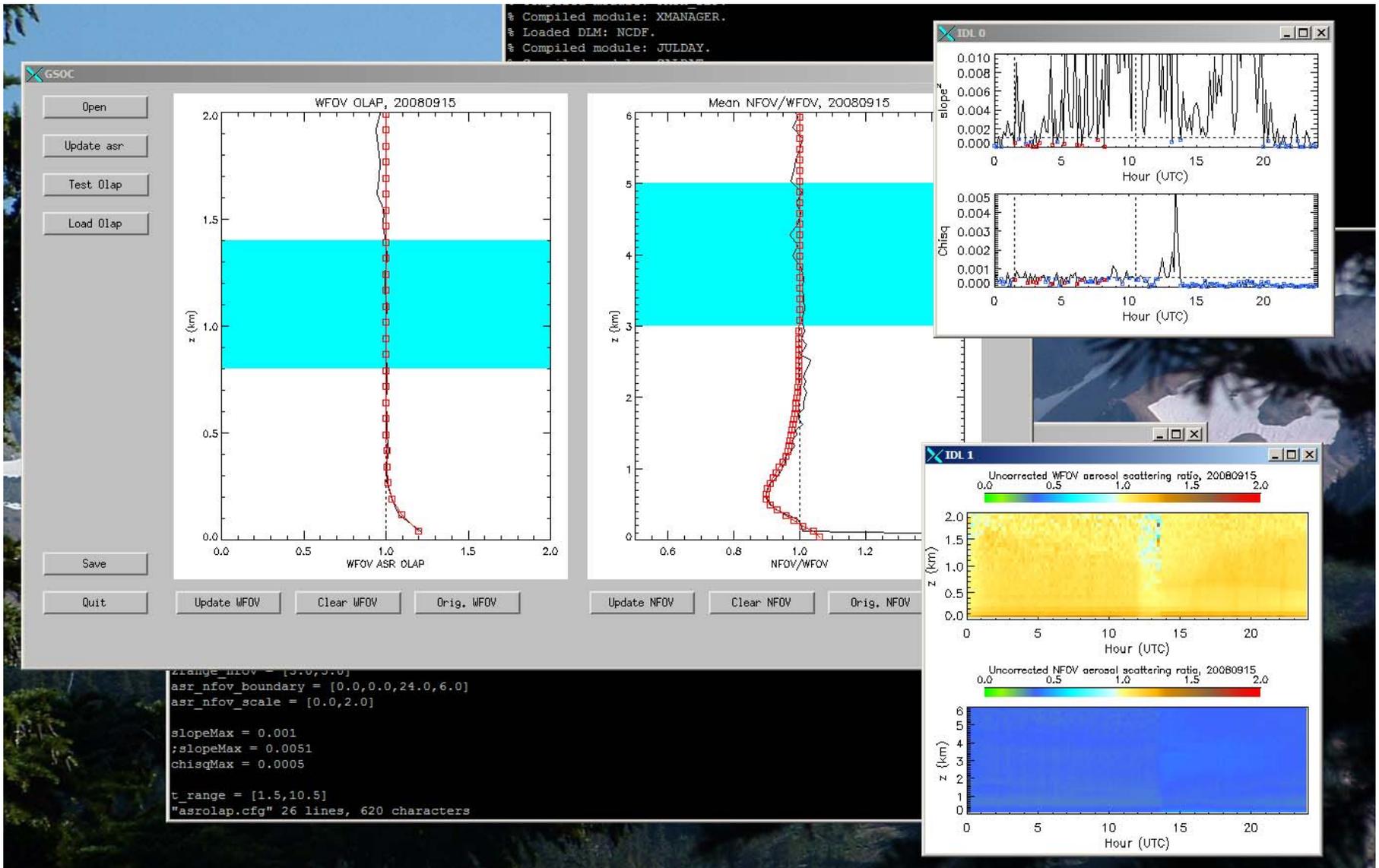
Results from MergeNews1



Water vapor biases are about the same as the Modified MERGE with time independent glue coefficients. However ...

- No need to specify deadtime parameters
- Polynomial fit requires only linear least squares estimation
- It executes about 6 times faster than the Baseline or Modified Merge
- Further “tuning” may yield better results

Tools for Generating Overlap Corrections



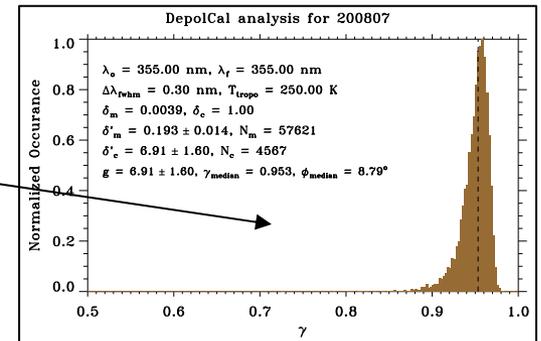
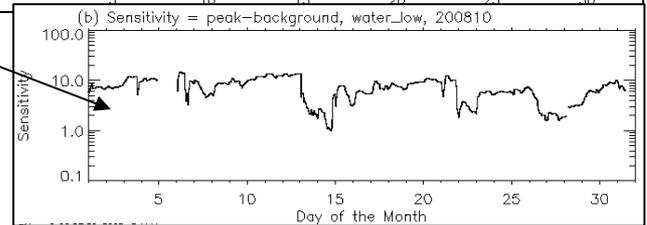
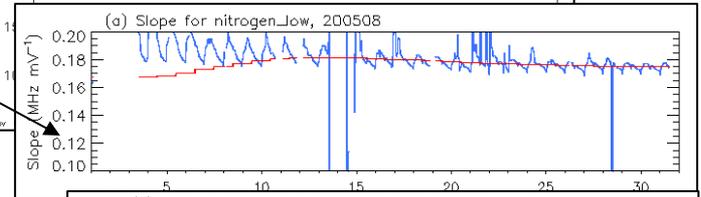
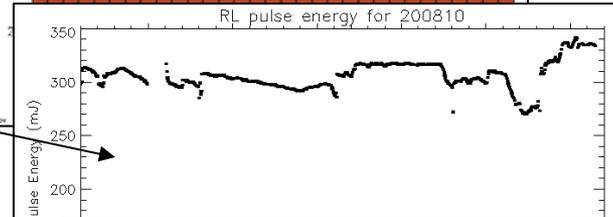
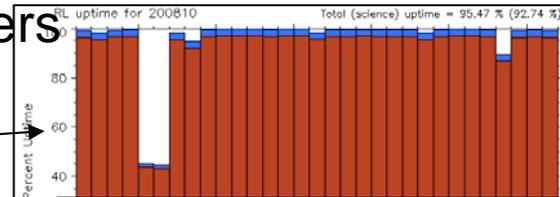
Semi-Automated Offline Analysis Tools

- Monthly monitoring of basic parameters

- Daily uptime stats
- Hourly averaged pulse energy
- Hourly averaged glue coefficients
- Hourly averaged Sensitivity

- Monthly monitoring to ensure proper configuration

- Deadtime coefficients
- Copol and Depol relative gain and Depol misalignment
- Modify configuration files as needed



Current Efforts and Issues

- Existing VAPs
 - Priority given to getting all the VAP data into the ARM archive (1 October 2004 to present)
 - Establishing and streamlining procedures
 - Using ARM Wiki to communicate between mentor and DMF
 - Doing overlap correction is a tedious and time consuming process – but critical
 - Need for updated “realtime” version of the RL VAP suite for system monitoring purposes
 - Update VAP web pages
- Update instrument handbook
- Get the temperature VAP going
- Hardware
 - We need a more stable AC
 - Licel lab tests suggest that we may not using the greatest PMTs (or voltage dividers)
 - What about the use of calibration lamps?
 - Is it possible ensure proper alignment of the depol/copol channels w.r.t. to outgoing polarization. What about possible birefringence in the window?

The End

