Deployment and Operational Status of the New ARM Lidars

Current ARM Lidar Inventory

- Raman (water vapor, aerosol backscatter, optical depth, temperature)
  - SGP
  - TWP-Darwin
- HSRL (aerosol backscatter, optical depth)
  - AMF2 (currently in Steamboat Springs)
  - NSA-Barrow
- Doppler (winds, aerosol attenuated backscatter)
  - SGP
  - TWP-Darwin
  - AMF1 (awaiting deployment to India)
- MPLs and Ceilometers at most sites

Ceilometer Update

- New ceilometers (Vaisala CL31) deployed at SGP/C1, NSA/C1, TWP/C1, TWP/C2, AMF1, AMF2
- All new ceilometers deployed and data available at ARM Archive before end of FY2010
- New ceilometers configured to improve detection of aerosol and mixing layers
- New boundary-layer cloud height algorithm not yet implemented

MPL Update?

Doppler Lidars

Doppler Lidar

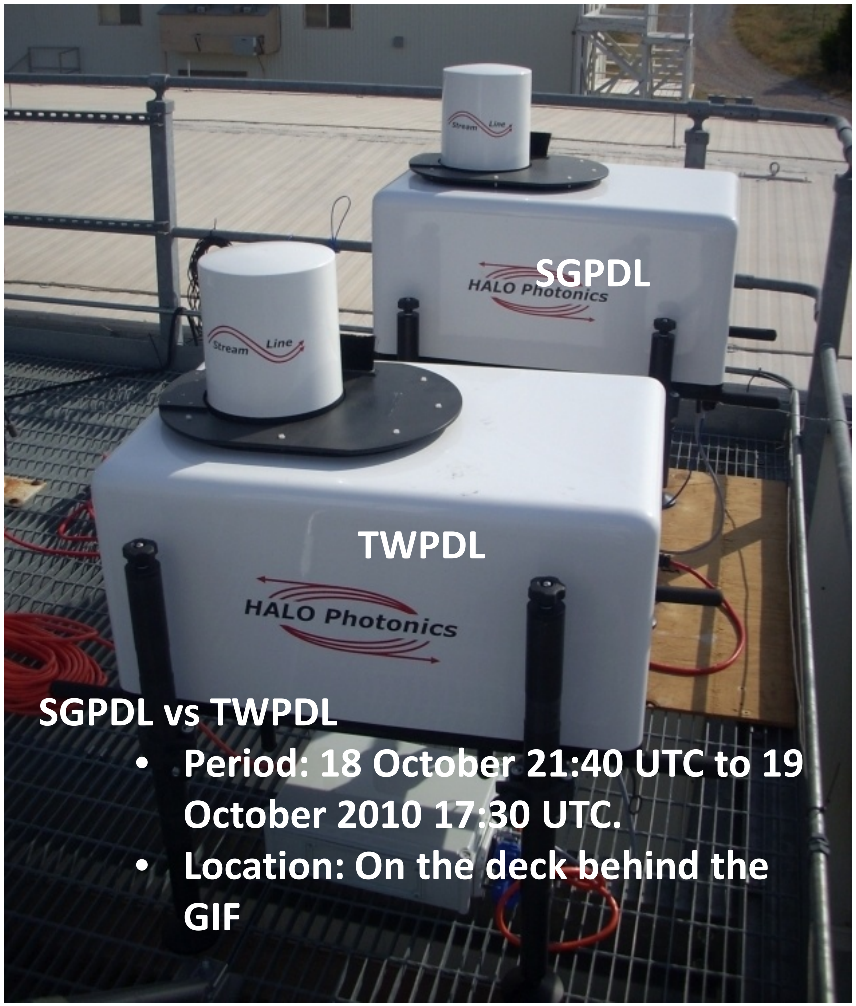
- October 2010:
  - Three systems shipped from Halo Photonics to SGP for acceptance testing
    - SGPDL – The SGP Doppler lidar
    - TWPDL – The TWP-Darwin Doppler lidar
    - AMFDL – The AMF1 Doppler lidar
  - Thorough acceptance testing performed
    - Side-by-side intercomparisons

Doppler Lidar Specifications

Manufacturer	Halo Photonics (UK)
Weight	85 kg
Aperture Diameter	75 mm
Pulse width	150 ns (22.5 m)
Pulse Energy	100 μJ
Wavelength	1.5 μm
Pulse rate	15 kHz
Minimum range	75m (Typical value)
Range for data collection	Standard: 0.06-10km
Receiver bandwidth	± 15ms-1
Eye-safety	Class 1M
Range gate length	20-50m
Scanner	Fully programmable, two axis, step-stare scanner
Enclosure	Portable, rugged, sealed system with active and passive cooling

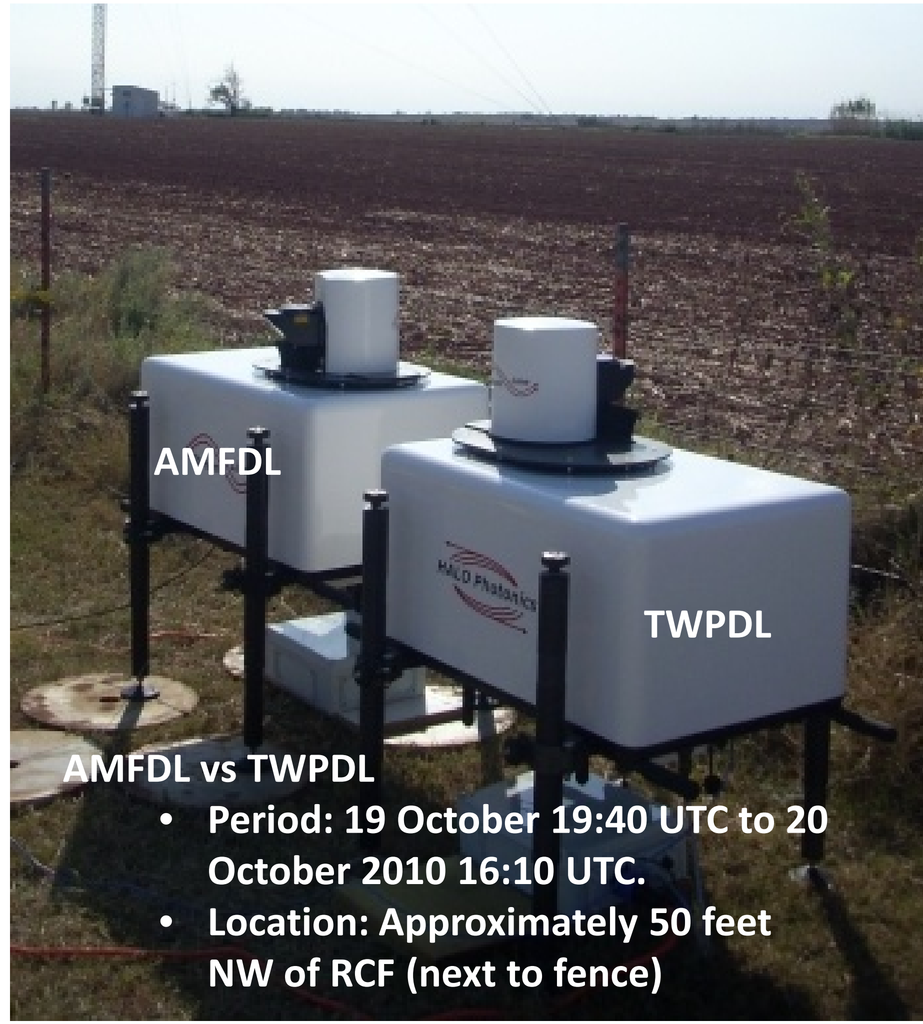
Uses heterodyne detection to measure Doppler shift of return.
Sensitive to aerosol scattering, insensitive to molecular scatering, insensitive to solar.

Side-by-Side Intercomparisons



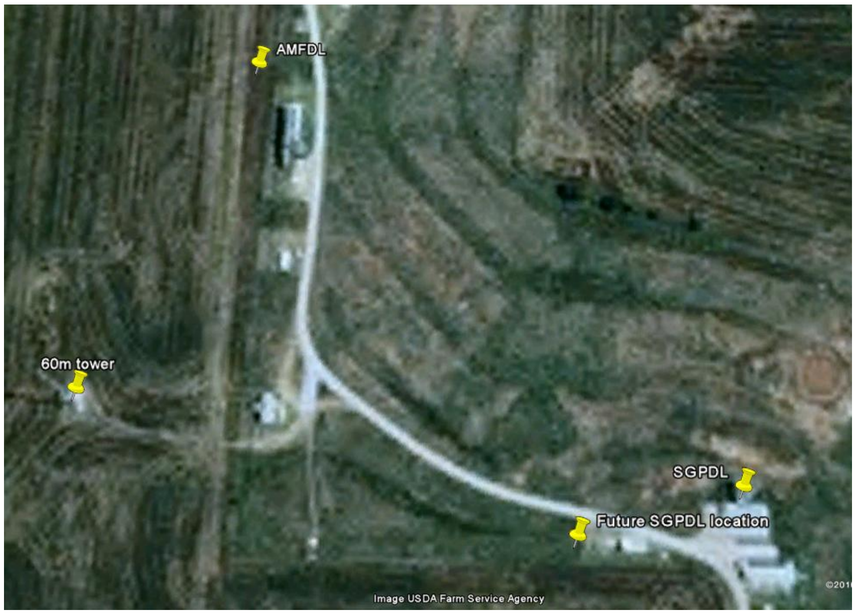
SGPDL vs TWPDL

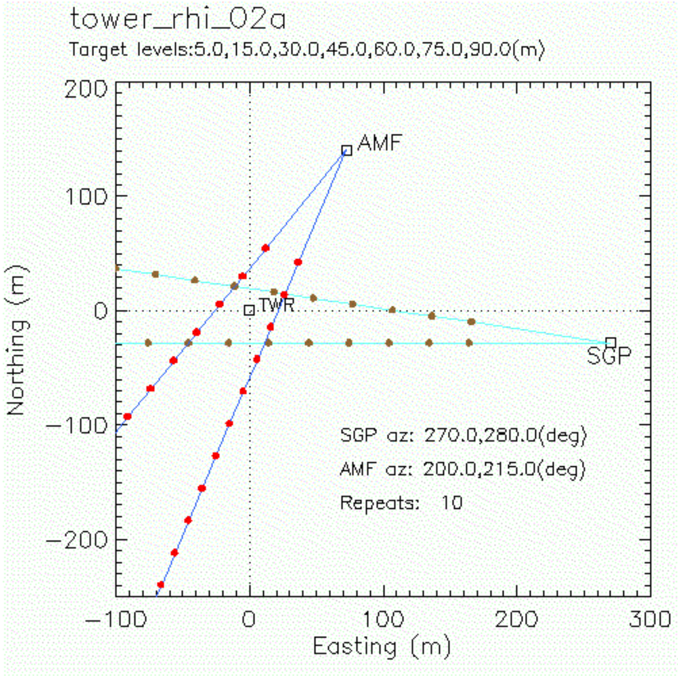
- Period: 18 October 21:40 UTC to 19 October 2010 17:30 UTC.
- Location: On the deck behind the GIF



AMFDL vs TWPDL

- Period: 19 October 19:40 UTC to 20 October 2010 16:10 UTC.
- Location: Approximately 50 feet NW of RCF (next to fence)


AMFDL
60m tower
SGPDL
Future SGPDL location
Image USDA Farm Service Agency


tower_rhi_02a
Target levels:5.0,15.0,30.0,45.0,60.0,75.0,90.0(m)
AMF
TWR
SGP
SGP az: 270.0,280.0(deg)
AMF az: 200.0,215.0(deg)
Repeats: 10
Northing (m)
Easting (m)
200
100
0
−100
−200
−100
0
100
200
300

Operating Modes

During the intercomparison periods the three lidar systems were configured as follows:

- Number of samples per gate = 10
- Number of range gates = 320
- Number of pulses averaged = 15000
- Points in FFT = 1024
- Vertical staring

The range resolution, or gate size, is determined by setting the number of the samples per range gate. Atmospheric returns are sampled at 50 MHz, which translates into 3 m between samples. The parameters listed above imply a gate size, or **range resolution of 30m**, and a **maximum measurement range of 9600m**. The pulse repetition frequency of the lidar is 15kHz, so averaging 15000 pulses results in a **temporal resolution of about 1 second**. All intercomparisons were performed with the systems staring vertically. Thus, radial and vertical velocities are one and the same.

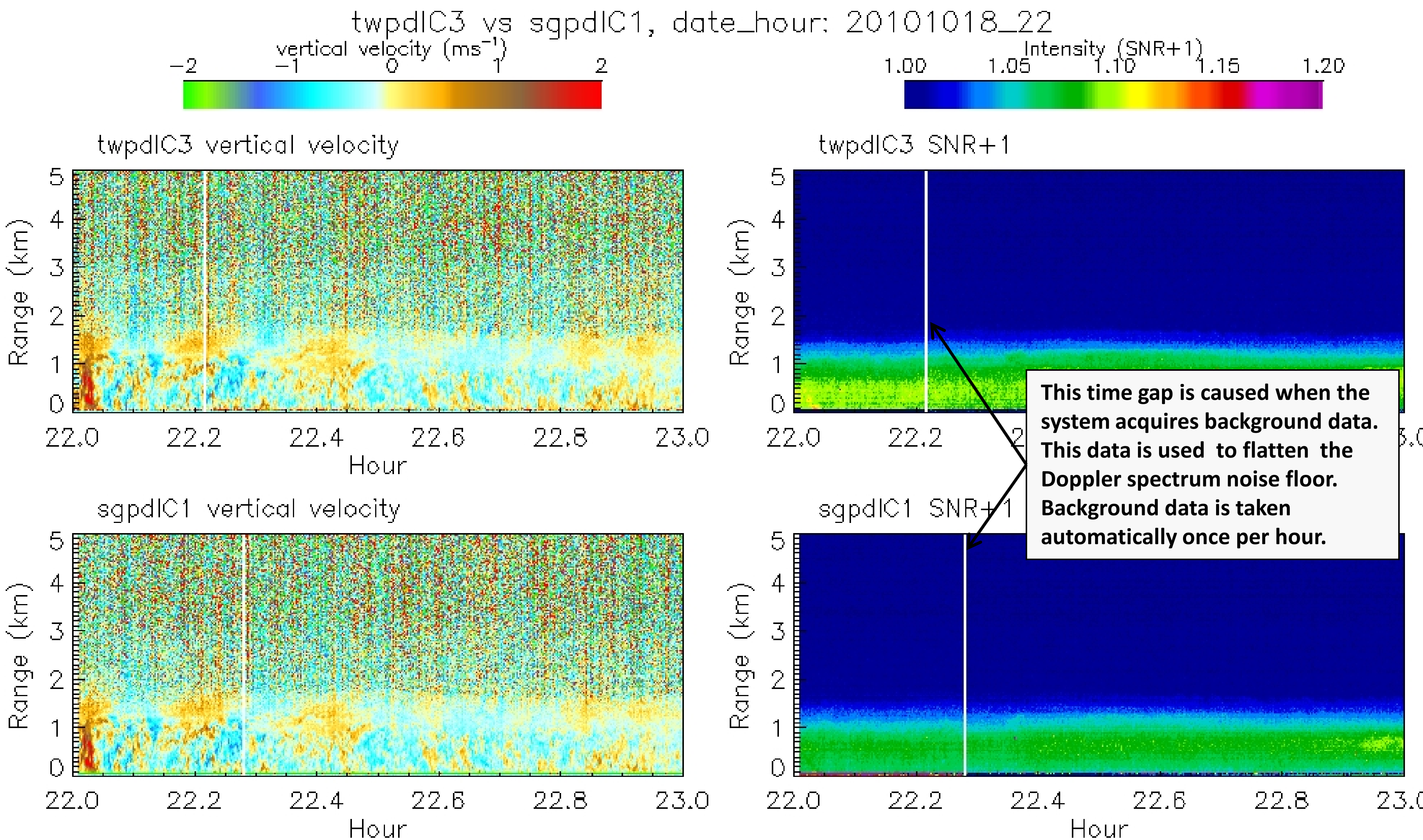
SGPDL vs TWPDL

22 UTC 18 October to 17 UTC 19 October 2010

SGPDL vs TWPDL

22-23 UTC, 18 October 2010

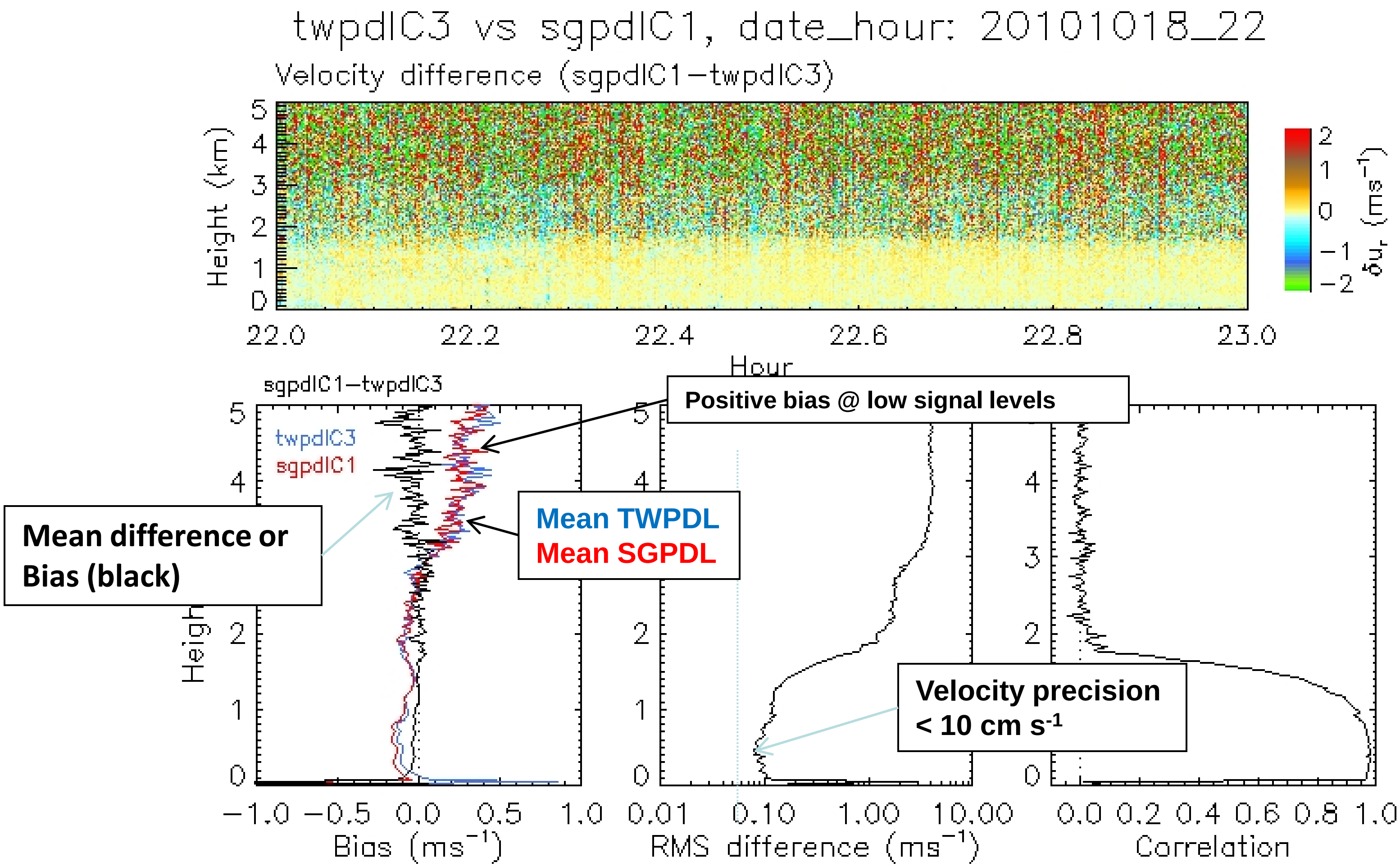
Vertical Velocity (left); Signal Intensity (right)



SGPDL vs TWPDL

22-23 UTC, 18 October 2010

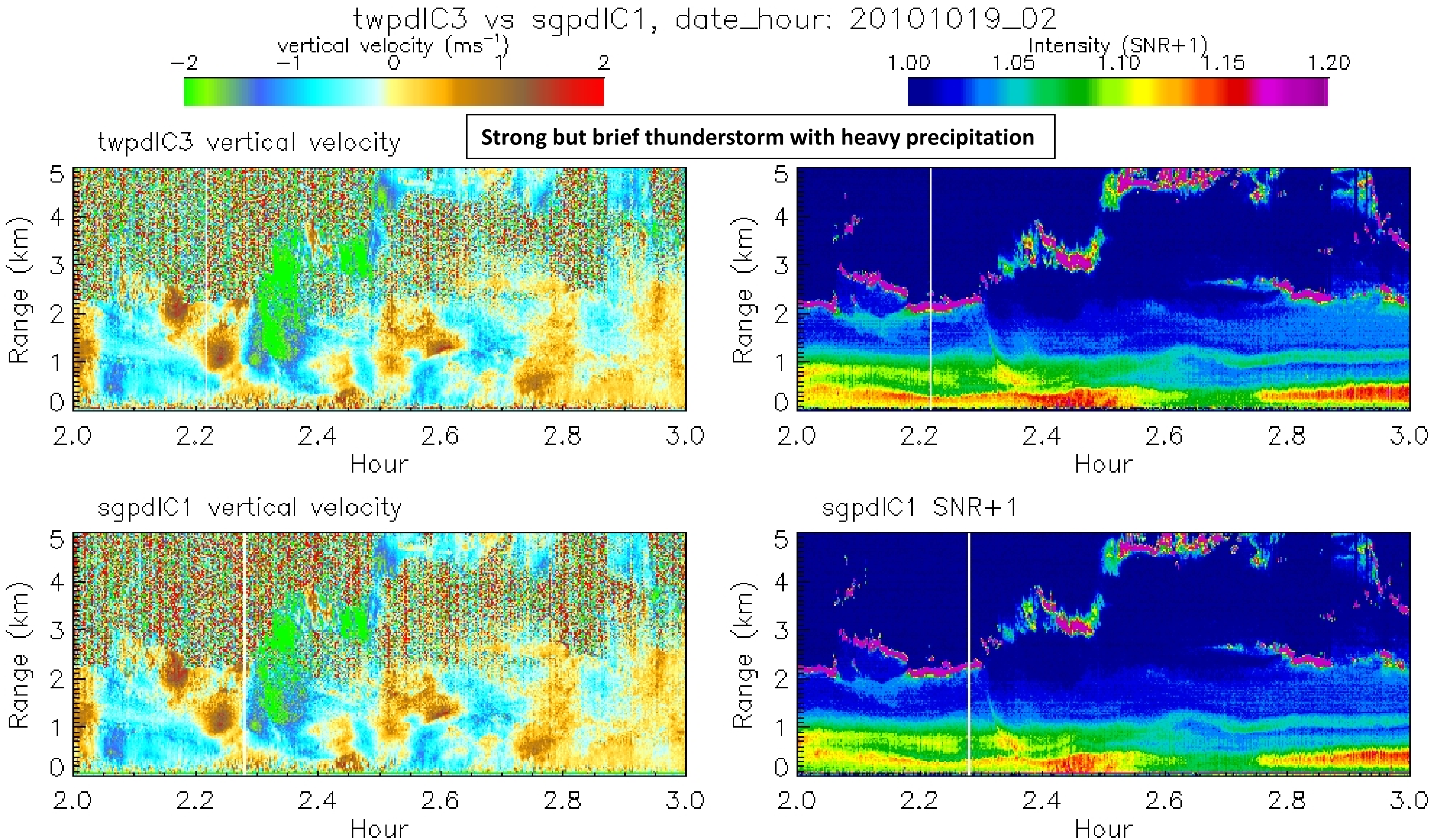
Difference (top); bias (bottom left); RMS deviation (bottom middle); correlation (bottom right)



SGPDL vs TWPDL

02-03 UTC, 19 October 2010

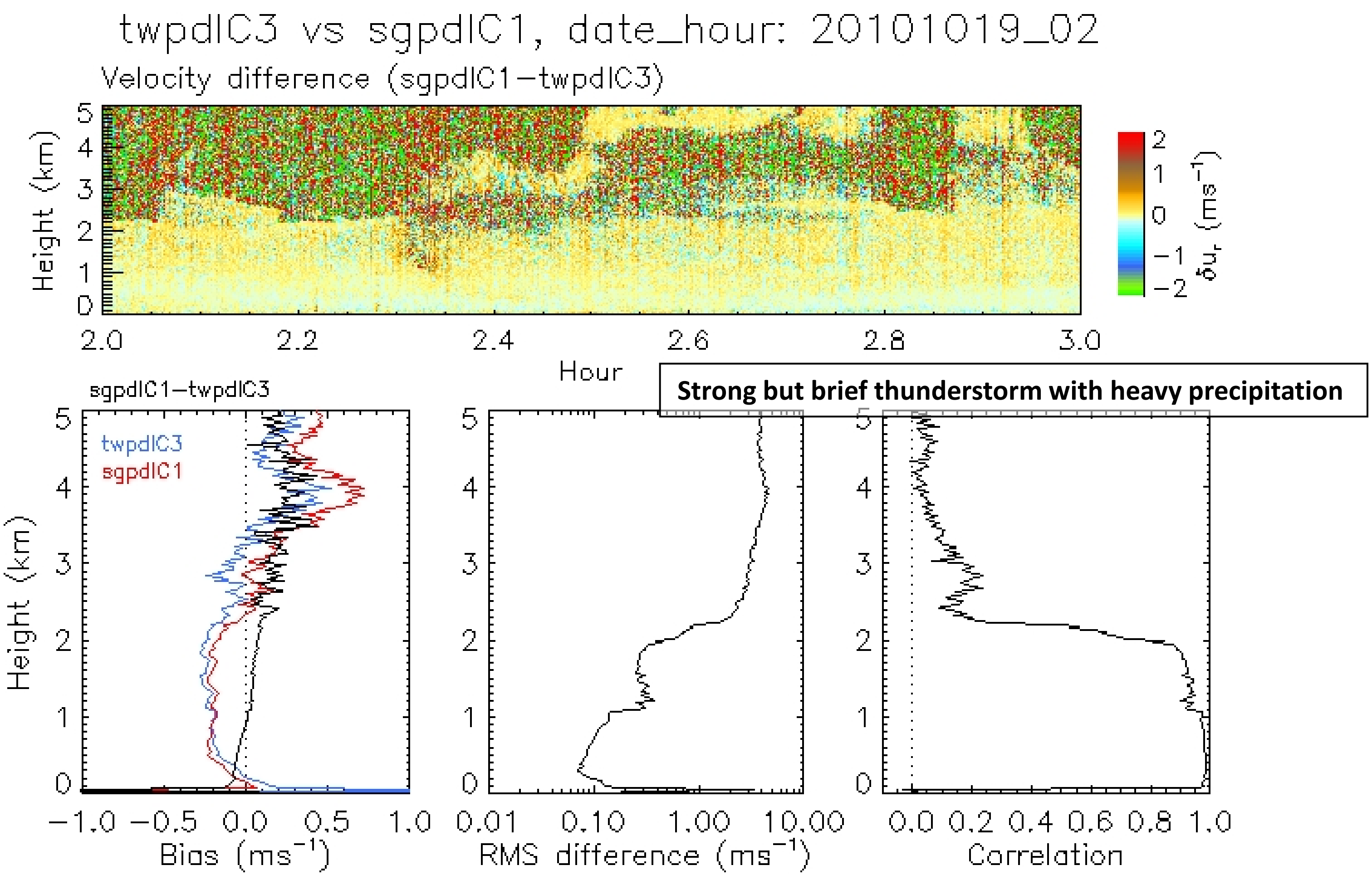
Vertical Velocity (left); Signal Intensity (right)



SGPDL vs TWPDL

02-03 UTC, 19 October 2010

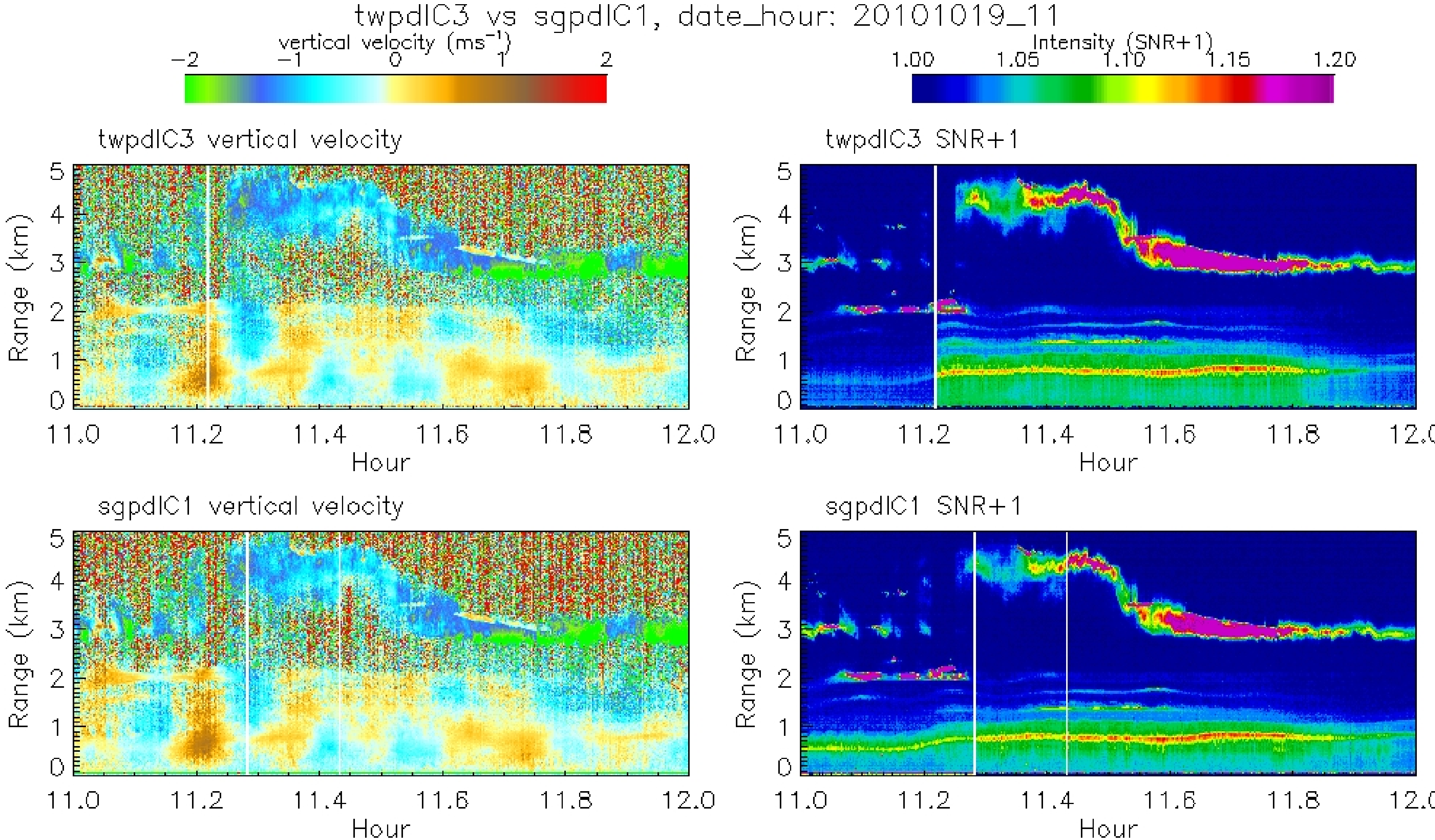
Difference (top); bias (bottom left); RMS deviation (bottom middle); correlation (bottom right)



SGPDL vs TWPDL

11-12 UTC, 19 October 2010

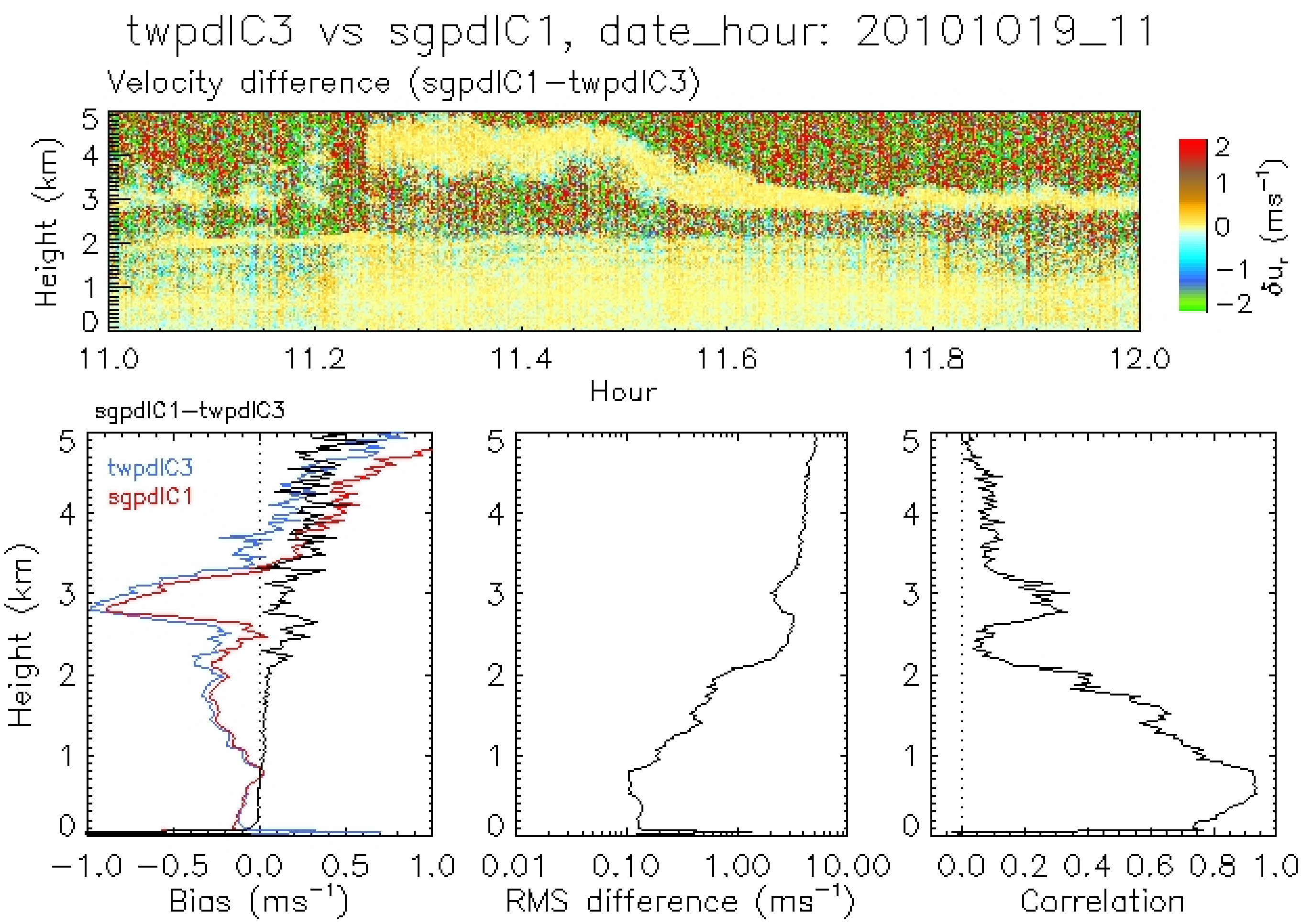
Vertical Velocity (left); Signal Intensity (right)



SGPDL vs TWPDL

11-12 UTC, 19 October 2010

Difference (top); bias (bottom left); RMS deviation (bottom middle); correlation (bottom right)



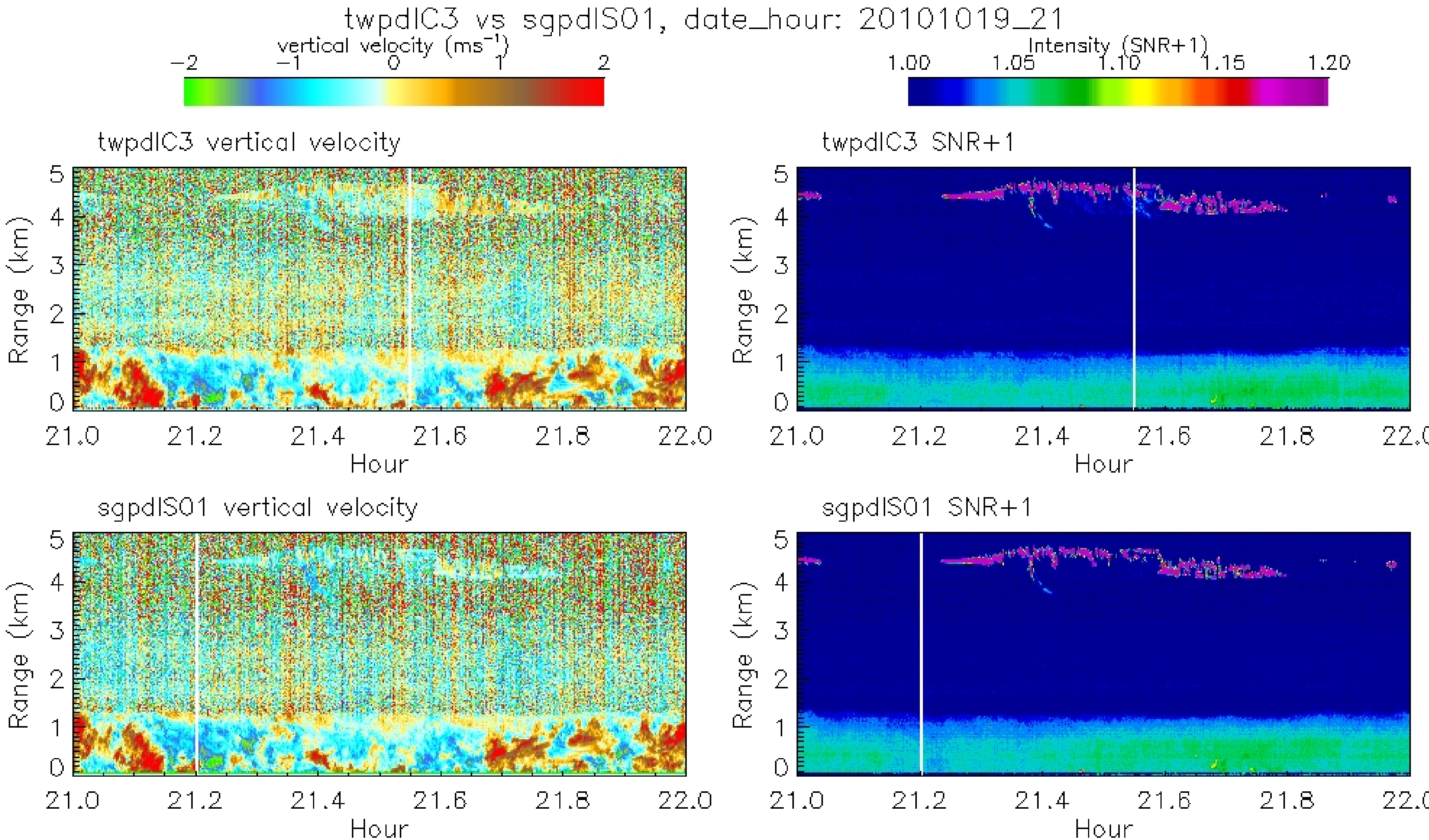
AMFDL vs TWPDL

20 UTC 19 October to 16 UTC 20 October 2010

AMFDL vs TWPDL

21-22 UTC, 19 October 2010

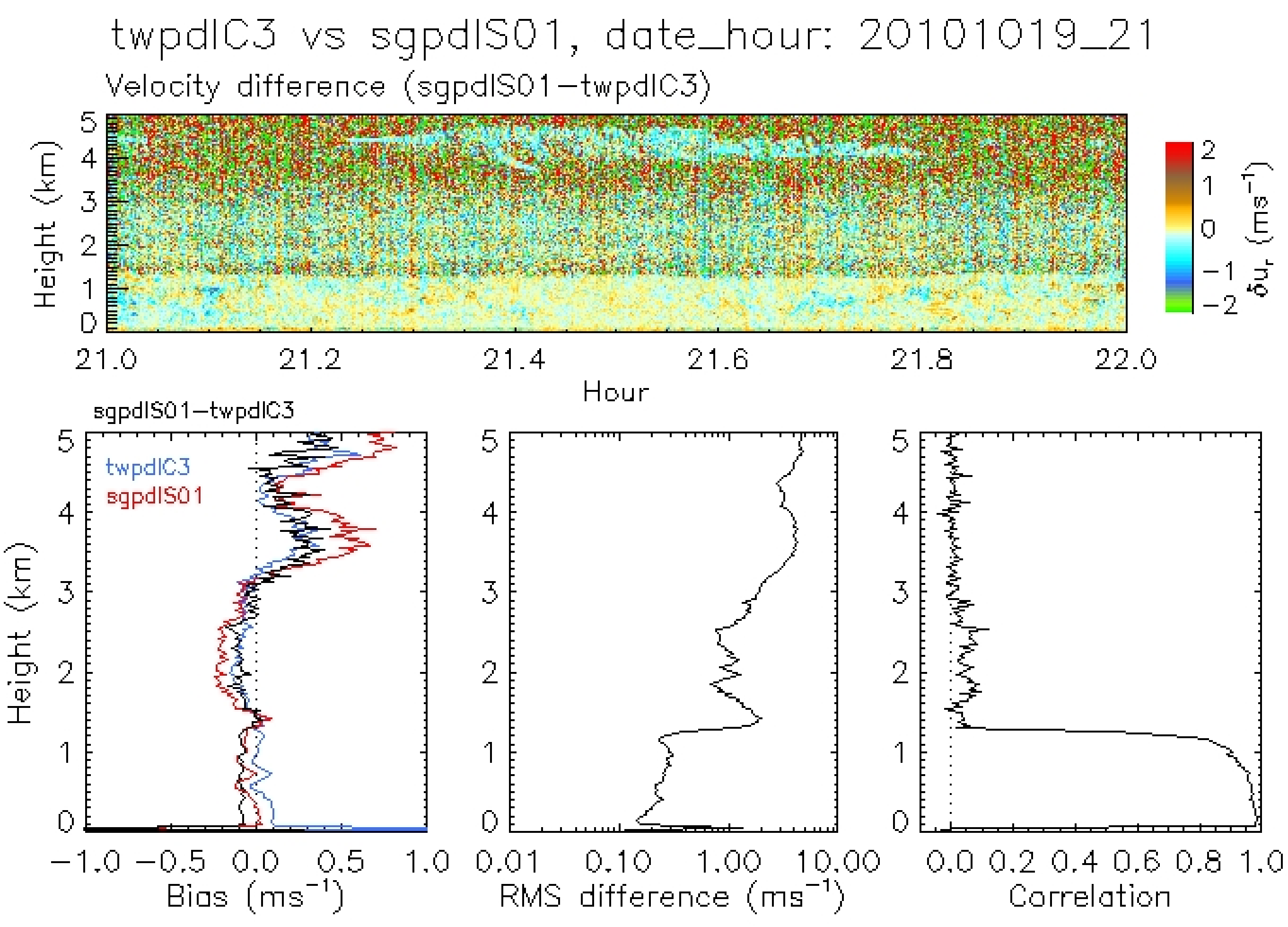
Vertical Velocity (left); Signal Intensity (right)



AMFDL vs TWPDL

21-22 UTC, 19 October 2010

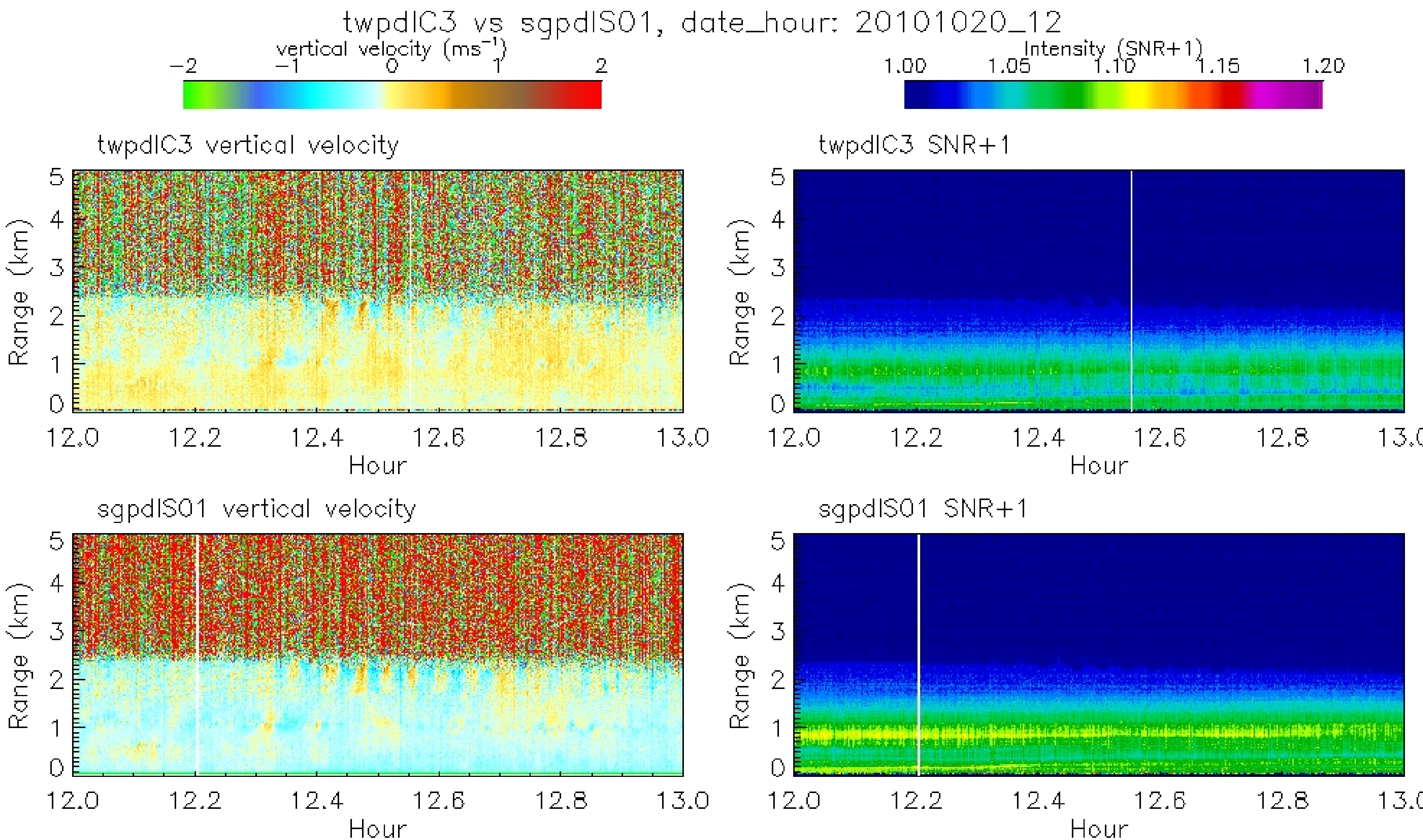
Difference (top); bias (bottom left); RMS deviation (bottom middle); correlation (bottom right)



AMFDL vs TWPDL

12-13 UTC, 20 October 2010

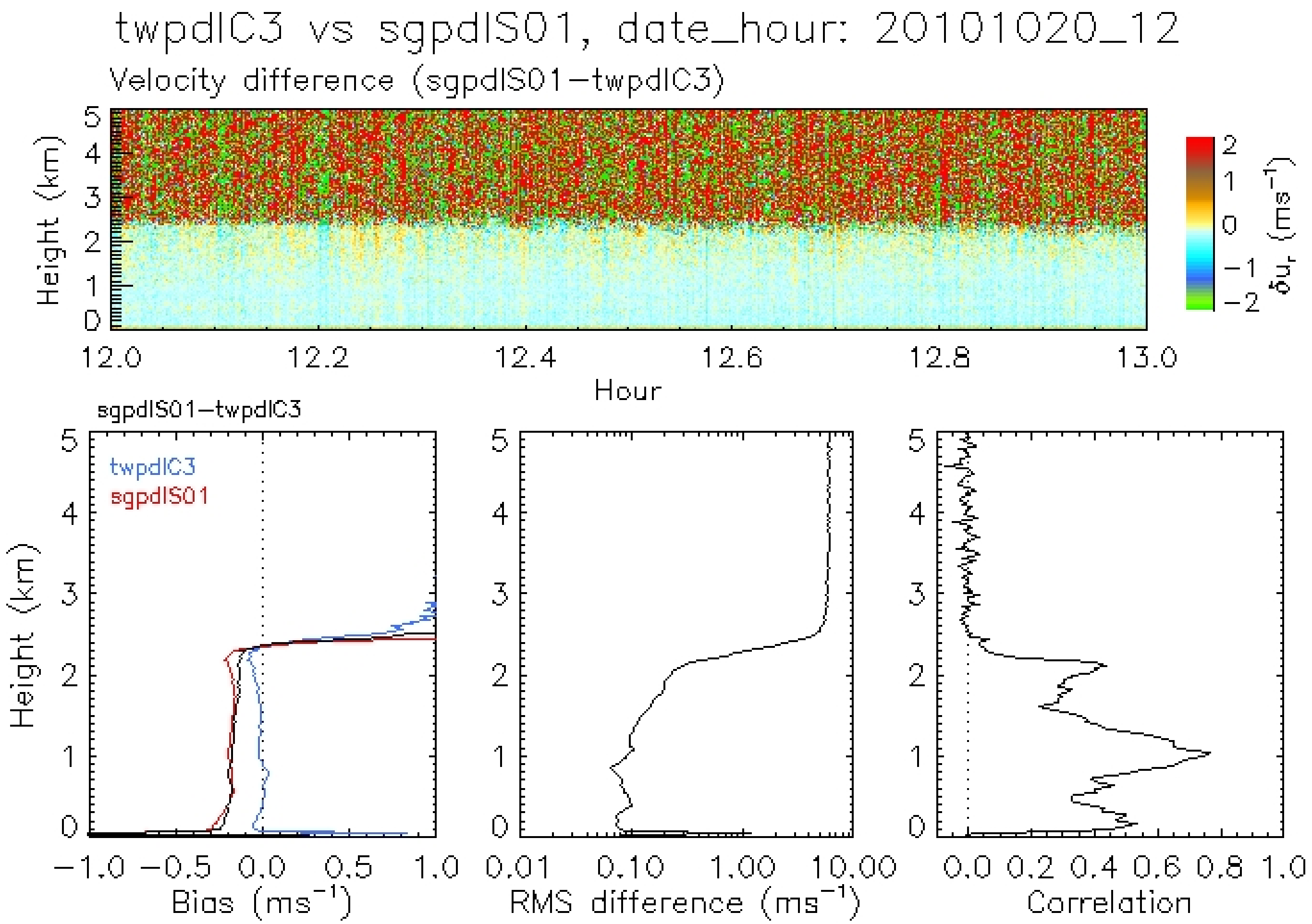
Vertical Velocity (left); Signal Intensity (right)



AMFDL vs TWPDL

12-13 UTC, 20 October 2010

Difference (top); bias (bottom left); RMS deviation (bottom middle); correlation (bottom right)



Velocity Precision vs Signal-to-Noise Ratio (SNR)

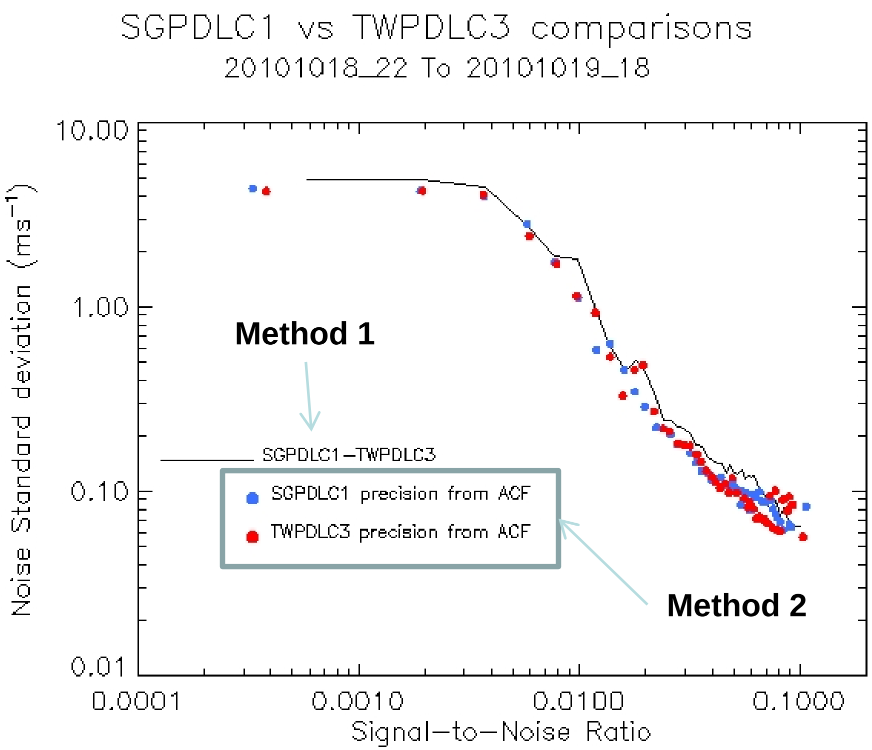
- Velocity precision = standard deviation of the measurement noise

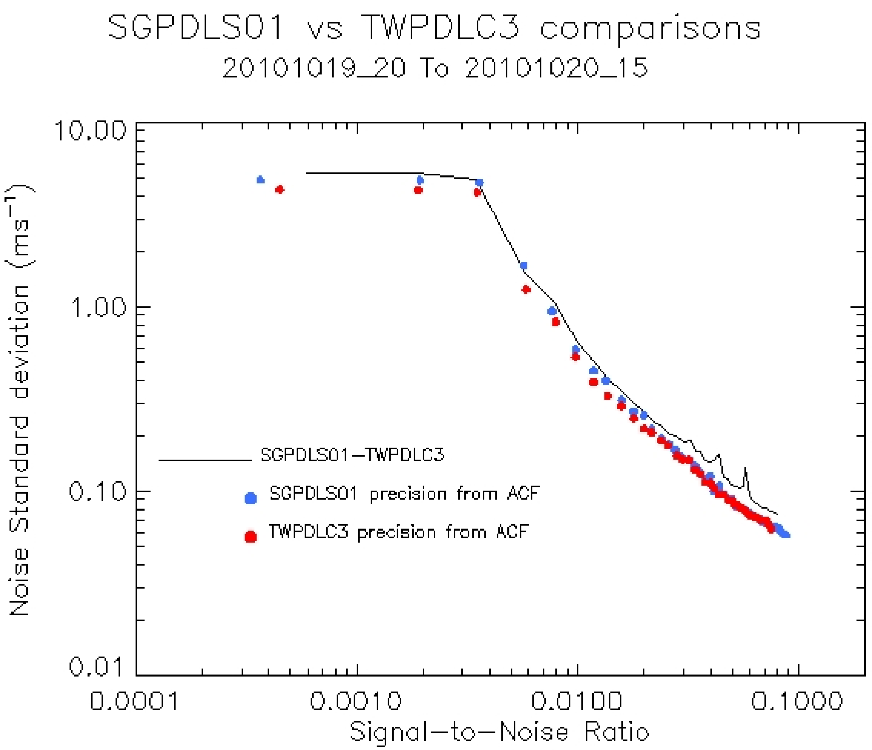
- Two methods were used to estimate velocity precision as a function of SNR

  - Method 1: Estimate velocity precision versus SNR by comparing measurements from two lidars

  - Method 2: Estimate velocity precision versus SNR from a single lidar using the autocovariance function.

Velocity Precision Estimates





- Two methods give very comparable results
- All three lidars show very similar behavior
- Velocity precision is better than 10 cm s^{-1} at high SNR.
- Saturation occurs at low SNR due to finite bandwidth (Nyquist velocity ~ 19.5 m/s). This is typical for Doppler lidars.

DL side-by-side intercomparisons: Conclusions

- All three lidars produce very consistent measurements. Correlation coefficients between lidar measurements exceed 0.9 within the atmospheric boundary layer under convective conditions. Correlation coefficients decrease as vertical velocity fluctuations decrease, e.g. under stably stratified conditions.

- Velocity precision:
  - <10 cm s^{-1} at high SNR
  - < 20 cm s^{-1} within the atmospheric boundary layer (below ~2km)
  - Indicates < 50 cm s^{-1} for clouds between 2-5 km in altitude

- Velocity Bias:
  - All three systems show a positive bias in velocity at low SNR. The magnitude of this bias appears to be system dependent, and can exceed 1.0 m s^{-1}.
  - AMFDL (a.k.a SGPDLS01 in this study) shows a negative bias in velocity at high signal levels. It is possible, however, that this bias may have been caused by improper leveling of the lidar. This is currently under investigation.

SGPDL

- Operated from the GIF deck from 15 October to ~20 December 2010
- November 2010: Dual-Doppler measurements conducted with AMFDL
- Initially operated without a problem, and exhibited good range performance
- Problems with instrument computer freezing up
  - Problems start in November, and become much more frequent in December
  - System moved indoors prior to Christmas for trouble shooting
  - Trouble shooting efforts from Jan-Feb 2011
    - New power supplies purchased and tested – didn't solve problem
    - File system, HDD, and virus scans – didn't solve problem
    - Registries cleaned – didn't solve the problem
    - Shipped back to Halo for repair at the end of February
      - Vendor replaces instrument computer, and problem goes away
      - System is being shipped back this week
  - System should be back in operation by mid-April
- April 2011: Will be deployed next to new location of the 915 MHz radar wind profiler (and also very close to the MMCR and SWACR)

AMFDL

- 18 October to 30 November 2010:
  - Operated next to fence line just to the NW of RCF at SGP
  - Performed coordinated dual-Doppler scans with the SGPDL
  - System performed well while at SGP
- Early December 2010:
  - System shipped to AMF1 staging facility in Pagosa Springs, CO
  - Currently awaiting deployment to India

TWPDL Deployment

- October/November 2010
  - Shipped from SGP to TWP-Darwin
  - Arrived in Darwin in mid-November 2010
- Early December 2010
  - System installed on top of ‘D’ Van at Darwin facility (next to MMCR) by Dave Turner, and others…
  - Data flow to DMF initiated ~ 13 December

TWPDL Issues

- Range performance was slightly disappointing
  - Probably due to shallow boundary layer and very clean free troposphere
  - Focus adjusted improved near range performance
  - Configuration adjusted to 2 second averages, 48 m range bin
- Internal humidity has been gradually increasing inside the box since January
  - May replace entire with new unit that has a valve dry-air purge retrofit

Data Lidar Datastreams

Datastream Name (specific to Darwin)	Description
twpdlC3.00	Raw Data (prior to ingest)
twpdlfptC3.a0	Fixed beam stare (Vertical or slant path)
twpdlrhiC3.a0	Single pass, 180o RHI scan
twpdlrhi2C3.a0	Single or multi-pass, limited sector RHI scan
twpdlppiC3.a0	Single pass, 360o PPI scan
twpdlppi2C3.a0	Single or multi-pass, limited sector PPI scan
twpdlusrC3.a0	User defined scan, could be anything
twpdlcal1C3.a0	Near horizontal stare for backscatter calibration
twpdlcal2C3.a0	Hard target scans used for azimuth calibration

Doppler Lidar VAPs

- Azimuth angle calibration (done but not operationally implemented)
- Horizontal wind profiles (done but not operationally implemented)
- Vertical velocity statistics (not started)
  - Variance, skewness, kurtosis
  - Mixing layer heights
  - CBH

Raman Lidars

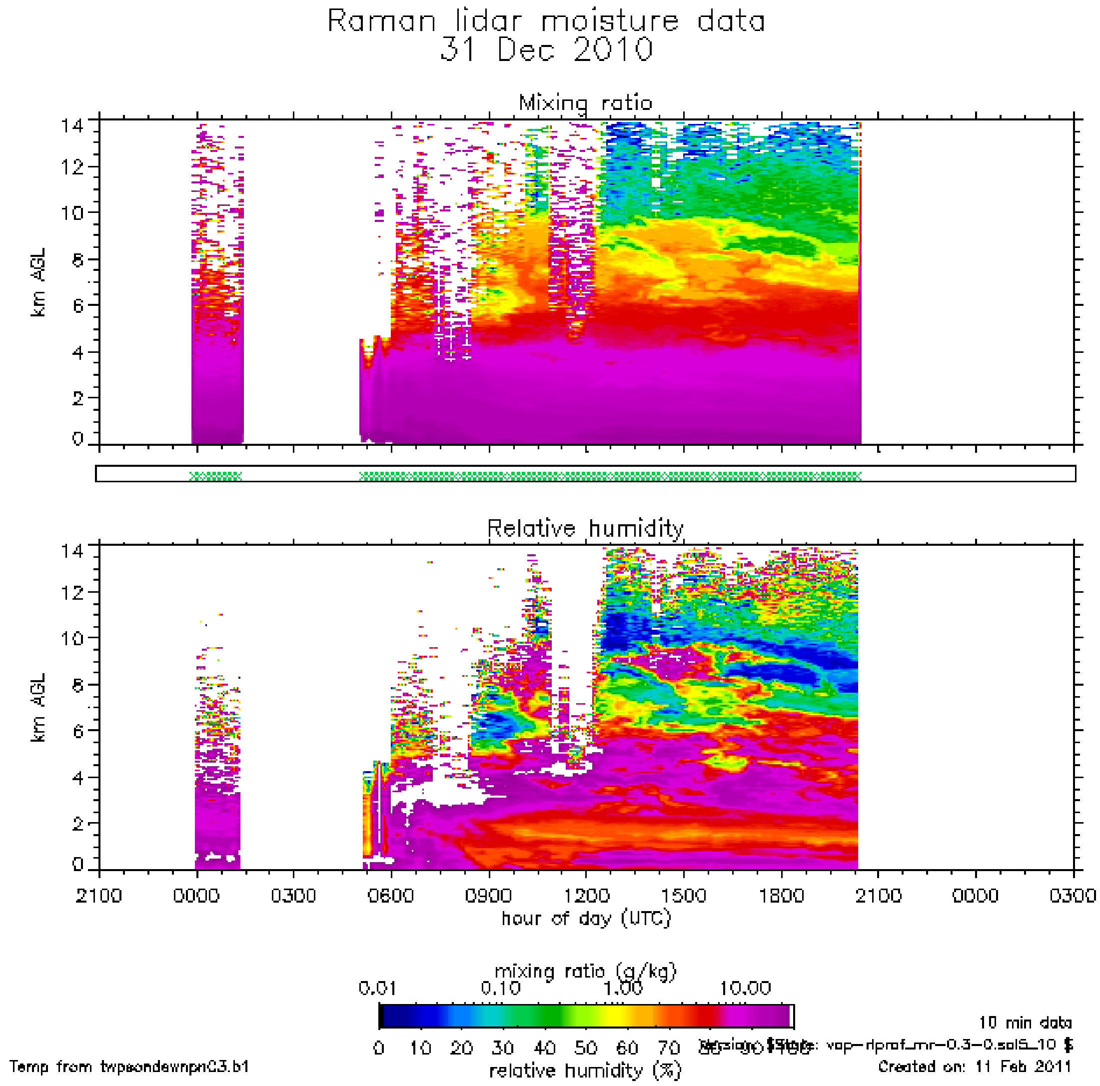
Raman Lidars

- ARM now has two Raman Lidars
  - SGP, SGPRL (aka CARL)
  - TWP-Darwin, TWPRL (aka DARL)
- Essentially identical designs (TWPRL doesn't have a liquid water channel)
  - 355 nm, 300 mJ, 30 Hz
  - Two FOVs (WFOV and NFOV)
  - 9 detection channels (10 for the SGPRL)
    - 3 Elastic, 355 nm (WFOV unpolarizied, NFOV copol and depol)
    - 2 Nitrogen, 387nm, (WFOV and NFOV)
    - 2 Water, 408 nm, (WFOV and NFOV)
    - 2 Rotational Raman (NFOV only)
      - 353 nm
      - 354 nm

TWPRL (aka DARL)

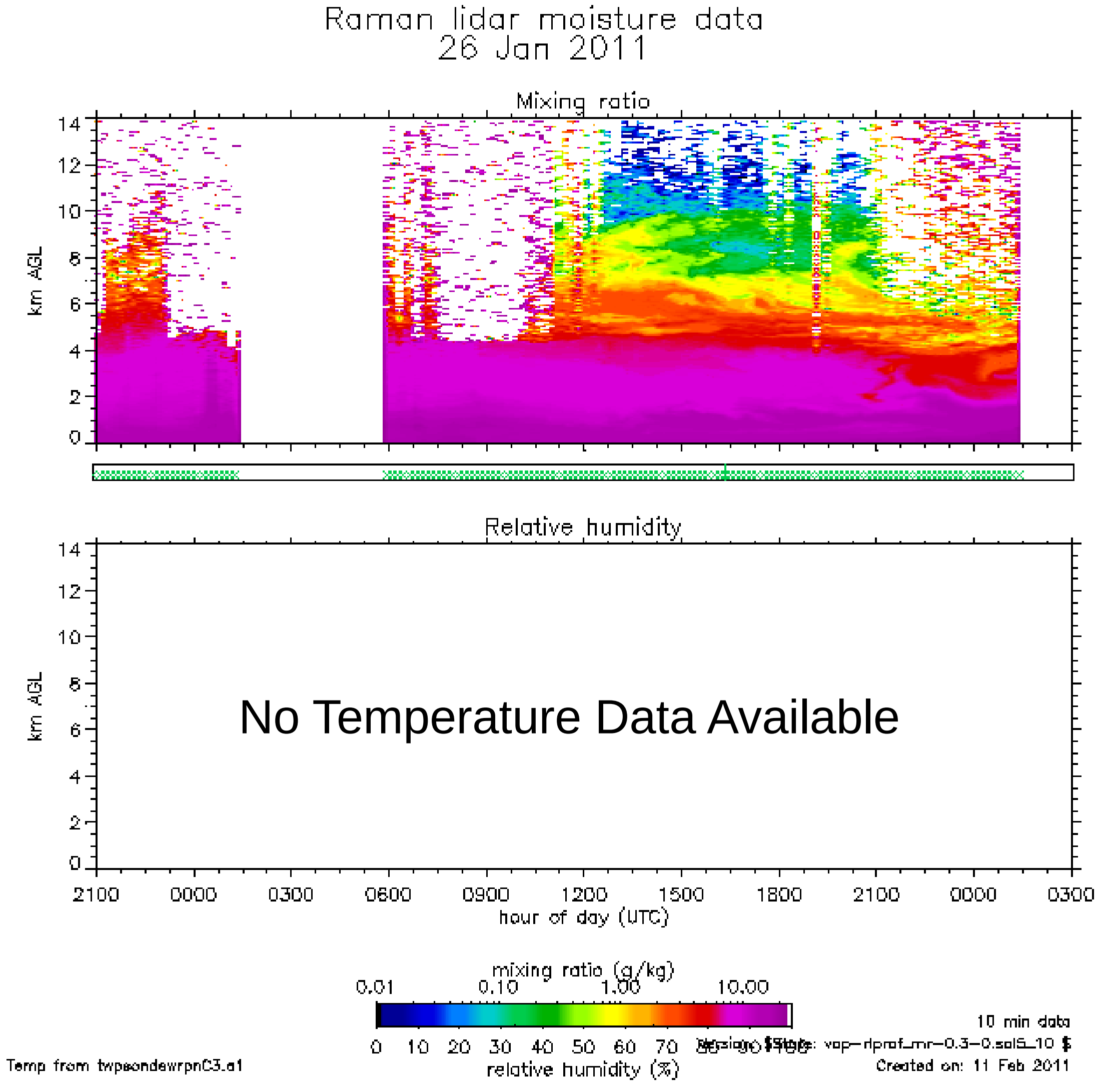
- Installed in Darwin in December by John Goldsmith and Dave Turner
- Data flow to DMF initiated ~15 December
- Initial results look really good
- A few relatively minor issues
    - “CPU creep” caused periodic computer crashes. Problem was fixed in February
    - Mode 0 data corrupted during last few days of February due to malfunction with the “flippers”. This issue has been resolved.
    - Background light contamination in WFOV mode 0 signals. Cardboard installed in late February improved the shielding.
    - Truncated header lines in raw data cause ingest at DMF to crash. Revised ingest code is being implemented.
    - As of 24 March the system has been down since March 7 when a high-voltage power supply in the laser failed. Replacement has been ordered and should be installed soon.

Results from TWPRL



RL VAPS were modified to accommodate new site

Results from TWPRL



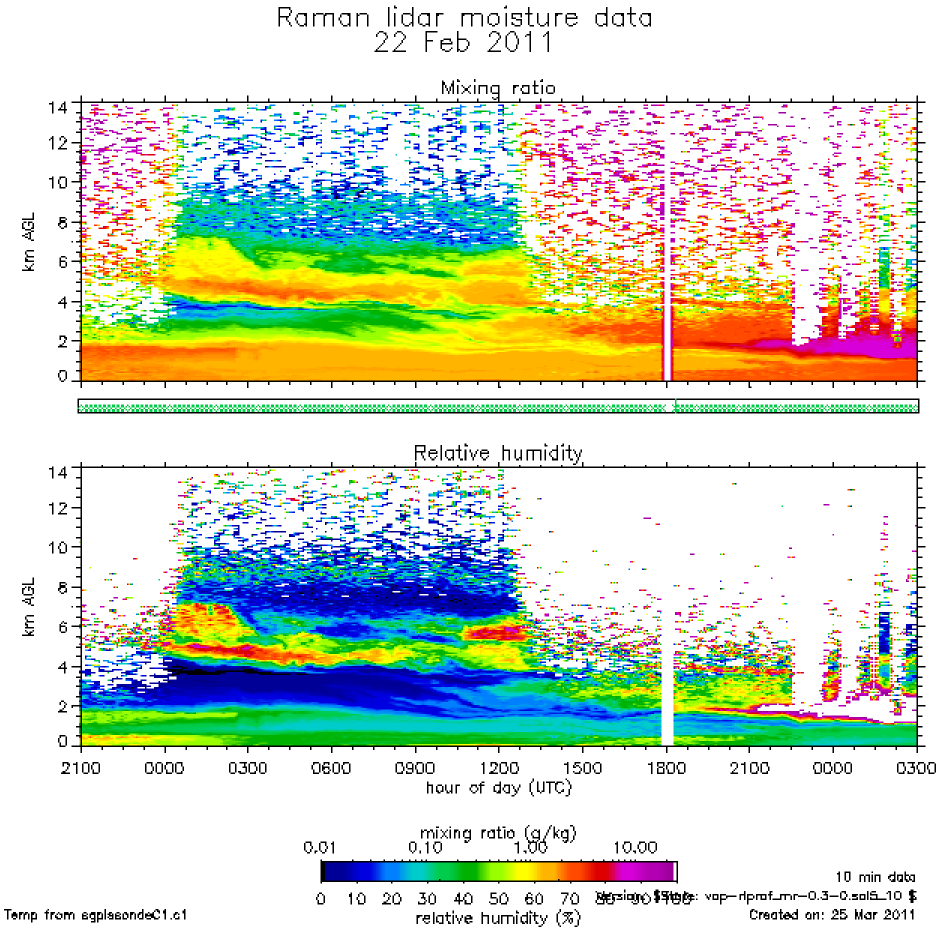
SGPRL Recent History

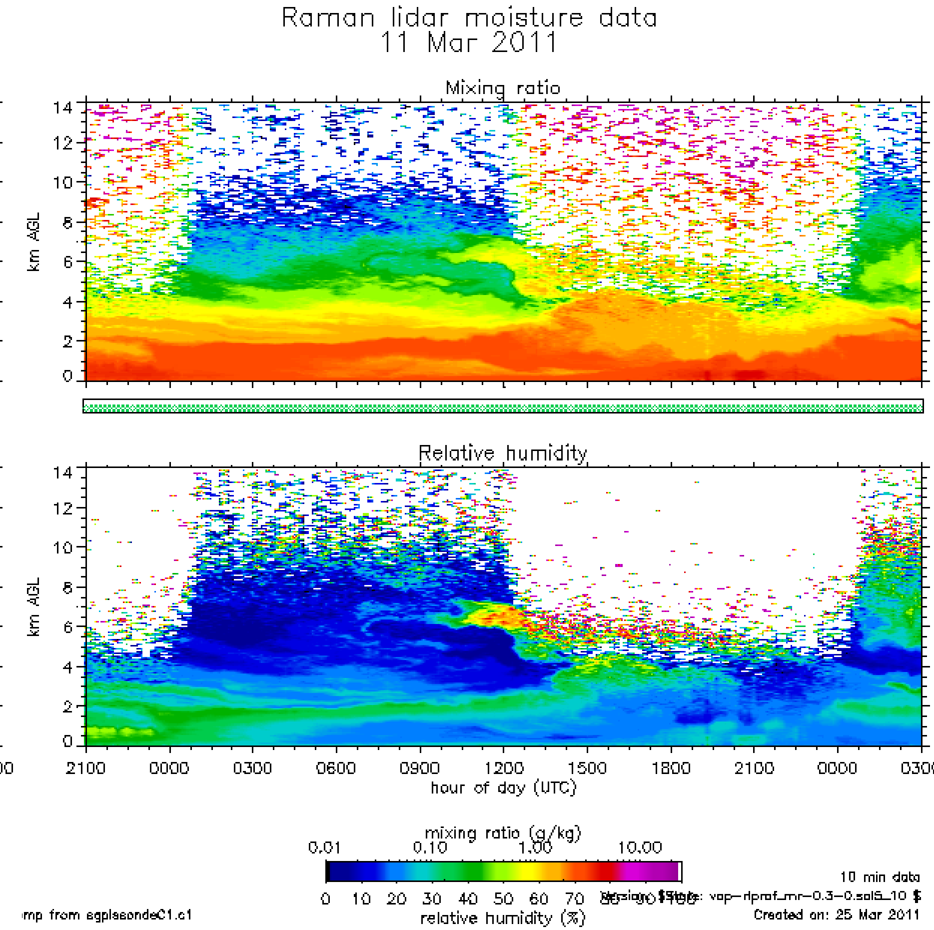
- The SGPRL has experienced a gradual loss in sensitivity over the past couple of years
- Primary culprit is optical damage in the laser beam expander
- In January 2011 an initial attempt was made at replacing the beam expander
  - Met with limited success
  - Sensitivity initially increased by 2x. But then …
  - Sensitivity rapidly degraded again
  - Aperture of the replacement expander was too small. Ablation of material from the edge of the aperture caused optical damage.
  - A new beam expander with a larger aperture was ordered

SGPRL Upgrade

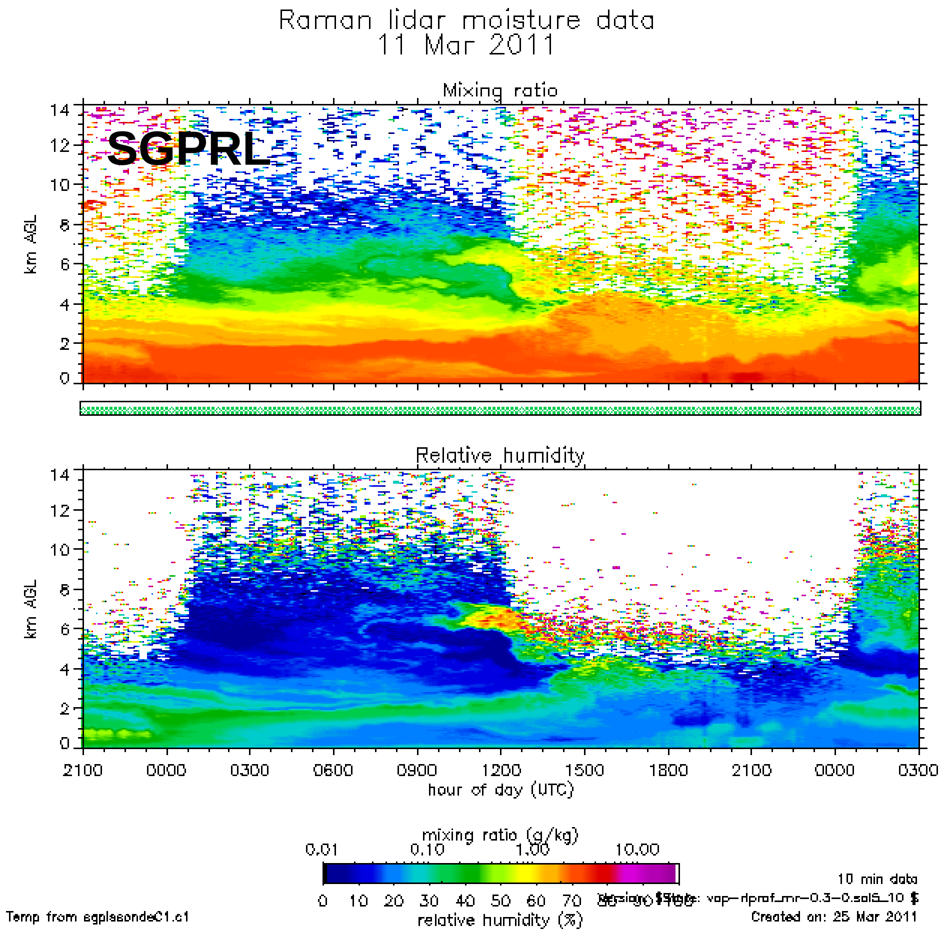
- Implemented by John Goldsmith and Chris Martin in early March 2011.
- Replaced laser heads and power supplies. Laser system installed and tested by Continuum tech.
- Control PC completely reworked
  - Replaced HDD
  - Added additional RAM
  - Replaced CD-RW with a DVD-RW
  - Upgraded OS from Windows 2000 to Windows XP
  - Upgraded to LabVIEW 2010. So the SGPRL now uses exact same Labview code as the TWPRL.
- Installed new "flippers" to block the signals to record backgrounds (previously done using old filter wheel).
- Replaced the input lens assembly in the laser-beam-expanding telescope with an assembly that has a larger input aperture
- Modified the altitude range used for the boresite controller (brought it closer to the ground, which is working well in Darwin)

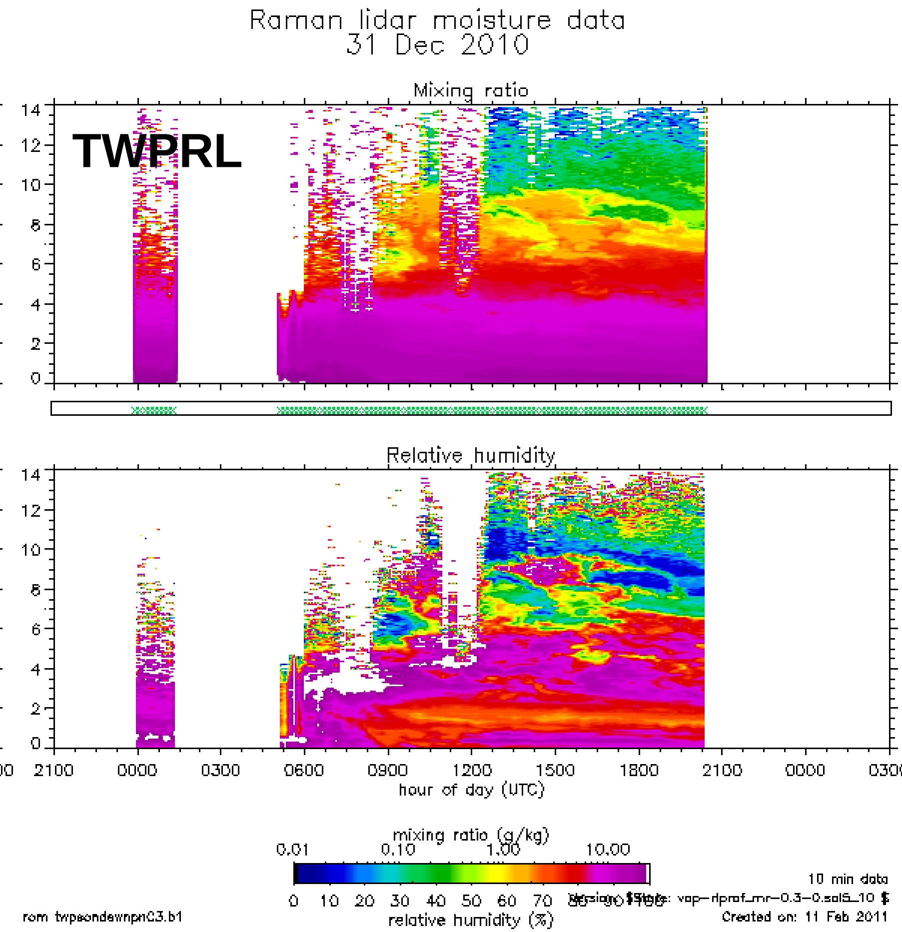
Before and After SGPRL Upgrade





SGPRL vs TWPRL





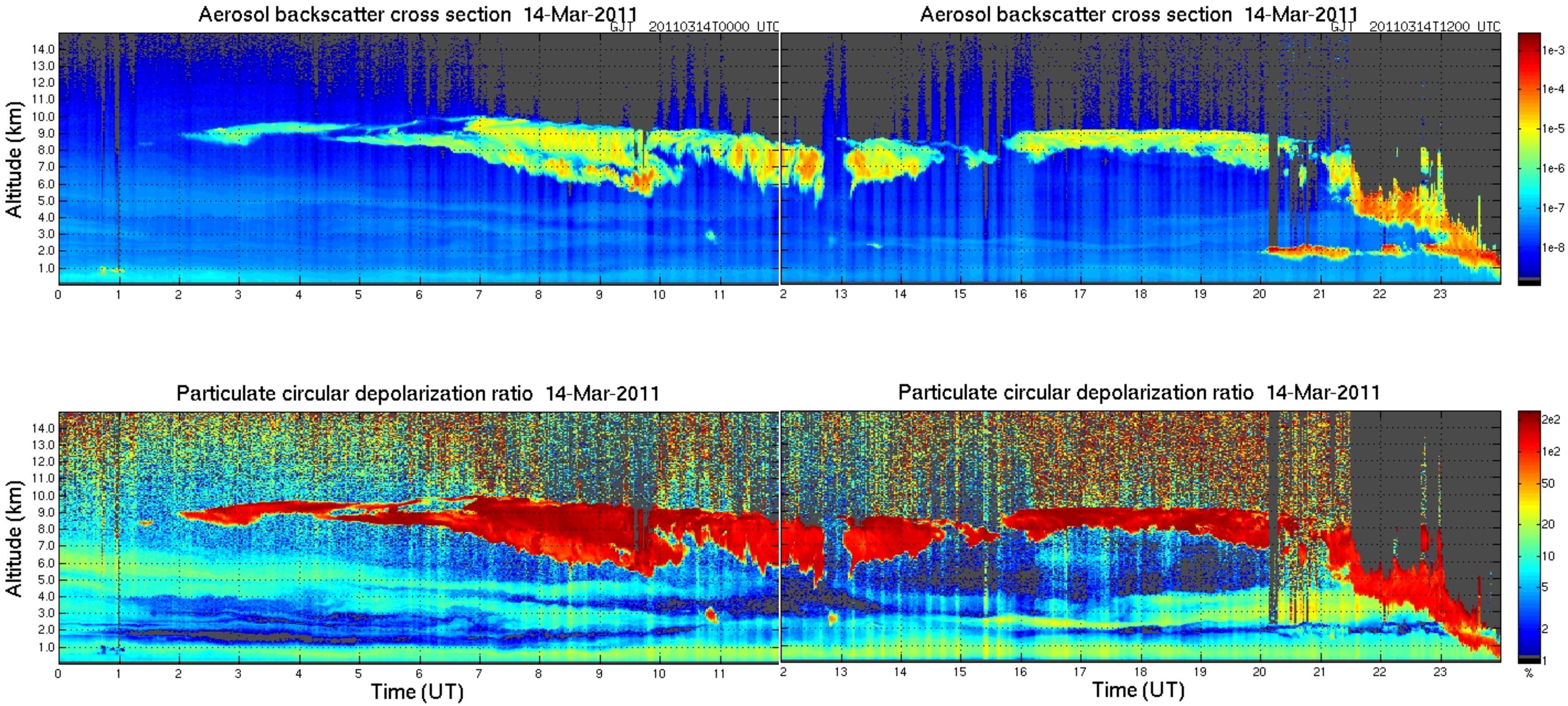
High Spectral Resolution Lidars (HSRL)

HSRL Deployments

- AMFHSRL
  - Deployed to Steamboat Springs in January 2011
  - Data “flowing” to DMF on 21 Janurary 2011

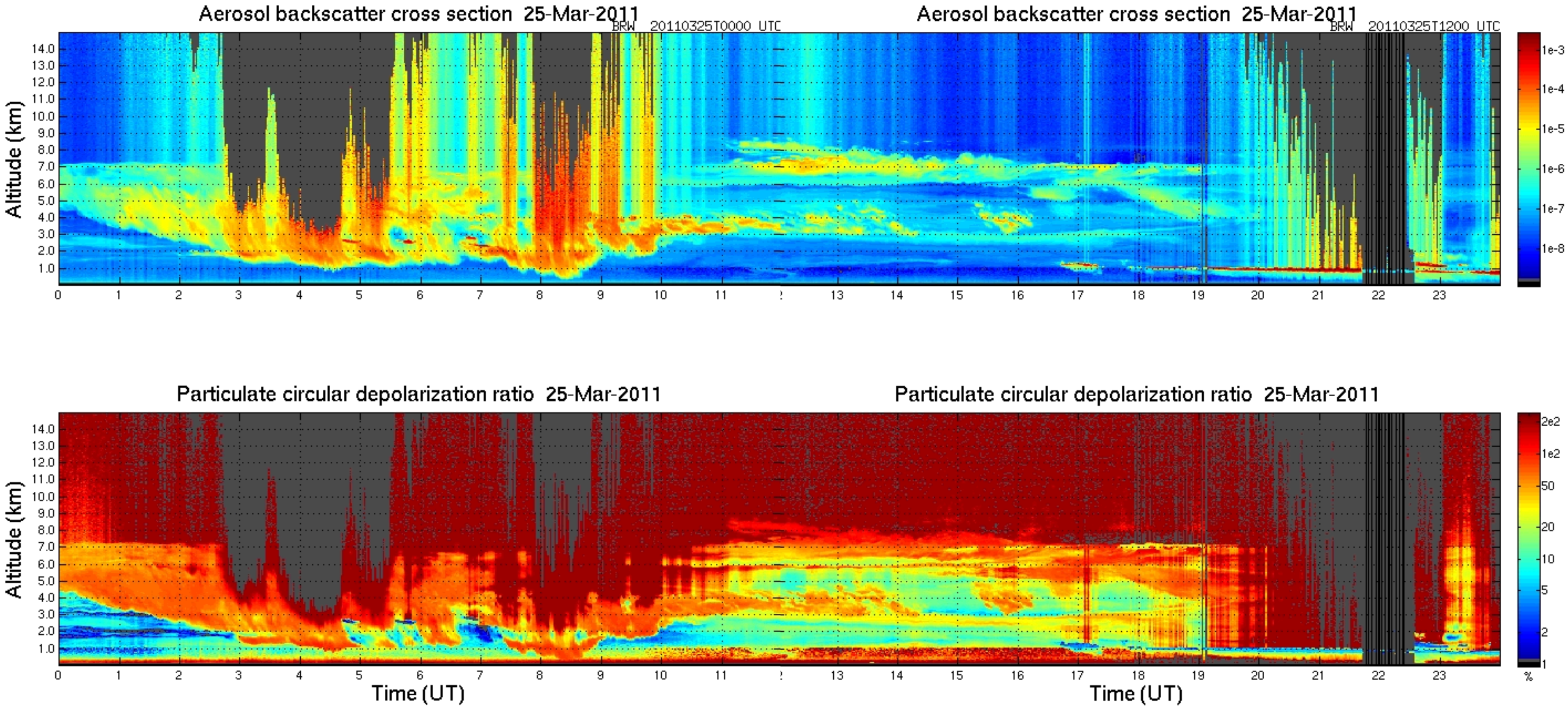
- NSAHSRL
  - Deployed to NSA-Barrow on ~18 March 2011
  - Data “flowing” to the DMF on 20 March (just in the nick of time)

AMFHSRL



Aerosol backscatter cross section 14-Mar-2011
GJT 20110314T0000 UTC
Aerosol backscatter cross section 14-Mar-2011
GJT 20110314T1200 UTC
Altitude (km)
Particulate circular depolarization ratio 14-Mar-2011
Particulate circular depolarization ratio 14-Mar-2011
Time (UT)
Time (UT)
1e-3
1e-4
1e-5
1e-6
1e-7
1e-8
2e2
1e2
50
20
10
5
2
1
%

NSAHSRL

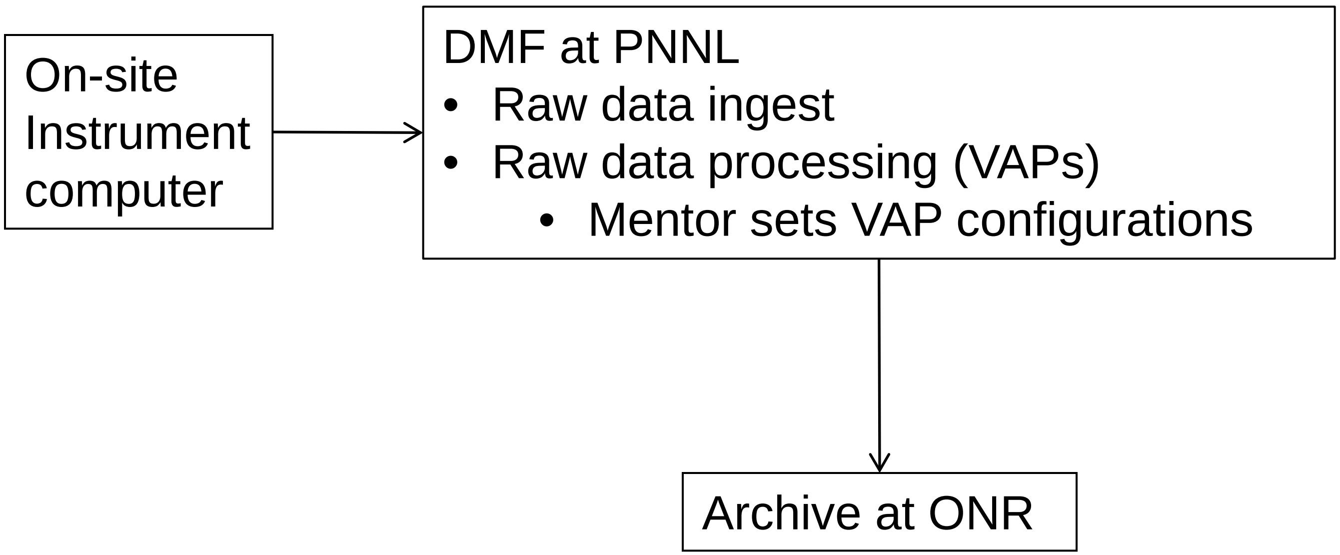


Aerosol backscatter cross section 25-Mar-2011
BRW 20110325T0000 UTC
Aerosol backscatter cross section 25-Mar-2011
BRW 20110325T1200 UTC
Altitude (km)
1e-3
1e-4
1e-5
1e-6
1e-7
1e-8
Particulate circular depolarization ratio 25-Mar-2011
Particulate circular depolarization ratio 25-Mar-2011
Time (UT)
Time (UT)
2e2
1e2
50
20
10
5
2
1
%

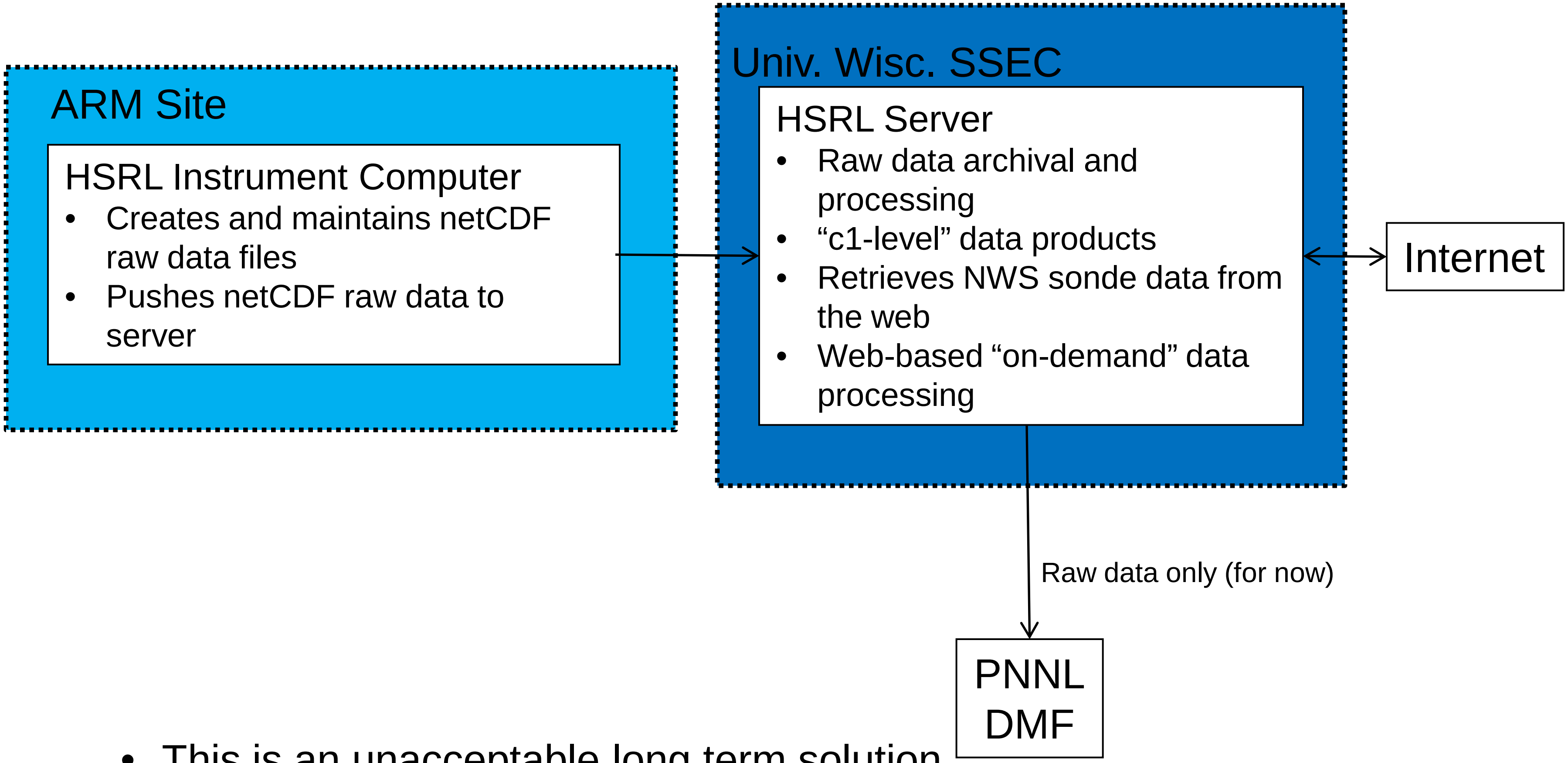
HSRL Issues

- Laser Issues
  - Vendor (Photonics) supplied lasers didn’t meet specs
    - Seed laser problems
    - Servo loop problems
  - Resulted in significant delays in the development of the lidar system
  - Inadequate testing prior to shipping to Barrow in order to meet milestone deadline (31 March)
- Integration of the existing HSRL data processing system into the DMF

Standard ARM Data Flow

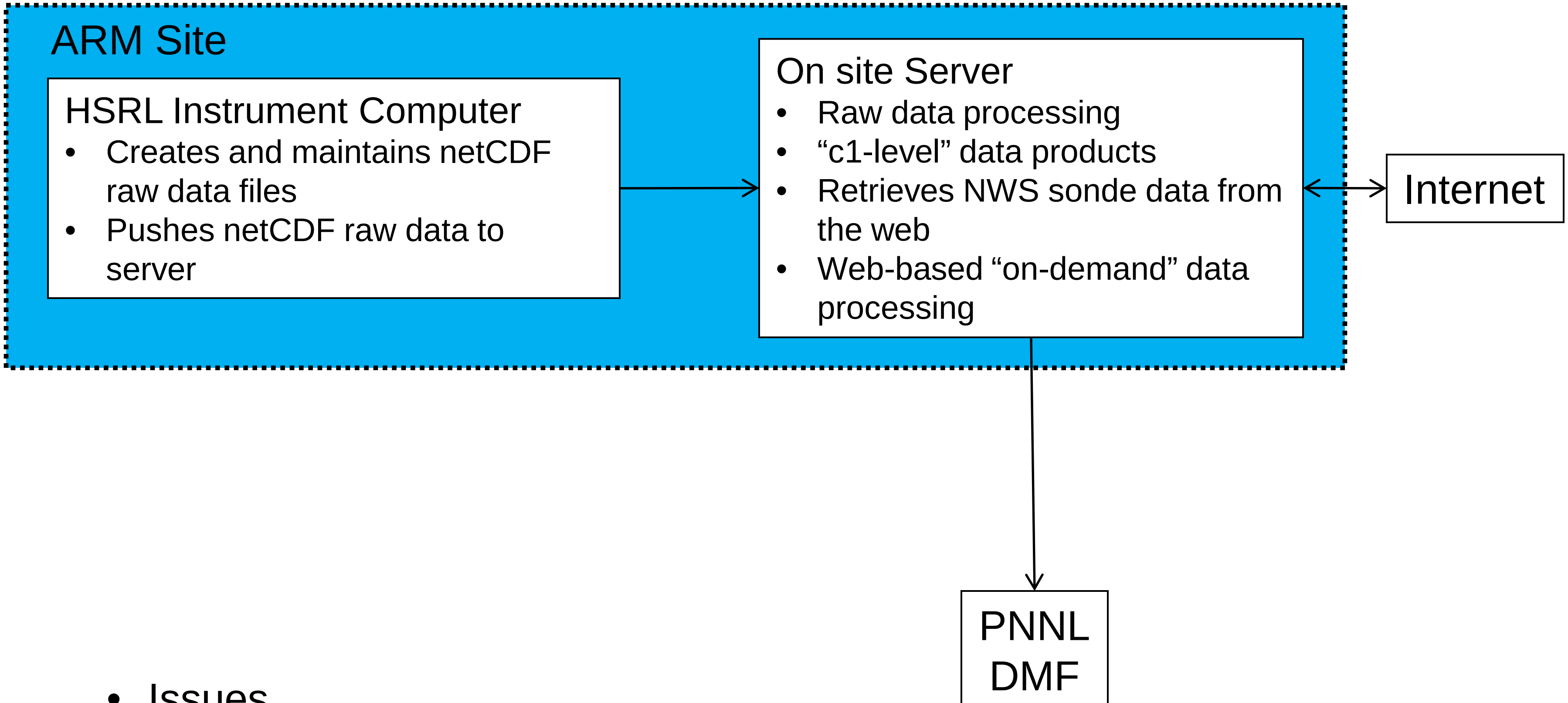


HSRL Data Flow



- This is an unacceptable long term solution
- Issues
  - Server function should be handled within the DMF
  - Data should only be accessible through the ARM web site
  - Limited control over instrument-to-server communications
  - Server should use internal ARM sonde or AERI data

Possible HSRL Data Flow



- Issues
  - On-site server should not be pulling in external data
  - Reprocessing would require pushing raw data back to the on-site server (unless the server archives ALL raw data)
  - Big problem with “on-demand” processing

Another Possibility

ARM Site

HSRL Instrument Computer

- Creates and maintains netCDF raw data files
- Pushes netCDF raw data to server

On site Server

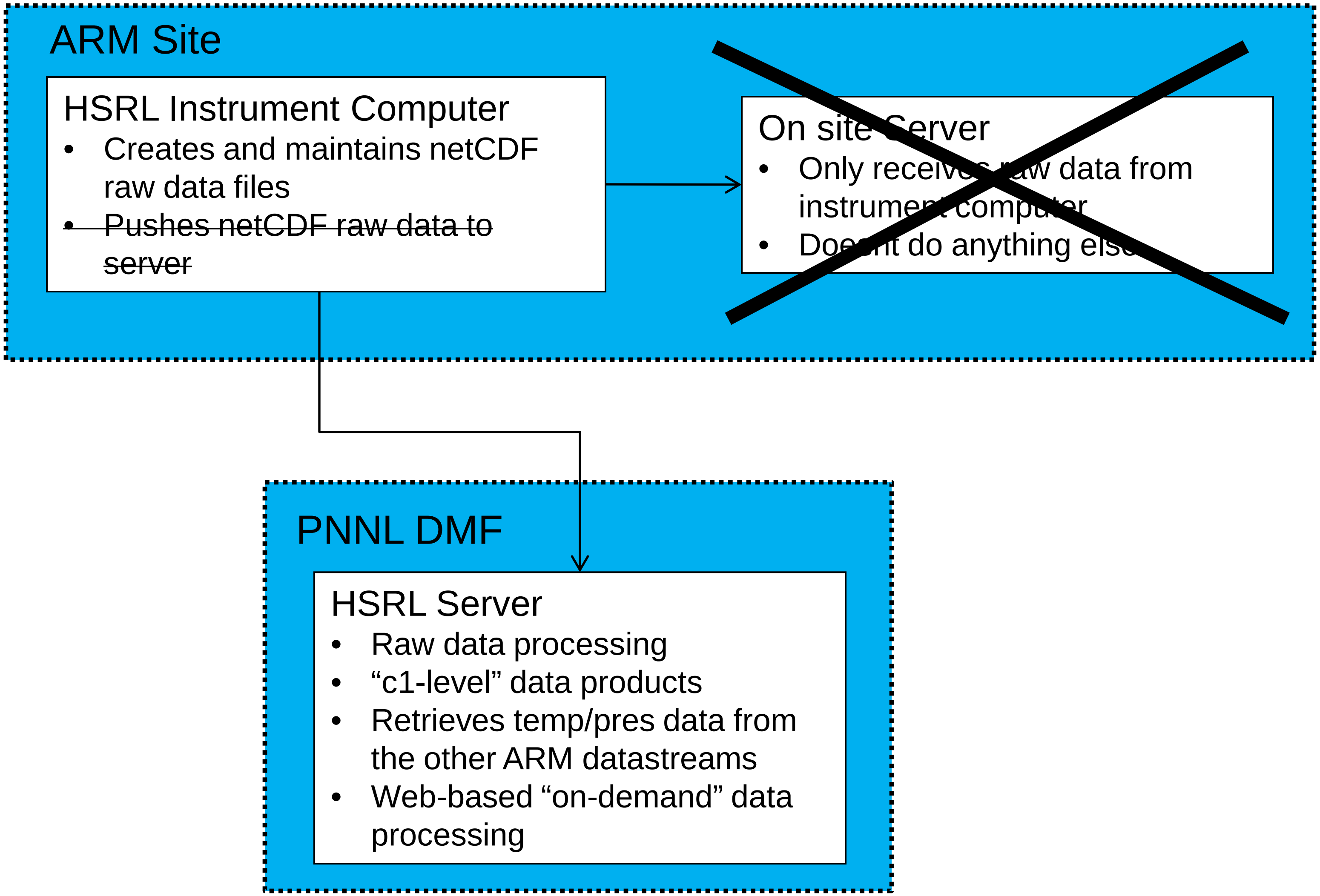
- Only receives raw data from instrument computer
- Doesnt do anything else

PNNL DMF

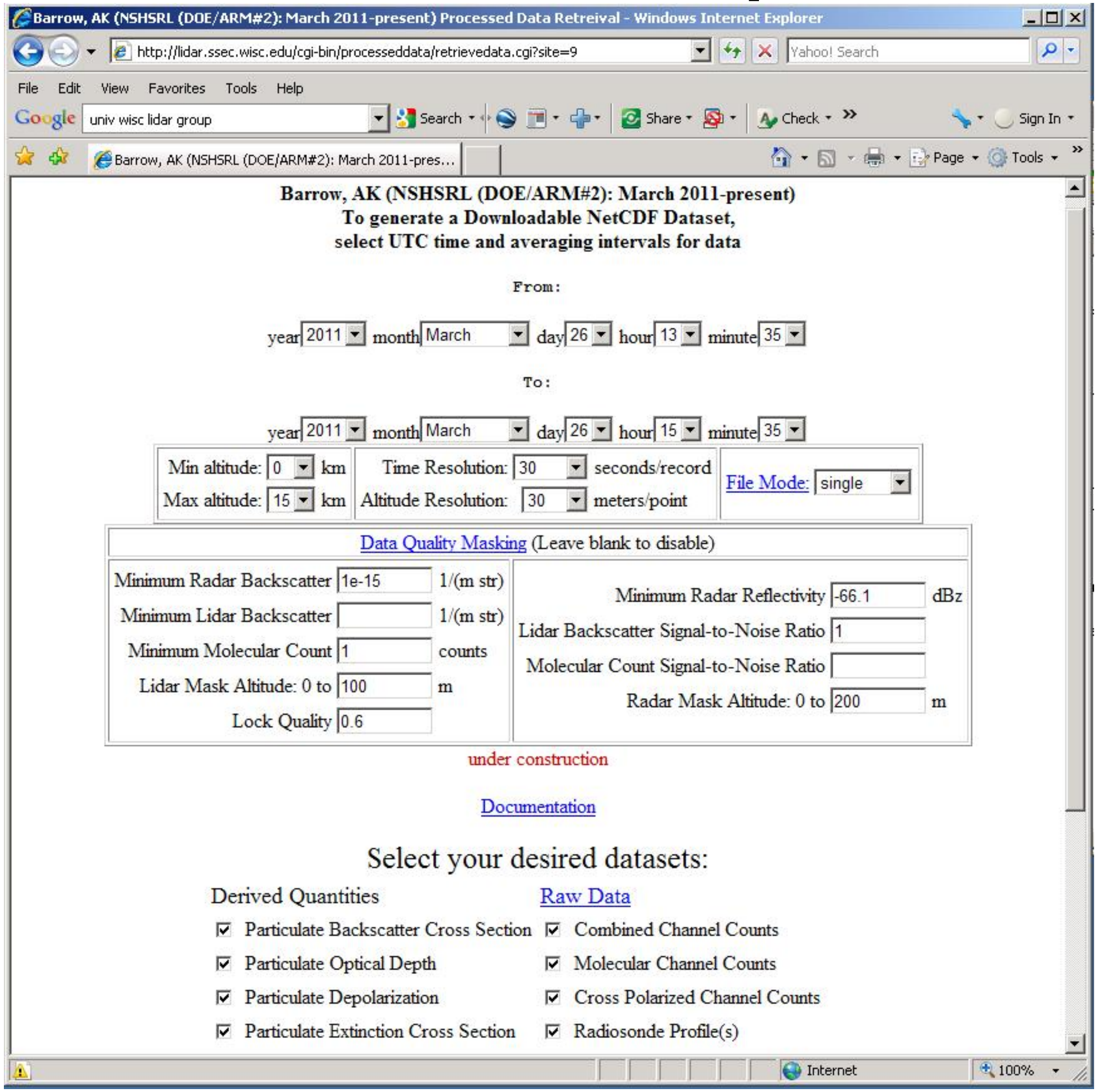
HSRL Server

- Raw data processing
- “c1-level” data products
- Retrieves temp/pres data from the other ARM datastreams
- Web-based “on-demand” data processing

OR


ARM Site
HSRL Instrument Computer
• Creates and maintains netCDF raw data files
• ~~Pushes netCDF raw data to server~~
On site Server
• Only receives raw data from instrument computer
• Doesn't do anything else
PNNL DMF
HSRL Server
• Raw data processing
• "c1-level" data products
• Retrieves temp/pres data from the other ARM datastreams
• Web-based "on-demand" data processing

HSRL web-based on demand data processing



Allows external users to select

- Resolution
- Quality control
- Variables to output
- netCDF output

Would like to implement something similar for the Raman lidar in order to get rid of the plethora of datastreams

HSRL On-demand Processing

- HSRL user community has gotten accustomed to the Univ. Wisc. ‘on-demand’ processing capability.
- Direct access to ARM data on the Univ Wisc. server will be disabled.
- ARM should offer something similar.

Questions?

Concerns?

Issues?