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Status of the TWiLiTE Direct Detection Doppler Lidar

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Oct. 16, 2012
Boulder, CO

Acknowledgements:
TWiLiTE was developed with support from the NASA ESTO IIP program. Additional support was provided by the Airborne Instrument Technology Transition program, Dr. Ramesh Kakar, Program Manager

Tropospheric Wind Lidar Technology Experiment (TWiLiTE) IIP

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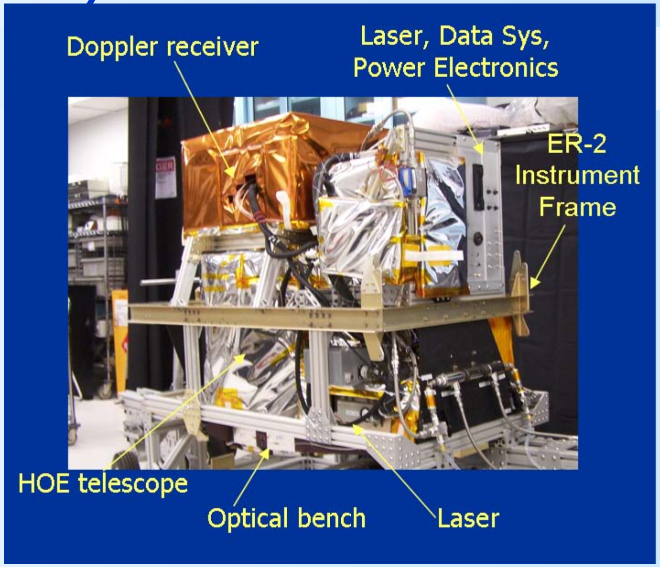
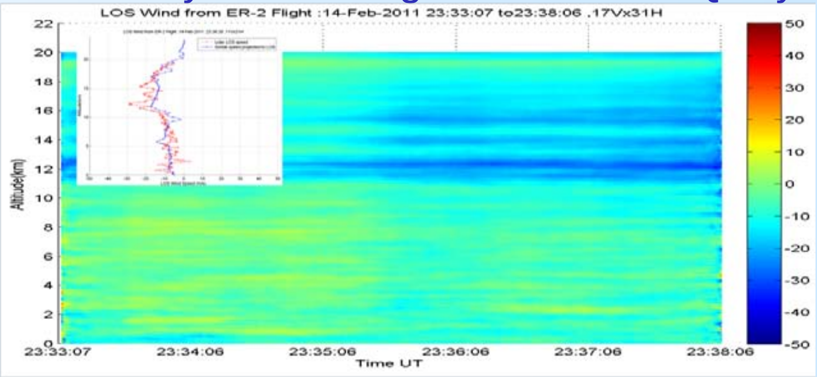
- The TWiLiTE instrument is a compact, rugged direct detection scanning Doppler lidar designed to measure wind profiles in clear air from 20 km to the surface.
- TWiLiTE operates autonomously on NASA research aircraft (ER-2, DC-8, WB-57, Global Hawk).
- Engineering flight tests on the NASA ER-2 in 2011 and 2012 demonstrated autonomous operation of all major systems.
- TWiLiTE will be reconfigured to fly on the NASA Global Hawk as part of the Hurricane and Severe Storm Sentinel Earth Venture Class Mission.

Data products	Vertical profiles of u,v wind field from aircraft to surface, clouds permitting
Velocity accuracy (m/s)	< 2.0
Range of regard (km)	0 -18 (ER-2,WB57); 0-12 km (DC-8)
Vertical resolution (km)	0.250 (programmable)
Horizontal integration per LOS (s)	10 s (programmable)
Nadir angle (deg)	45
Scan pattern	8 position conical step-stare (programmable)



TWiLiTE system configured for ER-2 QBay



TWiLiTE LOS wind profiles from Feb 14, 2011 ER2 test flight. A 10 minute segment taken over Fresno, CA is shown. Inset is a single TWiLiTE profile compared with wind profile data from the 00Z, Feb 15 NWS radiosonde launched from Oakland, CA.

TWiLiTE Instrument Parameters *A/TT*

Wavelength	354.7 nm
Telescope/Scanner Area	0.08 m^2
Laser Linewidth (FWHH)	150 MHz
Laser Energy/Pulse (8 W)	40 mJ @ 200 pps
Etalon FSR	16.65 GHz
Etalon FWHH	2.84 GHz
Edge Channel Separation	6.64 GHz
Locking Channel Separation	4.74 GHz
Interference filter BW (FWHH)	120 pm
PMT Quantum Efficiency	25%

ER-2 Test Flights
February, 2011 & October, 2012

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TWiLiTE Flight Test Modes
Fast Steering Mirror Alignment

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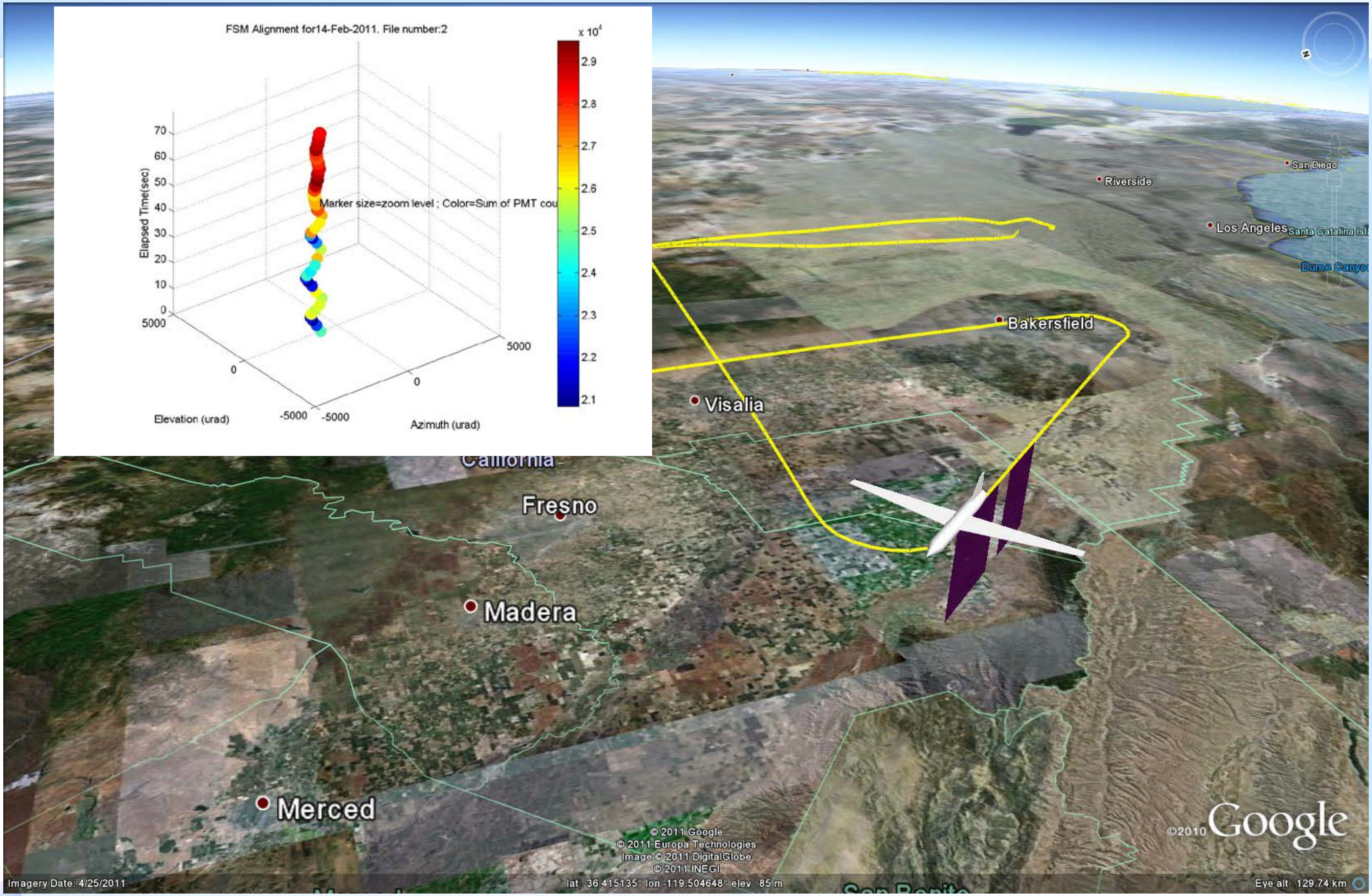

TWiLiTE Flight Test Modes

Etalon Calibration

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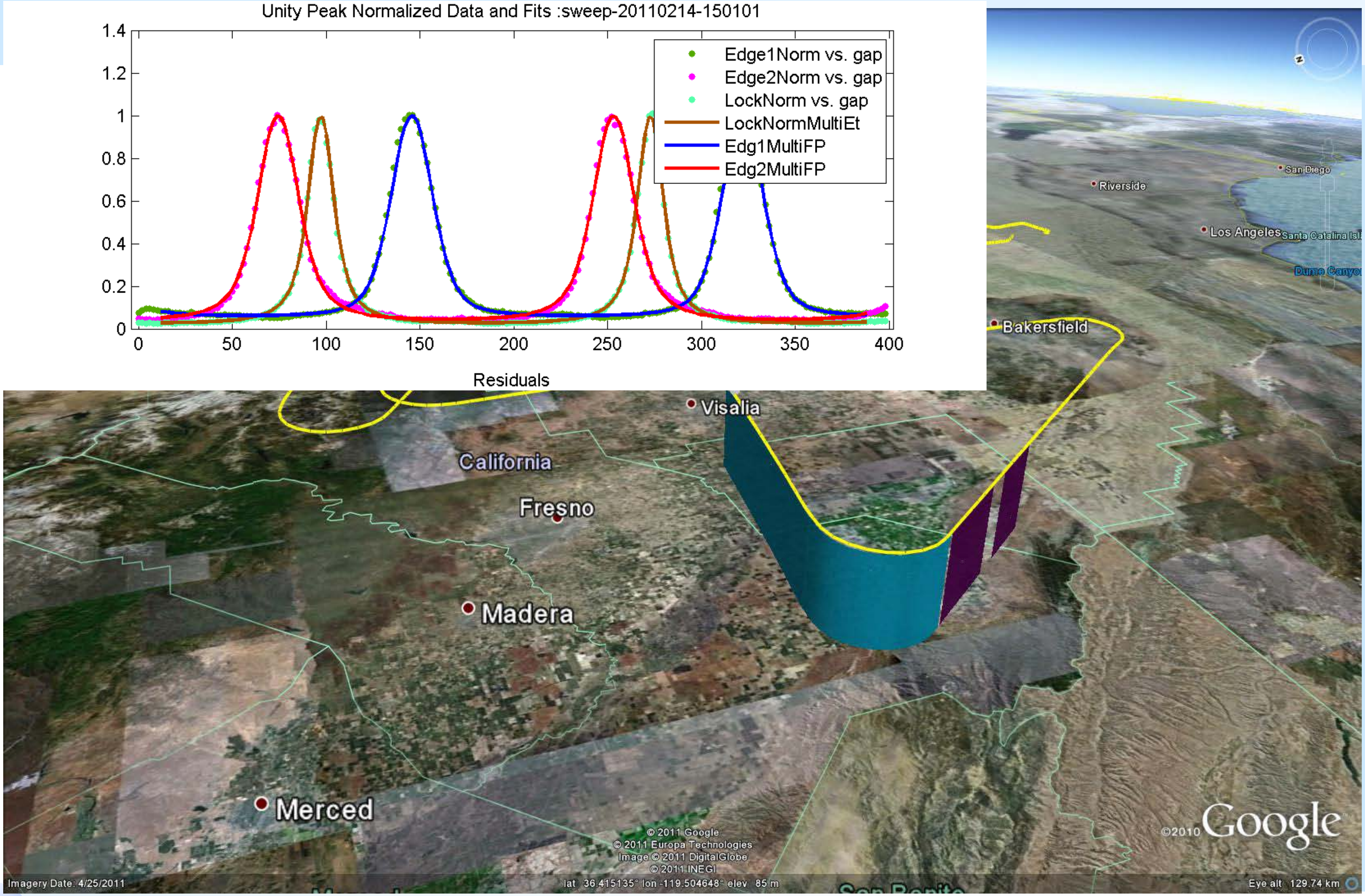
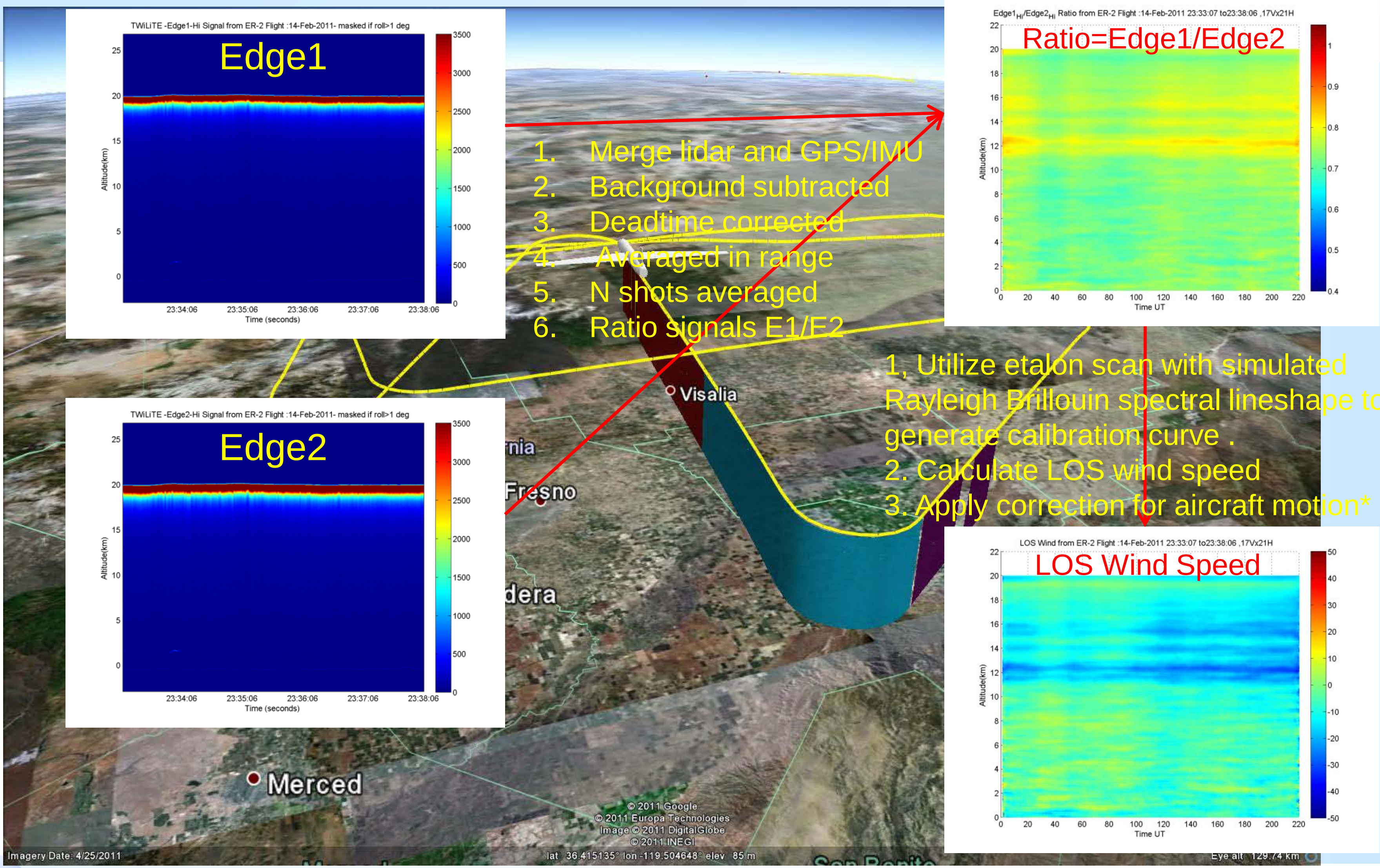


TWiLiTE Flight Test Modes

Science Data Acquisition



1. Merge lidar and GPS/IMU
2. Background subtracted
3. Deadtime corrected
4. Averaged in range
5. N shots averaged
6. Ratio signals E1/E2

1, Utilize etalon scan with simulated Rayleigh Brillouin spectral lineshape to generate calibration curve .
2. Calculate LOS wind speed
3. Apply correction for aircraft motion*

Feb 14, 2011 ER-2 Flight Track- Oakland NWS sonde comparison

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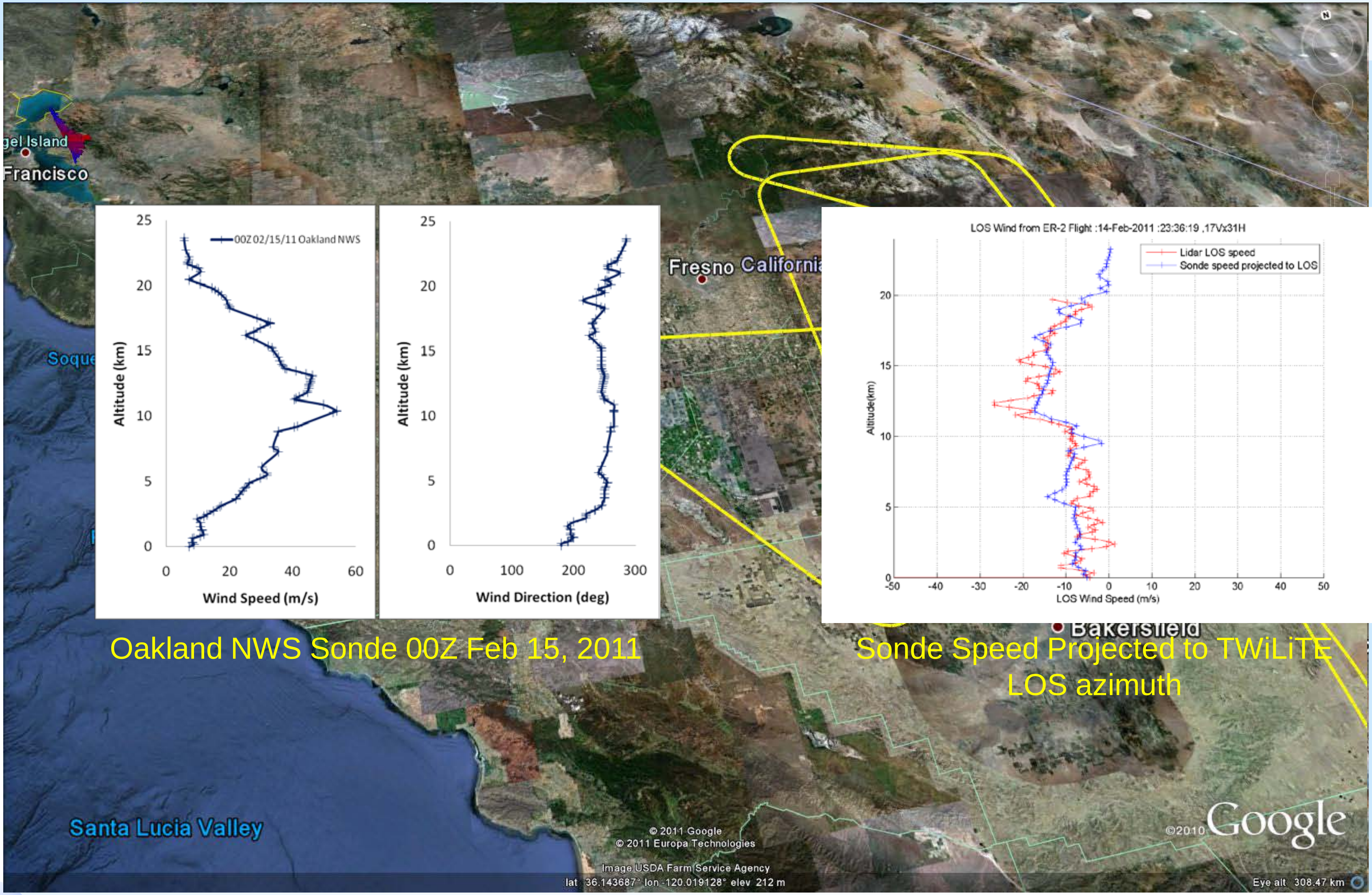
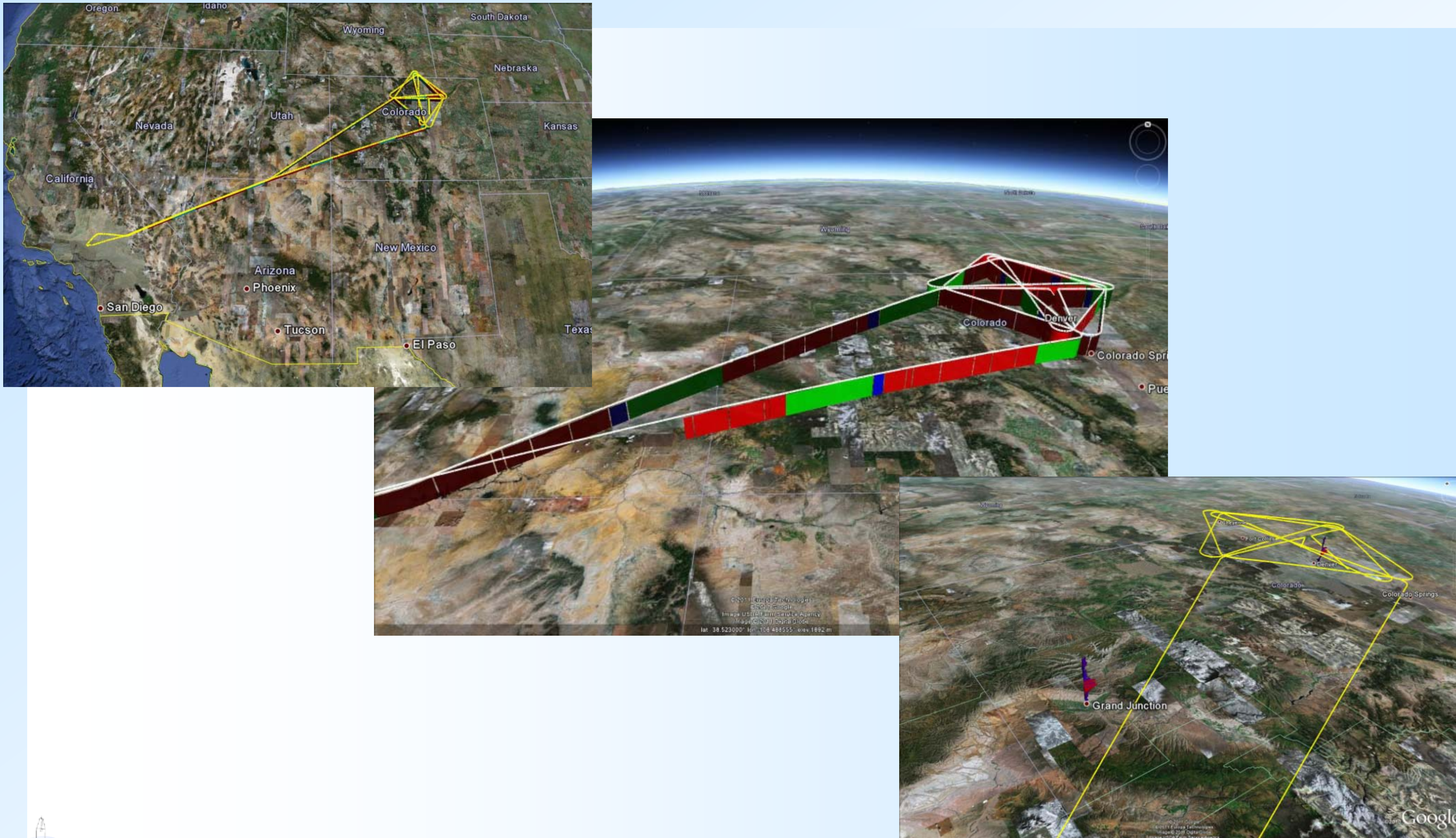


Oakland NWS Sonde 00Z Feb 15, 2011

Sonde Speed Projected to TWiLiTE LOS azimuth

February 15, 2011 flight Palmdale, CA to Denver, CO *AITT*



February 15,2011 flight Palmdale, CA to Denver, CO - 28

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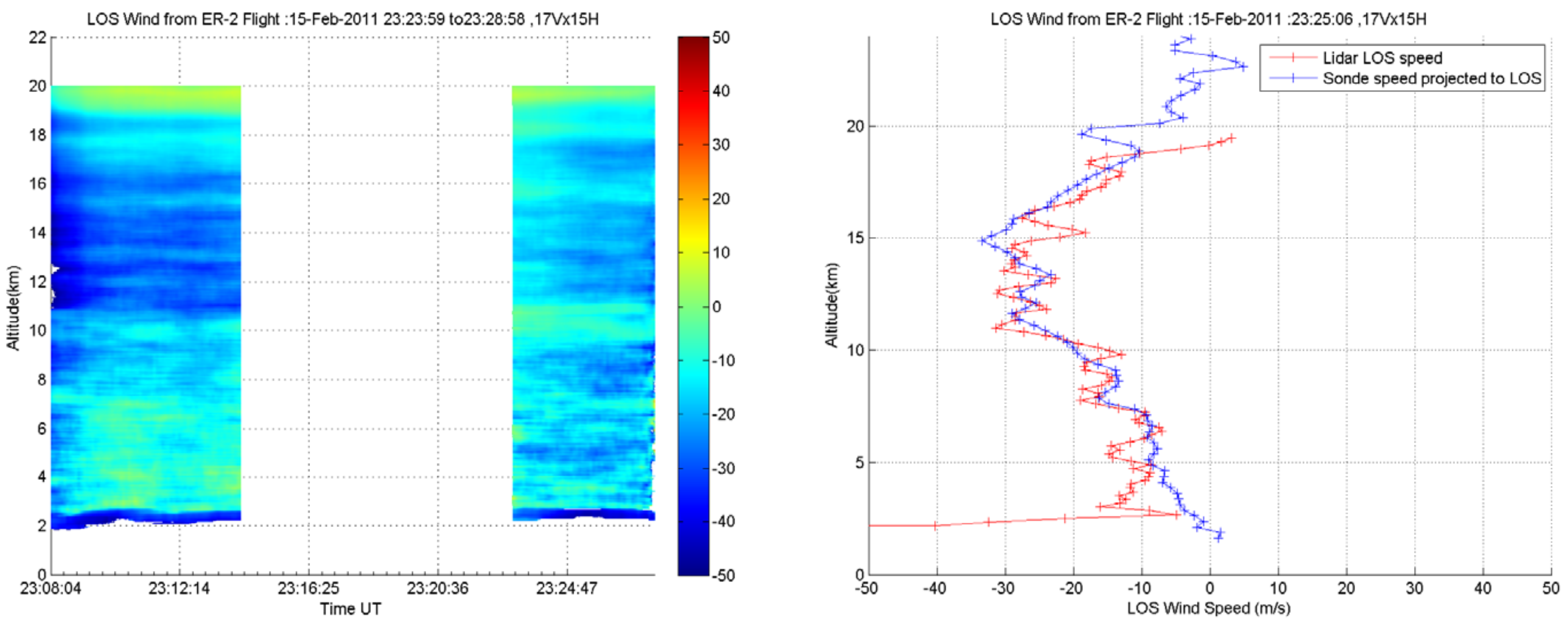
Δt_{avg}=11 seconds, Δz=253 m



17x11-139

October, 2012 Test Flight Summary

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- Four flights, totaling 20 hours of ER-2 flight time, were sponsored by HS3 in order to fully test the TWiLiTE instrument and software configuration which will fly in the Global Hawk during the 2013 HS3 campaign.
  - Especially important to demonstrate full scanning capability of the HOE telescope.
  - Also wanted to test and verify in flight, numerous changes in instrument electronics and software made in past year to improve performance and increase reliability of the system.
- Flew additional 3 flights, totaling 23 hours, as piggyback payload with Large Area Collector (LAC) instrument.
- Inland flight tracks coordinated to overfly NWS radiosonde and wind profiler sites. All LAC flights were over ocean.

October, 2012 Flight Tracks

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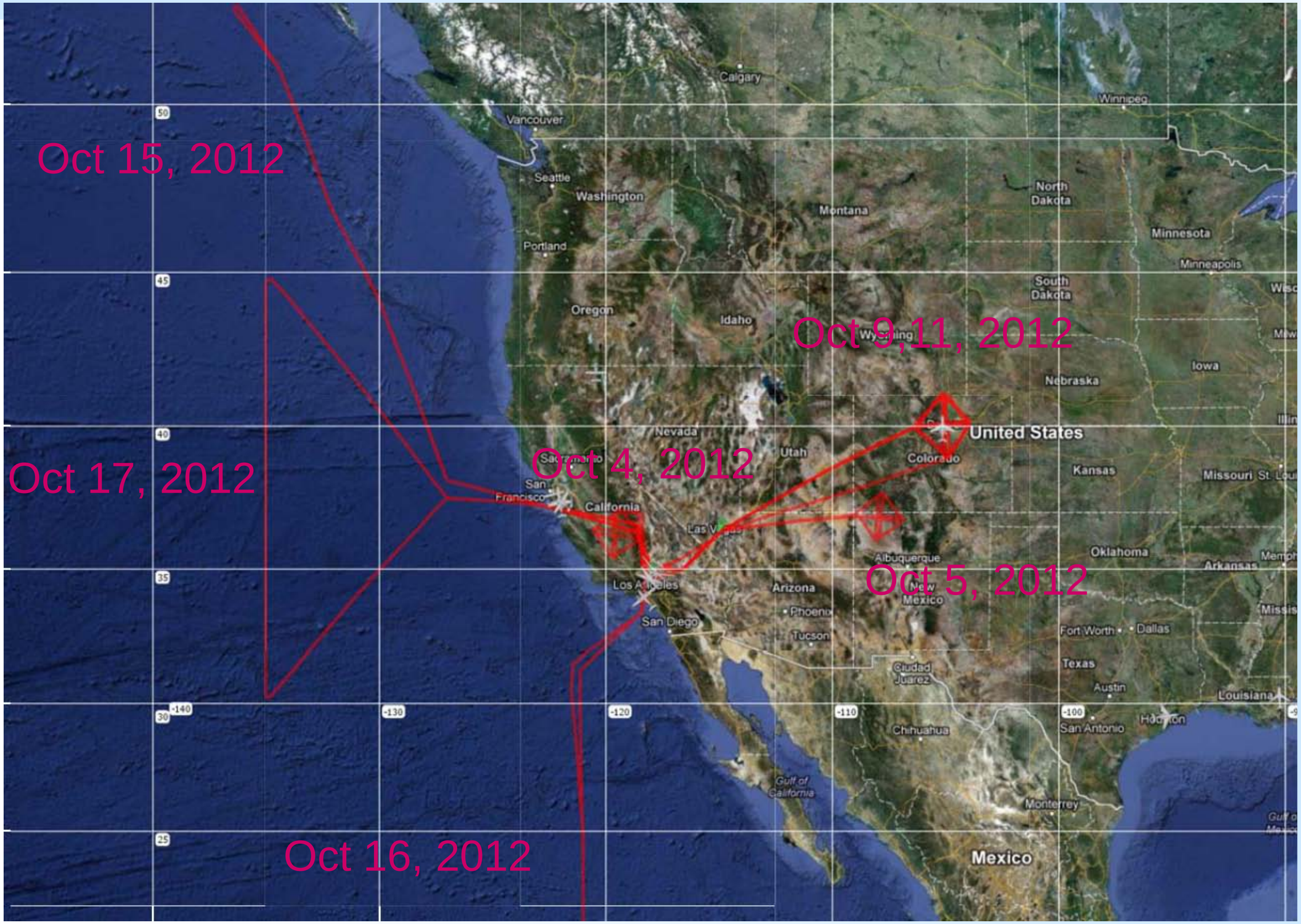
- 7 flights completed, 41 hours total flight time.



Edge 1 raw signal

October 15, 2012 – Cycle 52 of 64

Δt_{avg}=1 seconds, Δz=21 m

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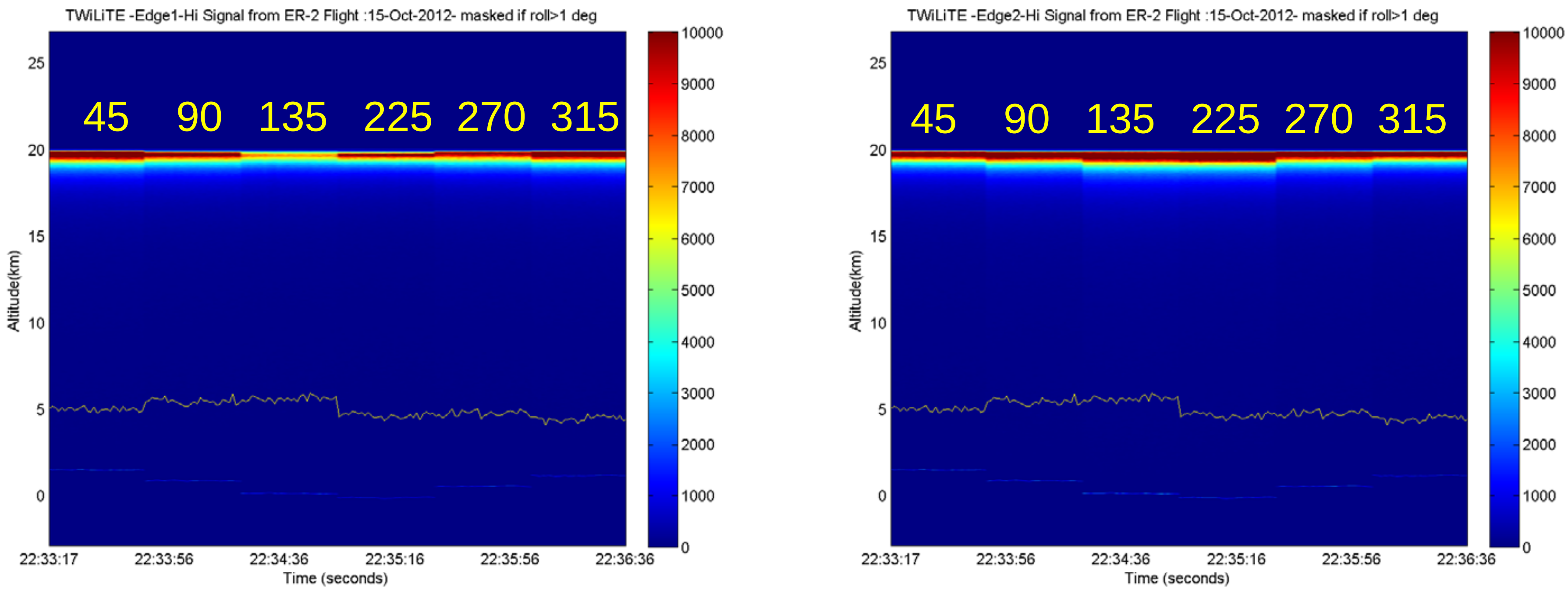

A 200 second time series(180, one second profiles) of raw signal vs altitude profiles from the Edge1 (left) and Edge2 (right) etalon channel PMTs. The ER-2 is flying at 20 km and TWiLiTE is pointing downward. This series represents one cycle of the 6 direction step-stare, azimuth scan of the HOE telescope. The azimuth angle is shown in yellow above each corresponding segment. Here 0 deg is in direction of travel of the plane, The color axis is the number of detected photocounts per 200 nsec range bin. Note the return signal in this example is nearly pure molecular backscatter

Edge 1 raw signal
October 15, 2012 - Cycle 26 of 64
Δt_{avg}=1 seconds, Δz=21 m

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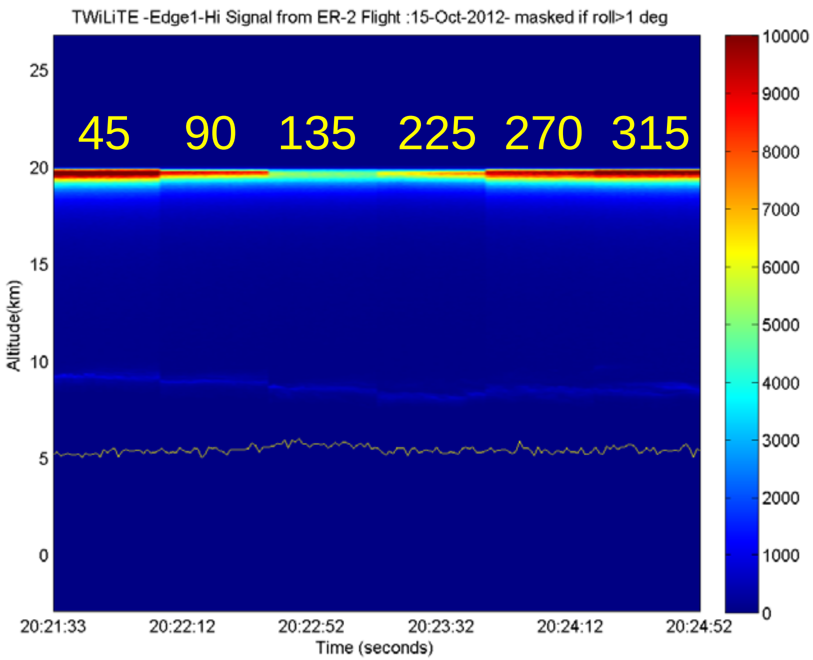

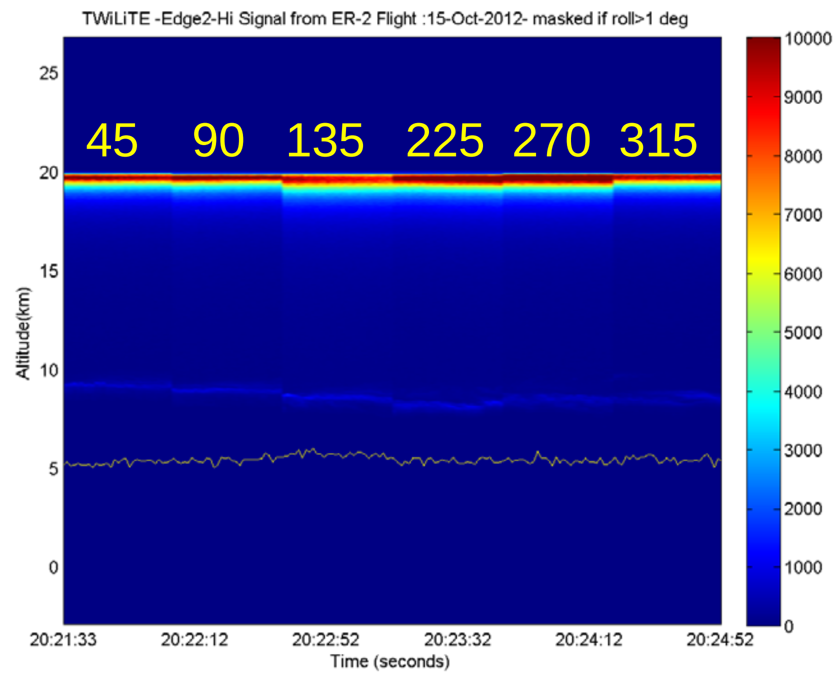

A 200 second time series(180, one second profiles) of raw signal vs altitude profiles from the Edge1 (left) and Edge2 (right) etalon channel PMTs. The ER-2 is flying at 20 km and TWiLiTE is pointing downward. This series represents one cycle of the 6 direction step-stare, azimuth scan of the HOE telescope. The azimuth angle is shown in yellow above each corresponding segment. Here 0 deg is in direction of travel of the plane, The color axis is the number of detected photocounts per 200 nsec range bin. Note the optically thick cloud at ~ 9 km in the return signal. Above this the signal is nearly pure molecular backscatter.

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 – Cycle 2
Δt_{avg}=10 seconds, Δz=258 m

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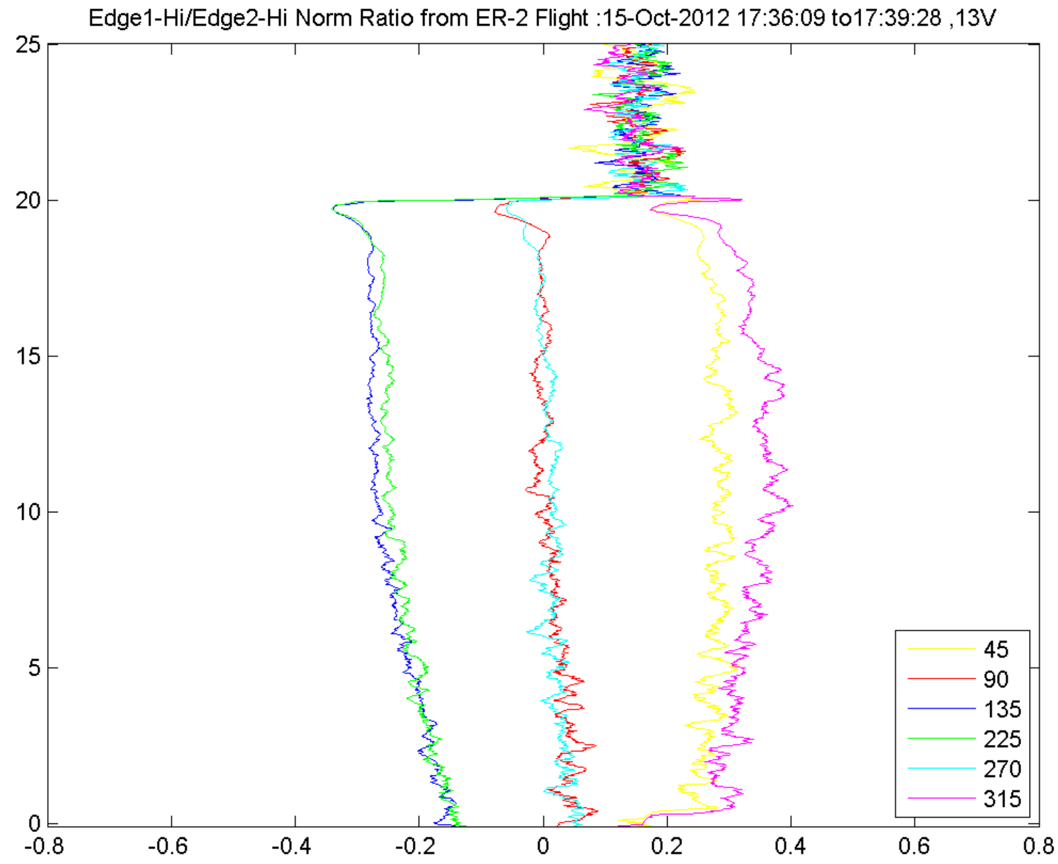

17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 31
Δt_{avg}=10 seconds, Δz=258 m

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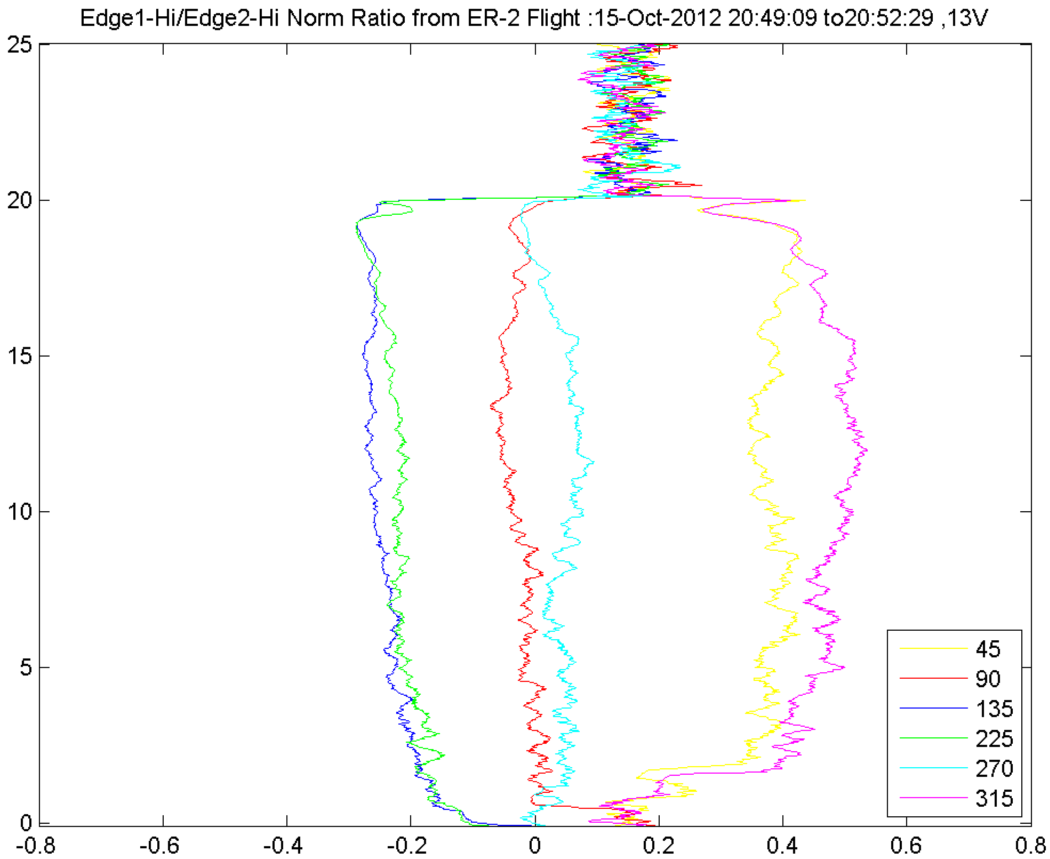
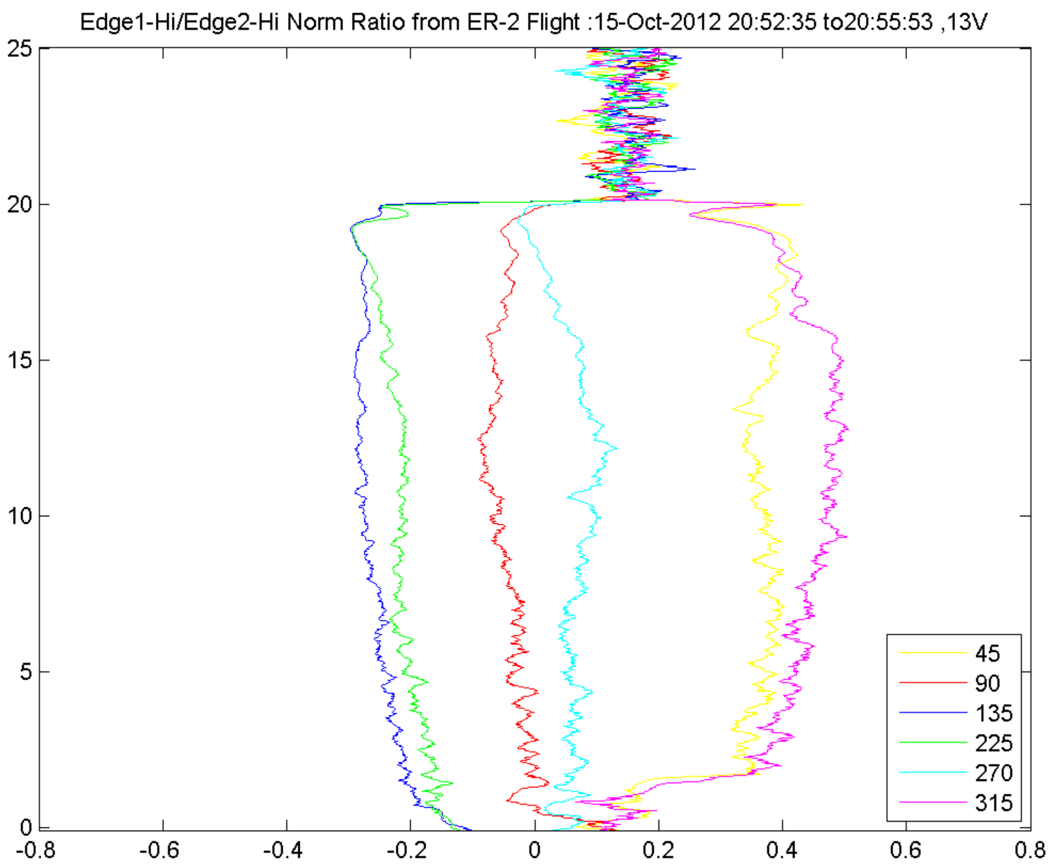


17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 32
Δt_{avg}=10 seconds, Δz=258 m

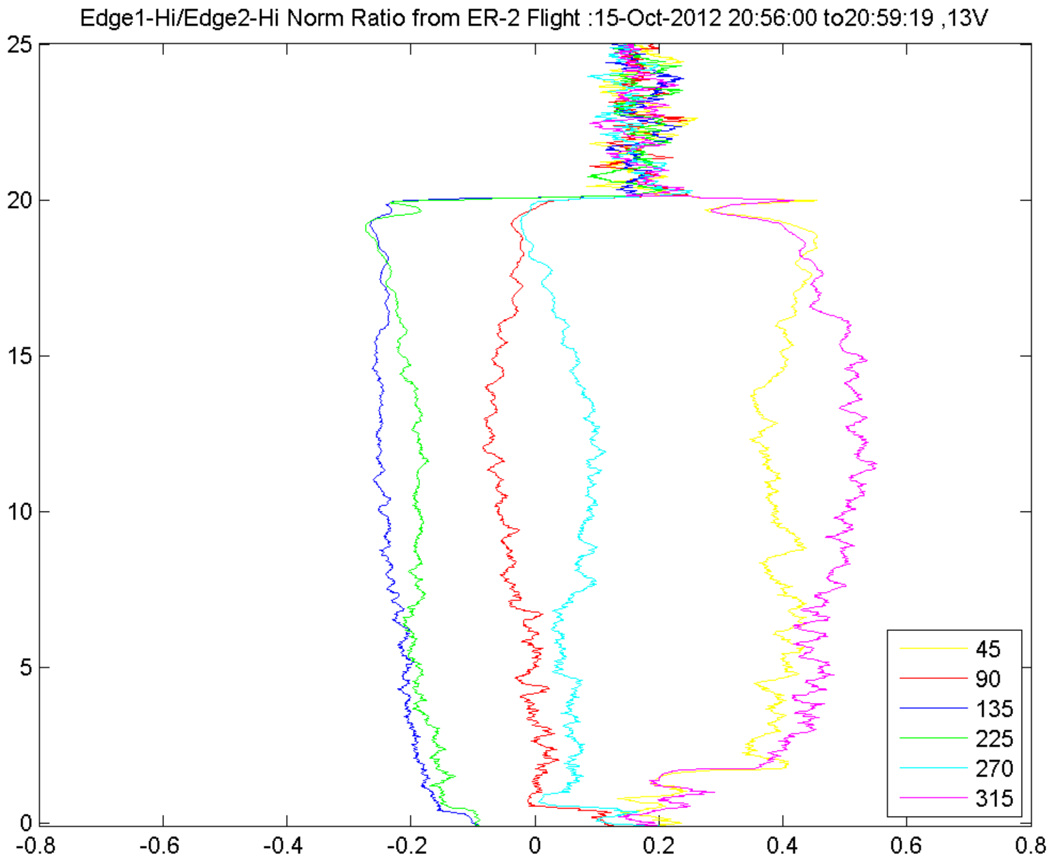
AITT



17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 33
Δt_{avg}=10 seconds, Δz=258 m

AITT



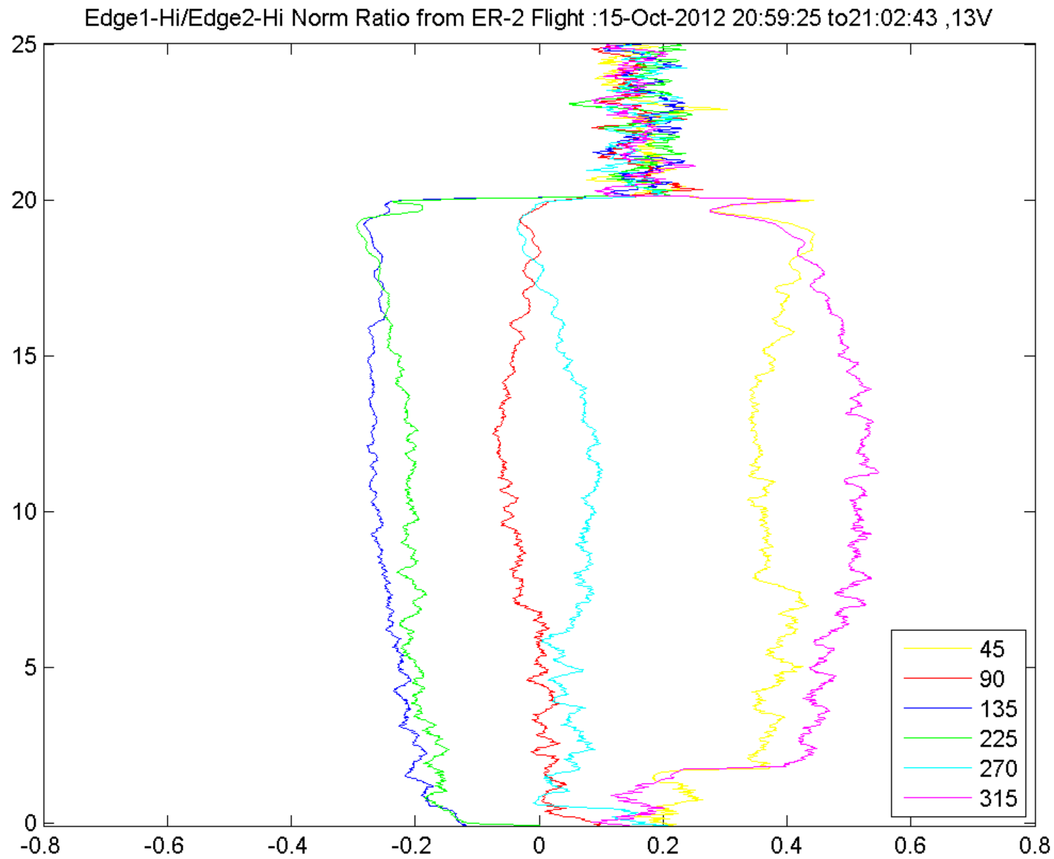
17x11-139

Uncorrected Edge 1/Edge2 ratio

October 15, 2012 - Cycle 34

Δt_{avg}=10 seconds, Δz=258 m

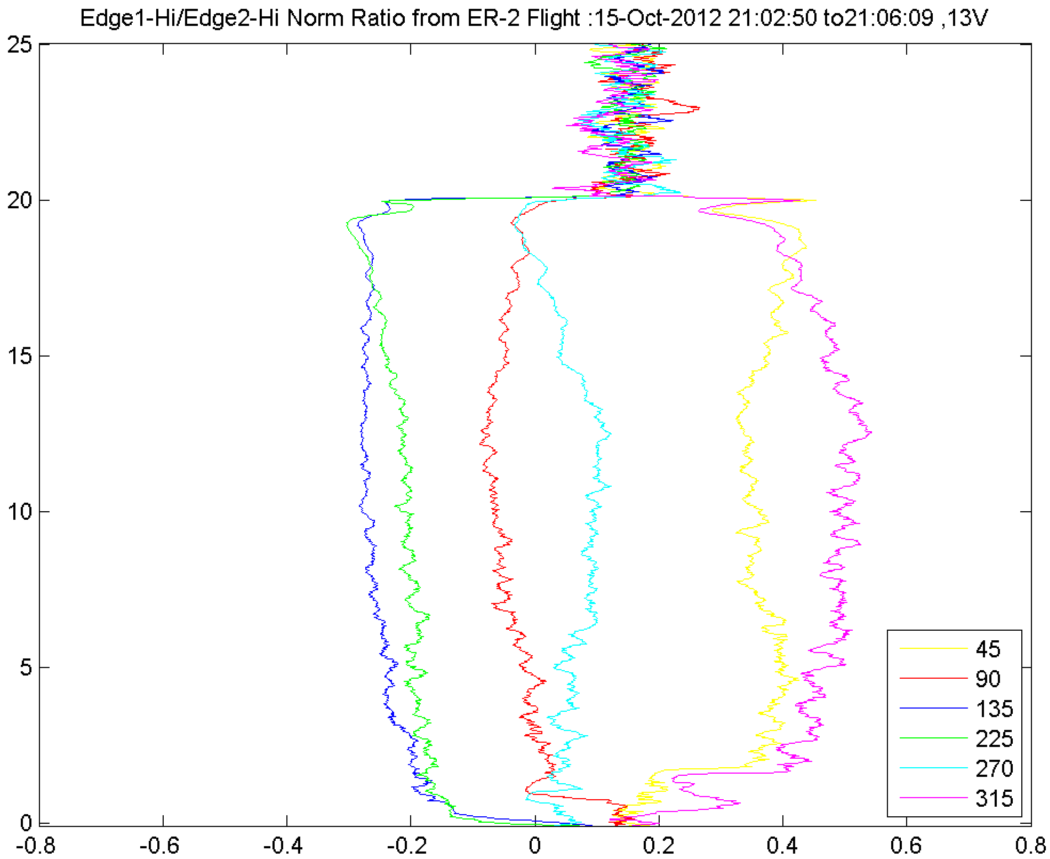
AITT



17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 35
Δt_{avg}=10 seconds, Δz=258 m

AITT



17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 36
Δt_{avg}=10 seconds, Δz=258 m

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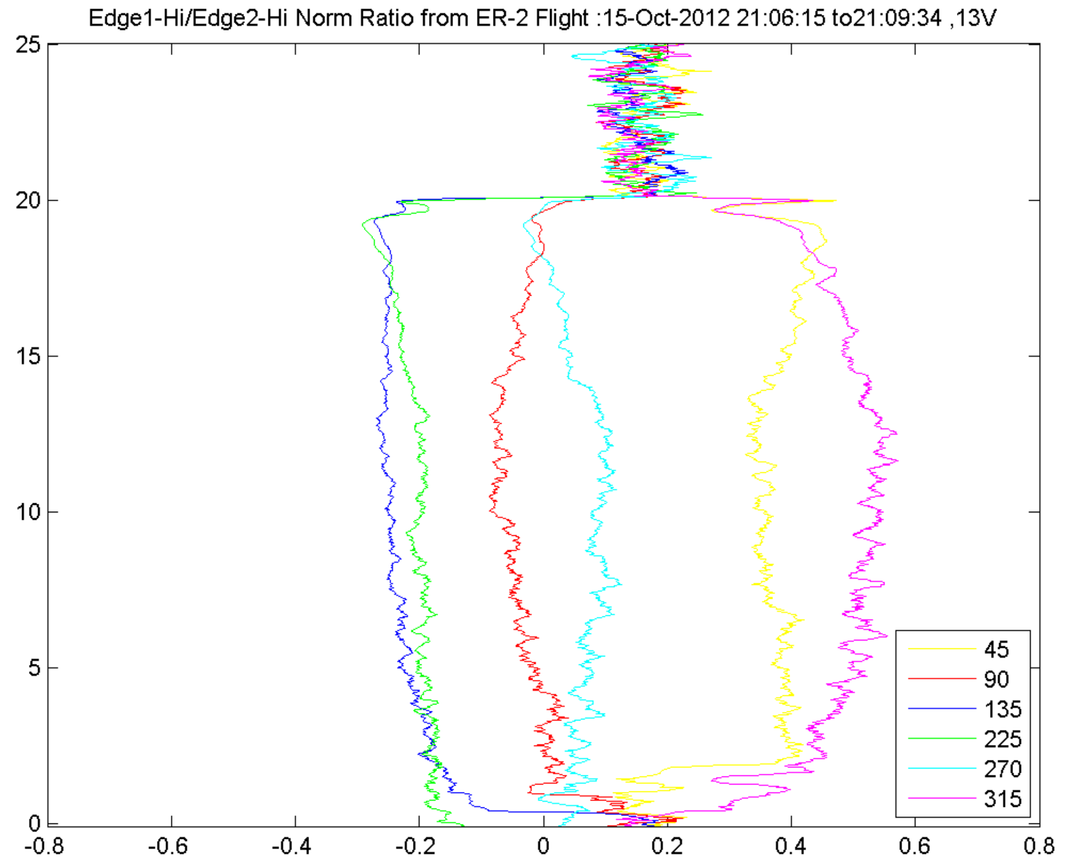

17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 37
Δt_{avg}=10 seconds, Δz=258 m

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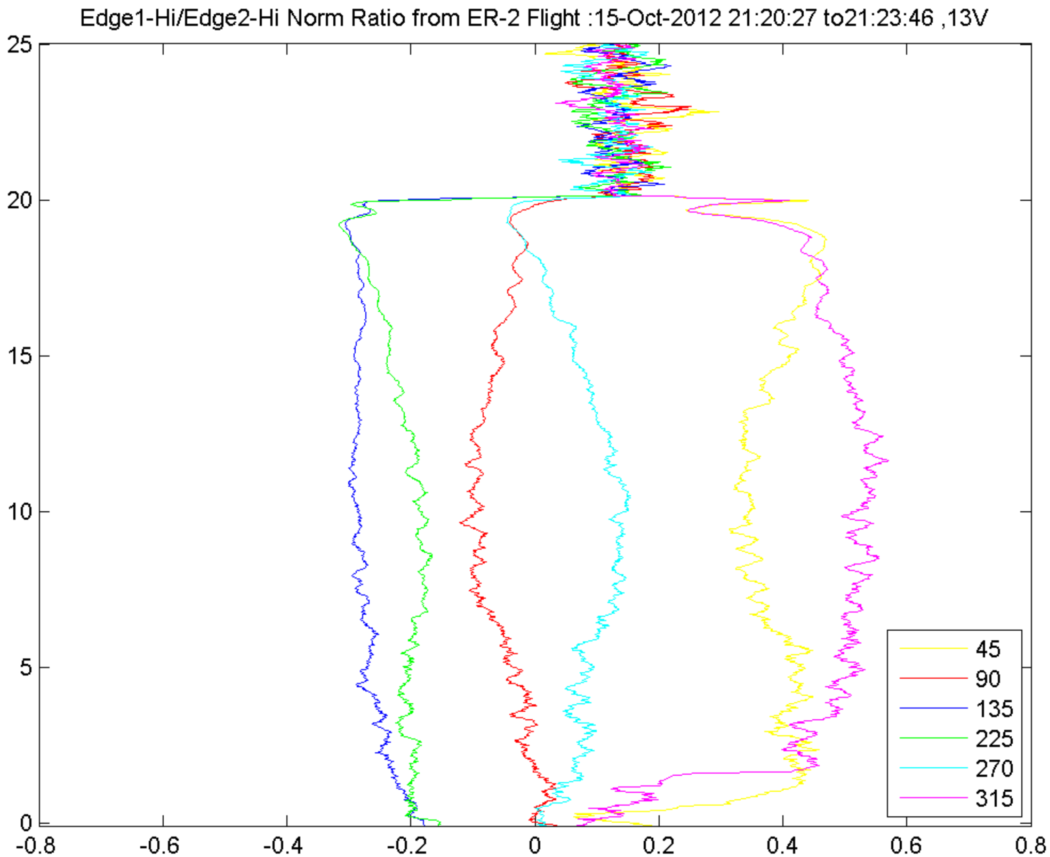


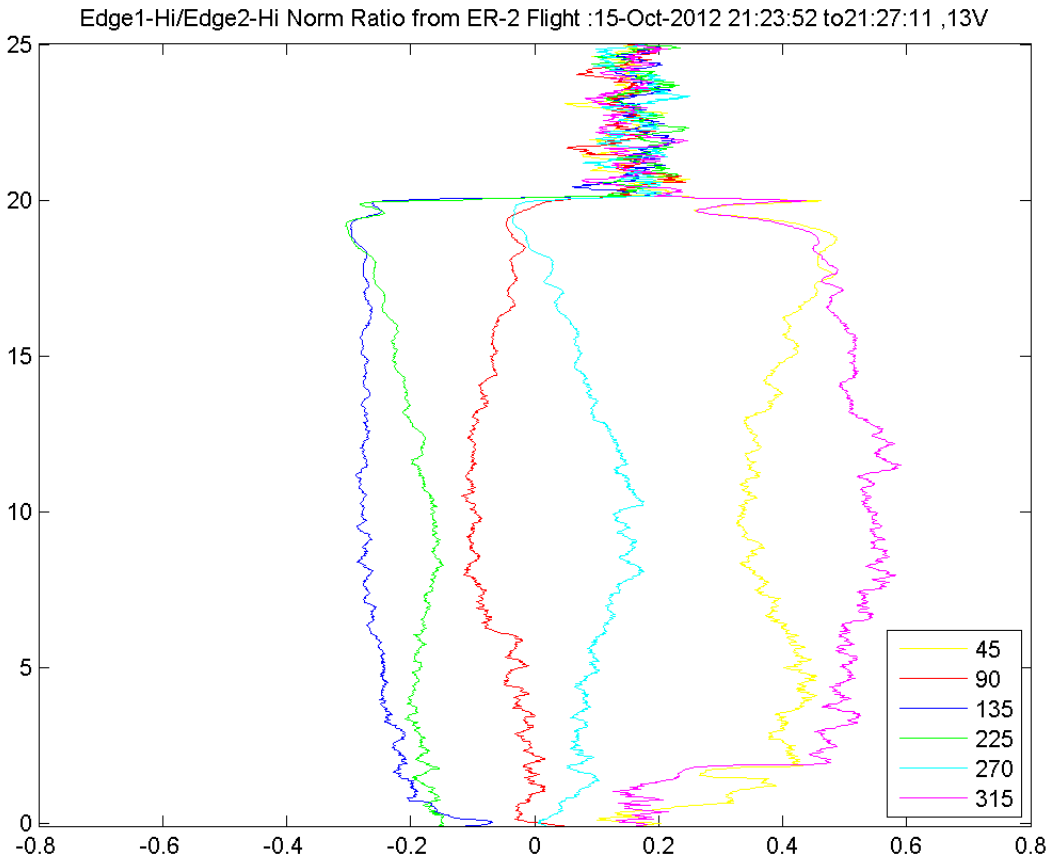
17x11-139

Uncorrected Edge 1/Edge2 ratio

October 15, 2012 - Cycle 38

Δt_{avg}=10 seconds, Δz=258 m

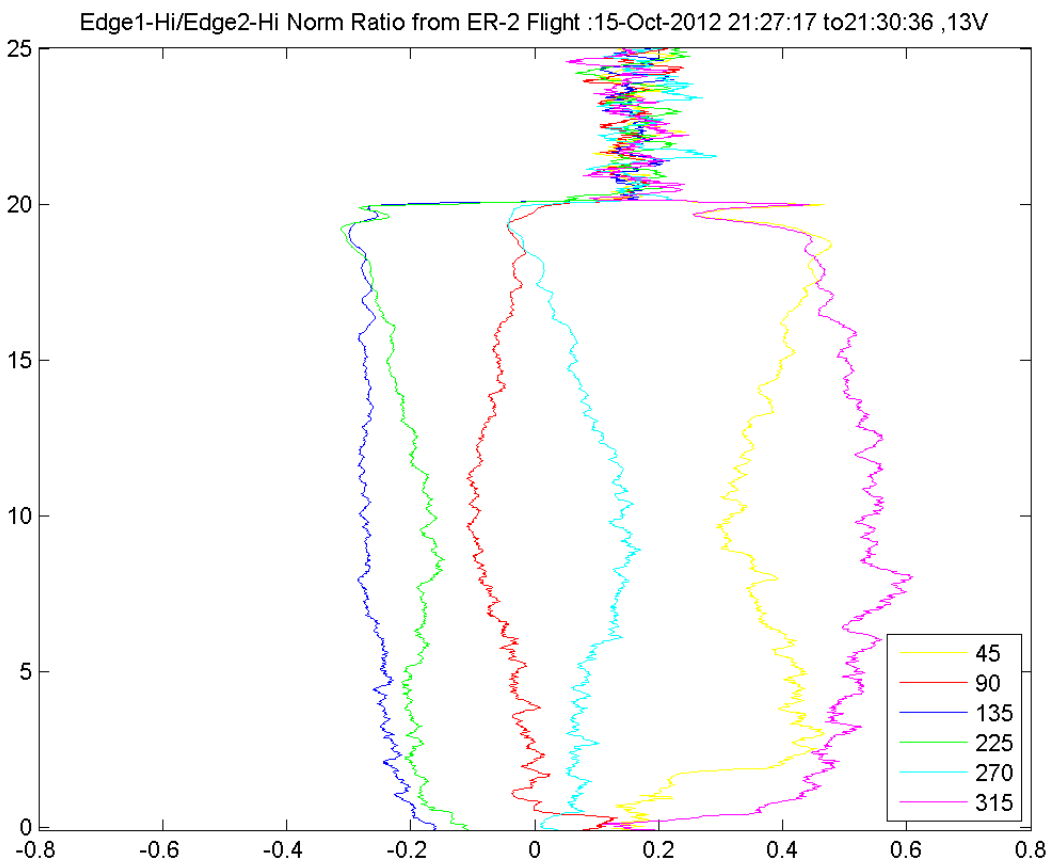
AITT



17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 – Cycle 39
Δt_{avg}=10 seconds, Δz=258 m

AITT



17x11-139

Uncorrected Edge 1/Edge2 ratio
October 15, 2012 - Cycle 40
6 directions; Δt_{avg}=10 seconds, Δz=258 m

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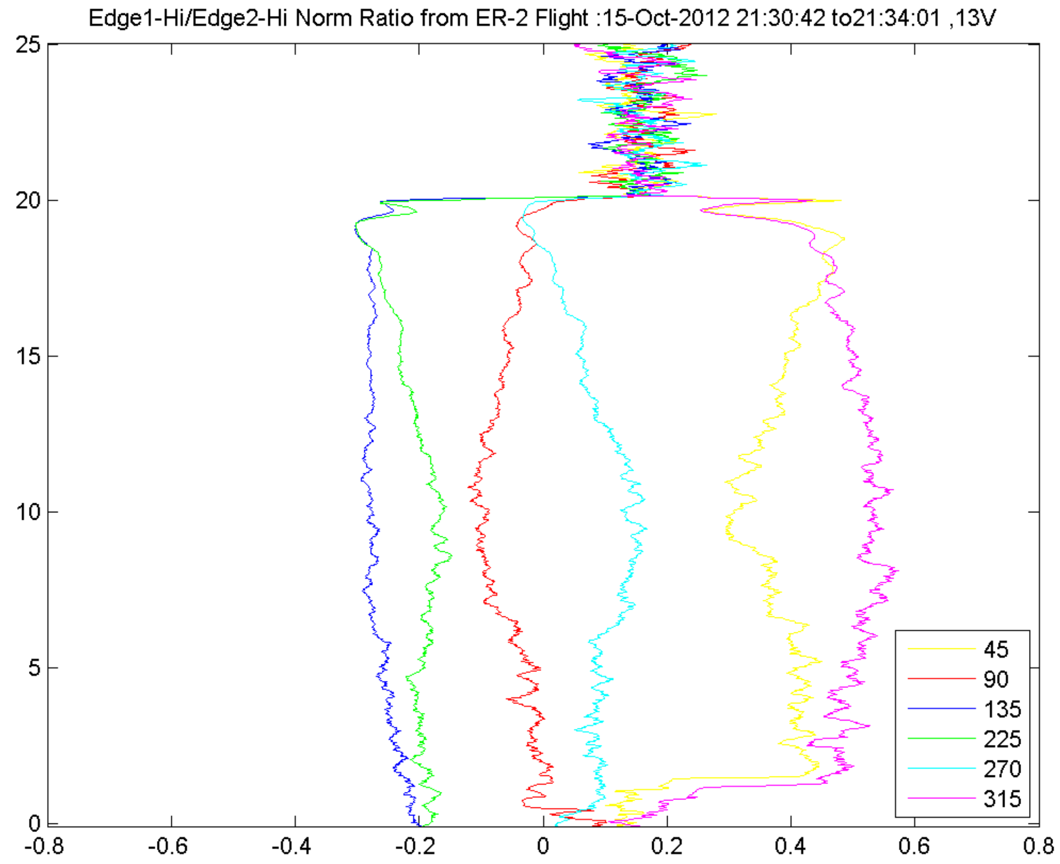


17x11-139

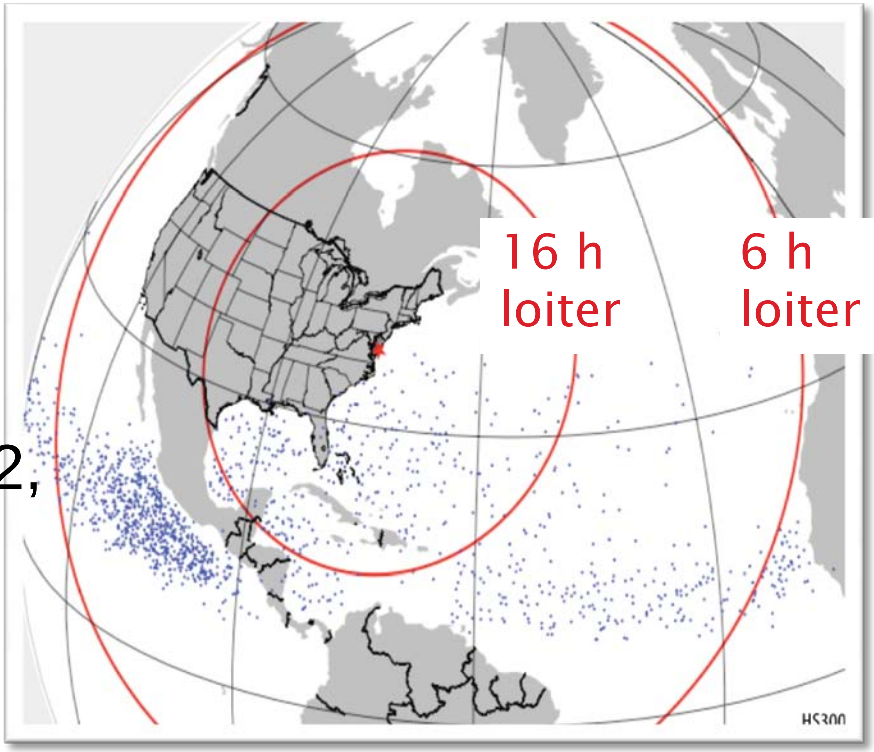
HS3 Mission Overview

• Two aircraft, one equipped for the storm environment, one for over-storm flights

• Deployments of GHs from the East Coast— Wallops Flight Facility in VA

• One-month deployments in 2012, 2013, and 2014

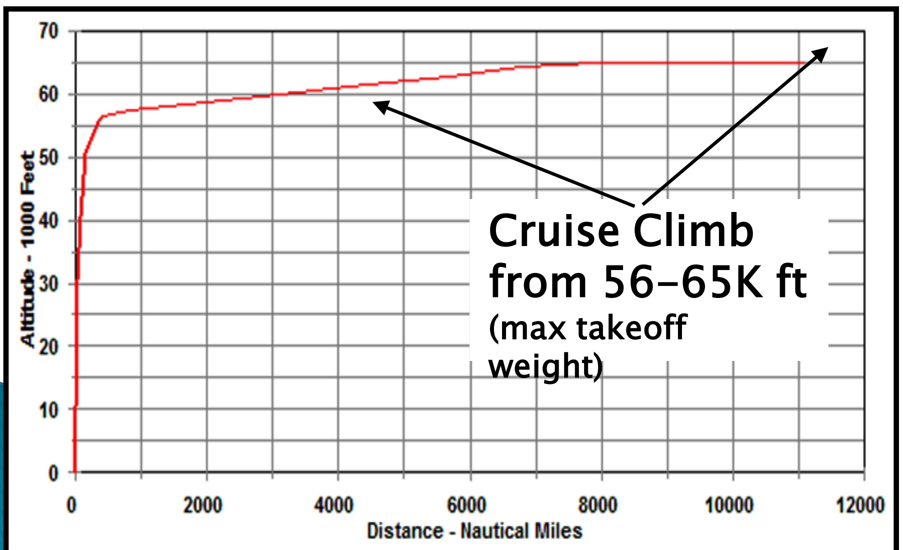
• 275 flight hours per deployment (10-11 flights)

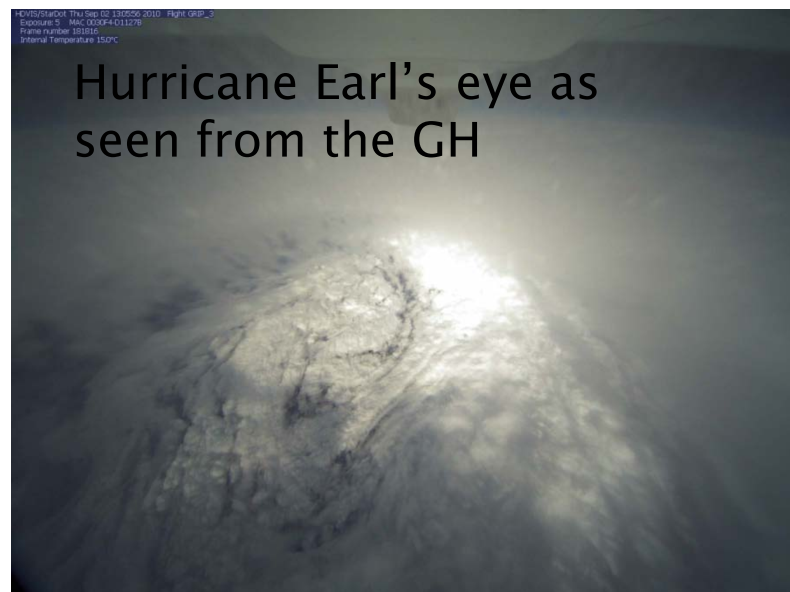


Dots indicate genesis locations. Range rings assume 26-h flights.

NASA's Global Hawk UAS

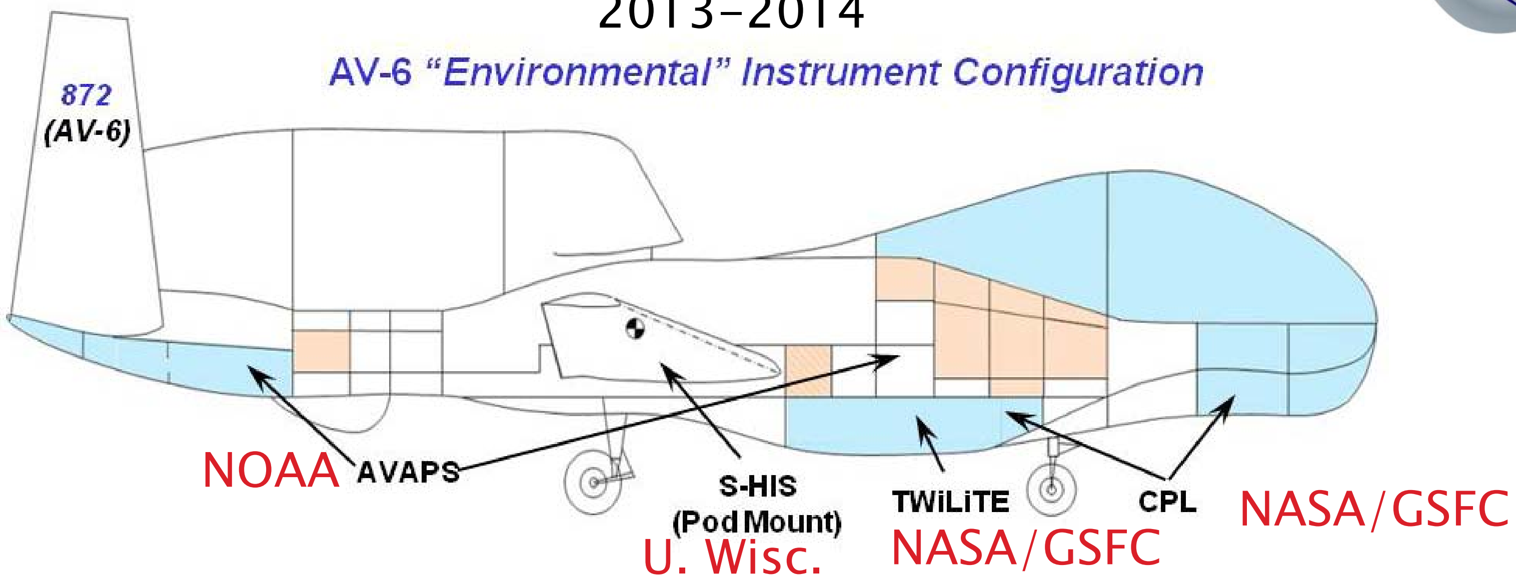
Endurance	> 30 hours
Range	>11,000 nmi
Service Ceiling	65,000 ft
Airspeed (55K+ ft)	335 KTAS
Payload	1,000-1,500 lb
Length	44 ft
Wingspan	116 ft





Environmental Payload

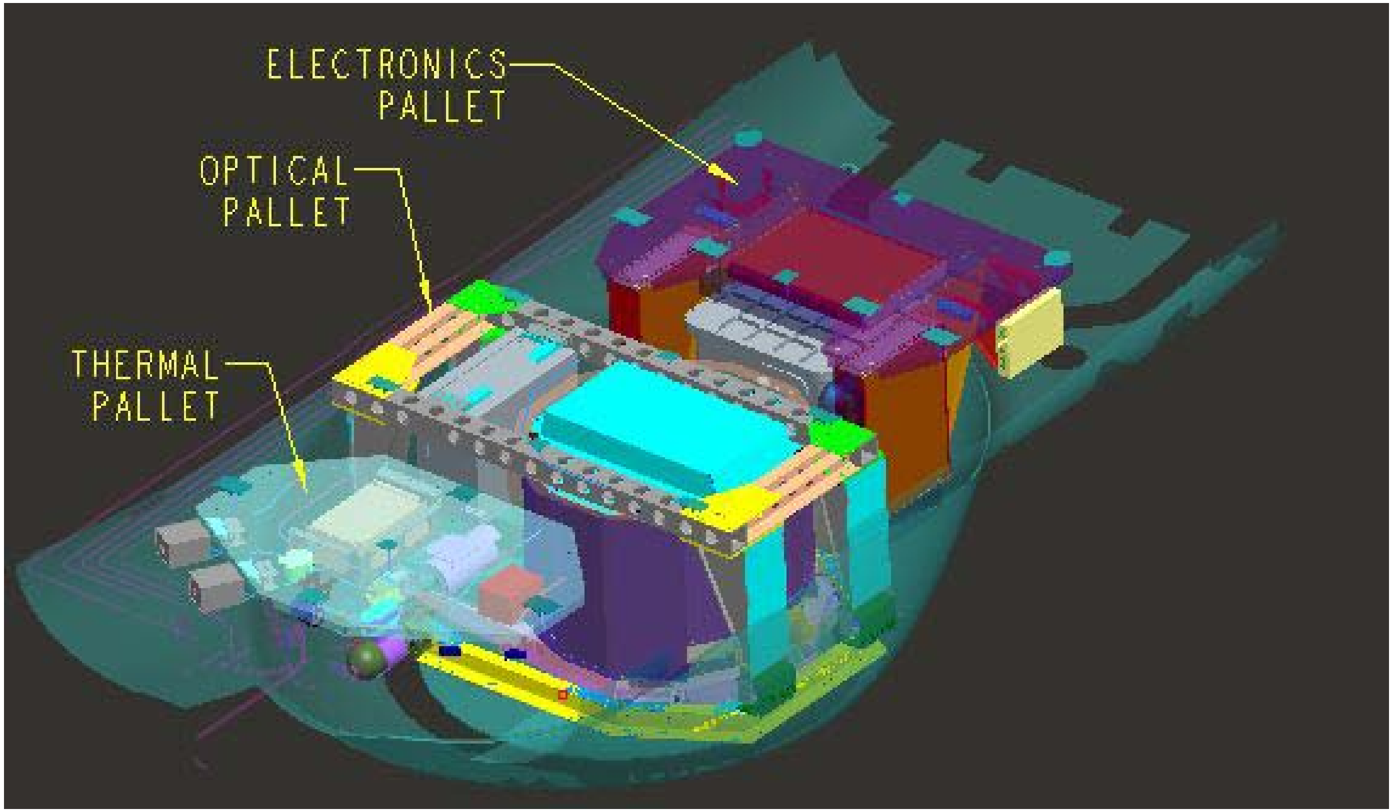
2013-2014



TWiLiTE wind lidar to be added in 2013

TWiLiTE-GH

- Instrument mounted on 3 pallets
  - Electronics
  - Optics
  - Thermal

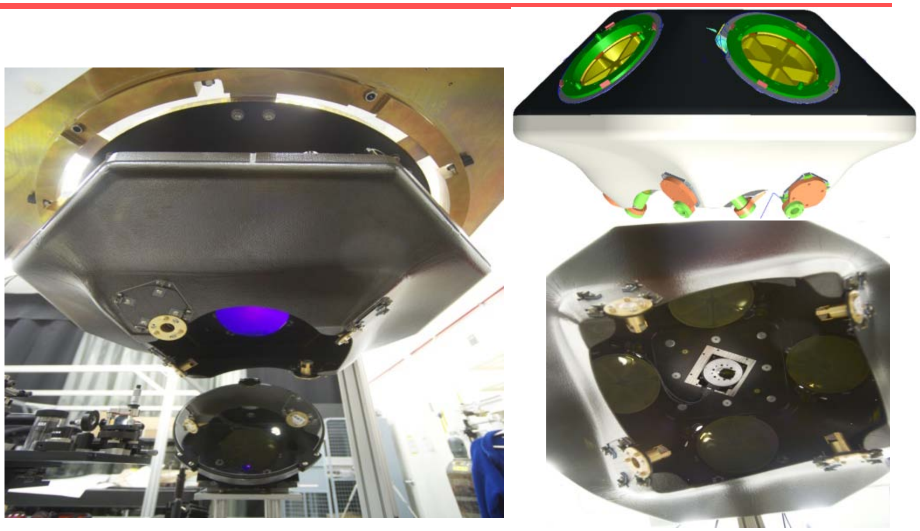


Hybrid Doppler Wind Lidar (HDWL) Transceiver

PI: Cathy Marx, NASA/GSFC

Objective

- Build a compact, light weight, 4 field-of-view (FOV) transceiver, including a reliable FOV select mechanism, in support of the Global Tropospheric 3-D Winds mission
- Test subsystem performance at both 355 nm and 2 µm
- Integrate the hybrid transceiver with ground based 355nm lasers and receivers



3-D model and pictures of 4-FOV HDWL transceiver

Accomplishments

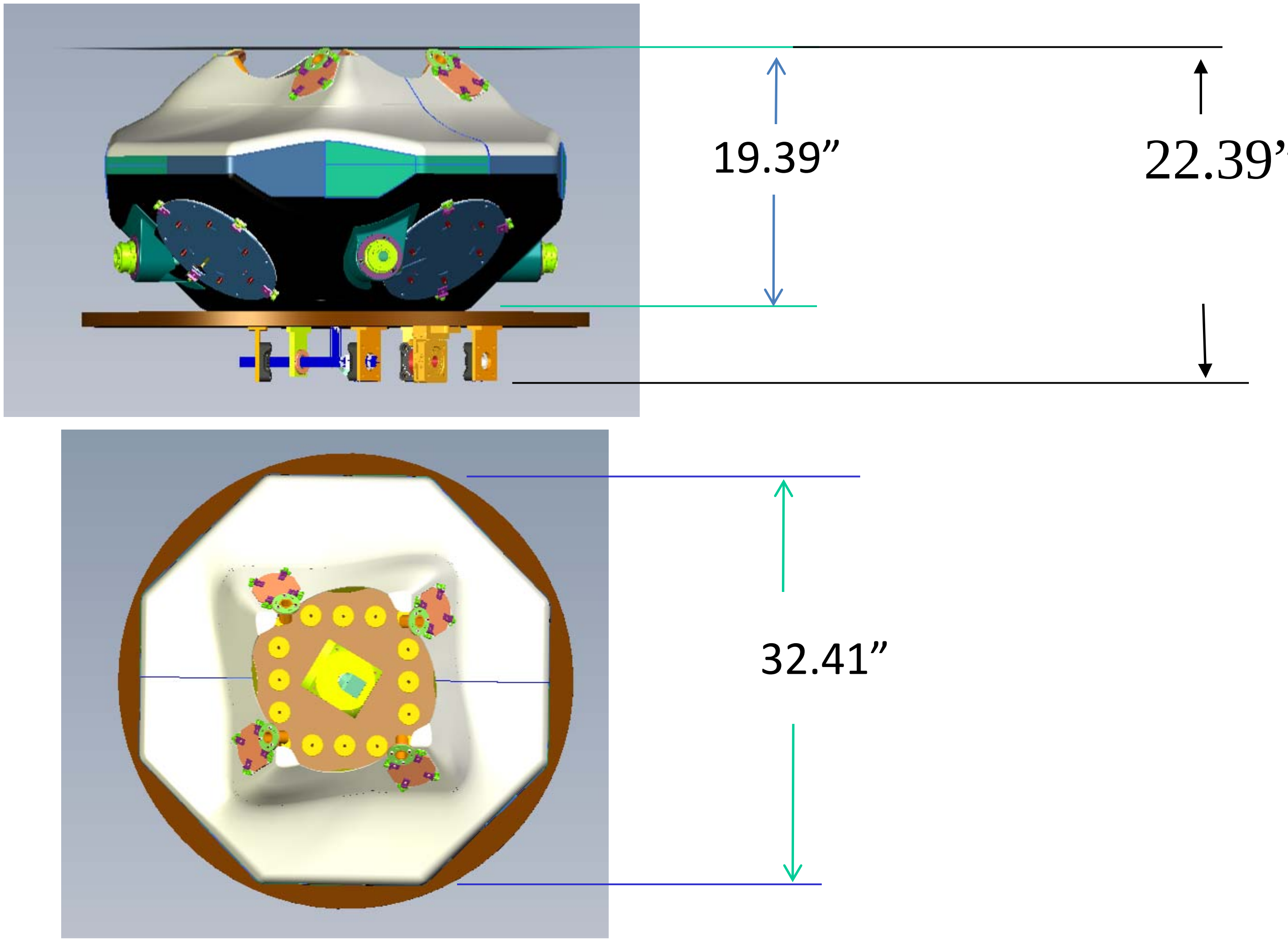
- Designed, analyzed, and built a compact, light-weight packaging of 4 optical assemblies
- Created monocoque composites structure which is precision, compact, light-weight, and thermally stable
    - Composite structure weight approximately 33% lighter than aluminum structure.
- Used four diffraction limited afocal telescopes with no secondary mirror obstructions
- Use of long lifetime mechanism selects operational FOV
- Developed high laser damage threshold mirror coatings with greater than 97% reflectivity at both 355 nm and 2 µm
- Verified performance in laboratory environment at both 355 nm and 2 µm
- Developed interface and hardware for testing with ground based wind lidar lasers and receivers

Co-Is/Partners

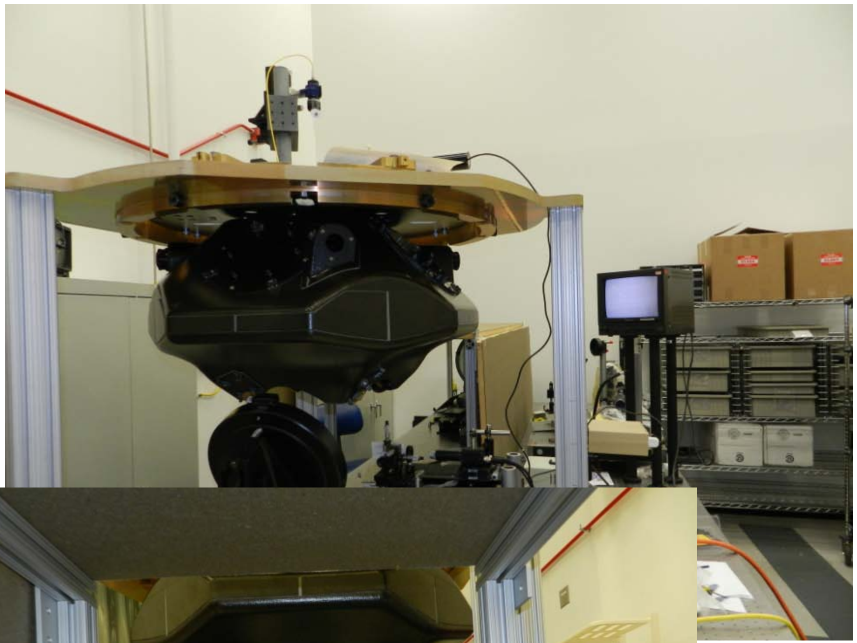
Bruce Gentry, Patrick Jordan, NASA/GSFC;
Michael Kavaya, NASA/LaRC

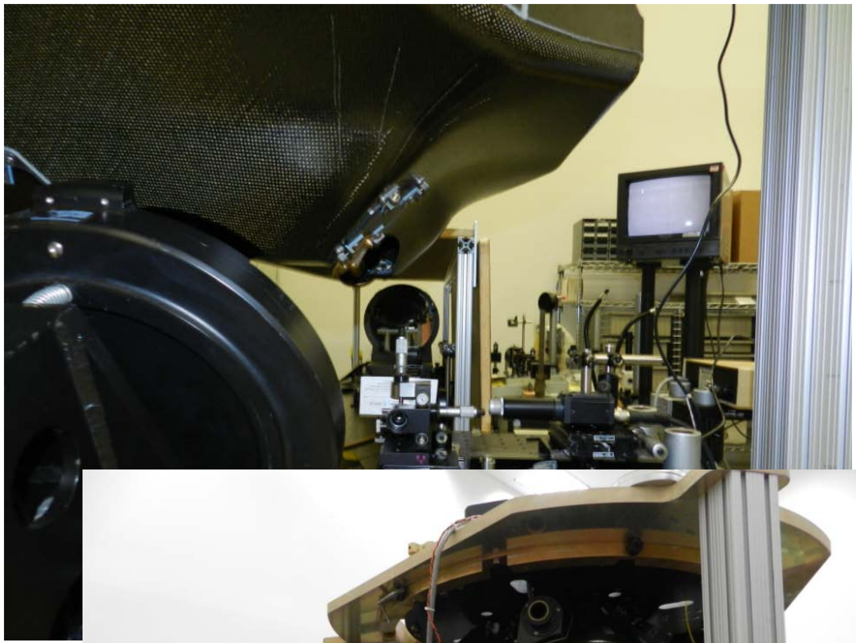
TRL_{in} = 2 TRL_{out} = 4

Structure Design Size



Fine Alignment

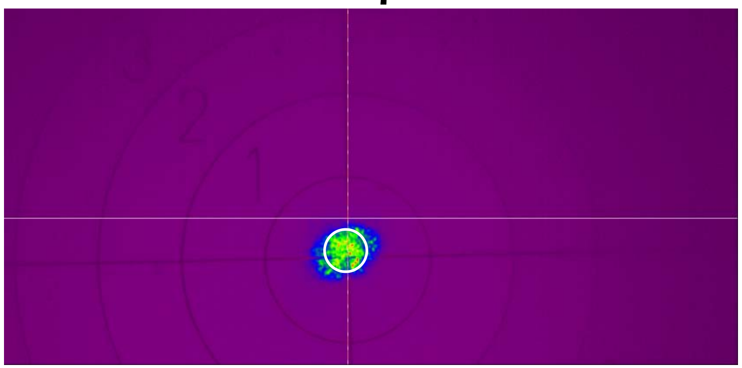




50 µm Fiber Illumination – 8/28/12 (355 nm)

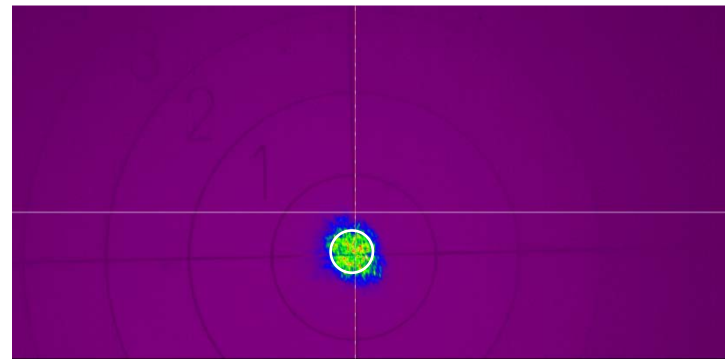
Telescope 1

~280 µm



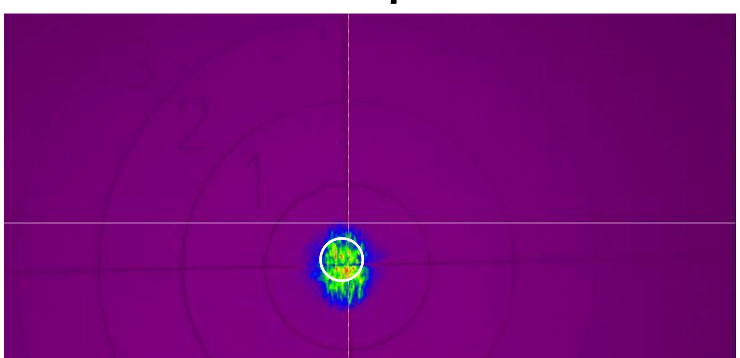
Telescope 2

~290µm



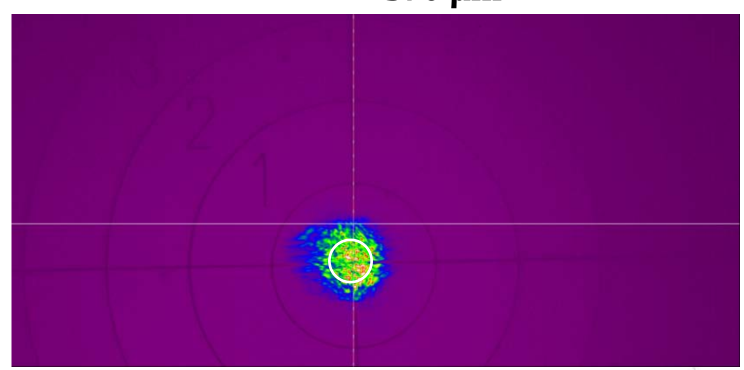
Telescope 3

~330 µm



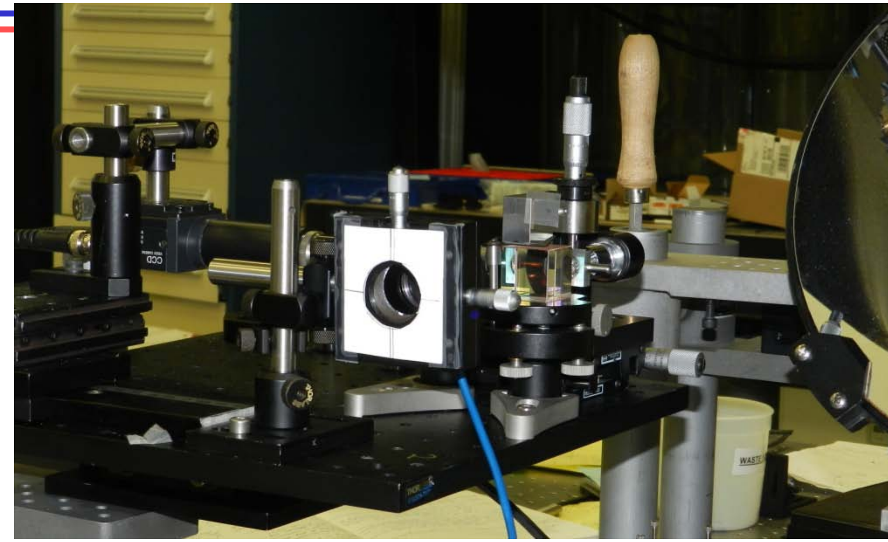
Telescope 4

~370 µm



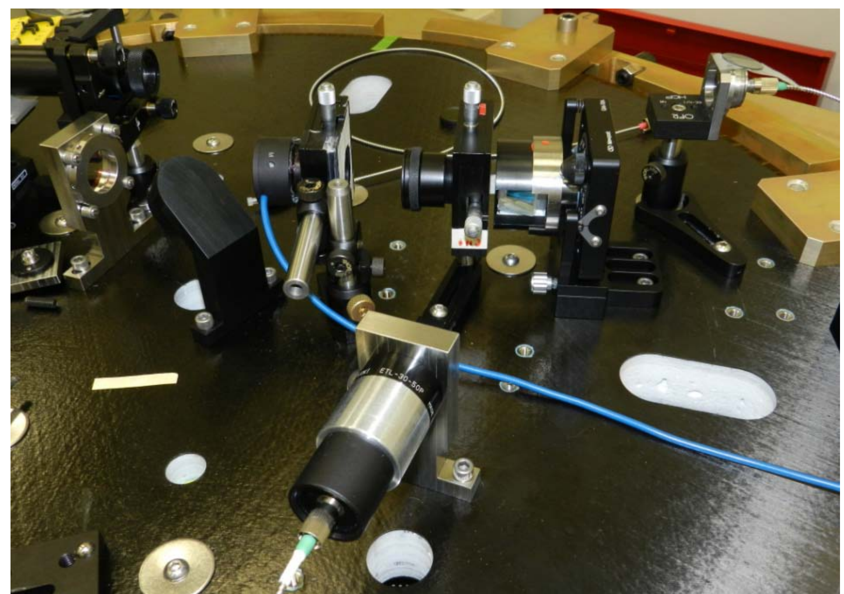
White circle corresponds to geometric magnification of 50 um fiber.

Subsystem Transmission Measurements at 355 nm



- Measurement included reflectivity of dichroic, fold mirror, select mirror, fold mirror, secondary mirror and primary mirror.
- Not a full aperture test.

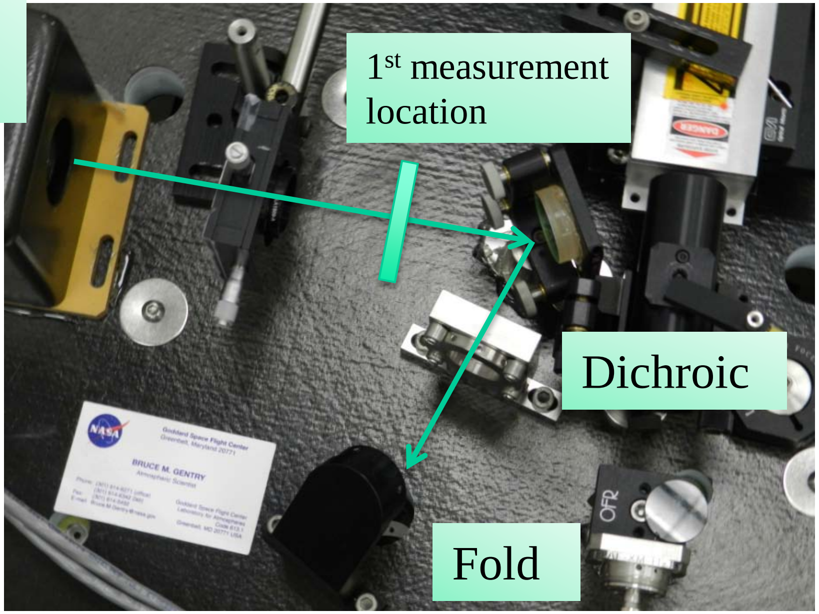
	Expected Value	Measured Value
Telescope 1	0.92	0.94 ± 0.06
Telescope 2	0.92	0.96 ± 0.06
Telescope 3	0.92	0.89 ± 0.06
Telescope 4	0.92	0.97 ± 0.07

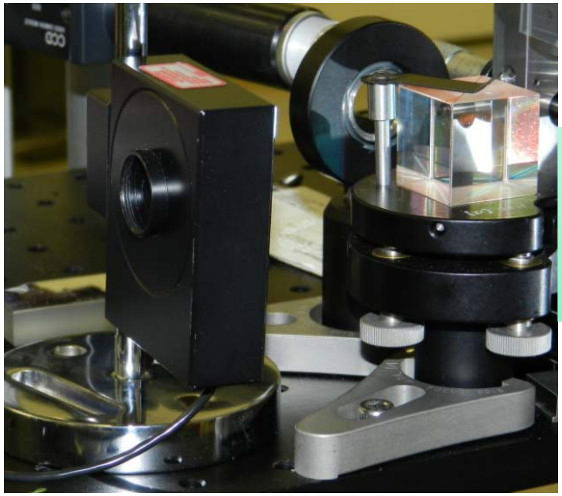


Subsystem Transmission Measurements at 2 µm

- Borrowed Ho:Tm:YLF laser at 2.05µm from Michael Kavaya, LaRC.
- Measurement included transmission of dichroic, and reflectivity of fold mirror, select mirror, fold mirror, secondary mirror and primary mirror.
- Assumed 96% reflectivity of lab flat and collimator (Aluminum coating)
- Not a full aperture test.

	Expected Value	Measured Value
Telescope 1	0.91	0.90





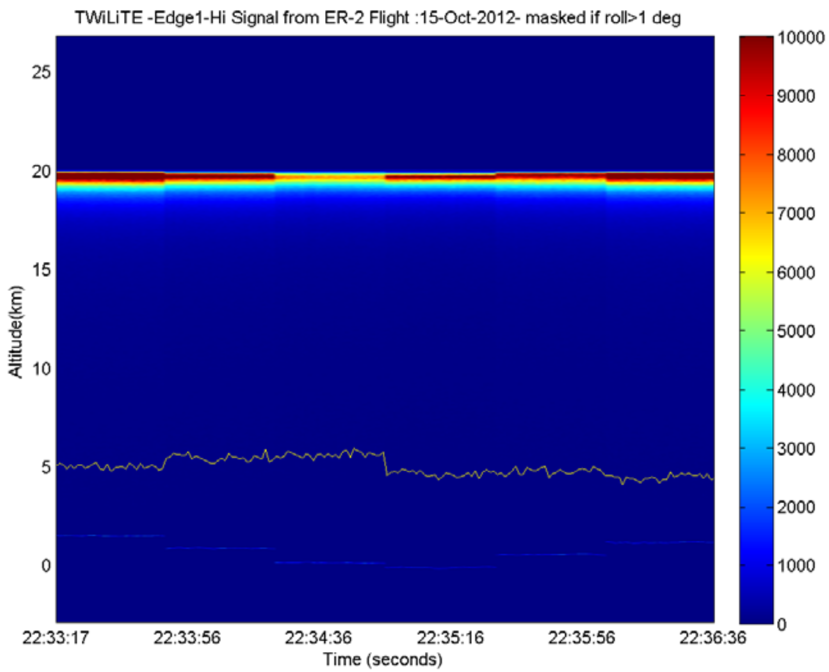
Conclusions and Future plans

- In October, 2012 and February, 2011 we completed two deployments to Dryden Aircraft Operations Facility in Palmdale, CA to integrate TWiLiTE in the ER-2 Q-Bay and fly ~60 hours of test flights.
- During these flights TWiLiTE demonstrated fully autonomous operation of all major lidar functions including etalon calibration, telescope/laser bore sight alignment and science data acquisition including step stare scanning of the HOE telescope (October,2012 only)
- After returning in late October, TWiLiTE will be reconfigured to fly in Zone 25 of the NASA Global Hawk for the HS3 EV-1 Mission in 2013.

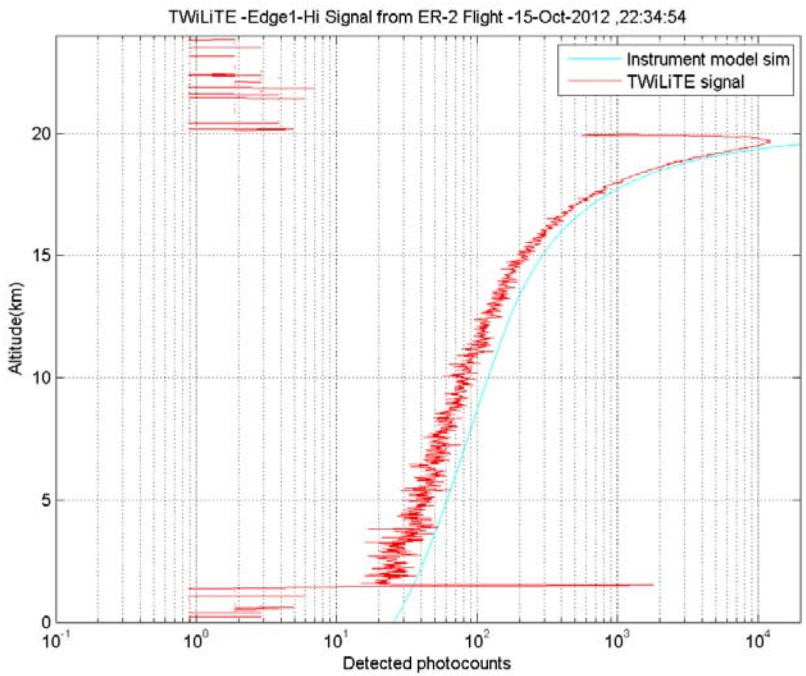
Backups

Edge 1 raw signal
October 15, 2012 – Cycle 52 of 64
Δt_{avg}=1 seconds, Δz=21 m

AITT



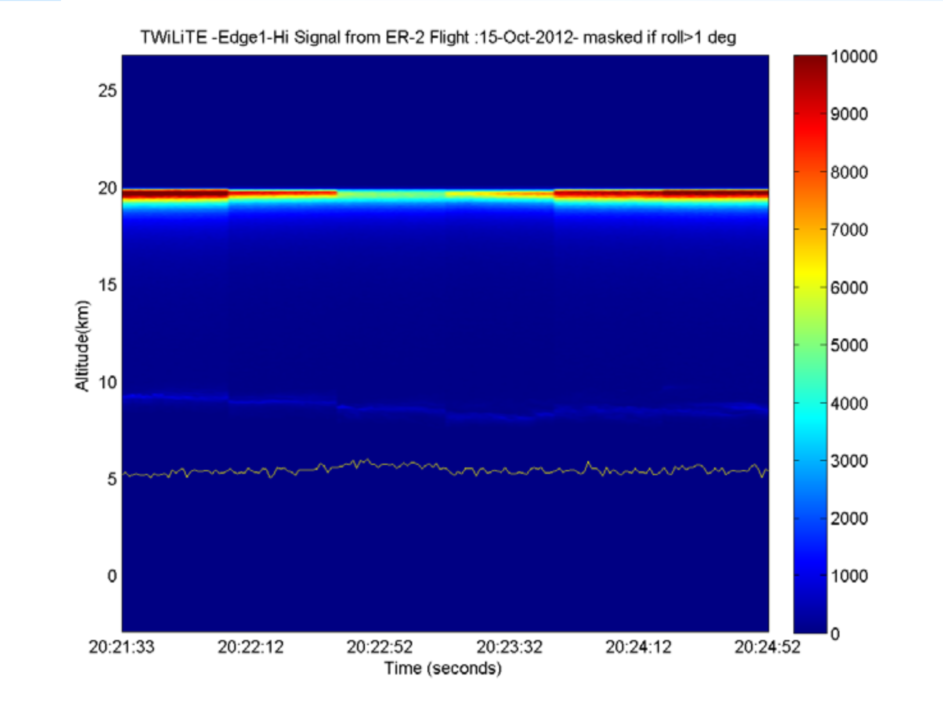
A 200 second segment (180 profiles) of raw signal vs altitude profiles for the Edge 1 etalon channel PMT. This segment represents one cycle of the 6 direction (45, 90,135, 225, 270, 315 degs) step-stare, azimuth scan of the HOE telescope. Color axis is number of detected photocounts per 200 nsec range bin.

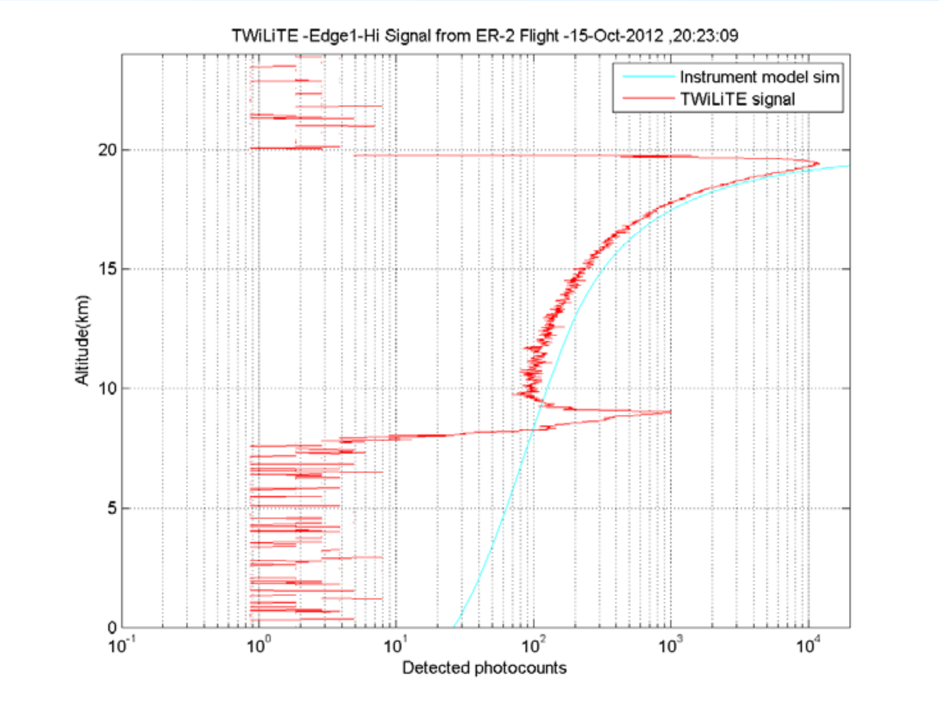


A semilog plot or detected signal vs altitude for a single profile selected from the time series shown at left. Note the return signal is nearly pure molecular bacscatter

Edge 1 raw signal
October 15, 2012 - Cycle 26 of 64
Δt_{avg}=1 seconds, Δz=21 m

AITT





A 200 second segment (180 profiles) of raw signal vs altitude profiles for the Edge 1 etalon channel PMT. This segment represents one cycle of the 6 direction (45, 90,135, 225, 270, 315 degs) step-stare, azimuth scan of the HOE telescope. Color axis is number of detected photocounts per 200 nsec range bin.

A semilog plot or detected signal vs altitude for a single profile selected from the time series shown at left. Note the optically thick cloud at ~ 9 km in the return signal. Above this the signal is nearly pure molecular backscatter