Backscatter and Velocity Measurements from Simulated River/Ocean Surfaces,

Recent Results Using the NASA MSFC 2-Micron Pulsed Doppler Lidar the NASA MSFC 9-11 Micron CW Doppler Lidar

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MSFC WATER VELOCITY EXPERIMENTS

as of July 12, 2002

Date	Instrument	Wavelength	Target
6/10/96	MACAWS (MSFC, JPL, ETL)	10.6 µm	Pacific Ocean, near California
1996/97	CW CO_2	9.1 µm	MSFC lab centrifuge
10/13/98	MACAWS (MSFC, JPL, ETL)	10.6 µm	Atlantic Ocean, near Bahamas
12/17/99	Pulsed solid state	2.02 µm	Pickwick Lake, Tennessee River
2/24/00	Pulsed solid state	2.02 µm	Pickwick Lake, Tennessee River
4/26/00	CW CO_2	9.1 µm	Wilson Dam, Tennessee River
11/14/00	Pulsed solid state	2.02 µm	Pickwick Lake, Tennessee River
5/18/01	Pulsed solid state	2.02 µm	hose, prototype waterslide
5/29/01	Pulsed solid state	2.02 µm	PVC nozzles, prototype slide
9/21/01	Pulsed solid state	2.02 µm	MSFC field waterslide
3/18/02	Pulsed solid state	2.02 µm	MSFC field waterslide
6/5/02	Pulsed solid state	2.02 µm	MSFC field waterslide
7/10/02	Tunable CW CO_2	10.2 µm	MSFC field waterslide

river tests inconclusive

2 micron pulsed ground based lidar

Water Velocity Signals

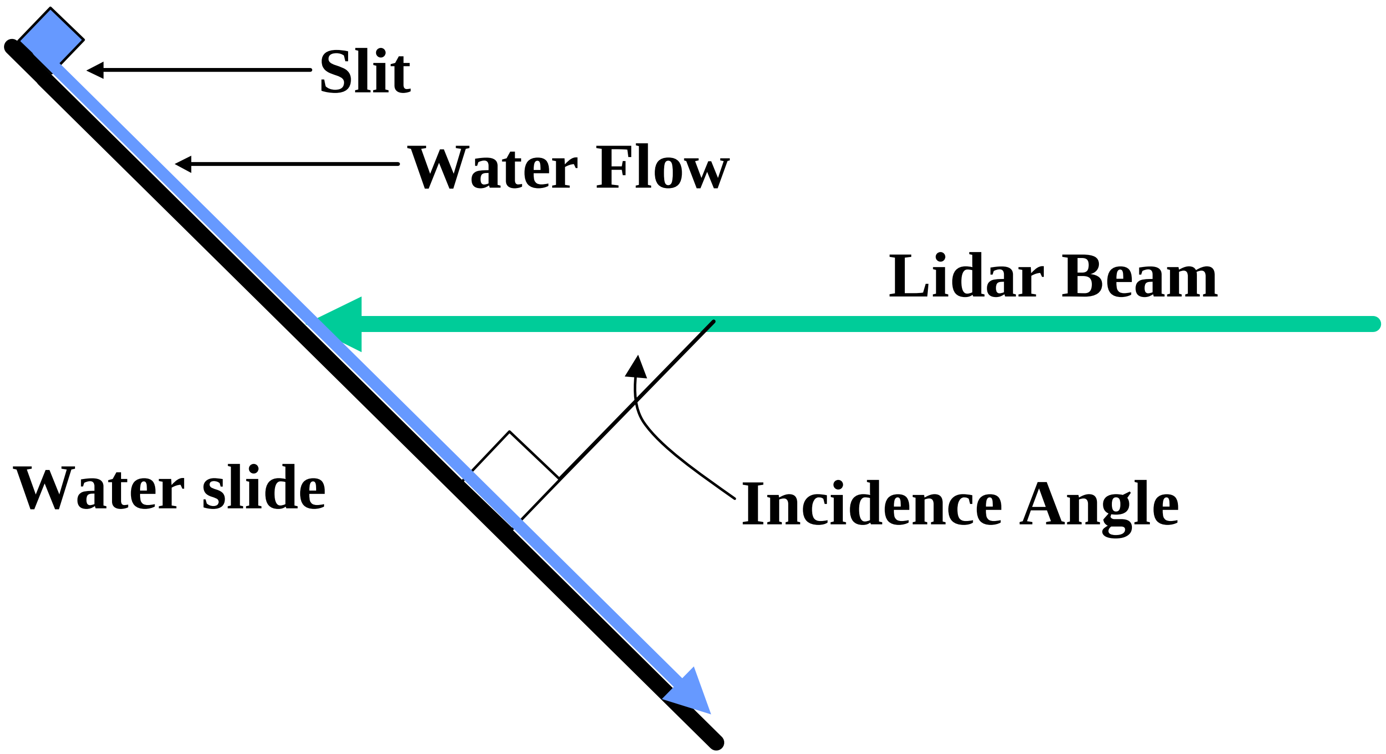
Water velocity signal strength depends on:

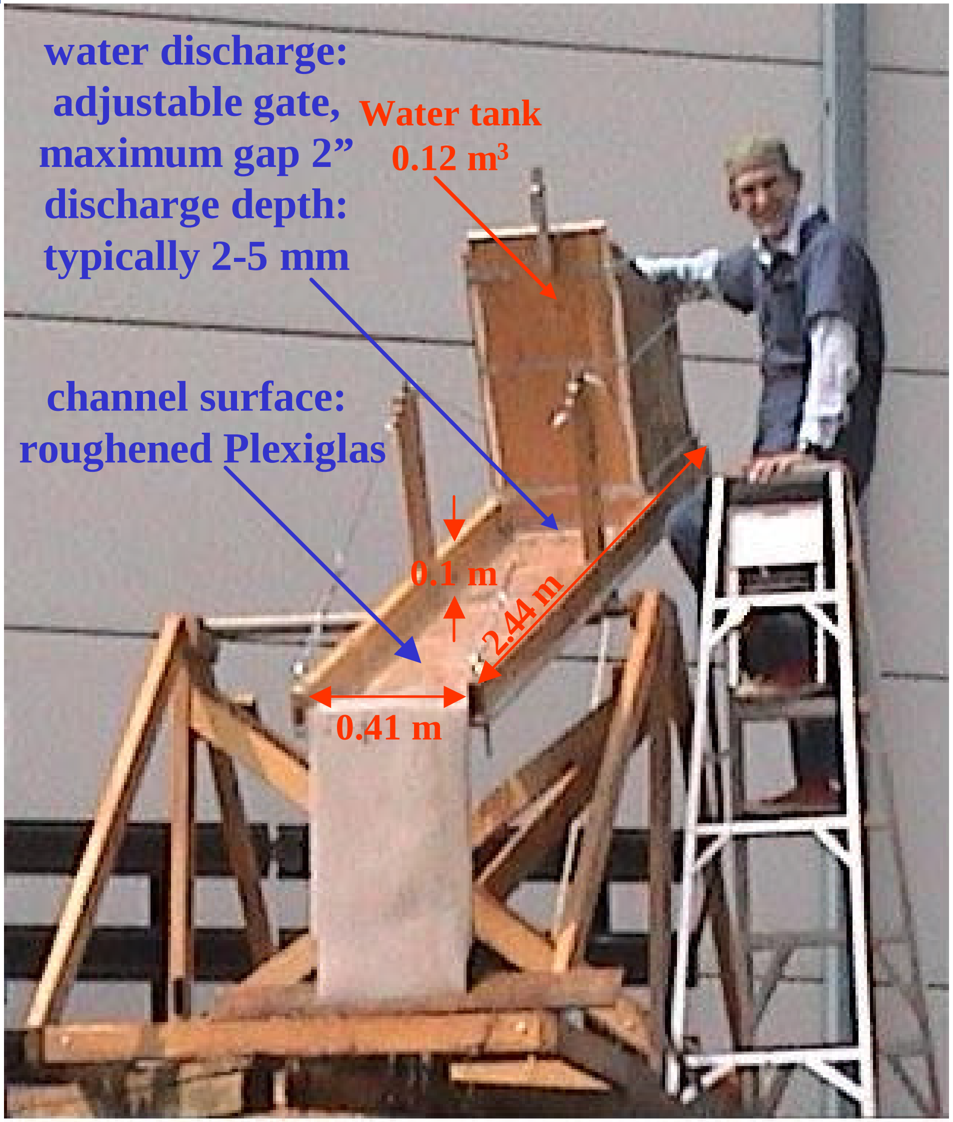
- Lidar beam *wavelength*
- Lidar beam *footprint size*
- Lidar beam *incidence angle*
- Lidar beam *azimuth angle*
- Lidar beam *penetration depth*
- Water surface *roughness*
- Water surface *layer turbidity*
- Water surface *contaminants* (e.g., foam, surfactants)

Water velocity signal interpretation depends on:

- Water surface currents, eddies, long and short waves
- Near-surface wind, spray, other aerosols

Water Slide Geometry



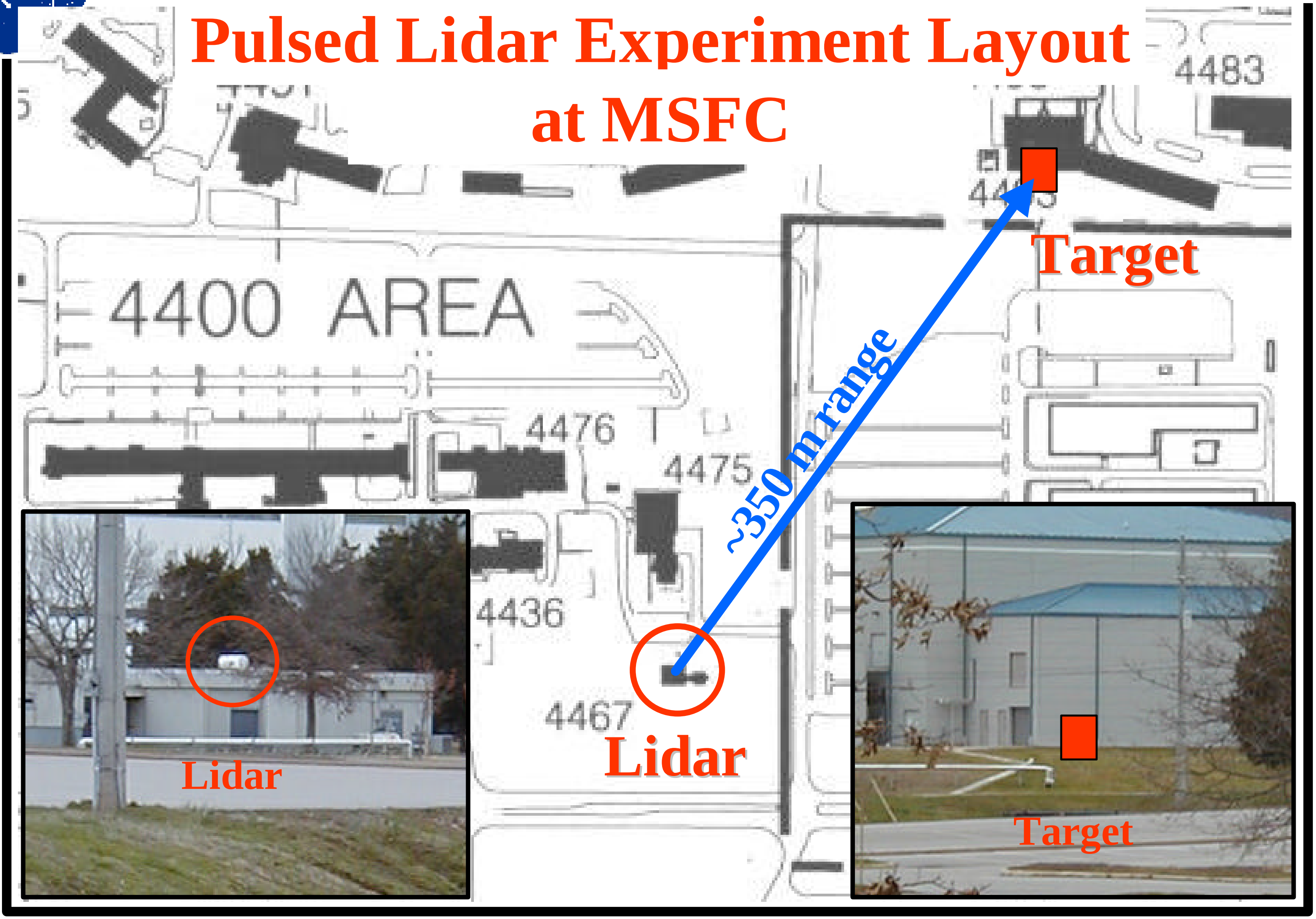


<u>MSFC Water Slide</u>

generates water flows with 170^o to 15^o incidence angles 10^o to 75^o slopes

photo courtesy of G.D. Emmitt

Pulsed Lidar Experiment Layout at MSFC



Pulsed Lidar Experiment Parameters

- **Lidar beam *output*: 2.017 μm, 50 mJ, 6.6 Hz**
- **Lidar beam *footprint*: ~10 cm**
- **Lidar beam *incidence angle*: typically 30°, 45°, 60°**
- **Lidar beam *penetration depth*: ~1 mm**

- **Range minimum: ~150 meters**
- **Range to target: ~350 meters**
- **Range gate, range plots: ~38.4 meters**
- **Range gate, velocity plots: ~210 m, centered on target**
- **Range gates in air near target: ~5 good gates**

- **Integration: varies, often 20 pulses**
- **Velocities toward lidar are negative (-)**

June 5, 2002: Waterslide Slope 45^o

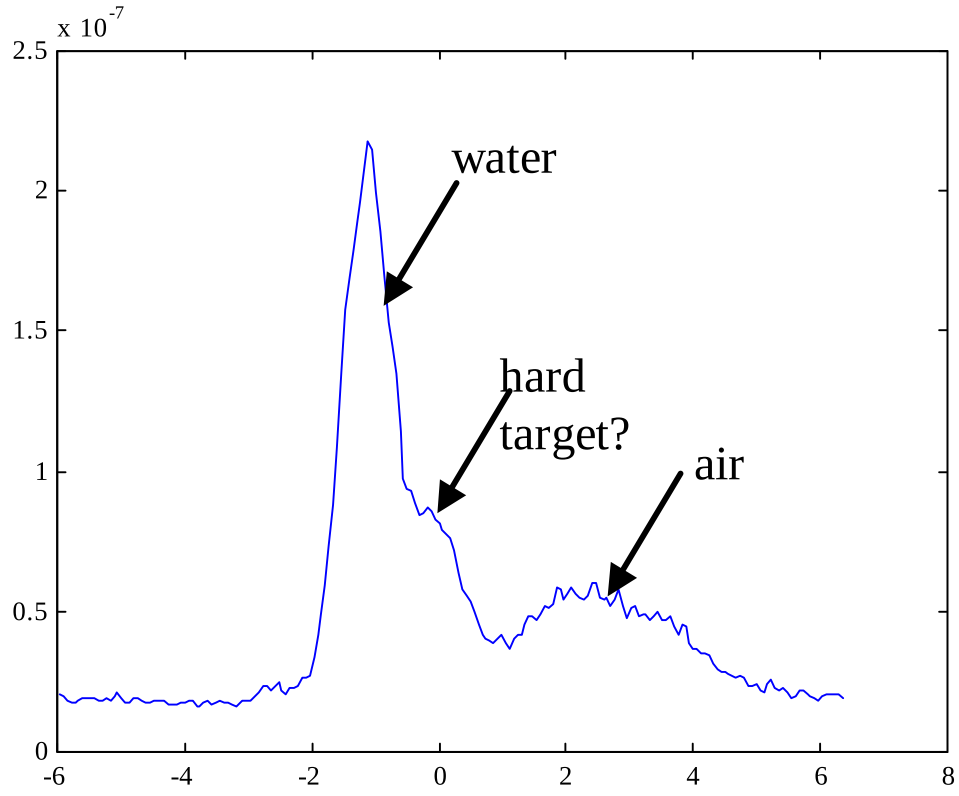


Figure 1 - Run 9, 254 Pulses Selected for Reference > 50 and Correct Reference Frequency

June 5, 2002: Waterslide Slope 45°

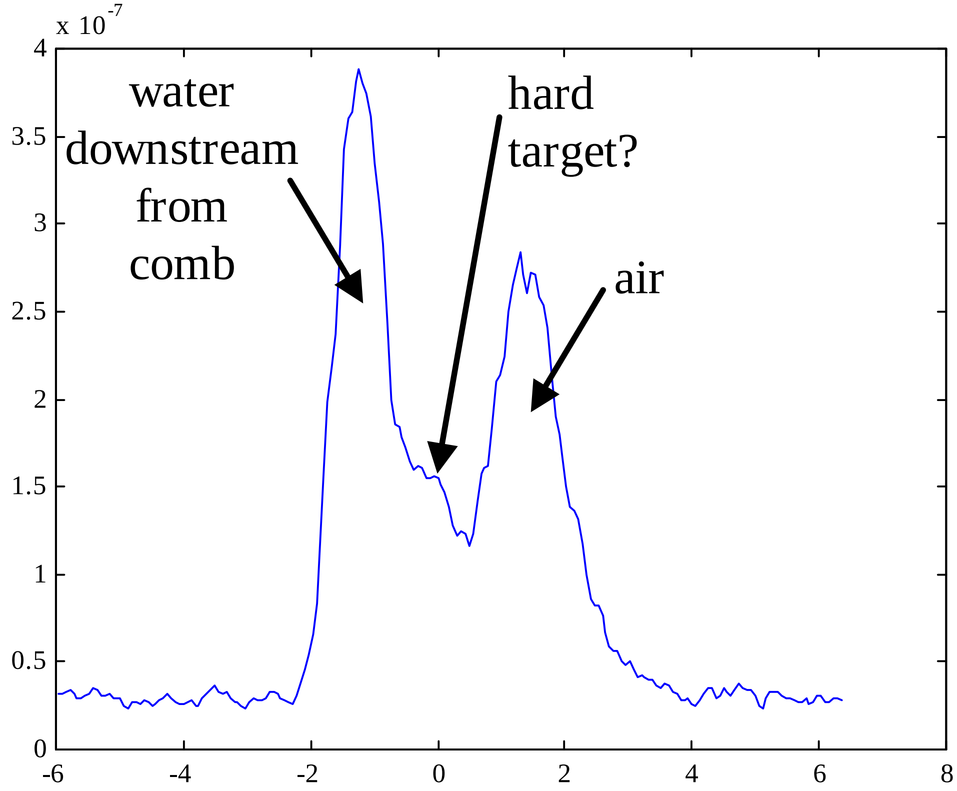


Figure 1 - Run 11, 127 Pulses Integrated, Selected for Reference > 50 and Correct Reference

June 5, 2002: Waterslide Slope 30°

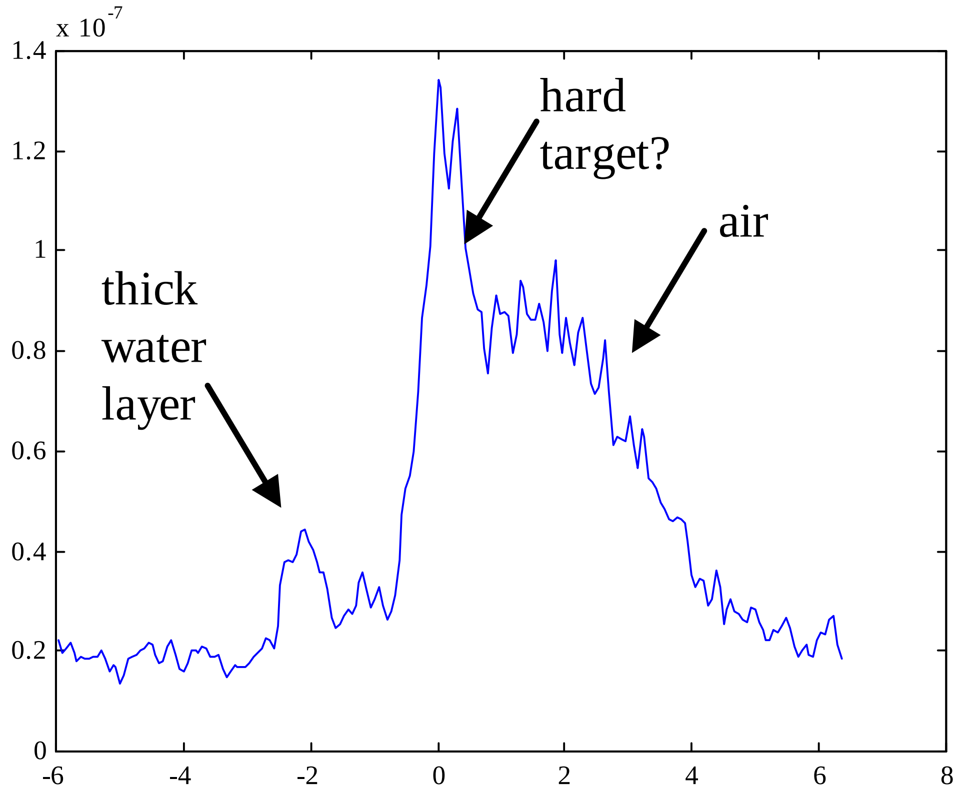


Figure 1 - Run 13, 86 Pulses Integrated, Selected for Reference > 50 and Correct Reference

Advantages of CW Focused Doppler Lidars

compact, short range

- **facilitate detailed parametric study in laboratory**
- **facilitate deployment to pulsed lidar sites**
- **minimize interference by ambient aerosols**

turning mirror(s) near target

- **allow nearly horizontal flow channel**
- **change beam interrogation angle without changing flow conditions**

small beam footprint

- **profile individual capillary waves**
- **compile wave facet retroreflection statistics**
- **study speckle effects by enlarging beam footprint**
- **separate water surface from spray and other aerosols**

multiple wavelengths

- **2 mm CW lidar => cal/val for pulsed 2 mm lidar & signal processing**
- **tunable 9-11 mm CW lidar discriminates water from other materials**
- **water signals dominated by surface layer "skin" at each wavelength**

2 micron pulsed ground based lidar

Required Equipment Improvements

lidars

- **2 mm pulsed** – **reduced chirp, beam detector, improved real-time display**
- **2 mm CW** – **acousto-optic modulator, telescope, real-time display**
- **9-11 mm CW** – **acousto-optic modulator**

targets

- **calibrated hard target**
- **lightweight turning mirror**
- **high efficiency beam dump**
- **large format for pulsed lidar, lab-scale for CW lidars**

waterslide

- **high-flow closed-cycle water supply system**
- **independent measurement of water surface velocity**
- **control and measurement of water turbidity and surface condition**
- **control and measurement of aerosol loading and air velocity**
- **improved water channel (increase width and depth, improve gate)**
- **same water channel and accessories for laboratory and field experiments**

Conclusions and Plans

Further progress requires

- **improved control and measurement on water and air properties**
- **deeper/wider channel, higher flow rates, closed cycle supply**
- **improved backscatter calibration accessories**

Plans – Phase I

- **implement minor upgrades to waterslide system and accessories**
- **move pulsed and CW Doppler lidars to new labs in NSSTC Annex**
- **conduct preliminary parametric experiments**

Plans – Phase II

- **implement major upgrades to lidars, waterslide system, and accessories**
- **conduct detailed parametric experiments, compare to theory & TODWL**