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EM & EO Properties of the Lower Atmosphere

by

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EM /EO Data for Navy METOC Support

E&M (RF refraction) and EO (optical propagation) data products are required for future systems. A new level in type and quality of observational data is needed for assimilation into numerical models.

Lidar profiles provide the best source for high quality meteorological profiles and EM/EO data.

Model prediction capability is based upon constraints provided by gridded fields of measured parameters.

High resolution data - both time and space - are needed to constrain advanced numerical models as they are applied to mesoscale features -- tens to hundreds of kilometers.

"Even if more capable models were available, our ability to supply the data needed to drive them is deficient."

Reference: 97 EM/EO Symposium, Edward Whitman (TD for Oceanographer of the Navy)

Our Research Goals . . . .

– Develop, demonstrate and use capabilities of Raman lidar to foster a wide range of applications that support atmospheric measurements, weather prediction, air quality monitoring, and model development (initialization and assimilation).

Goal of this paper . . .
show capability and status of Raman lidar for providing measurements required for Navy applications in EM/EO and meteorology.

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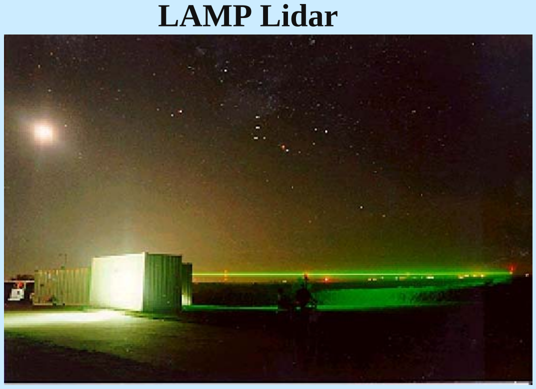
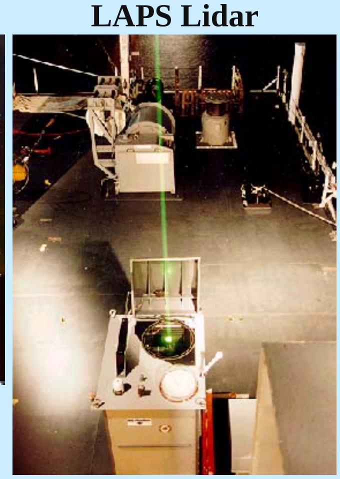
Raman Lidar Development

LAMP Lidar



LAPS Lidar



Five generations of Raman Lidar

1st GLEAM (1978)
2nd GLINT (1984)
3rd LAMP (1990)
4th LARS (1994)
5th LAPS (1996)

Breadboard Research Instrument ………….. to ..… Operational Prototype (ADM)

Arctic to Antarctic
Testing at Point Mugu

Testing on USNS Sumner
Advanced Development Model

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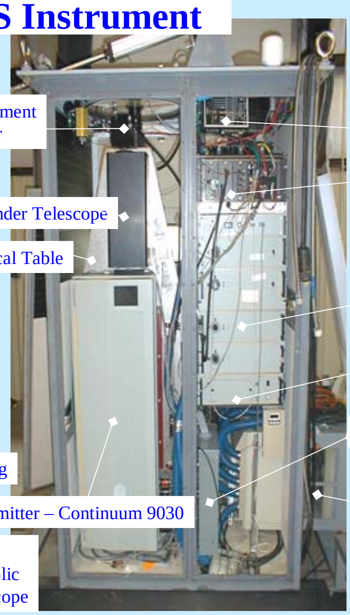
LAPS Instrument

The LAPS instrument is first prototype for an operational system – Rugged, weather-sealed, compact, semi-automated



Backside of LAPS Instrument

LAPS Instrument Characteristics and Measurements

Transmitter	Continuum 9030 (30 Hz) 5X Beam Expander	600 mj @ 532 nm 120 mj @ 266 nm
Receiver	61 cm Dia. Prime Focus Telescope	Fiber optic pickup
Detector	8 PMT Channels Photon Counting	528 + 530 nm – Temperature 660 + 607 nm – Water vapor 294 + 285 nm – Daytime Water Vapor 276 + 285 nm – Raman/DIAL
Data System	DSP 100 MHz	75 m bins (upgrade to 15 meter)
Safety System	Marine R-70 – X-Band	Protect near field and aircraft observers

Property	Measurement	Altitude	Time - Resolution
Water Vapor	660/607 (H_2O/N_2) 294/285 (H_2O/N_2)	Surface to 5 km Surface to 3 km	Night -1 min Day & Night -1 min
Temperature	528/530 Rotational Raman	Surface to 5 km	Night 10 to 30 min
Extinction 530 nm	530 nm Rotational Raman	Surface to 5 km	Night 10 to 30 min
Extinction 607 nm	607 nm N_2 1st Stokes	Surface to 5 km	Night 10 to 30 min
Extinction 285 nm	285 nm N_2 1st Stokes	Surface to 3 km	Day & Night 10 to 30 min
Ozone	O_2/N_2 (276/285)Raman/DIAL	Surface to 2-3 km	Day & Night - 30 min

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EM/EO Requirements for Refractivity and Extinction

EM requirement is for RF-refraction

Water Vapor Temperature	⇒	n index of refraction	⇒	m modified index	⇒	TREPS, RPO, RPOT, TPEM

EO requirement is for optical extinction

Upper Layer - Temperature Dew Point ⇒ Optical Extinction
Lower Layer - Aerosol Description & Visibility

Lidar ⇒ Water Vapor & Temp ⇒ EM Conditions
Lidar ⇒ Optical Extinction ⇒ EO Conditions

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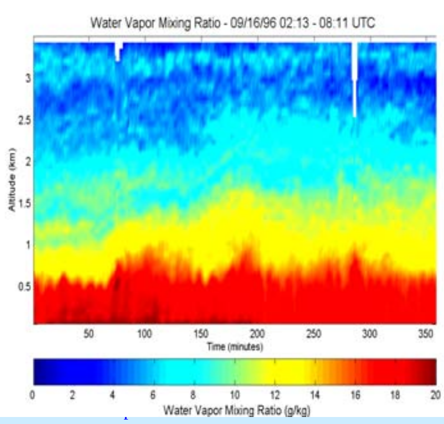
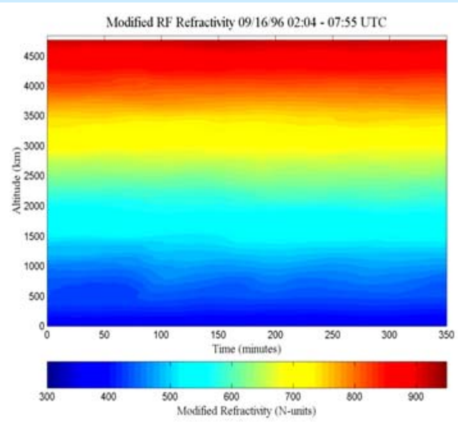
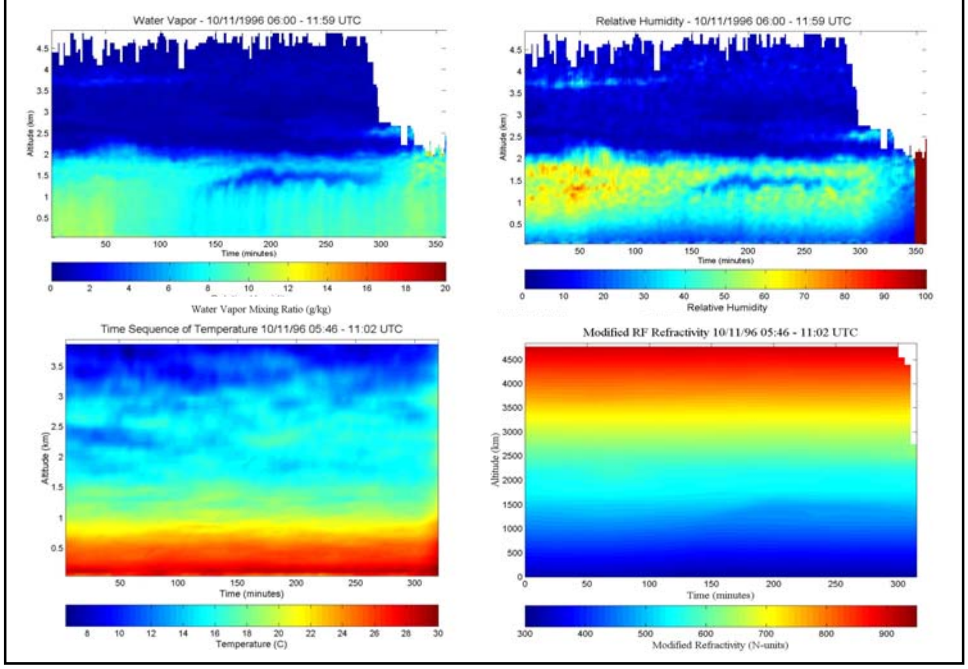
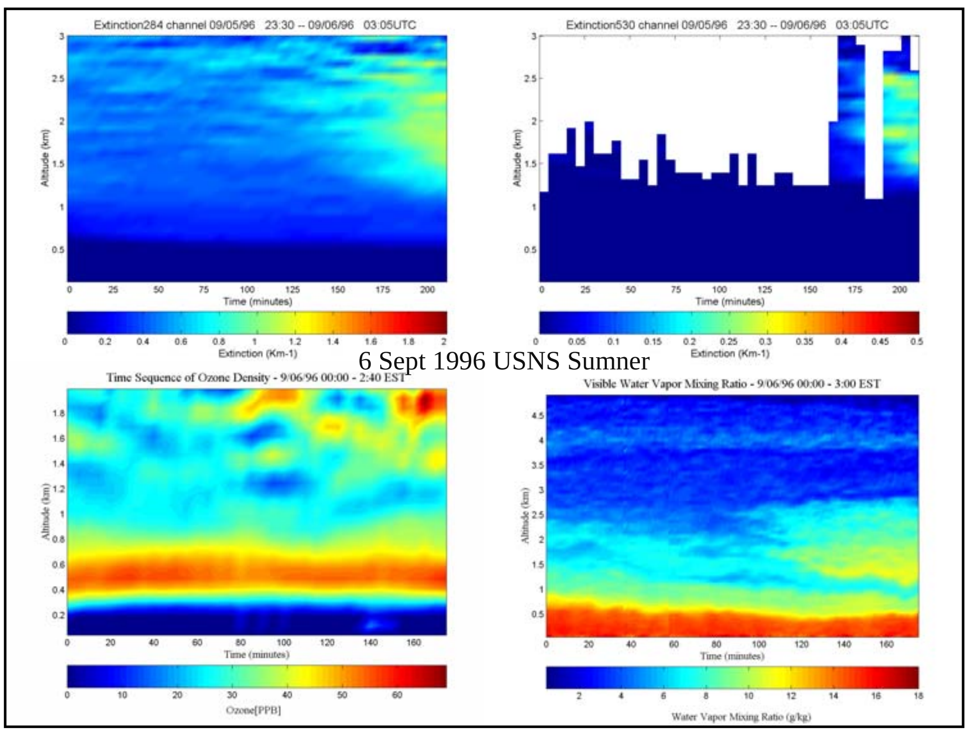
Water Vapor Variations Cause Refractivity Gradients





Water Vapor and Temperature





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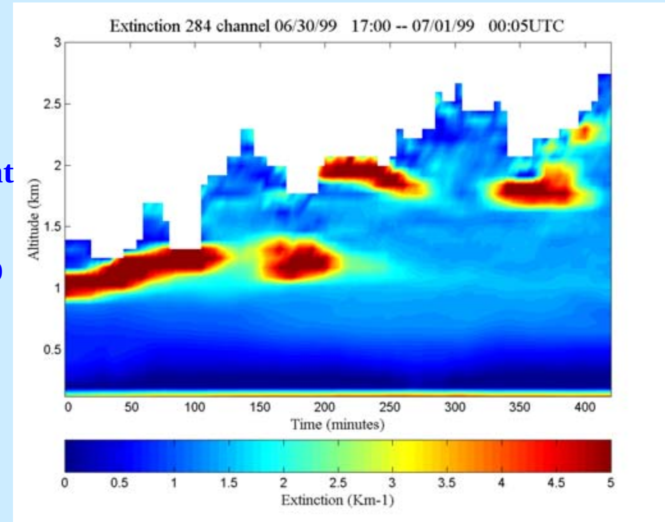
Cloud Development

Relatively dense clouds ($\alpha \sim$ 5-7km^{-1} OD ~ 1-1.5) can be measured to observe formation and growth/dissipation of clouds.



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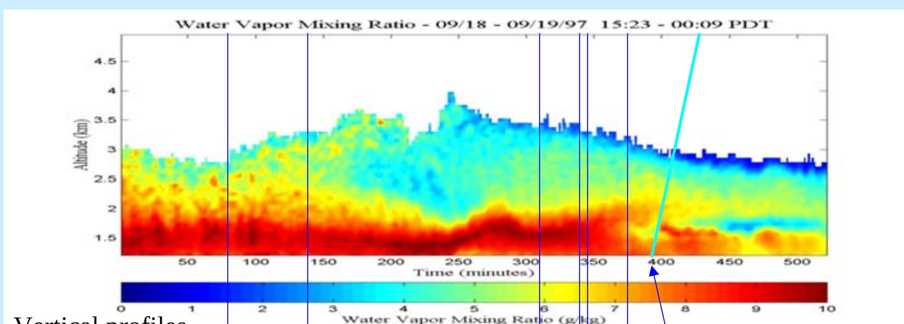
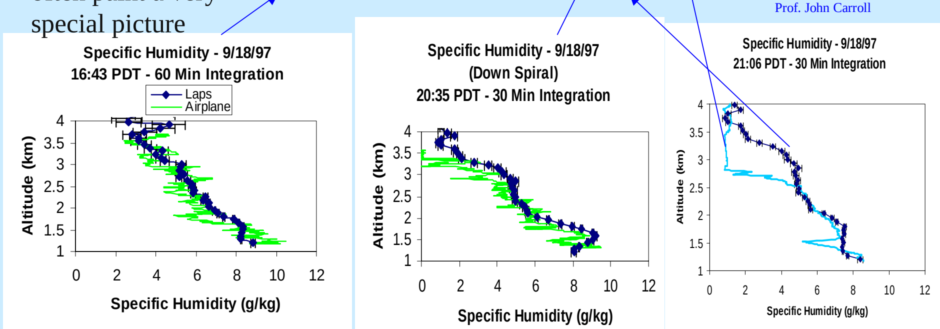


Vertical profiles often paint a very special picture

A/C Data provided by Prof. John Carroll



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LAMP & LAPS Campaigns

- LADIMAS – RV Polarstern, Tromso, Norway to Antarctica
  Oct 90-Jan 91
- VOCAR – Pt Mugu CA – 1993, 1994
- CASE – Wallops Island VA – Sept 1995
- NARSTO-Northeast – Gettysburg PA – July 1996
- USNS Sumner – Gulf of Mexico and Atlantic – Aug-Oct 1996
- SCOS97 – Hesperia CA – Aug-Sept 1997
- ARM and FIRE – Point Barrow AK – Feb-May 1998
- NARSTO-NE-OPS – Philadelphia PA – August 1998
- NARTSO-NE-OPS – Philadelphia PA – Jun-Aug 1999
- NARSTO-NE-OPS – Philadelphia PA – Jun-Jul 2001
- NEOPS-DEP-2002 – Philadelphia PA – Jun-Aug 2002

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Recent Accomplishments

- Tested new design of LAPS control electronics
- Improved analysis for temperature profiling from Raman signals
- Improved analysis for aerosol scattering results
- Examination of extended use for shipboard EO systems
- Conducted many tests of 5 days or more continuous operation

Current Activity

- Design and fabrication of improved detector
- Evaluation of technique for instrument self-calibration

ADM was prepared at PSU using machine shops on campus. The EDM should be prepared together with industry and user representatives to prepare deployable instrument.

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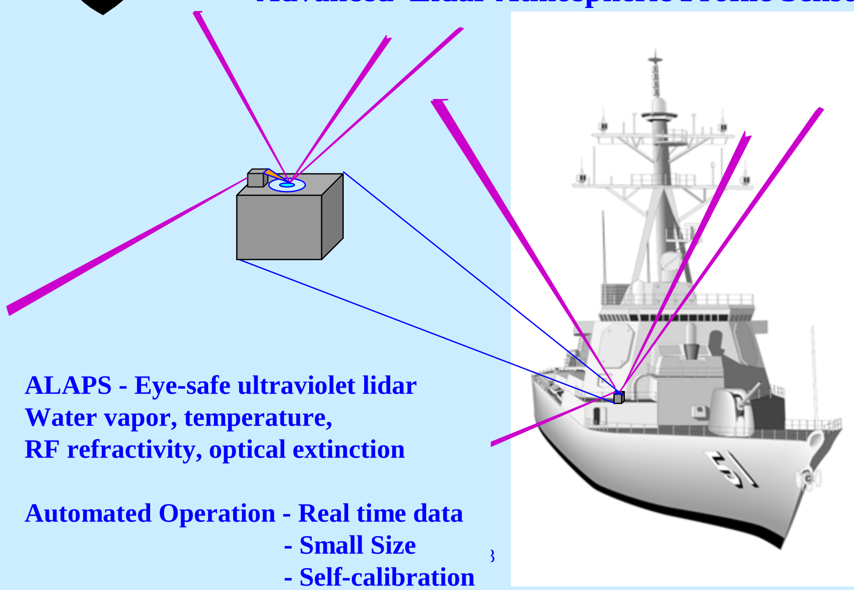
ALAPS

Advanced Lidar Atmospheric Profile Sensor



ALAPS - Eye-safe ultraviolet lidar
Water vapor, temperature,
RF refractivity, optical extinction

Automated Operation - Real time data
- Small Size
- Self-calibration

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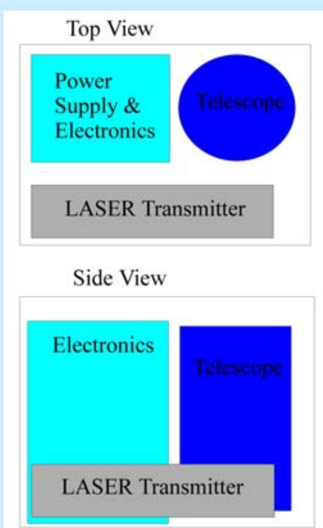
ALAPS Configuration



Major Systems

Transmitter – Nd:YAG 3rd Harmonic
- Transmit only 355 nm – 250 mj
- 10X expander

Receiver – 16 inch Cassigrain telescope

Detector – narrow band, self calibration
- 355 nm – backscatter ceilometer, range
- 351 and 353 nm – temperature
- 407 and 387 nm – water vapor
- 353, 387 nm – optical extinction

Data System – GHz photon counting, range resolution to 20 ns (3 m)

Environment – Heat and cool from ship system

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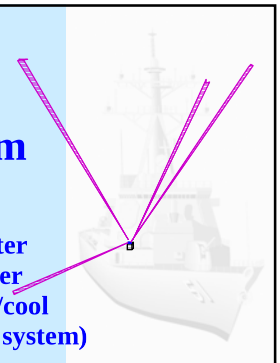
ALAPS Lidar System



- **1 GHz photon count electronics - resolution to 3 meter**
- **Eye-safe - ultraviolet wavelength with beam expander**
- **Power - 30% of LAPS, reduced laser EMI and heat/cool**
- **Size – 1 meter cube (no radar, smaller environment system)**
- **Automatic operation and self calibration**
- **EO propagation, multi-λ optical extinction, aerosol size**

Options –

- **Measure in a 10 km cube, forward/side spatial data**
- **Evaporation duct (20 - 50 cm height layers)**
- **Target range**
- **Direct detection wind velocity**

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ALAPS Performance

Parameters Measured Directly

Water Vapor – Ratio of 407 nm (H_2O) to 387 nm (N_2)
Temperature – Ratio of 352 nm to 354 nm signals
Optical Extinction – Slopes from 354 nm and 387 nm signals
Cloud height/Dust/Aerosol – Thickness and range

Space/Time Resolution

Profile surface to 5 km day/night (10 km at night)
Vertical resolution selectable 7 to 75 meters
Time resolution selectable 10 sec to 10 min

Parameters Calculated Directly

RF Index of Refraction Refraction
Visibility

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ALAPS Characteristics

- Size – 1x1x1 meter (40 inch cube) with power and data interface
- Eye-safe ultraviolet (transmit only 355 nm) – covert
- Vertical resolution selectable 3 to 75 meters (20 to 500 ns bins)
- Photon counting to 1 GHz
- Power requirement ~ 2 kW
- 4-month planned maintenance (replace items, cleaning)
  [10^8 shots at 10 Hz continuous operation]
- Weather sealed
- Automated operation - real-time continuous data product
- Self calibration mode
- Environmental control - either chilled water or forced air
- Options include evaporative duct measurement, target ranging, hemisphere profiling

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Lidar for Navy Future

LAMP – Breadboard demonstration of technology - 1992

LAPS – Operational Prototype (ADM) – 1996

Too large – Needs to be covert and eye-safe – Improve resolution

ALAPS – Engineering Model (EDM) – 200?

One-third size of LAPS
Uses eye-safe ultraviolet wavelength
Higher speed electronics for improved resolution
Fully automatic and self-calibrating
Replaces most needs for sonde systems with improved data
Real time continuous data product in scientific/engineering units

E&M Propagation – Radar Tracking, Detection Gaps, Communications

Lidar Water Vapor & Temperature RF Refractivity

EO Propagation – Visibility, Surveillance, Aircraft OPS

Lidar Optical Extinction Visual Range, Changing Conditions

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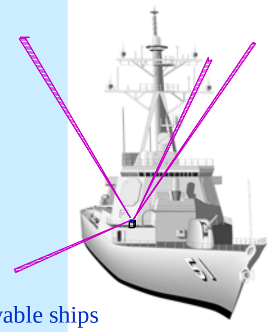
Summary



ALAPS Raman Lidar (EDM)

- 3-D picture of EM/EO environment
- vertical profiles of meteorological properties
- automated operation with real time data
- eye-safe and covert
- self-calibrating optical system and fast electronics
- small and self-contained, choice for future low observable ships

Design work and testing on LAPS since USNS Sumner tests

- upgrade to faster electronics - embedded microprocessor
- design to smaller size (~1/3) and self-contained
- design to eye-safe, self-calibration
- investigations of optical extinction, air pollution
- more than 50 papers, 20 MS thesis and PhD dissertations using LAPS for testing, analysis, design, studies of atmospheric properties

Raman Lidar is ready to be used by USN to augment balloon sondes with improved data product with high temporal and spatial resolution.

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