

A Multi-Wavelength Mini Llidar for Measurements of Marine Boundary Layer Aerosol and Water Vapor Fields

Shiv K. Sharma

Hawaii Institute of Geophysics & Planetology
2525 Correa Rd., Honolulu HI 96822

phone: (808) 956-8476 fax: (808) 956-3188 email: sksharma@soest.hawaii.edu

Barry R. Lienert

Hawaii Institute of Geophysics & Planetology

phone: (808) 956-7815 fax: (808) 956-3188 email: lienert@soest.hawaii.edu

John N. Porter

Hawaii Institute of Geophysics & Planetology

phone: (808) 956-6483 fax: (808) 956-3188 email: jporter@soest.hawaii.edu

Antony D. Clarke

Dept. Oceanography, University of Hawaii at Manoa
1000 Pope Rd., Honolulu HI 96822

phone: (808) 956-6215 fax: (808) 956-7112 email: tclarke@soest.hawaii.edu

Award #: N00014-96-1-0317

<http://www.soest.hawaii.edu/lidar>

LONG-TERM GOALS

Our long-term goal is to improve our understanding of dynamics of marine aerosols and water vapor fields in the coastal marine boundary layer using a scanning lidar and meteorological parameters.

OBJECTIVES

Our scientific objectives are to collect well-calibrated lidar data sets that can be used to improve and develop models of the aerosol optical properties in the coastal marine boundary layer (MBL). Various aerosol models exist (e.g., Fitzgerald, 1989), but few are appropriate for coastal regions. We are concentrating on the vertical aerosol structure in the 15-m of the atmosphere directly above the ocean surface.

APPROACH

We are using a scanning multi-wavelength lidar to measure the 4-D (space and time) aerosol optical fields in order to characterize the aerosol properties in a marine setting (Sharma et al., 1999; Lienert et al., 1999). These measurements have been carried out at Bellows Air Force (AFS) next to the University of Hawaii's Meteorological Tower (21° 21.848' N, 157° 42.584' W). We are now able to study the spatial structures of the aerosol scattering fields out to distances of up to 10 km from the shore. The scanning lidar data enables us to place the aerosol characteristics being observed by the shore-based instruments in the context of much larger scale variability in the aerosol scattering fields.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2001		2. REPORT TYPE		3. DATES COVERED 00-00-2001 to 00-00-2001	
4. TITLE AND SUBTITLE A Multi-Wavelength Mini Llidar for Measurements of Marine Boundary Layer Aerosol and Water Vapor Fields				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Hawaii Institute of Geophysics & Planetology,,2525 Correa Rd.,,Honolulu,,HI, 96822				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Our long-term goal is to improve our understanding of dynamics of marine aerosols and water vapor fields in the coastal marine boundary layer using a scanning lidar and meteorological parameters.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 8	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Dr. Shiv Sharma is the project director involved in all aspects of these efforts. Dr. Barry Lienert has developed the software and supervises the data collection. Dr. John Porter is involved in calibration and modeling of the data.

WORK COMPLETED

1. We have incorporated three custom-built logarithmic amplifiers (Lienert et al., 2001) into the detector circuitry at all three wavelengths improving both the effective range as well as the calibration accuracy.
2. We have continued to monitor the aerosol fields at Bellows beach on a regular basis, including one month of daily measurements.
3. We have analyzed the statistical properties of data collected during the SEAS experiment.

RESULTS

For a rapid scanning lidar, it is necessary to digitize the detector outputs in analog, rather than photon counting mode, with little or no averaging. This constraint limits the lidar's effective range, due to the rapid fall-off in the signal and the limited precision of the analog-to-digital convertors (ADC's). The horizontal calibration technique (Porter et al., 2000) also requires long range measurements. In order to

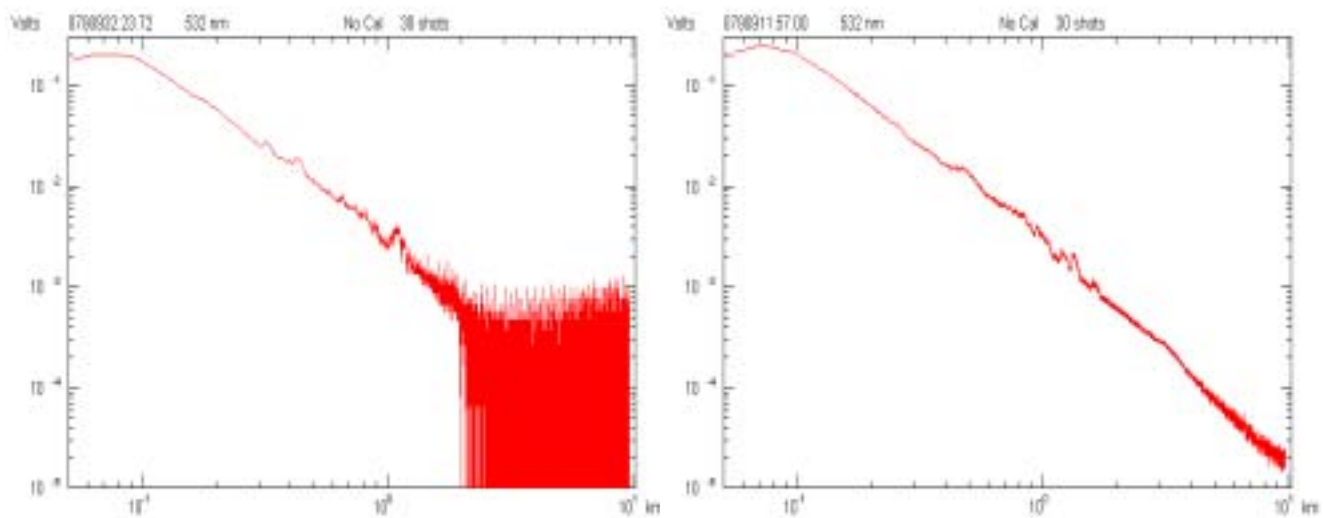


Figure 1: Comparison of 532 nm data digitized without (left) and with (right) the new log-amp.

address this problem, we installed custom-built logarithmic amplifiers (Lienert et al., 2001) on all three channels (1064, 532 and 1064 nm). Figure 1 shows an example of the dramatic reduction in the digitization error of the 532 nm channel. This improvement has allowed us to monitor changes that occur in the low-level marine aerosols generated by breaking waves, wind, etc., as they approach the shore from the open ocean.

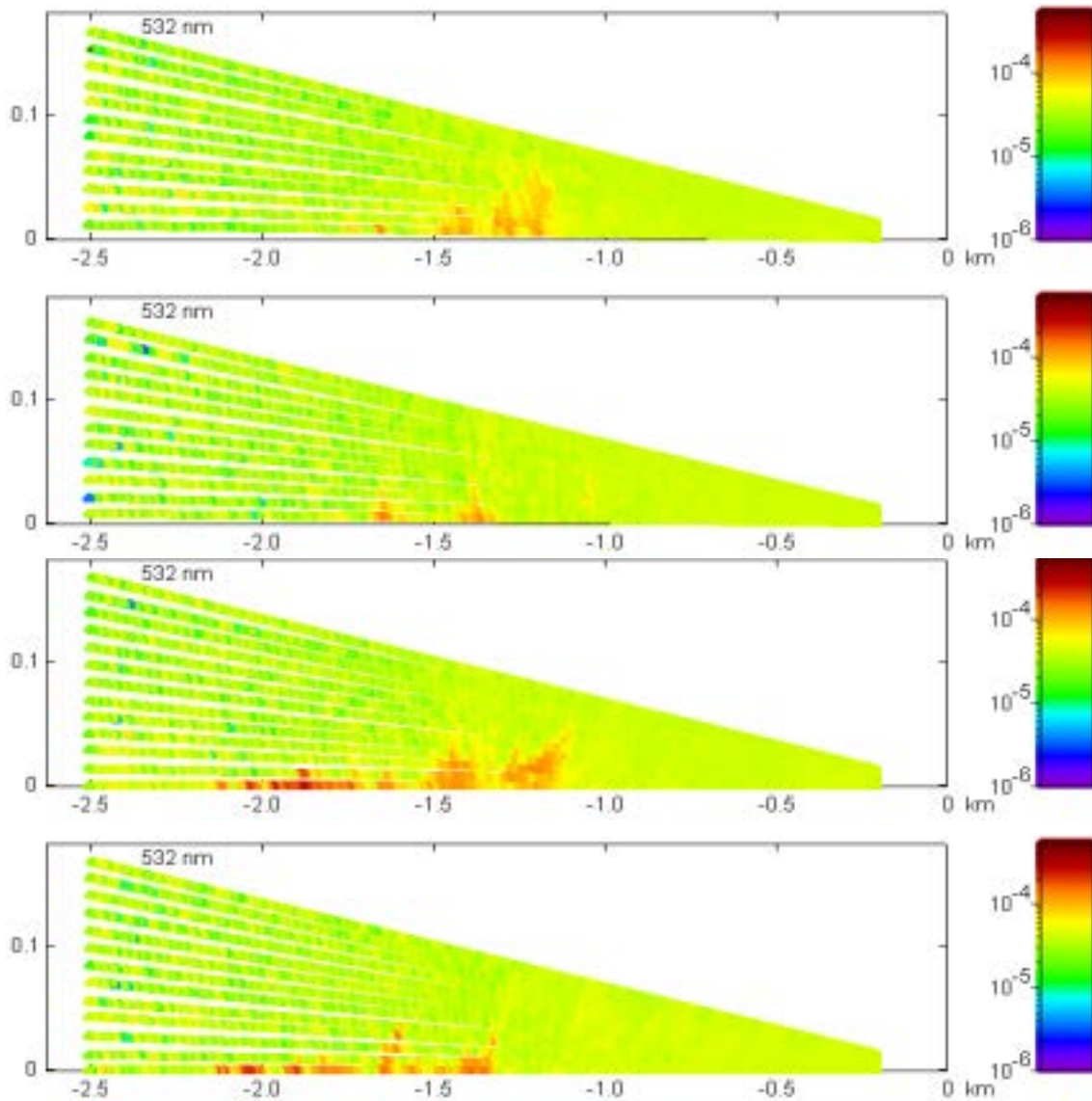


Figure 2: Vertical lidar scan of aerosol extinction taken 48°E off Bellows Beach on 3/27/01 at 09:40 HST. The wind direction is 78°E and the wind speed 7.7 m/s.

Fig 2. shows a 2-D vertical scan collected on 3/28/01 using the new log-amp. The mixed layer thickness (orange), as well as the boundary layer depth (green/yellow) increases from over the open ocean (left side) as the trade wind flow approaches the lidar site on the beach. This build up in thickness is due to the blocking effect of the island and the Ko'olau mountains 5 km downwind of the lidar site. This island blocking effect is not always present for trade wind conditions suggesting variability in the low level stability of the trade winds.

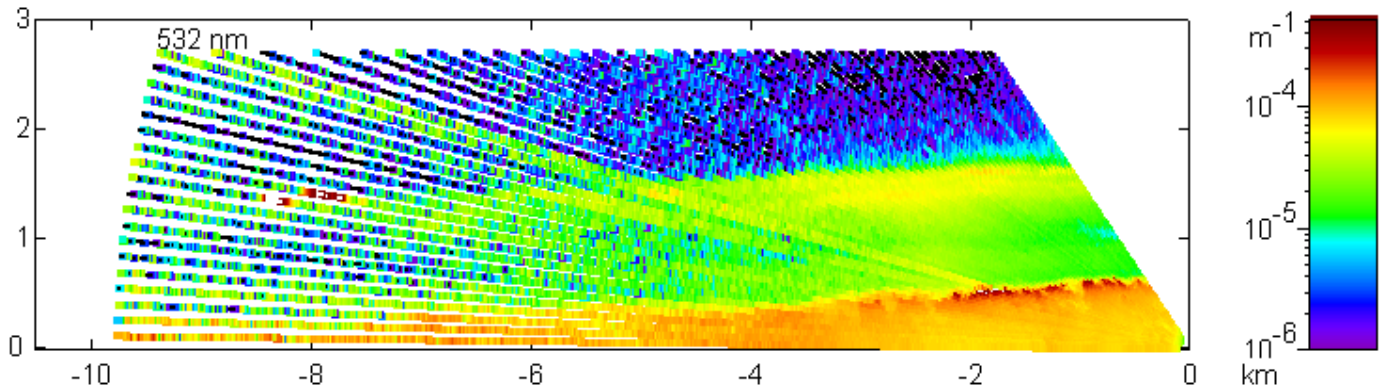


Figure 3. Sequential vertical lidar scans on 4/24/00 22:02 HST at 13 second intervals, showing derived aerosol scattering coefficients in m^{-1} . The Y-axis is the height from average sea surface (in kilometers). The larger values (red regions) correspond to salt spray coming off the waves breaking on a reef. The meteorological parameters during these scans were wind direction $48\text{--}52^\circ\text{E}$, wind speed= $8.1\text{--}8.3$ m/s, RH= $82\text{--}84\%$ and temperature= 23.4°C

Figure 3 shows a set of vertical lidar scans collected during the SEAS experiment under normal trade wind conditions. Plumes of salt spray rise to heights of about 50 m above a reef about 1.2 km from the shoreline. Figure 4 shows a time sequence of 1064 nm vertical scans taken under light wind conditions (~ 2 m/s) on 3/20/01. Large salt plumes more than 600 m high have developed over the same reef. The fact that these plumes persisted over an hour and were anchored over the reef means that they were indeed salt plumes and not from some other source. In this particular case the boundary layer (not shown) extended up to ~ 1400 m in height. Interestingly, the mixed layer was not seen, a situation that is uncommon near Hawaii. The more common case is for the mixed layer to be 300–700 m thick as it appears in Figure 2. The much greater height of the plume in Fig. 4 suggests that it is being dispersed less rapidly at the lower wind speed, allowing it to rise to greater heights. Earlier data collected at Bellows (Sharma et al., 2001) showed reef plumes rising to ~ 120 m/s in winds of ~ 5 m/s, indicating a consistent trend of increasing plume height with decreasing wind speed.

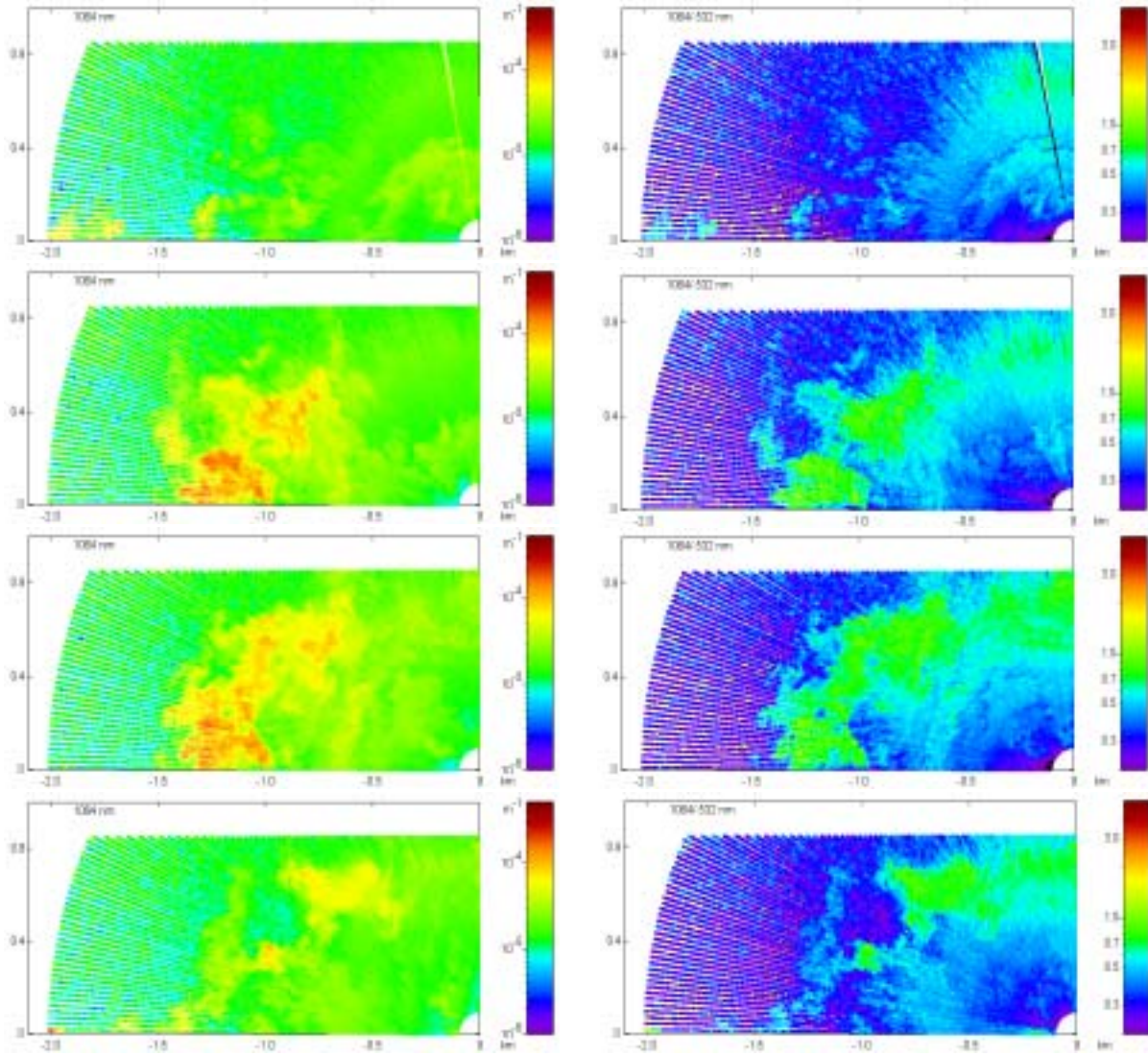


Figure 4: Time sequence (top to bottom) of the plume taken at 1064 nm (left side) and 100 second intervals on 3/20/01 08:21 HST. The wind direction is 31°E and the wind speed 1.9 m/s. Also shown (right side) is the ratio of the 1064 to 532 nm extinction.

The 1064 to 532 nm ratios in Figure 4 show marked wavelength dependence in the vicinity of the plume. The higher ratio values in the plume and its rapid appearance in <100 seconds suggest that the aerosols in the plume are larger in size than those in the surrounding air. The light wind conditions present for Figure 3 were conducive to sea surface temperature warming with enhanced thermal activity which may be contributing to lifting of the plume.

Deriving aerosol size information from multi-wavelength lidar data such as that in Fig. 5 is an ill posed problem due to non-uniqueness of the solution (Lienert et al, 2001). Using aerosol models (Porter and Clarke, 1997) at a range of relative humidities, we have developed a lookup table allowing us to derive the aerosol phase function and aerosol type (accumulation versus coarse mode) from the multi-wavelength lidar data. In order to apply this approach we find that the lidar calibration must be known individually for each wavelength, which is not a trivial problem. Secondly, the aerosol should be

dominated by either the accumulation or the coarse mode. Cases where each mode contributes similar amounts of scattering would create difficulties. We are currently working on this approach and expect to have it implemented in the near future.

We have also made good progress on analyzing the large data set we collected during the SEAS experiment. We have calculated the mean extinction values within rectangular boxes taken from vertical scans at 2-minute intervals for over 80 hours of data to yield time series which can be correlated with other SEAS data. We found that the variability in this data is better represented by a lognormal, rather than a normal distribution. This has important implications for estimating the means and the probabilities of occurrence of extinction values within a given range.

TRANSITIONS

We are making our efforts known through publications and meetings. We have also supplied our lidar data and software to Dr Tony Clarke (UH), Dr Tad Anderson and Dr Kusiel Shifrin (Univ. Wash.). Our software is being used by Prof. John Madey (UH Physics) for use in a DOD-funded lidar experiment.

RELATED PROJECTS

Our lidar efforts are closely related to the work being carried out by Dr. Clarke. We have supplied Dr. Clarke with a time-series of lidar data collected during SEAS that he has successfully correlated with his data. We have also supplied lidar data to Dr Kuseil Shifrin, who is applying his own analysis techniques to it and Dr. Tad Anderson, who is using it to test lidar ratios that he measured during the SEAS experiment.

REFERENCES

- Fitzgerald, J.W., 1989, Model of the aerosol extinction profile in a well-mixed marine boundary layer, *Applied Optics*, **28**, 3534-3538.
- Lienert, B., J. Porter, S. Sharma, N. Ahlquist and D. Harris. A 50 MHz Logarithmic Amplifier for use in Lidar Measurements, *J. Atmos. Ocean. Tech.*, 2001 (in press).
- Lienert, B. R., J. N. Porter, and S. K. Sharma, Repetitive Genetic Inversion of Optical Extinction Data , *Applied Optics*, **40**, 3417-3427, 2001.
- Porter, J., Clarke, A., An Aerosol Size Distribution Model Based on In-Situ Measurements. *J. Geophy. Res.*, **102**, 6035-6045, 1997.
- Porter, J.N., Lienert, B., S.K. Sharma. Using the Horizontal and Slant Lidar Calibration Methods To Obtain Aerosol Scattering Coefficients From A Coastal Lidar In Hawaii, *J. Atmos. Oceanic Technology*, **17**, 1445-1454, 2000.
- Sharma, S. K., B. R. Lienert and J. N. Porter. Scanning Lidar Measurements of Marine Aerosol Fields At A Coastal Lidar Site in Hawaii. *Proceedings of the SPIE Lidar Remote Sensing for Industry and Environment Monitoring*, Sendai, Japan, SPIE vol. **1453**, 159-166, 2001.

PUBLICATIONS

- Lienert, B., J. Porter, S. Sharma, N. Ahlquist and D. Harris. A 50 MHz Logarithmic Amplifier for use in Lidar Measurements, *J. Atmos. Ocean. Tech.*, 2001 (in press).
- Lienert, B. R., J. N. Porter, and S. K. Sharma, Repetitive Genetic Inversion of Optical Extinction Data , *Applied Optics*, **40**, 3417-3427, 2001.
- Lienert, B. R., J.N. Porter, and S.K. Sharma: Real Time Analysis and Display of Scanning Lidar Scattering Data, *Marine Geodesy*, **22**, 259-265, 1999.
- Porter, J.N., Lienert, B., S.K. Sharma. Using the Horizontal and Slant Lidar Calibration Methods To Obtain Aerosol Scattering Coefficients From A Coastal Lidar In Hawaii, *J. Atmos. Oceanic Technology*, **17**, 1445-1454, 2000.