PENNSTATE

Applied Research Laboratory

ALAPS: Advanced Lidar Atmospheric Profile Sensor
Lidar Applications for Atmospheric Characterization

by

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for

Lockheed Martin GES
Moorestown, NJ
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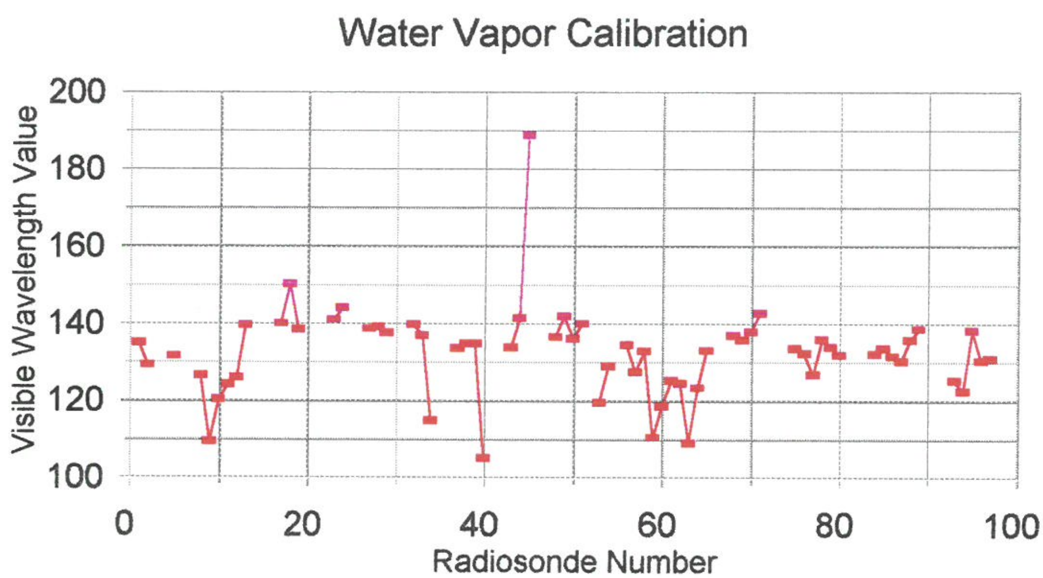
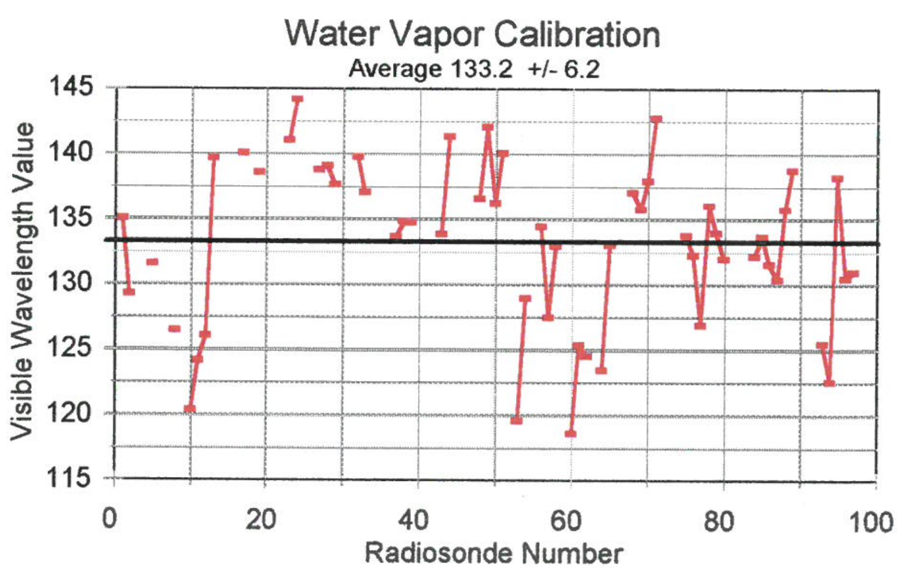
Balloon release profiles.

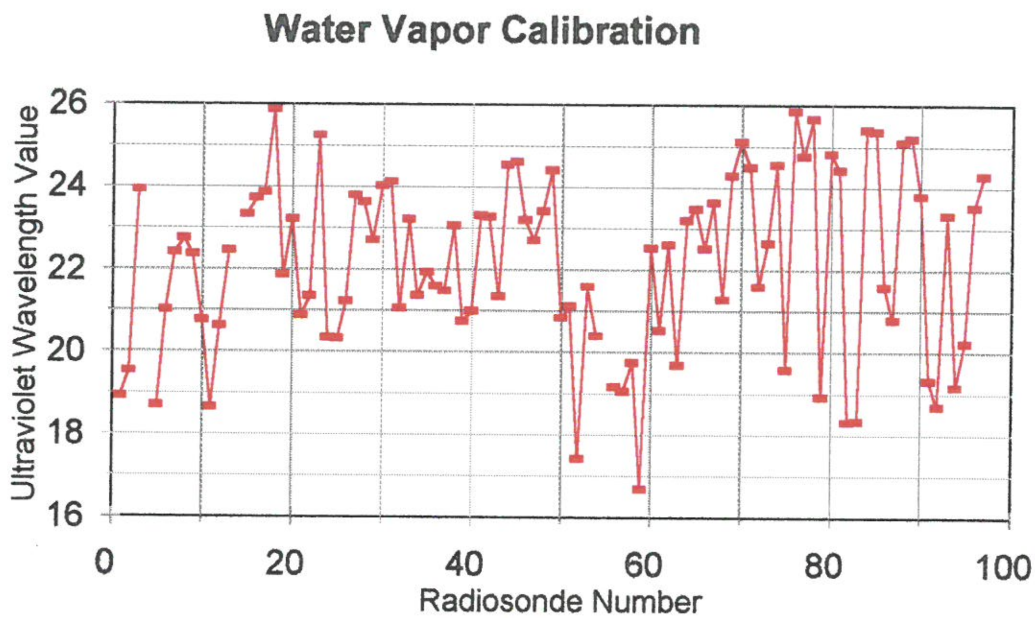
USNS Sumner Rawinsonde Balloon							
ID	File	Date	Time-GMT	Eval	D/N/T	Visible	Ultraviolet
1	96090503	Sept 5	0341	S	N	135.1	18.93
2	96090510	5	1012	S	T	129.3	19.54
3	96090513	5	1312	S	D		23.93
4	96090521	5	2100	F	D		
5	96090602	6	0133	S	N	131.6	18.7**
6	96090609	6	0902	S	N		21.02
7	96090622	6	2301	S	T		22.42
8	96090702	7	0139	S	N	126.5	22.76
9	96090710	7	1054	S	D	109.5**	22.37
10	96090800	8	0021	S	N	120.4	20.77
11	96090823	8	2335	S	T	124.2	18.66**
12	96090904	9	0401	S	N	126.1	20.63
13	96090907	9	0713	S	N	139.7	22.46
14	96090911	9	1138	S	D		
15	96090919	9	1925	S	D		23.34
16	96090923	9	2248	S	T		23.74
17	96091003	10	0340	F??	N	140.1	23.87
18	96091005	10	0540	S	N	150.3**	25.88
19	96091010	10	1031	S	T	138.6	21.88
20	96091012	10	1242	S	D		23.23
21	96091019	10	1923	S	D		20.90
22	96091023	10	2325	S	T		21.37
23	96091103	11	0307	S	N	141.1	25.25
24	96091109	11	0909	F	N	144.2	20.36
25	96091112	11	1227	S	D		20.33
26	96091123	11	2316	S	T		21.23
27	96091201	12	0110	S	N	138.8	23.81
28	96091203	12	0312	S	N	139.1	23.64
29	96091209	12	0933	S	T	137.7	22.72
30	96091220	12	2007	S	D		24.03
31	96091223	12	2306	S	T		24.13
32	96091602	16	0230	S	N	139.8	21.07
33	96091609	16	0807	S	N	137.1	23.22
34	96091611	16	1104	F??	D	115.0**	21.38
35	96091620	16	2008	S	D		21.94
36	96091623	16	2302	S	T		21.60
37	96091702	17	0206	F??	N	133.7	21.49
38	96091705	17	0506	S	N	134.9	23.07
39	96091708	17	0807	S	N	134.8	20.75
40	96091711	17	1109	F??	D	105.2**	21.00
41	96091714	17	1357	S	D		23.31
42	96091717	17	1659	F??	D		23.28
43	96091800	18	0012	F??	N	133.9	21.36
44	96091810	18	1035	S	D	141.4	24.55
45	96091811	18	1122	S	D	188.9**	24.62

46	96091812	18	1213	S	D		23.21
47	96091813	18	1256	F??	D		22.72
48	96091900	19	0029	S	N	136.6	23.42
49	96091910	19	1001	F??	T	142.1	24.42
50	96092002	20	0201	S	N	136.3	20.84
51	96092010	20	1009	S	T	140.1	21.13
52	96092820	28	1952	S	D		17.43**
53	96092900	29	0040	S	N	119.6	21.60
54	96092902	29	0206	S	N	129.0	20.41
55	96092910	29	1111	F	D		
56	96092923	29	2305	S	T	134.5	19.17
57	96093001	30	0102	S	N	127.5	19.06
58	96093002	30	0208	S	N	133.0	19.76
59	96093010	30	0955	S	T	110.6**	16.71**
60	96100101	Oct 1	0115	S	N	118.6	22.54
61	96100106	1	0556	S	N	125.4	20.54
62	96100110	1	0958	S	T	124.6	22.62
63	96100123	1	2325	S	T	109.1**	19.70**
64	96100201	2	0100	S	N	123.5	23.21
65	96100210	2	1012	S	T	133.1	23.49
66	96100212	2	1201	S	D		22.52
67	96100222	2	2154	S	D		23.64
68	96100300	3	0022	S	N	137.1	21.29
69	96100302	3	0159	S	N	135.8	24.30
70	96100400	3	2352	S	N	138.0	25.12
71	96100410	4	1003	S	T	142.8	24.50
72	96100414	4	1400	S	D		21.60
73	96100420	4	2005	S	D		22.66
74	96100712	7	1227	S	D		24.56
75	96100722	7	2312	S	T	133.8	19.59
76	96100801	8	0145	S	N	132.3	25.87
77	96100810	8	0957	S	T	126.9	24.77
78	96100901	9	0131	S	N	136.1	25.68
79	96100904	9	0358	S	N	134.0	18.94
80	96100908	9	0755	S	N	132.0	24.83
81	96100912	9	1159	S	D		24.44
82	96100916	9	1600	S	D		18.33
83	96100920	9	1956	S	D		18.35
84	96101000	10	2357	S	N	132.2	25.41
85	96101004	10	0446	S	N	133.7	25.37
86	96101008	10	0800	S	N	131.6	21.59
87	96101100	10	2356	S	N	130.4	20.81
88	96101104	11	0446(0358)	S	N	135.8	25.10
89	96101108	11	0800	S	N	138.8	25.20
90	96101112	11	1201	S	D		23.81
91	96101116	11	1559	S	D		19.33
92	96101120	11	1958	S	D		18.71
93	96101200	11	2357	S	N	125.5	23.33

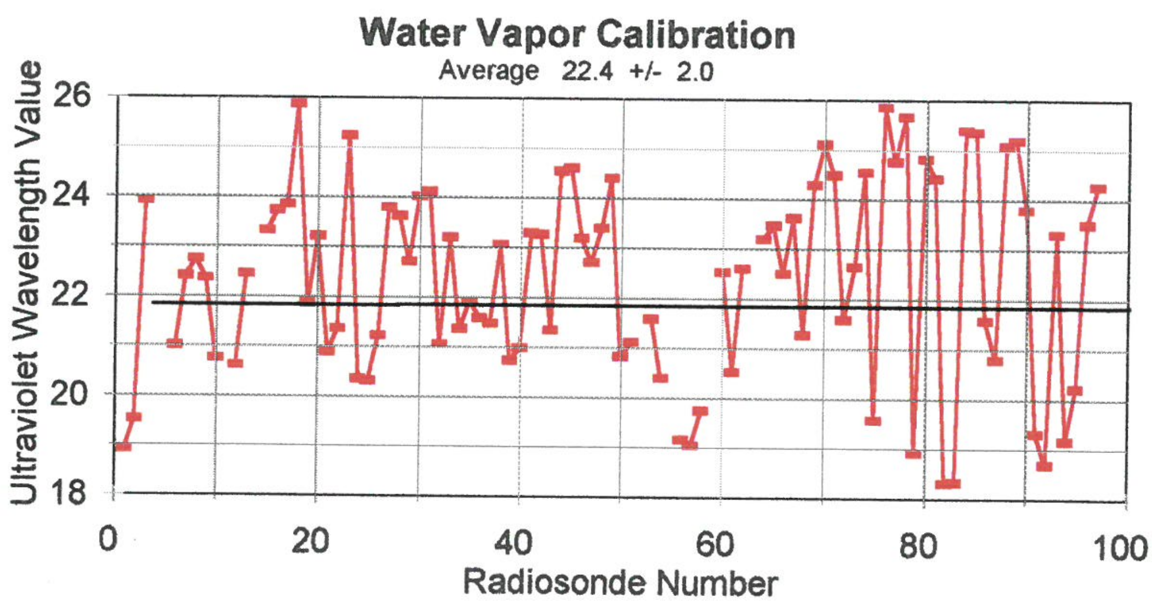
94	96101204	12	0404	S	N	122.6	19.18
95	96101208	12	0801	S	N	138.3	20.24
96	96101310	13	1032	S	T	130.5	23.53
97	96101402	14	0207	S	N	131.0	24.29
	AVERAGE		Using all	VIS	64	132.5	22.16
	SD(+/-)		points	UV	94	11.4	2.15
	AVERAGE		Using selected	VIS	57	133.2	22.38
	SD(+/-)		points	UV	89	6.1	1.97







Water Vapor Calibration
Ultraviolet Wavelength Value
26
24
22
20
18
16
0
20
40
60
80
100
Radiosonde Number



Water Vapor Calibration
Average 22.4 +/- 2.0
Ultraviolet Wavelength Value
26
24
22
20
18
0
20
40
60
80
100
Radiosonde Number

FUTURE ALAPS DEVELOPMENTS

The lessons learned from the LAPS development and the requirements for a smaller system have been addressed in a proposed design for an advanced system that will use an eye-safe ultraviolet diode pumped laser transmitter, improved detector, high speed electronics. The features include:

- Diode pumped laser using quasi-CW bar diodes
- 1 GHz electronics - selectable resolution of 3, 7, 15 meter
- Eye-safe transmitted beam at ultraviolet wavelength with 1 kHz repetition rate
- Power required about 20% of LAPS, reduced EMI and environment control
- Size reduction to 20% of LAPS, no radar, smaller environment system
- Automatic operation and self calibration
- Measures on any radial in a 5 km cube to provide spatial information
- Evaporation duct by pointing slightly below horizontal (20 cm height resolution)
- EO propagation, multi-λ optical extinction, aerosol size
- Direct detection technique for wind velocity

Major advances have been made with the development of diode pumped Nd:YAG and Nd:YLF during the past few years. Even though a penalty in power efficiency comes with using the double, triple and quadruple wavelengths, the advantages in scattering cross-section ($\sim 1/\lambda^4$) and quantum efficiency of detectors still made this an attractive approach. The laser beam can be made eye safe by lowering the peak power and moving to the ultraviolet spectral region where the eye safe radiation flux is much higher. By making the transmitted beam eye safe, the instrument can be used to measure the evaporative ducts by pointing at the sea at a distance of several hundred meters to the side of the ship (thus increasing the vertical resolution from the 3 to 15 meters attained with the new electronics to fraction of one meter). The instrument can be pointed in any direction to determine nearby atmospheric properties. The ALAPS instrument will be covert, that is no visible beam will be observed. The unit will be contained completely in a cube of approximately 1 meter and it will have simple interface connections for power and for data transfer of the final data product to a remote computer. The reduced EMI conditions which can be achieved using a diode pumped laser will allow the co-location of the laser and the sensitive detectors in the same instrument package. In preparation for the project of fabricating the actual ALAPS instrument, several tasks are outlined in the following section which provide significant steps toward the actual task of developing the ALAPS prototype instrument.

Outline of Tasks Leading to Task of ALAPS Fabrication

1. A single channel version of the new high speed detector electronics has been bench tested and the new electronics package appears to meet all of our expectations and requirements for performance. This new electronics will permit selectable range resolution bins of 3 to 75 meters, present commercial electronics limits the photon counting resolution to 75 meters. The higher speed electronics, 1 GHz photon count rate compared to the present commercial electronics of 100 MHz, leads to a ten fold increase in the dynamic range of the instrument. At present it is necessary to minimize saturation effects by reducing the sensitivity of the instrument on several channels, thereby limiting the signals to the range of linear response of the detector electronics. The eight channel version of this electronics will be prepared and tested using the LAPS instrument.
Time to complete: 7 months
Cost to complete: $110K (4 m-mo + $50K sub-contract)

2. A new detector design can provide major improvements in the lidar measurement and permit a self-calibration of the instrument. The present detector design uses an optical path which is long and leads to vignetting of the optical signal, causing an error in the low altitude signals for the temperature measuring channels. The optical path length can be reduced to less than one-third of the present design, thus eliminating the vignetting problem. The detector will use an optical/mechanical arrangement to permit a reliable self calibration mode for the instrument that can be performed automatically at the beginning of each data set. By completing the mechanical and electrical interface of the detector with the LAPS lidar and carrying out a performance test, we will be able to evaluate this design and prepare the final design for the ALAPS detector.
Time to complete: 5 months (in parallel with item #1)
Cost to complete: $80K (4 m-mo + $25K optical components)

3. Measurements of the daytime performance of the LAMP/LAPS lidars at 355 nm will establish filter requirements for the background signal values and investigate the useful range of measurements at this wavelength. Calculations provide estimates of expected performance in this region of the spectrum, however these estimates must be evaluated using actual sky background.
Time to complete: 3 months
Cost to complete: $50K (3 m-mo + $5K components)

4. Breadboard level development and testing of the direct detection wind measuring lidar can be carried out with modifications to the LAMP lidar instrument. These tests would be a necessary step toward the goal of determining the wind velocity with the same instrument so that the complete set of atmospheric dynamics, structure and important species profiles can obtained simultaneously. The wind will be measured using a quad-etalon of unique design. The etalon will be frequency stabilized and quadrature maintained by the seeding laser for the pulse output. A simulation of expected performance indicates that the wind velocity will be measured to better than ±1 m/s from the surface to 5 km. The task will include demonstration test of the wind measuring performance.
Time to complete: 12 months
Cost to complete: $200K (10 m-mo + $60K optical and mechanical components)

5. (OPTIONAL - Confidence building test for diode laser - for consideration if the $1M funds for the diode laser development are delayed) Initial testing of the laser and evaluation of several aspects of the high repetition rate diode laser transmitter can be tested using a smaller capability commercially available laser which will not meet the final requirements for the ALAPS instrument. The 1 kHz diode pumped laser of Lambda Physik could be tested as a breadboard instrument in the LAMP lidar to test the timing and other circuits as well as test the new detector optical and electrical sub-systems. The Yb:YAG, 3rd harmonic at 344 nm or the 4th harmonic at 256 nm, will also be considered for the final laser.
Time to complete: 6 months
Cost to complete: $240K (4 m-mo + $160k)

6. Special effort to design improved narrow band filters for the UV will be undertaken with the filter manufactures. Our special needs for 10^{12} rejection of the fundamental wavelength in the water vapor and temperature Raman filters will be a challenge at the UV wavelengths. The more stable metal oxides will be tested to meet the requirement at UV wavelengths and the stability of solid etalon devices will be tested.
Time to complete: 2 months
Cost to complete: $28K (0.5 m-mo + $20K)