C-1.2.2 Observational Study of Marine Mixed Layer by Ships

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Abstract:

Observations of atmospheric boundary layers (ABL) have been conducted around Japan using a ship-board Mie lidar and radiosondes.
Observations near Minamitorishima and Nansei-Shoto showed that the stabilities were almost neutral in most cases and the depths of the marine atmospheric boundary layer were 0.6-1.5km and sometimes stable multiple layers were formed. And in the continental cold air outflows over a warmer current at Oki islads, thick cloud topped ABL with convective plumes were observed.

1 Introduction

Marine atmospheric boundary layer plays an important role in long range transport of pollutants over the sea. In order to improve methods for estimating from local routine measurements layer parameters over the sea that are relevant for air pollution modeling a better understanding of the structure of this layer still needed. Using aerosols as tracers of atmospheric motion lidar enables us to infer both spacial and temporal information about ABL especially for over sea measurements where in situ methods will not work or are uneconomical. Case studies over the sea around Japan have been conducted in Pacific Ocean, Nansei-shoto and Oki islands using a lidar and radiosondes.

2 Observation

Ship-board Mie lidar consists of YAG laser associated with a 30 cm diameter Cassegrain type telescope and a scanning mirror.(Table 1) The lidar emits 532nm laser pulses at 10 Hz with a maximum pulse energy of 750mJ/Pulse. The ou tput of the photomultiplier is digitized with transient recorder on 12 bits and a range resolution of 7.5m. Signal to noise ratio has been improved by the gate operation and the background subtraction that measures the atmospheric radiance about 5msec after each shot. Rolling and pitching motions of the ship were recorded using phase-detecting GPS system. The radiosounding of temperature humidity and wind was obtained simultaneously at the lidar measurement site.

3 Results and Discussion

3.1 Depth of ABL

ABL has been extensively studied.[2,3,4] The neutral atmospheric boundary layer depth h is given by

$$h = cu_*/|f|$$

where u_* is the friction velocity and f is Coriolis parameter. The value of c depends on the exact definition of h. In our experiments h defined from the steep gradient above the surface layer is compared with that from the temperature inversion. In this study the stability is classified by Monin Obukhov's scale length (L_v) for ABL. The mean depth of ABL is derived from its probability distribution function of the top of ABL.[3,5] Lidar measurements were conducted Minamitorishima in Pacific Ocean and Nansei-shoto.(Table 2 and Table 3). The observed depths of ABL were 0.4 -1.5km and the stabilities were almost neutral ; the neutral criterion is $|L_v|>25$. For practical purpose the value of c is consider to be useful for comparison of depths in neutral condition. The value of c scatters between 0.124-0.452. Uncertainties of stability in the mixed layer and the presence of clouds might alter the physical system by introducing extra buoyancy and radiation effects.

3.2 Plumes over the sea

The stable stratification over a warmer water current in continental cold-air outflows is another important situations for air pollution modeling where pollutants seem to be transferred from the continent to Japan. Lidar observations were conducted at the monitoring site in Oki islands. Oki islands situate in the west side of Sea of Japan. The case studies were derived from six consecutive days in cold air outflows. On 4 th December 1995 the weakened low pressure remained in the Sea of Japan and drifted to the east. Peaks of SO_2 which was supposed to be transferred were detected at the monitoring site. Figure

1 shows that lidar time-depth presentation of ABL structure. The vertically aligned regions in the lower part of the figure correspond to plumes over the surface. Figure 2 shows the radiosounding corresponding to Fig. 1. The lidar data show that the preferred form of convection cells are plumes with roots near the surface. Majorities of plumes were 500m in width and 350m in height. FFT analysis of fluctuations at various heights in neutral mixed layer, the decay of power spectrum is agree with the " -5/3 power law ". The radiosounding shows the existences of vertically constant potential temperature layers of 200m above a steep inversion at the top of surface layer and also above an inversion of the top of the cloud layer. These layers continue to the thermally stable layer without potential temperature jump. Majorities of thickness of clouds layer in the six days extended 1 to 2 km in thickness. The top of cloud was estimated from lidar data through the breaks of clouds and the relative humidity.

4 Summary

A lidar is confirmed to be an effective method to measure spacial and temporal variations of ABL. Observations in Pacific Ocean and Nansei-Shoto showed that stabilities were almost neutral and the depths of the ABL were 0.4-1.5km and the value of c scatters between 0.124-0.452. At Oki islands in continental cold air outflows over a warmer current convective plumes were formed thick cloud layer developed to 2km in thickness.

References

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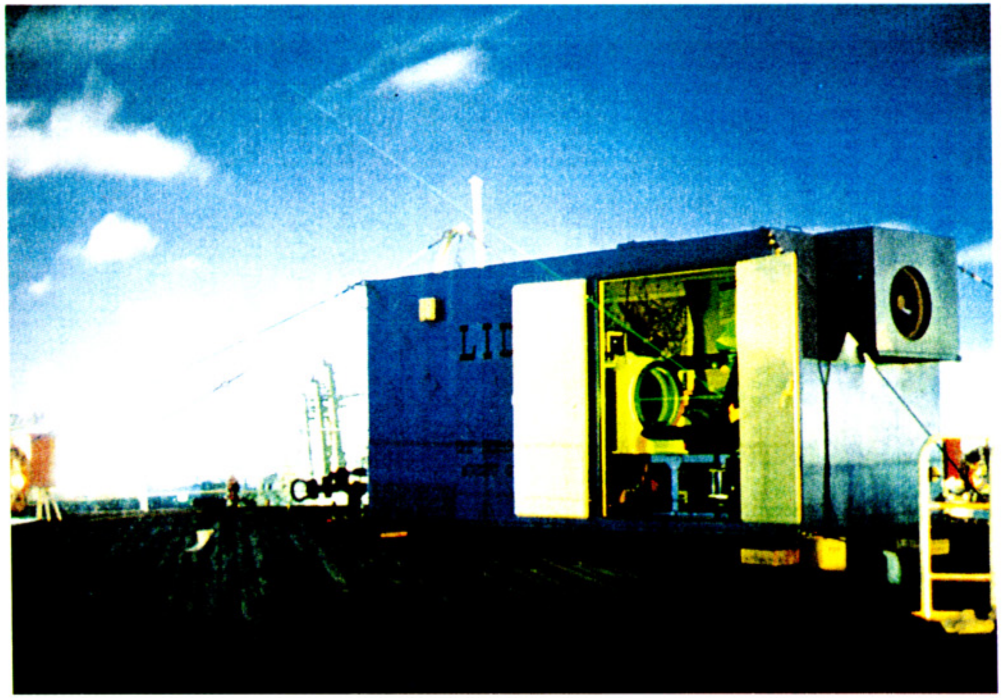

Lidar on-board

Table 1 Lidar specification

Laser	
Type	Nd:YAG
Wavelength	532,1064nm.
Output	140mJ
Repetition	1~14Hz
Pulse Width	6~9nsec
Transient Recorder	
Type	TR8818/2012F
Sampling	100/20MHz
Accuracy	8/12bit
Sensitivity	0.25/2V F.S.
Scanning	
Range	Az:40~100,260~320deg El:-20~80, 90deg
Resolution	<0.1 mrad
Accuracy	<0.4 mrad
Velocity	5 deg/sec
Output	BCD 5 Digit

Table 2 Obserbations near Minami torishima

No.	Mon. Day,Time	$\theta_v(°C)$	$\theta_w(°C)$	u(m/s)	Lv(m)	c	Cloud
1	11262000	15.0	16.0	13	-547	0.118	nct
2	11270800	13.2	16.9	5	-53.4	0.344	nct
3	11271100	16.8	16.0	4	179	0.173	ct
4	11281000	20.7	21.7	22	-1798	0.114	ct
5	12011100	26.0	27.2	25	-2018	0.110	ct
6	12011500	25.2	26.0	23	-2491	0.103	ct
7	12020700	25.0	25.1	12	-4585	0.161	ct
8	12021100	25.5	24.6	11	421	0.107	nct

Lv: Monin Obukhov Length, c : $h = c \cdot u_* / |f|$

Cloud condition ; ct:cloud top, nct: non-cloud top, c-c: separated cloud
Observed 1993.12, Minami-torishima oki-Tokyo

Table 3 Obserbation near Nansei shoto

No.	Mon. Day,Time	$\theta_v(°C)$	$\theta_w(°C)$	u(m/s)	Lv(m)	c	Cloud
1	12020900	20.8	19	5.1	116	0.396	ct
2	12021100	19.4	20.1	4.1	-219	0.260	ct
3	12021400	19.8	21.8	13.4	-293	0.124	ct
4	12021700	19.6	22.2	10.8	-140	0.169	ct
5	12030700	20.6	22.0	9.3	-188	0.122	ct
6	12031000	21.2	24.0	9.3	-94	0.128	nct
7	12031200	20.2	21.5	8.2	-154	0.195	ct
8	12032000	20.0	22.6	10.8	-140	0.181	nct-c
9	12051800	19.6	20.6	8.7	-228	0.452	nct
10	12052100	18.8	20.8	7.7	-331	0.251	nct
11	12061000	20.6	23.9	7.2	-166	0.250	c-c
12	12070530	18.6	21.2	4.6	-82	0.316	ct
13	12071000	20.5	24.5	5.1	-52	0.319	c-c

Lv: Monin Obukhov Length, c : $h = c \cdot u_* / |f|$

Cloud condition ; ct:cloud top, nct: non-cloud top, c-c: separated cloud
Observed 1994.12, Nansei-shoto

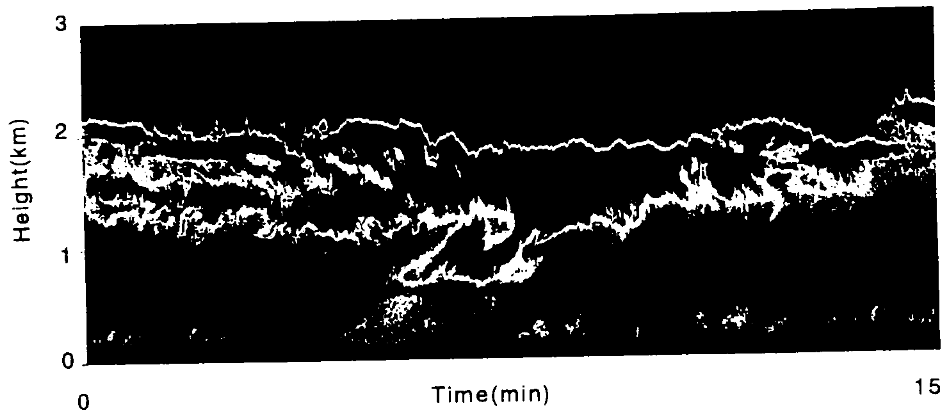

Fig. 1 Lidar time-depth presentation of ABL structure for 15 minites.
(Dec. 4, 1995,10:21, Oki)

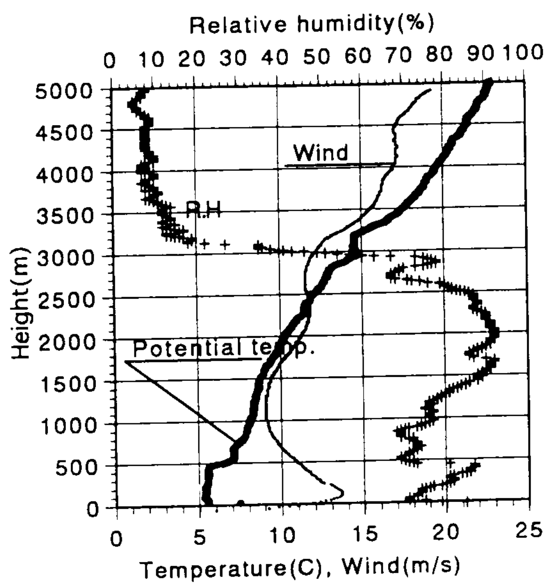

Fig. 2 Radiosounding of potential temperature, relative humidity and wind speed, data corresponding to Fig.1