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LIDAR OBSERVATION OF AEROSOL STRATIFICATION IN THE CASE OF SEA BREEZE CIRCULATION NEAR THE SHORE

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INTRODUCTION

The sea breeze circulation is a mesoscale phenomenon manifested near the shore as a local wind blowing from the sea to the shore, or vice versa, depending on the time of the day or night. In recent years, it has been the subject of both theoretical and experimental studies, mainly due to its relation with the atmospheric pollution.

Two experiments in the USA employed airborne lidars: the first [1] measured the atmospheric pollution above the city of Los Angeles, while the second [2] studied the formation of organized convection during cold air penetration over a warm sea surface. A mobile lidar experiment was also performed in Japan in the Kuyuguri and Sagami region, where the pollution in the coastal zone was studied [3]. Similar experiments were carried out in Bulgaria's Black Sea coastal zone [4, 5].

The object of the present work is the mesoscale phenomenon of sea breeze circulation. The study aimes at assessing the lidar equipment capabilities in monitoring the formation of the sea breeze circulation - from sea to shore during the day, from shore to sea during the night, as well as during the transition period.

EXPERIMENTAL TECHNIQUE AND EQUIPMENT

In these experiments, a scanning aerosol lidar was used, placed in the meteorological station (belonging to the Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, and located about 5 km from the town of Ahtopol) at 10-12 m above sea level. The lidar's main units are:

- Nd:YAG laser - pulse energy 25 mJ, pulse duration 15-20 ns;
- receiving antenna - Cassegrainian telescope with main mirror diameter of 200 mm and equivalent focal length of 1000 mm;
- photodetector - FEU 84 photomultiplier equipped with an interference filter with 1 nm transmission band;
- system for data acquisition and processing, based on a HP5180A analog-to-digital converter and a PC AT/386 computer.

A meteorological station was used to measure temperature, humidity, horizontal and vertical wind velocity, total solar radiation (using a pyranometer) and radiation balance in air (using balansometer).

EXPERIMENTAL RESULTS

The experiments were carried out mainly during clear days (anticyclon) in the presence of breeze circulation. The presence of such a circulation was established using the data from a pilot observation of the wind profile, as illustrated in Fig. 4.

The lidar monitoring technique is based on studying the aerosol structure and stratification over various underlying surfaces - land, sea, surf zone - for each sea breeze direction.

Different data acquisition modes were implemented during the lidar experiments:

- horizontal scanning - azimuth-range indicator (ARI) along 6 directions (336^0, 6^0, 30^0, 60^0, 90^0 and 110^0 with respect to the North **N**).
- vertical scanning - height-range indicator (HRI) steps of 1^0 from sea level to 10^0, and of 2-5^0 within the 10-30^0 interval.
- recording of time series along one or several directions.

The two main techniques for measuring vertical fluxes - gradient and pulsation - were employed during the experiments.

The lidar experimental data are presented as two-dimensional images of the variation of the back-scattered laser signals (corrected with respect to the square of the distance and the energy) as a function of the height and the distance along the sounded path at different azimuths.

The common feature of all the lidar data in the case of sea breeze are the zones of higher contrast observed in the lower part of the scanned area; they indicate a cold front, Fig. 1.

In the case of land breeze lidar data show a relatively slow night breeze formation after sunset, i.e., colder and dryer air starts to blow from land to sea. After the cold-air zone a thermal of warmer and more humid air is observed where the formation begins of the reverse part of the circulation cell, Fig. 2, 3.

In fact, if the lidar data from 21 June (Fig. 1, 2, 3) are compared with those obtained through direct temperature, humidity and wind measurements (used to determine the heat and humidity fluxes), a good agreement can be seen between the lidar data, behavior of the fluxes (which are not shown in the abstract) and meteorological parameters, Fig. 5, 6.

The lidar data taken reveals a humidity rise after 10 a.m. which is related to the change of the wind direction from sea to land. Around 13 p.m., the humidity above the land begins to drop again due to the stronger radiative processes, which is reflected in the variation of the lidar signal with the height.

A similar good agreement is seen in the case of lidar data comparison with the wind speed and direction data acquired by the mast sensors. The time of wind direction change on all three days is before 10:00, i.e., 20-40 min prior to the humidity change, and befor the lidar registers the aerosol stratification corresponding to an established sea breeze.

CONCLUSIONS

The lidar images allow one to make a distinction between the radiative and convective effects in the aerosol stratification near the shore.

A juxtaposition of the lidar data with those obtained via conventional measurements of the meteorological parameters (and with the calculated heat and humidity fluxes) discloses a good agreement thus confirming the potential of the lidar equipment in studies of mesoscale phenomena near the shore.

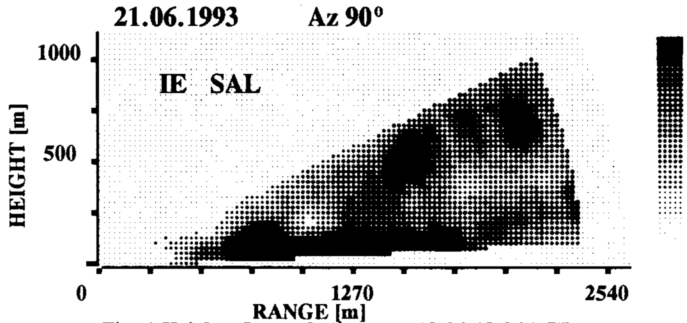

Fig. 1 Height - Range Indicator 13:04-13:26 LST

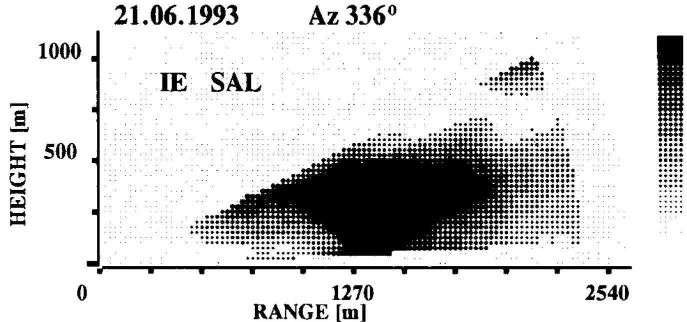

Fig. 2 Height - Range Indicator 20:24-20:42 LST

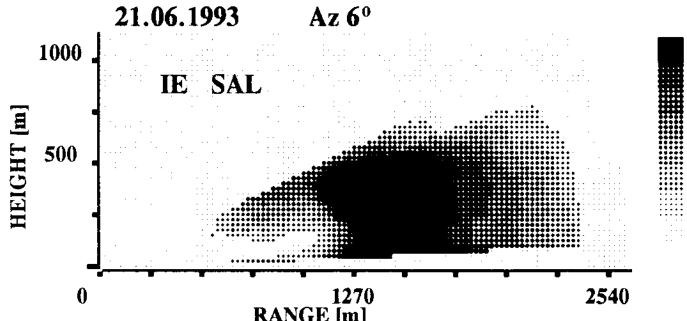

Fig. 3 Height - Range Indicator 20:52-21:09 LST

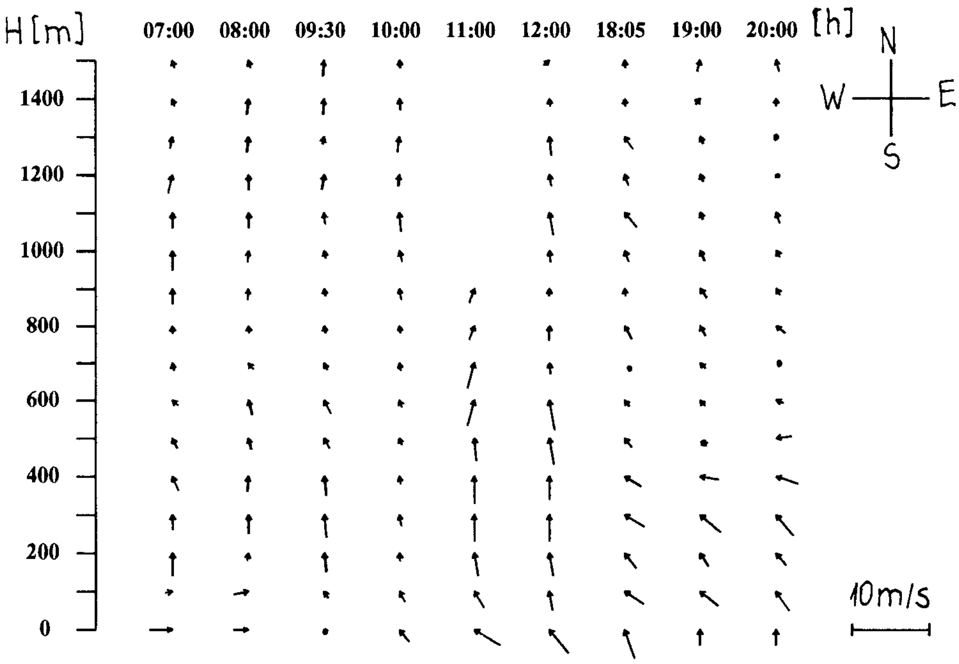

Fig. 4 Pilot Balloon Wind Profiles 23 JUNE, 1993

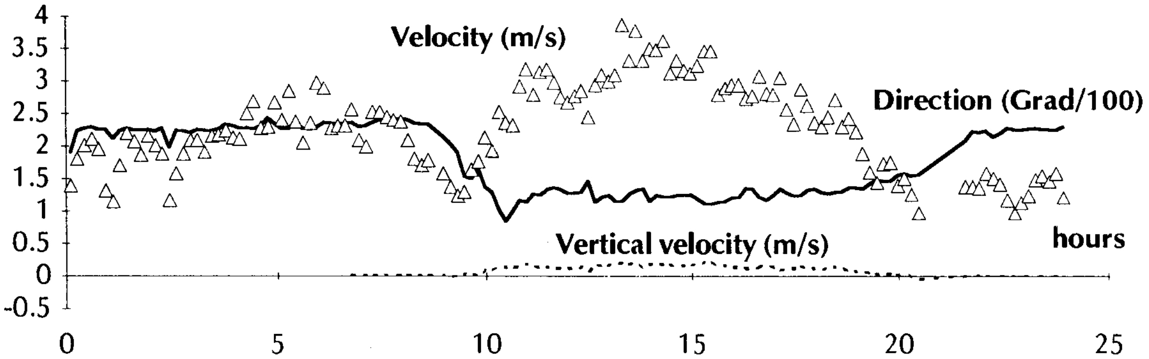

Fig. 5

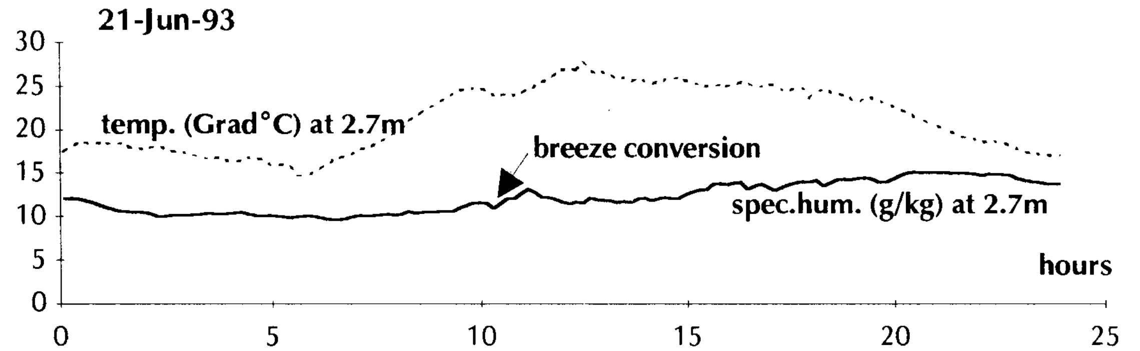

Fig. 6

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