Remote sensing measurements and investigation of the ABL temperature profile over large and broad mountain basin

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Abstract

Continuous Atmospheric Boundary Layer (ABL) temperature profile measurements are of particular interest in a variety of applications and studies, including air pollution and pollutants dispersion, agricultural meteorology, aeronautical meteorology, mesoscale meteorology, weather forecasting, climate studies, energy applications. Several methods have developed and are applied for these measurements, being both direct (in situ) by using sensors located on tower structures, balloon-borne instrumentation, until aircraft techniques and indirect or remote sensing techniques. The latest mainly involve transmitted acoustic, radio, or light energy, and the detection of the scattered energy due to atmospheric targets. Passive techniques involve the measurement of radiation naturally emitted from the atmosphere, for example, as in microwave and infrared radiometry. In this work, the technique of passive microwave radiometry for the measurement of the temperature profile in ABL is described and some measurements are presented and analyzed. These measurements carried out in the industrial area of Western Macedonia, a large and broad mountain basin in NW Greece, by using the MTP-5 system. MTP-5 is a remote sensing instrument that measures microwave radiation emitted from the lower 1000 m of the atmosphere, within the Planetary Boundary Layer. The measurements of the temperature profile during two typical cases (hot and cold season) are analyzed and the ABL development are being investigated. Finally, some concluding remarks are provided.

Keywords: Atmospheric Boundary Layer, temperature profile, passive microwave radiometry

1. Introduction

The bottom layer of the troposphere that is directly influenced by the presence of Earth's surface and responds to surface forcings in an hour or less time scale, known as the Atmospheric Boundary Layer (ABL), differs significantly from its other parts (Stull, 1988). The effects can be friction forces, wind field modification due to terrain, evaporation, transpiration, heat transmission. The measurements of the basic meteorological magnitudes (wind speed and wind direction, stability of the atmosphere, depth of mixing height) in this layer are of particular interest in atmospheric pollution studies. The ABL stability is an important parameter in investigating the dispersion of pollutants, and is determined by measuring the vertical temperature profile of the atmosphere above a measurement site [Stul, 1988; Scorer,1990; Garratt, 1994]. These measurements are performed with systems, the principle of which is based on various techniques - both in situ and remote sensing techniques. More generally, techniques based on the propagation of waves such as microwave (RADAR, Radio Detection And Ranging), sound (SODAR, Sound Detection And Ranging), light (LIDAR, Light Detection And Ranging) into the atmosphere [Kaimal et al., 1994 ; Luo et al., 2014] are used. In this work, the technique of passive microwave radiometry for the measurement of the temperature profile in ABL is described and some measurements are presented and analyzed. These measurements carried out in the industrial area of Western Macedonia, a large and broad mountain basin in NW Greece. Measurements of temperature and wind profile in the area, in representative cases of hot and cold period, were carried out in the past with tethered meteorological balloon and SODAR [Triantafyllou et al., 1995, 2001].

2. Experimental location, data and methodology

The experiment site is at the center of Western Macedonia and specifically in south part of Eordea basin (40.47oN, 21.75oE, 650 m ASL). This is a broad, relatively flat bottomed basin surrounded by mountains located at NW Greece. Around this site, the open lignite mines are being developed, namely Mavropigi Mine (north) and South Field (south). Based on the prevailing synoptic meteorological conditions, measurements of the temperature profile during two typical cases (hot and cold season) was analyzed and the ABL development was being investigated. The MTP-5 system of NPO ATTEX Company, Russia, was used. The technique used in MTP-5 for determining the air temperature profile is based on atmospheric thermal radiation measurements at the center of molecular oxygen absorption (about 5 mm), known as passive remote sensing. The determination of the temperature profile is based on thermal radiation measurements at different zenith angles in one azimuth plane [Troitsky et al., 1993; Kalygrov, 2009; Renju R., 2017;Triantafylla 2017]. The reception of radiation from the different zenith angles is achieved by mechanical rotation of a mirror-reflector. This reflector is mounted at 45 degrees relative to the receiver axis. Thermal radiation of the atmosphere from different zenith angles is reflected to the input of the receiver. The measured signal is amplified and processed in the receiver. The temperatures recording in different zenith angles allow the determination of the temperature profile as a function of altitude and time from ground level to 600/1000m with a 50 m resolution. Among the most important advantages of the MTP-5 system is the automatic instrument calibration, the wide range of operating conditions (covering fog, snow and rain conditions), zero emission radiation, and low operating costs while operating continuously. Figure 1 shows the system in the measuring location. It was installed on a special 4 meter height platform constructed for this purpose in order to meet the requirements of obtaining reliable measurements.

The MTP-5 system installed in the measuring location

Figure 2. shows the potential temperature profile from 15:00, 26/01/2018 to 14:00 the next day (cold period).

3. Conclusions

The potential temperature changes more quickly at lower altitude as well as during sunrise and sunset time period. During the night of the cold period, a stable layer with a surface based inversion up to 600m, that is the whole height of the measurement, is formed. After the sun rise and until the noon, a neutral layer up to 200 m is created, while higher up a sub-adiabatic and then more stable layer exist. On the contrary, in the warm period, the complete evolution of the daily cycle of the atmospheric boundary layer is observed, with the height of the formed layers to be characteristic of the area. This cycle is described from the formation of a superadiabatic layer in the noon up to about 300 – 400 m AGL and adiabatic layer higher, neutral layer in the afternoon, surface based inversion formation after sunset, which is destroyed in the next day with the east of the sun. It is, however, characteristic the maintenance of a slightly stable layer in the last 150 - 200 meters of measurement. Given the effect of the atmospheric boundary layer evolution on the pollutants' dispersion and the fact that lignite power stations with high stacks are operating in the area, the above finding underlines the need to take measurements up to a height greater than 600 meters.

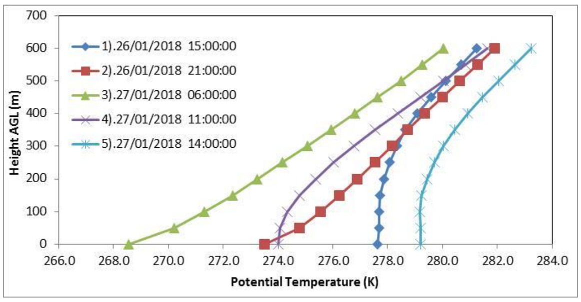

Figure 2. The potential temperature profile from 15:00, 26/01/2018 to 14:00 of the next day (cold period).

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