ANALYSIS OF ATMOSPHERIC BOUNDARY LAYER AND LAKE-LAND INTERACTION

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ABSTRACT

This study focuses on water and energy balance over the Central Anatolian's Lake Area. Analysis of meteorological parameters recorded in the atmospheric boundary layer with an instrumented aircraft (Vilga) during the measuring campaign between 29 and 31 August, 1999 are presented in this project. This paper presents some defiled results on 30th, August 1998. Measurements are carried out over the Lake Egirdir (Latitude: 37°48' and 38° 26' N, Longitude: 38° 18' and 31° 22' E, Altitude: 919m (msl)) and near vicinity of Central Anatolia. Sampling interval of measurements is one second. All flight and meteorological data is automatically recorded. Time variations of pressure (P), air temperature (Ta), Surface temperature (Ts), relative humidity (RH), turbulent fluxes of heat (SH) and moisture (LH) measured over the lake area are analyzed with respect to the distribution with height and horizontal scale, intercorrelation and relation to synoptic weather systems.

Air temperature values change in the range of 25°C and 35 °C. Lower values of air temperature (25 °C) are recorded over the Lake Egirdir during measuring campaign. Relative humidity values increases to 40% over the lake surface. Air pressure values are between 800hPa and 900hPa. Convective motions and turbulence are observed between 11:00am and 2:00pm. Surface temperature values change between 25°C and 35 °C in late morning. Their range is between 30°C and 55°C afternoon. Deviations of temperature and relative humidity values from the averages are higher over land area. Mean value of lake surface temperature is 17°C in the morning and 20.5°C in the afternoon.

Effects of spatial and vertical variation of meteorological parameters on dry and wet convection are presented in this study. During the last measuring campaign beginning from 11:00am developing convective clouds cause some decreasing trend over temperature values. Flight measurements are reanalyzed together with boat measurements and conventional surface data over the lake and near vicinity of it. Spatial and time variation of flux values. Bowen Ratio (SH/LH), Ri Number and Monin Obukhov Length are analyzed to define the lake surface effects on convective activities over the study area. The role of fluxes on moisture balance is discussed.

1. INTRODUCTION

Flight and surface measurements over complex topography and a lake surface are analyses in this paper. The purpose of this study is to define the basic and spectral properties of the boundary layer in central part of Anatolia. The surrounding mountain ranges are found to shelter the lake basin from most synoptic winds, thereby allowing local and regional thermally generated circulation to develop to ridge height, approximately 1500m above the surrounding landscape. During favorable synoptic conditions the local lake breeze becomes embedded within the regional valley wind forming an extended lake breeze.

The Earth - Atmosphere system is a closed system in the sense that it allows the exchange of energy with the space while it is closed to import and export of mass. The sole energy input to the Earth - Atmosphere system is the radiation emitted by the Sun. In the Earth - Atmosphere system, the transmission of energy takes place in three different modes, namely conduction, convection and radiation. The process of convection involves the vertical interchange of air masses and can only occur in liquids and gases. The atmosphere near the earth's surface may also be physically displaced while it is flowing over obstacles: This is called forced or mechanical convection. Basically, it depends upon the roughness of the surface and the speed of the horizontal – airflow over it. Often, free and forced convection coexist, giving mixed convection. Convection transports energy as both sensible heat and latent heat in the atmosphere.

Some studies closely related with this paper are summarized as below: Water and land breezes are undoubtedly the most researched of all termally driven circulation as shown by numerous empirical, theoretical and numerical studies dealing with them in meteorological and climatological periodicals, (Hamish et all, (5)). Radiometric surface temperatures, derived from measurements by the AVHRR instrument aboard the NOAA-9 and NOAA-ll polar orbiting satellites, were used in combination with wind velocity and temperature profiles measured by radiosondes, to calculate surface fluxes of sensible heat, (Brutsaert and Sugita, (3)). The bulk transfer coefficient for latent heat flux (Ce) has been estimated over the Arabian Sea from the moisture budget during the pre-monsoon seasons of 1988 (Sadhuram, (14)). The moisture is available through a deeper atmospheric layer when ridging anticyclones support uplift at the top of the boundary layer (Jury et al., (7)). The inland penetration of moisture determines whether subsequent convective rains are limited to the coast or become widespread over the interior plateau. Such differences in boundary-layer characteristics are vital to the agriculturally – based economy of this transition zone along the southeastern coast of Africa. Measurements are presented of the development of the convective boundary layer in the transition zone from the Upper Rhine valley to the Northern Black Forest during one special observation period of the

TRACT campaign conducted in September 1992, (Kossmann, et all, (9)). The data used in this study were obtained from airborne instruments as well as from ground-based stations. The analysis boundary layer structure shows a strong influence of the underlying terrain. Using a surface-layer model. Fluxes of heat and momentum have been calculated for flat regions with regularly spaced step changes in surface roughness and stomata resistance, (Klaassen, (8)). Mahrt (12) examines problems with application of the bulk aerodynamic method to spatially averaged fluxes over heterogeneous surface.

The need for well-defined lower boundary conditions for atmospheric numerical models is well documented (Bosilovich and Sun, (2)).

This paper describes the formulation of a land surface parameterization, which will be used in atmospheric boundary layer and meso-scale numerical models. These simulations show that the model is able to reproduce observed surface energy budgets and surface temperatures reasonably well.

Some experimental and theoretical results of dynamic and thermodynamic structures at the lake/land boundary layers are presented in this paper.(Aslan, et al (l) and Latif(10))

2. MODELLING TOOLS AND METHODOLOGY

Study Area

Flight measurements are carried out in and near vicinity of Isparta (Latitude: 37°18' and 38° 30' N, Longitude: 30° 02' and 31°33'E, Altitude: 1000-1050m (msl)) and Lake Egirdir. The flight path is shown in Figure 1.

Figure 1.

Data Sources

Flight data in atmospheric boundary-layer is listed in Table 1.

Table l.

Second data sets of meteorological parameters are recorded at meteorological stations (Yalvalc (Latitude: 38°18', Longitude: 31°11'E, Altitude: 1100m (msl)), Egirdir (Latitude: 37°52', Longitude: 30°50'E, Altitude: 950m(msl)), Senirkent (Latitude: 38°06', Longitude: 30°33'E, Altitude: 1000m (msl)), Isparta (city center) (Latitude: 37°48', Longitude: 31°22'E, Altitude: 1000m (msl))). These parameters are P, Ta, and RH. T5 recorded by using conventional ground measuring systems. Radiosonde data over city center of Isparta is also analyzed. Table 2 shows ground measurements on 30fh of August 1998.

Table 2.

Synoptic Station and Upper Layer Maps:

Study area is effected by warm air mass (warm advection) between two frontal bands. Westerly winds are observed over study area. There are two low-pressure centers and frontal systems over northern part of Russia and Greece at 00.00 GMT. A trough line is observed over European part of Turkey countries. Central Anatolia is effected by warm advection. Northerly winds increase over Eagean Sea and Mediterranean Sea. Upper layer winds are southwesterly.

Methodology

Energy Budget and Surface Layer Fluxes

The energy balance equation of the earth's surface includes the fluxes of energy between the surface element and surrounding space. The diurnal cycle of solar radiation reaching the surface drives diurnal variations in temperature values of land surfaces and in turbulent fluxes of latent and sensible heat which are essential features of surface - air energy exchanges. These fluxes include the radiative flux of heat the sum of which gives the radiation balance, (Brutsaert,(4))

Accordingly, the energy balance equation for the earth's surface is given by,

$$G = R - LH - SH \quad (1)$$

where G is storage rate of sensible heat, R, net radiation, LH, latent heat and SH, sensible heat. Sensible heat fluxes can be calculated by using the following equation:

$$SH=\rho Cp[K2v(T_g - T_a)]/[Ln(10/Zo)]^2 \quad (2)$$

where, ρ is density of air ($\rho \approx 1$), Cp, specific heat of moist air (C_p =1004 J/Kg°K), K*, Von Karman constant (C = 0.4), V, the surface wind speed, (T_s - T_a), difference between ground and air temperature, and, Zo roughness height.

For the roughness heights for study area, the values from NOM Data Archive Center have been considered. For the surface wind speed and air temperature, hourly average values have been taken into account. The ground temperature is the value observed during the flight by using fast thermal infrared thermometer system. The sensible heat flux is normally directed upward during the day, when the temperature difference (Ts -Ta) between the surface and overlying air is positive. In atmospheric models the surface fluxes of momentum (τ), sensible heat (SH) and latent heat (LH) are often expressed as (Holtslag, et al,(6)).

$$\tau=\rho C_m U_2^2 \quad (3)$$

$$SH=-\rho C_p C_H U_2 (\theta_2 - \theta_1) \quad (4)$$

$$LH=-\rho\lambda C_Q U_2 (q_2 - q_1) \quad (5)$$

Where ρ is density of air, C_p is the specific heat and λ the latent heat of vaporization. The symbols, U_2, θ_2 and q_2 are wind speed, potential temperature and specific humidity at 10m. θ_1 and q_1 are the corresponding 2m. C_M, C_H, C_Q are transfer coefficients for momentum, heat and moisture.

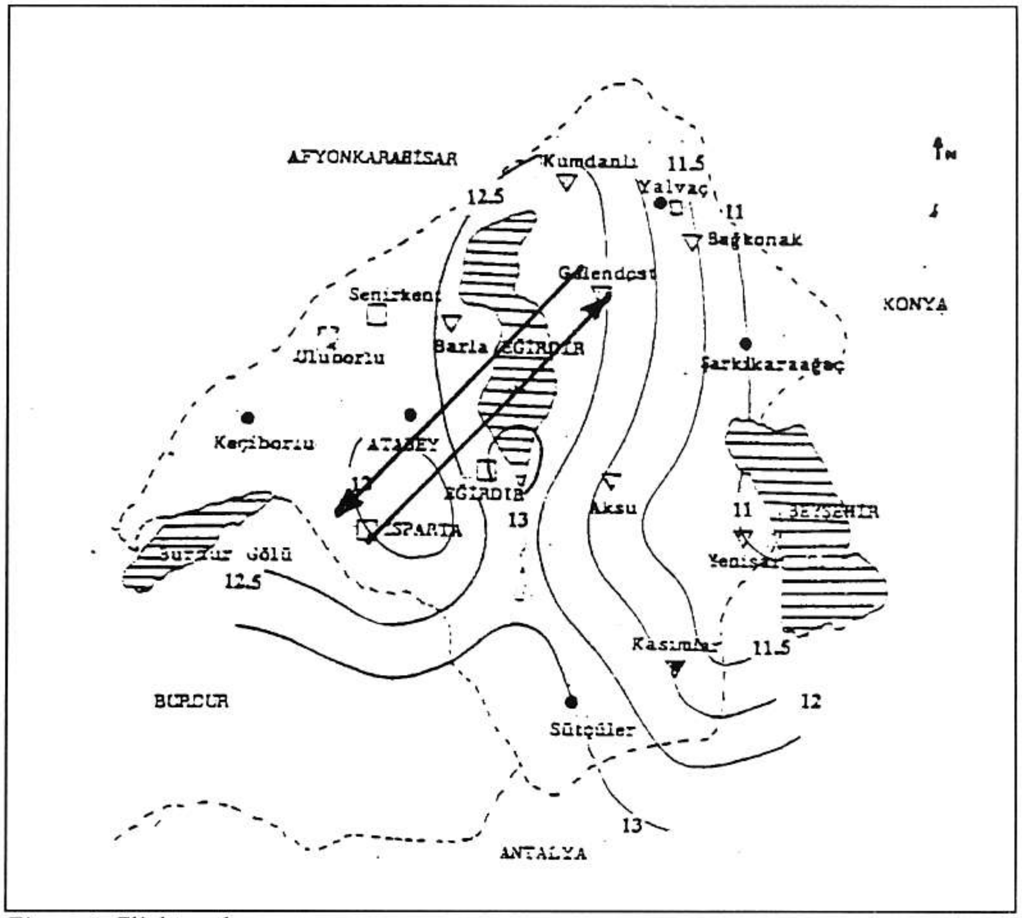

Figure 1. Flight path.

Date	August 30,1998
Flight Period	8.10 between 9.35 Local time
Sample rate	1 sec.
T_a (°C)	Vaisala Thermocouple
T_s (°C)	TIR(Infrared thermometer)
RH(%)	Visalia humidity-meter
P(hPa)	Pressure transducer

Table 1. Flight data and measuring systems.

TİME	ISPARTA			SENİRKENT			EĞİRDİR			YALVAÇ		
	P(hPa)	T(°C)	RH(%)	P(hPa)	T(°C)	RH(%)	P(hPa)	T(°C)	RH(%)	P(hPa)	T(°C)	RH(%)
8.00 (GMT)	903	23	60	907	20	52	910	21	70	893	20	60
9.00 (GMT)	903	26	53	907	23	47	910	25	50	893	25	46
10.00 (GMT)	903	29	50	907	26	45	910	26	55	893	27	39

Table 2. Surface data (August 30, 1998).

3. PROJECT RESULT

Table 3 presents some statistics of flight data over land and lake area Standard deviation values over lake area are lower then the values observed over land area. Mean air temperature values over land are higher than observation over lake area.

Saturated vapor pressure (e_s), actual (q) and saturated specific humidity (q_s), virtual temp (T_v), flight altitude (above mean sea level, msl) dry (sed) and humid (sen) static energy values over land and lake area are presented in Table 4, Saturated vapor pressure. Actual vapor pressure, virtual temperature values over land are greater than the observations over lake.

Table 5 shows model outputs based on Monin Obukhov Similarity Theory (U*: friction velocity (m/s), t*: temperature scale (°K); q*: humidity scale (g/kg); MH: momentum heat flux (N/m2); SH sensible heat flux (W/m2); LH: latent heat flux (W/m2); L: Obukhov Length (m); RN: Richardson Number; BR: Bowen Ratio (SH/LH)). During Flight 1 over land between first and 1062nd seconds Bowen Ratio values generally positive which trigged the convective activity.

Spatial variation of parameter:

Figure 2 and Figure 3 show spatial variations of air (T_a) and surface temperature (T_s) values respectively. Standard deviation of surface temperature values over land area is higher than the observation value over lake area. Air temperature deviations are similar over lake and land.

Figure 4 presents vertical variation of virtual temperature over land (Lag 1 between 1st and 1062nd). Mixing layer height is approximately 1500 m. above mls.

Figure 5 shows Vertical variation of relative humidity over land lag 1 between lst and 1062nd .

Vertical variation of temperature in mixing layer cup to ~1400 m. Air temperature values are in the range of 292-294 (°K). It is not observed an important variation in this layer above the mix in layer they decreases. But, vertical variation of relative humidity values change in the range of 22% and 42% relative humidity values would be considered as an indicator of convective motions.

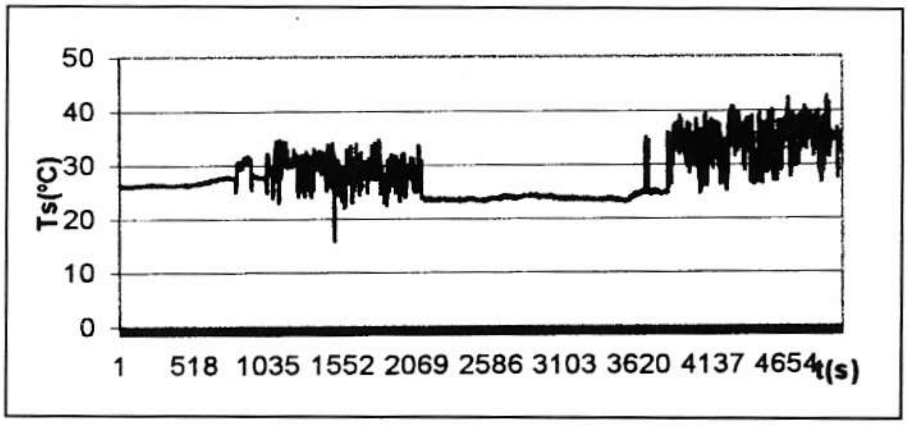

Figure 2. Spatial variation of Air Temperature over land and lake area. (August 30, 1998: 8:10 - 9:35 local time).

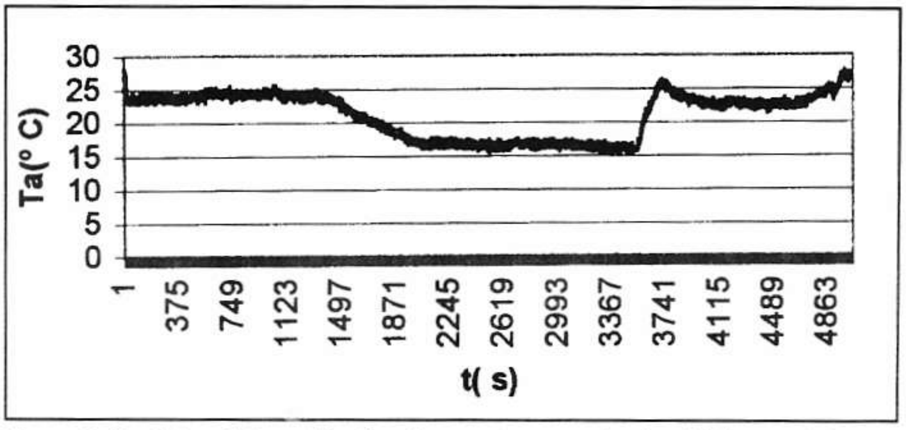

Figure 3. Spatial variation of Surface Temperature over land and lake area. (August 30, 1998: 8:10 - 9:35 local time).

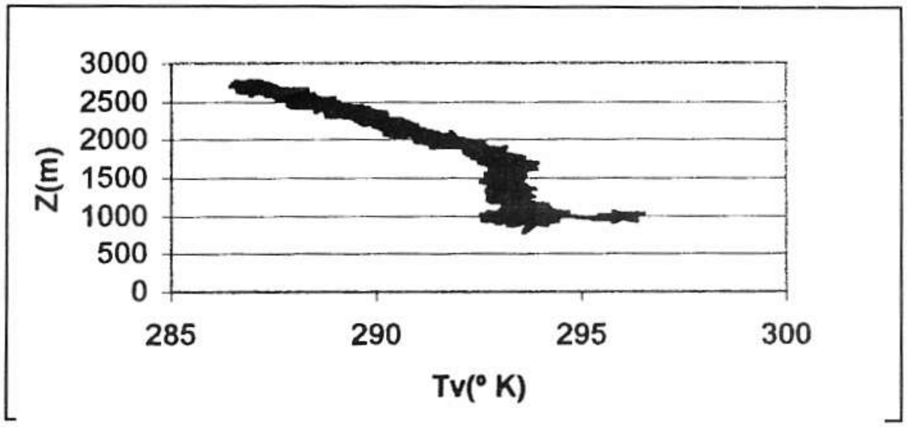

Figure 4. Vertical variation of Virtual Temperature over land (August 30, 1998: 8:10 - 9:35 local time).

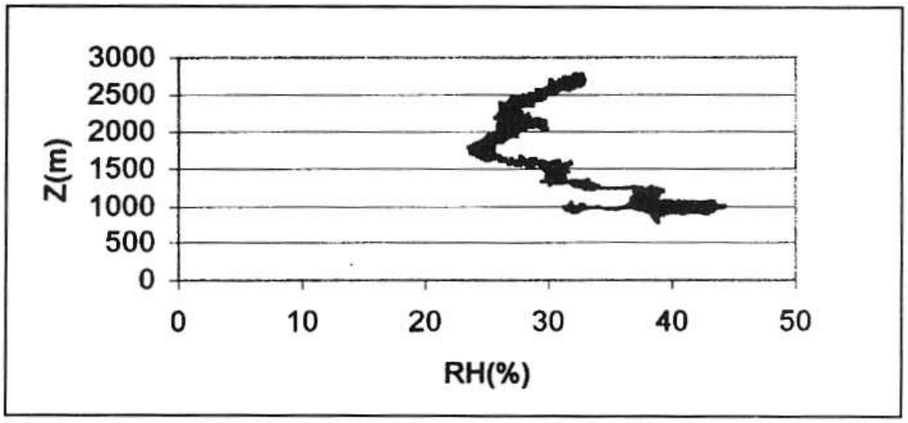

Figure 5. Vertical variation of relative humidity over land (August 30, 1998: 8:10 - 9:35 local time).

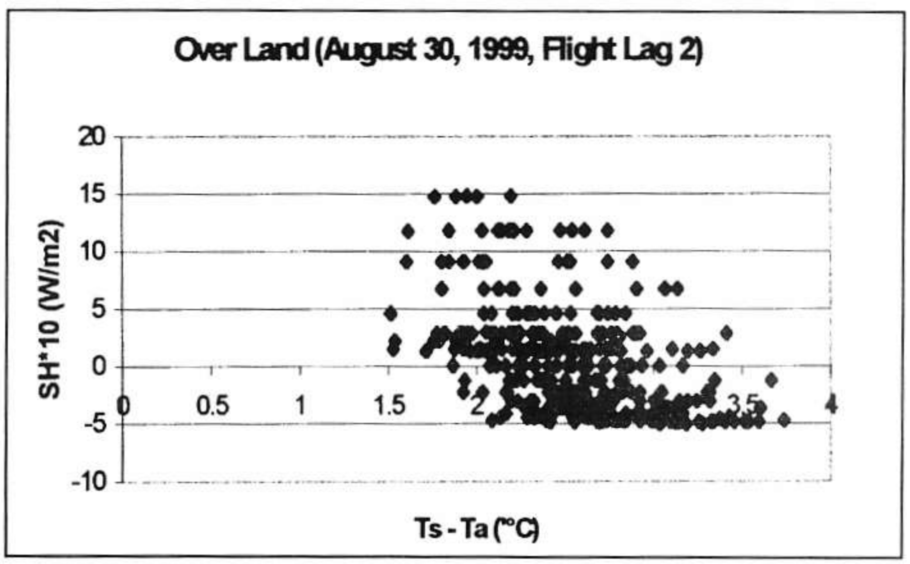

Figure 6. Variation of (SH) sensible heat flux values versus temperature differences between surface and air termeratures, ($SH = -5.216(T_s - T_a) + 13.822$).

AUGUST 30,1998	Parameter	MEAN	MAX	MIN	Standard Deviation
Start Time:8.10 1.Flight (overland)	P(hPa)	870.76	945	748	61.28
	Ta(°C)	22.64	28.1	15.9	2.45
	RH(%)	34.71	44.4	23.5	6.23
	Ts(C)	28.09	34.59	15.86	2.25
2.Flight (overlake)	P(hPa)	765.73	879	735	35.97
	Ta(C)	17.6	26.4	15	2.71
	RH(%)	30.85	35.1	24.3	1.87
	Ts (°C)	23.99	35.82	22.97	1.34
3.Flight (overland) Finish Time:9.35	P(hPa)	843.77	930	816	26.92
	Ta(°C)	23.29	27.6	21.2	1.5
	RH(%)	26.75	40.3	23.8	2.86
	Ts(°C)	34.27	42.6	24.61	3.53

Table 3. Statistics of flight data (August 30, 1998: 8:10 - 9:35 local time).

AUGUST 30,1998	Parameter	MEAN	MAX	MIN	Standard Deviation
1st Flight Overland	T (°K)	295.80	301.26	289.06	2.45
	e_s	27.69	37.94	18.03	3.80
	q_s	0.02	0.03	0.02	0.002
	q	0.007	0.0091	0.0045	0.0014
	T_v	292.25	296.54	286.44	2.14
	Z	1502.951	2776.178	778.94	618.42
	Sed	311893.28	318814.85	306160.57	3979.41
	Sen	329031.54	333289.78	325222.90	1122.08
2nd Flight Over Lake	T (°K)	290.76	299.56	288.16	2.71
	e_s	20.36	34.35	17.02	4.03
	q_s	0.0164	0.025	0.014	0.0023
	q	0.0050	0.0071	0.0043	0.00052
	T_v	287.84	295.09	285.66	2.27
	Z	2576.899	2914.33	1393.11	380.85
	Sed	317347.7	319396	313343	1150.2
	Sen	329956.7	332886.6	326879.6	883.96
3rd Flight overland	T (°K)	296.45	300.76	294.36	1.22
	e_s	28.61	36.86	25.13	2.23
	q_s	0.021	0.025	0.019	0.001
	q	0.0057	0.0084	0.0048	0.0008
	T_v	292.64	296.18	290.99	1.03
	Z	1738.97	2021.4	897.31	265.84
	Sed	314856.1	317226.31	309614.14	1566.57
	Sen	328979.8	332961.94	325705.87	977.06

Table 4. Atmospheric Boundary layers parameters calculated by thermodynamic equation over land and lake (August 30, 1998: 8:10 - 9:35 local time).

	U*	T*	Q*	MH	SH	LH	L	R N	BR
Mean	0.21462	-0.31603	-0.14111	0.088402	6.658704	6.897034	-590.5	0.020516	1.823035
Max	0.43252	0.17223	0.35365	0.230097	148.381	268.2238	5731.658	0.12013	948.0665
Min	0.04241	-2.23903	-1.6592	0.002213	-50.5088	-128.324	-9470.56	0	-25.008
SD.	0.16073	0.568803	0.283205	0.085513	46.76352	56.99398	2556.031	0.024311	29.30877

Table 5. Model's outputs based on Monin Obukhov Similarity theory.

Figure 6 Shows the linear relationship between the differences of air and surface temperatures and (SH) sensible heat flux values (W/m2). The linear regression coefficient (r) between SH and temperature differences at flight lag l-b (350 seconds and 700 seconds) is 0,49.

4. CONCLUSION

This paper is related with a theoretical and experimental pilot study over the Lake Egirdir area in central part of Turkey. It presents some results on lake and land interactions in summer months. Near the airport over partly orographic and bare area has a favorable convective condition. The forthcoming study will cover the more detailed analyses of observations and model results.

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