Hydrothermodynamic Model for Sea Surface Layer and its Realization on the Distributed Computing Cluster

Alexander G. Klovo, Gennady V. Kupovych,
Alexander G. Marchenko, Alexander I. Sukhinov*

Taganrog State University of Radio Engineering, Taganrog, Russia

Experimental researchers of sea surface layer hydrothermodynamic parameters were made in July - August (2000-2001) in water area of Taganrog Bay of the Azov Sea. Gradient measurings, made on distance about 2 km from a coast on special raft, included psychometrical measurements of temperature and wind speed at the levels of 0,15; 0,5; 1 and 2 meters. The analysis of the data has shown presence of steady temperature inversion (about 1°C) above the sea in the daytime at a distance from land. Thickness of inversion layer depends on values of stratification parameter (Ri) and of turbulent coefficient. In case of steady stratification (Ri>0) temperature inversion took place at all levels of measuring, at unstable stratification (Ri<0) the height of inverse layer did not exceed 1 meter.

For a quantitative estimation and finding out of the temperature inversion existence reasons we calculated and analyzed, so-called, virtual temperature [1]: $T_v=T+dT_v$, $dT_v=0.378\ Te/p$, where T - true temperature, dT_v - virtual additives, e - water steam partial pressure; p - atmospheric pressure.

Figures 1-2 show virtual temperature and virtual additive profiles, received above the sea and land. Absence of temperature inversion above the land surface, and also big values of virtual additive above the sea show an essential role of phase transition water steam in temperature profile formation near sea surface. At that values of true temperature unlike virtual temperature practically do not depend on height. Thus temperature virtual additive is a result of heat emission at phase transitions near sea surface. This phenomenon may cause inverse temperature distribution with minimum on sea surface.

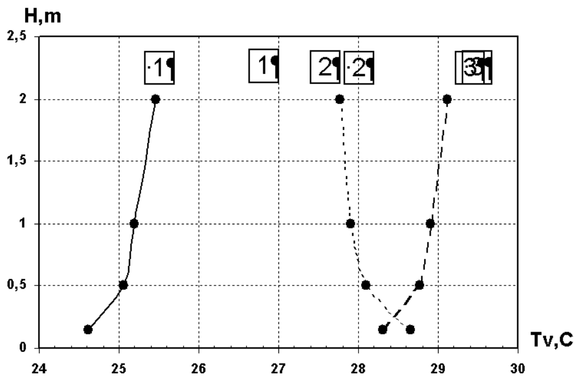

Fig. 1. Temperature profile (1-above water 2001, 2-above land 2001, 3-above water 2000).

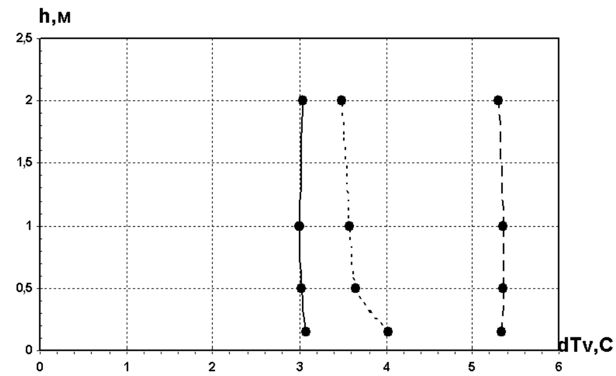

Fig. 2. Virtual additive profile.

Taking into account temperature (or potential temperature) and humidity changing depending on height above the sea level and distance from a coastline we come to the following problem:

$$\frac{\partial q}{\partial t}=u\frac{\partial q}{\partial x}+w\frac{\partial q}{\partial z}+\frac{\partial}{\partial z}\left(K_z\frac{\partial q}{\partial z}\right)+\frac{\partial}{\partial x}\left(K_x\frac{\partial q}{\partial x}\right)+f\left(q,x,z,t\right) \tag{1}$$

$$\frac{\partial \theta}{\partial t}=u\frac{\partial \theta}{\partial x}+\frac{\partial}{\partial z}\left(K_z\frac{\partial \theta}{\partial z}\right)-\frac{L}{C_p}\frac{\partial}{\partial z}\left(K_z\frac{\partial q}{\partial z}\right)-\frac{L}{C_p}\frac{\partial}{\partial x}\left(K_x\frac{\partial q}{\partial x}\right)+\alpha\left(x,z,t\right) \tag{2}$$

* Corresponding author. E-mail: sai@rec.tsure.ru

In domain *(0,h)x(0,l$_x$)* with corresponding boundary

$$\left.\frac{\partial\theta}{\partial x}\right|_{X=0}=\left.\frac{\partial\theta}{\partial x}\right|_{X=\ell}=0,$$
$$\theta|_{Z=0}=\theta_0,\ \theta|_{Z=h}=\theta_1, \tag{3}$$
$$\left.\frac{\partial q}{\partial x}\right|_{X=0}=\left.\frac{\partial q}{\partial x}\right|_{X=\ell}=0,$$
$$q|_{z=0}=q_m(x,t),\ q|_{z=h}=q_1$$

and initial conditions

$$T|_{t=0}=T_2(x,z),\ q|_{t=0}=q_2(x,z), \tag{4}$$

where T - temperature, q - specific air humidity, k - turbulent factor, W - water steam convective transport rate, *α(z)* - external heat source, z -height.

For the problem (1) - (4) solving parallel realization of seidel iterative process is used on 2-8 nodes, belonging to the distributed computing cluster. The cluster provides efficiency of 80-65 %.

For interpretation of experimental data numerical calculations were made. For non-stationary horizontal homogeneous sea surface layer without taking into account advection. The initial system of equations with boundary conditions were as follows [2]:

$$\frac{\partial T}{\partial t}=\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+\frac{L}{c_p}\frac{\partial}{\partial z}\left(k\frac{\partial q}{\partial z}\right)+\alpha(z)\ , \tag{5}$$

$$\frac{\partial q}{\partial t}=\frac{\partial}{\partial z}\left(k\frac{\partial q}{\partial z}\right)+W\frac{\partial q}{\partial z}+f(\mathrm{q})\ , \tag{6}$$

$$T|_{z=0}=T_0\ ,\ T|_{z=h}=T_1\ ,$$
$$q|_{z=0}=q_m\ ,\ q|_{z=h}=0 \tag{7}$$
$$T|_{z=0}=T_0\ ,\ q|_{t=0}=q|_2(z)$$

Member *f(q)* is admixture source function. Water steam plays its role. Dependences *α(z)* and *f(q)* have pretty complicated character and depend on meteorological conditions. Numerical experiments have shown that function *f(q)* may be chosen as $f(q)=C\cdot(q-q_\infty)^2$, where C - some constant, h - sea surface layer thickness (about 1 meter), q_m - the saturated value of specific humidity at preset values of T_0 and $T|_{z=h}$ near sea surface. T(z) and q(z) profiles are set as initial conditions in the time moment t=0. Present profiles come from the solution of the appropriate stationary problem.

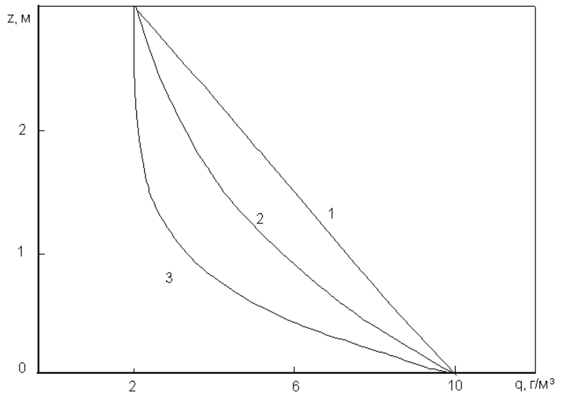

Fig. 3. Humidity computed results at various meteorological conditions
(curve 1- k=0,05 m^2/s, W=0 m/s;
curve 2- k=0,15 m^2/s, W=0,1 m/s;
curve 3- k=0,05 m^2/s, W=0,1 m/s).

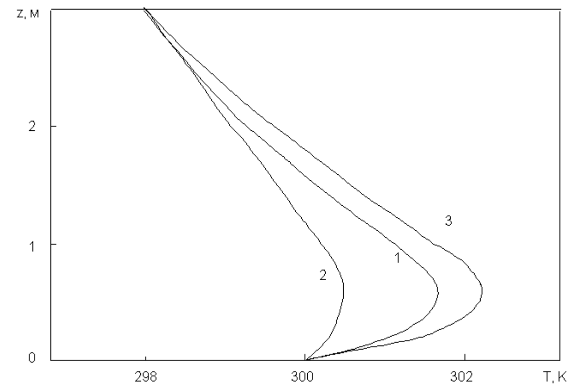

Fig. 4. Temperature computed results at various meteorological conditions
(curve 1- k=0,05 m^2/s, W=0 m/s;
curve 2- k=0,15 m^2/s, W=0,1 m/s;
curve 3- k=0,05 m^2/s, W=0,1 m/s).

Examples of computing for stationary sea surface layer are given at the figures 3-4. For this case conservative finite-difference scheme of equations (1) - (3) solving was built and computing on the basis of iterative processes were made [3].

The analysis of numerical experiment results shows that at small values of turbulent factor we may observe strong temperature inversion up to height of one meter. At turbulent mixing factor increasing temperature inversion decreases. The presence of convective transport increases temperature inversion and scale of its distribution on height. Results of theoretical calculations are good coordinated with the experimental data measured above the sea surface.

References

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