SURFACE LAYER

State of the surface layer has a significant impact on vegetable and animal kingdoms, on the activity and state of humanity as a whole, and on individual people.

All kind of exchange between surface and the atmosphere come about through the surface layer.

(*heat, momentum, water vapor fluxes go through it)*

Processes within the surface layer are different from all other layers of the atmosphere.

Some characteristics of the surface layer

- Surface layer (SL) is greatly influenced by the underlying surface. The latter supplies the SL with heat, water vapor, and admixtures and here the air currents experience the friction effect.
- Meteorological parameters experience variations with time and altitude that are much stronger than in the rest of the atmosphere.

	γ°C/100 m	*Diurnal temperature variation °C*	*Diurnal wind speed variation m/s*
SL	***-2…10***	***0…20***	***6…10***
F. A.	***0,6 – 0,7***	***0…4***	***2…4***

- Inversions are frequent phenomena in the surface layer.
- The most important process in the surface layer is EDDY MIXING.

$$\frac{\partial T}{\partial t} = -\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) - w(\gamma_a - \gamma) + \frac{\partial}{\partial z}K\frac{\partial \theta}{\partial z} + \frac{\varepsilon_r + \varepsilon_{ph}}{c_p}$$

For more clear reasoning, let's assume the following conditions:

no advection

vertical motion close to zero

ε_r=0, fair weather (no water phase transfer)

$$c_p\rho \frac{\partial T}{\partial t} = c_p\rho\frac{\partial}{\partial z}K\frac{\partial \theta}{\partial z}$$

$$c_p\int_0^z \rho\frac{\partial T}{\partial t}dz = c_p\int_0^z \rho\frac{\partial}{\partial z}K\frac{\partial \theta}{\partial z}dz$$

$$c_p\int_0^z \rho\frac{\partial}{\partial z}K\frac{\partial \theta}{\partial z}dz = c_p\int_0^z d\left(\rho K\frac{\partial \theta}{\partial z}\right) = \underbrace{c_p\left(\rho K\frac{\partial \theta}{\partial z}\right)_z}_{Q} \underbrace{- c_p\left(\rho K\frac{\partial \theta}{\partial z}\right)_0}_{Q_0}$$

$$c_p\int_0^z \rho\frac{\partial T}{\partial t}dz = c_p\rho\left|\frac{\overline{\partial}\overline{T}}{\partial t}\right|z = Q - Q_0$$

$$\boxed{Q = Q_0 - c_p\rho\left|\frac{\overline{\partial}\overline{T}}{\partial t}\right|z}$$

Let's define the altitude $z=h$, up to which the ratio $\frac{c_p\rho\left|\frac{\partial\overline{T}}{\partial t}\right|\cdot h}{|Q_0|}=\varepsilon$ remains very small.

For instance ε=0,1

$$c_p\rho\left|\frac{\partial\overline{T}}{\partial t}\right|\cdot h=\varepsilon\cdot|Q_0|$$

$$\boxed{h=\frac{\varepsilon\cdot|Q_0|}{c_p\rho\left|\frac{\partial\overline{T}}{\partial t}\right|}}$$

"***h***" **is altitude of SL**

According to measurements, Q_0=40…250 w/m².

Suppose, temperature variation is 5°C for 12 hours

$$h_1=\frac{0{,}1\cdot 40\cdot 12\cdot 3600}{1005\cdot 1{,}25\cdot 5}\approx 28m$$

$$h_2=\frac{0{,}1\cdot 250\cdot 12\cdot 3600}{1005\cdot 1{,}25\cdot 5}\approx 172m$$

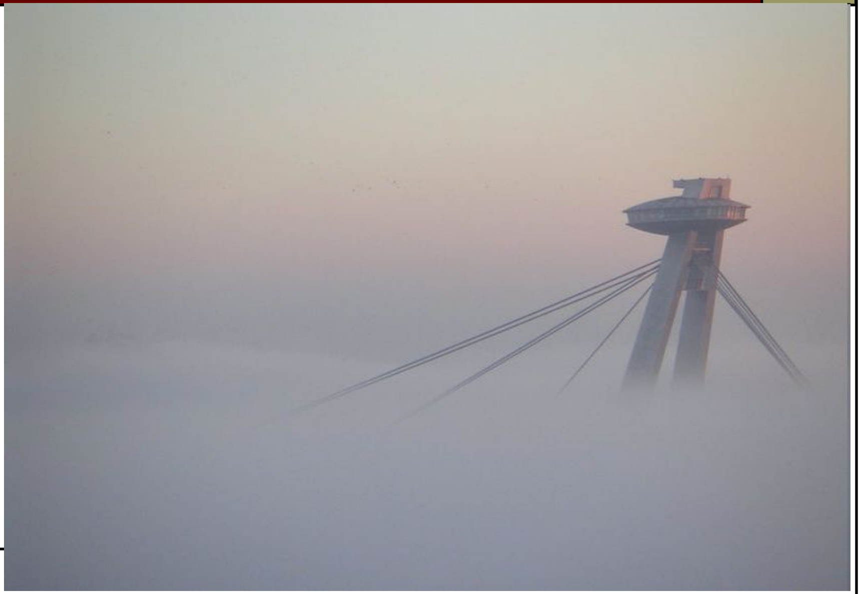
From the previous discussion we know

$$Q = Q_0 - c_p \int_0^z \rho \left| \frac{\partial T}{\partial t} \right| dz$$

The layer 0 – Z is relatively small. Therefore, within this layer temperature variation has the same sign at any altitude. It means that Z increase results in increase the integral too, and at Z<h the integral can not exceed the product $|Q_0| \cdot \varepsilon$

Thus, within the layer 0 – h $Q \approx Q_0$. The error will not be more than 10%

Temperature profiles in the surface layer



the New Bridge, Bratislava, Slovakia; Temperature inversion; 11 Nov 2005

Author: --Ondrejk 23:33, 21 Mar 2005 (UTC)

- eddy coefficient k grows up with z in the surface layer
- assume there's linear growth of k:

$$k = k_0 + az \qquad (13.5)$$

k_0 is k value at $z = 0$

$a = const$ determining k increase with altitude

Let's multiply both parts of (13.4) by *dz*

$$-C_p \rho k \frac{\partial \Theta}{\partial z} = Q_0 \qquad (13.4)$$

$$-C_p \rho k \frac{\partial \Theta}{\partial z} dz = Q_0 dz \qquad or \qquad -\frac{\partial \Theta}{\partial z} dz = \frac{Q_0}{C_p \rho} \frac{dz}{k_0 + az}$$

$$Since \quad \frac{\partial \Theta}{\partial z} dz = d\Theta, \quad -d\Theta = \frac{Q_0}{C_p \rho} \frac{dz}{k_0 + az} \qquad (13.6)$$

Let’s integrate (13.6) from z=0 ($\Theta = \Theta_0$) to arbitrary chosen z

$$\Theta(z) = \Theta_0 - \frac{Q_0}{C_p \rho_0 a} \ln \frac{k_0 + az}{k_0} \qquad (13.7)$$

we adopted that $\rho = \rho_0 = const$

(13.7) is a logarithmic law of air temperature distribution in the surface layer.

As known

$$\Theta(z) = T(z) + \gamma_a z$$

(13.7) can be rewritten as

$$T(z) = T_0 - \frac{Q_0}{C_p \rho_0 a} \ln \frac{k_0 + az}{k_0} - \gamma_a z \qquad (13.8)$$

- T_0 is measured just at the surface (significant inaccuracy). Let's reduce such errors (13.8 for $z=z_1$):

$$T_1 = T_0 - \frac{Q_0}{C_p \rho_0 a} \ln \frac{k_0 + az_1}{k_0} - \gamma_a z_1 \qquad (13.9)$$

$$T_0 = T_1 + \frac{Q_0}{C_p \rho_0 a} \ln \frac{k_0 + az_1}{k_0} + \gamma_a z_1$$

substitute in (13.8)

$$T(z) = T_1 - \frac{Q_0}{C_p \rho_0 a} \ln \frac{z}{z_1} - \gamma_a (z - z_1) \qquad (13.10)$$

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- sign of temperature variation with height depends on sign of heat flux Q_0
- *the air temperature* ***decreases*** *with height at*

$$Q_0 > 0$$

- *the air temperature* ***increases*** *with height at*

$$Q_0 < 0$$

Some empirical studies have shown that logarithmic law describes *T(z)* more or less correctly at **neutral stratification** when $\gamma \rightarrow \gamma_a$

- coefficient k_0 can be expressed with **roughness parameter z_{00}**

$$k_0 = a z_{00} \qquad (13.11)$$

- substituting (13.11) into (13.10):

$$T(z) = T_1 - \frac{Q_0}{C_p \rho_0 a} \ln \frac{z + z_{00}}{z_1 + z_{00}} - \gamma_a (z - z_1) \qquad (13.12)$$

$$T(z) = T_1 - \frac{Q_0}{C_p \rho_0 a} \ln \frac{z}{z_1} - \gamma_a (z - z_1)$$

$$\gamma \approx \gamma_a$$

order of magnitude Z_0
(snow,grass,water,desert) 10^{-2}m,
(forest,town,broken terrain) $10^{0} \ldots 10^{-1}$ m.
We may neglect Z_0 at $z, z_1 > 1\ m$.

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