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CLASSIFICATION OF FOEHNS AND THEIR NUMERICAL MODELING

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Abstract. Genesis of Foehns is in detail investigated. They are classified on dryadiabatic, mostadiabatic and most-dryadiabatic Foehns. A problem about numerical modeling of Foehns in frame of a flat, two-dimensional mesoscale boundary layer is stated. The problem is at a stage of numerical realisation. The first encouraging results are received.

Keywords and phrases: Foehn, numerical model, dry- and mostadiabatic gradients.

AMS subject classification: 60H10, 60H3X.

In meteorology there is a well-known term Foehn. It is a wind, as a rule, descending and, often, dry wind bearing heat. He plays an active role in a number of mesometeorological processes: atmosphere thermohydrodynamics, fog-and cloudformation, agro-and ecometeorology, hothouse effect, desertification processes; its account is actual at city, rural, resort and industrial planning; it is possible also to carry out active influence on it [1-5].

In research of Foehns (forecasting, influence of separate meteoelements, active influence)their numerical modeling can play an irreplaceable role.

Let's briefly review the mechanism of Foehn formation. It is known, that at descending dry air heats up according to dryadiabatic gradient $\gamma_a = 0.01°\text{C/m}$. Usually, it is considered air descending from upland ("shelf"), i.e. from mountain in a valley.

Here is also traditional definition of the Foehn. Let's consider genesis of the Foehn formation process more fully: beside of air descending we will take into consideration the process of initial stage i.e. air ascending and cloud-precipitation formations.

Case 1. We Will imagine a flow of mountain (height $H = 1000m$) by a dry air. We will admit, at the foot and before a mountain $t_1 = 20°C$. Because of dryadiabatic cooling at top of mountain air will be cooled to $t_H = 10°C$, and at a foot and behind mountain air will heat up dryadiabatic again to $t_2 = 20°C$.

Thus, at a mountain foot (both before and behind it) $t_1 = t_2 = 20°C$. Certainly, behind mountain we have the Foehn.

But if we consider process only behind a mountain, here air heats up from $10°C$ to $20°C$. This traditional kind of the Foehn we named as the dryadiabatic Foehn.

Case 2. At ascending of moist air process goes a little differently: if air reaches condensation level because of phase transformation of water steam takes place cloudformation and allocation of the latent warm of condensation and thereof in parallel to cooling there is air heating. Therefore adiabatic ascending air is cooled not at $1°C$, and at $0.6°C$ on 100m. In that case we deal mostadiabatic cooling of air (i.e. a mostadiabatic gradient $\gamma_m = 0.006°\text{C/m}$). We will underline, that in this case we consider process without formation of precipitations.

Naturally, behind the mountain air will descend on a mostadiabatic curve: $\gamma_m = 0.006°\text{C/m}$

That is, if at a foot before the mountain $t_1 = 20°C$, at top the temperature is more in comparison with a case 1, i.e. $t_H = 14°C$, and behind the mountain again $t_1 = t_2 = 20°C$.

Thus, at mostadiabatic crossing at a foot of mountain temperature identical both behind and before mountain $t_1 = t_2 = 20°C$, i.e. the same, as at dryadiabatic crossing only with that difference, that at mountain top at dryadiabatic crossing t_H is less, than at dryadiabatic crossing.

In that way, at mostadiabatic descing of air from upland the thermal heating will be less, than at dryadiabatic descing. This kind of the Foehn we named as the mostadiabatic Foehn.

If we consider air descending from upland then we can distinguish as dry and mostadiabatic Foehns. We will notice, that neither dry nor mostadiabatic Foehns are not "dry" winds, they bear only warmly on the inclined party (behind mountain). Nevertheless, at a mountain foot (before and behind mountain) the temperature does not vary: $t_1 = t_2$.

Case 3. Let's consider a more difficult scenario: ascending of most air after achievement of condensation level is carried out on a mostadiabatic curve ($\gamma_m = 0.006°$C/m), therefore the cloud is formed, at mountain top the precipitation drops out, and then already dehydrated dry air descending occurs, naturally, on a dryadiabatic curve ($\gamma_a = 0.01°$C/m) because of loss of precipitation.

In this case behind the mountain it had the higher degree of heating, than cooling at ascending (before mountain). As a result $t_2 > t_1$. Here it is valid air heating: both behind mountain, and at a foot (behind and before of mountain). This kind of the Foehn we named as most-dryadiabatic, fig. 1 (figure is resulted only for this case because of the limited volume of the article).

Thus, Foehns can be classified on dryadiabatic (Case 1), mostadiabatic (Case 2) and most-dryadiabatic (Case 3) kinds.

Let's notice, that at mountain crossing by air the Foehn is not always formed - behind mountain there are possible formation of wave movements (in this case there are wave clouds, "cloudy streets"...), external convective movements and high velocity of a running background wind resistances to process of foehnformation; because of high speeds and turbulence behind mountain vortical movements can be formed, etc.

Foehns are often formed at Suram ridge crossing, in the Alps.

Foehns play special role in formation of a Chile climate: along all this state (≈ 7000 km) are stretched Cordilleras (height ≈ 6000 m). The system of brightly expressed most-dryadiabatic Foehns are formed at air crossing from the east on the west (at ridge top precipitation drops out owing to what air ascending on a mostadiabatic curve descends on a dryadiabatic curve) that promotes desertification even for this huge oceanside state.

On table 1 (in of most-dryadiabatic case) air temperature at mountain top at its mostadiabatic ascending, air temperature at a mountain foot at its dryadiabatic descent and a difference of air temperatures behind and before the mountain are obtained at different heights of mountains. It is followed from it, that, for example, air is heated up on 20° at crossing by air of 5000 meter ridges. It is throwing huge energy behind a mountain (actually, the latent warm of condensation). Namely at the expense of it are obtained clouds (especially, convective), tropical cyclones, etc., "the second breath". It is possible to consider, that in atmosphere something is concealed under the pretext of the latent warm of condensation, like a perpetual mobile which should be used.

As to numerical modeling of Foehns we will notice, that in spite of the fact that the two-dimensional model of a mesometeorological boundary layer of atmosphere (MBLA) developed by us is flat, it is possible to simulate Foehn-like processes. It is known, that convections are, basically, of two types: forced and free. In the case of above-stated Foehns at air crossing over mountain we have a forced convection, i.e. the running air stream really forces air to flow over mountain. But at free convection in case of a flat problem we have a similar air ascending and descending, but for other reason, i.e. because of corresponding stratification of atmosphere. All three aforementioned kinds of the Foehn are here again possible. We think, that in this case temperature fields should be more smooth, than in the above-stated Foehns, because ascending and descending streams are spatially located is closer to each other, than in case of forced convection (here between ascending and descending airs we have mountain as a thermal protection).

So, we will consider a two-dimensional (in a plane $x-z$) problem about MBLA. The initial equations, boundary and initial conditions have the following form:

$$\frac{du}{dt}=-\frac{\partial\pi}{\partial x}+\Delta' u, \qquad \frac{d\theta}{dt}+Sw=\frac{L}{c_p}\Phi+\Delta'\theta,$$

$$\frac{\partial\pi}{\partial z}=\lambda\theta, \qquad \frac{dq}{dt}+\gamma_q w=-\Phi+\Delta' q,$$

$$\frac{\partial \mathrm{u}}{\partial \mathrm{x}}+\frac{\partial \mathrm{w}}{\partial \mathrm{z}}=0, \qquad \frac{dv}{dt}=\Phi+\Delta' v,$$

$$\frac{d}{dt}=\frac{\partial}{\partial t}+u\frac{\partial}{\partial x}+w\frac{\partial}{\partial z}$$

where u, w are horizontal and vertical components of air velocity, p, θ, q are deviations of pressure, temperature and water-vapour mixing ratio from their undisturbed fields, respectively, v is liquid-water mixing ratio, other designations are given in [6].

The boundary and initial conditions have the form:

$$at\ \ Z=0 \qquad u=0,\ w=0,\ \theta=F(x,t),\ q=0,\ v=0,\ c=0,$$

where $F(x,t)$ is temperature of MBLA underlying surface:

$$F(x,t)=\begin{cases} 0 & 0\le x\le 32\text{km}, \qquad 48\text{km}<\text{x}\le 80\text{km},\\ 5\sin\omega\text{t} & 32\text{km}\le \text{x}\le 48\text{km},\end{cases}$$

$$\text{at}\ \ z=Z \qquad u=0,\ \ \pi=0,\ \ \vartheta=0,\ \ \frac{\partial q}{\partial z}=0,\ \ \frac{\partial v}{\partial z}=0,\ \ \frac{\partial c}{\partial z}=0,$$

$$\text{at}\ \ x=0,X \qquad \frac{\partial u}{\partial x}=0,\ \ \frac{\partial \vartheta}{\partial x}=0,\ \ \frac{\partial q}{\partial x}=0,\ \ \frac{\partial v}{\partial x}=0,\ \ \frac{\partial c}{\partial x}=0,$$

$$\text{at}\ \ t=0 \qquad u=0,\ \ \vartheta=0,\ \ q=0,\ \ v=0.$$

As the control we result isolines of only vertical velocity of air meteofields $(w,)$ (fig. 2) (to save place) received on the basis of our model for not abnormal, ordinary processes at following parametres: $\mu=10^4 m^2/sec,\ \nu=10m^2/sec,\ f=0.95$. (ascending and descending currents have essential value for Foehns).

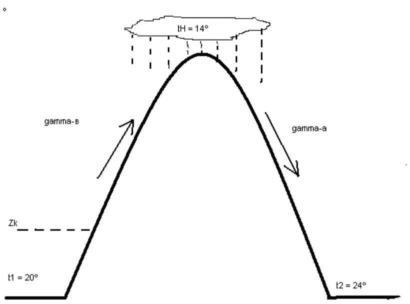

Fig. 1. The most-dryadiabatic Foehn.

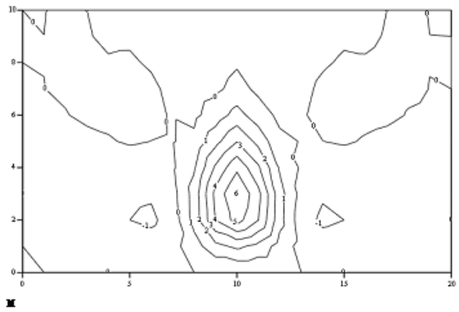

Fig. 2. Isolines of air vertical velocity w (cm/sec), (t=9h).

H m	γ_m ascending $t_H = t_1 - \gamma_m/H$	γ_a descending $t_2 = t_H - \gamma_a/H$	$t_2 - t_1 \circ C$
1000	14	24	4
2000	8	28	8
3000	2	32	12
4000	-4	36	16
5000	-10	40	20

Table 1. Dependence of Foehn elements from height.

For imitation of the most-dryadiabatic Foehn in the moment (t^*), when it is maximum of liquid-water mixing ratio we programmatically remove cloud water, i.e.

$$\text{At} \quad t = t^* \qquad\qquad f = 0,$$

where f is relative humidity.

The first ranging numerical experiments about imitation of most-adiabatic Foehn give encouraging results.

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