A Numerical Experiment of Mesolow on the Eastern Side of the Taihang Mountains

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Received March 4, 1988

ABSTRACT

A numerical experiment on the formation and decay process of a mesolow on the plain east to the Taihang Mountains has been conducted. The dynamical effect of the special topography of the Taihang Mountains and the Yanshan Mountains on the formation of the mesolow is very important. Namely, the difference of the heating between the Taihang Mountains and the North China plain plays an important role in the formation and decay of the mesolow.

I. INTRODUCTION

The mesolow discussed in this paper often occurs on the eastern side of the Taihang Mountains. It is an important synoptic system in North China(Liu et al, 1984). This paper deals with a numerical experiment on the formation and decay process of the mesolow by using Mass and Dempsey's one-level mesoscale model (1985). According to the topographic features of North China, the method of calculation has been modified. The results show that under this special terrain distribution, both the topographic and diabatic forcing play a crucial role in the formation and dissipation process of the mesolow.

II. BRIEF DESCRIPTION

1. *Equations of the Model*

The horizontal momentum equation of the model in sigma coordinates at earth's surface is:

$$\frac{\partial \vec{V}_s}{\partial t} = -\vec{V}_s \cdot \nabla_\sigma \vec{V}_s - f\vec{K} \times \vec{V}_s - (g\nabla_\sigma Z_s + RT_s \nabla_\sigma \ln P_s) + \vec{F} + K_m \nabla_\sigma^2 \vec{V}_s. \tag{1}$$

The model's surface temperature tendency equation can be derived from starting with the first law of thermodynamics:

$$\frac{\partial T_s}{\partial t} = -\vec{V}_s \cdot \nabla_\sigma T_s + \frac{RT_s}{C_p}\left(\frac{\partial \ln P_s}{\partial t} + \vec{V}_s \cdot \nabla_\sigma \ln P_s\right) + \frac{Q}{C_p} + K_t \nabla_H^2 T. \tag{2}$$

Combining the hydrostatic equation with the perfect gas law and integrating between the surface and the reference level gives:

$$\ln P_s = \ln P_r + \frac{g}{R}\int_{Z_s}^{Z_r} \frac{1}{T} dZ. \tag{3}$$

Eqs. (1),(2) and (3) are the model's equations. where $\vec{V}_s$, T_s, P_s and Z_s are the wind vector. temperature, pressure and height at earth's surface; P_r and Z_r are the pressure and height at the reference pressure level. respectively.

2. *The Designing of Numerical Methods*

The area of model running includes the eastern parts of the Taihang Mountains. the southern parts of the Yanshan Mountains and the North China plain (shown in Fig.1a). The cases in this paper is run on a 50 × 50 point grid field using an approximate resolution of 7.5 km. thus the domain covers approximately 375 km × 375 km in area (latitude. 37.5° N–41.5° N. longitude, 113.9° E–118.5° E).

The effects of low–level diabatic forcing which play an important role in the formation and decay process of mesolow are parameterized by introducing a term into the surface temperature tendency equation (2).

The frictional force in the boundary layer (F) can be expressed as the vertical divergence of the stress S:

$$\vec{F} = -\frac{1}{\rho}\frac{\partial \vec{S}}{\partial Z},$$

where ρ is density. At the surface the stress can be parameterized by a drag law:

$$\vec{S}_s = \rho C_d \vec{V}_s |\vec{V}_s|,$$

where C_d is the drag coefficient having the different values in mountains, plain and sea areas. And $\vec{V}_s$ is the surface wind vector; above the boundary layer $\vec{S}$ can be neglected. If a linear stress profile in which stress vanishes at the top of the boundary layer is assumed, the frictional forcing in the boundary layer can be estimated as:

$$\vec{F} = -\frac{1}{\rho}\left(\frac{\vec{S}_H - \vec{S}_s}{H}\right) = \frac{C_d \vec{V}_s |\vec{V}_s|}{H}.$$

III. A CASE STUDY

The model runs a real case on November 10. 1980. The integration begins at 8 pm and ends at noon the next day. The reference pressure level is 850 hPa. The model is first integrated to a steady state without diabatic forcing.This step only has topographic forcing. After several hours running. a minor north–south extended dynamical trough occurs on the eastern side of Taihang Mountains (see Fig.1a). The model is then run to the verification time with the varying diabatic forcing—cooling and heating(see Orlanski et al,1974).The amplitude and duration of diabatic forcing is assigned by first examining the actual surface temperature variations at observing station within the domain for the period preceding the verification time.The temperature variations of Zhangjiakou,on the Taihang Mountains and Beijing. on the North China plain, are chosen to represent the whole mountain area and the North China plain, respectively. The amplitude of cooling over the mountains is larger than that over the plain. After several hours running, a closed cyclonic circulation appears in Beijing area(see Fig.1b). The longer the model runs, the stronger the close cyclonic circulation is. Then we change the cooling to heating. In this step, the amplitude of heating over the mountains is larger than that over the plain. After several hours running, a closed mesolow appears on the North China(see Fig.2a) and the closed cyclonic circulation disappears(see Fig.2b). This result is somewhat similar to the actual synoptic process. It indicates that Mass and Dempsey's model can be employed to describe the formation and decay process of the mesolow.

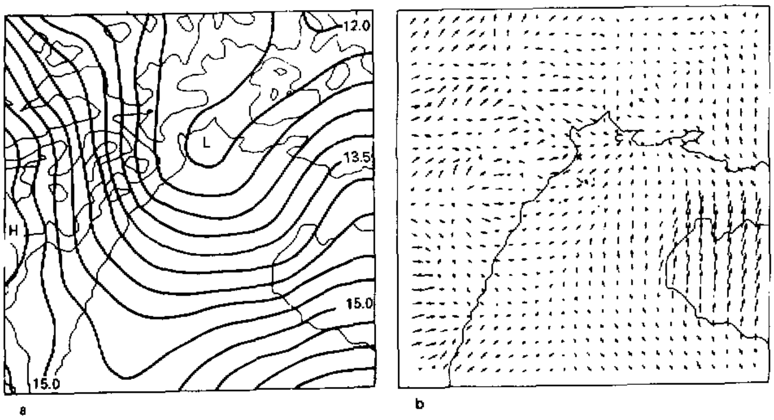

Fig.1. (a) : A dynamical trough on the eastern side of the Taihang Mountains caused by the effect of topographic forcing. (b): A closed cyclonic circulation on the eastern side of the Taihang Mountains caused by the effect of topographic and diabatic forcing(cooling). Heavy solid line: isobar in hPa (e.g.15.0 = 1015.0 hPa). Solid line: coastline,contourline (50 m, 500 m, 1000 m.......).

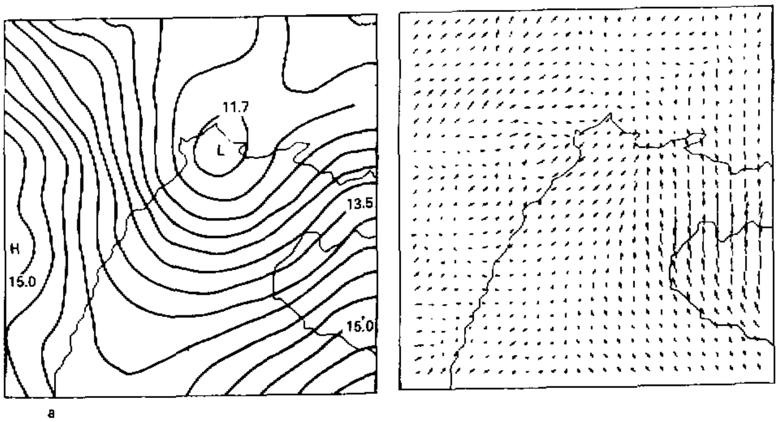

Fig.2. The surface pressure and flow fields caused by the effect of topographic and diabatic forcing(heating) (a): The mesolow on the eastern side of the Taihang Mountains. (b): The cyclonic circulation is disappeared. Solid line: Contourline(50 m) and coastline,other explanations as indicated in Fig.1.

IV. SOME NUMERICAL EXPERIMENTS ON THE FORMATION AND DISSIPATION PROCESS OF THE MESOLOW

In order to understand the effect of topography, the basic flow at the top of the boundary layer and diabatic forcing on the formation and decay process of the mesolow, we give an ideal flow and run experiments by modifying the flow as follows:

1. *Two Kinds of the Effects of Basic Flow at the Top of the Boundary Layer on the Formation and Dissipation Process of the Mesolow*

In this domain, the Taihang Mountains and the Yanshan Mountains stretch in different directions. The flow passing over the mountain is more favourable for the formation of the mesolow whenever the angles between the basic flow and the contours of elevation of these two mountains are larger.

When the basic flow over the eastern side of Taihang Mountains has obvious divergence or cyclonic curve, the mesolow would be formed by the effect of topographic forcing only, and will be very strong with no evident daily variation and vice versa.

2. *The Effects of Diabatic Forcing on the Mesolow*

The different diabatic forcing of the mountains and the plains is very important to the formation and dissipating of the mesolow.

In the experiments, the model runs with several diabatic parameters. The result suggests that the larger the difference of two cooling rates between the mountains and the plain, the easier the closed cyclonic circulation formation. The reason is that the temperature drops in the mountains more quickly than that at the same height over the plain,thus the extra flow (mountain breeze) is formed to the plain from the mountains. This flow would increase the positive vorticity over the plain. It is favourable for the formation of the closed cyclone.

On the contrary, the larger the difference of two heating rates between mountains and plain, the easier the dissipation of closed cyclone.

3. *The Relationship between Cold Advection and Mesolow*

The model runs several different basic flow field of cold advections. When the cold advection is weak, the mesolow would be formed easily. On the contrary, the mesolow does not appear, and even if the mesolow forms, the strong cold advection would destroy it.

We are indebted to Dr. David P. Dempsey and Prof. Sun Shuqing for their support to this work.

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