EGS XXIV - Den Haag - April 1999
Session OA11 Developments in Dynamic Meteorology

A Semi-Geostrophic Model of Frontal Interaction with Isolated Orography

Maurizio Fantini
Silvio Davolio
Piero Malguzzi

ISAO* - CNR Bologna Italy

*formerly FISBAT

Advantages:

- 2D Eady wave is a non linear solution
- Realistic frontal structure

Disadvantages:

- Linearized mountain
- “Slight” inconsistency

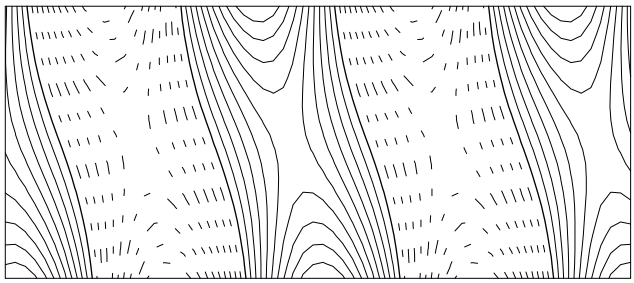
$$X = x + v_g/f_o$$

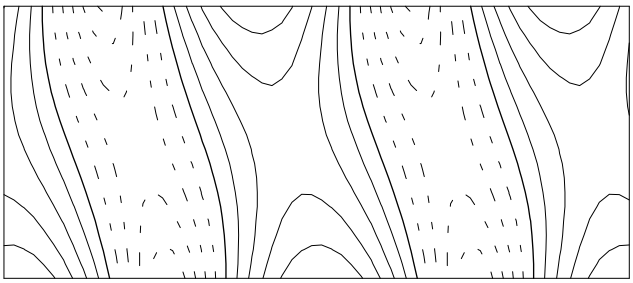
$$Y = y - u_g/f_o$$

$$Z = z$$

$$T = t$$

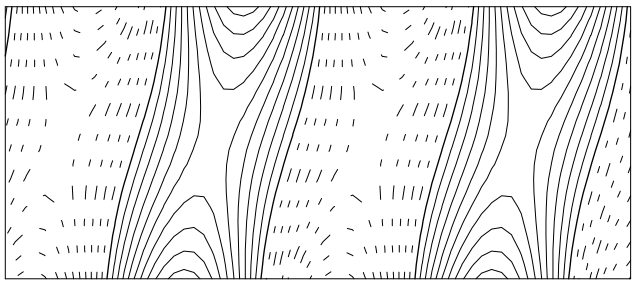
$$\Phi = \phi + \frac{1}{2}\left(u_g^2 + v_g^2\right)$$

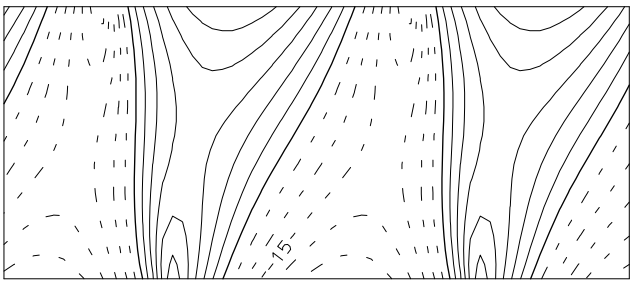




2-D Eady wave. Analytic solution at any amplitude.

Made to interact with linearized mountain ($w = \vec{u} \cdot \nabla h$ at z=0)





Equation for mountain-induced perturbation Φ^M

$$\Phi^M_{XX} + \Phi^M_{YY}\left(1 - \frac{1}{f_o^2}\Phi^E_{XX}\right) + \frac{f_o^3}{Q_B}\Phi^M_{ZZ} = 0$$

with boundary conditions:

$$\Phi^M_{ZT} + U\Phi^M_{ZX} + \frac{1}{f_o}\Phi^E_X\Phi^M_{ZY} -$$

$$\frac{1}{f_o}\Phi^M_Y\Phi^E_{XZ} - \Phi^M_X\frac{U}{H} = 0 \quad \text{(at} \quad Z = H)$$

$$\Phi^M_{ZT} - \Phi^M_Y\frac{1}{f_o}\Phi^E_{XZ} + \frac{1}{f_o}\Phi^E_X\Phi^M_{ZY} -$$

$$\frac{U}{H}\Phi^M_X + \left(\frac{Q_B}{f_o} + \Phi^E_{ZZ}\right)w_h = 0 \quad \text{(at} \quad Z = 0)$$

w_h given by interaction of 2D Eady wave Φ^E with topography

$$w_h = -\frac{\phi^E_y}{f_o} h_x + \frac{\phi^E_x}{f_o} h_y \qquad \text{(physical space)}$$

$$w_h = h_T + \frac{1}{f_o} \Phi^E_X h_Y \qquad \text{(geostrophic space)}$$

$$w_h = -\frac{1}{f_o^2} \Phi^E_{XT} h_x + \frac{1}{f_o} \Phi^E_X h_y \qquad \text{(mixed)}$$

Consistency condition

$$\left[\int\int \Phi_Z^M dX dY\right]_{Z=0}^{Z=H} = 0$$

At $Z = H$:

$$\partial_T \int\int \Phi_Z^M dX dY = 0$$

At $Z = 0$:

$$\partial_T \int\int \Phi_Z^M dX dY = -\int\int \left(\frac{Q_B}{f_o} + \Phi_{ZZ}^E\right) w_h dX dY$$

Length of primary wave: 5000 km

Static Stability: $1.5 \cdot 10^{-2}$ s^{-1}

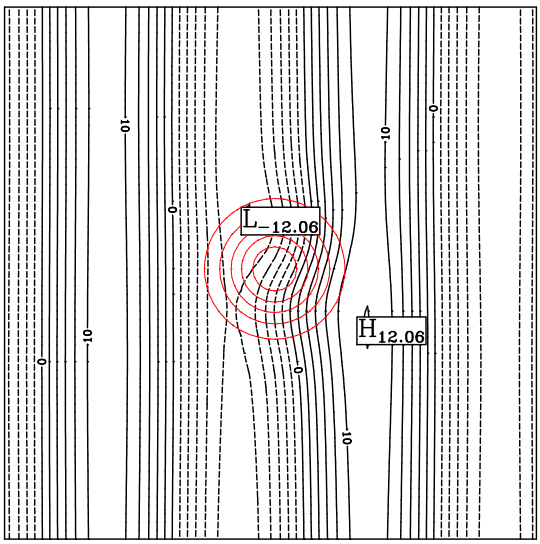
Mean Vertical Shear: $2 \cdot 10^{-3}$ s^{-1}

Mountain height: 1500 m

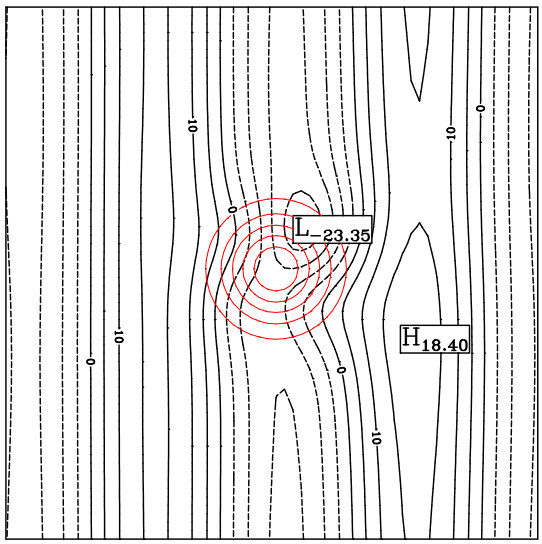
Mountain half-width: 1000 km

Domain size: $10000 \times 10000 \times 10$ km

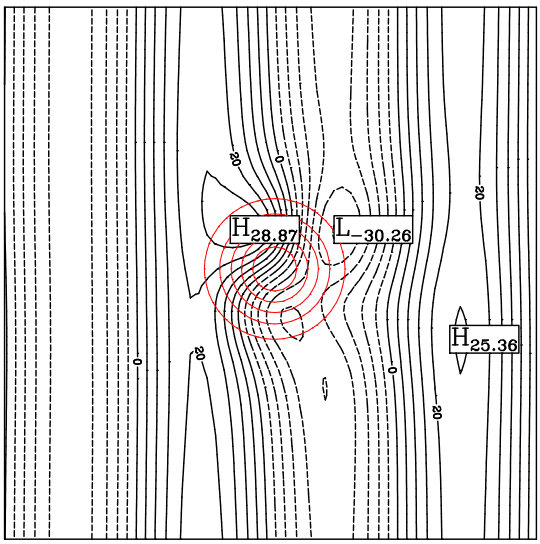
Small initial amplitude (10 Pa)



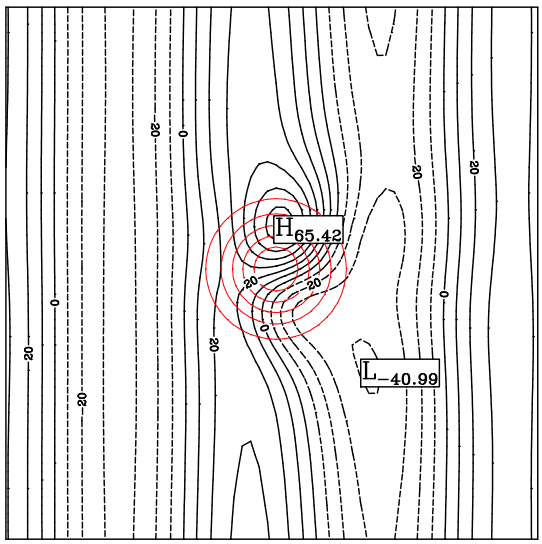
Time=$3 \cdot 10^4$ s



Time=$12 \cdot 10^4$ s



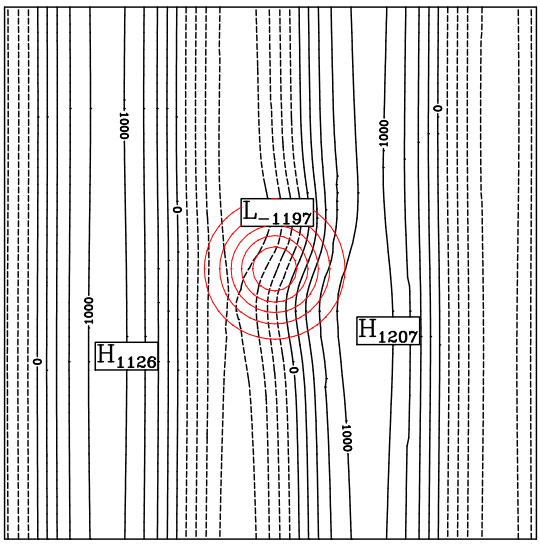
Time=$21 \cdot 10^4$ s



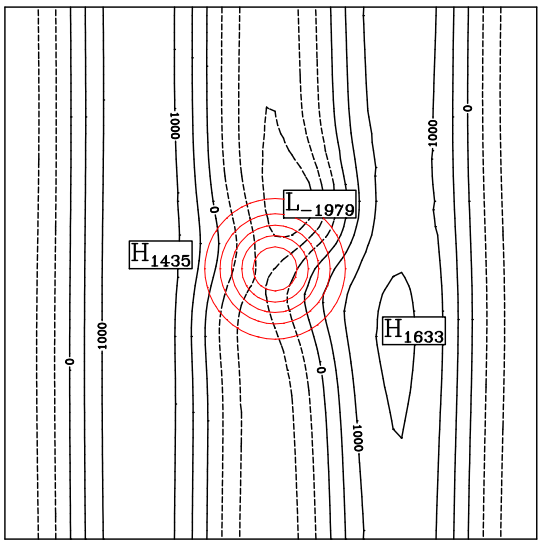
Time=$30 \cdot 10^4$ s

Large initial amplitude (1000 Pa)

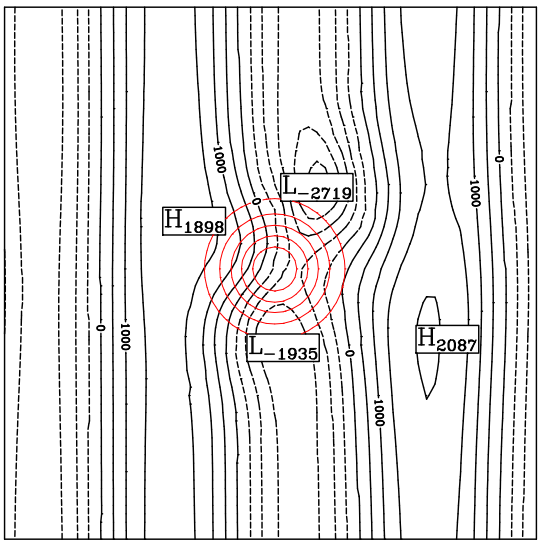
Surface Pressure



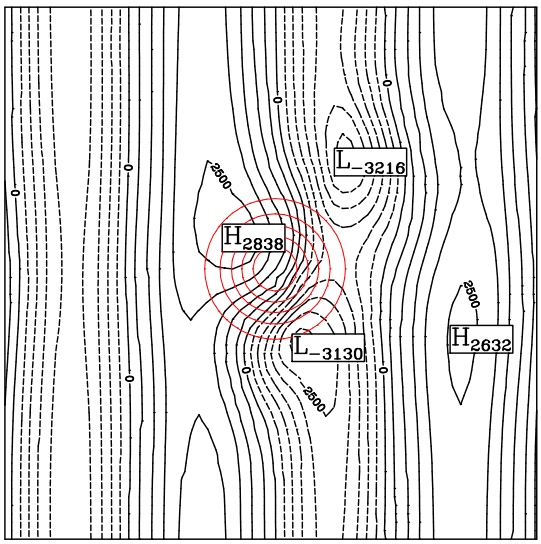
Time=$3 \cdot 10^4$ s



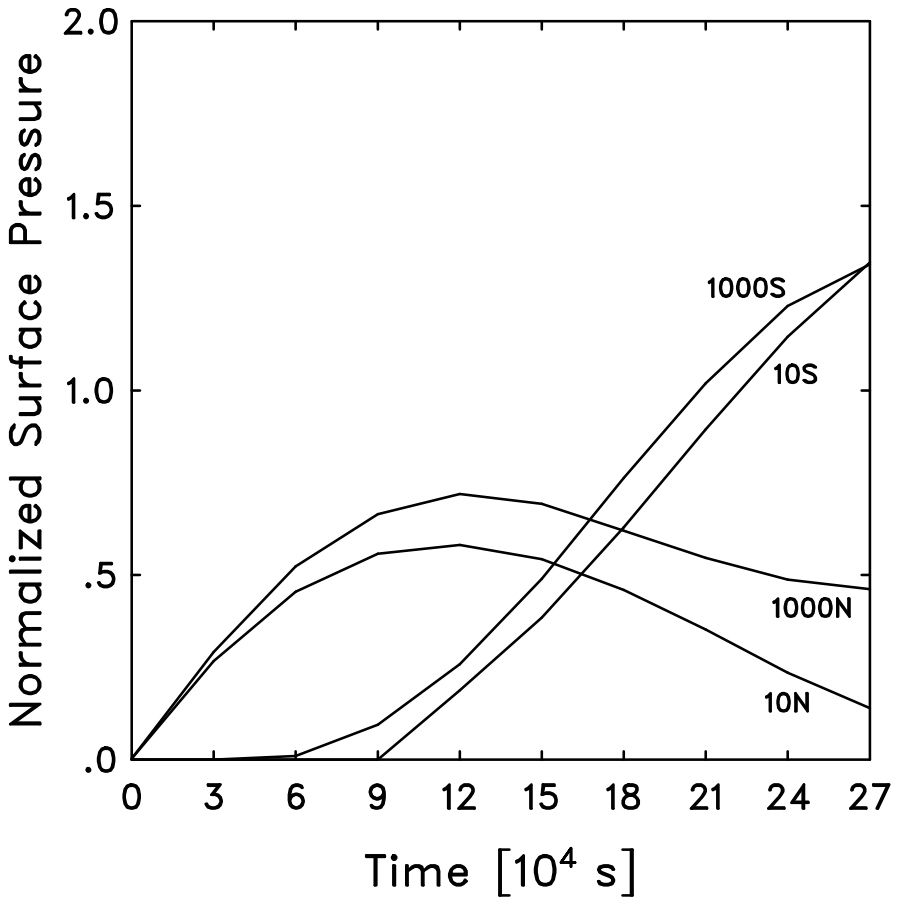
Time=$9 \cdot 10^4$ s



Time=$15 \cdot 10^4$ s

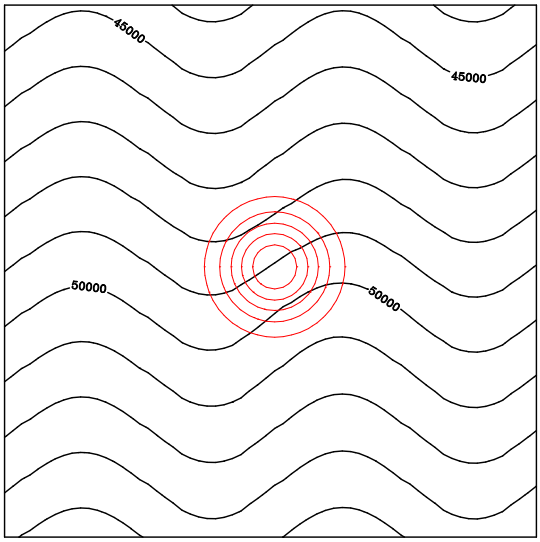


Time=$21 \cdot 10^4$ s

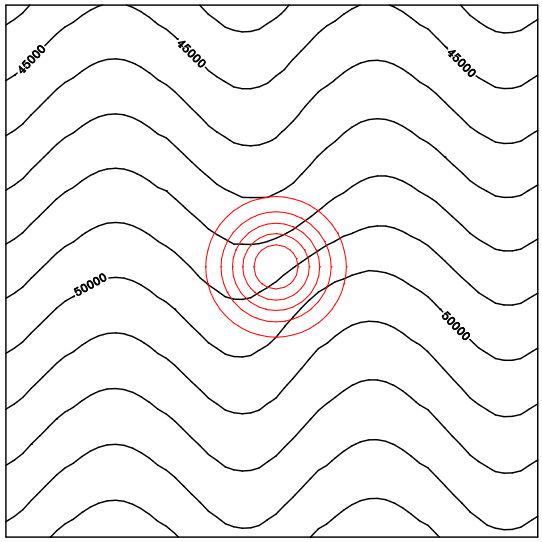

2.0
1.5
1.0
.5
.0
Normalized Surface Pressure
0
3
6
9
12
15
18
21
24
27
Time [10^4 s]
1000S
10S
1000N
10N

Large initial amplitude (1000 Pa)

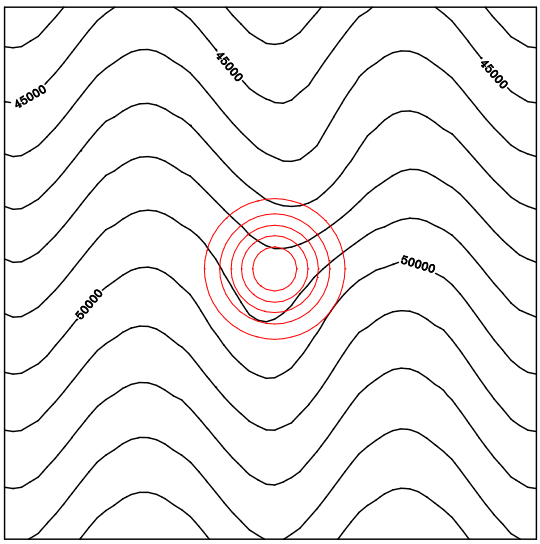
Pressure at 5 km



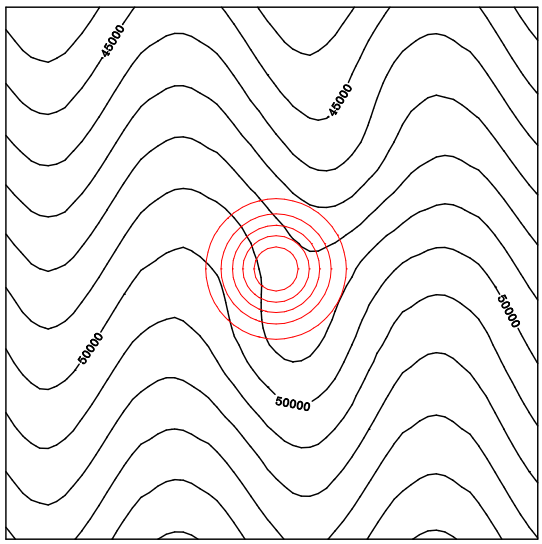
Time=$3 \cdot 10^4$ s



Time=$9 \cdot 10^4$ s



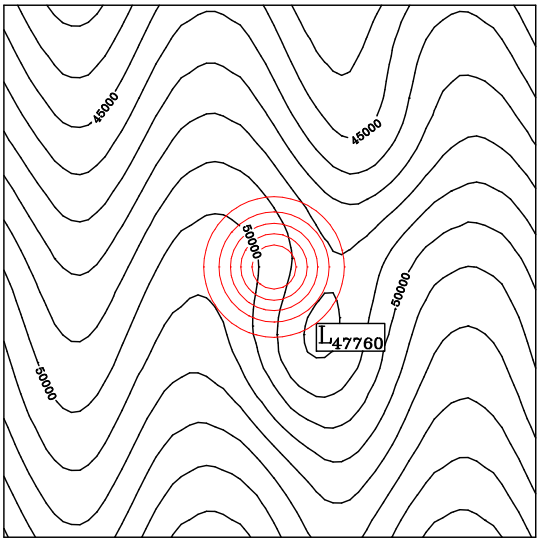
Time=$15 \cdot 10^4$ s



Time=$21 \cdot 10^4$ s

Large initial amplitude (1000 Pa)

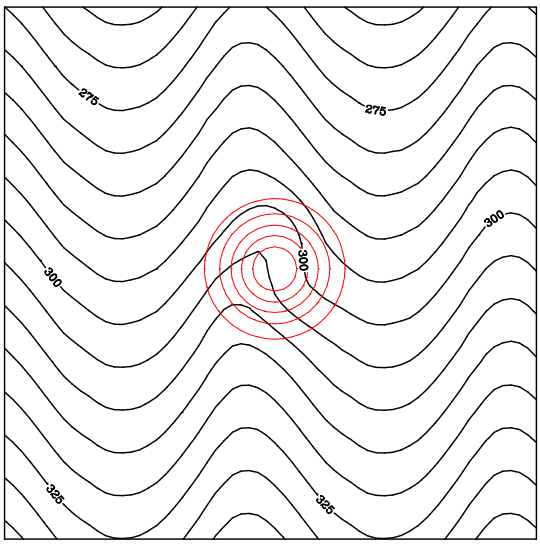
Pressure at 5 km



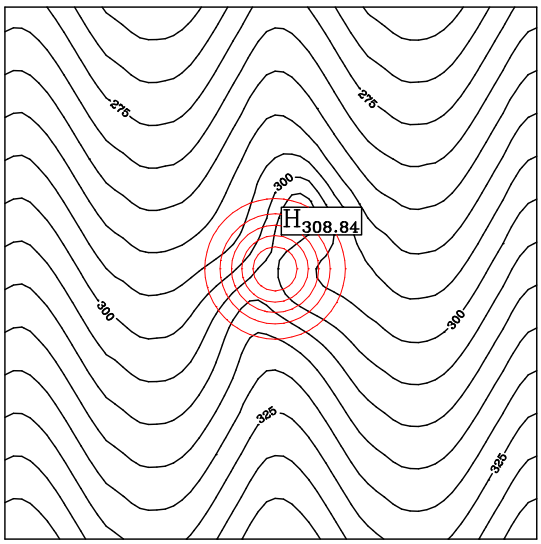
Time=$27 \cdot 10^4$ s

Large initial amplitude (1000 Pa)

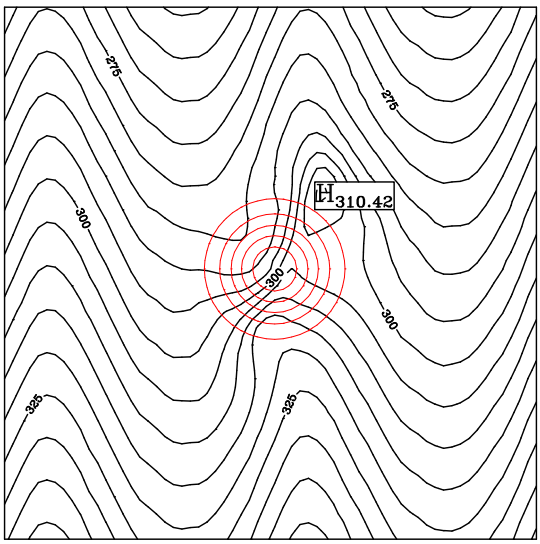
Surface Temperature



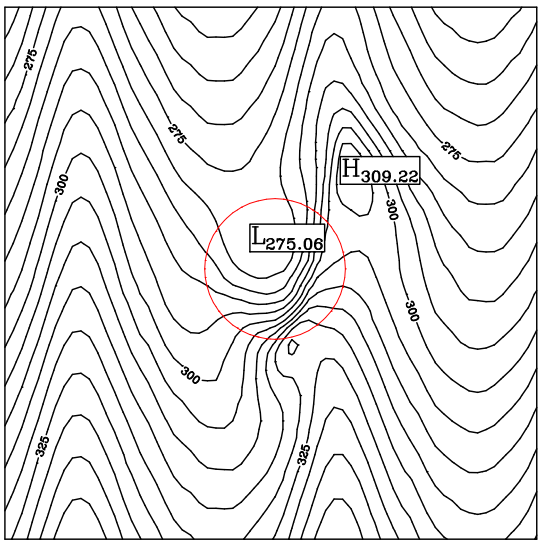
Time=$3 \cdot 10^4$ s



Time=$9 \cdot 10^4$ s



Time=$15 \cdot 10^4$ s



Time=$21 \cdot 10^4$ s

Future Directions:

- Elongated mountain
- Change relative orientation of front, mean wind, and mountain axis
- Terrain following coordinates
- Use the Primitive Equations

Work supported by
EU contract ENV4-CT96-0332
HERA