Oscillating motions in the stable atmosphere of a deep valley

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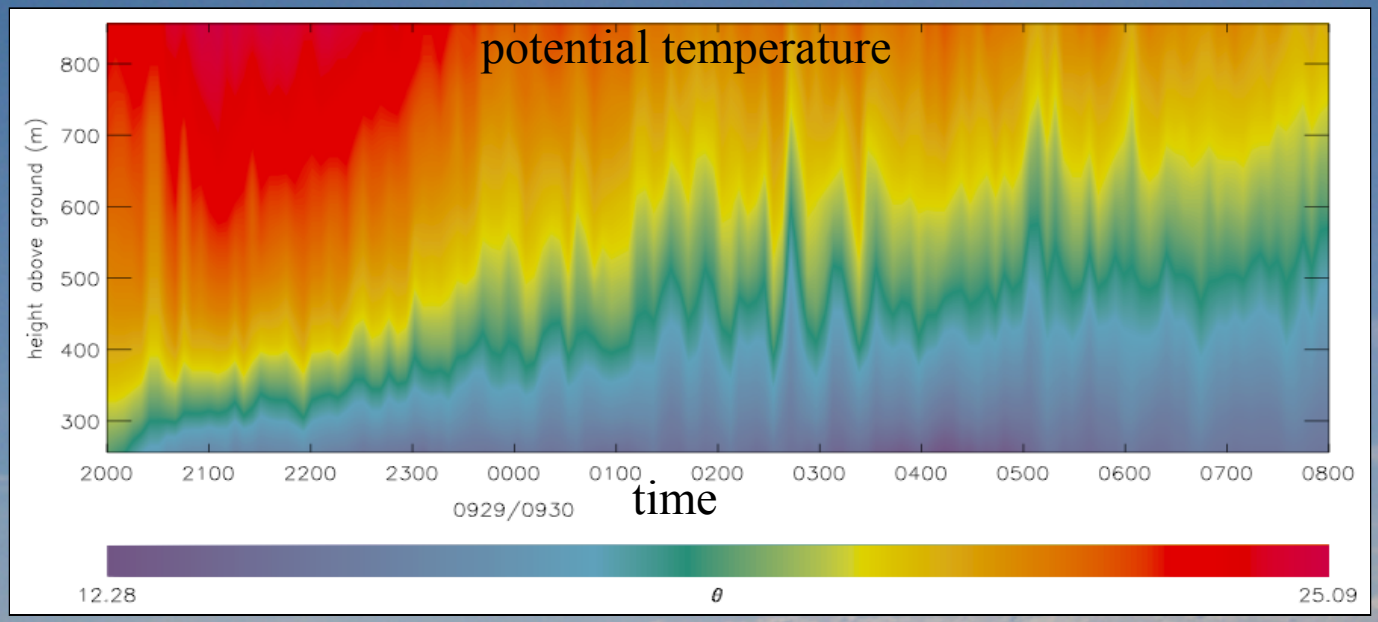
Katabatic wind

After sunset the ground surface cools (infra-red emission)
→ formation of a cold layer of air along the sloping surface
→ this cold layer flows down by gravity

Oscillations?

altitude

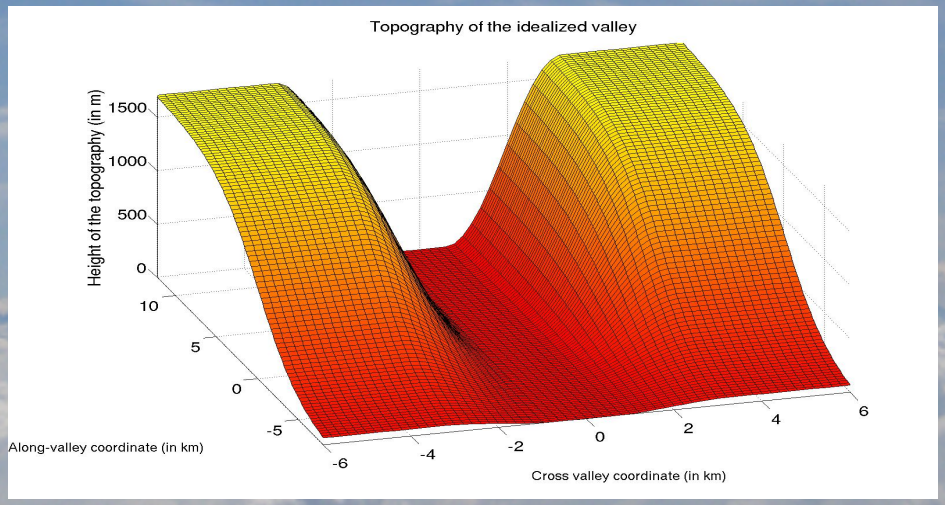


Van Gorsel et al. 2003 (Mesoscale Alpine Program, Riviera valley, Swit.)

Oscillations in the katabatic wind?
Internal gravity waves?

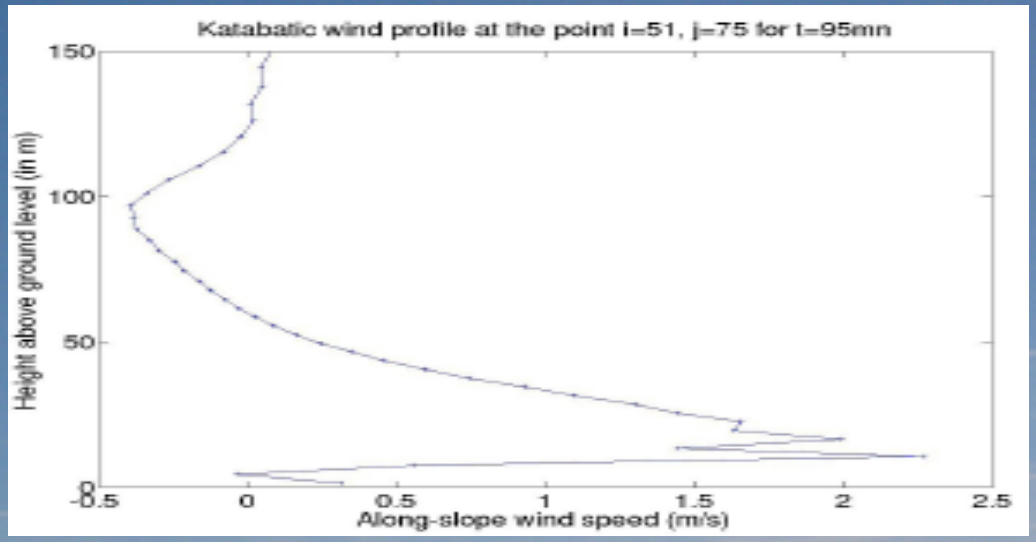
Numerical simulations

- ARPS code (Advanced Regional Prediction System)
- Idealized 3D topography
- Constant temperature gradient (8 runs: from 2 K/km to 15 K/km)
- $T_{air} - T_{ground} = 3^{o}$
- Soil model



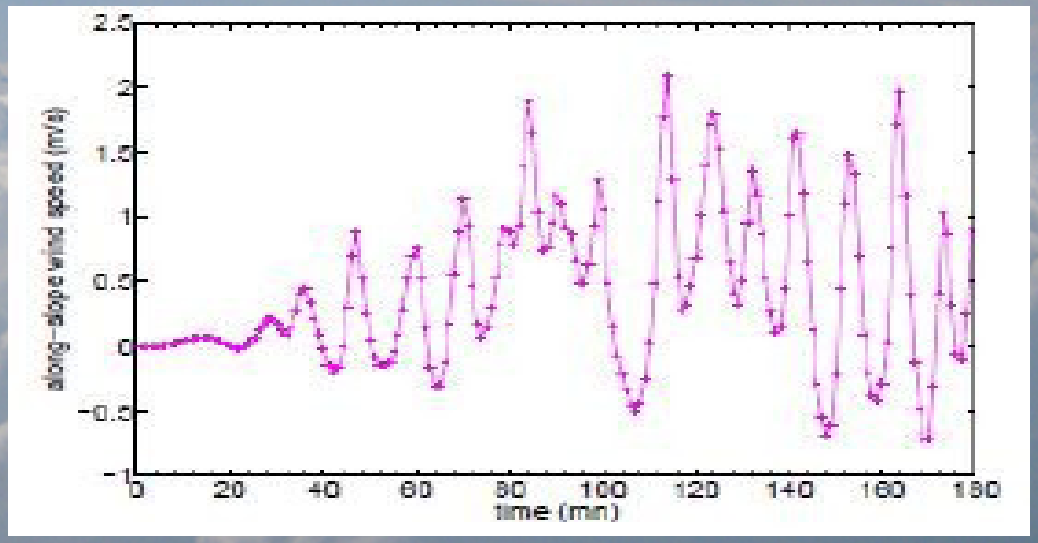
- 61 (x) x 103 (y) x 140 (z) grid points
- Horiz. resolution: 200 m, vert. resolution : 5 m (bottom)
- Computation starts at 22:00 on dec. 21st (45^{o} latitude)

Oscillations in the katabatic wind



Along-slope velocity versus coordinate normal to the slope

Along-slope velocity versus time

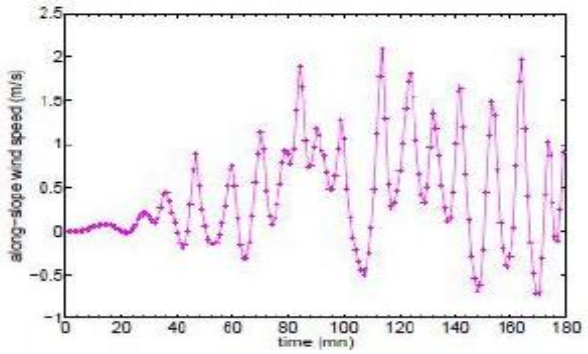


Oscillations in the katabatic wind

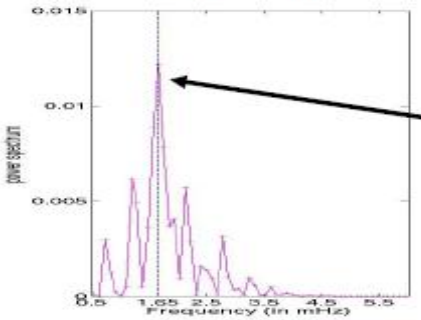
Mechanism of oscillations: the katabatic wind flows down into a stable medium (while being continuously cooled by the ground)

Fluid particle model of McNider (1982) for a simple slope α in a constant N fluid: **oscillations of the wind velocity at frequency N sin(α)**

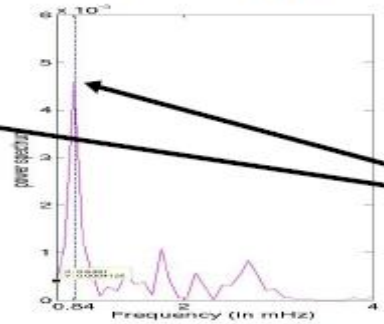
Along-slope velocity at a given location in the katabatic wind



Steep slopes



Weak slopes



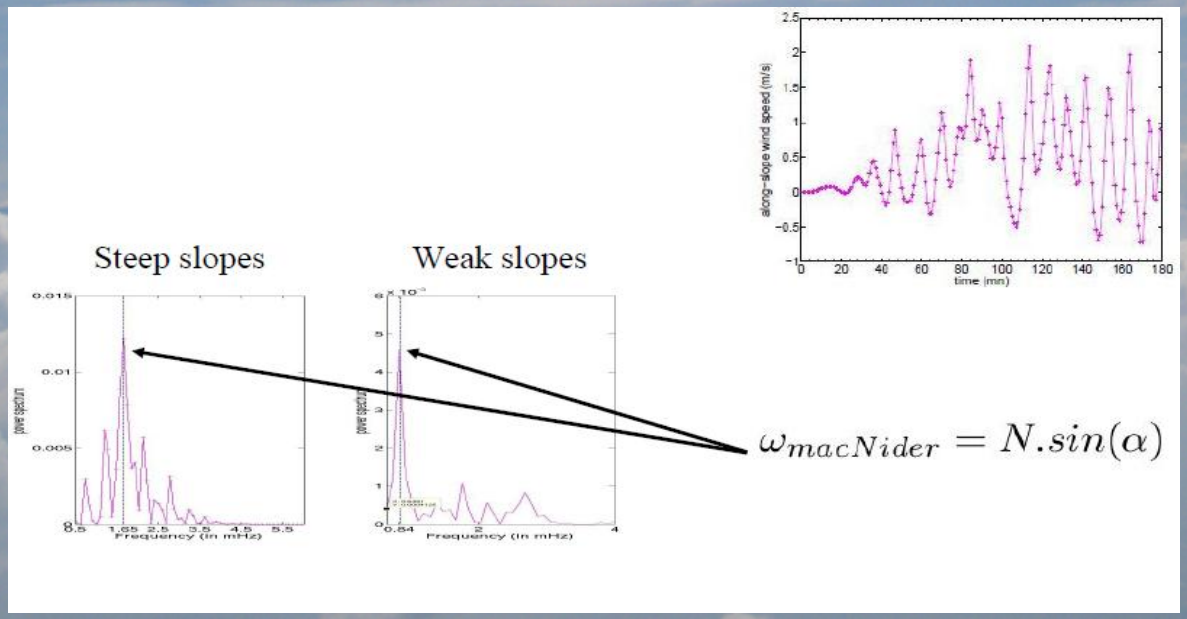
$$\omega_{macNider} = N.sin(\alpha)$$

Results consistent with in situ measurements (e.g. Gryning et al. 85, Helmis & Papadopulos 96, Monti et al. 02)

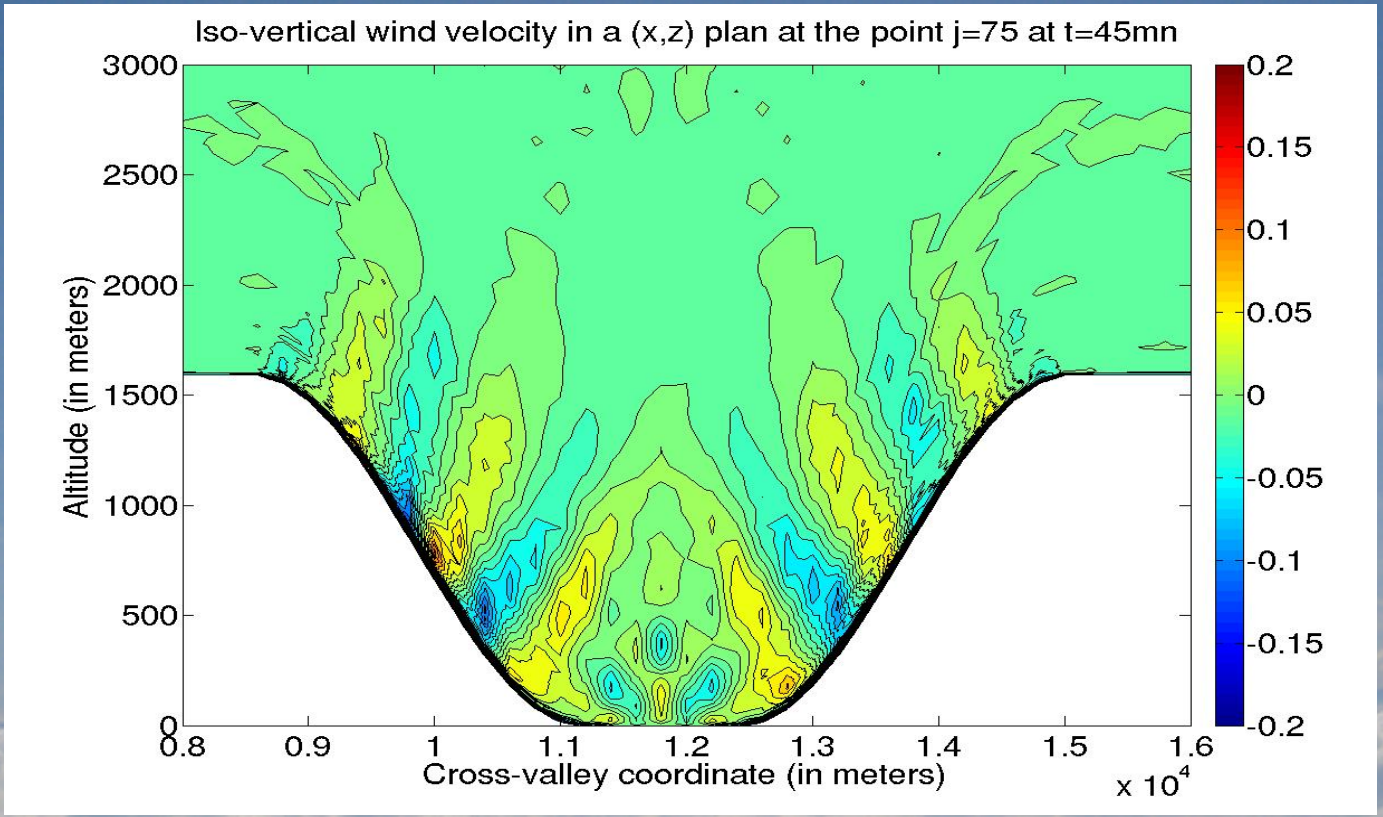
Oscillations in the katabatic wind

Could these oscillations of frequency N sin(θ) be associated with waves whereof group velocity is along the slope?

We found no phase propagation in the katabatic wind : these oscillations are temporal oscillations only



Emission of internal gravity waves

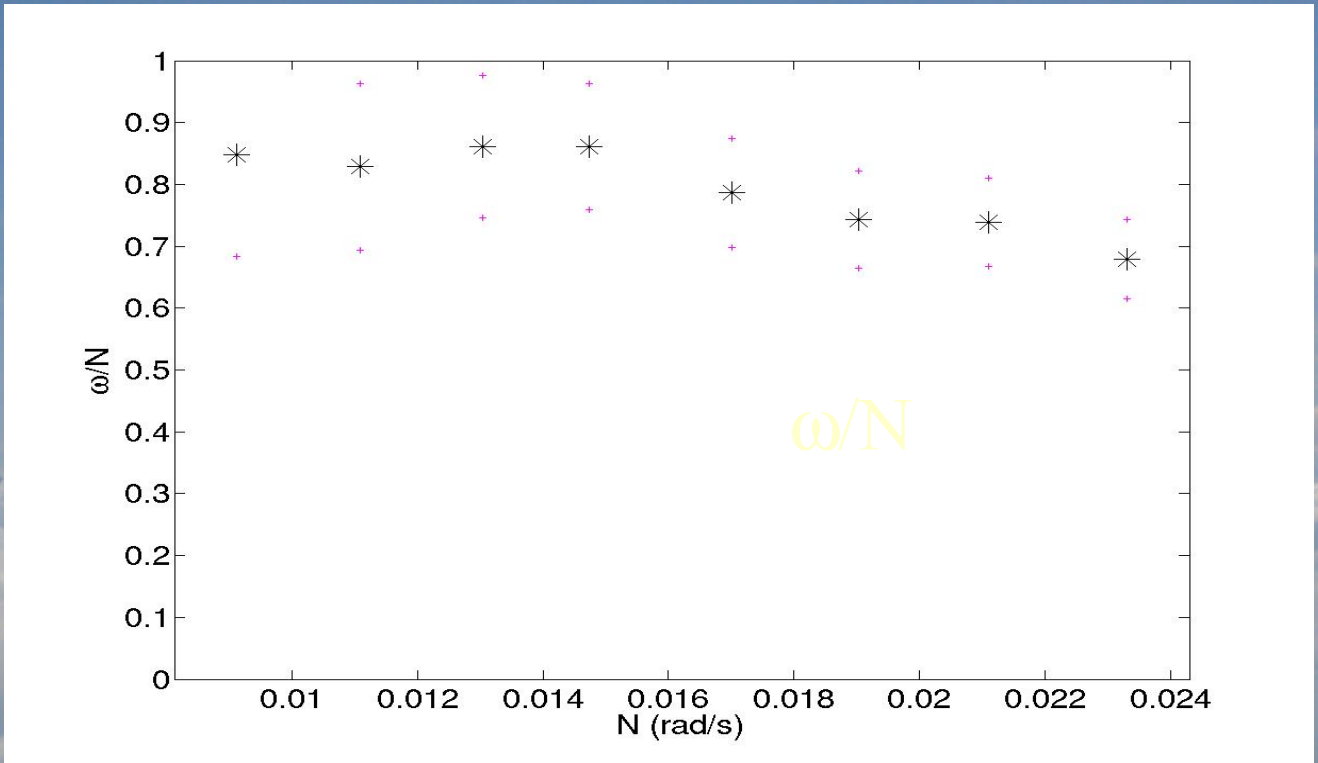


Phase lines of *w* in (x,z) plane at t=45 min.

Same inclination along the slope : the wave frequency does not depend upon the slope angle.

Emission of internal gravity waves

Frequency of the wave field
(ω/N averaged along the valley axis, versus N)



$0.7 \leq \omega/N \leq 0.9$

cf. Wu 69, Cerasoli 78, Sutherland & Linden 02, Jacobitz & Sarkar 02, Dohan & Sutherland 03

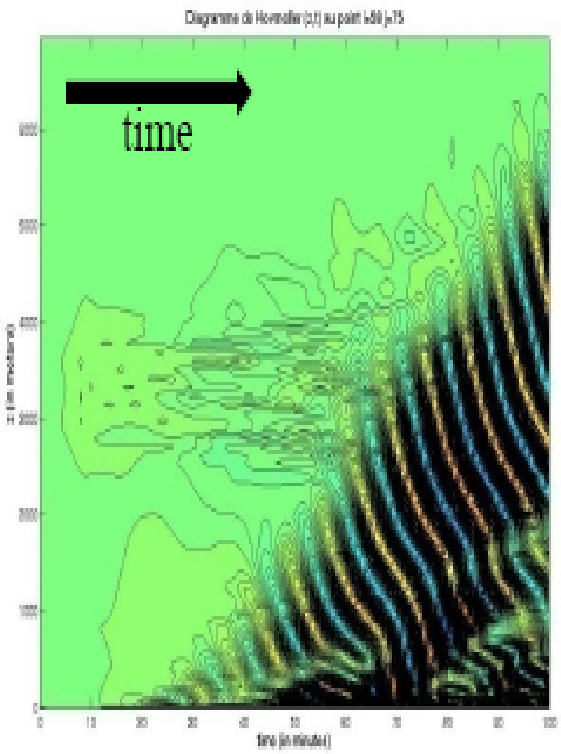
Emission of internal gravity waves

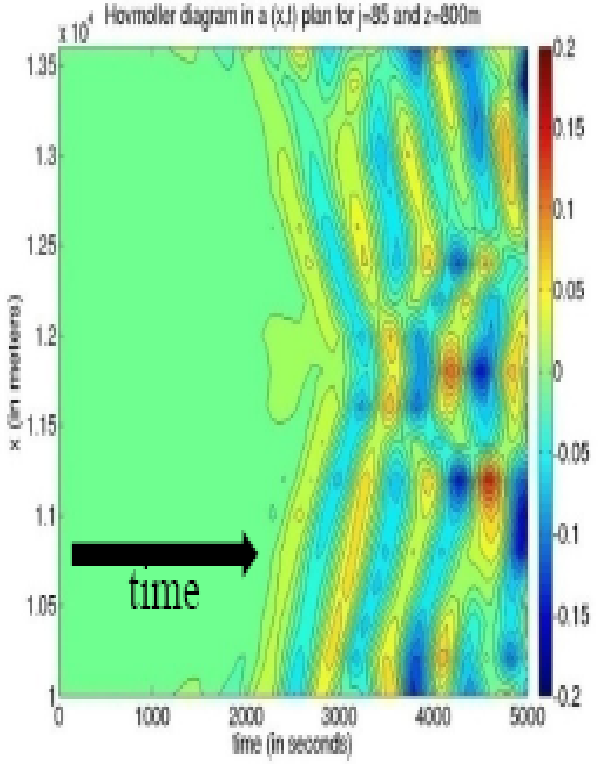
Wavelengths of the wave field

$$r_z = \frac{\omega}{k_z} = \frac{\lambda_z}{T}$$

$$r_z = -2.5m/s.$$

$$\lambda_z \approx 1300m$$





$$r_x = \frac{\omega}{k_x} = \frac{\lambda_x}{T}$$

$$r_x \approx 2,3m/s$$

$$\lambda_x \approx 1400m$$

→ the wavelengths are of the order of the scales of the valley

Conclusions

Two **distinct** systems of oscillation in the stably-stratified atmospheric boundary layer of a valley:

- In the katabatic wind, at frequency $\omega = N \sin \alpha$
  temporal oscillations of the wind only (not a trapped wave field)

- Emission of an internal gravity wave field by the katabatic wind, at frequency $\omega \approx 0.8N$ and wavelengths ≈ scales of the valley