# IMPACT OF DIFFERENT TYPES OF GRAVITY WAVES ON THE TURBULENT EDDIES, EXCHANGE COEFFICIENTS AND THE SPECTRAL GAP.

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## 1. INTRODUCTION

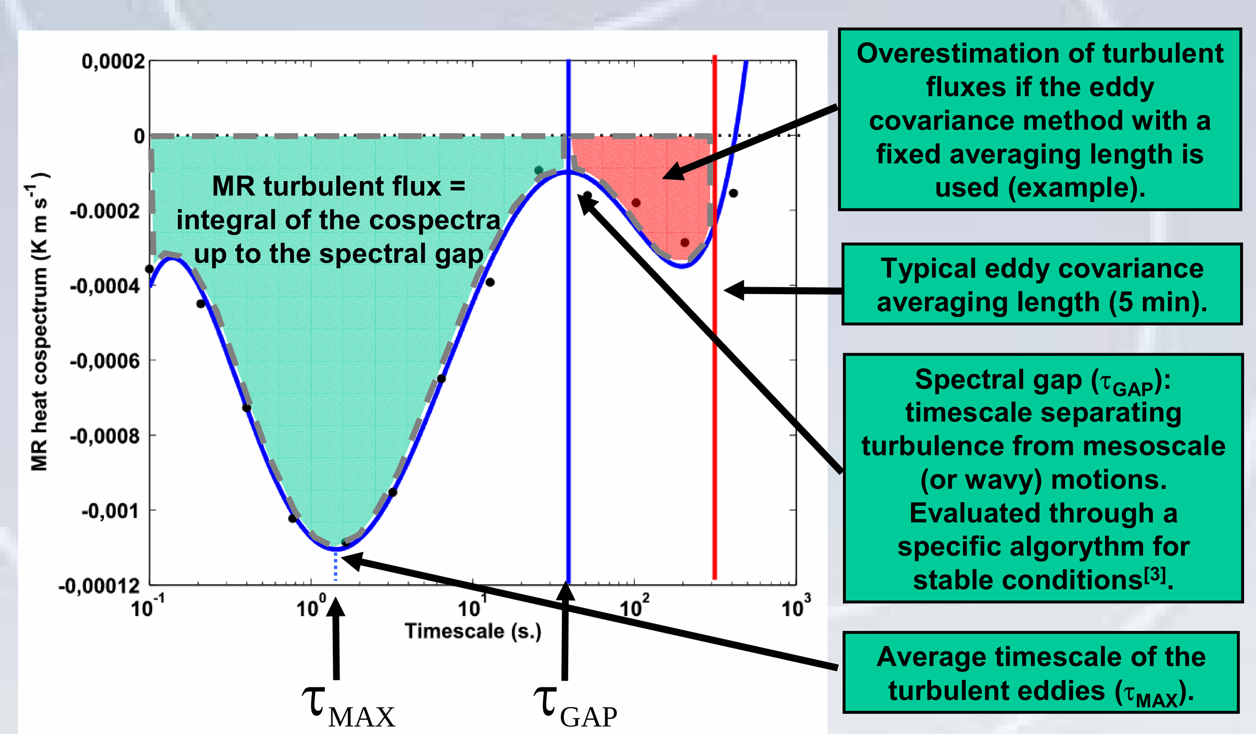
Turbulent motions developed in stably stratified atmospheric boundary layers with gravity wave activity show distinctive features compared with turbulence developed in unstable or weakly stable conditions. The flow can show a strong non-stationary behaviour due to the strong stratification, the presence of waves and their eventual collapse into turbulence. The wave-modified turbulence can extract or transfer energy to the wave; the turbulent fluxes usually show a periodic component, and appear sometimes accompanied by counter-gradient transfers produced by motions at the scale of the wave. In this study we compare the effect of three different gravity wave events on the main characteristics of turbulent motions.

## 2. DATA

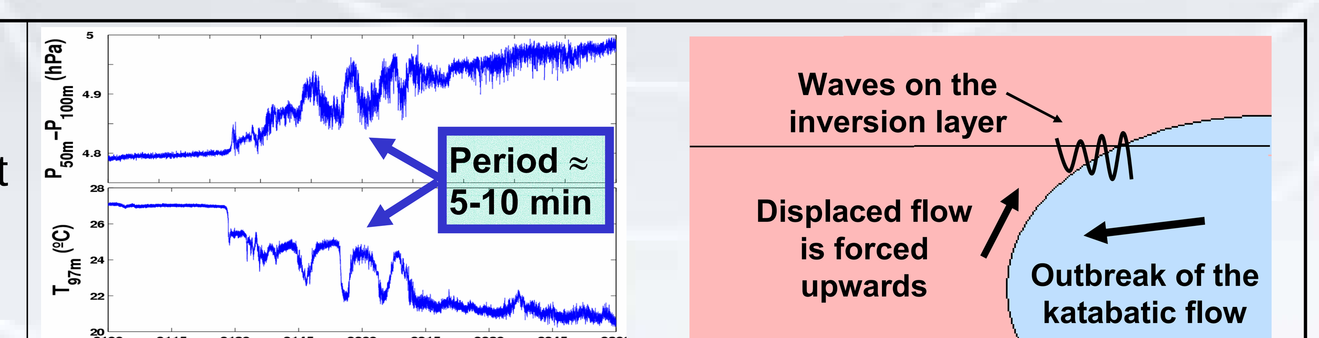
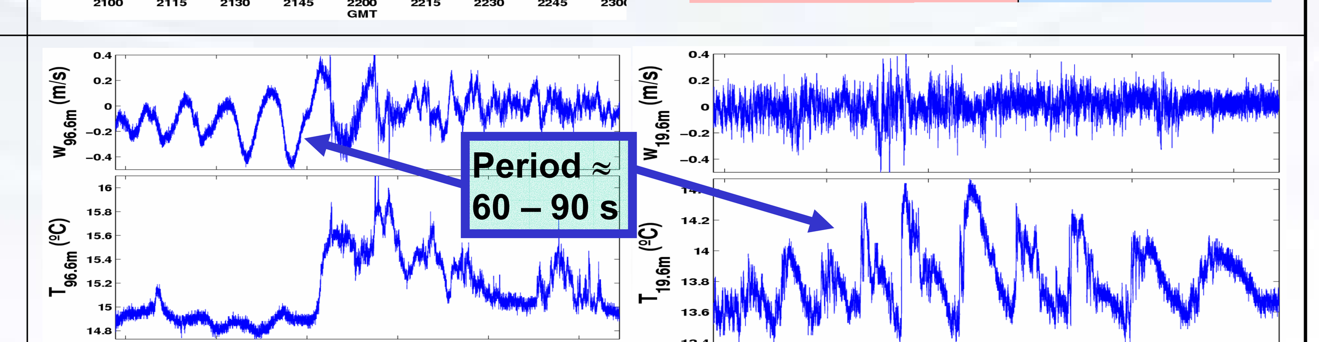
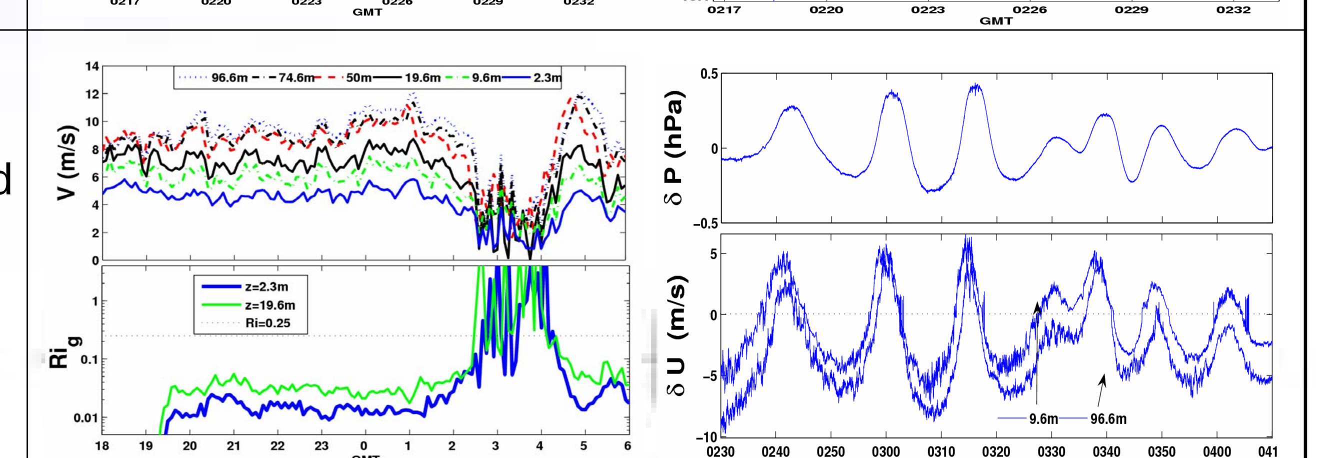
- SABLES2006 field campaign was carried out on a relatively flat and homogeneous terrain over an extensive high plain in the northern part of the Iberian Peninsula [1] (See poster A335, this session, for site characteristics).
- Main instrumentation, installed on a 100-m mast, included wind vanes, cup and sonic anemometers, thermometers and three microbarometers at different levels (plus 3 additional microbarometers deployed at surface level on a triangular array around the site). In this study turbulence is studied from sonic anemometer data at $z$=19.6m and $z$=96.6 m.

## 3. METHOD: MULTIRESOLUTION (MR) FLUX DECOMPOSITION

- It is a multivariate and multiscale spectral tool for computing turbulent fluxes and studying the contribution by different timescales $\tau$ [2].
- In stable conditions, MR cospectra of vertical heat flux ($\langle w\theta\rangle_\tau$) is usually studied.
- The effect of meso-scale events ( waves, irruption of katabatic flows, etc. ) in the spectra of turbulent motions can be tracked by studying the change in the contribution from different timescales, and the evolution of parameters related to the shape of the cospectra, such as $\tau_{MAX}$ or $\tau_{GAP}$ (see adjacent figure).

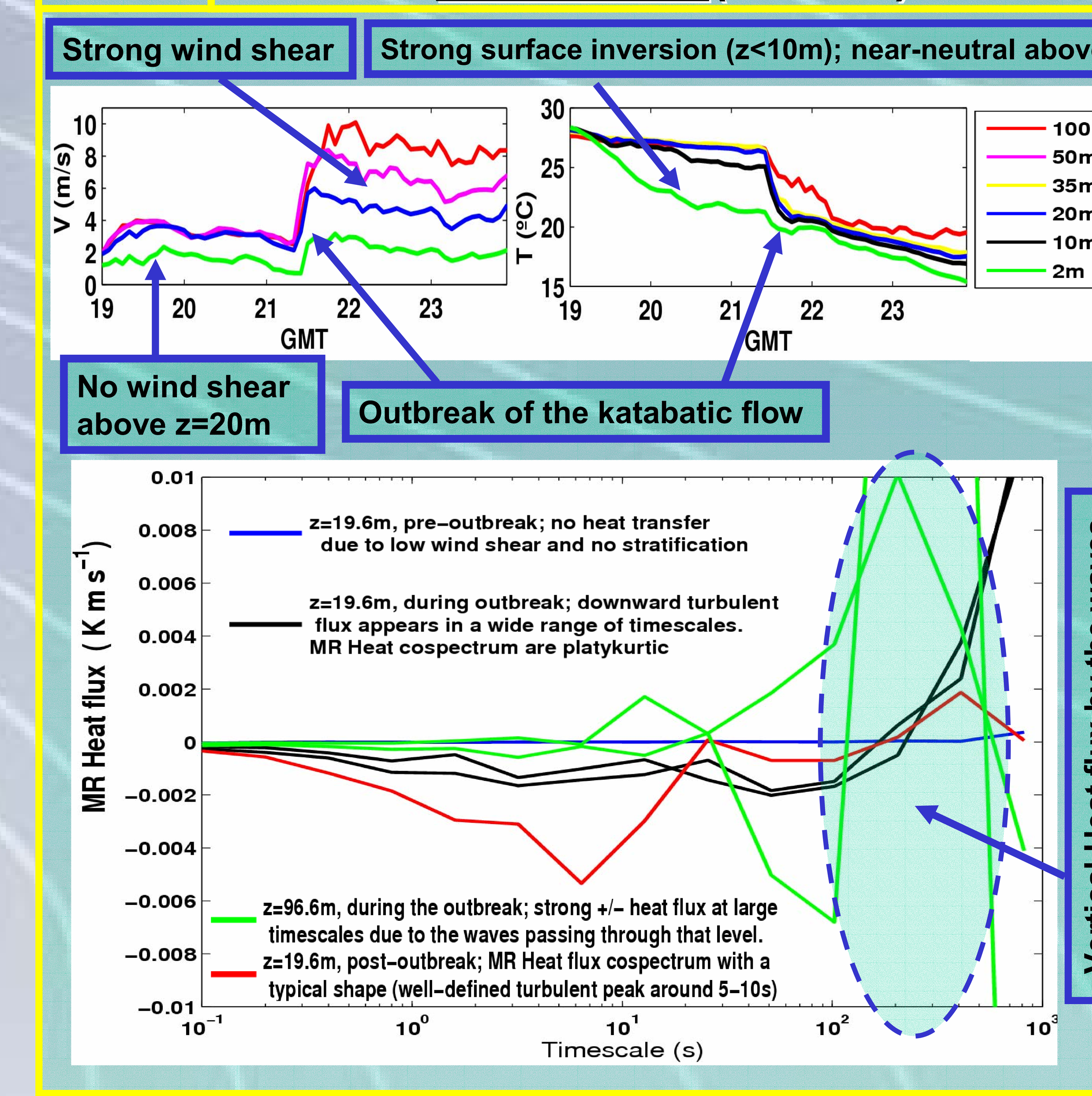



## 4. TYPES OF GRAVITY WAVES AT SABLES 2006

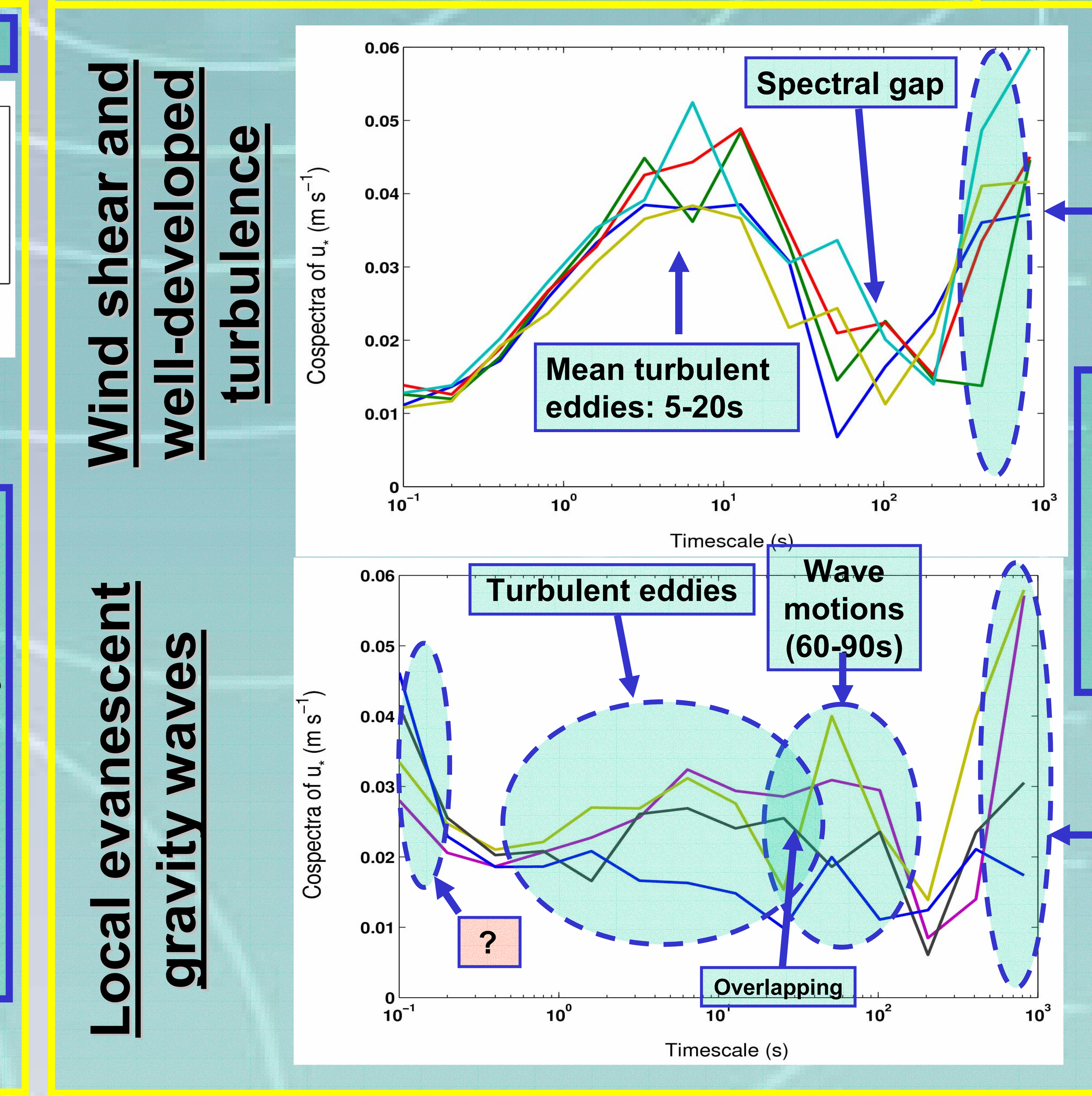
| | | |
|---|---|---|
| **A** | **Waves on the top of a drainage flow.** Detected on June 22 at 2130GMT. The outbreak of a katabatic flow at the site produces internal oscillations at the inversion layer, probably produced due to upward motions due to mass convergence at this level. (See EGU2009-2346, Friday 08:30-08:45, Room 36) |   |
| **B** | **Local evanescent gravity waves.** Detected on June 26 at 0230GMT. A gravity wave moves downward from $z$>100m to about $z$=20m. Interaction with local stratification is complex; the wave excites oscillations which are present simultaneously **at different levels but different variables** ($w_{96.6m}$, $T_{19.6m}$). |   |
| **C** | **Strong mesoscale ducted gravity wave.** Detected on July, 12, from 0230 to 0430 GMT. Periodic veerings of wind direction (NE-SW), very well correlated wind, temperature and pressure fluctuations. Wind shear decreases, stratification ($Ri_g$) increases. Wave parameters: $T$=17 min, $c$=9m/s, $\lambda$=9km, direction: from SW. |  |

## 5. RESULTS.

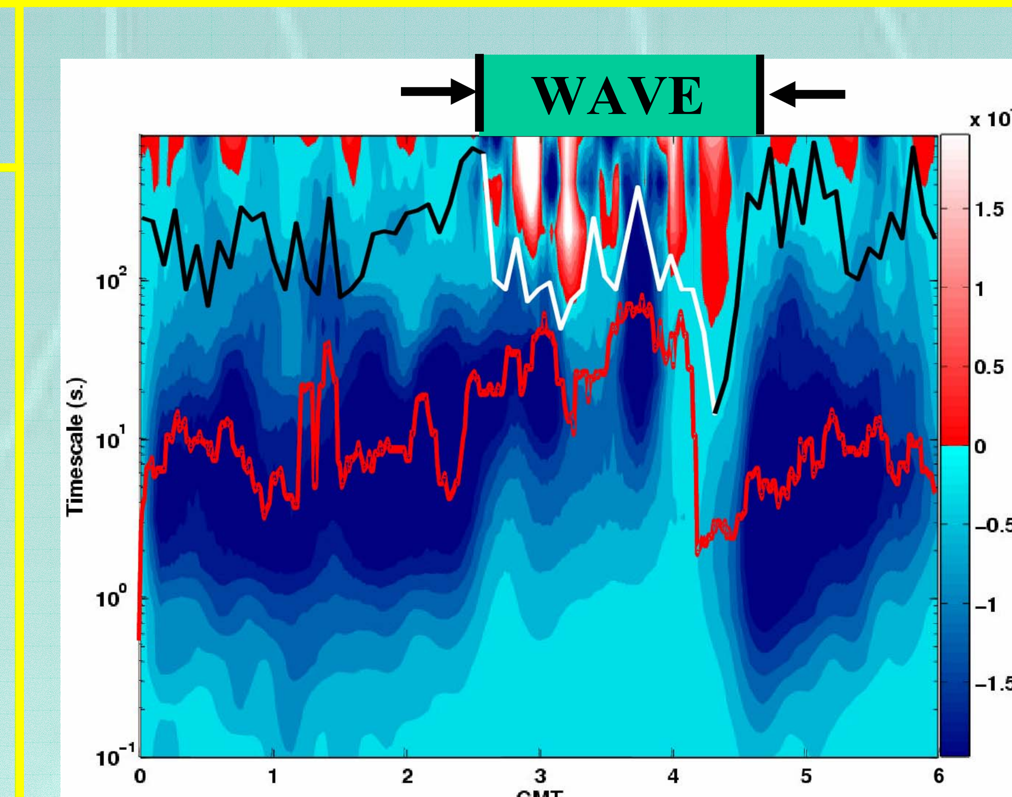
### A — Changes in the heat flux cospectra ($\langle w\theta\rangle_\tau$)




### B — Changes in the spectra of $u_*=(\langle uw\rangle_\tau^2+\langle vw\rangle_\tau^2)^{1/4}$




### C — Changes in $\langle w\theta\rangle_\tau$




MRFD of the heat flux (in K m s⁻¹) at z=19.6m. Black-white and red lines show the evolution of $\tau_{GAP}$ and $\tau_{MAX}$.

- Wave-related motions at large timescales (>100s) have large contributions to the cospectra, changing from positive to negative values regularly.
- Turbulence and wave cospectra overlap along timescales close to 100s. As a consequence, $\tau_{GAP}$ **(white line)** is poorly defined.
- Contribution by turbulent timescales (<100s) is reduced, but the smallest turbulent timescales (<10s) seem to be more affected than timescales from 10 to 100 seconds, possibly because turbulent eddies move slower due to the reduced windspeed and windshear.
- As a result, the timescale of the mean transporting eddies (red line) is larger.

**Implications in the evaluation of exchange coefficients:** →

$$K_m = -\langle u'w'\rangle / \frac{\partial \bar{u}}{\partial z} \qquad K_h = -\langle \theta'w'\rangle / \frac{\partial \bar{\theta}}{\partial z}$$

- A proper evaluation of turbulent fluxes <u'w'> and < w'θ'> (integrating MR cospectra up to the spectral gap) is crucial.
- As a general result, waves overlap, to a greater or lesser extent, with the spectra of turbulent motions.
- If no spectral gap can be identified, uncertainty in the evaluation of $\langle u'w'\rangle$ and $\langle w'\theta'\rangle$ increases (and thus, in $K_m$ and $K_h$). This effect is more important in strong stability conditions where waves develop, because turbulent fluxes tend to be very small).

## 6. REFERENCES

[1] Yagüe C, Viana S, Maqueda G, Lazcano M F, Morales G, Rees J M (2007) A study on the nocturnal atmospheric boundary layer: SABLES2006. Física de la Tierra 19: 37-53 (available online: http://revistas.ucm.es/fis/02144557/articulos/FITE0707110037A.PDF)

[2] Howell J F, Mahrt L (1997) Multiresolution flux decomposition. Boundary-Layer Meteorol 83: 117-137

[3] Voronovich V, Kiely G (2007) On the gap in the spectra of surface-layer atmospheric turbulence, Boundary-Layer Meteorol 122: 67-83

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