Counter gradient heat flux and lifted temperature minimum during evening transition

E. Blay-Carreras, E. R. Pardyjak, D. Pino, D. C. Alexander, F. Lohou, M. Lothon, S. W. Hoch, J. Cuxart, D. Martínez, and J. Reuder

WUR, 8 February 2016

Published in:

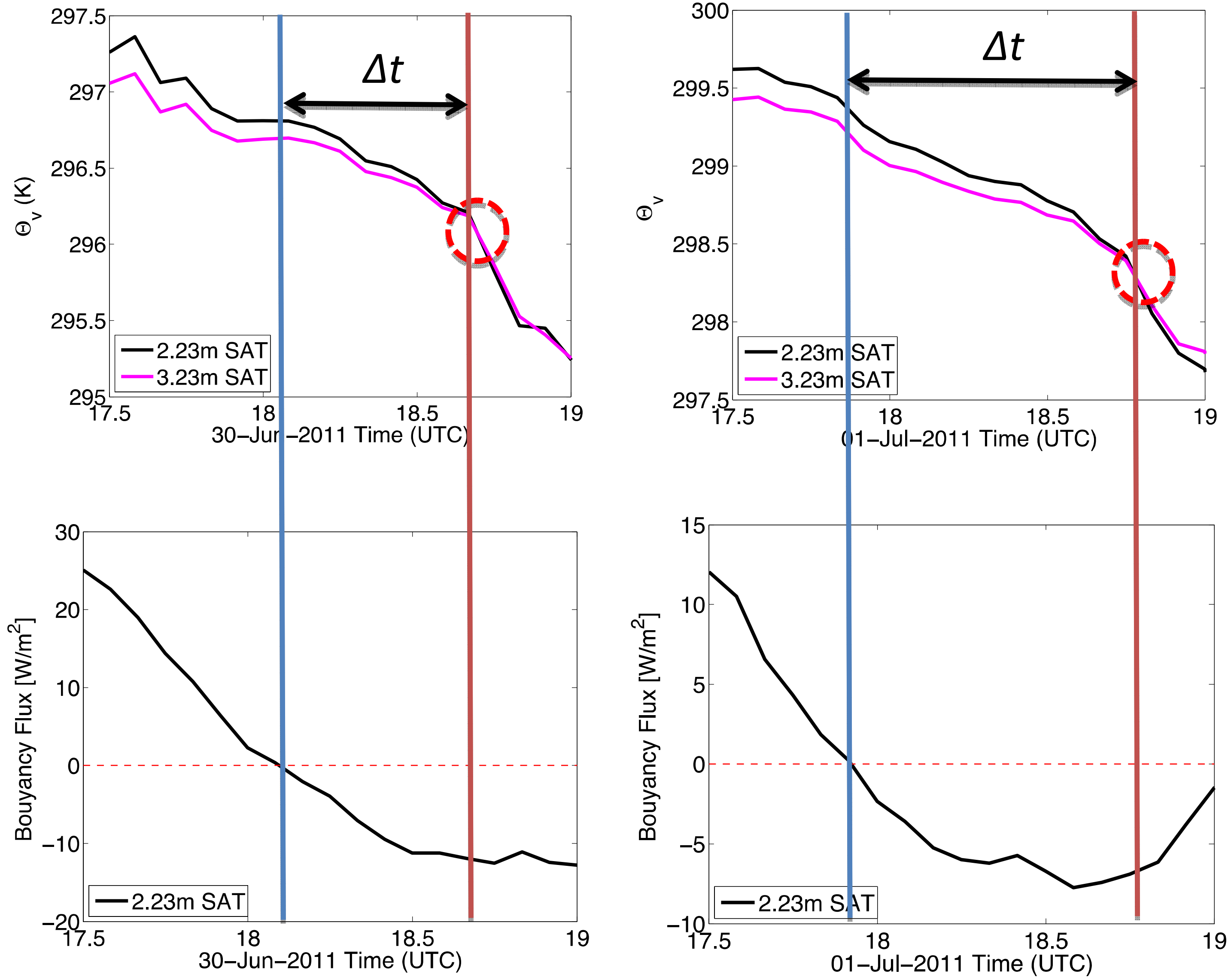
Atmos. Chem. Phys., 14, 9077–9085, 2014

Atmos. Chem. Phys., 15, 6981–6991, 2015

Counter gradient heat flux observations

The **hypothesis** → during the **evening transition**, a **delay** exists between the instant when the **buoyancy flux** goes to zero and the time when the local **gradient of the virtual potential temperature** changes sign.

Counter gradient heat flux observations

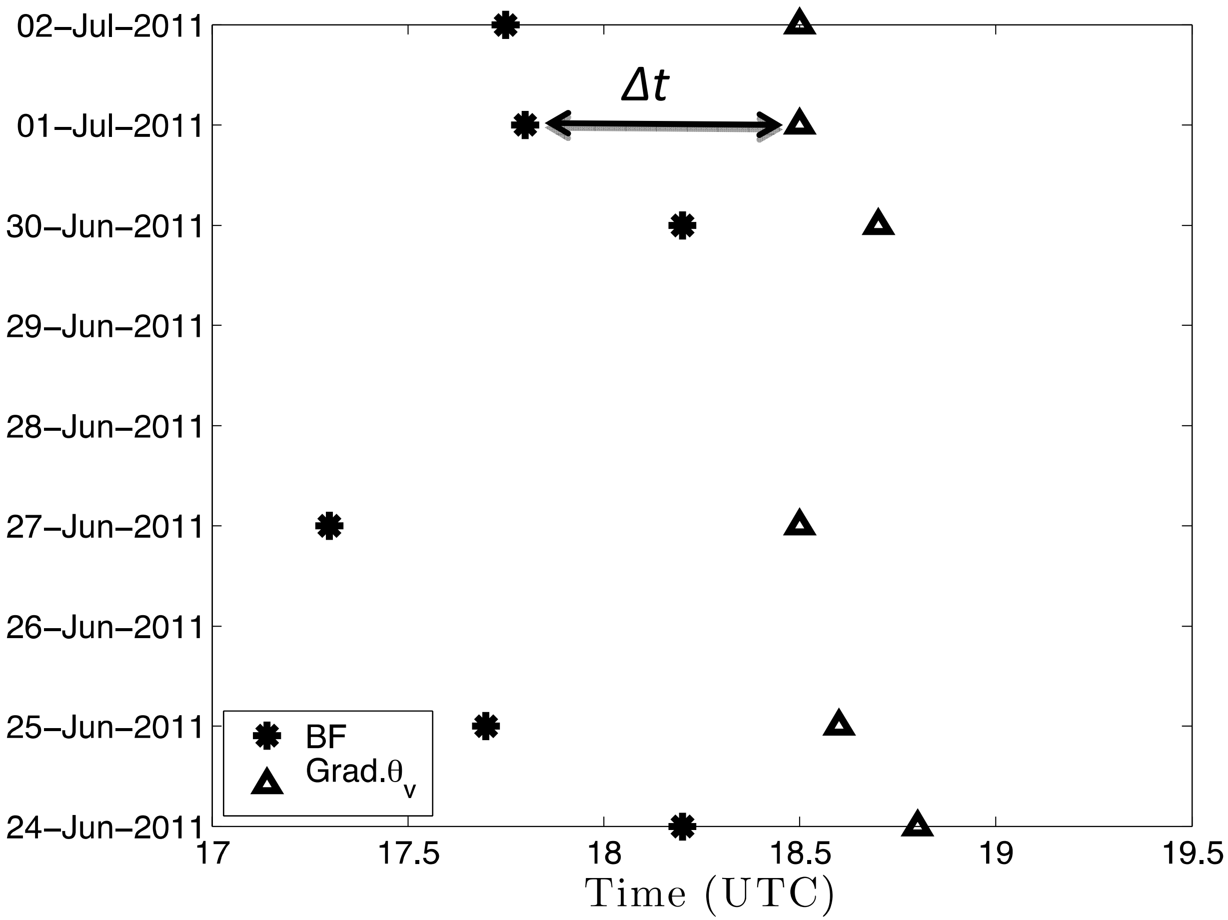


Change of the sign of the θ_v gradient

Change of sign of the buoyancy flux

Counter gradient heat flux observations

Delay time



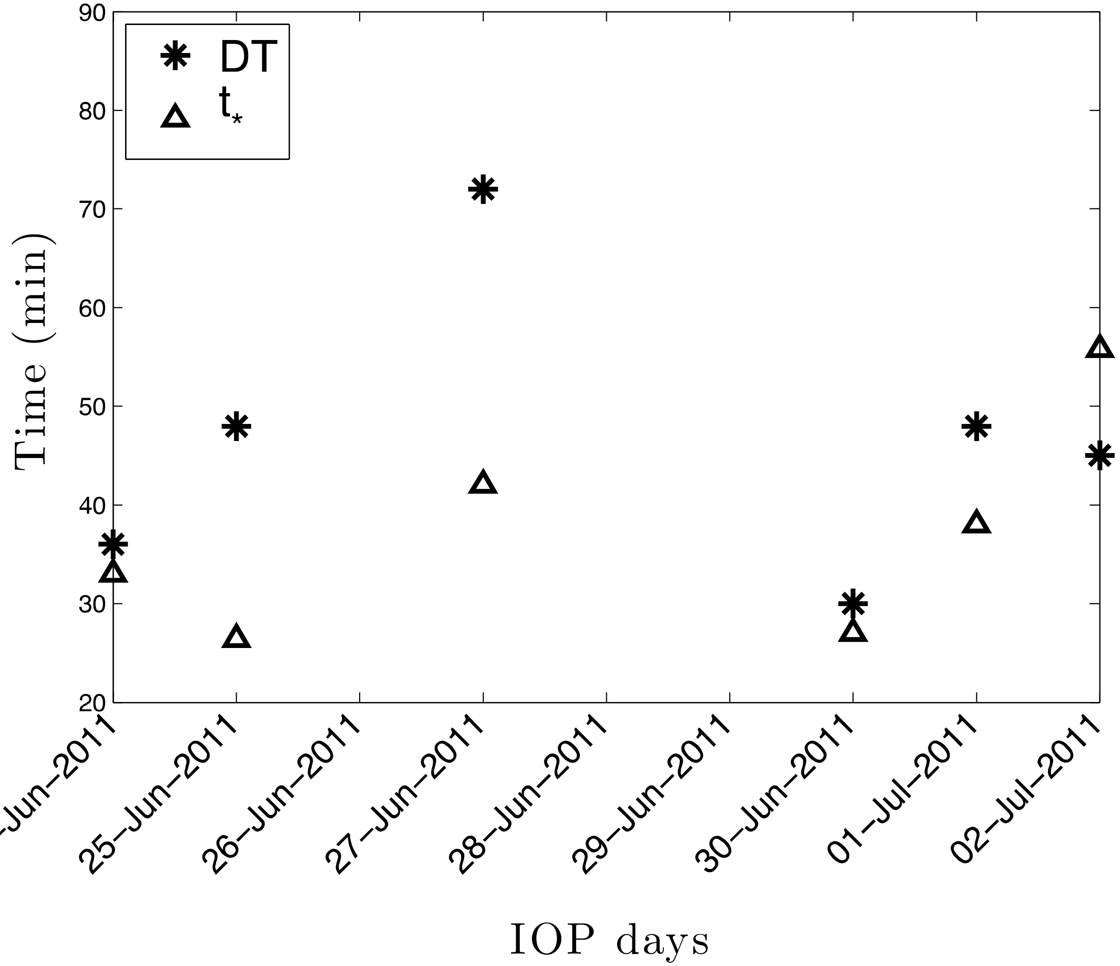
$$t\left(\overline{w'\theta'}_v\Big|_s \approx 0\right) \; vs \; t\left(\partial\theta_v / \partial z \approx 0\right)$$

There is a delay time in all the IOP analyzed (30-80 min)

Counter gradient heat flux observations

Convective time

Delay time (DT) = $t\left(\partial\theta_v/\partial z \approx 0\right) - t\left(\overline{w'\theta'_v}\Big|_s \approx 0\right)$



Delay time appear for the last eddy movements.

Convective time :

$$w_* = \left[\frac{g z_i}{\overline{\overline{\theta_v}}}\left(\overline{w'\theta_v'}\right)_s\right]^{1/3}$$

$$t_* = \frac{z_i}{w_*}$$

Why some days DT is similar to the convective time?

Counter gradient heat flux observations

Monin-Obukhov length analysis

Convective days

24/06 & 30/06: IOPs with **large *-z/L*** averaged between 12 UTC-16:45UTC have **small** DT-CT.

Weakly convective days

25/06 & 27/06 → ** IOP with **small *–z/L* averaged between 12UTC-16:45UTC have **large** DT-CT.

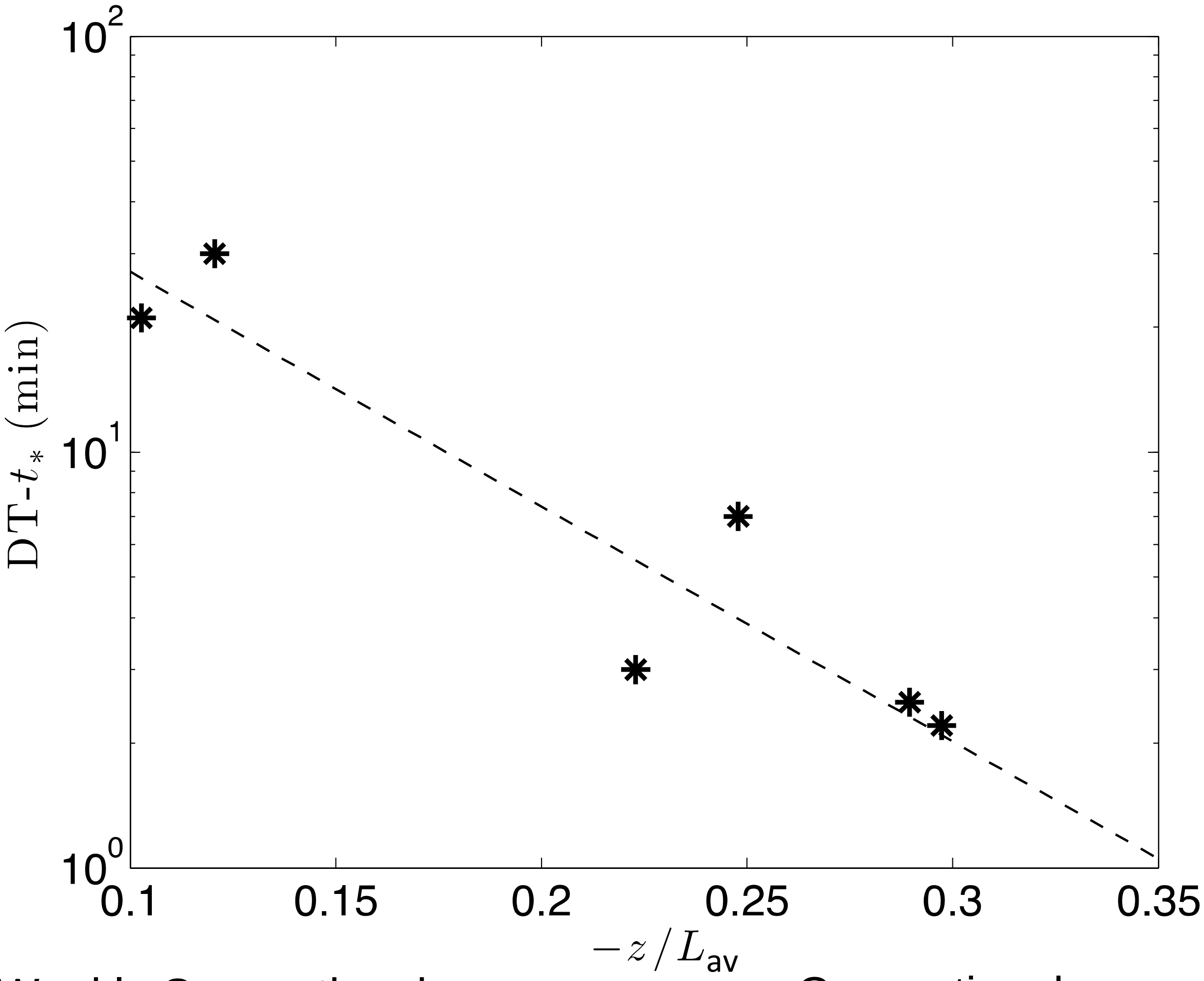
IOP day	DT (min)	Convective time (min)	-z/L	Convective intensity
24 June (IOP4)	38	36	0.297	Strong
25 June (IOP5)	48	26.37	0.102	Weak
27 June (IOP7)	72	42	0.1205	Weak
30 June (IOP8)	30	27	0.289	Strong
1 July (IOP9)	40	33	0.22	Moderate

Weakly convective IOPs have larger u_* → more horizontal turbulence → larger delay time

Counter gradient heat flux observations

Obukhov Length

Exponential relation between DT-CT and *–z/L*



Weakly Convective day

Convective day

Conclusions

Countergradient heat flux observations

- There is a **delay** between buoyancy flux cease and the change in the vertical gradient of θ_v.

- During moderate convective days, the delay time is small and close to the last eddy movement (**convective time**).

- When convection is lower, larger u_*, the delay time is larger due to the increase of **horizontal turbulence**.

- **Turbulent viscosity and thermal diffusivity** may help to slow down the last eddy movement increasing the convective time.

LTM during afternoon transition

- **Lifted Temperature Minimum** (LTM) is characterized by a temperature minimum some tenths of cm above to the surface (0.1-0.5 m).

- Our research **objectives** :

1. To investigate the **existence** of the LTM during the **evening transition**.
2. To study the relevance of mean **wind characteristics** (driven by orography).
3. To analyze the importance of **turbulence** to observe LTM during evening transition.
4. To analyze role **radiation** in the appearance of LTM.

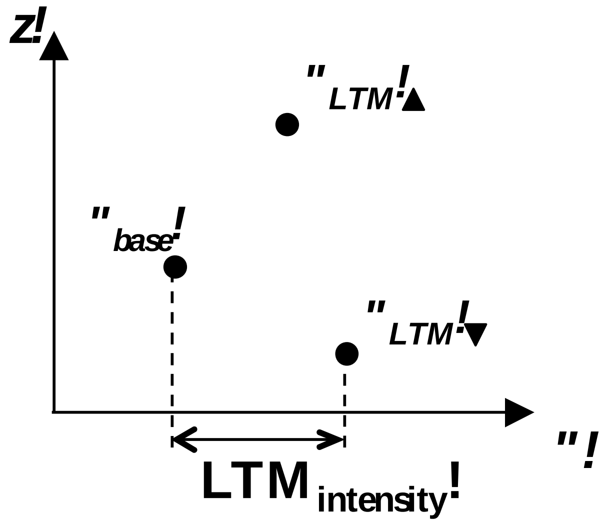
LTM during afternoon transition

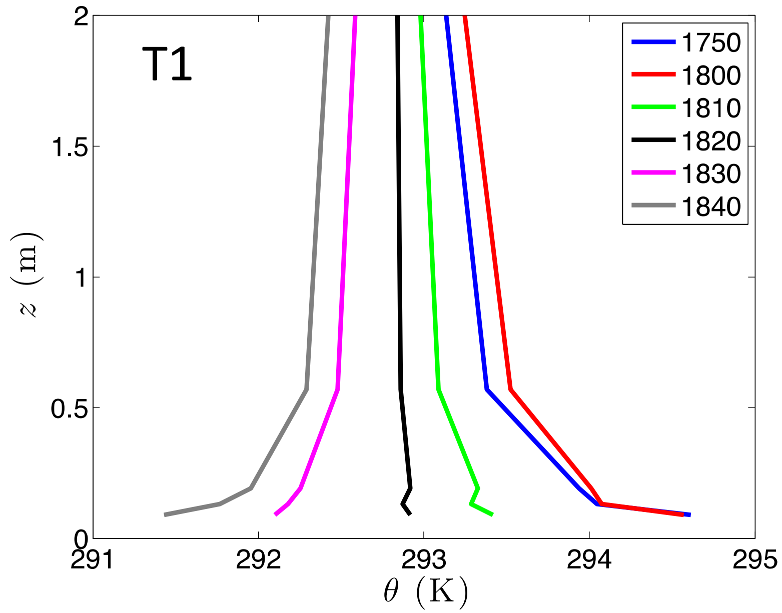
- By using **T1** and **T2** measurements on 24, 25, 27, 30 June and 1 and 2 July 2011.
- We detect and characterize LTM:

$$\theta_{\text{base}} - \theta_{\text{LTM}\downarrow} < 0 \quad \textit{and} \quad \theta_{\text{LTM}\uparrow} - \theta_{\text{base}} > 0$$

$$\text{LTM}_{\text{intensity}} = \theta_{\text{base}} - \theta_{\text{LTM}\downarrow}$$

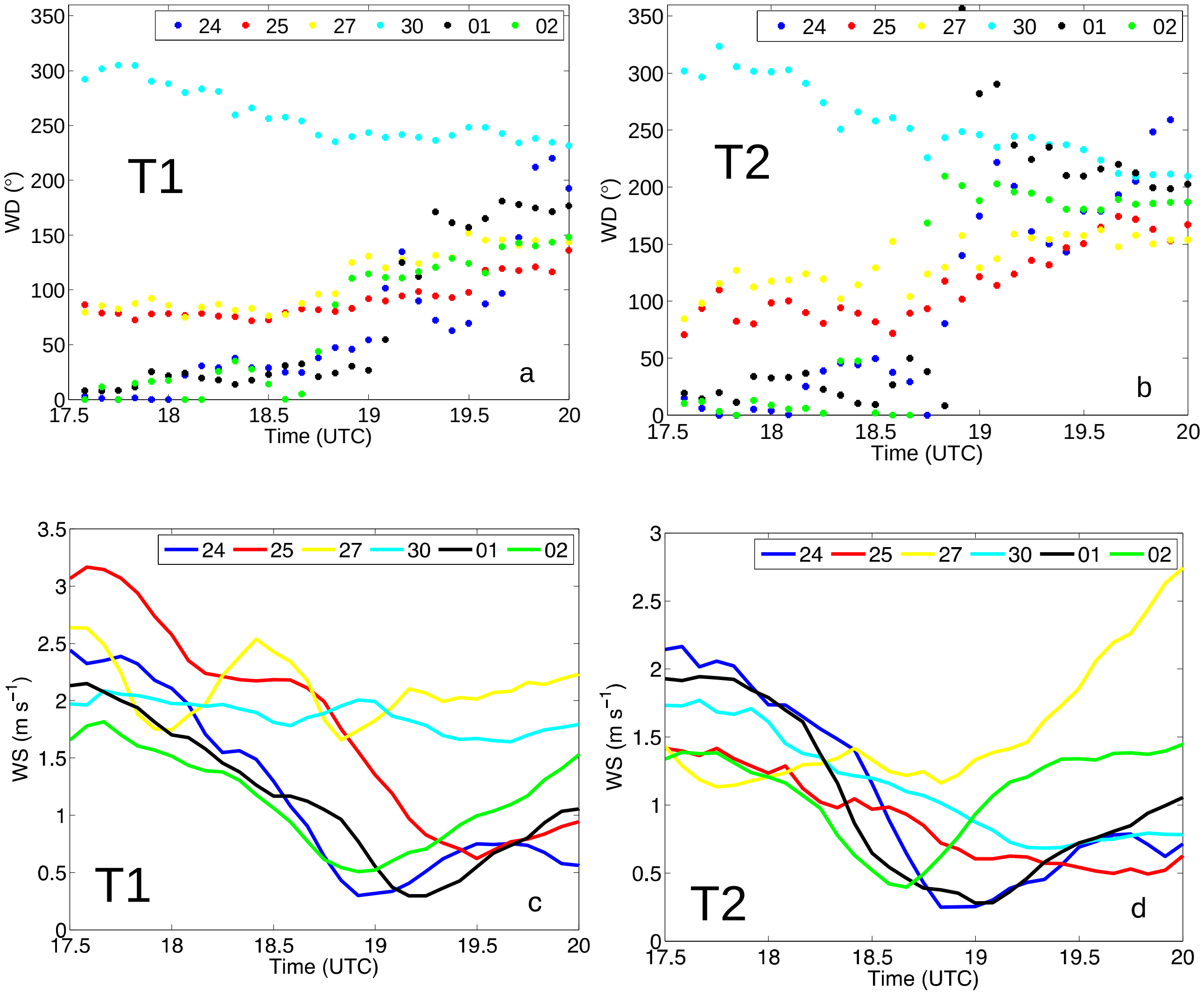
Mukund et al. 2010





LTM during afternoon transition

Mean wind characteristics (2.2 or 2 m)

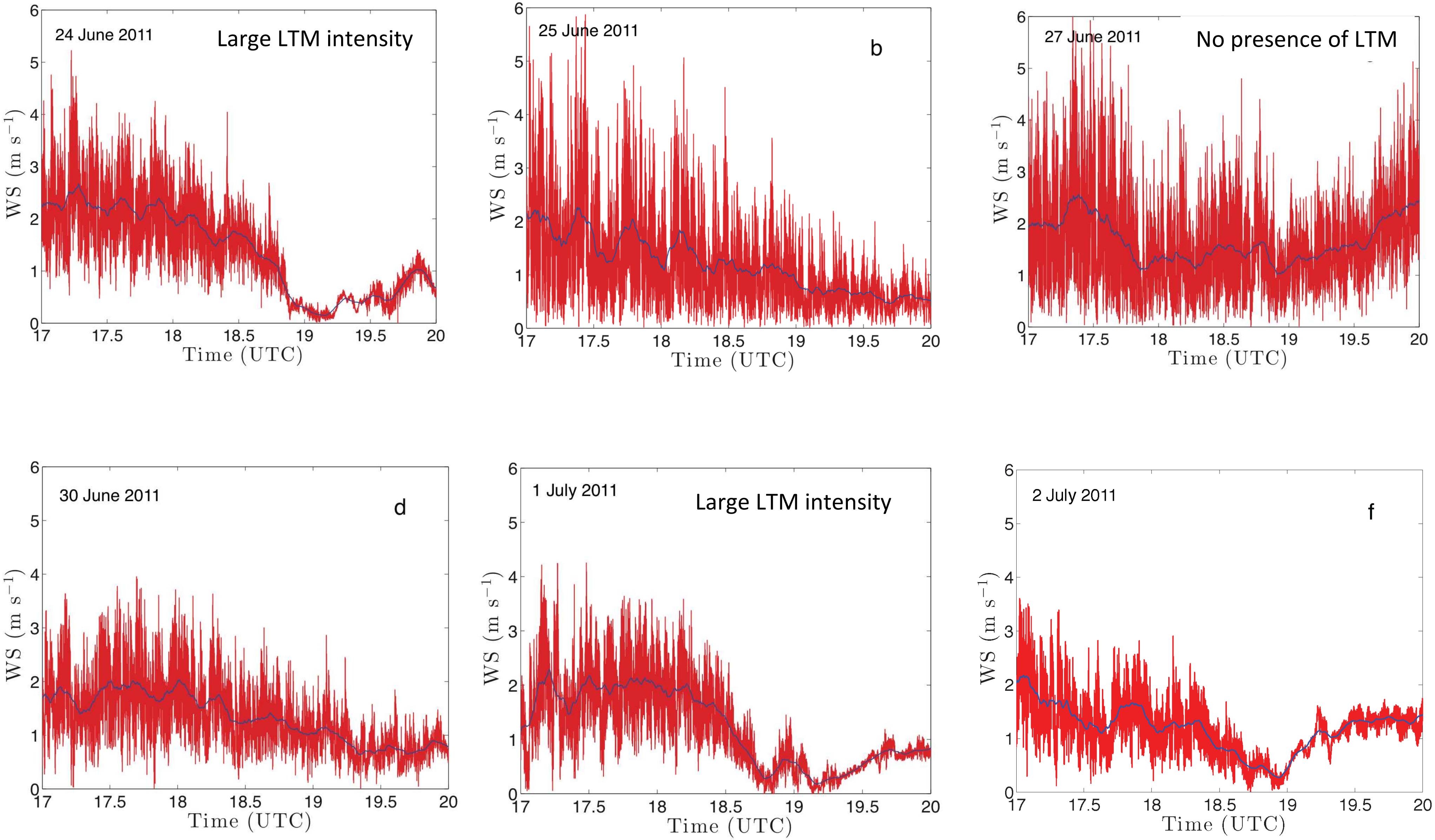


Typical **mountain–plain circulation**: daytime plain–mountain wind early evening calm conditions
and nighttime mountain–plain wind.

- 27 June 2011: no decrease of WS → LTM not observed.
- 1 July: WS decreases → Large LTM intensity.

LTM during afternoon transition

Turbulence (T2, 2 m) – Wind speed at 20 Hz



LTM during afternoon transition

Turbulence

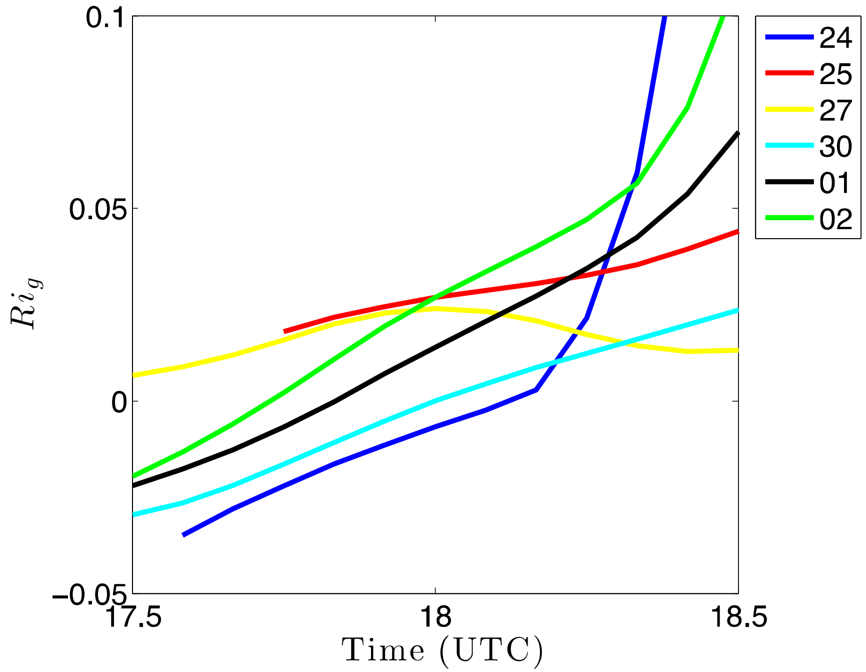
•Gradient **Richardson** number (Ri_g) crucial for studying LTM at night.

•Ri_g threshold 0.1 at night to observe LTM (Oke, 1970).

•We calculate Ri_g using T_{base} and $T_{LTM\uparrow}$

•**Large** increase rate of Ri_g is obtained in the cases with a faster decrease of turbulence.

$$Ri_g = \frac{g}{\overline{\theta_v}} \frac{\partial\overline{\theta_v}/\partial z}{\left(\partial\bar{u}/\partial z\right)^2 + \left(\partial\bar{v}/\partial z\right)^2} = \frac{stability}{mechanical\ tubulence}$$

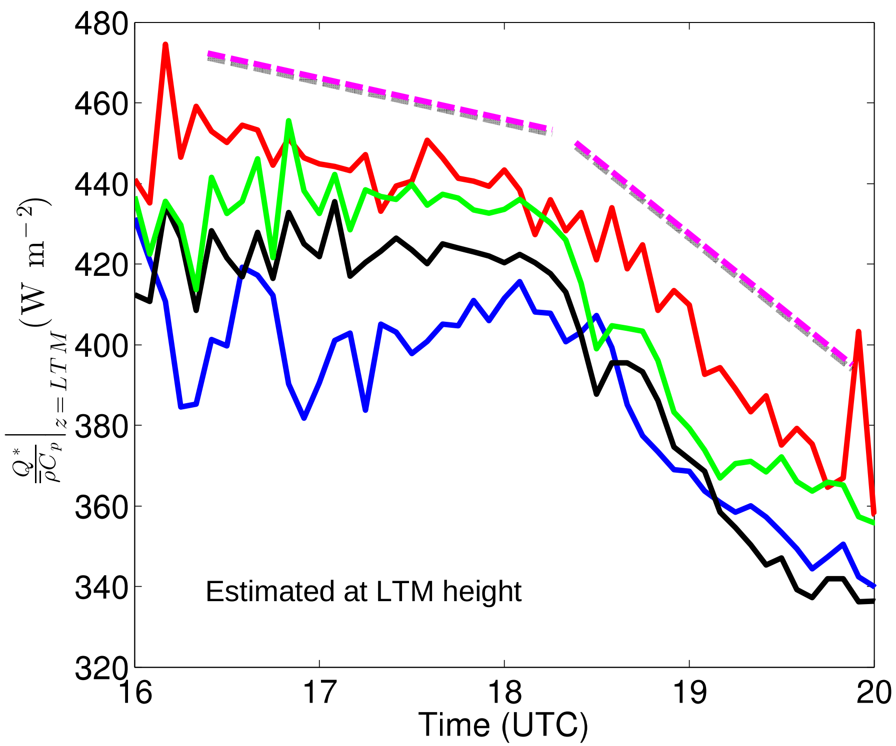


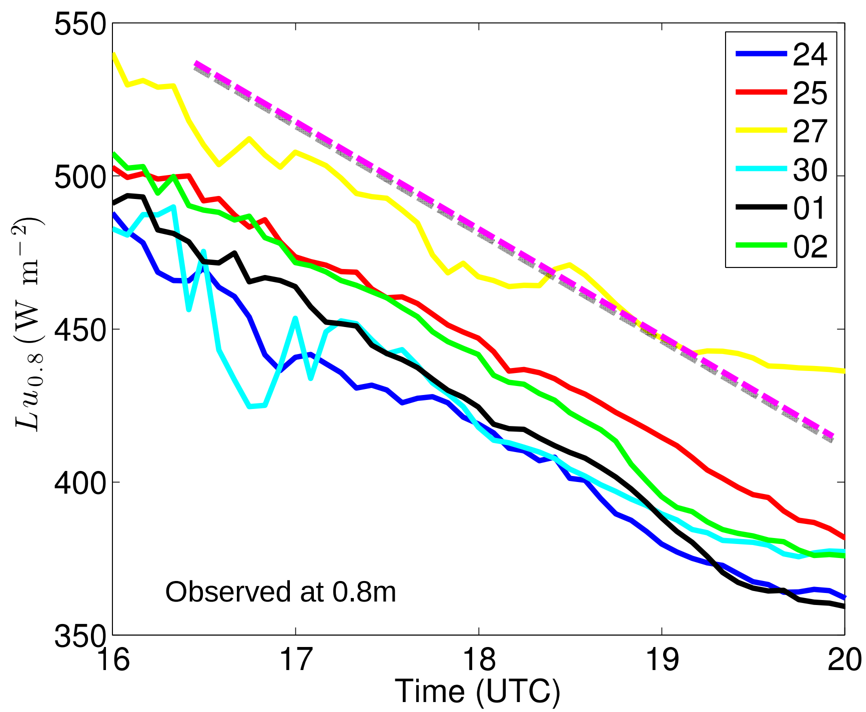
24 June, 1 July large increase rate of Rig

LTM during afternoon transition

Radiation

•LTM → radiative characteristics of the **air near the ground** is modified (Mukund et al., 2013).





•Change of decay rate at LTM height between 17:30-18:30 UTC.

Conclusions

Lifted temperature minimum during evening transition

- **LTM:** different intensity and duration for **all IOPs** (no LTM on 27/06/11).
- **LTM** is observed during **evening transition** in calm conditions (mountain–plain circulation).
- During early evening **calm** period, we observe a decrease in **wind velocity** and **turbulence.**
- LTM is observed due to a change in the **radiative conditions.**