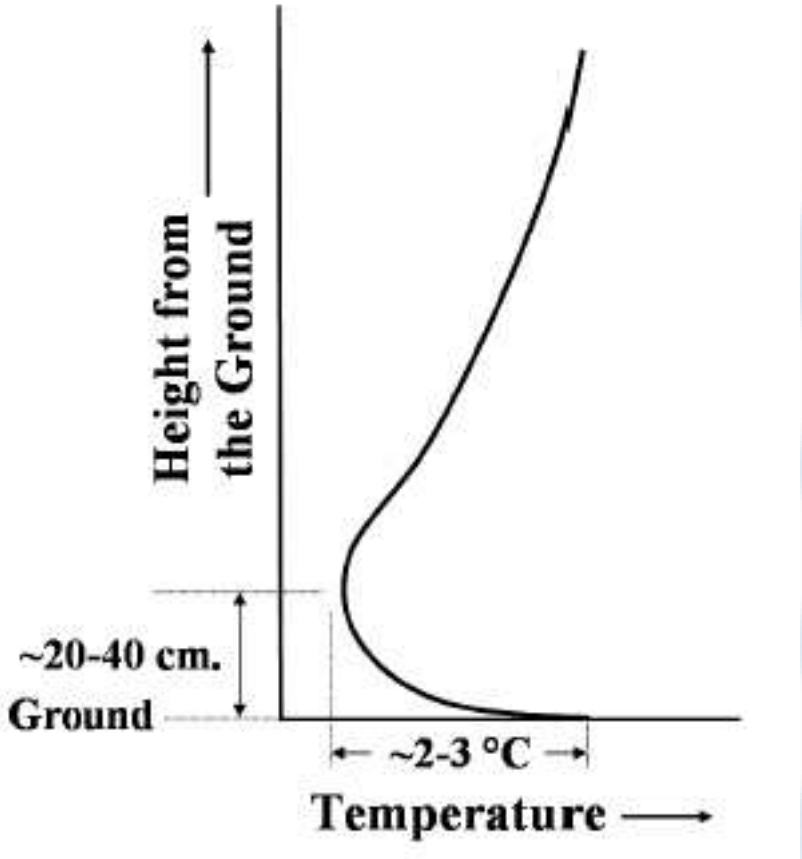
Lifted temperature minimum during the evening transition



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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).

- LTM during the **night** was first reported by **Ramdas and Atmanathan (1932).** Lake (1956) and Raschke (1957) confirmed it.

- **LTM profiles observed** over **natural** (Oke, 1970) and **artificial surfaces** (Mukund et al., 2010, 2013).

- Mukund et al. (2010) showed ↓ surface **emissivity** ↑ the **intensity** of LTM. **Thermal diffusivity** is also another important parameter.

LTM during afternoon transition

- LTM intensity was weaker with increasing **turbulence** (Oke, 1970). *Ri* is used to define the threshold of the turbulence.
- Narasimha (1991); Vasudeva Murthy et al. (2005); Mukund et al. (2010, 2013) stressed the **radiative origin** of LTM.
- LTM was observed with cloudless and calm conditions.
- Vasudeva Murthy et al. (1993) were the first ones to propose a **model**. Mukund et al. (2010) and Ponnulakshmi et al. (2012) **improved** it.

LTM during afternoon transition

- We analyze **LTM** occurrence during the **evening transition**.

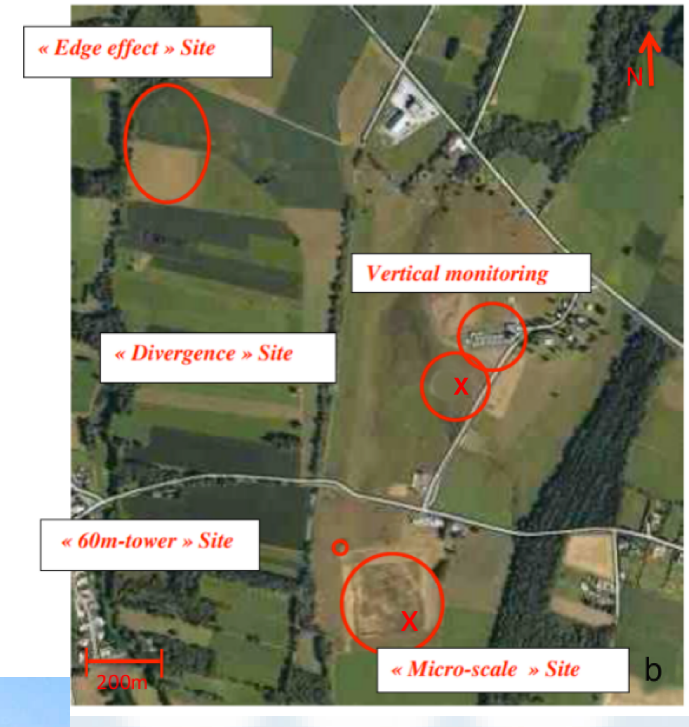
- Our research **objectives** :

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 the role **radiation** in the appearance of LTM.

LTM during afternoon transition

T1 → 10-m instrumented mast with six Sonic Anemometer Thermometers and Campbell Scientific nine FW05 FWs.

T2 → 2-m mast with eight FW3 FWs located at 0.015, 0.045, 0.075, 0.14, 0.3, 0.515, 1.045 and 1.92 m.



A Kipp&Zonen net radiometers RN-Lite2 was installed.

Surface moderate emissivity and thermal difussivity.

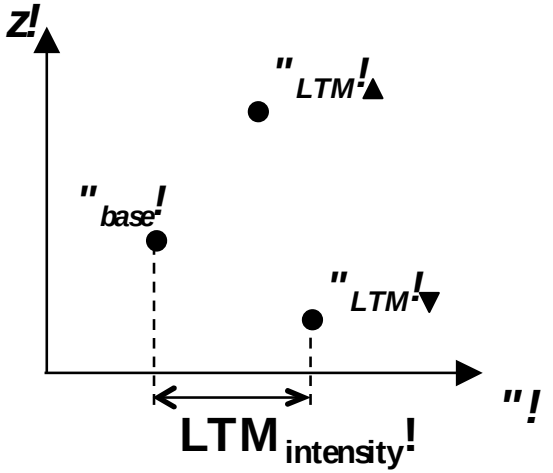
LTM during afternoon transition

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

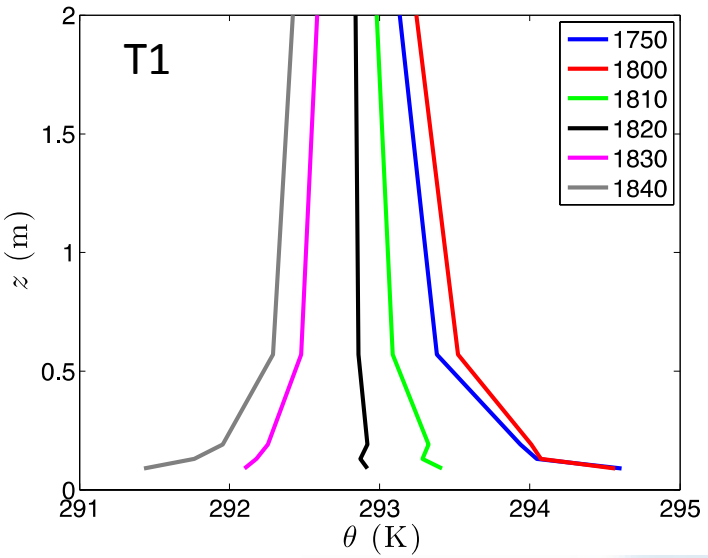
$$\theta_{base} - \theta_{LTM\downarrow} < 0 \quad and \quad \theta_{LTM\uparrow} - \theta_{base} > 0$$

$$LTM_{intensity} = \theta_{base} - \theta_{LTM\downarrow}$$

Mukund et al. (2010)



24 june 2011



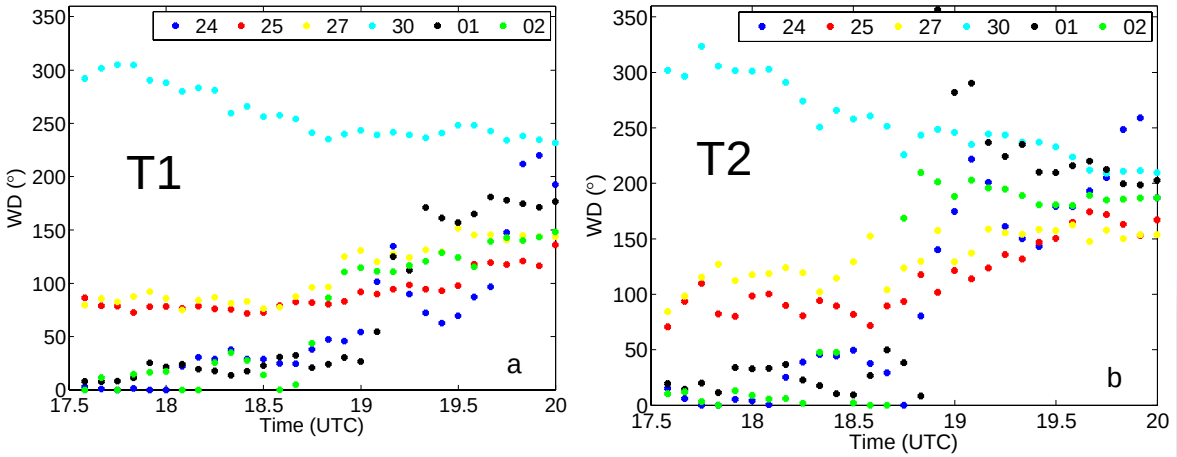
LTM during afternoon transition

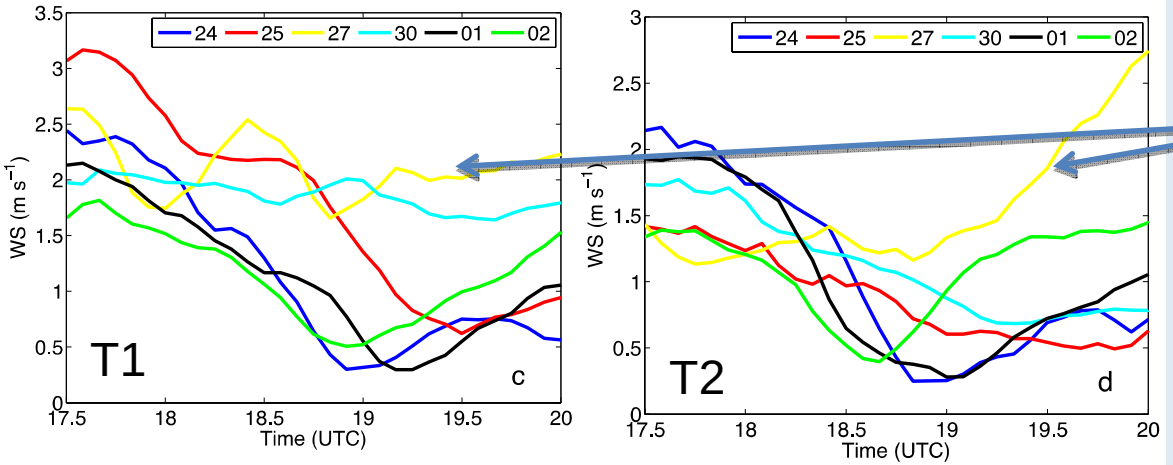
Characteristics of the observed LTM at T1 and T2 for all the studied IOPs.

IOP	LTM	LTM height T1 (m)	LTM height T2 (m)	LTM intensity T1 (K)	LTM intensity T2 (K)	LTM duration T1 (min)	LTM duration T2 (min)
24-Jun-11	YES	0.131	0.07-0.14	0.35	0.7	20	40
25-Jun-11	YES	0.131	0.3	-	0.5	-	40
27-Jun-11	NO	-	-	-	-	-	-
30-Jun-11	YES	0.131	0.07-0.14	0.5	0.3	20	40
1-Jul-11	YES	0.131	0.07-0.14	0.35	0.7	20	60
2-Jul-11	YES	0.131	0.07-0.14	0.3	0.5	40	70

LTM during afternoon transition

Mean wind characteristics (2.2 or 2 m)



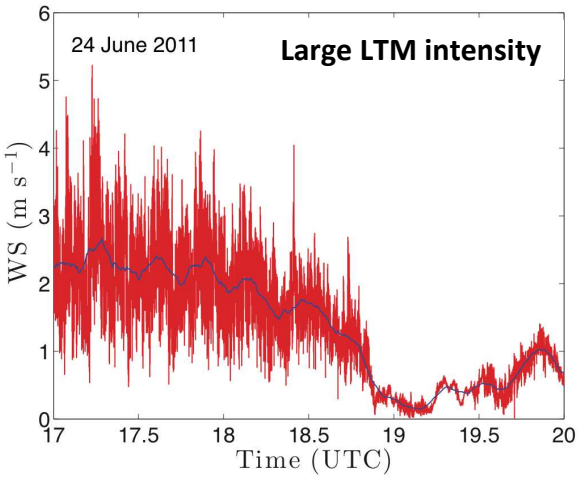


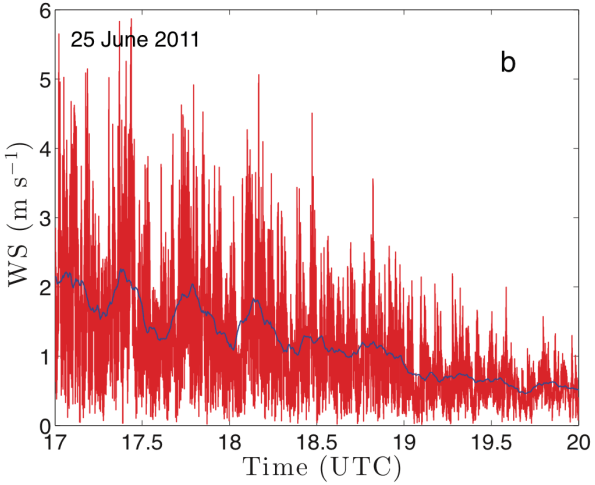
Typical **mountain–plain circulation**: daytime plain–mountain wind, **early evening calm conditions**, and nighttime mountain–plain wind.

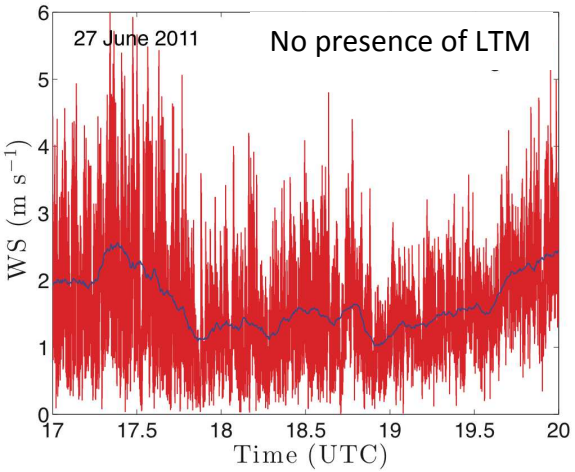
- **27 June 2011**: no decrease of WS → LTM not observed.
- 1 July: WS decreases → Large LTM intensity.

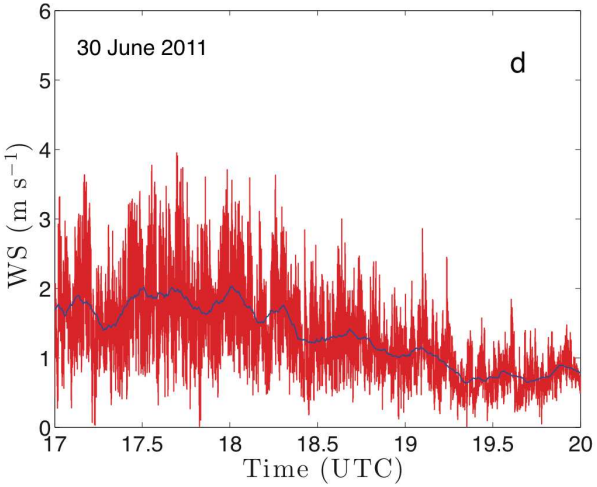
LTM during afternoon transition

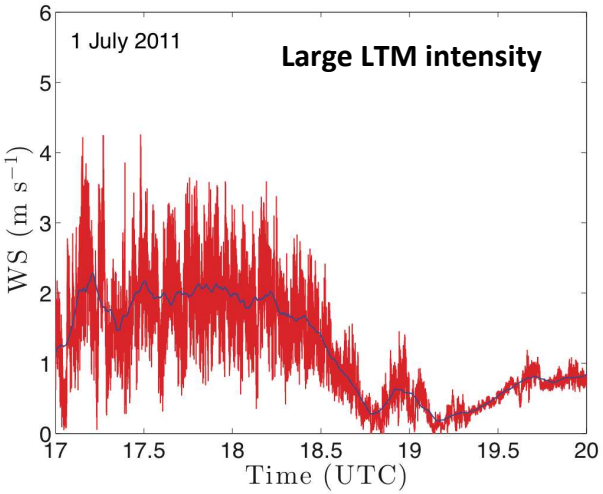
Turbulence (T2, 2 m) – Wind speed at 20 Hz

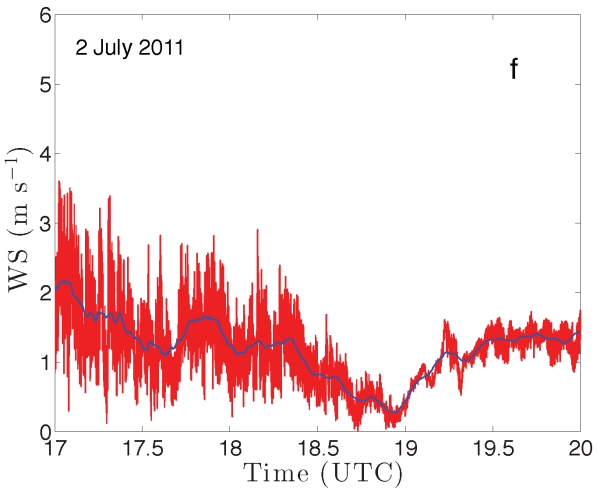










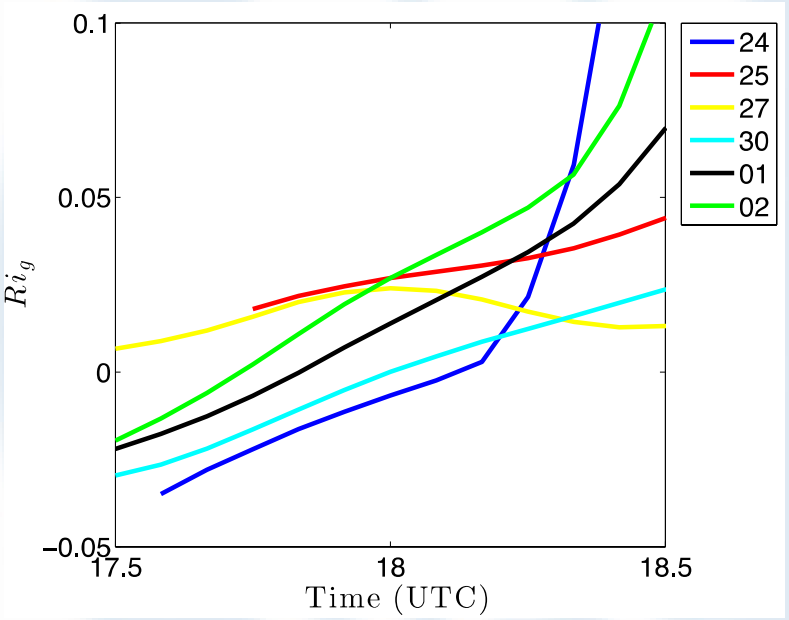


LTM during afternoon transition

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 Ri_g

LTM during afternoon transition

Radiation

•Narasimha (1991); Vasudeva Murthy et al. (2005); Mukund et al. (2010, 2013) pointed out the **radiative origin** of LTM.

•We estimate **longwave radiation** at **LTM height** by using the equation of conservation of heat:

$$\frac{\partial \bar{\theta}}{\partial t} + \overline{U_j}\frac{\partial \bar{\theta}}{\partial x_j} = \nu_\theta \frac{\partial^2 \bar{\theta}}{\partial x_j^2} - \frac{1}{\overline{\rho} C_p}\frac{\partial Q^*}{\partial x_j} - \frac{L_v E}{\overline{\rho} C_p} - \frac{\partial\left(\overline{u_j'\theta'}\right)}{\partial x_j}$$

– By assuming horizontal homogeneity and neglecting subsidence:

$$\frac{\partial \bar{\theta}}{\partial t} = \nu_\theta \frac{\partial^2 \bar{\theta}}{\partial z^2} - \frac{1}{\overline{\rho} C_p}\frac{\partial Q^*}{\partial z} - \frac{L_v E}{\overline{\rho} C_p} - \frac{\partial\left(\overline{w'\theta'}\right)}{\partial z}$$

– We integrate this equation from ground to LTM height:

$$\left.\frac{Q^*}{\overline{\rho} C_p}\right|_{z=LTM} = \nu_\theta \left.\frac{\partial \bar{\theta}}{\partial z}\right|_{z=0m} + \left.\frac{Q^*}{\overline{\rho} C_p}\right|_{z=0m} - \left.\overline{w'\theta'}\right|_{z=2m}$$

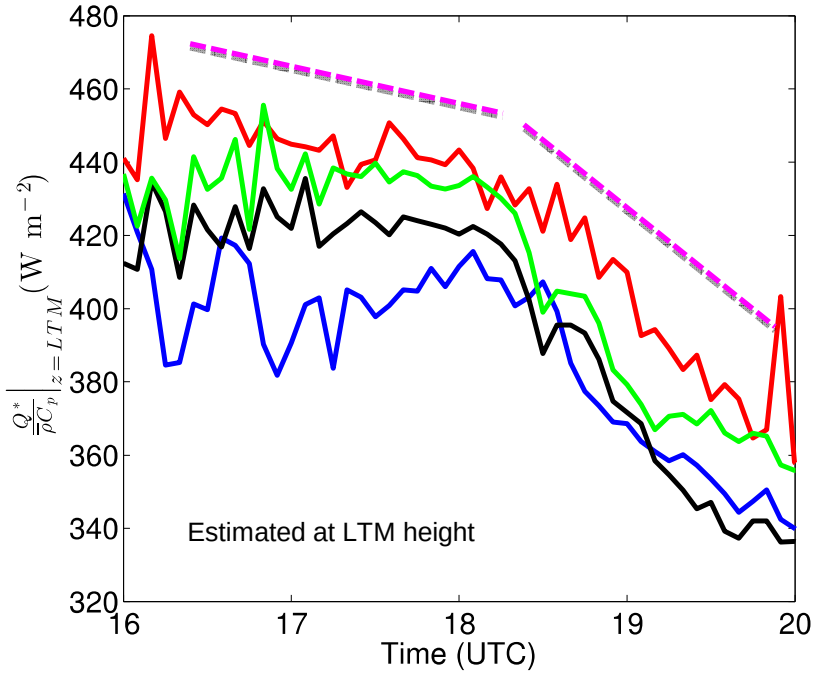
ground molecular diffusion value

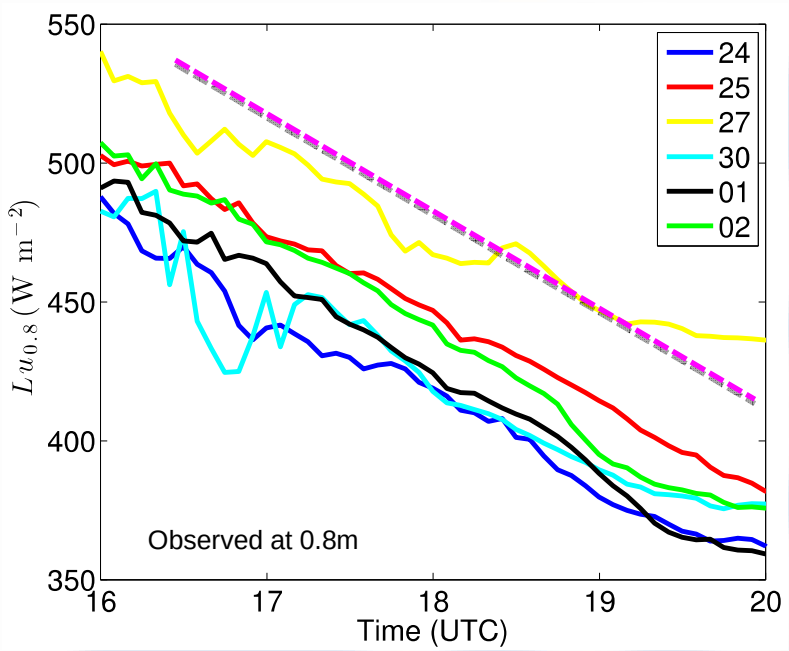
$$\left.\frac{Q^*}{\overline{\rho} C_p}\right|_{z=0m} \approx Lu\big|_{z=0m} = \varepsilon \sigma_b T_g^4$$

LTM during afternoon transition

Radiation

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

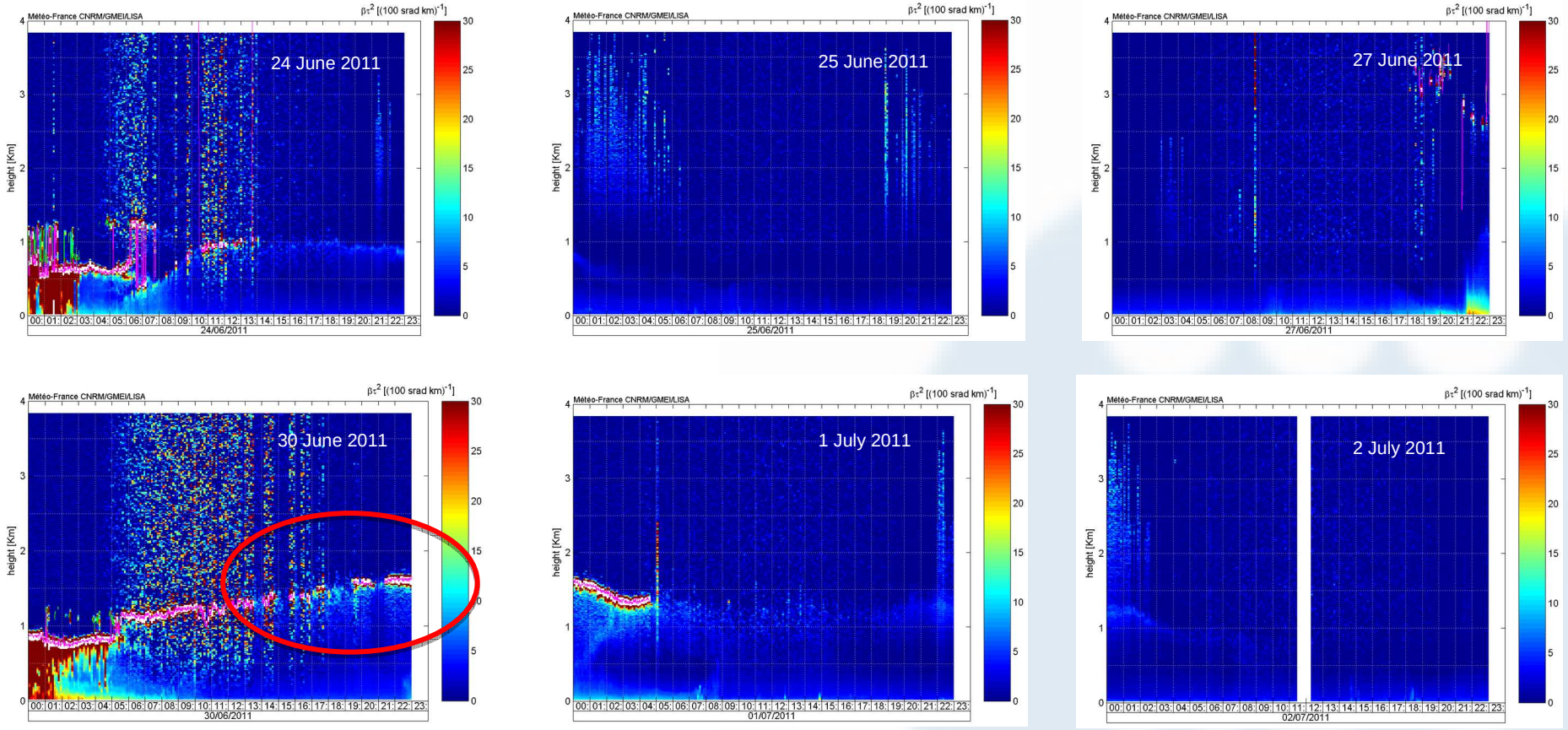




•Change of decay rate at LTM height between 17:30-18:30 UTC.

LTM during afternoon transition

Radiation - Cloud Cover



Mukund et al. (2010) reported that **LTM–intensity** decreases when **clouds** were present showing the importance of **radiation** in the LTM.

Conclusions

Lifted temperature minimum during evening transition

- **LTM:** different intensity and duration for **all IOPs** (no LTM on 27/06/2011).
- **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** that enhance the **intensity of the LTM.**
- LTM is observed due to a change in **radiative conditions.**

Thank you!!!