Boundary Layer Late Afternoon and Sunset Turbulence

TKE decay during BLLAST

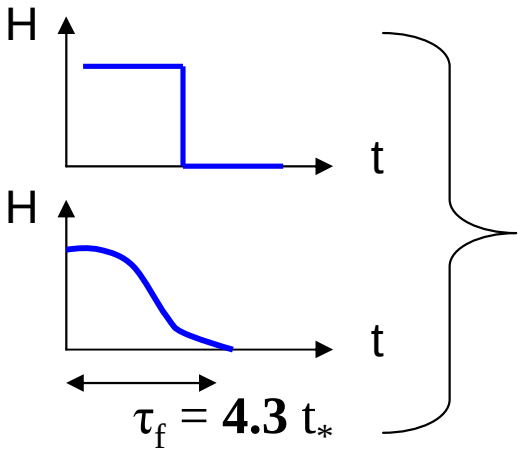
Fabienne Lohou, Clara Darbieu, Marie Lothon,
and all bllasters.

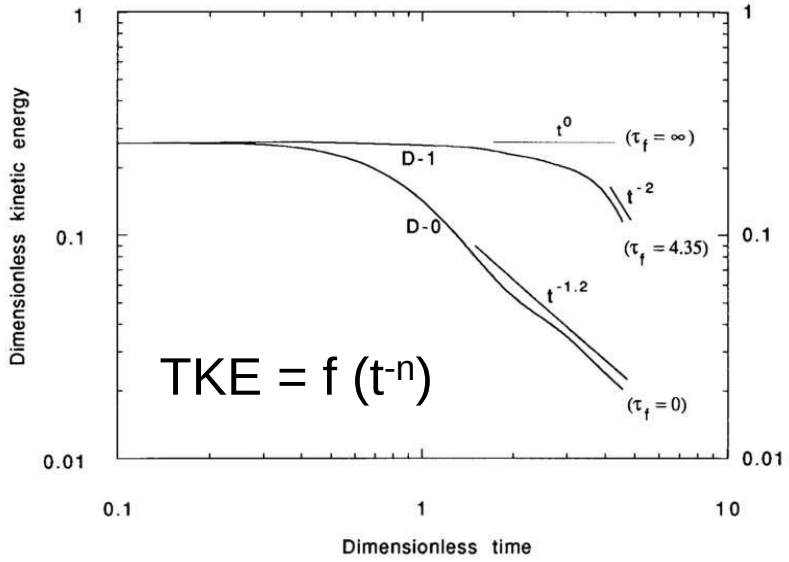
Bergen, 14-16 August 2013

1- Law of the TKE decay

Niewstadt and Brost (1986)

Sorbjan (1997)



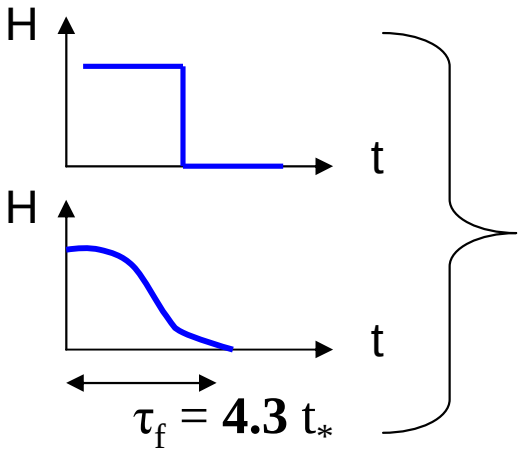


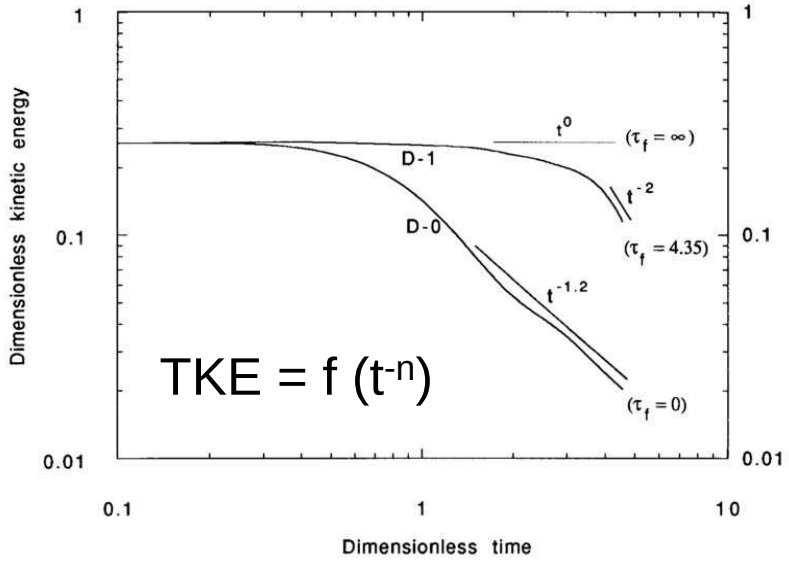
(Sorbjan,1997)

1- Law of the TKE decay

Niewstadt and Brost (1986)

Sorbjan (1997)





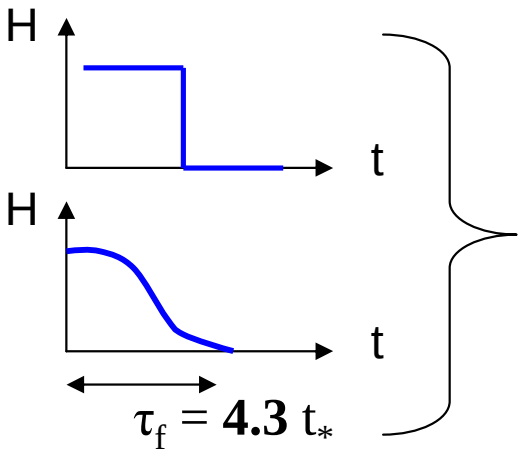
(Sorbjan,1997)

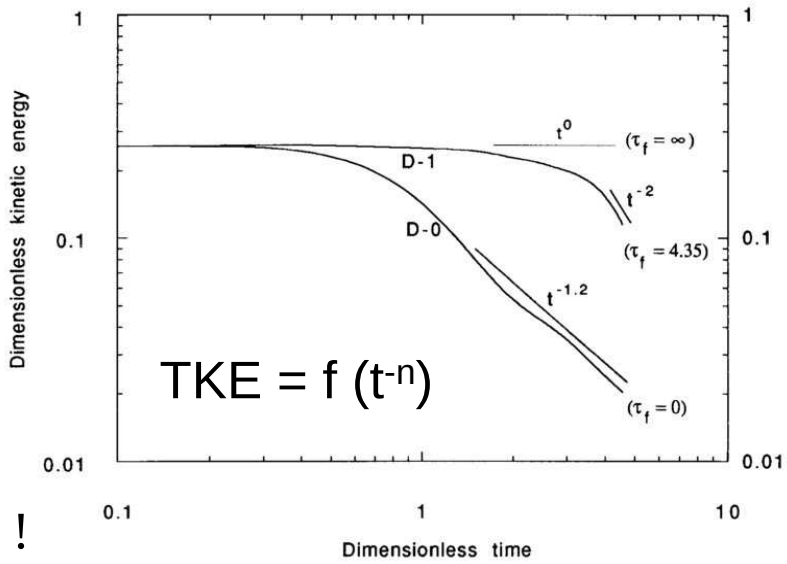
→ The power law t^{-n} is pointed out but τ_f is not realistic !

1- Law of the TKE decay?

Niewstadt and Brost (1986)

Sorbjan (1997)





(Sorbjan,1997)

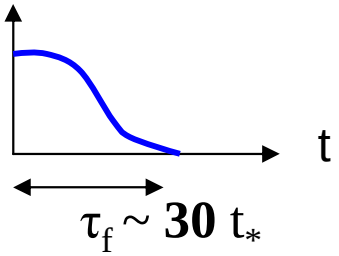
➡ The power law t^{-n} is pointed out but τ_f is not realistic !

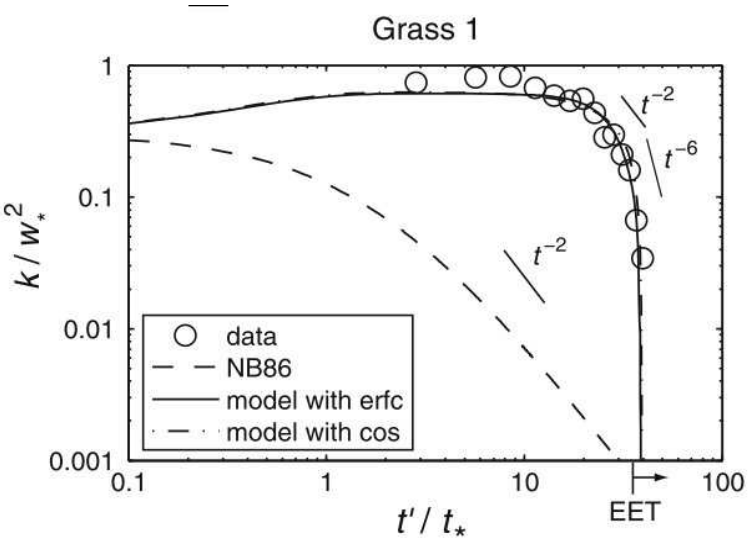
Pino et al. (2006) *(LES)*

Nadeau, Pardyjak et al. (2011)

(experiment at surface)

Rizza (2013) *(LES average BL)*





➡ The power law t^{-n} confirmed with n equals 2 to 6 during the LAT

(Nadeau et al, 2011)

2- Which forcing prevails?

Nadeau, Pardyjak et al. (2011)

Rizza (2013) *(LES average BL)*

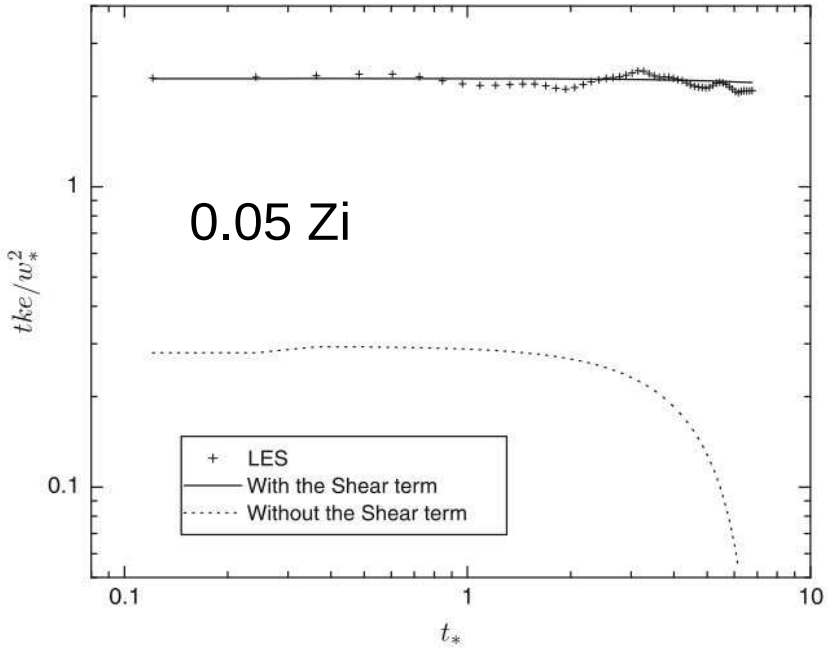
$$\frac{\partial \bar{e}}{\partial t} = \frac{g}{\theta}(\overline{w'\theta_v'}) - \varepsilon \quad \text{with} \quad \varepsilon = C\frac{\bar{e}^{3/2}}{zi}$$

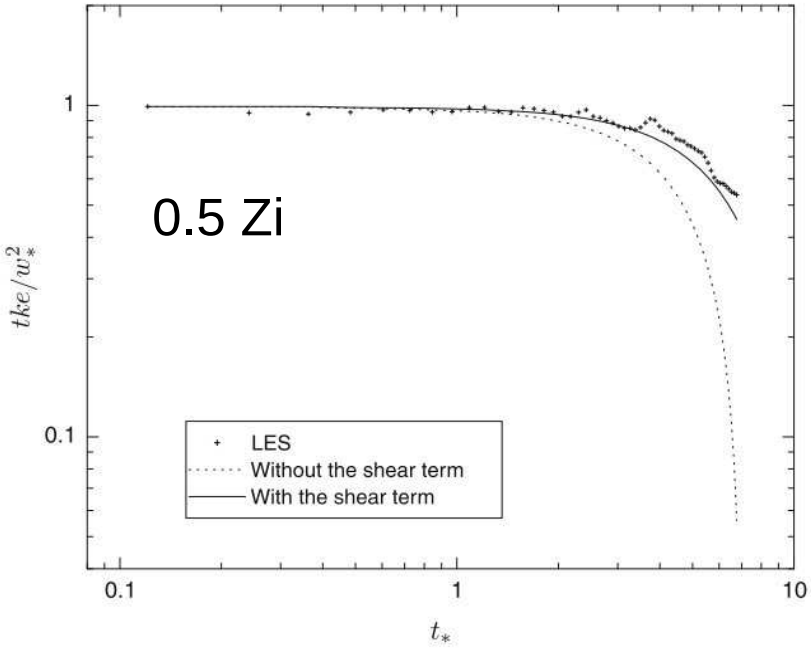
(Niewstadt and Brost, 1996)

agrees with Nadeau et al.

Pino et al. (2006) *(LES) : n depends on shear conditions*

Goulart et al. (2011) *(LES) : n depends on shear conditions at surface*





Goulart (2011) (LES of strong shear case Ug = 15 m/s)

Gibert, BLT2012: *Importance of transport and pressure terms*

Some remaining questions

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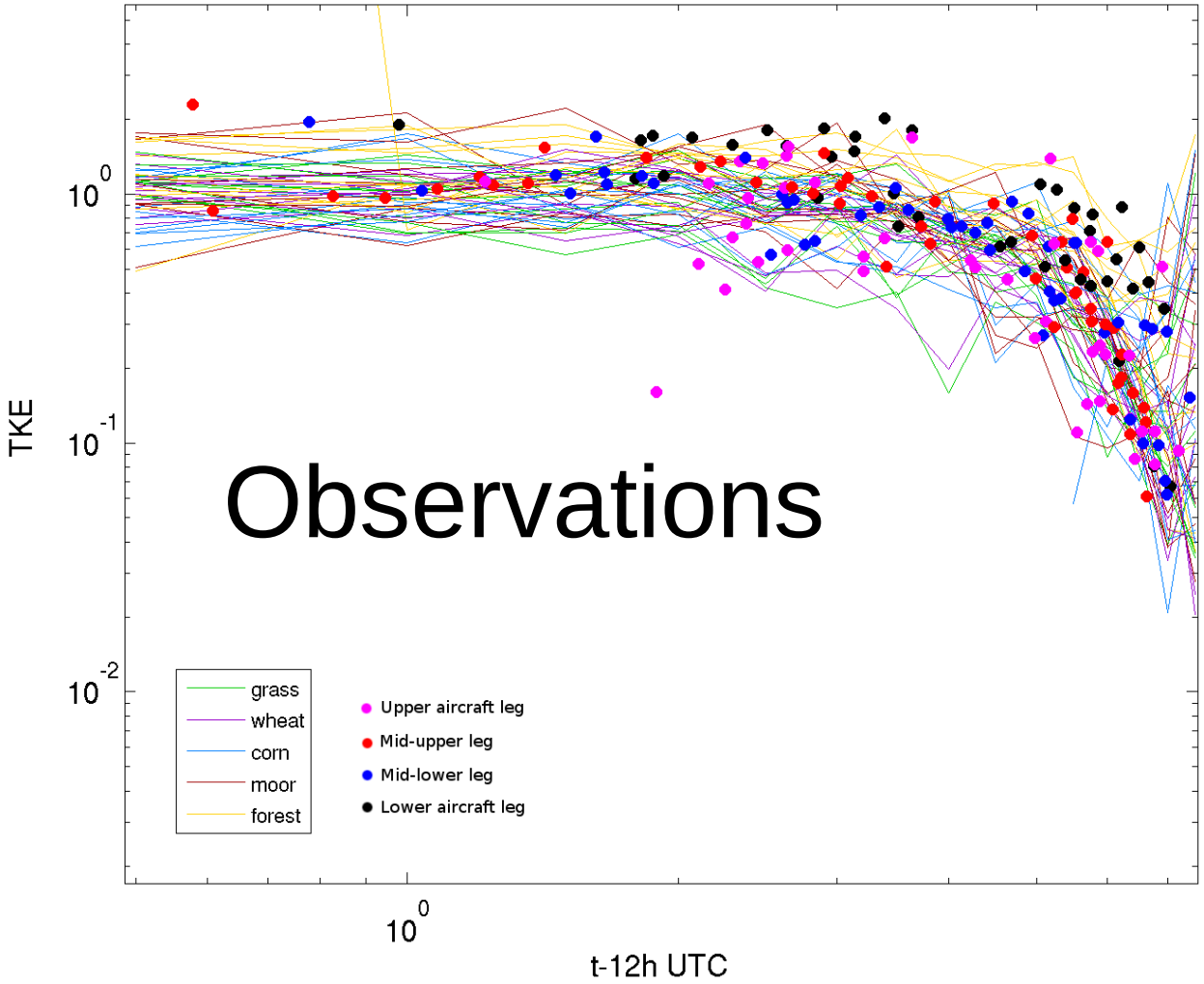
✓ Scaling of the TKE decay: TKE / w_*^2 = f (t / t_*) with w_* and t_* (or w_m in Pino et al., 2003) defined for fully convective conditions (Sorbjan, 1997).

✓ Going further in the vertical discretization of the TKE decay in the whole ABL.

- to extend the work on the decoupling
- to diagnose the forcings at the different heights

BLLAST contribution

All the IOP, All the surfaces, All the aircraft flights … + …. TB, RPAS to be added

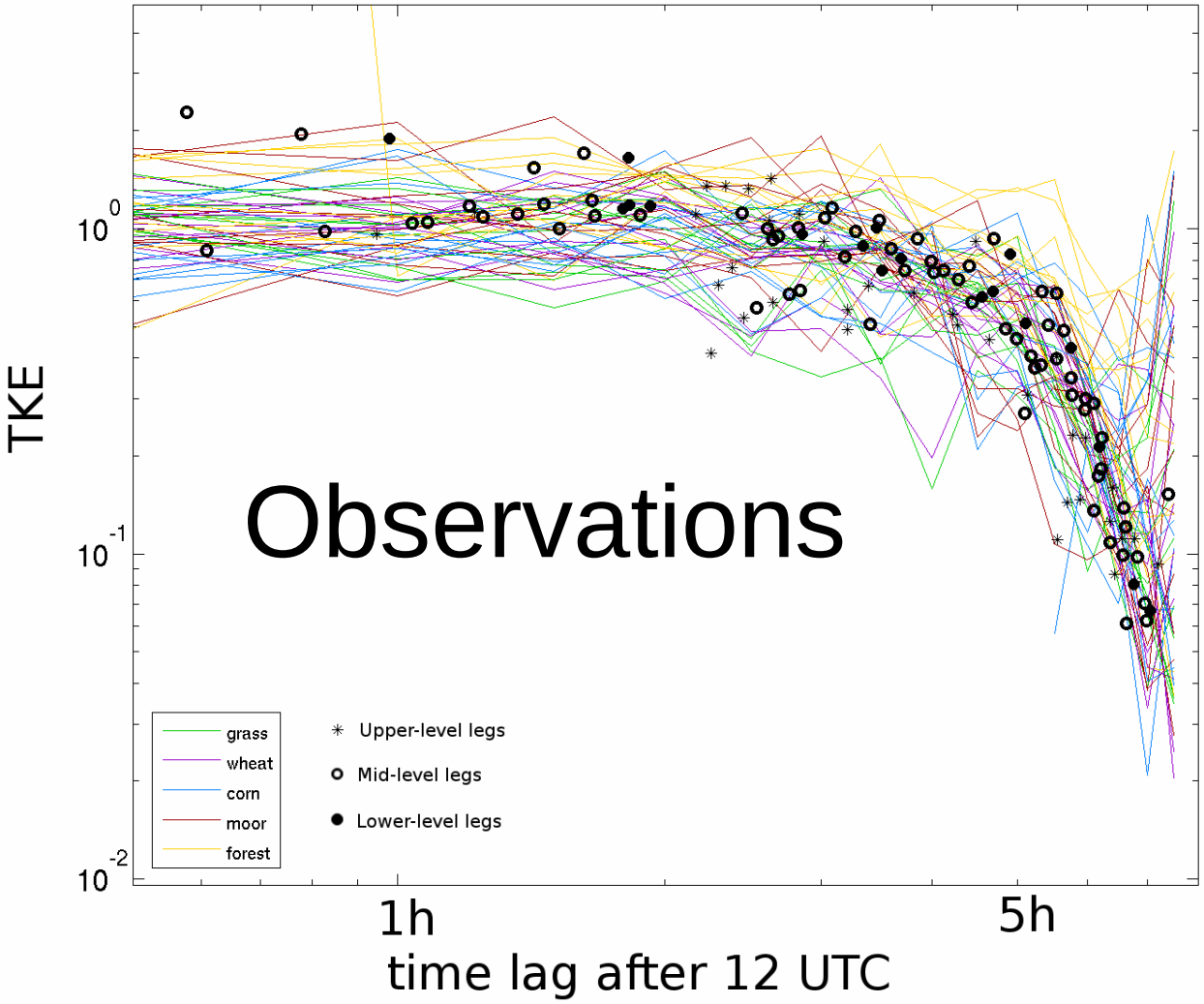


Observations + LES

BLLAST contribution

Boundary Layer Late Afternoon and Sunset Turbulence

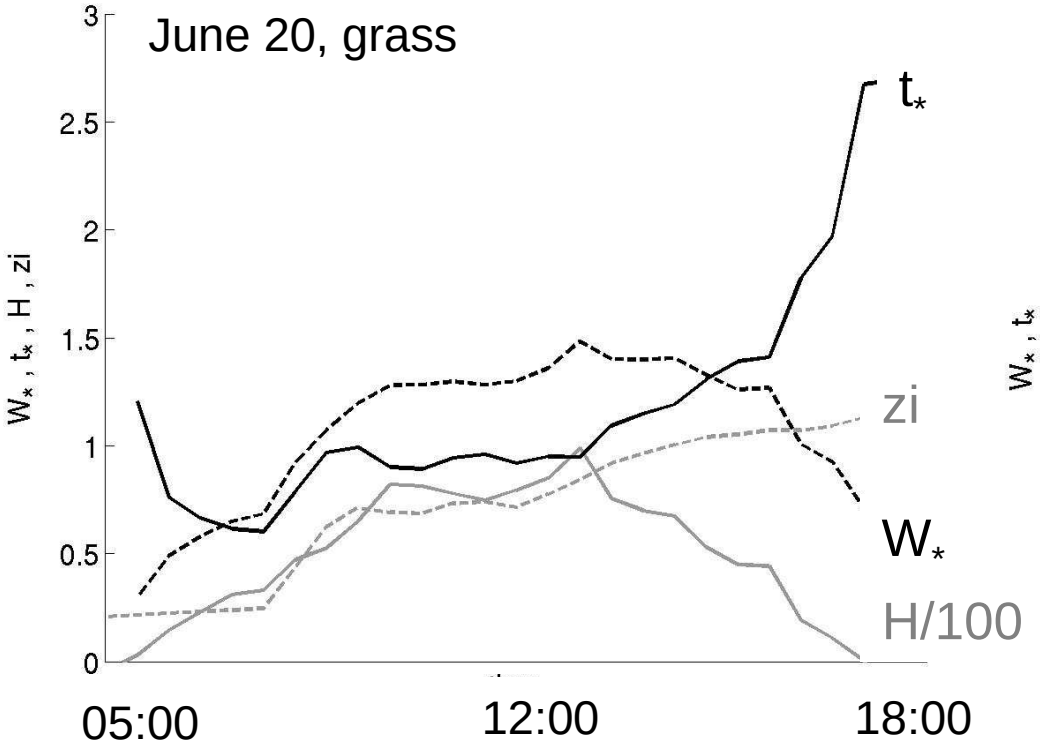
All the IOP, All the surfaces, All the aircraft flights

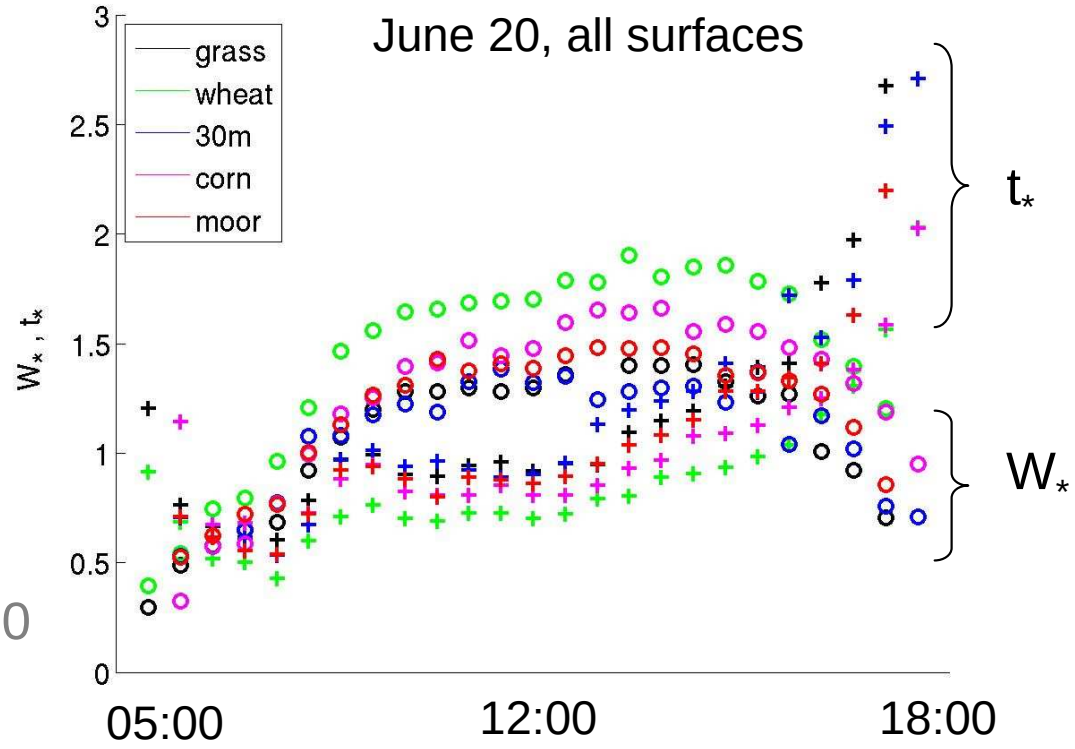


Observations + LES

So … a lot to do… but not much done up to now !

Scaling of TKE decay





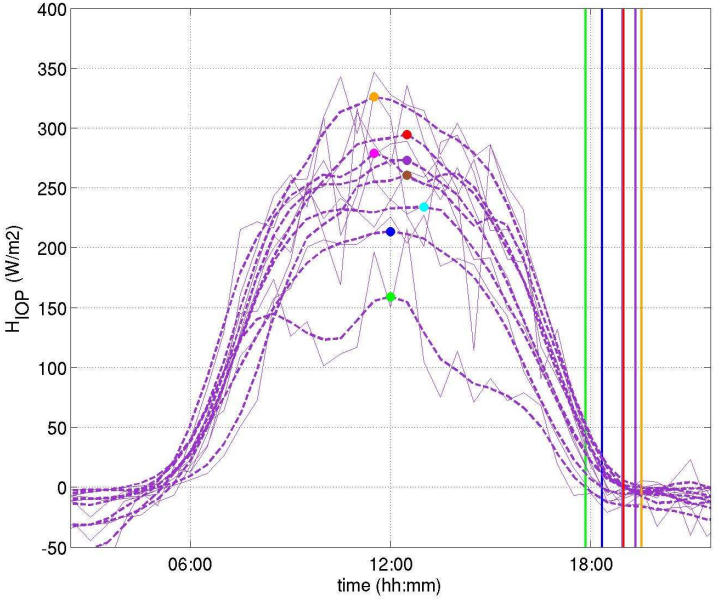
$$t_* = \frac{zi}{w_*} = \frac{zi}{\left(\frac{g}{\overline{\theta_v}} zi\overline{w'\theta_v'}\right)^{1/3}}$$

A normalization by w_* and t* defined when the conditions are fully convective do not give a real view of what is happening during the LAT over the different surfaces.

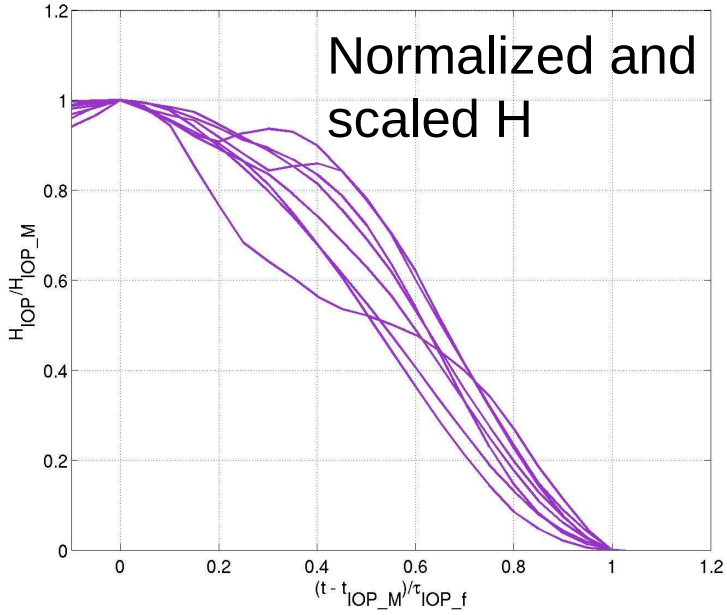
Scaling of TKE decay during BLLAST

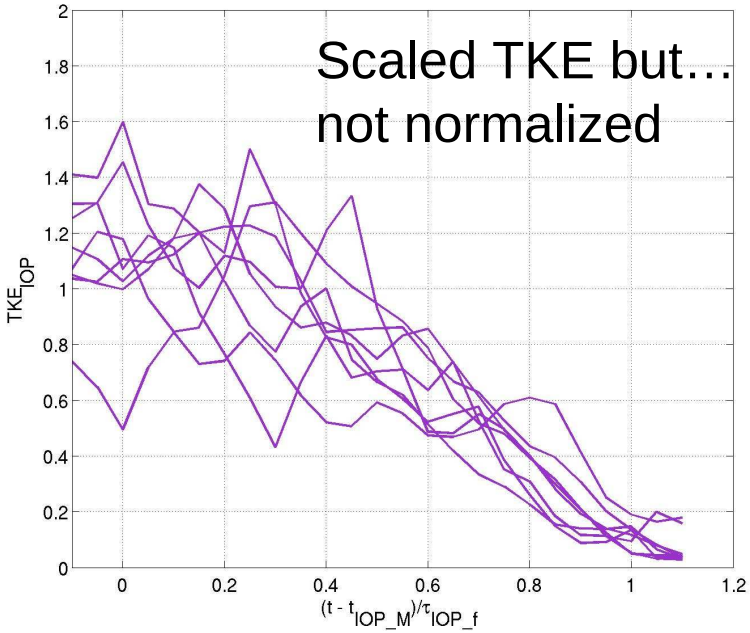
(H_{IOP_M}, t_{IOP_M}) $(H_{IOP} = 0, t_{IOP\_0})$

τ_{IOP_f}



normalisation





Timing of TKE decay during BLLAST

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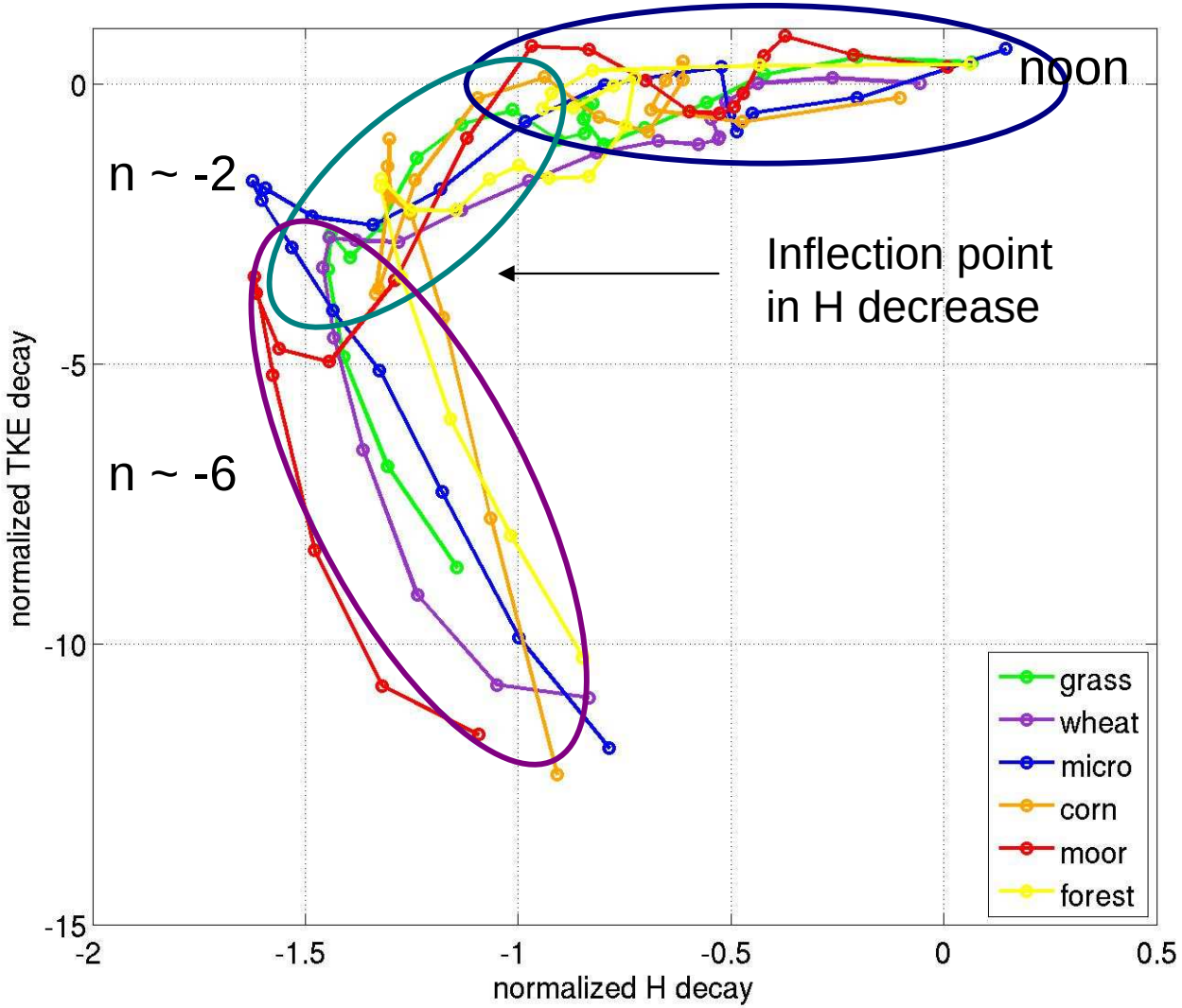
Mean evolution of the TKE decay rate against H decay rate

$$\left\langle \frac{\partial \log(TKE_{IOP})}{\partial \log(t)} \right\rangle_{IOP} = \left\langle \frac{\partial H_{IOP}}{\partial t} \right\rangle_{IOP}$$

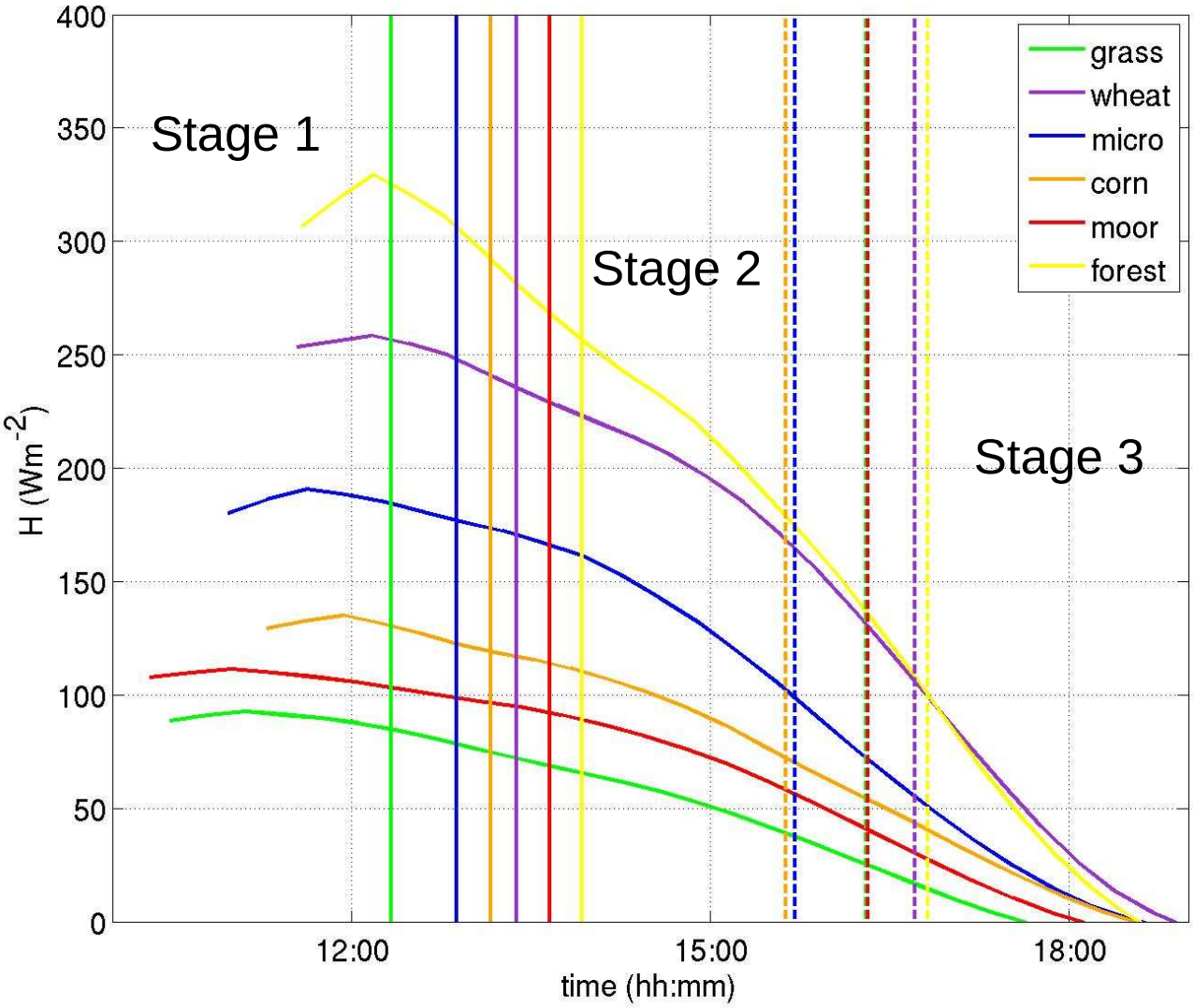


H decreases - n ~ 0

H decreases
n slowly decreases to -5

H decreases
n rapidly decreases from -5 to -12

Timing of TKE decay during BLLAST



Time shift between the different vegetation coverages

Forcings at surface

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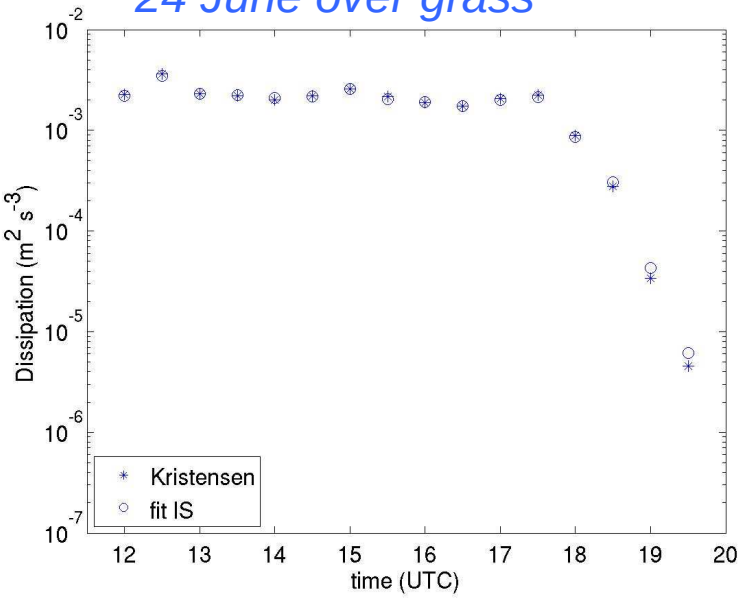
Assuming horizontal homogeneity:

$$\frac{\partial \overline{e}}{\partial t} = -\overline{(u'w')}\frac{\partial \overline{u}}{\partial z} + \frac{g}{\overline{\theta}}\overline{(w'\theta')} - \frac{1}{\rho}\frac{\partial}{\partial z}\overline{(w'p')} - \frac{\partial}{\partial z}\overline{(w'e)} - \varepsilon$$

Imbalance term usually estimated assuming **steady state**

24 June over grass



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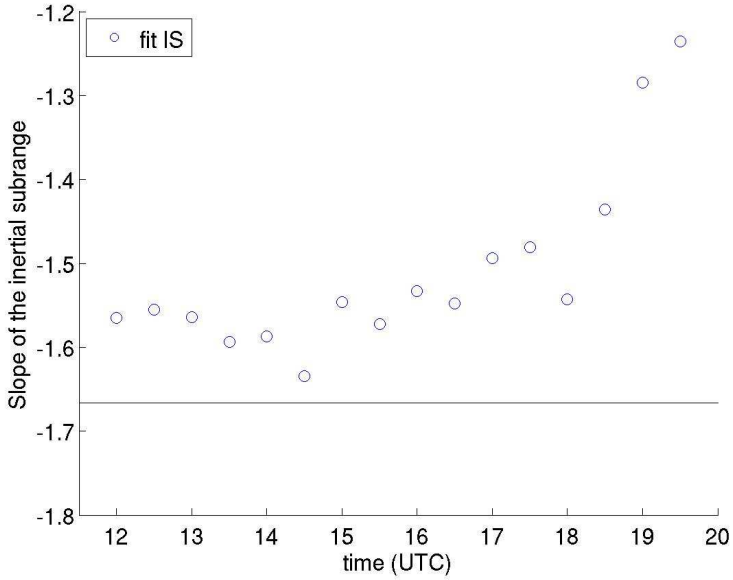


Forcings at surface

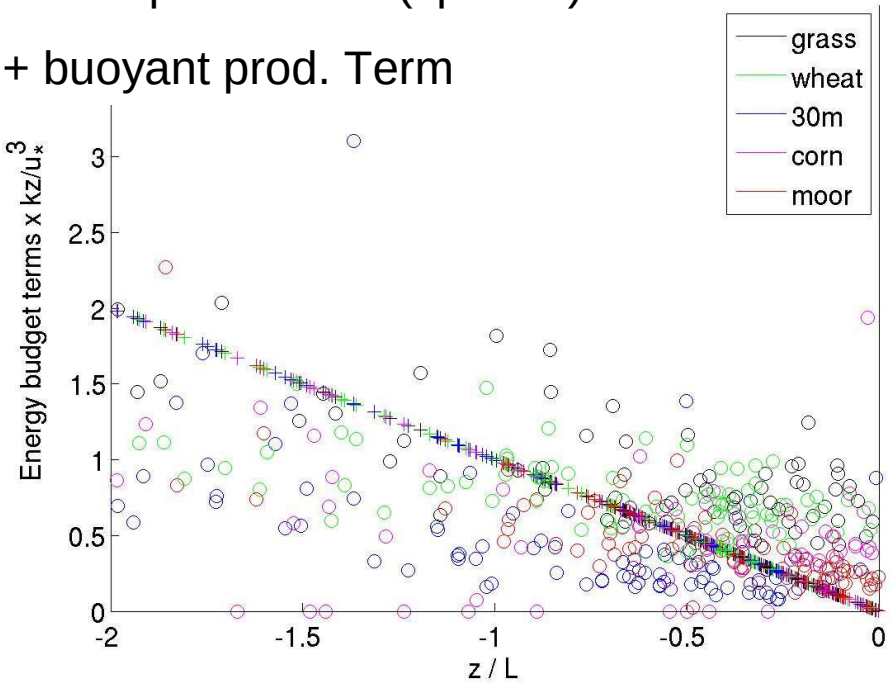
Assuming horizontal homogeneity:

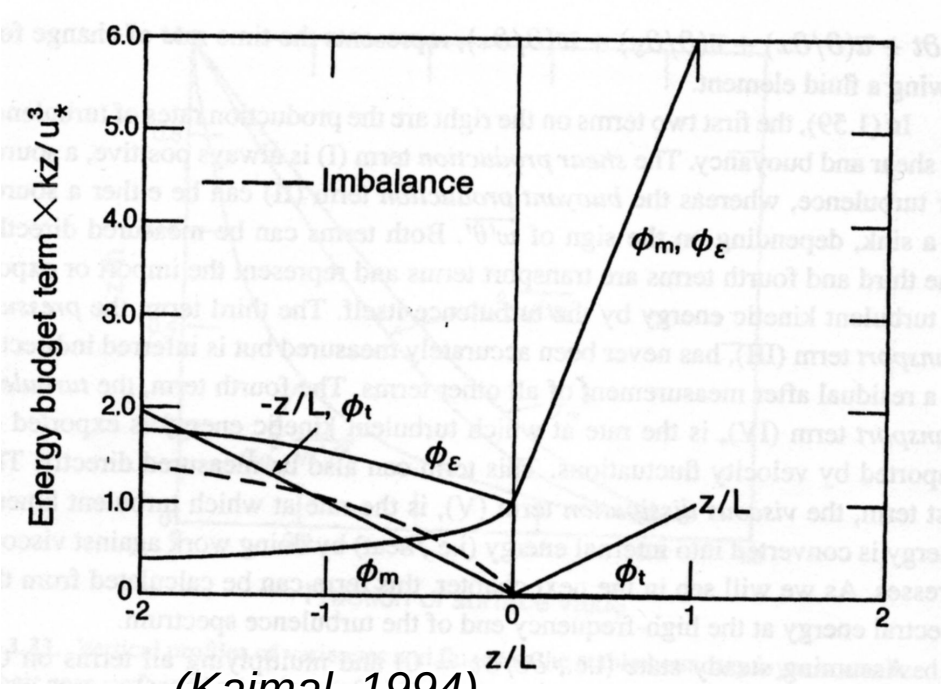
$$\frac{\partial \bar{e}}{\partial t} = -\overline{(u'w')}\frac{\partial u}{\partial z} + \frac{g}{\bar{\theta}}\overline{(w'\theta')} - \frac{1}{\rho}\frac{\partial}{\partial z}\overline{(w'p')} - \frac{\partial}{\partial z}\overline{(w'e)} - \varepsilon$$

Imbalance term usually estimated assuming **steady state**

o dissipation term (spectra)

+ buoyant prod. Term





(Kaimal, 1994)

Forcings at surface

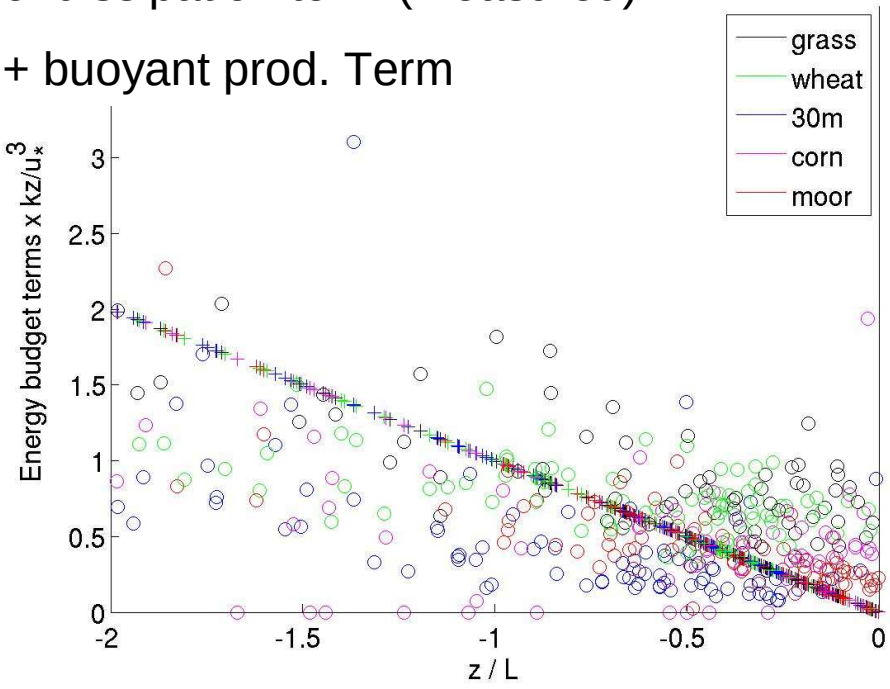
Assuming horizontal homogeneity:

$$\frac{\partial \bar{e}}{\partial t} = -\overline{(u'w')}\frac{\partial u}{\partial z} + \frac{g}{\theta}\overline{(w'\theta')} - \frac{1}{\rho}\frac{\partial}{\partial z}\overline{(w'p')} - \frac{\partial}{\partial z}\overline{(w'e)} - \varepsilon$$

Imbalance term usually estimated assuming **steady state**

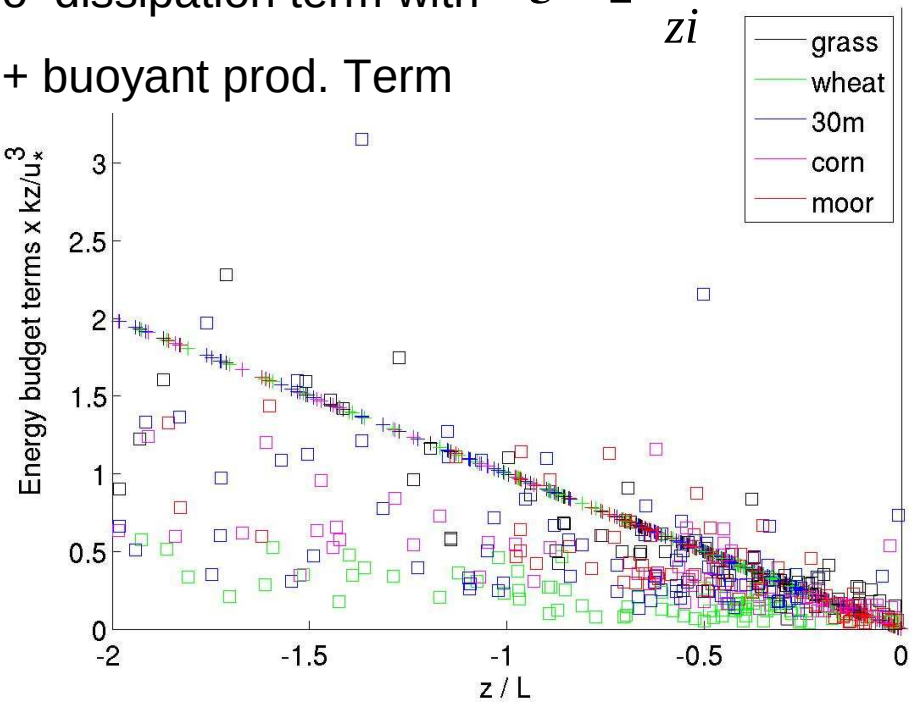
o dissipation term (measured)

+ buoyant prod. Term

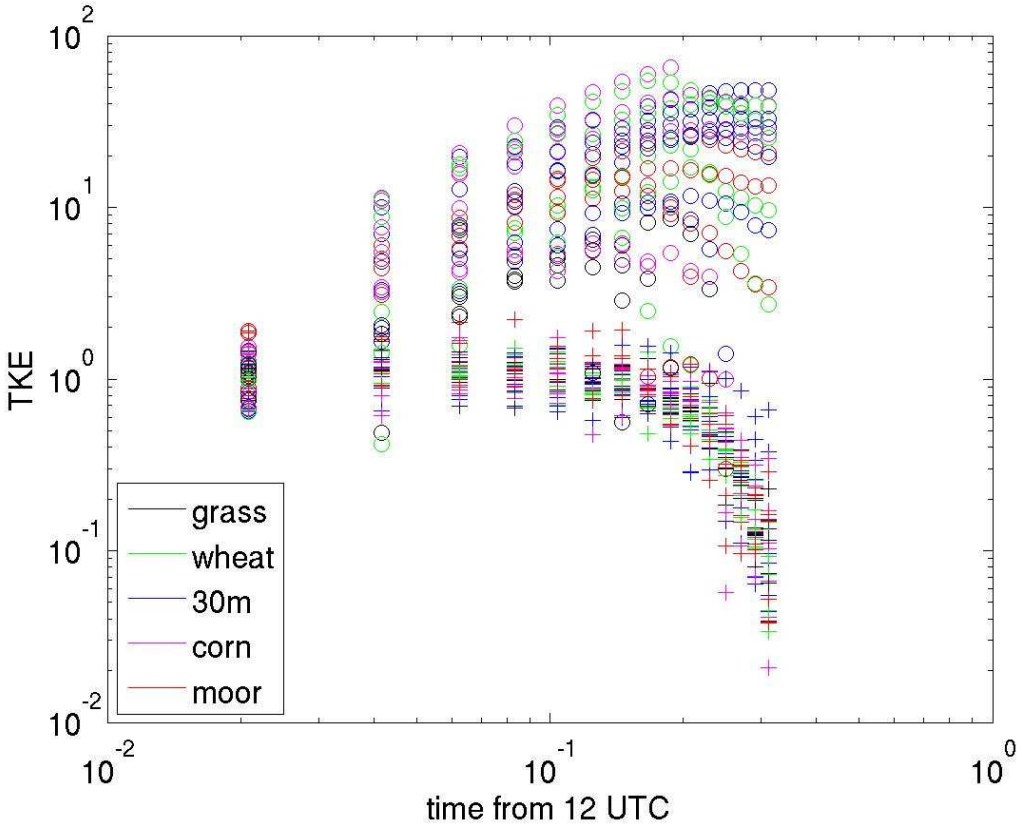


o dissipation term with $\varepsilon = 2\frac{e^{-3/2}}{zi}$

+ buoyant prod. Term



Forcings at surface



Temporal integration of

$$\frac{\partial \bar{e}}{\partial t} = \frac{g}{\theta}(\overline{w'\theta_v'}) - \varepsilon$$

or

$$\frac{\partial \bar{e}}{\partial t} = \frac{g}{\theta}(\overline{w'\theta_v'}) - 2\frac{\bar{e}^{3/2}}{zi}$$

TKE from measurements

During BLLAST buoyant production and dissipation do not seem to explain the TKE decrease.

Conclusions

- TKE timing
  - ➢ Scaling by w* and t* ? (Van Driel and Jonker, 2011)
  - ➢ no explanation for the link between TKE decay rate and H decay rate yet.

- Forcings
  - ➢ difficulty to estimate each of the TKE budget terms with surface data (dissipation and mechanical production).
  - ➢ buoyant production and dissipation not sufficient to model the TKE during BLLAST.

To be done:

- ➢ *Use of the divergence mast for the surface TKE budget.*
- ➢ *Use of the surface/ aircraft/ TB / RPAS data for a vertical description of the TKE decay in the whole ABL. And LES for the forcings.*