Surface wind variability due to convection

Introduction

- The average wind speed S is needed to calculate the turbulent surface fluxes.
- Numerical weather prediction models predict the grid-averaged wind vector (u,v).
- The average wind speed S can be obtained from V, the magnitude of the average wind vector, and U_g, the wind gustiness:

$$S^2 = V^2 + U_g^2$$

where

$$V^2 = u^2 + v^2$$

Wind gustiness

- The wind gustiness is due to subgrid-scale variability of the wind vector.
- For the clear convective boundary layer, the wind gustiness is proportional to the convective velocity scale.
- Wind gustiness is also produced by deep precipitating convection, and parameterized as a function of convective rainfall rate.

Wind variance and gustiness

- The variance of the horizontal wind speed, U_σ^2, can be related to the gustiness:

$$U_g = \alpha U_\sigma$$

- Theoretical methods give a value of 0.8 for α (Jabouille et al. 1996).
- U_g, and hence U, may be obtained if U_σ can be parameterized.

Examples of Gustiness in Numerical Simulations

TABLE 2. A list of numerical experiments performed with the prescribed large-scale advective cooling and moistening effects.

Experiment	Domain size	Advective forcing		Underlying surface	Geostrophic wind	Advection in V Eq.
		Period	Strength			
Q03	512 km	27 h	Strong	Ocean	No shear	Yes
Q02	512 km	27 h	Strong	Ocean	Shear	Yes
Q04	1024 km	27 h	Strong	Ocean	Shear	Yes

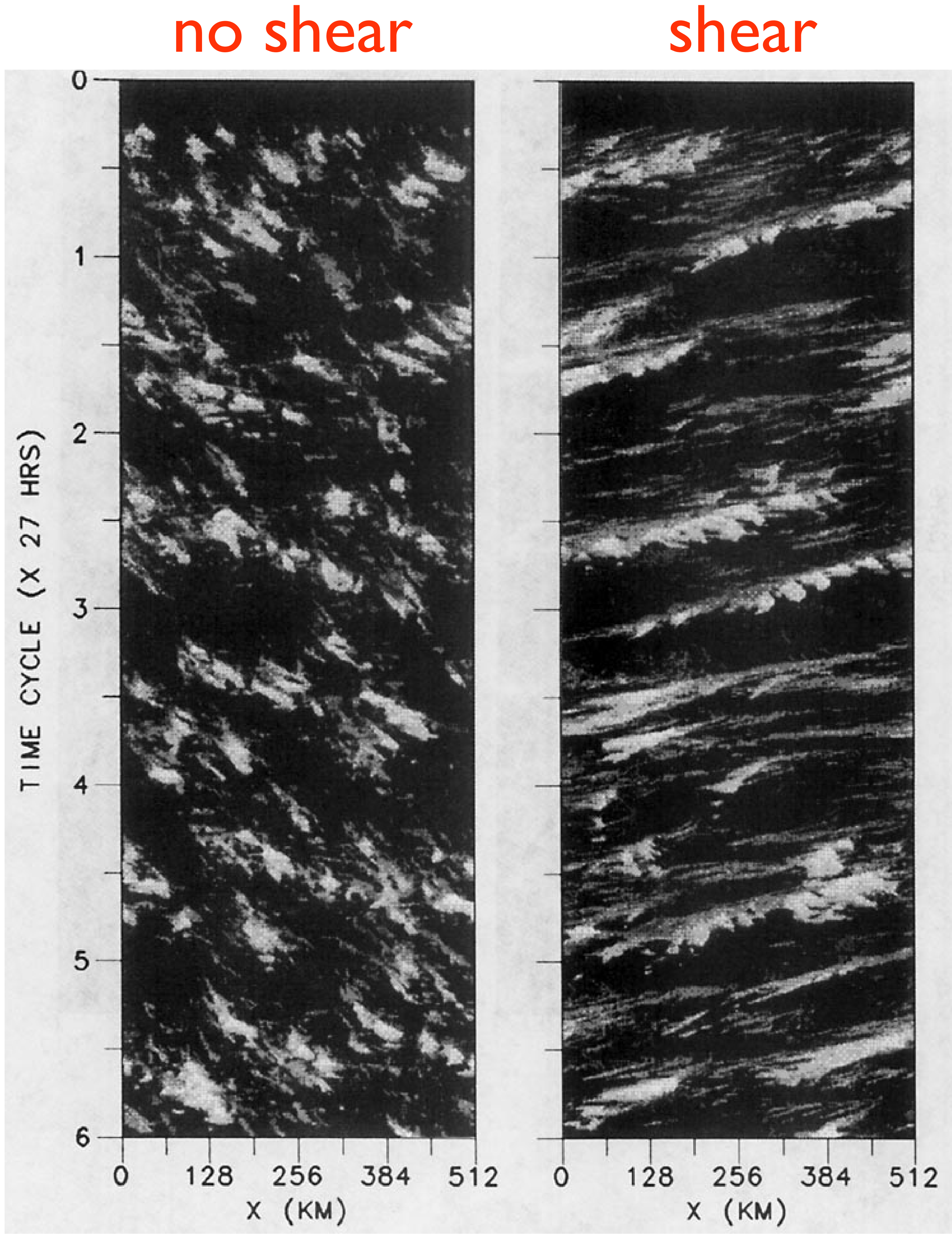
The simulations were performed with a 2D (x-z) cloud-resolving model at latitude 15 deg N.

The period of an inertial oscillation is $2\pi/f$, where $f = 2\,\Omega \sin\phi$, and $\Omega = 7.29 \times 10^{-5}$ rad/s.

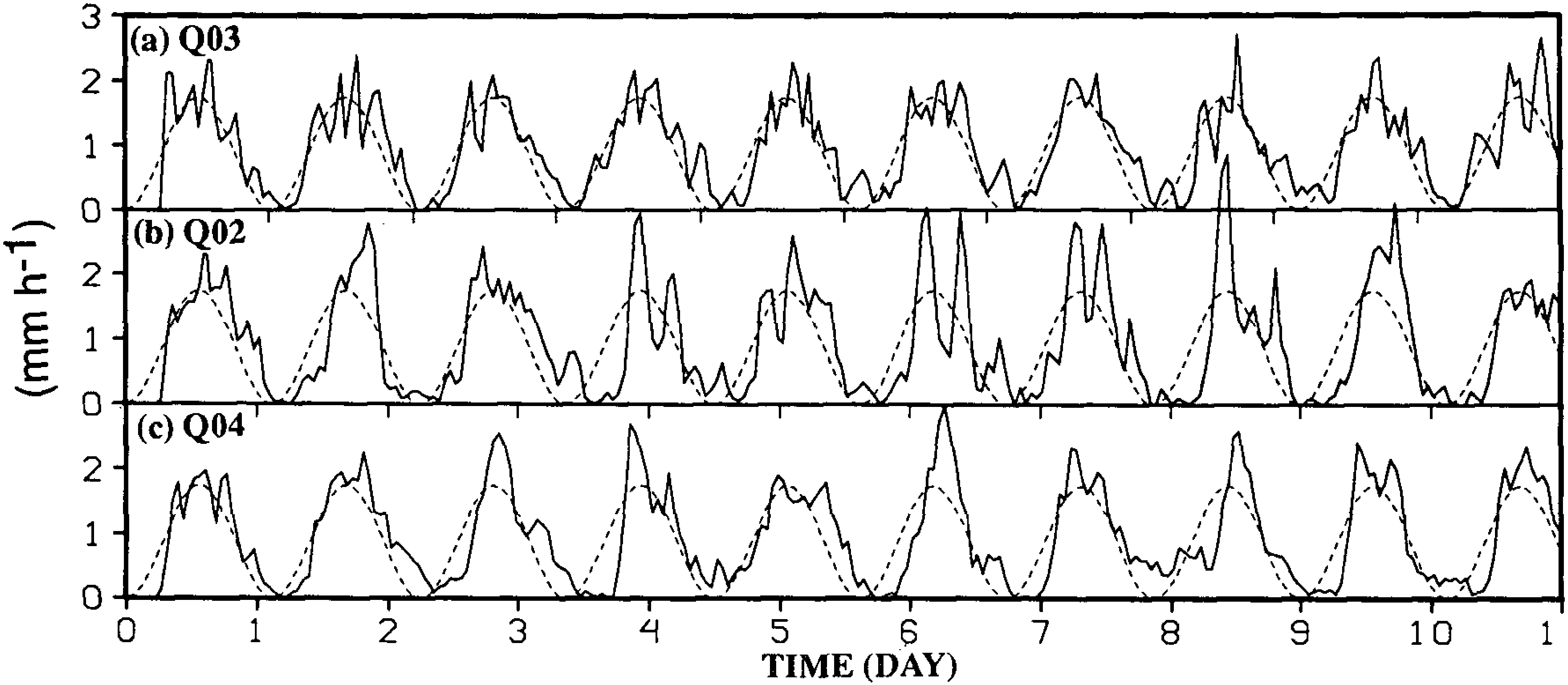
What is the inertial period at this latitude?

The plots show cloud-top temperature (white= 200 K, black = 300 K).

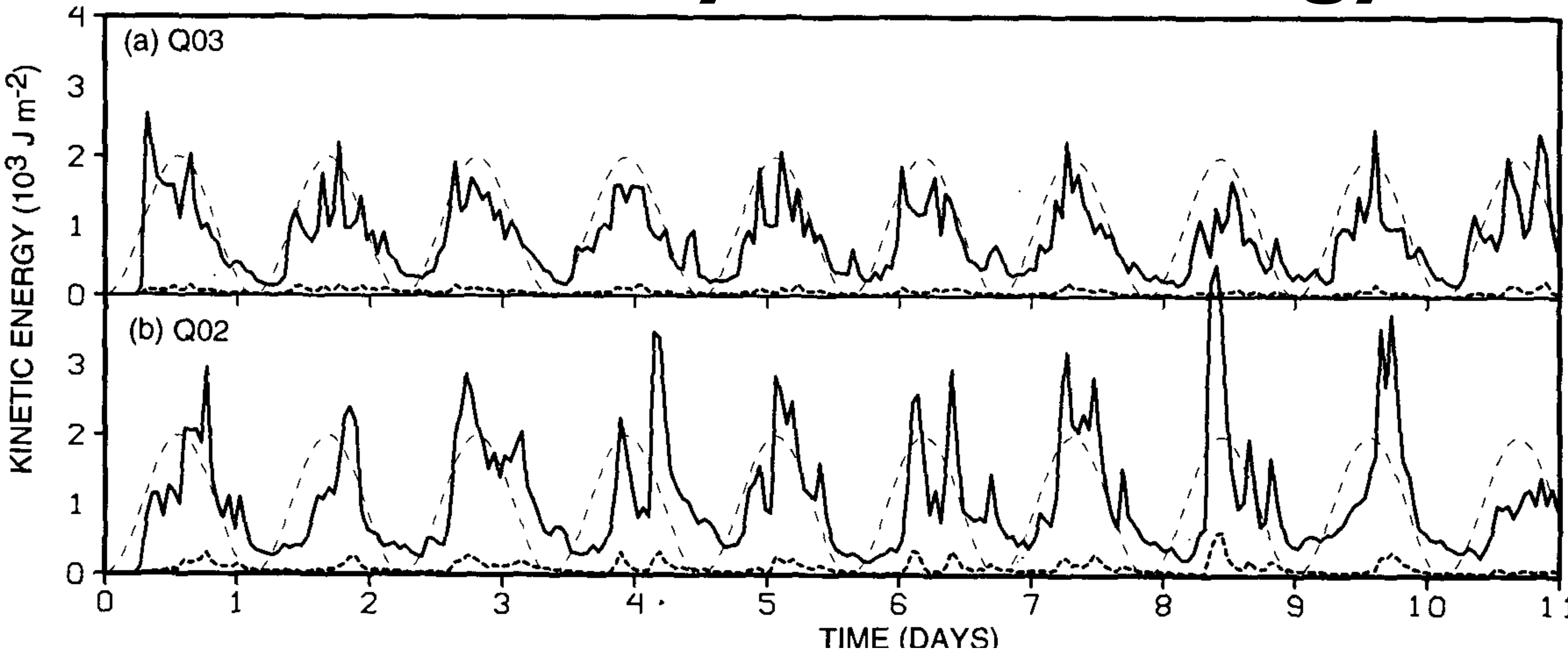
The plots show the effects of shear on convection organization.



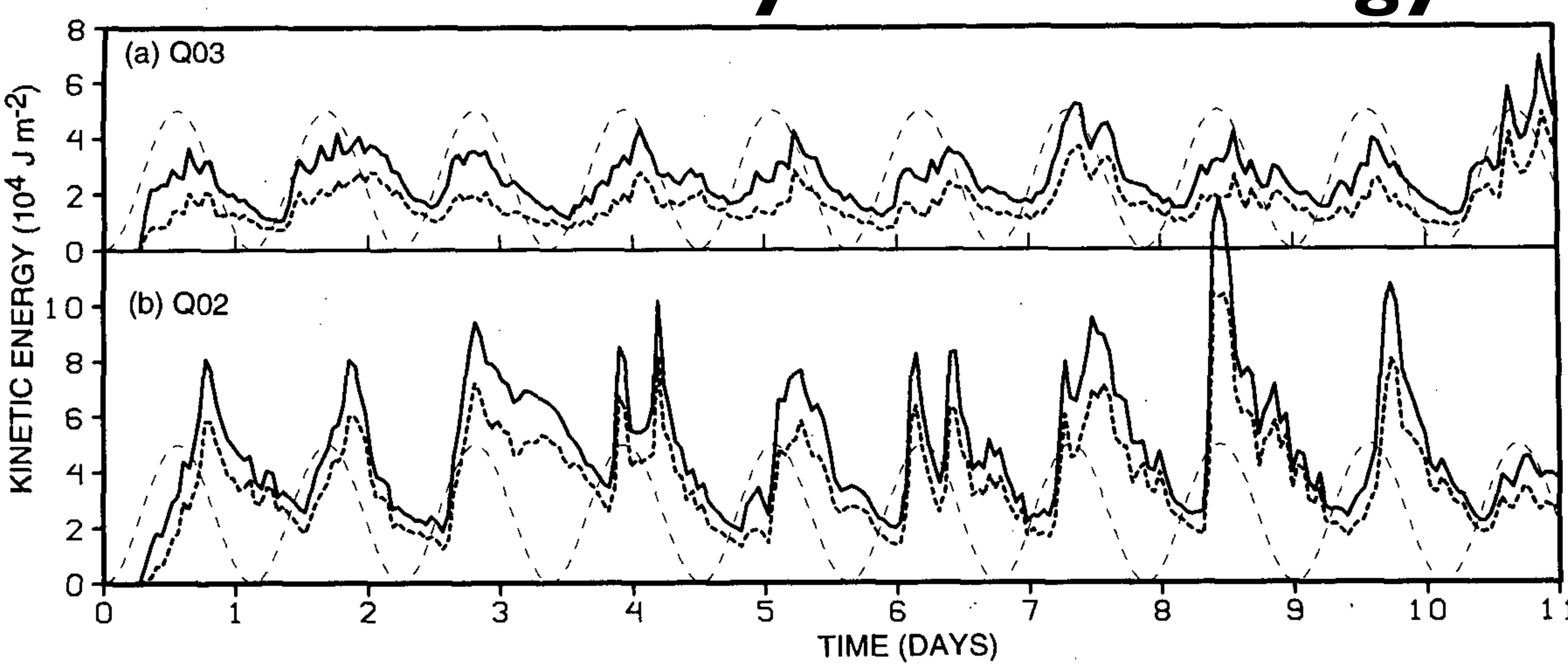
Surface Rainfall Rate



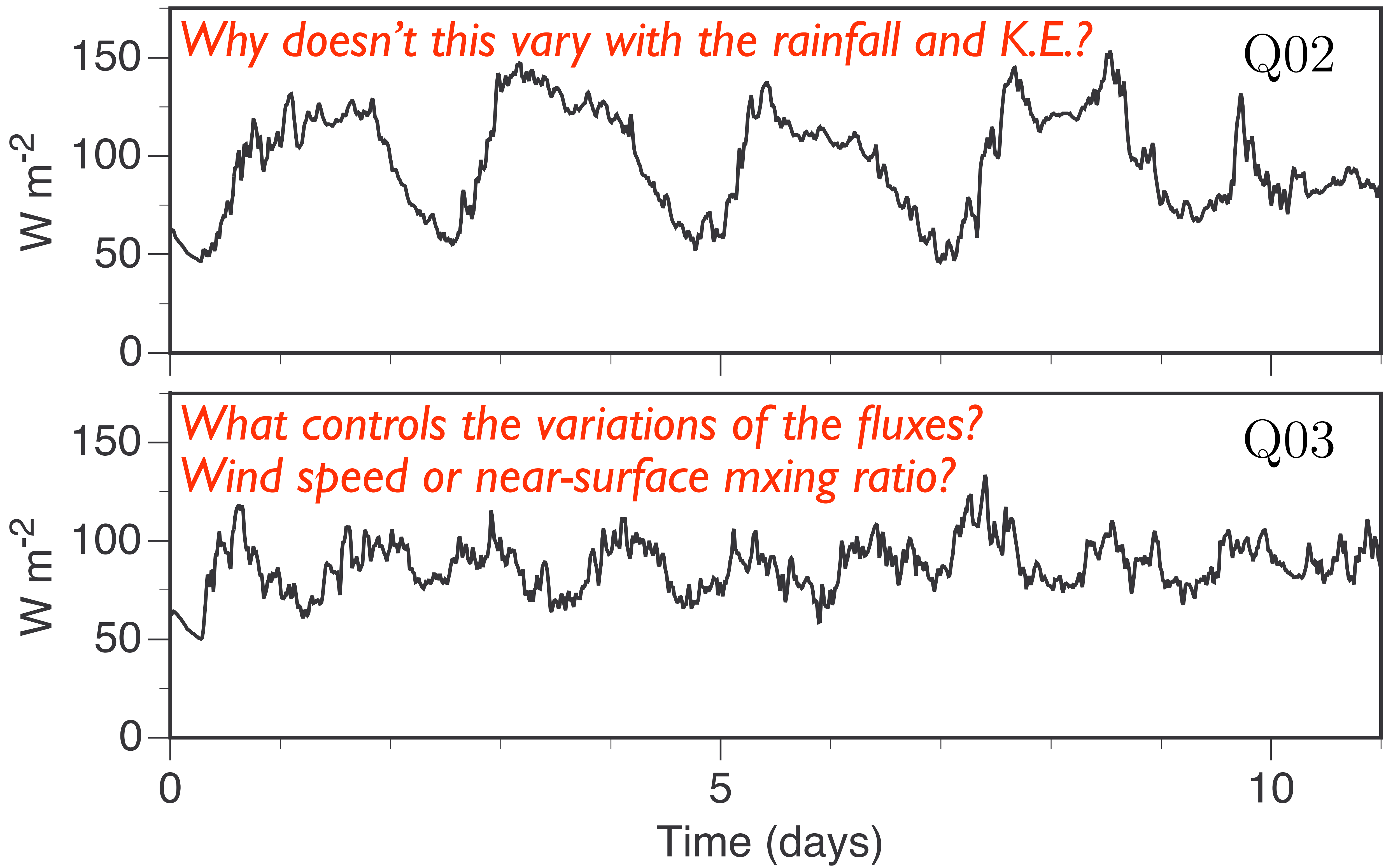
Vertical Eddy Kinetic Energy



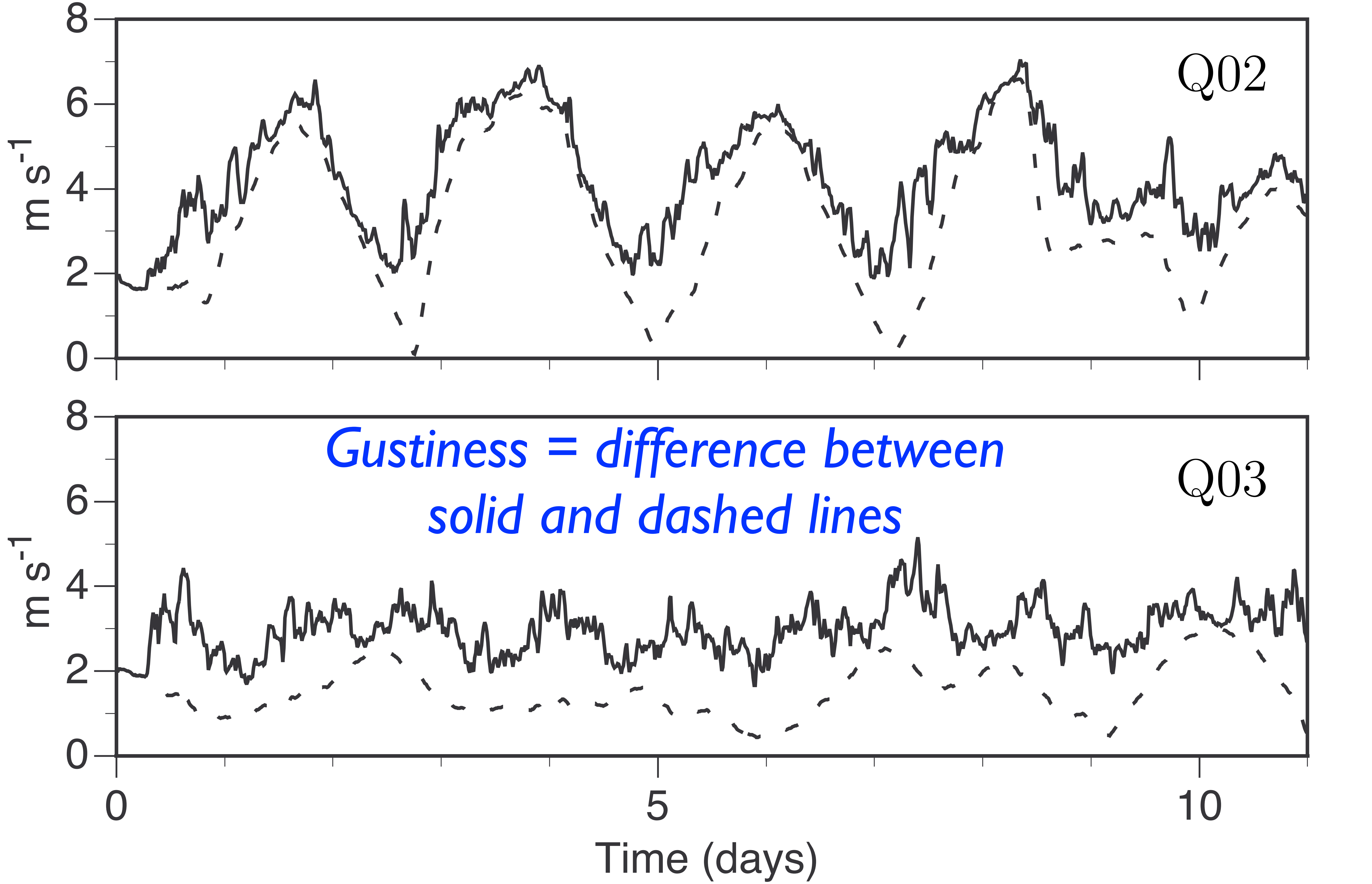
Horizontal Eddy Kinetic Energy



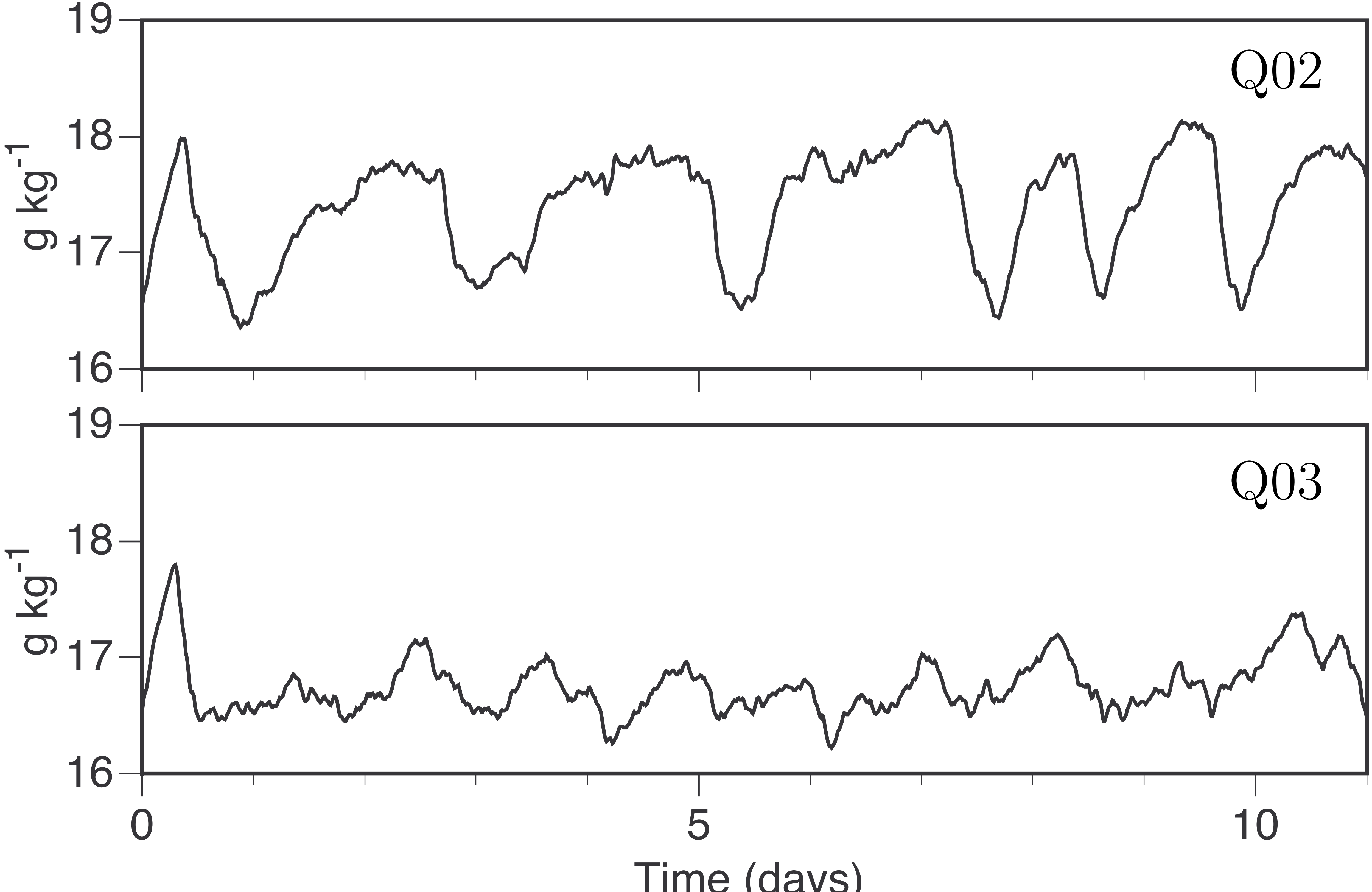
Latent Heat Fluxes



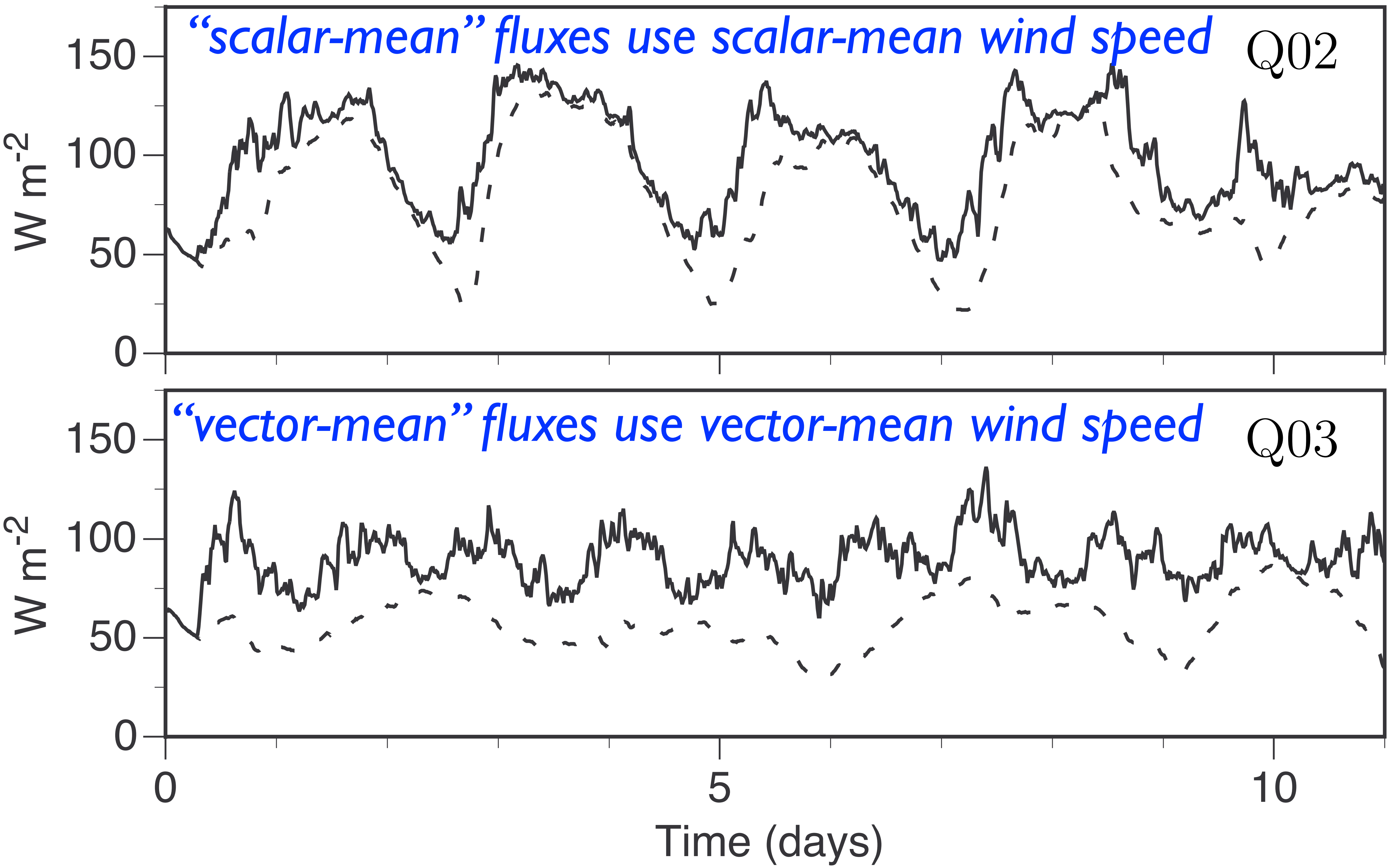
average near-surface wind speed (solid), and speed of average vector wind (dashed)



average near-surface water vapor mixing ratio



“scalar-mean” latent heat fluxes (solid), and “vector-mean” latent heat fluxes (dashed)



Differences between solid and dashed lines are due to gustiness

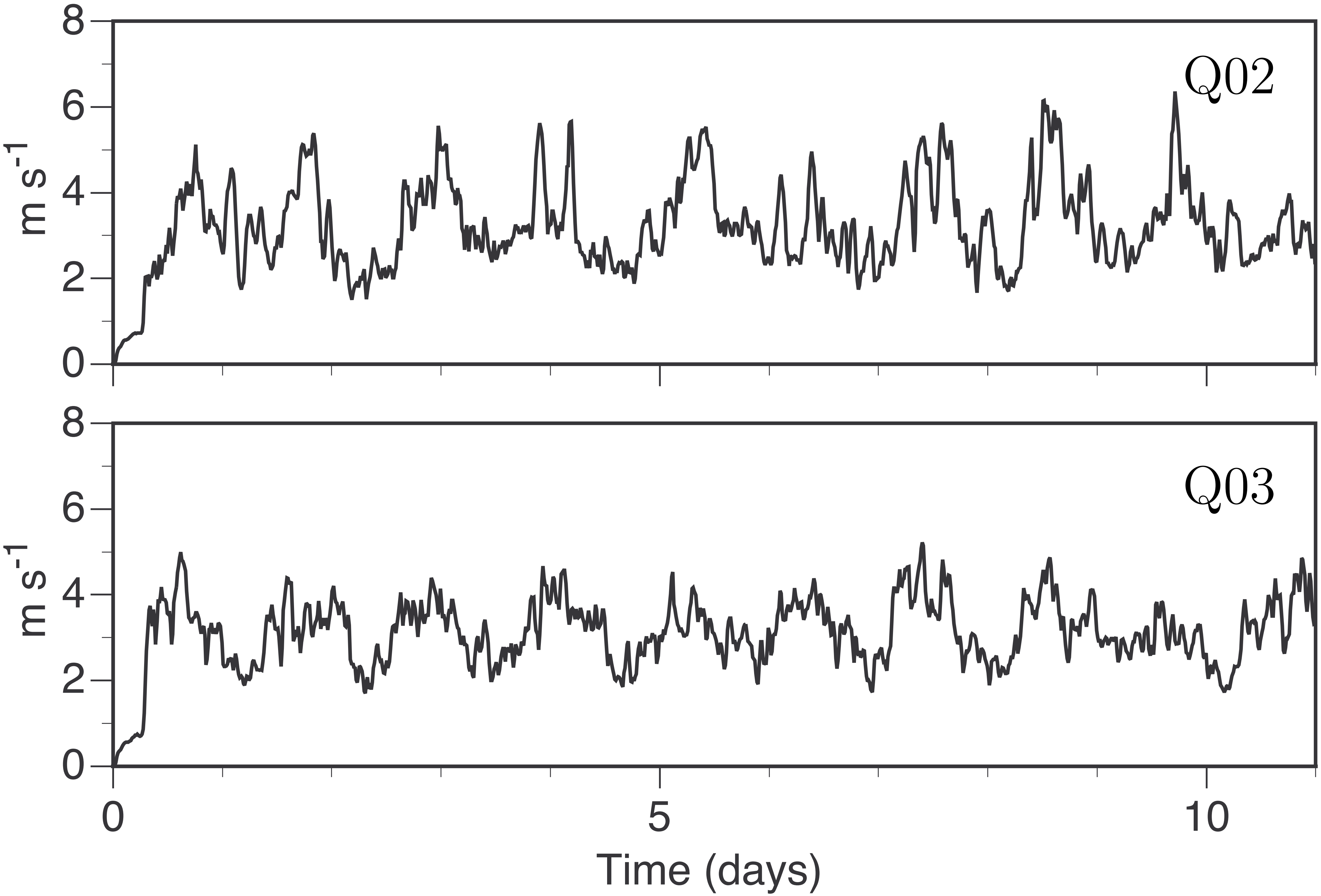
Wind variance and gustiness

- The variance of the horizontal wind speed, U_σ^2, can be related to the gustiness:

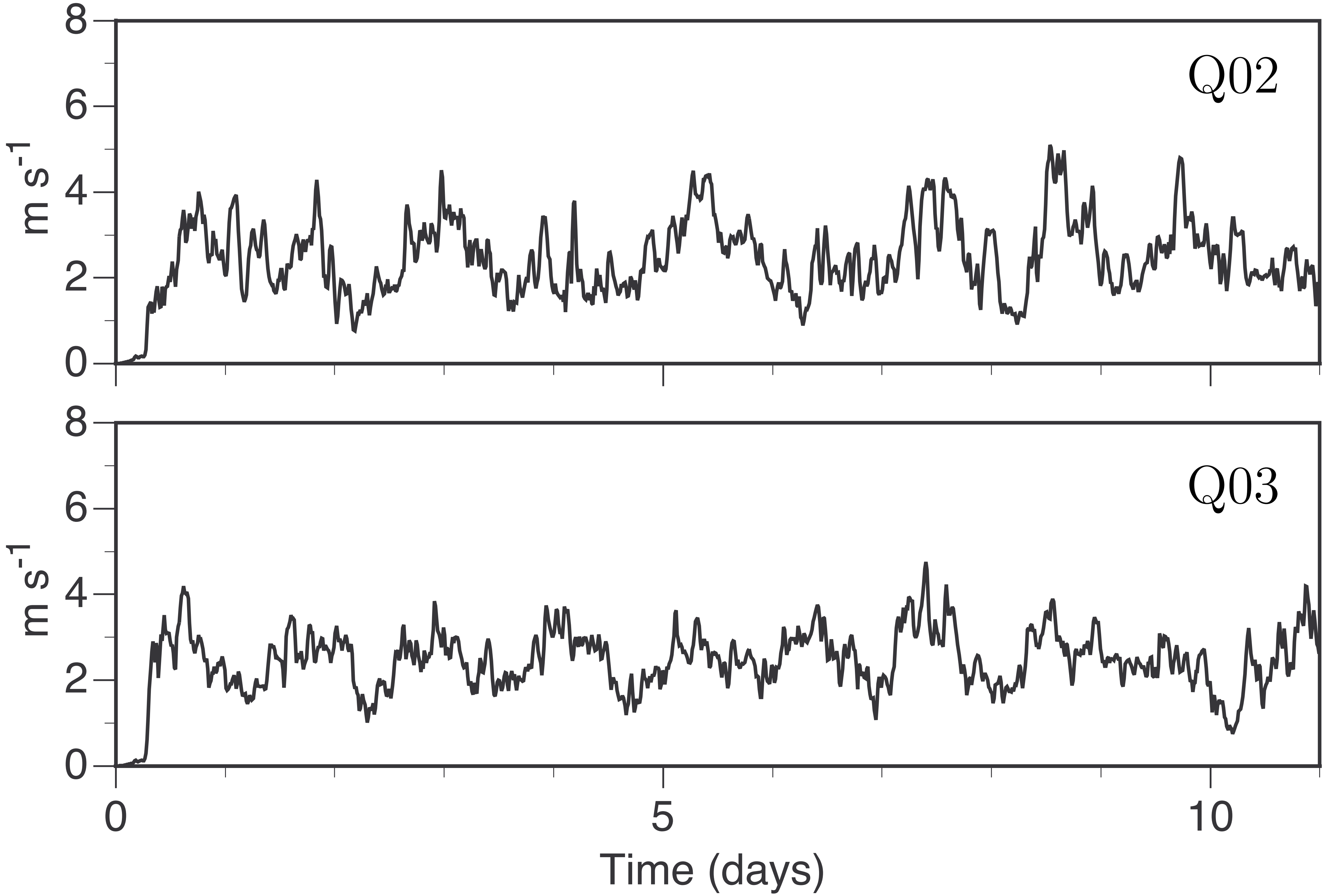
$$U_g = \alpha U_\sigma$$

- Theoretical methods give a value of 0.8 for α (Jabouille et al. 1996).
- U_g, and hence U, may be obtained if U_σ can be parameterized.

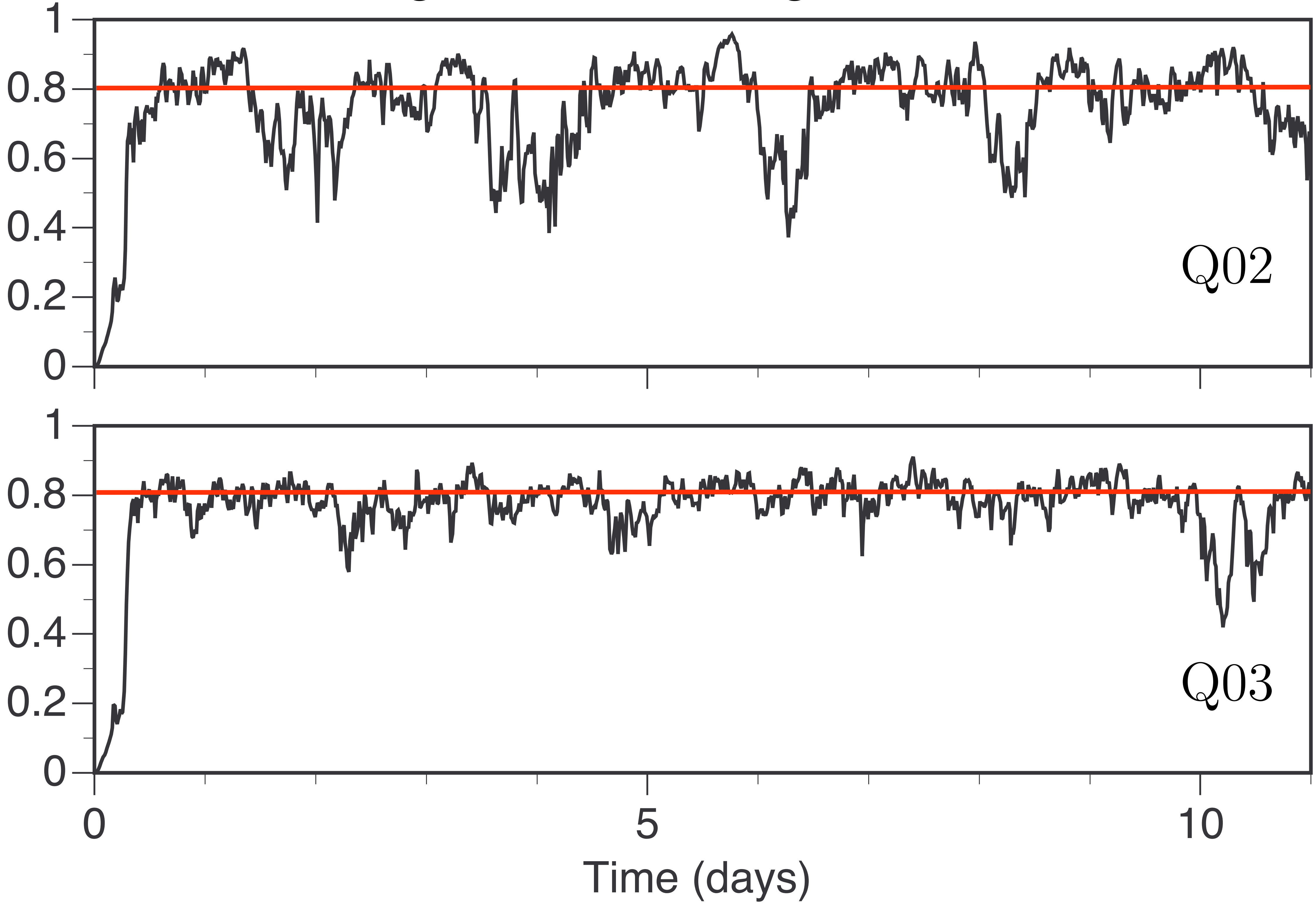
square root of the wind variance, U_σ



gustiness speed, U_g



the empirical constant that relates U_g and U_σ: U_g / U_σ



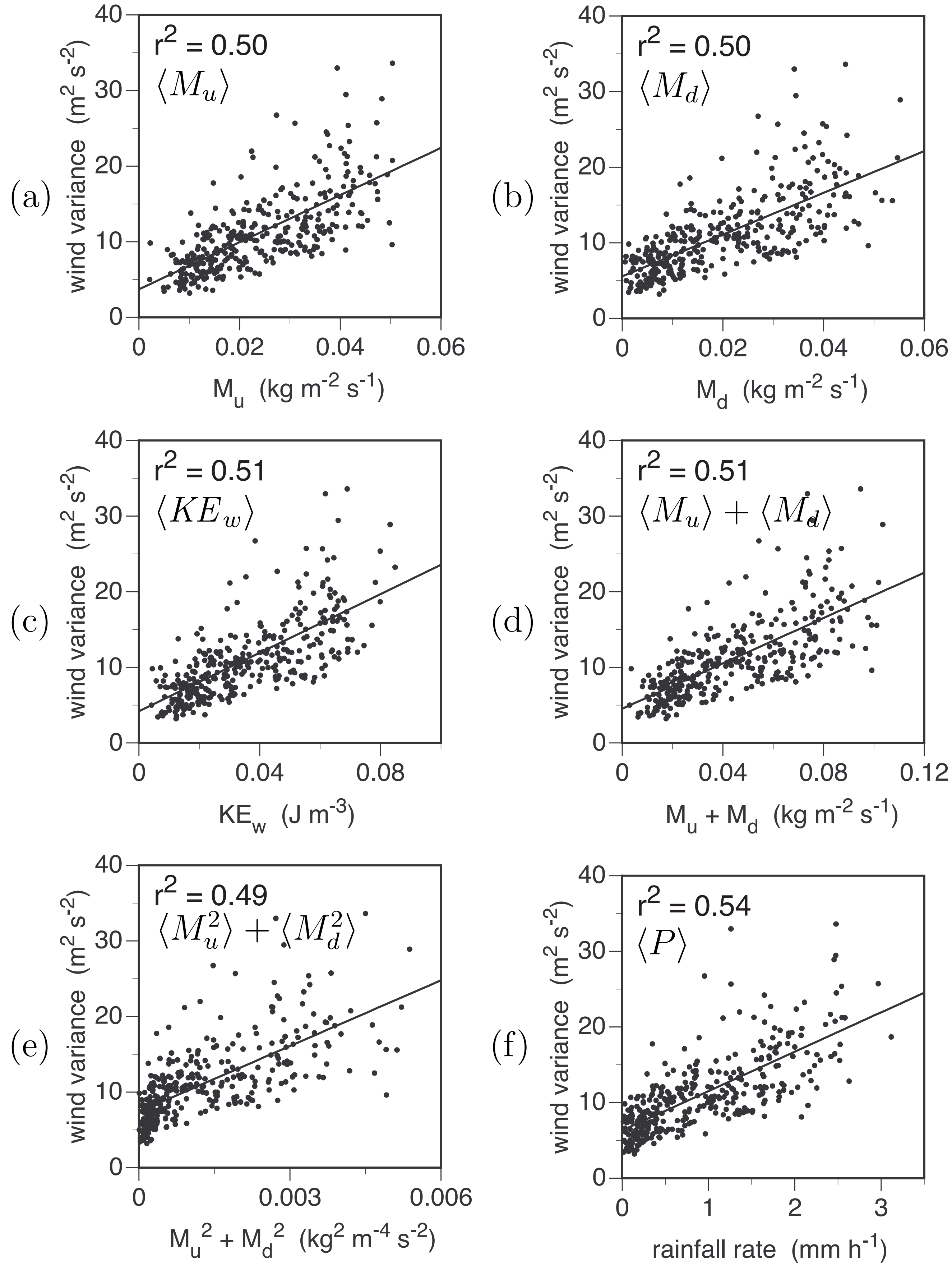
red line is theoretical value of 0.8

Parameterization of wind variance or gustiness due to convection

updraft mass flux, M_u

vertical component of kinetic energy

$M_u^2 + M_d^2$



downdraft mass flux, M_d

$M_u + M_d$

surface precipitation rate