The diurnal cycle of the TKE budget

Natalie Harvey | Steve Woolnough | Alison Stirling

Email: n.j.harvey@reading.ac.uk

University of Reading

Why study the diurnal cycle of the TKE budget?

- Understanding the factors which determine the transient behaviour of convection is vital to improving the diurnal cycle of precipitation.
- The Turbulent Kinetic Energy (TKE) Budget is a useful tool for analysing the interplay of turbulent processes influencing convection. Local changes in TKE are determined by vertical wind shear, buoyancy, turbulent transport, pressure fluctuations and dissipation.
- Here the budget of these has been analysed for an idealised 2D diurnal cycle case study performed in the Met Office Large Eddy Model. The main aim of this study is to develop tools and analysis methods that can be applied to large domain high resolution 3D simulations.

Case study description

- Idealised prescribed surface forcing based (see Figure 1) on EUROCS (Guichard et al., 2004), balanced by a specified large scale cooling of -2K/day. Initial profiles also based on EUROCS.
- 2D setup: 512 x 1km with 76 levels with 20 km top.
- Run for 20 days with 10 minute output.
- Details of LEM can be found in Grey et al. (2000, 2001).

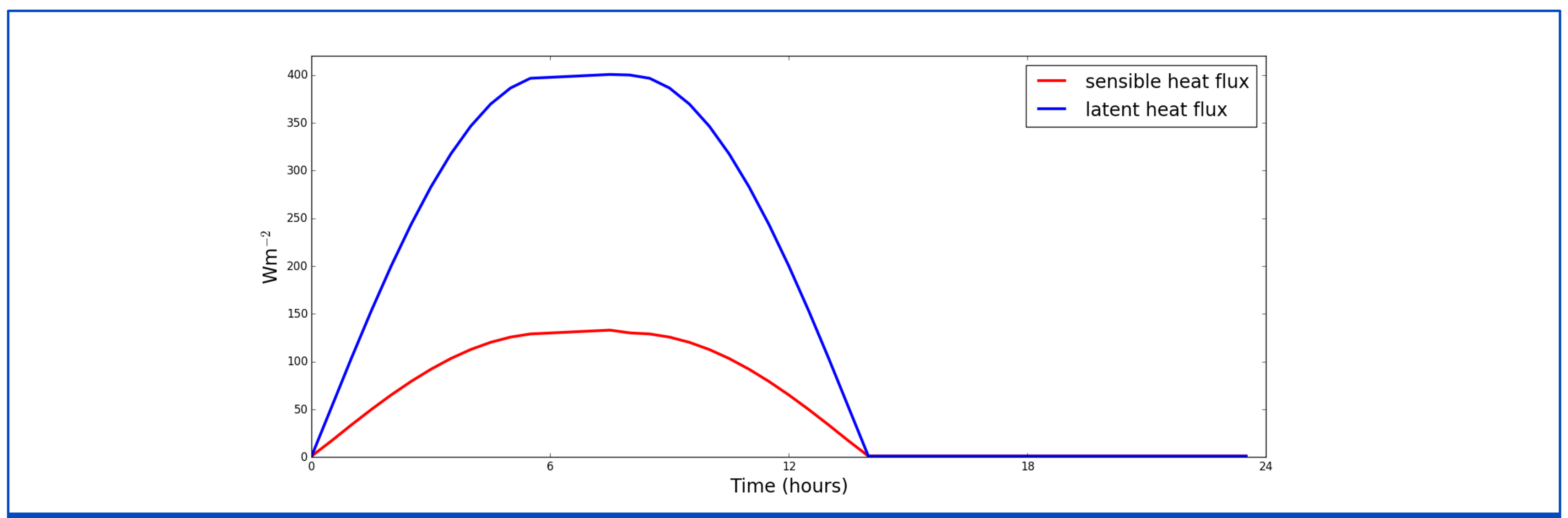


Figure 1: Idealised surface forcing applied in this case study.

How different are the cycles?

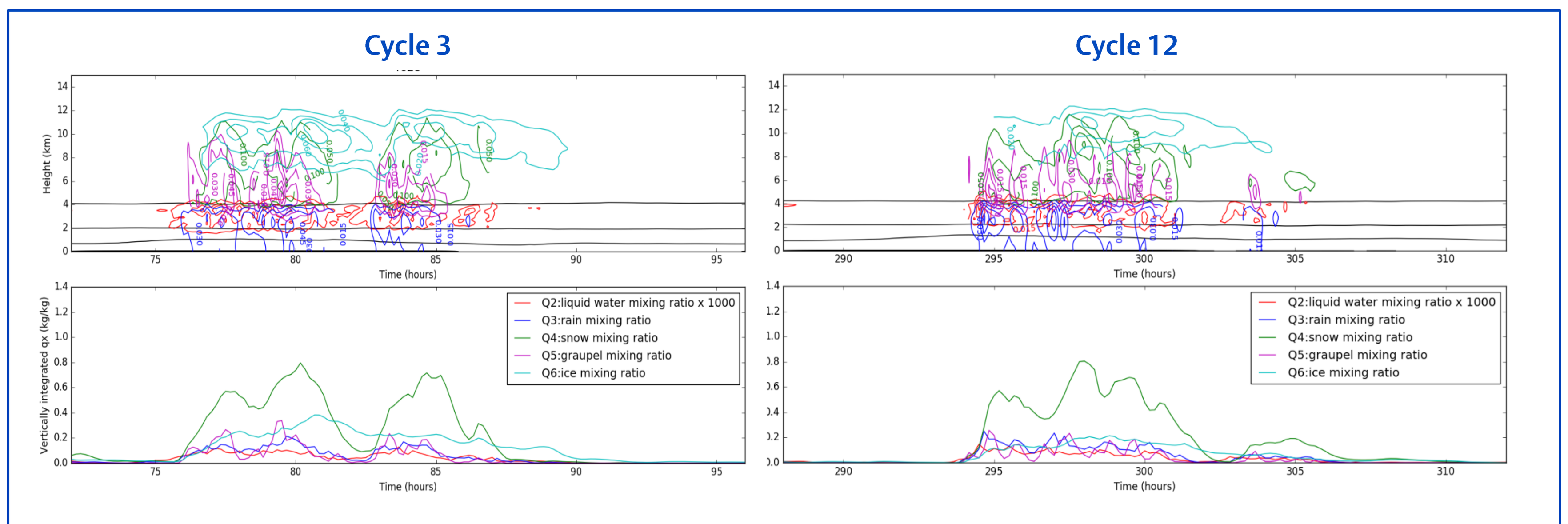


Figure 2: Evolution of domain mean cloud variables for cycle 3 and 12 in the case study simulation.

- With the same surface and large scale cooling each cycle displays very different cloud and precipitation evolution.
- Figure 2 shows the evolution of the cloud variables for cycle 3 and cycle 12 in the case study simulation. The convection in cycle 3 lasts longer than cycle 12 and has two distinct clouds.
- Figure 3 shows the evolution of the vertically integrated TKE and surface precipitation. Each cycle is very different with some cycles having precipitation peaks once the surface forcing has returned to zero.

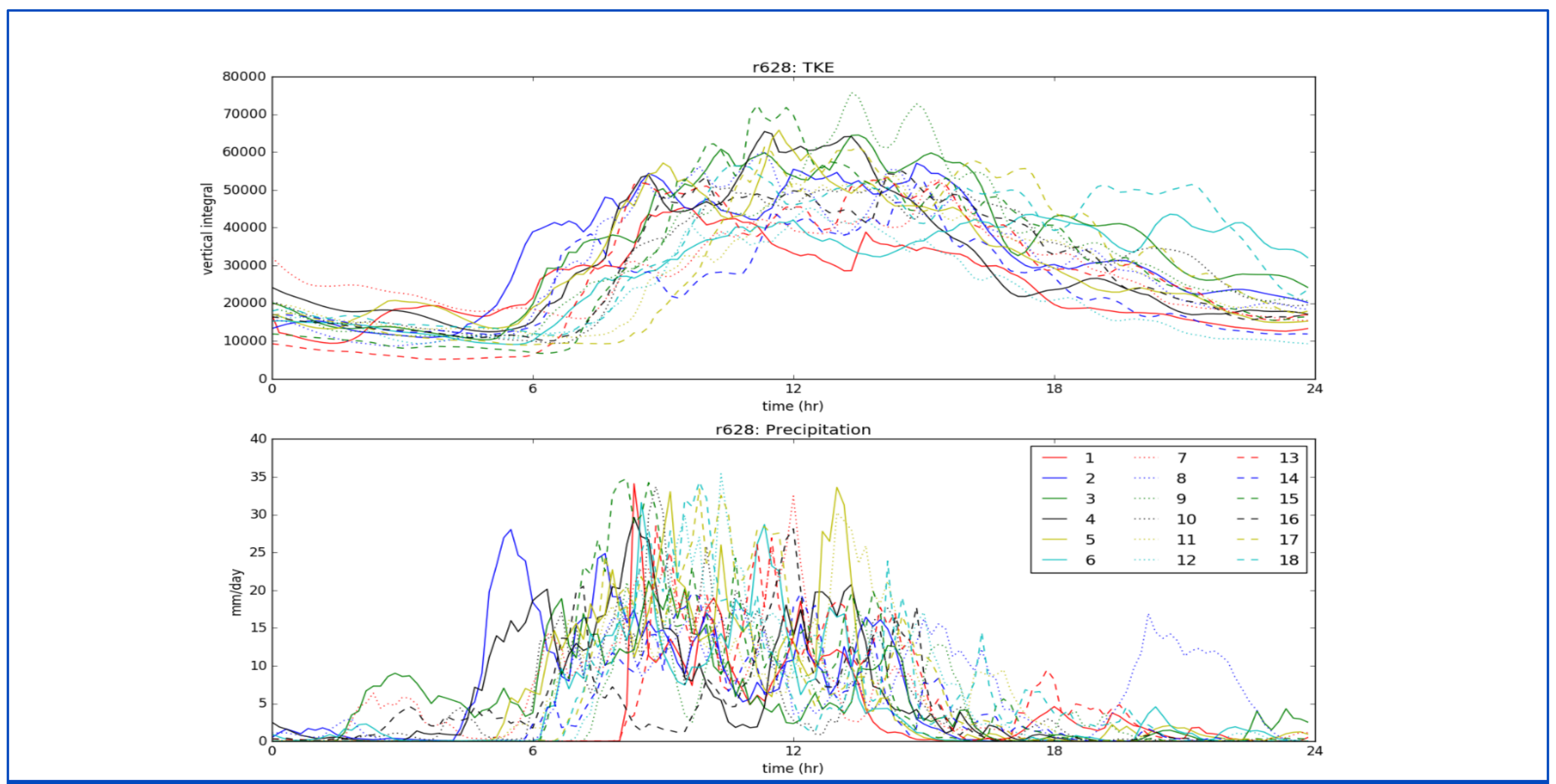


Figure 3: Evolution of the vertically integrated TKE and surface precipitation rate for all cycles in the case study simulation.

How does the TKE budget evolve?

Assume horizontal homogeneity and neglect subsidence

$$\underbrace{\frac{\partial \bar{e}}{\partial t}}_{I} = \underbrace{\frac{g}{\theta_v}\overline{(w'\theta'_v)}}_{III} - \underbrace{\overline{u'w'}\frac{\partial \bar{U}}{\partial z}}_{IV} - \underbrace{\frac{\partial \overline{w'e}}{\partial z}}_{V} - \underbrace{\frac{1}{\rho}\frac{\partial \overline{(w'p')}}{\partial z}}_{VI} - \underbrace{\epsilon}_{VII}$$

Tendency, Buoyancy, Shear, Turbulent transport, Pressure correlation, Dissipation

Figure 4: The evolution of each of the terms in the TKE budget for cycles 3 to 20 in the simulation. Note that the simulation relaxes the wind profiles back to zero which accounts for the very small contribution from the shear term.

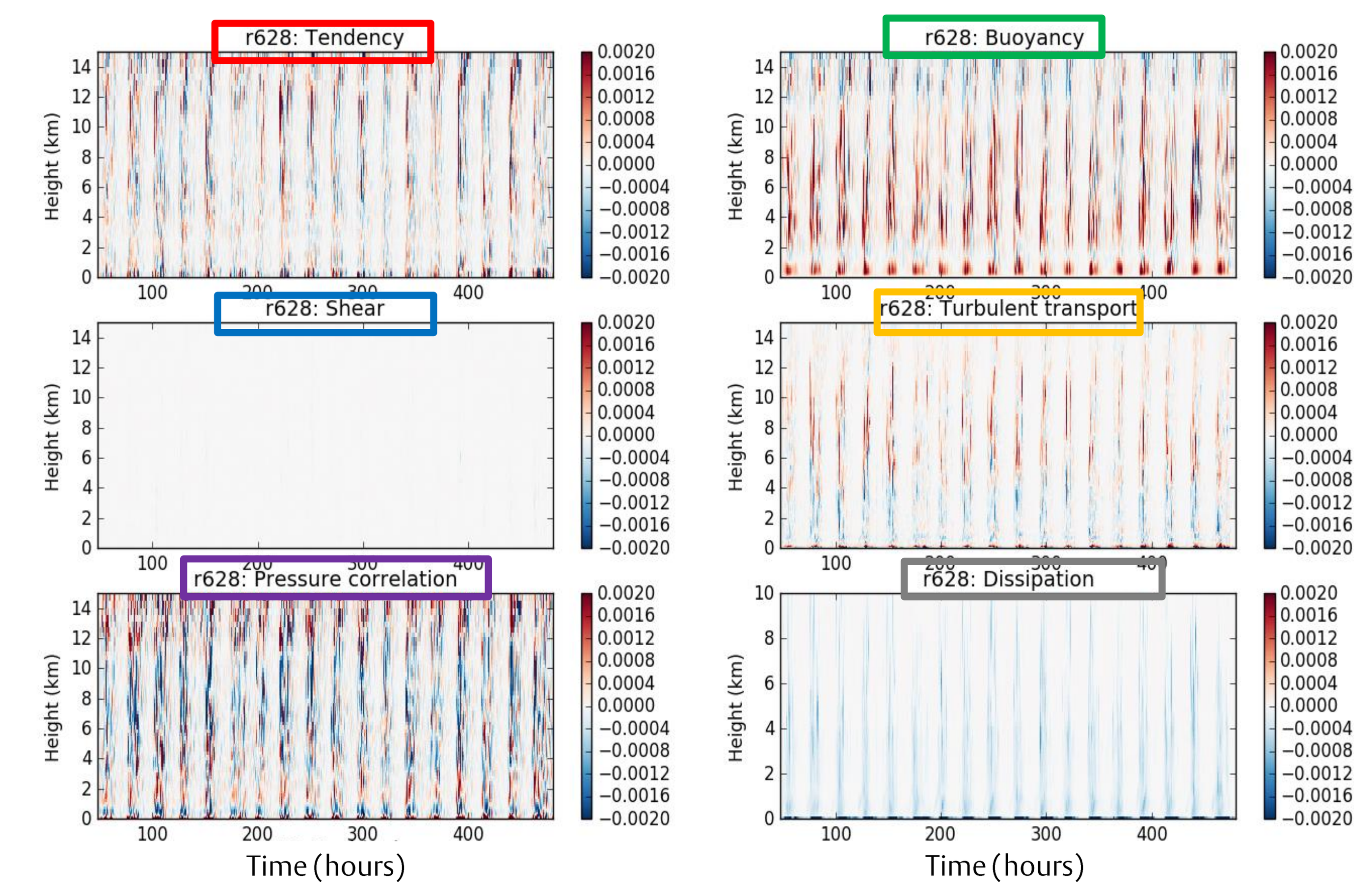


Figure 5: 18 cycle composite of each term in the turbulent kinetic energy budget. The dashed line indicates the strength of the surface forcing.

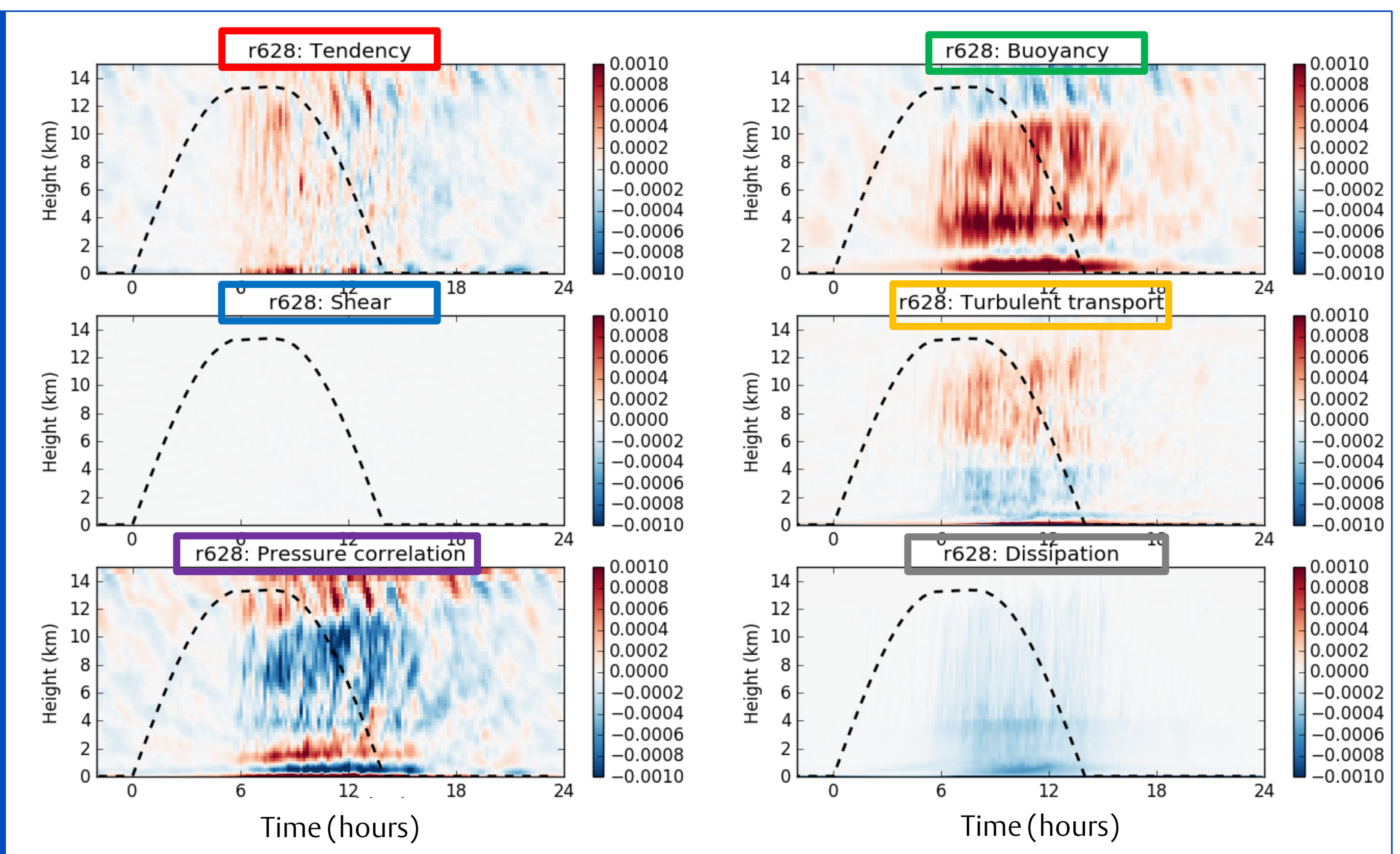
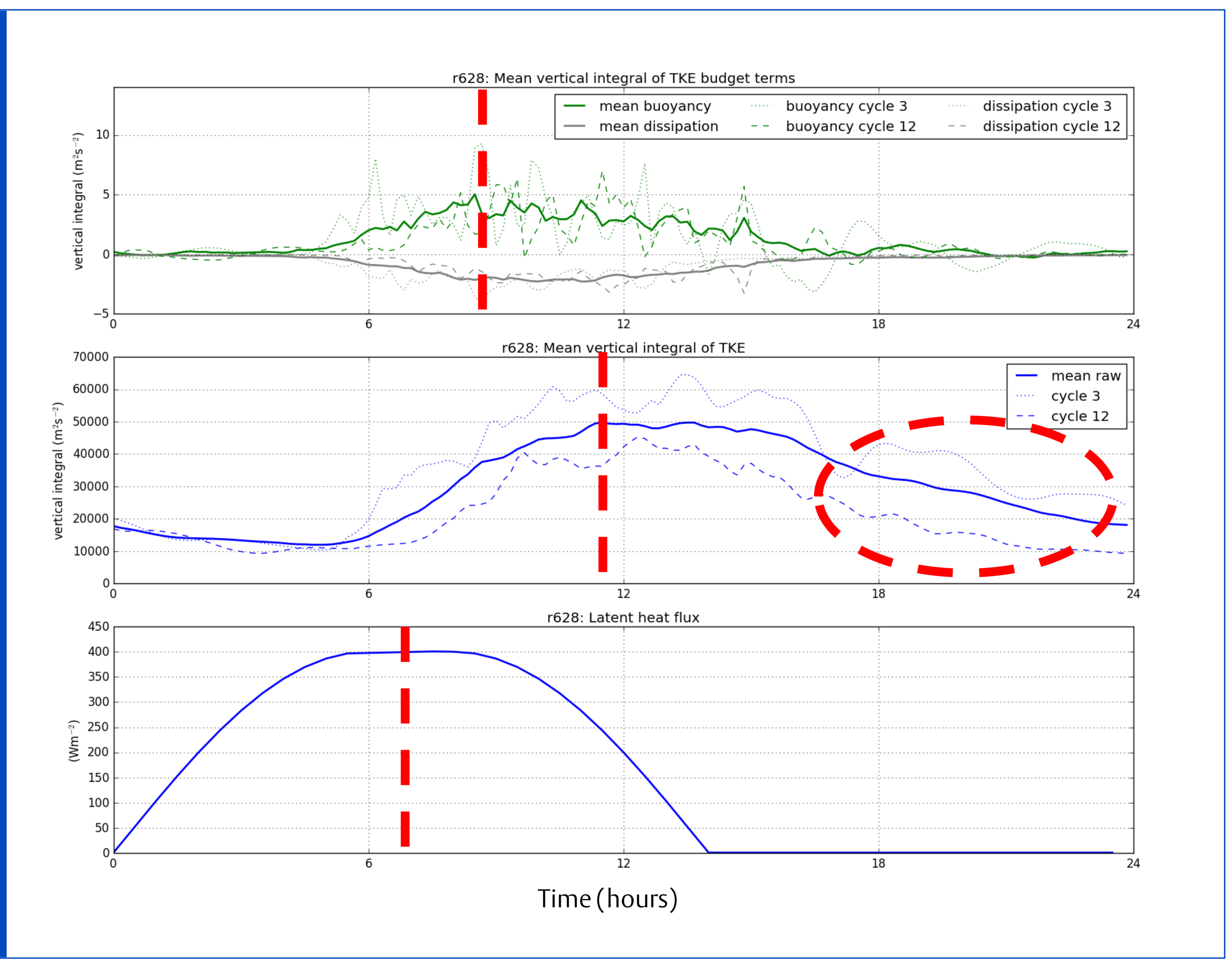


Figure 6: Composite vertical integrals of buoyancy, dissipation and TKE plus an indication of the forcing. Also shown are the vertical integrals for cycle 3 and 12.



Next steps?

- Apply analysis to large domain 3D simulation
- How does TKE relate to conditionally averaged diagnostics, such as regions with w >1 or buoyant cloudy updraughts?
- Can transport between scales be determined using 2D spectra?
- Extend to other Reynolds averaged budgets

References

Gray, M. E. B. "Characteristics of numerically simulated mesoscale convective systems and their application to parameterization." *Journal of the atmospheric sciences* 57.24 (2000): 3953-3970.

Gray, M. E. B., et al. "Version 2.3 of the Met Office large eddy model: Part II." *Scientific documentation. Met O (APR) Turbulence and Diffusion Note* 276 (2001).

Guichard, F., et al. "Modelling the diurnal cycle of deep precipitating convection over land with cloud-resolving models and single-column models." *Quarterly Journal of the Royal Meteorological Society* 130.604 (2004): 3139-3172.