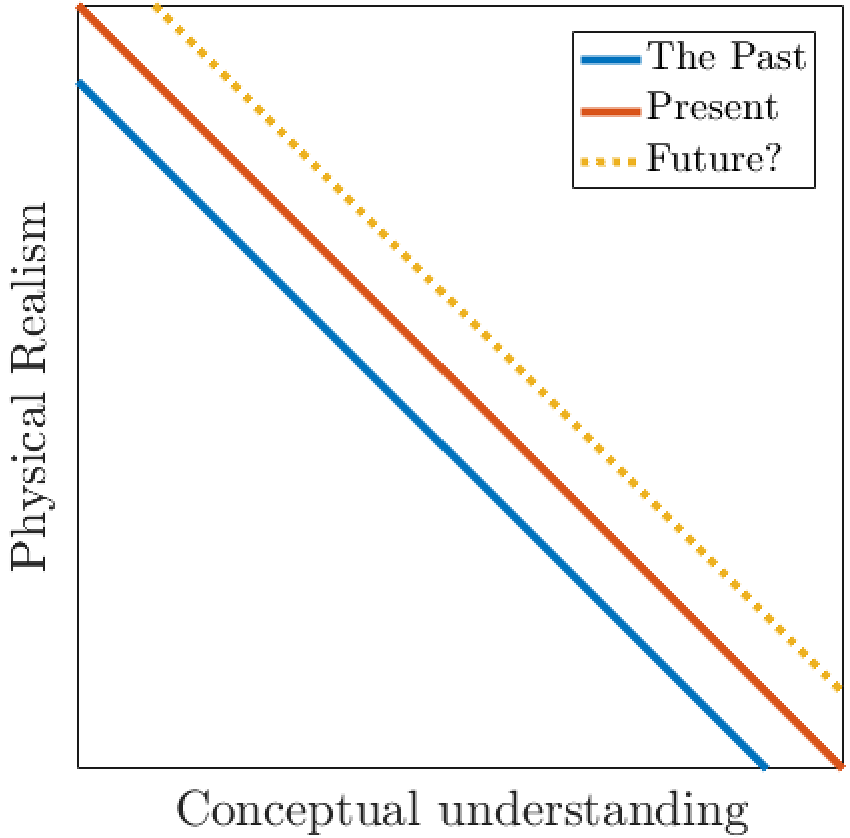
A Family of Diurnal Cycle Model Cases for the Dry ABL,

and an introduction to a few of its members

Antoon van Hooft,
Steven van der Linden, Credric Ansorge,
Maurice van Tiggelen and Bas van de Wiel.

An Idealized Diurnal Cycle

- Idealize with respect to reality to study the interactions between the most dominant processes



The Frontier of Meteorological Modelling: Plot adapted from H. Jonker. SBL Delft workshop (2017)

Forcing for momentum

The usual suspects:

A Pressure gradient and the Coriolis parameter introduce a so-called “geo wind” vector:

$$\boldsymbol{U_g} = \frac{\hat{\boldsymbol{k}}}{\rho f} \times -\boldsymbol{\nabla_h} P,$$

Initialize the relevant volocity components in a geostrophic balance:

$$\{u, v, w\}_{t=0} = \{\|\boldsymbol{U_g}\|, 0, 0\} = \{U_g, 0, 0\},$$

Moisture / water

The cases consider dry boundary layers

Forcing for the Thermodynamic Variable

Not prescibe heat flux or temperature at the bottom surface.

Rather: Employ a simple soil energy balance

$$Q_n = F_{\mathrm{soil}} + H.$$

Introducing buoyancy as the thermodynamic variable:

$$b = \frac{g}{\theta_{\mathrm{ref}}} \left(\theta - \theta_{\mathrm{ref}} \right),$$

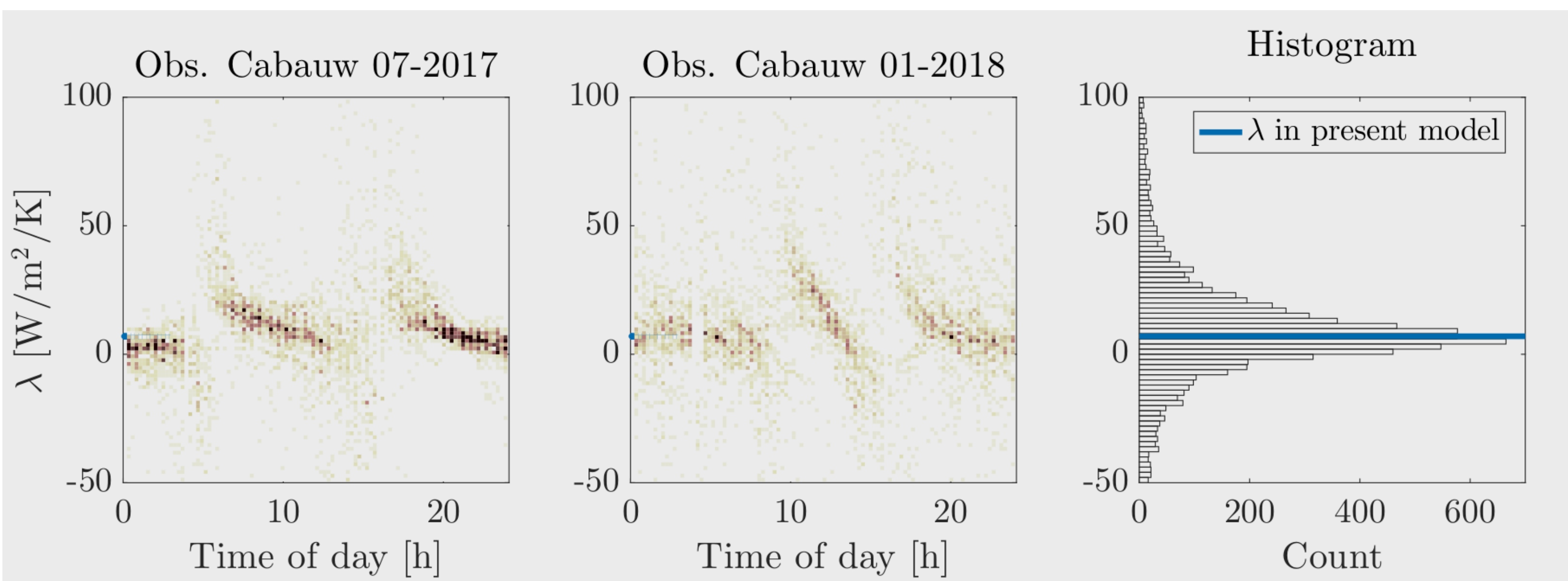
Forcing for the Thermodynamic Variable

$$Q_n = F_{\text{soil}} + H. \longrightarrow Q^* = G + B.$$

For the soil flux we use a simple “negative feed back”, based on a Lumped parameter (Lambda)*:

$$F = \lambda \left(T_s - T_d \right),$$

$$G = \Lambda(b_s - b_d),$$

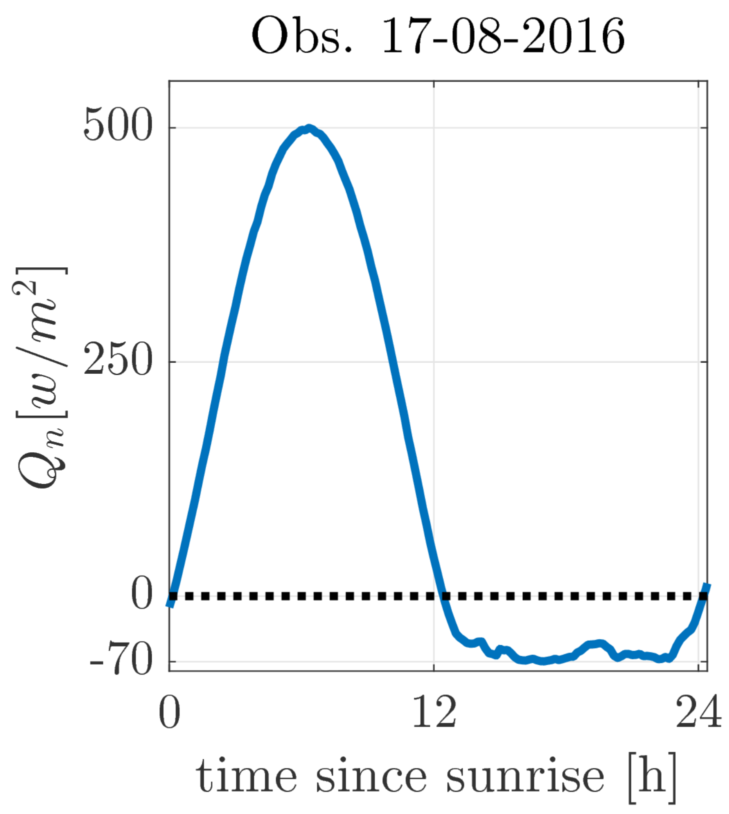


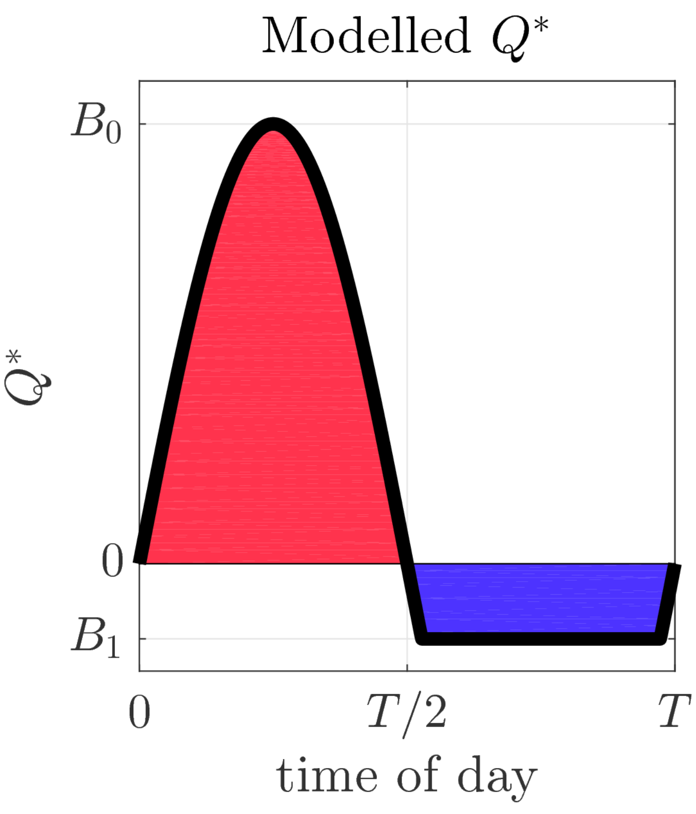
* See: Van de Wiel et al. *Regime Transitions in Near-Surface Temperature Inversions,* JAS (2017)

Forcing for the Thermodynamic Variable

For the net radiation we prescribe a typical evolution according to:

$$Q^* = \max\left[B_0 \sin\left(\frac{2\pi t}{T}\right), B_1\right],$$



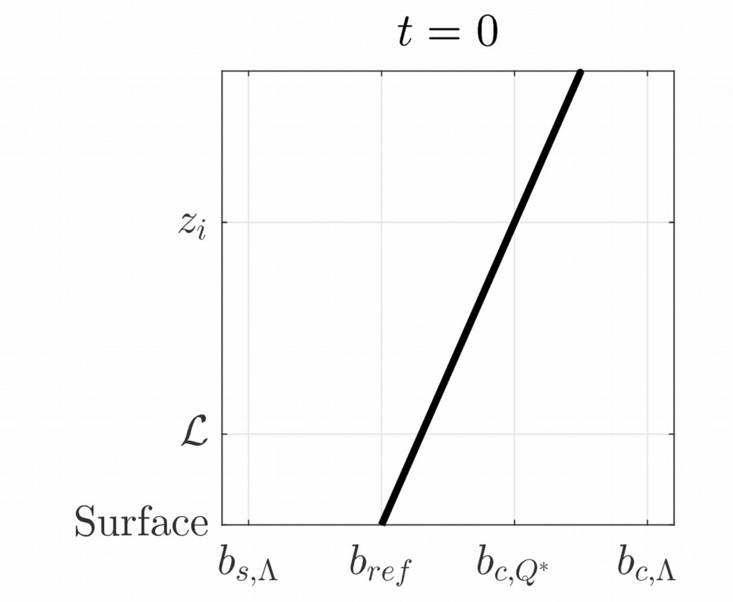


Initialization

A constant stratification:

$$b_{t=0}(z) = b_{s,t=0} + N^2 z,$$

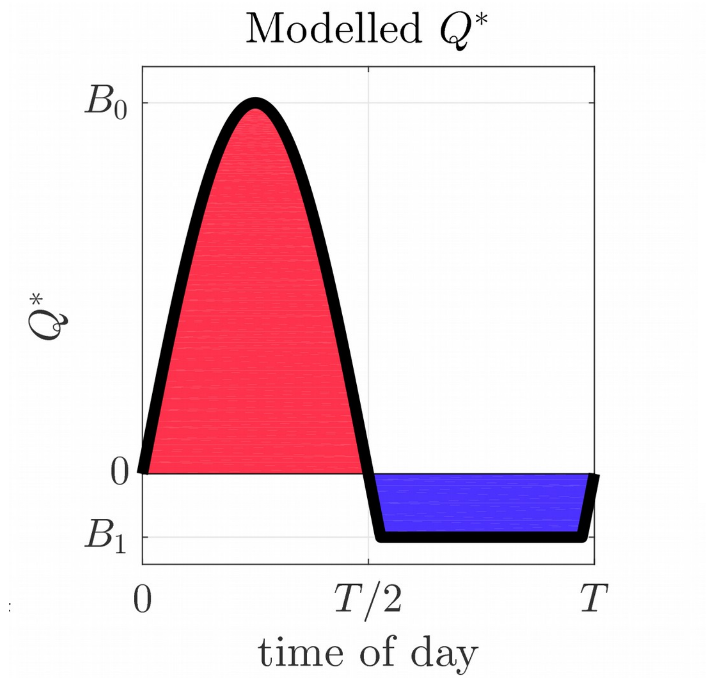
$$b_d = b_{s,t=0} = 0,$$



Conceptual model of the Diurnal Cycle

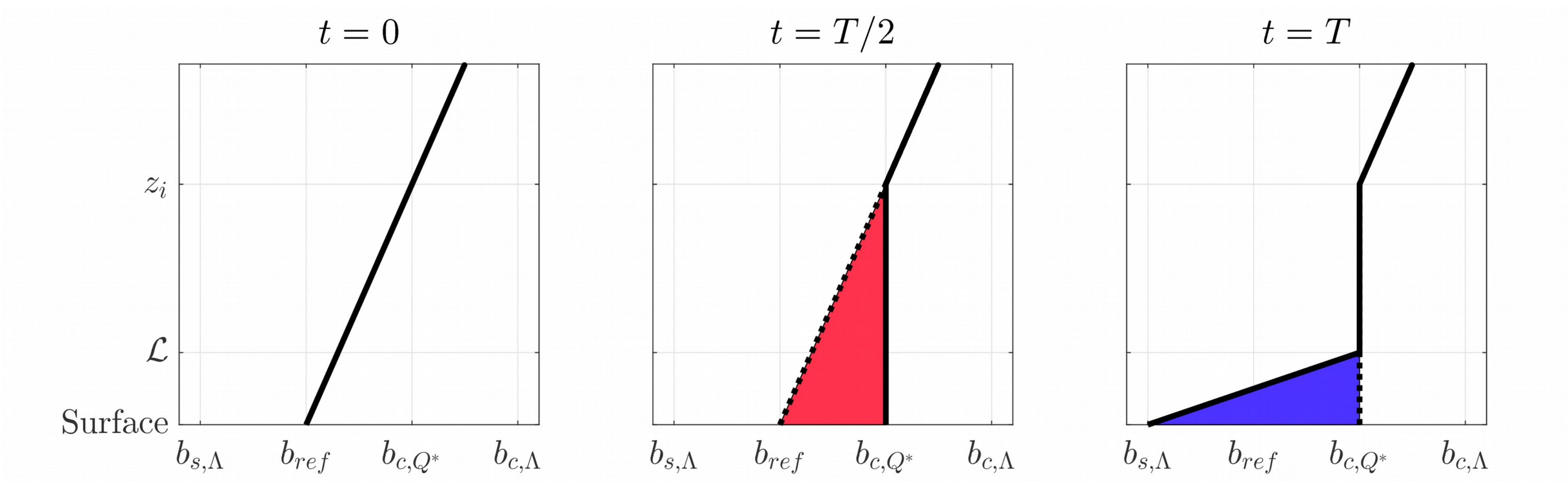
$$b_{s,\Lambda} = \frac{B_1}{\Lambda},$$

$$b_{c,\Lambda} = \frac{B_0}{\Lambda}.$$



$$\mathcal{L}_c = \sqrt{\frac{2B_0T}{\pi N^2}},$$

$$b_{c,Q^*} = \sqrt{\frac{2B_0TN^2}{\pi}}.$$



5 Parameters Describing this Cycle

$$\{B_0, B_1, T, N, f, \Lambda, U_g\}.$$

$$U_c = (B_0 \mathcal{L}_s)^{1/3}.$$

$$\Pi_1 = \frac{B_0}{B_1},$$

$$\Pi_2 = TN,$$

$$\Pi_3 = Tf,$$

$$\Pi_4 = \frac{\sqrt{B_0 T}}{\Lambda},$$

$$\Pi_5 = \frac{U_g}{U_c}.$$

5 Parameters Describing this Cycle

$$\{B_0, B_1, T, N, f, \Lambda, U_g\}.$$

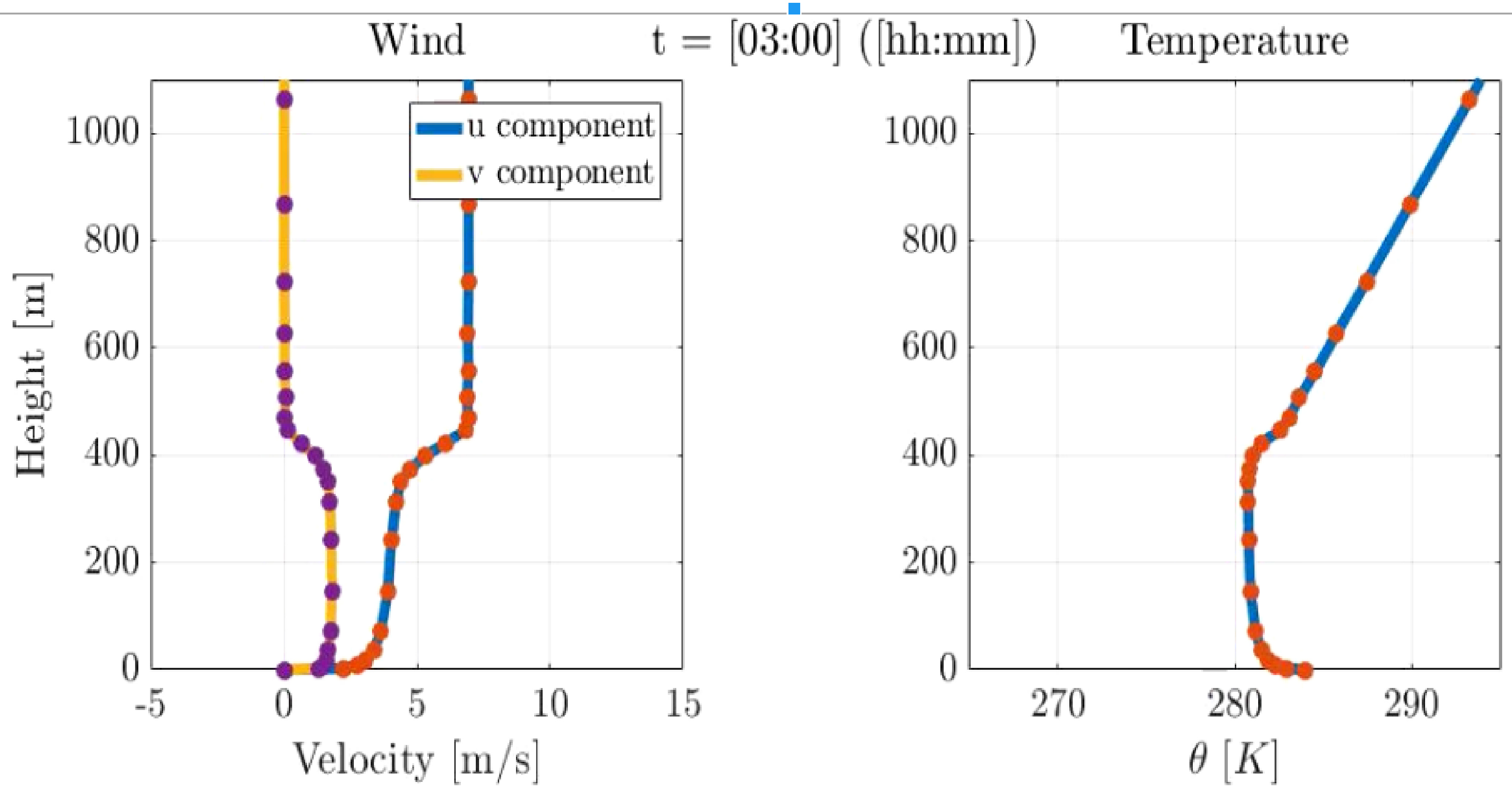
Physical Parameters		
Parameter Symbol	Value	Based on
B_0	1.2×10^{-2} m^2/s^3	Max.$(Q_n) \approx 360$ w/m^2
B_1	-0.2×10^{-2} m^2/s^3	Min.$(Q_n) \approx -60$ w/m^2
T	24 h	the duration of a Day
N	0.025 s^{-1}	0.0175 K/m and $\theta_{ref} = 280$ K
f	1.15×10^{-4} s^{-1}	Mid-latitude/Cabauw
Λ	6×10^{-3} m/s	$\lambda = 7$ w/m^2/K, Fig. 1
U_{geo}	[2–15] m/s	Van der Linden et al. (2017)
z_0	20 cm	Grass land

$$U_c = (B_0 \mathcal{L}_s)^{1/3}.$$

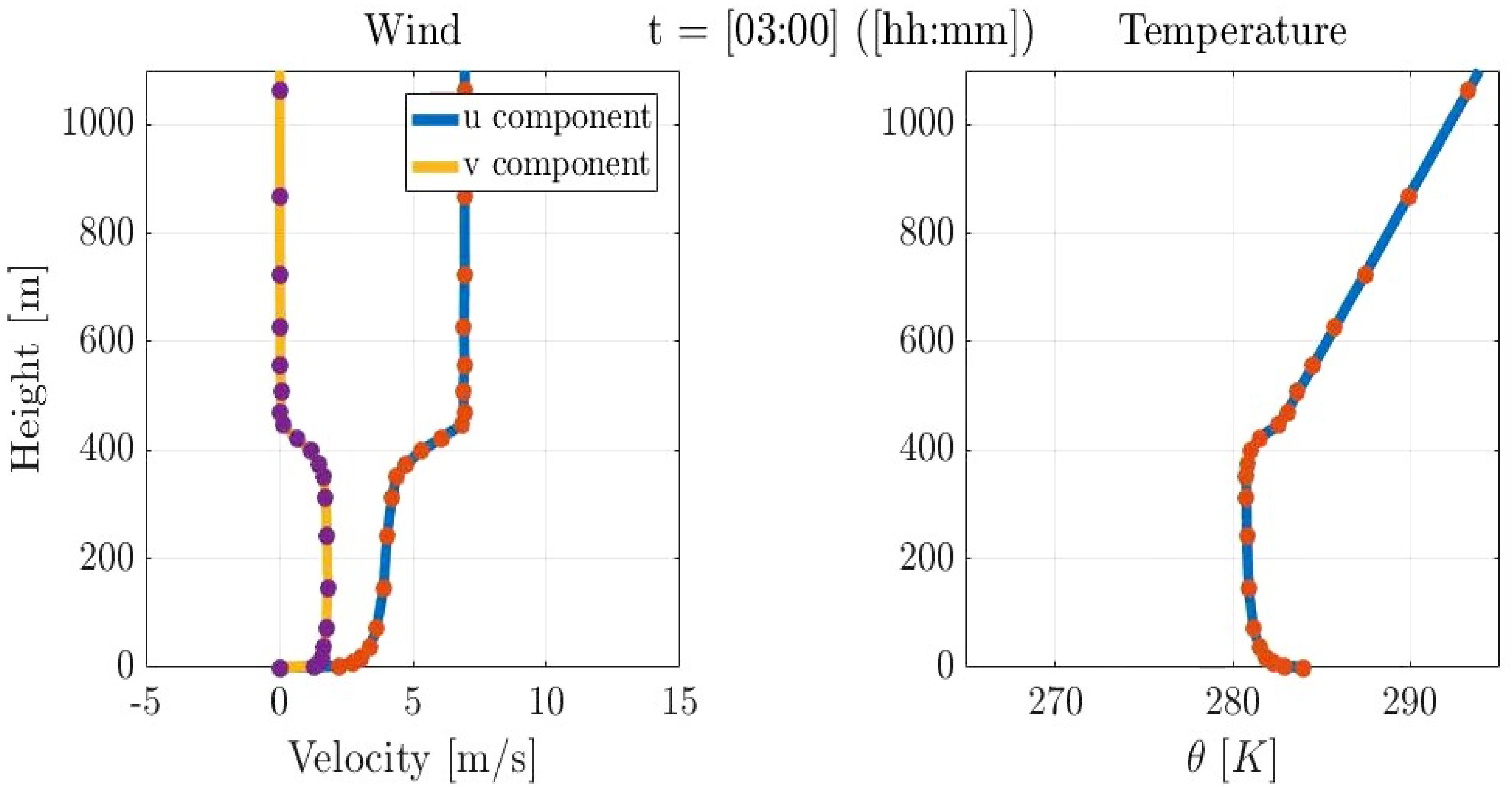
$$\Pi_4 = \frac{\sqrt{B_0 T}}{\Lambda},$$

$$\Pi_5 = \frac{U_g}{U_c}.$$

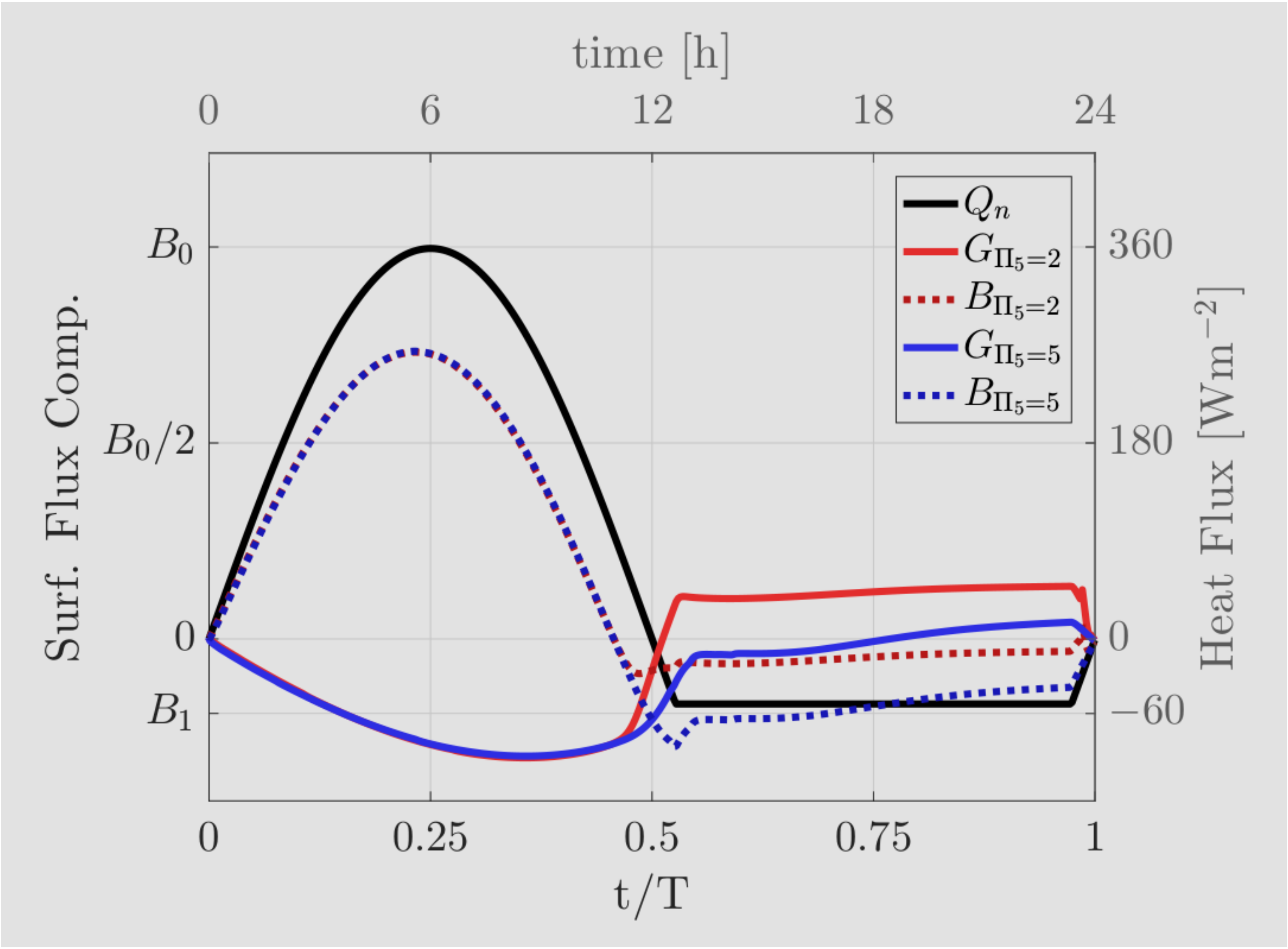
Single-Column Model Results



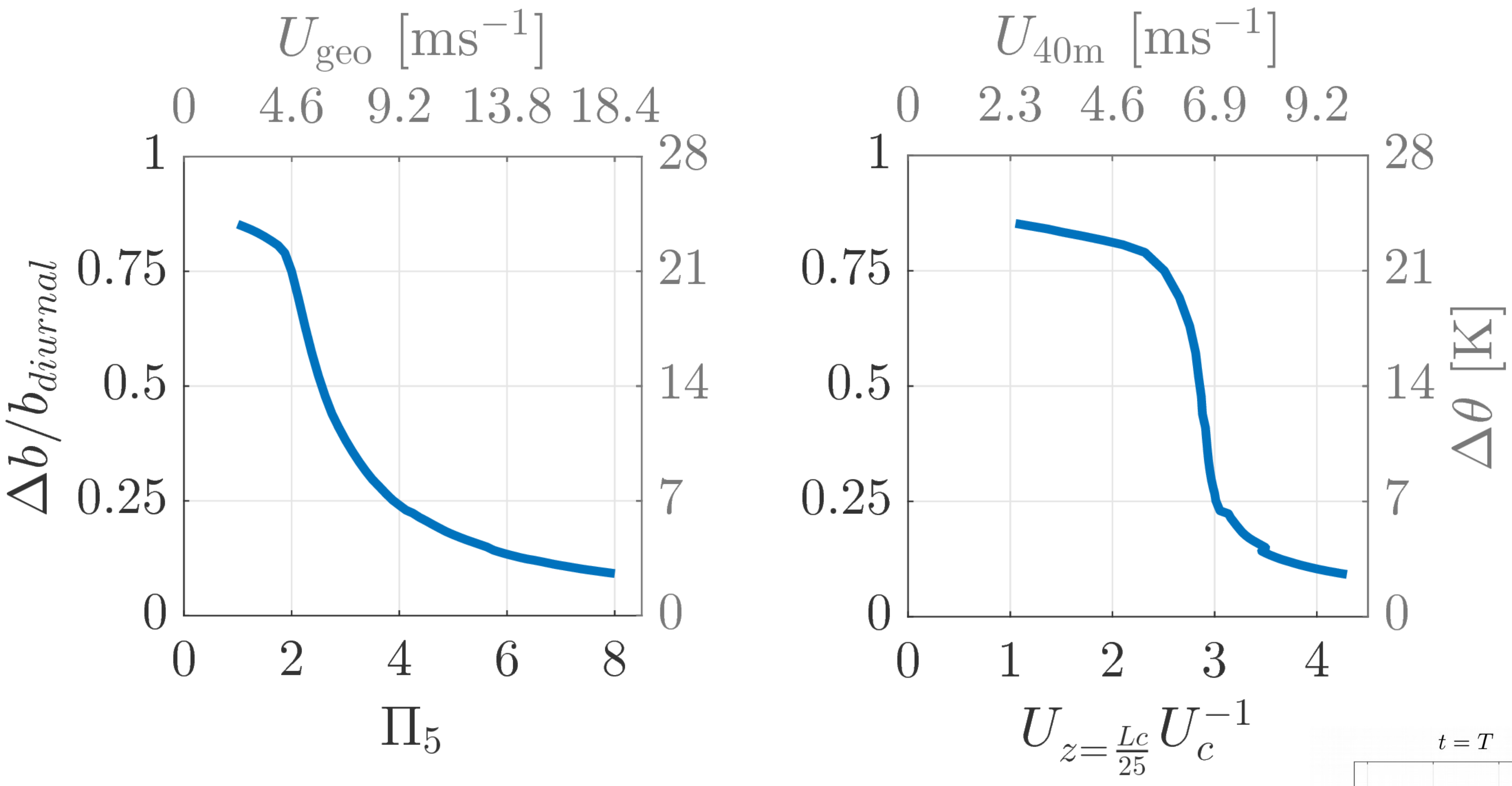
Single-Column Model Results

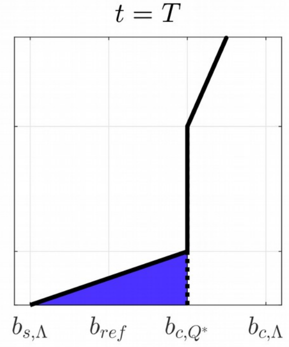


Single-Column Model Results



Single-Column Model Results





Large Eddy Simulation

Conclusion

The present model scenarios strike a sensible balance between model system complexity and physical realism for idealized studies on the diurnal cycle.