# P6.4 Modelling the atmospheric boundary layer in a climate model of intermediate complexity.

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## 1. INTRODUCTION

The atmospheric boundary layer plays a key role in determining the local climate. It determines how efficient heat, water vapor, carbon dioxide and trace gases are transferred from the surface of the earth to the free atmosphere.

In this study, we describe and validate a boundary layer module that can be implemented in the climate model of intermediate complexity ECBilt (Opsteegh et al. 1998). It includes the growth of the convective boundary due to thermal-forced turbulence, the additional heating of the boundary layer because of entrainment, the collapse of the convective boundary layer during the afternoon transition and the development of a stable boundary layer in stable conditions.

The model is validated using measurements in Cabauw and De Bilt. Its performance is compared with results obtained using the previous boundary layer module of ECBilt. In contrast to the updated module, the previous module simply assumes that the tropospheric profile of potential temperature can simply be extrapolated towards the surface. Furthermore, it adopts a constant one uniform exchange coefficient for unstable and one uniform exchange coefficient for stable conditions. (see Opsteegh et al. 1998).

## 2. UPDATED BOUNDARY LAYER MODULE

The evolution of the boundary layer in unstable conditions due to thermal convection, is described by the bulk model given by Tennekes (1973):

$$\frac{\partial h}{\partial t} = \frac{1+2\beta\left(\overline{w'\theta_v'}\right)_0}{\gamma_\theta h}$$

where h is the boundary layer height, $\gamma_\theta$ the gradient of the potential temperature in the free atmosphere, and $\left(\overline{w'\theta_v'}\right)_0$ the virtual heat flux density at the surface. The entrainment parameter, β, is defined as the ratio of the virtual heat flux density at the top of the boundary layer and at the surface.

In stable conditions, the boundary layer is assumed to relax towards an equilibrium boundary layer height. Thus, its evolution equation is given by (Nieuwstadt and Tennekes 1981):

$$\frac{\partial h}{\partial t} = \frac{h_{eq} - h}{\tau},$$

where τ is a time scale (taken as 4 hours), $u_*$ is the friction velocity, $T_r$ is a reference temperature and $h_{eq}$ represents an equilibrium boundary layer height. The latter is given by (Vogelezang and Holtslag 1996):

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$$h_{eq} = \frac{7u_*}{\sqrt{\frac{g}{T_r}\gamma_\theta}} .$$

The surface flux densities are calculated by means of bulk transfer relations. This implies that they are computed as the product of the potential difference over the surface layer and an exchange coefficient. The exchange coefficient is calculated using Monin-Obukhov similarity theory. Here, we use the relations given by Van den Hurk and Holtslag (1998) to calculate the impact of stability on the exchange coefficient. The top of the boundary layer is here taken as one tenth of the height of the boundary layer.

## 3. RESULTS

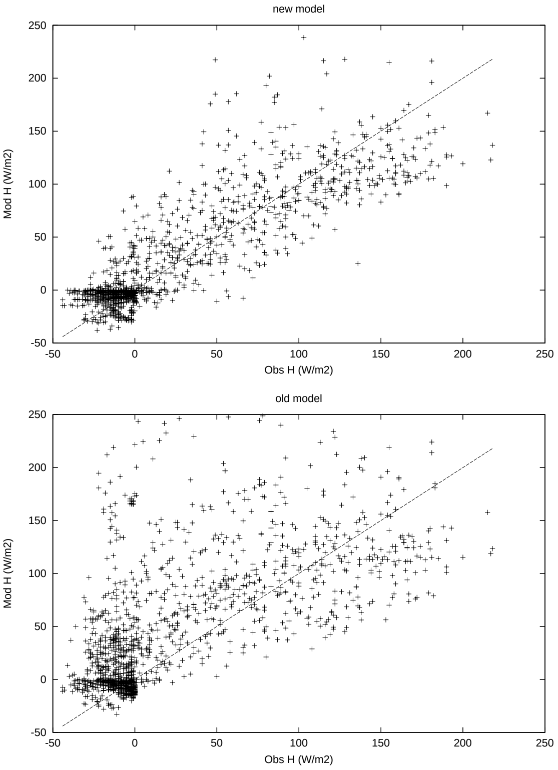

*Figure 1:modeled H versus observed H for updated module (upper) and previous module (lower) using a forced surface temperature.*

Figure 1 shows for both the updated boundary layer module and the previous boundary layer module the modeled sensible heat flux density versus the observed sensible heat flux density using surface temperature obtained from observations. It appears that the updated module works better than the previous module. Typically, the previous module underestimates the sensible heat flux density in convective conditions with low wind speed.

Figure 2 shows for both the updated boundary layer module and the previous boundary layer module the modeled sensible heat flux density versus the observed sensible heat flux density when the surface temperature is calculated by solving the surface energy budget. It appears that both modules perform comparably. However, as comes clear from Figure 3 the previous module

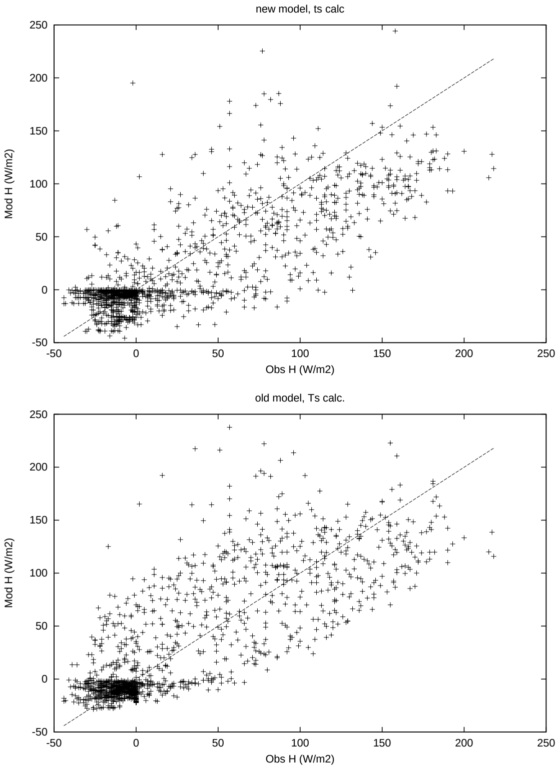

*Figure 2: modeled H versus observed H for updated model (upper) and previous model (lower) with the surface temperature obtained by solving the surface energy budget.*

tends to overestimate the surface temperature. This is caused because the previous module ignores the impact of stratification on the exchange coefficient. As a result, to release the absorbed incoming short wave and l;ong wave radiation, ECBilt with the previous module for the atmospheric boundary layer increases the surface temperature. In the updated module the exchange coefficient is much larger, leading to a smaller surface temperature. This is important since biological reactions appear to be strongly related to the surface temperature (Ronda et al. 2001).

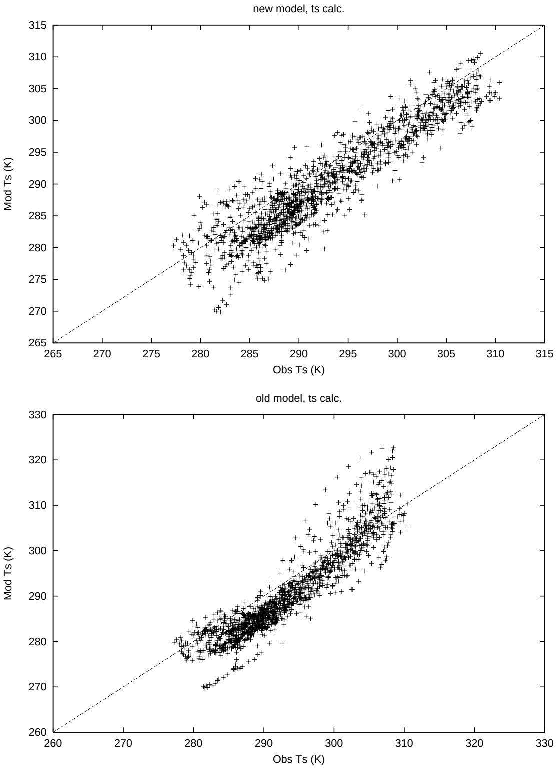

*Figure 3: modeled Ts versus observed Ts for updated module (upper) and the previous module (lower).*

## 4. CONCLUSION

A simple and robust module for the atmospheric boundary layer that can successfully be implemented in a climate model of intermediate complexity, has been validated with data obtained from Cabauw. It appears that 1) the updated module gives better estimates of the sensible heat flux density than a traditional boundary layer scheme, whereas 2) because of the incorporated influence of stability on the aerodynamic conductance, the updated module gives more realistic estimates of the canopy conductance.

## 5. REFERENCES

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