Remote sensing images used for aggregation of the scalar roughness, z_{0t}.

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OBJECTIVES

To calculate the area-averaged roughness for scalar transport ($<z_{0t}>$) and for momentum transport ($<z_{0m}>$) directly from a two-dimensional (horizontal domain) atmospheric flow model.

To compare the kB^{-1} values given as $kB^{-1}=ln(<z_{0m}>/<z_{0t}>)$ to values in the literature.

To validate the maps of surface sensible heat flux model results to in-situ sensible heat flux observations in various fields through a growing season.

AGGREGATION METHOD

Calculation of the sensible heat flux maps in heterogeneous terrain is done by use a new version of a surface-flux aggregation model. The model is a physically-based model that takes the surface roughness, surface temperature and leaf area variations into explicit account. The advantage of this new model version is that the ratio between the roughness for momentum and for scalars is *not assumed* to be known. Instead it is directly calculated by the model.

The new aggregation model concept is depicted (figure 1) and the inputs are
- •remote sensing surface temperature maps
- •remote sensing and cover maps (figure 2)
- •remote sensing leaf area index (*LAI*) maps
- •air temperatures
- •wind speed and directions

The land cover map is assigned relevant roughness values per land cover type and the water roughness is a function of wind speed (Charnock's equation). A set of equations per land cover type define the relationships between z_{0t} and *LAI*. The maps of friction velocity, u_*, and temperature scalar, θ_*, are calculated through iteration including the Monin-Obukhov stability functions. From the u_* and θ_* maps, the effective values of $<z_{0m}>$ and $<z_{0t}>$ are calculated and sensible heat flux map $H=-u_* \theta_*$ (in W m^{-2}) (figure 3).

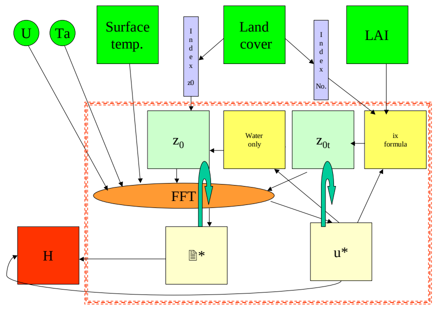
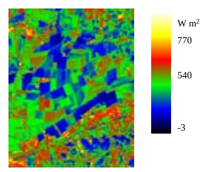


Fig 1. Aggregation model partly based on Hasager and Jensen (1999) but with new inclusion of leaf area index maps and z_{0t} equations.

Fig 2. Landuse map obtained from SPOT images

Fig. 3. Sensible heat flux map model result for the Alpilles area for day of experiment number 474.



VALIDATION STUDY

The aggregation model is validated to field flux observations in the Alpilles area, France. A land cover map of Alpilles is shown. The inputs to the model are described below:

•The surface temperature maps are from an airborne thermal radiometer flown at 1500 m and 3000 m heights on 18 days through the growing season in 1997. The maps are calibrated including the effect of emissivity.
•The roughness maps are based on the land cover map and field observation of vegetation height through the growing season. The vegetation height is related to the aerodynamic roughness and the roughness map vary per field through the growing season.
•The leaf area index maps are from POLDER NDVI and neural network methods (Weiss et al. 2002).
•The air temperatures and wind speeds are from the Arpège weather model and from radiosoundings at the Alpilles site.

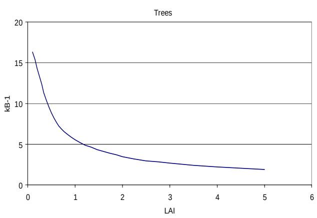


Fig. 4 Aggregation model results of the value of kB^{-1} as a function of *LAI* for vegetation with a roughness for momentum of 0.5 m.

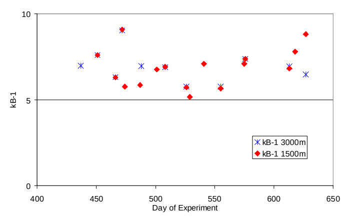


Fig. 5 Aggregation model results of the value of kB^{-1} as a function of day of experiment in the Alpilles where airborne remotely sensed surface temperature maps are available from 3000 m and 1500 m flight levels.

RESULTS

Objective 1: Fullfilled as an operational model version is developed.

Objective 2: The kB^{-1} value ranges from 2 to 15 for Danish landscapes based on synthetic data results representative for typical roughness values, *LAI* and patch sizes (Hasager et al. 2002). In much work a kB^{-1} value of 2.3 is assumed valid for vegetated landscapes even though there is ample experimental evidence that it varies greatly. The results from the aggregation model supports the experimental evidence of kB^{-1} to be highly variable. For dense canopy, kB^{-1} approaches 2.3 but for sparse canopy, kB^{-1} increases significantly (figure 4). For the Alpilles site, kB^{-1} is found to range between 5 and 9 during the growing season (figure 5).

Objective 3:
The sensible heat flux comparison between in-situ eddy correlation field observations and the aggregation model results are presented for 16 days in 7 fields
• Arpège weather model inputs: rmse 87 W/m^2 and bias -30 W/m^2 (fig 6)
• Radiosounding observations: rmse 69 W/m^2 and bias -34 W/m^2 (fig 7)

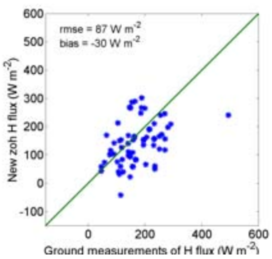


Fig 6 In-situ observations and aggregation model results based on Arpège weather model

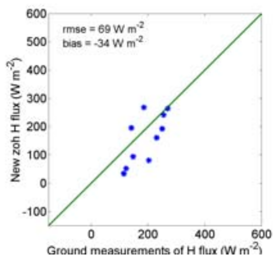


Fig. 7 In-situ observations and aggregation model results based on radiosoundings

CONCLUSION

A physically-based atmospheric modelling is now available for applied use when there is a need to upscale from a local point measure of sensible heat and water wapour flux to the larger scale in order to compare and verify the surface fluxes estimated from e.g. NOAA AVHRR (1 km), weather forecasting models (5-15 km) and hydrological models (grid and catchment).

The great advantages of the aggregation model is that no assumption has to be taken the kB^{-1} value when calculating the high resolution surface-flux maps.

References

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