Using Storm Tracker Observation to Get the Characteristics of the Boundary Layer Development – the Sensible Heat and the Latent Heat Flux

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1.Abstract

This study estimates the important characteristic parameters of boundary layer development observed from Storm Tracker(ST), including the sensible heat and the latent heat flux by using the mixed-layer conceptual model and high-resolution simulations. Using ST data released hourly over the plains in western Taiwan as an example, this study extracts boundary layer height and temperature characteristics from the observations. Through an ideal high-resolution model, the study simulates the development of the boundary layer under the main surface types, urban and grassland, in western Taiwan and obtains the parameter range of boundary layer development. Finally, this study uses the boundary layer height and temperature calculated by ST to infer the characteristic parameters of boundary layer development, including the surface sensible heat and the latent heat flux during ST observations.

2. Method

Step 1- Get *SH* 、*LH* values at each time

Large-eddy simulation under specific land type

Storm Tracker(ST) under the heterogeneous land type

Provide the *range* of k 、SH 、LH under specific land type

- Set initial condition of $\theta\ (t_0)$ 、$qv\ (t_0)$
- Input BLH 、θ_{BLH} 、qv_{BLH} at time t

Mixed-layer conceptual model

- Initial condition of $\theta\ (t_0)$
- Initial condition of $qv(t_0)$

k 、SH 、LH →

- BLH
- θ_{BLH}
- qv_{BLH}

Get the SH 、LH values that can derive the BLH 、θ_{BLH} 、qv_{BLH} at time t.

Step 2- Obtain the most possible *SH* 、*LH* from different times

- Repeat Step 1: input BLH 、θ_{BLH} 、qv_{BLH} at different times and get SH 、LH .
- Combine SH 、LH from different times and obtain the most possible values.

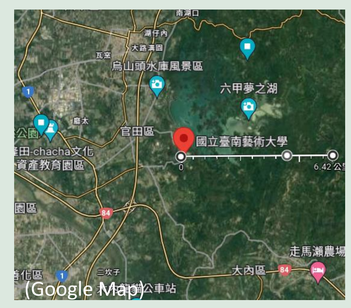
Well-mixed conceptual model

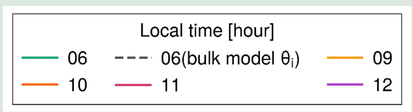
According to Stevens (2007), the development of the dry boundary layers can be simplified as the well-mixed layer, which is controlled by the surface sensible heat and the entrainment rate. In the study, the evolution of the surface heat flux is simplified as the sinusoidal function, so the time series can only be determined by the peak the surface heat flux.

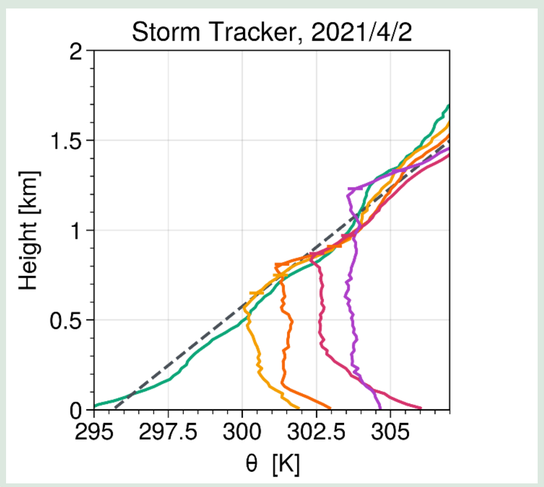
- $\boldsymbol{BLH(t) = \alpha h_*}$ **where** $\boldsymbol{h_* = (\frac{2\int_0^t SH(t)dt}{N^2})^{\frac{1}{2}}}$ **and** $\boldsymbol{\alpha = \sqrt{1-2k}}$
- $\boldsymbol{BLH(t) \times \theta_{BLH}(t) = \int_0^{BLH(t)} \theta_i dz + \int_0^t SH(t)dt}$
- $\boldsymbol{BLH(t) \times qv_{BLH}(t) = \int_0^{BLH(t)} qv_i dz + \int_0^t LH(t)dt}$

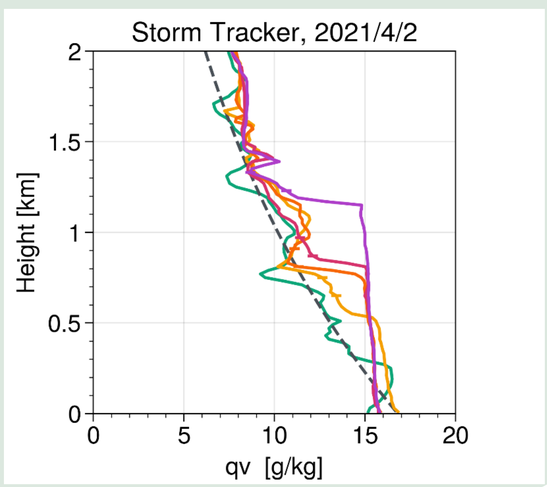
Storm Tracker (ST) observation at TNNUA

On 02 April 2021, there was no strong synoptic weather system around Taiwan, and it was almost cloudless over western Taiwan.









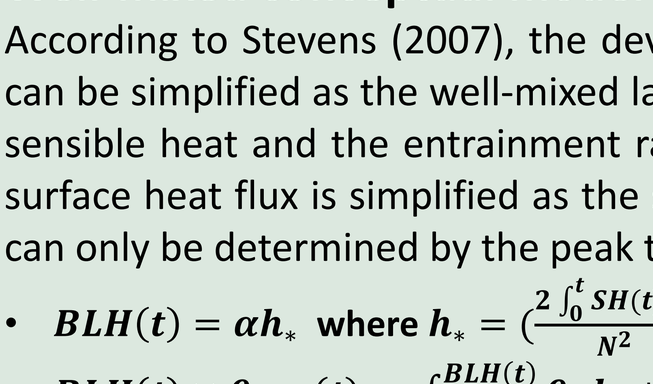
Vector Vorticity equation cloud-resolving Model (VVM) (Jung and Arakawa, 2008; Wu et al., 2019)

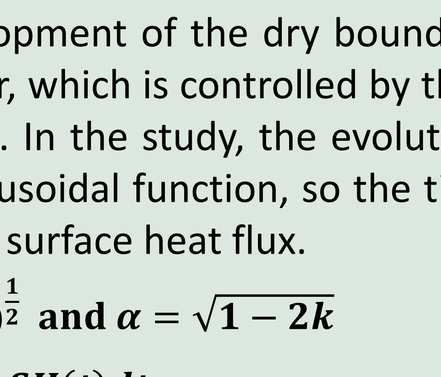
Two experiments with the urban and the grass land use are carried out. These two land types represent the main land use in western Taiwan.

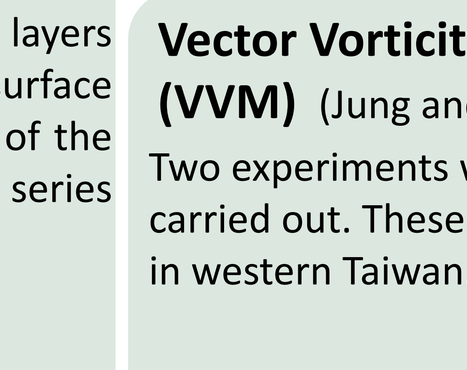
Land type	Grass 、 Urban
Initial condition	ST, 2021/04/02 06 LST
Time	06-24 LST with time step 10 sec
Domain	12.8 X 12.8 X 6km
Resolution	100 X 100 X 20 m

3. Result

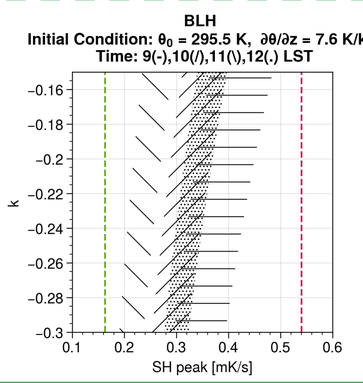
It is assumed that the features of the boundary layer development over the complicated heterogeneous land type in western Taiwan would be constrained by the features under the single land type. From the storm trackers at 09 to 12 LST over TNNUA, the peak of the sensible heat is about 0.3 to 0.35 mK/s. The peak of the latent heat is about 0.00013 to 0.00017 m/s.

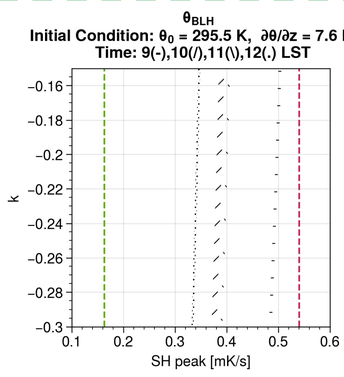


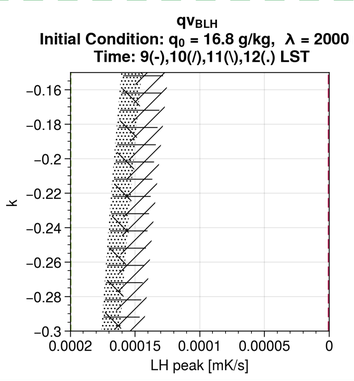




The three figures on the right side show the hourly boundary layer height, potential temperature, and mixing ratio ranges corresponding to sensible heat and latent heat fluxes from 09LST to 12LST. The time labels for each symbol are annotated on the figure.

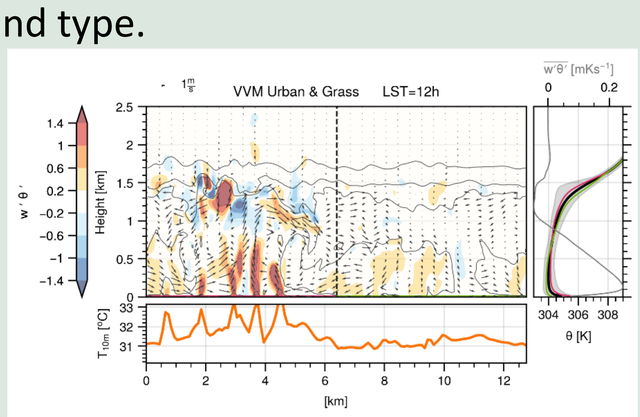






4. Future Work

To understand the potential circulation under the heterogeneous land type, we will carry out the numerical experiment with the combination of the different land type.



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Reference:

- Jung, J.-H., and Arakawa, A.: A three-dimensional anelastic model based on the vorticity equation. Monthly weather review, 136(1), 276-294. 2008
- Stevens, B.: On the growth of layers of nonprecipitating cumulus convection. Journal of the atmospheric sciences, 64(8), 2916-2931, 2007
- Wu, C.-M., Lo, M.-H., Chen, W.-T., and Lu, C.-T.: The impacts of heterogeneous land surface fluxes on the diurnal cycle precipitation: A framework for improving the GCM representation of land-atmosphere interactions. Journal of Geophysical Research: Atmospheres, 120(9), 3714-3727, 2015
- Hwang, Wei-Chun, Po-Hsiung Lin, and Hungjui Yu. "The development of the “Storm Tracker” and its applications for atmospheric high-resolution upper-air observations." *Atmospheric Measurement Techniques* 13.10 (2020): 5395-5406.